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Sedimentation Rates and Process in the Changjiang Estuary and Adjacent Continental Shelf Mud Deposits, East China Sea

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Abstract. To evaluate modern sedimentation and formation of sedimentary strata six cores from the East China Sea have been studied using the isotope Pb-210. There are two recent mud deposits in the East China Sea. The one extends from the Changjiang River mouth to the southward along the coast of China, and the other is in the outer shelf depression southwest of Cheju Island. These two recent mud deposits are different with respect to the material composition, sedimentation rate and other characteristics. The sediment in the inner shelf area is characterized by abundant silt and more coarser grain-size, but the outer-shelf mud deposits are characterized by rich clay with higher contents of water and organic carbon. At the boundary of the inner-shelf and outer-shelf mud deposits, bimodal sediment are forming the mixture of modern mud and ancient sand. The sediment accumulation rate in the inner shelf mud deposit is 1.70cm/yr or 1.63g/cm^2 · yr and the sediment is characterized by physical stratified mud. The sedimentation rate in the outer-shelf mud deposit shows 0.28cm/yr or 0.18g/cm^2 · yr, and the sediment is characterized by homogeneous mud. The difference in fine-scale stratigraphy is explained by the ratio of mixing rate to accumulation rate, which is much larger for the outer-shelf mud deposit(27.34) than for the inner shelf mud deposit(1.65). The larger ratio suggests biological mixing to destroy physical stratification.

Key Words : recent mud deposit, sediment accumulation rate, mixing rate, fine-scale stratigraphy, East China Sea

1. Introduction

The East China Sea extends from the north shore of the Changjiang Estuary mouth to Cheju Island, and through the Ryukyu Island to the southern tip of Taiwan to Fijian. It has an average water depth of about 65m and NE~SW trending of submarine contour lines which extend to the northern marine of Okinawa Trough with south-southeastward deeping through floor(Butenko et al. 1985).

For thousands of years the Changjiang and Huanghe Rivers brought a huge amount of sediment to the seas. Recently, the Changjiang River contributes about 500 $\times 10^6$ tons annually, while the Huanghe River discharges about 1,100 $\times 10^6$ tons. Thus, the continental shelf of the East China Sea is mainly flooded by the sediments from the two rivers(Yang and Milliman, 1983). Therefor, the continental shelf is wide and featureless.

This riverine particles accumulate in the marine environment forming sedimentary strata, and may also affect biological productivity and the dispersal of particle reactive pollutant. In the northern East China Sea, several current systems congregate with the Yellow Sea Warm Current flowing northwestward and entering the Yellow Sea from the east side, the Yellow Sea Coastal Current directs to the south from the west side and the northward residual of the Kuroshio spreading from the south, and in summer the Changjiang Plume plays an important role in the northern East China Sea(Mao et al. 1983).

There are two recent mud deposits distributed in the East China Sea continental shelf: the inner-shelf mud deposit extending from the Changjiang River mouth southward along the coast and the offshore mud deposit occurs in the outer shelf depression southwest of the Cheju Island(Chin, 1979; Jin and Sui, 1983).

In the present paper, we attempt to discuss the characteristics of sediment composition of the two mud deposits, rates of sediment accumulation and modern sedimentary structure from continental shelf deposit in the East China Sea during the past one hundred years.

2. Sample collection and Methods

Sediment samples were obtained from the East China Sea continental shelf during period in August 1997 and June 1998 using the Ara R/V of Cheju National University. A total of six sediment gravity core samples were collected from the study area(Fig. 1).

In laboratory, grain-size analyses were performed by standard procedures(Krumbein and Pettijohn, 1938), the sand fraction was analyzed by sieve methods and the silt and clay fraction by pipette

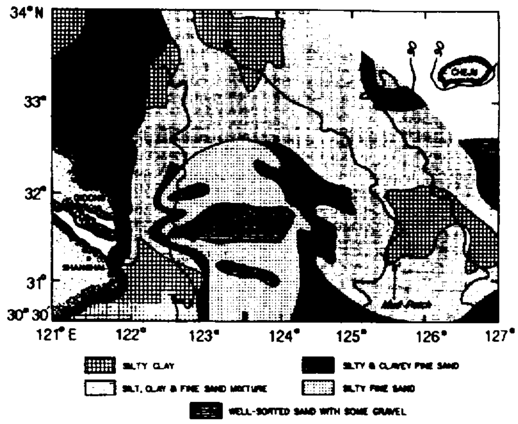

Fig. 1. Sampling sites and distribution of seafloor sediment characteristics in the East China Sea(after Butenko et al., 1985).

techniques. Organic carbon and nitrogen in the sediments were analyzed using a CHN Analyzer following the method of Byers et al(1978).

To estimating the flux of Pb-210 into sediment and determine the sedimentation rates three core samples was analyzed by the radiochemical techniques. Cores were sectioned into 1cm and each subcore samples was used for Pb-210 analysis. Various methods are available for Pb-210 analysis. The one employed is similar to that described by Nittrouer et al.(1979) and depends upon its secular equilibrium with Po-210.

Approximately 3.0g of dried sub-sediments, which has been passed through a one phi sieve to remove coarse particles, was spiked with a known amount of Po-208 tracer. The sample was dissolved totally with HNO_3, $HClO_4$, HCl and HF acids and then taken to dryness. The Po isotopes were digested in 1N HCl and plated onto $1cm^2$ silver planchets. The Po activities were determined by alpha spectrometry.

3. Results and Discussion

3.1 Muddy sediment characteristics

The sediment types in the Changjiang Estuary and its adjacent continental shelf of the East China Sea are composed of relict sand, silt, mud, ilty clay and sand-silt-clay mixtures sediments(Butenko et al. 1985). Modern land derived sediment consisting silty clay, silt and mud is distributed at the mouth of the Changjiang River and extends southward along the coast, and is also present the southwest offshore from the Cheju Island. The sediment in the inner-shelf area is characterized by abundant silt, and to the southwest offshore the Cheju Island it is characterized by rich clay. The well sorted medium to fine sand are distributed over the middle area, belonging to pleistocene relict sediments. The area between modern sediment and relict sediments presents palimsest deposit consisting of silty and clayey fine sand, silty fine sand and mud-silt-fine sand mixture(Fig. 1).

The composition of the inner-shelf mud deposit consisted of 8.89% sand, 59.05% silt, 32.06% clay and mean size of 6.90φ. The deposit is abundant silt relative to clay, and coarser than that in the offshore mud from the southwest Cheju Island (Table 1). The bimodal character at the station CJ98032 histogram in Fig. 2 reflects mixing of the sediment types. The boundary of the inner-shelf mud(st. CJ98032) is clearly a region where palimsest deposits are forming from combination of modern and ancient sediments. The outer-shelf mud is composed

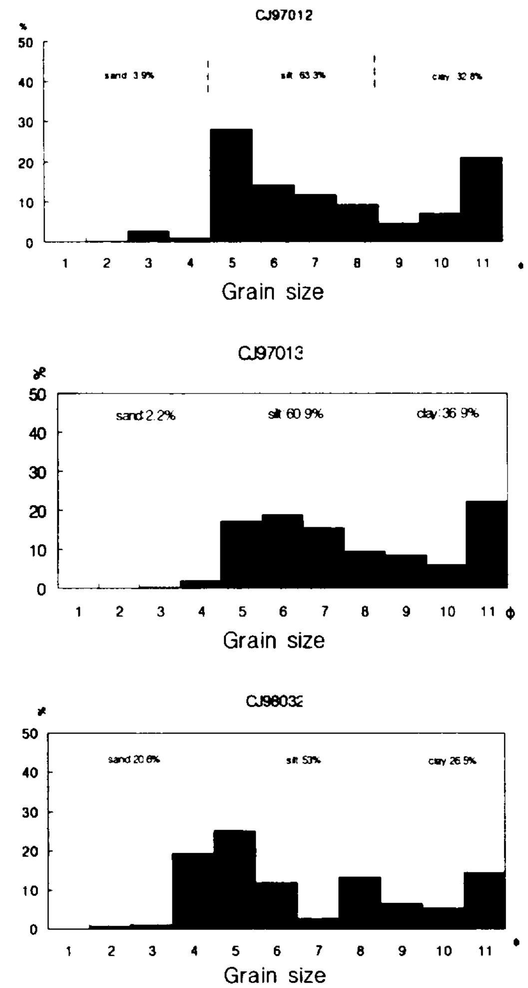

Fig. 2. Histograms of grain size observed in suface sediment from the inner-shelf mud deposit.

Table 1. Sediment type, textural parameter, physical property and C.N. content

Sedimentary Region	Station No.	Sediment composition: Sand (%)	Silt (%)	Clay (%)	Sediment Type	Textural parameters: Mean (φ)	Sorting (φ)	Skewness (φ)	Kurtosis (φ)	Physical property: Water content (%drywt)	Bulk density (g/㎤)	Organic matter: Organic -C(%)	Organic -N(%)	C/N Ratio (atomic)
Inner-Shelf Mud Deposit	CJ97012	3.87	63.30	32.83	Z	7.10	2.39	0.40	0.59	34.24	0.78	0.659	0.061	9.41
	CJ97013	2.23	60.90	36.88	M	7.27	2.27	0.29	0.61	42.57	1.05	0.733	0.075	10.78
	CJ97032	20.58	52.95	26.47	SZ	6.34	2.55	0.52	0.72	42.79	0.75	0.542	0.043	10.23
	Mean	8.89	59.05	32.06		6.90	2.40	0.40	0.64	39.87	0.86	0.645	0.060	10.14
Outer-Shelf Mud Deposit	CJ97004	1.18	34.88	63.95	M	8.74	1.83	-0.21	0.77	59.45	0.59	0.843	0.091	9.69
	CJ97005	0.47	35.25	64.28	M	8.70	1.80	-0.31	0.82	58.18	0.60	0.791	0.095	7.53
	CJ97007	15.85	33.50	50.65	SM	7.53	2.77	-0.31	0.83	51.82	1.45	0.636	0.072	8.83
	Mean	5.83	34.54	59.63		8.32	2.13	-0.28	0.81	56.48	0.88	0.757	0.086	8.68

Note : sM : sandy mud, sZ : sandy silt, M : mud, Z : silt, C : carbon, N : nitrogen of 5.83% sand. 34.54% silt. 59.63% clay and mean size of 8.32φ. The deposit is characterized by abundant clay. and has higher water content and organic matter. Organic carbon and organic nitrogen contents in the outer-shelf mud area are 0.757% and 0.086% respectively. and are higher than those in the inner-shelf mud deposits(Table 1).

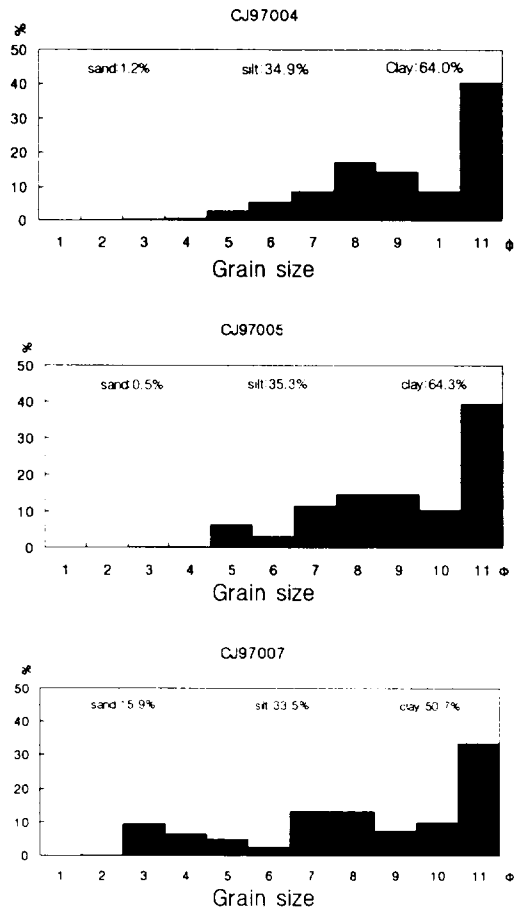

Fig. 3. Histograms of grain size observed in suface sediment from the outer-shelf mud deposit.

The Fig. 3 shows histogram of grain-size profiles from the outer-shelf mud deposit. The bimodal sediments(st. CJ97007) which probably reflect multiple sediment sources are forming at the boundary between the offshore modern mud and transgressive sand.

At a station near Changjiang River mouth. the contents of organic carbon and nitrogen in the inner-shelf mud area showed 0.645% and 0.060% respectively. A relationship could also be found between grain size of sediment and organic matter. The organic materials in the sediments showed that higher contents were closely related to the fine-grained sediments. The C/N ratio is commonly used to characterize various types of organic matter (Stein. 1990). The C/N ratio in the study area varies between 7.53 and 10.78(Table 1). and showed higher in the inner-shelf mud(10.14) rather than that of the outer-shelf mud deposit(8.68). The C/N ratio exceeding 10 in the inner-shelf mud indicates that large amounts of the organic matter have been supplied from the Changjiang River because marine organic matter exhibits less than 10 in C/N ratio(Stein. 1990).

3.2 Sedimentation rates and strata formation within the inner-shelf and outer-shelf mud deposits

Measurements of Pb-210(half-life of 22.4 yrs) are used in this study to evaluate the rates of sediment accumulation and rates of particle mixing on time scales of 100yrs. Pb-210 reaches the marine environment by atmospheric precipitation. riverine discharge as well as in-situ decay of its effective parent Ra-226. Pb-210 is insoluble in sea water and is scavenged from water column by settling particles.

Therefore. the profiles of Pb-210 are useful in characterizing sedimentary processes over a one hundred years time scale(DeMaster et al. 1985). To determine the sedimentation rate. the excess Pb-210 in the sediments must be decided rather than the total amount. Excess Pb-210 activity was determined by subtracting the Ra-226 activity from the total Pb-210 activity. The amount of parent supported Pb-210 is determined by measuring the activity of depths large enough to assure the atmospheric component to be negligible. The amount of excess Pb-210 represent in any particular sample is therefore the difference in activities between the sample in question and that of the parent supported sample(Nittroner et al. 1979). The Pb-210 supported activity(Ra-226 activity) determined in a few section core samples using the Rn-222 emanation method (Lucas, 1975).

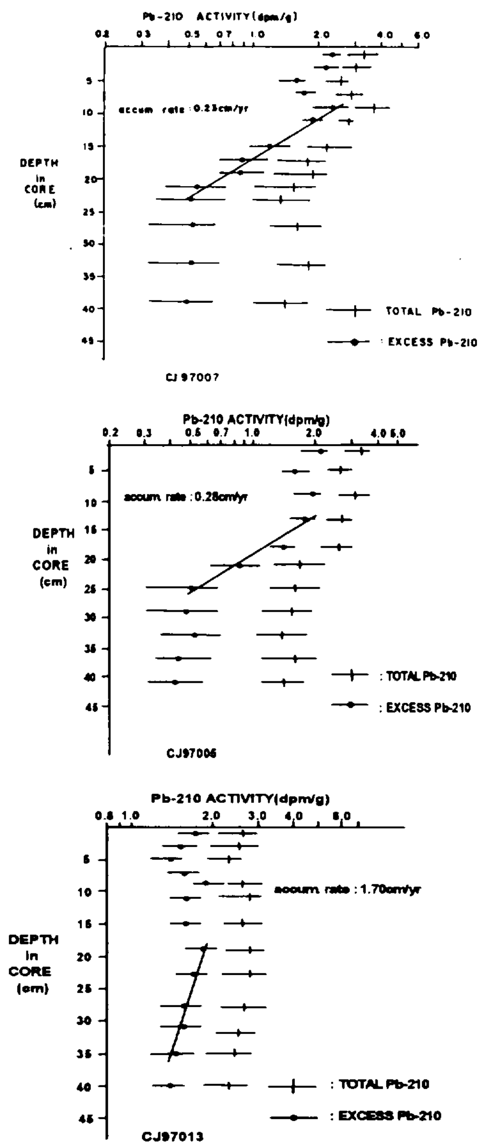

Fig. 4. Pb-210 profiles from the two recent mud deposits in the East China Sea.

The Pb-210 profiles from the recent mud deposits in the East China Sea are shown in figure 4, and Pb-210 dating results for the coring station shows table 2. The crosses represent the total Pb-210 activity and the closed circles indicate the excess Pb-210 activity which with the same point after background is subtracted. The sediment accumulation rate determined from the slope of the least squares fit to the log excess Pb-210 activity versus total accumulation profiles below the surface mixed layer (Fig. 4). The excess Pb-210 activity was used to compute sediment accumulation rates following the simplified equation of Nittrouer et al.,(1979) and DeMaster et al.,(1985).

The equation is given by $S = \lambda z / (\ln Ao/Az)$.

where S is sedimentation rate(cm/yr), λ is the decay constant of Pb-210(0.031/yr), z is depth in profile, and Ao/Az are the unsupported excess Pb-210 activity of the sediment surface(dpm/g) and the unsupported excess Pb-210 at depth z, respectively.

The sedimentation rate, sediment material flux and input of Pb-210 obtained using the Pb-210 radioactive decay formular in the inner shelf mud deposit(st. CJ97013) shows 1.70cm/yr, 1.63g/cm^2 · yr and 2.71dpm/cm^2 · yr respectively. The mixing layer can find the upper 15cm at station CJ97013. The mixing here caused by tidal currents which are reciprocal ones in the Changjiang River mouth area. A few biota structure are observed from the X-radiograps, but the radiograps from core CJ97013 in the inner shelf mud deposit reveal dominently preserved sedimentary horizontal lamination (Fig. 5).

According to the previous data, there have relationship between sedimentary structure and the ratio of mixing rate to accumulation rate(Nittrouer and Sternberg, 1981). The degree of homogenous is dependent on the ratio of mixing rate to accumulation rate, where this ratio is small, the primary physical stratification is preserved. Where it is large the mixing is effective and then the sediment strata

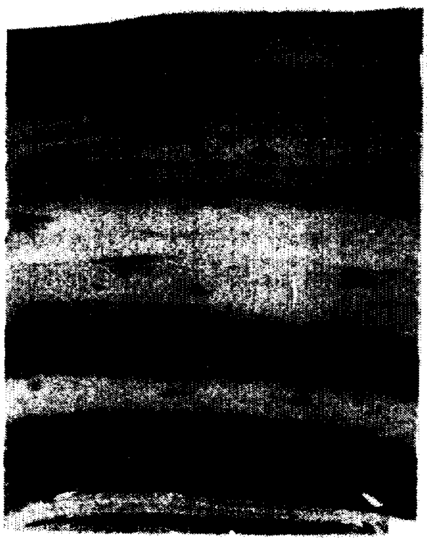

Fig. 5. X-radiograps of core CJ97013 the inner-shelf mud deposit showing distinct horizontal stratification. A high rate of sediment accumulation and low rate of sediments mixing (G value < 1.65) contributes to the preservation of primary sedimentary structure.

tends to become homogenized. Calculating the ratio(G) of mixing rate to accumulation rate is suggested in the following equation by Nittrouer et al., (1984).

$$G = \frac{\text{Volume of sediment processed per unit area of seabed per time}}{\text{net accumulation rate}} = \frac{D_b/L_b}{S_d}$$

where, D_b represent a mixing coefficient. L_b is the thickness of the surface mixed layer and S_d is the accumulation rate. At station CJ97013 in the inner shelf mud deposit, Pb-210 profiles demonstrate that the net accumulation rate(S_d) is 1.70cm/yr. and that a mixing coefficient(D_b) is 14.01cm^2/yr (Table 2) and a mixed layer(L_b) shows in the upper 15cm. Therefore, the ratio(G) of mixing rate to accumulation rate is 1.65. Above data indicate that particle mixing is very small due to the fast rate of sediment accumulation, and where is well stratified deposit preserved(Fig. 5).

The Pb-210 profiles from the outer-shelf mud deposits(st. CJ97005) is shown in figure 4. The Pb-210 data show a mixed layer in the upper 9cm of the core overing a region in which Pb-210 activity decreases logarithmically. The accumulation rate, sediment material flux and input of Pb-210 based on the decreasing Pb-210 activity between 11 and 25cm are 0.28cm/yr, 0.18g/cm^2 · yr and 0.63dpm/cm^2 · yr respectively, and that is lower than the inner shelf mud deposit(1.70cm/yr). The lower accumulation rate is due to lack of substance supply. At the station CJ97005 in the outer-shelf mud deposits, the calculated mixing coefficient(D_b) for the upper 9cm is 68.9cm^2 · yr, and net accumulation rate(S_d) is 0.28cm/yr(Table 2).

Therefore, the ratio(G) of mixing rate to accumulation rate is 27.34. This means that particle mixing is very high relative to the inner shelf mud deposit(1.65). As the ratio of these

Table 2. The Pb-210 dating results from the core samples in Changjiang Estuary and its adjacent continental shelf area

Sedimentary Region	Station No	Location		Initial Specific Activity of Excess Pb-210 (dpm/g)	Sedimentation Rate (cm/yr) (Sd)	Sediment Material Flux (g/㎠ · yr)	Pb-210 Sedimentation Flux (dpm/㎠ · yr)	Mixing Coefficient (cm2/yr) (Db)	Db/Sd Ratio (G)
		Lat(N)	Long(E)						
Outer-Shelf Mud Deposit	CJ97005	31° 30′	126° 00′	2.067	0.28	0.175	0.364	68.90	27.34
	CJ97007	31° 00′	125° 30′	2.327	0.23	0.212	0.458	76.63	37.02
Inner-Shelf Mud Deposit	CJ97013	31° 00′	122° 30′	1.735	1.70	1.630	2.714	14.01	1.65

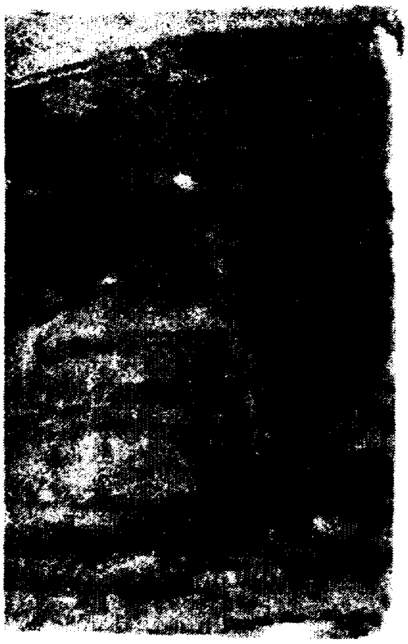

Fig. 6. X-radiograps of core CJ97005 from the outer-shelf mud deposit showing nearly homogeneous sedimentary structure. The lack of sedimentary structure is consistent with rapid of particle mixing and the relatively low rate of sediment accumulation(G value > 27).

factor(G) increases, sediment structure less distinct and the strata become more homogenous. The low sedimentation rate is likely to increase biological reworking, which in consequence induces the higher rate of biological mixing causing distruction of the original depositional structure(Nittrouer et al., 1984). The dominance of mixing(D_b=68.90cm^2 · yr) relative low sediment accumulation(S_d=0.28cm/yr) is also exemplified of X-radiograp in the outer-shelf mud core samples CJ97005 which reveals relatively homogenous sedimentary structure without bedding (Fig. 6). In the modern muddy deposit area of the outer-shelf , physical effect were weak due to the influence of the Yellow Sea circulation(Jin and Sui, 1983). Here, weak dynamics, small materials supply due to the far away from the river mouths, and slow sedimentation were favourable to the growth of benthic organism. Therefore, low energy disturbance dominated in the outer-shelf mud deposit.

4. Conclusions

A analysis of sediment composition, sedimentation rates by Pb-210 dating and X-radiograps for the two recent mud deposits in the East China Sea have been investigated. The inner-shelf mud deposits consisted of 8.98% sand, 59.05% silt, 32.06% clay and mean size of 6.90φ , and the organic carbon abundance is low. The outer-shelf mud deposit are composed of 5.83% sand, 34.54% silt, 59.63% clay and mean size of 8.32 φ , and also have higher water content and organic carbon. The C/N ratio showed higher in the inner-shelf mud(10.14) rather than that of the outer-shelf mud(8.68). The bimodal sediment located between the inner and outer shelf deposits are actively reworked. The sediment accumulation rate in the inner-shelf mud deposit is 1.70cm/yr and showing distinct horizontal stratification. The high rate of sediment accumulation and low rate of sediments mixing value(1.65) contributes to the preservation of primary sedimentary structure. The sedimentation rate in the outer-shelf mud deposit is 0.28cm/yr and showing homogenous sedimentary structure. The lack of sedimentary structure can be explained by the rapid rate of paticle mixing and the relatively low rate of sediment accumulation.

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Reference

Butenko. J., J. D. Milliman and J. C. Ye. 1985. Geomorphology. shallow structure and geological hazards in the East China Sea. Continental Shelf Research. 4. 121 141.

Byers. S. C., E. L. Mills and P. I. Stewart. 1978. A comparison of method for determining organic carbon in marine sediments with suggestions for a standard method. Hydrobiology. 58. 43~47.

Chin. Y. S. 1979. A study on sediment and mineral compositions of the sea floor of the East China Sea. Oceanic Selections. 2. 130~137

DeMaster. D. J., B. A. Mckee. C. A. Nittrouer. J. C. Qian and G. D. Chen. 1985. Rates of sediment accumulation and particle reworking based on radiochemical measurements from continental shelf deposits in the East China Sea. Continental Shelf Research. 4. 143~158.

Guinasso. N. L. and D. R. Schink. 1975. Quantitative estimates of biological mixing rates in abyssal sediments. Jour. Geophys., 80. 3032~3043.

Jin. Q and L. Sui. 1983. Modern sedimentation processes of the East China Sea. In: Sedimentation on the Continental Shelf. with Special Reference to the East China Sea. Springer-Velag. Belin. 497~510.

Krumbein. W. C. and F. J. Pettijohn. 1938. Manual of sedimentary petrography. Appleton Century Crofts. York. N. Y., p.549

Lucas. H. F., 1975. Improved los-level alpha scintillation counter for radon. Rev. science Inter., 28: 680~683

Mao. L., D. Hu. B. Zhav and Z. Ding. 1983. Cyclonic Eddy in the northern East China Sea. In: Sedimentation on the continental shelf. with Special Reference to the East China Sea. Springer-Verlag. Verlag. Berlin. 280~287.

Nittrouer. C. A., R. W. Sternberg. R. Carpenter and J. T. Bennett. 1979. The use of Pb-210 geochronology as a sedimentological tool : application to the Washington Continental Shelf. Marine Geology. 31. 279~316.

Nittrouer. C. A. and R. W. Sternberg. 1981. The formation of sedimentary strata in an allochthonous shelf environment: the Washington continental shelf. Marine Geology. 42. 201~232.

Nittrouar. C. A., D. J. DeMaster and B. A. Mckee. 1984. Fine-scale stratigraphy in proximal and distal deposits of sediment dispersal systems in the East China Sea. Marine Geology. 61. 13~24.

Stein. R., 1990. Organic carbon/sedimentation rate relationship and its paleoenvironmental significance for marine sediments. Geo-Marine Letters. 10. 37~44.

Yang. Z. and J. D. Milliman. 1983. Fine-grained sediment sources of East China Sea. Sedimentation on the Continental Shelf. China Ocean Press. Beijing. 405~415.

양자강 하구역과 인접 대륙붕 지역 니질 퇴적물의 퇴적률 및 퇴적작용

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요 약

동중국해에 분포하는 퇴적물의 퇴적률과 퇴적구조 형성과정을 밝히기 위해 채취된 6개의 코아시료에 대해 Pb-210 동위원소 분석을 하였다. 동중국해역에는 실트와 니토로 구성된 육성기원 현생 니질퇴적상이 양자강 하구역과 제주도 남서쪽 외대륙 지역에 분포하는데, 이들 두 니질퇴적상은 퇴적물조성 및 퇴적속도 등이 다른 특성을 보였다. 내대륙붕역의 니질퇴적상은 조립질이고 실트가 풍부히 함유한 반면, 외대륙붕역의 니질퇴적물은 많은 점토함량과 함수률 및 유기탄소 함량이 높은 특성을 보였다. Pb-210 동위원소를 이용한 내대륙붕지역 니질퇴적물의 퇴적률은 1.70cm/yr 혹은 1.63g/cm^2.yr이며 물리적 층리구조가 발달된 특성을 보이나, 외대륙붕역 니토대에서의 퇴적률은 0.28cm/yr 혹은 0.18g/cm^2.yr이며 균일한 층리구조를 보인다. 이들 두 니토대에서의 층리구조가 다른 것은 퇴적속도와 혼합률에 의해 설명되며, 이 비는 내대륙봉 니토대지역(1.65)보다 외대륙붕 니토대(27.34)에서가 높은값을 보이는데 이는 생물체의 교란작용에 의해 물리적 퇴적구조가 파괴되는 것으로 해석된다.

주요어 : 현생니토대, 퇴적속도, 혼합률, 층리구조, 동중국해