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AN EXAMINATION OF THE LIGHT FRACTION OF SOME EGYPTIAN SOILS

by

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INTRODUCTION

The following article contains the results of mineralogical study of sand separates of surface soil samples, i.e., the upper 20 inches, from widely separated areas in Egypt. The soils of the Nile Valley of Egypt are formed largely from the weathering products of the igneous rocks situated in the Ethiopian plateau. Erosion washes the soil into the Nile river which carries suspended material over hundreds of miles to the Egyptian delta. The clay fraction of these alluvial soils is mainly composed of illite (HAMDI, 1959).

The influence of the mineral composition of soils upon their agricultural value has been discussed by HAWKINS and GRAHAM (1951), Mc ALEESE (1958), BLACK (1957), MARSHALL and JEFFRIES (1946), JEFFRIES (1947, 1949) and many others. The presence of a fair amount of feldspars in soils seems to reflect their productivity and their ability to withstand intensive cultivation over long periods of time. The sand separates in soils, which were formerly regarded as inert, are now acknowledged also to play an important part in the chemical reactivity of soils. Moreover, the knowledge of the mineral composition of the sand separates in soils would contribute towards a greater understanding of the effects of weathering on the reserve plant-nutrient minerals.

The minerals that comprise the sand and silt fractions contain most of the elements essential for plant growth as a part of their crystal structure. The minerals other than quartz, include species that contain such nutrients as calcium, magnesium, and potassium. On weathering, the plant nutrients contained in such minerals are released gradually in soluble forms that can be used by plants. The content of these nutrients varies directly with the content of minerals other than quartz. The fertility of the soil increases with the percentage of such minerals. The data of NICOLS (1939) cited by BLACK (1957), as a further indication of the soil fertility implications of the mineralogical nature of sand separates, confirms that the fertility of the soil increases with the percentage of minerals other than quartz in the fine sand fraction.

The mineralogical methods offer a field of investigation which should greatly

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add to our knowledge of the general processes of soil formation. Generally, in petrographic examinations of sands, only the heavy fraction is examined, as this part usually permits of a good characterization of the sediment and its origin much more rapidly than this is possible with the light fraction. However, when the sediments from two or more source areas are mixed, the heavy fraction may afford no clear insight into the relative quantities of the different supplies, especially when their respective heavy mineral contents are widely divergent (KOLDEWIJN, 1955). An examination of the light fraction, since it constitutes a much greater part of the sediment may present a better picture of the actual proportions.

FUNDAMENTAL CONCEPTION OF METHODS USED IN SUBDIVIDING SEDIMENTS INTO MINERAL GROUPS

Isolation of mineral fractions preparatory to use of one or more methods of identification is a necessary pretreatment to many petrographic studies. It is usually difficult, if not impossible, to make a complete separation of the constituents of a heterogeneous mineral assemblage. The study of such an assemblage, however, is greatly facilitated by a separation into two or more groups, each of which is comparatively free from representatives of the other groups. In particular this procedure is advantageous where some constituents are present in very small proportion and where their isolation will not only furnish a quantitative estimate of their occurrence but will permit their closer study and more accurate identification.

Many types of separation methods are available but that based on specific gravity differences and the use of heavy liquids is the most favourable one. SULLIVAN (1927) has investigated most of the substances that have been proposed as heavy liquids. TWENHOFEL (1939) stated that separation of particles from the higher silt range upward is readily accomplished by gravity settling, but for particles of smaller dimensions a centrifuge is essential. Also many types of separation tubes have been devised for use with heavy liquids (ROSS, 1926). However, PETTIJOHN (1939) summarized the properties of ideal separating vessel as follows: 1- inexpensive. 2- not too fragile. 3- be so constructed as to reduce loss with volatile liquids to a minimum. 4- be so formed that the grains may be stirred or agitated, and 5- be so made that the mineral fractions may be readily removed and not so narrow that clogging occurs during separation.

The simple apparatus incorporating these properties as designed by Dr. J. Ch. L. FAVEJEE and as used in the following investigation is fairly satisfactory.

METHODS OF MINERALOGICAL IDENTIFICATION

The identification of the light minerals, that is the fraction which, after the separation by bromoform, remains floating on the surface of the heavy liquid, presents great difficulty. The distinctions of feldspar and quartz, are the main problems in the identification. The method developed by FAVEJEE, NOTA and BAKKER was applied. This method provides the distinction of all feldspars from quartz (NOTA and BAKKER, 1960) and in addition it concentrates the different minerals in distinct specific gravity groups (FAVEJEE[1]). Briefly, it consists of using mixtures of decaline ($C_{10}H_{18}$) and bromoform having fixed specific gravities for the separation. The general mineral groups that have been obtained are as follows:

[1] A paper dealing with the separation technique is in preparation by Dr. J. CH. L. FAVEJEE.

Group 1: Spec. grav. < 2.59: designated as orthoclase group and may include, orthoclase microcline, gypsum, chert and aggregates as well as clay minerals if present.

Group 2: Spec. grav. (2.59–2.63): designated as albite group and may include albite, traces of orthoclase, quartz with gas inclusions, chert and altered feldspar.

Group 3: Spec. grav. (2.63–2.67): designated as quartz group and may include quartz, oligoclase, aggregates and traces of andesine.

Group 4: Spec. grav. (2.67–2.89): designated as intermediate plagioclase, and may include andesine, labradorite, quartz with inclusions of heavy minerals, muscovite, biotite, chlorite group aggregates and altered feldspar.

Group 5: Spec. grav. > 2.89: designated as heavy minerals.

The first and second group are examined microscopically using a liquid having a refractive index 1.528. The third group is examined in Canada-balsam using the universal stage, in accordance with the method described by DOEGLAS (1940) to distinguish between quartz and oligoclase. The fourth group is examined in Canada balsam.

MATERIALS AND METHODS

The fraction of the samples used for light mineral analyses falls between 500 and 50 microns. That fraction was obtained during the preparation of the heavy mineral fraction, as described in a previous publication (KHADR, 1960). In the preparation of this fraction, it was boiled with concentrated HCl, and again with HNO_3 in order to clear mineral grains of iron oxide or other coatings. The mentioned fraction was then used for separation with bromoform (spec. grav. 2.89) in a special funnel. From the light separates slides were made with Canada-balsam. Countings have been made as described by EDELMAN and DOEGLAS (1933). The results obtained are tabulated in table 1. Owing to the treatment with concentrated acids, certain detrital minerals are likely to be partly or wholly dissolved. From the results it must be stated here that no gypsum, glasses, chlorite group, biotite and clay-like minerals were found. Of the intermediate plagioclases, also considered to be subject to complete or partial solution, only andesine in very small percentages was present in two samples. The localities at which the samples were obtained are shown in Fig. 1.

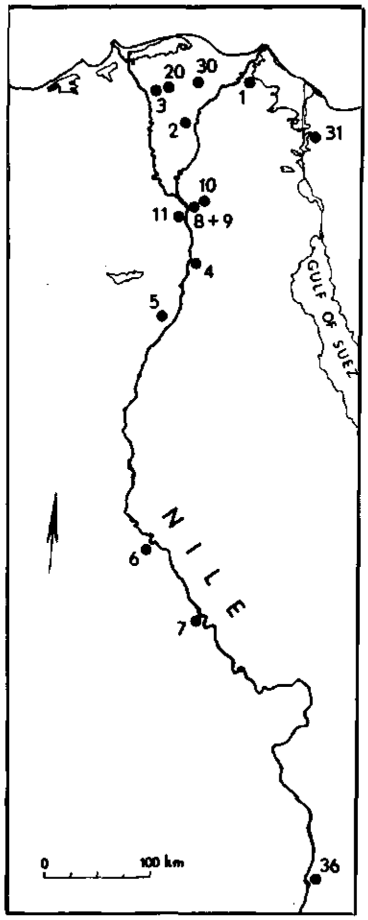


FIG. 1. Sketch map of Egypt showing locations of soil samples studied.

To have a detailed account of the minerals four samples (i.e., no. 3 from the middle of the Delta, no. 8 from the Nile-bank at Cairo, no. 10 at the fringe of the east desert near Cairo, no. 31 from the east desert at Kantara (east of Suez Canal), were selected and treated in the following way.

1) Preparation of samples:

20 grams of air-dry soil were oxidized with 10% H_2O_2 in a 1 liter beaker covered with a watch glass and heated on a steam bath to destroy organic matter. Then HCl (end-concentration ± O.2N) was added to remove carbonates and calcium ions. This treatment was carried out at room temperature for half an hour. After washing with distilled water, 0.005 N NaOH was used to disperse the soil. The suspension was poured through a 50 microns sieve. The fraction above 50 microns was treated with 10% $Na_2S_2O_4$ solution for fifteen minutes on a water bath and washed with O.2 N HCl followed by distilled water. Then it was collected in a beaker and dried at 105° C. Using the corresponding screens the sand was divided into the following fractions: 50–105 and 105–210μ.

TABLE 1. Mineral Composition of light fractions of sand separate (500–50 μ). Spec. grav. < 2.89.

Sample No.	Quartz	Orthoclase	Microcline	Albite	Oligoclase	Andesine	Muscovite
(1)	79	7	4	5	3	–	2
(2)	77	10	3	4	3	1	2
(3)	73	11	4	6	4	–	2
(4)	81	9	4	3	3	–	–
(5)	79	9	3	3	3	–	–
(6)	82	7	3	4	3	–	1
(7)	80	10	4	4	2	–	–
(8)	74	12	5	5	3	–	1
(9)	71	12	5	6	3	1	2
(10)	85	8	2	3	2	–	–
(11)	81	9	3	4	3	–	–
(20)	80	10	3	4	2	–	1
(30)	84	9	2	3	2	–	–
(31)	91	5	2	1	1	–	–
(36)	84	7	4	2	2	–	–

2) Mineral separation by specific gravity:

The two fractions selected (50–105 and 105–210μ) for this investigation were separated by means of a microsplitter. Further separations were carried out on 0.5 gm by a new method developed by Favejee getting the following fractions with specific gravity < 2.59, 2.59–2.63, 2.63–2.67, 2.67–2.89 and > 2.89. The last so called heavy fraction was not studied.

3) Minerals counts and description of the grain types:

From the light mineral content of the single slides, countings have been made following the method developed by NOTA (1960). Slides from the first group (spec. grav. < 2.59) were examined microscopically using a liquid having a refractive index 1.528. Orthoclase and microcline have refractive indexes lower than the liquid. They are in fresh state. Microcline shows, between crossed nicols, very typical spindle-shaped twin lamellae and orthoclase grains often show their negative optical character. Gypsum minerals were identified by their low birefringence, large axial angle with positive sign and strong dispersion. Those grains, now termed altered feldspars, were distinguished by the presence of many black spots of an altered nature but every grain as a whole still reserves its characteristic features. Glasses are mostly light-brown in colour with gas bubbles. Brownish and greenish-

Table 2. Percentages of the various specific gravity fractions found in the soils.

Sample No.	Specific gravity	Per cent found	
		210–105 μ	105–50 μ
(3)	< 2.59	12.5	12.0
	2.59–2.63	9.0	12.0
	2.63–2.67	70.0	56.0
	2.67–2.89	6.5	12.0
	> 2.89	2.0	8.0
(8)	< 2.59	17.0	17.0
	2.59–2.63	6.0	7.5
	2.63–2.67	59.0	36.0
	2.67–2.89	11.0	13.5
	> 2.89	7.0	26.0
(10)	< 2.59	6.5	12.0
	2.59–2.63	5.0	16.0
	2.63–2.67	78.0	54.5
	2.67–2.89	3.5	4.5
	> 2.89	7.0	13.0
(31)	< 2.59	5.0	7.0
	2.59–2.63	7.5	9.0
	2.63–2.67	84.0	70.0
	2.67–2.89	1.0	2.0
	> 2.89	2.5	12.0

yellow particles designated as group B and group G are found in ample amounts in samples no. 3, 8 and 10 respectively. These particles under the microscope appear to be composite in character with a flaky nature. Using the microscope, some of these particles were isolated by hand picking for further study. Optical constants were determined on these separated particles with the following results:

Very small axial angle, biaxial with a negative sign. $n\gamma$ and $n\beta = 1.566$, $n\alpha = 1.542$.

Examination of the X-ray photographs obtained by using cobalt radiation indicates that the particles are of nontronitic nature[1]. These results may support the suggestion that these particles represent an intermediate stage in the weathering cycle of the ferromagnesian rocks to clay minerals.

The second group (spec. grav. 2.59–2.63) was examined also in a liquid medium having refractive index 1.528. Albite has weak birefringence, positive optical sign, one refractive index $n\alpha$ lower than the liquid and the other refractive index $n\beta$ nearly equal (1.529). Traces of orthoclase were found in this group. Quartz grains were found also in this group having higher refractive index and inclusions of gas bubbles.

The third group (spec. grav. 2.63–2.67) was examined in Canada-balsam by means of the universal stage in accordance with the method described by Doeglas (1940) to distinguish between quartz and oligoclase. Little intermediate-plagioclases were found.

The fourth group (spec. grav. > 2.89) was examined in Canada-balsam medium. Andesine was the most predominant mineral found in the group so called inter-

[1] The author wishes to acknowledge here the generous help given by Dr. J. Ch. L. Favejee in this aspect of the work.

TABLE 3. Light mineral associations of selected samples.

Size grades in microns	210–105				105–50			
Sample No.	3	8	10	31	3	8	10	31
Spec. grav. < 2.59:								
Orthoclase	23	24	48	43	30	16	32	65
Microcline	12	16	27	43	18	14	15	23
Altered feldspars	3	3	3	4	3	5	–	–
Aggregates	24	18	8	7	18	30	19	10
Group B	12	18	–	–	15	19	14	–
Group G	2	4	–	–	3	3	–	–
Chert	4	3	2	3	3	5	4	2
Gypsum	18	12	11	–	6	8	16	–
Volcanic glasses	2	2	1	–	4	–	–	–
Spec. grav. 2.59–2.63:								
Orthoclase	3	3	2	5	6	7	6	7
Microcline	–	–	–	1	3	–	–	2
Albite	30	43	40	9	32	48	38	7
Oligoclase	–	–	–	1	1	2	–	–
Aggregates	30	25	16	7	25	20	22	6
Quartz	34	27	40	76	32	21	34	78
Chert	3	2	2	1	1	2	–	–
Spec. grav. 2.63–2.67:								
Oligoclase	6	7	5	2	10	12	7	9
Intermediate-plagioclases	2	2	1	–	3	2	4	1
Aggregates	2	3	7	3	2	4	12	1
Quartz	90	88	87	95	85	82	77	89
Spec. grav. 2.67–2.89:								
Intermediate-plagioclases	34	35	50	47	55	40	45	60
Altered feldspars	5	7	2	11	–	3	8	3
Aggregates	43	36	40	35	20	35	35	19
Muscovite	7	7	–	–	9	5	4	–
Biotite	2	8	2	–	3	5	–	–
Chlorite group	–	–	–	–	5	7	2	–
Quartz	8	4	4	5	8	5	6	18
Chert	–	1	–	2	–	–	–	–
Rock fragments	1	2	2	–	–	–	–	–

mediate-plagioclases. It has low birefringence and positive sign. Quartz grains were found also in this group. They have inclusions of heavy minerals. Muscovite was found in tabular crystals with strong birefringence, and negative sign. Biotite was found and characterized by its brownish colour, high birefringence, small axial angle and negative sign. The chlorite group was only found in the fraction 105–50 microns in the three samples no. 3, 8 and 10. Few rock fragments were found in this group.

Aggregates were found in rather great quantities in all the groups. They exhibit much diversity in size and are composed mostly of quartz aggregates which do not give complete extinction. Generally cryptocrystalline varieties of SiO_2, designated as chert, were found mainly in the first and second group. However, a very little chert having black inclusions, was found in the fourth group (spec. grav. 2.67–2.89) in fraction 210–105μ of samples no. 8 and no. 31. The results of counting the different minerals in the examined groups were recorded in table 3 and represented graphically in figure 2.

TABLE 4. Weight of individual light minerals per 100 gm of the corresponding fraction.

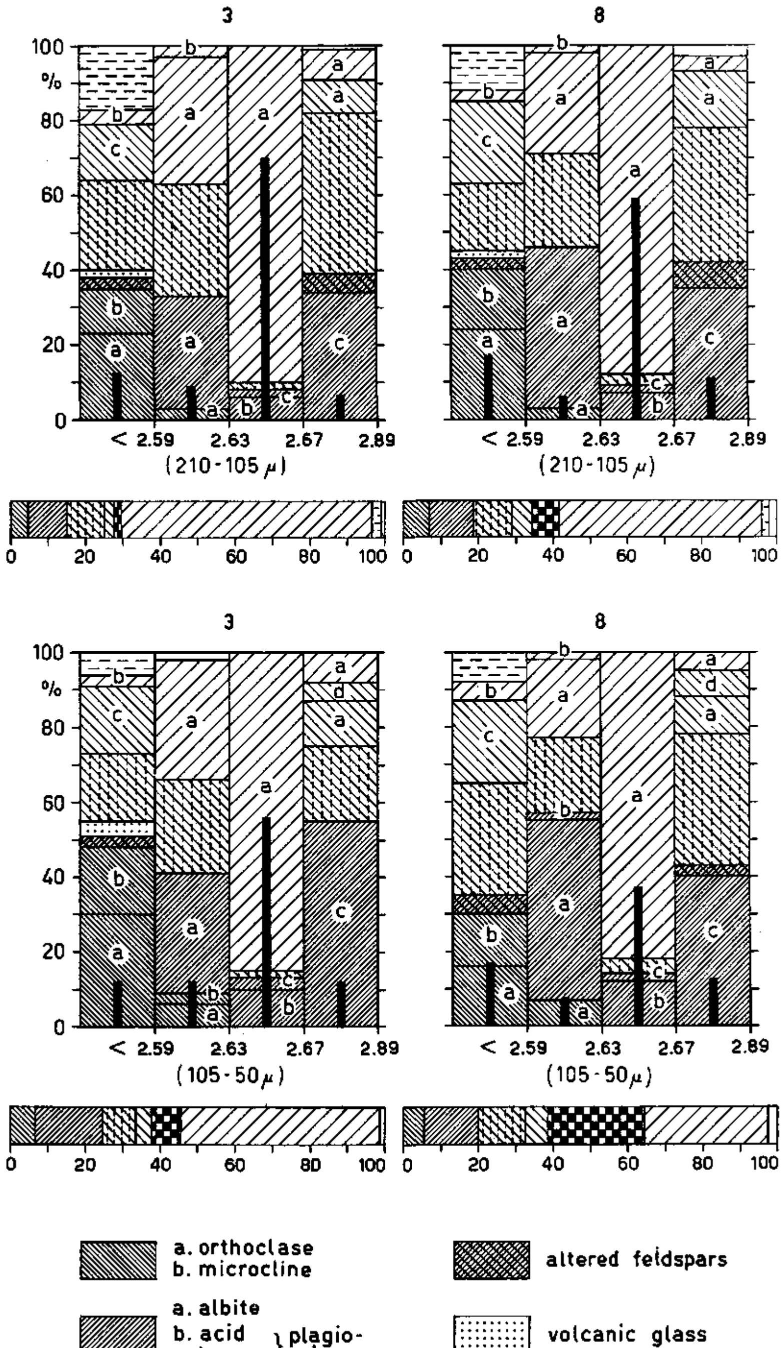
Sample No.	3		8		10		31	
Fraction	210 – 105	105 – 50	210 – 105	105 – 50	210 – 105	105 – 50	210 – 105	105 – 50
Orthoclase	3.15	4.32	4.26	3.25	3.22	4.80	2.53	5.18
Microcline	1.52	2.52	2.72	2.38	1.76	1.80	2.23	1.79
Gypsum	2.25	0.72	2.04	1.36	0.72	1.92	–	–
Group B and G	1.75	2.16	3.74	3.74	–	1.68	–	–
Albite	2.70	3.84	2.58	3.60	2.00	6.08	0.68	0.63
Oligoclase	4.20	5.72	4.13	4.47	3.90	3.82	1.76	6.30
Quartz	66.58	52.40	53.98	31.78	70.00	47.68	85.55	69.68
Intermediate Plagioclases	3.61	8.28	5.03	6.12	2.53	4.21	0.47	1.90
Chert	0.77	0.48	0.74	1.00	0.23	0.48	0.25	0.14
Altered feldspars	0.71	0.36	1.28	1.26	0.27	0.36	0.31	0.06
Aggregates	9.90	8.68	10.29	12.77	8.18	13.92	3.75	2.32
Muscovite	0.46	1.04	0.77	0.68	–	0.18	–	–
Biotite	0.13	0.36	0.88	0.68	0.07	–	–	–
Chlorite-group	–	0.60	–	0.95	–	0.09	–	–
Volcanic glasses	0.25	0.48	0.34	–	0.07	–	0	–
Rock fragments	0.07	–	0.22	–	0.07	–	–	–

DISCUSSION OF RESULTS AND CONCLUSIONS

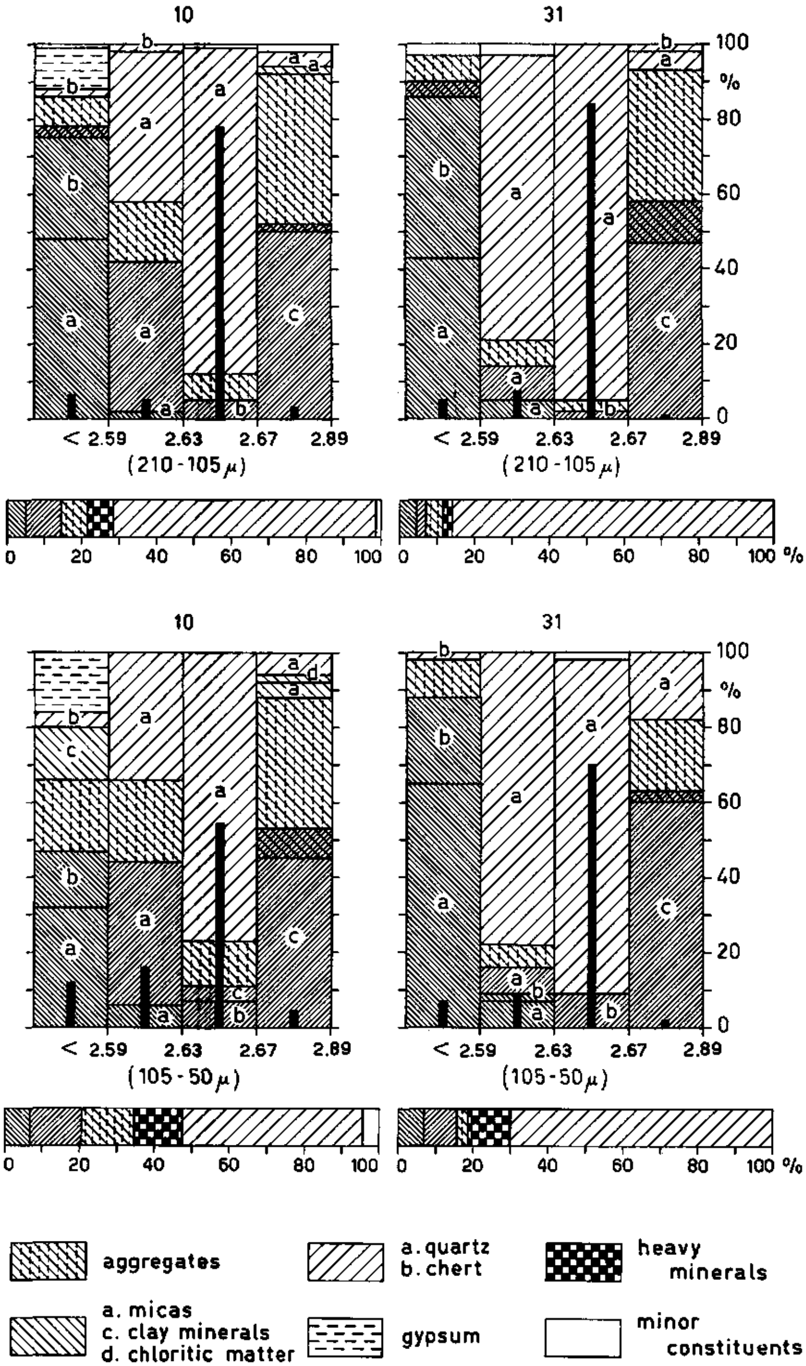
The percentages of the various specific gravity fractions found in the sand separates examined are tabulated in table 2. It is interesting to note the increase in quantity of light minerals (excluding quartz) as one passes from fraction 210 – 105μ to the fine fraction 105–50μ. The percentage of quartz group (spec. grav. 2.63–2.67) decreases significantly in the finer fraction.

From data presented in table 3 it is noticed that gypsum is absent in sample 31. Also the mineral groups B and G, glasses, rock fragments, chlorite group, muscovite and biotite are not found in the mentioned sample. The weight percentages of individual light minerals of each of the two sand fractions examined are calculated and presented in table 4. Potassium feldspars are present in ample quantities in all the samples as well as the intermediate-plagioclases. It is noticeable that potassium feldspars i.e., orthoclase plus microcline, predominate over the intermediate-plagioclases in the fraction 210–105μ in samples no. 3 and no. 8, whereas in fraction 105–50μ the picture is reversed. In samples no. 10 and no. 31 the potassium feldspars predominate over the intermediate-plagioclases in the two sand separates. It is noteworthy that the amount of intermediate-plagioclases in sample no. 31 is far less than the amount in the other three samples. In this sample quartz constitutes the bulk of the light fraction, which is much poorer in feldspars than the other samples. Thus sample no. 31 represents a completely different picture. It was collected from the east desert at Kantara east of Suez Canal. It is of interest to notice that gypsum, minerals of group B and G, muscovite, chlorite group, rock-fragments and glasses, all present in the Nile sediments (samples no. 3 and no. 8) are recorded in sample no. 10 (table 4). This sample, collected from a farm at the fringe of the east desert near Cairo under irrigation with the Nile water, thus reflects the intermixing of the Nile sediments with the desert sediments. The same conclusion was drawn from the study of the heavy minerals in a previous publication (KHADR, 1960). Figure 2 shows diagrammatically the relative frequencies of the light minerals.

FIG. 2. GRAPHIC REPRESENTATION OF THE LIGHT FRACTION
(Black columns give weight percentages of specific gravity fractions; hatched



OF SOME EGYPTIAN SOILS.
columns represent mutual percentages of components concerned.)



It is interesting to notice that the different minerals of the sand separates are found in distinct specific gravity groups. The results obtained indicate that separation by means of the specific gravity procedure here followed, offers considerable promise as a means of separating and concentrating the mineral species in the sand separates of soil. Thus the separation procedure mentioned before could be used to give an idea about the general trends in the regional distribution and stratigraphical sequence of sediments before applying the detailed petrographic methods. Also, in examining a great number of soil samples for the purpose of soil classification, it could be very helpful to give a general idea about the different soil types that may happen to occur.

From the data in table 4 the light mineral group constitutes an appreciable proportion of feldspars in a fresh state. The existance of gypsum, chlorite group, glasses, rock-fragments and biotite in noticeable amounts together with the feldspars indicate that transportation by the Nile river over hundreds of miles has a limited effect on the elimination of light detrital minerals. RUSSELL (1937) has shown, that in the Mississippi the loss of feldspars through attrition is a very slow process. KOLDEWIJN (1955) stated that the loss of feldspars through attrition plays only a very subordinate part in the Rhine sediments. The same conclusion stands fairly well in connection with heavy minerals (RUSSELL, 1937; VAN ANDEL, 1950; SHUKRI, 1950). It may therefore be safely assumed that the effect of transportation on the detrital minerals in general, is so negligible, that no changes in the detrital mineral composition of both the heavy and light fractions occur.

It is now generally accepted that a high level of fertility in the soils is necessary for maximum plant growth. It is considered that a knowledge of the mineral composition of the sand separates in soils would be of the greatest importance in elucidating the source of origin of fertility. Further it would contribute towards a greater understanding of the effects of weathering on the reserve plant-nutrient minerals. The present investigation indicates that orthoclase feldspar is common in Egyptian soils, occurring in ample amounts. Microcline is identified in an unweathered state. Intermediate-plagioclases also are found in ample amounts in addition to biotite and muscovite. This is anticipated on account of the high fertility of Egyptian soils and their ability to withstand intensive cultivation practised for a long period.

SUMMARY

The purpose of this paper is to report work of a mineralogical nature on sand separates of some Egyptian soils using a new technique developed by FAVEJEE, NOTA and BAKKER. The results of specific gravity separations of sand separates are given. Petrographic methods are employed to identify the mineral species and these in turn provide a control on the accuracy of the separation. It is found that the choice of specific gravities, adopted in the method, proves satisfactory in concentrating the mineral species in distinct assemblages. It is suggested that the new method would be of great help in provenance study and soil classification projects.

The specific gravity separations were almost complete. In the first group, clay-like minerals having a somewhat lower specific gravity than the separating liquid were present. These minerals, designated as group B and G, were identified as nontronite-like clay mineral representing an intermediate stage in the weathering cycle of ferromagnesian rocks to clay minerals.

The percentage distribution of minerals in the two sand fractions i.e., 210–105μ, is presented graphically in figure 2. The outstanding differences appear in the distri-

bution of quartz, feldspars, micas and gypsum. The quantity of minerals other than quartz increases in the finer sand separate.

Potassium feldspars, acid feldspars and intermediate- plagioclases occur in Egyptian soils in ample amounts. Biotite, muscovite, chlorite-group, volcanic-glasses and rock-fragments are found too. The presence of these minerals throw light on the origin of the high fertility of Egyptian soils. Transportation of feldspars over hundreds of miles by the Nile River has negligible effect on their loss through attrition.

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