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The History of Nickel Exploration in the Yilgarn Craton of Western Australia

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Acknowledgements

- This presentation is based on the Hronsky & Schodde (2006) paper published in SEG Special Publication 13

- Richard Schodde is acknowledged for his major contribution to the analysis reported in this presentation

- Much of the paper drew on the excellent summary by Marston (1984)

- David Burt, Jeff Gresham and Jim Ross are thanked for their input

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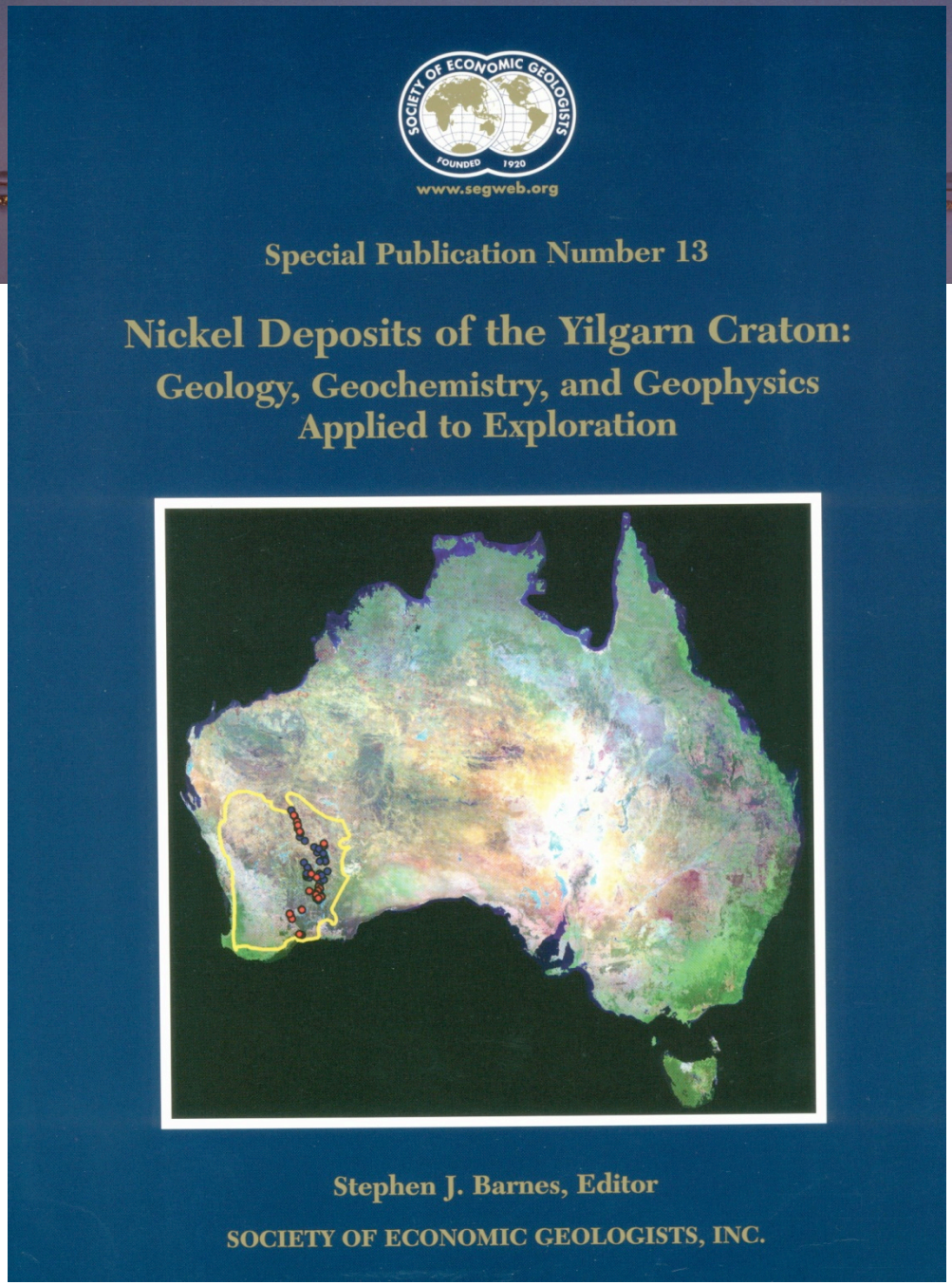


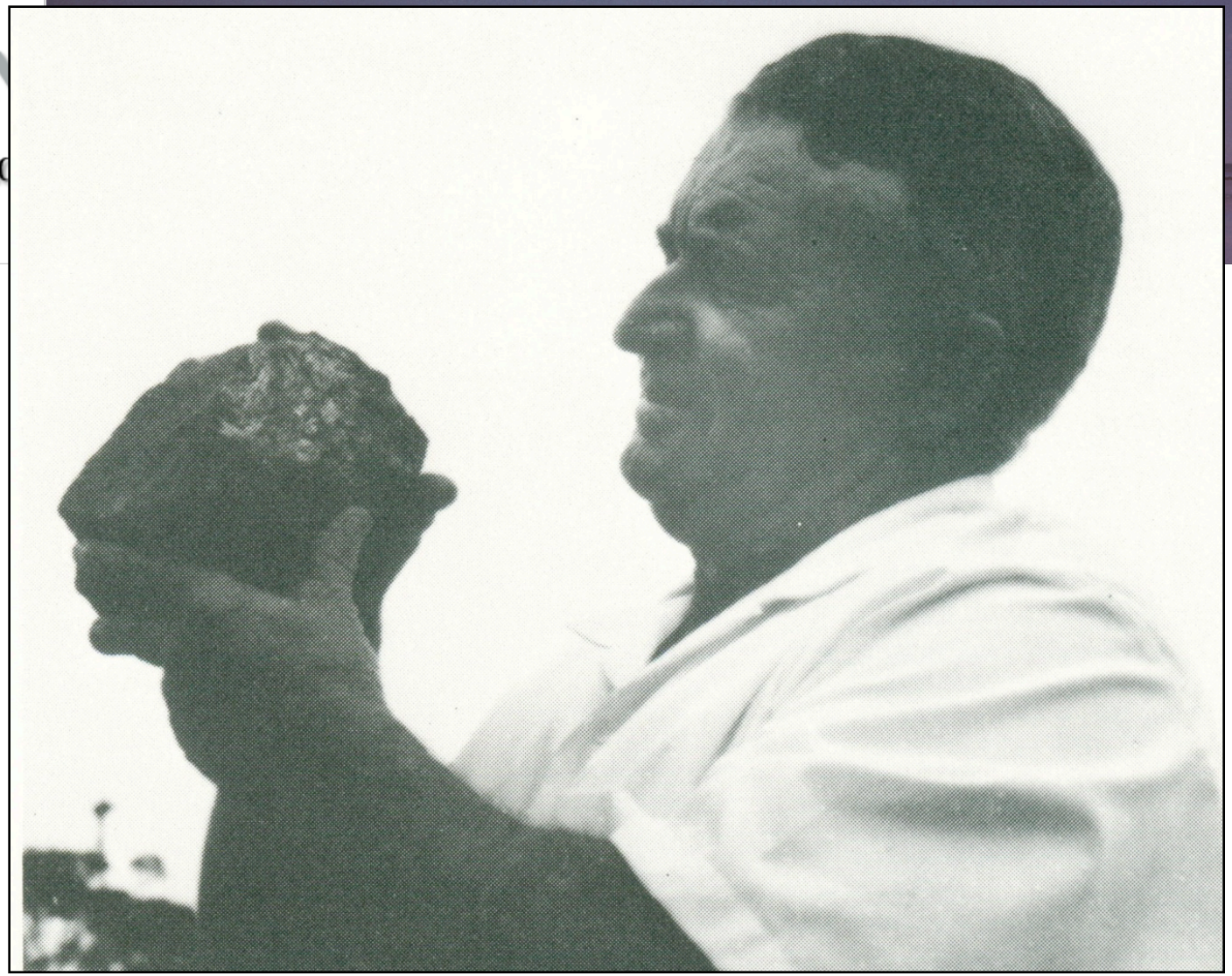
Why should we care?

- **Provides an important context to understanding of current Ni exploration potential of the Yilgarn Craton**

- **A very well constrained case-study of province-scale exploration (clearly defined in space and time) that provides general learnings regarding the mineral exploration process**

How it all began – A long gestation

- 1939 – Prospector George Cowcill digs green-stained gossan from pits near the abandoned Red Hill gold mine, near the abandoned gold mining town of Kambalda
- 1953 – INCO discovers first nickel deposit in WA, the Wingellina Ni laterite deposit
- 1954 – Samples of this gossan submitted for analysis to the Kalgoorlie School of Mines on the suspicion they contained uranium. Bill Cleverly, geology lecturer, reports no uranium but anomalous nickel
- 1964 – John Morgan, a friend of Cowcill, submits more gossan samples from Red Hill area to Roy Woodall from Western Mining Corporation
- 1964-65 – Follow up exploration by WMC defines extensive gossanous outcrops in Red Hill area
- 1966 – KD1 intersects 2.75m @ 8.3% Ni (in what would become Lunnon Shoot) on January 28



George Cowcill with a lump of Lunnon Gossan (Gresham, 1991)

Roy Woodall with student John McKay at the Kambalda field camp 1964-65 (Gresham, 1991)

The Silver Lake Shaft in 1966 (Gresham, 1991)
Shaft sinking began in July 1966, less than 6 months after KD1. First concentrate was produced in early June 1967

Why did it take so long?

- An intriguing aspect of the discovery of Nickel in WA is that outcropping deposits remained undiscovered for more than 70 years in the heart of a major mining region – Why?

- Maybe because:
  - Nickel was a relatively unknown commodity in WA (the first Ni explorers were the North American companies, Newmont and INCO)
  - Prior to the 1960s the Ni price was very stable so there were no price booms to drive interest
  - Geological thinking was dominated by the Sudbury model (large mafic intrusions)
  - The obscuring effect of the regolith in obscuring sulphide deposits and even their ultramafic hosts

A Play in Four Acts

- Four major phases can be recognised in the history of nickel exploration in the Yilgarn
- **The Nickel Boom (1966-1971)**
- **The Long Hiatus (1972-1987)**
- **The Sulphide Revival (1988- Present)**
- **The Laterite Boom (1996-2001)**

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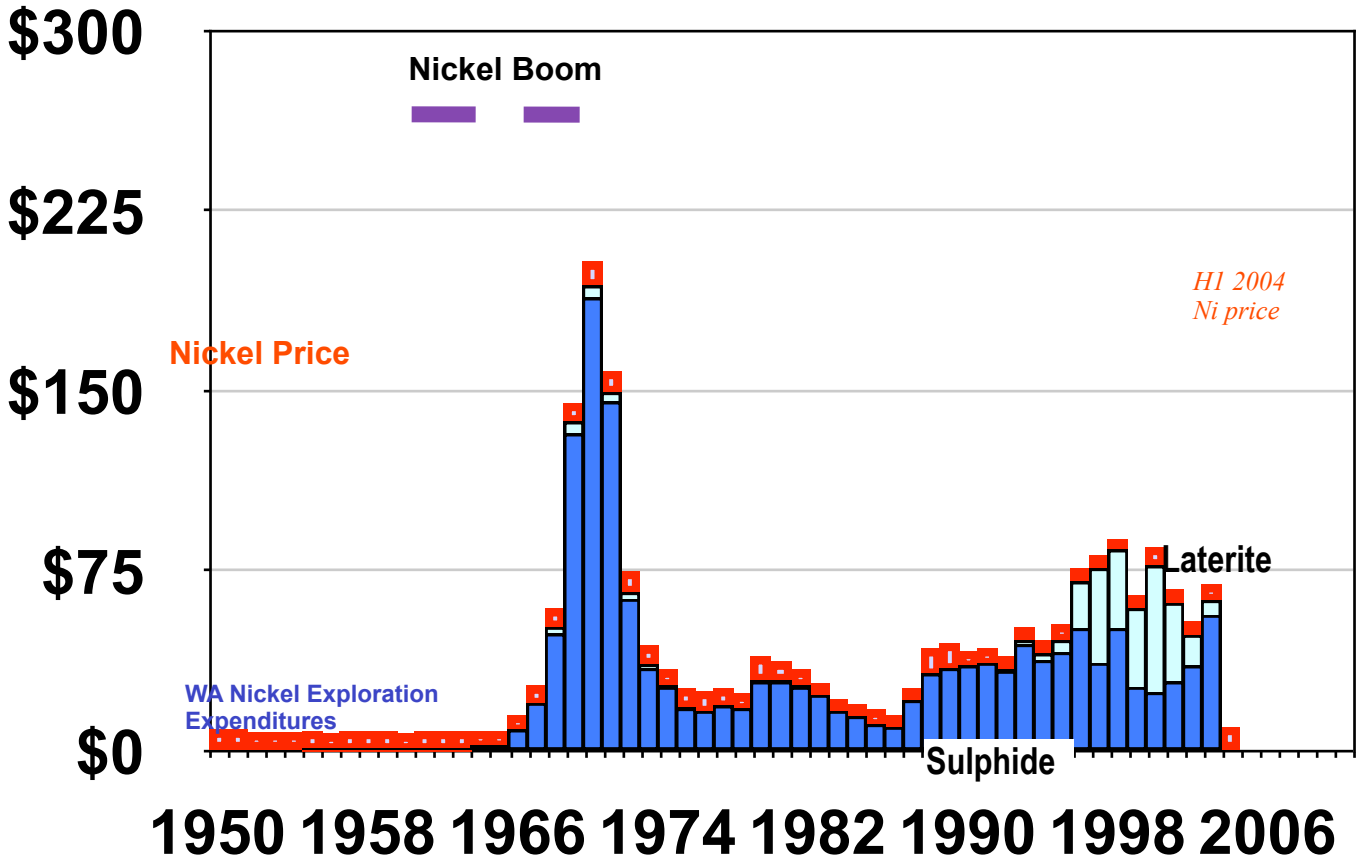
Expenditures (2004 A$ Million)

Nickel Price (2004 A$/lb)



Sources: ABS, Mackenzie and WMC

The Nickel Boom (1966-1971)

- 1966 – WMC announces Kambalda discovery on April 4
- 1967 – First discoveries outside Kambalda region (Widgiemooltha area) and by other groups by WMC
- 1968 – Discovery of Scotia and Nepean
- 1969 – Discovery of Mt Keith (largest deposit in Province and first discovery in the Agnew-Wiluna belt); Discovery of Mt Windarra by Poseidon on September 24
- 1970 – Poseidon peaks in early February at intraday high of $280 marking end of speculative boom; Discovery of Yakabindie; Peak year of exploration spend and peak year of Nickel Boom era nickel price
- 1971 – Discovery of Perseverance and Forrestania Camp
- 1972 – Nickel exploration spend falls to < 50% of 1971 level

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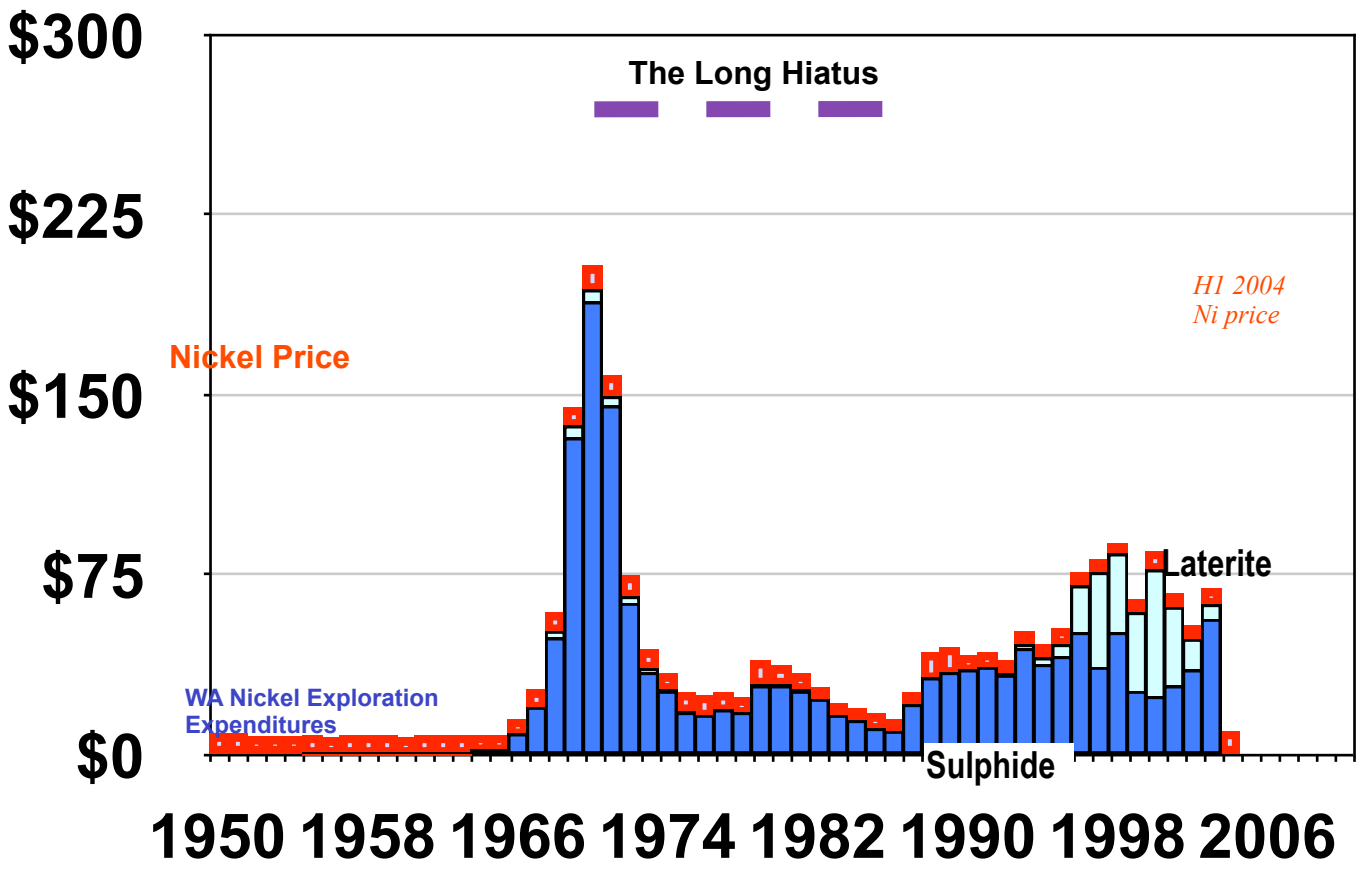
The Poseidon Adventure

The drama of Poseidon's December 1969 annual meeting over, Norm Shierlaw (left) and Boris Ganke have an amicable chat. Shierlaw is holding mounted a sample of Windarra drill core. *Picture — News Ltd.*

Picture from Sykes (1978) – Poseidon would eventually go into receivership and be subject to government enquiry

Expenditures (2004 A$ Million)

Nickel Price (2004 A$/lb)



Sources: ABS, Mackenzie and WMC

The Long Hiatus (1972-1987)

- Declining real nickel price through this period
- Effectively no junior exploration
- Most exploration focused around existing camps
- Gradual closure of mines
- In 1986 WMC became only remaining nickel producer (and stayed so until 1992 when Outokumpu developed Forrestania)
- In mid-1980s even WMC brownfields in Kambalda region fell below sustainable level
- From mid-1980s nickel overshadowed by major gold exploration boom in Yilgarn

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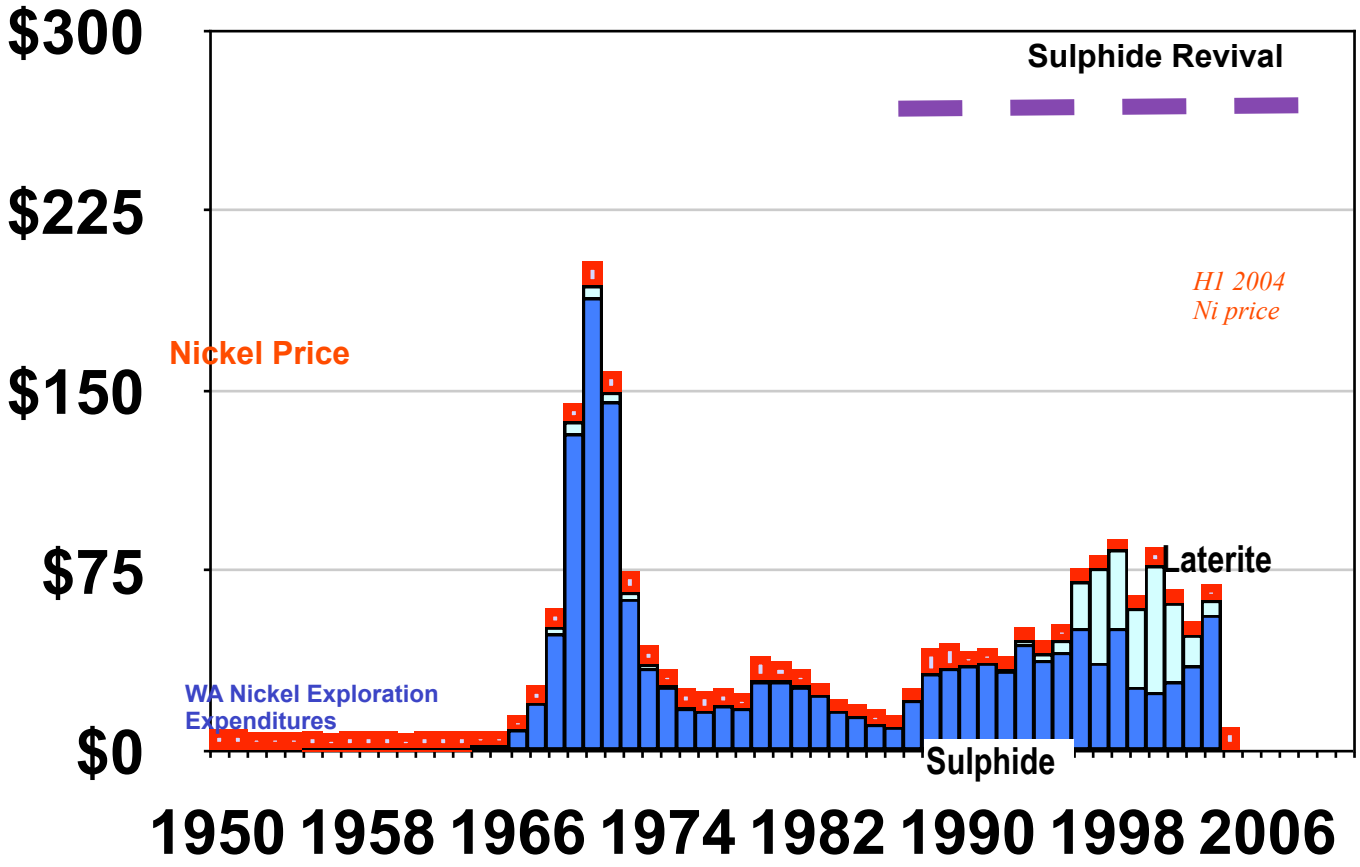
Expenditures (2004 A$ Million)

Nickel Price (2004 A$/lb)



Sources: ABS, Mackenzie and WMC

The Sulphide Revival (1988-Now)

- 1988 – Major (although short-lived) spike in nickel price
- 1988 – Purchase of Leinster Operations by WMC; rapid development of Rocky's Reward – renewed focus on Agnew-Wiluna belt
- Early 1990s- WMC revives Kambalda brownfields effort and is rewarded with success (Mariners, Miitell, Coronet)
- Early 1990s- Technological advances make low-grade deposits potentially economic; ACM leads with Mt Keith development
- 1995 – Silver Swan discovery by MPI; first junior discovery in >20 years
- 1997 – More junior discoveries; Cosmos (Jubilee) and Emily Ann (Forrestania Gold)
- 2000 – WMC begins Kambalda divestment process leading to several new junior nickel producers

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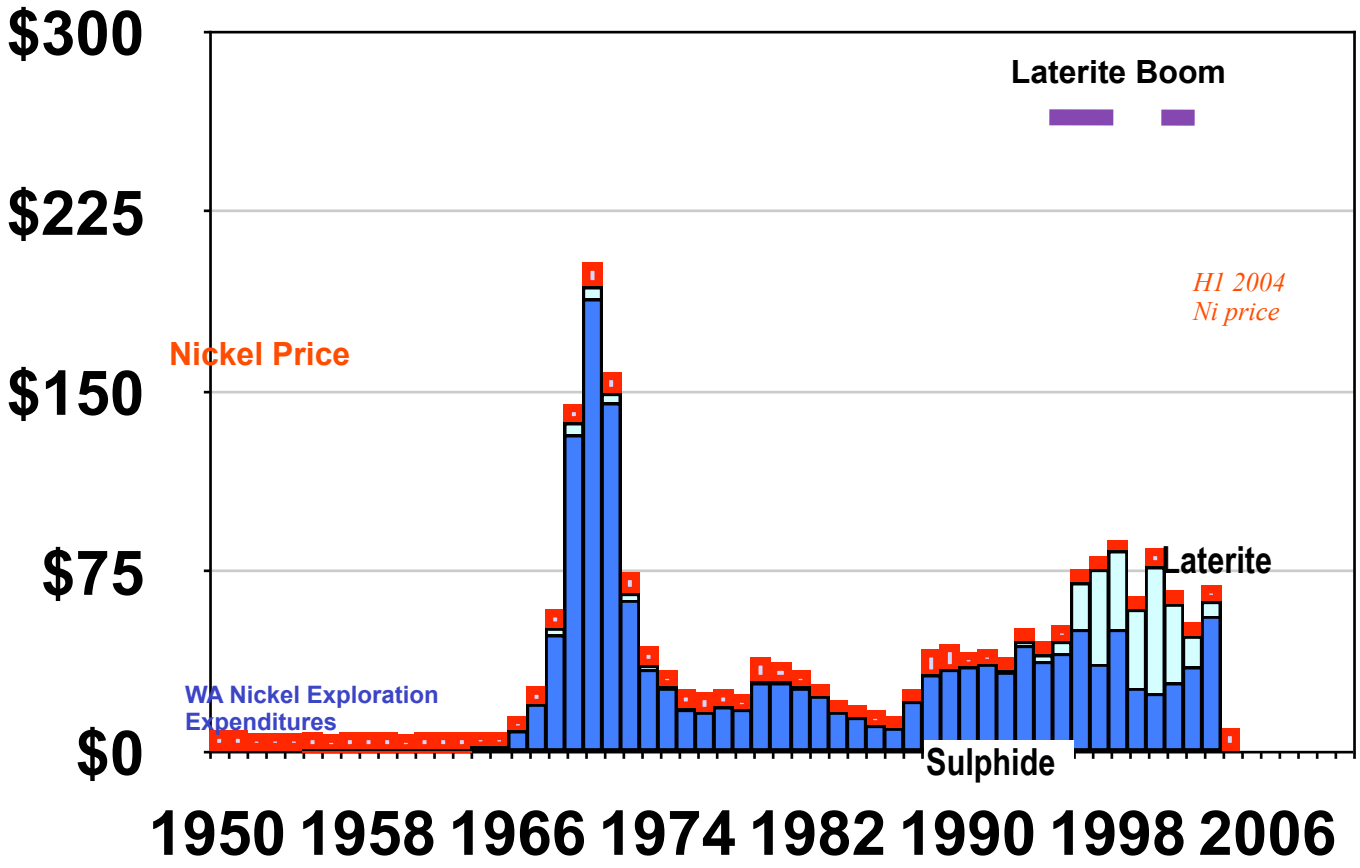
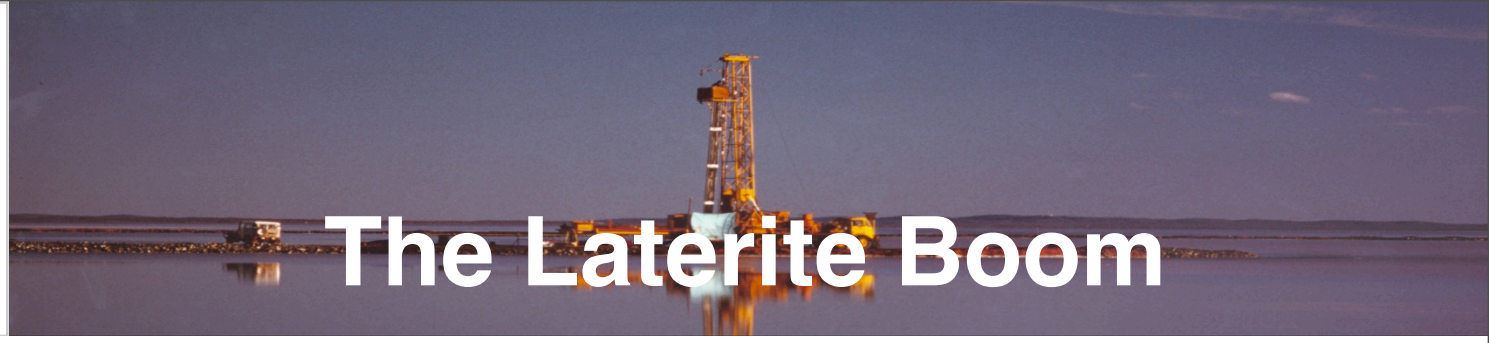
Expenditures (2004 A$ Million)

Nickel Price (2004 A$/lb)



Sources: ABS, Mackenzie and WMC



The Laterite Boom

- **Most nickel laterite deposits first drilled during nickel boom but not considered economically significant**
  - **Marston (1984) describes the Central Bore deposit as "…the possible presence of a large deposit of nickeliferous clay in lateritic profile…the nickel content of the clay averages between 0.8 and 1.5% and a tonnage approaching 100 MT could be present."**
  - **This area would later by developed by Anaconda as the Murrin Murrin deposit**
- **In the mid- 1990s the potential of the Pressure acid Leach (PAL) process to treat these ores was recognised, leading to a boom in nickel laterite exploration**
- **This drove Yilgarn nickel exploration spending to levels comparable with the nickel boom; laterite spending exceeded sulphide spending in 1997 and in 1999-2001, although much of this was resource delineation**
- **Three mines were developed in the late 1990s; Bulong (by Resolute), Cawse (by Centaur) and Murrin Murrin (by Anaconda);**

How were the deposits found? A tale of two halves

PERIOD	Direct Surface Expression	Surface Geochemical Anomaly	Discrete Geophysical Target	Recon. Drilling	Follow Up to known mineralization	Total
1966-71 (Nickel Boom)	24	5	2	5	6	42
1971-2003 (Post Boom)	6	-	1	6	22	35

Nickel boom era exploration was highly effective at locating outcropping NiS deposits

Subsequent success has been driven by follow up to known mineralization

The Nickel Boom
Discovery Technology Package

- Geological understanding that deposits were associated with the basal contact of ultramafic horizons, where these were locally of an anomalously magnesian nature
- The capability to map ultramafic rocks through obscuring regolith – in particular the application of magnetics
- The capability to discriminate Ni-bearing gossans from other ironstones (based on relict textures and geochemistry)
- The understanding that Cu analysis was required to supplement Ni in surface geochemistry because of the high Ni background in the host ultramafics

Which geological concepts made a difference?

- The “trough-flank” model first developed at Kambalda (Ross & Hopkins 1975) and then ultimately expanded in modified form to all sulphide deposits
- The recognition that high MgO komatiites can form in both prospective channellized facies and barren sheet flow facies (Hill et al, 1990)
- The understanding of laterite profiles over High-MgO ultramafic rocks (eg Elias et al, 1981) – important in understanding laterite deposits and exploring for sulphide deposits
- The recognition that in more highly strained environments, massive sulphide orebodies can occur dislocated (up to a 100m) from their host ultramafic unit

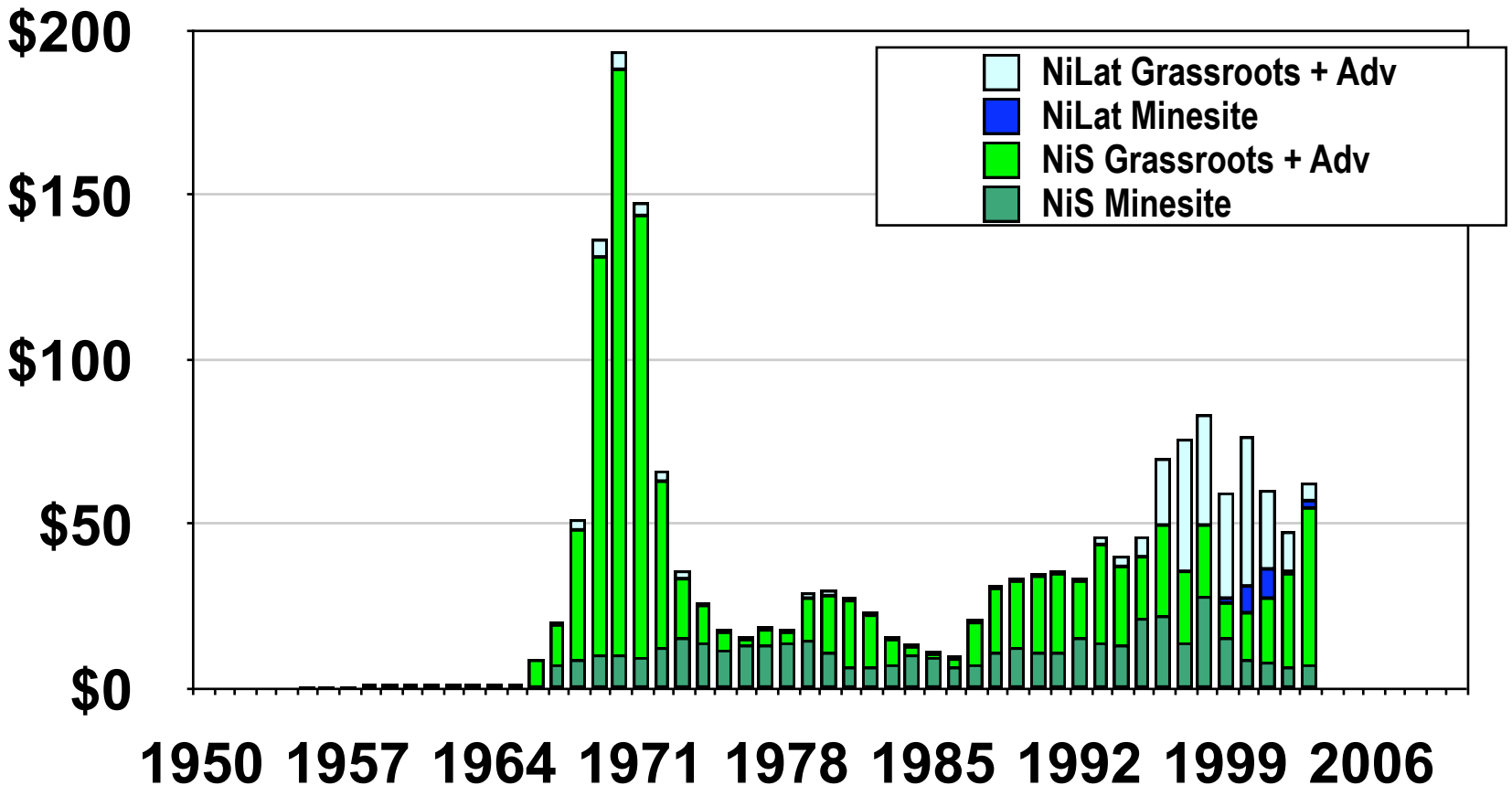
What drove exploration spend?

- **Exploration spend has been closely related to commodity price but this is *not* the complete story**
- **In both the early and late 1980s, a large price rise resulted in only small increases in expenditure**
- **The Laterite boom began against a background of low and falling prices**
- **The other critical factor is the opening up of a new *exploration search space***
- **The Nickel Boom was the "Perfect Storm" of a major price rise coinciding with a the opening of a large, completely-virgin search space**

How did it vary between Near-Mine and Grassroots?

Expenditures (2004 A$ Million)

Sources: WMC estimates

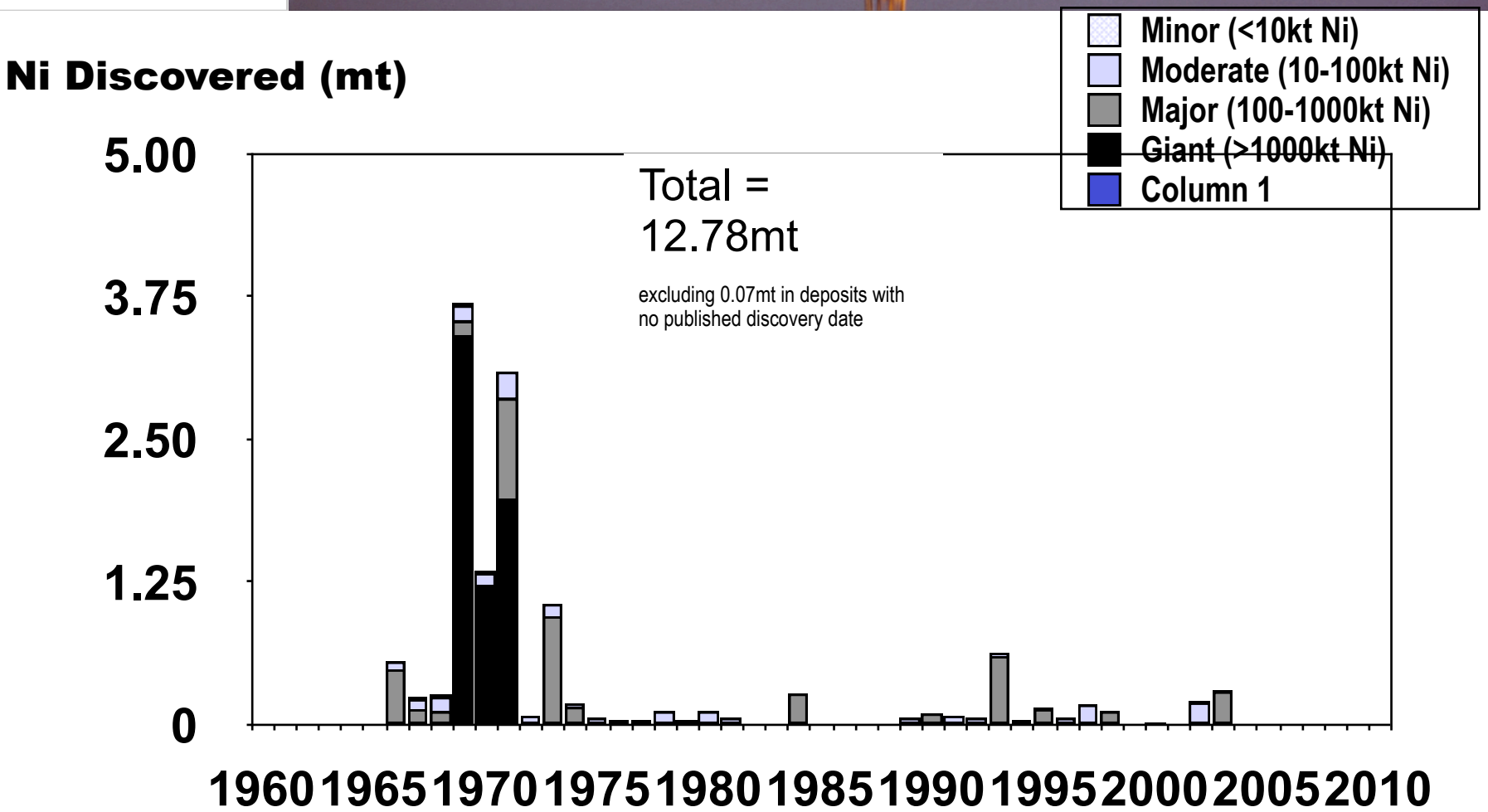


When was exploration most successful?

- For sulphide deposits, this question has a simple answer – right at the beginning!
- The first 6 years of Ni exploration in the Yilgarn resulted in the discovery of the overwhelming majority of the metal, all of the giant deposits, and most of the major deposits.
- This is a very good example of the benefits of moving early into a new exploration search space
- For laterites, this is a difficult question to answer meaningfully as most were already known before they were “discovered”

Sulphide Discovery History

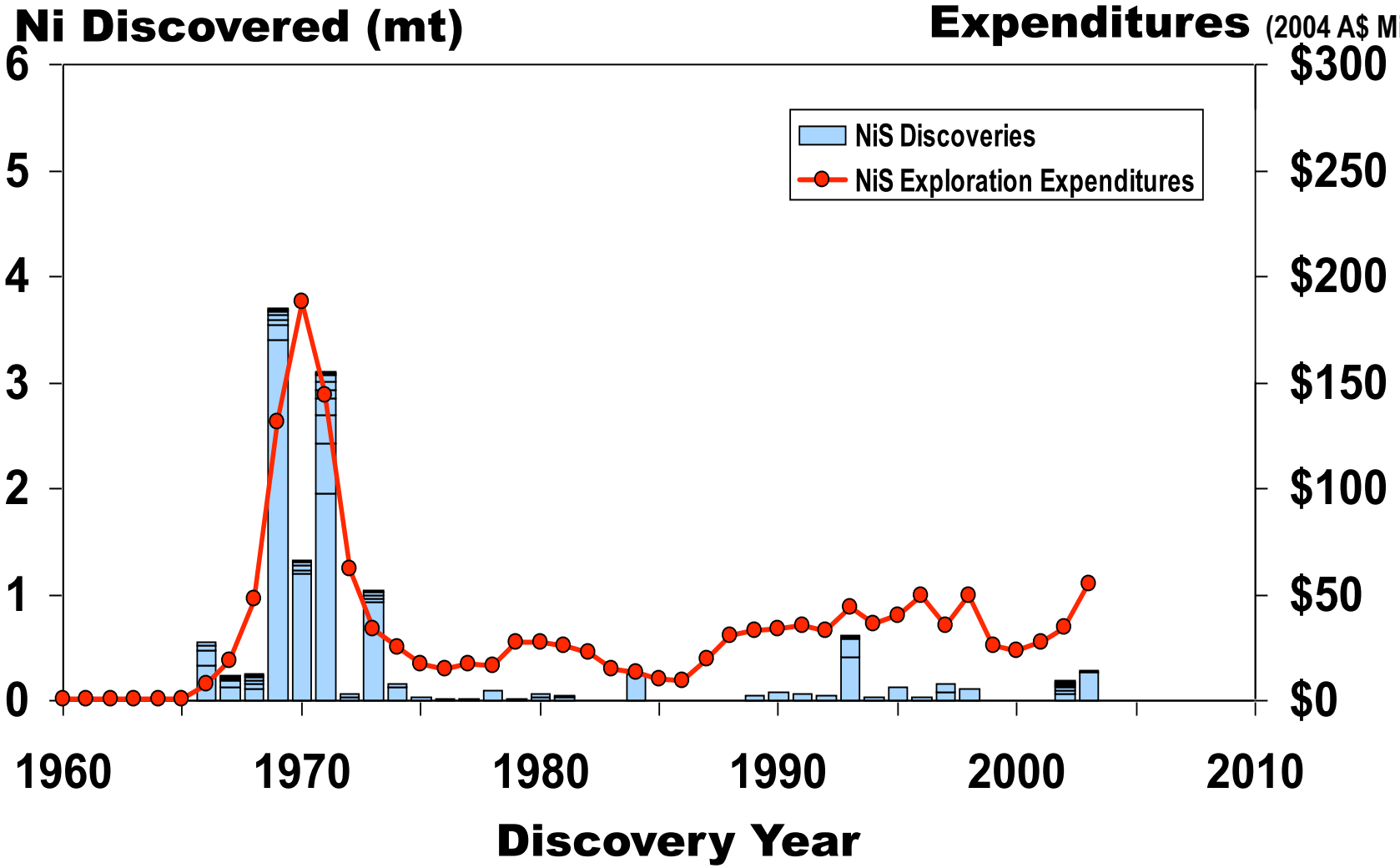
(Post-discovery growth is attributed back to the discovery date)



Excludes Prospects

Source: WMC

Expenditure vs Discovery Rate: Sulphide Deposits



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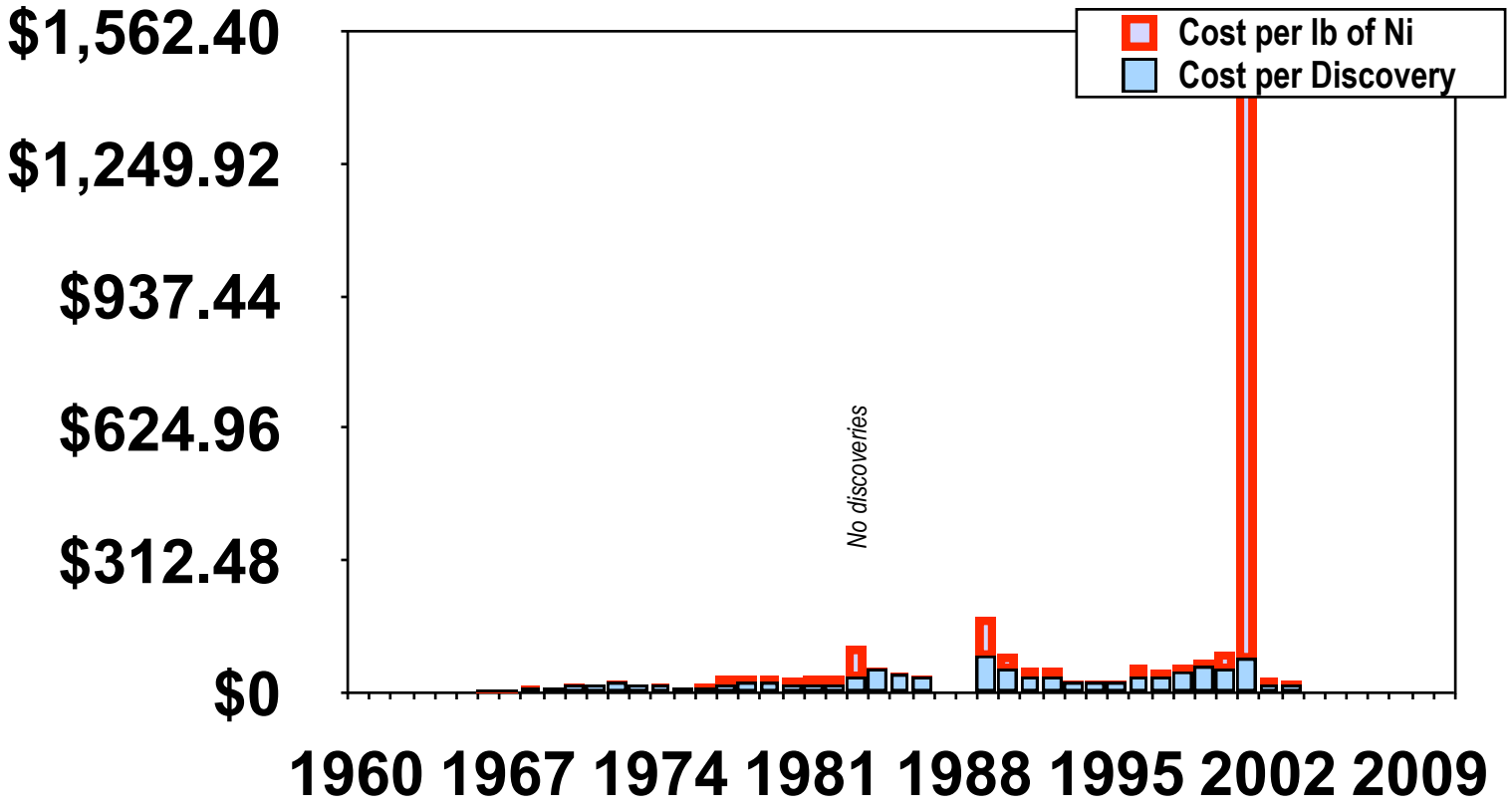
Average Discovery Cost: Sulphide Deposits

Cost per Discovery (2004 A$m)

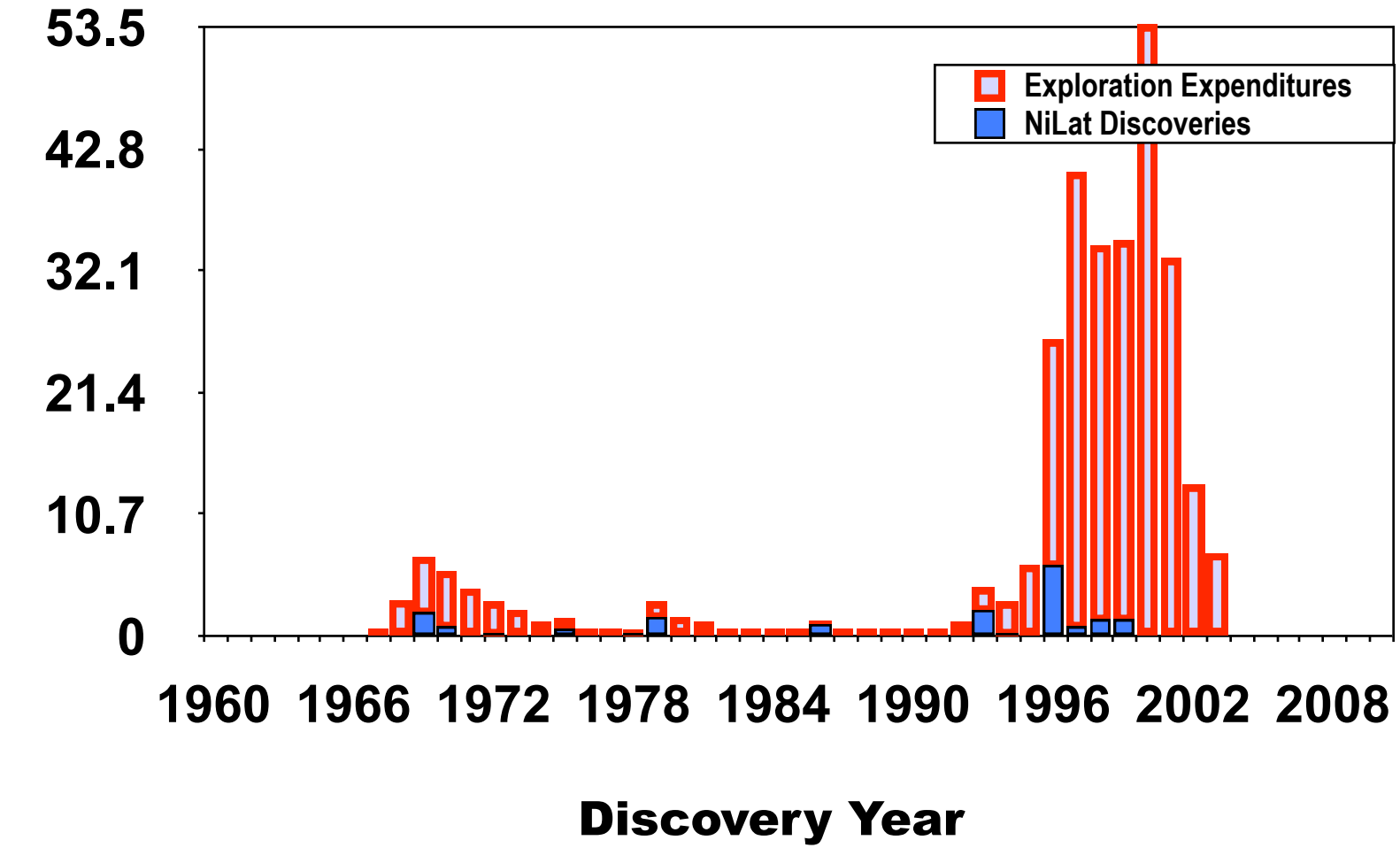
Cost per Pound (2004 A$ Cents/lb Ni)



Based on 3-Year Rolling Average

Discovery Year

Expenditure vs Discovery Rate: Laterite Deposits



Summary of Exploration Performance

1966 - 2003

Deposit Type	Total Spend	Ni Metal discovered	Av. Cost per pound Ni	Av. Cost per discovery
Sulphide	$1 485 M	12.78 mt	5.2	$17.7 M
Laterite	$280 M	19.5 mt	0.6	$6.5 M

Notes:
1.All currency amounts in 2004 AUD
2.Minimum deposit size 5kt Ni

Summary and Conclusions

- The Ni exploration history of the Yilgarn Craton is a great success story!
- In a period of less than 40 years, the known endowment of the craton has grown from zero to 14% of the global inventory of Ni resources (and 18% of global Ni sulphide resources)
- The most successful period of exploration was at the beginning when a major new search space was opened
- Exploration expenditure was driven by a combination of metal price and new search space
- Future exploration success will depend on continuing to develop the new technologies and concepts that

- Copies of this presentation are available for download at **www.wesminllc.com**

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