LEG 184

SOUTH CHINA SEA: EAST ASIAN MONSOON HISTORY

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ABSTRACT

Leg 184 will core hemipelagic sediments in the South China Sea (SCS) to determine the evolution and variability of the East Asian monsoon in the late Cenozoic. Of the six proposed drill sites (Fig. 1), five are located on the northeastern continental slope southeast of the Dongsha Islands, and one is on the southern slope south of the Nansha Islands near the Sunda Shelf, with water depths ranging from 625 m to 3190 m.

The main goal of Leg 184 is to improve our knowledge of the link between climate and tectonics. Land-based studies in China and other parts of East Asia have developed a four-stage model of monsoon evolution. The proposed drilling will calibrate the terrestrial record with that of the global ocean. It is suggested that uplift of the Tibetan Plateau is responsible for both the late Cenozoic global cooling and for the intensification of the Asian monsoon; therefore, a comparison between records of monsoons, denudation rates, and climate cooling in the SCS will test this hypothesis. Drilling of high-sedimentation-rate hemipelagic deposits in the SCS will provide the proxy records for this test.

There are four major scientific objectives for the leg: (1) to obtain a continuous marine record of East Asian climate history for the late Cenozoic and to compare the evolution of the East Asian monsoon system with the South Asian or Indian monsoon system; (2) to examine the possible relationship between the Tibetan Plateau uplift, monsoon evolution, and global cooling; (3) to improve our understanding of the stability of the Western Pacific Warm Pool and the role of seasonality changes in low-latitude marginal seas; and (4) to establish a detailed history of sea-level changes for the SCS.

INTRODUCTION

The atmospheric circulation of the Asian monsoon system is of primary importance in our understanding of global climate evolution. Despite the equally prominent significance of the two subsystems (East Asian and South Asian or Indian), paleo-monsoon studies up to now are very much dominated by those about the Indian monsoon. The East Asian paleo-monsoon studies have been restricted mainly to land-based work, with monsoon information commonly being obtained from the Chinese loess. Very little attention had been paid to the marine aspects of the East Asian monsoon until recently. Extensive hydrocarbon exploration in China and its surrounding offshore areas has accumulated tremendous amounts of geological data that are rich in Cenozoic paleo-monsoon information. Together with recent progress in Quaternary science for East Asia and the western Pacific, the data have led to the development of a four-stage model of East Asian monsoon evolution: the pre-monsoon stage (Paleocene and early Eocene), the transitional stage (late Eocene to Oligocene), the monsoon Stage I (Miocene and Pliocene), and the monsoon Stage II (late Pliocene [2.4 Ma] to present) (Table 1; Wang, 1997).

Table 1. Evolution stages of the East Asian monsoon in the Cenozoic based on land studies from China.

Stage	Time interval	Monsoon	Paleogeography
Pre-monsoon	Paleocene to early Eocene	Absent or insignificant	Smaller Asia without Tibetan Plateau
Transitional	late Eocene to Oligocene	Unstable	India joined with Asia
Monsoon I	Miocene to Pliocene	Summer monsoon developed	Plateau uplift started
Monsoon II	late Pliocene to Pleistocene	Summer and winter monsoon developed	Intensive plateau uplift

As shown by palynologic, paleobotanic, and lithologic data, the climate pattern in China underwent a profound reorganization around the beginning of the Neogene (Wang, 1990; Sun and Wang, in prep.). The Paleocene in China inherited the Late Cretaceous environmental pattern ("Pre-monsoon Stage"), with a broad arid zone traversing the whole country from west to east (Fig. 2A). In the

Miocene the arid zone retreated to northwest China, and eastern China became more humid (Fig. 2B; "Monsoon Stage I") because of the strengthening of the southeast summer monsoon, which brings moisture from the sea. This general regime has existed from the Miocene to the Holocene. The middle-late Eocene and Oligocene climate in China ("Transitional Stage") has been variable and intermediate between the Paleocene and Neogene regimes. During this time, unstable summer monsoons brought moisture to the otherwise dry areas, creating the most favorable conditions for nonmarine oil accumulation in China. The initiation of the winter monsoon in eastern Asia was much later, and it marked the beginning of deposition of the Chinese loess deposits at about 2.4 Ma ("Monsoon Stage II"; Liu and Ding, 1982). The loess deposits are a joint product of winter and summer monsoons. Because the Indian and East Asian monsoons share the same tectonic control factor in their evolution, we would expect to find the same more-or-less synchronous evolutionary stages. Deep Sea Drilling Project (DSDP) and Ocean Drilling Program (ODP) core studies have revealed the onset of the Indian monsoon at about 20 Ma and its intensification around 8 Ma (Prell and Kutzbach, 1992). If the East Asian monsoon record in the SCS supports this timing, it will be a strong argument in support of tectonic forcing as a cause for both of the Asian monsoons.

Among the continents of the world, Asia has been subjected to the most significant Cenozoic deformation. The Cretaceous-Paleocene topography of China was generally tilted to the west, with the coastal areas of the Tethys in the west and relatively high land and endorheic basins in the east. This paleogeographic pattern lasted until the late Eocene when India collided with Asia, thereby bringing the maritime conditions in western China to an end. The uplift of the Tibetan Plateau started about 21-20 Ma (Copeland et al., 1987; Harrison et al., 1991) and was accompanied by a general subsidence of East China. These tectonic changes led to a reversal of the topographic trend in China from west-tilting to east-tilting, with the west-east gradient in altitude increasing continuously since then. In addition, the early Miocene was also the time of formation for many of the western Pacific marginal seas. The radical changes that occurred in the topography of Asia during the Cenozoic must have had a profound impact on climate, including the onset or strengthening of the monsoon circulation in East Asia. The further development of east-sloping topography and monsoon precipitation has brought about the large river systems discharging enormous amounts of sediments into the newly formed marginal seas along the East Asian coast, building up extensive coastal plains and continental shelves.

The accelerating uplift of the Tibetan Plateau is thought to be responsible not only for the Asian monsoon, but also for late Cenozoic global cooling (e.g., Ruddiman and Kutzbach, 1989). Raymo et al. (1988) proposed that long-term increased chemical erosion in rapidly uplifted areas could reduce atmospheric CO_2 (Raymo, 1994). If this is the case, the evolution of Asian monsoon and global cooling should be correlated with each other. The proposed drilling in the SCS will test the hypothetical causal relationship between the three major environmental features in the late Cenozoic: global cooling, enhanced denudation, and the Asian monsoon.

BACKGROUND

Tectonic Settings

The opening of the SCS was genetically related to the deformation of Asia. The rhomboid-shaped Central Basin is the major deep-water oceanic crust feature of the SCS (Fig. 3A). Judging from the magnetic anomalies in the SCS Central Basin, seafloor spreading lasted from 32 Ma (magnetic Anomaly 11) to 16 Ma (Anomaly 5c), with a southward ridge jump at ~27 Ma (Anomaly 7/6b). It is suggested that the opening of the SCS basin is linked with the Red River fault zone, with at least 500 to 600 km of left-lateral displacement during the Oligocene and Miocene (Briais et al., 1993). The terrain system that migrated during the SCS opening is composed of coral reef groups: the Nansha (Reed Bank and Dangerous Ground) Terrain, the Xisha-Zhongsha Terrain (Macclesfield Bank and Paracel Island) Terrain and others (Jin, 1992).

One of the geologically best-studied parts of the SCS is in the northern continental margin where extensive oil exploration and geophysical studies have been done on crustal extension (e.g., Hayes et al., 1995). The sedimentary basins of the northern shelf show a typical double-layer structure, consisting of a lower section characterized by half-grabens formed during Paleogene rifting and an upper section with a wider distribution of deposits resulting from broad subsidence in the Neogene (Fig. 3B; Ru et al., 1994).

Sedimentology and Stratigraphy

Modern sedimentation in the SCS consists mainly of terrigenous material, biogenic carbonate and opal production, and a small portion of volcanic sediment input. Clastic sediment discharged into the SCS is mainly from the Mekong River, Red River, and Pearl River. The paleo-Sunda River system provided a great amount of sediment into the SCS during glacial time. However, sediment trap studies in the northern SCS have shown that the highest particle-flux rates are correlated with high wind speed during the winter monsoon and, hence, the suspended matter from the East China Sea and the Pacific may exceed the amount of river input into the SCS (Jennerjahn et al., 1992). With the high terrigenous input and the location of the modern carbonate compensation depth (CCD) at 3500 m, the SCS bottom is covered by abyssal clay in the deep-sea basin and biogenic carbonates around coral reef islands, but the hemipelagic sediments are the main component of the extensive continental slope. Two types of carbonate cycles are found in the late Quaternary SCS: the "Atlantic" type (above the lysocline), where the controlling factor is dilution by terrigenous clasts, and the "Pacific" type (below the lysocline). where deep-sea dissolution is the controlling factor (Wang et al., 1986; Bian et al., 1992; Thunell et al., 1992; Zheng et al., 1993; Miao et al., 1994; P. Wang et al., 1995).

Cenozoic deposits thousands of meters thick have been drilled by petroleum companies in many sedimentary basins in the SCS. They found nonmarine sequences underlying marine sediments that were deposited during the Miocene or late Oligocene. Reworked Paleocene and Eocene marine microfossils were present in Neogene deposits from the northern shelf, and Paleocene deltaic and Eocene marine sediments were found in the southern part of the SCS such as the Liyue Bank (Reed Bank) Basin, where carbonate deposition started from the middle Oligocene (ASCOPE, 1981; Jin, 1989; Fig. 4). Among the basins in the northern SCS, the Pearl River Mouth Basin is the most studied. Over 80 wells were drilled there and a quite detailed stratigraphy established for the marine sequence from the uppermost Oligocene to Pleistocene on the basis of various groups of planktonic microfossils (Huang, 1997).

Late Quaternary Paleoceanography

During the last glacial maximum (LGM), sea-level lowering caused remarkable alteration in the configuration and area of the western Pacific marginal seas. The three major shelf areas that emerged during the LGM (East China Sea Shelf, Sunda Shelf or the Great Asian Bank [Fig. 5A], Sahul Shelf or the Great Australian Bank) amount to 3,900,000 km^2, which is comparable in size to the Indian Subcontinent (Fig. 5A). The SCS lost half its area (over 52%) as a result of shelf exposure, which changed its configuration into a semi-isolated basin (Wang et al., 1997). Moreover, the most extensive shelf area of the SCS is located in the modern Western Pacific Warm Pool bounded approximately by the 28°C surface isotherm. The reduction in size must have profoundly influenced the thermodynamic role played by the Global Warm Pool.

The central portion of the SCS experienced a considerable decline in the sea-surface temperature (SST) during the LGM. The winter monsoon strengthened, the polar front shifted southward, and the Kuroshio Current migrated eastward. All these changes caused a drastic decrease in the winter SST in the West Pacific marginal seas in general and in the SCS particularly (Wang and Wang, 1990; Miao et al., 1994; P. Wang et al., 1995). Together with the negligible changes in the summer SST, the decrease in winter SST resulted in a much more intensive seasonality during the LGM (Fig. 5B; Wang, in press). Among the important consequences of the glacial changes of the SCS is the intensified aridity in China. The SCS is the main source of water vapor for precipitation in East China (Chen et al., 1991). The above-described shelf emergence and SST decline must have led to a reduction in evaporation and vapor supply from the sea to the land. A very preliminary estimate shows that the reduction in evaporation from the SCS during the LGM could correspond to 1/8 to 1/4 of the annual precipitation in all of China (Wang et al., 1997). The glacial reduction in vapor supply from the sea at least partially explains the intensification of aridity in the China hinterland as evidenced, for example, by the extensive distribution of loess deposits. Moreover, the glacial increase of seasonality in the marginal seas may offer an alternative approach (Wang, in press) to the tropical paleoclimate enigma in the Pacific, that is, the discrepancy between marine and terrestrial indicators of paleotemperature during the LGM (Stuijts et al., 1988; Andersen and Webb, 1994).

Before 1992, at least 31 cores from the SCS were studied for paleoceanographic and sedimentologic research. Deep-sea sediment cores from 39 sites recovered from the SCS during the joint German-Chinese expedition *Monitor Monsoon* in 1994 (Sarnthein et al., 1994) provide for the first time systematic and high-quality material for paleo-monsoon studies in the region (e.g., L.Wang et al., 1995; Sun, 1996). The IMAGES III Cruise in 1997 has taken several long cores of late Quaternary deposits from the SCS. The late Quaternary studies have demonstrated the great potential of the SCS's hemipelagic sediments to provide high-resolution paleoenvironment records.

SCIENTIFIC OBJECTIVES

The main goal of Leg 184 is to determine the evolution and variability of the East Asian monsoon during the late Cenozoic to improve our knowledge of the link between climate and tectonics. There are four major scientific objectives of the leg.

1. Obtain a continuous marine record of the climate history of East Asia during the late Cenozoic and compare the evolution of the East Asian with the South Asian or Indian monsoon system. One advantage of the SCS is the high average sedimentation rates of its hemipelagic deposits that are suitable for high-resolution stratigraphy. The sedimentation rate in the continental slope varies from 0.7 to 15 cm/k.y. for the Holocene to 1.3-31 cm/k.y. for the last glaciation, with the maximum values found near the mouth of the Pearl River and the paleo-Sunda River's entry to the SCS (P. Wang et al., 1995). Recent studies of a core near the Dongsha Islands, northeast of the SCS, revealed a new sedimentation rate record for hemipelagic deposits in the SCS, where the Holocene is nearly 7 m in thickness (Core 17940, 20°07´N, 117°23´E, in water depth of 1727 m; Sarnthein et al., 1994). This core enables a temporal resolution of less than 15 yr. The proposed drilling during Leg 184 will provide continuous records of monsoon variations back to the late Paleogene, enabling a comparison with the Indian monsoon records.

   Tremendous amounts of Cenozoic paleoenvironmental information have been gained from petroleum exploration and academic studies in East Asia, particularly in inland and offshore China. Due to the language barrier and commercial restrictions, little of this data has been available to the global scientific community, and the poor stratigraphic control of the mostly nonmarine deposits has made it difficult to correlate the sediment records with the global paleoenvironmental history. The proposed deep-sea drilling is expected to provide a direct stratigraphic calibration and to bridge the local or regional land-based studies with global ones. Special attention will be paid to the timing of drastic changes in denudation, monsoon and cooling, and to the leads or lags between terrestrial and marine records.

2. Examine possible relationship between plateau uplift, monsoon evolution, and global cooling. Land-based studies in China and other parts of East Asia have resulted in a four-stage model of monsoon evolution. The proposed drilling will calibrate the terrestrial records with those of the global ocean. Because it is suggested that uplift of the Tibetan Plateau was responsible for both the late Cenozoic global cooling and for the intensification of the Asian monsoon, a comparison between records of monsoons, denudation rates, and climate cooling in the SCS will test the hypotheses.

   However, the relationships between tectonics, erosion, and climate are complex and highly nonlinear. The tectonic control of the Asian monsoons, for example, is by no means limited to the plateau uplift. Only recently has the marine factor for monsoon evolution been discussed, but then only the role of the Paratethys was considered (Ramstein et al., 1997); whereas, the western Pacific marginal seas should have more direct impact on the evolution of the East Asian monsoon. SCS drilling will allow insights into the mechanisms of monsoon variation and will also throw new light on the debatable questions about the relative role of climate vs. tectonics in erosion and uplift.

3. Improve our understanding of the stability of the Western Pacific Warm Pool and the affect of seasonality changes on low-latitude marginal seas. Drilling in the southern part of the SCS will recover a continuous late Cenozoic sequence record of climate changes preserved in the pool. It will show whether the warm pool was formed during closure of the Indonesian Seaway, and whether the pool remained stable during glacial cycles. Moreover, seasonal variations must be considered in areas with monsoon circulation.

Although seasonality is not necessarily related to monsoon circulation, intensification of monsoon circulation can trigger an increase in seasonality. The glacial increase in seasonality within the SCS is at least partly attributed to the strengthening of the East Asian winter monsoon. Aside from SST estimates, seasonality can also be recognized through abundance of index species in planktonic fauna, for example, the planktonic foraminifer *Pulleniatina obliquiloculata*, which is a winter species found in tropical waters. The enhanced glacial/Holocene contrast in deposits demonstrates the conspicuous change in winter SST and seasonality there.

4. Establish a detailed history of sea-level changes for the SCS. The SCS area off the mouth of the Pearl River would be an ideal location for sea-level history studies because of the high sedimentation rates and its appropriate "Ice-House" age of development. Recently, the Research Center of the China Offshore Oil Nanhai East Corp., Guangzhou (CONHE) has proposed a sequence-stratigraphic profile across the Pearl River Mouth Basin to show the retrograding sequence since the Oligocene. The general trend of rising sea level is distinguished from that shown by Haq et al. (1988), implying that regional tectonics are superimposed on global sea-level fluctuations. In view of the significance of sea-level information for this densely populated region, sea-level history should be studied from the data collected at the proposed drilling sites in the northeast SCS and linked to the seismic stratigraphic framework under study (Wong et al., 1994) and the existing industrial wells.

DRILLING STRATEGY/PROPOSED SITES

Six sites are proposed for drilling (Table 2) and fall into two groups: northeastern continental slope and southern slope (Fig. 1).

1. Northeastern Continental Slope

Sites SCS-1 to 5 are located south of the Dongsha Islands in the northeast SCS. The five sites are designed to cover successive time intervals since the Oligocene (SCS-1: Pleistocene; SCS-2: middle Pliocene onward; SCS-3: Pliocene and Pleistocene; SCS-4: middle Miocene to Pliocene; SCS-5: Oligocene to Miocene). The continuous sequence will provide an opportunity to compare the timing of monsoon events in relation to changes in sedimentation rates and dissolved fluxes as possible responses to the uplift of Tibet, to verify and date the proposed stages of monsoon evolution in East Asia, and to establish a sequence of Cenozoic climate events, as well as to study the timing and amplitude of sea-level changes in the basin.

Site SCS-1

Proposed Site SCS-1 is distinguished by the highest sedimentation rate record in the SCS. The Holocene deposits in the nearby Core 17940 (20°07´N, 117°23´E, water depth 1727 m) reach almost 7 m in thickness, enabling decadal resolution in paleoreconstruction. Core MD97.2.146 taken from the same site by the IMAGES III Cruise in 1997 exceeds 38 m in length and its record extends back to the oxygen stages 4/5 boundary (C.Y. Huang, pers. comm., 1997). The summer monsoon cyclicity of 10^2 yr in the Holocene and the dry/humid cyclicity of 10^3 yr in the late Pleistocene found in Core 17940 (L.Wang et al., 1995; Sun, 1996) indicate the great potential of this site in delivering high-resolution monsoon records for the Pleistocene.

Site SCS-2

Proposed Site SCS-2 is located to the south of Site SCS-1 in water that is over 3000 m deep. With its lower sedimentation rate, this site will provide a continuous record of the middle Pliocene to Pleistocene (Holocene). As the sill depth of the Bashi Strait is located at ~2600 m, Sites SCS-1 and SCS-2 will also document the difference in water mass changes below and above the sill at the only connection of the SCS with the deeper water of the Pacific.

Site SCS-3

This is the only site from the upper slope (water depth 650 m) within the modern oxygen minimum zone. This site is expected to provide not only the sequence of Pliocene and Pleistocene history but also show the variations in paleoproductivity and oxygen content since the end of the Miocene.

Site SCS-4

The site is located south of Site SCS-3 in water that is over 2000 m deep. Judging from seismic records, the proposed site will recover the middle Miocene to Pliocene sequence, underlying very thin Pleistocene deposits.

Site SCS-5B

The purpose of drilling Site SCS-5B is to reveal the Oligocene to Miocene paleoclimate history, including the onset of the East Asian monsoon.

2. Southern Slope

One drill site is proposed for the southern slope south of the Nansha Islands. This area is characterized by a wide distribution of hemipelagic sediments with parallel seismic reflectors (Jiang et al., 1990). The two major sources of terrigenous deposits are the paleo-Sunda River and Mekong River, which directly drain the Tibetan Plateau. Drilling at this site will reveal the history of tropical East Asia and the Western Pacific Warm Pool.

Site SCS-8

Proposed Site SCS-8 is located south of the Nansha Islands, off northwestern Kalimantan at a water depth of 1800 m. The site is close to Cores V35-5 (7°11´N, 112°05´E, water depth 1953 m) and 17962. Core V35-5 is one of the first late Quaternary sequence cores dated by accelerator mass spectrometry (AMS) C^{14} in the 1980s (Broecker et al., 1988), and both Cores V35-5 and 17962 have high sedimentation rates and display high-frequency climate variations since the last glaciation. We propose to drill Site SCS-8, the only site from the southern part of the SCS within the Western Pacific Warm Pool, to 1100 mbsf to recover a sediment sequence of Eocene to Pleistocene age.

LOGGING PLAN

Leg 184 sites will recover mainly hemipelagic deposits with alternating carbonate-rich and -poor layers. Density, porosity, magnetic susceptibility, and resistivity variations will be valuable for constructing sediment composition time series as proxy records for paleoclimatic and paleoceanographic changes. Downhole logging will prove useful in sections that cannot be recovered completely by high-quality cores. All proposed sites will be drilled deeper than 400 m and will be logged using the triple-combo and geochemical logging (GLT) tools, geological high-resolution magnetometer (GHMT), and formation microscanner (FMS).

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FIGURE CAPTIONS

Figure 1. Location map of proposed drill sites for Leg 184 (solid circles). Open circles show previous ODP drill sites.

Figure 2. Distribution of the arid zones in China during the Cenozoic. **A.** Paleocene; **B.** Neogene; **C.** Location of sites with paleobotanic and/or lithologic data (from Sun and Wang, in prep.).

Figure 3. Tectonic setting of the South China Sea. **A.** Major tectonic elements of the northern and central parts of the South China Sea. Thick dotted line outlines the Central Basin with selected magnetic anomaly lineaments. Thin dotted and solid lines are isobaths of 200 m and 2000 m (Hayes et al., 1995). Thick dashed box corresponds to Figure 3B. **B.** Geological framework of the northern margin of the South China Sea (Ru et al., 1994). YGHB = Yinggehai Basin; QDNB = Qiongdongnan Basin; BBWB = Baibiwan Basin; PRMB = Pearl River Mouth Basin; SWTB = Southwest Taiwan Basin.

Figure 4. Cenozoic stratigraphy in some of the sedimentary basins in the South China Sea. Column A = Yinggehai Basin; Column B = Pearl River Mouth Basin; Column C = Liyue Bank (Reed Bank) Basin; Column D = Zengmu Basin; Column E = Bruneo-Sabah Basin (data from Jin, 1989; Liu, 1992).

Figure 5. Western Pacific marginal seas at the last glacial maximum (LGM). **A.** Black area denotes that portion of shelf seas emerged at the glacial maximum (Wang et al., 1997). Area A = East China Sea Shelf; Area B = Sunda Shelf or the Great Asian Bank; Area C = Sahul Shelf or the Great Australian Bank. **B.** Paleotemperature: seasonality in SST (summer SST minus winter SST) in the South China Sea and its adjacent western Pacific and marginal seas at the LGM (Wang, in press).

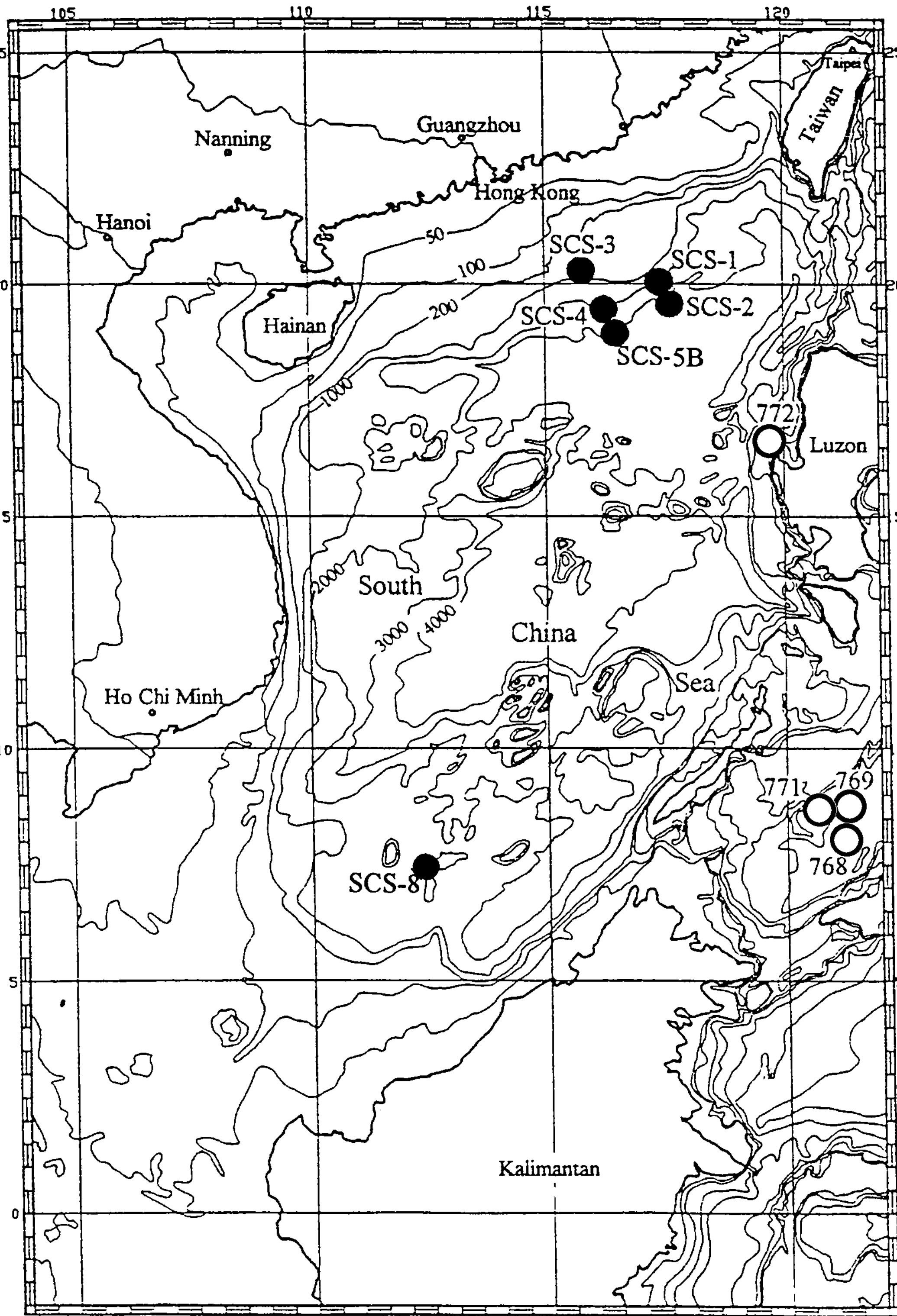

105
110
115
120
25
20
15
10
5
0
Nanning
Guangzhou
Hong Kong
Hanoi
Taipei
Taiwan
Hainan
50
100
200
1000
2000
3000
4000
SCS-3
SCS-1
SCS-2
SCS-4
SCS-5B
772
Luzon
South
China
Sea
Ho Chi Minh
771
769
768
SCS-8
Kalimantan

Figure 1

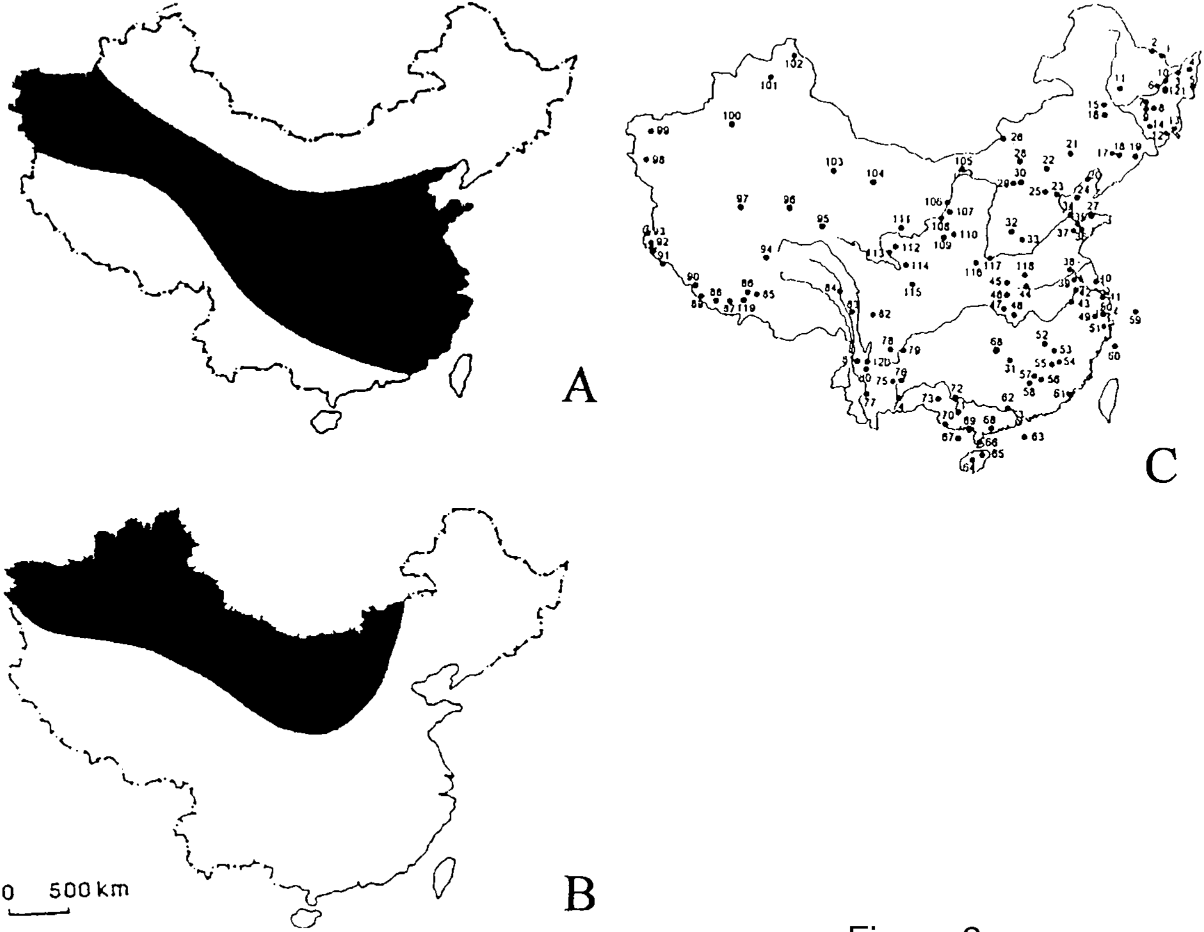
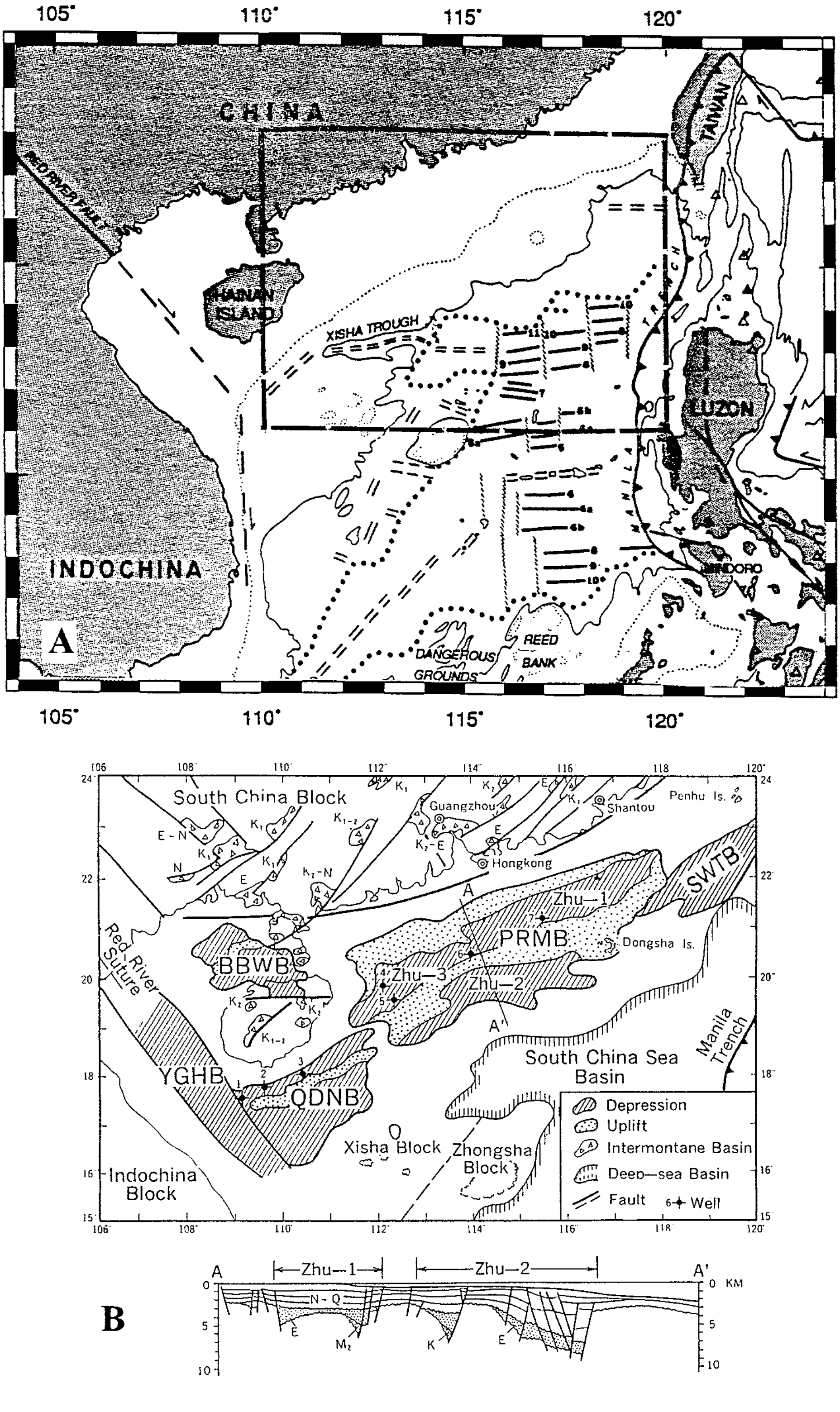


Figure 2



A
CHINA
INDOCHINA
HAINAN ISLAND
XISHA TROUGH
TAIWAN
LUZON
MINDORO
MANILA TRENCH
RED RIVER FAULT
DANGEROUS GROUNDS
REED BANK
105°
110°
115°
120°
25°
20°
15°
10°
B
South China Block
Guangzhou
Shantou
Penhu Is.
Hongkong
Dongsha Is.
SWTB
PRMB
Zhu-1
Zhu-2
Zhu-3
BBWB
Red River Suture
YGHB
QDNB
South China Sea Basin
Manila Trench
Xisha Block
Zhongsha Block
Indochina Block
Depression
Uplift
Intermontane Basin
Deep-sea Basin
Fault
Well
A
A'
N-Q
E
K
KM

Figure 3

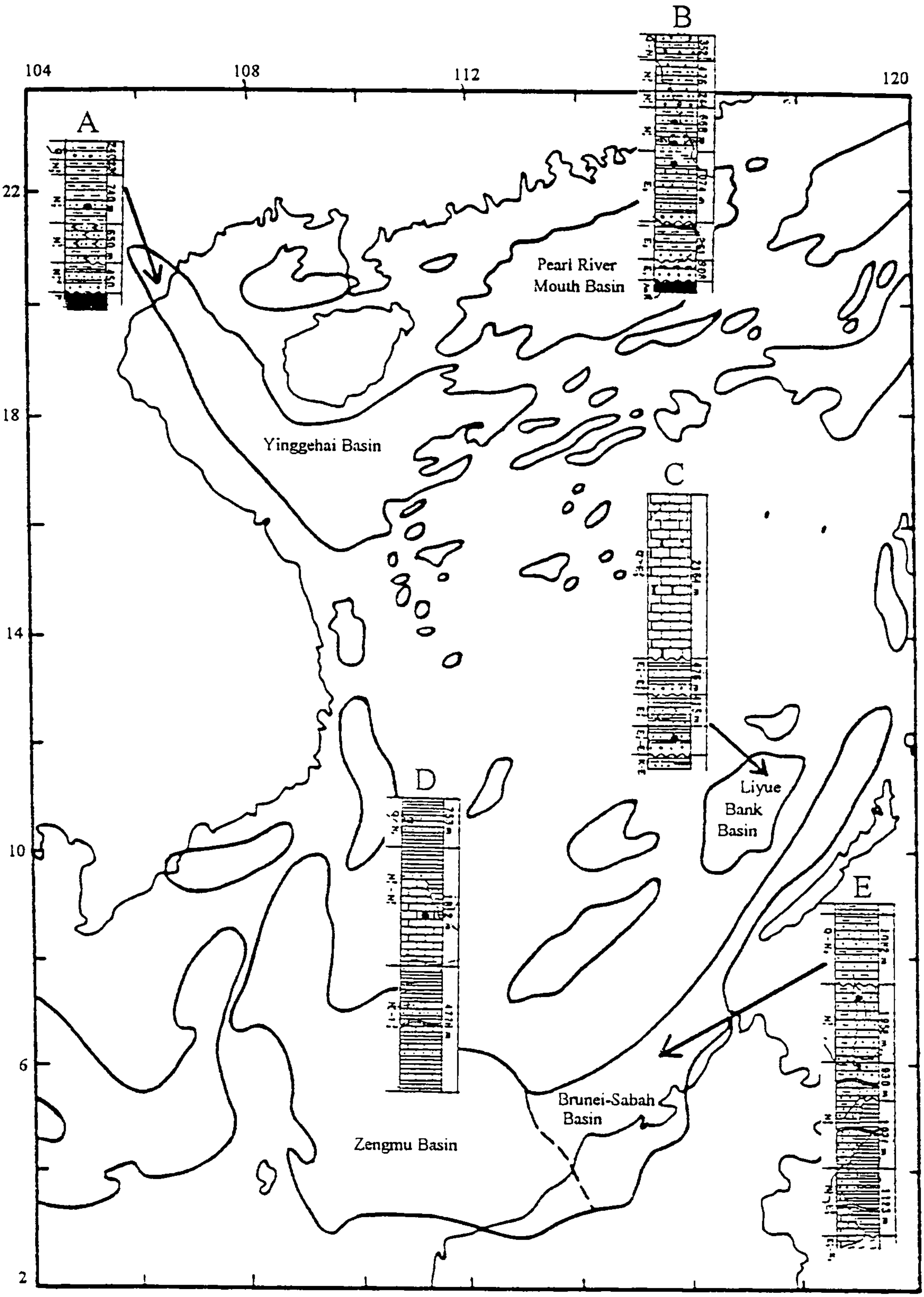

104
108
112
120
22
18
14
10
6
2
A
B
C
D
E
Pearl River
Mouth Basin
Yinggehai Basin
Liyue
Bank
Basin
Brunei-Sabah
Basin
Zengmu Basin

Figure 4

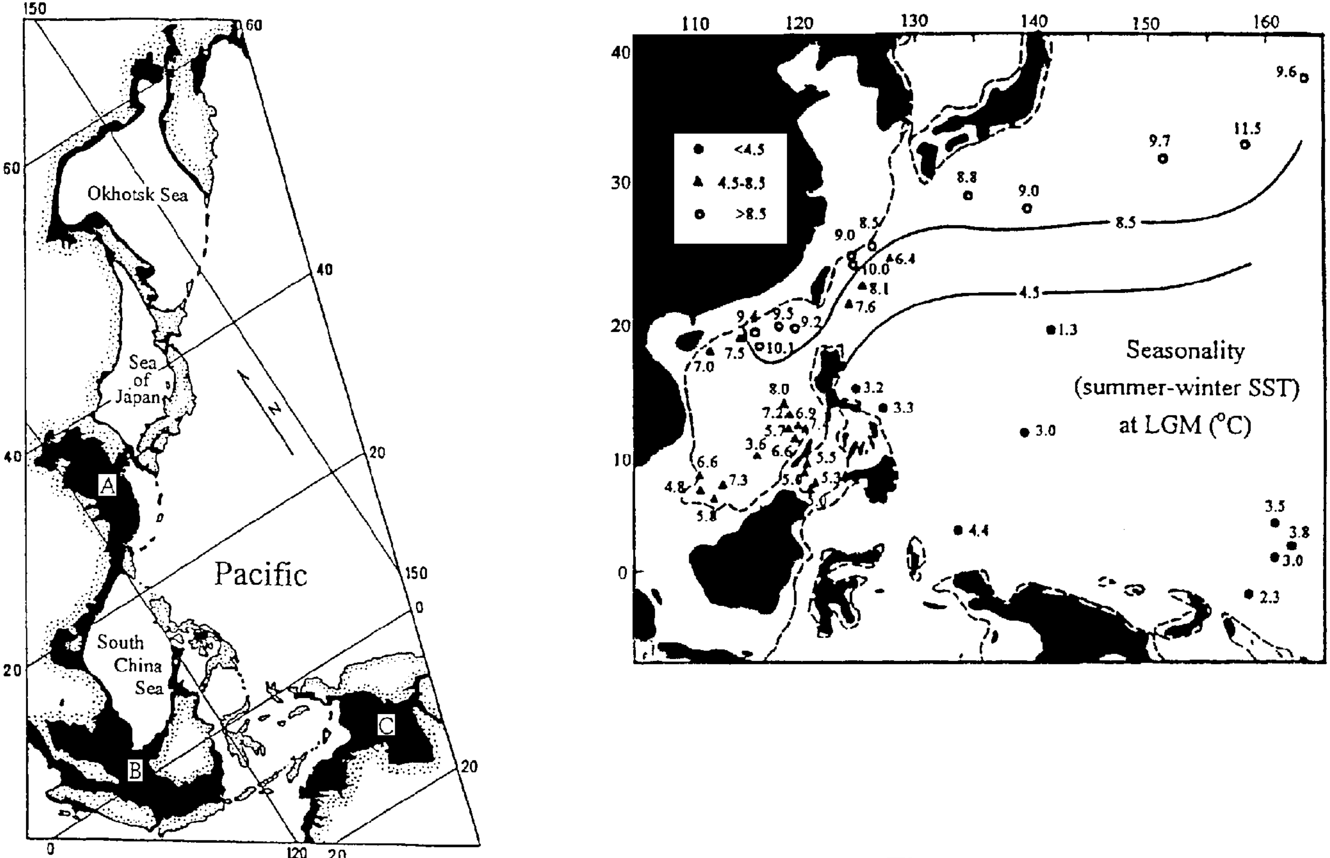

Okhotsk Sea
Sea of Japan
Pacific
South China Sea
A
B
C
N
<4.5
4.5-8.5
>8.5
Seasonality (summer-winter SST) at LGM (°C)

Figure 5

TABLE 2*

PROPOSED SITE INFORMATION AND DRILLING STRATEGY

SITE: SCS-1	**PRIORITY:** 1	**POSITION:** 20.0526°N, 117.4194°E
WATER DEPTH: 2050 m	**SED THICKNESS:** ~760 m	**TOTAL PENETRATION:** 450 m
SEISMIC COVERAGE: Intersection of SO-95 Profiles 10 and 20		

Objectives: Recover a continuous high-sediment-rate marine sequence hemipelagic sediment record to reconstruct the Pleistocene paleo-monsoon history.

Drilling Program: Triple APC to refusal, XCB to 450 mbsf

Logging and Downhole Operations: Triple-combo, GLT, GHMT, and FMS

Nature of Rock Anticipated: Hemipelagic mud

SITE: SCS-2	**PRIORITY:** 1	**POSITION:** 19.5835°N, 117.6313°E
WATER DEPTH: 3190 m	**SED THICKNESS:** ~870 m	**TOTAL PENETRATION:** 400 m
SEISMIC COVERAGE: Intersection of SO-95 Profiles 10 and Vema Profile 3068		

Objectives: Recover a continuous marine sequence hemipelagic sediment record to reconstruct the middle Pliocene to Pleistocene/Holocene paleo-monsoon history

Drilling Program: Triple APC to refusal, XCB to 400 mbsf

Logging and Downhole Operations: Triple-combo, GLT, GHMT, and FMS

Nature of Rock Anticipated: Hemipelagic mud and mudstone

SITE: SCS-3C	**PRIORITY:** 1	**POSITION:** 19.90°N, 116.07°E
WATER DEPTH: 1275 m	**SED THICKNESS:**	**TOTAL PENETRATION:** 300 m
SEISMIC COVERAGE: CPD 15600 on Line 5		

Objectives: Recover a hemipelagic sediment record to reconstruct the late Miocene to Pleistocene paleo-monsoon history; determine variations in oxygen content

Drilling Program: Triple APC to refusal, XCB to 550 mbsf

Logging and Downhole Operations: Triple-combo, GLT, GHMT, and FMS

Nature of Rock Anticipated: Hemipelagic mud and silt

*Site localities and/or drilling depths may be altered.

SITE: SCS-4	**PRIORITY:** 1	**POSITION:** 19.4540°N, 116.2642°E
WATER DEPTH: 2093 m	**SED THICKNESS:**	**TOTAL PENETRATION:** 520 m
SEISMIC COVERAGE: Intersection of SO-95 Profiles 4 and SO-72A Profile 18		

Objectives: Recover a hemipelagic sediment record to reconstruct the middle Miocene to Pliocene paleo-monsoon history.

Drilling Program: Triple APC to refusal, XCB to 520 mbsf

Logging and Downhole Operations: Triple-combo, GLT, GHMT, and FMS

Nature of Rock Anticipated: Hemipelagic mud and silt

SITE: SCS-5C	**PRIORITY:** 1	**POSITION:** 18.84°N, 116.55°E
WATER DEPTH: 3250 m	**SED THICKNESS:**	**TOTAL PENETRATION:** 700 m
SEISMIC COVERAGE: CPD 7500 on Line 5		

Objectives: Recover hemipelagic sediments to reconstruct the paleoclimate history from Oligocene to Miocene

Drilling Program: Triple APC to refusal, XCB to 450 m, RCB to 850 m

Logging and Downhole Operations: Triple-combo, GLT, GHMT, and FMS

Nature of Rock Anticipated: Hemipelagic mud and silt

SITE: SCS-8	**PRIORITY:** 1	**POSITION:** 7.3619°N, 112.5453°E
WATER DEPTH: 1800 m	**SED THICKNESS:**	**TOTAL PENETRATION:** 400 m
SEISMIC COVERAGE: Intersection SCS Profiles N9 and N15		

Objectives: Recover sediment record to reconstruct the paleoclimate history in the tropical SCS since Eocene; determine variations in supply of terrigenous sediment from the Mekong and other rivers

Drilling Program: Triple APC to refusal, XCB to 450 m, RCB to 1100 m

Logging and Downhole Operations: Triple-combo, GLT, GHMT, and FMS

Nature of Rock Anticipated: Hemipelagic mud, silt, and other clastic sediments and rocks

*Site localities and/or drilling depths may be altered.