The Discovery of structure confined blind ore extensions to the Ladolam Deposits, Lhir, PNG

Steve Hunt, Lihir Gold

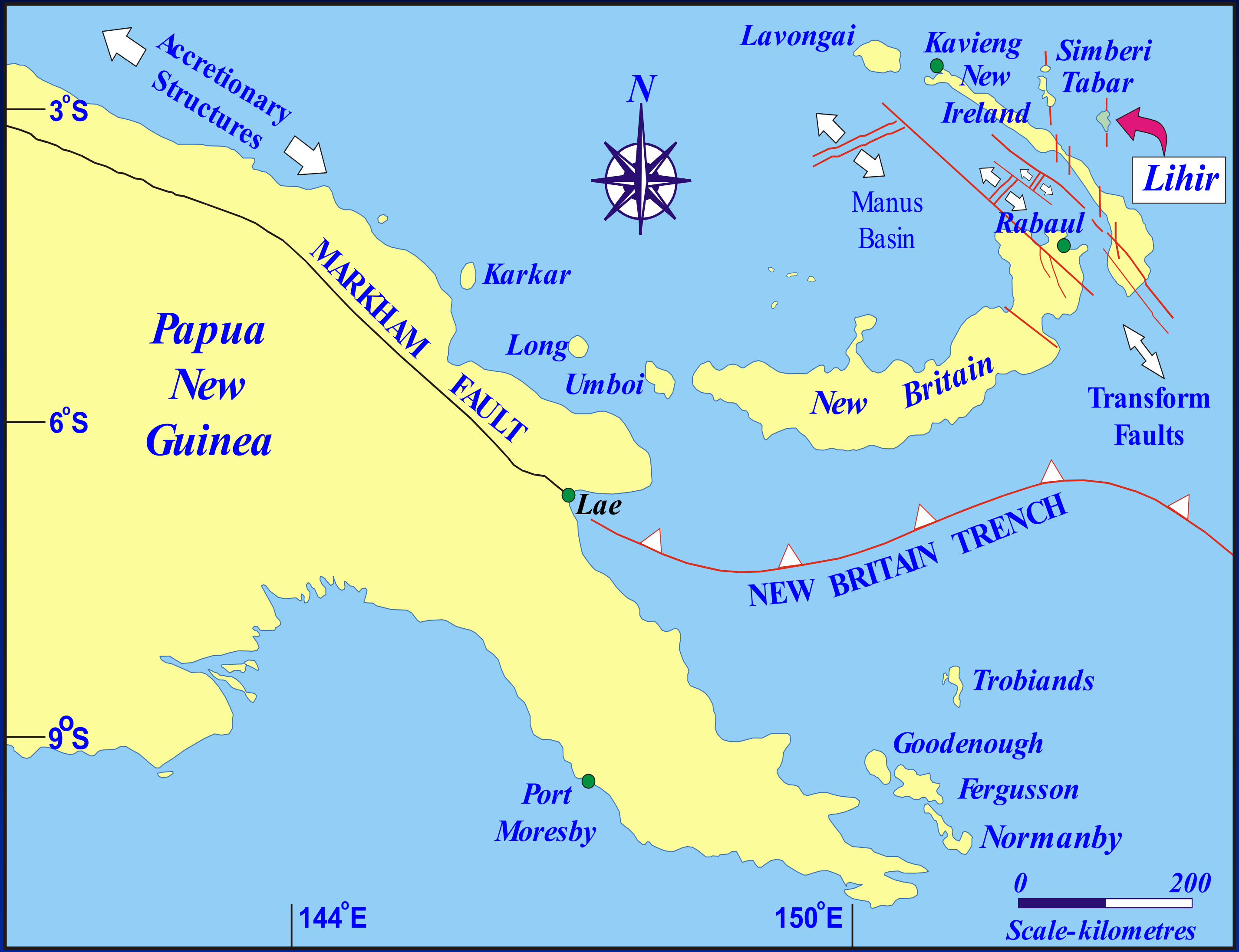
Exploration in the Shadow of the Headframe

October 11th 2002

Introduction

- The Ladolam gold deposit, at Lihir island in PNG is hosted within the remnants of the sector collapse and sea breached Luise volcano.
- This unusual setting has resulted in the formation of a telescoped porphyry to epithermal gold deposit of significant size (pre mining resource >40moz).
- While exploration on the island group has been underway since 1982, recent advances in understanding of ore controls has led to the discovery of a number of extensions to reserves, significantly enhancing the value of the project.

Location



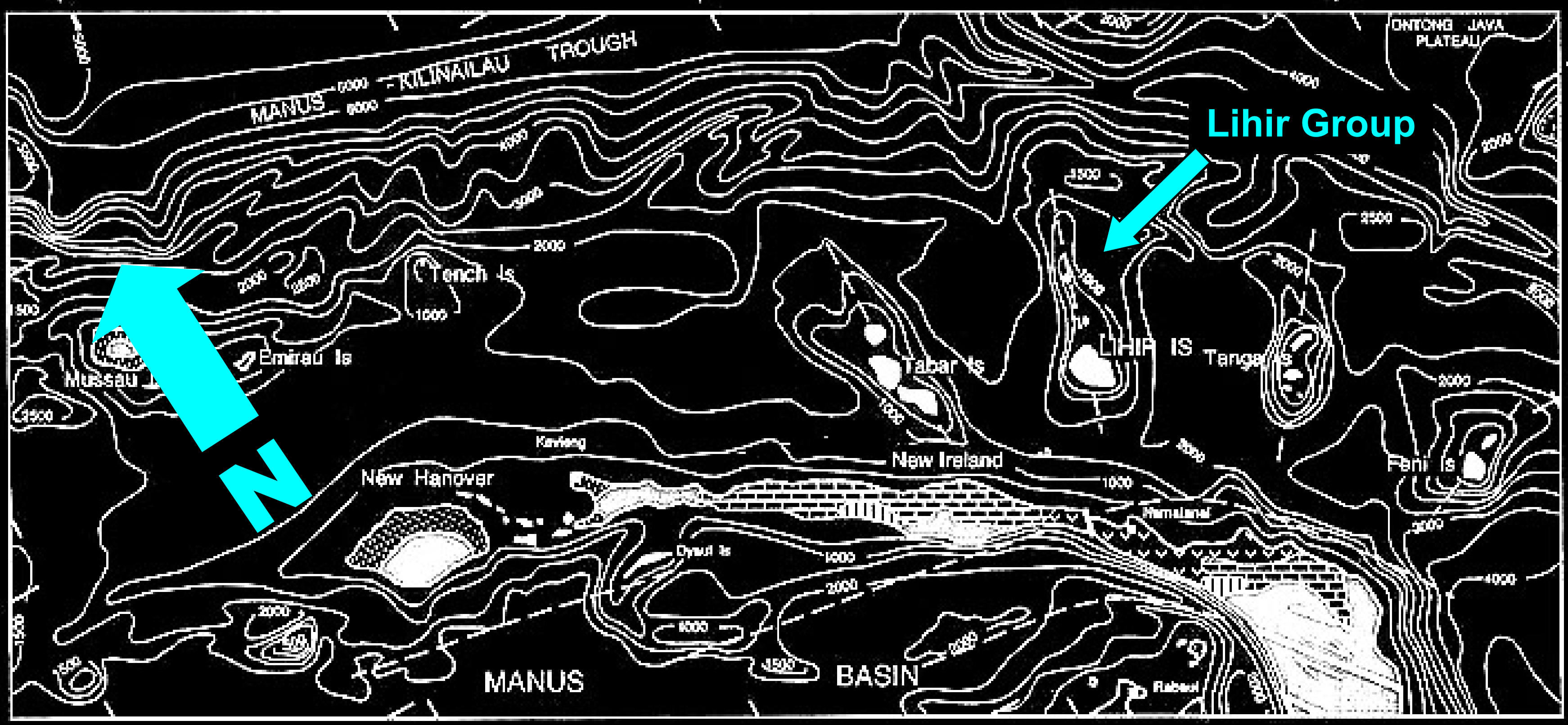
Accretionary Structures
3°S
6°S
9°S
Papua New Guinea
MARKHAM FAULT
Karkar
Long
Umboi
Lae
N
Lavongai
Kavieng
New Ireland
Simberi
Tabar
Lihir
Manus Basin
Rabaul
New Britain
Transform Faults
NEW BRITAIN TRENCH
Trobiands
Goodenough
Fergusson
Normanby
Port Moresby
144°E
150°E
0
200
Scale-kilometres

Location & Tectonic Setting

- Tabar-Lihir-Tanga-Feni form a chain of volcanic island groups, ~80km apart, lying between and parallel to New Ireland and the inactive (6000m) Kilinailau trough.

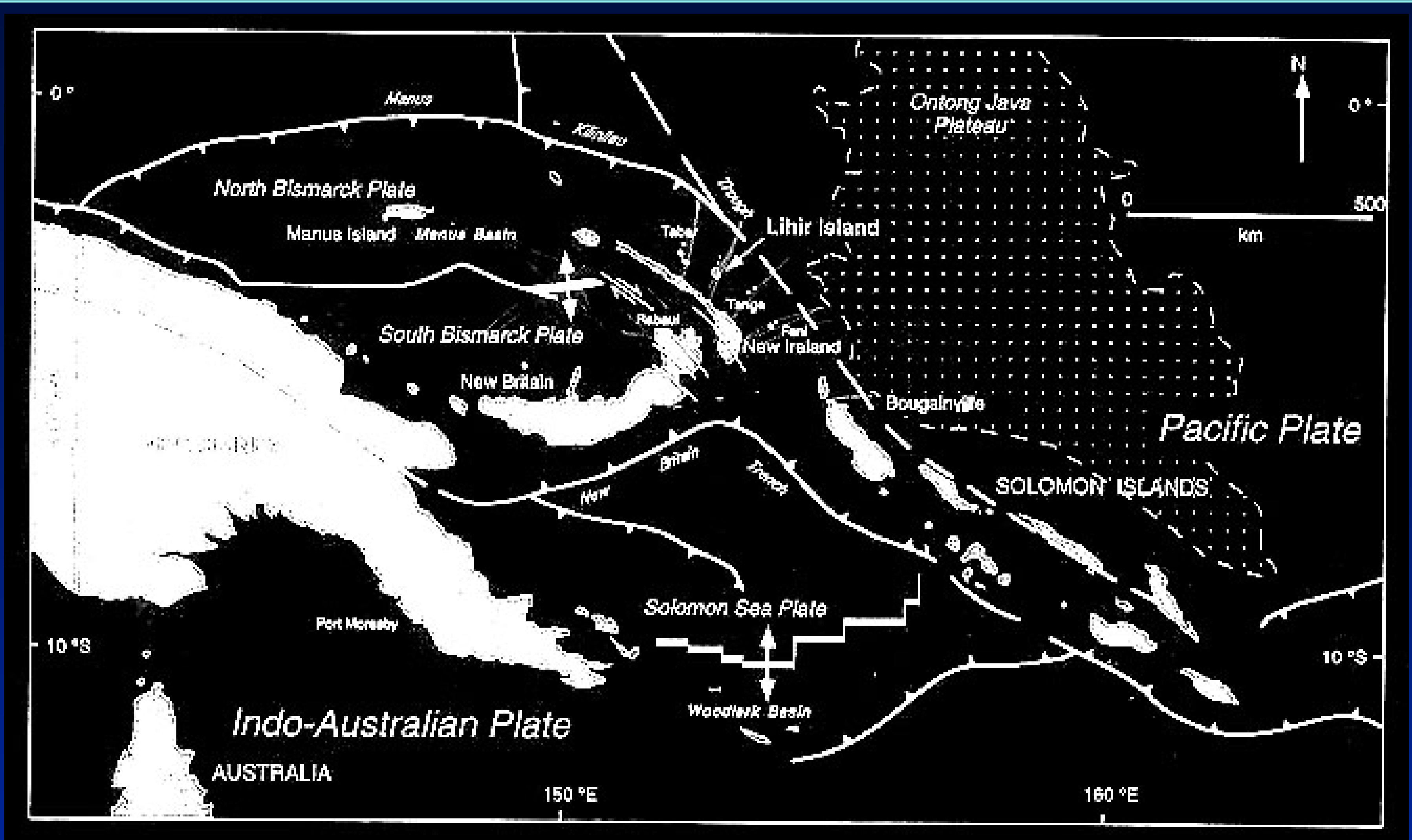
- Volcanic rocks of this island chain are Si-undersaturated alkaline intermediate-mafic trachy-basalts.
  - These compositions are different to the normal subduction type calcalkaline volcanics, and are typified by enriched volatiles and copper gold values.
  - The unusual composition is though to be the result of the partial melting of subduction modified lithospheric mantle, as a result of the stalled subduction along the Kilinailau trough

Location & Tectonic Setting

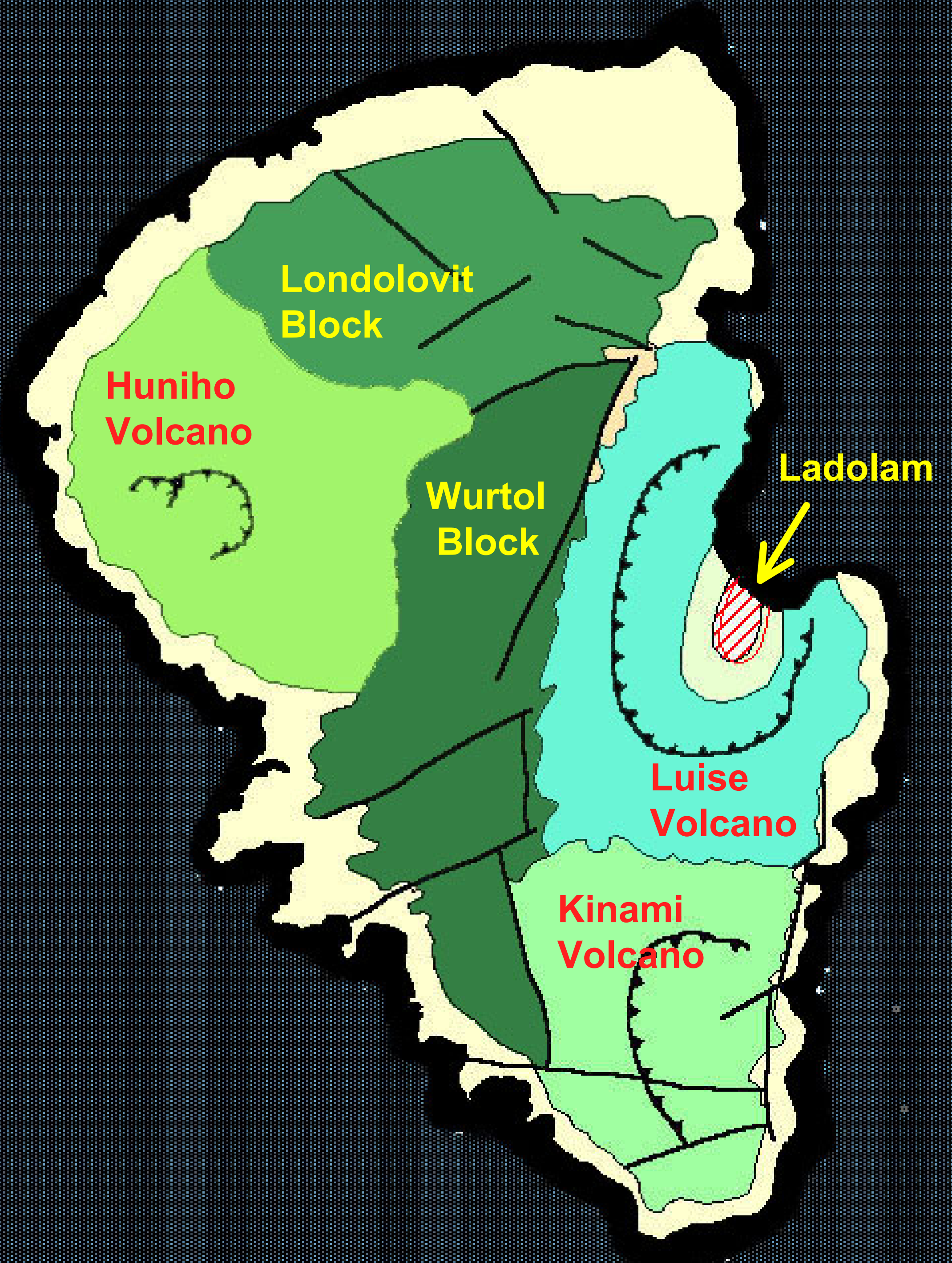


BATHYMETRY CONTOURS of NEW IRELAND REGION (from Carman, 1994)

Tectonic Setting



(from Carman, 1994)



Simplified Geology of Lihir Island

- Lihir is a 20 x 13km volcanic island constructed of 3 Pliocene-Pleistocene sub-aerial volcanoes: Huniho, Kinami & Luise.
- These were built on eroded remnants of 2 Late Miocene marine strato-volcanoes rising from 2000m water depth.

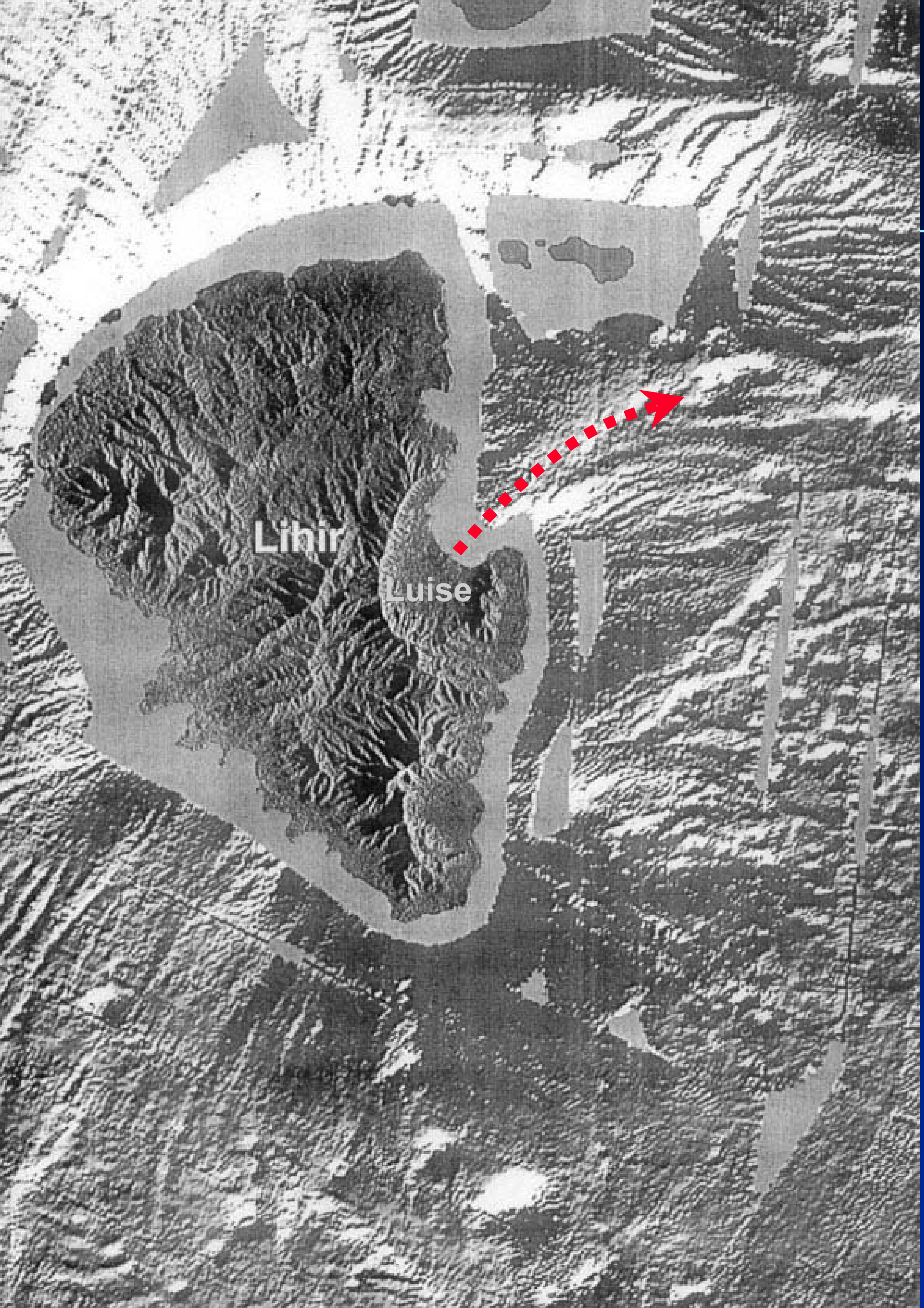
Volcanology

- Huniho, Kinami & Luise volcanoes all had seaward directed cone sector collapses.

- Luise is the youngest volcano, <1Ma. It has a 6 x 4km elliptical collapse crater with steep walls rising to 700m ASL; the original cone was probably twice that elevation.

- Stocks of alkaline monzonite were intruded into the base of Luise volcano, at least up to sea level, between 0.9-0.35 Ma.

- Rocks exposed in the crater floor are dominantly breccias.
  - Interpreted to include various magmatic-hydrothermal and phreato-magmatic explosive breccias and diatreme breccias.
  - Difficult to distinguish breccia types due to super-imposition of types and pervasive alteration.



Shaded Relief & Bathymetry image

Porphyry stage

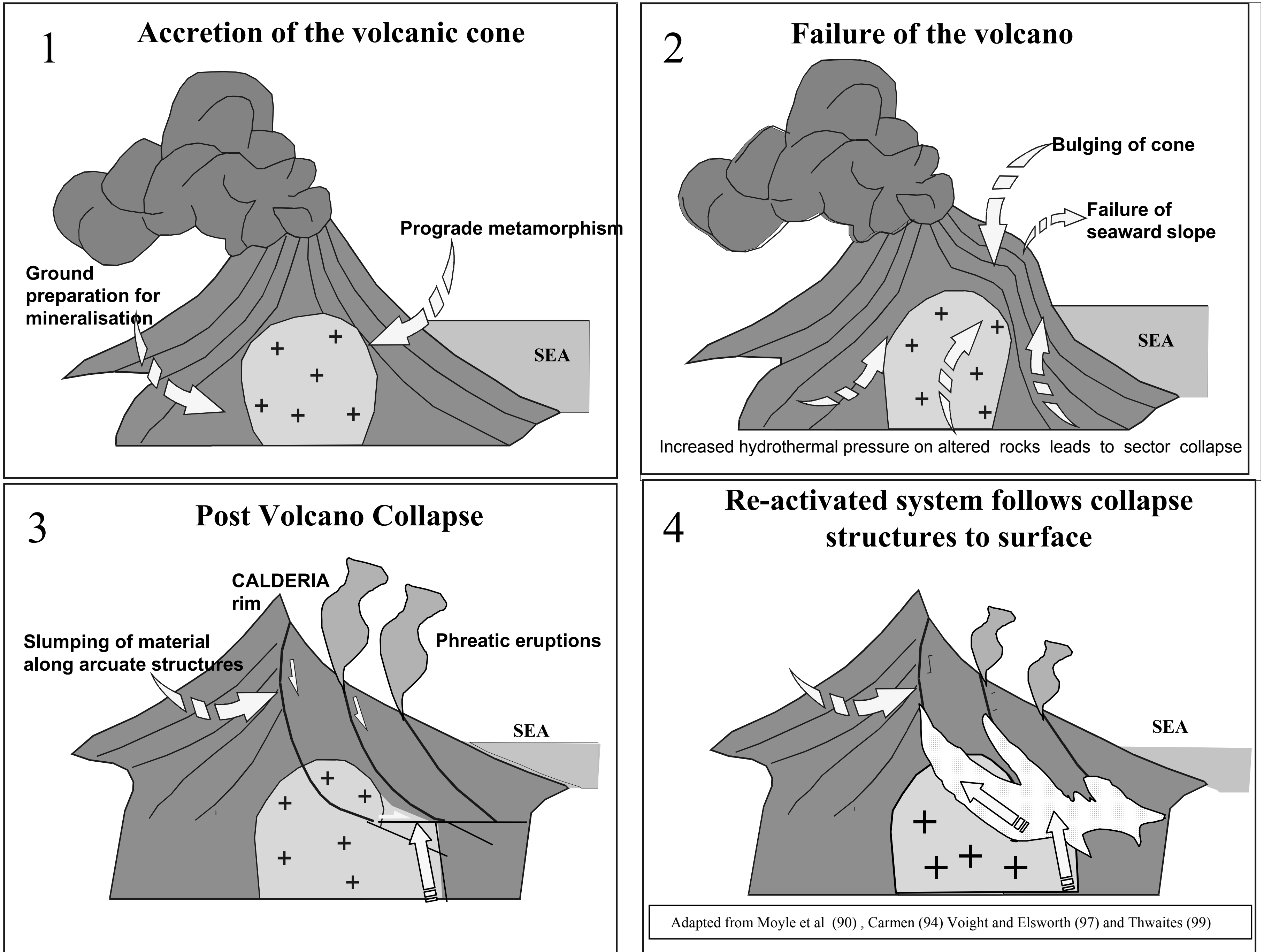
- **Early porphyry stage (0.9 to 0.35 Ma) 300-500^0 C , 0.5 kbar**
  - **driven by emplacement of alkaline intrusive stocks close to sea level**
  - **inner biotite potassic alteration (deeper Lienetz) , outer K feldspar (Most of Minifie)**
  - **propylitic on fringes, late magmatic phyllic overprint**
  - **alteration contained within the volcano, with estimated original cone height of 1200m**
  - **weakening of the cone through contained hydrothermal alteration**

Epithermal Stage

- Epithermal stage; caldera collapse driven (0.35 Ma)
  - Sector collapse probably gravity/ hydrothermal pore pressure initiated
  - unloading brecciation, and large scale phreatic and pheatomagmatic breccias form, assisting fluid migration
  - listric shaped collapse faults provide coduits and linkages between peremeable units.
    - Some mineralisation follows curved collapse paths
    - lateral spread into connected permeable units
  - adularia, argillic and advanced argillic alteration.
  - Precipitation of mineralisation by rapid seawater mixing and quenching of magmatic hydrothermal ore fluids
  - 200^0 C , within 200m of paleosurface

Late and Post Epithermal

- Low sulphidation qtz-calcite-adularia veins and stockworks deeper in system following cooling
  - bonanza veins with visible gold overprint earlier epithermals
- Waning geothermal systems
  - surface acid leach based on hotspring acivity.
  - masking advanced argilllic alteration forms, overlying and overprinting near surface mineralisation
- Current hotsprings
  - surface activity west Minifie, Lienetz and Kapit.
  - Mining up to ground temperatures of 150 ^{0}
  - Drilling of steam relief wells ahead of mining


1
Accretion of the volcanic cone
Prograde metamorphism
Ground preparation for mineralisation
SEA
2
Failure of the volcano
Bulging of cone
Failure of seaward slope
SEA
Increased hydrothermal pressure on altered rocks leads to sector collapse
3
Post Volcano Collapse
CALDERIA rim
Slumping of material along arcuate structures
Phreatic eruptions
SEA
4
Re-activated system follows collapse structures to surface
SEA
Adapted from Moyle et al (90) , Carmen (94) Voight and Elsworth (97) and Thwaites (99)

Summary of mineralisation

- In summary, the major controls are:-
  - Metals and fluids were provided by volatile rich silica under saturated alkalic mafic magma.
  - A sub-volcanic intrusion related porphyry type alteration system (0.9 – 0.35my) occurred, probably directly contributing to the ultimate sector collapse
  - Cone sector collapse (0.35my) that unroofed and de-pressurised the hydrothermal system and allowed ingress of seawater.
  - Permeable feeder zones provided by several sets and intersections of faults, particularly listric normal faults associated with sector collapse.
  - Permeable host rocks in various types of volcanic-eruptive, hydraulic and fault breccias.
  - Abundance of cold ground water - in the form of seawater - that effectively quenched hydrothermal fluids to precipitate gold.
  - Waning temperatures and late stage surface acid leach alteration by the geothermal system.

Discovery

- Discovered in 1982 by Kennecott & Nuigini Mining JV.
- Explorers recognised altered, pyritic volcanic breccia in coastal outcrops while sampling stream sediments. Outcrops contained up to 4.4g/t Au.
- Extensive drilling 1983- 1990 (57,000m ddh + 19,000m RC)
- Feasibility complete 1992
- Development approvals gained in 1995
- commisssioned 1997, over 600,000 oz pa production

Feasibility Model

- **Mineralisation typified by complex overprinting multiphase alteration and mineralising events.**
  - **Difficult to correlate grade continuity with recognisable (loggable) ore types.**
- **‘Ore type’ geology model used, based on alteration and texture.**
  - **Raw lithology could not be correlated between holes. Ore types used to model SG and milling parameters**
- **hard coded ‘grade zone’ boundaries based on downhole statistics were used to segregate different grade populations prior to kriging ; no direct link to geology was found**
- **Dominant sub horizontal control ‘boiling model’ was used to interpret boundaries, on section and bench, *at all depths***

Early exposures

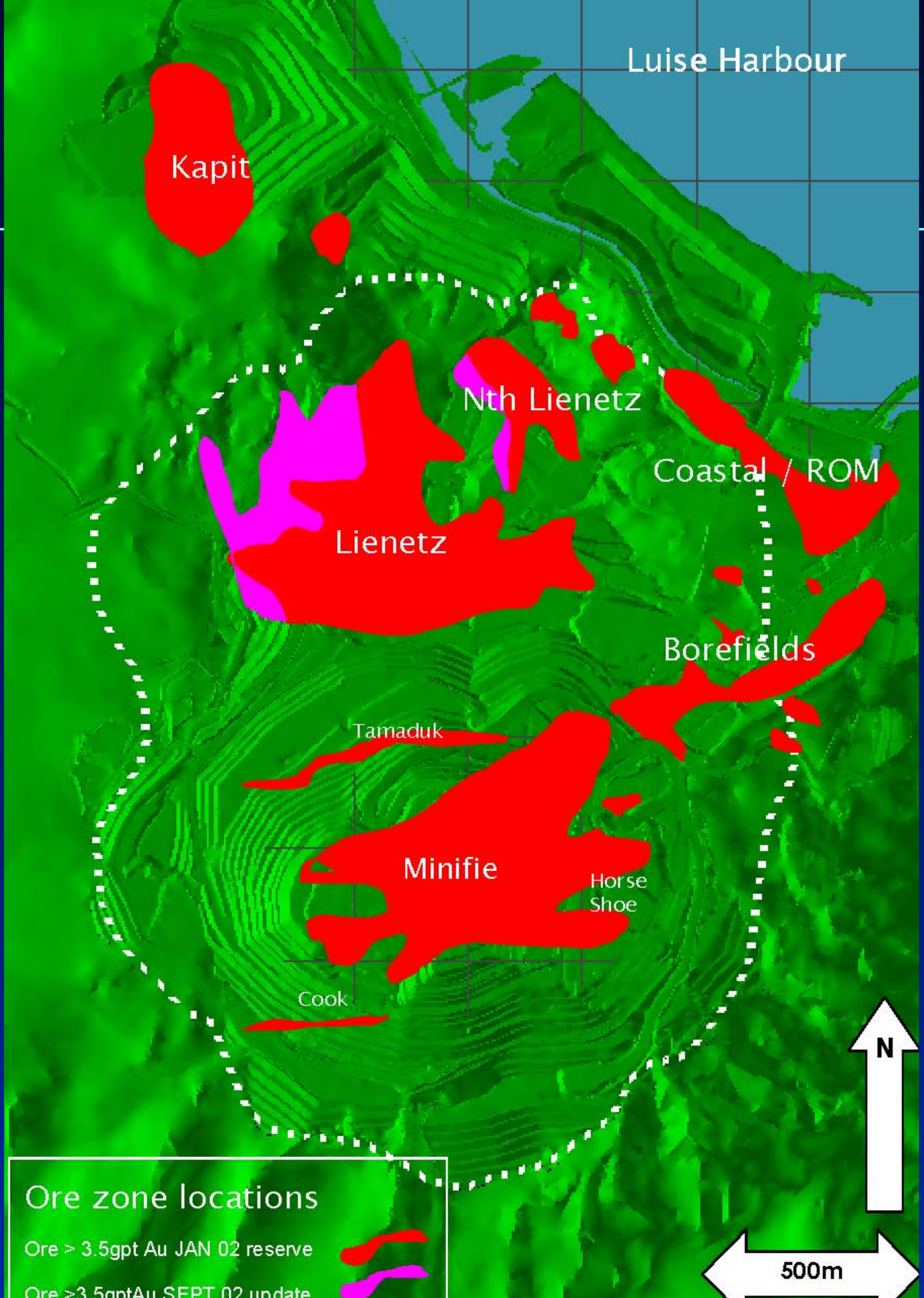
- From early mining exposures, importance of structure as boundary and feeder control apparent
- this was not anticipated in the original model,
  - led to ore losses where horizontal continuity incorrectly applied
  - ore reserve write downs in 1998
- however, close extensions to the ore system (especially steeper dipping zones) also were under drilled,
  - these zones targeted 1997- 1999

1997-99 Minifie extensions

- A number of key lessons were learned in this period:
  - There were both steep dipping and horizontal controls present, with the feeder structures being responsible for the transport of the ore fluids into the zone and the horizontal component consisting of dispersion away from feeders into 'wet' open space breccias
    - *there was more than one 'correct geometry'*
  - There were multiple feed points, and that some of these zones had no lateral connection to adjacent zones i.e. Drill closure of an ore zone did not mean that another could not reappear 100m away
    - *Not all the ore systems connect*
  - Highest grades occurred at the intersection of feeders with permeable units
    - *Steep pipes exist within flat blankets*

1997-99 Minifie extensions

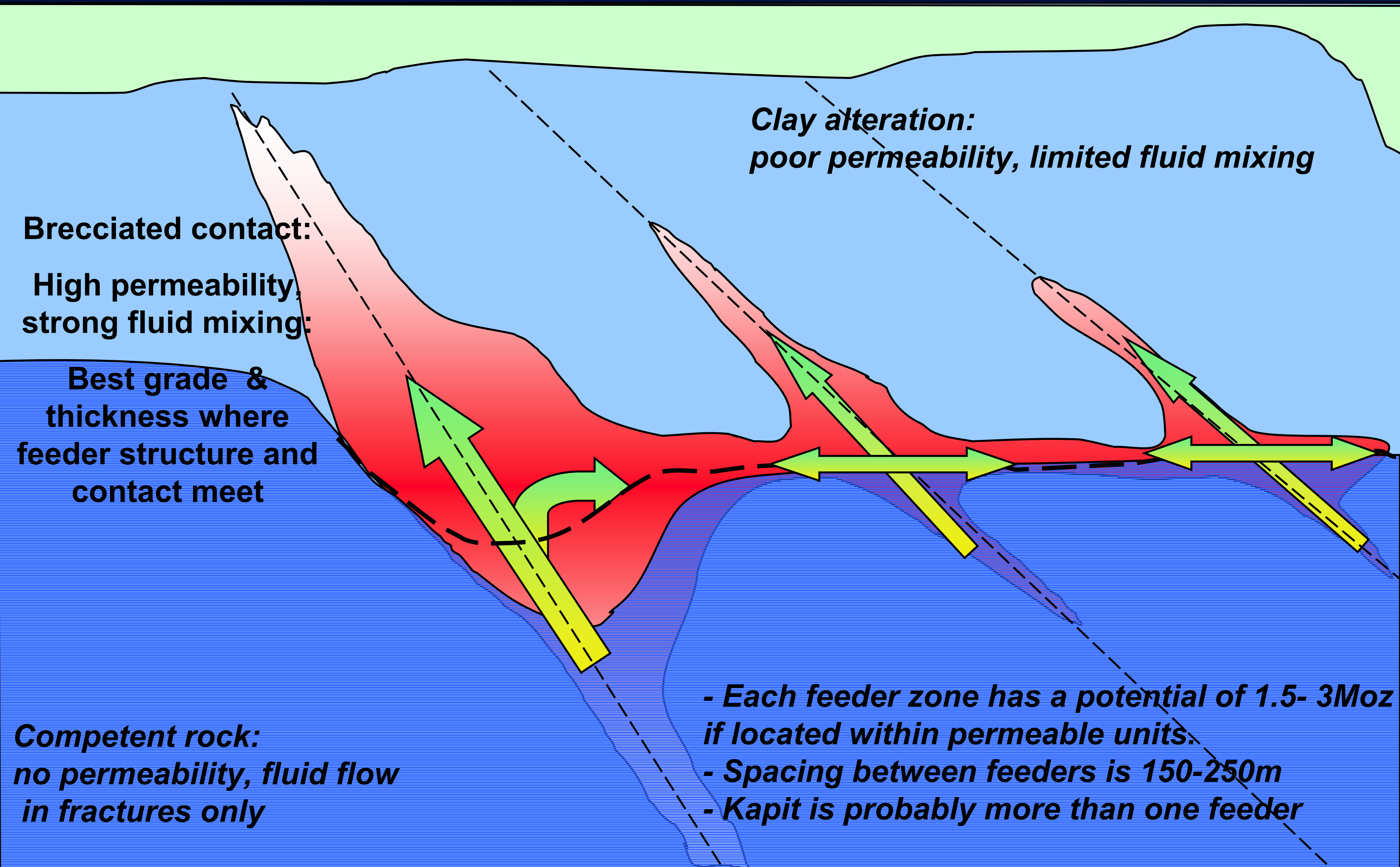
- A number of the mineralized zones discovered (e.g. Cook and Tamaduk lodes) were entirely constrained to the feeders within impermeable rocks, and as such maintained the geometry of the original fault planes.
  - *Some zones have no horizontal component at all*
- Only zones within competent rocks had strong surface gold geochemistry,
  - *Surface geochemistry anomalies were variable based on host permeability*
- The additional ore zones, while individually not of major tonnage, were the controlling factor in determining the true economic limits along the south and eastern flanks of Minifie.
  - *The ‘small’ edge ore zones define the mine*

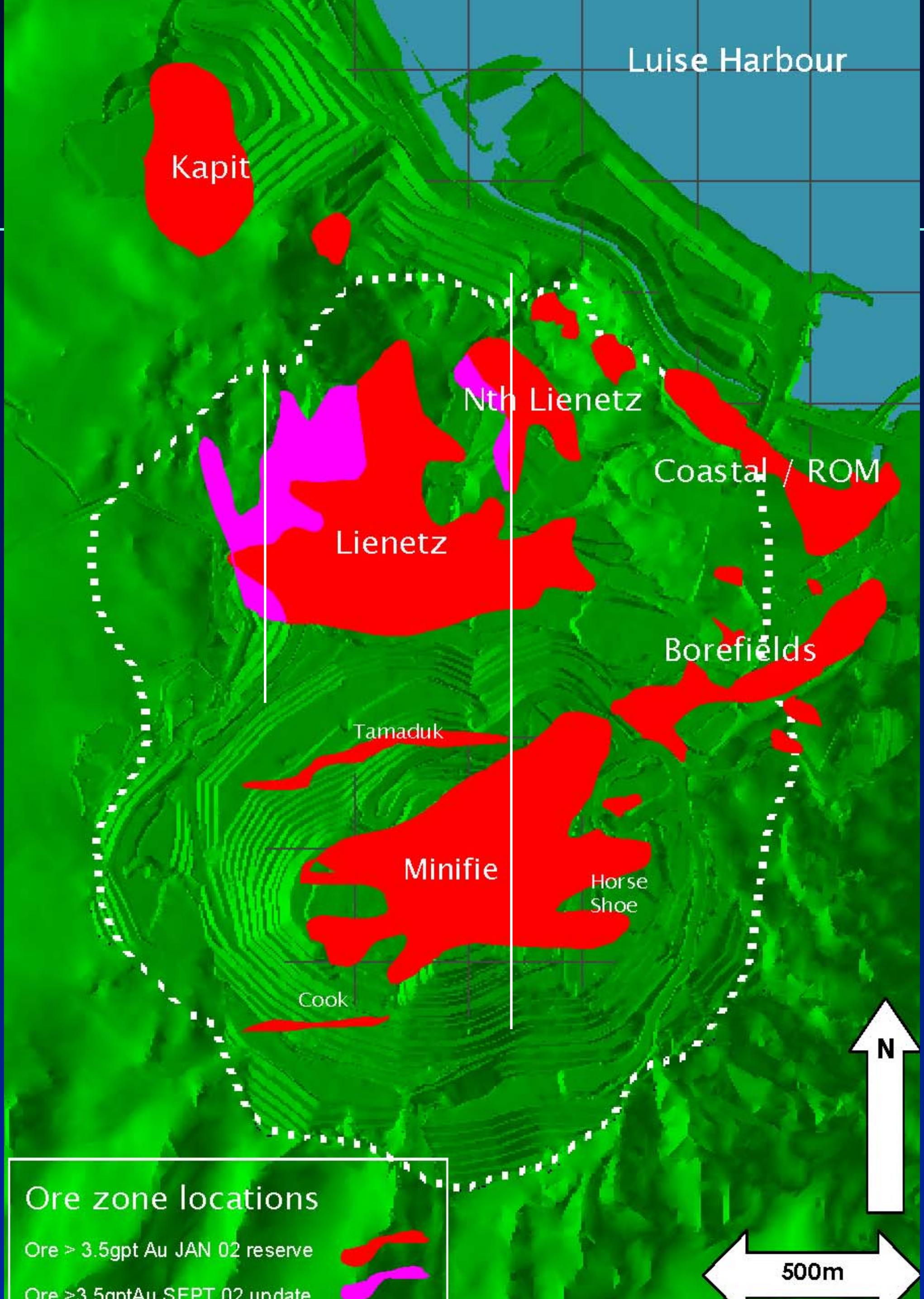

Luise Harbour
Kapit
Nth Lienetz
Coastal / ROM
Lienetz
Borefields
Tamaduk
Minifie
Horse Shoe
Cook
N
500m
Ore zone locations
Ore > 3.5gpt Au JAN 02 reserve
Ore >3.5gptAu SEPT 02 update

Testing the Model, 2000 -02

- Re - evaluation of existing drilling based on revised Minifie controls identified potential
  - of additional feeder zones (up dip leakage)
  - further lateral extensions (isolated high grade holes)
  - drilling gaps based on old alteration models
- multi feeder zones *and* horizontal breccia zone demonstrated in Lienetz
  - North Lienetz zone discovered
  - Main Lienetz feeder drilled (up and down dip)
  - large extensions to NW
  - high grades at feeder / bleeder intersections

Mineralisation controls

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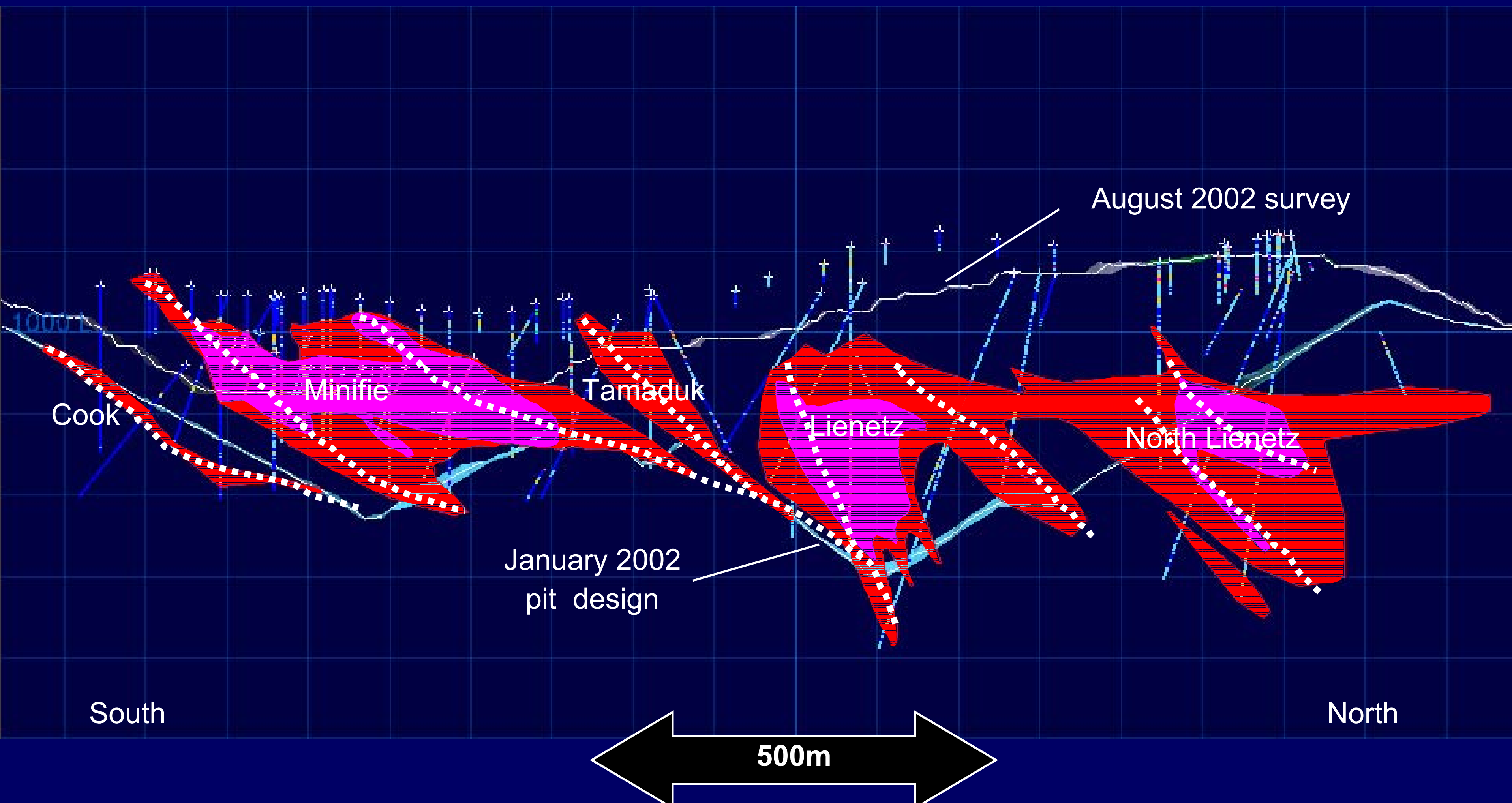
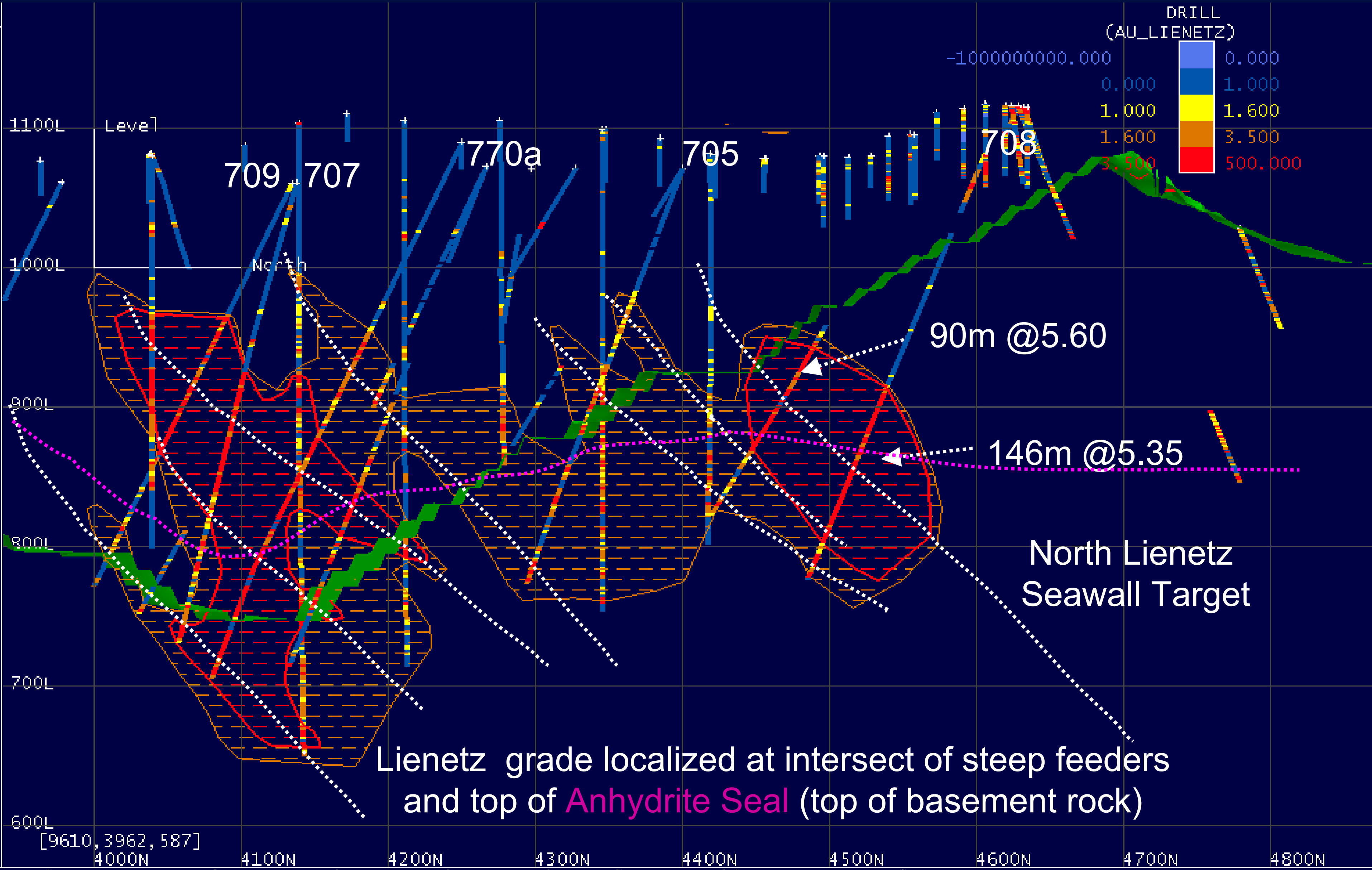
Long Section 9560 E

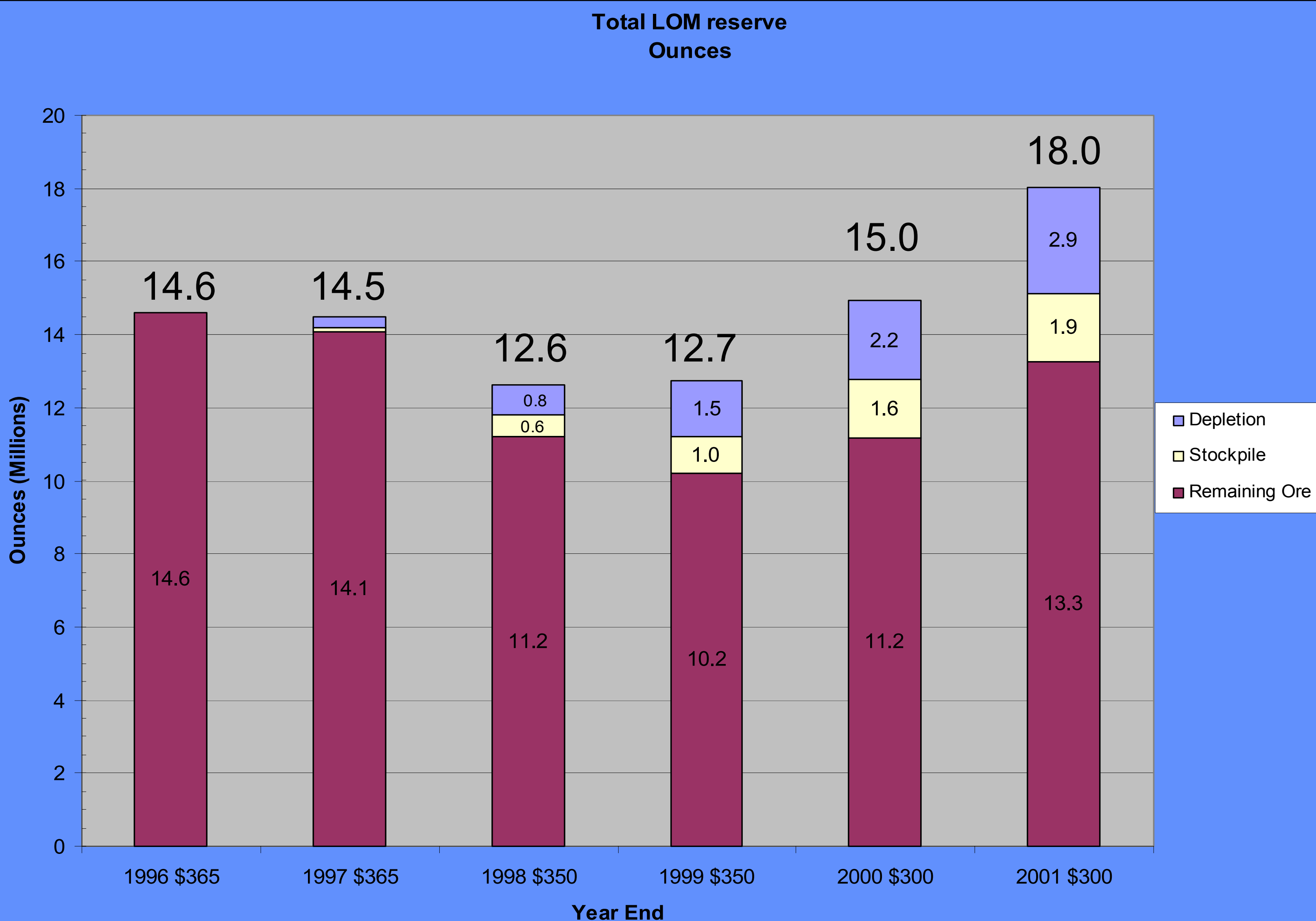


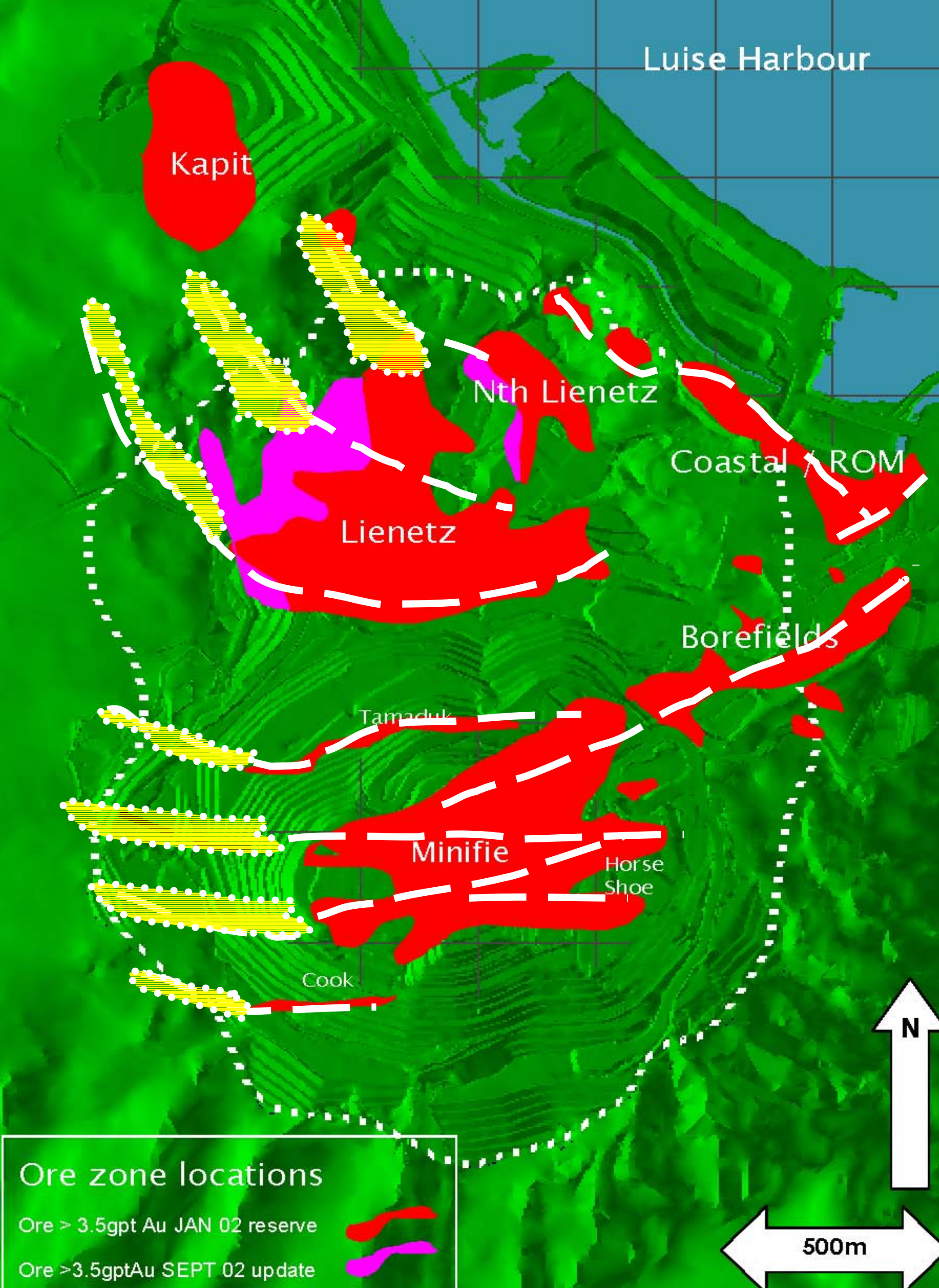
Lienetz Section 9610e



West Lienetz   Section 9105 E

Reserve ounces by year





2003 +

- New extensions to the west of Lienetz have come into the resource model since the January 02 results (purple zones)
- Drilling is continuing in West Minifie and Kapit 'Gap', with some minor infill in Lienetz. (yellow targets)
- New surface geochemistry and structure interps in western Caldera, drill 2003

Conclusion

- Despite significant drilling pre-production, the complex setting and significant burial depth of most of the Lihir deposits masked a detailed understanding of the controls on mineralisation.

- The apparent success of early ‘horizontal’ genetic ore models effectively stifled further development of the deposits, through the commitment to and comfort in wider spaced, vertical diamond drilling as the preferred method.

- Details of controls gained during the early mining period have since been successfully used to drive the discovery of a number of extension zones over the last four years. This ongoing process has lead to both significant reserve upgrades and increased understanding of the potential of the ore system .

Lessons for close mine exploration

- Don’t get trapped by a successful model
  - the presumption that controls are understood usually prevents them being further tested
  - there is *always* more than one correct answer
- You can never have too much reserve!
  - no investor gains if the tailings dam is sited over the orebody extension or the mill in hindsight was too small
- In feasibility, don’t confuse the need to stop and measure with the need to stop…..