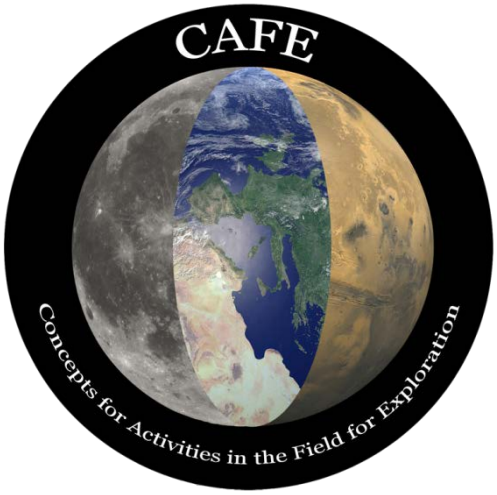
CAFE

Concepts for Activities in the Field for Exploration



Under ESA Contract # 4000104716/11/NL/AF

Executive Summary Report

Issue: 1

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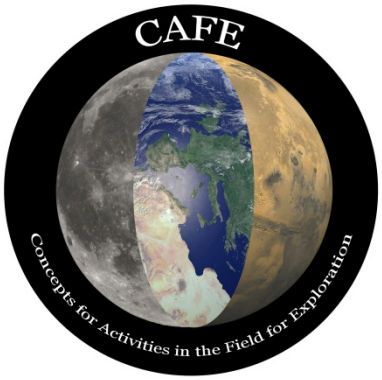


A considerable amount of supporting research and technology development has to take place on the Earth to allow humans to explore the Moon, Mars and beyond. The Concepts for Activities in the Field for Exploration (CAFE) project aims to support such aims in an international context by preparing a complete catalogue of terrestrial analogue environments that are appropriate for testing human space exploration-related scientific field activities. As no single analogue can provide an identical representation of landforms, materials and processes found on the Moon and Mars, it is necessary to select those analogues that best represent particular regions or processes of interest.

The current document provides an executive summary of activities carried out under ESA contract 4000104716/11/NL/AF. The study was led by the Open University UK, with support from ALTEC SpA (Italy) who contributed on the subject of human factors and related tools and technologies, and from Magna Parva Ltd (UK) who contributed expertise on tools and technologies for sample collection and analysis. The valuable contributions made by the attendees of the CAFE “experts meeting” convened under this study are gratefully acknowledged, as are the feedback, advice and support provided throughout the study by Dr Oliver Angerer.

2 Objectives and Requirements

The overall objectives of the CAFE study were to prepare for human space exploration related scientific field activities by preparing a complete catalogue of relevant analogue environments and providing scenarios and concepts for field campaigns in two high priority analogues.

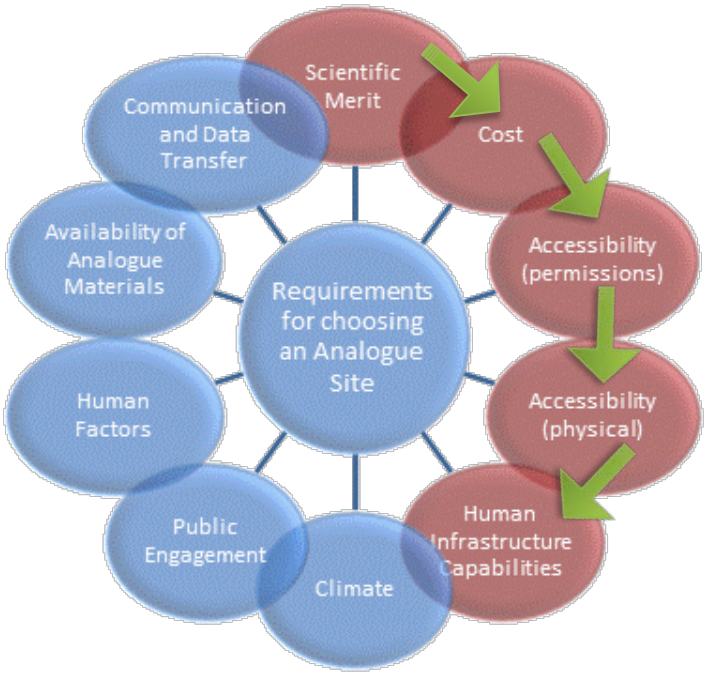
The tasks undertaken in the course of this activity involved the:

- organisation of an expert meeting, whereby requirements for exploration relevant analogue environments were produced;
- preparation of a catalogue of analogue environments and evaluation based on the previously defined requirements; and
- outlining of concepts for field campaigns in two of the highest priority analogues, as well as supporting technology developments.

3 CAFE Expert Meeting

The objective of this meeting was to bring together experts from different disciplines to discuss all relevant aspects of planetary analogue environments, such as planetary geology, astrobiology, technology, human factors and educational outreach to determine the requirements for exploration relevant analogue field studies. The invited participants reflected a wide range of interests that together covered the wide breadth of the goals of this study. The results of the expert meeting provided input to all activities of the CAFE study which involved the collation of requirements for selecting analogue sites and the analogue sites themselves.

The main criteria scientists and engineers take into account when choosing an analogue site for planetary analogue mission activities were discussed and rated on importance. The five requirements in red are sequential; the number one priority for choosing an analogue site, as determined by all the experts at the meeting, is scientific merit and relevance for the Moon and/or Mars. Once this criterion has been satisfied, the next consideration is the cost of the mission, followed by the accessibility of the site in terms of permits and physical access, and then the ability of the site to house the infrastructure needed for the mission to be run successfully. The requirements in blue are additional factors that need to be thought about and included in any decision making process but can be worked around if time and money allow.



Finally, a preliminary list of analogue sites was created through the expert presentations and group discussions during the meeting for priority incorporation into the catalogue.

4 Analogue Requirements

4.1 Exploration targets for the Moon and Mars

Detailed investigation into the sites on the Moon and Mars are important for future human exploration. On the Moon, important targets range from the ubiquitous presence of impact craters and their associated features, to volcanic constructs and terrains, granular flows and geological materials in the form of anorthosite and basaltic rocks. Locations that display evidence of frozen water and volatiles are also considered as these may prove to be of importance for future human exploration of the lunar surface. For Mars, the list of geological features is extensive due to the range of processes having operated on the planets' surface in comparison to the Moon, combined with the effects of liquid water. Impact features and volcanic landscapes are described, as well as fluvial features, aeolian processes, ice-related geomorphology, and subsurface water deposits; combined with their astrobiological potential. Many minerals and geological materials have been discovered on Mars and these have been investigated also.

4.2 Planetary Surface Activities

As part of the human effort currently being applied for planetary exploration, the various space agencies have proposed detailed mission scenarios for getting to the Moon and Mars. Surface operation mission architectures, human surface operations, logistics, supporting technologies, operative aspects, previous missions and an analysis of the difference between human surface exploration of the Moon and Mars have been documented. Factors influencing exploration include scientific merit vs. technology, daylight working hours, communication delays, trip duration and the effect on human physiology and psychology. Classes of human planetary surface activities and therefore terrestrial analogue activities include; robotic surveys, manned survey/human sortie, human in-situ analysis, human sample return, short traverse, long traverse and post-human robotic studies.

4.3 Tools and Technologies

An extensive description of tools and support technologies for planetary exploration field activities include those needed for terrain inspection and mission planning, sample acquisition and handling, sample storage and sample analysis, and mission infrastructure. This list is complimented with information on the technology readiness level of each instrument or process, the types of site where the tools would be useful, the substrates that the tools would work on and the infrastructure needed to be in place for these activities to be successful.

5 The Catalogue of Planetary Analogues

Planetary missions to the Moon and Mars have returned high-resolution images that show complex surface landforms in unprecedented detail. Spectral datasets from mission instruments reveal the presence of a wide array of mineral species on the surface. These discoveries are changing analogue site requirements for understanding the formation and processes occurring on our nearest neighbours, and for planning future exploratory missions. Analogue field sites are now expected to

include complementary examples of surface processes, rock types, mineral species, and microbial habitats as might be presently, or once were, present on the Moon and Mars. Over the last 60 years, the range and diversity of terrestrial analogues has expanded tenfold. The Catalogue of Planetary Analogues is a result of this growth and the need to collate these sites into a single space for use in scientific, engineering and mission planning activities.

The Catalogue of Planetary Analogues (The CPA) allows terrestrial analogue sites for important exploration targets on the Moon and Mars to be easily evaluated. Planetary analogue sites have been assigned for each of the features identified in the analogue requirements and from the expert meeting. An extensive list of analogue sites that can be used for astrobiological investigations is also included. In addition to scientific details; the catalogue includes information on location; environment; infrastructure available and needed for mission success; and key references.

At present around 90 sites have been identified, however, the CPA is a work in progress and will grow over time through user additions and future planetary mission results. The information included so far is a combination of literature research and contributions by academics, engineers and mission planners. As such some material may be currently missing or incomplete; however, as the information becomes available it will be included. The information provided is accurate at the time of writing and will be updated as necessary.

Name	Name	Name
Antarctic Dry Valleys	--Chebbi	Lonar Crater
Atacama Desert	--Lake Maider	Meteor Crater
Australia (central)	--Maider	Mistastin
Axel Heiberg Island	-Ouarzazate	-Discovery Hill
-Saline Perennial Springs	--Ben Haddou 1	-Cote Creek
-Polygonal Terrain	--Ben Haddou 2	Mount Etna
-Colour Lake Fen	--Stromatolites	Namibia
Barberton	--Travertine	Pavilion Lake
-Buck Reef	--Adad	-Kelly Lake
-The Josefsdal Chert	--Saoun	-Cariboo Plateau Lakes
Black Point Lava Flow	-Tan Tan	Pilbara
-Edge of BPLF and SP Lava Flow	--Sebkha Tazra	Ries Crater
Cinder Lake	--Sebkha Tah	Rio Tinto
Columbia River Flood Basalt	--Sebkha Oum Dba	Sudbury
-The Yakima Folds	--Sebkha Aridal	Sunset Crater
Golden	-Zagora	Svalbard
Haughton	--Zaouia	-Bockfjord Volcanic Complex
-Hydrothermal Supersite	--Zagora	-Ebbadalen Formation
-Impact Breccia Supersite	--Mhamid	-Murchison Fjord
-Ice Wedge Polygons	Iceland	-Adventtoppen & Hiorthfjellet
Ibn Battuta	-Askja	Teide National Park
-Alnif	-Eyjafjallajokull	-Minas de San Jose

--Tinertir	-Krysuvik	-Llano De Ucanca
--Alnif	-1783-1784 Laki Flow Field	-Cuevas Negras and Sima de Vicky
-Erfoud	Kamchatka	The Turpan Desert
--Rissani 1	-Avachinsky Area	Utah Desert
--Rissani 2	-Klyuchevskaya Volcano Group	-Kissing Camel Ridge
--Rissani 3	Kilauea	Yellowstone
--Kess Kess	-Ka'u Desert	-Grand Prismatic Springs
		-Chocolate Pots

Table 1: Analogue sites so far included in the Catalogue. Dark blue are the main analogue areas with the light blue cells indicating specific sites of interest.

6 Field Campaign Concepts

The sites within The Catalogue of Analogue Environments were evaluated to identify the top two most highly-rated sites. The sites were judged on their scientific merit, the cost of conducting fieldwork at them, the level of permissions needed, the ease or difficulty of accessibility, and the level of human infrastructure available or needed. These were ranked on a scale of 1 to 5 with 1 being the least scientifically relevant/hardest to get to/most expensive to work at; and 5 the best/ easiest/cheapest. The top 10 analogue sites were chosen.

A number of recommendations were suggested regarding the two analogue campaign concept studies proposed:

1. The sites should be evaluated on their scientific merit, followed by the costs involved and accessibility to the site and resources available to conduct the mission.
2. One site should allow analyses to be conducted that mimic physical and chemical features found on the Moon; and another the physical, chemical and astrobiological features on Mars.
3. The sites shall contain more than one geologic unit.
4. At least one site shall be based in a remote, extreme environment.
5. One campaign should simulate a short duration sortie mission; one a long duration sample return mission.
6. One campaign should be based in a 1 km area utilising single traverses, the other in a 20 km area to allow for multiple traverses.
7. One campaign should involve traverses that start and finish at a single point; the other traverses that start at the end of the previous traverse.

With these recommendations in mind Teide National Park in Tenerife and the area around the McGill Arctic Research Station on Axel Heiberg Island were chosen for concept campaign development.

6.1 Axel Heiberg Island

The scientific goal for this campaign was to assess the habitability of the area surrounding the McGill Arctic Research Station (MARS), and characterise any biological materials. The campaign was a Mars

analogue campaign. Five traverse plans were created on Axel Heiberg Island using MARS as the basecamp. Traverse 1 and 3 focused on the study of polygonal terrains as deep and shallow subsurface ice deposits on Mars could provide habitable niches for life. Traverse 2 and 4 lead to the anoxic cold perennial springs of Colour Peak and Gypsum Hill respectively. These springs and their mineral deposits are host to extremophilic microbial communities, similar to those that might have once existed or currently exist on Mars. Finally traverse 5 focuses on Colour Lake Fen, an ice covered lake near the MARS basecamp.

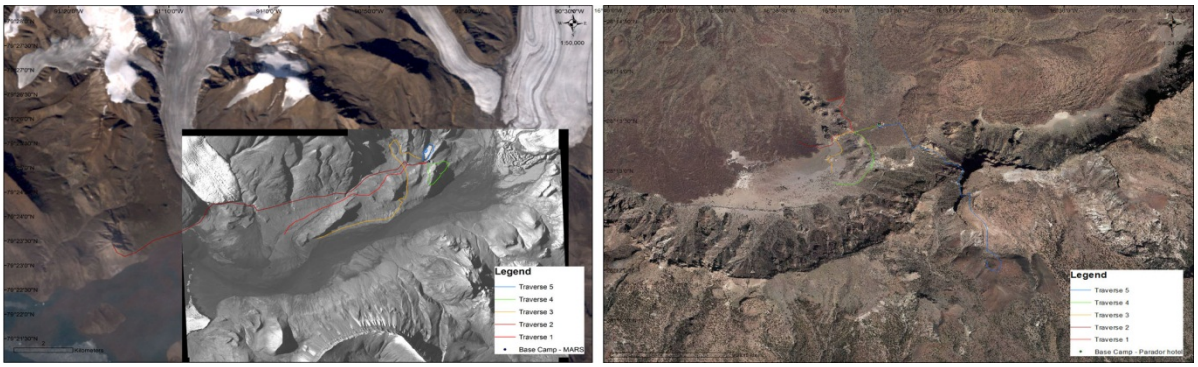


Figure: A) LANDSAT and IKONOS images of Expedition Fjord with the 5 traverses mapped. B) Aerial photograph of field area within Teide National Park with the 5 traverses mapped.

6.2 Teide National Park

The campaign concept at Teide focused on Teide as a lunar analogue. The scientific goal of the campaign was to understand the volcanic geology of the area and practice analysing such volcanic products using tools and equipment that could be used on the Moon. Specifically lunar-like palaeoregolith and soils were to be studied. Five traverse plans were created here to study multiple generations of lava flows, gullies, soils, palaeoregolith, scoria cones and possible geothermal deposits. The traverses focus around the Llano de Ucanca, which is located next to The Parador Hotel (basecamp).

7 Web Portal Pilot Study

This study included a feasibility study on a number of web-based applications that may be suitable to host the Catalogue of Planetary Analogues as well a study into the level of moderation required, user interface and “searchability”, and cost estimates. It is proposed that a website would be best suited to display the database online, hosted by ESA with a moderator to validate content and keep the site looking and working professionally.

8 Summary

The CAFE study has produced a detailed summary of sites on the Moon and Mars that are important for planetary exploration activities along with a catalogue of terrestrial analogue sites which could be used to simulate them. From these, two concept field studies were created for a number of lunar

and Martian geological, chemical and astrobiological features. A website has been proposed as the best way to bring the database online and for use by academics, educators and the interested public.