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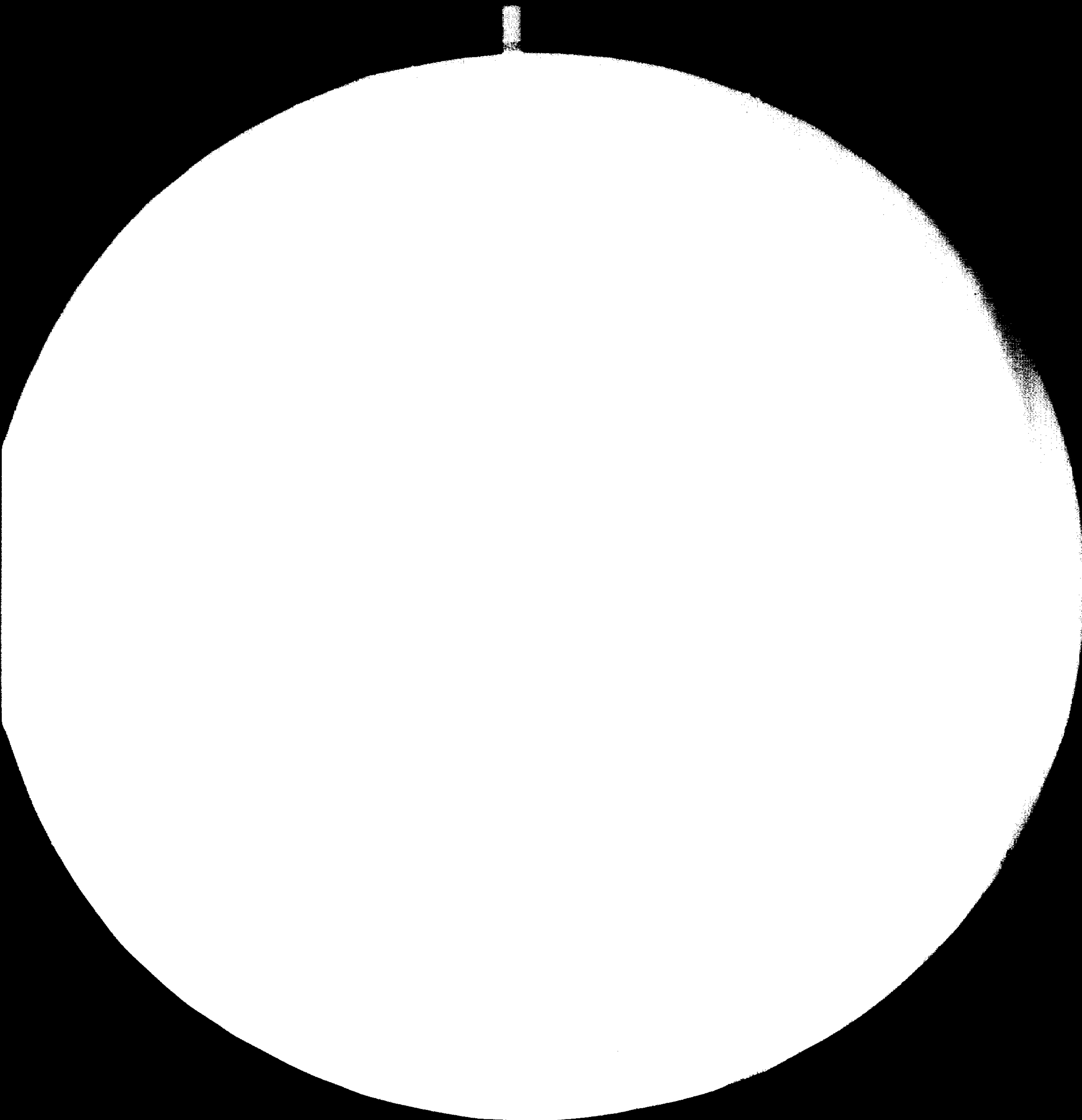

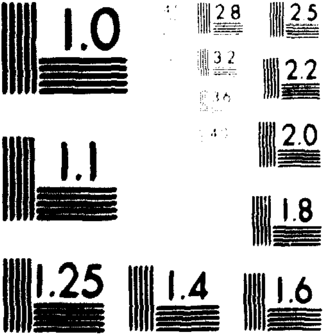

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU [illegible]

INSTITUTE FOR MATERIALS TESTING
S.O.A.L. - CENTRE FOR STRUCTURAL CERAMICS

11811

Sudan. TECHNOLOGICAL TESTS OF RAW MATERIALS FOR BRICK PLANT NEAR KHARTOUM, SUDAN

SI/SUD/81/801

authors →

BELGRADE

1982

INSTITUTE FOR MATERIALS TESTING

- CENTRE FOR STRUCTURAL CERAMICS -

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REPORT

ON CERAMIC TESTS OF SAMPLES FROM THE DEMOCRATIC REPUBLIC OF SUDAN

1.0. INTRODUCTION

In accordance with UNIDO substantive terms of reference dated 04.03.82, and the telex dated 13.05.82. Institut for Testing of Materials in Belgrade, carried out tests of samples from Sudan. The samples have been collected by mr.Petar Nićiforović during his geological exploration of Soba silt deposit and prospection of some other localies in accordance with the goal of his work on UNIDO project Si/Sud/81/801.

This report presents results of 29 individual ceramic tests; 5 complete ceramic tests, 8 study ceramic tests and some tests of kaolin samples from Fiteihab.Samples of black cotton soil and clay from pond on the bank of Blue Nile, have been tested on expansion.

Main goal of the research was to solve the problem of raw materials for new brick plant on location of Soba University Farm, near Khartoum.

Silt from deposit in Soba is considered as basic raw material , for brick making, while clay from pond, kaolin, black cotton soil dung and ground nuts hulls are considered as materials which can improve quality of the bricks if added in certain percentage.

One of the main obstacle which we met in work on this task was a limited quantity of samples that we got.This relates particulary to the samples which are provided from holes in Soba.

Only two tests which are carried out with addition of combustible materials, are sufficient enough for getting the indications of possibility of usage of such materials with multiple goal: 1.) to improve workability of raw material 2.) to improve fuel economy and 3.) to get brick products as light as possible.

Kaolin from location of Fiteihab was tested, through preliminary tests, for usage in fine ceramics. Quite sufficient results have been achieved. Also, sufficient results are achieved with mixtures in which kaolin was used for decreasing of the clay plasticity.

Characteristics of black cotton soil and clays from pond indicated their expandability and we have made elementary tests in this sense.

2.0. INDIVIDUAL CERAMIC TESTS

INSTITUT ZA ISPITIVANJE MATERIJALA SR SRBIJE I centar	Technological tests of raw materials for brick plant near Khartoum-Sudan	page No 2.

1. Laboratory tests of individual samples

Sample mark	Carbonate reaction	Linear shrinkage at drying (%)	Linear shrinkage at firing (%)
A-1 0,0-2,6 m	weak	3,50	0,52
A-1 2,6-5,7 m	strong	11,00	1,12
B-1 0,0-2,8 m	weak	8,00	1,63
B-1 2,8-5,7 m	-	-	-
C-1 0,0-2,85 m	strong	8,00	1,09
C-1 2,35-5,7 m	weak	7,00	0,0
A-2 0,0-3,0 m	weak	5,00	-
A-2 3,0-5,2 m	medium	6,00	0,53
B-2 0,0-3,6 m	strong	6,50	0,0
B-2 3,6-7,2 m	medium	4,50	3,14
C-2 0,0-3,0 m	strong	5,00	0,0
C-2 3,0-6,2 m	strong	5,00	1,05
A-3 0,0-3,4 m	strong	7,00	0,54
A-3 3,4-7,0 m	weak	6,50	0,0
B-3 0,0-3,2 m	-	7,00	0,54
B-3 3,6-7,2 m	-	-	-

Technological tests of raw materials for brick plant near Khartoum-Sudan

Sample mark	Carbonate reaction	Linear shrinkage at drying (%)	Linear shrinkage at firing (%)
white nile silt	strong	7,80	0,87
pond right north bank	medium	11,12	1,67
BCS	no	3,00	2,06
SAGAI	no	6,90	0,75
B-7/2 3,2-6,4 m	medium	11,00	2,13
B-7/1 0,0-3,2 m	weak	3,40	0,72
A-7/2 3,0-6,0 m	weak	3,60	1,04
A-7/1 0,0-2,6 m	no	7,00	0,54
C-5/2 3,2-7,8 m	no	2,40	0,41
C-5/1 0,0-3,2 m	weak	6,00	0,29
A-5/1 0,0-3,4 m	medium	7,30	-
C-3/1 0,0-3,4 m	medium	7,30	-
A-5/2 3,4-7,0 m	weak	5,00	-

INDENTIFICATION OF NONCLAY MINERALS IN SAMPLES OF SILT AND CLAYS FROM SUDAN

In this report the order of minerals is given in accordance with the abubdance of them in samples.
Dominant mineral in all samples is quartz. From colored minerals most abundant are amphiboles and biotite.
In a number of samples there is organic material - pieces of plants - which are here given as wood.
$CaCO_3$ is also present in all samples, indentified as rounded or angular concretions with dimensions of several milimeters to very fine grains. In the field, in some samples, were seen concretions biger than that.

A-I 0,0-2,6 m
Quartz - transparent, yellowish to reddish - particles of plants amphiboles, biotites and $CaCO_3$ as tiny concretions.

A-I 2,6-5,7 m
Quartz - transparent to blackish - wood, amphiboles , clay flakes, biotite.

A-II 0,0-3,0 m
Quartz, amphiboles, feldspar, wood, biotite and $CaCO_3$.

A-II 3,0-5,2 m
Quartz, sandstone, amphiboles, biotite, flakes of clay and $CaCO_3$.

A-III 0,0-3,4 m
Quartz, amphiboles, feldspar, biotite, wood, gypsum and $CaCO_3$.

A-III 3,4-7,0 m

Quartz - transparent to rossy - amphiboles, biotite, wood and $CaCO_3$.

A-V 0,0-3,4 m

Quartz - transparent, reddish to blackish, amphiboles, biotite, wood , feldspar and $CaCO_3$.

A-V 3,4-7,0 m

$CaCO_3$ - angular pieces and rounded concretions, quartz, biotite , muscovite, amphiboles.

A-VII 0,0-2,6 m

Quartz - transparent to reddish - rare amphiboles, muscovite and $Ca CO_3$.

A-VII 3,0-6,0 m

Quartz - transparent to reddish - sandstone, amphiboles and $CaCO_3$ concretions to 5 mm.

A-IX 0,0-2,0 m

Quartz - transparent, reddish to blackish - amphiboles and $CaCO_3$ concretions.

B-I 0,0-2,7 m

Quartz - transparent , white to reddish - amphiboles , muscovite flakes of clay, wood, biotite, feldspar and $CaCO_3$ concretions.

B-I 2,8-5,7 m

Quartz - transparent , reddish to black - amphiboles , biotite and $CaCO_3$.

B-II 0,0-3,6 m

Quartz - transparent to reddish - amphiboles , biotite , wood, $CaCO_3$ concretions.

B-II 3,6-7,2 m

Quartz - transparent, yellowish to reddish - biotite, flakes of clay, wood and $CaCO_3$ concretions.

B-III 0,0-3,2 m

Quartz,biotite,amphiboles,wood,feldspar and $CaCO_3$.

B-III 3,6-7,2 m

Quartz - transparent to reddish - amphiboles , biotite, feldspar and $CaCO_3$.

B-VII 0,0-3,2 m

Quartz - transparent to reddish - amphiboles and $CaCO_3$ concretions.

B-VII 3,2-6,4 m

Quartz, amphiboles and $CaCO_3$ concretions.

C-I 0,0-2,85 m

Quartz, amphiboles, biotite , feldspar , wood, garnet and $CaCO_3$.

C-I 2,85-5,7 m

Quartz,amphiboles, biotite, wood and $CaCO_3$.

C-II 0,0-3,0 m

Quartz - transparent to reddish - amphiboles, biotite , muscovite and $CaCO_3$.

C-II 3,0-6,2 m

Quartz,amphiboles,biotite,wood and $CaCO_3$.

C-III 0,0-3,4 m

Quartz,amphiboles,biotite,wood,$CaCO_3$.

C-III 3,4-6,0 m

Quartz - transparent to reddish - amphiboles, biotite,feldspar and $CaCO_3$.

C-V 0,0-3,2 m

Quartz - transparent to reddish - amphiboles, wood, piece of slag, feldspar and $CaCO_3$.

C-V 3,2-7,8 m

Quartz - transparent to reddish - amphiboles,biotite and $CaCO_3$.

Soba Pond

Nodules and flakes of clay,quartz,rare amphiboles and dispersed $CaCO_3$.

Right Bank pond

Clay flakes, quartz, wood and dispersed $CaCO_3$.

Sagai

Quartz - transparent to reddish - amphiboles , feldspar , flakes of clay and $CaCO_3$.

White Nile

Quartz - transparent to reddish - amphiboles , calcite and $CaCO_3$. concretions (much).

B.C.S.

Quartz - transparent to reddish - clay flakes, amphiboles , $CaCO_3$ concretions (much).

PARTICLE SIZE DISTRIBUTION ANALYSES

..AGRAM OF GRADING

SUDAN - SOBA

CUT A - 1

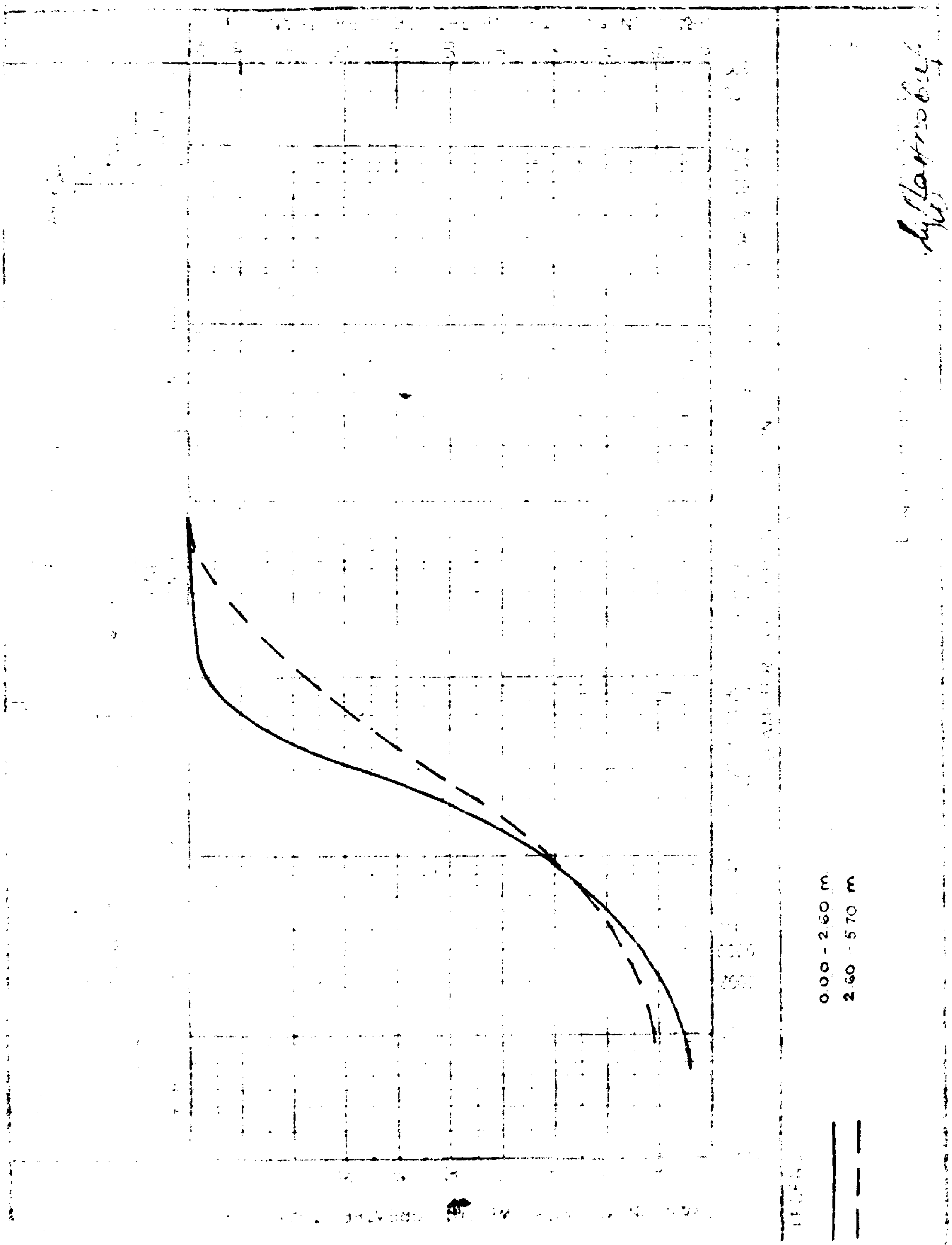
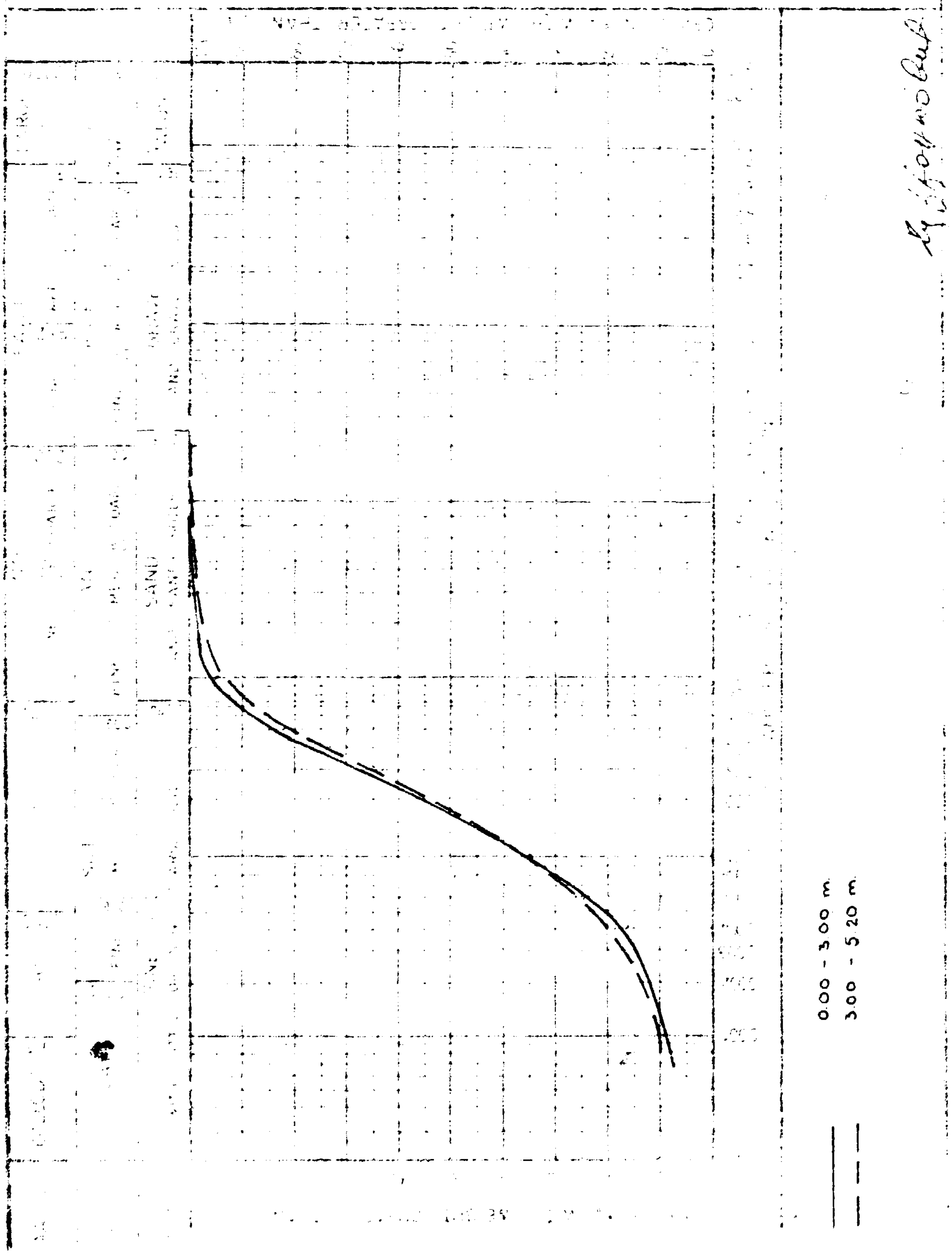
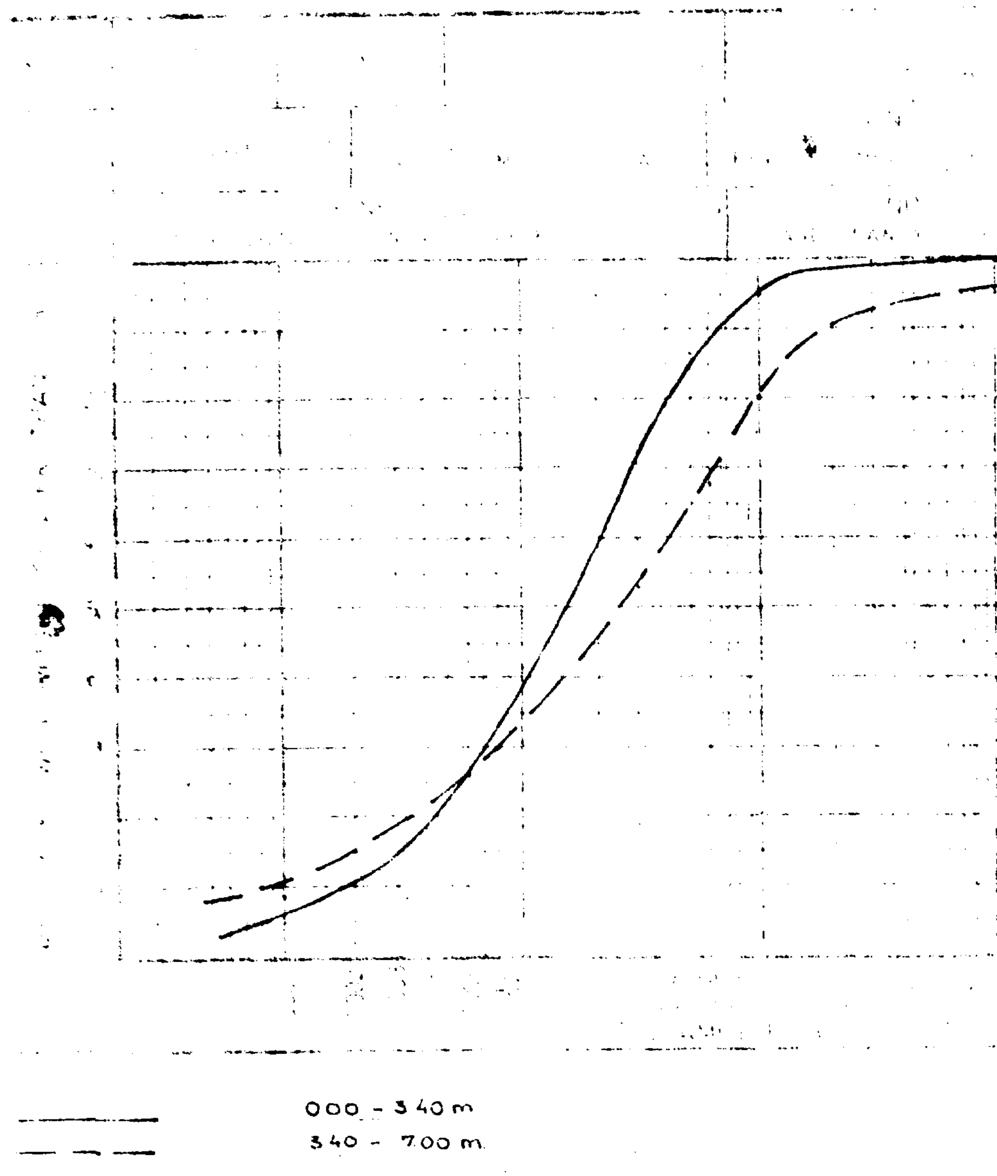


DIAGRAM OF GRADING

SUDAN - SOBA

HOLE A - 2





000 - 3.40 m
3.40 - 7.00 m

DIAGRAM OF GRADING

SUDAN - SOBA

HOLE A - 3

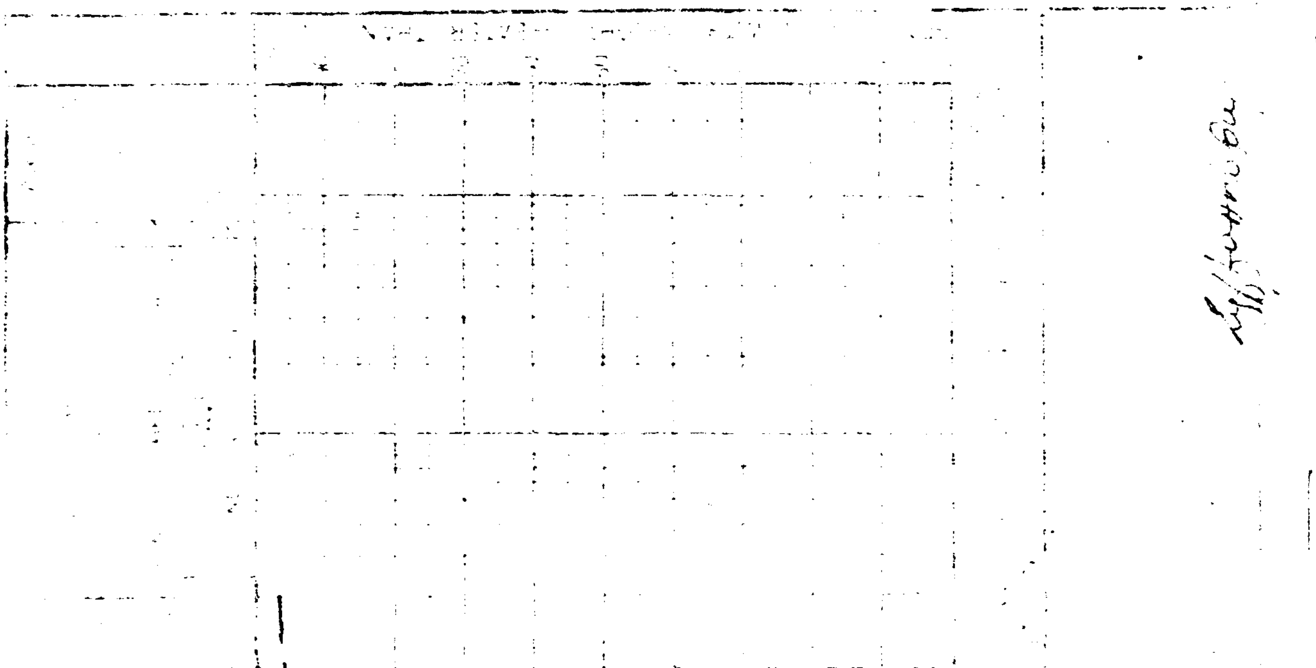


DIAGRAM OF GRADING

SUDAN - SOBA

HOLE A - 5

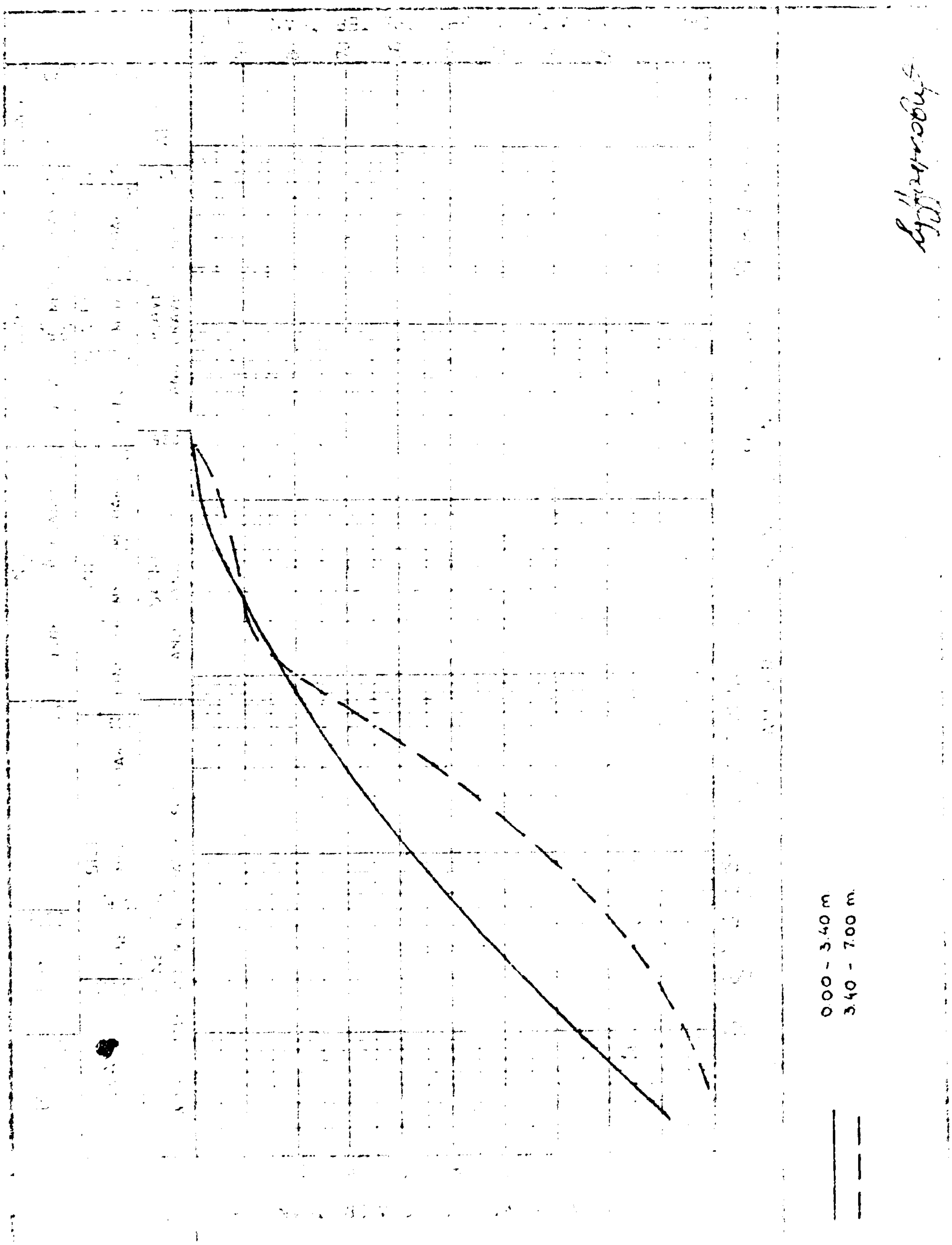


DIAGRAM OF GRADING

SUDAN - SOBA

HOLE A - 7

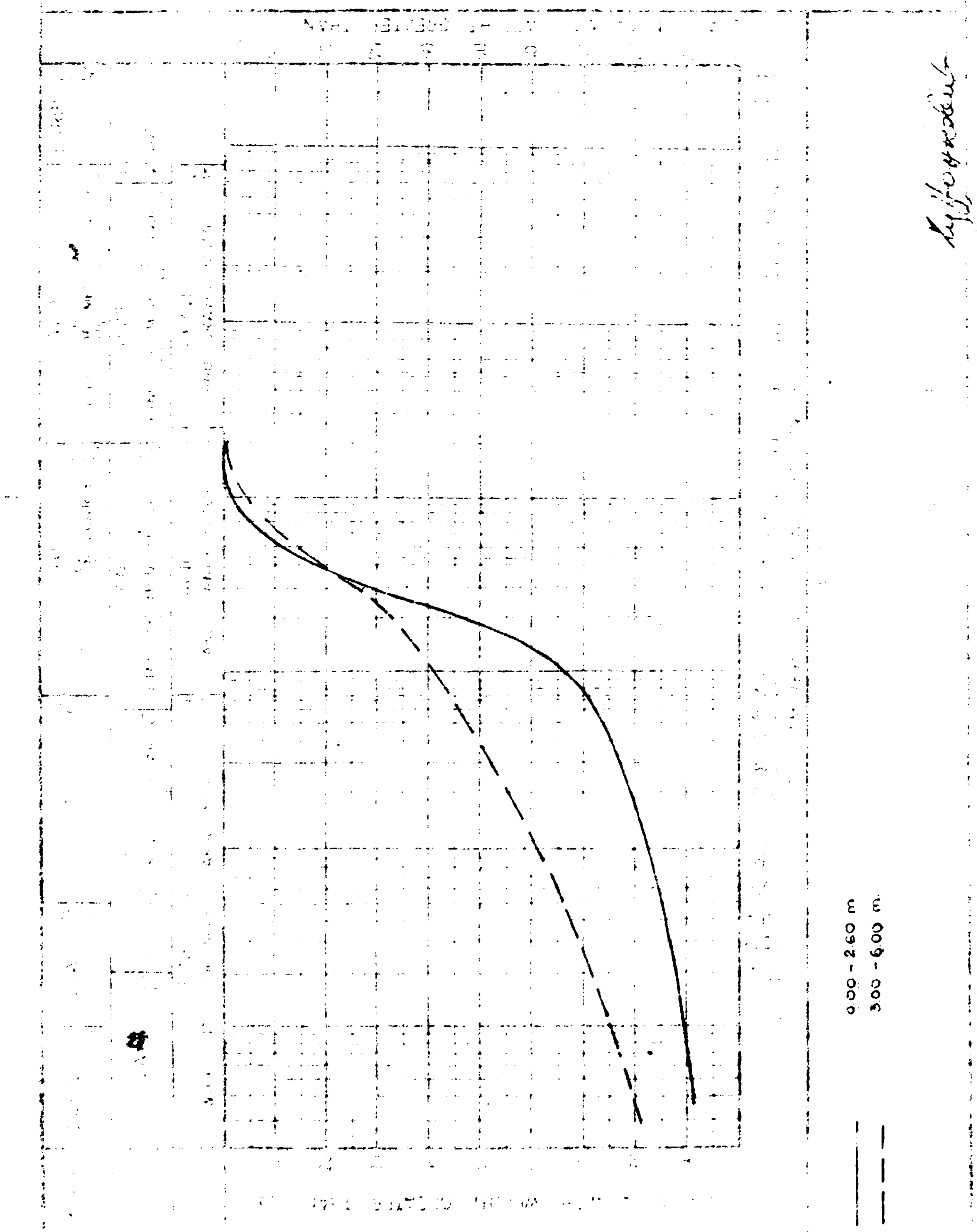


DIAGRAM OF GRADING

SUDAN - SOBA

HOLE A - 9

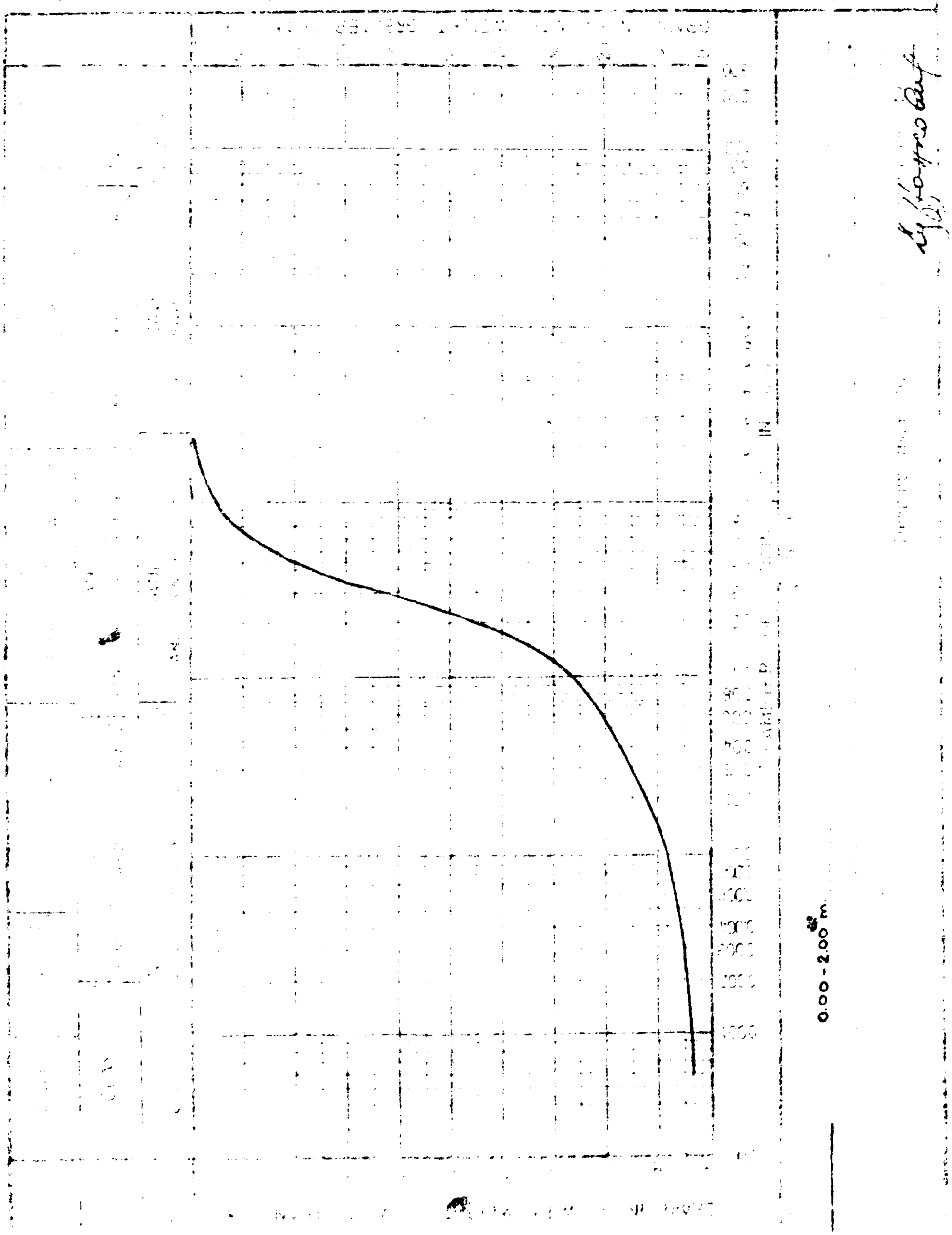
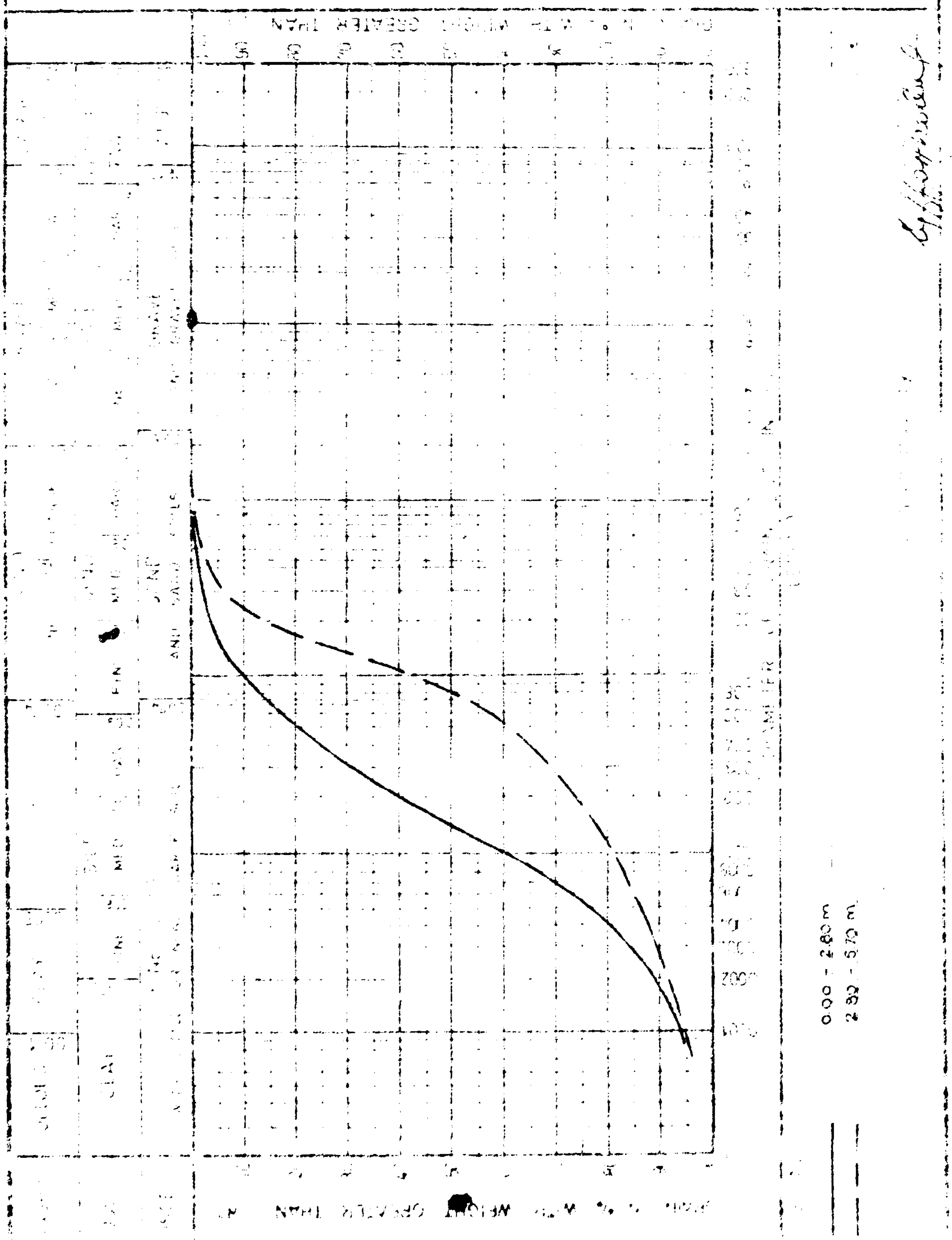


DIAGRAM OF GRADING

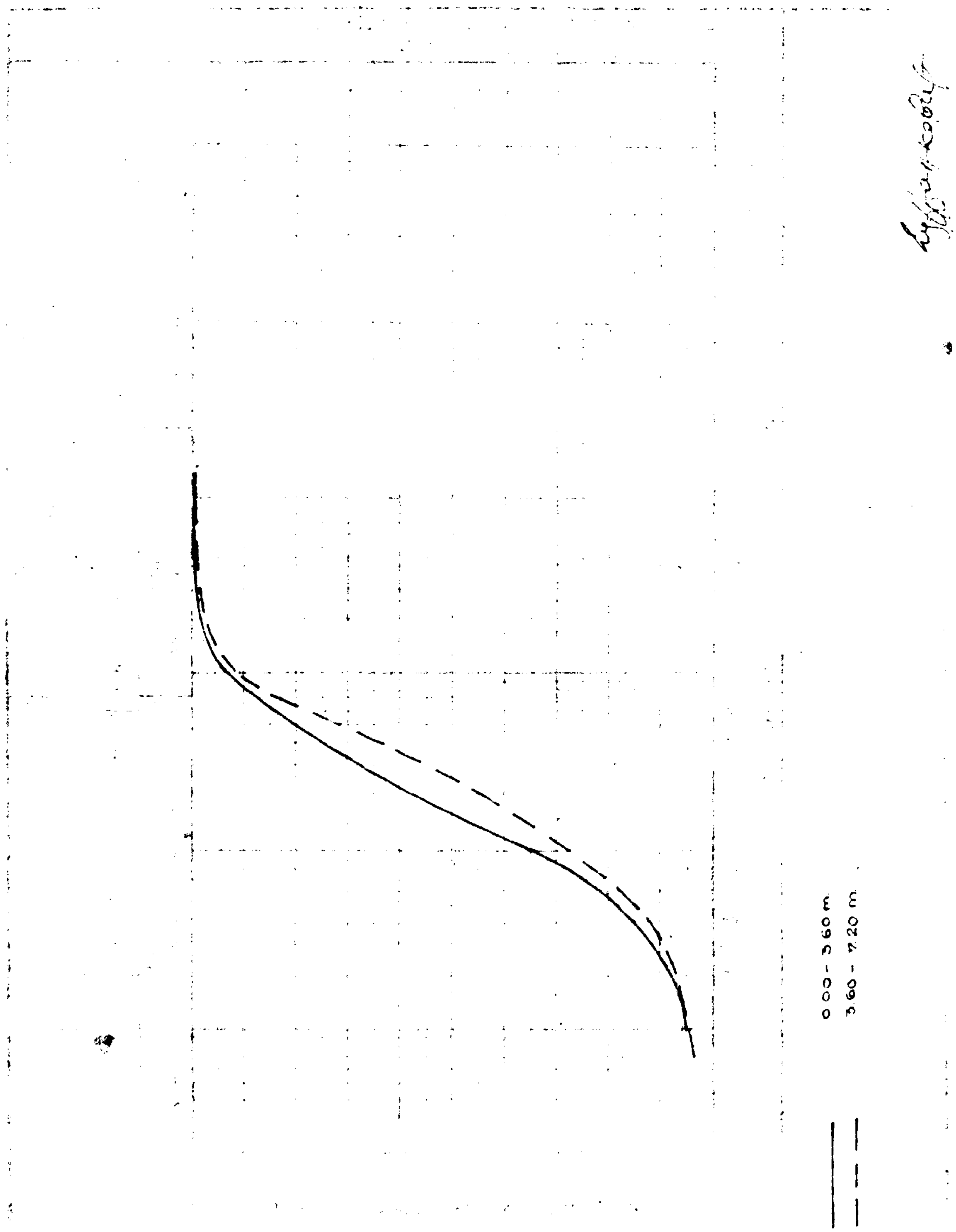
SUDAN - SOBA

CUT B - 1



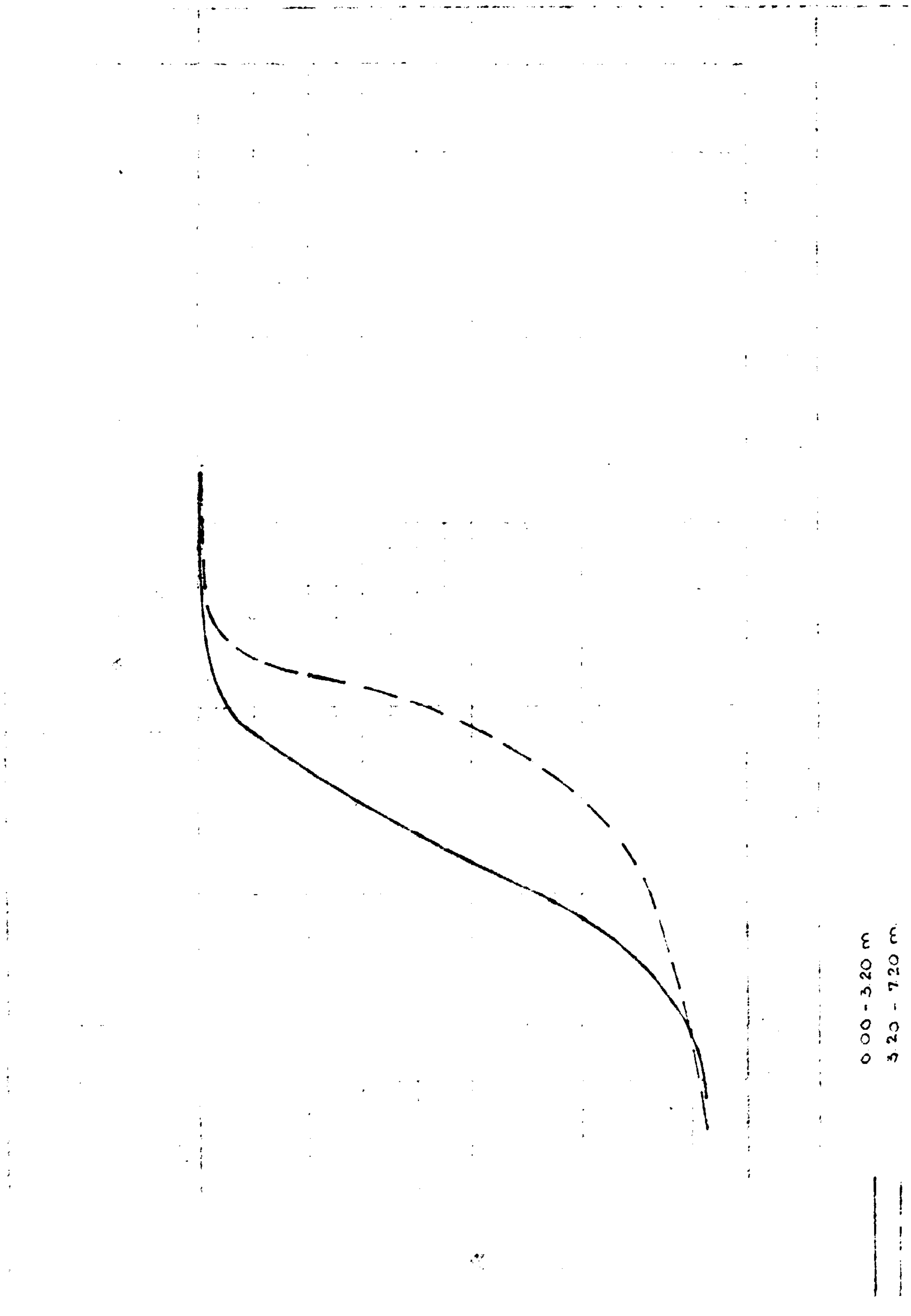
SUDAN - SOBA

HOLE B - 2



SUDAN - SOBA

HOLE B - 3



SUDAN - SOBA

HOLE B - 7

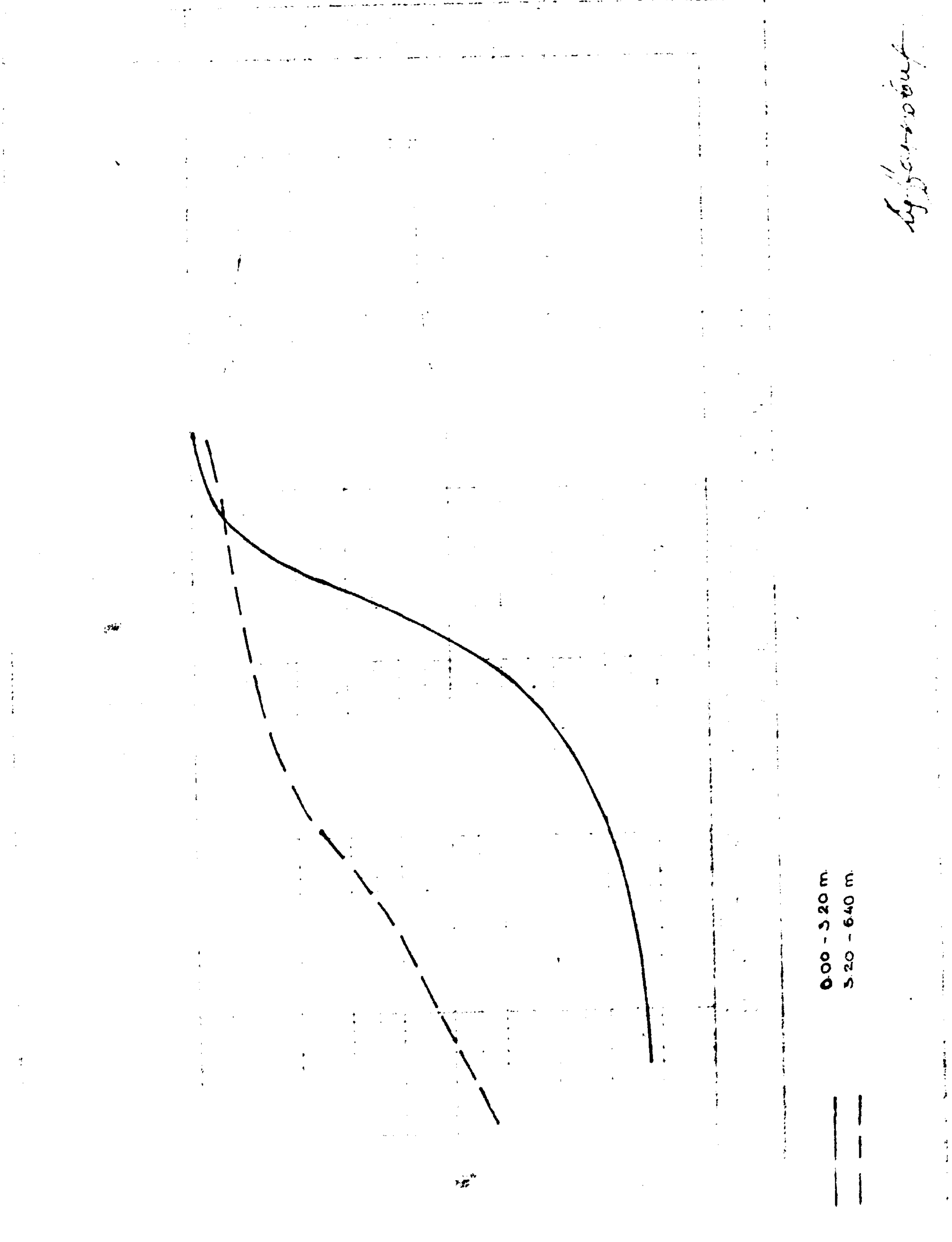
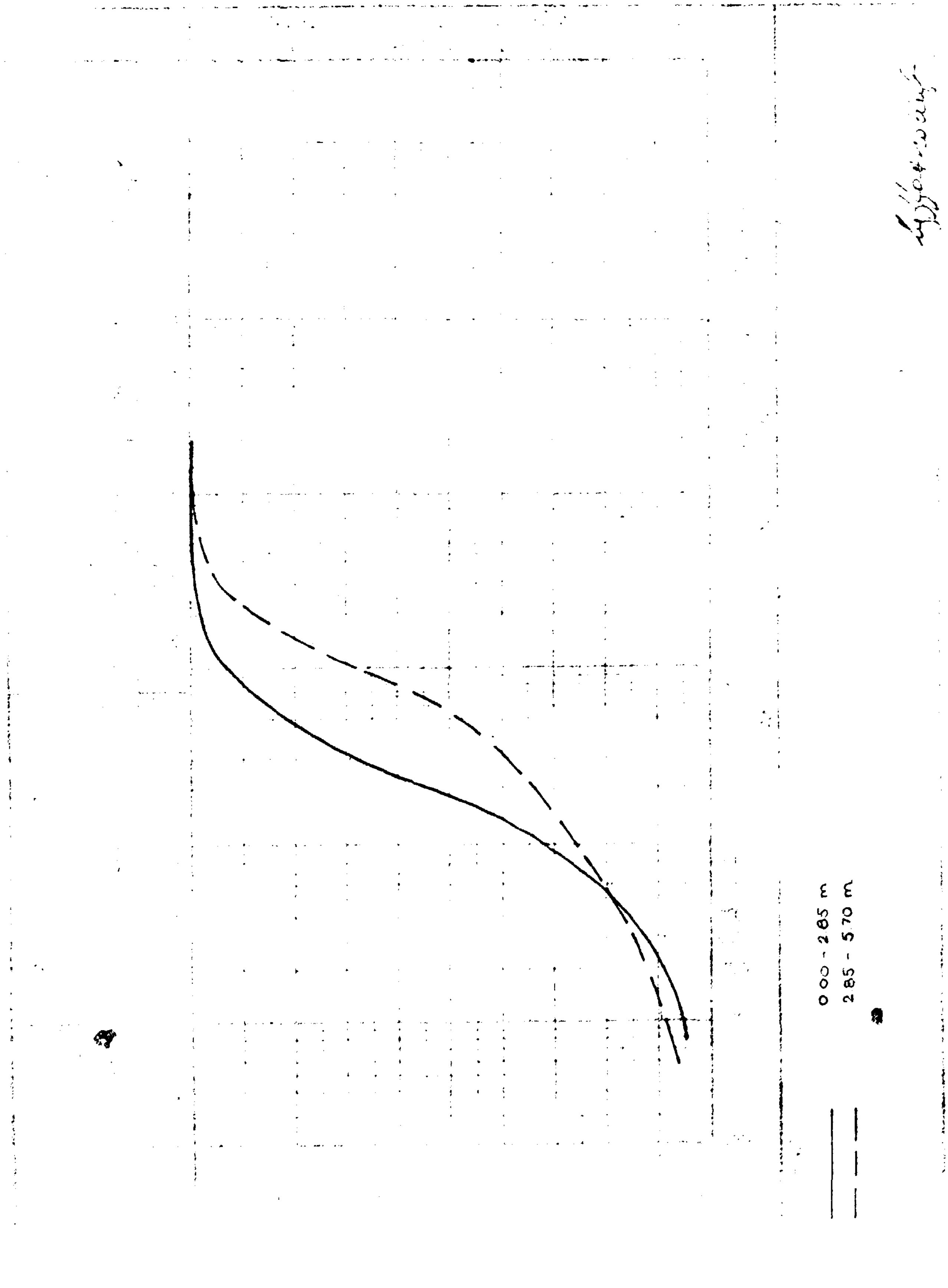


DIAGRAM OF GRADING

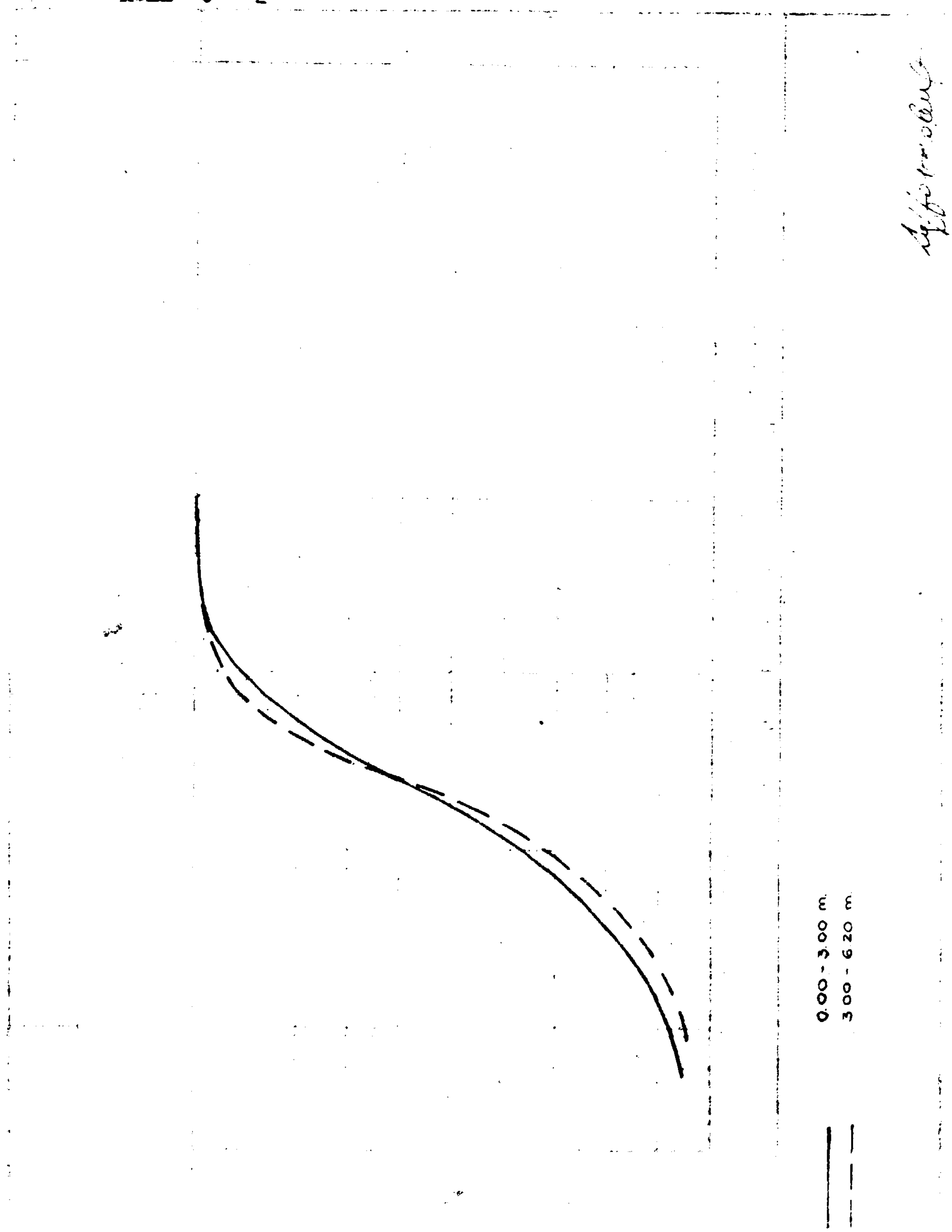
SUDAN - SOBA

CUT C - 1



SUDAN - SOBA

HOLE C - 2



SUDAN - SOBA

HOLE C - 3

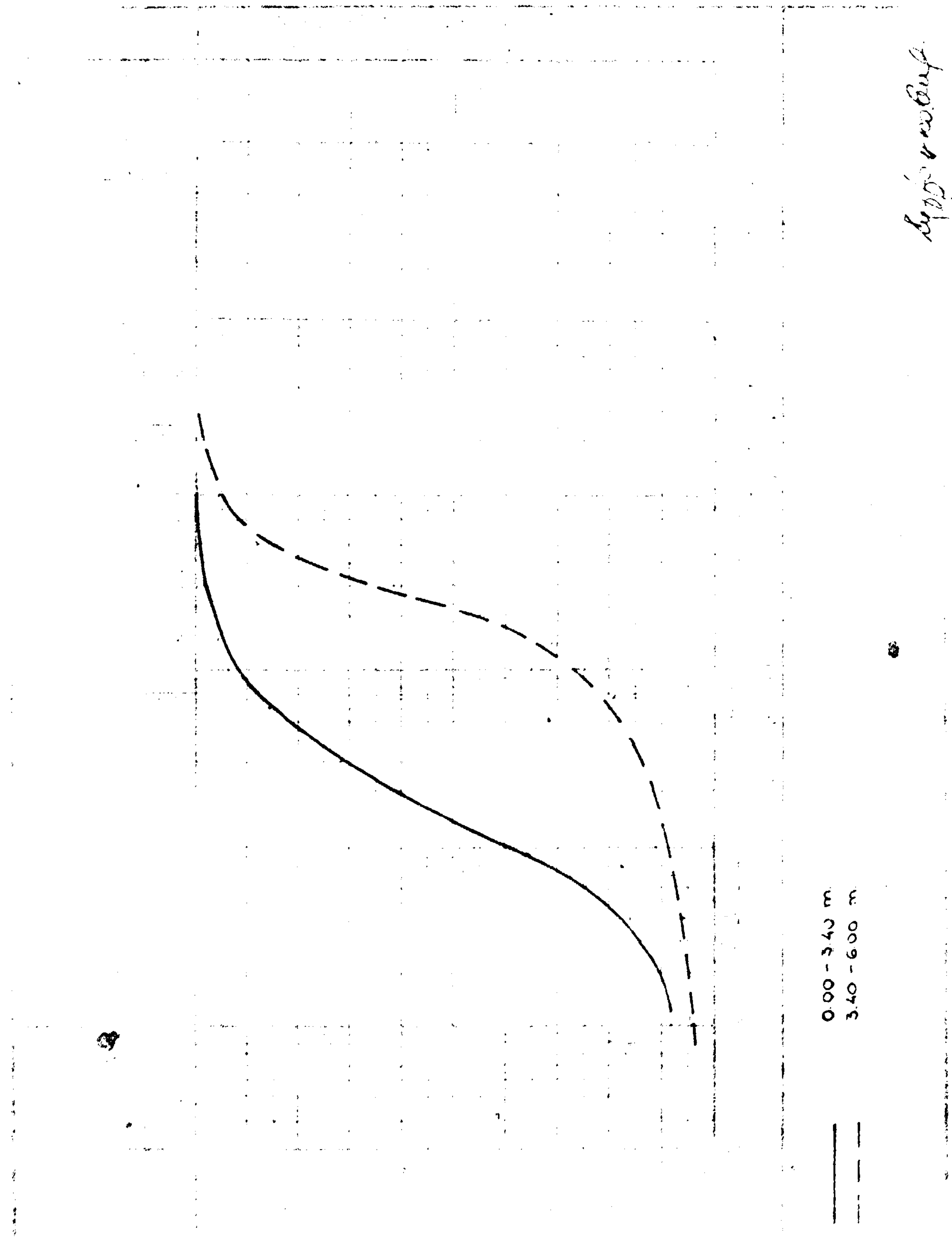


DIAGRAM OF GRADING

SUDAN - SOBA

HOLE C - 5

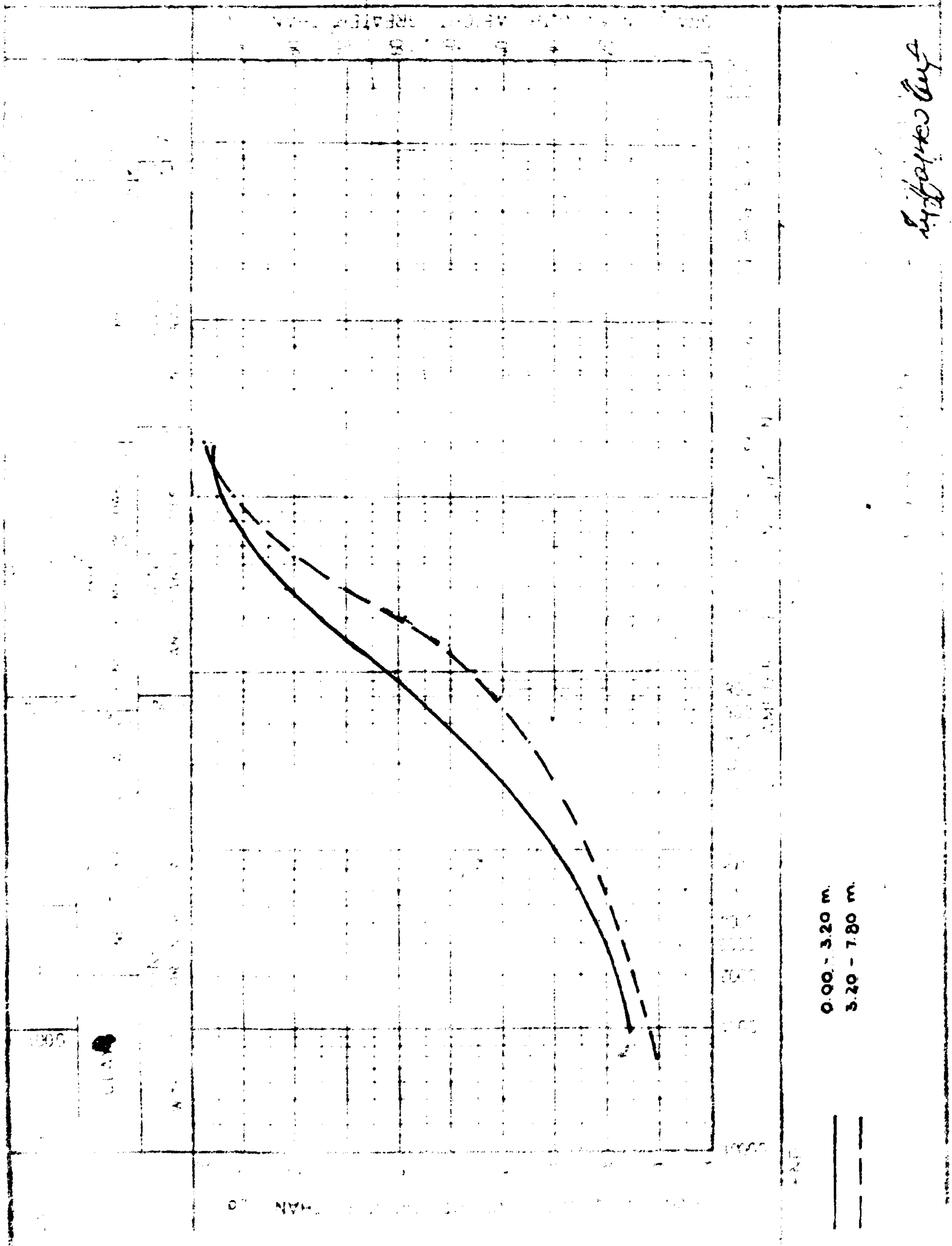


DIAGRAM OF GRADING

SUDAN - SAGAI

CLAY

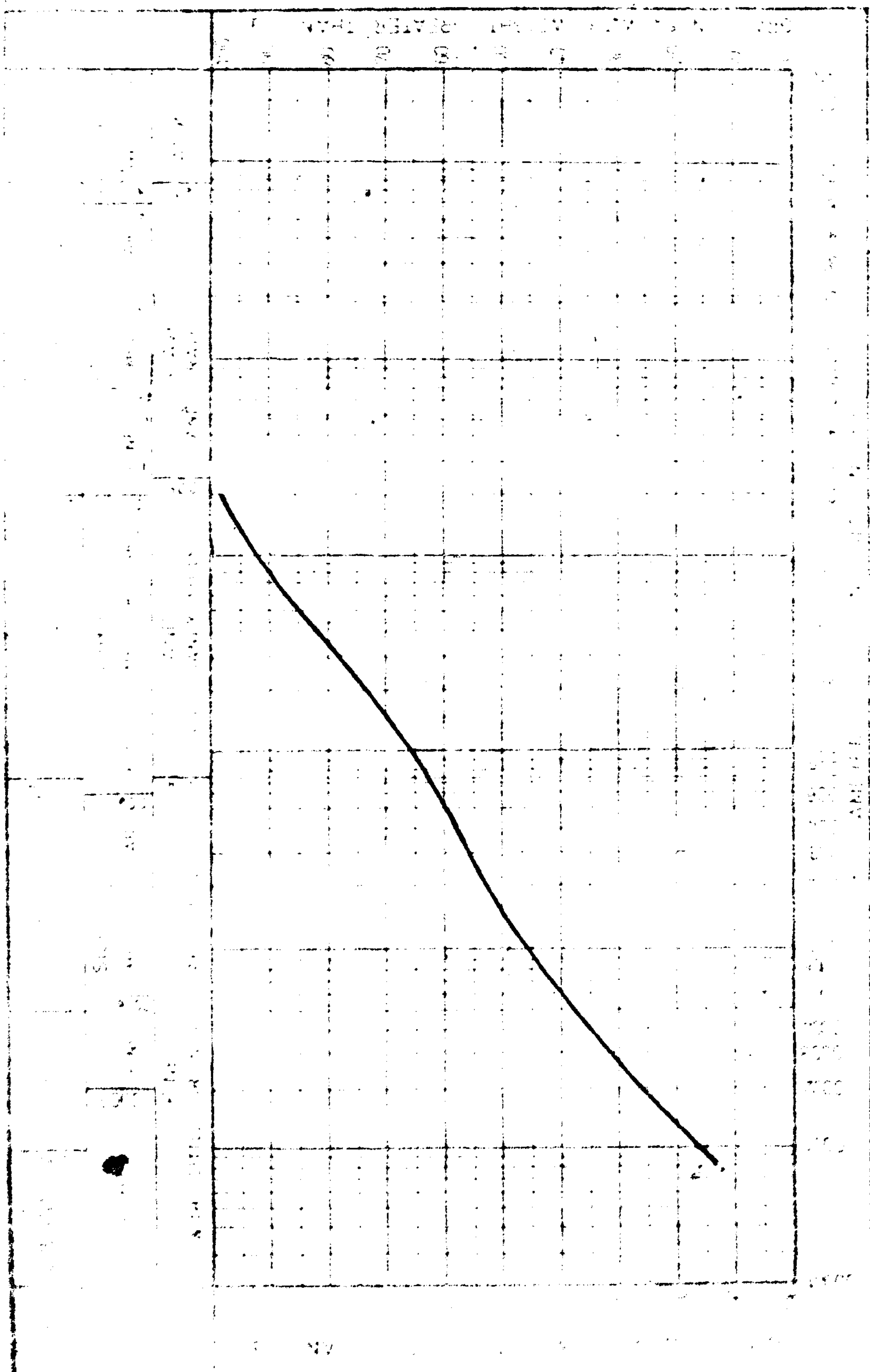
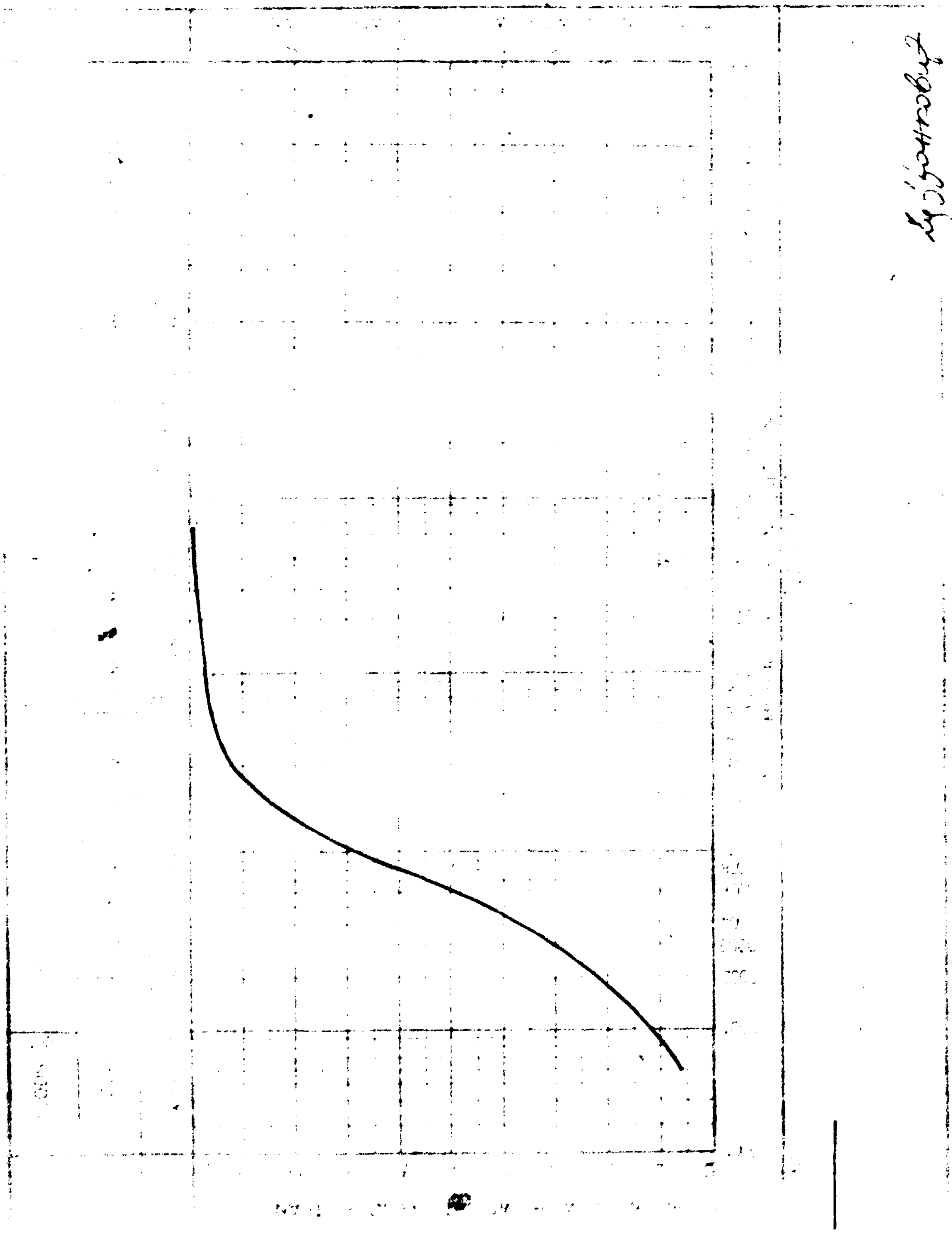


DIAGRAM OF GRADING

SUDAN - SOBA

POND



SUDAN - BLUE NILE RIGHT BANK

CLAY FROM POND

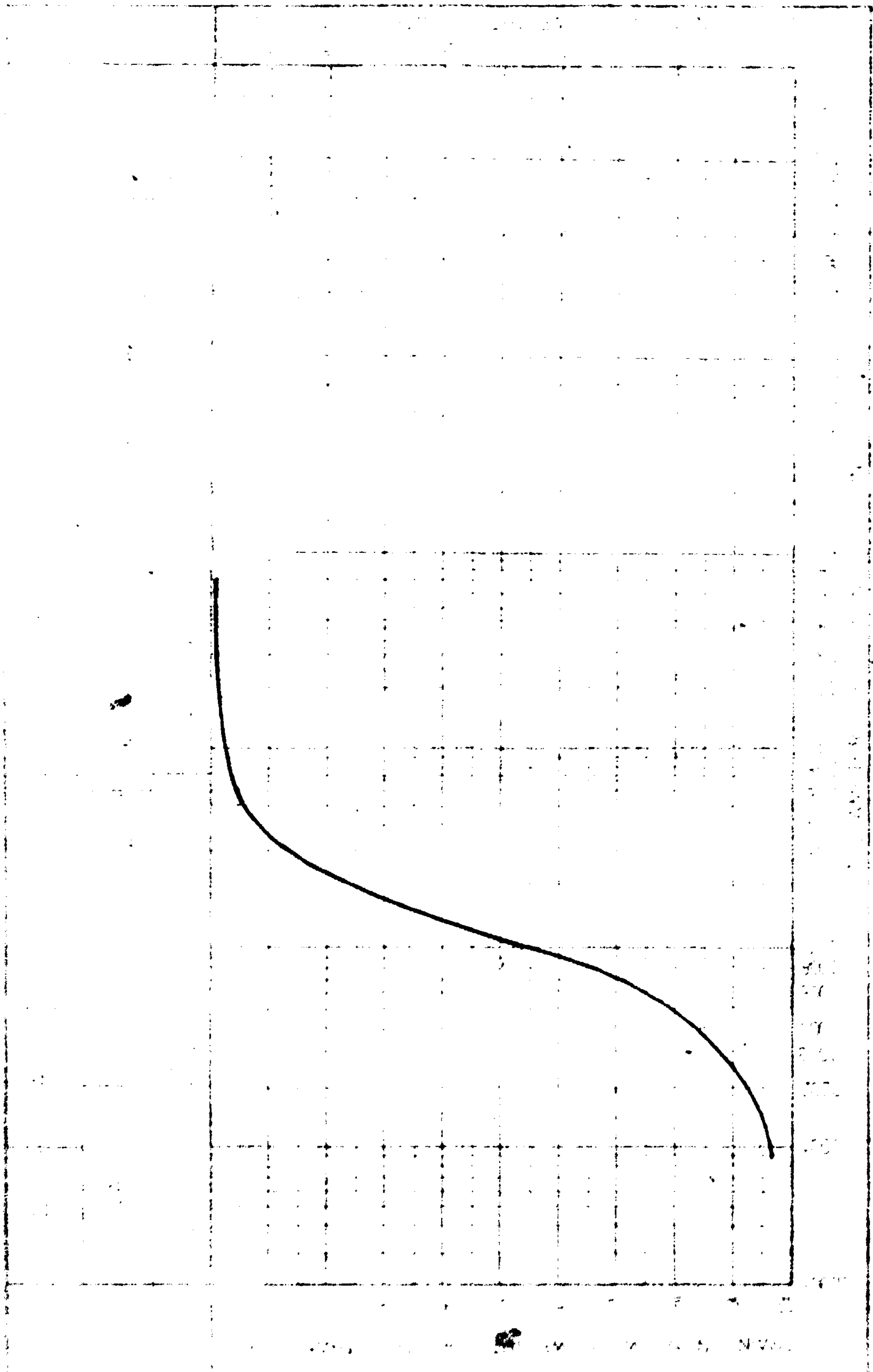
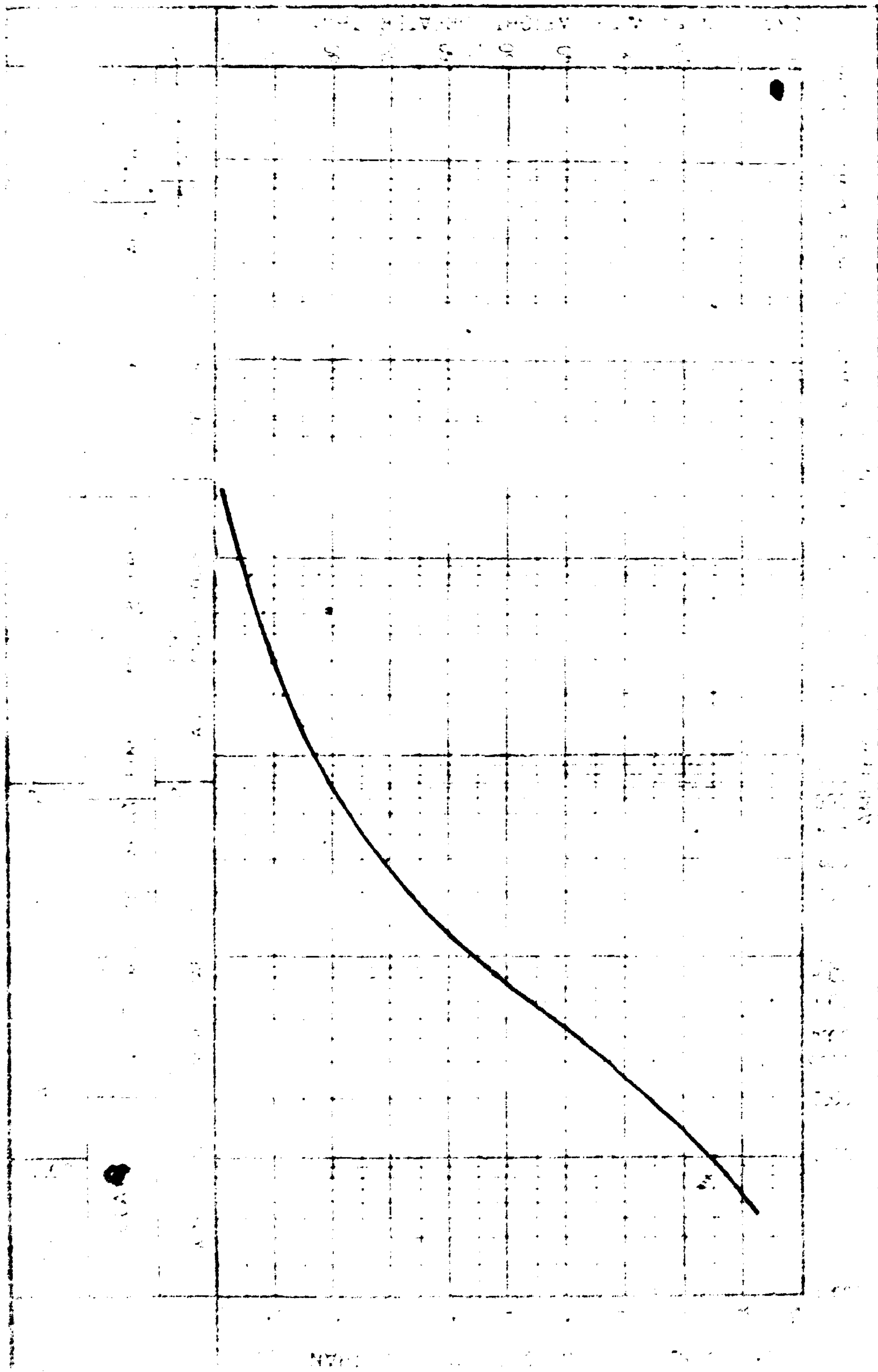


DIAGRAM OF GRADING

SUDAN - NORTH OF BLUE NILE

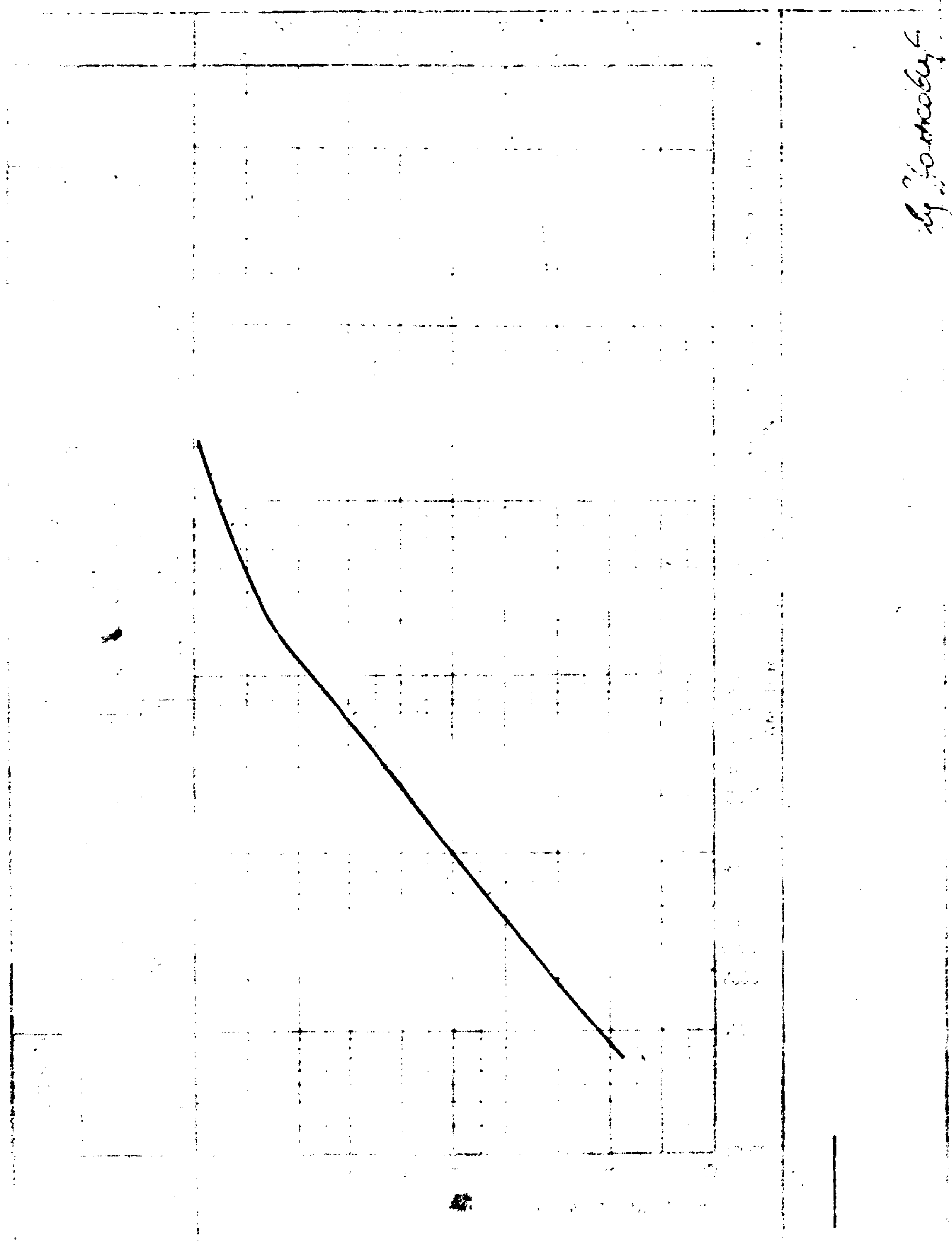
B.C.S



DIAGR[illegible] OF GRA[illegible]

SUDAN

WHITE NILE SILT



3.0. COMPLETE CERAMIC TESTS

Within the frame of complete ceramic tests, mineralogical, chemical and technological examinations have been performed. Results of such examinations are presented in this chapter.

REPORT

OF MINERALOGICAL AND CHEMICAL EXAMINATIONS OF SUDAN CLAYS

Institute for materials testing of Socialistic Republic of Serbia,B.O.A.L CENTAR for stone and structural ceramics,requested from us mineralogical and chemical examination of five clay samples brought from Sudan.

Materials received for examination were marked as follows:

1. TEST - 1
2. TEST - 2
3. TEST - 3
4. Black cotton soil
5. Pond silt-north bank of blue Nile

On all mentioned materials following examinations were carried out:

- particle size distribution content with quontative class extraction of sand powder and clay.
- quontative mineral class content of sand,powder,clay and sample as a whole.
- X-ray analyses
- differential thermal analyses (DTA) and thermo gravimetric analyses (TGA).
- chemical content
- water soluble salts

All results of these examinations are shown in Tables I/1-2 and II/1-6.Graphical survey is given on diagrams,supplements 1-9.

PARTICLE SIZE DISTRIBUTION

Results of particle size distribution are shown in Table I/1-2,diagram supplement 1-4.

On the basis of results obtained by examination sediments belong to:

TEST-1 and 2 , Sand powder unbound sediments,

TEST-3 and Black Cotton soil, sand powder clay sediments.

Pond silt north bank of blue Nile border between powder and clay powder sediments.

Examinations of samples presented content of sand from 1 to 51%, powder from 24 to 75% and clay from 18 to 45%.

With increase of sand content participation of larger grain is higher, so that at TEST No 3 we got a class over 1mm with content of 4%, while pond silt sample contained only 1% class of sand from 0,06 up to 0,1 mm.

Particle size distribution content of all tests shows that manufacture of brick products is possible.

MINERAL CONTENT

Result of quontative mineral class content examination of sand, powder clay and samples as whole shows that we have got almost thesame materials in view of quontative mineral presence.

Tests No 1,2 and 3 are of very similar content.They are belonging to quartz feldspar clay sediments where clay is a hydromica,kaolinite with smaller presence of chlorite,vermiculite.

Content of carbonates is small but gypsum appears in smaller quontities.

There is a difference among these three samples concerning content of quartz but on account of smaller clay mineral feldspar.

Tests of Black cotton soil and Pond silt are different in relation to previous three tests because they contain component of montmorillonite besides clay minerals which are mentioned above. Content of quartz and feldspar is lower, but however content of clay minerals is higher in Black cotton soil test, while higher presence of chlorite vermiculite was noticed in Pond silt test. X-ray diagrams , supplements 5 - 10, are confirming presence of quoted minerals.Reflections of quartz, feldspar and calcinite are characteristic.However, reflections of clay minerals particulary (CO_1) are weakly expressed and diffusive . Such distinction points at very weak crystallization of these materials, respectively at a very significant degree of their alteration. DTA and TGA curves,supplements 11 - 14 show that tests - 1,2 i 3 do not present any characteristic effect for clay minerals, due to degradation of clay minerals and participation of large number of mineral kind.Characteristic for TGA curves is substantial loss in weght up to the temperature of 200°C what is caused by moisture dehydration.Less dehydration occures at higher temperature, from 400° up to 700°C.

Black cotton soil, and Pond silt samples have hydrothermal effects at 100°C and 150°C and upon that at 500° and 700°C.This points at the presence if kaolinite and hydromica with possibility of vermiculite presence.From this comes out that presence of clay minerals is higher and that mixtures are more composite what makes it impossible for determination by this method. TGA analyses show the same caracteristcs as for previous three samples with exeption of dehydration losses which are considerably higher.

Results achieved by mineral content examination show that the basic mineral content of this clays as raw material for brick production is suitable.However, presence of gypsum in certain way appeares to be as a harmful component.

CHEMICAL CONTENT

Results of chemical content examination are shown in Table II - 6.Results achieved are showing that content of .silica and alumina is variable.Content of iron is very high and in cer tain way the content of alcaline metals is rather high. It is characteristic that all samples contain carbonate and sulphite calcite and gypsum respectively.Also significant content of organic matter was noticed.

Examination of water soluble salts, Table II/6 shows that the se clays are sulphate salted by presence of gypsum and other sulphates of alcalic metals.

Having in mind chemical content as well as water soluble salt it appears that clays of test are suitable for brick production. Black cotton soil appears to be less suitable.Remaining samples contain too much sulphates.

CONCLUSION

On the basis of mineralogical - chemical examination results, all samples are representing brick clays which are in a certain way suitable for brick production.However,in order to determina te certain clays we consider showing smaller sulphate con- tent are more siutable as raw materials.

Project manager

Prof.Dr. Dragoslav Nikolić

TABLE I/1

PARTICLE SIZE DISTRIBUTION ANALYSES OF SUDAN CLAYS

Class in mm	Test 1		Test 2		Test 3	
	d%	k%	d%	k%	d%	k%
+ 1,0	-	-	-	-	4,0	4,0
-1,0+0,6	-	-	1,5	1,5	5,5	9,5
-0,6+0,4	0,1	0,1	4,0	5,5	5,5	15,0
-0,4+0,2	4,9	5,0	8,0	13,5	10,5	25,5
-0,2+0,1	8,0	13,0	9,0	22,5	14,5	40,0
-0,1+0,06	9,9	22,9	8,5	31,0	11,7	51,7
-0,06+0,02	22,1	45,0	22,0	53,0	15,3	67,0
-0,02+0,005	36,3	81,3	28,2	81,2	8,0	75,0
-0,005+0,002	9,7	91,0	9,8	91,0	5,5	81,5
-0,002	9,0	100,0	9,0	100,0	18,5	100,0

	Test 1	Test 2	Test 3
Sand	22,9	31,0	51,7
Powder	58,4	50,2	24,3
Clay	18,7	18,8	24,0
Md (mm)	0,016	0,022	0,063

TABLE I/2

PARTICLE SIZE DISTRIBUTION ANALYSES OF SUDAN CLAYS

Class in mm	Black cotton soil		Pond-silt north bank of blue Nile	
	d%	k%	d%	k%
+1,0	-	-	-	-
-1,0+0,6	-	-	-	-
-0,6+0,4	-	-	-	-
-0,4+0,2	3,5	3,5	-	-
-0,2+0,1	8,5	12,0	-	-
-0,1+0,06	10,6	22,4	1,0	1,0
-0,06+0,02	17,4	40,0	24,0	25,0
-0,02+0,005	14,9	54,9	51,0	76,0
-0,005+0,002	6,1	61,0	14,0	90,0
-0,002	39,0	100,0	10,0	100,0

	Black cotton soil	Pond-silt north bank of blue Nile
Sand	22,6	1,0
Powder	32,3	75,0
Clay	45,1	24,0
Md (mm)	0,009	0,0079

TABLE II/1

RESULTS OF SUDAN CLAYS QUANTATIVE MINERALOGICAL CONTENT EXAMINATION

TEST 1

Fraction in mm	Sand 2,0-0,06	Powder 0,06-0,005	Clay -0,005	Whole sample
Percentage	22,9	58,4	18,7	100,0
Quartz	9,3	14,6	1,9	25,8
Feldspar	6,8	17,6	-	24,4
Mica	3,4	-	-	3,4
Accessory minerals	2,3	-	-	2,3
Chlorite	0,7	5,8	-	6,5
Vermiculite	-	5,8	1,8	7,6
Hydromica	-	8,8	10,8	19,6
kaolinite	-	5,8	2,8	8,6
halloysite	-	-	1,1	1,1
Carbonate	0,2	-	-	0,2
Org,mat.	-	-	0,4	0,4
Gypsum	0,1	-	-	0,1

TABLE II/2

RESULTS OF SUDAN CLAYS QUANTATIVE MINERALOGICAL CONTENT EXAMINATION

TEST 2

Fraction in mm	Sand 2,0 - 0,06	Powder 0,06 - 0,005	Clay - 0,005	Whole sample
Percentage	31,0	50,2	18,8	100,0
Quartz	14,6	12,0	1,9	28,5
Feldspar	9,3	12,5	-	21,8
Mica	3,1	-	-	3,1
Accessory minerals	3,1	-	-	3,1
Chlorite	0,3	7,5	-	7,8
Vermiculite	-	5,0	0,9	5,9
Hydromica	-	7,5	11,1	18,6
Kaolinite	-	5,2	3,8	9,0
Halloysite	-	-	0,9	0,9
Carbonate	0,3	-	-	0,3
Org.mat.	-	0,5	0,2	0,7
Gypsum	0,3	-	-	0,3

TABLE II/3

RESULTS OF SUDAN CLAYS QUANTATIVE MINERALOGICAL CONTENT EXAMINATION

TEST 3

Fraction in mm	Sand 2,0 - 0,06	Powder 0,06 - 0,005	Clay - 0,005	Whole sample
Percentage	51,7	24,3	24,0	100,0
Quartz	31,0	6,1	2,4	39,5
Feldspar	11,9	6,1	-	18,0
Mica	3,7	-	-	3,7
Accessory minerals	3,6	-	-	3,6
Chlorite	0,5	3,7	-	4,2
Vermiculite	-	2,4	1,2	3,6
Hydromica	-	3,4	15,6	19,0
Kaolinite	-	2,2	3,6	5,8
Halloysite	-	-	0,7	0,7
Carbonate	0,5	0,2	-	0,7
Org.mat.	-	0,2	0,5	0,7
Gypsum	0,5	-	-	0,5

TABLE II/4

RESULTS OF SUDAN CLAYS QUANTATIVE MINERALOGICAL CONTENT EXAMINATION

SAMPLE: BLACK COTON SOIL

Fraction in mm	Sand 2,0 - 0,06	Powder 0,06 - 0,005	Clay - 0,005	Whole sample
Percentage	22,6	32,3	45,1	100,0
Quartz	12,4	6,5	2,3	21,2
Feldspar	7,4	4,8	-	12,2
Mica	1,3	-	-	1,3
Accessory minerals	1,1	-	-	1,1
Chlorite	-	3,3	-	3,3
Vermiculite	-	3,2	2,3	5,5
Kaolinite	-	3,2	6,8	10,0
Hidromica	-	6,4	16,3	22,7
Halloysite	-	1,6	13,5	15,1
Montmorillonite	-	3,0	3,5	6,5
Carbonate	0,2	-	-	0,2
Org.mat.	-	0,3	0,4	0,7
Gypsum	0,2	-	-	0,2

TABLE II/5

RESULTS OF SUDAN CLAYS QUANTATIVE MINERALOGICAL CONTENT EXAMINATION

SAMPLE: POND SILT NORTH BANK OF BLUE NILE

Fraction in mm	Sand 2,0 - 0,06	Powder 0,06 - 0,005	Clay - 0,005	Whole sample
Percentage	1,0	75,0	24,0	100,0
Quartz	0,5	15,0	2,4	17,9
Feldspar	0,4	11,3	-	11,7
Accessory minerals	0,1	-	-	0,1
Chlorite	traces	11,3	-	11,3
Vermiculite	-	11,2	2,4	13,6
Hydromica	-	14,2	6,2	16,4
Kaolinite	-	7,5	7,2	14,7
Halloysite	-	3,8	3,6	7,4
Montmorillonite	-	4,0	2,0	6,0
Carbonate	traces	-	-	traces
Org.mat.	traces	0,7	0,2	0,9
Gypsum	traces	-	-	traces

TABLE II/6

CHEMICAL ANALYSES OF SUDAN CLAYS

	Sudan Test 1	Sudan Test 2	Sudan Test 3	Black cotton soil	Pond-silt north bank of blue Nile
SiO_2	48,53	53,05	62,28	51,67	40,02
TiO_2	2,05	1,82	1,15	1,30	2,33
Al_2O_3	13,90	13,02	9,71	12,63	13,61
Fe_2O_3	11,60	10,78	6,55	9,55	13,64
MnO	0,13	0,13	0,08	0,10	0,16
MgO	3,09	2,68	2,78	3,70	4,38
CaO	6,42	5,85	5,46	5,26	7,54
Na_2O	1,21	1,29	1,15	1,35	1,00
K_2O	1,35	1,35	1,23	0,95	1,23
SO_3	0,15	0,65	1,29	0,24	0,24
CO_2	1,28	1,10	2,38	1,46	1,28
Org.mat.	1,84	0,95	0,51	2,28	0,66
H_2O 110°	3,08	2,49	2,23	4,91	3,65
H_2O 1000°	6,02	5,36	3,31	4,86	10,19
Total	100,65	100,52	100,74	100,26	99,93

Water soluble salts

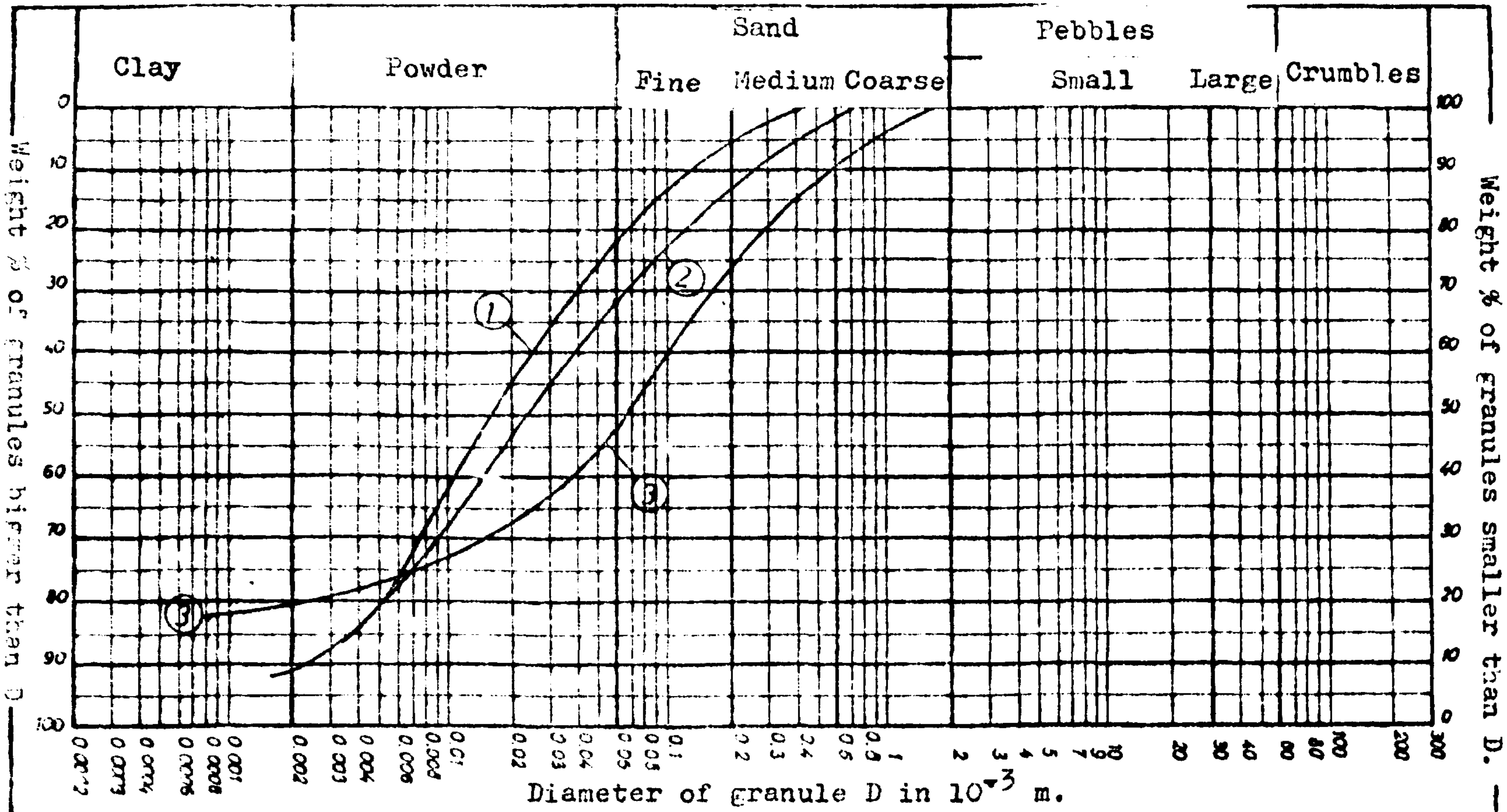
	Sudan Test 1	Sudan Test 2	Sudan Test 3	Black cotton soil	Pond-silt north bank of blue Nile
Na	0,0224	0,0772	0,3180	0,0240	1,4120
K	0,0316	0,0316	0,1472	0,0364	0,0248
Ca	0,0314	0,0236	0,0314	0,0550	0,0470
Mg	0,0096	0,0142	0,0096	0,0142	0,0096
Cl	-	-	0,0004	-	-
NO_3	-	-	-	-	-
HCO_3	0,1278	0,1278	0,2090	0,1974	0,1046
CO_3	-	-	0,0453	-	-
SO_4	0,1910	0,4238	0,4774	0,2510	0,3990

RGF-BEOGRAD BOAL-MK PG

Laboratory for mineralogy

SUPPLEMENT 1

PARTICLE SIZE DISTRIBUTION DIAGRAM OF SUDAN CLAYS



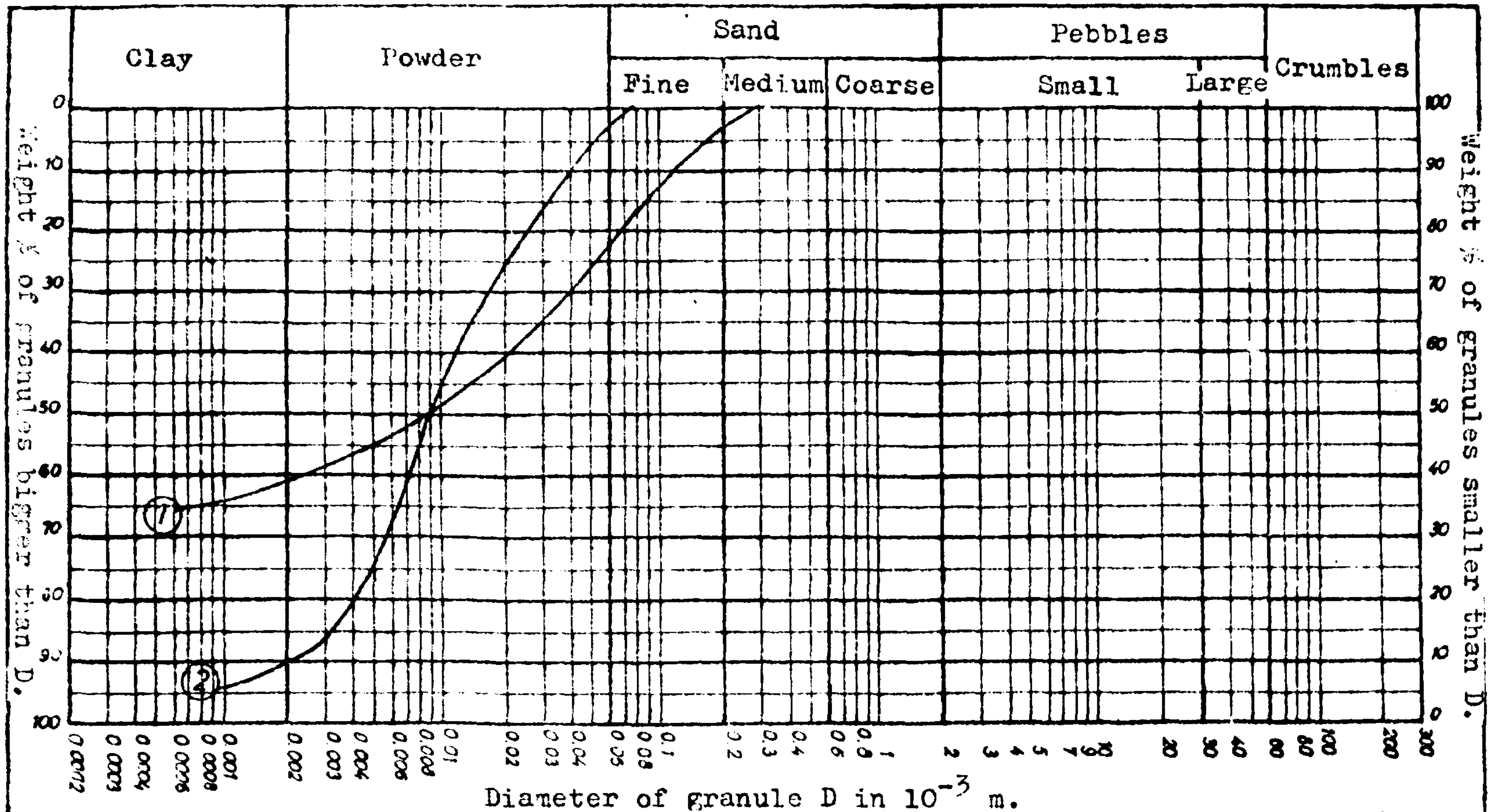
Legend

1. TEST - 1
2. TEST - 2
3. TEST - 3

RGF-BEOGRAD BOAL-MKFG

Laboratory for mineralogy

PARTICLE SIZE DISTRIBUTION DIAGRAM OF SUDAN CLAYS



Legend

1. TEST - 1
2. TEST - 2
3. TEST - 3

1. Black cotton soil
2. Pond silt - north bank of blue Nile

SUPPLEMENT 2

RGMF BEOGRAD

LABORATORY FOR MINERALOGY

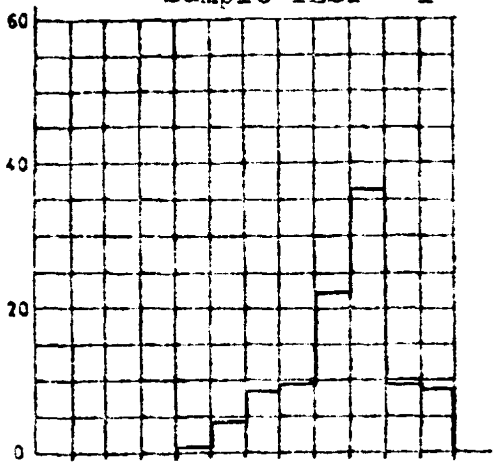
SUPPLEMENT 3

HISTOGRAM OF GRANULAR FRACTION SEDIMENTS DISTRIBUTION

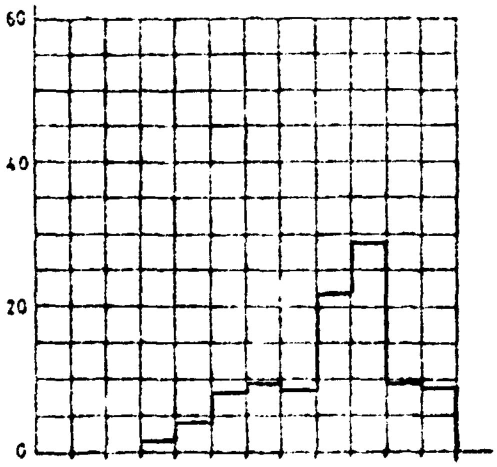
1% FRACTION

1. Table

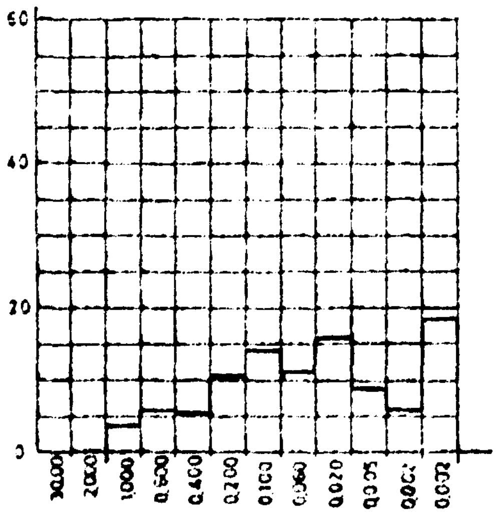
Sample TEST - 1



Sample TEST - 2

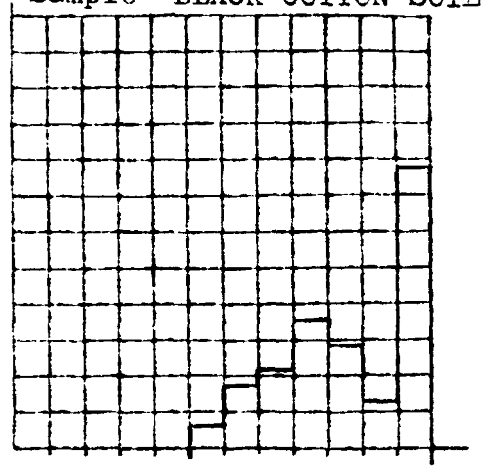


Sample TEST - 3

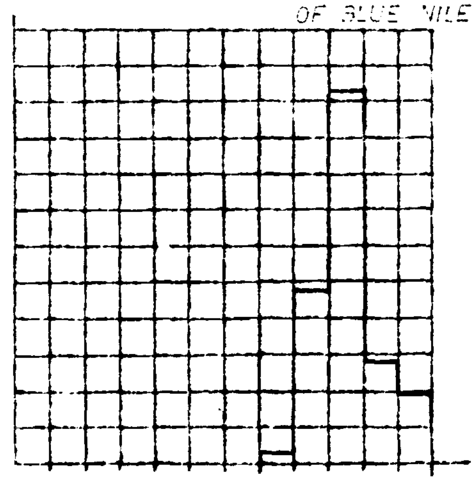


Table

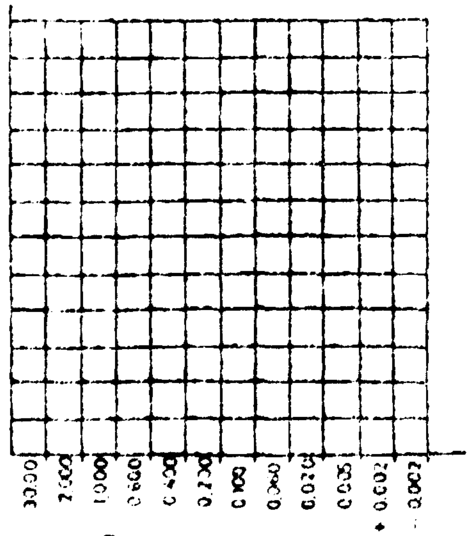
Sample BLACK COTTON SOIL



Sample POND SILT NORTH BANK OF BLUE NILE



Sample



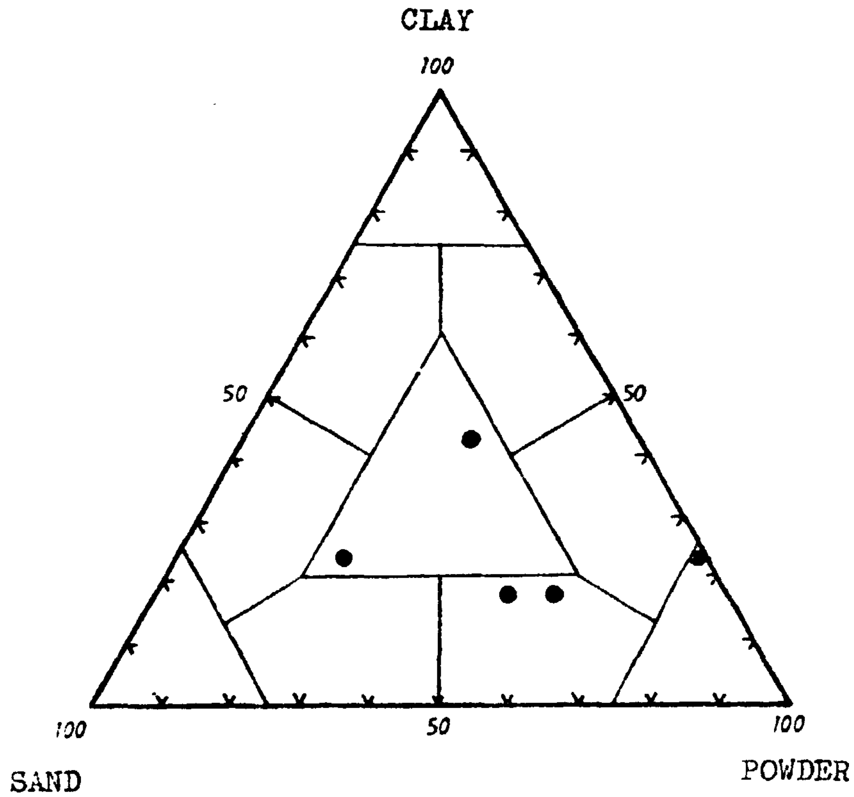
RGF - BEOGRAD

Laboratory for mineralogy

Supplement 4

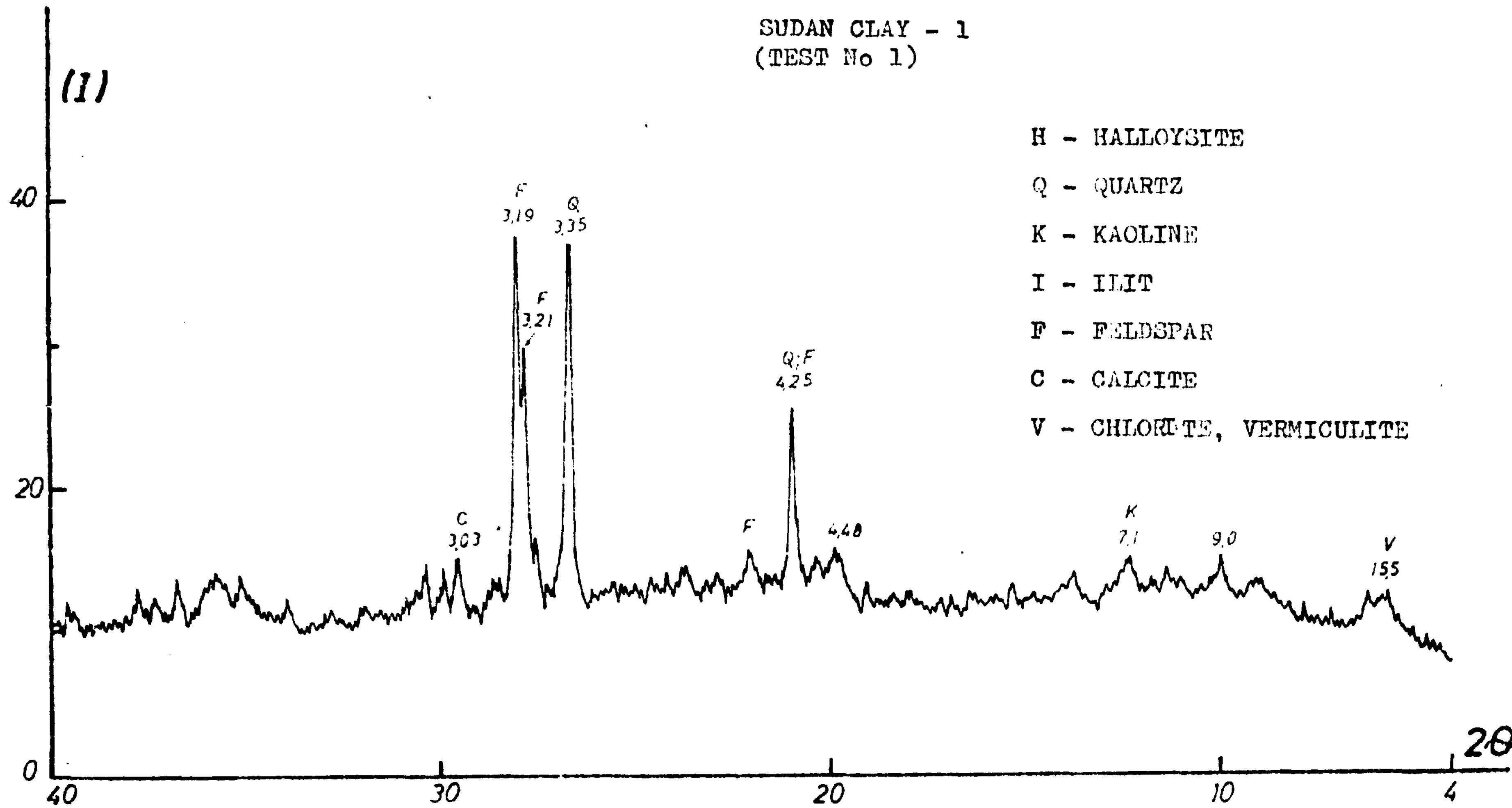
TRIANGULAR DIAGRAM BY SHEPARD

S U D A N   C L A Y

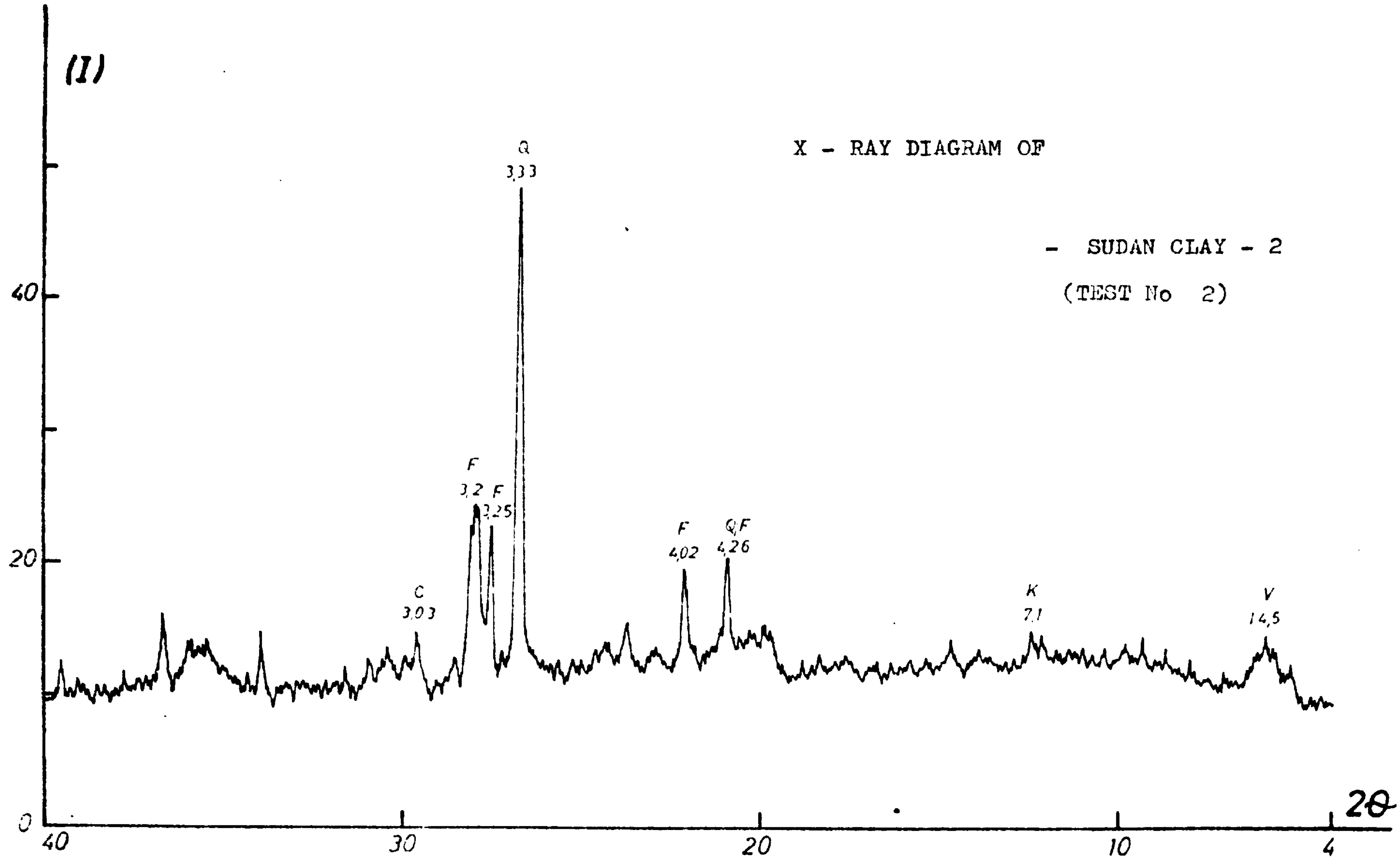


X - RAY DIAGRAM

SUDAN CLAY - 1
(TEST No 1)

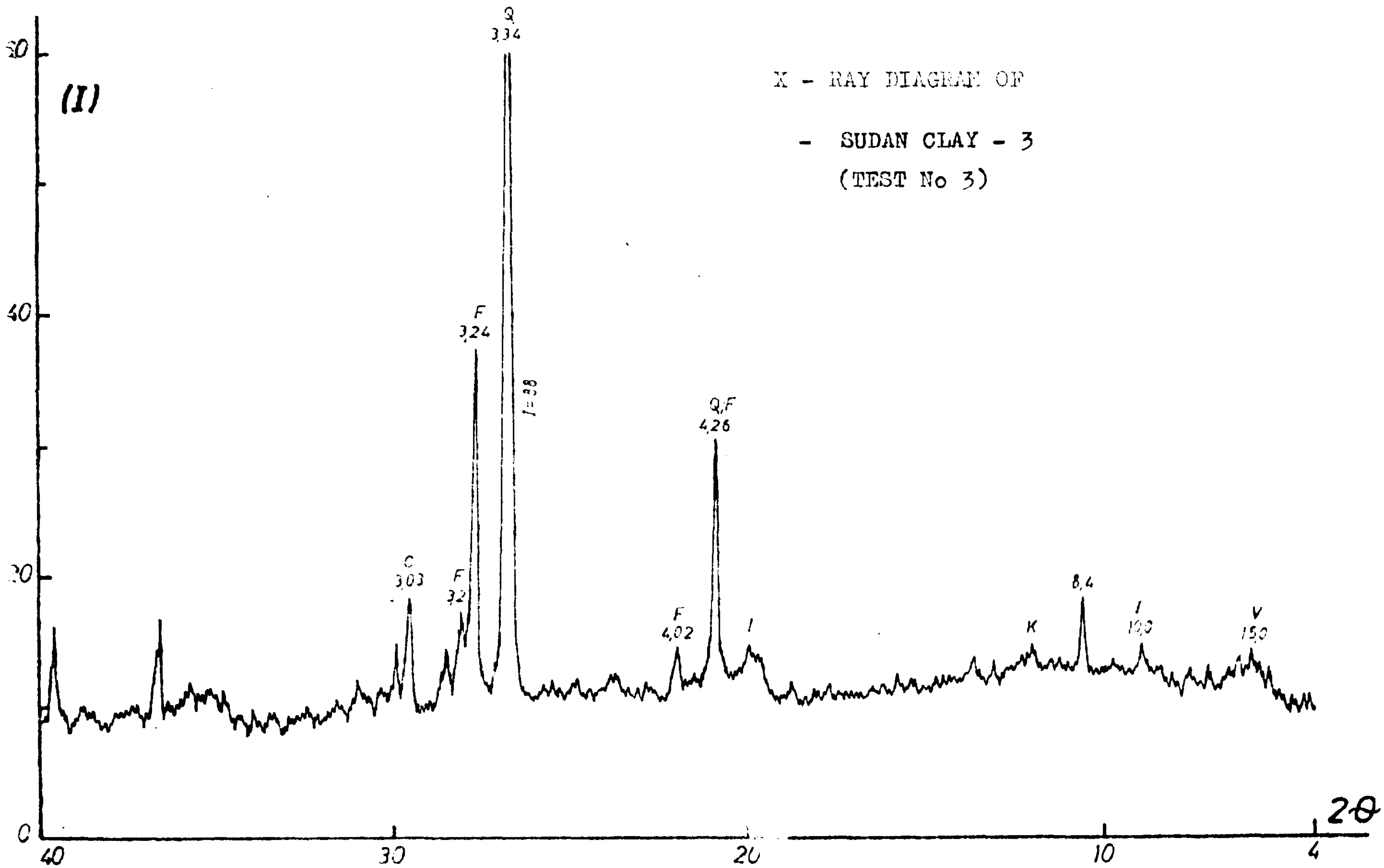


LABORATORY FOR MINERALOGY



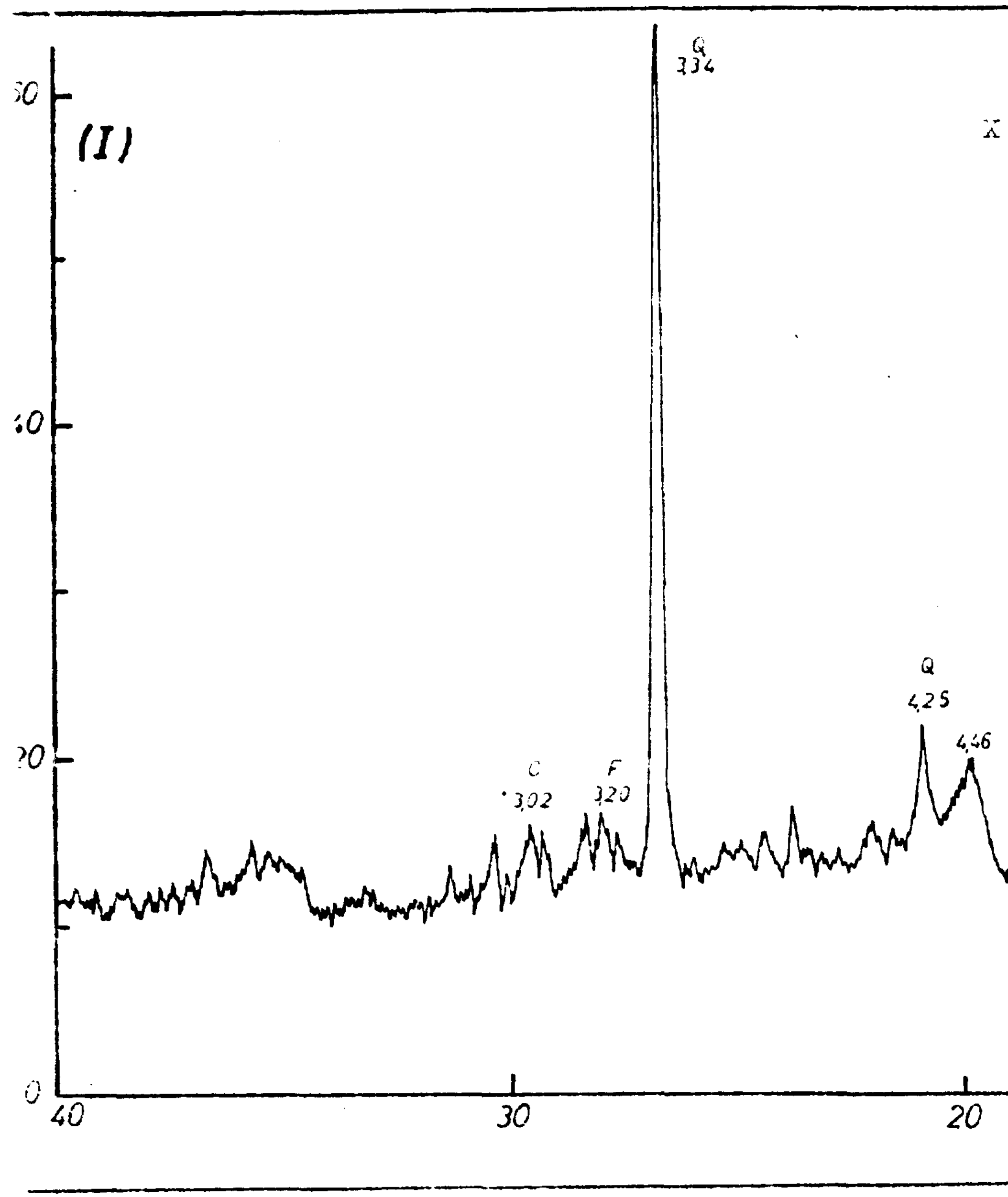
RGMF - BEOGRAD

SUPPLEMENT



LABORATORY FOR MINERALOGY

SUPPLEMENT

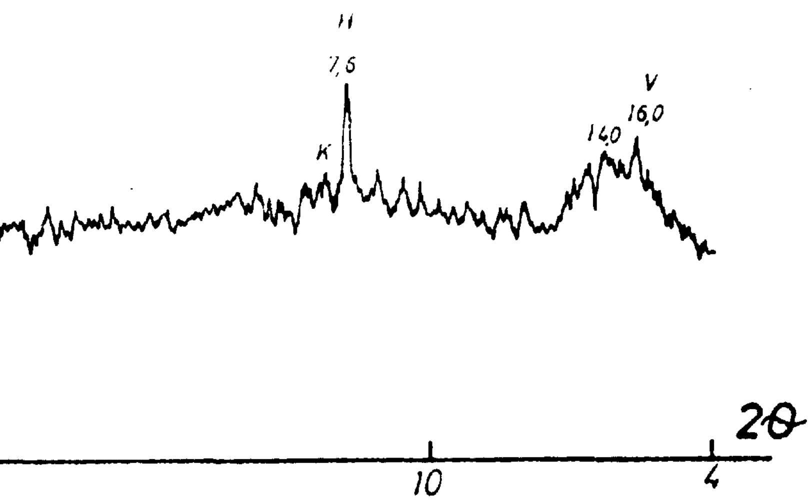


(I)
Q
3,34
Q
4,25
4,46
C
3,02
F
3,20
X
20
0
40
30
20

- RAY DIAGRAM OF

- BLACK COTTON SOIL

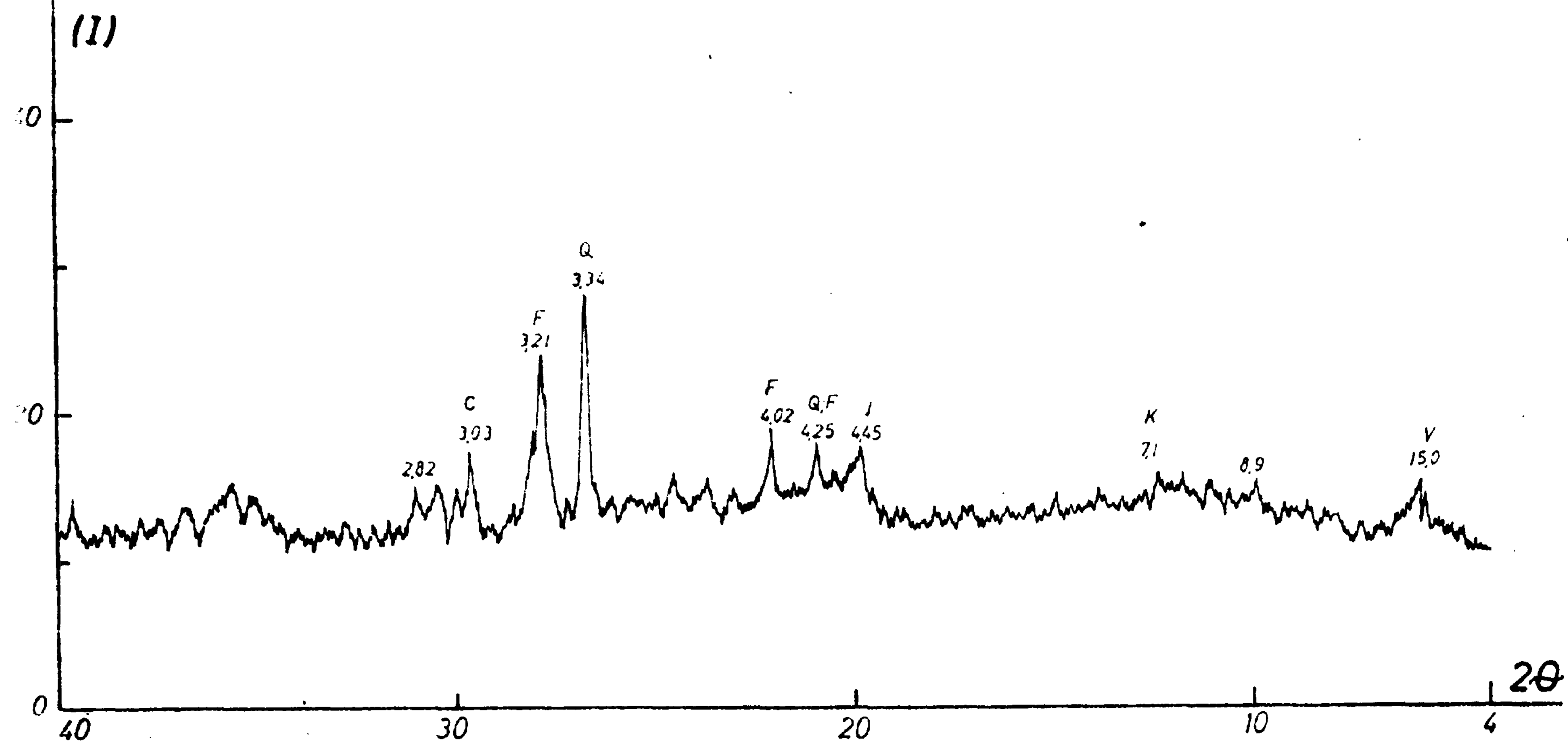
LABORATORY FOR MINERALOGY



SUPPLEMENT 8

X - RAY DIAGRAM OF

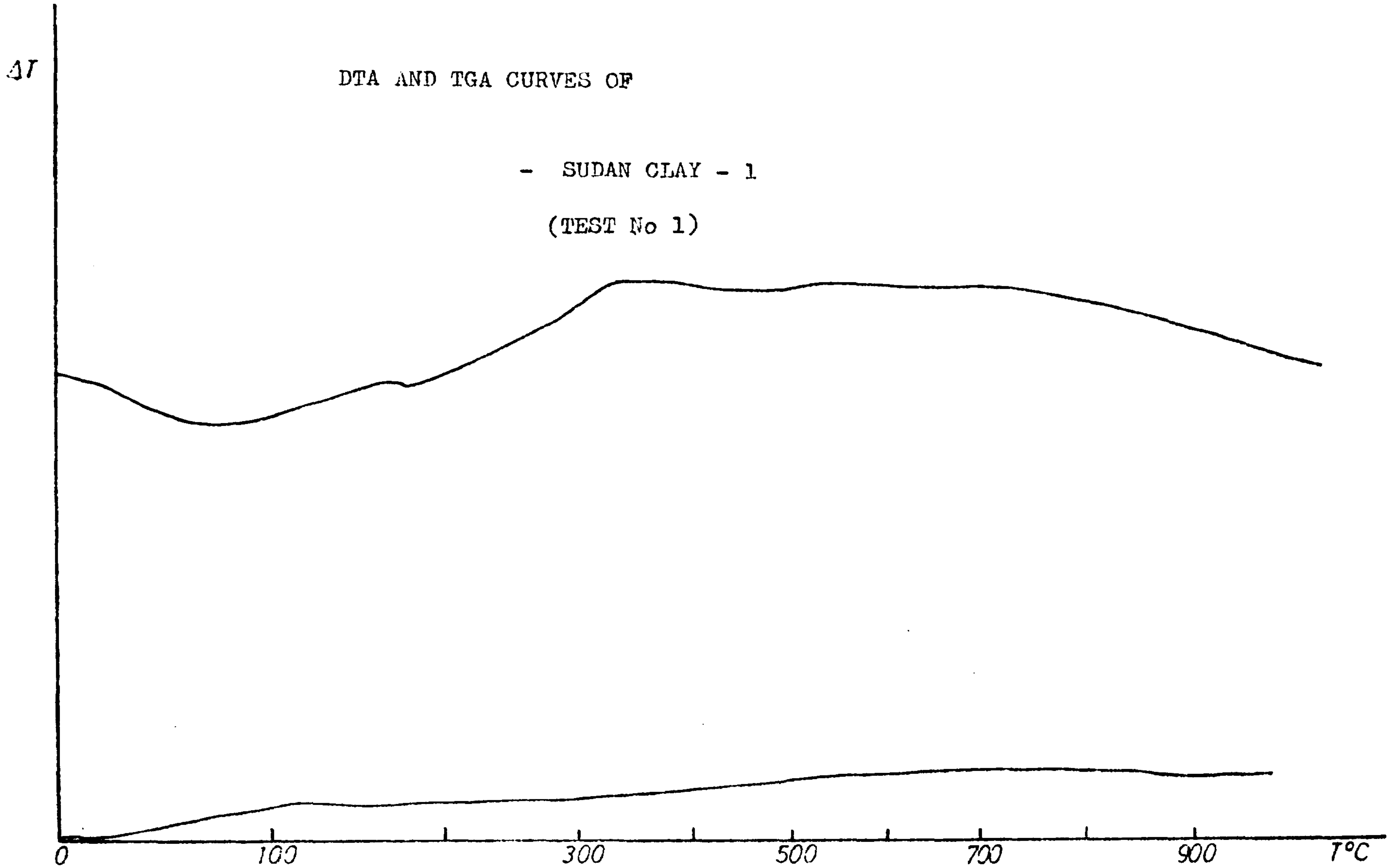
- POND SILT-NORTH BANK OF BLUE NILE



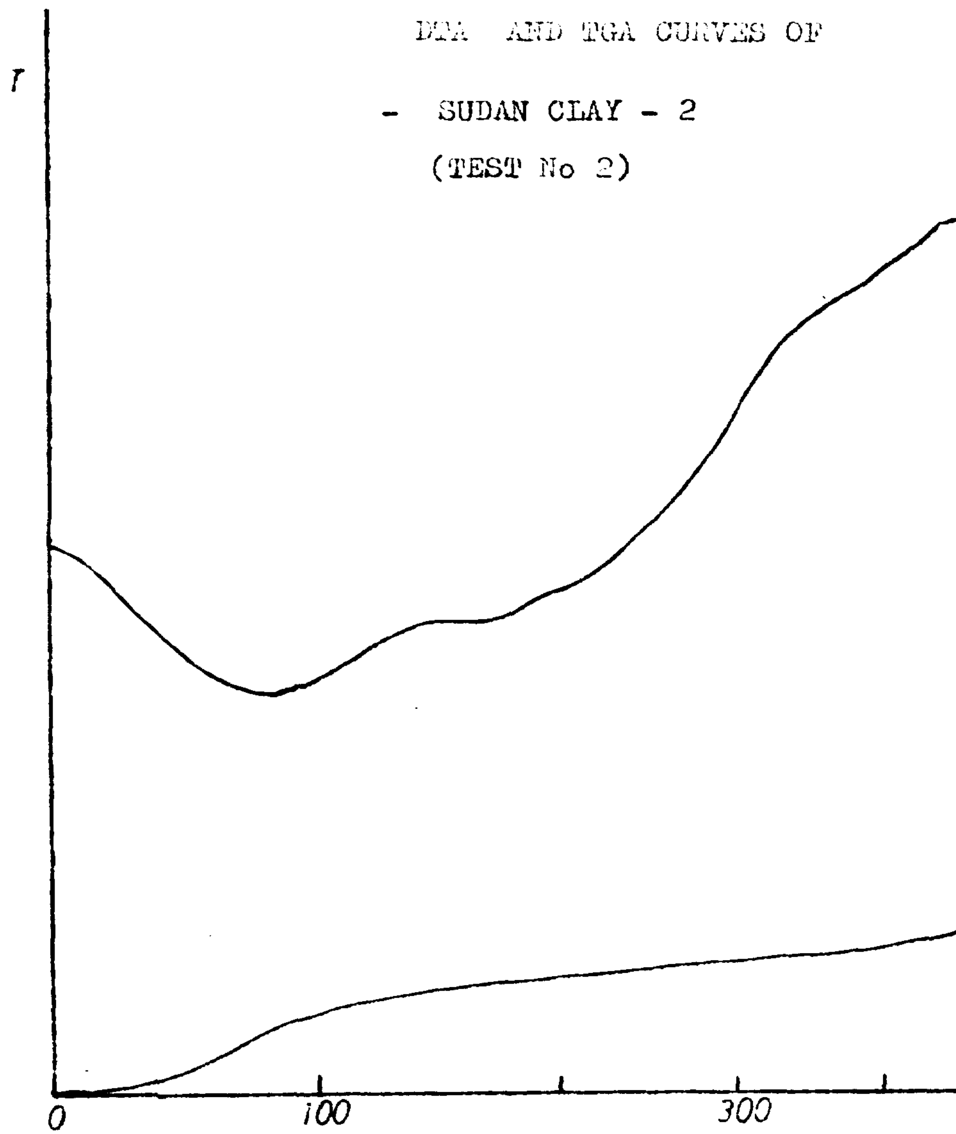
LABORATORY FOR MINERALOGY

SUPPLEMENT

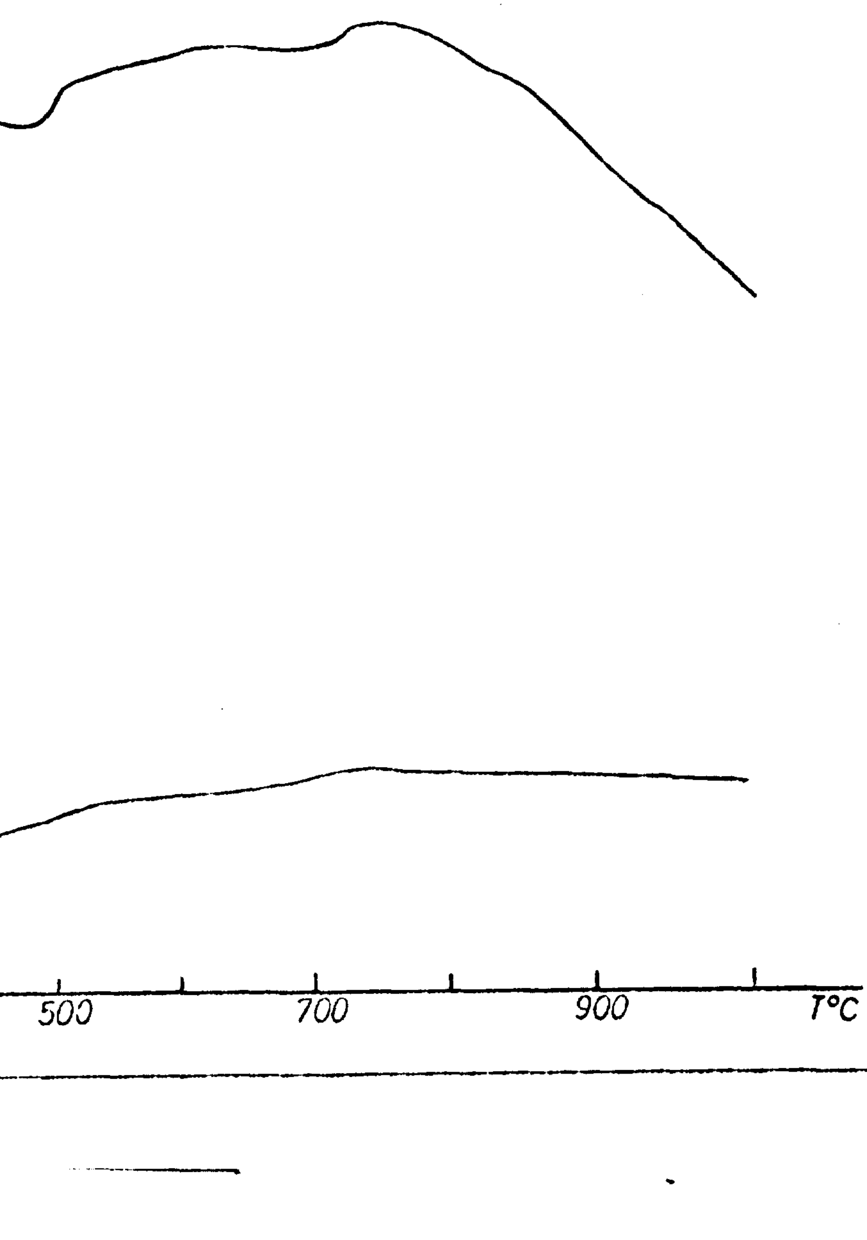
RGMF - BEOGRAD
LABORATORY FOR MINERALOGY



SUPPLEMENT 10

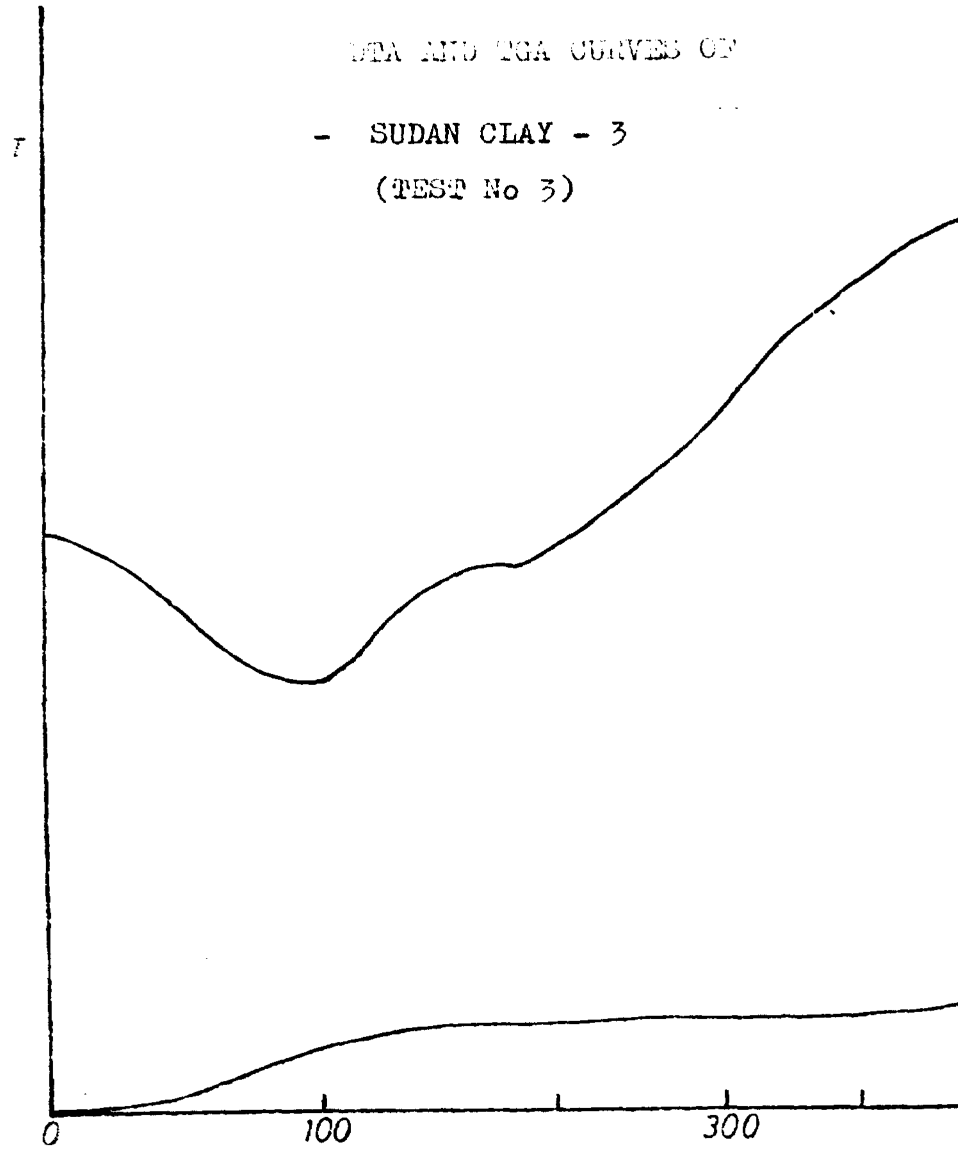


DTA AND TGA CURVES OF
- SUDAN CLAY - 2
(TEST No 2)
T
0
100
300



LABORATORY FOR MINERALOGY

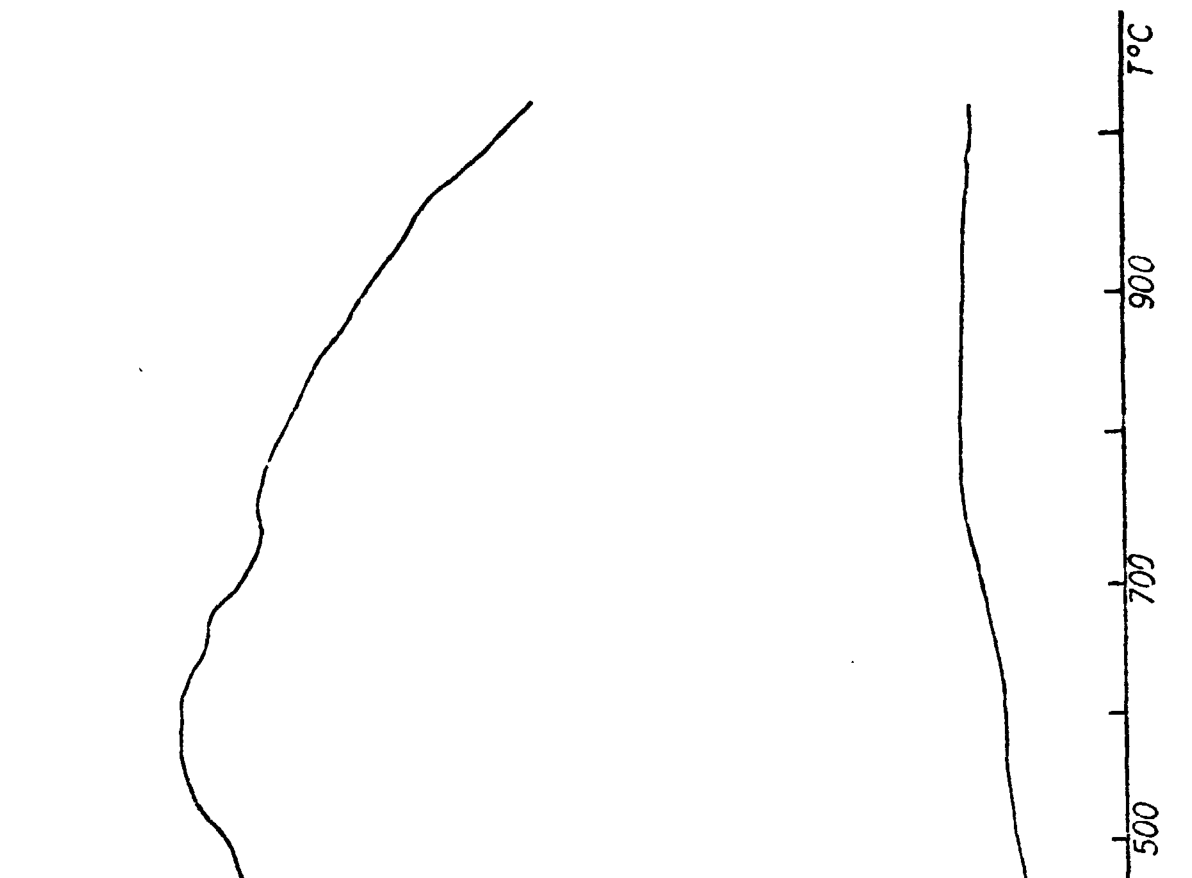
SUPPLEMENT II


DTA AND TGA CURVES OF
- SUDAN CLAY - 3
(TEST No 3)
T
0
100
300

RGMF BEOGRAD

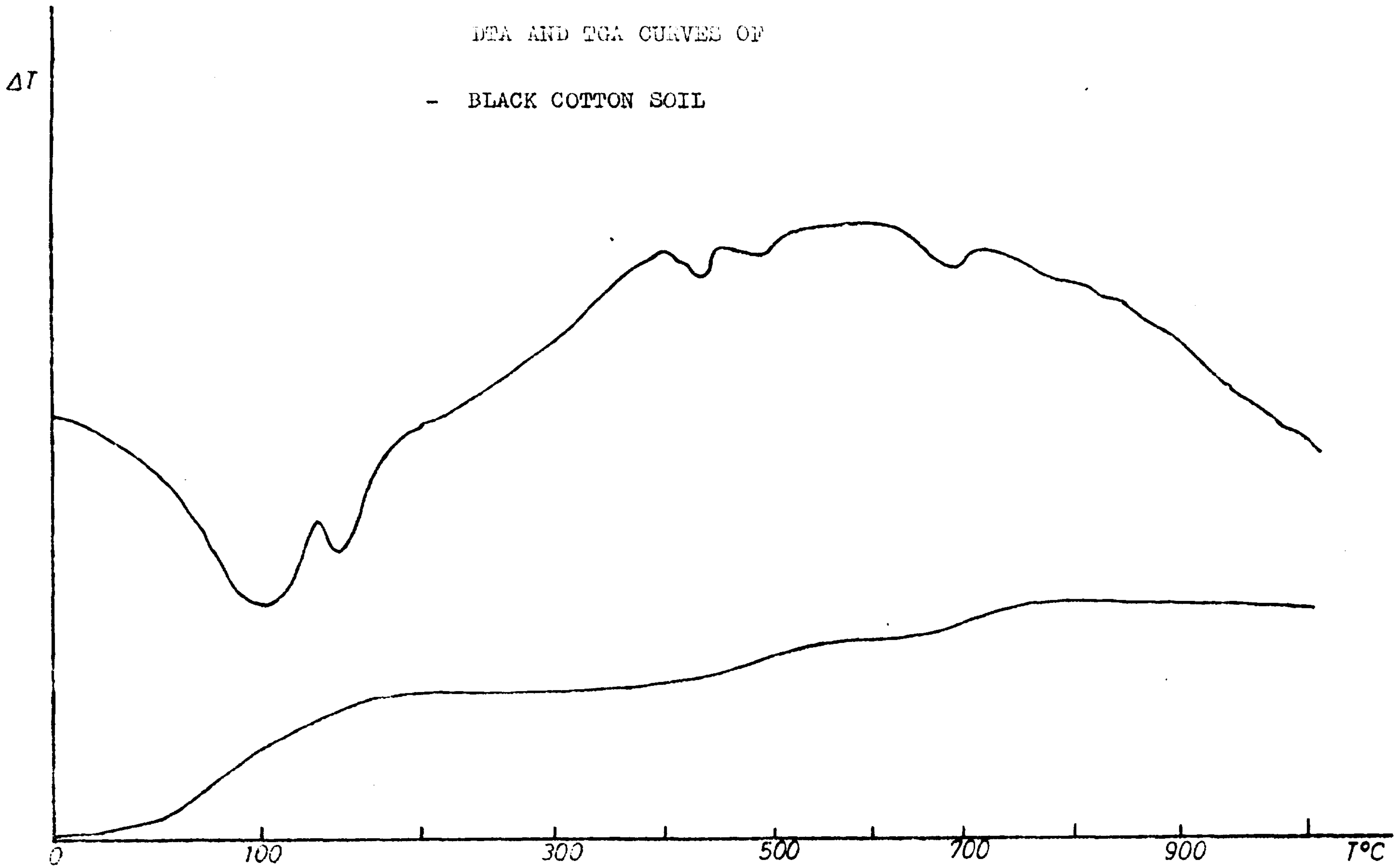
LABORATORY FOR MINERALOGY

SUPPLEMENT 12



DTA AND TGA CURVES OF

- BLACK COTTON SOIL

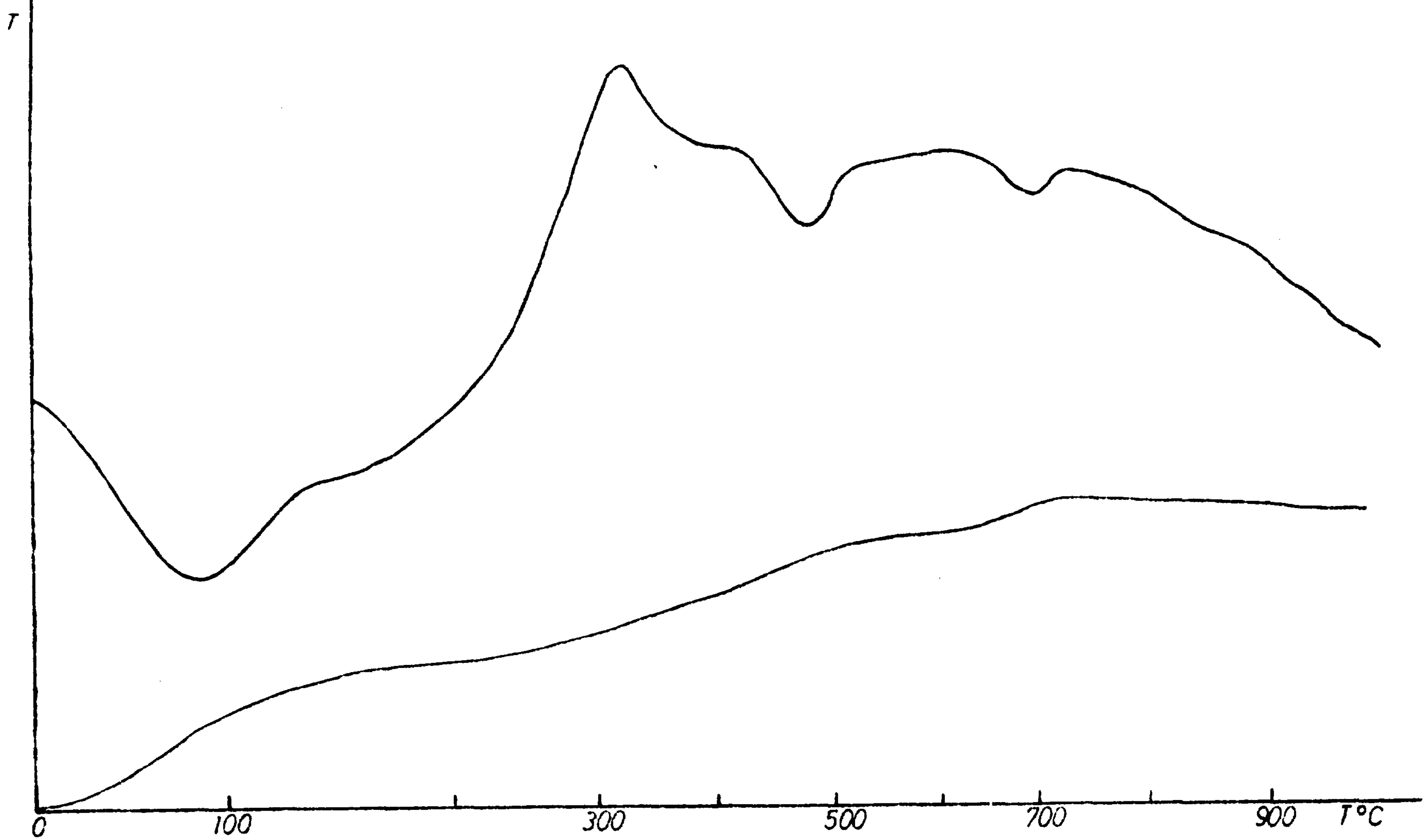


RGIF BEOGRAD
LABORATORY FOR MINERALOGY

SUPPLEMENT

DTA AND TGA CURVES OF

- POND SILT-NORTH BANK OF BLUE NILE



LABORATORY FOR MINERALOGY

DILATOMETRIC ANALYSIS

Dilatometric examinations have been carried out on electronic dilatometer model "Netzsch ".Measurement was done under following conditions:

- Maximum temperature - 1000°C
- Heating speed - 5°C/min.
- Cooling speed - 5°C/min (up to 500°C)
- Working atmosphere - air

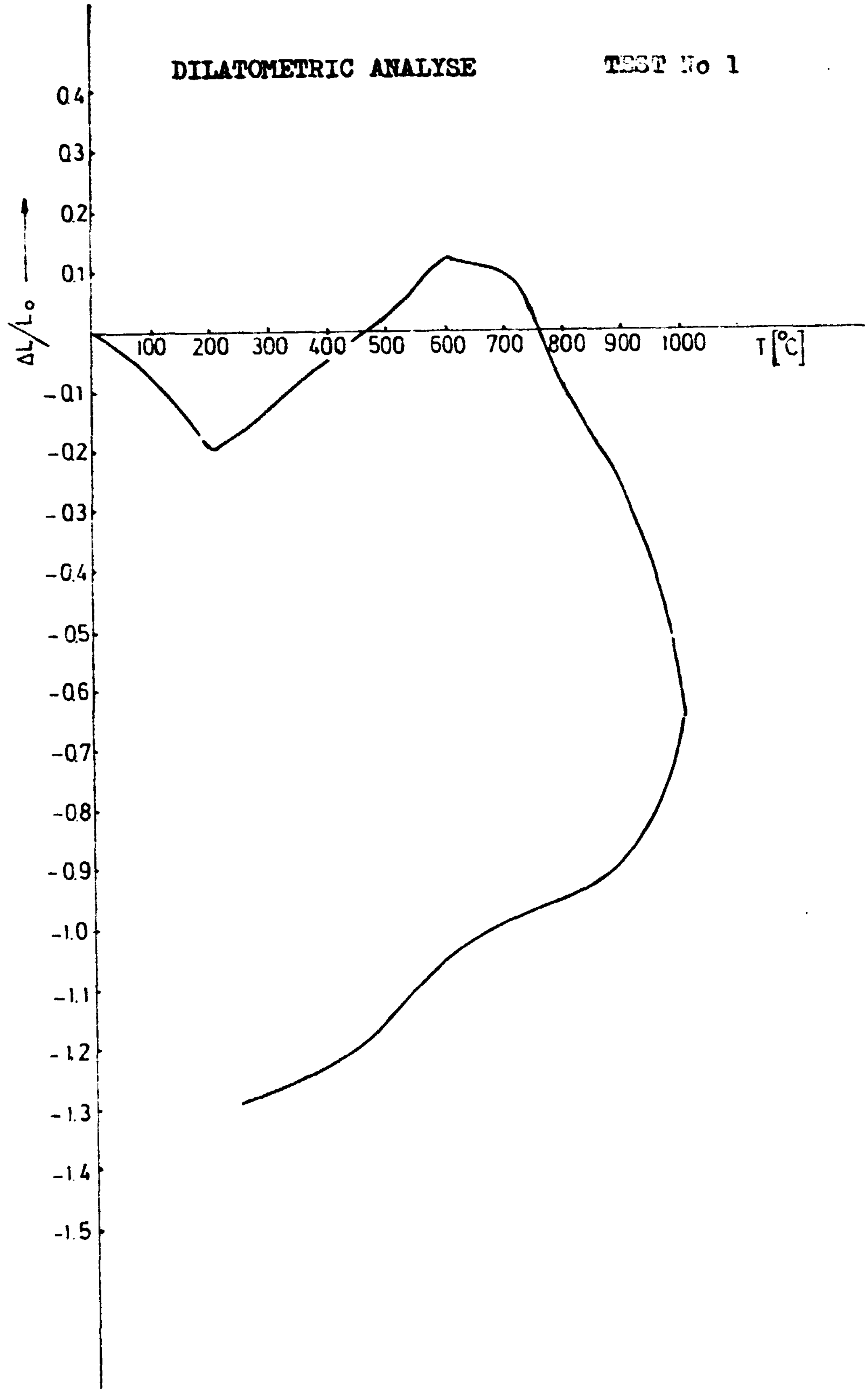
Dilatations registred are as follows:

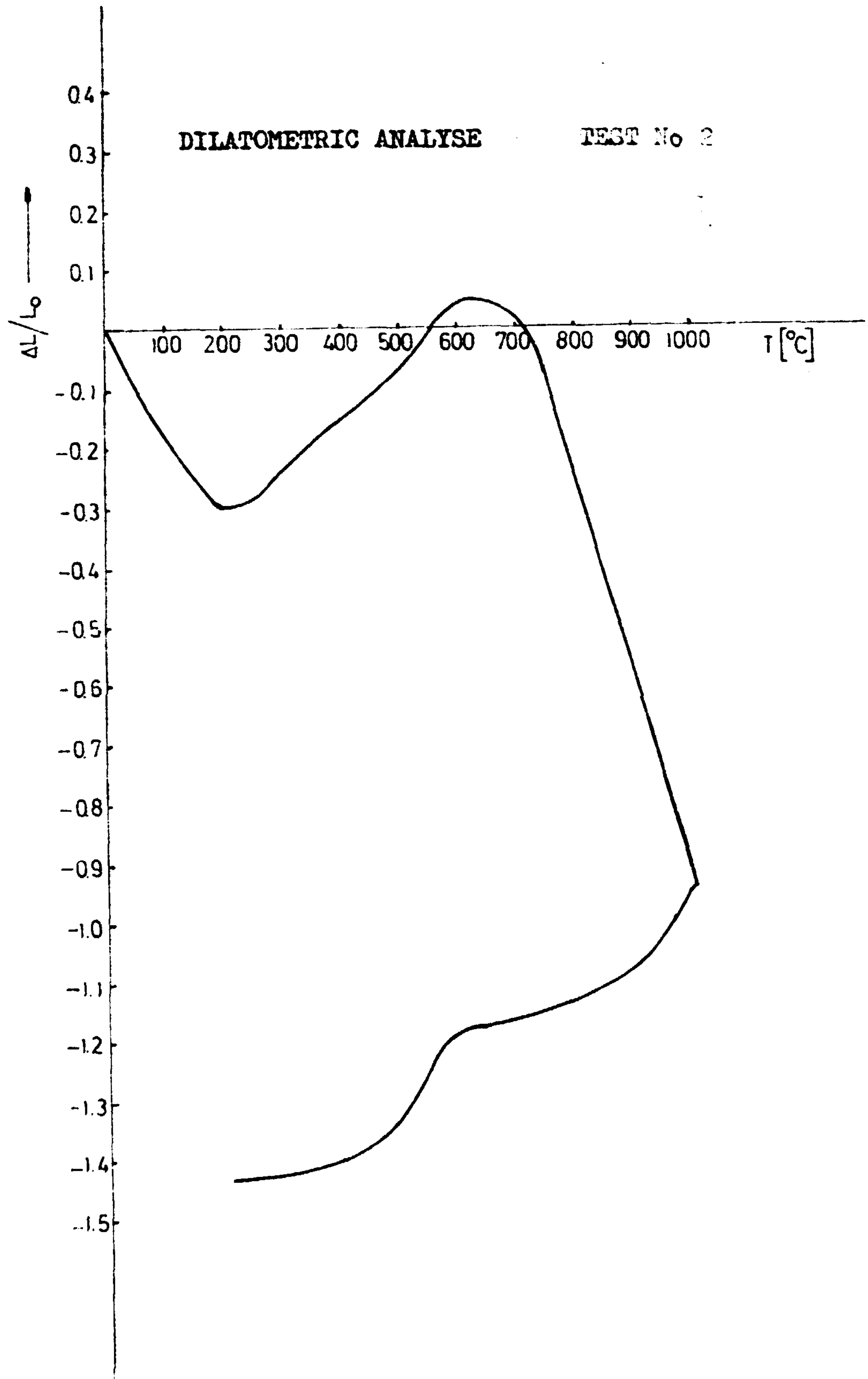
	Max.dilat. %	dilatation temp. °C
Test No 1	0,12	600
Test No 2	0,05	600
Test No 3	0,61	600
Test No 4	0,035	600

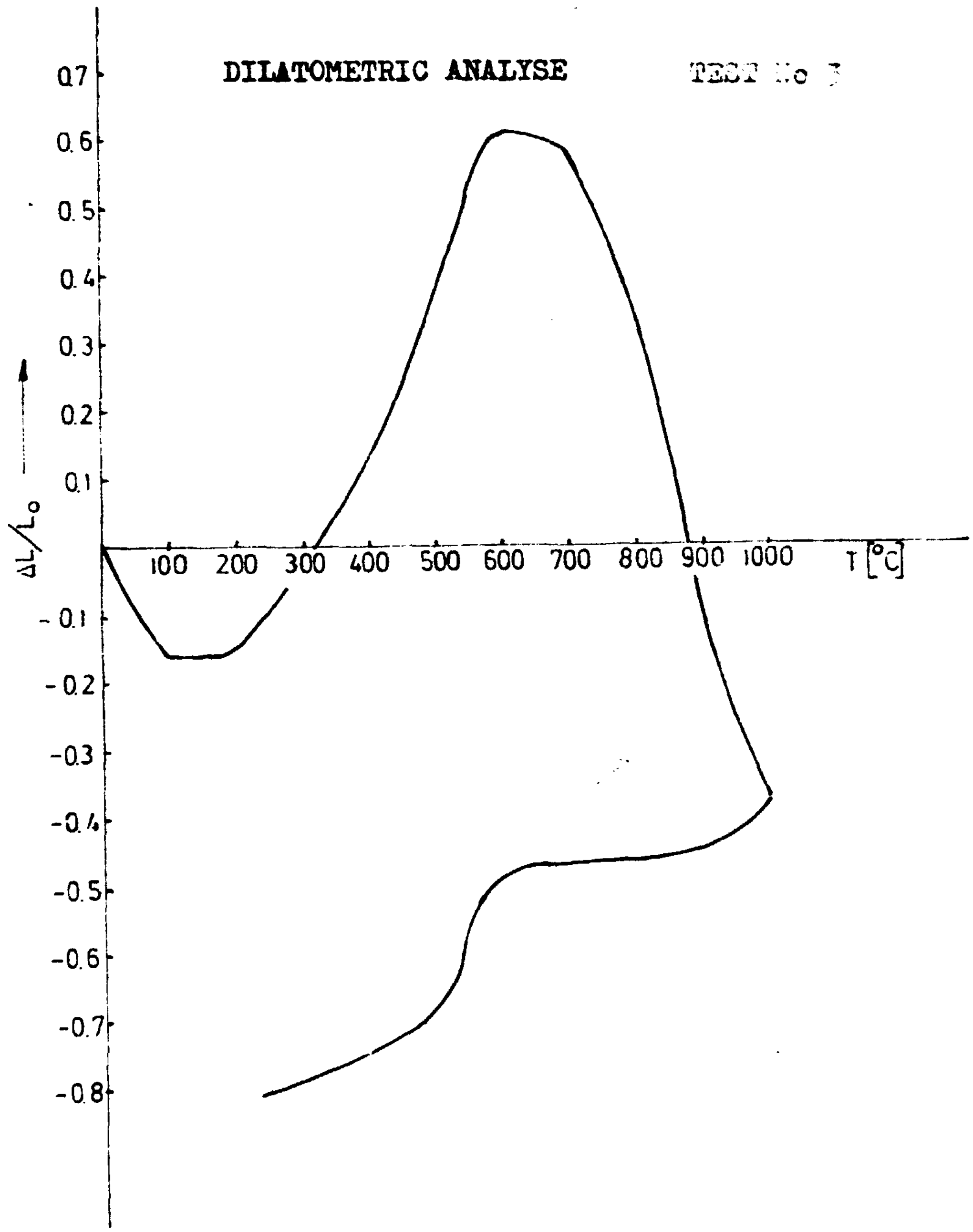
On the basis of dilatometric curves view it is visible that most intensive shrinkage of all four samples examined appears to be at the temperature of 200°C, what is actually consequence of water absorbtion from montmorilloniteDilatometric curves have a view characteristic for raw materials with high content of montmorillonite.

By measuring of infection value on dilatometric curve of cooling it can bee seen that all examined raw materials are very little sensitive at cooling.This considerably contributes to possibility of faster cooling at firing in Hoffmanor tunnel kilns, ,wereby the process of firing is significantly accelerated.

DILATOMETRIC ANALYSE TEST No 1

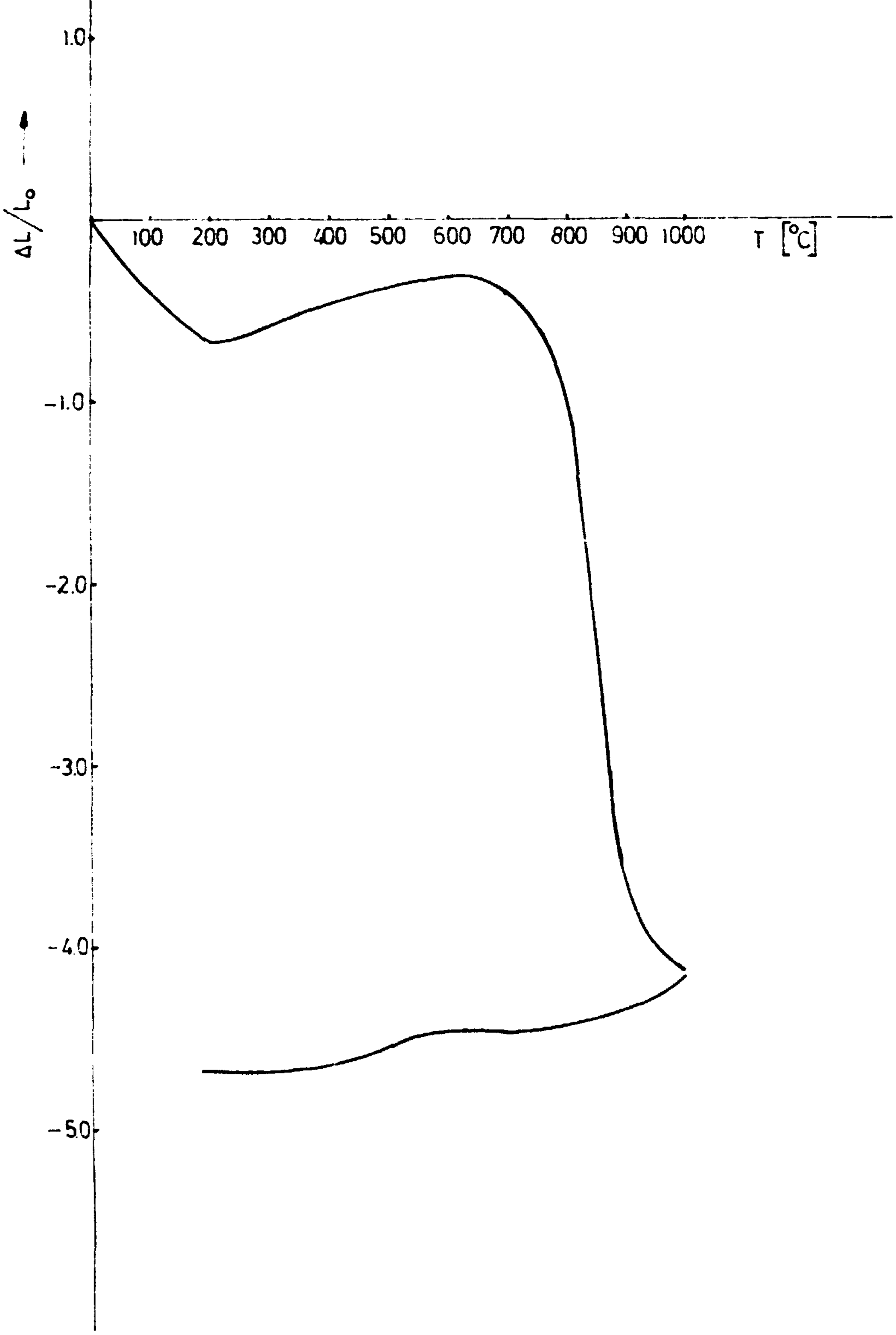



DILATOMETRIC ANALYSE TEST No 2
ΔL/Lo
0.4
0.3
0.2
0.1
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
-1.1
-1.2
-1.3
-1.4
-1.5
100
200
300
400
500
600
700
800
900
1000
T [°C]



DILATOMETRIC ANALYSE
TEST No
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
ΔL/Lo
100
200
300
400
500
600
700
800
900
1000
T [°C]

DILATOMETRIC ANALYSE BLACK COTTON SOIL



TEST 1 - [illegible]

[illegible]sitivity drying	Plasticity by Pfefferkorn	Linear shrink. at dry.	Water for shap.	Compr. strength (MPa)	Firing temperature (°C)	Loss of weight at firing	Linear shrinkage at firing	Water absorption	Compressive strength (MPa)
[illegible]	Plasticity index- [illegible] % Criterion of plasticity - very plastic	[illegible],0 %	[illegible],5[illegible]%	[illegible],00	900	[illegible],14 %	0,6 %	16,[illegible] %	11,4[illegible]
					960	[illegible],6[illegible] %	0,9 %	15,07 %	7,67
					1000	very damaged samples			

TEST [illegible] - SOBA

[illegible]itivity [illegible]rying	Plasticity by Pfefferkorn	Linear shrink. at dry.	Water for shap.	Compr. strenth (MPa)	Firing tempera-ture(°C)
[illegible] [illegible]itive	Plasticity index- [illegible] Criterion of plasticity - very plastic	[illegible],[illegible]	25,4[illegible]%	3,20	900
					960
					1000

Loos of weight at firing	Linear shrinkage at firing	Water absorbtion	Compressive streuth (MPa)
7,[illegible]0 %	+ 0,2 %	1[illegible],19 %	16,[illegible]
7,76 %	" 1,0 %	13,97 %	15,15
Very damaged samples			

TEST 3 - SOBA

[illegible]tivity [illegible] drying	Plasticity by Pfefferkorn	Linear shrink. at dry.	Water for shap.	Compr. strenth (MPa)	Firing tempera-ture(°C)	Loss of weight at firing	Linear shrinkage at firing	Water absorbtion	Compressive strenth (MPa)
[illegible]xtremly [illegible]	Plasticity Index- [illegible] % Criterion of plasticity - very plastic	[illegible],05	21,10%	[illegible],69	900	7,86 %	0,[illegible] %	12,72 %	1[illegible],75
					960	[illegible] %	1,0 %	11,9[illegible] %	10,08
					1000	very damaged samples			

TEST [illegible] - SOIL (ROUGH GRINDING) - BLACK COTON SOIL

[illegible] drying	Plasticity by Pfefferkorn	Linear shrink. at dry.stage	Water for shap.	Compr. strength (MPa)	Firing temperature(°C)	Loss of weight at firing	Linear shrinkage at firing	Water absorption	Compressive strength (MPa)
[illegible]	Plasticity index- [illegible],0 % Criterion of plasticity - very plastic	7,[illegible] %	[illegible]1,71%	[illegible],[illegible]0	900	9,5[illegible] %	[illegible],0 %	12,9[illegible] %	40,0
					950	9,91 %	[illegible],0 %	13,18 %	45,0
					1000	10,29	[illegible],0 %	13,14 %	45,0

TEST [illegible] - BORA - FORD SILT NORTH BANK OF BLUE NILE

[illegible]tivity [illegible] drying	Plasticity by Pfefferkorn	Linear shrink. at dry.	Water for shap.	Compr. strenth (MPa)	Firing tempera-ture(°C)	Loss of weight at firing	Linear shrinkage at firing	Water absorbtion	Compressive strenth (MPa)
[illegible] [illegible]itive	Plasticity index-[illegible] Criterion of plasticity - Outstanding plasticity	[illegible]	[illegible],51%	[illegible],01	900	10,20 %	0,6 %	1[illegible],18 %	51,[illegible]
					960	11,0 %	0,7 %	1[illegible],45 %	60,0
					1000	Very damaged samples			

Within the frame of " Soba " Sudan location exploration , three ceramic analyses have been done.They are marked here as test No 1, test No 2, and test No 3.Also,ceramic analysis of black cotton soil material from North bank of blue Nile location and analysis of pont silt material from White Nile location have been carried out.

It is characteristic for all raw material examined that they are very plastic and that on laboratorical samples of hollow block with vertical hollows appeared very big damage in view of longitudinal cracks.These cracks caused definitive breakage on samples roasted at 1000°C due to considerable linear shrinkage.

We are of an opinion that this was caused by the insuficient extrusion from laboratory vakuum press which worked at the considerably low forming pressure caused by shortage of raw material from " Soba " location at that moment,what actually prevented us from being able to repeat the extrusion.Reforming ~~subsequently delivered~~ of " Soba " location raw material was performed within the test No 1. examination with subsequently delivered raw material.

Reforming of subsequently delivered "Soba" location raw material was performed within the test No 1 examination, but at the pressure of 12 at.This gave much better results (see 4.0. STUDY TESTS).

Raw materials from"Soba" location which are examined within mentioned analyses can be utilised for exploitation in brick industry only with addition of the plasticity reducer.The same conclusion relates also to black cotton soil and pond silt raw materials.

Pont silt raw material posses very high linear shrinkage at drying and damages on laboratorical samples were quite substential after drying was finalized.

Hollow block samples with vertical hollows which are made of tests No 1,2 and 3 raw material have satisfactory value of compressive stress. It was noticed, that there is a small drop of this value on samples fired at 960°C in relation to the samples which were fired at 900°C.This appearance is actually contrary to the rule of ceramic material firing We are of an opinion that this is caused by bigger material shrinkage at increased temperature firing what brings to the broadening of the cracks originated in the drying phase whereby compressive stress value drops.

Results obtained by addition of kaolin, from Fiteihab location as it is a case here and by addition of other organic raw materials from mentioned locations, are shown in chapter 4.0.STUDY TESTS.

4.0 STUDY TESTS

EXAMINATION OF SAMPLE

EXPANSIBILITY

I - Examination was carri d out on formed samples of 1 cm^3 volume.They, were put into the kiln : at given temperature interval of 1050°C up to 1150°C.
Holding time of samples at given temperature was 5 minutes.
Three kinds of samples marked with S-4 , S-4a and S-5 were examined.

II - Results of examination

1. Sample S-4 (B.C.S.)

Firing temperature (°C)	Specific weight (Mg/m^3)	Coefficient of swelling
1050	1,12	1,42
1100	0,94	1,89
1150	0,54	2,00

2. Sample S-4a (B.C.S. - finy ground)

Firing temperature (°C)	Specific weight (Mg/m^3)	Coefficient of swelling
1050	1,23	1,43
1100	1,05	1,[illegible]
1150	0,70	2,03

3. Sample S-5 (pond)

Firing temperature (°C)	Specific weight (Mg/m^3)	Coefficient of swelling
1050	0,57	1,52
1100	0,47	2,83
1130	0,3[illegible]	2,82
1150	0,39	3,17

According to the examination results, following can be concluded:

- Biggest swelling effects are achieved with sample S-5. Temperature range in which swelling occured was rather narrow (about 50°C).

Suitability of this raw material for production of expanding materials should be investigated by the enlarged investigation programme, with addition of expansion supporting materials to the basic raw material.

- Samples S-4 and S-4a have shown weak tendency towards swelling (biggest coefficient of swelling = 2).

We are of an opinion that those raw materials have also to be tested in detail with addition of expansion supporting materials.

[illegible] 4a – (FINY GROUND)

[illegible] drying	Plasticity by Pfefferkorn	Linear shrink. at dry.	Water for shap.	Compr. strength (MPa)	Firing temperature (°C)	Loss of weight at firing	Linear shrinkage at firing	Water absorption	Compressive strength (MPa)
Extremly [illegible]	Plasticity index–[illegible] Criterion of plasticity – Outstanding plasticity	[illegible]	[illegible]	0,06	900	1?,0? %	?,?? %	10,?0%	Very
					950	1?,0 %	?,50 %	11,0 %	damaged
					1000	Very damaged samples			samples

T[illegible] [illegible]-[illegible] (75 % test Soba 1 = 25 % test Soba [illegible])

[illegible]itivity [illegible] drying	Plasticity by Pfefferkorn	Linear shrink. at dry.	Water for shap.	Compr. strenth (MPa)	Firing tempera-ture(°C)	Loss of weight at firing	Linear shrinkage at firing	Water absorbtion	Compressive strenth (MPa)
[illegible] [illegible]itive	Plasticity index- 75,[illegible] % Criterion of plasticity - Very plastic	7,[illegible]	18,[illegible]	6,[illegible]	900	10,1[illegible] %	[illegible],5 %	10,[illegible] %	20,61
					9[illegible]0	10,21 %	[illegible],[illegible] %	11,[illegible]7 %	19,[illegible]
					1000	10,[illegible] %	[illegible],0 %	11,50 %	15,[illegible]

[illegible] - 85 - B

Sensitivity drying	Plasticity by Pfefferkorn	Linear shrink. at dry.	Water for shap.	Compr. strength (MPa)	Firing temperature (°C)	Loss of weight at firing	Linear shrinkage at firing	Water absorption	Compression strength (MPa)
/	Plasticity index- Criterion of plasticity -/ /	[illegible]	[illegible]	/	900	11,[illegible] %	[illegible] %	15,[illegible] %	[illegible]
					950	11,[illegible] %	[illegible] %	[illegible]	[illegible]
					1000	11,[illegible] %	[illegible] %	15,[illegible]	[illegible],1[illegible]

TEST S3 - S5 - 0

Sensitivity drying	Plasticity by Pfefferkorn	Linear shrink. at dry.	Water for shap.	Compr. strength (MPa)	Firing temperature(°C)	Loss of weight at firing	Linear shrinkage at firing	Water absorption	Compressive strength (MPa)
/	Plasticity index- / Criterion of plasticity - /	[illegible]	[illegible],50%	/	900	15,58 %	6,[illegible] %	17,19%	6,93
					950	15,63 %	6,9 %	1[illegible],47 %	8,34
					1000	15,65 %	7,4 %	1[illegible],06 %	4,19

TEST S1-S[illegible] (90 % test S[illegible] 1 + 10 % test [illegible]

...sitivity drying	Plasticity by Pfefferkorn	Linear shrink. at dry.	Water for shap.	Compr. strength (MPa)	Firing tempera-ture(°C
/	Plasticity index- / Criterion of plasticity - /	[illegible],[illegible]%	1[illegible],[illegible]%	/	900
					900
					1000

...4a)

...)	Loss of weight at firing	Linear shrinkage at firing	Water absorbtion	Compressive strenth (MPa)
	8,15 %	[illegible],1 %	10,59 %	12,64
	[illegible],76 %	[illegible],5 %	11,85 %	14,6[illegible]
	[illegible],7[illegible] %	9,[illegible] %	9,72 %	15,59

TEST S-F (90% test Soba +10 % kaolin Fiteihab)										
[illegible]sitivity [illegible] drying	Plasticity by Pfefferkorn	Linear shrink. at dry.	Water absorption shap.	Compr. strength (MPa)	Firing temperature (°C)	Loss of weight at firing	Linear shrinkage at firing	Water absorbtion	Compressive strength (MPa)
[illegible]sitive	Plasticity index [illegible] % Criterion of plasticity - /	[illegible] %	10,[illegible] %	5,[illegible]	900	5,8[illegible] %	[illegible],5 %	13,[illegible] %	20,88
					960	9,08 %	[illegible] %	1[illegible],00 %	15,43
					1000	9,11 %	9,0 %	11,50 %	11,28

TEST 1 - [illegible] ([illegible]

[illegible] to drying	Plasticity by Pfefferkorn	Linear shrink. at dry.	Water for shap.	Compr. strenth (MPa)
[illegible]	Plasticity Index- [illegible] Criterion of plasticity - /	[illegible]	[illegible]	/

[illegible])				
Firing tempera-ture(°C)	Loss of weight at firing	Linear shrinkage at firing	Water absorbtion	Compressive strenth (MPa)
900	9,46 %	0,55%	11,5[illegible]%	[illegible]
950	9,[illegible]%	0,55%	1[illegible],9[illegible]%	2[illegible],9
1000	9,55%	0,55%	1[illegible],03%	28,0

[illegible] ([illegible])

[illegible]itivity drying	Plasticity by Pfefferkorn	Linear shrink. at dry.	Water for shap.	Compr. strenth (MPa)	Firing tempera-ture(°C)
[illegible]	Plasticity index- / Criterion of plasticity - /	10,[illegible]	[illegible]	/	[illegible]
					960
					1000

... 10 % pond)				
)	Loos of weight at firing	Linear shrinkage at firing	Water absorbtion	Compressive strenth (MPa)
	11,[illegible]%	1,[illegible]%	[illegible],78%	36,1
	11,44%	1,11%	11,82%	47,8
	11,63%	1,11%	11,31%	50,9

Experiments were carried out within the study tests, for evalutation of Black cotton soil and pond silt expansion possibility. Black cotton soil was rough ground (S_4) and fine ground (S_{4a}). Also following examinations of their mixtures were carried out:

- TEST S4a - Black cotton soil (fine ground)
- TEST Si - S5 - Composite 75% of TEST 1 and 25% of TEST 5
- TEST S_3 - S_5 - D - Composite 72,72% of TEST S_3, 18,18% of TEST S_5 and 9,09% of DUNG
- TEST S_1-S_{4a}- Composite 90% of TEST 1 and 10% of TEST S_{4a}
- TEST S - F - Composite 90% of TEST 2 and 10% of kaolin raw material from Fiteibhab
- TEST 1 (repeated) - repeated TEST 1 with increased extrusion pressure.
- TEST 6 - composite 90% of TEST 1 and 10% of pond silt.

Analysing results achieved by above tests we can conclude that ground raw material Black cotton soil had shown an increase of liner shrinkage value at drying and having in mind high plasticity of this raw material, fine ground should be taken out of further consideration.

Same occured with composite of test S_1 - S_{4a}.

Cracks which have appeared on the samples were caused by drop of the compressive stress value at roast temperature increase.

Suitable results we achieved with composite S-F (90% of TEST 2 and 10% of kaolin from Fiteihab), TEST 1 (repeated) and with TEST 6 (90% of TEST 1 and 10% of pond silt.

Tests with organe additions S3,S5 - D and S3,S5 - O represent only the basis for the further examination in this direction.

5.0. TESTS OF KAOLIN FROM FITEIHAB

Laboratory pressure tests have been carried out on kaolin sample from Fiteihab at the preasure of 14,7 MP.

After drying it has been confirmed that samples did not shrink.

Pressured samples were roasted at 1100°C , 1200°C and 1250°C.

Measurement of phisical and mechanical characterisics have shown following results:

	Linear shrinkage at firing	Loss at firing	Water absorbtion
1100°C	0,37%	7,17%	20,73%
1200°C	1,50%	7,20%	19,80%
1250°C	1,50%	7,17%	13,34%

Also refractorinesswas examined. Measured value equals to 17/18 SK (1500°C).

On the basis of the results obtained, the kaolin from Fiteihab location can be considered as a very interesting material for further examinations, and data obtained are showing possibility of its application in ceramic industry.

CHEMICAL ANALYSIS OF KAOLIN FROM FITEIHAB LOCATION

SiO_2	67,09
TiO_2	1,12
Al_2O_3	20,53
Fe_2O_3	2,25
MnO	0,01
MgO	0,22
CaO	0,40
Na_2O	0,15
K_2O	0,40
SO_3	traces
CO_2	0,18
org.mat.	no
H_2O 110°	1,04
H_2O 1000°	6,80
	100,19

Salt content

Mg	0,0048
Ca	0,0078
Na	0,0142
K	0,0042
	0,0310
Cl	0,0005
HCO_3	0,0017
NO_3	no
SO_4	0,0206
	0,0228

C O N C L U S I O N

On the basis of the results achieved by sample examinations of clay materials from the Democratic republic of Sudan, following can be concluded:

- Individual ceramic tests are shown that silt deposit of Soba is very heterogeneous.

This points out the necessity of raw material homogeneization in the process of exploatation, and production.

- Complete ceramic analyses are showing that tests 1 and 2 from Soba represent very sandy materials which in laboratorical conditions are rather difficult for shaping. At the same time they show sensitivity on drying.

Test - 3 shows material of higher plasticity and higher $CaCO_3$ content.

Test 4 - Black cotton soil shows that this material is not suitable as raw material for brick industry. Contenteally formed and dried the product disintegrated at firing.

- Test - 5, pond clay, shows high linear shrinkage at drying. It gives the product of good mechanical characteristics after roasting, but due to its sensitivity at drying and shrinkage of 13% this test appeares to be rather unsuitable as raw material for bricks production.

- Study tests have shown that properties of Soba silt best may be improved by addition of 10-15% of Fiteihab kaolin.

- Addition of 10-25% of clay from pond to silt essentially improves workability and mechanical characteristic of final product but at the same time sensitivity at drying intensifies.

- Addition of dung and ground nuts hulls as fuel, light weight gives final product and surly contributes decrease of fuel consumption at firing.

Solution of this problem requires further laboratorical examination.

- Basic problems which will be faced by brick [illegible] in Soba climate conditions (hot dry air and wind) in their work with basic raw materials, sensitive at drying, will be drying of the formed green bricks. We are recommending production of hollow blocks and drying in two phases. First phase of drying has to be done in closed space where drying procedure can be controlled and slowed down.

After critical phase, the products can be finaly dried at entirely open space or at roof covered space.

If silt is to be used as a basic raw material we recommend firing temperature of [illegible] °C.

Practice of this Institute is to perform tests in the industrial conditions before introduction of such sensitive raw material. Unfortunately, this time, above, can not be respected, what presents a [illegible] for the project.

- Examination of Fitaihab kaolin indicates that this is a very good ceramic raw material which have possibility of wider application range.

- Tests of clays from [illegible] are [illegible].

- Expansion tests of black cotton soil gave negative results but this is probably caused by the fact that delivered samples contained high amounts of [illegible] components. It is necessary to check [illegible] [illegible] black cotton soil is good raw material for production of light weight expanded aggregate.

C-970

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