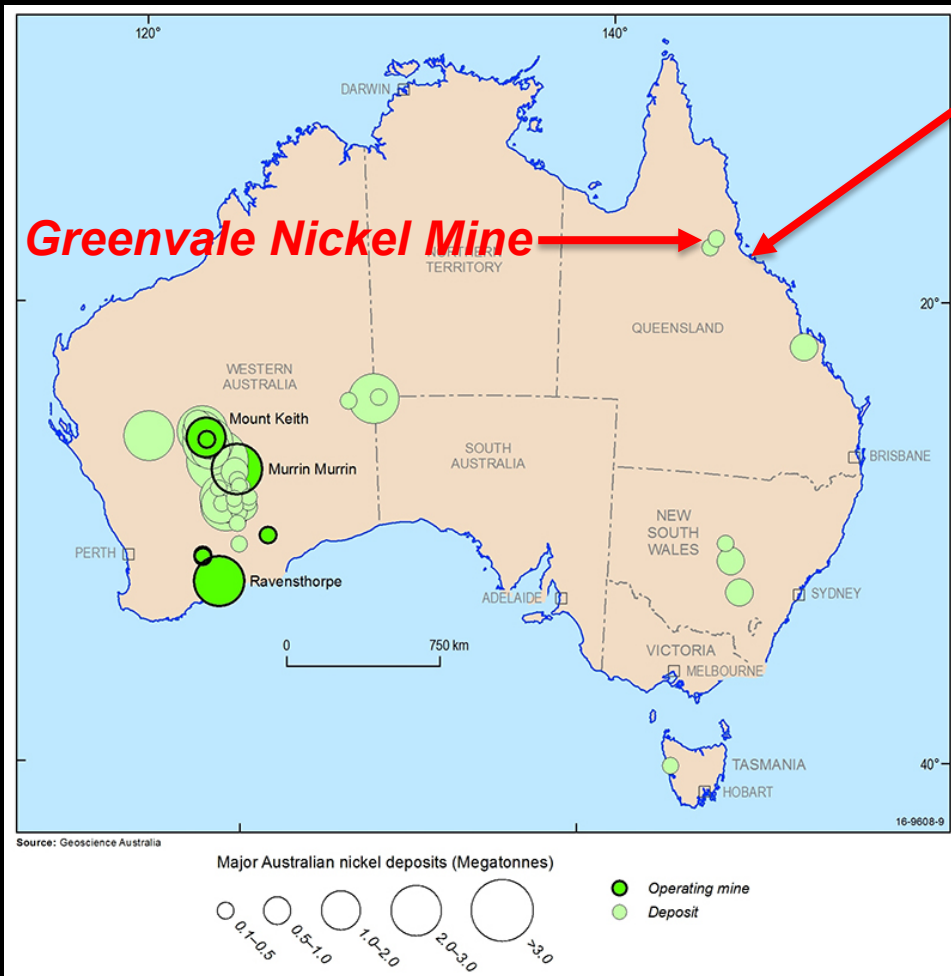


A History of Greenvale Nickel

Jim Morrison & Peter Burger, October 2019



Yabulu Nickel Refinery

METALS EXP. CLAIMS A BIG NICKEL FIND

Metals Exploration N.L. had discovered a very promising nickel prospect at Greenvale, in north Queensland, the chairman, Mr. R. Hare, told shareholders at the annual meeting in Melbourne yesterday.

project, far bigger than anything the company was involved in to date.

Mr Hare said consideration might even have to be given to building a smelter, if other necessary materials such as coke and sulphur were available.



Australia's Nickel Resources and Mines 2016 (green)

Source: Sydney Morning Herald, 16 Dec. 1966.

Source: <http://www.ga.gov.au/education/classroom-resources/minerals-energy/australian-mineral-facts/nickel> Photo, Anthony Jannink



J.M. acknowledges the College of Science, Technology and Engineering, James Cook University, Queensland, Australia.

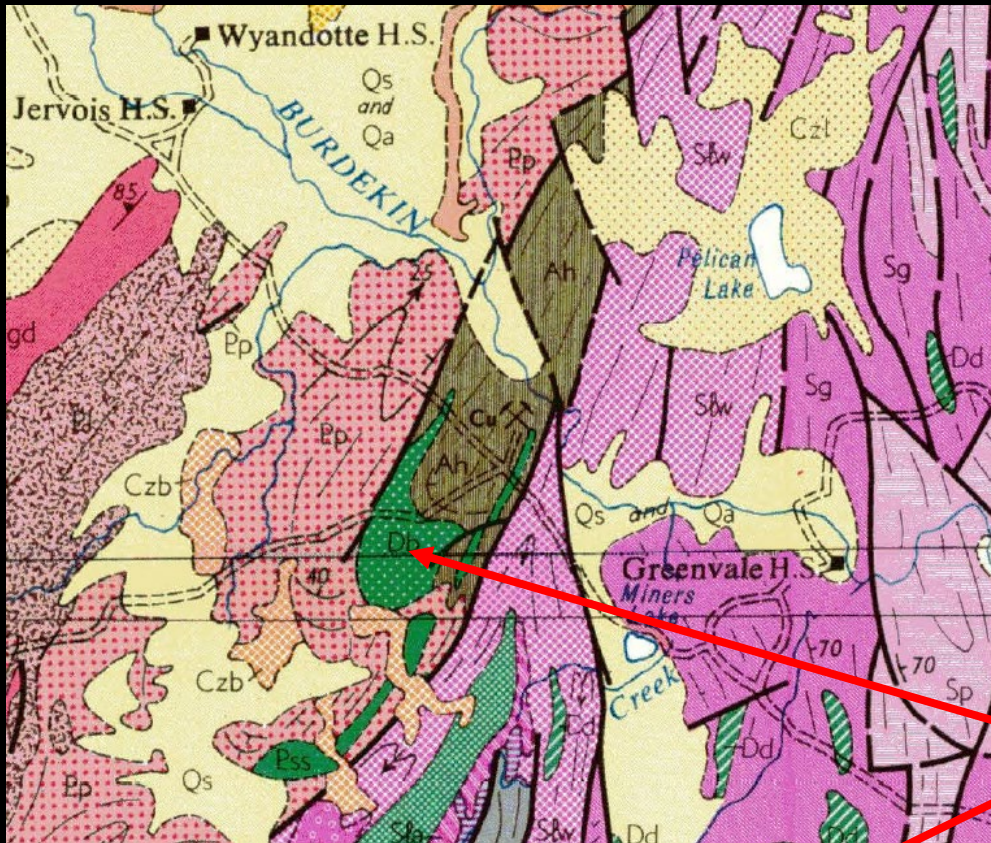
Acknowledgements

- Special thanks are extended to
 - Peter Burger, co-author; Greenvale Project Geologist for 16 years.
 - David Burt for permission to use extracts from his “Personal Account of some Orebody Discoveries 1966 – 2007” and other data.
 - Anthony Jannink for photos of the first drilling.
 - David Hunter for historic videos and technical papers on recent metallurgical advances at Yabulu, and to his colleagues particularly
 - Patrick Stokes and John Fittock papers.
 - A multitude of personal, internet and other sources.

Disclaimer

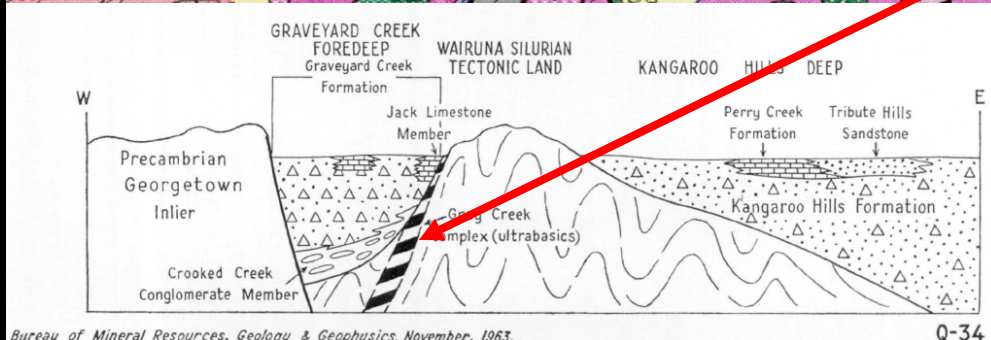
- *This presentation is intended to provide general information and is not intended to constitute legal, financial, accounting, tax, investment consulting or other professional advice or services. The information was collected from various sources, most of which do not guarantee or warrant correctness. Whilst the information has been collected with reasonable care, the authors do not guarantee or give any warranty as to its correctness. Although the information has been obtained from sources considered and believed to be both reliable and accurate, no responsibility is accepted for any opinion expressed or for any error or omission in that information. The authors shall not be liable for any special, direct, incidental, consequential or punitive damages or any other damages or loss whatsoever whether in an action of contract, statute, tort (including without limitation, negligence) or otherwise relating to the use of this presentation or information.*

BMR / GSQ Laterite Discovery

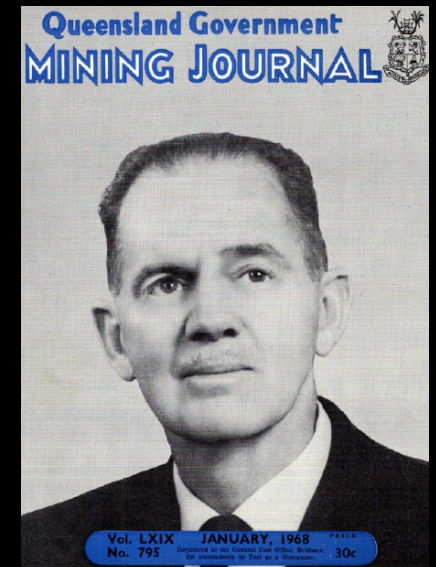


- 1950s Commonwealth encouraged new mining and funded the geological mapping of Australia after collapse of the Wool Boom.
- BMR / GSQ mapped the laterite during regional mapping 1956-1958.
- 1957 nickel first recognised by the Queensland Chief Government Geologist Alan Denmead.

**Greenvale
Serpentinites**



Bureau of Mineral Resources, Geology & Geophysics, November, 1963.



1957-58 BMR-GSQ Exploration



- 1957-1958 BMR geochemical testing of the serpentinite.
- Ni values decreased on entering the mottled zone.
- A lens 23 x 8m averaging 2.5% Ni was found 1.6km south of Halls Reward Cu mine.
- 1958 Boiler Gully serpentinite (Greenvale) drilled upper Fe zone confirmed low grade surface nickel (0.1 to 0.5 % Ni), **with 3.3% Ni at 10m in hole L1.** 8 km SW of Halls Reward.
- Not published until 1961 and not mentioned in 1962 Einasleigh 1:250,000 explanatory notes.

The results for nickel are summarised below:—

Locality	Maximum depth in ft.	Average Per Cent. Ni	Maximum Per Cent. Ni	Remarks
L 1	14	0.85	1.2 at 8-10 feet	ferruginous zone
L 1	33	2.4	3.3 at 30-33 feet	ferruginous zone
L 3	6	0.47	0.6 at 4 feet	ferruginous zone
L 4	14	0.43	0.5 at 10-12 feet	ferruginous zone
L 5	4	0.05	0.06 at surface	mottled zone
L 6	6	0.55	0.7 at 4 feet	ferruginous rubble
L 7	10	0.40	0.5 at 0-4 feet	ferruginous zone
L 8	8	0.10	0.2 at 4 ft.	4 in. ferruginous gravel at 4 feet overlain by recent alluvial clays
L 9	6	0.10	no maximum	mottled zone
L 10	6	0.15	0.3 at surface	mottled zone

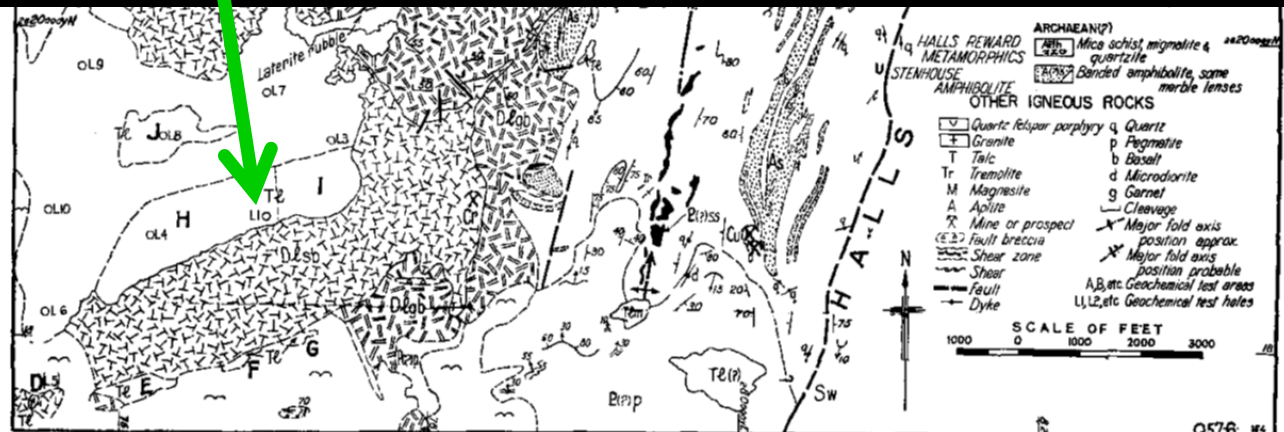
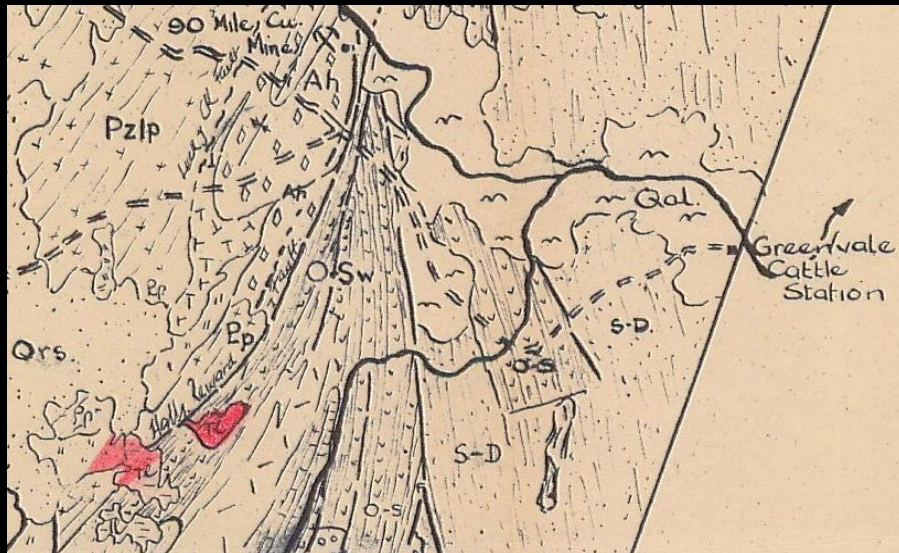
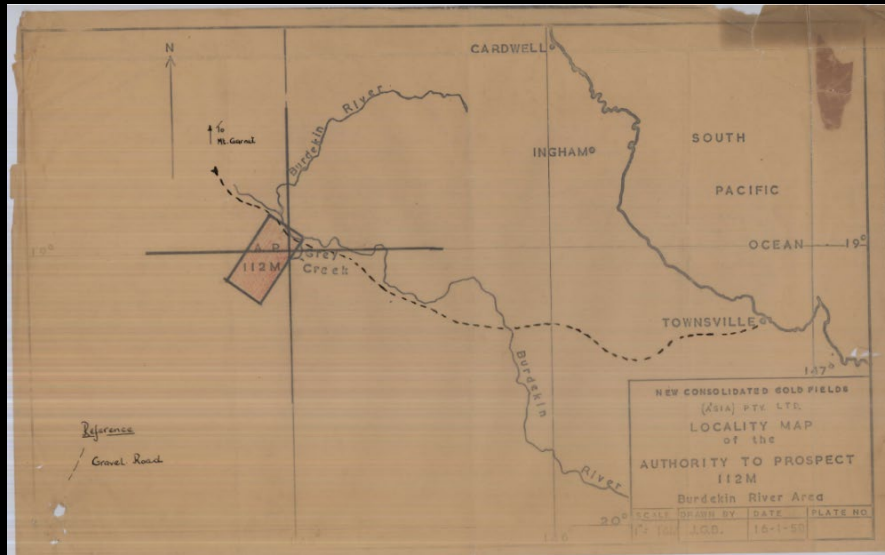


Figure 1

1957-60 New Cons. Goldfields



Source: Clark A B, 1958, 1959.

- 1957 Authority to Prospect (ATP122M) granted.
- 1959 followed up BMR results.
- Sampled the upper Greenvale iron-rich zone and some lateritised gabbros with costeans and some auger holes.
- 2 Mt of 0.8 %Ni was delineated.
- Concluded that the grades were too low or the deposits too small.
- 1960 relinquished the ATP.
- The laterite remained unpegged for 5 years.

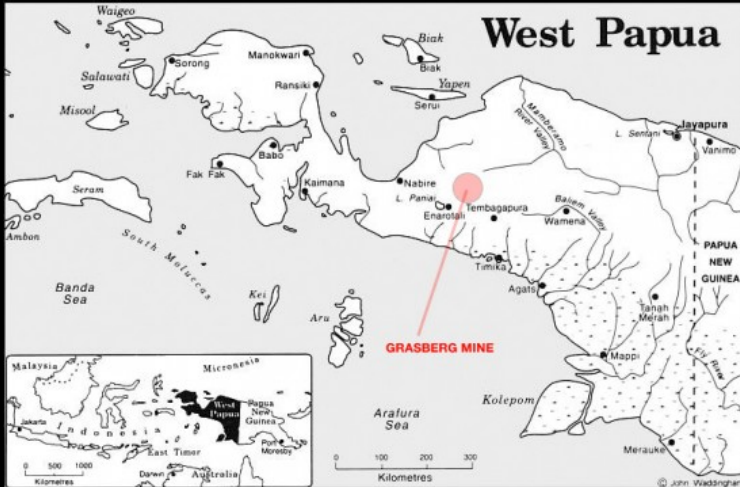
1950s Freeport Cuban Nickel



- Cuba hosts 34% of the world nickel resources in huge laterite deposits. (800 Mt Reserves, 2.2 Bt Resources)
- 1942- 1947 Freeport supplied Ni from Nicaro, Cuba.
- 1955 Freeport research developed new Ni-Co process.
- 1958 Freeport built mine at Moa Bay and a refinery in Louisiana.
- Partly financed \$100M by the US Government.
- 1958 Fidel Castro's revolution; Moa Bay feed stock lost to Freeport.
- 1960 Cuba confiscated US property.

Freeport Ni Refinery, Louisiana.

Freeport / Metals Ex JV



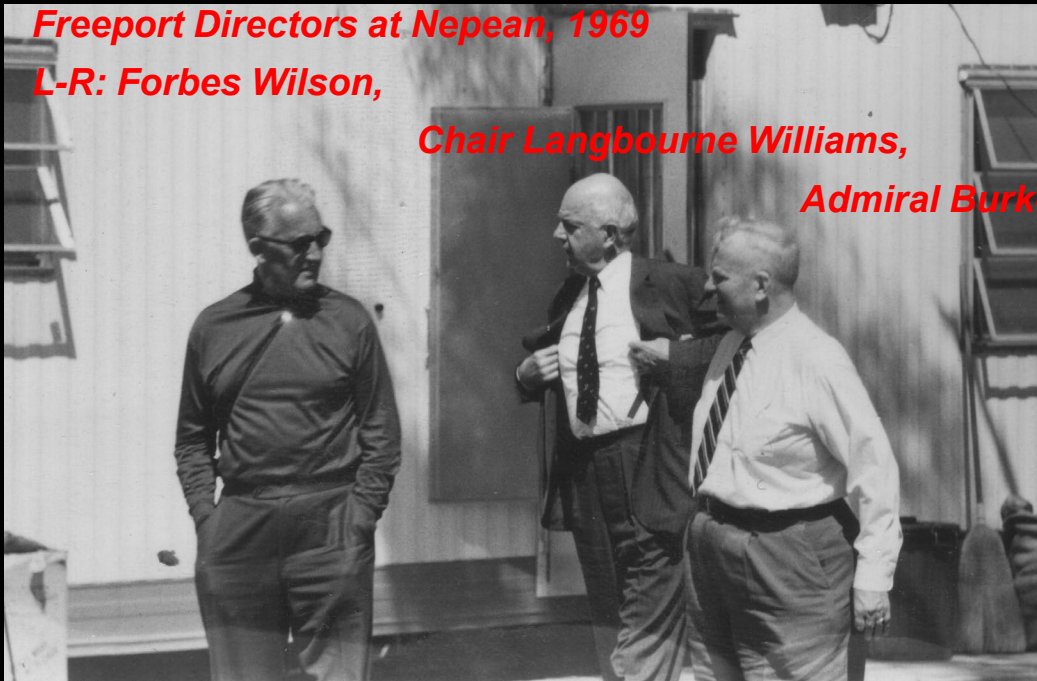
- 1960 Forbes Wilson's Freeport expedition to Dutch New Guinea re-discovered the Ertzberg (> Grasberg 1988).
- 1964 Freeport of Australia set up for minerals search in Australia and SW Pacific.
- ~1964 Reg Hare, needing funding for Metals Exploration NL concluded a J.V. with Freeport
- ~1965 (before WMC nickel discovery) application for Greenvale ATP335M on recommendation by Chief Geologist Paul Anthony.

Freeport Directors at Nepean, 1969

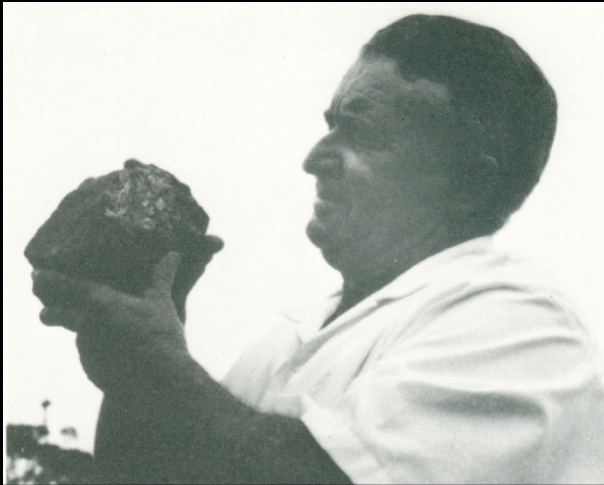
L-R: Forbes Wilson,

Chair Langbourne Williams,

Admiral Burke.

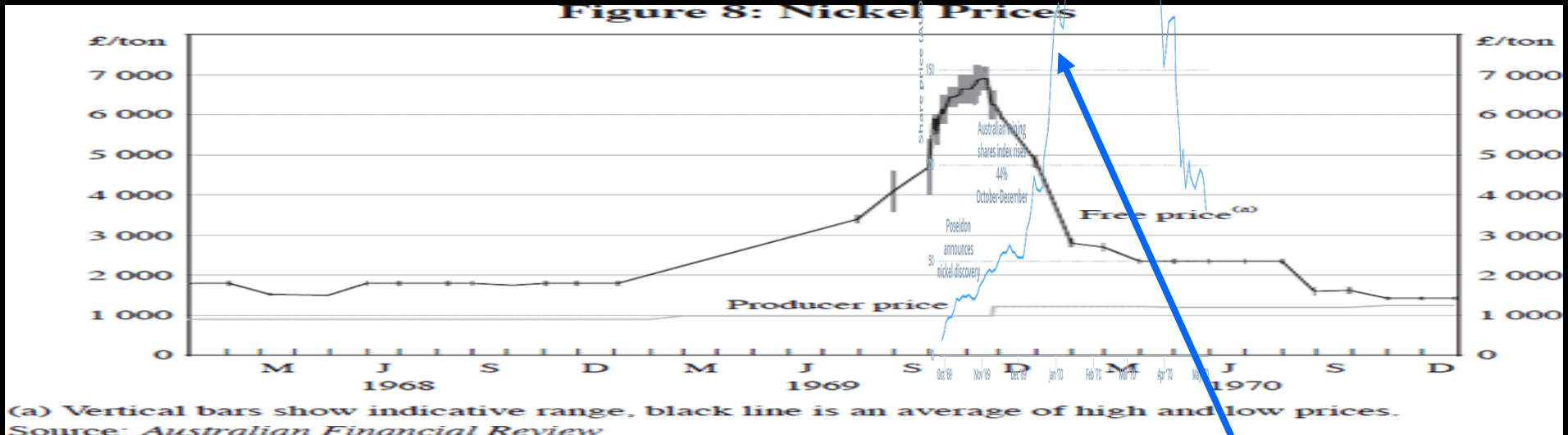


1960s Australian Nickel Boom



George Cowcill with a lump of Lunnon Gossan

- Late 1960s Ni price escalated 52% due to surge in stainless steel demand and for aerospace & munitions.
- January 1966 sulphide nickel discovered at Kambalda WA by WMC.
- 1966 Supply tightened due to strike at INCO Sudbury.
- The nickel boom took off in a “perfect storm” of major price rise coinciding with finding a new nickel province.
- Boom peaked in 1969 - 1970



Metals Exploration NL



Reg Hare, Metals Ex Chairman.

- Driven by supportive leadership of Reg Hare and Freeport, Metals Exploration NL reacted quickly to the nickel boom.
- From 1966 to 1969 discovered Greenvale, Nepean, Mt Keith and Ramu (PNG) deposits containing 3.2 Mt Ni set to produce ~1.6 Mt Ni, 80,000t Co.
- Nepean became Australia's second nickel mine.



Erecting Nepean headframe. 1969.

Source: Burt, 2015. *The Age*, 1970-10-30.

3 km long open pit, Mt Keith, 2016.



© 2013 Google
Image © 2013 Maxar Technologies

Google Earth

1966 Metals Exploration High Grade Discovery



Metals Exploration's first drill hole at Greenvale, 1967.

- April, 1966 research included comparisons with the major New Caledonian Ni laterites and recognised the deeper potential at Greenvale
- On grant of ATP 335M on 14 July 1966, David Burt and Anthony Jannink visited Greenvale to assess the in-depth potential
- Bulk samples averaged 1.5 -2.0% nickel over a 200m zone at the bottom of a deep erosion gully and the project was re-born.

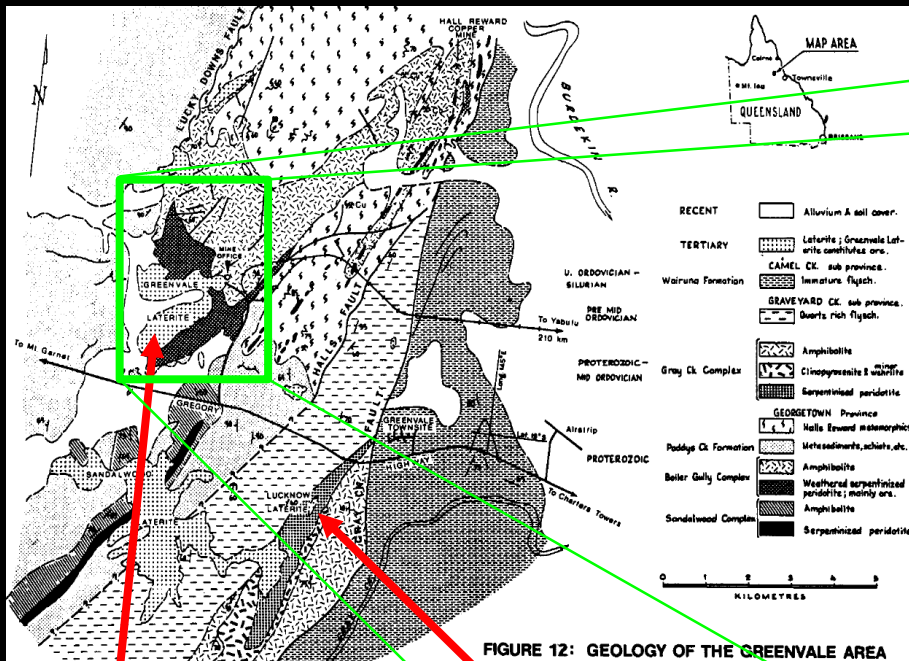


Burdekin River camp.



David Burt, 1969

Greenvale Geology

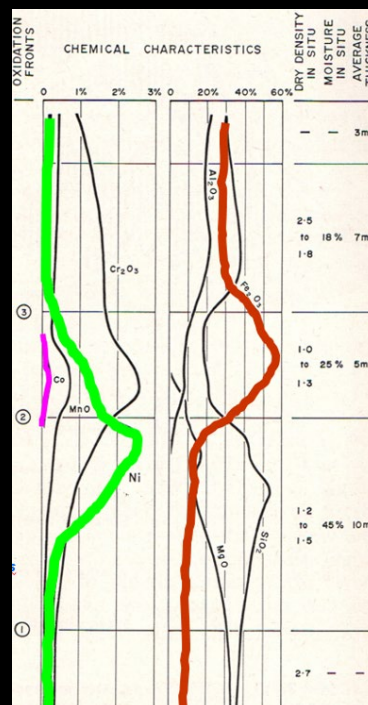
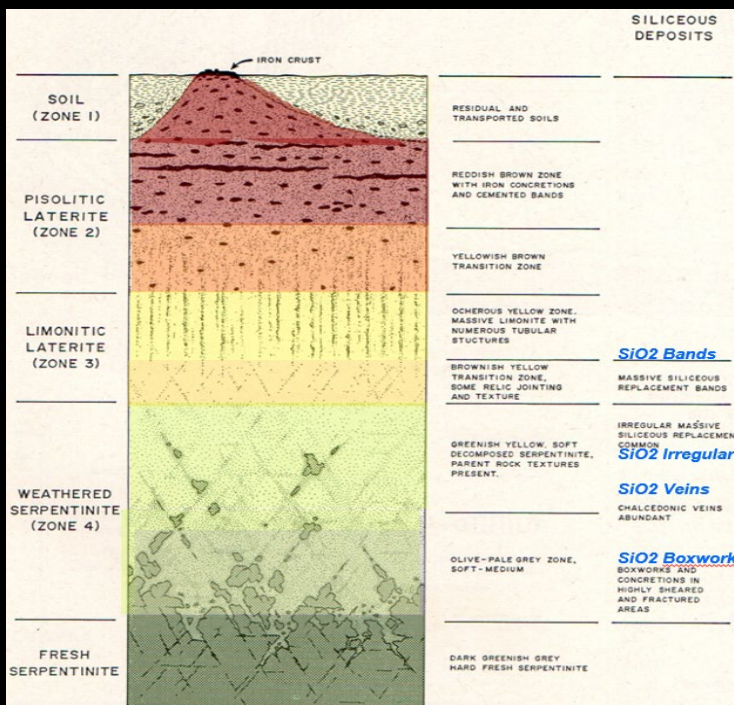


Greenvale laterite. Lucknow Laterite

- 1967 detailed plane table geological mapping by Tim Gosling used through mine life.
- Buff Zordan's shafts mapping and carefully sampled for metallurgical testing.
- Detailed mapping & RAB logging by Peter Burger later resolved structural, grade and metallurgical issues.

Laterite Geology

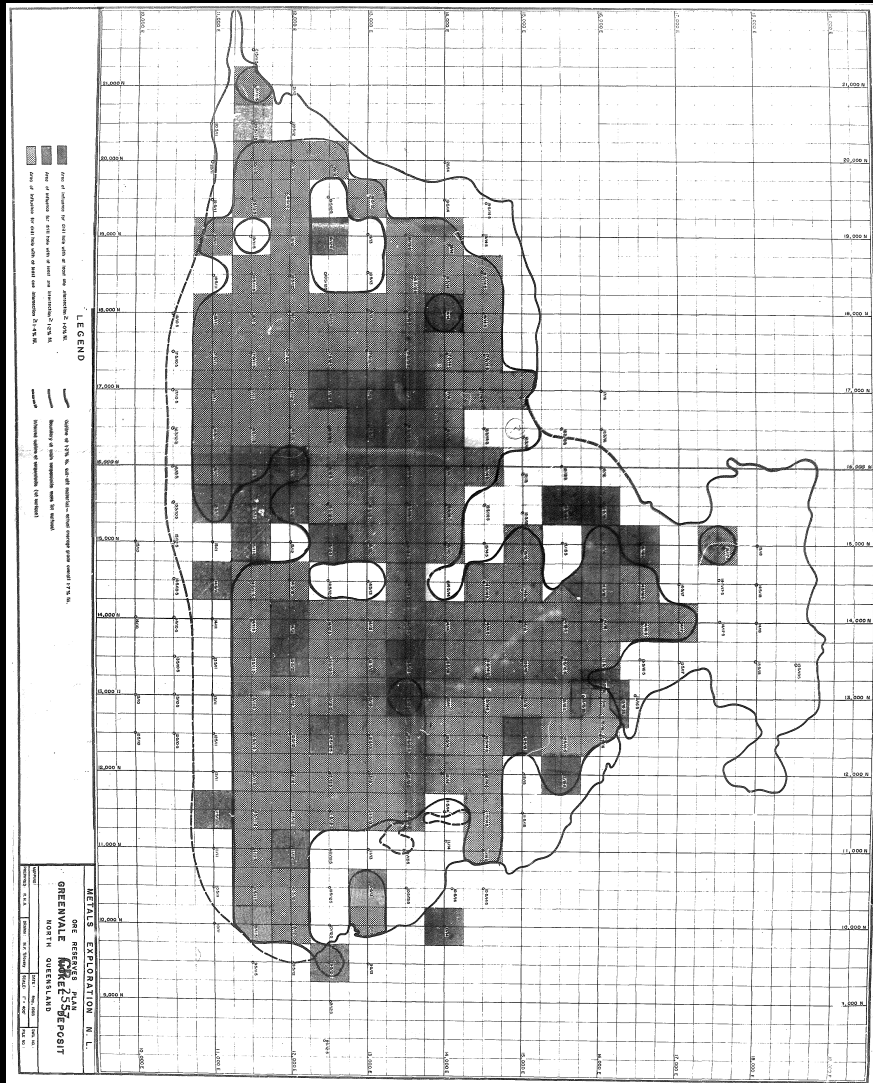
- Cyclic rainfall and groundwater through 0.2% Ni serpentinite.
- Soluble elements mobilised by acid water.
- Permeable faults helped alteration and flushing of soluble products.
- Si and Mg progressively depleted leaving Al & Fe surficial duricrust.
- Ni, Co, Mn, Cr accumulated in the middle levels.
- >3 times reduction in surface elevation through materials movement in solution.
- Erosion reduced the original 5.5 sq.km laterite to 3.3 sq.km.



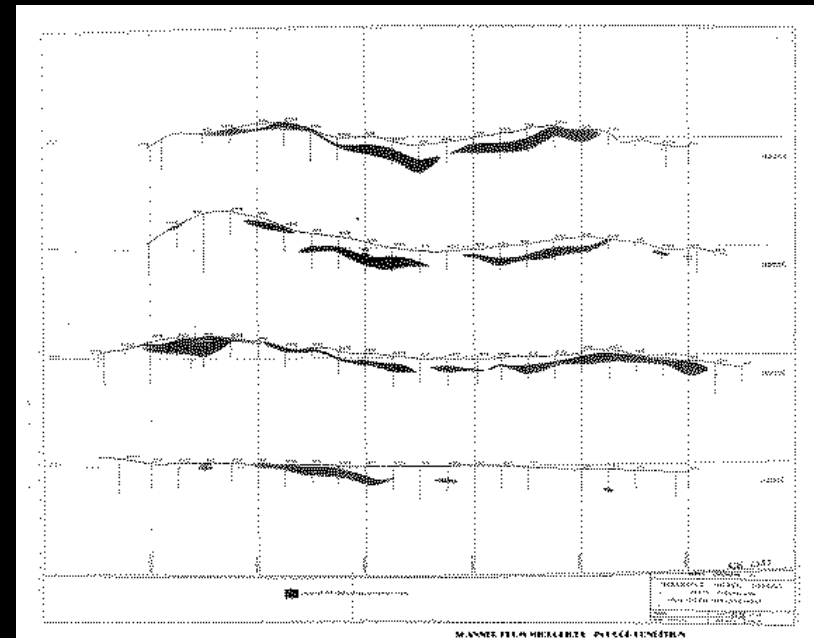
Laterite outcrop.

Resource Delineation

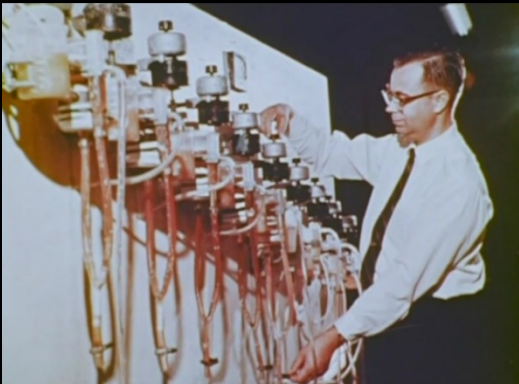
- 1967 drilling 221 holes, 5,400m.
- Initially on 300m centres closing to 150m.
- By mid-1969
 - delineated 37.2M dry t of nickel ore grading 1.57 % Ni and 0.12 % Co
 - preliminary metallurgical testwork and scoping completed.
- Ore interpreted as sub-horizontal based on broad spaced sampling.



1968 Ore Reserves

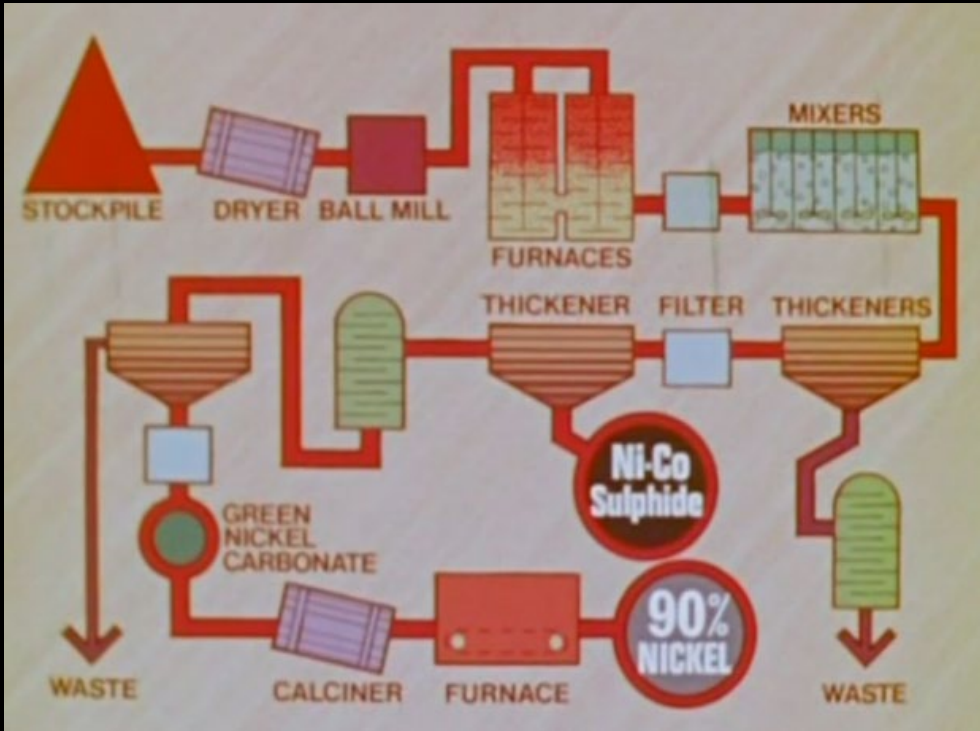


Pilot Plant testing

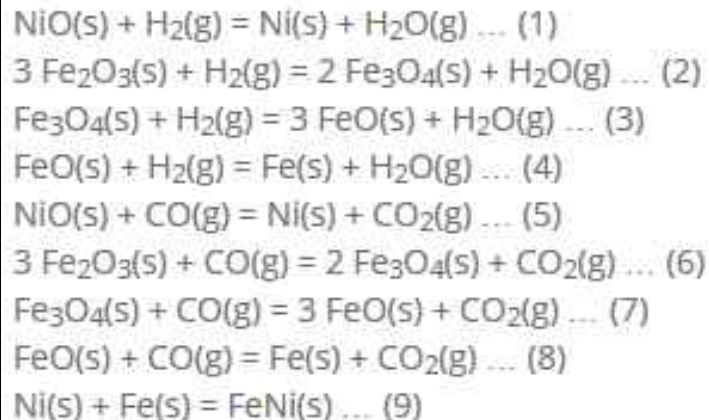


- A 2,000 t bulk sample was excavated
- Based on deposit-average grades for Ni, Co and Fe.
- Shipped to Freeport's research facility in Louisiana for pilot plant testing.
- Choice between pyro- and hydro-metallurgical treatment
- The Caron Process of reduced atmosphere roasting followed by ammonia leaching was selected.

Caron Process

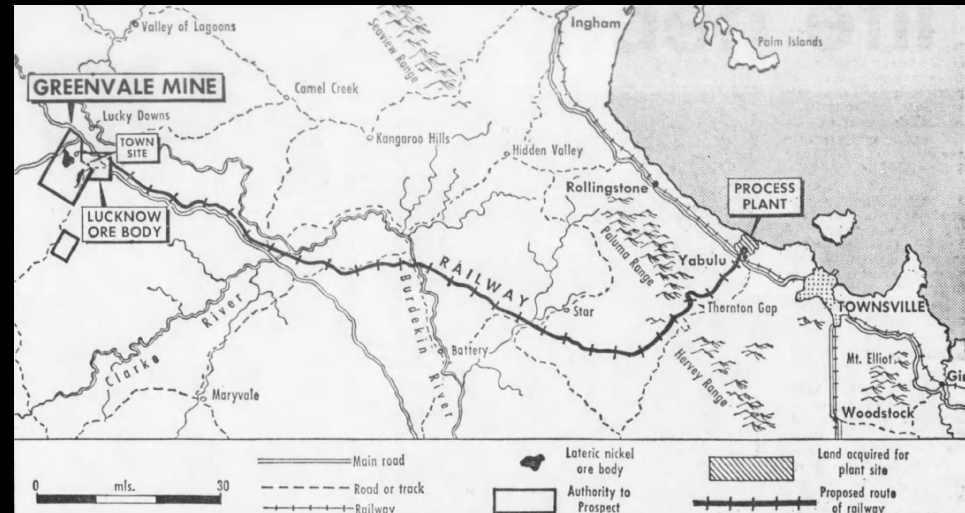
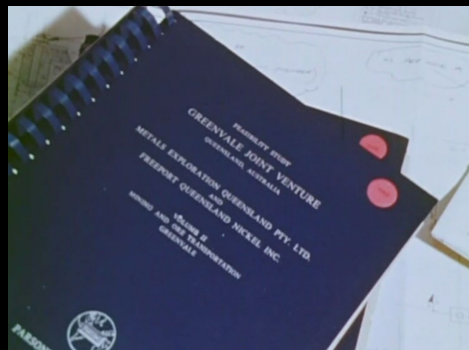


- Drying the ore to remove free moisture
- Grinding dried ore
- Reduction roast to metal in furnaces
 - Dehydroxylation from 350-650deg liberates metal oxides
 - Reduction with CO₂ & H₂ to reactive metals at ~750deg.
 - Metal sulphides from reaction with 3%S in fuel oil to Ni metal,
- ammonia / ammonium carbonate leaching to dissolve Ni & Co ammines.
- Precipitation of basic nickel carbonate (BNC).
- Decomposition of BNC
- Recovery of mixed nickel / cobalt sulphide
- Recovery of Ni oxide
- (90% Ni) nickel / nickel oxide as rondels.



Feasibility & Design

- Queensland Nickel Pty Ltd formed to develop the Project.
- 30 y.o. Ken Fletcher appointed Managing Director.
- \$10M feasibility study
- Coastal refinery site chosen
 - to allow future importation of ore.
 - Groundwater supply available
- Plant design by Parsons-Jurgen Corporation.



1970 Government Legislation Railway



QUEENSLAND NICKEL
AGREEMENT ACTS

QUEENSLAND NICKEL
AGREEMENT
INSTRUMENTS

QUEENSLAND NICKEL
AGREEMENT 1970

- Queensland Government assistance was required for the railway.
- 1970 Qld Government drove a hard bargain which delayed approvals by a year.
- The Government guaranteed the final \$50M of finance and the rail became owned by Qld Government with a \$45M guaranteed return.



Mr. Gordon Chalk

Talks are deadlocked

A critical deadlock in talks between the Queensland Government and two mining companies is jeopardising the \$190 million Greenvale nickel project.

The Queensland Treasurer (Mr. Gordon Chalk) revealed last night that the companies — Metals Exploration and Freeport Sulphur — wanted to pay only \$29 million in freight and royalties over the next 20 years.

But he was adamant his Government would not accept less than \$50 million. This followed a statement from Metals Exploration saying the partnership had been unable to secure any "substantial" financial assistance from the Government.



Agreement signing: Gordon Chalk, Reg Hare and Ken Fletcher

1971 Project Go-ahead & Financing

farce



"I said, we regret the unwarranted fluctuations of the share market — Do you hear me?"

Greenvale nickel gets the go-ahead

The Freeport-Metals Exploration joint venture has finally decided to go ahead with development of a \$150 million nickel mine at Greenvale in Queensland. It is expected to go on stream in 1974.

This was announced last night by the chairman of Metals Exploration (Mr. R. Hare). It has a 50 per cent. stake in the venture.

"We would anticipate a big proportion of the finance is going to come in loan funds by institutions and consumers of nickel against long term contracts," Mr. Hare said.

He said the company would not have announced the go-ahead for the Greenvale venture unless it was believed the finance and contracts could be obtained.

There were no plans to reduce the company's stake in the project, he added.

The partners have decided to use the ammonia leach process to treat the ore.

Outside sources

The mill will have annual throughput of 2,500,000 tons, which will produce 50 million lbs of nickel and three million pounds of cobalt yearly, worth \$92 million.

The nickel produced will be in the form of nickel oxide sinter, with a smaller quantity of a mixed nickel-cobalt concentrate.

Nickel oxide sinter is 90 per cent. nickel metal, and therefore highly refined. This will be ideal for export

markets — the basis of the operation.

Nickel ore will be transported along a 140-mile railway plant from the mine to the treatment plant on the coast.

"One of the reasons for putting the plant on the coast is that we visualise in the future there will be ore from outside sources after the Greenvale ore has been exhausted," Mr. Hare pointed out.

Pilot plant

Although the go-ahead has now been given, the partners appear to have a number of hurdles to cross.

Pilot plant results will be used to confirm a process flow sheet and provide data for the design of a treatment plant.

A decision on construction of the plant is contemplated by mid-1971, with nickel production expected in 1974.

Apart from loan funds and contracts, the company will also require assistance from the Queensland Government with supporting facilities, principally the proposed railway line.

Yesterday's announcement culminates more than three years investigation.

'Controls are adequate'

— BROKER



MR. A. C. GODDE

character. The market that was established in Melbourne and Sydney was continued in London while Australia slept.

A leading Melbourne they were first listed. Then

- 1971 decision to mine and treat 2M dry tpa to produce 25,000 tpa Ni & 1,000 tpa Co.
- Go-ahead announced the day of Tasminex share crash!
- To maintain its 50% interest in the \$224M project Metals Exploration obtained loan funds against long term nickel contracts.
- Shareholders contributed \$8.5M

Railway Construction

Contract changes give hope to Greenvale nickel railway

Work has resumed on the railway line which will connect the Greenvale nickel project with Yabal, near Townsville.

As a result, directors of Metals Exploration Ltd expect that the railway will be completed to a stage which will permit initial operations at Greenvale to begin on the scheduled date of June 18, 1974.

Work on the railway stopped on December 20 when the head contractor for the railway, Theiss Bros Pty Ltd, took out a writ against the principals, Metals Exploration Queensland Pty Ltd and Freeport Queensland Nickel Incorporated.

Metals Exploration and Freeport have a 50/50 interest in the Greenvale project.

These claimed there was a failure to achieve a workable arrangement with the principals.

Directors of Metals Exploration announced yesterday that all work on the railway was continuing under new contractual arrangements.

John Holland (Constructions) Pty Ltd, which was previously subcontracting the bridges and laying the track, as sub-contractor to Theiss Bros, resumed work on Wednesday, January 2, as a principal contractor, the Metals Exploration directors said.

Theiss Bros, which was the former head contractor, resumed work on the balance of the earthworks yesterday morning under direct supervision and direction of Queensland Nickel Pty Ltd, the management company for the Greenvale project.

Both John Holland and Theiss will now work directly to the principals instead of John Holland being subcontracted to Theiss as in the original arrangement.

Metals Exploration Queensland and its joint venture partner in the Greenvale project have each entered an appearance in the Supreme Court of Queensland to the writ issued against them by Theiss Bros.

The writ is still before the court but the case has yet to be heard and a date has so far not been set for a hearing.

A spokesman for Theiss said yesterday that so far as he was aware no-one had been laid off as a result of the dispute.

The railway line traverses rugged terrain and crosses 37 bridges on its way to the Queensland coast.

The line was about 80 per cent completed when work stopped on the project.

The estimated cost of the Greenvale nickel project was about \$225 million.

There are an estimated 44-million dry short tons of ore at Greenvale averaging 1.5 per cent nickel and 0.12 per cent cobalt.

The railway line is a 3ft 6in gauge and after construction it was planned that it be owned and operated by the Queensland Government.

Ore treatment is to be by the ammonia leaching process at the plant at Yabal.

Plant throughput is planned at 2,300,000 dry short tons a year to produce over 50,000,000 lb of nickel and 2,500,000 lb of cobalt for the world market.

Capital cost estimates were: Mine and Greenvale facilities, \$20-million; railway and rolling stock, \$30 million; and plant and Townsville facilities \$153 million.

The plant's consumption of fuel oil was estimated at 400,000 tons annually making it one of Australia's major users.

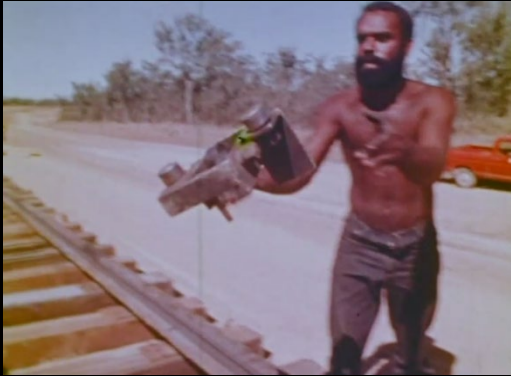


Theiss chairman Sir Leslie Theiss



Mr. K. Hans Metals EA chairman

- The 225km railway constructed to the Yabalu refinery.
- Construction and rolling stock paid for by the JV but owned by the Government.
- Joint contractors Theiss and John Holland.
- Huge 1973-74 wet season rainfall delayed work.



Building Greenvale Town



- 1974 a new township was constructed.
- 85 family houses, 16 flats.
- Greenvale was second last purpose-built mining town.
- Compared with FIFO operations, family life was more regular and less disrupted.
- Graziers appreciated open access to town facilities c.f. closed towns in the Pilbara.



1971-74 Mine Development

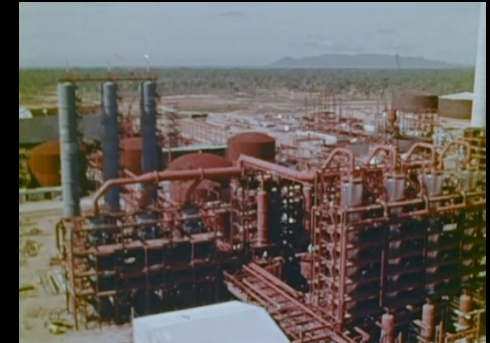
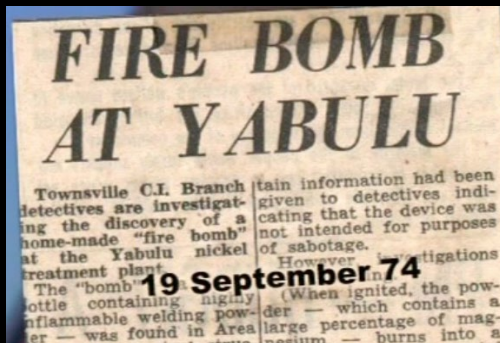
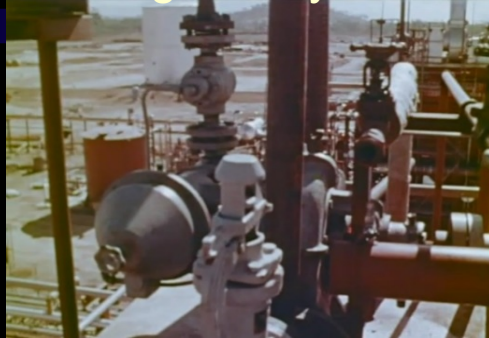


- Overburden removed by scrapers
- Drilling for blasting and grade control
- Draglines used based on tabular ore interpretation.
- Side-cast ore into windrows based on assays
- Front-end loaders reclaimed ore
- Dump trucks to crushing / screening plant
- +40mm siliceous oversize rejected (low grade).
- Ore blended based on Ni, Co, Fe & SiO₂ content.
- Ore stockpiled into 60,000t parcels
- Reclaimed by bucket wheel stacker-reclaimer for railing.

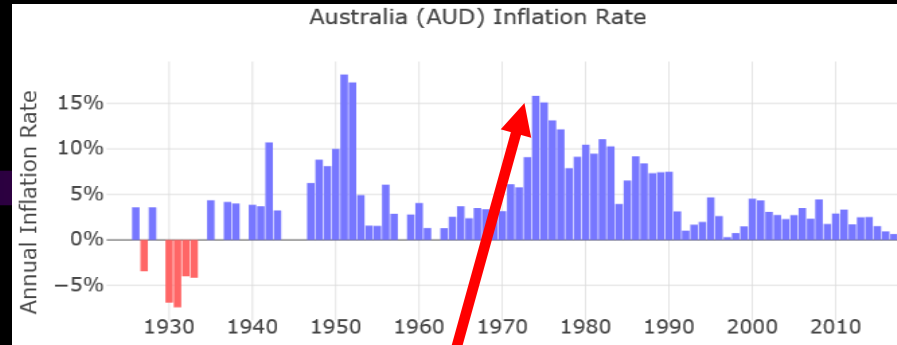


1970-74 Yabulu Construction

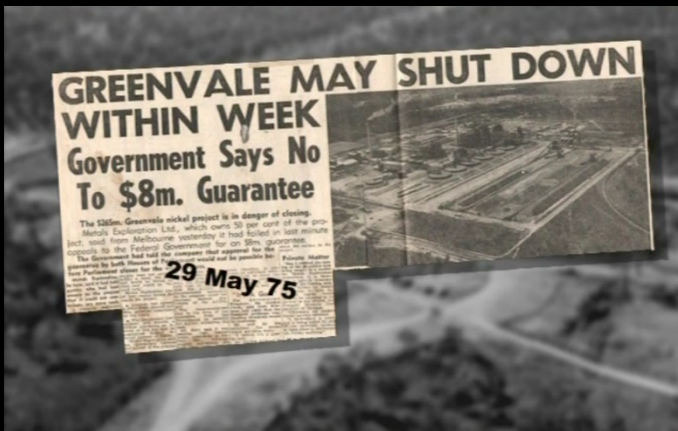
- With bad weather, air freight became essential.
- Components of a critical ore stacker washed overboard causing 3 month delay.
- Industrial action and sabotage delayed work at the refinery.



Oil Price & Inflation Shocks



- 1973 Severe set-back when oil for Herreshoff furnaces trebled.
- 1980 second oil price shock
- 1974 Inflation peak ~16% pa
- By the time production commenced, Ni prices had also fallen and labour costs had risen.
- Additional finance had to be acquired.
- Had feasibility studies been completed a year later, the project would have been cancelled.
- Whitlam Government rejected \$8M guarantee request.
- Loans were renegotiated with lenders.



Metals Ex \$4m rights issue

MELBOURNE, Friday, — Metals Exploration NL plans a \$4m rights issue to cover its share of a possible increase in the cost of the Greenvale Nickel project.

Announcing the issue today, the company also gave a detailed analysis of its position following the revaluation of the Australian dollar against the US dollar.

Directors point out Greenvale will not begin production for two years, and say they think the project is well timed in relation to the world nickel output.

The rights offer is being made because the company could not raise the \$4 million through loans with acceptable conditions, they say.

The new shares will be issued on a one-for-four basis at a premium of 50c a share, and rights to the issue will be renounceable.

The money will be used to offset any over-run of the \$2.5m capital cost of the project.

Metals Exploration and its joint venture partner, Freeport Sulphur of the US, have agreed to raise \$10m to provide the safeguard, \$8m of which will be provided by one of the lenders to the project, if necessary.

The money raised by the issue will replace a short-term loan from the Australia and New Zealand Banking Group.

Metals Exploration directors argue that a sharp increase in the US dollar price of nickel is inevitable, but the revaluation of the Australian dollar appears to have hit Greenvale's cash flow prospects hard.

Metals Exploration has provided its share of the capital cost of Greenvale from \$89m in loan funds and \$2.5m equity — an exceptionally high gearing.

On the basis of the planned output of Greenvale, the company stands to lose \$6.1m a year from its share of production through the recent revaluations of the Australian dollar against the US dollar.

Although the revaluation of the Australian dollar has more than offset the recent 15 per cent rise in nickel price, directors say that it is difficult to predict the effect on Greenvale during its initial production years.

The lower price will inhibit the development of new nickel deposits outside the US and Canada; and, unless Canadian producers can rapidly expand output, a new world nickel shortage will result, they say.

The issue will be underwritten jointly by Patrick Partners and Patrick Intermarine (Australia) Ltd. and will raise a total of \$4,186,666.

1970s Technical Advances

- Mine bottlenecks eliminated and moisture lowered 1%.
- Faster train loading; 24hr train turnaround.
- Geological structural control on grade recognised and dragline mining re-oriented.
- Ore boundaries delineated by closer drilling and mapping
- Chlorite and nontronite ore causing Yabulu roasting problems was promptly located from logs & eliminated from resources.
- RAB drilling problems (fines loss) identified; factors applied.
- Lateral and vertical ore dilution were controlled.



Nickel Laterite Geology

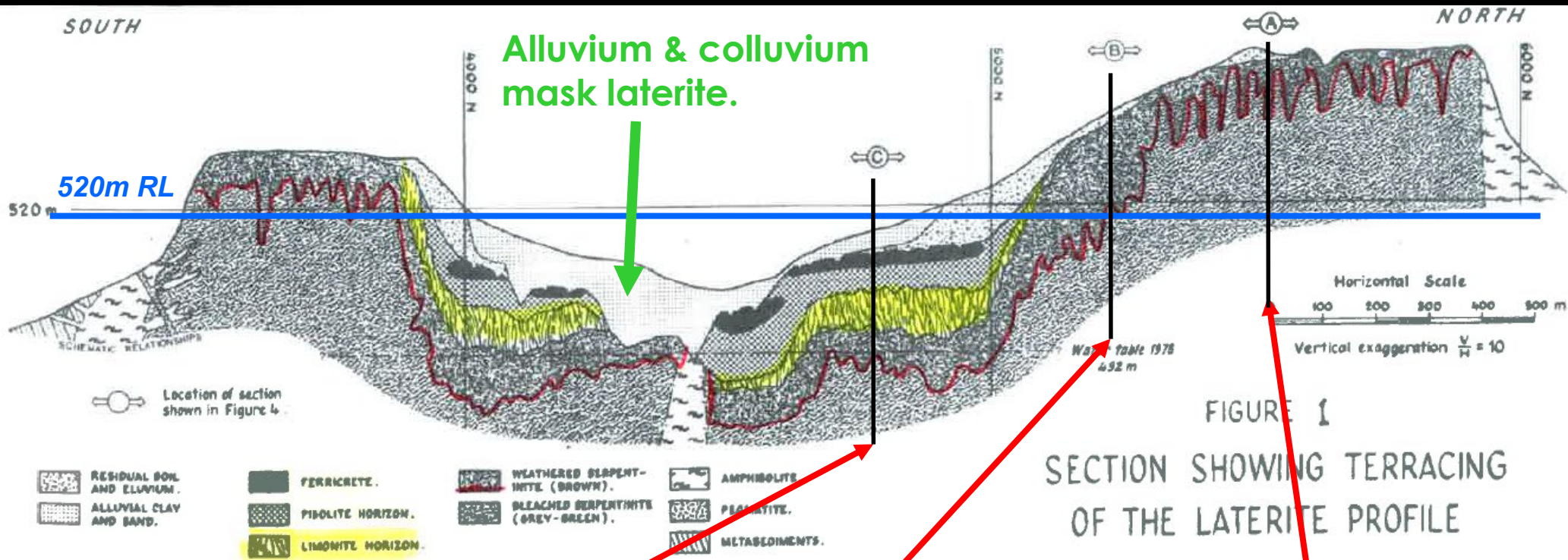
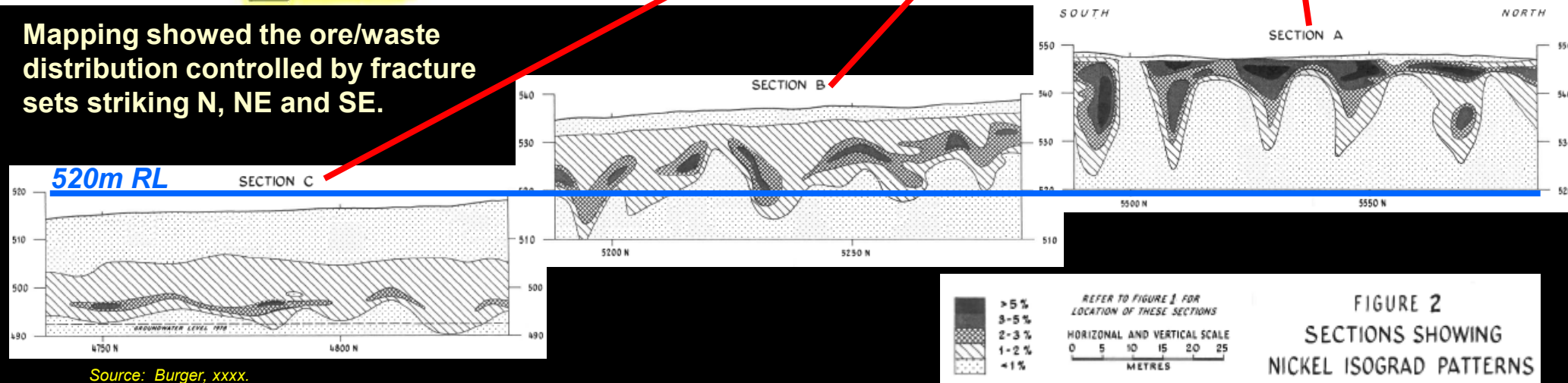
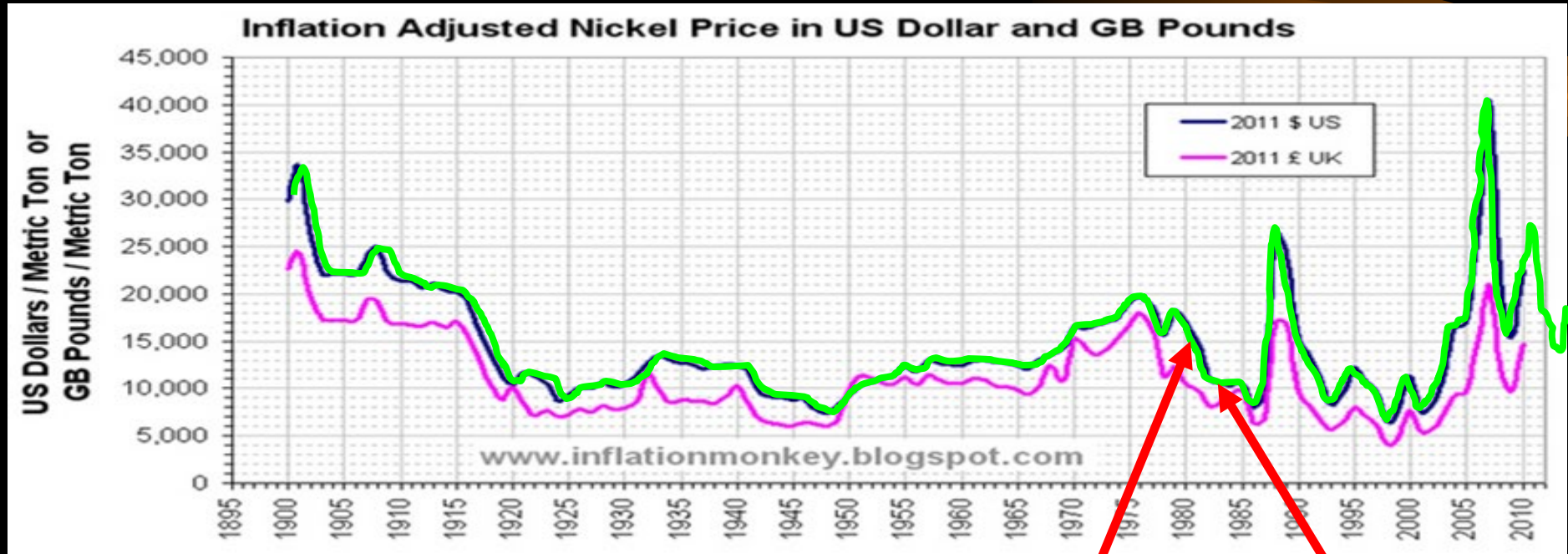


FIGURE 1
SECTION SHOWING TERRACING OF THE LATERITE PROFILE

Mapping showed the ore/waste distribution controlled by fracture sets striking N, NE and SE.



Early 1980s Ni Price Drop, Costs up



- World Ni capacity doubled in the 1970s.
- The Ni price fell dramatically in 1980 from \$3.40/lb mid-1980 to \$1.60/lb early 1983.
- Metals Exploration the only Australian Ni company able to cut production
- 1983 Greenvale operated at only 50% of 1983 levels.

1980s *Technical Advances*



- 1982 Roasters partly converted from heavy fuel oil / naphtha to pulverised coal
- New technology improved product quality.
- 1989 developed and patented a novel ammoniacal solvent extraction process separating Ni & Co
- Step change improvements in Ni and Co products.
- Sulphur kept in solution as ammonium sulphate allowing better recovery of process NH_4 & CO_2 with economic and environmental benefits.
- Kept the operation going through a time of low nickel prices.

Early 1980s Sam Gazal – Alan Bond



- By 1980 Mid-East Minerals had gained a interest in Metals Exploration
- 1980 Sam Gazal's Winthrop Investments took over Mid-East
- 1982 Metals Ex took control of North Kalgurli (Golden Mine). North Kal found to be broke. Golden Mile Kemlo open pit commenced.
- 1983 Alan Bond funded Australia's America's Cup win
- 1984-85 Alan Bond "Daisy Chain" investment method took over Mid East incl. 50% in Greenvale and North Kalgurli (part of the Super Pit).
- Mixed family (Dallhold) and corporate holdings.
- 1986 Freeport 50% sold to Bond for 15% of valuation
- 1991 Bond Corporation in administration; Banks lost \$5B
- 1992 Alan Bond declared bankrupt. Imprisoned for 7 years for siphoning off A\$1.2 billion from Bell Resources into Bond Corporation.

HOW THE MATES TURNED ON BOND

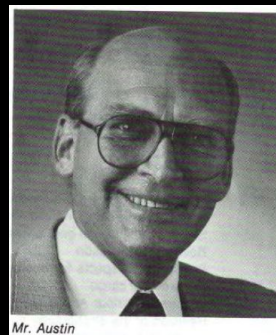


Queensland Nickel Joint Venture

- 1978 Deed of Agreement on debt guarantee with Queensland Government
- 1986 project's debt was \$940 million (2018 \$2.5B) and in danger of closure
- Bjelke Petersen government \$42M towards infrastructure to save 700 jobs
- 1986 Qld Government bought debt and swapped for equity under previous agreement.
- Queensland Nickel Joint Venture (QNJV) became operator.
- 1988 Queensland Nickel Agreement Act (Ahern Government)
- 1989 complex arrangements with Qld Government. Brian Austin, Minister for Mines.

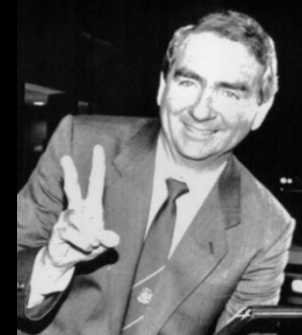


Joh Bjelke-Petersen



Mr. Austin

Brian Austin



Mike Ahern

1992 QNI Ltd float



Wayne Goss



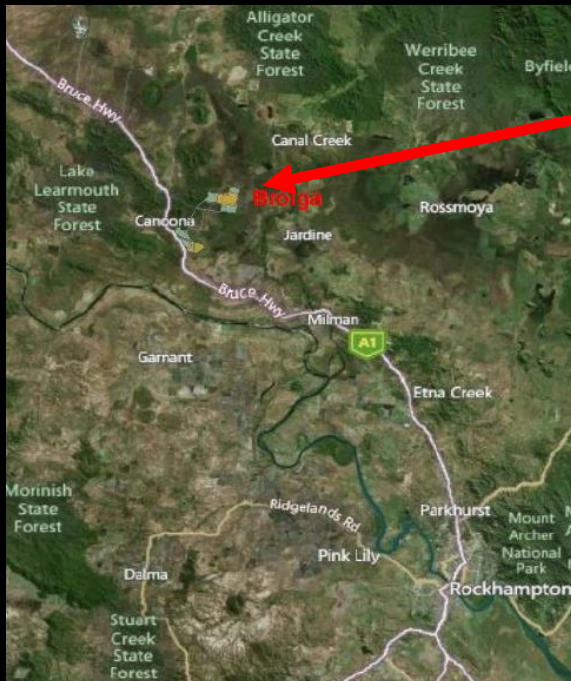
Keith De Lacy

- 1990 Goss Government honoured its legislated guarantee and increased its holding to 28% equity enabling the operations to continue.
- 1992 QNI Ltd was floated on ASX.
 - Dallhold (Bond) 80%,
 - Qld Government 20%
- 1995 State sold off its interests making a profit of over \$182M (2018 \$315M)

Post Greenvale mine Brolga Mine



- Mining at Greenvale ended in 1992.
- Last of the Greenvale ore processed in 1993.
- The railway was torn up in 1994.
- Nickel laterite ore railed from Brolga mine near Rockhampton, 1993 to 1995.





Herreshoff roaster additions



Cobalt refinery



Ni compacts

1990 Technical Advances

- 1996 the number of ore reduction roasters was increased from ten to twelve, increasing the ore treatment capacity to 2.4 million dry tpa.
- On-site development of patented Co solvent leach process involving leaching, solvent extraction and concentrate filtering stages to produce required products
- 1996 \$32M Co Oxide Hydroxide plant built
- 1997 commercial chemical grade Co production commenced following on from the 1989 solvent extraction breakthrough.
- Production levels from nickel laterite ore rose to 31,000 tpa of nickel and 2,000 tpa of cobalt.
- Ni compacts replaced Ni rondels.

Post Greenvale mine Importation of Nickel Ore



- 1986 first imported ore. from New Caledonia & Indonesia
- 1989, free of crippling Government debt, major expansion of Townsville port facilities.
- 1989 transition to imported ore with regular Indonesian and New Caledonian ore imports.
- New Caledonian ore typically 1.6%Ni, 0.18% Co but with higher water content, 35% c.f. 25% for Greenvale
- Enabled higher grades and higher recoveries
- 1989 Dallhold application for a permit to off-load nickel ore in Cleveland Bay. Rejected in June 1990.
- 1996 new Townsville unloading facility commissioned & Philippines ore importation.



BHP-Billiton 1997-2009



Importing nickel ore, Townsville.



- 1997 Billiton took over Yabulu
- 2001 Billiton merged with BHP.
- 2002 ~3.5M wet-tpa lateritic ore purchased from
 - New Caledonia
 - Indonesia
 - Philippines
- Later 190 000 wet tpa of mixed nickel-cobalt hydroxide intermediate from Ravensthorpe in W.A.
- Sales
 - Ni varying range of products 78% to 99.9% Ni
 - Co oxide/hydroxide
- Ni products: metal compacts, granular oxide & basic Ni carbonate filter cake.
- Co products: oxide / hydroxide powder & sulphide filter cake.

BHP-Billiton Ravensthorpe Plans



Ravensthorpe operations

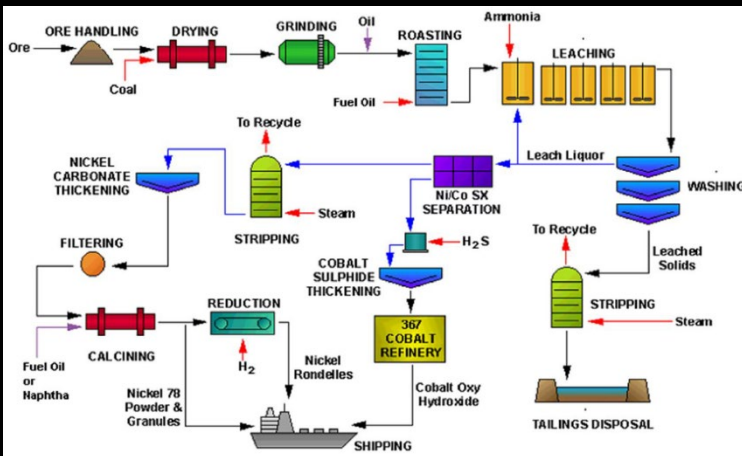


- ~2000 QNI purchased Ravensthorpe Laterite for \$36M
- Yabulu to be centralised plant for treatment of Ravensthorpe and New Caledonian laterites
- Proposed \$US500M development
 - Ravensthorpe complex pressure and atmospheric leaching to produce hydroxide for treatment at Yabulu.
 - Yabulu expansion to refine extra 40,000 tpa Ni
 - Reduced Yabulu unit costs
- Ravensthorpe 30% p.a. inflation during the mining boom; cost blew out from \$1.4B to \$3B.
- 2008 Ravensthorpe commissioned
- 2009 Ravensthorpe closed; (3.6B write-down).
- Sold to First Quantum for \$340M.

2000s Technical Advances



- 2000 Australia's largest RO water recycling plant
 - Avoiding discharge of excess water to sea.
 - Recycling half the 20 ML/day water used.
- 2000-2001 solar ore drying for imported ore. (35% H₂O v. Greenvale ore 25% H₂O)
- 2004-2007 refurbishment of
 - plant, port and ore handling
 - Improved performance, reliability and efficiency
 - expansion of refining capacity
 - ability to process Ni-Co(OH) intermediate feeds from Ravensthorpe.
- 2006 partial conversion to coal seam methane (pipeline).

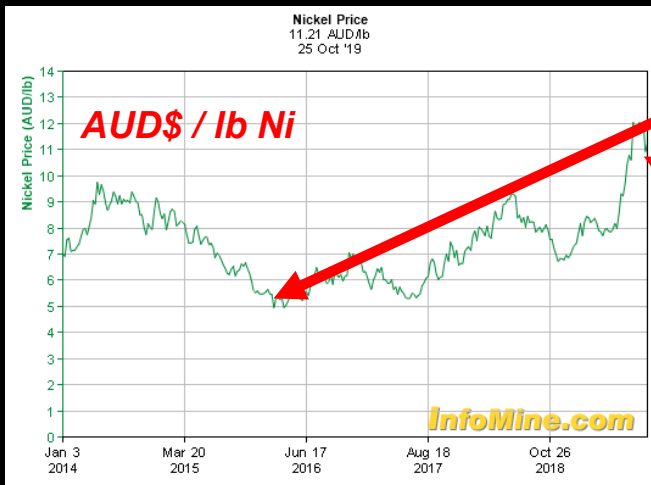




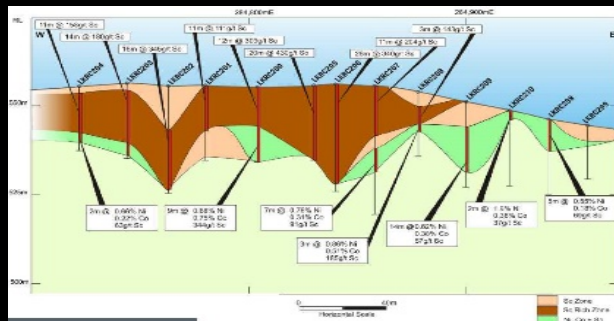
2009 Clive Palmer



- 2009 Invited by Anna Bligh, Clive Palmer purchased Yabulu from BHP
- 2010 the company increased production by 30%
- 2010 Yabulu profit of \$200M.
- 2009 to 2014 costs down from \$8.00 to \$4.40/lb.
- Enabled operations to keep going; \$150M in income and salaries, \$1.1B to local economy.
- Ni price collapse 2015-2016 to \$5/lb Ni.
- 2015 request for a \$35 million State Government guarantee to QNI refused by both major parties
- 2016 Operations closed \$5/lb Ni
- Nickel price now \$11 /lb Ni.



Metallica Minerals Ltd NORNICO / Scandium



- 1997 Metallica Minerals acquired the NORNICO project tenements north of the Greenville Mine.
- Greenville remnant Resources 4.5 Mt 1.12% Ni, 0.08% Co
- 2010 drilling programs discovered high grade scandium deposit at Lucknow.
- Sc in lateritised pyroxenite c.f. high Ni in lateritised serpentinite
- 99.99% Sc oxide valued at ~ \$4000/kg
- Sc worldwide usage only 10 to 15 tpa
- Lucknow Resource 6.1Mt 169 g/t Sc, 0.2% Ni, 0.04% Co.
- Flowsheet design of atmospheric acid leaching (AAL) and solvent extraction to produce Ni sulphate, Co sulphide & Sc oxide.



SCONI bulk sample



Perth demonstration HPAL plant

Australian Mines Ltd

- 2017 Australian Mines Ltd purchase of Sconi Co-Sc-Ni project.
- 2019 Resources 101 Mt @ 0.63% Ni, 0.07% Co
- Measured Reserves 18 Mt @ 0.83% Ni, 0.06% Co
- Bulk sampled for demonstration HPAL plant in Perth.
- Bankable feasibility 2018 proposed 53,000tpa Ni sulphate, 8,000tpa Co sulphate, 89tpa Sc oxide.
- Proposed \$1B capital cost and 300 person residential workforce.
- 2018 off-take agreement with SK Innovation (Korean EV battery Company)

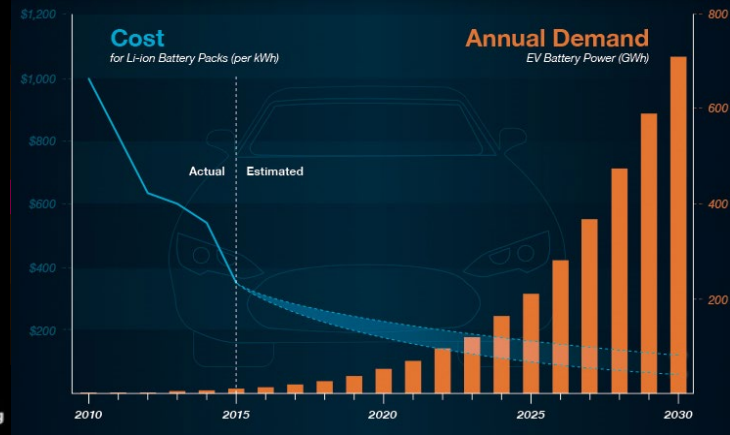
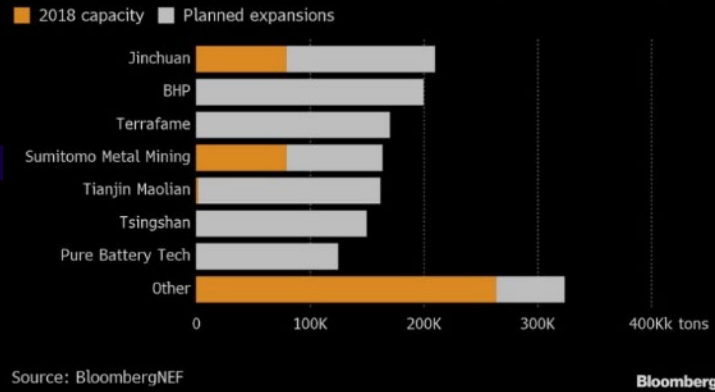
21% Co sulphate & 23% Ni sulphate products.



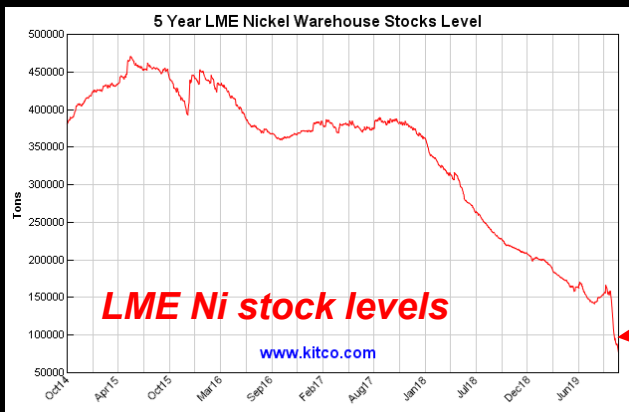
The Future?



BHP is planning the largest expansion of nickel sulfate production capacity



Ni pig iron



- Low cost SE Asian nickel pig iron for stainless steel
- 2018 Cobalt price collapse from supply surge and less Co (and more Ni) in EV batteries
- Lower than predicted EV take-up rates.
- Future growth in Electric Vehicle take-up and solar storage predicted.
- If 30% of vehicle market in USA by 2040, EV recharging requirements suggest 50% increase in electricity required.
- Current very low Ni stocks. Price potential?

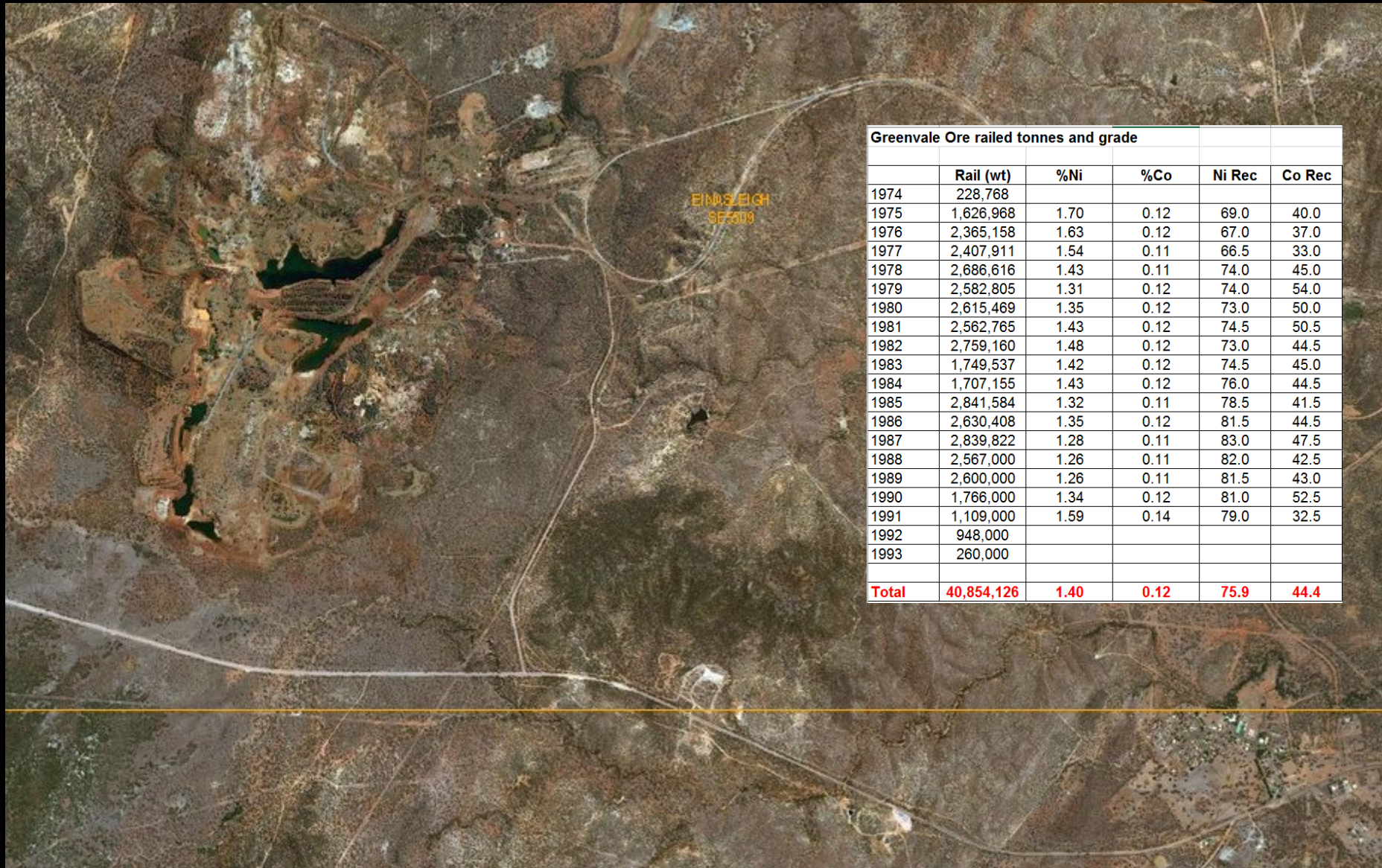
Conclusions 1

- Despite the challenges faced by the operations, Greenvale and Yabulu continued producing until the ore ran out in 1993.
- Greenvale production of 41 Mt of 1.4% Ni, 0.12% Co was remarkably close to the original Reserves of 37 Mt of 1.6% Ni, 0.12% Co.
- As originally planned the Yabulu refinery continued until 2015 with imported ore; 75Mt by 2013.
 - First additional ore was from Broilga near Rockhampton
 - Later imported from came from New Caledonia, Indonesia and the Philippines.
- Yabulu the only major Australian importer of ore to process in Australia.
- The nickel operations were a major contributor to the regional and national economy and workforce for 40 years.
- **Produced \$4,100M of nickel and \$400M cobalt at today's prices (\$4.5B).**
- Re-opening might be possible with higher metal prices but escalating energy costs cause difficulties for roaster economics.

Conclusions 2

- The Project became possible during the euphoria of the Nickel Boom, the encouragement of the Governments and lack of red tape.
- Unexpected difficulties arose from the “Unknown Unknowns” and energy price increases.
- Fluctuating metal price difficulties; positive cash flows but poor debt servicing
- Ni and Co recoveries were improved, costs controlled & problems fixed
- For almost its entire life, the Greenvale project operated under adverse economic conditions and never delivered original expectations.
- Greenvale mine life near design was achieved, and shareholders were actually paid a dividend one year.
- Amazing technical advances through the dedication, expertise and ingenuity of the workforce. The plant is NOT old technology.
- It was not death by a thousand cuts but life by many small advances!
- Government support 1970 and 1986 enabling continuation
- Government refusal 1975 and 2015. Catastrophic effect on local economy.

QUESTIONS?



Greenvale Ore railed tonnes and grade

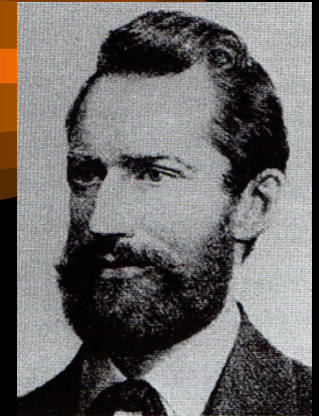
	Rail (wt)	%Ni	%Co	Ni Rec	Co Rec
1974	228,768				
1975	1,626,968	1.70	0.12	69.0	40.0
1976	2,365,158	1.63	0.12	67.0	37.0
1977	2,407,911	1.54	0.11	66.5	33.0
1978	2,686,616	1.43	0.11	74.0	45.0
1979	2,582,805	1.31	0.12	74.0	54.0
1980	2,615,469	1.35	0.12	73.0	50.0
1981	2,562,765	1.43	0.12	74.5	50.5
1982	2,759,160	1.48	0.12	73.0	44.5
1983	1,749,537	1.42	0.12	74.5	45.0
1984	1,707,155	1.43	0.12	76.0	44.5
1985	2,841,584	1.32	0.11	78.5	41.5
1986	2,630,408	1.35	0.12	81.5	44.5
1987	2,839,822	1.28	0.11	83.0	47.5
1988	2,567,000	1.26	0.11	82.0	42.5
1989	2,600,000	1.26	0.11	81.5	43.0
1990	1,766,000	1.34	0.12	81.0	52.5
1991	1,109,000	1.59	0.14	79.0	32.5
1992	948,000				
1993	260,000				
Total	40,854,126	1.40	0.12	75.9	44.4

A decorative graphic consisting of a horizontal line with a gradient from dark blue to yellow, ending in a large, stylized arrowhead shape with a gradient from dark brown to light yellow.

Spare Slides

Aboriginal History Gugu Badhan

- Aboriginal presence likely for ~50,000 years.
- Pre-1860s the Gugu Badhan people lived around the Valley of Lagoons wetlands.
- Ludwig Leichhardt passed through the area in 1845.
- European settlement from the 1860s and patrolled by Native Police.
- Sporadic conflict occurred until at least 1873.
- By 1911 some Gugu Badham were employed on the Valley of Lagoons Station.
- The Greenvale on SW boundary of their Native Title Determination.

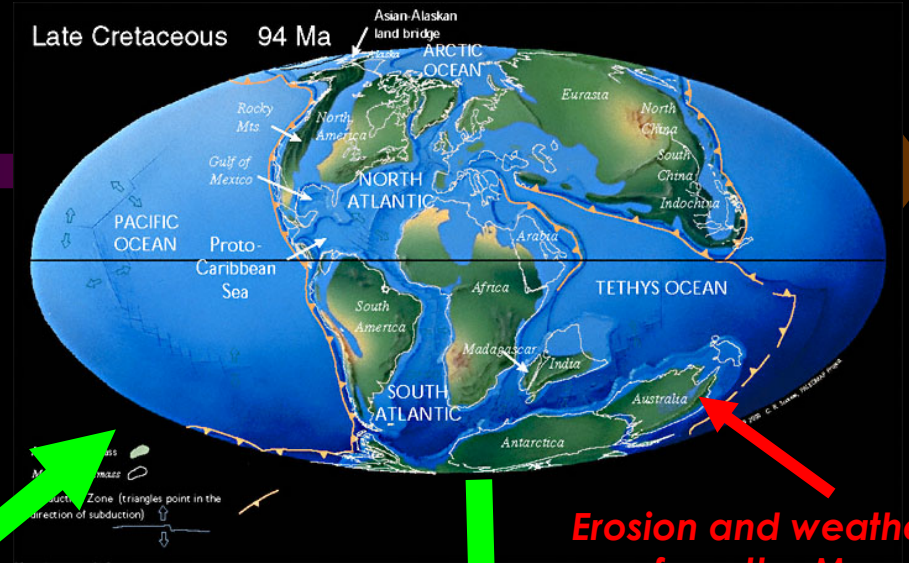
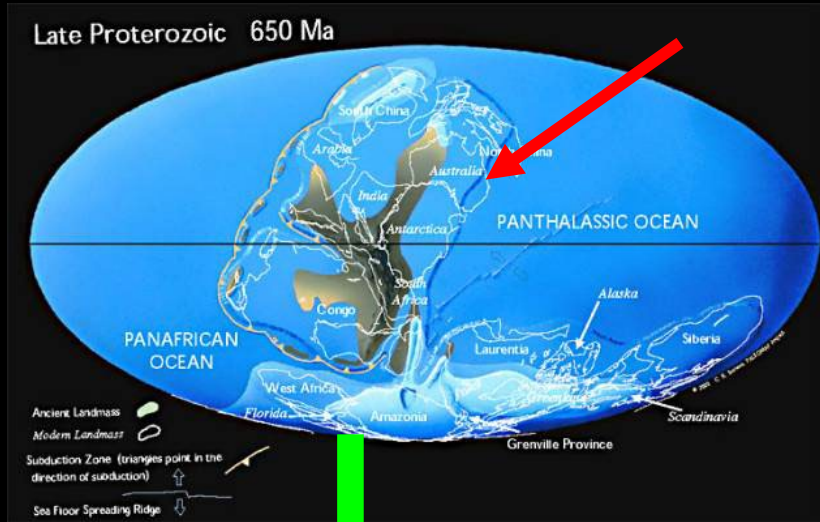


Ludwig Leichhardt, 1813–1848
(by Charles Rodius, 1846)



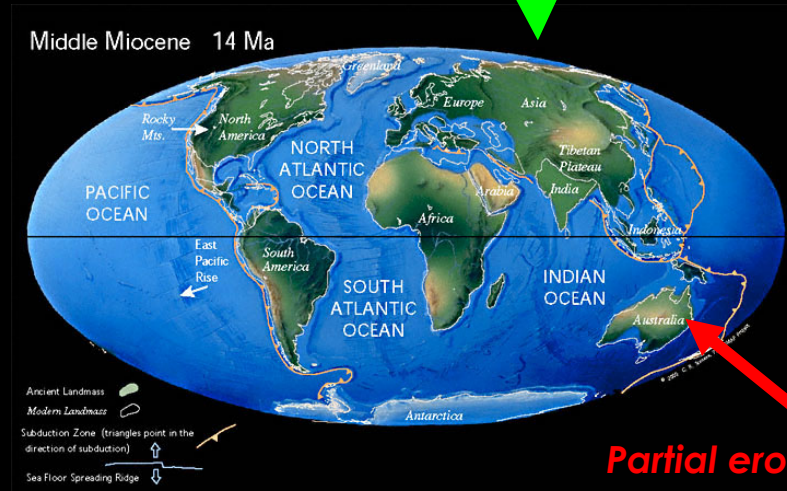
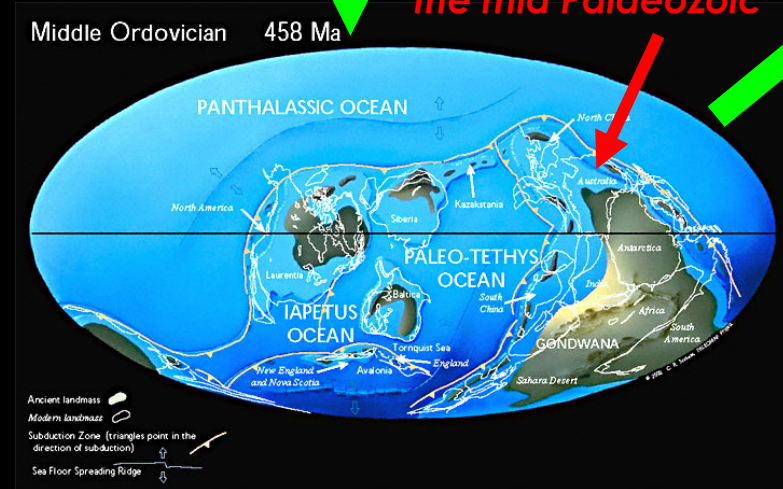
Geological History

Nickel-rich ultramafics from oceanic crust.



Erosion and weathering from the Mesozoic.

Serpentinised during the mid Palaeozoic



Partial erosion and nickel reconcentration.

Freeport of Australia



Freeport Directors at Nepean, 1969.

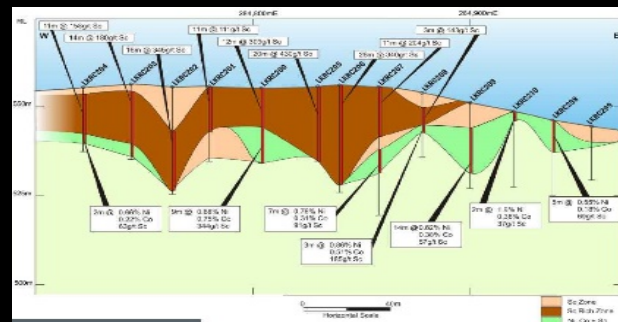
Forbes Wilson (rediscovered Ertsberg-Grassberg Cu, West Irian),

Langbourne Williams (Chairman) and

Admiral Arleigh Burke (ex US Chief of Naval Operations).

- 1960, Forbes Wilson's Freeport expedition to Dutch New Guinea re-discovered the Ertsberg (> Grassberg 1988).
- 1964 Freeport of Australia set up for minerals search in Australia and SW Pacific.
- 1967 established PT Freeport Indonesia.

Metallica Minerals Ltd NORNICO / Scandium

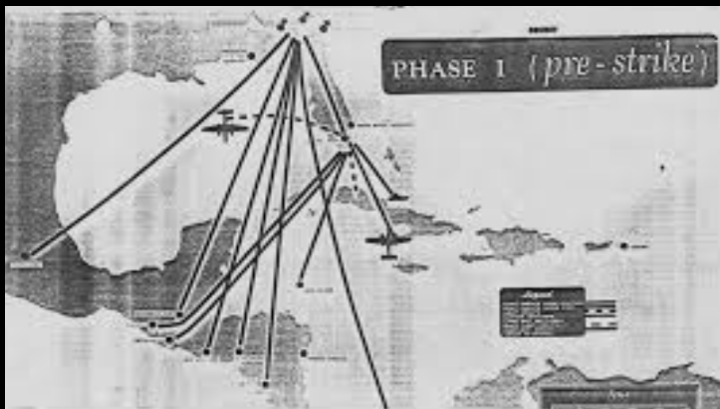


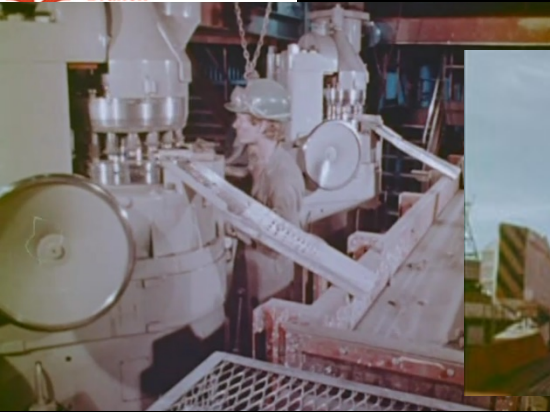
- In 1997 Metallica Minerals acquired the NORNICO project tenements north of the Greenvale Mine.
- **ASX listed in 2004 prefeasibility studies.**
- 2009 purchased Greenvale mine site and Lucknow tenements.
- 2010 drilling programs discovered high grade scandium deposit at Lucknow.
- Resources 45.5 Mt 0.81% Ni, 0.09% Co
- Lucknow & Kokomo deposits 15.1 Mt 133 g/t Sc.
- Flowsheet design Atmospheric acid leaching (AAL) and solvent extraction producing Ni sulphate, Co sulphide & Sc oxide.
- 99.99% Sc oxide ~ \$4000/kg
- Sc usage worldwide 10 to 15 tpa
- Greenvale remnant Resources 4.5 Mt 1.12% Ni, 0.08% Co, 36 g/t Sc.
- Lucknow Resource 6.1Mt 169 g/t Sc, 0.2% Ni, 0.04% Co.
- Lucknow Ni-Co; Resource 2.4 Mt 0.57% Ni, 0.20% Co 96 g/t Sc
- Kokomo Ni-Co Resource 16.3 Mt 0.67% Ni, 0.12% Co 36 g/t Sc.

Cuban Revolution



- 1958 Fidel Castro's revolution took control of Cuba.
- 1959 Moa Bay feed stock lost to Freeport.
- 1960 Cuba confiscated US property.
- 1961 CIA with Batista regime refugees mounted the disastrous counter revolution at the Bay of Pigs.
- President Kennedy refused to allow the US military to intervene.
- US sanctions against Cuba have remained ever since.
- Freeport search for new feedstock.





Yabulu Products

- 1975 first shipment of Greenvale Ni (to Japan).
- Originally Cobalt was separated by semi-selective sulfiding, and
- the mixed nickel-cobalt sulfide intermediate with Ni:Co >2 was sold to overseas refineries. The
- remaining nickel was precipitated, calcined, partially reduced, and sold as intermediate grade
- Ni/NiO rondels containing 85 to 90% Ni.
- Remaining Ni reduced, calcined, partially reduced to 85-09% Ni/NiO rondels.
- >2:1 Ni:Co sulphide to overseas refineries.
- From 1997 chemical grade Co
- Ni products: metal compacts, granular oxide & basic Ni carbonate filter cake.
- Co products: oxide / hydroxide powder & sulphide filter cake.
- At full capacity \$1Bpa to North Queensland economy
- 3000 jobs direct and indirect.



Problem Resolution On-Site Beneficiation

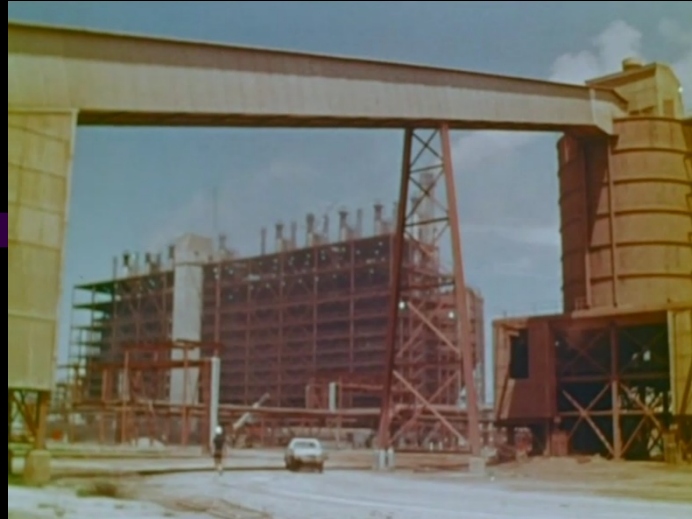


Greenvale siliceous ore.

- Hammer milling to <300mm showed
 - siliceous ores preferentially reported in the >25mm sizes
 - grade benefits were insufficient to offset the costs.
- A 75mm sized screen was installed to remove the low-nickel chert oversize
- Reduced grinding and abrasion costs at Yabulu.

Yabulu Ni & Co Recoveries

Yabulu



R070286

5 mm

Source: Burger 2019

- Initial Ni and Co recoveries were lower than forecast.
- Mill-feed was simply Ni, Co and Fe orebody average grades based on 0.8% Ni and 1.0% Ni cutoffs.
- Mineralogy was not considered significant.
- Chlorite and nontronite ore caused Yabulu problems.

Mine v. Mill Grade Reconciliation

Mine



- First comparison in 1975 gave alarming results !
- Yabulu grades significantly lower than the mine estimates.
- Mine grades were based on RAB bore sampling
- Yabulu grades were based on
 - sophisticated sampling method
 - reconciled against metal recoveries and tailings grades.
- The Yabulu grades were adopted.
- Quarterly reconciliations of mine vs mill tonnages and grades were conducted over the full 17.5 year mine life.
- Cheap RAB drilling overestimated grades.
- Dilution due to irregularities in the orebody.

Deleterious Mineralogy

- Chlorite



- Chlorite caused eutectic problems with the roasting.
- Chlorite schist shears in western third of the deposit.
- Early RAB logging had logged silky v. gritty feel to the cuttings.
- This enabled prompt delineation of problem areas.

- Nontronite



- Nontronite is the Fe³⁺ rich member of the smectite (swelling) clays
- Also caused problems in the Yabulu processing.
- Several million tonnes of nontronite “ore-grade”, laterite along the western boundary of the southern orebody had to be left.

Mine v Mill Grade Reconciliation

RAB Sampling Bias



- RAB blast hole sample reliability was tested for a range of ore types by
 - 150mm diameter Reverse Circulation drilling
 - 76cm Calweld holes twinned RAB holes.
- Calweld and RC samples were biased similar but smaller in magnitude than the RAB samples.
- RAB costs were third those of RC thus RAB continued over the mine life.
- The RAB blast hole biases were relatively constant.
- A factor was applied align with plant grades.



Problem Resolution Ore Reserves

- Initial resources drilled at ~150m centres
- Reserves were drilled at 40m x 40m centres
- Closed to 20m x 20m for overburden stripping where the ore top was regular
- Closed to 10m x 10m where ore horizon more irregular
- Closed to 5m x 5m for grade control where ore zone had high “amplitude”



Grade Dilution Mining



- Dilution from
 - walls of the sub-vertical shoots on the hilltops
 - from the top and base of the ore horizons.
- Dilution grades were to 30% below cutoff grades;
- Density was to 30% higher than the ore average.
- 5m x 5m RAB drill resolution of the ore/waste on the hilltops and upper slopes
- 10x10m centres were adequate for the more regular ore horizons on the lower slopes and valley floor.



Waste Minimisation Mining



- Draglines can only dig in line with the boom.
- Survey alignment of dragline operations.
- Ore shoots mined along strike on deeper ore zones
- The waste pinnacles were avoided.
- Dilution reduced to tolerable levels.
- 1981 hydraulic excavators replaced draglines giving improved mining precision.
- Commenced computer aided positioning of excavators from 1980.

Yabulu Closure



Cobalt Price Graph

- 2015 QNI request for \$35M State Government guarantee
- Refused due to requirement to release full details of donations to Palmer United Party
- 15 January 2016 the company terminated 237 workers. Palmer blamed
 - poor nickel prices, at a 12-year low, and
 - the refusal of the Queensland government to guarantee a loan of A\$35 million.
- The leader of the opposition supported the refusal
- 18 January 2016 voluntary administration.
- March 2016 proposal to transfer employment debts and residual cash to Palmer to continue operations refused.
- April 2016 Liquidation voted for by Creditors
- 2017 Palmer reported as saying Yabulu would not have gone under if CITIC had met its obligations over the Sino Iron project in the Pilbara
- April 2018 Palmer suing Liquidators for \$1.8B.