

論文内容要旨

(NO. 1)

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Abstract

This thesis is composed of three chapters. Here I describe abstract of each chapter. Banded iron formations (BIFs) are widespread in the Isua Supracrustal Belt, West Greenland. Detailed geological surveys of BIFs in the western side of Isua were performed to constrain their depositional environments. In 1, 2 and 3 areas of the studied zone, geochemical evidence suggests that clastic components were incorporated in BIFs, which preserved the primary micro-banding of magnetite/quartz. Such BIFs were not likely deposited in the relatively shallow ocean environments at ca. 3.8 billion-years ago. On the other hand, BIFs in 4 and 5 areas do not show geochemical evidence for detrital components, probably suggesting deep marine depositional environments.

Extensive carbonation of > 3.7 Ga volcanic and sedimentary rocks has been reported from the Isua Supracrustal Belt (ISB). However, their geological extension, nature of associated fluids and detailed chemical reactions are poorly understood, in particular for the low-strain zone of the ISB. I performed geological investigation and characterized geological and mineralogical features of the massive carbonate veins and the carbonated BIFs in the northwestern part of ISB (Chapter 2). Field observation indicates that the massive carbonate vein was developing inside folding axis

parallel to BIF's strike, probably due to the tectonic control precipitation. The massive carbonate veins indicate significant variety of appearances, thickness and chemical zoning in cm to micro m scale. The reaction center of the veins, located nearby BIF, comprises magnetite-siderite-magnesite rich, whereas the edge of the veins are dominated by dolomite and chlorite in northern part of the studied area. Fe, Mn, Mg, Ca and Al concentration in carbonate, chlorite and amphibole are also variable. Carbonate, chlorite and amphibole in the massive carbonate veins associated magnetite are Fe-rich compared to those without magnetite. Considering the solubilities of carbonate and geological occurrence, it is likely that carbonates were precipitated from migrated CO₂-bearing crustal fluid by using cations in the pre-existing rocks. The occurrence of chlorite indicates that chlorite precipitated after magnetite and carbonate precipitation at the later stage of vein generation. Carbon isotope compositions are also systematically changing with the mineral zoning. $\delta^{13}\text{C}_{\text{carbonate}}$ values in the massive carbonate veins with magnetite are lighter than those in the vein without magnetite. The $\delta^{13}\text{C}_{\text{carbonate}}$ are also heterogeneous in cm scale, which could be explained by Rayleigh isotope fractionation between fluids and carbonates. Our calculations suggest that the source of the CO₂ fluid that precipitated the massive carbonate veins are originated from metamorphic CO₂ from pre-existing oceanic rocks or magmatic CO₂.

Occurrence of graphite has been recognized from the >3.74 billion-years-old Isua Supracrustal Belt (ISB) in western Greenland. ¹³C-depleted graphite globules in turbiditic and pelagic sedimentary rocks are claimed as traces of ancient marine planktons. On the contrary, secondary origin of graphite formed by crustal processes is also widespread in ISB. Presence of contrast origin of graphite in the ISB postulates careful assessment of graphite genesis for tracing early life. Here I discovered new graphite-rich schist (up to 8.8 wt%), intercalated in banded iron formations (Chapter 3). They comprised chlorite, cummingtonite, quartz and graphite, representing fine-laminated structure in microscopic scale. Chemical compositions of examined schist have mixed characteristics between chemical and clastic sediments. $\delta^{13}\text{C}$ values of graphite yield as low as -23.8 ‰. Those values are heterogeneous in microscopic scale, suggesting that carbon isotope exchange occurred between examined graphite and carbonic fluid in a crust. HRTEM images of the examined graphite show onion-like structures in nano-scale. These structures are analogous with pyrorized and pressurized biogenic molecules in previous report. Those observations clarify characteristics of graphites generated in different process and provide new evidence for ancient traces of life in metamorphosed early Archaean rocks.

論文審査の結果の要旨

大友陽子は、東北大学大学院理学研究科博士課程に在籍していた時に、グリーンランドイスア地域に分布する世界最古の地層の地質学的地球化学的研究を行った。大友陽子は就職のために博士課程は退学したが、今回は、在学時代の研究が博士論文としてまとまったため、審査を行った。

大友陽子が行ったグリーンランドイスア地域の地層での最大の問題は、世界最古の生物の痕跡が地層の中に残されているかどうかである。また残されていた場合は、どのような環境で生きていた生物なのか、またどのようにして生物の痕跡と断定するかである。大友陽子は現地で詳細な地質調査を4年間行った。その結果、新たに38億年前の海洋堆積物を発見した。さらに、その海洋堆積物がグラファイトに富んでいることを見いだした。この発見が博士論文の主要部分となっている。大友陽子は、そのグラファイトに対して、組成分析、炭素同位体分析、SEM、TEM分析、ラマン分光分析などを行った。大友陽子が発見したグラファイトはTEM像でカーボンナノチューブ状組織を有すること、炭素同位体組成が特異的に12Cに富む事など新しい知見を得た。イスア地域には38億年前の地下で無機的に形成されたグラファイトが産する事も知られており、その無機的グラファイトとは全ての分析データにおいて明瞭に区別されることが見いだされた。よって大友陽子が発見したグラファイトは38億年前の生物由来のグラファイトであると結論付けた。更に関連する地層（縞状鉄鉱層）の地球化学的研究から縞状鉄鉱層の鉱物組成、化学組成が南北方向で変化する事を見いだした。北部の縞状鉄鉱層がグラファイトを含む堆積物に伴っていた。北部縞状鉄鉱層ほどマグネシウムやアルミニウムに富み、碎屑性成分の影響が顕著でより陸地に近いところで堆積した事を示した。このことは38億年前の生物は、陸地に近い浅い海で生息していた事を示す傍証である。

大友陽子は、独自に発見した地層に基づき、世界最古の生命の存在を示し、さらにその生息環境にまで言及した。その研究成果は極めて独創的で博士論文として適当と論文審査会において認められた。さらに研究成果は自立して研究活動を行うに必要な高度の研究能力と学識を有することを示している。したがって、大友陽子提出の博士論文は、博士（理学）の学位論文として合格と認める。