ESA PANGAEA – TRAINING ASTRONAUTS IN FIELD GEOLOGY WITHIN UNESCO GEOPARKS.

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Résumé: PANGEAE est une série de cours et exercices pratiques effectués sur le terrain dans des sites géologiques européens labélisés Géoparcs de l'UNESCO. Alors que les missions automatiques de type rovers sur la lune ou Mars sont guidés par des géologues, le corps des astronautes n'a plus été entrainé à la géologie depuis les années 70 et l'exploration de la Lune. PANGEAE forme les astronautes à la géologie de la lune et de Mars en vue de futures missions habitées dans lesquelles les astronautes seront amenés à effectuer des travaux géologiques détaillés dans des environnement complexes.

Introduction: Current automated missions (landers and rovers) to the Moon or Mars are lead by geologists to find adequate landing sites, and select the right rocks to analyze. Future Moon and Mars missions will require astronauts to select rock samples and perform science-focused surface exploration in complex geological environments. Yet, current astronaut corps have received limited field geology training in the last forty years. Field geology will be the focus of exploration on the Moon and Mars, meaning that for these individuals to effectively contribute to the preparatory and execution phases of these missions, varied levels of training in such disciplines is required. PANGAEA (Planetary ANalogue Geological and Astrobiological Exercise for Astronauts) is a geological and astrobiological field training course organized by ESA. Since 2016, four editions of the course have trained astronauts from three different space agencies, including members of the Artemis team, in different locations involving Geoparks in Europe.

Goals and structure: PANGAEA intends to impart core theoretical and practical knowledge of geology and geobiology to the trainees. A significant strength of the PANGAEA course is that it integrates both geology and astrobiology training into its field work. A focus is given to skills in areas relevant to future missions, such as decision-making, clear scientific descriptions and efficient documentation. For this reason, although portions of the course are taught in classrooms, significant focus is given to developing field skills in analogue geological environments, as was done for the Apollo missions [1, 2]. Trainees also have the opportunity to practice conducting field science under the additional constraints imposed by realistic spaceflight operational conditions.

Teaching in analogue sites within Geoparks: The primary field sites selected for the course are Permo-Triassic terrigenous sequences in the Italian Dolomites within the Bletterbach Geopark, impact crater lithologies in the Ries Crater Geopark in Germany (Fig. 1), a comprehensive suite of volcanic rocks in the Geopark of Lanzarote Island in Spain, and igneous petrology in the anorthosite massifs of Lofoten islands Geopark in Norway. Each is used as a base to deliver the main learning sessions, respectively; (1) Earth geology, igneous and sedimentary mineral/rock recognition, and sedimentology on Earth and Mars based on the mudstones, sandstones and evaporates observed on site at Bletterbach Geopark (Fig. 2), (2) Lunar geology and impact cratering using especially outcrops of breccia observed on site within Ries crater Geopark, (3) volcanism on Earth, Moon and Mars using the suite of volcanic rocks and landforms observed within Lanzarote Geopark, (4) Lunar highlands and crustal evolution (especially cumulate rocks) in the Lofoten islands. The last two are also focused on practical learning on execution of geological traverses and sampling techniques.

Fig. 1: Astronauts and lecturers in front of suevite outcrops at Ries crater Geopark, Germany.

Classroom lessons are conducted at these field sites using local facilities, in relation with each Geopark logistics. For the field work component, trainees are initially shown the basics of field geology during the first two sessions. In the third session they begin a process of becoming independent field scientists. This is enabled by having trainees conduct geological traverses with realistic scientific goals, such as determine the contact relationship between geological units and the relative timing of events, recognise stratigraphic and tectonic structures, and sample rocks that were exposed to high temperature fluids.

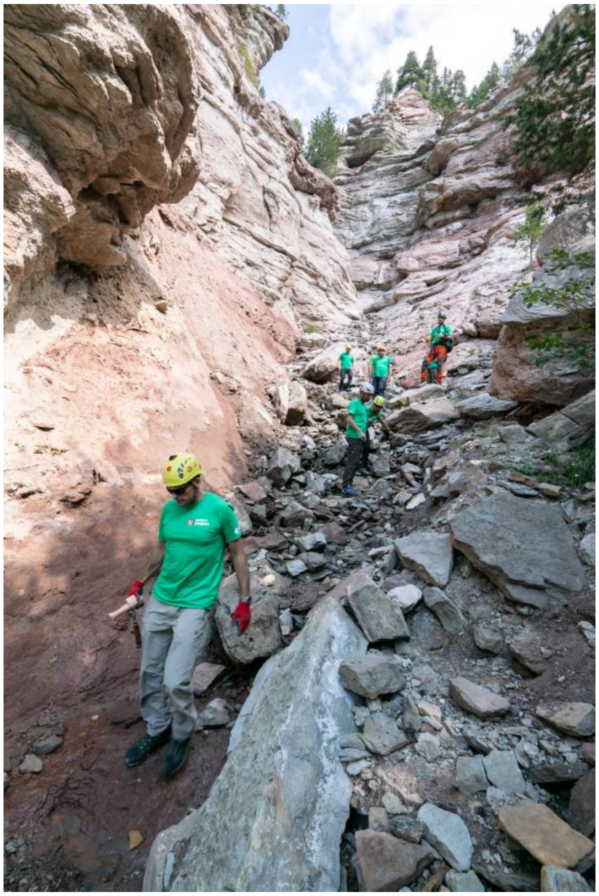

Fig. 2: Sampling sedimentary rocks at Bletterbach Geopark, Italy.

Conclusion: Preparations for human missions back to the Moon have already started, especially in the view of the Artemis programme. Improvements to surface mobility and extended surface exploration times enabled by the technological advancements made since Apollo, mean the time for scientific exploration will be extended significantly. It is therefore more important than ever to have astronauts capable of acting as independent field scientists, who can also understand and communicate efficiently with ground-based science teams. These astronauts will also be heavily involved in the planning, preparation and implementation of such missions, meaning even if they do not actually travel to the Moon or Mars, proficiency in geology and astrobiology will help them perform in many roles. Utilising terrestrial analogues from the four Geoparks cited above will ensure the best training. It also gives a window to these Geoparks to highlight these activities or provide information to the public in relation with space missions. For instance, the Bletterbach Geopark currently proposes an on site exhibition of Mars landscapes similar to those observed in the sedimentary rocks from the park, highlighting the analogy to Mars for visitors.

References: [1] Lofgren G. E. *et al.* (2011) Geological Society of America Special Papers, 483, 33-48. [2] Schmitt H. H (2011) Geological Society of America Special Papers, 483.