MINERALOGY AND STRATIGRAPHY OF A SULFATE-RICH INVERTED CHANNEL IN THE ATACAMA DESERT, CHILE: CLUES TO ITS FORMATION AND PRESERVATION. E. Z. Noe Dobrea[1], R. M. E. Williams[1], W. D. Dietrich[2], A. D. Howard[1], R. P. Irwin III[3], and J. Crawley[3],; [1]Planetary Science Institute, Tucson, AZ (eldar@psi.edu); [2]E&PS, University of California—Berkeley; [3]CEPS, Smithsonian Institution.

Introduction: Inverted channels are a geomorphic feature that results from the differential erosion of fluvial channels, occurring when the cemented or armored floor erodes at a lower slower rate than the surrounding, more erodible terrain. Although they present geomorphologically as ridges, they can often be identified in plan view by their sinuosity or by branching patterns that mimic those of fluvial features. Given their preservation of morphometric character and sediments, inverted channels provide the opportunity to investigate past climate, hydrology, and aqueous chemistry. For this same reason, the study of the distribution and morphology of sinuous ridges on Mars has been used to constrain the timing and nature of fluvial activity on Mars [1], [2].

Here, we describe the mineralogy and stratigraphy of the WIN ridge, a putative inverted channel located in the Pampa de Tamarugal, Atacama Desert, Chile. We document the bedding style and thickness, degree of induration, mineralogy, and stratigraphy of the exposed layers and present a model for the geological history of this ridge. We also show that resistance of the top surface is not the sole culprit for its preservation, but rather that the prevalence of cementing agents throughout its volume and the formation of salt armor along its escarpments have contributed to the existence of the ridge.

Setting: The Pampa del Tamarugal is a geologic province located within the Central Depression of the Atacama Desert, between 19°30' and 22°15' south latitude and bounded by the low (<2 km) Coastal Range to the west and the towering Andes Mountains (>3.5 km) to the east (**Fig. 1**). These mountain ranges are barriers to atmospheric moisture reaching the elevated plateau of the Central Depression and resulting in one of the driest places on Earth for at least the last 13 Myr [3]. The general environmental characteristics of the region are the hyperaridity, strong winds, and exceptionally little rainfall, which occurs as sporadic torrential rains. Additional sources of water in the region are water sourced from occasional torrential winter storms in the Andes to the east, and the thick coastal fogs, known as the Camanchacas, which can penetrate up to 100 km inland.

With little direct precipitation in the Atacama Desert (<3 mm/yr; e.g., [3]), both surface and groundwater are sourced from high in the Andes Mountains (e.g., [4]). Streams form from precipitation in the Andes Mountains and transport sediment approximately 150 km westward into the basin to form large alluvial fan complexes.

Infilling within the Pampa del Tamarugal basin is a sequence of alternating volcanic and nonmarine sediments comprising the Altos de Pica Formation with deposits from the Late Oligocene to recent (*e.g.*, [5],[6]). Sedimentary deposits near the terminal basin Salar de Llamara show relatively young cycles of deposition and erosion. 'Ancient' alluvial and playa deposits were emplaced during periods of enhanced precipitation in the Andes Mountains during the Early Holocene and Late Pleistocene, and more recent 'active' alluvial deposits cut the older, abandoned fan surfaces (e.g., [7]). Wind dissection of playa deposits has sculpted furrows and yardang fields. Short (<2 km) ridge segments on the distal bajada are interpreted as the wind-eroded remnants of fan distributary channels ('inverted channels') because the scale and configuration are consistent with nearby modern incised channels on the alluvial fans (**Fig. 2;** [8]). The inverted channel segment informally referred to as 'WIN' by the research team (-21.119°, -69.578°) is located near the distal end of these alluvial fans.

Methods: Excavation of the transect at WIN ridge was performed using hand shovels and rock hammers.

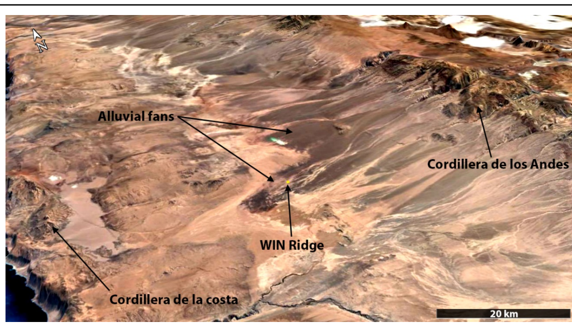

Figure 1. Perspective view of the Pampa del Tamarugal region, showing the western Andes (right) Cordillera de la Costa (left), and the highly dissected alluvial fans. WIN Ridge is indicated by the arrow.

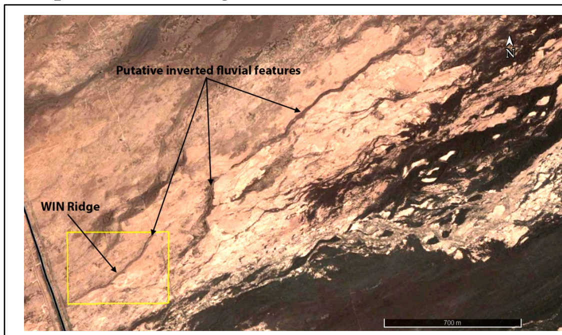

Figure 2. Plan view of the distal end of a fan sourced from the western Andes. Multiple ridges interpreted to be inverted channel segments are apparent in the region.

Measurements of layer thickness was performed using a Trimble differential GPS Pathfinder Pro XRS. The texture, color, and degree of induration were observed and recorded. *In-situ* spectral measurements in the visible through near-infrared (VNIR – 0.35 – 2.5 µm) were obtained using an ASD FieldSpec 3 with a contact probe. Collected samples were later measured in the lab using the same spectrometer as well as with an Olympus Terra portable XRD. XRD analysis was performed using the commercially available software XPowder. Quantitative estimates of relative abundances derived from the XRD pattern were performed using Reference Intensity Ratios methods.

Observations and discussion: WIN ridge is approximately 1 km long and about 1.2 m tall, flat topped, and with escarpments exhibiting slopes of about 20º. It is located within a field of yardangs, most of which are lower in height than the ridge. The terrain between yardangs is flat and fractured, forming decimeter-sized polygons. **Figure 3** shows the transect that was made on the east side of WIN ridge.

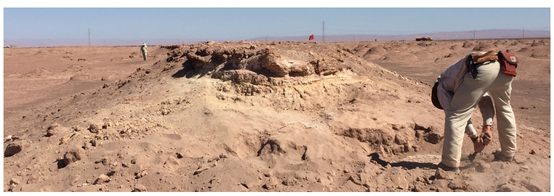

Figure 3. Frontal view of WIN ridge cross-section showing concave-up layering.

Layers were observed to exhibit a complex stratigraphy involving variations in grain size, bedding, colors, and mineralogy. Primary minerals, alteration products, and evaporitic salts were detected in discreet horizons. The ridge was found to be indurated throughout and capped by a discontinuous, thin (~1 cm) layer of indurated Ca-sulfate plates which exhibited a curious reticulation on the exposed side. The edges of the ridge's top exhibited a digitate morphology. The side slopes of the ridge were thinly mantled with unconsolidated material which, when scraped away, revealed a cm-thick slope-conforming indurated layer of halite that armored the slope.

In broad terms, we found that the ridge could be compositionally divided into a lower unit dominated by primaries and sulfates, and an upper unit dominated by sulfates and other evaporitic salts **(Fig. 4)**. The lower unit exhibited flat layering, suggesting alluvial deposition. The bottom of the upper unit exhibited concave-up layering whilst the top layers were once again flat, suggesting deposition and infilling within a shallow channel. Anhydrite was found to be present throughout the section in concentrations as low as 30 wt% in the lower unit and almost 95 wt% in the upper unit. Montmorillonite was also found throughout in minor abundances.

The section can best be described as a sequence of horizons and paleosols ranging (from the bottom up): an anhydrite paleosol at the base, an anhydrite-cemented sandstone consisting primarily of mostly unaltered alluvial detritus, a second anhydrite paleosol, an anhydrite-cemented and mottled jarosite-rich horizon, a paleosol consisting of gypsum-rich material, an anhydrite paleosol, an anhydrite-rich glauberite-bearing playa-like deposit, and a fourth paleosol consisting of gypsum and anhydrite. Root casts and associated orange stains were observed in the bottom portion of the lower unit as well

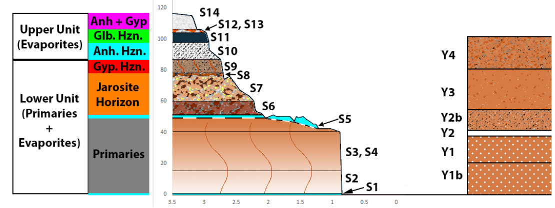

Figure 4. Simplified stratigraphic section of WIN ridge (left) and nearby yardang (right).

as in the gypsic horizon near the top of the lower unit. The presence of large fractions of anhydrite throughout the section and the mottling present in some layers suggest that early-stage diagenesis occurred throughout.

In addition to the complex stratigraphy, we also identified two new mechanisms that contribute to channel inversion and preservation. The first mechanism is anhydrite formation via groundwater upwelling. Within the lower unit anhydrite cements detrital materials. Evaporite formation within the pre-existing fluvially-carved channel constitutes the upper unit, the capping component of the ridge. The second mechanism we identified is the armoring of the lateral slopes of the ridge by a halite-rich cement. The slope-conforming armor formed by this second mechanism appears to have developed subsequent to the formation of the ridge (e.g., post-erosion) as a consequence of the remobilization of soluble salts. These newly identified mechanisms should inform us towards a better understanding of the multiple processes involved in channel inversion on Mars.

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