



www.thetruesize.com/Chile

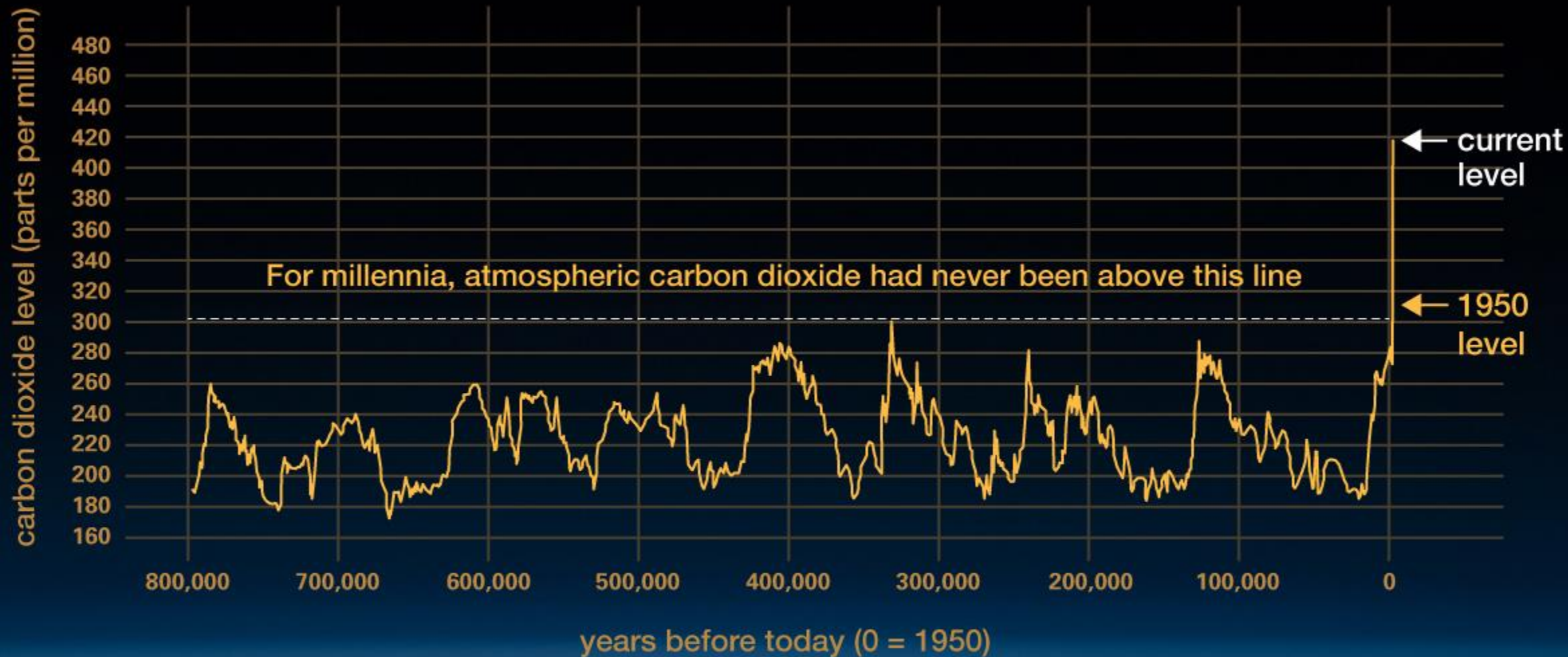
MDE Minerals Consulting

Geometallurgy of Cobaltiferous Copper Ores on the **Chilean Iron Belt**

10th Base Metals Conference | 13–15 June 2023

**Romke Kuyvenhoven
& Brian Townley**







Uganda and Ethiopia



Nigeria



Madagascar and Mozambique



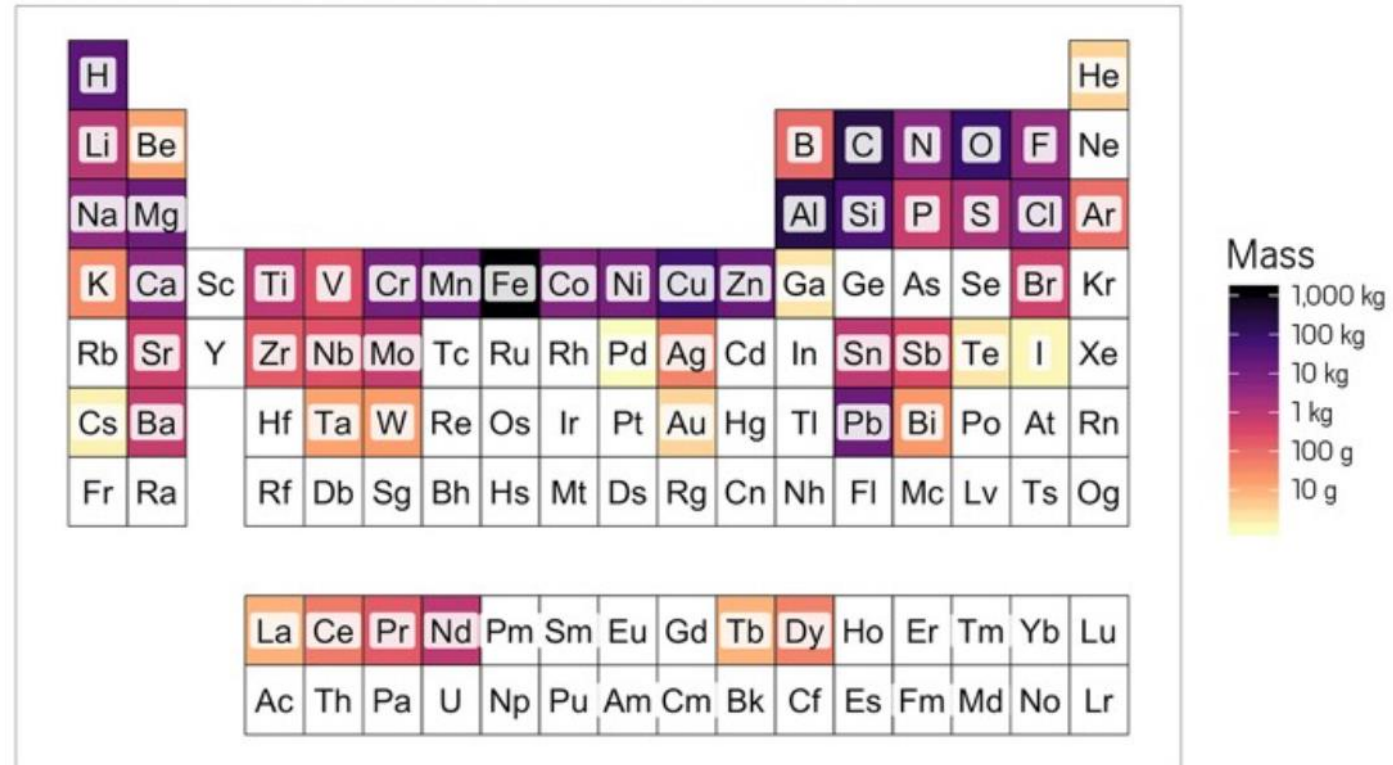
Algeria and Tunisia



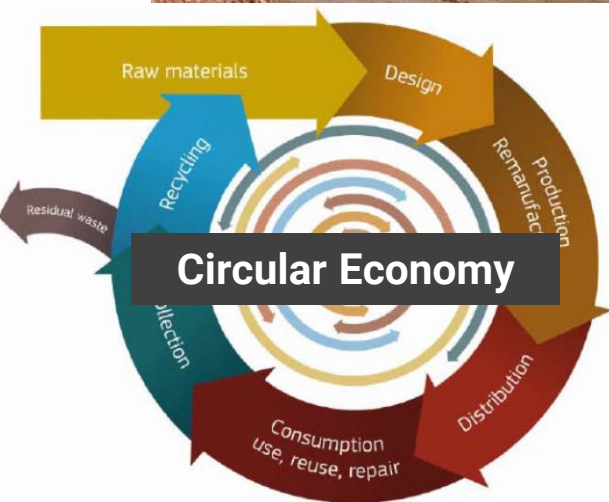
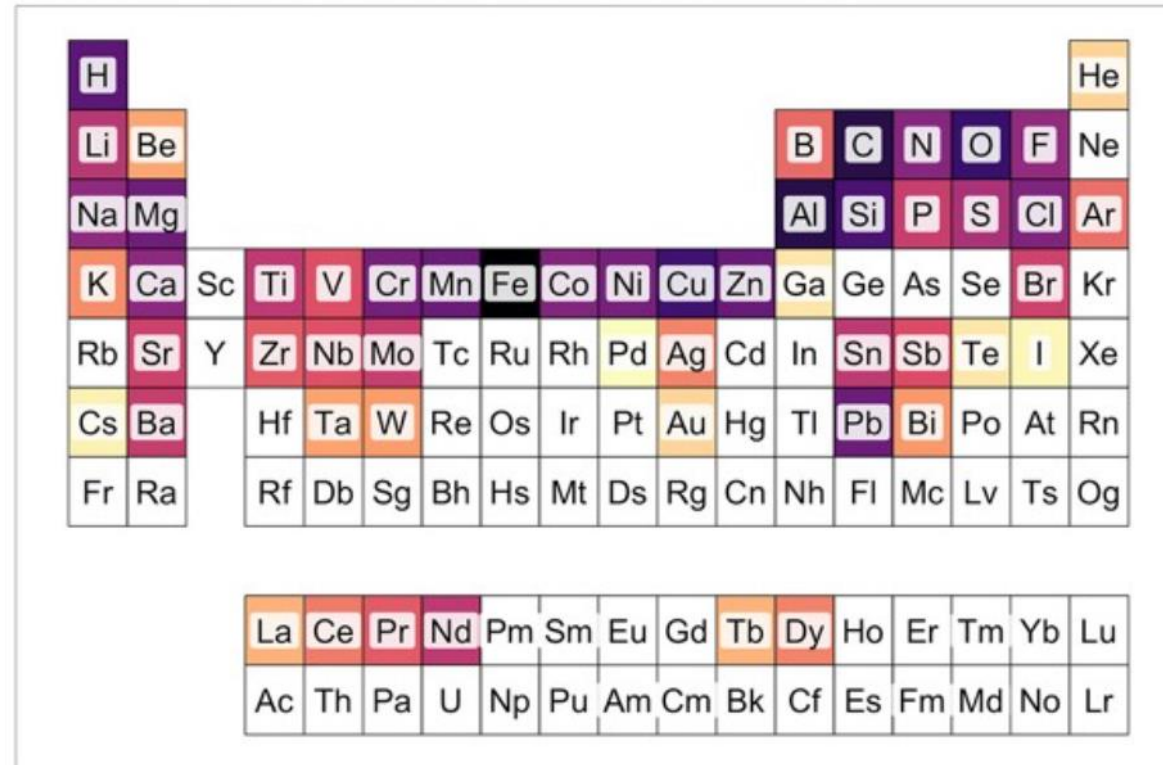




Average mass of elements for a plug-in hybrid vehicle



Average mass of elements for a plug-in hybrid vehicle

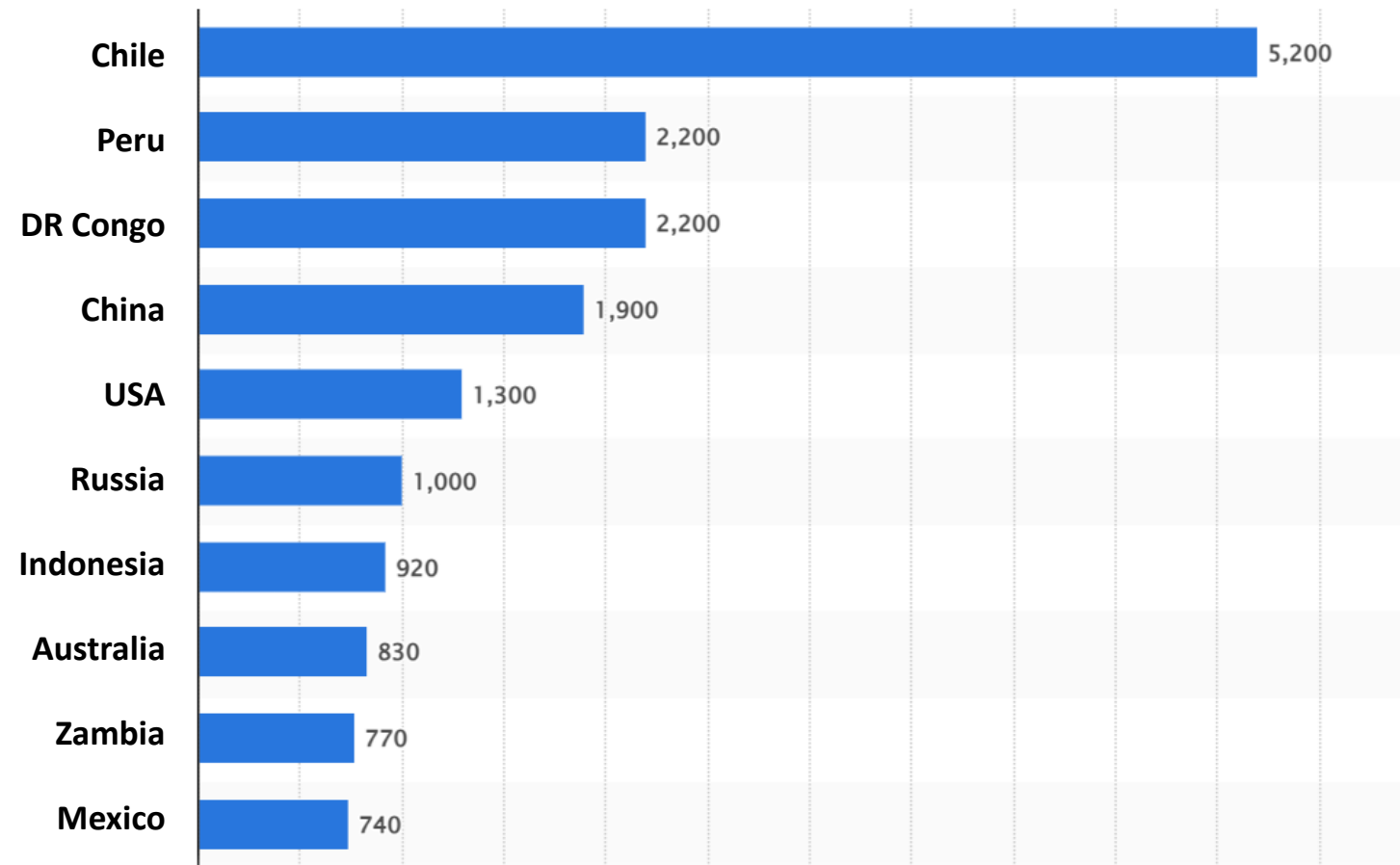


Source: <https://cen.acs.org/materials/chemical-elements-does-take-build/99/web/2021/07>



Major countries in copper mine production worldwide

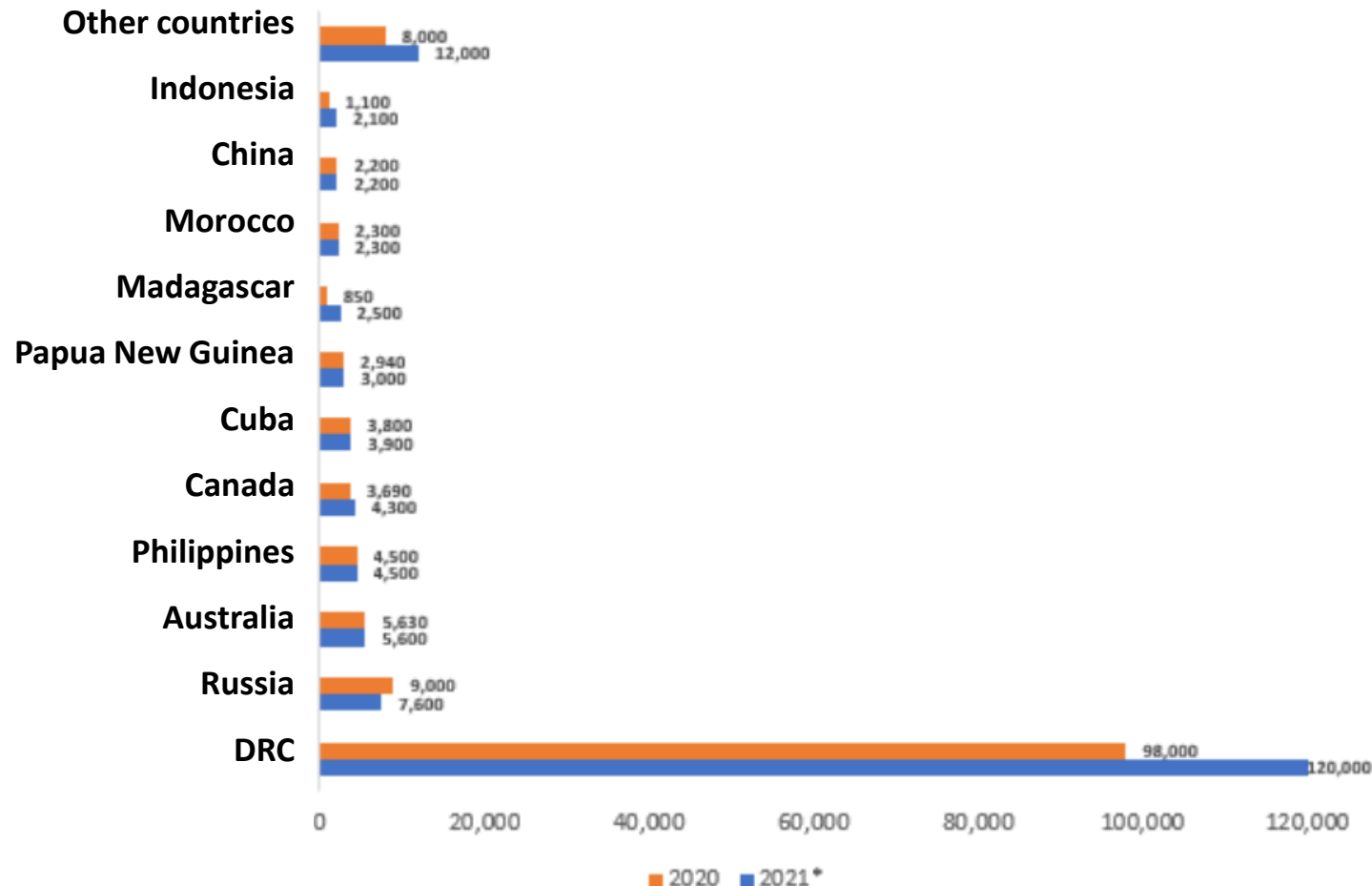
(in 1,000 metric tons)



Source: <https://www.statista.com/statistics/264626/copper-production-by-country/>



The world's largest cobalt producing countries



Cobalt in Chile?

Top Commodities in Chile

Copper (3,040)

Gold (1,205)

Silver (658)

Lead (306)

Iron (205)

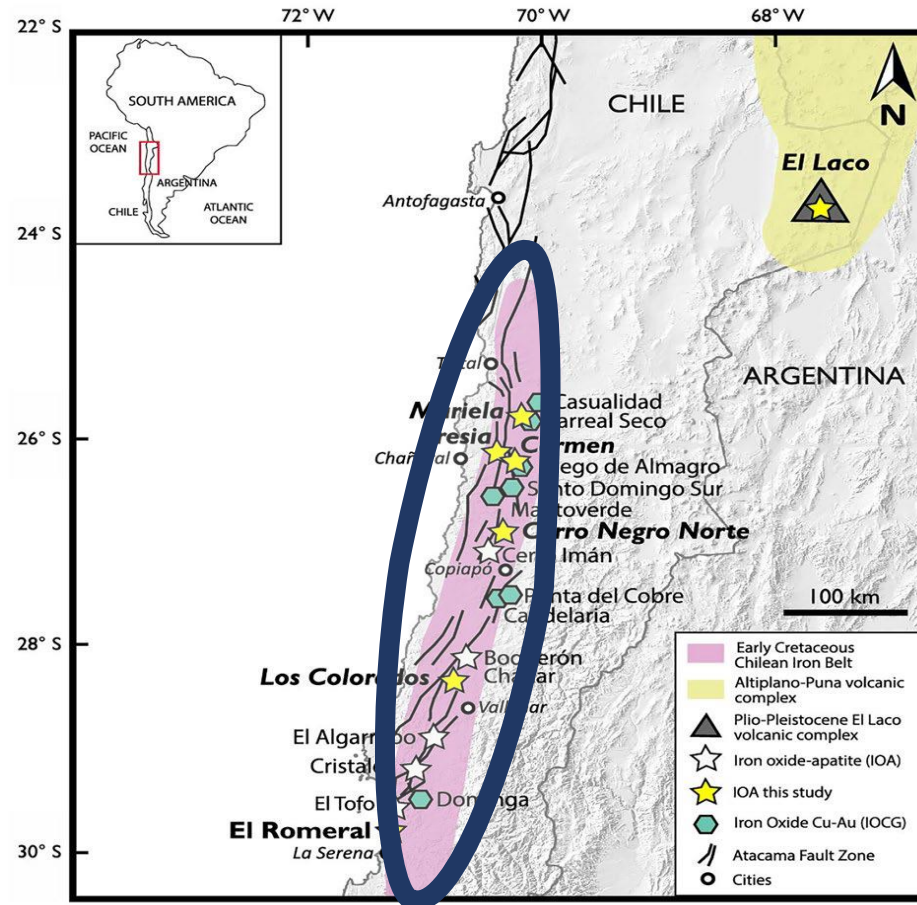
Zinc (201)

Molybdenum (131)

Manganese (126)

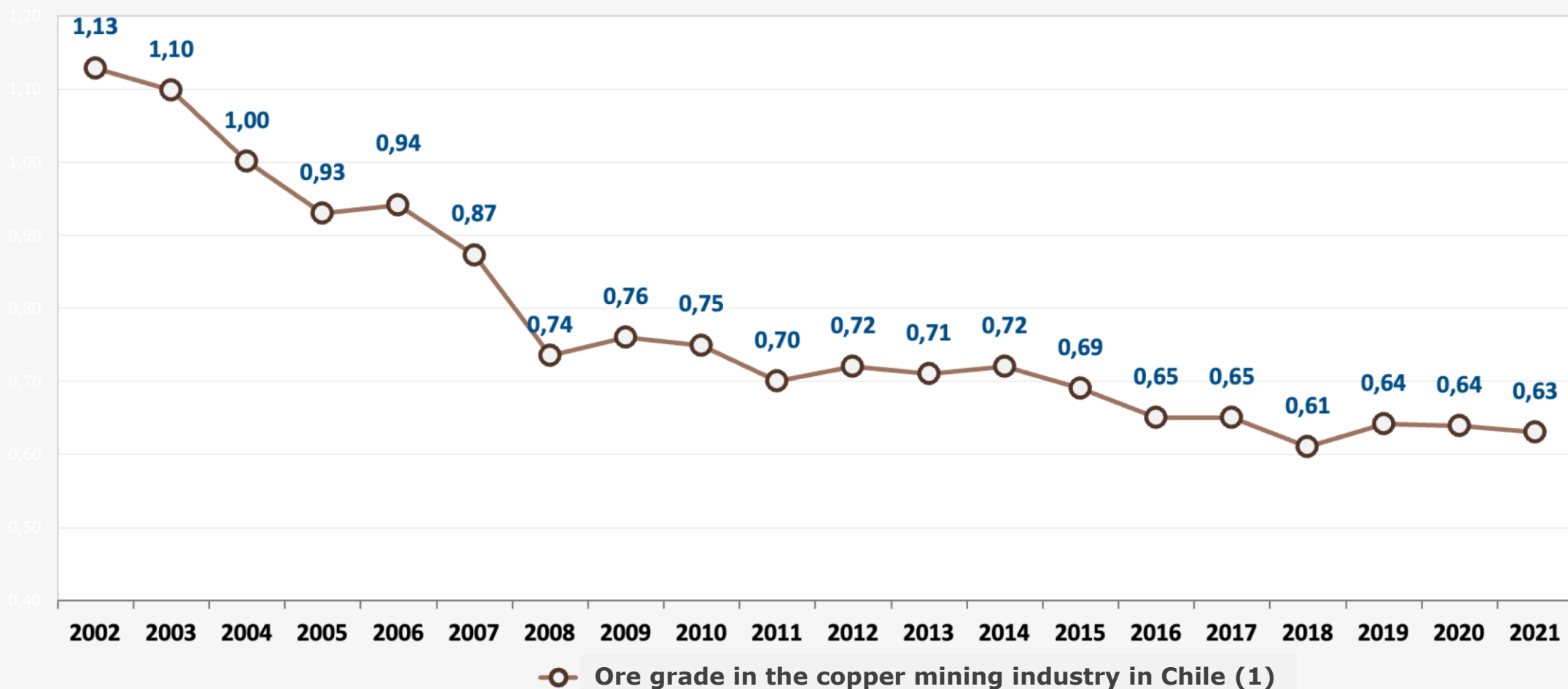
Cobalt (42)

Uranium (31)



Source: <https://thediggings.com/chl>

Ore grade in the copper mining industry in Chile



(1) Calculated as weighed average from the treatment of copper ores in concentration and leaching plants

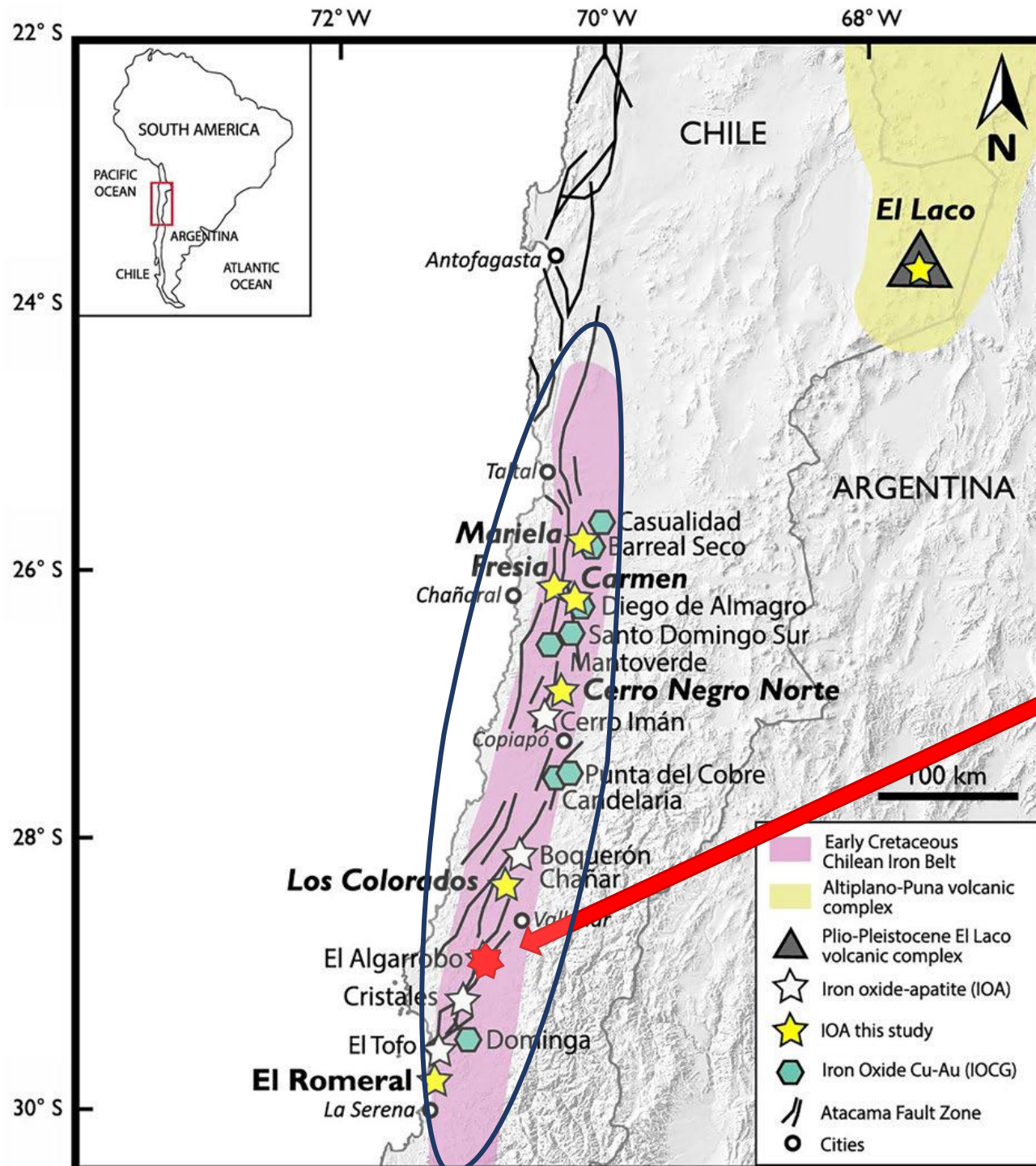
SOURCE: Mining Council from Cochilco data, 2022

Cobalt in Chile!

Example: IOCG ore from

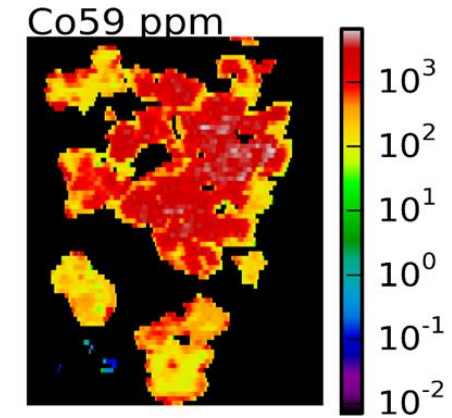
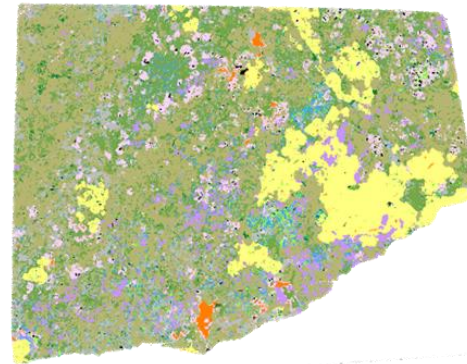
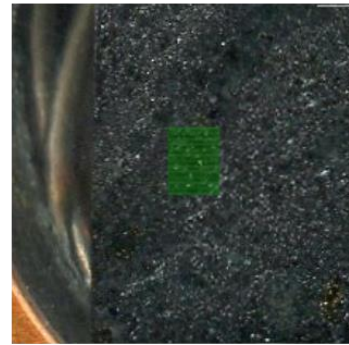
★ **La Estrella 3rd region**

- Cu: 0.2-1.0%
- Co: 200-1500 ppm
- Ni: 250-3000 ppm
- Fe >> 40%
- Va: 500-3000 ppm

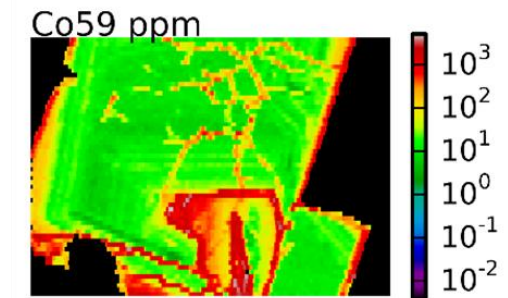
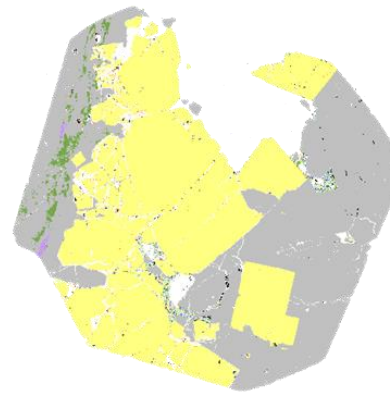
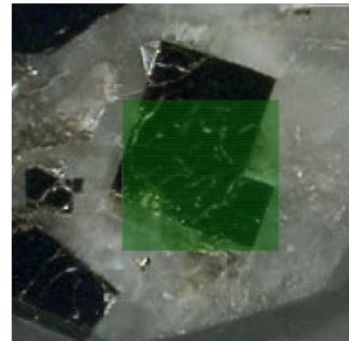


The use of ICP-MS-LA to visualize cobalt

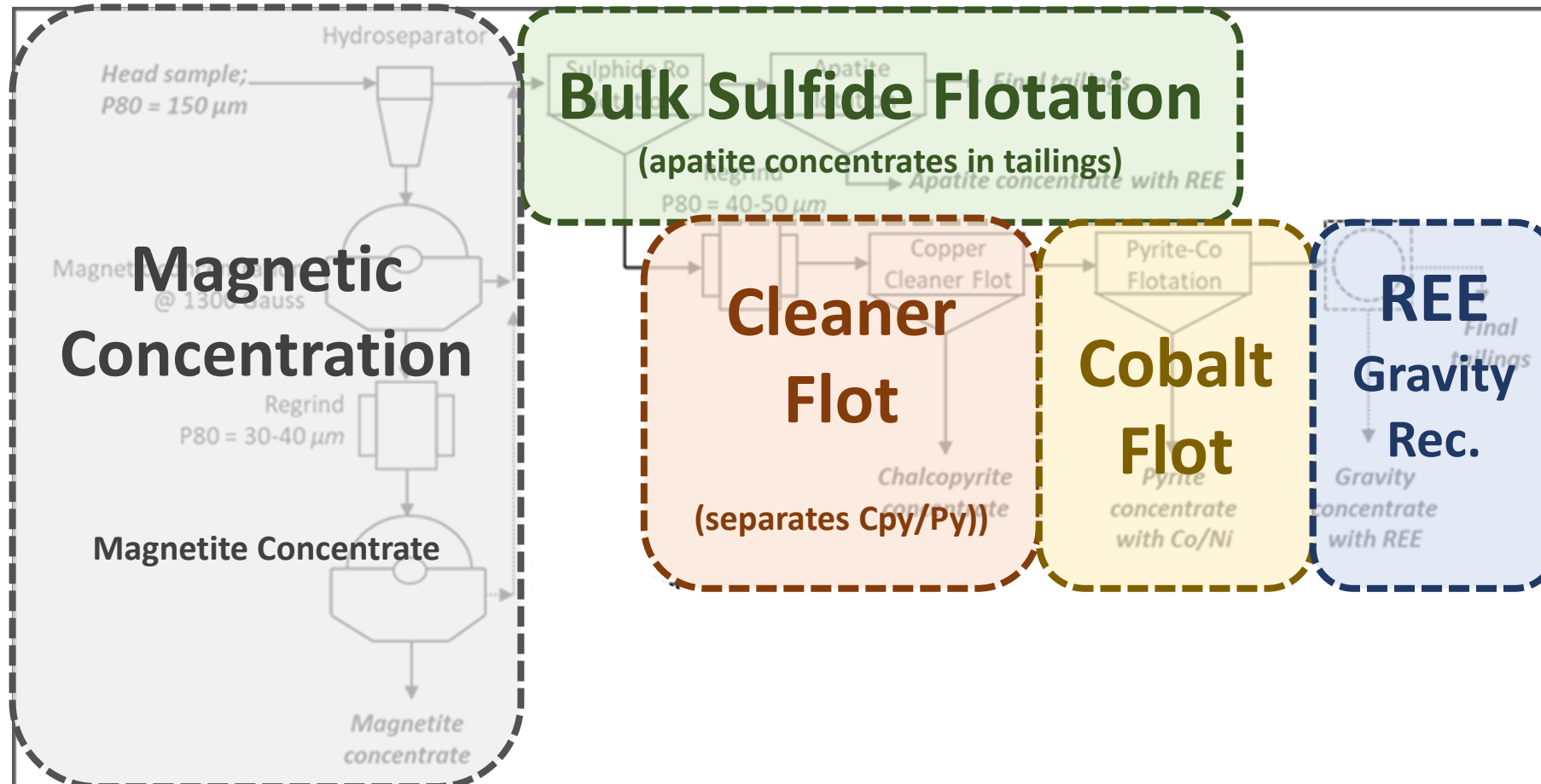
Small “amorph” Py grains



Large crystalline Py grains



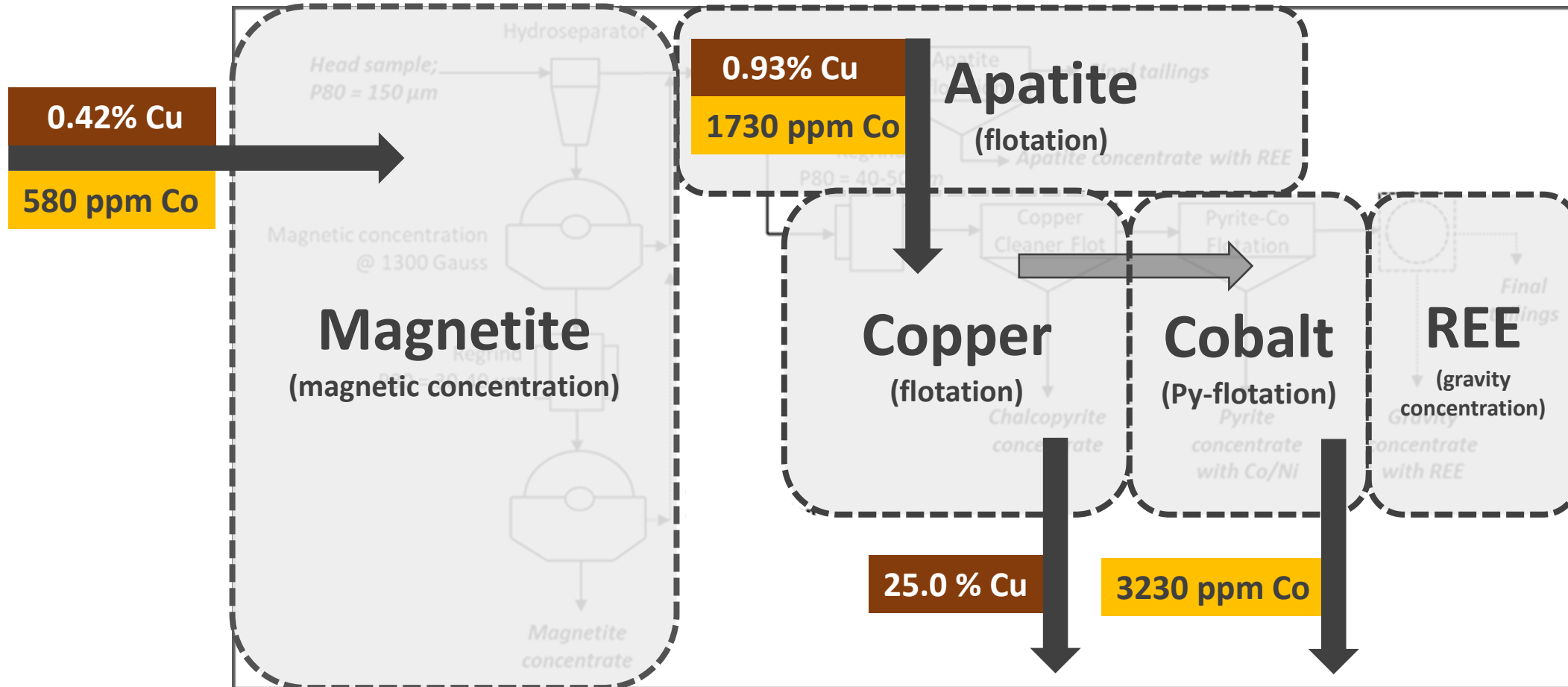
La Estrella proposed flowsheet for Fe/Cu/Co recovery



Source: Townley, Kuyvenhoven (2018)



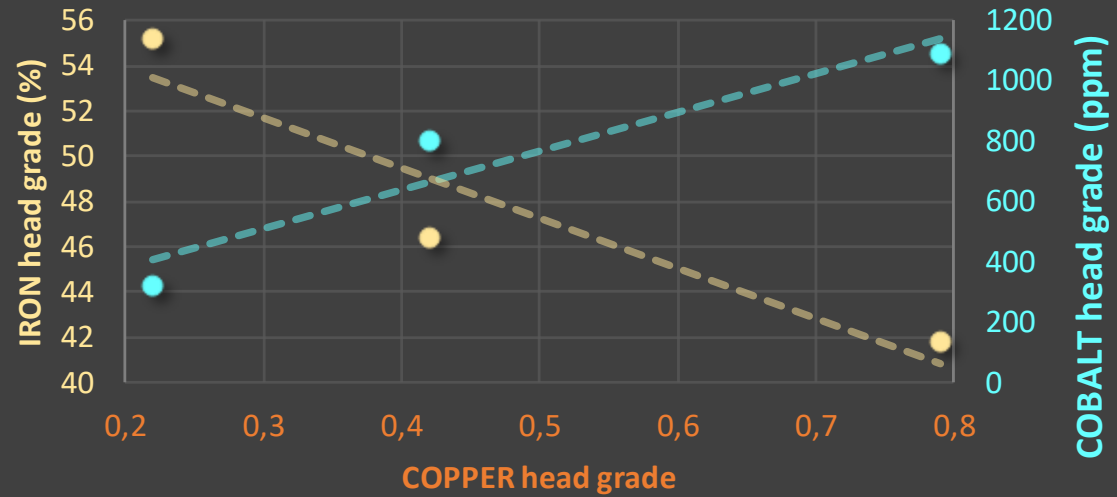
La Estrella based flowsheet for Fe/Cu/Co recovery



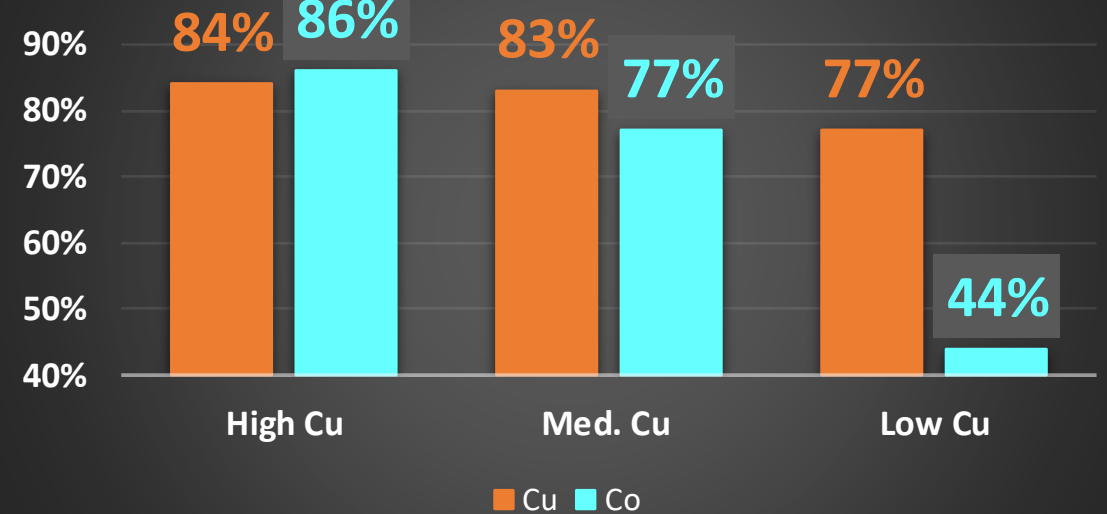
Source: Townley, Kuyvenhoven (2018)



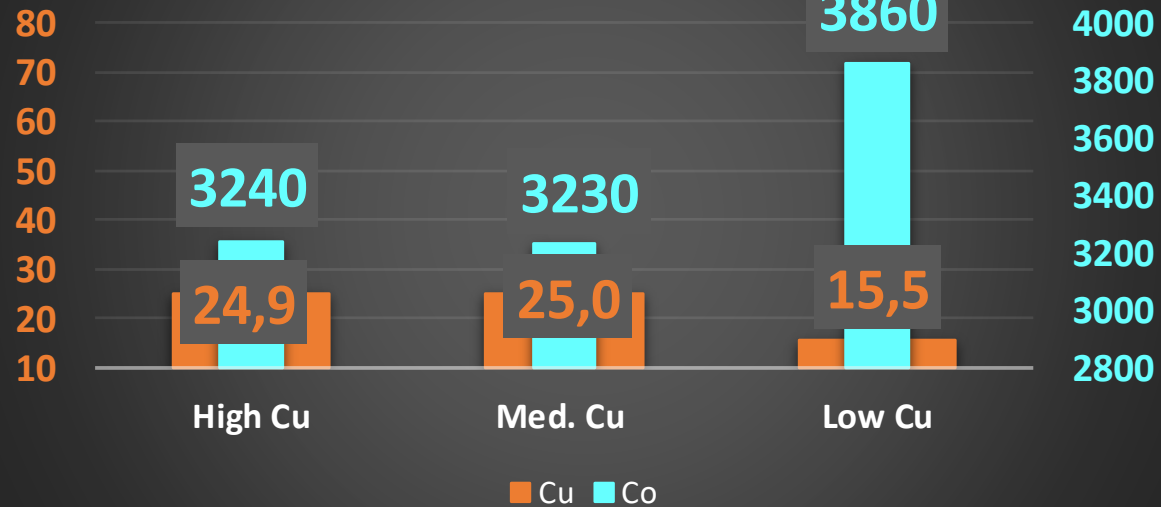
Head Sample Composition



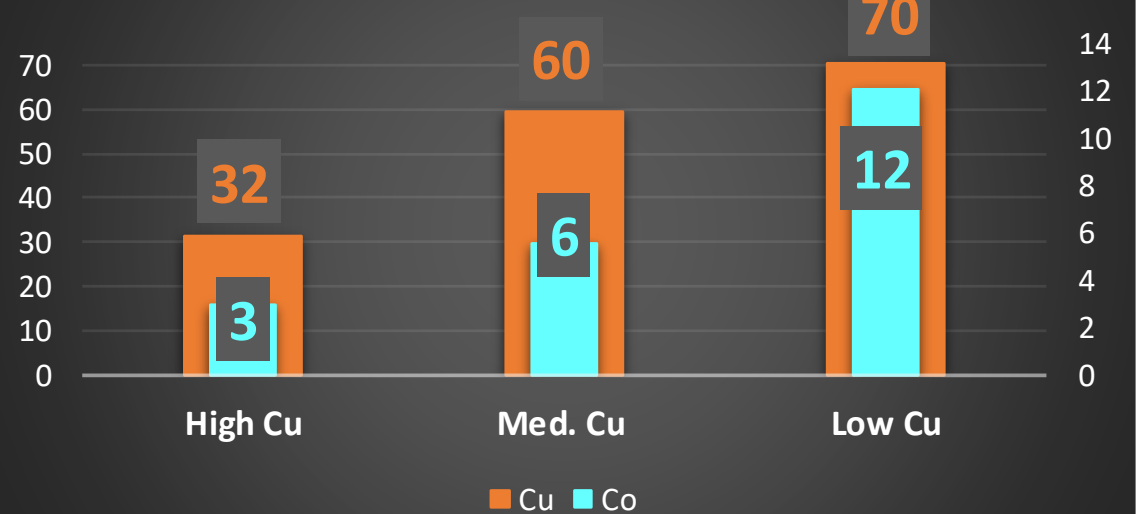
Recovery from Concentration



Concentrate Grade

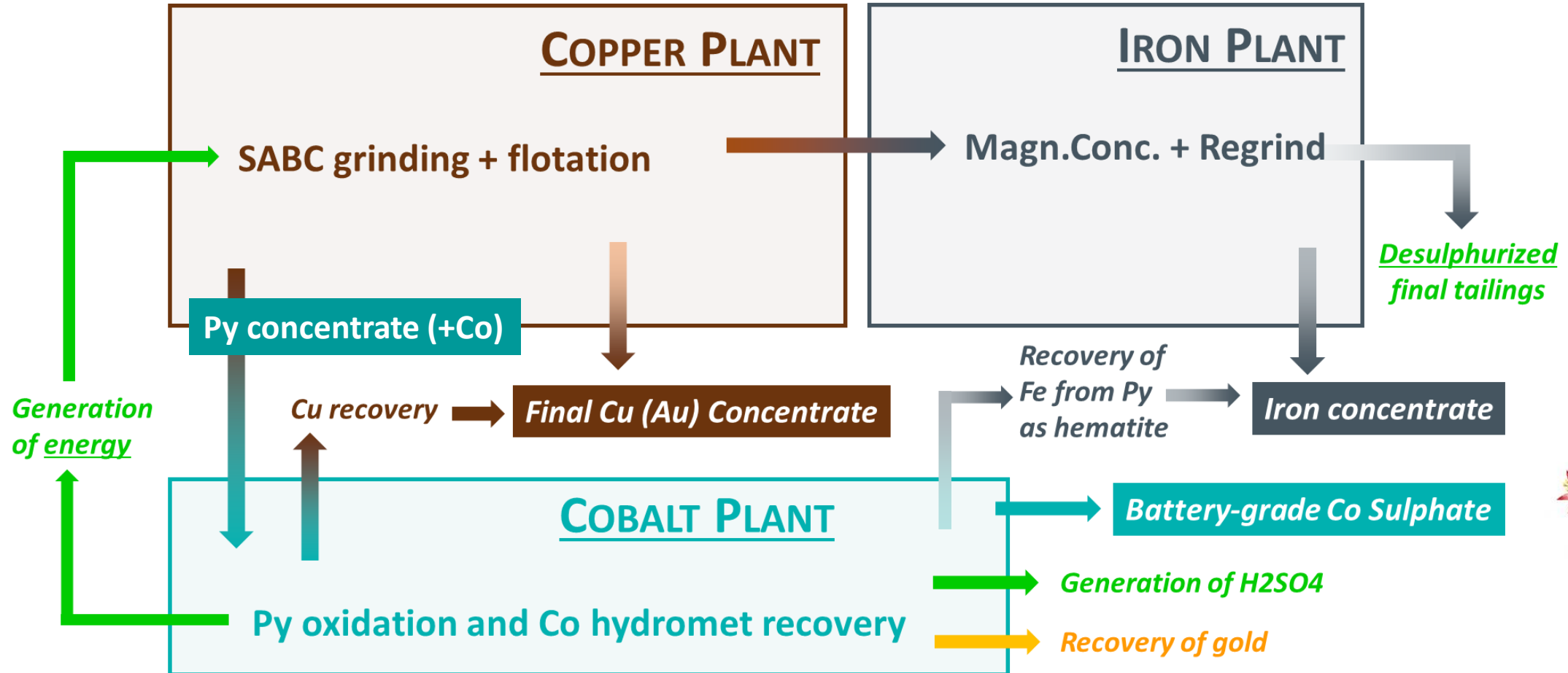


Concentration Ratio



Santo Domingo based flowsheet for Co recovery

(65 ktpd of ore, FS stage)



Source: MSD/Expomin 2021



Recent development: Biocobre® Technology



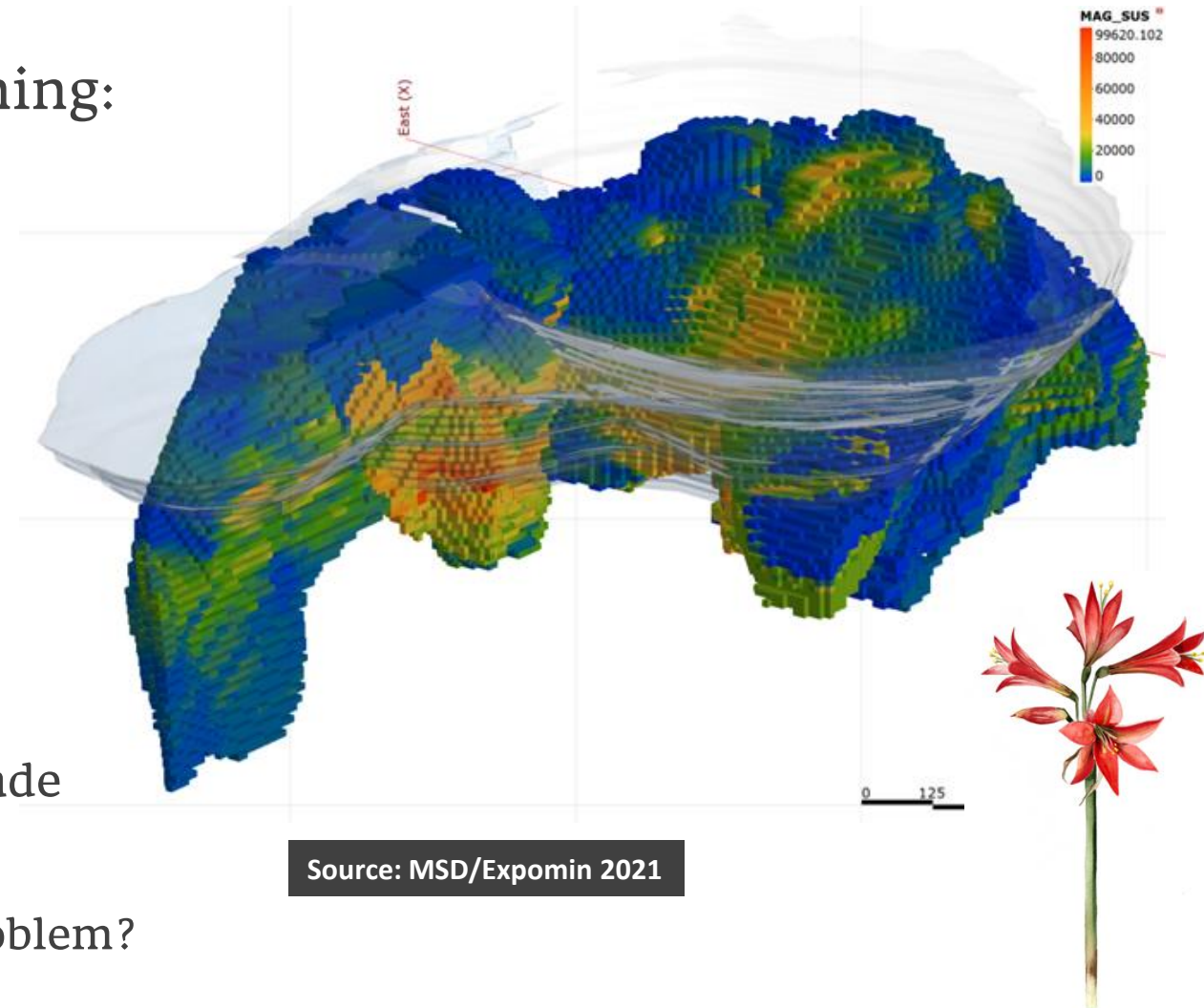
November 13 - 17, 2022.
COPPER INTERNATIONAL CONFERENCE
SANTIAGO/CHILE

BioCobre® Technology: an improved mineral concentrates leaching process.

Bordagorry-Acuña, Raimundo A, Laboratorio de Investigación Aplicada SpA.
Santiago, Gerencia Proyectos, Soc. Minera Pucobre, Copiapó, Chile.

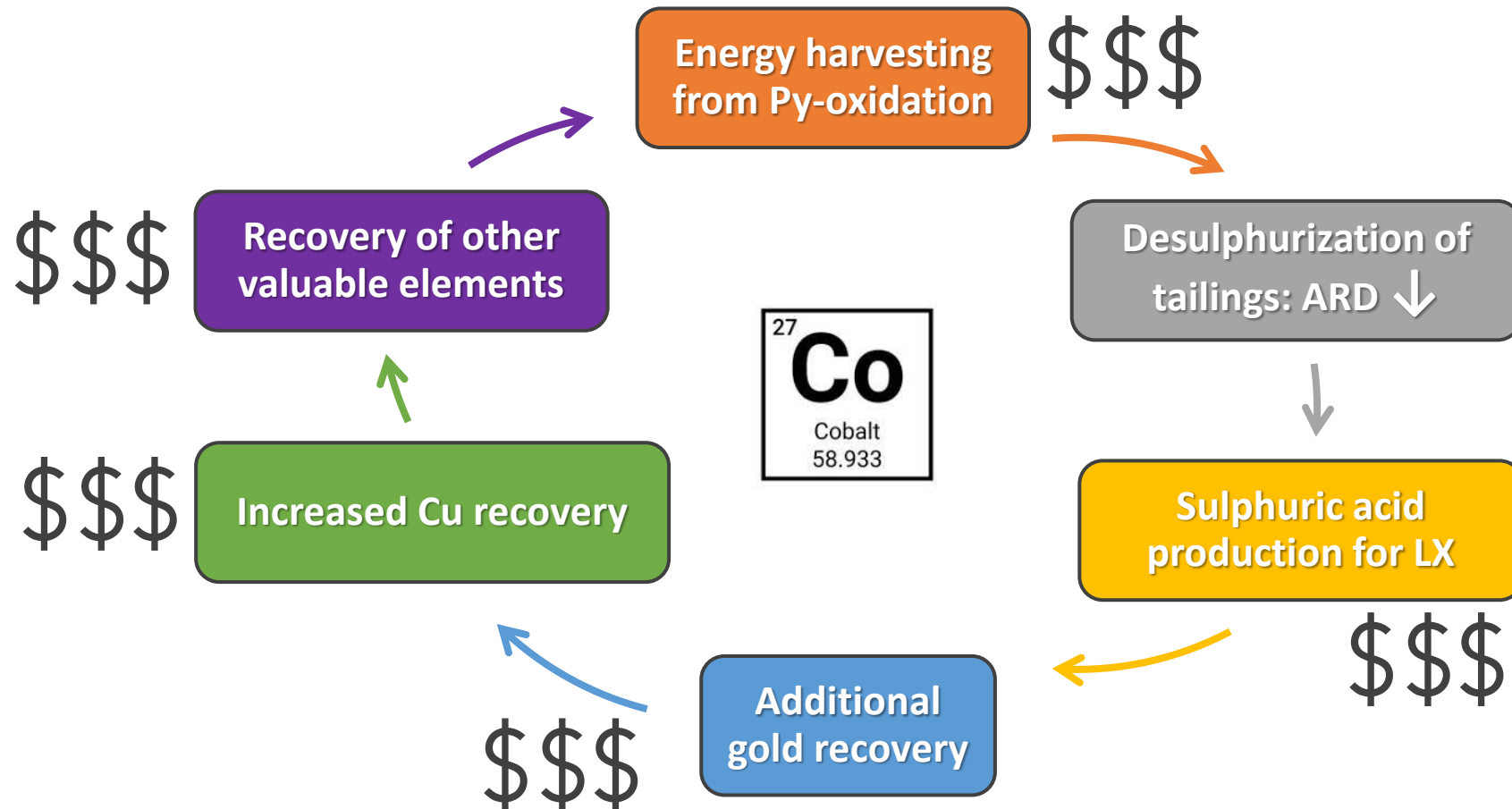
Geo-mine-metallurgy of cobaltiferous Cu-ores

- Multi-commodity based mine planning:
Cu + Co +
 - What is the value of all commodities?
- Neutral tailings (environmental)
 - What is the value of increased NNP?
- Energy harvesting (OPEX)
 - What is the value of reduced energy demand?
- FeS₂ activation... and rejection
 - Pyrite activates and reduces Cu con grade
 - Pyrite rejection decreases Cu recovery
 - What if... the cobalt plant solves that problem?



Source: MSD/Expomin 2021

Secondary benefits from Co recovery



Source: Kuyvenhoven 2022



Reference cases for Co-from-Py process design

Santo Domingo, Chile

Cu-Fe concentrator

Manto Verde, Chile

Cu concentrator

Biocobre, Chile

Biocobre® conc. LX

Dominga, Chile

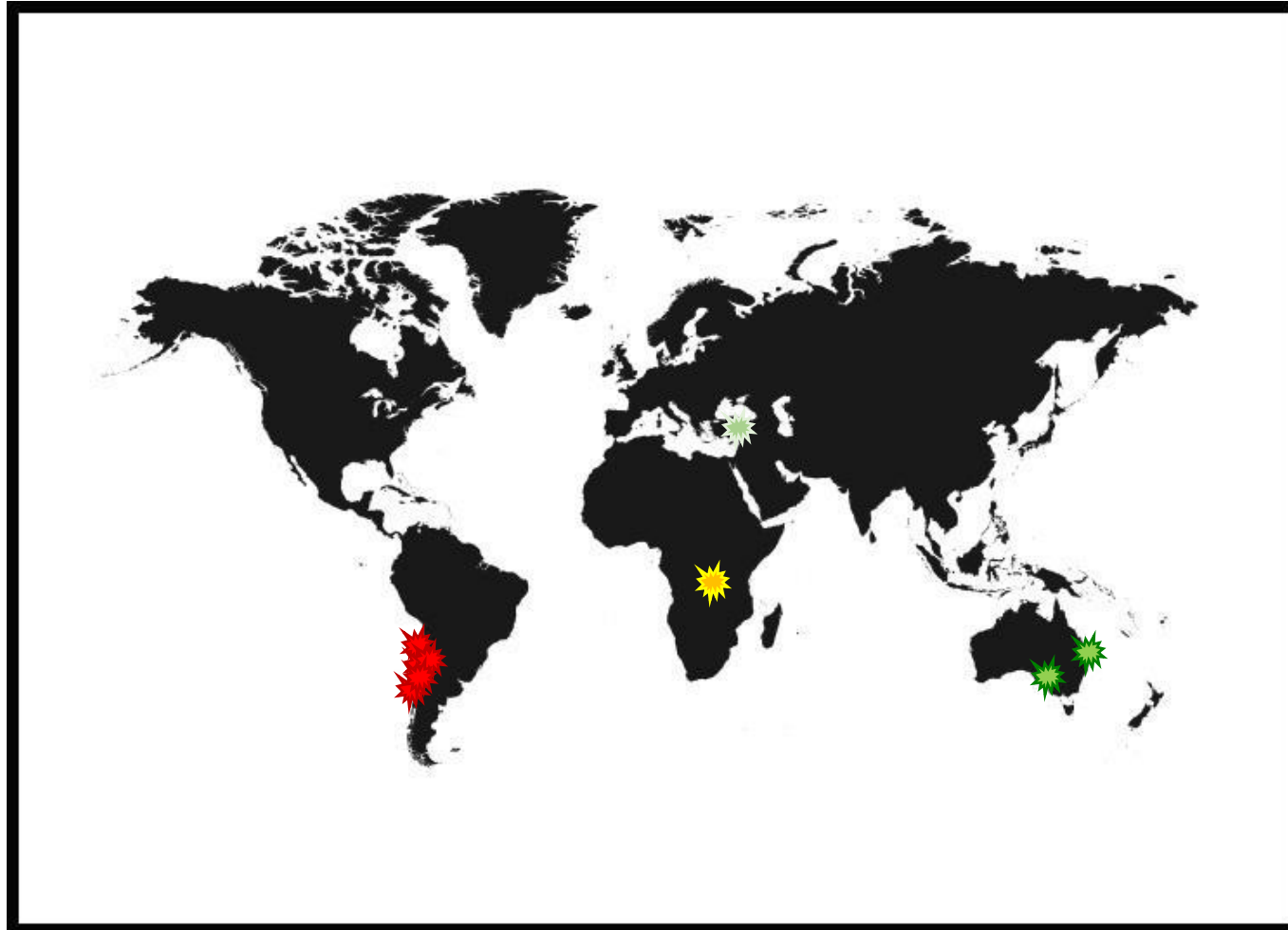
Fe-Cu concentrator

El Espino, Chile

Cu concentrator

Costa Fuego, Chile

Cu concentrator



Eti Bakir, Mazidagi, Turkey

Pyrite concentrate roast
(OPERATION)

Walford Creek, Australia

Pyrite concentrate heap leach

Thackaringa, Australia

Py thermal decomposition,
then pyrrhotite LX



Final remarks

- Apart from geological reasons such as consistently decreasing copper grades, there are geopolitical and environmental drivers that determine the feasibility and attractiveness of cobalt recovery in IOCG ores...within the volatility of the cobalt price
- The individual metallurgical processes for recovery of different commodities – such as Cu, Co, Fe₃O₄, Au, REE and/or others – are tightly interrelated and strongly dependent on geochemical and mineralogical characterization of the ore
- The secondary benefits for Co recovery – such as energy generation, desulphurization of tailings and additional recovery of copper and gold – have the potential to outweigh the primary benefit of Co recovery (which is related to the market value of cobalt)
- Thinking “outside the box” – after all, why would you look at cobalt at the first place in Chile – might give insight in other processing options and opportunities for value creation, that could make the mining operations financially more robust.



Thank you

