Australia's Iron Ore Product Quality

A Report on the Quality of Iron Ore Resources in Australia

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Abstract
Australia's iron ore production has seen strong growth over the past five decades and over this period of time a very significant change in the blend of Australian iron ore production has occurred. Initially there was a clear preference for the mining of Premium Brockman ores in the Pilbara, although these large resources are being depleted over time. This is reflected in Premium Brockman ores having the lowest expected resource life of the product types looked at in this report. The emergence of Channel Iron Deposits, Marra Mamba and hematite-goethite Brockman ores has been increasingly important in meeting global demand. Recent large increases in magnetite EDR and development of several magnetite projects indicate that magnetite will make an important contribution to the blend of iron ores being produced in Australia in the future.

The current resource life for iron ore of 70 years is skewed by the long life of magnetites of about 900 years. Excluding magnetites the life of Australia's iron ore resources are about 50 years. However, the resource life of Premium Brockman ore is 25 years. This report shows that Australia has large, high quality iron ore resources that at current production rates will sustain this nationally important industry beyond 2050.

Introduction
The Australian iron ore industry has experienced decades of strong growth and is likely to remain a major producer of high grade ores to the overseas market with 15% or 24 Billion tonnes (Gt) of economic demonstrated resources (EDR) in 2008 (GA, 2009). The development of Australia's iron ore industry followed the lifting of an embargo on iron exports in 1960 that was put in place in 1938 to protect the future of domestic iron ore use; due to 'direct shipping grade reserves' estimates of about 260 Million tonne (Mt). By 1960, estimates of reserves had not significantly increased, however exploration up to 2008 has rapidly increased Australia's EDR to be the third largest in the world behind Ukraine (19%) and Russia (16%). Australia now has a resource life of around 70 years and when magnetites are excluded the resource life is still long at 50 years. Total production of iron ore in Australia has increased from about 7 Mt to 354 Mt between 1965 and 2008.

Initially Premium Brockman ore was mined, however, with increasing demand from Japan and Korea, and more recently China, exploration and development of other iron ore products including Marra Mamba, Channel Iron Deposits (also known as pisolites), and hematite-goethite (H-G) Brockman ores occurred. While production of Premium Brockman ores has remained relatively constant since the 1970's other iron ore product types have increased in importance. The recent large additions of magnetite ores to Australia's EDR, totalling 6.8 Gt as of 2008, are likely to be an important contributor to the industry in the future.

Premium grade resources such as those mined in the Pilbara at Mount Tom Price and Mount Whaleback have been in production since the late 1960's. However expansion of these projects has been limited to maintain the resource life. Ores from surrounding deposits are blended with the premium Brockman ores to manage iron, phosphate, silica and alumina content so that the composition is suitable for further processing.

The purpose of this report is to develop an understanding of the evolution of the Australian iron ore industry by analysing data for iron ore production since 1965. These data will determine the quantity and quality of iron ore being produced as well as the resource life. This report examines the production histories and resource lives of the six major types of iron ore mined in Australia.

Background
The research was conducted at Geoscience Australia in Canberra. Major data resources include the Register of Australian Mining 1981/82 – 2008/09, Department of Mines and Petroleum 'Mines and Mineral Deposits' database, Bureau of Resource Sciences 'Australia's Iron Ore Resources' report (Pratt, 1993). Microsoft Office Excel was the primary software used.

For the purpose of the data analysis, six major classifications of product where developed.

Premium Brockman — The Premium Brockman ores are secondary enrichments of the Brockman Iron Formation, a Precambrian banded iron formation (BIF) (Harmsworth et al. 1990). The deposits contain high grade, low phosphorus, hard, microplaty hematitic ore. Currently there are only two deposits in Australia that produce Premium Brockman ore, that is, Mount Whaleback and Mount Tom Price. Typical composition for Premium Brockman ores is about 65% Fe, 0.05% P, 4.3% SiO_2, and 1.7% Al_2O_3.

Brockman — The Brockman ores are similar to the Premium Brockman ores, although they are not as hard, contain higher phosphorus, and have significant goethite content. They are formed by secondary enrichment of the Brockman Iron Formation. Significant production of Brockman ores comes from mines such as Channar, Paraburdoo, and Jimblebar. For example, Jimblebar reserves have a composition of 62.7% Fe, 0.10% P, 3.4% SiO_2, 2.4% Al_2O_3 and 4.0% LOI (loss on ignition).

Other Hematite — Other hematite ores, such as those mined at Middleback Range and the Goldsworthy region, form in a variety of geological contexts. What each has in common is that the primary mineralogy is hematite and that they do not fit into one of the other product types in this analysis. The composition of other hematites can range from Pardoo where reserves contain 57.4% Fe, 0.09% P, 7.07% SiO_2, 2.4% Al_2O_3 and 4.0% LOI to Koolan Island where reserves contain 63.8% Fe, 0.017% P, 6.13% SiO_2, 1.01% Al_2O_3 and 0.46% LOI.

Marra Mamba — Marra Mamba ores are characterised by ochreous hematite goethite mineralogy and occur in the Marra Mamba Iron Formation in the Pilbara. They are surface enriched BIFs with a brown colour due to the goethite content. A typical Marra Mamba ore contains about 62% Fe, 0.06% P, 3% SiO_2, 1.5% Al_2O_3, and 5% LOI. Significant deposits include those at Nammuldi, West Angelas, Mining Area C, Marandoo, Hope Downs, Cloud Break and Christmas Creek.

Channel Iron Deposit — Channel Iron Deposits (Pisolites) are becoming an increasingly important iron resource with significant increases in EDR at Marillana and Yandi in 2008. Ore bodies are found in ancient paleochannels resulting in cemented masses of concretionary iron oxides of hematite to hematite-goethite composition (Hall et al. 1990). Major producing Channel Iron Deposits (CID) include Robe River and Yandicoogina. Typical composition of ore from Yandicoogina is about 58% Fe, 0.05% P, 4.8% SiO_2, 1.4% Al_2O_3 and 10% LOI.

Magnetite — Large magnetite deposits such as those at Balmoral, Cape Lambert and Karara are increasingly attractive developments in the face of ever increasing demand. These deposits consist largely of magnetite and are most commonly BIF derived, although hydrothermal and igneous derived deposits do contribute significantly to economically demonstrated resources. Savage River pellets typically assay 66.3% Fe, 0.02% P, 1.9% SiO_2, 0.4% Al_2O_3 and 1.0% LOI

Initially data was gathered for all deposits contributing to Australia's current economically demonstrated resources. These data included production rates, mineralogy, location and deposit type. From there each deposit was put into the corresponding product type and the resource-production ratios (RP ratio or resource life) were calculated for each deposit. The

RP ratio was also calculated for the total resource and production rates for each product type. These figures indicate the production life of each deposit type if the production rate and EDR stayed constant (based on 2008 production rates). For example the resource life for Marra Mamba was about 50 years.

Secondly, historical production data were then retrieved for all active iron ore mines since 1965. Data from 1965 to 1990 were largely taken from Pratt's report on Australia's Iron Ore Resources 1993. More recent data were retrieved from various publications and databases including the Register of Australian Mining and Western Australian Department of Mines and Petroleum 'Mines and Mineral Deposits' database (MINEDEX), as well as annual reports from iron ore producers. All active mines for this period were categorised into their respective product type.

Where data were not available, estimations of production were made based on mine capacity and known production figures. Where only aggregated figures were available, such as the Newman group, production figures where based on the relative production capacity of the mines to the combined production figure. Production figures for magnetite ores reflect production of iron ore concentrate, which can be half the weight of magnetite ore mined.

A comparison of the total annual production from individual mines to the total production figures produced by ABARE was used as a measure of error, under the assumption that ABARE figures are accurate. The average difference in annual production was less than 3%.

Production figures were then sorted to display annual production by product type. These data were then graphed and interpreted.

Discussion

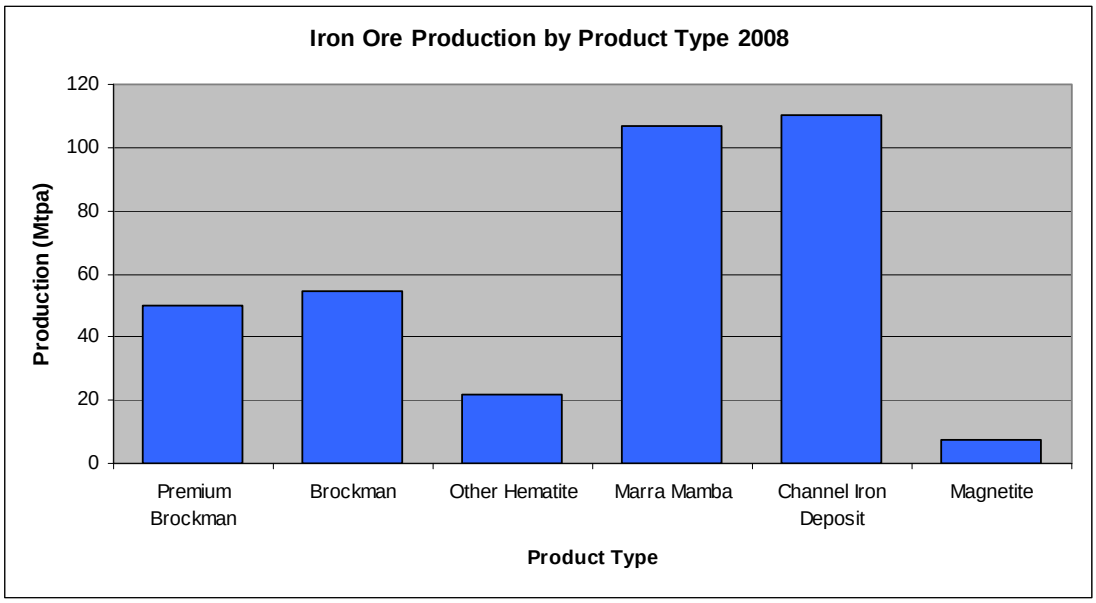

Figure 1. Iron ore production by product type for 2008.

The analysis revealed that production of Marra Mamba and Channel Iron Deposit ores made up more than 60% of iron ore production for 2008 (Figure 1). Magnetite production is low primarily coming from Middleback Range and Savage River. Production of Premium Brockman has remained relatively constant since the early 1970's. The production of Channel Iron Deposits is due to large production capacity at the Yandi, Yandicoogina and Robe River mine sites. Smaller but locally significant amounts of Other Hematites are produced at mines such as Koolyanobbing, Tallering Peak, Pardoo, Koolan Island, Middleback Range and Frances Creek.

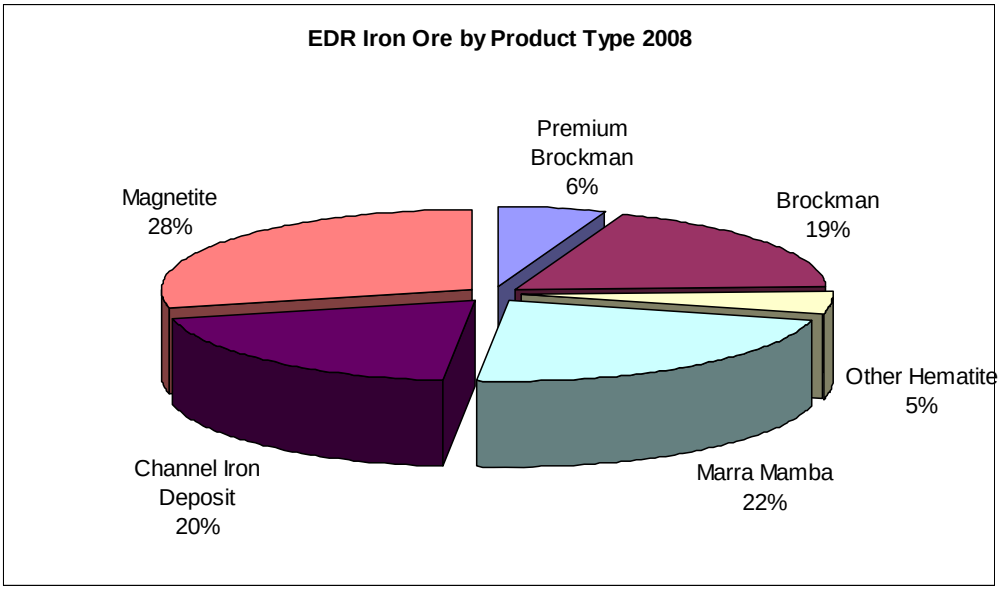

Figure 2. Australia's economically demonstrated iron ore resources (24 Gt) by product type.

The relatively low production of magnetite concentrate and high demonstrated resources (Figure 2) resulted in a very high RP ratio of around 900 years; for this reason it has been left out of figure 3. Figure 3 shows the projected life for each product type at 2008 rates of production and resource levels. Brockman has the longest projected resource life although current production rates (figure 1) are significantly lower than for Marra Mamba and Channel Iron Deposits.

The average resource life of iron ore in 2008 was about 70 years. However, magnetite ore skewed this figure somewhat because of the high R/P ratio. Without magnetite the resource life of Australian iron ore is 50 years at current production rates, prices and technology. The lowest RP ratio, 25 years, is Premium Brockman with about 1.3 Gt of remaining EDR. Total production of Premium Brockman up to 2008 is about 2 Gt with a total of 3.3 Gt expected to have been produced when the resource becomes exhausted.

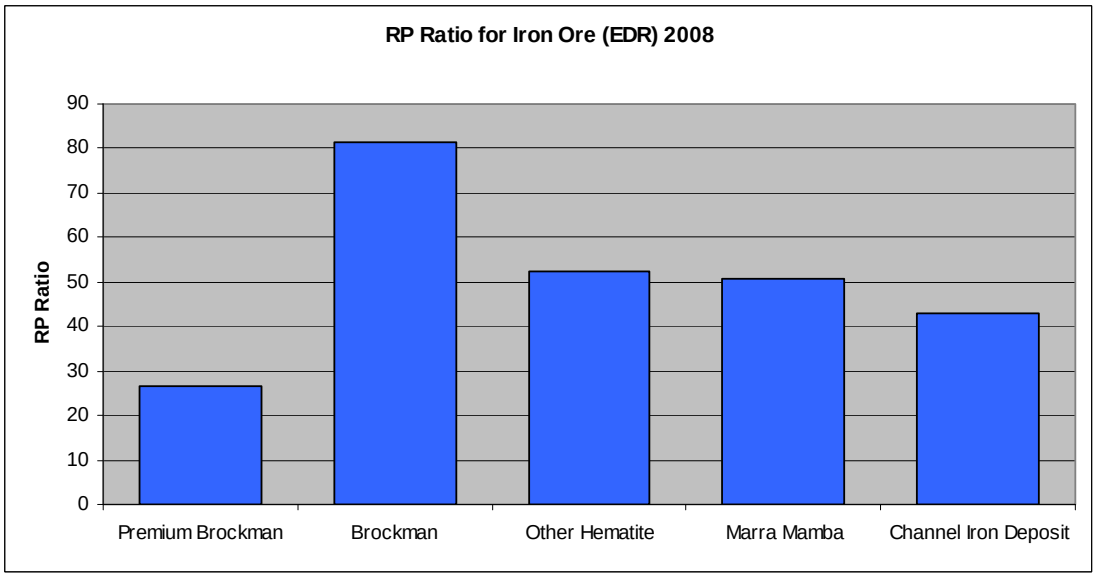

Figure 3. Resource-production ratio for EDR iron ore 2008.

Iron ore production since 1965 is shown in figure 4. The growth of the industry and relatively constant production of Premium Brockman ore after 1970 is clear. The development of Marra Mamba and Channel Iron Deposits can also be clearly distinguished at an increasing rate up to present. The change in the blend of Australian iron ore products is highlighted in figure 5, which shows the change from small production of other hematites followed by the development of premium Brockman production and the subsequent inclusion of Marra Mamba, Brockman and Channel Iron Deposits leading to the blend produced in 2008 as seen in figure 1.

Magnetite production has remained relatively constant throughout the 43 year period mainly from Savage River. While Marra Mamba production was only developed in 1989 with the development of the Newman satellite orebodies. Marra Mamba production ramped up with the opening of Marandoo in 1994, West Angelas in 2003, Mining Area C in 2004 and more recently Cloud Break, Christmas Creek and Hope Downs.

Brockman ore production began in 1973 with Paraburdoo producing to a capacity of 15Mtpa. It was not until 1989 and 1990 when Jimblebar and Channar mines opened up. Subsequent development of Newman satellite orebodies, Brockman No. 2 and Eastern Range have maintained the relative proportion of Brockman ore in the Australian blend (figure 5).

At the beginning of 2009, Channel Iron Deposits accounted for about 1.4Gt of Australian iron ore production since the late 1960's. The 1999 opening of a second mine at Yandicoogina by Hamersley Iron, along with various expansion projects at the Robe River Deepdale deposit and the BHP Billiton Yandi site, account for the rapid growth in CID production.

Conclusion

This data analysis shows a very significant change in the blend of Australian iron ore production over time. An early preference was shown for the mining of premium Brockman ores, as these have relatively low levels of contaminants such as phosphorus, silica and alumina. Channel Iron Deposits also have low phosphorus content and are generally large and shallow deposits making them attractive prospects as demonstrated by the development of Robe River, Yandi and Yandicoogina deposits.

The short resource life of Premium Brockman ores is not reflected in the aggregated figure of 70 years for Australia's iron ore resources. As there are no undeveloped EDR of premium Brockman ore and current production is being limited to preserve resource life, the iron ore industry will be looking to the Marra Mamba and Channel Iron Deposits to fill demand. The development of magnetite deposits is currently occurring at the Sino Iron Project and Karara Project. Other magnetite projects are in the planning stages such as Southdown and Ridley. Magnetite will constitute an increasing proportion of Australia's iron ore product blend in the future.

The product types produced over the past 45 years has changed from being predominantly a Premium Brockman to a mix now including Brockman, Other Hematites, Marra Mamba and Channel Iron Deposits. The proportion of Premium Brockman, Brockman and Other Hematites will continue to fall with Magnetites becoming an increasing proportion of the product types. Marra Mamba and Channel Iron Deposits will continue to be an important part of Australia's product types. This report has shown that Australia has large high quality iron ore resources which will sustain the industry for over 50 years based on current resources and production rates.

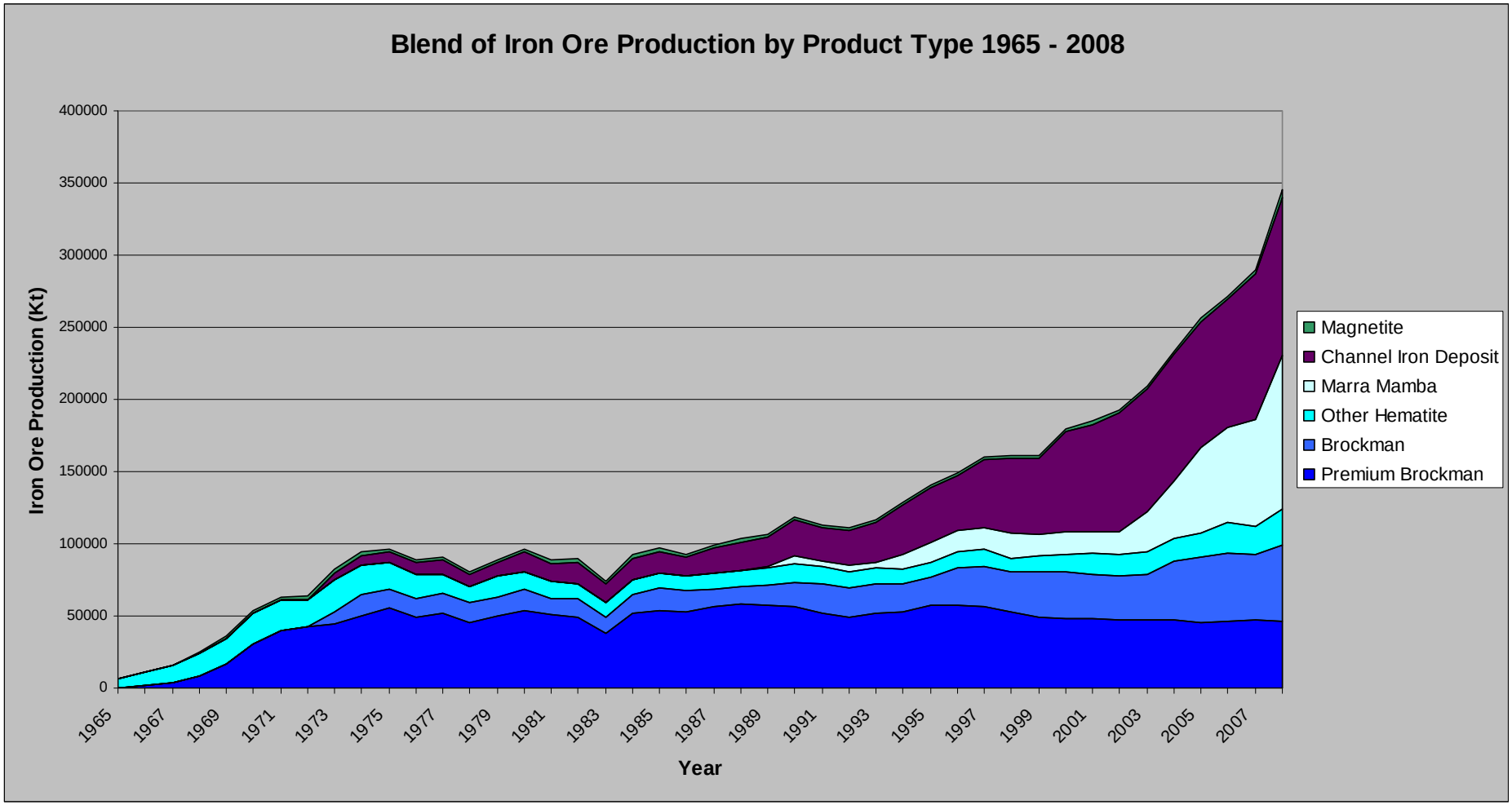

Figure 4. Production or iron ore since 1965.

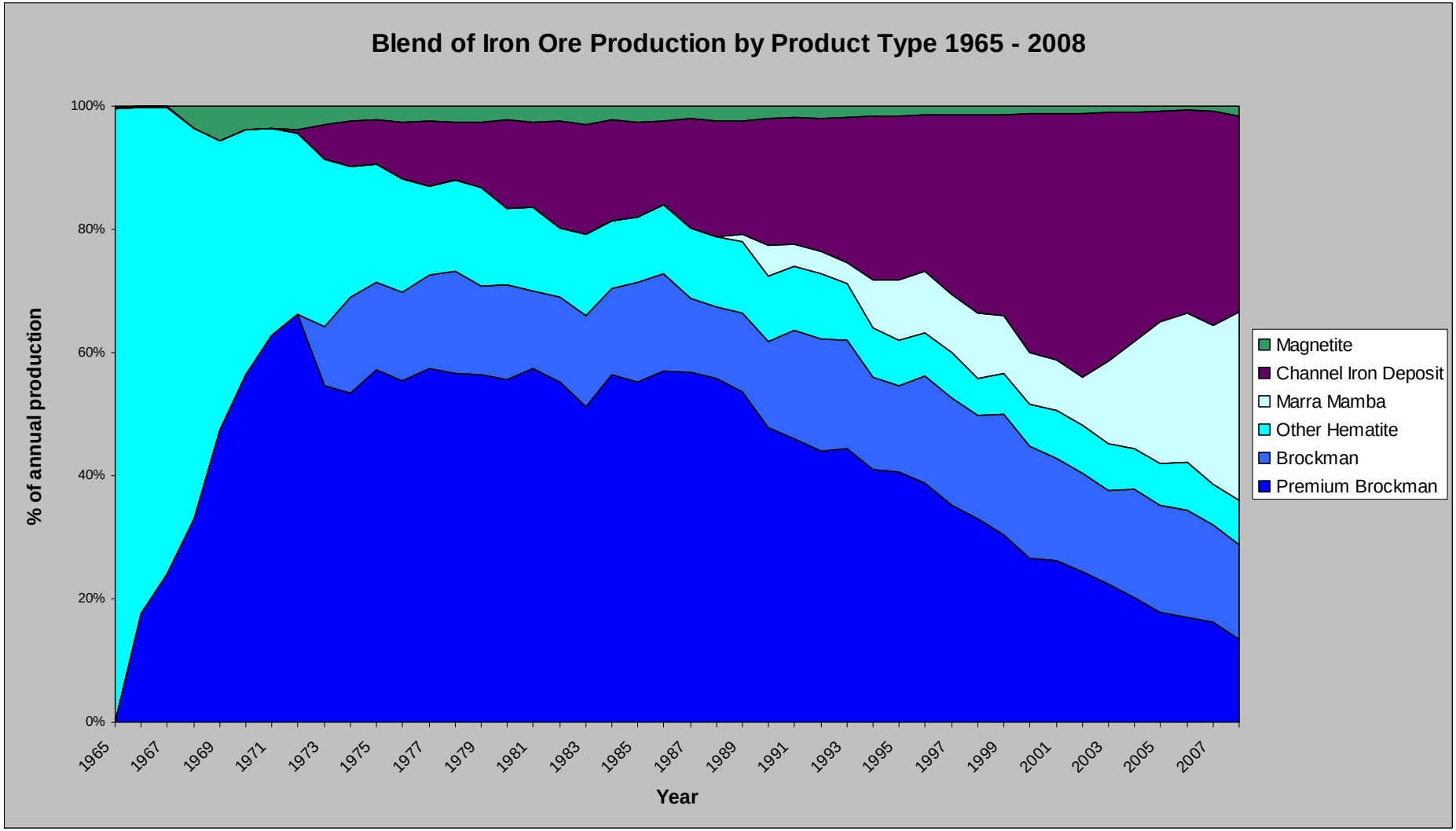

Figure 5. 100% graph of historical iron ore production (Identical data to figure 4.)

Acknowledgments

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