行政院國家科學委員會補助專題研究計畫成果報告

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計畫主持人：魏國彥

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☐國際合作研究計畫國外研究報告書一份

執行單位：國立台灣大學地質科學系

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行政院國家科學委員會專題研究計畫成果報告

利用鈣質超微化石組合與浮游有孔蟲鎂/鈣比進行南海晚第四紀古海表溫重建

Reconstruction of Late Quaternary Sea-Surface Temperature of the South China Sea:Two Alternative Approaches Using Calcareous Nannofossil Assemblages and Mg/Ca Ratio of Planktic Foraminifera

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主 持 人：魏國彥 台灣大學地質科學系

摘要

在過去的研究中，學者嘗試用各種不同的溫度指標（例如：浮游有孔蟲轉換函數、有孔蟲氧同位素、烯酮類不飽和指標, $U^{K'}_{37}$ 等）去重建南海的古海表溫度，希望對過去溫度的變化趨勢有進一步的瞭解。不過，利用這些溫度指標所重建的海表溫度變化並不是很一致，顯示了各種溫度指標之間所存在的問題與缺點。本計畫執行過程中發現鈣質超微化石因沉積物稀釋而含量不足，因此利用浮游有孔蟲鎂鈣比回推古海表溫度。

本研究利用國際海洋全球變遷研究(IMAGES)在南中國海所鑽取的岩心 MD972142 進行浮游有孔蟲 *Globigerinoides sacculifer* 之鎂鈣比分析。所分析的岩心長度約 11 公尺，涵蓋了海洋氧同位素第六階以來的古海表溫變化趨勢。除此之外，本研究也同時分析了 *Globigerinoides sacculifer* 的氧同位素值，與鎂鈣比值作進一步的討論。比對浮游有孔蟲的鎂鈣比記錄與氧同位素記錄，兩者之間呈現了相當一致的冰期-間冰期變化。由有孔蟲鎂鈣比所回推的古海表溫度記錄顯示，南海東南海域的海表溫在末次冰期以來上升了約 4-5℃。

關鍵詞：南中國海、浮游有孔蟲鎂/鈣比、海表溫度。

Abstract

Recent studies on foraminiferal Mg/Ca ratios showed increasing applicability as an effective paleotemperature proxy. Using the Mg/Ca ratios in the planktonic foraminifer *Globigerinoides sacculifer* from a well-preserved core MD972142, we have reconstructed a 170kyrs paleo-sea surface temperature (SST) record of the southeastern South China Sea. To our knowledge this is the first foraminiferal Mg/Ca ratio derived SST data from South China Sea. Modern temperature based on core top Mg/Ca ratio is ~28.4℃, corresponding to

the observed annual mean SST in this area. Our result suggests that SST increased by ~4-5°C from the Last Glacial Maximum to the Holocene. The Holocene values are comparable to those during oxygen isotope stage 5. The SST of glacial oxygen isotope stage 2 is slightly colder than that of oxygen isotope stage 6.

Keywords: South China Sea, Mg/Ca Ratio of Planktic Foraminifera, Sea Surface Temperature.

1. Introduction

The South China Sea (SCS) is the largest marginal sea in western Pacific and part of the Western Pacific Warm Pool (WPWP), which mainly controls the global climate system (Yan et al., 1992; Miao et al., 1994). Its critical location between the East Asian landmass and the western Pacific makes this marginal sea very sensitive to climate changes especially to the monsoon system, in both land and sea. The surface water circulation in SCS is mainly driven by the annually reversing monsoon winds which create large volumetric changes in surface water flow (Wyrtki, 1961). The SCS serves as an ideal location for paleoceanography and paleoclimatic studies because of its unique setting. By using planktonic foraminiferal transfer function, Miao et al. (1994) found that the winter temperature anomalies between Holocene and Last Glacial Maximum (LGM) reached as high as ~3-7.3°C in southern SCS. Other planktonic foraminiferal assemblage analyses in northern SCS showed that the glacial-interglacial SST changes are 6.8-9.3°C for winter and 2-3°C for summer (Wang and Wang, 1990). While SST derived using $U^{k'}_{37}$ demonstrated a ~2.8°C glacial-interglacial SST variation in southern SCS (Pelejero et al., 1999). Since each of the paleothermometers has its own advantages and drawbacks, development of a new independent proxy for SST will be of great utility in paleoceanographic studies. We use the newly developed foraminiferal Mg/Ca ratio as an independent proxy to estimate the paleo-SST (Nürnberg et al., 1996a, b) for this study. To our knowledge, this is the first foraminiferal Mg/Ca-derived SST (hereafter referred as Mg/Ca SST) in the SCS.

2. Samples and Analytical Method

Planktonic foraminifera, *G. sacculifer*, from core MD972142 (12°41.33'N, 119°27.90'E, 1557m) were used in this analysis. Foraminifera were handpicked from the 300-355 μm size fraction and were cleaned by performing trace-metal cleaning techniques in a HEPA laminar flow hood.

Magnesium and calcium were measured by flame atomic absorption spectroscopy (FAAS). The samples were dissolved and diluted in 0.002N HNO_3. Measurement precision of Mg/Ca was ±3%.

3.RESULTS AND DISCUSSION

For the temperature calibration, we used the species-specific Mg/Ca SST calibration curve for *G.sacculifer* (Nürnberg et al., 1996a, b). An exponential fit (Temperature, °C = 10.565ln(Mg/Ca)+11.32, R^2=0.94) was chosen. At 95% confidence interval, the error in the temperature estimate is ± 1.4°C in the range of 19.5-29.5°C.

The top 11 meters of core MD972142 covers a continuous record for the last 170,000 years (oxygen isotope stages 1-6). The Mg/Ca ratios range between ~3.0 and ~5.0

mmol/mol, corresponding to a temperature range of ~23 to 28.4°C. Clear glacial-interglacial oscillations in Mg/Ca are observed. Comparison of the Mg/Ca record and the $\delta^{18}O$ record of the same core indicates that oscillations in both records match fairly well, with an $r = -0.83$.

The Mg/Ca ratios of *G.sacculifer* are considered to record the annual mean SST (Hastings et al., 1998). In Core MD972142, this is supported by the core top Mg/Ca SST of ~28.4°C, which corresponds well to the observed sea surface temperature in this region (summer SST: >29°C, winter SST: ~27°C; Levitus and Boyer, 1994). Further support is found by comparing both the Mg/Ca SST record and the annual mean SST record derived from foraminiferal assemblages (Yu et al., 2000). The reconstructed paleo-SST record of MD972142 reveals an average Holocene SST of ~27.0°C and a LGM SST of ~22.9°C, showing a ~4°C glacial-interglacial SST warming. Our LGM-Holocene SST difference is slightly smaller than those estimates using planktonic foraminiferal transfer functions, which yield a 5-7°C LGM-Holocene winter SST anomalies in southern SCS (Miao et al., 1994) and a ~5°C LGM-Holocene mean annual SST difference for Core MD972142 (Yu et al., 2000). On the other hand, our result is larger than the ~2.8°C SST change estimated for southern SCS using $U^{k'}_{37}$ (Pelejero et al., 1999). However, this temperature offset between the Mg-SST and $U^{k'}_{37}$ might be explained by the difference in the time of signal generation and the depth habitats of the $U^{k'}_{37}$ signal producing coccolithophorids and foraminifera.

The SSTs during oxygen isotope stage 5 are comparable to those in Holocene, while the SSTs during stage 6 are slightly warmer than those in stage 2. Both the SST and $\delta^{18}O$ records show an obviously stable stage 5. The values of the substages 5.1, 5.3 and 5.5 are quite similar (~27.5-28°C), a pattern remarkably differs from that in the SPECMAP stack which shows cascading steps from substages 5.5 to 5.1. This pattern has also been observed from other cores in southern SCS (Lee et al., 1999; Pelejero et al., 1999). In addition, both the Mg/Ca SST record and fauna assemblages-derived SST record (Yu et al., 2000) of Core MD972142 show similar SST values through the interglacial stage 5. The SST values of both records are comparable during substages 5.1, 5.3 and 5.5. These consistent high SSTs between the Mg/Ca SST and the fauna assemblages-derived SST during stage 5, demonstrate the western extend of the WPWP in this region throughout the last interglacial. The SSTs in substages 5.1 and 5.3 were as high as those in substage 5.5, despite the cut off of warm water inflow from Indian Ocean through Sunda Shelf which might be caused by a sea level lowering of ~20-60m (Shackleton, 1987; Chapell et al., 1996). The $U^{k'}_{37}$ SST records of Core 17961 and Core 17964 indicated a ~2.6-2.8°C LGM-Holocene warming in southern SCS (Pelejero et al., 1999), which are smaller than that shown in our Mg/Ca SST record. However, the SST during substages 5.1, 5.3 and Holocene are similar (~28°C) to those observed in Core MD972142. The SST during substage 5.5 is about 1°C higher in Core 17961 and 17964 than that in Core MD972142, suggesting a warmer condition in the southern SCS during substage 5.5. By using the same SST proxy ($U^{k'}_{37}$), Wang, C.C. (1999) reported a ~4°C LGM-Holocene warming in Core MD972151 from southern SCS. The Holocene SSTs in this core (~27-28°C) are similar to that in Core MD972142; but, on the contrary, the SSTs in stage 5 show a cascading pattern from >28.5°C in substage 5.5 to ~27°C in substage 5.1, which is significantly different from Core MD972142.

The SST records from 3 cores (GGC-13, GGC-11 and GGC-9) in southeastern SCS were derived using planktonic foraminiferal transfer function (Miao et al., 1994). The calculated annual mean SSTs in LGM range from 24.2°C to 25.3°C, and the annual mean SSTs in Holocene range between ~28-29°C, leading to a LGM-Holocene warming of ~3-4.5°C. Similar LGM-Holocene warming amplitude was also reported in the western part of SCS and a core from west of Luzon (Wang et al., 1999). The Mg/Ca SST estimated for

Core MD972142 is in good agreement with other SST records from this region, hence, implying the reliability of foraminiferal Mg/Ca ratio as a SST proxy.

The last deglaciation was interrupted by a rapid return to colder condition, the so-called Younger Dryas (YD) event, occurred at about 10.5kyrs B.P. (Broecker et al., 1988). Temperature estimates from high-latitude climate records (e.g. Ruddiman and McIntyre, 1981; Dansgaard et al., 1989) indicate that cooler conditions existed during the Younger Dryas. This event was initially thought to occur at the high latitudes in and around the North Atlantic, however, it has now been established that the Younger Dryas event is also found in the tropical regions (e.g. Linsley and Thunell, 1990). Linsley and Thunell (1990) proposed that a cooling occurred in the western equatorial Pacific during Younger Dryas time based on changes in the planktonic foraminifera assemblages that were coeval with an $\delta^{18}O$ increase. More recently Wei et al. (1998) reported a temperature drop by ~1°C in the northeast SCS based upon foraminifera-derived SST and $U^{k'}_{37}$ SST. The Mg/Ca SST in Core MD972142 shows a ~1.4°C cooling at about 10-11ka which is consistent to an ~0.7‰ increase in the oxygen isotope record. Wang et al. (1999) has reported the occurrence of Younger Dryas event in Core 17940 and Core 17927, which showed synchronous cooling signal in SST and $\delta^{18}O$ records. The Younger Dryas event was also found in the $U^{k'}_{37}$ SST record of Core MD972151 and Core MD972148 from southern and northern SCS (Wang, C.C., 1999). The $U^{k'}_{37}$ SST of Core MD972151 showed a cooling of ~1.5°C, and is comparable to the Mg/Ca SST decrease in Core MD972142. The occurrence of the Younger Dryas in SCS confirms that this event is not only characteristic in high-latitude records, but also observed in the tropical regions as a global cooling event.

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出席 2000 年美國地球物理聯會秋季會議報告

魏國彥（台灣大學地質科學系教授）

一、參加會議經過

2000 美國地球物理聯會（AGU）秋季會於 12 月 15 日～19 日在舊金山召開，係廿世紀最後一場盛會。共有將近 5000 篇論文發表，參加人員接近 6000 人，破歷年大會之紀錄。

本人有兩篇論文發表：

(1) A Reassesement of the Post-Depositional Remanent Magnetization Lock-in Depth of the Brunhes/Matuyama Reversal in Depth-sea Sediments.

由共同作者李孟陽發表。

(2) Reconstruction of Paleotemperature and Paleointensity of the South China Sea for the Past 170kyrs Using Planktonic Foraminiferal Mg/Ca Ratios and Oxygen Isotopes.

此五日參加之論文組爲：

12 月 15 日上午：古海洋與古氣候學海報(I)。

12 月 15 日下午：古海洋與古氣候學：觀察與模型(II)。

12 月 16 日上午：半封閉海盆古海洋記錄(I)。

12 月 16 日下午：半封閉海盆古海洋記錄(II)。

12 月 17 日上午：古海洋與古氣候學：觀察與模型(Ⅲ)。

12 月 17 日下午：古地磁。

12 月 18 日上午：古海洋與古氣候海報(Ⅳ)。

12 月 18 日下午：西太平洋邊緣海海報(I)。

12 月 19 日上午：南半球高緯帶上新世更新世氣候變遷。

12 月 19 日下午：美洲海洋與大氣氣候。

二、與會心得

1. 高解析度之古洋研究

ODP 167 航次在加州外海鑽獲之岩心提供高解析度之古洋紀錄，學者利用這些岩心，進一步探討 Kennett（1996）等人所揭示的北太平洋中層水晚第四紀以來之快速高頻之溫度變化與冰芯之記錄中，Dansgard-Oeschger 旋回互爲「遙聯鎖」的關係。此外，ODP 165 航次之 Curiaco Basin，IMAGES 之北大西洋鑽探 drifts 之

岩心，中國南海的岩心均提供許多高時解之古洋記錄。

加州外海之紀錄顯示，碳酸鈣含量與冰心之 D-O 旋回有相同之韻律，高含量出現於 D-O 旋回之 interstadials，可能與該地之海岸湧升流減弱有關。當湧升流弱時，表層海水較穩定成層，有利於鈣質浮游生物之繁盛；由花粉中之莎草科（artemisia）增加可知，此時之加州陸上較為乾旱。另方面，各項有機指標（biomarkers）指示，藻類與細菌之高生產期與陽光照射強度（insolation）強期相同，可能是 insolation 強度控制了北太平洋亞極氣旋之強度，而該氣旋又控制了加州洋流的強度，調控了加州外海湧升流強度。

2. U_{37}^{k} 做為溫度指標的可信度

上述多項高時解古洋研究中均使用 U_{37}^{k} 做為溫度重建的工具，但也引發許多討論。

Julian Sachs 認為，即使使用不同的經驗方程，$U_{37}^{k'}$ 指數所得之溫度幅度極為相似。但另方面日本學者 Yamamoto 顯示，數種不同之 U_k 指標（用到 ketone 38 等 species）可得出相異之溫度，其中尤以 Alkenone 37:4 之含量變化造成相當大的影響。

較讓人憂心的是 Bonni Epatein 的研究顯示，在定溫下（18.1℃）培養的北大西洋 CCMP372 *Emiliania huxleyi* clone 因營養鹽、細胞分裂速率、細胞狀態之差異，其 $U_{37}^{k'}$ 的溫度重建指示可以差到 6℃。Epstein 並對北大西洋之另一藻株（BT6）及北太平洋之 55a 進行相同之實驗，結果均不相同，但均顯現非溫度因素之影響。因此結論：① 溫度之外的因素也可影響 $U_{37}^{k'}$ 值；② 對非溫度因素之反應，不同藻株（clone）亦相異之。

此外，雖然多數人喜歡用 Prahl et al（1988）的方程式，Conte 與 Weber 卻顯示西北大西洋之 $U_{37}^{k'}$—溫度之關係方程是非線性的，斜率在 22℃以上趨緩。此暗示以往用線性方程重建低緯度區之冰期海表溫度有低估的可能。

隨著 U_{37}^{k} 溫度指標研究之增加，對此一工具的可靠性卻也出現了更多的質疑。

3. 海洋沈積物風飄岩塵的意義

Clemens 針對印度洋 5 個沈積物捕獲器之研究，顯示其 lithogenic grain size（粒徑）與風速相關，但是其通量則落後 6～8 週，但與生物通量正相關，顯示沙塵從海水中之清除是受到生物作用（生物泵）之調控。

4. 上次最暖間冰期之相關問題

Kukla et al.（1997）認為歐洲 Eemian 之時程長度 2 倍於海洋之氧同位素 5e 期（IMS5e）。McManus 的報告顯示歐洲 Eemian 時期約有 20kyrs，而海洋之 MIS5e 僅 12kyrs，他們認為 MIS5e 之後，北大西洋底層水（NADW）增強，故而增加熱

量之傳送，使得北大西洋週邊的陸地仍持續溫暖，故有較長的 Eemian 暖期。

5. 晚第四紀冰盛期的氣候波動

證據顯示（Oppo et al., 1998），晚第四紀之冰期鼎盛期（MIS 2, 6, 8, 12）中之氣候波動的幅度均較冰消期或間冰期為小。而各冰消期（terminations）的節奏與冰期震盪（glaciation oscillations）的特徵相同，而與冰川體積，冰川形狀等各解冰期的動力過程無關。

6. 海洋沈積物火山灰含量之測定

火山活動旺盛地區之海洋沈積物中常含有不等量之火山灰，但是不易測定出其含量。以往多用重液分離等沈積學方法來測定。會議中 Boston University 的研究人員採用了一種 Sigurdson 創設的 Cr-based normative calculation，可以測出混染在沈積物中的火山灰含量，值得引進，研究南海的岩心。

三、建議

國科會所支持之大型整合計劃「國際古海洋變遷研究」（IMAGES）於 1997 年在南海及西菲律賓海所鑽之岩心品質優良，其岩心夠長，地層解析度很高，與國外近年相關之晚第四紀古環境研究所利用之岩心相比，不遑多讓，國際間相關之研究人員亦有所聞，十分艷羨。

此外，IMAGES 岩心在南海古海洋學及古地磁學方面的價值也令他國學者忌妒又羨慕。我國學者應加快腳步，通力合作，把這些岩心做最好的研究與發揮。

四、 攜回資料

1. AGU 2000 Fall Meting Abstract book. (EOS, V.79, No.17）。
2. Principle of Paleoclimatology（1999）（自購）。
3. Use of Proxies In Paleoceanography（1999）（自購）。

Reconstruction of Paleotemperature and Paleosalinity of the South China Sea for the Past 170kyrs Using Planktonic Foraminiferal Mg/Ca Ratio and Oxygen Isotopes

Kuo-Yen Wei, Ee-Ee Teh and Yue-Gao Chen
Department of Geosciences, National Taiwan University, Taipei, Taiwan R.O.C.

Recent studies on foraminiferal Mg/Ca ratio have confirmed its applicability as an effective paleotemperature proxy. Using the Mg/Ca ratios in the planktonic foraminifer *Globigerinoides sacculifer* from a well-preserved sequence of core MD972142 (12°41.33'N, 119°27.90'E, 1557m water depth), we have reconstructed a 170kyrs record of past sea surface temperature (SST) of the southeastern South China Sea. To our knowledge this is the first foraminiferal Mg/Ca ratio derived SST data from the South China Sea. Recent temperature based on core top Mg/Ca ratio is ~28.4°C, corresponding to the observed annual mean SST in this area. Further support is found by comparing both the Mg/Ca SST record and the annual mean SST record derived from foraminiferal fauna assemblages. Our result suggests that SST increased by ~4-5°C from the Last Glacial Maximum to the Holocene, and is in good agreement with other SST records from South China Sea. The Mg/Ca SST record reveals that the SST during substages 5.1, 5.3 and 5.5 were as high as those during the Holocene, demonstrates the western extend of the Western Pacific Warm Pool in this region throughout the interglacial substages during stage 5. The SST of glacial oxygen isotope stage 2 is slightly colder than that of oxygen isotope stage 6. We have also combined the Mg/Ca-SST record and the oxygen isotope record to construct the salinity variation for the past 170kyrs. The resulted sea surface salinity range from 30.5-34.5 per mil, however, the overall pattern is different from that observed from open oceans. The sea surface salinity variations in this region are mainly controlled by the balance between evaporation and fresh water input, which is mainly related to the East Asian Monsoon system, therefore the records are useful in monitoring the intensity of the monsoon system.

出席 2001 年「全球變遷公開科學會議」報告

楊天南 （台大地質科學所博士候選人）

一、參加會議經過

本次會議於七月十日至十三日在荷蘭阿姆斯特丹市召開，約 2000 人與會，發表的論文數約 1600 篇。是由國際地圈—生物圈計劃(International Geosphere-Biosphere Programme，後文簡稱 IGBP)、全球環境變遷之國際人類面相計劃(International Human Dimensions Programme on Global Environmental Change，後文簡稱 IHDP)及世界氣候研究計劃(World Climate Research Programme，後文簡稱 WCRP)等三個國際性全球變遷研究計劃群所籌辦，該三個國際性計畫進行地球系統的物理層面、生地化循環和生物過程以及全球變遷之人類面向探討研究，其共同贊助者爲聯合國的國際科學議會(International Council for Science)。

本人所發表的論文題目是：Vertical dynamic distribution of coccolithophorids in relation to movement of watermass: A case study of the southern East China Sea.(所製作壁報見附件一)

兩年前，IGBP 從事一個結合新舊計劃之綜合性計畫，遂有將過去十年的研究成果公開展示出來的構想，因而促成此一別開生面會議的召開。地球系統相當複雜且各層次相互緊密關連的特性，也讓此次會議的籌辦者留下深刻印象。於是一個整合性地球系統的觀點在 IGBP 綜合計劃中展現，例如針對生地化循環研究的 IGBP 綜合計劃也與 IGBP，IHDP 和 WCRP 之地球系統科學研究成果接軌。最近，第四個國際性全球變遷研究計劃——多樣性探討(DIVERSITAS)也參與這個研究團隊，增添地球系統的生物多樣性觀點。

在四天會期中的議程簡述如下：

第一天(七月十日)，會議主題爲『成就與挑戰』(Achievements and Challenges)。下午並有四項子題的壁報展示，四項子題分別爲，

一、 地球系統、行星新陳代謝和全球元素循環(Earth Science, Planetary Metabolism and Global Element Cycles)；

二、 檢視過去到未來：地球系統之古研究(Looking Back to the Future; Palaeo Studies of the Earth System)；

三、 水循環、水資源和用水安全(Water Cycle, Water Resources, Water Security)；

四、 氣候變動和氣候變遷(Climate Variability and Climate Change)。

第二天(七月十一日)，會議主題爲『認知的提昇』(Advances in Understanding)。下午時段進行兩場平行會議，每場會議各有七個子題分別在七間會議室進行。晚間還進行一場名爲「永續科學」(Sustainability Science)的特別專題研討會。

第一場的七個子題分別爲：全球碳循環(Global Carbon Cycle)、巨大城市與全球變遷(Megacities and Global Change)、過去和未來的氣候變動中之聖嬰及南方震盪現象(El Ni o Southern Oscillation in the context of past and future climate variability)、地球系統地面實像化(Ground-truthing the Earth System)、全球變遷對生物多樣性之效應(Global Changes in Biological Diversity)、全球變遷與火災(Global Change and Fire)以及人類在沿岸區的活動與交互作用(Human Interactions in the Coastal Zone)等。

第二場的七個子題分別爲：食物產量與環境之間的交易(Tradeoffs Between Food Production and Environment)、了解土地利用之更動與重建(Understanding Land-Use Changes to Reconstruct,)，描述或預測土地覆蓋度之更動(Describe or Predict Change in Land Cover)、冰圈與全球變遷(The Cryosphere and Global Change)—機制與指標物(Mechanisms and Indicators)、地球系統分析(Earth System Analysis)、陸地生物圈與全球變遷(The Terrestrial Biosphere and Global Change)、社會之轉型過程(Transformation Processes in Society)以及海洋與全球變遷(The Ocean and Clilmate Change)等。

第三天(七月十二日)，會議主題仍爲『認知的提昇』。下午進行第三場平行會議和展示另四項子題的壁報。晚間召開「全球變遷科學的人力建構」(Capacity Building for Global Change Science)之小組會議，該會議針對開發中國家的研究人員所需的援助提供服務。

平行會議七個子題分別爲：環境變遷造成水資源易受破壞(Vulnerability of Water Resources to Environmental Change)—一個系統性趨近(a Systems Approach)、置人們於地球系統中(Putting People into the Earth System)：犧牲品或惡徒，騷動或解決方案(Victims or Villains, Disturbance or Solution)、氣圈與全球變遷(The Atmosphere and Global Change)、全球變遷之非線性反應與驚愕(Non-Linear Responses and Surprises to Global Change)、生態系永續經營管理之長期遠景(Long Term Perspectives on Ecosystem Management for Sustainability)、科學與決策過程(Science and the Policy Process)：國際政府間全球變遷小組(IPCC)和來生以及全球變遷與高山區(Global Change and Mountain Regions)等。

壁報子題分別爲，

五、 海洋與海岸(Oceans and Coasts)；

六、 氣圈與它的介面(Atmosphere and its Interfaces)；空氣品質(Air Quality)；

七、 維持陸地(Sustaining the Land)：食物，生物多樣性與其他服務(Food, Biodiversity and Other Services)；

八、 人類的事業與全球永續(The Human Enterprise and Global Sustainability)：工業，運輸與團體的易受傷害性(Industry, Transport, Institutions Vulnerability)。

第四天(七月十三日)，會議主題爲『眺望未來：地球系統科學和全球永續性』(Looking to the Future: Earth System Science and Global Sustainability)。閉幕會議於下午四點舉行，邀請聯合國全球變遷組織常會執行秘書 M.Z. Cutajar 博士演講，及各研究計劃群主席作此次會議總結。

二、與會心得

本次會議內容呈現了地球系統紛雜多樣的特性，涵括有關地圈、氣圈、水圈、冰圈和生物圈的議題及研究。有關過去研究的進展、現今的認知及未來的方向，在短短四天的會期中，以完整而詳實的和與會人員分享。在所有報告的議題中，最令人印象深刻的就是地球系統裡非線性反應現象的研究。例如，過去被認爲屬線性反應的大西洋溫鹽環流系統，也有非線性的狀況存在。其實對於非線性的氣候系統之研究早就存在，也一直不斷發聲，端看大小尺度的選定，最有名的例子就是碎形幾何。因此，所研究題目的尺度決定反應現象的線性或非線性關係，是吾人所必須考量或注意的觀點。

參加此次國際會議除見識到部分大師級人物的邏輯思維、綜合各學門成果功力及表達能力外，也看到各國年輕一輩人才的投入現況。博、碩士研究生和博士後研究人員所發表之論文數頗眾，以同爲亞洲地區的日本和中國大陸爲例，出席不少年輕的研究人員，反觀我國的出席狀況，除本人外，其他十一位皆爲資深的研究學者，意味：(一)我國出現研究人才斷層，沒有新人投入與全球變遷相關的研究題材；(二)新人不缺，但訊息不夠通暢；(三)出國花費不貲，如碩士生沒有補助管道，因而喪失與國外專家學者交流機會。

除人員參與外，還有研究成果或相關資料提供的疑問。歐美國家不說，連中國大陸都在會場放置他們的 IGBP 國家委員會所發行的中國全球變遷國家報告第四號供與會人員索拿。我國投入對全球變遷的研究課題不少，心力也投注不低，但彙整的成果報告沒在會場出現，大失機會讓各國科學家了解我國的推展情形。

三、建議

全球變遷研究課題是當今舉世眾所矚目的焦點，對年輕的研究人才，如碩士生也需多些機會到國外接受激勵和交流，否則縱有滿腔熱忱，卻只是一介井底之蛙不知現今世界潮流走向，因此，多方管道的補助機會，對促進和提昇年輕研究人才的水準，實有必要。

在出版品方面，相關研究群的年報及論文集等刊物需有人統籌管理並交付欲出席國際會議人員攜帶至會場，除讓各國知悉我國推展情形外，同時也分享我國的經驗，以盡身為地球一分子的義務與責任。

四、攜回資料

1. 本次會議論文摘要集

2. IGBP 全球變遷報告第 33 號

3. 德國全球變遷國家委員會發行之 2001 年論文集

4. 中國 IGBP 國家委員會發行之國家報告第四號

5. IGBP、NASA、CLIVAR 等機構最新出版的研究通訊

附件一

P.5.0.050

Vertical Dynamic Distribution of Coccolithophorids in Relation to Movement of Watermass: A Case Study of the Southern East China Sea

T.-N. Yang[1], K.-Y. Wei[1], Y.J. Yang[2], T.Y. Tang[3]
[1]Inst. Of Geosciences, National Taiwan University, Taipei, Taiwan, Republic of China
[2]Dept. Of Applied Science, Chinese Naval Academy, Kaohsiung, Taiwan, Republic of China
[3]Inst. Of Oceanography, National Taiwan University, Taipei, Taiwan, Republic of China

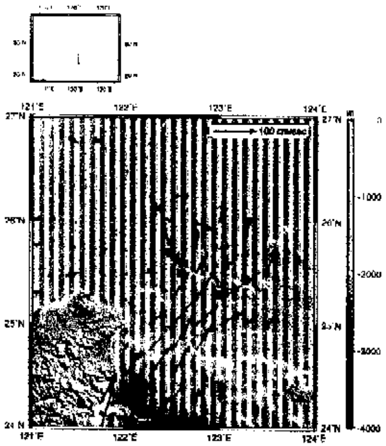
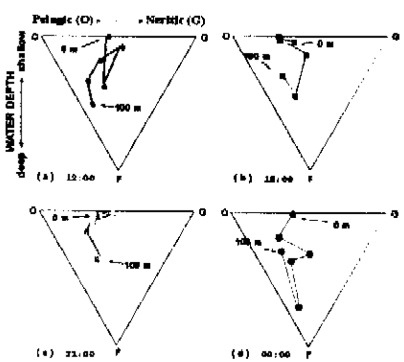


Fig. 1. Map of the southern East China Sea showing the studied site, A, and composite ship-board ADCP current vectors at 30 m in depth in fall obtained from *R/V Researcher I* oceanographic surveys around the studied area during 1992-2000. Current speed values exceeding 300 cm s^{-1} were deleted and the remaining data screened against a 3 standard deviation filter. Stations B and C only show values of temperature and salinity here. The topography data are from the Ocean Data Bank, National Center for Ocean Research, Taiwan, Republic of China.



Abstract--This study depicts the diurnal vertical dynamic distribution of coccolithophorid assemblages at a single site in relation to movement of watermass in a domain where Kuroshio interacted with shelf waters on the southern East China Sea continentalshelf. An Acoustic Doppler Current Profiler (ADCP)-mooring was deployed at the depth of 80 m level at a time series site, station A (Fig. 1.), on Nov. 10-13, 1995 for monitoring the current variations in detail at minute time-scale. At the last day of the deployment, from 04:00 Nov. 12 through 06:00 Nov. 13, a diurnal observation of physical conditions and coccolithophorid communities at this site was conducted. The T-S diagram of station A shows a complicated dynamic variations in hydrological conditions (Fig. 2). Furthermore, the sigma-t profile of water column at this site displays a vigorous dynamic variations between 20- and 70 m in depth (Fig. 3). We follow Okada's (1983) idea with minor modification in categorizing coccolithophorid assemblages into three groups to construct a triangular coordinate diagram on which the environmental affinities of coccolithophorid flora are characterized. The taxa included in the three apex are: (1)the deep-dwelling group (F), including *Florisphaera profunda*, *F. Profunda elongata* and *Thorosphaera flabelata*; (2)the neritic group (G), including *Gephyrocapsa* spp., *Anoplosolenia* spp. and *Calciosolenia murrayi*; and (3) the remaining species (O), representing open-ocean condition. Despite the fact that the investigated site is located on continental shelf with a maximum water depth of 110 m, the coccolithophorid assemblages contain abundant pelagic and deep-dwelling species. The triangular coordinate diagrams against monitoring time and investigated depth revealed by dynamic coccolithophorid distributions also show that the movement of watermass between 20- and 70 m in depth displayed dynamic complications during the monitoring period (Figs.4,5). It is evident that a strong influence of Kuroshio and associated upwelled cold water played major role in affecting the vertical distribution of coccolithophorids.

Fig. 4. Triangular coordinate diagrams showing the environmental affinity of coccosphere assemblages collected at various time. See the text of abstract for more explanation of the triangular diagrams.

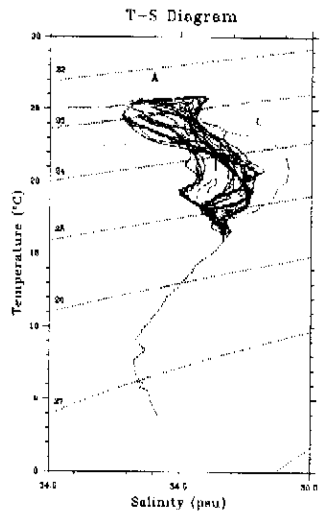
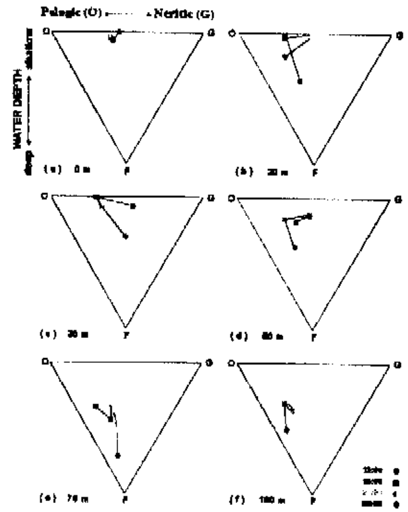


Fig. 2. Temperature-salinity plot of Stations A (red lines), B (green line) and C (blue line). All red lines represent the 27 data which were investigated at station A in every one hour from 04:00 Nov. 12 through 06:00 Nov. 13, 1995. The red line group shows a sophisticated physical condition, whereas stations B and C display both end-members, shelf and Kuroshio waters, respectively.



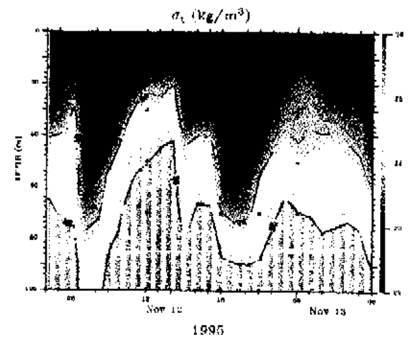


Fig. 3. The sigma-t profile of water column at time series station A from 04:00 Nov. 12 through 06:00 Nov. 13, 1995. The square symbols indicate that the coccolithophorid communities were investigated in water samples at various depth.

Fig. 5. Triangular coordinate diagrams showing the environmental affinity of coccosphere assemblages collected at various depths. A vigorous vertical dynamic distribution of coccolithophorids is documented at water depth between 20- and 70 m. See also the text of abstract for more explanation of the triangular diagrams.