MAGNETIC CLASSIFICATION AND SHOCK STAGE (OF PLAGIOCLASE) OF THE SARIÇIÇEK METEORITE (HOWARDITE)

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Sariçiçek Meteorite Fall 2015 and Magnetic Classification

At September 2, 2015, a large meteorite fall was observed and documented near the village of Sariçiçek in Turkey. Detailed results on the meteorite fall, find and laboratory investigations have been reported within a large consortium study [Unsalan et al., MAPS 2019, 1], see fig. 1. The meteorite was shown to be a howardite, a complex breccia which belongs to the HED clan. HED meteorites are believed to originate from the asteroid Vesta, see [1] for all further details.

In extension of this consortium study [1] we have investigated the magnetic signature, focusing on magnetic susceptibility (MS) as a fast stony meteorite classification tool. Magnetic susceptibilities were measured on several stones (#22 and #182 from the consortium). The investigations were done using both SM 30 and SM 100 Magnetic Susceptibility Meters manufactured by ZH Instruments, Czech Republic. The measurements were performed at a frequency of 9 kHz. In some cases, two or more fragments of the same stone were measured, in which case the magnetic susceptibility values for the same stone were averaged:

Sample	Comment	Mass	Log MS
# 22	Complete FC	3.81	3.08
# 182	Part FC	5.60	3.36
Individual #1	Complete FC	38.57	3.30
Average			3.25

Tab. 1: Magnetic susceptibility values of the investigated Sariçiçek samples (MS in log [10^{-9} m^3/kg]). FC – fusion crust.

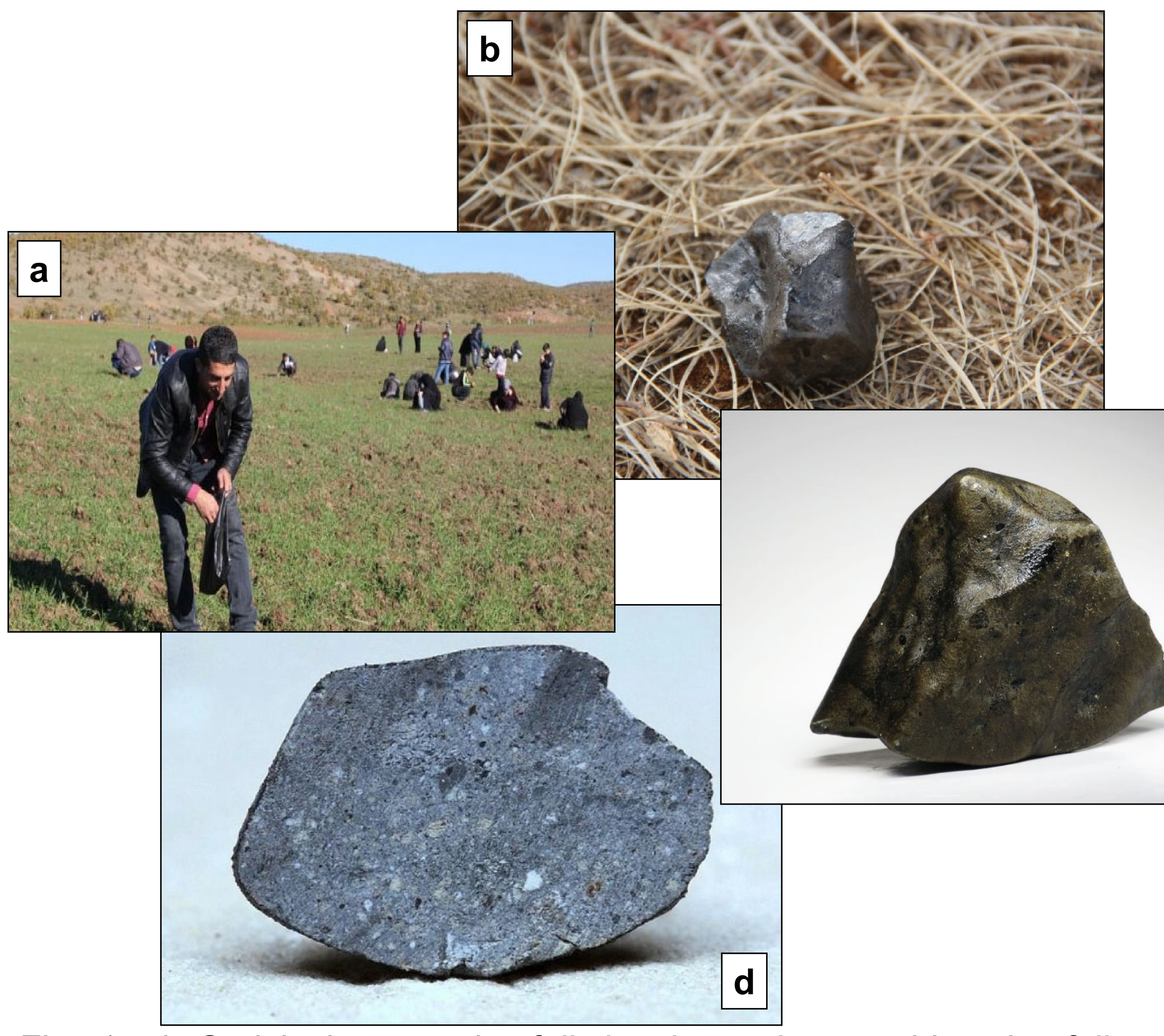

Fig. 1a-d: Sariçiçek meteorite fall: local people searching the fall area, small individual in field, a 300gr large mass and interior view after cutting ([7] and from internet).

HED type		Macke 2010/11	Rochette et al. 2009	Smith et al. 2006
Eucrites				
	All	3.07 (31)	2.95 (70)	2.85 (6)
	Falls	2.99 (17)	3.02 (24)	
	Finds	3.11 (14)	2.91 (46)	
Diogenites				
	All	3.04 (11)	3.02 (19)	3.43 (1)
	Falls	3.00 (7)	3.01 (11)	
	Finds	3.02 (4)	3.04 (8)	
Howardites				
	All	3.29 (15)	3.29 (28)	3.12 (2)
	Falls	3.37 (8)	3.34 (15)	
	Finds	3.24 (7)	3.25 (13)	

Tab. 2: Compilation of literature MS data of HED meteorites [2-5] for comparison and classification.

The relatively large range in values may arise from heterogeneities in the parent body of the Sariçiçek meteorite (asteroid Vesta). Lower magnetic susceptibility values could be also due to fusion crust related effects. A conversion of iron metal into iron-oxides in the fusion crust is accompagnied by a decrease in MS (see below).

MS Classification – Conclusions

- The MS values classify the Sariçiçek meteorite in the HED class.
- Sariçiçek MS fits quite well in the howardite range (falls/finds), concerning the likely background of MS enhancement of howardites, see below, 2nd box.
- Eucrite and diogenite MS value ranges overlap (falls and finds) – no simple discrimination by magnetic susceptibility alone.
- Howardite MS values do not reflect its petrology / formation processes – a regolith representing mainly a mixture of diogenites / eucrites – but howardite MS is significantly higher (falls and finds).

- Input of clasts of ultramafic diogenitic lithologies with much higher metal concentration and MS values (such as NWA 2968, MS = 4.28) which is significantly higher than for all other reported diogenites).
- Input of clasts or fragments of "exotic" meteorite lithologies in the Vesta regolith such as carbonaceous (CC) /ordinary chondrites (OC) with higher concentrations of magnetic phases: the result would be enhanced MS values – CC clasts in howardites have been reported [5].
- Shock transformation of Fe-bearing phases – e.g. olivine alteration and nano iron particle neo-formation / exsolution (known from other meteorite lithologies such as ureilites – the result would be enhanced MS values.
- Influence of space weathering / interaction with interplanetary/cosmic radiation: neo-formation of native iron or iron/silicon nano particles in thin surface layers, reported from returned Itokawa (JAXA Hayabusa) or Lunar regolith particles. The consequence of these processes would be also enhanced MS values.

Shock Classification on Plagioclase

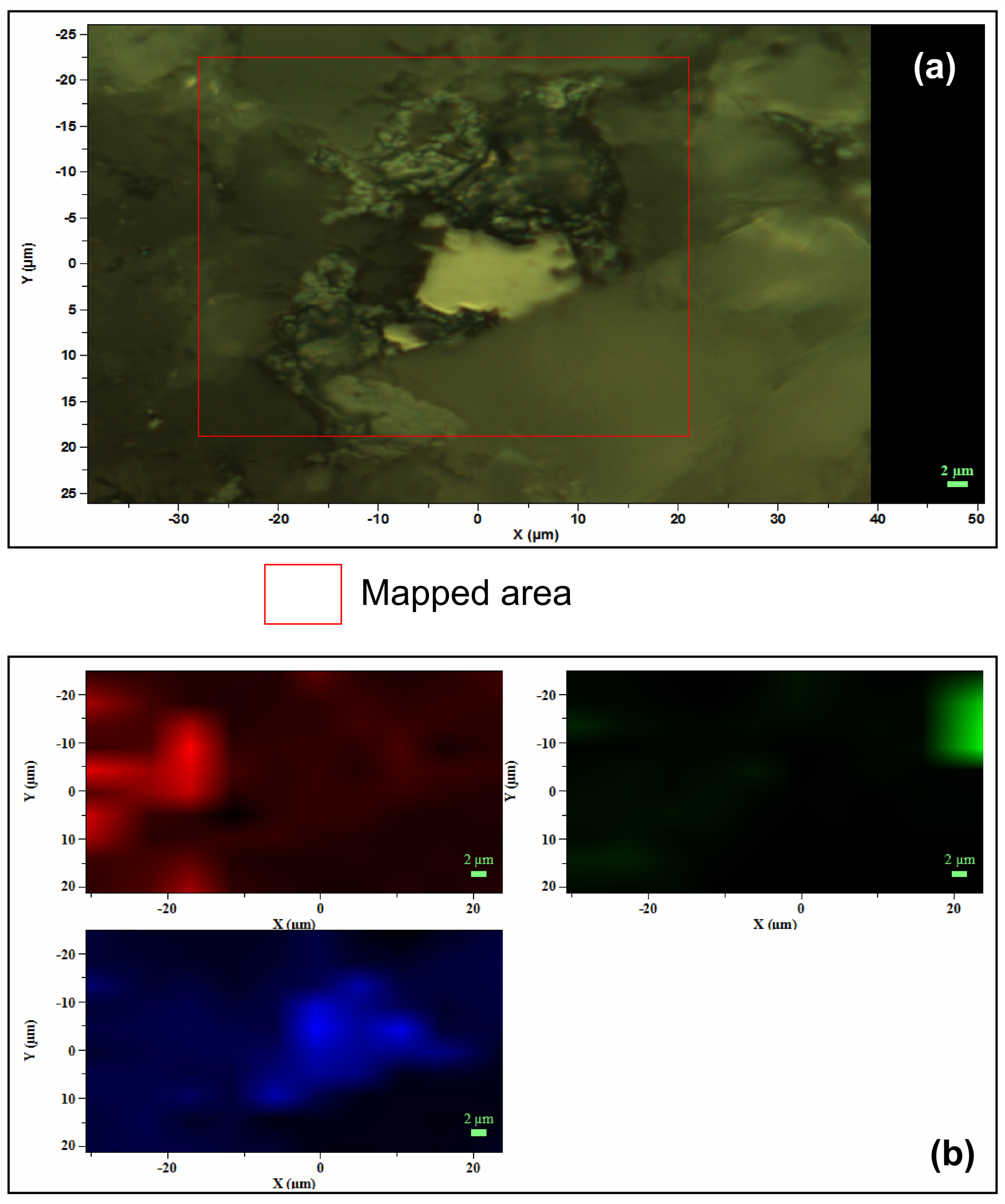

Fig. 2: (a, b) High resolution Raman Spectroscopy mapping of the distribution of plagioclase (red), olivine (green) and troilite (blue) within the selected area of (a) .

The shock stage of the Saricicek meteorite was investigated by LASER Raman spectroscopy on selected plagioclase grains. Polished thick sections of #182 have been prepared and first observed by optical microscope. LASER Micro Raman Spectroscopy was applied in order to study mineral phase composition and shock stage of the Sariçiçek howardite.

A Horiba Xplora Integrated confocal LASER micro Raman system was used with a Nd-YAG Laser (532nm) and a low laser power of less than 6mW. Magnifications were between 100 and 1000x (LD lenses) with acquisition times of 5 to 10 sec and accumulation numbers of 2–5.

An additional series of Raman experiments were performed on non-prepared specimen, pristine material that excludes any effects of sample preparation/polishing or sputtering (coating). High resolution mappings were performed in order to really detect and identify all present (including accessory) phases and also exsolution- /zonation-effects (fig. 2, 3). Varying the LASER energy allows to investigate sub-surface mineral phases.

The shock distribution was found to be quite inhomogeneous which should be expected in a regolith breccia. Most plagioclase Raman spectra point to quite low shock stages, S 1–2 (fig. 5), but also severely shocked feldspar grains have been detected, revealing maskelynite or even recrystallization effects (S 4-5) (fig. 6). We also have some indication for the presence of ringwoodite γ-$(Mg,Fe)_2SiO_4$ (here a very Fe poor member [6]), which would point to a minimum peak shock of at least 22 GPa (fig. 4).

Results of Raman Spectroscopy

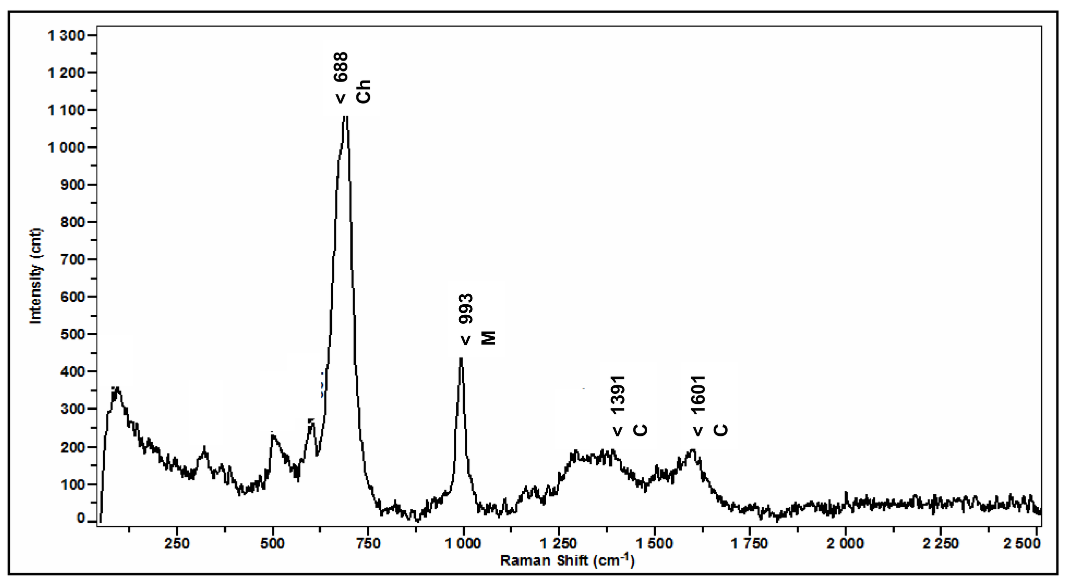

Fig. 3: Typical Raman spectra of mineral phases detected in the Sariçiçek howardite: **C**arbon, **M**errilite and **Ch**romite.

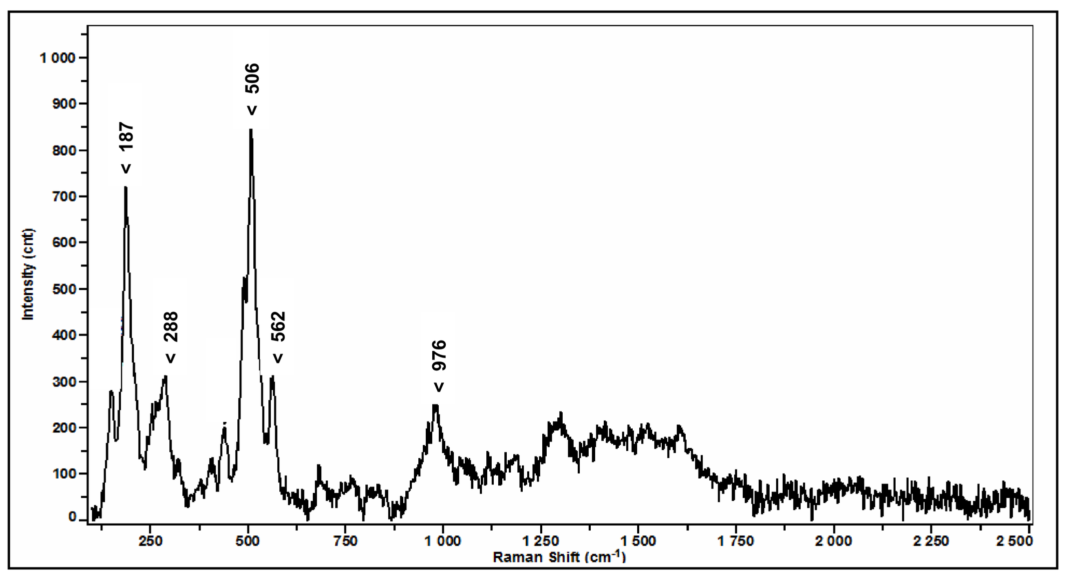

Fig. 5: Raman spectrum of a low-shock plagioclase from map1 (fig. 2).

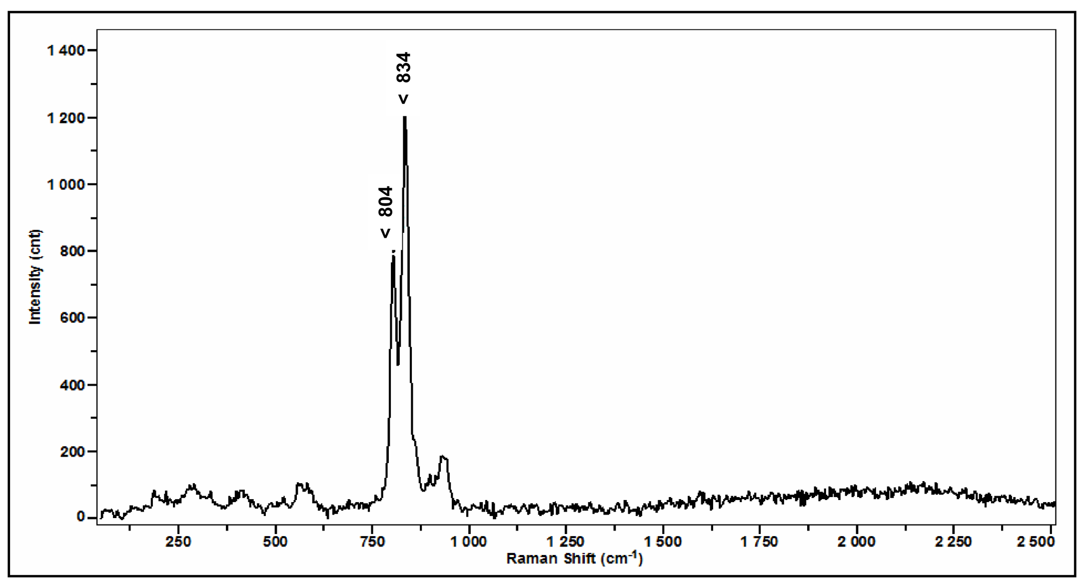

Fig. 4: Raman spectrum of a very Fe poor Ringwoodite, a clear indicator of shock pressures of at least 22 GPa.

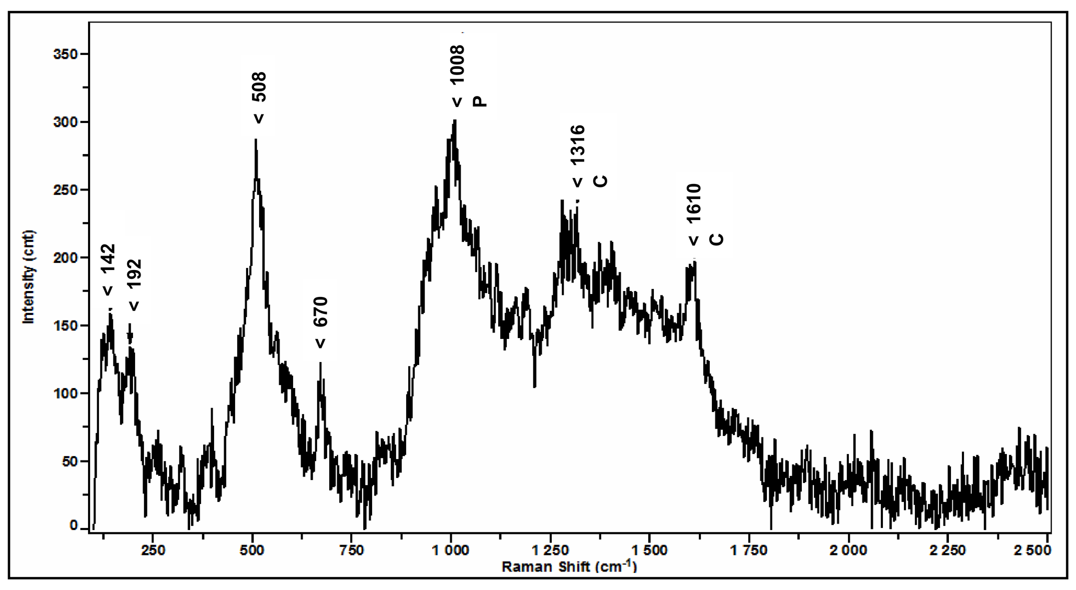

Fig. 6: Raman spectrum of a high-shock plagioclase from map1 (fig. 2). **C**arbon and **P**yroxene phases are also present.

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