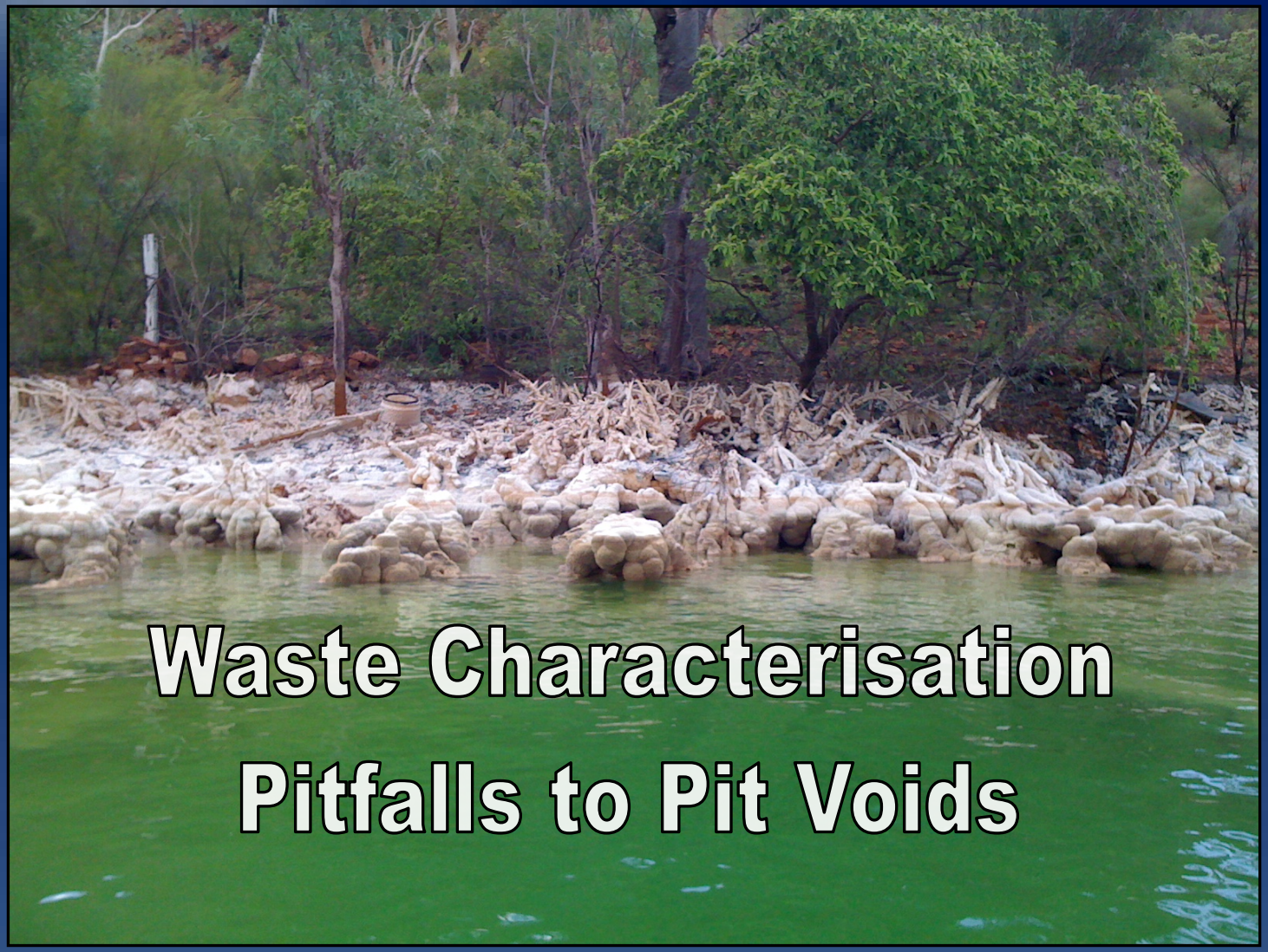

Waste Characterisation
Pitfalls to Pit Voids

Goldfields Environmental Management Group
Workshop on Environmental Management
Kalgoorlie-Boulder, May 2010

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MBS Environmental Geochemical Capabilities

- Waste characterisations for projects in WA, NT & Qld:
  - Waste rock characterisation for gold, copper, nickel, lead, zinc, chromium, manganese, iron, coal and diamond mines.
  - Tailings characterisation.
  - Rehabilitation of Tailings Storage Facilities.
  - Soil characterisation.
  - Plant nutrition.
  - Contaminated site assessments.

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Presentation Outline

- Waste Characterisation Procedures.
- Acid Mine Drainage:
  - Overestimates of acid production.
  - Underestimates of acid production.
- Neutral Mine Drainage.
- Soil Characterisation Procedures.

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DMP Guidelines

- It is essential that the potential of **acid** mine drainage (**AMD**), otherwise known as **acid** rock drainage (**ARD**), be determined and, if significant, management strategies put in place to deal with potentially **acid** forming (PAF) material in waste rock dumps and tailings storages.
- To deal with **AMD** issues, the mining proposal should include:
  - A summary of the characterisation of the mining wastes and tailings including chemical and physical characteristics such as sodicity, salinity and dispersive potential.
  - An assessment of the potential for sulphide oxidation leading to **acid** generation including specific **AMD** chemical analyses (pH, Total Sulphur, Net **Acid** Producing Potential (NAPP), Net **Acid** Generation (NAG), **Acid** Neutralising Capacity (ANC), multi-element composition and mineralogy of mine waste and tailings samples.

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Chemical Weathering

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Lessons from Ancient History

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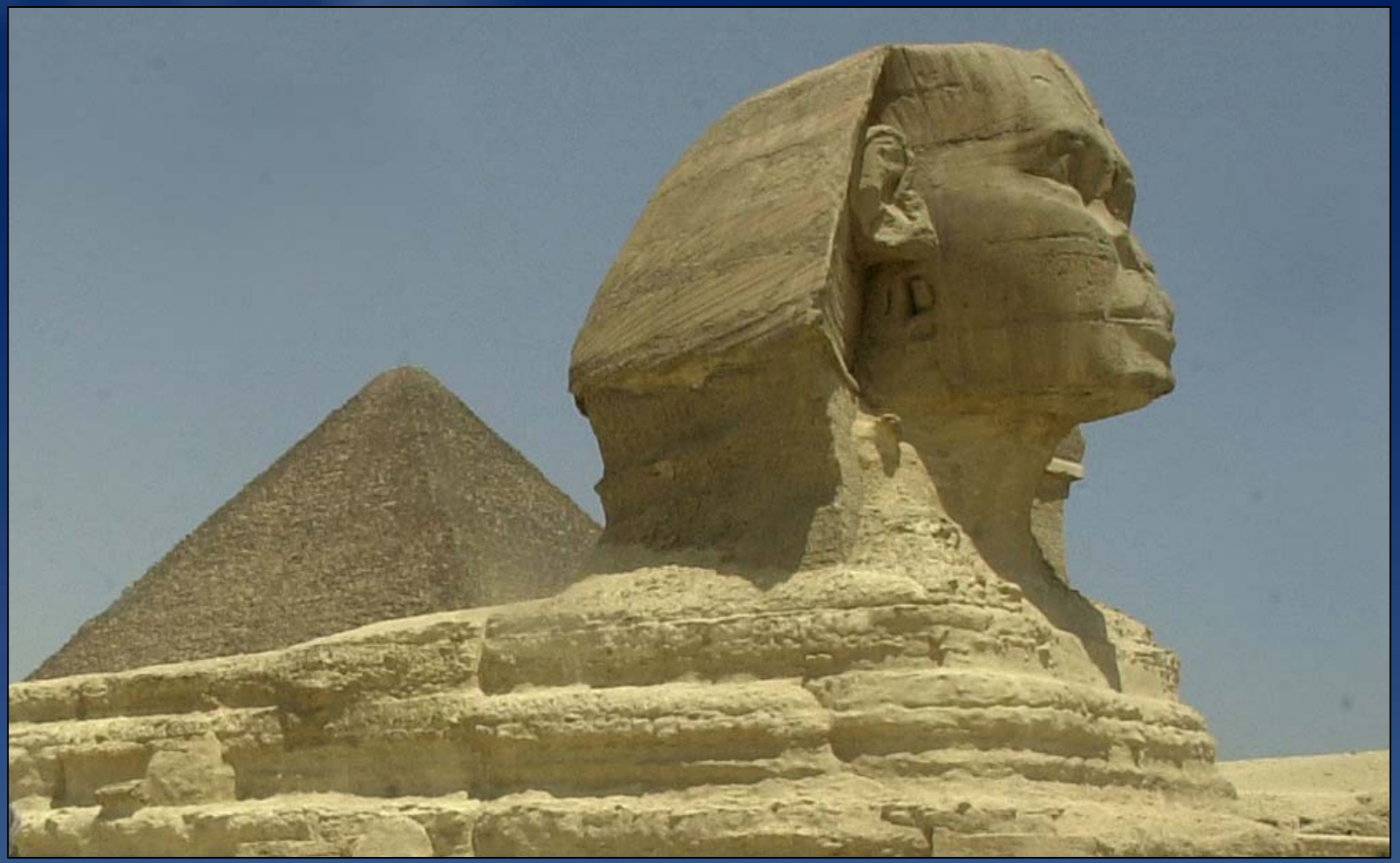
Lessons from Ancient History



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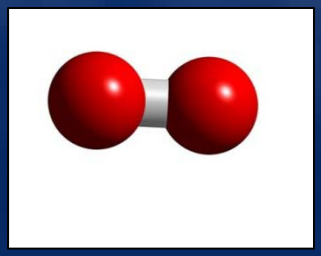
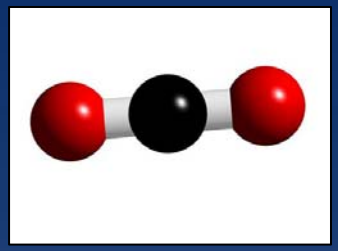
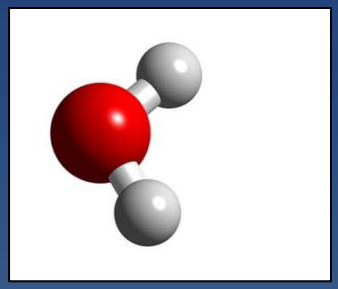
Chemical Weathering



- OXYGEN: Powerful oxidising agent – almost as reactive as chlorine. Only exists on earth because of photosynthesis.



- CARBON DIOXIDE: Dissolves in water to form a weak solution of carbon dioxide. Minerals that react rapidly with strong acids still react with carbonic acid – only more slowly.



- WATER: Physical weathering power as water and ice is obvious. Powerful solvent for salts. Also chemically reactive:

$$FeS_2 + {}^{15}/_{4}O_2 + {}^{7}/_{2}H_2O \rightarrow Fe(OH)_3 + 2SO_4^{2-} + 4H^+$$

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Acid Mine Drainage

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Natural Acidity

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Acid Mine Drainage

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Acid Mine Drainage

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Acid Mine Drainage

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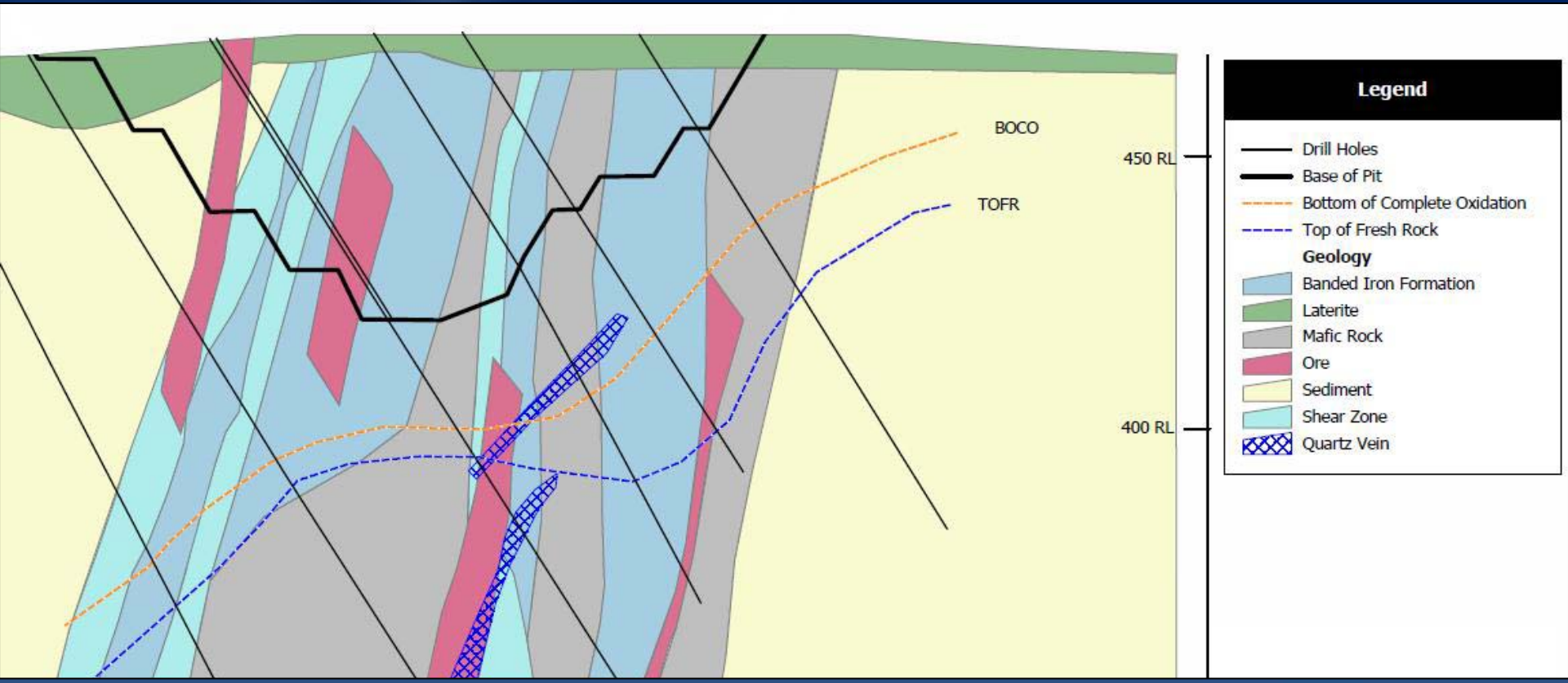
Step 1 - Sampling



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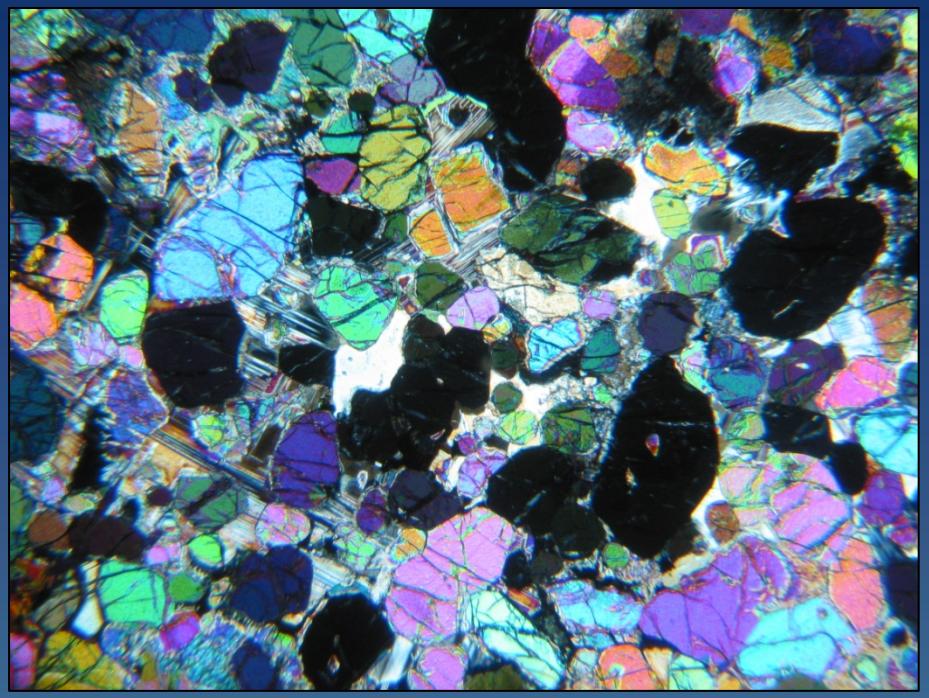
Step 2 - Examination

- Identification of major and accessory minerals using either modern instrumental techniques such as SEM or XRD.

OR

- Microscopic examination by an experienced geologist/ mineralogist.



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Step 3 - Acid / Base Accounting

- ACID GENERATION:
  - Measure total sulphur and sulphate-sulphur.
  - Calculate sulphide-sulphur (by difference).
  - MPA (kg H_2SO_4/tonne) = 30.6 * Sulphide-S.
- ASSUMPTIONS:
  - All non-sulphate-sulphur is sulphide-sulphur.
  - All sulphides oxidise to sulphuric acid.

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Step 3 - Acid / Base Accounting

- ACID CONSUMPTION:
  - Measure total carbon which assumes that carbonate minerals are responsible for acid neutralisation.
  - Measure Acid Neutralising Capacity (ANC) directly.
- CALCULATION OF NET ACID PRODUCTION POTENTIAL (NAPP)
  - NAF = acid generation < acid consumption.
  - PAF = acid generation > acid consumption.

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Step 3 - Acid / Base Accounting

- VERIFICATION:
  - Conduction of Net Acid Generation (NAG) test using hydrogen peroxide as oxidant.
  - If classification is still uncertain, additional testing will be required. Most common are the weathering or leaching column tests, which are designed to simulate weathering conditions in a Waste Rock Stockpile.

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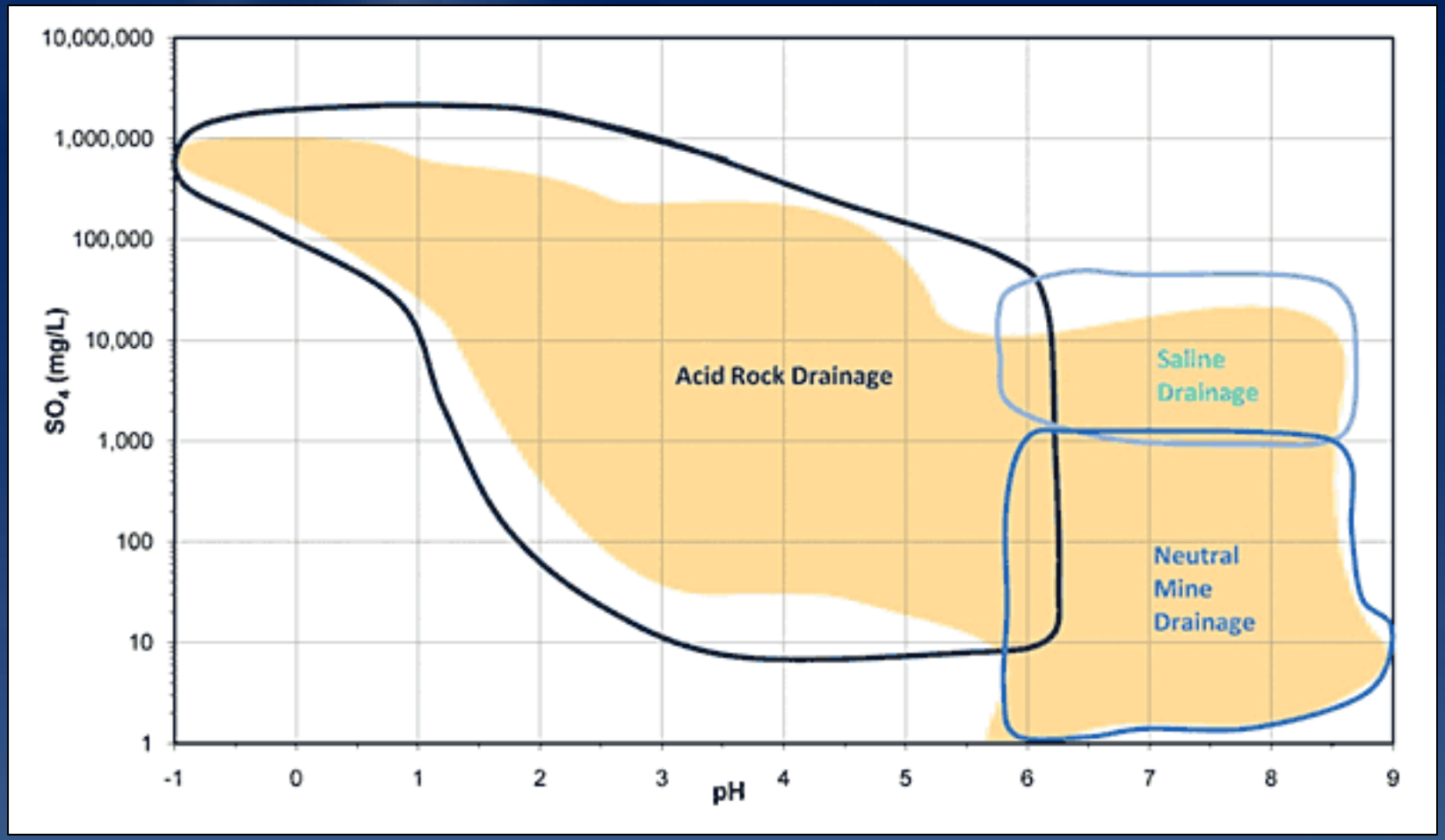
Step 4 – Neutral Mine Drainage and Saline Drainage Assessment



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Step 4 – Neutral Mine Drainage and Saline Drainage Assessment

- Water Leachate (1:5 or ASLP).
- Leachates analysed for:
  - Salts (chloride, sulphate, nitrate, calcium, magnesium & sodium).
  - Metals (bismuth, cadmium, copper, cobalt, iron, manganese, molybdenum, lead, nickel, thallium, uranium and zinc).
  - Metalloids (antimony, arsenic, boron and selenium).
  - Others (fluoride and hexavalent chromium).

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Step 5 – Soil Assessment

Mehlich-3 test for bio-available nutrients and metals.

- Provides results for:
  - Exchangeable cations (calcium, magnesium, sodium, potassium, CEC, ESP).
  - Nutrients (phosphorus, sulphur, boron, copper, iron, manganese, molybdenum and zinc).
  - Heavy metals and metalloids (arsenic, cadmium, cobalt, lead, nickel and selenium).

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Case Study 1

- Waste rock from nickel mining often contains pyrrhotite as the dominant iron sulphide mineral:
  - Complete oxidation of pyrite (FeS_2) produces 2 moles of acidity for every mole of S.
  - Complete oxidation of pyrrhotite ($Fe_{(1-x)}S$) also produces 2 moles of acidity for every mole of S.
  - However, pyrrhotite can also oxidise to produce sulphur species other than sulphate, depending on the availability of oxygen.

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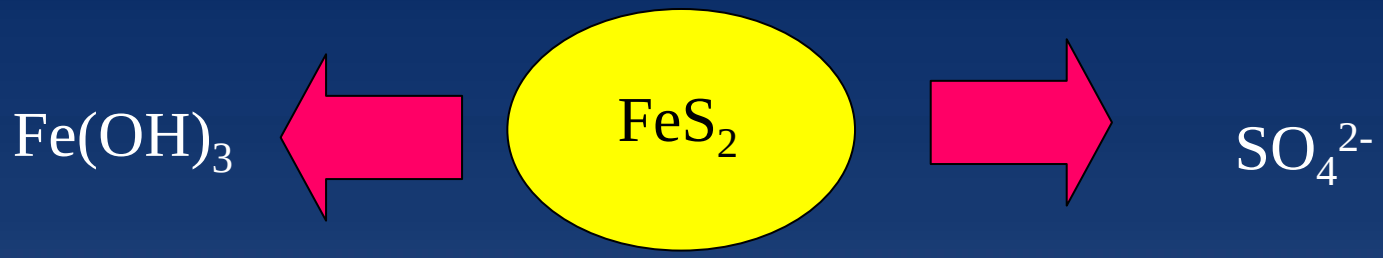
Oxidation of Pyrite



1% sulphur produces 30.6 kg H_2SO_4/tonne

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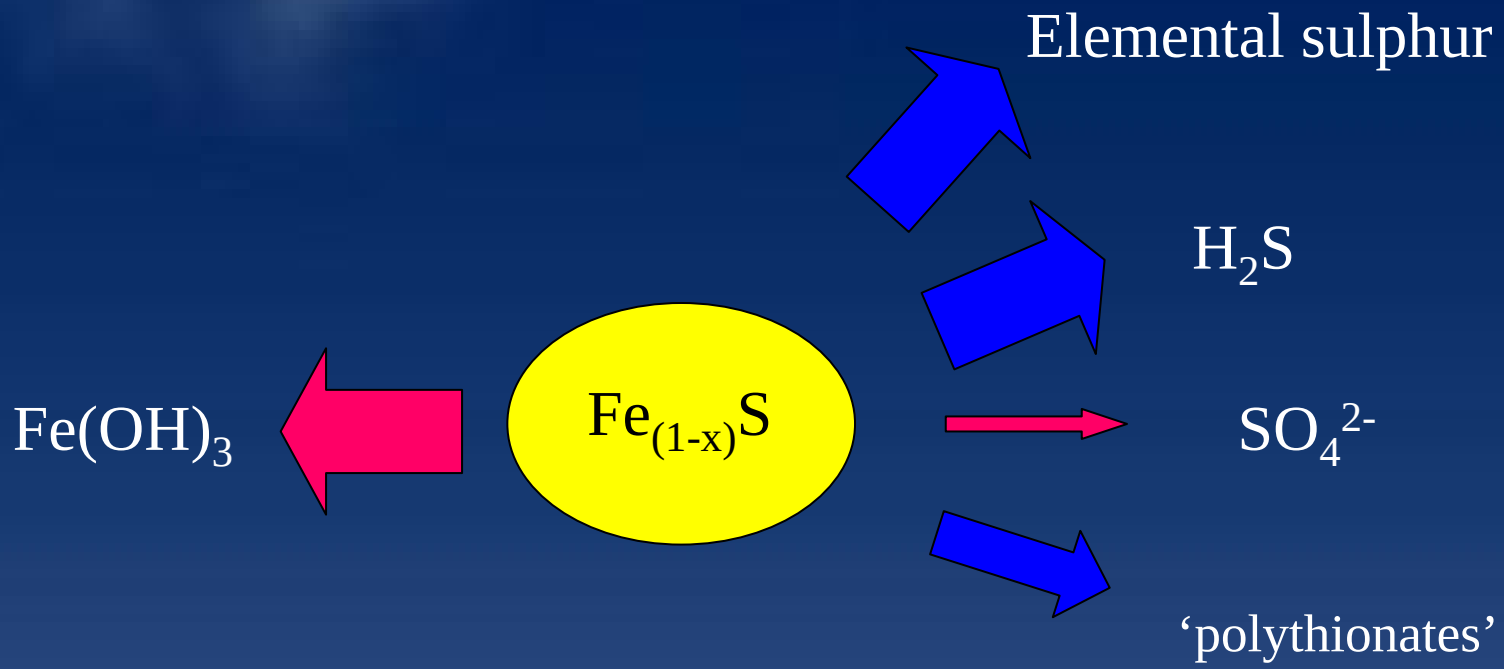
Oxidation of Pyrrhotite



1% sulphur produces up to 30.6 kg H_2SO_4/tonne

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Case Study 2

Neutral Mine Drainage:

- Thallium is a minor element associated with lead & zinc mineral deposits.
- Thallium sulphide is extremely insoluble.
- Oxidation of thallium sulphide forms monovalent & trivalent thallium ions, which are soluble in neutral and alkaline solutions.

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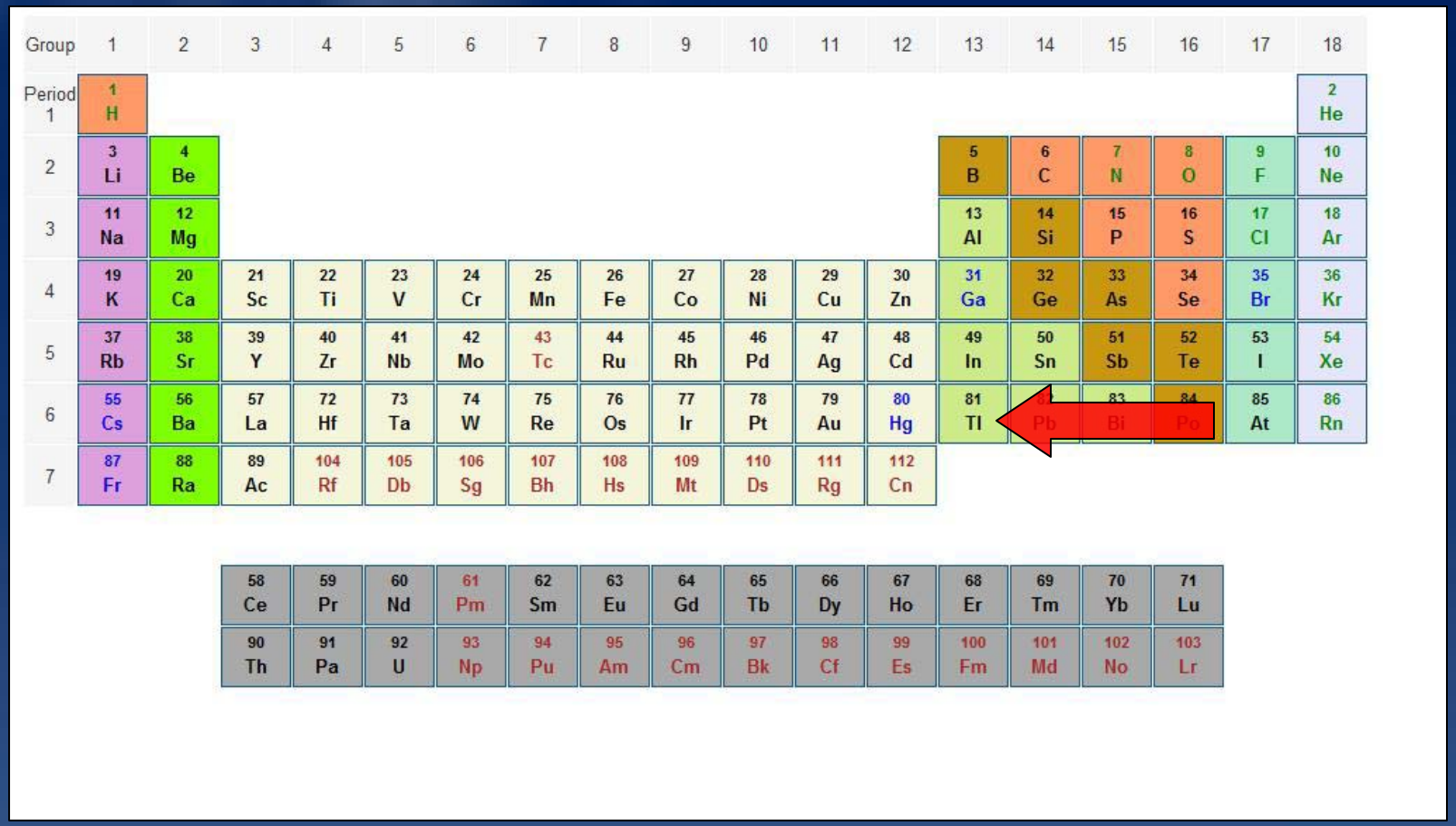
Thallium – A Toxic Heavy Metal



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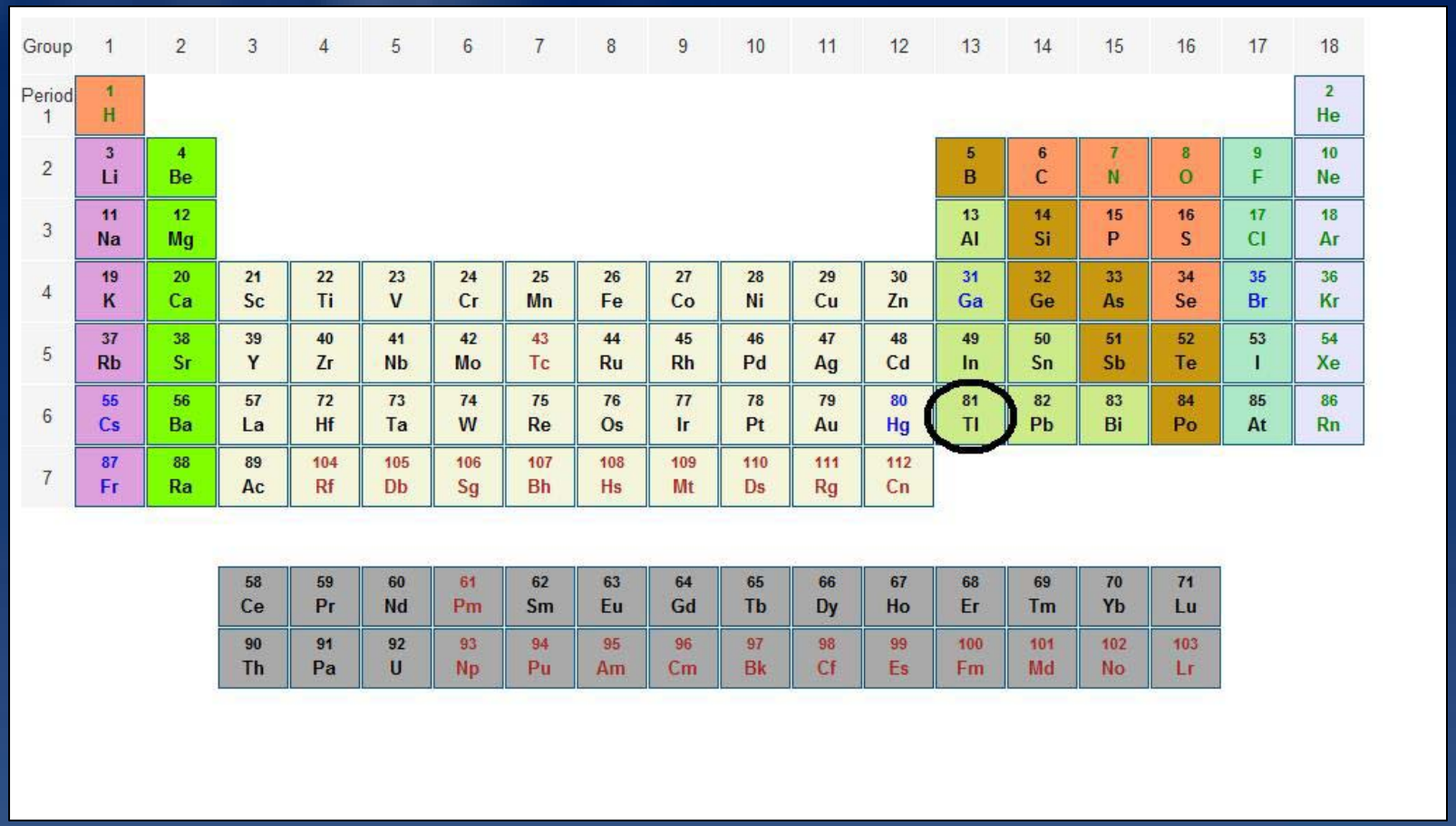
Thallium – A Toxic Heavy Metal



Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period 1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn						

	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

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Thallium in Lead-Zinc Tailings

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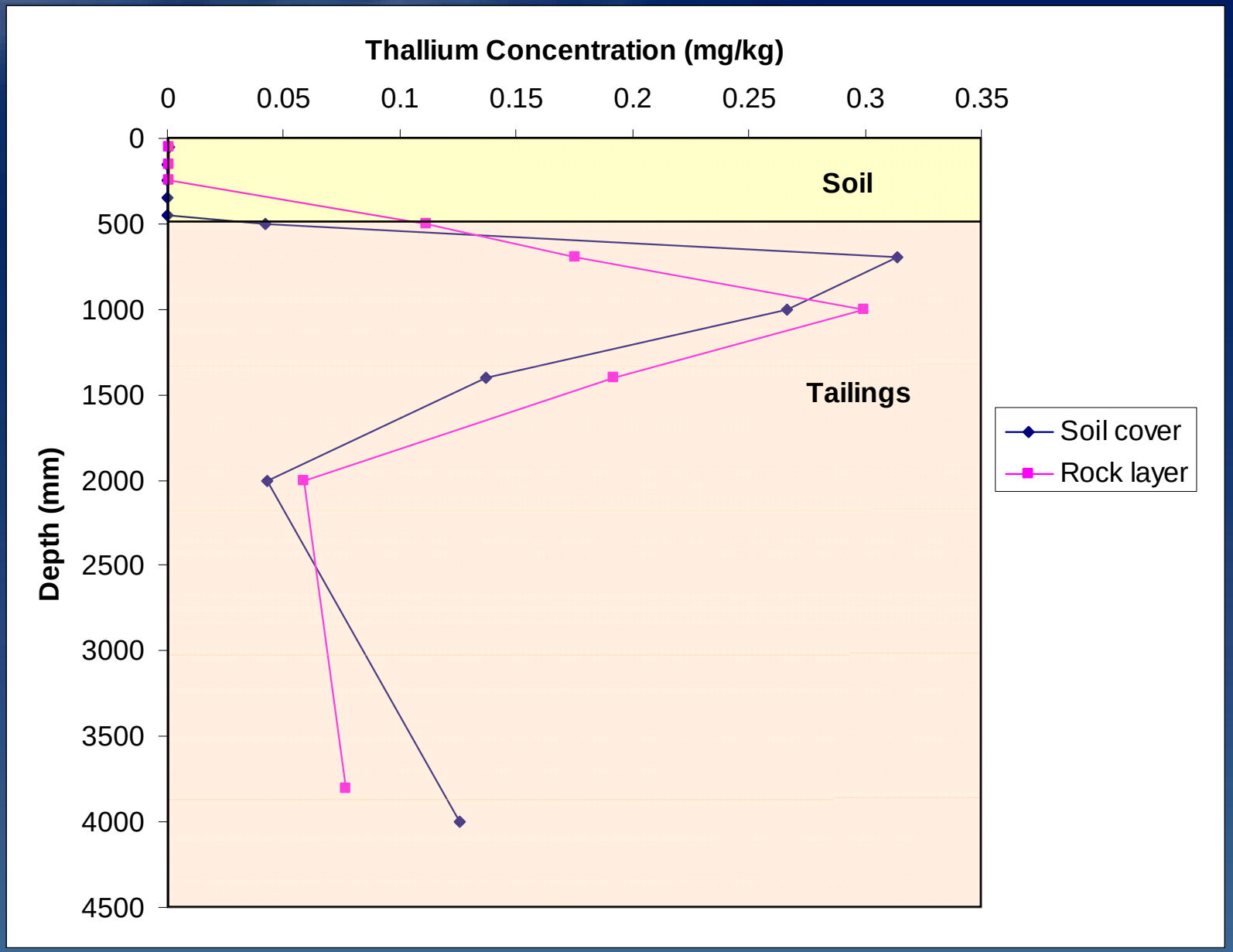

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Take Home Messages

- Understanding the properties of waste rock, tailings and soils is essential for effective rehabilitation of mine sites.
- Waste characterisation requires considerable expertise in geology, mineralogy, geochemistry and soil science.
- Many waste characterisations focus on prevention of AMD. However, impacts of Neutral Mine Drainage and Saline Drainage can be of equal or greater concern in some situations.
- Waste characterisation does not finish with submission of a Mining Proposal. On-going monitoring and field trials are required to validate predictions provided by pre-mining waste characterisations.

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