行政院國家科學委員會專題研究計畫　成果報告

碎屑鋯石同位素示蹤研究(I)：以孟加拉盆地為例

計畫類別：個別型計畫
計畫編號：NSC93-2116-M-002-014-
執行期間：93 年 08 月 01 日至 94 年 07 月 31 日
執行單位：國立臺灣大學地質科學系暨研究所

計畫主持人：鍾孫霖

報告類型：精簡報告
報告附件：出席國際會議研究心得報告及發表論文
處理方式：本計畫可公開查詢

中　華　民　國 95 年 1 月 20 日

碎屑鋯石同位素示蹤研究 (I) - 期終報告

計畫編號：NSC 93– 2116 – M – 002 - 014
執行期限：93年8月1日至94年7月31日

計畫主持人：台大地質科學系 鍾孫霖
計畫參與人員：溫大任、朱美妃、李皓揚（博士生）

一、中文摘要

大地構造活動和河流的侵蝕與沈積作用之間的互動，以及它們對區域乃至全球氣候、環境的影響或反饋，多年來一直是國際地球科學前沿研究的主題之一，最近幾年更已儼然成為焦點，有關的研究報導推陳出新，令人目不暇給，尤以Nature在2003年刊出的一系列論文可代表個中翹楚，反映出國際領先團隊在相關領域的最新研究進展（詳見本計畫內容說明）。本研究計畫以申請人過去兩年多來在西藏東南部地區的工作為基礎，擬利用鋯石的原位U-Pb定年和Hf同位素分析技術，測量選採自孟加拉盆地晚新生代沈積物中的“碎屑鋯石”(detrital zircons)，據以探討東喜馬拉雅造山結的隆升史和南亞三大河系（雅魯藏布江、布拉馬普特拉河及依洛瓦底江）之間的互動與演化關係。若蒙補助，預期本研究將能利用採自當今地表上研究「造山－剝蝕交互作用」最佳的天然實驗室的標本，針對上述焦點議題發聲，並提供嶄新的視野和重要的制約。

關鍵詞： 碎屑鋯石、同位素示蹤、構造活動、河流沈積、孟加拉盆地

The interactions between tectonic uplift, river erosion and alluvial deposition are fundamental processes that have continued to shape the Earth’s landscape we see today. Understanding of the relations or causal links among these processes, which are on-going and particularly active in mountainous regions such as the Himalayas, has attracted wide interests involving not only geomorphology, sedimentology and structural geology, but also hydrology, river engineering and mitigation of natural hazards. In this project, we propose to explore the relations between active tectonics and alluvial deposition records around the eastern Himalayan syntaxis, by performing in-situ U-Pb dating and Hf isotope analyses of detrital zircons from the late Tertiary-Quaternary sedimentary formations from the Bengal Basin. The aims of this study include: (1) to test the famous “tectonic aneurysm” model for the formation of the Namche Barwa syntaxis, within which the Tsangpo River cuts a cross-strike gorge through the eastern Himalayas and heads south to the Brahmaputra River in the foreland; (2) to test the popular hypothesis of river piracy linked with the Namche Barwa tectonics such that the Tsangpo River was the upper reach of the Irrawaddy River and it got captured by the Brahmaputra River only recently, say, within 4-5 million years from now; and (3) to better understand the Indian monsoon’s evolution in the late Cenozoic and causal

links between active tectonics and climate in this region based on the above two tests and evaluations of relevant geologic information. This project that involves investigations from high mountains (the roof of the Earth and sediment's major source provenance) to foreland basin (part of the largest sedimentary sink in the world) would depend essentially upon our work in southeastern Tibet done in the past 2-3 years to constrain the source components and a field excursion to Bangladesh and NE India to be collaborated with local geologists for collecting samples. The proposed in-situ zircon U-Pb experiments will be performed at the SHRIMP-II lab in the Chinese Academy of Geological Sciences, Beijing, while the Hf isotope measurements using LA-MC-ICPMS still have to reply heavily upon a continued collaboration with the GEMOC center, Macquarie University, Australia, before the newly purchased state-of-the-art machine of ours is fully set up in this department.

Keywords: detrital zircon; isotope tracers; active tectonics; alluvial rivers; Bengal basin

本研究計畫執行期間，主持人和研究生於93年8月25日至92年8月31日赴北京離子質溥儀分析中心，進行鋯石定年實驗；於94年4月26日至5月11日赴澳洲Macquarie大學GEMOC研究中心，進行LA-MC-ICPMS分析實驗。主持人和博士班研究生溫大任、碩士班研究生梁育瑄三人於93年12月12日至18日赴美國舊金山，參加AGU秋季大會，博士班研究生朱美妃、李皓揚兩人於93年8月15日至20日赴美國夏威夷，參加WPGM大會，發表論文摘要如下：

Abstracts for the WPGM Meeting, Hawaii, August 16-20, 2004

Rare Earth Element Chemistry of Apatites From the Cretaceous to Paleogene Granitoids, Southeastern Tibet

M.F. Chu (1), S.L. Chung (1), X.R. Liang (2), W.L. Griffin (3), N.J. Pearson (3), Y. Iizuka (4), X.H. Li (2), Y.Q. Zhang (2)
(1) Department of Geosciences, National Taiwan University, Taipei, Taiwan, (2) Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou, China, (3) GEMOC, Maquarie University, Sydney, Australia, (4) Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan
E-mail: f88224109@ntu.edu.tw/Fax: +886-2-23636095

Accessory minerals such as zircon and apatite occur widely in various rocks because of their wide stability in geological processes, which allow these minerals to be used as an indicator for not only igneous petrogenesis but also potentially for sedimentary source provenance. In this study, using EPMA and LA-ICP-MS composed of New Wave LUV-213 Nd-YAG laser and Agilent quadrupole ICP-MS, we measured major and trace element concentrations of apatite separates from two principal types of Cretaceous to Paleogene granitoids from SE Tibet. These are (1) the I-type Gangdese Batholith [~100-40 Ma; with SiO_2 = 50-75 wt. %, ASI= 0.78-1.12, (La/Yb)n= 2.3-14.6, (Eu/Eu*)n= 0.15-1.19, εNd(T)= -1.6 to 3.7] and (2) the S-type Nyainqentanglha magmatic belt [≥ 120 Ma; SiO_2 = 66-73 wt. %, ASI= 1.07-1.30, (La/Yb)n= 6.5-23.1, (Eu/Eu*)n= 0.31-1.03, εNd(T)= -10 to -16]. Although no systematic variations are observed in major elements for apatites from the two types of granitoids, their trace elements, in particular rare earth elements (REE), have markedly differences. Apatites from the I-type rocks are highly LREE-enriched and thus show steep REE patterns [(La/Yb)n= 56-67], in contrast to those from the S-type rocks which show flat REE

patterns [(La/Yb)n= 0.84-0.99]. Moreover, whereas the latter are characterized by strong negative Eu anomalies [(Eu/Eu*)n= 0.11-0.13], the former display only mild amounts of negative Eu anomalies [(Eu/Eu*)n= 0.78-0.84]. Given the fact that both I- and S-types of the Tibetan granitoids have LREE-enriched patterns, the "apparent" values of REE partition coefficients calculated by dividing REE abundances of the apatites over those of the host rocks are distinct between the two rock types. Our study indicates that REE chemistry of the apatites (1) changes between different types of the host magmas and thus may be used as a probe into igneous petrogenesis, and (2) has potential to be used as a sedimentary provenance indicator in particular when combined with *in-situ* Sr isotope determinations of these apatites to be carried out.

New age and geochemical constraints for the origin of the Linzizong volcanic successions, southern Tibet

H.-Y. Lee[1], S.-L. Chung[1], D.-J. Wen[1], C.-H. Lo[1], J.-Q. Ji[2], Q. Qian[3], T.-Y. Lee[4]

[1] Department of Geosciences, National Taiwan University

[2] School of Earth and Space Sciences, Peking University

[3] Institute of Geology and Geophysics, Chinese Academy of Sciences

[4] Department of Earth Sciences, National Taiwan Normal University

The Linzizong volcanic successions emplaced in the Lhasa terrane, southern Tibet are generally considered as products of northward subduction of the Neo-Tethyan slab underneath Asia that resulted in an Andean-type convergent margin before the India-Asia collision. Here we report new $^{40}Ar/^{39}Ar$ dating and geochemical data to better constrain the tempo-spatial distribution, petrogenesis and geodynamic significance of the Linzizong volcanic rocks. The results show two major episodes of eruptions, namely, a Cretaceous episode occurring dominantly in the northern Lhasa terrane from ~110 to 70 Ma and in the area around Lhasa city in the south at ~90 Ma, and an Paleogene episode erupting only in the southern part of the Lhasa terrane from ~60 to 45 Ma. These data allow us to re-evaluate the geologic context of the so-called Linzizong volcanic successions that are re-defined as comprising the younger episode. The Paleogene successions consist essentially of calc-alkaline rocks ranging from basalt to rhyolite, associated with a shoshonitic suite emplaced in the Linzhou area, ~50 km north of the Lhasa city. Our data furthermore suggest a southward migration and intensification of the volcanism marked by magmatic "flare-ups" around ~50-45 Ma, which we interpret as products of the ending phase of the Neo-Tethyan subduction in the early stage of the India-Asia collision because the overall geochemical characteristics of the volcanic successions are comparable to those of the arc lavas from modern subduction zones. This would require rollback and steepening of the Neo-Tethyan slab, a process that could have intensified corner flow in the mantle wedge and caused significant partial melting. To account for the generation of the Cretaceous and more widespread episode of volcanism, more detailed studies are needed so that different models, such as Cretaceous low-angle subduction of the Neo-Tethyan

slab in the south and lithospheric deformation following the Triassic-Jurassic suturing between the Lhasa and Qiangtang terranes in the north, may be better constrained.

Abstracts for the AGU Fall Meeting, San Francisco, Dec. 12-17, 2004
Detrital zircon study along the Tsangpo River, SE Tibet

Y.-H. Liang [1], S.-L. Chung [1], D.-Y. Liu [2], S. Y. O'Reilly [3], M.-F. Chu [1], J.-Q. Ji [4], B. Song [2], N. J. Pearson [3]
[1] Dept. Geosciences, National Taiwan University, Taipei P.O. Box 13-318, Taiwan
[2] Institute of Geology, Chinese Academy of Geological Sciences, Beijing, China
[3] ARC National Key Centre GEMOC, Macquarie University, Sydney, Australia
[4] School of Earth and Space Sciences, Peking University, Beijing, China

The interactions among tectonic uplift, river erosion and alluvial deposition are fundamental processes that shape the landscape of the Himalayan-Tibetan orogen since its creation from early Cenozoic time. To better understand these processes around the eastern Himalayan Syntaxis, we conducted a study by systematic sampling riverbank sediments along the Tsangpo River, SE Tibet. Detrital zircons separated from the sediments were subjected to U-Pb dating by the SHRIMP II at the Beijing SHRIMP Center and then *in-situ* measurements of Hf isotope ratios using LA-MC-ICPMS at GEMOC. These results, together with U-Pb ages and Hf isotope data that we recently obtained for the Transhimalayan plutonic and surrounding basement rocks, allow a more quantitative examination of the provenance or "protosource" areas for the river sediments. Consequently, the percentage inputs from these source areas can be estimated. Our study indicates that, before the Tsangpo River flows into the Namche Barwa Syntaxis of the eastern Himalayas where the River forms a 180\deg Big Bend gorge and crosscuts the Himalayan sequences, the Gangdese batholith that crops out just north of the River appear to be an overwhelming source accounting for $\sim$50 \% of the bank sediments. The Tethyan Himalayan sequences south of the River are the second important source, with an input of $\sim$25 \%. The proportion of sediment supply changes after the River enters the Big Bend gorge and turns to south: $\sim$25 \% of detrital zircons are derived from the Greater Himalayas so that the input from the Tethyan Himalayas decreases ($<$ 10 \%) despite those from the Gangdese batholith remains high ($\sim$40 \%). Comparing with the sediment budget of the Brahmaputra River in the downstream based on literature Sr, Nd and Os isotope information, which suggests dominant ($\sim$90-60 \%) but subordinate ($\sim$10-40 \%) contributions by the (Greater and Lesser) Himalayan and Tibetan (including Tethyan Himalayan) rocks, respectively, the change is interpreted to be a result of focused erosion along the Tsangpo-Brahmaputra river system that behaves as one of the most active mountain rivers on Earth.

下列為本計畫執行以來，已/將發表的相關研究成果：

(1) Lee, H.Y., S.L. Chung, J.J. Wang, D.J. Wen, Y.Q. Zhang, Y.W. Xie, C.H. Lo, T.F. Yang, T.Y. Lee, G.Y. Wu and J.Q. Ji (2003) Miocene Jiali faulting and its implications for Tibetan tectonic evolution. *Earth Planet. Sci. Lett.*, v.205, p.185-194.
(2) Chung, S.L., C.H. Lo and T.Y. Lee (2003) Petrologic case for Eocene slab breakoff during the Indo-Asian collision: Comment. *Geology*, v.31, p.e7-8.
(3) Chung, S.L., D.Y. Liu, J.Q. Ji, M.F. Chu, H.Y. Lee, D.J. Wen, C.H. Lo, T.Y. Lee, Q. Qian, Q. Zhang (2003) Adakites from continental collision zones: Melting of thickened lower crust beneath southern Tibet. *Geology*, v.31, p.1021-1024.

(4) Chung, S.-L., M.F. Chu, Y.Q. Zhang, Y.W. Xie, T.Y. Lee, C.H. Lo, X.H. Li, C.Y. Lan, Q. Zhang and Y. Wang (2005) Tibetan tectonic evolution inferred from temporal and spatial variations in post-collisional magmatism. *Earth-Sci. Reviews*, 68, 173-196.
(5) Wen, D.J., Song, B., S.L. Chung, D.Y. Liu, J.Q. Ji, M.F. Chu, T.Y. Lee, C.H. Lo (2006) Discovery of Late Cretaceous intrusions of adakitic geochemical compositions from the eastern Gangdese belt, southern Tibet. (to be submitted: *Lithos*).
(6) Lee, H.Y., S.L. Chung, C.H. Lo, J. Ji, Q. Qian, T.Y. Lee, D.J. Wen and M.F. Chu (2006) Implications of Eocene magmatic flare-ups in southern Tibet for collision tectonics and environmental changes. (submitted to: EPSL).
(7) Liang, Y.H., S.L. Chung, M.F. Chu, D.Y. Liu, S.Y. O'Reilly, B. Song, N.J. Pearson (2006) Detrital zircon study along the Tsangpo River, southern Tibet. (in prep.).
(8) Chu, M.F., S.-L. Chung, D.Y. Liu, S.Y. O'Reilly, B. Song, N.J. Norman, J. Ji, D.J. Wen (2005) Zircon U-Pb and Hf isotope constraints on the Mesozoic tectonics and crustal evolution of southern Tibet. *Geology*, in revision.
(9) M.F. Chu, Chung, S.-L., D.Y. Liu, S.Y. O'Reilly, J. Ji, Q. Zhang, B. Song, N.J. Norman, T.Y. Lee and C.H. Lo (2005) On the nature and timing of crustal thickening in southern Tibet. *EPSL*, in review.
(10) D.J. Wen, S.-L. Chung, D.Y. Liu, Chu, M.F., J.Q. Ji, Q. Qian, B. Song, T.Y. Lee and C.H. Lo (2005) Magmatic evidence for the evolution from accretionary to collisional orogeny in southern Tibet. (submitted to: *EPSL*).
(11) Chung, S.-L., J. Ji, R. Shinjo, X.H. Li, F.Y. Wu, D.Y. Liu, C.H. Lo and T.Y. Lee (2005) Collision-type adakites in southern Tibet: Ages, geochemical characteristics, petrogenesis and geodynamic significance. (to be submitted).
(12) Chu, M.F. S.-L. Chung, W.F Griffin, S.Y. O'Reilly, N.J. Pearson, D.Y. Liu (2006) Magma generation in southern Tibet: Constraints from zircon separates by in-situ analyses of Hf isotopes. (in prep.).