Gold and nickel deposits in the Archaean Norseman–Wiluna greenstone belt, Yilgarn Craton, Western Australia — an introduction

by

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Introduction

This field guide provides background technical information on the mines and localities to be visited during an excursion associated with the SEG 2004: Predictive Mineral Discovery Under Cover conference, held in Perth in September–October 2004. It covers world-class gold and nickel deposits in the extremely well endowed and deeply weathered Kalgoorlie Terrane, and investigates the main stratigraphic and structural features controlling the localization of hydrothermal (orogenic) gold and magmatic (komatiitic) nickel mineralization. The itinerary includes older established mines and recently discovered deposits, starting in the Kalgoorlie–Norseman district and then travelling 500 km north to the Wiluna–Leinster district.

The individual contributions address topics such as:

1. regional geology of the Eastern Goldfields Province of the Yilgarn Craton;
2. geological setting of several major gold and nickel ore deposits;
3. principle mineral assemblages in these gold and nickel deposits;
4. structural and lithological controls on gold and nickel mineralization;
5. principle alteration styles associated with the orogenic gold deposits;
6. exploration procedures that led to the discovery of each deposit;
7. future directions for predicting the discovery of these deposit types under cover.

The excursion first visits the main gold and nickel mines around and to the south of Kalgoorlie, such as the Golden Mile, Kanowna Belle, and Kundana gold mines, the St Ives gold camp, and the Miitel–Wannaway and Kambalda – Long Shaft nickel orebodies. The second part of the excursion visits the Thunderbox gold mine, and the Mount Keith, Cosmos, Honeymoon Well, and Waterloo nickel mines between Leonora and Wiluna. Presentations at the mine sites will include the latest mining information, detailed geological and structural settings, and most recent research results on ore deposit formation and controls on the location of mineralization. Representative diamond drillcore of host rocks, hydrothermal alteration, and mineralization styles will be examined in company core farms.

The excursion also visits the Joe Lord Core Library of the Geological Survey of Western Australia (GSWA). This facility archives diamond drillcore that is representative of the geology and mineralization of the Eastern Goldfields Province.

Modern history of gold and nickel exploration, and mining in the Yilgarn Craton

Gold

The modern gold rush in Western Australia commenced in the middle to late 1970s, when higher gold prices stimulated exploration. Exploration expenditure for gold in Western Australia is concentrated within the Yilgarn Craton, and particularly within the Eastern Goldfields Province. Expenditure rose from almost nothing to a peak of around A$500 million in the years 1987–88 (Flint and Abeysinghe, 2001). Both established miners and junior explorers re-evaluated all of the historic mining districts, including Southern Cross, Mount Magnet, Cue, Meekatharra, Norseman, Kalgoorlie, Menzies, Leonora, Laverton, Agnew, and Wiluna. Most developments were based on opencut mining of lower grade haloes left by earlier phases of mining. Several major camps were discovered from ‘greenfields’ exploration, including Plutonic, Boddington, Granny Smith, and Mount McClure.

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After a brief decline in exploration expenditure following the stock market crash of October 1987, a new peak of just over A$500 million was reached in 1996–97, and gold production increased steadily to a peak of 220 t in 1996 (Flint and Abeysinghe, 2001). In the 1990s, a more optimistic outlook and a change in exploration methods resulted in the discovery of more greenfields deposits. Deposits were discovered buried beneath Tertiary or Quaternary transported laterite cover, salt lakes, or both, including Bronzewing, Nimary–Jundee, Thunderbox, Kanowna Belle, Sunrise Dam – Cleo, Mount Pleasant, Bounty, and Yilgarn Star.

A new phase of exploration began in 1997–98 when a rapid weakening of the gold price led to a 40% decrease in exploration expenditure. During this period, greenfields exploration was largely abandoned and near-mine 'brownfields' targets were drilled to feed central treatment plants. A trend of amalgamation and take-overs resulted in fewer and bigger companies. Notable successes in brownfields exploration include deep extensions of Granny Smith, Gwalia, Mount Magnet, Kanowna Belle, and Ghost Crab. Near-mine 'blind' discoveries were made at Centenary at Darlot mine, Bellisle at Kambalda – St Ives, and Kundana near Kalgoorlie. The Laverton Tectonic Zone emerged as an even larger gold camp at the turn of the 21st century, with significant discoveries at Sunrise Cleo, Granny Smith, Red October, Chatterbox, and Wallaby.

Western Australia currently produces 8% (210 t) of annual global gold output, but production is set to decline unless major new deposits are discovered in the next three years. However, the steady increase in the gold price from 2001 onwards to the latest high of about US$427 in April 2004 has improved investors' confidence in gold as a hedge commodity. There has been even more consolidation of ownership in the last five years, such that the only remaining wholly Australian-owned companies with significant gold production are Newcrest Mining Limited and Sons of Gwalia Limited (recently entered voluntary administration). Nevertheless, a raft of new junior explorers with promising gold prospects has recently listed on the Australian Stock Exchange (ASX) and some, such as Siberia Mining Corporation Limited, are already in production.

Nickel

In 1992, Australia contributed 887 200 t or 6.5% of world nickel production (Department of Minerals and Energy, Western Australia, 1994). In that year, it was ranked as the world's sixth-largest producer of nickel behind the former Soviet Union, which contributed 24.8% of total production, Canada (21.7%), New Caledonia (11.3%), Indonesia (8.7%), and Botswana (6.7%).

In 2002, Western Australia produced 187 000 t of nickel, which was shipped as concentrates and refined product. Of this, about 60 000 t of metal was produced directly from lateritic nickel ores at Murrin Murrin.

Before the discovery of high-grade nickel sulfide ore at Kambalda in 1966, Western Australia had virtually no nickel reserves (Department of Minerals and Energy, Western Australia, 1994). However, rising world nickel prices and a prolonged strike at The International Nickel Company of Canada Limited's mine at Sudbury, Canada, meant that the discoveries made at Kambalda were developed rapidly, and the famous 'nickel boom' of 1967–71 ensued. During this period, many discoveries were made in a belt between Norseman and Wiluna, which is now recognized as one of the world's major nickel provinces.

Nickel ores in the Yilgarn Craton of Western Australia are divided into sulfide and lateritic ores. Nickel sulfide deposits associated with volcanic ultramafic rocks (komatiites) make up the largest proportion of the sulfide resource, and are also the most important economically. Current and future nickel sulfide production in the Yilgarn Craton comes from mines at Kambalda, Widgiemooltha, Silver Swan, and Carnilya in the Kalgoorlie district; Maggie Hayes – Emily Anne and Forrestania in the Lake Johnston – Southern Cross district; and Leinster, Mount Keith, Cosmos, Honeymoon Well, and Waterloo–Amorac in the Agnew–Wiluna district.

Current and future Archean gold and nickel research programs in Western Australia

Due to the substantial value of mine production for Australia, and with mineral resource exports comprising 78% of all exports in Western Australia, there is a significant focus of research into understanding the genesis of mineral deposits and the geological controls on their location.

The federal (Geoscience Australia, GA) and state government (GSWA) geological authorities are responsible for the acquisition and interpretation of broad-scale data, which are made available to the public.

Geoscience Australia has invested significant resources into terrane- to craton-scale geophysical surveys and the construction of three- and four-dimensional models of the Eastern Goldfields Province. Foundation mapping at local, district, and terrane scales is provided by GSWA. It has also compiled geochemical data at a district scale, and published mineral occurrence data. Reports such as Witt (1993) provide district-scale descriptions and interpretations of mineralization. GSWA also documents all company reports relating to exploration on Western Australian mining tenements.

Apart from the government authorities, significant research is undertaken by publicly and corporately funded organizations, including universities, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and AMIRA International.

The Centre for Global Metallogeny (CGM) at The University of Western Australia (UWA) was founded as a Key Centre for Teaching and Research in Strategic Mineral Deposits in the late 1980s by Professor David

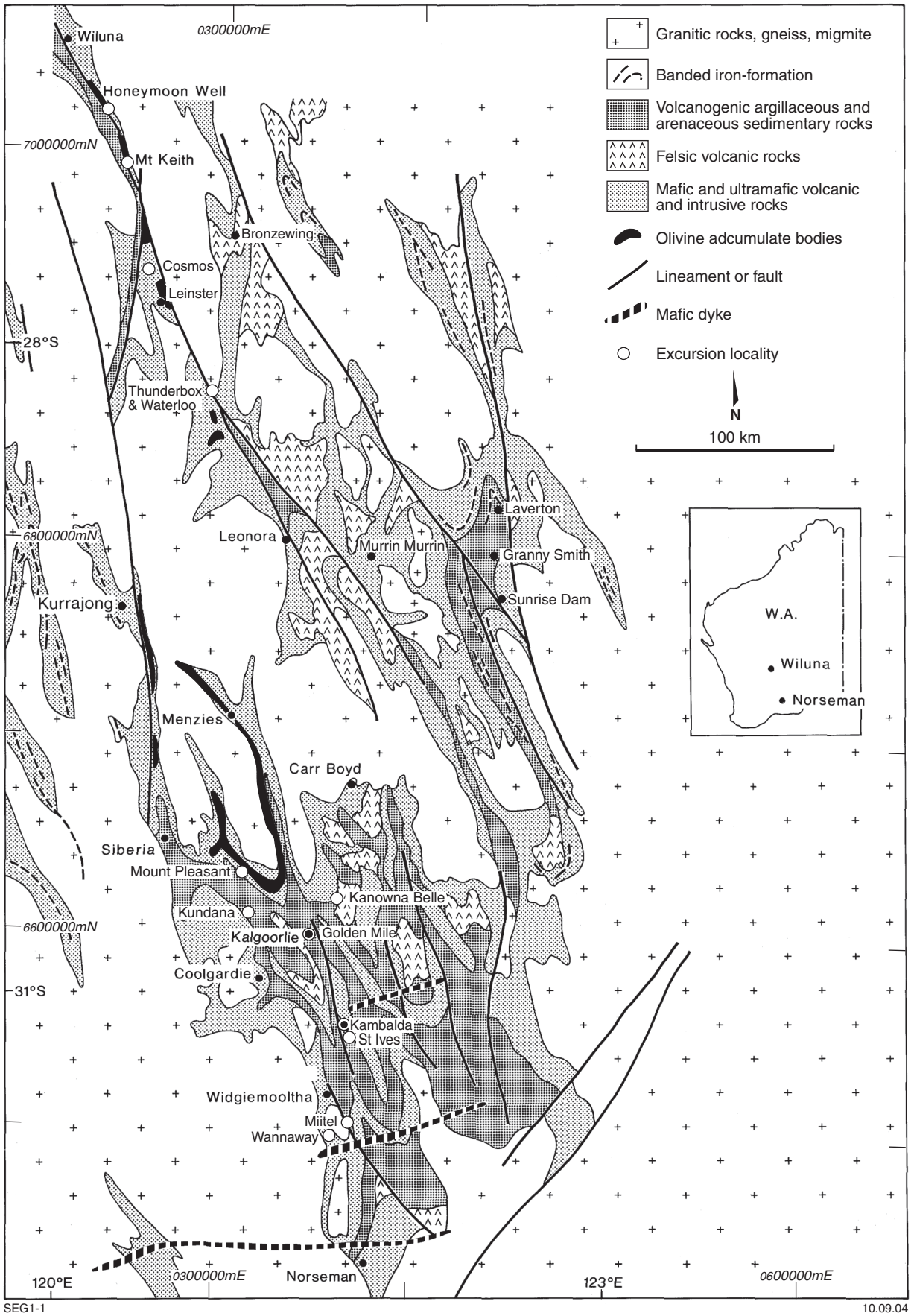

Figure 1. Simplified geological map of the Norseman–Wiluna greenstone belt showing excursion localities (adapted from Hill et al., 2001, fig. 1)

Groves. It has produced numerous research theses at Honours, Masters, and Doctoral levels on Australian and overseas deposits. Studies range from detailed mine-scale projects, to camp- and terrane-scale research on the fundamental controls on orogenic gold and komatiitic nickel deposits in the Yilgarn Craton and worldwide. The pertinent research on mineral deposits has attracted sponsorship and support from many international and national exploration and mining companies.

Despite a threefold increase in exploration expenditure over the past 30 years, the low rate of discovery of large, high-quality orebodies has become unsustainable. Although part of the problem is the ineffective use of available exploration funds, the increasing difficulties of discovering mineable deposits under cover is even more problematic. This has focused an Australian-wide research push into predictive mineral discovery under cover, and the financial resources of the federal government and a large number of industry sponsors were pooled to fund the Predictive Mineral Discovery Cooperative Research Centre (pmd*CRC), which consists of seven core partners (AMIRA International, CSIRO, GA, James Cook University, Monash University, The University of Melbourne, UWA). The centre aims to generate a fundamental shift in exploration practice and cost-effectiveness by improved understanding of mineral processes and four-dimensional understanding of the geological evolution of mineralized terranes. Research fields include enabling technologies, and detailed studies of mineralized terranes at all scales ranging from oreshoot through mine–camp to terrane.

In recent years, nickel research in Australia has been headed by collaborative Monash University and CGM studies. Studies have focused on detailed mine-scale volcanic and structure studies, ore remobilization, camp-scale mineral and whole-rock lithogeochemical vectors, terrane-scale volcanic and intrusive architecture, and strategic studies of recent brownfields and greenfields discoveries. This research has been supported by the Western Australian mineral industry, in particular.

Future nickel research directions include understanding the camp-scale 'fertility' of Western Australia's large nickel mining camps; fundamental controls on sulfur solubility, including the roles of pressure and volatiles; mobilization of sulfide magmas; platinum group element (PGE) and mantle heterogeneity; and fertility indicators including resistate minerals and whole-rock lithogeochemical vectors.

Technological advances over the past 20 years have been instrumental in some of the gold and nickel discoveries. At Kanowna Belle, for example, geochemical sampling and analytical procedures available in commercial laboratories have enabled the accurate and precise low-level detection of gold to parts per billion. Downhole electromagnetic surveying of the Forrestania nickel deposit has enabled the precise targeting of dense nickel-sulfide concentrations at great depths.

Organization

The field guide is organized so that camp and deposit descriptions follow the excursion route (Fig. 1). The first section covers the 'southern' nickel deposits in the Widgiemooltha area and Kambalda Dome, as well as gold deposits in the St Ives camp, and at Kanowna Belle, the Golden Mile, and Kundana. A short paper on the Joe Lord Core Farm explains the purpose of the facility. The second section of the guide describes nickel deposits in the 'northern' part of the excursion area, such as Waterloo, Mount Keith, Honeymoon Well, and Cosmos. It also describes the geological setting of the Thunderbox gold deposit.

Specific excursion stops are difficult to plan in active mining environments, so most papers cover detailed geological and structural settings, as well as hydrothermal alteration and ore mineral assemblages, rather than referring to precise stops. The excursion stops in mines will be determined shortly before the excursion arrives, and will depend on the mine schedule. Additional information will be provided to excursion participants upon arrival on site.

Acknowledgements

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