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GRAIN SIZE ANALYSIS OF SOME OLISTOSTROMES BETWEEN BALKUYUMCU AND ALCI (SW ANKARA)

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ABSTRACT._ Sedimentary features and the detailed grain size analyses of six olistostromes (debris flows) have been examined; they are located between Alcı and Balkuyumcu villages, 40 km. southwest of Ankara. Photograph-grid method and sieving methods are used for gram size distribution analyses. The distribution of clast sizes within olistostromes are shown as histograms and cumulative curves. After calculating the main gram size parameters, their relations with respect to each other are examined on distribution diagrams (scatter diagrams). So, some of the distinguishing characteristics of olistostrome clast size distributions have been established. Studies on the clast size distribution and clast roundness indicate that, olistostromes are, in general, very poorly sorted, either negatively or positively skewed, mostly platykurtic. Clasts are angular to sub angular. Generally, scatter plots of grain size parameters of olistostromes are distinct when compared with other sedimentary deposits.

INTRODUCTION

Olistostromes are considered to be submarine debrisflow deposits with heterogeneous material in different sizes ranging from clay to block. Grain size analyses have been carried out on six different olistostromes, occurring in an area covering 17 square kilometers, located between Alcı and Balkuyumcu villages, 40 km southwest of Ankara (Fig.1).

Each olistostrome has been sampled for grain size distribution at four, close but separate, localities. The sampling has been carried out at two levels: 1. Photographic grid sampling, 2. Sieve

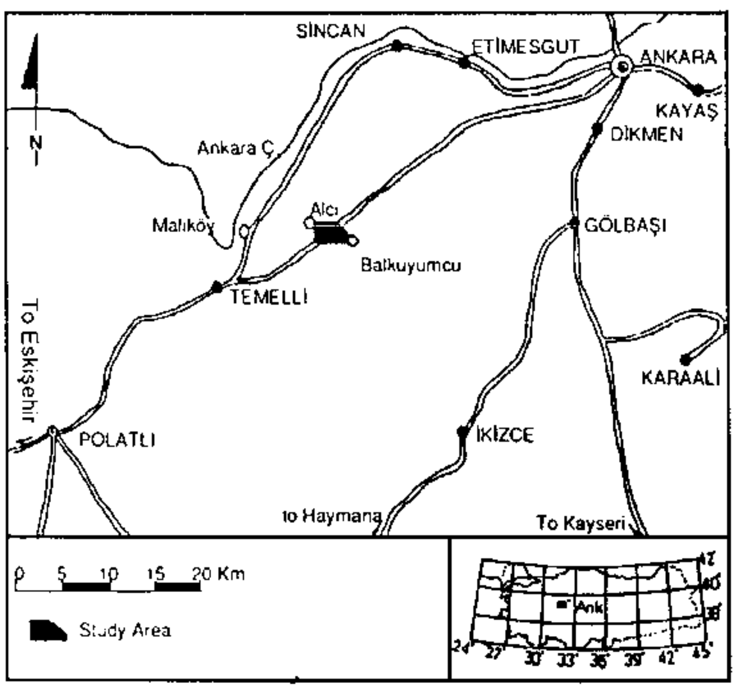


Fig. 1- Location map of the study area.

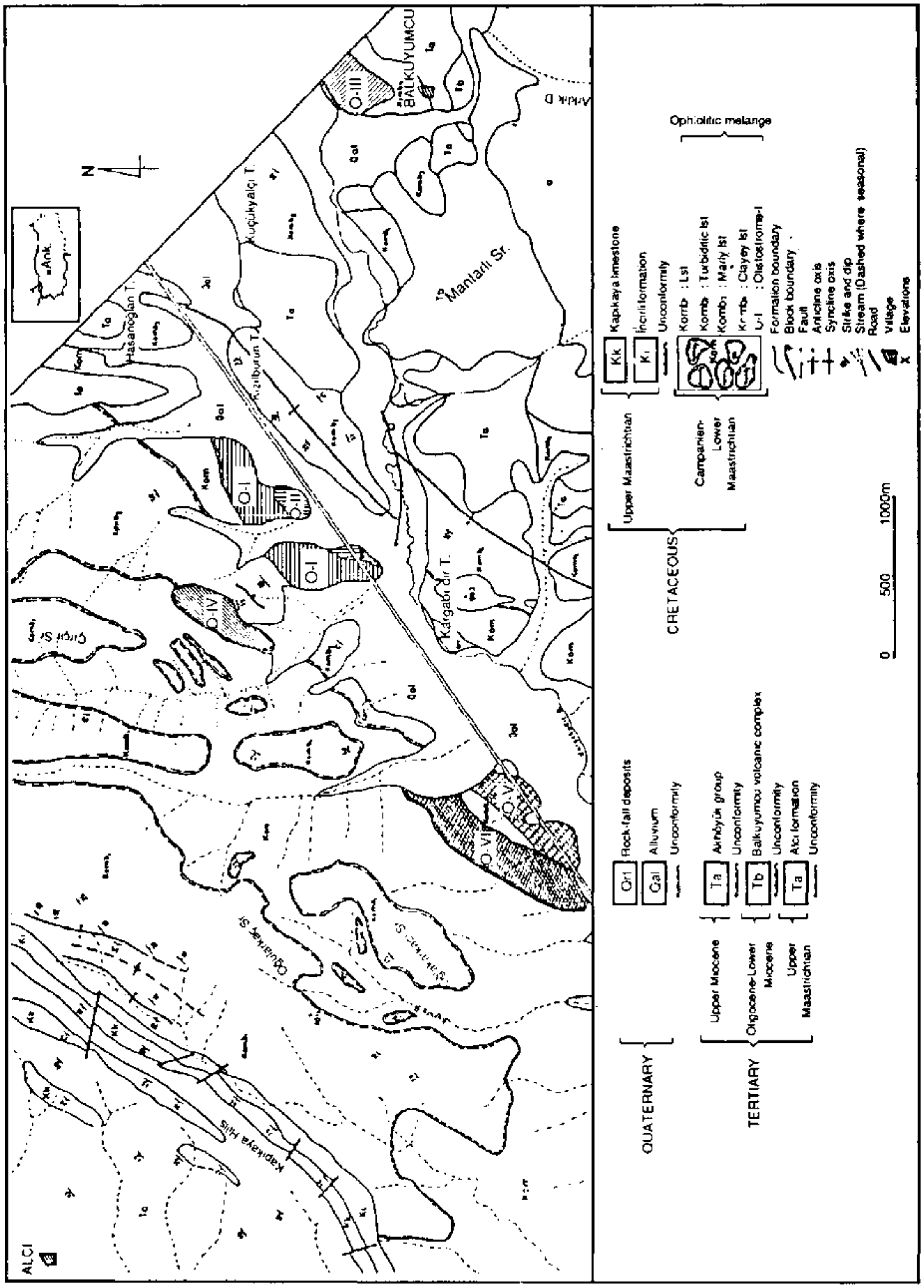


Fig. 2- Geological map of the study area (Modified from Koçyiğit and Lünel, 1987; Lünel, 1987).

sampling of matrix material. In addition, 70 thin sections of clasts and matrix material have been studied to identify the ages of olistostromes. During the studies of grain size distribution, the standard model analsis technique is applied to determine the volumetric distribution of different clasts within the matrix of olistostromes.

Flores (1955) first defined the term "olistostrome", from the Greek words "olistomai" (to slide) and "strome" (accumulation) as "accumulation due to sliding". Flores argued that olistostromes are sufficiently continuous to be mappable, lithologically heterogeneous, more or less admixed, showing no true bedding, consisting of rocks accumulated as a semifluid body. Other related studies are made by several workers; Marchetti (1957), Gansser (1959), Hoedemaker (1973), Hsü (1974), Gökçen and Şenalp (1975), Koçyiğit (1979), Norman (1975 and 1979) and Bayraktutan (1982). Recently, olistostromes are defined as a sedimentary deposit consisting of a chaotic mass of intimately mixed heterogeneous materials (such as bloks and muds) that accumulated as a semifluid body by submarine gravity sliding or slumping of unconsolidated sediments (Jackson and Bates, 1980).

Some grain size distribution studies have been made by Passega (1957 and 1977) Folk (1954, 1964 and 1980), Folk and Ward (1957), Folk and Mason (1958), Friedman (1961, 1962 and 1967), Sahu (1964), Visher (1969), Buller and Mc Manus (1972) for river, dune, beach and turbidite sediments, using different grain size distribution parameters. One study (Gökçen and Özkaya, 1981) deals with the discrimination of olistostromes and turbidites by some sedimentary parameters; otherwise, very little published work on the distribution of grain size properties of olistostromes is available.

STRATIGRAPHIC POSITIONS, AGES GEOMETRIES AND THICKNESSES OF OLISTOSTROMES STUDIED

The oldest rock units are the Late Jurassic to Early Cretaceous limestones in the study area (Lünel, 1987). They are observed as megablocks (olistolith sizes larger than 500 m) and olistostromes within an ophiolitic melange which also consists of different sizes of blocks of radiolarian chert, serpentinite and pillow basalts (Koçyiğit and Lunel, 1987). These different blocks are seen in a fine grainec matrix composed of greenish to gray colored shales, sandstones and pelagic mudstones. The studied six olistostromes are all situated in the ophiolitic melange and appear as blocks and lenses (Fig. 2). Where the boundary relations are clear, the olistostromes are seen to be conformable with the sedimentary rock units above and belove (Fig. 3). In the northern part, the units of the ophiolitic melange are unconformably overlain by thick continental and shallow marine deposits of I ertiary age. In the southern part of study area, (Fig. 3), they are unconformably overlain by Tertiary volcanics and Pliocene clastic deposits.

Two types of olistostromes (matrix supported and clast supported) are recognized in the study area. Matrix supported olistostromes are O-I, O-II, O-V and O-VI, in which the clasts are dispersed in a fine grained matrix forming lobe or lens shape features (olistostromes are briefly denoted as "O"). Clast supported olistostromes are O-III and O-IV, in which the clast framework accomodates little amount of matrix. Matrix supported olistostromes have generally a polygenic composition, having different limestone clasts together with many ophiolithic constituents of Late Cretaceous age (Santonian-Early Maastrichtian). On the other hand, clast supported olistostromes are moncgenic consisting of only limestone clasts with aqes ranging from Late Jurassic (Oxfordian-Tithonian) to Early Cretaceous (Berriasian-Hauterivian) (Olgun, 1988).

In the field, O-I is about 35 m. in thickness and its length is 1 km (Fig. 2). In O-I, a lobe shape is recognized and its longitudinal section shows a "snout" like feature towards west. Generally, coarse clasts are observed at this "snout" part, showing reverse grading. O-II shows a parallel trend to O-I and it is 15 m. thick and 300 m. long. O-III is interbedded with marly limestones around Balkuyumcu village. Its thickness is 28 m. and length is 400 m. O-IV is observed as a lens; its lateral extension is 600 m. and thickness is 20 m. O-V is, also, lens shaped, with a thickness of 18 m. and length 650 m. O-VI occurs parallel to O-V; it is about 25 m. in thickness and 1 km. in length. These olistostromes generally show a lateral extension in NE-SW direction. No clast preferred orientation or internal structure, except reverse gradation, is detected.

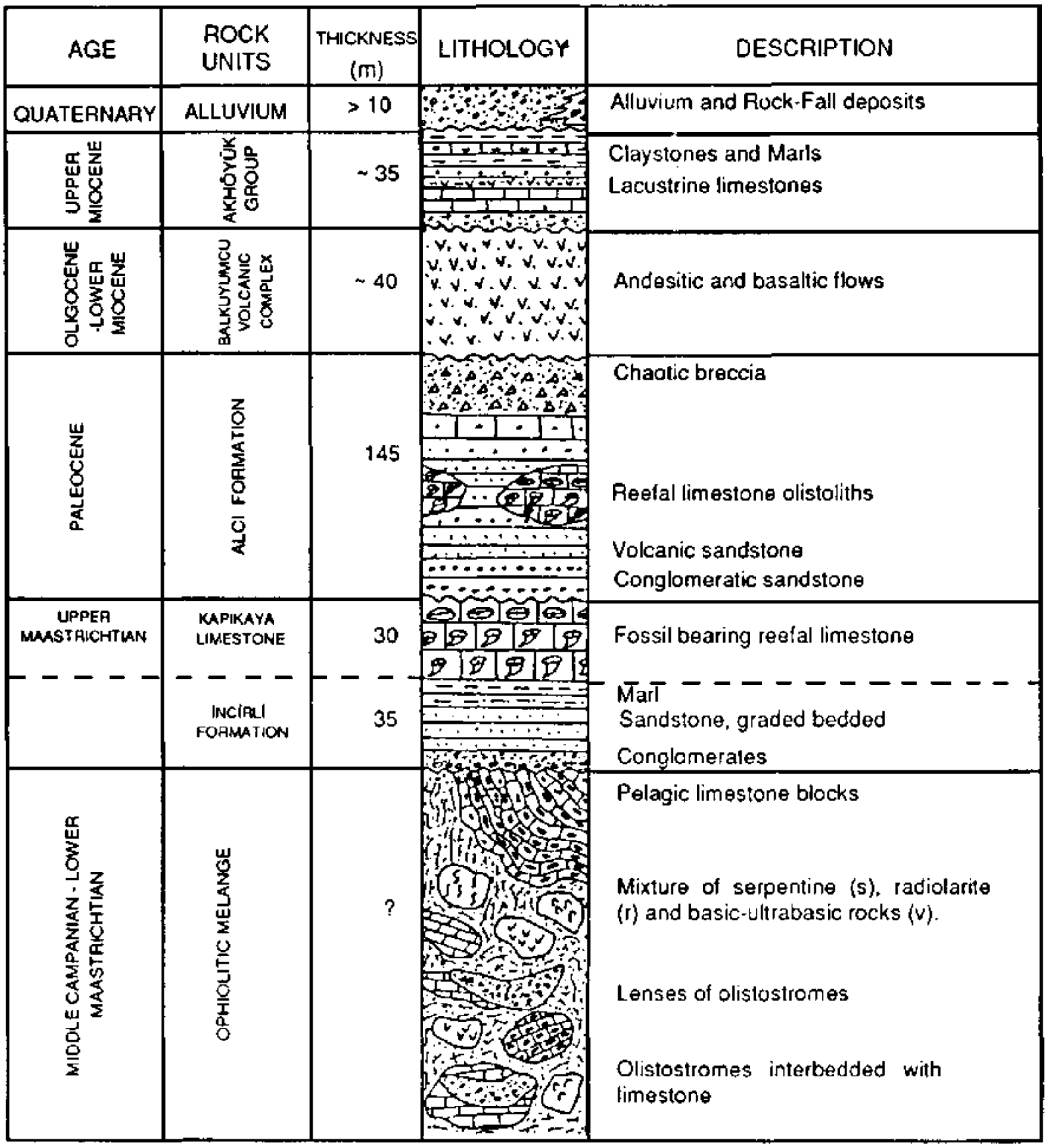


Fig. 3- Generalized stratigraphic section of the study area (Modified from Koçyiğit and Lünel, 1987; and Lünel, 1987).

GRAIN SIZE ANALYSES OF OLISTOSTROMES

a) Method: Since the olistostromes have very coarse size clast fractions (larger than any mesh or hole size of the available sieves) it is necessary to study their size distributions on photographs of outcrops in the field (Olgun, 1988).

To study the whole size range (mud to block) of an olistostrome, the "photograph-grid method" and the "sieving method" are combined to obtain the full grain size distribution.

Four photographs are obtained of each olistostrome outcrop (a scale is included in the photographs). In the laboratory, photographs are projected onto a grid of 50x50 cm. area, providing 400 grid points 2.5 cm. apart. On the image over the gridded screen, at each grid point, the longest and the shortest diameter of each clast is measured and coverted to length measurements in the field, based on the scale included on the photograph. Then, to obtain the clast size the geometrical mean of its diameters is calculated by / dlxds ; dl= the longest diameter (mm.), ds= the shortest diameter (mm.). Standard modal analysis technique (Chayes, 1956) is applied to determine the areal distribution of this clast size within the total amount. In this way, for each size class, a frequency (%) is obtained leading to the size distribution of the total sediment in the photograph. This process is repeated for all the photographs of the same outcrop.

In this study, the clast sizes between -2f (4mm.) and -10f (1024 mm.) are analyzed at 1f intervals, based on Wentworth grade scale. The counted grid points of clasts falling into the same size are added to obtain the proportion at that size class within the total area (i.e. the total number of points in the grid area). This proportion is used as the basis to calculate the size class distribution in the same area.

In the projected photographs, the grains finer than -2f (4mm.) are not clearly recognisable to make size measurements on them; this fraction is considered the "pan" fraction of the analysis. Sieving method is applied to this size fraction (represented by matrix) in order to separate them into different size classes. The sediment samples (matrix) are collected within the same locality of photographs. The sieve analysis is carried out using a stack of 7 sieves with apertures ranging from -1.0f (2 mm.) down to 5.0f (0.031 mm.) based on Wentworth grade scale. Then, each sieve fraction is weighed and the percentage sieve fractions are calculated to obtain the grain size distribution in the sieved sample.

Each olistostrome comprises two different sets of data: from grid analses on photographs, and from sieve analyses. The former measures size distribution by the number of grid points which gives areal proportions. The latter is based on the weight distribution of each size fraction which is weighed and calculated to obtain the size distribution in the sample. Since areal percentages in the firsi method are proportional to the volumetric percentages (Chayes, 1956), and the weight percentages of the second method are also proportional to the volumetric percentages, the data of the two methods used on the same sample can be combined on volumetric percentage basis to obtain total grain size distribution of the olistostrome on a single data sheet (Table 1). During this combination, sieve results of each matrix sample are multiplied by certain conversion factors to bring them into the same range as photographic grain size analyses. The combined data results are used to obtain the class percentage and cumulative percentage values, repeated at four localities on each of the six olistostromes. Histograms and cumulative curves of olistostromes are constructed and evaluated according to these results.

b) Results: Generally, bimodality is characteristic for all size distribution of the olistostromes studied (Fig. 4). The most common model size ranges for coarse materials are between -9.5f and -5.5f (boulder to pebble), and for finer (matrix) materials 0.5f and 4.5f (coarse sand to coarse silt). The general trend is almost trimodal for the histograms of O-II and O-IV. Third mode value between coarse and fine size concentrations range from -2.5f to -1.5f (pebble to granule) with a relatively low concentration value, the histograms of O-VI have an appearance of unimodal trend except for several small submode values.

The cumulative curves of O-I, O-II, O-IV and O-V show three different populations of grain size distribution. These separate populations (especially fine and coarse populations) are easily identified with their mean and standart deviation on the log-probability plot (Fig. 5). Generally, the coarse populations range between -13f (2048 mm.), and -50(32 mm.), and fine populations between -10 (2 mm.) and 4.5f (0.044 mm.). After constructing cumulative curves for each olistostrome, percentile values f1, f5, f16, f25, f50, f75, f84 and f95, are read off to calculate grain size parameters, such as first percentile (C), median (M), mean size (Mz), sorting (Gı), skewness (SKı) and kurtosis (KG), as proposed by Folk and Ward (1957) (Table 2 and 3). The first percentile values of the olistostromes range from -12.85f (7500 mm.) to -7.20f (150 mm.) with anaverage of -9.97f (1000 mm.). The mean size values of the olistostromes range from -6.420 (86 mm.) to -1.83f (3.5 mm.) with an average of -3.79f (14 mm.). The sorting values

Table 1- Combined data results for photograph-grid and sieving methods.

SIZE				TOTAL COMBINED DATA															
				OLISTOSTROME - I								*OLISTOSTROME - II*							
	Class	*mm.*	*phi(Ø)*	%	*Cum %*	%	*Cum %*	%	*Cum %*	%	*Cum %*	%	*Cum %*	%	*Cum %*	%	*Cum %*	%	*Cum %*
GRAVEL		1024	-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boulder	512	-9	13.00	13.00	-	-	22.00	22.00	-	-	-	-	-	-	-	-	-	-
		256	-8	10.00	23.00	8.50	8.50	10.75	32.75	6.50	6.50	-	-	-	-	7.75	7.75	-	-
	Cobble	128	-7	6.00	29.00	15.75	24.25	10.75	43.50	7.25	13.75	-	-	7.00	7.00	8.25	16.00	16.50	16.50
		64	-6	9.75	38.75	21.25	45.50	8.75	52.25	11.25	25.00	9.50	9.50	11.50	18.50	13.75	29.75	12.00	28.50
	Pebble	32	-5	4.75	43.50	12.75	58.25	5.00	57.25	15.50	40.50	20.75	30.25	5.50	24.00	5.25	35.00	6.75	35.25
		16	-4	3.75	47.25	4.50	62.75	1.50	58.75	3.00	43.50	15.25	45.50	3.25	27.25	2.50	37.50	3.75	39.00
		8	-3	2.25	49.50	3.25	66.00	1.00	59.75	1.75	45.25	5.25	50.75	2.25	29.50	2.00	39.50	1.75	40.75
		4	-2	2.25	51.75	1.25	67.25	0.75	60.50	1.75	47.00	4.12	54.87	5.54	35.04	1.59	41.09	8.46	49.21
	Granule	2	-1	1.74	53.49	1.77	69.02	0.50	61.00	0.88	47.88	3.45	58.32	4.54	39.58	6.17	47.26	3.68	52.89
SAND	V. Coarse	1	0.0	2.71	56.20	1.82	70.84	2.73	63.73	2.06	49.94	3.28	61.60	4.17	43.75	2.27	49.53	6.10	58.99
	Coarse	0.50	1.0	12.12	68.32	9.86	80.70	13.05	76.78	12.24	62.18	3.91	65.51	14.21	57.96	5.20	54.73	7.27	66.26
	Medium	0.25	2.0	13.69	82.01	7.82	88.52	7.12	83.90	18.63	80.81	13.18	78.69	14.21	72.17	13.49	68.22	10.78	77.04
	Fine	0.125	3.0	6.22	88.23	3.34	91.86	6.63	90.53	5.49	86.30	8.62	87.31	15.81	87.98	9.06	77.28	12.47	89.51
	V. Fine	0.0625	4.0	5.34	93.57	3.72	95.58	5.97	96.50	8.70	95.0	5.97	93.28	8.29	96.27	16.12	93.40	6.73	96.24
MUD	Coarse silt	0.031	5.0	6.19	99.76	4.32	99.90	3.20	99.70	4.92	99.92	5.12	98.40	3.32	99.59	5.81	99.21	3.54	99.78
	medium silt and clay			0.24	100.00	0.10	100.00	0.30	100.00	0.08	100.00	1.60	100.00	0.41	100.00	0.79	100.00	0.22	100.00

Continued to Table 1

SIZE				TOTAL COMBINED DATA															
				OLISTOSTROME - III								OLISTOSTROME - IV							
	Class	mm.	phi(Ø)	%	Cum %	%	Cum %	%	Cum %	%	Cum %	%	Cum %	%	Cum %	%	Cum %	%	Cum %
GRAVEL	Boulder	1024	-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boulder	512	-9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boulder	256	-8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.50	1.50
	Cobble	128	-7	-	-	-	-	-	-	-	-	11.00	11.00	2.00	2.00	-	-	11.50	13.00
	Cobble	64	-6	10.00	10.00	6.50	6.50	4.00	4.00	3.75	3.75	16.00	27.00	10.75	12.75	3.75	3.75	19.50	32.50
	Pebble	32	-5	23.25	33.25	29.00	35.50	30.00	34.00	27.75	31.50	16.75	43.75	16.75	29.50	17.50	21.25	8.00	40.50
	Pebble	16	-4	20.25	53.50	22.00	57.50	28.75	62.75	26.50	58.00	8.75	52.50	15.50	45.00	12.25	33.50	6.75	47.25
	Pebble	8	-3	7.25	60.75	8.75	66.25	6.25	69.00	6.50	64.50	2.25	54.75	7.25	52.25	8.50	42.00	1.50	48.75
	Pebble	4	-2	2.50	63.25	1.75	68.00	3.00	72.00	3.00	67.50	13.50	68.25	2.25	54.50	2.25	44.25	0.25	49.00
	Granule	2	-1	3.70	66.95	4.10	72.10	3.67	75.67	4.59	72.09	6.90	75.15	14.33	68.83	9.96	54.21	9.23	58.23
SAND	V. Coarse	1	0.0	3.05	70.00	3.02	75.12	3.45	79.12	4.50	76.59	2.07	77.22	1.71	70.53	3.50	57.71	6.09	64.32
	Coarse	0.50	1.0	7.39	77.39	6.06	81.18	5.57	84.69	6.91	83.5	2.71	[illegible]	3.52	74.06	3.02	60.73	3.78	68.10
	Medium	0.25	2.0	6.06	83.45	5.62	86.80	4.58	89.27	4.55	88.05	5.40	85.33	8.14	82.20	6.63	67.36	7.78	75.88
	Fine	0.125	3.0	6.38	89.83	5.34	92.14	4.73	94.00	5.73	93.78	7.11	92.44	7.02	89.22	9.56	76.92	11.61	87.49
	V. Fine	0.0625	4.0	4.62	94.45	3.80	95.94	2.56	96.56	3.05	96.83	5.73	98.17	9.60	98.82	8.52	85.44	9.48	96.97
MUD	Coarse silt	0.031	5.0	3.87	98.32	2.82	98.76	2.10	98.66	2.06	98.89	1.80	99.97	1.18	100.00	14.56	100.00	3.03	100.00
	medium silt and clay			1.68	100.00	1.24	100.00	1.34	100.00	1.11	100.00	0.03	100.00	-	-	-	-	-	-

Continued to Table 1

SIZE				TOTAL COMBINED DATA															
				OLISTOSTROME - V								OLISTOSTROME - VI							
	Class	mm.	phi(Ø)	%	Cum %	%	Cum %	%	Cum %	%	Cum %	%	Cum %	%	Cum %	%	Cum %	%	Cum %
GRAVEL	Boulder	1024	-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		512	-9	-	-	24.00	24.00	-	-	-	-	-	-	-	-	-	-	-	-
		256	-8	27.50	27.50	26.75	50.75	25.50	25.50	22.00	22.00	-	-	-	-	-	-	9.50	9.50
	Cobble	128	-7	15.25	42.75	9.50	60.25	22.75	48.25	13.50	35.50	8.50	8.50	8.00	8.00	-	-	1.75	21.25
		64	-6	21.25	64.00	9.25	69.50	17.50	65.75	14.50	50 00	5.25	13.75	4.75	12.75	6.75	6.75	2.75	24.00
	Pebble	32	-5	10.00	74.00	5.50	75 00	9.00	74.75	8.00	58 00	10.75	24.50	11.75	24.50	10.25	17.00	8.50	32.50
		16	-4	2 25	76.25	1 00	76 00	1.75	76.50	2.25	60 25	13.50	38 00	10.75	35.25	9.50	26.50	13 00	45.50
		8	-3	1.25	77.50	0.75	76.75	1 25	77 75	0.50	60 75	9 50	47.50	9.00	44.25	19 75	46.25	11.50	57.00
		4	-2	1 50	79 00	0 75	77.50	1 00	78 75	0.29	61 07	9.46	56 96	9.39	53.64	12.53	58.78	8.07	65.07
	Granule	2	-1	0 38	79 38	0 67	78.17	0 34	79.09	0.43	61 47	11.12	68.08	11.33	64.97	9.97	68.75	7.93	73.00
SAND	V. Coarse	1	0 0	0 91	80.29	1.10	79 27	1.16	80 25	2.58	64.05	7.09	75.12	7.43	72.40	6.65	75.40	5.05	78 05
	Coarse	0.50	1.0	5.66	85.95	5.52	84.79	5.31	85.56	9.77	73 82	8.53	83 70	8.07	80.47	5.57	80.97	6.67	84.72
	Medium	0.25	2.0	6.09	92.04	6.43	91.22	5 95	91.51	11.03	84 85	4 28	87.98	4.38	84.85	4.39	85.36	4.14	88.86
	Fine	0.125	3.0	3 05	95.09	3.79	95 01	3 27	94.78	7.12	91.97	4.97	92.95	6.38	91.28	6 00	91.36	4.67	93.53
	V. Fine	0.0625	4 0	2.54	97.63	2.57	97.58	2 44	97.22	4.09	96.06	4 25	97.20	6.07	97 30	5.65	97.01	4.42	97.95
MUD	Coarse silt	0.031	5 0	2.19	99.82	2.20	99.77	2.56	99.78	3.64	99.70	2.77	99 97	2.62	99.92	2.96	99.97	1.94	99.89
	medium silt and clay			0.18	100.00	0.22	100.00	0.22	100.00	0.30	100.00	0.03	100.00	0.08	100.00	0.03	100.00	0.11	100.00

range between -3.00 (8 mm.) and -5.00 (32 mm.), the results fall into very poorly to extremely poorly sorted category (Terminology from Folk, 1980), with an average of -3.900 (15 mm.). The bimodality is contributing greatly to the very poor sorting (Fig. 4). The skewness values of the olistostromes range from -0.462 (strongly coarse skewed) to 0.774 (strongly fine skewed) with an average of +0.29 (fine skewed). Nearly symmetrical distribution with zero skewness is also present. O-I, O-II have both positive and negative skewness values, while O-III, O-IV, O-V and O-VI have positive skewness. The kurtosis values range from 1.301 (leptokurtic) to 0.563 (very platykurtic) with an average of 0.806 (platykurtic) (Folk, 1980).

In order to establish the nomenclature of the major textural groups of sediments forming the olistostromes, the proportions of gravel, sand and mud, calculated from each olistostrome sample, are plotted in a ternary diagram (Fig. 6), proposed by Folk (1954). The sediments of olistostromes are mixtures of gravel, sand and relatively minor amounts of mud, and vary from sandy gravel to muddy sandy gravel as seen in the triangular diagram. The most striking feature is the, high amount of gravel size material which is generally more than the sum of other sediment types. The average valuers between 49.51 % and 74.53 % in the olistostromes studied. Average sand fractions range from 25 %-35 % and mud fractions from 2.64 %-5.20 %. The dominant mud class is coarse silt.

The clast roundness measurements are made on projected photograph samples, (two from each olistostrome, Table 4). The average roundness class intervals is computed by multiplying the mid points of the-roundness class intervals with the areal percentage values of those roundness classes (Powers, 1953). The computed results fall in partly angular to sub-angular (1.95-2.79) range.

DISCUSSION AND INTERPRETATION OF THE RESULTS

Grain size parameters are environmentally sensitive and combination of these parameters may permit seperation and .identification of different deposits (Mason and Folk., 1958). Different combinations of grain size parameters are plotted against each other, such as mean size (Mz) - sorting (G), mean size (Mz)-skewness ((SKı), mean size (Mz)-kurtosis (KGı), skewness (SKı),kurtosis (KGı), median (M)-first percentile (C) and median (M)-quartile deviation (QDa), and compared with the same parameter combinations from previously known environments. In the plots of mean size (Mz)-sorting (Gı), mean size (Mz)-skewness (SKı), sorting (Gı)-skewness (SKı), the plots of olistostromes are seen at the outside of previously constructed trends (Figure 7, 8 and 9). In the scatter diagram of quartile deviation (QDa) versus median (M), the plots of olistostromes occur within an envelope which is different from the envelopes of flaxoturbidites and proximal-distal turbidites (Fig. 10).

CONCLUSIONS

The conclusions reached in this study may be outline as follows:

1. Both bimodal and trimodal grain size distributions are characteristic for the studied olistostromes and the bimodality contributes to the very poor sorting. Skewness is not a significant parameter for olistostromes, varying in a wide range from strongly coarse skewed to strongly fine skewed. On the other hand, the kurtosis values are in platykurtic range due to poor sorting and polymodal nature; this may be considered one of the characteristic feature of olistostromes.

2. The sediment types of olistostromes vary from sandy gravel to muddy sandy gravel, in which the average mud fraction is less in amount than gravel and sand.

3. Scatter plots of grain size parameters fall generally outside the limits of river, beach and dune environments of several previous workers. However, plots of quartile deviation (QDa) versus median (M) seem to hold the best promise for distinguishing olistostromes from deposits of other environments.

4. The average roundness values of clast constituents of olistrostromes range from angular to subangular.

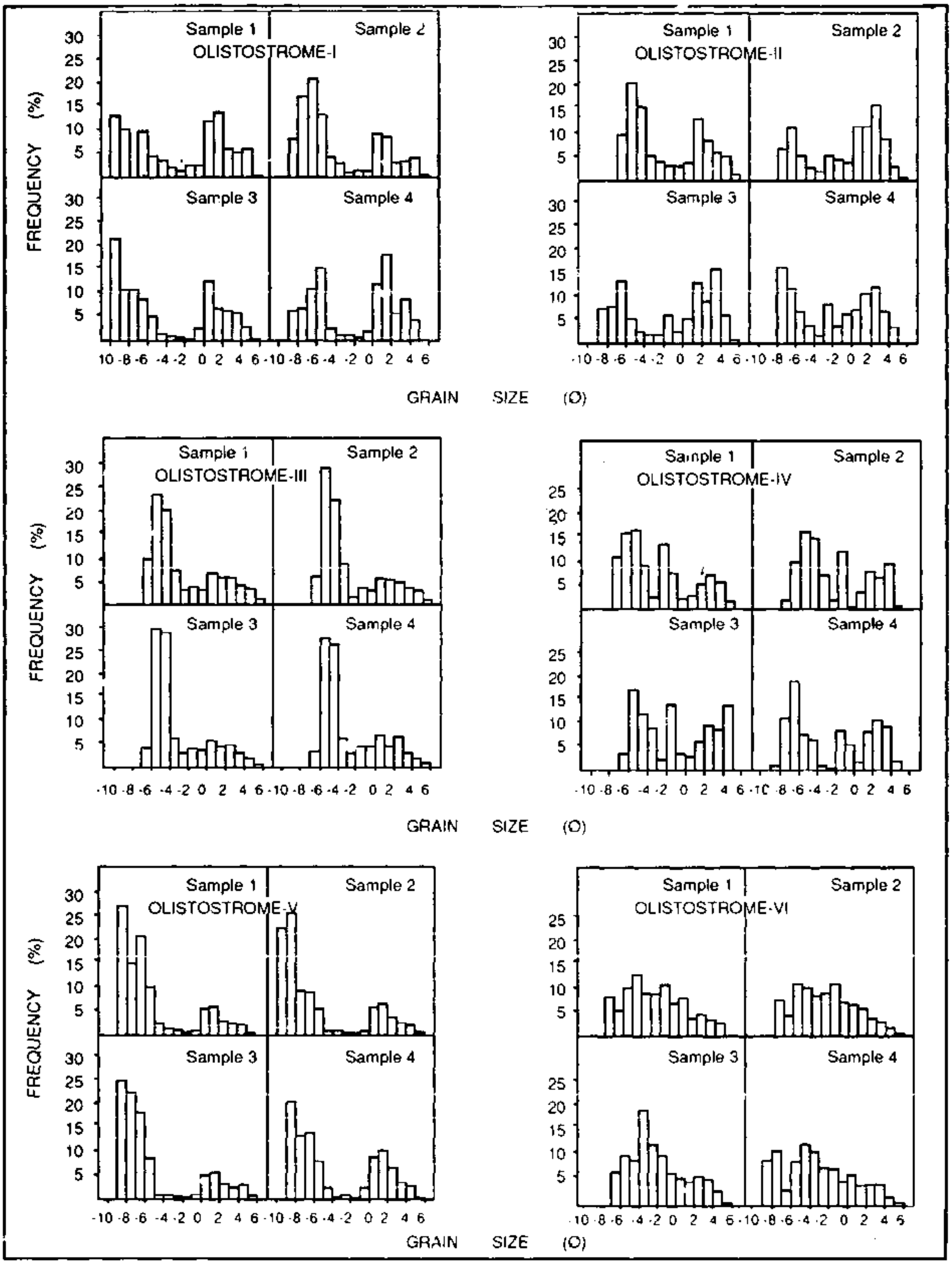


Fig. 4- Grain size distribution histograms of olistostromes (Four samples from each olistostrome unit).

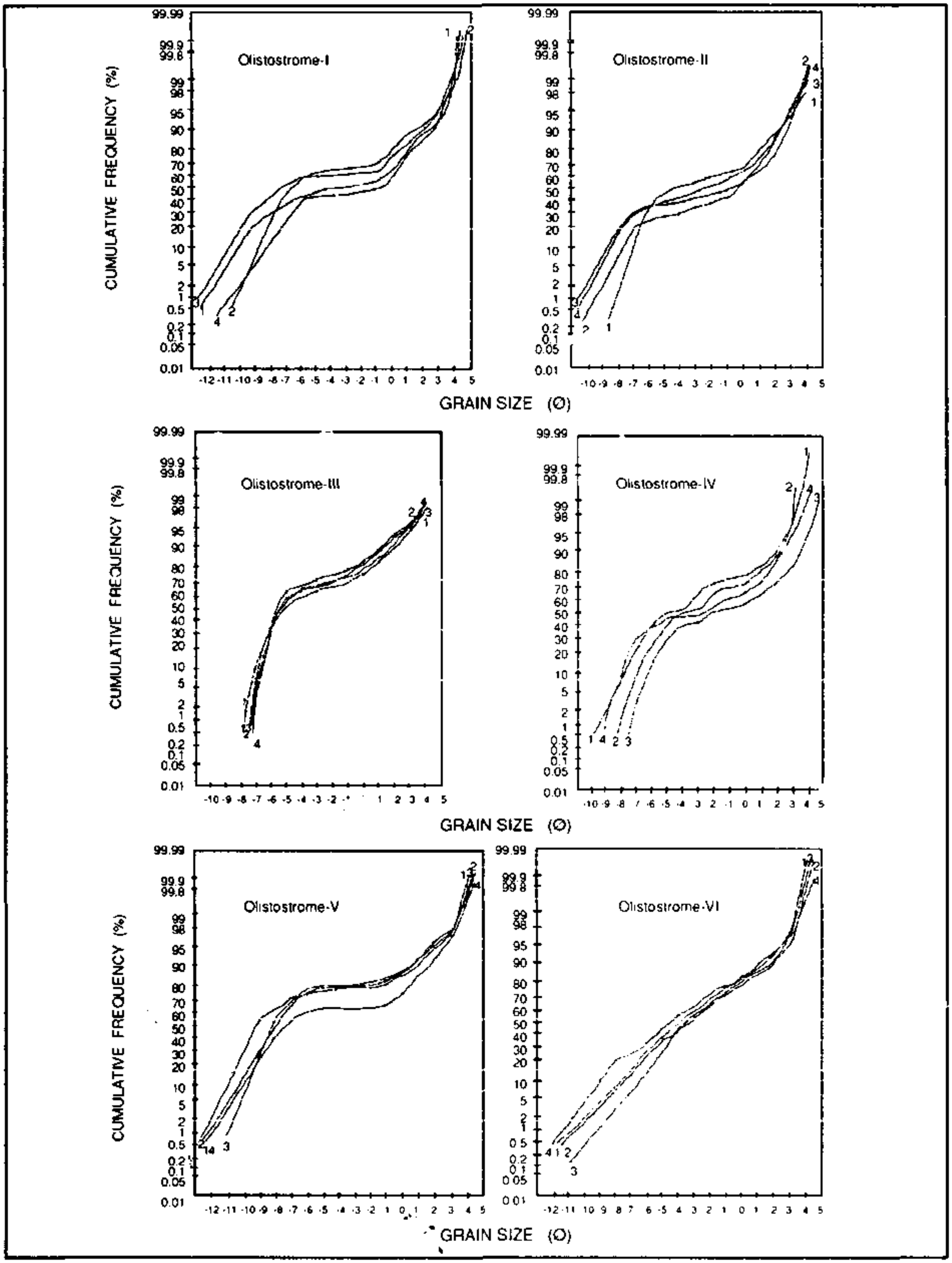


Fig. 5- Cumulative curves of olistostromes (Combined results of grain size analysis by photograph-gind method and sieve method). Four samples per olistostrome.

Table 2- Results of grain size distribution percentiles.

	PERCENTILES							
Olistostrome No.	*O1*	*O5*	*O16*	*O25*	*O50*	*O75*	*O84*	*O95*
	-12 20	-10 95	-9 75	-8 80	-4 00	0 45	1 20	3 35
	-12.40	-9 60	-8 35	-8 00	6 80	0 55	0 25	2 65
	-12 85	-11 50	-10 40	-10 00	-7 40	-0 30	0 95	2 80
	-10 90	-9 20	-7 80	-7 15	-1 00	0 95	1 70	3 20
II	-8 15	-7 30	-6 70	-6 30	-4 20	0 50	1 35	3 00
	-9 60	-8 10	-7 15	-5 50	-0 35	1 30	1 90	2 80
	-10 75	-9 30	-8 10	7 30	1 00	1 65	2 25	3 00
	-10 20	-9 20	-8 10	7 20	2 90	0 90	1 60	2 90
III	-7 65	-7 30	-6 70	6 25	5 10	0 20	1 20	3 20
	-7 30	-7 00	6 60	6 35	5 40	0 70	0 80	2 90
	-7 25	-7 00	-6 30	6 10	-5 60	2 20	0 25	2 60
	-7 20	-6 95	6 20	6 00	5 40	1 05	0 50	2 80
IV	-8 00	-8 40	7 60	7 10	5 35	1 60	0 95	2 55
	-8 20	7 50	6 70	6 20	4 30	0 10	1 30	2 70
	-7 45	6 80	6 00	5 45	2 40	1 95	2 90	3 85
	9 20	8 60	8 00	7 50	3 00	0 90	1 70	2 95
V	-12 15	-10 90	9 40	9 05	7 70	4 95	-0 20	2 20
	-12 40	-11 50	10 20	10 00	9 00	6 00	0 15	2 30
	-11 00	-10 20	9 20	8 95	7 90	4 00	0 10	2 15
	-11 80	-10 70	9 20	8 70	7 30	0 25	1 00	2 80
VI	-10 90	8 40	6 80	6 00	3 70	1 20	0 20	2 60
	10 50	-8 30	6 60	5 90	3 20	0 60	1 00	2 80
	9 20	7 20	5 70	5 00	3 55	0 95	0 70	2 90
	-11 20	9 40	8 35	6 90	4 40	1 70	0 30	2 55

Table 3- Grain size distribution parameters (in Ø units).

Olistostrome no	*First Percentile* (*c*)	*Median* (*m*)	*Mean Size* (*Mz*)	*Sorting* (σ_I)	*Skewness* (*SKI*)	*Kurtosis* (*KG*)
I	-12 20	4 00	4 18	4 83	0 008	0 611
	-12 40	-6 80	-4 97	3 95	0 507	0 652
	-12 85	-7 40	-5 62	4 89	0 509	0 573
	-10 90	-1 00	2 37	4 24	-0 375	0 622
II	-8 15	-4 20	3 18	3 57	0 395	0 597
	-9 60	0 35	1 87	3 91	0 462	0 656
	10 75	-1 00	2 28	4 45	-0 361	0 563
	10 30	2 90	3 13	4 26	0 057	0 612
III	-7 65	5 10	3 50	3 57	0 587	0 711
	-7 30	5 40	3 73	3 35	0 676	0 682
	-7 25	5 60	3 88	3 09	0 747	1 009
	7 20	5 40	3 70	3 15	0 722	0 807
IV	8 80	5 35	4 00	3 80	0 458	0 816
	8 20	4 30	3 23	3 55	0 386	0 664
	7 45	2 40	1 83	3 84	0 183	0 590
	-9 20	-3 00	3 10	4 18	0 000	0 564
V	-12 15	-7 70	5 77	4 12	0 640	1 200
	-12 40	-9 00	6 42	4 46	0 774	1 301
	-11 00	7 90	5 73	4 03	0 723	0 960
	11 80	7 00	5 07	4 40	0 589	0 592
VI	10 90	3 70	3 43	3 42	0 130	0 939
	-10 50	3 20	2 93	3 58	0 094	0 858
	9 20	3 55	2 81	3 13	0 303	1 022
	-11 20	-4 40	4 15	3 97	0 125	0 942

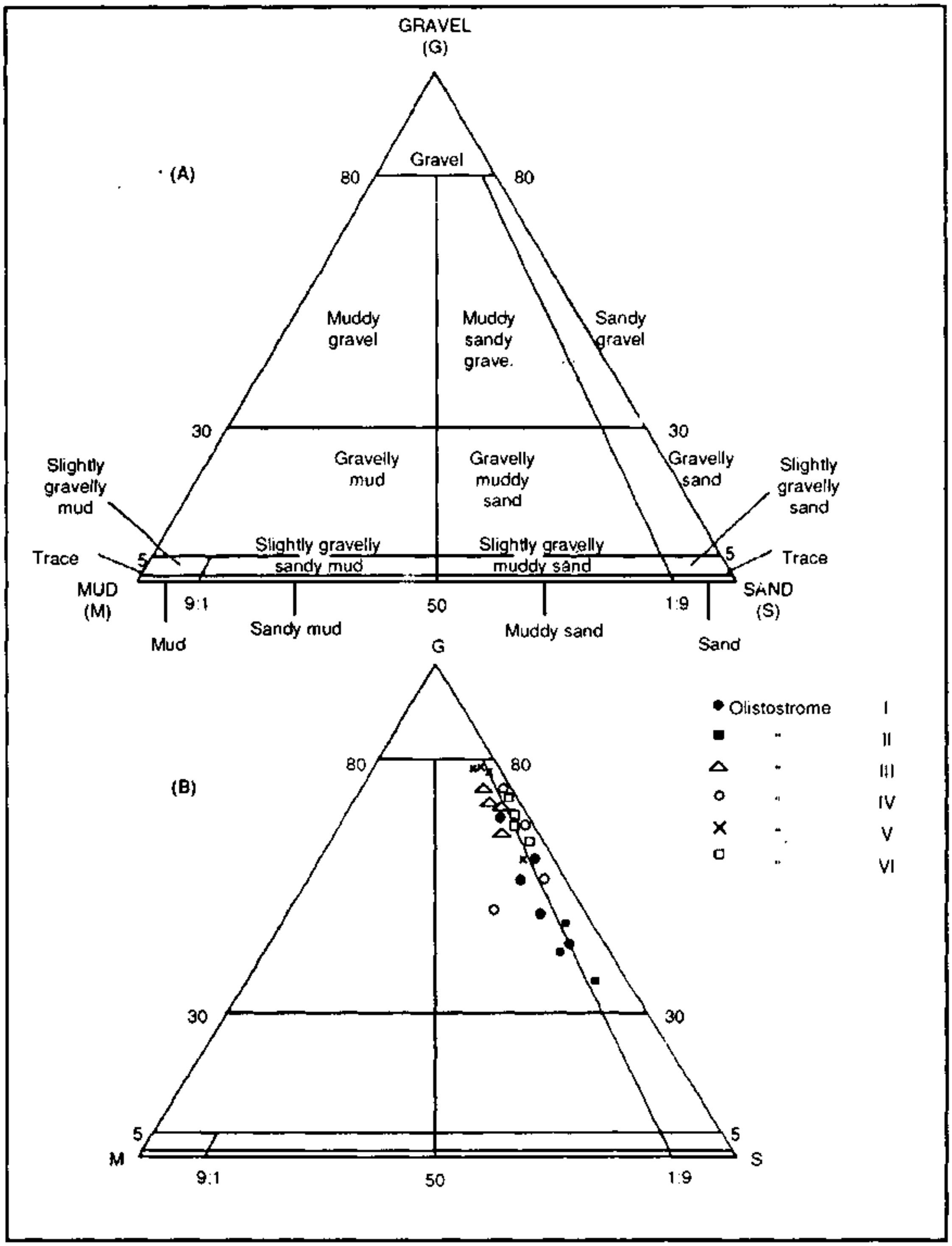
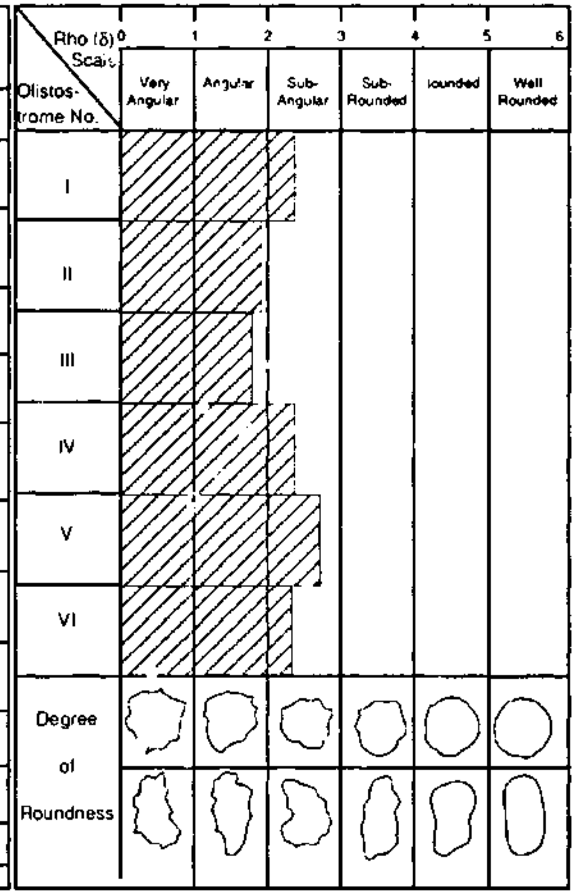


Fig. 6- A. Ternary classification of grain sizes in clastic rocks (Folk, 1954); 1. Gravel, 2. Muddy gravel, 3. Muddy sandy gravel, 4. Sandy gravel, 5. Gravelly mud, 6. Gravelly muddy sand, 7. Gravelly sand, 8. Slightly gravelly sand, 9. Slightly gravelly sandy mud, 10. Slightly gravelly muddy sand, 11. Slightly gravelly sand, 12. Mud, 13. Sandy mud, 14. Muddy sand, 15. Sand.

B. Distribution of sediment types in six olistostromes.

Table 4- Roundness values for two photograph samples of each olistostrome and their roundness histograms (Based on Powers, 1953)

Olistostrome No.	I				II				III				IV				V				VI			
Sample No.	1		2		1		2		1		2		1		2		1		2		1		2	
Rho (ρ) Scale	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Very Angular (0.0-1.0)	16	4	38	9	31	8	28	7	46	11	33	8	27	7	27	7	19	5	12	3	23	6	39	10
Angular (1.0-2.0)	70	18	118	30	83	21	53	13	137	34	82	20	70	17	75	19	69	17	49	12	64	16	98	25
Sub-Angular (2.0-3.0)	54	14	48	12	70	17	39	10	51	13	108	27	101	25	72	18	126	31	81	20	73	18	52	13
Sub-Rounded (3.0-4.0)	41	10	49	12	27	7	8	2	19	5	38	10	41	10	38	10	76	19	106	26	46	11	21	5
Rounded (4.0-5.0)	26	6	16	4	9	2	12	3	-	-	11	3	26	7	6	1	26	7	62	16	22	6	4	1
Very Rounded (5.0-6.0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total Number of Clasts	207	52	269	67	220	55	140	35	253	63	272	68	265	66	218	55	316	79	310	77	228	57	211	54
Matrix	193	48	131	33	180	45	260	65	147	37	128	32	135	34	182	45	84	21	90	23	172	43	186	46
Total	400	100	400	100	400	100	400	100	400	100	400	100	400	100	400	100	400	100	400	100	400	100	400	100
Average Roundness of Clasts	2.42		2.08		2.02		1.96		1.69		2.20		2.40		1.12		2.57		3.00		2.41		180	
	2.25				1.99				1.95				2.26				2.79				2.11			



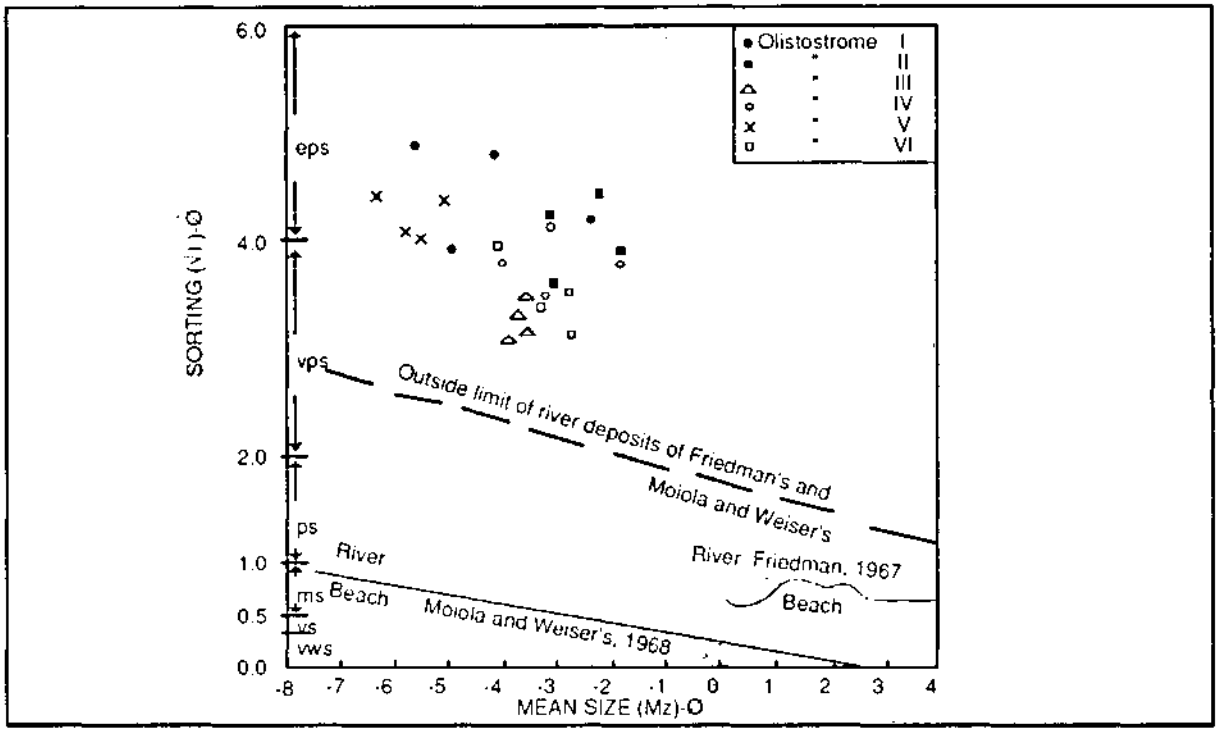


Fig. 7- Scatter diagram of Mean size (Mz)-Sorting (GI), (vws: very well sorted, ws: well sorted, ms: moderatelly sorted, ps: poorly sorted, vps: very poorly sorted, eps: extremely poorly sorted).

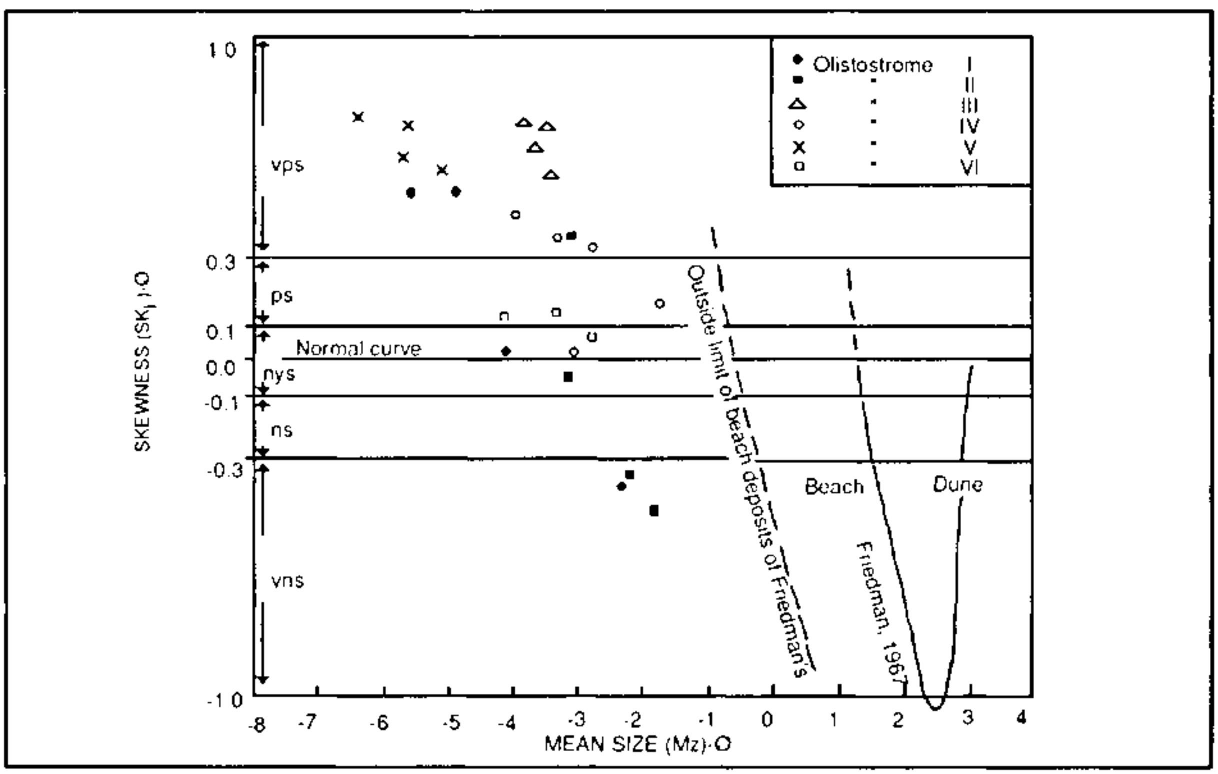


Fig. 8- Scatter diagram of Mean size (Mz)-Skewness (SKI), (scs: strongly coarse skewed, cs: coarse skewed, ns: near symmetrical, fs: fine skewed, sfs: strongly fine skewed).

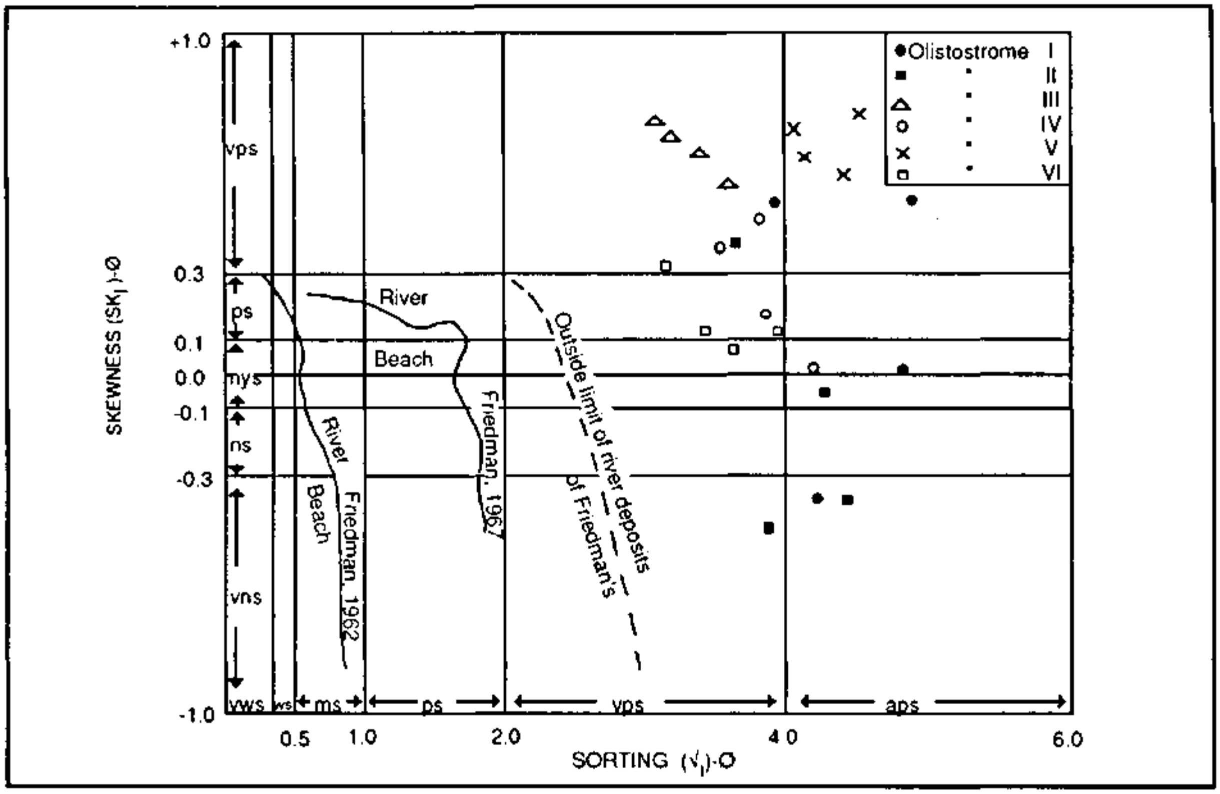


Fig. 9- Scatter diagram of Sorting (GI)-Skewness (SKI), (vws: very well sorted, ws: well sorted, ms: moderatelly sorted, ps: poorly sorted, vps: very poorly sorted, eps: extremely poorly sorted and scs: strongly coarse skewed, cs: coarse skewed, ns: near symmetrical, fs: fine skewed, sfs: strongly fine skewed).

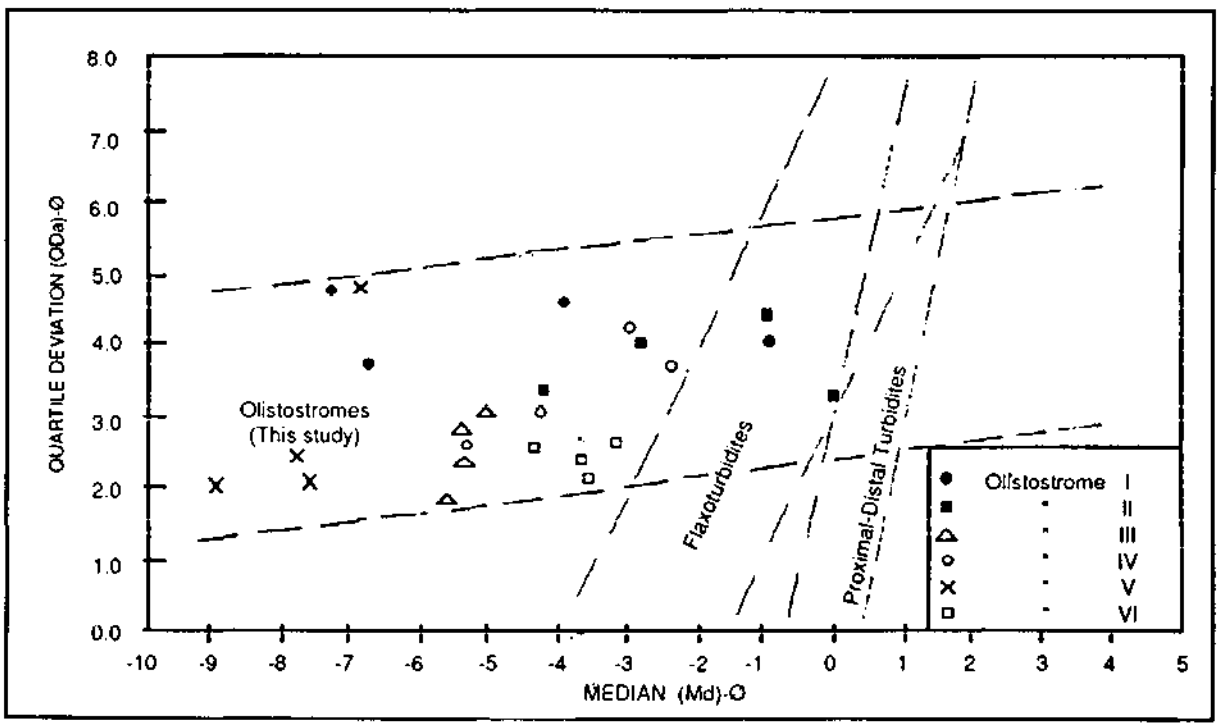


Fig. 10- Scatter diagram of Median (M)-Quartile deviation (QDa) (Based on Buller and Mc Manus, 1972).

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