

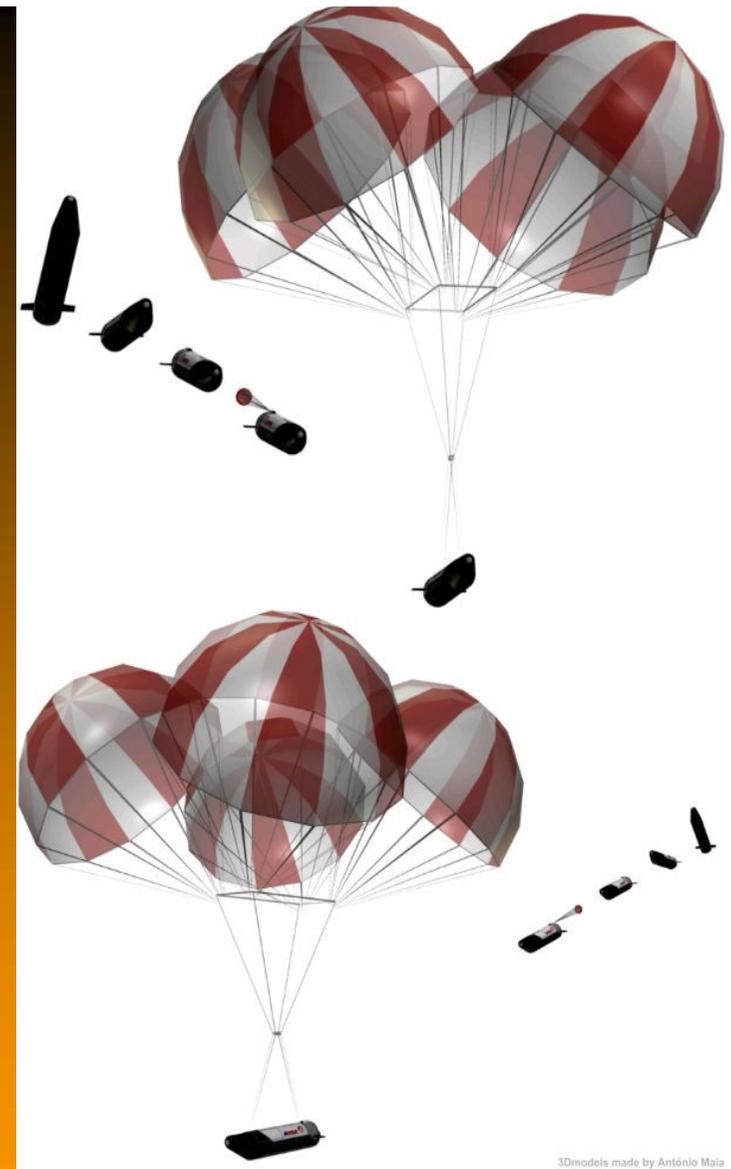
# IN-SITU RESOURCE UTILISATION THROUGH WATER EXTRACTION FROM HYDRATED MINERALS – RELEVANCE TO MARS MISSIONS AND AN AUSTRALIAN ANALOGUE



**Jonathan Clarke, David Willson, and David Cooper  
AMEC 2006**

## 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



3Dmodels made by António Maia

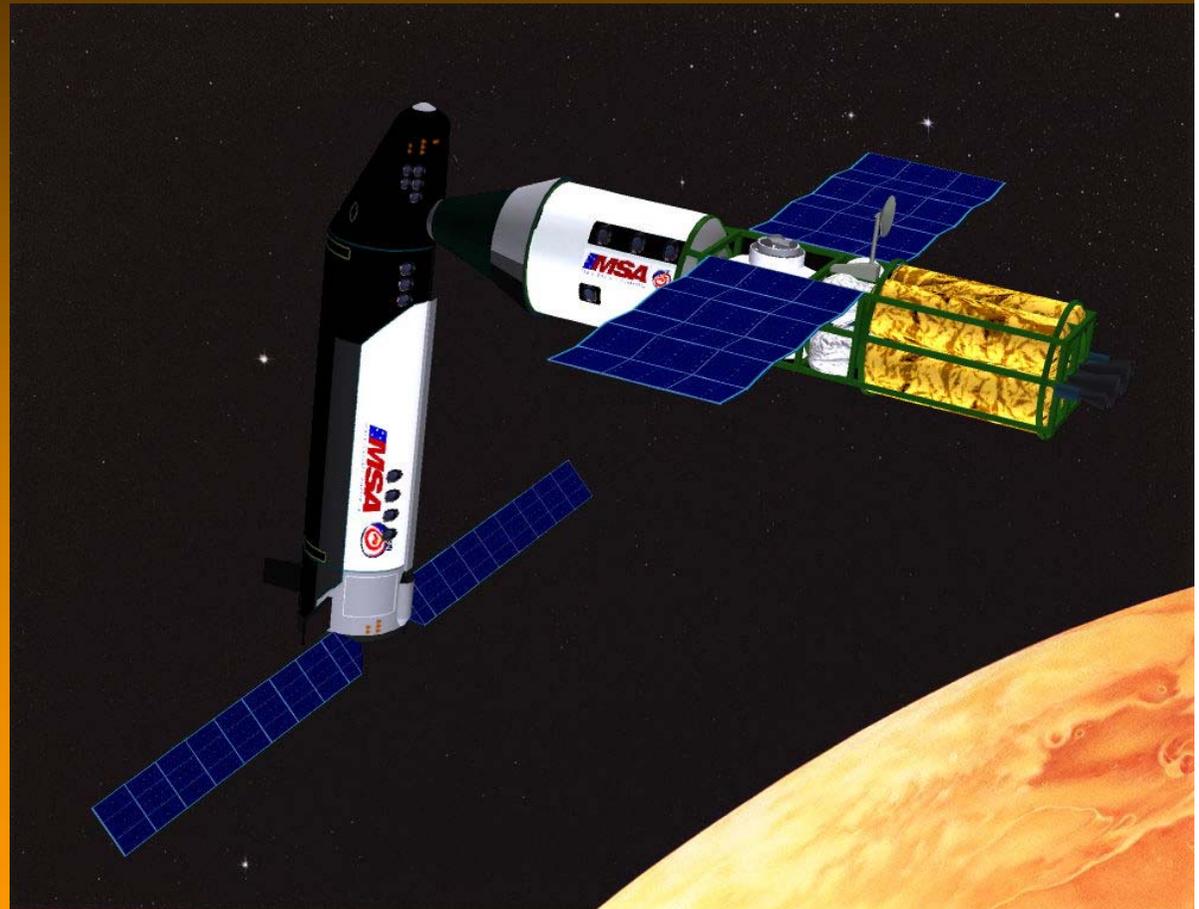
**1:4 RULE – 1 tonne on  
Mars = 4 tonnes in LEO**

**Ares 5 with MSA module**

## Reduction in consumables offers the best potential for mass reduction

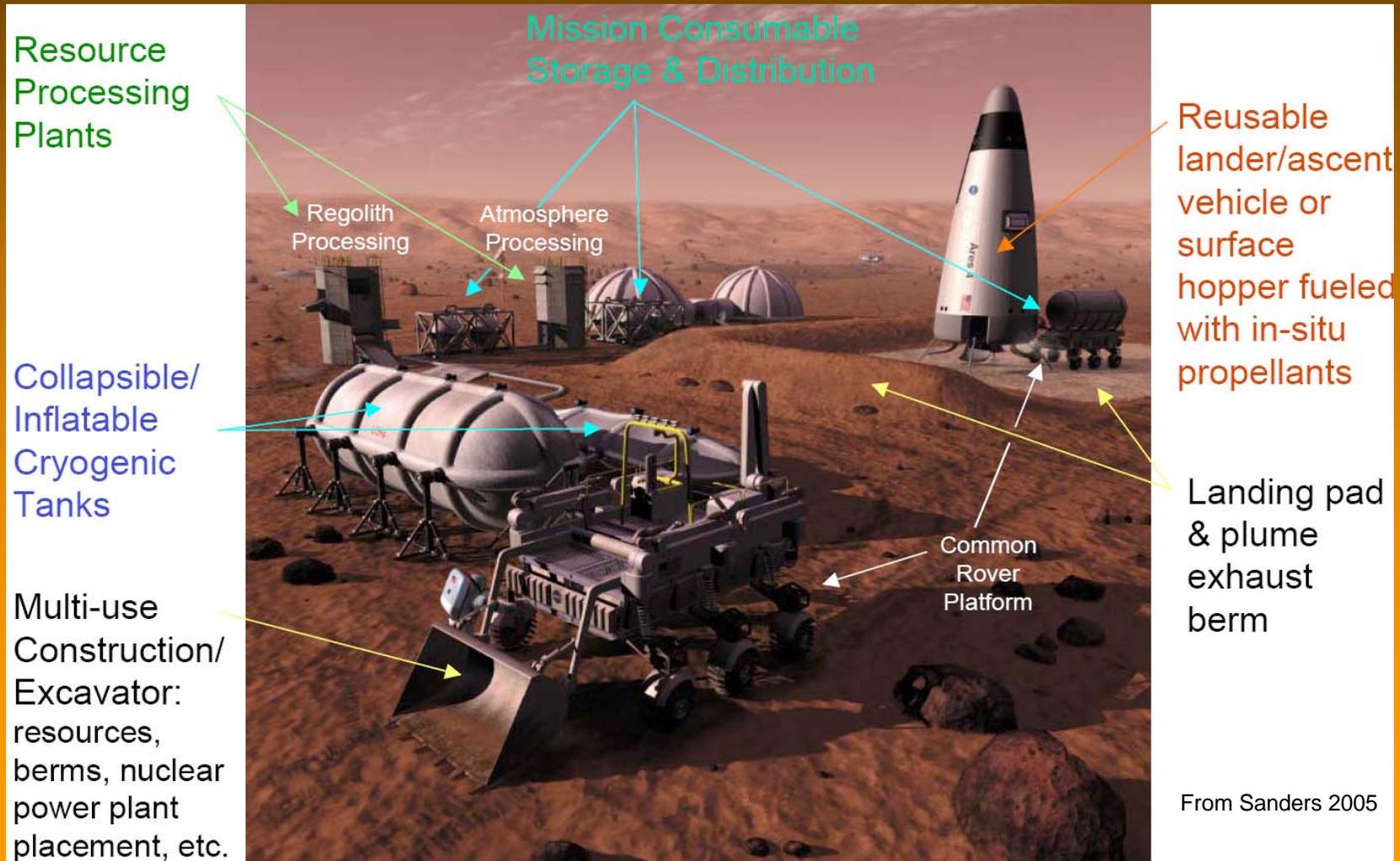
The MSA mission (four-persons on 600 day surface stay) will need:

- 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



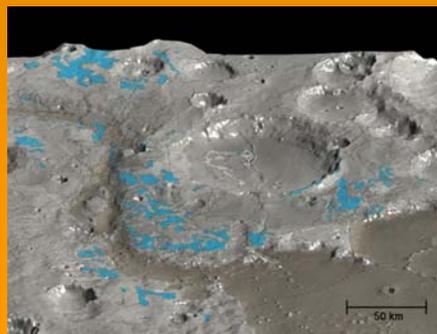
## *Atmospheric water*

- Global distribution
- Requires processing large volumes of air



## *Hydrated minerals*

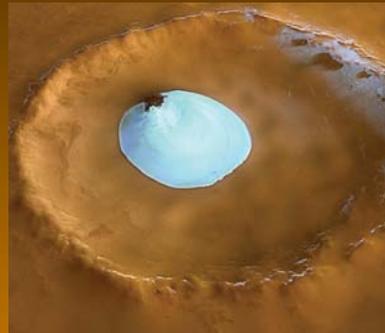
- Various scattered locations on Mars
- Easy extraction
- Known quality



# WATER ON MARS

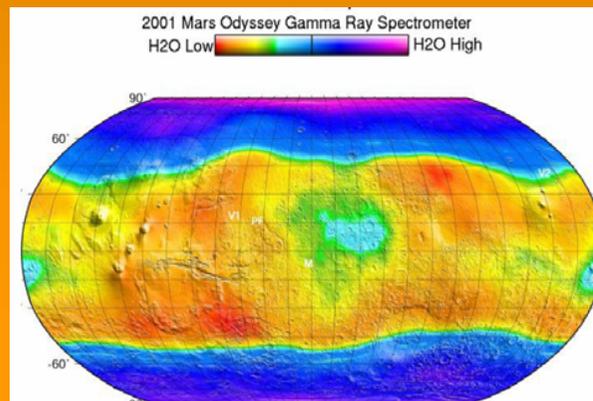
## *Polar ice*

- High latitudes
- Quality unknown



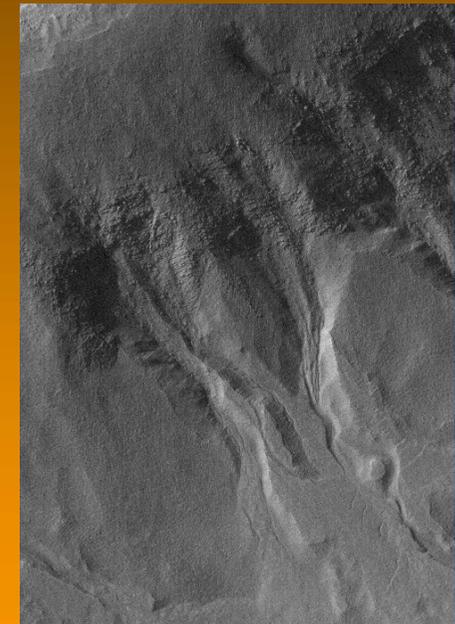
## *Ground ice*

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

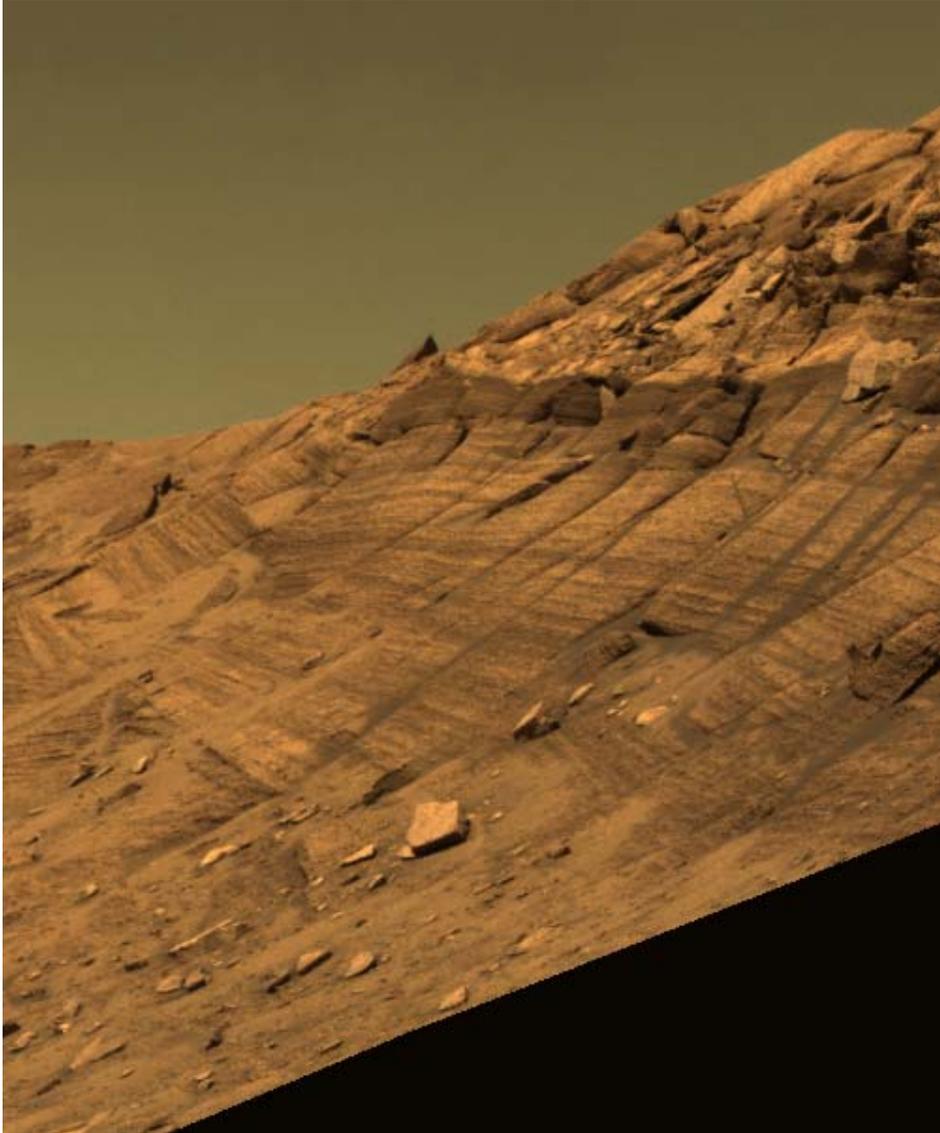


## *Shallow aquifers*

- 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 ( $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ ) = 51%  $\text{H}_2\text{O}$ )
- Kieserite ( $\text{MgSO}_4 \cdot \text{H}_2\text{O}$ ) = 14%  $\text{H}_2\text{O}$
- Hexahydrate ( $\text{Mg}(\text{SO}_4) \cdot 6\text{H}_2\text{O}$ ) = 47%  $\text{H}_2\text{O}$
- Bloedite ( $\text{Na}_2\text{Mg}(\text{SO}_4)_2 \cdot 4\text{H}_2\text{O}$ ) = 37%  $\text{H}_2\text{O}$

## OTHER COMMON HYDRATED MINERALS

### Calcium Sulphate

- Gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) = 14%  $\text{H}_2\text{O}$ 
  - Montmorillonite clay  
( $\text{Al}, \text{Mg}, \text{Fe}$ ) $_8$ ( $\text{Si}_4\text{O}_{10}$ ) $_3$ ( $\text{OH}$ ) $_{10} \cdot 12\text{H}_2\text{O}$ ) = 26%  $\text{H}_2\text{O}$

## 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 <sup>3</sup> )	Mass (kg)	Volume (m <sup>3</sup> )	Mass (kg)	Volume (m <sup>3</sup> )
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 <sup>3</sup> )	Area (m <sup>2</sup> )	Mass (t)	Vol. (m <sup>3</sup> )	Area (m <sup>2</sup> )	Mass (t)	Vol. (m <sup>3</sup> )	Area (m <sup>2</sup> )
<b>MD 54.0</b>	270	81.8	81.8	540	163.6	163.6	1080	327.2	327.2
<b>DRM 3.0 48.8</b>	244	74.0	74.0	488	148	148	976	296	296
<b>MSA 14.4</b>	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 ENVIRONMENT

## Requirements

- Prototype processing plant
- Suitable analogue site
  - Funding!

**A project for MSA?**



## **PROJECT 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

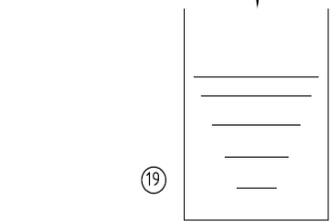
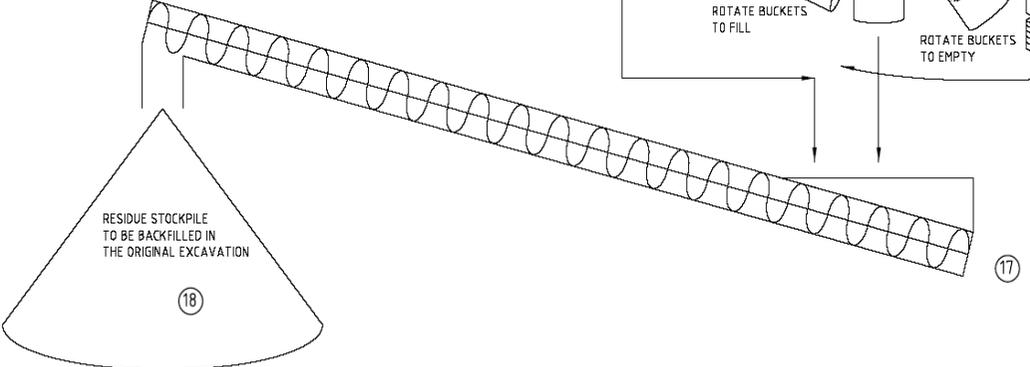
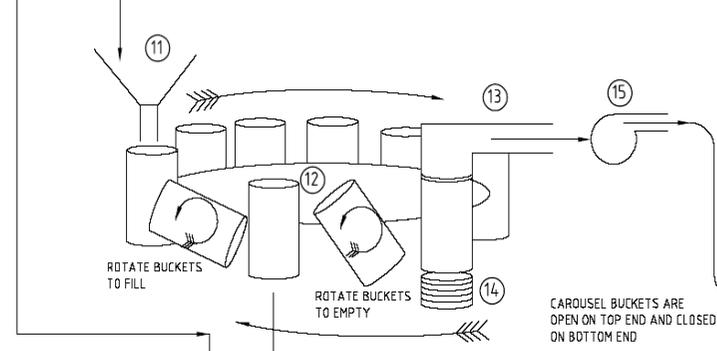
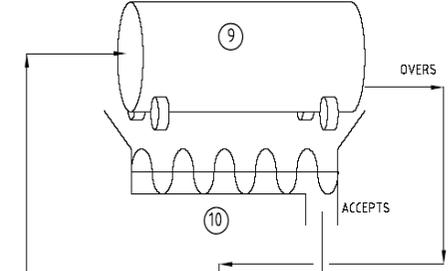
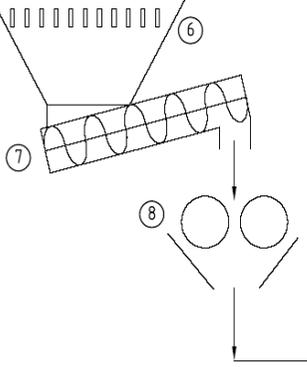
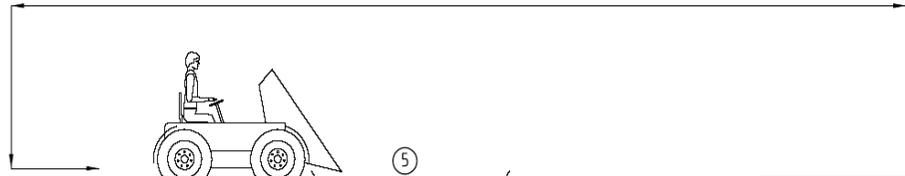
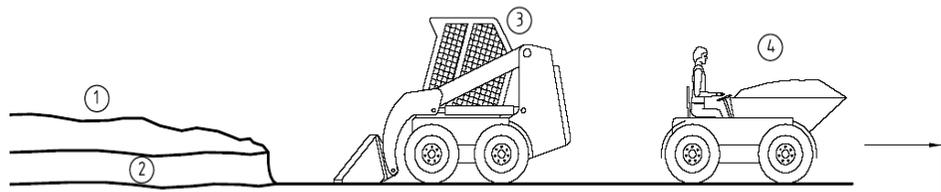
## Outcomes

- Geological documentation of the trial 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





INDEX

- ① REGOLITH
- ② EBSOMITE SALTS, GYPSUM 'PAY DIRT'
- ③ 'BOB CAT' FRONT END LOADER
- ④ FRONT TIPPING TRUCK
- ⑤ GRILL
- ⑥ HOPPER
- ⑦ SCREW CONVEYOR
- ⑧ ROCK CRUSHER
- ⑨ TROMMEL SCREEN
- ⑩ SCREW CONVEYOR
- ⑪ CAROUSEL BUCKET FEEDER
- ⑫ CAROUSEL AND BUCKETS
- ⑬ GAS COLLECTOR
- ⑭ HEATER
- ⑮ PUMP
- ⑯ RADIATOR
- ⑰ RESIDUE STOCKPILE CONVEYOR
- ⑱ RESIDUE STOCKPILE
- ⑲ COLLECTION WATER TANK

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

<b>Regolith required</b>						
	<b>20% recoverable water</b>		<b>10% recoverable water</b>		<b>5% recoverable water</b>	
	<b>Mass (t)</b>	<b>Volume m<sup>3</sup></b>	<b>Mass (t)</b>	<b>Volume m<sup>3</sup></b>	<b>Mass (t)</b>	<b>Volume m<sup>3</sup></b>
	0.5	0.33	1.0	0.67	2.0	1.33
<b>Over 7 days</b>	3.5	3.31	7.0	4.69	14.0	9.31
<b>Excavated m<sup>2</sup> over 7 days (0.5 m thickness)</b>	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:

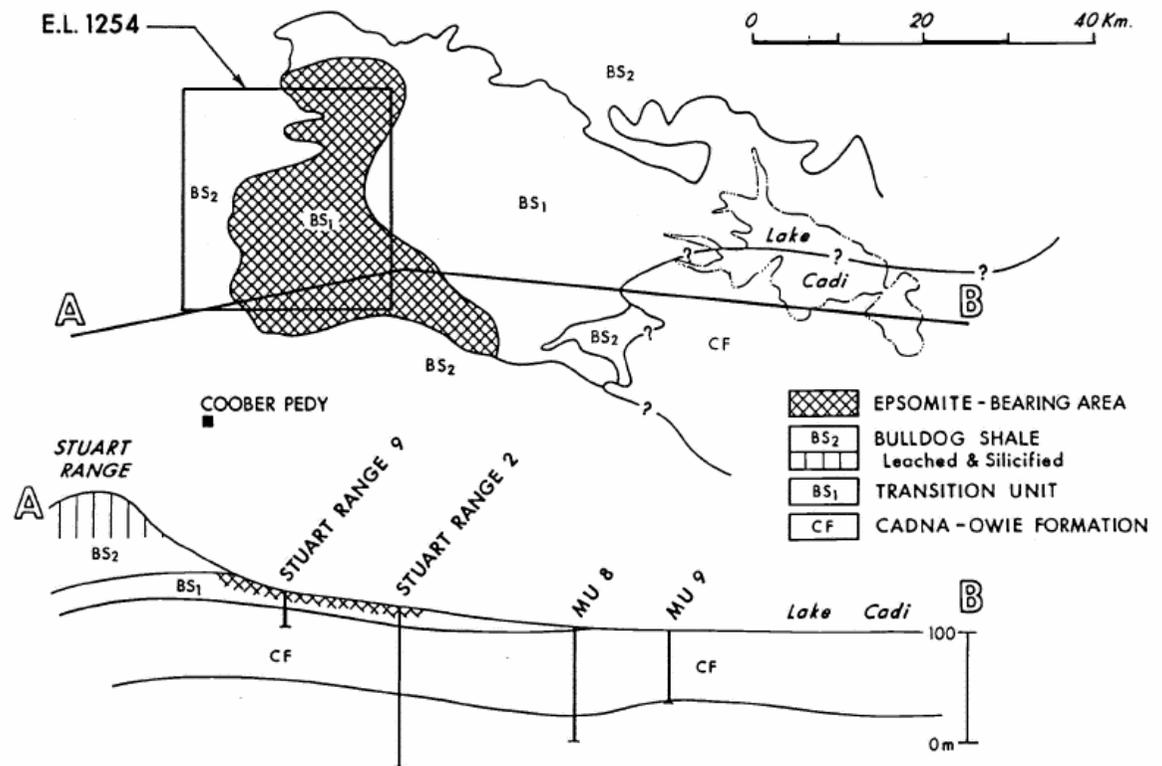
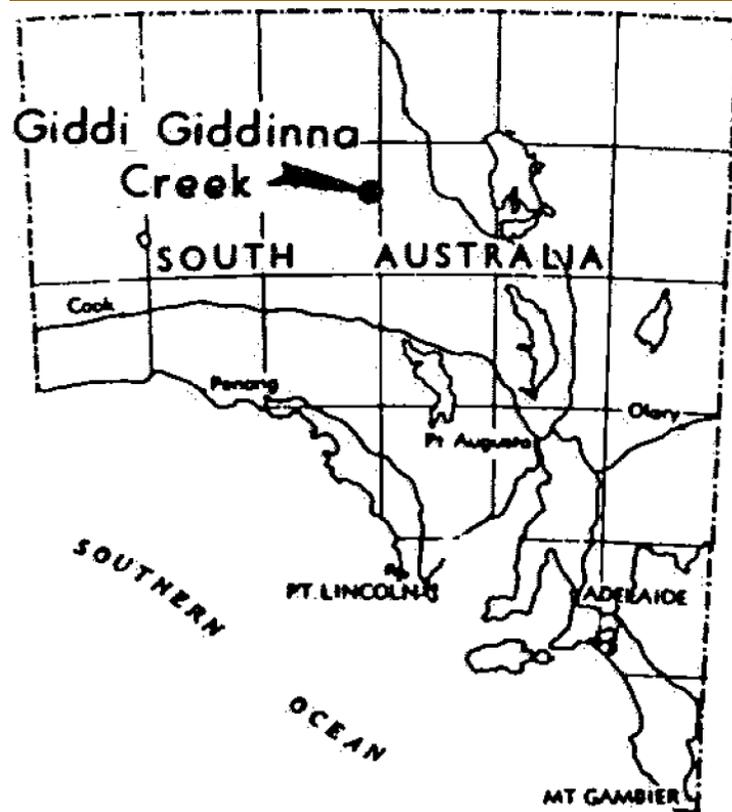
- ~10 Mars Direct missions ( 5% recovered water)
- ~100 X MSA missions
- ~500 X material at Moon Plain trial site

**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



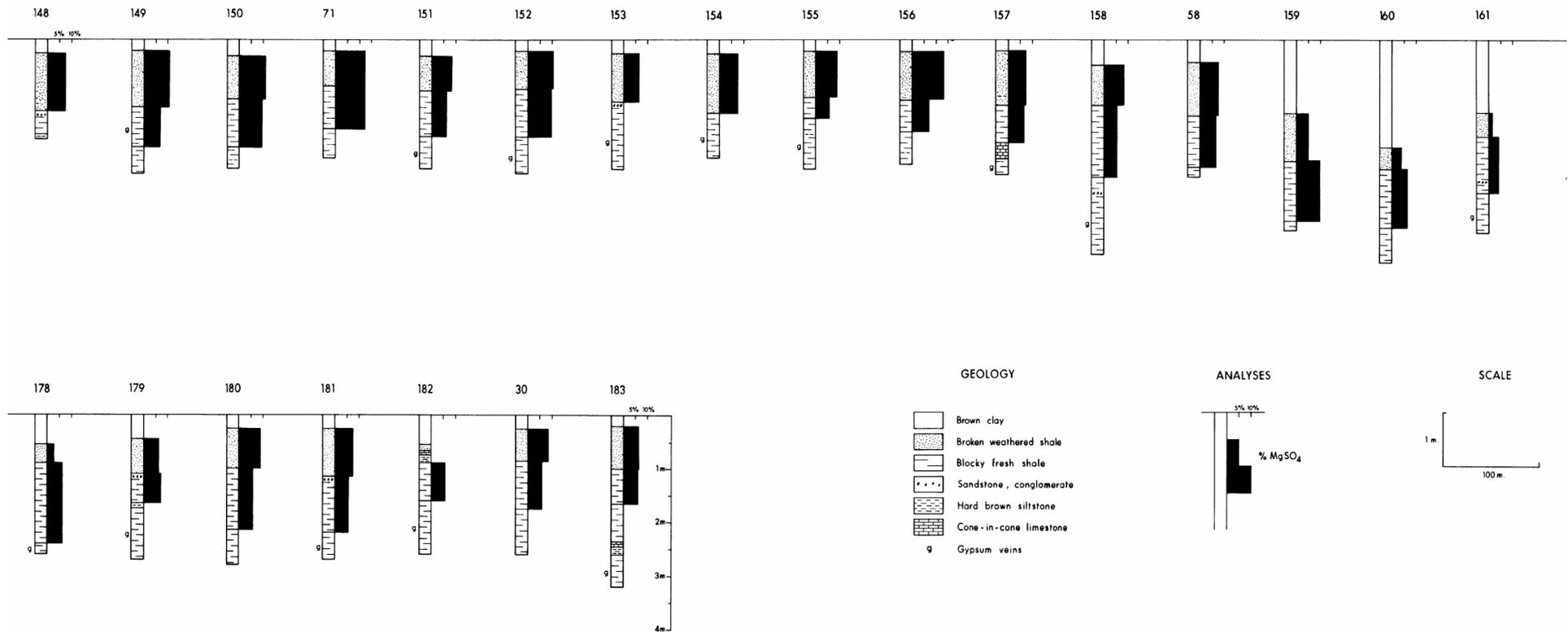
## WHY MOON PLAIN?

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



# CROSS SECTION OF DEPOSIT

- Host lithology weathered Bulldog Shale
- Depth generally < 2m
- Grades mostly 5-15% MgSO<sub>4</sub> (locally up to 22%)
- Equivalent to 2.5-8% water (max 11%)
- Note total water content will be higher (gypsum + clay + soil moisture)

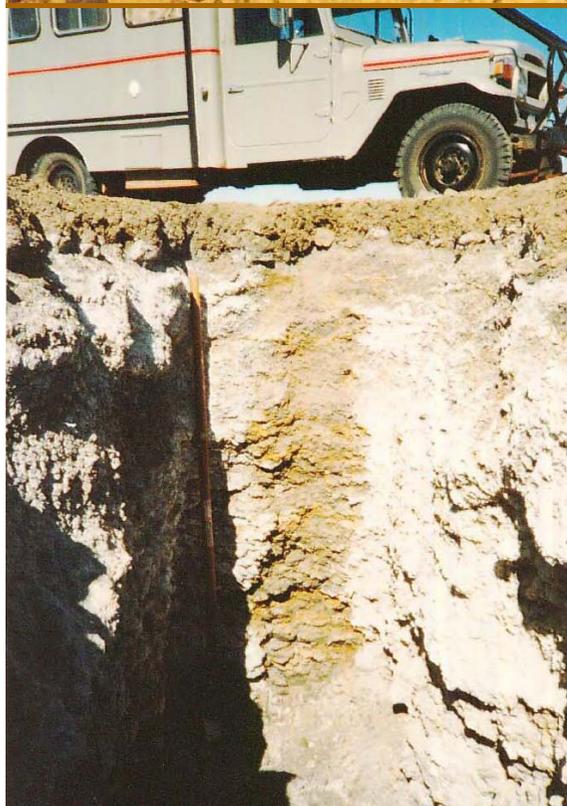
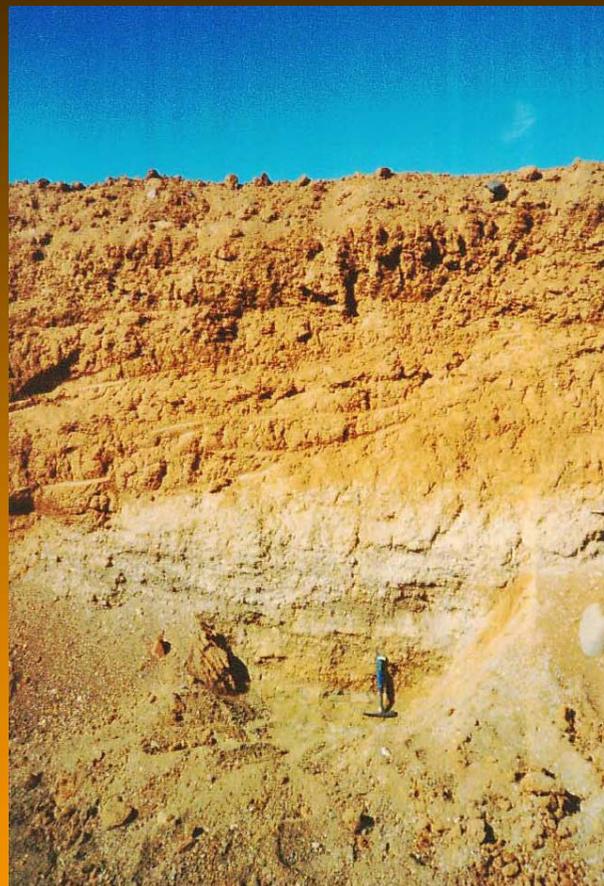


Looking southeast towards above sample pit from near edge of Benitos Clay cover; note change in colour of overburden.

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?**
- **Aquisition 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!**