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Interdisciplinary fieldwork activities for astrobiological studies in Italy

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Abstract. Field research, or fieldwork, represents an important step in the understanding of the processes observed through remote observations of our Solar System. In planetary sciences and astrobiology, studies on analog sites on Earth are of primary importance in understanding the factors influencing the presence and evolution of life, especially in extreme environments, where a large number of factors concur to the creation of very high-fidelity analog sites. However, the high geologic diversity of the Italian territory still offers several opportunities to study fossil and modern biosignatures in their environment. This work discusses the development of astrobiological field-studies gathering experienced Italian field-geoscientists from different disciplines into an interdisciplinary teamwork. This will require building teamwork among different different disciplines, building a common language to approach a common scientific problem. Efforts in this sense will offer the opportunity for the national astrobiological community to develop new studies where different experiments and data collection techniques are employed within the same study. These interdisciplinary studies represent the ideal environment to test combination of experiments or instrument prototypes for the design of payloads for future robotic or human interplanetary explorations.

Key words. Planetary Science: astrobiology – field-test – in-situ measurements – geology – mineralogy – near surface geophysics – geochemistry – interdisciplinary studies

1. Introduction

Fieldwork and survey campaigns are fundamental activities for a wide range of disciplines, from human to natural sciences. Within the scientific exploration of our Solar System, geoscientific fieldwork was introduced during the training of Apollo-era astronauts who explored the surface of the Moon applying the same survey techniques used on Earth for field geology, geophysics and geochemistry. Since then, direct access to our planet has been key to studies comparing Earth's environment and processes with those shaping the other bodies of the Solar System and still geoscientific field campaigns

are critical to current and forthcoming robotic and human missions (Hodges & Schmitt 2019).

One of the key goals of astrobiology is to explore bodies of our Solar System in order to determine their potential for habitability and extra-terrestrial life. Alongside laboratory analyses reproducing planetary and deep space conditions, astrobiology includes studies of field analogs exhibiting terrains and conditions similar to those we expect to find on planets and moons in our Solar System. These environments are characterized by extreme climates and are commonly found in remote areas of our planet (Martins et al. 2017). Within the last decade, planetary field analog sites have been identified worldwide and research in this topic is progressing fervidly (Marlow et al. 2002; Cavalazzi et al. 2019).

2. Analogs in Italy

Specialized analog locations like deserts, arctic regions and rifts are important references for analog astrobiological studies because they replicate a large number of physical and extreme environmental aspects found in extra-terrestrial worlds.

Identifying field-test sites still showing specific analog aspects for astrobiology which are easily accessible may be the key to develop a solid experience in astrobiological field-studies developed by the Italian community.

The Italian territory offers a combination of diverse climatic and geologic environments in a very limited area (Soldati & Marchetti, 2017). The climate ranges from cold-temperate in the alpine region to subtropical temperate in the south. The geology of Italy offers a similarly extensive variety of environments, from volcanic to sedimentary passing through different grades of metamorphism. Within this scenario we can identify analogs of Solar System bodies ranging from glacial landforms, hydrothermal systems over a wide temperature range, continental and marine sedimentary deposits at various degrees of weathering or aging, where the astrobiological community can study geological environments related to fossil and currently active bioforms (Fig. 1).

While astrobiological field studies of this kind organized abroad could have prohibitive costs and require long time to organize, undertaking such endeavors in Italy is surely more cost-effective and will require less bureaucracy to bring together the experiments and field geoscientists working in this research domain. As such, diverse field studies can be organized, extending the type of investigated environments, and optimizing the organization of the work.

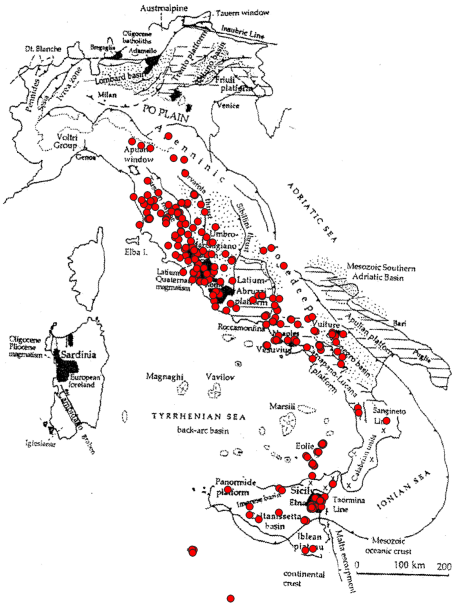

Fig. 1: Geology of Italy: paleo-environments and geologenic gas emissions sites. Black areas indicate magmatic provinces; dotted and dashed areas are sedimentary basins and carbonatic platforms, respectively. Red dots indicate gas emissions associated with hydrothermal activity over a wide range of temperatures (basemap from Doglioni & Flores (1997), and gas emissions sites are from the MaGa online catalog (Cardellini et al. 2014)).

3. From multi-disciplinary to inter-disciplinary studies

The variety and uniqueness of Italian geology has been extremely well studied by generations of geoscientists specialized in different geoscientific domains, often being an international reference in very specific fields.

However, astrobiological exploration of planetary surfaces requires the study of the context in which possible chemical and physical biosignatures could be hosted. In the case of Mars, for example, the radiation hitting the surface is capable of erasing any form of life. The Martian subsurface, protected from surface radiation, is thus the main target for astrobiological studies. The current generation of exploration rovers looking for trace of life on Mars therefore have on-board suites of instruments devoted to the mineralogic, geochemical, geophysical, morphological and structural characterization of both the Martian surface and subsurface.

This requires that also analog studies on Earth must be characterized by an interdisciplinary multi-experiment geoscientific characterization aimed at detecting extant and fossil biosignatures in their specific local context.

Geologic (morphologic, stratigraphic, and mineralogic) surveys give a synthesis of the evolution of the sequence of processes and events leading to the current setting of the studied area. Geophysics specializes in multi-dimensional imaging of the subsurface, deriving the physical parameters of rocks without directly accessing them. Geochemistry studies the variation in space and time of elements and compounds in liquid and gaseous phases.

Organizing field astrobiological studies supported by coordinated geologic, geophysical (e.g. Forte et al. 2016; Frigeri & Ercoli 2020), mineralogical (e.g. De Sanctis et al. 2017) and geochemical (e.g. Cardellini et al. 2017; D'Alessandro et al. 2009) observations will result into a more comprehensive description of the geoscientific context at the astrobiological analog test-site.

A field study of this kind requires a pool of experienced personnel, from specialized field scientists to experts supporting field campaign logistics and safety. As such, it requires coordination, the development common languages and also offers the opportunity to focus on how the integration and planning of experimental activities can be implemented and optimized.

The use of digital cartography and remote sensing data is key, as base maps facilitate planning of observations, the report, and publishing of results reduced to a common spatial reference system. Field logistics and safety are also important and shall be considered part of the program.

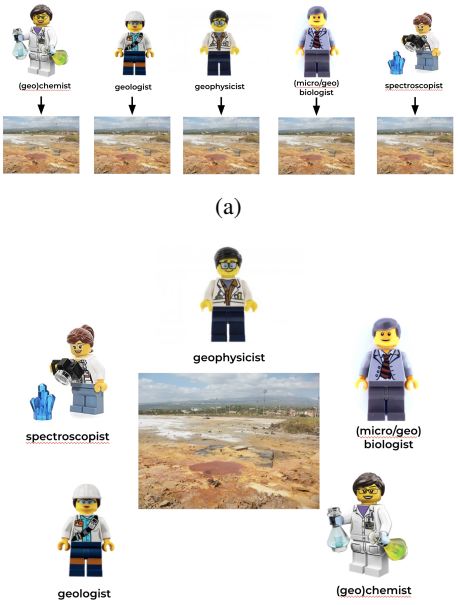

Fig. 2: Geologic sites in Italy have been extremely well studied by generations of field-geoscientists from different disciplines, at different times, offering a multidisciplinary view at each study area. Astrobiological studies of analog field sites benefit from an interdisciplinary approach, where observations from different domains have to be specifically planned and results analyzed with integrated methods, offering the most complete context for astrobiology-driven studies.

Combined, these aspects constitute the different elements which transform multidisciplinary campaigns into a single interdisciplinary research work where experts from different disciplines collaborate at solving the same scientific problem (Fig.2).

4. An opportunity for research, industry and space agency

The development of interdisciplinary astrobiological field studies and projects offers unique

opportunities to gather existing Italian excellencies from different fields.

Researchers will contribute to the common problem with their subject-specific skills consolidated through the years, which would be impossible to develop within a single project. The interdisciplinary approach requires the development of interfaces between disciplines through communication, building a common language within the specific astrobiological project.

Interdisciplinary investigation also entails bringing instruments to the field, and data integration will be a critical point for the success of the campaign.

This framework offers the Italian Space Agency an opportunity to observe experiments and instrument working in the field. Some specific combination of experiments can potentially be considered for future missions. Building experience in field-tests further offers the possibility of testing and improving industrial prototypes on the field before their integration into scientific payloads.

5. Conclusions

Now that NASA's Mars 2020 Perseverance rover acts as a geologist and astrobiologist on Mars, and since ESA's ExoMars rover is going to do the same when launched in 2022, developing a sound experience in interdisciplinary field analog studies is critical for current and future astrobiological studies. The Italian astrobiological community can thus further increase its experience and its role in future scientific explorations.

Although remote analog sites are important for their fidelity with extra-terrestrial environments, the Italian territory offers a rich range of geologic scenarios to study the context of the fossil and active bio-forms we expect to study on planetary bodies. This is ideal for organizing interdisciplinary astrobiological field studies where skilled field-geoscientists contribute to astrobiological studies with a complete and rich characterization of the geoscientific context. Moreover, maturing different campaigns with diverse experimental combinations can be critical in the design of payloads for future landed missions looking for the presence of life in the Solar System. This opens a scenario where a scientific campaign can be accompanied with technological testing of prototype instruments.

Investments in the design, organization, execution and publication of data and results from interdisciplinary astrobiological field-test in Italy will create new synergies within the scientific community in Italy and abroad, building the necessary experience to develop effective studies in the field of astrobiology and the planetary exploration in general.

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