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Sedimentary Features of Shelf North of Taiwan Revealed by 3.5 kHz Echo Character

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ABSTRACT

3.5 kHz echograms collected from the shelf north of Taiwan were classified and mapped to produce an echo character map which reveals the sedimentary features on the sea floor. Two major types and five subtypes of echoes were determined. Echo types are distributed generally into two major areas: A sandy, shelf with prolonged echoes and a large submarine sand-dune field which generates sediment waves echoes.

The echo character map shows that each sedimentary feature is characterized by a corresponding echo type. The upper reach of Men-Hua Canyon is characterized by prolonged bottom echoes with very rugged morphology, indicating down-cutting of sandy canyon bottom. The presence of a large asymmetrical sand waves field (5 to 30 km wide, 50 km long) in shelf northwest of Taiwan indicates that bottom currents are strong enough to move sand-size sediments on the sea floor. The general asymmetrical form of sand waves suggests that the bottom currents may flow from south to north.

(Key Words: 3.5 kHz Echograms, Sedimentary Features, Shelf, Taiwan)

Acta Oceanographica Taiwanica
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INTRODUCTION

The continental margin off northeastern Taiwan consists of East China Sea Shelf, East China Sea Slope and Okinawa Trough (Fig.1). The sea floor of the broad East China Sea Shelf is generally flat and nearly featureless (Emery et al., 1969). However, the shelf north of Taiwan, a small part of the East China Sea Shelf, is featured with low-relieved ridges, volcanic intrusions, channels and canyons despite its overall relatively flat platform morphology (Boggs et al., 1979, Yu and Hong, 1993, Yu and Shyu, 1994, Song and Chang, 1993). Locally, the shelf immediately north of Chilung, the coastal city of northern Taiwan, is called Chilung Shelf which is bounded by the Men-Hua Canyon to the north (Fig.1). The Chilung Shelf is cut by the Chilung Valley which extends from west to the continental slope for approximately 30 km and ends around 200 m isobath on the East China Sea Slope (Song and Chang, 1993). West of Chilung Shelf lies the Kuanyin Shelf which occurs northwest of the Tatun Volcano Group (Lee et al., 1973). The boundary between the Chilung Shelf and Kuanyin Shelf has not been determined yet. Yu and Shyu (1994) and Ma (1995) pointed out that the Chilung Shelf is different from the shelf north of Men-Hua Canyon in water depth and morphology of shelf break.

Boggs et at. (1979) suggested that both Chilung shelf and Chilung Valley may be of relict origin. They speculated that the Late Pleistocene Tamsliui River located northwestern Taiwan probably flowed northward and changed its course towards southeast through the Chilung Shelf which is now submerged close to the present coastline of Taiwan. The Late Pleistocene Tamshui alluvial valley north of Chilung has evolved into present Chilung Valley. Yu and Shyu (1994) noticed that the Chilung Valley is superimposed on a major strike-slip fault system. This valley may have developed along the weak fault zone indicative of structural origin. On the basis of topographic lineament analyses, Ma (1995) concluded that the Chilung Valley was mainly formed by movements of right-lateral strike-slip faults off northern coast of Taiwan.

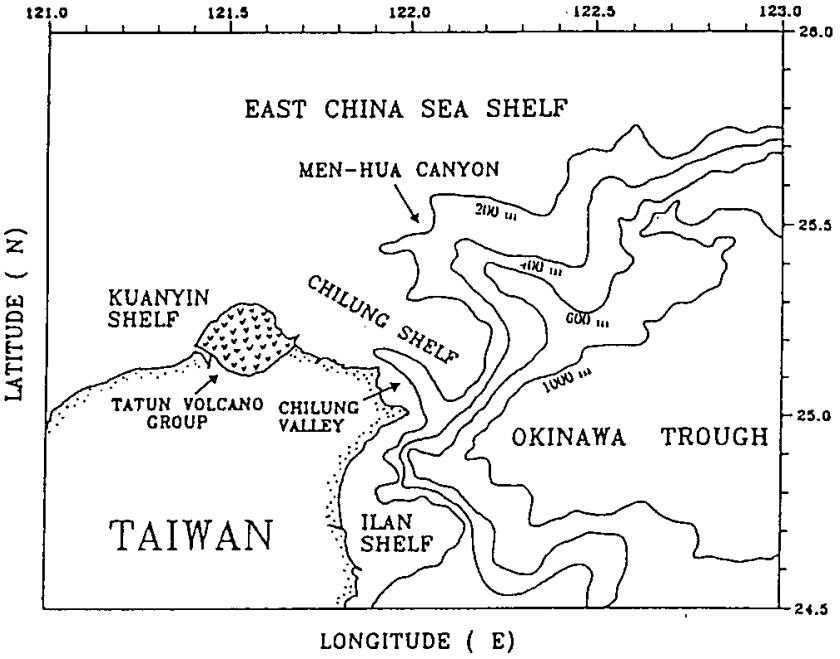

Fig. 1. Map showing physiographic provinces off northeast Taiwan. Note that the Chilung Shelf lies immediately north of Taiwan. (After Yu and Shyu, 1994)

The Men-Hua Canyon consists of two distinct units: (1) a broad trough-shaped channel cutting into the shelf, and (2) a narrow V-shaped canyon with steep walls on the upper slope (Yu and Hong, 1993). The channel/canyon system extends from the shelf to the slope for a distance of approximately 120 km (Fig.1). Rugged morpholgy of the upper reach of Men-Hua Canyon indicates submarine erosional down-cutting and lateral widening (Yu and Hong, 1993).

Boggs et al. (1979) and Chen et al. (1992) reported that sand is the dominant surface sediment on the shelf north of Taiwan. Coarse-grained sediments containing more than 25 percent gravel are present as small patches in restricted areas of the shelf north of Taiwan. The sandy sediments on the shelf of Taiwan also contain some biogenic remains which are characterized by abundant shell material. Bottom sediments in the shelf north of Taiwan are distributed generally into two major zones: a nearshore modem fine-medium sand facies (about 30 km wide) and a Late Pleistocene relict fine-medium sand facies farther offshore (Boggs et al., 1979, Fig. 21). The modem sands have originated from Taiwan, but the relict sands may be derived from China (Boggs et al., 1979).

Acta Oceanographica Taiwanica
Vol. 35, No. 2pp. 105-114, 5 figs, June 1996

PURPOSE AND SCOPE

The purpose of this study is twofold: to reveal sedimentary features of the shelf north of Taiwan using 3.5 kHz high frequency seismic profiling and to produce an echo character map, providing a quick reference of the sediment type, bedform and micro-topography of the sea floor. The detailed descriptions of micro-morphology and near-bottom sedimentary processes on the sea floor may provide clues to the better understanding of the geological nature of the shelf north of Taiwan. The results of this study may help to determine the boundary between the Chilung Shelf and Kuanyin Shelf.

The high frequency (3.5-12 kHz) echograms have been used widely in studying microtopography and near-bottom sedimentary processes on the sea floor, and in estimating lithological properties of the sediments of the uppermost sea floor (Damuth, 1980). The regional mapping of 3.5 kHz echo character has been successfully used to reveal near-bottom sedimentary processes on the sea floor off northeastern Taiwan (Hong et al., 1992). The echo character map (Hong et al., 1992, Fig. 7) shows that each of the physiographic units, e.g. shelf and slope, is characterized by a distinct echo type. Hong et al. (1992) showed that the dominant sedimentary processes change with corresponding echo types. For example, the upper East China Sea Slope off northeastern Taiwan, characterized by large irregular hyperbola echoes, is dominated by slumping and/or sliding processes.

It is expected that this study of 3.5 kHz echograms on the shelf north of Taiwan can be integrated into the regional 3.5 kHz survey east of 122°E by Hong et al. (1992).

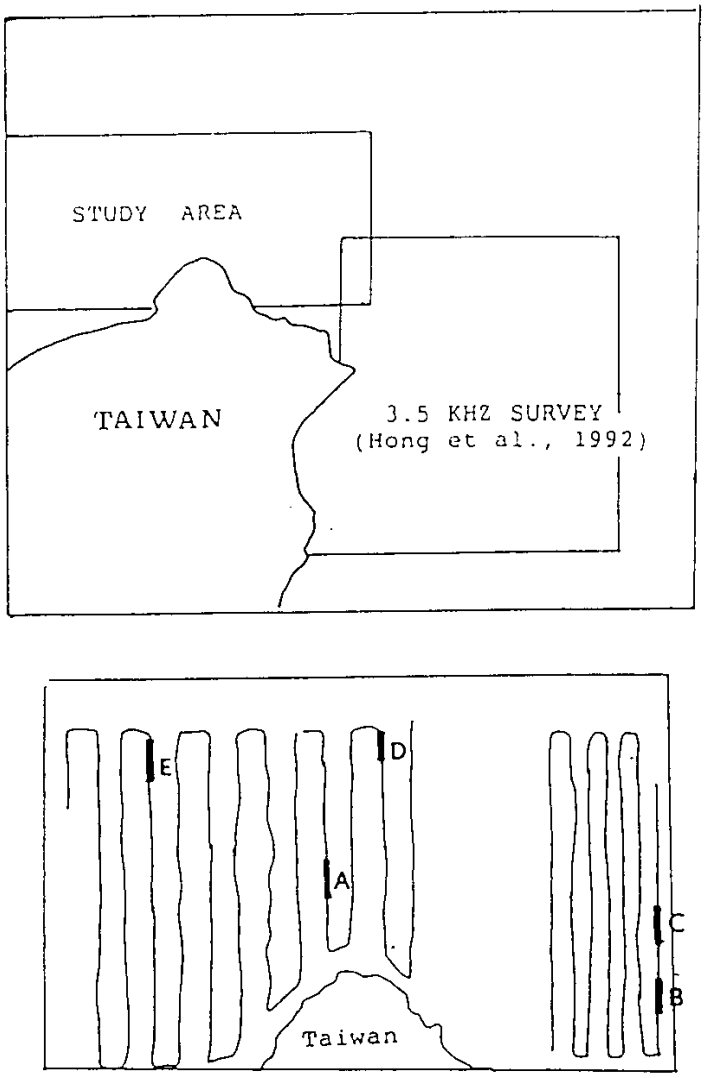

Fig. 2. The study area is in the shelf north of Taiwan between 121°E, 25°10' N and 122°E, 25°40' N. Solid lines oriented N-S in the box indiate locations of 3.5 kHz profiles of which short bar labeled as A, B, C, D and E are representative of five different echo types.

DATA

The study area is in the shelf north of Taiwan between 121°E, 25°10' N and 122°E, 25°40' N (Fig.2). Twenty 3.5 kHz profiles oriented N-S were collected using Ocean Research Equipment transducers on board R/V Ocean Researcher I (Fig.2).

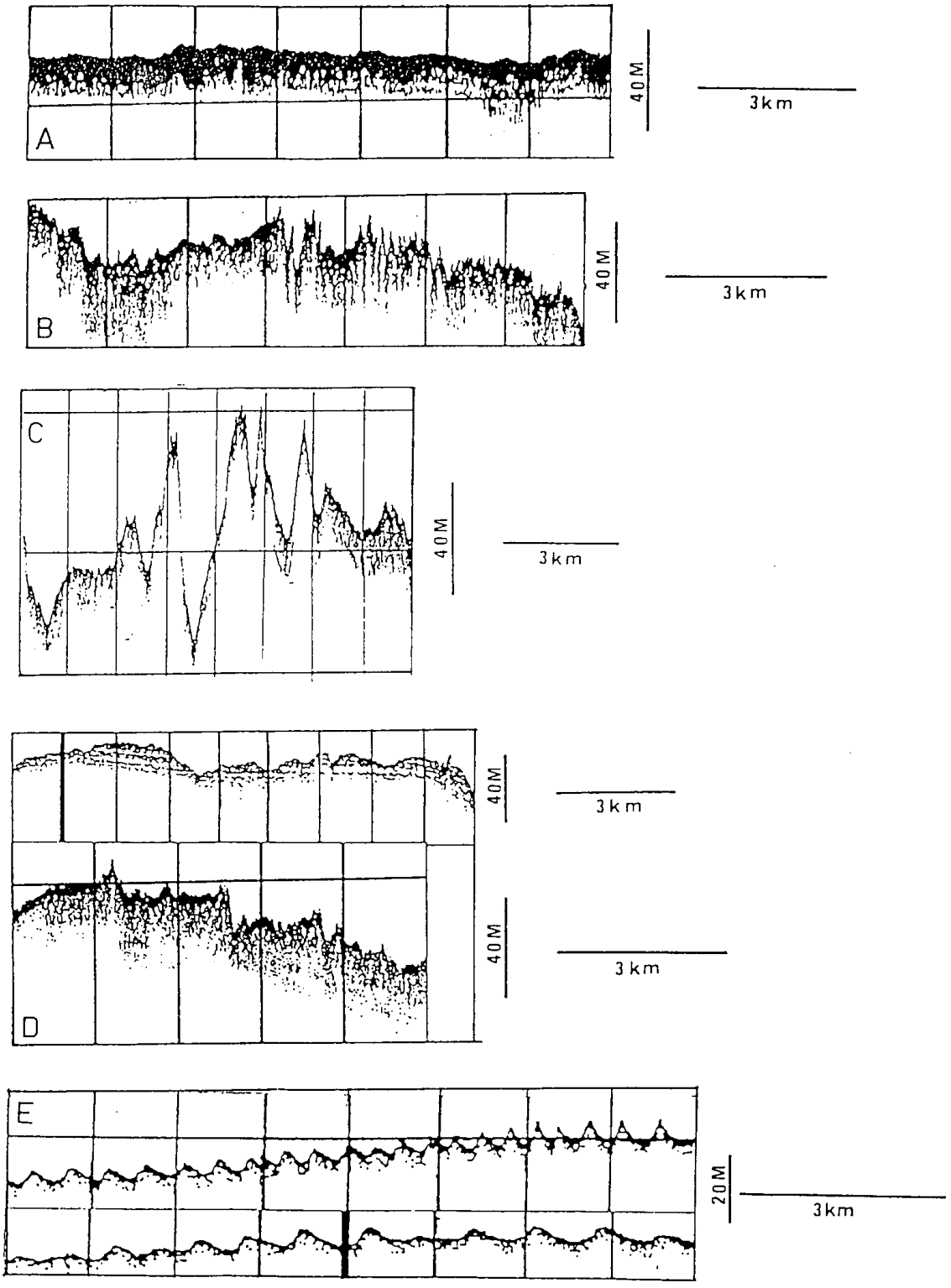

Fig. 3. Classification of 3.5 kHz echograms in the study area. Five individual echo types (labeled as A, B, C, D and E) are determined. Locations of these echoes are shown in Figure 2. Description of echo types are given in the text.

Acta Oceanographica Taiwanica
Vol. 35, No. 2pp. 105-114, 5 figs, June 1996

3.5 kHz ECHO TYPES

We have determined two major types from 3.5 kHz echograms on the shelf north of Taiwan. The classification of echo types of 3.5 kHz echograms is based on acoustic character and microtopography of the sea floor (Damuth, 1980, Laine et al., 1986).

Type (I) Indistinct echoes have an appearance of very prolonged to semi-prolonged bottom echoes. This indistinct echo has four subtypes as follows:

Type IA. Prolonged bottom echoes with no sub-bottoms, sea floor flat to undulating (Fig. 3A).

Type IB. Prolonged to semi-prolonged bottom echoes with no sub-bottoms, sea floor showing irregular saw-toothed surfaces (Fig. 3B).

Type IC. Prolonged bottom echoes with very rugged morphology (Fig. 3C).

Type ID. Prolonged bottom echoes with intermittent or discontinuous sub-bottoms, sea floor flat to undulating (Fig. 3D).

Type (II) Sediment waves echoes. These echoes having an appearance of a train of waves with varying height and length on the sea floor (Fig. 3E). *

ECHO CHARACTER MAP

The procedures for constructing the echo character map on the shelf north of Taiwan follow the guidelines proposed by Damuth (1980). The distribution of these five different echoes from this survey was mapped along the tracklines. A 3.5 kHz echo character map can be constructed by connecting boundaries between various echo types (Fig. 4).

The echo character map (Fig. 4) shows that prolonged bottom echoes with very rugged morphology (type IC) are restricted to the upper reach of the Men-Hua Canyon on the shelf Our finding of the prolonged echo suggests that the areas surrounding the upper reach of Men-Hua Canyon are characterized by bottom sediments containing high amount of bedded sand and silt. Yu and Hong (1993) reported that the upper reach of Men-Hua Canyon on the shelf is characterized by prolonged echoes with coarse-grained bottom sediments which were recovered by boxed cores. The rough morphology with relief greater than 200 in of the upper reach of Men-Hua Canyon resulted from canyon erosion. On the basis of Late Pleistocene lowstands of sea level, the Men-Hua Canyon could be partly of relict origin (Boggs et al., 1979). At least the Men-Hua Canyon was initiated by subaerial erosion when the sea level was about 140 in below the present coastline in Late Pleistocene. It appears that limited amounts of sediments eroded from north side of Taiwan were carried to the upper reach of Men-Hua Canyon so that the sediments could not fill up the submerged canyon bottom.

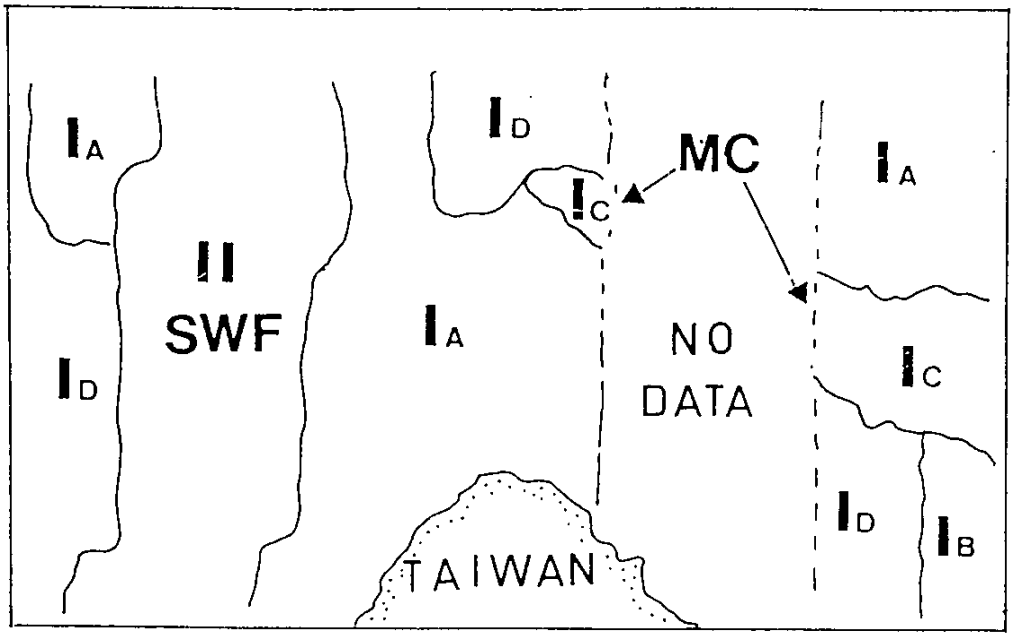

Fig. 4. Echo character map shows five individual echo types distributed on the shelf north of Taiwan. Note that the upper reach of Men-Hua Canyon (MC) is characterized by type Ic echo and the sand-wave field (SWF) is characteristic of type II echo.

The East China Sea Shelf north of Men-Hua Canyon is characterized by prolonged echoes with no sub-bottoms and relatively smooth sea floor (type IA), This echo type is reflected either from the sea floor (the upper few meters) containing great amount of bedded silts and sands or from the bedforms with sharp vertical relief (Damuth, 1980, Addy et al., 1982). The acoustic energy is scattered so that no sub-bottom echoes are reflected except a prolonged or fuzzy bottom echo. The surface sediments on the shelf north of Men-Hua Canyon consist mainly of relict fine-medium size sands (Boggs et al., 1979) which generally produce prolonged echoes. Therefore, the relatively smooth sandy shelf north of Men-Hua Canyon is dominated by type IA echo. The nearshore shelf north of Taiwan west of Long. 120°40' is characterized by prolonged echoes with no sub-bottoms (type IA) which probably reflects the modern fine-medium sands on the sea floor.

Only a small portion of shelf west of long. 122° exhibits prolonged to semi-prolonged echoes with an irregular saw-toothed surface (type IB) (Fig. 3). These low-relieved irregular sea floor could be relict bedforms formed by subaerial erosion during Late Pleistocene lowstand of sea-level. The sediments on the sea floor are mainly composed of coarse-grained shell debris and sands as recovered by boxed cores of Hong et al. (1992).

Prolonged or semi-prolonged echoes with sub-bottom intermittent parallel or inclined reflectors (type ID) occur in two small areas on the shelf (Fig. 4). The several tens of meters of the sea floor probably contain intermediate amount of bedded silts and sands to produce several sub-bottom reflectors (Damuth, 1980). The lateral crop-out sub-bottom reflectors suggest that erosion or truncation of strata probably occurred during the lowstand of sea-level in Late Pleistocene.

The sediment waves echoes (type II) occur in the areas north of Tatun Volcano Group, northwest of Taiwan (Fig. 4). These sediment waves echoes indicate the presence of large, asymmetrical sand waves (large submarine sand dunes) over an elongate feature of more than 50 km long and 5 km wide. Sand-wave fields were detected by echo sounding in the shelf northwest of Taiwan (Boggs, 1974). The height of the sand waves, as measured from 3.5 kHz profiles, ranges from about 2 to 20 m. The sand waves are generally less than 10 m in height (Fig. 5). The wave lengths of these sand waves range from 100 to 500 m. The dimensions of sand dunes revealed by our 3.5 kHz survey are comparable to those found by Boggs (1974) in the shelf northwest of Taiwan. The sand waves are either uniformly (A in Fig. 5) or irregularly spaced (D in Fig. 5). The cross-sectional shape of the sand waves are variable. Some are uniform and nearly symmetrical waves (A in Fig. 5). Some are asymmetrical (B in Fig. 5). These asymmetrical sand waves suggest that bottom currents may move through the shelf with velocities fast enough to transport sand-size sediments. On the basis of the asymmetrical form of sand waves it is suggested that the bottom currents may flow generally from south to north. The sand waves C and D (Fig. 5) are irregular in shape and suggest no prevailing directions of the bottom currents.

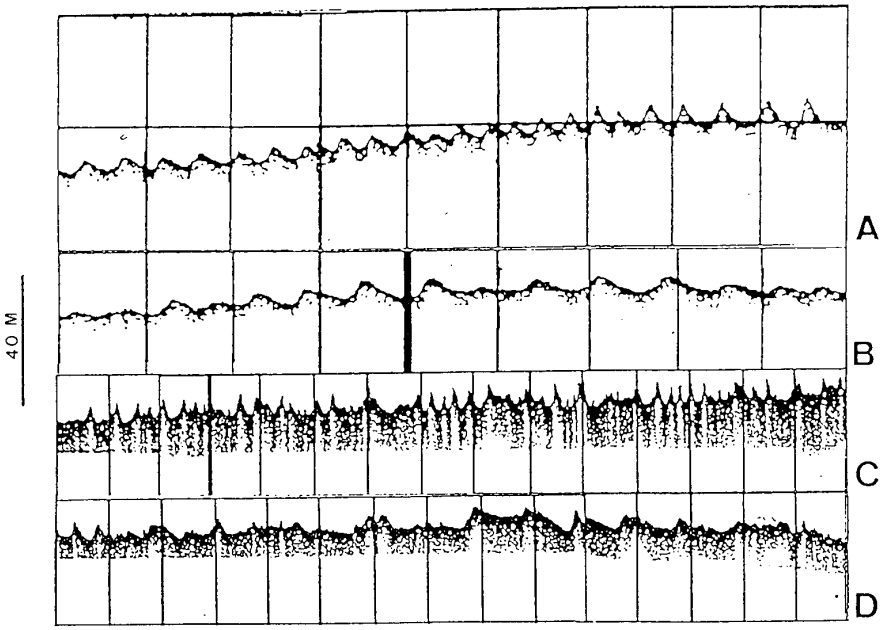

Fig. 5. The cross-sectional shapes of the sand waves recorded on 3.5 kHz profiles in shelf northwest of Taiwan. Hofizontal scale is not constant due to variations in ship speed. Horizontal distance along profiles A and B is around 9,000 m; distance along profiles C and D is 16,000 m.

Acta Oceanographica Taiwanica
Vol. 35, No. 2pp. 105-114, 5 figs, June 1996

SUMMARY

The mapping of areal distribution of 3.5 kHz echo characters of the shelf north of Taiwan provides a quick approximation to the sediment types, bedforms and micro-topography of the sea floor. Our results can be integrated into the previous regional mapping of 3.5 kHz echo character of the sea floor northeast of Taiwan. The combined studies of 3.5 kHz echograms generate an enlarged echo character map in the shelf and slope north and northeast of Taiwan. The use of 3.5kHz echograms to reveal sedimentary features can also apply to other shelf-slope areas around Taiwan. However, the use of 3.5 kHz profiles without other related studies is still qualitative due to the subjective classification of echograms. The limitation of usefulness of this study should be cautioned.

3.5 kHz echograms collected from shelf north of Taiwan were classified and mapped to reveal sedimentary features on the sea floor. Five individual echo types were recognized. The echo character map shows that each sedimentary feature is characterized by a corresponding echo type. Prolonged bottom echoes with very rugged morphology occur in the upper reach of Men-Hua Canyon, indicating erosional features. Large submarine sand dunes located on the shelf north of Tatun Volcano Group are characterized by the sediment waves echoes. This study demonstrated that the regional mapping of 3.5 kHz echo characters in the shelf north of Taiwan can provide valuable information of sedimentary features on the sea floor.

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Acta Oceanographica Taiwanica
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3.5 仟赫回聲特性顯示的台灣北方陸棚之沈積形貌特徵

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摘　　要

本文將台灣北方陸棚上收集之 3.5 仟赫回聲圖像分類，並將各類之回聲圖像描繪在陸棚上不同的區域而產生回聲特性圖。海床上的沈積形貌特徵可由回聲特性圖顯示出來。兩種主要回聲類型及五種次要回聲類型可以被分辨出。陸棚上不同的回聲類型分佈在兩個主要地區：一個砂質陸棚具有濃密狀回聲特性及一個大的海底砂丘區顯示沈積波狀回聲特性。

回聲特性圖指出每一個沈積形貌特徵相對應於一個回聲類型，例如棉花海底峽谷的上游具有崎嶇不平濃密狀的回聲特性，反應砂質谷底之下切現象，一個大的不對稱砂丘區（長約 50 公里，寬約 30 公里）出現在台灣西北方陸棚上表示此處海流的速度足以搬運海床上砂質的沈積物。從一般不對稱砂丘的形貌看出海流的方向可能由南向北。

關鍵詞：3.5 仟赫回聲圖，沈積形貌特徵，陸棚，台灣