

## Cosmic-ray exposure ages of 480 Ma old fossil meteorites: the L-chondrite parent-body break-up event?

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### Introduction

Fossil meteorites in sediments in southern Sweden indicate that the meteorite flux ~480 Ma ago was 1-2 orders of magnitude higher than today (Schmitz et al., 2001), presumably due to the L-chondrite parent-body break-up event evidenced also in a large number of ~500 Ma K-Ar ages. Here we determine exposure ages of fossil meteorites from different stratigraphic layers, extending over <1.7 Ma.

### Samples and Experimental

Meteoritic chromite grains are not significantly diagenetically affected (Schmitz et al., 2001) and appeared thus promising for this study. Gases were extracted from single grains by IR-laser heating and analysed in a mass spectrometer equipped with a compressor ion source with ultrahigh sensitivity for He and Ne. Exposure ages were calculated assuming "average" shielding (Heck et al., 2003).

### Results

All 6 measured relict chromite grains from one meteorite contain excesses of cosmogenic <sup>3</sup>He and <sup>21</sup>Ne (Heck et al., 2003). Contributions from nucleogenic <sup>21</sup>Ne and cosmogenic <sup>3</sup>He and <sup>21</sup>Ne produced on Earth can be neglected. Nominal <sup>3</sup>He and <sup>21</sup>Ne exposure ages are both around ~300'000 years for all grains. This suggests that both cosmogenic noble gas nuclides have been quantitatively retained. <sup>38</sup>Ar data from a pilot experiment agree with this conclusion, although within large error limits. At the conference, exposure ages of other meteorites in the sediment layer will be presented.

### Discussion

The age of ~300'000 years is unusually short for ordinary chondrites, but appears to be correct unless the studied meteorite fragment derives from an exceptionally highly shielded location. Further analyses of younger and older meteorites in the sediment column will rule on this. A very low exposure age may not be unexpected for the meteorites studied here. Zappalà et al. (1998) estimate that many large asteroid-family producing collisions deliver about 10% of the fragments arriving on Earth within about a million years. The fossil meteorites would then represent just the forerunners of the L-chondrite parent body break-up event ~480 Ma ago.

### References

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## Sulfidation state of hydrothermal systems: A Giggenbach perspective

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Oxidation and sulfidation states of fresh igneous rocks from arc environments, and sulfidation states of sulfide assemblages in calc-alkalic porphyry copper deposits and a variety of epithermal veins, are compared to vapor compositions of active volcanic and geothermal systems. Oxidation states of andesitic arc magmas cluster tightly between fayalite+magnetite+quartz and pyrrhotite+pyrite+magnetite. On equilibrating below the solidus, arc plutons deviate toward higher oxidation states. Sulfidation states of arc magmas are very low to low, lying between fayalite+magnetite+quartz+pyrrhotite and pyrrhotite+pyrite.  $R_H = \log(X_{H_2} / X_{H_2O})$  values versus measured temperatures for volcanic fumaroles agree with the isomolar  $SO_2 = H_2S$  curve (sulfur-gas buffer) at 900 to 500°C. Giggenbach thus concluded that the oxidation state of such vapors is controlled by their magmatic S composition, consistent with oxidation state trajectories for cooling plutons.

Reactive magmatic-hydrothermal fluids from active systems trend toward lower  $R_H$  and  $R_S = \log(X_{H_2} / X_{H_2S})$  values (higher oxidation and sulfidation states) with declining temperature. Below 200°C,  $R_H$  and  $R_S$  increase abruptly through interaction with wall rock. In contrast, geothermal fluids are relatively reduced, and their sulfidation state remains low to intermediate in the range 320-100°C. This may be caused by a greater degree of fluid-rock interaction at depth, a smaller magmatic component, or a distinct magmatic component. The reduced limit of geothermal compositions has an  $R_H$  value of about -3, equivalent to Giggenbach's rock buffer, where Fe-bearing minerals in fresh rock establish a "floor" to the oxidation state, just as the sulfur-gas buffer acts as a "ceiling".

The majority of porphyry copper deposits contain magnetite plus ore-grade assemblages of bornite and/or chalcopyrite without pyrite, indicating an intermediate sulfidation state. High-temperature volcanic fumaroles also plot largely in the bornite+magnetite field. By contrast, high sulfidation-state minerals are common in lower temperature epithermal veins. Sulfide mineral assemblages in porphyry copper deposits and many epithermal deposits, when taken together, describe a cooling path toward increasing sulfidation states from 600°C to 300°C, followed by an abrupt increase as equilibrium with the rock buffer is achieved. This pattern, also evident in fluid compositions from active magmatic-hydrothermal systems, suggests a continuum between these deposit types. Fluid compositions in active hydrothermal systems span the complete range of chemical and physical states that are commonly relegated to changing time in intrusion-centered ore deposits.