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GRAIN SIZE ANALYSIS AND CLAY MINERALS OF THE NILE BOTTOM SEDIMENTS, EGYPT

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Abstract. After the construction of the High Dam, the gradual northwards decline of the average particle size of the suspended- and bedload of the Nile is no more existent. Effects of annual flood have ceased, giving way to local geologic processes exerted by the controlled highly competent waters passing through the Dam gates. A diversity of sources of clastics and a paradoxy of transportation-deposition processes are, consequently, exhibited in the results of size analysis and clay mineralogy along the main stream and along the Rosetta and Damietta branches.

INTRODUCTION

This paper is concerned with the size analysis and clay mineralogy of some samples collected from the bottom of the River Nile. Twelve sampling sites are encountered from Nage' Hammadi to the Mediterranean along the main stream and along its two main distributaries. Along the main stream, samples were collected from Nage' Hammadi, Assuit, Beni Suef, Helwan, Rod El-Farag and El-Manashi. Samples of El-Qanater (Delta Barrages) represent the stream just at the divergence into its two branches. Along the Damietta Branch, samples were taken at Zefta, El-Mansoura and Farskour, and along the Rosetta branch samples were taken at Kafr El-Zayat and Edfina (Fig. 1).

EXPERIMENTAL

The samples were first examined macroscopically and using a binocular microscope for the reconnaissance of their clastic and biogenic constituents and to determine the convenient weight for mechanical analysis.

For size analysis, the samples were washed repeatedly with dilute (1.2%) HCl at 60—80°C while being gently stirred to dissolve any admixed carbonates. Hydrogen peroxide (30%) was used for the assimillation of organic material. The following fractions were separated by wet siev-

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ing: medium gravel (> 2000 μ), fine gravel (2000—1000 μ), coarse sand (1000—500 μ), medium sand (500—200 μ) and fine sand (200—63 μ). Finer fractions were separated by the sedimentation method according to their settling velocites applying Stoke's Law. These are: coarse silt (63—20 μ), medium silt (20—6.3 μ), fine silt (6.3—2 μ) and clay (< 2 μ). From the results obtained, cummulative curves were drawn and the values of sorting (So), skewness (Sk) and kurtosis (Ku) were calculated therefrom. The estimated values of sand, silt and clay were plotted on the ternary diagram of Picard (1971) in order to classify samples with respect to their contents of these size classes.

The clay minerals were identified in oriented slides of the < 2 μ fraction. Six millilitres of the clay suspension were spread over 3 glass slides (4×2.5 cm each) and left to settle and dry. X-ray diffractometry was carried out using a Philips equipment at the instrument settings of: cobalt radiation, iron filter, potential 32 kV, current 12 mA, panel voltage 1850 vdc, scanning speed 1° 2Θ per minute and chart speed 1 cm per minute. The runs were limited to the scanning range from 2 to 40° 2Θ. Three runs were taken for each sample, viz. untreated, glycolated (saturated with 1 : 10 glycerol in ethyl alcohol for twelve hours) and heated (at 550°C for two hours). The identification of clay minerals was carried out using the data given by Molloy and Kerr (1961), Millot (1970) and Carroll (1974). Semi-quantitative determinations of clay minerals were carried out after the consideration of Weaver (1958), Brown (1961), Pierce and Siegel (1969) and Carroll (1974).

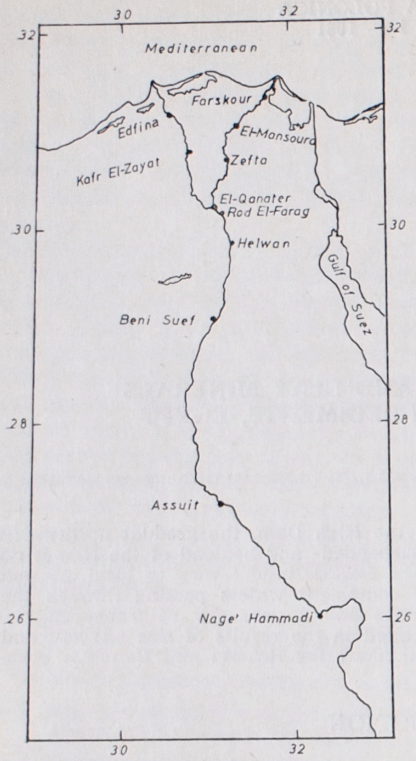

Fig. 1. Location map

RESULTS AND DISCUSSION

The Nile bottom samples exhibit a wide variety of grain size, content of plant remains and shells and shell fragments of fresh-water Gastropods and Pelecypods. In some samples, chips of limestone and/or building bricks represent fragments of the man-made stream linings along the urban areas of the Nile Valley.

The results of mechanical analysis (Table 1) show that most of the analyzed samples are either devoid of or contain negligible amounts of

Table 1

Mechanical analysis data

Location	Sample No	> 2000 μ	2000—1000 μ	1000—500 μ	500—200 μ	200—63 μ	63—20 μ	20—6.3 μ	6.3—2 μ	<2 μ	sol. + org. (%)
Nagé Hamadi	19	—	—	0.04	1.14	29.05	23.15	12.40	3.60	18.75	11.87
Assuit	8	—	—	—	3.42	47.96	21.04	3.84	1.56	2.96	19.22
	9	—	—	—	2.04	43.59	25.00	10.30	5.15	7.35	6.57
	10	—	—	—	1.72	43.38	23.50	9.80	5.40	11.20	5.00
	11	—	—	—	1.31	60.33	18.06	2.34	1.40	9.51	7.05
	18	—	—	—	1.04	69.90	11.50	2.05	1.15	8.05	6.31
Beni-Suef	29	—	—	1.22	2.15	51.76	27.0	6.50	2.85	7.15	1.37
	30	0.99	0.20	0.38	1.11	38.78	30.10	10.15	5.05	10.10	3.14
Helwan	2	—	—	—	0.24	45.95	24.15	9.05	4.45	8.45	7.71
	3	1.19	3.02	6.58	38.52	28.77	0.96	1.02	0.18	3.16	16.60
	15	1.54	1.99	16.74	50.20	18.67	3.83	0.45	0.40	2.35	3.83
	27	—	—	—	0.21	46.92	31.75	6.45	3.10	7.40	4.17
Rod El-Farag	1	—	0.74	2.39	4.31	47.91	23.85	5.05	3.25	4.25	8.25
	17	1.77	0.43	1.18	17.78	51.93	16.80	2.15	0.75	6.25	0.96
El-Manashi	4	—	—	—	0.03	5.94	46.95	14.80	4.95	13.55	13.78
El-Qanater	22	2.97	2.47	28.84	41.44	12.93	3.20	0.75	0.30	0.90	6.20
	23	1.30	0.23	2.60	58.13	27.98	0.20	0.10	0.05	0.50	8.91
	28	—	1.11	8.59	56.00	16.78	4.45	2.25	1.25	3.75	5.82
Zefta	5	1.57	1.16	0.71	18.13	59.98	3.73	1.10	0.57	8.50	4.55
	21	1.05	0.97	2.12	4.08	27.35	21.90	12.55	5.50	14.15	10.33
	25	—	0.19	2.94	38.29	50.66	1.95	0.35	0.20	0.75	4.97
El-Man-Soura	12	0.51	0.95	1.90	3.54	45.48	22.00	6.35	1.65	11.40	6.22
	13	—	—	—	0.17	53.30	20.90	5.70	2.30	13.00	4.63
	16	—	0.96	1.47	9.23	68.73	9.65	1.35	0.25	5.60	2.76
Faraskour	7	—	—	3.35	25.05	23.67	6.80	7.40	5.05	11.90	16.78
Kafr El-Zayat	14	—	—	—	0.19	24.67	18.15	12.35	7.05	28.2	9.39
	24	—	—	—	0.55	28.00	22.60	14.75	8.80	12.25	12.97
Edfina	6	1.08	0.66	3.18	17.97	38.49	9.45	2.90	1.75	9.95	14.57
	26	—	—	—	2.23	15.13	17.90	19.20	14.05	17.06	16.44

Frequency is given in weight per cent.
Sol. + org. = loss in weight due to HCl and H_2O_2 treatment.
Table 1: Cont.

particles coarser than 1mm. The presence of as high a percentage of this size as 34 in sample No. 22 from El-Qanater may indicate a local derivation from the bank rocks. However, the results reflect clear dissimilarities in the frequency of a given size fraction in the different localities and in samples from one and the same locality.

Before the construction of the High Dam, Semeika (1940) reported a continuous downstream decline in the average size of the suspended sediments of the Nile between Halfa and El-Gaafra. This decline may have been caused by either or both of the abrasive action and the decreased stream competence related to decline in stream gradient (Pettijohn, 1975), and must have been accompanied by a decline in the average size of the bedload along this relatively short distance. During the present study, no trend of decrease in median diameter (Md) was detected from south to north either along the main stream or along the Rosetta or the Damietta branches (a distance more than 800 km). Table 2 contains a list of the parameters calculated from the results and Fig. 2 is a plot of their values to show variation.

The values of the coefficient of sorting (So), calculated according to the equation of Trask (1932), showed no trend of variation from south to north (Fig. 2). Progressive sorting occurs when a decrease in gradient is accompanied by a relatively small increase in sediment discharge where some of the suspended load settles to the bottom and becomes a part of the bedload (Jordan et al., 1964). The view that sorting is not a measure of maturity since it may be achieved very quickly under normal conditions (Pettijohn, 1957) may explain the relatively high sorting values (values below 2) in some of the samples analyzed.

Fig. 2 shows that neither the values of skewness nor those of any of sand, silt or clay percentages show any trend of variation.

According to the classification of Picard (1971), the bottom sediments of the Nile are mainly sands and silty sands, with less frequent sandy muds and silty muds, and minor sandy silts, silts and clayey silts (Fig. 3). The plottings are confined to the two fourths representing sand and mud. The relatively high percentage of clay, above 15% of the total weight, shown in three samples (Table 1), may indicate previous flocculation of the clay particles into coarser aggregate particles during transportation and settling.

X-ray diffraction analysis has shown that the clay fraction is composed mainly of montmorillonite with subordinate illite and kaolinite. Chlorite was detected in only one sample (sample 8 from Assuit, Table 3). Montmorillonite constitues 88% of the total clay fraction in sample 19 from Nage' Hammadi. It is variable in other samples and is present only in minor amounts in samples 15 and 16 from Helwan and El-Mansoura, respectively. Illite content varies from 0 to 43% of the clay fraction. Kaolinite, on the other hand, does not exceed 24% (in sample 14 from Kafr El-Zayat) and is absent in some samples.

The concentration of the individual clay minerals in the different localities showed no trend of variation either from south to north or from the Rosetta to the Damietta branch. The average values of these minerals in the clay fraction of the samples studied are as follows: montmorillonite 61.5%, illite 21.4% and kaolinite 17.1%.

The origin of these clay minerals seems to be a complex problem. The Abbysynian Plateau cannot be abandoned as a source area. The

Table 2

Calculated mechanical parameters

Location	Sample No	Clastic %	Md (μ)	So[1]	Sk[2]	Ku[3]	sand[4] %	silt[4] %	clay[4] %
Nagé Hamadi	19	88.13	31	3.74	0.53	—	34	44	22
Assuit	8	80.78	80	1.67	0.88	0.27	64	33	4
	9	93.43	60	2.35	0.61	0.33	49	43	8
	10	95.00	59	2.61	0.44	—	48	40	12
	11	92.95	85	1.67	0.78	—	66	24	10
	18	93.69	96	1.43	0.90	0.22	76	16	8
Beni-Suef	29	98.63	70	1.72	0.62	0.24	56	37	7
	30	96.86	52	2.05	0.62	—	42	47	11
Helwan	2	92.29	62	2.09	0.55	0.28	50	41	9
	3	83.40	230	1.53	0.99	0.18	93	3	4
	15	96.17	330	1.60	0.76	0.24	92	5	3
	27	95.83	60	1.78	0.79	0.26	49	43	8
Rod El-Farag	1	91.75	70	1.60	0.88	0.20	60	35	5
	17	99.04	115	1.75	0.80	0.24	73	20	7
El-Manashi	4	86.22	20	2.06	0.51	—	7	77	16
El-Qanater	22	93.80	415	1.52	0.84	0.25	94	5	1
	23	91.09	235	1.29	0.98	0.23	99	0.5	0.5
	28	94.18	300	1.54	0.76	0.25	87	9	4
Zefta	5	95.45	125	1.50	1.03	0.18	85	6	9
	21	89.67	43	3.34	0.44	—	38	46	16
	25	95.93	180	1.44	1.08	0.25	97	2	1
El-Mansoura	12	93.78	72	1.96	0.67	—	55	33	12
	13	95.37	72	1.95	0.62	—	56	30	14
	16	97.24	105	1.53	1.19	0.26	83	12	5
Farskour	7	83.22	120	5.10	0.18	—	63	23	14
Kafr El-Zayat	14	90.61	17	—	—	—	27	42	31
	24	87.03	32	3.23	0.50	—	33	53	14
Edfina	6	85.43	120	1.99	0.77	—	71	17	12
	26	83.56	13	3.75	0.85	—	18	61	21

1 — Sorting coefficient, $So = P_{25}/P_{75}$

2 — Skewness, $Sk = \frac{P_{25} \times P_{75}}{P_{50}^2}$

3 — Kurtosis, $Ku = \frac{P_{25} - P_{75}}{2\ (P_{10} - P_{90})}$

where P_{10}, P_{25}, etc. are diameters at the given percentiles on the cummulative curve.

4 — Values for sand, silt and clay are obtained after correction of their sum to 100%.

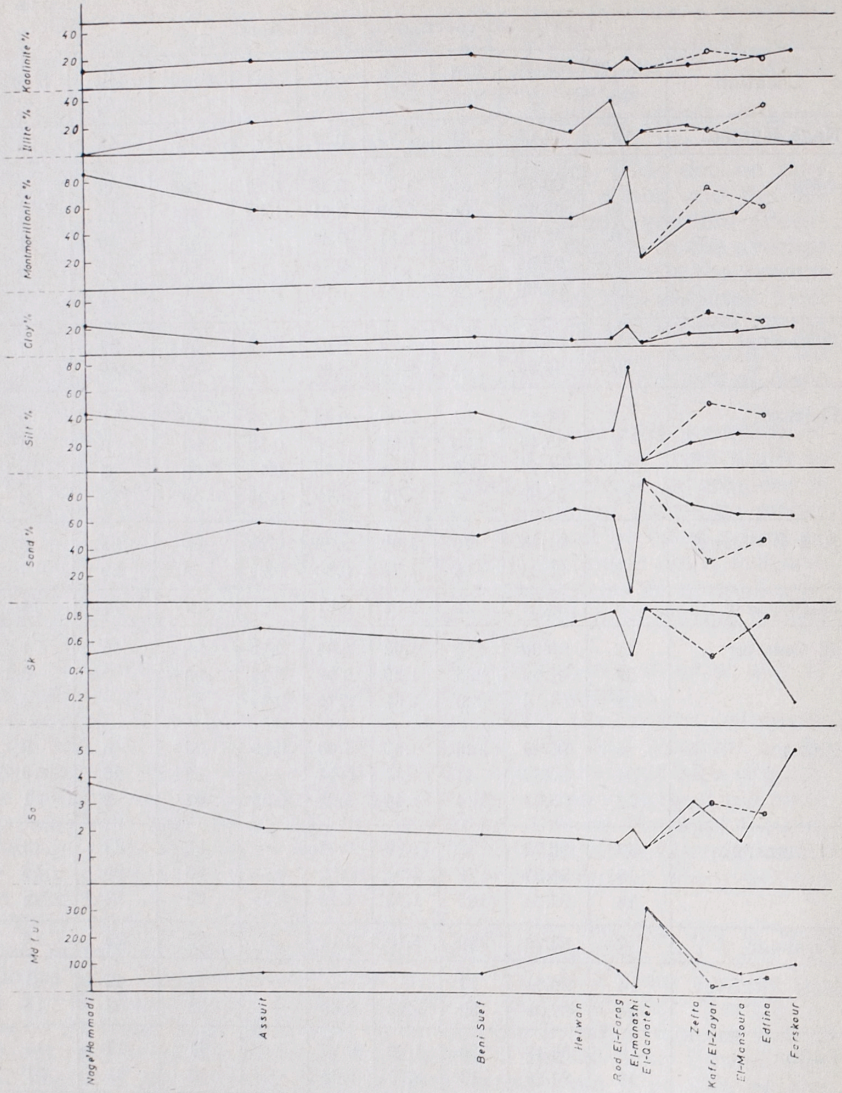

Fig. 2. Variation of mechanical parameters and mineral frequencies

High Dam settles most, but not all, of these sediments on the upstream side. Attia (1954) gave a comprehensive report wherein he stated that the Nile, in Egypt, carves into rocks from the Precambrian Basement to the Recent Delta. It thus passes through granites, syenites, schists and gneisses of the Precambrian, Nubian sandstones, Cretaceous limestones, chalky limestones and shales, Eocene limestones and minor Plio-

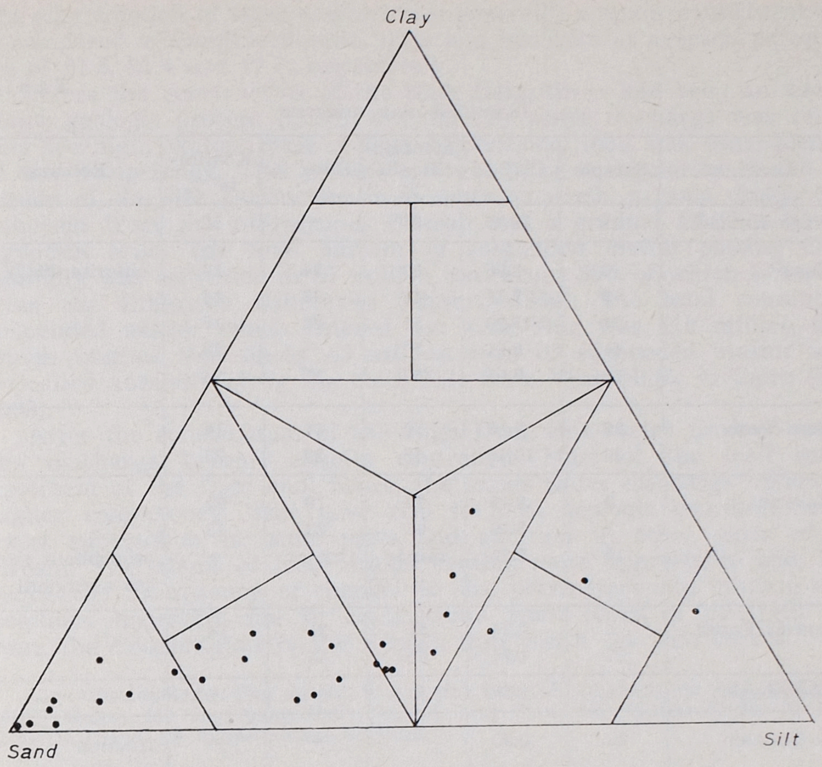

Fig. 3. Plots of analysed samples on the ternary diagram of Picard (1971)

cene and Pleistocene sediments intervening between the alluvial plain and the cliffs boardering the Valley, as well as in the wadies draining into it. The contribution of any of these rock units in the Nile sediments is indispensable and must be taken into consideration according to the order of its contribution, especially in such a case of high competency of the Nile waters on the downstream side of the Dam. Furthermore, the contribution of these sources in the non-clay constituents is of prime importance. The statement of Krumbein and Tisdel (1940) and Smalley (1966) that the texture and composition of the source rock formulates the shape, size and composition of river sediments much more than the transportation processes do, is important in this respect.

CONCLUSION

The Nile bottom sediments constitute a wide variety of grain size, composition and content of biogenic material. The clastic portion of these sediments is classified as sands, silty sands, sandy muds, silty muds, sandy silts and clayey silts. Most of these sediments are well-sorted, negatively skewed and give leptokurtic size-frequency diagrams.

Table 3

Identified clay minerals

Location	Sample	Clay %	Montmorillonite[1] %	Illite[1] %	Koalinite[1] %	Remarks
Nagé Hamadi	19	18.75	88	—	12	
Assuit	8	2.96	39	34	19	chlorite 8%(?)
	9	7.35	48	38	14	
	10	11.20	57	28	15	
	11	9.51	77	—	23	
	18	8.05	59	17	24	
Beni-Suef	29	7.15	50	34	16	
	30	10.10	48	29	23	
Helwan	2	8.45	68	10	22	
	3	3.16	65	22	13	
	15	2.35	minor	major	—	amorphous matter abundant
Rod-El Farag	1	4.25	55	31	14	
	17	6.25	60	40	—	
El-Manashi	4	13.55	83	—	17	
El-Qanater	22	0.90	—	—	—	fraction insufficient
	23	0.50	—	—	—	fraction insufficient
	28	3.75	47	32	21	
Zefta	5	8.50	56	26	18	
	21	14.15	69	18	14	
	25	0.75	—	—	—	fraction insufficient
El-Mansoura	12	11.40	63	19	18	
	13	13.00	79	—	21	
	16	5.60	minor	—	—	amorphous material abundant
Farskour	7	11.90	80	—	20	
Kafr El-Zayat	14	28.20	76	—	24	
	24	12.25	57	28	15	
Edfina	6	9.95	56	25	19	
	26	17.05	48	43	9	

1 — Clay minerals are given as percentages of the total clay.

The clay fraction of these sediments is generally a minor constituent and is composed of montmorillonite, illite and kaolinite at average percentages of 61.5, 21.4 and 17.1; respectively.

Before the construction of the High Dam, there had been an annual major geologic process (flood) wherein the water discharge was relatively too high. Waters were of high suspensional load and, consequently, of low competency. This process had exhibited a regularity in the variation of the size parameters from south to north, a main clastic contribution from the Abbysynian Plateau and a gradual addition to the Egyptian soils. The total amount of suspended matter passing Cairo annually was estimated as 57 million tons about 95% of which is derived from the Ethiopian tributaries (Shukri, 1950). The total amount of suspended matter which entered the main Nile was 110 million tons, which implies that about 53 million tons of suspended matter were deposited annually along the main Nile from Wadi Halfa to Cairo (Ball, 1939).

After the construction of the High Dam, this major process ceased, the discharge became strictly controlled. Most of the load settles upstream of the Dam and, hence, the lesser water discharge became of higher competency. This gave rise to local geologic processes which exert subtraction in some parts and addition in other parts of the stream. The effect of local drains became more appreciable and, consequently, inconstancy of changes in size parameters and mineral compositions appeared due to contribution from rocks of different age, from the Precambrian to the Recent, into which the Nile carves.

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Ahmad M. MORSY

SKŁAD ZIARNOWY I MINERAŁY ILASTE OSADÓW DENNYCH NILU (EGIPT)

Streszczenie

Budowa tamy assuańskiej spowodowała zmiany w składzie ziarnowym materiału transportowanego przez Nil. Zaobserwowano zanik prawidłowości polegającej na stopniowym zmniejszaniu się ku północy przeciętnej wielkości ziarn materiału zawieszonego i wleczonego po dnie Nilu. Skutki dorocznych powodzi ustały, ustępując miejsca lokalnym procesom geologicznym związanym z działalnością wód przechodzących przez śluzy tamy. Różnorodność źródeł osadów klastycznych oraz zakłócenia procesów transportu i sedymentacji znajdują odbicie w wynikach analizy składu ziarnowego i zespołu materiałów ilastych osadów wzdłuż głównego biegu rzeki oraz jej odnóg Rosetty i Damietty.

OBJAŚNIENIA FIGUR

Fig. 1. Lokalizacja próbek
Fig. 2. Zmienność parametrów rozkładu wielkości ziarn i składu mineralnego
Fig. 3. Analizowane próbki na tle trójkątnego diagramu Picarda (1971)

Ахмад М. МОРСИ

ЗЕРНОВОЙ СОСТАВ И ГЛИНИСТЫЕ МИНЕРАЛЫ ДОННЫХ ОСАДКОВ НИЛА (ЭГИПТ)

Резюме

Строительство Ассуанской плотины обусловило изменение зернового состава материала переносимого Нилом. Констатировано исчезновение закономерности заключающейся в том, что по направлению к северу постепенно уменьшалась средняя величина зерен материала переносимого во взвешенном состоянии или волоченного по дну Нила. Последствия ежегодных наводнений прекратились, уступая место локальным геологическим процессам, связанным с деятельностью вод проходящих через плюзы плотины. Разнообразие источников кластических осадков, а также нарушения процессов транспорта и осадкообразования находит отражение в результатах анализов зернового состава и комплекса минералов глинистых осадков вдоль главного русла реки и ее ответвлении Росетты и Даметты.

ОБЪЯСНЕНИЯ ФИГУР

Фиг. 1. Локализация проб
Фиг. 2. Изменчивость параметров распределения величины зерен и минерального состава
Фиг. 3. Анализированные пробы на фоне треугольной диаграммы Пикарда (1971)