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Complex micro- and spectroscopic study of the Chelyabinsk ordinary chondrite

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Abstract

In this work we present the complex petrographic-, element-, and phase analytical study of the different litholigies and shock-induced features of the Chelyabinsk ordinary chondrite meteorite.

1. Introduction

Recent complex material related analytical studies of impact chondrite meteorites provide profound information about the 4,6 billion year old story of the solar system. The Chelyabinsk meteorite, fallen in central-Russia in 2013 [1], had been greatly altered by slow thermal metamorphism of the parental body; external impact metamorphism of shock events and terrestrial weathering, consequently characterised as an LL5-6, S4, W0, S4 type ordinary chondrite breccia [2].

2. Methods

In this study, petrographic microscopy, cathode-luminescent micro- and spectroscopy, X-ray fluorescence microscopy and Raman spectroscopic analysis of shock induced melt-veins has been carried out on a thin section of the Chelyabinsk ordinary chondrite meteorite.

3. Results

3.1. Optical microscopy

In the 2x1.3 cm thin section of the meteorite fragment three different type of lithologies could be separated. The ordinary chondrite consists of a brecciated light and darkened lithology along with three different type of opaque shock-melt vein (Type I., II. and III.). The litholigies exhibit altered chondrite texture and different level of shock features.

3.2. Cathodoluminescent microscopy

Under cathodoluminescent microscopy of the thin section, feldspar and Ca-phosphate phases showed luminescence in various lithologies.

3.3. X-ray fluorescent microscopy

The results of the X-ray fluorescent microscopy showed that the S and Ni elemental abundance was greater in the substance of the darkened lithology, the Type III. melt-vein and outside zone of the Type II. melt-vein compared to the substance material of the light lithology and the Type I. melt vein.

3.4. Raman spectroscopy and statistical interpretation

Raman spectroscopic analysis of shock induced melt-veins have been carried out on a thin section of the meteorite. The raw results of the Raman line mapping had been refined with statistical methods and used for petrologic interpretation. The Type I. and II. melt-veins shows significant difference ($p \leq 0{,}01$) between expected values of peak positions and FWHM values of the Raman-active bands of substance olivine, however in some peak attribute means the Type II. melt-vein does not show significant difference with the other two vein type mean attributes ($p \geq 0.01$) [3,4].

4. Discussion and Conclusion

The external events caused shock-darkening of the original material, hence separation of different lithologies took effect [5,6]. The impact metamorphism generated brecciated texture in both light and darkened litholigies, additionally various shock features as shock melt-veins appeared in the chondrite.

The results have shown that shock features appeared more frequently between clasts of the light-coloured (precursor) as well darkened (shock-altered) lithology, as well as surrounding the shock-melt veins. The probable melt-vein induced shock darkening caused elemental distribution change of metals and metal-sulphides in the meteorite [4,5,6].

The three optically separated opaque shock melt-veins appearing in the thin section could represent two major genetics, a type between clasts (Type II. and III.) and a possibly younger, larger melt dike type (Type I.) [4].

The shock veins exhibit zoning in their thicker development (Type I. and II.). Each type of veins, along with developed intravein zones, differ not just in their thickness, but chemically and in their structure. These differentiations are manifested in variations in peak positions and half-widths of the Raman-active bands of substance olivine; intra- and extra-zone elemental distribution of the S and Ni; and grain size distribution of the metal and metal-sulphide melt droplets [4].

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