

# 行政院國家科學委員會專題研究計畫 成果報告

## 高精度珊瑚鈾釷定年技術及其古氣候重建之應用 (II)

計畫類別：個別型計畫

計畫編號：NSC93-2116-M-002-036-

執行期間：93 年 08 月 01 日至 95 年 03 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：沈川洲

計畫參與人員：李桂淑，林悅婷

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 4 月 20 日

行政院國家科學委員會補助專題研究計畫 ☒ 成果報告  
☐ 期中進度報告

高精度珊瑚鈾釷定年技術及其古氣候重建之應用 II

計畫類別：☒ 個別型計畫 ☐ 整合型計畫  
計畫編號：NSC 93-2116-M-002-036  
執行期間：93 年 08 月 01 日至 95 年 03 月 31 日

計畫主持人：沈川洲 台灣大學地質科學系

共同主持人：

計畫參與人員：李桂淑，林悅婷 台灣大學地質科學系

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執行單位：

中 華 民 國 93 年 4 月 日

# 行政院國家科學委員會專題研究計畫成果報告

## 高精度珊瑚鈾釷定年技術及其古氣候重建之應用 II

### NSC Project Reports

計畫編號：NSC 93—2116—M—002—036

執行期限：93 年 8 月 1 日至 95 年 3 月 31 日

主持人：沈川洲 台灣大學地質科學系

計畫參與人員：李桂淑，林悅婷 台灣大學地質科學系

#### 中文摘要

93 年 8 月至 95 年 3 月期間，我們執行了一個個別型研究計畫“高精度珊瑚鈾釷定年技術及其古氣候重建之應用 II”，主要目的是延續前一年之計畫“高精度珊瑚鈾釷定年技術及其古氣候重建之應用”，以使此尖端技術更成熟發展及更廣泛地應用在包括台灣在內之泛南中國海、印度洋及太平洋的珊瑚標本，以及東亞洞穴石灰岩標本。分析方法是利用過去兩年開發成功的高精度磁場式電漿質譜技術，同時利用台大地質系今年添購之多頻電漿質譜儀（MC-ICPMS, Thermo Electron NEPTUNE）發展更精準的鈾釷分析方法。本研究初步成果顯示，鈾同位素分析精準度，可達 0.3‰ 或更好。

鈾-230 定年技術將繼續分析採自南台灣、蘇門達臘群島、越南、印度和印尼的珊瑚標本及東亞洞穴石灰岩標本上，應用在古氣候重建及海洋循環等領域。在計畫執行期間，我們總共發表六篇學術期刊論文，其中 SCI 期刊（包含 *Nature* 及 *EPSL*）論文共五篇，及二十一篇會議論文。

**關鍵詞：**鈾-230、珊瑚、電漿質譜儀

#### Abstract

We executed a project “High precision coral uranium-thorium dating technique and its application to paleoclimatic reconstruction II” during August 2004 – March 2006. This study was to extend a previous NSC project “High precision coral uranium-thorium dating technique and its application to paleoclimatic reconstruction” so that this state-of-art technology can be well developed and applied to corals from Taiwan, South China Sea and Pacific and speleothems from East Asia. We also developed a new method by a multi-collector ICPMS (MC-ICPMS), Thermo Electron NEPTUNE, at the Department of Geosciences, NTU. The analytical precision offered is 0.3‰ (2sd) or better.

Th-230 dating method will be applied to more coral and speleothem samples from Nanwan of Taiwan, Sumatran Islands, Vietnam, India and Indonesia for paleoceanography and paleoclimatology. We had six refereed articles. Five of them were published in SCI journals, including *Nature* and *EPSL*. Twenty one conference papers were also published

**Keywords:** Th-230 dating, coral, ICPMS

## 1. Rationale and propose

Since 1993, long-term and high resolution coral-inferred climate records have been published every year. However, faithful interpretation of environmental and paleoclimatic records relies on trustable and accuracy age control. The chronology in the coral can be determined by dark-light annual band counting. For corals with non-distinct banding, chronology can be performed by tuning tracer records among corals adapted from dendrochronology. However, the assumption of annual growth with successively distinct banding is sometimes questionable and age biases may be induced by cross-checking long-term tracer records. For dead coral heads and fossils without any absolute dates and age makers due to mortality events or with unconformities during climatic and/or tectonic anomalies, the above mentioned methods are no more appropriate chronological tools.

## 2. Coral <sup>230</sup>Th dating techniques

Our newly-developed Th-230 dating technique offers a precision better than 1 year. To approach this objective, chemistry has been refined and only brings about an equivalent age uncertainty of 1-2 months. The most important factor limiting the precision and accuracy is the initial Th-230 content, incorporated into the growing matrix during crystallization. The initial Th-230 can be constrained by building a Th-230/Th-232 vs. U-234/Th-232 isochron plot. The initial Th-230/Th-232 ratio for modern *Porites* corals, collected from Nanwan, southern Taiwan, is  $5.2 (\pm 1.1) \times 10^{-6}$  (atomic ratio, hereafter), consistent with a value of  $4.0 (\pm 0.5) \times 10^{-6}$  in the dissolved fraction of seawater and higher than that of  $3.0 (\pm 0.7) \times 10^{-6}$  in the suspended particulate matter. The results indicate that the initial Th-230 content is attributable mainly to the dissolved phase of seawater. Isochron plots for modern and fossil corals, sampled from Nanwan and Sumatran Islands, display little temporal and spatial variations of initial Th-230/Th-232

ratio. Applications of the technique given in this study include determining the occurrence of earthquakes in the Sumatran Islands and the variability of ENSO system in the equatorial Western Pacific Ocean.

## 3. Applications

The newly developed Th-230 dating technique can offer a precision better than 1 year for low-Th-232 corals with an age less than 100 years old. This method has been applied to reconstruction of occurrence and cycle of giant paleo-earthquakes of Sumatran Islands and to offering a precise age model for long-term paleo-climate study at Santo, Vanuatu. In the near future, this coral Th-230 dating method can be applied to reconstructing high precision paleoclimatic mapping in the tropical oceans and understanding the long-term mechanism and teleconnection among climatological subsystems. Coral microatolls, combined with our dating technique, can also act as precise natural paleoseismic recorders.

## 4. Publications

Six articles were published during this project period:

1. Steinke, S., Chiu H.-I., Yu P.-S., **Shen C.-C.**, Lowemark L., Mii H.-S., and Chen M.-T. (2005) Mg/Ca ratios of two *Globigerinoides ruber* (white) morphotypes: Implications for reconstructing past tropical/subtropical surface water conditions. *Geochem. Geophys. Geosy.*, 6, Q11005, doi: 10.1029/2005GC000926. (SCI:2.570; T:0; ▲:0)
2. **Shen, C.-C.**, Liu K.-K., Lee M.-Y., Lee T., Wang C.-H., and Lee H.-J. (2005) A novel method for tracing coastal water masses using Sr/Ca ratios and salinity: A case study in Nanwan Bay, Southern Taiwan. *Estuarine, Coastal and Shelf Science*, 65, 135-142. (SCI:1.058; T:0; ▲:0)

3. **Shen, C.-C.**, Lee T., Liu K.-K., Hsu H.-H., Edwards R. L., Wang C.-H., Lee M.-Y., Chen Y.-G., Lee H.-J. and Sun H.-T. (2005) An evaluation of quantitative reconstruction of past precipitation records using coral skeletal Sr/Ca and  $\delta^{18}\text{O}$  data. *Earth Planet. Sci. Lett.*, **237**, 370-386. (SCI:3.499; T:0; ▲:0)
4. Moran, S. B., **Shen C.-C.**, Edwards R. L., Edmonds H. N., and, Smith J. N. (2005)  $^{231}\text{Pa}$  and  $^{230}\text{Th}$  in surface sediments of the Arctic Ocean: Implications for boundary scavenging. *Earth Planet. Sci. Lett.*, **234**, 235-248. (SCI:3.499; T:0; ▲:0)
5. Cai, Y.-J., Cheng H., An Z. S., Edwards R. L., Wang X., and **Shen C.-C.** (2005) The study on the initial thorium correction of the  $^{230}\text{Th}$ - $^{234}\text{U}$ - $^{238}\text{U}$  dating of the speleothem by using isochron method. *Advances in Earth Science*, **20**, 414-420.
6. Wang, X., Auler A. S., Edwards R. L., Cheng H., Cristalli P. S., Smart P. L., Richards D. A., and **Shen C.-C.** (2004) Wet periods in northeastern Brazil over the past 210 kyr linked to distant climate anomalies. *Nature*, **432**, 740-743. (SCI:32.182; T:12; ▲:10)
3. **Shen, C.-C.**, and Edwards R. L. (2005) U-Th-Pa analyses and determination of trace metals in carbonates. *2<sup>nd</sup> Omaha workshop & 6<sup>th</sup> International Conference on Magnetic Sector Field ICP-MS*, Omaha, Nebraska, USA, 15-18 August 2005.
4. **Shen, C.-C.**, Edwards R. L., Cheng H., Hsieh Y.-T., and Wang X. (2005) Isotopic measurements of natural uranium and thorium using HR-ICPMS with desolvating nebulizer systems. *2<sup>nd</sup> Omaha workshop & 6<sup>th</sup> International Conference on Magnetic Sector Field ICP-MS*, Omaha, Nebraska, USA, 15-18 August 2005.
5. Hsieh, Y.-T., Gallet S., and **Shen C.-C.** (2005) Epsilon-level precision on uranium isotopic and concentration measurements by MC-ICPMS. *Annual Meeting, Chinese Geol. Soc.*
6. Lin, H.-T., **Shen C.-C.**, Chu M.-F., and Yu E.-F. (2005) Development of high precision measurements of uranium isotope ratio and concentration by quadrupole inductively coupled plasma mass spectrometry. *Annual Meeting, Chinese Geol. Soc.*
7. Chiang, H.-W., **Shen C.-C.**, Chen Y.-G., and Fan T.-Y. (2005) Environmental variation and O/C isotopic compositions in Nanwan coral skeletons, southernmost Taiwan. *Annual Meeting, Chinese Geol. Soc.*
8. Li, K.-S., **Shen C.-C.**, Sieh K., Natawidjaja D., Wang X., Edwards R. L., Fan T.-Y., and Lee H.-J. (2005) High precision coral  $^{230}\text{Th}$  dating: Limits and applications. *Annual Meeting, Chinese Geol. Soc.*
9. Lin, Y.-S., Wei K.-Y., **Shen C.-C.**, Mii H.-S., Chiang H.-W., Chen C.-Y., and Chen Y.-G. (2005) Holocene paleoceanography in the upper reach of the Kuroshio. *Annual Meeting, Chinese Geol. Soc.*
10. Lo, L., Wei K.-Y., **Shen C.-C.**, and Chiang H.-W. (2005) Sea-surface paleotemperature and  $\delta^{18}\text{O}_w$  variation

Twenty one conference papers related to the developed high precision U-Th ICP-MS techniques have been presented in domestic and international conferences:

1. **Shen, C.-C.**, Li K.-S., Sieh K., Natawidjaja D., Wang X., Cheng H., Hsieh Y.-T., and Edwards R. L. (2005) Limits and applications of high precision coral Th-230 dating techniques. *AGU Fall Meeting*, San Francisco, USA, 5-9 December 2005.
2. Ludwig, K. A., Kelley D. S., Edwards R. L., **Shen C.-C.**, and Cheng H. (2005) U/Th geochronology of carbonate chimneys at the Lost City hydrothermal field. *AGU Fall Meeting*, San Francisco, USA, 5-9 December 2005.

- during the past 80 kyrs in the Solomon Sea. *Annual Meeting, Chinese Geol. Soc.*
11. Li, K.-S., **Shen C.-C.**, Sieh K., Wang X., Natawidjaja D., Lee H.-J., and Edwards R. L. (2005) Establishment of high precision coral  $^{230}\text{Th}$  dating techniques. *Workshop for 2005 Oceanographic Research Programs*, Abstract Volume, 202.
  12. Lin, H.-T., **Shen C.-C.**, Chu M.-F., and Yu E.-F. (2005) Uranium isotopic and concentration measurements by quadrupole inductively coupled plasma mass spectrometry. *Workshop for 2005 Oceanographic Research Programs*, Abstract Volume, 203-204.
  13. Lin, Y.-S., Wei K.-Y., **Shen C.-C.**, Mii H.-S., and Chiang H.-W. (2005) Decline of surface salinity in the Southern Okinawa Trough during the Holocene: Links to East Asian monsoon or tropical Pacific? *Workshop for 2005 Oceanographic Research Programs*, Abstract Volume, 205.
  14. **Shen, C.-C.**, Chiu H.-I., Chu M.-F., Chen M.-T., Wei K.-Y., and Steinke S. (2004) High-precision measurements of Mg/Ca and Sr/Ca ratios in carbonates by cool plasma quadrupole ICP-MS. *AGU Fall Meeting*, San Francisco, USA, 13-17 December 2004.
  15. Chiang, H.-W., **Shen C.-C.**, Chen Y.-G., and Chiu H.-I. (2004) Thermal, hydrological, and biological signals with constraints of geochemical records in coral skeletons, southern Taiwan. *AGU Fall Meeting*, San Francisco, USA, 13-17 December 2004.
  16. **Shen, C.-C.**, Chiang H.-W., Li K.-S., Chen Y.-G., Sieh K., X. Wang, and R. L. Edwards (2004) Application of coral geochemical tracers to understanding environmental changes. 10th Taiwanese Coral Reef Conference, Taipei, Taiwan, Abstract Volume, 4.
  17. **Shen, C.-C.**, Chen Y.-G., Li K.-S., and Chiang H.-W. (2004) Understanding environmental change and climate variation in the South China Sea Rim region using coral geochemical records. Proceeding, Vietnam-Taiwan Workshop on Marine Geology, Hanoi, Vietnam, 9 Dec 2004, Abstract Volume, 157.
  18. Chiang, H.-W., **Shen C.-C.**, Chen Y.-G., and Chiu H.-I. (2004) A preliminary study of seasonal variation during past twenty years by geochemical records in coral skeletons, Nanwan. *Annual Meeting, Chinese Geol. Soc.*, Abstract Volume, 63.
  19. **Shen, C.-C.**, Chu M.-F., Lin H.-T., and Yu E.-F. (2004) Uranium isotopic and concentration measurements by quadrupole inductively coupled plasma mass spectrometry. *Xth Symposium on Quaternary of Taiwan and Environmental Changes of Taipei Basin*, Taipei, Taiwan, 5-6 December 2004., Abstract Volume, 106.
  20. Steinke, S., Chiu H.-I., Yu P.-S., **Shen C.-C.**, Erlenkeuser H., and Chen M.-T. (2004) On the influence of sea-level and monsoon climate on the southern South China Sea freshwater budget during the last 18 kyrs. *8th International Conference on Paleoceanography*, Biarritz, France, 5-10 Sept 2004.
  21. Lee, H.-J., Liu K.-K., **Shen C.-C.** (2004) Effects of reduced Yangtze River discharge on the circulation of surrounding seas. *Workshop for 2004 Oceanographic Research Programs*, Abstract Volume, 14.