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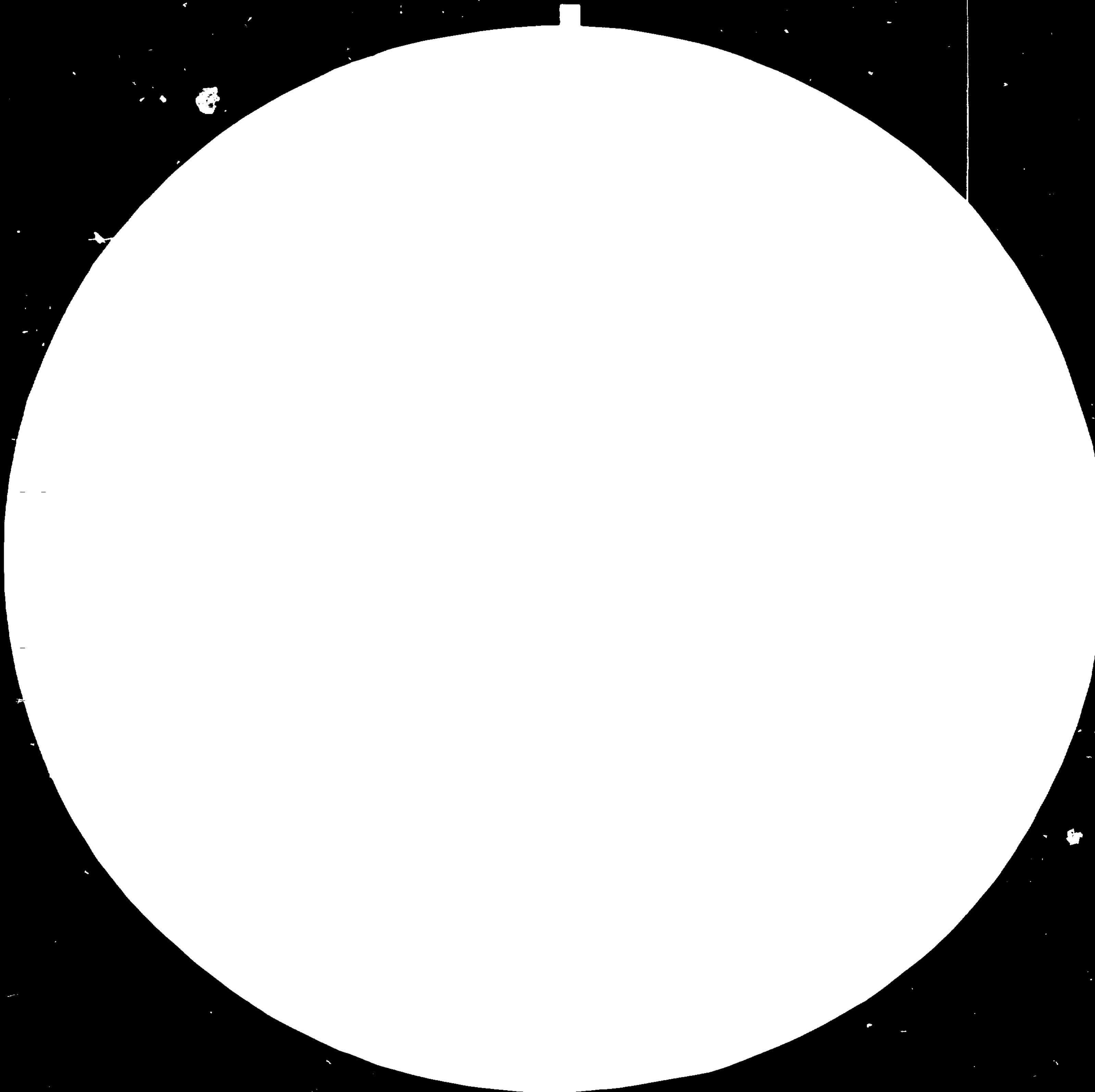

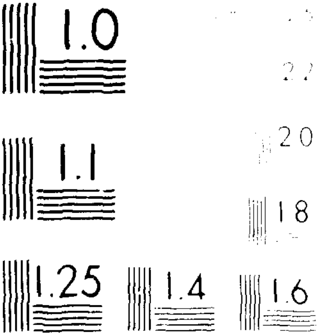
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ENGLISH

ASSISTANCE TO THE LIBYAN CEMENT FACTORY, BENGHAZI

TF/LIB/75/002
LIBYAN ARAB JAMAHIRIYA

Libya. New gypsum deposits

Prepared for the authorities of the Libyan Arab Jamahiriya
by the United Nations Industrial Development Organization

Based on the work of A.R. Marei, project co-ordinator

V. 82-24050

Explanatory notes

References to dollars ($) are to United States dollars, unless otherwise stated.

The monetary unit in the Libyan Arab Jamahiriya is the Libyan dinar (LD). During the period covered by the report, the value of the Libyan dinar in relation to the United States dollar was $US 1 = LD 0.296.

Reference to "tons" (t) are to metric tons.

The following forms have been used in tables:

A dash (-) indicates that the amount is nil or neligible

A blank indicates that the item is not applicable

Besides the common abbreviations, symbols and terms, the following have been used in this report:

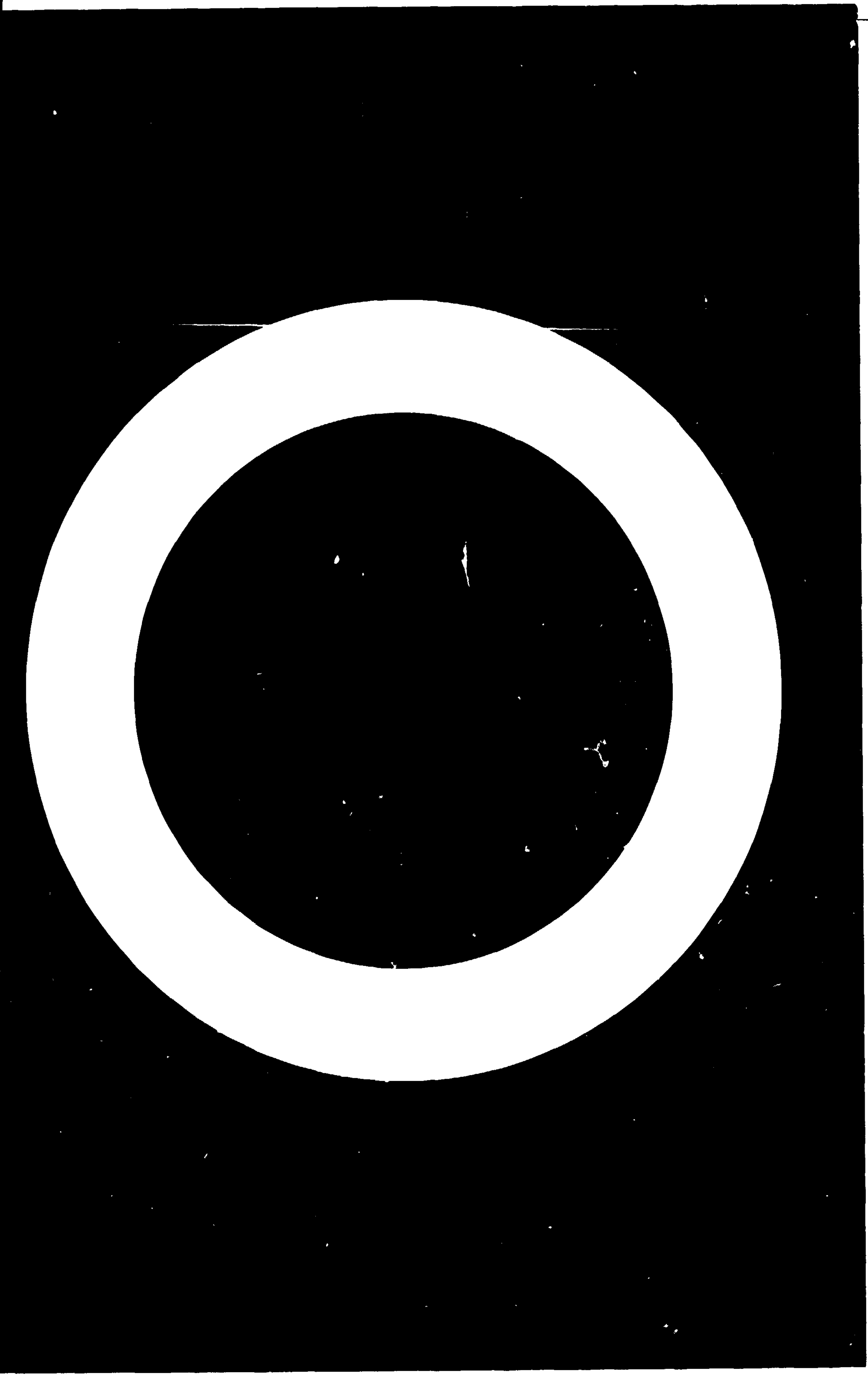
ASTM	American Society for Testing and Materials
LCC	Libyan Cement Company
LOI	loss on ignition

ABSTRACT

This project, "Assistance to the Libyan Cement Factory, Benghazi" (TF/LIB/75/002), is being carried out for the authorities of the Libyan Arab Jamahiriya by the United Nations Industrial Development Organization under a trust-fund agreement. The project is designed to give direct assistance to the cement industry. It was approved in 1975 and has been operating in the field since 1976.

The expert became co-ordinator of project activities in May 1980, monitoring the work of the technical-assistance team assigned to the Hawari Cement Plant, advising on technical problems arising in Libyan Cement Company (LCC) plants and acting as a consultant to the Libyan cement industry generally.

This report deals with the problem of assuring an adequate supply of gypsum for the cement industry. Two reports on gypsum deposits, in the As-Sidrah region and in the area near Benghazi, had been carried out by the Industrial Research Centre's Geological Research and Mining Department. These reports are summarized with the expert's comments and an economic evaluation of the cost of exploiting the As-Sidrah deposit. The expert also visited the new areas in the Benghazi region where gypsum has been found and gives his recommendations for their development.



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INTRODUCTION

This project, "Assistance to the Libyan Cement Factory, Benghazi" (TF/LIB/75/002), is being carried out for the authorities of the Libyan Arab Jamahiriya by the United Nations Industrial Development Organization (UNIDO) under a trust-fund agreement. This project, which was approved in 1975 and has been operating in the field since 1976, is designed to give direct assistance to the cement industry.

Industrial development in cement began in the Libyan Arab Jamahiriya, at Benghazi in 1972, with the start of the first rotary kiln with an annual production capacity of 200,000 tons. After rapid growth, the annual capacity reached 2 million tons of normal portland cement.

Industrial growth and the increasing need for trained staff made it necessary to request technical assistance and to initiate training for national personnel. The UNIDO project began in November 1976 with a building-materials adviser and by March 1981 had grown to include 73 experts covering various industrial activities in the field of cement and the building-materials industry under the control of the Libyan Cement Company, Benghazi. It is planned to expand this number to 100 experts with diversified specializations.

This report is based on the work of the expert who was appointed co-ordinator of the project on 10 May 1980 for an initial period of 18 months. His duties are to follow up and monitor the work of specialists assigned to the building-materials industry complex in Benghazi and also to act as technical adviser on the various problems arising in the Libyan Cement Company plants, Benghazi and Hawari, and as a consultant on developments in the Libyan cement industry generally.

Project background

One of the most important problems facing the Benghazi cement industry in the near future is the inadequate reserves of gypsum ore. The Libyan Cement Company (LCC) with its two cement plants with an annual production capacity of two million tons of normal cement gets its requirements of raw gypsum from the nearby gypsum quarries at Ar-Rajmah and Hawa Al Baraq.

These two areas have been prospected by the Czechoslovak firm, Geoindustria-Strojexport, in 1970 and by the Swedish technical consultants, AB Uniconsult, in 1974. Prospecting was carried out at four gypsiferous areas, Ar-Rajmah, Hawa Al Baraq, Al Gharah, and the Ar-Rajmah-Bu Barian field.

In these areas, gypsum deposits of high quality were discovered. The maximum thickness of the gypsum strata is 17 metres and the average thickness in the largest deposit at Hawa Al Baraq is 12.63 metres. The gypsum deposits are found in the form of lenticular bodies of different sizes. The gypsum deposit at Al Gharah was not recommended for exploitation as it is relatively thin with a high overburden in proportion to the amount of gypsum. Generally, the gypsum deposits belong to the Miocene formation.

The estimated reserves of gypsum in the Ar-Rajmah and Hawa Al Baraq quarry areas are 891,000 tons. As the estimated gypsum consumption is expected to reach approximately 120,000 tons annually, this means that the known gypsum reserves in these localities will be exhausted within the next few years. Therefore, the LCC will be faced with the problem of gypsum-ore supplies in the near future. The problem will exist not only for the LCC but also for the new Fatayeh Cement Project at Derna which has an annual production capacity of one million tons of normal cement. This project possesses no sufficient gypsum-ore reserves of its own. The prospecting carried out by Uniconsult in an area near the village of Al Himadah (about 25 kilometres west of Al Marj) showed that, of eight localities, only two had gypsum bodies which might possibly be worth exploiting.

It is estimated that the Hawa Al Baraq gypsum reserves would serve LCC cement production for about five years but that, if the cement production at Derna is taken into account, the reserves will only last for three and a half years.

As the Industrial Research Centre was aware of this gypsum-deficiency problem, it directed its Geological Research and Mining Department to start a reconnaissance study during 1975 on the gypsum reserves at Scellidima scarp, Ajdabiyah and As-Sidrah. As a result of the reconnaissance, it was recommended that more investigation should be carried out in the As-Sidrah area. A preliminary investigation for gypsum was carried out in 1976 between Ben Jawad and Ras Lanuf. A comprehensive study on the As-Sidrah area was carried out in the field season 5 August 1976 to 21 January 1977. A detailed report was submitted in June 1977.

The Industrial Research Centre has also carried out further gypsum investigations in the Benghazi and Derna areas, a report on which was sent to the expert in March 1980.

These two reports are summarized in chapters I and II.

Project activities

The expert was aware from the beginning of his mission of the serious problems caused to both cement companies by the lack of assured supplies of gypsum. Discussions with A. Fathi, the Works Manager, revealed the existence of the report on the As-Sidrah deposits situated some 370 kilometres west of Benghazi and 700 kilometres west of Derna. The expert studied this report and discussed his recommendations with the General Director, A.M. El Gheriani. A letter was sent to the Industrial Research Centre to try and arrange a visit to the As-Sidrah site.

In the meanwhile, the expert visited the quarries at Ar-Rajmah and Hawa Al Baraq and reported to the LCC the suspected presence of more gypsum reserves in the nearby areas which would require further investigation to establish. All this was discussed with A. Fathi and it was agreed that the expert should be provided with a car to facilitate further investigations.

Initially, the Industrial Research Centre reports on further gyspum deposits in the Benghazi and Derna areas were not available but in March 1980, after the Centre received the LCC's letter proposing a visit to the As-Sidrah site, they made these preliminary reports available to the expert. These confirmed that the gypsum deposits at Ar-Rajmah and Hawa Al Baraq extend in the area to the north and that a new gypsum deposit had been discovered in the Sidi Al Mabruk area. After receiving the report, the expert, together with A. Fathi, K. El-Ebeidi and B. Yousheh, a member of the Department of Geological Research and Mining, visited the Sidi Al Mabruk area where a trench in the site showed the presence of a crystalline gypsum deposit covered by only two metres of overburden.

Up to the time of writing, there had not yet been an opportunity to visit the As-Sidrah site. However, the expert made a study of the economic feasibility of exploiting this deposit and proposes to submit a technical report after visiting the site.

The expert's conclusions and recommendations as a result of studying the various reports and visiting the nearer sites are given in the following section.

CONCLUSIONS AND RECOMMENDATIONS

In the search for additional gypsum resources to serve the cement production of both the Libyan Cement Company in the Benghazi area and the Fatayeh Cement Company at Derna, no gypsiferous strata were found in the Derna area except for minor lenses in the clays at the bottom of the Al Fa'idiyah formation. Gypsum deposits were found in three areas. The conclusions of the studies of these areas are given, followed by numbered recommendations.

Sidi Al Mabruk area

Preliminary calculations of the probable gypsum reserves in this area give a figure of 3.5 million tons. The average thickness of the gypsum strata is from 7.75-17.30 metres. The ore is of high quality and the SO_3 content is between 39 and 45.75%.

1. The probable reserves in this area should be established more certainly by drilling additional boreholes. The overburden-to-deposit ratio should also be calculated.

2. Before this can happen, contact must be made with the relevant authorities as the area is cultivated land (first farm of the Al-Fateh project).

Hawa Al Baraq area

The preliminary survey confirmed that the gypsum deposits extend some kilometres to the north of the present gypsum quarry at Hawa Al Baraq. Additional gypsum reserves of 34,949 tons have been proved while a further reserve of 76,048 tons is probable. In the expert's opinion, the surrounding areas may contain yet more gypsum deposits.

3. The areas surrounding Hawa Al Baraq should be thoroughly investigated either by the Industrial Research Centre or using an LCC drilling machine under the expert's supervision, in order to confirm the extent of the probable reserves and to establish whether or not further gypsum deposits exist in the area.

As-Sidrah area

In this area, about 370 kilometres to the west of Benghazi, a huge deposit of high-quality gypsum ore has been discovered. The gypsum reserves are estimated to be around 23 million tons.

An economic evaluation carried out by the expert shows that the exploitation of this deposit would result in the following costs to each of the cement companies:

	(Libyan dinars)	
	LCC	Derna
Cost of investment	1,574,215	1,027,018
Annual running costs	511,997	341,019
Cost per ton of gypsum	7.314	9.743

4. As the exact extent of the gypsum reserves in the Benghazi area is not yet known and it is uncertain how many years the reserves will last, it is recommended that exploitation of the As-Sidrah gypsum should begin as soon as possible and that the nearer gypsum reserves in the Benghazi area should be kept as a safeguard against future contingencies.

5. The main item of cost in exploiting this deposit would be the transportation of the ore over very great distances and the large fleet of trucks this would require. As the As-Sidrah deposit lies not far from the coast and there is a nearby harbour, it is recommended that the gypsum ore should be transported to Benghazi and Derna by ship thus reducing the cost to both cement companies.

6. It is recommended that the relevant authorities should be contacted as soon as possible to arrange a visit to the site for a selected group from the LCC to investigate in detail the feasibility of exploiting the gypsum there. It is possible that the gypsum can be used not only for cement production but also for production of plaster of paris, agricultural fertilizer etc.

7. Action should be taken immediately by the authorities to reserve this area for development.

I. GYPSUM DEPOSITS IN THE BENGHAZI AND DERNA AREAS

A. Summary of the Industrial Research Centre's preliminary report

Geological setting

The gypsum-bearing stratum, locally exposed at Hawa Al Baraq and in the Sidi Al Mabruk area, is considered to be the upper part of the Wadi Al Qattarah member of the Middle-Miocene Ar-Rajmah formation. The gyspum deposit occurs as small lenses within the chalky chert and cavernous limestone. The area under study is mostly covered by reddish-brown loam and in places by a duricrust of Quaternary age which make it difficult to observe. In the Sidi Al Mabruk area (see figure I), areal photographs show a fault running NNW-SSE. The other fault shown on the map was deduced from the data obtained from borehole No. 8. This suggests that the new occurence at Sidi Al Mabruk is enclosed between two faults which probably join to the south. This area is a graben fault. At the upthrow sides, the gypsum is nearly completely eroded. Along the new asphalt road going from Hawa Al Baraq to the Sidi Al Mabruk tomb, a few gypsum boulders are present, perhaps from the basal part of the gypsum deposit.

Areas investigated

It is already known from previous geological work carried out in the Benghazi and Derna areas, that gypsum outcrops are limited to some few localities at Ar-Rajmah, Al-Gharah and Hawa Al Baraq.

In the Derna area, no gypsiferous strata have been found except for minor gypsum lenses and intercalations within the Um Ar Razam clays at the bottom of the Al Fa'idiyah formation. During the course of this investigation, the following areas were checked:

(a) Ghot Al Sidr, about 7 kilometres from Al Abiar towards Hawa Al Baraq. The gypsum is exposed on the surface for a few metres along the new asphalt road and no lateral extension was found in its surroundings. The area is covered by bushes;

(b) South-east of Wadi Al Qattarah dam, about 1.7 kilometres along the new asphalt road to Shakhnab. At that locality, the upper surface of the gypsum lens was seen in a small abandoned quarry through a crack two metres deep. This gypsum is overlain by a chert layer a few centimetres thick. Borehole No. 6 was drilled near to that exposure but had no gypsum in it;

(c) South-east of Wadi Al Gattarah dam, about 4.2 kilometres along the new asphalt road. At that locality, the gypsum lens is exposed in a small limestone quarry. Borehole No. 7 was drilled at that place but no gypsum was found;

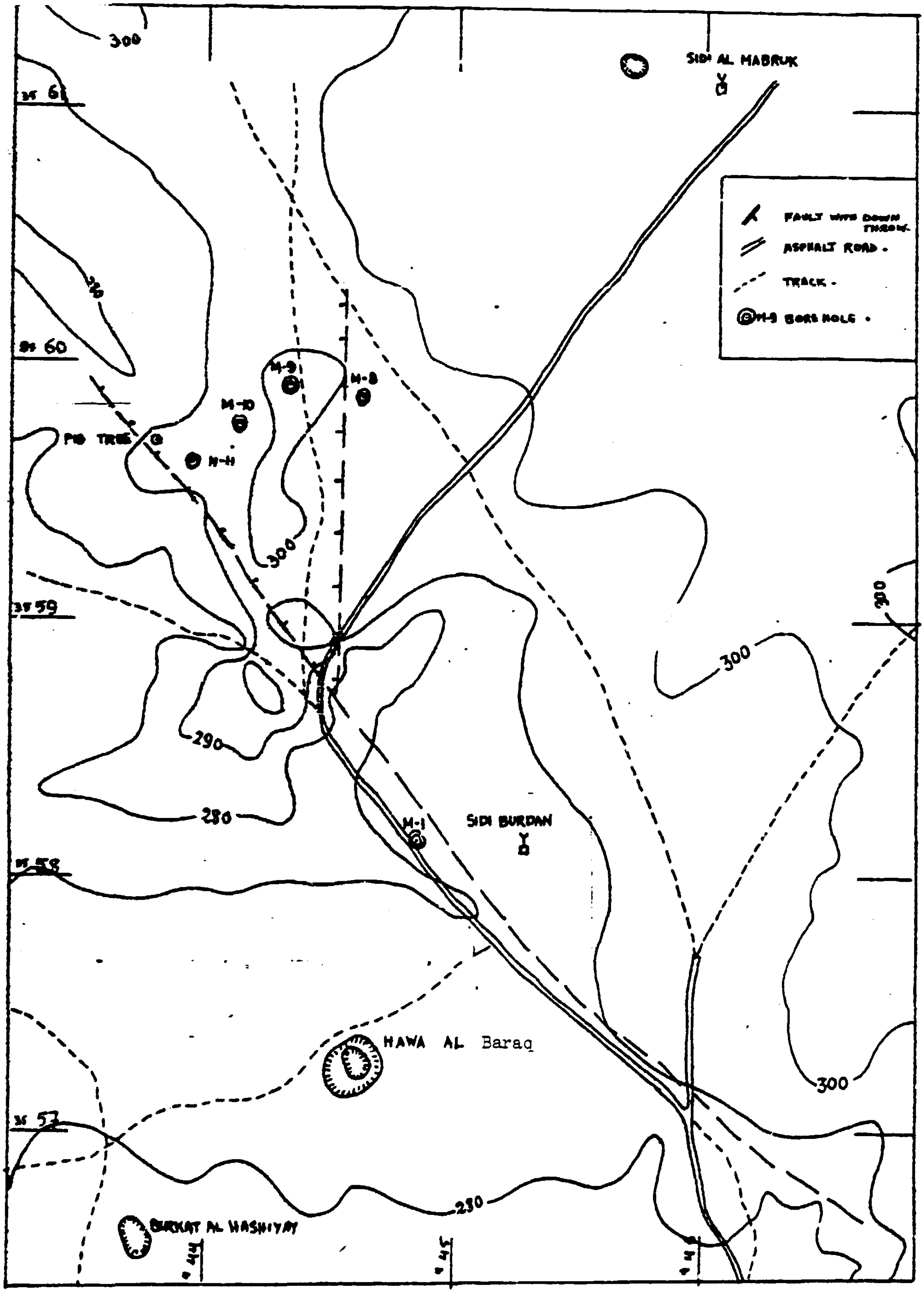


Figure I. Topography of the Sidi Al Mabruk area
(showing boreholes where gypsum was found)

(d) Al Himadah locality (sheet 3489 IV), along the road to Wadi Zazah. The Wadi Qattarah member is exposed with a few gypsum boulders where the new road has been cut and also a cave cut near here shows gypsum. Following this gypsum occurance, no other outcrops were discovered, though it may be covered by loam and duricrust;

(e) Um Ar Razam area, south east of Derna town. Although this was known to be devoid of any interesting gypsum deposits, it was checked and the results showed the existence of some gypsum crystals within the Um Ar Razam clays at the bottom of the Fa'idiyah formation of Lower Miocene age, but these proved to be of no economic value.

Chemical analysis of samples from the Benghazi area

A complete chemical analysis of each segment sampled was carried out in the Industrial Research Centre laboratories, according to the ASTM standards. The result of the chemical analysis is given for each borehole where gypsum was found in the Hawa Al Baraq and Sidi Al Mabruk areas. Tables 1 and 2 show the results for these areas respectively.

Mineral evaluation

The results of the mineral analysis of the gypsum deposits in each borehole are shown in table 3.

Calculation of gypsum reserves

Sidi Al Mabruk area. In this locality, three boreholes were drilled which reached the gypsum body, BH 9, BH 10 and BH 11. The three holes run in a straight line in a NE-SW direction and are about 250 metres apart. According to the chemical and mineral analysis, the gypsum deposits show negligible variations. The thickness in BH 9 is 17.3 metres due to the development of an upper gypsum layer which is eroded in the other two boreholes. Assuming a regular gypsum continuity between the three boreholes, each borehole will have an area of influence equal to r^2 where $r = 125$ metres, which is half the distance between two successive boreholes. Thus the area for each borehole will be $3.14 \times 125^2 = 49,062$ square metres.

Table 4 calculates the amount of gypsum reserves, assuming a specific gravity (stoichiometric) of 2.14. The total amount comes to 3,496,222 tons of probable gypsum reserve. The approximate location of the boreholes with their area of influence is shown in figure I.

Table 1. Chemical analysis of gypsum deposits near Hawa Al Baraq

Borehole number	Interval (m)	Thickness (m)	Sample number	Free H_2O %	Combined H_2O %	SO_3 %	CaO %	SiO_2 %	MgO %	Fe_2O_3 %	Al_2O_3 %	Na_2O %	K_2O %	Cl %
BH 2	19.50-21.00	1.30	14	0.06	19.75	44.95	32.51	0.005	0.33	0.08	trace	0.22	nil	trace
	21.00-23.50	2.38	15	0.09	19.51	44.88	32.23	1.10	trace	0.09	trace	0.21	nil	trace
	23.50-25.15	1.65	16	0.10	17.47	40.43	34.52	1.06	trace	0.13	trace	0.25	0.03	trace
	29.15-30.30	1.15	17	0.05	18.77	42.88	33.76	0.09	trace	0.07	trace	0.23	0.04	trace
	30.30-33.70	3.08	18	0.14	18.99	43.06	34.03	0.009	trace	0.07	trace	0.20	nil	trace
Average		9.56		0.10	18.93	43.29	33.42	0.47	0.04	0.08	trace	0.22	0.01	trace
BH 4	19.50-21.50	2.00	19	0.07	19.78	45.02	32.77	0.005	trace	0.076	trace	0.19	nil	trace
	21.50-22.68	1.18	20	0.08	19.56	45.45	32.88	0.01	trace	0.096	trace	0.18	nil	trace
	25.55-27.90	2.35	21	0.12	19.32	42.97	33.69	0.001	0.21	0.104	trace	0.20	nil	trace
Average		5.53		0.09	19.54	44.30	32.76	0.004	0.09	0.09	trace	0.19	nil	trace
BH 5	19.00-22.50	2.50	22	0.06	20.31	45.75	32.64	0.006	0.17	0.066	trace	0.18	nil	trace
	22.50-23.50	1.00	23	0.07	19.78	44.85	32.75	0.001	0.16	0.12	trace	0.19	nil	trace
	27.10-28.50	1.40	24	0.1	16.77	38.82	36.17	0.002	0.01	0.11	trace	0.21	nil	trace
Average		4.90		0.07	19.19	43.58	33.67	0.004	0.12	0.09	trace	0.19	nil	trace

Table 2. Chemical analysis of gypsum deposits in the Sidi Al Mabruk area

Borehole number	Interval (m)	Thick-ness (m)	Sample number	Free H_2O %	Combined H_2O %	SO_3 %	CaO %	SiO_2 %	MgO %	Fe_2O_3 %	Al_2O_3 %	Na_2O %	K_2O %	Cl %
BH 9	1.50- 5.40	3.90	1	0.05	20.40	45.75	32.42	0.34	nil	0.04	trace	0.37	0.02	trace
	5.40- 8.40	3.00	2	0.15	20.28	45.49	32.43	0.88	nil	0.015	trace	0.35	0.03	trace
	17.50-20.70	3.20	4	0.07	19.97	45.54	32.15	0.53	nil	0.04	trace	0.44	0.01	trace
	20.70-24.50	3.80	5	0.07	20.16	45.58	32.16	0.66	nil	0.06	trace	0.44	0.01	trace
	24.50-27.90	3.40	6	0.10	18.97	43.14	32.88	1.96	nil	0.11	trace	0.41	0.01	trace
Average		17.30		0.08	19.96	45.11	32.35	0.86	nil	0.05	trace	0.40	0.01	trace
BH 10	14.60-18.60	4.00	7	0.06	20.50	45.56	32.56	0.47	0.19	0.05	trace	0.40	0.005	trace
	18.60-21.35	2.75	8	0.06	19.74	44.90	32.52	0.67	0.18	0.08	trace	0.44	0.016	trace
	21.35-24.35	1.50	9	0.13	18.44	43.10	33.90	1.12	0.19	0.11	trace	0.42	0.008	trace
Average		8.25		0.07	19.87	44.89	32.79	0.65	0.19	0.07	trace	0.43	0.009	trace
BH 11	13.75-16.00	2.25	10	0.05	20.03	45.44	32.52	0.70	nil	0.07	trace	0.47	0.001	trace
	16.00-17.00	1.00	11	0.13	19.42	43.96	32.43	1.75	nil	0.15	trace	0.53	0.02	trace
	17.00-19.25	2.25	12	0.09	20.01	44.08	32.45	1.31	0.19	0.19	trace	0.50	0.02	trace
	19.25-21.50	2.25	13	0.15	17.45	39.01	34.09	2.25	0.18	0.24	trace	0.49	0.02	trace
Average		7.75		0.10	19.19	42.98	32.94	1.46	0.11	0.16	trace	0.49	0.016	trace

Table 3. Mineral evaluation of samples from both areas (Percentage)

Borehole number	Gypsum	.nhydrite	$CaCO_3$	$MgCO_3$	Silica	R_2O_3	Na_2O	K_2O
9	95.36	1.29	1.35	-	0.86	0.05	0.40	0.01
10	94.93	1.26	2.41	0.39	0.65	0.07	0.43	0.009
11	91.69	0.58	5.07	0.23	1.46	0.16	0.49	0.016
Average 9+10+11	94.39	1.11	2.48	0.15	0.95	0.08	0.43	0.01
2	90.45	2.09	5.53	0.08	0.47	0.08	0.22	0.01
4	93.36	1.50	3.10	0.19	0.004	0.09	0.19	-
5	91.68	1.60	5.62	0.25	0.004	0.09	0.19	-

Table 4. Calculation of gypsum reserves in the Sidi Al Mabruk area

Borehole number	Area (m^2)	Thickness of gypsum (m)	Volume (m^3)	Tonnage (t)	$CaSO_4.2H_2O$ (%)
9	49.062	17.3	848 772	1 816 373	95.36
10	49.062	8.25	404 761	866 189	94.93
11	49.062	7.75	380 230	813 693	91.69
Total	147.186	11.1	1 633 763	3 496 255	94.39

The north-east continuation of the Hawa Al Baraq gypsum qu- this area, three drill holes (Nos. 2, 4 and 5) penetrated the gypsu . The area is delimited to the north and the north-east by the e .al high-tension line. Borehole No. 3, which is located further to the north beyond the high-tension line showed no gypsum. The thickness of the gypsum deposit at boreholes 4 and 5 is small which also limits the extent of the reserves. In calculating the reserves, the triangle passing through boreholes Nos. 2, 31[1/], 29[1/], 23[1/] can be considered as the established gypsum area. From this area, a gypsum reserve of 34,949 tons, additional to the reserves calculated in 1970, has been definitely established and further reserves of 76,048 tons can be said to be very probable. The detailed calculation is shown in table 5. An isopach map has also shown the uninterruped continuity of the gypsum deposit in the drilled boreholes with that of the previous holes in 1970.

1/ Boreholes drilled by Strojexport in 1970.

Table 5. Calculation of gypsum reserves in the north-east extension of Hawa Al Baraq quarry

Block number	Borehole number	Thickness of gypsum (m)	Area (m^2)	Volume (m^3)	Mass (t)	$CaSO_4.2H_2O$ (%)
I	2	9.55				90.45
(Proved	31	11.10				98.3
reserve)	29	13.80				97.59
	23	14.70				98.4
Average		12.29	3 230	39 696	84 949	96.6
II	2	9.56				90.45
(probable	5	4.90				91.68
reserve)	23	14.70				98.4
Average		9.72	2 565	24 931	53 532	94.66
III	2	9.56				90.45
(probable	4	5.53				93.36
reserve)	31	11.10				98.3
Average		8.73	1 215	10 606	22 696	94.39

Calculation of overburden and stripping ratio for the new area north-east of Hawa Al Baraq quarry

An isopach contour map was constructed of the top of the main gypsum body at Hawa Al Baraq quarry as well as for its north-eastern extension. This, also showed the continuity of the deposit without any disturbance. The calculation of the overburden of the new reserve blocks and the stripping ratio is given in table 6.

Table 6. Calculation of overburden and stripping ratio for the new reserve area

Block number	Borehole number	Sterile thickness (m)			Area (m2)	Sterile volume (m2)	Gypsum volume (m2)	Stripping ratio
		Over-burden	Interbed	Total				
I	2	19.4	4.0	23.4				
	31	20.8	7.3	28.1				
	29	15.0	5.4	20.4				
	23	17.9	1.1	19.0				
Average		18.3	4.45	22.75	3 230	73 482.5	39 696	1:1.85
II	2	19.4	4.0	23.4				
	5	19.0	3.6	22.6				
	23	17.9	1.1	19.0				
Average		18.8	2.9	21.7	2 565	55 660.5	24 931	1:2.23
III	2	19.4	4.0	23.4				
	4	19.5	2.87	22.37				
	31	20.8	7.3	28.1				
Average		19.9	4.7	24.6	1 215	29 889	10 606	1:2.82

B. Comments on the study

This study has revealed some million tons of additional gypsum which can be used by the cement industries in Benghazi and Derna. The new gypsum reserves are in the Sidi Al Mabruk area and north-east of the present Hawa Al Baraq quarry.

It is the expert's opinion that the areas surrounding Hawa Al Baraq probably contain yet further deposits of gypsum. This is based on the following considerations:

(a) The great thickness of the gypsum deposits;

(b) The deposits of gypsum include more than one band with various thicknesses which suggests the probability that at least one band (the lower one) continues into the nearby areas;

(c) From knowledge of the geological formation of gypsum and in view of the thickness of these gypsum deposits, it seems probable that these deposits were made in large basins isolated from the sea. Accordingly, extensions of the gypsum deposits must be found in the nearby areas.

It is, therefore, proposed that the areas surrounding Hawa Al Baraq should be thoroughly investigated so that a definite conclusion can be reached as to the total extent of gypsum reserves in the area and how long they will suffice for LCC and Derna cement production.

At Sidi Al Mabruk, the area needs to be studied in more detail but conflict is likely to arise from the fact that this is cultivated land and is the first new farm of the Al-Fateh project. It is, therefore necessary to contact the relevant authorites before proceeding further.

Recommendations

1. If the relevant authorities agree to allow further exploration and exploitation in the Sidi Al Mabruk area, either the LCC or the Industrial Research Centre (Department of Geological Research and Mining) should start immediately on the following:

(a) Drilling a few boreholes to the north and south of the previously-drilled boreholes Nos. 9, 10 and 11;

(b) Drilling two boreholes on the small hills with unchecked spot elevation at the 303 metre and 300 metre contour lines. If the result is positive, further drilling should be carried out;

(c) Estimation of the gypsum quality and quantity as well as the overburden-to-deposit ratio.

2. At Hawa Al Baraq, the present quarry area should be mapped on a 1:1000 scale to show the actual quarrying boundaries in order not to loose any of the deposit.

3. The areas surrounding Hawa Al Baraq should be thoroughly investigated, either by the Industrial Research Centre or starting by using one of the LCC's drilling machines under the expert's supervision, in order to determine whether or not further gypsum reserves exist in the area.

II. THE AS-SIDRAH GYPSUM DEPOSIT

A. Summary of the Industrial Research Centre's 1977 report

Location and accessiblility

The area studied lies along the Gulf of Sirte about 370 kilometres west of Benghazi and about 8 kilometres straight inland from the main road, as shown in figure II. The area is accessible from the main road by a desert track from the radio antenna about five kilometres long. The northern part of the area is also accessible by a hard desert track starting near the As-Sidrah police station.

The area is formed of a plateau with some hillocks not more than 86 metres high. It has a triangular scarp with its base to the north. A tributary from Wadi Om Al Bagar crosses the southern part. The area is dry land with no vegetation. There are a few wells unsuitable for domestic purposes. Water is obtained at the As-Sidrah oil camp.

Local geology

The area investigated is covered by white limestone, sandy and fossiliferous, belonging to the Middle Miocene age (L. Conant and C. Goudarzi 1964). This sequence incudes a lower gypsum band about nine metres thick and a middle band about three metres thick, separated by three to four and a half metres of white fossiliferous, siliceous limestone. At the top, the white gypsiferous limestone band is exposed (locally eroded as at traverse points 12 and 1 which are represented by gypsum peaks). The strata have a general dip of about 1.5^{o} to the south. Some minor faults run from NNE-SSW while others run NNW-SSE. These are normal step faults with a very small displacement of up to about four metres. These faults may be related to the regional tertiary orogeny which affects the Red Sea and the Hun Graben. These faults will determine the direction of the excavation site. The top part of the lower gypsum band is usually characterized by its slight undulations and the lower gypsum is usually compact. The limestone which interbeds the gypsum bands contains very rare destroyed dwarf fossils of gastropods. Silica intercalations are present at the lower part of the limestone interbeds which contain silicified dwarf pelecypods and gastropods. The limestone bands underlying the middle gypsum band and that overlying it are similar and have the same characteristics in the field which sometimes makes it difficult to differenciate between the two gypsum bands if they are exposed separately in an area. In the southern part of the area, i.e. south of the drilling grid line C (see figure III), the gypsum bands were found to diminish or decrease in thickness. This result was observed from the outcrops to the west of borehole F.

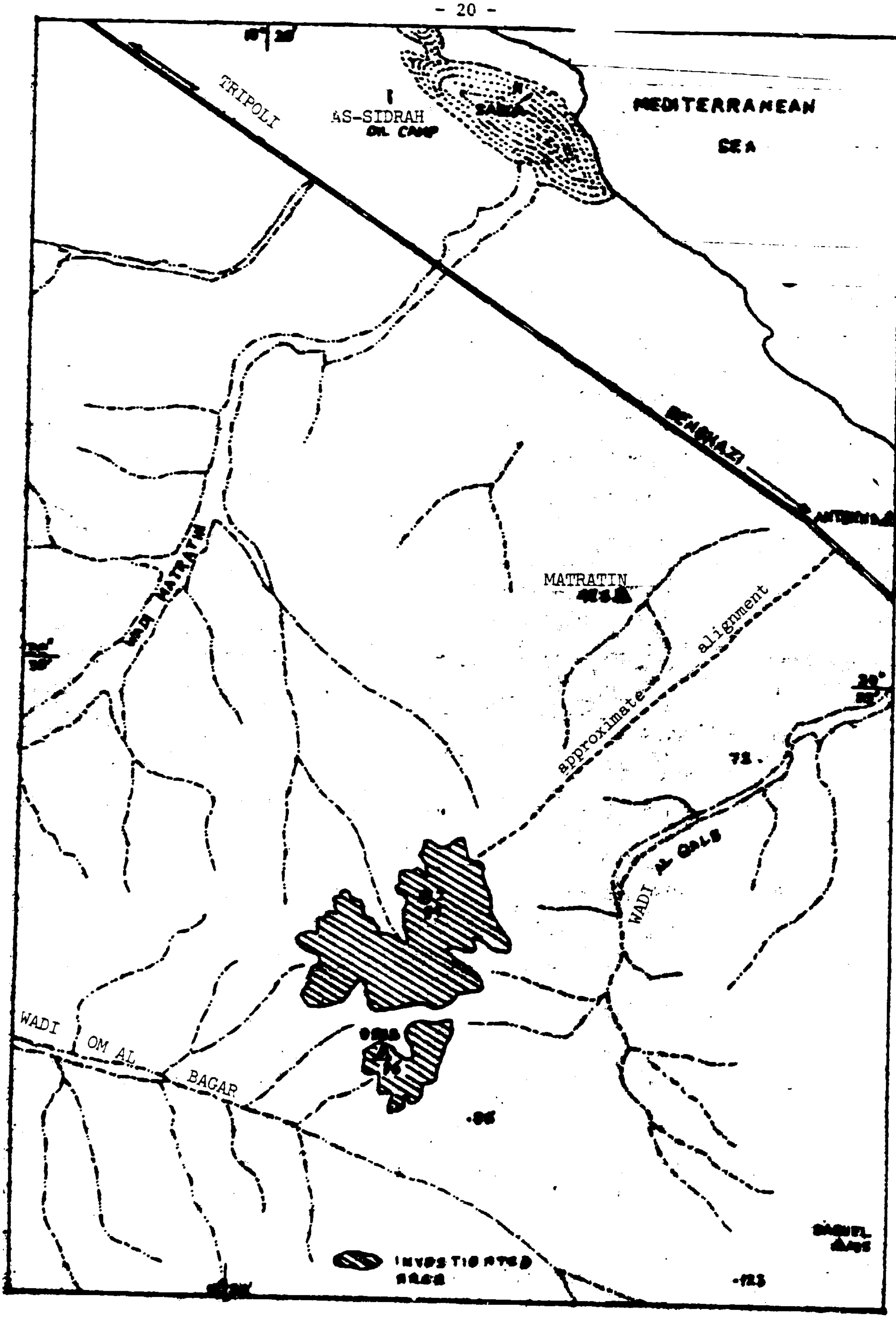


Figure II. Location of deposits in the As-Sidrah area

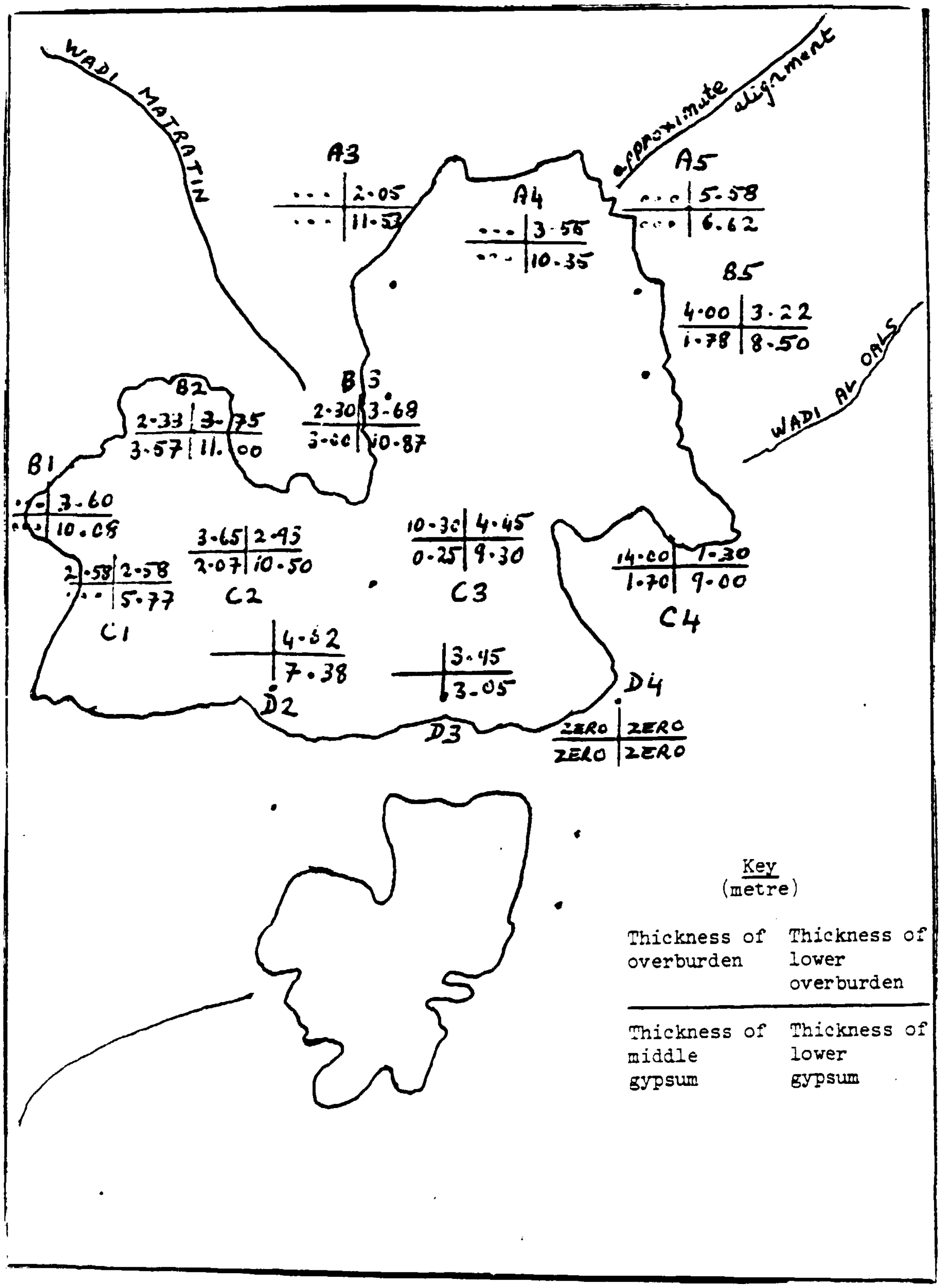


Figure III. Sketch map of borehole locations (indicating the thickness of middle and lower gypsum and overburdens)

Drilling work

Drilling work was carried out according to the grid system 400 metres by 400 metres starting from the northern part of the area with line A. From A1 and A2, going west to east, boreholes A3, A4 and A5 were drilled. Line B, to the south of line A, consisted of B1, B2, B3 and B5. B4 was not drilled because the location of B3 was shifted westwards due to topography and also to investigate the middle gypsum band. Line C, to the south of B, consisting of C1, C2, C3 and C4, were all nearly 400 metres apart and were all drilled. Line D started with D2, D3 and D4 since D1 was lying in a drainage area in which the lower gypsum was partly eroded. Finally, borehole F was drilled in the southern part of the area. D3 and D4 delimit the southern end of the northern area as shown in figure III.

Table 7 gives an analysis of samples from the boreholes showing thickness and chemical and mineralogical composition of the gypsum bands.

Calculation of reserves

Calculations were made with millimetric paper and planimeter to establish the amount of gypsum reserves in two categories, proved and probable. The estimated reserves are as follows:

	(Tons)	
	Proved	Probable
Middle gypsum band	1 598 400	1 [illegible]52 220
Lower gypsum band	20 284 800	21 567 540
Total	21 883 200	23 219 760

Mining and exploitation

It is suggested that mining and extraction should be done by open pit and stripping, with terraces like benches in order to utilize the two gypsum bands, the lower and the middle one. The suggested direction would be perpendicular to the prevailing fault systems which have NNE-SSW and NNW and SSE directions. It is recommended that exploitation should start from the northern part of the area, near boreholes A3 and A4, for the following reasons:

(a) The tributary of Wadi Matratin in the north can be used for dumping the overburden;

(b) The thickness of the overburden is least in the north and increases towards the south;

(c) The northern part of the area generally shows the maximum thickness of the lower gypsum band;

(d) The northern part of the area is the nearest to the main coastal road.

Table 7. Average chemical, mineralogical composition and thickness of gypsum in each borehole

Physical, chemical and minerological characteristics	Boreholes												
	A3	A4	A5	B1	B2	B3	B5	C1	C2	C3	C4	D2	F
						(percentage)							
H_2O(50°C)	0.117	0.24	0.24	0.186	0.15	0.118	0.16	0.23	0.126	0.23	0.28	0.20	0.13
H_2O(600°C)	19.43	18.88	18.48	19.74	19.348	19.40	19.62	19.06	19.455	19.07	19.07	19.19	19.33
LOI	2.16	3.17	3.12	1.45	2.47	2.24	1.71	1.59	2.32	2.70	2.97	2.73	2.2
CaO	33.34	33.03	33.05	32.47	33.277	33.3	32.64	34.20	32.79	33.23	33.29	33.14	33.09
MgO	0.348	0.77	0.76	0.53	0.405	0.36	0.65	0.64	0.491	0.52	0.53	0.59	0.42
NaCl	0.5	0.57	0.54	0.48	0.498	0.52	0.55	0.50	0.44	0.74	0.69	0.59	0.47
R_2O_3	0.017	0.41	0.415	0.189	0.016	0.018	0.210	0.29	0.098	0.40	0.40	0.26	0.08
SiO_2	0.62	1.5	1.47	0.82	0.62	0.61	0.65	1.3	0.549	0.92	0.95	0.84	0.59
SO_3	43.36	42.29	42.22	43.60	43.13	43.43	43.6	42.19	43.04	42.51	42.22	42.64	42.66
Gypsum	92.87	90.20	90.28	94.3	92.44	92.69	93.74	91.03	92.95	91.96	93.11	91.67	92.21
Anhydrite	0.3179	-	-	0.0	0.24	0.594	0.008	0.093	-	0.105	0.104	0.083	0.136
$CaCO_3$	5.1488	-	-	3.14	5.48	5.1488	3.758	6.47	4.497	6.4	3.4	5.5	5.05
$MgCO_3$	0.727	-	-	1.108	0.85	0.723	1.359	1.34	1.027	1.23	1.17	1.2	0.88
						(metres)							
Thickness	11.63	10.35	6.92	8.08	13.67	11.00	9.28	4.35	12.57	9.0	9.73	6.38	5.0

B. Comments on exploitation of the site

Loosening of rock gypsum by drilling and blasting

Modern quarrying places special requirements on the loosening of rock which is in most cases done by drilling and blasting. The blast should give the largest possible amount of rock per metre and per kilogramme of explosive used. The amount of blasted rock per metre borehole is a function of size, borehole depth (D), burden (B) and spacing between boreholes (S) (see figure IV). In other words, to effect a given degree of displacement and fracture, the explosive charge is proportional to the volume or mass of rock displaced (for given material and explosive). These factors have to be balanced carefully against each other so as to give the maximum output.

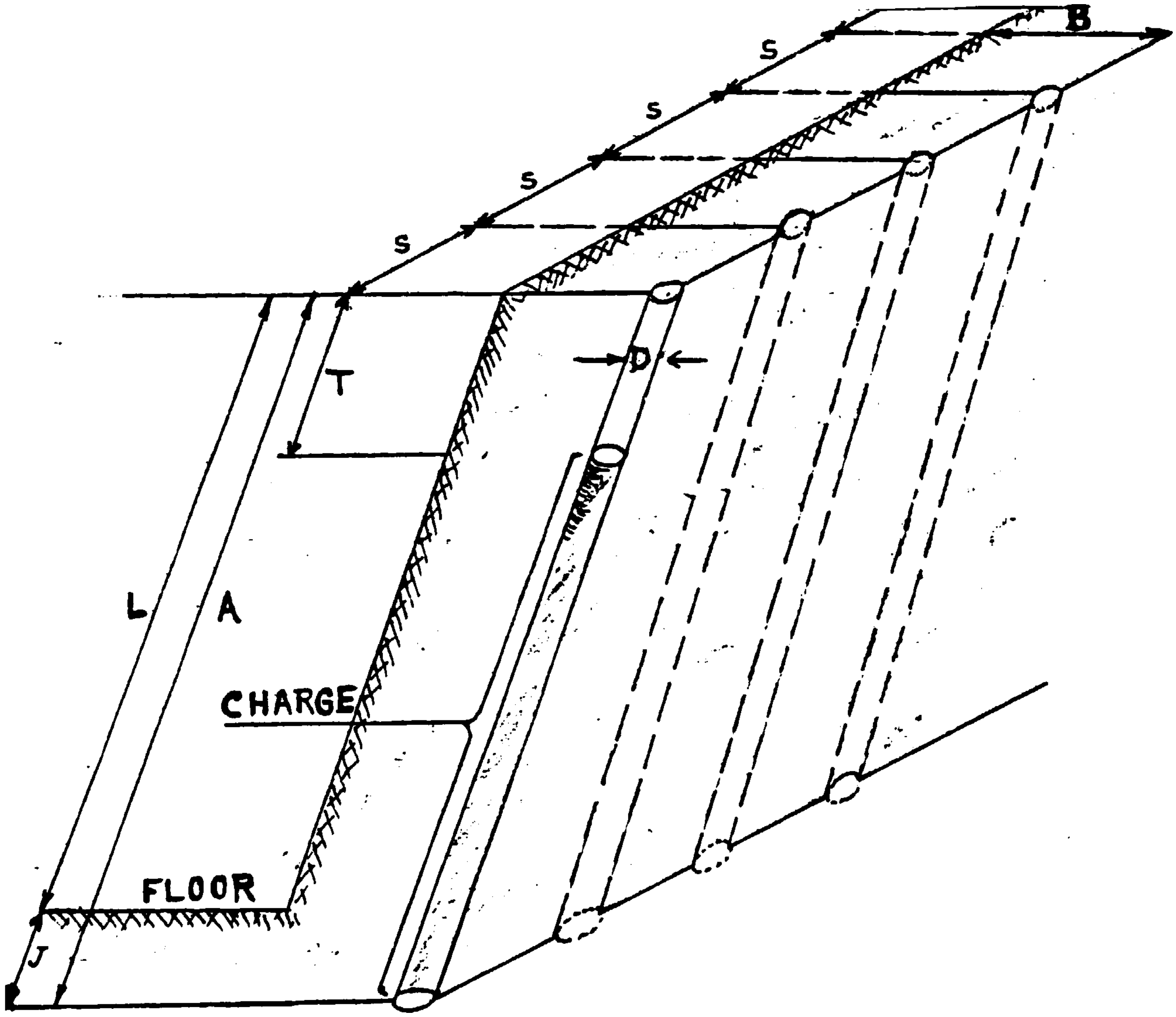
Drilling

As is suggested for the As-Sidrah gypsum quarry, small benching is often used for a certain period of time. This requires a light hand-held drill that can easily be moved around on the sloping quarry face. The same type of equipment is also used when preparing benches for big-hole drilling or to drill for selective blasting and sorting of a series of gypsum bands interbedded with other limestone beds, or to drill for secondary blasting. The most commonly used machines weigh around 16-25 kilogrammes. They use integral steel, and the drill depth seldom exceeds 3-4 metres. The output can be estimated as roughly 150 tons per machine shift. For medium-sized quarries operating with benches, like the As-Sidrah quarry, light or heavy wagon drills are used. These work with coupled drill rods to depths which are usually between 10 and 20 metres, and use drill bits up to 300 millimetres in diameter. These machines are mounted on tracks or wheels or may even be truck-mounted. The transporting of such machines depends on the size of the quarry and the road conditions which determine its accessibility. The drilling machines are of two types, rotary and percussion drilling. The first is commonly used in soft to medium rock (Mohs' scale <4). The second is most commonly used in hard to very hard rock (Mohs' scale >4). The first type is recommended for use in gypsum production. Its approximate drilling rates are about 30 metres per hour in limestone and 35 metres per hour in gypsum, whereas in granite, for example, it is 14 metres per hour. The output is around 300-500 tons per machine shift for the light wagon drills and around 500-1,000 tons per machine shift for the bigger ones.

The hand-held drills and the recommended light wagon drills would get their air supply either from mobile or stationary compressors. The mobile compressors usually have a capacity of either 7 cubic metres per minute or 17 cubic metres per minute. The bigger size is usually capable of running two heavy wagon drills, four light wagon drills, or seven hand-held drills. In large quarries with rather stable working conditions, stationary compressors are usually used.

Calculation of borings and explosives

The factors esssential for optimizing the product-to-explosive ratio are the number of free faces, the "line of least resistance", strength of rock, depth of hole, type of explosive etc. The modern concept of quarrying is that as far as possible the rock should be broken to the required size in the primary blast. In dense rocks, the holes are generally charged with high-strength gelatinous explosives such as ammonium gelatine 60%. For softer rocks, lower-density explosives may be employed.



Key: L Bench height

A Borehole length

B Burden, distance between charge and nearest free face (perpendicular distance)

D Borehole diameter

J Subdrilling length (drilled below quarry floor)

T Collar or stemming distance (not containing explosives)

S Distance between boreholes

Figure IV. Cross-section of bench

The following rules can be taken into consideration in the case of drilling and blasting (see figure IV).

(a) S (space between holes) is 1.0 to 1.3 times B;

(b) B (burden) is 25 to 40 times the borehole diameter D, depending on the explosive type;

(c) J (sub-drilling length) is 0.2-0.5 times B;

(d) T (stemming length) is approximately equal to 0.7 B;

(e) A (borehole depth) is approximately equal to 2.6 B, although in some European countries, 90 millimetres diameter holes, 20-40 metres deep, are commonly used;

(f) For the complete efficiency of explosions it will be taken into consideration that the distance between the face and the first series of boreholes or the second series will be four metres, but the distance beweeen two boreholes five metres.

From this the amount of gypsum produced from one borehole, assuming a mean depth of 15 metres and a density of 2.3 tons per cubic metre, can be calculated as 15 x (4 x 5) x 2.3 = 690 tons.

The number of boreholes can be drilled and charged according to the production required every month. This number can be estimated by the quarry engineer.

In calculating the quantity of dynamite to be used in the borehole, the charge length for one borehole is given by the formula A - 1.2 W, where W is the line of least resistance. Taking A = 16 metres and W = 4.5 metres (approximately), the charge length for a borehole comes out to be 16 - (1.2 x 4.5) = 16 - 5.4 = 10.6 metres, or 11 metres, approximately.

The dynamite charge can be proportionally distributed in the borehole depth of 11 metres. From previous experience, it is known that the quantity of dynamite required to produce one ton of gypsum is 100-120 grammes.

Accordingly, the quantity of dynamite required to produce approximately 700 tons from one drilled borehole would be 700 x 120 grammes = 84 kilogrammes.

The diameter of the borehole can be increased or decreased depending on the density of the dynamite or any other explosives used.

Loading

Mechanical loading is used where speed is required. The basic function of mechanical loaders is to grab loose-lying heaped bulk rock from its solid mass by blasting and to move it to the transportation facilities. The principal factors governing the use of such loaders are the prevailing conditions of the quarry such as the rock hardness, the cross-sectional area of the working place, the angle of dip, the dust conditions, the dump size etc. Mechanical loaders are distinguished by the way they transfer the load to transportation facilities (direct or step wise), by the construction of the carrier mechanism or chassis (wheel mounted, caterpiller mounted with walking arrangements or with rope-traction) and by whether they are self-propelled or not.

In most cases, however, loading is a separate operation which is performed after the stone has been properly prepared for loading by primary and secondary blasting. The loading is usually performed by shovels, but lately other types of equipment have been introduced such as front-end loaders (wheel loaders), traxcavators etc.

Front-end loaders are coming more and more into use as substitutes for shovels, especially in quarries with coarsely-shot material. The wheel loaders have some advantages such as higher mobility, greater versatility of application, clean-up ability, operational ease, high trade-in value and low initial cost. Their disadvantages can be stated as tyre wear, toe-loading difficulties, lower breakout force, safety risks on high benches and higher operator fatigue. The mobility of the front-end loader is its biggest asset, and if it comes to supplying stone from several points in the quarry or doing selective loading, such a loader should be chosen. If it comes to a more stationary type of loading of coarsely-shot material, the choice will be the shovel. A study shows that the average output of a 5 cubic yard loader is about equal to a 3 cubic yard shovel and that the cost per ton of the 5 cubic yard loader would roughly be the same as that of a 3.5 cubic yard shovel. The weak point in the economy of the loader is its short life of about 8,000 working hours against 20,000 hour for the shovel and accordingly the wheel loader tends to be more expensive in operation.

In the case of the As-Sidrah gypsum quarry, a wheel loader would be the best choice as both loading and transport operations can be carried out by the loader.

Loosening and ripping

It is economical to loosen and rip heavy soils, overburden and soft or highly-stratified or laminated chalky limestone rock (as in this case) by large tractors (bulldozers) weighing about 40 tons, powered by a 385 hp (285 kW) engine, equipped with 1-3 shanks which can be lowered and forced into the ground. The cost is lowest when the material is soft and under pressure of bands and layering of the overlying beds. On the other hand, with increasing rock hardness and with decreasing stratification, the output of the ripper declines rapidly and, when dealing with 400-500 tons per hour (ripped and bulldozered to piles) the ripper usually cannot compete with blasting in cost. Under severe conditons, the life of even the biggest tractor may be as short as 4,000 working hours and cases are known where a tractor of the biggest size had to be written off in one year.

Bulldozers are well suited to work on wet, slippery overburden and on overburden with stones and roots as they are hardy machines. They are built in many sizes of which only those with an engine power of more than 125 hp (95 kW) should be considered as suitable for stripping work. The capacity of the bulldozer falls rapidly with the transporting distance. So for instance, a 200 hp (150 kW) bulldozer can move 225 cubic metres of loose material per hour over a distance of 25 metres, but only 65 cubic metres per hour over a distance of 100 metres.

It is preferable to use a bulldozer in this case as there is a downward slope to which the removed overburden can be pushed. Besides, the bulldozer is useful if blasting is used in quarrying to remove or to push the blasted material into heaps. It can also be used to clear roads and prepare the site. The machine will help a lot in ripping the soft, chalky limestone, and the clay or marl layers.

C. Economic evaluation

The LCC operates two independent cement plants situated near each other in the Hawari district of Benghazi city. The two cement plants were designed for an annual production of 1 million tons of cement per year. Another company has been established to run the Fatayeh Cement Plant with a planned capacity of 1 million tons near Derna town. The proposed cement production of the two cement companies will be 3 million tons.

Gypsum as a retarding agent is mixed with clinker in an amount of 3-7% according to the quality of the gypsum ($CaSO_4 2H_2O$ content) and depending on the tricalcium aluminate (C_3A) content of the clinker produced.

It is proposed that the As-Sidrah quarries would serve both the LCC and the Fatayah cement plants, but the transport distance would be very great (370 and 700 kilometres respectively). As the As-Sidrah gypsum is of high quality and its $CaSO_4 2H_2O$ content is not less than 90%, it is suggested that not more than 3.5% of this quality gypsum would be transported from As-Sidrah to be mixed with other gypsum from the nearby quarries and limestone to reach the SO_3 concentration required.

The quantity of raw gypsum from As-Sidrah required for the production of cement in the two companies = 3 million tons x 3.5% = 105,000 tons approximately.

Our economic calculations will be based on considering that the As-Sidrah gypsum quarry will be an independent unit under the supervision of the LCC which is the main gypsum consumer.

Cost of fuel

Table 8 (at the end of the chapter) shows the total consumption of fuel, oil and lubricants required for the machines, equipment and vehicles serving the project. The cost of fuel to the respective cement companies would be:

				Libyan dinars
LCC	Total cost			46 167
	Cost per ton	$\frac{46\ 167}{70\ 000}$	=	0.66
Derna	Total cost			37 283
	Cost per ton	$\frac{37\ 283}{35\ 000}$	=	1.065

Cost of explosives

Current prices are:

Blasting gelatine	600 Libyan dinars per ton
Detonating cord	0.2 Libyan dinars per metre

Prices of fuses and detonators are not available and are estimated.

As 100 grammes of blasting gelatine is sufficient for the production of one ton of gypsum or the removal of one ton of the covering or intercalated limestone, and as the latter forms about 30% of the gypsum quantity, especially in the northern area, 130 grammes of gelatine will be needed to produce one ton of gypsum ore.

The cost of the required quantities of explosives for production of one ton of gypsum will be;

Blasting gelatine	= 0.078 Libyan dinars
Detonator, detonator cord, fuse etc.	= 0.030 Libyan dinars

If ammonium nitrate is used instead of some of the gelatine, the cost of explosives used decreases by about 40% as only a small amount of blasting gelatine is used with ammonium nitrate. Accordingly, the explosives needed for one ton of gypsum would cost approximately 0.047 Libyan dinars.

The total cost of explosives used in gyspum production for LCC would be 0.078 x 70,000 = 5,460 Libyan dinars per annum.

The total cost of explosives used in gyspum production for Derna would be 0.078 x 35,000 = 2,730 Libyan dinars per annum.

Cost of machinery, equipment and buildings

Table 9 (at the end of the chapter) shows the machinery, equipment and buildings required to serve the project. On top of the estimated costs, 20% has to be added for depreciation, maintenance and spare parts per year.

	Libyan dinars
Total value of installations	1 952 400
Cost to LCC	1 178 933
+ 20%	235 787
Cost to Derna	773 467
+ 20%	154 693

Investment required

The investment required for exploiting the As-Sidrah gypsum quarry can be expressed as follows:

	Libyan dinars	
1. Fixed assets	LCC	Derna
Machines, equipment, buildings	1 178 933	773 467
Spare parts etc. 20%	235 787	154 693
Land	30 000	20 000
Quarry and road preparations	50 000	25 000
Preliminary charges	20 000	15 000
Total	1 514 720	988 160
2. Moving capital (turnover, 3 cycles)		
Salaries and wages (see table 10)	34 286	21 665
Fuel, oil and lubricants	15 389	12 283
Explosives	1 820	910
Rent of land	2 000	1 000
Other expenses	6 000	3 000
Total	59 495	38 858
Total investments	1 574 215	1 027 018

Cost of transported gyspsum ore from As-Sidrah quarry to both cement companies

	Cost per year (Libyan dinars)	
	LCC	Derna
Depreciation, maintenance etc.	329 013	219 707
Salaries and wages	102 857	64 996
Fuel, oil and lubricants	46 167	37 283
Explosives	5 460	2 730
Price of land (10% of the total price)	3 000	2 000
Rent of land	2 000	1 000
Preliminary charges and other expenses	23 500	13 500
Total cost per year	511 997	341 019
Quantity of gypsum required per year	70,000 tons	35, 000 tons
Cost of one ton of gypsum transported to the cement companies	LD 7.314 (approx.)	LD 9.743 (approx.)

The following should be noted with regard to these calculations:

(a) All the prices given in this economic study are the prices current in 1980;

(b) Some prices were not available and therefore approximate higher prices have been used in our estimates;

(c) The working life of machines, equipment and trucks is taken as that under the worst conditions in which these machines can work;

(d) The staff shown in table 10 is the optimum staffing requirement for such a project.

Recommendation

As transportation of the gypsum ore to the cement factories represents the main cost item and many trucks will be required, and as there is a harbour near to the gypsum quarry, it is recommended that the gypsum should be transported to both cement factories by ship. The distance as well as the cost per ton would be less.

Table 8. Cost of fuel, oil and lubricants for the machinery, equipment and vehicles of the As-Sidrah gypsum project

Machines and vehicles	Number required	Cost of fuel, oil etc. of machines per day: Fuel (LD)	Oil (LD)	Speci oils (LD)	Lubri-cants (LD)	Total cost per day (LD)	Number of working days per year	Total cost per year (LD)	Ratio of cost LCC : Derna	Cost to each cement company: LCC (LD)	Derna (LD)
Buldozer D 9G	1	8.0	3.5	2.5	1.5	15.5	200	3 100		2 067	1 033
Crawler loader	1	10.0	4.5	3.5	2.0	20.0	150	3 000		2 000	1 000
Wheel-mounted loader	1	10.0	4.5	3.5	2.0	20.0	100	2 000	2 : 1	1 333	667
Compresor	1	2.0	1.5		0.3	3.8	200	760		507	253
Landrover car	1	1.5	0.5		0.2	2.2	250	550		367	183
VW service car	1	1.5	0.5		0.2	2.2	200	450		293	147
Trucks	34	cost is estimated according to the distance							17 : 12	39 600	34 000
									Total cost	46 167	37 283

Price list

			(Libyan dinars)
Solar	(per litre)	=	0.040
Petrol	(per litre)	=	0.072
Oil	(per kilogramme)	=	0.330
Hydraulic oil	(per kilogramme)	=	0.246
Lubricant	(per kilogramme)	=	0.414

Table 9. Cost of machines, equipment and buildings required for the As-Sidrah gypsum project

Machines equipment and buildings	Number required	Cost per unit (thousand LD)	Total initial cost (thousand LD)	Depre-ciation (%)	Depreciation per year (LD)	Maintenance and spare parts at 10% a year (LD)	Total running cost (depre-ciation plus maintenance per year)(LD)	Ratio of cost LCC : Derna	Running cost to each company per year LCC (LD)	Derna (LD)
Bulldozer D9G	1	97	97	10	9 700	9 700	19 400		12 933	6 467
Crawler loader with rippper	1	75	75	10	7 500	7 500	15 000		10 000	5 000
Wheel loader	1	75	75	10	7 500	7 500	15 000		10 000	5 000
Crawler-mounted drilling unit	1	23	23	10	2 300	2 300	4 600	2 : 1	3 067	1 533
Screw-type compressor with diesel engine	1	18	18	20	3 600	1 800	5 400		3 600	1 800
Rock drills with standard spares	2	1.2	2.4	20	480	240	720		480	240
Trucks	34	46	1 564	20	312 800	156 400	469 200	20 : 14	276 600	193 200
Landrover car type L 109	1	5	5	20	1 000	500	1 500		1 000	500
VW service car	1	3	3	20	600	300	900		600	300
Buildings, construction and furniture		30	30	5	1 500	3 000	4 500	2 : 1	3 000	1 500
Garage and service station		50	50	5	2 500	5 000	7 500		5 000	2 500
Set of quarry tools	1	10	10	50	5 000		5 000		3 333	1 667
Total		433.2	1 952.4		354 480	194 240	548 720		329 013	219 707

Table 10. Staff required for the As-Sidrah gypsum project and their wage rates

Post	Qualifications and experience	Grade	Number of personnel required	Salary per month (LD)	Total salaries per year (LD)	Ratio of salaries to each company LCC : Derna	Cost of salaries to each company LCC (LD)	Derna (LD)
Quarry manager	B.Sc Eng. or B.Sc in geology + at least 5 years experience	3	1	307	3 684		2 456	1 228
Foreman	Industrial secondary school + at least 5 years experience	5	1	234	2 808	2 : 1	1 872	936
Store chief	General Certificates of Education	6	1	195	2 340		1 560	780
Clerk	Ditto	6	1	195	2 340		1 560	780
Mechanic	Industrial school + 5 years years experience	5	2	234	5 616	20 : 14	3 304	2 312
Bulldozer operator	Primary school + at least 10 years experience in driving bulldozers	9	1	124	1 488		992	496
Loader operator	Ditto	9	1	124	1 488	2 : 1	992	496
Truck driver	Primary school + 10 years experience in driving heavy-duty trucks	9	34	124	50 592	20 : 14	29 760	20 832
Service car driver	Primary school + 5 years experience in driving cars	10	1	102	1 224	2 : 1	816	408
Assistant mechanic	Training centre certificate	8	6	140	10 080	20 : 14	5 929	4 151
Workers and guards		11	10	85	10 200	2 : 1	6 800	3 400
Total			59		91 860		56 041	35 819
	<u>Other staff costs</u>	Desert allowance (30%)					16 812	10 746
		Danger allowance (LD20 per man/month)					944	472
		Insurance					3 974	2 496
		Bonus per year (one month's salary)					4 670	2 985
		Overhead service					7 000	4 000
		Subtotal					89 441	56 518
		Supervison 15%					13 416	8 478
		Total					102 857	64 996