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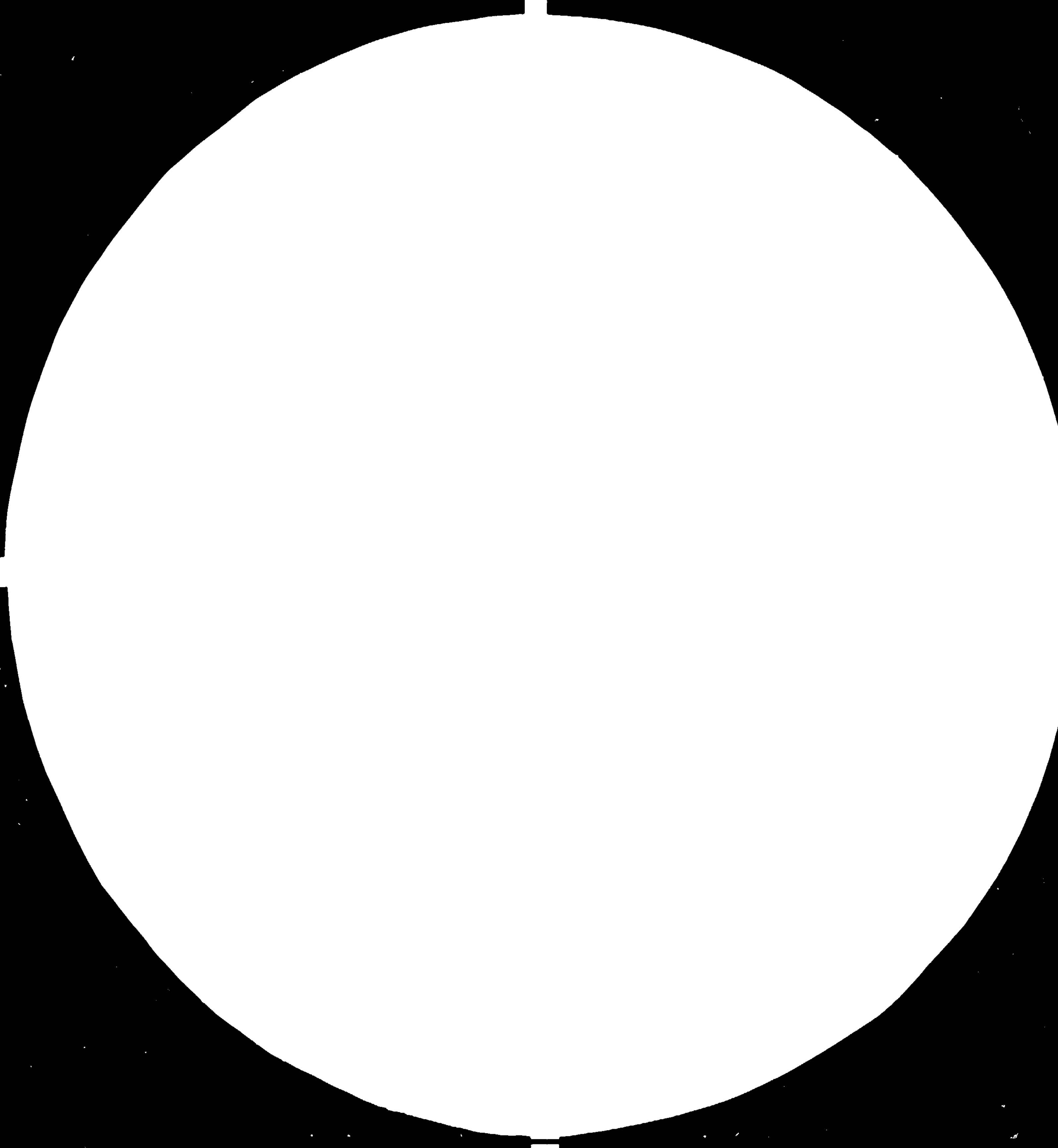

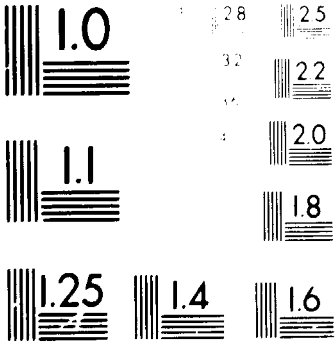

MICROCOPY RESOLUTION TEST CHART

13679

Investigation of Raw Materials

for the Production of Glass Containers

in South Niger and North Nigeria

UNIDO Project

DP / RAF / 77 / 020

Humboldt Wedag AG, Cologne

Date February 1984

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Table of contents page

1.1 Objective

KHD Humboldt Wedag AG, Cologne, have been asked by UNIDO in Vienna to examine under a prefeasibility study (UNIDO Project DP/RAF/ 77/020) raw material deposits of silica sand, limestone, dolomite, feldspar and soda existing in Niger and North Nigeria, as to their suitability for the production of glass containers and to estimate the existing reserves. Drafting of this study has been suggested by the Niger-Nigerian Joint Commission for Cooperation, Niamey.

1.2 Summary

Out of a total of 31 single deposits only those are listed below which are most promising with respect to their chemical and mineralogical composition as raw material basis for the production of glass containers in Niger and North Nigeria and which, therefore, can be recommended. The comments made below duly consider the geographical location of the promising deposits in Niger and North Nigeria respectively with regard to a probable site for setting up a glass container manufacturing plant. It is assumed that because of infrastructural prerequisites (traffic network, water- and energy supply) and potential markets for the containers produced (breweries, production of jams and marmalades) Niamey or Maradi could most probably be chosen as site for a glass factory in Niger.

1.2.1 Quartz sand deposits and occurrences

There are 5 sand deposits in South Niger which are considered very promising according to first investigations.

- The sand described under 2.1.1.1 and located near Gazoua is very well suitable for the production of glass containers judged by is chemism and grain size distribution. Apart from that, adequate geologic reserves exist.

  The deposit is situated approx. 110 km east of Maradi and easily accessible over the tarred road (RN 1).

- The sand deposit described under 2.1.1.2 and located in the Dallol Bosso contains acceptable glass sand quality. The estimated reserves are adequate. The sand should be processed for improving grain size distribution and chemical purity so as to guarantee a constant raw material quality.

  From geographical point of view, the deposit is advantageously located to Niamey.

- The deposit referred to under 2.1.1.3 in the Dallol Bosso contains even purer glass sand than the deposit mentioned under 2.1.1.2) below. The reserves are again estimated to be sufficient.

- Analyses of samples taken from the sand-gravel pit described under 2.1.1.4 - named Lefebre - revealed that the material is sand of good quality for the production of glass containers.

  However, the raw sand includes a high portion of fines and will have to be classified and deslimed before being used for the production of glass.

  Being located 2 km from Maradi the deposit profits of a very favourable geographical location.
  The reserves are estimated to equal 190,000 m^3 of sand at a minimum.

- Apart from quartz, the sand-gravel deposit described under 2.1.1.5 includes recoverable amounts of feldspar. Using that sand for the production of glass offers two advantages:

  a) vicinity to Maradi, low transport costs.
  b) after processing and separation of the raw sand, quartz sand and feldspar of constant and high quality will be available with respect to grain size and chemical composition.

The reserves are estimated to be adequate for justifying additional examinations.

1.2.2 Limestone and dolomite deposits and occurrences

- The limestone deposit of Wajee/Niger referred to under 2.2.1.2 is the only limestone occurrence investigated which appears suitable to be used for the production of glass.

  It is recommended to have constant quality and reserves checked by further investigations.

- The dolomitic limestone occurrence near Ibesseten described under 2.2.1.3 will be suitable as Mg supplier - thereby substituting dolomite - for the production of glass containers on the condition that the chemical composition remains constant over the deposit. It is recommended to have chemical stability of the reserves checked by core drilling and chemical analyzing and to confirm the raw material reserves which are considered to be sufficient.

- A complete chemical analysis of a sample taken from the Burum dolomitic marble - described under 2.3.2 - and located in the Plateau State/ Nigeria revealed that there are parts within the dolomitic marble occurrence where the raw material meets the quality requirements for glass production. These deposit batches including dolomite of good quality will have to be checked by detailed geologic tests.

1.2.3 Feldspar

Larger feldspar deposits exist in Niger, also south of Tillabery and near Tera.
According to the results of a chemical analysis of a sample taken at location 30 (see location map) the feldspar existing in this area is suitable for the glass production.
Constant raw-material quality will have to be verified by further investigations.

1.2.4 Natural soda does not occur at economic quantities in South Niger and North Nigeria.

After having chosen the possible site of the container glass factory depending on the location of the most promising raw material occurrences, it is urgently recommended to investigate in detail these occurrences with respect to the constancy of their quality and to their exact amount of reserves.

Item 3) is an outline of the quality requirements to be met by the main raw materials for producing flat or hollow glass. In addition, it includes comments made by the department for glass technology at KHD Humboldt Wedag AG as to the suitability of the raw materials investigated under this prefeasibility study.

1.3 Preparation of trip and route

The route for investigating possible raw material occurrences in South Niger and North Nigeria was fixed on the basis of existing literature about occurrences located earlier. Extensive information of this type has been available for Niger. As regards Nigeria, available reports mentioned almost exclusively deposits in central and south Nigeria as can be seen from the list of literature dealing with glass raw material deposits in Nigeria which was handed over to KHD Humboldt Wedag AG by the Niger-Nigerian Joint Commission for Cooperation. This situation was confirmed during a 2-days' stay at the Geological Survey of Nigeria at Kaduna for evaluating additional publications. Therefore, occurrences of glass raw materials in the North of Nigeria could not be included in the itinerary on the basis of reliable data shown in the literature but the route had to be fixed instead on the basis of the possible geological potential. The only exception in North Nigeria was the limestone deposit near Sokoto.

November 8, 1983	- departure from Cologne to Niamey, i.e. to the project area
November 9 to 10,1983	- Investigation of dolomite occurrences nr. Ayorou and Firgoun/Niger and of feldspar deposits nr. Tillaberi and Tera/ Niger
November 11, 1983	- unexpected but unavoidable stay at Niamey because the vehicle had to be inspected

November 12, 1983 -	Investigation of sands nr. Birni N'Konni and of limestone nr. Malbaza/Niger
November 13, 1983 -	Investigation of limestones nr. Tahoua and Idessetene/ Niger
November 14, 1983 -	Investigation of limestone at Malbaza and of glass sands near Maradi/Niger
November 15, 1983 -	Investigation of glass sands nr. Tessaoua and Dan Kada/Niger
November 16, 1983 -	trip from Maradi/Niger to Kaduna/Nigeria
November 17, 1983 -	Evaluation of literature at the Geological Survey at Kaduna; inspecting a sand deposit near Kaduna
November 18, 1983 -	Trip from Kaduna to Sokoto/ Nigeria
November 19, 1983 -	Prospecting of glass sand in the Wurno and Taloka formations located between Sokoto and Taloka Mafara, as well as of alluvial sands of the Sokoto River near Bakura/Nigeria
November 20, 1983 -	Prospecting of feldspar between Taloka Mafara and Sado/Nigeria
November 21, 1983 -	Investigation of limestone deposits nr. Sokoto/Nigeria and trip to Malbaza/Niger.

November 22,	1983 -	Trip from Malbaza to Niamey and investigation of glass sands in Dallol Bosso/ Niger. Moreover, a quartzite deposit nr. Say/Niger has been tested.
November 23,	1983 -	Discussions with Mr. Semerdjan, Mr. Quedraogo (both PNUD), Mr. Wali, Mr. Gado (Niger-Nigerian Joint Commission for cooperation) and Mr. Svejnar (PNUD Joint Commission). In addition, the samples were prepared for dispatch to Germany.
November 25,	1983 -	Return flight to Cologne from Niamey.

In the course of the above terrain activities, 31 deposits of glass raw materials were investigated and evaluated; a total of 4,800 km were travelled by car.

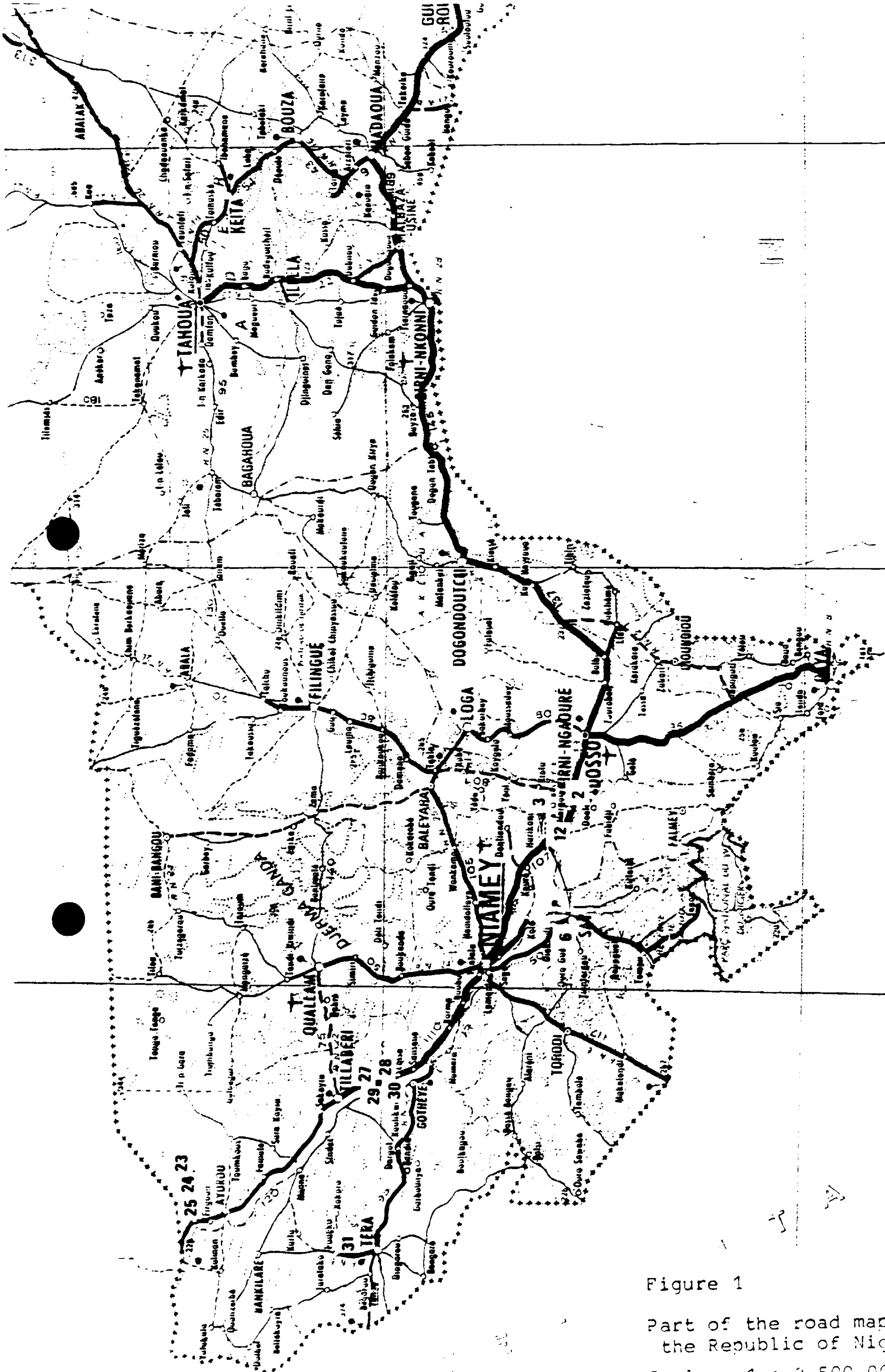

Figure 1

Part of the road map of the Republic of Niger

Scale: 1 : 2,500,000

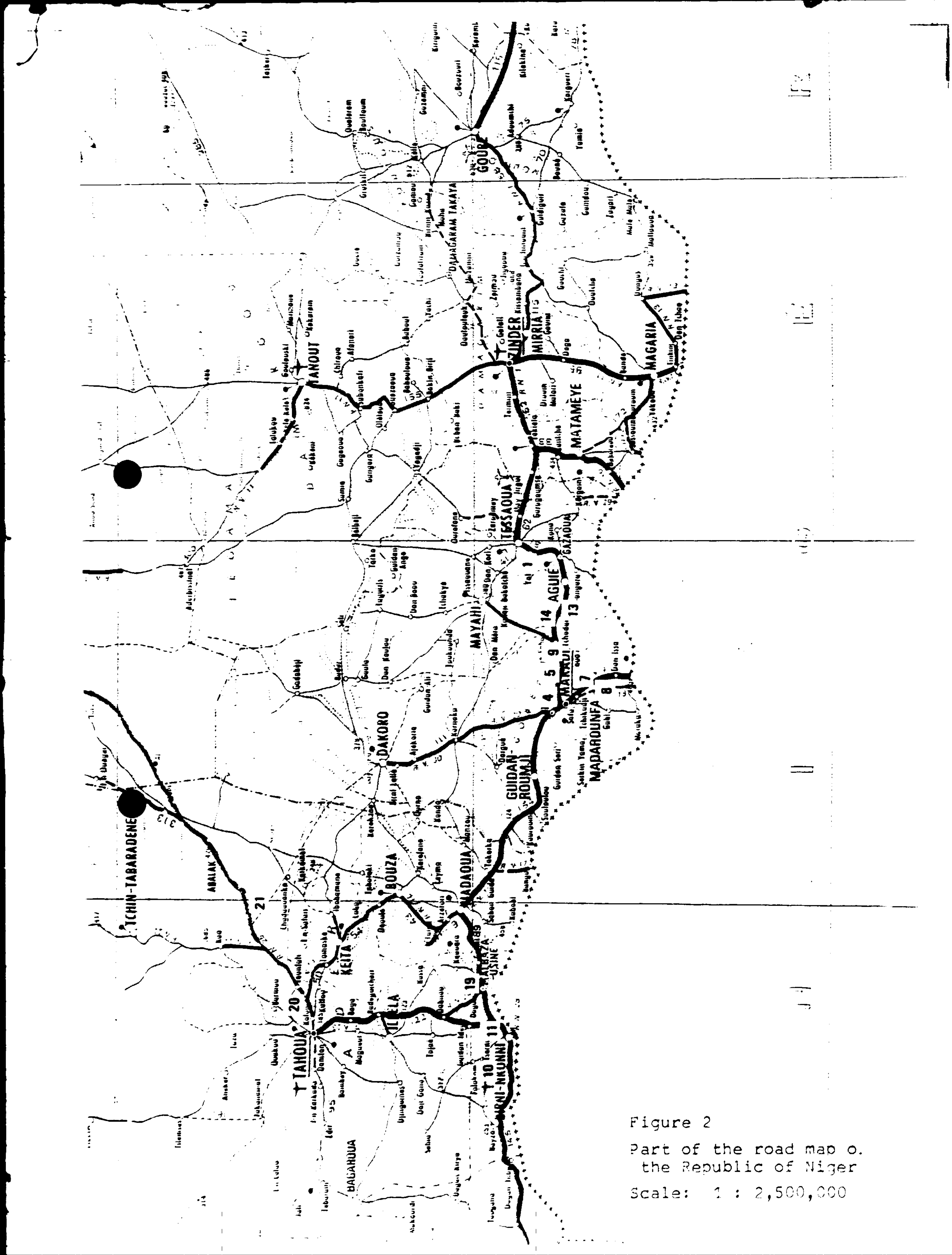

Figure 2

Part of the road map o. the Republic of Niger

Scale: 1 : 2,500,000

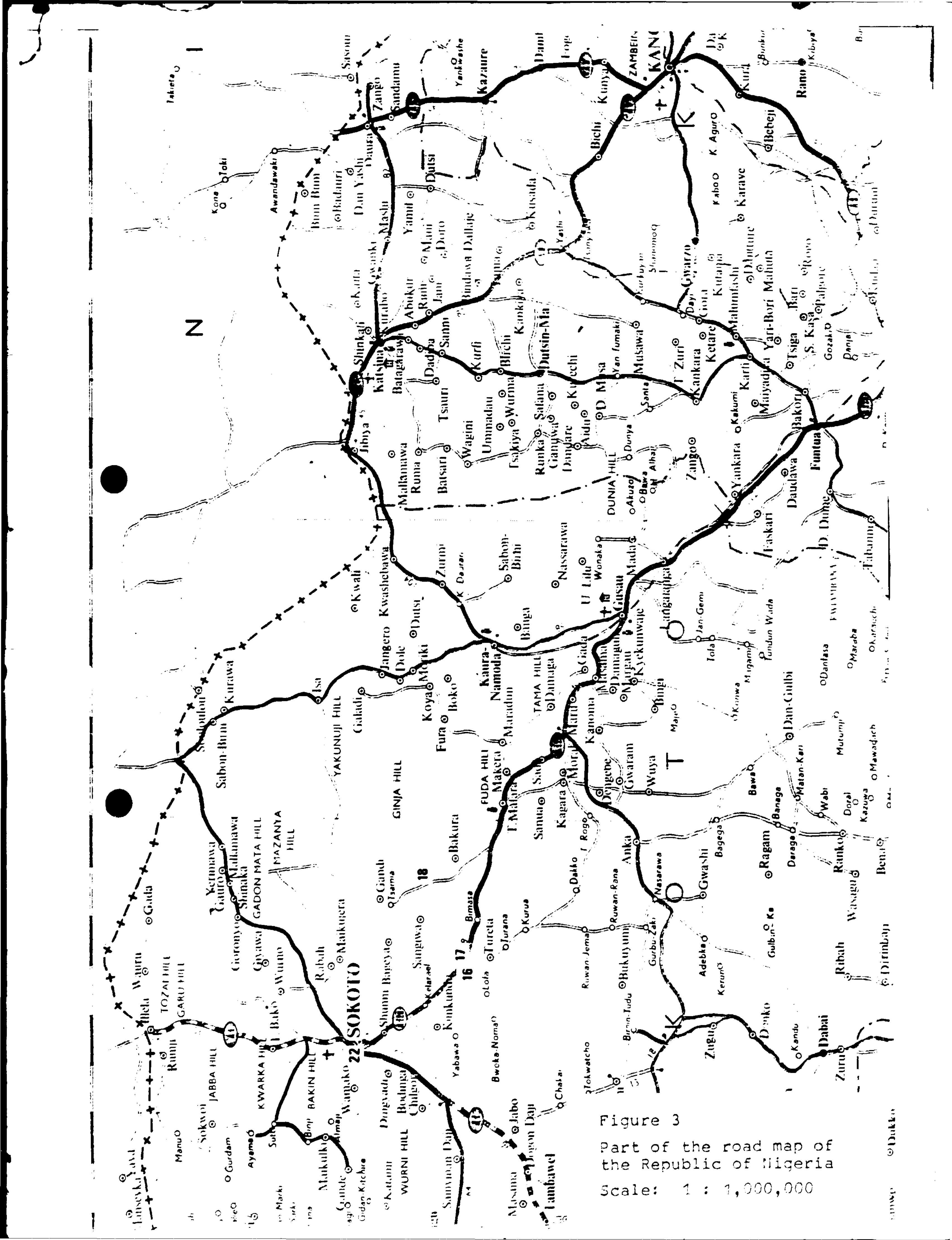

Figure 3

Part of the road map of the Republic of Nigeria

Scale: 1 : 1,000,000

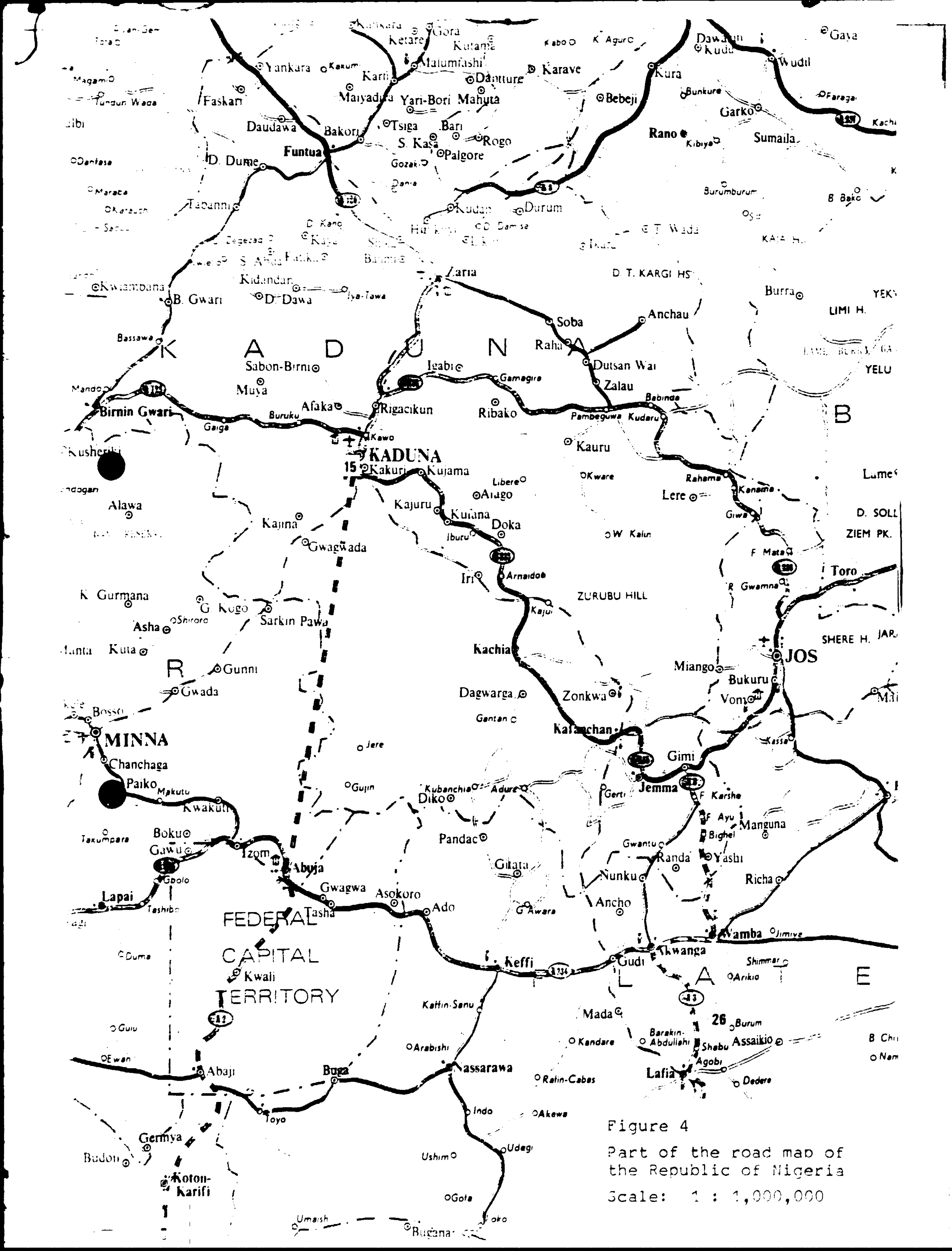

Figure 4

Part of the road map of the Republic of Nigeria

Scale: 1 : 1,000,000

2.0 Investigation of the raw material deposits

The single occurrences described below can be identified by consecutive numbers on the location maps attached.

2.1 Glass sand

Geology and potential

The maximum potential of pure quartz sands in South Niger exists in the predominantly north-south oriented dry valleys filled with unconsolidated clastic sediments. A typical example is the Dallol Bosso.

Little potential exists in the mainly fine clastic sediments of continental deposits of the Wurno- and Taloka formations in Nigeria and of the Contentinal Terminal in Niger.

Very little potential exists in stream valleys with still active rivers because the sands occurring there are mostly iron-bearing and have high feldspar contents.

2.1.1 Deposits examined in the South of the Republic of Niger.

2.1.1.1 Small sand pit approx. 15 km north of Gazoua, some 300 km west of a bridge across a river along the road Maradi-Zinder (RN 1) (location 1).

The deposit occurs in a north-south oriented dry valley of 2.0 - 3.0 km width filled with light grey to white fluviatile quartz sands.

3 trenches were dug.

Trench 1: Trench starting some 2.0-2.5 m below grade in an existing sand pit, abt. 30 m north of the road; depth of trench is 2.10 m, then it collapsed because of the loose, not bonded sand.

Fig. 1: Trench 1

Lithology:
White to white-brown quartz sand, of fine to medium grain size; the quartz is as clear as water, a small portion displays reddish coating. Dark components occur at about 0.5 - 0.2 %.

The cross-bedded sand includes layers of fine gravel which have a thickness from 2.0 to 5.0 cm. A 1.0 m long channel sample (G 24) was taken from the trench; it was earth-damp when taken.

Trench 2: This trench is located in a sand pit of some 4 - 5 m depth, 15 - 20 km south of the road. Trenching had to be discontinued at a depth of 1.20 m after repeated collapsing.

The lithological data are identical to those given for trench 1. Sample (G25) taken over the complete trench length was again earth-damp when being taken.

Trench 3: This trench was started at the sand pit wall between trench 2 and the road. After repeated collapsing, this wall could be exposed over a length of no more than 2.0 m which was necessary for obtaining access to fresh sample material (G26).

Lithology is identical to that specified above for trench 1 and 2 respectively.

Fig. 2: Trench 3

The samples taken from the trenches have the following grain size distribution:

Table 1: Screen analysis results determined for samples taken from three trenches

grain size (mm)	trench 1 sample no. G24 %	trench 2 sample no. G25 %	trench 3 sample no. G26 %
+ 0.8	2.6	3.8	0.1
0.8 - 0.5	7.3	6.1	1.0
0.5 - 0.1	89.9	89.9	98.6
- 0.1	0.2	0.2	0.3

The grain size distribution of samples G-24 and G-25 is almost identical. 89.9 % of the sand grains are within the fraction required for glass production. The grain size distribution of sample G-26 originating from trench 3 is ideal for the production of glass, i.e. 98.6 % of the sand grains are within the fraction of 0.1 - 0.5 mm required for glass production.

The results of chemical analyzing of the samples taken from the trenches mentioned above are listed in the table below:

Table 2:

sample no.	trench 1		trench 2		trench 3
	G-24		G-25		G-26
grain size (mm)	0.1-0.8	+0.8	0.1-0.8	+0.8	0.1 - 0.8
element (%)					
L.O.I.	0.10	0.13	0.15	0.0	0.27
SiO_2	99.03	96.96	98.97	98.51	98.55
Al_2O_3	0.37	1.69	0.33	0.67	0.53
Fe_2O_3	0.06	0.07	0.06	0.05	0.10
TiO_2	0.05	0.03	0.08	0.03	0.05
CaO	traces	traces	traces	traces	traces
MgO	traces	traces	traces	traces	traces
Cr_2O_3	0.06	0.05	0.03	traces	0.06
$Na_2O + K_2O$	0.21	1.22	0.23	0.36	0.15

The chemical analyses indicate that the quartz sand from all three trenches at the Gazoua deposit is extremely well suitable for the production of glass containers. For the fraction 0.1 - 0.8 mm, all three samples have SiO_2 contents of more than 98.5 % at Fe_2O_3 contents between 0.06 and 0.1 %:

Because of the particularly favourable size distribution and the chemical composition, the sand of the Gazoua deposit can be recommended as silicate raw material for the production of glass containers.

The reserves of this deposit are difficult to estimate. Based on conservative assumptions they should, however, equal 2 million m^3 of sand at a minimum.

2.1.1.2 Sand pit at the road Niamey-Dosso (RN 1), some 92 km south-south-east of Niamey, approx. 300 m south of the exit of Margou (location 2).

This deposit exists in the fluviatile unconsolidated sediments of the Dallol Bosso.

A white to white-grey, well assorted, fine-grained quartz sand containing feldspar and very isolated light mica (sample GS-4) is superimposed by a quartz sand of medium grain size. It is white-grey to white and includes some isolated dark grains (?ilmenite) apart from white and light-pink feldspar (less than 3 %). The well rounded quartz is transparent to translucent and some 5 % of it - predominantly coarser grains - has a reddish to reddish-brown coating (sample GS-3).

In the course of mineralogic examinations, isolated tourmaline was identified in both samples.

The screen analysis for the samples yielded the following results:

Table 3:

grain size (mm)	sample no. GS-3 %	sample no. GS-4 %
minus 0.8	4.9	0.3
0.8 - 0.1	93.3	91.5
minus 0.1	4.9	8.2

The following table quotes the analytical results of the size fractions obtained by screening.

Table 4:

sample no.:		GS-3			GS-4		
grainsize (mm)		+0.8	0.8 to 0.1	-0.1	+0.8	0.8 to 0.1	-0.1
element							
L.O.I.	%	0.26	0.29	0.72	0.77	0.36	1.06
SiO_2	%	95.3	97.37	91.0	94.0	96.34	91.5
Al_2O_3	%	2.73	1.81	4.51	2.95	2.55	4.25
Fe_2O_3	%	0.11	0.12	1.06	0.16	0.15	0.83
TiO_2	%	0.06	0.04	1.73	0.13	0.04	1.36
CaO	%	0.10	0.12	0.39	0.14	0.16	0.36
MgO	%	0.10	0.10	0.20	0.20	0.10	0.3
SO_3	%	0.05	0.05	0.05	0.05	0.05	0.05
K_2O	%	1.37	0.63	1.71	1.17	0.96	1.29
Na_2O	%	n.d.	0.11	n.d.	n.d.	0.22	n.d.
P_2O_5	%	0.05	0.05	0.05	0.05	0.05	0.05
BaO	%	n.d.	0.10	n.d.	n.d.	0.10	n.d.
Cr_2O_3	ppm	n.d.	11	n.d.	n.d.	9	n.d.

This results in the following overall chemism of the two samples:

Table 5: Analyses of the raw sand 'Margou'

sample No.	GS - 3	GS - 4
element	%	%
L.O.I.	0.30	0.42
SiO_2	97.15	95.94
Al_2O_3	1.90	2.69
Fe_2O_3	0.14	0.20
TiO_2	0.07	0.12
CaO	0.12	0.12
MgO	0.10	0.10
SO_3	0.05	0.05
K_2O	0.68	0.99
P_2O_5	0.05	0.05

The moisture of the two samples prior to drying at 105°C amounted to 1.9 % for GS-3 and to 2.7 % for GS-4.

The quartz sand fraction being of interest for the production of glass, i.e. 0.1 - 0.8 mm, including 93.3 % and 91.5 % of the grains respectively, has SiO_2 contents of 97.37 % and 96.34 % respectively. The fine fraction minus 0.1 mm contains the maximum alumina contents, i.e. 4.51 % and 4.25 %. The Fe_2O_3 contents of the fraction 0.1 to 0.8 mm, equalling 0.12 % and 0.15 %, are low.

Because of its granulometric and chemical composition, this sand will be interesting for the production of glass containers. Moreover, the geographic location of the deposit near RN 1 and the relatively short distances to Niamey and Dosso are of advantage.

In view of the geological environment of the sand pit, the sand reserves are estimated to equal several 100,000 m^3.

2.1.1.3 Dallol Bosso some 10 km north of Birni N'Gaouré (location 3).

A 1.30 m deep trench was dug at this location (G-29). After an 0.90 m thick humic, clayey-sandy overburden, a grey medium-grained sand was found which was still impurified by humus matter. This sand was within the area of groundwater of that 'dallol' (dry valley) at the time of investigations in the field.

The granulometric and chemical analyses yielded the following results:

Table 6:

grain size (mm)	sample no. G-29 %
+ 0.8	3.2
0.8 - 0.5	10.4
0.5 - 0.1	85.8
- 0.1	0.6

Table 7: Chemical analysis of the fraction 0.1-0.3 mm originating from sample G-29

L.O.I.	0.08 %	CaO	traces
SiO_2	98.14 %	MgO	traces
Al_2O_3	0.98 %	Cr_2O_3	0.04 %
Fe_2O_3	0.06 %	Na_2O + K_2O	0.39 %
TiO_2	0.05 %		

In view of the size distribution and the chemical composition ascertained, the sand is suitable for the production of glass containers.

It is assumed that the sand reserves amount to several 100,000 t in the vicinity of the location investigated.

It has to be duly considered, however, that the ground-water table will be subject to seasonal fluctuations with maximum values of 1.0 to 2.5 m below grade which might imply wet mining.

2.1.1.4 Sand-gravel pit of Messrs. J. Lefebre, abt. 1 km east of Maradi, north of the road Maradi-Zinder (RN 1) (location 4).

The alluvial, quarternary terrace gravel occurring in this area is being mined for road construction.

The gravel made up of brown to grey-white quartz pebbles is superimposed by white to light-grey fine to medium-grained sands of 1.0 to 2.5 m thickness (G 20 and G 21). The topmost 0.50 m thick layer of these sands below the grass cover are impurified by humic matter.

Fig. 3: Section of the sand-gravel pit of Messrs. J. Lefebre

Granulometric testing yielded the following results:

Table 8:

grain size (mm)	sample no. G-20 %	sample no. G-21 %
+ 0.8	1.1	0.5
0.8 - 0.5	1.5	0.7
0.5 - 0.1	87.4	72.3
- 0.1	10.0	26.5

The above values reveal that 10.0 % and 26.5 % resp. of the sand grains are minus 0.1 mm in diameter; this fraction is unsuitable for glass production and has to be removed by screening.

The results of chemical analysis of the fraction 0.1 - 0.8 mm are given in the following table.

Table 9:

sample no. element %	G - 20	G - 21
L.O.I.	0.14	0.29
SiO_2	98.55	98.17
Al_2O_3	0.66	0.75
Fe_2O_3	0.10	0.09
TiO_2	0.12	0.15
CaO	tr.	tr.
MgO	tr.	tr.
Cr_2O_3	0.08	0.05
Na_2O + K_2O	0.24	0.24

Judged by its chemical composition, the sand would be suitable for the production of glass containers.

However, the raw sand requires careful classification and desliming because the fraction 0.8 - 0.1 mm - when used for the production of glass - must not contain any outsize material.

Being about 2 km away from Maradi, the deposit is most advantageously located to a possible production site.

The deposit covers several 100 m along the road Maradi - Zinder (RN 1) and has a width of some 200 - 300 m at identical level. At an estimated average thickness of 1.50 - 2.00 m, reserves of at least 190,000 m^3 of sand exist.

2.1.1.5.1 Sand-gravel pit about 2.8 km east of Maradi south of the road Maradi-Zinder (RN 1) (location 5).

This sand-gravel pit is located within the extension of the deposit described under 2.1.1.4 above, i.e. in eastern direction. Its stratigraphy is analogous to that described under 2.1.1.4: coarser clastic sediments are superimposed by grey to light grey fine sands which - depending on the morphology - vary in thickness between 1 and 4 m. Their lithology corresponds to that of the fine sands described under 2.1.1.1 above. In this area they are penetrated by irregular iron-rich horizons which have a thickness of a few cm.

The underlying, coarse clastic sediments (G22/23) are light-grey to white fine- to coarse-grained sands with 10 - 30 cm thick grey-brown bands of coarse gravel. The sand fraction is made up of water-clear, rounded quartz grains and- subordinately - of white, unrounded kaolinized feldspars. The clay fraction is represented by kaolin.

The exposed thickness equals 4.0 - 6.0 m.

Fig. 4: Detailed photograph of the quartz-feldspar-sand

Because of the feldspar included in the sand-gravel deposit, the samples have also been investigated with a view to recover not only quartz sand but also pure feldspar sand.

To that end, the raw-sand sample was tested chemically, mineralogically and with respect to its grain size distribution. Chemical analyses were carried out also of the single fractions plus 0.8 mm, 0.5 - 0.8 mm, 0.1 - 0.5 mm and minus 0.1 mm.

Subsequently, a quartz/feldspar separation was carried out. On the basis of the results of chemical analyzing it was decided that only the fraction 0.1 - 0.5 mm of an overall feldspar content of 11.5 % should be used for the dressing test. All products were again subjected to chemical-mineralogic testing. Moreover the quantity balance of the flotation laboratory test was determined.

2.1.1.5.2 Results of special testing of samples G-22 and G-23 which have been combined to a collective sample

a) Screen analysis

Table 10:

	+	0.8 mm	31.8 % by weight
0.5	-	0.8	27.2 % by weight
0.1	-	0.5	36.6 % by weight
	-	0.1	4.4 % by weight

b) Chemical analyses

After suitable sample preparation, test specimens were produced by smelting with $Li_2B_4O_7$. The chemical composition of these specimens has afterwards been ascertained with the aid of a computer-controlled X-ray fluorescence facility.

Table 11: Chemical analyses

sample designation / oxide	raw sand 0-X mm %	fraction + 0.8 mm %	fraction 0.5-0.8mm %	fraction 0.1-0.5mm %	fraction -0.1 mm %
SiO_2	92.9	97.1	96.2	90.4	62.7
Al_2O_3	4.16	1.60	2.13	5.61	23.3
Fe_2O_3	0.18	0.09	0.09	0.25	0.79
TiO_2	0.11	0.03	0.04	0.19	0.46
K_2O	1.22	0.46	0.63	1.90	4.77
Na_2O	0.03	0.02	0.03	0.03	0.05
CaO	0.03	0.03	0.03	0.03	0.07
MgO	0.15	0.13	0.15	0.16	0.20
L.O.I.	1.09	0.50	0.61	1.35	7.31

c) Mineralogic analyses

Evaluating the X-ray diffraction pattern with the aid the JCPDS file, yielded the following qualitative mineral constituents:

main constituent	quartz
secondary constituent	potassium feldspar
	kaolinite
traces	sodium feldspar
	mica

In addition, Fe- and Ti minerals exist although these cannot be evidenced by X-ray methods. The mineral analyses were calculated for the various fractions on the basis of the chemical analyses.

Table 12: Mineralogic analyses

sample mineral	raw sand 0-X mm %	fraction + 0.8 mm %	fraction 0.5-0.8mm %	fraction 0.1-0.5mm %	fraction -0.1 mm %
quartz	84.8	94.0	92.0	78.9	45.1
potassium feldspar	7.1	2.7	3.7	11.2	27.5
sodium feldspar	0.3	0.2	0.3	0.3	0.4
total feldspar	7.4	2.9	4.0	11.5	27.9
kaolinite	7.1	2.7	3.5	8.9	45.1
mica	-	-	-	-	1.0
other constituents	0.7	0.4	0.5	0.8	2.8

d) Laboratory flotation

On the basis of the result of chemical-mineralogic analyzing of the various fractions and with a view to the grain size required for the production of glass, only the fraction 0.1 - 0.5 mm of a total feldspar content of 11.5 % by weight has been subjected to flotation for quartz/feldspar separation.

The material was subjected to attrition, desliming, conditioning and then to quartz/feldspar flotation.

d.1) Quantity distribution

After drying of all products, the following quantity distribution resulted:

feed material 0.1 - 0.5 mm	100.0 % by weight
fines after attrition	7.0
feldspar concentrate	11.6
quartz	81.4

The quantity distribution - related to the raw material - is then calculated as follows:

feed material 0.1 - 0.5 mm	36.6 % by weight
fines after attrition	2.6
feldspar concentrate	4.3
quartz	29.7

d.2) Chemical analyses

The analytical values of the feed material were taken from table 11. The feldspar concentrate and the quartz were examined chemically. The fines remaining after attrition and desliming were not analysed.

Table 13: Chemical analyses of the flotation products

sample / oxide	feed 0.1-0.5 mm %	feldspar concentrate %	tailings/quartz %
SiO_2	90.4	68.4	97.6
Al_2O_3	5.61	17.2	0.95
Fe_2O_3	0.25	0.20	0.18
TiO_2	0.19	0.19	0.27
K_2O	1.90	12.2	0.62
Na_2O	0.03	0.26	0.02
CaO	0.03	0.02	0.03
MgO	0.16	0.13	0.03
L.O.I.	1.35	1.16	0.18

d.3) Mineralogical analyses

The mineralogical analyses of the flotation products were calculated on the basis of the diffraction analysis and the values of chemical analyzing:

Table 14:

sample / mineral	feed 0.1-0.5 mm %	feldspar concentrate %	tailings/quartz %
quartz	78.9	16.5	94.8
potassium feldspar	11.2	70.9	3.7
sodium feldspar	0.3	2.2	0.2
total feldspar	11.5	73.1	3.9
kaolinite	8.9	7.9	0.6
mica	-	1.8	-
residual constituents	0.8	0.7	0.7

In summarizing the findings it can be said:

The fraction 0.1 - 0.5 mm required for the production of glass equals 36.6 % by weight of the raw sand. Laboratory flotation yielded 4.3 % by weight of feldspar concentrate - related to the raw material - at a total feldspar content of 73.1 % by weight.

3.9 % by weight of feldspar remained in the quartz tailings (related to the raw material that portion equalled 29.7 % by weight). Taking into account that because of the small quantity available no more than one flotation test could be carried out and that, moreover, the feldspars had been previously subject to heavy kaolinization, the result has to be called satisfactory.

It is known by experience that large-scale processing yields improved results upon two-stage attrition with intermediate desliming and secondary cleaning by way of flotation (feldspar concentrate about 90 % by weight of total feldspar; feldspar contained in the quartz tailings some 2-3 % by weight). It has not been investigated to what extent Fe_2O_3 and TiO_2 can be reduced with the aid of a preceding heavy mineral flotation.

Using the sand occurring in the sand-gravel pits east of Maradi for the production of glass offers two advantages:

1) proximity to Maradi, low transport costs
2) after processing and separation of the raw sand, quartz sand and feldspar of constant and high-grade quality - with respect to grain size and chemical composition- will be available.

The sand-gravel occurrence extends over several km along the road where it is mined for building material in several pits. The width of the valley is some 1 - 2 km. Assuming an average thickness of 5 m, minimum reserves of 2 million m^3 result. It will have to be verified, however, whether the deposit is characterized by uniform mineralogic composition over the entire area.

Judged by their quality and quantity, the following occurrences have to be classified as less promising:

2.1.1.6 Quartzite deposit at the road from Niamey to Say, about 500 m north of the branching to Say (location 6). Reddish, coarse-grained, very hard quartzite is outcropping over an area of about 20 m^2.

Because of the existing overburden, no statements can be made about extension and thickness.

Chemical analyzing yielded the following contents:

SiO_2	Al_2O_3	TiO_2	Fe_2O_3	L.O.I.
98.72 %	0.35 %	0.16 %	0.99 %	0.23 %

The high SiO_2 content of more than 98 % and the Fe_2O_3 content of 0.99 % determined in the sample have the quartzite appear suitable for the production of glass. However additional preliminary tests (core drilling) will have to be carried out for ascertaining the reserves contained in the deposit. Moreover, high mining costs and significant expenses for crushing and grinding will accrue for preparing the raw material for the production of glass containers.

2.1.1.7 Dan Markao area opened up along the road Maradi-Nigeria (RN 9), some 18.5 km south-east of Maradi, (location 7).

Deposit made up of terrace gravel compacted by iron minerals, predominantly consisting of quartz pebbles. This material is unsuitable as glass raw material.

2.1.1.8 Stream bed - about 1 km north-east of Madarounfa along the RN 18 (location 8)

The stream bed which was dry during the investigation is filled with grey-red quartz sand, rich in biotite and of medium grain size. The quartz grains are mainly covered by thin limonite coating which give a reddish colour to the quartz. Feldspar exists at some percent.

Because of the ferriferous constituents - perceivable even macroscopically - comprising limonite and biotite, and in view of the high feldspar content, the sand is not suitable as glass raw material.

2.1.1.9 Sand trench near Dan Kachi, about 11 km east of Maradi at the road Maradi-Zinder (RN 1) (Location 9).

Grey to brown-grey quartz sand of fine to medium grain size was encountered in the trench; it is strongly interspersed by brown, iron-rich schlieren. In view of the impurities which are noticable even macroscopically, the sand is not suitable as glass raw material.

2.1.1.10 Group of hills north of Bazaga, some 15 km west of Birni N'Konni (location 10)

These hills are predominantly made up of red-yellow clay-, silt and fine sandstone of the Continental Terminal.

Apart from red-yellow sediments of higher iron content, 1.0 - 2.0 m thick horizons of light-grey to white clay- and siltstones with small portions of fine sand are intercalated. These are impurified by iron hydroxides occurring on bedding joints and joints.

Because of the very high portion of fines in the sediment and of partial impurities due to iron segregation on bedding joints and joints, this rock is not considered suitable for the production of glass. Furthermore, it is covered by fairly compacted sediments of a thickness of 10 - 15 m.

2.1.1.11 Hills near Mango - 5 km north-east of Birni N'Konni along RN 1 (location 11)

This deposit is analogous to that described under 2.1.1.10) above.

2.1.1.12 Outcrop at the road from Niamey to Dosso (RN 1) some 80 km south-east of Niamey near Kondo (location 12)

This sand deposit is located at the eastern boundary of the Dallol Bosso which is filled with extensive fluviatile, clastic unconsolidated sediments.

A trench brought down to 0.70 m yielded white-brown well assorted fine- to medium-grained quartz sand interspersed by irregular bands of iron hydroxide.

Because of the high portion of ferriferous constituents, this sand is unsuitable as glass raw material.

2.1.1.13 Sand pit - about 7 km west of Dan Kada, near the road from Maradi to Zinder (RN 1) located south of the road (location 13)

A trench of 1.60 m was brought down in the sand pit. The trench profile is made up of light-brown fine grained sand which has been impurified by iron solutions.

In view of the ferriferous constituents, the sand will not be suitable as glass raw material.

2.1.1.14 Sand pit - about 9 km west of Dan Kada, near the road from Maradi to Zinder (RN 1) north of the road (location 14)

A trench of 1.20 m depth was dug in the pit. The trench profile showed a fine-grained quartz sand, strongly interspersed by brown, iron - bearing schlieren. Brown colouring caused by iron becomes more intense with greater depth.

The sand is not suitable for the production of glass because of the high iron content.

2.1.2 Glass sand occurrences investigated in North Nigeria

2.1.2.1 At the road bridge crossing the Kaduna river near Kaduna (location 15)

This occurrence had been inspected earlier, i.e. in the early 50-ties, by the Geological Survey of Nigeria.

This is a subrecent, fluviatile deposit of coarse sand. The Fe_2O_3 content equalling 1.63 % is fairly high.

Since the early 50-ties Kaduna has become much larger and the sand occurrence is, therefore, located in the centre of the city resulting in its having been strongly contaminated.

Because of its location, the relatively high iron content and the contamination mentioned above, this sand occurrence is not considered suitable as raw material for the production of glass.

2.1.2.2 Some 9 km west of the road branching off to Tureta, at the road from Zaria to Sokoto, some 19 km southeast of Sokoto (location 16)

Light grey to medium-brown sandy siltstones belonging to the Upper Cretacious 'Wurno' formation (Coniacian to Santonian) is outcropping up near the road.

Because of the high portion of fines in the sediment (clay and silt), the material is unsuitable as raw material for the production of glass.

2.1.2.3 Some 4 km west of the road branching off to Tureta, at the road from Zaria to Sokoto, approx. 23 km south east of Sokoto (location 17)

Some 500 m south of the road, grey siltstones of the Upper Cretacious 'Gundumi' formation (Turonian) are outcropping at a small hill. Iron-bearing solutions have penetrated into the rock and deposited on bedding joints and joints.

The high iron content and the large portion of fines make the material unsuitable for glass production.

2.1.2.4 North of Nasarawa in the valley of the Sokoto river (location 18)

The recent river sand of the Sokoto River is light-red to brown, poorly assorted coarse sand, rich in feldspar and unsuitable for the production of glass.

2.2 Limestone

The most promising potential for suitable limestone occurrences within the area inspected are the Lower Tertiary carbonatic sediments which extend from Tahoua and Keita in Niger to the south over Malbaza/Niger to Sokoto in Nigeria and further on in south-west direction to Aliero/Nigeria.

Moreover, limestones and marls occur in the sediments of Upper Cretacious age.

2.2.1 Limestone occurrences investigated in Niger

2.2.1.1 Quarries of the lime- and cement plant Malbaza (location 19)

The working level of both quarries consists of light-grey clays to clay marls. These are superimposed by a sequence consisting predominantly of calcareous marls rich in fossils. The fossil shells are limonitized; similarly, iron was noticed as limonite on joints and bedding joints. Moreover, limestones occur by layers most of which, however, have been decomposed into nodules and boulders of 0.2 to 1.5 m in diameter because of heavy karstification within some areas; the voids between the nodules and boulders are filled with clayey material. The thickness of the calcareous sequences varies between 0 and 6.50 m.

Two analyses of limestone nodules originating from the quarry of the limeplant at Malbaza yielded the following results:

Table 15:

element	hard yellow limestone %	soft white-grey limestone %
L.O.I.	28.35	36.74
SiO_2	9.33	5.04
Al_2O_3	2.14	1.10
TiO_2	-	-
Fe_2O_3	1.07	0.70
CaO	56.39	54.95
MgO	3.24	2.07
K_2O + Na_2O	100 ppm	100 ppm

According to information from the cement plant, the raw material reserves within the close vicinity of the plant site equal approx. 3.4 million t of calcareous marl.

It should be noted in this connection that the overburden/limestone ratio may become 1:1.

Fig. 5: Limestone quarry of the
Malbaza cement plant

The analyses reveal that even the limestone concentrated in nodules has too high contents of SiO_2, Al_2O_3 and Fe_2O_3 to be suitable as raw material for the glass production.

2.2.1.2 Quarry Wajee, some 30 km east of Tahoua, 1.5 km north of the road Tahoua-Agadez (RN 25) (location 20)

Long stretched-out hills rise from the lightly undulating terrain north of the road. The top layer of these hills is made up of lightly clayey limestone (G-15 and G-17) which latter has been mined for road construction. On the surface the rock has been decomposed in very hard nodules which latter are characterized by pronounced dissolution phenomena. The flat lying limestone reaches a maximum thickness of 3 m. The average thickness is estimated to equal 2.0 - 2.50 m.

The limestone is underlain by a white, weakly marlaceous, sandy limestone (G 16) which is rich in fossils like that at Malbaza. The basis of the carbonate sequence is again light-grey clays and clay marls.

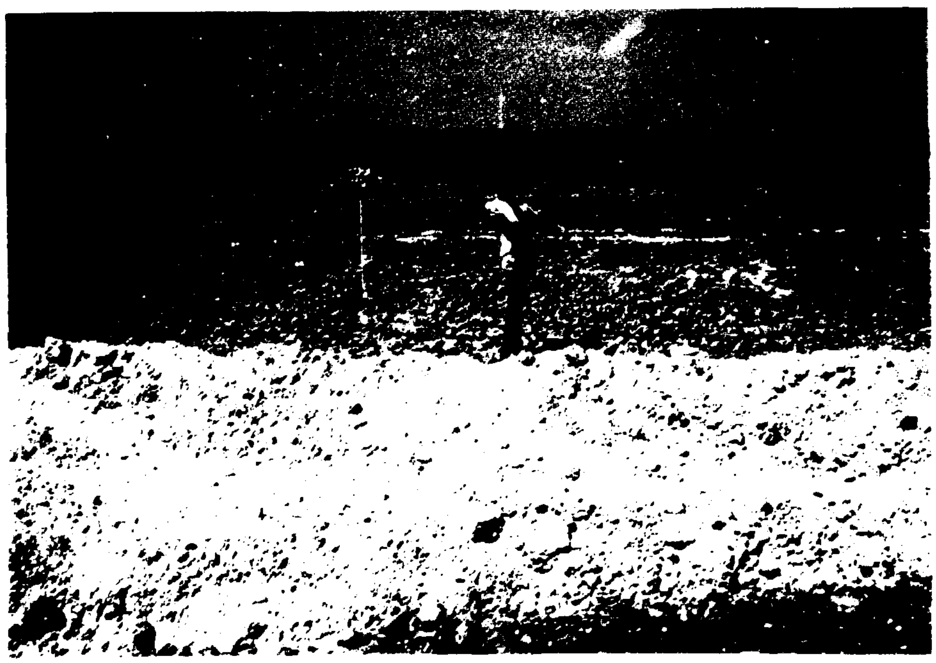

Fig. 6: Limestone area near Wajee

The following table quotes the results of chemically analyzing three samples:

Table 16:

sample no. / element %	limestone G - 15	limestone G - 16	limestone G - 17
L.O.I.	43.58	40.40	43.11
SiO_2	0.28	5.98	0.75
CaO	54.88	48.58	54.03
MgO	0.38	1.81	0.36
Fe_2O_3	0.06	0.59	0.28
Al_2O_3	tr.	1.53	0.48
TiO_2	tr.	0.05	0.04
P_2O_5	0.06	0.31	0.04
SO_3	tr.	tr.	tr.
Na_2O / K_2O	0.24	0.30	0.20

Based on the first chemical analyses of samples G-15 and G-17 resulting in $CaCO_3$ contents of approx. 98.46 % and 97.14 % resp. and in SiO_2 values of 0.28 % and 0.75 % resp., the upper horizon of the limestone appears suitable as additive for the production of glass, whereas the lower, marly horizon features too high clay contents to be suitable for that purpose; these high clay contents are reflected in increased SiO_2 and Al_2O_3 contents.

It is recommended to have the Wajee limestone occurrence checked for constant quality by way of core drillings and additional chemical analyses and, moreover, to determine the limestone reserves more accurately.

The limestone reserves of the upper horizon which can be mined easily are estimated to equal 335,000 t of limestone at a minimum.

2.2.1.3 Quarry nr. Ibesseten, some 2 km south of the road Tahoua-Agadez (RN 25) (location 21)

Hard, grey-white dolomitic limestone of 1.5 - 2.0 m thickness, interspersed by dark schlieren of a few cm length, were mined in the quarry for road construction. According to the geological map, the dolomitic limestone and the underlaying marls and marly limestones are of Upper Cretacious age (Upper to Medium Senonian).

The reserves of the occurrence stretching out south of the quarry are estimated to include at least 330,000 t of dolomitic limestone.

Chemical analyzing of the sample (G-18) yielded the following results:

Table 17

L.O.I.	43.66 %	TiO_2	traces
SiO_2	3.23 %	P_2O_5	0.24 %
CaO	41.33 %	SO_3	traces
MgO	10.26 %	Na_2O + K_2O	0.45 %
Fe_2O_3	0.43 %		
Al_2O_3	0.31 %		

On the condition that the chemical composition remains constant over the deposit, the raw material would be suitable for glass production as substitute of pure dolomite, thus serving as Mg supplying constituent.

It is recommended to have the constancy of chemical composition checked by core drilling and chemical analyzing and to confirm at the same time the adequate raw material reserves.

2.2.2 Occurrences in North Nigeria

2.2.2.1 Quarry of the Cement Company of Northern Nigeria Ltd. at Sokoto (location 22)

The marls and limestones existing at this location are mined as raw materials for the captioned cement plant.

Stratigraphically they occur within the belt of early Tertiary limestones stretching from Tahoua and Keita in Niger southward via Malbaza/Niger to Sokoto/Nigeria and further southwest to Aliero/Nigeria.

The working level of the quarry consists of clays and marls of the Dange formation (Paleocene). They are superimposed by about 1-2 m thick limestones of the Kalambeina formation (Paleocene/Eocene) and by calcareous marls of 3-4 m thickness. These two layers are mined as cement raw material.

The carbonate sequence is superimposed by iron oölites, iron sandstones and laterites reaching thicknesses up to 5 m.

The limestone horizon between the two clayey layers is the aquifer of the area which implies that the limestone has been subjected to heavy karstification. It has been decomposed in nodules and boulders of dm- and m-dimensions. Some of the voids formed by karstification have been filled with clayey material. Due to such karstification, the thickness of the limestone varies from 0.5 to 2.0 m. Analyses of this material provided by the chemist of the cement plant, revealed the following chemical composition:

$CaCO_3$ in the nodules:	+80 %	-90 %
$CaCO_3$ over complete calcareous section:	60 - 80 %	
Fe_2O_3 :	3 - 4 %	
Al_2O_3 :	4 - 5 %	
MgO :	3 %	
SiO_2 :	21 - 22 %	
TiO_2 :	0.2 %	
$Na_2O + K_2O$:	0.6 -0.7 %	
H_2O :	15 - 20 %	

During the rainy season the water content of the limestone may exceed 40 %.

Reserves of 100 million t have been specified to exist within the vicinity of the cement plant. Because of its high SiO_2, Fe_2O_3 and Al_2O_3 contents and insufficient $CaCO_3$ contents, the limestone mined in this quarry is unsuitable as raw material for the production of glass.

Fig. 7: Limestone quarry of the cement plant
Sokoto/Nigeria

2.3 Dolomite

Geology and potential

The maximum potential of dolomite rock within the investigated area is included in weakly metamorphic Precambrian sedimentary sequences in shallow-water facies in which dolomites may be imbedded.

Batches of dolomite of little economic potential can be anticipated to exist in the limy sequences of the Upper Cretacious and of the Paleocene.

2.3.1 Occurrences investigated in the Republic of Niger

The occurrences described below are situated some 220 road-km north-north-west of Niamey; half of that road distance, i.e. up to Tillaberi, has been asphalt paved.

2.3.1.1 North of Ayorou 1.5 km north of the place Kakelia a path marked by stones branches off the RN 1 in north-east direction; it runs to one of the three dolomite deposits existing within this area. The deposit is some 3 - 4 road km away from the RN 1 (location 23).

This is a very fine to medium-grained, very hard, light pink coloured metadolomite or dolomitic marble. It has been silicified and interspersed by numerous, up to 5 mm thick quartz veins which have healed burst joints. In addition to quartz veins, calcite veins occur as

Fig. 8: Metadolomite near Firgoun/Niger

fissure fillings (sample G-5). This dolomitic marble occurs lenslike, obviously concordant in a sequence of black, slightly silty sericitic schists which strike by 130° (northwest-south-east) and which dip at 35° to north east. The sericitic schists are superimposed by a sequence of quartzites characterized by banded structure at the surface.

The dolomitic marble has a thickness of about 5 m within this area. Taking it for granted that the dolomitic marble extends over 15 m at a minimum within the dip, reserves of 3,750 m^3 result for an opened-up length of 50 m. In other words, at a gravity of 2.5 of the material the quantity equals 9,000 t of dolomitic marble.

2.3.1.2 2.0 to 2.5 km west of the deposit described above, another dolomitic marble occurrence is outcropping over a surface of 10 x 10 m (location 24)

This is white-grey to yellow-grey, fine-grained dolomitic marble (sample G-6). No quartz has been noticed as fissure filling.

Dark quartzitic schists and lydites occur as country rocks. The bedding situation is similar to that described under 2.3.1.1) above.

Based on the preconditions assumed for 2.3.1.1 above, reserves of about 1,800 t result.

2.3.1.3 1 km south-west of 2.3.1.2 above (location 25)

At this location a dolomitic occurrence outcrops over an area of 6 x 10 m. Its lithology is identical to that detailed under 2.3.1.2 above.

The reserves within the opened-up area are estimated to amount to 1,100 t of dolomitic marble.

Chemical analyzing yielded the following results:

Table 18

sample no. / element	G - 5 %	G - 6 %
L.O.I.	40.27	40.37
SiO_2	10.30	10.23
CaO	27.25	27.52
MgO	17.23	17.38
Fe_2O_3	0.63	0.66
Al_2O_3	1.50	0.93
TiO_2	0.04	0.02
P_2O_5	0.04	0.02
SO_3	0.10	0.37
$Na_2O + K_2O$	1.12	1.03
MnO	0.62	0.43
Cl	0.10	0.10

The samples taken from two occurrences have almost identical chemical composition. In view of the relatively high Al_2O_3 and SiO_2 contents, however, the quality of the material is such that the dolomite from Ayorou can be used with significant restrictions only as additive for the production of glass containers.

Apart from that, the reserves estimated to equal about 12,000 t for the three deposits altogether are very small at present.

2.3.2 Occurrences in Nigeria (location 26)

Evaluation of the literature available at the Geological Survey of Nigeria (GSN) did not give any hint regarding possible dolomite occurrences within the region of North Nigeria that has been investigated.

GSN Report no. 1191 describes the Burum Dolomitic Marble located within the Plateau State some 30 km north-east of Lafia.

The deposit has been examined by way of drilling. The total reserves are specified to equal 4,850,000 t.

The weighted average contents of $CaCO_3$ and $MgCO_3$ are 36.4 % for $MgCO_3$ and 51.4 % for $CaCO_3$ at minimum values of 33.1 % $MgCO_3$ and 47.9 % $CaCO_3$. The maximum levels are 40.0 % $MgCO_3$ and 54.5 % $CaCO_3$.

A complete chemical analysis yielded the following results:

SiO_2	3.88 %	MnO	0.01 %
Al_2O_3	0.24 %	CaO	31.35 %
Fe_2O_3	0.42 %	MgO	20.52 %
TiO_2	traces	SO_3	nil
P_2O_5	0.03 %	L.O.I.	43.45 %

It can be seen from the above weighted average contents that $MgCO_3$ + $CaCO_3$ vary quite considerably within the Burum Dolomite Marble deposit which fact prejudices suitability of this raw material as additive for glass production.

However, the complete chemical analysis quoted above suggests that there are batches within the Burum dolomite deposit where the raw material fully meets the quality requirements laid down for the production of glass.

2.4 Feldspar

Recoverable feldspar occurrences are assumed to exist in Niger and North Nigeria in pegmatites of the crystalline basement.

2.4.1 Occurrences in the west of the Republic of Niger

2.4.1.1 Basement outcrop, some 11 km south of Tillaberi along the road Niamey-Tillaberi (RN 1), east of the road (location 27)

The basement that is exposed within this area is a coarse- to medium-grained biotite granite penetrated by numerous pegmatite veins which reach maximum thicknesses of 0.25 m. Apart from feldspar, the pegmatites carry 10 - 15 % (estimated value) of quartz and some 3 % of biotite. On joints and crystal surfaces, the rock is seriously impurified by limonite.

Because of the little thickness of the pegmatite veins and in view of the presence of quartz and limonite, this feldspar is unsuitable as glass raw material.

2.4.1.2 Basement outcrop, some 13 km south of Tillaberi, along the road Niamey-Tillaberi (RN 1), east of the road (location 28)

This basement outcrop is made up of granite gneiss penetrated by numerous pegmatite, aplite and dolerite veins. At this location a pegmatite vein made up predominantly of white feldspar reaches a maximum thickness of 0.4 to 0.6 m. Moreover, quartz and mica as well as limonite occur at the vein surface. The pegmatite vein can be followed more than 50 m over the terrain.

This vein contains but small quantities of feldspar which, in addition, can be recovered with difficulty only.

Fig. 9 : Pegmatite vein

2.4.1.3 Basement outcrop in a river bed, some 15 km south of Tillaberi, along the road Niamey-Tillaberi (RN 1), west of the road (location 29)

In this river bed 12 pegmatite veins of thicknesses between 0.5 and 1.5 m crop out. One group of veins runs subparallel to the road (130°) and dips to south west under 40°. It is crossed by a second group which strikes at 70° and displaced the first group 1.0 to 2.0 m.

The principal minerals of the pegmatites are white feldspars some of which have been subjected to kaolinization. In addition, quartz and subordinately biotite occur. The material is interspersed by iron hydroxides at the surface. No representative sample could be taken because of these surface impurities.

Qualitative evaluation of the raw material is detailed under 2.4.1.4 below in view of the petrographic-mineralogic similarity.

As it may be assumed that the pegmatite continues under the sand cover, it can be expected that the feldspar comprises several thousand tonnes.

2.4.1.4 Basement outcrop some 19 km south of Tillaberi, along the road Niamey-Tillaberi (RN 1) (location 30)

This is the continuation of the outcrop described under 2.4.1.3 above, i.e. in southward direction. A pegmatite vein of approx. 2 m thickness has been exposed at this location which - in contrast to that mentioned under 2.4.1.3 above - is relatively free of surface impurities caused by limonite. Otherwise, the mineralogic composition corresponds to that detailed under 2.4.1.3 above.

The chemical analysis resulted in the following values:

Table 19

L.O.I.	0.25 %	TiO_2	traces
SiO_2	68.20 %	P_2O_5	0.02 %
CaO	traces	SO_3	traces
MgO	traces	Na_2O	1.54 %
Fe_2O_3	0.25 %	K_2O	12.13 %
Al_2O_3	16.97 %		

The chemical analysis specified above indicates that the feldspar is suitable as glass raw material.

However, to enable a final assessment, the deposit should be further investigated for verifying its constant quality.

2.4.1.5 Pegmatite occurrence some 10 km north of Tera (location 31)

Two pegmatite veins are outcropping at this point over a width of approx. 10 - 20 m; they are separated by biotite granite which reaches widths between 30 and 50 m. The two pegmatite veins can be followed along their direction of strike of 60^o - 70^o over a distance of about 300 m in the terrain. The pegmatites are made up predominantly of white feldspar. They are rich in quartz and impurified at the surface and on joints by iron hydroxides.

Apart from the above, garnet up to 10 mm diameter and light coloured mica have been observed in samples taken from both veins. The latter might be lepidolite (lithium mica).

The occurrence of Tera is the largest coherent pegmatite deposit which could be located during the prospecting work in Niger. However, the existing surface impurities did not allow sampling with the aid of the appliances available.

Macroscopic examination of the rock justifies the assumption that the feldspar becomes cleaner at greater depth so that it might be suitable as additive for the production of glass containers.

The geological reserves are estimated to amount to a minimum of 50,000 tonnes.

2.5 Soda ash

Neither in the south of the Republic of Niger nor in North Nigeria are indications for economic occurrences of natural soda.

3.1. Specification of the main raw materials required for the production of flat and/or hollow glass, resp.

The qualities given should be reached to the largest possible extent in order to be able to obtain the qualities required for the final product.

In case the raw materials available in the country should not meet the requirements, the suitability of the available raw materials must be determined in particular.

In this connection it must possibly be taken into consideration to carry out a separate raw material preparation or to import any of the raw materials required.

Sand (prepared)

a) Chemical composition, Indicated in wt%

SiO_2 content	>99.5
$Al_2O_3 + TiO_2$	< 0.2
Fe_2O_3	< 0.05 (tot. iron content determined as Fe_2O_3) max. admissible iron content for flat glass.
Fe_2O_3 content	0.5 - 4 wt% for bottle glass, green glass and black glass.
Annealing loss	~0.1
$RO + R_2O$	~0.2

The absolutely obtained percentages conc. the chemical composition must not exceed the following tolerances:

SiO_2 content	±	0.2
$Al_2O_3 + TiO_2$ content	±	0.05
Fe_2O_3 content	+	0.00
	-	0.02

Minerals of any other kind, especially corundum and chromite, must not exceed 0.3 mm in their grain size and 0.2 g in 100 kg of sand in their total weight.

b) Grain Mixture

Size ranges in mm	Wt%
0.63 - 0.5	< 1
0.5 - 0.4	< 10
0.4 - 0.1	88
smaller than 0.1	< 1
water content at the time of supply	< 4

Soda (heavy soda, glass works quality)

a) Chemical composition, Indicated in wt%

Na_2CO_3 content	> 99.6
NaCl content	< 0.3
$NaHCO_3$ content	< 0.01
residue insoluble in water	< 0.05

b) Grain Mixture

Size ranges in mm	Wt%
> 1	4
1 - 0.5	~ 33
0.5 - 0.1	~ 60
< 0.1	3

bulk density 1.1 - 1.3 t/cbm

Sodium Sulphate (coarse)

a) Chemical composition, Indicated in wt%

Na_2SO_4 content	> 99.7
NaCl content	< 0.07
$CaSO_4$ + $MgSO_4$ content	< 0.01
residue insoluble in water	< 0.05

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b) Grain Mixture

Size ranges in mm	Wt%
> 1	< 4
1 - 0.6	~ 10
0.6 - 0.1	~ 75
< 0.1	< 10

Dolomite

a) Chemical composition, Indicated in wt%

$CaCO_3$ content	55
$MgCO_3$ content	44
HCl - insoluble residue	< 0.8
Al_2O_3 content	< 0.3
Fe_2O_3 content	< 0.2

The absolutely obtained percentages of the chemical composition must not exceed the following tolerances:

$MgCO_3$ content	+	0.5
	-	0.7
HCl insoluble residue	+	0.0
	-	0.4
Al_2O_3 residue	+	0.0
	-	0.2
Fe_2O_3 residue	+	0.0
	-	0.1

b) Mineralogical Composition

Quarzite Residue:

The insoluble proportion of grain size < 1 mm, dissolved in HCl, must be < 2 g from 5 kg material.

Chromite- and corundum grain mixtures must be < 0.3 mm.

c) Grain Sizes

Size ranges in mm	Wt%
1 - 0.5	~ 15
0.5 - 0.2	~ 25
0.2	~ 60

water content at the time of supply 1 ± 0.3

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Lime

a) Chemical composition, Indicated in wt%

	Wt%
$CaCO_3$	> 98
Al_2O_3	< 0.15
Fe_2O_3	< 0.1
HCl - insoluble residue	< 1

The absolutely obtained percentages of the chemical composition must not exceed the following tolerances:

$CaCO_3$ content	±	0.5
Al_2O_3 content	±	0.05
Fe_2O_3 content	±	0.05
HCl - insoluble residue	+ / -	0.2 / 0.5

b) Mineralogical Composition

The insoluble proportion of grain size > 1 mm, disolved in HCl, must be < 2 g from 5 kg material.

c) Size ranges

Grain diameters in mm	Wt%
> 1	0.5
1 - 0.5	~ 15
0.5 - 0.2	~ 35
< 0.2	~ 60
water content at the time of supply	0.7 + 0.3 / - 0.2

Feldspar

a) Chemical composition, Indicated in wt%

SiO_2	65
Al_2O_3	18
Fe_2O_3	< 0.3
$Na_2O + K_2O$	10
K_2O	9.5

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The absolutely obtained percentages of the chemical composition must not exceed the following tolerances:

	Wt%
SiO_2 content	± 0.2
Al_2O_3 content	± 0.7
Fe_2O_3 content	+ 0.0 - 0.1
$Na_2O + K_2O$ content	± 1
K_2O content	± 1
chromite and corundum must be	< 0.4 mm

b) Size ranges

Grain diameters in mm

0.5 - o.4	< 0.1
0.4 - 0.3	< 1
0.3 - 0.2	< 3
0.2 - 0.1	<10
0.1	>90
water content at the tima of supply	< 0.5

Coal

a) Chemical composition, Indicated in wt%

ash content	<12

b) Size ranges

Grain diameters in mm

>1	2
1 - 0.6	~ 3
0.6 - 0.1	~75
<0.1	20

3.2 Raw materials for the production of container glass

The most important raw materials for the production of glass containers are:
glass sand, soda ash, lime, dolomite, feldspar and sulfates or salpeter.

The chemical and physical requirements to be met by these raw materials can be taken from the "Specification of the main raw materials required for the production of flat and/or hollow glass resp." referred to under item 3.1 above.

Depending on the glass quality to be produced (flat glass, container glass, glass for domestic use, etc.) the requirements, e.g. as to the iron content, on the raw materials may differ. Apart from that an additive of inferior quality may be used on the condition that such deficiency will be equalized by correspondingly better analytical values of the remaining raw materials. The decisive aspect will always be the overall result, i.e. the chemical composition of the glass melt and the final product respectively. Typical analytical values of glass are given below:

SiO_2	71.9 %
Al_2O_3	1.2 %
CaO	9.8 %
MgO	2.2 %
Na_2O	14.9 %

In the event that raw materials of the composition detailed in the enclosed specifications will be used, it is anticipated that the following quantities will be required for the production of glass containers:

Sand	approx. 56.5 %	approx.	720 kgs/t	of gross glass production
soda ash	17.5 %		210 kgs/t	
lime	14.0 %		172 kgs/t	
feldspar	6.5 %		80 kgs/t	
dolomite	4.5 %		56 kgs/t	
sulfates	0,86%		1o.5 kgs/t	
salpeter	0,14%		1.5 kgs/t	
	100.0 %		1,250.0 kgs/t	

The cullets accumulating during the production have not been considered because these are recycled to the melt.

The report drafted about raw material occurrences in Niger and Nigeria reveals that basically no more than soda ash and other minor components will have to be imported. Several sand occurrences exist. It should be considered whether it will be more economic to have a sand of good quality (deposit near Gazoua) transported over longer distances or whether a sand processing facility should be set up instead. Although the latter will involve increased operating cost (for water, electricity) it offers the opportunity, e.g. for the deposit near Maradi - detailed under 2.1.1.5 above - to recover besides quartz also feldspar.
This feldspar would be accurately defined as regards its chemism and would allow, as mentioned earlier, to use another additive (e.g. dolomite) of a somewhat different analysis.

Other raw materials occurring, such as lime, dolomite, etc., could be made use of as well.

The department of Glass Technology at KHD Humboldt Wedag AG will be readily available to answer any query with respect to the erection of glass works (production, programme, layout, erection, operation, management, etc.)

C-486

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