PISIDA SALT DEPOSIT
LIBYA

by

Gus H. Goudarzi
United States Geological Survey

PISIDA SALT DEPOSIT

LIBYA

by

Gus H. Goudarzi 1918 -

United States Geological Survey [Reports - Open file series]

United States Operations Mission

UNITED KINGDOM OF LIBYA

This report is preliminary and has not been edited for conformity with Geological Survey format and nomenclature

☆ U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171

To accompany
(00) Weld - Int. 2905
290
0.659

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Washington, D. C.

For release August 15, 1962

The Geological Survey is releasing in open files the following reports. Copies are available for consultation in the Geological Survey Library, 1033 GSA Bldg., Washington, D. C.; plus other offices as listed:

1. Geology of the Cortez 2° quadrangle, Utah-Colorado by J. David Vogel. 1 map and explanation. On file in Bldg. 25, Federal Center, Denver, Colo.; 345 Middlefield Rd., Menlo Park, Calif.; 437 Federal Bldg., Salt Lake City, Utah; and 468 New Custom House, Denver, Colo.

2. Pisida salt deposit, Libya, by Gus H. Goudarzi. 27 p., 2 pl., 6 tables.

12570

CONTENTS

	Page
Abstract	1
Introduction	2
Location and extent	2
Nature of the deposit	2
Previous investigations	3
Present field investigation	4
Laboratory experiments	18

TABLES

Table 1.	Chemical analyses of crust	6
2.	Chemical analyses of undercrust	8
3.	Chemical analyses of brine	11
4.	Chemical analyses of Pisida brine and salts precipitated on evaporation of the brine	20
5.	Relation between specific gravity, density and volume of brine at various stages of evaporation	21
6.	Composition of natural brines, from several areas	22

PLATES

Plate I	Map of Pisida salt flats showing locations of sample pits and analyses	In pocket
II	Sketch map - Pisida salt flat showing natural channel at Bu Kammash	Follows page 22

☆ U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171

PISIDA SALT DEPOSIT

LIBYA

by

Gus H. Goudarzi

Abstract

The Pisida salt deposit, located about 165 kilometers west of Tripoli on the Mediterranean coast, covers an area of about 50 square square kilometers in Libya.

Thin layers of salts, less than 50 centimeters thick, are deposited on the surface as a result of the evaporation of the percolating sea water which is brought to the surface by capillary action.

Halite (NaCl) and sylvite (KCl), the least soluble salts, crystallize at the surface, resulting in a relatively high content of magnesium in the residual brine.

The deposits were investigated by collection and analyses of salts and brine samples from 19 test pits and two drill holes. The chemical analyses indicate that small amounts of potassium salts (Average 3.5 percent potassium) occur in the surface evaporites and the brine contains an appreciable amount of magnesium (Average 3 percent magnesium). Cores collected from the two drill holes indicate that the deposits are surficial and no salt stratum occurs at depth.

☆ U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171

Laboratory experiments indicate that fractional crystallization may be applied to recover potassium and magnesium salts from the brines at Pisida.

INTRODUCTION

Location and extent:--The Pisida salt deposit is on the Mediterranean coast in the northwestern part of Libya at about latitude 33°N and longitude 12°E. It lies 165 kilometers west of Tripoli and may be reached by a narrow, hard-surface Coastal Highway. The deposit in Libya is about 5 kilometers wide and slightly more than 15 kilometers long. It parallels the coast westward from the village of Pisida and crosses the Libyan-Tunisian border. A small harbor near Zuara is 43 kilometers east of Pisida.

Nature of the deposit:--The Pisida deposit is a natural salt flat in a depression separated from the Mediterranean sea by a narrow sandy barrier. It is an ephemeral deposit of brine-impregnated salt, formed during the dry season by solar evaporation of sea water percolating through a previous sand barrier. The deposit consists of a surficial crust of fairly pure salt (NaCl), 3 to 10 cm thick, and an undercrust of impure salt as much as 30 cm thick. The undercrust has a high brine content.

☆ U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171

Chemical analyses of the crust show small concentrations of potassium and magnesium chlorides. The cool and humid climate of the area prevents the completion of the ideal cycle of evaporation and thereby restricts the amount of concentration of these salts. Halite (NaCl) and sylvite (KCl) are less soluble than $MgCl_2$ and crystallized to form both the surface and subsurface crusts thereby leaving a residual brine high in $MgCl_2$.

Previous investigations:--The Pisida salt deposit was studied by the Italian chemists in 1929. Under the direction of Dr. Niccoli, extensive experiments were carried out for recovering potassium and magnesium salts from the brine of the Sebcha. A process called the "Niccoli Process" was developed whereby the brine was concentrated by solar evaporation to produce bitterns relatively rich in potassium. These potassium-rich bitterns were further treated in three stages to prepare a commercial-grade product.1/

1/ Torino, "L'Industria Chimica" Notiziario Chimico Industriale" Bulletin No. 6

A United Nations expert, W. H. Campbell, studied the Pisida deposit in 1953. The results of his work are not available.

☆ U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171

Present field investigation:--The Pisida deposit was examined by the author during a low-altitude flight over the area in 1955. Several landings were made and samples were collected from the surface (crust), the subsurface (undercrust), and from an old vat. The samples were analyzed and the results are as follows:

PERCENT (the insoluble components were not determined)

	NaCl	KCl	$MgCl_2$
Crust	56.01	0.21	0.62
Undercrust	3.66	5.49	4.46
Crystals in old vat	94.19	0.33	1.09

The scale of work at the Pisida deposit was augmented in 1956 by the Minerals Investigation program of the Libyan American Reconstruction Commission. Nineteen test pits were dug to the water table, a maximum depth of about 50 centimeters. Samples of the crust, the subsurface or undercrust, and the brine were collected.

The separation of samples of crust from undercrust was commonly difficult. The undercrust in most of the test pits was arbitrarily subdivided into upper samples (A) and lower samples (B) as shown in Plate I and Table 2. The A samples were sandy and contained small amounts of soluble salts. The relatively high calcium and sulfate (SO4) content indicate presence of gypsum. The B samples were essentially crystalline salts with a high moisture content.

☆ U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171

For practical purposes, the crust and the undercrust may be considered as one unit about 30-40 cm thick, which contains most of the sodium and potassium chlorides. Samples were collected from the brines seeping into the pits. These contained considerable amounts of Mg in form of $MgCl_2$. The chemical analyses of each type of samples are shown in tables 1 to 3.

Two diamond-drill holes were drilled to depths of 15.40 and 18.83 meters to explore for salt beds at shallow depths beneath the Sebcha. None were found. (See logs of drill holes on pages 14 to 18.) Plate 1 shows locations of drill holes and of test pits from which samples were obtained.

The concentration of potassium and magnesium chlorides is greatest in the northwestern part of the area (sample localities 5, 8, 9, 10, and 11). Here the KCl content of the crust and undercrust averages about 7 percent as compared with an average of about 5.5 percent at other localities. In the same five holes, the $MgCl_2$ content of the brine ranges from about 11 to 20.5 percent and averages about 14 percent, whereas in other holes it commonly ranges between 5 and 9 percent and averages only about 7 percent. The reason for this local concentration of these two salts is not known.

☆ U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171

TABLE 1

Chemical Analyses of Crust

(in percent)

Locality	Water Sol. Salts	SO_4	Cl	Mg	K	Na	Ca	Insol. Components by difference
1	99.12	1.18	58.51	0.21	2.55	33.50	0.35	3.70
2	99.34	1.06	58.31	0.29	2.82	35.04	0.30	2.18
3	99.03	1.45	57.95	0.23	4.07	34.65	0.47	1.18
4	99.62	1.25	59.14	0.21	2.81	35.15	0.33	1.11
5	99.35	0.94	57.22	0.25	3.20	37.25	0.30	0.84
6	99.75	1.39	58.23	0.22	3.32	34.74	0.47	1.63
7	98.94	2.05	56.46	0.28	4.52	33.75	0.74	2.20
8	99.68	0.89	58.50	0.17	4.83	33.75	0.36	1.50
9	99.30	0.92	58.60	0.24	3.45	35.74	0.28	0.77
10	99.93	1.10	58.23	0.25	3.88	33.52	0.29	2.73
11	99.68	1.04	58.14	0.26	2.46	36.26	0.41	1.43
12	99.65	1.03	58.32	0.24	3.55	36.08	0.26	0.52
13	98.67	1.95	57.26	0.39	4.07	35.73	0.27	0.33
14	98.16	1.19	57.26	0.25	3.33	35.42	0.33	2.22

TABLE 1

(continued)

Locality	Water Sol. Salts	SO_4	Cl	Mg	K	Na	Ca	Insol. Components by difference
15	96.62	1.44	54.75	0.19	4.28	34.76	0.53	4.05
16	61.50	1.56	33.36	0.43	4.74	20.32	0.39	39.20
17	54.85	1.22	30.75	0.36	3.72	18.02	0.20	45.73
18	58.85	1.15	33.24	0.27	3.69	20.10	0.25	41.30
19	13.28	0.71	6.99	0.22	0.32	4.44	0.07	87.25
Average	88.18	1.24	51.12	0.26	3.45	30.96	0.34	12.61

TABLE 2

Chemical Analyses of Undercrust
(in percent)

Locality	Water Sol. Salts	SO	Cl	Mg	K	Na	Ca	Insol. Components by difference
1	99.40	2.41	57.12	0.21	2.58	34.51	0.91	2.26
2	13.79	3.59	4.91	0.62	0.49	2.70	0.78	87.91
3	85.41	4.16	46.43	0.31	2.58	28.25	1.58	16.69
4 A	15.58	3.08	5.85	0.95	0.36	4.06	0.56	85.14
4 B	99.78	2.58	57.69	0.13	3.11	34.33	1.01	1.15
5 A	61.65	4.31	30.75	0.42	3.26	18.68	1.62	40.96
5 B	99.83	1.72	57.79	0.10	5.05	33.91	0.72	0.71
6 A	66.58	4.09	35.28	0.28	3.43	21.19	1.57	34.16
6 B	99.90	0.83	58.42	0.07	3.94	35.62	0.32	0.80
7 A	10.22	2.51	3.01	0.39	0.20	1.31	0.89	91.69
7 B	98.92	1.87	57.14	0.13	2.80	35.07	0.75	2.24
8A	17.27	2.93	6.38	0.62	0.78	4.71	0.93	83.65
8 B	99.90	2.63	57.59	0.15	5.35	33.03	1.03	0.22
9 A	94.41	2.87	53.44	0.18	4.21	32.56	1.12	5.62

TABLE 2

(continued)

Locality	Water Sol. Salts	SO_4	Cl	Mg	K	Na	Ca	Insol. Components by difference
9 B	99.90	2.64	57.79	0.12	5.15	33.54	0.92	0.00
10 A	89.98	4.07	49.37	0.29	3.55	27.53	1.49	13.70
10 B	99.90	2.47	57.79	0.12	3.40	36.53	0.96	0.00
11 A	85.97	4.12	46.36	0.33	3.89	26.46	1.51	17.33
11 B	99.95	1.20	58.86	0.11	3.24	36.86	0.43	0.00
12 A	84.83	4.63	45.74	0.26	3.02	27.90	1.79	16.66
12 B	99.98	1.56	57.97	0.01	3.51	36.68	0.54	0.00
13 A	15.58	3.74	5.41	0.70	1.70	2.87	0.95	84.63
13 B	99.70	2.99	57.36	0.21	2.87	36.45	1.01	0.00
14 A	11.33	2.66	3.55	0.46	0.42	3.32	0.90	88.69
14 B	99.26	0.82	57.62	0.07	3.10	37.30	0.27	0.82
15 A	15.42	1.76	6.65	0.43	1.01	4.67	0.83	84.65
15 B	99.77	2.84	57.59	0.07	3.25	35.38	0.55	0.32

TABLE 2

(continued)

Locality	Water Sol. Salts	SO_4	Cl	Mg	K	Na	Ca	Insol. Components by difference
16 A	20.12	4.58	7.18	0.90	1.64	4.09	1.30	80.31
16 B	99.50	3.58	56.38	0.09	9.13	29.06	1.14	0.62
17 A	15.74	2.77	6.23	0.39	0.94	3.95	0.83	84.89
17 B	99.95	3.50	56.51	0.05	3.81	35.03	1.10	0.00
18 A	12.60	2.66	4.43	0.37	1.02	3.31	0.80	87.41
18 B	93.00	1.48	52.48	0.13	5.39	32.35	0.71	7.46
19 A	16.01	2.43	7.06	0.39	0.36	4.69	0.68	84.39
Average A Samples	39.58	3.33	19.79	0.46	1.86	11.96	1.11	61.49
Average B Samples	99.28	2.18	57.26	0.10	4.21	34.74	0.77	0.96 *
Total Average	68.27	2.80	37.76	0.29	2.89	22.88	0.95	32.55

* (0.96) because of several sums of minus numbers this sum will not have any value.

TABLE 3

Chemical Analyses of Brine

(in percent)

Locality	Dissolved solids	SO_4	Cl	Mg	K	Na	Ca	Undetermined by difference
1	-	-	-	-	-	-	--	-
2	40.03	2.75	19.27	2.27	0.57	8.37	0.02	6.78
3	39.03	2.39	18.65	2.16	0.57	9.15	0.04	6.07
4	38.47	2.69	18.75	1.59	0.40	10.35	0.04	4.65
5	38.89	2.63	18.82	5.21	0.66	8.55	0.04	2.98
6	39.33	2.78	18.92	2.17	0.53	8.69	0.03	6.21
7	39.50	2.14	17.94	2.23	0.61	9.11	0.03	7.44
8	43.10	2.64	18.95	2.87	0.74	8.58	0.02	9.30
9	41.60	3.88	19.20	4.24	0.91	6.21	0.02	7.14
10	42.25	2.89	19.00	2.80	0.68	8.60	0.02	8.26
11	43.06	4.06	18.87	3.03	0.74	7.19	0.02	9.15
12	44.77	2.72	18.85	2.11	0.54	9.06	0.02	11.47
13	44.36	2.76	19.25	1.95	0.51	9.06	0.03	10.80
14	43.23	2.39	19.00	2.00	0.45	10.00	0.03	9.36

TABLE 3

(continued)

Locality	Dissolved solids	SO_4	Cl	Mg	K	Na	Ca	Undetermined by difference
15	39.44	2.23	19.07	1.80	0.45	9.20	0.04	6.65
16	40.98	2.29	19.05	1.76	0.36	7.54	0.04	9.94
17	36.95	1.28	18.96	0.68	0.10	4.16	0.02	11.75
18	35.43	1.39	13.55	1.31	0.25	11.45	0.06	7.42
19	43.60	1.51	15.72	1.66	0.18	10.12	0.05	14.36
Average	40.77	2.52	18.43	2.32	0.51	8.63	0.03	8.32

The undetermined components are essentially the moisture not driven off by evaporation and the water absorbed after drying; may include some water of hydration.

DIAMOND-DRILL HOLE No. 1

From (m)	To (m)	Thickness (m)	Description
0.00	0.74	0.74	Quartz sand, light to medium-brown, fine-grained; mostly angular calcareous shell fragments.
0.74	0.96	0.22	Quartz sand, light-brown, fine-grained; abundant shell fragments.
0.96	2.85	1.89	Quartz sand, white, milky appearance, fine-grained, rounded; abundant shell fragments.
2.85	4.75	1.90	Quartz sand, white, very fine-grained, rounded; abundant shell fragments.
4.75	9.50	4.75	Quartz sand, white to very light-brown, very fine-grained; varying amounts of shell fragments.
9.50	10.85	1.35	Quartz sand, light to dark-brown, fine-grained; abundant shell fragments.

DIAMOND-DRILL HOLE No. 1
(Continued)

From (m)	To (m)	Thickness (m)	Description
10.85	13.11	2.26	Quartz sand, reddish to dark-brown, sparse shell fragments.
13.11	13.71	0.60	Quartz sand light-gray, fine-grained; shell fragments.
13.71	14.24	0.53	Quartz sand, light to medium-brown, fine-grained.
14.24	15.40	1.16	Quartz sand, light to medium-brown, fine-grained.

DIAMOND-DRILL HOLE No. 2

From (m)	To (m)	Thickness (m)	Description
0.00	0.60	0.60	Quartz sand, reddish-brown, fine-grained, rounded, loosely cemented. Some larger round calcareous particles.
0.60	1.68	1.08	Quartz sand, light-brown, coarse to medium-grained, well cemented; contains shell fragments.
1.68	2.88	1.20	Quartz sand, poorly cemented, white, abundant shell fragments, fine-grained, angular to rounded.
2.88	4.33	1.45	Quartz sand, very light-brown, rounded to angular grains, sparse shell fragments; very poorly cemented.
4.33	4.86	0.53	Quartz sand, white, coarse-grained; abundant rounded shell fragments and calcareous oolites; fairly well cemented.

DIAMOND-DRILL HOLE No. 2
(Continued)

From (m)	To (m)	Thickness (m)	Description
4.86	6.04	1.18	Quartz sand, white, fine to medium-grained; abundant shell fragments; well cemented.
6.04	6.55	0.51	Quartz sand, white, coarse-grained, rounded; abundant shell fragments; well cemented.
6.55	7.40	0.85	Quartz sand, yellowish-brown, coarse-grained; very poorly cemented; some macrofossils.
7.40	10.09	2.69	Calcarenite, white, very fine-grained; abundant fine-grained quartz, macrofossils.
10.09	10.33	0.24	Quartz sand, white, coarse-grained, rounded; abundant shell fragments; well cemented.
10.33	11.48	1.15	Quartz sand, light-gray, fine-grained; macrofossils.
11.48	12.33	0.75	Quartz sand, light-brown, fine-grained.

DIAMOND-DRILL HOLE No. 2
(Continued)

From (m)	To (m)	Thickness (m)	Description
12.23	14.13	1.90	Quartz sand, light-brown fine-grained, argillaceous.
14.13	16.13	2.00	Quartz sand, light-gray, fine-grained, calcareous; macrofossils. Base coarser and well cemented.
16.13	18.33	2.20	Quartz sand, reddish-brown, medium to coarse-grained, sub-angular to rounded grains; sparse shell fragments.

Laboratory Experiments:--Experiments in fractional crystallization of the Pisida brine were carried out at the Chemical Laboratory of Sidi Mesri. The main purpose of the experiments was to determine whether the Niccoli process could be used to recover potassium and magnesium salt.

One thousand liters of the brine was used in the experiment. The original brine had a specific gravity of 24^0 to 25^0Baume' at 30^0C, and a chemical composition as follow:

Chemical analysis of brine
(in percent)

Sodium (Na)	10.718
Potassium (K)	0.348
Magnesium (Mg)	1.276
Calcium (Ca)	0.044
Chloride (Cl)	18.67
SO_4	2.570
HCO_3	0.023

The brine of 24°Baume' was allowed to evaporate under normal temperature conditions in the laboratory. Halite started to form at 25°Baume' and after two months practically all of it had crystallized out by the time the brine reached 34°Baume'.

The salts precipitated were collected and analyzed, and a residual 123 liters of brine was allowed to evaporate, reaching 35°Baume' within 2 weeks. Further evaporation for another 15 days raised the specific gravity to 36°Baume'.

The composition of the original solution at 24°Baume' and the composition of solids precipitated at various stages of evaporation are given in table 4.

TABLE 4

Chemical analyses of Pisida brine and salts
Precipitated on evaporation of the brine

(Percent)

Degrees Baume'	Na	K	Mg	Cl	SO_4	Temp. in ^{o}C	SP. GR.	Remarks
24	10.72	0.35	1.28	18.76	2.57	30^{o}	1.2	Brine
25 *	36.78	0.17	0.47	57.94		30^{o}	1.32	Salt crystals
34 *	32.62	0.36	2.14	55.84		30^{o}		"
35 *	16.88	0.79	8.58	32.06	22.08	30^{o}		"
36 *	13.62	5.27	8.50	36.21	20.43		1.33	"
37 *	8.37	4.05	10.03	35.95	10.65	30^{o}	1.34	"
37 *	1.38	1.18	12.36	31.48	9.40	10^{o}-12^{o} C		"

* Precipitated salt crystals were dried at $105^{o}C$ before analysis

By allowing the concentrated solutions to stand at cool winter temperatures of $10^{o}C$ to $12^{o}C$, a mixture of magnesium chloride and magnesium sulphate crystallized out along with minor amounts of sodium and potassium chlorides. Table 5 shows relation between specific gravity, density and volume of brine at various stages of evaporation.

TABLE 5

Specific Gravity	Density	Volume of Brine
24^{o}Baume'	1.20	1000 liters
35^{o}Baume'	1.318	123 liters
36^{o}-37^{o}Baume'	1.33-1.34	65 liters

Field studies and the results of the experiments indicate that a modified "Niccoli process" or a fractional crystallization method may be used to extract crude potassium and magnesium salts from the Pisida brines. Limited laboratory facilities for this type of evaporation study prevented further work. Consequently additional laboratory experiments and field studies are needed to determine the practical and economic feasibility of such an undertaking on a commercial basis at Pisida.

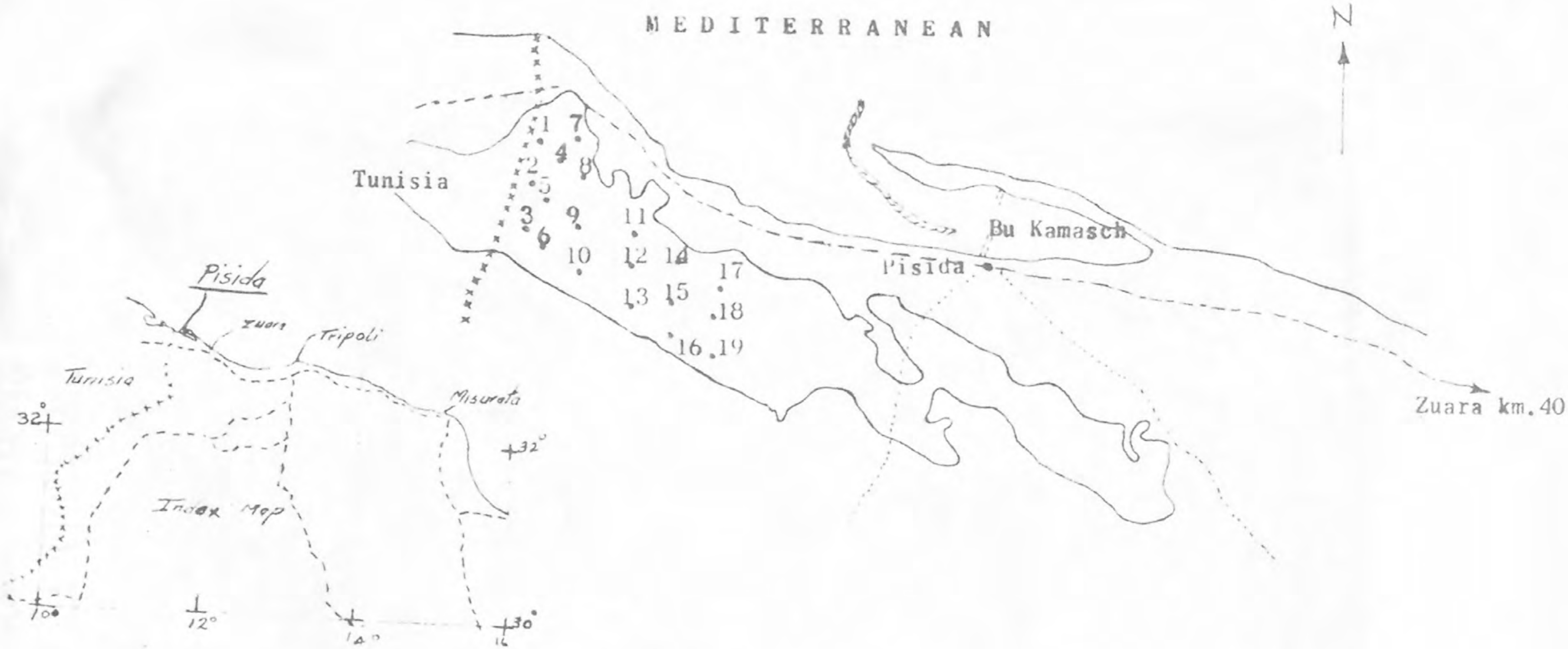
By comparison with some of the well-known salts areas of other countries, brines at Pisida are relatively rich in NaCl but are low in KCl and $MgCl_2$. The following table illustrates these differences.

Composition of natural brines from several areas

(grams per liter)

Location	Density	Degrees Baume'	KCl	NaCl	$MgCl_2$	$MgSO_4$
*1) Dead sea brine- south plant operation files.	1.20	23.75	11.5	85.0	138.0	
*2) Tunisia-Sebcha el Melah Aioun. No. 3 Sorepta average.	1.24	28.1	15.0	110.0	179.1	34.0
*3) United States-California salt (Bitterns).	1.24	28.0	17.2	197.0	74.0	52.0
4) Libya-Pisida brines	1.20	24.0	6.6	272.0	50.0	

* A Report on factors related to potash development in Tunisia - 1957-8
J. H. Heginbotham P-10.



EXPLANATION

Natural Channel

Road

Track

Sample Pits

International Boundary

PISIDA SALT FLAT

Diagramatic Sketch

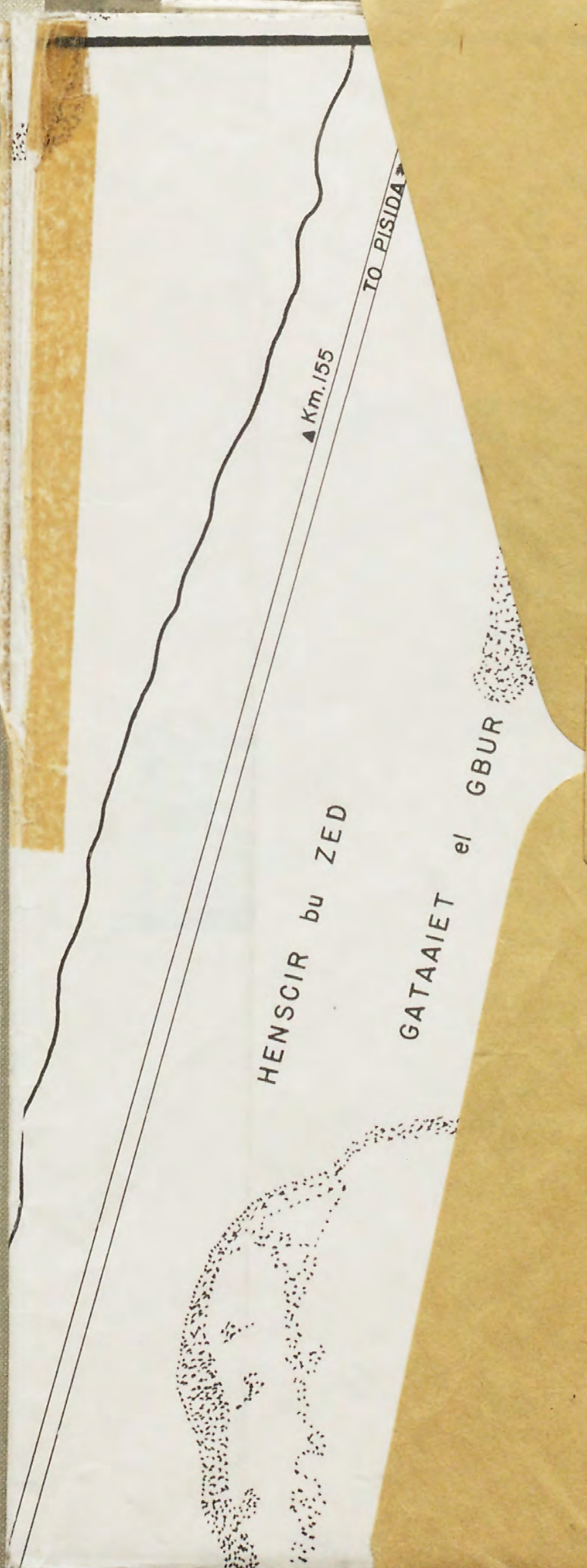
Scale 1:250,000 (Approx.)

PLATE III

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

This map is preliminary and has not been edited for conformity with Geological Survey format


TO PISIDA
Km.155
HENSCIR bu ZED
GATAAIET el GBUR