Europlanet TA Scientific Report

PROJECT LEADER

Project number: 20-EPN2-020
Name: Jakub Ciazela
Home Institution: Institute of Geological Sciences, Polish Academy of Sciences
TA Facility visited: Planetary Field Analog in Rio Tinto, CAB-CISC, Spain

Project Title:

Scientific Report Summary.
(plain text, no figures, maximum 250 words, to be included in database and published)

The Rio Tinto area hosts the largest known volcanogenic massive sulfide deposits on Earth. We have investigated 614 sites along a river bed (Fig. 1) located 3 m from each other. At each site, we investigated 5 random samples for pyrite content. The pyrite content was always estimated by 2 to 4 researchers, and the average for each site was computed. The average pyrite content in the entire investigated area is 7.0 vol.% (12.6 wt.%). We have observed two fields, 30 x 30 m, and 30 x 60 m, with average pyrite contents >50 wt.%, which should be suitable for its detection from the orbit, both with Sentinel-2 (field resolution of 10 m) and Landsat (30 m). Principle Component Analysis of the obtained spectra from Sentinel-2 (Fig. 2) gives similar results to mineralogical data we have retrieved in the field during our geological mapping.
By establishing our test field for remote sensing of sulfide deposits in a planetary field analog on Earth, we will be able to determine abundance thresholds for the detection of major sulfide phases on Mars and identify their key spectral features. Our results will help in 1) more efficient use of the current NIR Martian spectrometers to detect ore minerals and 2) designing new space instruments optimized for ore detection to include in future missions to Mars such as one developed at the Institute of Geological Sciences and the Space Research Centre of the Polish Academy of Sciences called MIRORES (Martian far-IR ORE Spectrometer).

Full Scientific Report on the outcome of your TNA visit

Sulfides are the most important group of ore minerals and are especially crucial for copper, silver, and gold. Despite the lack of direct evidence, sulfide ores are anticipated on Mars (Pirajno and van Kranendonk, 2005; West and Clarke, 2010). Rover and orbiter data along with geochemical modeling suggest the presence of pyrite (FeS_2), marcasite (FeS_2), and pyrrhotite ($Fe_{1-x}S$) at the Martian surface (Ehlmann and Edwards, 2014). In addition, Martian meteorites show that the Martian crust is significantly enriched in chalcophile elements compared to the Martian mantle (Wang and Becker, 2017) and host a variety of magmatic and hydrothermal sulfides similar to that on Earth (Baumgartner et al., 2017; Lorand et al., 2018).

Infrared spectrometers orbiting Mars with high capabilities to use in mineralogical studies include CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) operating in a wavelength range of 0.4–3.9 µm onboard Mars Reconnaissance Orbiter (MRO), OMEGA (Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité; 0.4–5.1 µm) and PFS (Planetary Fourier Spectrometer; 1.3–45.0 µm) onboard Mars Express (MEX). To date, however, few works were able to localize sulfides from the orbit due to difficult interpretation caused by spectral interferences with common silicates, which are impossible to resolve without ground calibration (Horgan et al., 2014). To overcome this, we have mapped for pyrite content a 500 m x 100 m test field rich in pyrite within the Rio Tinto planetary field analog mining area in Spain for pyrite to compare the obtained results with remote sensing data from the Landsat 8, Sentinel-2, and ASTER satellites.

The Rio Tinto area hosts the largest known volcanogenic massive sulfide deposits on Earth (Martin-Izard et al., 2015). We have investigated 614 sites along a river bed (Fig. 1) located 3 m from each other. At each site, we investigated 5 random samples for pyrite content. The pyrite content was always estimated by 2 to 4 researchers, and the average for each site was computed. The average pyrite content in the entire investigated area is 7.0 vol.% (12.6 wt.%). We have observed two fields, 30 x 30 m, and 30 x 60 m, with average pyrite contents >50 wt.%, which should be suitable for its detection from the orbit, both with Sentinel-2 (field resolution of 10 m) and Landsat (30 m) (see Ciazela M. et al., this session).

Principle Component Analysis (PCA) of the obtained spectra from Sentinel-2 (Fig. 2), which has the best field resolution (10 m) of the three, gives similar results to mineralogical data we have retrieved in the field during our geological mapping in March 2022.

By establishing our test field for remote sensing of sulfide deposits in a PFA site on Earth, we will be able to determine abundance thresholds for the detection of major sulfide phases on Mars and identify their key spectral features. Our results will help in 1) more efficient use of the current NIR Martian spectrometers to detect ore minerals and 2) designing new space instruments optimized for ore detection to include in future missions to Mars such as one developed at the Institute of Geological Sciences and the Space Research Centre of the Polish Academy of Sciences called MIRORES (Martian far-IR ORE Spectrometer).

References:

Baumgartner R. J., Fiorentini M. L., Lorand J. P., Baratoux D., Zaccarini F., Ferrière L., Prašek M. K. and Sener K. (2017) The role of sulfides in the fractionation of highly siderophile and chalcophile elements during the formation of martian shergottite meteorites. *Geochim. Cosmochim. Acta* **210**, 1–24.

Ehlmann B. L. and Edwards C. S. (2014) Mineralogy of the Martian Surface. *Annu. Rev. Earth Planet. Sci.*, 291–315.

Horgan B. H. N., Cloutis E. A., Mann P. and Bell J. F. (2014) Near-infrared spectra of ferrous mineral mixtures and methods for their identification in planetary surface spectra. *Icarus* **234**, 132–154.

Lorand J. P., Pont S., Chevrier V., Luguet A., Zanda B. and Hewins R. (2018) Petrogenesis of martian sulfides in the Chassigny meteorite. *Am. Mineral.* **103**, 872–885.

Martin-Izard A., Arias D., Arias M., Gumiel P., Sanderson D. J., Castañon C., Lavandeira A. and Sanchez J. (2015) A new 3D geological model and interpretation of structural evolution of the world-class Rio Tinto VMS deposit, Iberian Pyrite Belt (Spain). *Ore Geol. Rev.* **71**, 457–476.
Pirajno F. and van Kranendonk M. J. (2005) Review of hydrothermal processes and systems on Earth and implications for Martian analogues. *Aust. J. Earth Sci.* **52**, 329–351.
Wang Z. and Becker H. (2017) Chalcophile elements in Martian meteorites indicate low sulfur content in the Martian interior and a volatile element-depleted late veneer. *Earth Planet. Sci. Lett.* **463**, 56–68.
West M. D. and Clarke J. D. A. (2010) Potential martian mineral resources: Mechanisms and terrestrial analogues. *Planet. Space Sci.* **58**, 574–582.

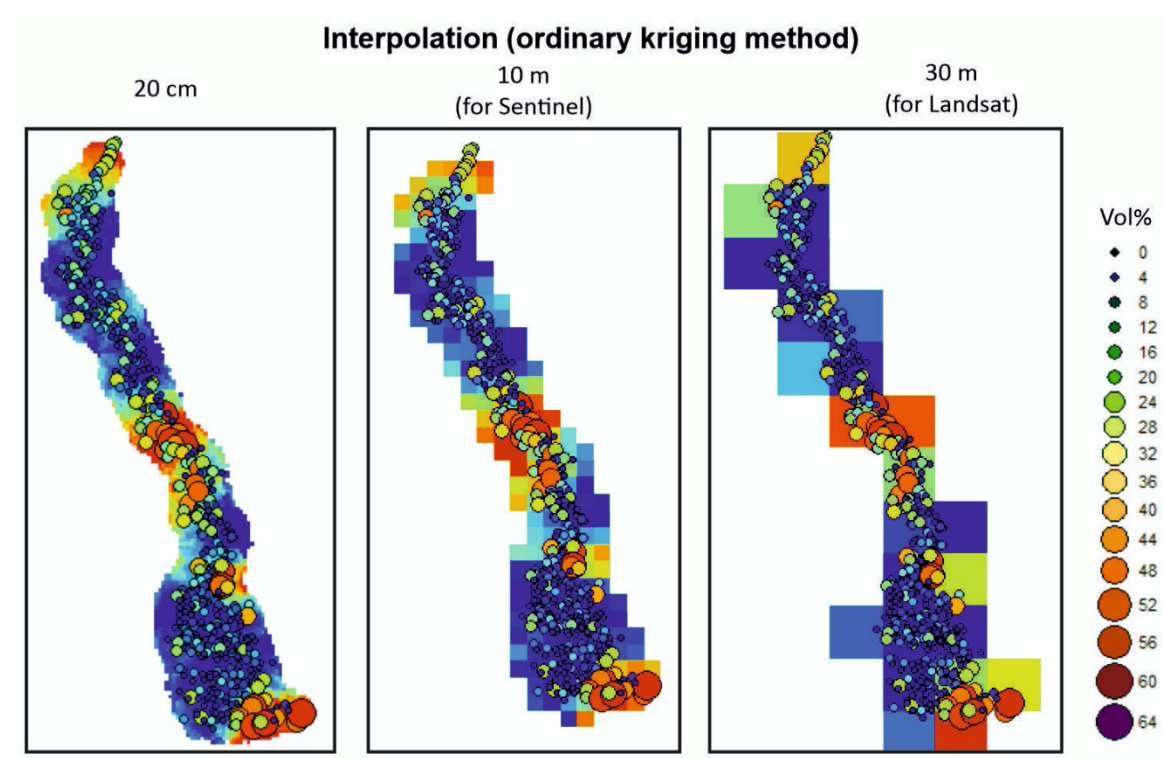

Figure 1. The ordinary kriging interpolation maps of pyrite content based on 614 sampling sites.

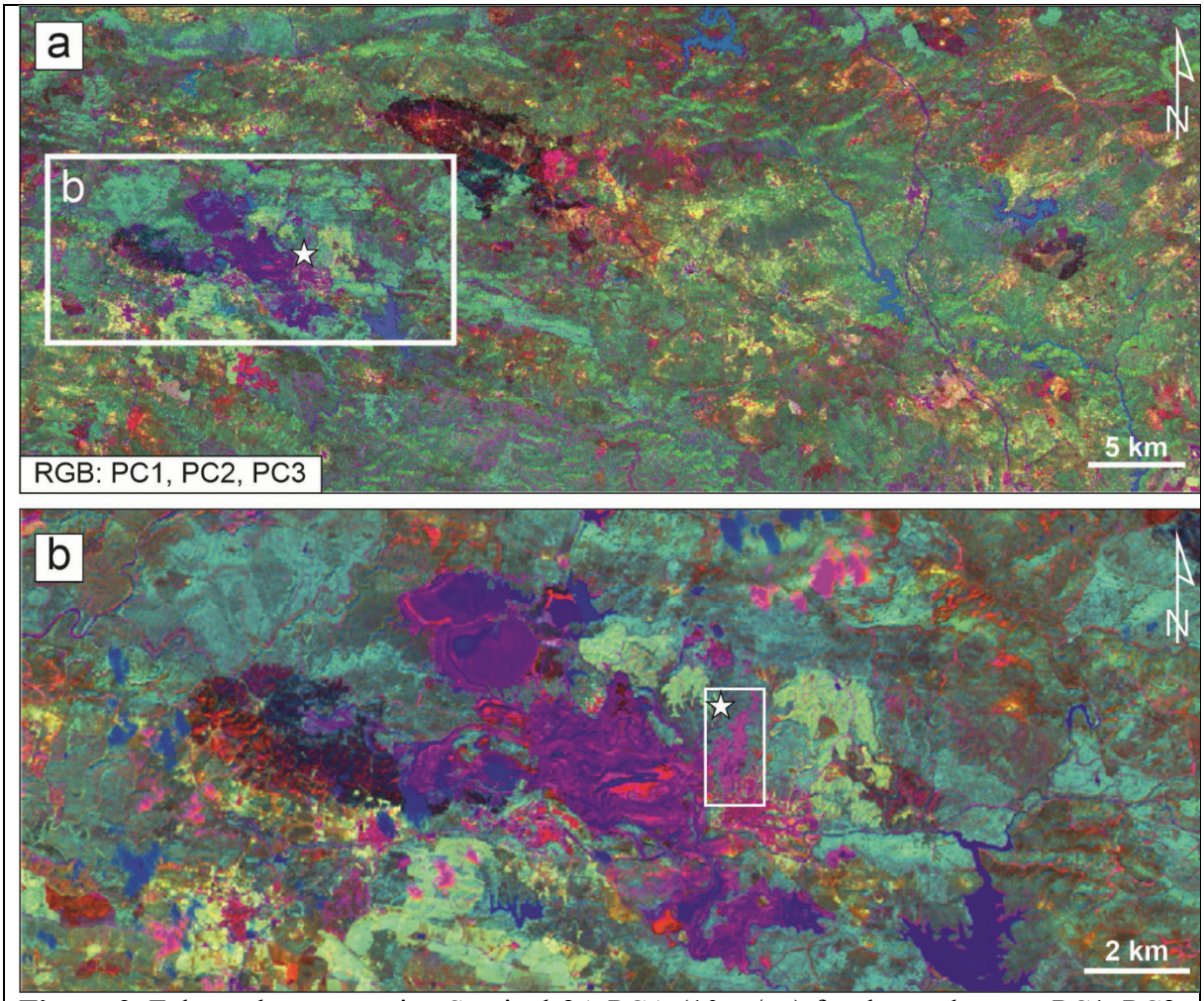

Figure 2. False-color composite, Sentinel-2A PCA (10 m/px) for the study area: PC1, PC2, and PC3 in R, G, and B channels, respectively. PCA image was calculated from the original 9-band (VNIR + SWIR) of Sentinel-2A (bands 1, 9, and 10 were excluded from this analysis as they do not contain mineralogical/geological information). Three first PCA components (PCA1, PCA2, and PCA3), containing the highest topographical and spectral information, are suitable for lithological discrimination, especially for arid region such study area. The pink color indicates areas with high pyrite content. The white frame in panel 'a' marks the region of the Rio Tinto Mining area in Spain. The white frame with the star in panel 'b' shows our study area for geological mapping.

- Give details of any publications arising/planned (include conference abstracts etc)

Ciazela, J., Marciniak, D., Ciazela, M., Gomez, F., and Pieterek, B. (2022)**.** Towards prospecting ore deposits on Mars: geological mapping of the planetary field analog in the Rio Tinto mining area, Spain. European Planetary Science Congress, Granada, Spain, September 18–23, 2022. EPSC Abstracts Vol. 16, EPSC2022-1119. [**accepted for poster**]

Ciazela, M., **Ciazela, J.**, Pieterek, B., Marciniak, D., and Gomez, F. (2022)**.** Towards prospecting ore deposits on Mars: remote sensing of the planetary field analogue in the Rio Tinto mining area, Spain. European Planetary Science Congress, Granada, September 18–23, 2022. EPSC Abstracts Vol. 16, EPSC2022-1090. [accepted for poster]

Ciazela, M., **Ciazela, J.**, Marciniak, D., and Pieterek, B. (2022). Sulfide ore deposits remote detection in the Rio Tinto area, terrestrial analog of Mars. Goldschmidt Conference, Honolulu, Hawaii, USA, July 10–15, 2022. [poster]

Ciazela, M., **Ciazela, J.**, Pieterek, B., and Marciniak, D. (2022). The use of infrared remote sensing to prospect ore deposits on Mars. Preliminary results from a planetary field analog in the Rio Tinto mining area in Spain. EGU General Assembly, Vienna, May 23–27, 2022. [oral presentation]

Ciazela M., **Ciazela, J.**, Pieterek, B., and Marciniak, D. (2021). Wykorzystanie teledetekcji w bliskiej podczerwieni w poszukiwaniu minerałów i złóż na Marsie. Wyniki badań pilotażowych na obszarze górniczym Rio Tinto w Hiszpanii. Ad Astra. Konsiliencyjna Konferencja Kosmiczna, Gdańsk, Poland, November 26–28, 2021. [oral presentation]

One full paper combining geological and remote sensing results is planned and it will be submitted in 2023.

- Host confirmation

Please can hosts fill in/check this table confirming the breakdown of time for this TA project:

Dates for travel to accommodation for TA visit (if physical visit by applicant)	Start Date of TA project at facility	Number of lab/field days spent on TA Visit pre-analytical preparation	Number of days in lab/field site for TA Visit	Number of days spent in lab for TA Visit data analysis	End Date of TA project at facility	Dates for travel home (if physical visit by applicant)
Departed: dd-mm-yy Arrived: dd-mm-yy	17-03-22 27-03-22		11	0	27-03-22	Departed: 16-03-22 Arrived: 28-03-22

The host is required to approve the report agreeing it is an accurate account of the research performed.

Host Name	**Rio Tinto Facility – Coord. Felipe Gómez**

Host Signature	GOMEZ GOMEZ FELIPE - DNI 02617123E Firmado digitalmente por GOMEZ GOMEZ FELIPE - DNI 02617123E Fecha: 2022.08.24 10:21:23 +02'00'
Date	

- Project Leader confirmation

Do you give permission for the full version of this TA Scientific Report (in addition to the 250 word summary) to be published by Europlanet 2024 RI on its website and/or public reports? YES ~~/ NO~~

Project Leader Name	**Jakub Ciazela**
Project Leader Signature	Jakub Ciążela Digitally signed by Jakub Ciążela Date: 2022.08.24 21:57:41 -02'00'
Date	