Department
Solar System, Impacts & Meteorites


Josephine Anderson
M.Sc Student


Dr. Christof Sager
Postdoctoral Researcher


Dr. Alessandro Airo
Senior Scientist


Andrea Miedtank
B.Sc. Student


Franzi Schwonke
M.Sc. Student


Dr. Jenny Feige
Senior Scientist

Infrastructures:

Geochemical and microanalytical facilities

ERC project
"Novel perspectives on our Solar System History recorded in the Atacama Desert"

Exploring Polygonal Patterned Grounds in the Hyper-arid Atacama Desert: Insights into Formation Mechanisms and Implications for Martian Analogues

Motivation

It is essential to study the **polygonal patterned ground** in hyper-arid environments, such as the **Atacama Desert**, to understand potential **analogous Martian landscapes** and to offer insight into extraterrestrial surface processes.

Despite extensive research on periglacial polygons, the formation mechanisms in hyper-arid regions remain underexplored, necessitating further investigation into the unique interplay of **desiccation, haloturbation, and thermal contraction** in extreme dry environments.

Atacama as a Martian Analogue

Hyper-aridity: The Yungay Valley is one of the driest places on Earth, with an annual precipitation of less than 2 mm [1].

Geological Stability and Salt Accumulation: The Atacama Desert is unique for its 15 million years of hyper-aridity and climatic stability [2, 3], rendering it an exceptional site for studying processes on Mars. The presence of the salts, such as sulfates and chlorides, further supports the suitability as an analogue for Mars' saline polygonal features [4, 5].

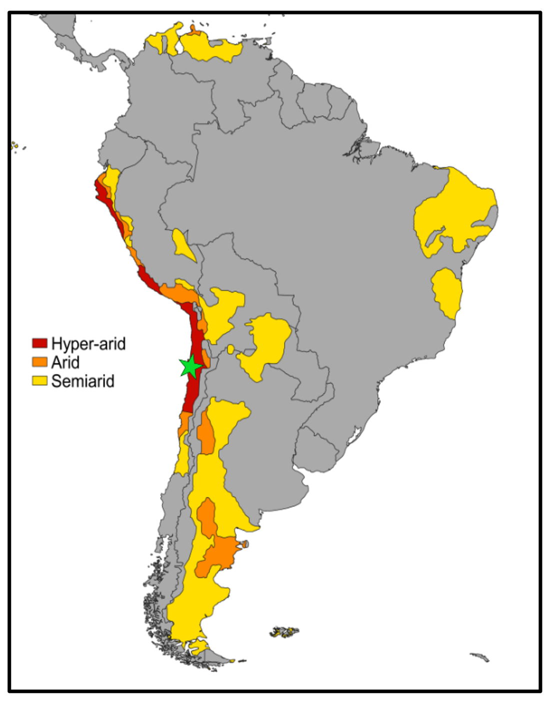


Figure 1: Map of South America with dry zones. Green star marks the sample area in the hyper-arid zone (Source: UNEP- WCMC).

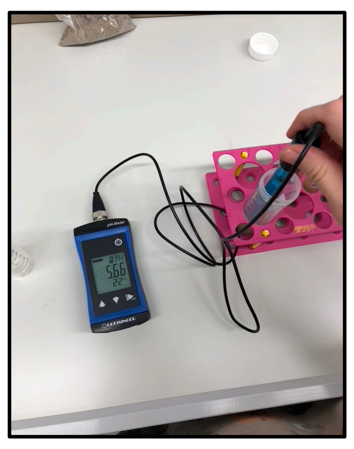
Methods

We excavated a **trench** in polygonated ground in the **Yungay Valley** of the Atacama Desert and systematically collected over **80 soil samples** covering an entire polygon, its adjacent sand wedges, and underlying sediments (190 x 190 cm).

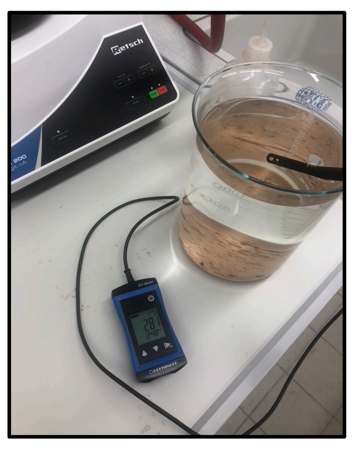
Yungay Trench (YT) Samples → Splitting

- Grain Size Fractions
  - Leach samples → Sieve → Grain size fractionation analysis
  - Take pH and EC
- XRD — Mineral composition
- XRF — Elemental composition
- SEM — Morphology and grain compositional analysis
- Ion Chromatography — Measures concentration of anions (chloride, nitrates, sulphates, etc.)
- Depositional Dating — Formation evolution and ages of sediment

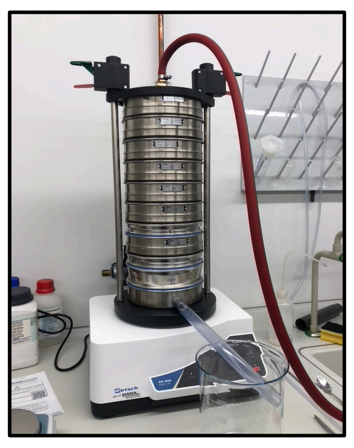
Sampling in the Atacama Desert



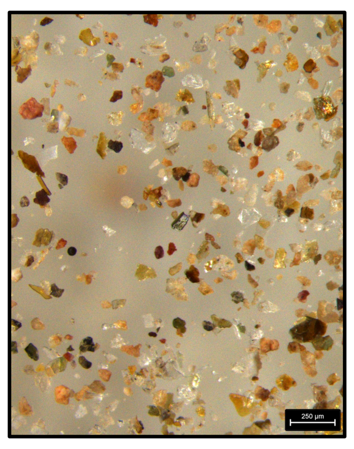
pH and EC (electrical conductivity)



H_2O salt leaching (e.g. chlorides, sulfates)



Wet sieving



Grain size and shape analysis

Initial Analysis

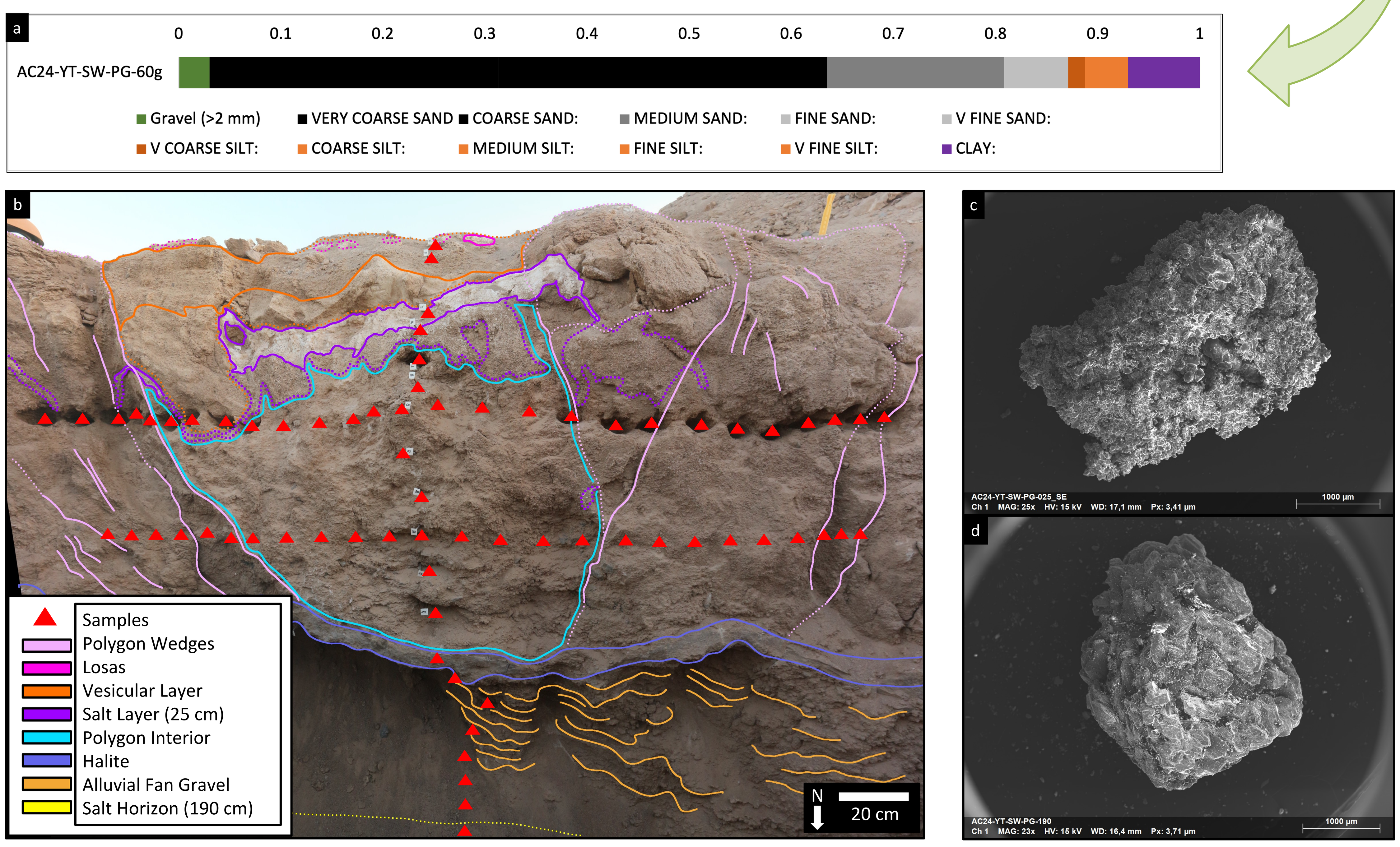


Figure 2:

(a) Grain size distribution chart in wt% of one sample from the Yungay Trench (YT) at 60 cm in depth. Chart derived from GRADISTAT 8.0 particle size analysis software.

(b) Image of the Yungay Trench wall showing outlined geological lithologies, including a cross-section of a polygon along with its adjacent sand wedges and underlying sediment. 72 samples were collected from this section, with vertical sampling conducted at approximately every 10 cm from 0 to 190 cm, and horizontal sampling at 60 cm and 90 cm.

(c) SEM imaging of a sample from the salt layer at 25 cm reveals a fine-grained and heterogeneous morphology. Compositional analysis indicates that the sample is putatively **blödite**, a sulfate mineral that typically forms in evaporitic and arid environments [6].

(d) SEM imaging of a sample from the salt layer at 190 cm reveals a coarse-grained, homogeneous, and idiomorphic morphology. Compositional information indicates this sample is putatively **glauberite**, which is also a sulfate mineral that can form in nitrate deposits in arid climates [6].

Earth versus Mars

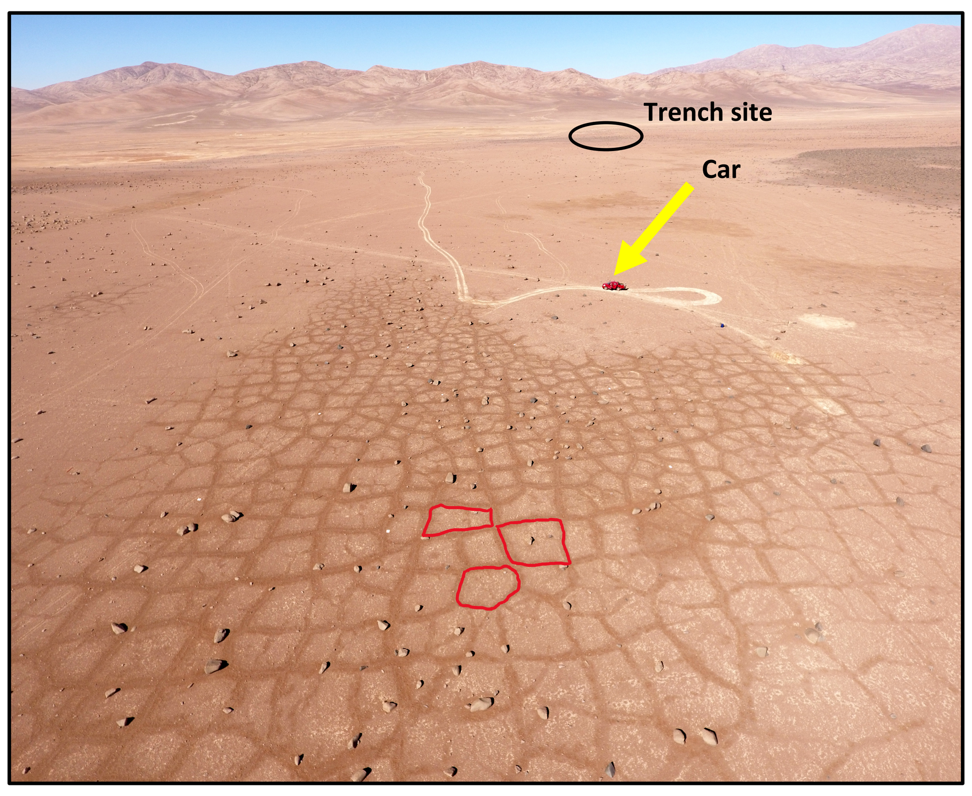


Figure 3: Polygonal patterned ground located in the Yungay Area (hyper-arid core) of the Atacama Desert, Chile. The Yungay Trench site is approximately 1.3 km away and outlined in black. Car for scale. Three of the polygons are outlined in red. This image is facing south. Source: [4]

Most Martian polygons are predominantly hypothesized to originate from desiccation or periglacial processes, both requiring liquid water. However, the Atacama Desert offers a **model for salt forming polygons**. Could this process also occur on Mars, and might it even be more prevalent than previously thought?

Thermal Contraction and Salt Dehydration processes: In the Atacama Desert, thermal contraction and salt dehydration contribute to the formation of polygonal patterns [4,5]. On Mars, temperature fluctuations induce cracking, and sulfate and chloride deposits suggest a similar mechanism of salt-based thermal contraction cracking [5].

Erosional Insights and Surface Morphology: Aeolian deflation in the Atacama Desert, though significant, is insufficient at the Yungay Trench to expose underlying polygonal patterns, which may imply that dust or regolith can obscure polygonal patterns on Mars.

By studying these polygonal patterns in the Atacama Desert, we can develop a model for the **formation and evolution of polygonal ground on Mars**, helping to identify locations that may be habitable or provide clues on planet's **climatic history**.

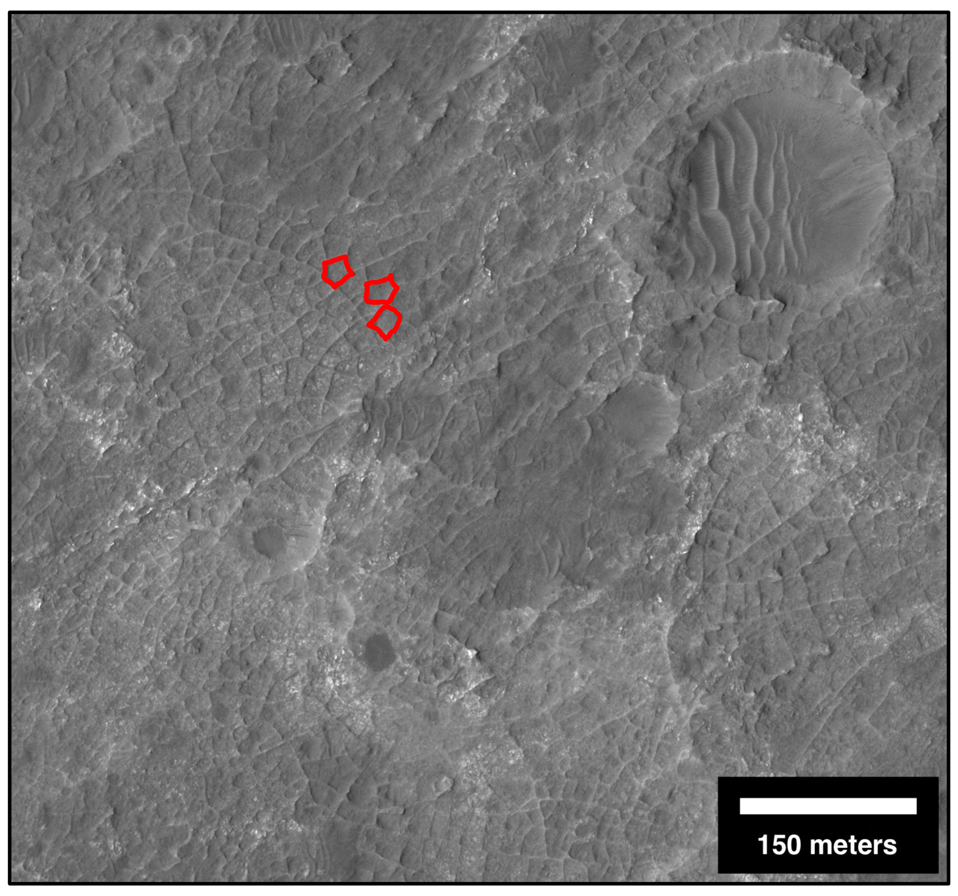


Figure 4: Polygonal patterned ground in supposed chloride deposit within the Ladon Valles Basin on Mars. Three of the polygons are outlined in red. HiRISE image ID: ESP_047343_1610. (Source: NASA/JPL-Caltech/UArizona).

References: [1] Houston, John (2006), International Journal of Climatology, Vol. 26, Issue 15, pages 2181-2198. [2] Dunai, Tibor J. et al. (2005), Geology 2005, Vol. 33, Issue 4, pages 321-324. [3] Ritter, B. (2023), Journal of Geophysical Research: Earth Surface, Vol. 128, Issue 3. [4] Sager, C. et al. (2021), Geomorphology, Vol. 373, 107481. [5] Sager, C. et al. (2022), Scientific Reports, Vol. 12, 12394. [6] Anthony, John W. et al. (n.d.), Handbook of Mineralogy, Mineralogical Society of America.

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