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Genesis and Sources of the East China Sea Shelf Sediments Based on Quartz-Grains Morphometric Analysis

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ABSTRACT

The roundness and shape of clastic quartz-grains 0.25-0.315 mm fractions from the East-China Sea Shelf sediments were investigated. Quartz-grains of most stations are characterized by great flatteness typical of that of sediments of large river under-water deltas. It is supposed that only some samples contain material from beach and shallow shelf sediments or aeolian. The supposed deltaic reworking sediment covers the shelf zone from the Changjiang River estuary to the shelf break.

(Key words: Genesis, Quartz morphometry, East China Sea, Shelf sediment)

1. INTRODUCTION

The East China Sea outer continental shelf is covered with a relatively thin layer of the late Pleistocene-Holocene sediment that was deposited in fluvial, littoral and deltaic environments during the last lowstand and was subsequently reworked to varying degrees during and after the Holocene transgression (Butenko *et al.*, 1983). The upper parts of this sediment cover have been reworked under recent conditions and are mainly residual with a mixture of recent thin layer. Understanding the genesis of these sediments is very hard because usually the petrographic technique for differentiating sediments from different sources, namely, heavy mineral analysis, is most readily applicable to fine-sand fractions, which may be transported by permanent and tidal currents occurring on the outer shelf (Zhao *et al.*, 1983).

The coarse sandy material could not be redeposit under recent conditions, so it may be used for the recognition of the genesis and sources of initial sediments. In addition to the mineralogy the shape of the quartz grains is another property of sediments that records the source of those sediments. The shape analysis of quartz-sand grains has been used in the past to differentiate coarse-grained sediments, derived from different sources (Kashik *et al.*, 1979; Mazzullo and Crisp, 1985; Bui *et al.*, 1989; Astakhov, Vashchenkova, 1993).

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However for the East China Sea sediments, the grain morphometric analysis has only been made earlier for single stations or small areas (Wang, 1961; Wang *et al.*, 1983; Chen *et al.*, 1992). The method of morphometric analysis has been successfully used to divide most aeolian and aquatic deposits and to reveal under-water submarine deltaic sediments in aquatic ones. This is recognized by more intensive rounding of 0.1-0.5 mm quartz grains during the aeolian transportation than in aquatic ones and indifferent sorting in grain-forms under these conditions (Corey, 1949; Samad, 1983; El Fishawi, 1984; Goossens, 1987; Bui *et al.*, 1989; Astakhov and Vashchenkova, 1993).

The recognition of aeolian and underwater deltaic sediments produced better results. In a marine environment, the sediment under investigation (size 0.25-0.315 mm) might have been transported only by storm waves in a shallow sea zone. Thus, analytical data obtained for all stations under study located below 20-30 m show which quartz grains were transported from the areas covered with relict sediments of different ages and genesis and which formed under the lower sea level.

2. MATERIAL AND METHODS

The 0.25-0.315 mm fraction prepared by wet sieving from surface sediments (Figure 1) was used for this investigation. Core samples from underlying sediment layers were used in the cases where this fraction was absent in surface sediments (Table 1). Roundness was defermined by comparison with the standard roundness scale of N. V. Razumikhin (1965) based on a Wadell's (1933) method of roundness measurement. The grain shape was defined by measuring their long, medium and short axes with the help of a microscope with a mirror device (Willets and Rice, 1983). In all samples 30-40 quartz grains were analyzed.

For shape recognition, some nondimentional morphometric coefficients and their statistical extents were calculated in specific terms of sphericity, flatteness and lengthiness by Cailleux (1952), shape-factor by Janke (1966), sphericity by Sneed and Folk (1958), shape-factor by Corey (1949). All of these coefficients are closely allied (Astakhov and Vashchenkova, 1993), and therefore coefficient V_1, a reversed flatteness ($2c/(a+b)$) according to Cailleux (1952) and côefficient $V_2 = c/b$ were used in this work (a, b, c - long, medium and short axes of grain, accordingly). The mean and standard deviation values of these coefficients, roundness and axis lengths were calculated for each sample (Table 1). Statistical cluster analysis was performed for samples grouping and for defining shelf sediment provinces with morphologically homogeneous quartz-grains.

3. RESULTS

The results of this analysis are summarized in Table 1, Figures 2 and 3. The interpretation, however was complicated because the samples were of different ages and genesis. The main differences in quartz-grains morphometry are between recent muds and relict sands over the shelf surface. In places this prohibits the morphometric coefficient values being mapped on the available station basis.

The common property of quartz grains in the samples from the East China Sea is their great flatteness (small V_1 value) which is typical of large river underwater deltas (Astakhov and Vashchenkova, 1993). The quartz taken at E8 and E33 stations is distinguished by the V_1 value being less than 0.50. Samples with such a small average sphericity were not found in any other regions.

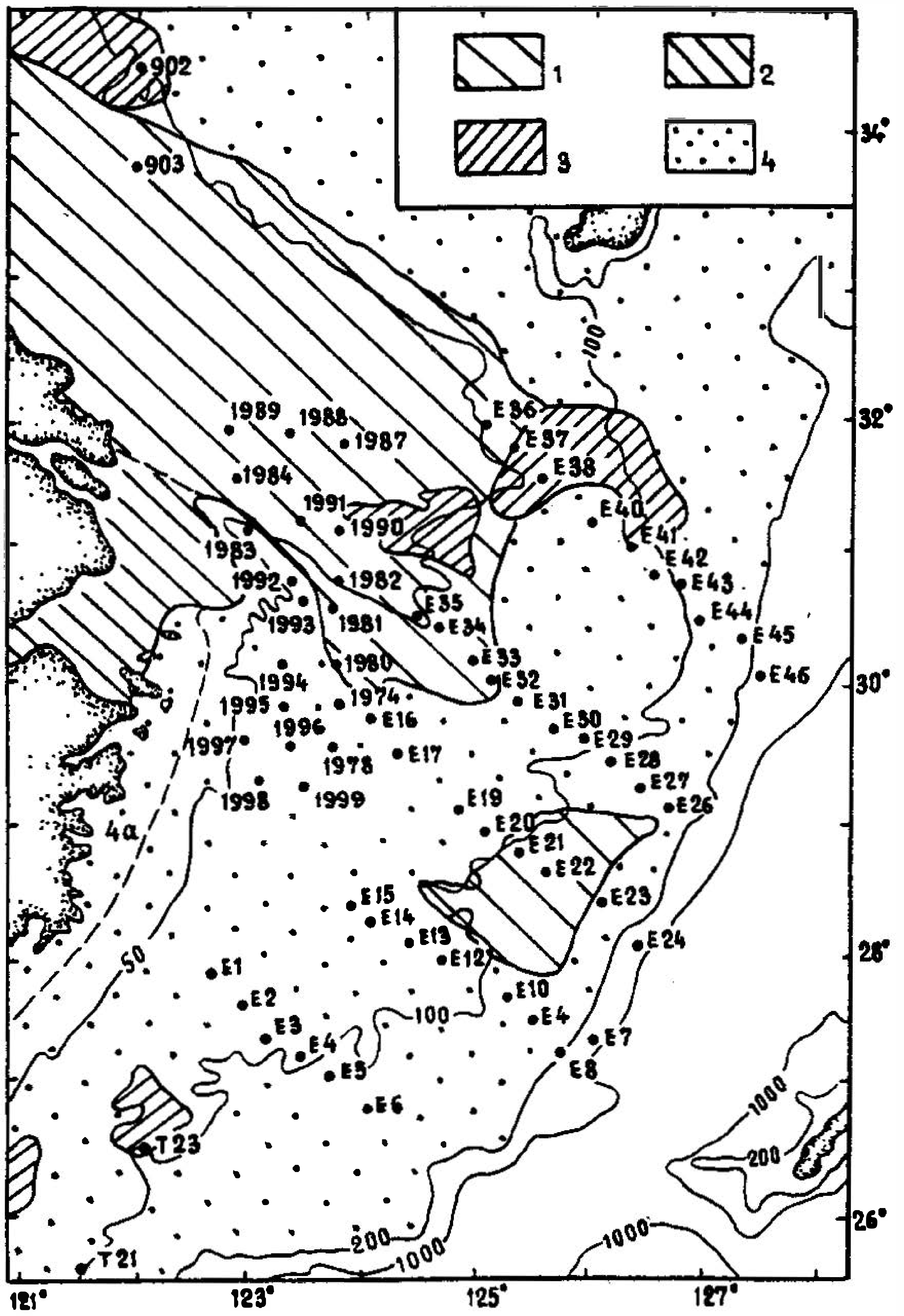

Fig. 1. Station locations and some features of bottom geomorphology (from Li, 1990). The 1,2 - estuary and delta accumulation forms: 1 - fossil, 2 - recent; 3 - limnetic and shallow sea accumulation forms; 4 - marine depositional plains and depressions recent (4a) and fossil.

According to the diagram (Figure 4), the samples are mostly related to underwater delta sediments. Nondifferentiated quartz that is typical of shelf sediments characterized by different origin is found in many samples. The roundness and shape of quartz grains in some samples are similar to samples of aeolian origin (Astakhov and Vashchenkova, 1993). The sand supply from the recent underwater deltaic sediment was tested for curtain at stations 902 and 903 only, located near the old delta of the Huanghe River. Other samples are related to relict sediments. Taking into consideration quartz-grain morphometric features, one may presume which underwater deltaic sediments not differentiated and sorted in littoral environments predominate.

Another common property of the sediments under study is the poor roundness (subangular quartz grains prevail). The sediments with more rounded quartz (large admixure of subrounded grains) occupied the zones extending along the depths of 20-30, 50-70, 110-130 m (Figure 1). These sediments indicate that relict sediments have been worked under the surf zone regimes. On the other hand, the areas of sediments with subangular and angular quartz grains could be defined as areas with sediments not reworked

Table 1. Average shape characteristics of quartz grains 0.25-0.315 mm fraction: a, b, c, - long, medium and short axis lengths (mm); r -roundness; V_1 - sphericity $(2c/(a+b))$; V_2 - c/b; Fr, FV_1 and FV_2 - the standard deviation of r, V_1 and V_2 coefficients.

Station No.	*Core interval, cm*	a	b	c	r	Fr	V_1	FV_1	V_2	FV_2
E1	0	0.286	0.222	0.156	0.202	0.159	0.623	0.119	0.715	0.145
E2	20	0.300	0.230	0.157	0.190	0.108	0.603	0.144	0.695	0.166
E3	0	0.308	0.228	0.153	0.170	0.139	0.589	0.163	0.688	0.182
E4	4	0.321	0.241	0.174	0.132	0.079	0.646	0.167	0.729	0.132
E4	200	0.296	0.230	0.153	0.201	0.106	0.590	0.133	0.680	0.155
E5	0	0.304	0.224	0.158	0.178	0.107	0.611	0.160	0.719	0.184
E6	30	0.290	0.222	0.148	0.161	0.123	0.593	0.156	0.679	0.170
E7	0	0.297	0.231	0.144	0.069	0.075	0.564	0.179	0.638	0.177
E8	180	0.323	0.220	0.127	0.119	0.100	0.474	0.129	0.591	0.183
E9	0	0.333	0.239	0.161	0.231	0.124	0.575	0.143	0.687	0.167
E10	0	0.301	0.226	0.167	0.110	0.072	0.648	0.139	0.755	0.172
E12	0	0.294	0.221	0.156	0.138	0.101	0.615	0.151	0.719	0.172
E13	0	0.315	0.232	0.142	0.196	0.113	0.528	0.134	0.623	0.167
E15	130	0.305	0.231	0.142	0.153	0.082	0.538	0.153	0.627	0.191
E16	0	0.287	0.227	0.168	0.198	0.103	0.662	0.131	0.748	0.147
E17	0	0.304	0.229	0.165	0.100	0.064	0.633	0.170	0.733	0.185
E19	0	0.300	0.228	0.177	0.193	0.086	0.679	0.111	0.784	0.117
E20	0	0.296	0.226	0.165	0.165	0.120	0.639	0.114	0.740	0.137
E21	0	0.311	0.232	0.177	0.161	0.083	0.662	0.109	0.779	0.142
E22	0	0.300	0.235	0.184	0.177	0.089	0.694	0.130	0.797	0.169
E23	0	0.285	0.211	0.143	0.157	0.092	0.591	0.139	0.695	0.163
E24	5	0.290	0.223	0.155	0.136	0.102	0.601	0.176	0.704	0.209
E24	60	0.324	0.231	0.168	0.216	0.174	0.619	0.177	0.737	0.186
E26	0	0.301	0.235	0.157	0.180	0.074	0.595	0.137	0.682	0.157
E27	0	0.311	0.243	0.178	0.162	0.085	0.650	0.135	0.743	0.154
E28	0	0.308	0.233	0.168	0.172	0.101	0.650	0.135	0.727	0.141
E29	12	0.297	0.232	0.159	0.137	0.100	0.625	0.115	0.693	0.130
E29	15	0.288	0.222	0.173	0.265	0.147	0.687	0.117	0.787	0.128
E30	0	0.308	0.234	0.153	0.158	0.076	0.578	0.151	0.671	0.169
E31	0	0.301	0.236	0.158	0.127	0.090	0.600	0.132	0.686	0.160
E32	5	0.303	0.235	0.148	0.140	0.097	0.561	0.122	0.638	0.133
E33	0	0.340	0.240	0.134	0.076	0.072	0.472	0.133	0.576	0.178
E34	0	0.309	0.233	0.148	0.123	0.079	0.562	0.127	0.647	0.143
E35	0	0.309	0.238	0.138	0.107	0.084	0.523	0.194	0.598	0.216
E36	0	0.317	0.236	0.146	0.146	0.088	0.539	0.164	0.630	0.174
E37	0	0.301	0.229	0.169	0.171	0.107	0.648	0.144	0.747	0.158
E38	310	0.282	0.230	0.175	0.255	0.159	0.686	0.104	0.767	0.132
E38	570	0.302	0.238	0.156	0.127	0.092	0.589	0.152	0.666	0.168
E40	85	0.303	0.233	0.184	0.295	0.145	0.698	0.126	0.798	0.134
E41	0	0.298	0.231	0.178	0.228	0.130	0.682	0.140	0.781	0.155
E42	0	0.311	0.231	0.155	0.216	0.113	0.579	0.126	0.678	0.144
E43	0	0.297	0.226	0.172	0.285	0.139	0.668	0.152	0.772	0.165

Table 1. (Continued)

Station No.	*Core interval, cm*	*a*	*b*	*c*	*r*	*Fr*	V_1	FV_1	V_2	FV_2
E44	0	0.295	0.228	0.173	0.219	0.129	0.676	0.138	0.774	0.149
E45	0	0.291	0.228	0.166	0.264	0.145	0.647	0.132	0.738	0.152
E46	0	0.293	0.220	0.154	0.182	0.117	0.606	0.116	0.710	0.157
902	0	0.309	0.229	0.159	0.243	0.158	0.599	0.161	0.706	0.193
903	0	0.306	0.234	0.151	0.202	0.124	0.573	0.153	0.662	0.181
1978	0	0.319	0.250	0.178	0.151	0.062	0.597	0.137	0.684	0.173
1979	0	0.309	0.252	0.183	0.147	0.045	0.657	0.142	0.728	0.151
1982	0	0.302	0.235	0.150	0.117	0.043	0.570	0.144	0.653	0.164
1983	0	0.288	0.232	0.184	0.166	0.079	0.711	0.158	0.796	0.164
1987	0	0.320	0.256	0.163	0.123	0.061	0.576	0.140	0.647	0.150
1989	0	0.333	0.250	0.176	0.163	0.074	0.610	0.106	0.712	0.130
1990	0	0.319	0.242	0.166	0.144	0.035	0.609	0.152	0.699	0.162
1993	0	0.300	0.252	0.169	0.129	0.079	0.626	0.172	0.687	0.190
1994	0	0.327	0.261	0.175	0.157	0.059	0.603	0.121	0.679	0.125
1995	0	0.336	0.263	0.165	0.150	0.045	0.560	0.164	0.644	0.198
1997	0	0.326	0.256	0.172	0.180	0.041	0.600	0.140	0.677	0.141
1981	0	0.348	0.259	0.163	0.175	0.106	0.552	0.155	0.645	0.180
1980	0	0.326	0.257	0.181	0.264	0.119	0.631	0.103	0.718	0.110
1991	0	0.335	0.253	0.193	0.234	0.114	0.667	0.123	0.772	0.129
1992	0	0.327	0.253	0.179	0.225	0.133	0.628	0.144	0.715	0.145
1996	0	0.326	0.255	0.163	0.189	0.080	0.568	0.113	0.648	0.138
1998	0	0.321	0.258	0.161	0.159	0.064	0.561	0.127	0.629	0.139
1999	0	0.344	0.258	0.169	0.232	0.124	0.563	0.152	0.658	0.179
1988	0	0.344	0.258	0.152	0.140	0.073	0.518	0.154	0.605	0.183
1986	0	0.328	0.250	0.164	0.218	0.137	0.574	0.115	0.657	0.110
1984	0	0.342	0.253	0.134	0.231	0.110	0.630	0.131	0.738	0.142

under nearshore conditions. The most common conditions for their formation are underwater deltaic environments, where the sediment discharged by rivers is rapidly covered by other layers without any processing. A better roundness (absence of angular grains) is also typical of the samples taken in the northern part of the region (station 902, 903, E38-E46). This is probably attributable to the Huanghe River sediment sources.

4. GENESIS SEDIMENT SOURCES PROVINCE RECOGNITION

The data from Table 1 (a, b, c, r, V_1, V_2) and their standard deviation were used for cluster statistical analysis. The sediment samples of the East China Sea shelf can be divided into four main groups. Their general distribution (corresponding to provinces) is shown in Figure 5.

Group 1 combines the samples with small values of V_1 (less than 0.55-0.60) and V_2 (less than 0.65-0.70); here, tabular and bladed grains privail. Their roundness is generally poor (a large amount of angular bladed grains). Only samples 902, 903 from the region near the old Huanghe River mouth are characterized by better roundness, but grains of a flattening

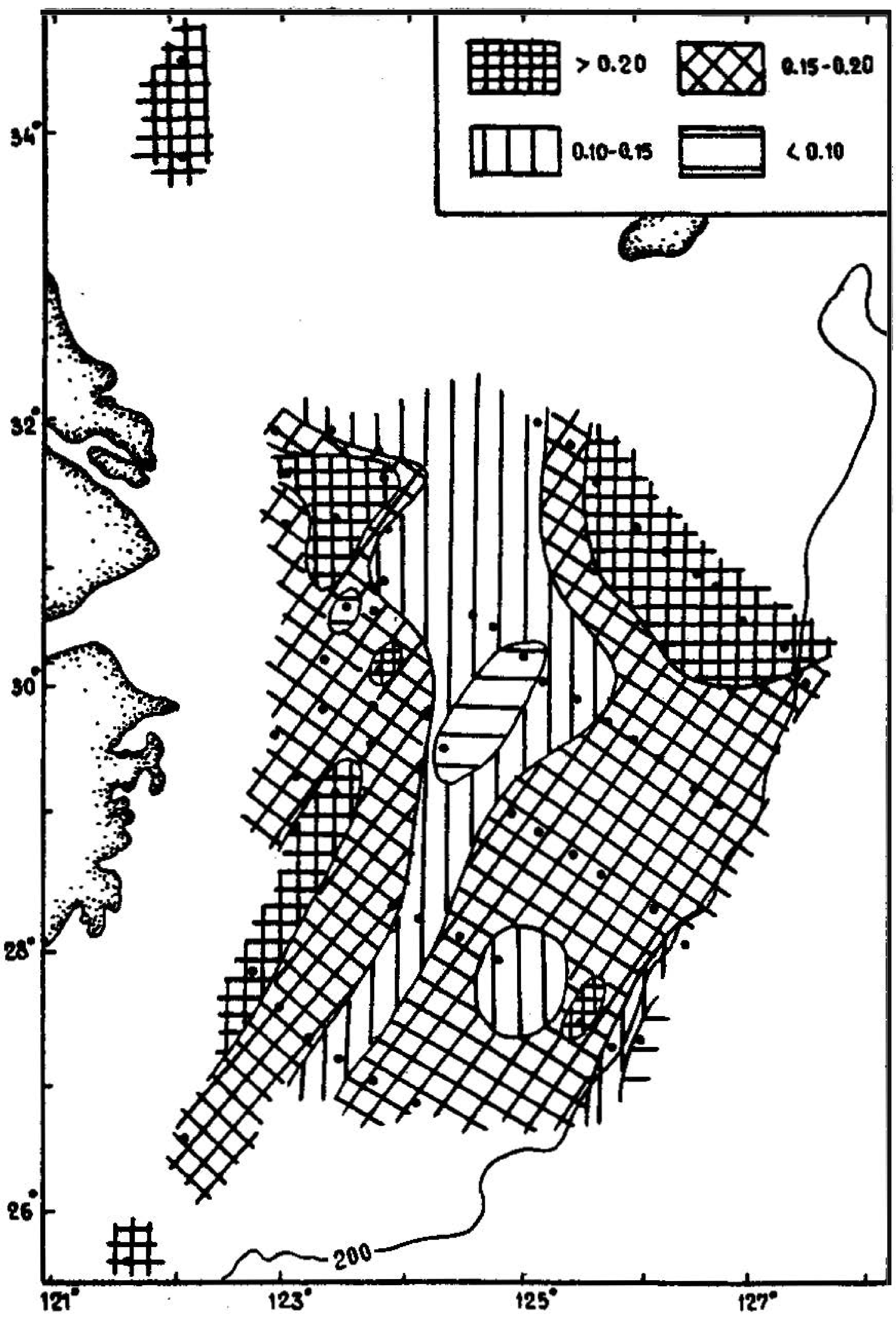

Fig. 2. The roundness of quartz grains of 0.25-0.315 mm fraction from bottom sediments of the East China Sea.

shape prevail. The samples of Group 1 together with single samples, very changeable in shape and not involved into any sample group, compose Province 1 (Figure 5). The genesis of the sediments from Province 1 can be defined as nearmouth, with a predominance of an underwater deltaic complex.

The samples from Group 2 (Province 2) are similar to those of the first one, with the quartz grain less flattened (a bladed and tabular shape with an admixture of equant grains) and more uniform (FV_1 value 0.11-0.16, FV_2 value 0.13-0.18). It is suggested that the sediments of this zone were formed on the near delta shelf and then differentiated in the wave zone.

The samples from Group 3 (Province 3) are characterized by the predominance of better rounded (r more 0.20) and sphericity (V_1 more 0.60 and V_2 more 0.70) quartz-grains. Angular quartz grains are absent. Equant and tabular grains (in shape) prevail. They were presumably supplied by the nearest land and differentiated only in the wave zone. The sand grains from the Huanghe and Changjiang River discharges form a smaller part of the sediments in this zone. The intensive differentiation and mixing of the material provided by various sources are common in this Province.

Quartz-grain morphometric features of Group 4 are similar to the ones of Group 3, but they are distinguished by their worse roundness (0.12-0.18) and better flatteness (V_1

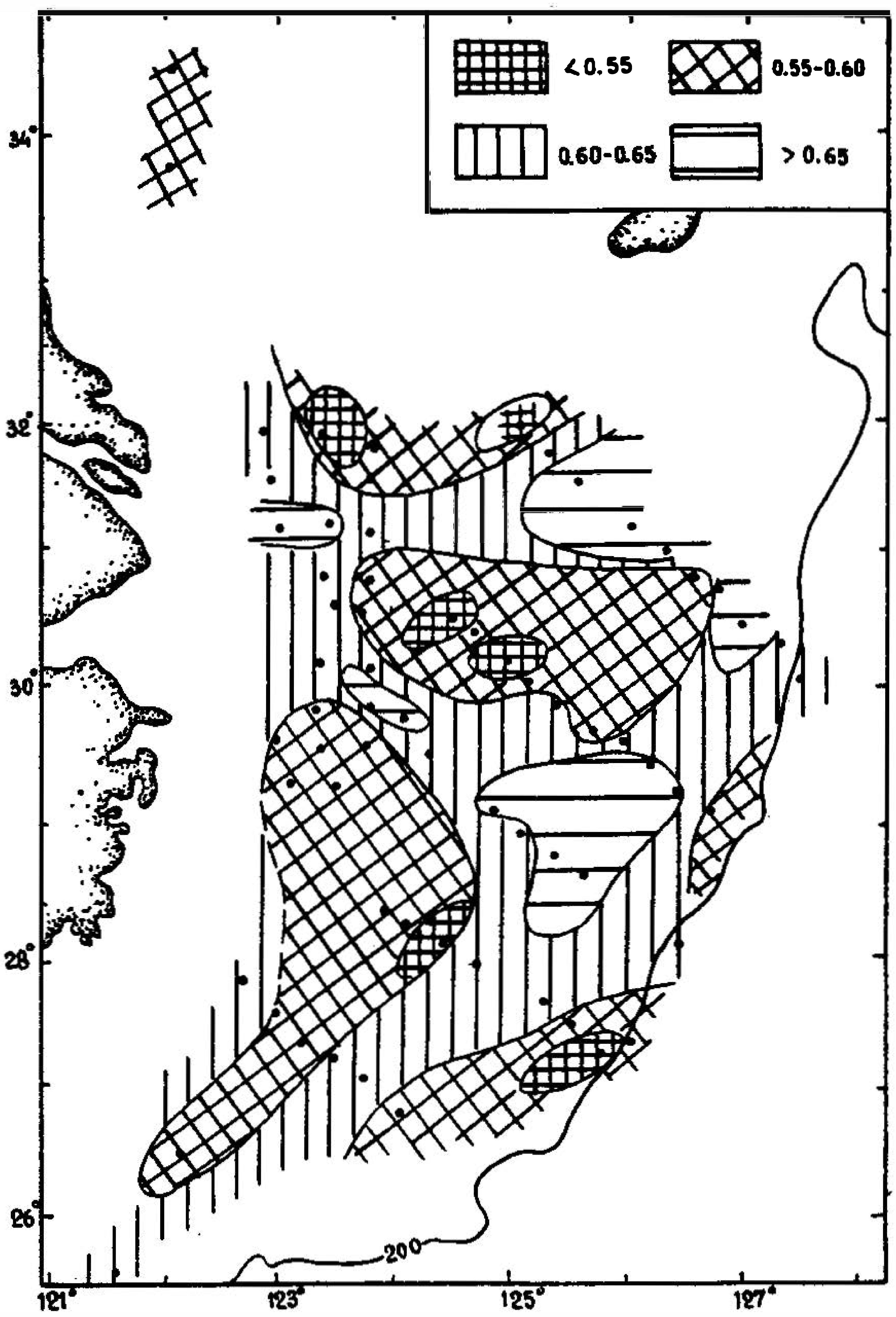

Fig. 3. The sphericity (2c/(a+b)) of quartz grains of 0.25-0.315 mm fraction from bottom sediments of the East China Sea.

.56-0.64; V_2 0.63-0.73). Genetically the sandy part of the sediments from Province 4 orresponds to that of Province 3, but it contains more admixture of highly flattened quartz-rains from Provinces 1 and 2.

A more careful facial analysis based on terrigenous quartz-grain morphometry cannot be one due to the very high changeability of the relict sediments under investigation. Changes n a sediment group could be retraced by the preliminary, obtained from the columns data. or example, sandy sediments from core E38 of 320 cm are related to Group 4 (the shelf ediment), while the sediments from the lower layers are related to Group 2 (submarine delta ediments). This corresponds to the conventional changeability in the facial conditions in the ate Pleistocene low-stand sea transgression.

. CONCLUSIONS

Quartz-grain morphometric features of Group 3 are similar to those of Group 4, but they re distinguished by their worse roundness and better flatness. Genetically, the sandy part of ediments from Province 3 corresponds to that of Province 4, but it contains more admix-ure of highly flattened. Analytical data on the roundness and shape of quartz-grains confirm

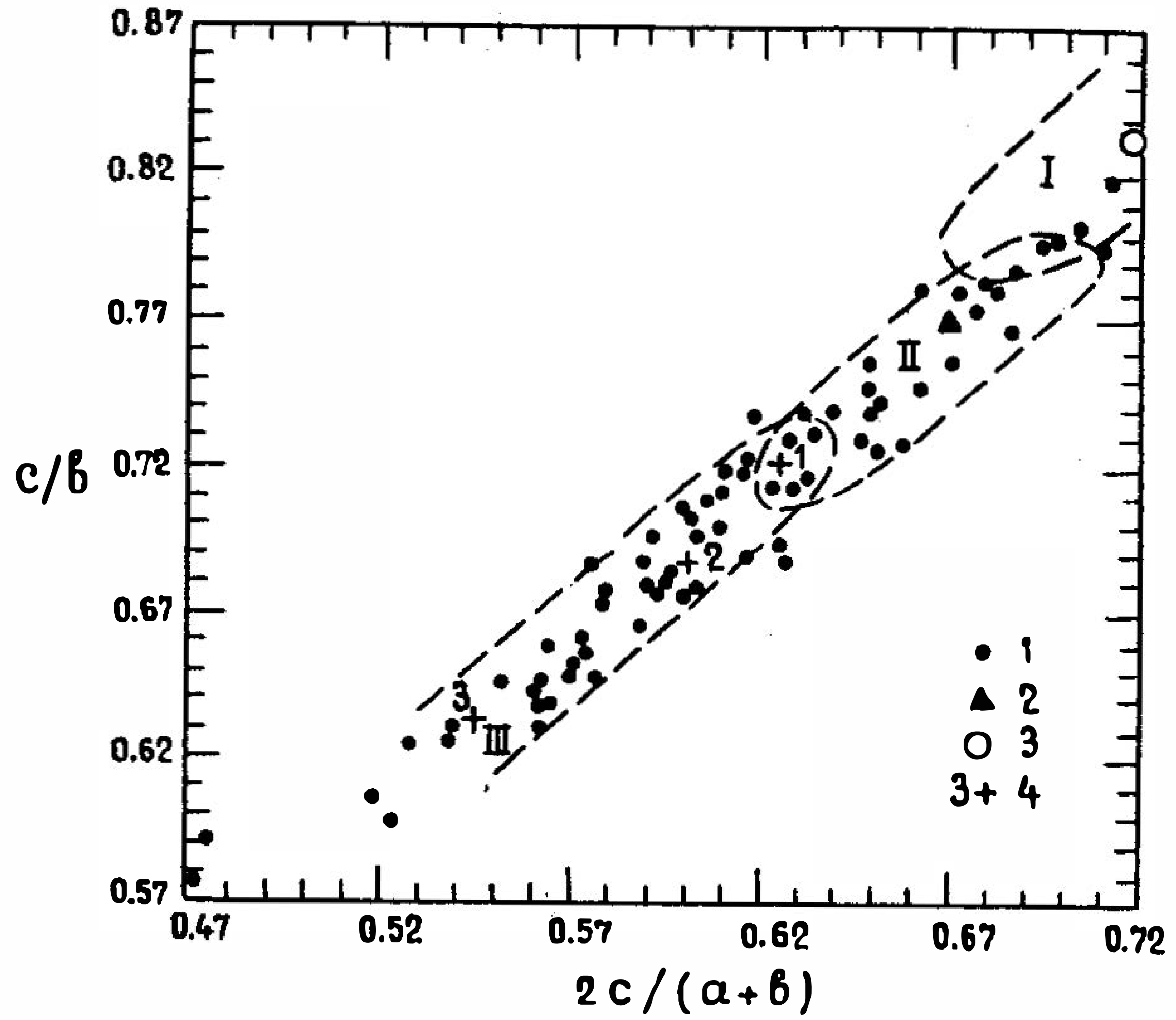

Fig. 4. The plot of c/b versus $2c/(a+b)$ for quartz grains of 0.25-0.315 mm sediment fraction. I-III - environmental groups of sediments (from Astakhov, Vashchenkova, 1993): I - aeolian, II-III - aquatic (III - submarine deltas). 1-4 - samples location: 1 - East China Sea sediments, 2 - weathering granites from Singapore Island, 3 - Sakhara Desert sand, 4 - under-water deltaic sediments (1 - Amur River, 2-3 - Mekong River).

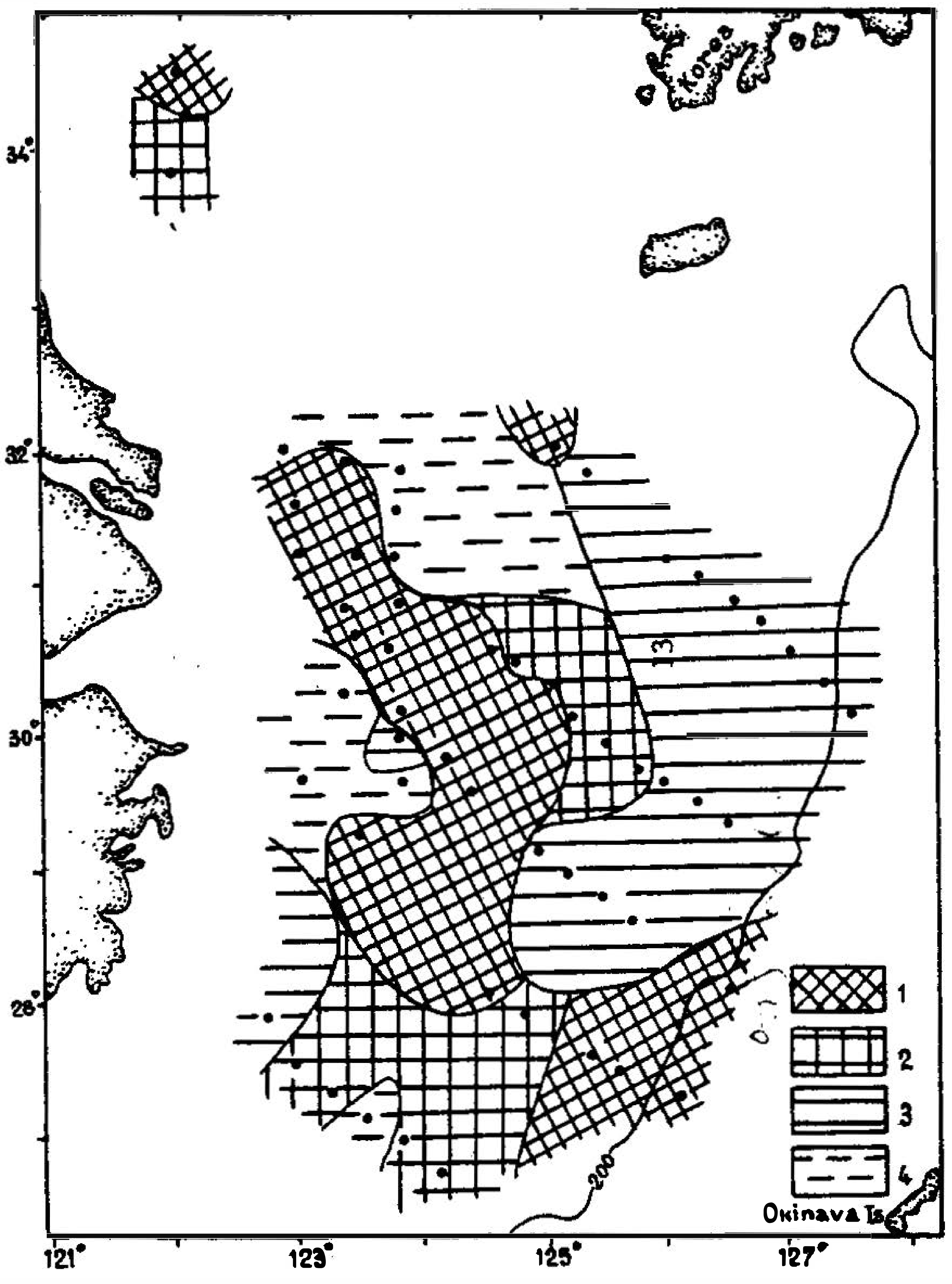

Fig. 5. The bottom sediment provinces based on cluster statistical analysis of quartz 0.25-0.315 mm grain shape.1-4 - sediment Provinces (see the text).

the opinion that sandy sediments of the East China Sea shelf have been transported by the Huanghe and Changjiang Rivers. Furthermore, the results obtained suggest an occurrence of under-water delta sediments formed during the last sea-level low stand on the outer shelf. Underwater delta sediments are spread in the middle part of the shelf as a wide zone from the Changjiang River mouth to the shelf break. Northward they occur only in the subbottom sediment layers under the cover of the Holocene sediments (E38 station). The northern part of the region is distinguished by the roundness of the quartz-grains. Better roundness suggests the supplies of a sand by the Huanghe River taking place during the sea-level lowstand period. A more detailed interpretation of morphometric data requires additional sediment information (including grain-size, mineral composition and age).

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REFERENCES

Astakhov, A. S., and N. G. Vashchenkova, 1993: Morphometric analyses of terrigenous quartz for lithodynamical and paleogeographical reconstructions. *Lithologiya i poleznie iskopaemie*, **5**, 106-117 (in Russian).

Bui, E. N., J. M. Mazzullo, and L. P. Wilding, 1989: Using quartz grain-size and shape analysis to distinguish between aeolian and fluvial deposits in the Dalloe-Bosso of Niger (West Africa). *Earth Surf. Proces. Landf.*, **14**, 157-165.

Butenko, J., Ye Yincan, and J. D. Milliman, 1983: Morphology, Sediments and Late Quaternary History of the East China Sea. Proc. International Symposium on Sedimentation on the Continental Shelf, with Special Reference to the East China Sea, Beijing, China Ocean Press, 653-677.

Cailleux, A., 1952: Morphoscopische Analyse der Gesehtebe und Sandkorner und ihre Bedeutung fur die Paleoklimatologi. *Geol. Rdscn.*, **40**, 11-19.

Chen, M. P., S. C. Lo, and K. L. Lin, 1992: Composition and Texture of Surface Sediment Indicating the Depositional Environments off Northeast Taiwan. *TAO*, **3**, 395-416.

Corey, A. T., 1949: Influence of shape on the fall velocity of sand grains. M. Sci. Thesis. Fort Collins: Colorado A. and M. College, 102pp.

El Fishawi, N. M., 1984: Roundness and sphericity of the delta coastal sands. *Acta Mineral.-Petrogr. Szeged.*, **26**, 235-245.

Goossens, D., 1987: Interference phenomena between particle flattening and particle rounding in free vertical sedimentation processes. *Sedimentology*, **34**, 155-265.

Janke, N. C., 1966: Effect of shape upon the settling velocity of regular convex geometric particles. *J. Sedim. Petrol.*, **36**, 370-376.

Kachik, D. S., O. A. Miklukho-Maklae, G. M. Romm, and A. Ex. Rybalko, 1979: Grain size and grain morphology of the Lower and Middle Miocene sandy sediments of the Continental Slope off North-western Africa. Initial reports of the DSDP, Wash. US Gov. Print. Off., 47, 683-698.

Li, Q. (Ed.), 1990: Marine Atlas of Bohai Sea: Yellow Sea, East China Sea. Geology and Geophysics. China Ocean Press, Beijing, 82pp.

Mazzullo, J., and J. A. Crisp, 1985: Quartz-Grain Shape: A Record of the Source of Fine-Grained Sediments. *Geo-Mar. Letters*, **4**, 197-202.

Razumikhin, N. V., 1965: The experimental investigation of the rock fragment roundness. Leningrad: Leningrad State University Press, 121pp. (in Russian).

Samad, A., 1983: The effects of transportation on roundness and shape of River Tamar sands, S. W. England. *J. Geol. Soc. India*, **24**, 460-467.

Sneed, E. D., and R. L. Folk, 1958: Pebbles in the Lower Colorado River, Texas. A study in particle morphogenesis. *J. Geol.*, **66**, 114-150.

Wadell, H., 1933: Sphericity and roundness of rock particles. *J. Geol.*, **41**, 310-331.

Wang, C. S., 1961: Sand-fraction study of the shelf sediments off the China coast. *Geol. Soc. China Proc.*, **4**, 33-49.

Wang Y., G. Vilks, and D. J. W. Piper, 1983: The surface texture of quartz sand grains from continental shelf environments. Examples from Canada and China. Proc. Int'l Symposium on Sedimentation on the Continental Shelf, with Special Reference to the East China Sea, Beijing, 920-931.

Willetts, B. B., and M. A. Rice, 1983: Practical representation of the characteristic grain shape of sands: a comparison of methods. *Sedimentology*, **30**, 557-565.

Zhao, J., R. Qiao, R. Dong, J. Zhang and S. Yu, 1983: An analysis of current conditions in the investigation area of the East China Sea. Proc. Int'l Symposium on Sedimentation on the Continental Shelf, with Special Reference to the East China Sea, Beijing, 288-301.