IN SITU MAGNETIC IDENTIFICATION AND CLASSIFICATION OF METEORITES IN ANTARCTICA. P. Rochette[1], J. Gattacceca[1] , P. Eisenlohr[1] and L. Folco[2], CEREGE CNRS, University of Aix-Marseille 3, France (e-mail: rochette@cerege.fr), [2]Museo Nazionale Antartide Siena Italy.

Magnetic susceptibility (χ) measurement is a rapid and sensitive way to discriminate meteorites from terrestrial rocks, as well as to partially classify them, based on laboratory measurements of more than 1500 different meteorites (Fig.1 and [1,2]). Due to their large content in metal or magnetite, most classes of meteorites have their log χ (in 10^{-9} m^3kg^{-1}) above 4. Among chondrites, only R, some CM and CV are in the log χ range 3 to 4. Among achondrites, HED, lunar and martian are in the log χ = 3 range. On the other hand, most sedimentary, metamorphic and plutonic terrestrial rocks have log χ well below 2, as exemplified by a collection of rocks from Victoria Land (Fig. 1). Only volcanic rocks (like the basalts and dolerites of the Ferrar Volcanic Suite) reach the values of the rare weakly magnetic meteorites.

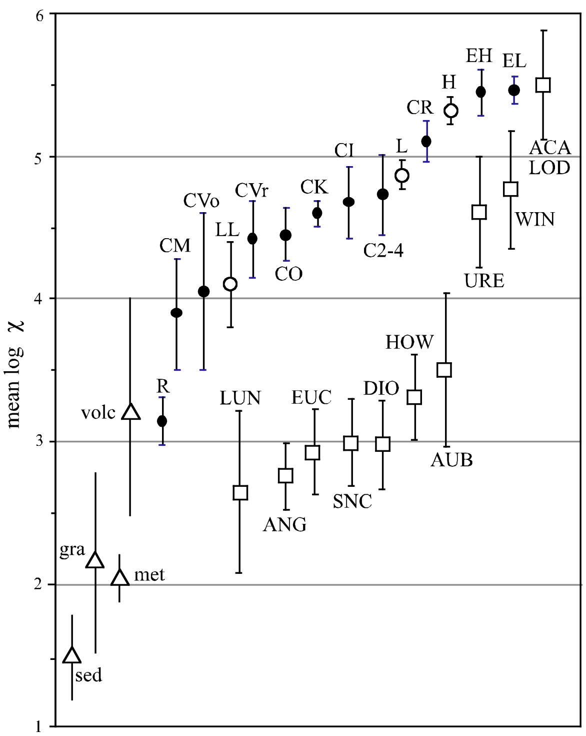


Figure 1: decimal logarithm of magnetic susceptibility in 10^{-9} m^3/kg (mean with s.d.) for different classes of meteorites (open circles: ordinary chondrites, solid circles: non ordinary chondrites, boxes: achondrites) and various sedimentary, granitic, metamorphic and volcanic rock samples from northern Victoria Land (triangles). Meteorite values are from falls only. Weathered metal bearing meteorites show slightly lower values.

To provide easy *in situ* measurements of log χ on boulders of any size and shape, we have calibrated a hand held contact probe (SM30 from ZH instruments; [3]). The raw measurement, corresponding to the volume susceptibility (K) of a half space, can be corrected to obtain log χ with a precision of about 0.1, knowing sample mass and assuming a given density (initially 3.4). Moreover, we found that an estimate of sample volume can be obtained combining SM30 measurements at 3 different distances from the sample. A simple Excel sheet can handle the data processing (volume computation and subsequent correction of raw measurement). Therefore a log χ value can be obtained in a minute on a sample laying on the ice (or on any weakly magnetic surface). This measurement can be used, by a scientist or a robot equipped with a SM30 probe, to decide before collection if a stone is terrestrial or meteorite, as well as to give a first insight on the meteorite classification.

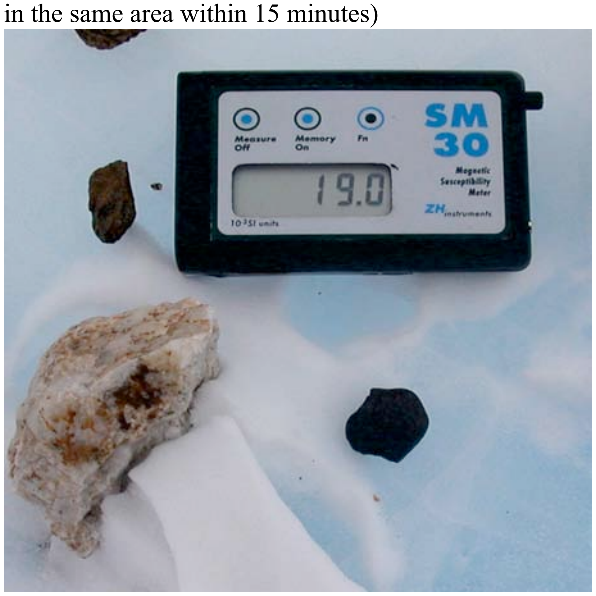
We have tested this technique during the 2003-2004 PNRA meteorite collection expedition in northern Victoria Land. In the Miller Butte area (where 4 meteorites were collected) meteorite visual recognition was very difficult due to the abundance of dark metamorphic rocks, with weathered aspect and smooth shape due to wind transport. Even for trained searchers the SM30 -without any data processing- appeared in some cases useful to decide if a stone was terrestrial (Fig.2a and b).

Indeed these paramagnetic rocks are about 1000 times less magnetic than the real meteorites found in this area. Clearly in such a context a robotic search based on color and shape recognition would be a complete failure, while adding SM30 measurements should lead to efficient recovery. Being able to give partial clues on the meteorite classification during the field campaign, SM30 also proved to be useful to provide early evidence of pairing and select rare types for first priority investigations in laboratory. As an example, 12 fragments (from 15 to 700 g) found scattered in a 1 km^2 area of the Johannessen Nunataks blue ice field yield a mean log χ of 5.08±0.06, confirming that they belong to the same weathered H chondrite fall.

The very high magnetic susceptibility of most meteorites can also be used to detect them when buried under snow or glacial or aeolian deposits of terrestrial rocks. We tested a rugged field magnetic gradiometer GA-72Cd from Schonstedt company (Fig. 3). Optimal conditions are found in Antarctica due to the terrestrial magnetic field being maximum (B_t=62 µT instead of 45 µT in Europe) and vertical (thus giving the anomaly right over the target). Especially stable background gradient is also present due to ice coverage, lack of human pollution and magnetic rocks (away from Ferrar volcanics and rare metamorphic rocks outcrops). For shallow targets the maximum vertical field "gradient" is practically the field created by the target on the lower sensor: B_t m □ / 2□ h^3, m and h being the sample mass and depth (assuming induced magnetization). For a 10 g sample of H chondrite at 10 cm depth in Antarctica, one gets a gradient variation of 20 nT, compared to a typical stable background gradient of 100 nT found in the Frontier Mountain area and a sensitivity of 1 nT. Actual detection level (on previously found meteorites laid on and under the snow) was better than predicted from these computations. Four meteorites, weighing from 1 to 20 g, were recovered under a few cm of snow, in particular within crevasses situated in a previously thoroughly searched area [4]. It is planned to confront the efficiency of this technique with respect to a metal detector (D. Loretta, pers. com.). Magnetic detection may prove more effective for weathered or magnetite bearing meteorites, whose conductivity are low but susceptibility still high.

References: [1] Rochette P. et al. (2003) *MAPS*, 38, 251-268. [2] Rochette P. et al. (2004) *Planet. Space Sc.*, in press. [3] Gattacceca J. et al. (2004) *Geophys. J. Int.*, in press, [4] Folco L. et al. (2002) *MAPS*, 37, 209-228.

Figure 2: SM30 probe with its raw output after measuring the sample directly on the ice (both photos taken in the same area within 15 minutes)



a) a 11 g, fusion crusted H chondrite;

b) rounded schist fragment found in the same moraine.

Figure 3: searching in a snow-bridged crevasse with the magnetic gradiometer in Frontier Mountain blue ice field [4].