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DEPOSITION OF CARBON, IRON AND NICKEL AT GEOLOGICAL BOUNDARIES AT THE ENDS OF THE PERMIAN AND CRETACEOUS PERIODS

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Abstract

Carbon, Fe and Ni-bearing grains are analyzed in two different ways in this study. One is their typical elemental abundances compared in crustal and meteoritic rocks. The other way is considered to be relicts on limestone rocks at the samples of the Cretaceous-Tertiary (KT) and Permian-Triassic (PT) geological boundary in European and Chinese countries, respectively. The latter material evidences are obtained by an in-situ observation with the Field- Emission analytical scanning electron microscopy (FE-ASEM) shown as various spherules and grains probably formed during rapid-impact reaction.

Key words: P/T boundary, K/T boundary, Carbon, Iron and Nickel spherules, FE-ASEM

Introduction

The end of the Permian Period (ca.250Ma, used as PTB) is the largest known mass extinction of fossil record on the Earth, as about 96% of all species on the Earth disappeared (Kaiho et al., 2001, 2002; Miura, 2006a-e), as well as major known mass extinction of fossil record at the end of the Cretaceous Period (ca. 65Ma, used as KTB).

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The main purpose of present paper is to reveal material evidences of impact (French B. M., 1998) by carbon (C) and iron-nickel (Fe-Ni) compositions of the micro-spherules and particles. The samples used are from Meishan PTB (Permian/Triassic Boundary) sections in Southern China, and European KTB (Cretaceous/Tertiary Boundary) section, Denmark and Spain.

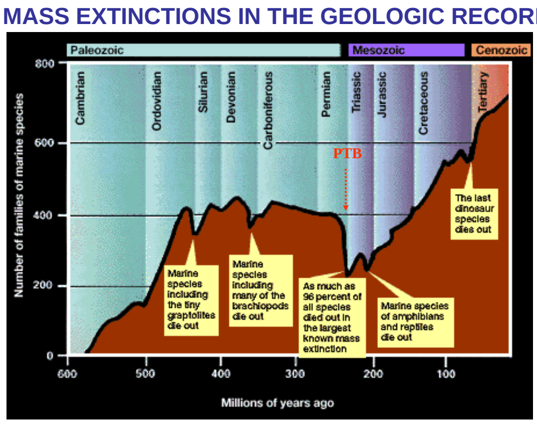


Fig. 1 Mass extinction with geological time on the Earth. The PTB is shown by a red arrow

Carbon abundances in the Universe and the Solar System

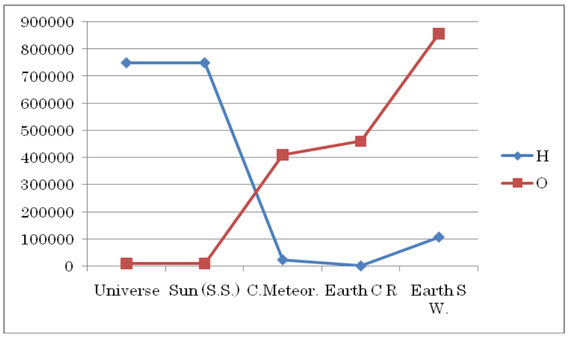
Four elements which are hydrogen (H), oxygen (O), carbon (C) and nitrogen (N) are inevitable for the natural re-sources and living-species for circulation system on the Earth. The elemental abundances of C, H, O and N in Universe, the Sun, carbonaceous meteorites, and crustal rocks, and sea water on Earth (University of Sheffield, 2006; Miura, 2006a-e), may be summarised as follows (tab. 1, fig. 1).

1. Element H which is originally produced in nuclear reactions in the stars (including the Sun as reducing condition) has a huge abundance in the Universe and the Sun than in terrestrial water.

2. Element O is more abundant on the Earth, in water and crustal rocks (as oxidizing condition).

3. Elements C and N have the same behaviours, more concentrated in rocks than in any extra-terrestrial materials (rocks as stored materials in circulation system produced oxides).

Carbonaceous chondrites (stony meteorites), concentrated in H, C and N, are relicts of oxidizing rocks from the Solar System transported to the Earth by impact growth process (Miura, 2006a-e). Therefore, carbon is added to the terrestrial rocks by meteoritic projectors due to their higher concentration in this element than the Sun and the Universe (fig. 1).



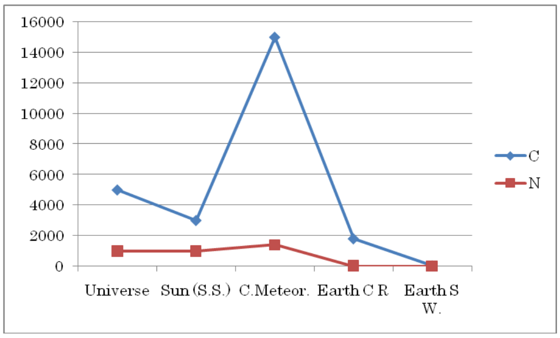


Fig. 1 Elemental abundances of C, H, O and N in the Universe, the Solar System, the Sun, and carbonaceous meteorites, compared with the Earth materials as crustal rocks and sea water (University of Sheffield, 2006; Miura, 2006a-e).

Tab. 1 Elemental abundances of C, H, O and N in the Universe, the Solar System, the Sun, and carbonaceous meteorites, compared with the Earth materials as crustal rocks and sea water

Loc./ppm	H	O	C	N
Universe	750000	10000	5000	1000
Sun (S. S.)	750000	9000	3000	1000
C. Meteor.	24000	410000	15000	1400
Earth C. R.	1500	460000	1800	20
Earth S. W.	107800	857000	28	0.5

Fe and Ni abundances in the meteorites and terrestrial rocks

Apollo lunar samples compositions indicate that extra-lunar elements as Pt-group elements and so on, typical in meteorites, are especially found in breccias samples (Heiken G.H. et al., 1991). The elemental abundances of Fe and Ni compared in carbonaceous meteorite and terrestrial crusts (University of Sheffield, 2006), indicate that Fe is 3 times higher and Ni 138 times higher in carbonaceous chondrites than in the terrestrial crust.

Carbon with Fe and Ni mixture formed by impact reaction

During impact reaction by meteorite and terrestrial rocks, carbon may remain among other light elements due to its high melting and vapour points. Fe and Ni elements which are the main or major heavy-elements in the iron and stony meteorites, are easily combined with isolated carbon element or oxide carbon (CO or CO_2) (Miura, 2006a-e; 2007a,b).

Meteorite → (impact reaction) → Materials of (1) C with minor Fe and Ni, or (2) Fe, Ni with C

Carbon-rich and Fe-Ni-rich spherules of the European KTB samples

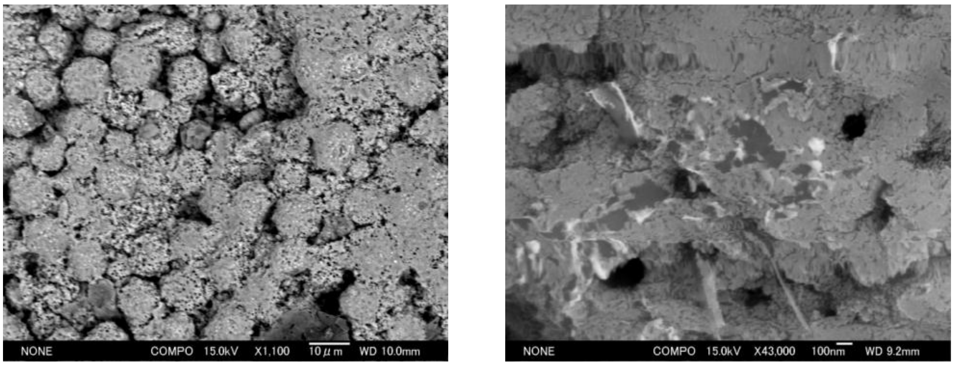
There are no direct observation of meteoritic elements as iron-group elements (Fe,Ni) and separated carbon (with minor calcium) for spherules found at geological boundaries (Miura, 2006a-e; 2007a,b). Impact history on Earth has been discussed by crater records on terrestrial surface so far. Carbon-rich grains with iron-group elements (Fe, Ni) by impact on limestone rocks has been obtained at the samples of the Cretaceous-Tertiary (KT) geological boundary in European countries by in-situ observation with the Field-Emission analytical scanning electron microscopy (FE-ASEM) which shows aggregates of spherules with Fe-Ni-Si-C (in 10μm size) as shown in figure 2.

The KT spherules show mixtures of Fe-S-Si, Fe-Si-Ni and C-Fe-Ca systems in composition (fig. 2). Large spherules (600μm in size) contain smaller spherules (10μm in size, fig. 2a) with minor grains (1μm and 100nm in size, fig. 2b), which is a direct evidence of impact vaporization from meteorite and target rocks.

Carbon-rich and Fe-Ni-rich spherules of the Meishan PTB samples

Among many magnetic spherules of the Meishan PTB samples (Kaiho et al., 2001, 2002), the following are the main results in this study (Miura, 2006a-f; Miura, 2007a,b):

1. carbon-rich spherules (10 vol.%) with “56 ～90wt.%C and 2 ～36wt%FeO “ in composition and 1 to 20μm in size;



(a) (b)

Fig. 2 FE-ASEM image of spherules of Fe, S, Ni and Si from the KT geological boundary in Europe. a. large spherules; b. small spherules. Bar of compositional image is 10μm and 100nm respectively. Bright parts are rich in Fe and Ni, whereas dark parts are rich in carbon.

2. Ni-rich spherules (10%) with "24 ～31wt.%NiO and 29～33 wt% FeO" in composition and with 100nm～5μm in size, are found irregularly with minor mixed phases of Fe-Al-Si-K-Ca-Co-Cu (analysed by in-situ ASEM) which are considered to be of impact origin on target rocks of the crust rocks on the Earth. All major elements found at the PTB spherules can be explained by an impact event on limestone and silica-rich target rocks on the crust due to few mantle-derived and volcanic rocks with much Mg (fig. 4).

Carbon grains of the drilled Akiyoshi limestone breccias samples

Drilled Akiyoshi limestone breccias from Yamaguchi, Japan (Miura, 1985) are used as related limestone with the Meishan PTB samples originally from Southern Equator transported by continental-drift after impact event (Miura and Tanaka, 2004). Carbon spherules and grains which are varied from 0.5μm to 30μm in size with nanostructure of 10nm size show 41～93wt.%C and 2～54wt% Ca with minor elements as Fe, Si, Al, Na, K and S (but without Mg).

Origin of carbon in the Akiyoshi breccias can be derived from limestone during impact reaction due to strong correlation with C and Ca, and significant Fe-Ni-Co contents of these bulk samples with ICP analyses (Miura, 2006a-e; 2007a,b).

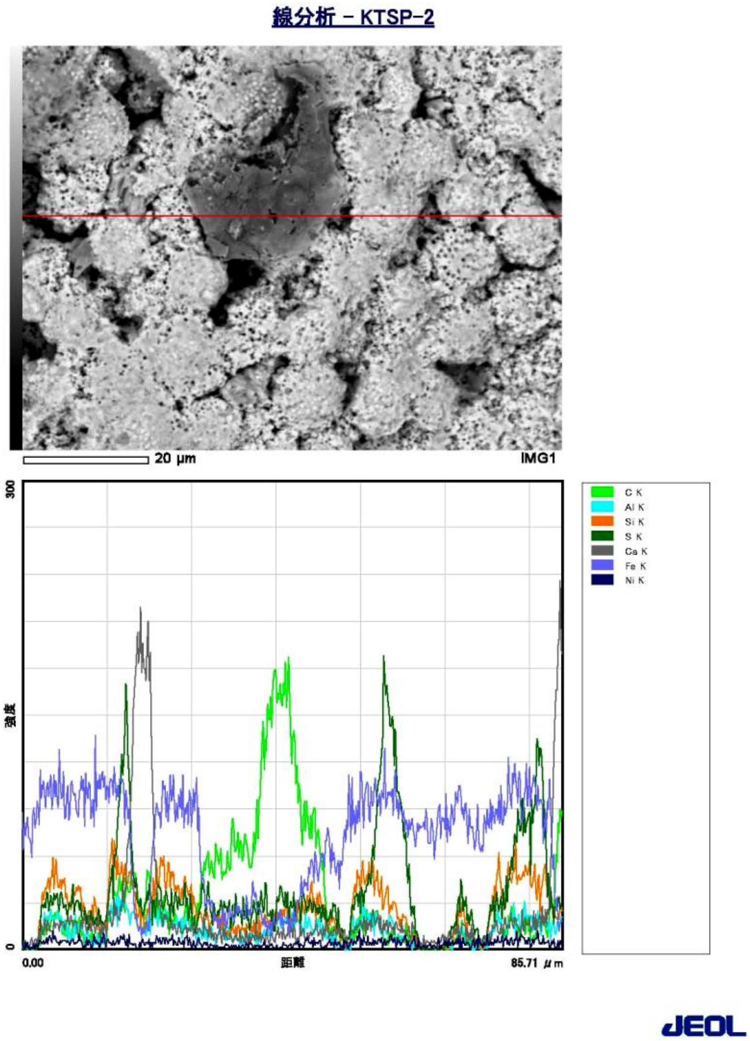


Fig. 3 Line profiles of carbon-rich grain (93%CO_2) with 20µm in size with the FE-ASEM image from European KT sample. Bar of compositional image is 20µm (upper fig. 3). Lines (lower fig. 3) show light green C, orange Si, deep green S, grey Ca, blue Fe and black Ni.

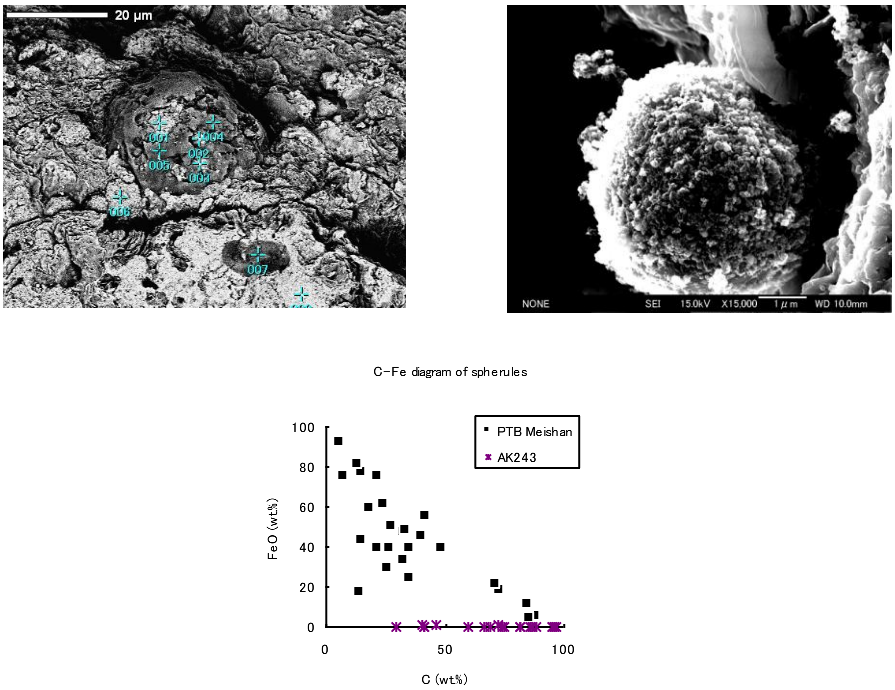


Fig. 4 Electron-micrograph BEI (back-scattering) image of carbon spherules (89C%) with minor Fe, Ca and Si elements (left), SEI (secondary) image of Ni-Fe spherules (31%Ni and 29%Fe) from sample of the Meishan PTB, China, and C-FeO diagram of spherules from PTB Meishan, China and Akiyoshi drilled 243m in depth in Yamaguchi, Japan. All analyzed data are obtained from in-situ analytical scanning electron micrograph ASEM (JEOL7000F; Miura, 2006a-e).

Conclusion

The present results are summarized as follows:

1. The Earth has a large cycle of major C-H-O-N elements which are connected originally from extra-terrestrial solid-rocks (meteorites or comets) by impact reaction.

2. During impact reaction by meteorite and terrestrial rocks, carbon can be preserved among other light elements to combine with Fe and Ni elements in the iron and stony meteorites, which are easily formed with isolated carbon element or oxide carbon compounds (CO2).

3. Carbon-rich grains with minor Fe and Ni by impact on limestone rocks have been obtained at the samples from the Cretaceous-Tertiary (KT) geological boundary in European countries by in-situ observation with the Field- Emission analytical scanning electron microscopy (FE-ASEM) as multi-sized spherules formed during rapid-impact reaction.

4. The Meishan PTB spherules have also C-rich (up to ca.90%C) and Ni-Fe rich (31%Ni and 29%Fe) compositions as impact mixing products.

5. Akiyoshi drilled limestone breccias from Yamaguchi, Japan contain C-rich grains with Ca from limestone target rocks.

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