A comparison between the PGM mineralogy of the pristine sulphide and oxidised ores of the Wedza Subchamber, Great Dyke - Zimbabwe.

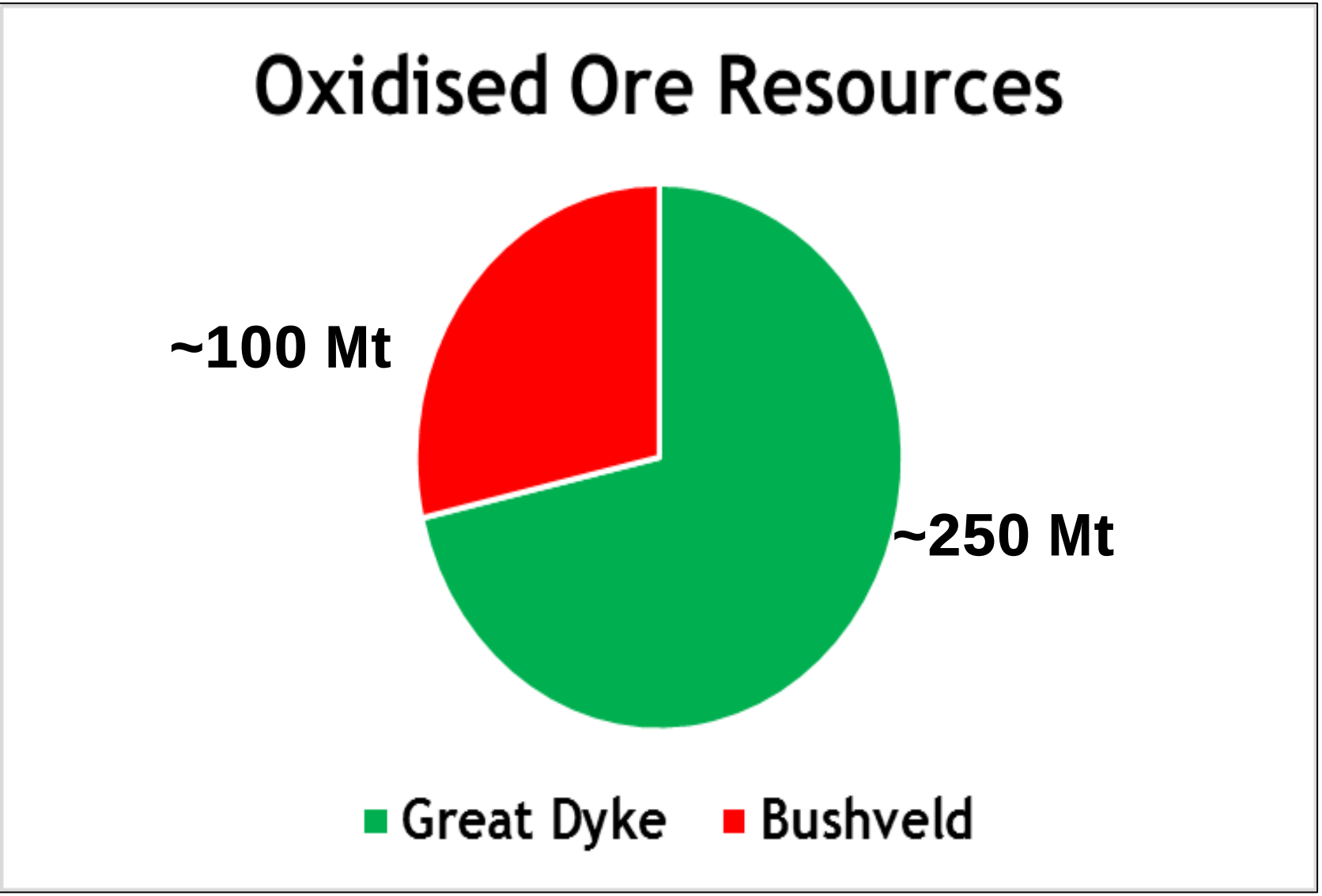
Freddy Chikwiri

Outline

- The Great Dyke
- Wedza Subchamber
- Pristine vs. Oxidised Main Sulfide Zone (MSZ)
  (Petrography, Geochemistry, PGE distribution, PGM mineralogy)
- Ore Resources
- Further Work, Conclusions

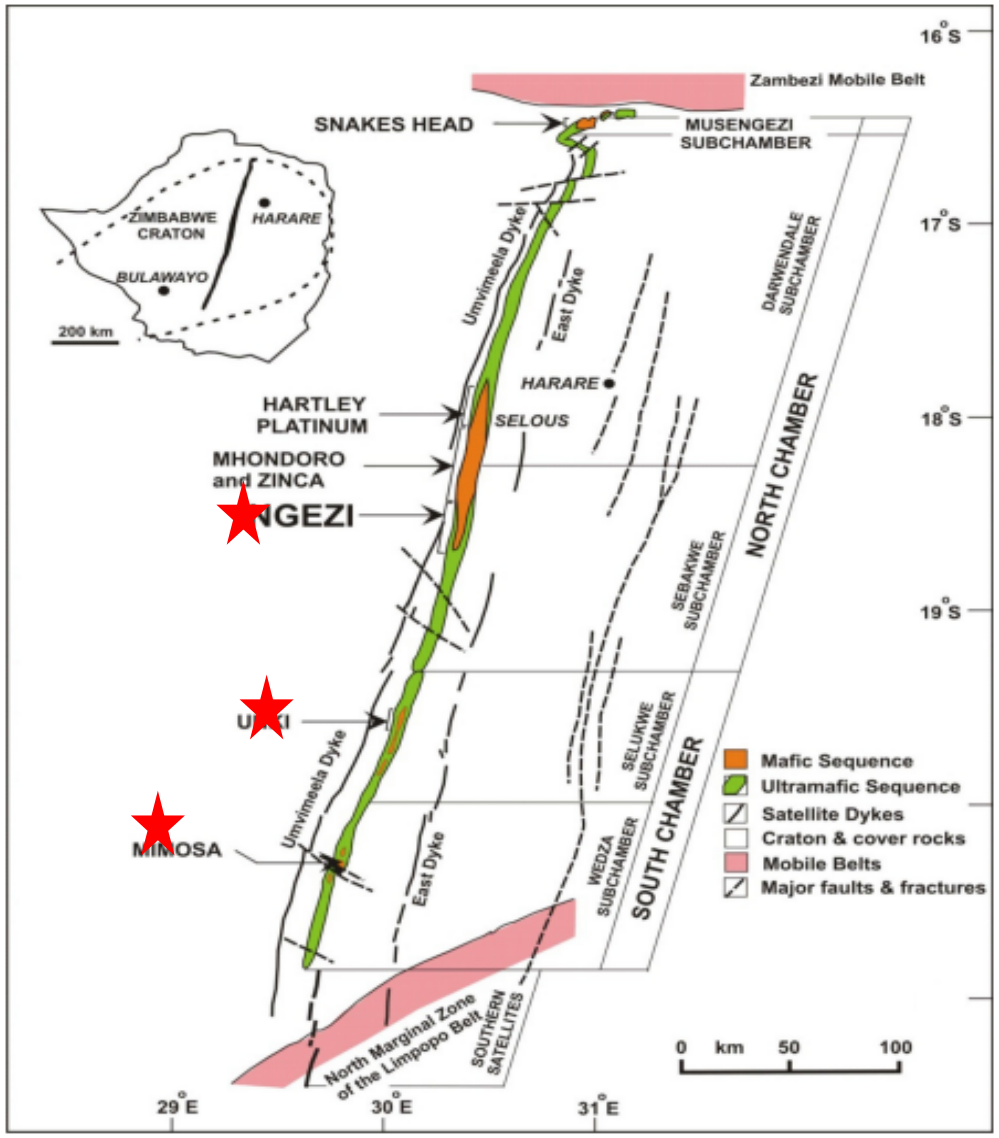
**PGM mineralogy data represents most weathered samples*

Oxidised Ore Resources



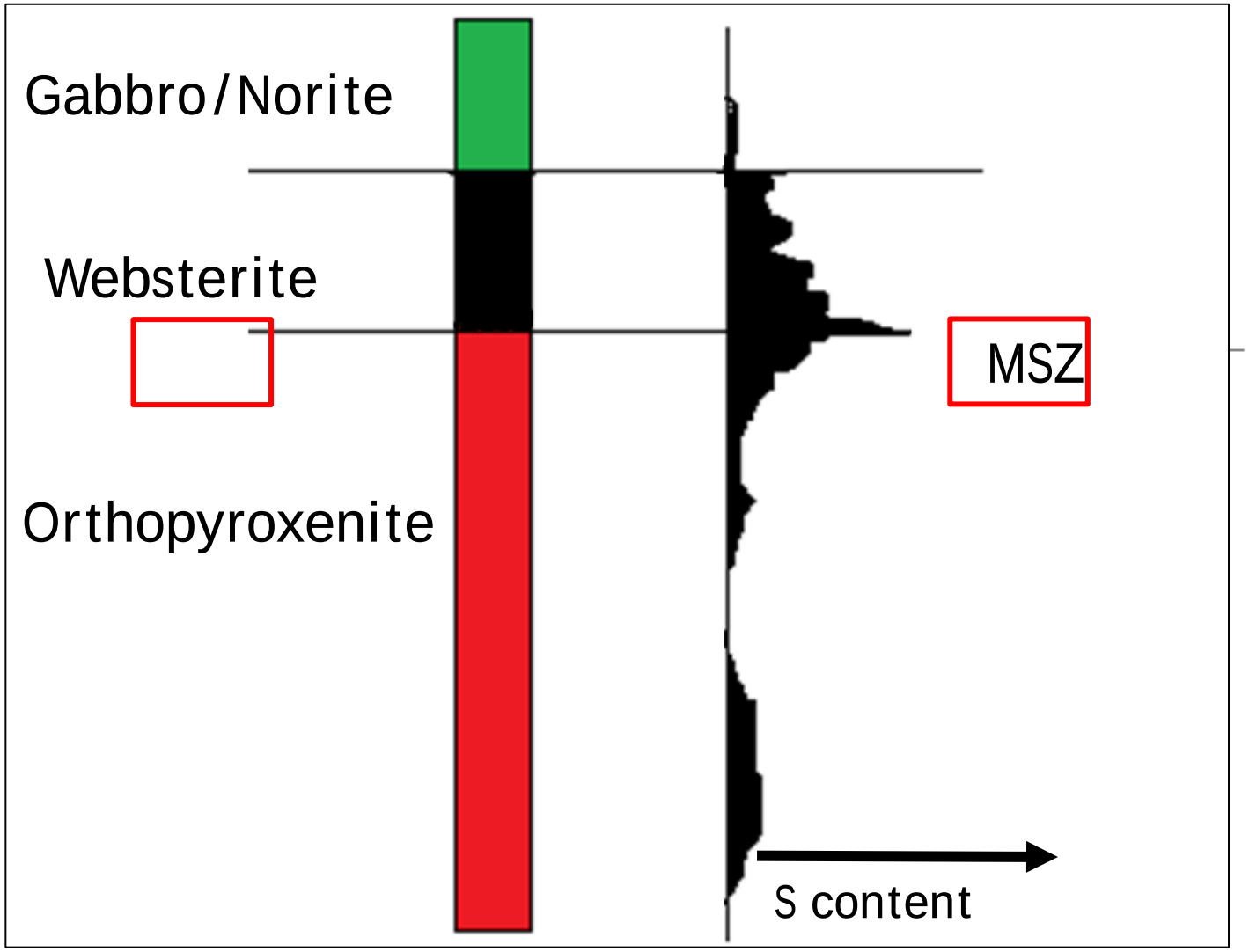
- ~30% recovery using conventional recovery methods
- Future treasure chest waiting for extraction

The Great Dyke



- Linear layered intrusion
- Archaean (2575.4 ± 0.7 Ma; Oberthur et al., 2002)
- Upper mafic and lower ultramafic succession
- Two chambers and five subchambers
- World's second largest reserve of platinum group elements (PGE).

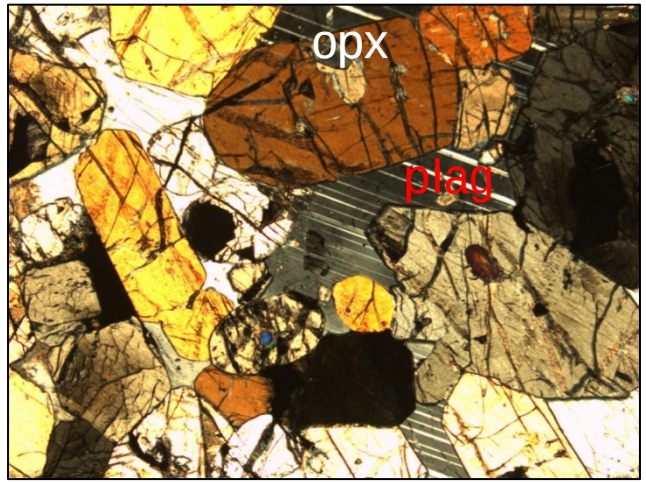
The Wedza Subchamber

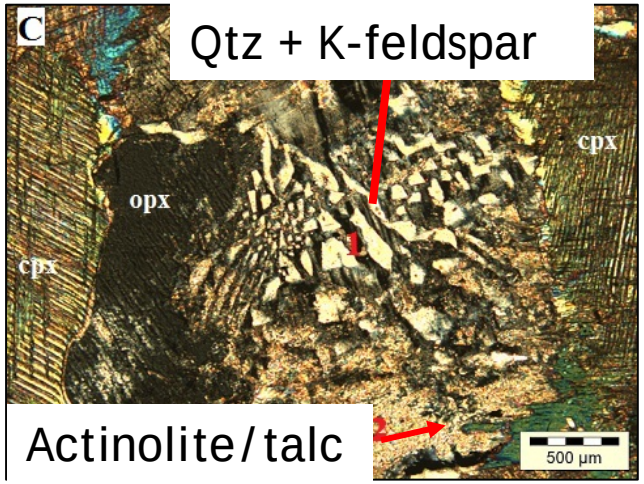


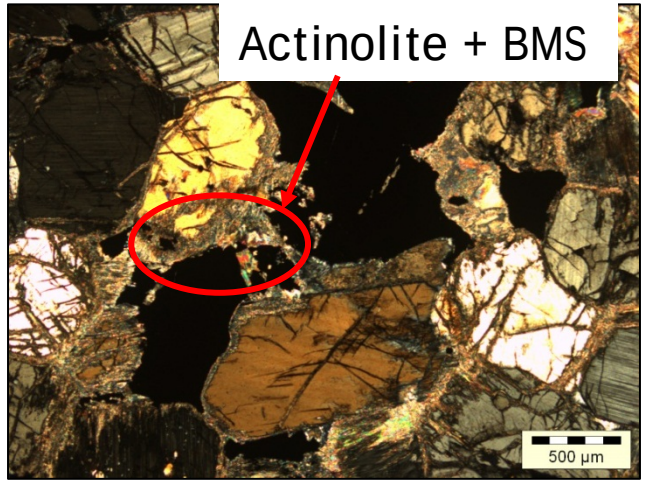
- Shallowly dipping, from 14° at margin to 0° at axis
- MSZ holds economic concentrations of PGE
- MSZ is in the P1 layer and occurs a few metres below the transition from the ultramafic to the mafic sequence

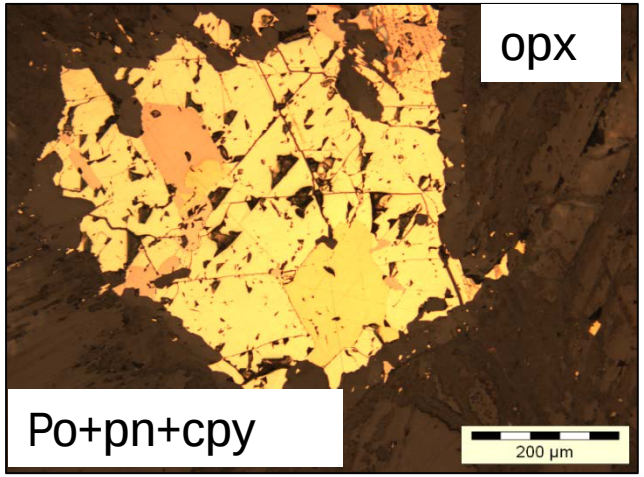
Petrography

Sulphide Ore

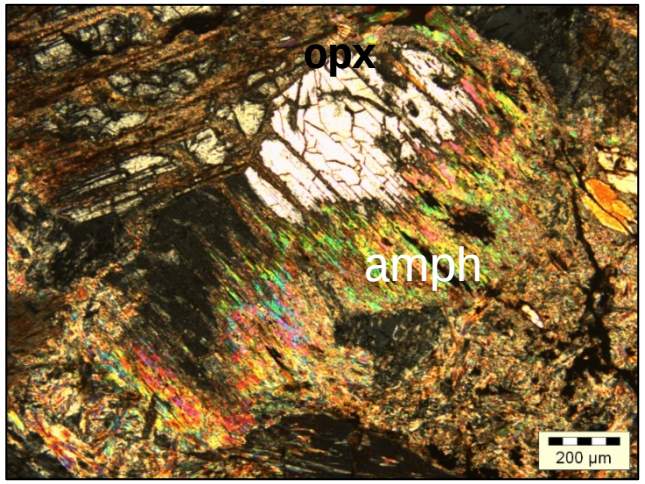


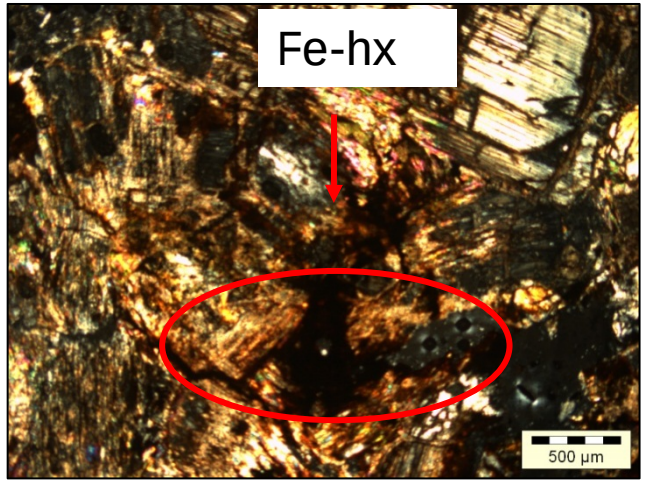




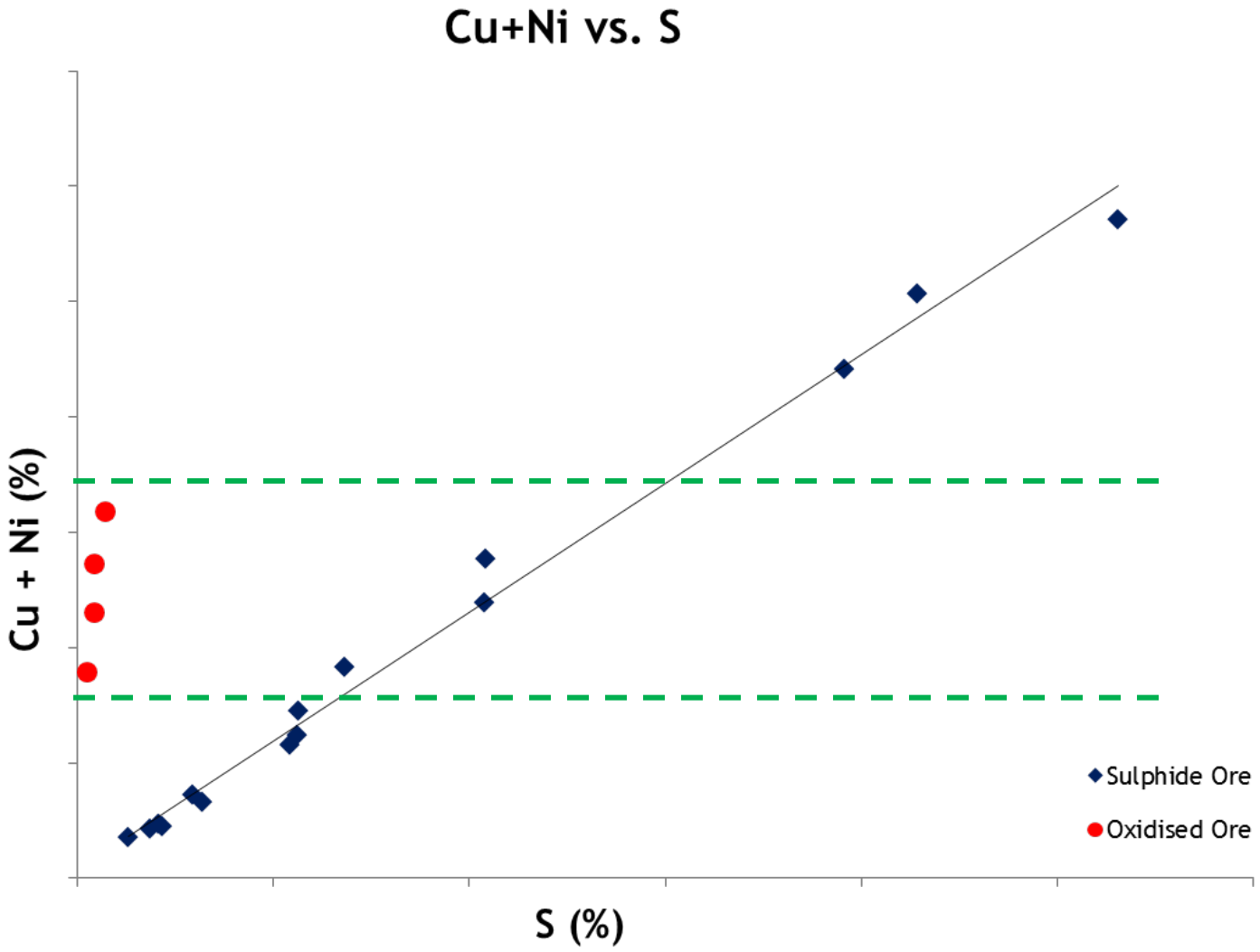


Oxidised Ore



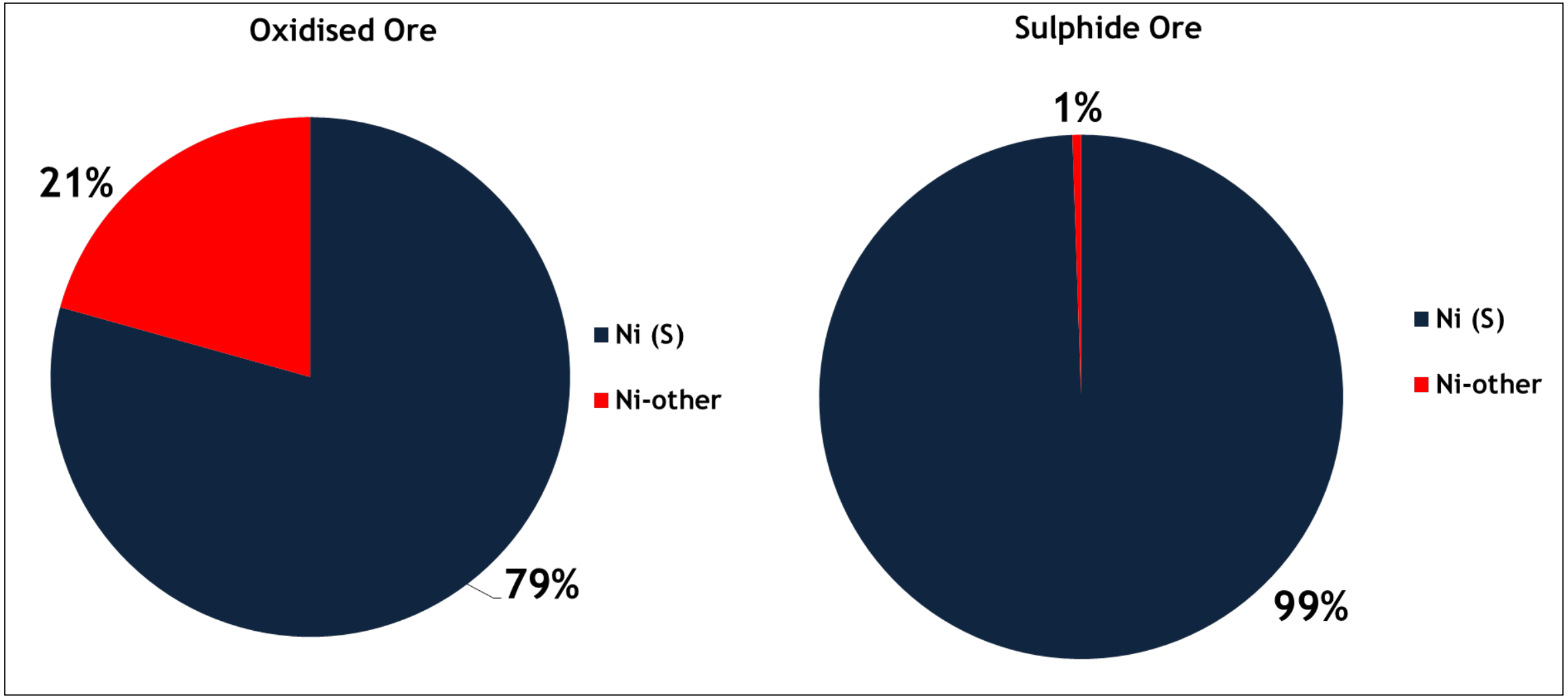


Cu, Ni Distribution

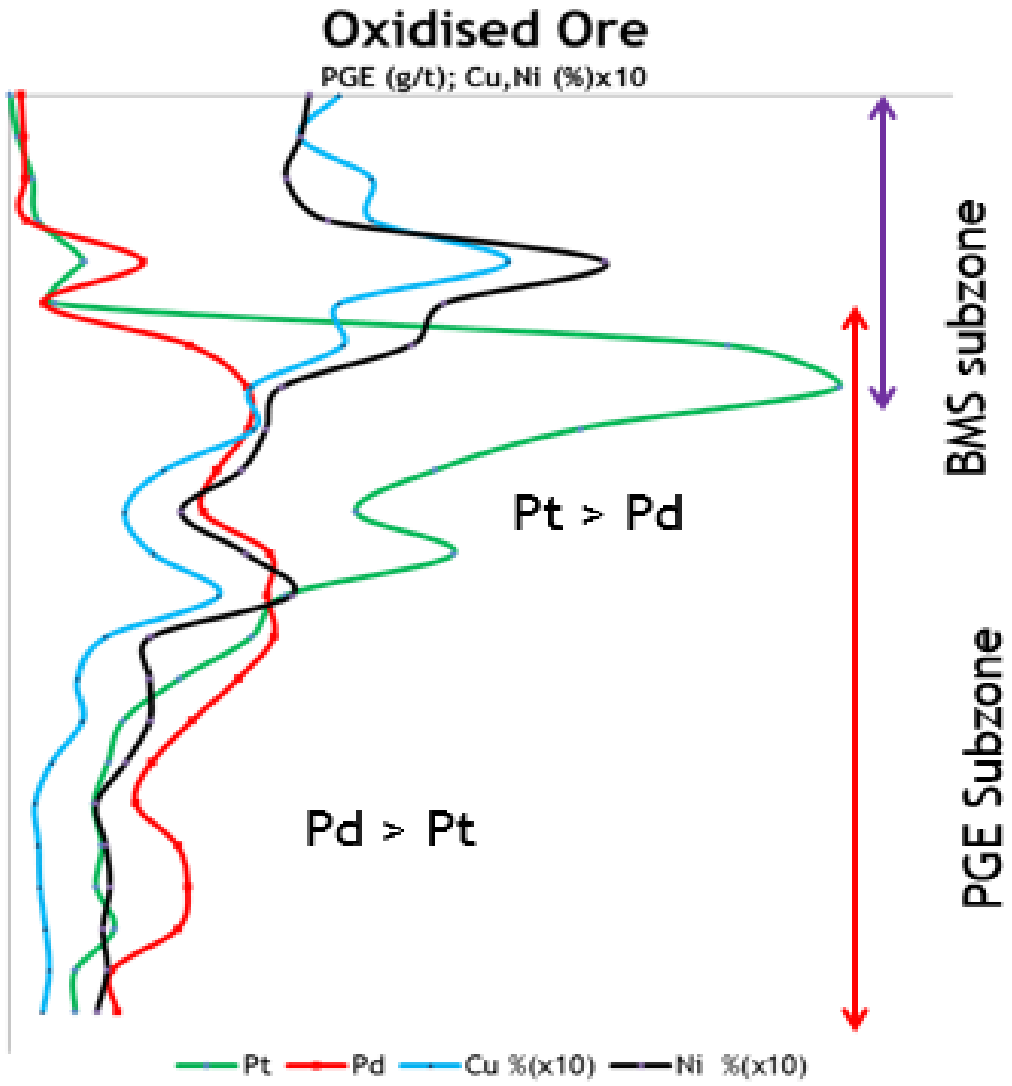


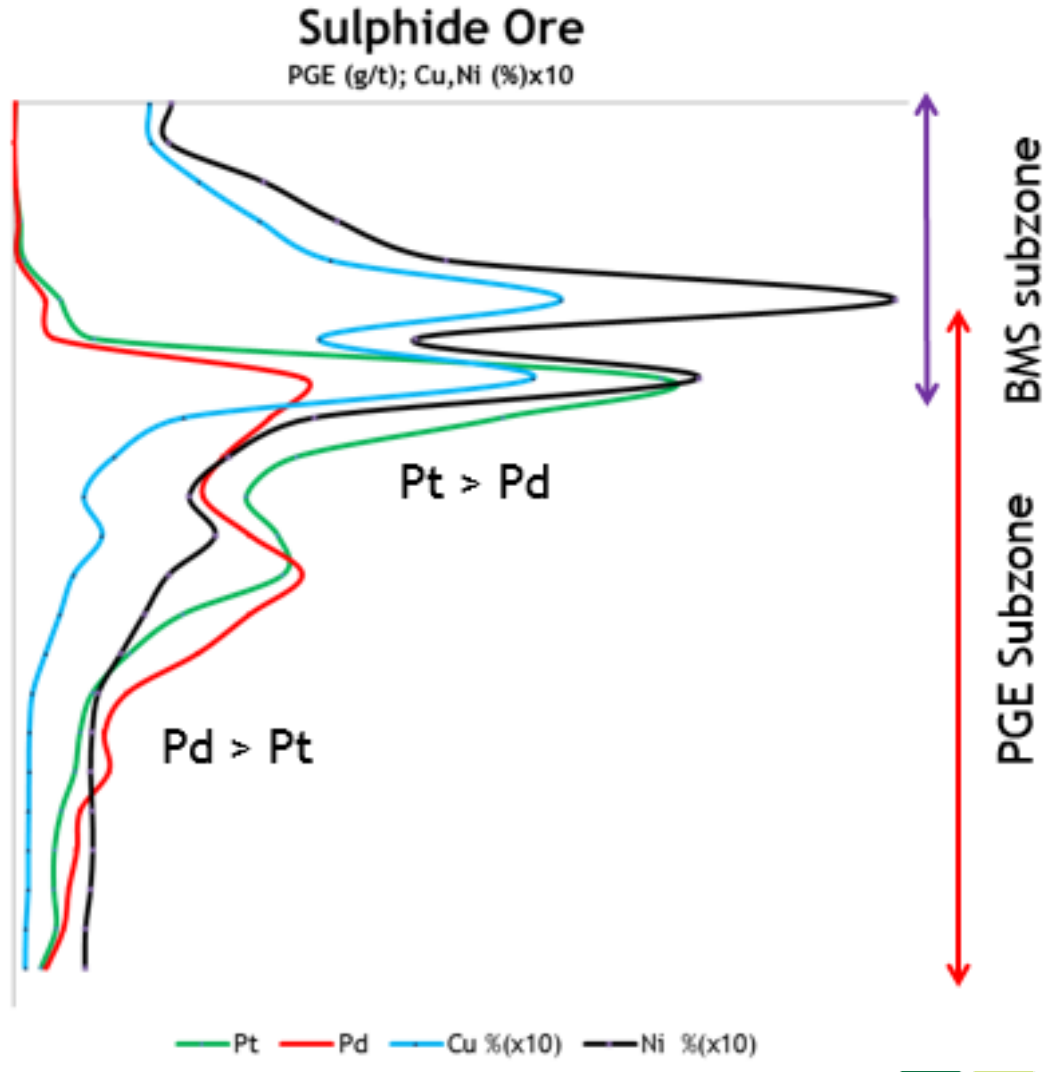
- Cu and Ni increase with S in sulphide ore
- Increases in Cu and Ni don't correlate with S increase in oxidised ore
- Low S % in oxidised ore
- Similar Cu, Ni grades

Cu, Ni Distribution

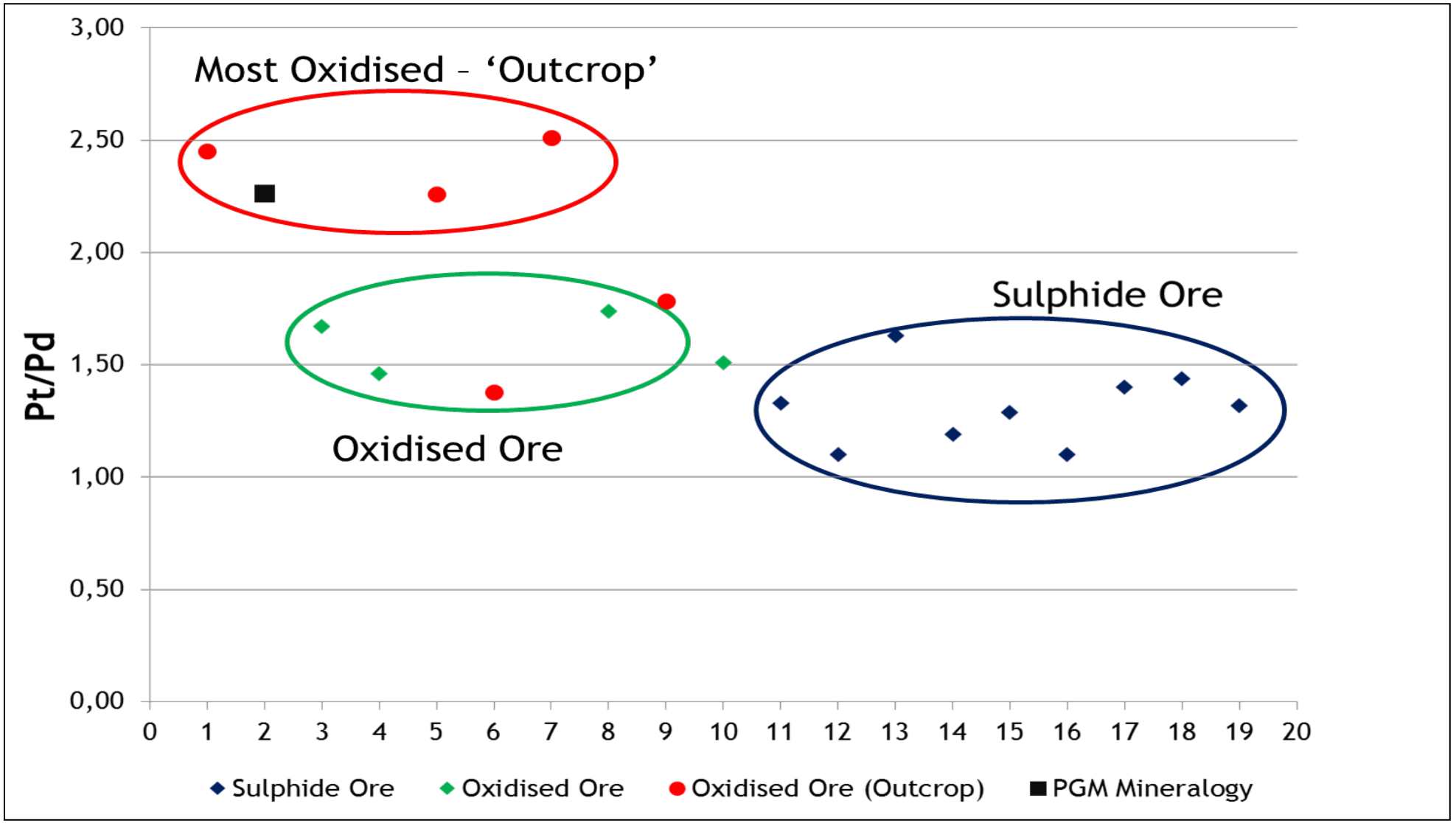


PGE Distribution 'offsets'

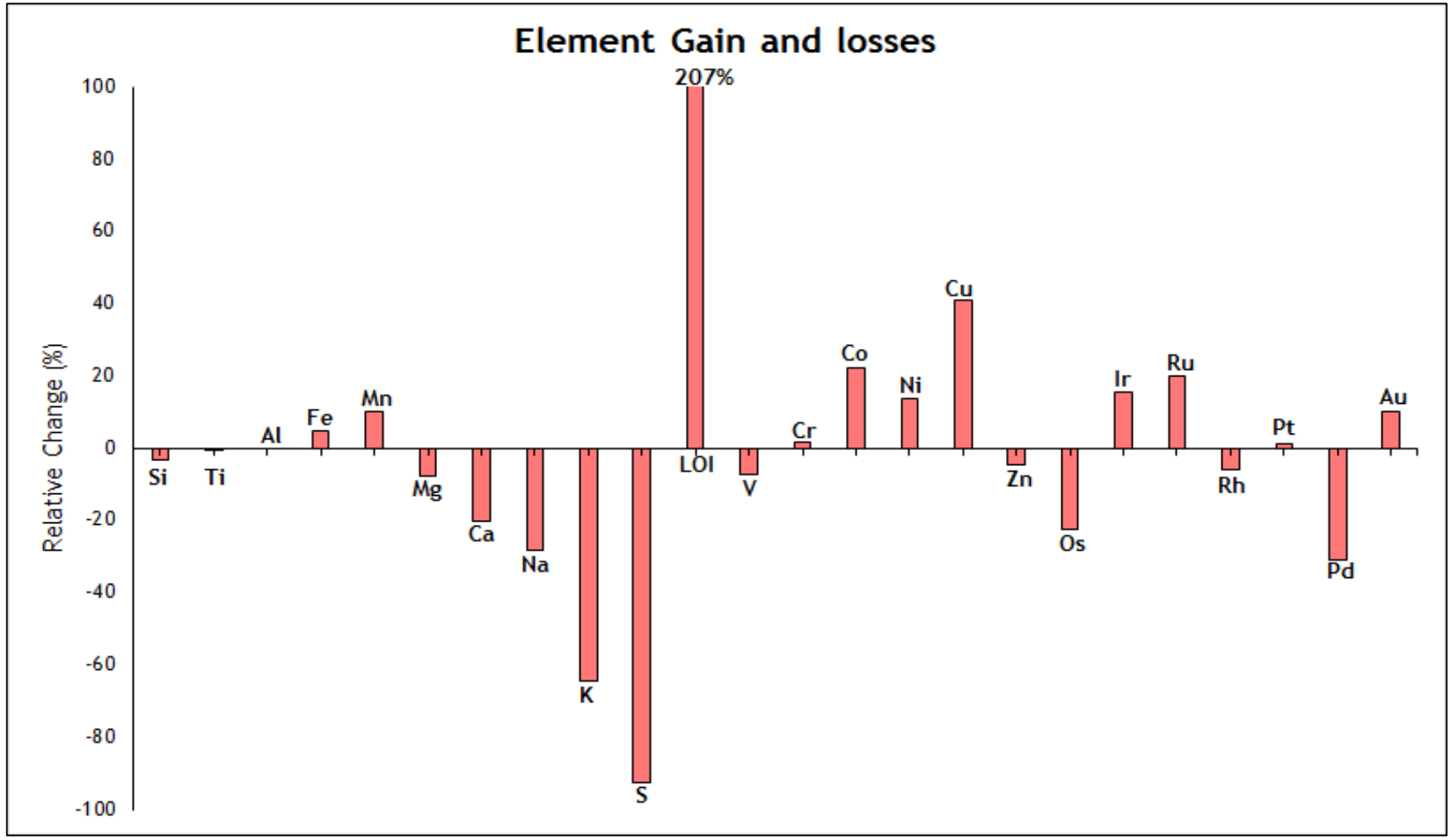




Pt/Pd Ratios


Most Oxidised – 'Outcrop'
Sulphide Ore
Oxidised Ore
Pt/Pd
3,00
2,50
2,00
1,50
1,00
0,50
0,00
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Sulphide Ore
Oxidised Ore
Oxidised Ore (Outcrop)
PGM Mineralogy

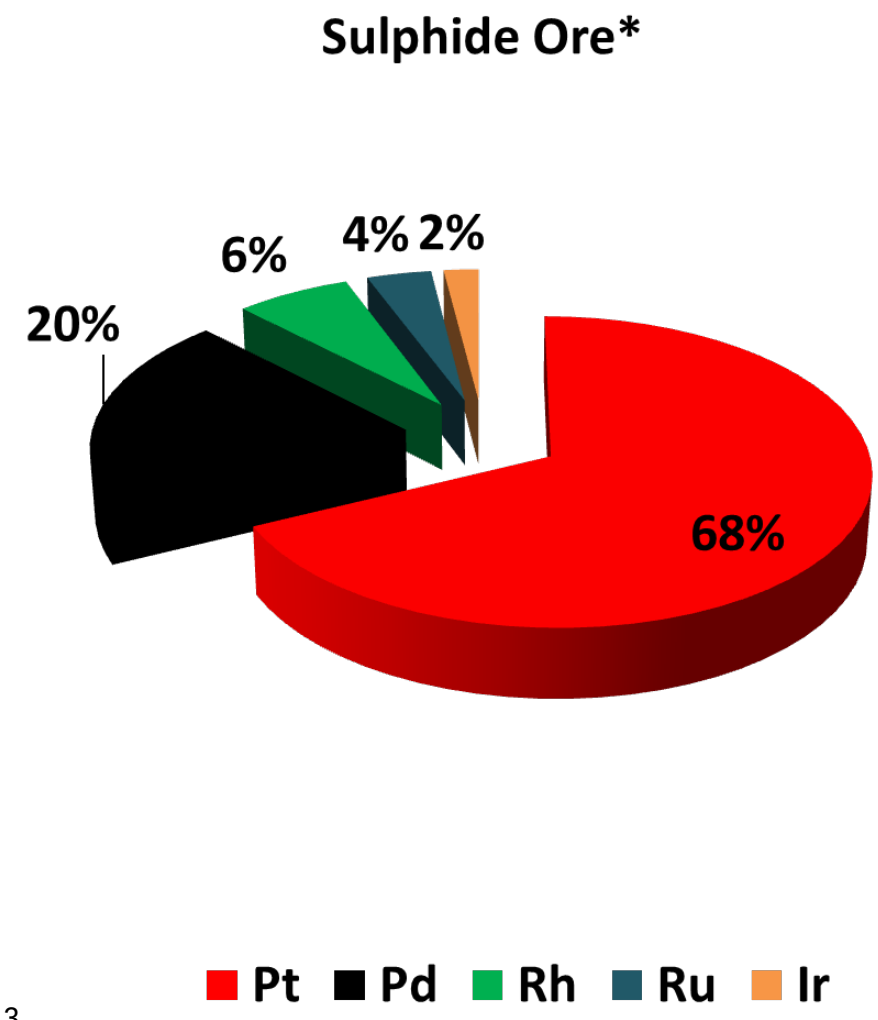
Gains/Losses

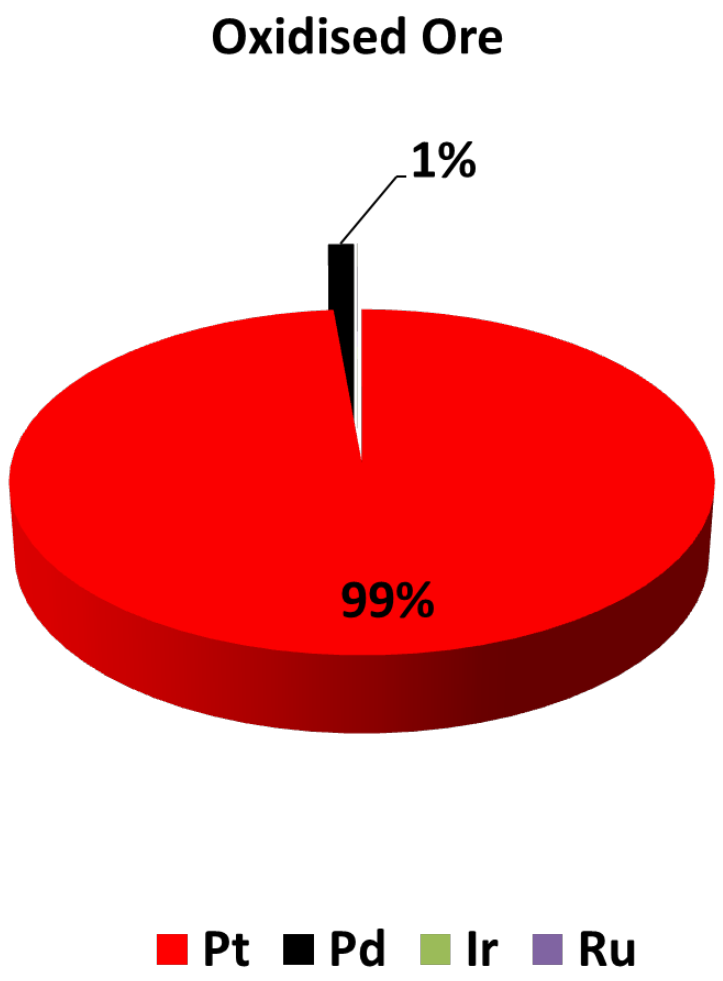


After Gresens (1967); Al=constant

- 91 % S loss
- 37 % Pd loss
- 207 % LOI gain
- 41 % Cu gain

PGM by dominant PGE (%)



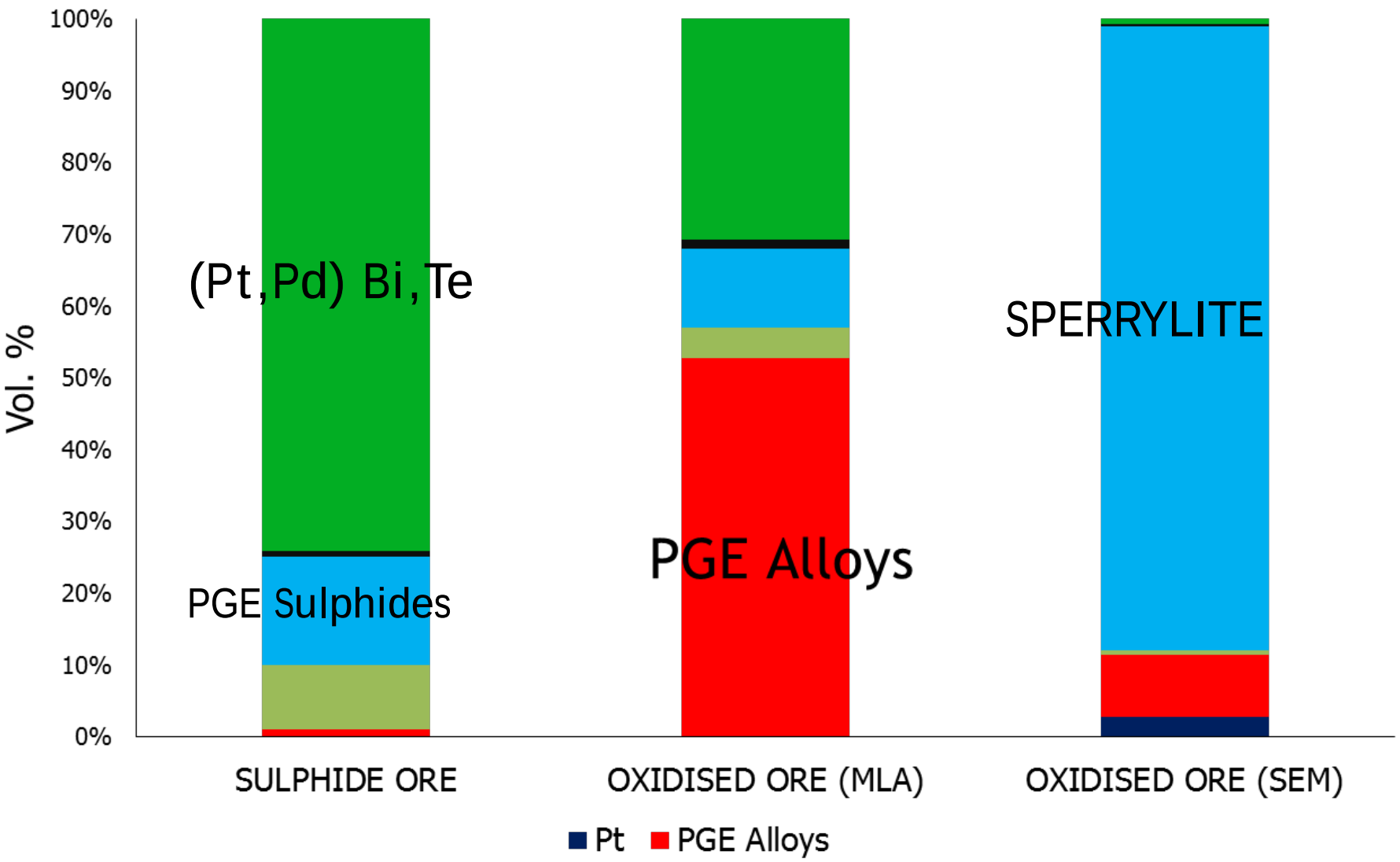


*After **Oberthür** 2013

Mineralogical siting of PGE

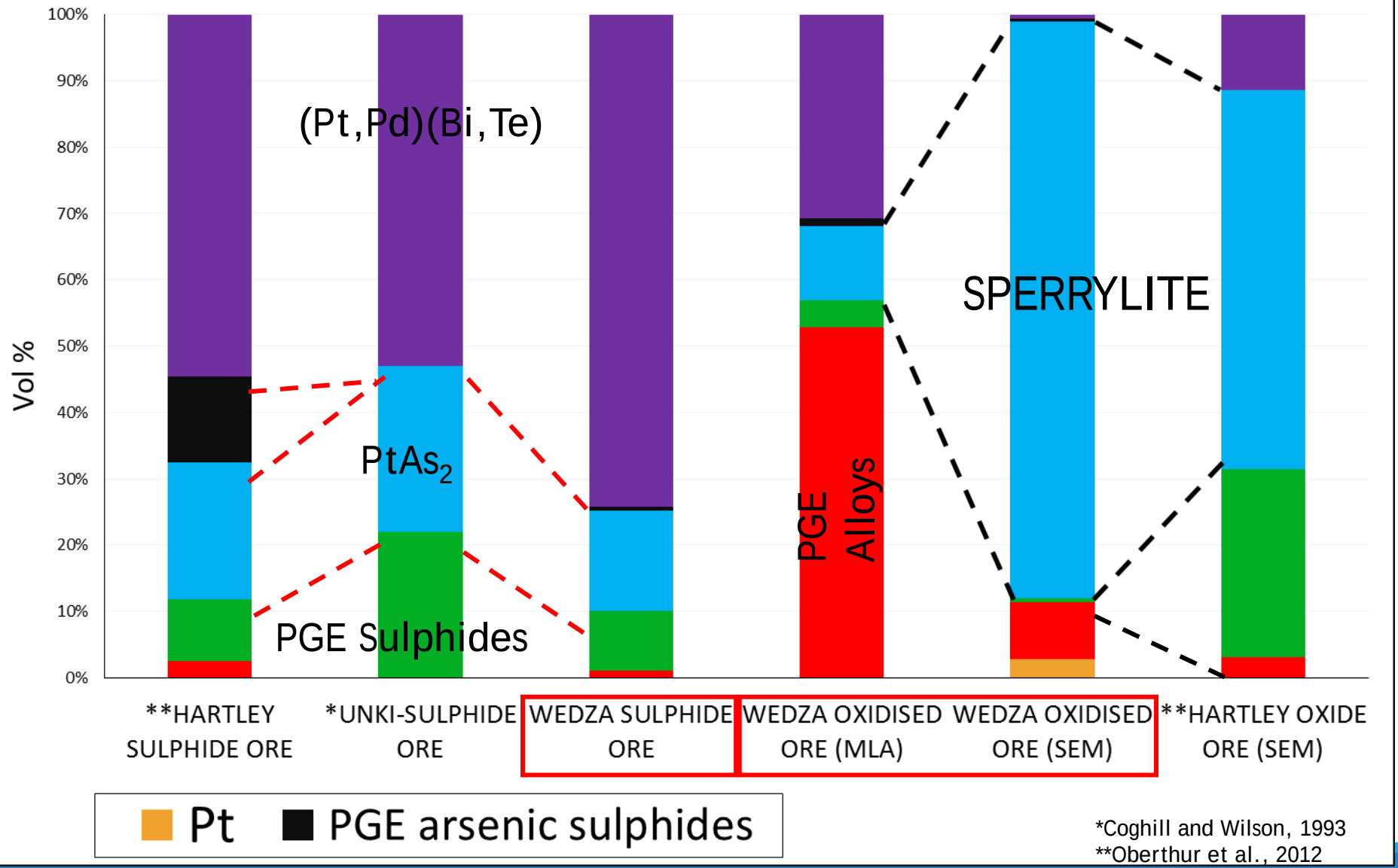
- Pt – dominantly in discrete PGM
- Pd – only small proportion in PGM
- Where is Pd?
- Mainly in BMS (pentlandite) ~ *80% of Pd is in pentlandite* (Selukwe Subchamber)*
- Implications during decomposition of base metal sulphides during weathering?

PGM Modal Abundances



- Sperrylite most stable in the supergene environment
- Decomposition of PGE bismuthotellurides and sulphides
- Newly forming PGE alloys in oxidised ore
- SEM data statistically more reliable (n = 789) vs. MLA(n=113)

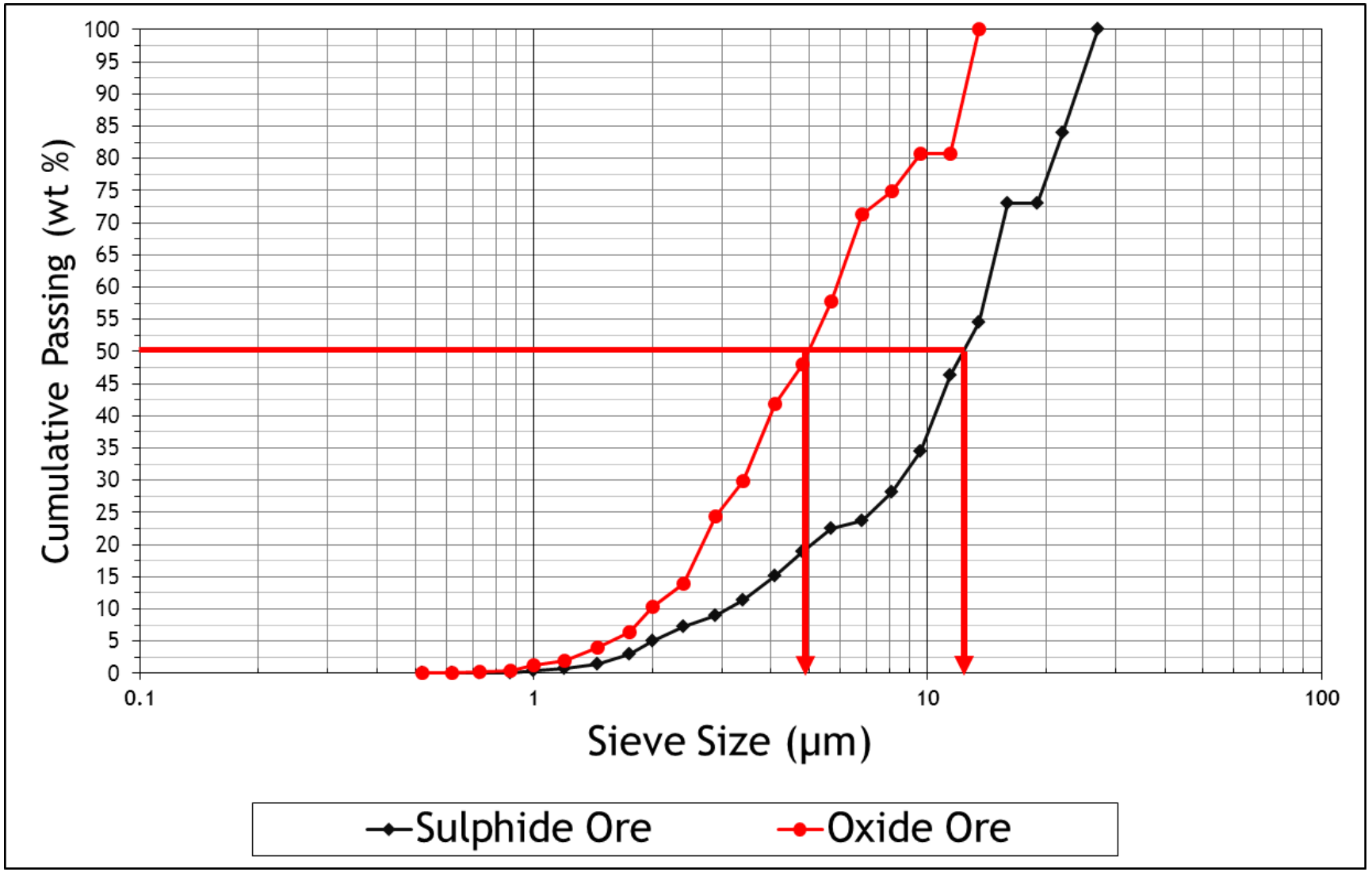
PGM Modal Abundances



*Coghill and Wilson, 1993
**Oberthur et al., 2012

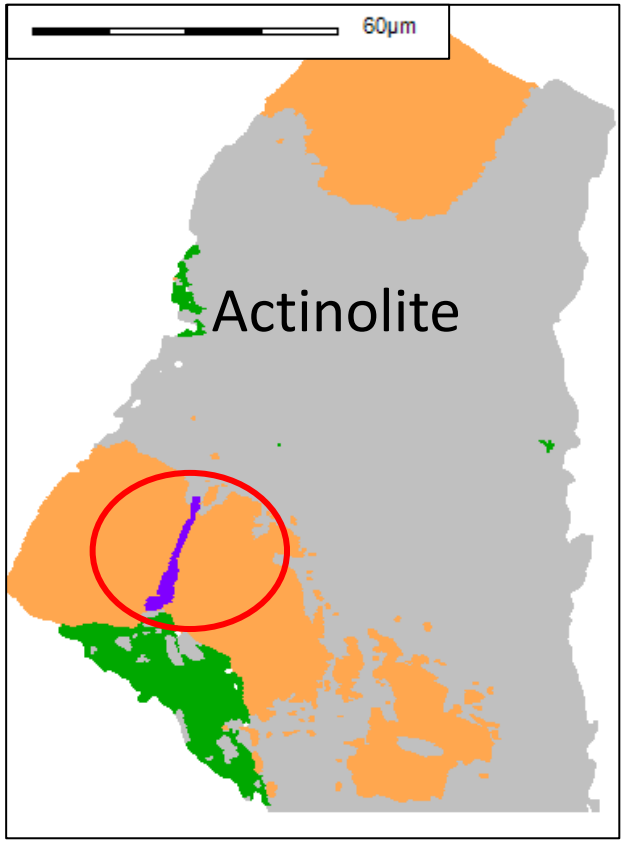
- (Pt,Pd)(Bi,Te) = PGE bismuthotellurides dominant mineral in pristine sulphide ore
- PGE alloys in oxide ore
- $PtAs_2$ preserved during weathering
- Little to no PGE sulphides preserved at Mimosa
- SEM and MLA data very different

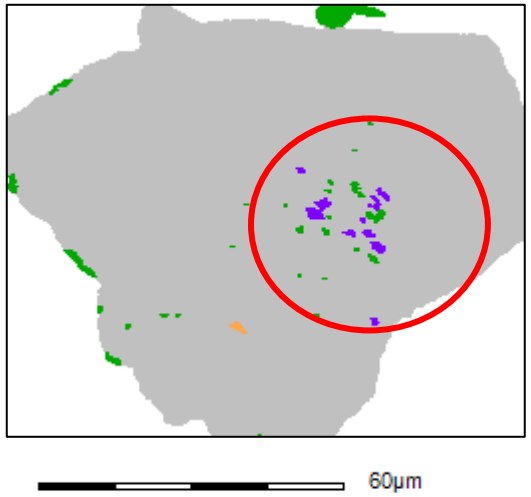
PGM Grain Size Distribution

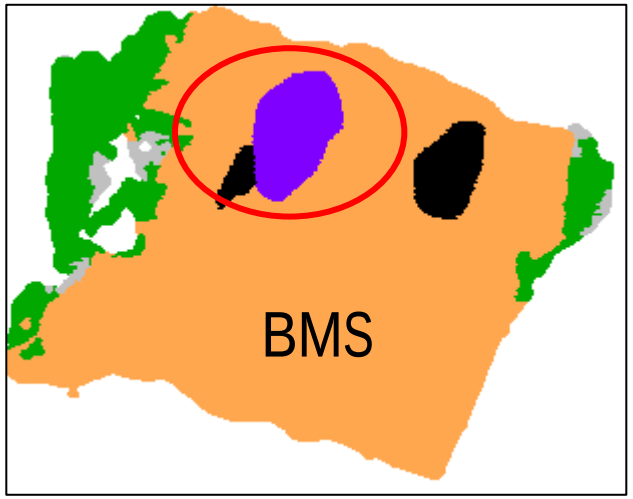


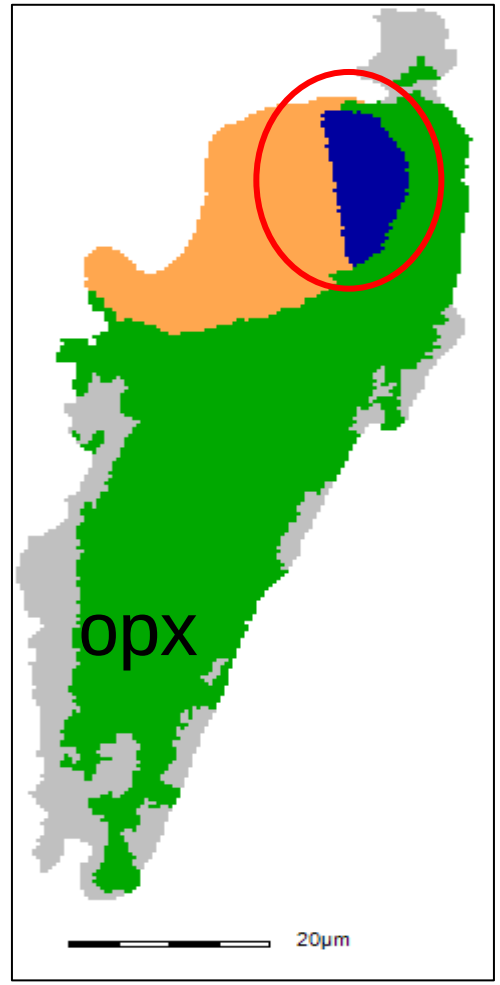
- 50 vol. % are ≤ 5 µm in the oxidised ore
- 50 vol. % in the sulphide ore are ≤ 10 µm.
- 2D view in polished sections
- Biggest size found in longest direction = 150 µm for oxidised ore.

PGM Mineralogy (Sulphide Ore)





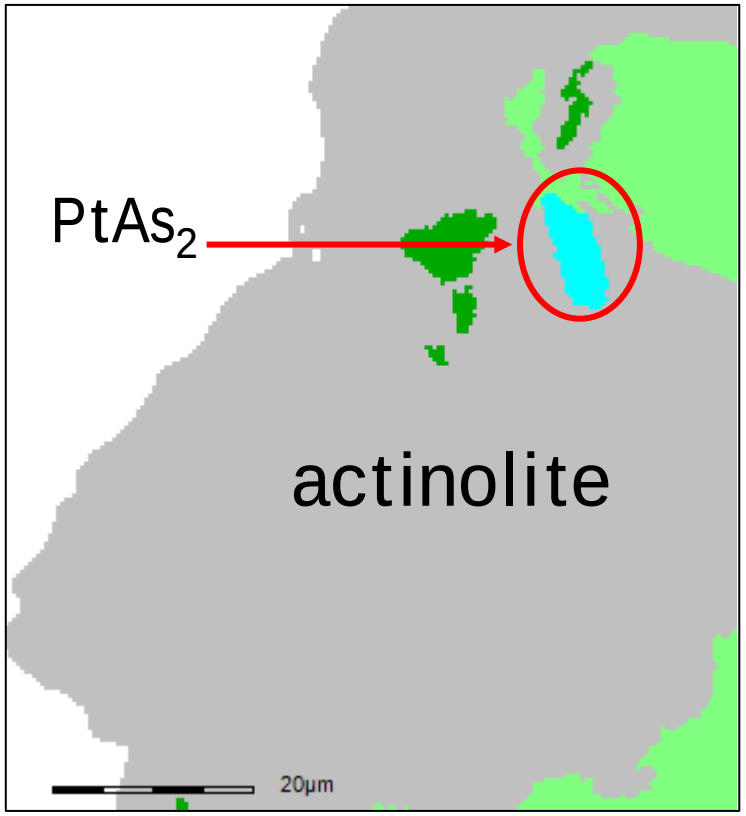


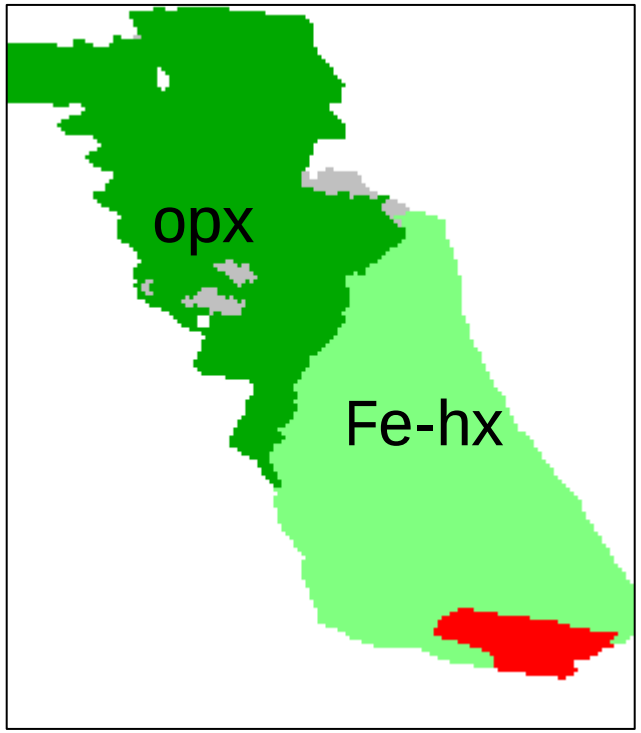


PGE Alloys
PGE Sulphides
PGE arsenic sulphides
PGE bismuth tellurides
Silicates
Hydrous Silicates
Fe-Oxides
BMS

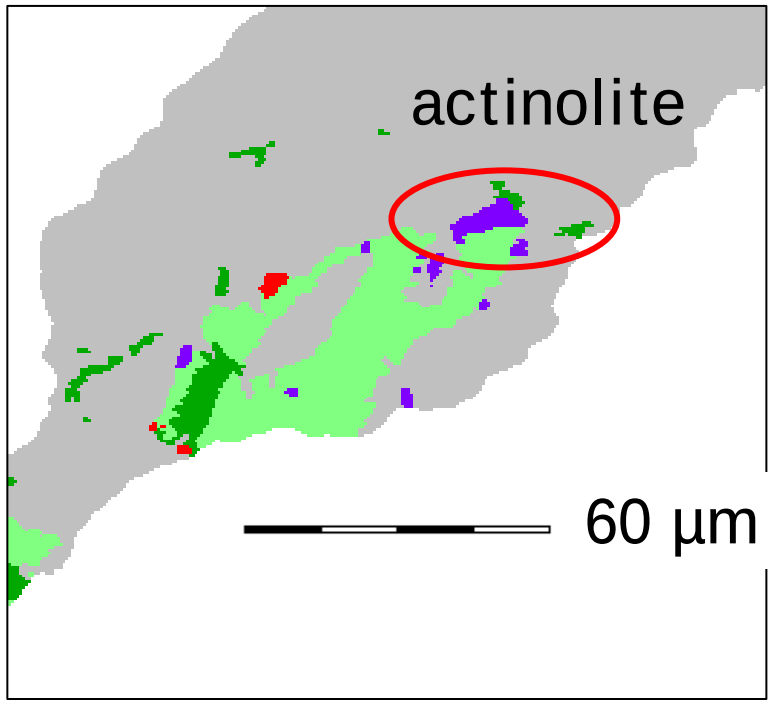
*MLA Images

PGM Mineralogy (Oxidised Ore)



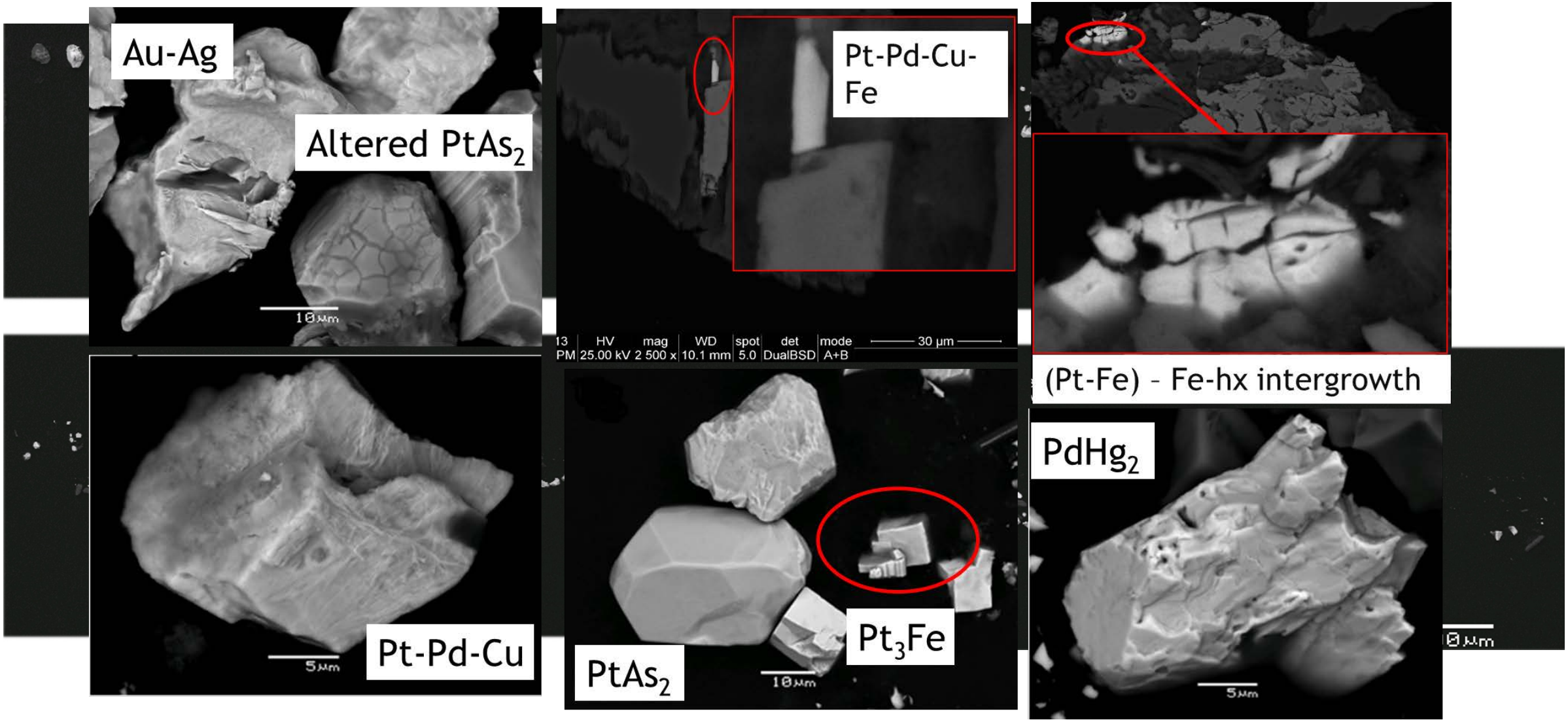


20 µm

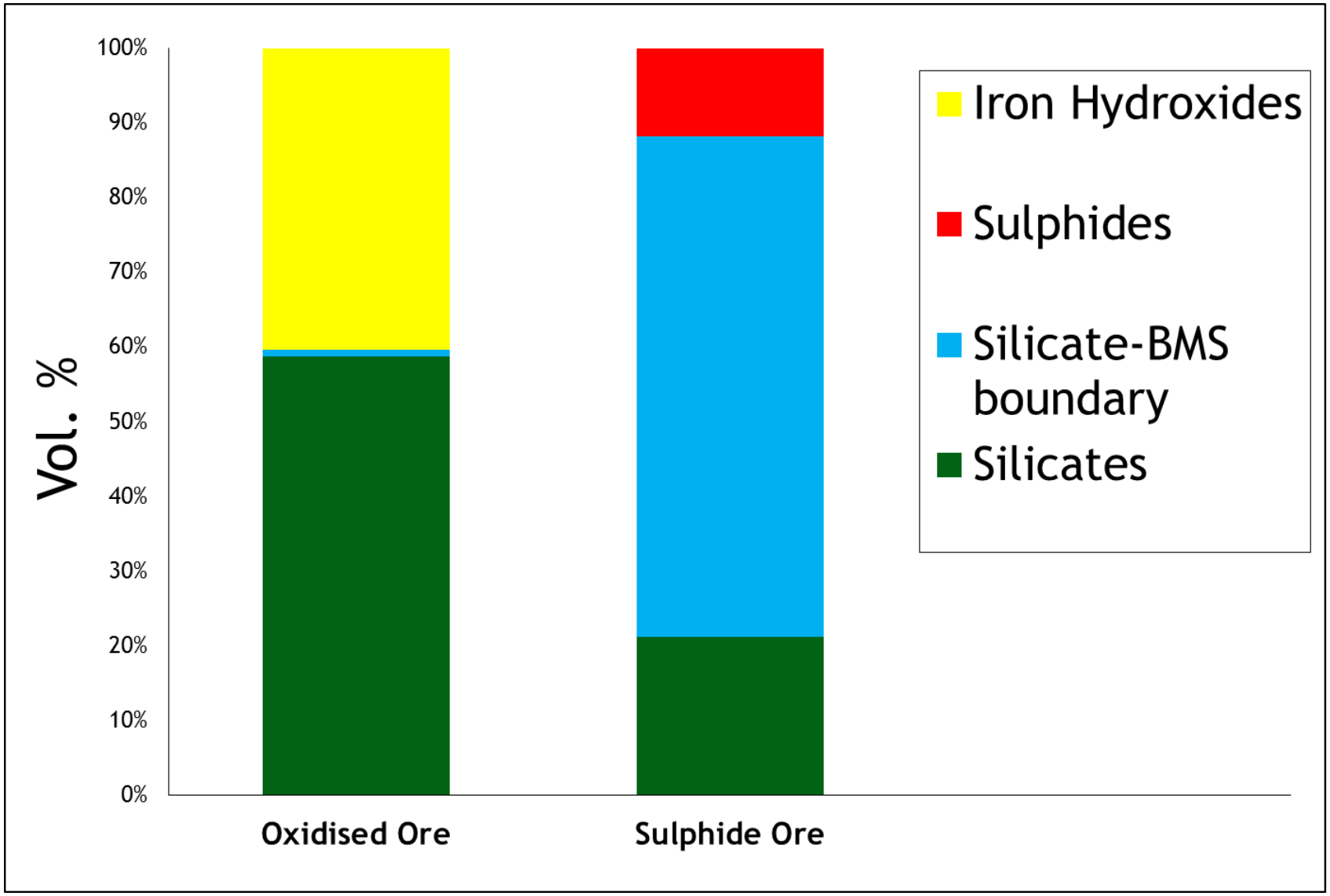


PGE Alloys
PGE Arsenides
Silicates
PGE bismuth tellurides
Fe-Oxides
Hydrous Silicates

PGM Mineralogy (Oxidised Ore)



PGM Mineral Association



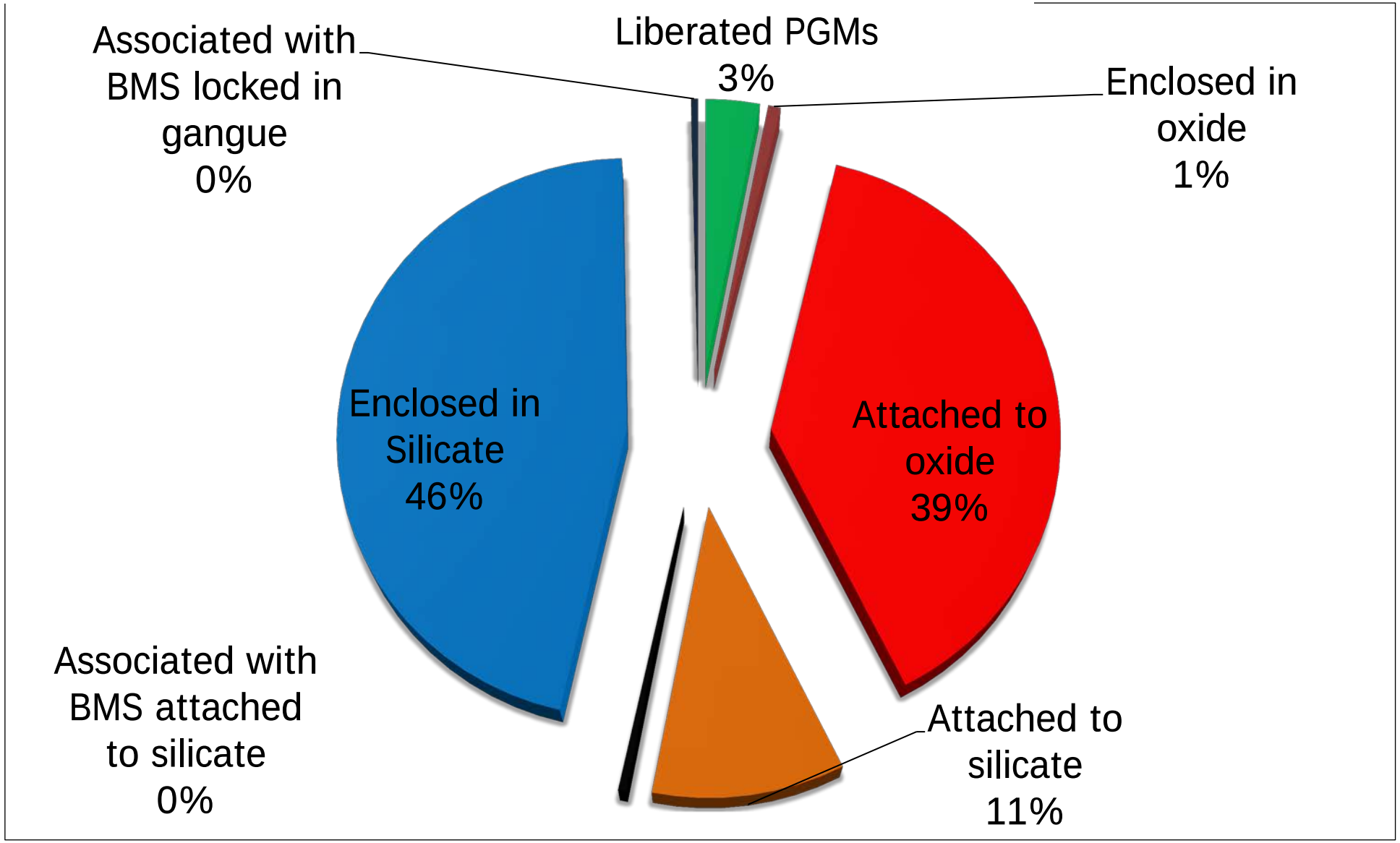
Sulphide Ore:

65 % - 80% BMS association

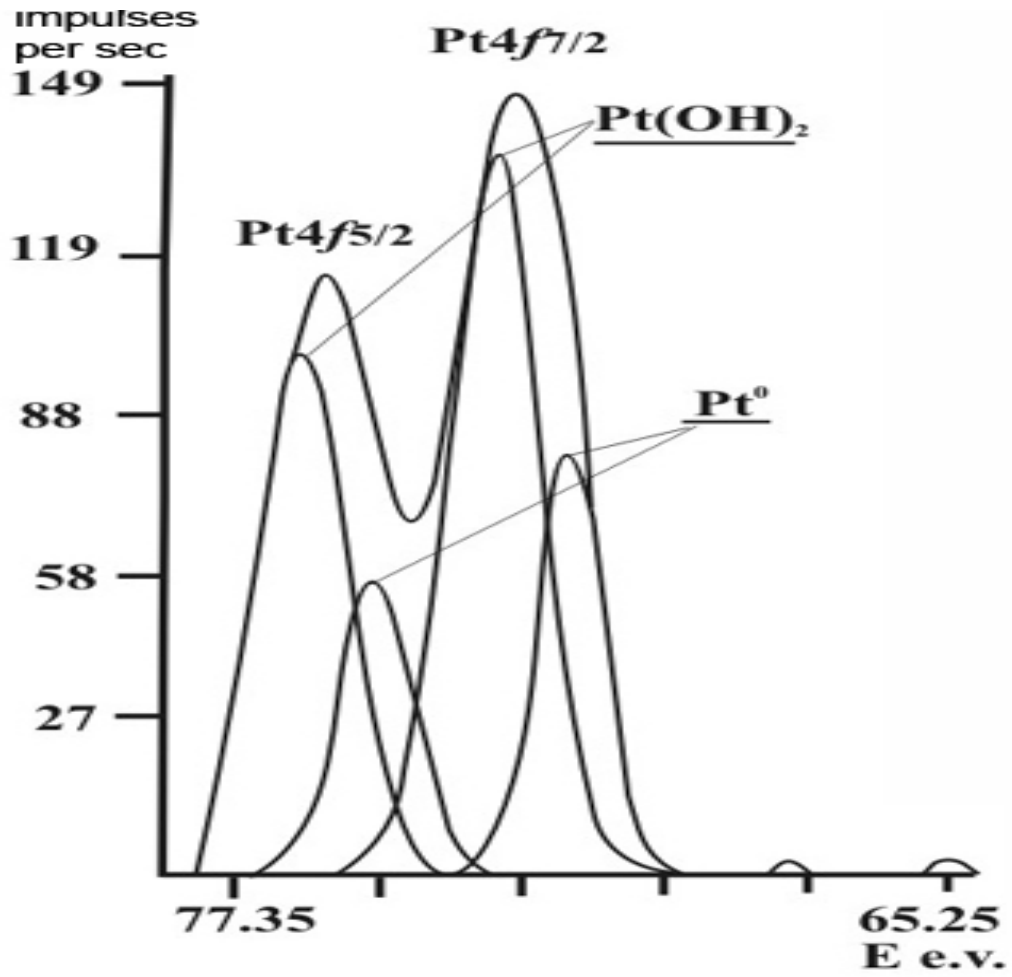
Oxidised Ore:

< 1 % BMS association

PGM Mode of Occurrence (Oxidised Ore)



X-ray Photoelectron Spectroscopy



*Courtesy of Institute of Ore Geology, Petrography, Mineralogy, and Geochemistry (IGEM) RAS

- Preliminary study confirming presence of Pt hydroxides
- Spectra of native Pt and Pd hydroxide together with Fe, Mn, Ni, Cr, Al and Cu hydroxides were identified.
- Pd was found however to exist as PdO and PdO_2.

Effects of Weathering

(Pt,Pd)(Bi,Te) decompose

Non stoichiometric admixtures of Pt ± Bi, Te, Pd alloys

Almost complete decomposition of PGE sulphides and BMS

Pt ± Fe,Cu; Pt-Pd-Cu-Fe alloy

Stable $PtAs_2$
Loss of Pd (31 %), S (91%)
Huge LOI gain (207%)

Polymodal distribution of PGE:

- Relict primary PGM; Secondary neoformations (Pt-Fe, Pt-Pd-Fe-Cu) & PdO, PdO_2, $Pt(OH)_2$; PGE in FeOOH, smectites, Mn-Co-OH
- PGM increasingly associated with Fe-hydroxides and silicates

PGE Distribution

Sulphide Ore (bimodal distribution)

1. ***PGE in primary PGM:***
   - *PGE (Bi,Te)*
     - ❖ Maslovite
     - ❖ Kotulskite
     - ❖ Moncheite
   - *Sperrylite*
   - *PGE Sulphide*
     - ❖ Cooperite-Braggite
     - ❖ Kharaelakhite
2. ***PGE in sulphides (Pd mainly hosted in pentlandite)****

Oxidised Ore (polymodal distribution)

1. ***PGE in relict primary PGM***
   - *Mainly Sperrylite*
   - *Minor PGE (Bi,Te) and PGE sulphides*
2. ***Newly forming PGE Alloys***
   - ❖ Admixtures of Pt-Bi±Te, Pt-Fe±Cu, Pd-Hg and Pt-Pd-Fe-Cu
3. ***PGE oxides/hydroxides***
   - Altered primary PGM
   - Neoformations (Pt(OH)2, PdO, PdO2)
4. ***PGE in FeOOH, smectites, Mn-Co-OH?***

PGM Textural Setting

Sulphide Ore

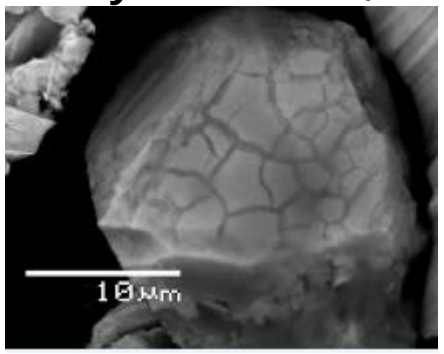
1. Attached to silicates
2. Locked in silicates
3. Attached to BMS locked in silicates
4. Associated with BMS attached to silicates
5. Associated with liberated BMS

Oxidised Ore

1. Enclosed in iron hydroxides
2. Attached to iron hydroxides
3. Attached to silicates
4. Enclosed in iron hydroxides

Further Work (Research Opportunities)

- PGE and PGM distribution in oxidised ore differs from Subchamber to Subchamber (controlled by extent of weathering)?
- MLA (AutoSEM) for PGM textural relationships
- SEM -PGM quantification
- Electron Microprobe for PGE in solid solution (in Fe-hx, Mn,Cu hydroxides, BMS & relinct BMS?)
- XPS to confirm the presence of PGE oxides and hydroxides
- Where does the Pd go???
- Development of novel mineralogical methods for conversion of these resources to reserves



THANK YOU