LULEÅ UNIVERSITY OF TECHNOLOGY
WORLD-CLASS RESEARCH AND EDUCATION

SUMIRCO EIRL

A review of the scientific and environmental challenges for the Region on other uses of the deep sea environment.

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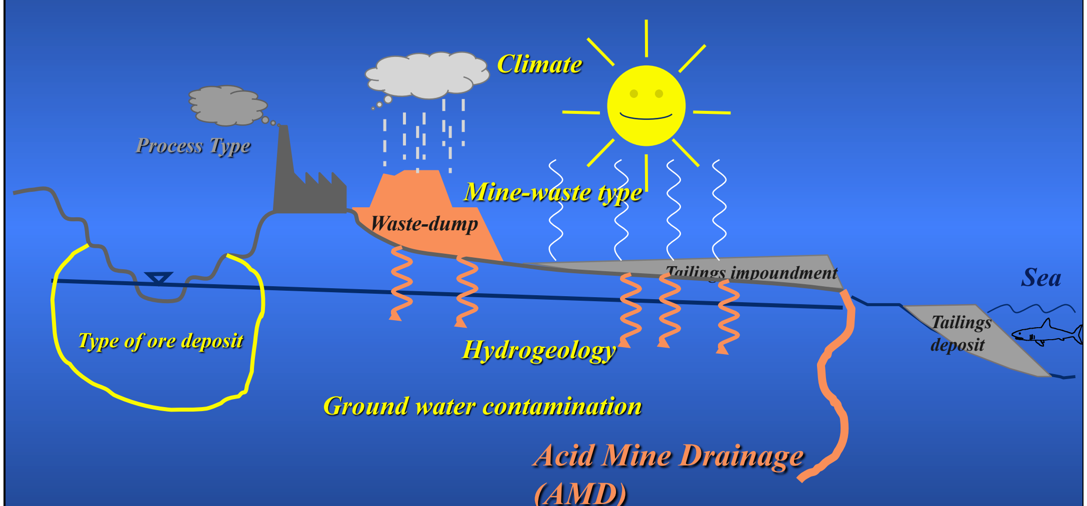
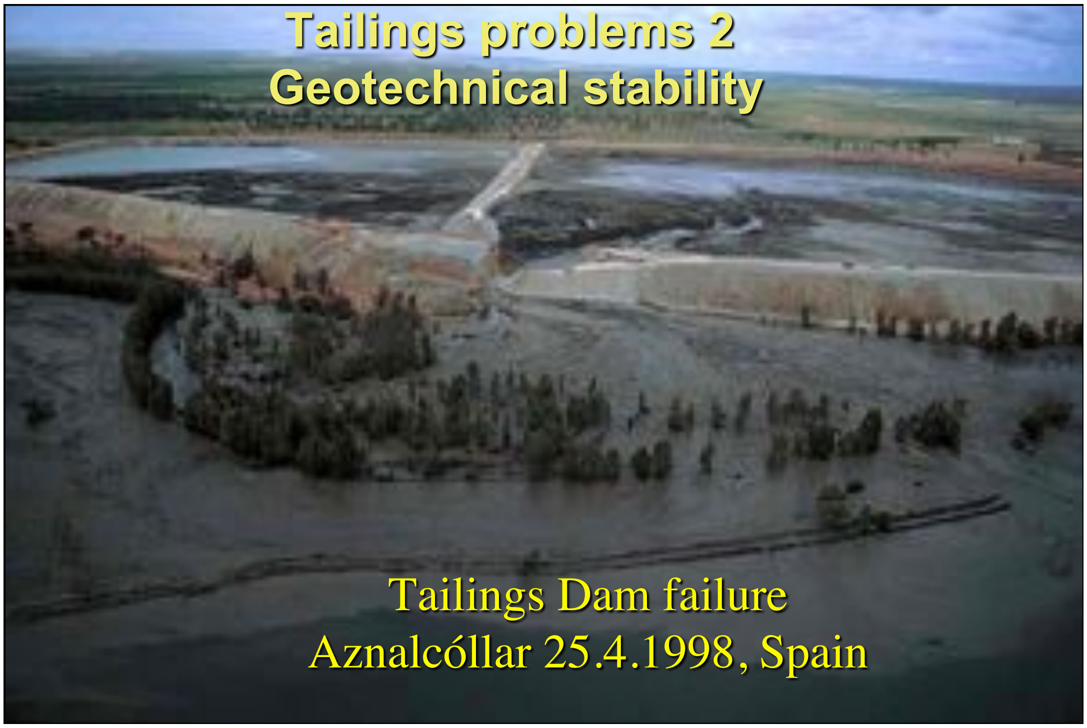
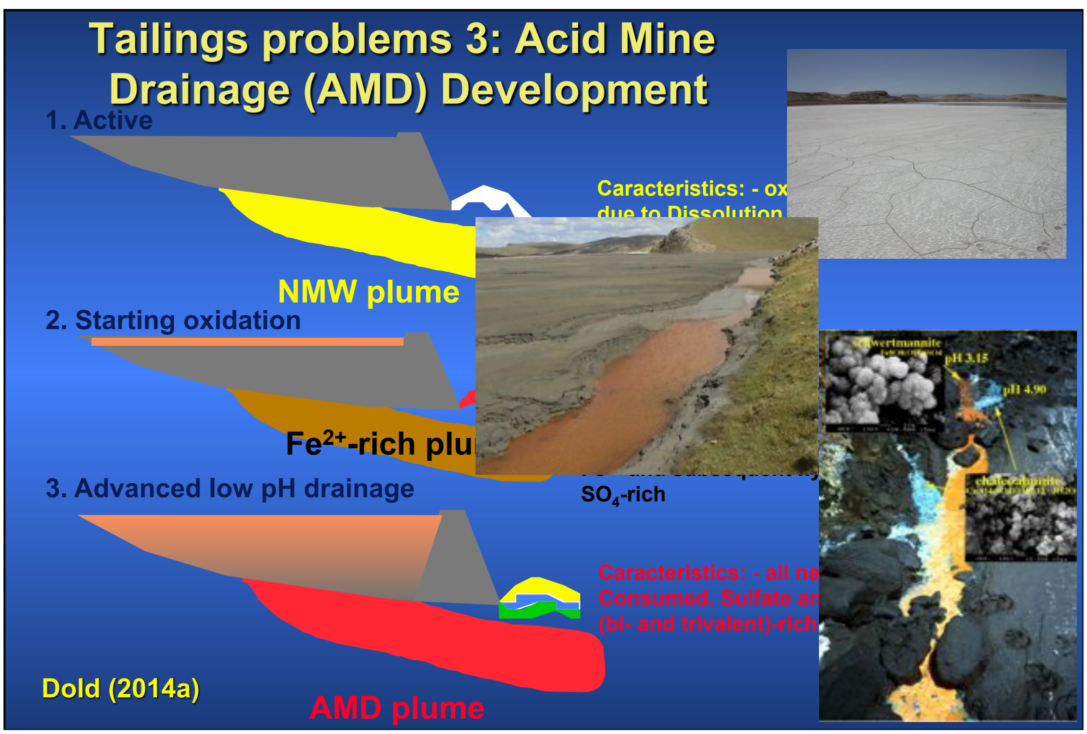
Dold, B. (2014): Submarine Tailings Disposal – A Review. Special Issue: Mine Waste Characterization, Management and Remediation. Minerals, 4(2), 642-666.

Tailings production in Mining




Tailings problems 1:
Surface occupation
Image © 2015 CNES / Astrium
Image © 2015 DigitalGlobe
Calama
Imagery Date: 3/9/2015 22°21'49.58" S 68°50'28.93" W elev 2441 m eye alt 33.74 km
Google earth

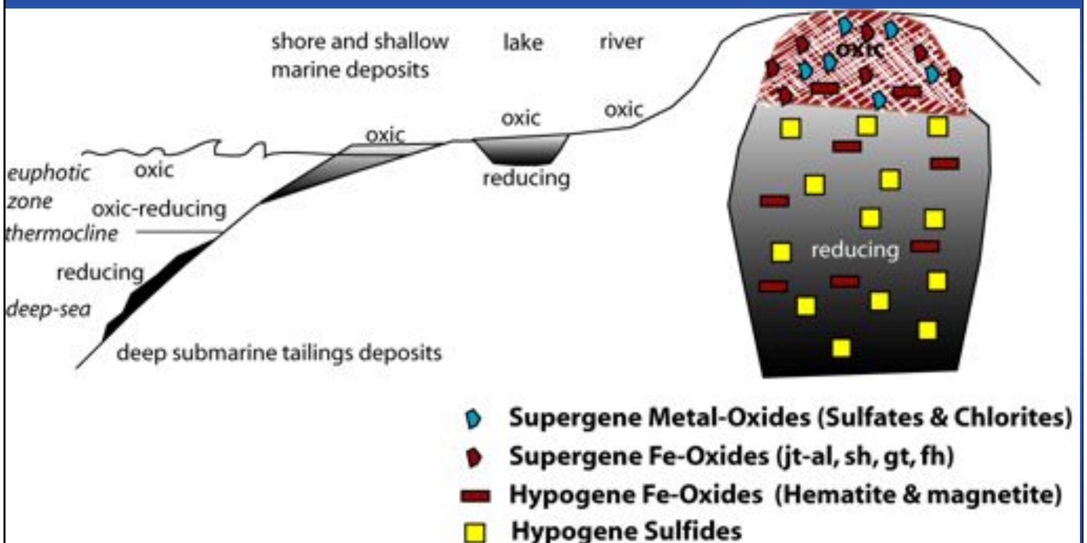

Tailings problems 2
Geotechnical stability
Tailings Dam failure
Aznalcóllar 25.4.1998, Spain


Tailings problems 3: Acid Mine
Drainage (AMD) Development
1. Active
Caracteristics: - ox
NMW plume
2. Starting oxidation
Fe2+-rich plu
SO4-rich
3. Advanced low pH drainage
Caracteristics: - all ne
Consumed. Sulfate an
(bi- and trivalent)-rich
pH 3.15
pH 4.90
Dold (2014a)
AMD plume


Acid Mine Drainage (AMD)
Acid Rock Drainage (ARD)
Acid Drainage (AD)
Neutral Mine Waters
(NMW)

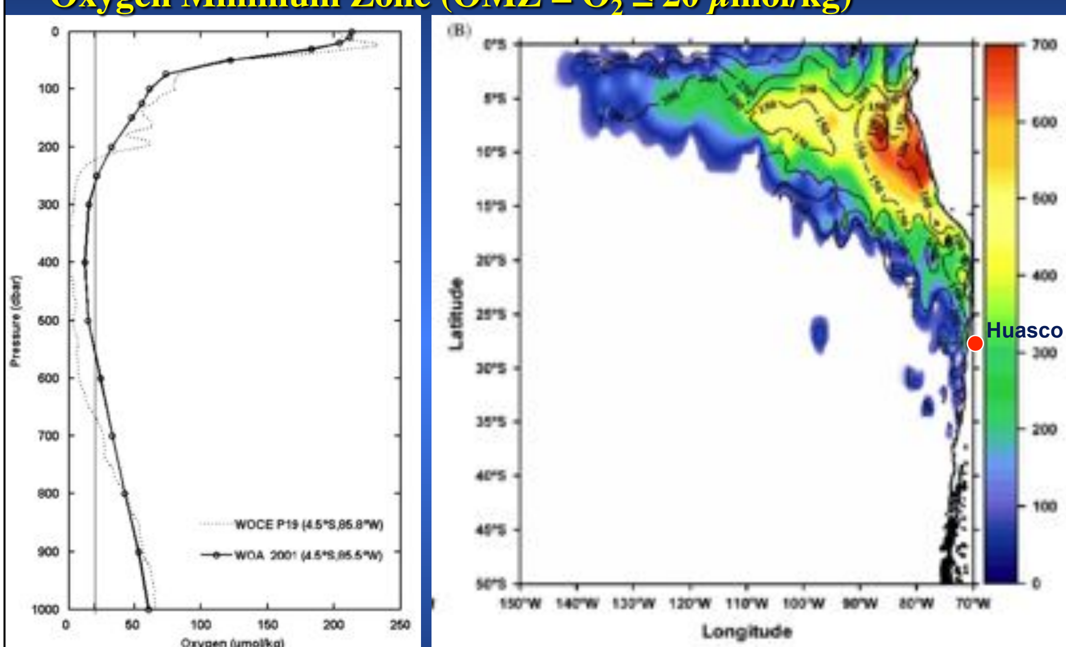

Tranque El Mauro
Ubicación
Los Pelambres must destroy part, or all, of the tailings dam wall.
RTT News 10/03/2015
60 km
Relaveducto MLP
Mina Los Pelambres
SALAMANCA
Planta MLP
LOS VILOS
Caimanes
Chillepin
Tranque El Mauro
PROVINCIA DE CHOAPA
ARGENTINA
El muro
1,4 kilómetros
es el largo del muro.
240 metros
CAIMANES
CORTINA TRANQUE
VALLE DEL PUPÍO
Chile court rules tailings dam for Antofagasta's Los Pelambres mine safe
Reuters: 23/04/2015

The Idea



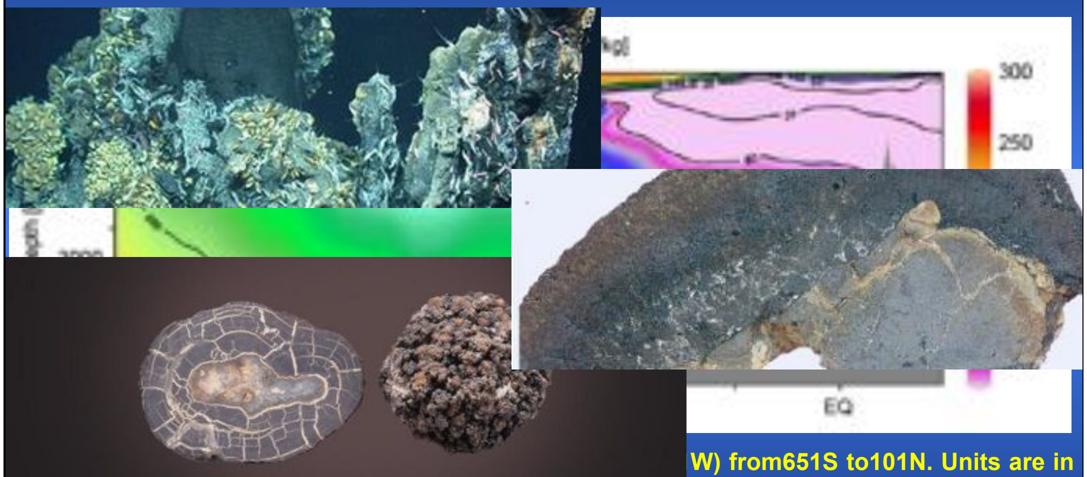
Dold (2014b)

Oxygen Minimum Zone (OMZ = $O_2 \leq 20$ μmol/kg)



(Fuenzalida et al., 2009)

Dissolved oxygen in the deep sea



W) from651S to101N. Units are in mmol kg1 with contour intervals of 60mmol kg1. Station spacing is about 11 latitude.

(Fuenzalida et al., 2009)

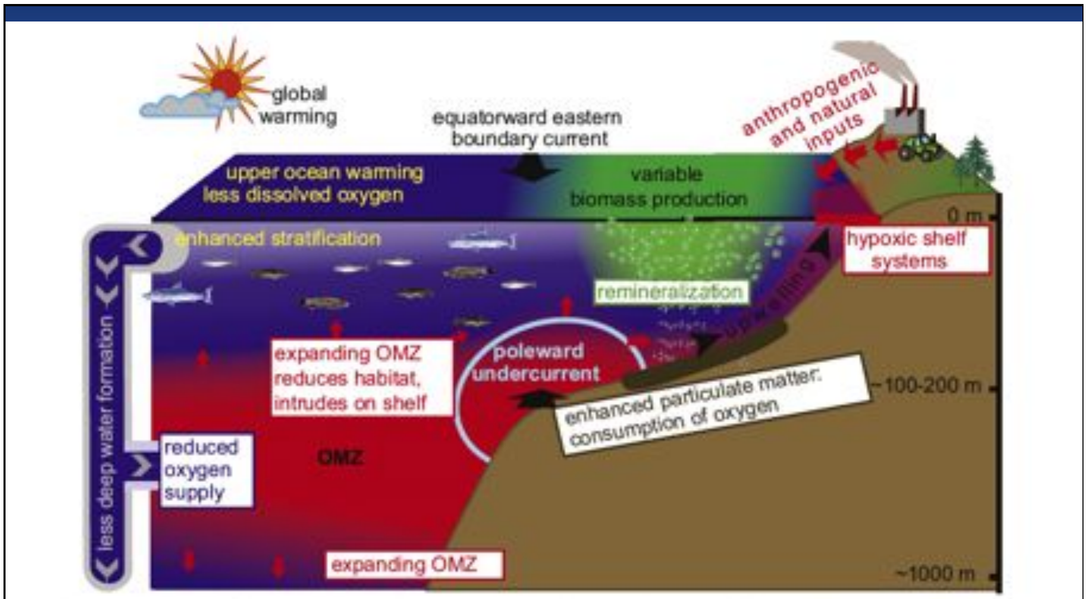


Fig. 6. Schematic of interactions of open ocean oxygen minimum zones (OMZ, red) with hypoxic shelf systems and dead zones (Diaz and Rosenberg, 2008) on continental shelves of eastern ocean boundaries.

(Stramma et al., 2010)

Marine tailings disposal

Marine shore tailings deposition
Deep-sea disposal ("deep" is not well defined, usually below the euphotic zone ~ 150m depth)

Most scientific studies are published using the terms:

Submarine Tailings Disposal (STD) 41,
Submarine Tailings Deposition (STD) 10,
Deep Sea Tailings Disposal (DSTD) 18,
Deep Sea Tailings Placement (DSTP) 5,
and Sub-Sea Tailings Deposition (SSTD)

Locations of marine tailings disposal

Dold (2014b)

Pros

Commonly Mentioned Advantages of STD Are:

-Prevention of acid mine drainage

-Tailings are more geotechnically stable

-Minimal land surface is used.

-Less long-term maintenance required after deposition

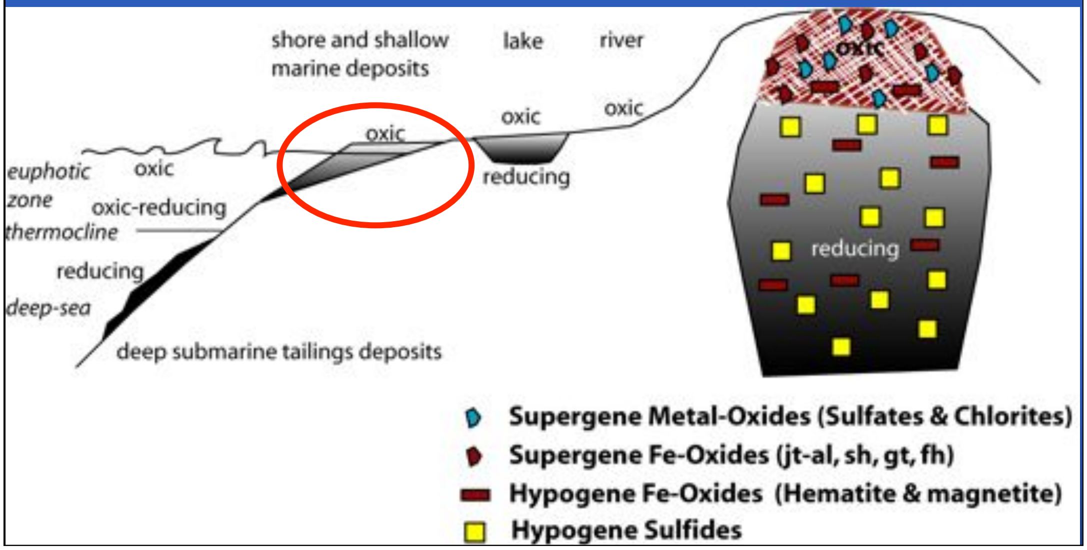
- Low-cost

Cons

Commonly Mentioned Disadvantages and Risks of STD Are:

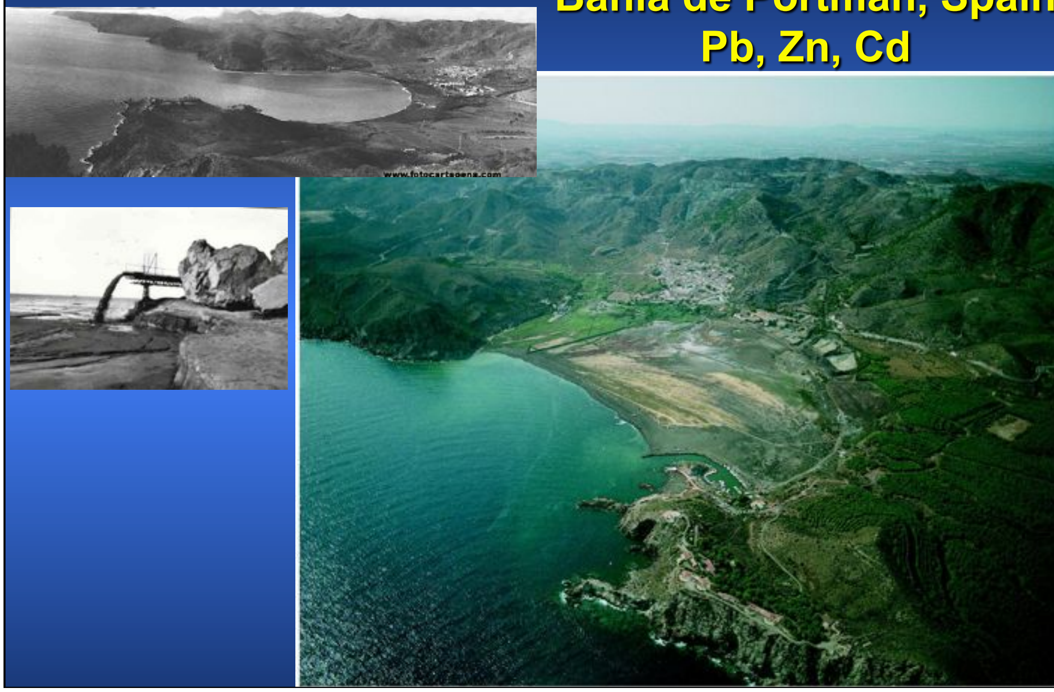
- Smothering benthic organisms
- Reduced number of species and biodiversity
- Risk of liberation of toxic elements from the tailings
- Bioaccumulation of metals through the food chains
- The water content of the tailings cannot be recovered
- The deposited tailings cannot be recovered
- Larger footprint on the seabed than on land
- Potential toxicity of the flotation reagents
- Plume sharing
- Relocation of the tailings due to upwelling and currents.

MARINE SHORE TAILINGS DEPOSITS (MSTD)

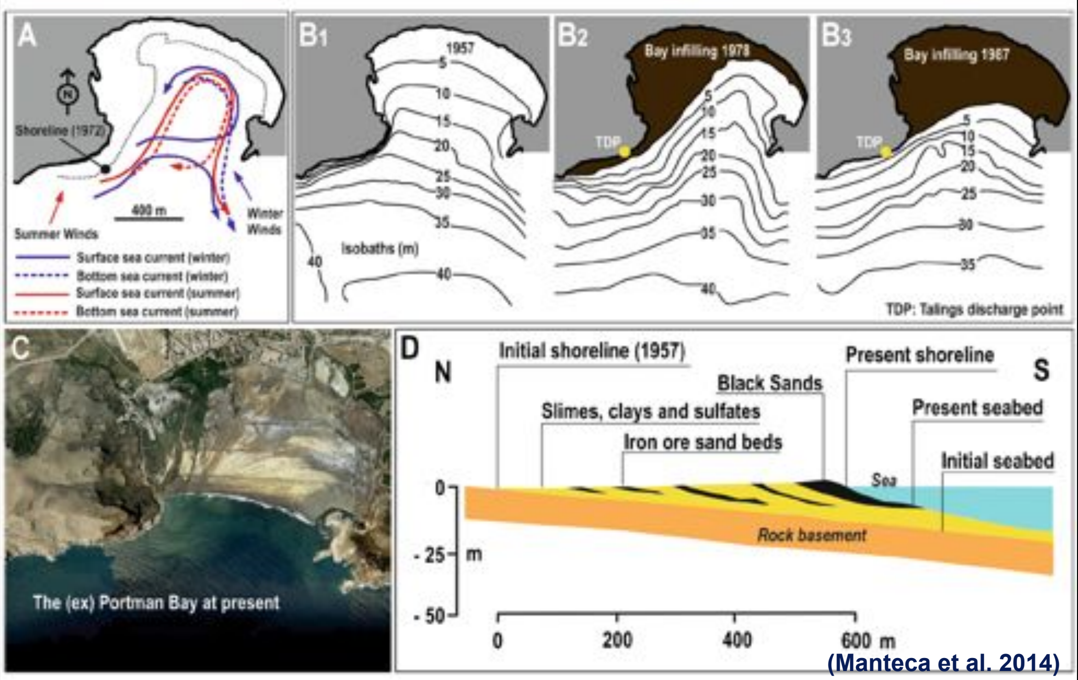


Freeport McMoRan's Grasberg Cu-Au mine, Indonesia

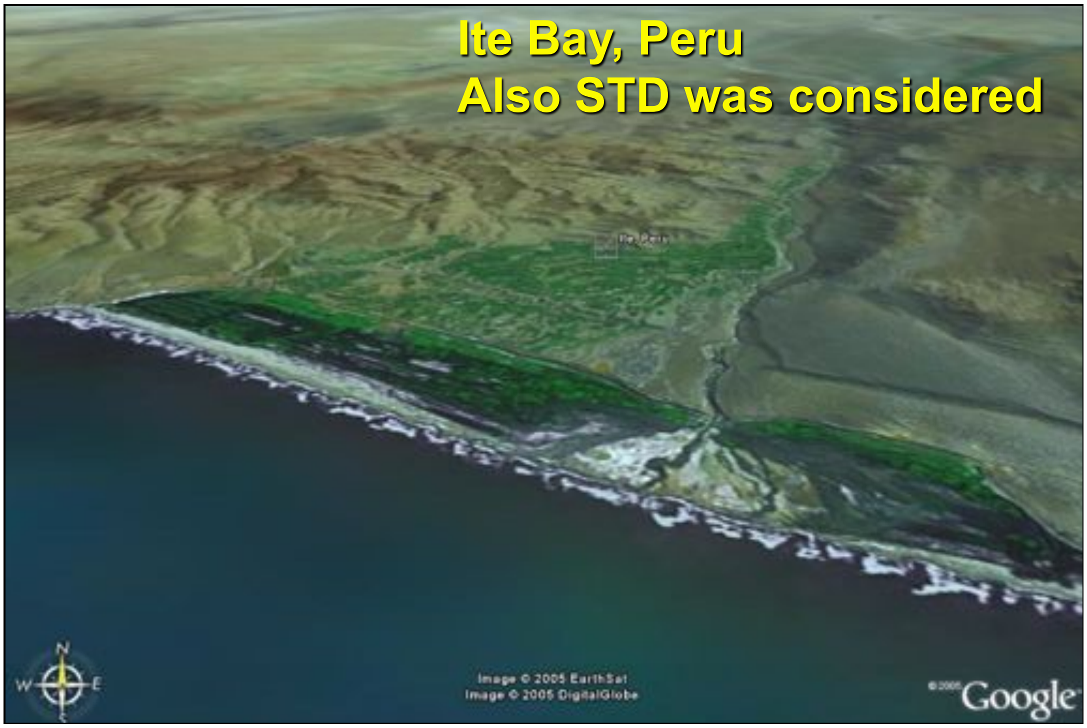
Bahía de Portman, Spain
Pb, Zn, Cd



Miner Deposita (2014) 49:777–783 781



(Manteca et al. 2014)

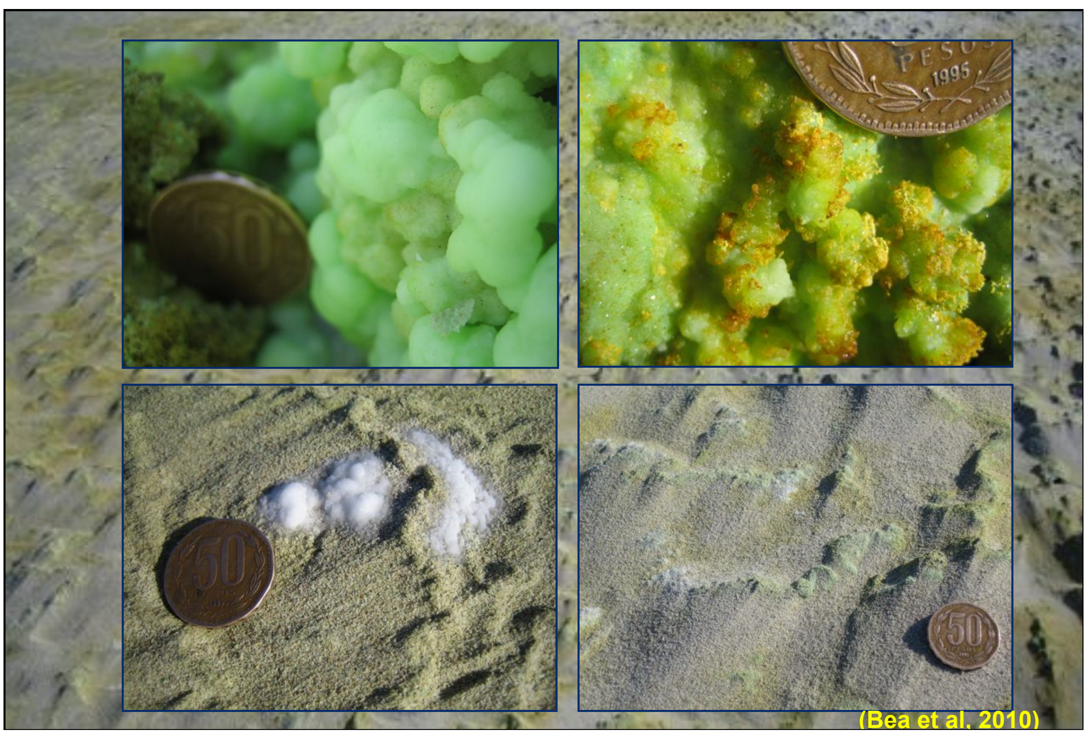

Ite Bay, Peru
Also STD was considered
Image © 2005 EarthSat
Image © 2005 DigitalGlobe
Google

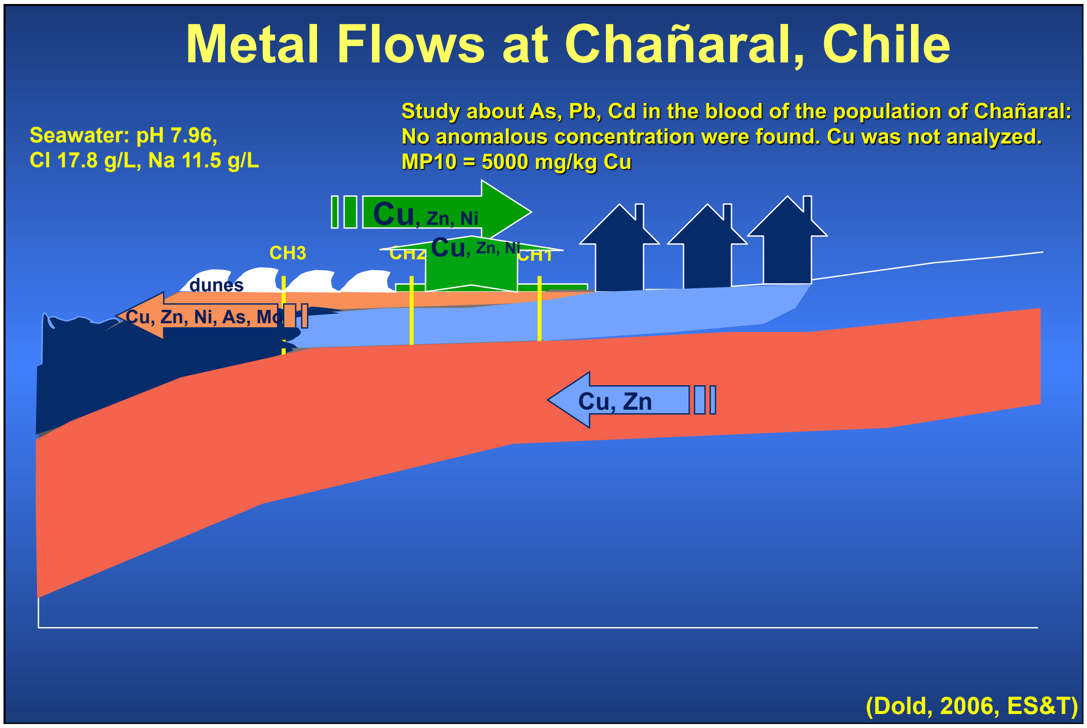

(Dold et al. 2011, Diaby et al. 2014 & 2015)

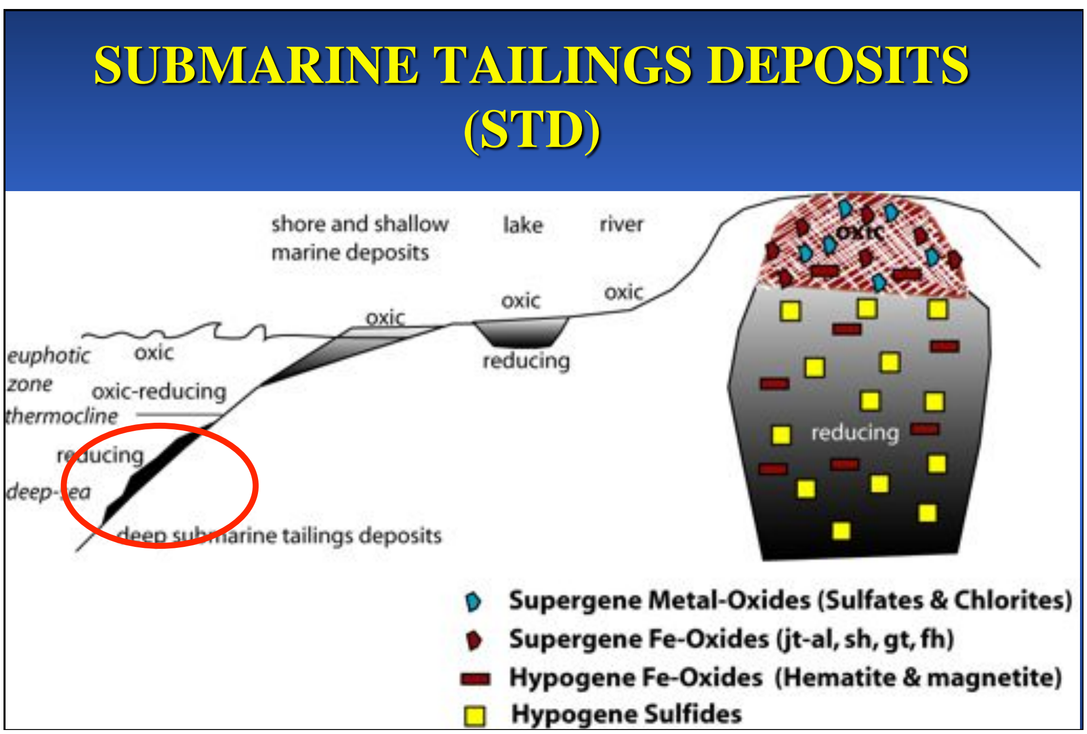

(Dold et al. 2011, Diaby et al. 2014 & 2015)

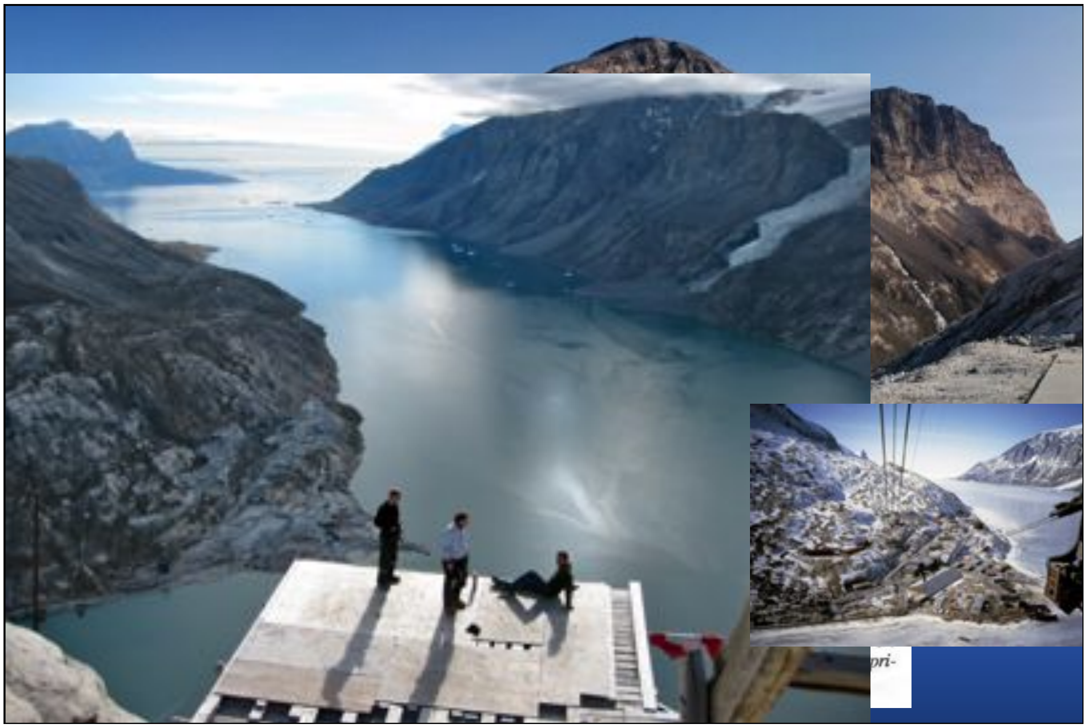

Chañaral, Chile
Chañaral
Chañaral, Atacama, Ch
Google
Pointer 26° 18'46.90"S 70° 39'14.26"W elev 23 ft
Streaming
100%
Eye alt 19775 ft


October 2003
Eriochalcite $CuCl_2 \cdot H_2O$
(Dold, 2006; Bea et al. 2010)


(Bea et al. 2010)

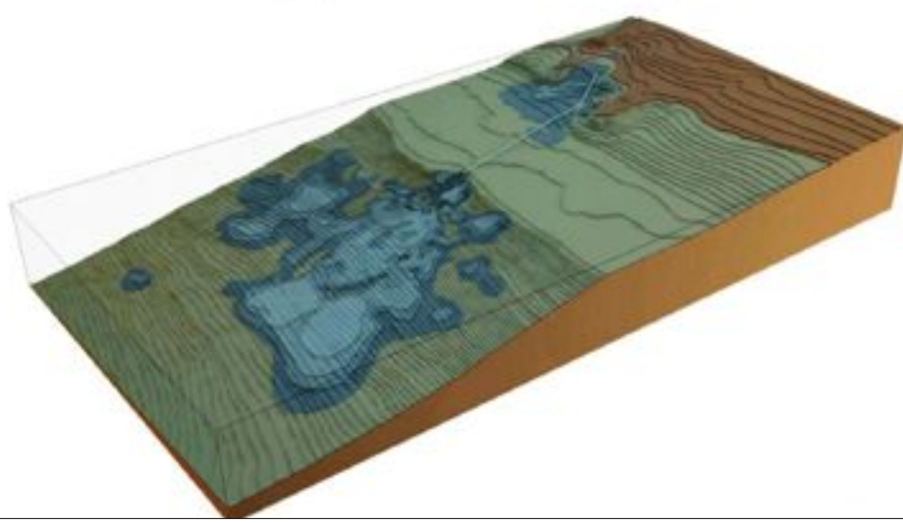

Metal Flows at Chañaral, Chile
Study about As, Pb, Cd in the blood of the population of Chañaral: No anomalous concentration were found. Cu was not analyzed.
MP10 = 5000 mg/kg Cu
Seawater: pH 7.96,
Cl 17.8 g/L, Na 11.5 g/L
Cu, Zn, Ni
Cu, Zn, Ni
CH3
CH2
CH1
dunes
Cu, Zn, Ni, As, Mo
Cu, Zn
(Dold, 2006, ES&T)


SUBMARINE TAILINGS DEPOSITS
(STD)
shore and shallow
marine deposits
lake
river
oxic
oxic
oxic
euphotic
zone
oxic
oxic-reducing
thermocline
reducing
reducing
deep-sea
deep submarine tailings deposits
oxic
reducing
Supergene Metal-Oxides (Sulfates & Chlorites)
Supergene Fe-Oxides (jt-al, sh, gt, fh)
Hypogene Fe-Oxides (Hematite & magnetite)
Hypogene Sulfides



Ensenada Chapaco, Huasco, Chile

Figura 1.1-3: Área de depositación de relaves existente (más cercano a la costa) y futuro punto de descarga junto a área de depositación proyectada (al año 50).



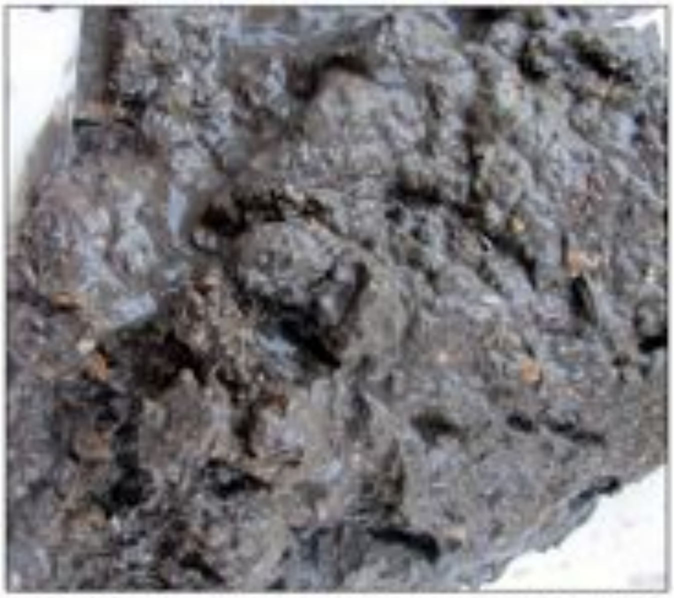
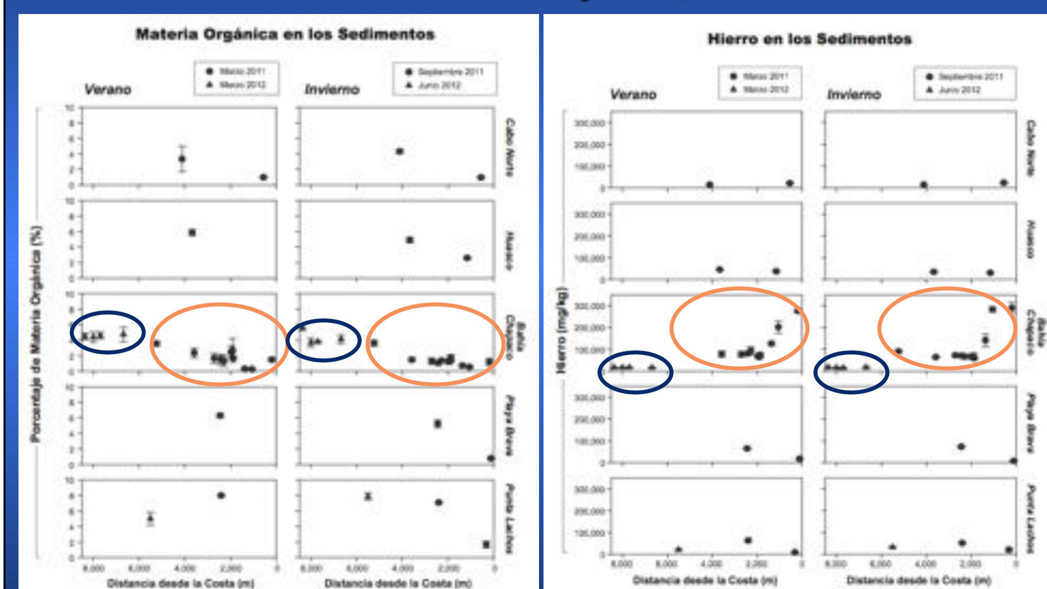


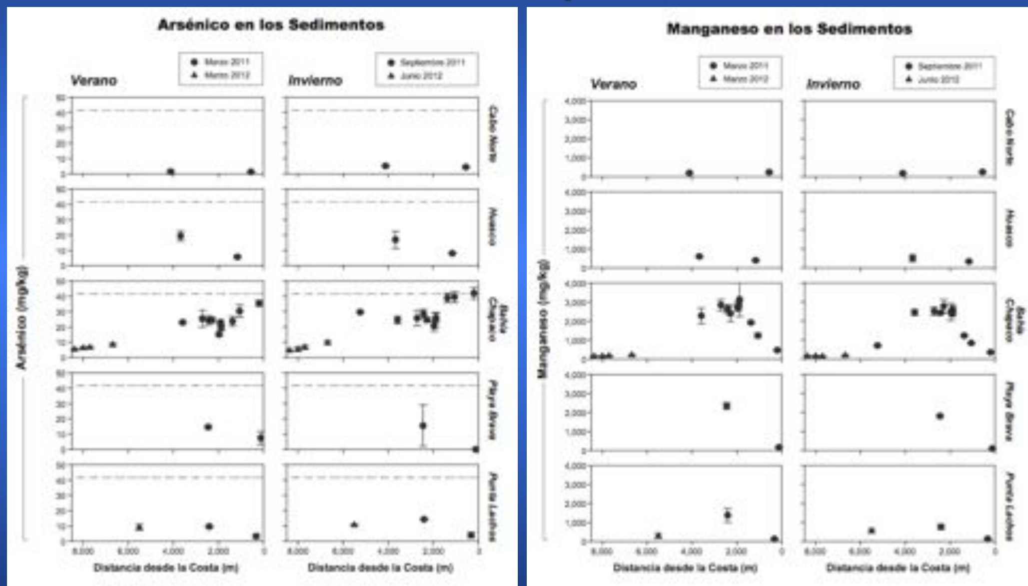
Lámina 2.10-4. Imagen de sedimentos típicos de las estaciones CH 13 y CH 14. Ensenada Chapaco, marzo de 2011.

Magnetite from the Fe-oxide belt, Chile have several trace elements associted, like V, Ni, Zn y Cu (Nyström and Henriquez, 1994). Data from a recent EIS suggests also As, Mn, and Pb

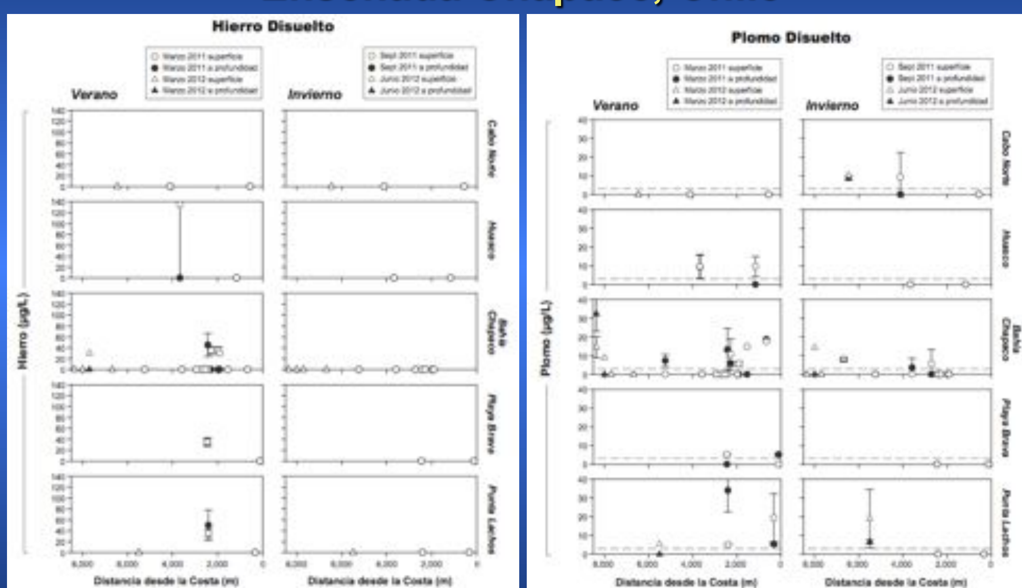
Organic matter and Fe in the sediments, Ensenada Chapaco, Chile



As and Mn in the sediments, Ensenada Chapaco, Chile



Dissolved Fe and Pb, Ensenada Chapaco, Chile



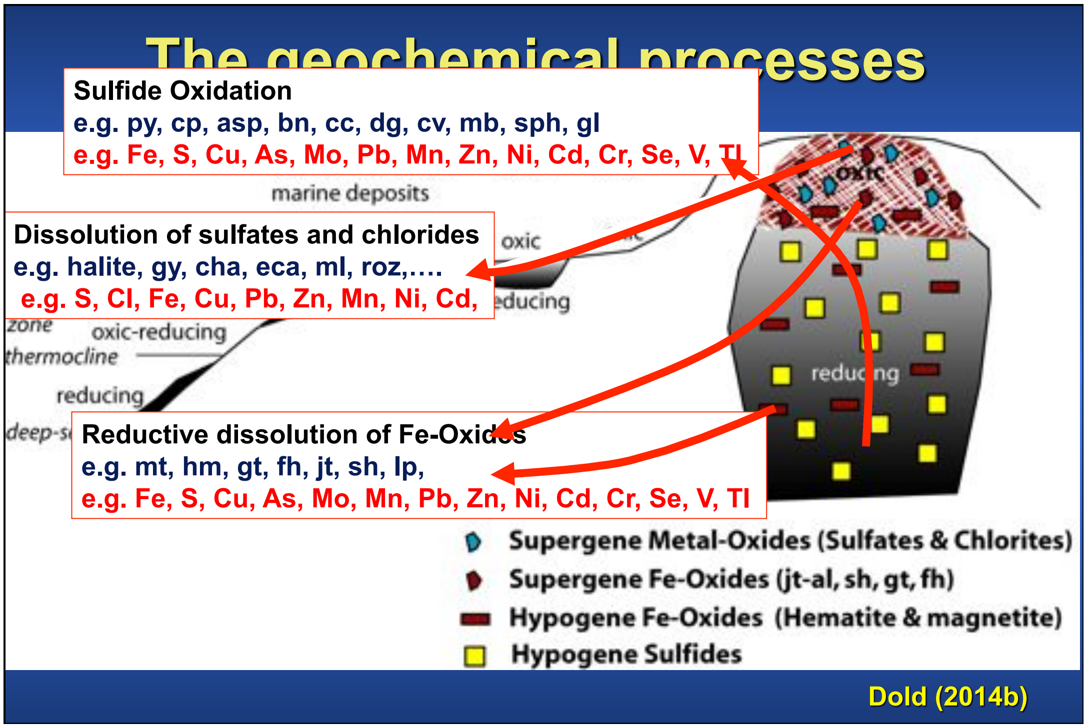


Table 1: Average concen trations of metals in the earth crust with the average concentrations exploited by mining and the enrichment factors. Some concentrations of element still present in mine tailings are shown to highlight the still strong enrichment of these elements in the waste material. Modified after (Evans, 1993).

Metal	Ø Crust (%)	Ø by mineral exploitation (%)	Enrichment Factor	Ø In mine tailings	Enrichment Factor tailings
Cu	0.005	0.4	80	0.1 – 0.3	20 - 60
Ni	0.007	0.5	71	0.2	28.4
Zn	0.007	4	571	2 – 4	275 - 571
Mn	0.09	35	389		
Sb	0.0002	0.5	2500		
Cr	0.01	30	3000		
Pb	0.001	4	4000	1 - 2	1000- 2000
Au	0.0000004	0.0001	250		

(Dold.2008: RESB)

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Final Conclusion

Mine Waste of today will be a resource of tomorrow

Thank you!

Conclusions

- Minerals are generally stable in the geochemical conditions of formation, If this is changed trough natural or anthropogenic processes, they may oxidation or reductive processes leading to their dissolution and release associated elements.

- Little is known of the behavior of the different mineral groups in the marine environment.

- Most ore deposits have both sulfide and oxide minerals, and in this environment of element anomalies, both have often important concentrations of trace elements associated

- The receiving environment need long-term stable geochemical conditions (reducing for sulfides or oxic for oxides), but very difficult to find such sites (ENSO cycles and climate change)

- Plume sharing has to be prevented (nearly no information of impact of fine particles on the marine food chain)

- Smothering of benthic organisms will be always associated

- The oceanic setting must be proven to be without currents and upwelling

- Mineralogical and geochemical study if material is suitable
- Oceanographic study