# The Planetary Terrestrial Analogues Library

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The **P**lanetary **T**errestrial **A**nalogues **L**ibrary project aims to build and exploit a spectral data base for the characterisation of the mineralogical and geological evolution of terrestrial planets and small Solar System bodies.

Basis for the library are a collection of natural **field-collected** and artificial planetary (often Martian) analogue materials as well as materials, which have been altered in **laboratory** experiments.

## Techniques

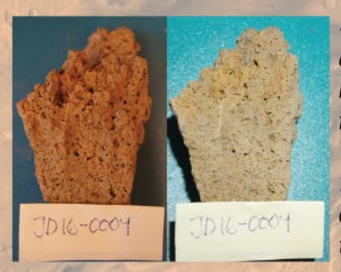
For one example sample (JD16-0004), which was collected at a road cut of the John Day Formation in Oregon, USA, we here introduce the products we will have in the PTAL data base. This sample is part of a weathering profile in basalt and could be considered analogous to the mineralogical setting of Mawrth Vallis, Mars.

Starting with the collection site:



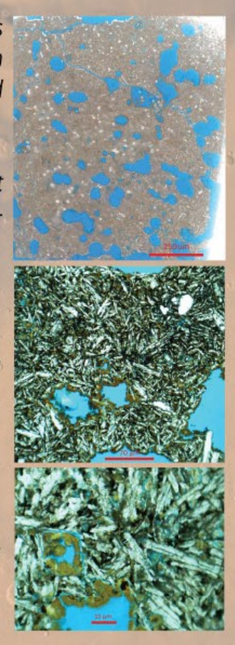
*One of the field sites for sample collection is the John Day Formation in Oregon, USA (left). At Picture Gorge along the road (right), for example, we collected 295 g of the 16 million years old altered basalt, part of the Columbia River Basalt group.*

Sample characterisation includes photo and thin section:



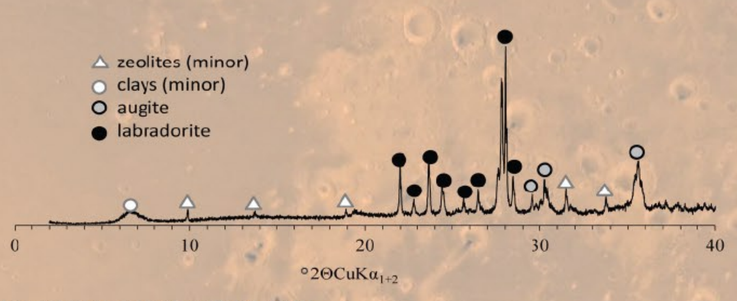

*< Sample photos are provided in natural (left) and flash (right) light.*

*> Thin sections at different resolutions.*



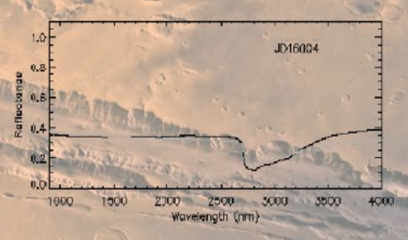
This provides a first order identification of minerals present, in this case for example: Feldspars, mostly labradorite, in a very fine matrix. Walls of voids (filled with blue epoxy) coated with zeolites. Some of the feldspars appears weathered. The fine grained matrix consists mostly of augite and plagioclase.

The **XRD** spectrum confirms the presence of major components such as labradorite, augite and minor component: e.g., Zeolite and clays.




*The XRD pattern for JD16-0004.*

***Near-Infrared Hyperspectral Imaging*** can be performed both on satellite and landed platforms, and is a non-destructive technique to detect most potential constituents: silicates, oxides, salts, hydrated minerals, ices and frosts, as well as organic compounds, discriminating between specific members in each family (e.g. low and high Ca pyroxenes, or Mg and Al rich phyllosilicates). The Flight Spare of MicrOmega with a FOV of 3.2 mm$^2$, IFOV of 25 µm, and a λ range of 1-3.5 µm. MicrOmega is used when the sample to be analyzed is heterogeneous. These samples correspond to the bulk samples. Otherwise a laboratory Perkin Elmer FTIR point spectrometer with a FOV of 500 µm and a λ range of 0.9-4.1 µm is used for homogeneous samples, and the spectral information provided is sufficient for characterization. All samples can be studied as bulk, fine and coarse graind powders.



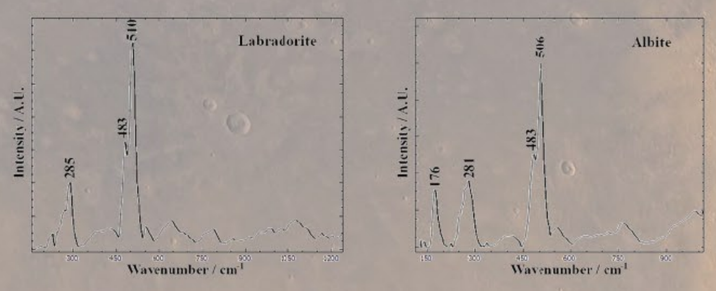

| XRD Results | Raman Results | NIR Results |
|---|---|---|
| feldspar | feldspar | |
| labradorite | labradorite | |
| augite | | NO pyroxene |
| zeolite | | NO zeolite |
| | hematite | |
| | clinoptilolite (K) | |
| | | smectite |

*For sample JD16-0004 in the NIR spectrum smectite is identified, but neither pyroxene nor zeolite were identified.*

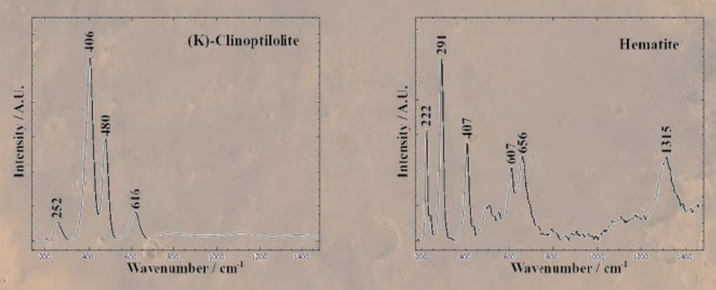
When comparing the different methods we identify different mineral components. This evaluation of the comparision of the different methods is dicussed in the poster by Lantz et al. on this conference.

***Raman Laser Spectroscopy*** is a powerful technique used in a wide range of applications from mineralogy to biosciences or industry. The Raman spectrum shows very sharp bands, which allow unambiguous molecular identification of materials.

Raman study of sample JD16-004 was performed by using two laboratory systems in a complementary way. The overall characterization of fine powder was carried out through the RLS system, which is provided with a neodymium-doped (1%) yttriumaluminum garnet ceramic (Nd:YAG) excitation source emitting at 533nm. On the other hand, a micro-Raman equipped with a He-Ne 632.8nm excitation laser and coupled to a Nikon Eclipse E600 microscope was mainly used for the study of coarse powder.

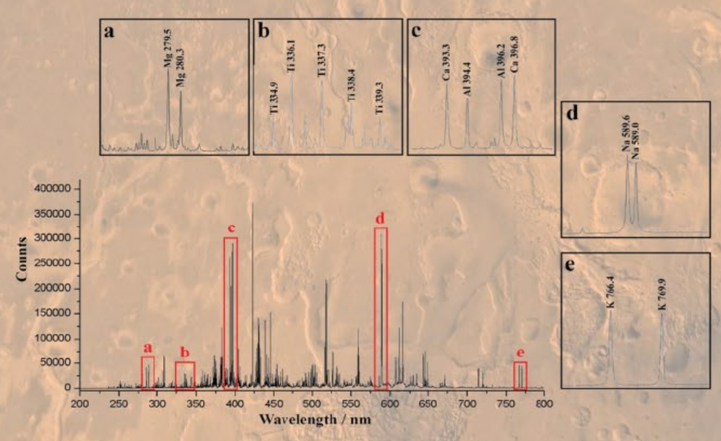



*The vibrational peaks (left) detected at 285, 483 and 510 cm$^{-1}$ proved the presence of labradorite (feldspar group, $(Ca,Na)(Al,Si)_4O_8$). Vibrational profile (right) characterized by the presence of intense peaks at 176, 281, 483 and 506 cm$^{-1}$, indicating the additional presence of albite (feldspar group, $NaAlSi_3O_8$).*




*Zeolites (left) were also identified thanks to the detection of the characteristic vibrational signals of (k)-clinoptilolite ($K_6(Si_{30}Al_6)O_{72}\cdot 20H_2O$) at 251, 406, 480 and 616 cm$^{-1}$. The Raman spectrum (right) obtained from one of the red crystals observed in the coarse powder is seen to consist of hematite ($Fe_2O_3$, 222, 291, 407, 607, 656 and 1315 cm$^{-1}$).*

***Laser-Induced Breakdown Spectroscopy*** is an active analytical technique that makes use of a laser pulse to analyse materials of interest at a distance by producing short-lived plasma with atoms in an excited state. Spectral analysis of the emitted light makes it possible to identify elements present in the sample from their characteristic emission lines: major elements (O, Na, Mg, Al, Si, K, Ca, and Fe), minor and trace elements (i.e., H, Li, Be, C, N, F, P, S, Cl, Ti, Cr, Mn, Ni, Cu, Zn, Rb, As, Sr, Cd, Cs, Ba, Pb).




*The LIBS spectrum from analysis of sample JD16-004 over the spectral range of 200–800 nm provides a very complex profile dominated by Fe emission lines. Even though the large number of iron peaks makes it difficult to distinguish signals proceeding from additional elements, the presence of magnesium, titanium, calcium, aluminum, sodium and potassium has been ascertained by the detection of their fingerprint emission lines: 279.5 and 280.3 nm for Mg (in a), 334.9, 336.1, 337.3, 338.4 and 339.3 for Ti (in b), 393.3 and 396.8 for Ca (in c), 394.4 and 396.2 for Al (in c), 589.6 and 589.0 for Na (in d) and 766.4 and 769.9 for K (in e).*

All collected samples of rocks and the "produced" samples of their alteration / weathering products will be characterised as input for the **spectral library** with standard commercial and dedicated spacecraft instrumentation (NIR, RAMAN, LIBS, but also XRD, thin sections as decribed above) under laboratory conditions, and where possible on in-situ field campaigns at Earth analogue sites.

All data will be published and fed to the **data base**, which will allow **users** to jointly interpret laboratory results and newly gathered in-situ or remote sensing data using **instruments** (LIBS, NIR, RAMAN) on board of current and future space missions (e.g., Hayabusa-2, Curiosity, ExoMars, Mars2020). The main aim of the database is the use of spectra stored for purposes related to comparison, identification, quantification and spectral calculation when spectroscopic instruments such as NIR, Raman and LIBS operate in planetary missions and/or analysing materials in the field or in the laboratory.

***Mineral Alteration Experiments***: Natural and artificial analogue materials will be altered in Parr and Hastelloy reaction bombs in aqueous solutions under various controlled experimental conditions to analyse alteration pathways. All products will be identified by XRD and SEM analyses. Under controlled conditions and documenting rock alteration of analogue materials, the impact of varying environmental conditions (e.g., gas pressure and composition, temperature, pH-value) can be quantified.



*Experimental setup 1: Closed systems, 3 weeks duration at a temperature of 120 °C, a water-rock ratio of 20, in pure water, the rock powder grains are < 10 µm under varying atmospheres : 100% N2, 90% N2/10% CO2, 100% CO2. First results are presented in Viennet et al. 2017.*



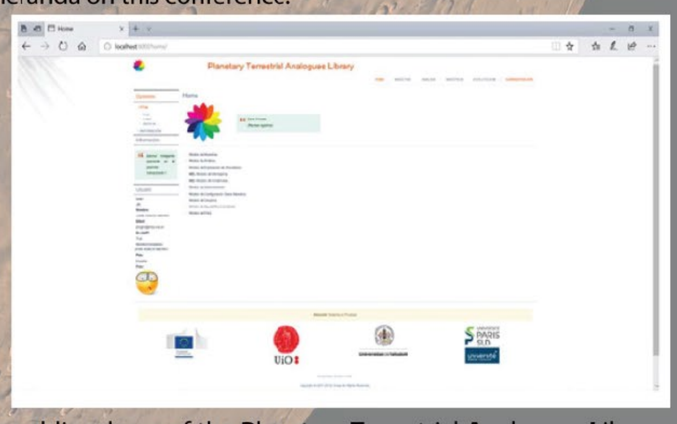
*Experimental setup 2: Open system with different "shelfs" at a flow rate of 0.05 ml/min (tres 53 H), 3 week duration ,the rock powder grains are < 10 µm of basaltic glass at 3 different levels, and the experiments are run at for example temperatures of 150°C, input solutions and atmospheres have been varied to study wethering profiles under potential Martian conditions throught Martian times.*

***Synergy – Joint Inversion***: The terrestrial analogue sites and their materials are useful for testing technology and instruments for planetary exploration, such as the evaluation of combined analytical conditions, to test standards and portable instruments, and to define the Planetary Terrestrial Analogues Library spectral input data. Because of the complementarity of their selection rules, Raman and IR spectroscopy are ideal to be combined for analysis of minerals and organic compounds. All natural, artificial and alteration product samples will be characterised by each of the sensing methods.

## PTAL – The spectral library

The goal of the **P**lanetary **T**errestrial **A**nalogues **L**ibrary database is to allow the use of spectra stored for purposes related to comparison, identification, quantification and spectral calculation when spectroscopic instruments such as NIR, Raman and LIBS operate in planetary missions and/or for analysing materials in the field or in the laboratory. The spectra are classified in close correlation with the samples from which they were obtained.

This data base features spectral tools allowing for the spectral data treatment and normalisation, such as baseline correction, intensity normalisation, instrument response correction, and includes linear combination (e.g., simple difference), automatic identification and pseudo-quantification by specific bands or spectral regions. Implementation plans are the integration of the database management and algorithms in an end-user platform with graphical interfaces for the use of the data and analysing tools. Compare for details the poster by Veneranda on this conference.




The public release of the **P**lanetary **T**errestrial **A**nalogues **L**ibrary will be at the end of year 2020.

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