The Pampa-A strewn field, Antofagasta Region, Northern Chile

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Resumen / La elipse de dispersión puede ser definida interpretando las características de los diferentes fragmentos del meteoroide pertenecientes al mismo evento de caída. Presentamos el estudio de una caída múltiple de meteoritos descubierta en 1986 por coleccionistas privados en Pampa de Mejillones, norte de Chile. El meteorito, Pampa-A, fue clasificado como una Condrita Ordinaria tipo L6 / S4 / W2, y está compuesto por 16 fragmentos, 14 de los cuales corresponden al mismo evento de caída. Ellos fueron emparejados de acuerdo a sus características físicas, petrográficas y/o químicas. La forma de la elipse cubre un área de 1.5.5 km^2. Basado en la dispersión de los fragmentos en la superficie inferimos una entrada desde el NW al SE con un buzamiento de 106° desde el norte. Para estimar el tamaño pre-atmosférico del meteoroide asumimos una forma esférica y una pérdida de material debido a la ablación entre 90 % y 99 % del peso inicial. Por lo tanto el diámetro del meteoroide se estimó en 16.7 cm y 36 cm, respectivamente. Esto debería ser considerado diámetro estimado mínimo, ya que en el área de caída algunos fragmentos pueden permanecer sin ser encontrados o informados.

Abstract / The strewn field can be defined interpreting the characteristics of the different fragments of the meteoroid belonging to the same fall event. We present the study of a multiple meteorite fall discovered in 1986 by private collectors in Pampa de Mejillones, in northern Chile. The meteorite, Pampa-A, was classified as an Ordinary Chondrite type L6 / S4 / W2, and is composed of 16 fragments, 14 of which correspond to the same fall event. They were paired according to their physical, petrographic and / or chemical characteristics. The shape of the ellipse covers an area of 1.5×0.5 km^2. Based in the dispersion of the fragments on the surface we can infer an entry from the NW to the SE with a dip of 106° from the north. For estimating the pre-atmospheric size of the meteoroid we assumed spherical shape and a loss of material duo to the ablation between 90 % and 99 % of its initial weight. Therefore the diameter of the meteoroid was estimated at 16.7 cm and 36 cm, respectively. This should be consider the minimum estimated diameter as some fragments can remained not found or not reported in the fall area.

Keywords / meteorites, meteors, meteoroids

1. Introduction

In the past two decades, a big number of meteorites have been collected from hot deserts around the world, including the Sahara desert (Bischoff & Geiger, 1995), Mojave desert (Kring et al., 2001), Oman desert (Gnos et al., 2009), and Atacama desert (Hutzler et al., 2016).

The meteorite strewn fields found in hot deserts are still relatively rare (Zeng et al., 2018). The few rare examples include the Vaca Muerta strewn field (Pedersen et al., 1992), the Gold Basin strewn field (Kring et al., 2001), and the Jiddat al Harasis (JAH) 073 strewn field (Gnos et al., 2009).

In the Pampa de Mejillones there are 27 official meteorites published by the Meteoritical Bulleting*.

The fragments in areas of high accumulation may contain cross-scatters of different fall events at different times. The Pampa-A meteorite was the first found in this area in 1986 (Graham, 1987).

Here we present the characterization of the physical properties of the 14 fragments recognized as Pampa A.

The main mineralogy of all samples as well as the description of their surface morphology was established through a macroscopic inspection.

Eleven of the samples were selected for a microscope study to define their texture and minerals in five of them and the chemical compositions, including whole rock and specific minerals of this five samples.

2. Samples and Methods

In the Pampa de Mejillones area, located ~ 9 km south of the city of Mejillones, sixteen rock pieces have been collected as part of a same fall, named Pampa-A (Fig. 1). The total mass reached 904 g. In this research fourteen fragments were analyzed (PMP-A1 to PMP-A14), with a total mass of 841 g.

Five of these fragments are complete (a single pieces with fusion-crusted) and nine are fractions of the total

*https://www.lpi.usra.edu/meteor

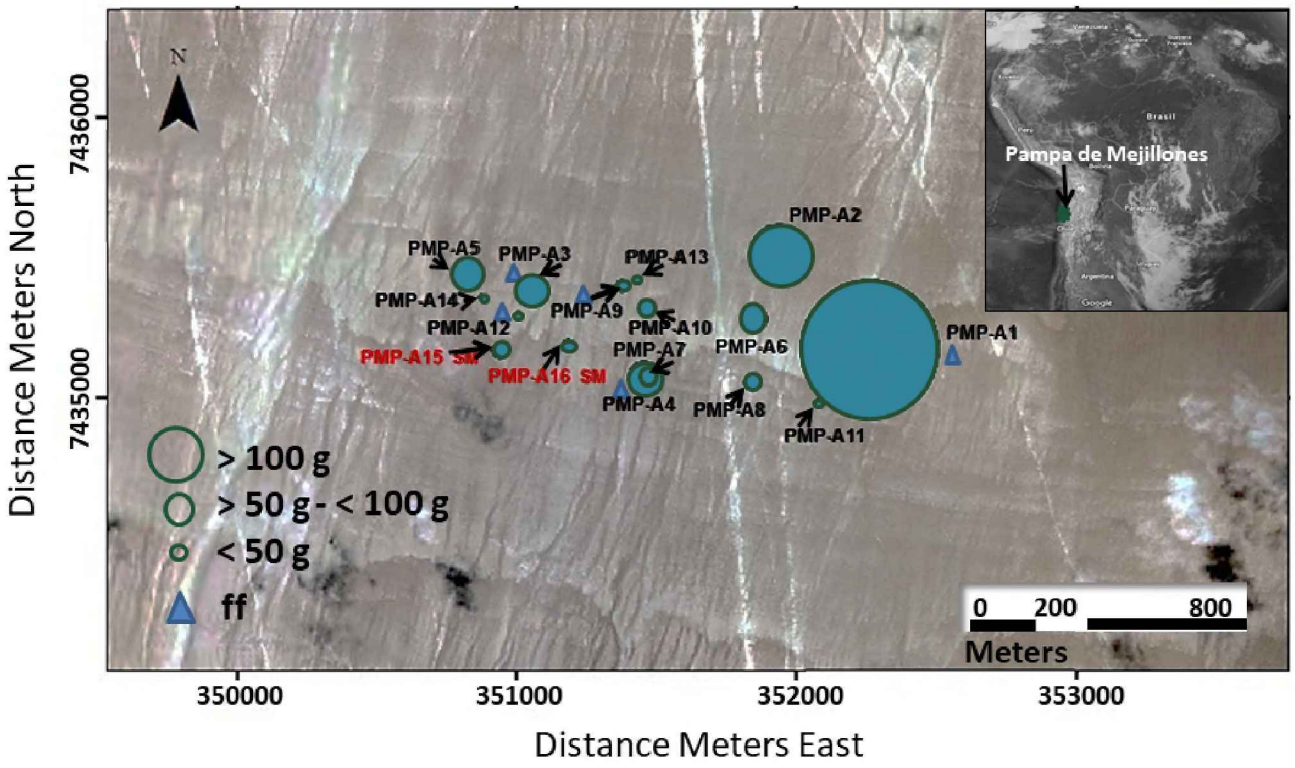

Figure 1: Map of the strewn field in the Pampa-A area, Atacama Desert, north of Chile. The samples in red show the material not available for investigation. The samples with triangle show the full fragments (ff).

sample. Only five of these fractions (PMP-A2, PMP-A4, PMP-A5, PMP-A8 and PMP-A10) were selected to make polished thin section (PTS) for microscopic description and chemical analysis.

The magnetic susceptibility was measured with the SM30 equipment, covering three different directions that allow homogenizing the variation of clasts/minerals in each fragments. The density was calculated using the volume measured by the Dial-0-Gram (Ohaus) -310 g-precision to the hundredth of a gram. The porosity was measured in proportion to its porous space through mineralogical maps using QEMSCAN.

The description of the macroscopic petrography was made with a Nikon SMZ645 steroscopic zoom microscope, focusing on the fusion crust and surface alterations. Five PTS were studied in the optical microscope OLYMPUS BL to define the petrographic textures and the abundance (in percentages ratios) of chondrules, crystals and matrix.

The chemical analysis were carried out using a QEMSCAN E430 model, which is based on a scanning electron microscope (SEM) ZEISS EVO 50 combined with energy dispersive spectrometer (EDS) detectors to analyze the elemental components and mineral phases. The measurements were made in alloys of Fe-Ni (21); SFe: troilite (50); silicates: plagioclase (2), olivine (50) and pyroxene (7).

3. Results

3.1. Physical properties

The average magnetic susceptibility (in log χ 10–9 m^3 kg^{-1}) is 4.41, with a standard deviation of 0.17. The average bulk density is 3.44 g cc-1, with a standard deviation of 0.25. The average porosity is 3.21 vol%.

3.2. Petrography

The meteorites are mostly composed of crystals (~15%) with sizes greater than 0.5 mm. The presence of Chondrules in the studied thin section vary from 15 to 20 % with apparent diameters from 0.3 mm to 3 mm. Their textures types are porphyritic olivine (PO), porphyritic olivine pyroxene (POP) and barred olivine (BO). The matrix covers ~65% of the samples with crystals having less than 0.3 mm in size. Concerning the mineralogy, the samples are mainly composed of two main phases, olivine (~55 %) and pyroxene (~30 %) with minor amounts of troilite (~4 %), chromite (~1%), kamacite (~4 %), taenite (~1 %) plagioclase (~2 %), zircon (~1 %) and apatite (~1 %).

The absence of chondrules with well defines borders and the presence of chromite, plagioclase and apatite among other features, indicate a thermal metamorphism degree marching the type 6 (Van Schmus & Wood, 1967).

With regard to the shock degree, the presence of irregular and planar fractures, some primary veinlets filled with opaque minerals as well as undulating extinc-

tion and incipient mosaicism present in olivine point towards a degree of shock between S3-S4. In addition presence of Fe oxides that can be replacing primary opaques phases between 0 and 100 %, with an average of 45 to 55 % in different samples. Also it can be observed in most of the samples the development of secondary weathering veins filled with Fe oxides. These observations support an alteration degree of W2.

3.3. Chemical composition

The chemical composition of Fe^0/ Fe has ranges between 0.37 and 0.33, with a total Fe content between 22.1 and 23.8 $wt\%$. This allows classifications of the sample as an ordinary chondrite type L. The average chemical composition of the main mineral phases is: olivine Fa_{24}; orthopyroxene $En_{70}Wo_{1.7}$ and plagioclase $An_{10}Al_{80}$.

4. Discussion

4.1. Pairing

The criteria used for the pairing of Pampa A fragments included physical properties, petrography descriptions and chemical composition, all of them described and explained in previous works (Benoit et al., 2000; Hutzler et al., 2016).

The physical characteristics of the samples as their different shapes and sizes point towards slight dispersions, as described by (Consolmagno et al., 2006). The petrographic studies show that all samples share the same components, varying in slight percentages due to the heterogeneity that is typical for ordinary chondrites (Hutchison, 2004). The [Fe^0/ Fe] ratio and total Fe content of the analyzed samples range in the values assigned to type L ordinary chondrites 0.33 ± 0.07, as established in Van Schmus & Wood (1967).

According to our results, when samples paired the three criteria, that is: chemical analysis, mineralogy and physical characteristics, the certainty in pairing samples increase. While in the studied fragments in which only the physical features could be measured, the pairing is less precise. However, one of the determinant features for matching meteorites is their closeness in the distribution area (Benoit et al., 2000).

4.2. Strewn field and entrance

The dispersion of the fragments on the surface has an elliptical shape, with the major axis in NW-SE direction. The larger pieces are at the SE end, because they flew a large distance due to their great inertia (Fig. 1). This indicates an entry from the NW to the SE with a dip of 106° from the north. The ellipse covers an area of 1.5×0.5 km^2 relatively small if compared to others which can reach dozens of km on its major axis (Hutchison, 2004). The absence of impact structures in the surface related to the fragments is a robust argument to propose a low speed entrance of the meteoroid. In addition, the direction of the fall match that of the terrestrial rotation direction.

For estimating the pre-atmospheric size of the meteoroid we took into account the average density of the fourteen fragments of Pampa-A (3.44 g cc-1) and the total mass collected (841 g), similarly to what has been done for the JAH 073 Strewn field (Gnos et al., 2009). In addition, we assumed a spherical shape and a loss of material due to the ablation varying between 90 % and 99 % of its pre-atmospheric weight, like the principal ablation percentage in ordinary chondrite (Sears et al., 2016). Therefore, the diameter of the meteoroid was estimated at 16.7 cm (90 %) and 36 cm (99 %). This should be consider the minimum estimated diameter as several fragments can remained not found or not reported in the fall area.

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