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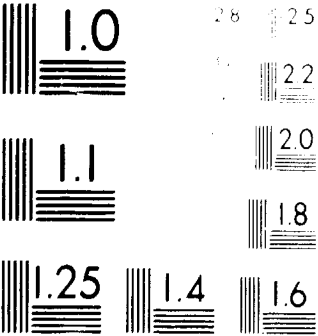
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Sudan.

# AN ASSESSMENT OF CONDITIONS FOR CONSTRUCTION OF PILOT BRICK PLANT NEAR KHARTOUM

SI/SUD/81/801

SUDAN

Terminal report*

Prepared for the Government of the Democratic Republic of the Sudan
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of P.N. Niciforovic,
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United Nations Industrial Development Organization
Vienna

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ABSTRACT

Pilot Brick Plant in Soba near Khartoum - Sudan, SI/SUD/81/801

The objectives of the project were to solve the problem of raw materials and choose adequate technological solutions and equipment for the production process.

The Report is covering work in two split missions: in January-February and July-August, 1982, lasting six weeks each, i.e. 12 weeks in all.

Estimated reserves are covering requirements of the plant for about 10 years. Results of technological tests carried out in the Institute for testing of Materials in Belgrade, gave solution for appropriate mixture of silt and kaoline as raw material.

Recommended are changes for primary propositions, for solutions and equipment for winning of silt, first stage of preparation of raw materials and drying.

Specified are necessities for training of Sudanese technicians and assistance in mounting and commissioning of plant.

Given are recommendations for future development of brick and some other building material industries in Sudan.

## INTRODUCTION

Building materials are a limiting factor in the development of the Sudan now, and it will be even more in the future if efficient measures are not taken to increase and diversify production. Import has a leading role in the supply of Sudanese market with a wide range of building materials except of bricks and partially for cement.

Goals of the current Six Year Plan, become a net exporter of cement after 1981-82, are not achieved. Bricks are not on the import list, but individual producers supplying the market without of the standard bricks, are not able to cover demand.

Between efforts to improve the situation in domestic production of building materials, Sudanese Government initiated action with UNIDO to construct a pilot brick plant as a first step in development of modern brickmaking. Besides commercial production, the plant is aimed to serve as a training and testing facility.

In the Solidarity Meeting of Ministers of Industry for cooperation in the industrial development of the Sudan, held at Khartoum from 23-26 March 1981, attended by 22 developing countries and 6 development financing institutions, the main purpose was to explore ways in which the participating countries should cooperate in promoting the industrial development of the Sudan.

In the Meeting, officially is inaugurated project ECDC/SUD/UK/81 titled "Pilot Plant for Production of Bricks" - now UNIDO Project SI/SUD/81/801, for which Yugoslav Government offered a grant of equipment valued $900,000, UNIDO covering intellectual services and Sudanese Government to provide constructions and other, to complete implementation of the project.

In accordance with the above mentioned, the author of this report is nominated Consultant to the Committee for Construction of Brick Pilot Plant at Building and Road Research Institute of the University of Khartoum, to assist in the necessary exploration and other preparatory works and in the preparation of feasibility study.

On results of geological prospection, exploration of Soba silt deposit and technological tests of samples, are suggested necessary changes in winning of silt and preparation of raw materials phase of the process, with suggestions for necessary change of equipment.

On these results, we are foreseeing problems in drying process and suggesting possible solution for them. Basic raw material silt is very sensitive on drying and relatively heavy in making, so green bricks cannot stand drying on open under influence of changes of temperature, humidity of air and wind - in the course of day and year - from 10 to almost 50°C. with normally low air humidity from 10 to 55% and winds blowing almost all the time. In Annex 5 are given meteorological dates.

The main difficulty for giving any solution for this problem is the fact that there are no possibilities to do pilot or industrial scale test. Proposed solution with drying chambers (to slower first phase of drying) is lowering risks for production; but unfortunately this means increase of investment costs.

Existence of such facilities will enable avoidance of risks for future brick plant projects in the Sudan, thanks to the possibility to make such tests.

I would like to say that cooperation with the Committee and BRRI staff were very good. Through constant contacts and discussions, number of questions were solved the way they are in this report.

## I. SUMMARY OF FINDINGS AND RECOMMENDATIONS

Soba University Farm is a good location for pilot brick plant. Explored silt deposit on the farm will supply plant with basic raw material for the period of about 10 years. To improve quality of bricks and facilitate production process, it is highly recommended to add to silt about 10% of kaolinitic stone from Omdurman area.

Exploitation of silt need to be done by Multibucet excavator, instead of tractor loader, to get more uniform raw material.

In the beginning of the production process, have to be added wet pan for better milling and mixing of materials after addition of kaolinitic stone.

To achieve drying with minimal damages, first stage of it must take place in drying chambers, where it may be to some extent controlled.

To improve productivity and lessen losses in manipulation with green bricks between cutting table and kiln, it is recommended to use appropriate shelves.

Chosen production programme of to 50% hollowed bricks of standard dimensions is recommended to be widened as soon as possible by bigger blocks with horizontal and vertical perforations, but it is expected to improve economy of the enterprise, and also that of building.

For the future similar projects (with bigger capacities), it is recommended well in advance to carry out geological exploration and technological tests of available raw materials.

In future considerations of development of building materials industry in Sudan, need to emphasize materials as perlites, mineral wool and light-weight aggregates from clays.

## II. PROSPECTION AND EXPLORATION OF RAW MATERIALS

Probably the main reason for the choice of Soba as the location for pilot brick plant's site, was the belief that silt on location is good raw material for brick production. Confirmation for that was the fact that there existed brick plant in the past and that local brickmakers work around.

In the limits of the farmland in accordance with the project made (Annex 3 ), were made detailed exploration works consisting of drilling, cutting, sampling, and geological mapping. Detailed results of this work are given in a separate report (Annex 4 ).

Geological mapping of holes showed that river sediments are of very changeable quality, vertically (in holes), and horizontally (between holes). From coarse sands, fine grain sands, sandy clays, to very plastic clays materials are passing one to other with thickness of individual beds from less than 1 cm. to sometimes more than a metre.

Underground water level found in holes generally corresponds with that of the river, and thanks to the porous character of sediments, it is less or more so in the course of the year.

There is probability that usable raw materials may be expected also in deeper beds, but underground water practically prevented deeper drilling, and from expected difficulties in exploration of material under that level.

High water level of the Blue Nile in flood season is expected to stop works on exploitation of silt to about 3 months every year. So, in the other 9 months it is necessary to win silt for the whole year.

From the obtained results are estimated reserves of

| | |
|---|---|
| Category A | 61.426 $m^3$ |
| " B | 70.230 $m^3$ |
| | 131.656 $m^3$ |

Results of technological tests, taken together with the geological interpretations, showed that Soba silt is a relatively good raw material from the river bank to about 200 metres inland; after that line, it contains more $CaCO_3$ concretions. It is the reason that reserves between profiles V-VII are not considered to be exploitable.

Technological laboratory tests indicated that Soba silt itself is pretty poor and sensitive raw material for production of quality bricks.

This conclusion led to the prospection of a number of localities in Khartoum area, with the goal to find complementary materials and adding them to Soba silt to improve its characteristics.

Prospected were zones of Saggai with negative conclusion. On two locations from both sides of the Blue Nile, were taken samples of pond clays used in local brickmaking. On locality Um Domm is taken sample of black cotton soil, and with particular interest is prospected the zone around Omdurman where are, from earlier, known outcrops of kaoline.

It is possible to conclude that outcrops of kaoline in this zone may be expected in a number of places and that only detailed exploration will give data of reserves, quality and suitability of outcrops for exploitation. For us it is clear that addition of 10% of kaolinitic stone to Soba silt will very much improve quality of final product. Of course, these kaolines are interesting raw material for other ceramic products and for the use in other industries.

## III. TECHNOLOGICAL CHARACTERISTICS OF RAW MATERIALS

UNIDO rewarded the Institute of testing of materials in Belgrade with subcontract worth $10,000, to make technological laboratory tests of the samples sent there from Sudan. Results of these tests are given in a separate report.

Individual ceramic tests indicated that deposit in Soba is characterized by uneven quality of material. Some of the individual samples were difficult to form in mould, because of the scarcity of clay faction. In several cases after firing appeared a lime bursting in dangerous form.

Complete ceramic tests from Soba showed that samples 1 and 2 are similar while sample 3 differs from them. The first two are very sensitive on drying while sample 3 is extremely sensitive. Shrinkage in drying is 7,0 - 6,8 and 6,0% while compressive strength after drying at 900°C is 13,73 - 16,92 and 13,73 MPa respectively.

Black cotton soil (sample 4) showed that it is possible to form it by plastic extruding process. Sensitivity in drying is even lower than in samples from Soba, a linear coefficient of shrinkage in drying is 7,2% but in firing samples are practically destroyed.

Tests of pond clay showed that it is very sensitive material with only small content of sand and high content of dust with high - 11,8% - shrinkage in drying and fired at 900°C is giving compressive strength of 51,30 MPa - highest obtained of all tests.

Of all study tests, best results showed test S-F from the mixture of 90% of Soba clay (sample 2) and 10% of kaolinitic stone from Fiteihab. Extruded with 19.33% of water appeared to be (only) sensitive in drying, with 8,21% of shrinkage and giving compressive strength 11,28 MPa at 900°C and 15,43 MPa at 960°C firing.

Workability of Soba silt may be improved by addition of pond clay, but this will increase sensitivity in drying. If the drying process pass good, compressive strength of product will be improved also, as it happened in test S1 - S5.

For the study test black cotton soil sample was finely ground in ball mill. Sensitivity increased to extremely sensitive in comparison with unground material. Shrinkage in drying fell to 8,2 but the main problem is behaviour in firing is unchanged - samples were again destroyed.

With sample 1 as basic material, were made two tests with addition in the case of test S1 - S4a - 10% of ground black cotton soil and in a test S1 - S5 with addition 25 of pond clay (on 75% of silt 1), a linear shrinkage increase to 7,4 and 7,8 respectively. With a very sensitive mark on drying for test S1 - S5 and compressive strength for forms fired at 900°C 12,64 MPa and 30,61 MPa. Last result is under question because of lower mark when fired at 960 and 1000°C.

Tests S3 - S5 - D and S3 - S5 - O only gave indications that from Soba silt (probably corrected with some other materials) it is possible to produce lighten bricks when the basic material is added combustible waste material.

Tests of kaolinitic stone from Fiteihab showed that it is a good ceramic material with content of some 20% of $Al_2O_3$, $Fe_2O_3$ content of 2,25% with low content of alkalis and almost with no soluble salts and organic material.

Pressed forms when fired gave a whitish passing on higher temperature (1250°C) to greyish colour. There is indication that material is kind of refractory.

Tests in which were made trials to produce light weight aggregates from natural and finely ground black cotton soil failed, but it is a real hope that with some dressing of material before, it will expand well. From the pond clay is obtained very good aggregate on temperature 1130°C with expansion coefficient of about 3.

Materials from old alluvian west of Omdurman used locally for adobe houses, obviously cannot be used in brickmaking because of very high content of $CaCO_3$ concretions. Chemical analysis showed content of $CaCO_3$ above 40% and there is possibility that in future may be used, after some dressing, as raw material for production of cement.

## IV. DEFINITION OF PRODUCTION PROGRAMME

A Yugoslav supplier of equipment for the plant, proposed the production of standard bricks 25 x 12 x 6,5 cm. big (USF) and hollowed blocks 25 x 19 cm. (4,6 USF).

Standpoint of author is that technologically and economically best production programme may be 2 types of blocks 25 x 19 x 19. First with 60% of horizontal hollows at expected compressive strength about 2,0 MPa, what means on the level of the first class domestic bricks, and second one to be 40% of vertical hollows and compressive strength about 10,0 MPa, suitable for bearing walls in Sudanese conditions, with no seismic activities.

After discussions with Sudanese counterparts, I accepted the standpoint that, for the market reason, production needs to start and for some time go with standard dimensions 50% perforated bricks, having much nearer dimensions to domestic ones (20 x 10 x 5 cm.). Later discussions will be produced with dimensions adapted to Sudanese modular coordination system.

## V. DESCRIPTION OF PRODUCTION PROCESS AND SUGGESTIONS FOR APPROPRIATE SOLUTIONS AND EQUIPMENT

Brickmaking process starts by winning of raw material. In our case, there are two raw materials with different conditions for exploitation.

In Yugoslav offer for equipment for the plant, tractor loader is given as machine for exploitation and loading of clay on tipping truck. This solution, very good somewhere else, cannot be accepted here because of very changeable beds in deposit, what have to be surpassed by use of Multibucet excavator. This change is supported by the fact that the deeper part of deposit, near and underwater level, are not passable for heavy machines.

Transportation of silt, to at most 300 metres far plant, will be done by tractor with self unloading trail. Tractor needs to be with loading shovel, to be able to help in feeding raw materials to box feeder.

Our proposition is Multibucet excavator, Delit BK-V with electro-motor 18,5 kw. and capacity to excavate up to 40 metres$^3$/hour. Maximum depth of excavation is 9 metres.

Necessity of average 88 tons of silt will be met easily in one shift by both machines.

Preparation of raw materials will start in box feeder SD-1000-5. By partial barrier, feeder is to be divided in smaller and bigger sections. In first one will be fed kaoline, passing below barrier in thin layer, on what come silt in 9 times thicker layer, what will be regulated by barrier on other end of feeder.

By slate conveyor 650/10 metres raw material is going in wet pan k-15, where ground and first mixing will take place.

By a rubber belt conveyor 650/13 metres material is transported to coarse differential rolling mill GM 1000/650. By the same means as before to fine differential rolling mill FM 1000/650.

Separately given is ROLLS Polishing machine.

So prepared material is, by a rubber belt conveyor GTR 650/15 metre transported to mixer, after that to vacuum press VP-450, with possibility to form bricks and blocks with maximum profile 25 x 19 cm.

Supported by horizontal roller conveyor(type HKT-320-1,4 metres) plastic beam is passed to cutting table ILR-38 where is cut in pieces of desired dimensions.

Formed green bricks are then, by rubber belt conveyor GT-400-10 metres, transported where to be taken by workers and set on shelves for drying.

The critical phase of the process cannot be passed successfully by simple drying under the sheds as it is proposed primarily. It has to be done in closed drying chambers, where influence of wind may be avoided and humidity of the air to some extent controlled. In the course of 3 days green bricks will be slowly dried for around third part of moisture content (firing temperature to be 960°C), and after that be able to stand finishing drying outside in the following three days.

To meet standards of transportation tractor for them, shelves must have dimensions 130 x 60 cm. with height of 175-200 cm., depending on production programme. The number of levels on the shelves have to be chosen in accordance with modular coordination system accepted in Sudan, to which bricks and blocks must correspond. Moving of the shelves will be done by two tractors TV-418, with green bricks to drying chamber, from there later on open drying, and finally to the kiln and after that empty shelves will be turned back aside belt with green bricks.

About 600 square metres of drying chambers will cover requirements of first stage drying.

Capacity of a shelf is 200 bricks. As daily production of plant is 28,572 divided by 200 multiplied by 6 (days of drying) is 857 rounded out on 860 shelves.

Because of different working week, production of green bricks 5 days firing 7 days, it seems that real necessities will be covered by about 1000 of shelves, that manipulation with semi-dry and dry bricks so will go continuously.

Total clear area of drying chambers is to be about 600 square metres.

Chamber for drying of 4000 bricks on 20 shelves will have dimensions 3,95 x 5,4 x 2,2 metres. Front side need to have 2 doors, opening it fully and on the back side need to be 2 narrow doors (on both sides) to enable to some extent control of drying conditions.

From shelves dry bricks will be set in kiln, where in the course of 4 days firing (firing temperature to be 960°C), process will take place, in 2 tunnels. Hoffman kiln each 45 metres long. Mazout will be fuel. Norms of fuel and other, are given in Annex 6.

From the kiln, full sets of fired bricks will be taken out with fork lift tractor 20 D.

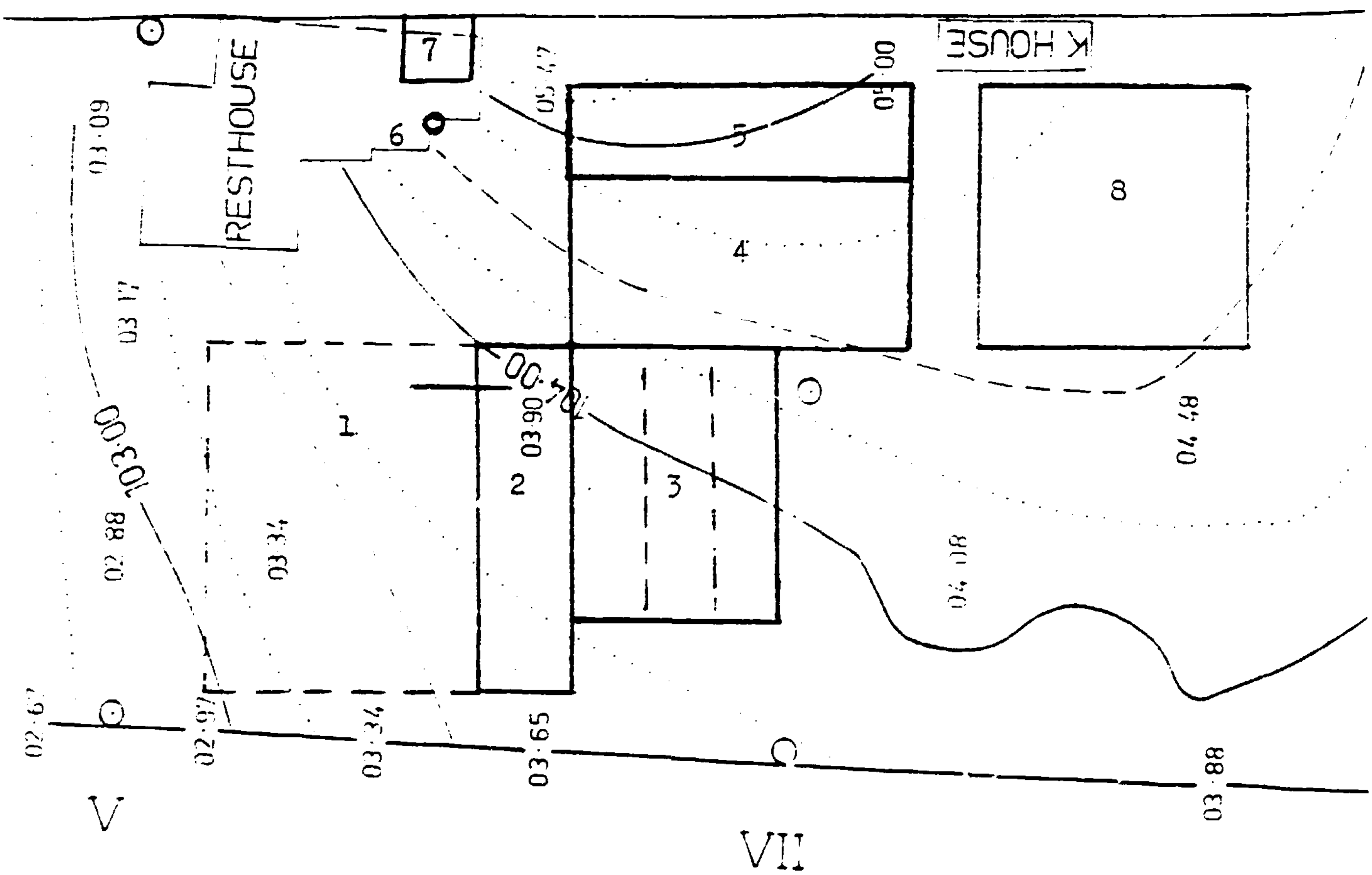
Suggestion for general disposition of elements of the plant is given on page 15. Suggested solution enables connection of the kiln with existing old chimney on the location.

## VI. DELINEATION OF RESPONSIBILITIES

In realization of the project are involved three parties: UNIDO, Yugoslav and the Sudanese Governments, What may easily produce confusion

POSSIBILE DISPOSITION OF

SOBA PILOT BRICK PLANT




1. Storage of raw materials
2. Production line building
3. Drying chambers area
4. Open drying area
5. Kiln
6. Existing chimney
7. Mazout reservoir
8. Brick storage

is some questions are not cleared as early as possible. Considering the physical side of the project from the existing offer and expected changes, Yugoslav supplier need to send Multibucet excavator for winning of clay, but it is expected from Sudanese counterpart to supply about 200 metres (used) rails and wooden sleepers.

For the production line for Yugoslav equipment, Sudanese partner will make buildings and fundaments for machine, bring water pipes and electricity to the points of meeting, which may be precisely specified in projects.

For the drying, Yugoslav partner will supply two tractors but Sudanese need to supply shelves and construct chambers for drying as described earlier in this report.

There is possibility to cut the number of shelves to half (on about 500). In case the investor decides, after first phase of drying, further manipulation of semi-dried bricks, to do without shelves, what is possible but it is going to increase drying area covered with sheds and also increase the number of workers and losses in this phase of the process.

Yugoslav will supply all steel parts for the construction of the kiln and of course sets of burners with pipelines, fan and a fork lift for evacuation of bricks from the kiln, electrical equipment. There is possibility, instead of elements for steel chimney, to connect kiln with existing one and in equivalent value send spare parts.

Sudanese partner need to supply normal bricks, refractory materials, bricks shamot, lafarge cement, etc., and a roof above kiln, reservoirs for mazout and connection pipe and electric cables to points where it is supposed to meet Yugoslav supply. It is clear now that in this segment refractory materials, valued $133,000 + transportation costs and $50,000 for construction of the kiln are biggest costs.

Here are not described in all details, obligations of Yugoslav supplier because they are contained in the official offer and will be also in a new offer to come, because of proposed changes. It is supposed that increased value of equipment, due to changes proposed, will be covered by Yugoslav Government.

Of course, here are not specified other necessities as buildings for administration, sanitary facilities, stores and similar, what is on Sudanese partner to solve.

Considering services - UNIDO-funded mission of a Consultant from Yugoslavia and testing of samples of raw materials.

For the 3 months training of 3 Sudanese technicians in Yugoslavia, there is officially not confirmed solution for - UNIDO to pay transportation costs, Yugoslav Government and supplier of equipment to cover costs of stay in Yugoslavia and training.

It is expected that UNIDO cover costs of technological, mechanical and electrical project for the plant, valued $30,000.

For 3 Yugoslav Experts, necessary to work in the phase of mounting of equipment and commissioning of plant, costs are supposed to be $67,500 and are also expected to be covered by UNIDO.

All said in this Chapter is based only partially on valid documents, but need to be officially settled between interested parties.

## VII. TRAINING AND ASSISTANCE

The goal of training of 3 Sudanese technicians in Yugoslavia is of crucial importance for further work of the plant, because they will be for a long time (after commissioning) only bearers of production.

Suggested profiles of trainees are: engineer technologist, technicians, mechanic and electrician.

Best time for their training in Yugoslavia is the period of equipment being finishing in supplier's factory and the transportation is in course, so that they arrive on time to be present in Soba in the course of mounting.

First period of a week or two training is supposed to be ILR factory in Zeleznik near Belgrade. For the technologist, it will be good to be some time in the Centre for Stone and Ceramics of the Institute for Testing and Materials in Belgrade, to acquaint himself with methods of testing of raw materials and final product as with usage of digital instruments for control of air humidity in drying facilities and firing temperatures in the kiln.

The main part of training must take place in brickmaking plant or plants with similar technology and equipment. Such possibilities exist in the vicinity of Belgrade.

To maintenance and on-the-spot reparations of equipment must be given priority, for the mechanic and electrician, while the technologist needs to study production problem through the whole process.

For the Yugoslav experts my suggestion is that, when all equipment is in Soba and fundaments and other conditions prepared, arrive the mechanic and electrician to assist in the mounting process, and near the end of that is supposed the arrival of technologist to start commissioning all of them and the technologist to stay some time after the first two return to Yugoslavia.

## VIII. FUTURE DEVELOPMENT OF BRICKMAKING IN THE SUDAN

It is said that one of the main objectives of Pilot Brick Plant in Soba is to promote future development of such industry in the Sudan, by offering opportunities for training and for pilot and industrial scale tests.

These goals will get maximal support,if at the same time is organized work on preliminary exploration of prospective raw materials in areas of interest for the construction of new brick plants, followed by technological tests.

In the geological approach to the problem, aside tertiary and quarternary to recent clayly formations, attentions need to be given to older mudstones, shales and similar formations as possible resources of good raw materials.

Black cotton soil, as a very abundant material in huge parts of the Sudan, needs to be technologically studied to find means for usage of these as raw material in brickmaking. Aim is not easy but it looks feasible.

In advance, acquired knowledge about separate localities will give possibility to do appropriate pilot scale tests in Soba, and to choose appropriate technological solutions and equipment for future plants.

In the Soba plant, after the first period of the work, it is suggested to start diversifying production programme, first two bigger blocks for different usages,expected to give better economy.

Production of elements for (one of several) systems for floor-ceiling construction may help improve existing techniques in building, applied in the Sudan.

Elements for fences probably will find very good market here. Projected plant will be able also to produce kind of floor tiles.

Sudan Six Year Plan (see Annex 5 ), Battele Institute's Report elaborating Plan's figures, found out that in Khartoum Province it is supposed to be constructed:

| | | |
|---|---|---|
| First Class Housing | 7030 | units |
| Second Class Housing | 13820 | " |
| Third Class Housing | 108150 | " |
| Total | 129000 | units |

From the same sources, demand for bricks in the period 1977/78 to 1982/83 will be as follows:

| Year | Housing Requirements pieces of bricks | Public Sector Req. '000 pieces of bricks | Total Demand bricks |
|---|---|---|---|
| 1977/78 | 591 592 000 | 28231.632 | 619,823,632 |
| 1978/79 | 591 592 000 | 30772.479 | 622,364,479 |
| 1979/80 | 591 592 000 | 33542.001 | 625,134,001 |
| 1980/81 | 591 592 000 | 36560.781 | 628,152,781 |
| 1981/82 | 591 592 000 | 39851.251 | 631,443,251 |
| 1982/83 | 591 592 000 | 43437.864 | 635,029,864 |
| Total | | | 3,761,948,008 |

The total for Khartoum Province represents 73% of the total for the whole Sudan, which seems reasonable when compared to the volume of investment in buildings and construction in Khartoum area versus the rest of the country.

Now and for some period in the future, the market will be supplied only or predominantly from small producers using technology, what need to be seriously studied, with the aim of improving it, with expected result of lessening total breakage of about 50% now (green bricks-fired bricks). In this respect must be expected improvement of quality of production. The question of consumption of almost 5 times more energy in firing than in industrial processes, has to be regarded with special attention.

Usage of agricultural and agriculture-based industries wastes in brickmaking seems promising, as possibility to produce lighter brick elements, with better thermal insulation properties, and to save part of mazout in firing process. Statistical data about sources and quality of such material have to be collected.

Future development as suggested above, may be realized best, if good cooperation is established between geologists and technologists. The latter will need improved laboratory facilities to be able to meet such demands.

## IX. FUTURE DEVELOPMENT OF SOME OTHER BUILDING MATERIAL INDUSTRIES IN THE SUDAN

Growing population of the Sudan, particularly fast growing in greater Khartoum and other cities, arises increasing need for materials suitable for fast and unexpensive building, with quality corresponding to the climate. Author's opinion is that best results may be achieved with lightweight building materials of different kinds.

Under available informations there are at least three known occurrences of pumice (frothy volcanic glass) in El Fasher area, near Atbara and in Red Sea Hills. Mentioned and in future to be discovered pumice may be, crushed and sieved, used as excellent aggregate for lightweight concrete blocks or precast elements for constructions.

Because of genetical connections, in the areas of appearance of pumice, are probable occurrences of perlite (riolitic volcanic glass), which, if thermally processed, is giving an extremely light finely grained aggregate with weight of under 100 kg./$m^3$ to some more, depending on nature of mineral and process applied. Mentioned characteristics make raw perlite transportable because it is normally to process it in area of usage.

Application of expanded perlite goes from plasters to prefabricated gypsum-perlite walls, suitable for fast and fabricated unexpensive construction of buildings or partitions.

Basalts are known in a number of places in the Sudan. Some kinds of them are excellent raw material for the production of mineral wool, by thermal process. The product is found in elastic pillows or, to some extent, hardened boards, giving excellent thermal insulation when used under corrugated sheets or applied in sandwich combinations with other building materials. As perlite, basalt is also transportable from significant distances, but processing is recommended near the market.

Expanded clays are aggregate with volume mass in range of several hundreds to more than 1000 kgs/$m^3$ in loose state. Mechanical characteristics depend on volume/mass and requested characteristics of concrete depending on percent of cement added.

Expanding process is thermal one. Application in precast elements for different types of constructions, walls, to production of blocks is possible.

Kaoline deposits near Omdurman, with abundance of quartz and known deposits of feldspar are good ways for development of ceramic industry, probably to start with sewer pipes or wall and floor tiles.

# Project of Exploration Works of Soba silt deposit

CONTENTS

## INTRODUCTION

In accordance with promemoria dated 20.3.81, between delegations of Yugoslav and Sudanese Governments about grant of equipment for brick making plant from Yugoslavia and with assistance of UNIDO in intellectual services, author of this project is nominated to assist in exploration works and preparation of feasibility study for the brick plant. The Sudanese Government is going to provide constructions and infrastructure.

This project, when realised, need to give data about quantity and quality of reserves of Soba Silt deposit and some data about quality of other suitable materials.

Stated task is going to be realised in cooperation with the Technical Committee for Brick Plant and Building Road Research Institute of University of Khartoum. The last is going to realise drilling with own equipment and team of workers and is supplying fund for this part of work.

Geological works on field and later elaboration of materials will be done by author of the project.

It is supposed that laboratory, minerological, chemical and technological tests will be done in Institute for Testing Materials in Belgrade, Yugoslavia, and be funded by UNIDO.

Locality of Soba is chosen for exploration because there is University of Khartoum farm on which in earlier period were situated brick making plant. Land is available and there exists some infrastructural facilities.

## GEOGRAPHICAL POSITION AND GEOLOGY

Locality of Soba farm is situated near 20 km South-east from centre of Khartoum on the very bank of Blue Nile (Appendix 1). The Farm's land is long about one kilometre with average width of something more than 100 m. and lies perpendicularly on the river course. Terrain is almost plain even with slightly lower parts along the river bank. The lower parts are normally flooded every year.

Location of new brick plant on perimeter of Khartoum must be considered as good one, because from the town to near Soba village pass 15 one of the main asphalted roads from Khartoum to Wad Medani and from this road on 18 km. to the farm, leads field road long about 2 km.

Necessary workers for the plant will be easily recruited from Soba village without necessity for the everyday transportation except management and leading technical personnel.

Geological characteristics of terrain, in accordance with seen unpublished geological map of Khartoum area and after reading available reports on matter, is very simple. Along River Blue Nile it is a belt with different width made of river silt, To inland silt pass in sandy materials characterised with appearance of $CaCO_3$ concretions and coarse sand on surface.

This profile is characteristic for the left bank of the Blue Nile in the vicinity of Soba and generally for the space between the two Niles from Khartoum southwards.

On the northern bank of the Blue Nile, opposite of Soba, is again belt of silt passing inland in formation of Black Cotton Soil.

Ground water level at location of the farm in Soba is on the depth between 5-7m. in accordance with results of drillings earlier and now in course.

Partial data about quality of river silt, with interbedded intervals of plastic clays indicate that average material will be lean.

FIELD WORKS

Main method of exploration of silt deposit in Soba will be core drilling combined with some simple handy works, to clean three profiles on the bank of the Blue Nile for sampling and mapping, instead of drilling on these points.

With goal to get on time mapping 1:1000 will be done in course of exploration works and at the same time will be established exact position of holes, located with help of metre belt, starting from easily fixed points on terrain, as shown on sketch 1:2500 (Appendix 2).

As seen from sketch, the terrain is divided into two separate entities:

- between the river and existing building, and
- after building away.

It is supposed that the exploitation of silt will start from the river bank. Proposition is to establish the reserve of category A with 6 holes and 3 cuttings in river bank, between all mutual distance will be of about 50 m.

Terrain to be explored is "cut" with three (ABC) long and number of short (1-15) profile lines with mutual distance of about 50 m. (not exactly on 50 m. because of limitations of farm contours).

In the points where cross profile lines ABC with 1, 2 and 3 will be located 3 cuts on the bank of the river and 6 holes, giving block of A reserves with surface of about 10,000 $m^2$.

On crossing points between profiles A and C with profile 5 will be done 2 holes, closing with the ones on profile 3, block of reserves category B (distance of 100 m.).

Terrain from building is proposed to be drilled on profiles A and C on every 100 m. so to get reserves of B category, idea was to do 10 holes but first results are not encouraging so that these numbers are expected to be reduced at the same time the reserves.

Assumed depth of holes (to the underground water level) is 6-8 m.

Expected reserves of category A are 60.000 and reserves B, in block between profiles 3 and 5, 50-60,000 $m^3$ and from profile 5 away, will depend on assessment of quality. In the best case they may reach 200,000 $m^3$ but not likely.

With number of 18 holes (maximum) with average depth of 7 m. it means 126 m of drilling.

Because of almost certain need for plastic clay, for correction of plasticity of silt it will be necessary to spare 20-30 m. for drilling of suitable location.

Geographical mapping and sampling will follow the drilling.

Sampling will comprise whole core of drilling (about 07 kg/m). Every hole will be divided into two samples, shallower and deeper.

## LABORATORY TESTS

Laboratory tests will be as follows:

- individual ceramic tests
- complete ceramic tests
- study of different combined raw materials
- elaboration of results in report.

Individual ceramic tests comprise:

- Reaction on $CaCO_3$
- forming of prisms
- linear shrinkage in drying
- firing
- shrinkage after firing
- minerological determination of biggest particles
- granulometric analysis.

Complete ceramic tests comprise:

- composition of sample, drying and grounding
- volume and specific gravity
- colour of material
- moisture
- minerological identification of residue on sieve 6,000
- reaction on $CaCO_3$
- soluble salts
- points of clincering and sintering
- dilatometric an.
- forming series of two forms on vacuum press
- drying shrinkage (linear)
- barelatographic test
- compressive strength of dried forms
- firing on 3 temperatures
- absorption of water of fired forms
- compressive strength of fired forms
- groundmetric an.
- RO (X Ray)
- IR

- DTA
- TGA
- thermomicroscopic test
- chemical an.

From the Soba locality it is supposed to be taken cca 30 samples for individual ceramic tests. From them will be made 3 composites for complete ceramic tests.

Two complete tests need to be made from chosen plastic clays.

Five study tests will consist of preparation of samples of different raw materials, plastic and leen and some with addition of combustible materials as (dung or groundnuts hulls), forming on vacuum press, drying firing with measurement of shrinkage change of weight and volume weight of product and mechanical characteristics.

**Recapitulation**

1. Mapping 1:1000 8 Hg. @ ................................
2. Geological mapping of holes 150 m. .....................
3. Sampling of drilling core 150 m. .......................
4. Drilling 150 m. @ .....................................
5. Transport of samples to Yugoslavia .....................
6. Individual ceramic tests 30 @ $60 ...................... $1,800
7. Complete ceramic tests 5 @ $1,050 ...................... $5,250
8. Study tests 5 @ $400 ................................... $2,000
9. Technological report ................................... $ 950

## Conclusion

Works made in accordance with this project will show how much reserves of Soba silt are available and are these reserves suitable to be used in modern brick making, by itself or will it be necessary to add some different plastic raw materials. Now it looks that Black Cotton Soil is a solution for this problem, but laboratory tests will show how real this solution is.

There is possibility that after initial exploitation of Soba silt, pond will be formed in which it will be in every flood season accumulated new raw material suitable for brick making. It looks likely, but this problem must be carefully studied through the period of several years before definite conclusion. There is probability that it is possible to influence quantity and quality of render of new silt by the shape and depth of pond but it must be carefully studied by a specialist. As a result of laboratory tests of Soba silt, other clays and different blends will be given recommendations for conditions for process of drying of formed bricks and conditions for firing.

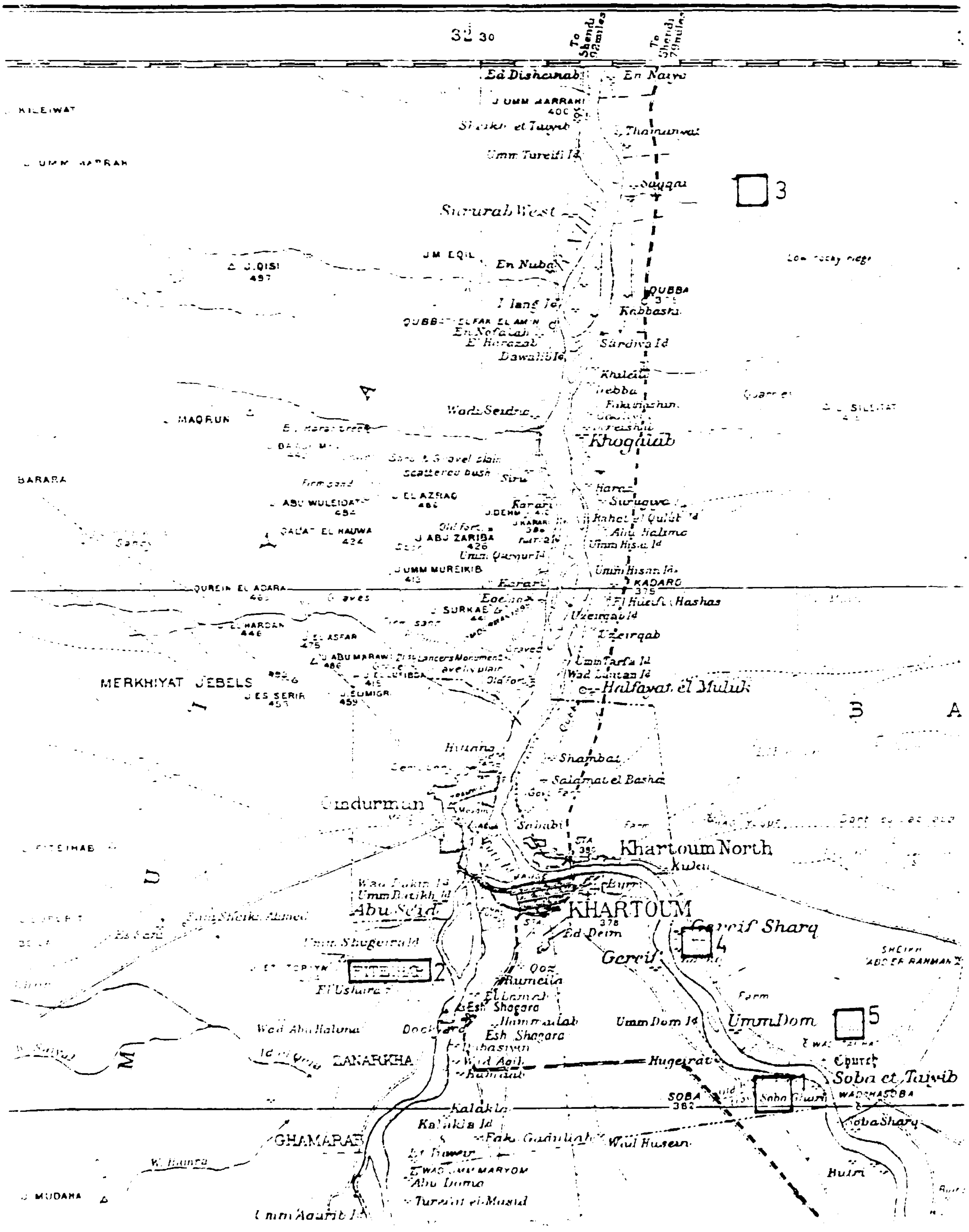
APPENDIX 4

KHARTOUM

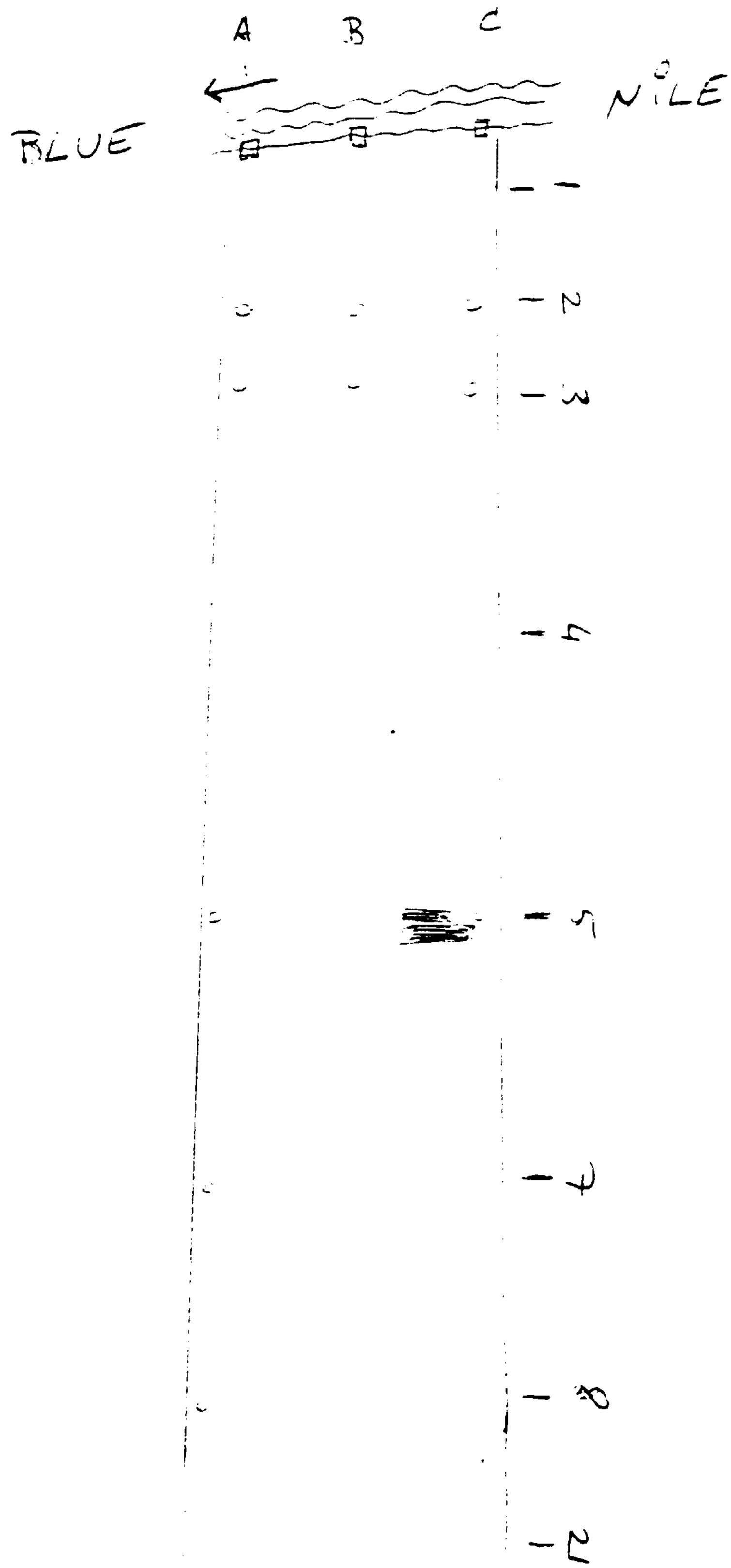
SHEET ND-35-B

Scale 1:250000

( PART OF )



SOBA - UNIVERSITY FARM



# Report of Exploration of silt deposit in Soba and prospection of other raw materials in Khartoum Area

## CONTENTS

## INTRODUCTION

Prospection and exploration of raw materials together with the laboratory tests for necessities of future pilot brick plant were the first important step in realization of UNIDO-Yugoslav and Sudanese Government Project for the construction of such a plant in the vicinity of Khartoum.

In the course of January and February 1982, the author of this report, in cooperation with the Committee for the Construction of Pilot Brick Plant and the staff of Building and Roads Research Institute of the University of Khartoum, prepared "Project of Exploration Works of Silt Deposit in Soba", and in accordance with this in the period of 23.01 to 08.02 1982 were finished drillings and other field works.

Before and after Soba drillings, together were visited and prospected localities of Saggai (3 on Map on Appendix No. 1) where were checked materials from the holes made earlier. Conclusion is that material there is so full of gravels.

On locality of Fiteihab were collected samples of kaolinitic stones for laboratory tests.

On localities Um Ushus 5 on Map Appendix 1 and Gereif Sharg 4 were taken samples of black cotton soil, as a very widespread type of soil in Sudan, and samples of pond clay used for traditional brick making in Khartoum area, a sample of pond material is also taken on locality 500 metres west of the Soba University Farm. Some localities west of Omdurman were visited and samples taken with no direct interest for brickmaking plant.

Mentioned localities were prospected because material from the holes in Soba gave impression that by itself, it is not going to be good enough, and we together made an effort to find suitable complementary materials. Results of laboratory tests proved such an opinion.

All samples were prepared for shipment to the laboratory of the Institute of Testing Materials in Belgrade and, together with samples of dung and ground nuts hulls - as combustible materials - were sent there.

Results of technological tests will be given in a separate report and with this one will make entirety.

Location of Soba University Farm, chosen from the very beginning as the site of pilot brick plant, looks now as a good choice, although silt by itself is not likely going to be the only raw material, but other advantages as free land and some infrastructures existing there are of importance.

## I. GEOGRAPHICAL POSITION AND OTHER CONDITIONS

Soba University Farm is situated on the left (southern) bank of the Blue Nile, about 20 kms south east from the centre of Khartoum (1 on the Map Appendix No. 1).

Farmland has a form of a strip starting on the river bank with width less than 100 metres and going inland about 1 km. with finishing width of almost 140 metres.

The farm is only partially cultivated by fruit trees and there exists a building some time used as a resthouse and ruins of old brick plant. With smaller reparations the building may be used for the necessities of brick plant administration.

Approximate coordinates of the farm are:
lat. 15°31 long. 32°39

Absolute height is somewhere about 380 metres. On the map of the farm on Appendix No. 3 are given relative heights, where absolute height of 380 approximately correspond to 100 metres on the map.

Terrain between the two Niles on which lies Khartoum and its southern suburbs, to the Soba, is plain.

The farmland is also almost plain with slightly lower part along the river, while the very bank is steep.

In the normal flood season, only narrow strip of land (50-100 metres) along the river is flooded, while other land is staying dry.

From Khartoum to near Soba village passes one of the main asphalt roads to Wad Medani, and from this road at 18 km. to the farm, leads field road long about 2 km.

About 6 km. from the farm passes also a railroad but the nearest station is in Khartoum.

There is possibility that in the future the Blue Nile become a path for transportation of bricks.

It is suggested that in brickmaking process, besides silt from Soba, is to be used about 10% of kaoline from deposit between Fiteihab and Abu Said or some other in the zone of Omdurman. Outcrops of kaolinitic stones are on the left bank of the White Nile some 2-3 kms from the White Nile bridge between Khartoum and Omdurman (2 on Appendix No. 1) from the bridge to the kaoline outcrops leads field road and total distance from them to Soba is something about 25 km.

The Soba Farm is connected with electrical net, but it is necessary to check capacity of lines.

Industrial water will be supplied from the river.

Climatic conditions of Khartoum area are of desert nature, with temperatures in range of 10°C to almost 50°C. Air is with very low average humidity 18-55% and area is getting an average of 161 mm. of rains every year, all in summer autumn period.

## II. GEOLOGICAL CHARACTERISTICS OF KHARTOUM AREA

About 100 kms east from Khartoum on the surface are appearing the oldest-basement complex formation - represented with "shist group", the same group is appearing also on the east side of the Nile about 30 km. north of Khartoum represented with "Gneiss group".

Except between the two Niles, dominant formation in Khartoum area is "Nubian sandstone formation" of cretoceous age represented by sandstones, silt stones, mud stones and conglomerates.

South of Khartoum, terrain between the two Niles is covered by tertiary and quarternary Gezira formation represented by clays, silts, sands and gravels.

Quarternary and recent formations are represented with sediments of older, higher river terraces, recent (lower) river terraces, desert sands and gravels.

North of Khartoum granite is representing intrusive magmatic stones, while the West of Omdurman is appearing basalt, representing extrusive volcanic stones.

## III. EXPLORATION AND CHARACTERISTICS OF SILT DEPOSIT IN SOBA

Explored is only a part of silt deposit situated along the left bank of the Blue Nile. Exploratory drillings are done in almost regular net. By project, proposed is drilling for Category "A" reserves with distance between holes (and cuts) of 50 metres, with exception of cut C-I, 61 metres away from hole C-II, but less than 50 metres from cut B-I.

For reserves of Category B maximal distance between holes is 100 metres. Disposition of cuts and holes is given on Map 1:1,000 Appendix No. 3.

Primary planned holes for reserves $C_1$ Category are not made, because made drillings showed that in southward direction quality of silt is worsening and there is no reason to do anything there.

Extrapolation of reserves, away from holes, is done only with holes on profiles A and C, along profiles I-V to the limits of farm ground, for several metres, in both A and B reserves.

Exploitation works of Soba silt deposit comprise 3 cuts - 17,1 m. and 11 holes with total depth of 73,4 m.

Holes are drilled by penetrometer (10 tons), product of NV GOUDSHE MACHINEN FABRIEK GOUDA HOLLAND. Core were collected in plastic cylinders long 20 cm. and with ⌀ 30 mm. giving about 07 Kg./m. of core if all collected. In some cases it was impossible to get core, in dry sands and more often in materials under level of ground water. Such intervals are indicated on geological profiles (Appendices 5-18) "no core".

Samples are in cylinders transported to the laboratory of BPPI and there, core is carefully taken out, mapped and put on drying, before being packed, upper and lower half of every hole separately, except hole A-IX with only one sample.

Main characteristic of the deposit is change of material in horizontal and vertical direction, so that it is impossible to make correct interpretation between neighbouring holes, as shown on geological profiles on Appendix No. 4.

Geological profiles of every separate hole are given as Appendices 5-18, starting with cut A-I and finishing with C-V. Vertical changes of materials, sand, silt, finely clays are sometimes so intimately intermixed that it is impossible to show it on given scale on profiles. Appearance of $CaCO_3$ concretions is carefully observed in all samples and shown on profiles as accurate as possible.

Going along profiles A, B and C from the river inland, it is visible that in the beginning there is no $CaCO_3$ concretions in the core, and that it appears first time in the hole A-III, then some more at the deepest part of holes A-V and C-V, but concretions in holes on profile 7 are more abundant while on the profile 9 $CaCO_3$ presence is visible even at the very surface. Concentration in $CaCO_3$ in concretions produced also increased plasticity of clays in which they are.

Samples of material from cuts were taken by continuous collection and are vertically divided in two separate samples for the necessity of individual ceramic tests. In the case of holes all core were taken, again divided vertically in two samples.

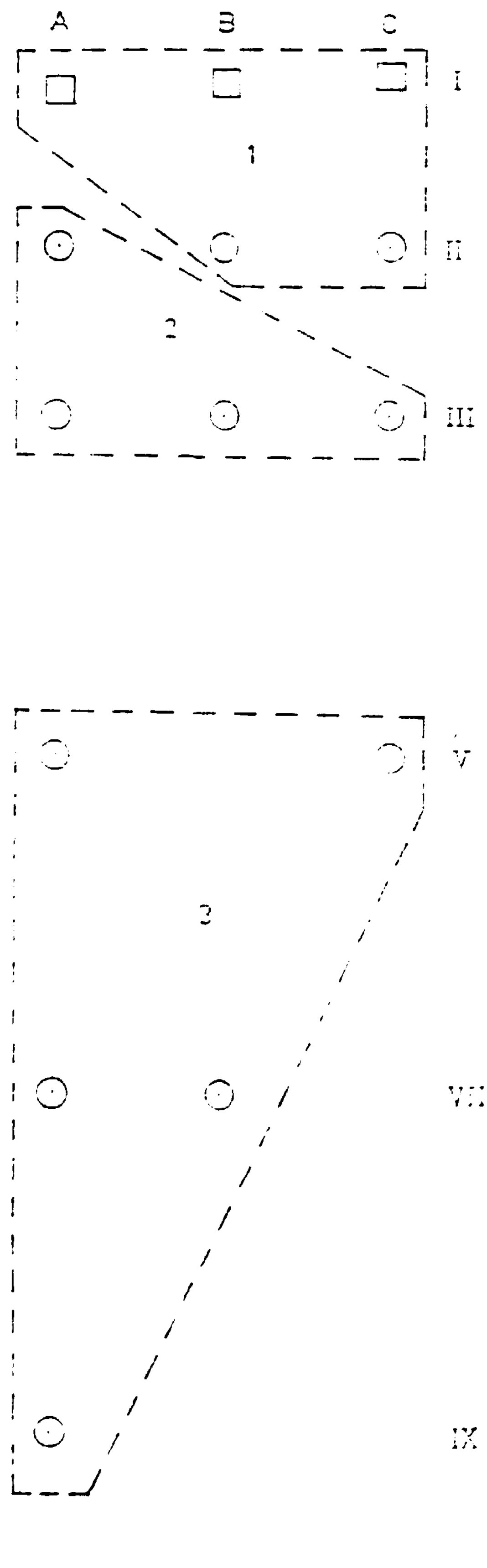
Composition of samples and complete ceramic tests of Soba silt is made by mixing samples from three groups of holes as shown on the scheme on the following page.

From reserves Category A it is taken 2 samples (1 and 2) and one (3) from holes giving reserves B Category.

For the complete ceramic analysis are also taken samples of black cotton soil from shallow shaft allocated in Umm Domm.

Typical pond clay were taken with random collection of clay on the northern bank of the Blue Nile near Gireif Sharg.

# SCHEME OF SAMPLING



Examination of biggest particles separated from all silt samples, under binoculars, showed that practically in all samples miniacule concretions of $CaCO_3$ may be seen, but because of their dimensions there are no danger for final product.

Under ground water level is corresponding with level of the Blue Nile but as shown on geological profiles there are some smaller irregularities produced by intensive watering of surrounding farmlands.

Porosity of sediments make easy influence of the river level on underground water in the course of the year.

Although the mechanical tests were not made, it seems that the beds will stand winning supposedto go to the $60^{\circ}$ angle. except may be, smaller pulling down of material on the contact with water if exploitation go as expected slightly deeper than the water level.

## IV. PROSPECTION

In an effort to find complementary materials to Soba silt, as it is said, were prospected number of locations around Khartoum and Omdurman.

For the production of pilot brick plant, of biggest interest is the zone around Omdurman where there are a number of outcrops of kaolinitic materials. Near Fiteihab there are several outcrops on almost a line in the distance of more than 1 km. where are seen kaolinitic stones and kaoline clays - plastic often with high percentage of $CaCO_3$ concretions. It is clear that kaolinitic stones (mudstone) is a member of Nubian sandstone formation, lying concordantly under small angle, between relatively fine grained conclomerates, sandstones, kaoline bounded sandstones and kaolinitic stones, sample of which was tested, showing very good characteristics when added 10% of Soba silt.

It is impossible to give reliable assessment about reserves, but the fact that kaoline is a member of so huge formation as Nubian sandstones are, is giving real hope that big reserves exist in area.

It looks that alteration and transportation of the part of kaolinitic stones being made, giving as result plastic clays but in some cases they are heavily contaminated with $CaCO_3$ concretions. Detailed exploration needs to show reserves of different types of kaoline and differences in quality. It looks that both types of kaoline are interesting for different applications in ceramic and other industries, taking into consideration that some kind of dressing will be applied.

At Saggai some drilling was made earlier with the intention, that if results are satisfying, to locate there a brick plant. On the basis of the materials from holes saved at the spot, it is possible to conclude that the material represent finely ground quartz gravel and sand bound with the type of black cotton soil, and it is obviously of no use for brickmaking.

Pond clay from Gireif Sharg zone is used by local brickmakers with addition of some sand for dung for the production of bricks in traditional technology, as it is done in Soba. Reserves of such material are enough for small producers which exploit in the course of the year some pond and in the flood season new replenishment is again giving reserve for further production. Pond clays by itself is characterized by 12% of linear shrinkage in drying, and cannot be used in plastic forming technology except in some mixtures.

Black cotton soil from Um Domm localities is not typical, because of high content of sand and dust, but it showed in the laboratory test that it is not suitable as raw material for brickmaking, except probably after some special treatment. This type of soil is covering huge surfaces in Sudan.

## V. TECHNOLOGICAL CHARACTERISTICS OF RAW MATERIALS

In the Institute for testing of materials in Belgrade are tested all samples from Soba and other prospective localities. Results of individual, complete and study ceramic tests will be presented in a separate report. Here, we will give only main characteristics of materials and conclusions about their possible use.

Individual ceramic tests indicated that deposit in Soba is characterized by uneven quality of material. Some of the individual samples were difficult to form in mould, because of the scarcity of clay faction. In several cases after firing appeared a lime bursting in dangerous form.

Complete ceramic tests from Soba showed that samples 1 and 2 are similar while sample 3 differ from them. The first two are very sensitive on drying while sample 3 is extremely sensitive. Shrinkage in drying is 7,0 - 6,8 and 6,0% while compressive strength after drying at 900°C is 13,73 - 16,92 and 13,73 MPa respectively.

Black cotton soil (sample 4) showed that it is possible to form it by plastic extruding process. Sensitivity in drying is even lower than in samples from Soba, a linear coefficient of shrinkage in drying is 7,2% but in firing samples are practically destroyed.

Tests of pond clay showed that it is very sensitive material with only small content of sand and high content of dust with high - 11,8% - shrinkage in drying and fired at 900°C is giving compressive strength of 51,30 MPa - highest obtained of all tests.

Of all study tests, best results showed test S-F from the mixture of 90% of Soba clay (sample 2) and 10% of kaolinitic stone from Fiteihab. Extruded with 19.33% of water appeared to be (only) sensitive in drying, with 8,21% of shrinkage and giving compressive strength 11,28 MPa at 900°C and 15,43 MPa at 960°C firing.

The black cotton soil samples were finely ground in ball mill. Sensitivity increased to extremely sensitive in comparison with unground material. Shrinkage in drying fell to 8,2 but the main problem is behaviour in firing is unchanged - samples were again destroyed.

With sample 1 as basic material, were made two tests with addition in the case of test S1 - S4a - 10% of ground black cotton soil and in a test S1 - S5 with addition 25 of pond clay (on 75% of silt 1), a linear shrinkage increase to 7,4 and 7,8 respectively. With a very sensitive mark on drying for test S1 - S5 and compressive strength for forms fired at 900°C 12,64 MPa and 30,61 MPa. Last result is under question because of lower mark when fired at 960 and 1000°C.

Tests S3 - S5 - D and S3 - S5 - O only gave indications that from Soba silt (probably corrected with some other materials) it is possible to produce lighten bricks when the basic material is added combustible waste material.

Tests of kaolinitic stone from Fiteihab showed that it is a good ceramic material with content of some 20% of $Al_2O_3$, $Fe_2O_3$ content of 2,25% with low content of alkalis and almost with no soluble salts and organic material.

Pressed forms when fired gave a whitish character passing on higher temperature (1250°C) to greyish colour. There is indication that material kind of refractory.

Tests in which were made trials to produce light weight aggregates from natural and finely ground black cotton soil failed, but it is a real hope that with some dressing of material before, it will expand well. From the pond clay is obtained very good aggregate on temperature 1130°C with expansion coefficient of about 3.

Materials from old alluvium west of Omdurman used locally for adobe houses, obviously cannot be used in brickmaking because of very high content of $CaCO_3$ concretions. Chemical analysis showed content of $CaCO_3$ above 40% and there is possibility that in future may be used, after some dressing, as raw material for production of cement.

## VI. ESTIMATION OF RESERVES OF SOBA SILT DEPOSIT

Reserves of Soba silt deposit will be estimated in accordance with Yugoslav professional standards, similar to those used in other countries.

From the geological standpoint, explored is only part of silt deposit along the Blue Nile Bank, with no uniform quality. In exploration of A Category reserves holes are set in a net with mutual distances of 50 metres, with exception in the case of Cut-I, where distance from the hole C-II is 61 metres, while distance to the B-I is 45 metres.

For the reserves of Category B maximum distance applied is 100 metres.

In the case of both category reserves extrapolation is made from some holes to the limits of the farmland. For the estimation will be used the method of geological blocks. In the calculation are not in some cases taken the deepest part of holes from which is not obtained sufficient core.

Between profiles denoted by Roman numerals I to IX explored terrain is divided in a series of blocks whose surface is measured. From 2 or 3 holes on a profile is obtained mean productive depth. Mean arithmetic value between two neighbouring profiles is giving mean thickness of the block.

Product of the surface (expressed in metres square) and thickness in metres is giving reserves in metres cube. Elements for estimation are taken from the holes where profiles are shown on Appendices 5-18 and from the map and profiles on Appendices 3 and 4.

On the tables below are given elements No. 1 and made estimation of reserves No. 2.

Table 1

| | Productive Depth of Holes | | | Profiles Mean Depth | Blocks Mean Thickness |
|---|---|---|---|---|---|
| | A | B | C | | |
| I | 5,60m | 5,80m | 5,70m | 5,70 m | |
| | | | | | 6,25 m |
| II | 6,80" | 7,20" | 6,40" | 6,80 " | |
| | | | | | 6,83 " |
| III | 7,00" | 7,00" | 6,60" | 6,86 " | |
| | | | | | 7,13 " |
| V | 7,00" | - | 7,80" | 7,40 " | |
| | | | | | 6,80 " |
| VII | 6,00" | 6,40" | - | 6,20 " | |
| IX | 2,00" | - | - | | |

Between profiles I-II and II-III are estimated reserves of Category A.

Reserves of Category B are estimated between profiles III-V and V-VII but the last block must not be taken in consideration for reserves and future exploitation because of worsened quality of material.

Table 2

| | Blocks | Surface | Average Thickness | Volume of Reserves |
|---|---|---|---|---|
| Cat. A | I-II | $4.692m^2$ | 6,25 m | $29.325\ m^3$ |
| Cat. A | II-III | 4.700 " | 6,83 " | $32.101\ m^3$ |
| | | | | $61.426\ m^3$ |
| Cat. B | III-V | $9.850m^2$ | 7.13 m | $70.230\ m^3$ |
| Cat. B | V-VII | 7.700 " | 6,80 " | $52.360\ m^3$ |

Block V-VII is not exploitable because of worsened quality.

Amounts of exploitable reserves are:

| | |
|---|---|
| Category A | $61.426\ m^3$ |
| Category B | 70,230 " |
| Total | $131,656\ m^3$ |

## VII. CONCLUSION

The type of material explored in Soba, from the geological standpoint, is extremely abundant on both banks of the Blue Nile. Quality of material is changing horizontally and vertically in the range from very plastic clays to coarse grained sands. Recent sediments near the river are with rare or very tiny concretions $CaCO_3$. Going inland presence of $CaCO_3$ concretions and their dimensions increase.

Plasticity of material depends on the rate clay: dust: sand, while clay by itself is extremely plastic and sensitive on drying. Organic materials are found in all samples (except kaolinitic stone). In Soba content is passing 1% near the river - lessening inland.

Technological test showed that it is possible to produce bricks from Soba silt, but behaviour of material in production process and properties of final production will be essentially improved if to Soba silt is added about 10% of kaolinitic stone from Omdurman area.

Kaoline at Fiteihab is the only prospect. On the base of the scene, it may be concluded that geological reserves if kaolinitic stone are substantial, but it is advisable to do some exploration work in the future.

By appropriate exploitation Soba silt may and must be homogenized before and in the course of production. Production line must be composed so to add fine homogenization to raw material.

Estimated exploitable reserves of 131656 $m^3$ may cover necessities of brick plant with capacity of 10 millions UNF/year for about 10 years.

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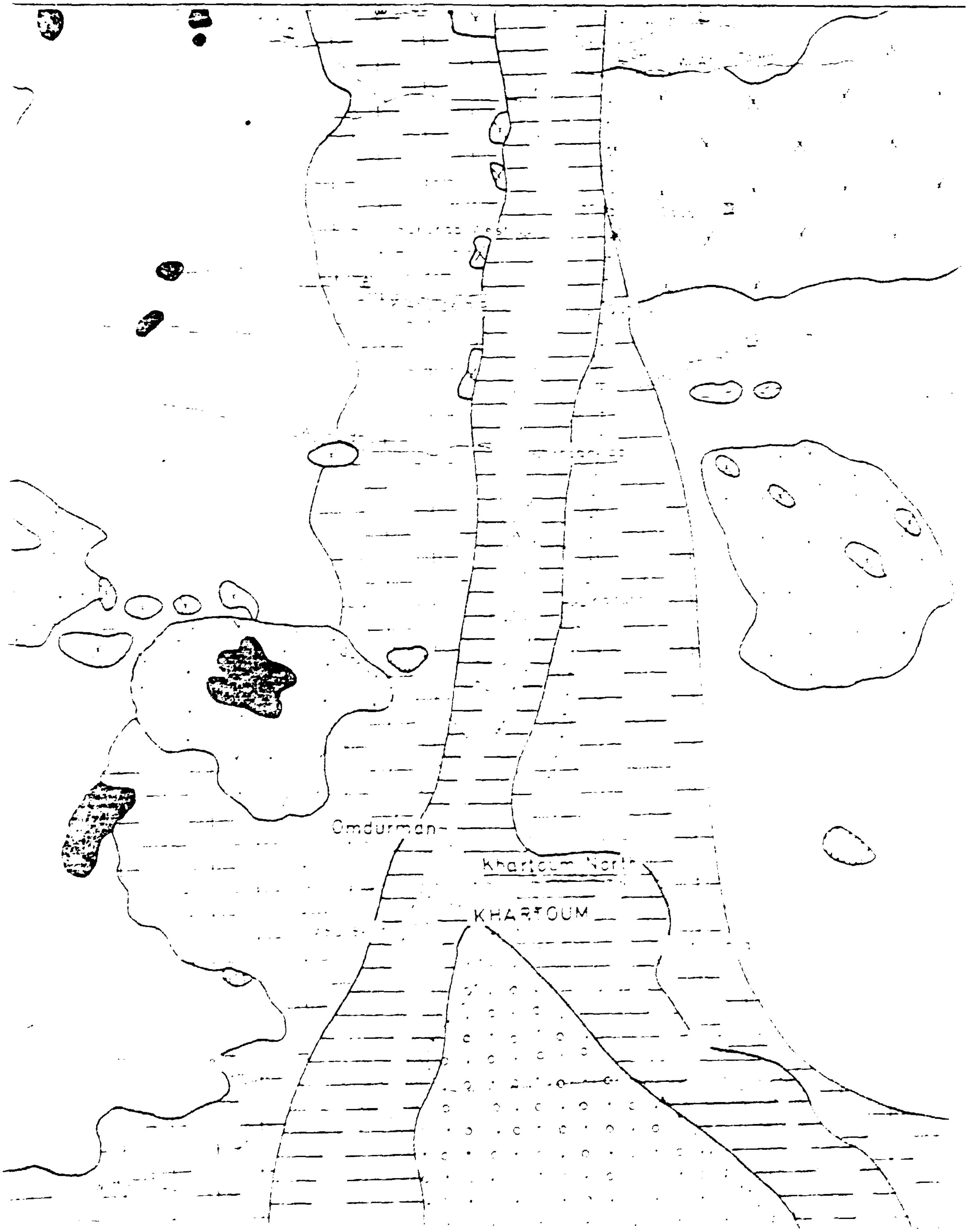
   Map 1 : 250,000 1981

APENDIX N 2

# BUILDING MATERIALS AROUND KHARTOUM

Scale 1:250.000

Geologist I.A.Malik



## L E G E N D

RECENT ALLUVIAL CLAY TERRACES

OLDER ALLUVIAL CLAY PLAINS

DUNES AND SWALES

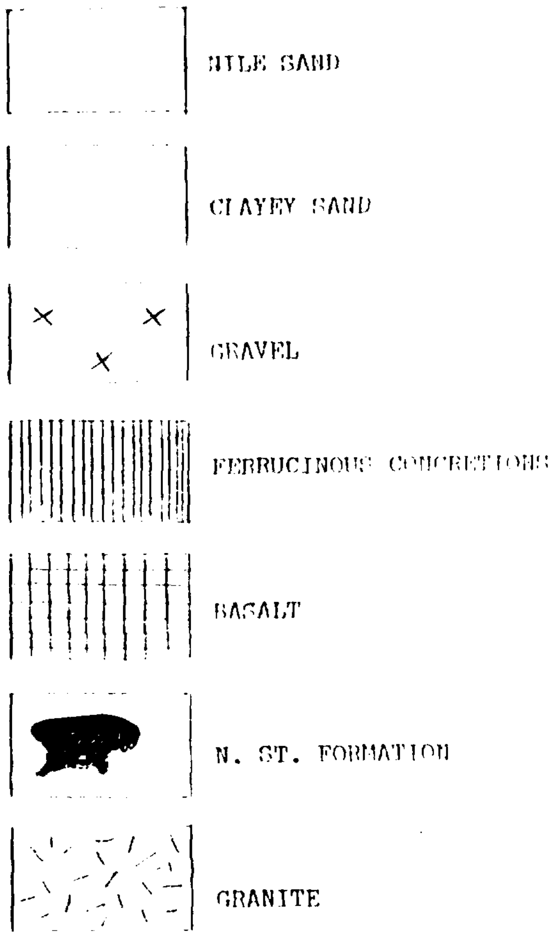
OLDER ALLUVIAL CLAY PLAINS
WITH MINOR LACUSTRINE PLAINS

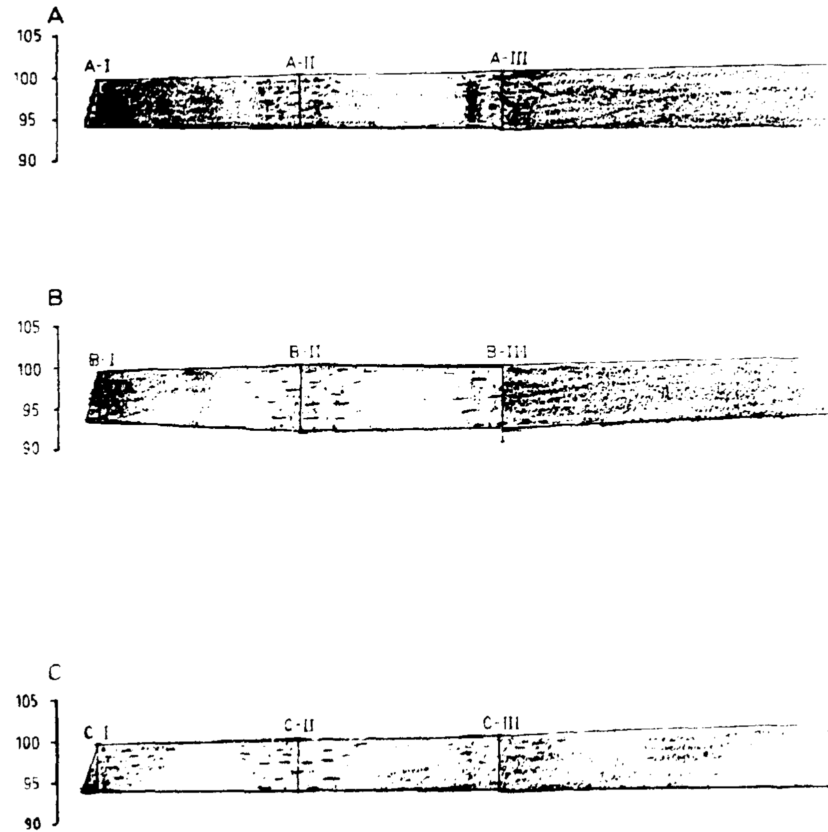
BLUE NILE ALLUVIAL FAN

SAND SHEET

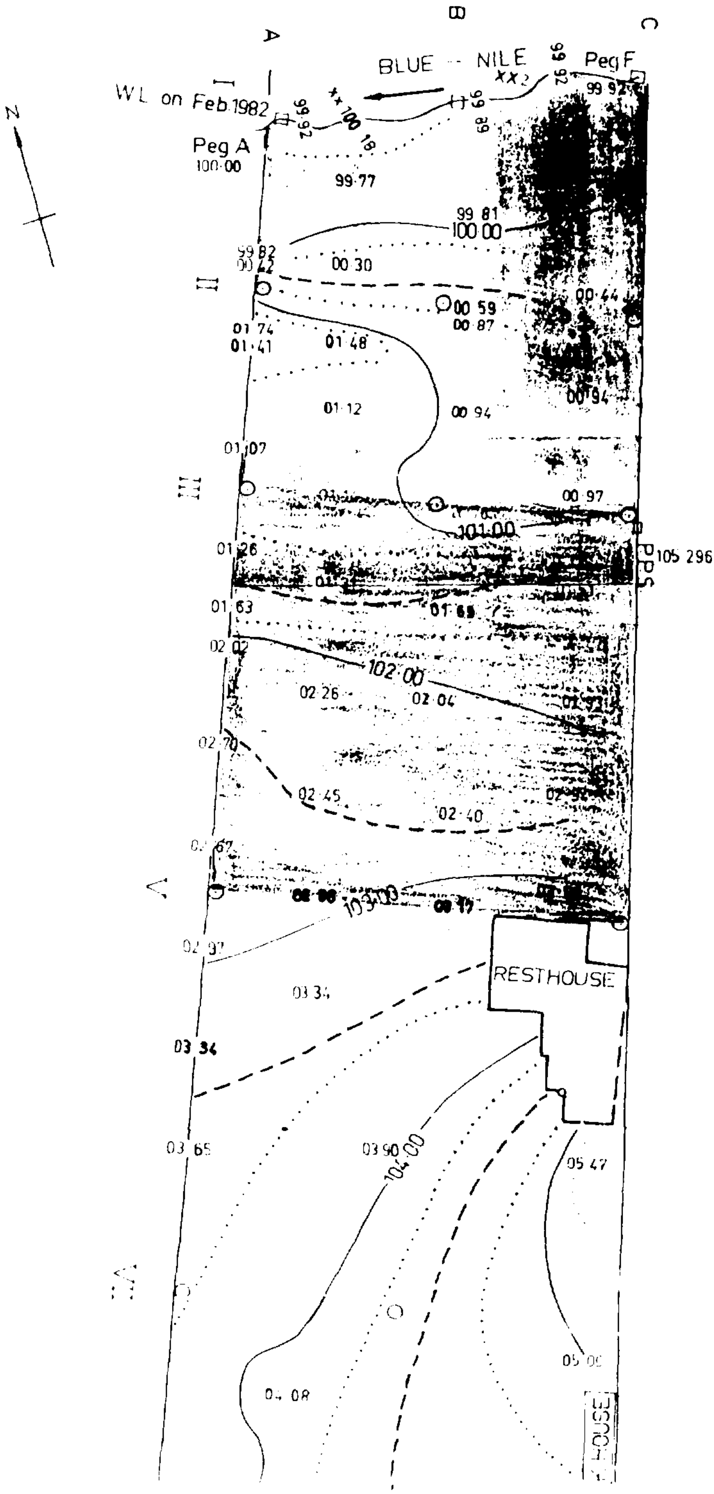
OLDER SAND DUNES

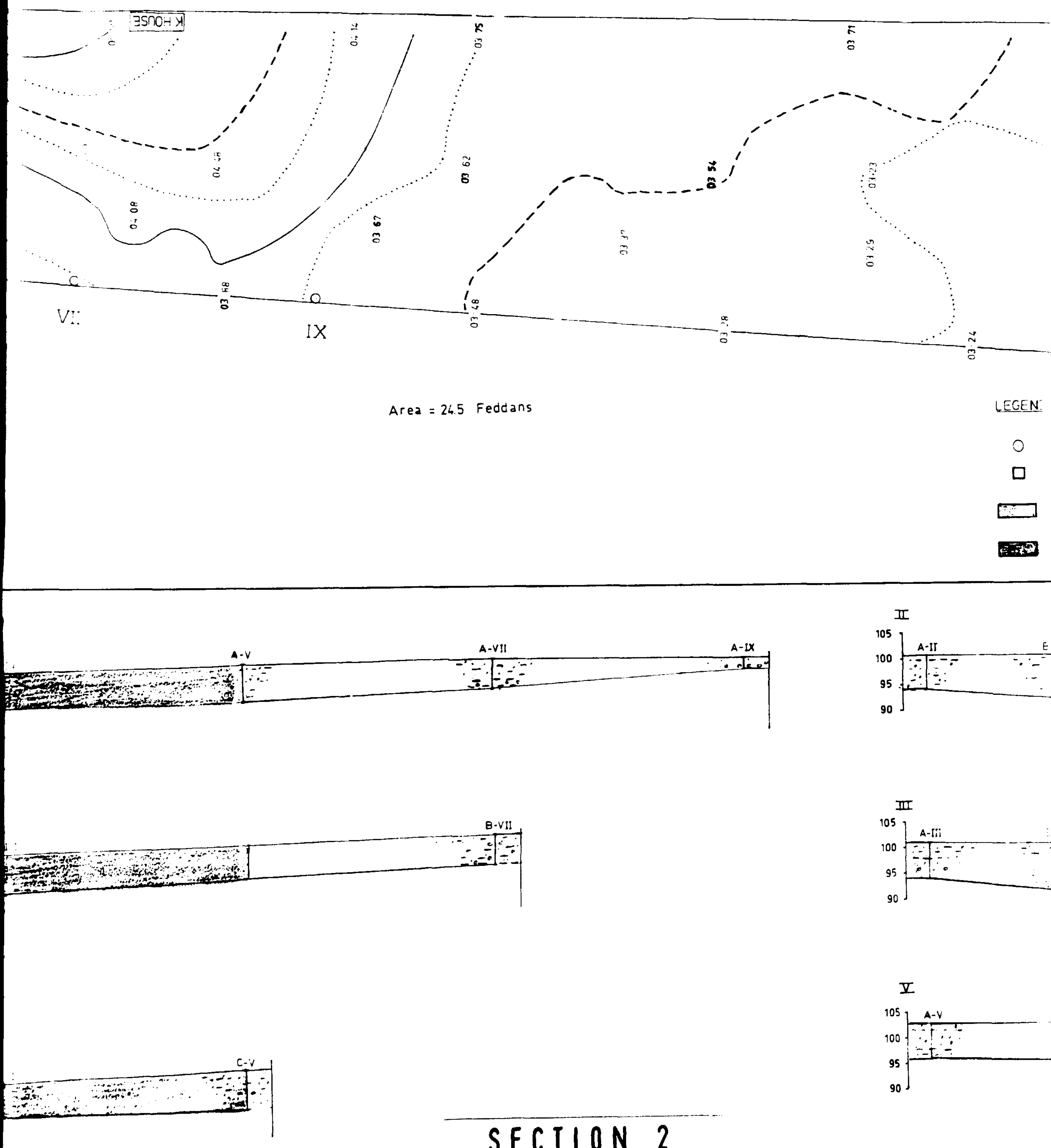
APPENDIX No 2a




A
105
100
95
90
A-I
A-II
A-III
B
105
100
95
90
B-I
B-II
B-III
C
105
100
95
90
C-I
C-II
C-III

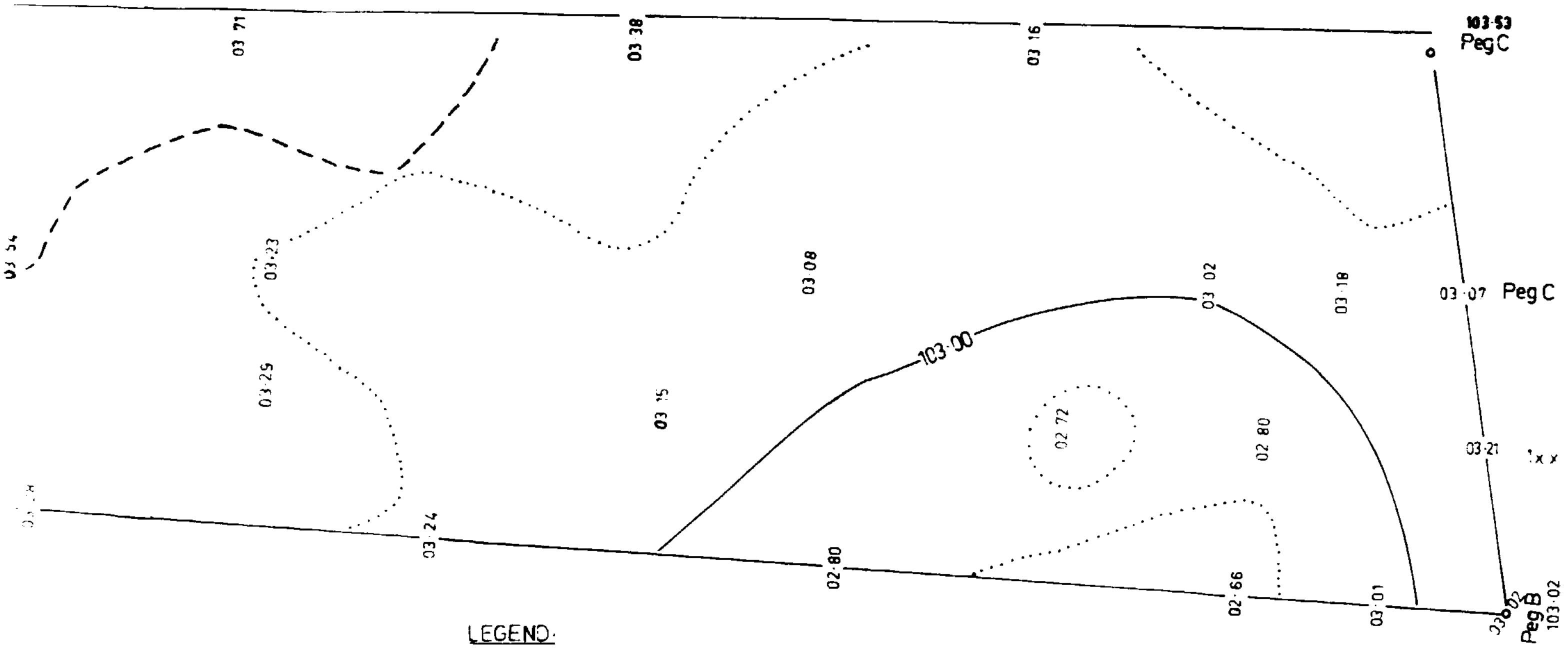
SECTION 1


A
B
C
BLUE NILE
Peg F
WL on Feb 1982
Peg A
100·00
N
100·00
101·00
102·00
103·00
104·00
PPS
105 296
RESTHOUSE
I
II
III
V
VI


K HOUSE
04 14
03 75
03 71
04 48
03 62
03 54
03 23
04 08
03 67
03 25
03 88
03 48
VII
IX
Area = 24.5 Feddans
LEGEN
II
105
100
95
90
A-V
A-VII
A-IX
A-II
B-VII
III
A-III
V
C-V
SECTION 2

APENDIX Nº 3

KHARTOUM PROVINCE
SOBA WEST UNIVERSITY FARM
Red Brick Demonstration Plant - Location

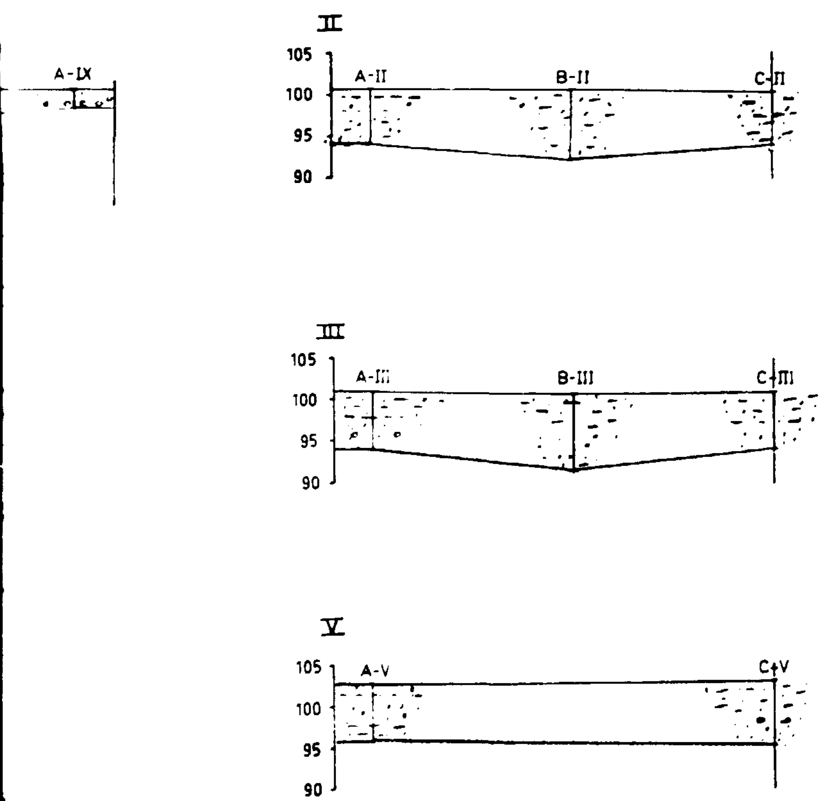



LEGEND:

- ○ Holes
- □ Cuts on the bank
- Reserves A categories
- Reserves B categories

| MAP OF RESERVES | |
|---|---|
| OBJECT | SILT DEPOSIT |
| LOKALITY | SOBA UNIVERSITY FARM |
| INVESTOR | BRRI - UNIVERSITY of KHARTOUM |
| | P. NIĆIFOROVIĆ, dipl. ing. UNIDO EXPERT |

APENDIX Nº 4

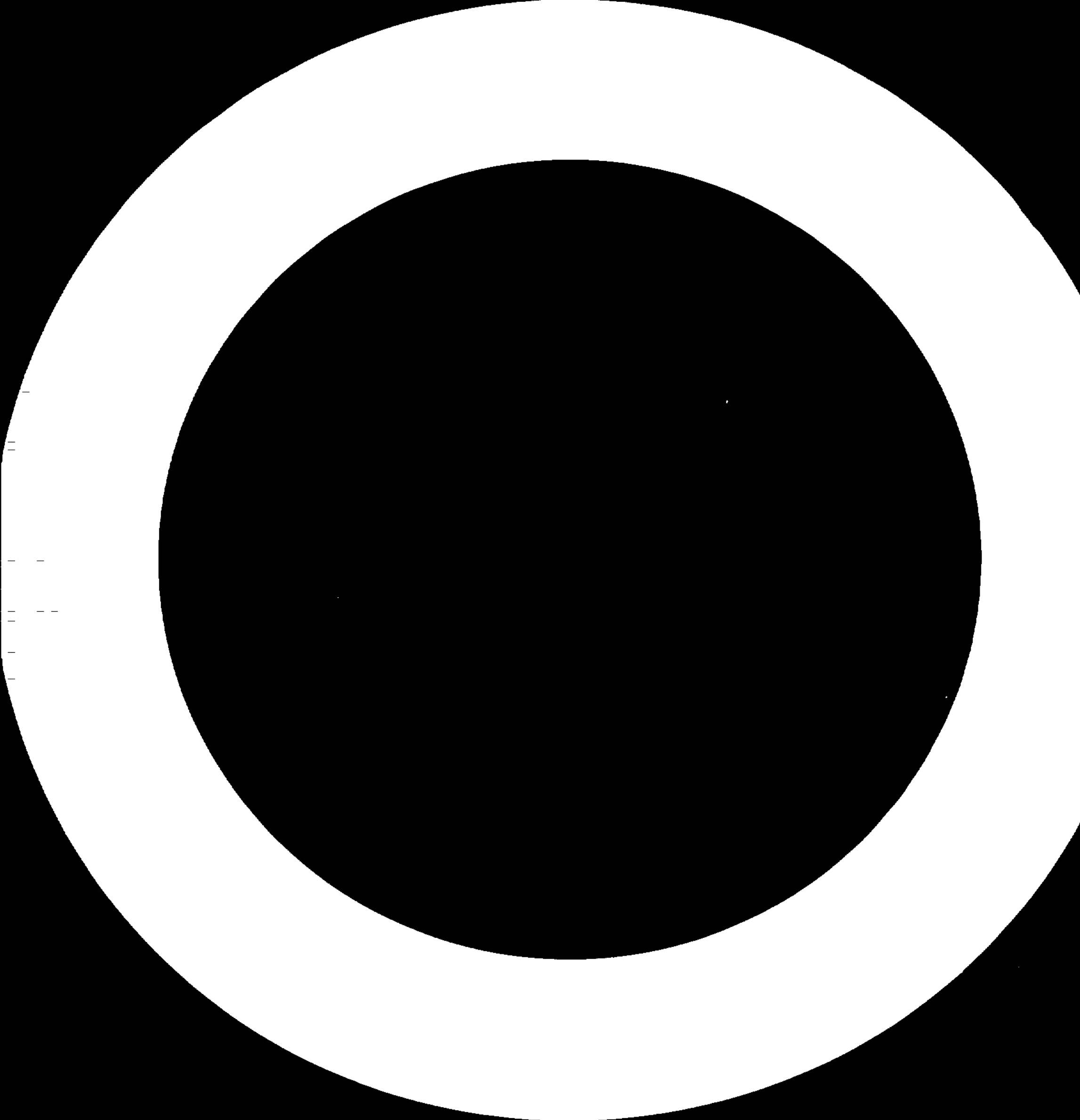



LEGEND:

- SILT
- SAND
- CLAY
- $CaCO_3$ CONCRETIONS
- RESERVES A CATEGORY
- RESERVES B CATEGORY

| GEOLOGICAL PROFILES | |
|---|---|
| OBJECT | SILT DEPOSIT |
| LOKALITY | SOBA UNIVERSITY FARM |
| INVESTOR | BRRI UNIVERSITY of KHARTOUM |
| | P. NICIFOROVIĆ, dipl. ing. UNIDO EXPERT |

# SECTION 3



APENDIX N°5

# GEOLOGICAL PROFILE of
## CUT A-I

OBJECT: SILT DEPOSIT

LOKALITY: SOBA UNIVERSITY FARM

INVESTOR: BRRI - UNIVERSITY of KHARTOUM

LEVEL 99.95 SCALE 1:100

| DEPTH m | TICKNESS m | GRAFIC PRESENTATION | LITOLOGICAL DESCRIPTION | W.L. |
|---|---|---|---|---|
| 1.00 | 1.00 | | Sandy silt | |
| 2.60 | 1.60 | | Sandy and claily silt | |
| 2.80 | 0.20 | | Sand | |
| 4.00 | 1.20 | | Brown sandy silt | |
| 4.50 | 0.50 | | Brown claily silt | |
| 5.60 | | | Gray silt | 5.60 |

APENDIX Nº 6

# GEOLOGICAL PROFILE of HOLE A-II

OBJECT: SILT DEPOSIT

LOKALITY: SOBA UNIVERSITY FARM

INVESTOR: BRRI - UNIVERSITY of KHARTOUM

LEVEL 100,75

SCALE 1:100

| DEPTH m | TICKNESS m | GRAFIC PRESENTATION | LITOLOGICAL DESCRIPTION | W.L. |
|---|---|---|---|---|
| 1,00 | 1,00 | | Sandy Brownish silt | |
| 1,20 | 0,20 | | Brown sandy clay | |
| 2,80 | 1,60 | | Brown claily sand | |
| 4,40 | 1,60 | | Claily silt | |
| 5,20 | 0,80 | | Graish silt | 5,20 |
| 6,80 | | | Claily sand | |

APENDIX No 7

# GEOLOGICAL PROFILE of
# HOLE A-III

OBJECT: SILT DEPOSIT

LOKALITY: SOBA UNIVERSITY FARM

INVESTOR: BRRI - UNIVERSITY of KHARTOUM

LEVEL 101.10 SCALE 1:100

| DEPTH m | TICKNESS m | GRAFIC PRESENTATION | LITOLOGICAL DESCRIPTION | W.L. |
|---|---|---|---|---|
| 1.00 | 1.00 | | Brown claily sand | |
| 1.40 | 0.40 | | Brown sandy clay | |
| 2.00 | 0.60 | | Brown claily sand | |
| 2.60 | 0.60 | | Brown plastic clay | |
| 3.80 | 1.20 | | Brown claily sand | |
| 4.10 | 0.30 | | Black clay with $CaCO_3$ | |
| 4.80 | 0.70 | | Brown claily sand | |
| 6.00 | 1.20 | | Brown claily sand | |
| 6.20 | 0.20 | | Sand | |
| 7.00 | | | Brown claily sand | 6.70 |

APENDIX N° 8

# GEOLOGICAL PROFILE of HOLE A-V

OBJECT: SILT DEPOSIT

LOKALITY: SOBA UNIVERSITY FARM

INVESTOR: BRRI - UNIVERSITY of KHARTOUM

LEVEL 102.80 SCALE 1:100

| DEPTH m | TICKNESS m | GRAFIC PRESENTATION | LITOLOGICAL DESCRIPTION | W.L. |
|---|---|---|---|---|
| 0.80 | 0.80 | | Brown sandy clay | |
| 2.80 | 2.00 | | Brown plastic clay | |
| 3.30 | 0.50 | | Yellow-Brownis sandy clay | |
| 5.00 | 1,70 | | Yellowish claily sand | |
| 5.80 | 0.80 | | Yellowish-Brown sandy clay | |
| 7.00 | | | Yellowish-Brown claily sand with $CaCO_3$ (6.m.) | 6.80 |

APENDIX No 9

# GEOLOGICAL PROFILE of HOLE A-VII

OBJECT: SILT DEPOSIT

LOKALITY: SOBA UNIVERSITY FARM

INVESTOR: BRRI - UNIVERSITY of KHARTOUM

LEVEL 103.70

SCALE 1:100

| DEPTH m | TICKNESS m | GRAFIC PRESENTATION | LITOLOGICAL DESCRIPTION | W.L. |
|---|---|---|---|---|
| 1.60 | 1,60 | | Brown sand-claily | |
| 2.60 | 1.00 | | Claily sand | |
| 3.20 | 0.60 | | Sand ? ( no core ) | |
| 5.70 | 2,50 | | Sandy silt passing to Brown plastic clay with $CaCO_3$ | |
| 6.00 | | | Brown sandy clay | |

APENDIX № 10

# GEOLOGICAL PROFILE of HOLE A-IX

OBJECT: SILT DEPOSIT

LOKALITY: SOBA UNIVERSITY FARM

INVESTOR: BRRI - UNIVERSITY of KHARTOUM

LEVEL 103.70

SCALE 1:100

| DEPTH m | TICKNESS m | GRAFIC PRESENTATION | LITOLOGICAL DESCRIPTION | W.L. |
|---|---|---|---|---|
| 1.30 | 1.30 | | Sand yellowish - Brown | |
| 1.90 | 0.60 | | Sand with dispersed $CaCO_3$ | |
| 2.00 | ------ | | Sand bonne with $CaCO_3$ | |

APENDIX No 11

# GEOLOGICAL PROFILE of CUT B-I

OBJECT: SILT DEPOSIT

LOKALITY: SOBA UNIVERSITY FARM

INVESTOR: BRRI - UNIVERSITY of KHARTOUM

LEVEL ..........

SCALE 1:100

| DEPTH m | TICKNESS m | GRAFIC PRESENTATION | LITOLOGICAL DESCRIPTION | W.L. |
|---|---|---|---|---|
| 0.45 | 0.45 | | Sandy silt | |
| 1.60 | 1.15 | | Brown silt | |
| 1.85 | 0.25 | | Clayey silt | |
| 2.90 | 1.05 | | Brown-gray silt | |
| 3.45 | 0.55 | | Sandy clay | |
| 5.80 | | | Sand | 5.80 |

APENDIX No 12

# GEOLOGICAL PROFILE of HOLE B – II

OBJECT: SILT DEPOSIT

LOKALITY: SOBA UNIVERSITY FARM

INVESTOR: BRRI – UNIVERSITY of KHARTOUM

LEVEL 100.60

SCALE 1:100

| DEPTH m | TICKNESS m | GRAFIC PRESENTATION | LITOLOGICAL DESCRIPTION | W.L. |
|---|---|---|---|---|
| 1.00 | 1,00 | | Brown silt | |
| 3,15 | 2,15 | | Brownish silt | |
| 3,60 | 0,45 | | Gray clayey silt | |
| 4,50 | 0,90 | | Gray silt | |
| 5,20 | 0,70 | | Silt | 5,20 |
| 6,00 | 0,80 | | Sand ? (no core) | |
| 7,20 | 1,20 | | Gray silt | |
| 8,00 | 0,80 | | Sand ? (no core) | |
| 8,20 | | | Gray sandy silt | |

APENDIX Nº 13

# GEOLOGICAL PROFILE of
## HOLE B-III

OBJECT: SILT DEPOSIT

LOKALITY: SOBA UNIVERSITY FARM

INVESTOR: BRRI - UNIVERSITY of KHARTOUM

LEVEL 100.80 SCALE 1:100

| DEPTH m | TICKNESS m | GRAFIC PRESENTATION | LITOLOGICAL DESCRIPTION | W.L. |
|---|---|---|---|---|
| 1.20 | 1.20 | | Brownish silt | |
| 3.05 | 1.85 | | Same more plastic | |
| 3.40 | 0.35 | | Silt | |
| 6.60 | 3.40 | | Brownish sand | 6.50 |
| 7.00 | 0.20 | | Gray silt | |
| 9.00 | 2.00 | | No core | |
| 9.20 | | | Gray clayey silt | |

APENDIX No 14

# GEOLOGICAL PROFILE of HOLE B-VII

OBJECT: SILT DEPOSIT

LOKALITY: SOBA UNIVERSITY FARM

INVESTOR: BRRI - UNIVERSITY of KHARTOUM

LEVEL 104.30

SCALE 1:100

| DEPTH m | TICKNESS m | GRAFIC PRESENTATION | LITOLOGICAL DESCRIPTION | W.L. |
|---|---|---|---|---|
| 0.40 | 0.40 | | Earth ? | |
| 1.80 | 1,40 | | Sand with fine concretions of $CaCO_3$ | |
| 2.30 | 0.50 | | Brownish claily sand | |
| 3.10 | 0,80 | | Brown sand | |
| 6.30 | 3,20 | | Claily silt with $CaCO_3$ conckretions | 6.00 |
| 6.40 | | | Plastic clay | |

APENDIX Nº 15

# GEOLOGICAL PROFILE of
## CUT C-I

OBJECT: SILT DEPOSIT

LOKALITY: SOBA UNIVERSITY FARM

INVESTOR: BRRI - UNIVERSITY of KHARTOUM

LEVEL 99.90 SCALE 1:100

| DEPTH m | TICKNESS m | GRAFIC PRESENTATION | LITOLOGICAL DESCRIPTION | W.L. |
|---|---|---|---|---|
| 0.70 | 0.70 | | Sandy silt | |
| 2.85 | 1.15 | | Claily silt | |
| 3.30 | 0.45 | | Sand-claily silt | |
| 3.75 | 0.45 | | Sand | |
| 4.45 | 0.70 | | Sand-silt | |
| 5.70 | | | Gray sandy silt | 5.70 |

APENDIX No 16

# GEOLOGICAL PROFILE of HOLE C-II

OBJECT: SILT DEPOSIT

LOKALITY: SOBA UNIVERSITY FARM

INVESTOR: BRRI - UNIVERSITY of KHARTOUM

LEVEL 100.45

SCALE 1:100

| DEPTH m | TICKNESS m | GRAFIC PRESENTATION | LITOLOGICAL DESCRIPTION | W.L. |
|---|---|---|---|---|
| 1,40 | 1,40 | | Gray sandy silt | |
| 2,50 | 1,10 | | Brown sandy silt | |
| 3,00 | 0,50 | | Brown sandy clay | |
| 3,60 | 0,60 | | Brown silt | |
| 5,40 | 1,80 | | Gray sandy silt | |
| 6,00 | 0,60 | | Gray claily silt | |
| 6,40 | | | Gray silt | |

APENDIX No 17

# GEOLOGICAL PROFILE of
# HOLE C-III

OBJECT: SILT DEPOSIT

LOKALITY: SOBA UNIVERSITY FARM

INVESTOR: BRRI - UNIVERSITY of KHARTOUM

LEVEL 100.80 SCALE 1:100

| DEPTH m | TICKNESS m | GRAFIC PRESENTATION | LITOLOGICAL DESCRIPTION | W.L. |
|---|---|---|---|---|
| 0,70 | 0,70 | | Yellow-Brown silt | |
| 1,80 | 1,10 | | Brown silt | |
| 3,90 | 2,10 | | Silt with clay and sand | |
| 5,20 | 1,30 | | Sand (with clay) | |
| 6,00 | 0,80 | | Sand | 5.00 |
| 6,40 | 0,40 | | Coarse sand | |
| 6,60 | | | Sand | |

APENDIX No 18

# GEOLOGICAL PROFILE of HOLE C-V

OBJECT: SILT DEPOSIT

LOKALITY: SOBA UNIVERSITY FARM

INVESTOR: BRRI - UNIVERSITY of KHARTOUM

LEVEL 103.20

SCALE 1:100

| DEPTH m | TICKNESS m | GRAFIC PRESENTATION | LITOLOGICAL DESCRIPTION | W.L. |
|---|---|---|---|---|
| 0.80 | 0.80 | | Brown clayly sand | |
| 1.60 | 0.80 | | Sandy silt | |
| 2.20 | 0.60 | | Grey sandy clay | |
| 3.00 | 0.80 | | Sand ? No core ! | |
| 3.20 | 0.20 | | Grey plastic clay | |
| 4.00 | 0.80 | | Sand ? No core ! | |
| 4.60 | 0.60 | | Brown clay with $CaCO_3$ | |
| 7.80 | | | Brown-grey sand | 5.00 |

## LIST OF PERSONS INTERVIEWED

1. Ms. Mahassin Khidir, Ministry of National Planning, Department of Industry

2. Mr. Mohamed Hamid, Ministry of National Planning, Loans Department

3. Mr. Omer Mohamed El Hassan Fagieri
   B.Sc. (Eng.), DIC, M.Sc., Ph.D., IWSc. HSES
   Director, BRRI.

4. Dr. Mutasim Abdalla El Zamzami
   B.Sc (Honours) Chemistry, M.Sc. (Ceramics), Ph.D. (Cement technology), Lecturer BRRI, University of Khartoum.

5. Dr. Omer Ibrahim Yagi,
   Dip., Ph.D. Chemical Engineering; Lecturer BRRI, U. of K.
   Chairman of the Technical Committee Entrusted with the Execution of Soba Demonstration Plant.

6. Mr. Mohamed Hussein Hamid,
   B.Sc. Chemical Eng., Post graduate Dip. in Ceramics,
   Executive Director of Soba Demonstration Plant and
   Member of the Technical Committee entrusted for the Execution of the Plant.

7. Mr. Abdel Raouf Abdel Atti,
   General Director, Khartoum Central Foundry

8. Mr. Mustafa Nour El Dayem,
   Manager, Economic Studies Department,
   Industrial Research and Consultancy Institute, P.O. Box 268,
   Khartoum, Sudan.

9. Mr. Adam Babiker Salih,
   Ph.D., University of Khartoum, Faculty of Engineering,
   Department of Surveying.

10. Mr. Ibrahim A. Gadir Malik,
    Geologist, Ministry of Energy and Mining,
    Geological and Mineral Resources Department.

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