USGS
science for a changing world

Mineral Deposit Economics

To Mine Or Not To Mine

Keith R. Long
Mineral Economist
Tucson, AZ
klong@usgs.gov

U.S. Department of the Interior
U.S. Geological Survey

Decision Process for a New Mine

- Sequential information-generating process
- Complex, multi-disciplinary effort
- Multiple stakeholders
- Long lead-times
- High-risk
- Costly – direct costs and opportunity costs

USGS

Sequential Process

- Some 12 principal steps and decision points
- Resulting flow chart too complex to visualize easily
- Each step yields an incremental increase in information
- Each step ends with an evaluation of the new information and what that implies for the risked value of the project

USGS

Complexity

- Multiple disciplines used to evaluate an exploration project
- Geology
- Geochemistry
- Geometallurgy
- Geophysics and rock mechanics
- Environmental science
- Economics
- Mining and mineral processing engineering

USGS

Stakeholders

- Investors
- Mine developers and operators
- Land and mineral right owners
- Water and access right owners
- Government agencies
- Indigenous peoples
- Potential employees
- Neighbors and local communities

USGS

Lead Time

- 17 new metal mines developed in the US from 2000 to 2010
- Time required to *permit* an operation ranged from 2 to 17 years
- Statistics on *total* lead time difficult to generate
- Here I use the Cadia Hill mine as an example – 12 years from start of exploration to full production

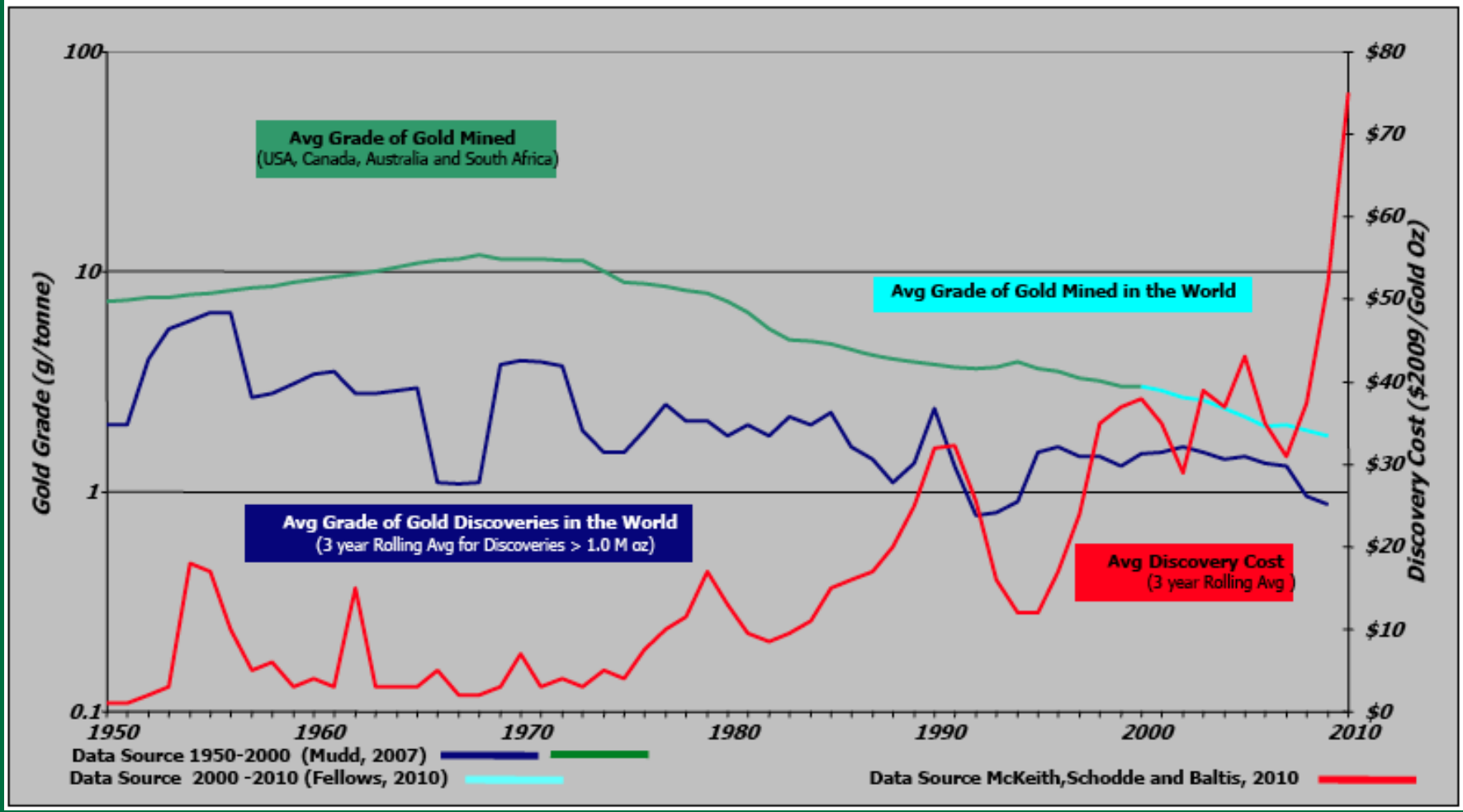
USGS

Risks

- Low exploration success rate – historically Rio Tinto had one mine per 3,000 prospect ideas; since reduced to 2,000
- Many other risks – political, economic, environmental
- Compare with oil and gas – 3 productive wells for every 10 exploration drill holes
- Compare with pharmaceuticals – 16 percent of new drugs approved

USGS

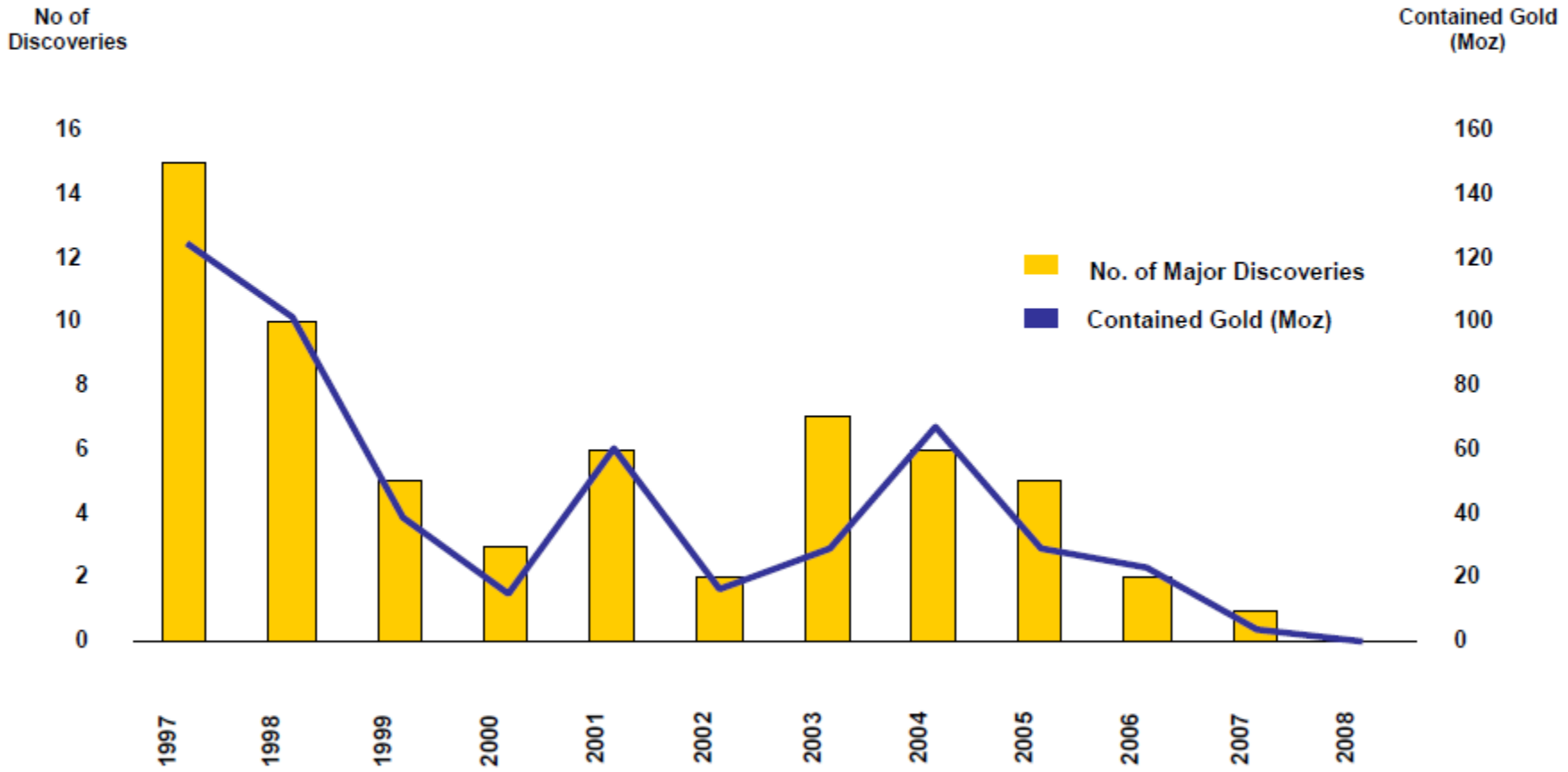
Gold Grades and Discovery Costs



USGS

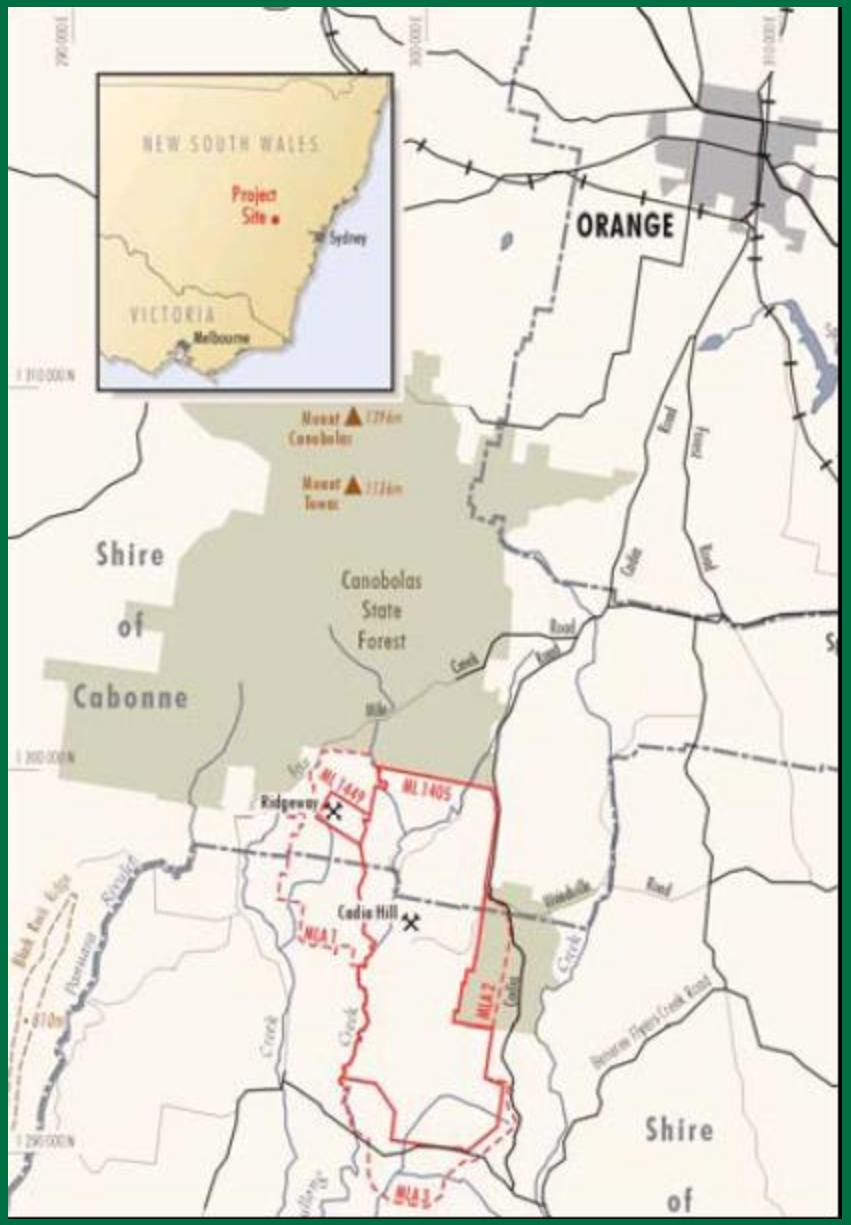
Gold Discoveries

Declining Rate of New Discoveries



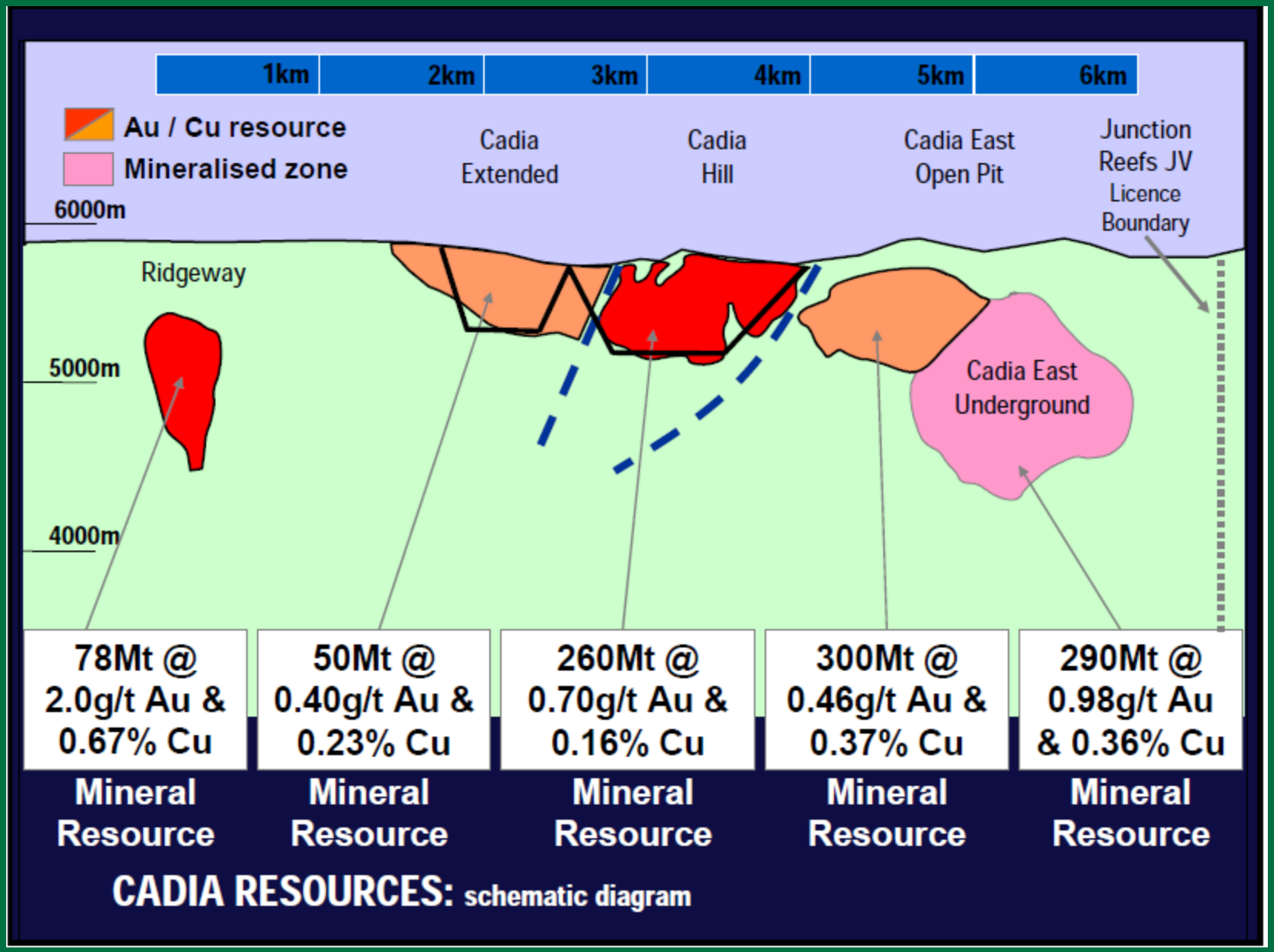
Cadia Valley Mine

- Located in East Central New South Wales, Australia
- Orange District is a rural farming and ranching community
- First large mining operation in area
- Newcrest Mng. Ltd.



USGS

USGS


1km
2km
3km
4km
5km
6km
Au / Cu resource
Mineralised zone
6000m
5000m
4000m
Cadia Extended
Cadia Hill
Cadia East Open Pit
Junction Reefs JV Licence Boundary
Ridgeway
Cadia East Underground
78Mt @ 2.0g/t Au & 0.67% Cu
50Mt @ 0.40g/t Au & 0.23% Cu
260Mt @ 0.70g/t Au & 0.16% Cu
300Mt @ 0.46g/t Au & 0.37% Cu
290Mt @ 0.98g/t Au & 0.36% Cu
Mineral Resource
Mineral Resource
Mineral Resource
Mineral Resource
Mineral Resource
CADIA RESOURCES: schematic diagram

USGS

Cadia Valley Time Line

- 1986 – First modern exploration
- 1991 – Porphyry copper deposit targeted
- 1992 – Deposit discovered
- 1994 – Completed exploration – began EIS
- 1995 – EIS filed and approved
- 1996 – Began mine development
- 1998 – Commercial production achieved

USGS

Step 1 – Exploration Objective

- Exploration begins with a target or objective, usually a type of mineral deposit with a specified minimum amount of contained metal
- Early 1980s – Australian geologists examined possibility of a porphyry copper-gold deposit in New South Wales (~0.15% Cu, 1.2 gpt Au)
- Such deposits were economic in British Columbia

USGS

Step 2 – Identify Prospects

- Generally begins with a literature search
- Areas with potential are ranked, risked, and selected for further work
- Orange District NSW – found to have favorable geology
- A small Au-Cu mine (skarn) was noted in the area
- Orange District was at top of list of prospects by 1986

USGS

Step 3 – Acquire Exploration Rights

- Every political jurisdiction has its own procedures for securing the right to conduct exploration
- Orange District NSW – surface land privately owned, mineral rights held by state of NSW
- Newcrest purchased existing Exploration Licenses and surface lands from 1986 to 1990

USGS

Step 4 – Preliminary Field Survey

- Test and verify exploration concept – is the geology right?
- Generate an exploration strategy
- Methods used are geological mapping, remote sensing, geochemical sampling
- By 2/1992 – Newcrest verified widespread porphyry Cu-related alteration and other favorable geological characteristics

USGS

Step 5 – Select Drill Targets

- Based on preliminary geological surveys, identify places to drill that will test the hypothesis: is there a deposit of sufficient size and grade in the favorable area?
- The most cost-effective drilling strategy selected
- 5/1992 – Newcrest detailed mapping and sampling led to an initial 5-hole grid

USGS

Step 6 - Discovery

- Usually one or two holes are sufficient to indicate the presence of a large deposit of required grade
- 9/1992 – Newcrest began drilling
- Based on early drill results decided to add additional holes
- Sixth hole was discovery hole – 243 meters 1.21 gpt Au 0.15% Cu AUD 20/t

USGS

Step 7 – Selection Among Discoveries

- A large mining company may make multiple discoveries and will chose those of greatest potential and “farm out” the rest
- Competition between firms for investor’s dollars results in a selection process among companies with one or a few discoveries
- Newcrest’s discovery was a very high quality one – had no trouble getting capital to continue – 4/1993 decided to make Cadia its first priority

USGS

Step 8 – Deposit Delineation

- The size, grade, and other characteristics of a discovery must be determined before feasibility of mining can be determined
- From 4/1993 to 1/1994 Newcrest drilled out the deposit on a 100 by 150 meter grid (64 holes totaling 23,000 meters)
- Delineated an inferred resource of 97,000,000 metric tons with 1.1 gpt Au and 0.19% Cu
- At 3.4 million ounces gold – objective met

USGS

Step 9 – Preliminary Economic Evaluation

- Also known as a scoping study
- Evaluate economic potential of the deposit and principal impediments to economic extraction
- Cadia Hill positives: close to existing infrastructure, shallow, simple mineralogy
- Cadia Hill negative: low grade would require close attention to keeping mining and mineral processing costs low
- Study completed in 1994

USGS

Step 10 – Feasibility Study - Permitting

- Feasibility study requires designing a mine and plan of operation – with sufficient detail for a financial evaluation with ±15% accuracy
- Permitting typically begins at this stage
- Newcrest increased drill density to 50x50m to get better handle on economics due to low Au grade
- Newcrest purchased land and water rights
- Newcrest completed environmental studies

USGS

Step 10 – Feasibility Study – Permitting ctd

- Late 1994 Newcrest hired a consulting group to conduct the EIS
- EIS filed 11/22/1995 – 1,000 pages long
- Public comments period 11/22 to 12/22/1995
- Development application filed 11/20/1995
- Commission of Inquiry held hearings 3/26/1995 to 7/31/1996
- 9/6/1996 – Development consent granted

USGS

Feasibility Study Results

- Mine Plan: 204Mt 0.74 gpt Au 0.17% Cu in 12 years
- Initial Capital Cost: $320 million (1995 USD)
- LOM Capital Cost: $369 million (1995 USD)
- Operating Cost: $5.15 per metric ton milled
- Revenue: $9.08 per metric ton milled
- Gross Margin: $3.93 per metric ton milled or roughly $800 million (1995 USD)

USGS

Step 11 – Development & Construction

- Mine workings developed
- Surface facilities constructed
- Infrastructure constructed and connected
- Newcrest began work within days of receiving approval
- A two-year process completed 8/1/1998

USGS

Step 12 - Commissioning

- Once construction complete, operations begin at a gradually increasing tempo as equipment is tested
- When the mine is operating at planned capacity within regulatory performance standards commercial production has been achieved
- Newcrest shipped its first copper concentrate on 6/27/1998 and commercial production achieved 8/1/1998

USGS

Wait – There's More!

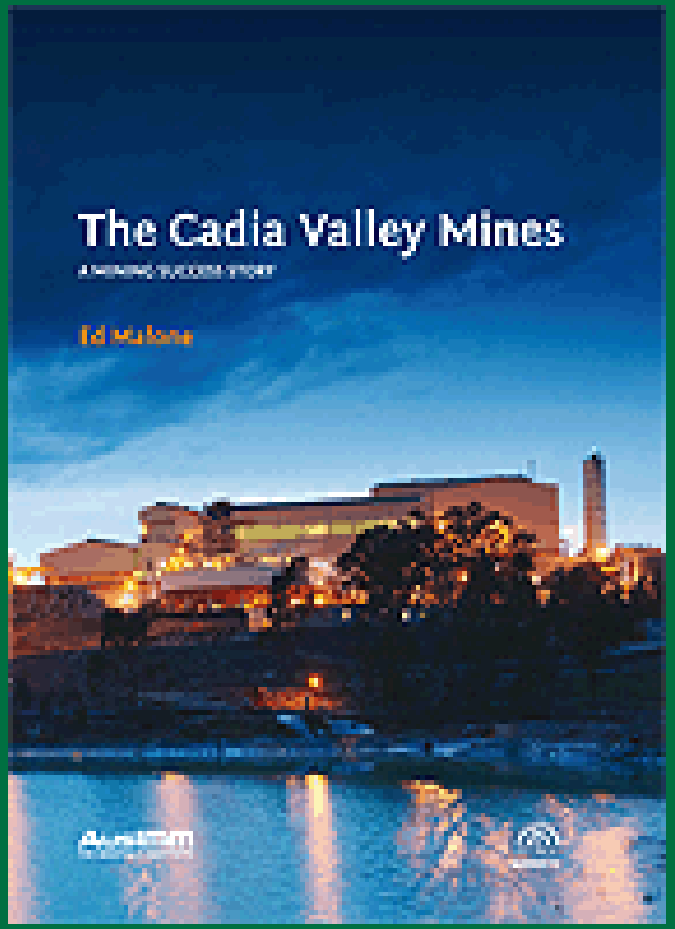
- Cadia Valley mines will be in production for decades to come
- When mining ends the property will be reclaimed
- All equipment, structures, and infrastructure will be removed
- Dumps and impoundments will be recontoured, sealed, and revegetated
- Mine workings closed, sealed, and fenced off

USGS

More Information

Cadia Valley story well documented in a publication of the Australasian Institute of Mining and Metallurgy

www.ausimm.com.au



USGS