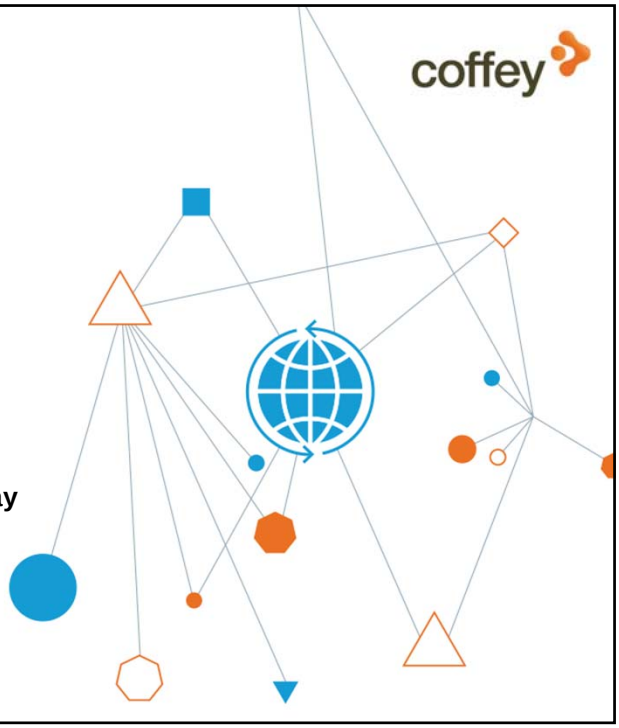
When you think with a global mind problems get smaller



Platinum Group Metals (PGE): Best Practice Sampling Methods, Assay Techniques and Quality Control

Ken Lomberg,
Senior Principal

Agenda

Geology of PGE deposits of Southern Africa

Bushveld Complex & Great Dyke

- Geology, Economic Horizons & Mineralogy

History of sampling and grade control

SAMREC Code

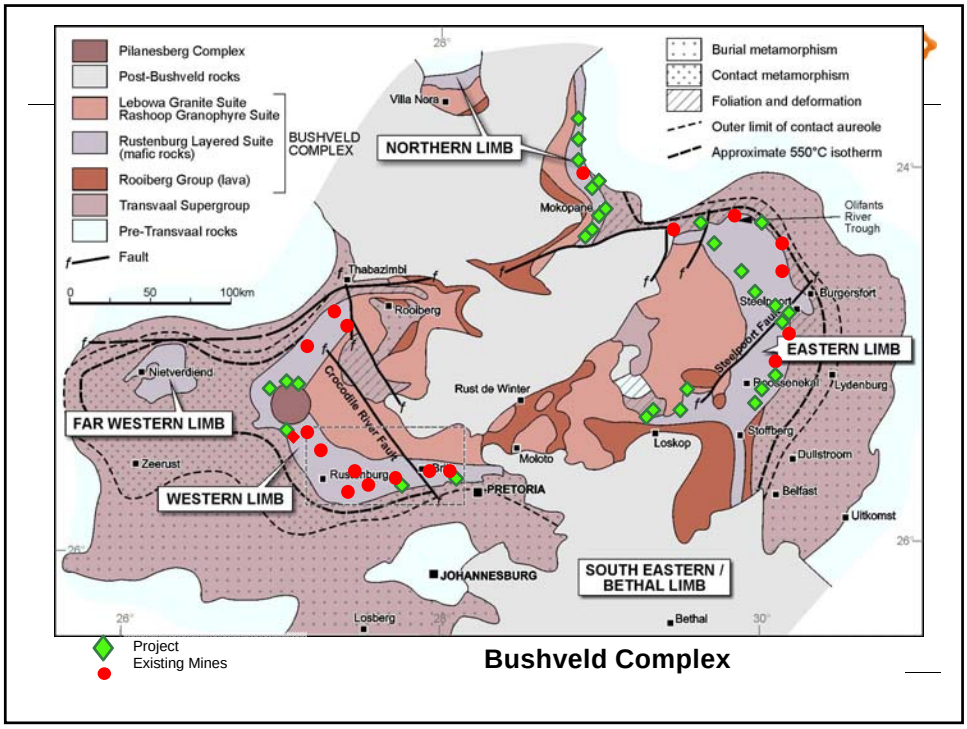
Sampling methodology

- Borehole Core
- Underground
- Blast Hole

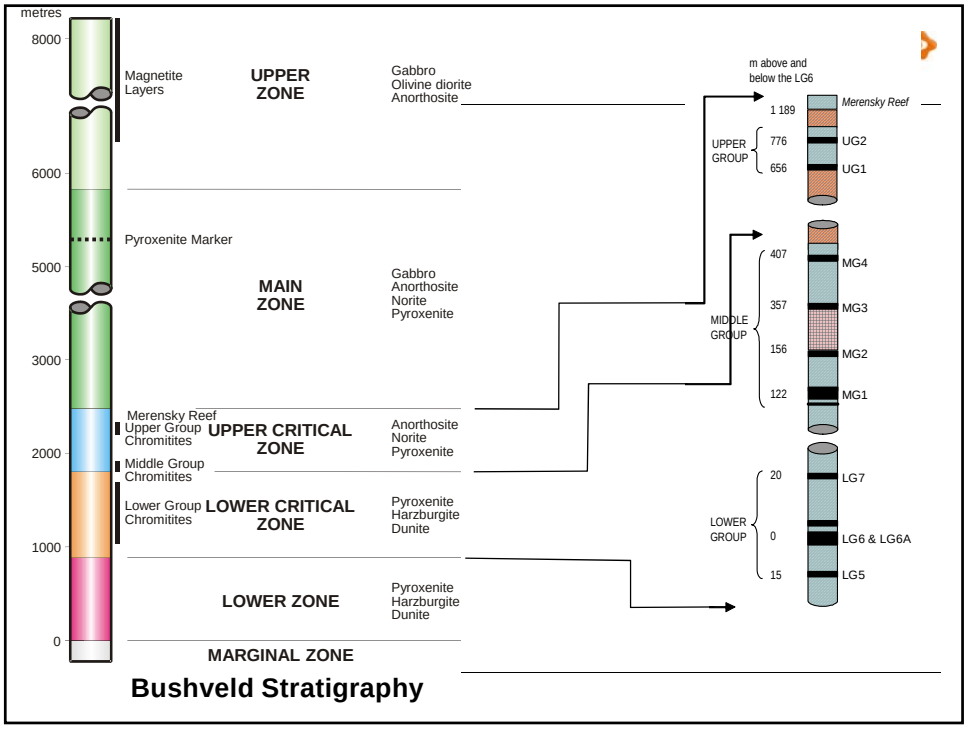
Analytical Techniques

- PGEs
- Base Metals

Quality Assurance/Quality Control



Bushveld Complex



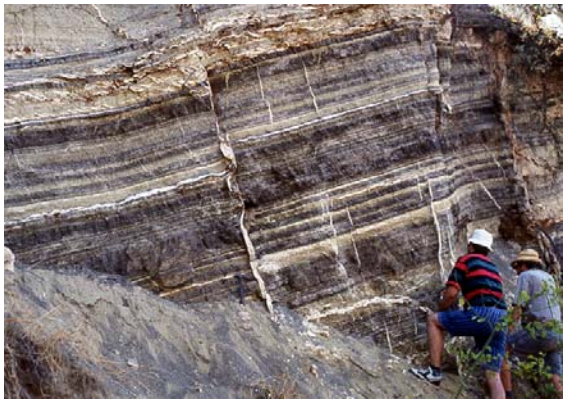
Bushveld Stratigraphy

PGE Mineralisation

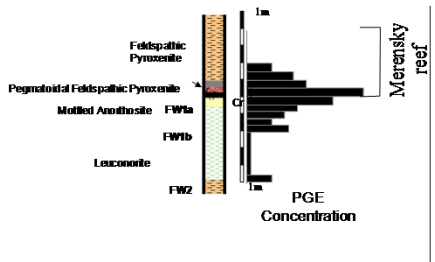
Merensky Reef

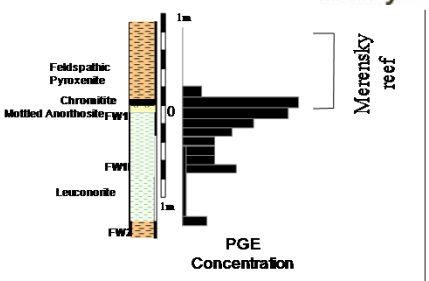
UG2 Chromitite Layer

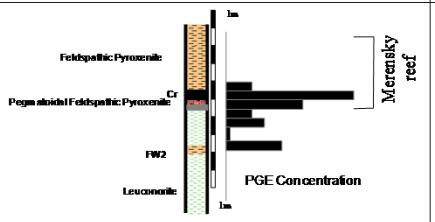
Platreef



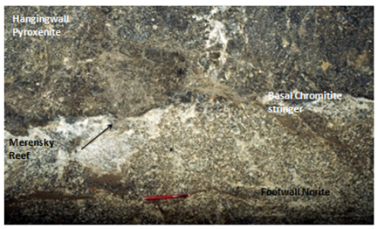
Merensky Reef Histograms





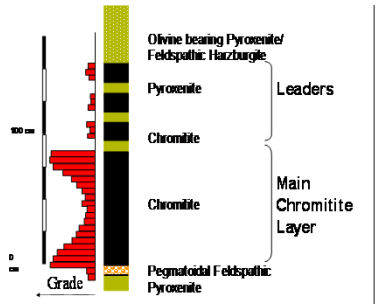


Merensky Reef at Western Platinum Mine, Western Bushveld



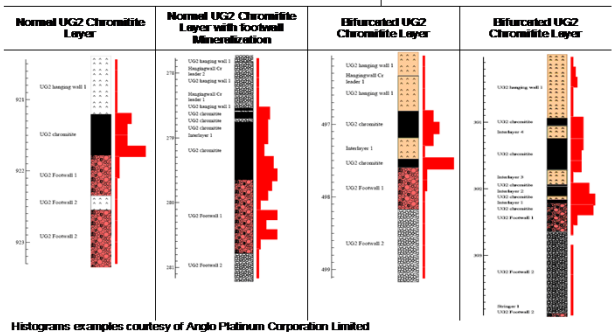
Photograph Source: Dept of Geological Sciences, University of Cape Town

UG2 Chromitite Layer Histograms



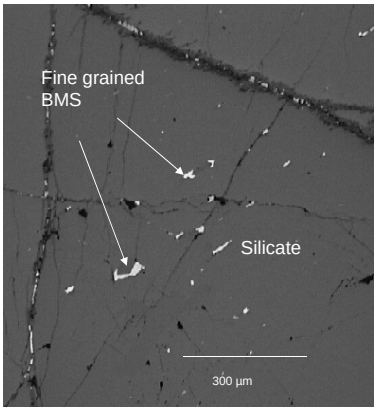
UG2 Chromitite Layer, with PGE mineralisation grade profile, Western Platinum Mine, Western Bushveld

Source: Dept of Geological Sciences, University of Cape Town

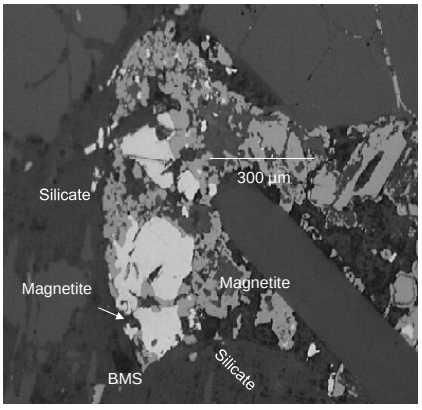


Histograms examples courtesy of Anglo Platinum Corporation Limited

PGE Mineralogy

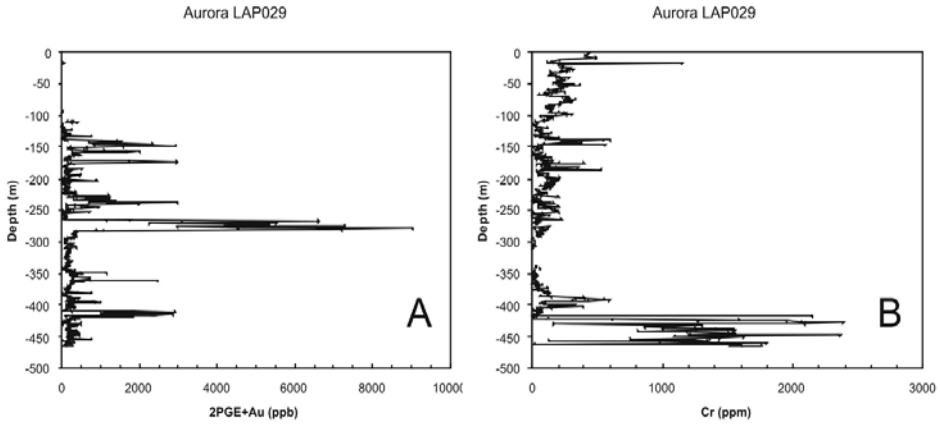


Fine grained BMS in silicate



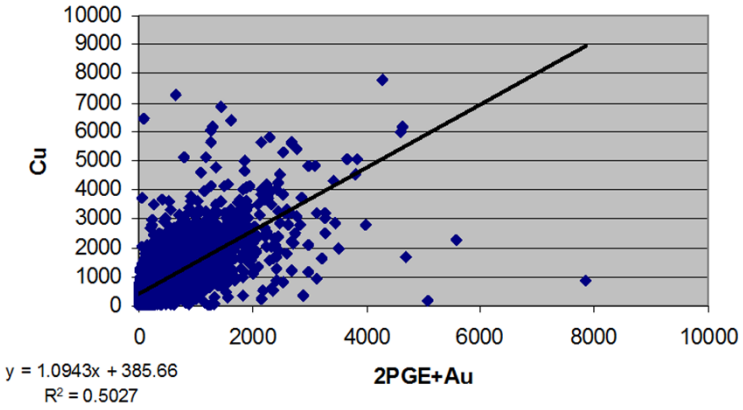
BMS associated with magnetite and silicate alteration.

Platreef Grade Histogram

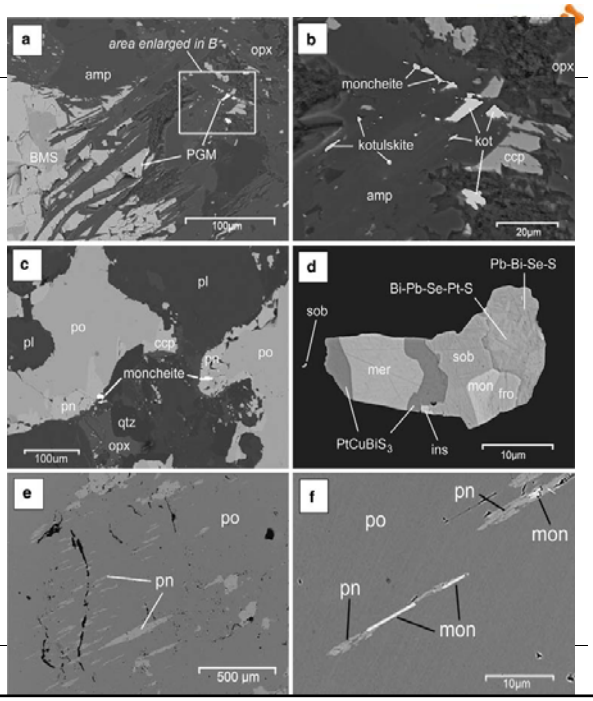


Source: MacDonald And Harmer, 2010

Use of the Relationship to Another Element

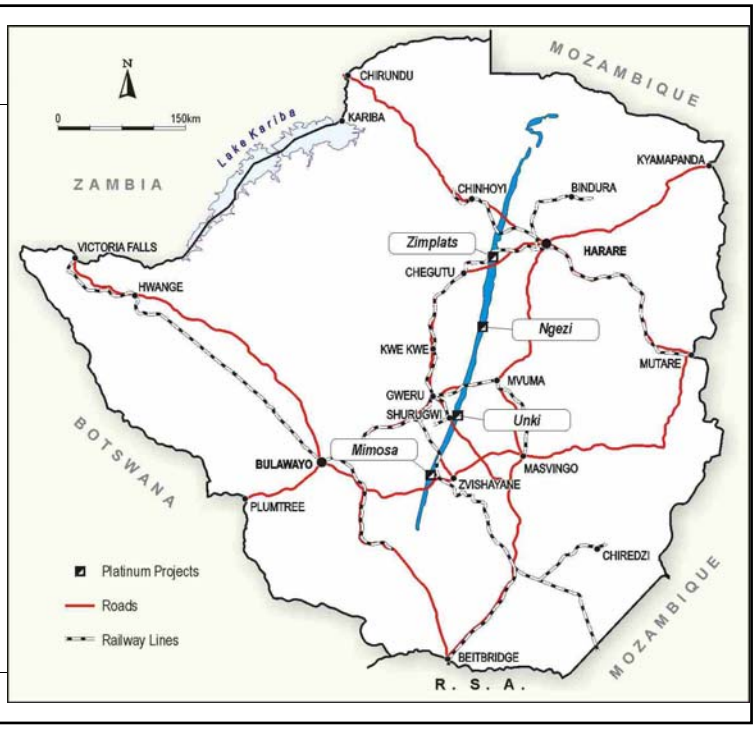


Platreef PGE Mineralogy

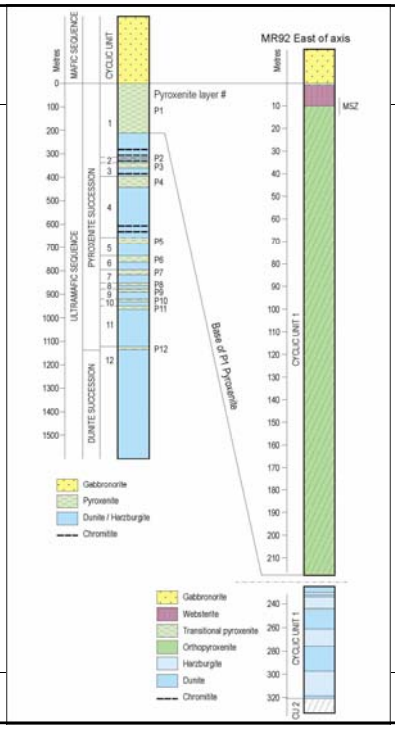


Source: D. A. Holwell and I. McDonald (2007)

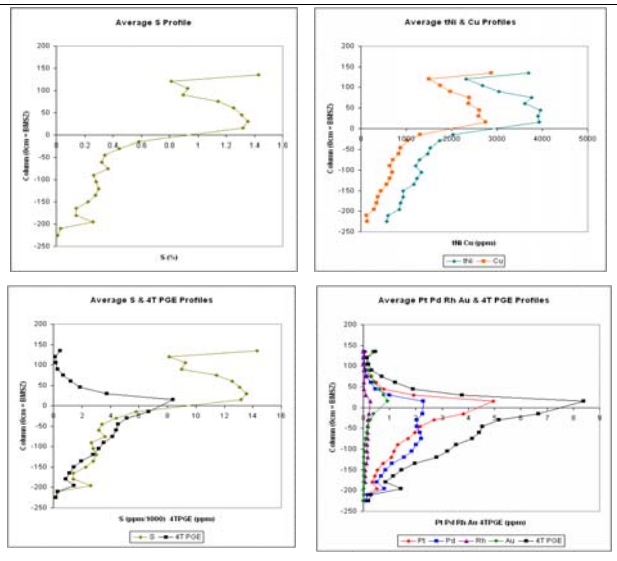
The Great Dyke

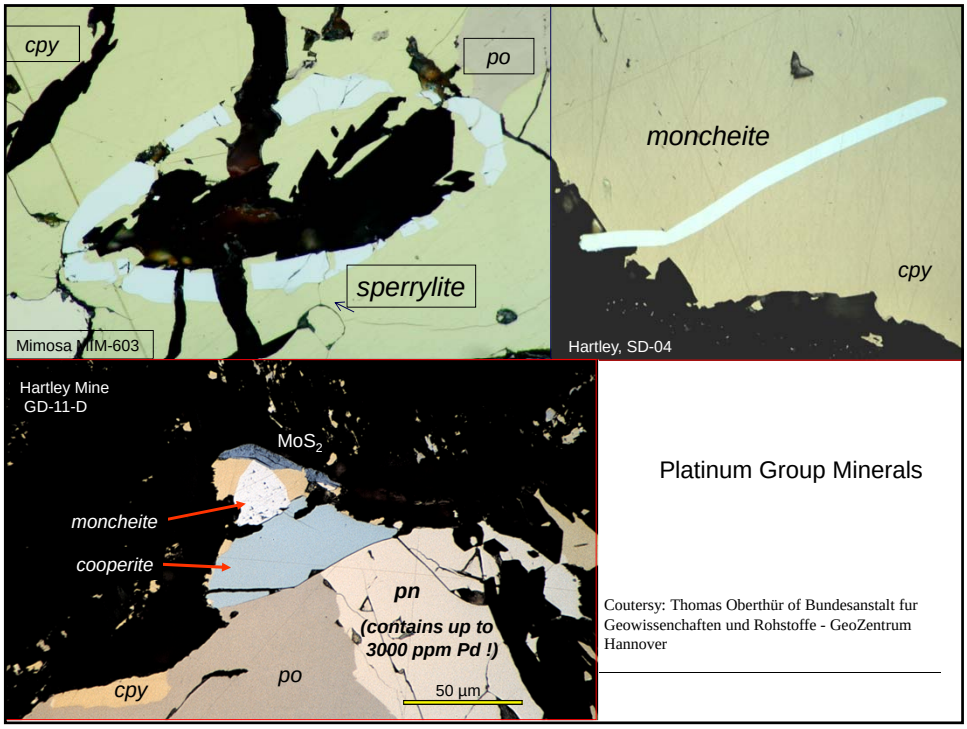


Stratigraphy of the Great Dyke



Main Sulphide Zone (MSZ)





Platinum Group Minerals

Coutersy: Thomas Oberthür of Bundesanstalt fur Geowissenchaften und Rohstoffe - GeoZentrum Hannover

History of Sampling and Grade Control

coffey

Use of Witwatersrand Gold Sampling Methods

JCI (now Anglo Platinum) and Impala

Very secretive industry

Similar methodologies developed

Mining and exploration

Mining cut instruction - Merensky Reef

UG2 Chromitite Layer

- Geotechnical analysis of the hangingwall
- Grade
- metal content

The Competent Person
SAMREC CODE

A **Competent Person** must have a minimum of five years relevant experience in the style of mineralisation or type of deposit under consideration and in the activity which that person is undertaking..

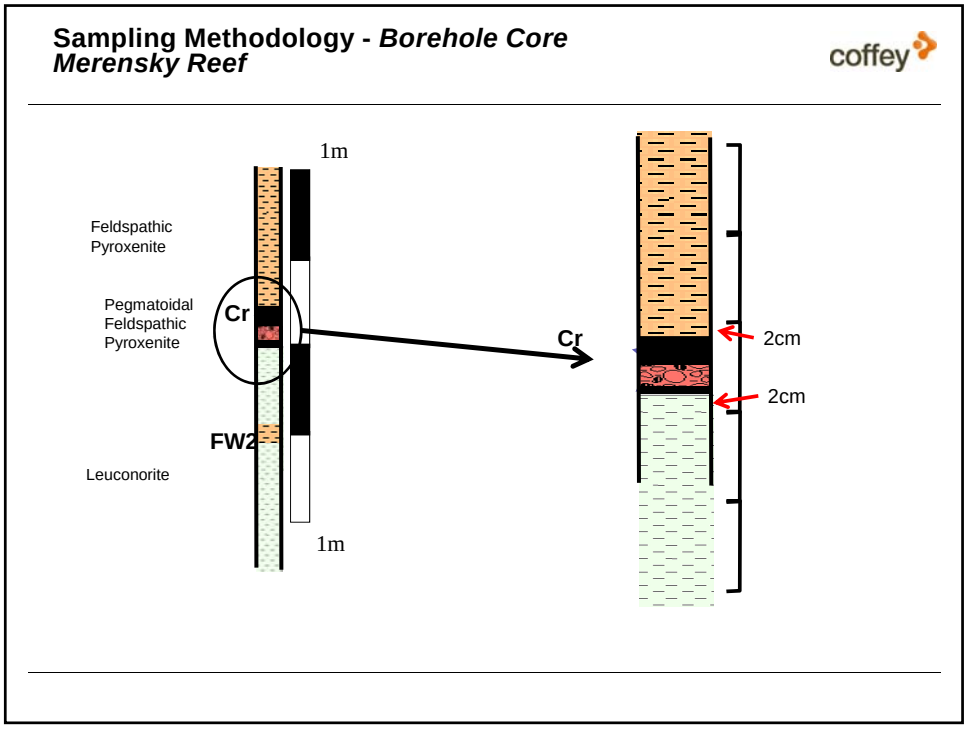
Persons being called upon to sign as a Competent Person must be clearly satisfied in their own minds that they are able to face their peers and demonstrate competence in the commodity, type of deposit and situation under consideration.

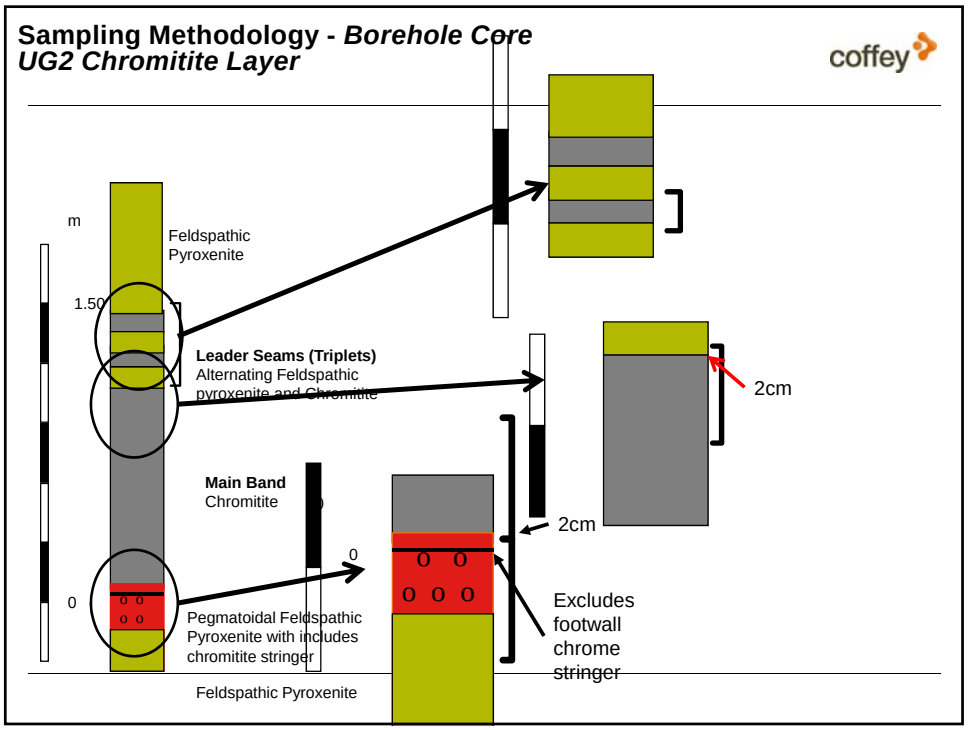
Documentation detailing Exploration Results, Mineral Resources and Mineral Reserves from which a Public Report is prepared must be prepared by, or under the direction of, and signed by a Competent Person.

SAMREC
THE SOUTH AFRICAN CODE FOR THE REPORTING OF EXPLORATION RESULTS, MINERAL RESOURCES AND MINERAL RESERVES

Sampling Methodology - *Borehole Core*

Photo Credit: PTM


Sampling Methodology - *Borehole Core*
Merensky Reef
coffey
1m
Feldspathic
Pyroxenite
Pegmatoidal
Feldspathic
Pyroxenite
Cr
Cr
FW2
Leuconorite
1m
2cm
2cm


Sampling Methodology - *Borehole Core*
UG2 Chromitite Layer
coffey
m
Feldspathic
Pyroxenite
1.50
Leader Seams (Triplets)
Alternating Feldspathic
pyroxenite and Chromitite
2cm
Main Band
Chromitite
0
2cm
0
Excludes
footwall
chrome
stringer
Pegmatoidal Feldspathic
Pyroxenite with includes
chromitite stringer
Feldspathic Pyroxenite

Source: Kameni Ltd

Sampling Methodology - *Borehole Core Platreef*

"Once the logging is complete, the drill hole is marked up for sampling. Because of the nature of the mineralisation, almost the entire length of the drill holes is sampled on a metre interval"

Sampling Methodology - *Borehole Core*
Main Sulphide Zone

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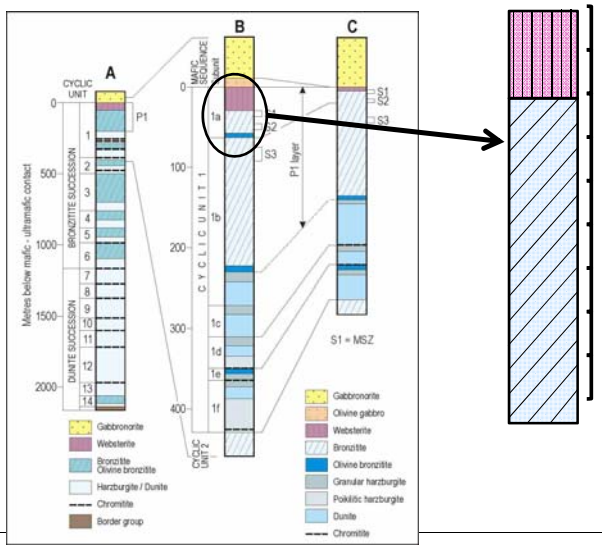

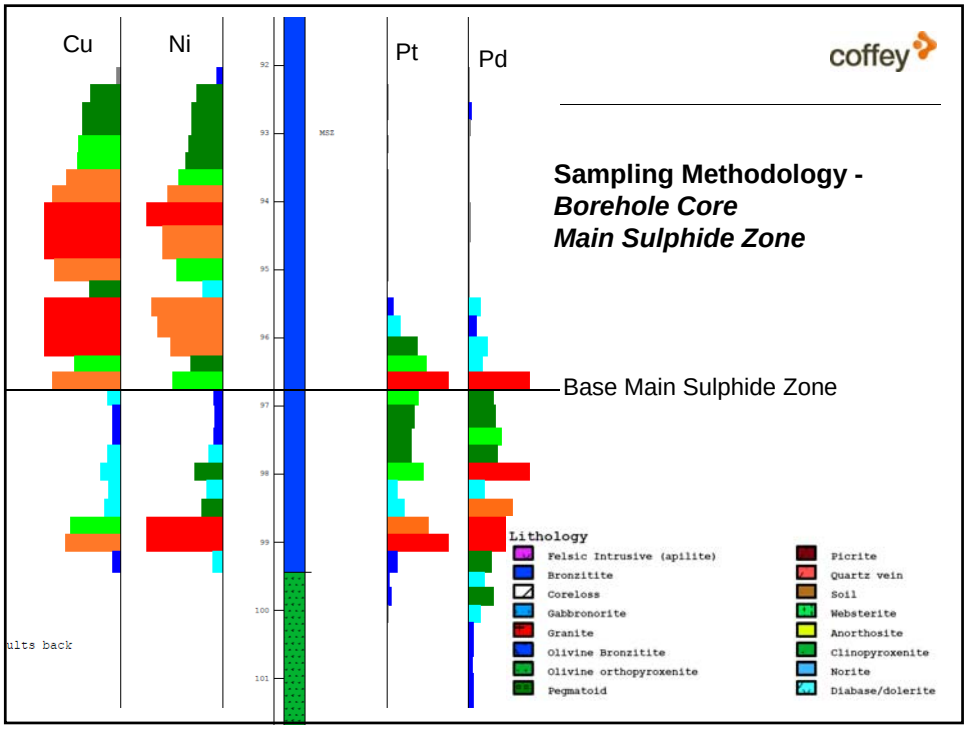

Sampling Methodology -
Borehole Core
Main Sulphide Zone

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Sampling Methodology – *Underground*

Intended to mimic borehole core

Underground sampling protocols similar to those used for core

Differences relate to the access to the underground face and the equipment limitations.

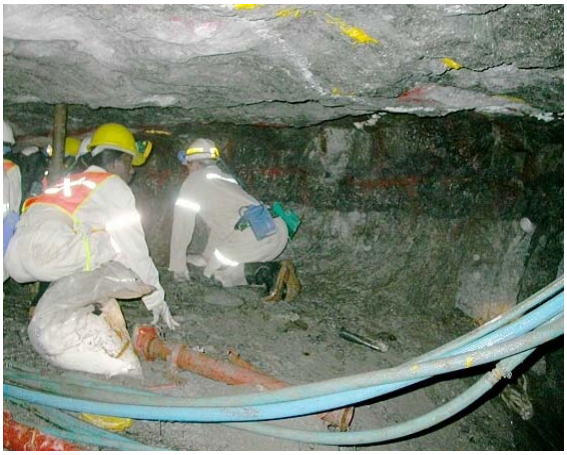
Traditionally underground sampling - a hammer and a cold chisel

The inherent with sampling errors ∴ use of diamond saws

Development ends

Specific Protocols

Sampling Methodology – *Underground*



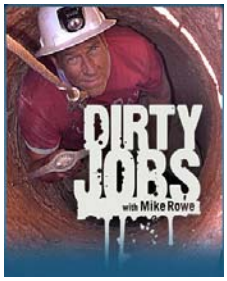


Photo: UCT gallery

Sampling Methodology – *Underground*

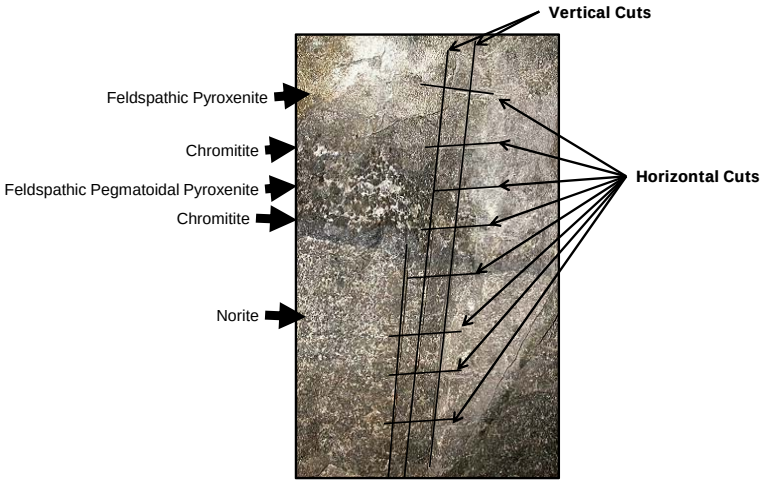


Photo: UCT gallery

Sampling Methodology – *Blasthole*

Mogalakwena Platinum Mine

- Determination of grade
- Indicates to which stockpile the material should be dispatched
- The blast holes are designed and drilled for blasting purposes with 310mm, 250mm and 165mm size bits.
- Blast hole drilling replaced with reverse circulation (RC) drilling

Courtesy: Trust Muzondo, Anglo Platinum Corporation

Sample Size

Need to define mineralised cuts => sufficient small samples to define mineralised or mining cut

Sufficient mass to apply sampling theory

Use of as much sample as possible => 50g aliquot for fire assay

PGE deposits have moderate to high “Nugget Effect”

The sample preparation and communation protocol is very sensitive the grain size of the precious metals

Fire assay method

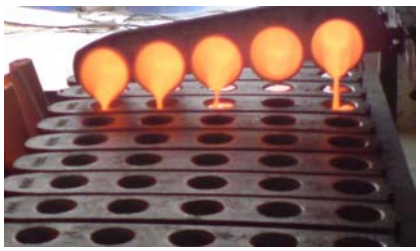
coffey

Advantages

- Can handle large sample weights with low analyte concentrations
- Addresses non-homogeneity
- Addresses `nugget effect';
- Assurance of quantitative collection of all the PGM (NiS-fire assay)
- Complete separation from base metals and other matrix elements

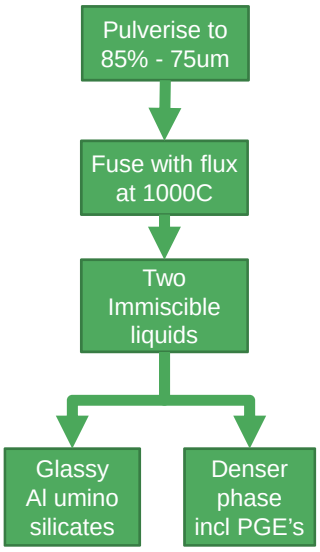
Disadvantages

- Uses PGM in sample decomposition and solution preparation
- Selection of suitable flux composition is important
- Generalised flux weights lead to erroneous results;
- Requires skilled personnel.



Analytical Techniques - PGEs

- Difficult to determine at low concentration
- Appropriate methods and protocols developed to determine PGE concentration with required accurate and precision
- Emphasis of prill or individual elements
- Important aspect is the type of collector
- Pb collector – Pt, Pd, Rh, Au
- Ag – allows detection limit 0.1ppb Pt and 0.5ppb Pd
- Ni – Sulphide collector
- Detection limit for commercial laboratories 0.02 – 0.005 ppm
- Economics of deposits much greater than possible detection limits



Analytical Techniques – Base Metals

- Emphasis on PGEs
- Cu, Ni and Co important components of
  - Mineralisation
  - Revenue
- level of base metal OOM lower than a primary base metal deposit
- Detection limit

Commonly used techniques

- Pressed pellet and X-ray fluorescence (XRF)
- Aqua Regia leach
- Four Acid Digestions
- Sodium Peroxide Fusion
- Wet chemistry

Quality Assurance/Quality Control

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- Confirm both the precision and accuracy of assays
- Ensure that they can be confidently relied upon
- The control samples recommended in every 20 samples
  - Two different standards,
  - Blank
  - Duplicate
- Additionally – 5% referee laboratory
- on-going QA/QC analyses and addresses queries to the laboratory.

"The value in a good QA/QC programme is that it identifies potential weaknesses in the sampling procedure or sampling errors and allows the geologist to correct or minimise them prior to them negatively influencing the assay data. "

Approach to Sampling for PGE Mineralisation

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✓Application of specialist knowledge

✓Understanding of each parameter applied to the sampling protocols

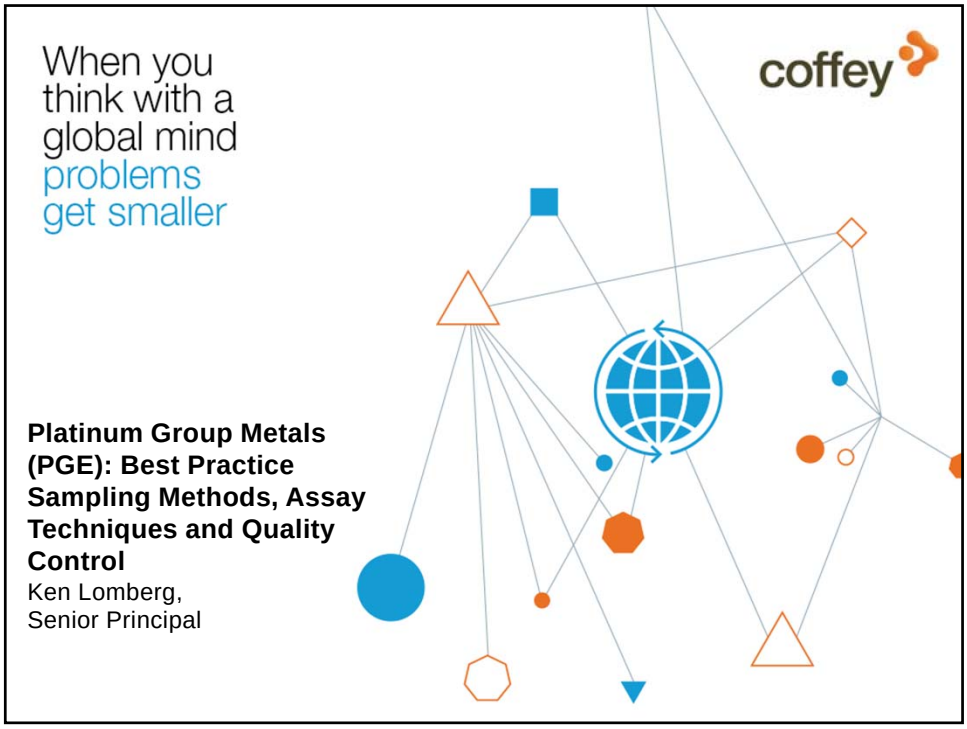
✓Full understanding of the geology and mineralisation

✓Understanding of analytical approaches

✓Appreciation of the very low concentrations

× Application of a procedure (Black Box Approach)

⇒ Reduces uncertainties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