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論文審査委員	主査　島根大学教授　三瓶　良和 島根大学教授　入月　俊明 島根大学教授　高須　　晃 島根大学准教授　ロザー B.P. 島根大学准教授　酒井　哲弥

論文内容の要旨

Upper Cretaceous to Tertiary clastic sediments from the western margin of the Central Myanmar succession have been investigated to evaluate the source of organic matter (OM), maturity, hydrocarbon potential, paleo-depositional environment, and paleoclimate based on CNS elemental analysis, vitrinite reflectance, Rock-Eval pyrolysis, $\delta^{13}C$ measurements, XRF analysis and gas-chromatography-mass spectrometry (GC–MS). Ninety-four outcrop samples including coals, coaly shales, mudstones and sandstones were collected from different stratigraphic units throughout the western margin of the Central Myanmar Basin (CMB) in the Upper Cretaceous and Paleogene-Neogene periods. The CMB succession includes Upper Cretaceous (Kabaw Formation), Paleocene (Paunggyi Formation), Eocene (Laungshe, Tilin, Tabyin, Pondaung, and Yaw Formations), and Pegu Group (Shwezetaw, Padaung, Okhmintaung, Pyawbwe, Kyaukkok, and Obogon Formations) in ascending order.

Extensive coals and coaly shales were deposited at the western margin of the Central Myanmar Basin (CMB) during the Late Eocene. Moderate weathering was recognized in three coaly shales, as manifest by microscopic cracks, holes, and rim structures in vitrinite. A sample pair of fresh and weathered coaly shale collected from one seam showed that HI, Pr/Ph ratio, PAHs and long chain *n*-alkanes (>nC_{20}) bonded to kerogen in the coaly shales decreased drastically due to weathering, and OI increased. These results suggest that potential of hydrocarbon generation of the coaly shale as an oil/gas source rock was decreased to about one tenth by the weathering, whereas the free *n*-alkanes, biomarkers such as steranes and triterpanes, and $\delta^{13}C$ ratios of kerogen were not affected. Facies change from the coaly shale layers (Phase-I) to the coal layers (Phase-II) was accompanied by variations in origin of the organic matter. The source of the OM was mainly terrestrial herbaceous vegetation and/or aquatic plants, deposited in oxic to

oxygen-poor peat swamps associated with an estuarine/fluvial-deltaic setting. Phase-I was relatively rich in gymnosperm biomarkers such as retene and 1,7-dimethylphenanthrene (DMP), whereas Phase-II showed an increase in angiosperm proxies such as oleanane content and oleanane/C_{30}hopane ratio, with $\delta^{13}C$ values ranging from -24.6‰ to -26.5‰. Based on HI values of unweathered samples, Phase-I is characterized by type II-III kerogen, while Phase-II contains type III kerogen. Higher values of HI, Pr/Ph ratios, nC_{29}/nC_{19} alkane ratios (>1.5) and higher concentrations of conifer-derived 1,7-DMP in Phase-I suggest a significant attribution of resinous higher plant origin. High Fla/(Fla+Py) ratio in the uppermost coal suggests occurrence of wildfire, probably related to dry climate in Phase-II. The unweathered CMB samples show good source rock quality, with potential generation of liquid/gas hydrocarbons.

The western margin of the CMB has been classified into three phases based on biological markers. [1] In the first phase (Upper Cretaceous to Paleocene) mudstones, the OM was sourced from terrestrial land plants including angiosperms, with a minor amount of aquatic plants accumulated under oxic to oxygen-poor conditions, with periodical marine water influences. Aquatic materials are more significant in the Upper Cretaceous mudstones. Gymnosperms were lesser contributors in the first phase. Lesser contents of perylene show dry condition. [2] The second phase (Lower to Upper Eocene) mudstones consists of abundant inputs of terrestrial land plants with lesser amount of aquatic plants and bacteria, deposited in freshwater oxic to anoxic conditions, with frequent marine water fluctuation due to sea level rises. Lower Eocene (Laungshe Fm.) and middle to Upper Eocene (Tilin and Yaw Formations) contains more aquatic materials. Gymnosperms are more predominant in the middle Eocene mudstones, while less abundant in the other mudstones. Low to high contents of perylene indicate dry (warm) to wet (humid) climatic conditions. [3] The third phase (Pegu Group: Oligocene to Miocene) mudstones contain mixed inputs of terrestrial higher plants including angiosperms and gymnosperms and aquatic plants accumulated under oxic to anoxic conditions, with periodic sea water influence according to eustatic sea level changes. Aquatic materials are more abundant in the middle to Upper Oligocene (Padaung and Okhmintaung Formations) and middle Miocene mudstones (Pyawbwe and Kyaukkok Formations). Oligocene mudstones (Shwezetaw, Padaung, and Okhmintaung Formations) show abundant contributions of gymnosperm vegetations. Perylene contents are relatively higher in the third phase, indicating wet (humid) climatic conditions.

Various maturity parameters for mudstones in the western margin of Central Myanmar succession (WMCMS) showed an immature to very early mature in the OM. According to the Hydrogen Index (HI~ 200 mg HC/g TOC) values of the Upper Eocene coals and coaly shales in the CMB, potential of hydrocarbon generation is reasonably good, mostly gas prone.

In addition, Upper Cretaceous to Eocene deposits were mostly generated from geochemically intermediate sources, and the Pegu Group is from recycled materials associated with continental island arc. CIA values indicate moderate to high source weathering in the Upper Cretaceous to Miocene mudstones may exhibit alternating shifts of dry (hot) and wet (humid/seasonal) climatic conditions. Upper Cretaceous and Paleocene mudstones could be mainly sourced from both the tectonically stable Eurasia Plate and active continental margins. Eocene and Oligocene mudstones were generated from active continental margins such as uplifted Myanmar (Burmese) margins and Himalaya and partly from passive margin (i.e. Eurasia Plate). Some Oligocene and Miocene mudstones were sourced from both the passive margin and Himalaya during active tectonism. Upper Cretaceous to Eocene materials are mainly originated from the Myanmar magmatic arc as an intermediate source. The Pegu Group (Oligocene and Miocene) mudstones and sandstones may have been generated from both the Myanmar arc and Himalayan detritus. The Pegu Group contains recycled quartzose materials and the Eocene sediments indicate partly some inputs of recycled materials.

論文審査結果の要旨

本論文の学術的意義は、大きく分けて２つ認められる。１つめは、石炭と炭質頁岩の風化（肉眼では分かり難い弱~中程度の風化）による炭化水素生成ポテンシャルの低下度を明らかにし、風化で変化する有機物指標と変化しない有機物指標を明らかにしたことである。２つめは、ミャンマー中央堆積盆地（CBM）西縁において後期白亜紀から中期中新世までの長いスパンで、主に有機物を用いて古環境と古気候を復元し、それがインド大陸衝突に密接に関係し、かつ細かな変動を繰り返しながら大きく変化したことを明らかにしたことである。この１つめの成果は、堆積有機物ケロジェンの基本的な特性変化としてほとんど議論されて来なかった風化の影響を詳細に明らかにしたことに新規性があり、２つめの成果は、古環境復元がミャンマーで始めて明らかにされたことに高い価値が認められる。

本論文の成果の具体的内容は以下のようにまとめられる。
①中程度に風化した炭質頁岩の炭化水素生成能力が約 10 分の 1 に落ち、ケロジェンにはカルボキシル基・カルボニル基が相対的に増え、高分子側の *n*-アルカン側鎖が減る。
②中程度に風化した炭質頁岩でも、バイオマーカー、フリーn-アルカン、δ^{13}C 値には影響がなかった。
③後期白亜紀～暁新世では被子植物が多く裸子植物は少なく、乾燥気候を示した。
④前期始新世以降には、藻類の影響が増え裸子植物が増加し、乾燥－湿潤の変化がある気候に変化した。これらの大きな変化はインド大陸の衝突によってミャンマー北東部が隆起したことに起因する。
⑤Zr/Sc 比は､インド衝突の前後で堆積物粒子が塩基性岩起源から酸性岩起源に変化することを示した。

Ei 氏が用いた地質試料は、石炭・炭質頁岩・泥岩・砂岩の計９４試料であり、本人自らが博士１年時に行った地表地質調査によって得られたものである（当初は MOGE 所有のボーリングコアの使用を考えていたが、ミャンマー政府の許可がおりなかった）。分析は、CNS 元素組成、ビトリナイト反射率、XRF 分析、GC─MS 分析、コンピュータモデリングを行い、自ら全て技術を習得して確かなデータを得た。一部、ロックエバル熱分解分析、δ^{13}C 値については外部委託して行ったが、データの吟味・解釈は自ら行った。Ei 氏は有機地球化学的手法をマスターし、一部、無機化学的手法も修得することで幅広い技術・知見を身に付けたため、今後、研究者として活躍する基礎が確立したと判断される。博士論文からは、本人の能力・修得した知識・技術・研究遂行能力が十分であることを読みとることができ、博士論文として十分な内容・成果を有していると判断される。