A synopsis of the channel iron deposits of the Hamersley Province, Western Australia

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ABSTRACT

The channel iron deposit type or CID is one of the two major iron ore types mined in the Hamersley Province (Ramanaidou et al., 2003; Macphail and Stone, 2004; Heim et al., 2007; Morris et al., 2007; Vasconcelos et al., 2007). CID provided around 40% of the total of 394 Mt of iron ore mined from the Hamersley Province in 2009, and the current CID resource is around 7 billion tonnes. CID deposits occupy numerous meandering palaeochannels in a mature surface that includes Precambrian rocks and ferruginous Palaeogene valley fill. These palaeochannels are generally less than a kilometre but can range to several kilometres in width and from one metre to more than 100 m thick. There are two currently mined CID areas – the first in the western Hamersley Province in the Robe palaeochannel, and the second in the eastern Yandi palaeochannel. These two major CID channels extend over 100 km to 150 km, with the Robe system up to 5 km wide. The granular ore facies typically contains ooids and lesser pisoids with hematite nuclei and goethite cortices, with abundant goethitised wood/charcoal fragments and goethitic peloids, minor clay, and generally minimal porous goethitic matrix. Post-deposition weathering is common and produced secondary facies.

Ooids and pisoids were mostly derived from the stripping of a well-vegetated, deep ferruginous surface. The peloids were derived intra-formationally from both fragmentation and reworking of desiccated goethite-rich mud. Minute wood/charcoal fragments in the soil were initially replaced by goethite and then dehydrated to hematite, forming nuclei for many ooids and pisoids. In addition, abundant, generally small ($\leq 10$ mm) fragments of wood/charcoal were replaced in situ by goethite within the consolidating CID. This profusion of fossil wood, both as ooids and pisoids nuclei and as discrete fragments, as well as the local presence of kenomagnetite suggests major episodic wild fires in heavily vegetated catchments. The goethitic matrix was the result of chemically precipitated iron hydroxyoxides, resulting from leaching of iron-rich soils in an organic environment.
INTRODUCTION

Iron ore production in Western Australia has been increasing strongly from 2005 to 2010 (Figure 1) and relies on two different types of iron ore: the bedded iron deposits and the channel iron deposits. There are three main iron ore types in the Pilbara craton and Hamersley province: the banded iron-formation - hosted hematite and hematite–goethite bedded iron deposits; the goethite-hematite channel iron deposits or CID, and the minor hematite–goethite detrital iron deposits. The current production of CID from the three mines (Mesa J, Yandicoogina and Yandi) represents approximately 40% of the total iron ore production from Western Australia.

The general term CID includes the Robe Formation (previously known as the Robe Pisolite, including the Mesa J deposit), the Marillana Formation, (including the Yandi deposits), the Poondano Formation of the northern Pilbara and the minor deposits of the Yilgarn Craton, all in Western Australia, and the lesser known fluvial to lacustrine deposits of Kazakhstan.

CHANNEL IRON DEPOSIT DISTRIBUTION

CID occupy meandering palaeochannels on a mature surface that includes Precambrian rocks and ferruginous Palaeogene valley fill. CID are generally less than one km wide (up to five km) with a preserved thickness now ranging from one to rarely over 100 m. The Robe palaeochannel is the longest with CID partly preserved over a distance of 150 km (Figure 2). In the Robe Valley, CID are often preserved in an inverted topography as remnant mesas in the centre of the palaeochannels (Figure 3). In other cases, CID abut the margin of the palaeochannels.

A variety of facies can be found within the CID - granular with local intra-formational conglomerate, bedded and altered types: conchoidal, leached, and surface types. The granular facies is the only type which typically meets the specification to be considered as ore.
A section of Marillana Formation typically comprises from bottom to top: a basal conglomerate and a basal clay zone (Munjina Member); lower or basal CID and higher or main CID (Barimunya Member, Kneeshaw in Ramanaidou et al., 2003). The Robe Formation shows similar general features.

**GENERAL GEOLOGY**

CID consist of the Miocene (Ramanaidou et al., 2003; Macphail and Stone, 2004; Heim et al., 2007; Morris et al., 2007; Vasconcelos et al., 2007) iron-rich detrital horizons of the channels. Their granular components include very rare lithic fragments, but contain abundant diagnostic ferruginised wood fragments. The granular material ranges from coarse sand to fine gravel (typically 1–10 mm) and includes varying proportions of peloids [fragments of fine-grained to silty a structural goethite], pelletoids [ooids (<2 mm) and pisoids (2-10 mm) - rounded ferruginous particles consisting of a nucleus surrounded by a goethitic cortex], and fossil wood fragments (Figures 4 and 5). The nuclei vary widely between almost perfect spheres and irregular shapes. Nuclei are either simple or complex. A typical nucleus has a primary centre (core) with a series of layers that now form a single coherent particle. Kenomagnetite - maghemite is randomly disseminated within the peloids, occasionally in the nuclei and frequently along layer boundaries and cracks. A porous, ramifying goethitic matrix with minor secondary goethite and silica infill, encloses and cements the granules.

Numerous electron microprobe analyses of CID showed that aluminium (Al) and silicon (Si) increase from the hematitic nuclei to the matrix, and then the cortex. In the Robe Valley deposits, Al content in the nuclei ranges from 0.5 to 2.8% whereas in the Yandi deposits, Al ranges from 0.2 to 0.7%. The Al content in cortex is either twice as high (Robe CID) or three times (Yandi CID) as the Al content of the nucleus.

**GENESIS OF WESTERN AUSTRALIAN CHANNEL IRON DEPOSITS**
A detailed account of the genesis of Western Australia CID has been presented in Morris and Ramanaidou (2007). Large terrestrial iron-rich ooidal/pisoidal deposits are rare. Apart from WA and Kazakhstan, only minor concentrations have been reported elsewhere. Relic rock textures are extremely rare in the Australian CID components in contrast with abundant martite and hematite/goethite-pseudomorphed banded iron formation textures found in the underlying and overlying detrital iron deposits that occur stratigraphically above and below CID. The huge volume of CID pelletoids contrasting with the small amount of comparable pelletoids in the underlying and overlying detrital iron deposits implies very specific climatic conditions during the forming and stripping of the mid-Miocene surface. Although highly resistant lithic material is rare, CID are notable for the abundance of preserved ferruginised wood/charcoal fragments. The accretionary coatings on the pelletoids (Figure 8) with their evidence of multiple cycles of burial, ferruginisation, and re-exposure suggest rapid and recurring changes from pluvial to arid conditions. The presence of a heath-like surface is suggested by the time the CID horizons began to accumulate. We suggest that unlike the current cuirass style, the mid-Miocene Hamersley surface was a relatively easily eroded ferruginised soil produced by a prolonged warm non-seasonal climate of moderate rainfall - the ‘Miocene climatic optimum’. The ferruginised soil was probably dominated by poorly -structured goethite, with abundant minute fragments of ferruginised wood/charcoal and root material. The stripping phase culminated at around 12 Ma, with increasing cold arid conditions indicated by the overlying calcretised limestone of the Oakover Formation, before the onset of the Pliocene warming reversal. Fires played a significant role by dehydrating surface goethite to hematite (or kenomagnetite-maghemite) with consequent fracturing along cracks. Consolidation of the iron-dominated colluvium occurred at breaks in the slopes, as today, where conditions were favourable for ferruginisation to form soil hardgrounds. The combination of chemical and physical weathering re-exposed and released the goethite-coated fragments, typically dehydrated to hematite with time. This process repeated itself further downslope through many cycles before final deposition as pelletoidal CID in the channels. The general lack of chert and clay in the ore CID suggests that the shed from this weathering surface was largely iron oxide.
CONCLUSIONS

The CID is one of the two major mineable iron ore types in the Hamersley Province and accounts for 40% of current production. CID include the Robe Formation, the Marillana Formation, the Poondano Formation, and minor deposits of the Yilgarn, as well as the large deposits of Kazakhstan. CID occur in palaeochannels one to five km wide and one to 100 m thick with the Robe paleochannel being the longest.

CID are iron-rich detrital accumulations comprising coarse sand to fine gravel size granules that include: pelletoids (ooids and pisoids); peloids, ferruginised wood (goethitic wood in the matrix and hematitic wood in the nucleus) and a porous matrix that envelops the granules. Al and Si increase from the hematitic nuclei to the matrix, and then the cortex.

The proposed genetic model starts with a well vegetated surface growing on deeply ferruginised rock. The stripping of the ferruginous surface generates pelletoids often with hematitised wood as nuclei. The abundant presence of ferruginised wood/charcoal and kenomagnetite-maghemite suggests extensive fires. The goethitic matrix is dominantly chemically precipitated within the channels, and the goethitised wood was probably ferruginised within the consolidating CID.

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REFERENCES


Figures

Figure 1. Iron Ore Production in Kt (ABARE, 2007)

Figure 2. CID distribution in the Hamersley Province with the Robe and Marillana palaeochannels.

Figure 3. A CID mesa in the Robe Valley.

Figure 4. CID ooidal texture: a polished thin section of the Robe Valley area.

Figure 5. Polished thin section of CID under reflected light, showing irregular to spheroidal pelletoids with ferruginised wood in a ramifying porous matrix of goethite. [H = hematite]

Figure 6. Polished thin section showing accretionary growths of goethite on the hematite nucleus of a pelletoid showing variable levels of dehydration to hematite. The outermost layer is essentially partly ferruginised soil of the current cycle.
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