IN-SITU RESOURCE UTILISATION THROUGH WATER EXTRACTION FROM HYDRATED MINERALS – RELEVANCE TO MARS MISSIONS AND AN AUSTRALIAN ANALOGUE

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WHY ISRU?

- **Each person on Mars will need over 600 days:**
  - 2 tonnes water
  - 0.75 tonnes oxygen
- **Plus**
  - >25 tonnes methane + oxygen for direct earth return
  - **OR** >3.5 tonnes for ascent to Mars orbit

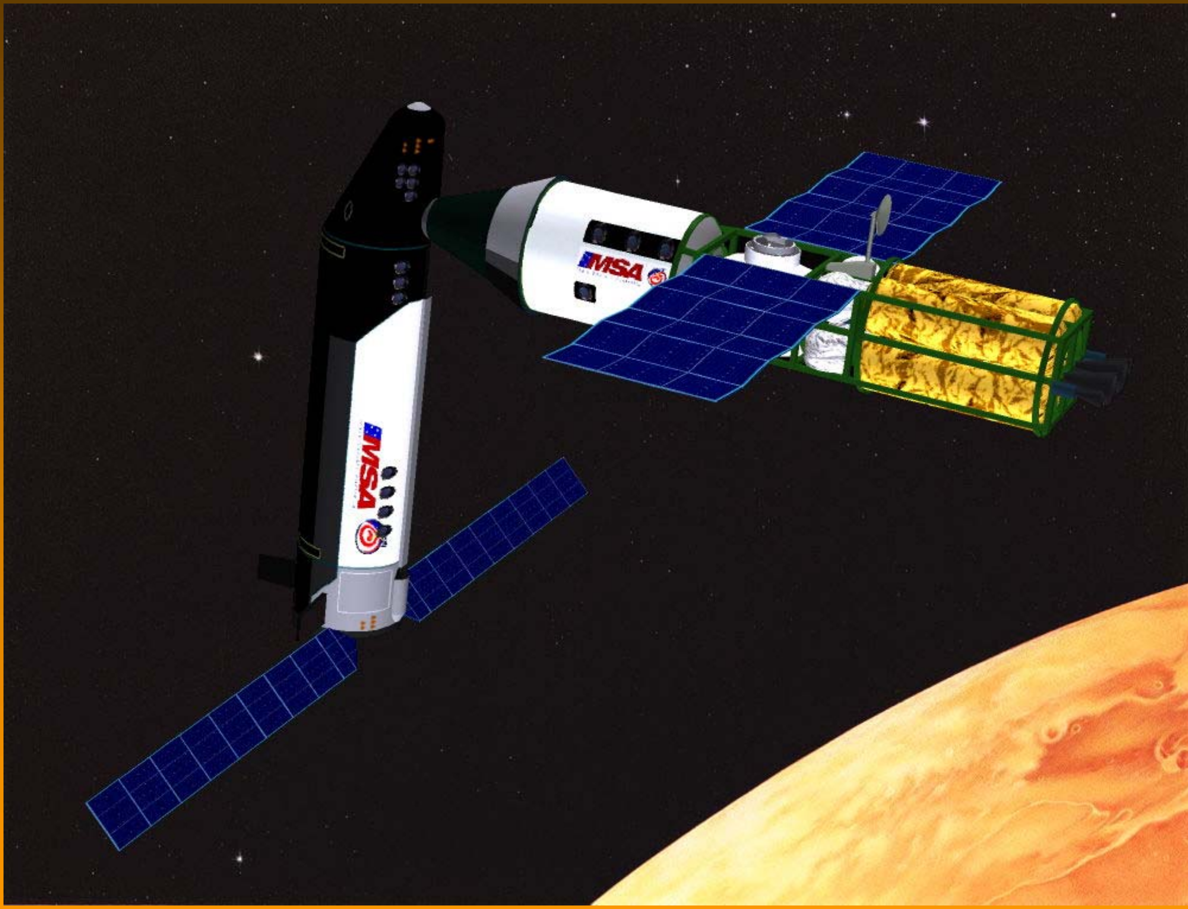
1:4 RULE – 1 tonne on Mars = 4 tonnes in LEO

Ares 5 with MSA module

Reduction in consumables offers the best potential for mass reduction

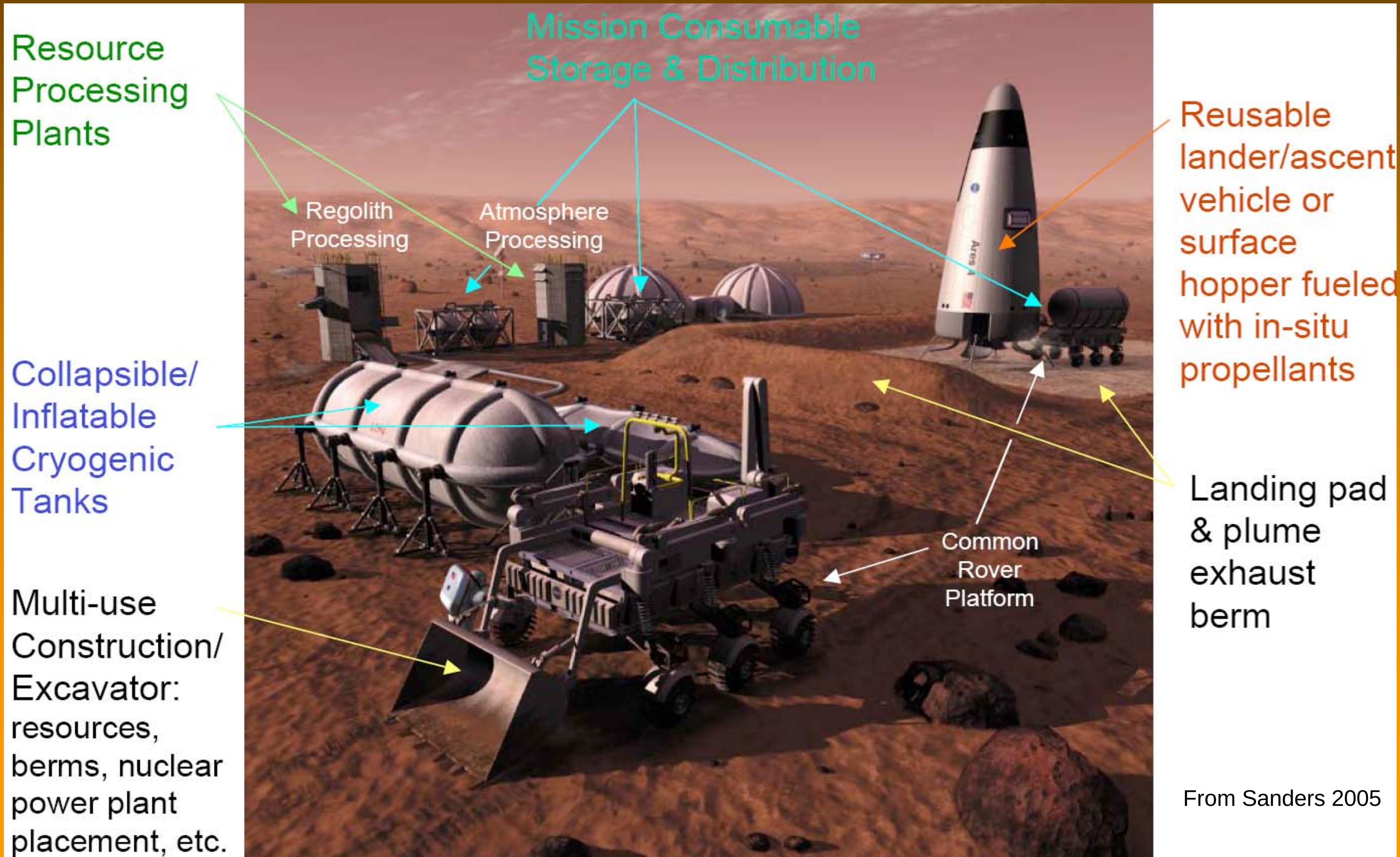
The MSA mission (four-persons on 600 day surface stay) will need:

- 8 tonnes water
- 3 tonnes oxygen
- 2 tonnes hydrogen (reactant)
- 14 tonnes of methane-oxygen propellant (ascent to Mars orbit)
- In total 27 tonnes of potentially water-based consumables
- If all supplied by *in situ* water reduce landed mission mass by ~32% over missions where these are imported



Using Martian resources thus:

- **Minimises mission mass**
- **Minimises mission costs**
- **Minimises risks**
- **Increases flexibility**
- **Increases capability**
- **Allows expanded human presence**

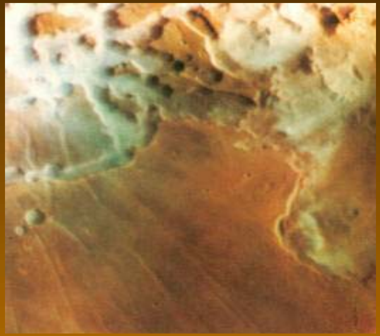


From Sanders 2005

WATER ON MARS

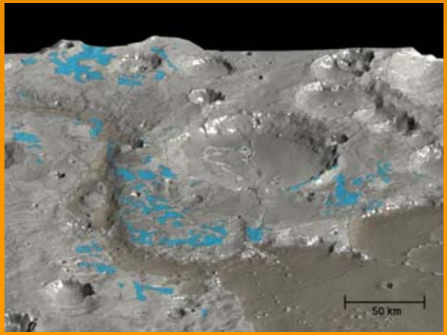
Atmospheric water

- Global distribution
- Requires processing large volumes of air



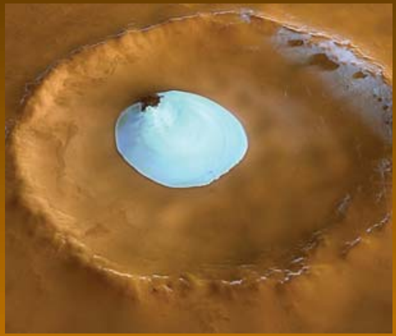
Hydrated minerals

- Various scattered locations on Mars
- Easy extraction
- Known quality



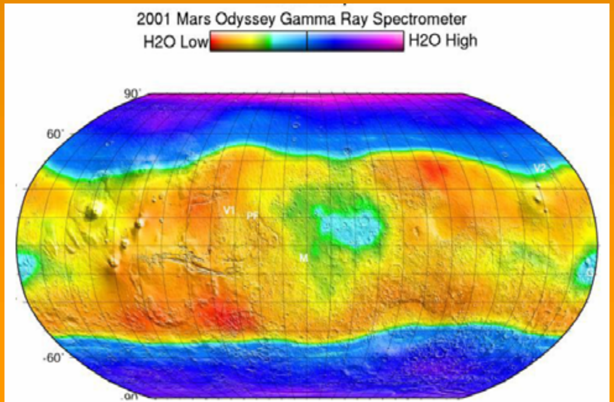
Polar ice

- High latitudes
- Quality unknown



Ground ice

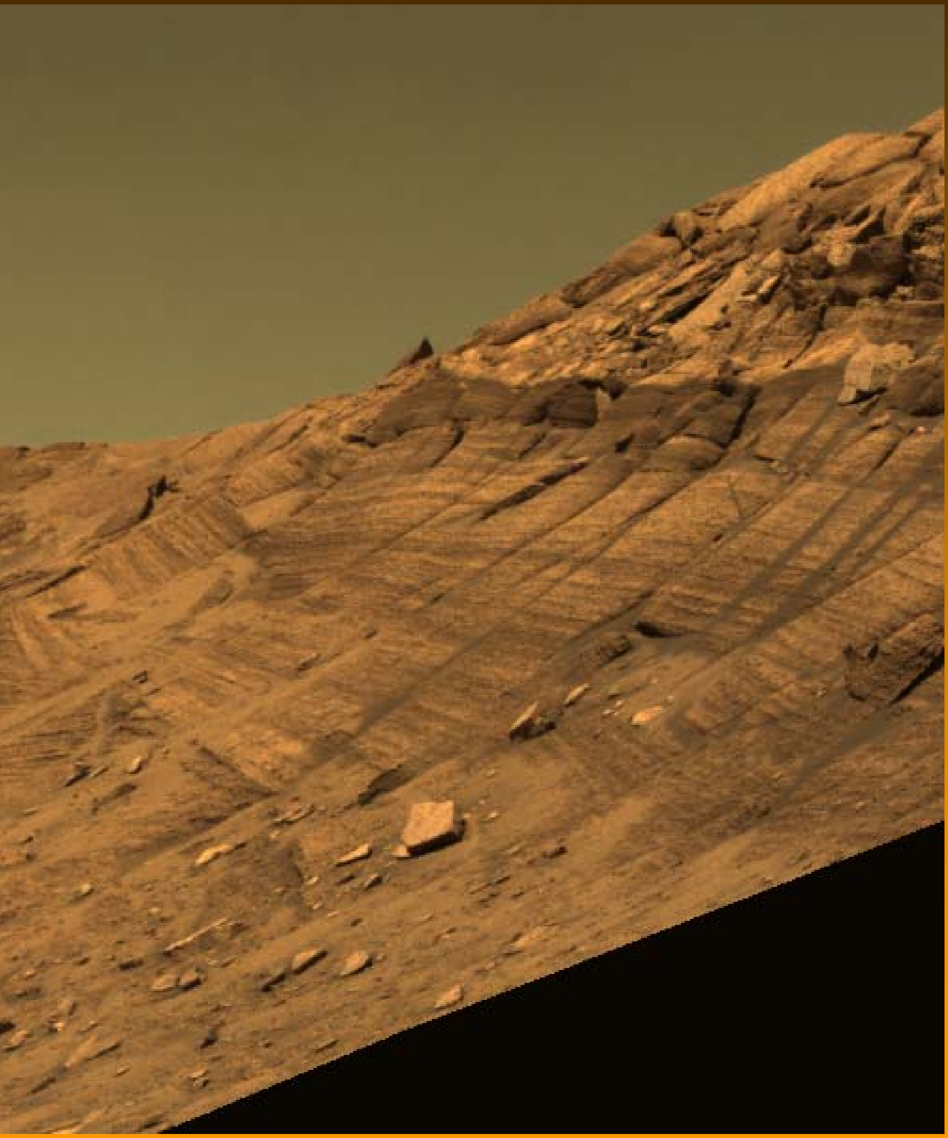
- Mid to high latitudes
- Quality unknown
- Extraction may be difficult



Shallow aquifers

- Mid latitude gullies
- Current activity unknown
- Will need deep drilling (100's of m)
- Quality unknown

HYDRATED MINERALS AT MERIDIANI PLANUM



COMMON HYDRATED MG-SULPHATE MINERALS

- (Epsomite ($MgSO_4.7H_2O$) = 51% H20)
- Kieserite ($MgSO_4.H_2O$) = 14% H_2O
- Hexahydrite ($Mg(SO_4) \cdot 6H_2O$) = 47% H_2O
- Bloedite ($Na_2Mg(SO_4)_2 \cdot 4H_2O$) = 37% H_2O

OTHER COMMON HYDRATED MINERALS

Calcium Sulphate

- Gypsum ($CaSO_4.2H_2O$) = 14% H_2O
- Montmorillonite clay $(Al,Mg,Fe)_8(Si_4O_{10})_3(OH)_{10}.12H_2O$ = 26% H_2O

HOW MUCH WATER WOULD WE NEED?

Tonnes hydrogen & water for specific Mars mission proposals

	Mars Direct	MSA	NASA DRM 3.0
Imported hydrogen	6	1.6	5.42
Water equivalent	54	14.4	48.78

Water extraction requirements & rates for Mars mission proposals

	Mars Direct	MSA	DRM 3.0
Total water required (tonnes)	54	14.4	48.78
Daily rate (kg) (over 510 days)	106	29	97

HOW MUCH MATERIAL DO WE NEED TO PROCESS?

Daily mass hydrated sediment processed assuming D = 3.3

Mass water (kg)	Mass hydrated material required					
	20% recovered water		10% recovered water		5% recovered water	
	Mass (kg)	Volume (m^3)	Mass (kg)	Volume (m^3)	Mass (kg)	Volume (m^3)
MD 106	530	0.161	1060	0.322	2120	0.643
DRM 3.0 97	485	0.147	970	0.294	1940	0.588
MSA 29	145	0.044	290	0.088	580	0.176

Total amounts sulphate-bearing sediment processed

Mass water (t)	Hydrated material required								
	20% recovered water			10% recovered water			5% recovered water		
	Mass (t)	Vol. (m^3)	Area (m^2)	Mass (t)	Vol. (m^3)	Area (m^2)	Mass (t)	Vol. (m^3)	Area (m^2)
MD 54.0	270	81.8	81.8	540	163.6	163.6	1080	327.2	327.2
DRM 3.0 48.8	244	74.0	74.0	488	148	148	976	296	296
MSA 14.4	72.0	21.8	21.8	144	43.6	43.6	288	87.2	87.2

Assuming 1 m excavation depth

FIELD TRIALS IN AN ANALOGUE ENVIROMENT

Requirements

- Prototype processing plant
- Suitable analogue site
- Funding!

A project for MSA?

PORJECT OBJECTIVES

PRIMARY OBJECTIVE

That an analogue plant for the practical extraction of water from hydrated minerals can be successfully field trialled

The success criteria for the plant will be:

Extraction of a minimum of 100 kg of water per day over 1 week.

The project would provide baseline data on:

- Preferred heating methods & optimal operating temperature
- Time & power requirements for operation
- Process rates
- Plant masses
- Water extraction efficiencies

FOLLOW-ON OBJECTIVES

Whether analogue plant can be operated under direct human control in simulated space suits

Feasibility of operating the plant under remote control using various levels of autonomous and/or teleoperated systems

PROJECT STRUCTURE

Phase 1

Preliminary visit to Coober Pedy to:

Discuss project with local interests to determine statutory and cultural framework
Documentation of the regolith profile and mineralogy
Collect samples for preliminary analysis and testing
Select the site for further work

Phase 2

Development of ISRU plant for analogue materials in the laboratory. Issues include:

The optimum feed stock parameters
The optimal processing rates
Method of heating (e.g. microwave, resistance heaters, solar)
Water collection and storage technology
Energy requirements

Phase 3

Development of an excavation & processing system for field trials . Plant would include:

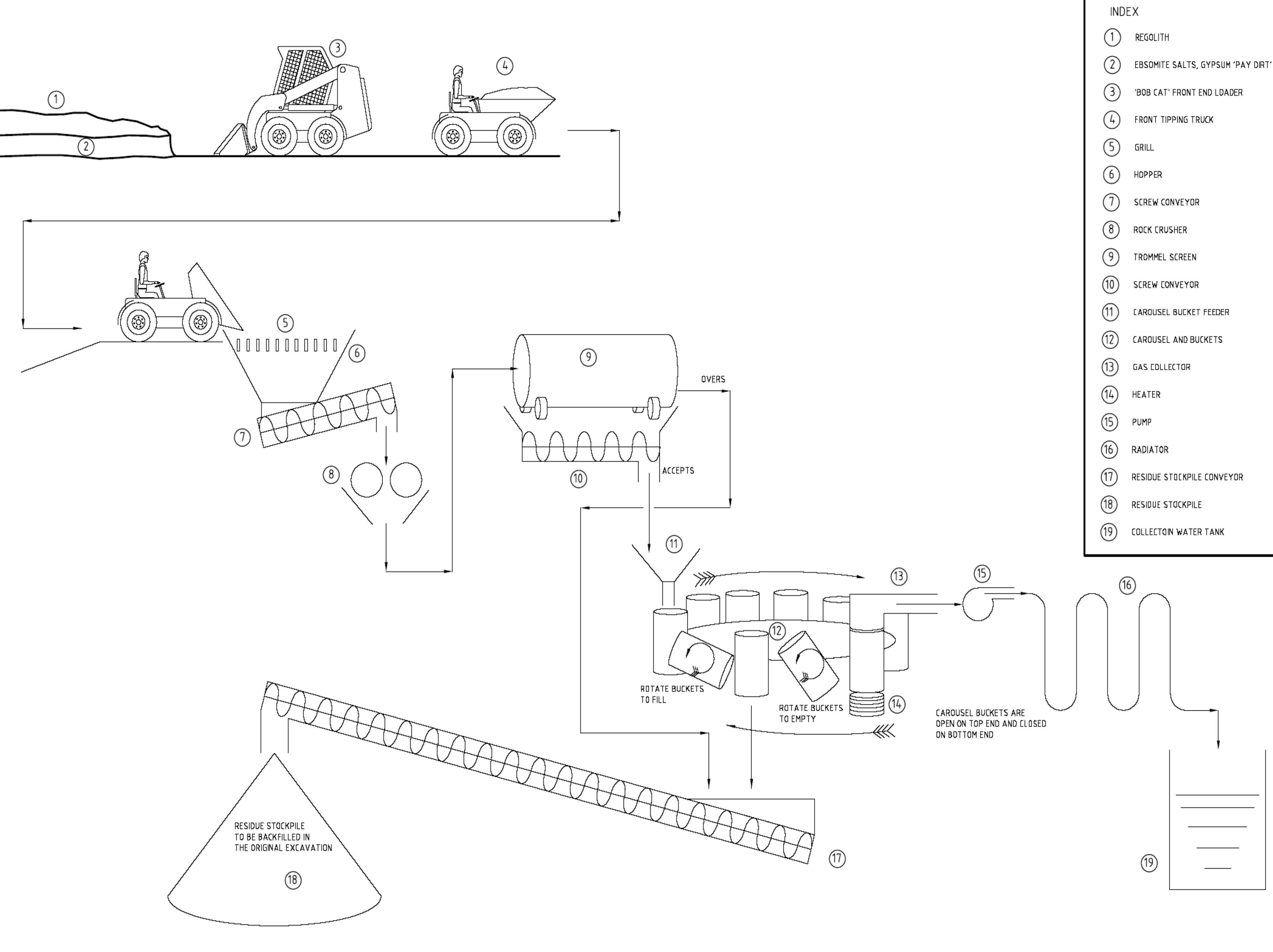
Excavation and transportation system
Storage and milling system
Oven
Water condenser and storage system
Waste disposal system

Outcomes

- Geological documentation of the trail area(s).
- Identification of issues associated with operating a mineral-water extraction plant
- Demonstration of a full scale concept plant in a terrestrial analogue
- Develop a platform for further ISRU studies in the field
- A platform for investigation of plant using simulated space suits
- A platform that can be used for robotics research
- An operational ISRU water supply system that can be incorporated in M.A.R.S.
- Education and outreach;
- Opportunities student participation in a space-related field engineering project
- Publicity for the research and education activities of the participating organisations.

Deliverables

- Geoscientific paper on the trial area(s)
- Engineering papers on the design and operation of the processing plant
- Research papers on the feasibility of water of hydration-based ISRU on Mars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2 EBSOMITE SALTS, GYPSUM 'PAY DIRT'
3 'BOB CAT' FRONT END LOADER
4 FRONT TIPPING TRUCK
5 GRILL
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7 SCREW CONVEYOR
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18 RESIDUE STOCKPILE
19 COLLECTOIN WATER TANK
OVERS
ACCEPTS
ROTATE BUCKETS TO FILL
ROTATE BUCKETS TO EMPTY
CAROUSEL BUCKETS ARE OPEN ON TOP END AND CLOSED ON BOTTOM END
RESIDUE STOCKPILE TO BE BACKFILLED IN THE ORIGINAL EXCAVATION

Test plant daily processing requirements for 100 L water per day (assumed D = 1.5)

Regolith required						
	20% recoverable water		10% recoverable water		5% recoverable water	
	Mass (t)	Volume m^3	Mass (t)	Volume m^3	Mass (t)	Volume m^3
	0.5	0.33	1.0	0.67	2.0	1.33
Over 7 days	3.5	3.31	7.0	4.69	14.0	9.31
Excavated m^2 over 7 days (0.5 m thickness)	6.61 (2.57 X 2.57 m)		9.38 (3.06 X 3.06 m)		18.62 (4.32 X 4.32 m)	

EXAMPLE OF SMALL SCALE MINING – RALLINGA TIN MINE, SW TASMANIA

- Alluvial tin 0.5 kg (cassiterite) per tonne
- 1.5 m overburden, pay gravels 0.5 m thick
- ~5 tonnes cassiterite produced each year
- Plant processes ~5 tonnes per hour, 36 hrs per week
- ~ 10,000 tonnes of gravel & 22,000 tonnes overburden excavated yearly
- Area effected annually 10,000 square metres (100 X 100 m)

THIS IS ~EQUIVALENT IN PROCESSED MASS TO:

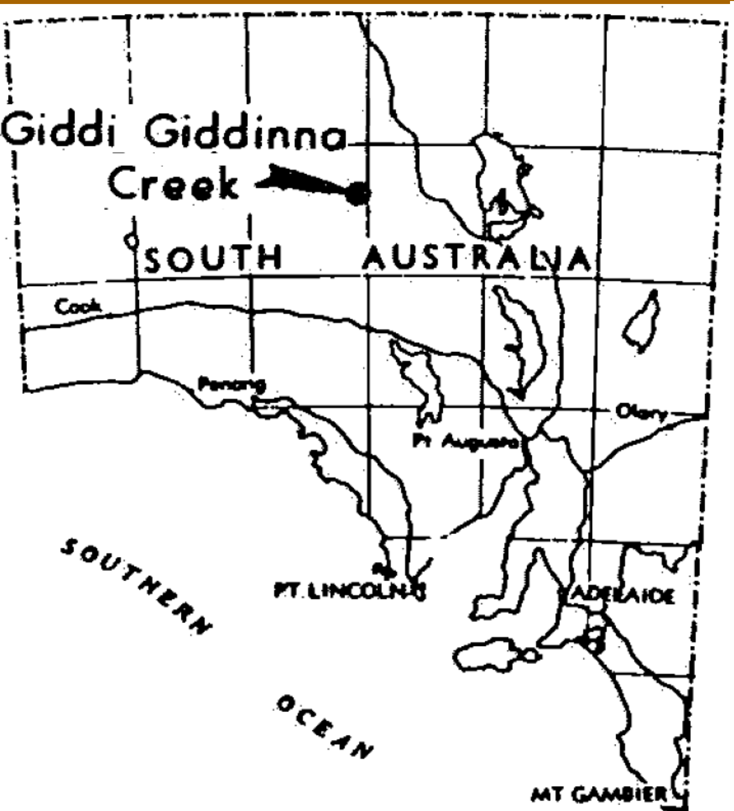
- ~10 Mars Direct missions (5% recovered water)
- ~100 X MSA missions
- ~500 X material at Moon Plain trial site

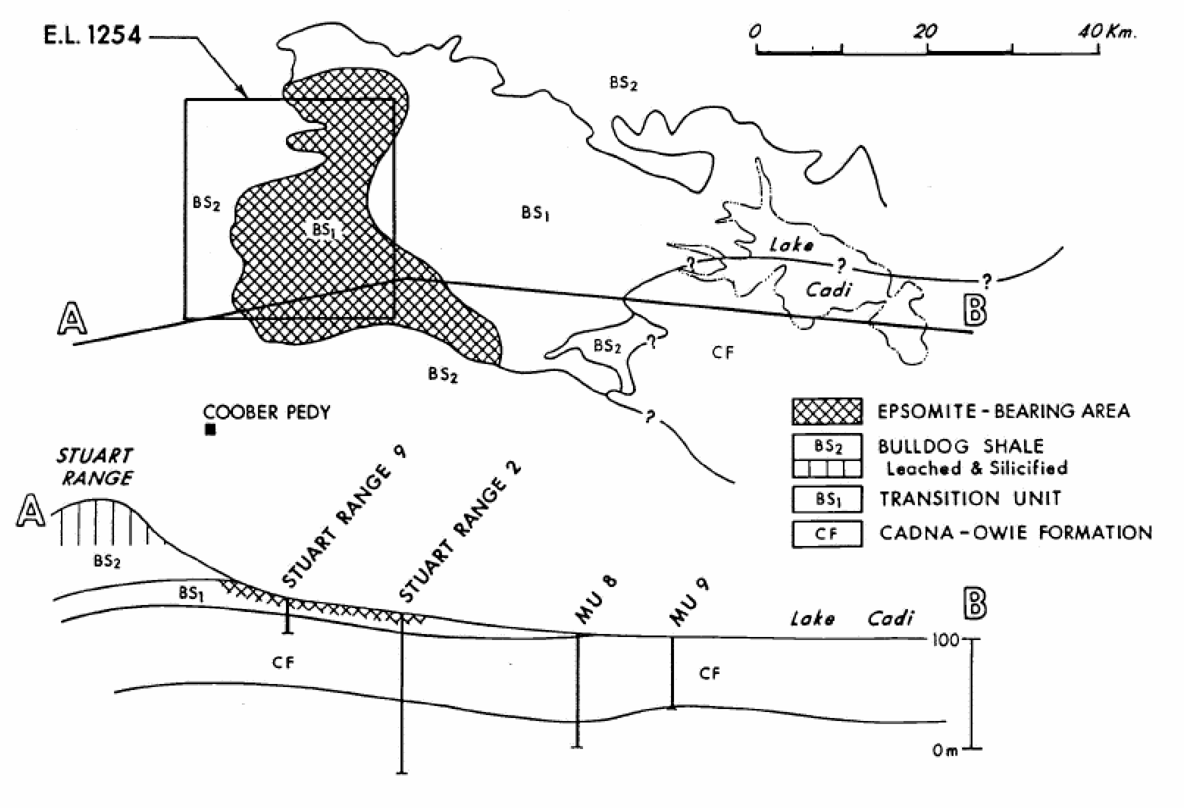
EXCAVATING FOR WATER EXTRACTION FROM HYDRATED ROCKS ON MARS IS OF SMALLER SCALE THAN SMALLEST TERRESTRIAL MINES

GIDDI DIDDINNA Ck EPSOMITE DEPOSIT AT MOON PLAIN, SA

A possible trial area

- NW of Cooper Pedy
- World's largest epsomite deposit
- Visited during JNT-1



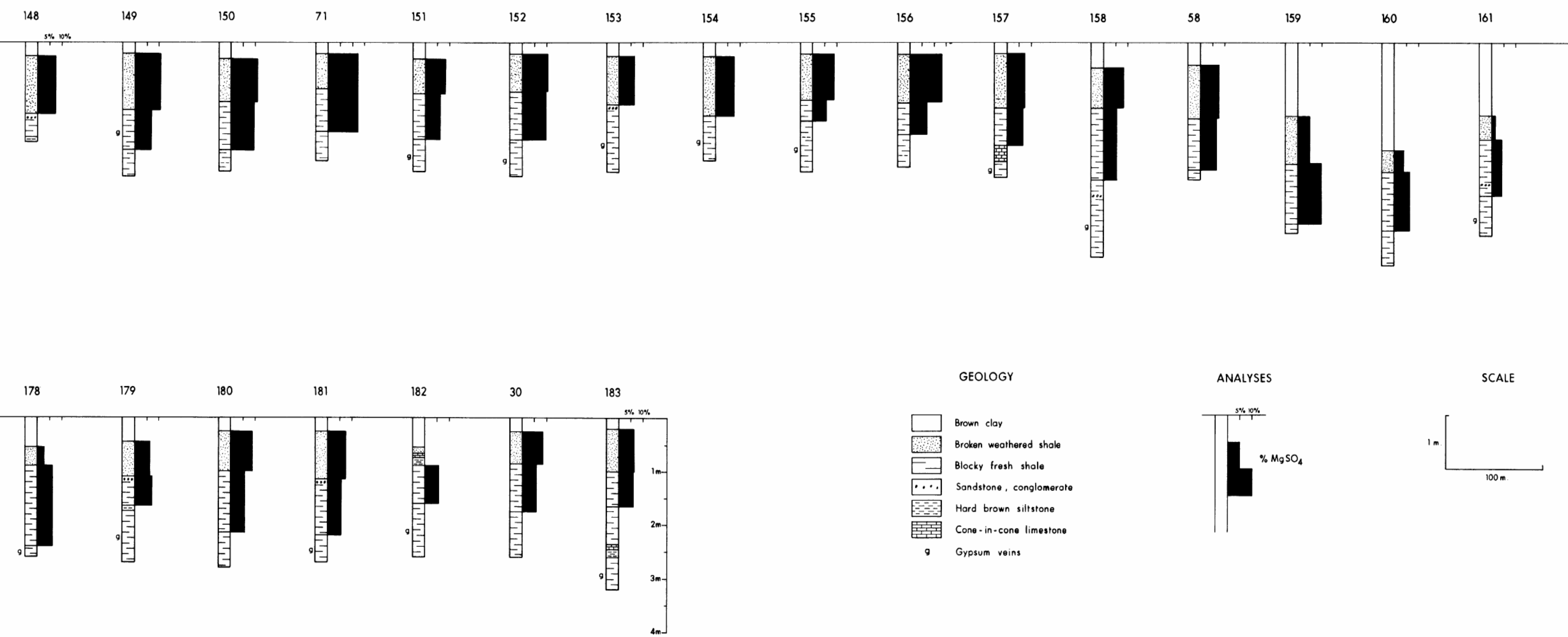


WHY MOON PLAIN?

- Similar mineralogy to Mars (Mg-Ca sulphates, clays)
- Simple excavation
- Arid with dry soil (especially in summer)
- Good access with nearby mining infrastructrure
- Local support for project likely

CROSS SECTION OF DEPOSIT

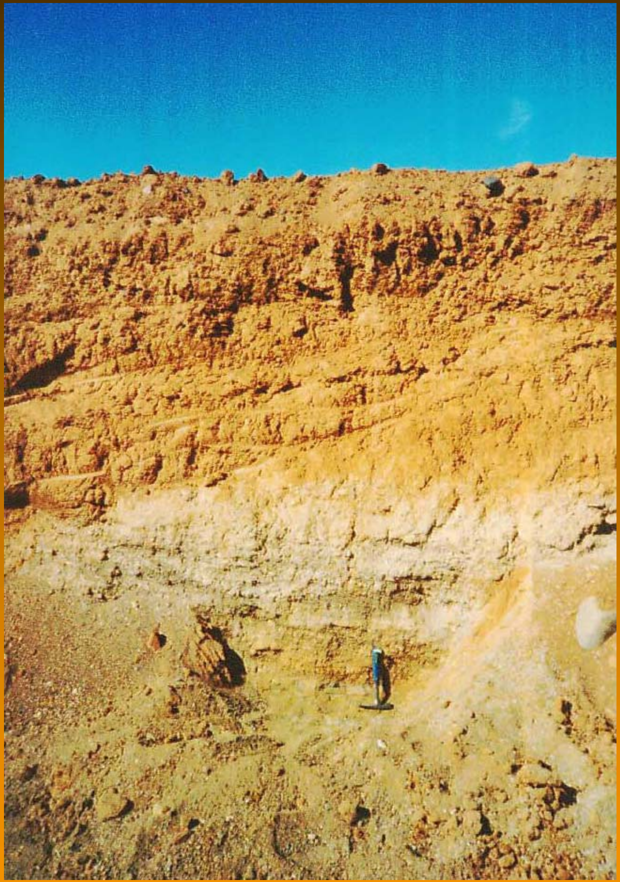
- Host lithology weathered Bulldog Shale
- Depth generally < 2m
- Grades mostly 5-15% $MgSO_4$ (locally up to 22%)
- Equivalent to 2.5-8% water (max 11%)
- Note total water content will be higher (gypsum + clay + soil moisture)

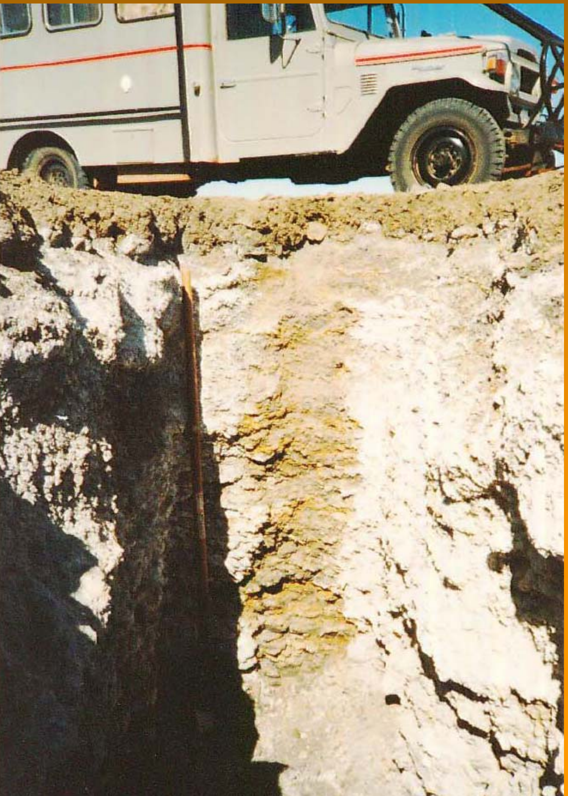


Looking southeast towards above sample pit from near edge of Benitos Clay cover; note change in colour of overburden.

Aminco

Exposure of Benitos Clay (1.2m) overlying Oolgelima Gravel (90cm) over lower member shales in Highways Quarry. Sample location 8326 - very low grade.





Backhoe pit (February '83) coated with sulphate efflorescences, chip channel sampled in July '83 - Nos. 8343-94

QUESTIONS FOR THE ROAD AHEAD

- Should MSA get involved in this project?
- How would it best be managed?
- Funding sources?
- Which partnerships should be formed?
- Who will develop processing plant?
- Aquisiton of mining equipment and needed training?
- What site clearances are needed?
- Are other test sites desirable?
- If so, how many?
- Can the study be incorporated into other projects?

FEEDBACK WELCOME!