［地球科学］

以下の問（１），（２）に答えよ．

（１）地球の形成史に関する以下の文章を読み，以下の問(a)～(f)に答えよ．

地球はⓐ微惑星の衝突･合体によって形成した．その衝突エネルギーによって，初期地球の表面は高温となり，やがてマグマオーシャンと呼ばれる融けた岩石に覆われるようになった．マグマオーシャンは次第に地球内部にまで及び，その過程でⓑ軽い岩石と重い金属鉄が分離し，核が形成されていった．一方，微惑星に含まれていた水や二酸化炭素などの揮発性成分の一部は，マグマオーシャンに溶けこんだと考えられている．やがて地球が冷えてマグマオーシャンの固化が始まると，マグマオーシャンに溶けていた揮発性物質は地表に放出され，大気や海洋が形成された．図 1 に示すように，大気の組成は地球史を通じて現在まで変化し続けている．

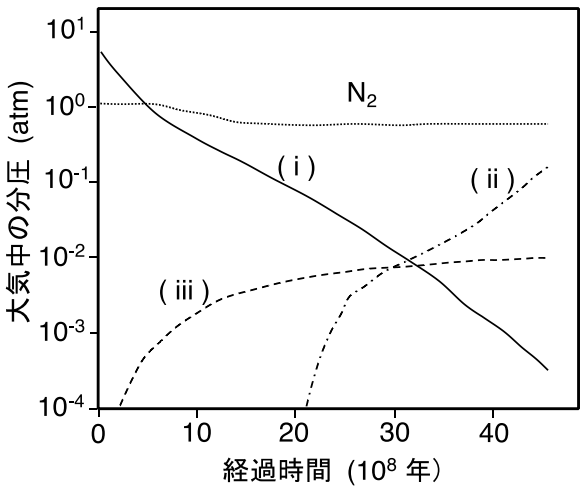

図 1　地球形成後の大気構成成分の分圧変化（1 atm = 1.0 × 10^5 Pa）

(a)下線ⓐに関して，地球を形成した微惑星は，太陽系形成初期に存在していた始源的物質が凝集してできたと考えられている．このような微惑星に由来する始源的隕石を何と呼ぶか．その名称を記せ．また，その隕石の鉱物組織的な特徴を簡潔に答えよ．

(b)下線ⓑに関して，マントル中のニッケル濃度は，始源的な隕石の化学組成および大気圧での岩石-金属鉄間のニッケルの分配係数から予想される濃度と比べると異常に高い．一方，高圧下では，ニッケルの金属鉄側への分配係数は圧力の上昇とともに 1 に近づくことがわかっている．これらの実験･観察事実からマグマオーシャンについて推定できることを簡潔に答えよ．

(c)マグマオーシャンは月の岩石の分析によって，最初に月において提唱された概念である．なぜ月にマグマオーシャンがあったと考えられたか，月の地殻の鉱物･岩石に着目しながら 50～100 字程度で答えよ．

(d)図 1 中の（i）は何か. 化学式で答えよ.（i）が地球形成初期に多かったとする間接的な証拠の一つに，暗い太陽のパラドックスと呼ばれる矛盾がある．暗い太陽のパラドックスについて，100 字程度で説明せよ.

(e)図 1 中の（ii）は何か. 化学式で答えよ.(ii)の同位体組成を分析することで過去の海水温を推定することができる. どのような手法か 100 字程度で説明せよ.

(f)図 1 中の (iii) は何か. 化学式で答えよ. また，太陽大気などの宇宙における (iii) の同位体存在比と地球大気のそれとは大きく異なる．どのように異なるか，その理由とともに 100 字程度で説明せよ.

（2）地球科学に関連した ①〜⑦から 3 つを選び，各用語の違いがわかるように, それぞれ 100 字程度で説明せよ．必要に応じて図を用いてもよい．図は字数に含めない.

① リソスフェアとアセノスフェア

② 適合元素と不適合元素

③ 大陸地殻と海洋地殻

④ 花崗岩と流紋岩

⑤ 生物ポンプとアルカリポンプ

⑥ 正断層と逆断層

⑦ 動的同位体効果と平衡論的同位体効果

［**Earth Science**］

Answer the following problems (1) and (2).

(1) Read the following sentences on the formation history of the Earth and answer the following problems (a)－(f).

The Earth was formed by the collision and coalescence of ⓐplanetesimals. The surface of the early Earth became hot due to the collision energy and was eventually covered by molten rocks called magma oceans. The magma ocean gradually extended into the interior of the Earth, and in the process ⓑlight rocks and heavy metallic iron separated and formed the core. On the other hand, some volatile components such as water and carbon dioxide contained in the planetesimals are thought to have dissolved into the magma ocean. When the Earth cooled and the magma ocean began to solidify, the volatile components dissolved in the magma ocean were released to the surface, and the atmosphere and oceans were formed. As shown in Fig. 1, the composition of the atmosphere has continued to change throughout the history of the Earth.

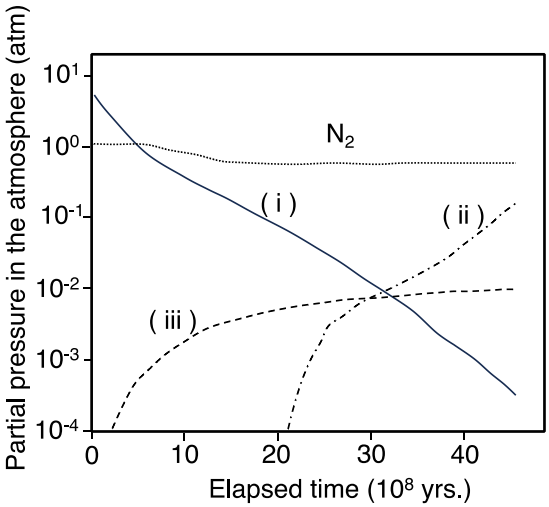

Fig. 1 Change in partial pressure of atmospheric components after the formation of the Earth. (1 atm = 1.0×10^5 Pa)

(a) Regarding the underlined part ⓐ, it is considered that the planetesimals that formed the Earth were formed by the aggregation of primordial materials that existed in the early stage of the formation of the solar system. What is the name of the primitive meteorite derived from such planetesimals? Give its name. Briefly describe the mineralogical features of the meteorite.

(b) Regarding the underlined part ⓑ, the concentration of nickel in the mantle is unusually high compared to that expected from the chemical composition of the primitive meteorite and the partitioning coefficient of nickel between rocks and metallic iron at atmospheric pressure. On the other hand, according to high-pressure experiments, the distribution coefficient of

nickel to the metal approaches unity with increasing pressure. Briefly answer what can be inferred about magma oceans from these experimental and observational facts.

(c) Magma ocean is a concept first proposed for the Moon based on the analysis of lunar rocks. Explain why we can consider the existence of magma oceans on the Moon, focusing on minerals and rocks of the lunar crust in about 25－50 words.

(d) Give the chemical formula of (i) in Fig. 1. One of the indirect evidence that (i) in Figure 1 was common in the early stage of the formation of the earth is a contradiction called the faint young Sun paradox. Explain the paradox in about 50 words.

(e) Give the chemical formula of (ii) in Fig. 1. By analyzing (ii), we can estimate past sea temperatures. Explain the method in about 50 words.

(f) Give the chemical formula of (iii) in Fig. 1. In addition, isotopic abundance ratios of (iii) in the solar atmosphere and other space environments are very different from those on the Earth. Explain how and why they are different in about 50 words.

(2) Select three pairs of terms from ① through ⑦ that are related to Earth science, and explain the content of each term in about 50 words, giving examples and figures if necessary. Figures are not included in the word count.

① Lithosphere and asthenosphere

② Compatible elements and incompatible elements

③ Continental crust and oceanic crust

④ Granite and rhyolite

⑤ Biological pumps and alkali pumps

⑥ Normal faults and reverse faults

⑦ Dynamic isotope effects and equilibrium isotope effects