Metadata for
Gawler Craton iron oxide Cu-Au (-U) potential map
First Edition (March 2006)

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Abstract

The map of iron oxide copper-gold (IOCG) potential of the Gawler Craton, South Australia, shows the spatial distribution of key ‘essential ingredients’ of IOCG ore-forming systems. These ‘ingredients’ include: (a) rock units of the Gawler Ranges-Hiltaba Volcano-Plutonic Association, subdivided by supersuite; (b) faults/shear zones subdivided by interpreted age of youngest significant movement; (c) copper geochemistry (>200ppm) from drill holes intersecting crystalline basement (Mesoproterozoic and older); (d) hydrothermal alteration assemblages and zones, based on drill hole logging, potential-field interpretation, and inversion modelling of potential-field data; and (e) host sequence units considered important in localising IOCG alteration and mineralisation. Also shown are Nd isotopic data and the mineral isotopic ages of late Palaeoproterozoic to early Mesoproterozoic magmatism and hydrothermal minerals. Areas with the greatest number of ‘essential ingredients’ are considered to have the maximum potential for IOCG mineralisation. IOCG potential of the Gawler Craton is shown as domains with ranks from 1 (highest) to 4. Notes detailing the sources of data and methods used in constructing the map are provided in a separate file available on the Geoscience Australia website.

Availability of the map, and printing

A low-resolution image of the map is available at: http://www.ga.gov.au/minerals/research/regional/gawler/gaw_mapgis.jsp as a downloadable PDF file (4.1 Mb). A CD with high-resolution print files and PDFs, or a printed copy of the map, are available from the Geoscience Australia Sales Centre for the cost of transfer (post: GPO Box 378, Canberra, A.C.T. 2601, phone: 02 6249 9966, email: sales@ga.gov.au). The map is designed to be printed at 1:500,000 scale, but may be printed at other scales if desired. A scale of 1:750,000 fits the width of A0 paper, whereas at 1:500,000 scale the map prints at ~106 cm width.

This First Edition of the map (March 2006) may be subject to amendment; please send feedback to: Roger Skirrow (email: roger.skirrow@ga.gov.au, phone: 02 6249 9442).

General comments on approach used in constructing the map

A ‘mineral systems’ approach underpins the construction of this thematic map, in which, the mineralisation in question is the product of a set of crustal- to regional- to deposit-scale ‘essential ingredients’ (Wyborn *et al*., 1994). These ‘ingredients’, as outlined for iron oxide Cu-Au systems in the Gawler Craton (Skirrow, 2006), may be spatially represented as ‘mappable criteria’. Areas with the greatest number of ‘essential ingredients’ are considered to have the maximum potential for IOCG mineralisation.

It should be noted that outcrop of prospective crystalline basement is abundant *only* within parts of the central Gawler Craton. Elsewhere, the extent of outcrop is generally <1%, and almost all the eastern Gawler Craton basement is obscured by tens to several hundreds of metres of sedimentary cover and regolith. Much of the information for these covered areas is, therefore, based on drill hole samples and interpretation of geophysical data.

The principal ‘essential ingredients’ displayed on the map, and detailed below, are as follows:

- Rock units of the Gawler Ranges-Hiltaba Volcano-Plutonic Association, subdivided by supersuite (Budd, submitted);
- Faults/shear zones subdivided by age of youngest known significant movement;
- Copper geochemistry (>200ppm), from drill holes intersecting crystalline basement (Mesoproterozoic and older);
- Hydrothermal alteration assemblages and zones, based on drill hole logging, interpretation of potential-field data, and inversion modelling of potential-field data; and
- Host sequence units considered important in localising IOCG alteration and mineralisation (e.g., Wallaroo Group and equivalents, Hutchison Group and equivalents, BIF).

Also shown are the mineral isotopic ages of early Mesoproterozoic IOCG mineralisation and related alteration, the ages of rocks of the Gawler Ranges-Hiltaba Volcano-Plutonic Association, and ages of minerals in shear zones active during the Palaeo- and Mesoproterozoic. Geochronology data for older and younger geological units have been omitted for clarity.

For reference, samarium-neodymium (Sm-Nd) isotopic data are presented as epsilon-Nd values, calculated at the age of the rock. See below for further details.

The boundaries of the Olympic Cu-Au province (Skirrow *et al*., 2002) and Central Gawler Gold Province (Drown, 2002; Budd, 2002a, b; Ferris and Schwarz, 2003) broadly enclose known Cu-Au and Au prospects, respectively.

Metadata for specific coverages

Aeromagnetic data and half vertical derivative grid and image

Total magnetic intensity (TMI) airborne magnetic grid data covering South Australia was compiled into a single composite grid with a cell spacing of 80 m, in June 2005. The original survey grids form part of the Geoscience Australia Magnetic Anomaly Grid Database of Australia (MAGDA), which contains publicly available airborne magnetic grid data for on-shore and near-offshore Australia (Milligan *et al*., 2004). Original data covering South Australia were acquired over several decades by the Department of Primary Industries and Resources, South Australia, by Geoscience Australia and by exploration companies. The TMI composite grid has been further processed in the Fourier domain to produce a half vertical derivative grid. This is essentially a high-pass filtering operation that enhances the shorter spatial wavelengths in the data at the expense of the longer wavelengths, but not to the degree of a first vertical derivative. This half vertical derivative grid is displayed as a greyscale image on the map.

Geology polygons

Gawler Ranges-Hiltaba Volcano-Plutonic (GRHVP) Association supersuites

Polygons are from the 1:1,000,000 scale map of the Gawler Craton of Fairclough *et al*. (2003), with some modification for the Gawler Range Volcanics after Allen *et al*. (2003), and by Anthony Budd (Geoscience Australia) for some granites. Attribution is based on a geochemical classification from Budd (submitted). Note that only sampled igneous rocks have been attributed with geochemical type; unsampled rocks are labelled ‘unassigned’; they require dating to confirm their age-equivalence with Hiltaba-units or GRV.

Other highlighted geological units

With the exception of some GRHVP polygons (see above), all geology polygons of the crystalline basement are taken from the 1:1,000,000 *Interpreted crystalline basement geology of the Gawler Craton* map (Fairclough *et al*., 2003). This map incorporates geological interpretations of the eastern Gawler Craton by Direen and Lyons (2002) and Raymond (2002), and central Gawler Craton by Hoatson *et al*. (2004). The metasedimentary successions of the Wallaroo Group and equivalents (e.g., Moonabie Formation, Jagodzinski, 2005), Hutchison Group and possible equivalents, and iron formations, have been highlighted with deeper colours on the map. These rock units, particularly the Wallaroo Group, appear to be preferentially altered and mineralised within IOCG systems of the Olympic Cu-Au province. However, there are important exceptions, for example the Olympic Dam deposit (hosted by Roxby Supersuite of the

GRHVP), and Carrapateena prospect (hosted by brecciated ?Donington Suite granitoid). All other basement units are uncoloured on this map, and users are referred to the 1:1,000,000 map of Fairclough *et al*. (2003) for a more complete geological reference.

Faults/shear zones

The ages given to faults and shear zones are those of the youngest significant determinable activation. As most of these structures appear to have undergone reactivation, the age given is not, necessarily, the time of first movement. Ages have been determined by (re)setting of isotopic systems used for dating; the known age of associated alteration and mineralisation; or overprinting relationships that constrain the age. We have assumed that some faults and shear zones are members of a family of structures of the same age and consider it reasonable, therefore, to assign the same age to all faults thus identified.

~1.73 Ga The oldest faults shown are those generated during the Kimban Orogeny (~1.73 Ga). They mostly occur in the eastern half of the craton, where they have been dated (e.g., Vassallo & Wilson, 2002). Deep crustal seismic reflection profiles suggest that some of the northwest-trending ~1.60 Ga faults are reactivated Kimban structures.

~1.60 Ga IOCG mineralisation formed at ~1.59 Ga (Johnson & Cross, 1995; Skirrow *et al*., submitted). Most of the faults coeval with IOCG mineralisation have inferred ages due to the presence of contained Fe-oxide alteration. The east–west-trending Yerda and Oolabinna Shear Zones, in the centre of the Craton, have been isotopically dated (Fraser & Lyons, submitted) and field-relationships with rocks of known age also provide temporal constraints (Ferris, 2001).

~1.45 Ga The youngest pre-cratonic faults and shears occur in the west of the craton, in the Fowler Orogenic Belt, and generally trend north-northeast to northeast. Their ages have been determined by ^{40}Ar/^{39}Ar and EMPA dating (Fraser & Lyons, submitted; Swain *et al*., 2005). The Karari Shear Zone, separating the Fowler Orogenic Belt from the deeply buried parts of the Craton, to the northwest, is a major structure in the Gawler Craton.

Early Neoproterozoic and Phanerozoic The ages of basin-bounding faults are determined by the age of the oldest known units of the basins.

Undetermined/unknown A number of faults and shears have not been assigned ages. Although the timing of last activation can be weakly inferred, we feel it would be misleading to give any an ages to such faults and shears in the absence of better supporting evidence.

Geochronology

^{40}Ar/^{39}Ar data presented on the map come from the following sources: Foster and Ehlers (1998), Budd and Fraser (2004), Fraser *et al*. (submitted), Fraser and Lyons (submitted), and Skirrow *et al*. (submitted). The biotite data for the Moonta-Wallaroo district are from Raymond and Fraser (unpublished Geoscience Australia data).

Re-Os (molybdenite) data are from Skirrow *et al*. (submitted) and unpublished Geoscience Australia data.

U-Pb (titanite) data are from Skirrow *et al*. (submitted), and from Raymond (unpublished Geoscience Australia data) for the Moonta-Wallaroo district.

U-Pb (zircon) data are from Cooper *et al*. (1985), Fanning *et al*. (1988), Mortimer *et al*. (1988), Creaser (1989), Rankin *et al*. (1990), Cooper and Creaser (1993), Johnson (1993), Fanning (1997), Daly *et al*. (1998), Johnson and Cross (1995), Roach and Fanning (1994), Teasdale (1997), Ferris (2001), Wenlong Zang (unpublished PIRSA data), Jagodzinski (2005), Holm (2005), Budd (submitted), and Fraser *et al*. (submitted).

Alteration

Hydrothermal alteration related to IOCG mineral systems is depicted in two ways on the map:

(1) Alteration assemblages logged in drill holes are represented as large open symbols at the position of the drill holes. Multiple overprinting assemblages have more than one symbol;

(2) Alteration zones interpreted from potential-field data (e.g., in Moonta-Wallaroo district, Raymond, 2002) or from constrained inversion modelling of potential-field data (in Olympic Dam district, Williams *et al*., 2005) are shown as patterned zones. The limits of coverage of these alteration zones are those bounded by the map area of Raymond (2002) and the 150 km × 150 km inversion model area of Williams *et al*. (2005), respectively. In the case of the alteration mapped by inversion modelling, voxels represented volume-elements of $1\ \text{km}_x \times 1\ \text{km}_y \times 0.5\ \text{km}_z$; hence, the 1% contour of magnetite on the map represents 1 volume-percent magnetite (and/or other magnetic minerals) within each volume-element of crust, with no information as to how susceptible material may be distributed within that volume. The contours are extracted from a 3-dimensional model, sectioned at the unconformity between Pandurra Formation and crystalline

basement. ‘Hematite alteration’ represents any dense non-magnetic mineral including sulfides, contoured as if all of this mineral content were hematite. Given our knowledge of alteration in the district (Skirrow *et al*., 2002; Bastrakov *et al*., submitted), we attribute much of this excess mass (relative to assumed rock properties) to hematite alteration although dense silicates such as amphibole, pyroxene and garnet could be a source of excess mass in some areas. ‘Sericite alteration’ represents any rock with lower density than that initially assumed for the particular rock volume in the constrained inversion modelling. Constraints on rock properties are based on measurements from drill hole samples assigned to the geological map polygons from Direen and Lyons (2002).

Geochemistry

Copper geochemistry

Two sets of copper assay data were used in this map. In the first dataset, covering the entire Gawler Craton, values of >200ppm Cu were extracted from the SARIG database, filtered to show only values from crystalline basement. Most of these data are from drill holes, and generally represent 1 m- to 2 m-intervals of variably fresh to weathered basement. Some data represent surface rock samples of unknown analytical quality.

The second dataset was compiled at Geoscience Australia, from Open File Envelopes, for drill holes in the Moonta-Wallaroo district. These digital data are now with PIRSA. The results are shown in the inset map of the Moonta-Wallaroo district. From approximately 15,000 analyses, copper values >200ppm and intersection intervals from basement were combined to produce values of metres × Cu percent. The majority of data from the southern Moonta-Wallaroo district are from bottom-of-hole samples of basement from RAB drilling (<1 m in many cases). These samples are substantially less representative of basement geochemistry than the more extensive diamond drill holes which sampled longer basement intersections in the northern part of the district.

Sm-Nd isotope data

The primary sources of whole rock Sm-Nd isotopic data are: Creaser (1989, 1995), Turner *et al*. (1993), Stewart (1994), Johnson and McCulloch (1995), Stewart and Foden (2001), Fanning (2002), Budd (submitted), and Skirrow *et al*. (submitted). Data are presented on the map as epsilon-Nd values calculated at the age of the rock. Note the variation in epsilon-Nd values for samples of the ~1575–1595 Ma Gawler Ranges-Hiltaba Volcano-Plutonic Association, particularly the higher values in the central and western parts of the craton (Ferris and Schwarz, 2003).

IOCG potential rankings

Areas are outlined with one of four rankings of potential for IOCG mineralisation. The ranks are based on an assessment of the presence of ‘essential ingredients’ for IOCG systems in the area (Skirrow, 2006). The boundaries should not be considered ‘hard and fast’, but simply enclose areas containing favourable geological ‘ingredients’, including, for example, A-type granitoids, mafic Hiltaba Association intrusions, iron oxide-rich alteration, and anomalous copper. Lower ranking areas have fewer known ingredients, but this may in part be due to lack of information. For example, an area with rank 4 in the central part of the Gawler Range Volcanics is based on the presence of A-type igneous rocks (Yardea Dacite of the Roxby Supersuite) and gravity anomalies. However, there is no known iron oxide alteration nor copper anomalism; the potential for IOCG mineralisation may lie beneath the ‘cover’ of GRV.

Readers should also note that the potential for other related mineralisation styles is not shown in this map, except for the boundary of the Central Gawler Gold Province. These gold systems have features in common with both orogenic gold and intrusion-related gold deposits (Ferris and Schwarz, 2003; Budd, submitted; Fraser *et al.*, submitted). Other mineralisation styles that may be present in the map-area include epithermal intrusion-related gold, skarn, and porphyry Cu-Au mineralisation.

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