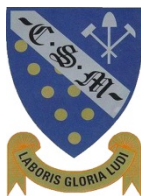# Mineralogy and mineral processing of carbonatite-hosted REE and $P_2O_5$ at Songwe Hill, Malawi

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Frances Wall[1]     Richard Pascoe[1]     William Dawes[2]     Aoife Brady[2]

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## Outlines

- ✓ Importance of REE and $P_2O_5$

- ✓ The Study area (Songwe Hill)

- ✓ Aims of the study

- ✓ Chemistry of the deposits

- ✓ Mineralogy of the deposits

- ✓ Mineral processing tests

- ✓ Conclusions

# Application of Rare Earth Elements



## The Many Uses of Rare Earths

**Catalysts**
- Petroleum refining
- Chemical processing
- Catalytic converter
- Diesel additives
- Industrial pollution scrubber

**Electronics**
- Display phosphors (CRT, PDP, LCD)
- Medical imaging phosphors
- Lasers
- Fiber Optics
- Optical temperature sensors

**Glass**
- Polishing compounds
- Optical glass
- UV resistant glass
- Thermal control mirrors
- Colorizers/ Decolorizers

**Other**
- Water Treatment
- Fluorescent lighting
- Pigments
- Fertilizer
- Medical Tracers
- Coatings

**Ceramics**
- Capacitors
- Sensors
- Colorants
- Scintillators

**Magnets**
- Motors
- Disc drives & disk drive motors
- Power generation
- Actuators
- Microphones & speakers
- MRI
- Anti-lock brake system
- Automotive parts
- Communication systems
- Electric drive & propulstion
- Frictionless bearings
- Magnetic storage disk
- Microwave power tubes
- Magnetic refrigeration
- Magnetostrictive alloys

**Metal Alloys**
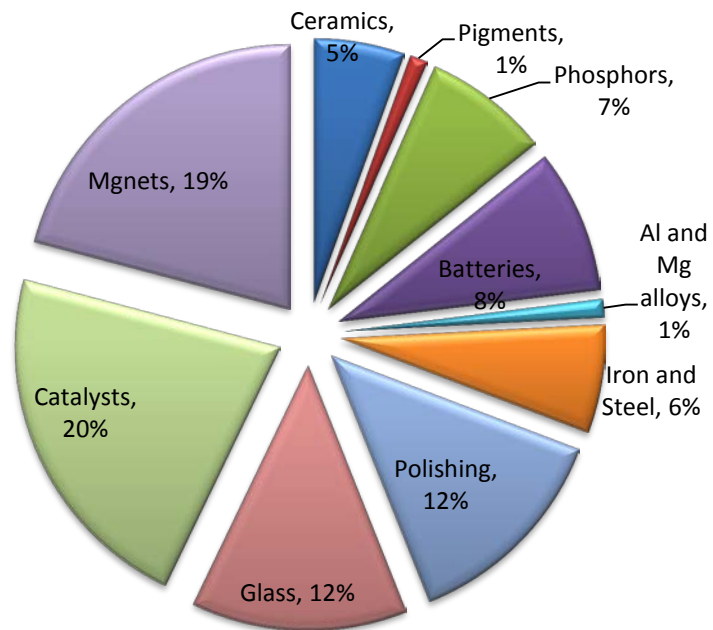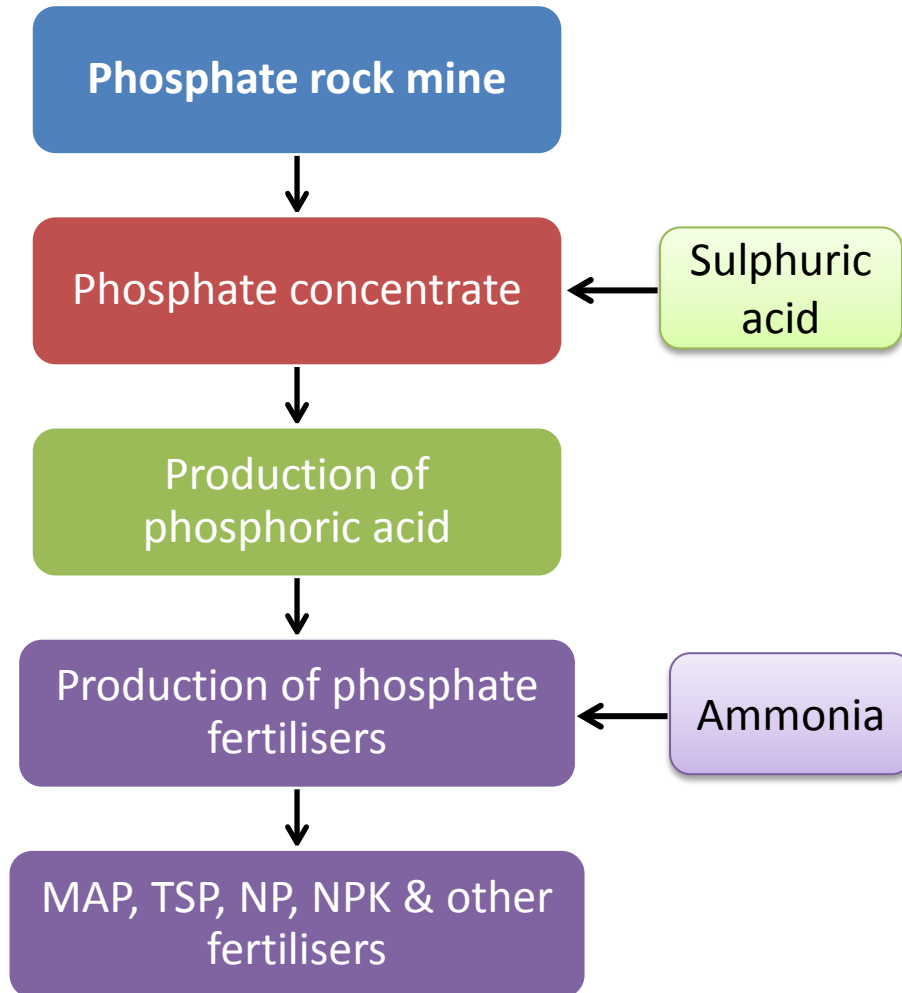- Hydrogen storage (NiMH batteries, Fuel cells)
- Steel
- Lighter flints
- Aluminum/ Magnesium
- Cast iron
- Superalloys

| REE | Wind turbines | Vehicles | | Lighting | Fluid Cracking Catalysts | Polishing Powders | Auto Catalysts |
|-----|---------------|----------|----------|----------|--------------------------|-------------------|----------------|
| | Magnets | Magnets | Batteries | Phosphors | | | |
| La | | | ● | ● | ● | ● | ● |
| Ce | | | ● | ● | ● | ● | ● |
| Pr | ● | ● | ● | | ● | | |
| Nd | ● | ● | ● | | ● | ● | ● |
| Sm | ● | ● | | | | | |
| Eu | | | | ● | | | |
| Tb | | | | ● | | | |
| Dy | ● | ● | | | | | |
| Y | | | | ● | | | |

# Importance of P$_2$O$_5$

```
┌─────────────────────────┐
│   Phosphate rock mine    │
└─────────────────────────┘
             │
             ▼
┌─────────────────────────┐      ┌──────────────┐
│  Phosphate concentrate   │◄─────│  Sulphuric   │
└─────────────────────────┘      │    acid      │
             │                    └──────────────┘
             ▼
┌─────────────────────────┐
│     Production of        │
│    phosphoric acid       │
└─────────────────────────┘
             │
             ▼
┌─────────────────────────┐      ┌──────────────┐
│ Production of phosphate  │◄─────│   Ammonia    │
│       fertilisers        │      └──────────────┘
└─────────────────────────┘
             │
             ▼
┌─────────────────────────┐
│ MAP, TSP, NP, NPK & other│
│       fertilisers        │
└─────────────────────────┘
```

## The Songwe Hill carbonatite
Chilwa Alkaline Province
Late Jurassic/early Cretaceous.
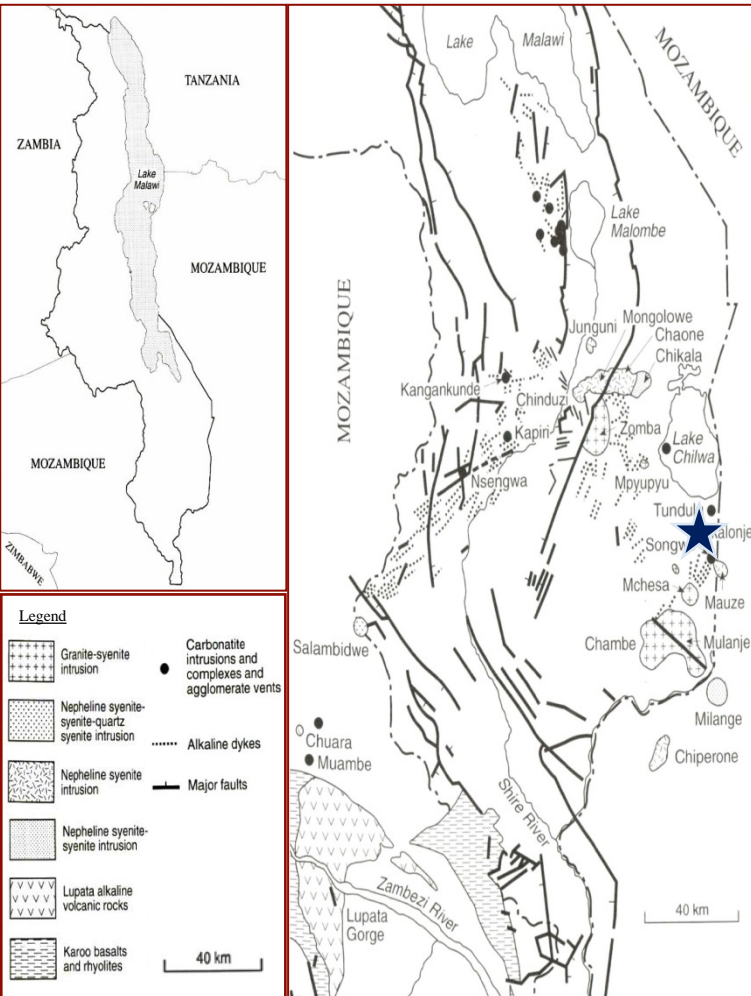


Google earth image shows the Songwe Hill area, Malawi.

# Geological Map with drill hole collars and traces

* Indicated mineral reserve of 13.2mt, grading 1.62% at 1.5% TREO cut-off grade
* Inferred mineral reserve of 18.6mt, grading 1.38 at 1% TREO cut-off grade.
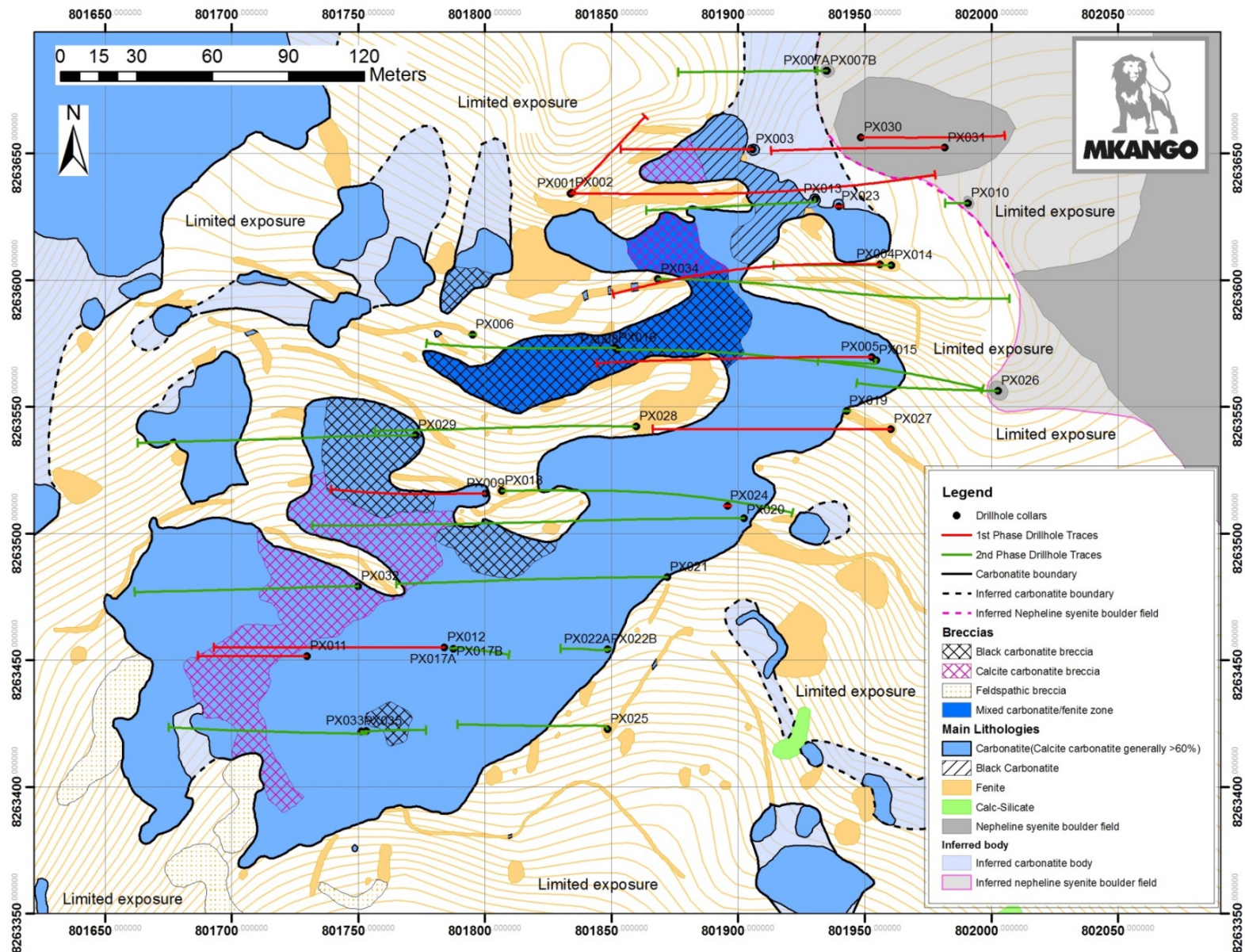
*PX013*

*PX09*

*PX012*

*PX05+15*

*PX022B*

*PX021*

*PX033*

*PX035*

# Aims of the study

1. Perform **chemical analyses** to identify major, minor and rare earth elements in all samples

2. Identify and quantify the **mineralogy** of carbonatite deposits **liberation and association**.

3. Undertake selected **laboratory mineral processing experiments** to separate apatite and synchysite.

**Carbonatite rock**



**Rare earth elements**



**Phosphate fertiliser**

# Chemistry of the deposits
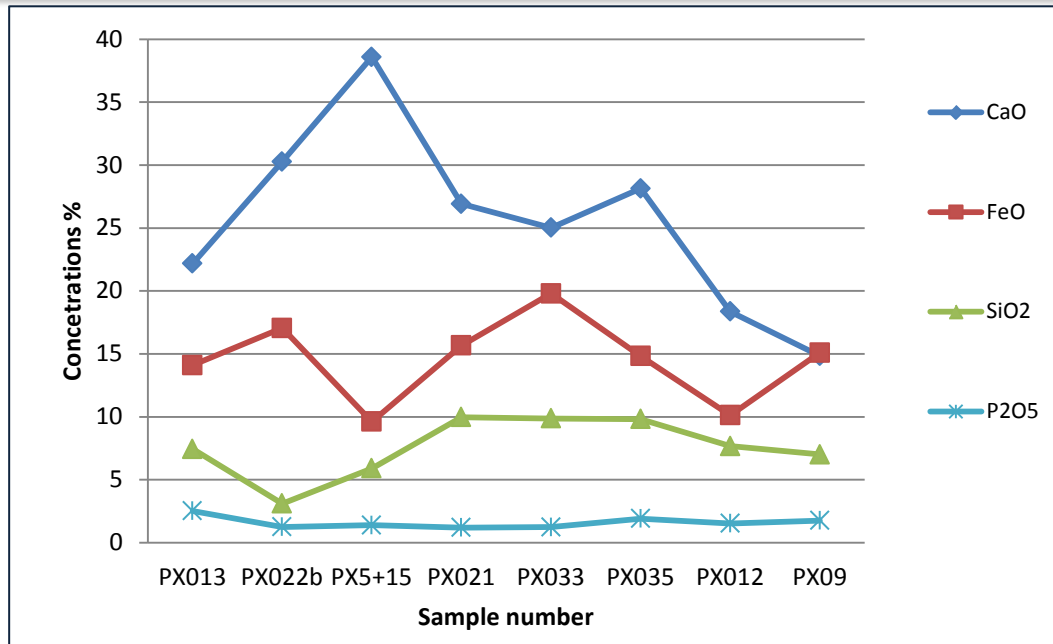


Concentration major oxides in Songwe ore samples.
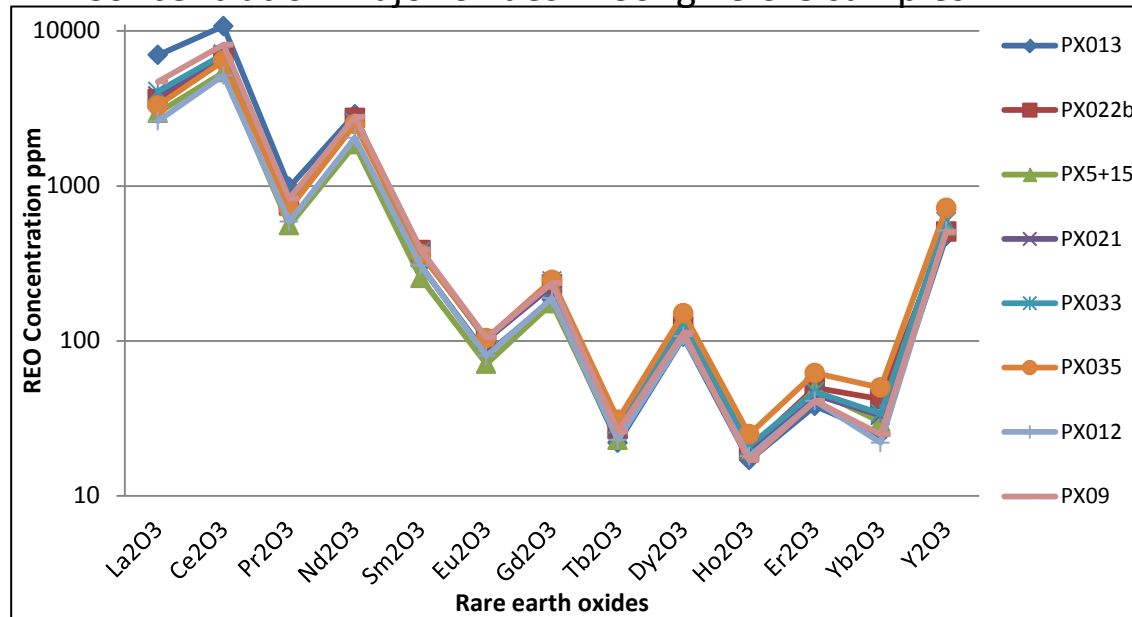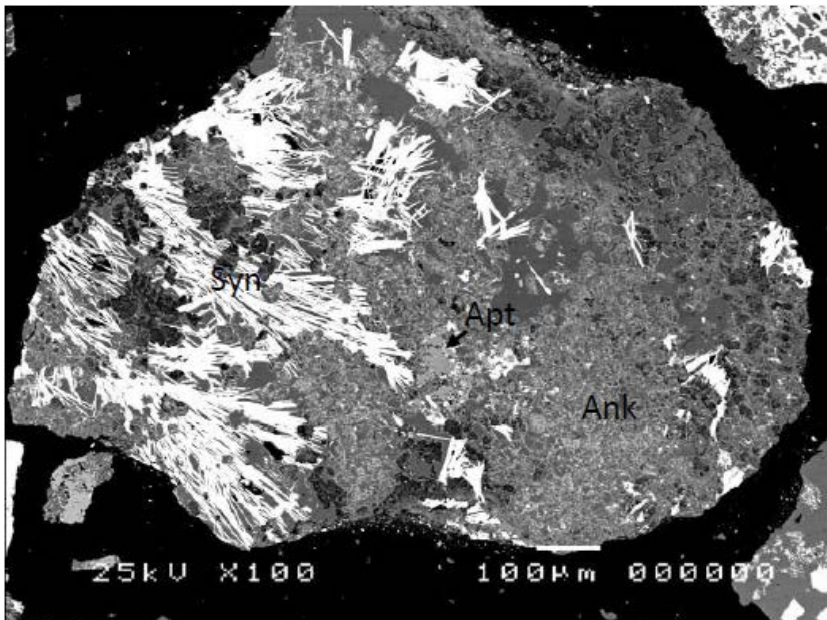


Rare earth oxide concentrations in Songwe ore samples.

# X-ray diffraction profiles
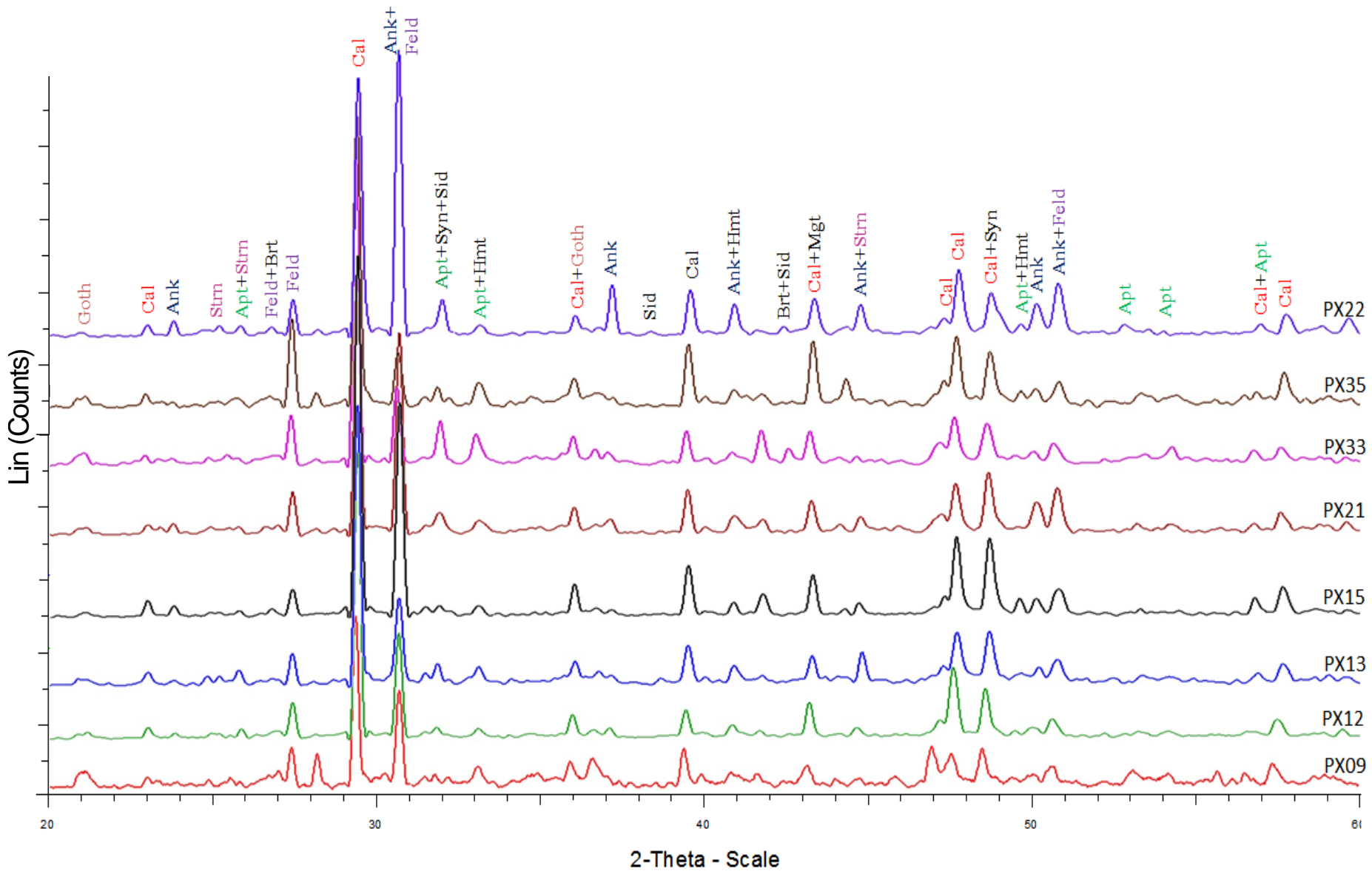


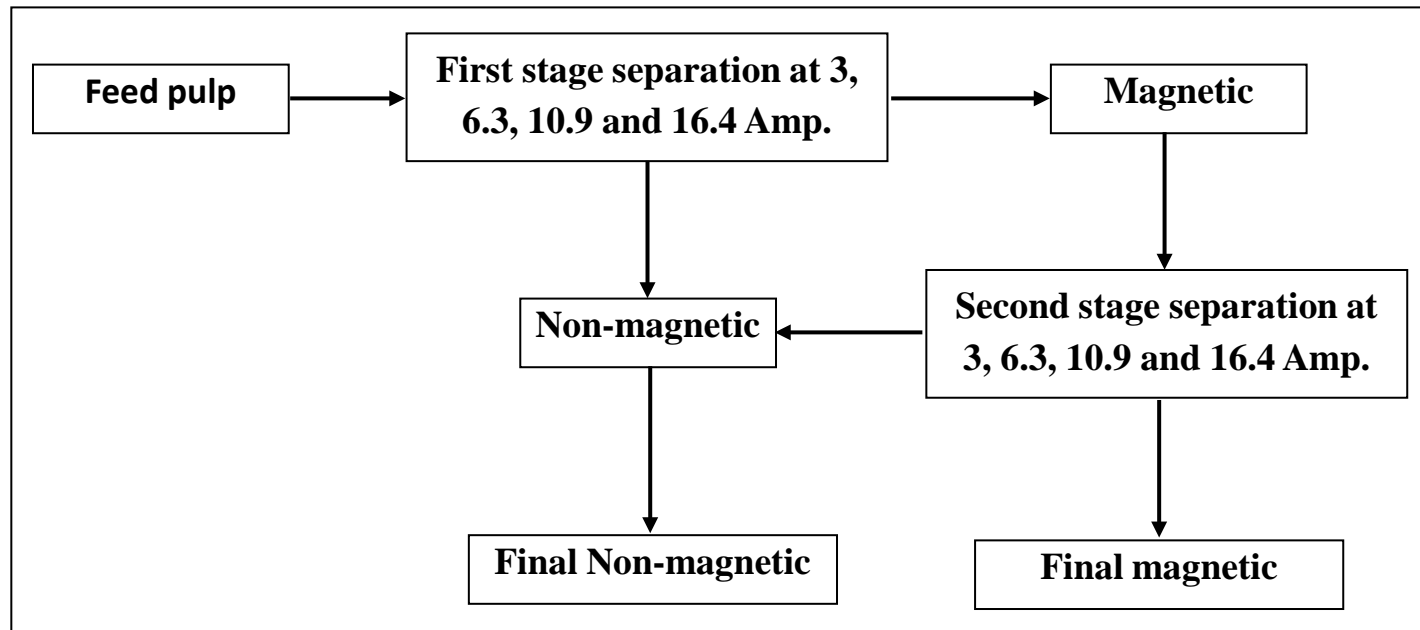**XRD profiles of all the crushed core Carbonatite samples.**

# SEM/EDS observations
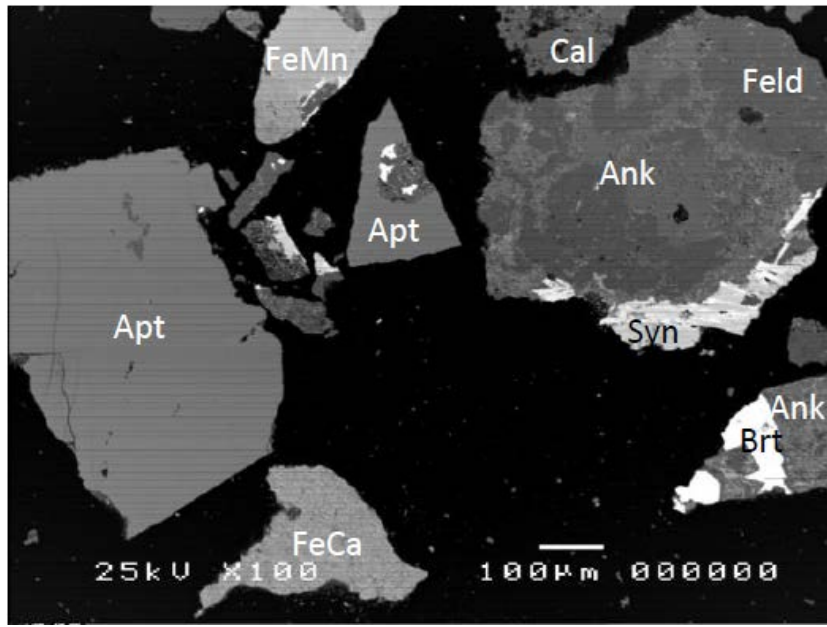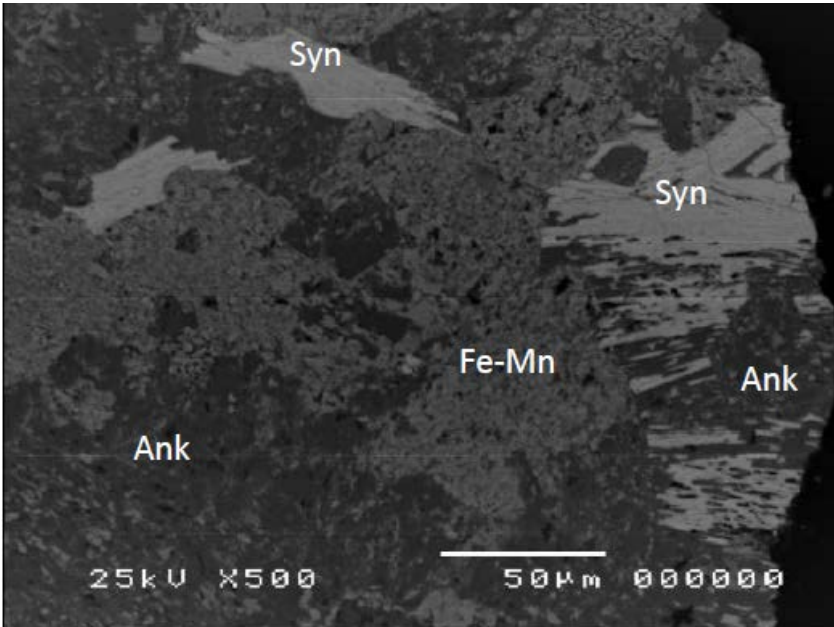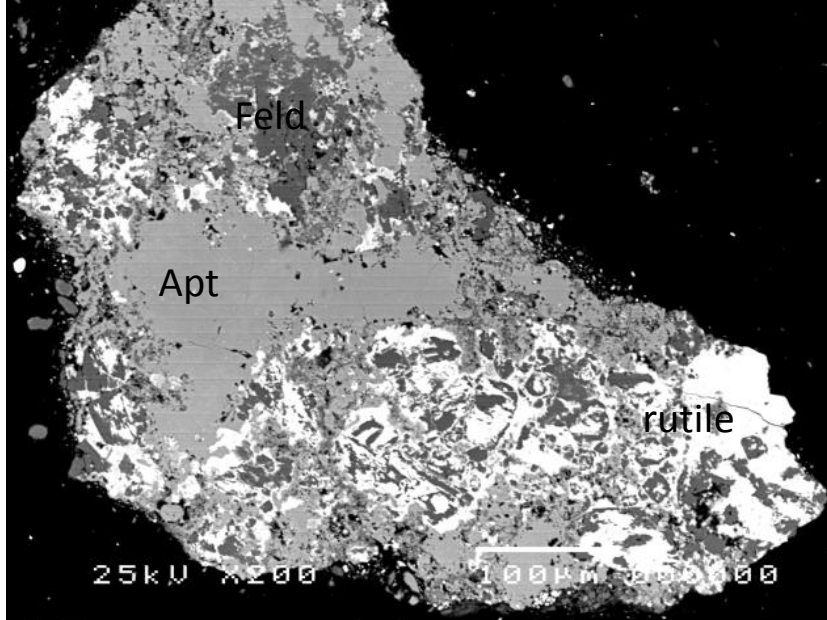
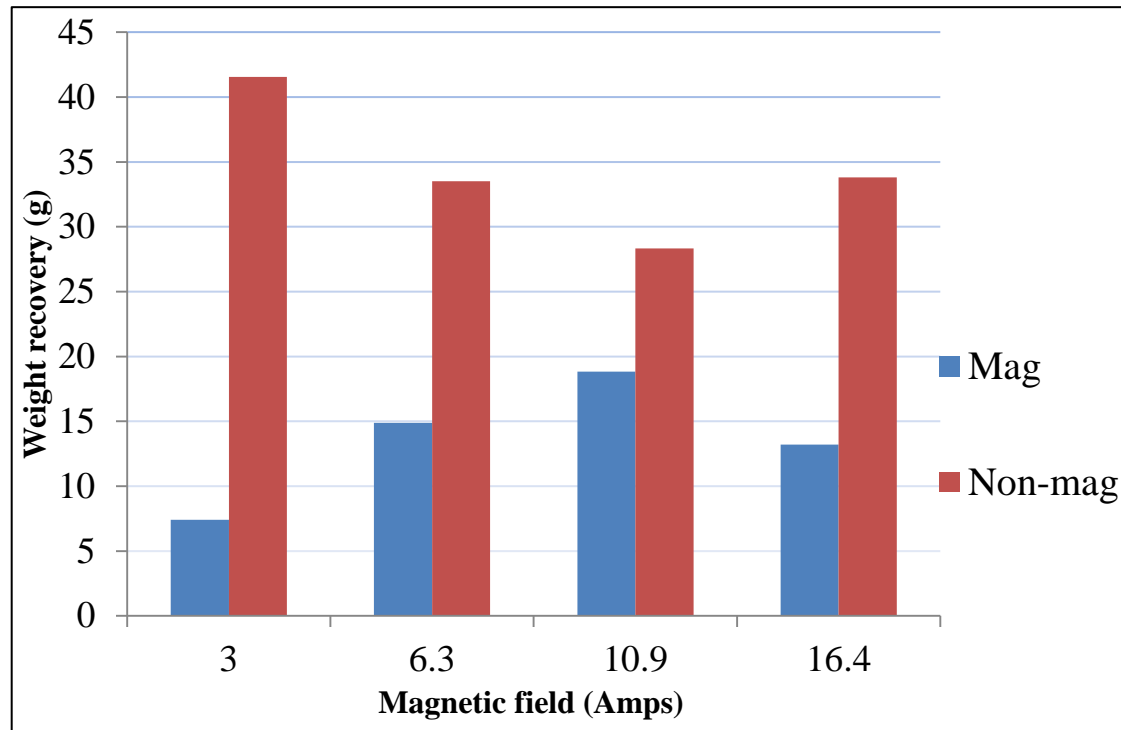# Mineral processing tests



Flow sheet test work was completed at Mintek in South Africa
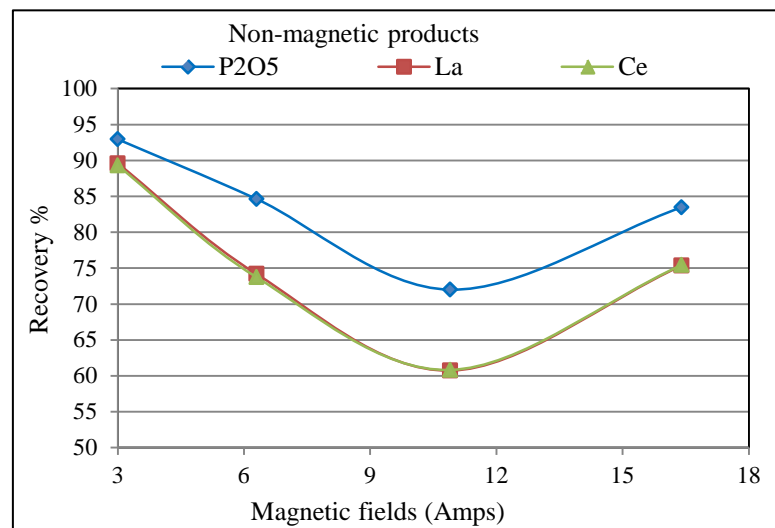


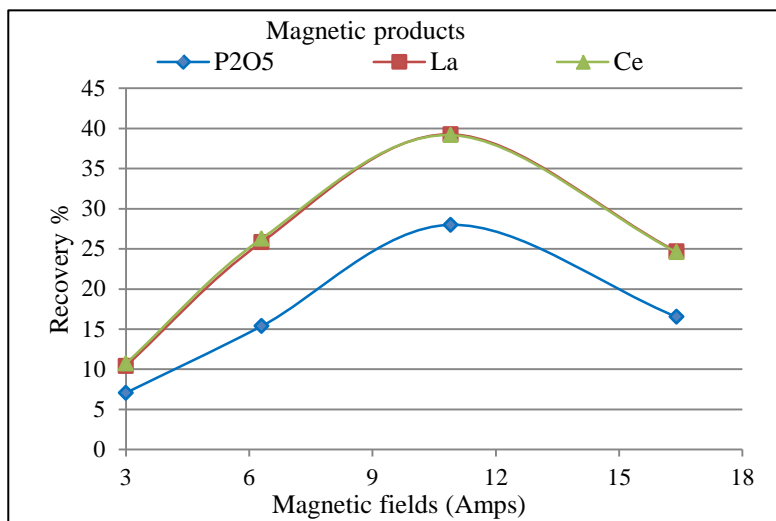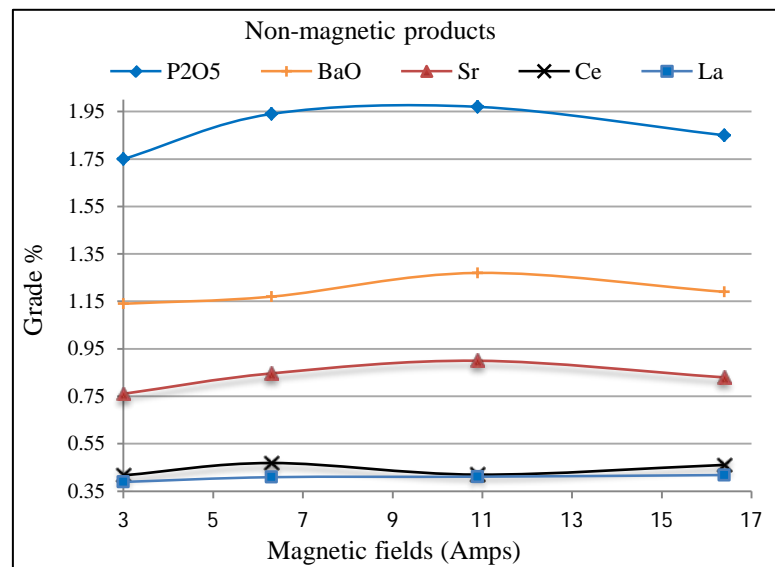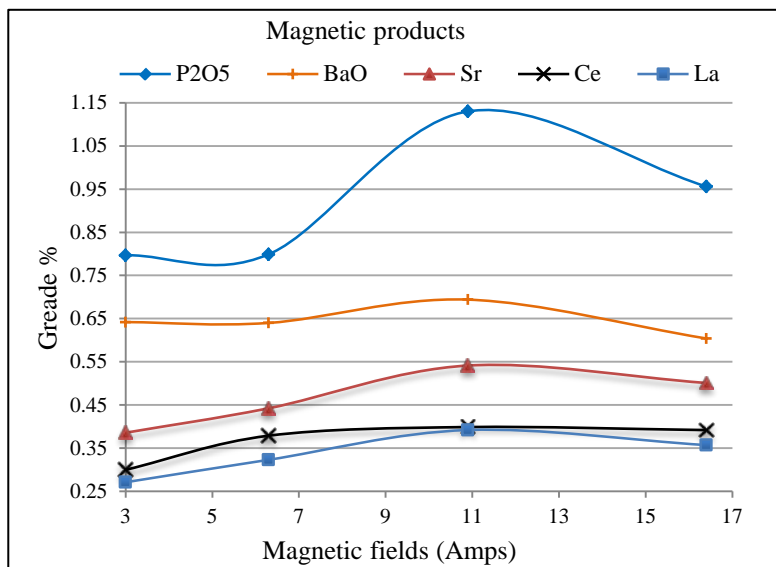Schematic of two-stage separation on WHIMS completed at CSM

# Wet high intensity magnetic separation results



Weight recovery of the separated fractions at various magnetic fields

# Wet high intensity magnetic separation results



The grades and recovery of the P$_2$O$_5$, BaO, Sr, Ce and La in (A) the magnetic and (B) non-magnetic products as a function of magnetic field strength

## Conclusions

✓ The target ore minerals are apatite which hosts the phosphorous and HREE and synchysite-(Ce) which hosts the LREE.

✓ Ankerite and calcite are the main predominant gangue minerals.

✓ All RE-minerals are associated with all gangue minerals (especially, ankerite and calcite) in different proportions.

✓ XRD is not qualified technique to identify the ore minerals in the current samples.

✓ the only finer grinds can be done to separate apatite and synchysite minerals successfully as they occurred as fine grains.

✓ Good results obtained at 6.3 Amp with grade 1.94% and recovery 84% of $P_2O_5$ in the non-magnetic products -63 µm, but still 0.80% is reported at magnetic product.

✓ It seems that apatite is better to be recovered using WHIMS while synchysite needs more grinding to be more liberated and then separate it.

✓ Further work is needed with very fine milled feed samples at P80 -38 µm at 6.3 Amp.

# Thanks for listening