

Geological factors influencing the design of a narrow-reef autonomous gold miner

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Introduction



CMI Carlow Road Campus

CMI focus areas

Real time risk management

monitor underground conditions

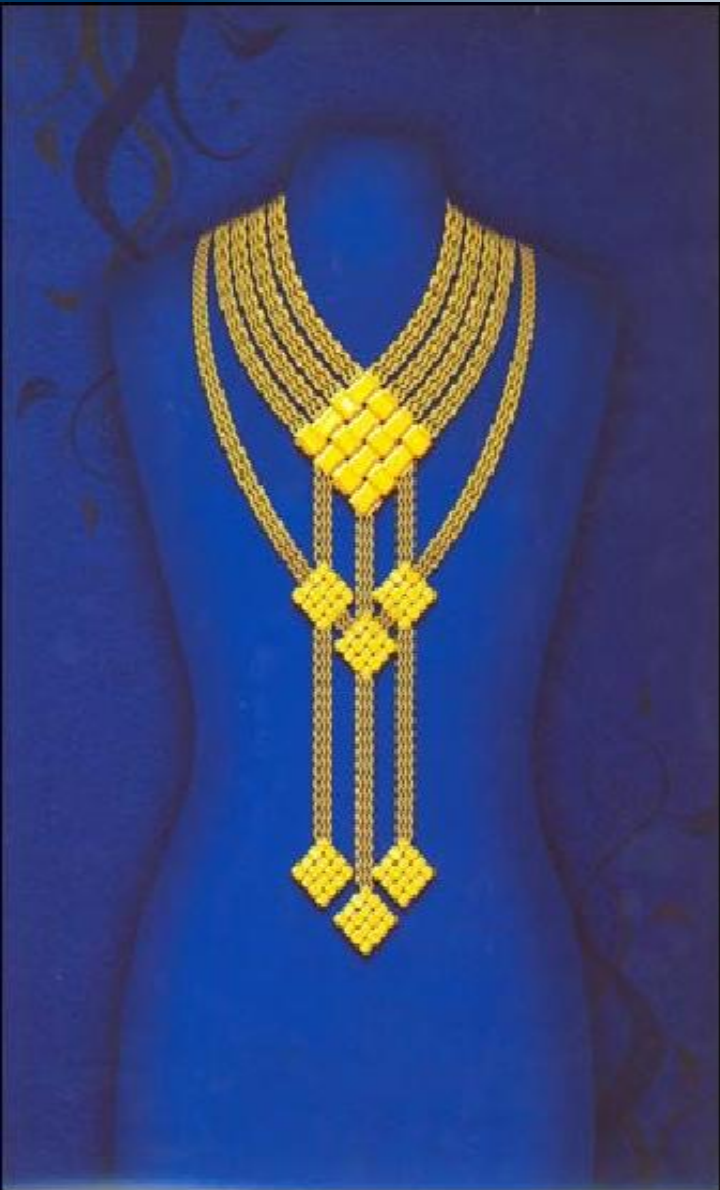
Human factors in mining

safety, health (dust, diesel fumes, heat, hearing loss, stress)

Novel mining methods

autonomous mining, non-explosive rock breaking, *in situ* leaching

Why autonomous mining?



Costs

Safety

Resources to reserves

Costs



Mine headgear

Closed West Wits Consolidated open pit mine



Deep underground mining
expensive

capex, labour, electricity

Comparison

current gold price ~ US\$ 1 700/ounce
(R380 000/kg)

surface mine – cut-off grades ~ 1g/t Au

typical deep South African gold mine
cut-off grades ~ 7 g/t Au over
a 1m stoping width

Tau Tona Gold Mine



Underground mining is a high risk activity

- high stress environment
 - mining-induced seismicity
 - rock falls
 - rock bursts

- rock handling accidents – box-holes, tramming

- heat and humidity

Reduce number of miners exposed to high risk areas (working face)

Increase reserves



Basal Reef – Free State
Visible gold with carbon
Red scale bar 1 mm

South Africa has over 40% of the world's gold resource base, according to the Department of Mineral Resources – 36 000 metric tons

Most are in the SAMREC *resources* category – deep

CMI research – convert much of the *resources* into mineable *reserves* in the future using novel, safe mining technologies



Great Noligwa Mine

Photo: courtesy AngloGoldAshanti



Burnstone Gold Mine – longhole mining

Photo: courtesy Great Basin Gold

How?

Conventional mining methods

1 m stope width
drill and blast
labour intensive

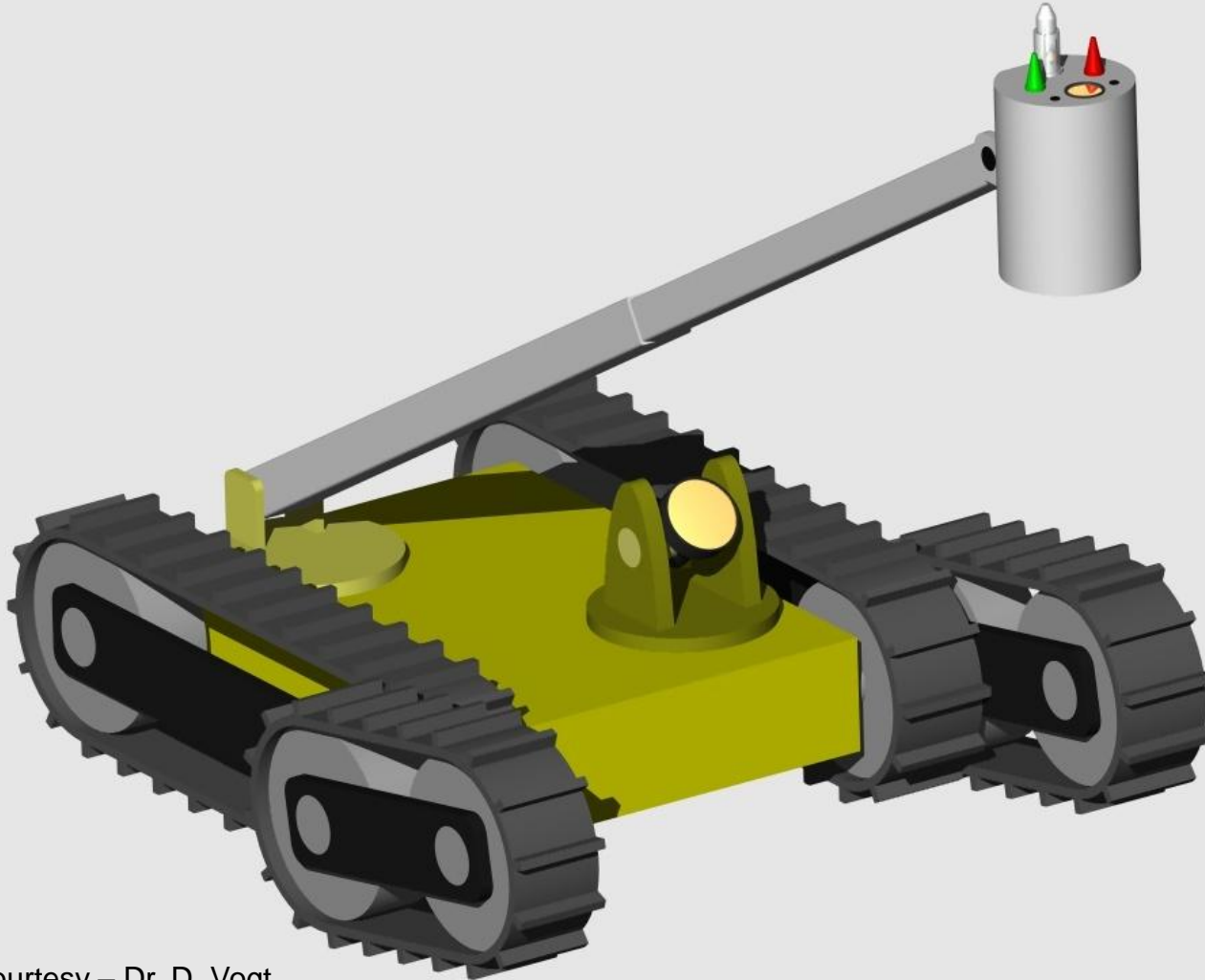
Longhole mining

drill and blast
<1 m stope width, ~70-80cm
can be partly mechanised

Narrow reef autonomous mining

designed to be <50cm high
autonomous – minimal human control
mines only ore – no waste

Narrow reef autonomous mining machine - concept



Functional attachments

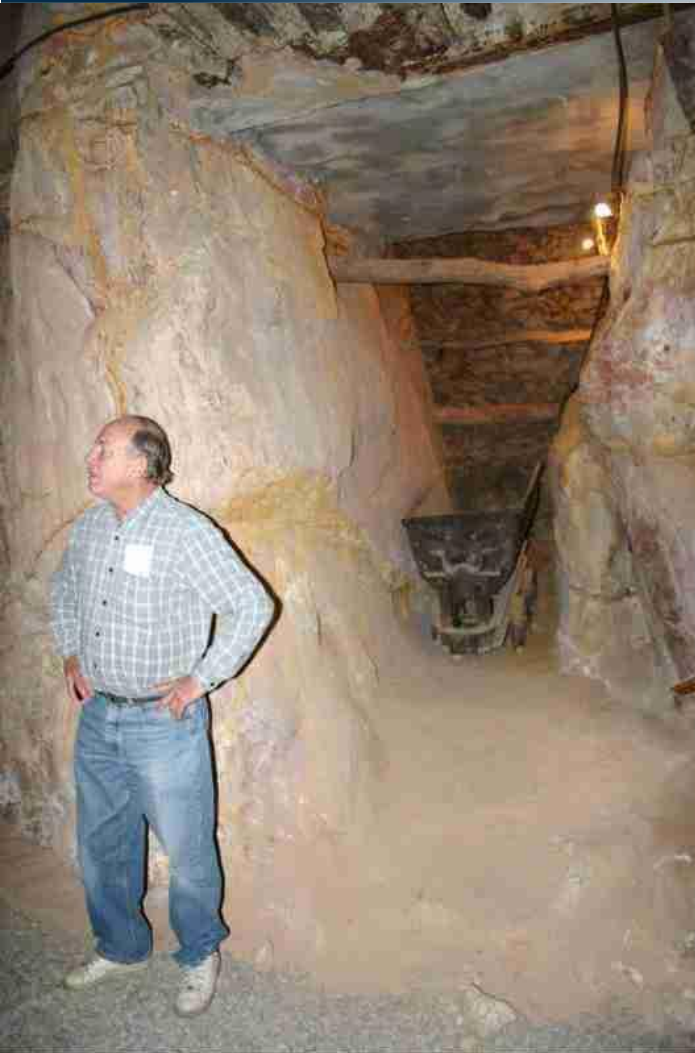
- Underground navigator
- Sounding device
- Gold analyser
- 3D scanner – mapping
- rock breaker - miner

Platform

Max. height < 50cm

Courtesy – Dr. D. Vogt

Geological factors - critical



Standard Bank Museum
Main Reef Stope

Dip of reef

typical Wits at surface – 45 to 70
Langlaagte outcrops of Main Reef

ideal dip – 0 to 30

otherwise too steep

Geological factors – critical



Strength of rock

Quartz-rich
Tough!

Rock Breaking

Drill and blast - cheapest

Non-explosive

impact ripper
drilling out the reef
controlled foam injection
diamond wire cutting
electrical methods

Main Reef Leader – City Deep Gold Mine

Geological factors - critical

Gold Analyser – COMRO 1990



Nature of the orebody

Composition/mineralogy

gold

in situ detection

XRF

Laser

uranium

radioactivity

pyrite

XRF

carbonaceous matter

Geological factors - critical

Savuka Gold Mine

Joints



Structural disturbance

Folding

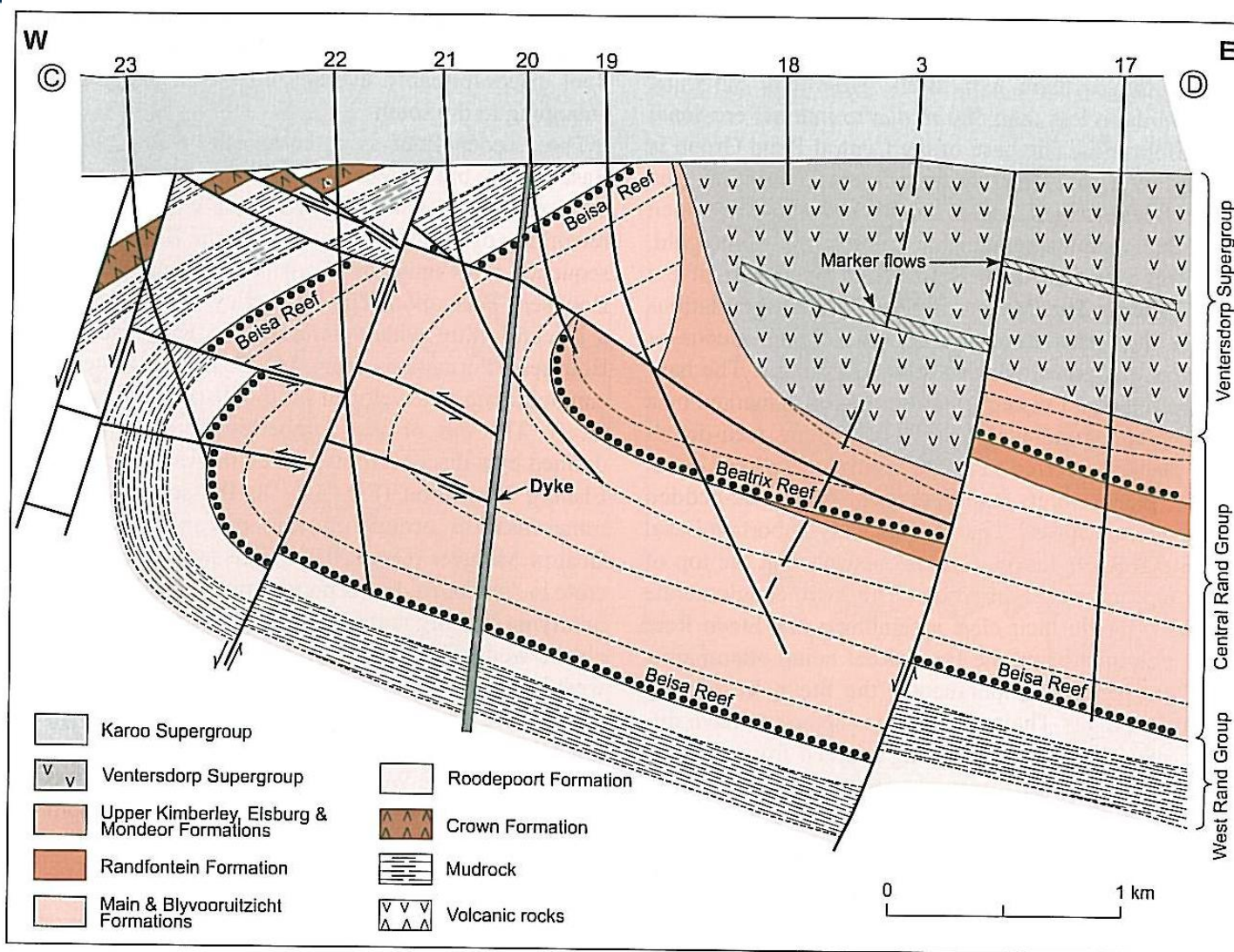
determines amount of dip

Faulting

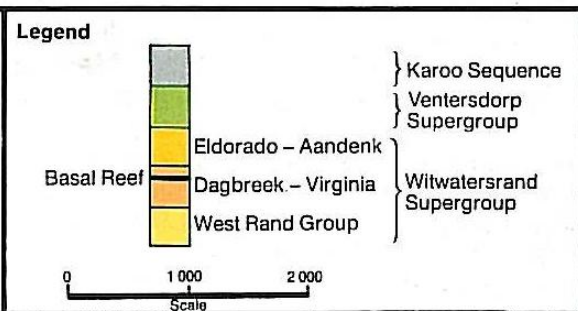
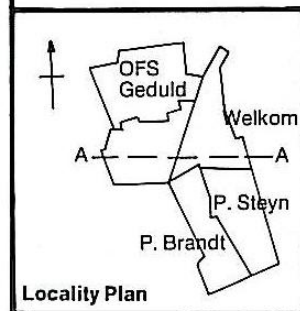
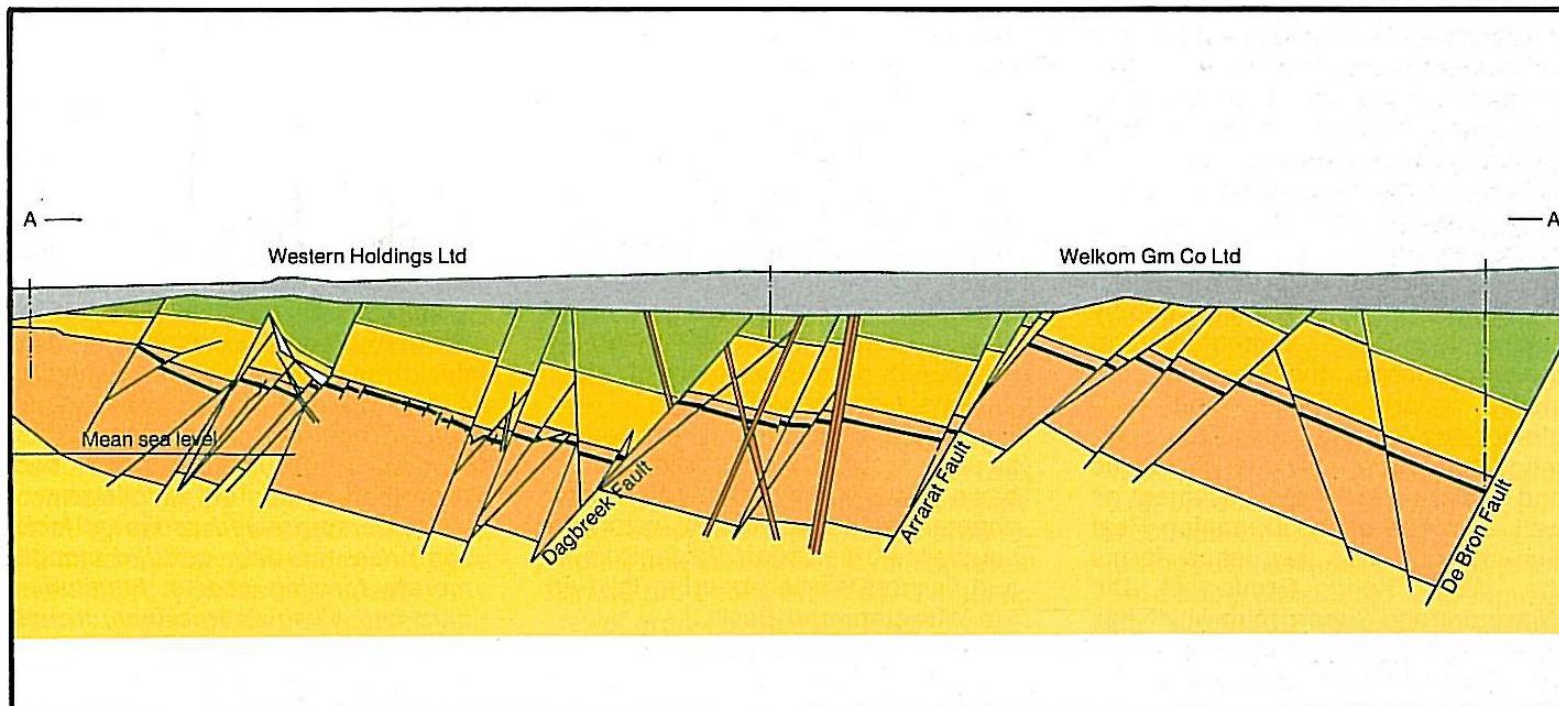
abrupt disruptions

Ideally – map out area ahead of mining, but not always possible

Free State Goldfield - folding



Free State Goldfield - faulting



Faulting of Basal Reef

Geological factors - other

Kimberley Reef - Gold Reef City



Hanging-wall rocks

Determines roof support - costly

horizontal parting planes

bedding planes – cross beds

Geological factors - other

Kimberley Reef
Gold Reef City



Footwall rocks

quartzitic – stable

shaley – heaving of footwall

Kimberley Reef - Gold Reef City



Footwall heaving

Geological factors - other

Savuka Gold Mine
Core discing – high stress



Underground stress orientation

determination of mining direction

South Africa

principal stress σ_1 vertical (at depth)

general σ_2 NW-SE direction

local modification by faults,
dykes/sills

Geological factors - other



Dykes and sills

Ages

Ventersdorp (~2700 Ma)

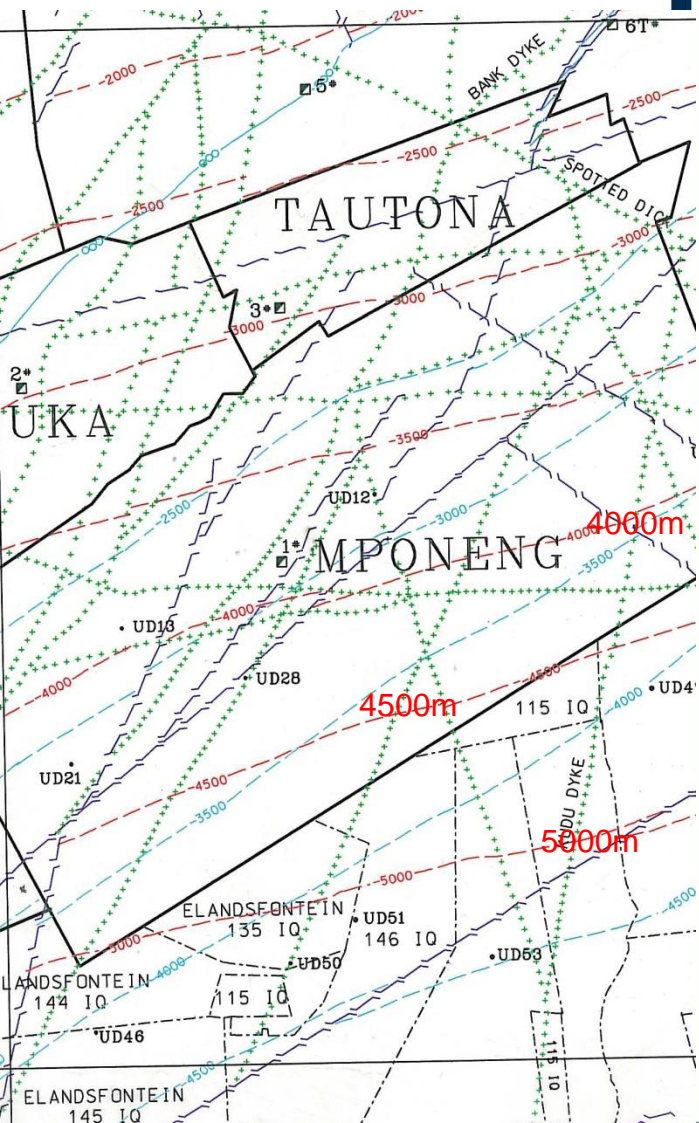
Pilanesberg (~ 1120 Ma)

Karoo (~180 Ma)

In general not problematic unless associated with fault displacements

Geological factors - other

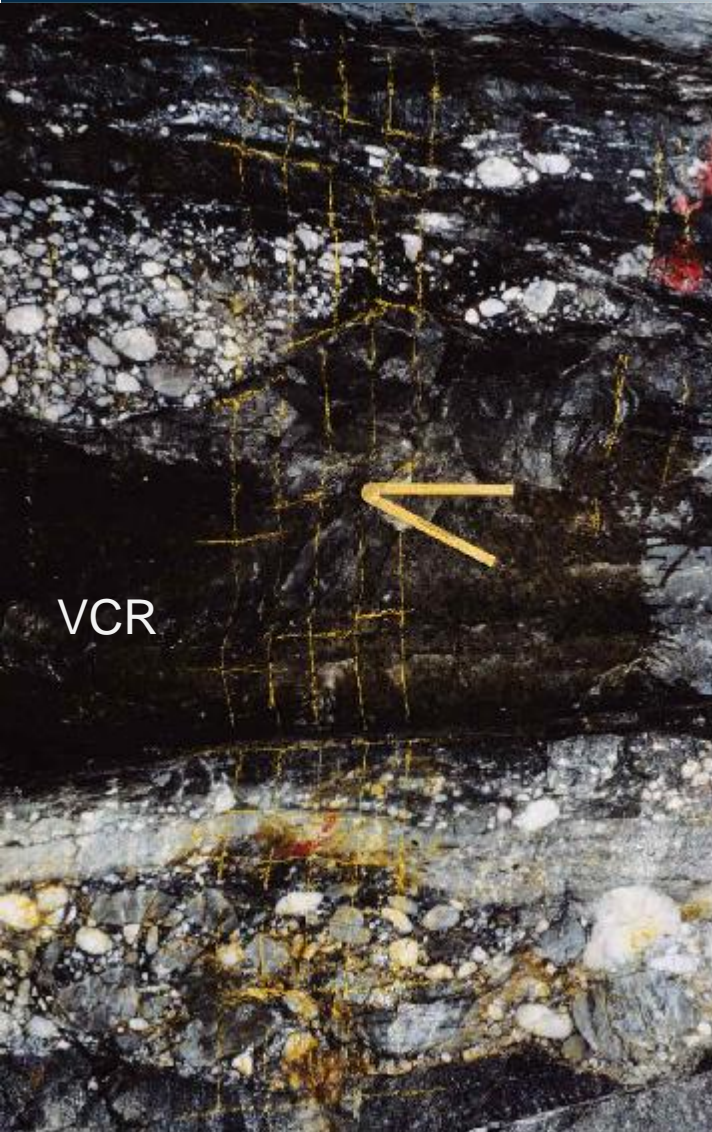
Carbon Leader structure contours



Depth

Autonomous miner will be designed for extreme depths

Geological factors - other



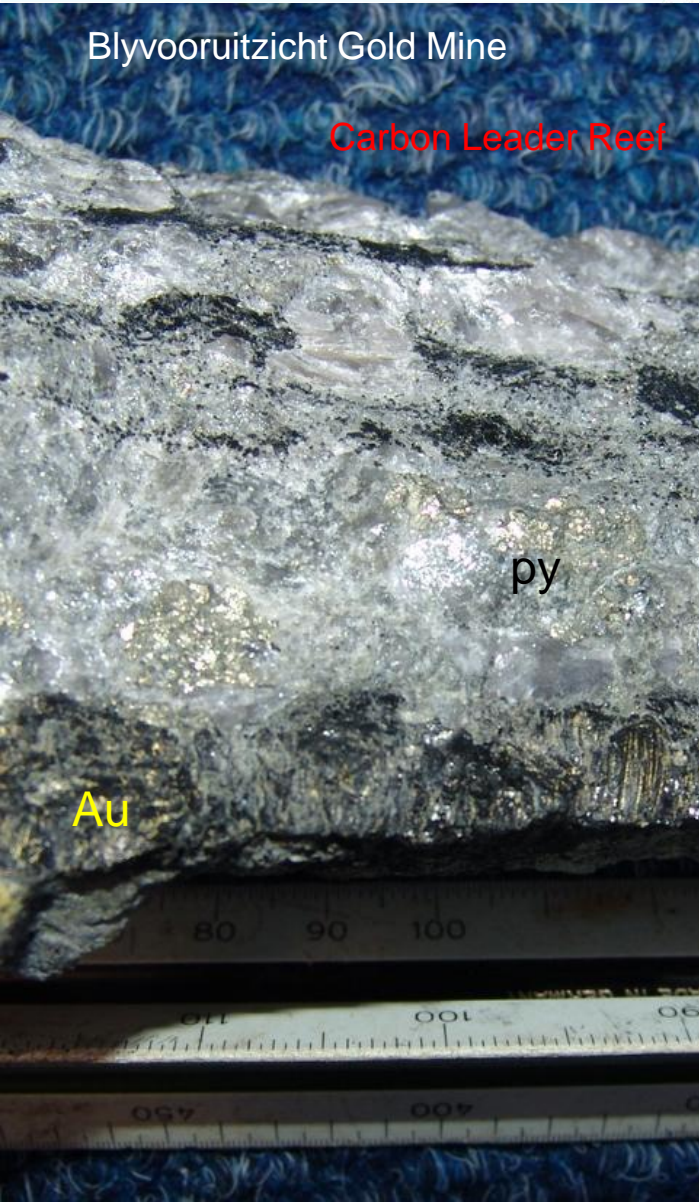
Type of conglomerate reef

matrix- or clast-supported

thick or thin

carbon-seam

Geological factors - other



Gold distribution

bottom loaded
in carbon seam

top loaded

disseminated



Mapungubwe rhino (12cm)

Conclusion

Geological factors play an important role in the design of any autonomous narrow-reef miner in South Africa.

Thank you.

Questions?