氏　　名	Young Sansfica Marlyn
学位の種類	博士（理学）
学位記番号	総博甲第８８号
学位授与年月日	平成２５年９月２４日
学位授与の要件	学位規則第４条第１項
文部科学省報告番号	甲第４９６号
専　攻　名	マテリアル創成工学専攻
学位論文題目	Mass transfer processes and impact on the geochemistry of terrestrial, estuarine and marine environments in Sri Lanka and SW Japan （スリランカと日本の河川における陸域、河口域と海洋環境の物質移動過程とその地球化学組成への影響の評価）
論文審査委員	主査　島根大学教授　石　賀　裕　明 島根大学教授　入　月　俊　明 島根大学教授　三　瓶　良　和 島根大学准教授　酒　井　哲　弥 島根大学准教授　Roser,Barry,P

論文内容の要旨

Study 1 - Mahaweli River and Trincomalee Bay system

The Mahaweli River is of a continental river and is the longest with a length of 335km and an altitude of 2500m. The Kuma River is of Japanese Island arc and is the longest river in Kyushu, south west of Japan with a length of 115km and an altitude of 1500m. Both rivers are dammed and thus were selected to be studied and to find out the mass transfer processes and the geochemical impacts of Mahaweli River and Trincomalee Bay System and the Kuma River and Yatsushiro Bay System.

Geochemical variations in stream sediments (n=54) from the Mahaweli River of Sri Lanka have been evaluated from the viewpoints of lithological control, sorting, heavy mineral concentration, influence of climatic zonation (wet, intermediate, and dry zones), weathering, and downstream transport. Compositions of soils (n=22) and basement rocks (n=38) of the catchment and those of <180 μm and 180 – 2000 μm fractions of the stream sediments were also examined. The sediments, fractions, soils and basement rocks were analyzed by X-ray fluorescence. Abundances of HFS and ferromagnesian elements in the sediments indicate concentration of durable heavy minerals including zircon, tourmaline, rutile, monazite, garnet, pyriboles, and titanite, especially in <180 μm fractions. The basement rocks range from mafic through to felsic compositions, as do the soils. $Al_2O_3/(K_2O+Na_2O)$ and K_2O/Na_2O ratios of the sediments and LOI values of the soils correlate well with the climatic zones, suggesting intense weathering

in the wet zone, lesser weathering in the intermediate zone, and least weathering in the dry zone. Low Sr and CaO contents and Cr/V ratios in stream sediments in the wet zone also suggest climatic influence. Fe-normalized enrichment factors (EF) for As, Pb, Zn, Cu, Ni and Cr in stream sediments in the main channel are nearly all <1.5, indicating there is no significant environmental contamination. The chemistry of the sediments, rocks and the soils in the Mahaweli River are thus mainly controlled by source lithotype, weathering, sorting, and heavy mineral accumulation. Enrichment Factor (EF) and composition of heavy minerals were used to examine the effects of climatic and weathering conditions, variation of river gradient, and hydraulic fractionation. The EFs of stream sediments in the Mahaweli River and its tributaries show that fining, accumulation due to transport, influence of tributaries, climate and weathering are major geochemical and physical factors contributing to downstream variation.

Compositions of sediments from three sectors in Trincomalee Bay (Koddiyar Bay, Thambalagam Bay and the Inner Harbour) in Sri Lanka were examined to determine fluvial and marine contributions, and the effects of sorting and heavy mineral concentration. Sediments in the three sectors differ significantly in chemical composition, according to position relative to the Mahaweli River delta source, depositional environment, heavy mineral concentration, and marine influence. Sediments in Koddiyar Bay, closest to the Mahaweli River delta, have geochemical compositions similar those supplied by the river. Sediments in the semi-enclosed and more distal Thambalagam Bay are also mainly derived from the Mahaweli River, but are modified by additions of Ca, Mg, and Sr from marine biogenic carbonate sources. This marine component is even greater in the Inner Harbour.

Compositions of four core sediments from the Trincomalee Bay were examined to determine possible depositional environment and provenance of the sediments. Heavy mineral content and variation in C1 differed from the other cores. C3 contained clay and organic matter in the middle part of the core. The results show that the bottom most C1 for the sediments were subjected to major wave and current activities. Sand bar formation near the Mahaweli River mouth acted as a barrier, causing weaker currents entering the area of C1. Finer sediments then accumulated. The study indicates that the sediment texture is the major controlling factor in the distribution of elements here. The deposition of sediments within Trincomalee Bay is dominantly controlled by wave and current activity. The CMI index and SiO_2 of >80% content suggest that the sediments are highly matured.

In the Trincomalee Bay 89 ostracode taxa were identified from surface sediments in the study area. Many of these taxa were typical tropical water species that have been reported from inner bay and shallow marine areas around the coasts of the Indo-Pacific region. Comparison with the trace element distributions showed that ostracod biofacies were not associated with heavy metal pollutions.

Study 2 - Kuma River and Yatsushiro Bay system

Surface and bottom sediments from 10 cm long cores (representing before and after dam removal), and two grain size fractions (fine 0.075 – 0.25 mm and medium 0.25 – 0.85mm) of the Kuma River and Yatsushiro Bay were compared. As the next step the chemical composition of sediments from the Yatsushiro tidal flat, Kuma River, and Arase dam (southwest Kyushu, Japan) have been determined to examine changes between 2002 and 2012. In 2002 sediment delivered to the bay by the Kuma River was restricted by the Arase dam; however in 2010 two gates were opened, allowing resumption of natural sediment transport.

Abundances of 24 elements in Yatsushiro tidal flat sediments, suspended solids in the bay, Kuma River stream sediments and suspended solids were determined by XRF. Water physical-chemical parameters, temperature, pH, EC, DO and ORP were determined in the field using a Horiba D-24 pH/Conductivity

meter. Grain size was measured for all sediments. Diatoms were classified using SEM.

Surface and bottom sediments do not show major chemical changes due to the removal of Arase dam. However, the grain size analysis shows that there is a significant difference before and after dam removal. Lower Br and Zn than 2000 indicate that biogenic processes and redox conditions have changed in the Kuma River. The removal of the Arase dam caused a decrease in most elemental concentrations. The elements for which changes are observed (As, Pb, Zn, Cu, Ni, Cr, V, Fe and total sulfur) can be very environmentally important, affecting the chemical behavior in the river and bay sediments. Abundance of these elements has decreased after dam removal. Ripple marks in the Yatsushiro tidal flat indicate inflow of coarser material from the reinvigorated river. Bulk chemical composition of the tidal flat sediments has changed since 2002, with marked decreases in As, Zn, and total sulfur, and lesser and more variable decrease in Pb. Manganese values are higher (>0.16ppm) in the northern tidal flats, suggesting anoxic conditions in the sediments at those sites. Suspended solids in both the Kuma River and Yatsushiro Bay have very low values of heavy metals, indicating low absorption, flocculation and dilution by organic matter due to strong water circulation. Kuma River sediments are characteristically coarser than those in Yatsushiro Bay, except at three locations. Average values in both suites are similar to UCC.

Thus as the synthesizing conclusions, the Mahaweli River falls to the Trincomalee Bay a deep natural canyon and sand is deposited, fine fraction is flushed to the open sea while the Kuma River forms a large tidal flat at Yatsushiro Bay with mud at distal end and sand at the proximal end. In the Mahaweli River the sediments are fractionated, influenced by tributaries, dams, heavy minerals, weathering. The wet and intermediate zone sediments are mixing in the dry zone due to length and heavy minerals are deposited in the Koddiyar Bay by winnowing and wave actions. No such mixing due to short distance of the Kuma River. Flooding occurs in the Mahaweli River but is weakened since river is long, and the sediments are transported to the bay. In the Kuma River flooding causes mud drapes and sand deposits in the Yatsushiro Bay and flooding causes mud drapes and sand deposits in the Yatsushiro Bay.

論文審査結果の要旨

申請者はスリランカペラデニア大学出身で留学生特別プログラムの博士前期課程に入学し、後期課程へ続けて研究を行ってきた。自国の地下水・土壌汚染、河川と沿岸域の管理と保全に関する研究をテーマとして野外調査を始めてきた。博士論文の主題は河川システムと沿岸環境との関係で河川流域圏の総合的な評価を行うことである。その評価手法として堆積物や土壌、岩石の地球化学的分析を用いて行うものである。本人とはスリランカの地下水調査の折に面談して、共同研究として始めたが、その後特別プログラムに応募してもらった経緯がある。また、現地ペラデニア大学の Pitawala 教授とも留学生指導を通して共同研究を進めている。

スリランカの Mahaweli 川は 300km に達する延長を持ち、上流の地質は High land complex と呼ばれる高温の変成岩からなる地域である。この地域は 2000m を越える高地でこれより河川勾配は次第に低下して、下流では傾斜は緩くなり堆積物の混合が進む。スリランカは歴史時代の古くからため池や堰によるダム建設が行われ、堆積物の流下を妨げている。このような状況で支流の堆積物は強い風化作用を受けて重鉱物の濃縮がおこり、Ti や Zr、Th、Nb 等に富む元素組成を持つ。沿岸の Trincomale 湾でもこれらの重鉱物の濃縮が生じて特異な海浜砂が形成されている。このような元素濃縮の過程を精密な分析と詳細な検討から評価した。

また、本邦でも河川から沿岸干潟までの流域の研究をあわせて行った。これは九州球磨川における研究で荒瀬ダムが撤去されることに関連して河川環境がどのように変化するかを評価したものである。研究指導者の石賀は 2000 年頃から不知火海と球磨川の堆積物の元素組成から水環境の評価を行う研究を行ってきた。そのため、2003 年の試料がアーカイブとなり今回比較研究に役立った。また、2010 年の荒瀬ダムのゲートの開放による河川状況の変化とも合わせて、環境変化の評価を行った。

野外調査は条件的にも困難を伴うことが多くその実施は難しいことが多い。しかし、申請者はその苦労も経験しながら調査を行ったことは学術的にもスタンダードと成る貢献を行った。また、不知火海の干潟環境調査は潮位差が大きいといえども、大潮の時に限られそのタイミングや気象条件をはかることも重要である。幸いにも複数回の野外調査をへて球磨川から不知火海の干潟環境までの総合的な知見を論文にまとめることが出来たことは高く評価される。

また、スリランカでは津波堆積物の研究も行っており、地球科学研究の幅広さが高く評価できる。

論文はこれら２つの研究分野についてまとめており、河川・沿岸流域圏の総合的研究の新しい分野の開拓を行ったといえ高く評価できる。以上のことから博士論文として高い評価を与えられるものである。