THE GEOLOGY OF THE LACUSTRINE TRAMPEADERO FORMATION, WITH APPLICATION TO THE MSL LANDING SITE, MARS J. W. Nußbaumer, Johannes Gutenberg University, Mainz, Germany

Introduction: Lacustrine sediments have been found at the MSL landing site in Gale crater, Mars. For a better understanding of the rocks at this landing site, the following analysis of lacustrine sediments is presented. Within the scope of this work, an area of 17 sqkm was mapped in a scale of 1 : 15000. The area is located in the northwestern part of Argentina, northeast of La Rioja, and southwest of Catamarca. It is is situated in the sierras pampeanas, which forms a morpho-structural unit with metamorphic and magmatic basement. In the mapped area, proterozoic rocks of the metamorphic basement are migmatits with intrusions of orthogneisses. Cambric? metamorphic rocks of the La Cébila Formation represent clastic sediments of pellitic and psammitic origin. The upper-carbonic lacustrine sediments of the Trampeadero Formation (TF, see Fig. 1) are part of the Paganzo-basin and mainly examined in this work. These lake sediments were deposited in a tectonic graben-structure, between migmatits in the east and Cébila formation in the west. They passed during the sedimentation a glacial phase, beginning with humid climates, then glacial conditions, ending with transgression because of increasing temperatures. A delta moving from the northwest to the southeast and synsedimentary slumping structures in warve-like layers refer to a hydrologically open glacial lake with steep margins. Quaternary units are fanglomerats, younger and older Quarternary.

Geographical location: The mapping area is located in northwestern Argentina, about 150 km northeast of La Rioja and 150 km southwest of Catamarca in the Sierra Ambato, at 28 ° 45 south and 66 ° 21' west. Cartographic basis was a grayscale aerial image with a scale of 1: 50,000. The settlements Mazan and Villa Mazan with about 2000 inhabitants is about 25 km west from the work area in the valley known for its hot springs. The deepest point of the territory is located at 1250 m and the highest at about 1500 m. The surrounding mountains are about 3000 m high. The local animals are condors and parrot species, as well as the black-yellow-red striped coral snake (micrurus) and a tarantula species, which can reach a size of about 20 cm. Desert foxes, pumas and lamas are also part of the local fauna.

Previous work: One of the first works about the area is from [1]. He describes the antimon mineral deposits southwest of the territory. [2] wrote a general study about the area. Then [3] performed a study where he put the sediments of Trampeadero-Formation in the Tertiary. [4] examined the crystalline basement, the upper carboniferous - sediments and the petrography of the rocks. Because of the discovery of microflora in the neopaleozoic outcrops, the sequence was determined a carboniferous unit. [5] described the migmatites and the La Cébila Formation and analyzed their structural character. [6] developed a facies model in the north and identified two mega sequences with a transgressive character, and a basal regressive section. Further studies about the micro - and macrofauna were performed. [7] examined the biostratigraphy based on the microfossils and associated the individual facies to certain energy levels, thus forming a water-level model.

Surrounding Geology: The mapped area forms an extensional Horst - Graben - structure. In this rift valley were lacustrine continental sediments (sandstones and arkose) deposited from the adjacent areas. In the eastern part of the mapped area is an open metamorphic basement with migmatits and orthogneisses. In the western part are metamorphic pelitic rocks and the psammitic formation La Cébila. The diagenetic solidified sediments of the Trampeadero formation are part of the northeastern Paganzo group. The Paganzo basin consists of glaciolacustrine and glaciomarine formations. Within the lake sediments, the TF forms a post-carbonic saddle structure. Since one of the greater glaciations in the permo-carboniferous gondwana continent took place in the area, the TF was probably a glacial lake [8] [9] and was formed in a rift valley with steep banks and great depths.

Stratigraphy of the Formation Trampeadero: The lacustrine sediments are unconformably above the Formation La Cébila and the basal sector of Grupo Paganzo. Through discoveries of fossil flora as Gingkophyl, Cordaites riojanus and Gondwanidium sp., these sediments are part of the upper carboniferous (Westphal-Stephan) [9] [10]. After [11] dominates Cristatisporites spp. with a small percentage of pollen. The TF is about 274 m thick [7]. The continental sediments show low diagenetic solidification. The former lake represents a siliciclastic, glacial type, whose depth ranges are divided into the epilimnion, and metalimnion and hypolimnion [12]. The Epilimmnion represent the shallow shore areas, the hypolimnion the deep, unmoved sedimentation basin with anaerobic environment and the metalimnion is the area around the temperature thermocline (thermocline) in 10-30 meters Depth. At this thermocline, fine suspensions are deposited as a pelagic fallout deep in the lake. Because of the winter circulation and summer stagnation due to different temperatures, layers gradually change with the

seasons, the sedimentation relationship result in an alternation of sandstone and mudstone within the basin sediments. Thus, the different sectors can be divided into beach facies, deep basin facies of the hypolimnion, basin rim facies of the metalimnion and delta/shore facies. The frequent alternation of different facies in the mapping area is called facies gearing. In the summer there are high sedimentation rates with silt, in the winter, there are significantly lower accumulation rates between 0.3 and 5 mm / y [13].

Beach and dune facies: This facies consists of conglomerates and gray-white sandstone, whose feldspates are weathered to kaolinite, suggesting semi-arid conditions. The rocks do not form layers and show partially fine lines in the mm - range, and have a slightly darker shade. Microscopically, the main ingredients are quartz, kaolinite, and feldspar (microcline). Minor constituents are hydroxides, muscovite and calcite. The main components are feldspar and quartzite. Quartz is often overgrown with calcite. The muscovite contains partially zirconium minerals. The grain sizes vary between 0.1 and 0.8 mm, (coarse sandstone). The mafic rock is sorted poorly and the minerals are better rounded than other rocks in the same formation. Rarely, the quartz clears undulos out, suggesting several places of origin. The matrix consists of calcite and kaolinite. Oxidation seeds occur in the dune facies, these are red, rounded areas with raised iron oxide content. With the emergence of such beach dunes, a wind speed of 16 km \ h is a prerequisite. Partly in this area, there are petrified trees (xylite, lignite).

Shallow water facies of the epilimnion: These facies represent the proximal area of flat water in beach-proximity (metaIimnion ~ epilimnion) and are of 10-20 cm thickness. They show clear ripple marks, which change with shale layers. The ripple marks suggest a preferred water flow direction and a deltaic formation mechanism. The grain size of the shale layers are between 0.02 to 0.1 mm. The grain size of layers with ripple marks are about 0.25 mm, with well sorted grains. The dimensions of the wave -ripple marks enables a reconstruction of the water flow conditions in the mapped area. The ripple marks are about 2.5 cm high and 10-12 cm in length. Calculated with [14], the water flow speed was about 30-40 cm/s.

Deep lake facies of the hypolimnion: These rocks are characterized as alternating fine sand and shale deposits with layers of about 1 cm and represent the annual laminations, a yearly rate of accumulation in the lower basin. These facies represent the distal part of the basin in the cold, deep water, the hypolimnion. Coarse grained summer-layers with calcitic matrix and fine-grained bituminous winter layer are present. Layers of this type are called varves. A varve like stratification in Paganzo Basin was described by [15] too. Wave energy, in the form of turbulence, reaches the metalimnion but the hypolimnion is not affected, since the density gradient in the metalimnion acts as an energy barrier [16]. The grain size is 0.05 - 0.2 mm, the grains are angular and well stocked. These rocks are called siltstones. In these layers, synsedimentary folds have been observed. These slumping structures are caused by rising deltaic weight and steepening. These folds hint for deeper basins and are signs for steep topography in the upper carboniferous [16].

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Fig. 1: Aerial view of the mapped area, the arrows point to the Trampeadero Formation, clearly visible as light toned deposits.