

# FROM EXPLORATION TO REHABILITATION: THE LIFE OF A GOLD MINE



Geological Survey of  
Western Australia



Department of  
Industry and Resources

## Outline:

- Exploration to discovery
- Mining techniques
- Processing techniques
- Uses of gold
- Rehabilitation



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# Where do we look for gold?

In the Eastern Goldfields, gold is predominantly found in:

- structurally controlled zones (faults or shear zones)
- quartz veins and sulphide-rich zones within greenstones (ultramafic to mafic rocks, and some sedimentary rocks), less commonly in granite



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## In the Eastern Goldfields:

- the gold mineralization event is thought to be largely about 2640 million years in age
- ore grades vary from 30 g/t to 2 g/t (e.g. in the Superpit)

About 300 000 kg of gold are produced every year in Australia, the majority of which is extracted in the Goldfields of Western Australia



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Exploration is commonly the longest and riskiest “stage” on the road to establishing a gold mine, and can take up to several years for each project.

For one successful prospect that will develop into a gold mine, many more will be abandoned without any further development.

The cost of exploration can vary incredibly depending on a number of factors, but can easily run up to \$60/oz (by comparison, mining costs are about \$300/oz).

Exploration activity is largely conducted by geologists and geophysicists, assisted by field samplers, drillers, and laboratory personnel (for chemical assays).

## **Greenfields exploration**

- in previously unexplored areas

## **Brownfields exploration**

- in areas with known occurrences, typically adjacent to mining centres where the same commodity is already extracted

How exploration is conducted and its cost can vary significantly, depending on whether a company is exploring greenfields or brownfields areas. The difference between these two types of exploration is described in this slide.



Gone are the days when prospectors were roaming the country in the hope of stumbling across a lode of gold or a gold-bearing quartz vein. Old-timers found gold in the loose surface material and then dug in the hope of finding the source of the gold (or 'mother-lode'). Although the location of historical digs is still a useful indication in the search for new mineral deposits, gold mining has come a long way from the panning and dryblowing of the original diggers.

Today exploration avails itself of many technological advances that allow the ground and what is below it (up to a depth of several kilometres) to be evaluated in great detail.

# Tools for mineral exploration:

## Remote sensing tools:

- aeromagnetic and radiometric surveys
- gravity surveys
- seismic surveys

## Ground exploration:

- historical data
- geological mapping
- GIS (Geographic Information System)
- magnetic surveys
- drilling (RAB, RC, diamond)
- sampling (soil, chip, rock, etc.)
- chemical assays

Mineral deposits possess physical properties that are different from those of the surrounding rocks. Explorers use scientific techniques called geophysical methods to measure these variations in physical properties of rocks (e.g. density, magnetism, electrical conductivity, natural radioactivity, heat capacity, etc) as a tool to locate mineral deposits.

Geophysical methods offer a means of seeing into the earth itself, something few other exploration techniques can do. They are a very important component of most modern exploration programs.

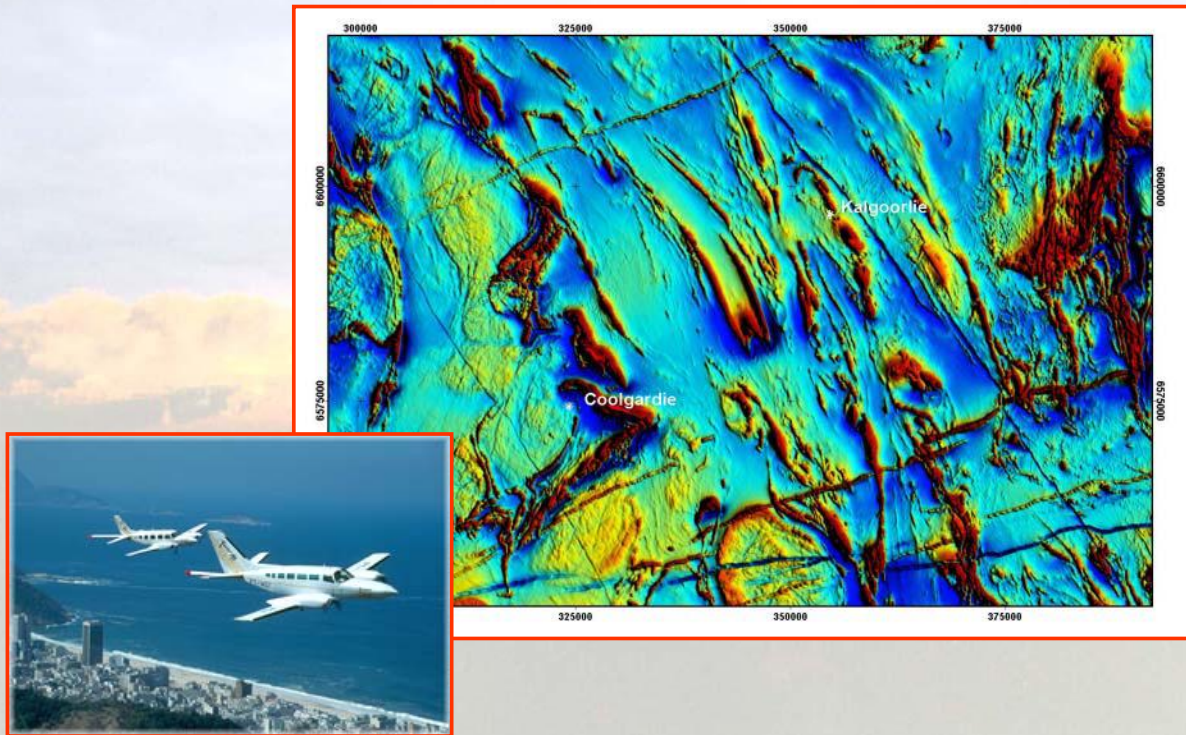
When conducted from the air, geophysical exploration is known as remote sensing. It may be undertaken from fixed-wing aircraft or helicopters normally flying 60 to 200 m above the surface or from satellites up to 1000 km above the earth.

Ground geophysical surveys can be expensive and are generally only undertaken over relatively small target areas of particular interest.

## What tools are used depends on:

- whether we are exploring in brownfields or greenfields areas;
- the size and accessibility of the area to be explored;
- whether we are looking for deposits exposed at surface or 'blind' deposits (i.e. deposits hidden under variably thick cover —up to several hundreds of metres);
- the stage of exploration.

# Aeromagnetic surveys



Source of photo:

<http://www.fugroairborne.com.au/Services/airborne/MAG/index.shtml>

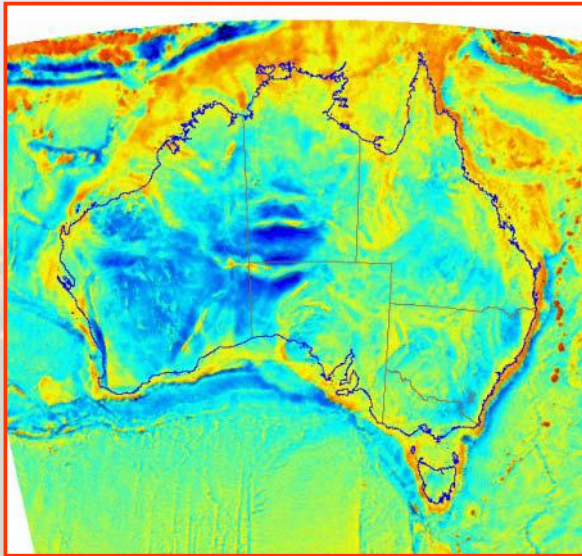
Aeromagnetic maps depict in different colours the content of magnetic minerals (e.g. magnetite, pyrrhotite, etc) for different rock types, with red = high magnetic mineral content, and blue = low magnetic mineral content.

Aeromagnetic surveys are commonly conducted by flying airplanes at a constant altitude along variably spaced regular grids. The response measured is influenced by the depth and magnetic 'strength' of the variably magnetic rocks. For example, banded iron-formation and ultramafic rocks are highly magnetic, whereas granites and most sedimentary rocks are less magnetic. In the Eastern Goldfields, this allows clear separation between areas of greenstones and areas of granite.

Aeromagnetic maps also highlight structures such as folds, faults or shear zones, lithological boundaries between different rock types, crosscutting features (e.g. dykes, borders of intrusions) — all features that can assist in locating a mineral deposit.

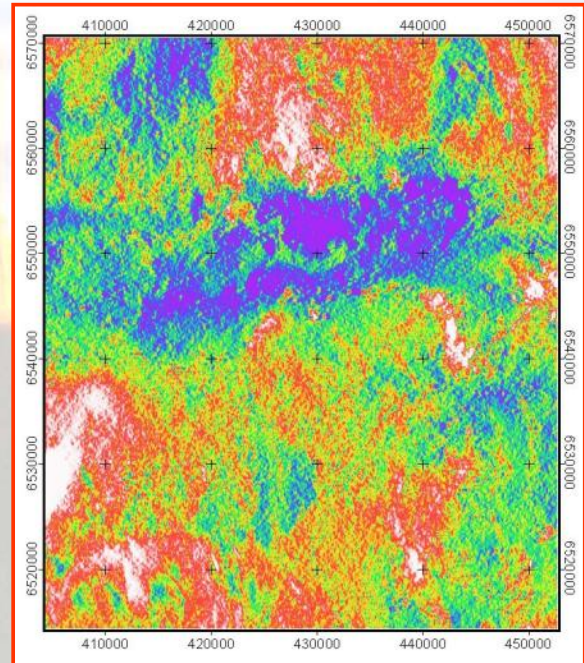
# Gravity and radiometric surveys

## K radiometric image of Mount Belches



**Gravity map of Australia**

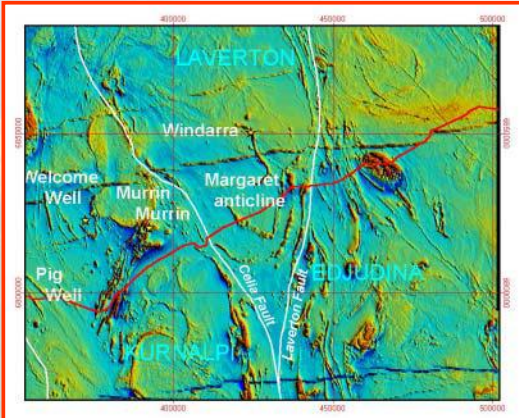
*Source of image: <http://www.ga.gov.au>*



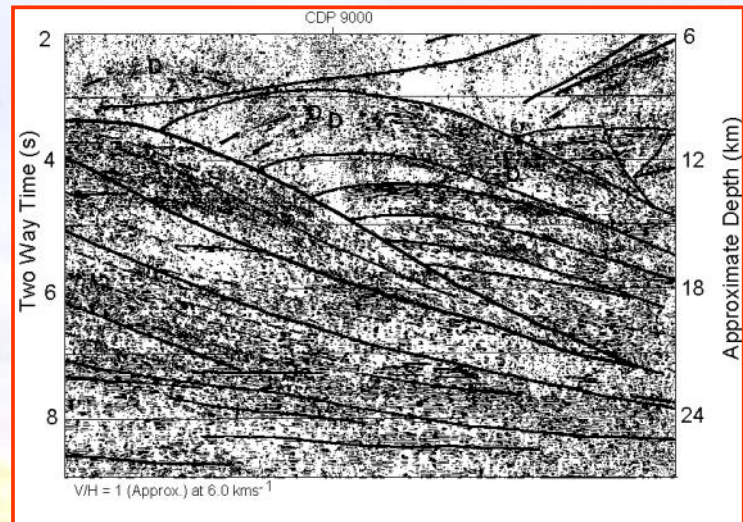
Gravity surveys record the density of different rock types, and are influenced by the types of rocks present at depth. Typically, many ore minerals have a higher density than the surrounding rocks. By measuring variations in the Earth's gravity field over an area, an indication of the nature of the underlying geology and the likely presence of deposits can be obtained. Surveys are often undertaken over large areas, and provide regional information on the nature of rocks, even those at considerable depth.

Radiometric surveys measure variations in the natural radioactivity of an area (as many rocks and minerals are naturally radioactive at very low levels). Surveys of this type are normally undertaken from the air. Radiometric images differentiate between geological units with distinct gamma-ray spectra, and basically depict the distribution of Th, U and K in different rocks. The potassium channel is displayed as red, thorium as green, and uranium as blue. Radiometric images allow easy separation of different geological units and are particularly suitable to identify granite and greenstones.

# Seismic surveys



**Deep seismic transect**



**Interpreted seismic profile**  
(Drummond, Goleby, and Swager, 2000)



**VIBROSEIS**

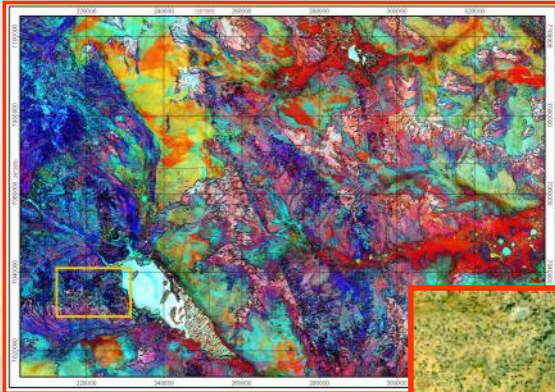
Seismic profiles allow geologists to study the ground beneath the surface to depths of several kilometres, up to the transition between the crust and mantle (which in the Goldfields occurs at a depth of about 35 to 45 km).

A seismic profile is obtained by producing surface vibrations that propagate through the ground (using explosives or specially designed trucks called VIBROSEIS). These are reflected back to the surface whenever a change in rock type or a structural discontinuity are encountered at depth.

By studying and interpreting the profiles obtained in this way, it is possible to identify structures that might have acted as favourable conduits to mineralizing fluids. Of particular interest are structures that tap into the mantle and emerge at surface, such as the ones identified in the recent seismic profiling from Leonora to Laverton and Yamarna.

Ref: DRUMMOND, B. J., GOLEBY, B. R., and SWAGER, C. P., 2000. Crustal signature of Late Archaean tectonic episodes in the Yilgarn Craton, Western Australia: evidence from deep seismic sounding: *Tectonophysics*, v. 32, p. 193–221.

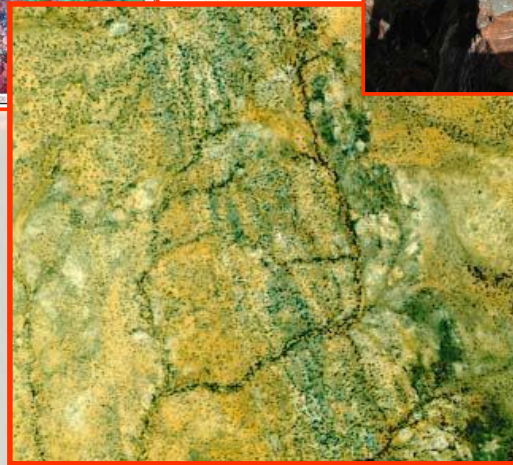
# Geological mapping



Landsat image



Sampling



Aerial photography

Geological mapping allows geologists to identify all rocks and structures exposed at surface and to characterize the cover (or regolith) that most commonly hides them.

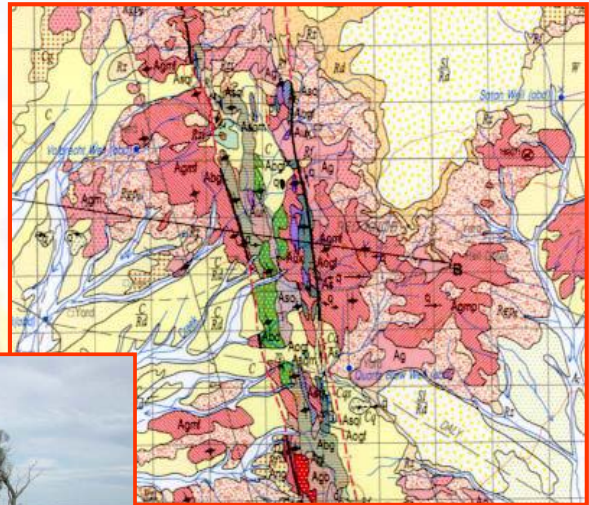
In the Eastern Goldfields the regolith cover represents about 90% of the surface exposure. In the search for 'blind' deposits, it is very important to recognize whether the regolith cover is in situ or has been transported.

Due to the limited exposures of rocks in the Goldfields, geological mapping and interpretation always take into account information provided by other sources, particularly aerial photography, Landsat images, and aeromagnetic images. With all the available information, a geologist will interpret the likely distribution and structure of rocks beneath the cover, a very important step to identifying the possible location of mineral deposits.

# Geological mapping



Field work

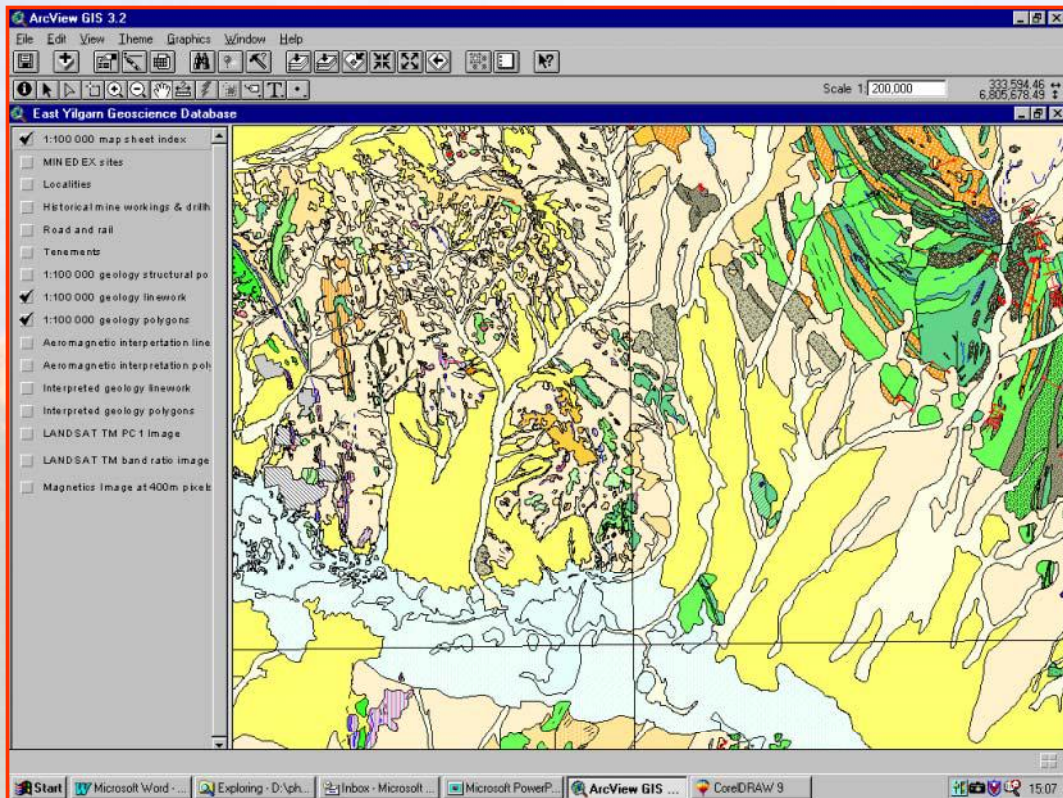


1:100 000 map sheet



Field work

# GIS — Geographic Information System

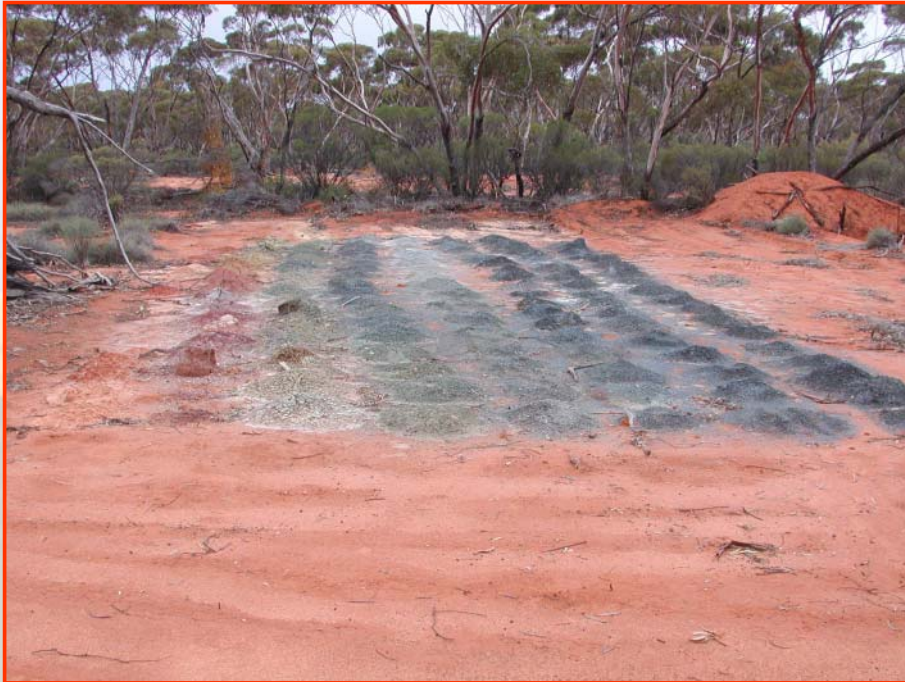


GIS (Geographic Information System) is a powerful tool that allows us to explore the spatial relationships between different parameters by means of statistical analysis.

For example, it allows analysis of gold deposits that have yielded a certain production in relation to their distance from structural lineaments (faults, shear zones) with a particular orientation, or the distance of gold occurrence from the margins of granite intrusions.

From this type of analysis, it is known that 70% of gold findings are in mafic rocks (gabbro, basalt), within a distance of 5 km from major faults or shear zones.

## Drilling: RAB (rotary air blast)



**RAB chips from drilling at Yardilla**

Drilling is a very important tool to 'see' what is hidden under the ground. Three main techniques are used in the Goldfields: RAB (rotary air blast), RC (reverse circulation), and diamond drilling.

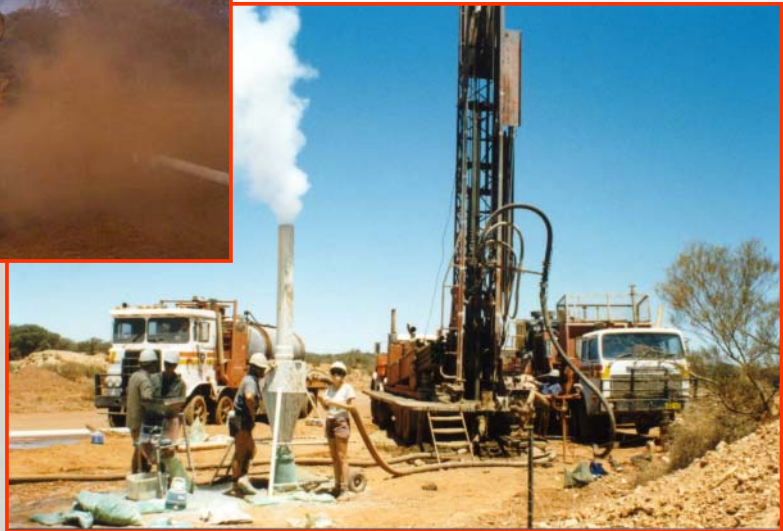
Rotary air blast (or RAB) drilling is the cheapest and least penetrative type of drilling used in the Goldfields. It makes use of compressed air (or a mixture of compressed air and water) to 'break' the ground. Compressed air is pumped down the hole through a drill pipe, and the cuttings are blown up the hole along the space between the drill pipe and the wall of the hole. The cuttings are laid in distinct mounds (each representing 1 or 2 m of drilling), and then described, identified, and analysed.

RAB drilling only penetrates the weathered cover above fresh (or unweathered) rocks, and generally extends for only some tens of metres (60–70 m on average). Typically, the cost of RAB drilling is in the order of about \$6/m.

## Drilling: RC (reverse circulation)



RC drilling at Darlot



Reverse circulation (or RC) drilling penetrates deeper than RAB drilling and can usually reach depths of 70–200 m.

The system makes use of a dual-wall pipe. High-pressure air or water is forced down the outer pipe to the drill bit, and is then directed to the centre of the pipe. The air returns the cuttings to the surface via the inner pipe. RC chips are typically stored in plastic bags, each representing 1 m of drilling.

Typically, the cost of RC drilling is in the order of \$30–35/m for the first 100 m of drilling, and \$42–44/m from 100 to 200 m in depth.

# Drilling: Diamond



## Diamond drilling in the Goldfields

Diamond drilling is the most expensive type of drilling (of the order of \$75–100/m, depending on the diameter of the core), but it also allows the greatest penetration and recovery of whole samples of rocks (not just chips). A depth of several hundred metres is commonly reached in the Goldfields; elsewhere diamond drilling has been extended to a depth of several kilometres (e.g. in sedimentary basins in the search for oil).

Diamond drilling allows clear identification of rock types and their relationships, as well as providing samples for analyses. It also allows 3-dimensional assessment of the lateral extent and depth of an orebody.

# Drilling: Diamond

GSWA Kalgoorlie core library

Abandoned core yard at Nepean



Diamond cores can have variable diameters, and are usually stored in core yards. The GSWA (Geological Survey of Western Australia) core libraries in Perth and Kalgoorlie house a selection of representative cores from various parts of the State that represent different styles of mineralization and mineral deposits from different localities.

# Sampling techniques

Sampling techniques are aimed at mapping the distribution of gold and various elements associated with gold (e.g. so-called pathfinders such as As, Te), using samples of soil, alluvium, rock, chip (after drilling), and so on.

Sampling of various media is done at different stages during exploration. For instance, soil sampling over large areas can help in establishing background values for a region and can assist in identifying more prospective areas and specific targets. Chip and diamond core samples are specifically targeted at identifying mineralization grades in later stages of exploration.

# Chemical assays

## Drilling results from near Leonora

Hole	North AMG	East AMG	Interval (m)	Gold intersection	Type
BMR054	6811081	356681	32–36	<b>4 m @ 4.1 g/t</b>	RAB
BMR354	6816143	352178	53–57	4 m @ 1.54 g/t	RAB
BWR216	6820084	348522	20–28	8 m @ 3.42 g/t	RAB
CAR186	6804678	361634	9–13	<b>5 m @ 5.60 g/t</b>	RAB
CAR192	6804668	361616	15–19	4 m @ 1.53 g/t	RAB
CAR219	6804536	361792	33–37	4 m @ 1.55 g/t	RAB
CAR221	6804498	361720	38–54	16 m @ 3.07 g/t	RAB
CARC001	6804506	361735	40–51	11 m @ 2.57 g/t	RC
CARC002	6804487	361700	54–59	5 m @ 1.72 g/t	RC
			72–78	6 m @ 2.24 g/t	
CARC005	6804365	361810	73–77	4 m @ 3.46 g/t	RC
CARC007	6804524	361770	112–113	<b>1 m @ 14.5 g/t</b>	RC
CARC019	6805276	361485	88–110	22 m @ 1.78 g/t	RC
			88–94	6 m @ 2.79 g/t	RC
			107–110	<b>3 m @ 5.00 g/t</b>	
CARC021	6804647	361660	22–24	<b>2 m @ 11.3 g/t</b>	RC
CARC023	6804661	361686	39–47	8 m @ 1.76 g/t	RC

Chemical analyses (or assays) of samples collected during exploration provide the precise gold content of rocks and allow geologists to establish what the distribution of the gold mineralization is in the area under assessment. This allows the exploration geologists to make a decision as to whether or not a gold mine is feasible.