Global Centre for Environmental Remediation (GCER)

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

Sources and management of acid mine drainage (AMD)

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THE UNIVERSITY OF NEWCASTLE AUSTRALIA

Walk the talk

- ✓ Acid mine drainage (AMD):
  - *The issue*
  - *Sources of AMD*
  - *Characteristics of AMD*
- ✓ Environmental impact of AMD:
  - *Heavy metal mobilization*
  - *Ecosystem toxicity*
- ✓ Treatment and management of AMD:
  - *Active treatment*
  - *Passive treatment*
- ✓ Conclusions

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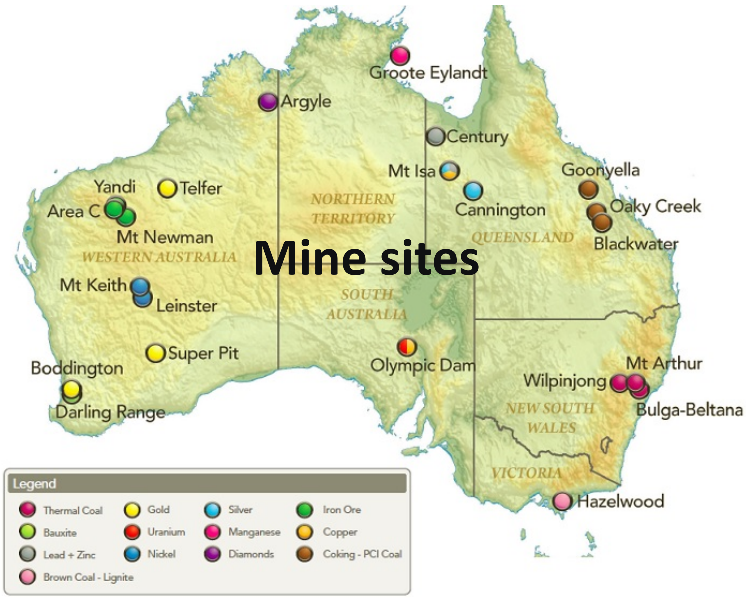
The Issue – the extent of AMD

- ✓ Acid mine drainage (AMD) is caused by leachate, seepage, or drainage affected by the oxidation of sulfide mineral rocks when exposed to air and water.
- ✓ A survey on > 400 sites producing AMD in Australia, 54 sites are managing significant amounts of AMD waste (>10 waste), resulting in >10^6 tonnes (Mt) of AMD wastes.
- ✓ About 62 additional sites are managing some AMD wastes but < 10% of the total wastes and < 10 Mt (Harris, 1997).

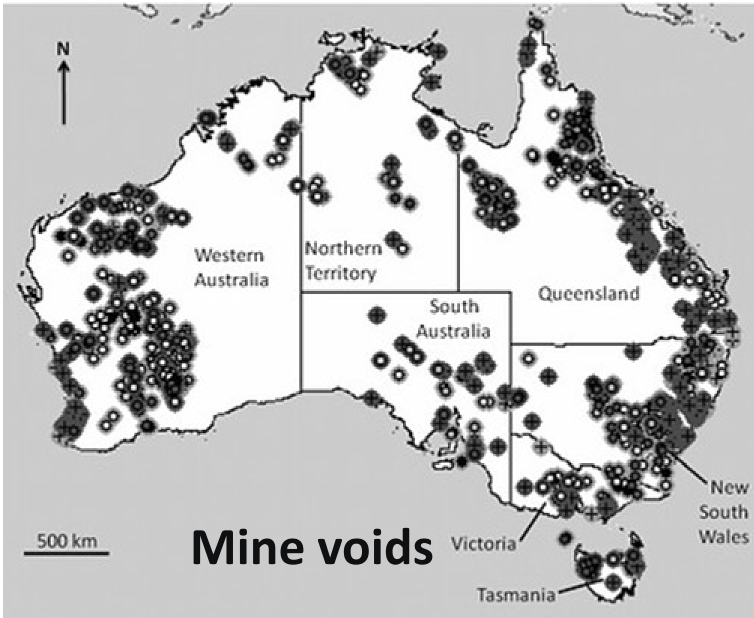


The Issue – impact of AMD

- ✓ The management of AMD wastes is a major environmental issue for mining industries.
- ✓ Major costs may arise after mine closure if proper waste management strategies are not in place from the beginning of mine operations.
- ✓ The governments want to ensure that the environmental risks and financial liabilities are not transferred to the community.

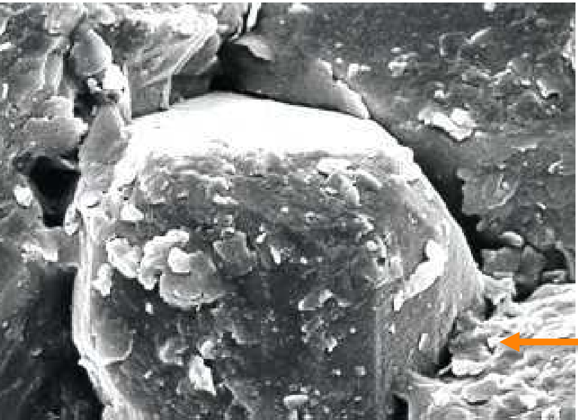
The Issue – cost of AMD remediation

- ✓ The average cost of covering AMD wastes at currently operating mine sites is estimated to be about $40 000 ha^{-1}$.
- ✓ For the Australian mining industry, the additional cost of managing AMD wastes at operating mine sites is estimated to be about $60 million per year.
- ✓ This includes the costs of cover installation, selective placement of wastes, waste characterisation and water treatment.
- ✓ The costs of treating contaminated water-filled voids or seepages from adits would be additional.



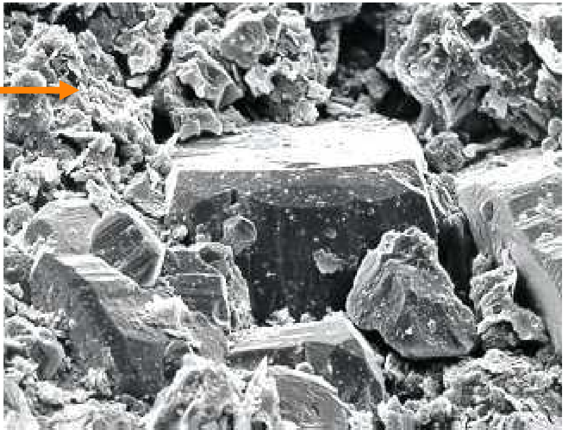
Sources of AMD

- ✓ Acid mine drainage (AMD) occurs when sulphide-bearing rocks and sediments are exposed to oxidising conditons
- ✓ Exposure mainly caused by: mining activity, infrastructure development, forestry, agricultural practice & natural disaster.
- ✓ When exposed, sulphide minerals (e.g. pyrite) react with oxygen and water to form sulphuric acid.
- ✓ One of the major watershed pollution problem is AMD from abandoned mines.

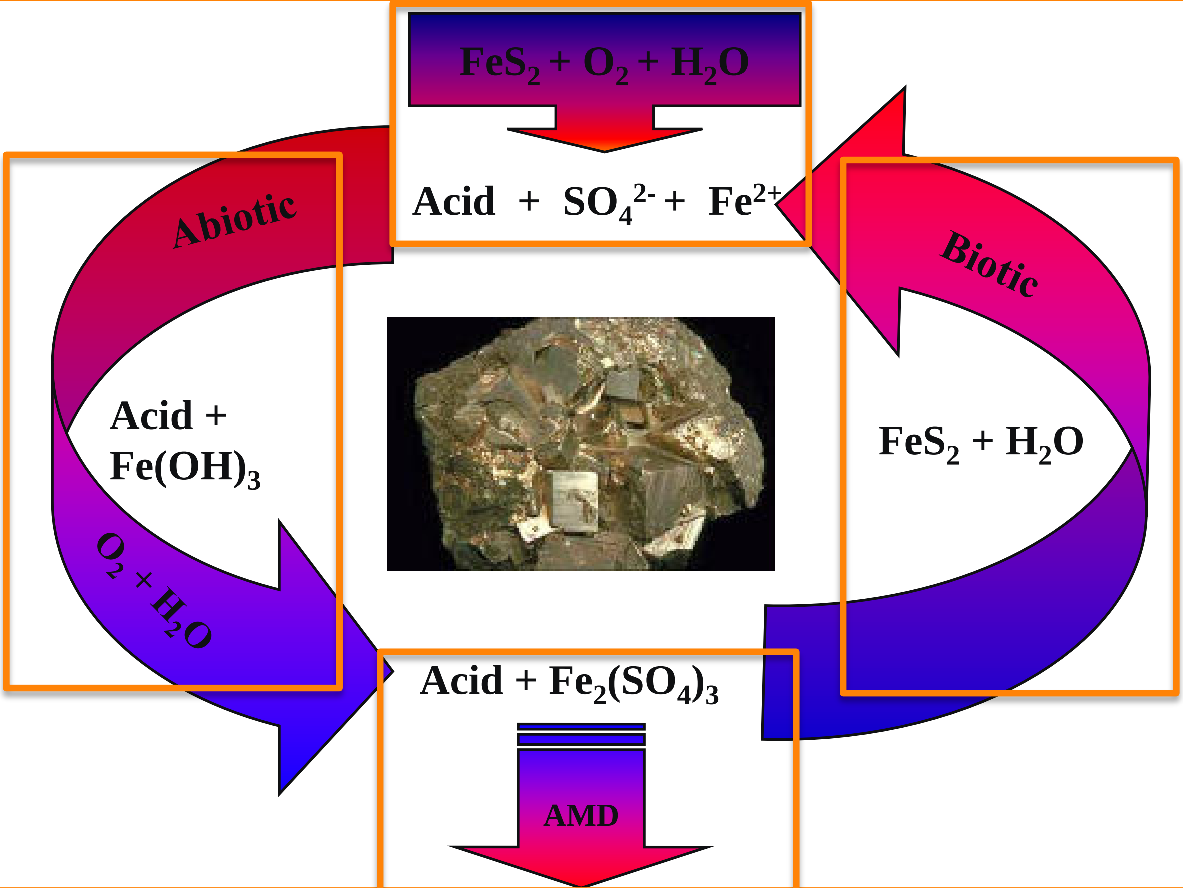


weathered pyrite

Fresh pyrite



Acid generation process

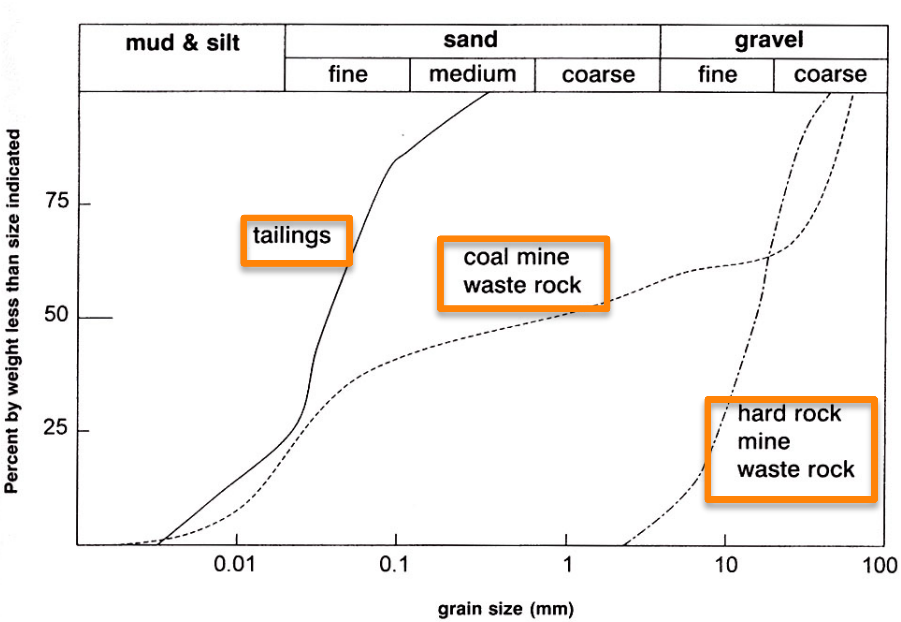


Pyrite + water + air → low pH + metals

$4FeS_2 + 14\ H_2O + 15\ O_2 \rightarrow 4Fe(OH)_3 + 8\ SO_4^{2-} + 16\ H^+$

AMD - characteristics

- ✓ Surface area
  - – smaller grains, more surface area
  - – more surface area, faster rate of oxidation and AMD generation



Chemical properties

Parameters	Units	Fresh rock	Weathered rock
pH (H_2O)		7.3	2.1
EC	dS m^{-1}	0.1	3.8
SO_4^{2-}	mg kg^{-1}	460	7440
Soluble Fe	mg kg^{-1}	477	4100
Soluble Mn	mg kg^{-1}	215	328
Exchangeable Al	$cmol_c$ kg^{-1}	2.1	14.9
Ca	$cmol_c$ kg^{-1}	7.7	5.3
Mg	$cmol_c$ kg^{-1}	2.5	1.3
K	$cmol_c$ kg^{-1}	0.3	0.7
Na	$cmol_c$ kg^{-1}	0.4	0.2
ECEC	$cmol_c$ kg^{-1}	13.0	22.4
Base saturation	%	84	33

✓ Oxidised pyritic rock has very low pH and elevated levels of EC, SO_4^{2-}, soluble metals, and a general depletion in base cations.

Acid Base Accounting - ABA

- ✓ Weathered rock has higher net acid producing potential (NAPP) than fresh rock due to depletion of acid neutralizing capacity (ANC).
- ✓ NAPP and ANC are critical in estimating the neutralizing materials for the remediation of AMD.

Acid base accounting (ABA) analysis of pitwall rock

		Sulphur forms, %			$kg\ CaCO_3\ t^{-1}$		
Sample	pH	Total	Sulphate	Sulphide	APP	ANC	NAPP
Fresh	7.3	2.56	0.046	2.51	78	27	51
Weathered	2.1	3.36	0.744	2.62	82	8	82

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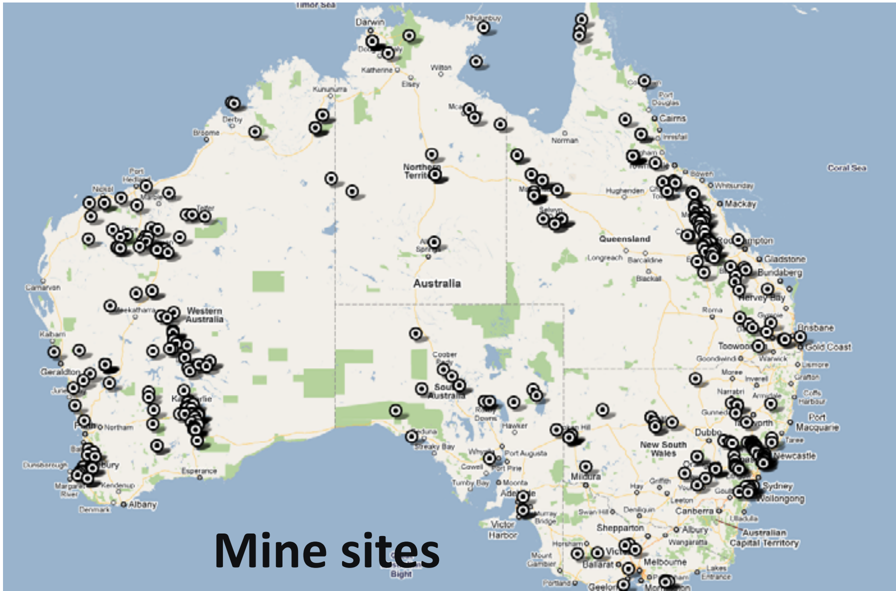
AMD - Environmental Effects

- ✓ The AMD has the potential to mobilize heavy metals and thus have detrimental impacts on the ground and surface water.
- ✓ If disturbed, acid generated from oxidation of pyrite can result in AMD pollution of surface & ground waters.
- ✓ AD from disturbed ASS can be toxic to aquatic life, plants & animals.
- ✓ Loss in soil fertility, land degradation and acid corrosion to infrastructure are costly liabilities.



AMD - Stream Effects

- ✓ Colored waters:
- ✓ "Yellow boy"
  - Iron oxides, basically rusting the stream floor
- ✓ White
  - Aluminum
- ✓ Black
  - Manganese
- ✓ Determined by shifts in pH

Clear streams do not necessarily mean clean streams

AMD - Stream Effects

- Runoff drainage from pyritic source material will have very low pH and elevated levels of metal loading.
- The effect of on drainage chemistry decreases with distance from the pyritic source.

Distance	pH	EC	SO_4^{2-}	Fe,	Mn	Al
(m)		dS m^{-1}		mg L^{-1}		
0	2.44	3.68	8300	17040	495	7940
10	2.83	2.77	6800	13400	423	5400
20	2.85	2.74	4680	8200	383	3940
30	2.80	2.27	4190	7100	381	3550
40	2.86	2.10	2900	4200	364	2980
50	2.88	2.12	3200	3700	323	3150
60	2.92	2.14	2660	2300	248	1770
70	3.12	1.81	2100	1600	140	1690

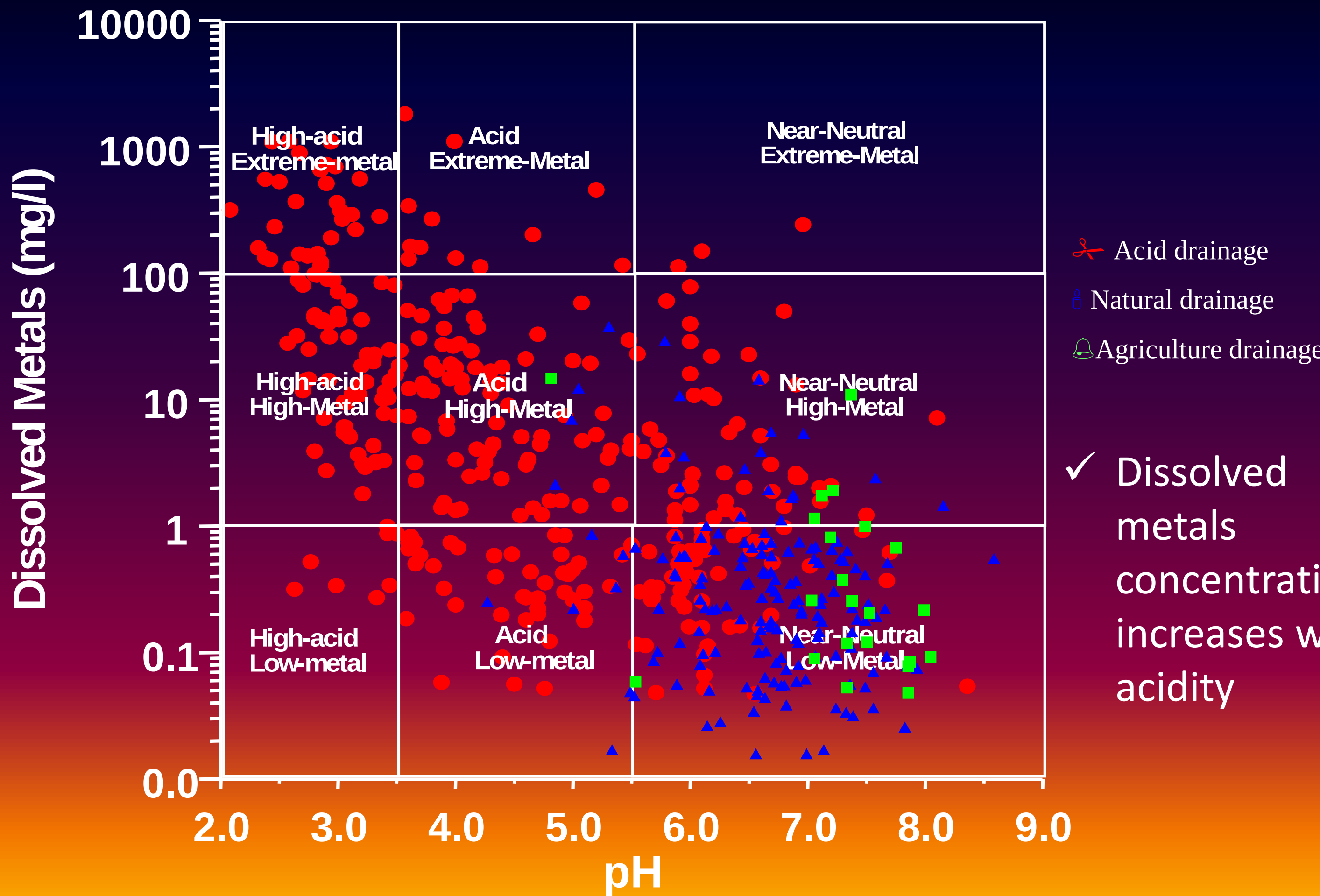
Why is AMD Harmful?

The resulting acid and dissolved metals are toxic to terrestrial and aquatic life.

Silver Lead Ck, Zeehan

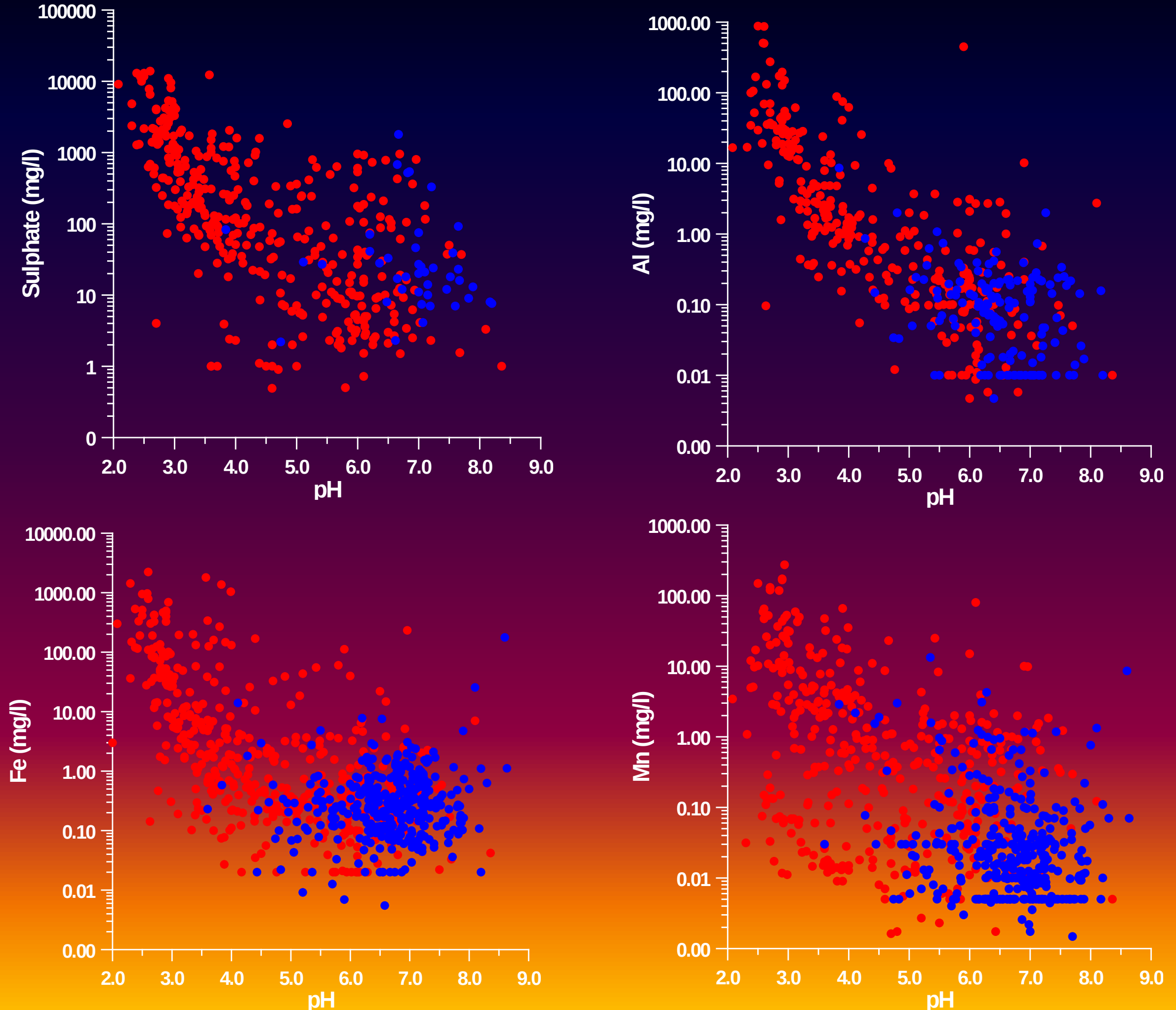

Mt Bischoff

Geochemical composition of surface water



✓ Dissolved metals concentration increases with acidity

Dissolved metal concentrations of AMD as a function of pH



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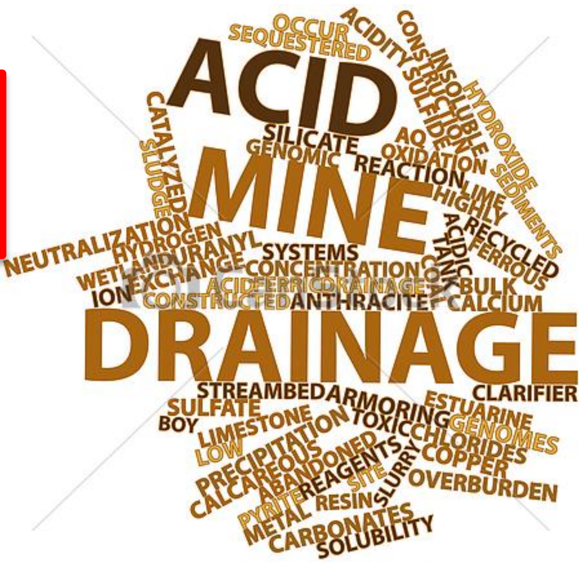
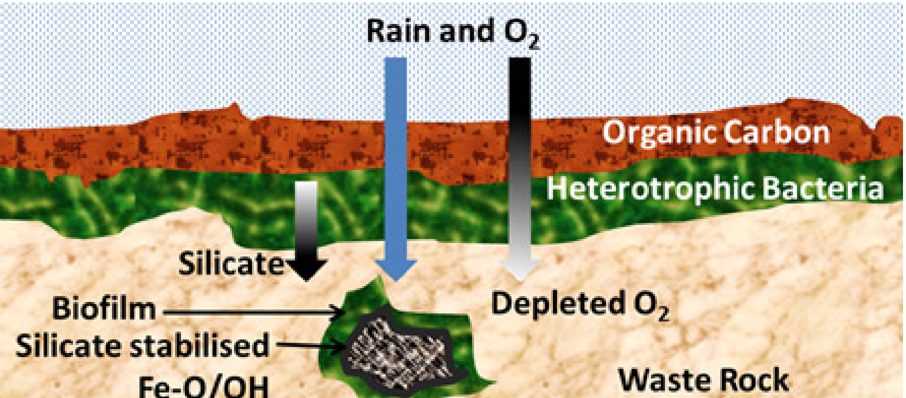


AMD Treatment

- ✓ Active
  - physical addition of alkalinity to raise pH
  - High cost
  - effective
- ✓ Passive
  - Naturally available energy sources
  - Little maintenance
  - Driven by volume



Active Treatment

Typical treatment processes ("ODAS")

- -oxidation
- -dosing with alkali
- -sedimentation

Chemical alkali treatments

Anhydrous ammonia

Hydrogen peroxide

Calcium oxide

Coal combustion products

AMD Lime Requirements (LR)

Liming materials	LR_{Buffer} (C_{ER}) kg $CaCO_3$ t^{-1}	$CaCO_3$ equivalent (%)	Actual rate kg t^{-1}	LR_{Total} kg t^{-1}
$CaCO_3$	29	100	29	111
LST	32	95	34	120
DOL	25	114	22	94
FBA	30	42	71	266
RPR	88	27	326	630

LST = Lime stone; DOL= Dolomite; FBA = Fluidised bed boiler ash; RPR = Reactive phosphate rock. Actual rate is based on the $CaCO_3$ (%) equivalent of the neutralising materials. $LR_{Total} = LR_{Buffer} + LR_{NAPP}$ (82 kg $CaCO_3$ t^{-1}).

✓ Application of such large amounts of liming materials may not be conducive to plant growth due to high alkalinity created during active neutralization period.

Passive Treatment of AMD

Wetlands

Alkaline beds

Open limestone channels

Phytocapping

AMD Management

- ✓ The best method to treat AMD is prevention
- ✓ This can be done by using clay or soil or liming material or geotextile or plant cover, which prevents air and/or water from reaching the pyritic materials.

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Conclusions

- ✓ Most base-metal abandoned mine sites are potential point and diffuse sources of AMD
- ✓ The AMD database is an important environmental management tool for scoping future direction in the remediation of AMD.
- ✓ Prescriptive amendments need to be formulated for site-specific amelioration of low pH condition created by AMD.
- ✓ In practice, the placement of the amendments in AMD channels/streams/pits remains an engineering challenge
- ✓ AMD prevention can be achieved by using clay or soil or plant cover.

THANKS (to past/present HDR students)

There are known knowns; known unknowns; unknown unknowns" – Donald Rumsfeld

Although AMD has been researched for decades, perhaps there are more "unknown unknowns" in *"treatment and management of AMD"*