

# The Abra deposit: a breccia-pipe polymetallic mineral system in the Edmund Basin, Capricorn Orogen: implications for mineral exploration

by

F Pirajno, A Hell<sup>1</sup>, AM Thorne, and HN Cutten

Abra is a blind, stratabound, sedimentary rock-hosted Fe–Pb–Zn–Ba–Cu(–Au–Ag–Bi–W) deposit, located within the easterly trending Jillawarra rift sub-basin of the Mesoproterozoic Edmund Basin (see fig. 1 in Thorne et al., 2009; this volume). It was discovered in 1981. The Edmund Basin corresponds to the present-day outcrop of the Edmund Group, a 4–10 km-thick succession of siltstone, sandstone, dolomitic siltstone, and stromatolitic dolomite. The age of the Edmund Group is between 1.62 and 1.46 Ga (Martin and Thorne, 2004). Igneous activity in the Jillawarra Sub-basin includes high-K rhyolite (Tangadee Rhyolite; Fig. 1), with a poorly constrained U–Pb zircon age of 1.64 Ga (Pearson et al., 1996). Elsewhere in the Edmund Basin dykes and sills of alkaline affinity are present (Gifford Creek Alkaline Complex; Pearson et al., 1996). In addition, the Edmund Group is intruded by voluminous c. 1465 Ma and c. 1070 Ma mafic sills, which caused inflation of the stratigraphic thickness of up to 60% (Morris and Pirajno, 2005, and references therein).

The Abra mineralization was described by Vogt and Stumpff (1987), Boddington (1990), Collins and McDonald (1994), and Vogt (1995), and reported on in Cooper et al. (1998). More recently, Austen (2007) carried out a petrographic, fluid inclusions, and isotope systematics study of the Abra deposit.

## Abra deposit

The Abra deposit, as yet unmined and at the time of writing still in the exploration stage, is estimated to contain approximately 93 Mt of ore, grading 4% Pb and 10 g/t Ag, and 14 Mt at 0.62% Cu and 0.5 g/t Au (<http://www.abramining.com.au/>, viewed November 2008), beneath a 200 to 350 m cover of the Kiangi Creek Formation (Edmund Group; Martin and Thorne, 2004; Thorne et al., 2009). Recent drilling results confirm the giant status of this deposit, with some intersections yielding 58 m at 9.7% Pb and 4.5 g/t Ag; 12.8 m at 9.5% Pb, 15.5 g/t Ag, and 2.8% Zn; 56 m at 3.4% Pb, 15 g/t Ag, and 0.3 g/t Au (Abra Mining Limited, media release to the Australian Stock Exchange, January 2008). In addition, drilling programs



FMP1075

22.01.09

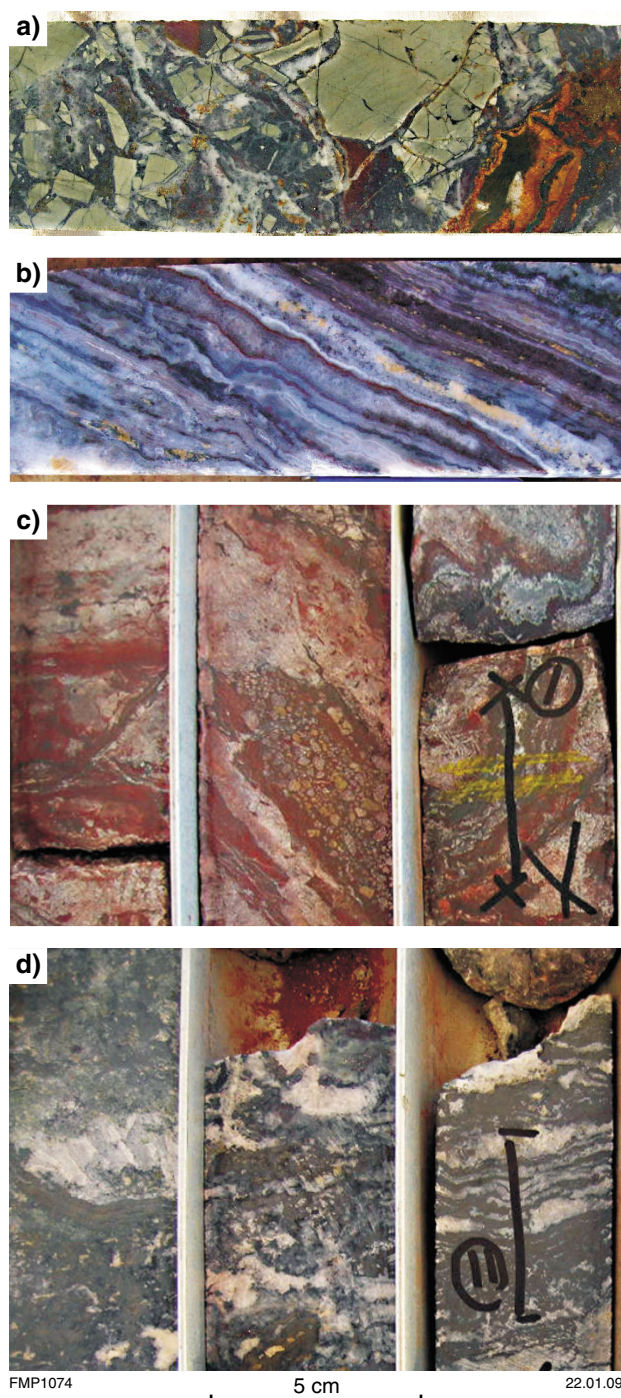
Figure 1. Outcrop of Tangadee Rhyolite

have revealed the presence of similar prospects to the west (Hyperion) and east (Genie) of Abra, along an easterly trend.

This polymetallic deposit is hosted by siltstone, dolostone, and sandstone rocks of the Irregully and Kiangi Creek Formations, but the mineralized zone does not extend above an erosion surface marking the change from fluvial to marine facies in the lower part of the Kiangi Creek Formation (Thorne et al., 2009; this volume).

The Abra deposit is characterized by a funnel-shaped brecciated zone, interpreted as a breccia feeder pipe, overlain by stratabound mineralization. The stratabound mineralization includes a Red Zone and an underlying Black Zone (Fig. 2). The Red Zone is characterized by banded jaspilite, hematite, galena, pyrite, quartz, abundant barite, and siderite. The jaspilite and hematite cause the predominant red colouration. Barite is a major component, and in places forms massive zones. The Black Zone consists of veins and rhythmically banded Pb, Zn, and minor Cu sulfides, laminated and/or brecciated hematite, magnetite, Fe-rich carbonate, barite, and scheelite. The ore minerals are galena, sphalerite, and pyrite, with minor tetrahedrite, chalcocopyrite, and scheelite. In both the Red and Black Zones, laminations and bands of ore minerals, iron oxides, barite, and quartz commonly exhibit colloform textures. The feeder breccia-pipe (called the stringer zone) merges with the

<sup>1</sup> Abra Mining Limited, 57 Havelock Street, West Perth, 6005, Australia



**Figure 2.** Core from the Abra deposit: a) jigsaw fracturing in a breccia pipe (green = chloritized siltstone country rock, black = magnetite); b) banded silica and jasper of the Red Zone; c) typical rocks of the Red Zone; d) black and white-banded Black Zone (black = galena and magnetite, white = silica)

Black Zone and consists of a stockwork of iron carbonate and quartz, barite, pyrite, magnetite, and chalcopyrite veins and disseminations, with abundant fluidized and/or jigsaw textures that cut through a wider alteration envelope of chlorite and siderite in rock units of the Irregularly Formation (Fig. 2). Boddington (1990) noted that the upper part of the stringer zone contains higher Ba–Ag–Pb than the lower parts, which are enriched in Cu–Au.

The Abra mineral system is characterized by several overprinting phases of hydrothermal activity, from several stages of brecciation and fluidization, barite, and sulfide veining to barren low-temperature chalcidonic (epithermal style) veining. Hydrothermal alteration minerals include multi-stage quartz, chlorite, prehnite, Fe-rich carbonate, and albite. Albite (Na-metasomatism) is an early alteration phase, whereas Fe-rich carbonate is a late phase. Fluid inclusion studies by Austen (2007) suggested that the metals may have been derived from the sedimentary rocks and that the ore fluids had temperatures ranging from 162 to 250°C, with salinities ranging from 5.8 to about 20 wt% NaCl. The sulfur isotopic system shows  $\delta^{34}\text{S}$  values ranging from 19.4 to 26.6‰ for sulfides (chalcopyrite, pyrite, sphalerite, galena) and from 37.4 to 41.9‰ for barite (Vogt and Stumpfl, 1987; Austen, 2007). Sulfur isotope thermometry between sulfides and sulfide–barite pairs yield values ranging from 219 to 336°C, whereas oxygen isotope thermometry from coexisting pairs (e.g. quartz, chlorite, hematite, and magnetite) show a wider range of temperatures, from 228 to 452°C (Austen, 2007).

The age of the mineralization, so far only constrained by the above-mentioned erosional surface and the host sedimentary rocks, is as yet to be accurately determined. Sulfide and hydrothermal sericite samples have been submitted for age dating using the Re–Os and the Ar–Ar isotopic systems, respectively.

### A preliminary genetic model and implications for exploration

Vogt and Stumpfl (1987) and Collins and McDonald (1994) linked the genesis of the Abra deposit to c. 1.64 Ga rift-related tectonics and felsic magmatism, and suggested that the source of the Pb and Ba may have been the associated arkosic sediments. The association of the deposit with felsic magmatism in a rift setting, together with Fe-rich and chlorite alteration of the host sedimentary rocks, raises the possibility that the Abra deposit may be a variant of the Iberian Pyrite Belt (IPB) mineral systems, which are typically associated with thick siliciclastic successions in a rift setting and exhibit widespread chloritic alteration. Recent work on IPB systems by Tornos (2006) and Tornos and Heinrich (2007), supports the idea of a genetic relationship between the sulfide mineralization and siliciclastic sedimentary successions as a metal source. Tornos and Heinrich (2007) also envisaged that the heat energy may be provided by an underlying igneous source and a mechanism of sulfide precipitation by mixing of S-deficient metalliferous brines with biogenic  $\text{H}_2\text{S}$ -rich fluids. They pointed out that the IPB (and Abra) mineral systems share features that are common to SEDEX systems, rather than to volcanogenic associations. However, the IPB deposits have an undeniable link with coeval felsic magmatism and this would support a volcanogenic association. The case is less clear for Abra, although there appears to be a spatial link with felsic volcanism, represented by the Tangadee Rhyolite, which is stratigraphically part of the Kiangi Creek Formation and outcrops in the vicinity of the deposit.

A tentative genetic model envisages that basinal fluids were possibly heated by the magmatic system associated with the

Tangadee Rhyolite. Alternatively, the voluminous mafic sills that intrude the sedimentary rocks of the Edmund Basin may have provided the thermal energy. Heating of basinal fluids and of pore fluids could have caused rapid expansion and boiling, resulting in eruption or venting of hydrothermal fluids and the inception of pipe-like structures (stringer zone). These eruptions would have occurred time and again, resulting in several stages of hydrothermal activity, with multiphase hydrofracturing and overprinting textures (Black Zone) at several localities. The hydrothermal eruptions also deposited chemical sediments similar to banded iron-formation, represented by laminated iron oxides and barite (Red Zone). The abundance of barite can be explained by leaching of evaporitic minerals in the sedimentary succession. The model suggests that there may be several of these hydrothermal breccia pipes and that each of these pipes would be associated with distal hematite–barite chemical sediments, enhancing the prospectivity of the Jillawarra Basin.

Field, petrographic, and geochronological studies of the Abra polymetallic mineral system are continuing.

## References

- Austen, S, 2007, Isotopic and thermal constraints on the origin and formation of the Abra polymetallic deposit, Jillawarra Sub-basin, Western Australia: University of Southampton, United Kingdom, School of Ocean and Earth Science, MSc thesis (unpublished).
- Boddington, TDM, 1990, Abra lead–silver–copper–gold deposit, *in* Mineral deposits of Australia and Papua New Guinea *edited by* FE Hughes: Australasian Institute of Mining and Metallurgy, Monograph 14, p. 659–664.
- Collins, PLF, and McDonald, IR, 1994, A Proterozoic sediment-hosted polymetallic epithermal deposit at Abra in the Jillawarra sub-basin of the central Bangemall Basin, Western Australia: Geological Society of Australia; 12th Australian Geological Convention, Perth, Western Australia, 1994, Proceedings; Abstract Series, no. 37, p. 68–69.
- Cooper, RW, Langford, RL, and Pirajno, F, 1998, Mineral occurrences and exploration potential of the Bangemall Basin: Geological Survey of Western Australia, Report 64, 42p.
- Martin, DMcB, and Thorne, AM, 2004, Tectonic setting and basin evolution of the Bangemall Supergroup in the northwestern Capricorn Orogen: Precambrian Research, v. 128, p. 385–409.

- Morris, PA, and Pirajno, F, 2005, Mesoproterozoic sill complexes in the Bangemall Supergroup, Western Australia: geology, geochemistry and mineralization potential: Geological Survey of Western Australia, Report 99, 75p.
- Pearson, JM, Taylor, WR, and Barley, ME, 1996, Geology of the alkaline Gifford Creek Complex, Western Australia: Australian Journal of Earth Sciences, v. 43, p. 299–309.
- Thorne, AM, Cutten, HN, Hell, A, and Pirajno, F, 2009, Kiangi Creek Formation paleogeography and the geological setting of the Abra polymetallic deposit: Geological Survey of Western Australia, Record 2009/2, p. 29–30.
- Tornos, F, 2006, Environment of formation and styles of volcanogenic massive sulphides: the Iberian Pyrite Belt: Ore Geology Reviews, v. 28, p. 259–307.
- Tornos, F, and Heinrich, CA, 2007, Shale basins, sulphur-deficient ore brines and the formation of exhalative base metal deposits: Chemical Geology, v. 247, p. 195–207.
- Vogt, JH, 1995, Geology of the Jillawarra area, Bangemall Basin, Western Australia: Geological Survey of Western Australia, Report 40, 107p.
- Vogt, JH, and Stumpfl, EF, 1987, Abra: a stratabound Pb–Cu–Ba mineralisation in the Bangemall Basin, Western Australia: Economic Geology, v. 82, p. 805–825.