naturhistorisches museum wien

New Insights in Preservation of Meteorites in Hot Deserts: The Oldest Hot Desert Meteorite Collection.

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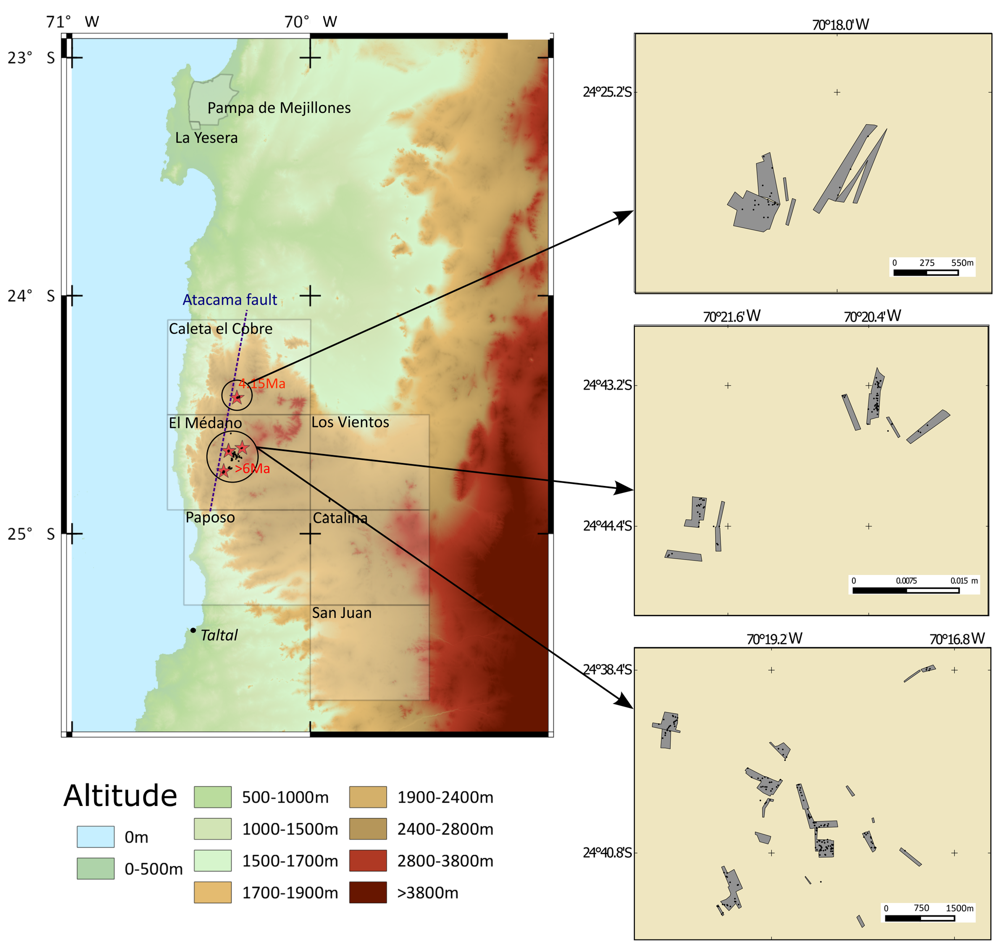
Deserts experience semiarid to hyperarid climates which allow preservation and accumulation of meteorites. In hot deserts, the lack of vegetation and the favorable geomorphologic features simplify the search for meteorites.

The Atacama Desert (Chile) is the oldest continuously arid region on Earth. We investigated two contiguous DCAs, El Medano and Caleta el Cobre (see map). Recovery expeditions focused only on the Central Depression, the hyperarid part of these DCAs. A total area of $1.5 km^2$ was searched sytematically on foot. 213 meteorites were recovered, and are now studied and curated at CEREGE, Aix-Marseille University (France).

Recovery on foot allows high-rate recovery, and hence ensure a robust calculation for meteorite density. Meteorite concentration is up to 170 meteorites over 10g per km^2 [1]. Without any clear evidence for physical concentration, and with flux models [2] giving a falling rate of 80 meteorites over 10g per Ma per km^2, the time needed to reach such a density is in the order of million years.

We selected a subset of 24 ordinary chondrites from the collection, and 4 chilean iron meteorites and measured terrestrial ages. We describe here how terrestrial ages were obtained, and present the results for the 24 ordinary chondrites, the 4 iron meteorites and 5 other Chilean iron meteorites [3].

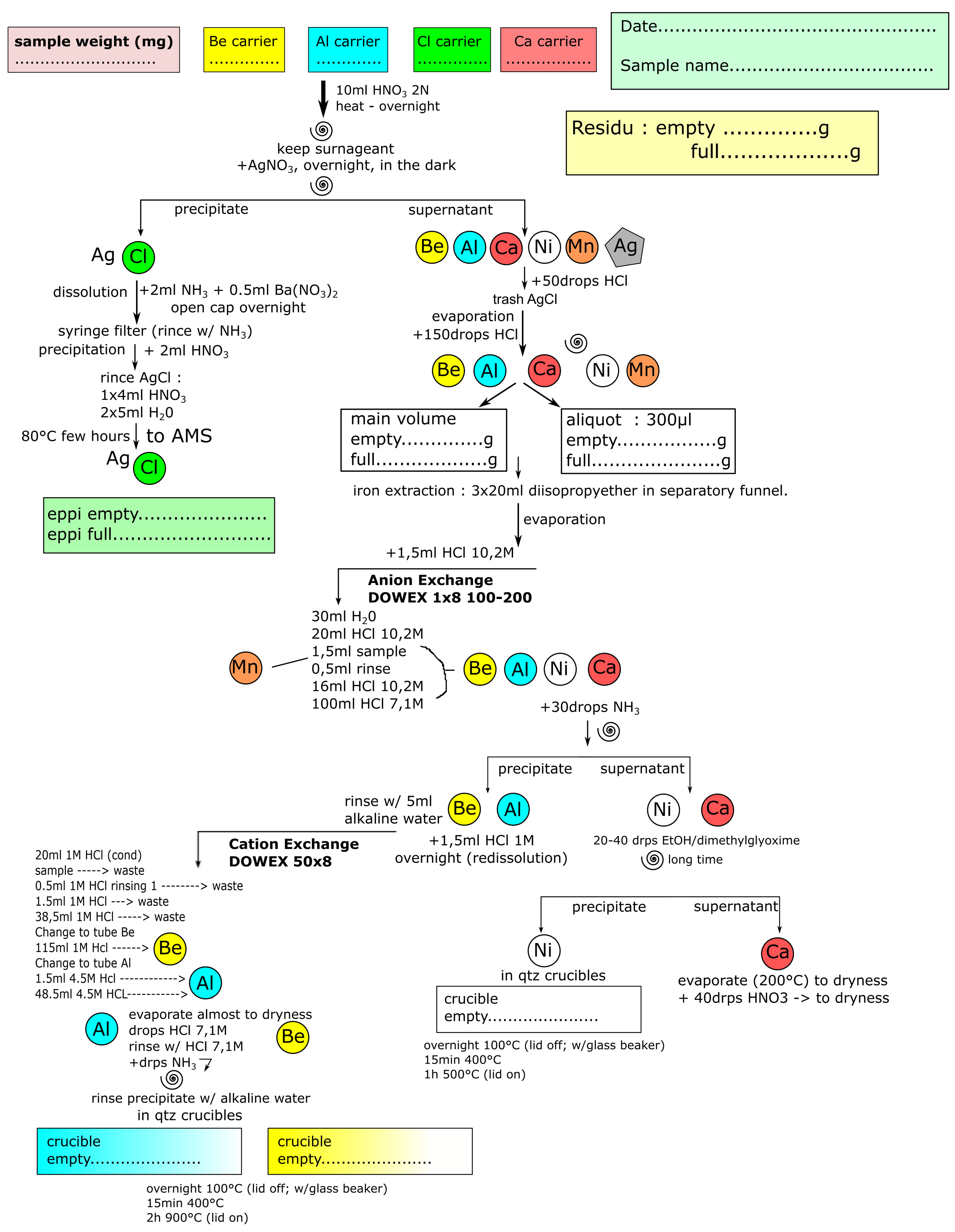


Chilean DCAs and explored areas in the Caleta el Cobre DCA and the El Medano DCA. Meteorites are represented by black dots. The Atacama fault is indicated on the main map. The datawere obtained through the online Data Pool at the NASA Land Processes Distributed Active Archive Center (LP DAAC).ASTER GDEM is a product of METI and NASA.

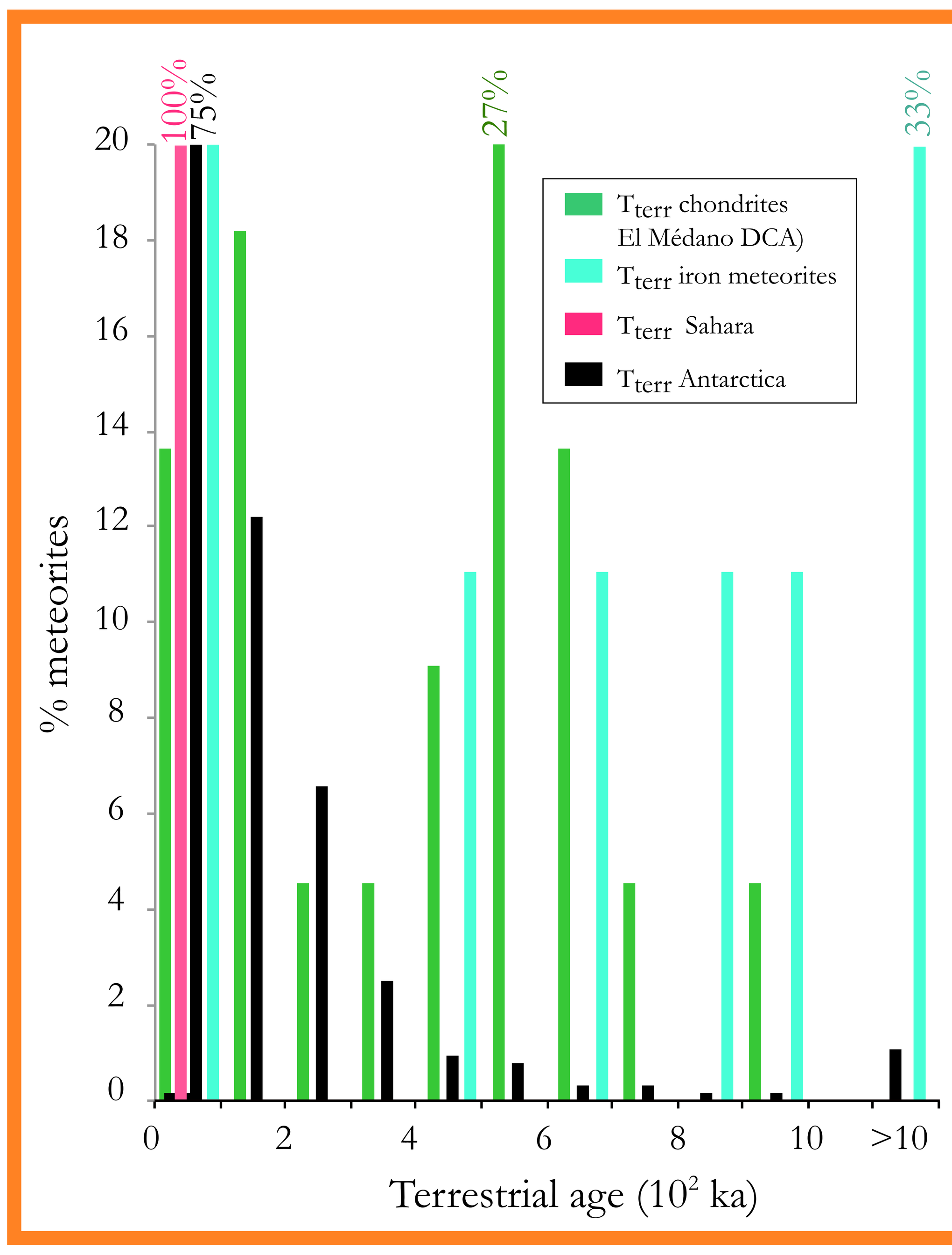
Methods

Iron fraction extraction: meteorites are crushed in a metal grinder, then in an agate mortar. Powder is cleansed with ethanol in an ultrasonic bath to remove attached silicates. It is then subjected to magnetic separation using a handmagnet. The remaining magnetic powder is then dried. Sample is demagnetized using a Molspin demagnetizer (30 mT alternative field). These steps are repeated 3 to 5 times. Sample is placed within a 0.2N HCl solution for 30 minutes in an ultrasonic bath to dissolve troilite. Then, a diluted HF solution in a cold ultrasonic bath for 10 minutes is used to remove remaining silicates. The resulting powder is examined under a microscope and non-metallic minerals are handpicked and discarded.

Chemical extraction: Iron fraction of chondrites and pieces of iron meteorites between 200 and 500mg are processed following the protocole below. Carriers are added at the beginning to the solution (1-5mg Cl, 1mg Al, 10mg Ca and 1mg Be).
All target elements are then compressed with a conductive powder if necessary (Nb powder for BeO and Ag powder for CaF_2 and Al_2O_3).
Isotopes ratios of ^{10}Be, ^{26}Al, ^{36}Cl and ^{41}Ca. are then measured at the French national Accelerator Mass Spectrometry (AMS) facility ASTER.



Terrestrial ages



The terrestrial ages of the El Médano collection meteorites (green bars) are distributed between 35 ka and 1 Ma ($^{36}Cl/^{41}Ca$ method), with an unweighted average of (0.41±0.26) Ma. Terrestrial ages of the Chilean iron meteorites (blue bars) range between 0 and 2.7 Ma, with an unweighted average at (0.43±0.43) Ma.

This distribution highlights significantly older terrestrial ages than those related to other hot desert collections (pink bars). It is comparable to the age spectrum for DCAs from Antarctica (black bars), such as Allan Hills.

Histograms of terrestrial ages of ordinary chondrites from Chile (this study, green, 24 samples), from Sahara (MetBase, pink, 112 samples) and from Antarctica (MetBase, black, 639 samples) and chilean iron meteories (this study and literature, blue, 9 samples).

Calculation of terrestrial ages

We mainly used the purely physical model presented in [6] (see equation below).

$$P_i(R,S,M) = \sum_{j=1}^{N} c_j \frac{\mathcal{N}_A}{A_j} \sum_{k=1}^{3} \int_0^{\infty} \sigma_{i,j,k}(E) \times J_k(E,R,S,M)\, dE$$

We used an iterative fixed-point method to find a set of value for [CRE age]/[Terrestrial age]/[Radius]/[Shielding depth].

The model can reflect reality only if the meteoroid spent enough time on space to reach saturation level. Cosmic-Rays Exposure (CRE) age is usually detemine with noble gases. In our case, we measured radiogenic nuclides only, hence we started from the assumption that all meteorites'CRE were over 10 times the half-life of the nuclides of interest. If we use ^{36}Cl and ^{41}Ca, that means a CRE age over 3 Myr. Considering literature estimate, iron meteorites' CRE ages are over 10 Myr and chondrites' CRE ages are between 1 and 15 Myr. Hence, we felt confident in using the model.

Conclusion

According to these results, it is possible for a meteorite collection to be preserved for over 1Ma in a hot desert environment, providing the environment shows long-standing hyperarid conditions. In view of its exceptional old age, the El Médano meteorite collection offers the possibility to study the meteorite flux to Earth on the million years time scale.

These results also confirm the calculation of a falling rate of meteorites on Earth at 80 meteorites (>10 g) Ma^{-1} km^2 [2].

References [1] Hutzler A. et al. 2016. Meteoritics & Planetary Science 51:468-482. [2] Halliday, I. et al. 1989. Meteoritics 24:87-122 [3] Koblitz J. 2005. Metbase, version 7.1. [4] Hutzler A. 2015. PhD Thesis, Aix-Marseille-University. [5] Arnold et al. 2010. Physics Research B 268:1954-1959.[6] Leya I. and Masarik J. 2009. Meteoritics & Planetary Science 44, 1061-1086. [7] Nishiizumi K. et al. 1989. Earth and Planetary Science Letter 93:299-313.
Acknowledgements: the first author would like to thank the Barringer Family Fund for a Travel Award.