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Characteristics, origin and significance of Mesoproterozoic bedded clastic facies at the Olympic Dam Cu–U–Au–Ag deposit, South Australia

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ABSTRACT

Mesoproterozoic bedded clastic facies occur in the Olympic Dam Breccia Complex which hosts the Olympic Dam Cu–U–Au–Ag deposit, South Australia. Contacts of the bedded clastic facies with breccia of the Olympic Dam Breccia Complex are faulted and/or brecciated; fragments of the bedded clastic facies occur in the breccia complex. The bedded clastic facies comprise five main facies associations, four of which are organised into mappable units. These associations have distinct textures and components and have not been mixed. Major sources of detritus were felsic and mafic volcanic units and granitoids of the ∼1590 Ma Gawler Silicic Large Igneous Province. Archean and Paleoproterozoic zircons in well-sorted quartz-rich sandstone indicate that older Gawler Craton basement successions also contributed sediment to the bedded clastic facies. Accumulation of the bedded clastic facies was at least partly contemporaneous with rhyolitic explosive eruptions from vent(s) probably tens of km away because bubble-wall shards are present in tuffaceous mudstone facies. Deformation of the bedded clastic facies prior to final lithification produced folds that have diverse shapes and sizes, and that lack cleavage. The folds have a reasonably consistent gentle plunge to the northeast. These soft-sediment folds could be related to slumping on a northeast-striking paleoslope that dipped either to the northwest or southeast. The depocenter in which these facies accumulated may have been bounded by a combination of northeast-striking and northwest-striking faults. Because the bedded clastic facies occur at the top of the Olympic Dam Breccia Complex and contributed clasts to it, the fault-controlled sedimentary basin was in place when the breccia complex and the Olympic Dam ore deposit formed.

1. Introduction

The supergiant Olympic Dam Cu–U–Au–Ag deposit is famous for its size and polymetallic character (e.g., Ehrig et al., 2012), and for being one of the deposits upon which the iron oxide–copper–gold (IOCG) ore deposit class is based (Hitzman et al., 1992). When first discovered but prior to major underground development, the breccia-dominated host succession to the deposit was interpreted to be largely sedimentary and was described in terms of two formations that were further divided into members (Roberts and Hudson, 1983). Extensive underground exposure and further drilling led to the recognition that the clastic host rocks are part of a breccia complex formed mainly by a combination of hydrothermal and tectonic processes (Olympic Dam Breccia Complex, ODBC; Reeve et al., 1990). Reeve et al. (1990) also reported "volcaniclastic rocks in diatreme structures" associated with mafic dykes and showed five such diatremes on their map (Reeve et al., 1990, Fig. 2A). The diatremes were interpreted as the roots of maar volcanoes where hydrothermal and phreatomagmatic eruptions had taken place. Even though the mapped diatremes occupy less than 2% of the total area of the ODBC (∼17 km^2), Reeve et al. (1990) attributed much of the brecciation to eruption-related decompression. Domains of well-bedded, mostly fine-grained lithologies in the ODBC were thought to be "crater facies epiclastics". The maar-diatreme interpretation has been developed and/or repeated in several subsequent papers on Olympic Dam and has been incorporated in genetic models for Olympic Dam and for IOCG deposits

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in general (e.g., Cross et al., 1993; Haynes et al., 1995; Johnson and Cross, 1995; Skirrow et al., 2002; Groves et al., 2010; Hayward and Skirrow, 2010).

McPhie et al. (2011) proposed that the well-bedded, mostly fine-grained clastic lithologies in the ODBC were the remnants of a Mesoproterozoic sedimentary basin, using data on facies characteristics and relationships, and on the clastic components. Here we provide new data on the facies, stratigraphy, age and structure of the bedded clastic facies at Olympic Dam. Our data come from a selection of the ~1000 drill holes drilled between 2003 and 2008 in the eastern two-thirds of the deposit; these drill holes are the most recent available. They represent ~60% of the total number of holes, and of the total metres drilled, at Olympic Dam, and have added substantially to knowledge and understanding of the deposit and its setting (Ehrig et al., 2012). These data are used to argue that the bedded clastic facies were deposited in a fault-bounded sedimentary basin. The presence of mappable internal stratigraphy cannot be accommodated by deposition of the bedded clastic facies in the isolated maar craters interpreted by Reeve et al. (1990). Because the fault-bounded basin was present when the Olympic Dam ore deposit formed, this setting ought to be considered in models of ore genesis.

2. Regional geological setting of Olympic Dam

Olympic Dam is on the eastern edge of the Gawler Craton in South Australia (Fig. 1). The Gawler Craton comprises Meso- to Neoarchean complexes surrounded by Paleoproterozoic to Mesoproterozoic successions (Swain et al., 2005; Fanning et al., 2007; Fraser et al., 2010). In the southern and eastern Gawler Craton, the Paleoproterozoic sedimentary and igneous units were deformed during the Cornian Orogeny (around 1850 Ma, Hand et al., 2007), and the Kimban Orogeny (1730–1690 Ma, Hand et al., 2007).

Voluminous igneous units dominate the Mesoproterozoic successions of the Gawler Craton. In the central and eastern Gawler Craton, the principal units are the Hiltaba Suite (1595–1575 Ma; Hand et al., 2007) and the Gawler Range Volcanics (~1591 Ma, Fanning et al., 1988) which together constitute the Gawler Silicic Large Igneous Province (SLIP; Allen et al., 2008). The lower Gawler Range Volcanics include mafic and felsic lavas, and felsic ignimbrites and other pyroclastic facies (Giles, 1988; Blissett et al., 1993; Allen et al., 2008; Agangi et al., 2012). The upper Gawler Range Volcanics are dominated by three large-volume rhyolite lavas (Allen and McPhie, 2002; Allen et al., 2008).

The Gawler Range Volcanics and younger units are flat-lying or gently dipping and have not been metamorphosed. Regional deformation roughly synchronous with the Gawler SLIP (1590–1570 Ma, Hand et al., 2007) was limited to movement on faults and shear zones in response to northwest-southeast directed shortening. Similarly, younger deformation events (Kararan Orogeny, 1570–1540 Ma, Hand et al., 2007; Coorabie Orogeny, 1470–1450 Ma, Direen et al., 2005; Hand et al., 2007) involved reactivation of fault and shear zones, mainly in the northern and western parts of the Gawler Craton.

The eastern Gawler Craton in the region of Olympic Dam is overlain by the Pandurra Formation which is composed of continental sedimentary rocks (Cowley, 1993) that are neither deformed nor metamorphosed. The age estimate of the Pandurra Formation is 1424 ± 51 Ma (Rb–Sr date, Fanning et al., 1983). The Pandurra Formation is overlain by Neoproterozoic to Cambrian sedimentary rocks of the Stuart Shelf (Preiss, 1993). East of the Torrens Hinge Zone, the sedimentary formations belong to the Adelaide Geosyncline and they are markedly thicker. The Gairdner Dyke Swarm comprises a 180–250 km-wide, northwest-striking group of mafic dykes which intruded the eastern and northern Gawler Craton around 825 Ma (Wingate et al., 1998).

3. Geology of Olympic Dam

The Olympic Dam Cu–U–Au–Ag ore deposit occurs in the Olympic Dam Breccia Complex (ODBC) which is surrounded by and has gradational contacts with the Roxby Downs Granite (Reeve et al., 1990). The Roxby Downs Granite has an age of 1594 ± 5 Ma (U–Pb in zircon, Jagodzinski, 2014) and is part of the Burgoyne Batholith, a member of the Hiltaba Suite; it is surrounded by the Paleoproterozoic Hutchison Group, Donington Suite and the Wallaroo Group. Both the Roxby Downs Granite and the ODBC are unconformably overlain by 300–350 m of Neoproterozoic and Cambrian Stuart Shelf sedimentary formations. The Gawler Range Volcanics have been logged in drill holes at nearby prospects (Wirrda Well, Snake Gully, Acropolis; all <25 km from Olympic Dam) but only a single unit of almost intact Gawler Range Volcanics has been identified at Olympic Dam (strongly altered olivine-phyric picrite; Ehrig et al., 2012). The Pandurra Formation is not present at Olympic Dam, but it occurs to the west, north and south.

The main protolith of the ODBC was the Roxby Downs Granite and granite clasts are weakly to intensely hematite-altered (Reeve et al., 1990). In the granite-rich breccia, granite clasts are weakly to moderately altered whereas in the hematite-rich breccia, the granite clasts are strongly to intensely altered and a hematite-rich, fine-grained matrix is present (Reeve et al., 1990). The ore minerals (Cu sulfides and uraninite, coffinite and brannerite) are typically fine-grained and disseminated in the hematite-rich breccia of the ODBC. There is a gross zonation in the Cu sulfides from chalcopyrite at depth through bornite to chalcocite at the shallowest levels (Reeve et al., 1990).

In the southern mine area, the ODBC also includes large domains of polymictic breccia composed of feldspar-phyric clasts of the Gawler Range Volcanics, and two areas of bedded clastic facies (Fig. 2A). The distribution of the bedded clastic facies shown in Fig. 2A is constrained by intersections in 302 diamond drill holes. The northern area of bedded clastic facies is 600 m long, 370–380 m wide and 210 m in vertical extent below the unconformity with the Stuart Shelf sedimentary formations. It reaches the deepest point below the unconformity in the northwest where the basal contact slopes shallowly to the northwest. The southern area of bedded clastic facies is 750 m south of the northern bedded clastic facies. It comprises one main domain and nearby outliers to the northeast (northern outlier) and southwest (western outlier). The main domain of the southern bedded clastic facies is elongate east-west and is 1300 m long, up to 380 m wide and 700 m in vertical extent below the unconformity with the Stuart Shelf sedimentary formations. The contact of the southern bedded clastic facies with breccia of the ODBC is deepest at the western end and shallower to the east. Intervals of the bedded clastic facies have been internally deformed and they have both faulted and gradational contacts with the ODBC. At the gradational contacts, the bedded clastic facies are commonly brecciated and separated from hematite-rich breccia or granite-rich breccia by intervals composed of fragments of the bedded clastic facies in hematite-rich breccia or granite-rich breccia.

Mafic dykes intrude the ODBC and the Roxby Downs Granite (Reeve et al., 1990). Relatively fresh plagioclase-pyroxene-phyric basalt and dolerite dykes belong to the ~825 Ma Gairdner Dyke Swarm (Huang et al., 2015a,b). Variably altered olivine-phyric, aphyric and doleritic dykes are considered to be of Gawler Range Volcanics age (~1590 Ma; Johnson and McCulloch, 1995; Huang et al., in review). In the northern mine area, these dykes are intensely altered and commonly mineralised.