Study on impact materials around Barringer Meteor Crater by ED-SEM and micro-PIXE techniques

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Introduction

Until now, ~170 impact craters created by passing asteroids, meteorites and comets have been explored on the Earth's surface. By preserving their debris, impact craters can be regarded as the main source of extraterrestrial materials. Thus they provide reference data on the composition of the primordial planetary matter and parent cosmic bodies [1, 2]. The most famous and well-preserved meteorite crater is the approximately 50,000 years old Barringer Meteor Crater (Arizona, USA). Previous studied [3, 4, 5] proved that micro-PIXE technique is quite useful for study of impact materials. Moreover, it was also revealed that impact particles may have irregular form and rugged surface, and may show mineralogically complex textural patterns.

The combined application of Scanning Electron Microscope, Energy Dispersive X-ray Analysis (SEM-EDX) and a Scanning Nuclear Microprobe (SNM) is a powerful technique for the complex characterization of such materials. SEM provides the fine textural information and the concentration of the major elements. SNM with Proton Induced X-ray Emission (PIXE) method serves for the determination of both the major constituents and the important minor and trace elements such as the Platinum Group Elements (PGE): Ru, Rh, Pd. In this study analytical data are presented for S-Fe-Ni-Cu systems which may help to understand the major characteristics of impact materials.

Material

The samples were collected on the plain some hundreds of meters away from the southern rim of the Barringer Meteor Crater. Magnetizable micro-objects to be studied were prepared from sand samples by using magnetic separator. The micro-objects were embedded in synthetic resin, and polished. Finally, three black colored lustrous objects with irregular shape and more or less rugged surface were selected for analysis (Fig. 1).

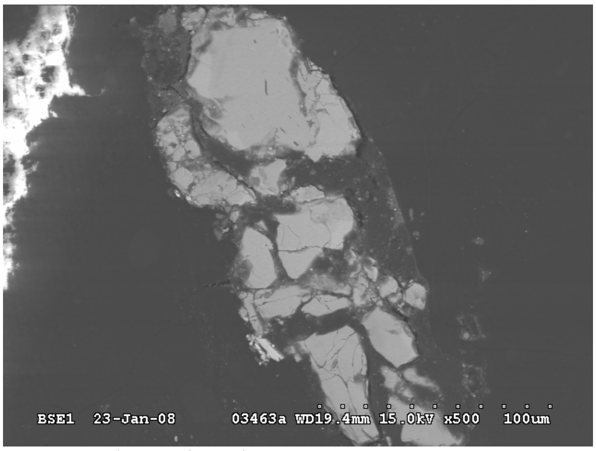

Fig. 1: SEM image of sample 1.

Method

Comparative micro-PIXE investigations were carried out at the Microanalytical Center of the Jožef Stefan Institute and the laboratory of Ion Beam Applications of ATOMKI in the framework of a joint Science and Technology project. The ion beam laboratory of JSI is based on a HVEE 2 MeV Tandetron accelerator while that of ATOMKI on a 5 MV Van de Graaff electrostatic accelerator. Both laboratories are equipped with Oxford Microbeams-type nuclear microprobe facilities [6, 7, 8]. The experimental setups consisted of two Si(Li) X-ray detectors at both places for the simultaneous and efficient detection of light, medium and high Z-number elements. At JSI, conventional, Be-windowed detectors while at ATOMKI an ultra thin windowed and a Be windowed detectors were applied [9]. For the evaluation of spectra and creating true elemental images the PIXEKLM-TPI program package was used [10, 11]. Calibration was carried out using pellets of pure chemical elements (such as Si, Ti, Cu, Mo, Pb) and compounds as well as the NIST610(ATOMKI)/NIST620 (JSI) glass standard reference materials. The accuracy of calibration was typically 1-3% and <5 % for all of the major elements. In order to determine the morphology and texture of samples and have concentration data for intercomparison, SEM-EDX measurements were carried out by

S4300-CFE Hitachi-type scanning electron microscope at the Joint Lab.

Results and discussion

SEM-patterns of the selected impact materials evidence heterogeneous structure characterized with grain sizes in the sub micrometer to 100 µm range. In such heterogeneous samples the exciting proton beam will penetrate through numerous small grains, and the produced characteristic X-rays may emerge through some other ones laying in the direction of the detector. In polished sections the sample thickness may arbitrarily vary across the surface, therefore, the saturation thickness for characteristic X-rays may not be reached for all elements at each point. At the present state of the existing PIXE imaging methods calculations are implicitly based on the supposition of sample homogeneity within a volume of probing depth dimension, furthermore, on a known sample thickness. When these conditions are unfulfilled — especially at grain boundaries or at the rim of the samples — significant bias in the calculated concentrations may be expected. In this study, the elemental composition was calculated by the PIXEKLM-TPI program supposing saturation thickness at each measurement point. Lateral distributions of elemental concentrations (true elemental images) were created for all of the detectable elements in the oxygen lead atomic number region. In order to extract analytical information for the constituents of the samples regions with similar compositions were grouped into clusters (Fig. 2).

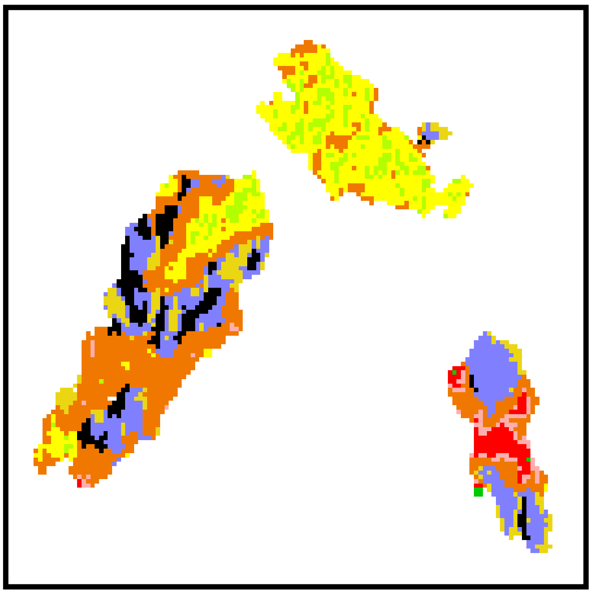

Fig. 2: Clusters crated by PIXE analytical data.
Legend: blue: S-Fe system (pyrrhotite); yellow and green: S-Fe-Ni system (pentlandite); red: S-Fe-Cu system (chalcopyrite).

The analytical results show that the samples are consisted of a silica-bearing shell and an S-Fe-(Ni, Cu) core. The cores are basically composed of three different types of minerals such as pyrrhotite, pentlandite and chalcopyrite in varying proportions. Beside the major constituents S-Fe-(Ni, Cu) most of the detected elements belongs to or enriched in the siliceous shell. Cobalt and zinc are trace elements within the S-Fe-(Ni, Cu) system. Cobalt shows a significant positive correlation with nickel. An interesting result of this measurement is that REE elements are enriched between the silica-bearing shell and the core. For example, a grain composed of S-Fe-Cu-Zn major constituents contained 1 % Rh and 5% Pd.

Conclusion

The combined use of SEM-EDX and micro-PIXE analytical methods revealed the structural and compositional complexity of impact materials. The applied true elemental PIXE imaging technique provided valuable analytical information on their S-Fe-Ni-Cu systems attributable to the Barrringer Meteorite as well as the enclosing silica-bearing shell.

Acknowledgements

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