diameter and 1.5 m in length. The diameter of the cores is 85 mm. A diamond bit has been used.
In Oran the drilling has been done from the boat "La Mordjane". The drilling machine, standing on three supports, has been placed under water. The machine was connected by flexible tubes with the hydraulic power source and the water pump, placed on the boat. All drilling operations have been done under water, by qualified divers-drillers. For normal drilling operations the water depth should not exceed 15 m. Samples have been taken from the drilling cores and brought to the laboratory for soil-mechanical testing.

The locations of the drillings can be seen in figures 2.4.1, 2.4.9 2.4.10 and 2.4.15.

2.4.2 The Port of Algiers

(1) General topography and geology

The port of Algiers is located on the west side of a large bay, 15 Km in diameter, open to the Mediterranean sea.
The port is delimited by the Mustapha jetty, on its NE side, at a distance of 160 m from the coast and by the eastern breawater. The sea bottom descends to the north, developing a gentle slope of 0.8 degrees off-shore from the coast. The water depth reaches -12 m at the Mustapha jetty, -50 m at 4 Km off-shore of the coast. The west side of the bay, delimiting the "Old" port of Algiers (north part of the port of Algiers), is a hilliy terrain, consisting of Triassic schist (Fig.2.4.2). The weathering of this formation results into a clayey deposit which can be encountered in the sea bottom of the north part of the port (the "Old" port of Algiers). The basement under the sea bottom of the "Old" port is expected to be Triassic schist.

The coast along the SW side of the bay, where the "New" Port (Mustapha basin) is located, is a narrow plain, 1 Km wide, composed of recent sand and gravel. Behind this flat zone the topography rises rapidly up till 160 m. The flat-top hills consist of Upper Pliocene limestones covered by Pleistocene limestones and alluvial deposits and recent sands and gravels. The sea bottom of the "New" port mainly consists of recent deposits underlain by a Pliocene basement. There are no outcrops of this basement in the close surroundings of Algiers.

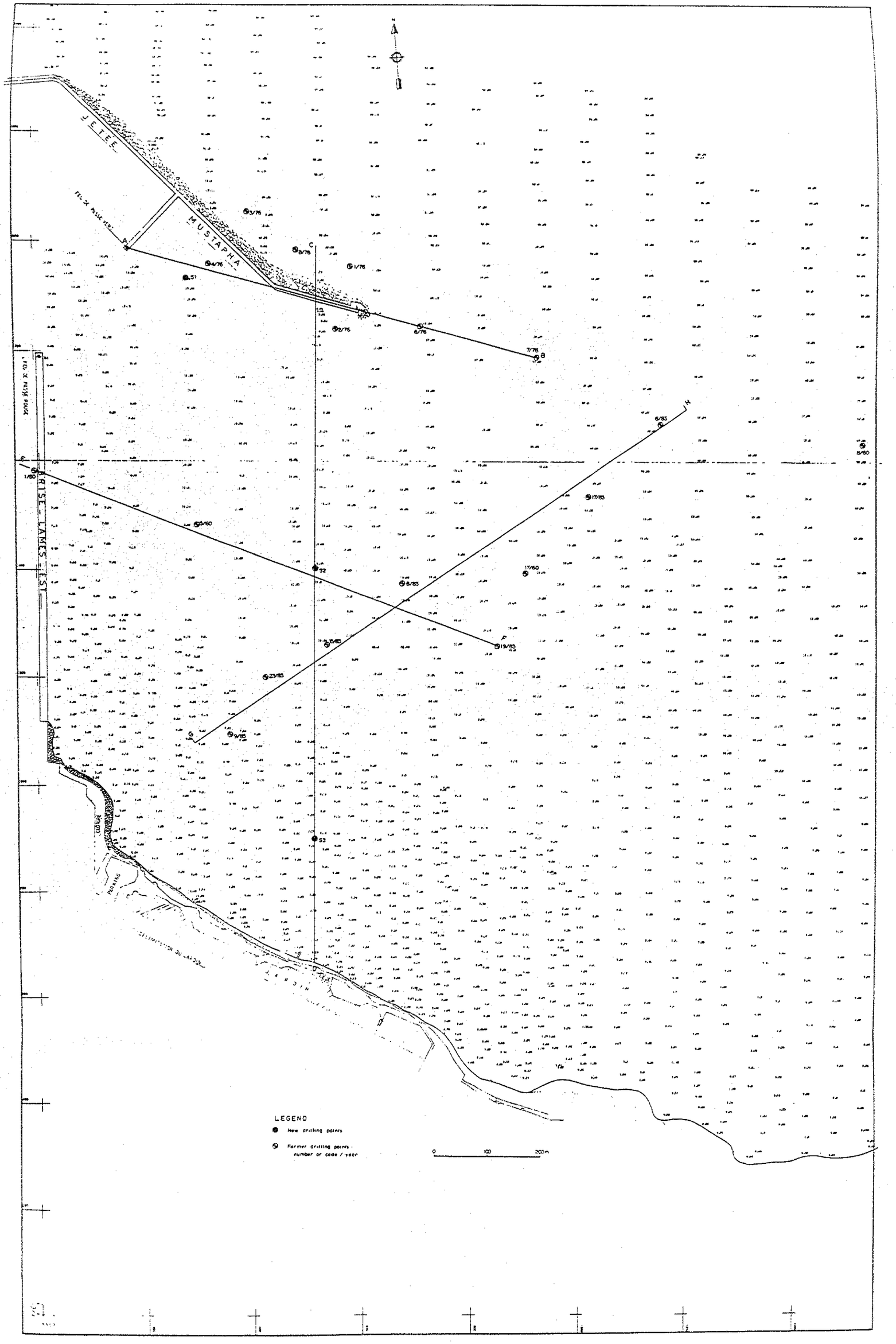

Fig. 2.4.1 Port of Algiers: location of the boreholes and geological cross-sections

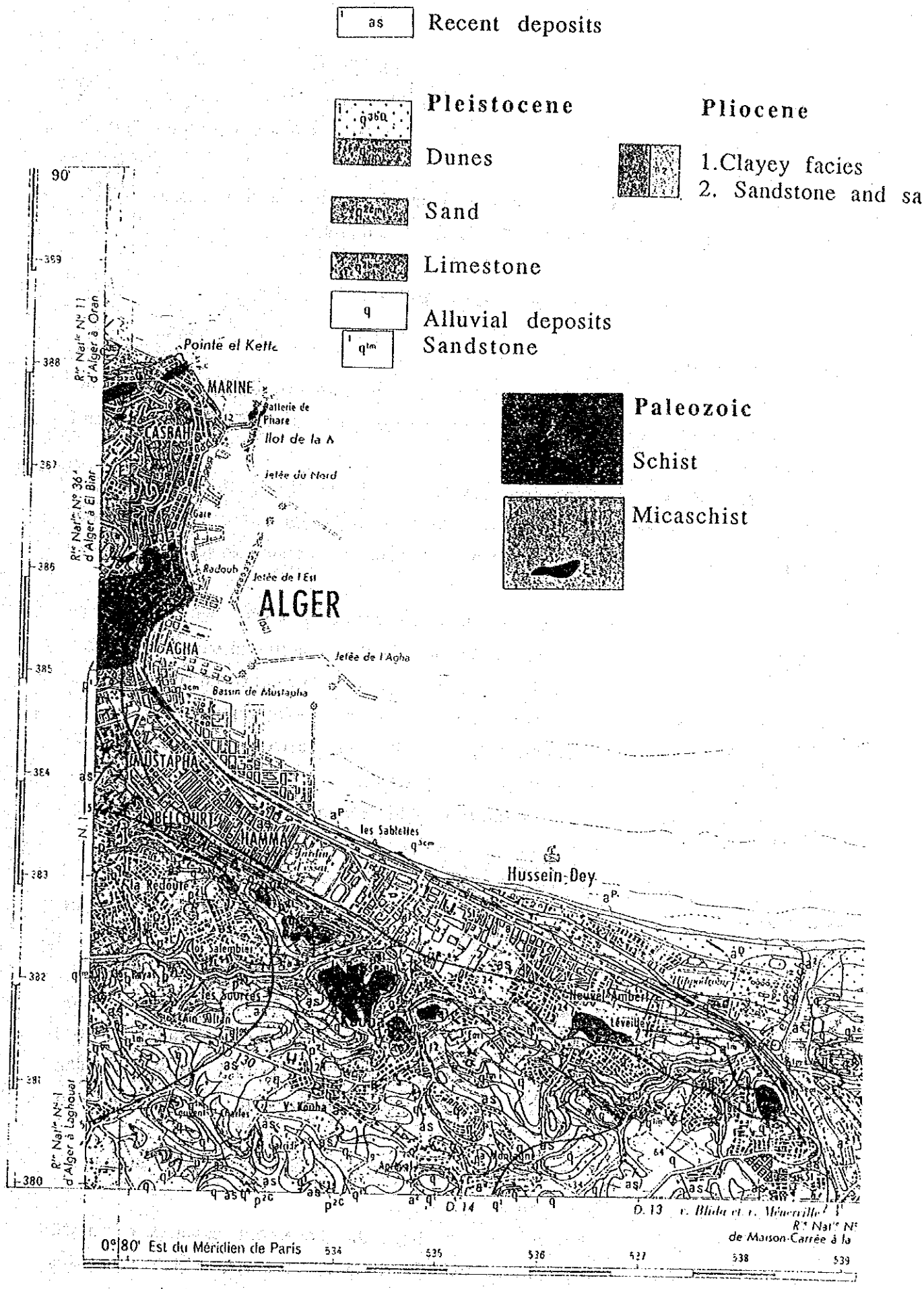

Fig. 2.4.2 Geological map of Algiers (scale 1:50,000m)

(2) Detailed geology of the sea bottom in the study area

The study area stretches out from the eastern breakwater of the "New" port to the east.
Three drillings have been done (S1 to S3), located as indicated in figure 2.4.1. The drilling logs are shown in figures 2.4.3, 2.4.4 and 2.4.5.

The "cover" of the sea bottom consist of the following deposits:

Recent to Pleistocene deposits:
- Upper layer a: organic black "mud", thickness in between 1 and 2.5 m, particle size corresponding to silt in S3 and to sand with 30-50% fines in S1 and S2, oversaturated;
- Layer b: Mixture of fine sand and clay (various proportions), thickness from 1 m till 5 m (at S2) or more: the thickness of this layer seems to increase from the eastern breakwater towards the east and from the coast towards the off-shore;
- Layer c1: gravel and conglomerate, thickness between 0.5-2.3 m (S3 and S1); the gravel results from the decalcification of the conglomerate; Layer C2: heterogeneous deposit of blocks, boulders and gravel, encountered only in S2, thickness 4.5 m; this layer is not continuous, it passes laterally into c1;
- Layer d: clay, thickness between 1-0.7 m. This layers extension is limited to a narrow stroke along the Mustapha jetty (Fig.2.4.6).
- Layer e: limestone, very rich in shells (called "Lumachelle").

The basement of the long shore (south part) of the bay of Algiers consists of Pliocene sedimentary rocks. The following two rock formations can be distinguished:
- Formation a: the Upper Pliocene ("Astien") Molasse-type formation, consisting of sandstone, cemented by carbonate, rich in fossils and sand. The erosion products of the paleotopography have been transported into the sea and deposited together with calcareous material, resulting into the so-called Molasse. The thickness is not known and the formation seem to be present only to the east from the eastern breakwater;
- Formation b: the Lower Pliocene ("Plaisancien") Marl formation, which can reach a thickness of 1000 m or more.

Under the "new" port, located SW of the bay, the basement consists of marl. From her to the east, it is replaced by the molassic deposit, which increases

gradually in thickness. The area concerned by this study, represents the transition zone from a proper marine environment (marl) to a more continental-marine environment (Molasse). Thus the basement of the study area is an alternation of calcareous sandstone (Molasse) and marl.

DRILL LOG

SITE	ALGIERS			HOLE No.	S1
LATITUDE	384796.03	LONGITUDE	534005.31	ELEVATION	14.50m
DATE	13 November 1991			DEPTH	18.00m
ANGLE	180° UP / DOWN 0° / 90°	DIRECTION	N 0° / W 270° / E 90° / S 180°	SLOPE	HORIZON 0° / 90°
				DRILLED	SONATRAM
				LOGGED	I.C.P.

SCALE	DEPTH	ELEVATION	GEOLOGICAL AGE	ROCK TYPE	COLUMN SECTION	ROCK CLASS	DESCRIPTION
1–2			RECENT	Mud			Black mud: 82% silt and clay, 10% sand and organic material, oversaturated.
2	2.50	-17.00				CL	
3–5			PLEISTOCENE (?)	Sand and Clay			Gray sandy clay.Dilatancy: slow/no plasticity/low toughness/dry strength: medium/cohesive consistecy: very soft. 15% coarse particles: quartz grains, fossil fragments (can easily be broken down to smaller sizes), rock and biotite fragments.
5	5.00	-19.50				SC-CL	Clayey sand: 50% sand and 50% fines.
6	6.00	-20.50					Silty-clayey sand
7–8	7.90	-22.40				GW	Yellow conglomerate.Pebbles: size range 1mm-6cm/ mean size 1cm/rounded/quartzites, black shales (flat pebbles), limestone, large shells/ cemented by carbonate/ porous, hard rock
9–10	10.32	-24.82		Conglomerate			
11				Clay		CL	Gray clay, upper 20cm sandy. Medium plasticity/medium dry strength/contains fossil fragments mm-size. From 10.5 m sticky silt/ consistency: stiff/no reaction to shaking/high dry strength.
12	11.85	-26.35					
13–17			LOWER PLIOCENE	Marl		(CL)	Gray, sandy marl with 18-32 % sand and 41% of Ca CO3. Consistency: very stiff/no plasticity/humide/rich in fossiles: brachiopodes, shells, gastropodes, corals, 2-3 mm size. Between 16.5-18 m 8% coarser grains: limestone fragments and quartz.
18	18.00	-32.50					

BIT & DIAMETER: Diamond Bit 86mm

WATER LEVEL

CORE RECOVERY % (m) / R.Q.D % (m)

Run	Core recovery % (m)	R.Q.D % (m)
1 (1.50)	22	0
3 (3.00)	100	0
4 (4.50)	66	0
5 (6.00)	58	0
7 (7.50)	20	0
9 (9.00)	65	33
10 (10.50)	12	0
12 (12.00)	100	100
13 (13.50)	100	100
15 (15.00)	100	100
16 (16.50)	100	100
18 (18.00)	100	100

STANDARD PENETRATION TEST

Depth	Result
3.15	N=9/30cm
3.45	
4.65	N=8/30cm
4.95	
6.15	N=12/30cm
6.45	
7.65	N=17/30cm
7.95	

*R.Q.D is Rock Quality Designation. R.Q.D=(Total length of cylindric cores longer than 10 cm)/(Total drill length) x 100%
*LUGEON VALUE is l/min/m under injection water pressure of 10kg/cm2
*DEPTH and ELEVATION are in meter
*DIAMETER is in millimeter

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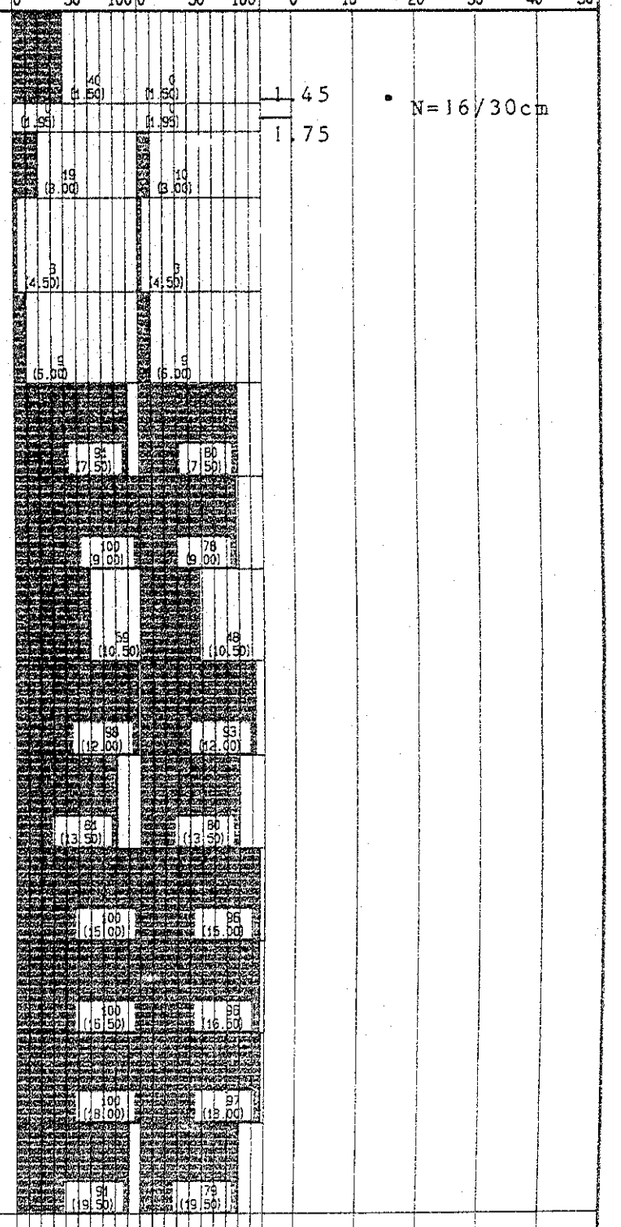
Fig. 2.4.3 Drill log - Algiers S1

DRILL LOG

SITE	Algiers			HOLE No.	S2
LATITUDE	383781.03	LONGITUDE	534220.31	ELEVATION	-14.40m
DATE	12 November 1991			DEPTH	19.50m
ANGLE	180° UP / DOWN 0° / 90°	DIRECTION	N 0° / E 90° / S 180° / W 270°	SLOPE	HORIZON 0° / 90°
				DRILLED	SONATRAM
				LOGGED	I.C.P.

DEPTH	ELEVATION	GEOLOGICAL AGE	ROCK TYPE	ROCK CLASS	DESCRIPTION	DATE	BIT & DIAMETER	WATER LEVEL
1.30	-15.70	Recent	Muddy sand	SM	Muddy gray sand, 30% fines. Quarts grains-, 0.2 mm in diameter and shell fragments. Cohesive consistency: soft.			
6.00	-20.40	Pleistocene (?)	Heterogeneous deposit		Heterogeneous blocks deposited into sand or gravel matrix 1.75- 3m: 7 cm gravel composed of limestone frag. GP/ Limestone fragments, cemented by CaCO3: -grain supported/20% quartz -gray/grainsupported/cavy/banded -gray, foraminifer-rich.			
9.00	-23.40	Pliocene (""Astien"")	Alternation of Sandstone/Marl		Detritical gray marl, fossil rich and carbonaceous sandstone. Sandstone: moderatly hard, gray, fossil rich, cemented by CaCO-3. bedding: horizontal.			
10.50	-24.90				Sandsone and marl.Marl contains 20% detritital grains/slight plasticity/low toughness/moist.		Diamond 85mm	
12.00	-26.40			CL	Sandy marl (48% carbonate) and sand: fine grains, angular, shell fragm.till 4 mm, consistency: soft, no plasticity of fines/SM.			
13.50	-27.90				Sandstone: calcareous.			
15.00	-29.40				Very sandy, gray marl, consistency: very stiff, fossil fragments till 5cm length.			
16.50	-30.90				Alternation sandstone and very sandy marl Marl: moist/ detritical grains concentrated in lenses/ consosistency stiff to hard.			
19.50	-33.90				Alternation marly sand and calcareous sandstone.Marly sand: SW/consistency: stiff.			

CORE RECOVERY % (m) / R.Q.D % (m) / STANDARD PENETRATION TEST



*R.Q.D is Rock Quality Designation, R.Q.D=(Total length of cylindric cores longer than 10 cm)/(Total drill length) x 100%
*LUGEON VALUE is l/min/m under injection water pressure of 10kg/cm2
*DEPTH and ELEVATION are in meter
*DIAMETER is in millimeter

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Fig. 2.4.4 Drill log - Algiers S2

DRILL LOG

SITE	Algiers			HOLE No.	S3
LATITUDE	383781.03	LONGITUDE	534220.31	ELEVATION	-7.80m
DATE	9 November 1991			DEPTH	24.00m
ANGLE	180° UP / DOWN 0°, 90°	DIRECTION	N 0°, E 90°, S 180°, W 270°	SLOPE	HORIZON 0°, 90°
				DRILLED	SONATRAM
				LOGGED	I.C.P.

SCALE	DEPTH	ELEVATION	GEOLOGICAL AGE	ROCK TYPE	COLUMN SECTION	ROCK CLASS	DESCRIPTION
1	1.20	-9.00	RECENT	Mud		CL	Dark grey mud: 30% fine sand, organic material/oversaturated.
2	2.60	-10.40	PLEISTOCENE	Limestone			Yellow cavy limestone consisting of mainly shells (called "Lumachelle"), cemented by CaCO3/contains also quartz/hard
3	3.00	-10.80		Sandstone			Fine sandstone/ moderatly hard/ porous and karstified/voides are filled with chalcedony/no cementation/ moderatly hard
4	3.75	-11.55		Gravel		GW	Gravel consisting of subrounded fragments of sandstone, diameter 4 cm
5	5.50	-13.30		Sandstone			Yellow or grey sandstone: - till 4.2 m soft -4.2-5.3 m grey/cemented/moderatly hard/ white shells mm size, can be further broken down - 5.3 m conjugated fracture, dipping 30 - 5.3-5.5 m gradual passage into sandy marl.
6	8.50	-16.30		Marl		CL	Grey marl: sandy and 4% gravel (fragments of sandstone, 2cm in diameter)/ cohesive consistency: soft/ no plasticity - lowe part is very sandy/ consistency: medium stiff to stiff/ dry strength medium to high/rich in fossils (white shells)
9	10.50	-18.30		Alternation of Sandstone and Marl			Alternation: - 8.5-8.8 m grey sandstone soft/rich in fossils - 8.8-9.1 m sandy marl/rich in shels 9.1-10 m soft sandstone -10-10.5 m soft sandstone and marl with fossils concentrated into layers, thus indicating horizontal bedding.
11	13.95	-21.75		Marl		CL	Grey marl (59% CaCO3): - 10.5-11.5 m very sandy - 11.5-12.5 m medium stiff/ less sandy - 12.5-13.95 m sandy/ medium stiff/ shells are concentrated into layers.
14	15.58	-23.38		Sandstone			Grey sandstone/ moderatly hard/ few shells.
16	24.00	-31.80		Alternation of Sandstone and Marl			Alternation of grey sandy marls and sandstone: -15.58-16.5 m sandy and gravely marl silty (5%) - 17-17.5 m very soft sandstone/many shells: gastropodes 2 cm in diameter -17.5-18 m very sandy marl -18-21.6 m sandstone/ moderatly hard/ horizontal bedding indicated by fossiles -21.6-24 m soft sandstone/ finer grained/ large fossil fragments/ last 5 cm consist of sand.

BIT & DIAMETER: Diamond 85mm

WATER LEVEL

CORE RECOVERY % (m) / R.Q.D % (m)

STANDARD PENETRATION TEST

1.35
1.65
N=32/30cm

*R.Q.D is Rock Quality Designation. R.Q.D=(Total length of cylindric cores longer than 10 cm)/(Total drill length) x 100%
*LUGEON VALUE is l/min/m under injection water pressure of 10kg/cm2
*DEPTH and ELEVATION are in meter
*DIAMETER is in millimeter

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Fig. 2.4.5 Drill log - Algiers S3

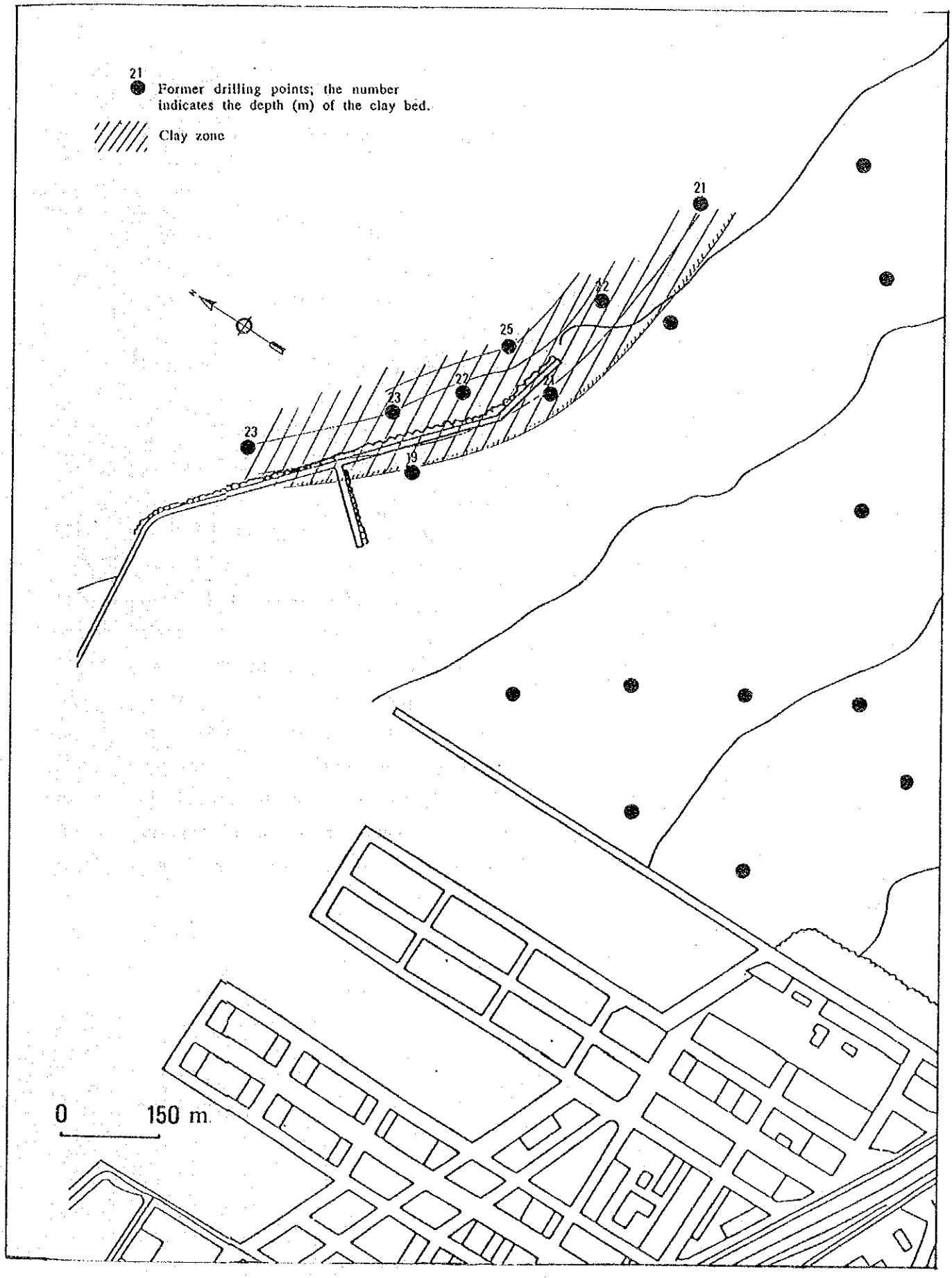


Fig. 2.4.6 The extension of the clay bed in the port of Algiers

(3) Geotechnical conditions

An overview of the lithology of the study area, thickness and continuity of the beds, as well as the results of the Standard Penetration Tests can be seen in fig.2.4.7 and table 2.4.4.

The cover of the study area consists of different sediments, having geotechnical characteristics as explained bellow.
The upper "mud" layer consists of silt, 40-90% and of fine sand. It is oversaturated, has a low plasticity index and a low liquid limit.
According to the Unified Soil Classification System (USCS), the above deposit is a CL-ML soil.
In drilling S3, at 1.2 m depth from the sea floor, a hard limestone, 1.5 m thick, has been found. This layer has a variable thickness and is not continuous. Therefore it can not be used for the foundation.
In drilling S1 (close to the jetty), at 2.5 m depth, a 5.5 m thick sand and clay layer (USCS classification SC-CL) has been encountered. A rough estimation of the allowable bearing strength of this deposit has been effectuated, resulting into values of 13 tons/m^2 (-4.5 m depth from the sea floor) and 17 tons/m^2 (-6 m depth). These estimations are based on the results of Standard Penetration Tests, where 8 to 12 blows have been required for 30 cm penetration. An empirical correlation between the number of blows in the standard penetration test and the cohesion of a clayey soil indicates a cohesion of 8 t/m^2 for N= 12. This value can be directly used in Terzaghi's formula for the calculation of the bearing strength. Only structures with an effective stress of 15 tons/m^2 or less can be supported by this bed. The thickness of the sand and clay layer is diminishing rapidly towards the coast.

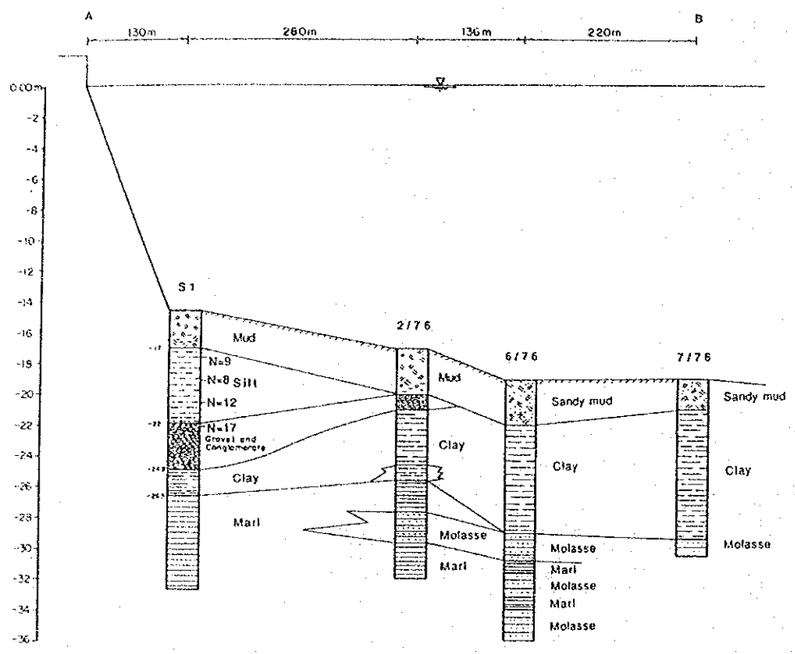
Table 2.4.2 Laboratory physical test data of Algiers

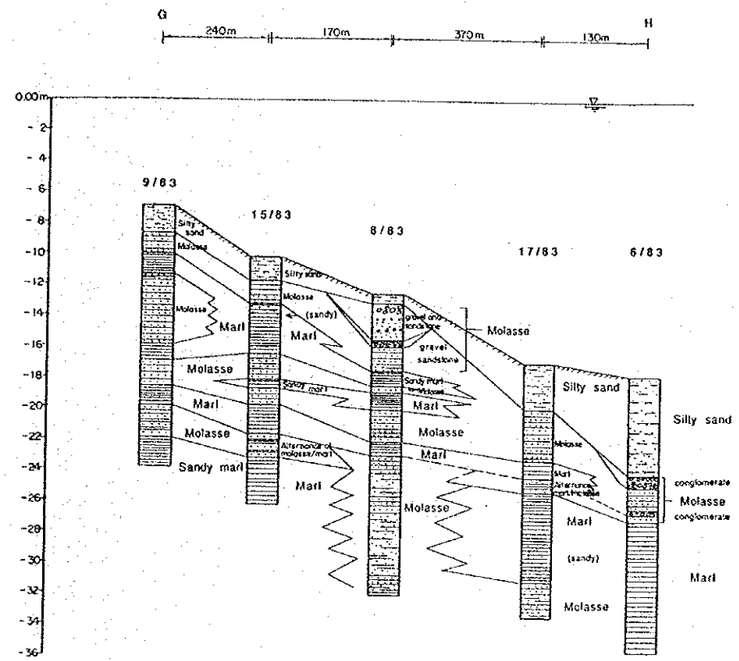
Algiers-drilling S1						
Depth of sampling (m)	0.0-2.0	2.4-2.9	5.0-6.0	10.5-11.5	12.7-13.45	15.15.5
Type of soil	Mud:95% fines	Sandy clay:16% sand	Clayey sand:52% fine sand,48% fines	Sandyclay,17% sand	Sandy marl:18-32% sand	Sandy marl
Classification	CL	CL	SC-CL	CL	CL	CL
Carbonate(%)					41	41
Grainsize(%)<2mm; <80 <20 ;<3	100/98/61/8	100/92/10.2/7	99/69/7/4	100/88/18/7	100/89/41/6	100/78/27/6
Water content %		24.8	24.32	30.78	29.85	28.93
Dry density T/m3		1.68	1.65	1.49	1.65	1.52
Wet density T/m3		2.08	2.05	1.95	1.99	1.96
Degree of saturation (%)		100	100	100	100	100
Liquid limit	49	26	23	42	40	42
Plasticity Index	24	8	7	20	16	18

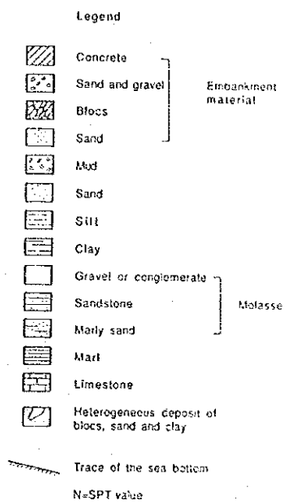
Algiers-drilling S2				
Depth of sampling (m)	0.0-1.3	7.0-8.0	9.35-9.7	11.0-11.6
Type of soil	Mud:fine sand	Calcareous standstone	Marl(grainsize 20% coarse-42% fine sand	Marl
Classification	SM		CL	CL
Carbonate(%)				
Grainsize(%)<2mm; <80 ;<20 ;<3	99/28/9/2		99/63/15/4	98/46/19/3
Water content %			32.78	29.8
Dry density T/m3			1.46	1.53
Wet density T/m3			1.94	1.985
Degree of saturation (%)			100	100
Liquid limit			35	37
Plasticity Index			16	14

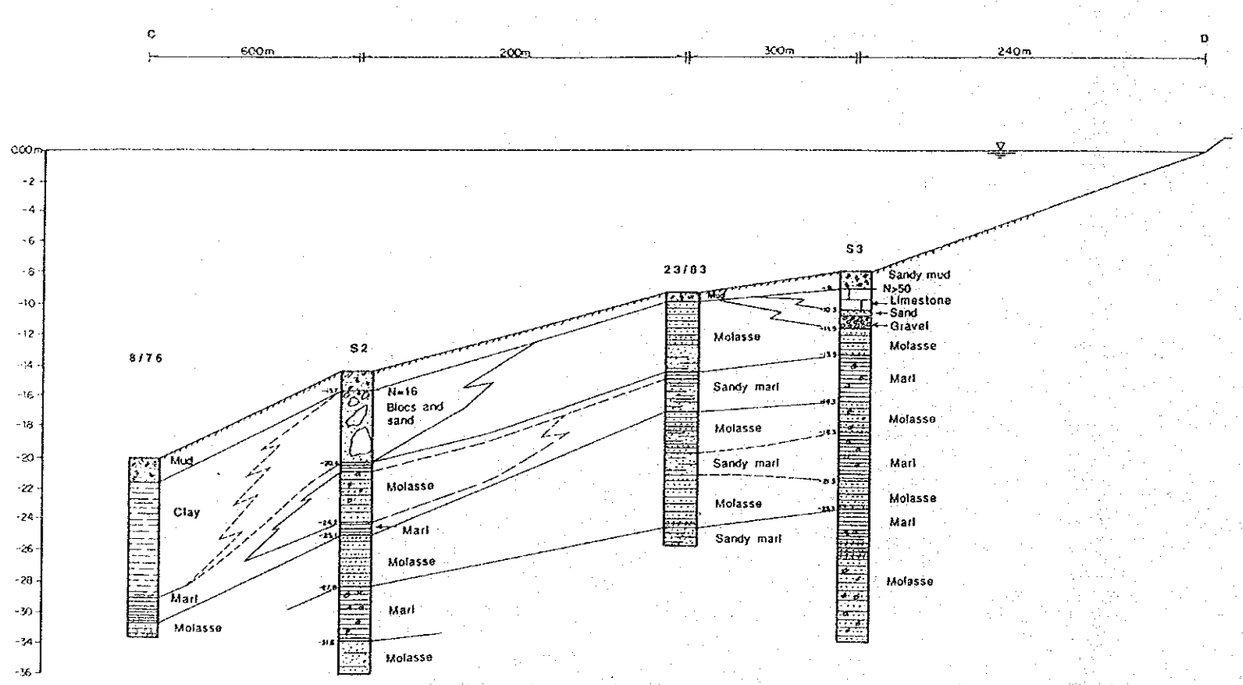
Algiers-drilling S3						
Depth of sampling	0.0-1.2	4.0-5.0	6.9-7.5	13.5-13.8	17.75-18.0	23.6-24
Type of soil	Mud:50% fines, 30% fine sand,	Sandstone	Marl	Marl	Sandy marl	Sandy marl
Classification	CL		CL	CL	CL	CL
Carbonate(%)			34.4	53		49.2
Grainsize(%)<2mm; <80 ;<20 ;<3	100/50/6/4		100/90/43/5	97/71/30/5	92/64/30/5	97/59/14/4
Water content %			33.58	46.17	20.94	21.45
Dry density T/m3			1.53	1.25	1.64	1.71
Wet density T/m3			2.04	1.83	1.98	2.08
Degree of saturation (%)			100	100	87	100
Liquid limit	25		37	38	31	30
Plasticity Index	8		19	16	10	8

ALGIERS









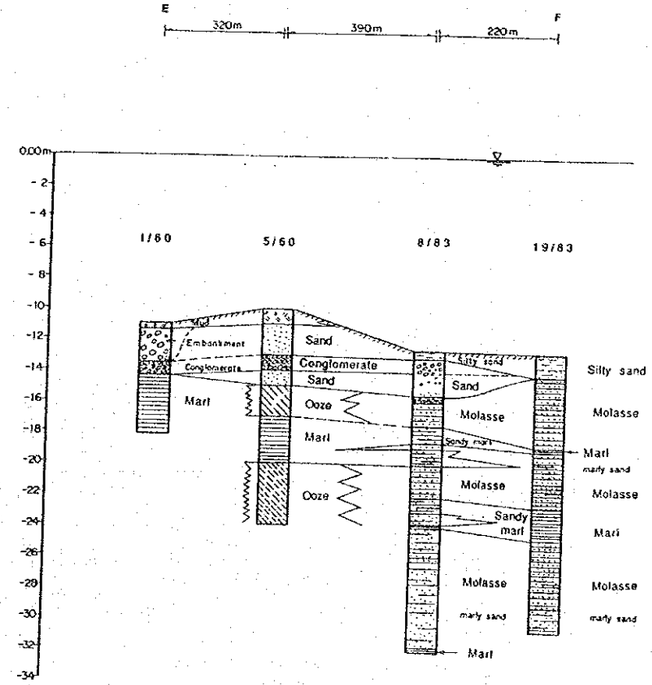


Fig. 2.4.7 Geological cross-sections of the port of Algiers

Table 2.4.3 Laboratory mechanical test data of Algiers

Location	Depth range (m)	Consolidation test: Compression index	Consolidation test: Swelling ratio	Pre-consolidation stress (Kg/cm2)	Shear test: Conhesion (Kg/cm2)	Shear test: Friction angle ø (degrees)
Algiers S1	10.5-11.5	0.084	0.03	3.6		
	12.7-13.45	0.057	0.027	2.6	1.1	40
	15.0-15.5	0.058	0.017	2.8	0.9	23
Algiers S2	9.35-9.7	0.167	0.041	2.6	0.75	35
	11.0-11.6	0.111	0.022	4.25	1.0*	35*
Algiers S3	6.9-7.5	0.116	0.037	4.25	0.48	45*
	13.5-13.8	0.502	0.036	6.25		
	17.75-18.0	0.074	0.019	4.5		

*-Values obtained from triaxial tests

Table 2.4.4 Results of the standard Penetration Test in Algiers

Location	Depth	Lithology	Nr.of blows per	N-value	Cohesion (t/m2)	Friction angle ø(degrees)
Algiers S1	2 m	clay + silt	4/3/6.	9	4	0
	4.5 m	fine sand	5/3/5.	8	6	0
	6 m	clayey sand	3/5/7.	12	8	0
	7.5 m	conglomerate		17	0	34
Algiers S2	1.3 m	sand	6/7/9.	16	0	34
Algiers S3	1.2 m	gravel	15/17/no	32		

Under the slit bed there is a conglomerate, 2.5 m thick. A SPT-test has been done at the top of this conglomerate, where the rock is deemed to be rather weathered and disintegrated into fine gravels, giving 17 blows for 30 cm penetration. This value can be roughly converted into an allowable bearing strength around 30 tons/m^2. Again it should be mentioned that this layer is not continuous.

Under the conglomerate there is a 1 m thick, stiff clay. From the laboratory data (tables 2.4.2 and 2.4.3) the clay has been classified as CL soil, 100% saturated, medium plasticity. From the granulometric curve it is rather a silt with 17% fine sand. Clay intercalations. have been already noticed in the conglomerate bed above. Downward, the clay is gradually passing into the marl formation. From the shearing test this clay has a cohesion of 2 kg/cm^2. According to this value, much higher than expected, the clay is very similar and probably a part of the marl formation. This fact does not correspond to the much softer aspect of the fresh clay (compared to the marl), in the site.

Because of the Ambiguous appearance some more considerations should be made about this clay layer, based on former data obtained by in-situ testing. An SPT value of 14 has been registered at 7 m depth from the sea floor. This roughly corresponds to an allowable bearing strength of 17 tons/m^2. Other information has been obtained from borehole loading tests, using the pressiometer, along the Mustapha jetty. The ultimate pressures which have been measured range from 0.7 to 3.5 bar,indicating the following:

- the tested bed is a clay with varied strengths and different consolidation rates (ultimate pressure between 1.5 and 3.5 bar), but generally speaking stiff;
- close to the base of this bed (-25 to-27 m depth from the sea level), the clay is relatively softer (ultimate pressure 0.7-1.5 bar), especially around the end of the Mustapha jetty.

The clay bed cannot by considered as reliable foundation bed.

The Pliocene basement of marl or Molasse (mainly sandstone, moderately hard), is well consolidated and will provide a sufficiently reliable foundation bedrock to support the heavy structures of the port facilities.

From previous and present drilling data, this basement can be reached within 10 meters from the sea floor at the Mustapha jetty, within 5 m at the eastern breakwater and within 6-7 m in the study area. At the jetty and at the eastern breakwater basement consists of Marl.,while in the study area it can be Molasse or Marl. In situ vane test data from previous investigations (1983) show that the shearing resistivity in the marls is 28 tons/m^2, at 7 m depth from the sea floor.

Further information over the basement formation is given in tables 2.4.2 and 2.4.3.

According to the physical tests, when disintegrated, the marls consist of rather fine material (the granulometric curves show up till 80% silt or clay). According to the USCS the marls fall under the cathegory of CL-soils with low to medium plasticity, 100% saturated, but they also can be classified as soft rocks. The mechanical characteristics of the marls are shown in table 2.4.3. The simple shear tests and the triaxial shear tests indicate 1.0 kg/cm^2 for the cohesion and 35 degrees for the internal angle of friction. Using Terzaghi's formula the values of the calculated allowable bearing strength, ranging between 60 and 300 t/m^2, correspond to the characteristics of soft rocks.

According to the consolidation tests, the marls are said to be normally to over consolidated, the pre-consolidation stresses are ranging from 26 ton/m^2 to 62 ton/m^2. These values seem to have been taken lower than the real values, depending on the shape of the graph of logarithmic pressure vs. void ratio (the curves do not show clear breaking points). The compression index is low meaning that no substantial settelement will occur.

As for the Molasse deposits, the unconfined compressive strength measured on a sandstone sample, corresponds to a weak rock (102 $tons/m^2$).

Conclusion

The superficial cover of the sea bottom is not suitable as a foundation bed for heavy structures, causing higher stress than mentioned above. In such a case deep foundation work or piles should be driven into the Tertiary bedrock. This may be required along the Mustapha jetty and its extension. A foundation depth around 12 m from the sea floor should be considered there.

In the area to the east from the eastern breakwater, the foundation bed should be the Pliocene (Tertiary) sedimentary rocks, which can be encountered within the depth of 6 m from the sea floor.

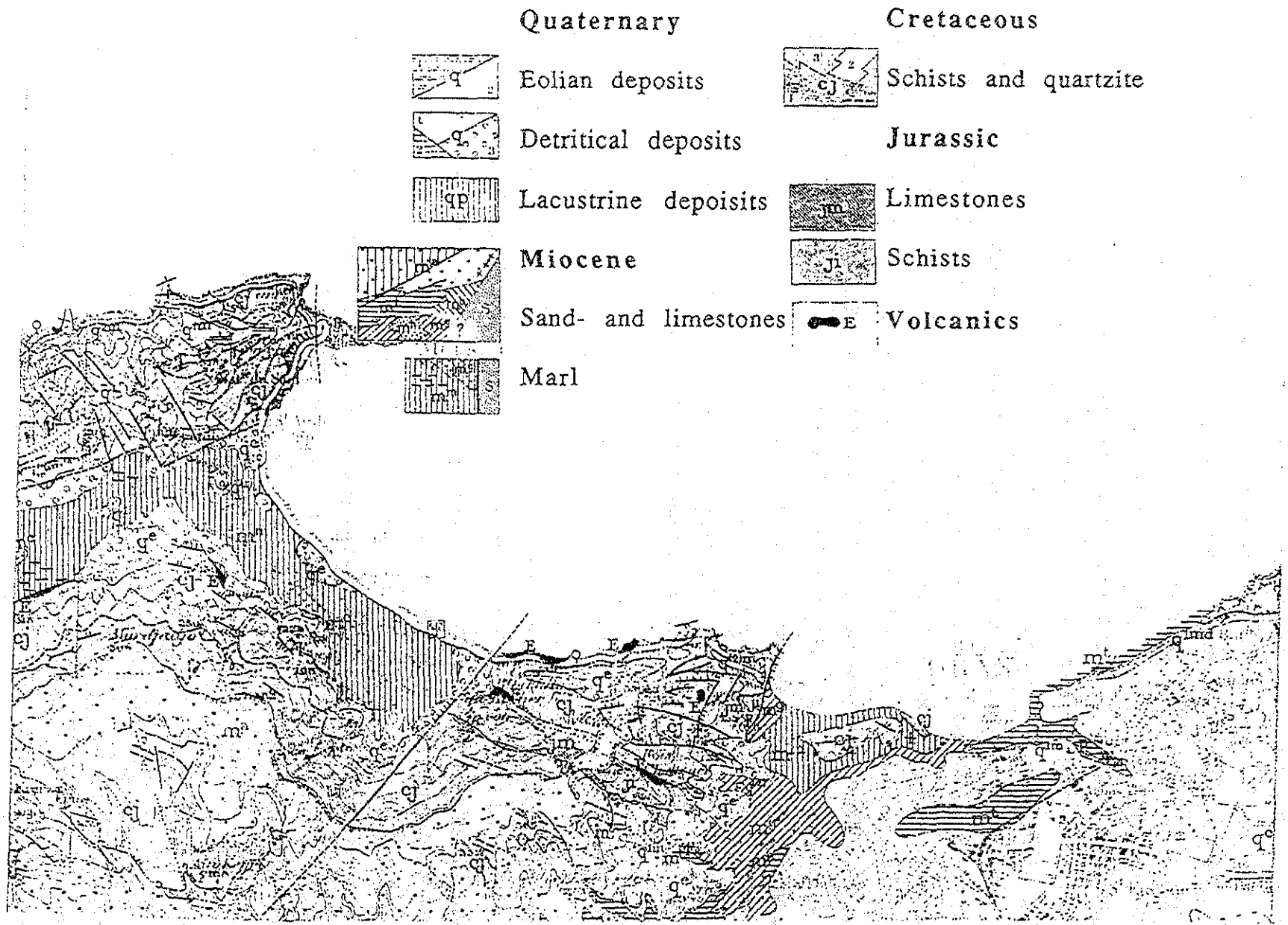


Fig. 2.4.8 Geological map of Oran (scale 1:50,000m)

2.4.3 The Port of Oran

(1) General topography and geology

The port of Oran is located in the middle of a 28 Km large bay and it is surrounded by cliffs, the altitude being higher on the west side than on the east side. At the west, the port is limited by a steep slope, rising up till 400 m, which is part of the mountain called "La Montagne du Lion". This mountain has steep slopes and a long, flat crest, with the highest peak reaching 611 m. From this mountain to the east the city of Oran has been built on a plateau, around 100 m above the sea level. The border of this plateau on the sea side is a cliff, several Km long. Because of the steep topography the area covered by the port facilities is very limited.

The sea bottom is gently dipping 2 degrees from the coast to the jetty and 3 degrees from the jetty to off-shore. At the jetty the water depth is close to 20 m.

The geological map of Oran is shown in figure 2.4.8. The west cliff bordering the port consists of Lower Cretaceous limestone and Jurassic schists. The cliff is dislocated by a normal fault,

the east part being the down-thrown block. This fault puts the Cretaceous sediments in contact with Miocene sediments. The Miocene consists of grey marl and conglomerate on top of it. The cliffs east from the Montagne du Lion consist of marl.

Furthermore the Oran plateau is covered by Quaternary alluvial deposits.

From a structural point of view, the Montagne du Lion represents a horst and the plateau to the east represents a graben, due to vertical movements along faults. These movements have started during the Neogene. The faults were reactivated during the Quaternary.

(2) Detailed geology of the sea bottom in the study area.

The study area consists of the last basin against the breakwater, the so called "avant-port" and the area to the east of the breakwater. Three drillings have been done (S1 to S3) their locations being indicated on the attached map of the port of Oran (Fig.2.4.9 and 2.4.10). The drilling logs are shown in figures 2.4.11, 2.4.12 and 2.4.13.

The cover of the sea floor in the port of Oran consists of the following layers:

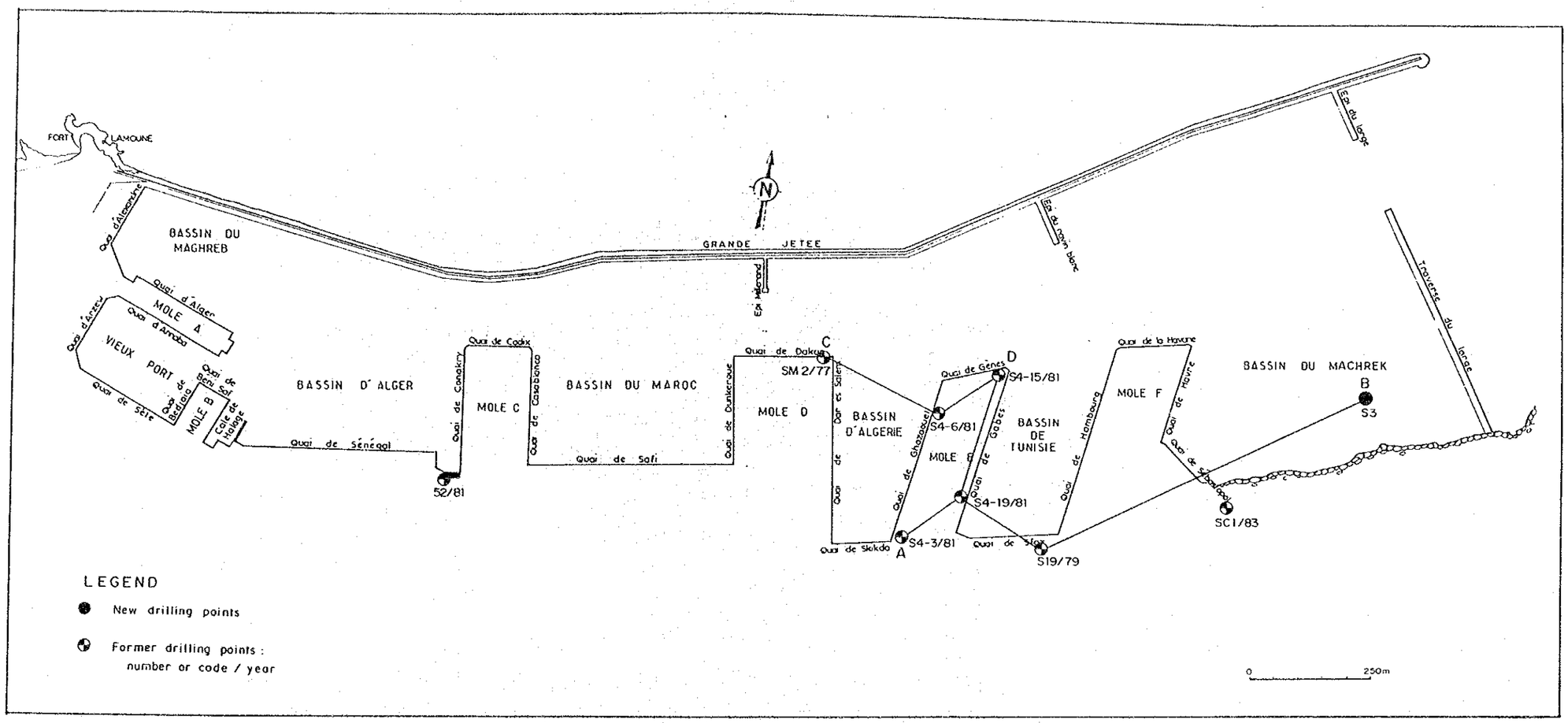
Recent to Pleistocene:

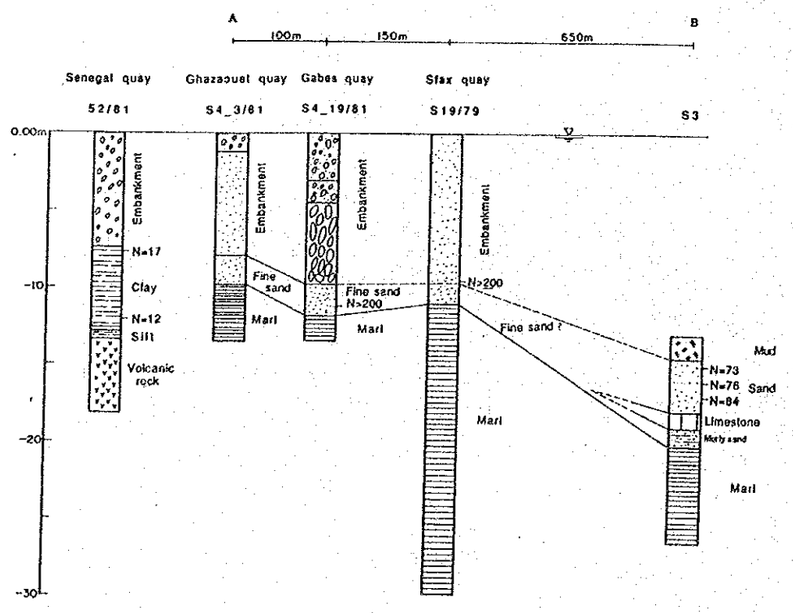
- Upper layer a: black, organic "mud", up till 2 m thick;
- Layer b: clean medium sand, 3.5-5 m thick, consolidated:
- Layer c: limestone or calcareous sandstone, rich in shells, called "Lumachelle" 1 m thick, not continuous;

Pliocene (?):

- Layer d: sandy and gravely clay, rich in fossils, 0.6 m thick, containing fragments of detrital limestone. Gradual passage into marl (only in S3).

The basement rock under the sea floor consists of Miocene grey marl, of unknown thickness with a varying sand content.





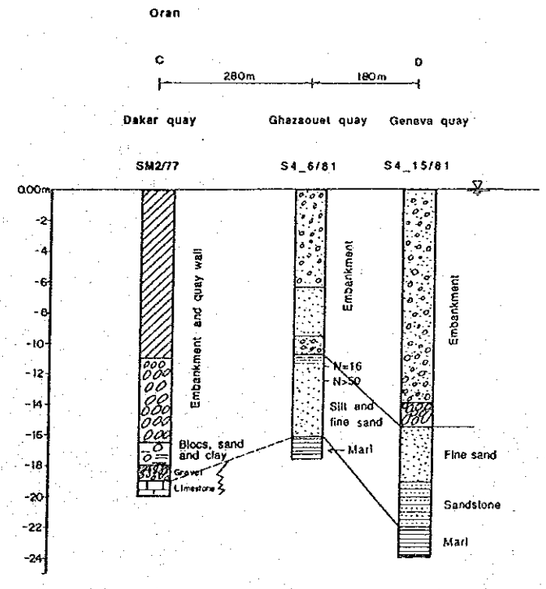


Fig. 2.4.9 Port of Oran: location of former boreholes and geological cross-sections

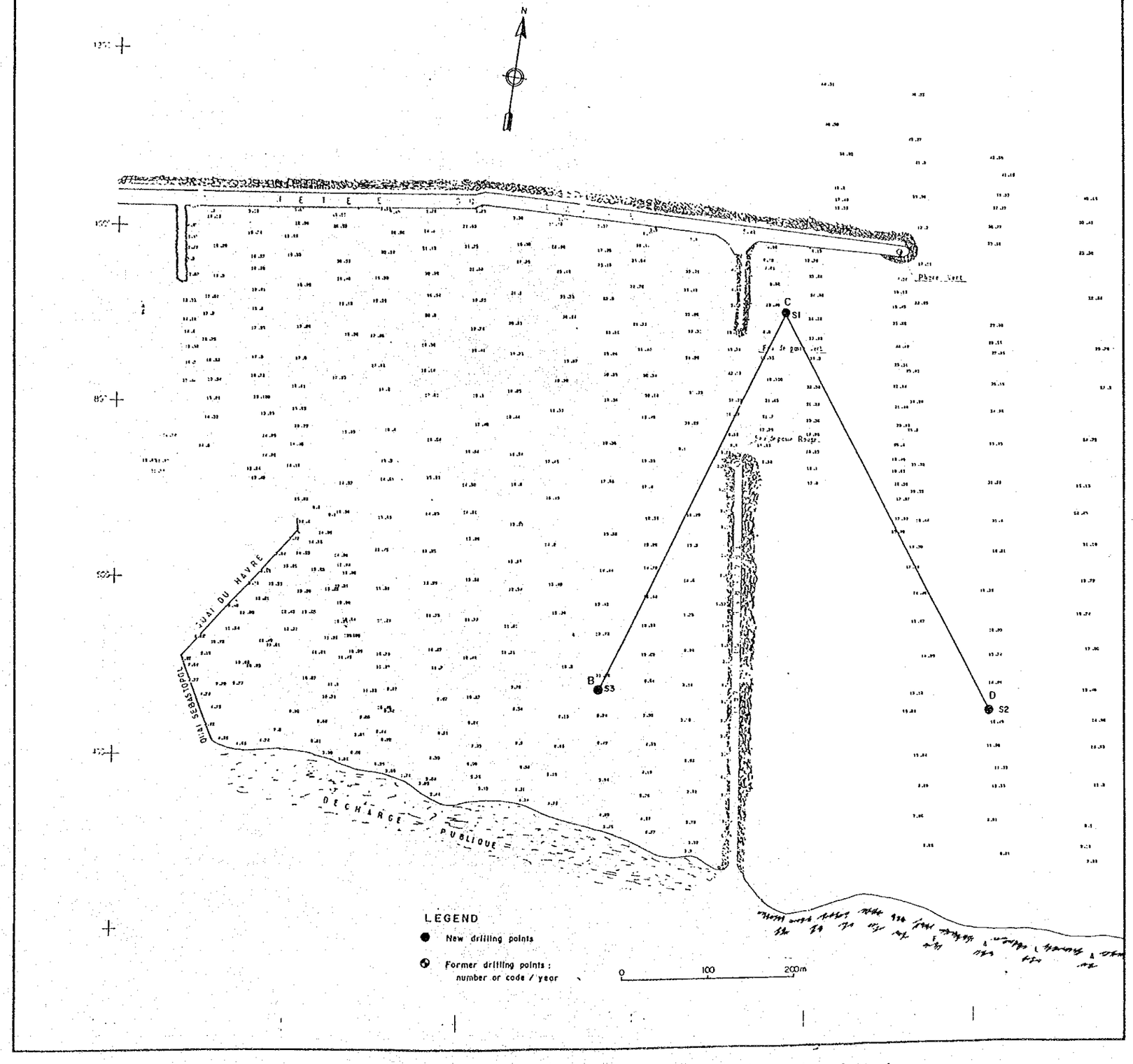


Fig. 2.4.10 Port of Oran: location of the new drill holes and geological cross-sections

DRILL LOG

SHEET NO. 1 OF 1

SITE	Oran	HOLE No.	S1
LATITUDE		LONGITUDE	ELEVATION -22.00m
DATE	12 December 1991	DEPTH	15.00m
ANGLE	180° UP / DOWN 0° / 90°	DIRECTION N 0° / E 90° / S 180° / W 270°	SLOPE HORIZON 0° / 90°
		DRILLED	SONATRAM
		LOGGED	I.C.P.

SCALE	DEPTH	ELEVATION	GEOLOGICAL AGE	ROCK TYPE	COLUMN SECTION	ROCK CLASS	DESCRIPTION	DATE	BIT & DIAMETER	WATER LEVEL	CORE RECOVERY % (m)	R.Q.D % (m)	STANDARD PENETRATION TEST
1			Recent	Mud		SC-CL	Black, organic silty-clayey sand: fine to medium sand (56%), silt (44%).				0 (1.50)	0 (1.50)	
2													
3			Pleistocene	Sand		SW	Clean medium sand/grey/ well graded/ 5 % coarse graines/ no clay.				0 (3.00)	0 (3.00)	3.15 N=50/30cm
4													3.45
5											0 (4.50)	0 (4.50)	4.15 N>50/30cm
6													4.45
													5.15 N>50/30cm
											0 (6.00)	0 (6.00)	5.45
				Sands-tone			Coarse, gray sandstone, calcareous cement, very rich in shells.						6.15 N>50/30cm
7			Pliocene	Sandy Marl		ML	Sandy marl (around 20% of sand), crumbly at the top.		Diamond 85mm		100 (6.70)	29 (6.70)	6.45
8							Gray sandy marl.				77 (7.50)	64 (7.50)	
9											68 (9.00)	47 (9.00)	
10						ML or CL	Clayey marl (90% fines)/gray/fossil fragments.				83 (10.50)	20 (10.50)	
11													
12						CL	Sandy marl/ grey/easily crumbling.				68 (12.00)	68 (12.00)	
13											99 (13.50)	99 (13.50)	
14													
15											32 (15.00)	24 (15.00)	
16													
17													
18													
19													
20													
21													
22													
23													
24													
25													
26													
27													
28													
29													
30													

*R.Q.D is Rock Quality Designation. R.Q.D=(Total length of cylindric cores longer than 10 cm)/(Total drill length) x 100%
*LUGEON VALUE is l/min/m under injection water pressure of 10kg/cm2
*DEPTH and ELEVATION are in meter
*DIAMETER is in millimeter

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Fig. 2.4.11 Drill log - Oran S1

DRILL LOG

SHEET NO.1 OF 1

SITE	Oran	HOLE No.	S2
LATITUDE	LONGITUDE	ELEVATION	-15.00m
DATE	13 December 1991	DEPTH	13.50m
ANGLE	180° UP / DDWN 0° / 90° — DIRECTION — N 0° / W 270° / E 90° / S 180° — SLOPE — HORIZON 0° / 90°	DRILLED	SONATRAM
		LOGGED	I.C.P.

SCALE	DEPTH	ELEVATION	GEOLOGICAL AGE	ROCK TYPE	COLUMN SECTION	ROCK CLASS	DESCRIPTION	DATE	BIT & DIAMETER	WATER LEVEL
1	0.80	-15.80	Recent	Mud	//	CL	Black mud, fine and medium (45% : 27%) sand and silt (23%).			
2			Pleistocene	Sand		SW	Clean medium sand with 20 % fine sand/ grey/ shell fragments.			
3										
4										
5										
6	6.00	-21.00								
	6.70	-21.70		Sands-tone			Sandstone/coarse to fine/ gray to yellow/ calcareous cement/ very rich in shells.			
7			Pliocene	Sandy Marl		MH or CH	Sandy marl (around 20% of sand)/gray and yellow/very soft (crumbly).		Diamond 85mm	
8										
9	9.00	-24.00								
10						CH	Gray marl, fractured.			
11										
12										
13	13.50	-28.50								
14										
15										
16										
17										
18										
19										
20										
21										
22										
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25										
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27										
28										
29										
30										

CORE RECOVERY % (m) 0 50 100

R.Q.D % (m) 0 50 100

(1.50) 0 (1.50) 0
(3.00) 0 (3.00) 0
(4.50) 0 (4.50) 0
(5.00) 0 (5.00) 0
(5.70) 0 (5.70) 0
(7.50) 50 (7.50) 88
(9.00) 83 (9.00) 67
(10.50) 94 (10.50) 68
(12.00) 96 (12.00) 90
(12.50) 98 (13.50) 79

STANDARD PENETRATION TEST

0 10 20 30 40 50

2.15
2.45 N>50/30cm
3.15
3.45 N>50/30cm
4.15 N>50/30cm
4.45
5.15
5.45 N=50/30cm
6.15
6.45 N>50/30cm

*R.Q.D is Rock Quality Designation. R.Q.D=(Total length of cylindric cores longer than 10 cm)/(Total drill length) x 100%
*LUGEON VALUE is l/min/m under injection water pressure of 10kg/cm2
*DEPTH and ELEVATION are in meter
*DIAMETER is in millimeter

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Fig. 2.4.12 Drill log - Oran S2

DRILL LOG

SHEET NO. 1 OF 1

SITE	Oran	HOLE No.	S3
LATITUDE		LONGITUDE	ELEVATION -13.00m
DATE	3 December 1991	DEPTH	13.50m
ANGLE	180° UP, DOWN 0°, 90°	DIRECTION N 0°, E 90°, S 180°, W 270°	SLOPE HORIZON 0°, 90°
		DRILLED	SONATRAM
		LOGGED	I.C.P.

SCALE	DEPTH	ELEVATION	GEOLOGICAL AGE	ROCK TYPE	COLUMN SECTION	ROCK CLASS	DESCRIPTION	DATE	BIT & DIAMETER	WATER LEVEL	CORE RECOVERY % (m)	R.Q.D % (m)	STANDARD PENETRATION TEST
1			Recent	Mud		CL	Black, organic mud: silt (50%), fine to medium sand (42%).				0 (1.50)	0 (1.50)	
2			Pleistocene	Sand		SW	Clean medium sand/grey/ well graded/ no clay/ round quartz grains 0.5mm in diameter, dark grains 0.2mm and angular fossil fragments.				10 (3.00)	0 (3.00)	2.15 2.45 N>50/30cm; 3.15 3.45 N>50/30cm
5				Lime stone			Yellow limestone ("Lumachelle")/ very rich in shells				10 (4.50)	0 (4.50)	4.15 4.45 N>50/30cm
5							Yellow clay+ siltenveloping limestone fragments/ medium plasticity/ cohesive consistency: soft/ Lower 6 cm: yellow, soft limestone.				20 (6.00)	19 (6.00)	
7			Pliocene	Clay									
7				Sandy Marl		CH	Sandy marl /grey with yellow inclusions/very soft/ fossils (white forams.)/moist.		Diamond 85mm		90 (7.50)	45 (7.50)	
9				Marl			Grey marl/ soft/spherical fossils (foram.)0.5-1mm in diameter/moist -7.2-9 m fractures, dip 90 and 72; on the fracture planes concentration of organic material (algae) -10.5-12 m moderatly hard/vertical, closed fracture.				100 (9.00)	90 (9.00)	
11											93 (10.50)	90 (10.50)	
12											100 (12.00)	100 (12.00)	
13											38 (13.50)	22 (13.50)	
14													
15													
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29													
30													

*R.Q.D is Rock Quality Designation. R.Q.D=(Total length of cylindric cores longer than 10 cm)/(Total drill length) x 100%
*LUGEON VALUE is l/min/m under injection water pressure of 10kg/cm2
*DEPTH and ELEVATION are in meter
*DIAMETER is in millimeter

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Fig. 2.4.13 Drill log - Oran S3

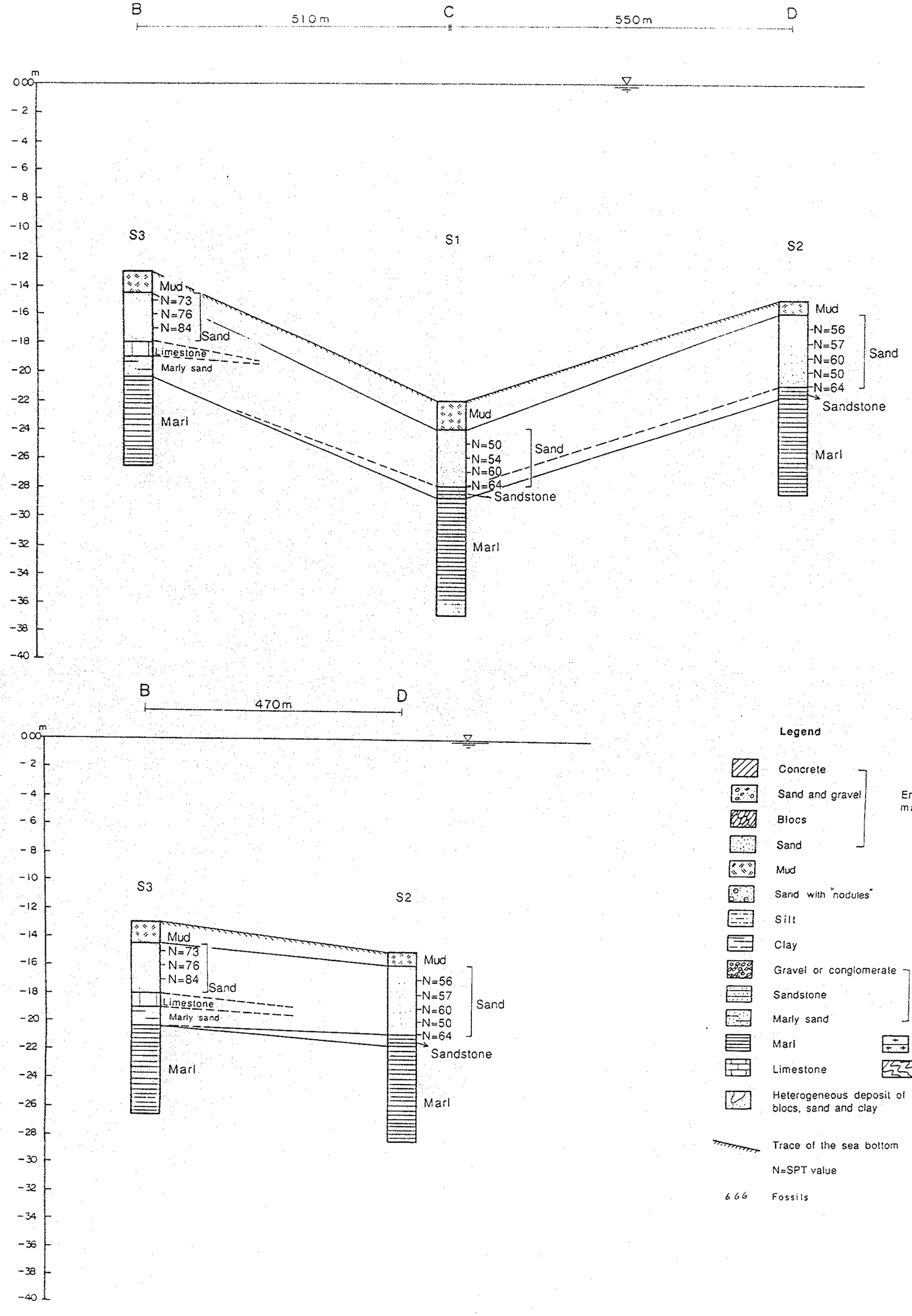

Fig. 2.4.14 Geological cross-sections of the port of Oran

Table 2.4.5 Laboratory physical test data of Oran

Oran-drilling S1								
Depth of sampling	0.0-2.0	3.0-6.0(SPT)	6.7-7.5	7.5-7.9	9.0-9.4	10.5-11.1	12.0-12.5	12.5-15.0
Type of soil	Clayey sand (44% fines)	Clean medium sand	Sandy marl(20% sand)	Sandy marl (30% sand)	Clayey marl (90% fines)	Sandy marl (40% fine sand)	Marl	Marl
Classification	SC-CL	SW	ML	ML	ML or CL	CL	CL	CL
Carbonate(%)			43.38	44.28	29.52	36.05	44.28	31.98
Grainsize(%)<2mm; <80 <20 ;<3	100/52/16/3	100/2/0/0	100/86/41/14	100/88/32/8	100/98/62/33	100/90/41/14	100/90/39/14	100/92/52/21
Water content %				26.47	26.02	26.96	27.15	
Dry density T/m3				1.53	1.62	1.62	1.6	
Wet density T/m3				2.01	2.04	2.06	2.03	
Degree of saturation (%)				100	100	100	100	
Liquid limit	47	25.8	49	46	50	48.53	43	49.3
Plasticity Index	23.9	9.47	21	18.17	22.61	23.2	17.97	26.77

Oran-drilling S2							
Depth of sampling	0.0-0.6	0.6-6.0(SPT)	6.0-7.0	7.0-7.5	7.5-7.7	9.0-9.5	11.0-11.5
Type of soil	Black mud:72% fine sand	Clean medium sand	Sandstone	Sandy marl	Sandy marl	Marl	Marl
Classification	CL	SW		CH	MH	CH	CH
Carbonate(%)				45.1		32.8	
Grainsize(%)<2mm; <80 <20 ;<3	100/34/14/2	100/4/0/0		100/81/37/17	100/71/45/16	100/98/63/23	100/98/38/14
Water content %					26.47	26.4	24.4
Dry density T/m3					1.59	1.6	1.63
Wet density T/m3					2.01	2.02	2.03
Degree of saturation (%)					100	100	100
Liquid limit	44.3	24.9		53	51	53.07	50
Plasticity Index	22.76	7.81		24.82	12.73	29.07	24

Oran-drilling S3					
Depth of sampling (m)	0-1.0	2-4(SPT)	6.0-6.6	6.6-7.0	8.0-8.5
Type of soil	Mud:58% silt +clay,42% sand	Medium sand	Sandy clay,sand 26%	Sandy marl	Marl
Classification	CL	SW	CH	MH/CH	CH
Carbonate(%)				45.92	31.16
Grainsize(%)<2mm; <80 <20 ;<3	100/65/29/4	100/5/0/0	100/81/61/13	100/80/34/15	100/98/65/24
Liquid limit	41.2	25.8	55	53	51.3
Plasticity Index	15.53	10.62	28	24	26.93

Table 2.4.6 Laboratory mechanical test data of Oran

		Consolidation test			Shear test	
Location	Depth range (m)	Compression index	Swelling ratio	Pre-consolidation stress (Kg/cm2)	Conhesion (Kg/cm2)	Friction angle ø (degrees)
Oran - S1	7.5-7.9	0.035	0.006	4.25	3	42
	9.0-9.4				1.62	28
	10.5-11.1	0.051	0.015	2.5	1.9*	29*
	12.0-12.5	0.045	0.011	3.2	3.5	47
Oran - S2	7.5-7.7	0.071	0.016	4.25		
	9.0-9.5	0.072	0.013	7	1.4	52.5

Notice*-indicates the Values from triaxial shear tests

Table 2.4.7 Results of the standard Penetration Test in Oran

Location	Depth	Lithology	Nr.of blows	N-value	Cohesion (t/m2)	Friction angle ø (degrees)
Oran S1	3m	sand	20/23/27	50	0	44.4
	4m	sand	23/26/28	54	0	45
	5m	sand	25/29/31	60	0	45
	6m	sand	30/30/34	64	0	45
Oran S2	2m	sand	24/27/29	58	0	45
	3m	sand	27/27/30	57	0	45
	4m	sand	29/29/31	60	0	45
	5m	sand	22/25/25	50	0	44.4
	6m	sand	29/31/33	64	0	45
Oran S3	2m	sand	23/32/41	55	0	45
	3m	sand	27/33/43	60	0	45
	4m	sand	25/37/47	62	0	45

(3) Geotechnical conditions

The sedimentary cover of the sea floor in the study area shows good geotechnical characteristics. Standard Penetration Test data (table 2.4.7) indicate N-values exceeding 50 blows for the depth range 2-6 m from the sea floor, in a sand bed. It is a medium sand, well graded, with round grains, containing fine material in considerable proportions. It has a low plasticity index, low porosity and is strongly compacted. This characteristics imply an internal angle of friction more than 45 degrees. The sand has been encountered in all the three drillings (fig. 2.4.14). To the west, the sand extends till the quay of Geneva. Its off-shore extension is at least till the jetty. This bed is encountered at 1 to 2 m under the sea floor and has a thickness of 3 to 5 m. As far as it is continuous, it can be considered a reliable foundation bed.

The basement rock under the sea floor in the port of Oran is shallow. In all the three drillings the basement has been reached at a depth of 7 m from the sea floor (or -20 m from the water surface, in drilling S3 and 29 m from the water surface in S1, close to the jetty; fig.2.4.14). To the west, at the Ghazaouet, Gabes and Sfax quaies, the marly basement can be reached at a depth between 8 and 11 m form the water surface (cross section A-B in fig.2.4.9). At the Geneva quay the marl lies 22 m under the water surface (cross section C-D, fig.2.4.9). It is probable that the surface of the marl formation is inclined (a dip of 3 degrees) towards the off-shore. Former Standard Penetration Test data give an N-value of 50 blows per 30 cm,at the top of the marls. From the mechanical tests the marl seem to be overconsolideted,the preconsolidation stresses are between 25 and 70 ton/m^2. The shear tests indicate cohesion values between 0.4 and 2 kg/cm^2 and friction angles of 28-45 degrees. This means the allowable bearing strength is a few hundreds t/m^2.

The marl formation can also be used as a foundation rock.

The west part of the port has a different lithology. Former drillings at the quay of Senegal show a clay bed covering a volcanic basement (cross section A-B, fig 2.4.9). This lithology does not extend further than the basin of Maroc.

2.4.4 The Port of Annaba

(1) General topography and geology

The Port of Annaba is located on the west side of a 40 Km wide bay, between two capes, i.e. the "Cap de Garde" to the west and the "Cap Rosa" to the east.

From the Cap de Garde till the city of Annaba the topography is steep and mountainous. The highest peak just next to the city of Annaba, called Abd el Salam is 328 m high.

The mountain range continues westwards, along the coast line. The altitude is rapidly increasing to 845 m at the peak of Seraide, 18 Km west from Annaba.

East from Annaba, along the bay, an alluvial plain, almost 20 Km wide, is developed. This plain stretches NE-SW in between the mountain of Seraidi, to the NW and the mountains of Medjerda to the SE. Many rivers stream off these mountains, the "Oued Seybouse" being one of the largest. The river mouth was originally located in the port zone itself, but it has been deflect 500 m to the south, to its present position.

The Port of Annaba is located SE of the ciyt, enclosed between the long breakwater to the SE and the jetty called "Jetee du Lion" to the NE.

The sea bottom in the port and east from it (along the whole bay) is gently dipping 0.4 degrees. From the jetty to the north the sea bottom topography is steeper, dipping 2.3 degrees.

The water depth at the jetty is 14 m, increasing to a depth of 20 m, at 400 m distance, north from the jetty.

The mountain chain starting at the Cap de Garde and continuing till Seraido consists of Palezoic gneiss, schist and marble. All these rocks show a high degree of deformation. Especially the schists are strongly folded and foliated. The weathering material from this rocks has been redeposited on the see bottom as a micaceous sand or silt.

Under the alluvial deposits of the large plain bordering the bay of Annaba, Tertiary calcareous sediments can be found.

(2) Detailed geology of the sea bottom in the study area

The study area is located to the SE from the breakwater of the existing port of Annaba.
Three drillings S1 to S3 have been done, their positions being indicated on the figure 2.4.15. The detailed geological log can be seen in figures 2.4.16 to 2.4.18.

The basement of this area consists of marble and underneath gneiss and schist. Outcrops can be seen just behind the port. The surface of this rock formation is rapidly plunging to the SE. Therefore, in the port, under the basin "La Petite Darse", the basement lies -8 m under the sea floor and -26 m at the breakwater. Compiling the results of the former drilling the roof of the basement shows the following topography. Under the basin it forms a gently dipping terrace (1.5 degrees) till the breakwater. From the breakwater to the SE the "terrace" becomes narrow; it continues only at the jetty-side of the breakwater, like a "tongue", towards the SE (the gneiss lies at -45 m in drilling S3, the same as in former drillings S10/85, which is very close to the breakwater). In all the drillings located between this "tongue" and the coast, the basement has not been encountered. It seems that the gneiss is plunging 6 degrees under the plain of Annaba. The configuration of the surface of the basement is most likely the result of the erosion.

Quaternary deposits lie directly on the gneiss, forming the sedimentary cover of the study area. These sediments are similar to those described in the plain of Annaba: clay and sand, their thickness attends more than 60 m (drilling S18A/85), in the shallow water zone and between 20 and 30 m close to the jetty. The sands are especially rich in shells. Six layers can be roughly distinguished as follows:

- Upper layer a: block, organic mud and/or sand, thickness 1.5-2 m:
- Layer b: clayey or gravely sand different degree of consolidation, thickness 0-8.5 m;
- Layer c: clay and sandy clay with intercalations of sand and clayey sand, soft to slightly consolidated, thikness 12-14 m;
- Layer d: consolidated sand and sand with iron concretions ("nodules") overlaying a soft sandstone, thickness 6-12 m;
- Layer e: clay or sandy clay, generally stiff, including sand lenses, thickness

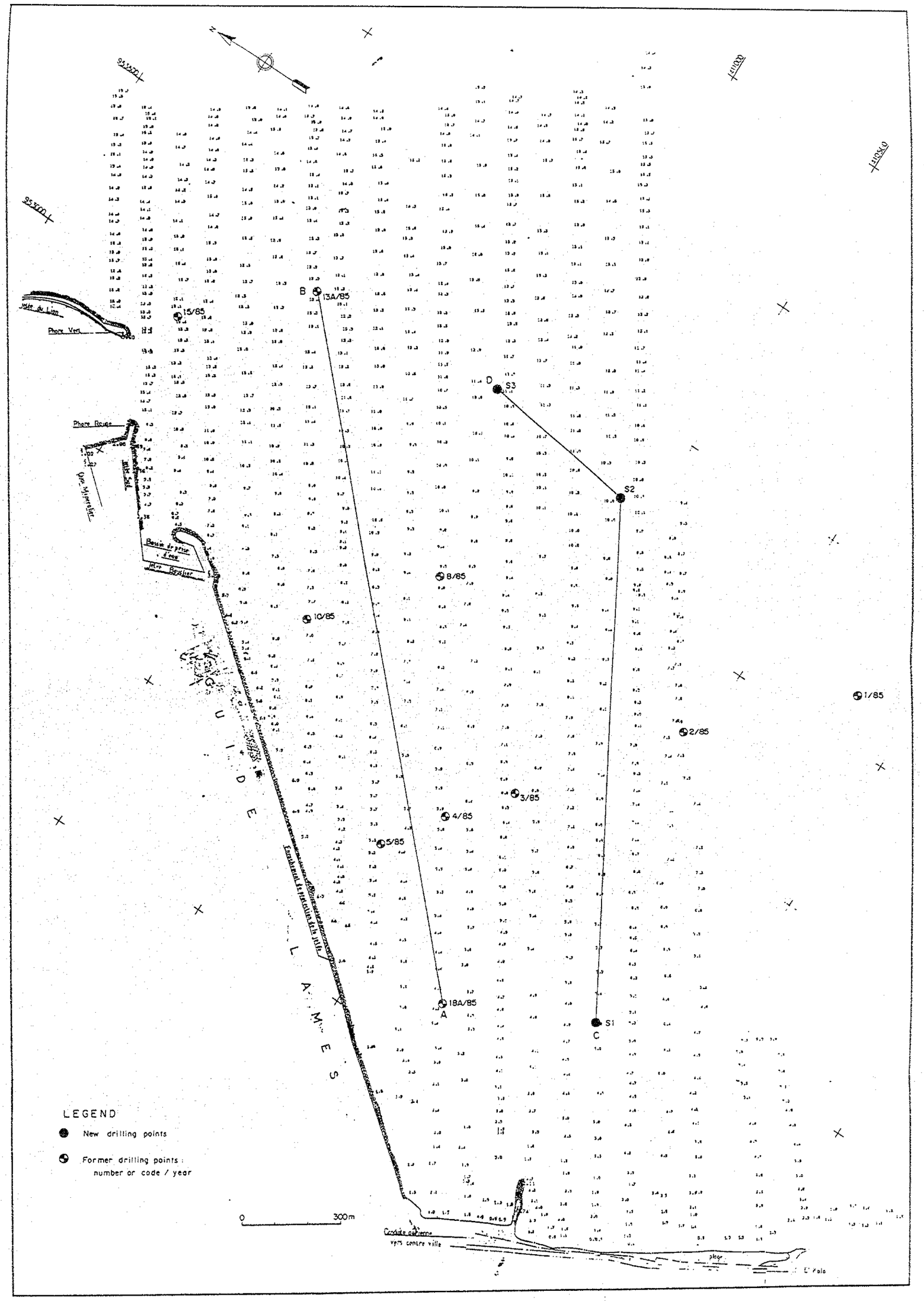

Fig. 2.4.15 Port of Annaba: location of the boreholes and geological cross-sections

12 m or more (drilling S1 to S3);

- Layer f: boulders, gravels and sand belonging to an ancient river bed, only locally developed (limited lateral extension).

A fault has been supposed to dislocate the area of the port of Annaba. As it also has been mentioned by a former report (1985), from the present drilling campaign no evidence of faulting could be found. The Quaternary sediments seem to fill up and cover the topography of the Paleozoic basement, a fact which explains their thickness variations.

DRILL LOG

SHEET NO. 1 OF 2

SITE	ANNABA	HOLE No.	S1
LATITUDE	LONGITUDE	ELEVATION	-6.50m
DATE	23 January 1992	DEPTH	46.00m
ANGLE	180° UP / DOWN 0° — 90°	DIRECTION	N 0° / E 90° / S 180° / W 270°
SLOPE	HORIZON 0° — 90°	DRILLED	SONATRAM
		LOGGED	I.C.P.

DEPTH	ELEVATION	GEOLOGICAL AGE	ROCK TYPE	ROCK CLASS	DESCRIPTION
1.50	-7.00	RECENT	Mud		Black mud, organic material
8.00	-13.50		Fine Sand		Fine, Clayey Sand, containing few coarse grains and fossils.
10.50	-16.00		Clay and Sand		Gray, plastic Clay, alternating with Silty Sand.
13.50	-19.00		Clay	CH	Fat Clay, high plasticity, 5 % sand, 90% saturated.
16.50	-22.00	PLEISTOCENE	Clay and Silt	CL CH	At the top Clayey Silt and Silty Clay (27--50% silt and 8% sand), the lower part consists of Clay.
21.00	-26.50		Silty Clay	CL	Patchy Clay, high plasticity, alternating with Very Sandy Clay levels.
30.00	-35.50		Clayey or Silty Sand		Clayey and Silty Sand, variable degree of consolidation, gray or yellow, rich in fossils, clay intercalations.

DATE | BIT & DIAMETER: Diamond 85mm | WATER LEVEL

CORE RECOVERY % (m) | R.Q.D % (m)

STANDARD PENETRATION TEST

3.15 – 3.45	N=25/30cm
4.65 – 4.95	N=25/30cm
6.15 – 6.45	N=25/30cm
7.65 – 7.95	N=28/30cm
9.15 – 9.45	N=12/30cm
10.65 – 10.95	N=11/30cm
15.15 – 15.45	N=8/30cm
18.15 – 18.45	N=8/30cm
21.15 – 21.45	N=9/30cm
24.15 – 24.45	N=29/30cm
27.15 – 27.45	N=33/30cm

*R.Q.D is Rock Quality Designation, R.Q.D=(Total length of cylindric cores longer than 10 cm)/(Total drill length) x 100%
*LUGEON VALUE is l/min/m under injection water pressure of 10kg/cm2
*DEPTH and ELEVATION are in meter
*DIAMETER is in millimeter

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Fig. 2.4.16 Drill log - Annaba S1 (sheet 1)

DRILL LOG

SITE	ANNABA			HOLE No.	S1
LATITUDE		LONGITUDE		ELEVATION	-5.50m
DATE	23 January 1992			DEPTH	46.00m
ANGLE	180° UP / DOWN 0°, 90°	DIRECTION	N 0°, E 90°, S 180°, W 270°	SLOPE	HORIZON 0°, 90°	DRILLED	SONATRAM
						LOGGED	I.C.P.

SCALE	DEPTH	ELEVATION	GEOLOGICAL AGE	ROCK TYPE	COLUMN SECTION	ROCK CLASS	DESCRIPTION	DATE	BIT & DIAMETER	WATER LEVEL
31–60	33.00	-38.50	PLEISTOCENE	Sand			Yellow sand, consolidated with iron concretions, diameter 2-3 mm, clayey.		Diamond 65mm	
	34.50	-40.00		Sandstone			Fragments of sandstone cemented by carbonate, rich in fossiles, intercalations of clayey sands.			
	46.00	-51.50		Clay			Gray clay, few sand, high plasticity.			

CORE RECOVERY % (m) / R.Q.D % (m)

	CORE RECOVERY % (m)	R.Q.D % (m)
33.00	42 (33.00)	0 (33.00)
34.50	26 (34.50)	0 (34.50)
36.00	40 (36.00)	0 (36.00)
37.50	100 (37.50)	0 (37.50)
39.00	80 (39.00)	0 (39.00)
41.50	74 (41.50)	0 (41.50)
43.00	54 (43.00)	0 (43.00)
44.50	84 (44.50)	0 (44.50)
46.00	46 (46.00)	0 (46.00)

STANDARD PENETRATION TEST

30.15 – 30.45	N=35/30cm
33.15 – 33.45	N=42/30cm

*R.Q.D is Rock Quality Designation, R.Q.D=(Total length of cylindric cores longer than 10 cm)/(Total drill length) x 100%
*LUGEON VALUE is l/min/m under injection water pressure of 10kg/cm2
*DEPTH and ELEVATION are in meter
*DIAMETER is in millimeter

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Fig. 2.4.16 Drill log - Annaba S1 (sheet 2)

DRILL LOG

SITE	ANNABA	HOLE No.	S2
LATITUDE	LONGITUDE	ELEVATION	-11.00m
DATE	4 February 1992	DEPTH	31.50m
ANGLE	180° UP / DOWN 0° / 90°	DIRECTION	N 0° / E 90° / S 180° / W 270°
SLOPE	HORIZON 0° / 90°	DRILLED	SONATRAM
		LOGGED	I.C.P.

SCALE	DEPTH	ELEVATION	GEOLOGICAL AGE	ROCK TYPE	COLUMN SECTION	ROCK CLASS	DESCRIPTION
1	1.20	-12.20	RECENT	Mud			Black mud, organic material
2	2.00	-13.00		Fine Sand			Fine sand, clayey, shells, at the top a level of gravel
	2.20	-13.20		Silty Clay		MH	Silt with 5% sand, gray, plastic behaviour, unsaturated.
3	3.00	-14.00					
4	4.00	-15.00		Sand		MH (?)	Fine, gray Sand with Silt intercalations.
	4.50	-15.50		Silt			Silt, slight plasticity.
5				Clay		CH and MH	Clay, high plasticity, saturated, interbeded with Silty Sand, varying in grainsize from fine to coarse.
6							
7							
8							
9							
10	10.00	-21.00					
11				Silt and Clay		ML and OL	Sandy silt, 20-27% sand, rich in fossiles, with lenses of organic silt-clay.
12	12.00	-23.00					
13				Silty Clay		CL	Gray Clayey Silt or Silty clay, plastical behaviour, high silt content (40-56%) and sand (up till 20%), thin beds of Clayey/Silty Sand.
14							
15							
16	16.50	-27.50	PLEISTOCENE				
17				Clayey Sand			Clayey Sand, yellow, slightly consolidated, few concretions.
18	18.00	-29.00					
19	18.90	-29.90					Clayey Sand, yellow and gray.
20				Sandstone			Soft Sandstone, white, medium grains, carbonate cement, fossil rich.
21							
22	22.50	-33.50					
23				Sandstone and Clay			Fragments of Sandstone, underneath green clay, silty sand and again clay.
24							
25	25.50	-36.50					
26				Sand			Coarse Sand, fossil rich, lower part: sandy clay.
27	27.00	-38.00					
28				Clay			Gray Clay, plastic behaviour.
	28.50	-39.50					
29				Clay and Sand			Gray clay, underneath clayey sand and again gray clay, plastical behaviour.
30							

DATE | BIT & DIAMETER: Diamond ø59mm | WATER LEVEL

CORE RECOVERY % (m) | R.Q.D % (m) | STANDARD PENETRATION TEST

1.65	N=6/30cm	4.65	N=7/30cm
1.95		4.95	
3.15	N=12/30cm	6.15	N=8/30cm
3.45		6.45	

*R.Q.D is Rock Quality Designation, R.Q.D=(Total length of cylindric cores longer than 10 cm)/(Total drill length) x 100%
*LUGEON VALUE is l/min/m under injection water pressure of 10kg/cm2
*DEPTH and ELEVATION are in meter
*DIAMETER is in millimeter

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Fig. 2.4.17 Drill log - Annaba S2 (sheet 1)

DRILL LOG

SITE	ANNABA	HOLE No.	S2
LATITUDE	LONGITUDE	ELEVATION	-11.00m
DATE	4 February 1992	DEPTH	31.50m
ANGLE	180° UP / DOWN 0° / 90°	DIRECTION	N 0° / E 90° / S 180° / W 270°
SLOPE	HORIZON 0° / 90°	DRILLED	SONATRAM
		LOGGED	I.C.P.

SCALE	DEPTH	ELEVATION	GEOLOGICAL AGE	ROCK TYPE	COLUMN SECTION	ROCK CLASS	DESCRIPTION	DATE	BIT & DIAMETER	WATER LEVEL	CORE RECOVERY % (m)	R.Q.D % (m)	STANDARD PENETRATION TEST
31	31.50	-42.50	PLEISTOCENE	Clay and Sand					Diamond 86mm		0 50 100 20 (31.50)	0 50 100 0 (31.50)	0 10 20 30 40 50
32													
33													
34													
35													
36													
37													
38													
39													
40													
41													
42													
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54													
55													
56													
57													
58													
59													
60													

*R.Q.D is Rock Quality Designation, R.Q.D=(Total length of cylindric cores longer than 10 cm)/(Total drill length) x 100%
*LUGEON VALUE is l/min/m under injection water pressure of 10kg/cm2
*DEPTH and ELEVATION are in meter
*DIAMETER is in millimeter

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Fig. 2.4.17 Drill log - Annaba S2 (sheet 2)

DRILL LOG

SITE	ANNABA	HOLE No.	S3
LATITUDE		LONGITUDE	ELEVATION -10.10m
DATE	8 February 1992	DEPTH	37.00m
ANGLE	180° UP / DOWN 0° / 90°	DIRECTION	SLOPE / HORIZON 0° / 90°
		DRILLED	SONATRAM
		LOGGED	I.C.P.

SCALE	DEPTH	ELEVATION	GEOLOGICAL AGE	ROCK TYPE	COLUMN SECTION	ROCK CLASS	DESCRIPTION	DATE	BIT & DIAMETER	WATER LEVEL	CORE RECOVERY % (m)	R.Q.D % (m)	STANDARD PENETRATION TEST
1			RECENT	Mud			Black Mud, organic material.				(1.20)	(1.20)	
2				Very Fine Sand			Silty very fine sand, sometimes gravelly, with shells.				10 (4.50)	0 (4.50)	1.65 N=4/30cm
3													1.95
4													3.15 N=3/30cm
5													3.45
6				Clay		CH	Clay with less than 10 % sand.						4.65 N=4/30cm
7											32 (7.50)	0 (7.50)	4.95
8													6.15 N=4/30cm
9													6.45
10													7.65 N=4/30cm
11													7.95
12											28 (10.50)	0 (10.50)	9.15 N=6/30cm
13													9.45
14													12.15
15			PLEISTOCENE	Clayey Sand			Clayey Sand.		Diamond 85mm				12.45 N=5/30cm
16				Silty Sand and Clay		CL and ML	Gray Silty Sand with shells, interbeded with Clay, medium plasticity.				76 (13.50)	0 (13.50)	
17													15.15
18													15.45 N=5/30cm
19				Silt, Sand and Clay			Yellow soil, mixure of Silt (52%), Sand (25%) and Clay (23%), coarse grains, slightly consolidated.				30 (16.50)	0 (16.50)	
20													
21											48 (19.00)	0 (19.00)	
22				Sandstone Fragments			Fragments of white Sandstone.						
23											22 (23.50)	0 (23.50)	
24				Clay		CH	Gray Clay, plastical behaviour.						
25											26 (25.00)	0 (25.00)	
26													
27											24 (28.50)	0 (28.50)	
28													
29				Clayey Sand			Fine Sand, silty and clayey.				100 (29.50)	0 (29.50)	
30				Silty/Gravely Clay		CL	Gray Silty Clay, sand (10%), medium plast-				34 (30.00)	0 (30.00)	

*R.Q.D is Rock Quality Designation, R.Q.D=(Total length of cylindric cores longer than 10 cm)/(Total drill length) x 100%
*LUGEON VALUE is l/min/m under injection water pressure of 10kg/cm2
*DEPTH and ELEVATION are in meter
*DIAMETER is in millimeter

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Fig. 2.4.18 Drill log - Annaba S3 (sheet 1)

DRILL LOG

SITE	ANNABA	HOLE No.	S3
LATITUDE	LONGITUDE	ELEVATION	-10.10m
DATE	8 February 1992	DEPTH	37.00m
ANGLE	180° UP / DOWN 0° / 90°	DRILLED	SONATRAM
DIRECTION	N 0° / E 90° / S 180° / W 270°	LOGGED	I.C.P.
SLOPE	HORIZON 0° / 90°		

SCALE	DEPTH	ELEVATION	GEOLOGICAL AGE	ROCK TYPE	COLUMN SECTION	ROCK CLASS	DESCRIPTION	DATE	BIT & DIAMETER	WATER LEVEL	CORE RECOVERY % (m)	R.Q.D % (m)	STANDARD PENETRATION TEST
	31		PLEISTOCENE	Silty/Gravely Clay		CL	icity, including levels of green Gravely Clay.		Diamond 85mm		34 (34.00)	0 (31.00)	0 10 20 30 40 50
	32												
	33												
	34										51 (34.00)	0 (34.00)	
	35			Marble Fragments			Marble fragments.				87 (35.50)	0 (35.50)	
	36			Gneiss			Augen** Gneiss, with cm-size quarts porphyroblasts, foliated.				54 (37.00)	20 (37.00)	
	37												
	38												
	39												
	40												
	41												
	42												
	43												
	44												
	45												
	46												
	47												
	48												
	49												
	50												
	51												
	52												
	53												
	54												
	55												
	56												
	57												
	58												
	59												
	60												

*R.Q.D is Rock Quality Designation, R.Q.D=(Total length of cylindric cores longer than 10 cm)/(Total drill length) x 100%
*LUGEON VALUE is l/min/m under injection water pressure of 10kg/cm2
*DEPTH and ELEVATION are in meter
*DIAMETER is in millimeter

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Fig. 2.4.18 Drill log - Annaba S3 (sheet 2)

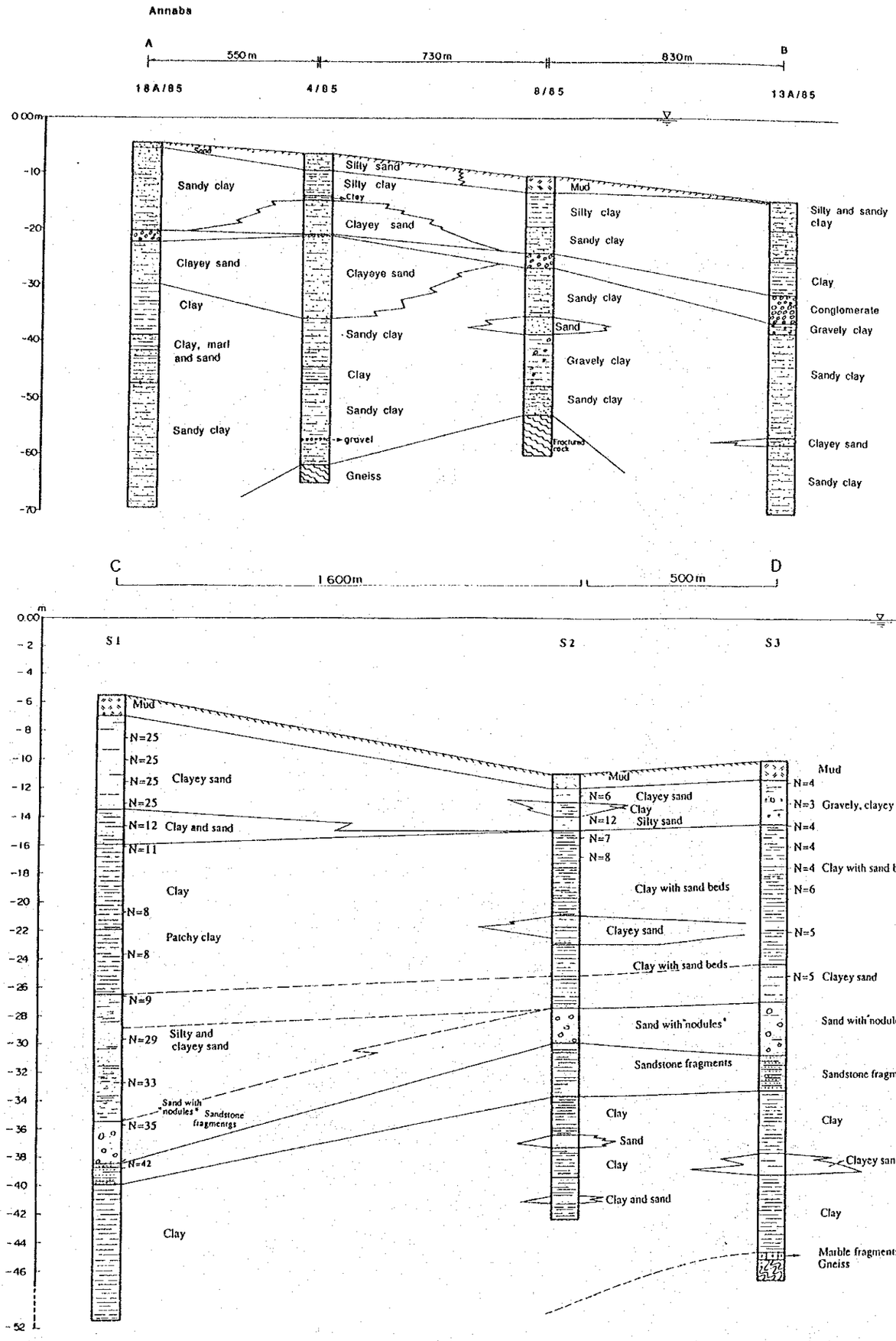

Fig. 2.4.19 Geological cross sections of the port of Annaba

Table 2.4.8 Laboratory physical test data of Annaba

Annaba-drilling S1							
Depth of sampling (m)	10.5-10.9	11.5-11.9	13.1-13.4	14.0-14.3	15.8-16.2	16.8-17.2	20.1-20.45
Type of soil	Silt with 6% sand	Clay,veryhigh plasticity	Clay,high plasticity, 5% sand	Clay, medium plasticity	Clay, very high plasticity	Clay,high plasticity	Very sandy clay
Classification	MH	CH	CH	CL	CH	CH	CL
Grainsize<100(%)	98.5	99.5	99	98	99	99	99
Water content %	32.3	44.3	47.2	39.6	41.9	39.1	30.4
Dry density T/m3	1.42	1.17	1.15	1.27	1.26	1.28	1.44
Wet density T/m3	1.88	1.69	1.705	1.785	1.805	1.795	1.885
Degree of saturation (%)	96.9	91.5	94.5	95	99	95	93.6
Liquid limit	51.2	68.5	65.1	46.8	62	56	46.8
Plasticity index	21.5	40.2	39.5	21.1	37.7	34.4	27.5

Annaba-drilling S2							
Depth of sampling (m)	2.2-2.8	5.1-5.5	6.9-7.3	10.10-10.5	11.2-11.8	13.05-13.5	15.8-16.2
Type of soil	Silt,with 5% sand	Clay,high plasticity	Silt with 6% sand	Sandy silt(20% sand)	Organic silt-clay (27% sand)	Clay,with 9% sand	Sandy clay(21% sand)
Classification	MH	CH	MH	ML	OL	CL	CL
Grainsize<100(%)	100	100	100	83.5	77.5	99	82
Water content %	46.3	45.4	34.9	32.2	27.1	28.2	25.4
Dry density T/m3	1.21	1.22	1.325	1.435	1.54	1.5	1.52
Wet density T/m3	1.77	1.775	1.78	1.895	1.96	1.92	1.9
Degree of saturation (%)	100	100	90.8	97.8	97.8	95.2	89
Liquid limit	61.5	60.5	61.5	48.5	38	48.5	33
Plasticity index	29.2	29.2	31.8	21.4	11.9	24.5	15.3

Annaba-drilling S3				
Depth of sampling	12.7-13.1	16.2-16.7	18.4-18.7	32.2-32.5
Type of soil	Clay with 9% sand	Clay med.plast, 8% sand	Sandy silt/clay,23% sand	Clay med. plast, 10% sand
Classification	CH	CL	ML/CL	CL
Grainsize<100(%)	99	99	81	94.5
Liquid limit	52.5	49	43.5	44
Plasticity index	24.27	23.19	17.16	24.38

Table 2.4.9 Laboratory mechanical tst data of Annaba

		Consolidation test			Shear test	
Location	Depth range (m)	Compression index	Swelling ratio	Pre-consolidation stress (Kg/cm2)	Conhesion (Kg/cm2)	Friction angle ø (degrees)
Annaba S1	10.5-10.9	0.3	0.05	1.1	0.11	3
	14.0-14.3	0.44	0.01	0.7	0.05	4
	16.8-17.2	0.362	0.092	1.02	0.2	22.5
	20.1-20.45	0.189	0.094	1.9	0.55	16
Annaba S2	5.1-5.5				0.45	1.5
	11.2-11.8	0.163	0.014	1.7	0.25	1.5
	15.8-16.2	0.244	0.052	0.77	0.15	15

Table 2.4.10 Results of the Standard Penetration Test in Annaba

Location	Depth	Lithology	Nr.of blows per	N-value	Cohesion (ton/m2)	Friction angle ø (degrees)
Annaba S1	3m	clayey sand	10/10/15	25	0	32
	4.5m	clayey sand	10/11/14	25	0	32
	6m	clayey sand	12/12/13	25	0	32
	7.5m	clayey sand	12/13/15	28	0	33
	9m	sandy clay	4/6/6.	12		
	10.5m	clay	4/4/7.	11	7	0
	15m	clay	2/3/5.	8	5	0
	18m	clay	3/3/5.	8	5	0
	21m	clayey sand	2/3/6.	9	5	0
	24m	clayey sand	13/14/15	29	0	33
	27m	clayey sand	10/15/18.	33	0	34
	30m	sand	15/15/20	35	0	35
	33m	sandstone fra	11/20/22.	42	0	0
Annba S2	1.5m	clayey sand	2/2/4.	6	0	23
	3m	clayey sand	2/5/7.	12	0	27
	4.5m	clay	2/3/4.	7	4	0
	6m	clay	3/3/5.	8	5	0
Annba S3	1.5m	fine sand	2/2/2.	4	0	22
	3m	fine sand	1/1/2	3	0	21
	4.5m	clay	1/2/2.	4	2	0
	6m	clay	2/2/2.	4	2	0
	7.5m	clay	2/2/2.	4	2	0
	9m	clay	3/4/2.	6	2	0
	12m	clay	2/3/2.	5	2	0
	15m	clayey sand	3/2/3.	5	0	23

3) Geotechnical conditions

The results of the drilling campaign are illustrated in the cross section CD of the figure 2.4.19. The cross section AB has been drown with the data of a former drillling capaign (1985). The positions of the drilling points are indicated on the map of the port of Annaba, figure 2.4.15. Both sections, running parallel to the breakwater, show that the depth of the basement decreases from the coast (more than 60 m) to jetty (45 m deep).
The table 2.4.8 contains the physical test data in the laboratory, for all the samples. The soil has been classified as a MH or ML till 11 m depth, with an intercalation of CH clay, depending on its sand content. The grain size distribution of almost all the samples corresponds to that of silt and clay. The liquid limit is high and the plasticity ranges from medium to very high. Most of the samples are saturated (>95%).

Table 2.4.10 shows the results of the SPT-tests. In drilling S1 a clayey sand has been found between 0-8m and bellow 24 m. From the N-value of 25 blows, applying Terzaghi's formula, the allowable bearing strength of this bed has been estimated around 12 t/m2. In between the clayey sand beds there is a soft clay, with an estimated allowable bearing strength of 5 t/m2. According to the SPT values and to the results of the shearing tests (table 2.4.9) in S2 and S3, the soil behaves like a soft clay at least till the depth of 16 m.

From the consolidation test data the soil of Annaba is still unconsolidated, the pre-consolidation stresses are low (1 Kg/cm2). the compression index is higher than in the other two sites (0.2-0.4), indicating that the soil is still compressible.

The weak foundation bed in Annaba will require due treatment, e.g. friction piles, sand piles or formation of an extensive base, etc. Also the problem of settlement by consolidation of the thick clay bed will have to be examined in terms of actual dimensions and load of the structures to be designed.

2.5 Bathymetric survey

In every port the so called "study area" was covered by a bathymetric survey. the survey has been done from a boat, carrying an echo-sounder and moving from the coast to the off-shore, in straight lines. The line spacing was generally 100 m, except for the shallow zones (water depth less than 15 m) of Algiers and Oran, where the line spacing has thought to be 50 m. Every 25 m along such a line the water depth has been recorded. The position of the moving boat has been followed by a topographer and recorded. The results have been shown on maps indicating the real positions of the boat and the corresponding water depth, relative to the hydrographic zero.

In the case of the port of Algiers, the survey has been done at two locations:

- east from the eastern breakwater, in an area 1.75 Km long and 1.5 Km wide;
- along the middle part of the Mustapha jetty, 600 m along the jetty and 300 m perpendicular to it.

The resuts have been represented on the 1:2000 m scale maps, fig.2.5.1 and 2.5.2.

In Oran the bathymetric survey has been done at two locations:

- east from the breakwater, the dimensions of the survey zone being 1.1 Km length x 1 Km width;
- 1.3 Km along the jetty in a 200 m wide zone.

The results have been represented on the 1:2000 m scale maps, fig.2.5.3 and 2.5.4.

In Annaba the survey has been done along the eastern breakwater, in a 3.3 Km long and 1.6 Km wide zone. The resuts can be found on the 1:5000 m scale map, fig.2.5.5.

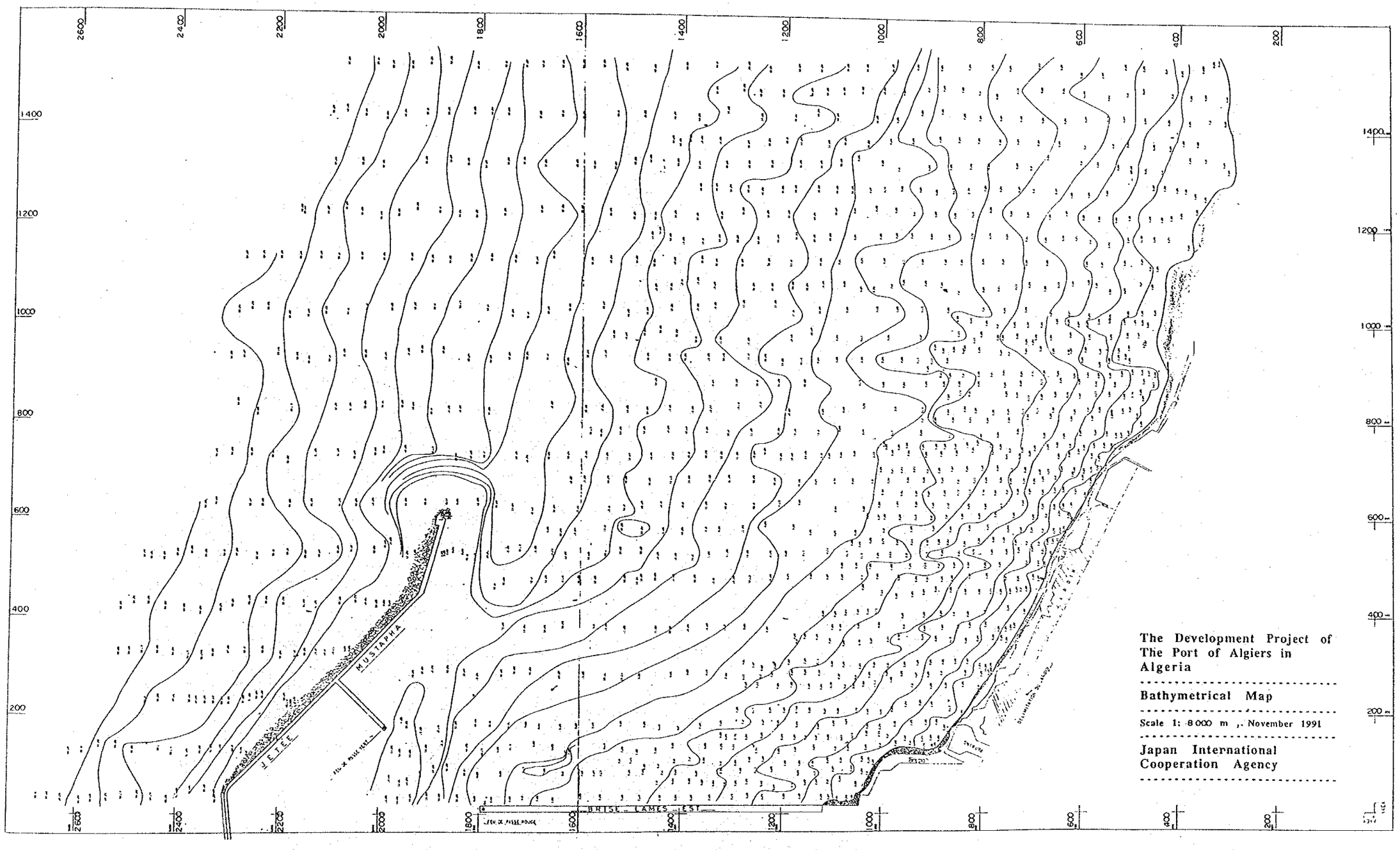

Fig. 2.5.1 Bathymetrical map of the port of Algiers
(area at the end of the Mustapha jetty)

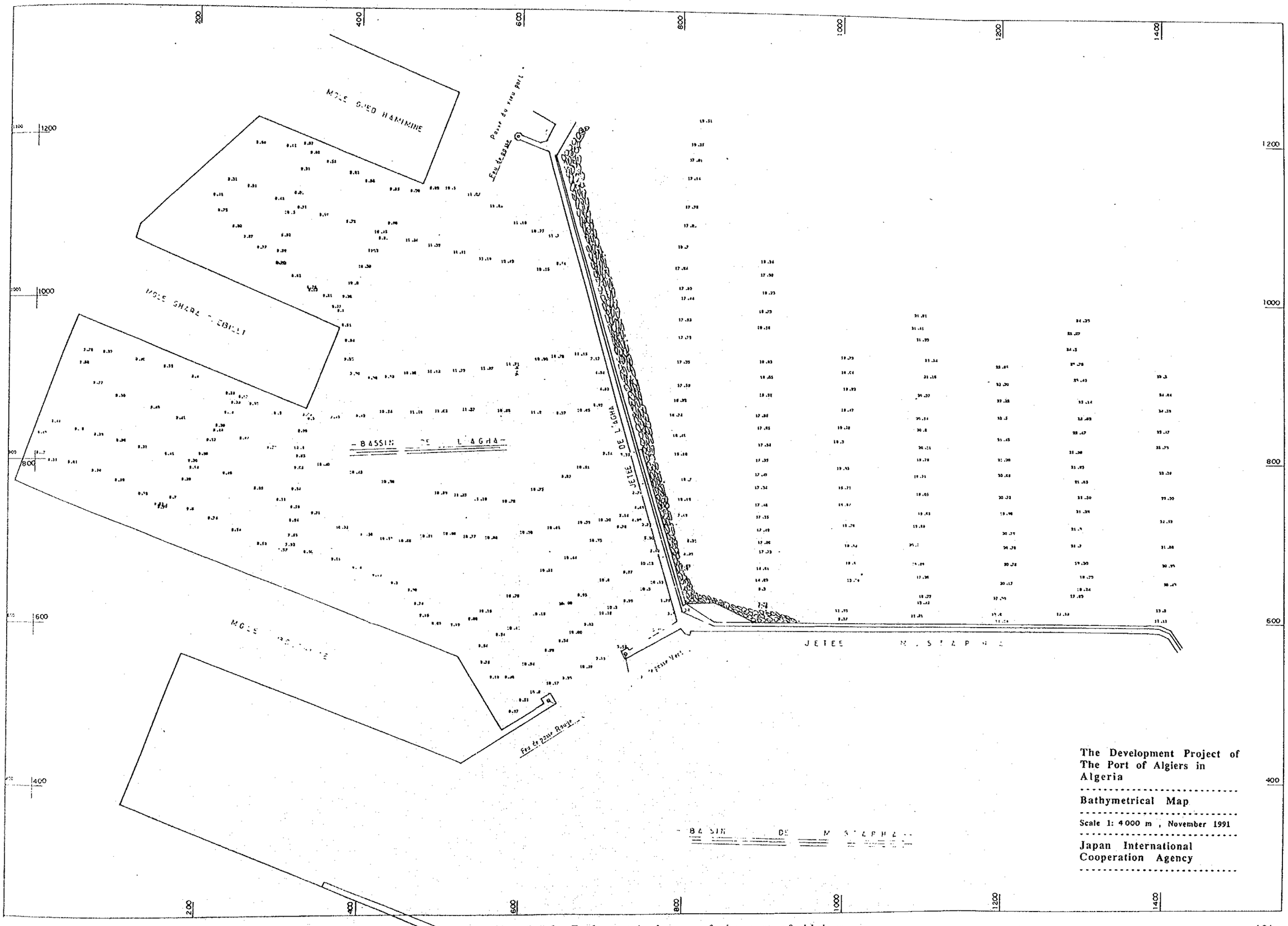

Fig. 2.5.2 Bathumetrical map of the port of Algiers
: the "old port" and outside of the Mustapha jetty

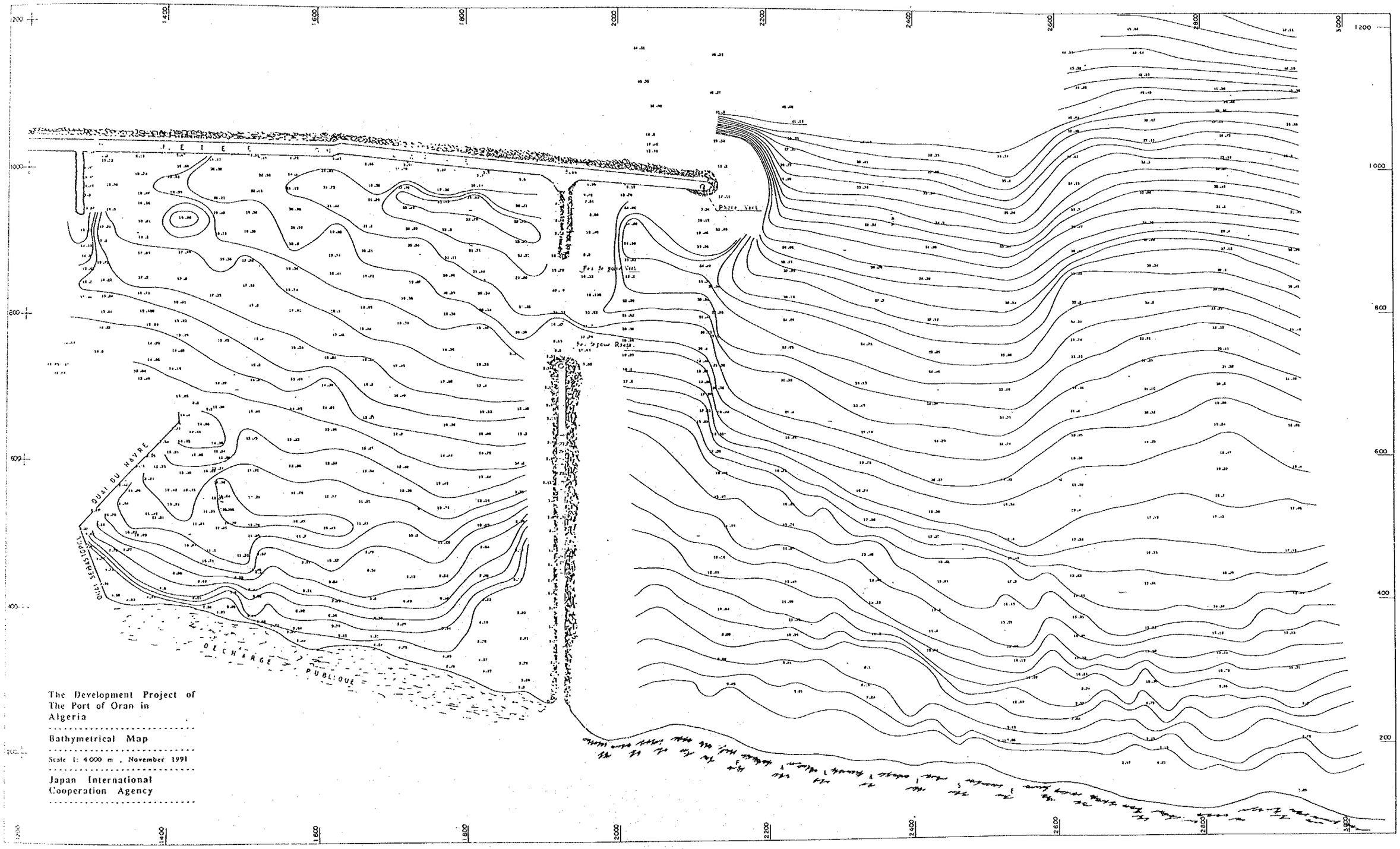

Fig. 2.5.3 Bathymetrical map of the port of Oran: Machreck basin.

Fig. 2.5.4 Bathymetrical map of the port of Oran: outside of the jetty

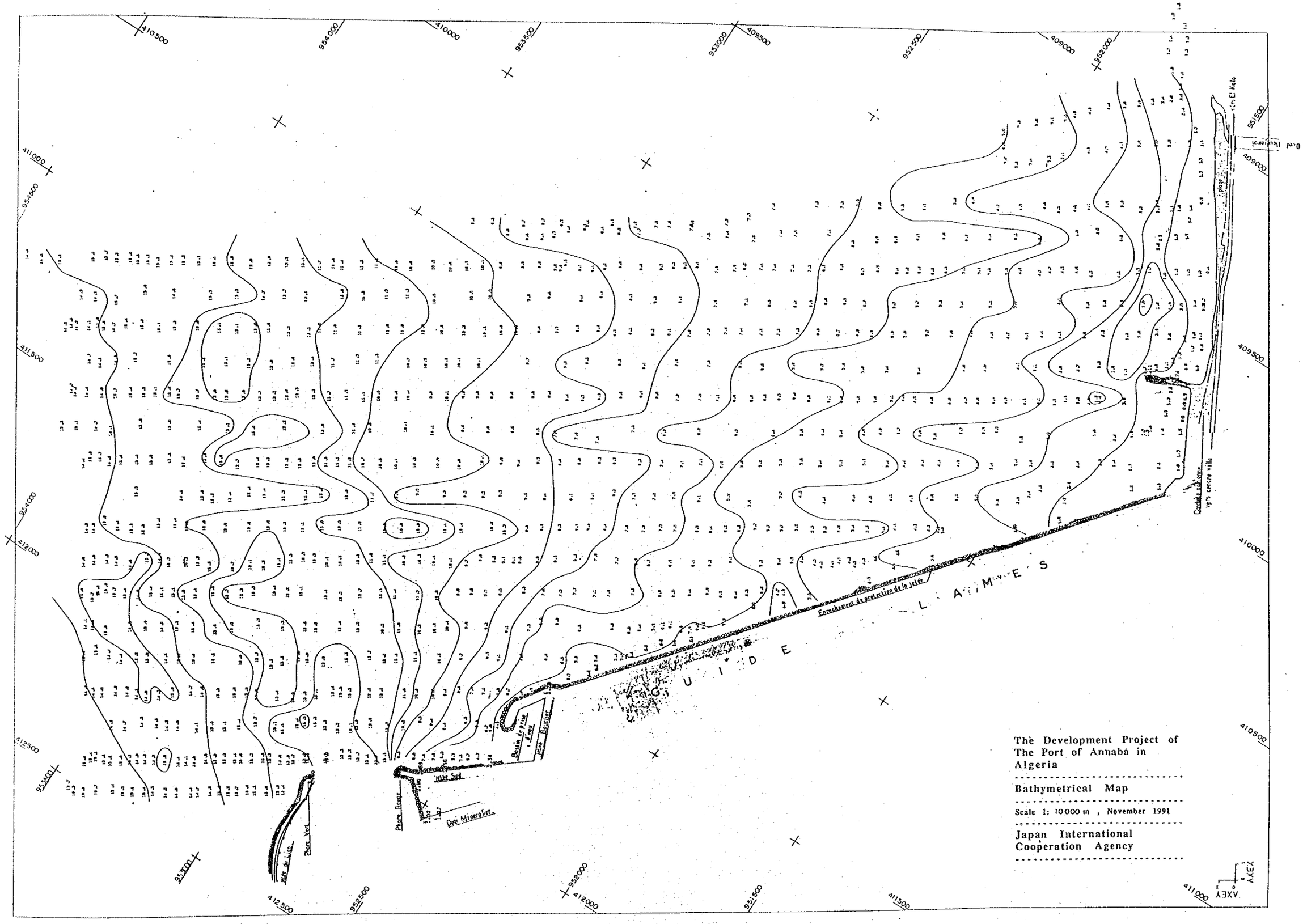

Fig. 2.5.5 Bathymetrical map of the port of Annaba

2.6 Seismic activity

During the 20th Century around 90 earthquakes, with magnitude higher than 4 have been registred in the northern part of Algeria. The most important one happend in October 1980, with a magnitude of 7.7. The epicenter was located 36.2 N and 1.4 E, in the region of Chlef. A considerable earthquake, concerning the close vicinity of Alger, has occured in October 1989. The magnitude of 5.9 has been registred above the epicenter, located at 36.8 N and 2.4 E.

As it is shown figure 2.6.1, north Algeria has been divided into the following seismic zones;

- Zone 0 : negligeable seismic activity
- Zone I : weak sismic activity
- Zone II : intermediate seismic activity
- Zone III: strong seismic activity.

The relative scale applied above takes into account the intensity and the frequency of earthquakes.
From the figure 2.6.1 it can be seen that the seismic activity diminishes from the Mediterranean coast towards the south.
The region of Chlef, located half-a-way between Algiers and Oran, appears to have a strong seismic activity (zone I), while the rest of the coast has been classified as zone II, medium seismic activity. The three project ports are all included into the medium seismic activity zone. Consequently, the seismicity shall be taken into account for the construction works.

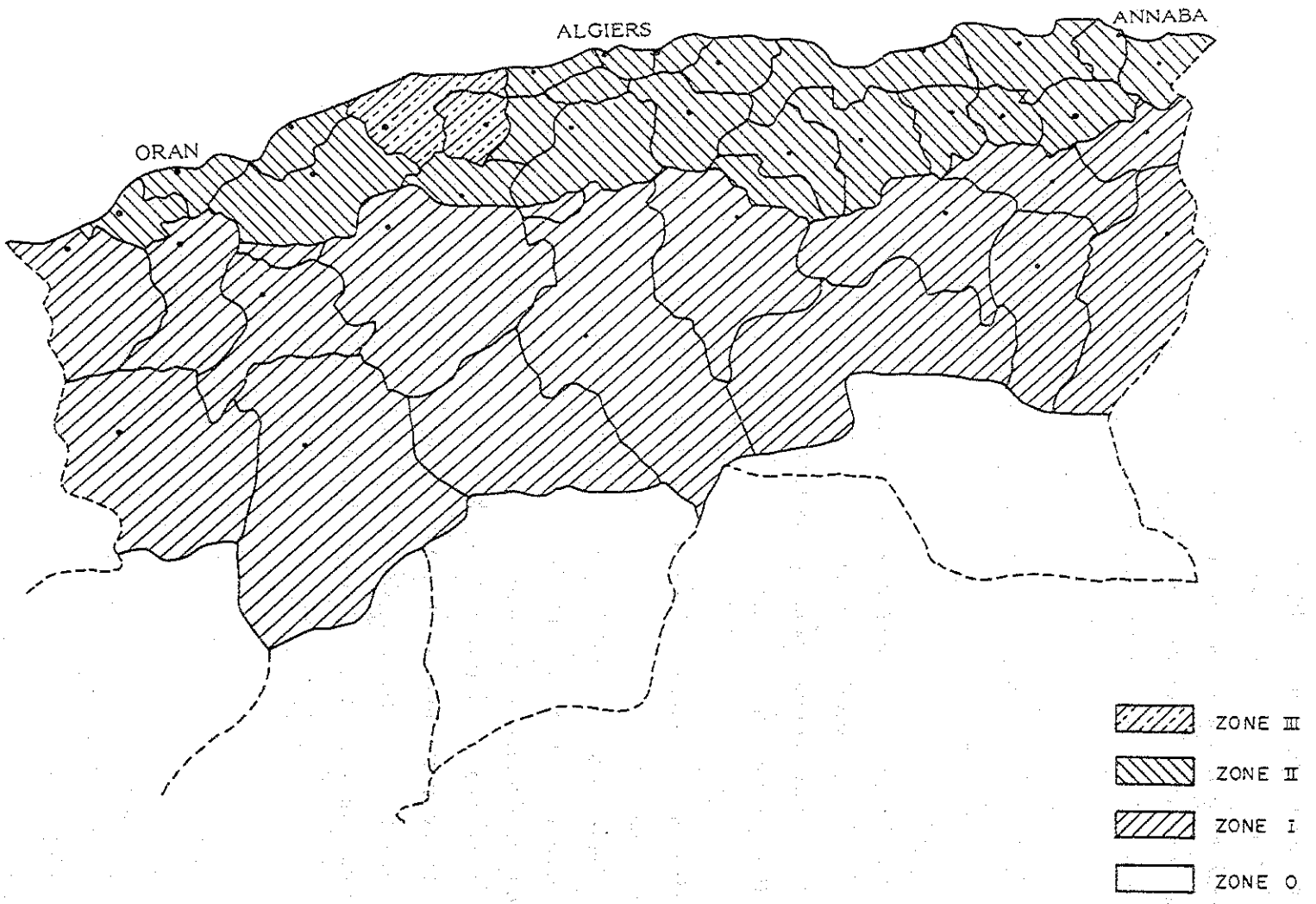

Fig. 2.6.1 Seismic Zones of Algeria

CHAPTER 3 PRESENT SITUATION OF ALGERIAN MARITIME TRANSPORTATION

3.1 Algerian Flag Merchant Fleet

The number of Algerian Flag Merchant Vessels in 1989 is 76 ships with 1,094,619 DWT which are categorized into 5 types "Ro-Ro Vessel", "Cargo Vessel", "Bulk Carrier" "Tanker" and "Car Ferry". The average age of the fleet is 13.9 years.

The average DWT and age per type of vessel are shown in Table 3-1, whose source is the Annuaire Statistique de l'Algeria,1989.

Table 3-1 Average DWT and Age of Algerian Flag Fleet

Type of Vessel	No.of Vessel	Total DWT	Average DWT	Average Age
Ro-Ro Vessel	14	42,083 (3.9%)	3,006	14.3
Cargo Vessel	28	276,239 (25.2%)	9,866	14.4
Bulk Carrier	9	287,697 (26.3%)	31,966	9.7
Tanker	19	477,229 (43.6%)	25,117	13.1
Car Ferry	5	11,371 (1.9%)	2,274	20.0
Total	75	1,094,619	14,595	13.9

Table 3-2 No.of Vessel per Age

Age	Ro-Ro Vessel	Cargo Vessel	Bulk Carrier	Tanker	Car Ferry	Total
0 - 5	0	0	0	0	0	0
6 - 10	0	3	5	5	0	13
11 - 15	10	17	4	11	0	42
16 - 20	3	6	0	0	5	14
Over 20	1	2	0	3	0	6
Total	14	28	9	19	5	75

(As of 1991)

Ro-Ro vessel are assigned in liner services between Algerian ports and Mediterranean ports and/or North European ports. Principal carried cargoes are palletized cargoes.

The deployment of cargo vessels is separated into 2 groups "liner service" and "tramper service". Small sized vessels under 5,000 DWT are engaged in liner services in the Mediterranean Sea. Medium sized vessels ranged between 7,000 to 9,000 DWT are assigned in tramper service to North American ports and North European ports. Main cargoes are foodstuffs in sacks and steel goods. Large sized vessels over 10,000 DWT are assigned in long route liner services.

The bulk carriers, except one panamax bulk carrier, are engaged in transportation of import cereals in bulk which is mainly loaded at North American ports. One panamax bulk carrier is engaged in transportation of coal in bulk.

Among to tanker fleet of 477,277 tons, the core of tankers is composed of LNG Tankers of 394,370 DWT in total which are engaged in the international transportation.

3.2 Maritime Enterprise

There are four maritime enterprises in Algeria

(1) SNTM-CNAN (Societe National de Transportes Maritime & Companie Nationale Algerienne de Nav.)

CNAN was established in 1963 immediately after the Algerian independence. CNAN has been following national policy of strengthening maritime transportation system as it most important issue. CNAN's maritime activity started in 1967 and its fleet increased rapidly along with the implementation of various development programs. In due course CNAN became a one of the biggest shipping company in Africa. They were active in the fields of transporting general cargo, Oil, LNG, Grain, Sugar, Wine, Iron Ores and so on.

Following the progress of reorganization of Algerian governmental structure, CNAN was divided into two companies in 1982 : SNTM-CNAN and SNTM-HYPROC. Also a passenger transportation company named ENTMV was established in 1987.

The company owns a fleet consisting of 50 vessels with 588,719 DWT. Most part of the fleet are cargo vessels and bulk carriers. Also the company is chartering more than 50 vessels from other countries so that more than 100 vessels are under their operation. The share of cargoes transported by their operated vessels is some 30 % of the total cargo volume transported by liner service and tramper service to/from Algerian ports every year.

(2) SNTM-HYPROC (Societ National de Transportes Maritimes des Hydrocarbures et des Produits Chimiques)

In 1982, the company was separated from CNAN and set up as an exclusive transportation company for oils, natural gases and chemical products. The company owns a fleet consisting of 15 vessels with 460,359 DWT and also chartered some tankers from other countries.

(3) ENTMV (Enterprise Nationale de Transports Maritimes des Voyageurs)

In 1987, a part of activities was separated from CNAN to set up the ENTMV as an exclusive passenger transporting company. The company is currently owning five car ferries built in 1971 and carry out the regular car ferry service between ports of Algiers, Oran, Annaba, Skikda and Bejaia and South European ports.

Their car ferry service competes with the car ferry service supplied by French shipping company. They consider their way toward strengthening of fleet in order to cope with the necessity of modernization of maritime transportation in Algeria.

(4) CALTRAM (Compagnie Algero-Libyenne de Transport Maritime)

This is joint venture company established by 50%-50% capitals from Algeria and Lybia. The company owns 5 vessels of 34,170 DWT as a total tonnage and they also charter some vessels from foreign shipping companies.

3.3 Liner Service

In accordance with the Yearbook 1991 of Containerization International, 12 shipping companies including CNAN and CALTRM carry out liner services between North African ports and European ports with Ro-Ro vessels and semi-container vessels. All the companies operates their owned or leased containers, Their vessels engaged in liner service can handle containers

The general cargoes handled at the Algerian ports are transported by liner service and tramper service, and the transporting volume of each of seems to be nearly the same. Major part of the cargoes transported by general cargo vessels and Ro-Ro vessels in liner services are dominated by palletized cargo amounting to over 50 % of them, and the increase containerization of cargoes is inactive in Algeria. Foodstuffs, "Semolina, Sugar, Flour, etc. in sacks" log and steel goods are mainly transported by tramper service, in which vessels are loaded in bulk for each consignment.

On the other hand many foreign shipping companies operate long route liner service with fully-cellar container vessels calling South European ports such as Marseilles. The feeder service net works originated from their calling ports are set up widely within the Mediterranean Sea.

However the Algerian ports are not a in stage of calling fully-cellar container vessels yet, and feeder service net works joining the long route container services are not organized sufficiently.

3.4 Tramper Service

Currently, almost all of the solid cargoes in bulk handled at the ports are transported by various sized bulk carriers in tramper services. Since the limitation of port facilities, except coal in bulk discharged at Annaba port, solid cargoes in bulk are transported by smaller sized vessels than panamax bulk carrier.