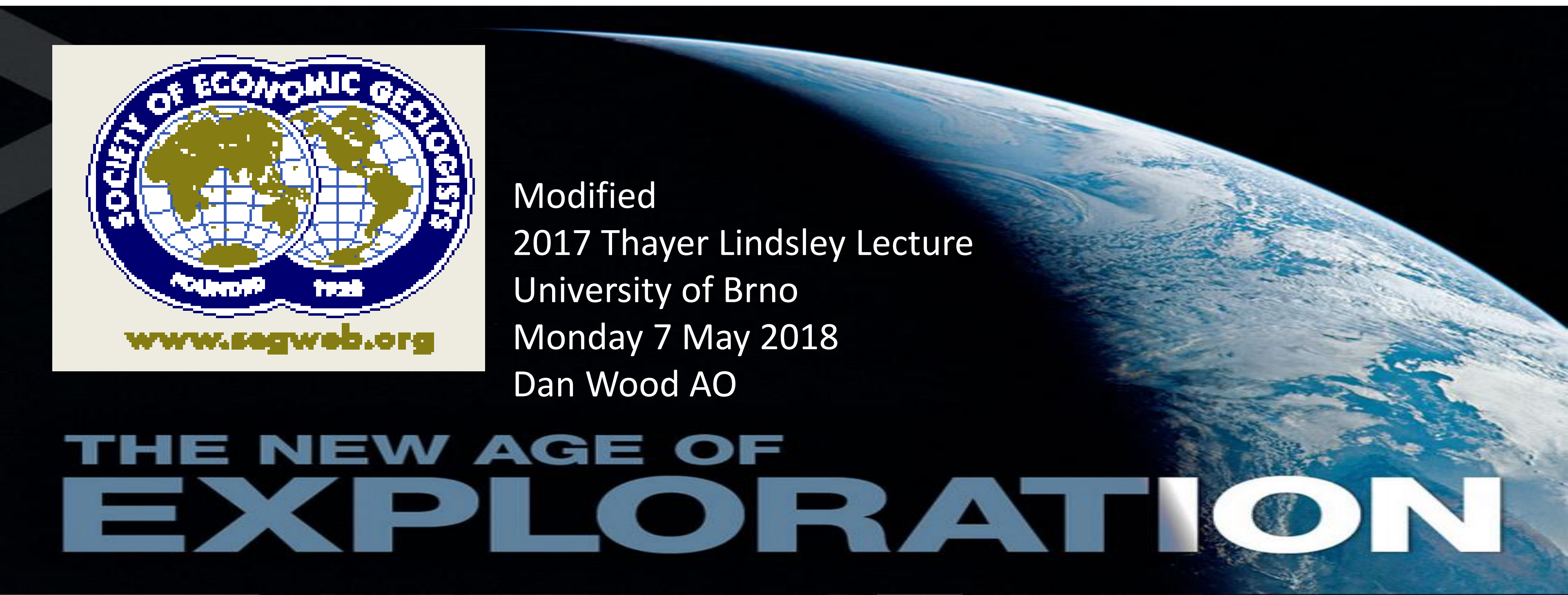
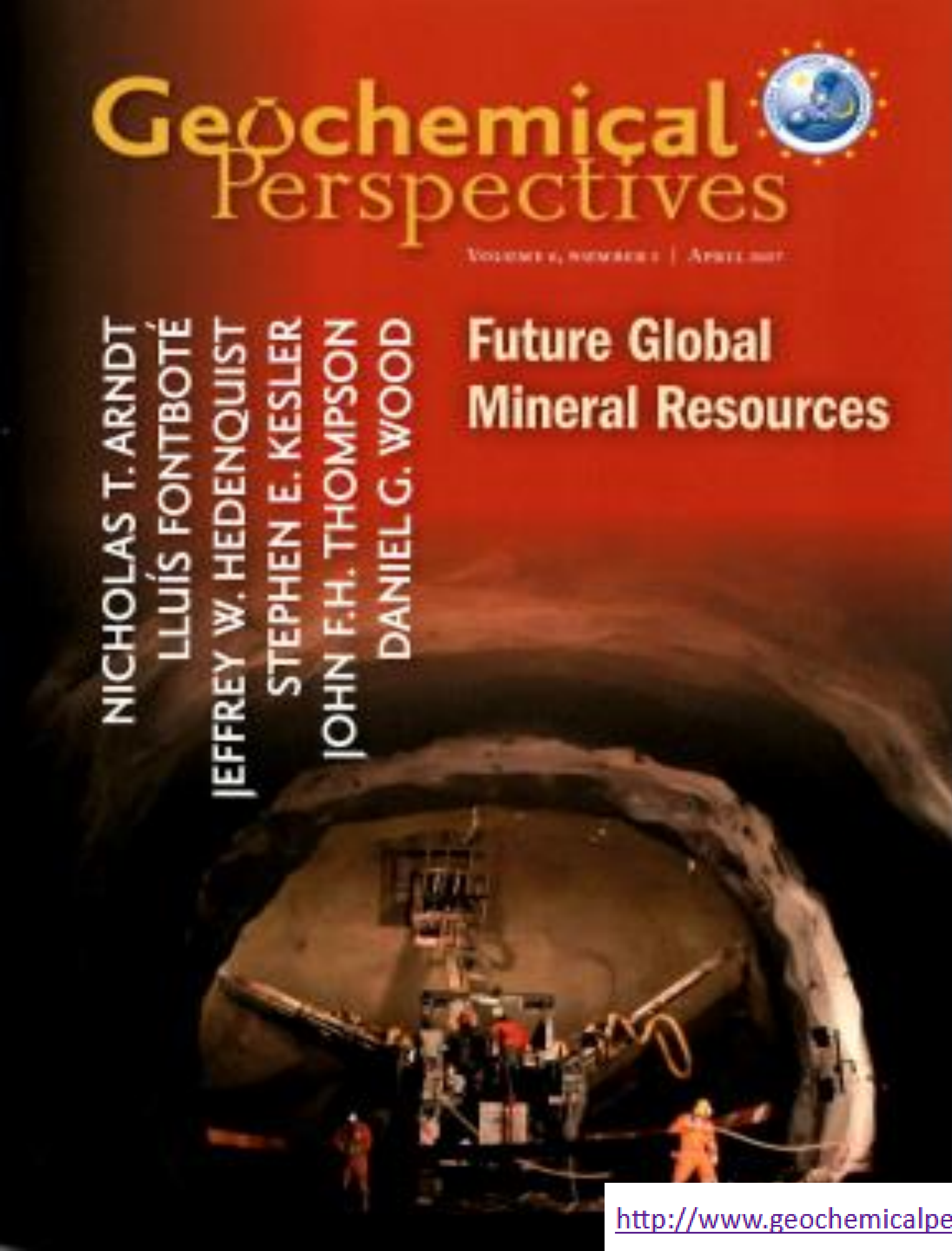
Talk 7
University of Brno
Discovery Challenges Seminar
7 May 2018

Challenges Related
To
Exploring for Ore Deposits



Modified
2017 Thayer Lindsley Lecture
University of Brno
Monday 7 May 2018
Dan Wood AO



A Useful Reference

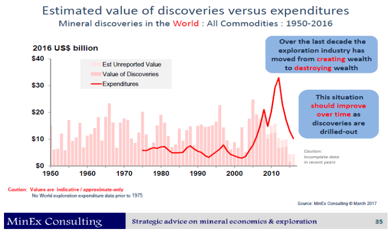
(Free online from Geochemical Perspectives)

http://www.geochemicalperspectives.org/wp-content/uploads/2017/05/v6n11.pdf

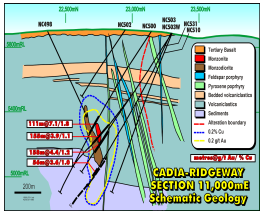
Content

- Some comments on exploration and what it entails

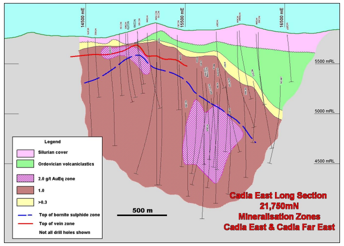
- *How we presently explore*



- Exploration performance in recent years and what this means for how we should explore



- *Some relevant porphyry Au-Cu discoveries, two of which produced mines*



- Some concluding remarks

What is Mineral Exploration?

It's the principal process for discovering ore deposits

There are two components

- *how to do it?*
  - *the "theory" side*
- *what tools to use?*
  - *the practical side*

This talk will focus on the "theory"

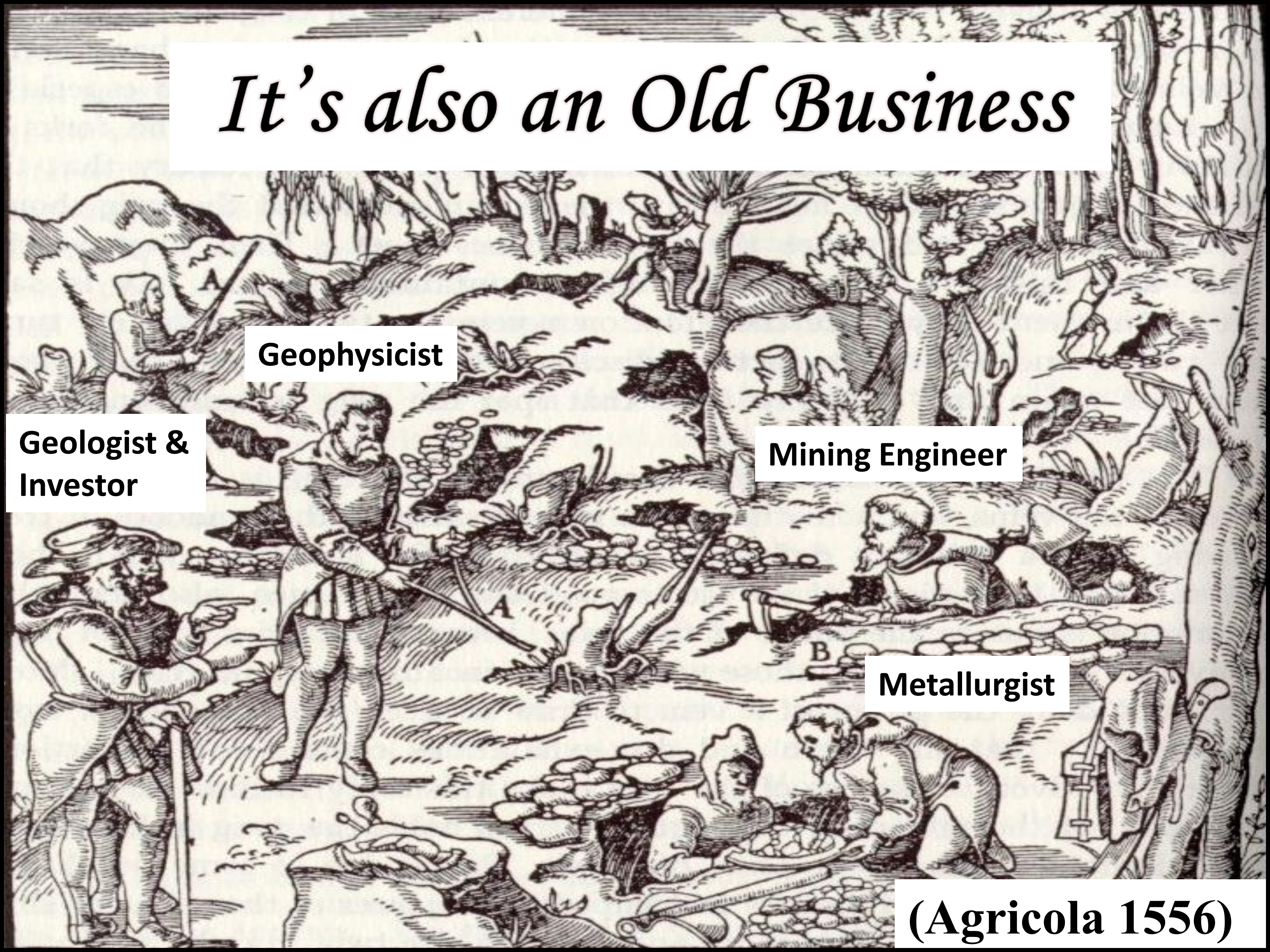
What is it in Practice?

It's detective work

We seek clues to discover ore bodies

It's research by another name

It's also an Old Business



(Agricola 1556)

How do we Explore?

We use inductive reasoning

As did Sherlock Holmes, the detective

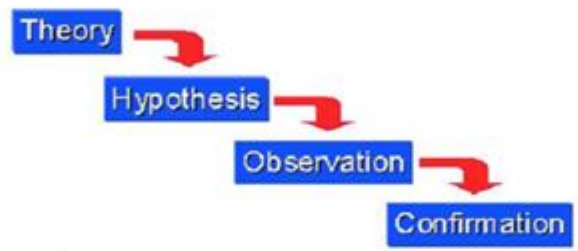
Success often comes from taking intuitive leaps based on meagre data

And finding lateral connections

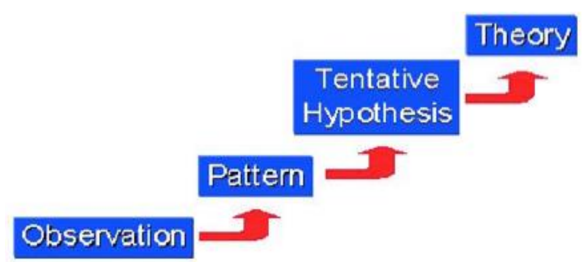
Deduction vs Induction?

Mathematics is a deductive science

Deduction



Exploration & Natural Sciences use induction



Induction

Induction in Exploration

A Qualitative Paradigm

Observation

↓

Pattern

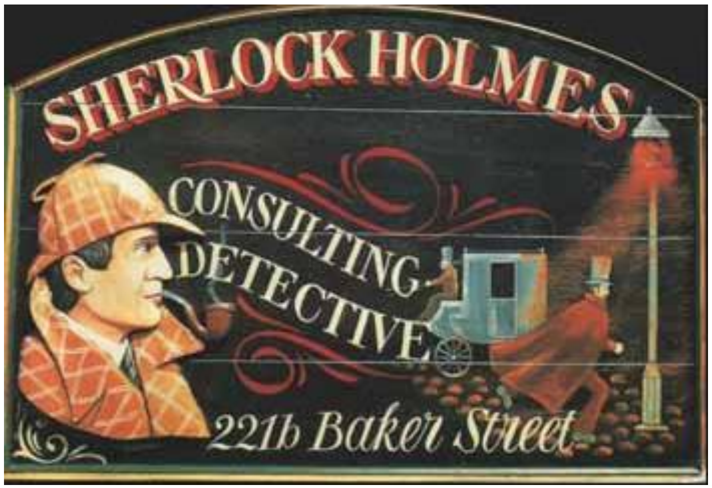
↓

Tentative Hypothesis

↓

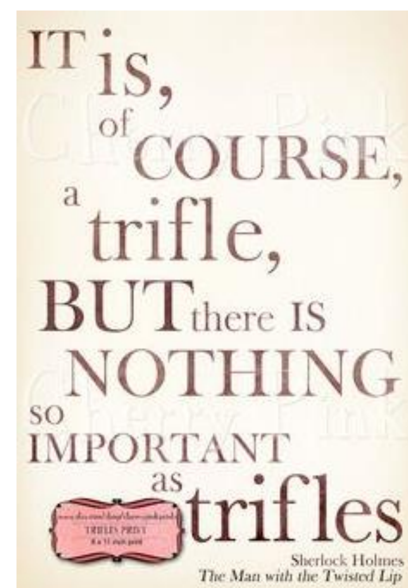
Discovery

An Important Observation



Absence of Evidence
is not
Evidence of Absence

Particularly in exploration
where
Evidence is often difficult to recognise
and
What is important may not appear so



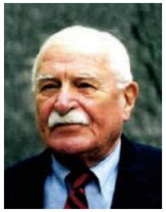
Why we get Paid ?

- **We get paid for only one reason:**

- ***To create wealth***  = 

- By discovering ore  to mine 

- ***<u>Not</u>*** *mineralisation, which does not have immediate value – it may in the future when re-evaluated, probably by another company* 



Sig Meussig's Canons

"IQ gets you there, but NQ finds it!"

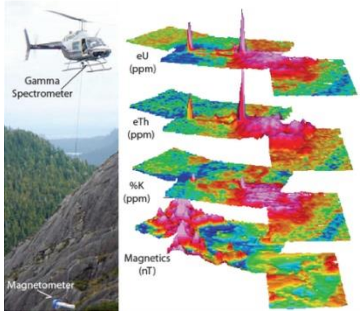
- Exploration is not a science
- **Go with the facts, forget the theory**
- Try for the definitive test
- **The odds are best in the shadow of the headframe**
- Save the agonising for mineralised trends
- **Look for ore, not mineralisation**
- **To find an ore body, you have to drill holes**
- **There needs to be room for the ore**
- Improve it or drop it
- Do not chase spurious anomalies
- Do not be preoccupied with explaining anomalies
- **Do not be preoccupied with pathfinders**
- **Do not be preoccupied with stereotyped concepts**
- **Do not be technology driven**
- Acquire first, study later
- Disregard competitor's previous actions
- Go for the jugular
- It's the drill hole, stupid!

DREGS 1993

How we Presently Explore

How is Exploration Conducted?

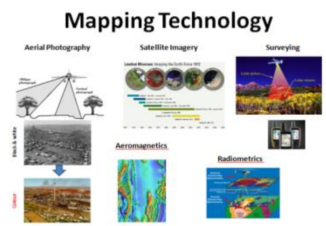
- The earliest explorers were prospectors who relied on observation for their discoveries
- **After the 1950s, prospecting became more sophisticated – modern exploration was born**

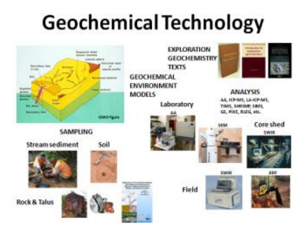


- Observation is still crucially important, but it is commonly supplemented by geochemistry and geophysics
- ***Exploration usually follows a process***

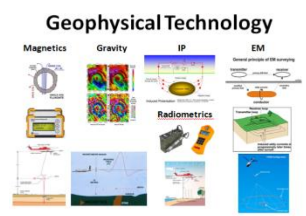
Exploration Toolkit

- **From the 1960s onwards, exploration was conducted using an expanding toolkit of techniques and technologies** – backed by increasing use of computing – **which included:**
  - Enhanced **mapping** capability

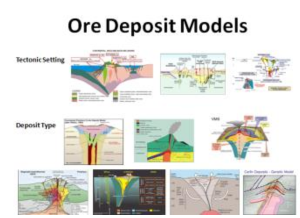




  - **Geochemical** technology



  - **Geophysical** technology

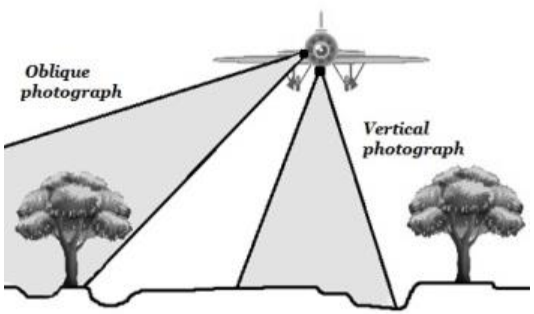


  - Ore deposit **models**

  - Improved **drilling** technology

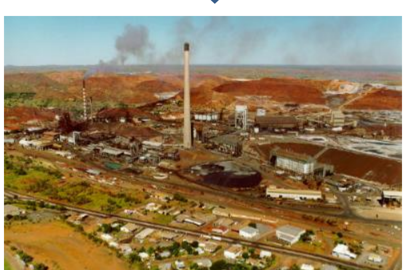
Mapping Technology

Aerial Photography

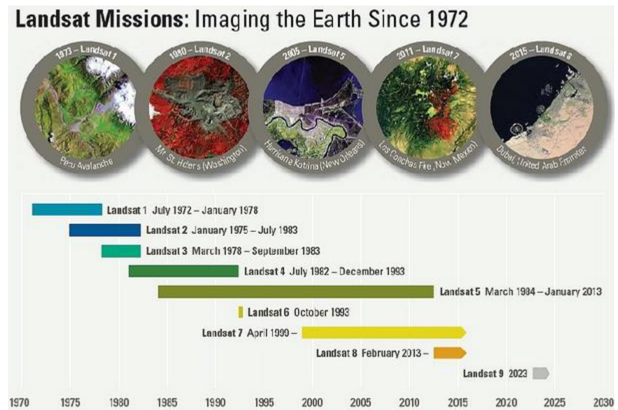


Black & white

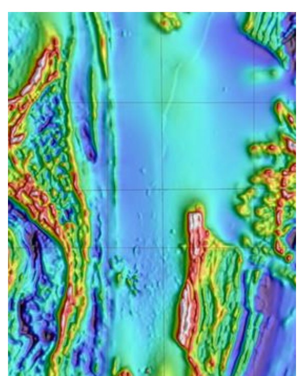
Colour



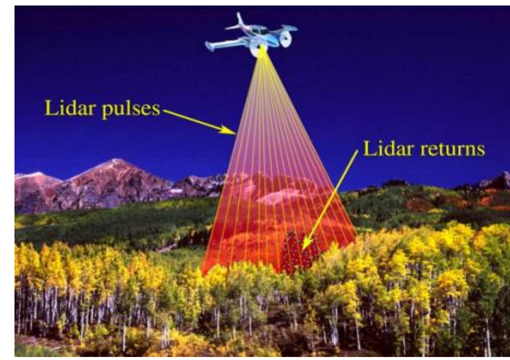
Satellite Imagery



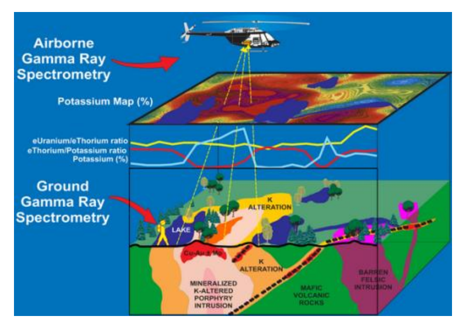
Aeromagnetics



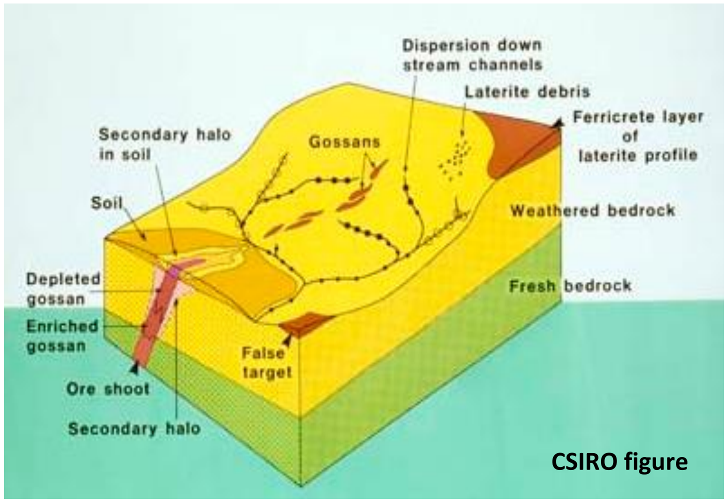
Surveying



Radiometrics

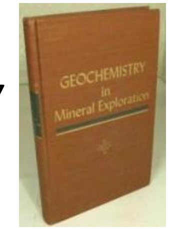


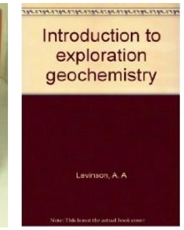
Geochemical Technology

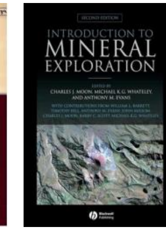


CSIRO figure

EXPLORATION GEOCHEMISTRY TEXTS







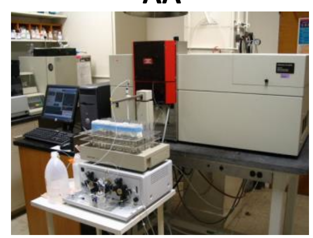
GEOCHEMICAL ENVIRONMENT MODELS

ANALYSIS

AA, ICP-MS, LA-ICP-MS, TIMS, SHRIMP, SIMS, GS, PIXE, BLEG, etc.

Laboratory

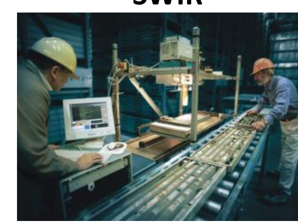
AA



SEM

Core shed

SWIR



Field

SWIR

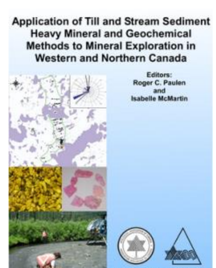
XRF

SAMPLING

Stream sediment

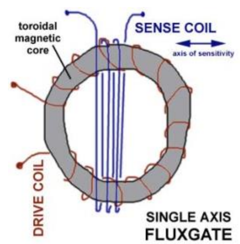
Soil

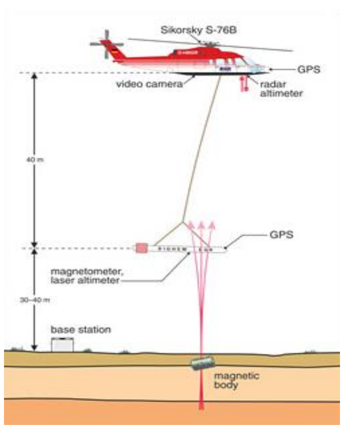
Rock & Talus



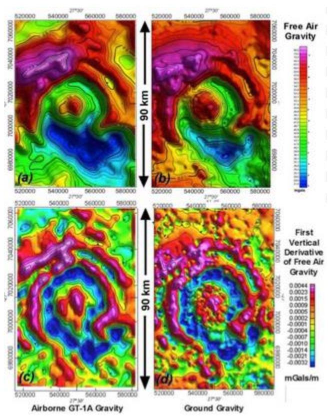
Geophysical Technology

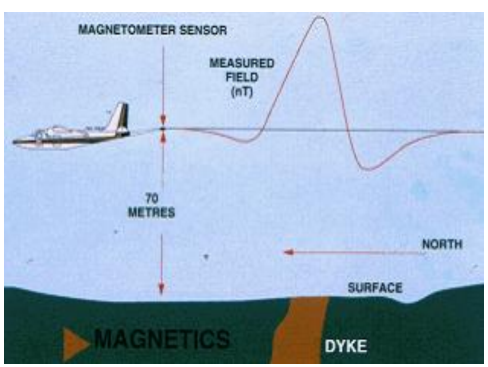
Magnetics



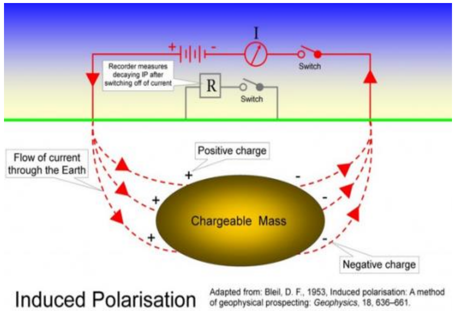


Gravity

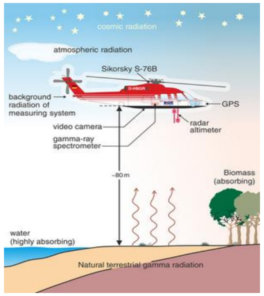




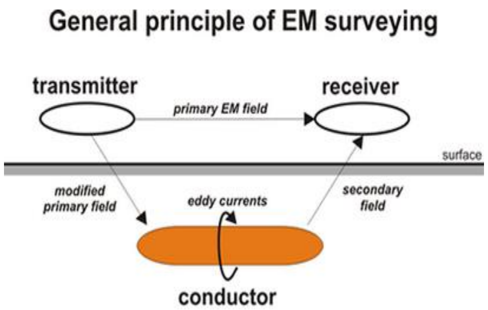
IP

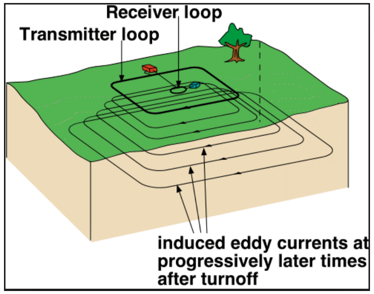


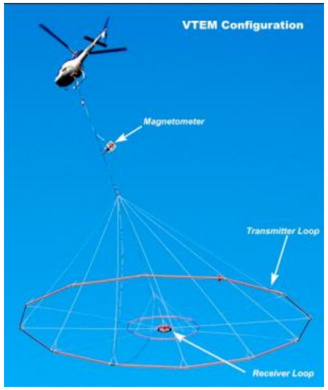
Radiometrics



EM

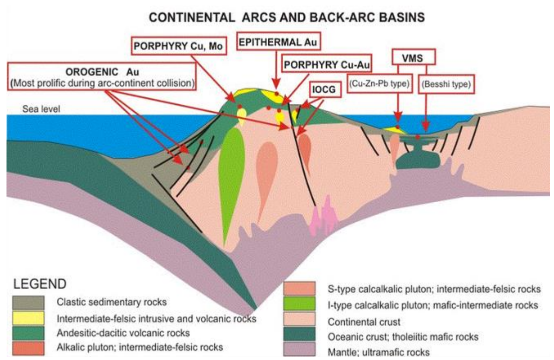


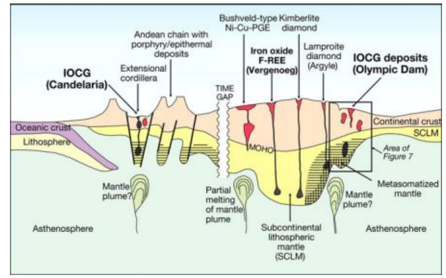


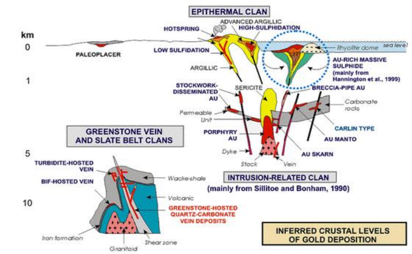


Ore Deposit Models

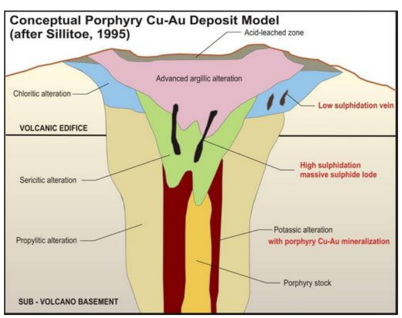
Tectonic Setting

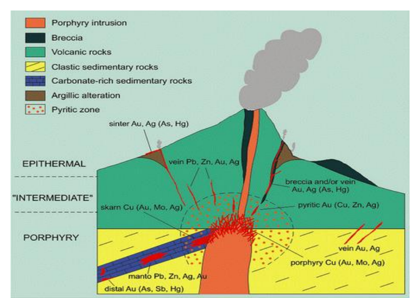


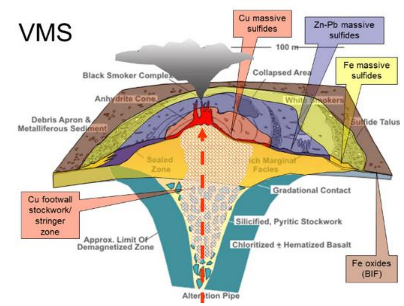


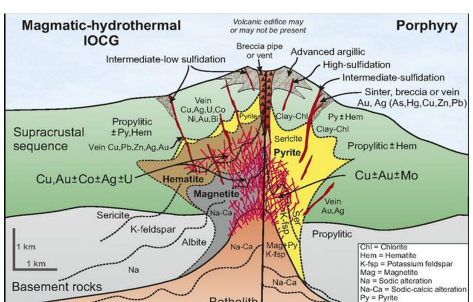


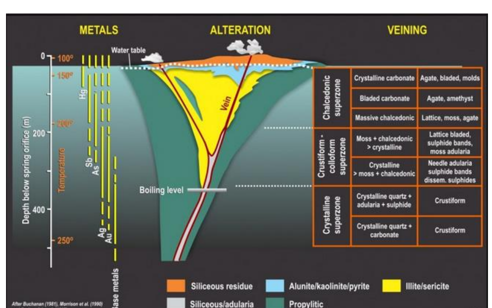
Deposit Type

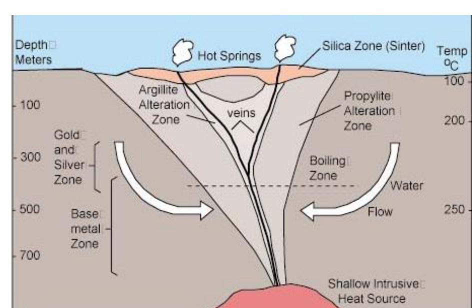


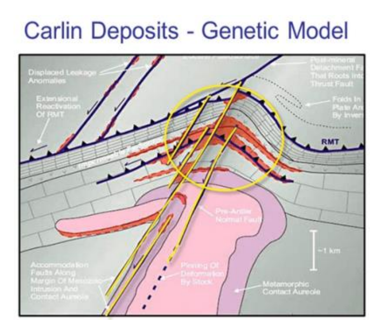






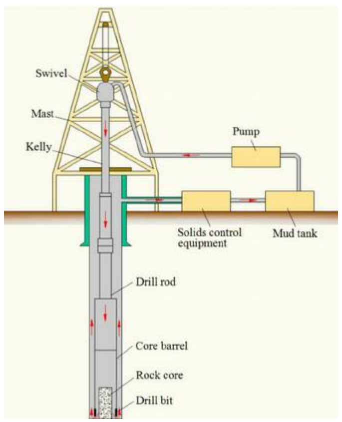






Drilling Technology

Diamond coring



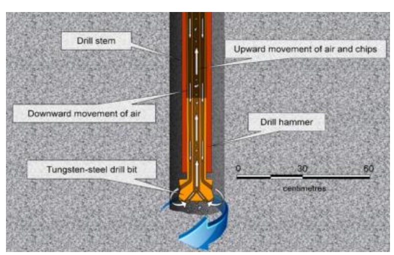
Improved Drill bits

Wireline

Multi-purpose

Rotary-percussion

Reverse-circulation



Improved Hammers

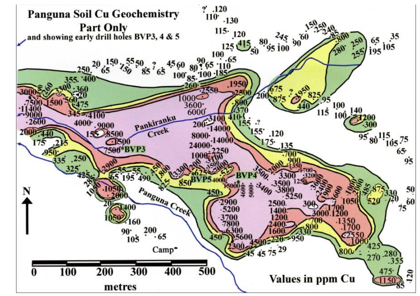
Geochemical Sampling

Aircore

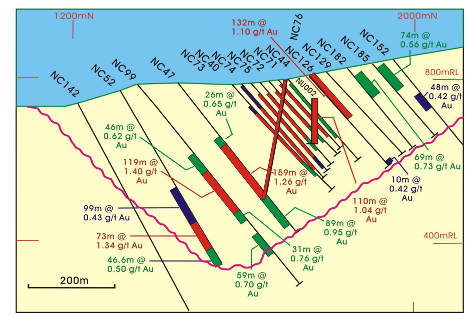
Auger

Ore Discovery Process

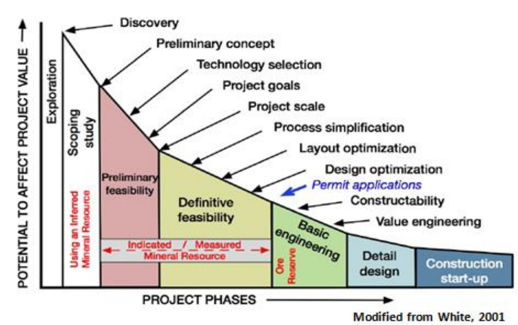
– **Detect an anomaly** related to a deposit containing a mineral resource, **and discover the deposit** by drilling a number of holes



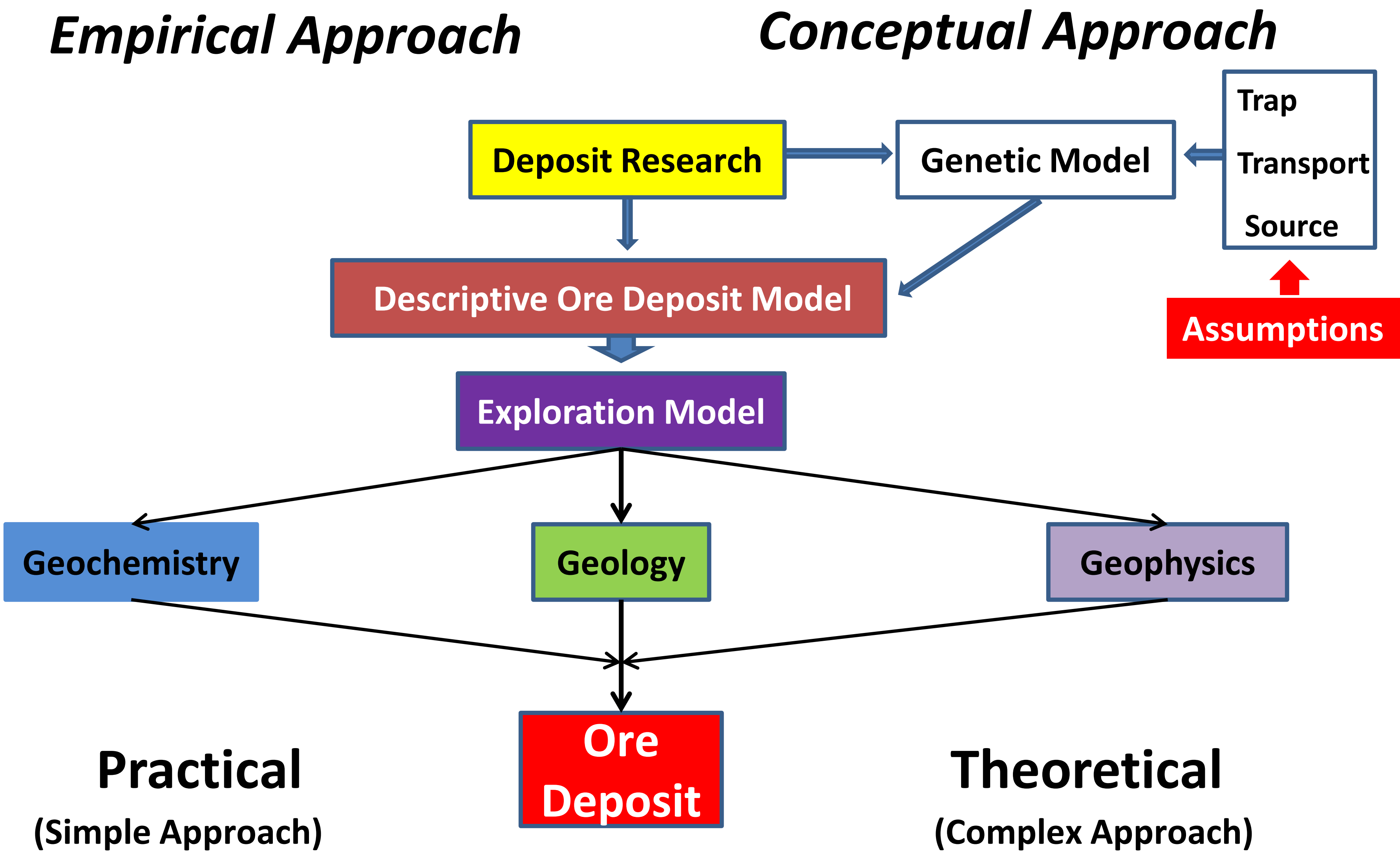
– **Identify & quantify** the mineral resource by drilling and sampling many more holes



– **Convert the mineral resource to ore** by conducting mining studies



Changing Approaches



Elements of Exploration Process

- **Exploration Objective**
- **Discovery Target**
- **Discovery Strategy for Success**
  - *Major versus junior company*
  - *Strategy & tactics*
  - *Chance of success*
  - *Risk*
  - *Mining method*
  - *Environmental & social*
- **Exploration Budget**
  - *Economic decisions in exploration*
  - *Discovery cost*
  - *Discovery challenges – why is discovery rarely achieved?*
- **Exploration Techniques**
  - *Principal Search Methods*
  - *Geology*
  - *Geochemistry*
  - *Geophysics*
- **Exploration Programme**
  - *Regional exploration*
  - *Prospect exploration*
  - *Discovery drilling*
  - *Deposit drilling*
- **Discovery Assessment**
  - *Resource delineation & definition*
  - *Resource estimation*
  - *Mining studies*

Only a few elements are addressed in this seminar

Exploration Objective

- **To discover an ore deposit, cost-effectively and efficiently**
- ***To do this we have to:***

  - *know what is ore*

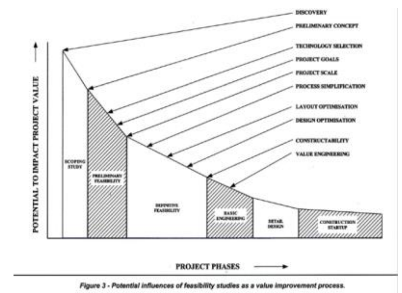
  - *determine how much it is sensible to spend in making a discovery*

  - *and, how much time we have in which to do this*

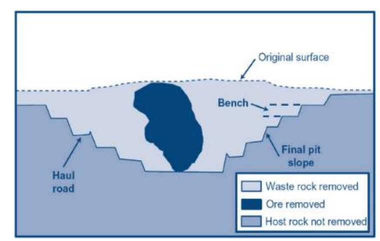
What is Ore?

- Ore is an economic term, **it is not mineralisation**

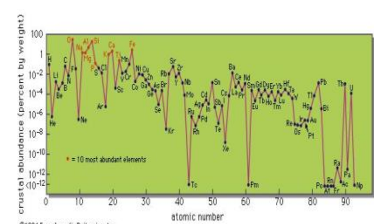
- *Mineralisation becomes ore by crossing mining, resource recovery, and economic hurdles*



- The grade at which mineralisation becomes ore and is mineable is the *cut-off* grade of a deposit



- *For Cu, Au & most metals this grade 100-1,000 times the crustal metal value*



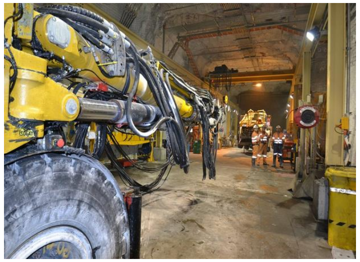
The Current Issue with Ore

- Ore is becoming more difficult to find
- It is trending to lower grade
- It is increasingly more deeply located

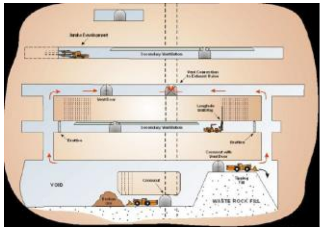
Mining Ore

- There are essentially two forms of mining: **open pit & underground**
- *Open pit mining is a matter of scale, how small or how large?*

- Underground mining is similarly one of scale and is of one of two types:

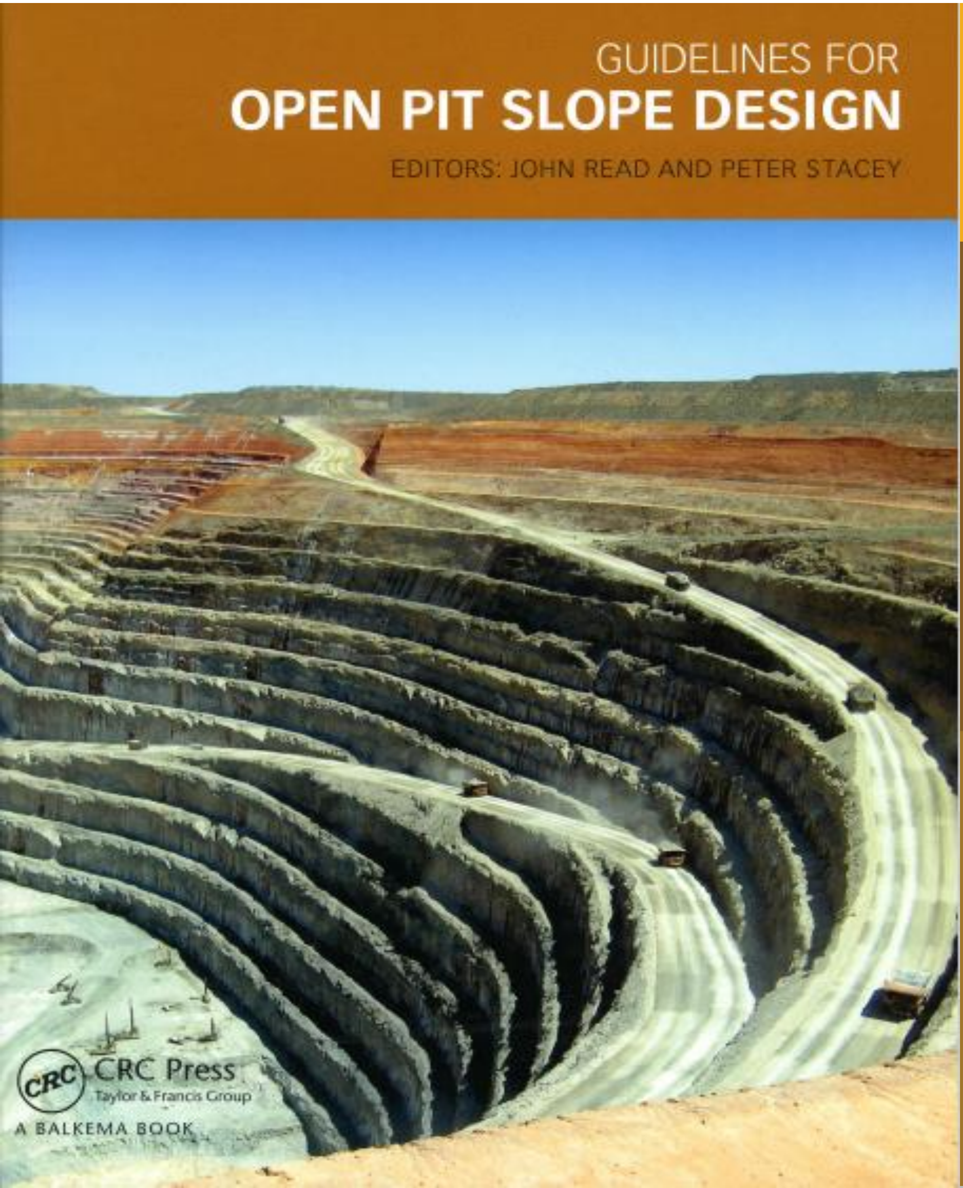


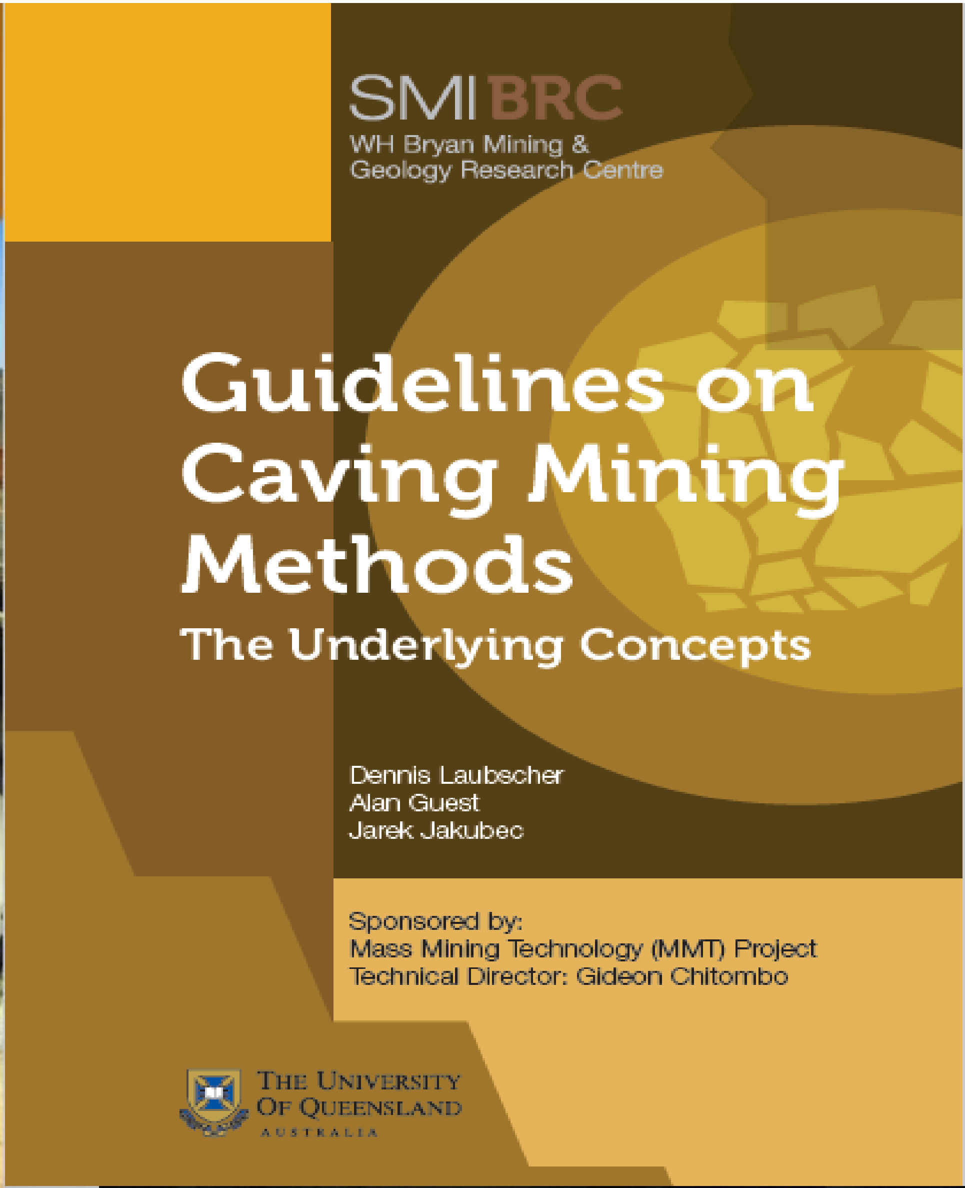
Narrow-body, mining many hundreds of tonnes per day



Mass mining, and mining many thousands of tonnes per day, up to 100,000 tpd

Two Mining Texts worth Consulting





Discovery Challenges?

- There are three important types:
- *Geology-related*
- *Mining-related*
- *Corporate and self-inflicted*

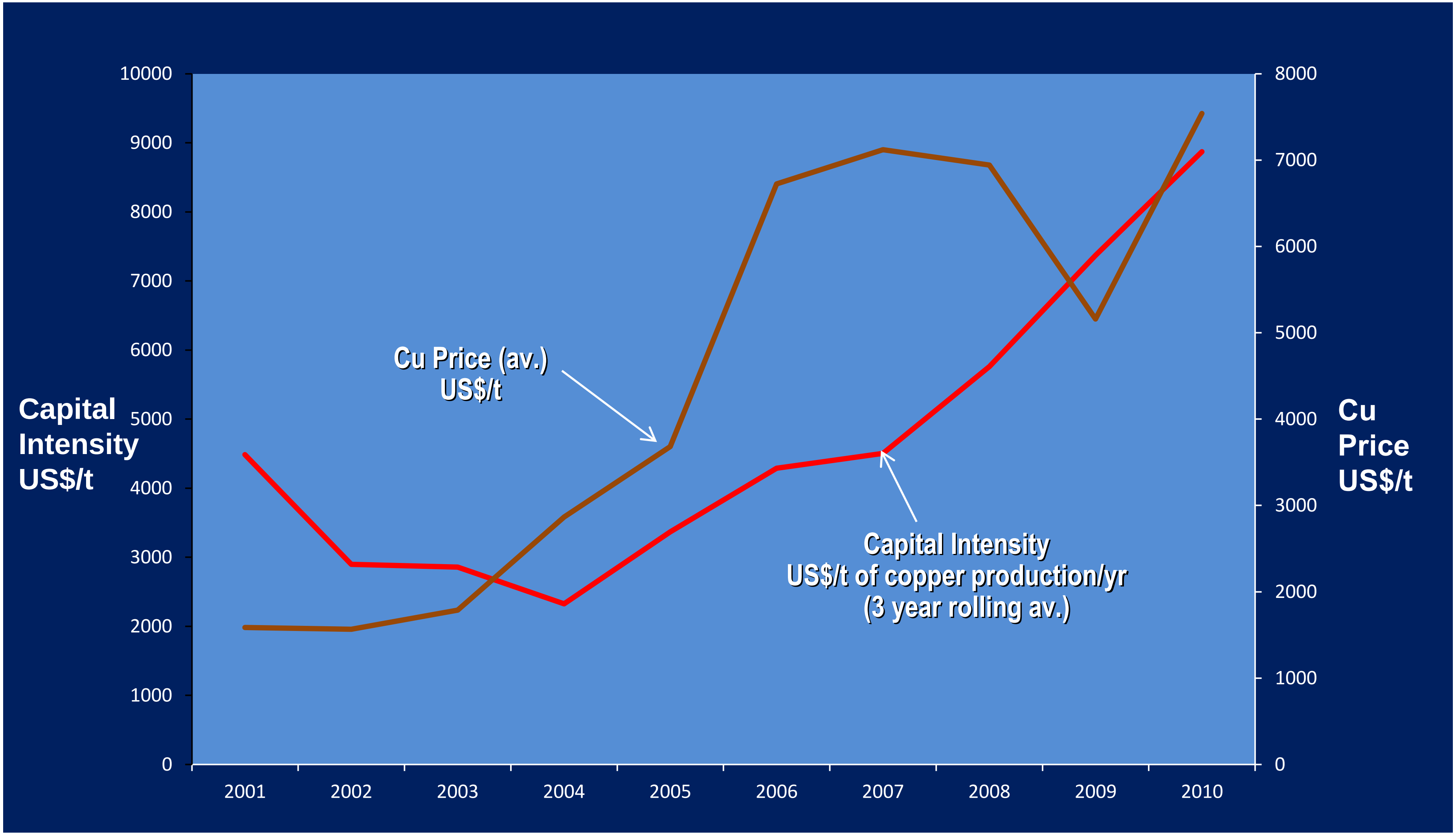
Crucial Geology Challenges?

- There are three obvious challenges:
- *The evidence of ore is absent or difficult to recognise*
- *Good 4D geology is unavailable*
- *Ore deposit 'models' are inadequate*

Crucial Mining Influences?

- There are three that affect ore:
- *Rapidly increasing Capital Intensity*
- *Developing need for by-product credit*
- *Use of NPV to determine mine size*

Capital Intensity vs Cu Price for New Cu Mines, 2001 - 2010



Discovery to Production?

- It is a lengthening time-frame
- It will impact future target ore grade
- For a >5 Moz Gold deposit it is >10 years
- For a >5 Mt Copper deposit it is >20 years

Corporate Challenges?

- There is a manic desire for “growth”
- The choice is discovery *or* acquisition
- Discovery is seen to be too high risk
- Acquisition favoured, discovery needed

Corporate Challenges Cont.

- Bewilderment with discovery process
- Discovery risk is not understood
- Desire to ‘manage’ discovery, not lead
- Need for a discovery ‘business’ model

The Crucial Challenges?

- Trying to predict 10 – 20 years ahead
- For target geometry, size & grade
- Given increasing mine capital intensity
- Poor 4D geology & ore deposit models
- And detracting corporate influences

Some Reflections

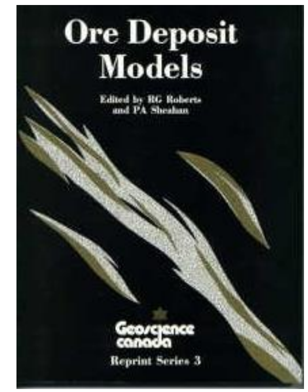
- Discovery is a business
- Science-based risk-taking is essential
- Risk needs to be reduced quickly
- Better ore deposit models are required

Reflections Continued

- Large deposits are easier to find
- Discovery is random and unscripted
- Correct exploration decisions are not always MBA material

Discovering Ore

- **We use geosciences and ore deposit models to discover mineralization to convert into ore:**
  - ***no two deposits are exactly the same*** *and the models should be used only as a guide,* ***not prescriptively***



- ***Discovery is usually achieved by:***
  - *making mostly surface geological observations*
  - *collecting mostly surface geochemical data*
  - *combining these data with geophysical data, where acquired*
  - *to formulate a hypothesis to test*
- **Hypothesis-driven science is then used:**
  - to ask the right questions
  - using creativity in determining which questions to ask
  - e.g., might these observations?
  - discover this?

Past Discoveries

- By comparison with future discoveries:
- *Past discoveries appear simple*
- *‘Easy’ to make in many respects*
- *Many cropped out or were near-surface*
- *But, geology was often very important*

A Prior Discovery Model

- "Where best to look – shadow of the headframe" – Sig. Muessig, Getty
- Why – "the closer to ore, the lower the risk" – Sig. Muessig, Getty
- It worked then and still does

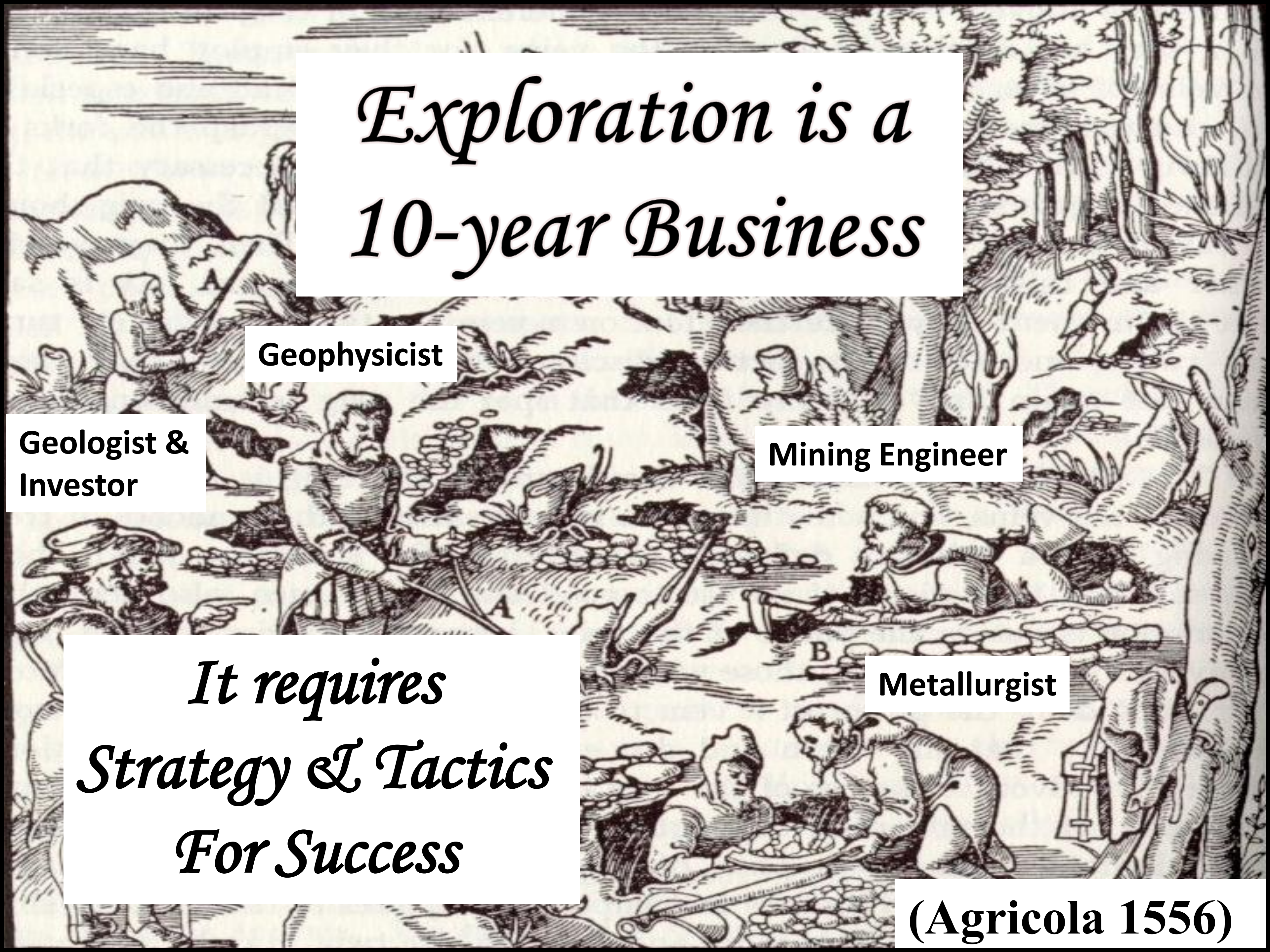
Conducting Exploration

- **There are really only two ways in which an ore deposit may be discovered**
- ***Casino Approach*** : *and rely completely on chance (luck) or good fortune*

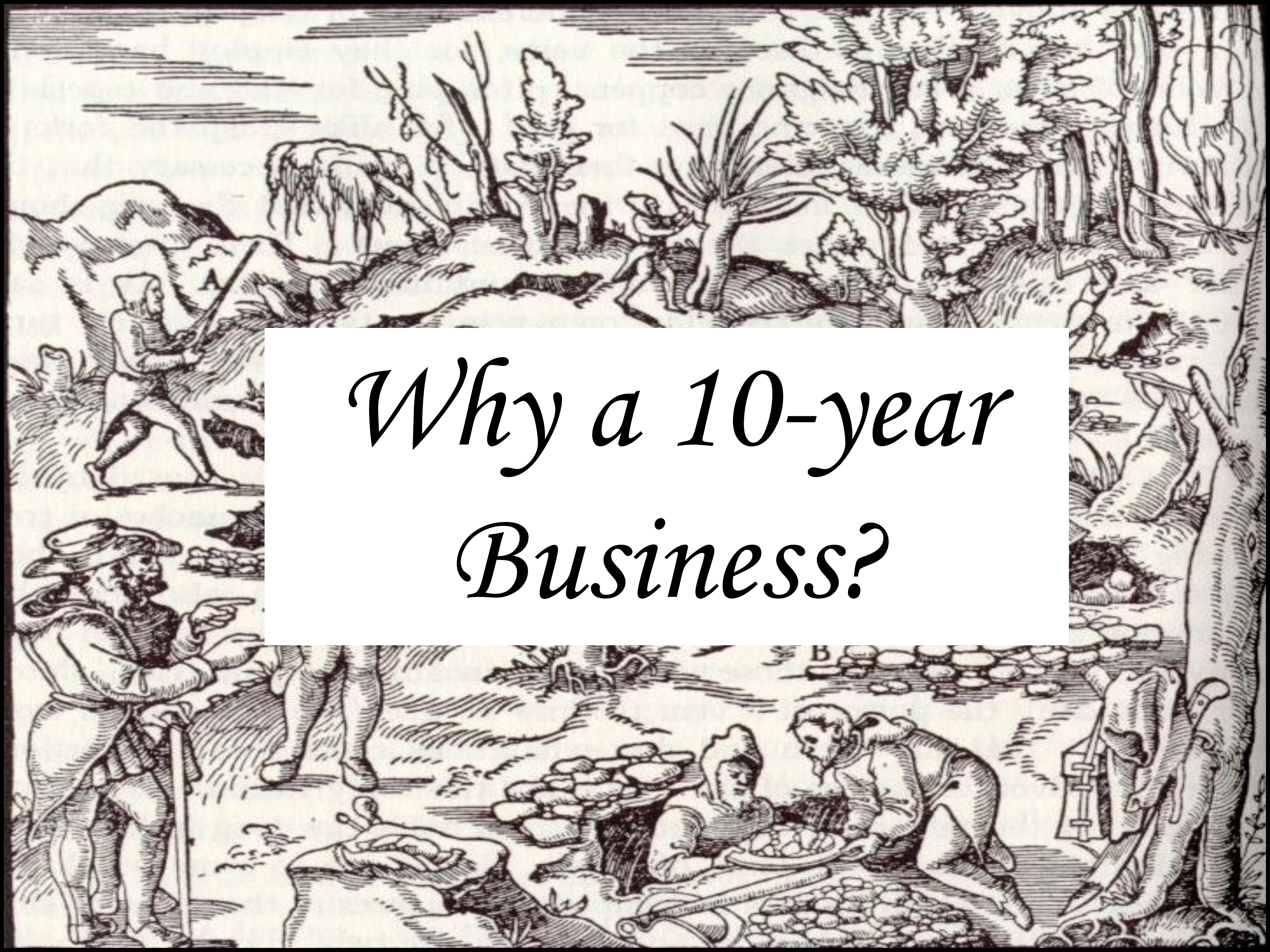
- ***Business Approach*** : *and try to manufacture a discovery, but not as in producing, e.g., a car*

- ***Casino Approach*** : is gambling & requires an endless supply of money, which usually isn't available
- ***Business Approach*** : uses science, economics & money and has more chance of success than does the casino approach

Exploration is a 10-year Business



It requires Strategy & Tactics For Success

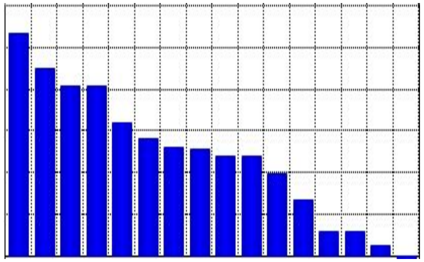


Why a 10-year Business?

10-year Reasons

- *Any shorter period is under-estimating the challenge and the difficulty*

- Success will have a different meaning depending on the size of the exploring company



- *Success will have a different dimension for a major company to what it will have for a junior explorer*

Exploration as a Business

- Exploration may succeed if there is a good business model

- *The principal challenge is managing risk*

- The major risk is exploring in the wrong place

- ***Area selection is the crucial decision***

Area Selection

- "It is very difficult to find a black cat in a dark room" **Old saying**
- Even worse if it is Schrödinger's cat
- ***The difficulty in exploration is not only the state of the "cat", but whether or not it is there!***

Selecting the Right Area?

How to manage the risk & uncertainty?

The lowest risk approach is to explore where additional mineralisation may exist:

- close to an old mine
- in a known mining district, or
- where potential is indicated geologically

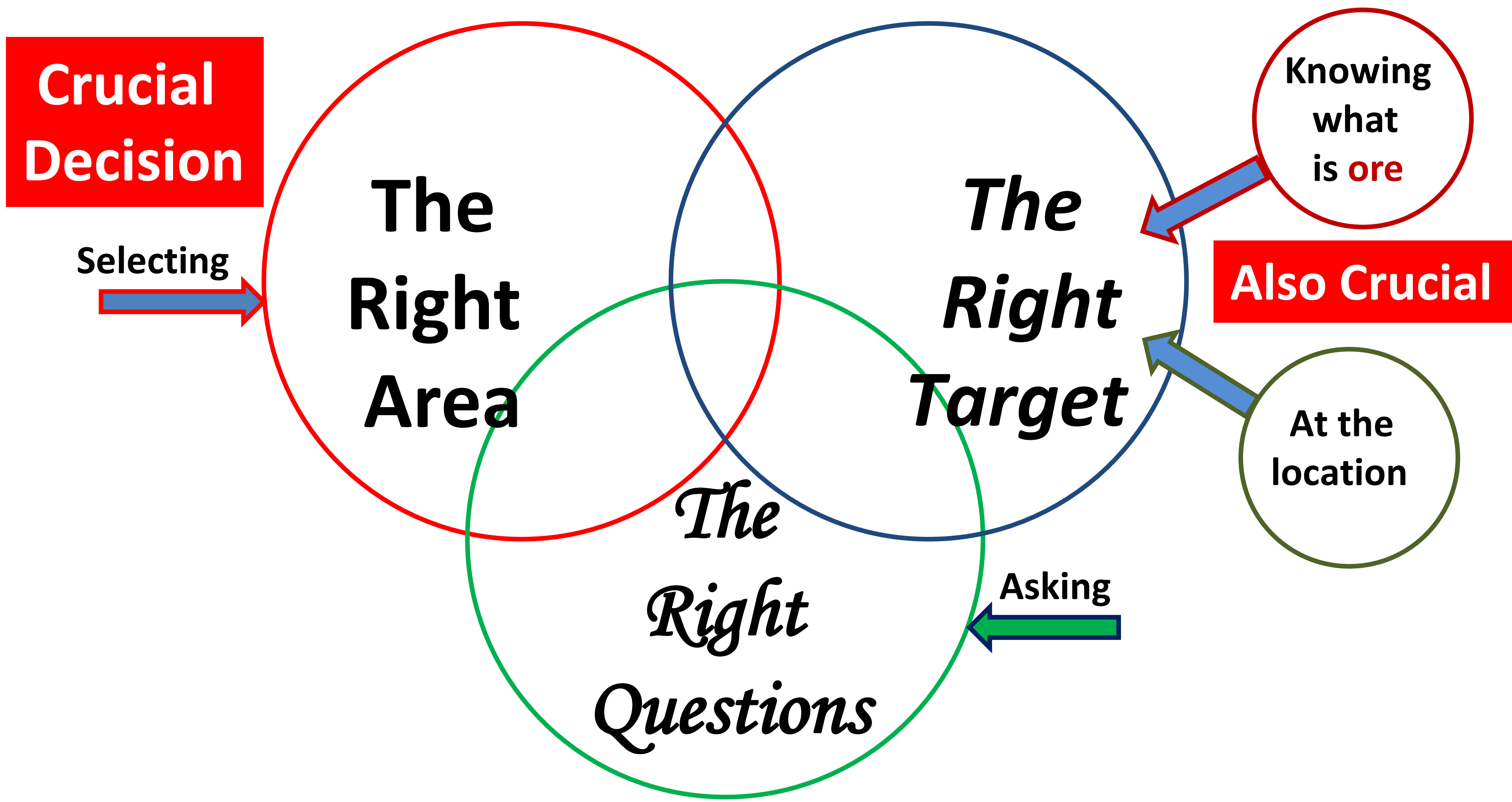
The highest risk is where there is no evidence of mineralisation

Uncertainty can only be resolved by drilling

Discovery Target

- Until well into the 2nd half of the 20th century companies explored without a defined target
- ***Until the mid-1970s, it made sense to simply examine an area previously explored only by prospectors, or not at all***
- Companies would explore an area for a range of resources, depending on:
  - *the geology of the area and known mineralisation*
  - *previous discoveries by prospectors*
  - *prevailing ideas of the area's resource potential*

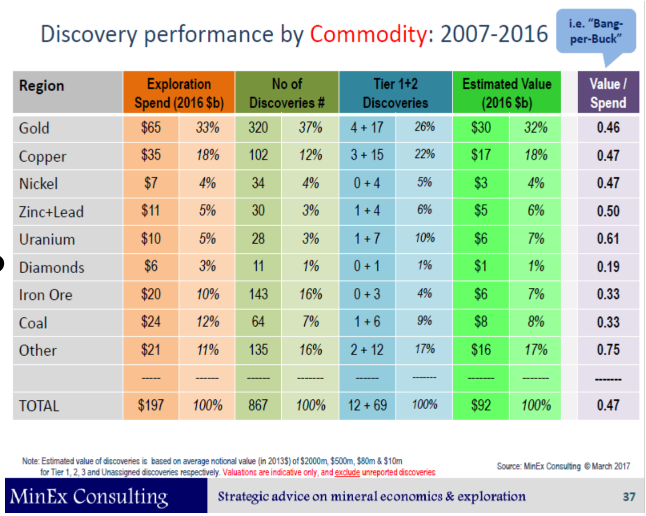
Present Exploration Model



The Present Discovery Model

- Focused mostly on near-surface discoveries, sometimes recognisable in outcrop

- *That is, ore bodies that can be mined by open pit*
- **Historically, the model has been very successful**
- However, its success rate has fallen substantially in recent years
- ***It is not an economically sustainable model for the majority of required future discoveries, in my opinion***



Discovery performance by Commodity: 2007-2016

i.e. "Bang-per-Buck"

Region	Exploration Spend (2016 $b)		No of Discoveries #		Tier 1+2 Discoveries		Estimated Value (2016 $b)		Value / Spend
Gold	$65	*33%*	320	*37%*	4 + 17	*26%*	$30	*32%*	**0.46**
Copper	$35	*18%*	102	*12%*	3 + 15	*22%*	$17	*18%*	**0.47**
Nickel	$7	*4%*	34	*4%*	0 + 4	*5%*	$3	*4%*	**0.47**
Zinc+Lead	$11	*5%*	30	*3%*	1 + 4	*6%*	$5	*6%*	**0.50**
Uranium	$10	*5%*	28	*3%*	1 + 7	*10%*	$6	*7%*	**0.61**
Diamonds	$6	*3%*	11	*1%*	0 + 1	*1%*	$1	*1%*	**0.19**
Iron Ore	$20	*10%*	143	*16%*	0 + 3	*4%*	$6	*7%*	**0.33**
Coal	$24	*12%*	64	*7%*	1 + 6	*9%*	$8	*8%*	**0.33**
Other	$21	*11%*	135	*16%*	2 + 12	*17%*	$16	*17%*	**0.75**
	-----	------	------	-------	------	-------	-------	-------	**-------**
TOTAL	$197	*100%*	867	*100%*	12 + 69	*100%*	$92	*100%*	**0.47**

Note: Estimated value of discoveries is based on average notional value (in 2013$) of $2000m, $500m, $80m & $10m for Tier 1, 2, 3 and Unassigned discoveries respectively. Valuations are indicative only, and exclude unreported discoveries

Source: MinEx Consulting © March 2017

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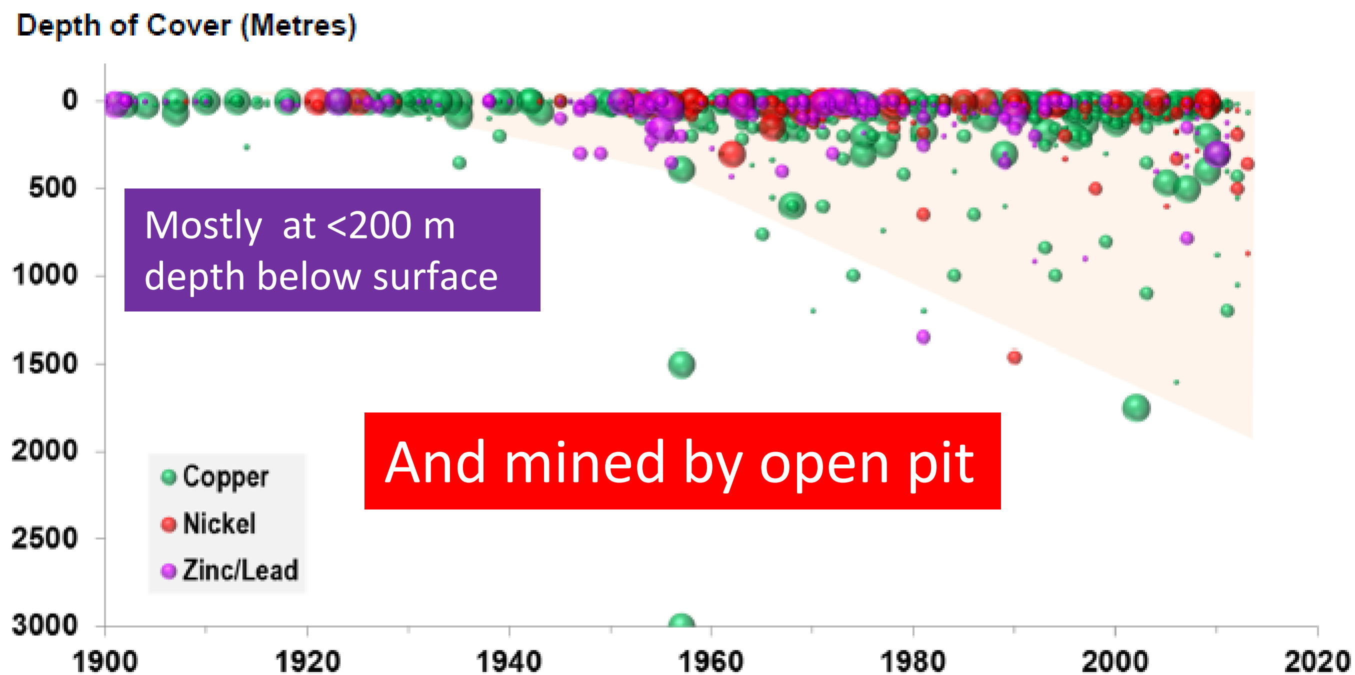
Model Reflected by Discoveries

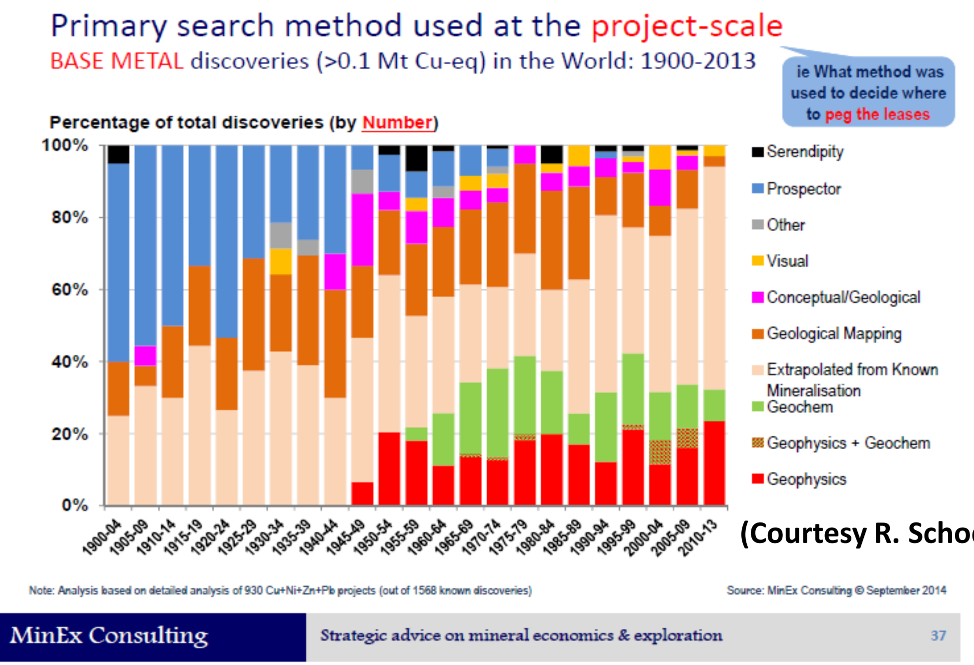
World base metal discoveries 1900 – 2013

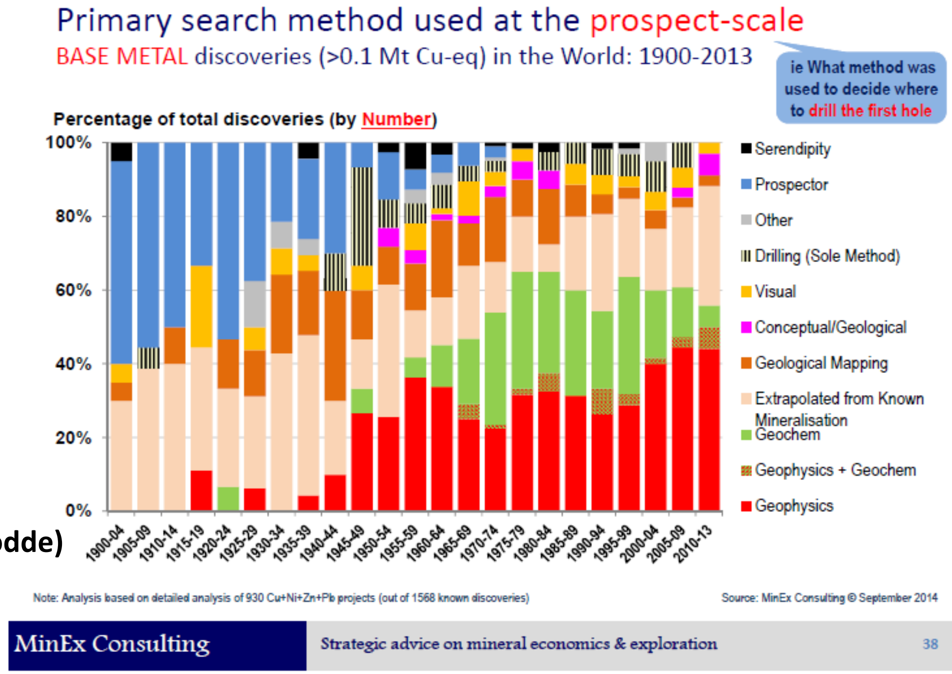


N = 1034
Note: Size of bubble refers to "Moderate", "Major" and "Giant"-sized deposits.
Excludes Nickel Laterite deposits

(Courtesy Richard Schodde)

Use of Search Technology





(Courtesy R. Schodde)

- Geochemistry or geophysics was used in 20 – 40 % of cases to **acquire an exploration project** after 1945

- Geochemistry or geophysics was used 30 – 60 % of time to **select 1st drill site** after 1945
- **DRILLING STILL REMAINS THE MAIN METHOD OF DISCOVERY, HOWEVER**

Three Discovery Examples

Panguna, PNG 1964

Porphyry Cu-Au deposit

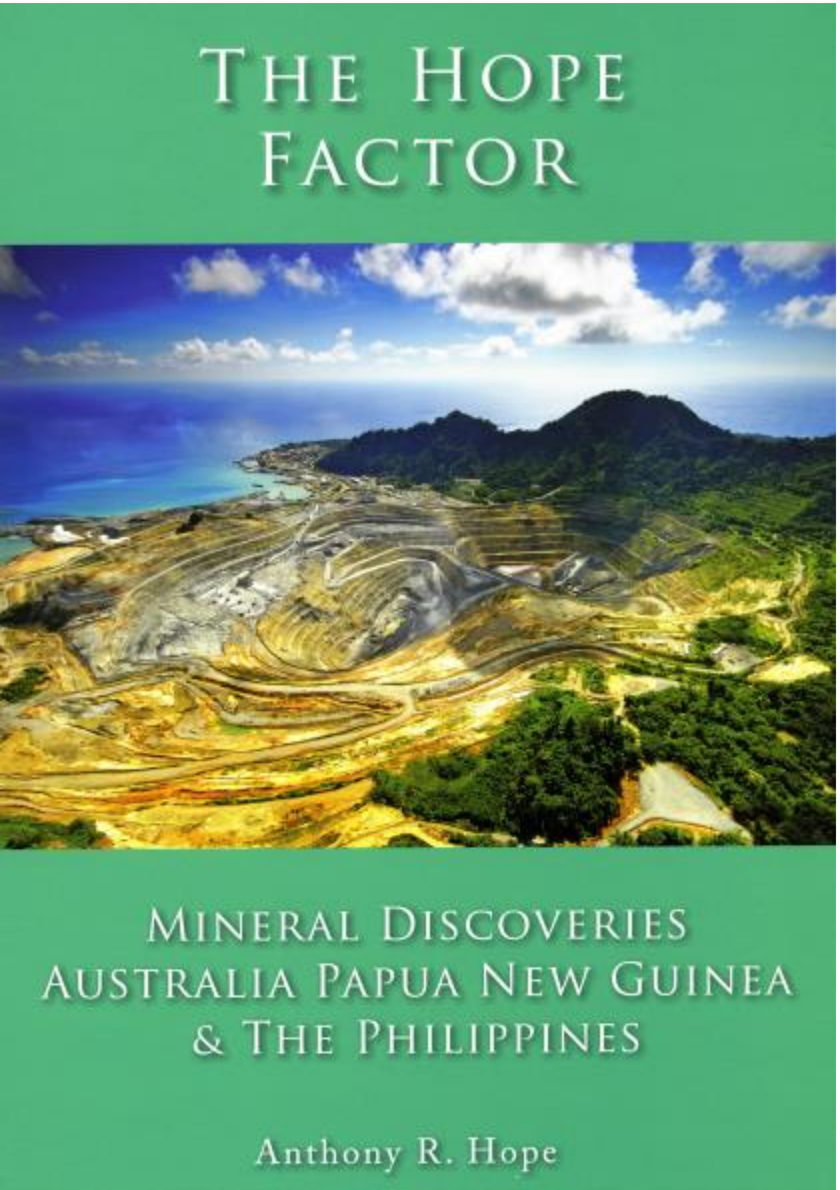
Ok Tedi, PNG 1969

Porphyry Cu-Au deposit

Cadia Hill, Australia 1992

Porphyry Au-Cu deposit

Reference for Panguna & Ok Tedi



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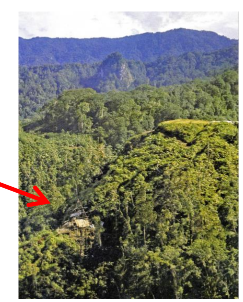
Panguna Deposit, PNG

Lead-up to Panguna Discovery

- In early 1961, Consolidated Zinc (precursor to CRA) began a search for porphyry Cu deposits in Eastern Queensland, Australia using stream geochemistry, led by Ken Phillips

- *In March 1963, Phillips visited the Atlas porphyry Cu mine in Cebu in the Philippines, on holiday*
- The visit convinced him that he should re-focus the search onto younger rocks in Papua New Guinea

- *Phillips was advised to read a 1936 report on the Kupei area on Bougainville Island, which included description of mineralization similar to what he had seen at Atlas*
- Field work in the Kupei-Panguna area started in April 1964; the discovery hole was drilled in December 1964

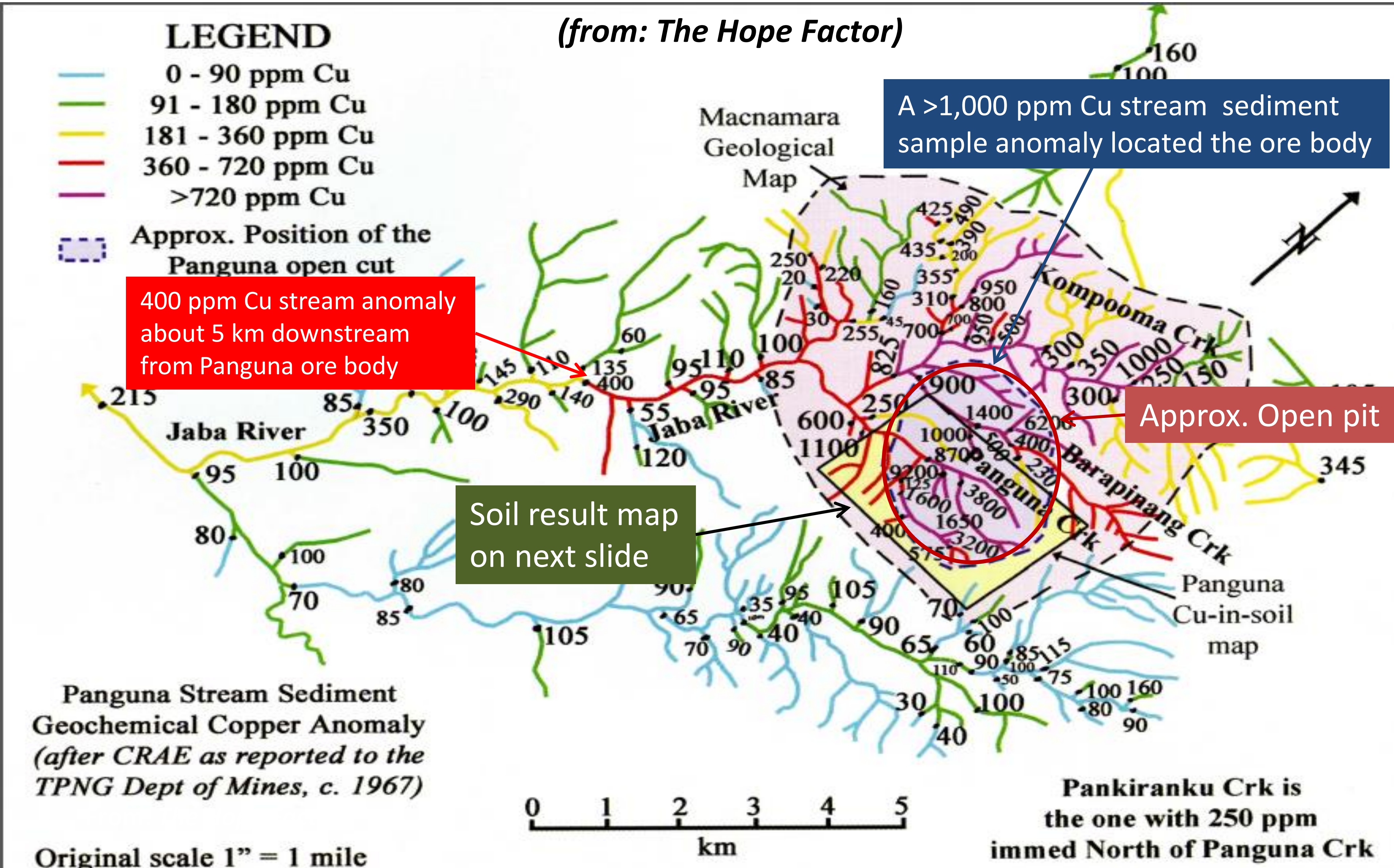


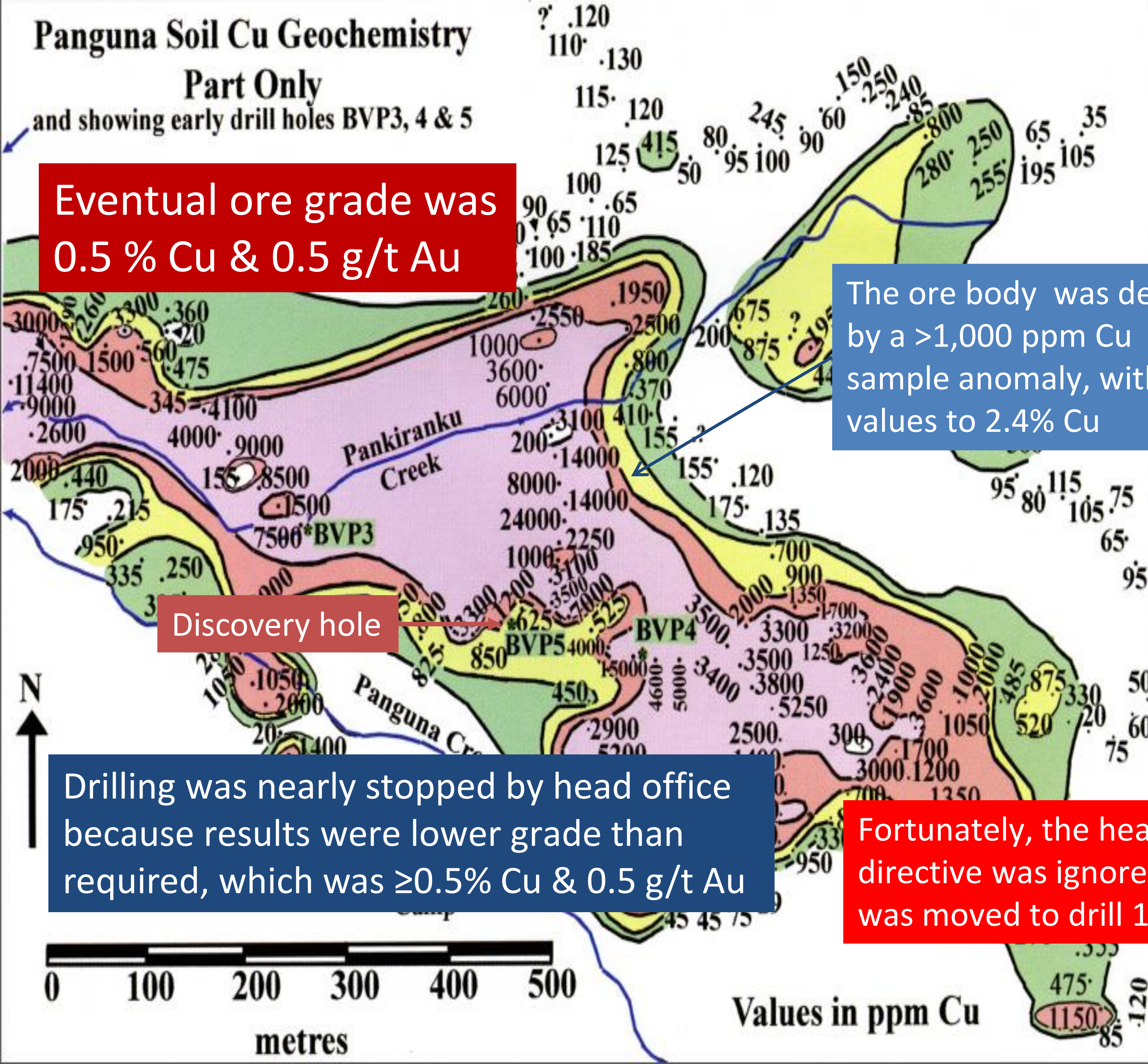
Extracted from Hope Factor

Panguna PNG

(Courtesy Tony

Stream Sediment Cu Geochemistry

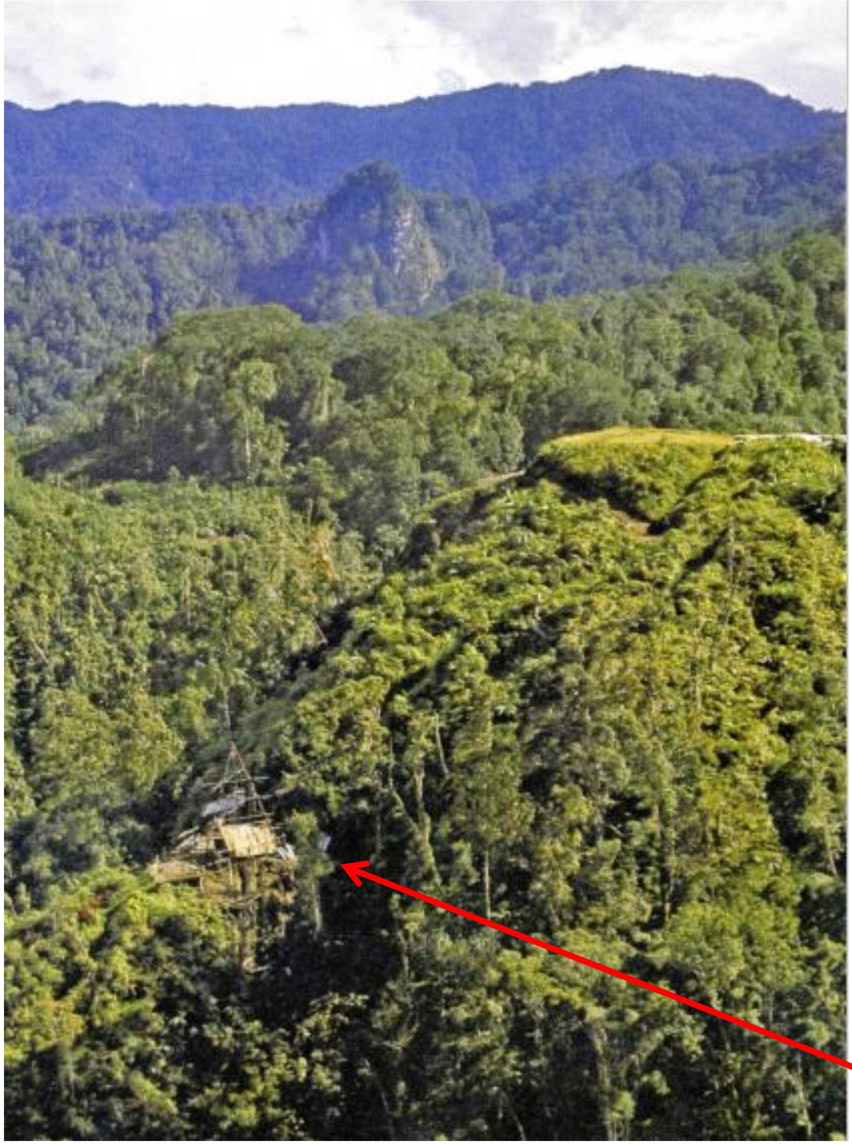


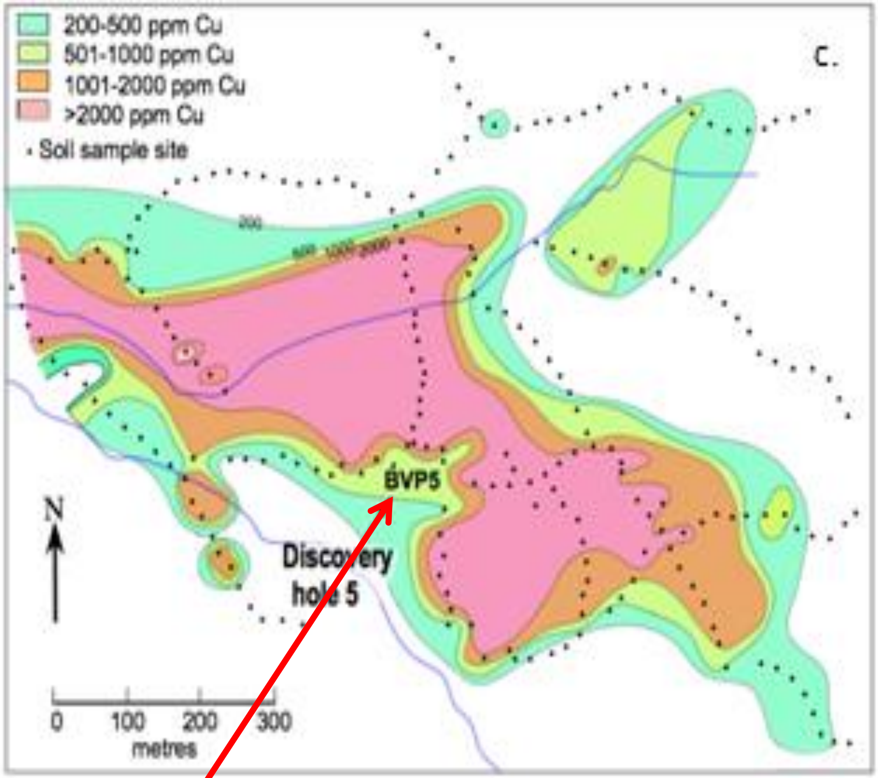


Soil Anomaly

(The Hope Factor)

Discovery hole Panguna





Initial drilling used a very small rig which recovered E-size core to a depth of~70 m

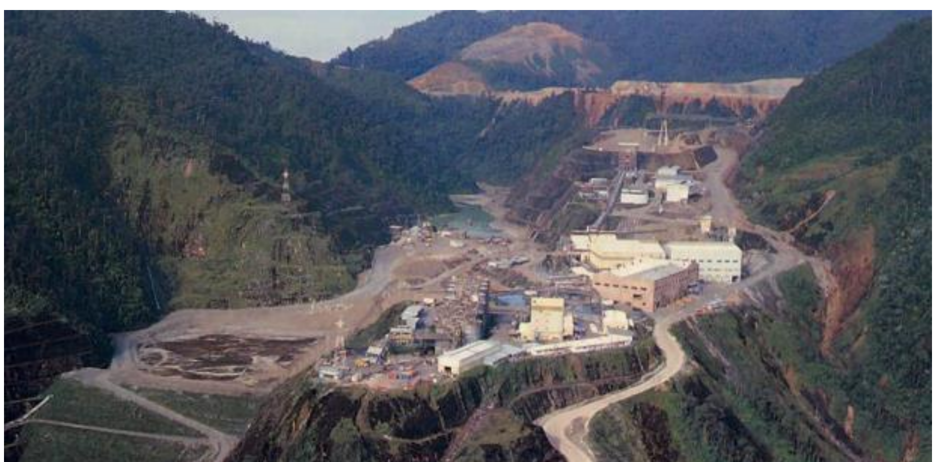
Hole 5 intersected strong oxide Cu and 6 m @ >1.0% Cu in sulphides

Likely reasons for discovery?

- Decision to explore for porphyry Cu deposits in eastern Australia using stream geochemistry
- Ken Phillips' visit to Atlas deposit in Philippines
- His reading of 1936 report on Kupei area in PNG and decision to redirect search to PNG
- Stream sediment and soil geochemistry
- **Ignoring directive to stop drilling**

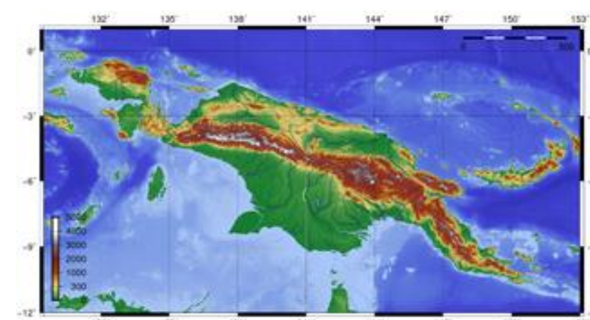
(My opinion)

Ok Tedi Deposit, PNG



Lead-up to Discovery

- European contact with local (Min) people in this western part of Papua New Guinea first occurred in 1963
- *Kennecott Copper Corporation began exploring the region in June 1968, five years later*
- The company had been exploring for porphyry Cu deposits in the Eastern Highlands of PNG since 1965
- *The Kennecott exploration area was on trend from the Erstsberg Cu-Au skarn deposit, re-discovered in 1960 to the west, in Irian Jaya*
- Stream geochemistry was used by Kennecott to explore in an area of exceptionally high daily rainfall (300 inches)



Extracted from Hope Factor

Ok Tedi

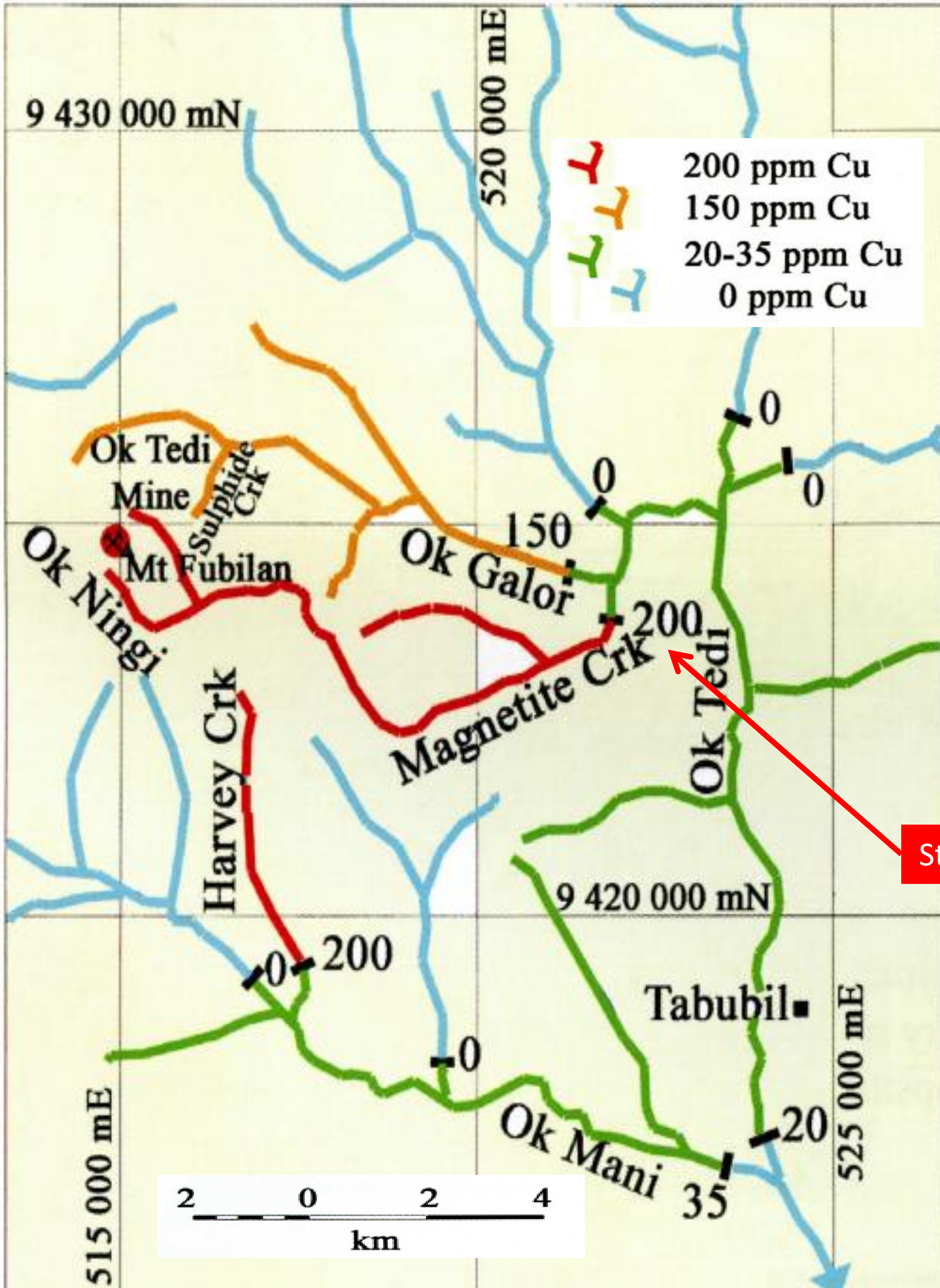
(Mt Fubilan)

(from The Hope Factor)

Vegetation Anomaly

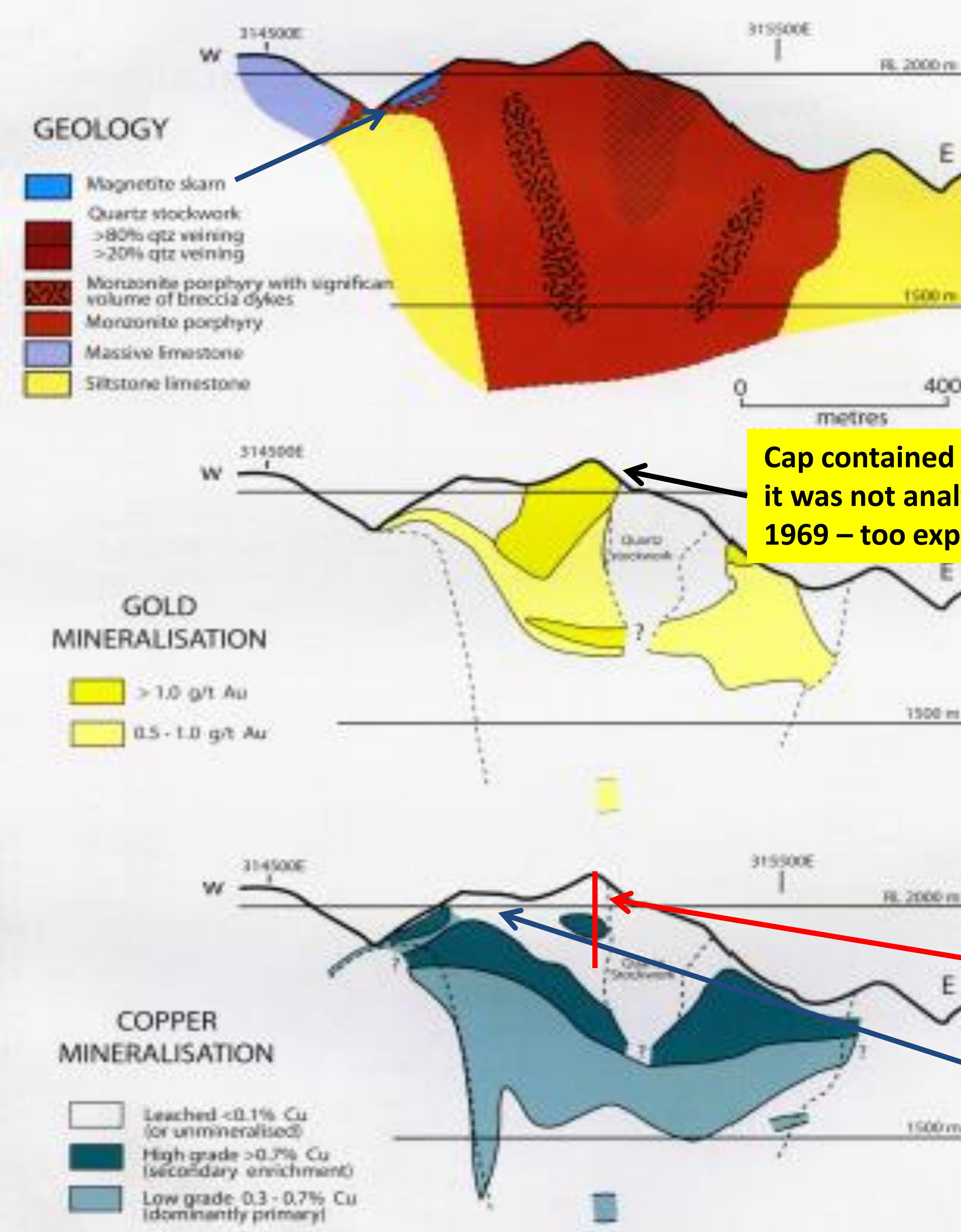
(from the Hope Factor)

Ok Tedi
Steam Geochemistry



Stream Cu anomaly detected Cu skarn mineralization

Ok Tedi Geology Mineralization



Cap contained Au, but it was not analyzed in 1969 – too expensive

Discovery hole was drilled through cap

Porphyry deposit had a Cu-barren leached cap

Likely reasons for discovery?

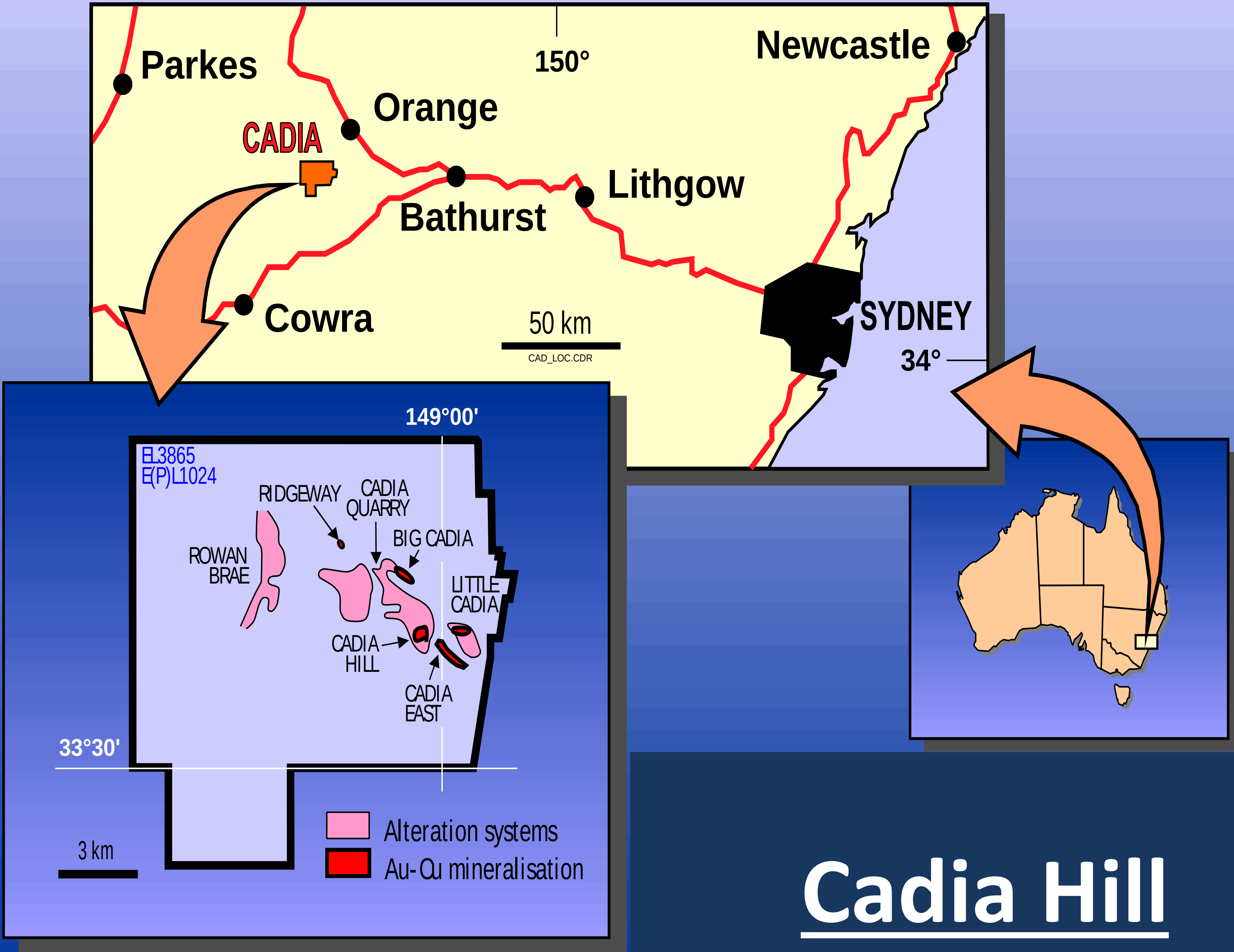
- Stream sediment geochemistry
- Ken Phillips became exploration manager in 1969
- **His decision to drill through leached cap**
- **It is not uncommon for a geologist to be involved with several discoveries**

(My opinion)

Cadia Hill Deposit, Australia

Lead-up to Discovery

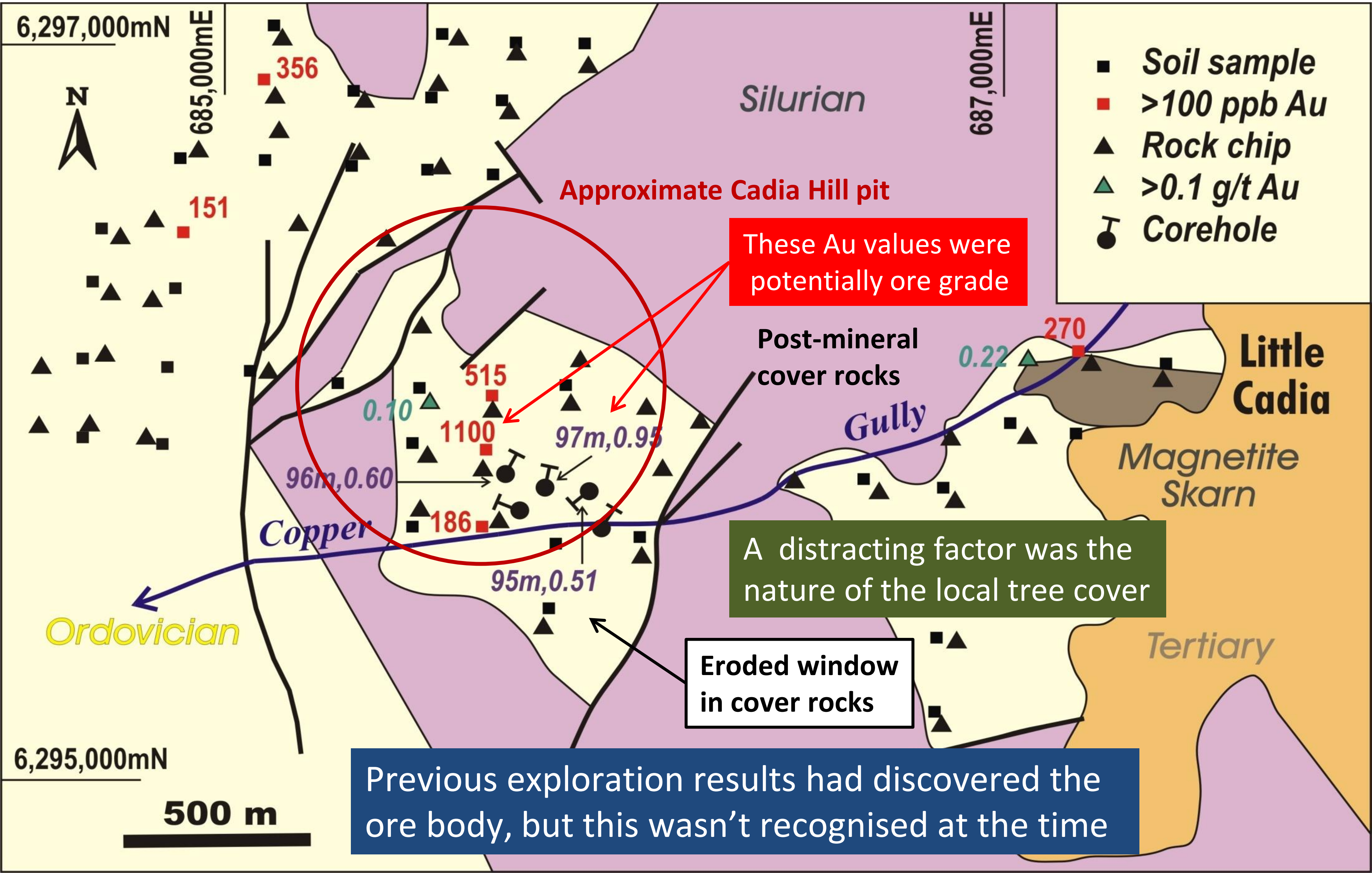
- Cu was discovered at Cadia in 1851 and mining of Cu oxide and oxidized magnetite deposits continued, intermittently, until the end of WW2
- *Several companies explored the Cadia district for Cu during the 1950s and 1960s; Cadia Hill was first explored (by Pacific Copper) in 1968*
- Pacific Copper outlined two small Cu-Au deposits: at Big Cadia (30 Mt @ 0.5% Cu & 0.4 g/t Au) and Little Cadia (8 Mt @ 0.4% Cu & 0.4 g/t Au*)*
- *And drilled four shallow core holes on the eastern side of Cadia Hill, producing a best interval of 97 m @ 0.95 g/t Au*
- In 1985, Homestake Mining recorded 1.1 g/t Au in a soil sample from Cadia Hill and drilled additional shallow holes on the eastern side
- ***Newcrest acquired the Cadia district in March 1991 to search for oxidized Au ore as mill-feed for its nearby Browns Creek Mine***



Parkes
CADIA
Orange
150°
Newcastle
Lithgow
Bathurst
Cowra
50 km
CAD_LOC.CDR
SYDNEY
34°
149°00'
EL3865
E(P)L1024
RIDGEWAY
CADIA QUARRY
ROWAN BRAE
BIG CADIA
LITTLE CADIA
CADIA HILL
CADIA EAST
33°30'
3 km
Alteration systems
Au-Cu mineralisation

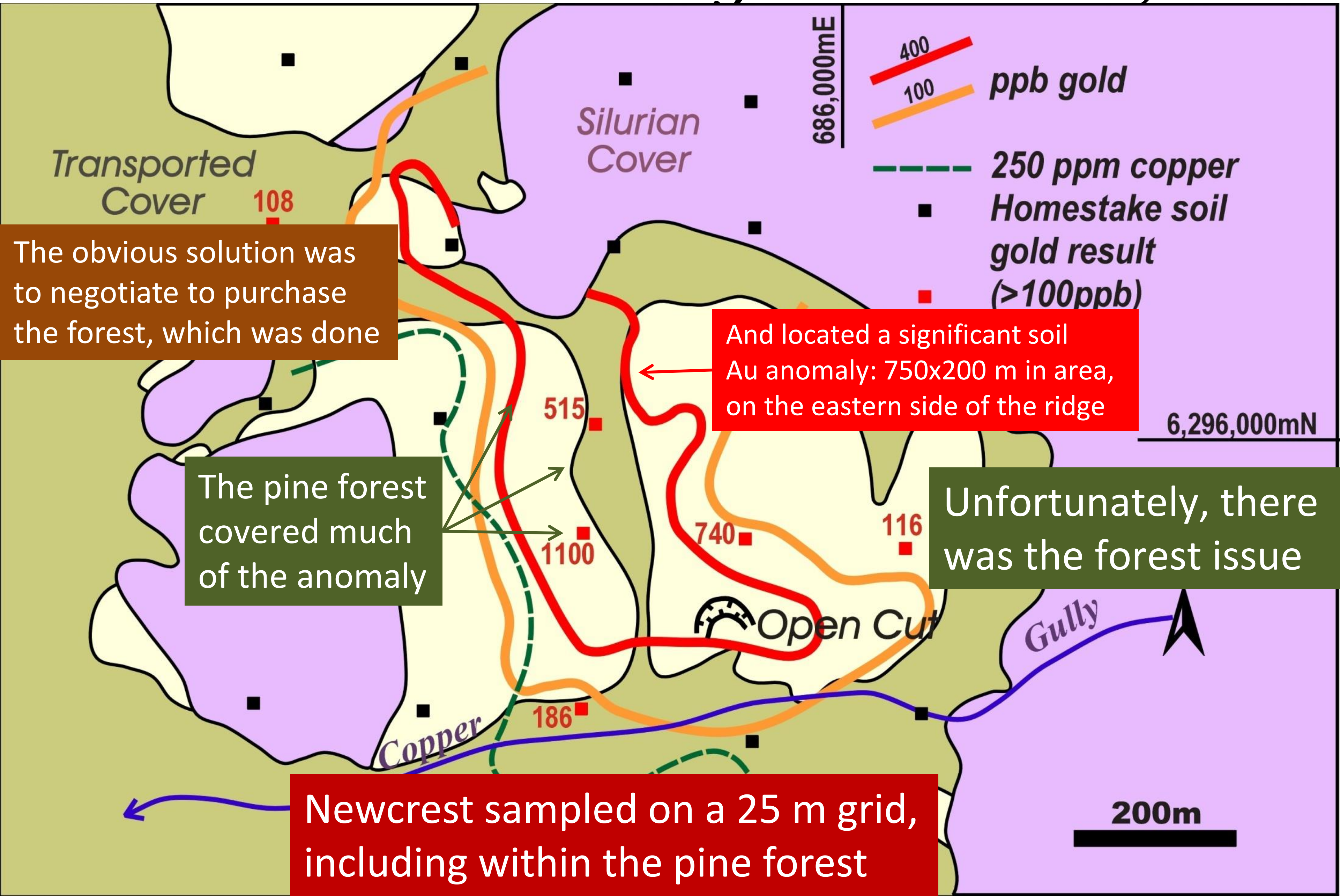
Cadia Hill

Pre-Newcrest Exploration Results



Western Cadia Hill – Pre-discovery

Newcrest Soil Geochemistry



The obvious solution was to negotiate to purchase the forest, which was done

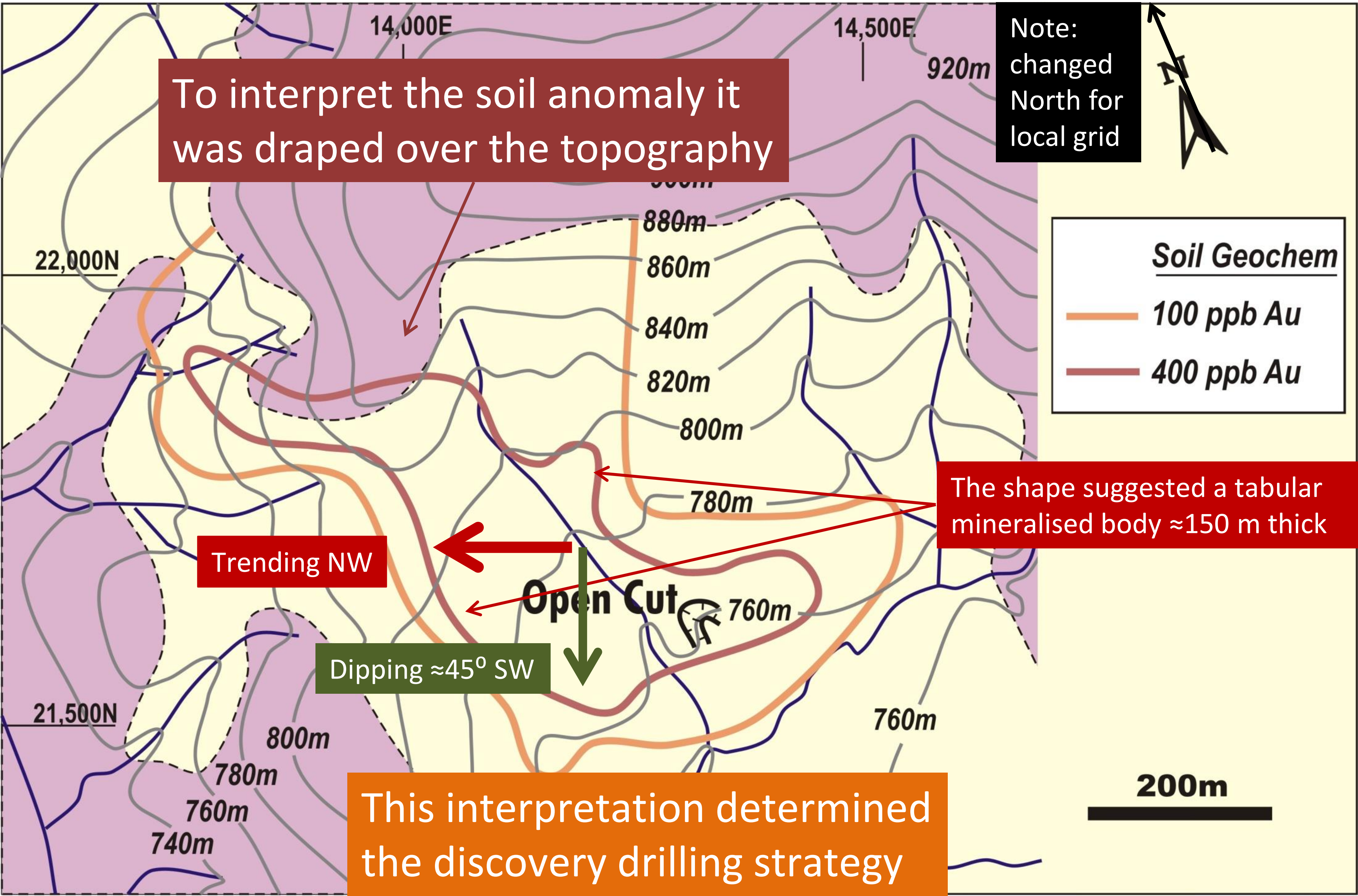
And located a significant soil Au anomaly: 750x200 m in area, on the eastern side of the ridge

The pine forest covered much of the anomaly

Unfortunately, there was the forest issue

Newcrest sampled on a 25 m grid, including within the pine forest

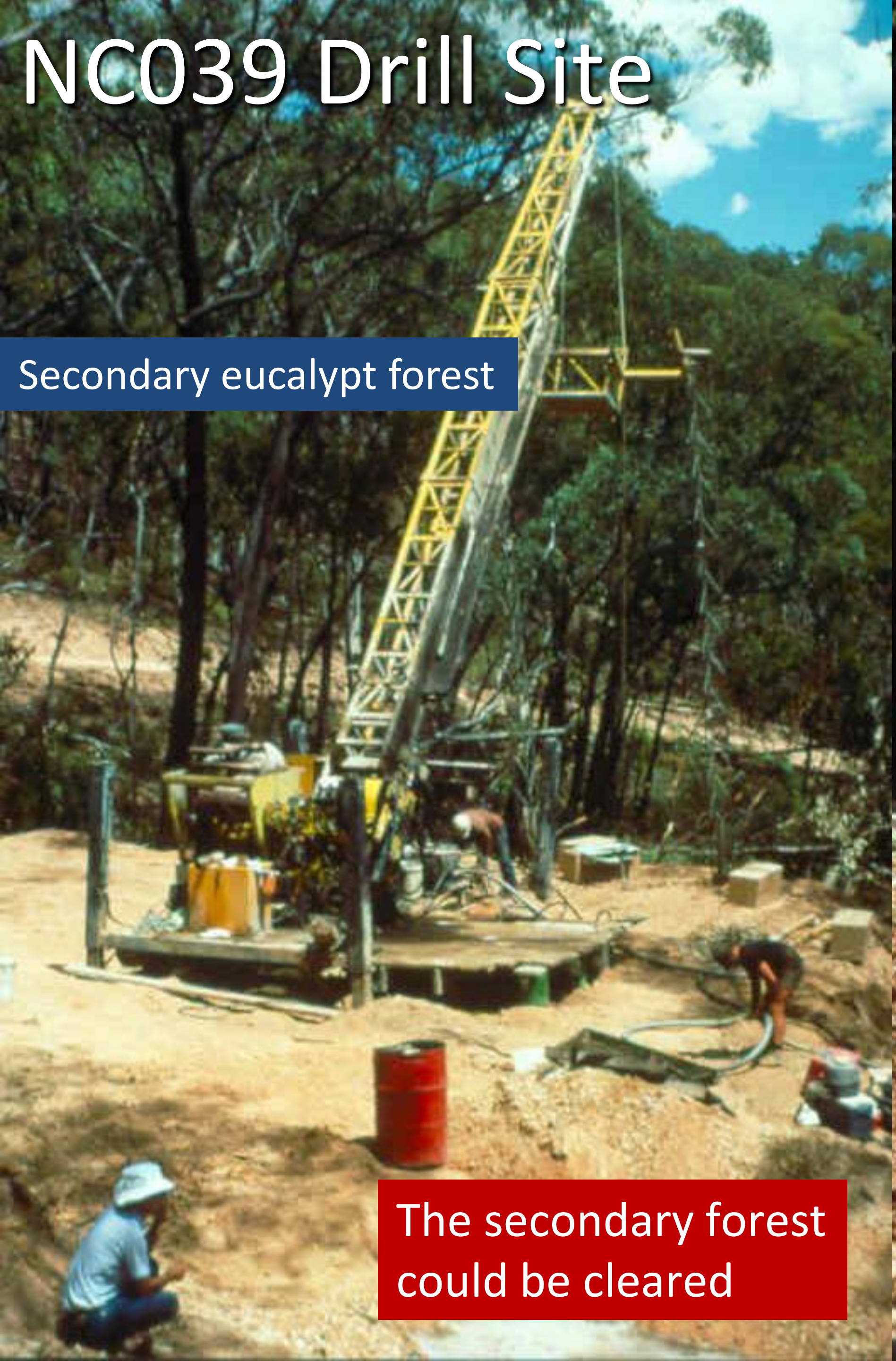
Topography and Soil Au



Old Cadia Hill Open Cut

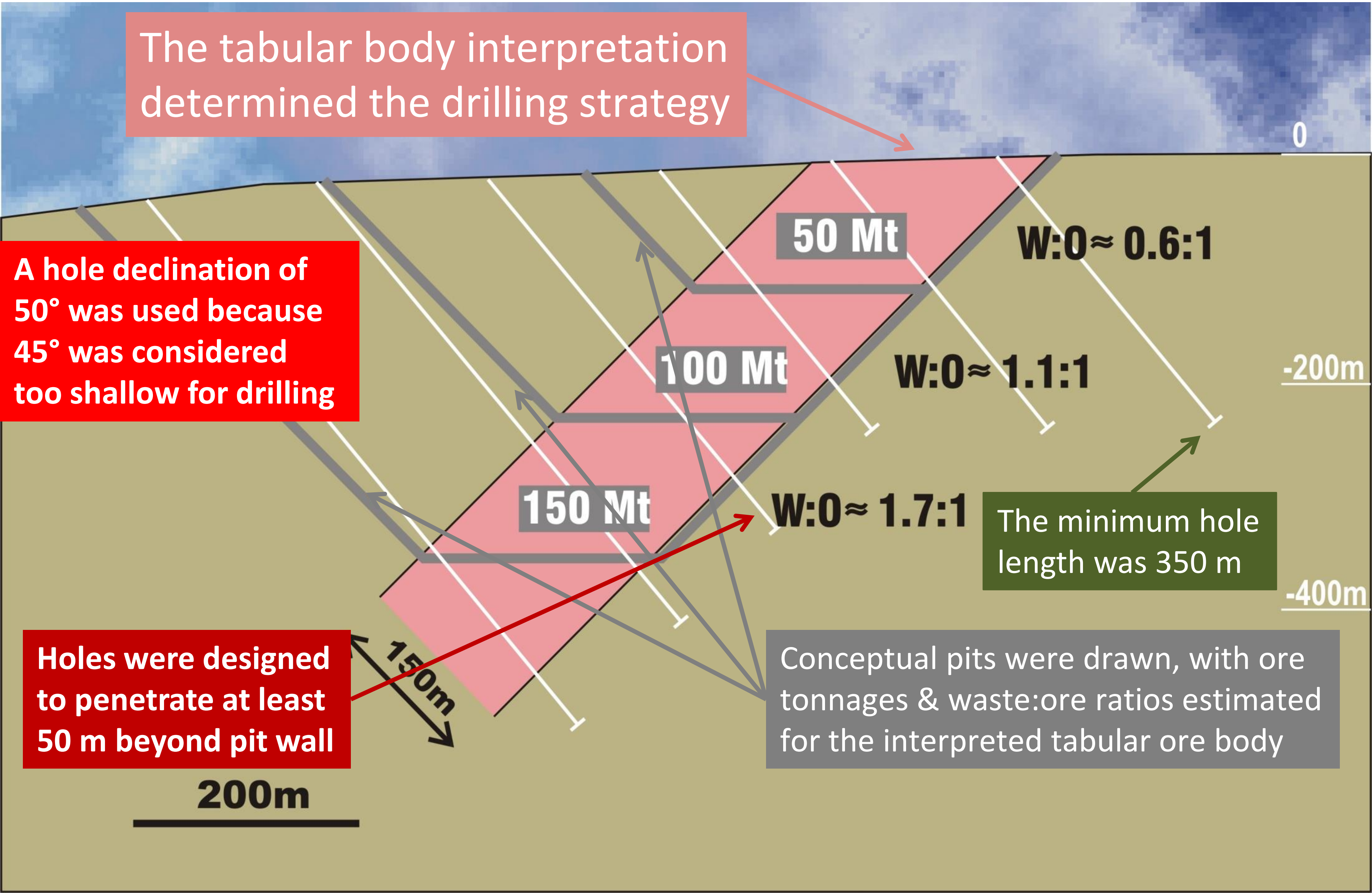
Logging the Pine Forest

By selling the logs, Newcrest recovered the cost of the forest purchase and logging


NC039 Drill Site
Secondary eucalypt forest
The secondary forest could be cleared

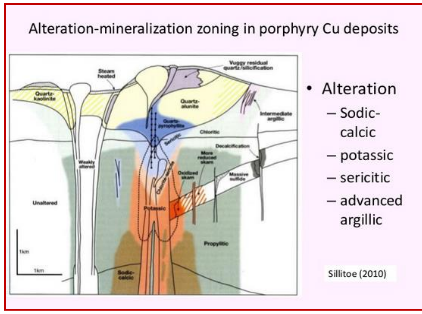

Looking Grid North
Degraded pine forest
This is the forest that had to be purchased before drilling

Discovery Drilling Concept



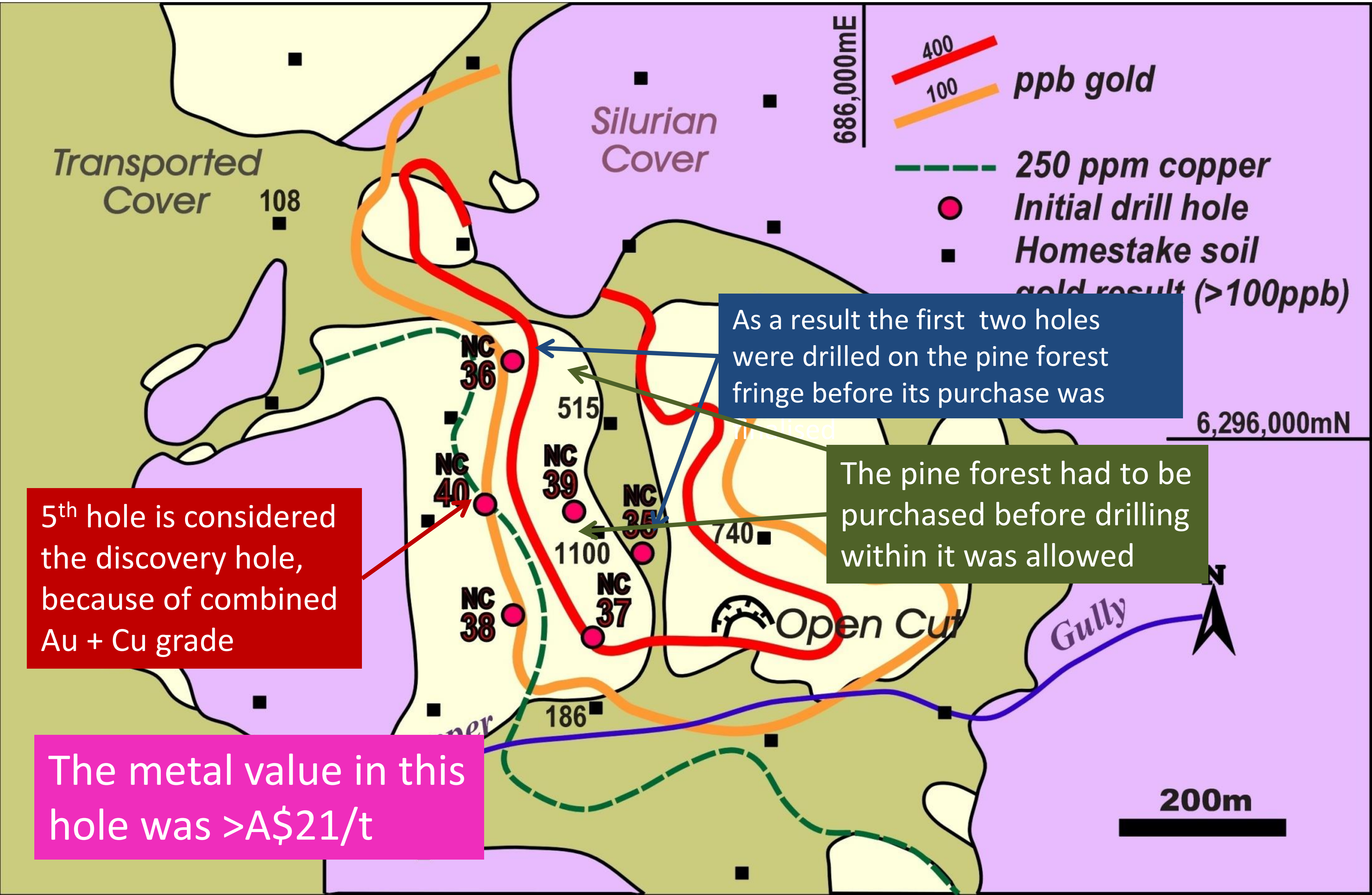
Selling Concept to Board

- **When Newcrest started exploring for a porphyry deposit at Cadia in 1992, it was recognised that the Big & Little Cadia deposits were magnetite skarns, similar to those at Ok Tedi, and not VMS deposits as thought at the time**
  - *the Cadia skarns were promoted as possible indicators of porphyry Cu-Au mineralization, as at Ok Tedi*



- **In Board presentations, drill-hole intersections were converted to a nominal A$ value/tonne of mineralised rock, using prices of US$333/oz for Au & US$1.07/lb for Cu**
  - *a combined Au + Cu value of A$10/t (US$7/t) was suggested as a possible cut-off grade for large-scale mining at Cadia*
  - *>A$20/t (US$14/t) mineralisation was suggested as ore, if a sufficiently large quantity were to be discovered, say ≈200 Mt*
- ***Drill hole results were presented to the Newcrest Board as Australian-dollar rock values***

Discovery Drilling



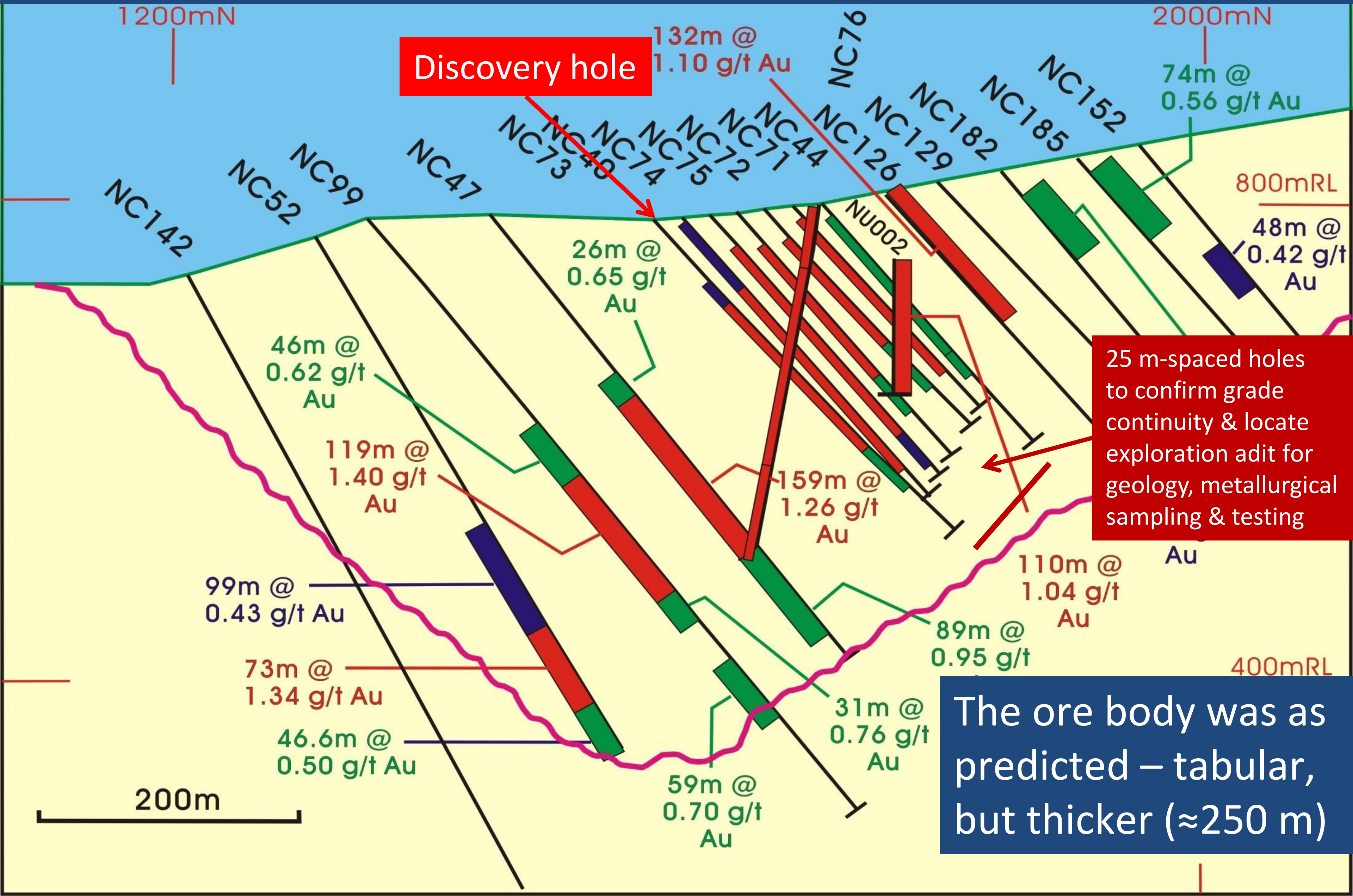
As a result the first two holes were drilled on the pine forest fringe before its purchase was realised

The pine forest had to be purchased before drilling within it was allowed

5th hole is considered the discovery hole, because of combined Au + Cu grade

The metal value in this hole was >A$21/t

Section 14,020 E – Drilling Results

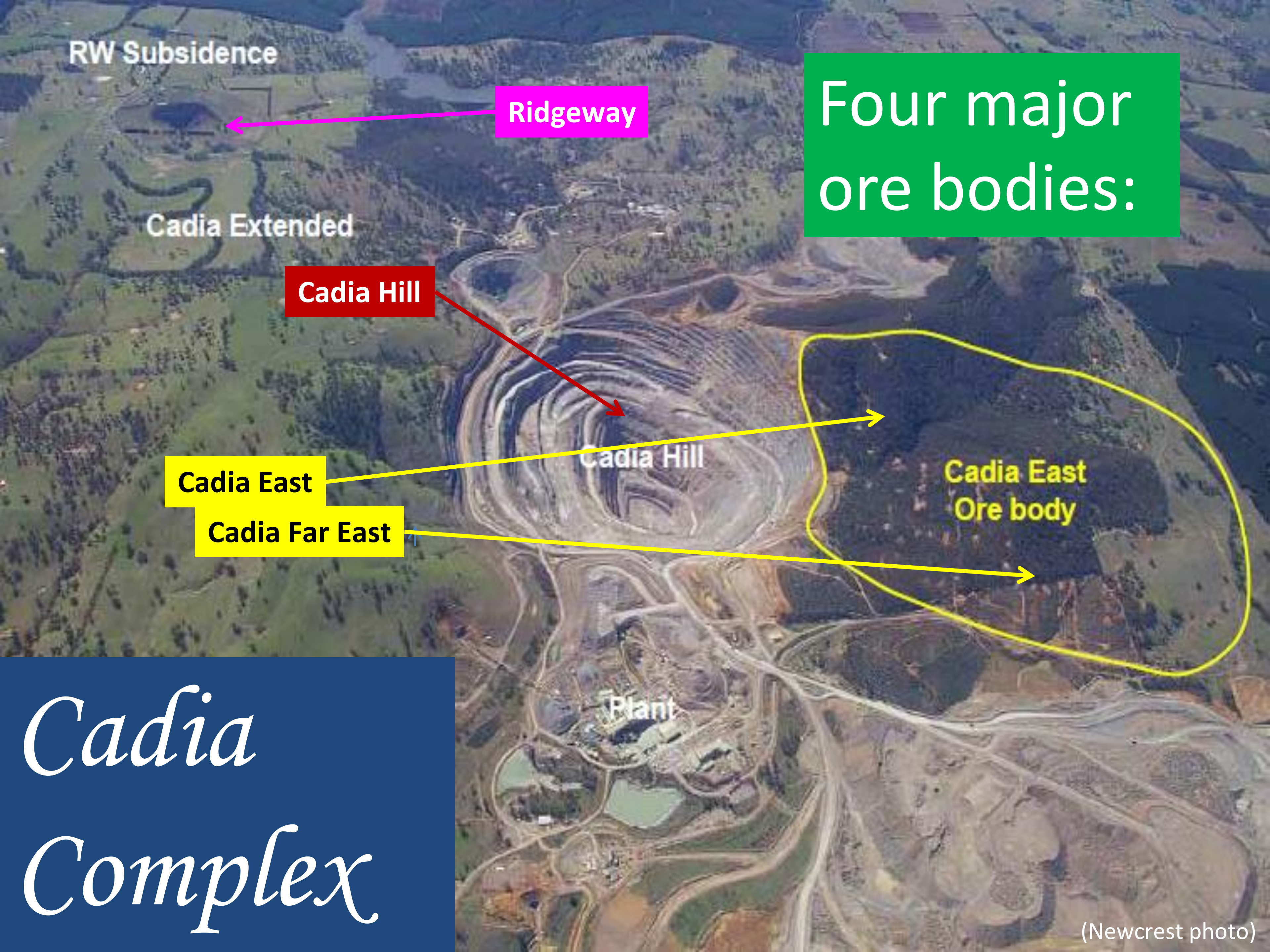


The ore body was as predicted – tabular, but thicker (≈250 m)

Likely reasons for Discovery?

- Recognising that the Big and Little Cadia deposits were magnetite skarns and not volcanogenic massive sulphide deposits
- **Availability of previous exploration results and drill core**
- Purchasing the degraded pine forest
- Soil sampling and correctly interpreting the meaning of the shape of the anomaly

(My opinion)


RW Subsidence
Ridgeway
Four major ore bodies:
Cadia Extended
Cadia Hill
Cadia Hill
Cadia East
Cadia Far East
Cadia East Ore body
Plant
Cadia Complex
(Newcrest photo)

Five Minute Break

How has Exploration Performed?

Results suggest the discovery rate has fallen since 2005

Notwithstanding an average 3-fold funding increase

The cause isn't a lack of money!

Discovery Performance

Acknowledgement

The Global Shift to Undercover Exploration
- How fast ? How effective ?

Richard Schodde
Managing Director, MinEx Consulting
Adjunct Professor, University of Western Australia

Society of Economic Geologists 2014 Conference
30th September 2014, Keystone, Colorado

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Recent Trends and Outlook for Global Exploration

Richard Schodde
Managing Director, MinEx Consulting
Adjunct Professor, Centre of Exploration Targeting, University of Western Australia

PDAC 2017
6th March 2017, Toronto

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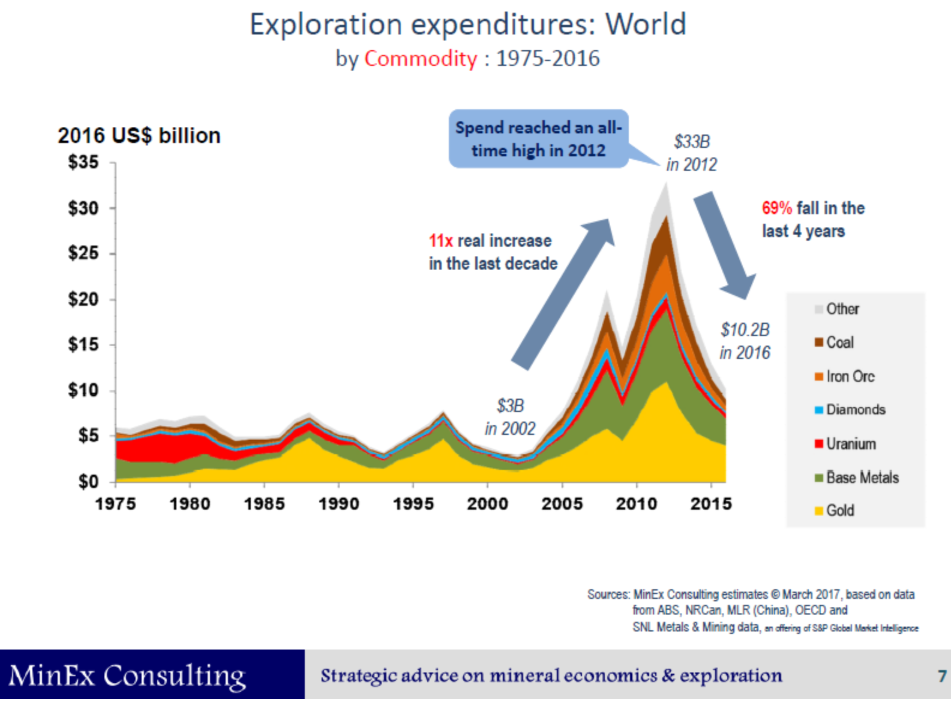
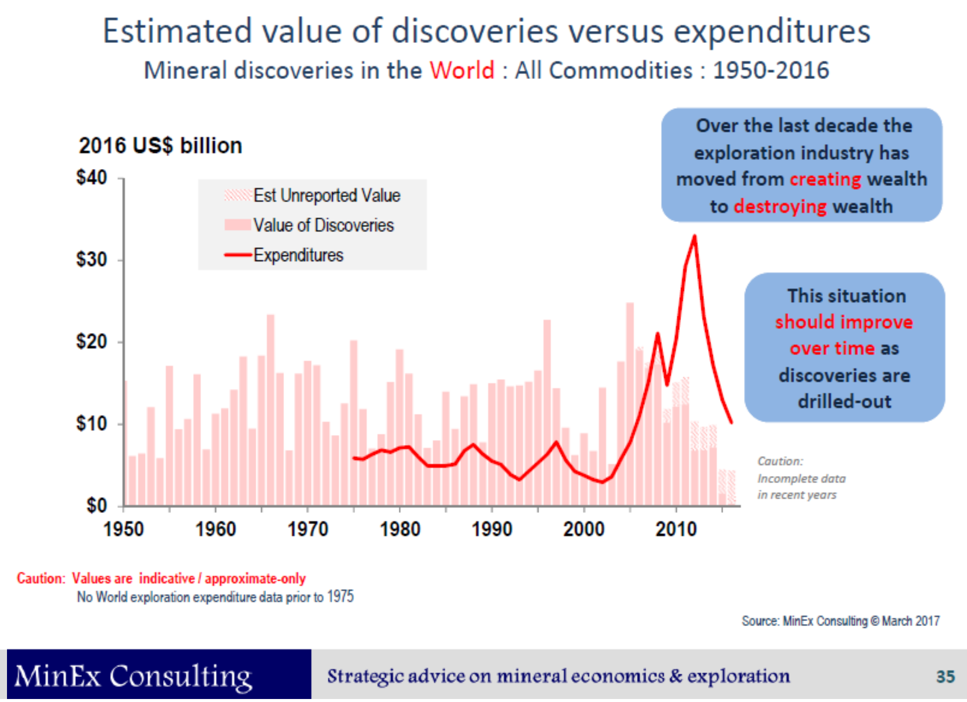
Exploration Expenditure

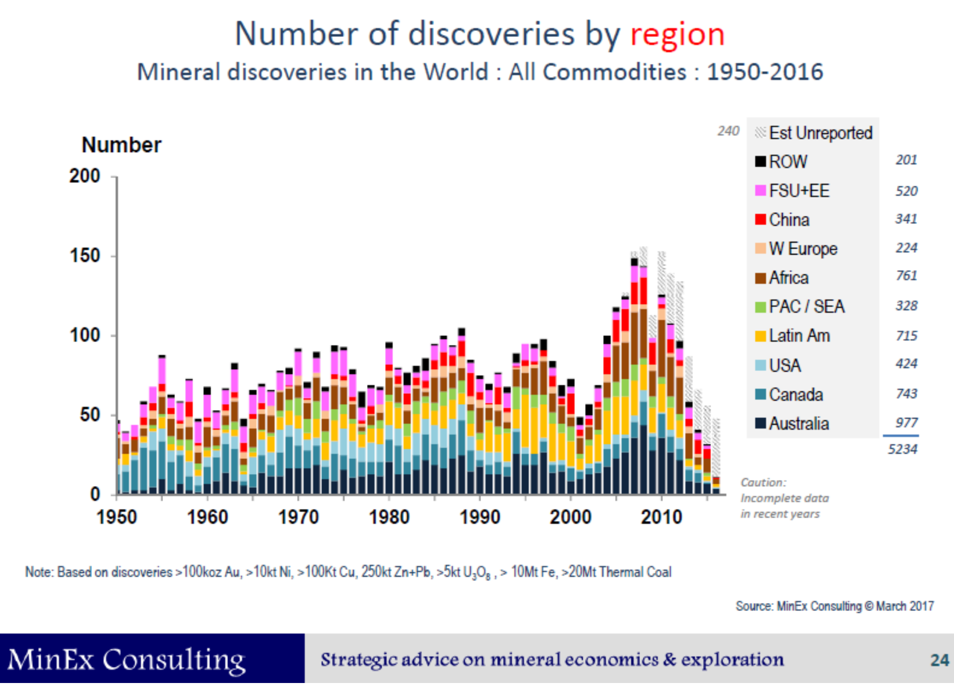


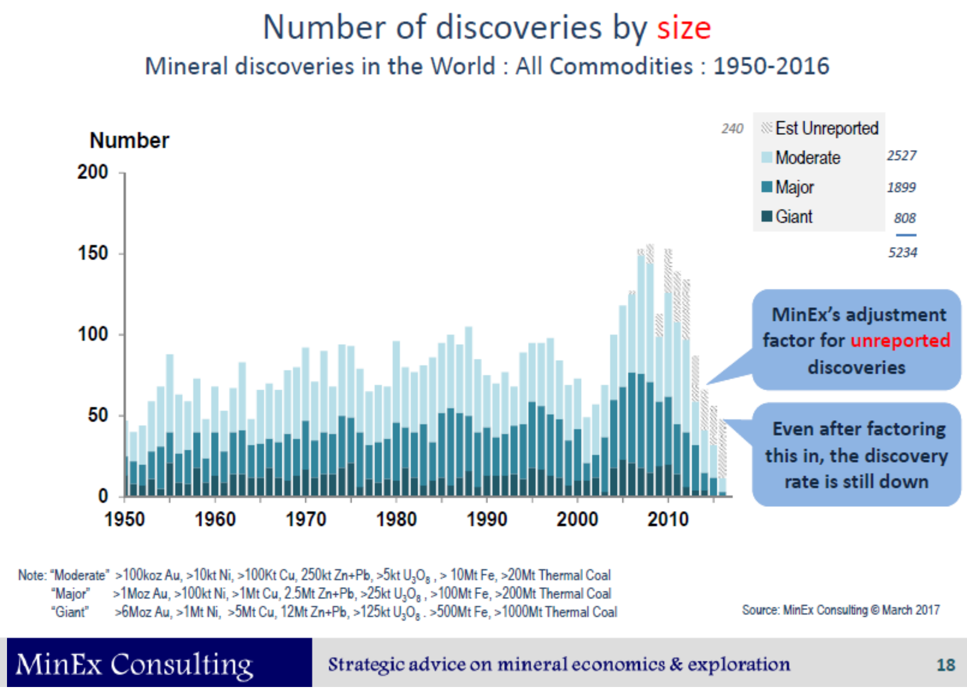


- **From 2005, annual expenditures on exploration far exceeded those prior to 2005**
- **Particularly for gold and base metals targets**
- **In hindsight, this seems irrational**

- **Up until 2008, wealth was created through exploration**
- **This doesn't seem to have been the case since then**
- **THIS WILL BE AFFECTING INVESTOR CONFIDENCE AND SUPPORT FOR EXPLORATION**

Discoveries

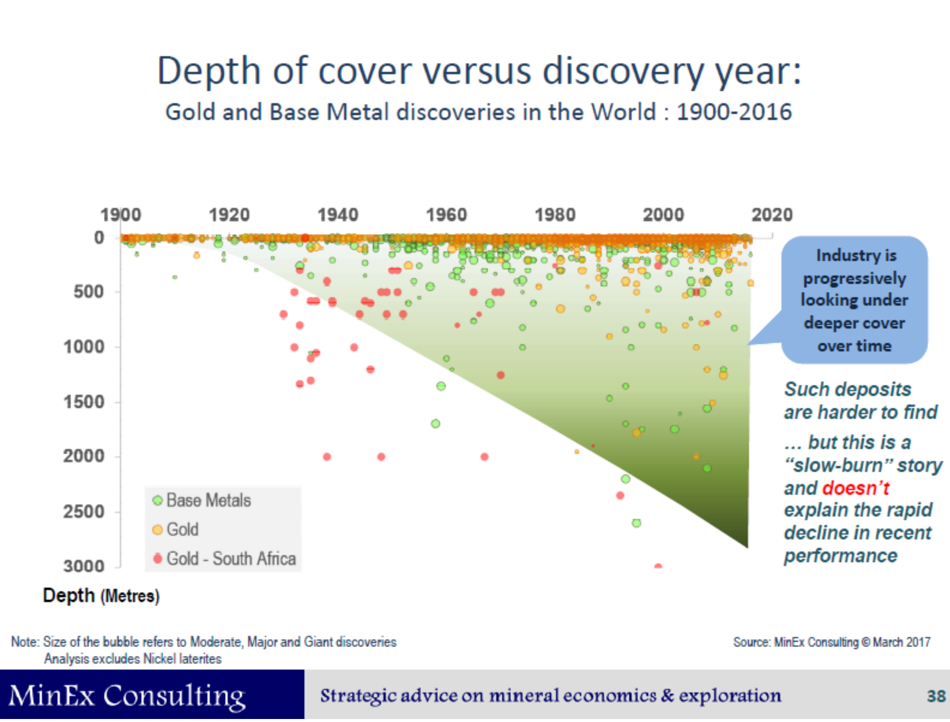


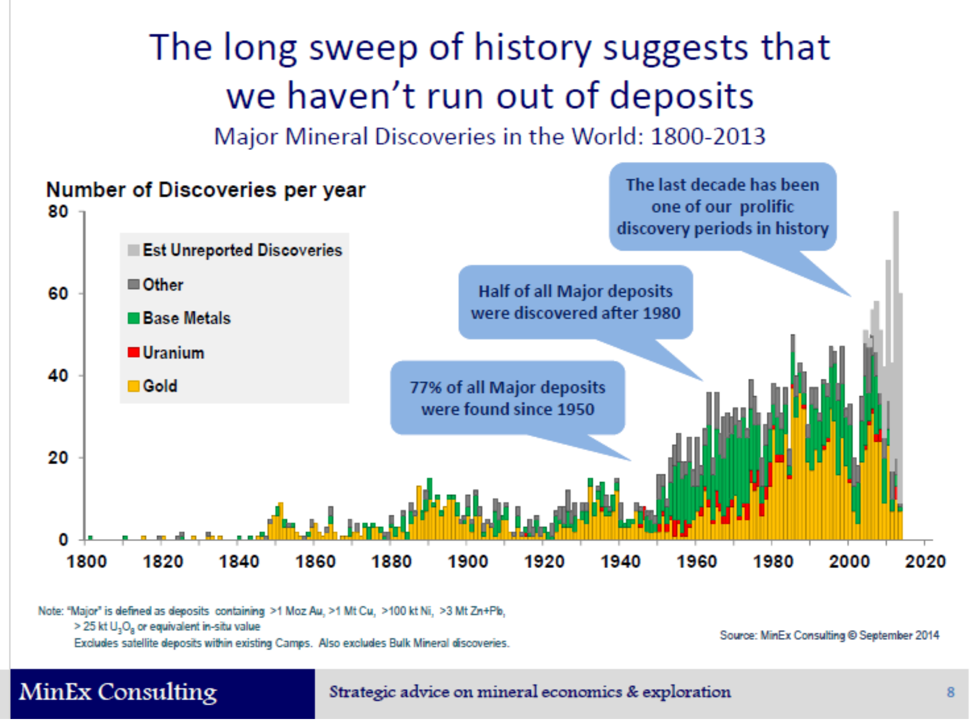


- **Since the late-2000s the number of discoveries per region seems to have fallen**
- **Which is strange given the different stages of maturity of the various regions**

- **It seems as though this fall off in discovery numbers is irrespective of deposit size**
- **OF GREAT CONCERN IS THE FALL IN NUMBER OF VERY LARGE DISCOVERIES, IF IT IS REAL**

Future Implications

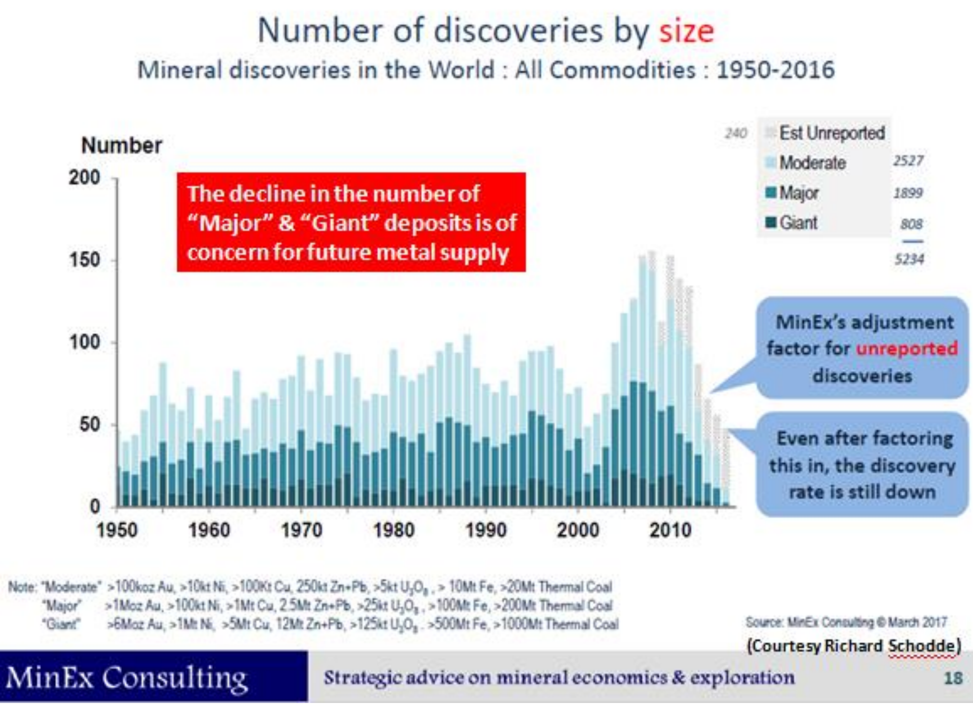


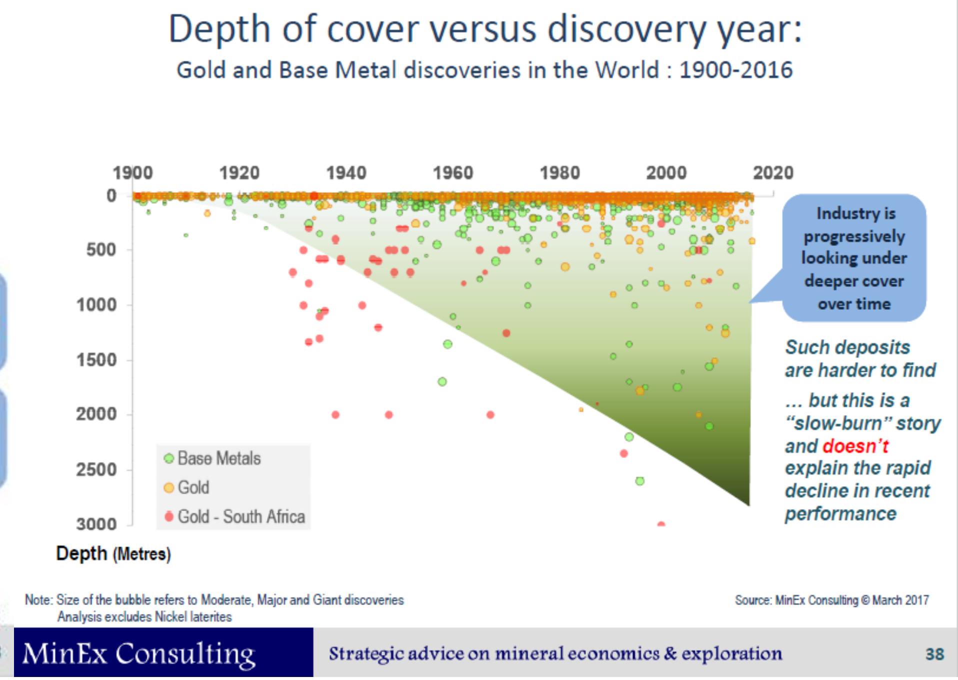


- **Most gold & base metals deposits occur at shallow depth (<200 m)**
- **They are/were mined mostly by open pit, which usually was the discovery objective**

- **Logically , there should be a large number of deposits to be discovered at >200 m depth, to 2,000 m, and the number should far exceed the post-1945 discovery total**
- **BUT THEY WILL BE MINED UNDERGROUND**

Future Focus?





- **On supplying the growing demand for mineral resources while replacing the major mines that will close**
- **By increasing the number of 'Major' and 'Giant' discoveries**

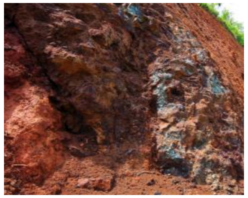
- **To do this we need to explore deeper**
- **Which means we need to understand what is an ore deposit at depth**
- **BUT WE NEED TO FOCUS ON FIRST DISCOVERING AN "ORE SYSTEM"**

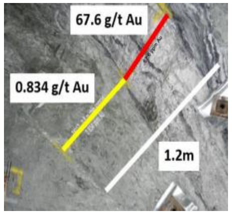
Why the Model needs Change?

- **The increase in exploration expenditure post-2005 hasn't been justified by the value of discovered ore**; previously wealth had been created
- *Richard Schodde estimates that less than 50 % of the total expended on exploration was recovered in the value of discoveries made between 2007 and 2016*
- **Investors are less likely to fund exploration unless the rate of return improves substantially**

What is the Future for Exploration?

- **The present model will still work**
  - *In poorly explored areas*
    - for deposits that crop out
    - *for deposits under cover*
      - both shallow & deeper
    - and for deeper deposits
      - *either narrow & high grade, or massive & lower grade*





- **The model is failing economically, however**
- **And a new way of exploring is definitely required**
  - *Particularly in well explored areas and known mining districts*
    - for large deeper deposits, **e.g., porphyry Cu deposits**
    - ***but not necessarily for deposits under cover***
- ***These deeper deposits will have to be mined by an underground method, not by open pit***

Exploring under Cover & Risk

- **THE RISK IS LOW TO UNACCEPTABLE**

- **Low-risk is where evidence of mineral potential (**e.g., mine, vein extension or alteration**) is recognised on the edge of thin cover (**sand dune, mesa, etc.)



- **High-risk is where evidence of mineral potential is absent and cover is thick and consolidated**

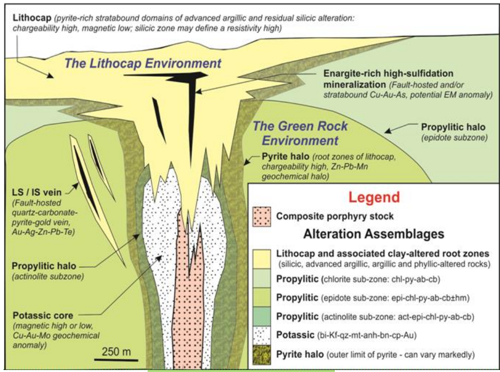
- **Unacceptable risk is where the target is to be caved and the cover includes a known aquifer, which would flood the mine when breached by subsidence**

Future Exploration Needs?

A deeper-discovery exploration approach

- *A discovery business model that is understood and strongly supported by senior corporate management, which accepts the need for consistent funding, time and a focus on caving*

- **Ore deposit models that reduce discovery risk by more accurately forecasting proximity to possible ore using:**
  - *geological attributes*
  - *geochemical signatures*
  - *geophysical techniques*



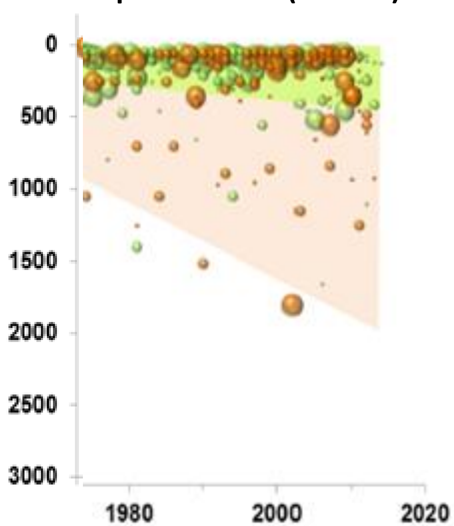
(Cooke, et al)

- ***Cheaper discovery drilling technology/capability***

Deep Exploration Technologies

Coiled tubing drilling: Objective of $50/m cost & fast penetration rate

Where is the Opportunity?



(Courtesy Richard Schodde)

- **Deeper in the Earth's crust**
- *The great majority of known deposits have been discovered at <300 m depth, and mostly <200 m*
- There have been deeper discoveries and there is every reason to expect that additional deeper discoveries will be made
- *A major reason for the dominance of near-surface discoveries is because these have been the target of most exploration, mainly because they usually can be mined by open pit which can be a lower cost mining method*
- **Exploring deeper than 300 m is the new Greenfield territory**

Deeper Discovery Exploration

Re-focusing the Model for Caving

- **The present model is basically modern prospecting –** *we target ore using different ways of "observing" than did old-time prospectors* **– so far usually for mining by open pit**
- ***The present model will continue to be effective in seeking shallow deposits for open pit mining***
- **Discovering deeper ore bodies to be mined by caving, however, requires a refocusing of the exploration model**
- ***This is needed to avoid wasted expenditure in discovering deposits that cannot be mined for known and predictable reasons***

Present model

Observation

↓

Pattern

↓

Hypothesis

↓

Drilling

↓

Discovery?

A Mining-focused Model

- **Because of the extra uncertainty about location with a deep deposit, we need to first discover a larger target –** *which may contain a deposit that can be mined*
- **This means we should explore to first discover a potential "Ore System"**
- **To achieve this we need to "observe" with an "Ore System" in mind –** *in the hope that it may host an ore deposit*
- **When drilling we need to identify risks to mining if we were to discover a deposit**
- **High mining risk will downgrade a target**

Proposed model

Observe for "System"

↓

Apply target scale

↓

Identify mining risk

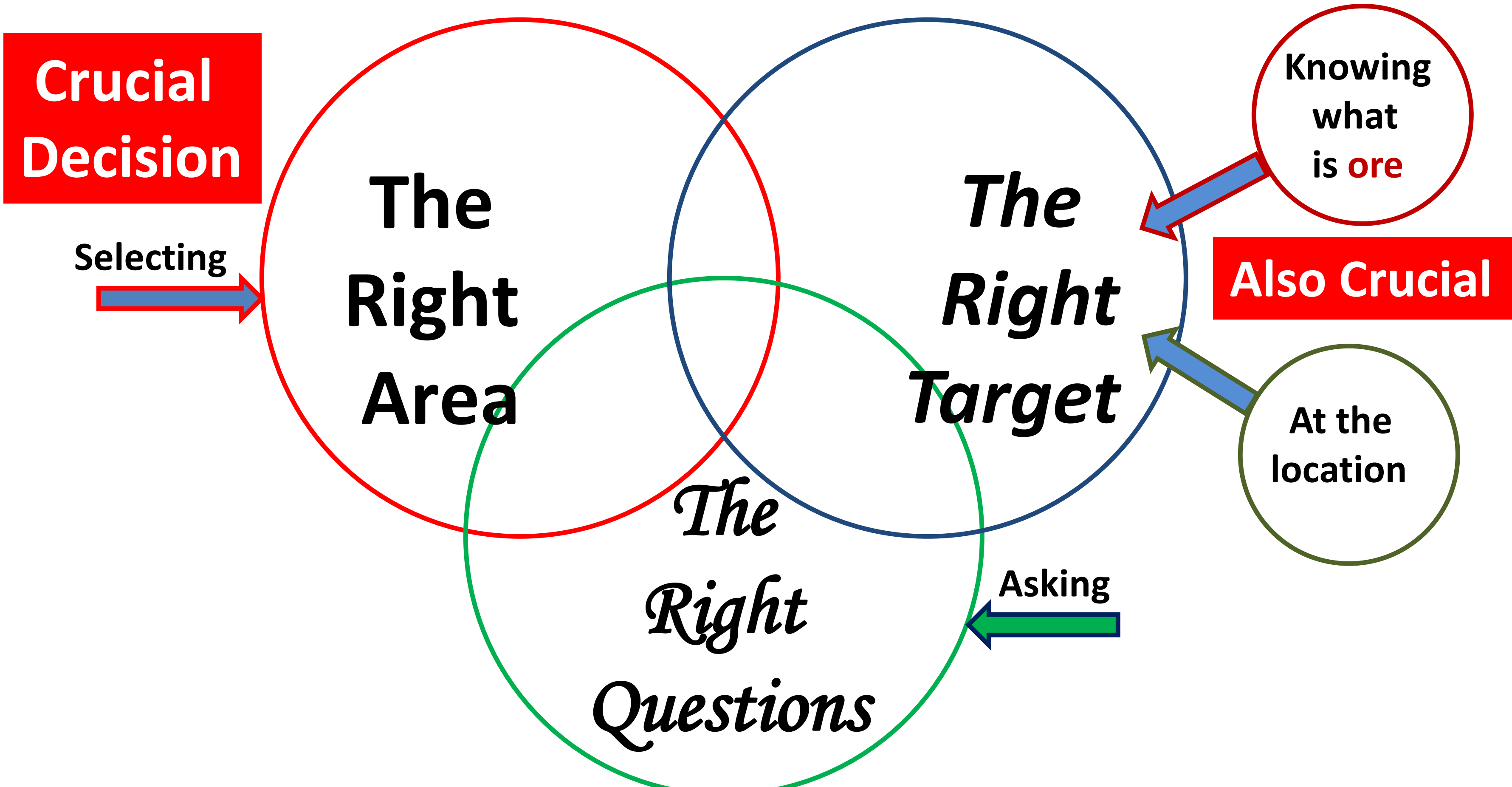
↓

Widely-spaced drilling

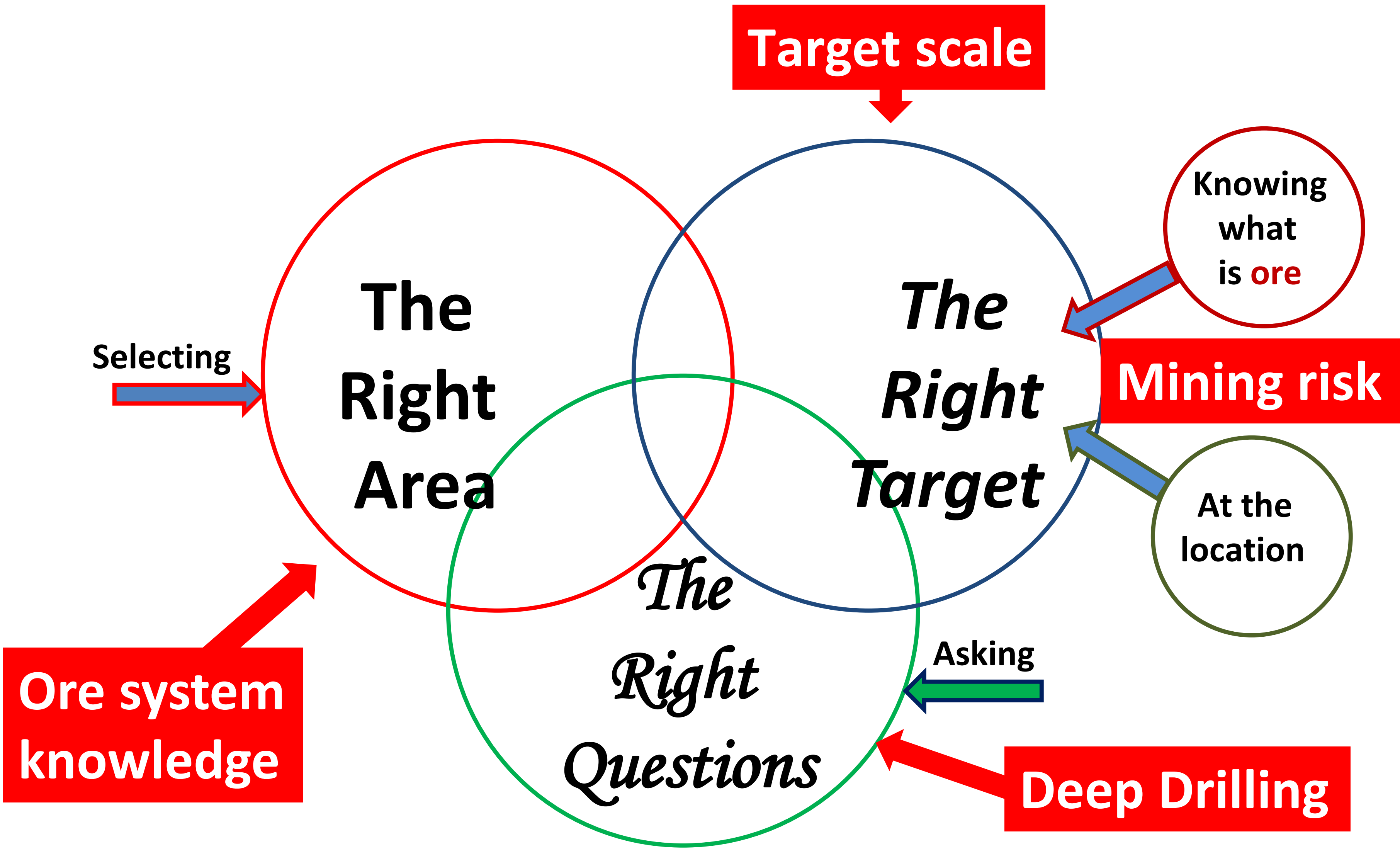
↓

Discovery?

Present Exploration Model

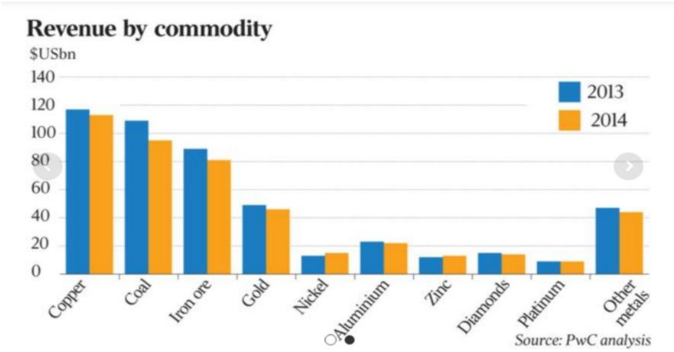


Future Exploration Model



Future Targets?

- **The target will depend on company size**
- ***Copper, coal, iron ore, and gold produce the most revenue***
- **Of the metals, Cu plus Au are by far those most sought after presently**
- ***Porphyries are possibly the easiest Cu + Au deposits to discover***
- **Drilling below or near a porphyry open pit is the obvious place to explore for a deeper porphyry Cu ± Au deposit**
- ***However, deeper Au (**and other metal**) deposits with suitable grade, tonnage, geometry, etc. may also be amenable to caving***



Revenue by commodity. *Source:* TheAustralian

(NASA image)

NASA changed this image

Beware Conventional Wisdom

to

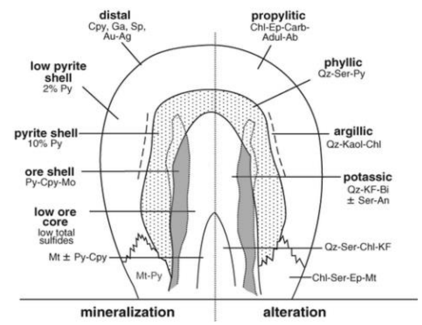
Think Differently

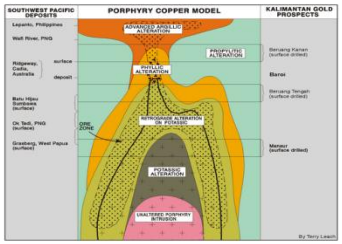
Because this is how the earth should look

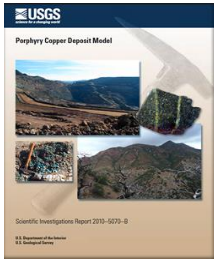
(NASA image)

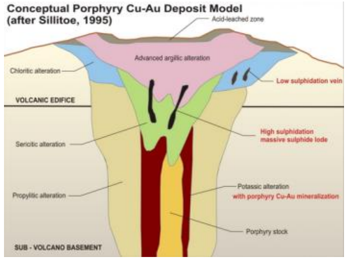
Porphyry Mineralisation Models

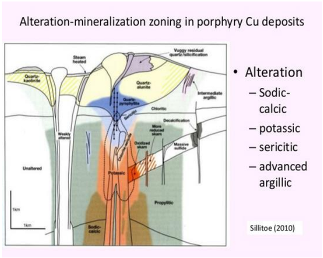
- The earliest and most widely used model is based on the San Manuel deposit in Arizona – Lowell & Guilbert
- *Since 1970, additional models have been proposed – and different models apply in different parts of the world*
- Most models share common features: hydrothermal alteration assemblages, positioning of ore, postulated depth of formation, etc.
- ***However, no two deposits are exactly the same and this creates opportunity when exploring***

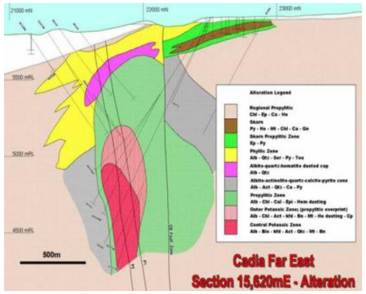


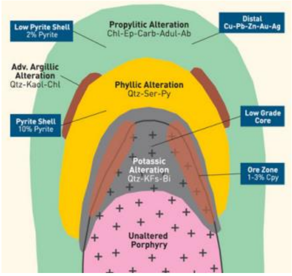








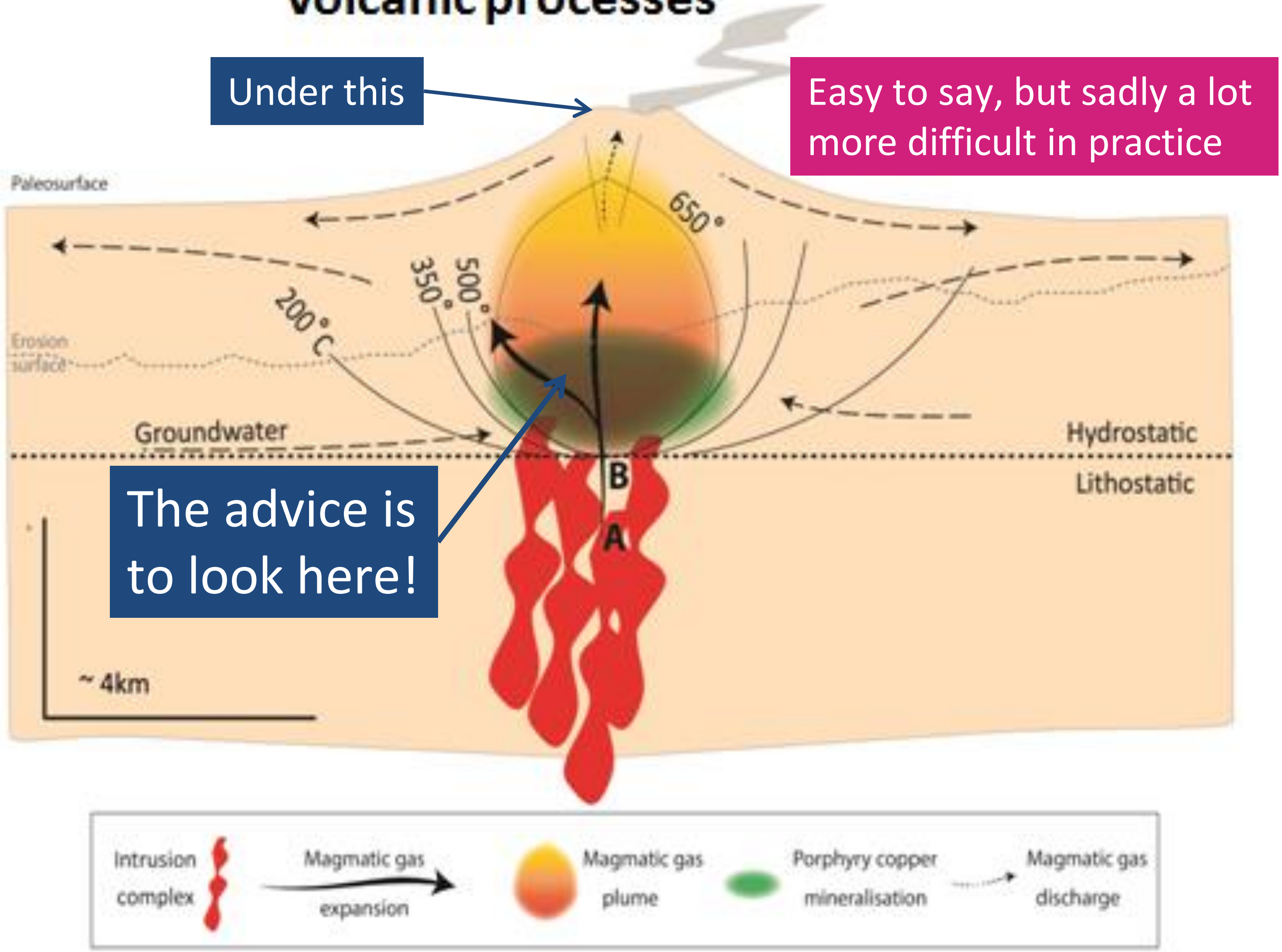





Mostly, the models involve
Old Stratovolcanoes
By.K

General gas plume schema for porphyry copper deposits and sub-volcanic processes

Heterogenous non-equilibrium gas-phase chemical reactors with pressurised gas cores



How are porphyry copper-gold and volcanic processes related?

(Courtesy Dick Henley)

Re-focused Model – "Ore System"

- **Understanding and visualising the "ore system" that may host an ore deposit is crucial**
- *In this, knowing what the ore may look like is obviously important*
- However, of most importance is being able to identify signs that may indicate proximity to ore
- ***We need to look for clues that suggest an ore body may be present and act on the clues, no matter how tenuous the evidence may be***

Proposed model

Observe for "system"

↓

Apply target scale

↓

Identify mining risk

↓

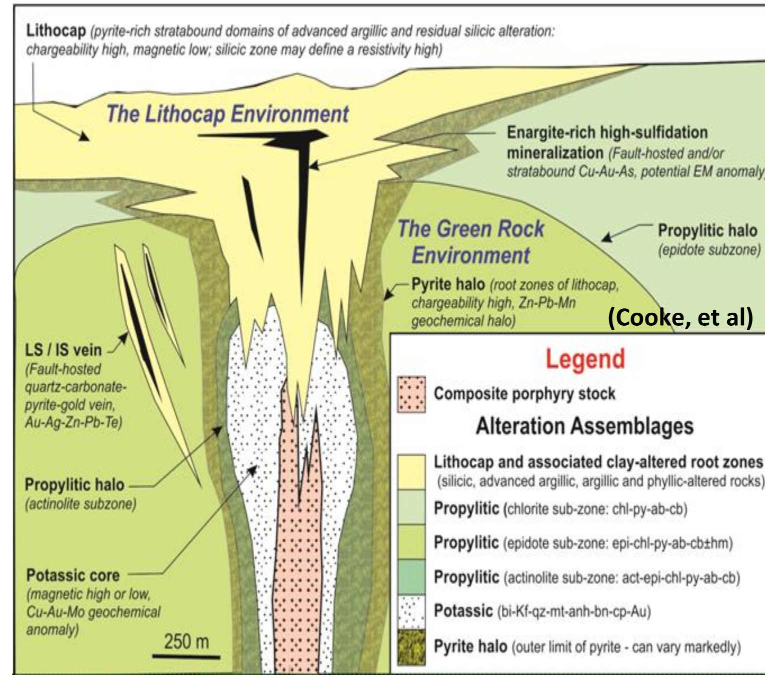
Widely-spaced drilling

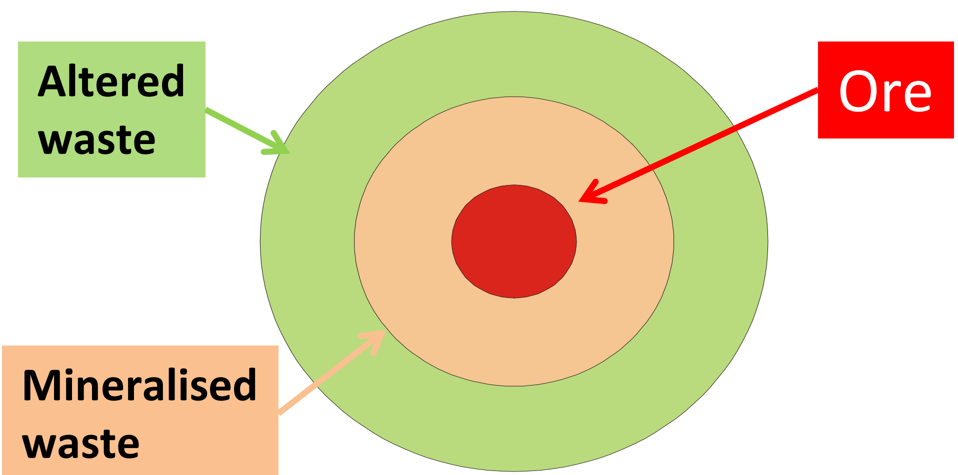
↓

Discovery

A Porphyry "Ore System"

- **The basic ingredients are:** potassic (ore-bearing), phyllic (pyrite halo) & propylitic alteration, arranged in roughly concentric shells; with, possibly, an upper advanced argillic alteration overprint
- **A deposit may have a barren core**
- **The mining counterparts are:** ore and mineralised waste, altered waste, and overprinting waste, if present

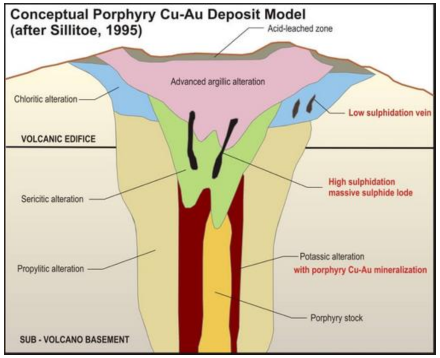


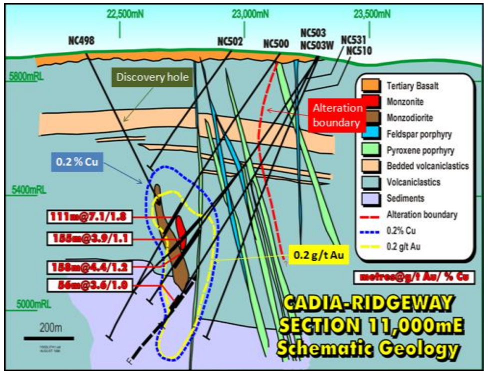


- Drilling will intersect one of the 3D-dartboard rings, laterally and vertically
- **It will also produce evidence of leakage from ore, if recognisable**
- The task is to follow the clues

“Leakage” and Porphyry Deposits

- **Recognising possible “leakage” can greatly assist in identifying potentially productive, porphyry alteration systems**
- *“Leakage” can be:*
  - *directly related, as in mineralised veining*
  - *possibly related, as in skarn or epithermal deposits*
  - *and may be recognised above or adjacent to a porphyry deposit*
- **“Leakage” in the form of Au-Cu veining was used in the discovery of the high grade Ridgeway deposit at Cadia**



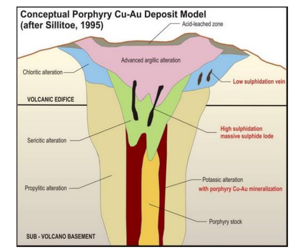


Porphyry Discovery Process

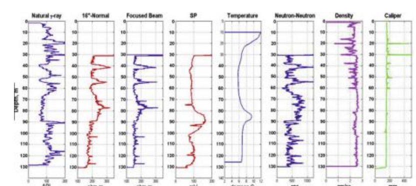
Achieve two objectives: ***1.Locate a possible ore system at depth***

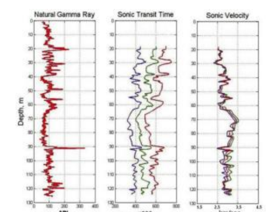
2. Indicate ore potential in the system

- **Role of Surface Mapping**
  - Identify associated mineralisation, e.g., epithermal, skarn, etc.
  - Indicate possible alteration halo assemblages, e.g., propylitic/chloritic, phyllic/sercitic, advanced argillic
  - Detect evidence of ore-leakage, e.g., veining

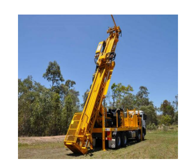


- **Role of Geochemistry**
  - Possibly to provide evidence for a permissive alteration halo
  - Support leakage interpretation
- **Role of Geophysics**
  - Identify possible ore system
  - Collect engineering data by applying relevant down-hole geophysical logging technology, as used in coal exploration





- **Role of Ore Deposit Models**
  - Identify the halo to possible ore by providing better description of this aspect of the ore system
- **Role of Drilling**
  - Prospecting to locate possible ore system, cheaply
  - Conventional deposit delineation & definition



Porphyry Model – Target Scale

- **Porpyhry deposits are large: volumetrically and in horizontal and vertical dimensions**
- *They are characterised by having continuity of mineralisation throughout the deposit, except where impacted by post-mineral intrusions or faulting*
- Horizontal dimensions are relatively equal and can range from <200x200 m to >1,000x1,000 m
- *The vertical dimension can range from <500 m to >1,500 m*
- **Also, they have a large “footprint” which means widely-spaced discovery drilling can be used –** *e.g., a hole spacing of 500 – 1,000 m*

Proposed model

Observe for “system”

↓

Apply target scale

↓

Identify mining risk

↓

Widely-spaced drilling

↓

Discovery

Re-focused Model – Mining Risk

- **The model is re-focused on discovering ore deposits that will be exploited using one of several underground mass mining methods**
- *These methods impose constraints on the type of deposit that can be mined economically*
- **The constraints are mostly related to geology and the physical characteristics of a deposit**
- *Some, however, are the result of the non-selective nature of this mining method*
- **The absence of internal waste is almost always a pre-requisite for applying this mining method**

Proposed model

Observe for "system"

↓

Apply target scale

↓

Identify mining risk

↓

Widely-spaced drilling

↓

Discovery

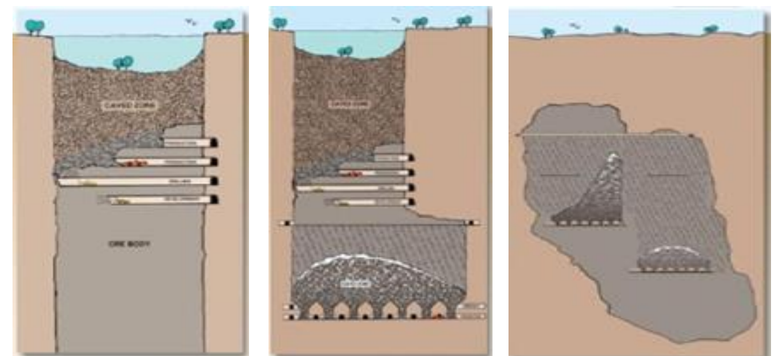
What are Mining Constraints?

- ***Geometry & in situ technical issues are the major constraints that can preclude using a mass underground mining method and have to be considered while exploring***

- Geological conditions that will affect caving also have to be identified, recorded and quantified during exploration
- ***It is crucial for successful mass underground mining (caving) that these aspects of the geology and their potential effects are fully addressed during the mining feasibility study***

Why is this – what does it mean?

- **The constraints are determined by the need to mine the ore by some form of caving**
- *What are the available caving methods and what is caving?*
- Caving results from complex interactions between inherent properties of the ore to be caved and an induced condition resulting from undercutting the ore by mining
- ***Put simply, remove enough of the ore from below the roof and the roof will fall down (cave)!***



Sublevel

Sublevel above

Block Caving beneath

Panel Caving

Figures from Newcrest report

What is Caving?

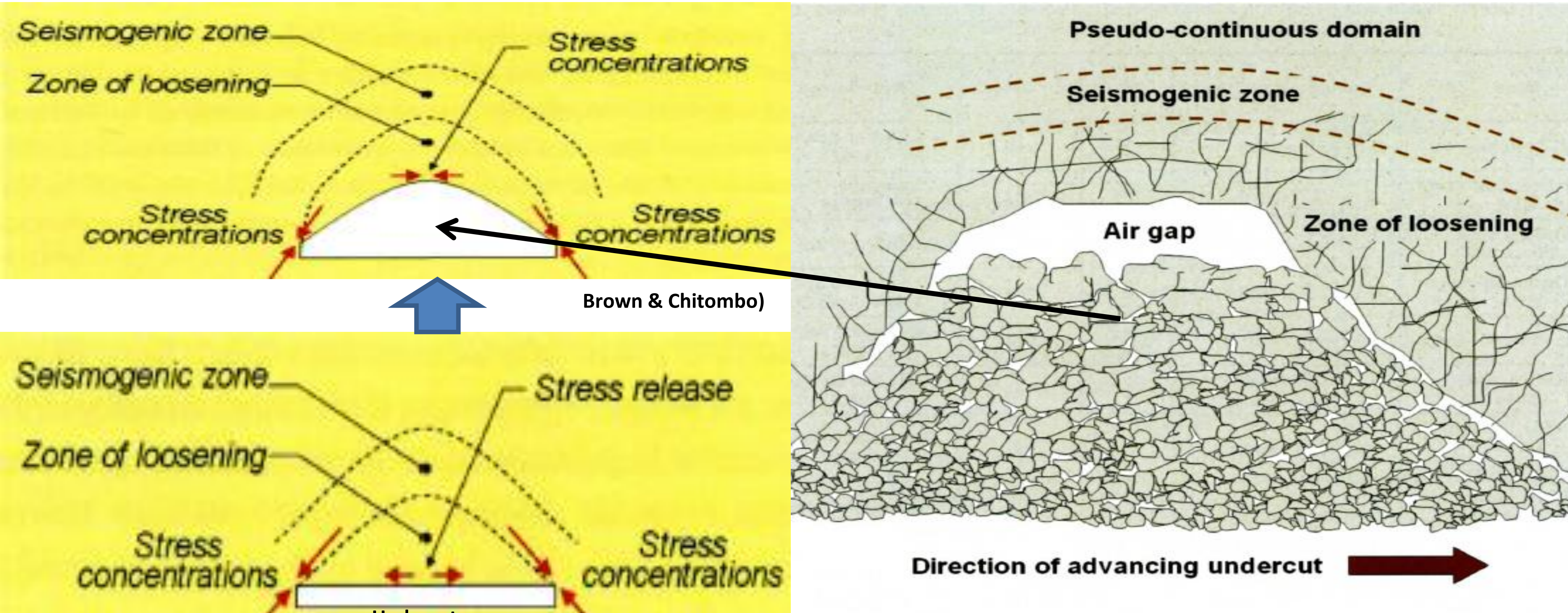


Figure 12: Conceptual model of caving (after Duplancic & Brady 1999)

- **Caving occurs because of gravity and induced stress in ore that has been undercut by removing ore**
- **UNFORTUNATELY, NOT ALL ROCK CAN BE CAVED, ECONOMICALLY**
- **Unlike open pit mining, CAVING IS UNFORGIVING – a failure usually cannot be recovered**
- **A cave may stall because of cave roof asymmetry, for example**

Caving Advantages

- **Much reduced environmental impact**
  - **Surface opening is limited to surface subsidence**

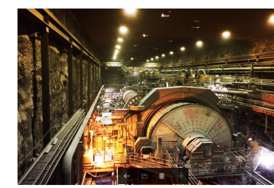
versus

  - **No waste pile from extracting ore**

  - Removes possibility for failure of waste stored on surface

- **There is also the possibility of further reducing the impact**
  - **By relocating surface ore processing plant**

  - To deep underground



  - **By removing need for surface storage of tailings**

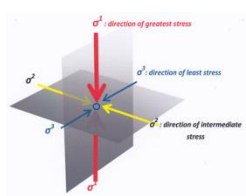
  - Using cemented tailings stored in surface subsidence void

Some Caving Challenges

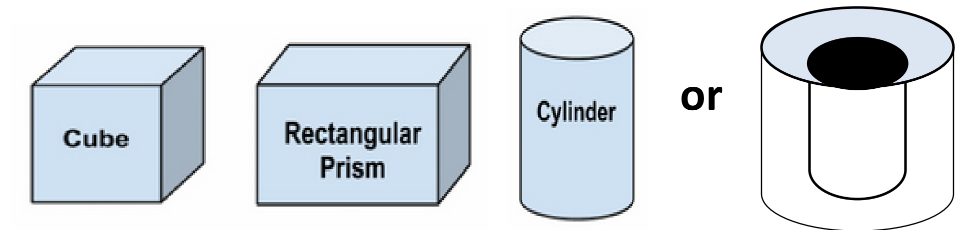
- **Caving requires an ore deposit with a regular geometrical shape, without internal waste to dilute the ore grade**

- **Faulting within an ore deposit will affect performance of the cave, but this usually can be managed**

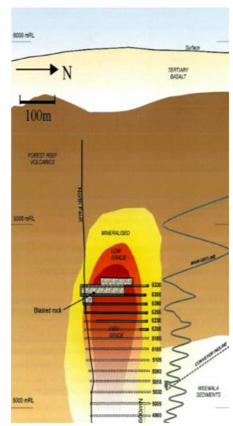
- **The caving process uses gravity and operates better where in situ stress is low**

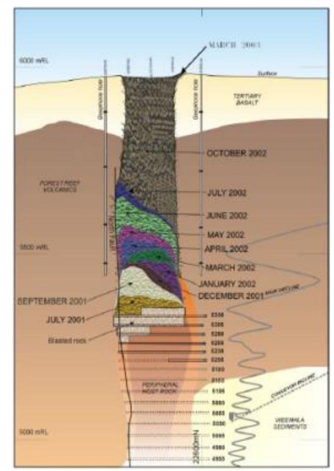


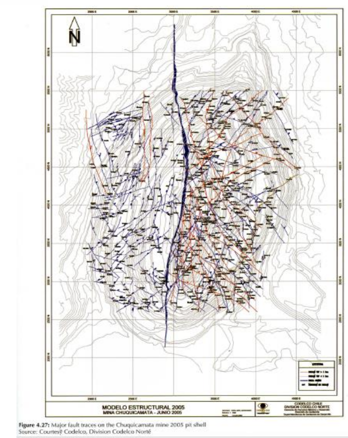
Annular shell

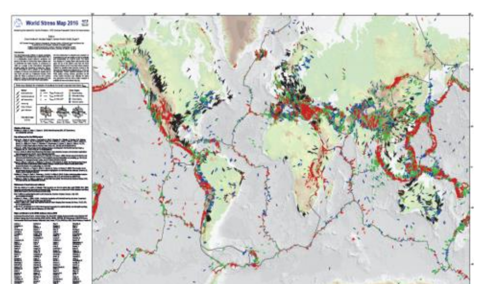


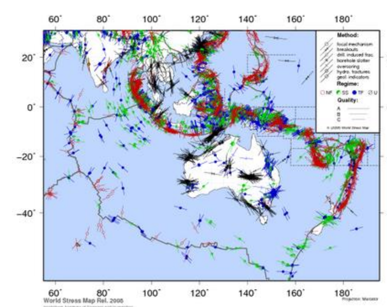
Ridgeway, Cadia







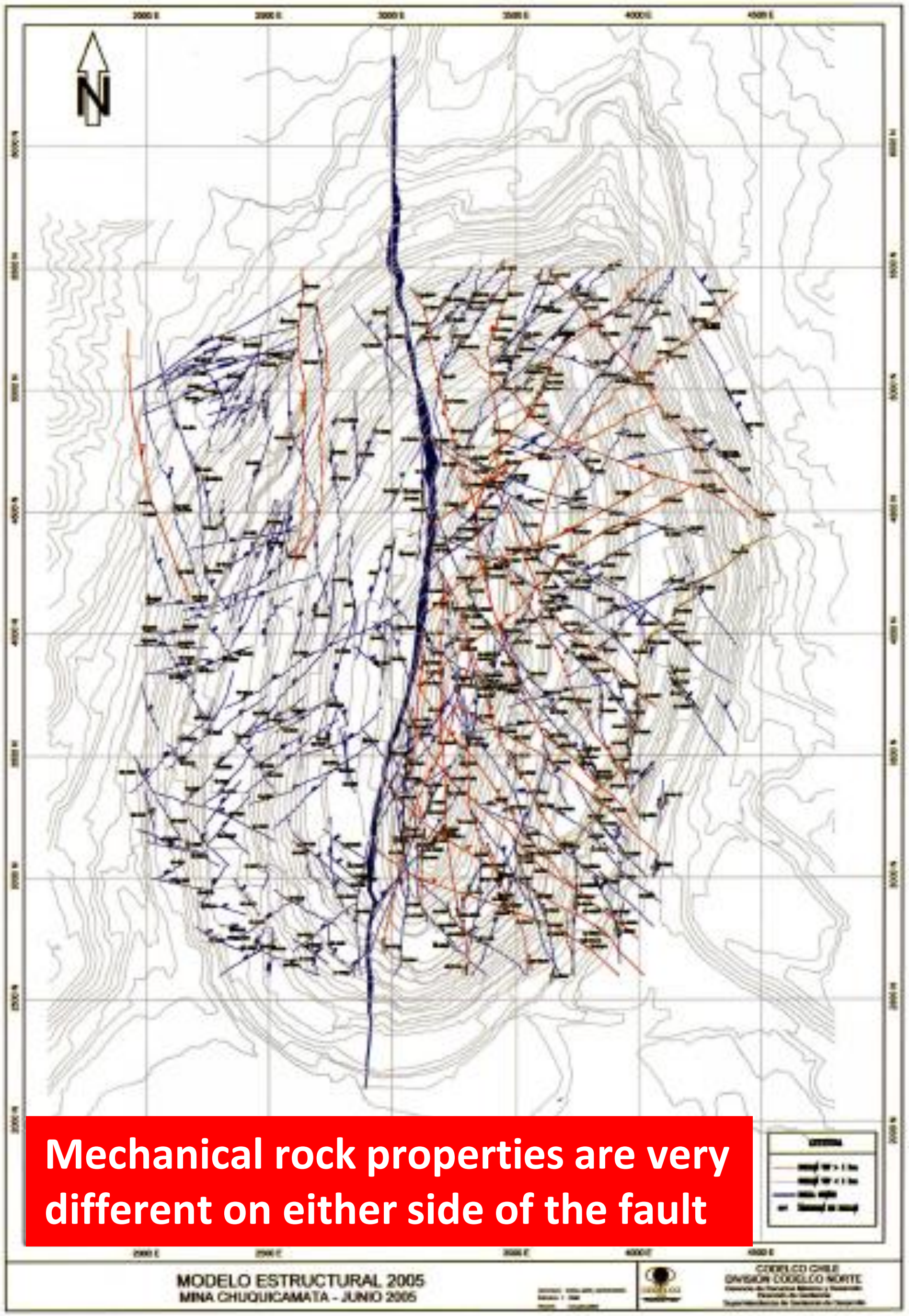




Source: GFZ Data Services

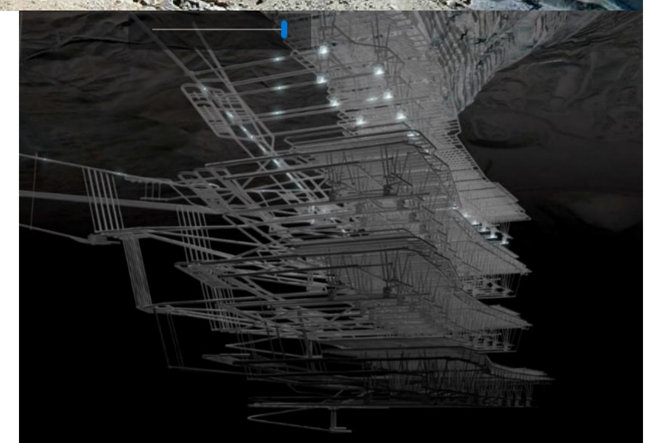
Effect of Faults

Chuquicamata Pit, Chile



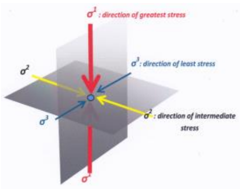
Mechanical rock properties are very different on either side of the fault

Figure 4.27: Major fault traces on the Chuquicamata mine 2005 pit shell
Source: Courtesy Codelco, Division Codelco Norte



Other Caving Challenges

- **Some aspects of caving work better with low horizontal stress**



Courtesy: G. Chitombo

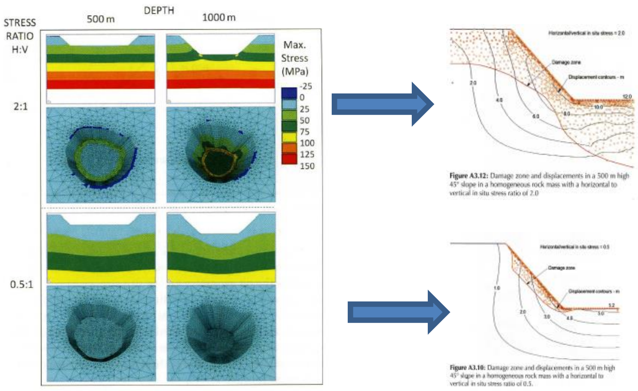
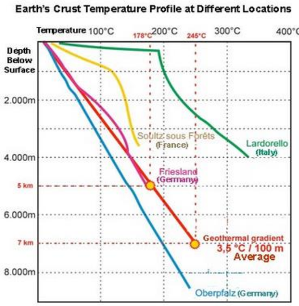
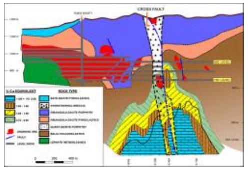


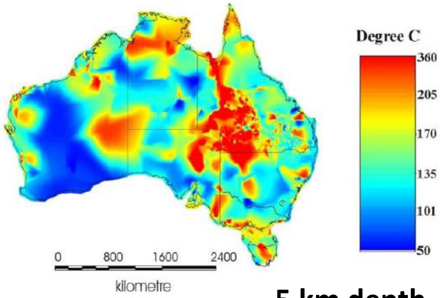
Figure A3.7: 3D modelling showing the effect of pit depth and stress ratio on the stresses induced in the rock mass surrounding an open pit with 45° slopes

Read & Stacey, 2009

- **High rock temperature is a mining issue, e.g., Resolution & Far South East deposits**

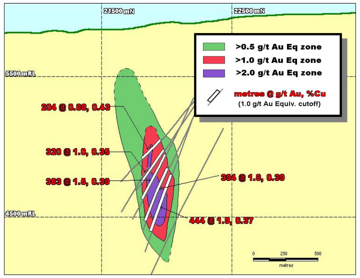






5 km depth

- **As with open pit mining, caving economics may be enhanced by starting mining in high grade; but not always**



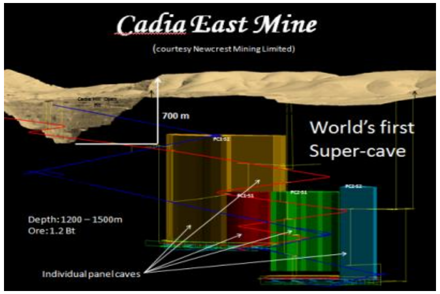


Image Source: BRC

Caving is extending to present deep open pits

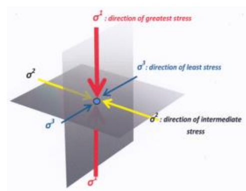
A pit depth of >1,000m may be too deep for open pit mining to continue

These mines are unlikely to be deepened and mining will cease

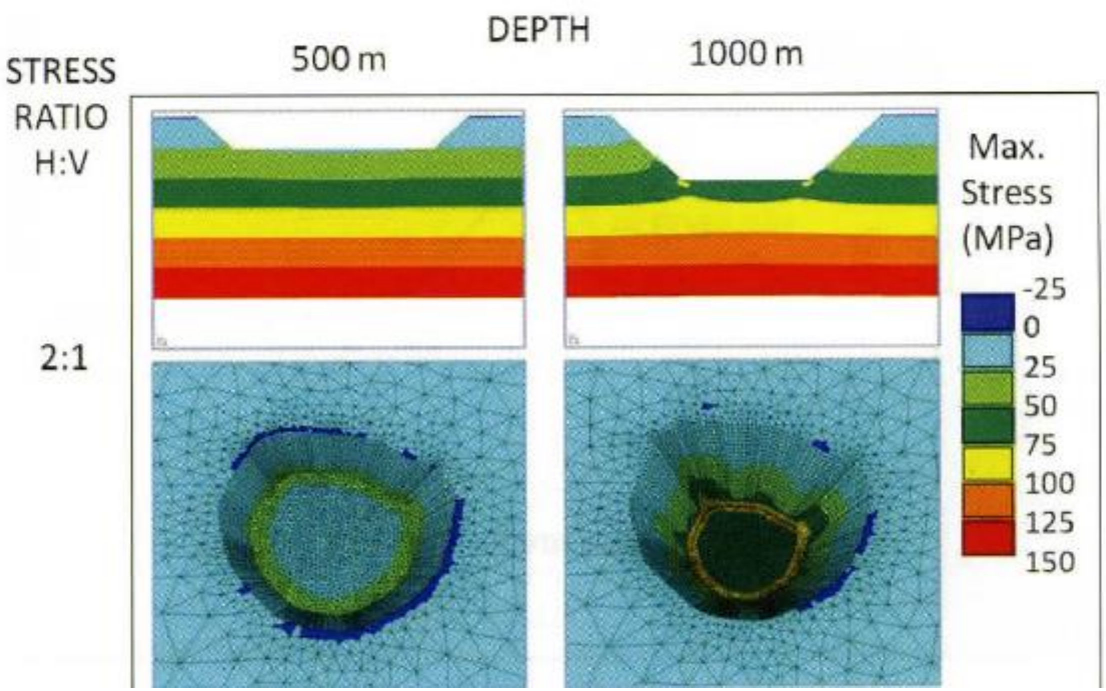
Unless there is sufficient ore remaining that can be caved

Possible Difficulty for Caving

Caving works better with low horizontal stress, but a high horizontal stress will induce caving, also



If open pit mining is stopped because of a high in situ Hz:V stress ratio, this ratio may impact the suitability of the deposit for cave mining – on the production level, for example



Source: Read & Stacey

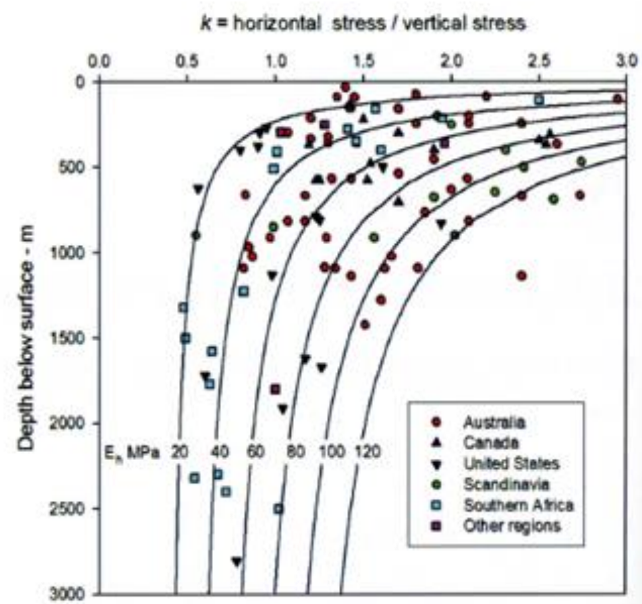


Figure A3.2: Measurements of horizontal stress in different regions of the world
Source: After Hoek & Brown (1980b)

Likely Scale Comparison

(Courtesy G. Chitombo)

- **Contemporary cave**

  Footprint : 200 m x 200 m

  Block height: < 500 m

  Production: 10,000 – 40,000 tpd

  Undercut level : < 1,000 m deep

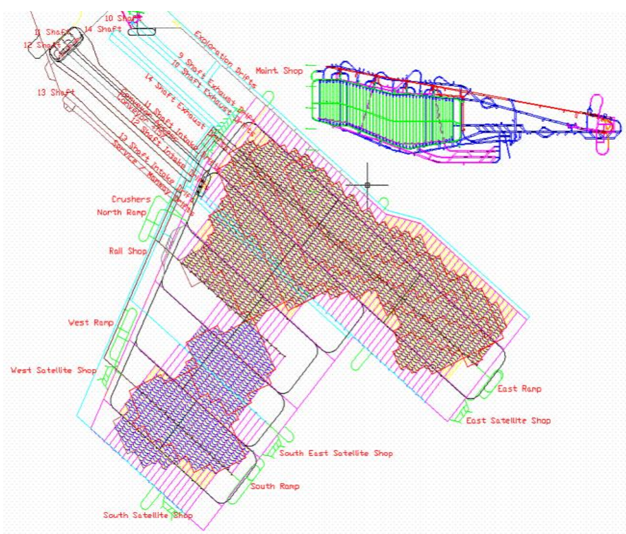
- **Supercave**

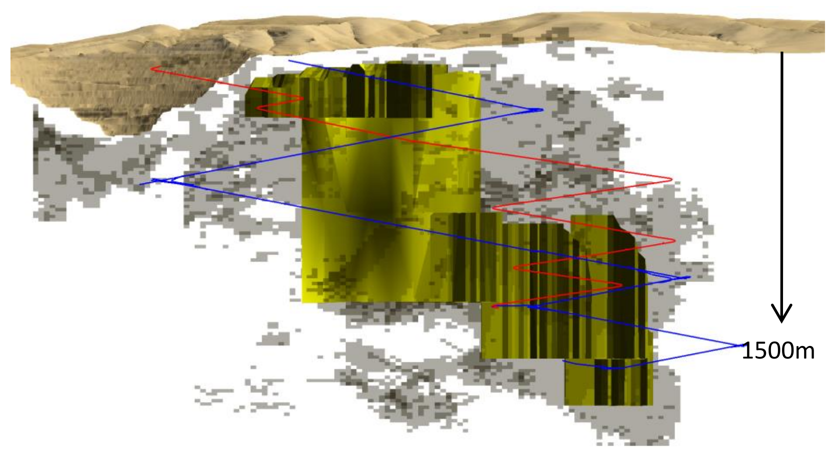
  2,000 m x 2,000 m

  >500 – 800 m

  70,000 – 100,000 tpd (single panel)

  >1,500 – 2,000 m deep





Massive Rock Caves

Two Different Operating Mines

Two Different Planned Mines

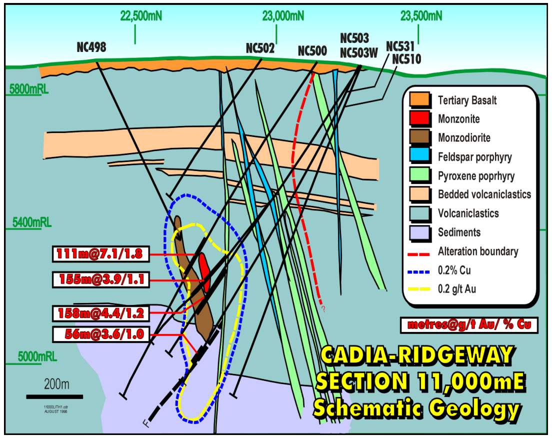
(Brown & Chitombo, 2007)

Figure 15: Orebody cores from some current and planned BPC mines

Caving produces surface subsidence

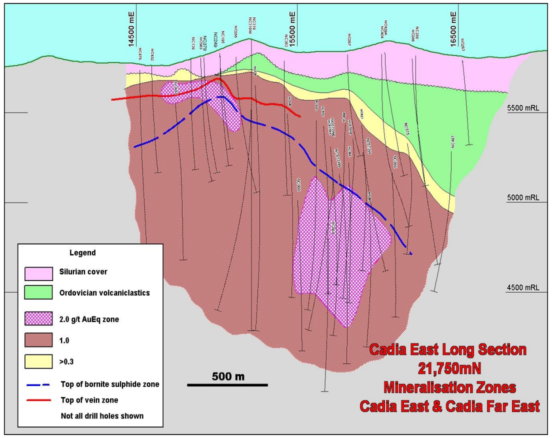
Two Deeper Discovery Examples

1994
Ridgeway
Operating mine



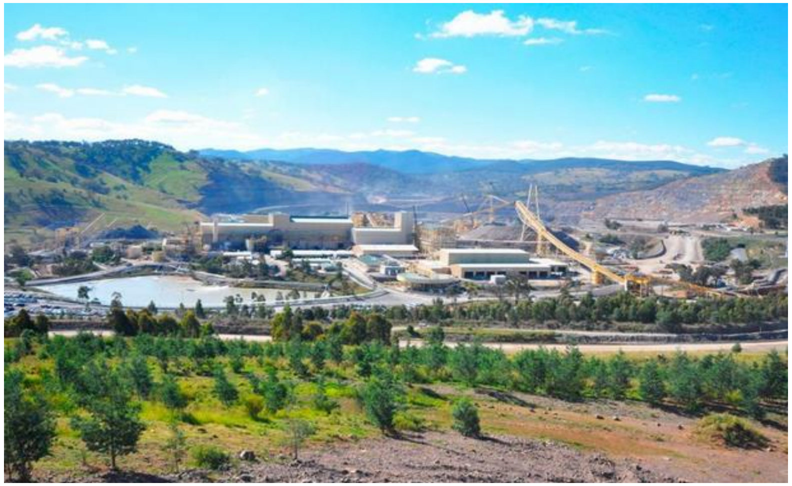
Porphyry Au-Cu deposit, 500m to top under post-mineral cover

1996
Cadia Far East
Operating mine



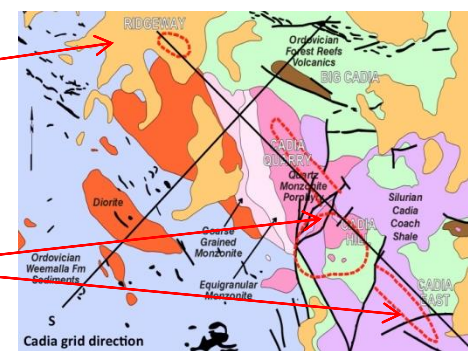
Porphyry Au-Cu deposit, 800m to top under post-mineral cover

Ridgeway Deposit, Australia

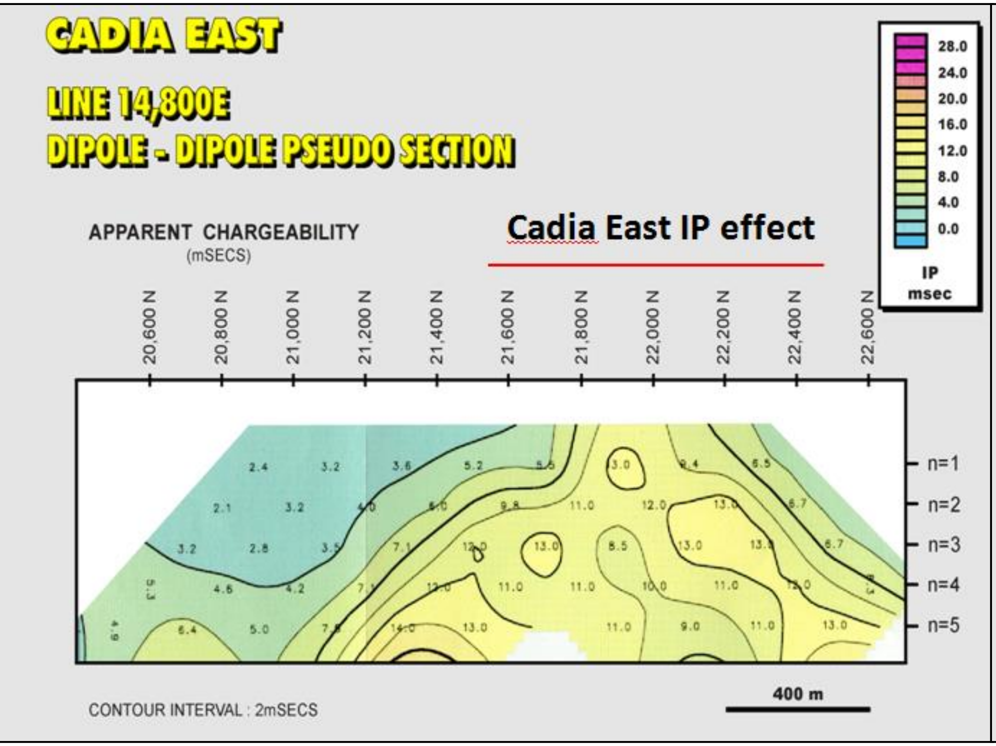


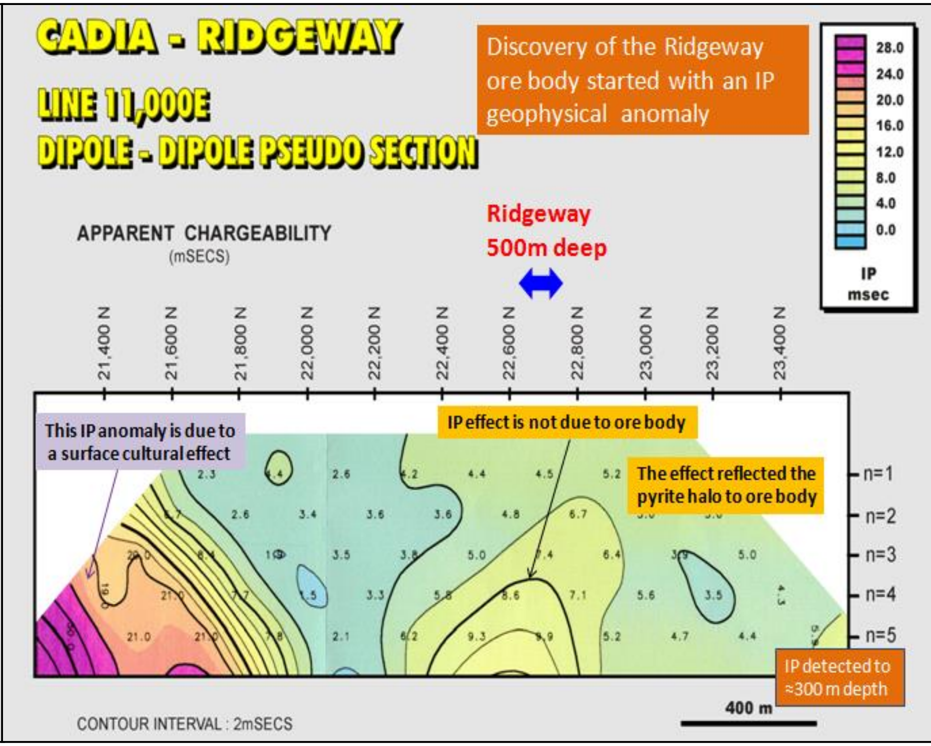
Lead-up to Discovery

- In 1992, Newcrest geologists discovered the Cadia Hill Au-Cu porphyry deposit in NSW
- *A zone of hydrothermal alteration was mapped for several km to the NW, and extending some distance under cover to the SE*
- Drilling to the SE intersected part of the Cadia East deposit, beneath ~200m of post-mineral cover rocks
- *Drilling 2km to the NW intersected un-mineralised intrusion for 1km before it was covered by Tertiary basalt*
- IP was trialled over Cadia Hill and East as a possible method for detecting porphyry mineralisation beneath the basalt cover



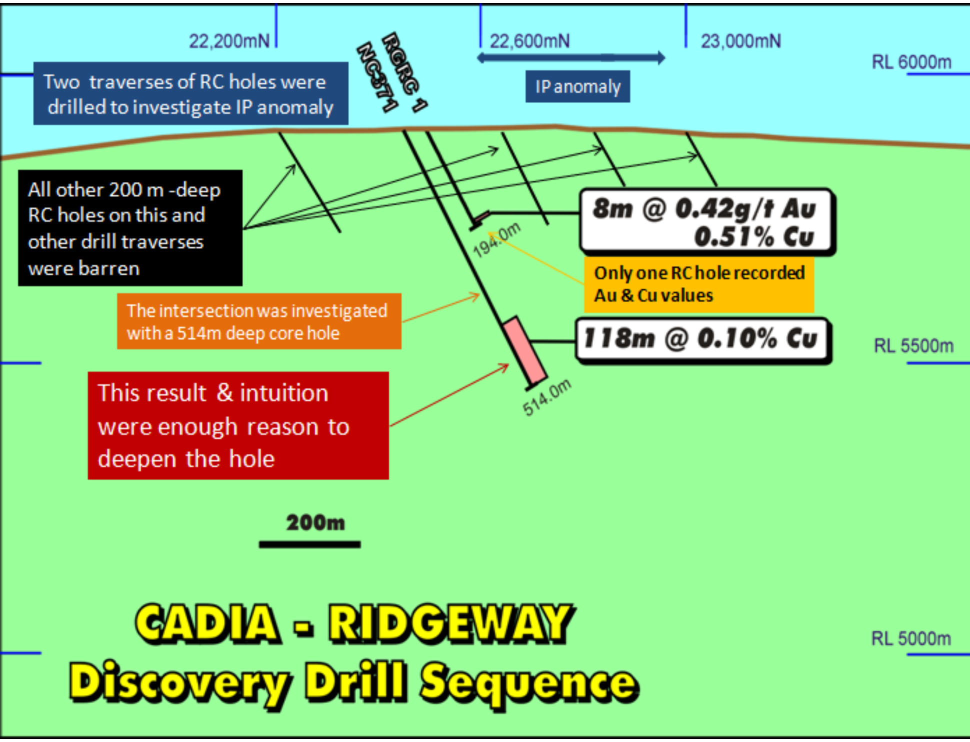
Basalt cover – Ridgeway

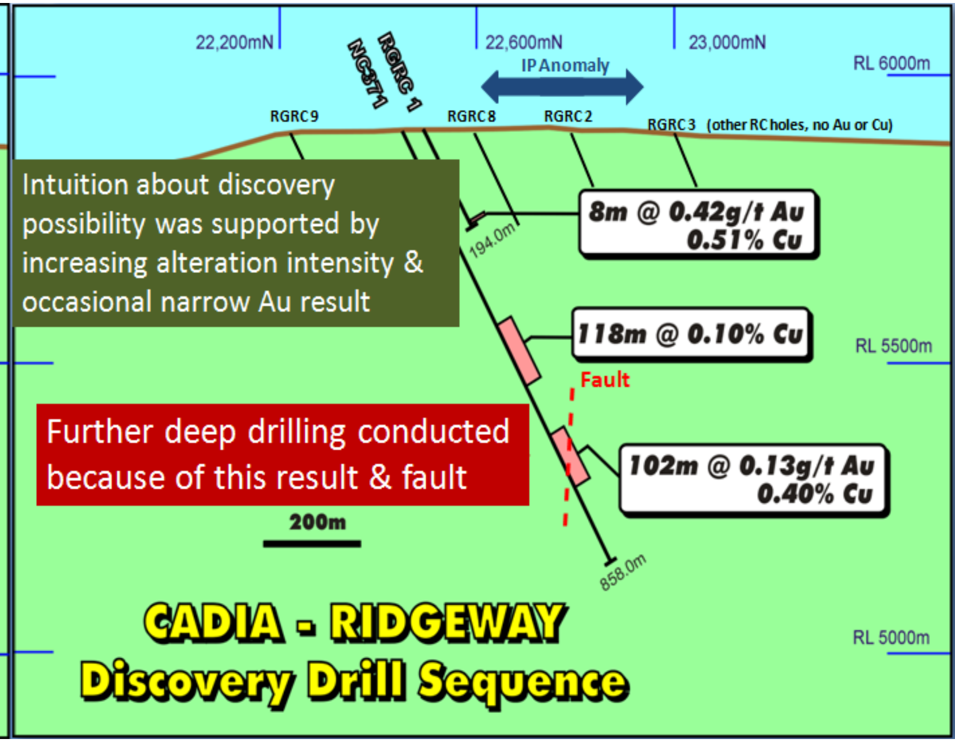




- **An IP survey using a 200 m dipole-dipole array was trialled over the outcropping Cadia Hill and covered Cadia East deposits**
- **At Cadia East, a well-defined chargeability anomaly was detected beneath 200 m of post-mineral siltstone cover**
- **In an area of Tertiary basalt cover a weaker and much smaller chargeability anomaly was detected**
- **The IP anomaly was investigated with two traverses of 200 m-deep angled RC holes**

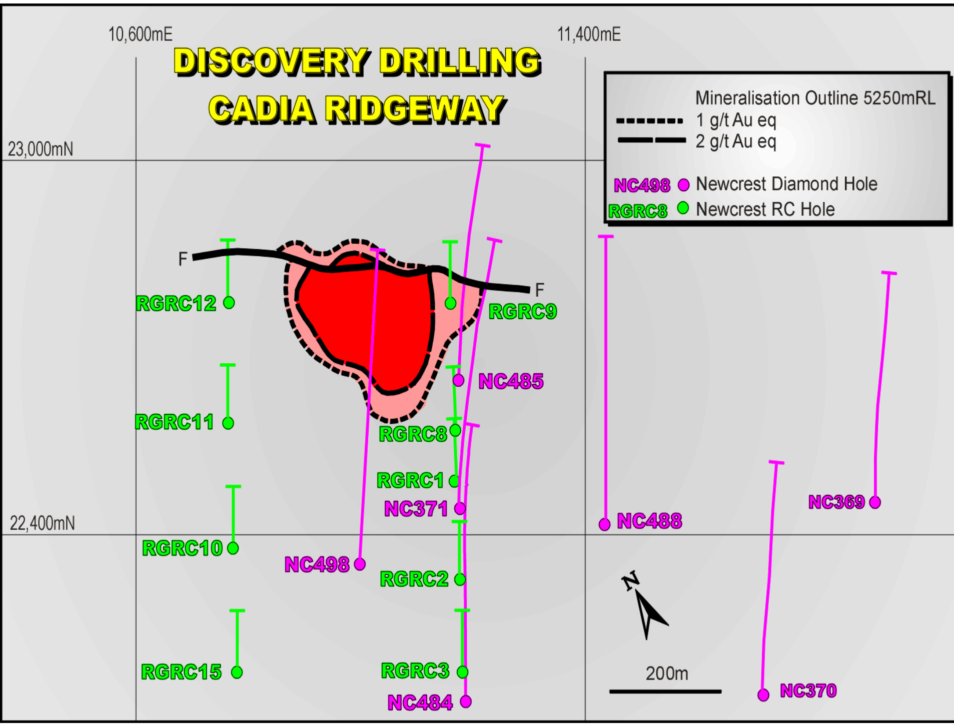
Ridgeway Discovery Drilling

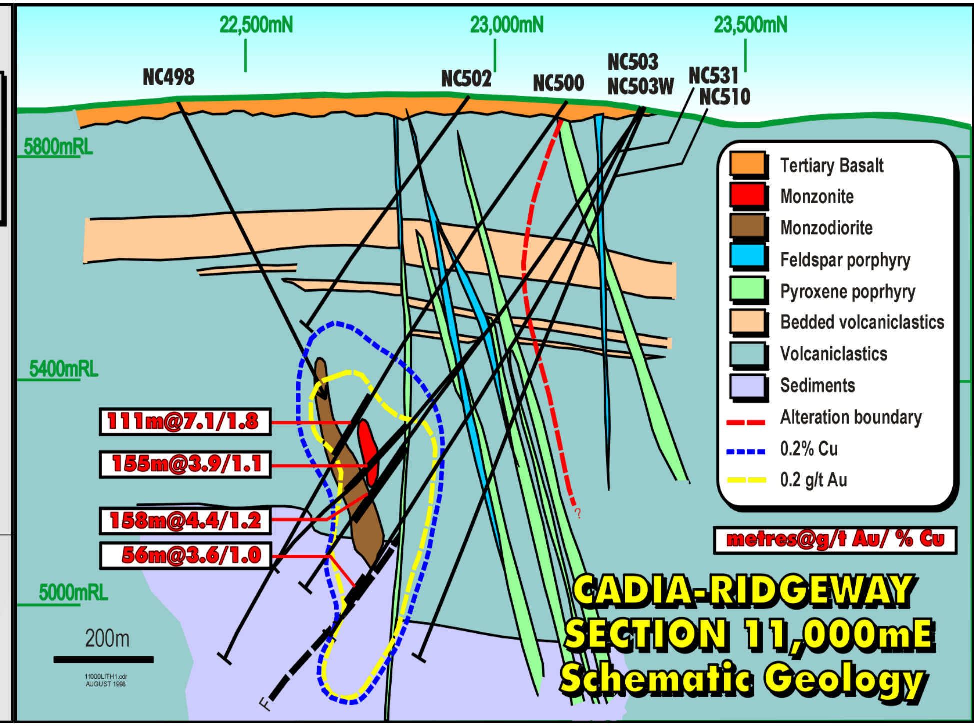




- The IP chargeability anomaly, 8m @ 0.4 g/t Au & 0.5 % Cu in one RC hole and Zn anomalism in another hole, plus pyritic (>0.5 vol. %) propylitic alteration was tested with a 'wildcat', 514 m-deep core hole
- The hole recorded 118 m @ 0.1 % Cu with several 1 m intervals of >1.0 g/t Au, plus one 2 m interval @ 10 g/t Au
- Deepening produced 102 m @ 0.1 g/t Au & 0.4 % Cu with chalcopyrite-bearing quartz veins, truncated by a fault
- Below the fault, 3 m @ 4.4 g/t Au and 3 m @ 0.3 % Cu were recorded
- Four deep core holes were drilled to investigate these results and increased alteration "reddening" and intensity

Ridgeway Discovery



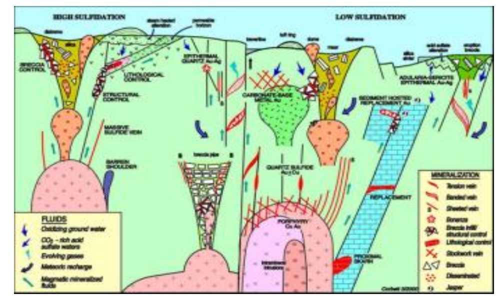


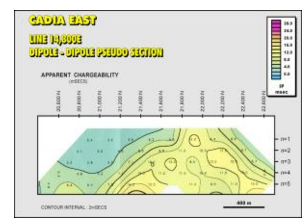
- The higher grade Au intersections and the 3 m @ 0.3 % Cu were vertical, and probably lateral, 'leakage' from the Ridgeway deposit
- Discovery came with the fourth hole – 145 m @ 4.3 g/t Au & 1.2 % Cu, plus 84 m @ 7.4 g/t Au & 1.3 % Cu
- The top of the deposit was located 500 m below surface, beneath 20 – 80 m of basalt cover

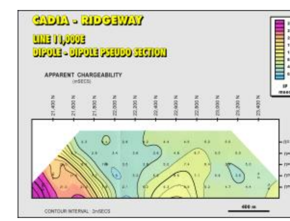
- Basic components to discovery were:
  - IP anomaly detected the pyritic alteration halo
  - Propylitic and 'red rock' alteration increased in intensity with depth
  - Drill-hole intersections leading up to drilling the four holes were interpreted as evidence of 'leakage' from a possible ore deposit

Likely Reasons for Discovery

- **Discovery of the Cadia Hill and Cadia East sheeted-vein deposits proved the district could host possibly economic Au-Cu porphyry deposits**
- *This opened up the possibility of other different types of porphyry deposit, including smaller breccia deposits*
- The initial Ridgeway target, however, was a sheeted-vein deposit similar to those at Cadia Hill and Cadia East
- *Conducting trial IP surveys over the Cadia Hill and Cadia East deposits provided a technique for locating targets under the Tertiary basalt*
- **The key to discovery was doggedly following up the weak IP anomaly overlying the Ridgeway deposit with drilling, and interpreting the meaning of the alteration and metal values recorded in deeper holes**

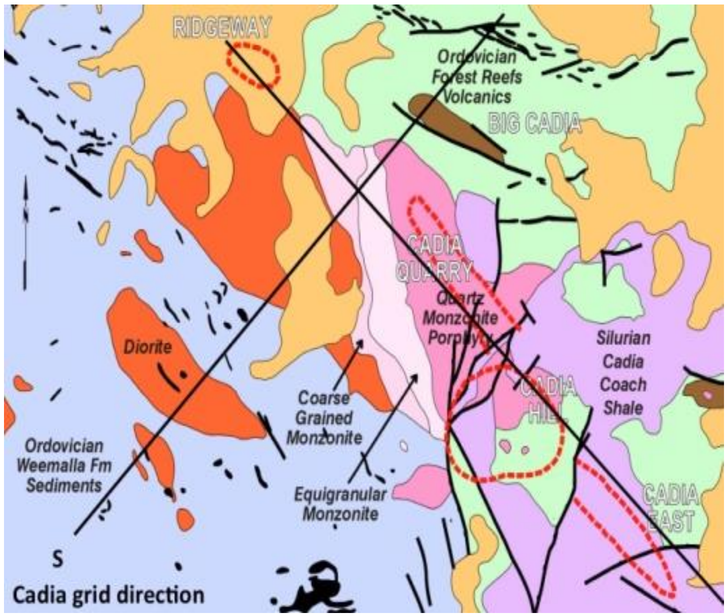


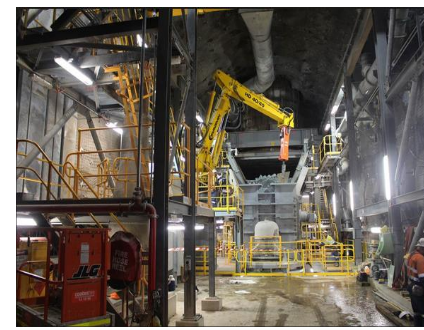




(My opinion)

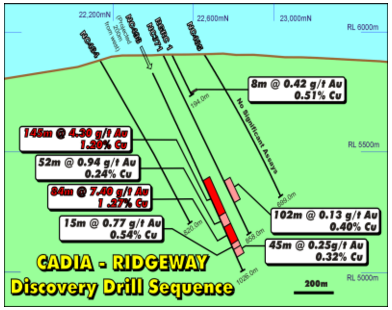
Cadia Far East, Australia

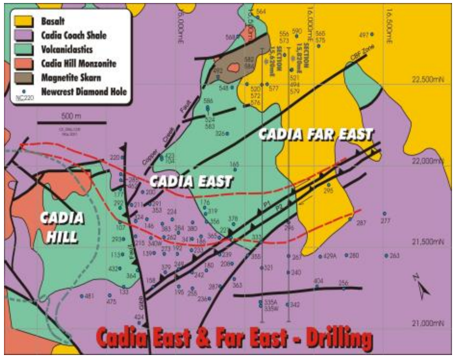


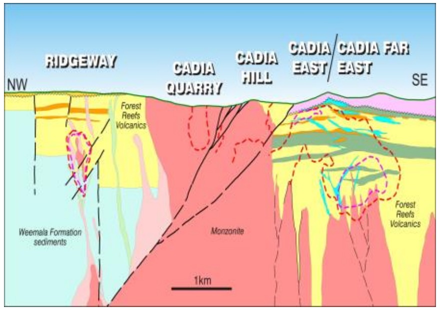


Lead-up to Discovery

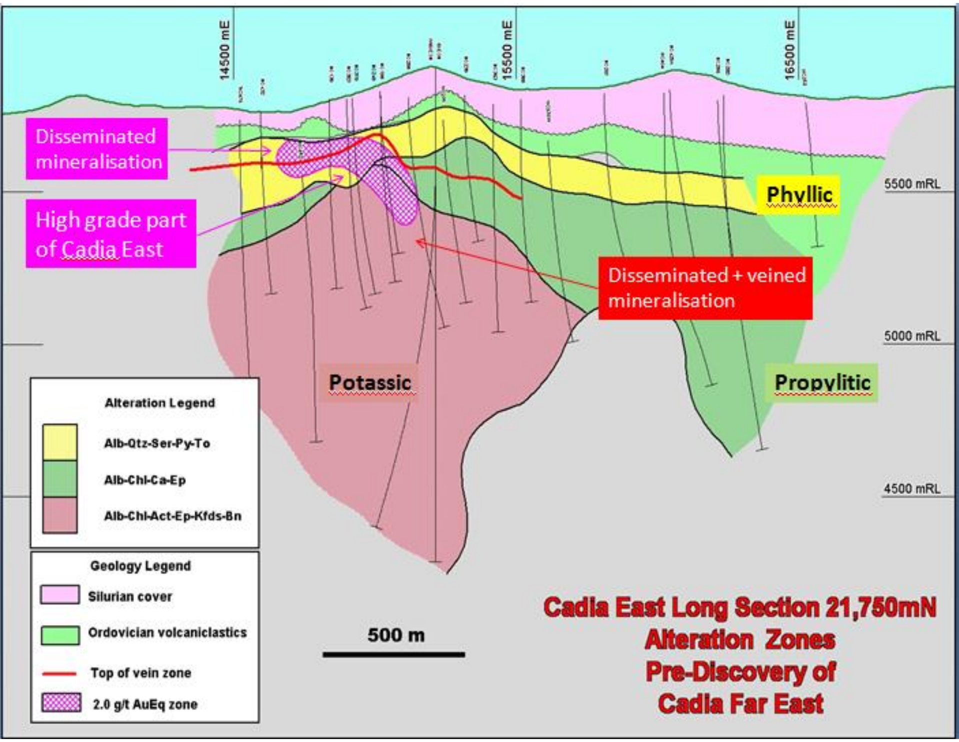
- Delineation of the Cadia Far East deposit was delayed by discovery of the Ridgeway deposit in 1996, even though the Cadia Far East discovery hole (NC494) was drilled in August of that year, while the Ridgeway discovery hole was not drilled until November
- *The NC494 intersection was 229m @ 1.3 g/t Au & 0.49% Cu from 1,103m down-hole, whereas there were two better Ridgeway intersections (hole NC498) of 145m @ 4.3 g/t Au & 1.2% Cu from 598m and 84m @ 7.4 g/t Au & 1.3% Cu from 821m.*
- **There was only sufficient budget available to accelerate definition of one of the two deposits and the Ridgeway hole had the higher grade intersections**
- *Only 10 holes were drilled into Cadia Far East over the next 2½ years, while Ridgeway was being defined*

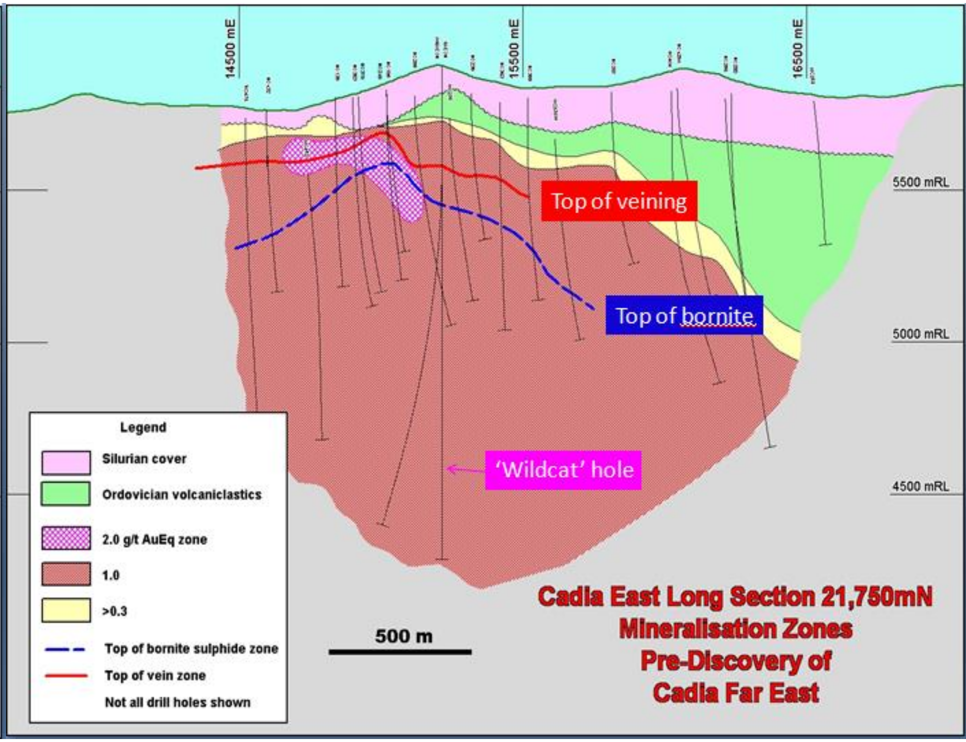






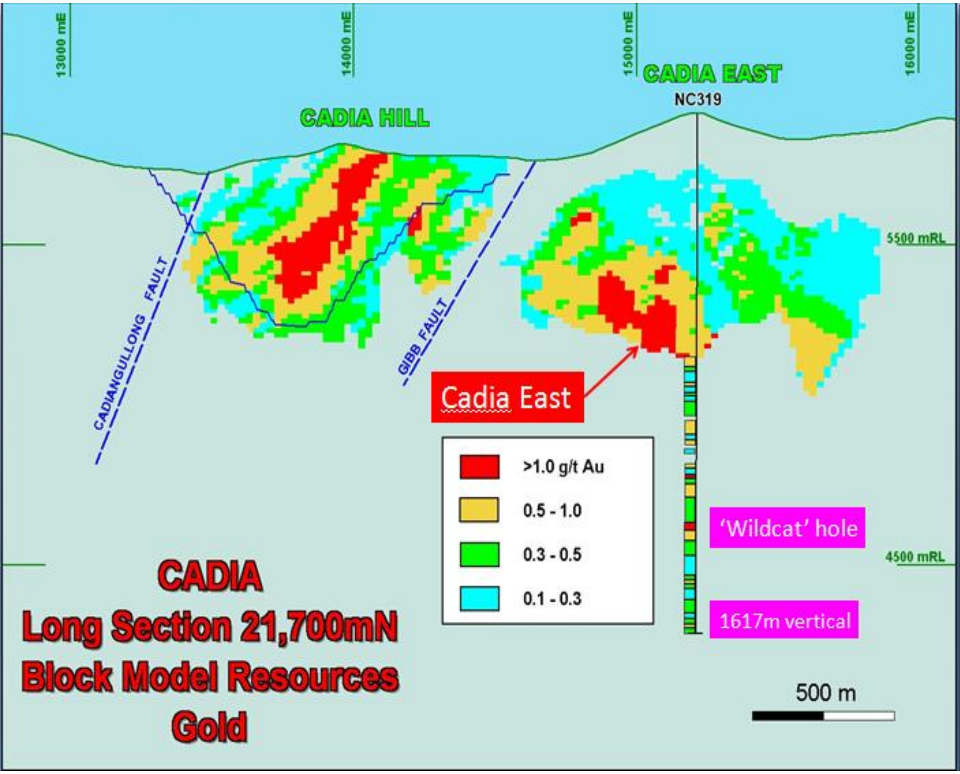
Cadia East Mineralisation

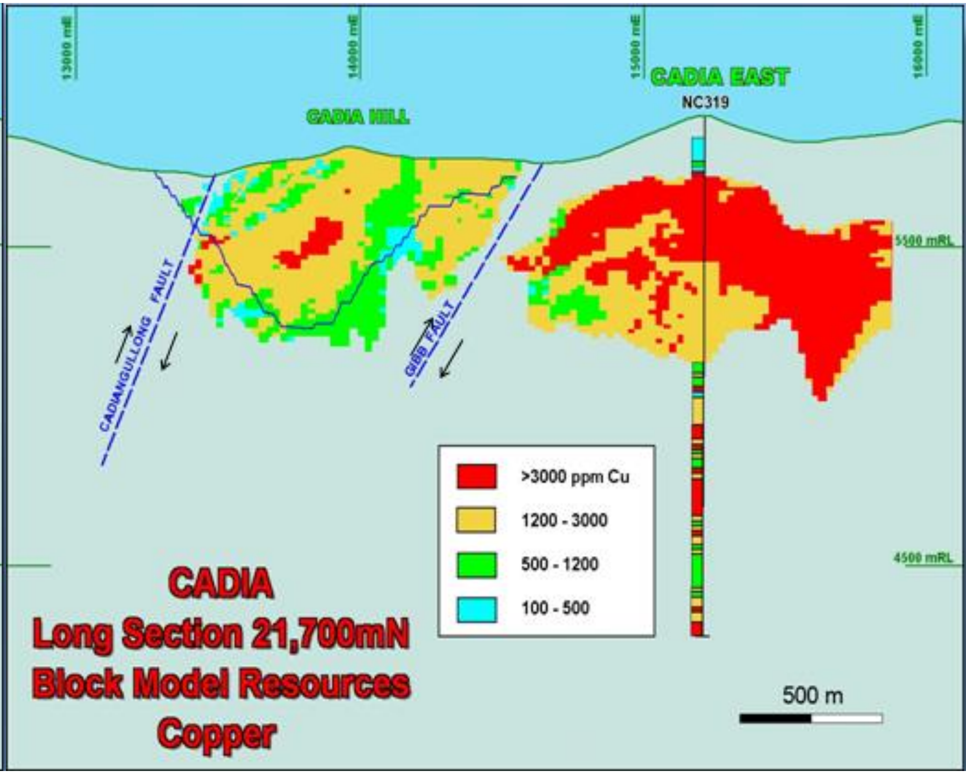




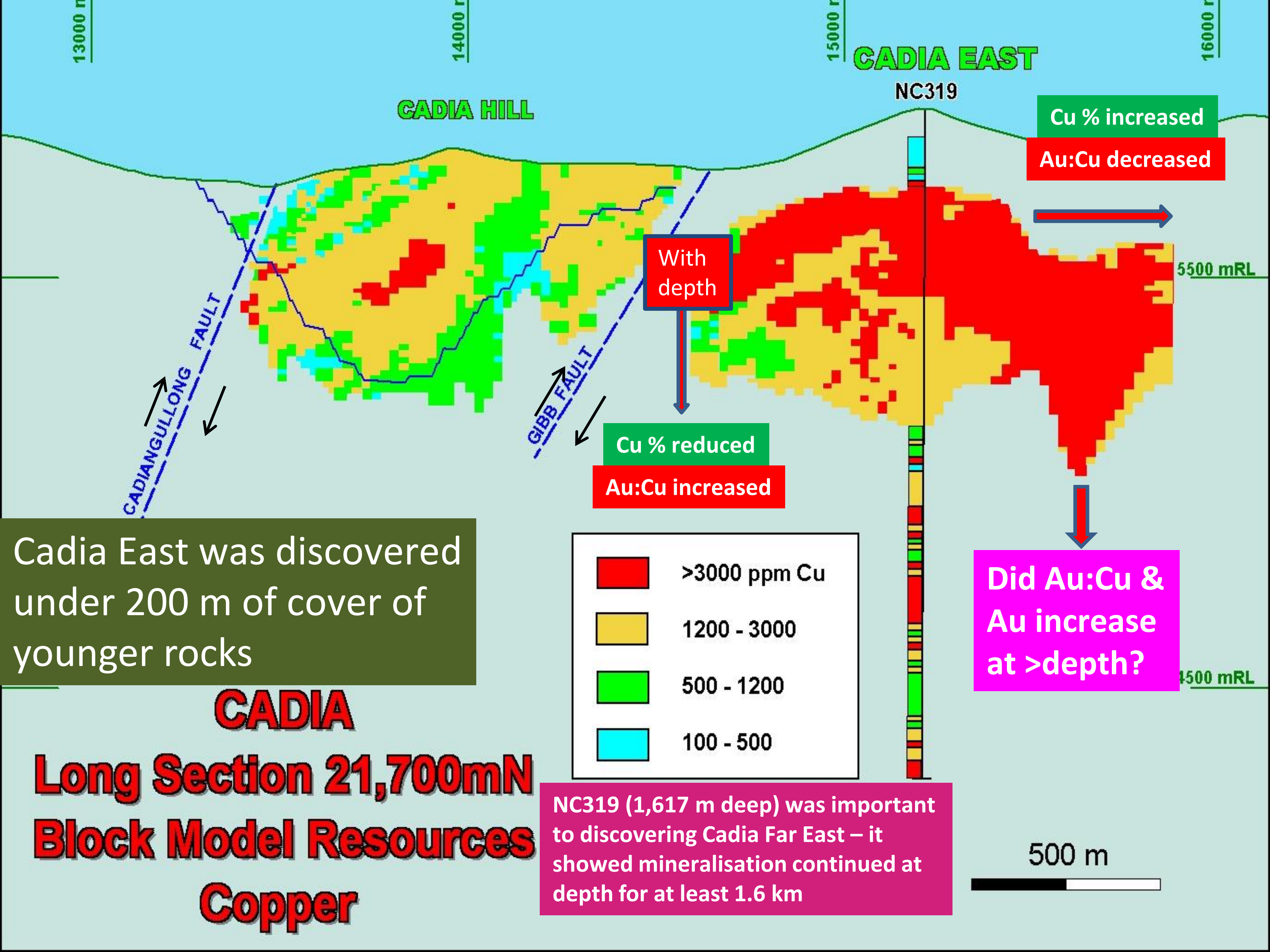
- **Disseminated and vein controlled Au-Cu mineralisation discovered at Cadia East is hosted in a flat-lying volcanic succession, to the vertical limit of drilling at the time of discovery**
- **Chalcopyrite is the dominant Cu sulphide in the upper part of the mineralised zone, passing into bornite-dominant mineralisation at depth**

Cadia East Gold and Copper

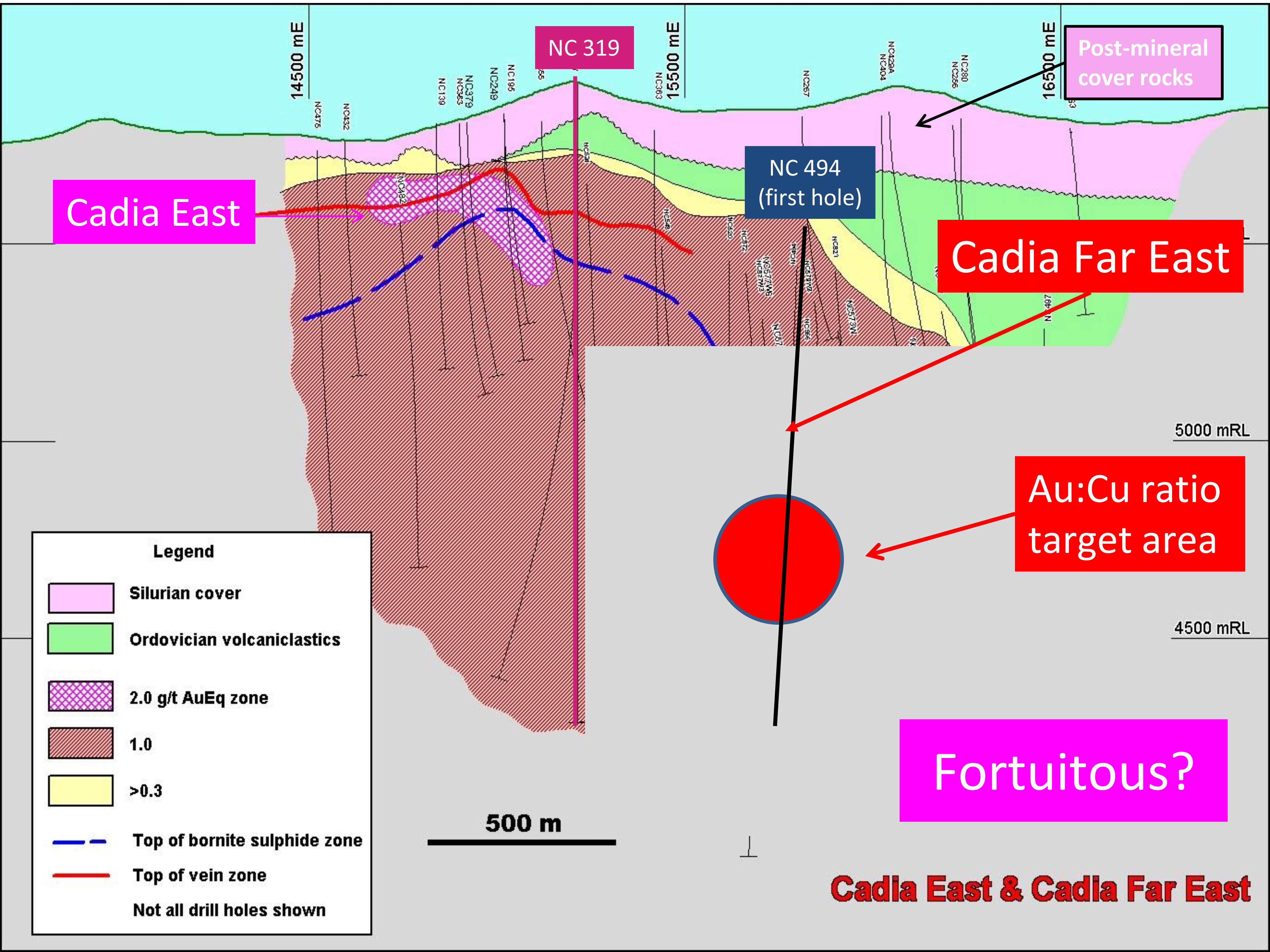




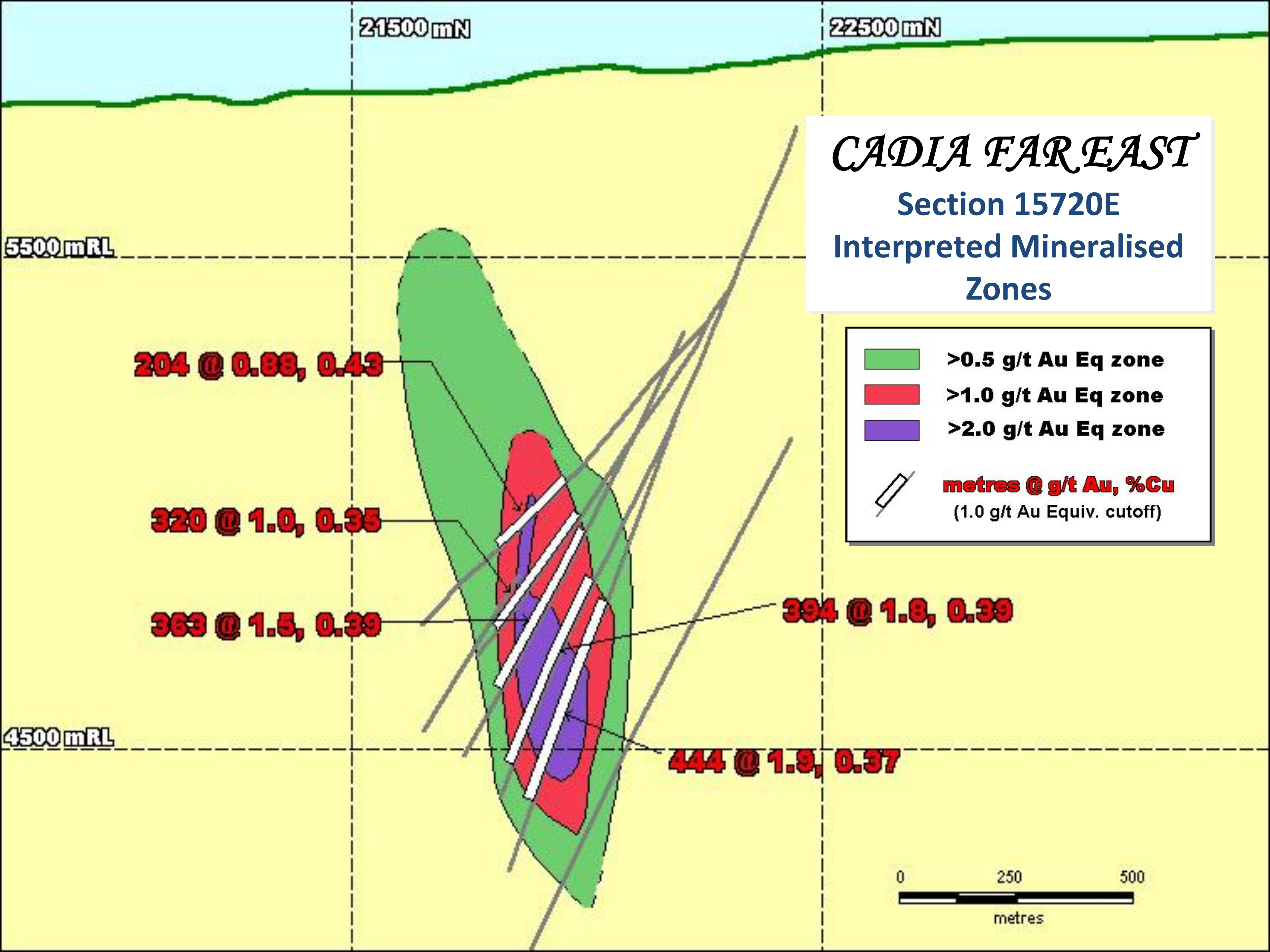
- **At Cadia Hill and in the Cadia East deposit Au is the dominant economic metal, with a well-defined zoning of grade apparent in both deposits**
- **The correlation between Au and Cu is well defined at Cadia Hill, whereas at Cadia East the pattern is different**



13000
14000
15000
16000
CADIA HILL
CADIA EAST
NC319
Cu % increased
Au:Cu decreased
With depth
5500 mRL
CADIANGULLONG FAULT
GIBB FAULT
Cu % reduced
Au:Cu increased
Cadia East was discovered under 200 m of cover of younger rocks
>3000 ppm Cu
1200 - 3000
500 - 1200
100 - 500
Did Au:Cu & Au increase at >depth?
4500 mRL
CADIA
Long Section 21,700mN
Block Model Resources
Copper
NC319 (1,617 m deep) was important to discovering Cadia Far East – it showed mineralisation continued at depth for at least 1.6 km
500 m

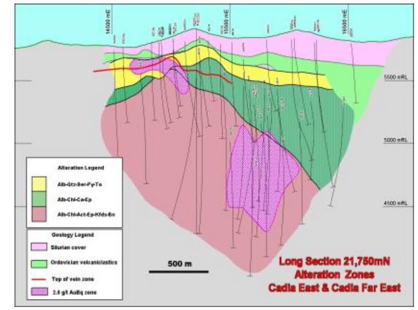


14500 mE
NC 319
15500 mE
16500 mE
Post-mineral cover rocks
Cadia East
NC 494 (first hole)
Cadia Far East
5000 mRL
Au:Cu ratio target area
4500 mRL
Legend
Silurian cover
Ordovician volcaniclastics
2.0 g/t AuEq zone
1.0
>0.3
Top of bornite sulphide zone
Top of vein zone
Not all drill holes shown
500 m
Fortuitous?
Cadia East & Cadia Far East

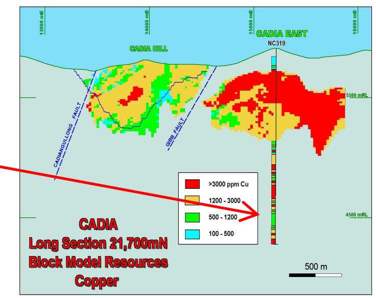


CADIA FAR EAST
Section 15720E
Interpreted Mineralised Zones
21500 mN
22500 mN
5500 mRL
4500 mRL
204 @ 0.88, 0.43
320 @ 1.0, 0.35
363 @ 1.5, 0.39
394 @ 1.8, 0.39
444 @ 1.9, 0.37
>0.5 g/t Au Eq zone
>1.0 g/t Au Eq zone
>2.0 g/t Au Eq zone
metres @ g/t Au, %Cu
(1.0 g/t Au Equiv. cutoff)
0
250
500
metres

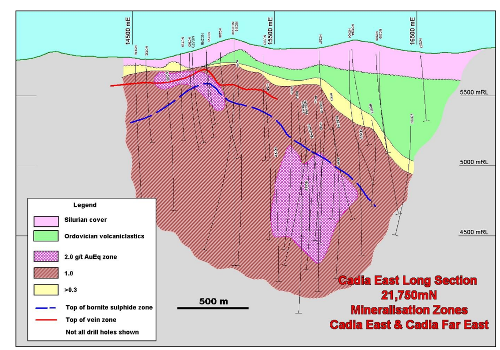
Likely reasons for Discovery



- **Geological intuition and constructing an observation- based, hydrothermal alteration model for Cadia-style porphyry mineralisation played a very important role – exploration decisions were not made using other porphyry deposit models that were different**



- *The early decision to drill a 'wildcat' hole to 1617m vertical depth to investigate the geology was similarly important; it established that Au-Cu mineralisation continued to >1,600m depth*
- **The freedom to drill fully-cored holes to 2 km depth**
- *The technical reason for discovery was interpreting the Au:Cu ratio as a possible indicator of Au grade*

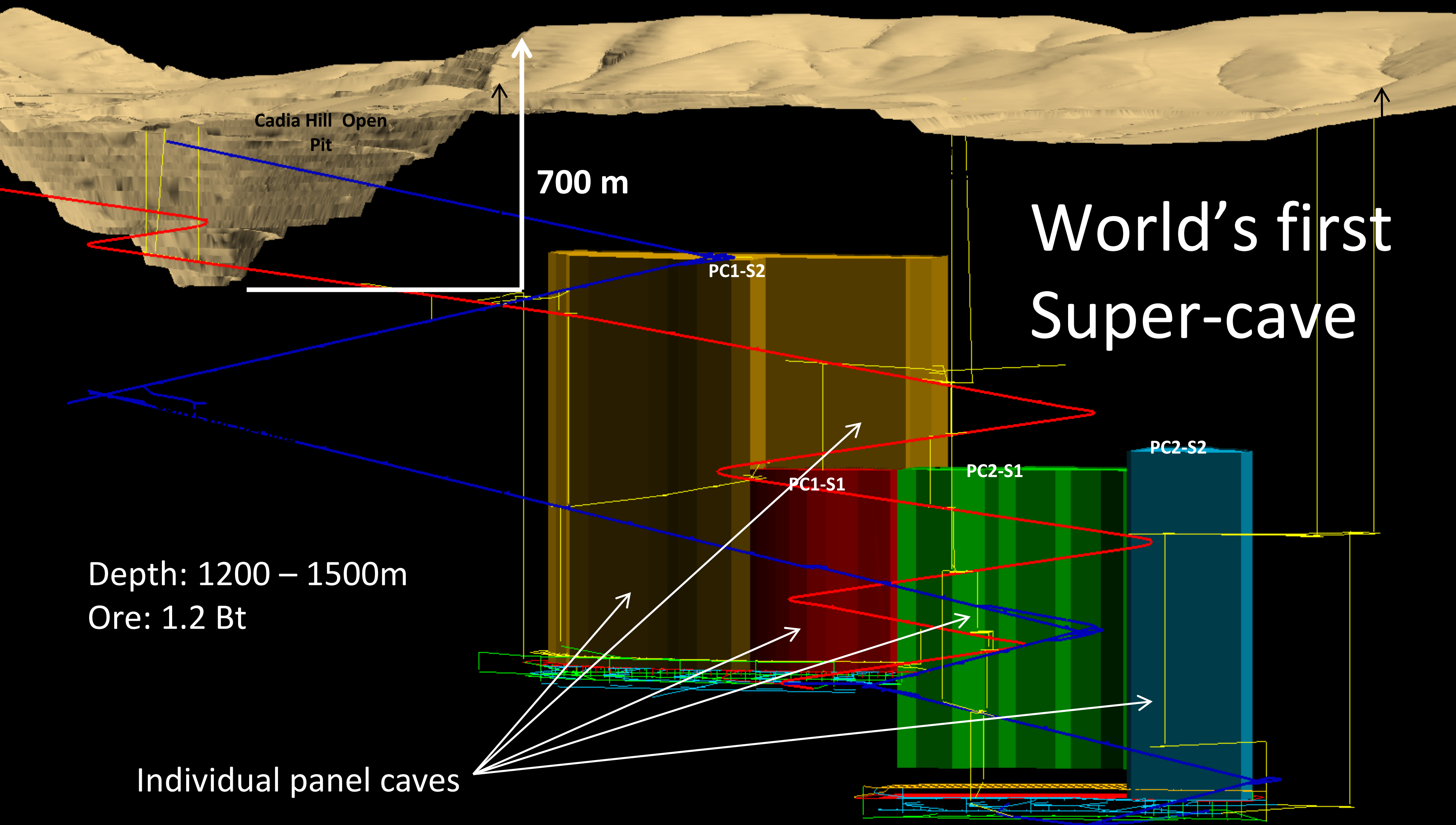


- **The key was testing this interpretation with a fortuitously-sited deep hole – NC 494 – which penetrated the centre of the higher grade part of the Cadia Far East deposit**

(My opinion)

Cadia East Mine

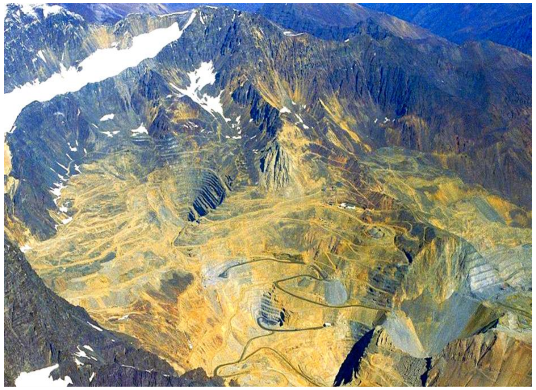
(courtesy Newcrest Mining Limited)

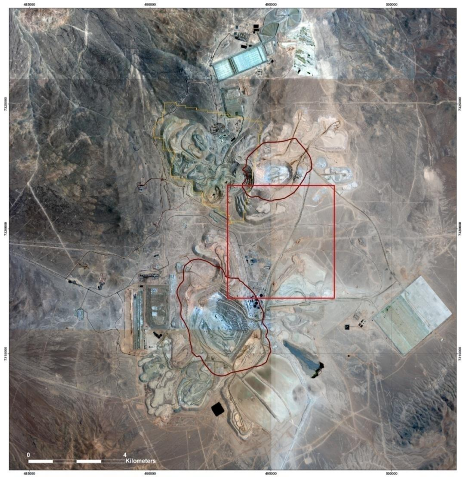



Ridgeway
Big Cadia skarn
Cadia Quarry
Cadia Hill
Cadia East

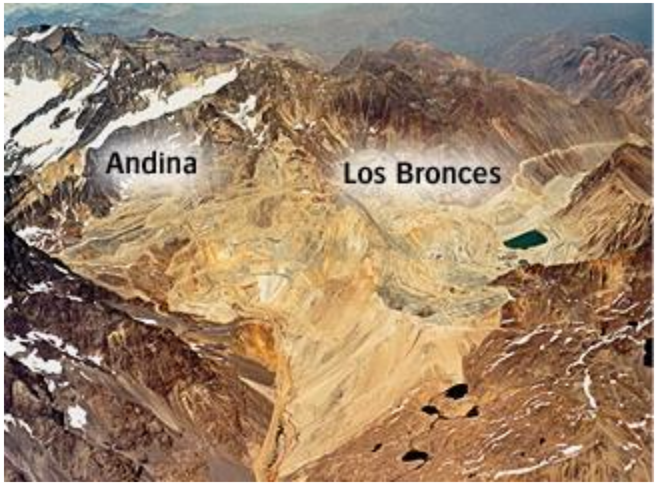
Other Deeper Discoveries

- **Andina Mine, Chile**
- *La Americana and Cerro Negro Cu-Mo porphyry deposits in Rio Blanco-Los Bronces District (Rivera et al., 2012)*
- **Escondida Mine, Chile**
- *Pampa Escondida (Herve, 2011)*





Recent Andina Discoveries



Andina Mine, Chile

2011 production 234 Kt Cu + 3 Kt Mo
Resources: 16.5 Bt at 0.56% Cu or 92.6 Mt Cu

La Americana discovery (2009)

Andina Mine area looking south

Cerro Negro discovery (2011)

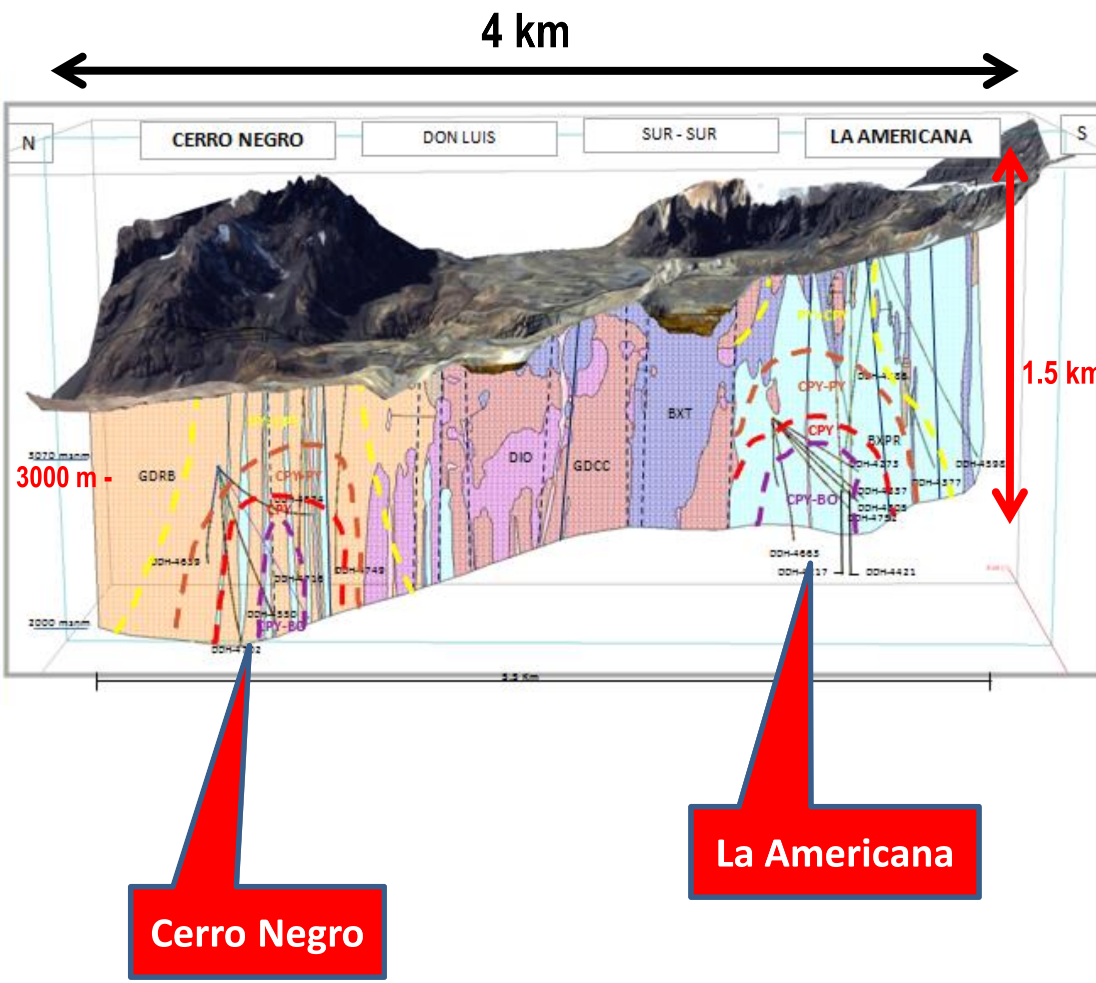
(Courtesy: Sergio Rivera)

La Americana & Cerro Negro

(deep porphyry Cu-Mo discoveries)

discoveries)

La Americana – Cerro Negro long section (looking east)



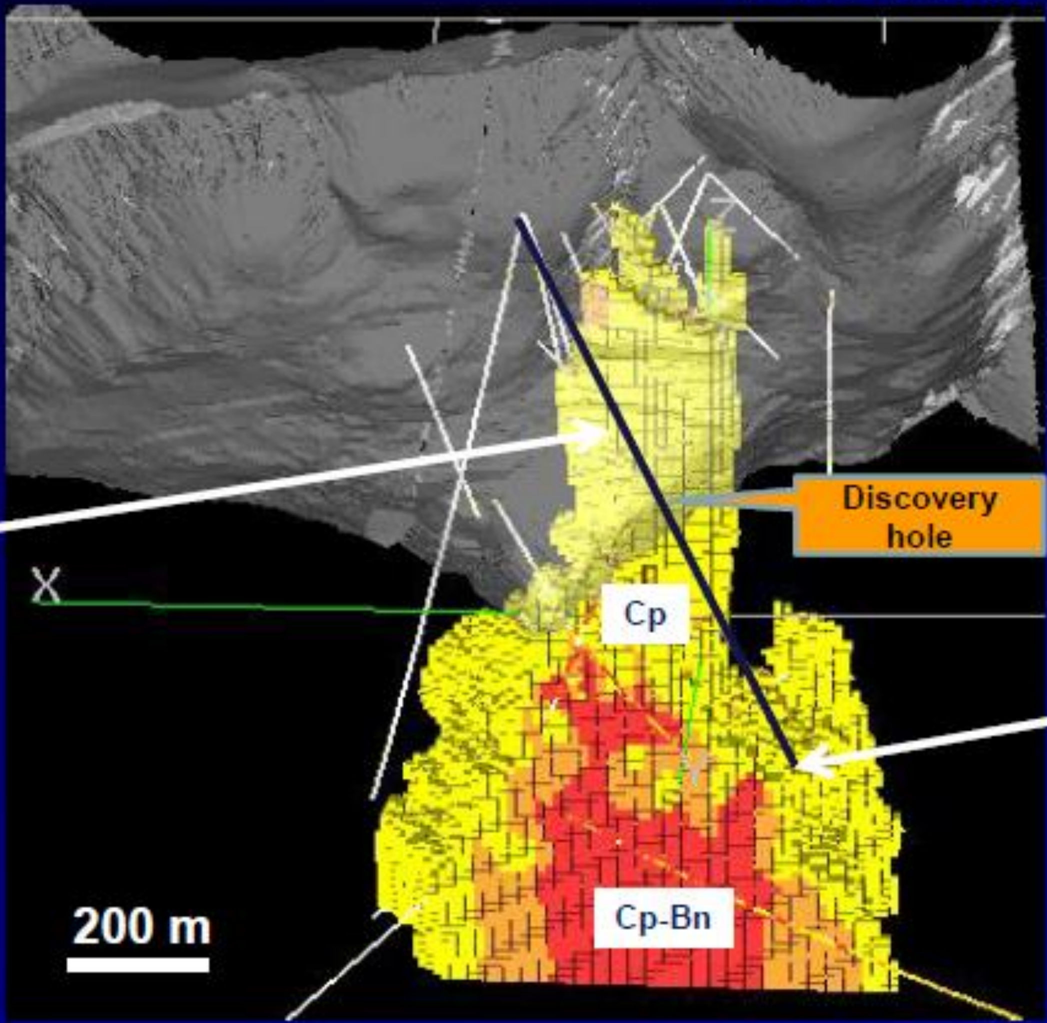
Andina Mine operation and exploration areas

(Courtesy: Sergio Rivera)

La Americana geology and mineralization: Resources > 850 Mt at 0.6% Cu + 0.02%Mo

(Codelco, Memoria Anual 2009 and 2010)

Breccia style



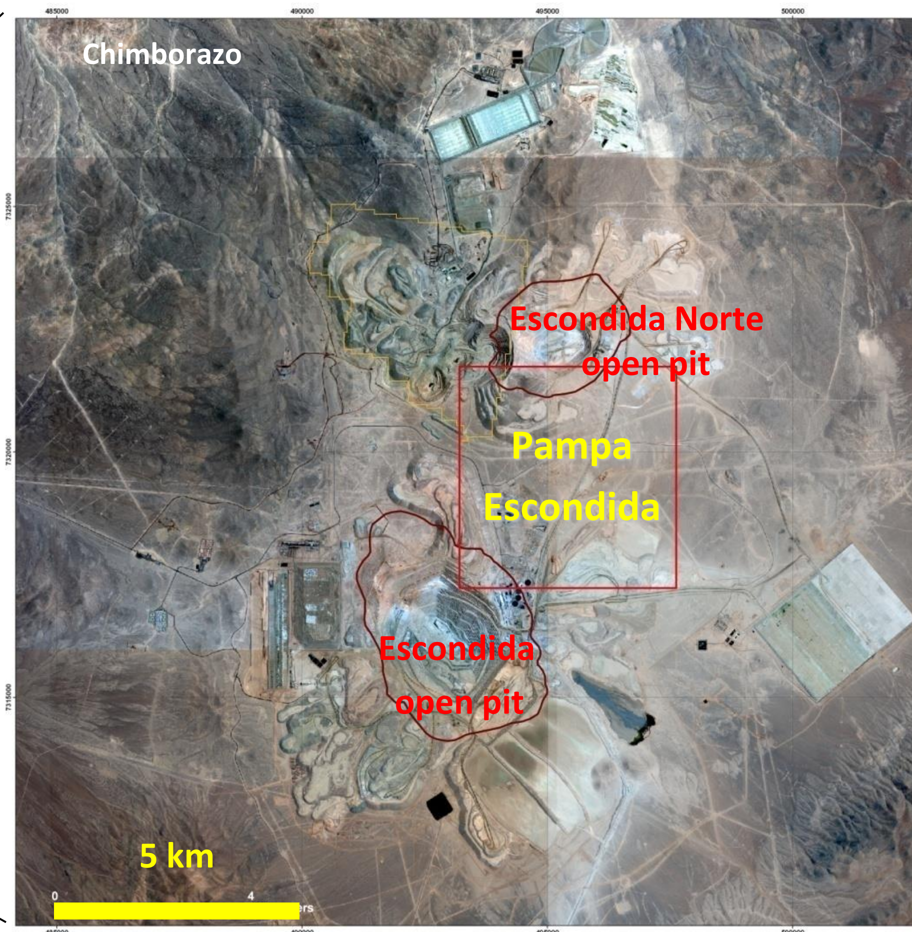
La Americana 3D Block Model

Porphyry style

(Courtesy: Miguel Herve)

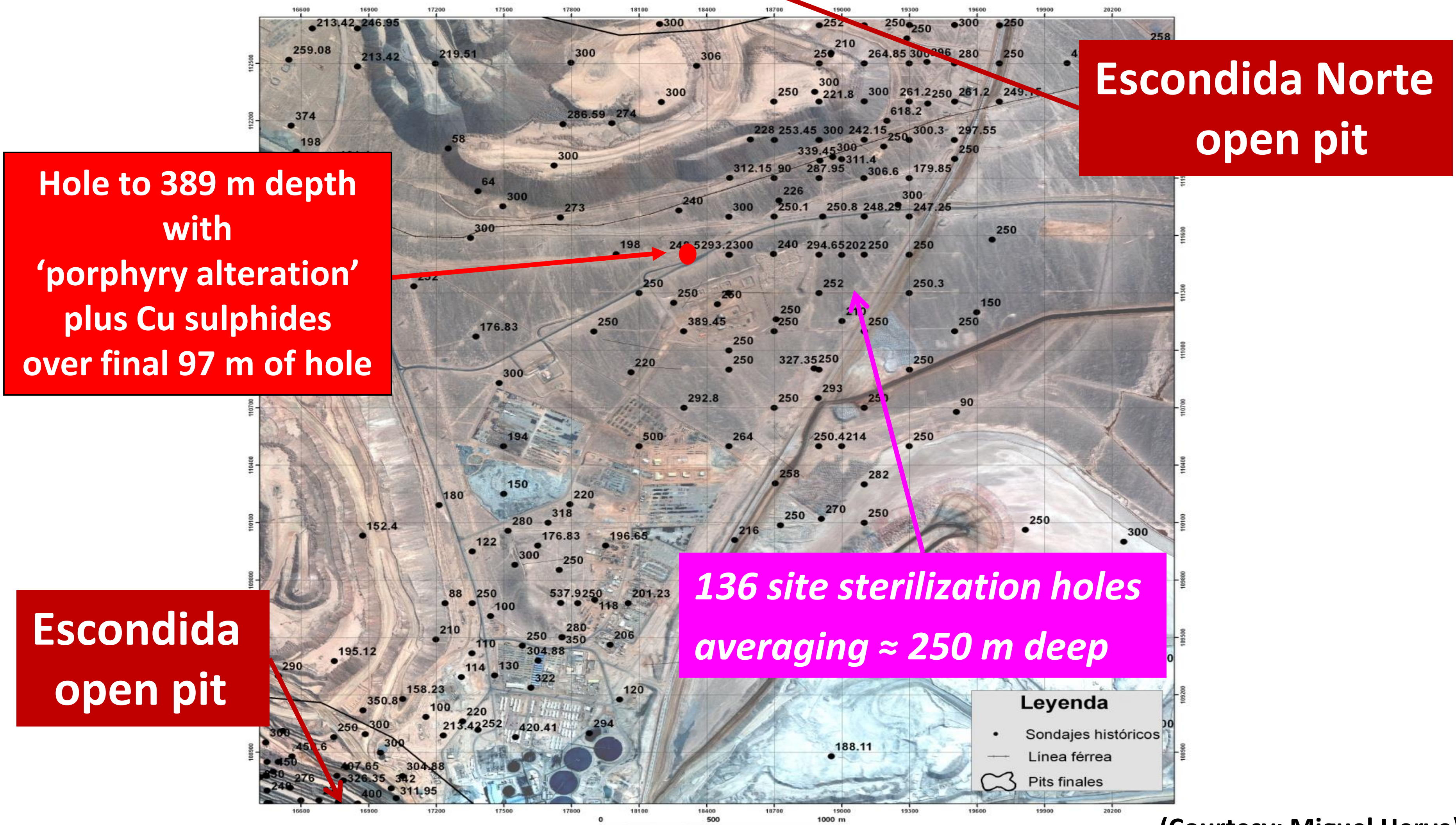
Pampa Escondida Discovery

Pampa Escondida, Chile



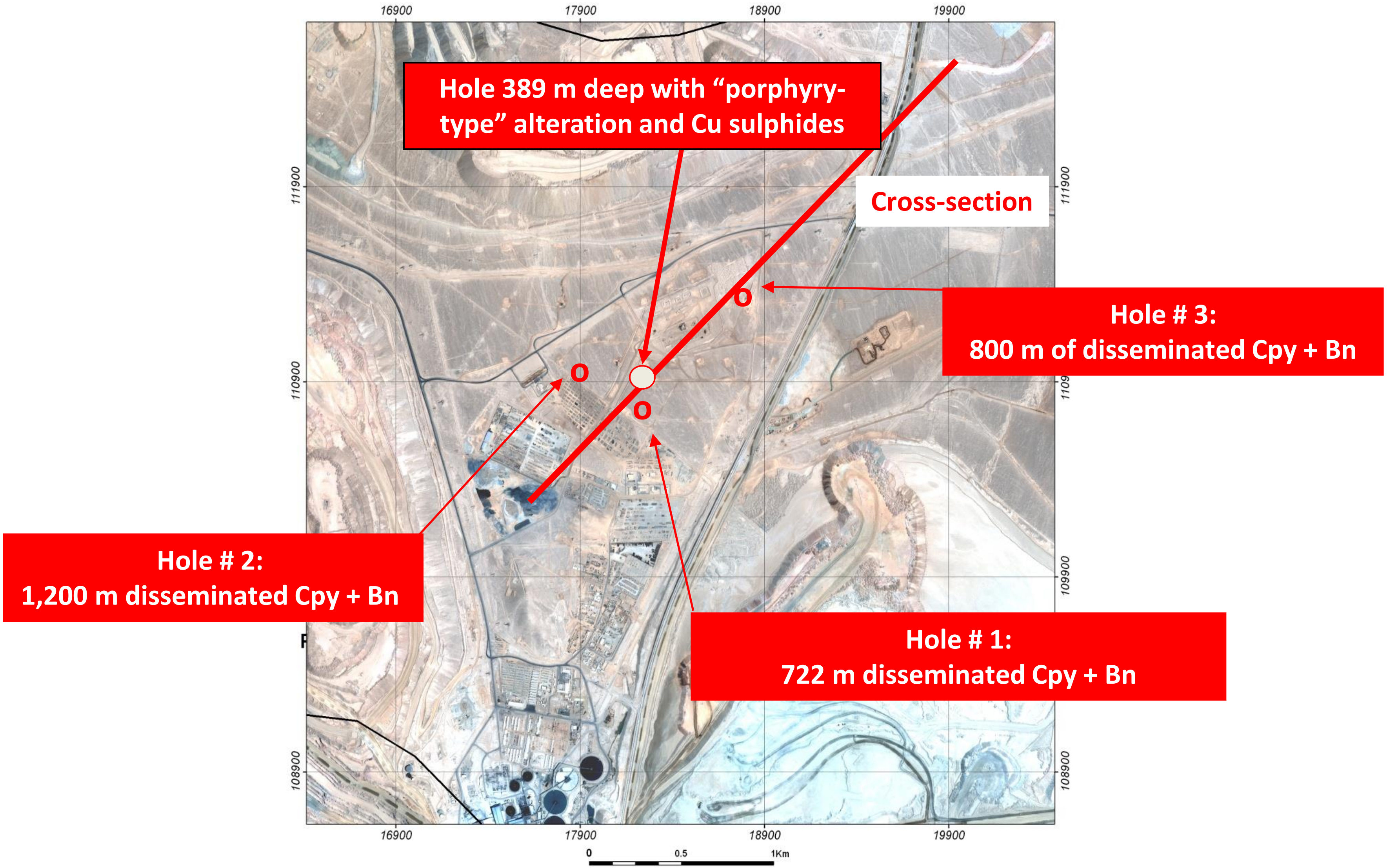
(Courtesy: Miguel Herve)

Pre-discovery Drilling



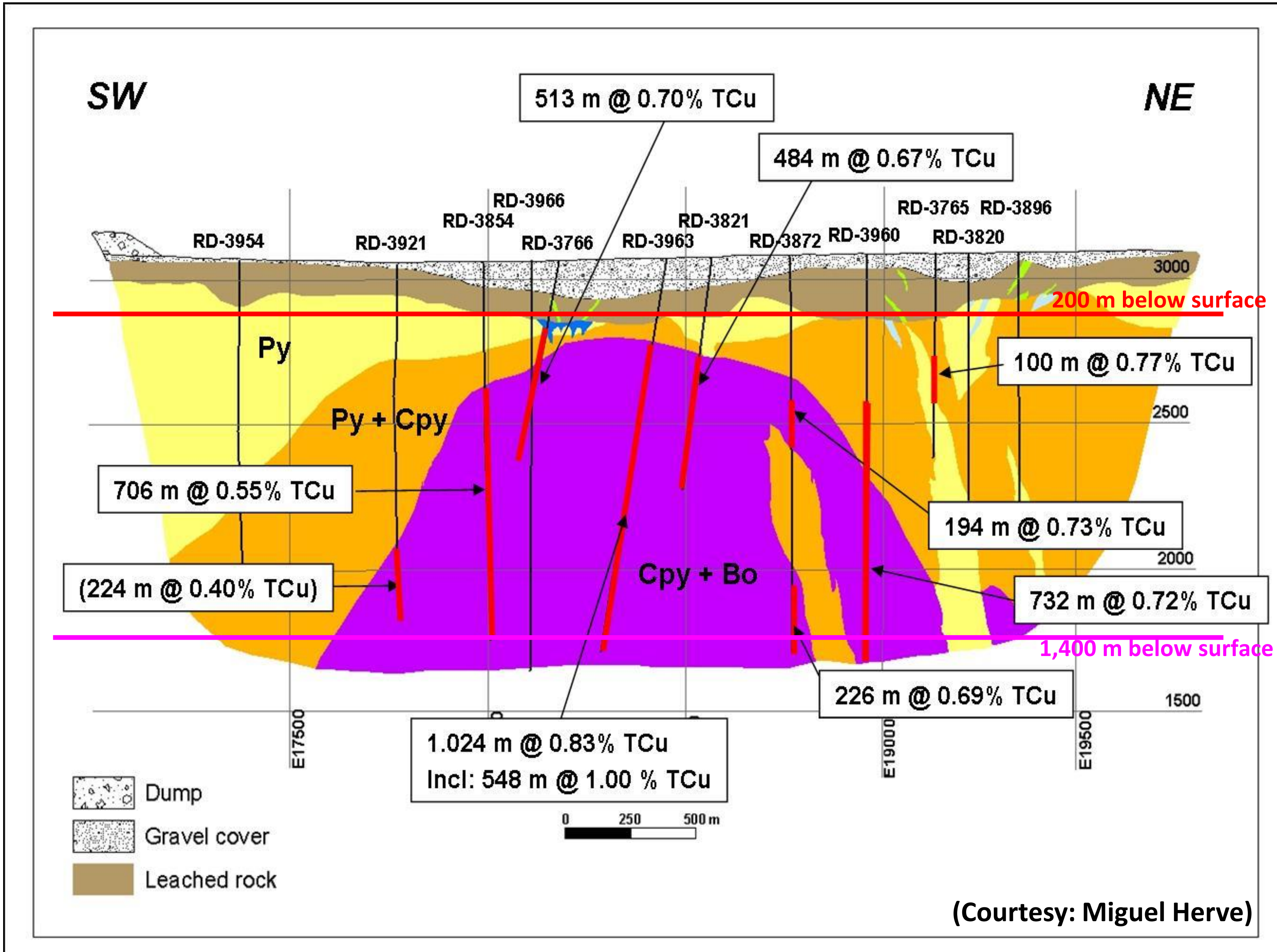
(Courtesy: Miguel Herve)

First three holes *(January – June 2007)*

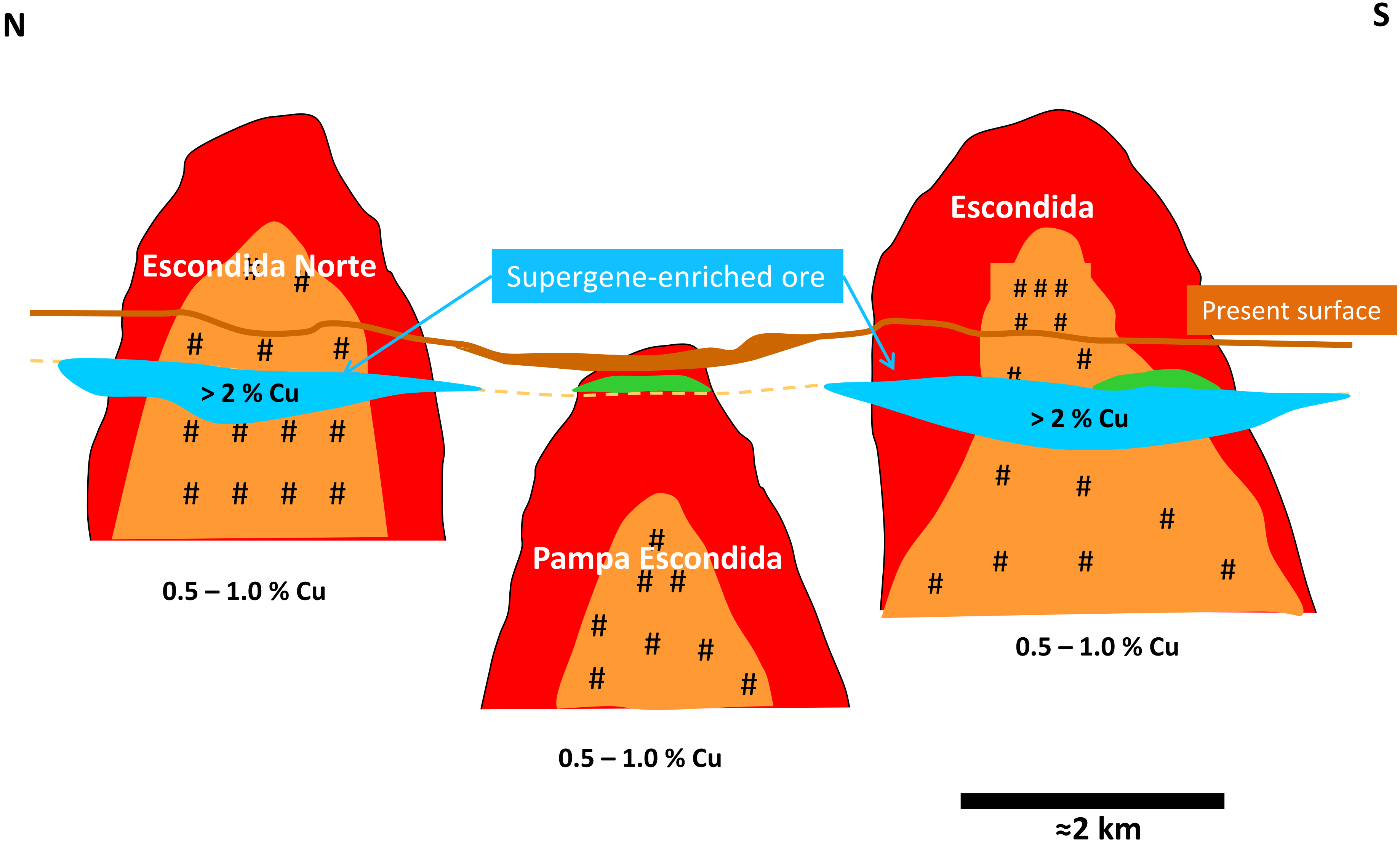


(Courtesy: Miguel Herve)

June 2008 Intersections



Schematic N-S Section



(Courtesy: Miguel Herve)

Likely Reasons for Discovery

- **Interpreting geological information in the context of an ore body model**
- *Identifying the presence of bornite at the bottom of an existing hole*
- **Deep drilling to investigate "hypothesis" based on observation**

(My opinion)

Some Concluding Remarks

Follow Sig Meussig's canons:

- Look for ore, not mineralisation
- To find an ore body, you need to drill holes
- There needs to be room for the ore

Deeper is the new Greenfield

- Deeper only means >300 m depth
- In seeking underground mining targets, know what is required for mining

- **Above all, Drill Holes!** *(The worst outcome of drilling is failure to discover ore, which is essentially guaranteed in exploration, anyway!)*

Drilling for Geology is OK

A Drilling Rig is only a very large geology hammer

Thinking this way makes it easier to drill deep holes


Future Mining & Ore Processing
Deep Underground


Thankyou