The EXOMHYDR project reveals that volcanic activity of Mars is only dormant, not extinct, and that hydrothermal activity should be ongoing

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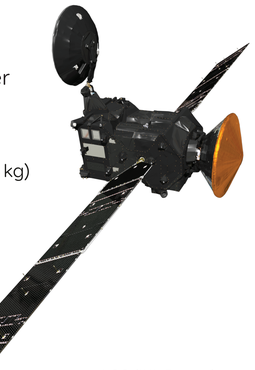
ExoMars TGO Launch. Credit: ESA

ExoMars Trace Gas Orbiter



Science orbit: 400x400 km
Mass: 3755 kg (instruments 114 kg)
Science orbit inclination: 74°
Period of science orbit: 2h
Recurrence time: 30 days

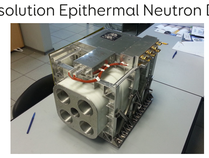
NOMAD (Royal Obs., Belgium)
Nadir and Occultation for Mars Discovery

1 UV-VIS spectrometer: 0.2 - 0.65 µm
2 IR spectrometers: 2.2 - 4.3 µm

ACS (IKI, Russia)
Atmospheric Chemistry Suite

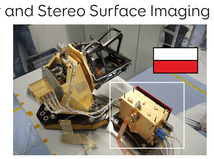
1 NIR spectrometer: 0.7 - 1.7 µm
1 MIR spectrometer: 2.2 - 4.4 µm
1 TIR spectrometer: 1.7 - 17 µm

FREND (IKI, Russia)
Fine Resolution Epithermal Neutron Detector



1 neutron detector 0.4 eV - 500 keV
1 neutron detector 0.5 MeV - 10 MeV

CaSSIS (Univ. Bern, Switzerland)
Colour and Stereo Surface Imaging System

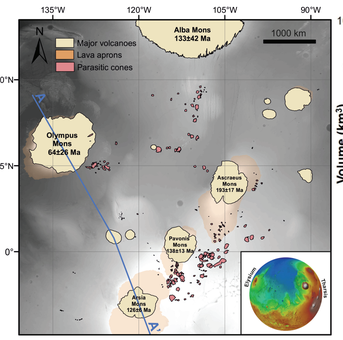


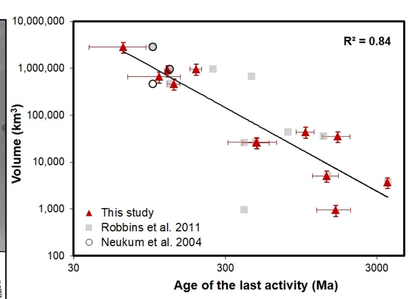
SRC PAS contribution: power converter

4 filters (Pan, Blue-Green, 2 NIR)

In April 2018, five months after the beginning of the EXOMHYDR project, the ESA/Roscosmos ExoMars Trace Gas Orbiter (TGO) started science observations, aiming in particular at characterising with two spectrometer suites, ACS and NOMAD, the sources of CH4 sporadically detected earlier by other instruments. EXOMHYDR is dedicated to the understanding of the geology of past and current hydrothermal sites in volcanic regions of Mars which might host some of these CH4 sources. The TGO spectrometers have not yet identified CH4 in the atmosphere of Mars. However, geological analyses conducted under EXOMHYDR are revealing that the largest volcanic area of Mars, the Tharsis bulge, must still be magmatically active, though volcanically dormant at present, implying ongoing hydrothermal activity, and providing a rationale for some of the earlier CH4 detections. Using the CaSSIS 4-band stereo camera of TGO (to which the Space Research Centre PAS has technologically contributed), we are also reconstructing the succession of volcanic and tectonic activity in Tharsis since its formation ~4 Gy ago to understand the context of the Tharsis hydrothermal activity better. Using the comprehensive dataset of observations from the PFS instrument (to which SRC PAS contributed too) of Mars Express (ESA), a global study of Martian surface temperatures has also been undertaken that will help determine whether abnormally hot regions currently exist. The results of the project help interpret future CH4 detections in the atmosphere on Mars by ExoMars TGO, as well as the heat flow and seismic data being collected by NASA's InSight mission.

New age dating of the last volcanic activity at the giant Tharsis volcanoes and associated smaller edifices



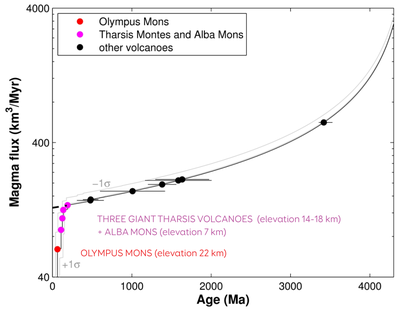


The most recent lava flows of each volcanic edifice is inversely proportional to the total edifice volume.

After a coeval beginning of volcanic activity in the entire Tharsis province in Early Noachian (~4.5 Ga), small magma reservoirs would have stopped working early, yielding smaller volcanoes, whereas larger magma reservoirs underneath the largest volcanoes lasted longer and might be still active.

Volcano volume vs. age of the last activity at the 12 summit calderas in the Tharsis volcanic province. Note the high correlation coefficient. The volume error bars represent the average relative difference between volcano volumes calculated using two different methods (see the Method section). The age relative error bars are derived from the number of craters used to fit an isochron to the determined Crater Size Frequency Distribution.

Absence of observed volcanic activity in the last decades cannot hide that it was ongoing between 3.5 Ga and a few million years ago.



Modelled magma flux in the Tharsis province vs. age. The dots represent the 12 largest Tharsis volcanoes. Dot age represents the last volcano activity. The corresponding magma flux rate is the total flux in Tharsis at this time. Olympus Mons and some other giant volcanoes (pink dots) do not go in line with the rest of the model and are possibly still active. The model predicts a decrease of the total Tharsis eruptive flux from 164 to 129 km³/myr between 1000 and 200 Ma. This implies that an ongoing average flux of ~80-120 km3/myr would be more realistic than the assumption of a completely extinct volcanism. This is in line with the estimated current global Martian flux of 8-400 km³/myr Kiefer et al. 2015).

We propose that volcano volume is controlled by a function of age (A) and initial magma reservoir volume. The shape of this is likely similar to a function of crustal production for Mars. Approximating the function of crustal production for the 4.5-0.0 Ga time interval from Kiefer et al. (2015), we obtain volcano volume as a fonction of age and initial magma reservoir volume. We then perform iteration of the Kiefer function using the 12 edifice volumes and the 12 ages (as a set of 24 constraints), and obtained the final function, which predicts the volume evolution of all 12 volcanoes over time. Magma flux over time is obtained from its derivative for a given volcano, and summing of the 12 derivatives predicts the total eruptive magma flux over time in the Tharsis area under the assumption that the whole erupted material would be enclosed in the 12 volcanic cones.

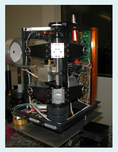
The Tharsis magma flux is found to decrease exponentially with time from >800 km³/myr at the birth of Tharsis, to ~80-120 km³/myr today. These values are for the erupted lavas only; they do not take the magma intruded in the crust and the low-density residuum into account. To maintain high volcano topography, the erupted volumes need to be only a small fraction (1/5th-1/10th) of the total magma generated.

We calculate the current rate of production of magma currently being stored for tomorrow's eruptions.

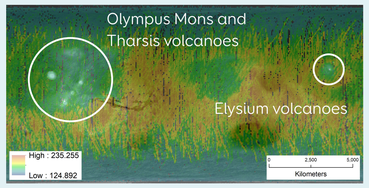
Cited reference: Kiefer W. S. et al. 2015, Geochem. Cosmochem. Acta 162, 247–258.

Are there surface temperature anomalies related to ongoing magmatic heating? (in progress)

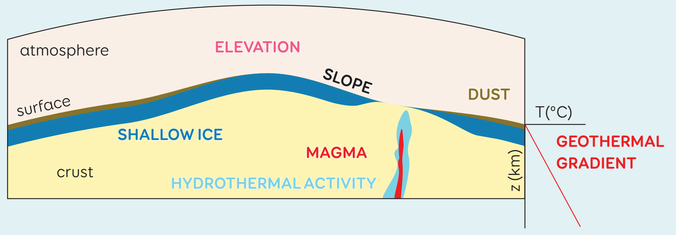
NIGHT TIME SURFACE TEMPERATURE OVER 9 MARTIAN YEARS (since 2004)



Planetary Fourier Spectrometer
(INAF Italy, SRC PAS Poland)
ESA/Mars Express mission



MAIN FACTORS INFLUENCING SURFACE TEMPERATURE AT NIGHT TIME



EVALUATION OF CONTRIBUTORS TO THE OBSERVED TEMPERATURES

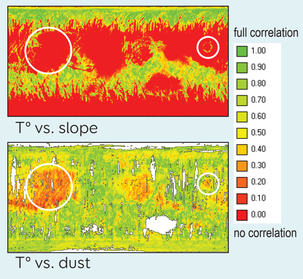
SLOPE

No correlation between nighttime surface temperature and topographic variations

DUST

No correlation between nighttime surface temperature and dust distribution

Fuzzy Kappa statistics



ELEVATION

As expected, high volcanoes are correlated with low night time temperature.

SHALLOW ICE

Correlation with hydrogen abundance from FREND (currently in acquisition) willhelp assess if H2O at depht < 1 m is correlated with night time surface temperature

MAGMATIC and HYDROTHERMAL ACTIVITY

Temperature variations that do not follow seasonality nor shallow ice distribution will inform on possible presence of magmatic and/or hydrothermal activity at depth.

TEAM project international publication activity: current state of the art

Peer-reviewed: Processes on Mars:
Ciazela, J., Mège, D., Pieterek, B., Ciazela, M., Gurgurewicz, M., Lagain, A., Tesson, P.-A. Active magmatism in Tharsis on Mars. Submitted to Nature Geoscience.
Tesson, P.-A., Conway, S., Mangold, N., Ciazela, J., Lewis, S., Mège, D. Evidence for thermal fatigue on Mars from rockfall patterns on impact crater slopes. Submitted to Icarus.
Ciążela, M., Gurgurewicz, J., Ciążela, J., Mège, D., High resolution thermal inertia mapping of sloping terrain on Mars: an Apparent Thermal Inertia-based method, in revision for Icarus.
Peer-reviewed: Terrestrial analogues:
Rooney, T., Krans, S., Mège, D., Arnaud, N., Korme, T., Kappelman, J., and Yirgu, G., 2018. Constraining the magmatic plumbing system in a zoned continental flood basalt province. Geochemistry, Geophysics, Geosystems, https://doi.org/10.1029/2018GC007724.
International meetings and conferences: Processes on Mars:
Ciążela, J., Mège, D., Pieterek, B., Ciążela, M., Gurgurewicz, J., Lagain, A., Tesson, P.-A., 2019. Largest Tharsis volcanoes keep growing and mark > 4 Ga lasting Martian hot spots. 50th LPSC, Abstract 1354.
Massironi, M., De Toffoli, B., Pozzobon, R., Mège, D., Marinangelli, L., Gurgurewicz, J., Pompilio, L., Rossi, A.P., Sauro, F., Pajola, M., Lucchetti, A., Tornabene, L., Cremonese, G., Thomas, N., 2019. Late laval flows and hydrothermal alteration in Ladon basin, Mars. Geophys. Res. Abs. 21, EGU2019-19135.
Gurgurewicz, J., Mège, D., 2018. Deep tectonics exposed in northern Valles Marineris, Mars. EPSC Abstracts, 12, EPSC2018-430.
Mège, D., Ciążela, M., Pirajno, F., 2018. The role of ACS in the EXOMHYDR project. Invited talk, ACS Science Working Team, Guyancourt, April 5, 2017.
Mège, D., Gurgurewicz J., 2018. SHARAD dielectric view of the Ladon site, a Ladon cross_section, and joint analysis of VNIR +IR data for the CRISM cube covering the CaSSIS image of Ladon. Invited talk, CaSSIS SWT meeting, Bern, September 25, 2018.
Mège, D., Gurgurewicz, J., 2018. Mapping of regional C-C'-S shear zones on the floor of Valles Marineris troughs. EPSC Abstracts, 12, EPSC2018-739-1.
Mège, D., Gurgurewicz, J., Douté, S., Schmidt, F., Schultz, R.A., 2019. Brittle-plastic shear zones on Valles Marineris floor: identificaifon and implications. 50th LPSC, Abstract 2064.
Pieterek, B., Ciążela, J., Mège, D., Lagain, A., Tesson, P.-A., Ciążela, M., Gurgurewicz, J., Lagain, A., Muszynski, A., 2019. Parasitic cone sin the Tharsis volcanic province on Mars: implications for its recent magmatic plumbing system. 50th LPSC, Abstract 1369.
Pieterek, B., Ciążela, J., Mège, D., Lagain, A., Tesson, P.-A , Ciążela, M., Gurgurewicz, J., Muszynski, A., 2019. Link between parasitic cones and giant Tharsis volcanoes: new insights into the Tharsis magmatic plumbing system. Geophys. Res. Abs. 21, EGU2019-12535.
Tesson, P.-A., Conway, S., Mangold N., Ciążela, J., Lewis, S., Mège, D., 2019. Evidence for thermal fatigue on Mars from rockfall patterns on impact crater slopes. 50th LPSC, Abstract 2352.
Tesson, P.-A., Mège, D., Gurgurewicz, J., Ciążela, J., Ciążela, M., 2019. Hydrae Cavus: A pull-apart basin that provides new insights into Valles Marineris region tectonic history. Geophys. Res. Abs. 21, EGU2019-11425-2.
International meetings and conferences: Terrestrial analogues:
Mège, D., Hauber, E., De Graen, M., Moors, H., Minet, C., 2018. Discovery of a hydrothermal fissure in the Danakil depression. EPSC Abstracts, 12, EPSC2018-381-1.
Rooney, T.O., Peterson, L., Phillips, R., Krans, S.R., Steiner, R.A., Mège, D., Nelson, W., and Hanan, B.B., 2018. Insights from the magmatic record into the development of the East African Rift (Invited). Fall Meeting, AGU, Washington, D.C., 10-14 Dec., V24A-01 2018.

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