
**In Memory of Rob Duncan (1948-2021)**

Mt Weld open pit in the background (July 2008)

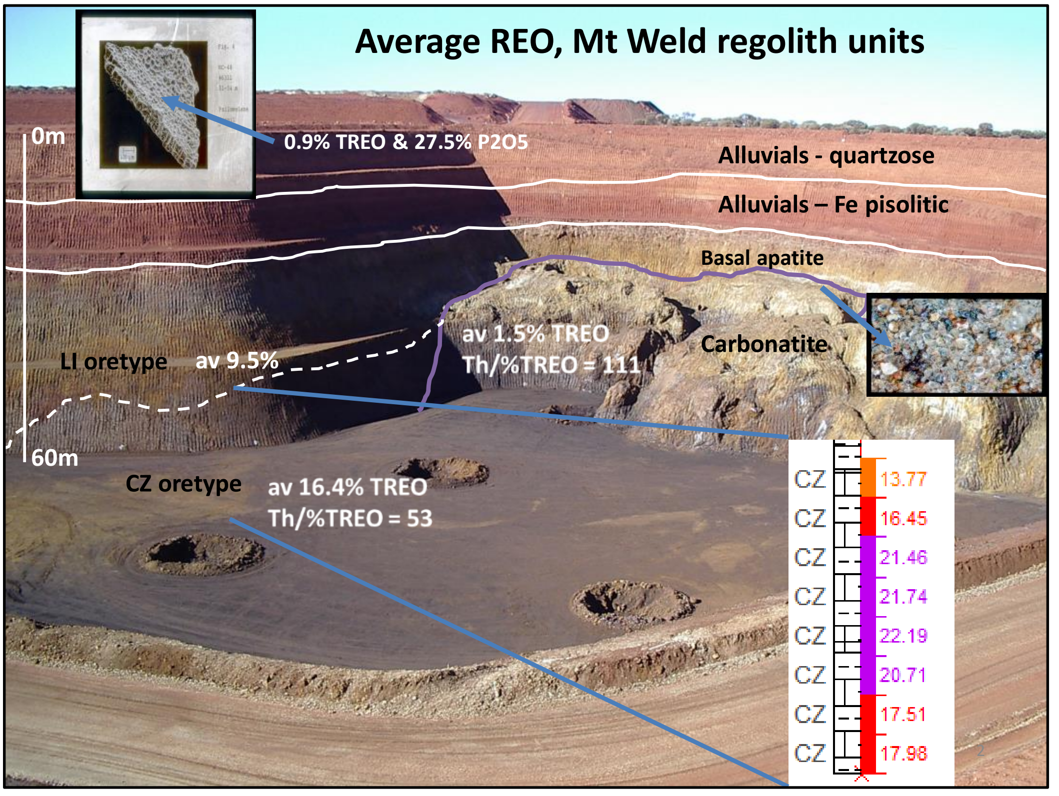
Rob led the geological studies over many years from exploration to feasibility and into early production. His tireless dedication, perseverance, friendship and ethical leadership are remembered in the “Duncan Deposit”, just to the southeast of the Central Lanthanide Deposit (“CLD”, as it was called).

Rob was involved with Mt Weld from the early 1970s with Utah Development when the origin of the magnetic anomaly was not yet understood.

His connection with Mt Weld continued throughout his career with various companies including Union Oil, Carr Boyd and finally Lynas Corporation who developed the mine.

He recalled getting down on his knees at one stage, begging Oliver Warin of Utah to pay a small amount to keep the leases in good standing. It was Rob who supervised removing the overburden from the CLD and mining the first ore. It was his proudest moment as a geologist.

With help from Allison Clark
Photo, July 2008: P L Hellman




A circular aeromagnetic anomaly was generated in 1966 by Australia's then Bureau of Mineral Resources ("BMR").

The carbonatite was subsequently identified by Utah Development Company which was granted tenements over the area in 1967 and later confirmed by drilling that the carbonatite was lying beneath 20 to 50m of superficial sediments. First production began in 2014, some 50 years after the original geophysical survey.

This is an amazing success story that should emphasize the importance of long lead-time Government-backed research.

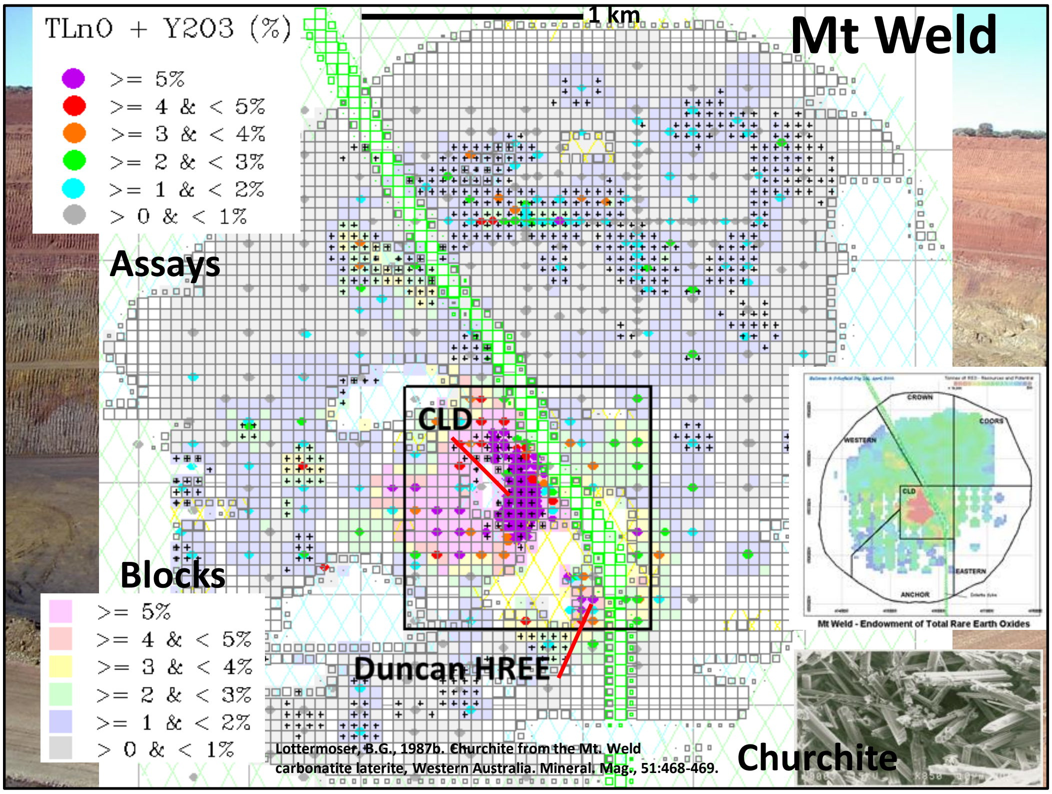
Here is a generalised stratigraphy showing the karst-like topography on top of the residual dolomitic carbonatite. The age is 2.1By. Overlying the carbonatite are units comprising the regolith responsible for upgrading the sub-2% TREO intrusion to exceptionally high grades of REE such as seen in the "CZ" unit within which the drill hole grades (TREO) shown occur.

NB REE-replaced fossil (the best thing that happened to it) as well as the basal and residual apatite zone. The existence of REE-replaced fossils demonstrates the ability of REE to be mobilised and re-precipitated at higher concentrations than their original sources.

70-130m thick regolith with important zones of secondary REE associated with manganiferous and Fe rich secondary oxides.

Lacustrine sediments overlie the regolith which are overlain by alluvials. Described as a steeply dipping diatreme with a contact alteration zone known as glimmerite (phlogopite rich) or fenite, carbonatitic breccias, pyroclastic ash and quench textures suggest an explosive eruptive event (see reference on Slide 8).

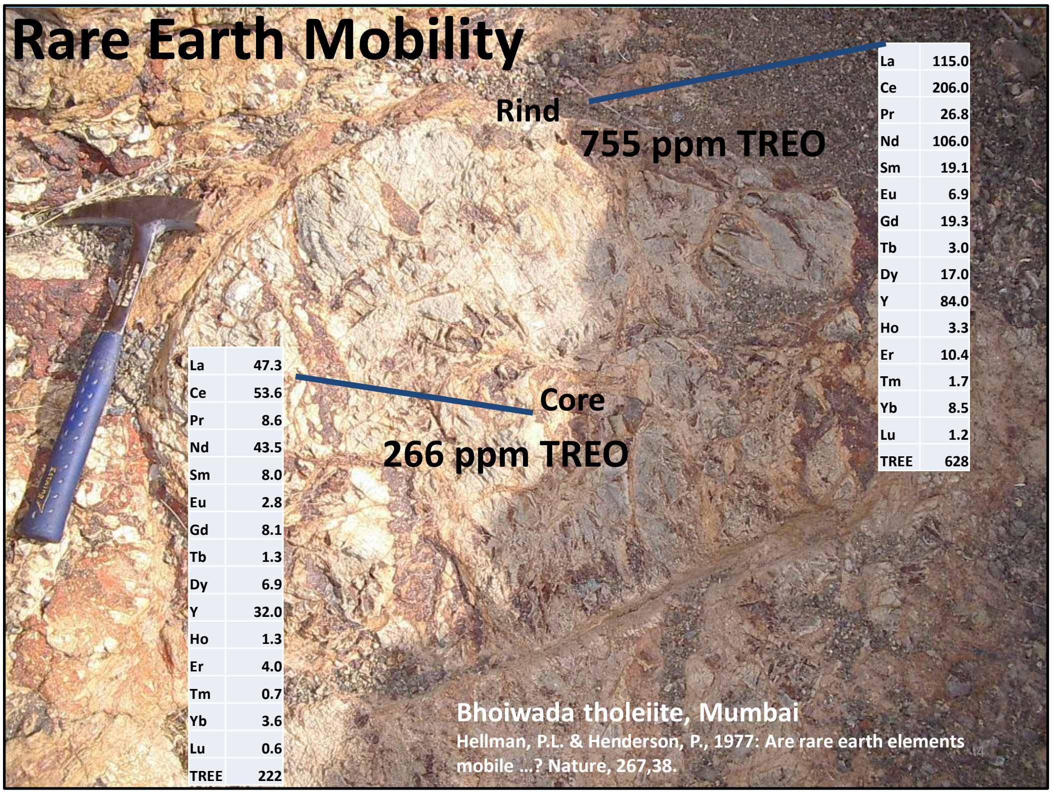
The basal apatite (see photograph in slide) zone was regarded by Rob Duncan in early feasibility studies as being problematical from a processing perspective and was never included in Resource Estimates.




Plan view showing various sectors, dyke and the P, Nb, Ta, REE resource in Coors and Crown deposits (northern part of carbonatite).

CLD + Duncan Deposit (note the churchite lower right).

Now a diversion into some fundamental geochemistry to help understand processes in both primary and secondary rare earth deposits. It is always a challenge to illustrate what is happening to the 15 rare earth elements (atomic number 57 to 71, plus Y). The rare earth industry traditionally has excluded Sc though it is counted a rare earth in chemistry text books.




An example of rare earth mobility – the fundamental mechanism for formation of Ionic Adsorption Deposits ("IAD"). Here a tholeiitic pillow lava shows secondary enrichment in REE in the devitrified rind.

Pillow basalt, rind vs core; devitrified glass to smectites (after chlorite?) and sphene (=titanite].

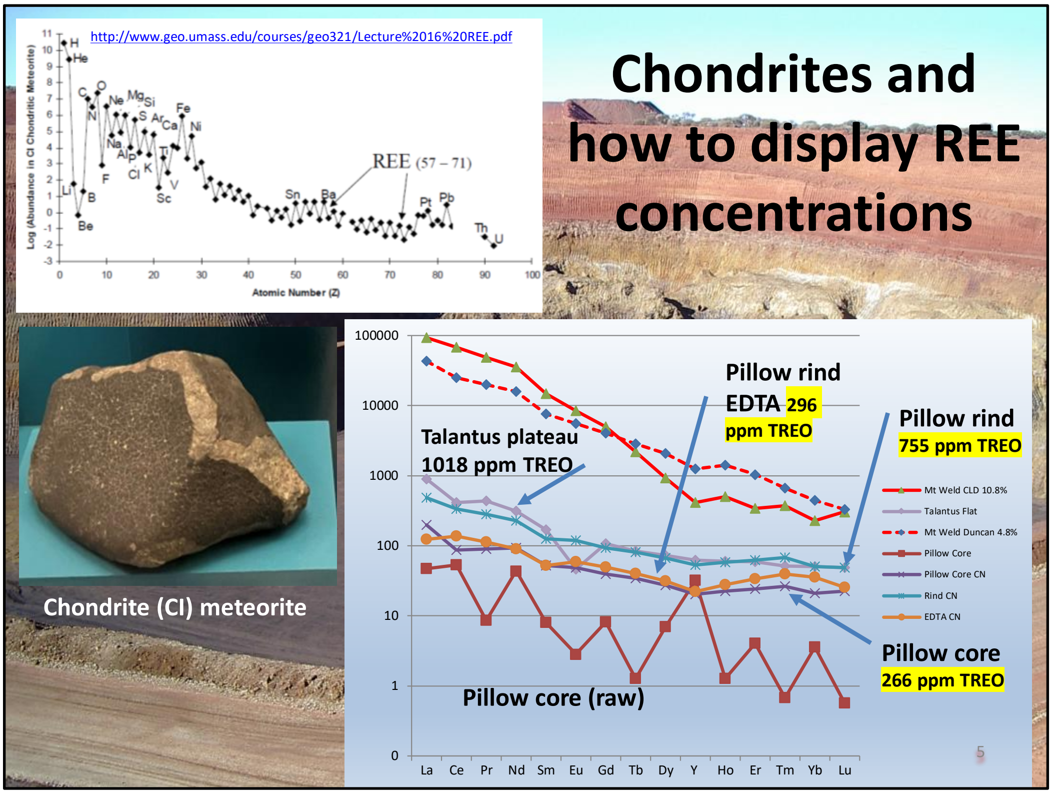
Note TREO = 755 ppm from the pillow rind, similar to typical grades in IADs from Talantus (Madagascar), S China and other IADs. It can be expected that more REE-enriched basalt types will provide a better starting composition for subsequent enrichment by secondary processes.

References:


Hellman, P.L. & Henderson, P.: 1977. Are rare earth elements mobile …? Nature, 267,38

Hellman, P.L., Smith, R.E. and Henderson, P.: The Mobility of the Rare Earth Elements. Contrib. mineral. Petrol. 71, 23-44 (1979)

Sr isotopic evidence on the spilitic degradation of the Deccan basalt KVSUBBARAO Department of Earth Sciences, Indian Institute of Technology, Mumbai (Bombay) 400 076, India. Indian Academy of Scienceshttps://www.ias.ac.in › article › fulltext › jess by KV Subbarao · 2022




To overcome the zig-zag (“Oddo-Harkins”) effect on abundance graphs, which is due to even atomic number elements being more abundant than odd numbered elements (except hydrogen plus a few others), concentrations of REE can be displayed using chondrite-normalised plots.

Compared to all the meteorites found to date, CI chondrites possess the strongest similarity to the elemental distribution within the original solar nebula. For this reason they are also called primitive meteorites.

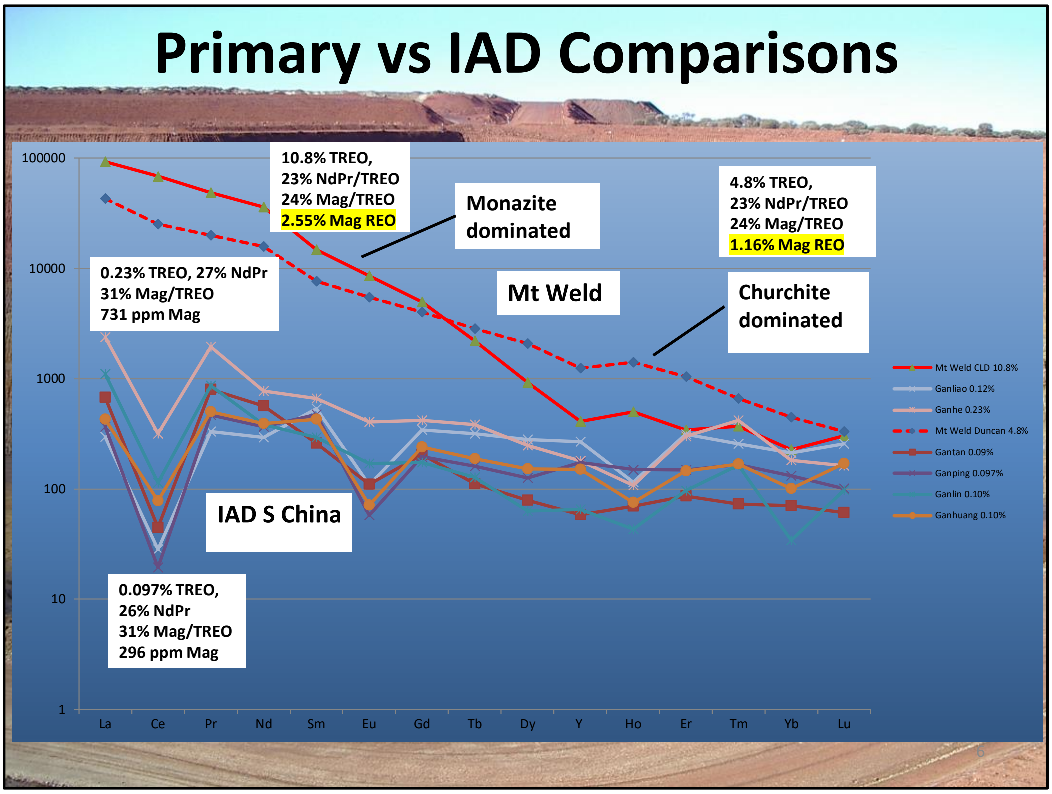
Because of this strong similarity, it has become customary in geochemistry to normalize rock samples versus CI chondrites for a specific element.

See the zig-zag effect on the graph that shows the raw data for the pillow core and compare that with the normalised data.

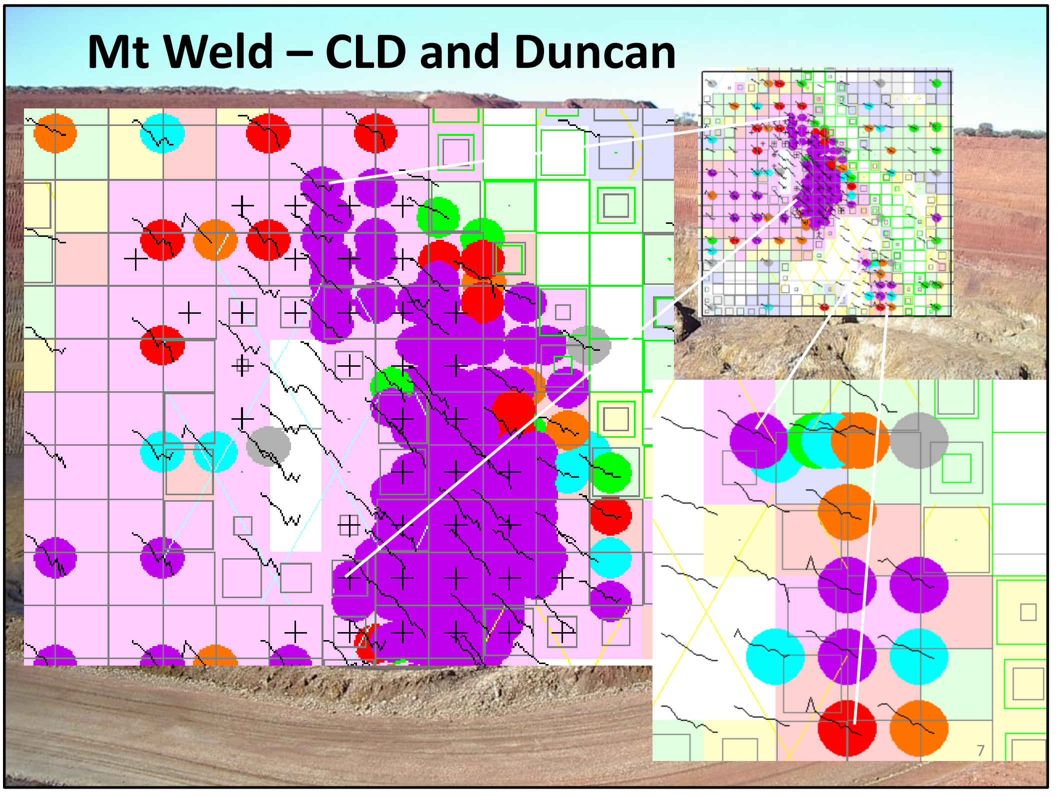
Mt Weld CLD and Duncan chondrite-normalised graphs shown

Effect of EDTA stripping off the REE from the pillow rind is shown.

Talantus, Madagascar, one of the more advanced IADs, TREO Measured and Inferred Resource of 880 ppm, will be discussed further



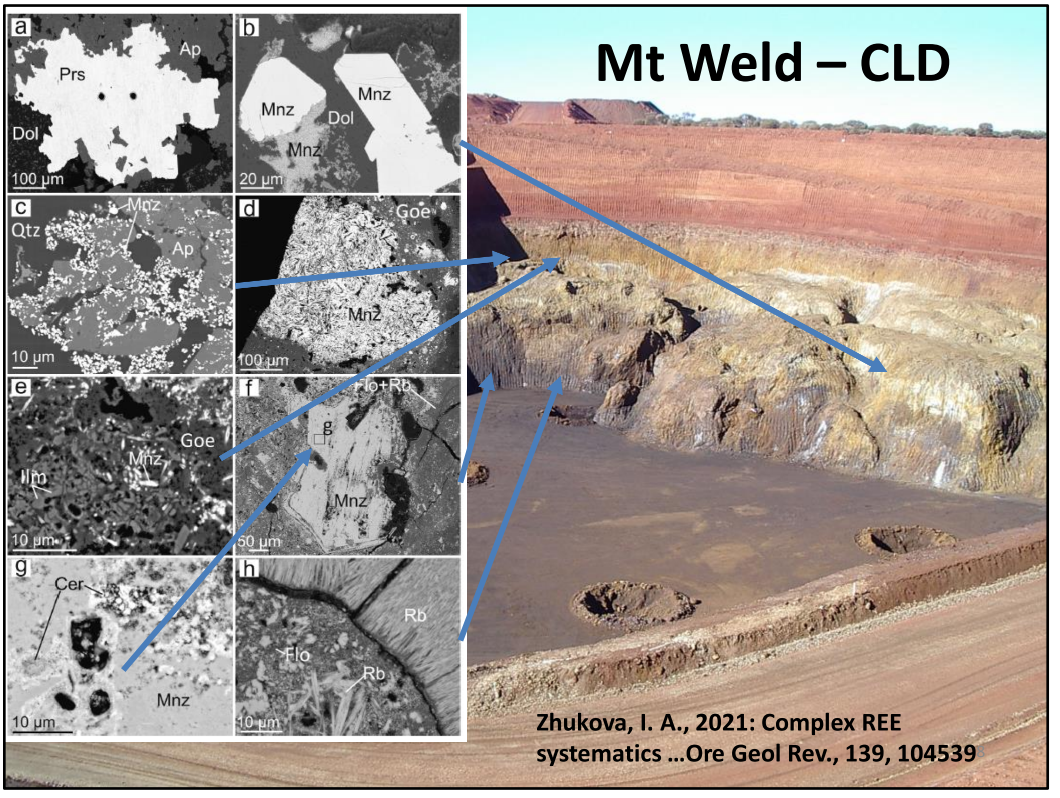

Primary (Mt Weld) vs Chinese IAD (Ionic Adsorption deposit) comparisons with %ages of NdPr (as totals of TREO) and grades of Mag REO (Nd+Pr+Dy+Tb, ppm; % in the case of Mt Weld for original Ore Reserve > 4% TREO). S China data from Chi and Tian, 2008.




Chondrite graphs plotted on plan for CLD (Central Lanthanide Deposit) and Duncan.

Spikes in patterns – what do they teach us? +ve Ce anomalies show the effect of mobility of REE with oxidation of Ce and precipitation due to low solubility.

The flatter patterns (ie HREE enriched cf CLD) from Duncan contrast with the steeper LREE patterns from the CLD.




Difficult mineralogy at Mt Weld due to the effect of weathering on monazite and other REE phases, see reference on slide.

A,B Clean parisite Ca(LREE) CO3 F; monazite in carbonatite; Ap = hydroxylfluorapatite

C monazite around apatite in silcrete

D monazite and goethite in ferricrete

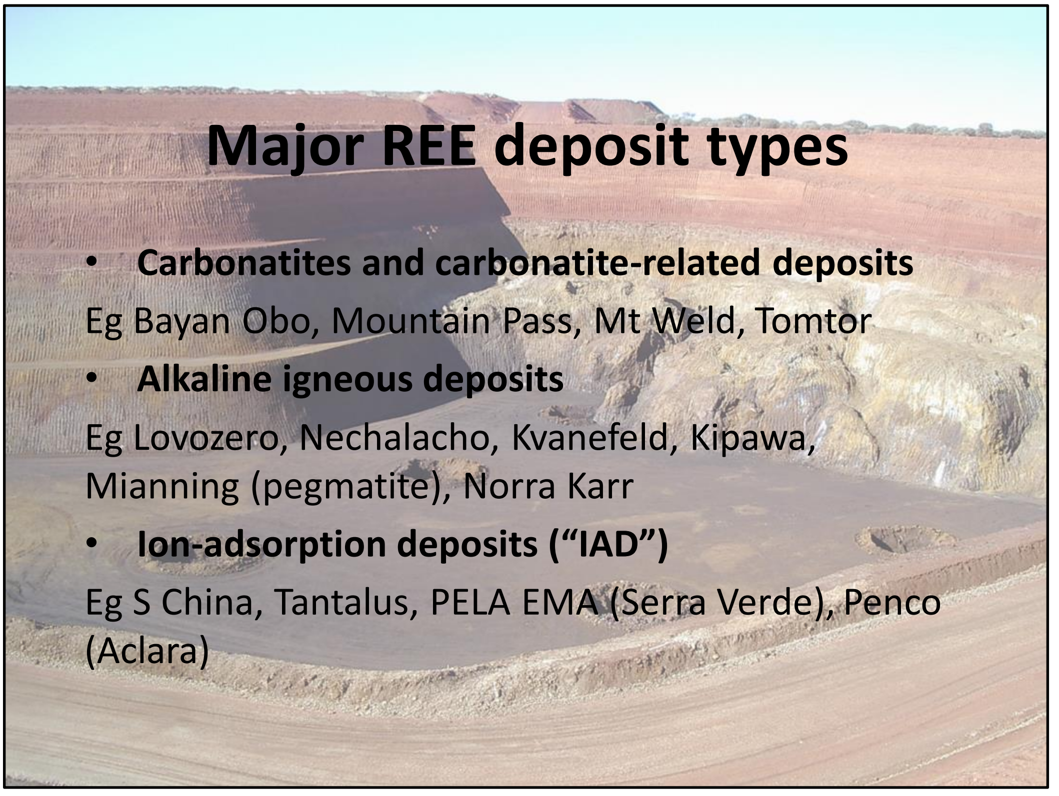
E ferricrete

F relict Mz in florencite = Ce Al phosphate and rhabdophane = hydrated LREE phosphate, high REE regolith

G close up showing cerianite

H = rhabdophane plant in florencite matrix

These microphotographs provide insight into the processes that may result in the mobility of rare earths initially locked in refractory phases such as monazite that need alkali fusions to dissolve them before ICP determination. The occurrence of cerianite (g) and goethite illustrate the way that REE may be fixed in the non-ionic responsive part of the regolith which helps explain the origin of the spikes in the REE patterns (due to cerianite, etc) in the previous slide.




There are more than 600 known carbonatites but only a few significant rare earth deposits associated with them. It is no accident that the deposits associated with alkaline igneous deposits have the more difficult rare earth mineralogies such as zircon-silicates (eg eudialyte)

# Major REE operations

| DEPOSIT | M TONNES | REO% | Kt METAL | NOTES |
|---|---|---|---|---|
| Bayan Obo | 57.4 | 6 | 3444 | "Reserve", Fan et al: 2016; COG?; bastnasite (Ce), monazite (Ce), … |
| Mt Weld | 54.7 | 5.3 | 2877 | MIF Resource, Lynas: Oct 2022; 2.5% COG; monazite, apatite, plumbogummite, churchite (excluding Nb-rich northern deposit) |
| Mt Weld | 18.6 | 8.2 | 1527 | Ore Reserve, Lynas: Oct 2022; 2.5% COG; |
| Mountain Pass | 27.6 | 6.36 | 1755 | Ore Reserve, 2.49% COG, MP: Feb 16, 2022, SE; bastnasite (parasite, monazite) |
| Mianning | 17 | 3.7 | 629 | "Reserve", Li & Yang, 2014; bastnasite, chevkinite, … |
| Tomtor | 11.4 | 14.5 | 1653 | +6.45% $Nb_2O_5$ not in production, (Polymetal 19 April 2021) |
| S China IAD | >10?? | 0.05-0.2 | ?? | Various ion-adsorption clay deposits |

Always difficult to get accurate figures for Chinese REE deposits, "reserves" and "resources" are not used in the same way as western definitions.

Note the high cut-off grades used for both Mt Weld and Mountain Pass operations compared with cut-offs used for many other primary deposits.

# Emerging Primary REE projects[1]

| DEPOSIT | M TONNES (with cut-off) | REO % | NdPr | Kt METAL | NOTES |
|---|---|---|---|---|---|
| Ngualla, Tanzania | 18.5 > 1% REO | 4.8 | 1.02 | 888 | **OR**, Peak Resources, 2017; bastnasite |
| Yangibana, WA | 20.9 > $Value | 0.9 | 0.33 | 188 | **OR**, Hastings, 6 Feb 2023; Value COG (~0.2% NdPr); monazite |
| Nolans Bore, NT | 29.5 > $Value | 2.9 | 0.77 | 856 | **OR**, Arafura, 16 Mar 2020; 95% fluoro-apatite, monazite. Value COG. 13% P2O5 additional. 1% COG for resource. |
| Cummins Range<br><br>(Phos + Rare Dyke) | 6.5 > 1.0% REO<br>(18.8 > 0.5% REO<br>(519 | 1.98<br>1.15<br>0.32 | 0.38<br>0.23<br>0.07 | 1.29<br>2.16)<br>1600) | **IF**, RareX, Oct 2018, May 2023; Phosphate + REO resource > 2.5% $P_2O_5$ COG; 519 mt @ 4.6% $P_2O_5$, 580 ppm Nb2O5, 0.32% TREO (1600 Kt REO); monazite, bastnasite, parasite |
| Kangankunde Malawi | 4.7 > 3% REO | 3.8 | na | 180 | **F**, Lindian, Lynas 22 Dec 2010, monazite |
| | | | **Dy** | | |
| Browns Range, NT | 10.8 > 0.15% Dy | 0.76 | 0.64 | 82 | **MIF**, Northern Minerals, 10 Oct 2022; xenotime. |

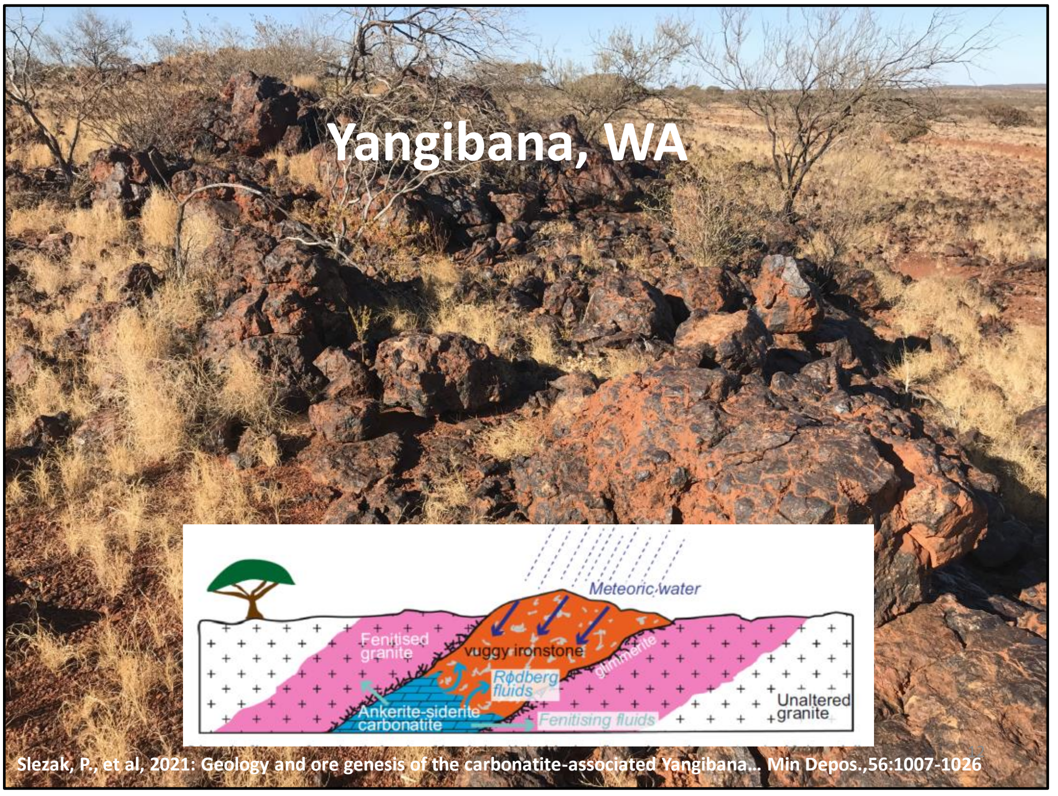
**1. Australian companies that have reported on the basis of REO; "OR" = Ore Reserve, "MIF" = Measured, Indicated, Inferred Resource**

Note Browns Range (xenotime- (yttrium phosphate) hosted deposit), Dy used as a cut-off due to it (and terbium's (Tb)) value to the project.

Other potentially significant projects include those with REE as by-products from Zr and Ti mineral sand deposits and those from mixed commodities (eg the Zr, Nb, Hf, REE Toongi deposit, NSW).

OR = Ore Reserve

F = Inferred Resource
IF = Indicated and Inferred Resource.
M = Measured Resource

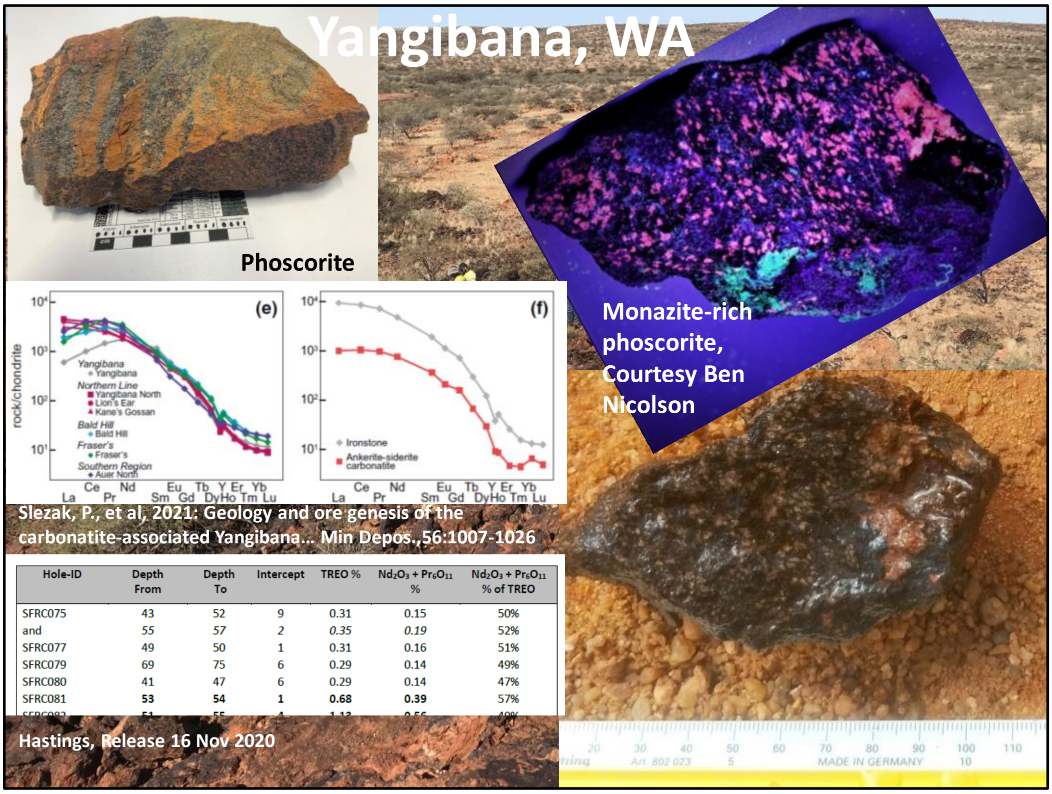



The rare earth mineralisation at Yangibana is hosted by the Gifford Ck Carbonatitic Comples, includes a variety of Mg, Fe rich carbonatites, phoscorites, fenites and per-alkaline dykes. Rare earths are hosted predominantly in monazite. Hematite-calcite-dolomite carbonatite.

The ironstones and less oxidised equivalents at depth seen in the slide host the rare earth mineralisation that is the focus of the development. The dykes can be traced for kilometres and at depth consist of phlogopite, magnetite, siderite. Slezak et al (see reference on slide) provide evidence that rare earths' enrichments have resulted in part by significant removal of carbonate minerals such as ankerite and siderite.

Ironstones – almost certainly these or similar outcrops would have been sampled as part of regional gossan sampling however they contain no sulphides and I am confident that they would have attracted no attention due to insignificant base metals, Ag, Au, As, Sb, etc. However, here is something for those of you involved in exploration. Fortunately there is a superb heritage of gossan geochemistry in Australia such as that produced by CSIRO based in Perth. It is just possible that elements such as Y, La and Ce as well as Th, Zr and Nb may have been reported which would offer a ready source of interesting locations for follow-up.

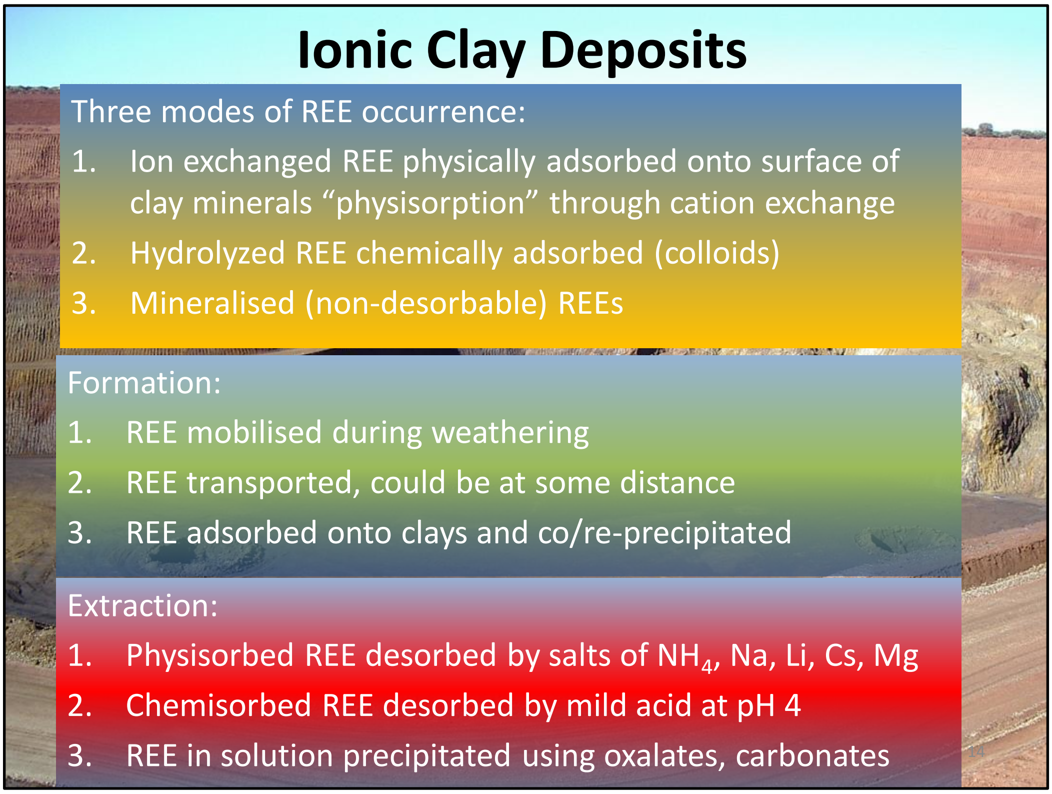
To Hastings' credit mineralisation that is predicted to contain significant amounts of siderite have been excluded from Resource Estimates.




The unusual feature of the Yangibana mineralisation is the exceptional enrichment of NdPr due to the composition of the monazite and the ability of the ore to be concentrated by a reported factor of 22 times resulting in a concentrate grade of approximately 27% TREO containing 11% NdPr which then results in a final mixed rare earth carbonate with a TREO grade of 59% and 22% NdPr. Note the NDPr enrichment in Yangibana monazite.

I included Yangibana to illustrate that my prejudice about grade being the whole story does not always hold up as well as giving you explorers some hope.

Sometimes the combination of mineral chemistry, oxidation and friendly metallurgy can produce winners. Best wishes to Hastings.




**Modes of occurrence**

An example of a Chinese IAD is REE as ~80% ion exchangeable phase, ~5% in colloidal phase and 15% in “mineral” phase.

These vary considerably with a large S American IAD having 32% of Dy being physically ion adsorbed, 8% colloidal and 60% as mineral.

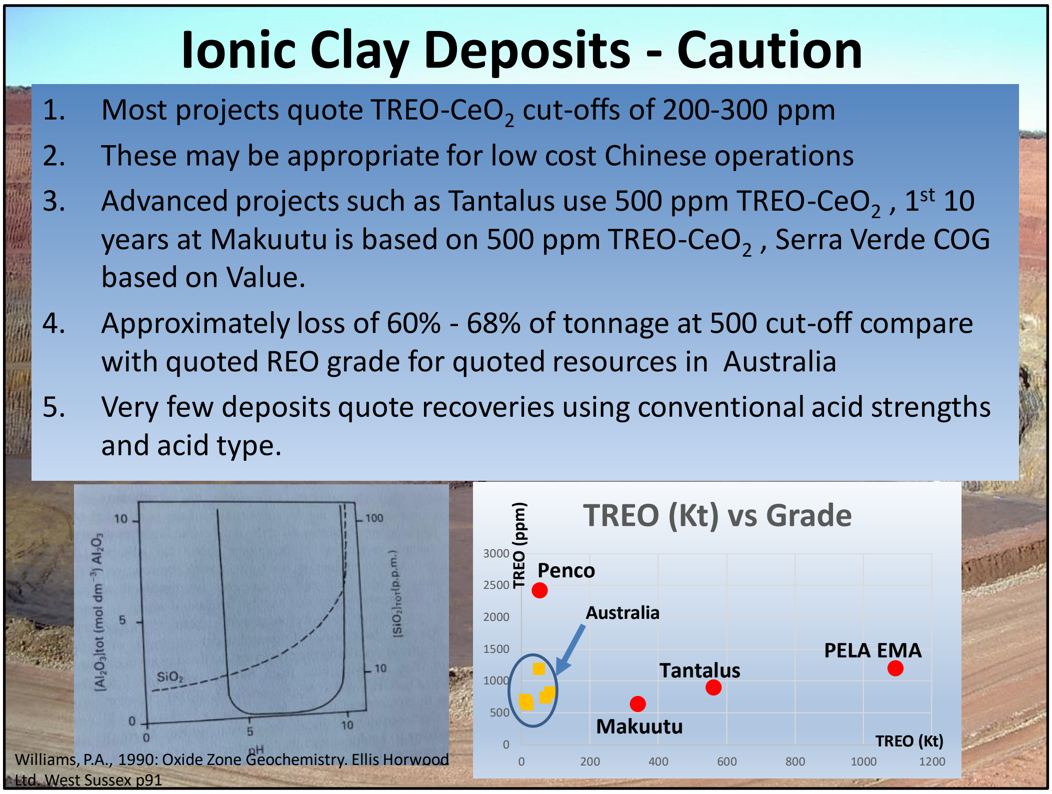
**Formation**

Fairly straightforward at the concept level.

Extraction, NaCl is proposed for Serra Verde; ammonium sulphate is the traditional eluant used.

The first port of call for getting advice on testing potential IAD should be the process metallurgists, these are friendly people and, in my experience, used to dealing with geologists. You need to ensure they have a history of processing and are also experienced in the various U/Th decay series and implications for choice of eluant etc.

I acknowledge helpful discussions with Bob Ring from ANSTO over the years.




All the clay-hosted REE Australian projects are a work in progress and only a relative few have published resource estimates.

In general, the cut-off grades used for clay-hosted clay deposits in Australia are too low and are not based on preliminary economic studies with published inputs such as estimated costs, recoveries and realised prices. My view is that a TREO-CeO2 cut-off of 500 ppm or more is likely to be more reasonable. It is possible that many clay-based REE projects are not dominantly ionic.

Note the reason why lowering pH will cause problems: Th & Al dissolved, resulting in co-precipitation and difficulties in further extractions. The use of low pH is common with the majority of Australian clay-hosted deposits.

Other key issues to note:

Price projections, check when they were made and how realistic they are under current conditions.

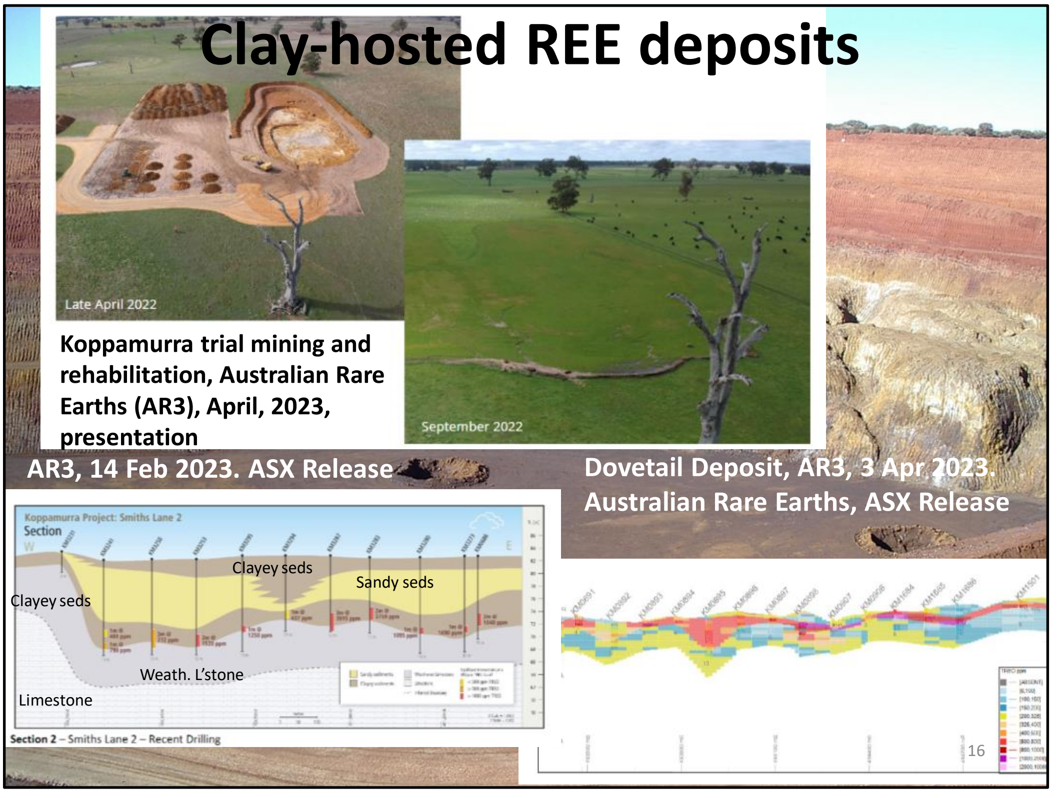
Mode of operation – In-situ methods are unlikely to be viable in the Australian context.

Likely – vat leach, tanks, …

Unlikely – heap leach – remember dealing with clay (used as impermeable barriers at the bottom of dams, etc), will need agglomeration and likely to be difficult due to ponding, channelling, loss of strength, impermeability and collapse.

Thank you Randy Scheffel for conversations about HL;.

An area where second opinions are needed.




Australian Rare Earths has done the emerging REE industry a great service with these photographs on their website. In passing, for those on the front line having to explain rare earths to land-owners, members of the public, stakeholders, etc you should be aware of their role in medicine eg:

MRI (role of NdPr in high strength magnets), Gd - Gadolinium contrast media used in magnetic resonance imaging scans and Lu (isotope used for cancer treatment; active research as a superconductor). Remember, rare earths are useful to everyone.

The Koppamurra deposit shows us that theories about the best places to explore should be re-thought.

It is not developed over an alkaline granite or equivalent, nor near a carbonatite and sits on the most barren of barren rocks, limestones but is there due to REE mobility.

Look for cross sections of grade models, juxtaposed with drill hole data and geology, in public reports (eg lower right). It is often difficult to get to the bottom of the robustness of these models, one feature to look for is over-domaining whereby modelled grades look like horizontal stripes as if the higher grade intervals have been joined together creating the impression of unrealistic ribbons. The cross-section of modelled grades at lower right shown does not display these issues.


In 1969 the ion adsorption type of REE mineralisation was first discovered in Longnan, Jiangxi, China. Exports to Japan, Europe and Europe began in 1983. REE mining rapidly expanded from 1986 to 1995. From 1996 to 2009 REE mining went out of control with the government clamping down on dreadful environmental outcomes. Exploration is by shell-type augers, pitting with shovels, shallow drilling, but depths can reach 50m.

In an example of recent trends Wang et al (China Geology, 2018) document the delineation of orebodies based on individual recoverable values with a cut-off grade used of 500 ppm for one example resulting in a production grade of 800 ppm REO.

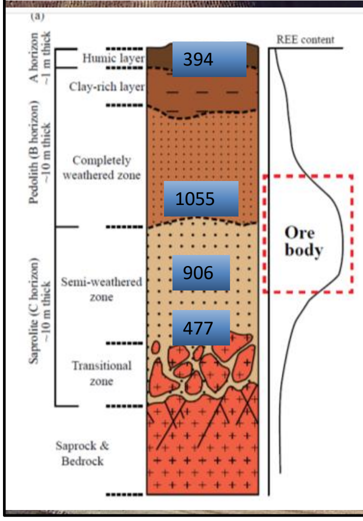
Typical mining practices involved surface mining, spraying acid, injecting wells, tanks, ponds, gutters all resulting in landslides, contaminated ground and surface water and mine collapses.

Lower right illustrates how rare earths have been an integral part of China's mineral economy. The photo (2018) is from a museum in Guangzhou.

# Zudong, World's Largest Regolith-hosted HREE Deposit

**TABLE 1.** Summary of bulk mineralogical and geochemical properties of the Zudong deposit

| Soil horizon | Proportion of kaolinit e group mineral (%)[1] | Soil pH[1] | Proportion of particle size (%) <2 µm | 2–20 µm | 20–50 µm | >50 µm | Bulk REE concentrartion (ppm)[1] | Proportion of the Total REEs (%)[1] Extractable adsorbed REEs | Fe-Mn oxyhdroxide-adsorbed REEs | Fe-Mn oxyhdroxide-bound REEs | Organic substance-bound REEs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Humic layer, Upper pedolith | 25 | 4.74 | 22.9 | 57.5 | 14.8 | 4.8 | 394 | 46 | 2.5 | 1.5 | 0.5 |
| Lower pedolith | 12 | 5.55 | 11.6 | 47.6 | 26.3 | 14.6 | 1055 | 66 | 2.3 | 0.8 | 0.4 |
| Upper saprolite | 13 | 5.40 | 9.3 | 37.7 | 25.1 | 27.9 | 906 | 60 | 2.1 | 0.5 | 0.2 |
| Lower saprolite | 10 | 5.94 | 8.3 | 31.1 | 18.9 | 41.7 | 477 | 61 | 1.9 | 0.8 | 0.5 |




- Parent granite: ~200-400 ppm
- Accessories: synchysite[1], gadolinite[2], hingganite[3], yttrialite[4], fluorite, euxenite[5], fergusonite[6] – all Y-varieties + zircon, thorite[7]
- HREE-dominant, ~0.1% REO
- Few metres - ~30m thick
- 30% REE in supergene (chernovite[8], cerianite[9]) and relicts;
- 70% REE adsorbed onto clay
- 0.5M $(NH4)_2SO_4$ only (no acid)
- 55-70% kaolinite, 25-35% halloysite
- Poorly crystalline halloysite + kaolinite in deep regolith promotes REE adsorption
- <20 micron tested
- Ore body ~2500 ppm

1. $CaY(CO_3)_2F$
2. $Y_2Fe^{2+}BeSi_2O_{10}$
3. $(Y,REE,Ca)_2(Fe^{2+})Be_2[SiO_4]_2(OH)_2$
4. $(Y,Th)_2Si_2O_7$
5. $(Y,Ca,Ce,U,Th)(Nb,Ta,Ti)_2O_6$
6. $YNbO_4$
7. $(Th,U)SiO_4$
8. $(Ce,Y)(AsO_4)$
9. $CeO_2$

Kaolinite - $Al_2Si_2O_5(OH)_4$
Halloysite - $Al_2Si_2O_3(OH)_8$ (hydrated kaolinite)

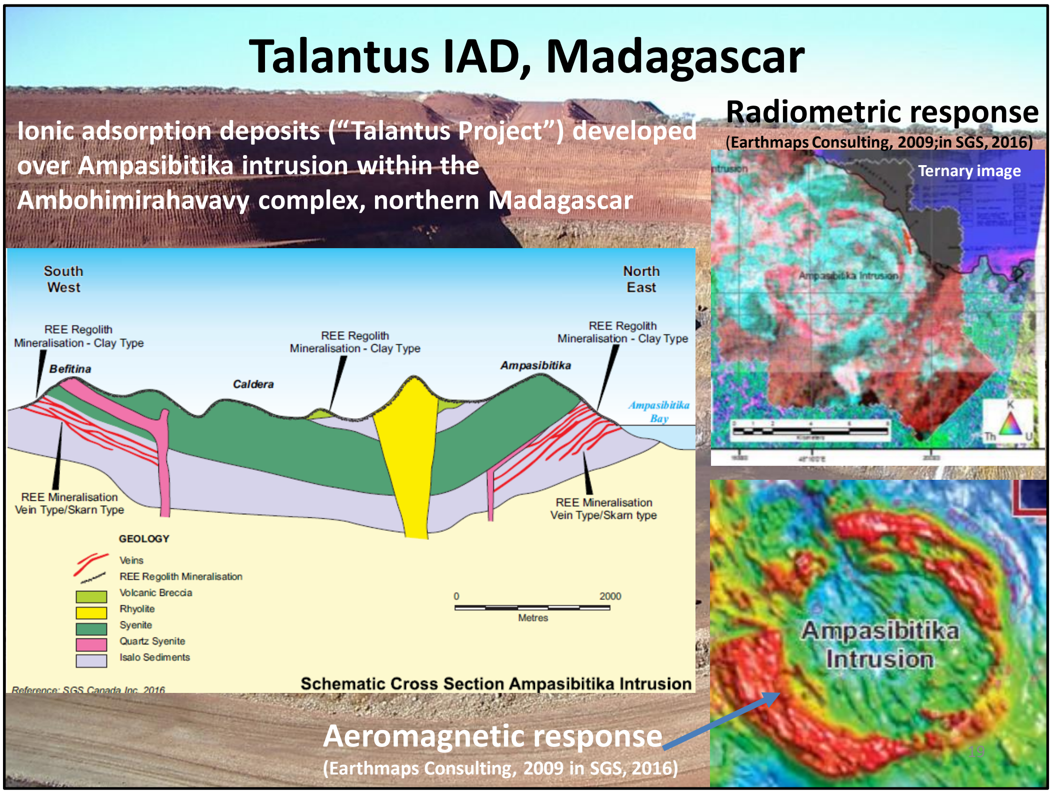
LI, M Y H & Zhou, M-F, 2020: The role of clay minerals in formation of the regolith-hosted heavy rare earth element deposits. Amer. Min.,105, 92-108

The Zudong (see Li and Zhou, 2020) heavy rare earth element (HREE) deposit in South China is the largest regolith-hosted HREE deposit in the world, with a resource of ~17,600 tonnes (t) of rare earth oxides (REOs) at an average grade of ~0.1 wt % REOs. Despite more than 40 years of exploration and exploitation, the genesis of this deposit is poorly understood. Subtropical weathering of the parent A-type granite formed orebodies hosted mainly within the lower B to upper C horizons of the resulting soil, which is developed on the hillsides of a moderately incised landscape (relief ~150 m). The thickness of the orebodies varies from a few meters to up to 10 m.

REE concentrations increase from ~300 ppm in the A horizon to ~1,500 ppm in the lower B to upper C horizons and decrease with further depth in the profile. The entire soil profile is enriched in HREEs, with (La/Yb)N ratios <1, but the REE-rich lower B horizon is less enriched in HREEs, with (La/Yb)N values up to 0.9, than the underlying upper C horizon.

Exchangeable REEs, representing REEs that are adsorbed in the deposit, constitute ~65% of the bulk REE content; the light REEs (LREEs) are preferentially adsorbed. The main minerals adsorbing the REEs are kaolinite and halloysite; the proportions of REEs adsorbed by Fe-Mn oxyhydroxides and organic matter are negligible.

N = chondrite normalised value



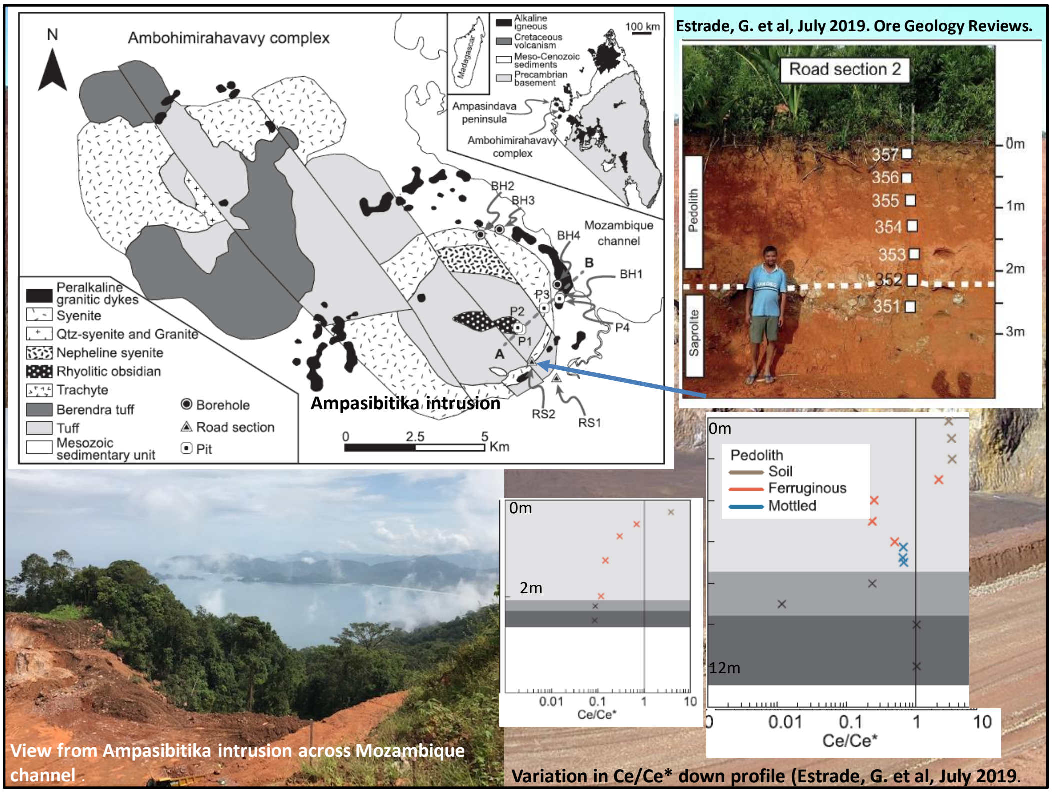

A well researched (see papers by Estrade et al, 2014, 2015, 2019, 2020; University of Toronto, numerous studies) IAD from Madagascar.

Note the geological setting, all the right alkaline rocks for REE enrichment due to secondary processes in the regolith.
Helicopter magnetic (lower right) and radiometric surveys were also undertaken in 2008 and revealed the two major circular caldera features corresponding to the Ampasibitika intrusion in the southeast and the Tsarabariabe intrusion to the northwest.

Peralkaline granitic ring dykes and sills around the rims of the caldera were noted as hosting 'fasibitikite' mineralisation with REE-bearing accessory minerals including chevkinite, eudyalite, monazite, pyrochlore and zircon. However, drilling and sampling showed that while some mineralised veins occurred within the 'hard rock' these intersections were relatively sporadic and low grade, while the upper weathered regolith horizons contained more consistent concentrations of rare earth minerals.

It was recognised that the Tantalus regolith REE mineralisation had possible similarities to the ion adsorption clay-type rare earth mineralisation in southern China, which is a major source of current world REE supply.

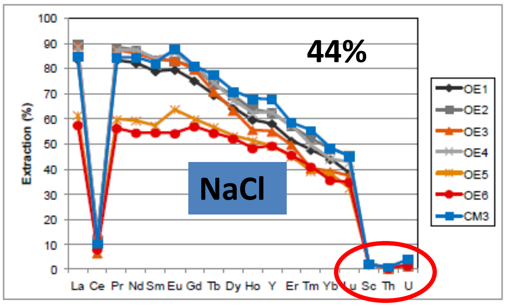
(See also: SGS Canada, 2016. Updated NI 43-101 Technical Report – Resources for the Tantalus Rare Earth Ionic Clay Project Northern Madagascar.)




Note the regolith profile, >1 Ce/Ce* near surface, declining to <1 at depth demonstrating the existence of REE mobility with the possibility of enrichment of REE at depth (with depletion of Ce). See Estrade et al, 2019 for an excellent discussion.

# Extractions

Based on these results, a concentration of 1M ammonium sulphate at an adjusted pH of 4 were selected as the best conditions when working with ammonium sulphate as eluant.



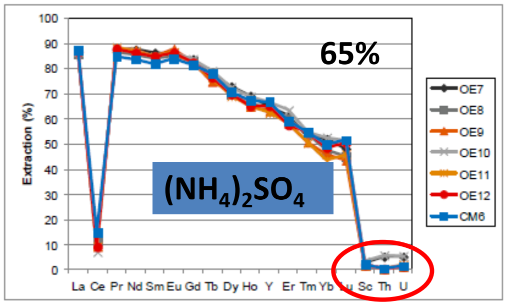




Table 1-1: Resource Base Case – COGs of 300 and 500 ppm TREO excluding Ce (TREOnoCe)

| Classification | Tonnage (t) | Volume ($m^3$) | Area ($m^2$) | Density ($t/m^3$) | Thickness (m) Total | Thickness (m) PED | Thickness (m) SAP | TREO (ppm) | TREOnoCe (ppm) | CREO (ppm) | HREO (ppm) | LREO (ppm) | HREO / TREOnoCe ratio | Contained TREO * (t) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Measured | 40,103,550 | 35,948,700 | 6,618,600 | 1.12 | 5.4 | 2.8 | 2.6 | 975 | 660 | 296 | 187 | 788 | 28% | 39,092 |
| Indicated | 157,580,640 | 143,150,400 | 20,998,800 | 1.10 | 6.8 | 2.6 | 4.2 | 878 | 554 | 255 | 166 | 712 | 30% | 138,292 |
| **Measured + Indicated** | **197,684,190** | **179,099,100** | **27,617,400** | **1.10** | **6.5** | **2.7** | **3.8** | **897** | **575** | **263** | **170** | **727** | **30%** | **177,383** |
| Inferred | 429,999,525 | 390,900,600 | 70,396,200 | 1.10 | 5.6 | 2.7 | 2.9 | 894 | 574 | 247 | 149 | 745 | 26% | 384,552 |

- The cut-off grade is applied to TREOnoCe because it has good correlation with the material value. Ce has high grades but low recovery and market price.
- The cut-off grade is 300 ppm TREOnoCe for areas sloping greater than 5 degrees
- The cut-off grade is 500 ppm TREOnoCe for flat areas

* Contained TREO is presented as in-situ. Values do not account for recovery losses.

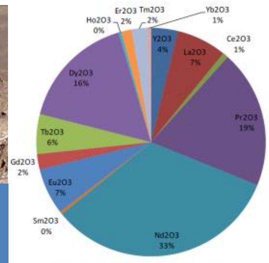
TREO = LREO+HREO TREOnoCe = TREO-$Ce_2O_3$

CREO = $Nd_2O_3+Y_2O_3+Eu_2O_3+Tb_2O_3+Dy_2O_3$

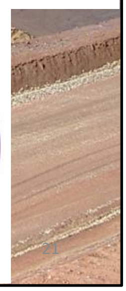
HREO = $Y_2O_3+Eu_2O_3+Gd_2O_3+Tb_2O_3+Dy_2O_3+Ho_2O_3+Er_2O_3+Tm_2O_3+Yb_2O_3+Lu_2O_3$

LREO = $La_2O_3+Ce_2O_3+Pr_2O_3+Nd_2O_3+Sm_2O_3$

**SGS Canada, 2016. Updated NI 43-101 Technical Report – Resources for the Tantalus Rare Earth Ionic Clay Project Northern Madagascar.**



REO Value Distribution - Sales



Extractions from Talantus showing:

Why CeO2 is excluded from resource statements and reporting of REE drilling results, Why NH4 so effective, average of 65% recovery, contrast this with very low extractions being achieved in some so-called IADs;

plus the minefield of presenting results.

Note Sc, U, Th recoveries.

(Ref: SGS Canada, 2016. Updated NI 43-101 Technical Report – Resources for the Tantalus Rare Earth Ionic Clay Project Northern Madagascar.)

Despite high Sc levels, Syerston, NSW (~400 - ~700 ppm), Owendale (~400 ppm) , Flemington (450 ppm) and Nyngan ( ~300 - 400 ppm) are still not off the ground.

# Public Releases – Scope for Confusion

"Exceptional 86% recovery of high value magnet REE with critical REE Nd 95%. Ionic adsorption deposit confirmed"

| Cut-off TREO-Ce[1] (ppm) | TREO[2]-$CeO_2$ (ppm)[2] | Tonnes (mT) | TREO (ppm) | LREO[3] (ppm) | HREO[4] (ppm) | MREO[5] (ppm) | MRec[6] (%) | TRec[7] (%) |
|---|---|---|---|---|---|---|---|---|
| 200 | 400 | 78 | 600 | 350 | 250 | 200 | 66 | 80 |
| 500 | 600 | 8 | 900 | 500 | 400 | 360 | 86 | 90 |

1. Ce elsewhere in report quoted as $Ce_2O_3$ (mixed up with $CeO_2$) = TREO (Total REO) - $CeO_2$
2. TREO, Total REO = $La_2O3+CeO_2+Pr_6O_{11}+Nd_2O_3+Sm_2O_3+Eu_2O_3+Gd_2O_3+Tb_4O_7+Dy_2O_3+Ho_2O_3+Er_2O_3+Tm_2O_3+Yb_2O_3+Lu_2O_3+Y_2O_3$
3. LREO, Light REO = $La_2O_3+CeO_2+Pr_6O_{11}+Nd_2O_3+Sm_2O_3$
4. HREO, Heavy REO = $Eu_2O_3+Gd_2O_3+Tb_4O_7+Dy_2O_3+Ho_2O_3+Er_2O_3+Tm_2O_3+Yb_2O_3+Lu_2O_3+Y_2O_3$
5. MREO, Magnet REO = $Nd_2O_3+ Pr_6O_{11}+Tb_4O_7+Dy_2O_3$
6. MRec, Magnet REO Recovery. TRec, TREO recovery

A few issues: 86% recovery is based on three tests at pH=2 with a non-conventional acid.
Quoted recoveries are completely unrepresentative. Sometimes MREO may refer to Middle REO
How is the magnetic REE recovery calculated – based on TREO or TREO-$CeO_2$? Ditto for TRec.
Are Tonnes based on a cut-off grade using TREO-CeO2 or on TREO?
Note the dramatic decline in tonnes using the higher cut-off.

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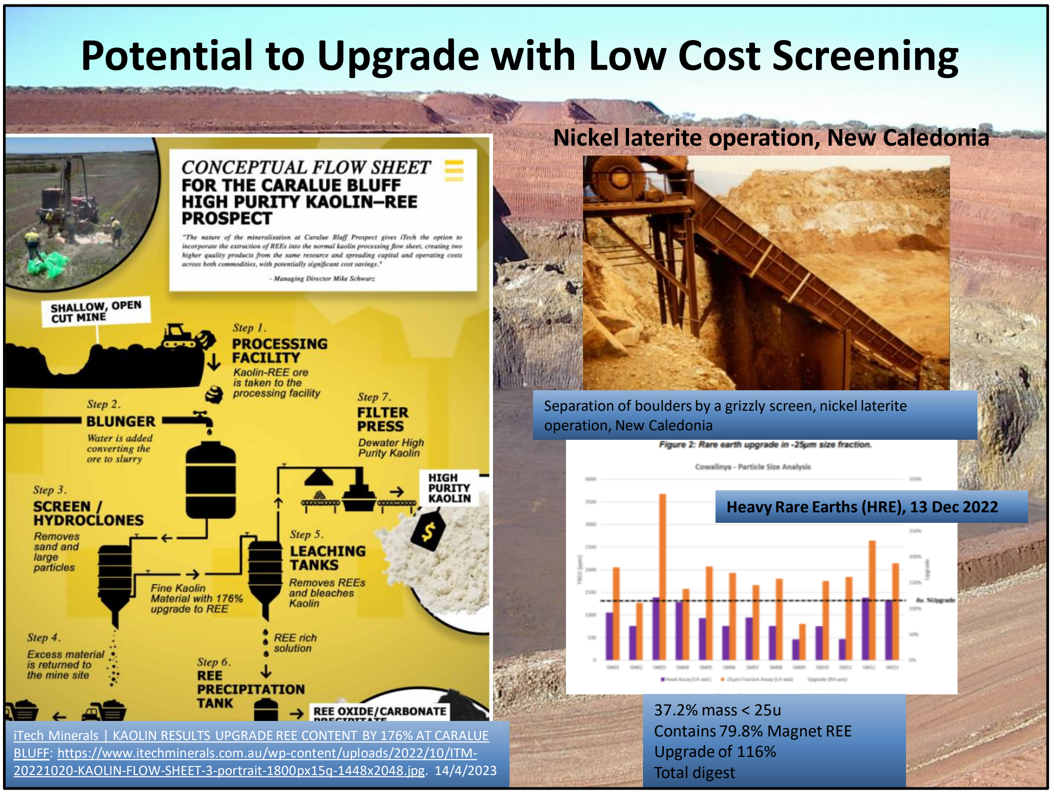
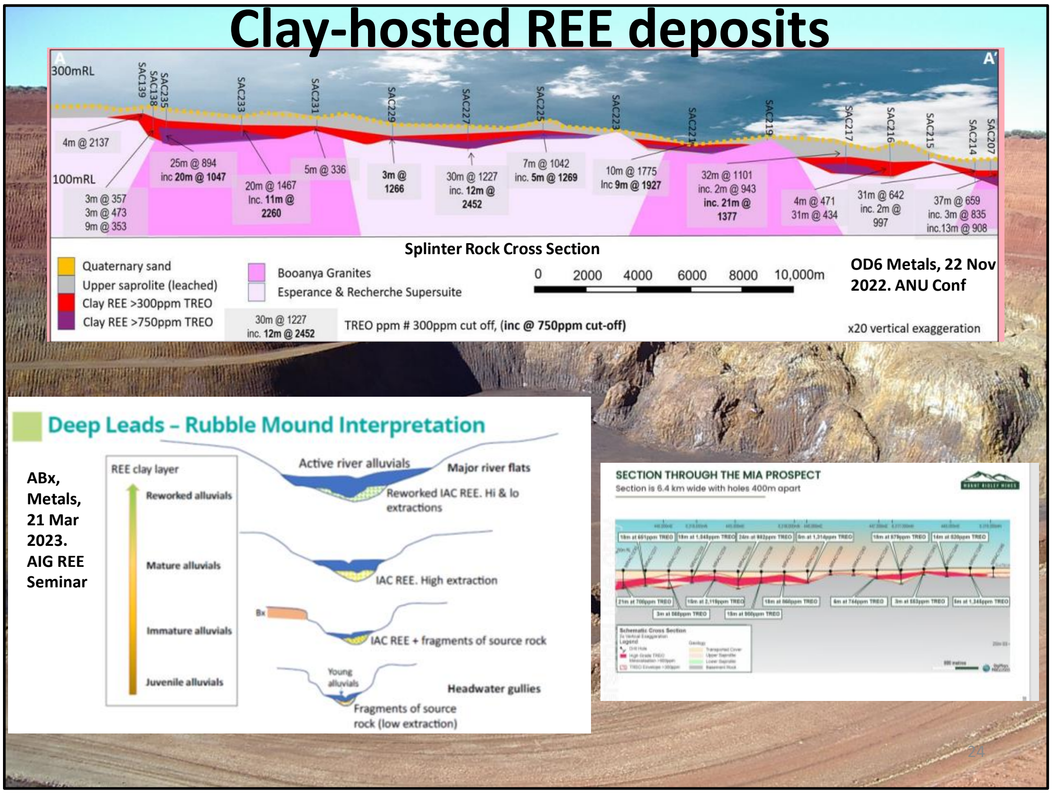
The presentation of REO results is not always clear and understanding the numbers is not straightforward. It is important to check the basis of %ages for recoveries (divided by TREO, TREO that includes Y, TREO-CeO2 or what?). Check what acid was used, the pH, temperature, etc. Is there a grade-tonnage curve? Have the stoichiometries been correctly calculated? Are there detailed cross sections?



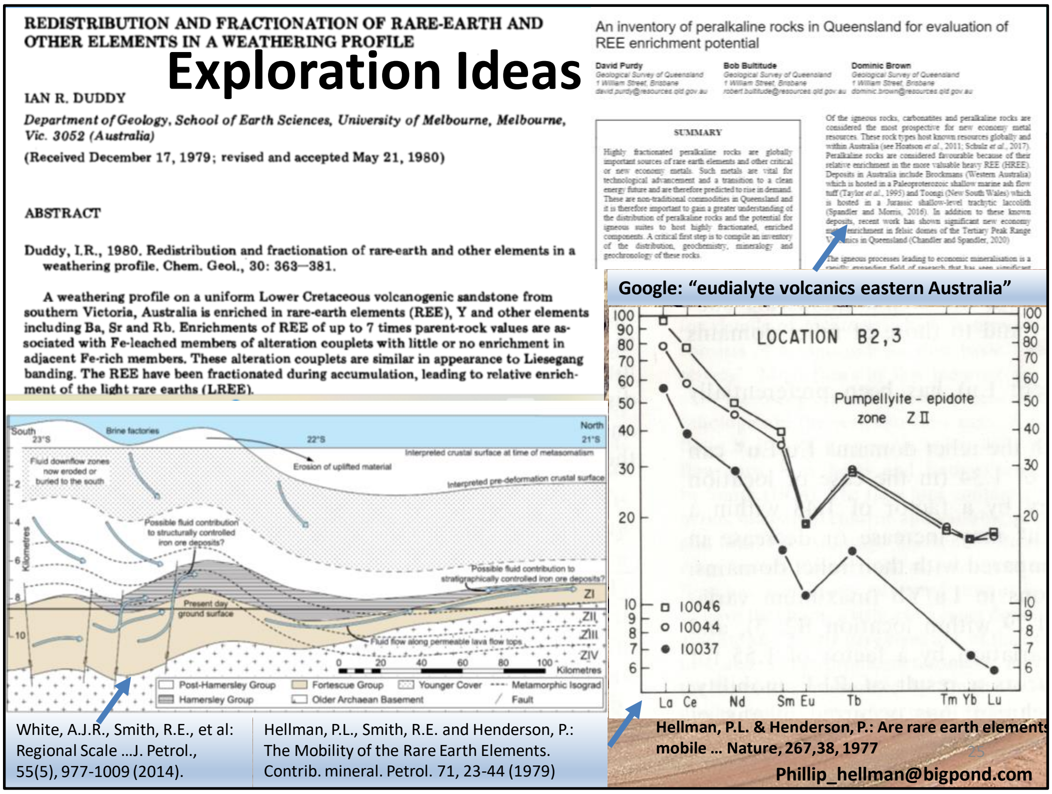

Importance of considering how potential IADs are sampled. Cobbles and boulders and floating fresh rocks will be irrelevant as in Ni-laterites (see use of grizzly in slide).

Role of low cost screening in upgrading such as the first stage of a Ni laterite operation.

See the impressive actual results from Cowalinya, (HRE:ASX) for upgrading by screening out oversize material.




Examples of cross sections of three clay-hosted REE prospects, Australia.




Here are some ideas for explorers:

1. Here (top left) is a documented REE anomaly near Lavers Hill in the Otway Group of Victoria.(top left) with all the right features – **up to 7 x concentration** of bed-rock with notes in the paper about REE being “absorbed” in **vermiculite**, all with a figure showing a zone of enrichment of Nd and Y!
   Vermiculite is often grouped with the smectites and is described “the cation exchange capacity is greater than that of the smectites and indeed is the highest of all the clay minerals” , maybe go and buy some from Bunnings, analyse it for REE, find out where it comes from and you may have an IAD REE deposit.
2. Look at the papers of the soil scientists who research soil profiles and often provide chemical analyses.
3. Google “eudialyte” etc (top right) and find occurrences in alkaline and peralkaline igneous rocks not for primary eudialyte but for the regolith over the top and flanking the occurrences. There is a good paper by Burcher Jones (on Tantalus) mentioning the accessory minerals eudialyte, monazite, pyrochlore, chevkinite and zircon that can be sources for REE enrichment.
4. This one is a big concept, look at the REE depletion in the flow tops of the Maddina Volcanics, Fortescue Group, Hamersley Basin (lower right). The REE must have travelled somewhere. See the references to White, Smith et al (2014) and Hellman, et al. (1979) per slide.
   In the opening Abstract (lower left) we read “**the scale of the fluid flow observed in the Fortescue Group which occurred through zones of inherent permeability has significant implications for the size of metasomatic systems …with potential consequences for the exploration for hydrothermal mineral deposits**”. Imagine an area 450km by 200km of REE depletion, where have the REE gone?

   With my best wishes,
   Phillip Hellman
   4 May 2023