our quality story

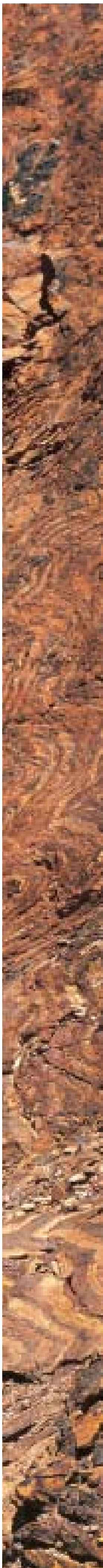
bhpbilliton

Iron Ore

This publication answers a number of technical questions that customers and potential customers have asked. The answers fit logically into a theme: Our quality story. We are proud to tell that story, because those continuing technical and organisational accomplishments show how we reliably meet the current and future needs of our customers.

Graeme Hunt

PRESIDENT
BHP BILLITON IRON ORE & BOODARIE IRON



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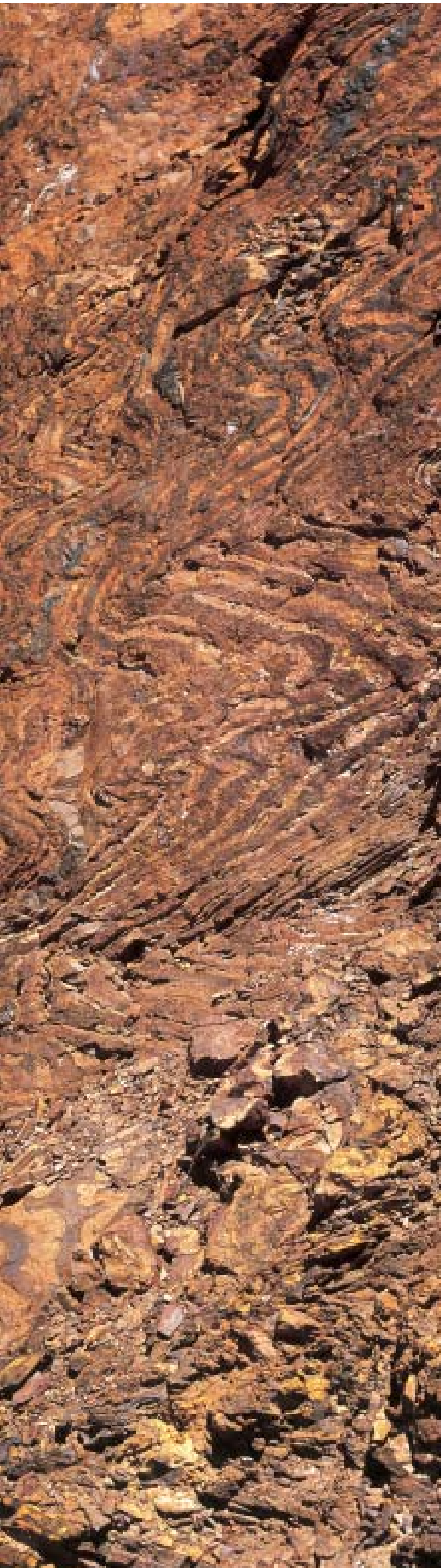


We begin with the formation of the ores about 2500 million years ago, and end with the performance of our products in our customers' steel plants today.

"Our quality story" is intended for people who already know something about iron ore mining, who may have visited some of our mine sites, and who may already be our customers.

For more general information on our operations, contact your local BHP Billiton representative (see page 60).

Left *A folded section of banded iron formation.*

Quality strategy throughout the production process

BHPBIO's quality strategy has always aimed at minimising the variability of our shipped ore. The results prove the strategy has been effective, and we have been able to improve it further by bringing in fully integrated planning. Our customers are well aware of our success at maintaining quality and controlling variability. They monitor it closely.

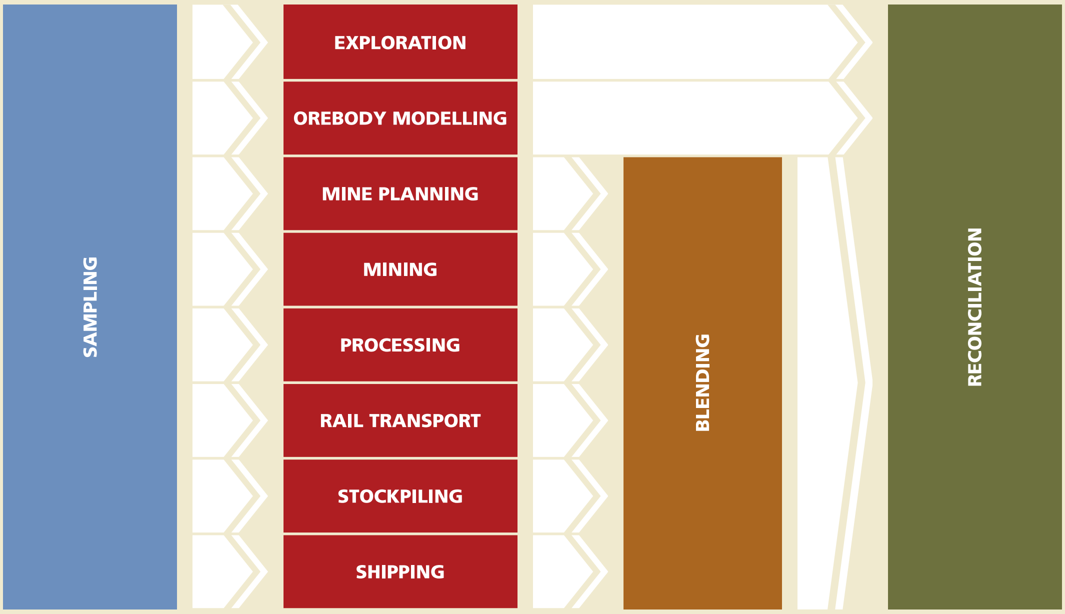
Our quality assurance system conforms to the International Standard AS/NZS ISO 9001:2000. Quality control systems cover all processes from drilling exploration holes, forming the geological model and the mining model, working out the pit designs and long-term plans, deciding on short-term plans and the daily pattern of blastholes and blocking them into recoverable sizes and product definitions. All these processes are controlled by the Quality Controllers through to shiploading.

Both our quality strategy and the process flow are subject to continuous improvement and change. We keep up with the technology of the steel mills, the requirements of our customers and consider the need for new products.

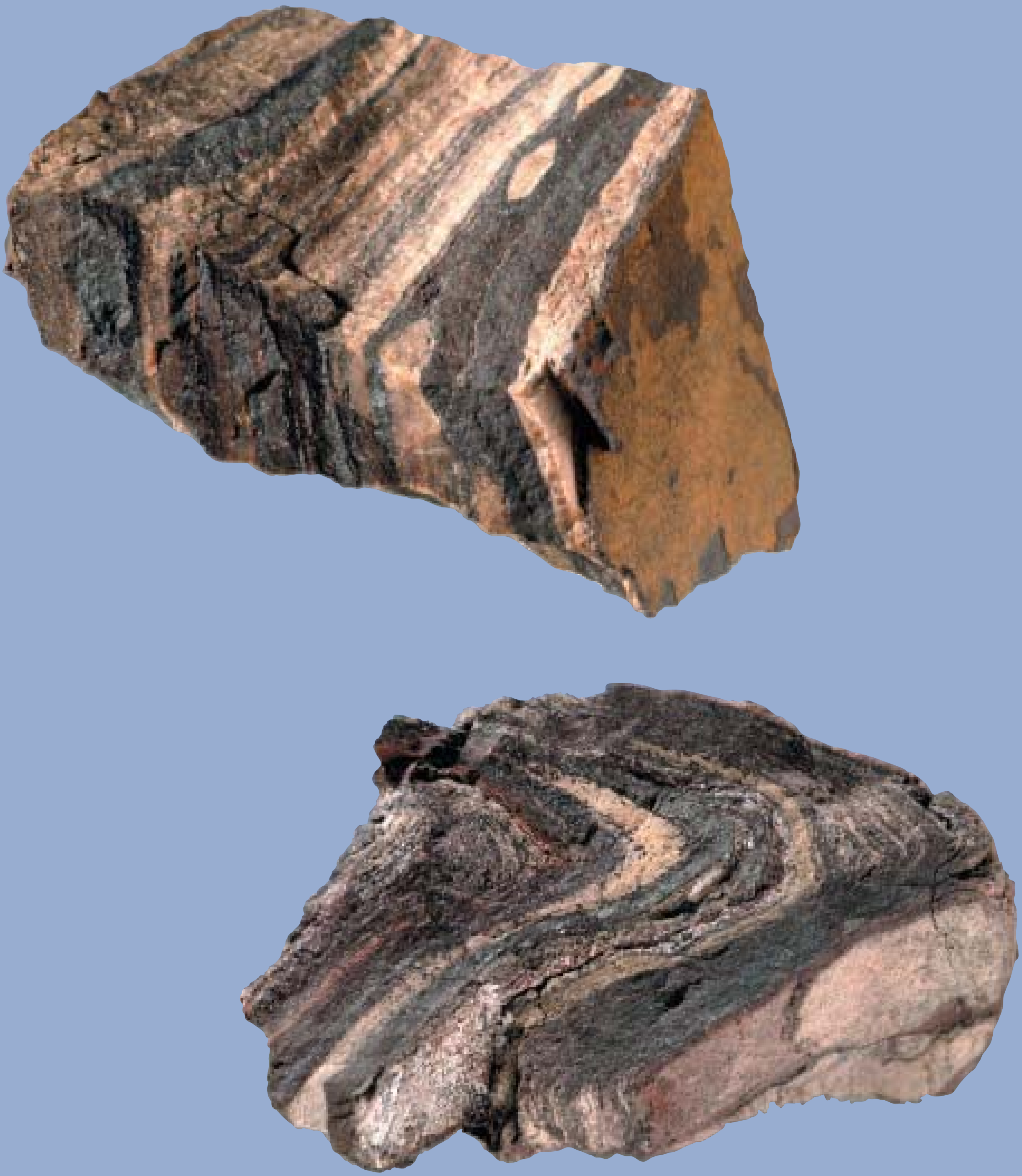
Our formal improvement process is called the Value Improvement Process (VIP). It is a systematic way to brainstorm and challenge our processes with questions such as: Can we do it better? Should we be doing it a different way? Once a process is singled out in this way in VIP, it is tackled by an operational excellence team. Their questions are: Will it improve the business? Is it cost effective? If it passes these tests, operational excellence coaches work with the people in the right areas to carry out the improvement.

Nothing is taken for granted in VIP. Even the simplest processes can become a subject of the VIP process.

Quality process flow



Page **Contents**



Above *BIF from the Pilbara*

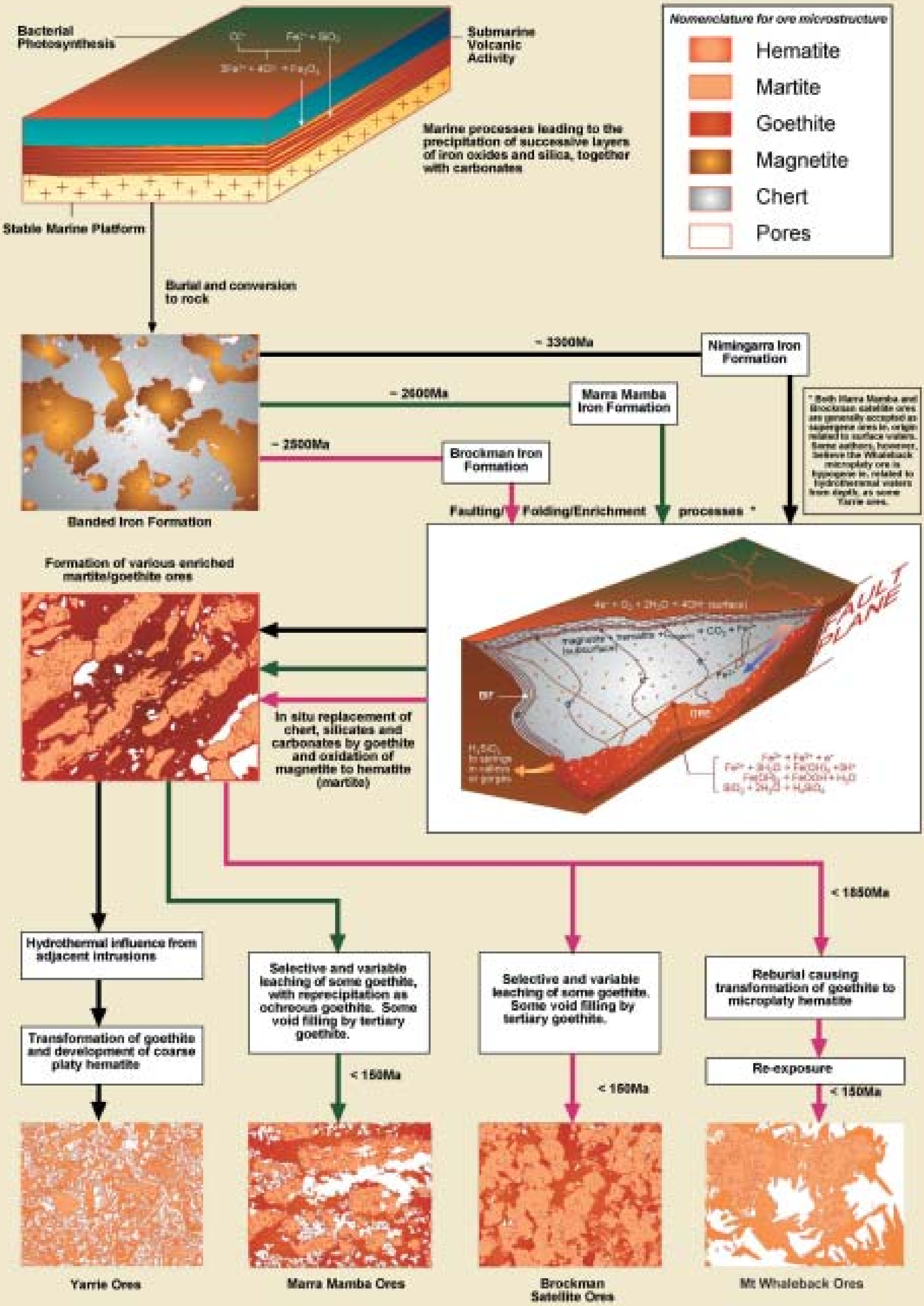
Formation of ore deposits

The rocks that now host the iron ores of the Hamersley Province were laid down during the Archaean and Proterozoic geological periods (see the glossary on page 16). Chemical sediments were laid on the floor of a large ocean basin as a result of undersea volcanic activity and oceanic chemical processes. These chemical sediments were later buried under several kilometres of other sediments (dolomite, shale, etc). The compaction from those overlying sediments dehydrated the chemical sediments and converted them into the solid rock we know today as banded iron formation, or BIF. Where the early BIF is unaltered today, it can still be seen to be made up of various iron oxides, chert, silicates and carbonates.

There are a number of BIF areas in the Pilbara, but the main ones of interest are the Marra Mamba and Brockman Iron Formations in the Hamersley Province, and the older Nimingarra Iron Formation in the Yarrie area. The Brockman BIF was laid down about 2500 million years ago and the Nimingarra BIF about 3300 million years ago. The BIF in both areas was later lifted above sea level by earth movements and much of the sedimentary rock on top of the BIF was worn away by erosion over hundreds of millions of years.

Where the BIF was exposed to groundwater flow at the land surface, in certain locations it was gradually converted to ore. The processes involved converting the original iron-oxide minerals to other iron oxides, and replacing the chert, carbonate and silicate minerals by iron hydroxides. This process is known as *supergene enrichment*. Other processes such as leaching, metamorphism due to re-burial, occasional hydrothermal activity (Yarrie), and later re-exposure have further changed some of these BIF-derived ores and yielded the wide variety of ore types in the Hamersley Province.

Genesis of BIF Derived Iron Ores

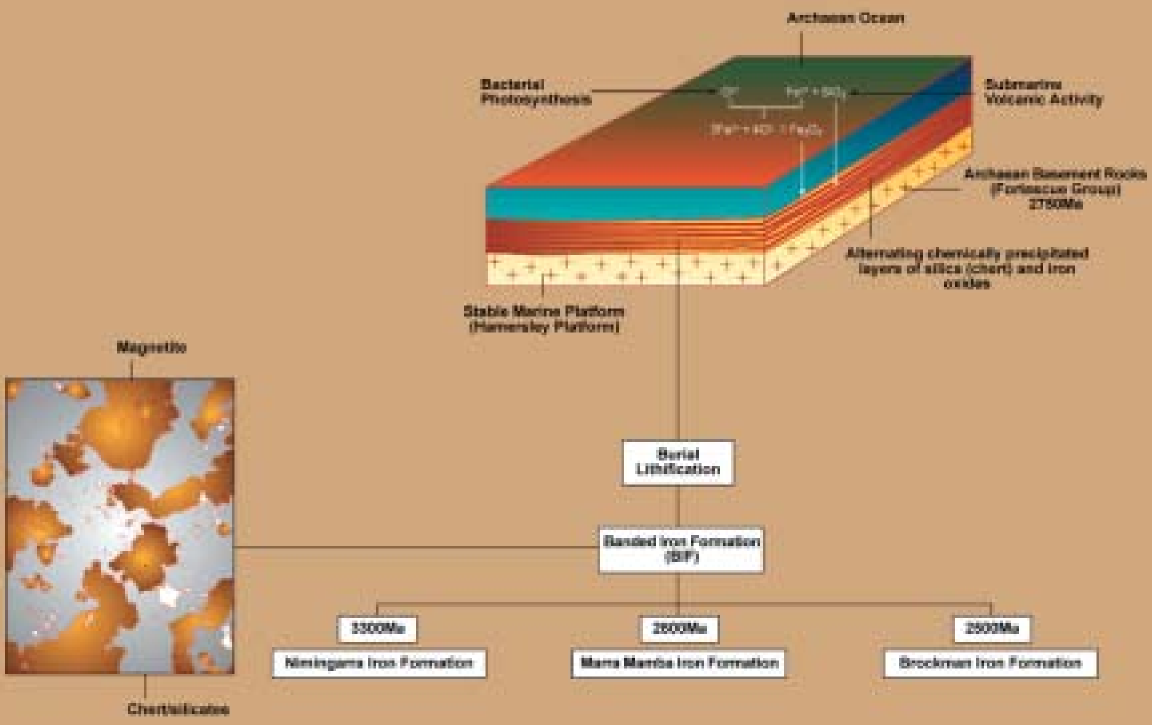


The origin of banded iron formations

Most of the world's large iron ore deposits came from the enrichment of banded iron formations. The Western Australian Pilbara BIFs were laid down as chemically precipitated sediments in large ocean basins between 3300 million years ago (Yarrie area) and 2500 million years ago (Hamersley area). Large amounts of iron and silica were being released into the ocean from undersea volcanoes. Because of the relative lack of oxygen in the water, the iron could be distributed widely and evenly before it settled on the ocean floor. It settled as layers of iron oxides (magnetite and, less commonly, hematite), along with carbonates, and silica in the form of chert (a variety of quartz) and iron silicates. Sediment bands that were rich in iron oxides alternated with bands that were poor in iron oxides. The alternation is believed to have been caused by seasonal (annual) changes.

The early BIFs were later buried under younger rocks (dolomite, shale and volcanics, etc) and that burial then compacted, dehydrated, and recrystallised the early BIFs to the rock we now know as BIF. They are the banded formations found in the Pilbara, for example, in the Marra Mamba, Brockman and Nimingarra Iron Formations.

BIF formation

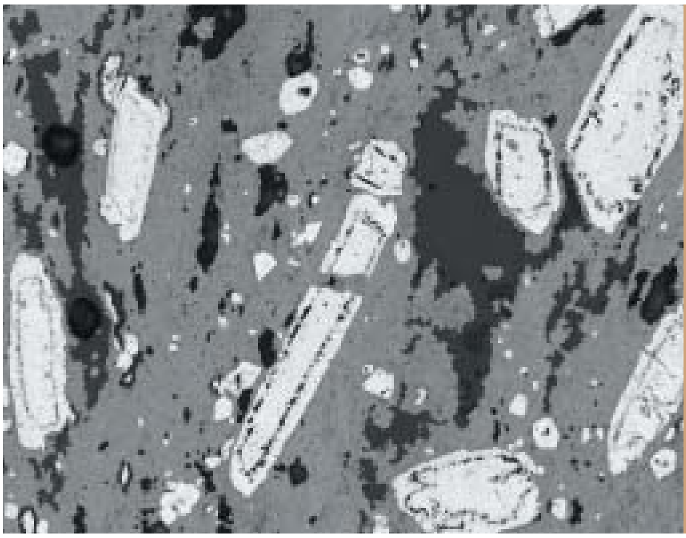


The origin of Mt Whaleback ores

These hematite ores were formed by *supergene enrichment* within the Dales Gorge and Joffre Members of the Brockman Iron Formation. The process is best explained by the CSIRO-AMIRA genetic model: for enrichment to take place, folded BIF beds must be part of a rock system that allows the access of groundwaters derived from the surface. A second essential is for some structural feature (such as a fault or fold) to allow initial groundwater access to BIF that lies well below the surface. As the groundwater flows through the system, silica/silicate/carbonate minerals are systematically replaced by hydrous iron oxides (the mineral goethite). This replacement (and hence ore formation) starts at the initial contact of groundwater and BIF, and then grows towards the surface. Experimental evidence shows that the rate that quartz dissolves may be greatly increased by reaction with ferrous iron in groundwater, if a cyclic reduction-oxidation system is set up. This replacement perfectly preserves the original banding and textures in the BIF.

The Mt Whaleback ores are essentially free of goethite. The CSIRO-AMIRA model explains that this happens because the ores were originally formed by a *supergene metasomatic* process around 2000 million years ago, when first exposed at the surface. Then, some 1850 million years ago, the enriched BIF was re-buried under a great depth of new sediment and then subjected to low grade *burial metamorphism*. This converted most of the goethite (iron hydroxide) to a secondary microplaty form of hematite. These martite-microplaty hematite [M-(mplH)] ores are typical of Mt Whaleback, but can be found in smaller amounts in some of the Brockman satellites.

A recent hypothesis proposes that the origins of the martite-microplaty hematite deposits are structurally controlled along old normal fault systems, and result from heated water removing gangue minerals, yielding residual concentrations of iron. This is known as *hydrothermal* or *hypogene enrichment* (i.e., related to heated waters from below). At this time, there is not a lot of documented evidence to support this hypothesis.

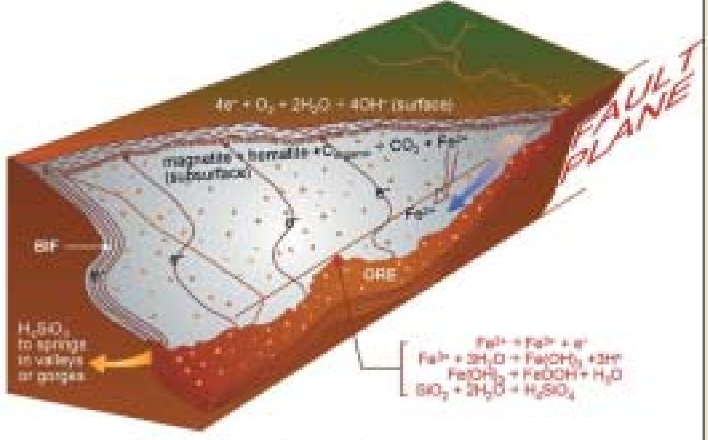


***Left** Mt Whaleback lump sample, showing sub-parallel martite rafts enveloped by microplaty hematite replacing BIF chert. Black areas are pores. Reflected light micrograph of polished section. Field of view is 0.69mm across.*

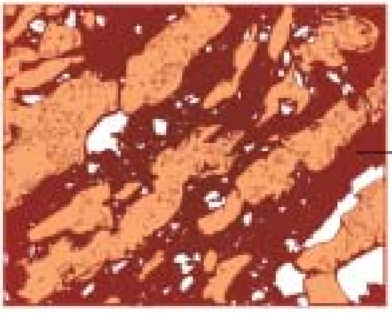
BIF to Mt Whaleback

Brockman Iron Formation

Joffre and Dales Gorge Members



Metasomatic replacement of chert and silicates by goethite and oxidation of magnetite to hematite (martite)



Martite-Goethite Ores

Reburial at 1850Ma.
Burial Metamorphism
Goethite converted to microplaty hematite

Re-exposure round 150Ma

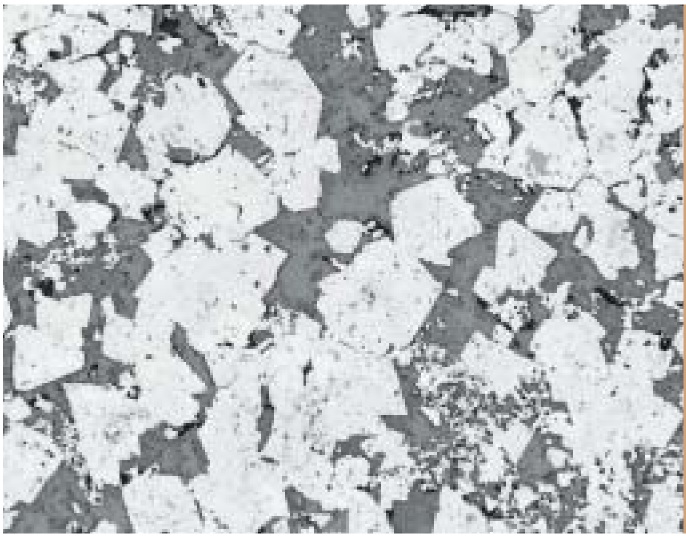
MT WHALEBACK

Martite-microplaty hematite ore

The origin of Brockman satellite ores

The Brockman satellite ores, known collectively as martite-goethite (M-G) ores, are much more recent than the Mt Whaleback ores. However, the first stages in the ore-forming process were much the same. Like the Mt Whaleback ores, they were also formed by *supergene enrichment* within the Dales Gorge and Joffre Members of the Brockman Iron Formation. They are widely distributed in the Hamersleys, and they are the more typical Brockman ore. In the Newman area, there are deposits to the north and east of Mt Whaleback, along the Ophthalmia Range and out to Jimblebar.

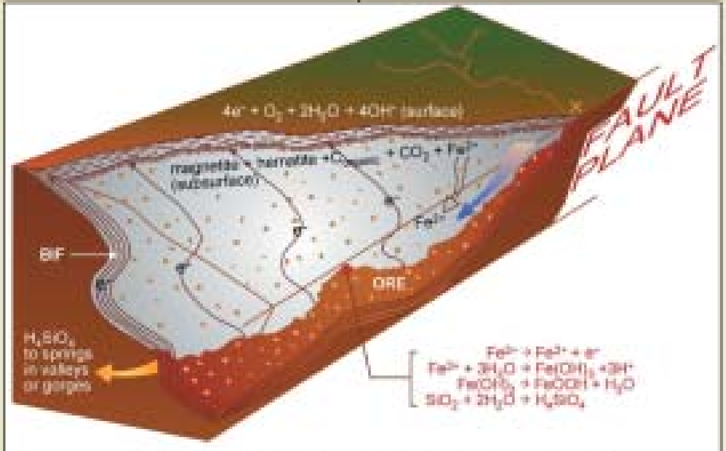
The Brockman satellite ores formed relatively late in the geological history of the Hamersley Geological Province, around 150 million years ago, probably during the *Mesozoic-Tertiary*. They appear to be associated with the *Mesozoic* drainage pattern that controls the river systems today. In contrast to Mt Whaleback-type ores, these martite-goethite ores have not been subject to burial metamorphism.



Left *Martite crystals in matrix of metasomatic goethite replacing the BIF chert component.*

Brockman Iron Formation

Joffre and Dales Gorge Members



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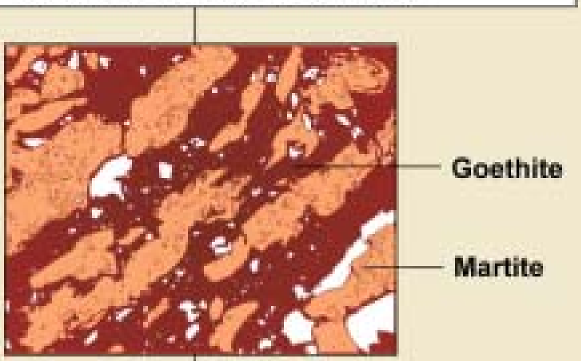
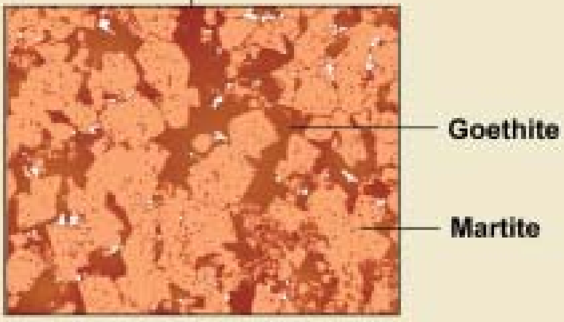


150Ma

Selective and variable leaching of some goethite. Some void filling by tertiary goethite



Martite-Goethite Ores

BROCKMAN SATELLITES

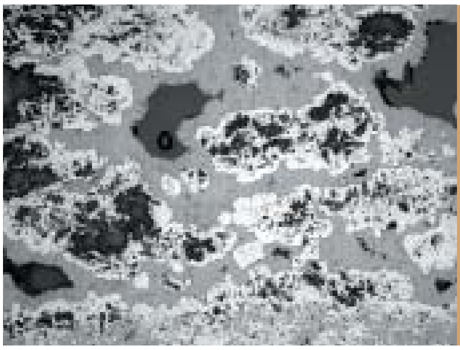
The origin of Marra Mamba ores

The Marra Mamba ores, also known as martite-goethite (M-G) ores, are also much more recent than the Mt Whaleback ores. Again, the first stages in the ore-forming process were much the same. However, these ores were formed by *enrichment* within the Newman Member of the older Marra Mamba Iron Formation. The Newman Member lies under the Brockman Iron Formation and also under the thick layers of dolomite (Wittenoom Dolomite) and shale (Mount McRae Shale) which lie below the Brockman Iron Formation.

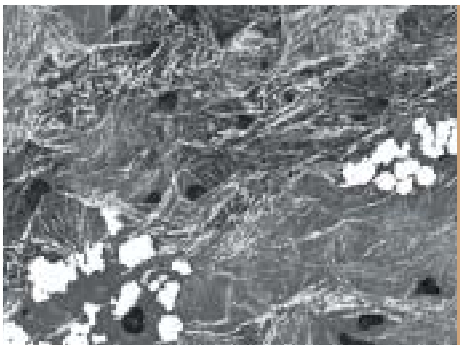
These Marra Mamba ores (of which MAC™ and Orebody 29 are a typical examples) differ from the Mt Whaleback [M-(mplH)] and Brockman Satellite (M-G) ores in that the gangue in its original BIF contained abundant carbonate, together with the chert and silicate minerals. The ore-forming enrichment process replaced these with goethite, as in the Brockman satellite model. This goethite sometimes remained unaltered. More commonly, later leaching/reprecipitation by groundwaters progressively changed it to yellow, non-crystalline *ochreous* goethite (limonite). Ores rich in this very porous ochreous material are known as martite-ochreous goethite (M-oG) ores, and were extensively formed in some parts of Orebody 29. At Mining Area C, less leaching has generally yielded a harder M-G ore than those at Orebody 29.

Like the Brockman Satellite ores, these ores were probably formed during the *Mesozoic-Tertiary* around 150 million years ago, and again appear to be associated with the *Mesozoic* drainage pattern that controls the river systems today. Unlike the martite-microplaty hematite ores, these martite-goethite ores have not been metamorphosed.

Note that both Marra Mamba and Brockman M-G ores often contain late-stage goethite, deposited in voids throughout the ore, particularly in upper levels of the deposits.



Left *Porous and skeletal martite rafts (white) in dense secondary goethite (grey). Pores are black.*

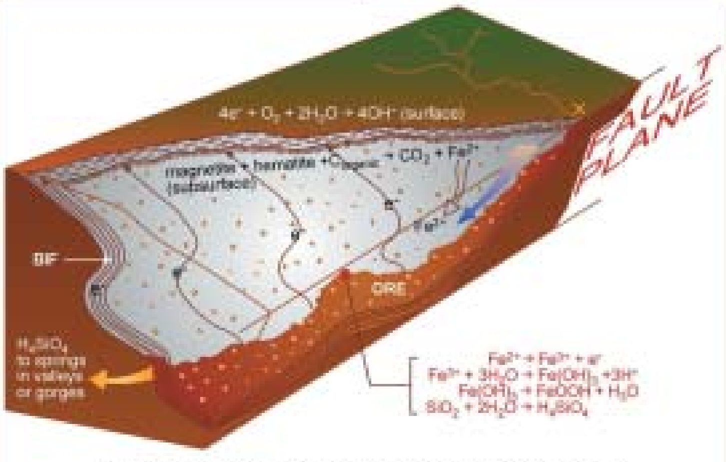


Left *Marra Mamba ore (Orebody 29) showing goethite replacing fibrous BIF iron silicate minerals, with areas of martite crystals (white) in quartz. Black areas are pores. Reflected light micrograph of polished section. Field of view is 0.69mm across.*

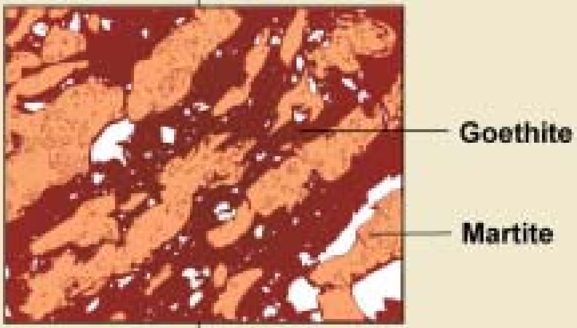
BIF to Marra Mamba

Marra Mamba Iron Formation

Newman Member

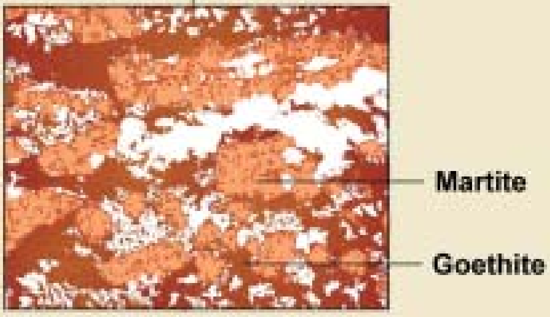


Metasomatic replacement of chert and silicates by goethite and oxidation of magnetite to hematite (martite)



150Ma

Leaching of metasomatic goethite and re-deposition as secondary goethite in voids



MAC™

Martite-Goethite ore

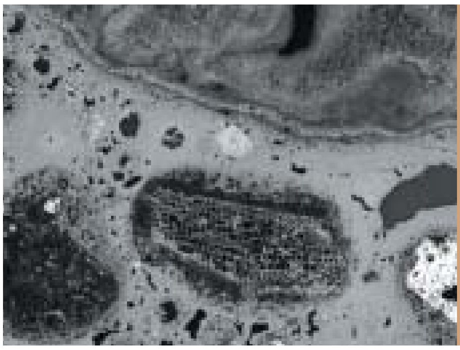
The origin of Yandi Channel iron ore deposits

The development of these ores began with hematite-rich fragments accumulating in soils that were derived from an iron-rich lateritic surface. The lateritic surface had developed on underlying iron-rich sediments, such as BIF and intrusive basic igneous rocks. The warm-to-tropical climate at the time favoured the precipitation of further goethite as concentric layers around these hematitic cores, as well as around fragments of woody material (later replaced by goethite).

Weathering and erosion gradually moved the iron-rich gravel-like material into the bed of an incised meandering low-energy stream. It concentrated there during the Tertiary (5 to 25 million years ago). Later more goethite was deposited in the matrix between the fragments and cemented them into the characteristic *pisolitic* texture we see today.

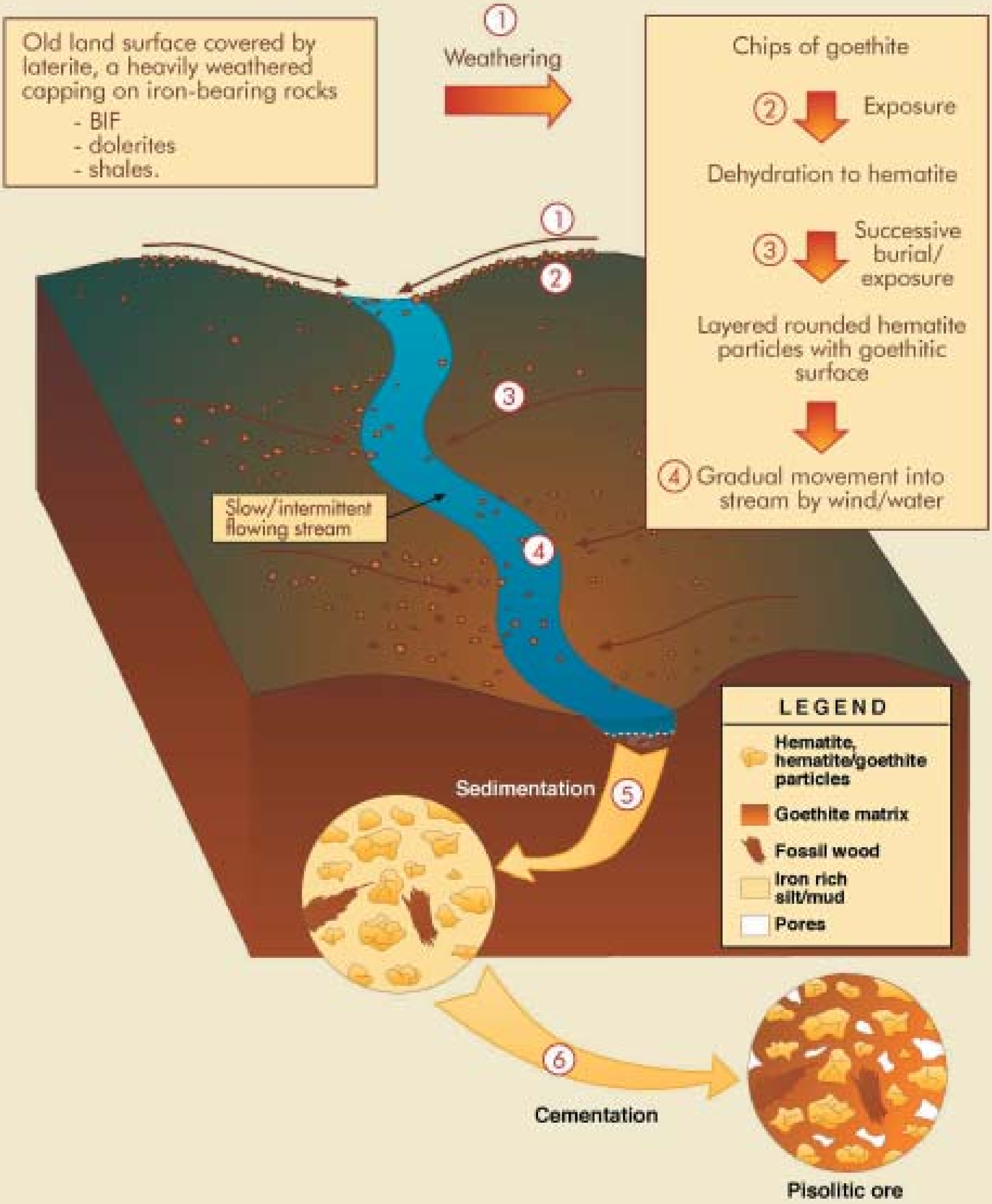
Later in the Tertiary, the climate again changed and the deposits were partially eroded, leaving some remnants perched above the present river valleys as low *mesas*. These deposits used to be called pisolitic limonites, but they are now referred to as channel iron deposits. They have been found in quantity in the Marillana Creek and Robe River areas, but small residual accumulations are widespread in the Hamersley Range.

Deposits have been found that are up to 750 metres wide and 70 metres thick. They are covered either by weathered ore or gravels, and they rest on conglomerates. Their iron content is typically 40 to 60 weight percent.



Left *Reflected light micrograph of polished section of Yandi fines showing core regions of porous earthy goethite (top and left), fossil wood (centre) and hematite (right) enclosed by porous zones and cemented by dense colloform goethite.*

Genesis of Yandi Channel Ore Deposits

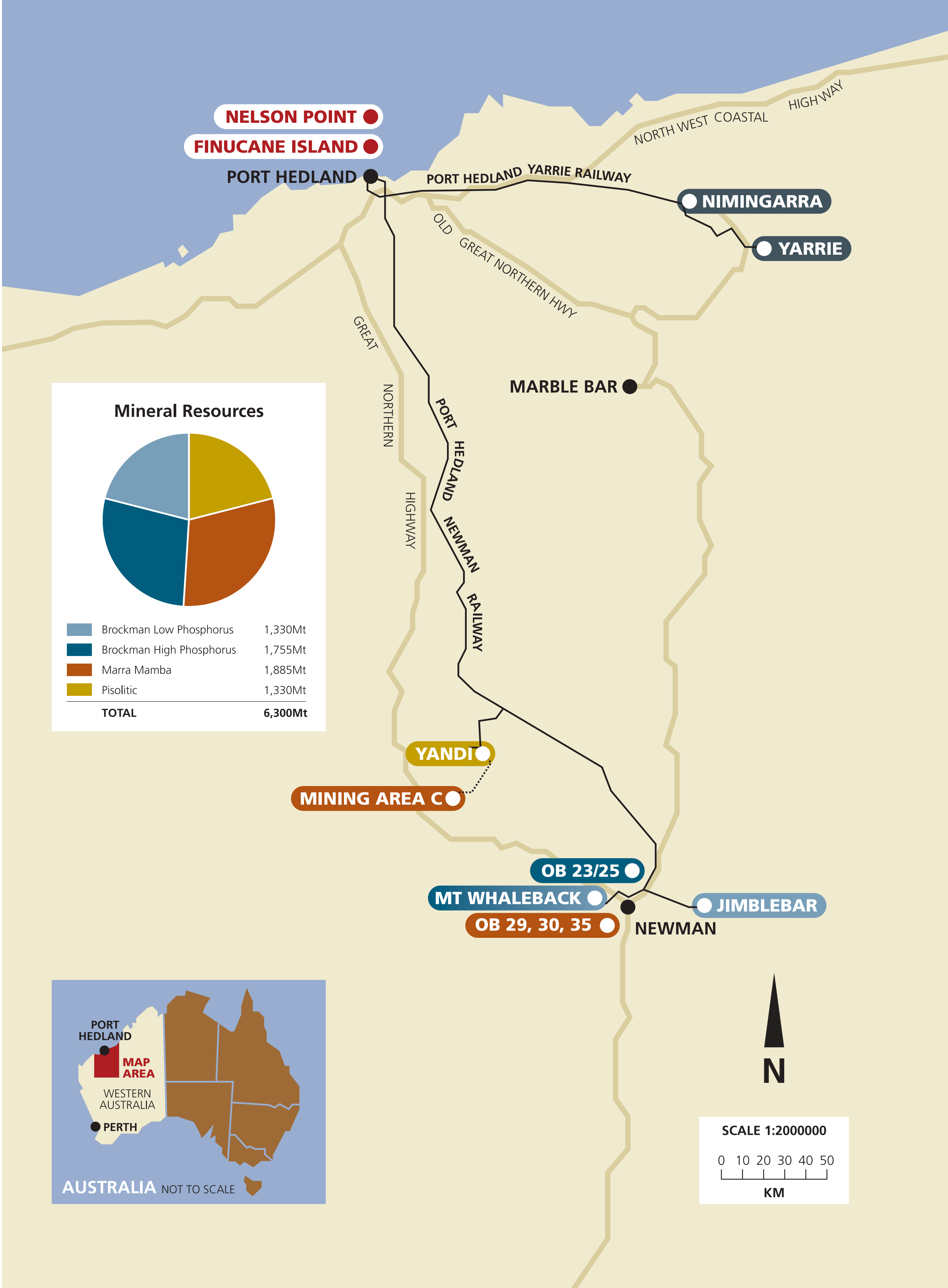


Glossary of terms

Archaean Ocean	Archaean simply means ancient. It generally refers to rocks older than 2500 million years. It is followed by the Proterozoic era.
Basement Rocks	This is a term commonly applied to metamorphic or igneous rocks that lie beneath a sedimentary sequence. In other words, the pre-existing rocks on which the sediments above are deposited. It also implies that these basement rocks act as a stable base and do not deform by folding.
Burial Metamorphism	A process that changes the texture and internal structure (but usually not the composition) of a rock or unconsolidated sediment because of the high pressure and temperature from being buried under later sediments.
Enrichment	Natural processes that increase the metallic content of an ore. (In this ore-formation outline, the process is supergene metasomatic replacement.)
Fault	A fracture or fracture zone in rock where there has been displacement of the two sides relative to one another. Faults typically open up channels for groundwater or mineralising fluids.
Fold	The structure of rock layers bent into a dome (anticline) or basin (syncline).
Gangue	Undesirable (uneconomic) minerals in an ore, usually non-metallic ones.
Goethite	A later derived oxide often formed by weathering of hematite. Composition FeO (OH).
Groundwater	Water that permeates rock masses, filling their pores and fissures. The water collects at or below the water table and usually originates from rain. (The water table is the upper limit of water saturation in porous rocks.)
Hematite	The principal iron oxide mineral present in iron ore deposits in the Newman area. Composition is Fe_2O_3.
Hydrothermal	A term applied to hot fluids or vapours that are high in water content, usually coming from volcanic activity or igneous intrusions.
Hypogene	Processes that involve upward-moving heated water coming from inside the earth's crust. Hypogene enrichment takes place when this heated water dissolves (or removes) metals to produce an orebody.
Igneous Intrusions	Liquid magma that has forced (intruded) into other rocks and then cooled and solidified. Igneous intrusions vary greatly in size and include dykes, sills, laccoliths, stocks, and batholiths (the largest intrusions).
Igneous Rocks	Rocks that have cooled and solidified from a molten state.
Laterite	A residual soil (usually red, from its high iron content) that forms in humid, tropical and sub-tropical regions where good drainage can remove soluble material (including silica). It is a type of iron ore, when it is rich in iron oxides/hydroxides.
Lithification	The process that converts newly deposited sediments into solid rock. This may take place simply through burial, because that can dehydrate and compact the sediments.
Ma	An abbreviation for millions of years.
Metamorphism	Any process that alters the composition, texture and/or internal structure of a rock. It usually involves pressure, heat and/or the introduction of new chemical substances.

[M-(mplH)]	An example of the CSIRO-AMIRA research project's short-hand notation for major iron ore types. M-(mplH) Martite-microplaty hematite M-(mplH)-g Martite-microplaty hematite-minor goethite M-(H)-g Martite-minor primary hematite-minor goethite M-G Martite-goethite M-oG Martite-ochreous goethite Upper-case indicates major amounts, and lower-case minor amounts
Martite	A term referring to the texture of a hematite that has replaced magnetite in a process of natural oxidation. The hematite is said to be a pseudomorph after magnetite, and is called martite to note its origins.
Mesa	A high, broad, flat tableland bounded by steep cliffs.
Mesozoic	One of the major divisions of geological time, between 65 and 250 Ma. It came after the Palaeozoic (550-250 Ma) and before the Cenozoic (55 Ma-present). Also refers to rocks formed during that period.
Metasomatic replacement	A process of ore formation where pre-existing rock (in this case BIF) is partly or completely replaced by the ore minerals. Hence the ore (and ore minerals) are said to be metasomatic.
Microplaty Hematite	A texture of hematite formed by goethite dehydrating under the effects of low-grade burial metamorphism. The texture is made up of an interlocking meshwork of small plates or thin tabular crystals.
Ochreous	Earthy or friable material, usually red, yellow or brown, depending on the grain size of the component material.
Pisolite	A spherical concretionary body over 2mm in diameter and made of concentric internal layers that developed around a nucleus.
Pisolitic	Consisting of rounded grains, often pea-size, like pisolites.
Proterozoic	One of the major divisions of geological time, between 2500 and 550 Ma. It came after the Archaean and before the Palaeozoic (550-250 Ma). Also the rocks formed during that period.
Stable Marine Platform	An extensive flat sea bed that is not subject to major tectonic movements.
Supergene	Processes that involve downward percolating water. Supergene enrichment dissolves metal in water that originated from rain or groundwater above, and then redeposits the metal below, enriching the underlying ore.
Tertiary	The earlier of the two geological periods in the Cenozoic era. Also the rocks deposited during that period.
The CSIRO-AMIRA Genetic Model	An ore-formation model that was developed over more than a decade of co-operative research between CSIRO and industry through the Australian Mineral Industry Research Association (AMIRA). The CSIRO-AMIRA research project was founded in 1976 when BHP, Hamersley Iron Pty. Ltd. and Mt. Newman Mining Co.Pty.Ltd. jointly sponsored research into phosphorus in iron ores of the Hamersley Iron Province. The research was carried out at the CSIRO Division of Mineralogy in Perth. The sponsor group was joined by CRA Services Limited (Iron Ore Division) and Robe River Iron Associates in the 1980s. The project resulted in the first detailed understanding of the generation of iron ores from BIF and culminated in the CSIRO-AMIRA conceptual model of iron ore genesis.

Location plan of Western Australian operations



Mineral Resources

🟦	Brockman Low Phosphorus	1,330Mt
🟦	Brockman High Phosphorus	1,755Mt
🟧	Marra Mamba	1,885Mt
🟨	Pisolitic	1,330Mt
	TOTAL	**6,300Mt**

Reserves and resources

BHPBIO's exploration and mining leases cover more than 3500 square kilometres of the Pilbara. Not all of this has been fully explored.

BHPBIO has vast resources of three highly sought-after ore types:

- low phosphorus Brockman hematite ores (centred on the remaining 750 million tonne Mt Whaleback deposit)
- low alumina goethite-hematite pisolitic ores at Yandi (1300 million tonnes)
- low silica and alumina goethite-hematite Marra Mamba ores, especially those at Mining Area C (900 million tonnes)

These are the core of the extensive resource base that BHPBIO has in its Pilbara operations. They will allow long-term production of products at grades that are very attractive to our customers. The large resource base also allows operational flexibility to meet customers' demands in a changing market.

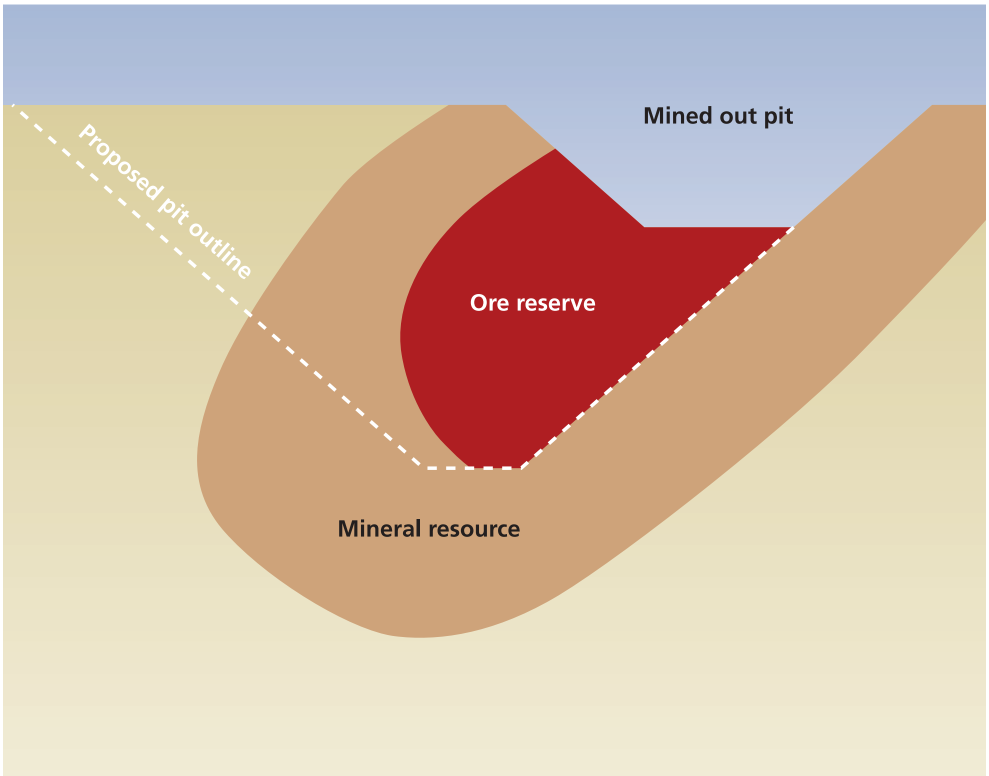
Mineral resource versus ore reserve

BHP Billiton uses an internationally recognised reporting code when making public statements on tonnage and grade of mines and mineral deposits for iron ore and other mineral commodities. The code is commonly referred to as the Joint Ore Reserves Committee (JORC) Code.

Under the JORC Code, a "Mineral Resource" is mineralisation that is likely to undergo economic extraction in the future and where its location, quantity, grade, geological characteristics and continuity are well known. These data are estimated from geological information such as drill logging and assaying.

An "Ore Reserve" is the economically mineable part of the Mineral Resource. It allows for the following to be considered: mining, metallurgy, economics, marketing, legal, environment, social and government. The Ore Reserve is a subset of the Mineral Resource.

Mineral resource versus ore reserve

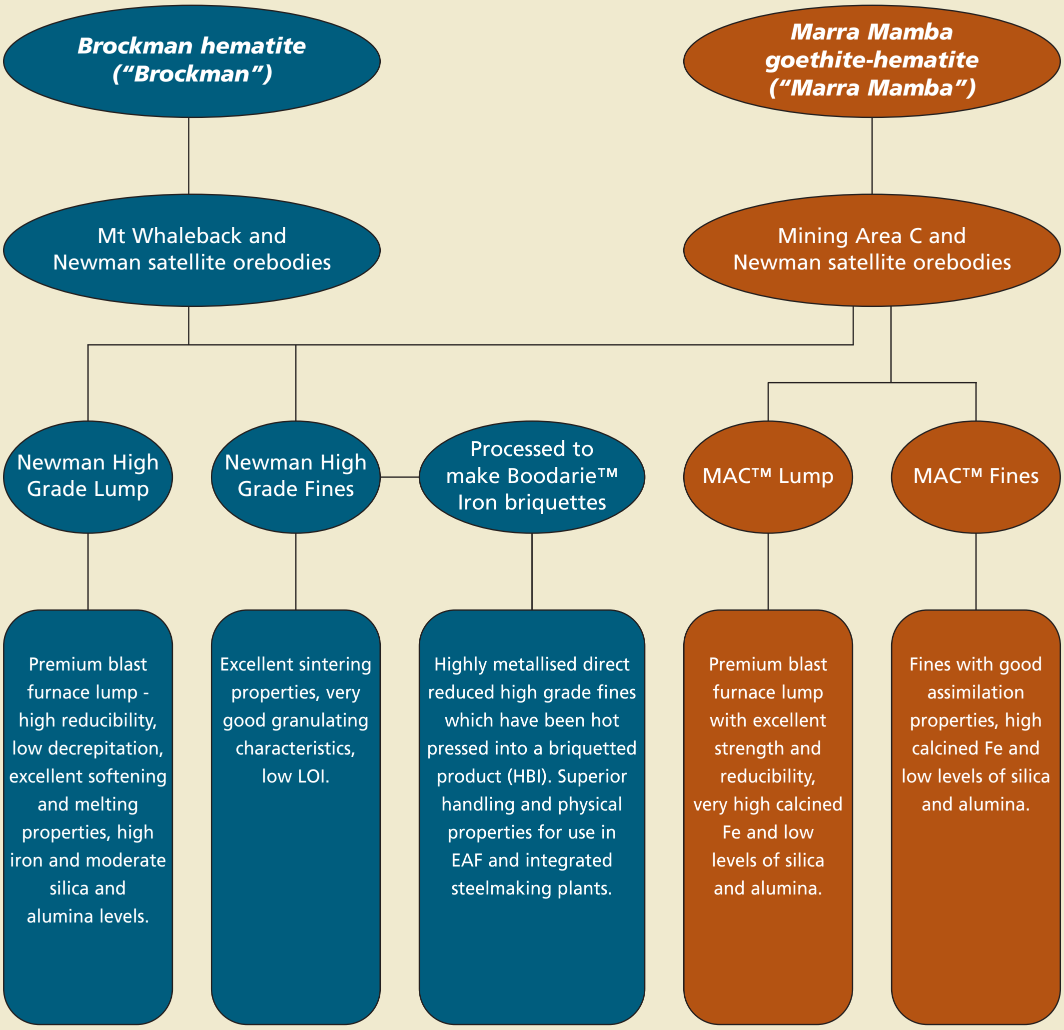


From ore types to products

From the individual ore types described in the previous section, BHPBIO develops products to meet customer needs. This section outlines the range of those products and the products under development, and summarises their properties. These enormous and diverse ore resources give BHPBIO the flexibility to develop new products as customer requirements evolve.

We work closely with our research laboratories and our customers to develop new products that deliver value.

Iron ore products



Premium blast furnace lump - high reducibility, low decrepitation, excellent softening and melting properties, high iron and moderate silica and alumina levels.

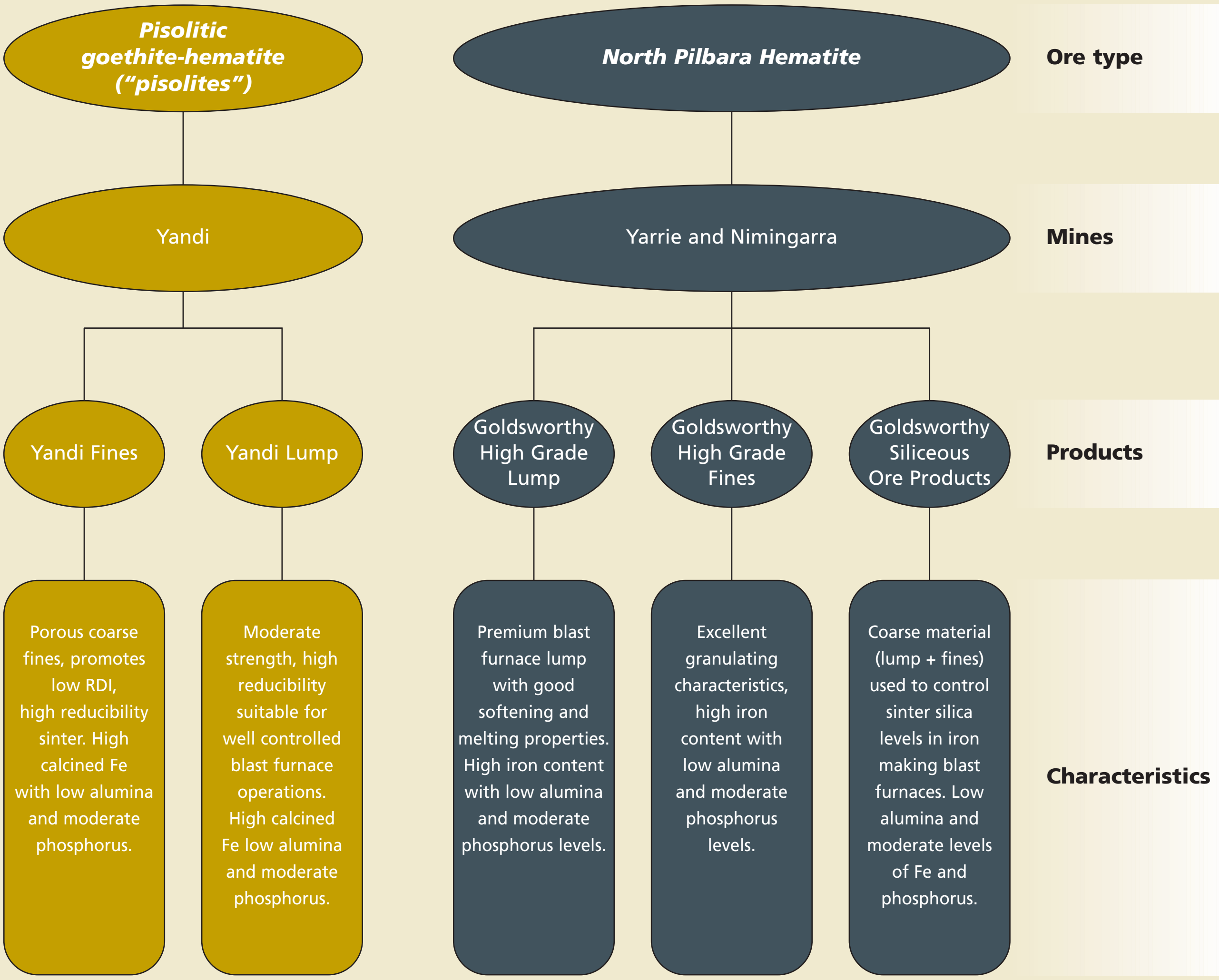
Excellent sintering properties, very good granulating characteristics, low LOI.

Highly metallised direct reduced high grade fines which have been hot pressed into a briquetted product (HBI). Superior handling and physical properties for use in EAF and integrated steelmaking plants.

Premium blast furnace lump with excellent strength and reducibility, very high calcined Fe and low levels of silica and alumina.

Fines with good assimilation properties, high calcined Fe and low levels of silica and alumina.

Left *Primary crushed ore stockpile at Yandi.*



Ore type

Pisolitic goethite-hematite ("pisolites")

North Pilbara Hematite

Mines

Yandi

Yarrie and Nimingarra

Products

Yandi Fines

Yandi Lump

Goldsworthy High Grade Lump

Goldsworthy High Grade Fines

Goldsworthy Siliceous Ore Products

Characteristics

Yandi Fines: Porous coarse fines, promotes low RDI, high reducibility sinter. High calcined Fe with low alumina and moderate phosphorus.

Yandi Lump: Moderate strength, high reducibility suitable for well controlled blast furnace operations. High calcined Fe low alumina and moderate phosphorus.

Goldsworthy High Grade Lump: Premium blast furnace lump with good softening and melting properties. High iron content with low alumina and moderate phosphorus levels.

Goldsworthy High Grade Fines: Excellent granulating characteristics, high iron content with low alumina and moderate phosphorus levels.

Goldsworthy Siliceous Ore Products: Coarse material (lump + fines) used to control sinter silica levels in iron making blast furnaces. Low alumina and moderate levels of Fe and phosphorus.

Ongoing and extensive test work is carried out on our iron ore products to provide data on their characteristics. Examples of typical data are shown in the following table.

Chemical Analysis dry wt %		**Newman**		**Yandi**	
		Fines	**Lump**	**Fines**	**Lump**
Fe, natural		64.0	65.4	58.5	58.9
Fe, calcined		65.6	66.7	64.9	64.8
Fe, metallic					
LOI		2.4	1.9	9.8	9.1
SiO_2		3.7	3.0	5.0	5.1
Al_2O_3		1.95	1.3	1.3	1.1
P		0.070	0.057	0.040	0.037
S		0.010	0.009	0.010	0.012
CaO		0.06	0.05	0.04	0.03
MgO		0.09	0.07	0.04	0.05
Mn		0.06	0.13	0.03	0.02
Na_2O		0.008	0.005	0.009	0.009
K_2O		0.013	0.007	0.003	0.003
Cl		0.0189	0.0012	0.0088	0.0024
Zn		0.002	0.001	0.001	0.001
V		0.0025	0.0023	0.0030	0.0041
TiO_2		0.08	0.04	0.05	0.06
Cu		0.0025	0.0029	0.0005	0.0006
As		0.0014	0.0014	0.0007	0.0018
Cr		0.0058	0.0116	0.0019	0.0024
Cd		<0.0001	<0.0001	<0.0001	<0.0001
Pb		0.0004	0.0001	0.0003	0.0002
Ni		0.0017	0.0024	0.0004	0.0006
Sn		<0.0001	<0.0001	<0.0001	0.0001
Co		0.0008	0.0008	0.0005	0.0004
Be		0.0003	<0.0001	0.0001	0.0001
Hg		0.000002	0.000002	0.000006	0.000004
Moisture		5.6	3.3	8.0	5.5
Ag		<0.0001	<0.0001	<0.0001	<0.0001
B		0.0013	0.0013	0.0011	0.0011
Ba		0.0035	0.0021	0.0012	0.0017
Bi		<0.0001	<0.0001	<0.0001	<0.0001
Br		<0.0010	<0.0010	<0.0010	<0.0010
Ce		0.0021	0.0013	0.0012	0.0008
F		0.0061	0.0018	0.0057	0.0040
Ga		0.0004	0.0002	0.0003	0.0001
Mo		<0.0001	0.0002	0.0002	0.0001
N		0.15	0.20	0.08	0.05
Na		0.006	0.006	0.007	0.007
Nb		<0.0001	0.0003	0.0011	0.0006
Ni		0.0017	0.0017	0.0008	0.0008
Pt		<0.0001	<0.0001	<0.0001	<0.0001
Rh		<0.0001	<0.0001	<0.0001	<0.0001
Sb		0.0001	<0.0001	<0.0001	<0.0001
Se		<0.0001	<0.0001	<0.0001	<0.0001
Sr		0.0012	0.0008	0.0004	0.0003
Te		<0.0001	<0.0001	<0.0001	<0.0001
Th		0.0002	<0.0001	<0.0001	<0.0001
U		0.0001	<0.0001	0.0002	<0.0001
CO_2		<0.02	0.02	0.24	0.24
NO_3		0.0786	0.0308	0.0003	<0.0001
SO_2		0.012	0.012	0.025	0.025
C					
Radioactivity** (Bq/kg)		461	278	355	
Fines Sizing (mm)	-9.5	98		92	
	-6.3	88		84	
	-3.15	73		61	
	-1.18	52		38	
	-0.6	41		24	
	-0.3	31		13	
	-0.15	18		8	
Lump Sizing (mm)	-35		95		95
	-31.5		89		89
	-25		79		72
	-20		62		53
	-15		45		33
	-10		23		18
	-8		13		7
	-6.3		4		6
	-3.15				4
Bulk Density (t/m^3)	Loose	2.5	2.3	2.0	1.85
	Compacted	2.7	2.5	2.2	
Shatter (% +10mm)	(JISM 8711)		96		95
Tumble (% +6.3mm)	(ISO 3271)		85		77
Decrepitation (% -5.0mm)	(Aust Mining Ind Std)		5		14
RDI (% -2.8mm)	(JSM Standard)		25		64
Reducibility (% Redn)	(ISO 7215)		66		61
Softening/Melting S Value (to max ^ P)	(BHPB Standard)		70		
Abrasion (% -0.5mm)	(ISO 3271)		9		12

**NOTE: Average total radioactivity for the earth's crust is 1434 Bq/kg

Goldsworthy			**MAC™**		**Boodarie™ Iron**
Fines	**Lump**	**GSO**	**Fines**	**Lump**	
64.5	65.1	57.0	62.1	63.0	92.3
65.2	65.7	57.7	65.9	67.0	
					84.0
1.1	0.9	1.2	5.8	6.0	
4.7	4.55	15.3	3.0	2.2	2.0
1.65	1.2	1.3	1.73	1.27	0.9
0.044	0.042	0.036	0.066	0.057	0.058
0.006	0.006	0.004	0.017	0.013	0.015
0.03	0.05	0.04	0.03	0.08	0.05
0.03	0.05	0.04	0.06	0.08	0.30
0.04	0.04	0.05	0.14	0.1	0.05
0.005	0.004	0.02	0.01	0.009	<0.01
0.060	0.020	0.040	0.020	0.01	0.004
0.0010	<0.0010				
0.0020	0.001	0.001	0.002	0.002	0.0032
0.0029	0.0021	0.0015	0.0015	0.0011	0.0025
0.1	0.06	0.03	0.04	0.03	0.06
0.0049	0.0022	0.001	0.0021	0.003	0.0007
0.0018	0.0013	0.001	0.0004	0.004	0.0010
0.0166	0.0112		0.0030	0.0026	0.0016
<0.0001	<0.0001		<0.0001	<0.0001	<0.0001
0.0006	0.0005		0.0005	0.0068	0.0002
0.0086	0.0065		0.0020	0.0018	0.0011
0.0002	<0.0001	<0.001	0.0001	0.0001	0.0003
0.0006	0.0004		0.0019	0.0071	0.0005
0.0001	0.0002		0.0001	0.0001	0.0002
<0.000002	<0.000002		<0.000002	0.000002	
4.9	2.9	1.2	8.0	4.5	
<0.0001	<0.0001		<0.0001	<0.0001	<0.0001
			<0.005	<0.005	
0.0074	0.0040		0.0047	0.0027	0.0024
<0.0001	<0.0001		<0.0001	<0.0001	<0.0001
<0.0010	<0.0010		<0.0010	<0.0010	<0.0005
0.0021	0.0015		0.0014	0.0014	0.0009
0.0031	0.0144		0.0030	0.0036	0.0045
0.0005	0.0003		0.0002	0.0002	0.0002
0.0002	0.0002		0.0001	0.0001	0.0001
0.19	0.20		<0.05	<0.05	<0.05
			0.0105	0.007	0.009
0.0002	<0.0001		0.0005	0.0004	<0.0001
			0.002	0.0018	0.0013
<0.0001	<0.0001		<0.0001	<0.0001	<0.0001
<0.0001	<0.0001		<0.0001	<0.0001	<0.0001
0.0002	0.0001		0.0001	0.0001	<0.0001
<0.0001	<0.0001		<0.0001	<0.0001	<0.0001
0.0059	0.0034		0.0003	0.0003	0.0005
<0.0001	<0.0001		<0.0001	<0.0001	<0.0001
<0.0001	<0.0001		0.0001	<0.0001	<0.0001
0.0001	0.0001		<0.0001	<0.0001	0.0002
0.36	0.13		0.15	0.11	
0.0377	0.0234		0.0050	0.003	<0.0005
			<0.001	<0.0001	
			0.082	0.117	1.4
281	238		161	145	
88			95		
			84		
			67		
			54		
			42		
17			25		
	98				
	90	98		91	
	62			56	
	25			21	
	6	50		4	<2
	2.2		1.9	1.8	2.8
	2.4		2.3	2.3	2.8
	95			97	
	83			88	98
	2			6	
	20			21	
	54			59	
	46				
	9			7	1.2

Sintering research – delivering value to the customer

While BHPBIO can control the product specification (size, chemical composition) and variability of products offered to the market, each product has distinct inherent properties that are determined by how the deposit was formed. The behaviour of a fine ore during sintering and a lump ore in a blast furnace depends on both the product specification and its inherent properties.

BHPBIO aims to give unrivalled technical support to customers on the use of our iron ores. To help us achieve this, BHPBIO supports fundamental research programs at the BHP Billiton Newcastle Technology Centre (NTC) to advance the current understanding of ore utilisation. Over the last two decades, with the introduction of several new ore types into existing blends or as separate products, the research programs have given penetrating insights into the optimal utilisation of our products.

NTC has developed unique bench-scale tests, under carefully controlled conditions, to quantify the behaviour of an ore during sintering. To this end, new terminologies have been introduced, and conventional understanding of sintering fundamentals have been challenged and revised. NTC also maintains a close association with BHP Steel, and the Port Kembla sinter plant.

In line with the emerging prominence of the Pilbara's goethitic ores (i.e. ores containing significant goethite, FeO.OH), NTC has carried out detailed studies to understand the differences in sintering behaviour between Brockman, pisolite and Marra Mamba ores. However, studies have not been confined to Australian ore: to assist BHPBIO customers in their operations, NTC has also developed a detailed understanding of overseas hematite and magnetite ores. In the last decade, NTC has published more than 30 research papers in *Transactions of the Institution of Mining and Metallurgy, SectionC: Mineral Processing and Extractive metallurgy*, and *The Journal of Iron and Steel Institute of Japan (ISIJ) International*.

While NTC's research in iron ore utilisation and sintering is recognised worldwide, it is important to note that NTC has a very broad technical base in iron making. There are resident experts in coal, cokemaking, blast furnace operations and pulverised coal injection. This means that NTC is able to offer a broad coherent understanding of the properties of all raw materials – their individual, collective and interactive influence on iron making costs and efficiency. In the iron ore area, an important activity is supporting customers with their use of BHP Billiton materials.

Technologies applied

Ultra-micro indentation system (UMIS)

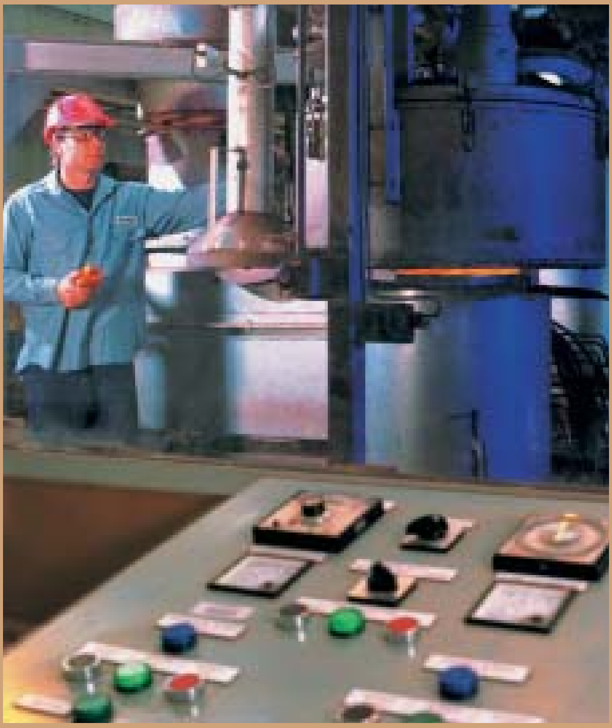
Sinter is an assemblage of many phases and minerals of varying properties. The strength of sinter before and after reduction can be improved by the preferential formation of certain phases during sintering. The UMIS is used to determine the mechanical properties of the components in the sinter, and then obtain information about preferred bonding phases.

Infra-red image furnace

A sophisticated infra-red image furnace that simulates sintering temperature profiles. It is used to understand reactions and individual ore behaviour in the sintering process.

Bed rigidity determination

A bed under sintering is subjected to various conditions before it reacts in the flame front to form a melt. If the granules disintegrate, sinter plant productivity will decline. This rig allows us to characterise granulated beds that have been humidified, dried and calcined.



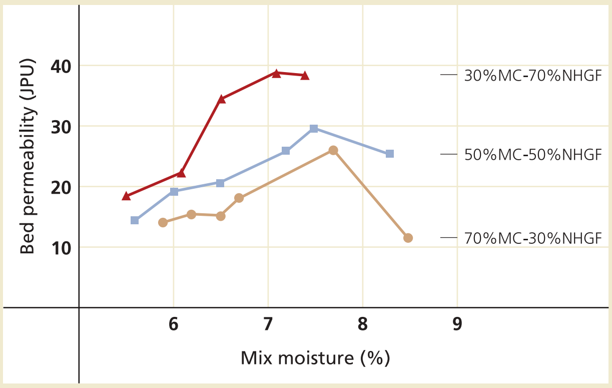
Pilot-scale sinter pot

The complex nature of sintering means that pilot-scale tests are required to verify hypotheses formulated from bench-scale tests. The facility is also used to understand flame front properties, and to carry out tests aimed at understanding the effects of BHPBIO iron ores on customer blends.

We present two major areas of research to illustrate BHPBIO's understanding of the effects of ore properties on sintering.

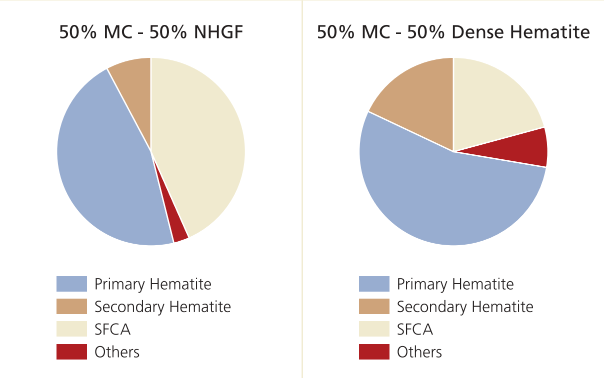
Newman High Grade Fines (NHGF) – *Improving the performance of magnetite ore blends*

Granulation properties



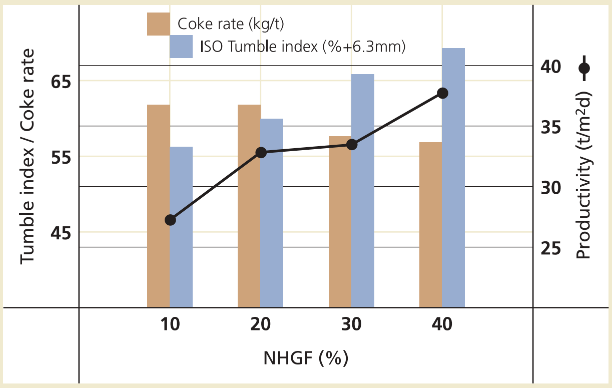
Granulation is the first stage of sintering and this process must be carried out efficiently to ensure that the bed formed on a sinter strand is permeable. NHGF is an excellent granulating ore because it contains large percentages of particles that behave as nucleus material (48%) and adhering material (41%). The figure shows that increasing the percentage of NHGF in a magnetite concentrate (MC) blend gives significant increases in green-bed permeability.

Bonding phase formation



NHGF is a porous hematite ore, with quartz and clay as its main gangue minerals. In blends with magnetite, NHGF is much more reactive than a dense hematite ore. The formation of more melts that contain appropriate levels of alumina and silica – from the fine, reactive clays – results in sinters that contain high levels of SFCA. This is the preferred bonding phase in modern sinters, because it forms at low temperatures and gives sinters good strength and reducibility.

Sintering performance



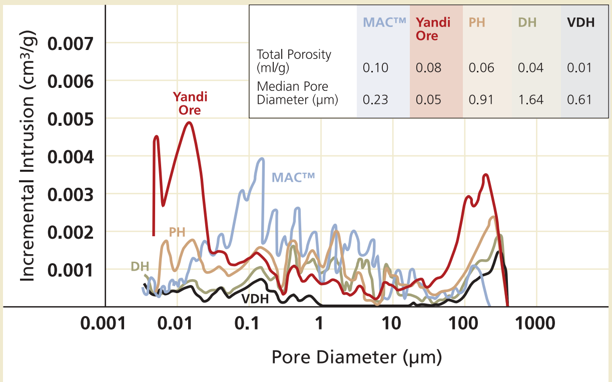
The good granulating properties of NHGF lead to higher productivity as the NHGF levels are increased in a typical MC blend. Recent studies also show that the clays in NHGF act as binders, and reduce granule breakdown in the drying zone of a sintering bed. This would contribute to the observed large improvement in productivity. The ability of NHGF to promote SFCA formation is reflected by higher sinter strength, even though the coke rate is reduced.

Benefits to customers

Newman HGF. Plant trials are often carried out using the results of targeted pilot-scale tests. While such an approach is reliable, it does not give insights into the contribution of the various components to the blend. PRC magnetites and NHGF have very different properties and the approach used at NTC explains why NHGF has a positive effect on generic magnetite ore blends.

Goethitic ores – *properties that affect sintering performance*

High particle porosity



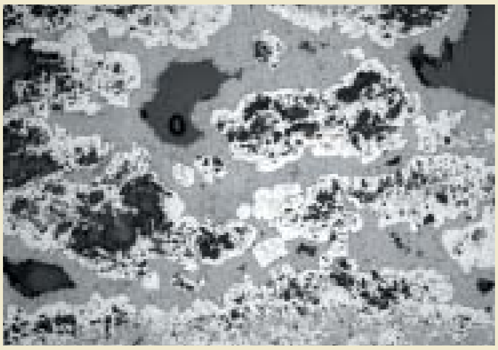
	MAC™	Yandi Ore	PH	DH	VDH
Total Porosity (ml/g)	0.10	0.08	0.06	0.04	0.01
Median Pore Diameter (µm)	0.23	0.05	0.91	1.64	0.61

Goethitic ores are more porous than most commercially traded ores. The figure shows that both Yandi and MAC™ have a large network of very fine pores and a higher total porosity than hematite ores (0.08 and 0.10 ml/g respectively, compared with 0.01ml/g for a very dense hematite). They require more water for granulation to get high green bed permeability. Sinter plant productivity will normally deteriorate if water addition is not increased when goethitic ores are introduced or increased.

Low particle density

Sinter plant productivity is expressed in tonnes of product per day, but as shown in the picture, a sinter machine operates on a fixed volume. So to maintain productivity, machine speed has to be increased when using goethitic ores. Machine speed can be increased by improving sintering bed permeability. Further increases in green-bed permeability may be needed in order to do this and maintain sinter plant productivity.

Goethite content

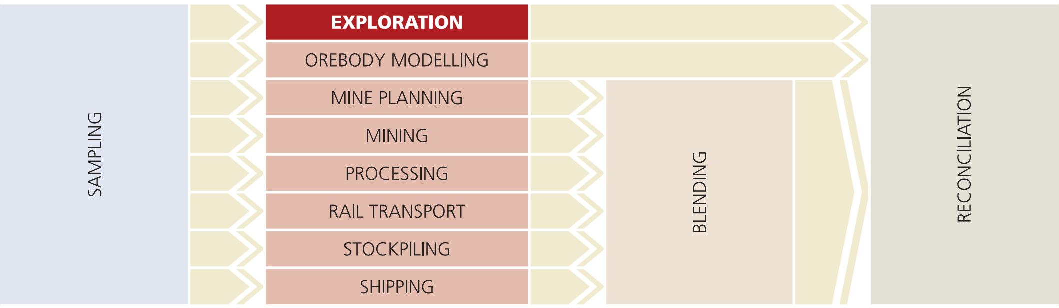


The goethite content of goethitic ores depends on the ore type. (Goethite is the grey material in the figure, bonding the white hematite grains. The pores are dark.) Goethites require energy for calcination, and an increase in coke consumption is to be expected for the process. However, studies often show no deterioration in sinter strength at the same coke rate. Goethitic ores are very reactive (in addition to high particle porosity, calcined goethite is very porous) and comparable melt volumes can form at lower sintering temperatures.

Benefits to customers

Goethitic ores. NTC research on goethitic ores, and the open disclosure of our research results at forums and in international publications, has given the steel industry a fundamental understanding of the sintering requirements of these ores and a basis for changing their steel plant operations. Work is continuing in the area, with a view to understanding how blends that contain high percentages of goethitic ores can be sintered very effectively.

Managing quality during production

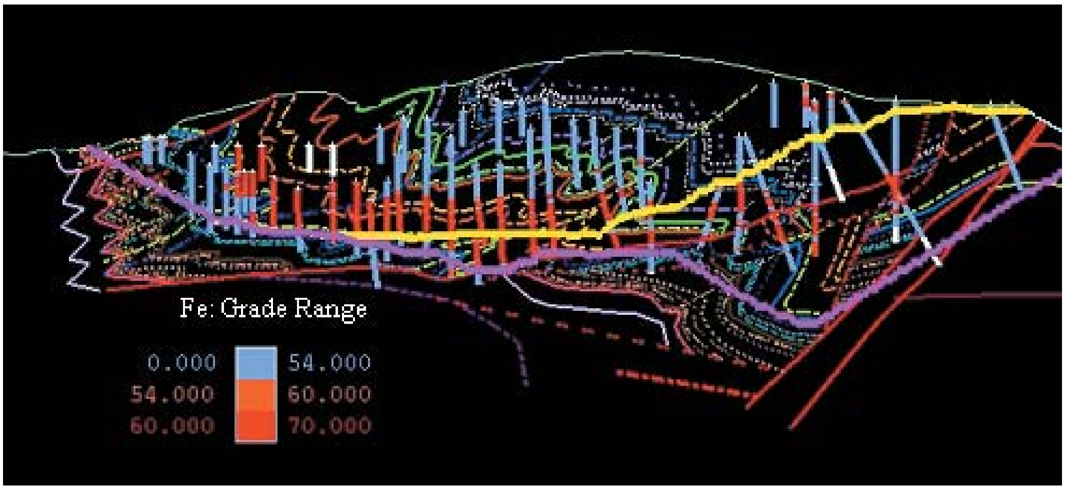


Exploration

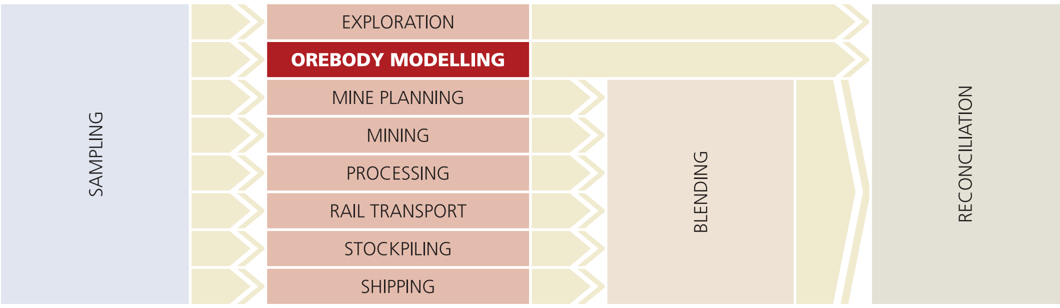
Initial exploration involves geological mapping of the mineralised surface exposures. The second phase is to see how far the surface exposure continues below ground and to see if the iron enrichment is a high enough grade to be classed as "ore".

This is done by drilling a regular grid of holes over the potential orebody. The drilling method we currently use is Reverse Circulation (RC) drilling. The drill bit breaks the rock into small chips, they are forced to the surface by compressed air, and collected in a cyclone. The chips are sampled at 3m intervals. The chemistry of the sample is then analysed in the laboratory. A geologist also visually identifies the type of rock in each 3m sample interval.

Each drill hole is also analysed by down-hole geophysics. The gamma radiation down-hole trace is used to identify the geological sequence intersected.



Above *A combination of down-hole chemistry, visual inspection of rock chips and geophysics collected on a regular grid is used to produce a three-dimensional geological interpretation of the orebody.*



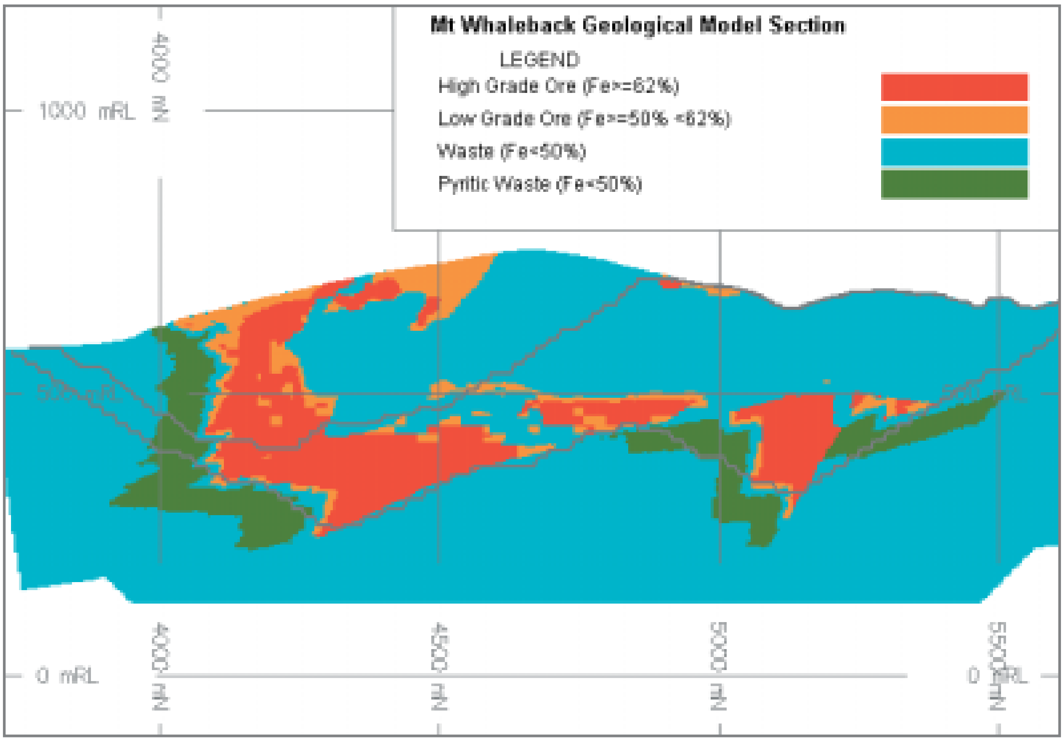
Orebody modelling

Geological Model

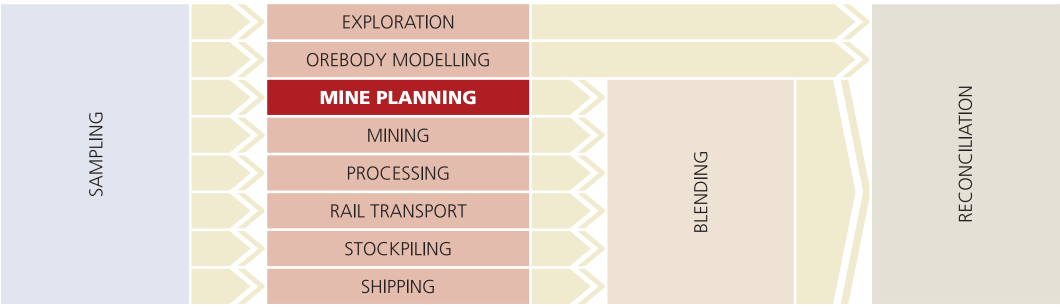
The exploration data is analysed to digitally produce a three-dimensional image of the geological units, mineralisation and associated waste by using geological sections and bench plans. A resource block model is created from this image, using modelling software. This process divides the model into blocks and determines their size by using the geological structure, lithology and mining bench height. Quality data such as chemical grade, material type and density is interpolated into each of these small blocks.

Mining Model

A mining model is then created from the geological model. It groups some cells into larger blocks that will best simulate the tonnage and grade, in the same way that the deposit will be mined. The grouping of cells is determined by parameters such as bench height, minimum mining width, practical mining advance and rules that dictate which cells can be merged.



Above *A typical section though a diluted mining model showing material types and pit design limits.*



Mine planning

Optimised Final Pit

The diluted block model is analysed using a 3-D pit optimisation program to generate an optimum final pit shell. Parameters such as average pit slope, ore prices and mining costs are used to generate many shells. These shells are then studied to decide on the most practical optimised final pit. This shell is then used to design the final pit, which includes haul roads and geotechnically designed batter/berm combinations.

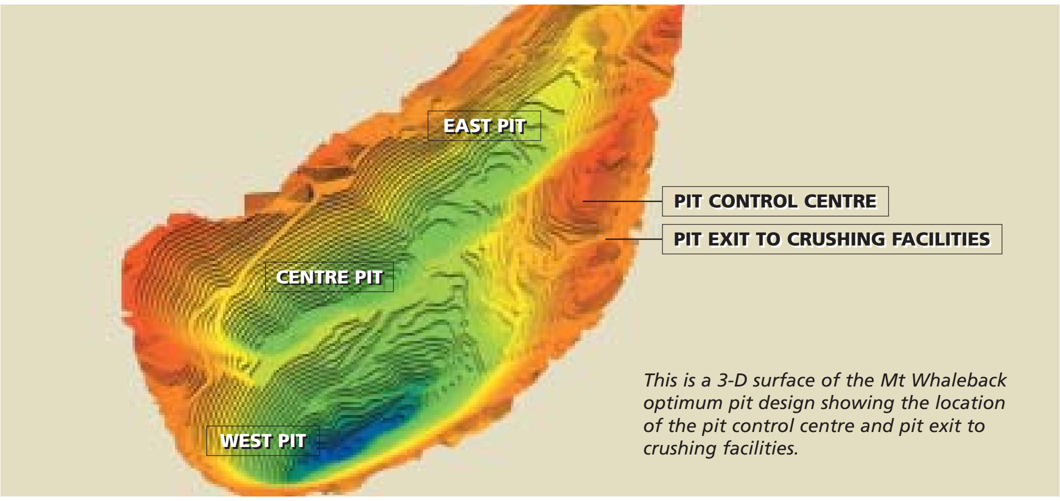
Scheduling

Once a final pit has been designed that maintains the required waste:ore ratio, an orebody reserve is calculated. Mining sequence plans are prepared for each orebody in order to determine the optimum ore-extraction sequence.

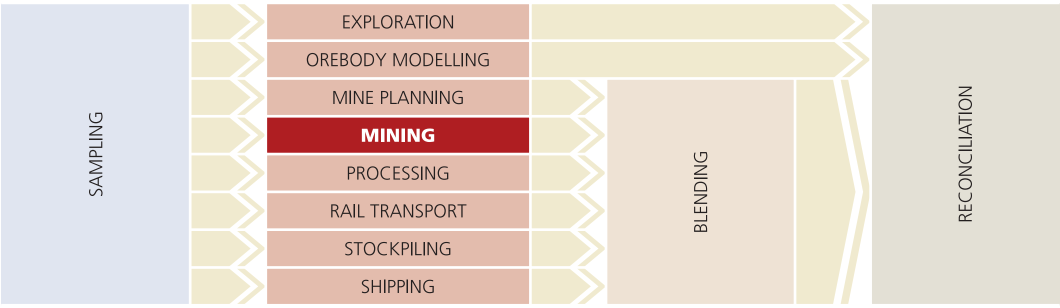
To meet the required sales projections and product target grades, a production schedule is calculated by optimising the blending of each contributing ore sequence into the most economic mine plan.

Life of Mine Schedule	***1-5 year increments***	***For life of mine***
Medium-term schedule	Monthly, quarterly and yearly increments	1 year to 5 years
Short-term schedules	Monthly increments	3 month rolling plan

Optimum pit shell



This is a 3-D surface of the Mt Whaleback optimum pit design showing the location of the pit control centre and pit exit to crushing facilities.

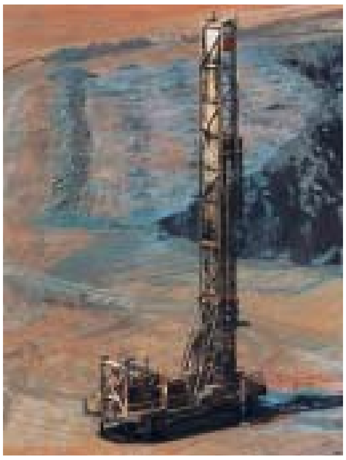


Mining

Drill and blast

Our drill crews follow world's best practice. It is a key to our quality control process in mining, because it gives chemical data for close spacings of the ore that we are about to mine.

In order to optimise the sizing and other characteristics of the ore that is blasted, we match the blasting pattern (the spacing and charge) to each type of material. This gives close control over the breakage. If more explosive were used than necessary, there would be overfracture and that would reduce the amount of lump. Optimum blasting also greatly reduces contamination: in a contact zone between high-grade material and shale, if a high-energy blast pattern were used in both parts, there would be considerable mixing. By identifying the contact zone, it is usually possible to "peel" the ore from the shale.



***Above** Mt Whaleback mine.*

Operation optimisation

Different mining techniques and equipment are used in different mines. The operating criteria depend on the mine, and many factors influence their selection: geological and geotechnical complexity, hydrogeology, pit geometry, wall and haul road design, mining bench heights, desired extraction rates, and others. These factors are considered in determining the best combinations of trucks and loading units.

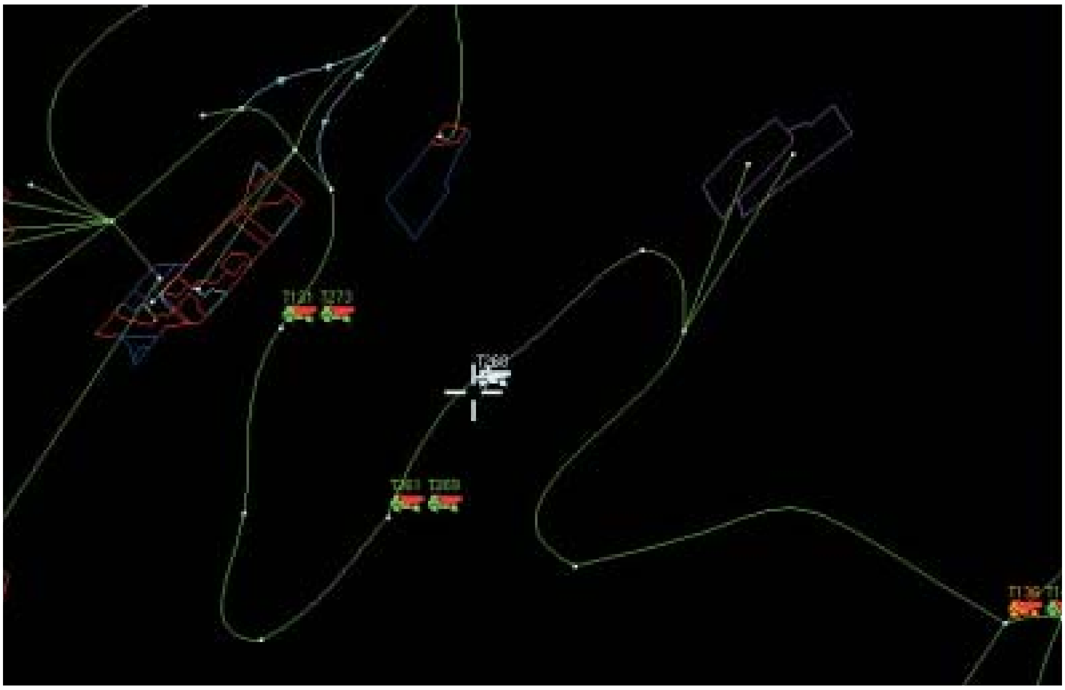
Essentially, a lot of attention is directed towards selecting equipment to maximise ore recovery.

***Above** Jimblebar mine.*

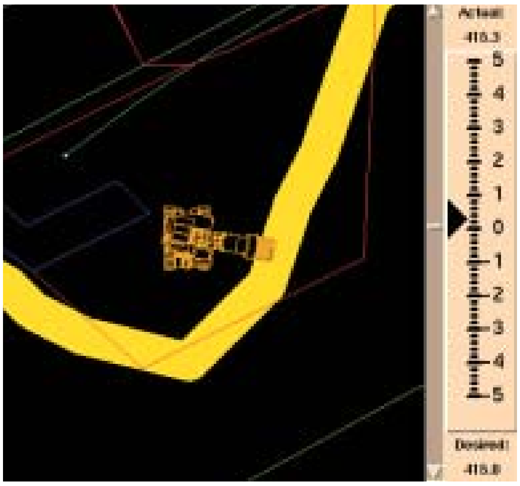
Advanced technology

BHPBIO optimises the use of improved technology, where appropriate, in all its operations. At our Mt Whaleback pit at Newman, for example, the operating equipment fleet is managed using a truck dispatching computer-control system. The system monitors and co-ordinates the work and performance of all equipment, using a high resolution Global Positioning System (GPS).

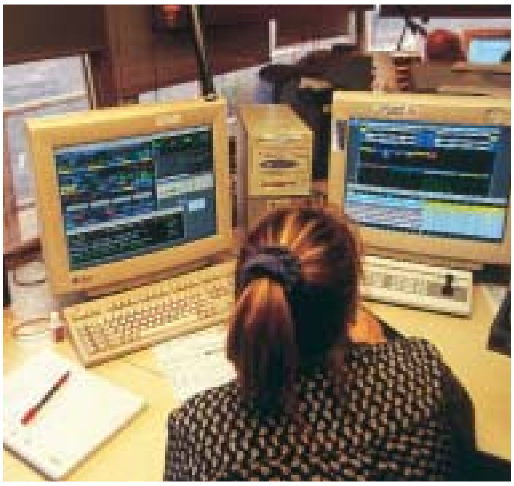
The system also allows better management of production versus plan performance and enhances quality control.



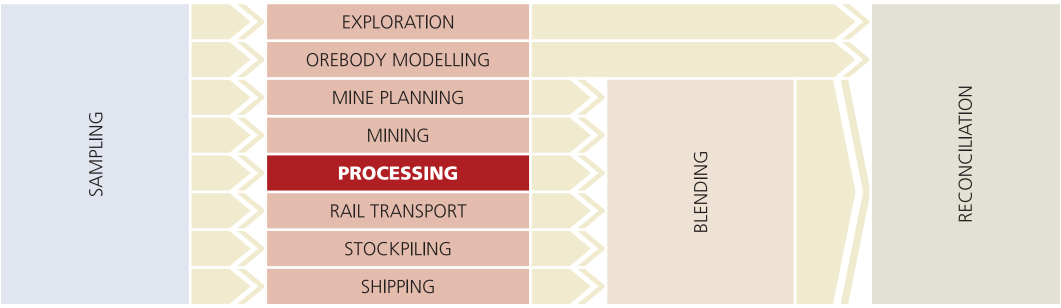
Above *Our truck dispatch system records everything from trucks to loading units, and makes accurate control not only possible, but routine. Screens like these are used to track each truck.*



Above *This is a real-time window of a loading unit. The system ensures that the loading unit loads and records ore from the correctly assigned ore block after blasting. The right-hand side of the screen has a slider that shows the height that the loading unit is operating, compared to the target bench height. The area shaded yellow highlights the progressive digging face of broken material.*



Above *The truck dispatch control centre links all mining work to the mine plan.*



Processing

All of BHPBIO's mining operations have some ore-processing capability at the mine sites. Ore is typically moved by haul truck direct from the pit to the primary crusher. There ore is crushed and screened, followed by secondary crushing of oversize material. Because of quality and operational considerations, all ore from the Newman satellite mines is rehandled from pre-crusher stockpiles, rather than going direct from the pit into the crusher.

At the Mt Newman Joint Venture mines, ore is railed as secondary crushed ore (nominally -100 mm) to Nelson Point. There the ore is tertiary screened and crushed to finished products.

On the other hand, at the Yandi mines, ore is crushed and screened to final product-size specifications (lump and fines) before railing to Port Hedland.

BHPBIO has facilities to upgrade lower-grade ores at both Mt Whaleback and Finucane Island. The Mt Whaleback beneficiation plant treats contact ores using heavy medium (ferrosilicon) drum, cyclone and spirals circuits. This plant has recently been upgraded from 6 Mtpa concentrate output to 7.5 Mtpa.

Lower grade ores from the Mt Goldsworthy Joint Venture mines (Yarrie and Nimingarra) are railed to Finucane Island, where the ores are upgraded through a WHIMS (wet high intensity magnetic separation) circuit, and spirals and jigs.

The beneficiated ores from Mt Whaleback and Goldsworthy are blended with other BHPBIO ores to make the final product mix.

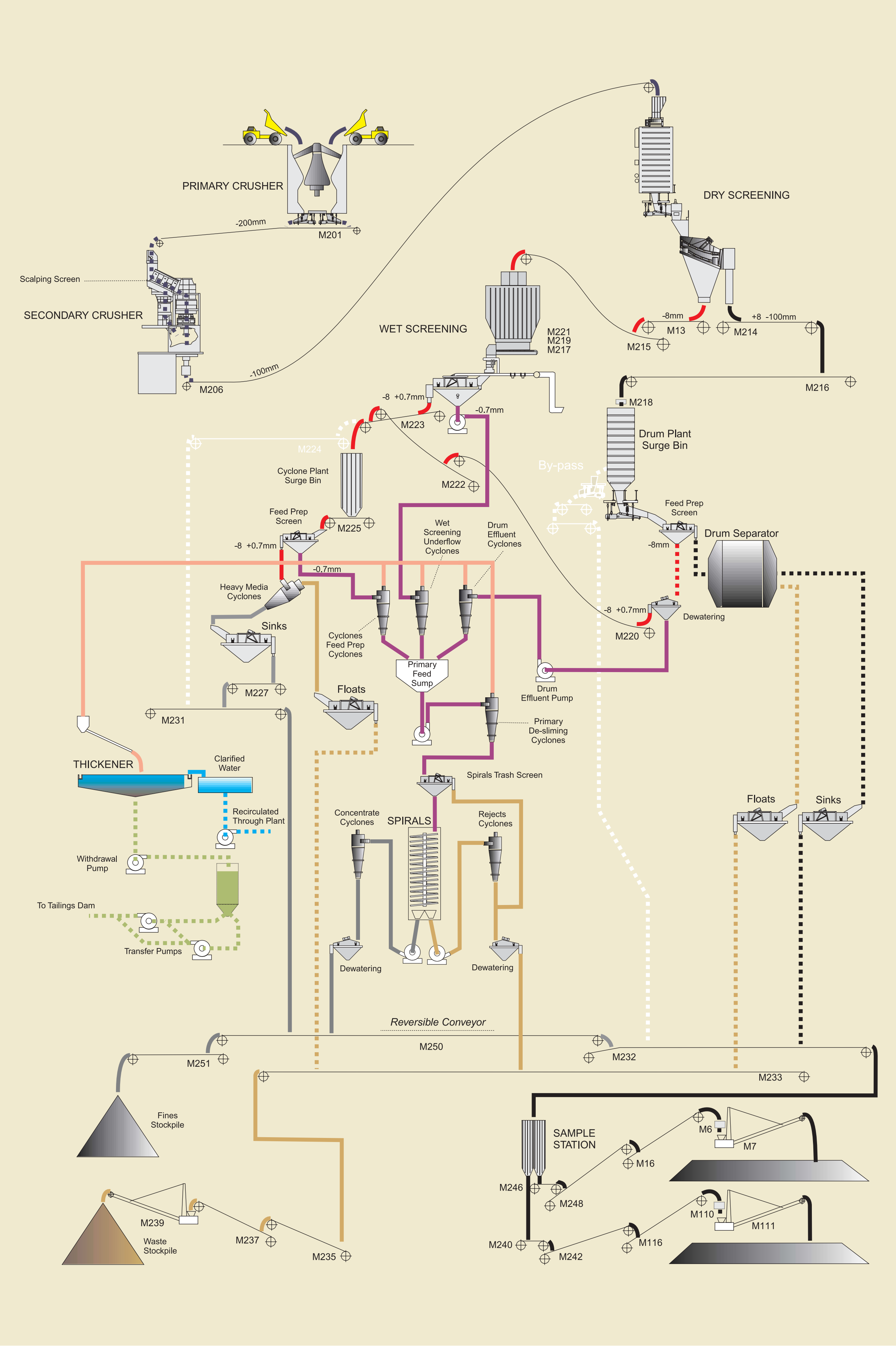
There is also a gravity and magnetic separation beneficiation plant at Boodarie. It further upgrades the Newman Fines that are used as the feed for the HBI plant.

Ore from the Mt Newman and Mt Goldsworthy Joint Venture mines is further processed at Nelson Point and Finucane Island facilities, respectively, into lump and fines products.

***Above** Orebody 25 view looking south from the apron feeder towards the main conveyor and bin loader.*

***Above** Mt Whaleback Crushing and Beneficiation Plants.*

Newman Beneficiation Plant Product Flowchart

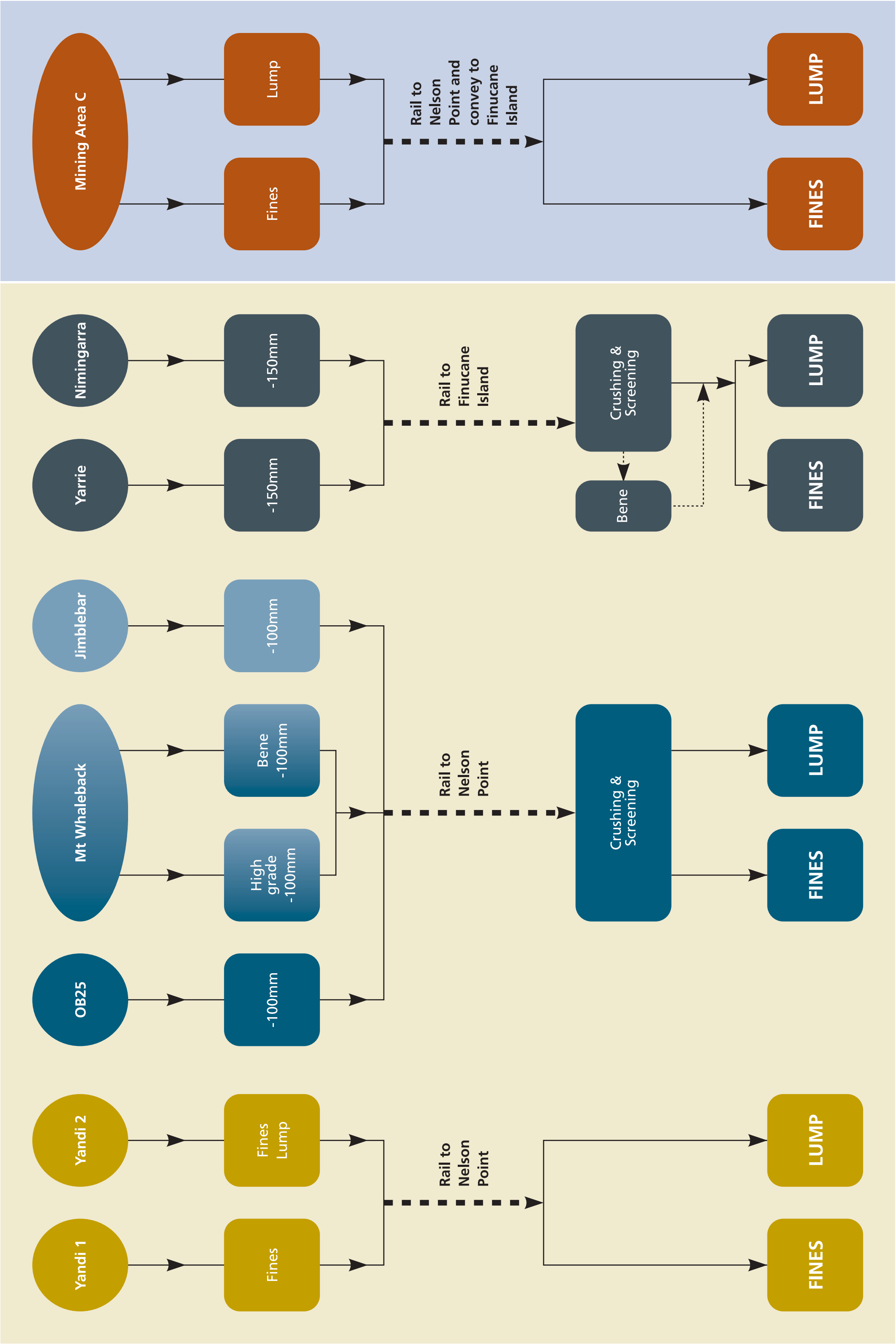


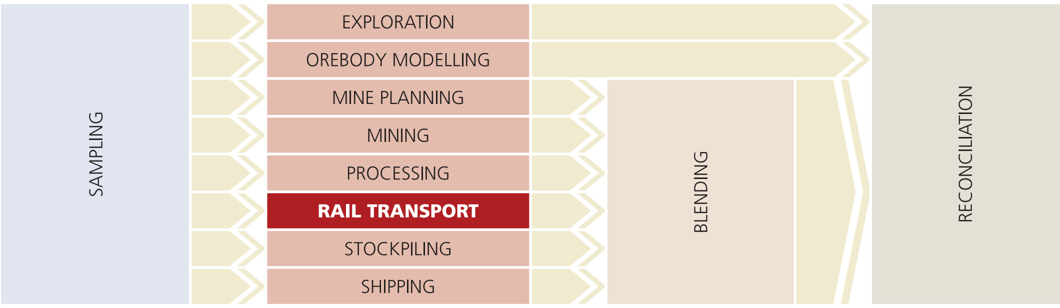
PROCESSING

Once ore is processed at the mines, the ore or product is stockpiled in loadout facilities. From there, it is loaded into ore cars, for railing to Nelson Point.

Ore processing facilities at most sites have automatic sampling stations. Lump products are processed through lump rescreening plants prior to shiploading.

Ore process flow





Rail Transport

The railway is the critical link for transporting iron ore between the mines and ports. Before modern heavy-haul railways, the ore was thought to be too far from the coast to be mined economically.

BHPIO's heavy-haul railway has evolved to the point where we now run the longest and the heaviest trains in the world (on the Newman and Yandi lines). The trains are up to 336 cars long and are powered by 6000-horsepower General Electric AC locomotives, distributed at intervals along the train. These long trains increase production throughput and reduce congestion delays.

As part of our continuing research and development work on longer trains, BHPIO ran the world's longest and heaviest train in June 2001. It stretched 7.4 km, had 682 ore cars, eight 6000-horsepower locomotives, a gross weight approaching 100,000 tonnes and moved 82,262 tonnes of ore from Yandi Junction to Port Hedland. The train was operated by a single driver.

Leading-edge technology ensures the railway operates at world's best practice. We are self-sufficient in track maintenance, rolling stock and locomotive repairs. Modern workshops and the latest equipment keep the fleet and plant at world-class standards. Monash University works closely with us in reviewing and testing new technology.

All train movements are managed from the Traffic Control Centre in Port Hedland, using a solid-state interlocked control system. Specialised computer hardware and digital communications support the signalling system. The control systems in the field are powered by solar technology. The systems not only control train movements but also warn about unsafe conditions (overheated wheels and bearings, dragging equipment), as well as monitoring wheel impacts and weighing the cars as they go by.

Safety is further enhanced with Automatic Train Protection (ATP). The system includes built-in braking curve data in the locomotives, and field systems that prevent trains from entering unauthorised tracks.

Drivers are trained on a computerised simulator. The simulator is also used to test operation strategies in order to optimise fuel consumption and to test train handling techniques on track that has not yet been built.

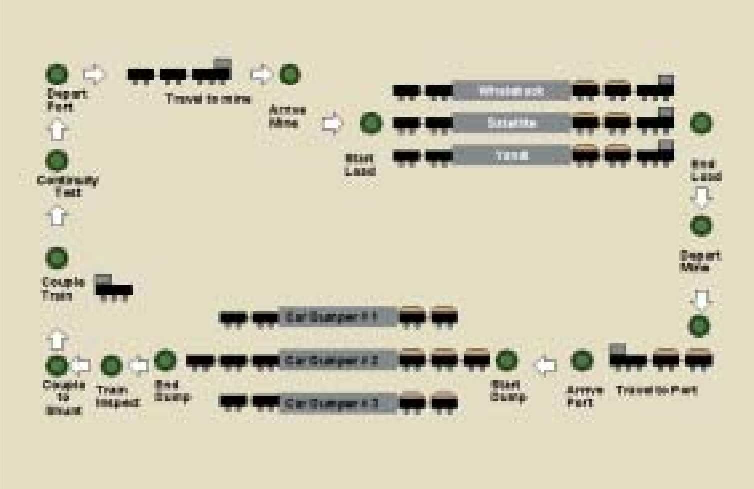
The result: a railway that safely and reliably transports the scheduled tonnages of ore, ensuring that the required products are always available to meet our customers' changing needs.

Above *The world's longest train, June 2001.*

Above *Reliable trains depend on reliable and up-to-date data. This is one of the electronic sensors that collects wheel temperature and other data as the train passes over. The data is transmitted immediately to the traffic-control centre in Port Hedland.*

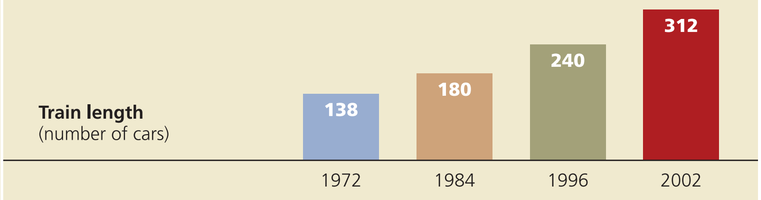
BHPIO Railroad - Train Cycle

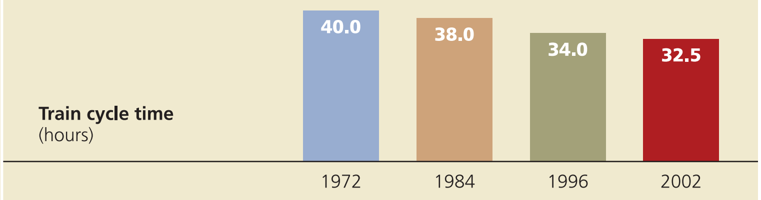
Keeping this cycle on schedule guarantees a reliable supply of the right-quality ores to the port.

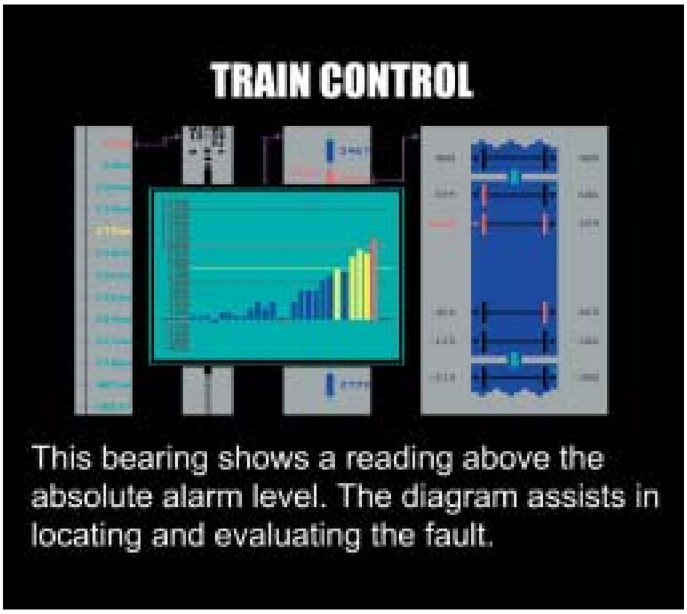


Operating Improvements

Ore quality at the port depends on many links, including increasing the rail capacity as shipping requirements rise. The most efficient way to accommodate more capacity is to use longer trains.

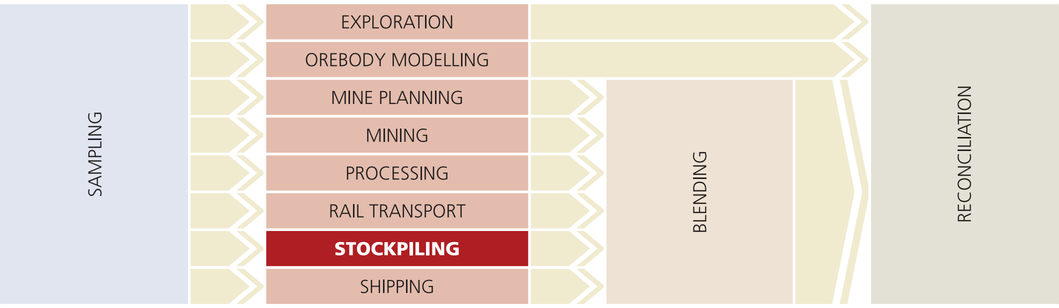






This bearing shows a reading above the absolute alarm level. The diagram assists in locating and evaluating the fault.

Left *Monitoring a train for reliability and safety. The temperature of every wheel is measured at many points along the track, while the train passes over sensors at full speed (typically 80 km/h). We can tell if a wheel is getting hot. If it heats up, it can break, and if it breaks the train could be derailed. At the same time, the temperature of each bearing is measured. We also check for cold wheels, because that tells us if the brakes on that wheel are not working correctly. There is a wheel-impact monitor, which tells if the wheel is round or out of round. We can also identify each car as it passes, so if the configuration of the train changes, that appears on the computer screen.*



Stockpiling

Port processing

There are two port facilities: Nelson Point and Finucane Island, connected to each other by a 1.4km under-harbour tunnel conveyor and by road and rail to the inland mines.

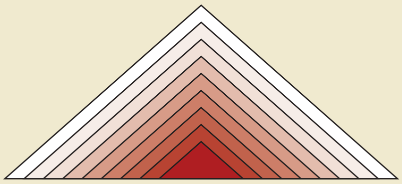
The combined port stockpile capacity is 8 million tonnes, when completely full. The port can handle more than 70 million tonnes a year, and there are expansion plans to increase that to 100 million tonnes.

Above *Finucane Island and Nelson Point ports, looking from Finucane Island.*

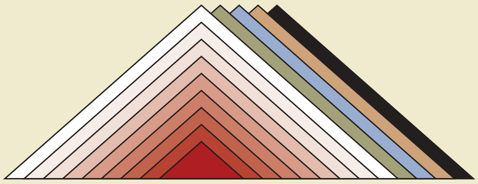
Homogenising and reclaiming

When each stockpile is built, it is blended (homogenised) at the same time. When it is later reclaimed and loaded to ships, each reclaimed part of a stockpile has a grade that closely matches the overall stockpile characteristics.

Stockpiles are built by selecting an empty "footprint" where a certain weight of ore can be stockpiled (for example, 250kt). The next train comes in and the stacker spreads the ore up and down along whole length of that footprint (typically 250m for a stockpile that will hold 250kt). A train may take three hours to empty, and the stacker may make four to six passes along the stockpile length, adding a little to the height of the stockpile on each pass. The next trainload is stacked on top, in the same way. The method is called chevron stacking, because a cross-section of the different ore layers does indeed resemble a chevron.



Typical stockpile cross-section, showing the chevron pattern. Taking a cross-section through this when the stockpile is reclaimed yields a composition that is close to the average for the whole stockpile.

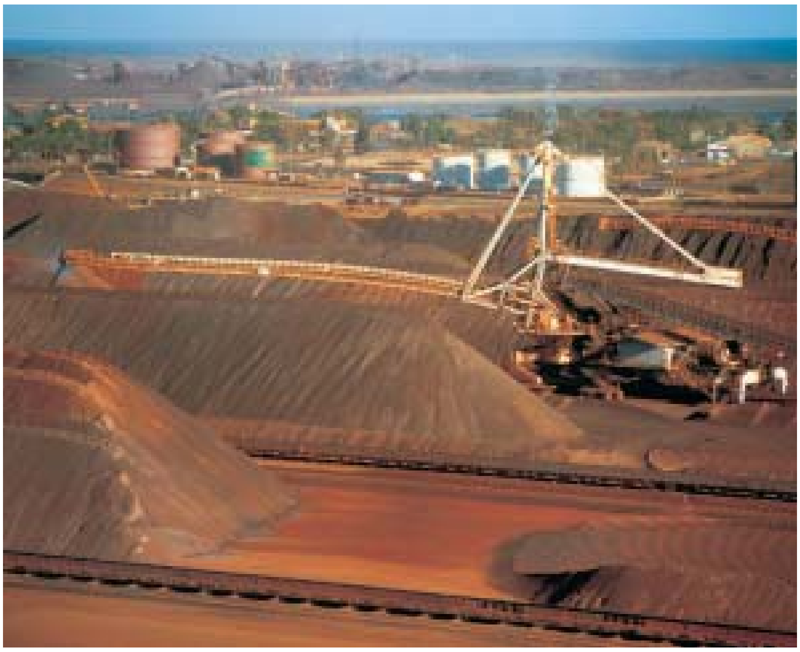


A chevron pile can be made wider by stacking a number of ply layers on one side of the pile. The average ore quality remains the same.

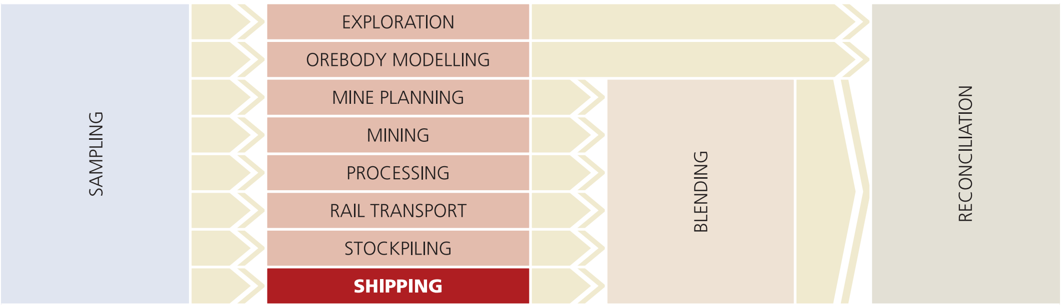
This homogenising means that grade deviations from cross-section to cross-section are greatly decreased compared with the original ore-stream when spread on the pile.

For example, if a ship needs to be loaded with 80,000 tonnes of lump, it might be taken from a 250kt stockpile like the one just described. An 80m length might be removed from the end. The average grade of that will equal the average grade of the whole stockpile. The stockpile is reclaimed this way, in segments, as needed, at 90° ("bench reclaiming").

Support facilities at the port include sampling and sample-preparation areas. They produce samples for analysis in the Quality Control Laboratory, where the measurements are used in process control and final product certification.



Left *A stacker building a chevron stockpile, and in that way homogenising the pile for uniform quality as it stacks.*



Shipping

Nelson Point and Finucane Island loaded 430 ships in 2001, with 86% of them loaded at Nelson Point. Most shipments (95%) are on a Free On Board (FOB) basis, with the buyer responsible for shipment. The rest are shipped on Cost & Freight (C&F), for which BHPBIO is responsible.

The average ship is 165,000 dwt and the average cargo is 160,000 wet metric tons. Ships up to 330m long and 250,000 dwt can be loaded in the port. A single marked channel, 45km long, is used by fully laden ships. There is an alternative Eastern channel, but it is strictly reserved for inbound ships.

To accommodate marketing sales projections, there will be an expansion of the port in the near future. The bulk of the development will be at Finucane Island.

Nelson Point

Nelson Point is serviced by two shiploaders, each rated at 10,000 tonnes per hour. The expected turnaround time of vessels is 64 hours, with an average loading time of 36 hours.

Finucane Island

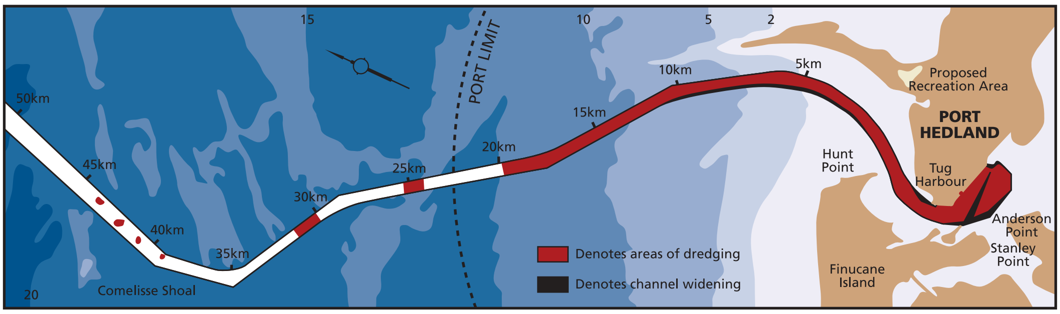
The shiploader at Finucane Island can load at 6,000 tonnes per hour. However, the reclaimer rate is restricted to 4500 tonnes per hour. Ships at Finucane Island can be loaded with ore from Nelson Point using the under-harbour tunnel, which can transfer up to 4000 tonnes per hour. With the PACE project (see page 54) additional facilities will be constructed, including a new 10,000 tonnes per hour shiploader and berth.

Sailing draughts and sailing windows are determined by a Dynamic Underkeel Clearance (DUKC) computer program, managed by the Port Hedland Port Authority. DUKC is a real-time underkeel clearance system that uses tide and wave measurements made before the ship uses the channel. The system calculates the minimum safe underkeel clearance along the complete route from berth to deep water.

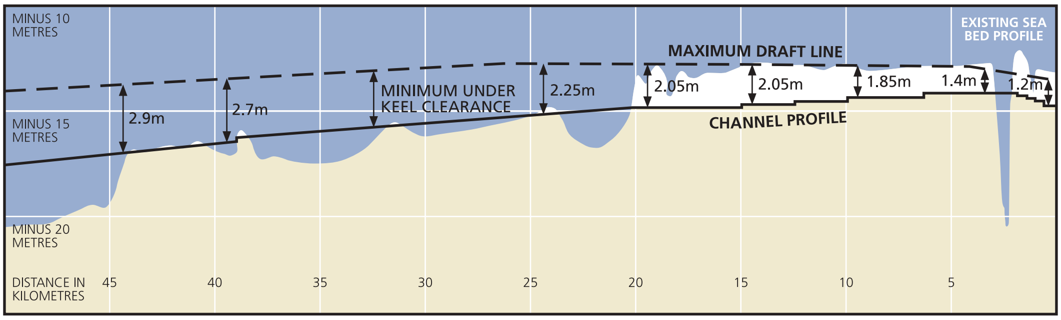
The system allows ships to be loaded to a greater draft than is possible using the fixed UKC rules (determined by safety requirements in extreme swells and using negative tidal residuals). The DUKC system therefore increases port productivity and capacity without requiring new port infrastructure, extra capital, dredging, and all without compromising safety.

Customising the DUKC system to take into account ship dynamics has added further benefits in draft and time windows. The system now gives an extra 60-70cm of draft opportunity on most tides, extra sailing windows of 30-60 minutes on spring tides and 3-4 hours on neap tides. The DUKC system was first introduced to Port Hedland in 1996 and it has increased port capacity by about 9 million wet metric tonnes.

Shipping Channel Plan



Sea Bed Profile



Boodarie™ Iron production

The BHP Billiton Hot Briquetted Iron (HBI) plant at Port Hedland produces direct-reduced iron and uses two main raw materials:

- Newman High Grade Fines
- Natural Gas from the North West Shelf

Above *The tall structure was a combined result of technical quality requirements and economics. The reactor and lock hopper system needed to be 100m high, and also withstand Category 5 tropical cyclones. A single reactor structure was built to house all four reactor trains, because a single structure minimised the structural steel. The reactors and briquetting presses are in that high structure, but the plant actually has two separate modules with two reactor trains.*

The product

The briquettes have uniform physical and chemical specifications. They are one of the easiest cold ferrous feeds to handle, are easily discharged from ships and can be stored in open air with little oxidisation. Because the briquettes are made from fine iron ore rather than pellets, they are stronger and less fragile than pellet-produced types of direct-reduced iron.

The BHPB HBI plant has a high production rate, so that customer requirements can always be met, given reasonable notice. We supply more than half the market for direct-reduced iron.

The process

The first step is removing gangue from the Newman High Grade Fines in the beneficiation plant. The fines are processed by gravity and magnetic separation. That yields concentrate with more than 67% Fe and reduces the sum of SiO_2 and Al_2O_3 to less than 2%.

The concentrate is fed into a fluid-bed ore drier, then into the top of the reactor train, which is the first of four fluid-bed reactors. The fluidised ore reacts chemically with carbon monoxide and hydrogen (produced from natural gas, using heat and steam). The reaction removes the oxygen bound to the iron. In chemical terms, the ore is reduced. Hence the name “direct reduced iron”.

The metallic iron granules are then compressed into briquettes at about 650°C.

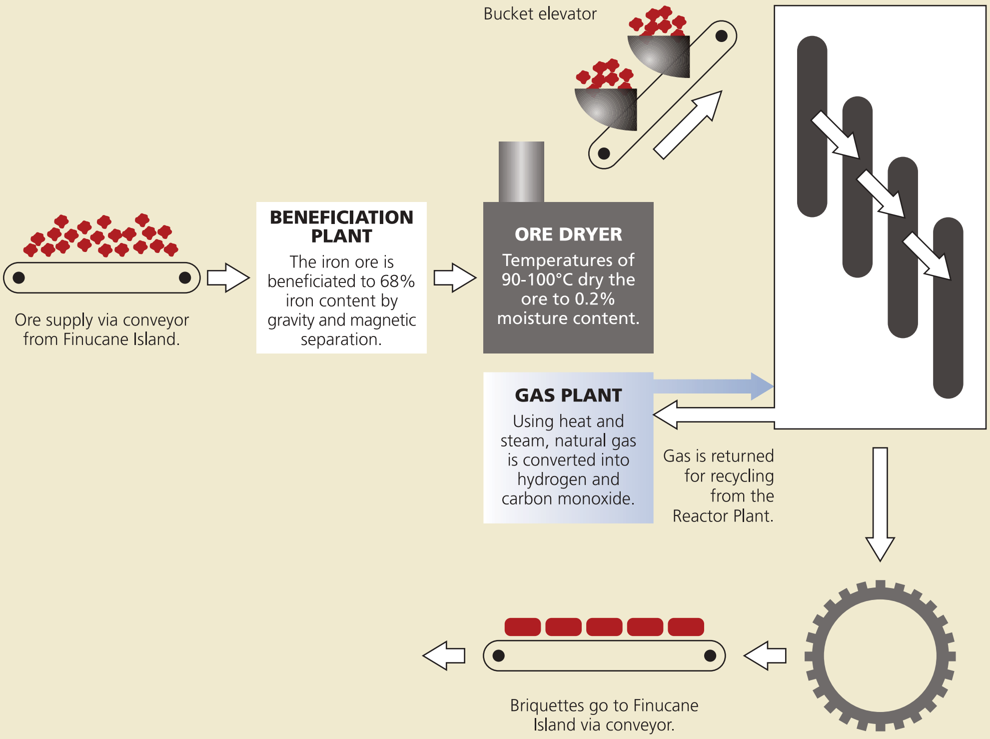
The product’s specifications (the total iron, gangue, phosphorus, sulphur and the very low residuals) have been consistent since the start of production. The superior quality of Boodarie™ Iron yields a superior steel, and at competitive cost.

The Direct Reduced Iron process

The HBI plant uses a ‘direct reduction’ process to convert iron ore into briquettes of metallic iron.

REACTOR PLANT

The combination of heat, hydrogen and carbon monoxide progressively changes the chemical composition of the iron by stripping away the oxygen molecules, chemically reducing it from hematite (Fe_2O_3) to metallic iron granules (Fe).



Ore supply via conveyor from Finucane Island.

BENEFICIATION PLANT

The iron ore is beneficiated to 68% iron content by gravity and magnetic separation.

ORE DRYER

Temperatures of 90-100°C dry the ore to 0.2% moisture content.

GAS PLANT

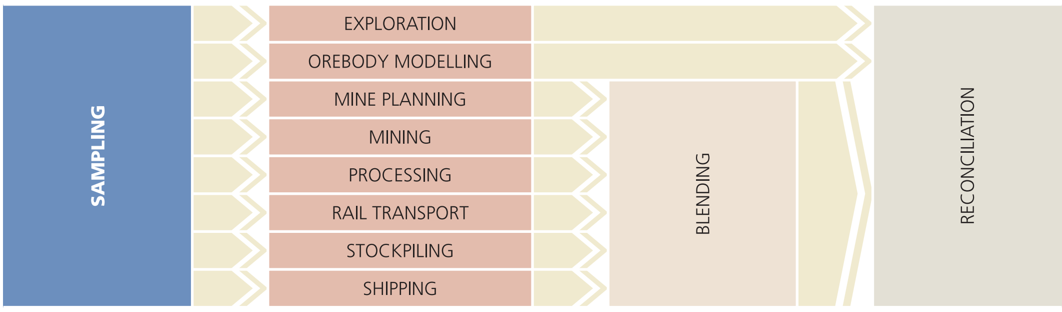
Using heat and steam, natural gas is converted into hydrogen and carbon monoxide.

Gas is returned for recycling from the Reactor Plant.

Briquettes go to Finucane Island via conveyor.

BRIQUETTE PLANT

Metallic iron granules are compressed into briquettes at temperatures of 650°C.



Sampling

BHPBIO recognises the very tight quality constraints under which its many iron and steel-making customers operate. As such, high standards of quality control and quality assurance are fundamental at all stages of the production chain for BHPBIO.

Exploration

The first stage of sampling is at the exploration site. All exploration drill rigs have approved automated sampling systems to ensure best practice sampling. Drilling methods used for exploration are either reverse circulation (RC) or diamond drilling. Diamond drilling is generally used below the water table, where the concerns about sample contamination are greater. RC drilling is more cost-effective above the water table.

The orebody model (and resultant mining schedule) is generated from the results of the exploration drilling programme.

***Above** Sample preparation robot, Nelson Point Quality Control Laboratory.*

Mining

The ore is drilled and blasted before it can be extracted by a loading unit. BHPBIO samples the blastholes at all its mine sites. The sampling method is continually refined to ensure that the best practices are used. The sample results are used to generate a short-term grade control model for the mine. That model allows better control of mining than the orebody model, because it uses far more detailed information, from closer-spaced drilling.

Ore processing

There are sample stations in most ore-processing plants at the mines and ports. These give important and continuous feedback for quality control of products. Many sample stations are also set up to allow metallurgical samples to be taken, as well as chemical ones.

Ship loading

There are sample stations on all ship-loading circuits, at both Nelson Point and Finucane Island. All product cargoes are allocated a physical and chemical quality certificate. The certificate is sent to customers after their cargoes have been loaded.

Sample analysis

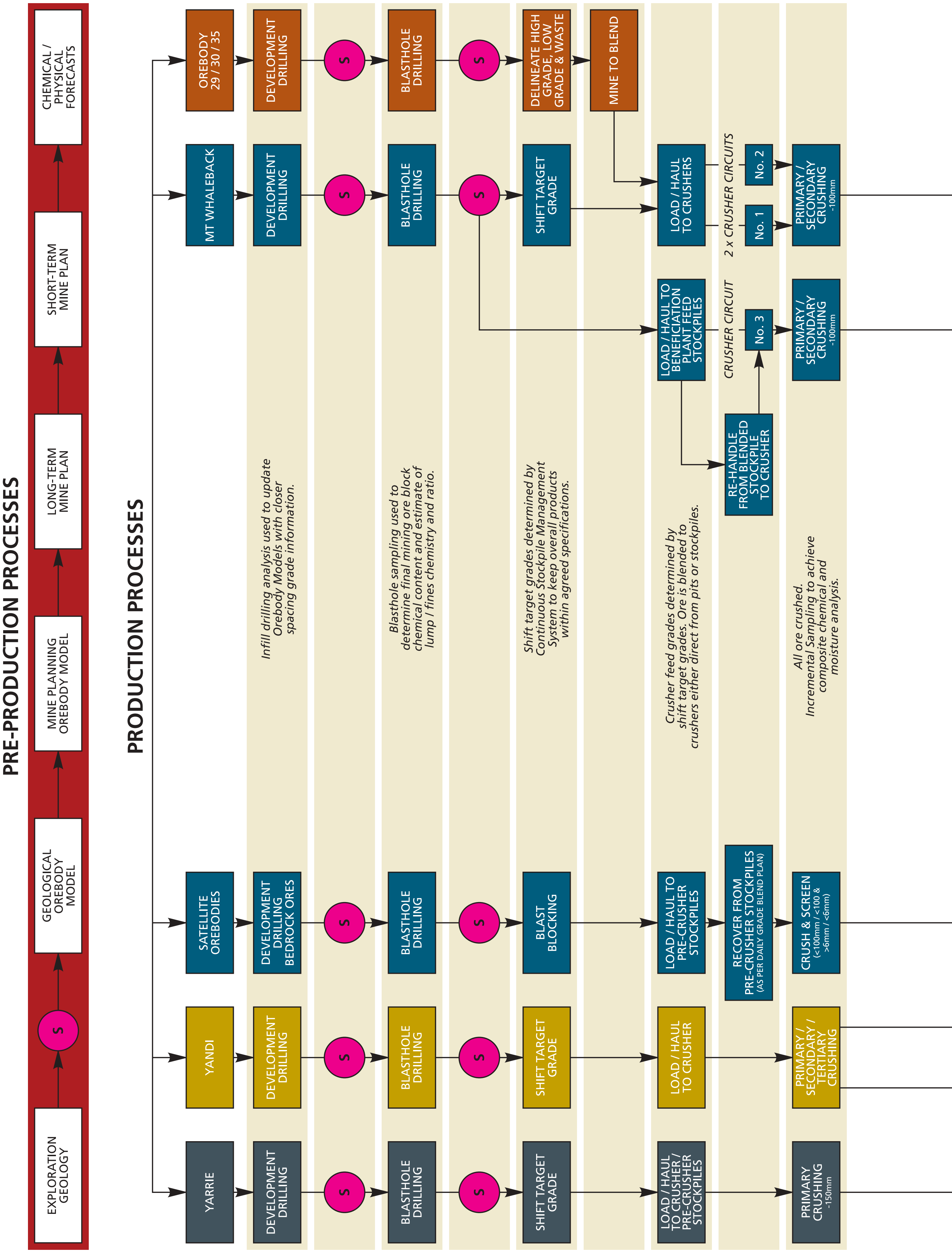
Samples from all stages of the production process are prepared and analysed at approved and certified analytical laboratories at BHPBIO operational sites. In particular, the company operates quality control laboratories at Newman, Nelson Point and Yarrie. Exploration samples are normally sent to commercial laboratories in Perth.

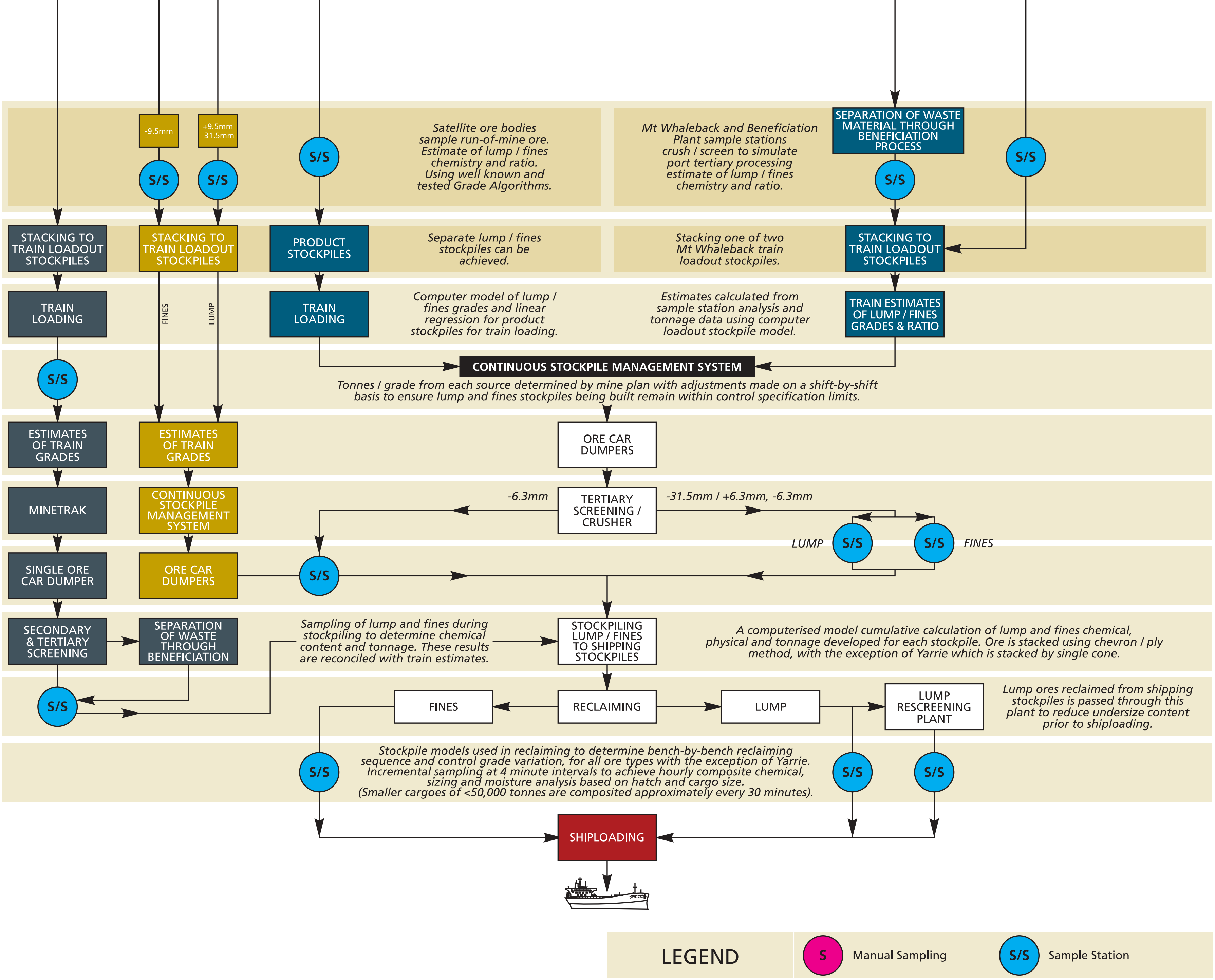
Stringent quality assurance procedures at all laboratories ensure that sample results meet international standard procedures. Samples are also returned to the client promptly to meet site operational requirements.

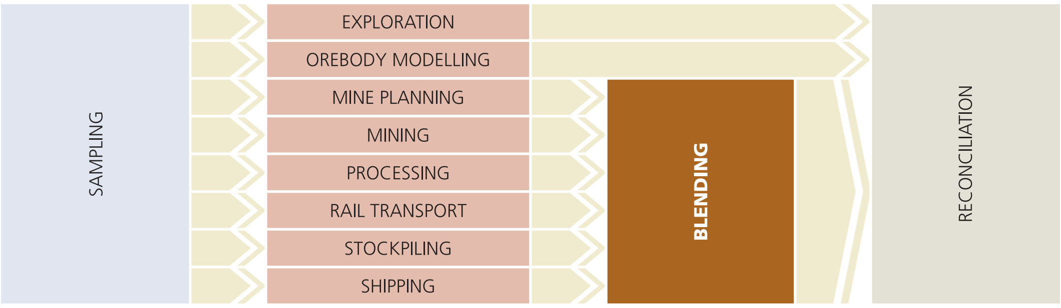
Auditing

The critical quality steps of the process are routinely audited as part of BHPBIO’s quality assurance system. BHPBIO has AS/NZS ISO 9001:2000 quality certification. Conducting scheduled internal and external quality audits is one of the requirements of being quality certified, as is the calibration of critical equipment such as sample stations, laboratory equipment (XRF spectrometers, balances, etc) and belt weightometers.

Sampling processes summary




-9.5mm
+9.5mm
-31.5mm
S/S
Satellite ore bodies sample run-of-mine ore. Estimate of lump / fines chemistry and ratio. Using well known and tested Grade Algorithms.
Mt Whaleback and Beneficiation Plant sample stations crush / screen to simulate port tertiary processing estimate of lump / fines chemistry and ratio.
SEPARATION OF WASTE MATERIAL THROUGH BENEFICIATION PROCESS
STACKING TO TRAIN LOADOUT STOCKPILES
PRODUCT STOCKPILES
Separate lump / fines stockpiles can be achieved.
Stacking one of two Mt Whaleback train loadout stockpiles.
TRAIN LOADING
FINES
LUMP
Computer model of lump / fines grades and linear regression for product stockpiles for train loading.
Estimates calculated from sample station analysis and tonnage data using computer loadout stockpile model.
TRAIN ESTIMATES OF LUMP / FINES GRADES & RATIO
CONTINUOUS STOCKPILE MANAGEMENT SYSTEM
Tonnes / grade from each source determined by mine plan with adjustments made on a shift-by-shift basis to ensure lump and fines stockpiles being built remain within control specification limits.
ESTIMATES OF TRAIN GRADES
ORE CAR DUMPERS
MINETRAK
CONTINUOUS STOCKPILE MANAGEMENT SYSTEM
-6.3mm
TERTIARY SCREENING / CRUSHER
-31.5mm / +6.3mm, -6.3mm
LUMP
FINES
SINGLE ORE CAR DUMPER
SECONDARY & TERTIARY SCREENING
SEPARATION OF WASTE THROUGH BENEFICIATION
Sampling of lump and fines during stockpiling to determine chemical content and tonnage. These results are reconciled with train estimates.
STOCKPILING LUMP / FINES TO SHIPPING STOCKPILES
A computerised model cumulative calculation of lump and fines chemical, physical and tonnage developed for each stockpile. Ore is stacked using chevron / ply method, with the exception of Yarrie which is stacked by single cone.
FINES
RECLAIMING
LUMP
LUMP RESCREENING PLANT
Lump ores reclaimed from shipping stockpiles is passed through this plant to reduce undersize content prior to shiploading.
Stockpile models used in reclaiming to determine bench-by-bench reclaiming sequence and control grade variation, for all ore types with the exception of Yarrie. Incremental sampling at 4 minute intervals to achieve hourly composite chemical, sizing and moisture analysis based on hatch and cargo size. (Smaller cargoes of <50,000 tonnes are composited approximately every 30 minutes).
SHIPLOADING
LEGEND
S Manual Sampling
S/S Sample Station



Blending

BHPBIO quality control starts up to 25 years before mining

Work done	***Up to 25 years***	***Up to 10 years***	***Up to 5 years***
Exploration	●		
Infill drilling		●	●
Winzing		●	
Orebody modelling		●	●
Mine planning		●	●
Customer samples		●	●
Iron making testwork		●	●
Quality control systems			●

Our records show we can consistently meet our customers' quality expectations. It has been achieved through more than 30 years experience and the use of sound mining practices.

Blending starts at the mine planning stage and includes ore types and their physical and chemical properties.

Integrated planning

BHPBIO uses an integrated planning approach to meet customer requirements. The approach embraces the mines, railways, port operations and our market sales projections. Our knowledge and experience of the overall business interact with our ability to set achievable plans and those factors jointly drive the integrated planning.

Grade control

The aim of our grade control system is to maintain a blending strategy that consistently produces shipment grades within acceptable tolerances, while economically mining ore from pits that have diverse grades. In addition, we aim to consistently unload trains and load ships at maximum rates, with no interference caused by grade issues.

The technical core of the integrated planning is the Continuous Stockpile Management System (CSMS). The system is a mathematical approach to balance all measured elements in both lump and fines, with the aim of optimising the overall grade.

The system is based on decision support, not decision making. The mine scheduling recommendations are modified by the technician to take into account mining preferences. The computer is good at analysing large amounts of data; people are good at judgement. The two combined have the potential to work more effectively than either alone.

How it works

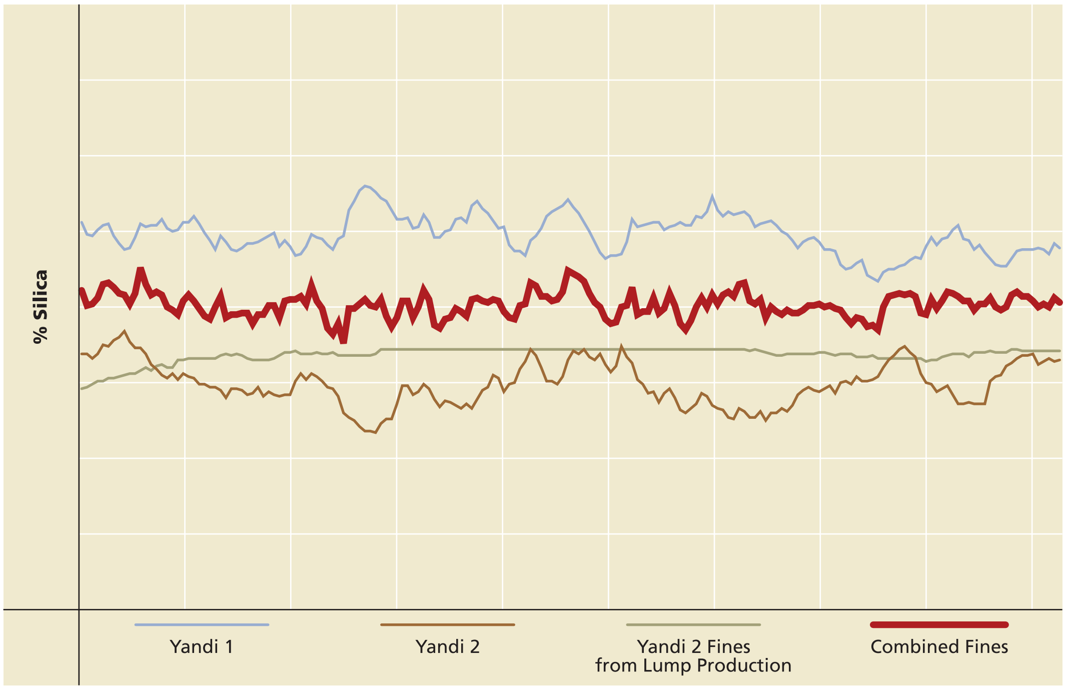
The system is based on two mathematical principles:

- Exponential Smoothing
- Grade Stress

Exponential smoothing

Individual train grades are multiplied by an exponentially decreasing factor, depending on the train’s position in the time-based sequence.

Smoothed grades from each pit



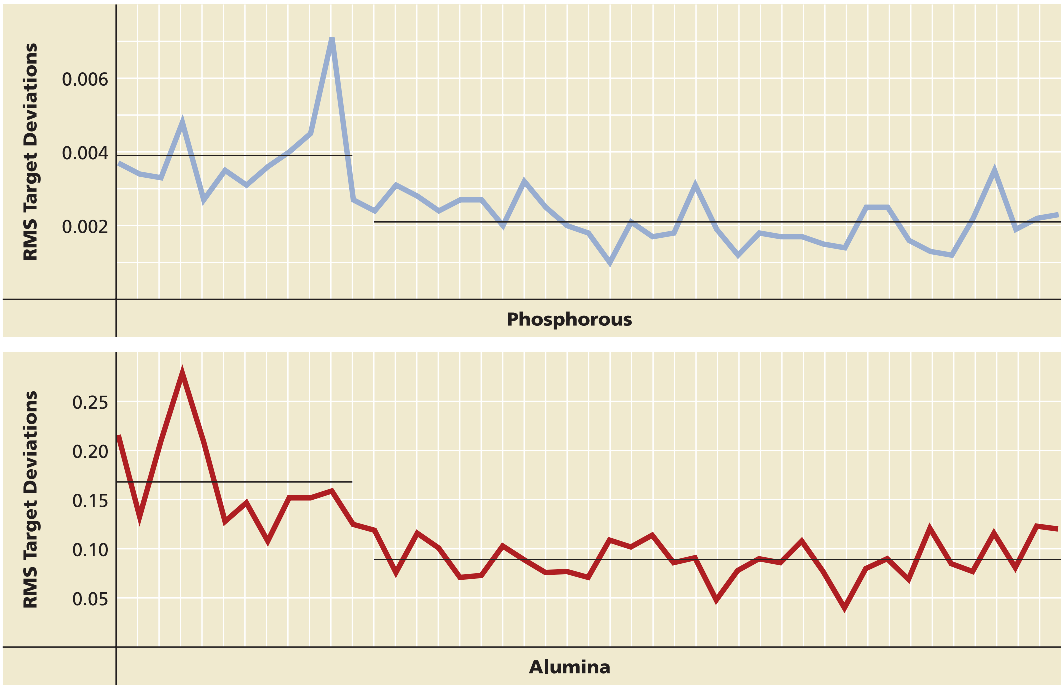
These numbers are combined to give a smoothed value that is used as the grade in the “Continuous Stockpile Model”. Variability between trains is smoothed out and the trends become evident.

Recent train grades are given more emphasis and the influence of each train drops gradually (exponentially), as shown in the above graph.

The grade control system does not rely on individual trains being on grade. Instead, the system relies on trains that have been selected to make a definite series, even though they may come from different ore sources with varying grade ranges.

The CSMS was introduced in early 1999. The benefits of using this system is clearly shown by the step improvement in daily quality variability, illustrated in the graphs below.

Product variability



Continuous Stockpile Grade is the exponentially smoothed value for each element for all on-track and processed trains, from all contributing ore sources to the blend.

Continuous Stockpile Model is made up of a value of Continuous Stockpile Grade for each of the four major elements (Fe, P, SiO_2, and Al_2O_3), for both lump and fines.

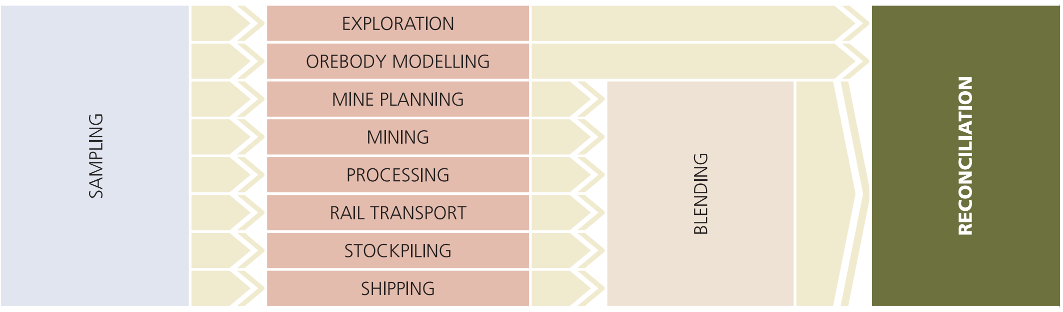
The aim is to keep the Continuous Stockpile Grade for each element, for both lump and fines, within individual shipping limits.

The series of trains arriving at the port must be loaded into one stockpile at a time. There is a minimum stockpile size that statistically guarantees that the whole stockpile will be on grade.

Grade Stress

The CSMS is based on the concept of "Total Stress". The stress of any element is the difference at any time between the actual continuous stockpile grade and the target grade, as a ratio to its tolerance. The Total Stress is the square root of the sum of stresses for all elements used for grade control. CSMS aims to maintain minimum Total Stress for a continuously created and endless "stockpile".

This system requires discipline at the port. Once a stockpile size is planned, the process must continue until that stockpile is complete. Unauthorised change is not allowed. This may mean that some flexibility is reduced. However, it improves interactive maintenance and quality planning because each stockpile is on grade and there is no requirement to blend from various stockpiles in a unscheduled way. It was found that a CSMS stockpile of about 200kt was optimal, depending on the product. (The range is from 150kt to 250kt.)



Reconciliation

The performance of each orebody model is continuously monitored to accurately predict the tonnes and grade of the ore being mined.

At the end of each month, the boundaries of the areas excavated are accurately surveyed. The predicted tonnes and grade from the model for these areas are then compared with the actual tonnes and grade excavated. The actual data are received from crusher weightometers and the sample station chemical analyses that are used to control quality.

If parts of the orebody model are not predicting the tonnes and grade accurately, the reasons are investigated and the model is modified. Further drilling and reinterpretation of the geology are done regularly as a result of learning from reconciliation data. Therefore the orebody model is continually improved, so that the best possible data are available for mine planning and quality control.

Reconciliation is also done for the monthly plans derived from the short-term model. To ensure that short-term variability is minimised, monthly grade and tonne targets are calculated for all contributors to the blend. In determining the individual contributor target grades, ore-dependent algorithms are used to model head grade into lump and fine grades.

These calculations are continuously updated by recording physical and chemical data from the sample stations. At the end of the month, the actual performance is compared with the plan. Discrepancies in grade or tonnes are investigated and the findings applied to future monthly plans.

The Company

BHP Billiton Iron Ore (BHPBIO) and Boodarie™ Iron (BHP Direct Reduced Iron Pty Ltd) are part of Carbon Steel Materials, a business group of BHP Billiton. BHPBIO encompasses the Mt Newman, Mt Goldsworthy and Yandi joint ventures (joint venture partners are Mitsui and Itochu) and the Jimblebar mine (100% BHPB).

BHPBIO's first mining in Western Australia began in 1950 at Cockatoo Island off the north-west coast. It closed in 1986. Mining began at Koolan Island in 1964 and closed in 1996. More than 100 million tonnes of iron ore were extracted before the operation was closed in 1996.

In 1969, BHPBIO began producing high-grade iron ore from the Mt Whaleback mine, near Newman. Since then, extensive exploration and drilling in the Pilbara has expanded resources to over 10,000 million tonnes.

BHPBIO holds quality certification to the International standard AS/NZS ISO 9001:2000.

History

The catalyst for developing the Pilbara's iron ore resources was the Federal Government lifting an embargo on iron ore exports. That happened in 1960.

Goldsworthy Mining, now part of BHPBIO, was the first to begin development. It mined from the Mt Goldsworthy deposit east of Port Hedland and shipped the first ore through its Finucane Island berth in June 1966. The same year, BHP joined a consortium with AMAX-CSR to form the Mt Newman Joint Venture in order to develop Mt Whaleback. In 1967, they were joined by Selection Trust Limited, Mitsui and CI Minerals (now Itochu).

BHPB acquired 30% of the joint venture and was appointed manager of the Project. BHP geologists soon realised the enormous potential of Mt Whaleback. They proved high grade iron ore resources of 1.5 billion tonnes.

Principal contracts for the development were let in 1967, sparking one of the most intensive engineering and construction projects in Australian history. Construction camps sprang up on sandy tracts at Nelson Point and in the bush at the base of Mt Whaleback. Work began on the Mt Whaleback minesite, and iron ore processing and shipping facilities at Nelson Point, Port Hedland and a 426km railroad.

Meanwhile, 21.4 million cubic metres of material was dredged from Port Hedland harbour, so that it could handle 100,000-tonne iron ore ships. Most of the dredgings were used to reclaim land around Nelson Point. Subsequent dredging has lifted port capability to ships up to 250,000dwt.

In 1992 the Yandi project added Yandi Fines to BHPBIO's product range. This was rapidly expanded from the initial 5 million tonnes per annum to it's current capacity of over 30 million tonnes per annum to satisfy strong customer demand.

Left *Mt Whaleback mine in the early 1970s.*

Ongoing development

BHP Billiton is committed to continuing to develop and diversify the suite of ores it has available for its many customers. Over the years, new products have been added and currently five main products are available:

- Newman High Grade Lump
- Newman High Grade Fines
- Yandi Fines
- Goldsworthy High Grade Lump
- Goldsworthy High Grade Fines

Additional minor products are also available on request.

BHP Billiton has recently committed to developing two new mining projects that will add three new products that are already keenly sought by our customers: Yandi Lump, Marra Mamba lump and fines (from Mining Area C).

BHP Billiton has a formal process for evaluating its major new capital projects. There are a series of independent peer reviews from internal and external experts before a project is presented to the Board for approval. Both the Yandi Lump and Mining Area C Projects have recently passed successfully through this process.

Yandi Lump

BHP Billiton has been producing limited amounts of Yandi Lump on a trial basis since late 1998. That production was a response to customers' requests, and it pointed to a strong demand for additional lump products. BHP Billiton's board approved the Yandi Project to be modified to allow 4 million tonnes of Yandi Lump per year to be produced at the Yandi 2 ore processing facility from mid 2002.

Mining Area C

The development of the Mining Area C project sees BHP Billiton re-establishing itself in the market for direct sales of Marra Mamba ore, a market we pioneered in the 1980s by further developing the Orebody 29 mine next to Mt Whaleback.

The Mining Area C project will produce both lump (MAC™ Lump) and fines (MAC™ Fines) from C Deposit. The lump and fines will be produced at the mine and railed to Port Hedland as direct shipping ore (DSO). BHP Billiton Iron Ore has committed major resources to investigating and developing this new project and received Board approval to develop the project in March 2002. The development will be completed in readiness for the first ore shipments to customers before the end of 2003.

Typical qualities of these new products are shown in the Products section. Strong market demand is expected for the new products and that will add further value-in-use for our customers.

Yandi expansion

The continuing strong demand for pisolitic ore by our worldwide customers has seen the Yandi Project producing at record levels (30 Mtpa) for the past few years. To continue to meet the demand, we are investigating options to expand production from the project.

To assist in meeting the immediate demand, a temporary crushing and screening facility has been built at the Yandi 2 ore processing plant. This allows additional production of 5 Mtpa from July 2002. A further study to increase expansion to over 40 Mtpa is currently underway.

Products and Capacity Expansion Project

The Products and Capacity Expansion Project (PACE) was investigated at the same time as the Mining Area C development. PACE recognised the need to expand rail and port facilities to allow for both tonnage growth and expansion of the range of our products.

Approved at the same time as the Mining Area C Project, PACE will see the facilities at both Nelson Point and Finucane Island upgraded and expanded progressively over the next ten years, from the current capacity to above 90 Mtpa. In particular, the facilities at Finucane Island will be considerably expanded to better utilise the full potential of the Island with the Goldsworthy project nearing completion of known ore reserves by around 2005. This will include a new berth, a new stockyard and rescreening facilities.

Environment & community

Part of the community

BHP Billiton is committed to ensuring that the communities in which we work share in our success.

Over more than 30 years, we have sought to contribute to community development to the benefit of our employees, contractors, their families and the broader Pilbara community, including Aboriginal people with ties to the land on which we operate.

In addition to the traditional economic benefits that flow from our activities – such as royalties, taxes and business and employment opportunities – we work in partnership with local government, community and sporting organisations to support a range of initiatives.

Recent significant initiatives have included a 10-year commitment to provide additional funding to the East Pilbara Shire to help it maintain community facilities and services in Newman. In Port Hedland, we contributed $3.5 million in recent years to help local government upgrade infrastructure and community facilities in South Hedland.

Environment

We are committed to sustainable development, believing we can achieve outstanding financial performance without compromising safety, environmental or social performance. We are guided by a commitment to continual improvement and a goal of "zero harm" to people and the environment.

Comprehensive environmental management policies cover all aspects of our operations. In recent years we have made significant progress on issues such as acid rock drainage, rehabilitation/closure planning and dust abatement, but significant challenges still remain.

We take the environmental consequences of our actions seriously, and are making progress in minimising these effects in dialogue with interested stakeholders.

Investing in Aboriginal relationships

While we have had a long track record of working with Aboriginal people in the Pilbara, these relationships have become more important as we negotiate access to land covered by registered Native Title claims.

Aboriginal employment is a key issue and we have set a goal to increase the level of Aboriginal employment in our operations from the present 3% of our workforce to 12% by 2010, reflecting the representation of indigenous people in the Pilbara population. This is a challenging target, but we are supporting it with a range of education, training and employment initiatives.

Another initiative has involved working with the Graham "Polly" Farmer Foundation, the Education Department and local community educators on the development of a program to help indigenous students in Port Hedland both remain and achieve their potential in the secondary education system. The program is to commence at the beginning of 2002.

We have also developed a cross-cultural training program to help employees learn more about local Aboriginal history and cultures and to build support in the workplace for other Aboriginal relations initiatives.

Above *Aboriginal apprentice works with a Technical Training Officer.*

Above *Environmental impact monitoring.*

Above *Where is the dust? Dust management is part of every BHPBIO ore-handling system.*

Above *Another method of dealing with dust: a large vacuum-extraction system. Rail cars are turned upside-down and dumped in this building.*

Left *Inspecting the acid rock drainage dam and evaporation ponds to ensure that no contaminates discharge from the site. Controlling the acid rock is important, because after the mine is shut down and rehabilitated, the rock will continue to produce acid for thousands of years.*

Products to customers

BHPBIO has long-term supply relationships with its customers in major markets throughout the world. Customers want stable supply and quality, in order for them to optimise their operations. Not only does BHPBIO provide a range of quality products, which are being continually updated to meet evolving customer needs, but we also offer full, wide-ranging support. Because of our operational knowledge and research and steel connections, we are in a pre-eminent position to provide customer support.

Our customer support team members are well-qualified iron makers – some of them with decades of experience. We not only assist the buyers in our customers' head offices, but go with them to their plants and meet the people who manage their raw materials yards, sinter plants and blast furnaces. We help with technical matters, and those discussions also give us important feedback about changing needs in the industry. It helps us ensure we have the right products available as the market changes.

HBI advice

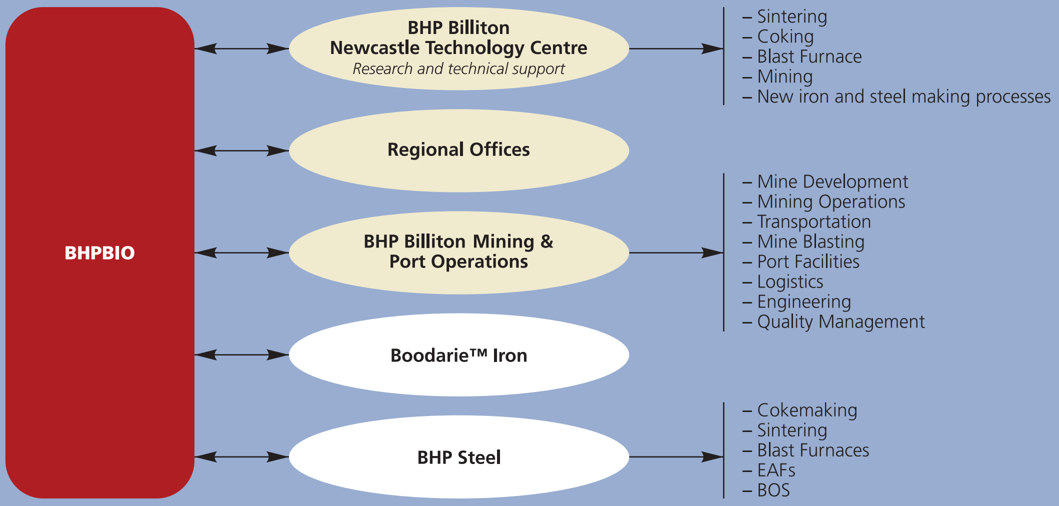
We offer wide-ranging technical support, including technical advice at the buyer's plant. Boodarie™ Iron has been used with complete success in:

- Electric Arc Furnaces with continuous feeding, bucket feeding, or shaft feeding.
- Basic Oxygen Furnaces, either as a scrap replacement or as a trim coolant.
- Blast Furnaces.

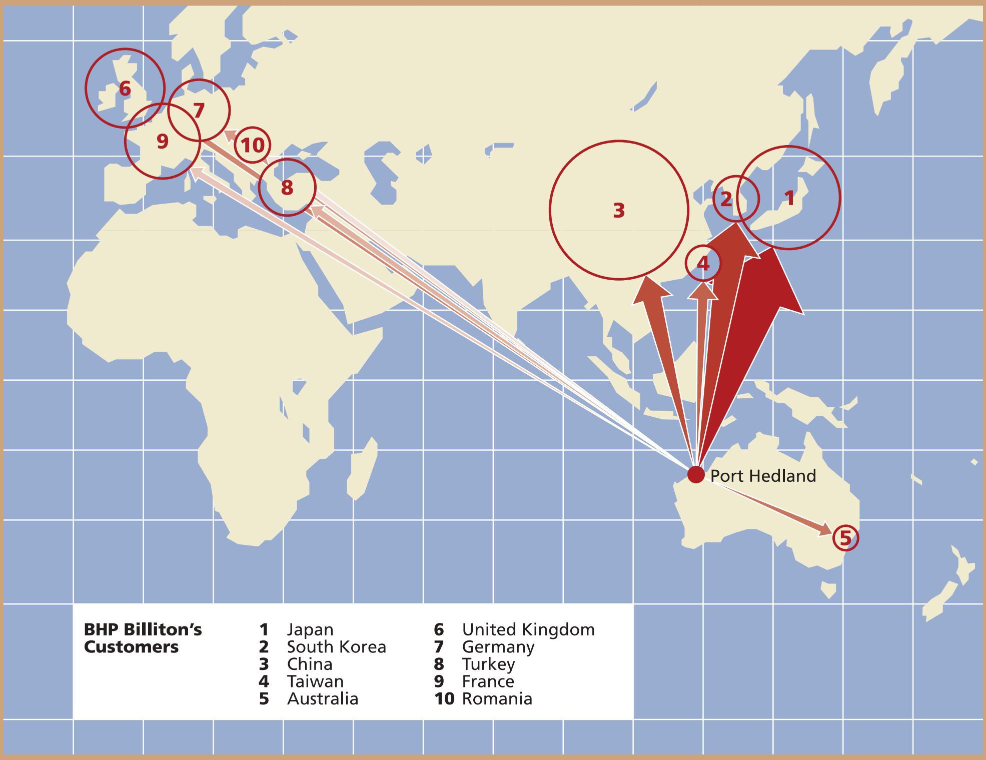
One frequent request we receive is to show customers how to check the composition of the briquettes, because that is not straight-forward.

We also offer an interactive CD that lets potential customers evaluate the possible uses of the briquettes in their own industry. To order a copy of the CD, or for any other queries, please contact one of our marketing offices shown on page 60.

BHP Billiton Iron Ore's Technical Capability



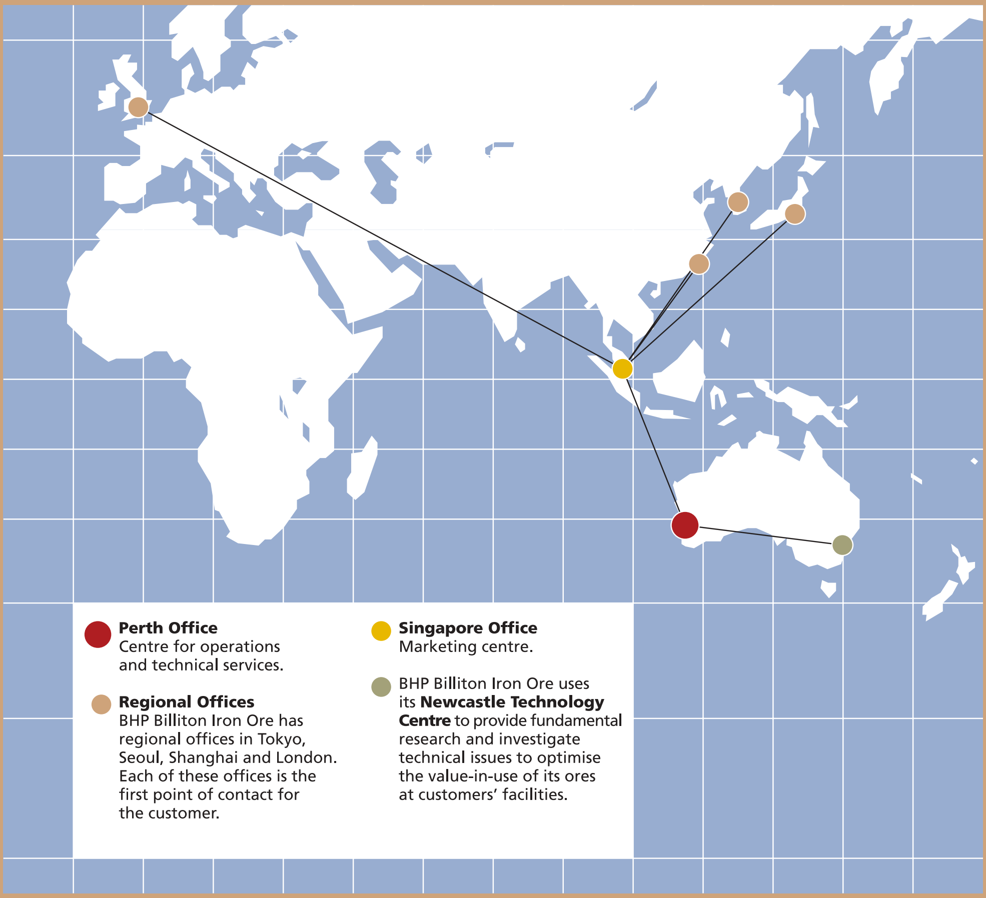
Where BHP Billiton Iron Ore is sold



BHP Billiton's Customers

1	Japan	**6**	United Kingdom
2	South Korea	**7**	Germany
3	China	**8**	Turkey
4	Taiwan	**9**	France
5	Australia	**10**	Romania

Customer support network



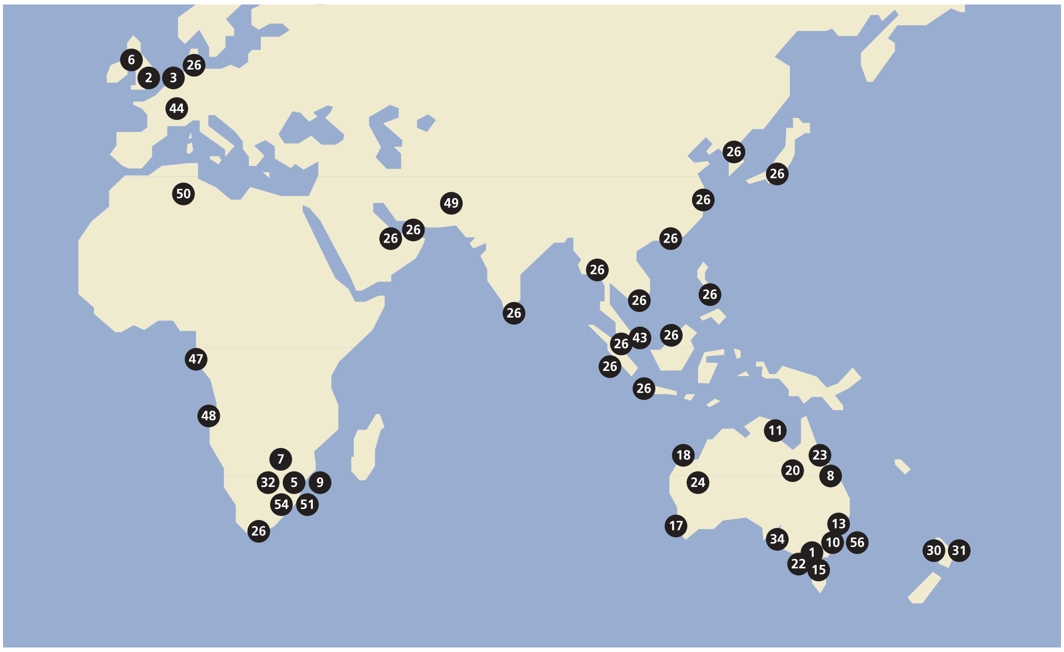
● **Perth Office**
Centre for operations and technical services.

● **Regional Offices**
BHP Billiton Iron Ore has regional offices in Tokyo, Seoul, Shanghai and London. Each of these offices is the first point of contact for the customer.

● **Singapore Office**
Marketing centre.

● BHP Billiton Iron Ore uses its **Newcastle Technology Centre** to provide fundamental research and investigate technical issues to optimise the value-in-use of its ores at customers' facilities.

Global contacts



Customer sector group - Base Metals

CONTINENT	*SITE/ASSET*	*DESCRIPTION*	*MAP REF*
South America	Escondida, Chile	57.5% held in one of the largest copper mines in the world.	14
Australasia	Cannington, Queensland	A silver, lead and zinc deposit in North-west Queensland.	20
South America	Antamina, Peru	33.75% stake in a copper-zinc mine in Peru - set for completion in 2001.	21
South America	Cerro Colorado, Chile	Mine in North Chile produces copper cathodes and concentrates.	28
North America	Highland Valley Copper, Canada	33.6% stake in Highland Valley Copper mine in British Columbia.	29
North America	Selbaie, Canada	Wholly owned open pit operation producing zinc concentrate and by-products including gold and silver.	37
South America	Alumbrera, Argentina	25% interest in Alumbrera copper concentrate producer, with gold by-products.	42
South America	Tintaya, Peru	99.5% interest in Tintaya that produces copper concentrated within the "Skarn Belt" of South Eastern Peru. Concentrate is transported by road to a Peruvian smelter or to the port of Matarani.	52

Customer sector group - Carbon Steel Materials

CONTINENT	*SITE/ASSET*	*DESCRIPTION*	*MAP REF*
Africa	Samancor	60% share of Samancor Limited, integrated producer of chrome and manganese ores and ferroalloys. (Also part of Stainless Steel Materials Customer Sector Group.)	7
Australasia	Bowen Basin, Queensland	Queensland coal mines producing high quality metallurgical coal for steel production.	8
Australasia	Illawarra Coal	Five underground coal mines.	10
Australasia	GEMCO	60% stake in Groote Eylandt Mining Co Pty Limited producing manganese ore.	11
Australasia	TEMCO, Tasmania	60% held in Tasmanian Electro Metallurgical Company Pty Limited (TEMCO). Produces manganese alloys.	15
Australasia	Iron Ore operations, Western Australia	The Pilbara iron ore mines rank amongst the world's best long-life iron ore assets.	24
South America	Samarco, Brazil	50% interest in Samarco, an efficient low cost producer of iron ore products.	53

Customer sector group - Petroleum

CONTINENT	*SITE/ASSET*	*DESCRIPTION*	*MAP REF*
Europe	Liverpool Bay, UK	Five gas fields in the Irish Sea.	6
North America	Gulf of Mexico	Several producing assets in the Gulf of Mexico.	16
Australasia	North West Shelf	One of Australia's largest resources projects, producing LNG and domestic gas.	18
Australasia	Bass Strait	50% share with Esso (the operator). The Bass Straits operations produces oil, condensate, LPG, natural gas and ethane.	22
South America	Trinidad	Petroleum's exploration portfolio includes test areas in Trinidad.	45
South America	Bolivia	Petroleum's exploration portfolio includes both production and test areas in Bolivia.	46
Africa	Gabon	Petroleum asset.	47
Africa	Angola	Petroleum asset.	48
Asia	Pakistan	Petroleum's exploration portfolio includes test areas in Pakistan.	49
Asia	Algeria	Petroleum's exploration portfolio includes test areas in Algeria.	50

Corporate Centres

CONTINENT	*LOCATION*	*MAP REF*
Australasia	Melbourne (Head Office)	1
Europe	London	2
Africa	Johannesburg	32
North America	Houston	33
Australasia	Adelaide	34
North America	Toronto	38
North America	Vancouver	39
South America	Santiago	40

Marketing Offices

CONTINENT	*LOCATION*	*MAP REF*
Europe	**Marketing Office The Hague** Mariahoeveplein 6 Den Haag 2591 TV The Netherlands Phone: (31 0 70) 315 6666 Fax: (31 0 70) 315 6769	3
Asia	**Marketing Office Singapore** 168 Robinson Road # 10-01 Capital Tower Singapore 068912 Phone: (65) 349 3333 Fax: (65) 349 4000	43
Europe	Zug, Switzerland	44

Customer sector group - Aluminium

CONTINENT	*SITE/ASSET*	*DESCRIPTION*	*MAP REF*
Africa	Mozal, Mozambique	47% stake in the Mozal aluminium smelter.	9
Australasia	Worsley, Western Australia	86% share in the integrated Worsley alumina refinery/bauxite mine.	17
South America	Alumar, Brazil	Alumina refining plant and aluminium smelt.	35
South America	BMS, Suriname	Billiton Maatschappij Suriname (BMS) alumina refining plant.	36
South America	Valesul Aluminio. SA, Brazil	46% interest in aluminium smelter.	41
Africa	Hillside/Bayside, South Africa	Wholly owned aluminium production smelters.	51

Customer sector group - Stainless Steel Materials

CONTINENT	*SITE/ASSET*	*DESCRIPTION*	*MAP REF*
Africa	Samancor	60% share of Samancor Limited, integrated producer of chrome and manganese ores and ferroalloys. (Also part of Carbon Steel Materials Customer Sector Group.)	7
Australasia	Yabulu, Queensland	The Yabulu refinery is one of the major lateritic nickel-cobalt processing plants in the world.	23
South America	Cerro Matosa, Colombia	Integrated ferro-nickel mining and smelting complex in North Colombia.	27

Customer sector group - Steel

CONTINENT	*SITE/ASSET*	*DESCRIPTION*	*MAP REF*
Australasia	Port Kembla, Australia	Flat steel products centred in Port Kembla.	56
World	Multiple	27 operations worldwide. Plans are to spin-out the Steel business before the end of 2002.	26
Australasia	Waikato North Head Mine New Zealand	Iron sand mine operated by New Zealand Steel that has an exclusive 100-year lease.	30
Australasia	Taharoa Mine New Zealand	The site of the Taharoa mine has been leased from its Maori owners for 70 years. Lease commenced in 1972.	31

Customer sector group - Thermal Coal

CONTINENT	*SITE/ASSET*	*DESCRIPTION*	*MAP REF*
Africa	Ingwe	Largest coal producer in South Africa.	5
North America	New Mexico Coal	Three open pit thermal coal in the Four Corners region of New Mexico.	12
Australasia	COAL	Coal Operations Australia Ltd (COAL) has two operations in Australia.	13
South America	Carbones del Cerrejon	One third interest in Carbones del Cerrejon, steaming coal.	19
South America	Cerrejon Zona Norte Coal	One third of a 50% stake in the largest open pit coal mine in Latin America.	25

Other Assets

CONTINENT	*SITE/ASSET*	*DESCRIPTION*	*MAP REF*
North America	Ekati, Northwest	Diamond mine Territories of Canada.	4
Africa	Richards Bay Minerals, South Africa	50% stake in world's largest producer of titanium slag.	54

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