行政院國家科學委員會專題研究計劃年度報告

計劃名稱：【河口泥沙積聚對河口泥沙物質傳輸之影響研究：以高屏溪口和長江口為例（1）】
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一、中文摘要

本研究發現：1. 高屏海底峽谷內成泥質沉积物富集之處而且是泥質沉积物傳輸之通道。2. 在峽谷頭部地形轉折處，有一沖積中心存在。3. 在沖積中心的位置經常發現類似河口區之溼度極大值的現象。4. 高屏海底峽谷內之和密度場有關之穩定度受到高屏溪豐水期的影響。5. 懸浮泥沙物分布和密度場層化的季節性變化有密切的關連。本研究並提出一個假說，認爲溼度極大值的形成特別是在豐水期，和峽谷內的內波的傳播和反射所造成的。

關鍵詞：高屏溪、高屏海底峽谷、泥沙傳輸、河口泥沙傳輸、沖積中心、泥沙富集、靜力穩定度

Abstract

This study examines the influence of a submarine canyon on the dispersal of sediments discharged by a nearby river and on the sediment movement on the inner shelf. The study area includes the head region of the Kao-ping Submarine Canyon whose landward terminus is located approximately 1 km seaward from the mouth of the Kao-ping River in southern Taiwan. Within the study area 143 surficial sediment samples were taken from the sea floor. Six hydrographic surveys along the axis of the submarine canyon were also conducted over the span of one year. Three different approaches were used in the analysis of grain-size distributions. They include 1) a combination of 'filtering' and Empirical Orthogonal Function (EOF) analysis technique, 2) the McLaren Model, and 3) 'transport vector' technique. The results of the three methods not only agree with with one another, they also complement with one another. This study reveals that the Kao-ping Submarine Canyon acts as a trap and conduit for mud exchange between the Kao-ping River and offshore. A depocenter of mud exists in the canyon. Internal waves at tidal frequencies are proposed to account for the observed turbidity-maximum-like features and corresponding mud deposition in the canyon. This mechanism, however, is modulated by the seasonal variability of the static stability field in the canyon. Outside the submarine canyon, the northward longshore sediment transport dominates over the southward longshore transport, which is a common theme on the west coast in southern Taiwan.

Keywords: Submarine canyon, river sediment dispersal, trap, depocenter, grain-size distribution, EOF analysis, McLaren Model, transport vector, static stability
二、缘由与目的

Submarine canyons are sometimes incorporated into a larger depositional system. From a dynamics point of view, submarine canyons could be regions of enhanced mixing, and thus of enhanced exchange of properties between the shallow continental shelves and the deeper regions of the continental slope and rise (Hotchkiss and Wunsch, 1982). Important dynamic processes in canyons include internal waves, tides, quasi-geostrophic flows, turbidity currents, and storm-induced currents (Hotchkiss and Wunsch, 1982).

Sediment transport processes in submarine canyons are related to some of these processes. The goal of this study is to examine how the existence of a submarine canyon affects the dispersal of river sediment dispersal and nearshore sediments transport from the perspective of grain-size distributions on the surface of the sea floor. Our particular attention is given to the head region of a submarine canyon located immediately seaward of the mouth of a river.

三、結果與討論

Despite of the seasonal difference, the Kao-ping Submarine Canyon is a stratified environment as indicated by isopycnals (Fig. 1). In fact, the density stratification reflects the contrast between the water above the canyon and the water inside the canyon. On several occasions, density perturbations were observed as indicated by loops of isopycnals (Figs. 1a, 1b, and 1d). These perturbations are associated with perturbations in the temperature field (not shown).

Although the hydrographic surveys were conducted during flood and dry seasons and at different tidal stages, all the observed SSC distributions share the following common characteristics: (1) There are localized spots of high SSC in the lower part of the water column that resemble the turbidity maximum in estuaries (Fig. 1). (2) In the water column, higher SSC values are generally near the sea floor. Except for the two flood season surveys (Figs. 1a, and 1b), higher SSC values also tend to occur toward the seaward end of the canyon. During the flood season, suspended sediments carried by the river effluent are evident in upper part of the water column near the head of the canyon (Figs. 1a, 1b, and 1c). It is worth noting that the density field and the SSC distributions seem to be correlated as indicated by the coincidence of turbidity-maximum-like features with density perturbations (Figs. 1a and 1b). In addition, on one occasion in July, 1999 (Fig. 1b) the movement of suspended sediment seems to follow the isopycnal surfaces.

In general, the six hydrographic surveys have reasonably established the climatology in the Kao-ping Submarine Canyon. The canyon is filled with cold and salty offshore water which is little affected by the change of seasons. During the flood season of the Kao-ping River, the river...
effluent expands seaward over the canyon. However, no effective mixing takes place between the two water masses. Because of the plume water, the density stratification in the canyon region is intensified during the river flood season.

Fig. 1. Contoured isopycnals (sigma-t) plotted over the SSC (in mg/l), whose range is indicated by the color bar below, surveyed on (a) June 4, (b) July 22, (c) August 17, (d) October 26, 1999, (e) January 12, and (f) March 20, 2000, along the Kao-ping Submarine Canyon axis. The dashed curve delineates the upper and seaward boundary of the surveyed portion of the submarine canyon. The horizontal distance is measured relative to the most landward station on each transect. The depth values used in the sea floor masking in these plots were the actually echo sounding depths recorded at the end of each profiling operation. Arrows point to locations where turbidity-maximum-like phenomena in lower water column occurred.

A simple hypothesis is proposed to explain the seasonal variability of the depocenter and stronger landward trend of sediment transport within the mud conduit as revealed by the surficial texture. The effects of tidal and subtidal flows, which might be important, are not considered at this point. The all-year-round stratification inside the canyon creates an overall statically stable environment that generally inhibits the agitation of sediments even as fine as mud. During the flood season (summer), the sediment-laden river effluent delivers sediments (largely mud) to the coast and the head of the submarine canyon. Since the mean annual SSC of Kao-ping River is 4.2 kg/m³ (believed to be an overestimation), which is much smaller than the required value for forming hyperpycnal plumes (35-45 kg/m³, Skene et al., 1997), the effluent exits the river mouth most likely as the buoyant plume (Fig. 2a), similar to what we observed on June 4 and July 22, 1999 (Figs. 1a, 1b). The turbid yet buoyant plume water moves seaward following the isopycnal surfaces inside the canyon. As the river effluent diffuses, sediment settles gradually to the deeper part of the canyon. Due to the well-developed stratification in the flood season, internal waves excited at the seaward end of the canyon or at the shelf break propagate landward through the canyon along isopycnal surfaces. These internal waves transport colder water from deeper part of the canyon landward. It is speculated that some internal wave energy is trapped within the middle section of the canyon due to its geometry. This high energy pocket not only causes perturbation (instability) in the density field, the trapped internal waves also cause the SSC to concentrate forming the observed turbidity-maximum-like features. This mechanism provides an explanation for the observed concentration of mud on the sea floor, and the possibility of the depocenter as suggested by the transport vector method. Furthermore,
since the internal waves are generated offshore and propagate onshore, sediment transported landward by internal waves would dominate over that transported seaward inside the canyon as suggested by the EOF method and McLaren Model.

There are many physical similarities between the settings of Kao-ling River and Tseng-wen River mouths including the magnitude and grain-size makeup (mud domination) of the river sediment discharge, the annual hydrological pattern, the coastal tidal flow characteristics, and the wave climate (Liu et al., 1998; Liu et al., 2000). Yet the Tseng-wen River sediment discharge is found to have the greatest influence on the textural characteristics in the nearshore region off the river mouth. A major difference between the two settings, however, is in the sea floor topography seaward of the river mouth. The Tseng-wen River sediments are dispersed over a broad and shallow submarine platform so that the textural characteristics of the river sediments (textural signal), including the mud portion, are widely spread over the study area. At the mouth of Kao-ling River, however, the Kao-ling Submarine Canyon acts as a trap for the sediments especially the mud portion.

Fig. 2. Schematic diagram depicting the hypothesis regarding the trapping of mud and the formation of turbidity-maximum-like features inside the stratified Kao-ling Submarine Canyon for (a) flood season, and (b) dry season of Kao-ling River.

During winter time (dry season thus little sediment input from the river), due to the deepening of the surface mixed layer, the water column in the canyon is less stratified. Consequently, internal wave-related transport is less likely to occur. On the other hand, the relaxation of stratification is probably less inhibitive to the vertical transfer of momentum, which leads to localized resuspension of bottom sediment (Fig. 2b). This is probably a period of quiescence for sediment movement and transport.

参考文献


