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Upgrading iron-ore deposits by melt loss during granulite facies metamorphism

Laura J. Morrissey [a,*], Martin Hand [a], Kathleen Lane [a], David E. Kelsey [a], Rian A. Dutch [a,b]

[a] School of Physical Sciences, University of Adelaide, Adelaide, South Australia 5005, Australia
[b] Geological Survey of South, Australia, Department for State Development, Adelaide, S.A. 5000, Australia

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ABSTRACT

Forward modelling of Fe-rich phyllite is used to evaluate the effects of partial melting and melt loss on the concentration of iron in the residual rock package, leading to enrichment in Fe-oxide minerals (magnetite and hematite). The effect of melt loss during prograde metamorphism to peak conditions of ~850 °C was modelled using a series of calculated pressure–temperature (*P*–*T*) phase diagrams (pseudosections). The results show that metapelitic rocks with lower iron content are more fertile, produce more melt and therefore show a more significant increase (up to 35%) in the Fe-oxide content in the residual (melt depleted) rock package. Rocks with primary Fe-rich compositions are less fertile, lose less melt and therefore do not experience the same relative increase in the amount of Fe-oxides in the residuum. The results of the modelling have implications for the formation of economic-grade iron ore deposits in metamorphic terranes. Fe-rich compositions that represent primary ore horizons prior to metamorphism may not experience significant enrichment. However, those horizons with lower primary iron contents may be significantly upgraded as a result of melt loss, thereby improving the overall grade of the ore system. The application of the modelling to the highly metamorphosed Palaeoproterozoic Warramboo magnetite–hematite deposit in the southern Gawler Craton suggests that melt loss during granulite facies metamorphism led to upgrading of sub-economic units within the low-grade Price Metasediments to form the economically viable granulite facies Warramboo ore system. The results of this study suggest that high-temperature metamorphic terranes offer attractive exploration targets for magnetite-dominated iron ore deposits.

1. Introduction

Hematite ore has traditionally been considered to be of greater economic importance than magnetite ore, as high-grade hematite ore contains fewer impurities and therefore has lower processing costs (McKay et al., 2014). Australia is one of the largest global producers of iron ore, and the dominant ore exported by Australia is hematite ore (McKay et al., 2014). However, there has been a gradual decrease over time in the discovery of large hematite ore bodies, as well as a decline in the quality of hematite ore exported from large-scale producers such as Australia (McKay et al., 2014; Mudd, 2010). As a result, magnetite deposits are increasingly generating economic interest, as simpler procedures for concentrating the ore allow for the formation of a high quality beneficiation product that attracts high prices (IronRoad, 2014; McKay et al., 2014). Magnetite deposits hosted in granulite facies rocks are additionally of economic interest, as the coarse-grained nature of the rock allows for easier concentration of the iron ore (e.g. IronRoad, 2014).

In the southern Gawler Craton, the Warramboo deposit is an example of an economic-grade, granulite facies, magnetite-dominant iron ore deposit (Figs. 1, 2). Recent work has correlated the magnetite gneisses at Warramboo to the Price Metasediments, a sequence of magnetite and hematite-bearing phyllites in the southern Gawler Craton (Fig. 1; Lane et al., 2015). The stratigraphic links between the greenschist facies Price Metasediments and the granulite facies magnetite gneisses that comprise the Warramboo deposit provide an opportunity to model the effect of high-grade metamorphism and partial melting on the iron concentration of a primary magnetite and hematite-bearing sedimentary package.

An average pelite may produce up to 50–60 vol.% total melt at conditions attainable during orogenesis (Clemens, 2006; Clemens and Vielzeuf, 1987). As melts are mobile, and many granites contain appreciable volumes of crustal material, volume reduction in the source region associated with melt loss is a mechanism to concentrate elements such as iron in the residual rock package (e.g. Brown, 2013; Droop et al., 2003; Redler et al., 2013; Sawyer, 1994; Vielzeuf and Holloway, 1988; White and Powell, 2002; Yakymchuk and Brown, 2014). For a layered sequence that contains variable amounts of magnetite and hematite, up to and including ore-grade concentrations, the concentration of iron as a result of melt loss may be an important process in improving iron ore grades.

* Corresponding author.
E-mail address: laura.morrissey@adelaide.edu.au (L.J. Morrissey).

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In this paper we investigate the effect of melt loss on bulk rock iron content ($Fe_2O_{3(TOTAL)}$) and the proportion of magnetite and hematite using samples from the Price Metasediments. The computed metamorphic phase diagrams from the greenschist facies Price Metasediments are compared with those using compositions from the residual (melt depleted) granulite facies Warramboo deposit to show that melt loss from the Price Metasediments is a plausible mechanism to upgrade sub-economic Fe-bearing sequences. We also model the effect of varying oxidation state of the bulk rock and its impact on the proportion of magnetite to hematite.

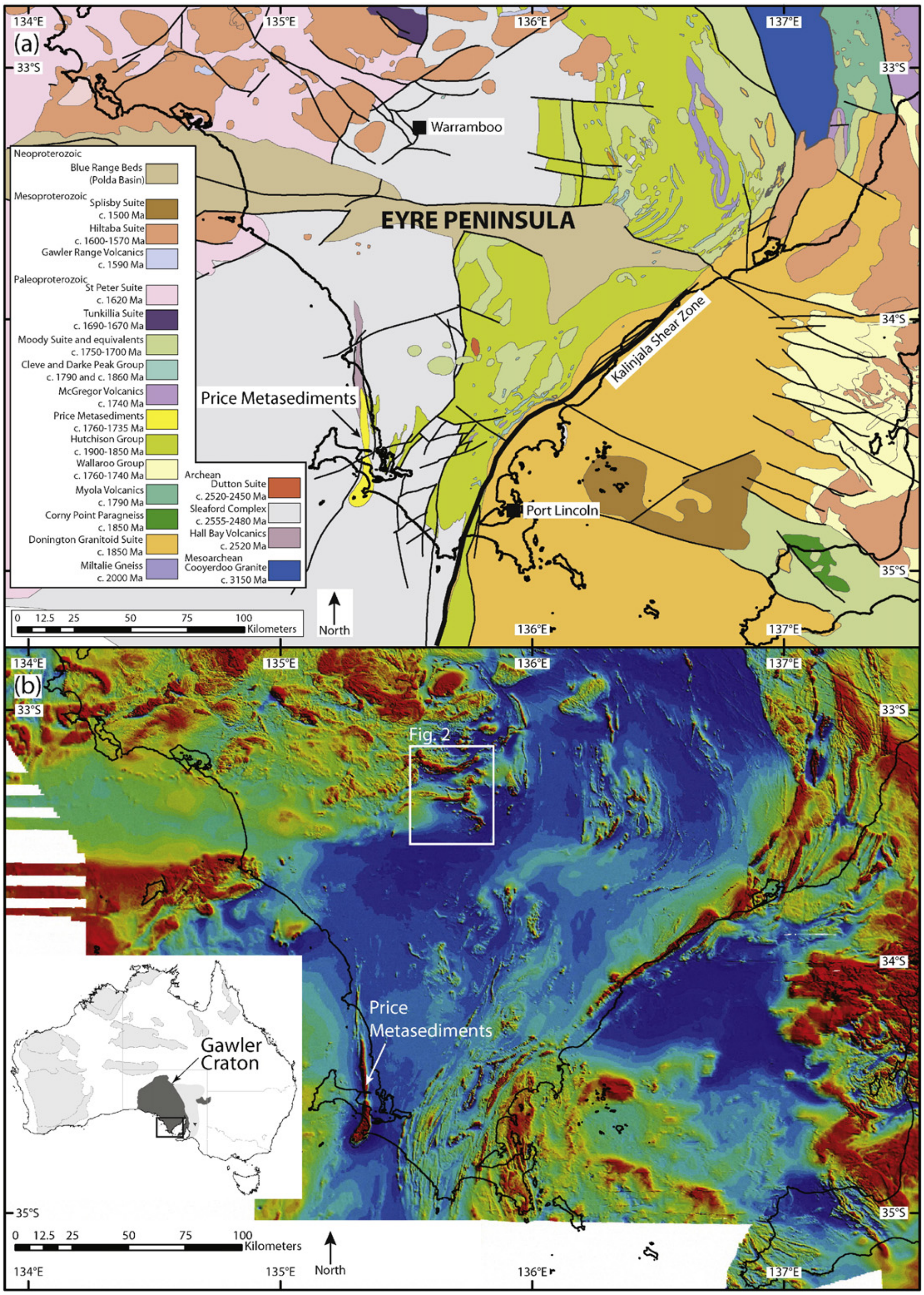

Fig. 1. Interpreted geology of the southern Gawler Craton, after Lane et al. (2015). b) TMI magnetic image of the southern Gawler Craton. (From SARIG <https://sarig.pir.sa.gov.au/Map>).