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研究課題名（和文） 第２世代の砕屑岩の起源とテクトニクス場識別図

研究課題名（英文） Second-Generation geochemical discriminants for determination of provenance and tectonic setting of clastic sediments

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研究成果の概要（和文）： 包括的な全岩化学分析から砕屑堆積岩の起源指標である微量元素判別図の再評価を行った．判別図において，よりフェルシックな活動的大陸縁（ACM）の堆積岩は海洋性島弧(OIA)および大陸性島弧(CIA)から明瞭に区分されることが明らかとなった．一方 活動的大陸縁（ACM）とシリカに富む非活動的大陸縁（PM）の堆積岩の化学組成は完全に重複する結果が得られた．

研究成果の概要（英文）： Trace element discrimination diagrams for clastic sediments have been re-evaluated using a large suite of comprehensive whole-rock analyses. Active continental margin (ACM) sediments are distinct from OIA and CIA as a result of their more felsic nature. However, ACM and silica-rich passive margin (PM) sediments show almost complete overlap in composition.

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（金額単位：円）

	直接経費	間接経費	合 計
2008 年度	800,000	240,000	1,040,000
2009 年度	100,000	30,000	130,000
2010 年度	100,000	30,000	130,000
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研究分野：数物系科学
科研費の分科・細目：地球惑星科学・地質学
キーワード：(1) 地球化学 (2) 砕屑性堆積物 (3) 識別図 (4) 堆積物の起源 (5) テクトニック・セッティング

１．研究開始当初の背景

Major element-based tectonic setting discrimination diagrams for sedimentary rocks have been applied since the 1980’s. These have attempted to identify sediments deposited in oceanic island arc (OIA), continental island arc (CIA), active continental margin (ACM) and passive margin (PM) settings. Similar diagrams using trace elements have also been proposed and utilized. Both approaches have come under some criticism, in part because of the comparatively limited datasets used to define them originally. Moreover, the trace element discriminants proposed are based on data for sandstones, and hence cannot be applied to the finer-grained rocks that form large parts of many sedimentary sequences.

Development of newer analytical

techniques such as ICP-MS has led to a rapid increase in the volume of quality data available for sedimentary sequences.

２．研究の目的

The purpose of this project was to:

(1) Re-evaluate fields on existing trace element-based tectonic setting discrimination diagrams using an extended database, and to test new combinations of alteration resistant trace elements for effectiveness;

(2) Evaluate data for finer-grained sediments (siltstones and mudstones) to determine whether sorting effects produce characteristic tectonic setting signatures in these lithologies;

(3) Determine if rare-earth element (REE) parameters can also be used to determine tectonic setting.

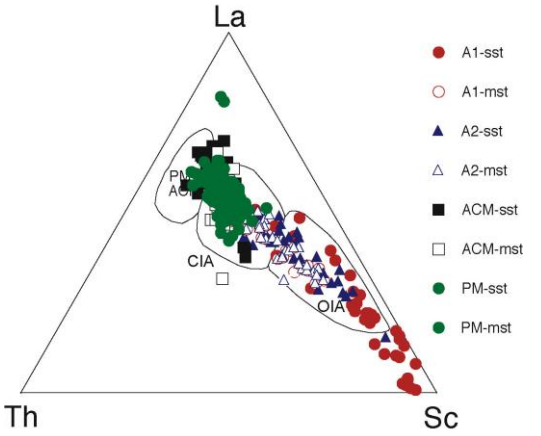
３．研究の方法

A “training” set of 450+ of published and unpublished analyses of sandstones and mudrocks from New Zealand Mesozoic terranes of established tectonic setting was assembled. These were then applied to the existing discrimination diagrams, and field boundaries redefined based on the larger dataset. Several additional combinations were also tested (e.g. Zr/Sc-La/Sc, Zr/Ti-Ce/Ti) along with other plots commonly used in the literature but for which no provenance fields had been proposed (Zr/Sc-Th/Sc; Y/Ni-Cr/V).

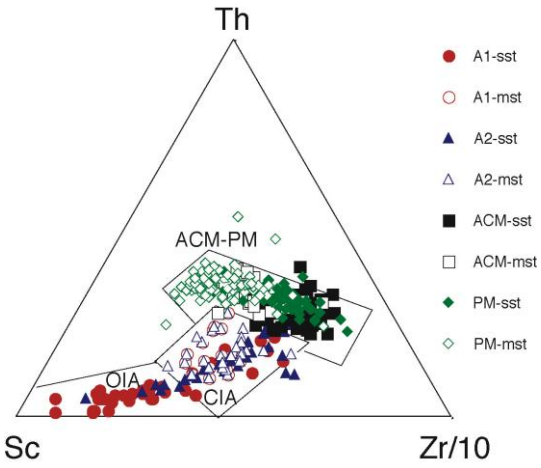
The redefined fields were then tested using data from Japanese terranes and other data, previously classified into specific tectonic settings on the basis of geologic, petrographic and major element geochemical characteristics. The test data used were from the Shimanto terrane (ACM) and associated fore-arc basin deposits of the Tanabe Group, Idonnappu-Yezo (CIA-ACM) Nemuro Group (OIA), Oshima Belt (ACM), plus the Kanmon Group (PM rift) and correlative sediments in the Gyeongsang belt of Korea, the Sylhet basin in Bangladesh, and other published work.

４．研究成果

(1) Ternary Th-Sc-Zr/10 and La-Th-Sc plots (Bhatia & Crook, 1986) for the training set (Fig. 1) show that on both plots the field for OIA could be extended toward the Sc apex; however, overlap between the OIA and CIA data is extensive. Data for the ACM and PM training sets overlap the field originally defined for CIA, and also overlap each other, even



though separate fields were originally defined from ACM and PM on the



La-Sc-Zr/10 diagrams. Consequently, no distinction can be made between ACM and PM using these plots.

Fig. 1: *La-Th-Sc and Th-Sc-Zr/10 ternary diagrams for the training sets. Original field boundaries of Bhatia & Crook on the La-Th-Sc plot; possible revised boundaries on the Th-Sc-Zr/10 plot, which also fails to discriminate between ACM and PM.*

(2) Plots based on immobile element

ratios such as the examples listed above show the same patterns. The most mafic OIA (A1) sediments plot in unique fields, but more evolved samples overlap extensively with CIA (A2) sandstones and mudstones, as shown in the example for Zr/Sc-Th/Sc (Fig. 2). There is no consistent sorting fractionation of ratios between sandstones and mudstones. Although separate from OIA and CIA, ACM and PM data overlap almost completely, but show marked sorting fractionation on almost all combinations of variables.

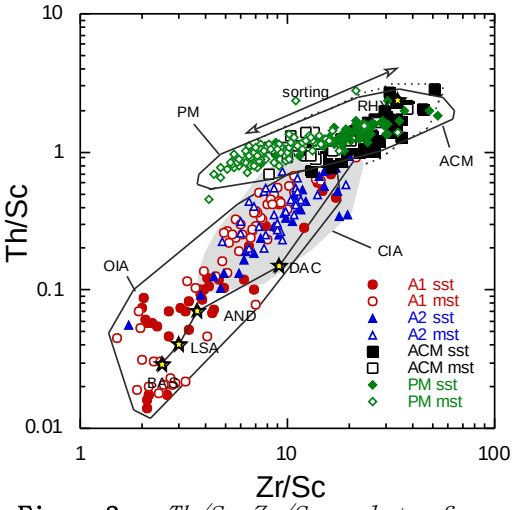


Fig. 2. *Th/Sc-Zr/Sc plot for the training set, and broad overlapping fields for the four tectonic settings. Only the most mafic OIA samples plot in unique positions, and ACM-PM overlap is complete.*

(3) REE variables show similar features, with low La/Sc, La_N/Yb_N and La_N/Sm_N ratios and smaller Eu/Eu* generally increasing from OIA to CIA, but with major overlap. As shown by a La/Sc-Ti/Zr plot (Fig. 3), ACM and PM data distributions are indistinguishable. These latter categories cannot be distinguished using the REE.

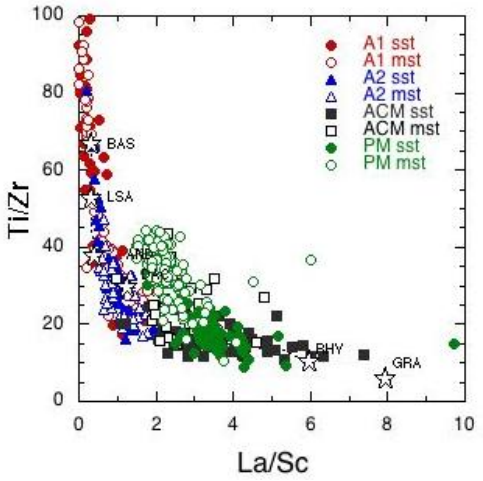
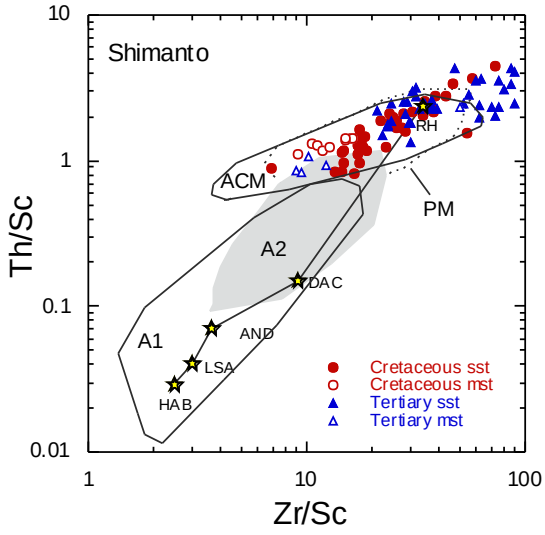


Fig. 3. *La/Sc-Ti/Zr plot for the training set.*

(4) Results for the Japanese terrane test data reinforce the patterns seen above. Demonstrably ACM Shimanto sediments and recycled sediments in the Tanabe Group forearc deposits have immobile element ratios almost identical to more mature ACM sediments in the Oshima Belt (Fig. 4), and passive margin basin deposits of the Sylhet basin in Bangladesh. Idonnappu-Yezo CIA-ACM sediments do have lower immobile element ratios in keeping with an intermediate source, but supposedly PM-rift sediments from the Kanmon and Gyeongsang Groups have similar signatures due to the presence of a cryptic mafic component, and hence would be misclassified. OIA sediments from the Nemuro Group spread across both OIA and CIA fields due to stratigraphic shift from mafic to felsic volcanism.



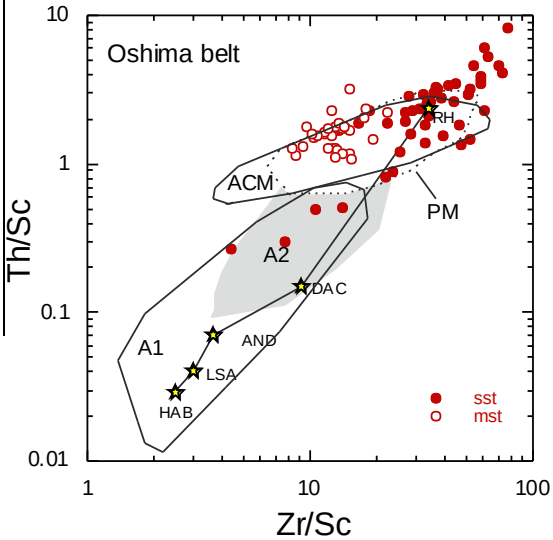


Fig. 4. *Th/Sc-Zr/Sc plot for Shimanto and Oshima terrane sandstones and mudstones, illustrating the compositional overlap in these contrasting terranes. Fields A2, A2, ACM, PM from Fig. 2.*

(5) Overlap between OIA and CIA and lack of fractionation between sandstones and mudrocks indicates that in these categories the bulk composition is controlled by the proportion of individual lithic clasts, and hence the nature of volcanism in the source (provenance) is more significant that tectonic setting *per se*. Inevitably, compositions of these categories must overlap, and only the most mafic OIA sediments may give reliable signatures. The total overlap between ACM and PM reflects "end state" conditions where both groups are derived from highly evolved felsic rocks.

Their trace element abundances are thus mainly determined by resistant heavy mineral contents and the proportion of clay present. The immobile nature of the elements used (Th, Sc, Zr, Sc, Hf, REE) means that the effects of weathering and recycling that mark PM sediments and influence their modal and major element are minimized. Consequently, the ratios between immobile element pairs remain unchanged, and the ACM and PM categories cannot be distinguished using trace element parameters.

Residence of the incompatible elements Th , Zr, Hf, and REE in abrasion-resistant heavy minerals such as zircon and monazite is the driver for possible identification of recycling, and (by inference) passive margin deposition, using higher values of ratios such as Zr/Sc and Ce/Sc as fingerprints. However, samples from ACM and evolved CIA such as the Shimanto, Tanabe and Idonnappu suites can exhibit high ratios, even in environment that were clearly accretionary and subductive. The bulk geochemical fingerprints of heavy mineral concentration are therefore not unique to passive margin deposition.

(6) Although the OIA-CIA and ACM-PM groups can be distinguished using trace elements, separation within these two is difficult. The OIA-CIA overlap and similarity of ACM and PM reflects the use of immobile elements, the abundances of which ultimately reflect the average source composition rather than the tectonic setting of deposition as such. Evaluation of tectonic setting using trace element abundances must therefore be made in conjunction with other methods and evidence, and not in isolation. Such evaluation should be made in combination with geologic, tectonic, geochronological and petrographic information, and other geochemical data including major element analyses and isotopes.

５．主な発表論文等
（研究代表者、研究分担者及び連携研究者には下線）

〔雑誌論文〕（計 3 件）

(1) Hossain, H.M.Z., Roser, B.P., Kimura, J.-I. Petrography and whole-rock geochemistry of the Tertiary Sylhet succession, northeastern Bengal Basin, Bangladesh: Provenance and source area weathering. Sedimentary Geology 228, **(2010), 171-183.**

(2) Ulak, P.D., Roser, B.P. and Hossain, H. M. Z. Major and trace element analyses of sandstone and mudstones from the Siwalik Group, Bakiya Khola, central Nepal. Geoscience Reports of Shimane University 27, **(2008), 43-51.**

(2) Hossain, H.M.Z., Ulak, P.D. and Roser, B. P. Geochemical analyses of sandstones and mudstones from the Siwalik Group, Bakiya Khola, central Nepal, Geoscience Reports of Shimane University 27, **(2008), 53-60.**

〔学会発表〕（計 0 件）

〔図書〕（計 0 件）
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○出願状況（計 0 件）

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種類：
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〔その他〕
ホームページ等

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