TECHNICAL REPORT OF THE FIRST-STAGE EVALUATION
FOR
ASEAN ROCK SALT - SODA ASH PROJECT (THAILAND)
AT
BAMNET-NARONG ROCK SALT DEPOSIT
IN
NORTHEASTERN THAILAND

AUGUST, 1980

JAPAN INTERNATIONAL COOPERATION AGENCY

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FOREWARD

Japan, as a fellow Asian country, sincerely wishes for the prosperity of members of the Association of Southeast Asian Nations (ASEAN) and hence is deeply interested in the successful execution of the ASEAN Rock Salt - Soda Ash Project in Thailand as part of ASEAN's industrialization plan.

At the request of the Government of the Kingdom of Thailand, the Japanese Government some time ago decided to make an evaluation and survey on the basis of the Report on the Feasibility of a Rock Salt - Soda Ash Project in Thailand, prepared by SNC Inc. of Canada concerning a survey it had previously conducted under the ASEAN industrialization program. The Japanese Government commissioned the work to Japan International Cooperation Agency (JICA).

As a consequence of a preliminary investigation carried out by JICA in March 1979, the Thai and Japanese parties agreed that, prior to conducting a comprehensive evaluation and survey, it was necessary to resurvey the rock salt deposit. Thus, a first stage survey, limited to the analysis of the rock salt deposit, was carried out for the Rock Salt - Soda Ash Project.

The present report summarizes the results of the first stage survey carried out against the background just described.

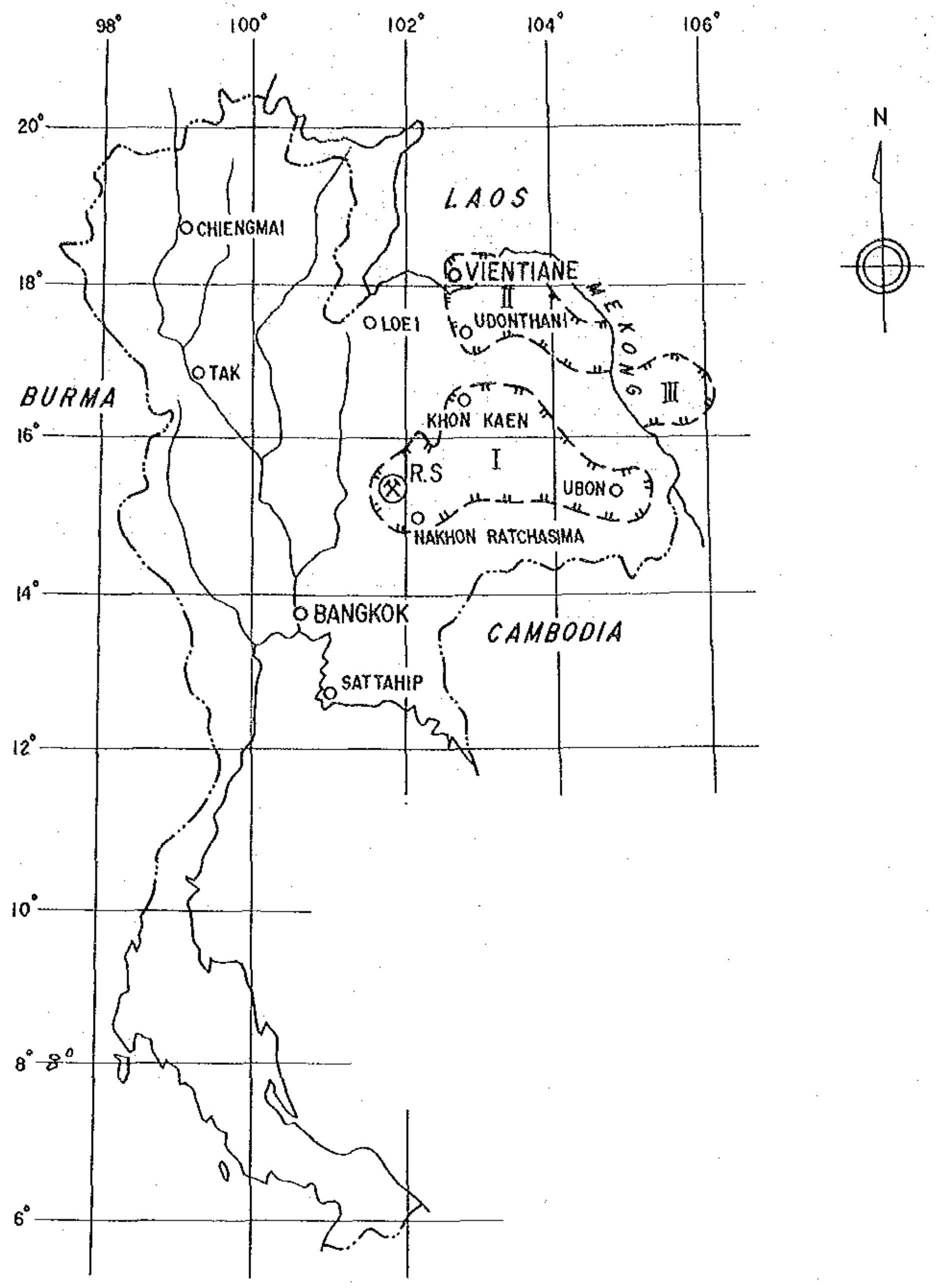
In undertaking the comprehensive evaluation and survey scheduled to take place in the near future, it is hoped that this report will be utilized to the maximum.

I would like to express my heart-felt gratitude to concerned personnel of the Government of the Kingdom of Thailand and of the Japanese Embassy in Thailand for the generous cooperation they have given us in making the first stage survey possible, and also to officials of the Ministry of Foreign Affairs and the Ministry of International Trade and Industry for assisting us in the dispatch of the survey team to Thailand.

August, 1980

Keisuke Arita

Keisuke Arita
President
Japan International Cooperation Agency



EXPLANATION

SEDIMENTARY BASINS UNDERLAIN EXTENSIVELY OR COMPLETELY BY ROCK SALT AND GYPSUM/ANHYDRITE

I : KHORAT BASIN (THAILAND)

II : SAKHON NAKHON BASIN (THAILAND)

III : MUONG PHALANE BASIN (LAOS)

R.S ROCK SALT MINING SITE (BAMNET NARONG)

Fig. 1 Index map of Thailand

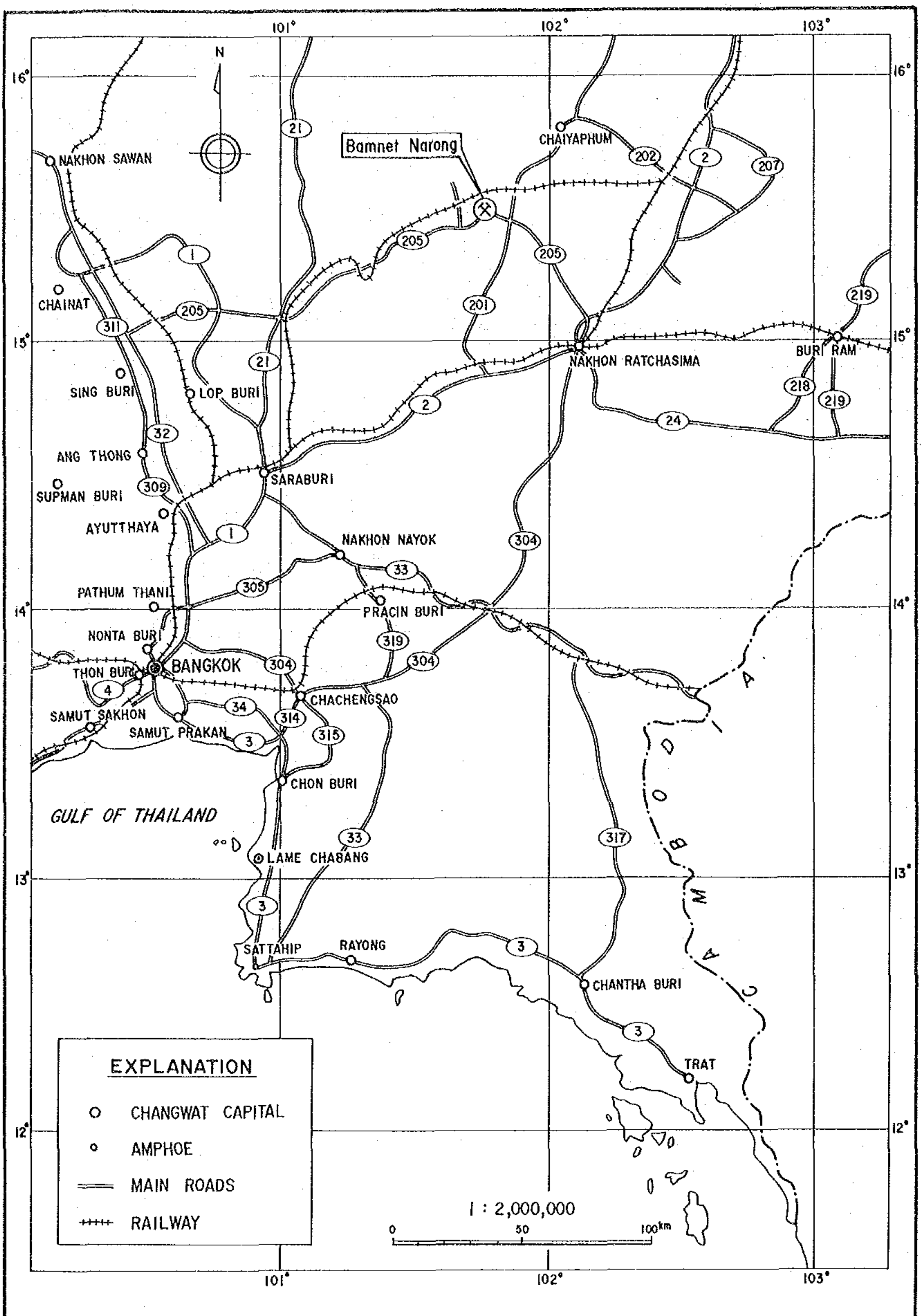


Fig. 2 Index map of project area

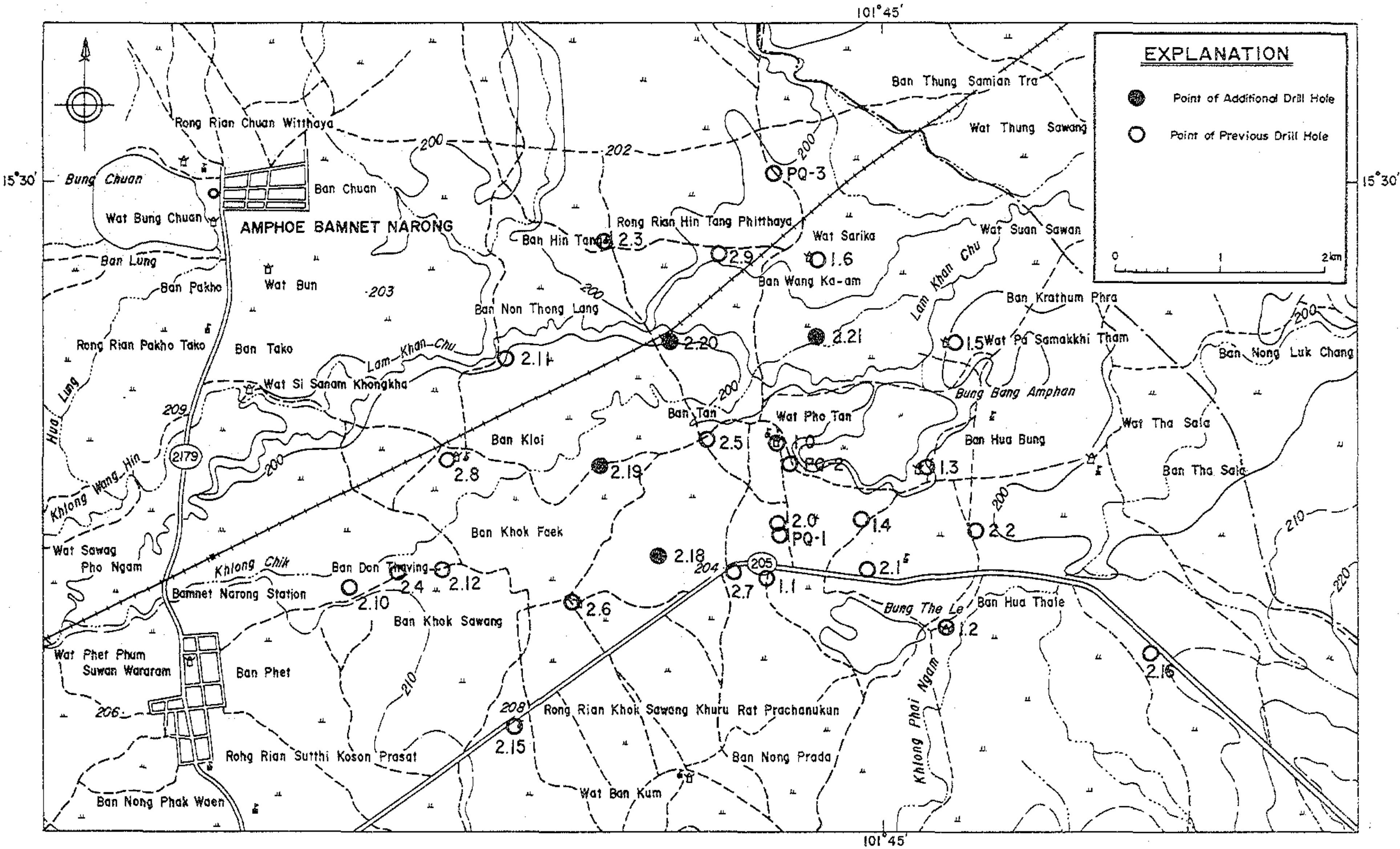


Fig. 3 Location map of drill holes in the Bamnet – Narong rock salt deposits

(Drill holes locations taken from DMR data, Nov, 1979)

SUMMARY

Bamnet-Narong rock salt deposit is situated approximately in lat. 15°28'N and long. 101°24'E. in the southwest of Khorat Plateau, northeastern Thailand.

For implementation of ASEAN Rock Salt-Soda Ash Project (Thailand), which is to be realized with this deposit as the material source, the first-stage survey was carried out to obtain the data on which the project is based, in advance of the comprehensive evaluation to be conducted in the near future. The survey was made from August 1979 to June 1980.

The first-stage survey includes additional drilling, drill core investigation, chemical analysis, rock mechanics tests, and studies of the results of such works.

These works have disclosed the following:

1. In Bamnet-Narong rock salt deposit, there is occurrence of a rock salt 100 m to 280 m in thickness, having an enormous amount of reserves of rock salt.

2. This rock salt can be divided into the two beds of Halite-A and Halite-B.

3. In distribution of Halite-A bed, one part of it occurs in D-area and the other in S-area.

4. Among these, Halite-A bed in S-area is excellent in both structure and quality.

5. From this Halite-A bed in S-area, rock salt with NaCl content of more than 95% will be well secured according to the result of chemical analysis, but it all-pervasively has a little more contents of anhydrite and water-insoluble matters than the salt imported to Japan recently.

6. On the other hand, it is found that the physical properties of the rock salt permit underground mining. For one thing, compressive strength of Halite-A is about 210 kg/cm^2.

7. We also confirmed physical properties required for mining design, including creep property and behavior under confining pressure, which are properties peculiar to rock salt.

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CHAPTER 1. INTRODUCTION

1.1 Progress in the Past and Object of Survey

It was decided that Japan International Cooperation Agency was to make the survey of ASEAN Rock Salt - Soda Ash Project (Thailand) at the request of the Governmet of the Kingdom of Thailand. Prior to carrying out the comprehensive evaluation, a preliminary survey team was sent over to Thailand in March 1979.

At the time of this preliminary survey the Thai Government expressed their intent to the following effect: Full study had not been made of Bamnet-Narong rock salt deposit to supply the raw material for this project. So that, before making the comprehensive evaluation, chemical analysis to determine the purity and impurities of the rock salt of the deposit and rock mechanics tests of the rock salt to support formation of the rock salt mining plan were required. The Thai Government would conduct an additional drilling work for a total length of 3,000 ft. in Bemnet-Narong area, financing it out of the Government budget, on the premise that the chemical analysis and rock mechanics tests would be conducted by the Japanese side.

As the result of study of this proposition by the Japanese side, the necessity for an advance survey of the rock salt deposit was recognized, and it was decided that chemical analysis of the rock salt and the rock mechanics tests should be made by the Japanese side. For this survey, which was titled "the first-stage survey for ASEAN Rock Salt-Soda Ash Project (Thailand)", technical experts were dispatched to Thailand, and analysis of the collected samples and their test were conducted in Japan.

As above-mentioned, the object of the first-stage survey is to obtain the basic data necessary for the resources survey of the rock salt and formation of the mining plan which are to be made in the comprehensive evaluation.

1.2 Location of Bamnet-Narong Rock Salt Deposit

Bamnet-Narong rock salt deposit is located in the district of Bamnet-Narong, Chaiyaphum Prefecture, about 220 km in a straight line to the northeast of Bangkok and about 70 km in a straight line to the northwest of Nakhon Ratchasima City. It is situated approximately in lat. 15°28'N and long. 101°24'E. (Found in 1/50,000 scale topographical map of Amphore Bamnet Narong, 5,339, IV.)

Near this area run National Highway 205 (a paved, 2-lane road) and a national railway line.

1.3 Progress of Survey

The additional drilling, technical discussion about the drilling work, investigation of the cores from the drilling, the sampling work, and various kinds of analysis and tests in Japan progressed as set forth on Table 1.1.

Table 1.1 Progress of First Stage Survey

		'79 Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	'80 Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.
Thai side	Additional drilling			(RS. 2. 18) (RS. 2. 19)	(RS. 2. 20)			(RS. 2. 21)						
Japan side	Technical meeting		(Sending a geologist to Thailand)											
	Investigation					(Sending two geologists to Thailand)								
	Chemical analysis													
	Rock mechanics test													
	Studies													

1.4 Persons engaged in Survey

a. Additional drilling:

Drilling team of Department of Mineral Resources,
Ministry of Industry, Thai Government

b. Technical meeting to discuss the additional drilling:

Dept. of Mineral Resources	Dr. Anant Suwanapal Thawat Japakasetr
J.I.C.A. (Nittetsu Mining Co., Ltd.)	Atsushi Ofusa

c. Drill core investigation and sampling work:

J.I.C.A, (Nittetsu Mining Co., Ltd.)	Atsushi Ofusa Jun Matsunaga

The same work about drill hole RS.2.21 was made by the Department of Mineral Resources, Ministry of Industry.

d. Chemical analysis:

Mitaka Research Laboratory,
Research & Development Dept.,
Nittetsu Mining Co., Ltd.

e. Rock mechanics tests:

Mitaka Research Laboratory,
Research & Development Dept.,
Nittetsu Mining Co., Ltd.

Dept. of Mineral Development Eng.,
Faculty of Eng.,
University of Tokyo

f. Analytical research:

(a) Geology

Atsushi Ofusa	Exploration Dept., Nittetsu Mining Co., Ltd.
Jun Matsunaga	Engineering Dept., Nittetsu Mining Co., Ltd.

(b) Chemical analysis

Atsushi Ofusa	Exploration Dept., Nittetsu Mining Co., Ltd.

(c) Rock mechanics tests

Yoshiyuki Imai	Nittetsu Mining Consultants Co., Ltd.

1.5 Report of Survey in the Past

SNC Inc. of Canada, entrusted by the Asian Development Bank, made a survey of Bamnet-Narong area from 1977 to 1978. The result of the survey is described in "Report on the Feasibility of a Rock Salt – Soda Ash Project in Thailand".

CHAPTER 2. SURVEY AT SITE

The additional drilling of four holes, 967.65 m in total length, in Bamnet-Narong rock salt deposit was made by Department of Mineral Resources, Ministry of Industry.

The drill core investigation and sampling work for the three drill holes of 2.18, 2.19, 2.20, which had been finished by late in October 1979, out of the four holes in the additional drilling were made by two geologists sent from Japan. For the remaining drill hole of 2.21, sampling work was made by the Thai side by the same method as the Japanese geologists made, because of the delay in drilling work.

The survey work at the site is described in the following.

2.1 Drilling Work

The drilling work was made by Department of Mineral Resources in two times. This division of work was necessary because drill hole 2.21 was situated in a paddy region and the work had to be made after harvest of the paddy there, three or four months later than the work of the other three drill holes.

The drilling was made with a PQ size (85 mm), and the rock salt core recovery was quite high.

The result of these drilling operations is summarized in Table 2.1.

2.2 Core Investigation and Sampling Work

(1) Core Investigation

Examination and recording were made of the cores obtained by drilling for rock names, color tones, core recovery, horizons, hardness, and structure. The result of such investigation is summarized in Appx. 1 (a) to 1 (d). Also photographs were taken of the cores. The photos are shown in Appx. 9.

Table 2.1 Result of Core Drilling Operations

Drill hole	Period of work	Elevation	Depth	Rock salt range		Core recovery
				Intervals	Thickness	
RS. 2. 18	Aug. 19, '79 – Sep. 18, '79	204 m	242.00 m	108.78 m – 240.47 m	131.69 m	100%
RS. 2. 19	Aug. 22, '79 – Sep. 12, '79	204 m	246.40 m	64.00 m – 246.40 m	182.40 m	99.8%
RS. 2. 20	Sep. 23, '79 – Oct. 20, '79	204 m	218.35 m	75.10 m – 216.61 m	141.51 m	99.9%
RS. 2. 21	Jan. 18, '80 – Jan. 28, '80	204 m	260.90 m	68.72 m – 258.70 m	189.98 m	100%
Total			967.65 m			

(2) **Taking Samples for Rock Mechanics Tests**

Samples of a 30 to 35 cm length each were taken from rock salt cores retaining good shape at about 6 m intervals of the core. The weight of one sample is about 4 kg. In taking the samples, the rock salt cores were cut with a hacksaw.

(3) **Taking Samples for Chemical Analysis**

After taking samples for rock mechanics tests, the samples for chemical analysis were taken. In taking them, all of the rock salt cores were cut lengthwise with equipment brought from Japan, including a powered cutter, diamond saw, and transformer. The samples thus cut were divided at intervals of about 3 m, making each of them one sample.

The sample made in this manner were pulverized using a small stone mortar, and then subjected to averaging reduction with a riffle sampler and sieve, to make the finished samples about 500 g in weight each.

For the five drill holes of 1.3, 1.6, 2.2, 2.5 and 2.9 which were formerly worked out, the samples for chemical analysis were taken by Department of Mineral Resources.

The core investigation and sampling work are summarized in Table 2.2.

2.3 Transport of Samples

The samples taken for chemical analysis and rock mechanics tests were securely packed up considering prevention of moisture and damage from shocks. They were transported to Japan by air in two times.

(a) First transport
Samples from three drill holes of 2.18, 2.19 and 2.20, 722 kg in total weight, arriving at Narita Airport on Nov. 14, 1979

(b) 2nd transport
Samples from one drill hole of 2.21, 265 kg in weight, arriving at Narita Airport on Mar. 19, 1980.

Photographs at site are shown in Appx. 8.

Table 2.2 Summary of Core Investigation and Sampling Work

Drill hole		Cores investigated	Number of samples		Investigation	Period of work
			For chemical analysis	For rock-mechanics tests		
Additional hole	RS. 2. 18	242.00 m	43	23	Two Japanese geologists & cooperating Thai staff	25 Oct., 1979 ~ 13 Nov., 1979
	RS. 2. 19	246.40	58	30		
	RS. 2. 20	218.35	46	26		
	RS. 2. 21	260.90	63	32	D.M.R., Thai Govt.	Jan., 1980
	Total	967.65 m	210	111		
Previously made hole	RS. 1.3	-	10	-	D.M.R., Thai Govt.	Nov., 1979
	RS. 1.6	-	10	-		
	RS. 2.2	-	10	-		
	RS. 2.5	-	10	-		
	RS. 2.9	-	10	-		
	Total	-	50	-		
Total			260	111		

CHAPTER 3. CHEMICAL ANALYSIS AND ROCK MECHANICS TESTS

The samples brought into Japan were subjected to chemical analysis and rock mechanics tests as undermentioned. In addition, X-ray diffraction, microscopic observation and microphotography were conducted on part of the samples.

3.1 Chemical Analysis

(1) Samples, Components for Analysis, and Analytical Instruments

All the samples for chemical analysis, after arrival in Japan, were chemically analyzed, which is described in the following:

a. For all the 210 samples from the additional four drill holes, chemical analysis of the rock salt for its main components, H_2O, water insoluble matters, Cl, SO_4, Ca, Mg, K, Na and NaCl, was made by the wet chemical analysis method in accordance with "Methods for Salt Analysis, 1961, by the Japan Monopoly Corporation".

b. For 17 samples of the above-mentioned ones, analysis for the heavy metals of Cd, Cr, Hg, Fe, Cu, Zn, Pb, As, V and Mn was made by atomic absorption spectroscopy with a Shimazu Atomic Absorption Frame Spectrophotometer.

c. For 210 samples from the additional four drill holes, analysis for Br was made by the fluorescence X-ray method with a Rigaku Denki Fluorescence X-ray Geiger Flex.

d. For the remaining part of the samples from the formerly made drill holes (50 samples from the five holes), which had been chemically analyzed by Department of Mineral Resources, analysis was made for the components of Cl, SO_4, Ca, Mg, K and NaCl by the same method as in a. above. This was made for the purpose of a comparative study of the result of the analysis by the said department with that by the Japanese side.

The items of the chemical analysis above-mentioned are summarized in Table 3.1.

Table 3.1 Details of Components by Chemical Analysis

		Number of Samples	Main Component										Trace Component												Total
			H_2O	I.M	Cl	SO_4	Ca	Mg	K	Na	NaCl	Total	Cd	Cr	Hg	Fe	Cu	Zn	Pb	As	V	Mn	Br	Total	
Additional Drilling	2.18	43	43	43	43	43	43	43	43	43	43	387	5	5	5	5	5	5	5	5	5	5	43	93	480
	2.19	58	58	58	58	58	58	58	58	58	58	522	7	7	7	7	7	7	7	7	7	7	58	128	650
	2.20	46	46	46	46	46	46	46	46	46	46	414	5	5	5	5	5	5	5	5	5	5	46	96	510
	2.21	63	63	63	63	63	63	63	63	63	63	567	–	–	–	–	–	–	–	–	–	–	63	63	630
	Total	210	210	210	210	210	210	210	210	210	210	1,890	17	17	17	17	17	17	17	17	17	17	210	380	2,270
Previous Drilling	1.3	10	–	–	10	10	10	10	10	–	10	60	–	–	–	–	–	–	–	–	–	–	–	–	60
	1.6	10	–	–	10	10	10	10	10	–	10	60	–	–	–	–	–	–	–	–	–	–	–	–	60
	2.2	10	–	–	10	10	10	10	10	–	10	60	–	–	–	–	–	–	–	–	–	–	–	–	60
	2.5	10	–	–	10	10	10	10	10	–	10	60	–	–	–	–	–	–	–	–	–	–	–	–	60
	2.9	10	–	–	10	10	10	10	10	–	10	60	–	–	–	–	–	–	–	–	–	–	–	–	60
	Total	50	–	–	50	50	50	50	50	–	50	300	–	–	–	–	–	–	–	–	–	–	–	–	300
Total		260	210	210	260	260	260	260	260	210	260	2,190	17	17	17	17	17	17	17	17	17	17	210	380	2,570

(2) Results

The results of the chemical analysis are set forth in Appx. 2, 3 and 4.

3.2 Rock Mechanics Tests

(1) Selection of Samples for Tests

Out of the 111 samples taken from four additional drill holes and brought to Japan, 43 were selected for rock mechanics tests after studying the logging (Appx. 1).

The 43 samples consisted of 4 from Halite-A and 5 from Halite-B in Drill Hole 2-18 in D-Area; 5 from Halite-A and 4 from Halite-B in Drill Hole 2-19 in D-Area; 6 from Halite-A in Drill Hole 2-20 in S-Area; and 19 from Halite-A in Drill Hole 2-21 in S-Area. (See 4.1 (2))

Out of the 43 samples, 4 were used to prepare test pieces for the creep test. Attempts were made to prepare creep test pieces from samples collected from Drill Hole 2-20, but failed because the core had been embrittled.

The relationship between sampling points and halite beds is shown in Table 3.2. Fig. 3.1 illustrates the relationship with the logging. Sampling depths from the surface are indicated in Table 3.3.

Table 3.2 Samples Classified by Halite Beds

Area	Drill Hole No.	Halite Bed	Samples for uniaxial compression and Brazilian tests	Samples for creep test	Total
D	RS. 2. 18	Halite-A Halite-B	4 4	- 1	4 5
	RS. 2. 19	Halite-A Halite-B	4 4	1 -	5 4
S	RS. 2. 20	Halite-A	6	-	6
	RS. 2. 21	Halite-A	17	2	19
Total			39	4	43

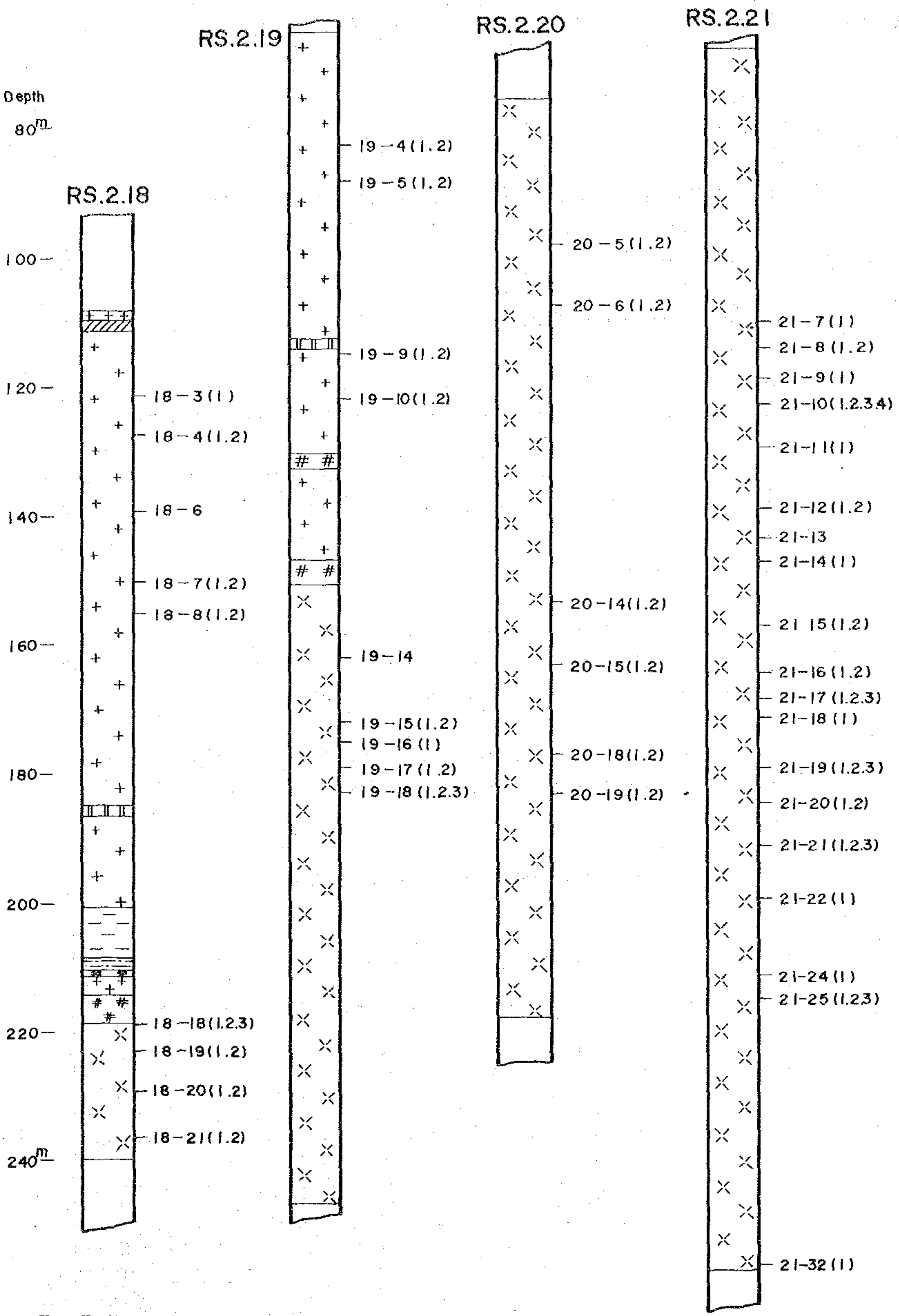


Fig.3·1 Sample location of Rock Mechanics Test
(for log legend see Fig.4·2)
( ) shows sub number of test pieces

Table 3.3 Depths of Sampling Site

Sample No. for Rock Mech. Test	Depth from Surface	Sample No. of Rock Mech. Test	Depth from Surface
	(m) (m)		(m) (m)
18 - 3	121.70 – 122.00	20 - 18	176.83 – 177.16
4	127.82 – 128.14	19	183.11 – 183.43
6	139.63 – 139.95	21 - 7	110.38 – 110.65
7	150.00 – 150.33	8	114.64 – 114.95
8	155.30 – 155.61	9	119.70 – 120.00
18	218.96 – 219.32	10	123.33 – 123.65
19	222.90 – 223.25	11	129.20 – 129.54
20	228.55 – 228.88	12	139.23 – 139.53
21	236.01 – 236.35	13	144.70 – 145.00
19 - 4	83.13 – 83.44	14	147.59 – 147.92
5	88.02 – 88.33	15	157.20 – 157.50
9	115.00 (±)	16	164.14 – 164.46
10	122.00 (±)	17	168.11 – 168.45
14	161.62 – 161.97	18	171.50 – 171.83
15	171.55 – 171.85	19	179.47 – 179.80
16	174.72 – 175.05	20	184.50 – 184.90
17	179.49 – 179.82	21	191.23 – 191.70
18	182.95 – 183.25	22	199.75 – 200.05
20 - 5	98.87 – 99.15	24	211.75 – 212.10
6	107.89 – 108.21	25	214.13 – 214.47
14	153.81 – 154.13	32	256.40 – 256.72
15	163.40 – 163.70		

(2) Preparation of Test Pieces

a. Test pieces for uniaxial compression and Brazilian tests

Samples taken from Drill Holes 2-18, 2-19, and 2-20 were sealed with adhesive tape to prevent crumbling during cutting and end smoothing. After cutting and smoothing, the tape was removed, and the test pieces were stored in an oven (kept at about 60°C) until use in tests.

Samples from Drill Hole 2-21 were resampled by means of a small core sampling machine with a 50 mm diameter. Kerosene was used as lubricant for resampling. Resampling was performed for two reasons: To hold the difference between the maximum and minimum heights of the test piece within 0.1 mm, and to facilitate adhesion of the test piece and the cantilever for measurement of lateral displacement.

The samples were cut in the desired length with a hacksaw and the ends were smoothed by means of sandpaper No.400 and kerosene.

b. Test pieces for creep test

Test pieces for the creep test were prepared through resampling in the same way as described above.

Since the site of cutting had to be selected carefully so as to prevent damage to the test pieces, the ratio of test piece height vs. diameter could not be made uniform. Nevertheless, the difference between maximum and minimum heights was held within 0.1 mm.

c. Numbers of test pieces

The numbers of test pieces prepared for the rock mechanics tests are presented in Table 3.4.

Table 3.4 Numbers of Test Pieces Classified by Tests

Drill Hole No.	For uniaxial compression test, incl. P-wave velocity	For Brazilian test, incl. Shore hardness	For creep test	Total
RS. 2. 18	8	16	1	25
RS. 2. 19	9	14	1	24
RS. 2. 20	6	12	-	18
RS. 2. 21	7	33	2	42
Total	30	75	4	109

(3) Measurement

a. Items

The rock mechanics tests were performed with regard to the following eight items:

Uniaxial compression test:

1. Compressive strength (Sc)
2. Young's modulus (E)
3. Poisson's ratio (ν)

Brazilian test:

4. Tensile strength (St)

Other tests:

5. P-wave velocity (Vp)
6. Density (ρa)
7. Shore hardness (Hs)

Creep test:

8. Creep modulus (E, η)

b. Numbers of measurements

The numbers of measurements taken are classified by test items and drill holes in Table 3.5.

Table 3.5 Numbers of Measurements

Item / Drill hole	Sc	E	ν	Vp	St	ρa	Hs	E, η	Total
RS. 2. 18	8	8	8	8	16	25	7	1	81
RS. 2. 19	9	9	9	9	14	24	7	1	82
RS. 2. 20	6	6	6	6	12	18	8	-	62
RS. 2. 21	7	7	7	7	33	9	4	2	76
Total	30	30	30	30	75	76	26	4	301

Measured results are listed in Appx. 7.

(4) **Instruments and Measuring Methods**

a. Uniaxial compression test (Fig. 3.2 (a) - (h))

An Amsler type 100 ton compression tester (manufactured by Tokyo Koki Seisakusho) was used to measure stress and strain, from which compressive strength, Young's modulus, and Poisson's ratio were calculated. To measure axial displacement for obtaining Young's modulus and Poisson's ratio, a linear variable differential transformer (LVDT) was used. To measure lateral displacement, a special cantilever was employed for test pieces with an 85 mm diameter, and a ring gauge for those with a 49.4 mm diameter. Axial displacement, lateral displacement, and load were recorded by means of an X-Y-Y- recorder.

For compressive strength, peak strength was measured. For Young's modulus, tangential Young's modulus near the origin and secant Young's modulus at 80% peak strength were obtained.

Poisson's ratio, as in the case of Young's modulus, was calculated from tangential Poisson's ratio near the origin, and 80% secant Young's modulus.

Axial strain speed was controlled to 10^{-5} mm/sec.

b. Brazilian test (Fig. 3.2 (i))

For the Brazilian test, an Amsler type 20 t. universal testing machine (manufactured by Tokyo Koki Seisakusho) was used. From fracture load, tensile strength was calculated by the elastic theory.

c. P-wave velocity (Fig. 3.2 (k) (l))

P-wave velocity was measured from the oscilloscope image on an ultrasonic wave measuring instrument (manufactured by Riken Electronics K.K.).

d. Density

The test pieces were dried in an oven and density was represented by the weight per unit volume in a dry state.

e. Shore hardness (Fig. 3.2 (j))

A Type C Shore hardness tester was used.

f. Creep test (Fig. 3.2 (m), (n))

A 5 ton creep test machine (manufactured by Tokyo Koki Seisakusho) was used. Test pieces from samples 18-6 and 19-14 were tested at 80% stress level, and those from samples 21-11 and 21-13 at 30% stress level.

The times required for the test were as follows:

Test piece No.	Time required (minutes)
18-6	7,206
19-14	6,860
21-11	18,435
21-13	28,620

In load measurement, a load cell was used to measure the load applied directly to the test piece. For axial strain, a linear variable differential transformer (LVDT) was used because the large rock salt particle size made it impossible to use a gauge. Output of the LVDT was recorded on a universal digital recorder, UCAM-8B (manufactured by Kyowa Electric K.K.) through a dynamic strain meter. At the same time, time-strain-stress curves were also output.

To prevent the test pieces from absorbing humidity, room temperature was maintained at 20°C.

(5) **Results**

a. Uniaxial compression test, P-wave velocity, density

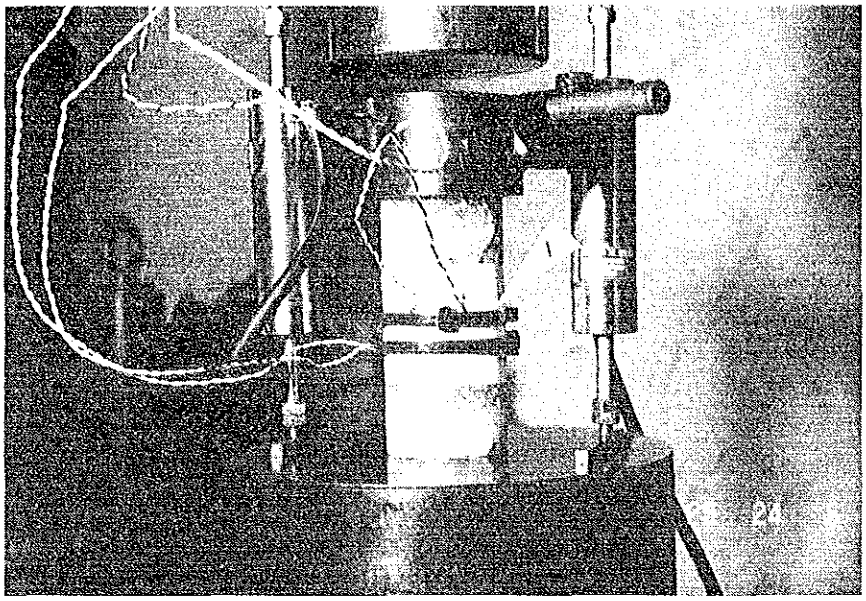
Compressive strength (Sc), tangential Young's modulus (E tan), 80% secant Young's modulus (E 80% sec), tangential Poisson's ratio (ν tan) and 80% secant Poisson's ratio (ν 80% sec) measured in the uniaxial compression test are given in Table 3.6, which also shows P-wave velocity (Vp) and density (ρa).

Typical stress-strain curves are shown in Fig. 3.3 (a), (b), (c), (d), (e) and (f).

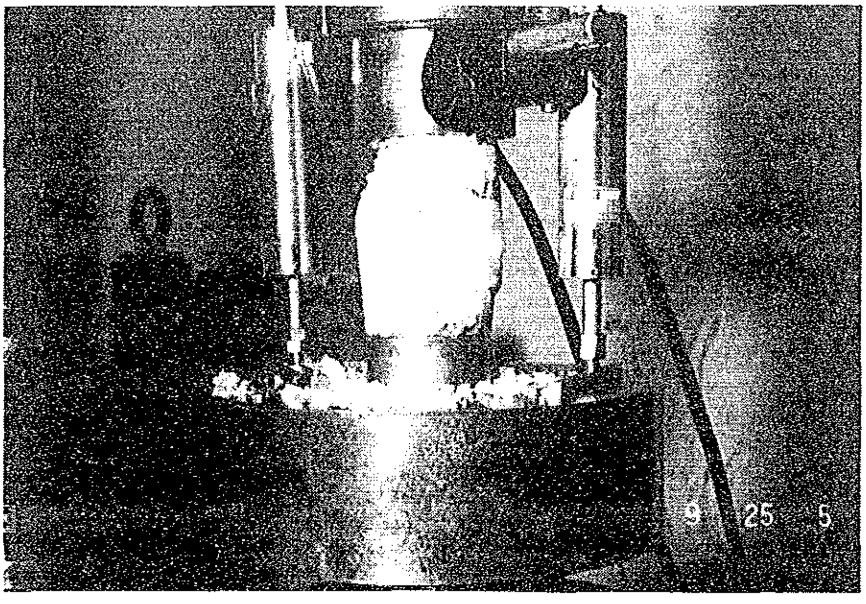
Table 3.6 Results of Uniaxial Compression Test, P-wave Velocity and Density Measurement

Test Piece Number \ Item	Test Piece Dimension		Density	P-wave Velocity	Compressive Strength	Young's Modulus		Poisson's Ratio		Remarks
	Diameter	Length	ρa	Vp	Sc	E tan	E 80% sec	ν tan	ν 80% sec	
	(mm)	(mm)	(g/cm^3)	(x 10^3 m/sec)	(kg/cm^2)	(x 10^3 kg/cm^2)	(x 10^3 kg/cm^2)			
18 - 3	85.20	176.0	2.2	4.5	297	45.8	11.4	0.28	0.54	Halite B in D Area
4	85.15	175.2	2.2	4.4	315	34.4	12.9	0.33	0.57	Halite B in D Area
7	85.00	177.0	2.2	4.2	338	53.9	12.8	0.27	0.69	Halite B in D Area
8	85.00	174.5	2.2	4.4	343	41.2	10.6	0.32	0.57	Halite B in D Area
18	84.80	165.3	2.2	3.7	298	36.5	10.0	0.24	0.87	Halite A in D Area
19	85.20	177.2	2.2	3.8	320	51.0	9.7	0.40	0.40	Halite A in D Area
20	85.25	176.6	2.2	3.9	286	25.3	11.0	0.19	0.81	Halite A in D Area
21	85.20	177.5	2.2	3.7	303	20.7	8.7	0.24	0.68	Halite A in D Area
19 - 4	85.00	175.5	2.2	4.0	275	35.9	13.0	0.20	0.79	Halite B in D Area
5	85.00	175.5	2.2	3.7	284	28.6	8.9	0.44	0.72	Halite B in D Area
9	85.10	177.4	2.2	4.2	293	53.2	16.6	0.15	0.61	Halite B in D Area
10	85.00	175.2	2.2	4.1	261	59.7	16.3	0.23	0.67	Halite B in D Area
15	85.30	176.2	2.2	3.9	280	25.7	10.6	0.22	0.67	Halite A in D Area
16	85.20	137.9	2.2	3.4	303	27.6	9.7	0.26	0.72	Halite A in D Area
17-1	85.00	127.0	2.2	3.8	295	14.9	9.4	–	–	Halite A in D Area
17-2	85.00	166.5	2.2	3.7	300	21.3	10.7	0.32	0.73	Halite A in D Area
18	85.20	176.4	2.2	3.8	290	25.1	10.6	0.27	0.57	Halite A in D Area
20 - 5	85.00	178.5	2.2	3.9	198	20.3	10.7	0.31	1.00	Halite A in S Area
6	85.00	175.6	2.2	3.6	191	20.0	13.4	0.30	0.95	Halite A in S Area
14	85.20	174.1	2.2	2.7	153	9.3	8.2	0.17	0.73	Halite A in S Area
15	85.30	173.5	2.2	2.2	186	8.0	5.2	0.50	–	Halite A in S Area
18	85.00	173.5	2.1	2.9	240	21.3	10.1	0.23	0.75	Halite A in S Area
19	84.95	174.5	2.2	3.6	245	30.6	13.9	0.16	0.77	Halite A in S Area
21 - 7	49.30	93.7	2.1	2.9	237	16.2	10.4	0.24	0.61	Halite A in S Area
8	49.40	103.9	2.1	N.D	191	8.4	3.8	0.06	0.52	Halite A in S Area
9	49.30	83.2	2.1	N.D	135	6.4	3.3	0.23	0.73	Halite A in S Area
11-1	49.30	90.2	2.1	2.3	200	10.2	5.6	0.36	0.71	Halite A in S Area
24	49.40	77.3	2.1	N.D	247	13.2	6.6	0.32	0.51	Halite A in S Area
25	49.40	102.8	2.1	2.3	265	13.9	7.8	0.09	0.45	Halite A in S Area
32	49.20	97.7	2.1	2.6	254	14.2	8.0	0.17	0.43	Halite A in S Area

N.D: no data

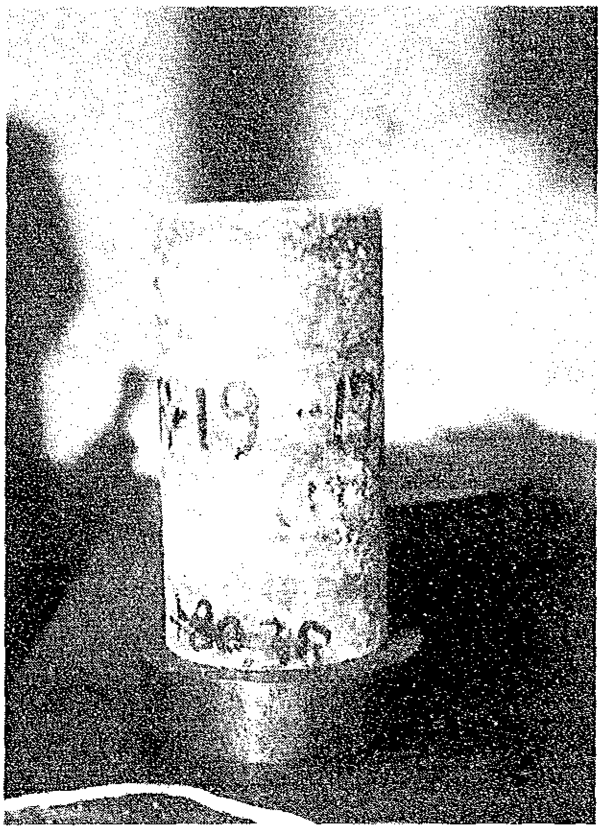


(a) Uniaxial compression test machine.
1. Ring gauge

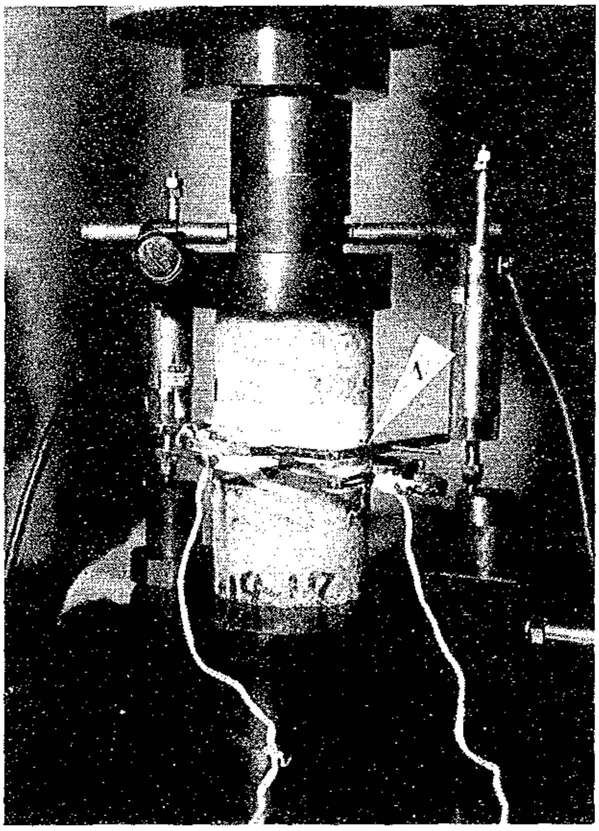


(b) Uniaxial compression test.
Failured test piece.

Fig. 3.2 (a) (b) Photographs Showing Rock Mechanics Tests

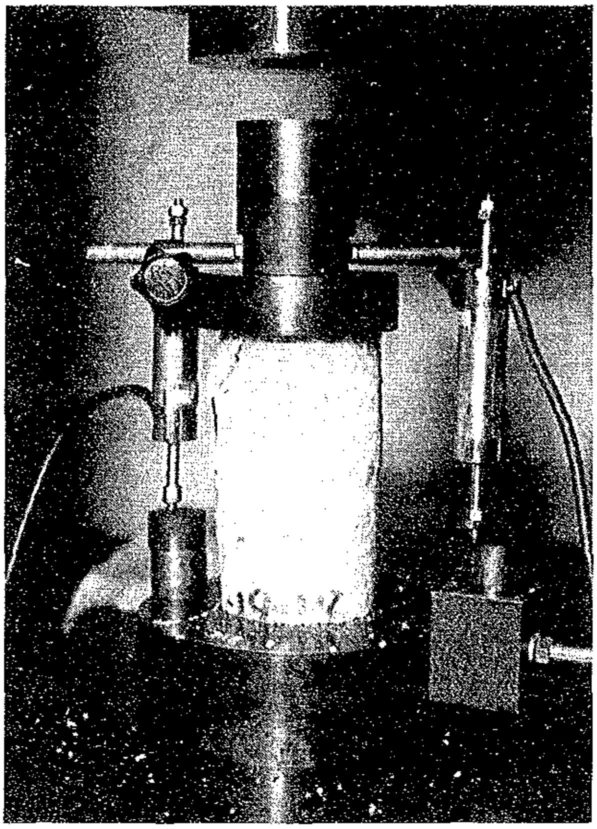


(c) Uniaxial compression test.
Sample before test.

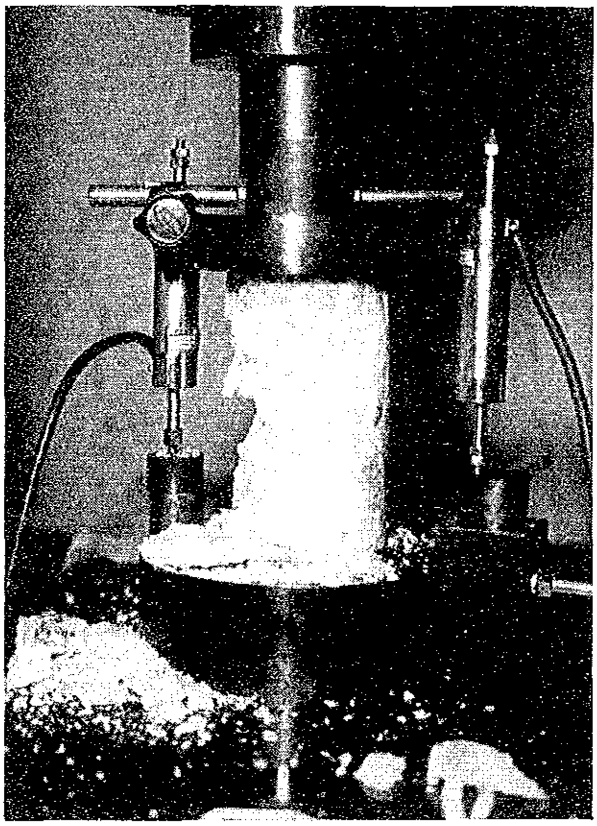


(d) Uniaxial compression test.
Special cantilever to measure radial displacement.

Fig. 3.2 (c) (d) Photographs Showing Rock Mechanics Tests

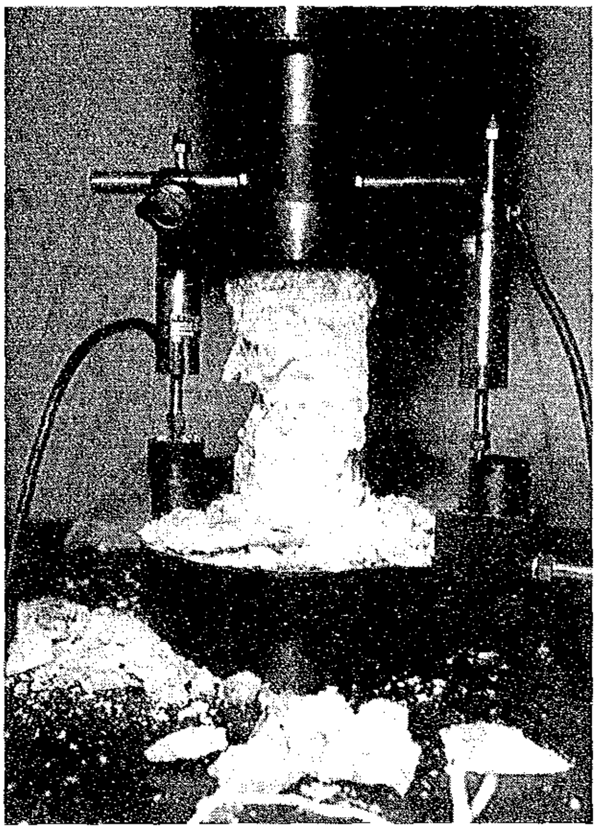


(e) Uniaxial compression test.
Fracture process (1).

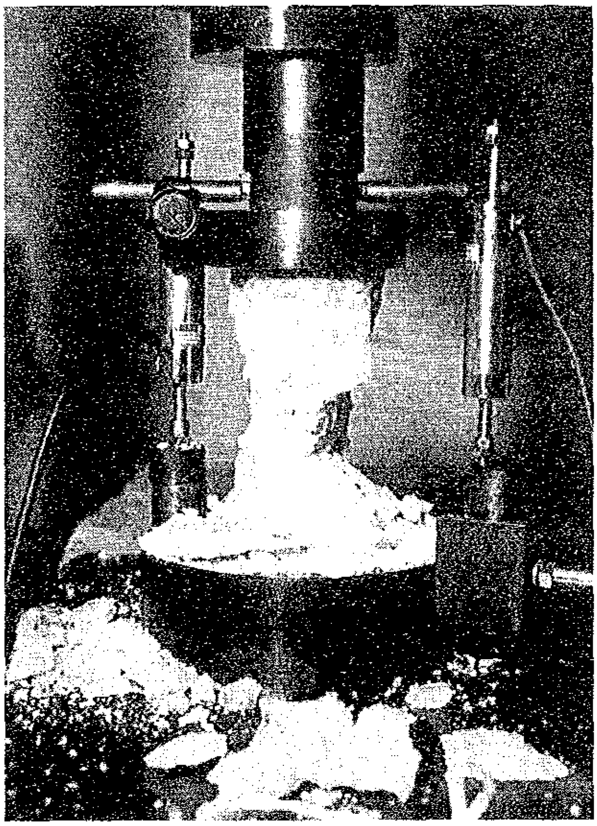


(f) Uniaxial compression test.
Fracture process (2).

Fig. 3.2 (e) (f) Photographs Showing Rock Mechanics Tests



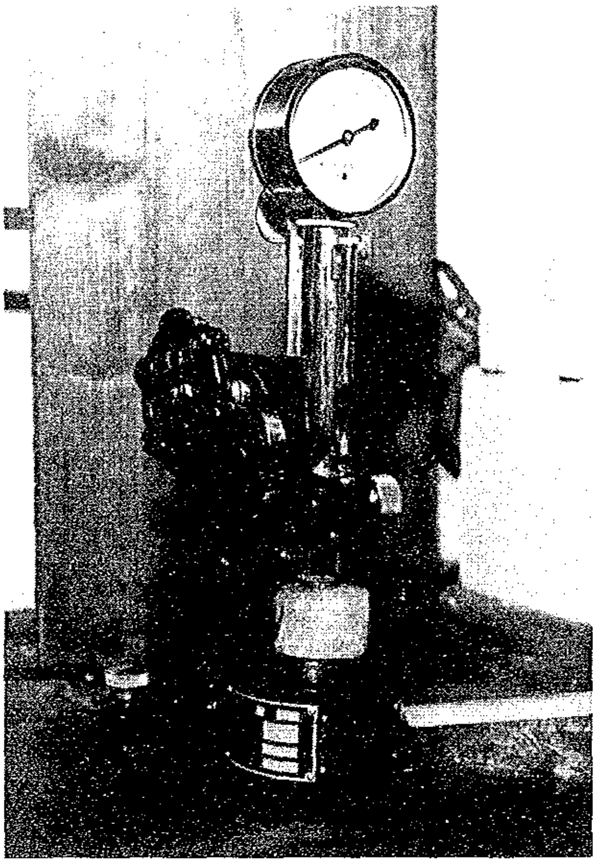
(g) Uniaxial compression test.
Fracture process (3).



(h) Uniaxial compression test.
Fractrue process (4).

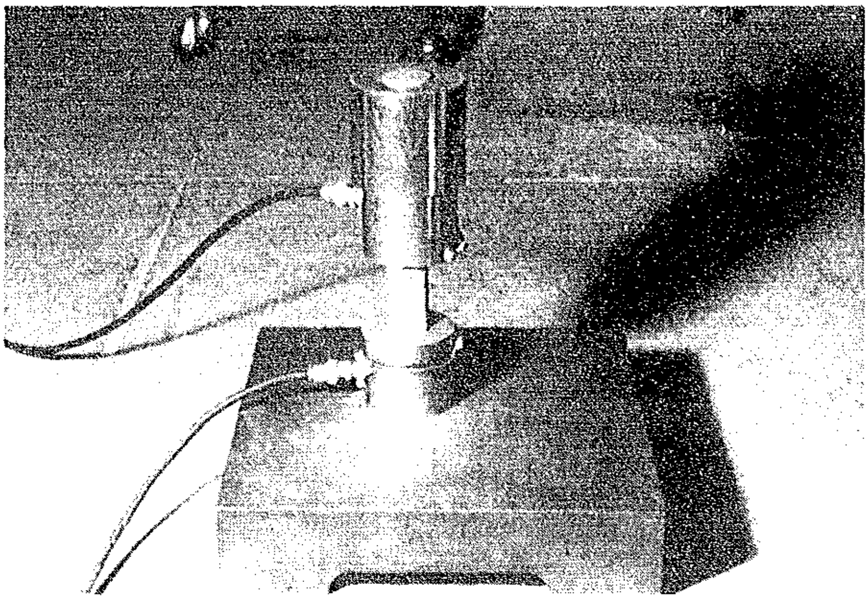
Fig. 3.2 (g) (h) Photographs Showing Rock Mechanics Tests

(i) Brazilian test.

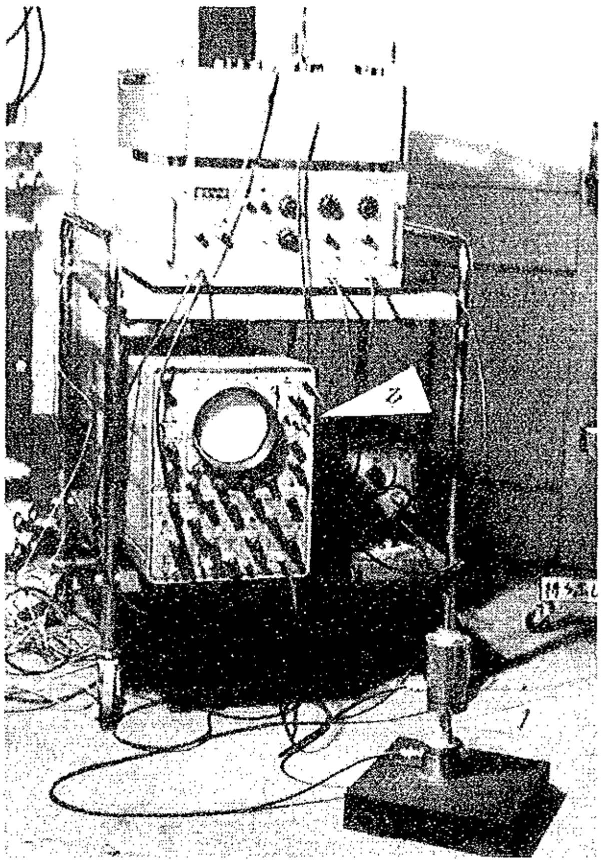


(j) Measurement of shore hardness.

Fig. 3.2 (i) (j) Photographs Showing Rock Mechanics Tests



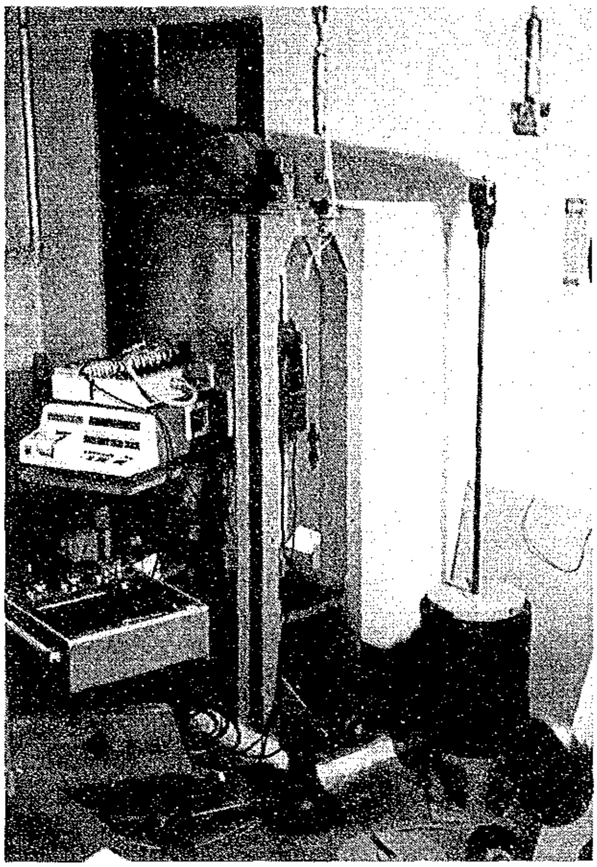
(k) Measurement of P-wave velocity.



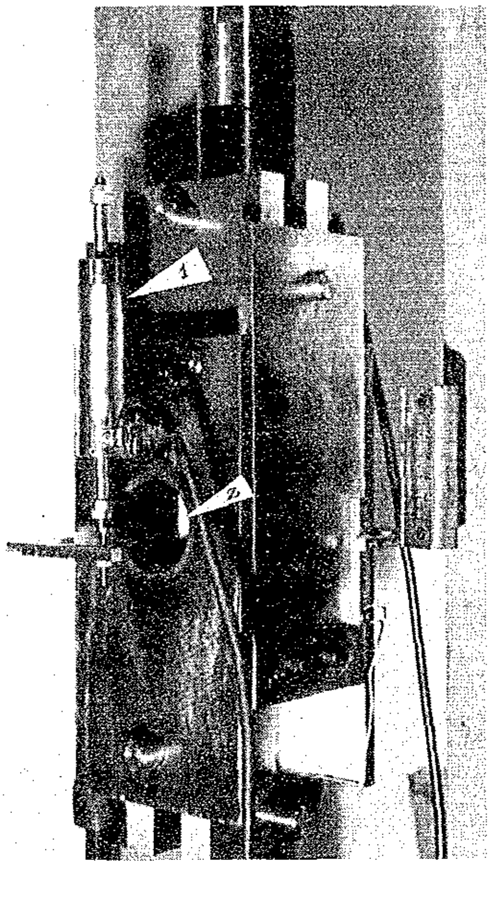
(l) Measurement of P-wave velocity

1. Test piece
2. Oscillograph.

Fig. 3.2 (k) (l) Photographs Showing Rock Mechanics Tests



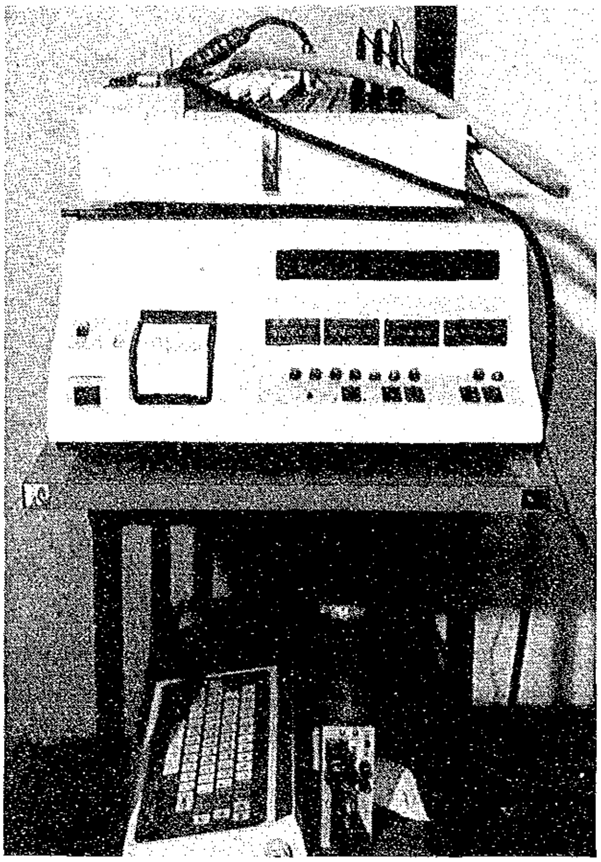
(m) Creep test.



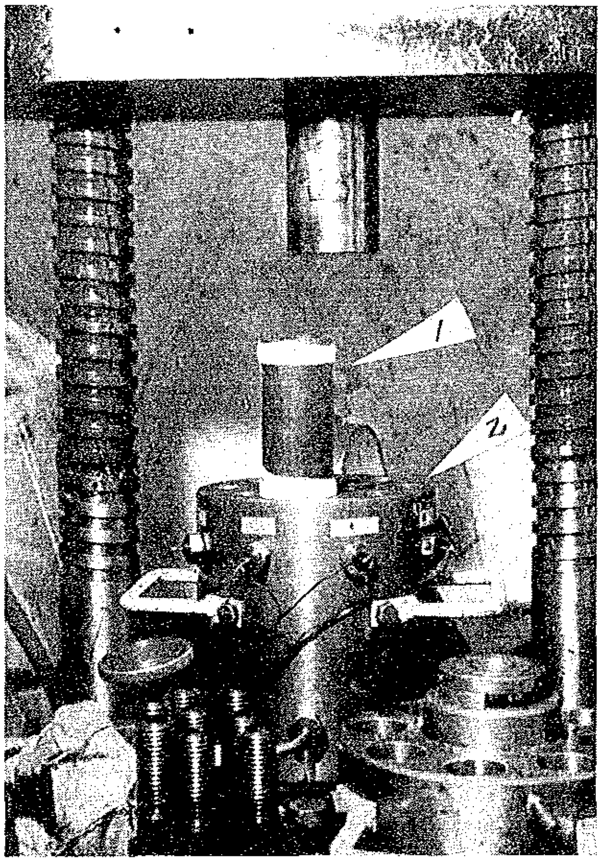
(n) Creep test

1. LVDT
2. Test piece.

Fig. 3.2 (m) (n) Photographs Showing Rock Mechanics Tests



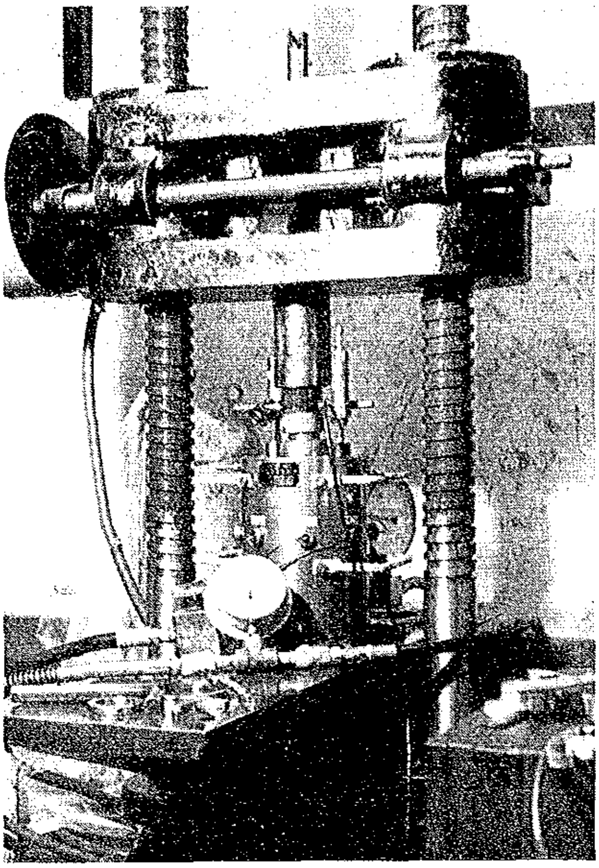
(o) Universal digital recorder.



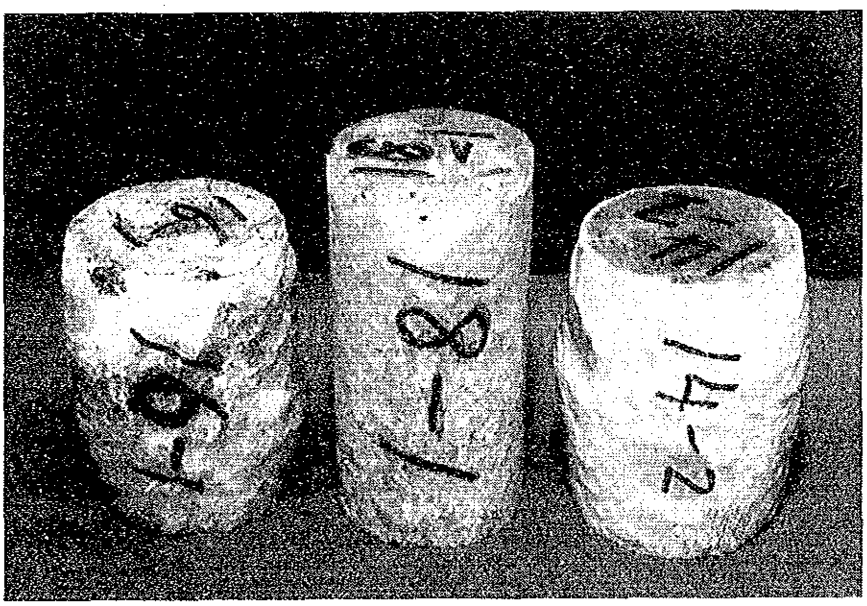
(p) Triaxial compression test

1. Sample
2. Vessel.

Fig. 3.2 (o) (p) Photographs Showing Rock Mechanics Tests

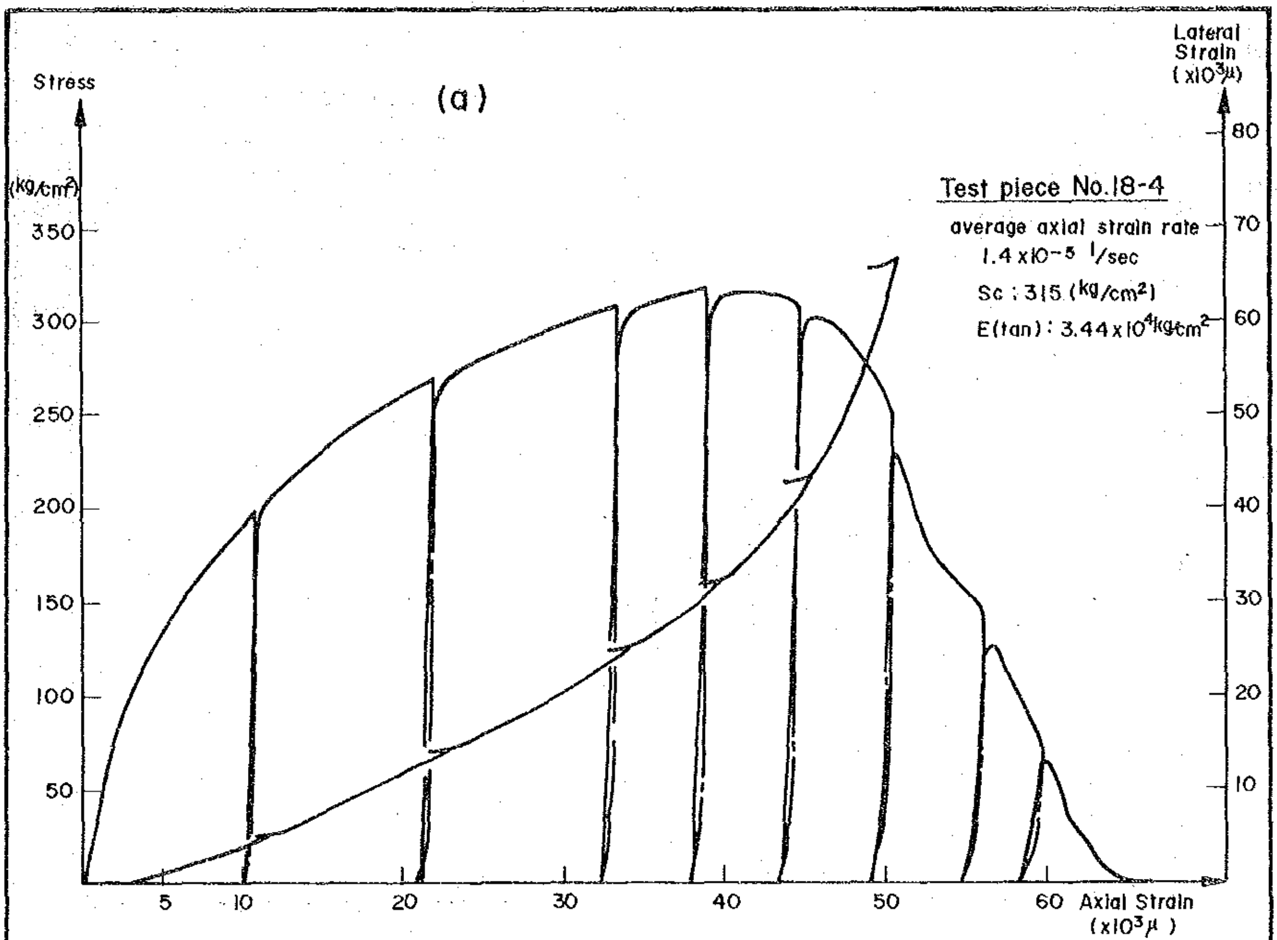


(q) Triaxial compression test.
Under testing.



(r) Triaxial compression test.
Test piece after and before testing.

Fig. 3.2 (q) (r) Photographs Showing Rock Mechanics Tests



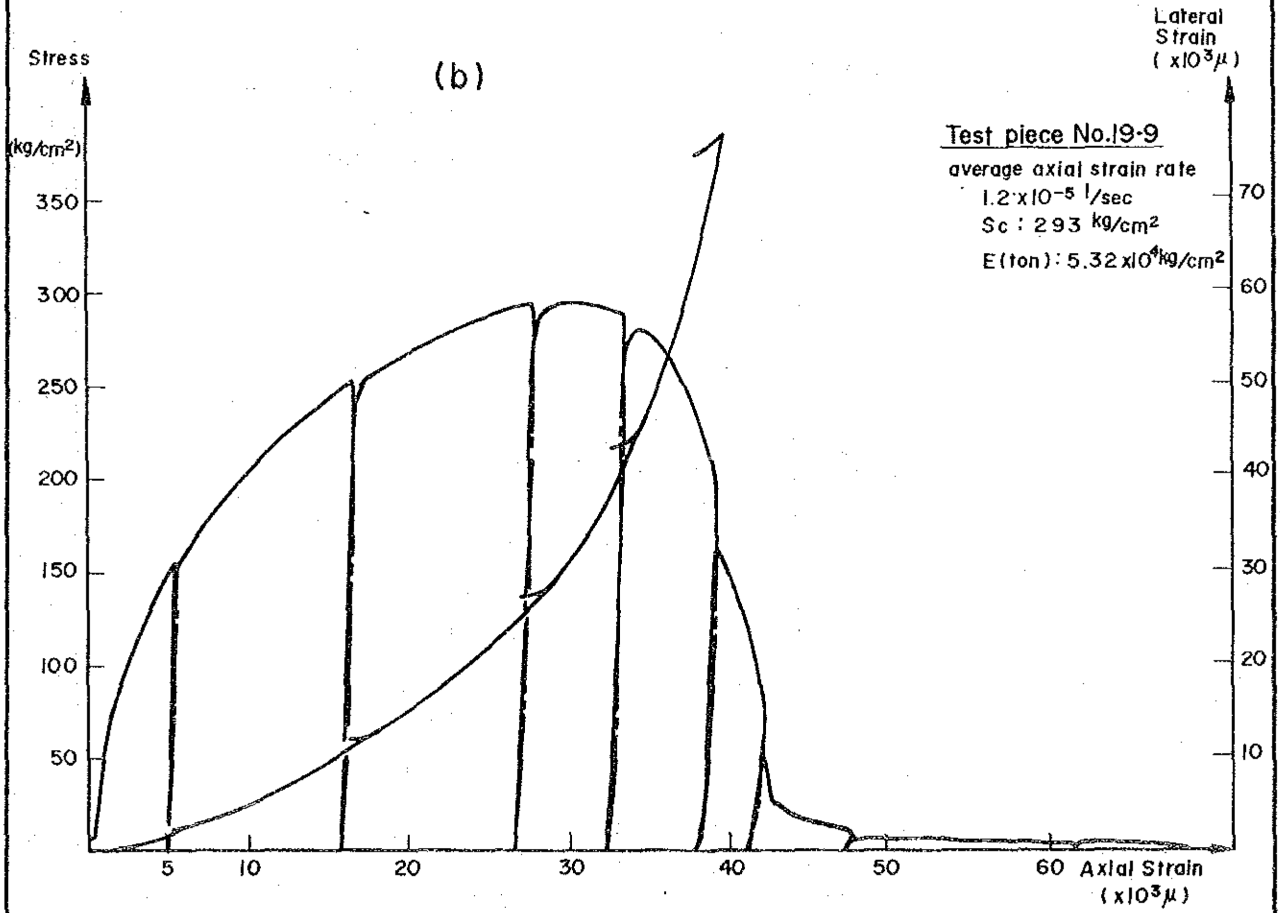
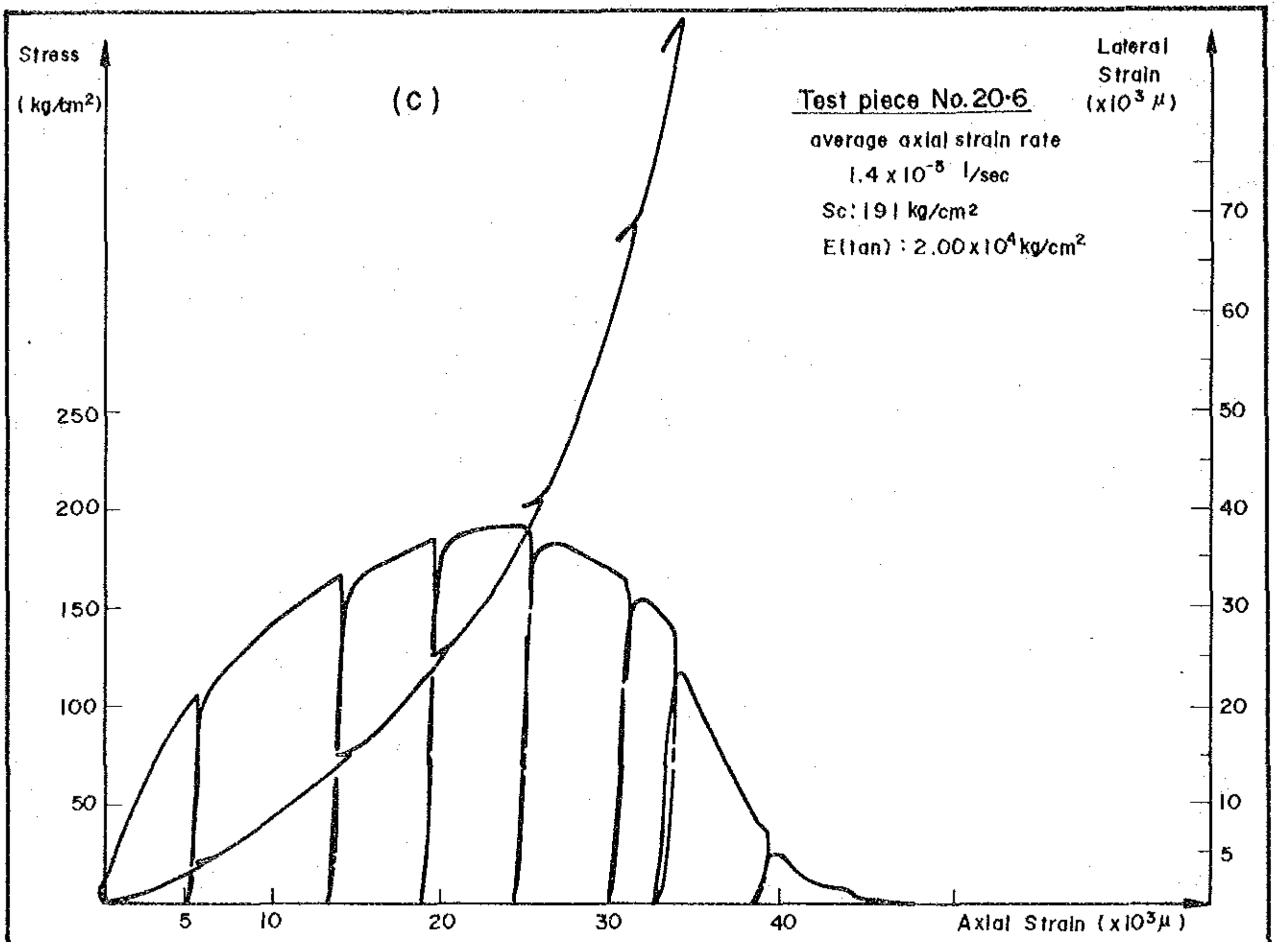


Fig. 3·3 (a),(b) Stress – strain curve



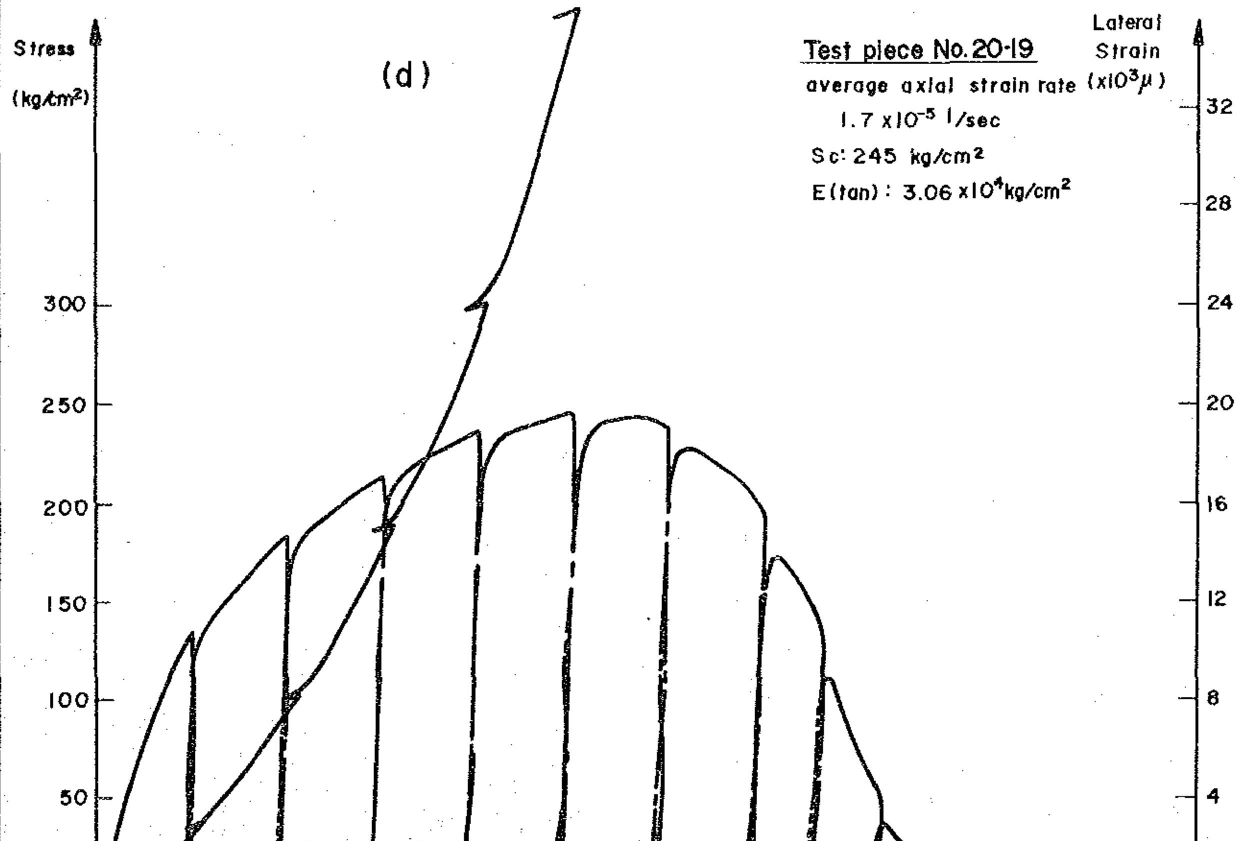
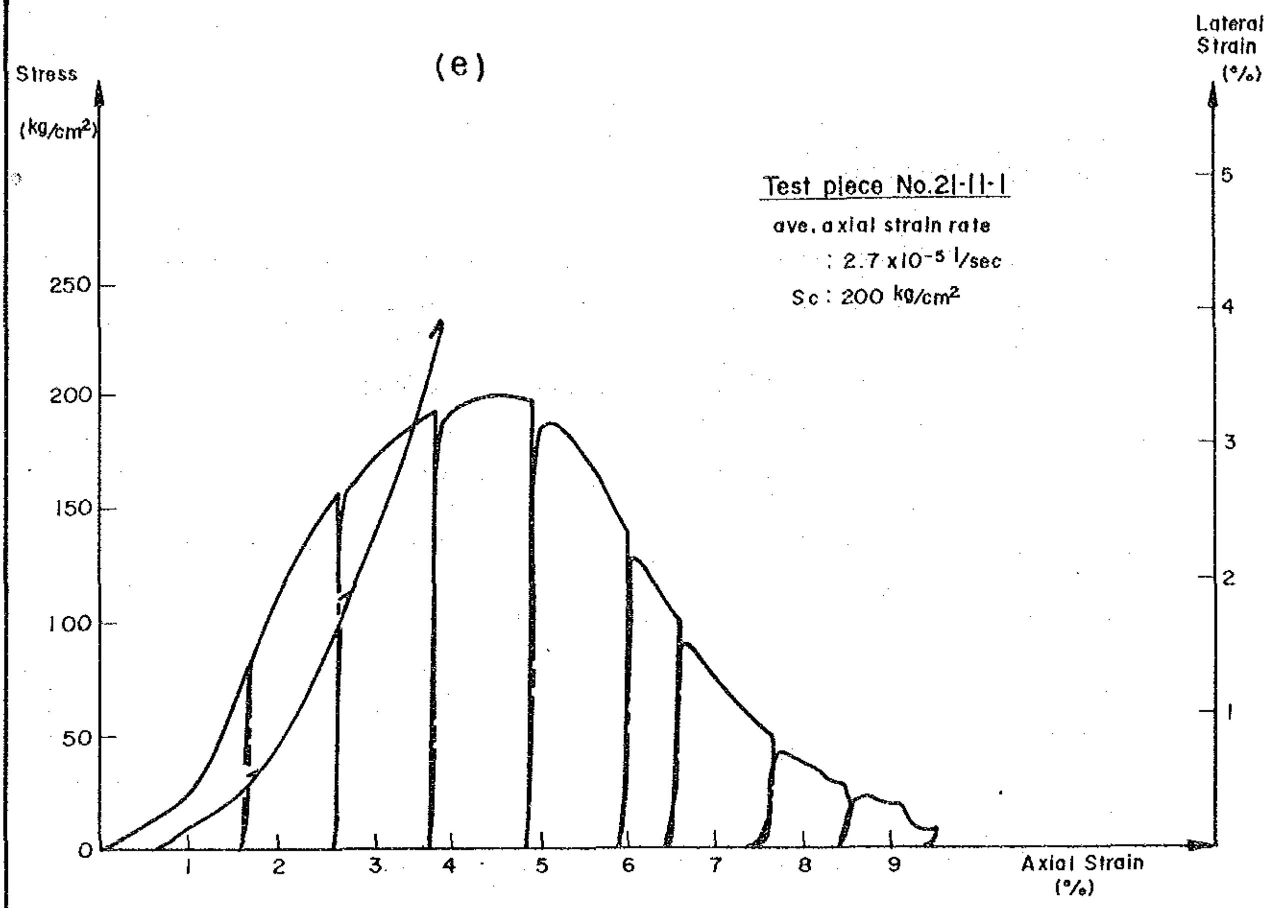


Fig. 3·3 (c),(d) Stress – strain curve



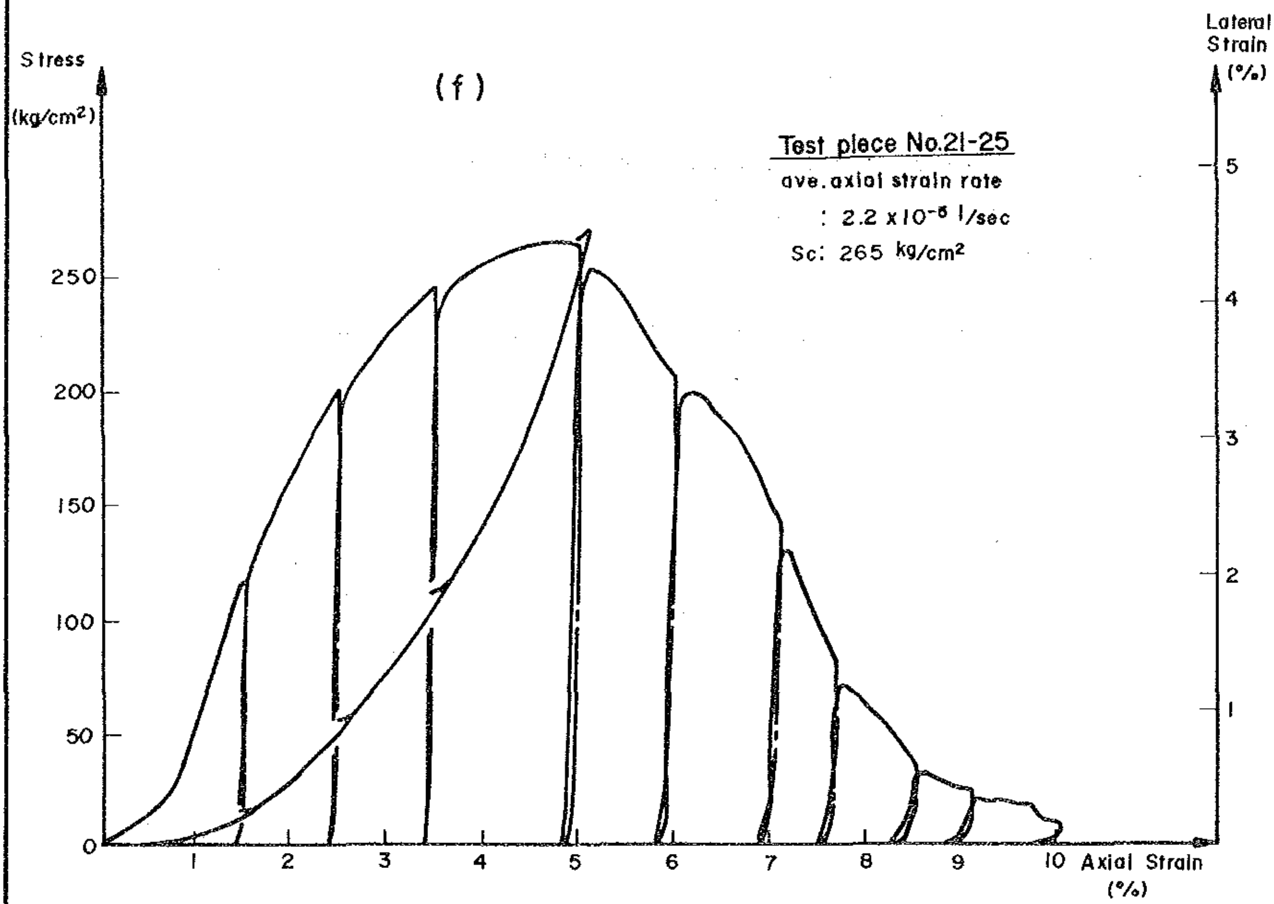


Fig. 3·3 (e),(f) Stress – strain curve

b. Shore hardness

Shore hardness values measured for test pieces from Halite-A and B and those with bands containing anhydrite (see 4.3 (1) b.) are presented in Table 3.7.

Table 3.7 Results of Shore Hardness Test

Drill hole	Halite-A	Halite-B	Anhydrite band
RS. 2. 18	9.7 ± 1.2 (80)	10.2 ± 1.3 (60)	23 ± 5.5 (20)
RS. 2. 19	9.6 ± 2.0 (60)	10.1 ± 1.1 (80)	
RS. 2. 20	10.3 ± 2.0 (80)	–	–
RS. 2. 21	6.8 ± 1.5 (85)	–	–

Parenthesized figures indicate numbers of measurements.

c. Brazilian test

Results of the Brazilian test are given in Table 3.8.

d. Creep test

Reuslts of the creep test are found in Table 3.9. Strain-time curves are shown in Fig. 3.4 (a), (b), (c) and (d).

Table 3.8 Results of Brazilian Test

Test Piece No.	Diameter D	Length L	Density ρa	Fracture Load P	Tensile Strength St	Test Piece No.	Diameter D	Length L	Dencity ρa	Fracture Load P	Tensile Strength St
	(mm)	(mm)	(g/cm^3)	(kg)	(kg/cm^2)		(mm)	(mm)	(g/cm^3)	(kg)	(kg/cm^2)
18- 3-1	85.0	45.8	2.2	1,089	17.8	20-15-2	85.0	47.0	2.1	880	14.0
4-1	85.2	45.4	2.2	1,213	20.0	18-1	85.0	42.0	2.2	910	16.2
4-2	85.2	45.9	2.2	1,031	16.8	18-2	85.0	41.0	2.2	1,183	21.6
7-1	85.2	41.5	2.2	1,394	25.1	19-1	85.0	46.8	2.2	1,100	17.6
7-2	85.2	47.0	2.2	1,148	18.3	19-2	85.0	44.6	2.2	1,036	17.4
8-1	85.1	46.6	2.2	1,100	17.8						
8-2	85.2	45.0	2.3	1,729	28.7	21- 7-1	49.4	33.2	–	356	13.8
18-1	85.3	47.0	2.2	1,210	19.2	8-1	49.4	29.7	–	278	12.1
18-2	85.3	44.8	2.2	1,108	18.5	8-2	49.4	34.2	–	196	7.4
18-3	85.3	48.9	2.0	1,022	15.6	10-1	49.3	25.9	–	285	14.2
19-1	85.3	47.9	2.2	1,313	20.5	10-2	49.3	25.3	–	224	11.2
19-2	85.3	41.1	2.2	1,169	21.2	10-3	49.3	29.7	–	326	14.2
20-1	85.1	44.9	2.2	1,163	19.4	10.4	49.3	27.5	–	394	18.5
20-2	85.3	44.7	2.2	1,255	21.0	11-1	49.3	31.3	–	198	8.2
21-1	85.1	44.0	2.2	1,180	20.1	12	49.3	31.2	–	254	10.5
21-2	85.3	45.0	2.2	800	13.3	13	49.4	41.2	–	265	8.3
						14	49.3	35.3	–	346	12.7
19- 4-1	85.0	44.6	2.2	710	11.9	15-1	49.4	28.0	–	217	10.0
4-2	85.3	44.8	2.2	1,174	19.6	15-2	49.4	38.4	–	290	9.7
5-1	85.2	44.1	2.2	1,480	25.1	16-1	49.4	32.0	–	326	13.1
5-2	85.1	50.7	2.2	1,333	19.7	16-2	49.4	27.3	–	292	13.8
9-1	85.2	44.1	2.1	1,354	22.9	17-1	49.4	26.7	–	229	11.1
9-2	85.1	44.7	2.3	1,080	18.1	17-2	49.4	31.4	–	286	11.7
10-1	85.2	44.7	2.2	1,502	25.1	17-3	49.4	33.9	–	190	7.2
10-2	85.1	44.0	2.2	1,458	24.8	18	49.4	42.0	–	402	12.3
15-1	85.2	44.6	2.2	1,122	18.8	19-1	49.4	23.2	–	154	8.6
15-2	85.2	46.1	2.2	1,100	17.8	19-2	49.4	30.9	–	214	8.9
16-1	85.2	49.8	2.0	825	12.4	19-3	49.4	24.4	–	250	13.2
18-1	85.1	44.3	2.2	892	15.1	20-1	49.4	32.2	–	346	13.8
18-2	85.1	47.1	2.2	972	15.4	20-2	49.4	34.8	–	368	13.6
18-3	85.3	45.2	2.1	1,109	18.3	21-1	49.4	43.4	–	532	15.8
						21-2	49.4	29.0	–	146	6.5
20- 5-1	84.8	44.4	2.3	654	11.1	21-3	49.4	20.0	–	106	6.8
5-2	85.0	47.4	2.2	984	15.5	22	49.4	34.0	–	235	8.9
6-1	85.0	43.5	2.1	534	10.9	24-1	49.4	31.3	–	359	14.8
6-2	85.0	44.1	2.2	760	12.9	25-1	49.3	42.3	–	367	11.2
14-1	85.5	45.3	2.1	640	10.5	25-2	49.4	32.2	–	372	14.9
14-2	84.5	47.0	2.2	672	10.8	25-3	29.4	38.4	–	382	12.8
15-1	85.0	46.7	2.2	770	12.3	32-1	49.3	32.9	–	346	13.6

Table 3.9 Results of Creep Test

Test Piece No.	Diameter D	Length L	Weight W	Density ρa	Stress Level σa	Lheological Model	Modulus of Visco-elasticity						Test Hours
							E_1	E_2	E_3	η_1	η_2	η_3	
	(mm)	(mm)	(g)	(g/cm^3)	(kg/cm^2)		(kg/cm^2)	(kg/cm^2)	(kg/cm^2)	$(kg{\cdot}min/cm^2)$	$(kg{\cdot}min/cm^2)$	$(kg{\cdot}min/cm^2)$	(min)
18 - 6	39.75	89.4	239	2.2	243 ±1.2 (78%)	1-Maxwell and 1-Voigt	2.51×10^4	4.51×10^4	–	2.39×10^8	8.70×10^6	–	7,206
19 - 14	39.75	71.7	184	2.1	227 ±1.3 (79%)	1-Maxwell and 1-Voigt	0.561×10^4	1.57×10^4	–	4.45×10^3	10.1×10^6	–	6,860
						* 1-Maxwell and 2-Voigt	0.559×10^4	1.57×10^4	8.66×10^4	4.47×10^8	1.00×10^7	5.04×10^6	
21 - 11	49.40	100.75	402	2.1	67.8 (33.9%)	1-Maxwell and 1-Voigt	0.272×10^4	2.55×10^4	–	1.10×10^4	0.968×10^6	–	28,620
21 - 13	49.30	66.55	271	2.1	73.3 (37%)	1-Maxwell and 1-Voigt	0.407×10^4	6.92×10^4	–	1.65×10^9	6.17×10^6	–	18.435

Remark: * See 4.9

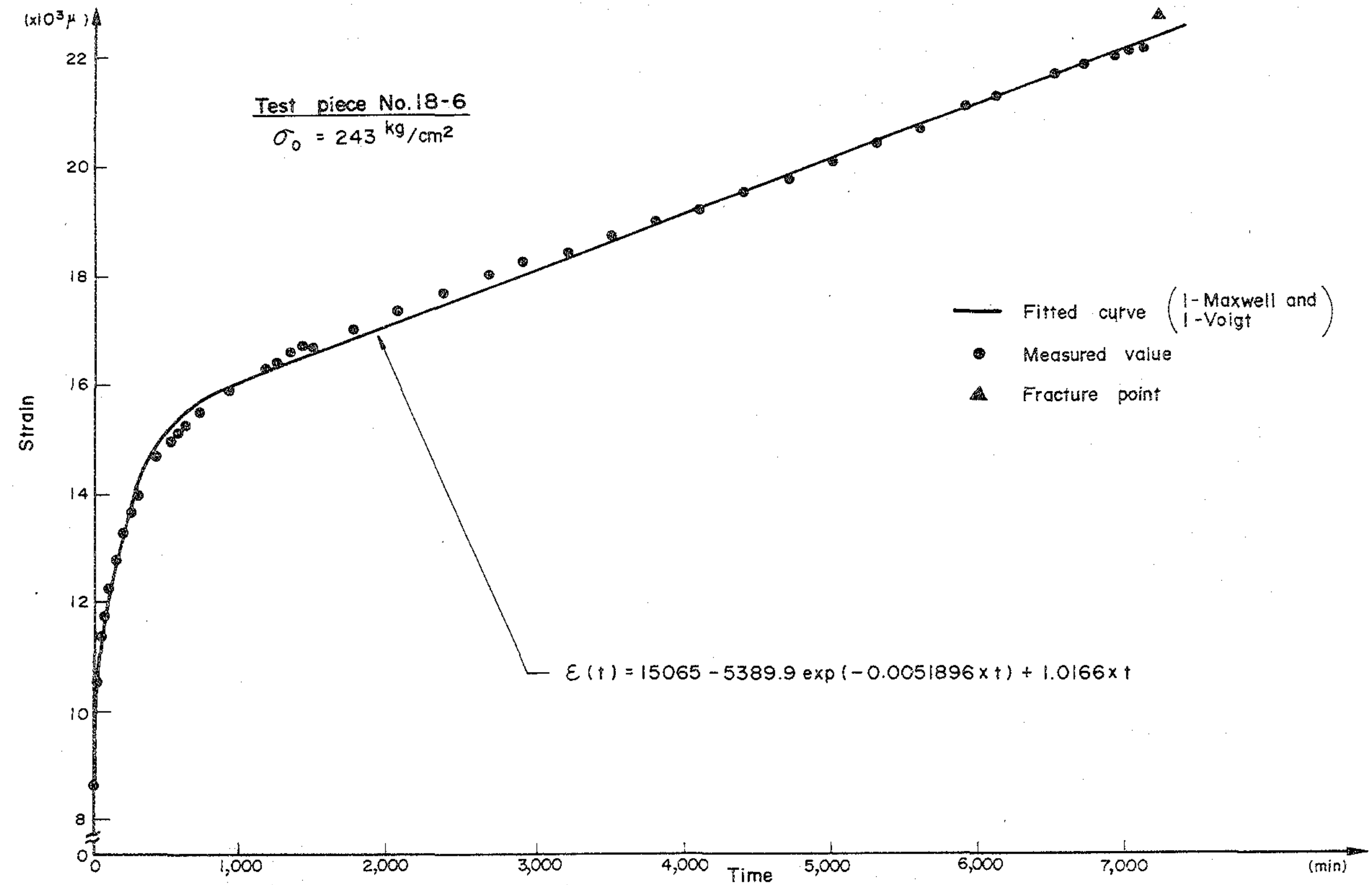


Fig.3·4 (a) Strain – time curve for constant stress

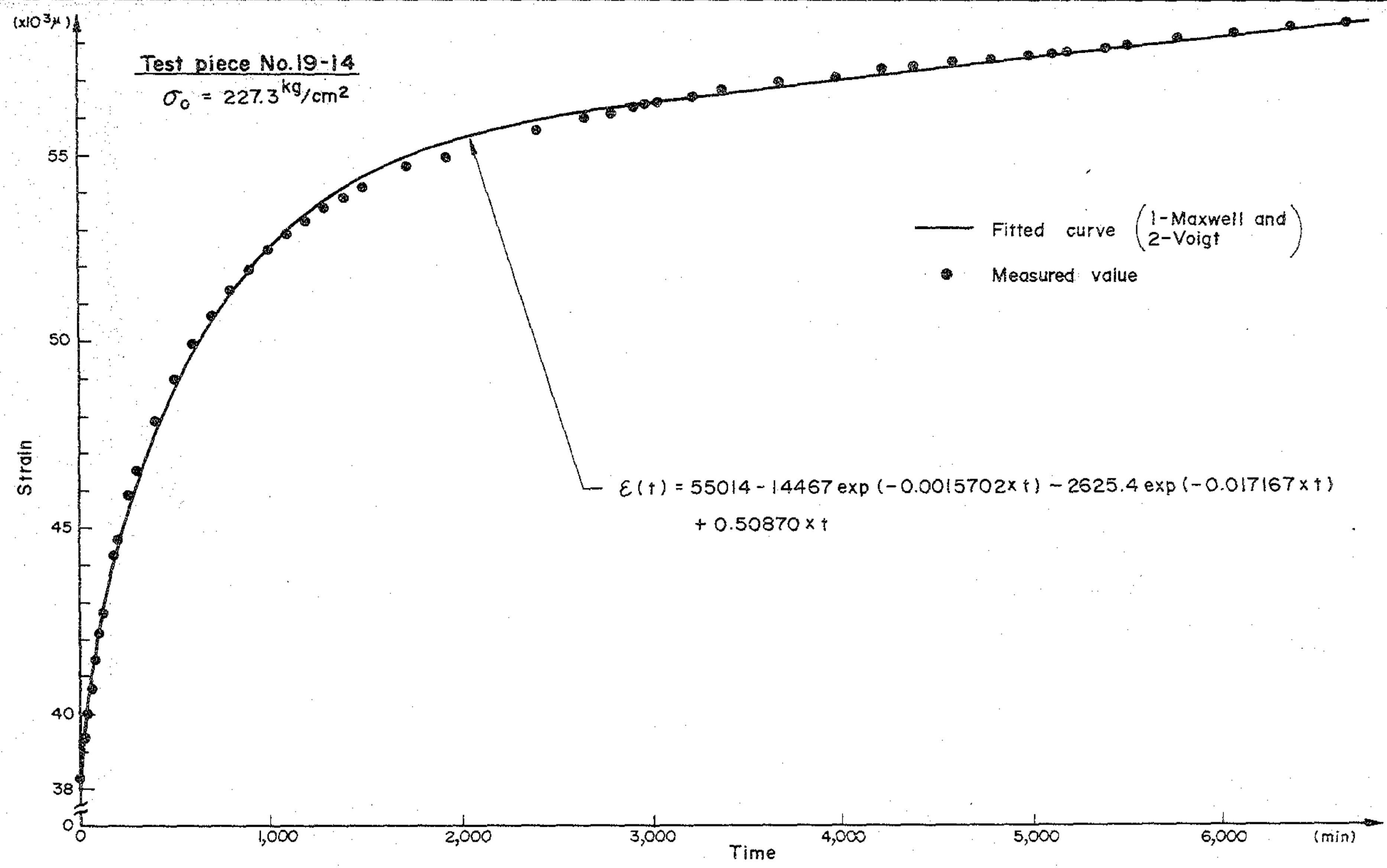


Fig.3·4 (b) Strain – time curve for constant stress

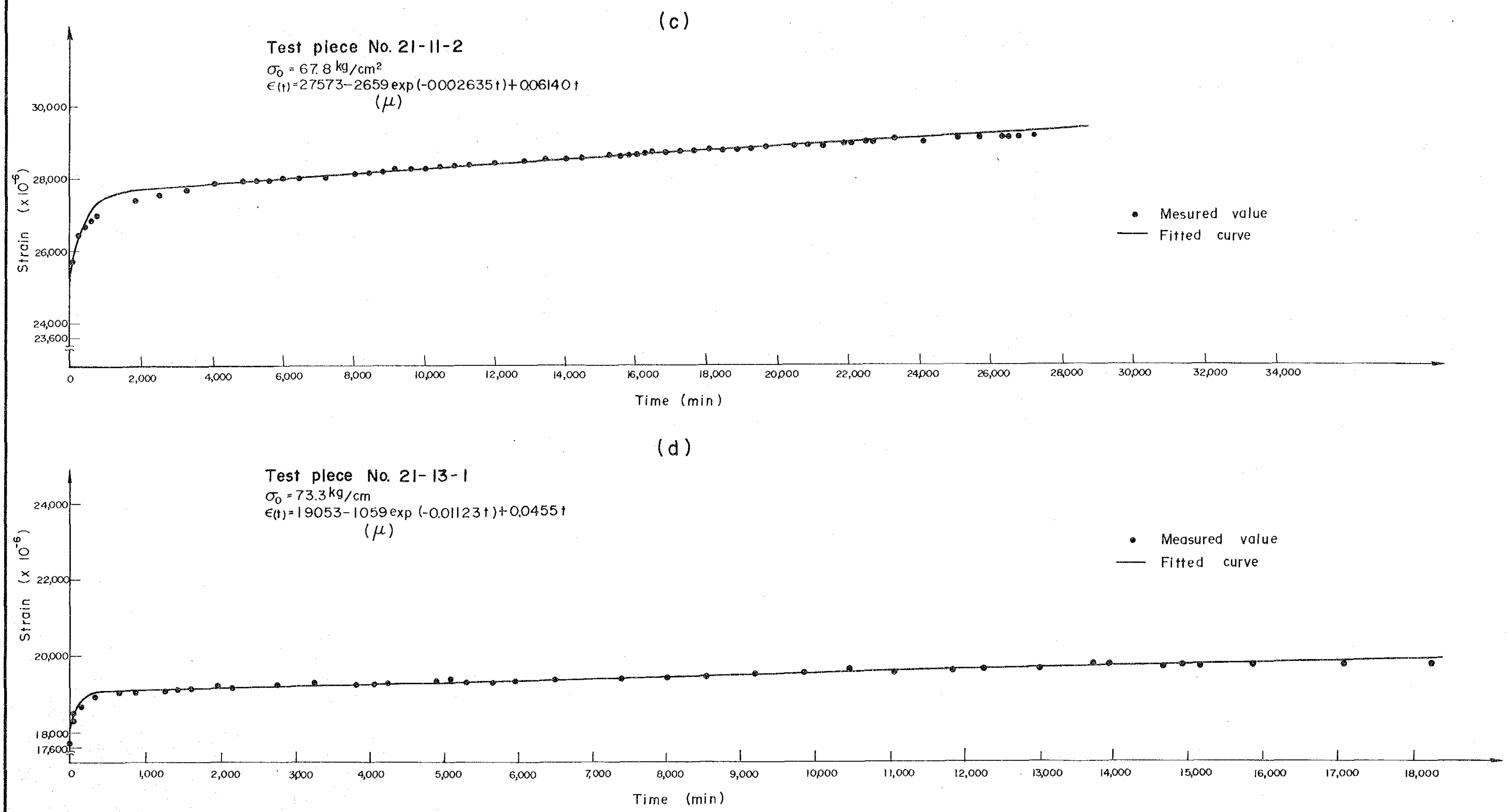


Fig. 3·4 (c),(d) Strain-time curve for constant stress

(6) **Additional Rock Mechanics Tests – Triaxial Compression Test**

In addition to the rock mechanics tests described above, a triaxial compression test under confining pressure was performed in order to investigate deformation behavior and strength characteristics.

a. Preparation of test pieces

Test pieces were prepared by the same method described in 3.2 (2) a. above.

b. Measurement

Prior to the confining pressure test, the test pieces were subjected to measurement of dimensions, P-wave velocity, and density. Axial displacement and load were measured under the confining pressures of 20, 30, 50 and 70 kg/cm^2.

c. Test apparatus and method

A 250 kg/cm^2 vessel manufactured by Tokyo Koki Seisakusho was used. The hydraulic test machine, also a product of the same manufacturer, was an Amsler type 100 ton machine. To prevent the oil from mixing with the test pieces, they were wrapped in two layers of rubber tube.

To measure axial displacement, a linear variable differential transformer (LVDT) was used. Radial displacement was measured by means of a ring gauge; in addition, vernier calipers were used to take measurements during the test.

To enable confining pressure to be measured in the vessel, a special load cell was provided.

The two outputs of axial displacement and load were amplified by means of a dynamic strain amplifier and recorded on an X-Y recorder.

Axial load strain velocity during the test was of the order of 10^{-5} mm/sec.

d. Test results

Results of the triaxial compression test are shown in Table 3.10.

Representative stress-strain curves of triaxial compression test are shown in Fig. 3.5.

Table 3.10 Results of Triaxial Compression Test

Confining pressure σ_3	No. of test piece	Diameter D	Length L	Density ρa	P-wave velocity Vp	Peak load P	Axial strain ε	Differential stress $\sigma_1 - \sigma_3$	Strength σ
(kg/cm^2)		(mm)	(mm)	(g/cm^3)	(m/sec)	(kg)	(%)	(kg/cm^2)	(kg/cm^2)
20	21-10-1	49.30	96.70	2.2	4,200	8,230	7.86	431	451
	21-10-2	49.30	95.60	2.2	2,730	7,710	9.20	404	424
	21-12-1	49.30	99.00	2.2	3,540	8,170	9.09	428	448
	21-15-2	49.30	97.95	2.2	2,800	8,460	11.03	443	463
30	21-7-1	49.30	95.00	2.2	3,800	9,810	14.1	514	544
	21-20-2	49.30	99.00	2.2	3,670	10,800	15.4	566	596
	21-21-2	49.30	104.40	2.2	3,600	9,240	13.2	484	514
50	21-17-1	49.30	99.65	2.1	2,260	11,990	18.2	628	678
	21-18-2	49.30	97.55	2.1	2,440	11,380	18.6	596	646
70	21-14-2	49.30	104.40	2.2	3,730	14,350	25.2	752	822
	21-16-1	49.30	103.40	2.2	3,130	14,250	25.4	747	817

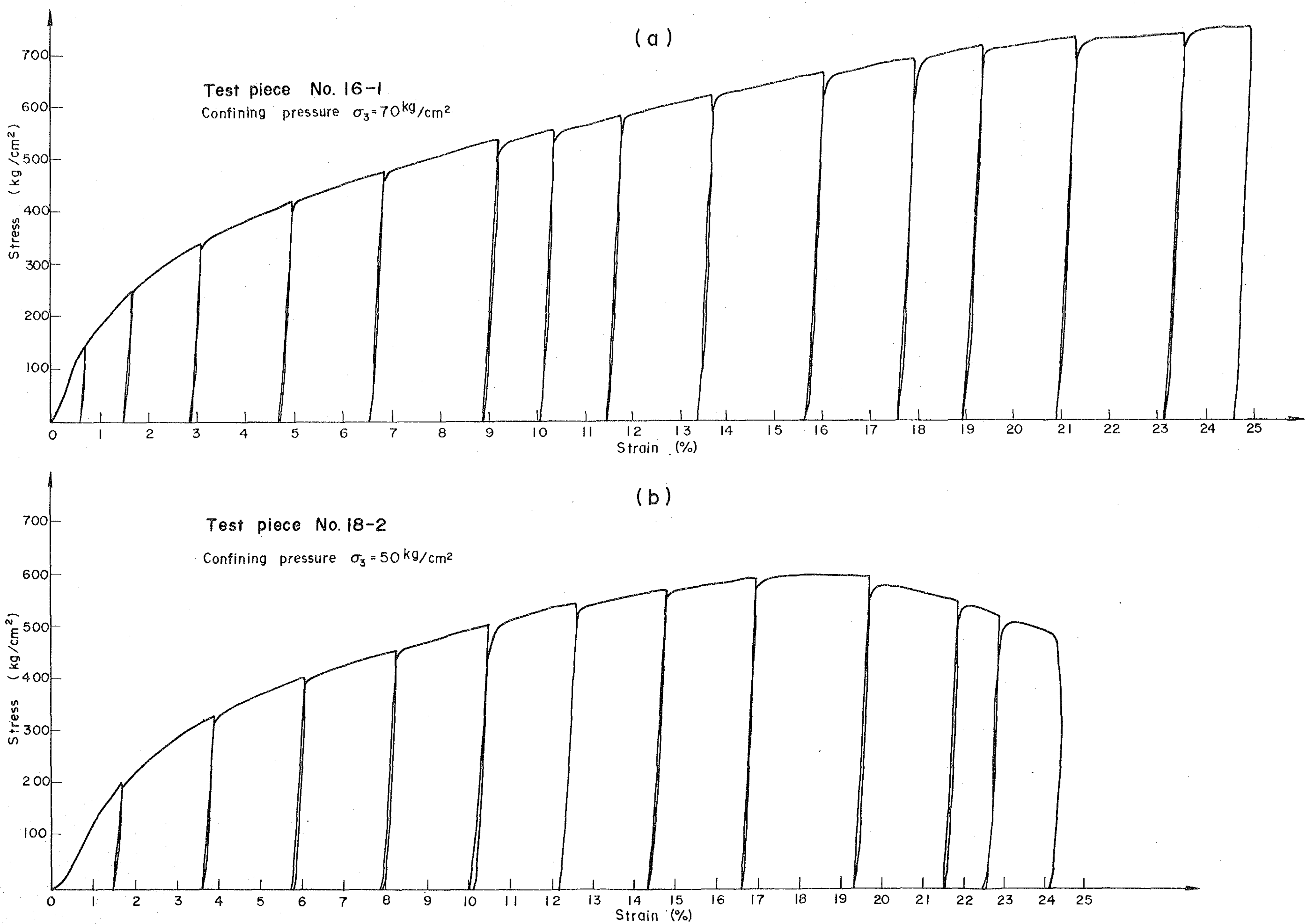


Fig. 3·5 (a),(b) Stress-strain curve of triaxial compression test

CHAPTER 4. STUDIES

Technical analysis was made on the basis of the data obtained by the investigation of cores from the additoinal drilling in Bamnet-Narong and by the chemical analysis and rock mechanics tests of the samples brought into Japan. Such studies are outlined hereunder.

4.1 Geology

(1) General Geology of Northeastern Thailand

Northeastern Tahiland, called Khorat Plateau, is a semi-arid region.

In this plateau, sporadic distribution of salt-containing soil, briny wells, and brine springs has been known from of old. Drilling works for surveying ground water which have been done in this region since 1952 confirmed existence of rock salt beds in a number of places.

Places where rock salt beds occur are geologically of basin structure, and the beds are accompanied by gypsum, anhydrite, potassic salt, and other minerals. These rock salt beds, judged from the components contained in them and geological structures found there, are considered to be marine evaporite deposits formed by seawater having evaporated over a long period of time.

Khorat Plateau is mostly formed of the Khorat Series. This series is sedimentary strata ranging from the Upper Triassic to the Cretaceous. Though the strata have flat to gently inclined sturcture generally, extensive basin structure is found in two places, the northern being called Sakon-Nakhon basin and the southern Khorat basin. Bamnet-Narong rock salt deposit is situated on the west side of Khorat basin.

The Khorat Series is composed generally of mudstone, shale, sandstone, claystone, conglomerate, and rock salt beds, but in the south found are stocks and dikes of igneous rock of the Tertiary period. Paleozoic strata, which are the basement of this region, are seen in the northwest and the west.

The general stratigraphy and the geological map of this region are shown in Table 4.1 and Fig. 4.1 respectively.

(2) Rock Salt Beds of Bamnet-Narong District and its Division

The Khorat Series is divided into the three formations of Maha Sarakam, Phu Phan, and Phu Khadung, and in all of these formations occur rock salt beds.

Bamnet-Narong rock salt deposit is known to be a rock salt bed belonging to Maha Sarakam formation from the results of a number of drilling holes made in Khorat Plateau.

In Bamnet-Narong district more than 20 drill holes including the additional ones have already been bored, and through this work a rock salt bed 100 to 280m in thickness has been confirmed. The quantities of rock salt reserved in this district are considered enormous.

Fig. 4.2 shows how the rock salt occurs as found by the additional four drill holes. In the finding from the additional holes 2.18 and 2.19, the rock salt is formed of two beds; in this report the lower rock salt bed is called Halite-A, and the upper Halite-B.

On the other hand, the rock salt is formed of one rock salt bed in drill holes of 2.20 and 2.21. This corresponds to Halite-A bed as described in the following and is also reffered to as Halite-A bed. (Fig. 4.2)
The area where Halite-A and Halite-B beds occur, the former underlying the latter, e.g., the area of drill holes 2.18 and 2.19, is called D-area (double rock salt bed area), while the area where only Halite–A bed occurs, e.g., the area of drill holes 2.20 and 2.21, is referred to as S-area (single rock salt bed area).

From the results of investigation of cores from the additional drilling and analysis of the data of the former drilling, the distribution of D-area and S-area in Bamnet-Narong district is inferred as shown in Fig. 4.3. According to it, about the center of Bamnet-Narong rock salt deposit is taken up by S-area, while the surrounding parts consist of D-area. Also a schematic profile of the rock salt bed is shown in Fig. 4.4.

Table 4.1 **Stratigraphy of Northeastern Thailand**
(Herbert S. Jacobson and Charles T. Pierso 1969)

Age	Rock Units			Character
Quaternary	Unnamed			Unconsolidated clay, sand, and gravel; laterite.
Tertiary	Unnamed			Basalt flows (only overlying, Khorat Series on Khorat Plateau).
Cretaceous	Khorat Series	Upper	Maha Sarakam Foramtion	Sandstone, siltstone, shale, salt, and anhydrite-gypsum.
			Khok Kruat Formaiton	Sandstone, siltstone, and shale.
Jurassic		Middle	Phu Phan Formation	Massive sandstones with conglomerate sandstone, siltstone, and shale.
			Sao Khua Formation Phra Wihan Formation	
Triassic		Lower	Phu Khadung Formaiton	Sandstone, siltstone, and conglomerate (including basal conglomerate).
			Nam Phong Formation	
	Unnamed			Andesite, rhyolite, tuff, agglomerate.
	Unnamed			Granodiorite and other intrusive rocks.
Permian	Kanchanaburi Series		Ratburi Limestone	Massive limestone with shale and sandstone.
Carboniferous			Unnamed	Sandstone, siltstone, shale, tuff and limestone.
Devonian	Unnamed			Sandstone, quartzite, phyllitic shale, slate, and limestone.
Silurian and older	Unnamed			Argillite, quartzite, slate, phyllite, schist.

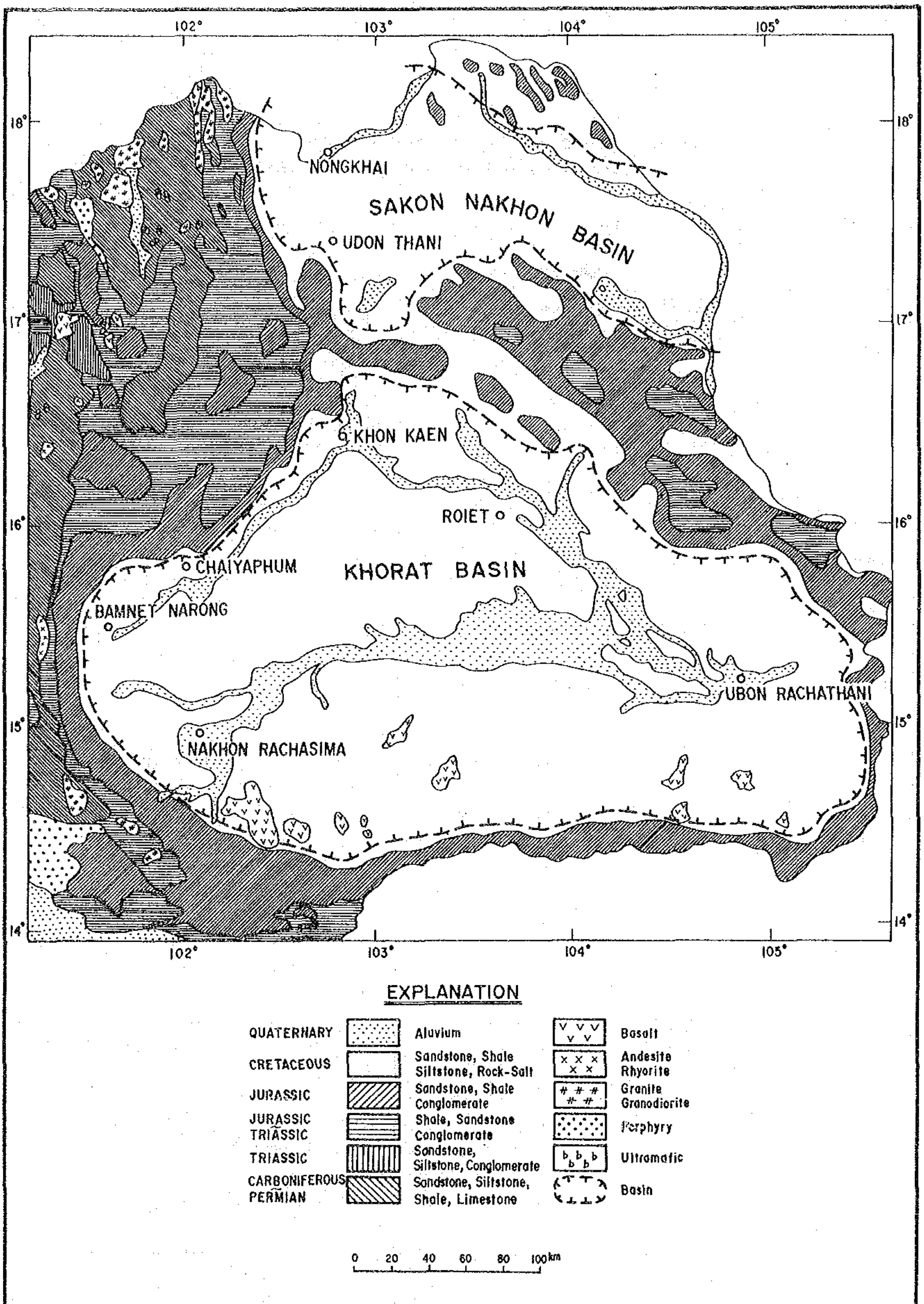


Fig.4·1 Geological map of northeastern Thailand

Map modified from The geologic map of Thailand
compiled by Jumchet C. Javanaphet (1969)

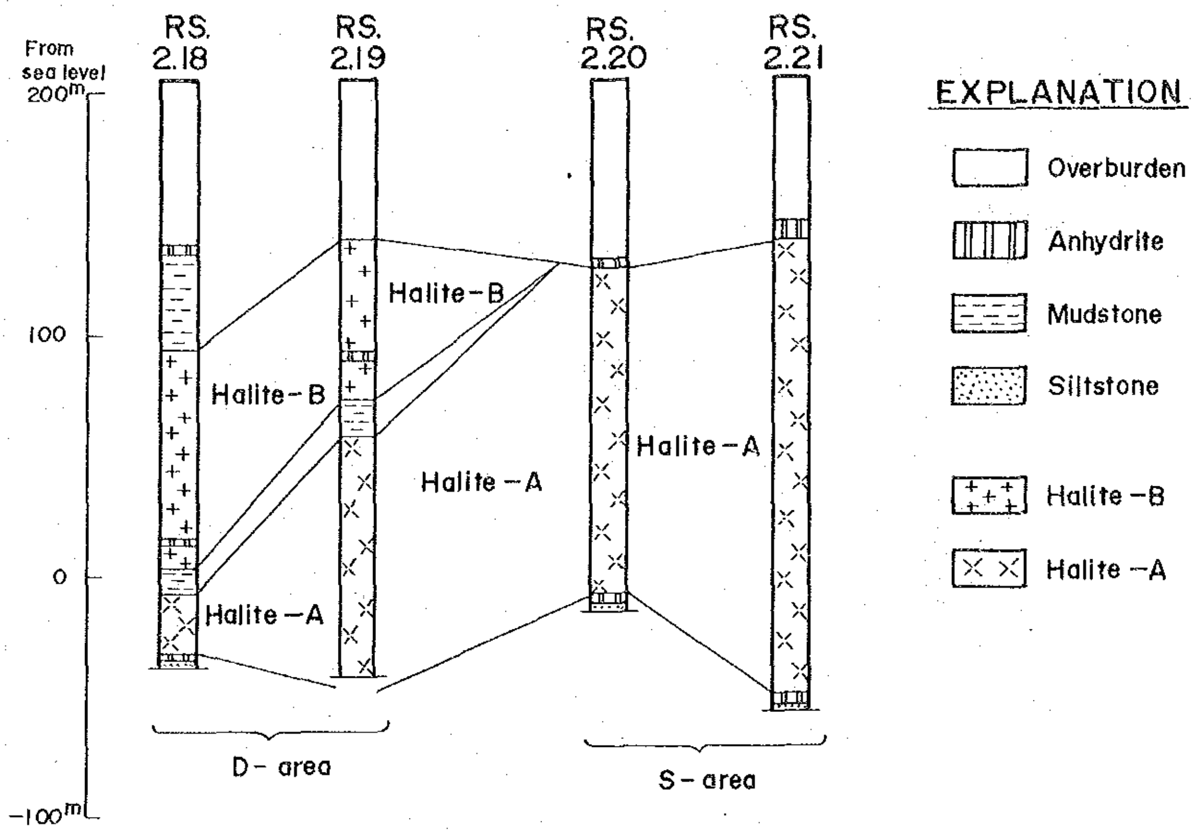


Fig.4·2 Columnar-stratigraphic sections of additional drill holes at Bamnet - Narong

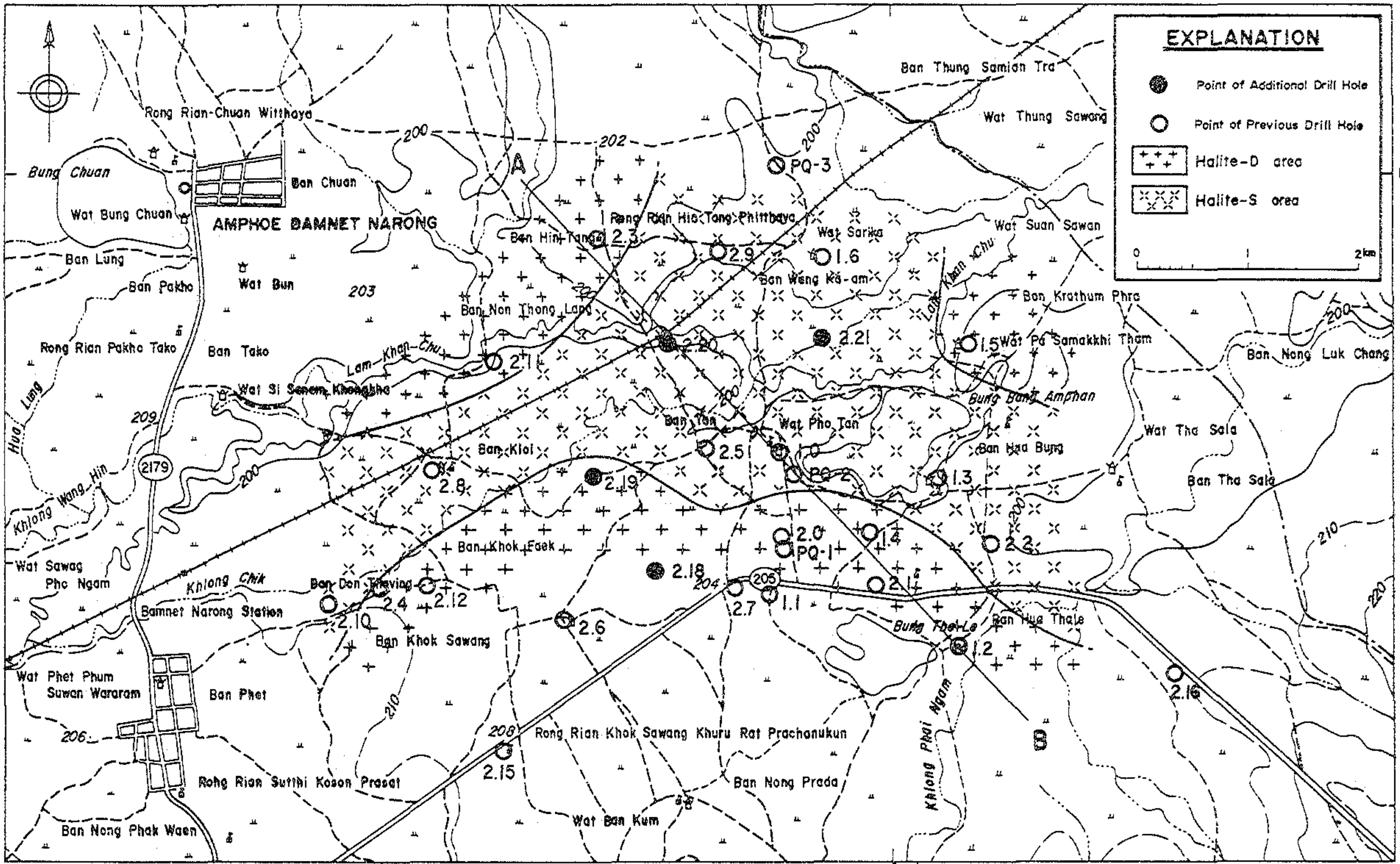


Fig.4·3 Map showing distribution of Halite-D area and Halite-S area

D area : Double rock salt beds area
S area : Single rock salt bed area
(Drill holes locations taken from DMR data, Nov, 1979)

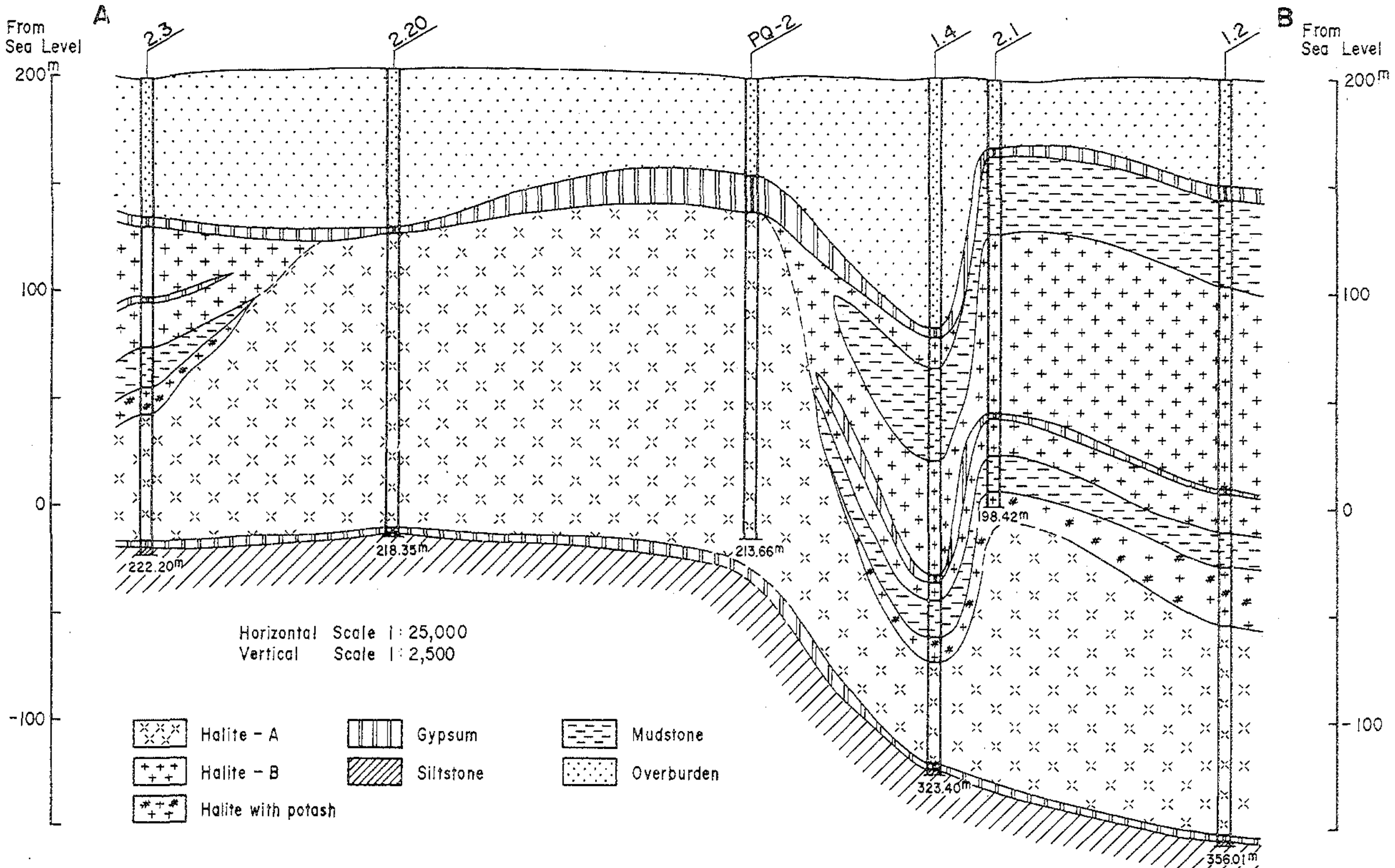


Fig.4·4 Schematic profile of the rock salt bed at Bamnet - Narong (Along A-B Fig.4·3)

(3) **Characteristics of the Rock Salt Bed**

The characteristics of the rock salt bed found on the basis of data obtained by the additonal four drill holes are set forth as follows:

(a) Halite-A bed occurs on an anhydrite layer about 1m in thickness, lying on the basement of hard silt-stone.

(b) Stratigraphically Halite-B bed lies above Halite-A bed; between them a clay stratum 5 to 15m in thickness is found.

(c) Seen with the naked eye, Halite-A bed has less impurities and better quality than Halite-B.

(d) According to the result of chemical analysis too, Halite-A bed has higher average content of NaCl and less scattering of NaCl content than Halite-B.

(e) In some cases, Halite-A bed, in the upper parts, contains potassium.

(f) Halite-A bed in S-area is thicker than Halite-A in D-area.

(g) This might be accounted for by the result of the following situations: after sedimentation of Halite-A bed local erosion and other conditions caused formation of small basins, in which such sediment as mudstone and then Halite-B were deposited, thus forming D-area; in prallel with the progress of such sedimentation, loads acted on the strata, and S-area rose in a flowing manner.

(h) However, the condition of containing Br, Mg and other contents differs between Halite-A bed in S-area and Halite-A in D-area, as mentioned in the following section, suggesting different salinity during sedimentation of the rock salt. (Figs. 4.6 (a), (b), (c) and (d)).

(i) This leads to the presumption that the same Halite-A bed was formed in some sedimentary environment differing in D-area and S-area.

(j) Halite-A in D-area is compared with that in S-area as shown in Table 4.2.

Table 4.2 Comparison between Halite-A in D-area and that in S-area

	Contents by chemical analysis						Rock salt bed thickness
	NaCl	I.M.	SO_4	K	Mg	Br	
Halite-A in D-area	96.92%	1.29%	1.01%	occurs in upper part	the upper, the higher gradually	the upper, the higher gradually	thin
Halite-A in S-area	97.86%	0.51%	0.90%	not occurs	occurs uniformly	occurs uniformly	thick

(k) Halite-A bed, it can be asserted, corresponds to the Lower Salt bed of Maha Sarakam formation occurring in northeastern Thailand, while Halite-B to the Middle Salt bed.

In the above description division of the rock salt beds and comparison among them thus divided have been made: to confirm these, analysis of the data of the former drilling in Bamnet-Narong district is further needed.

(4) Rock Salt Bed for Mining Operation

To determine the rock salt bed for mining operation, more intensive analysis should be made in the stage of comprehensive evaluation, but it is considered that Halite-A bed in S-area is appropriate, judging from the geological data that have been obtained from the additional four drill holes and the chemical analysis data set forth in the following section.

4.2 Chemical Analysis

(1) Main Components of Rock Salt

The 210 samples taken from the additional four drill holes were analyzed for main components of rock salt. With the result of it the frequency distribution of the analysis values of NaCl was worked out for 197 samples with not less than 90% of NaCl content as set forth in Fig. 4.5 (a).

This clearly indicates a "two-peak distribution" though slightly, suggesting heterogeneous matters being contained in some degree. When the frequency distribution is taken only for Halite-A as divided in Subsection 4.1 (2) above, it comes out as shown in Fig. 4.5 (b) below, the "two-peak distribution" disappearing.

This signifies that Halite-A and Halite-B divided stratigraphically in Subsection 4.1 (2) can be divided in terms of chemical composition also.

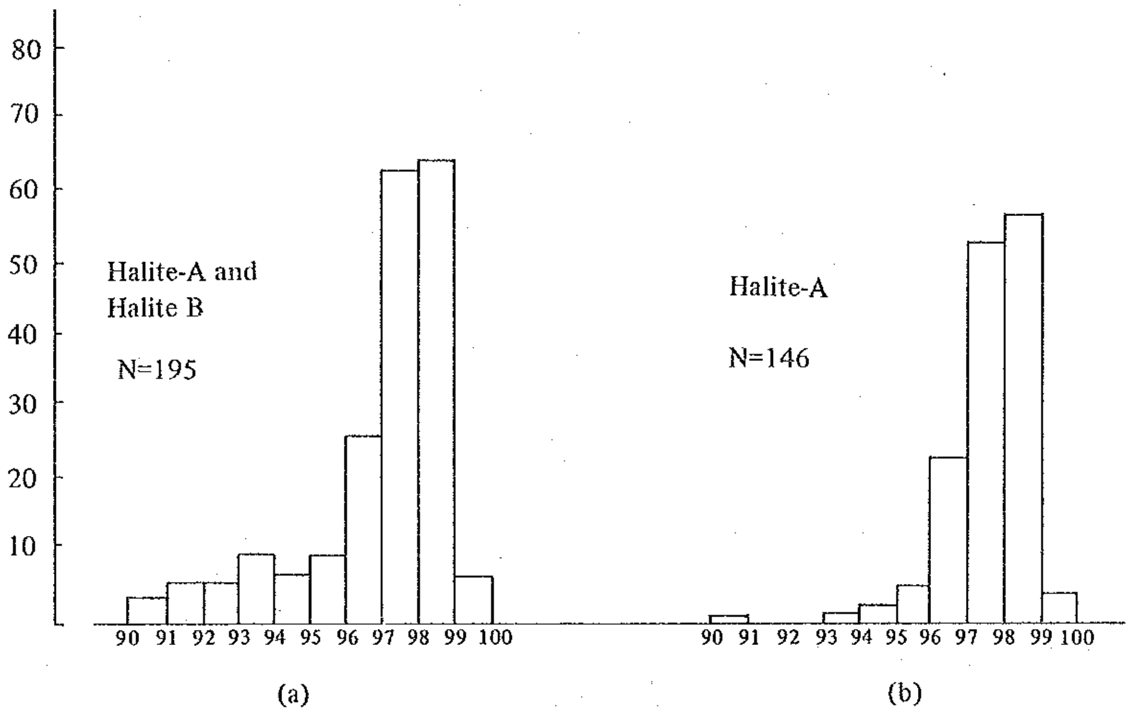


Fig. 4.5 Histograms showing NaCl content distribution in rock salt of additional drilling holes

For the additional four drill holes, the vertical variation of analysis values of the main components is shown in Figs. 4.6 (a), (b), (c) and (d). These indicate evident differences in the main component contents between Halite-A and Halite-B beds. In more detail, as for NaCl its content is less scattered and its values are higher in Halite-A than in Halite-B.

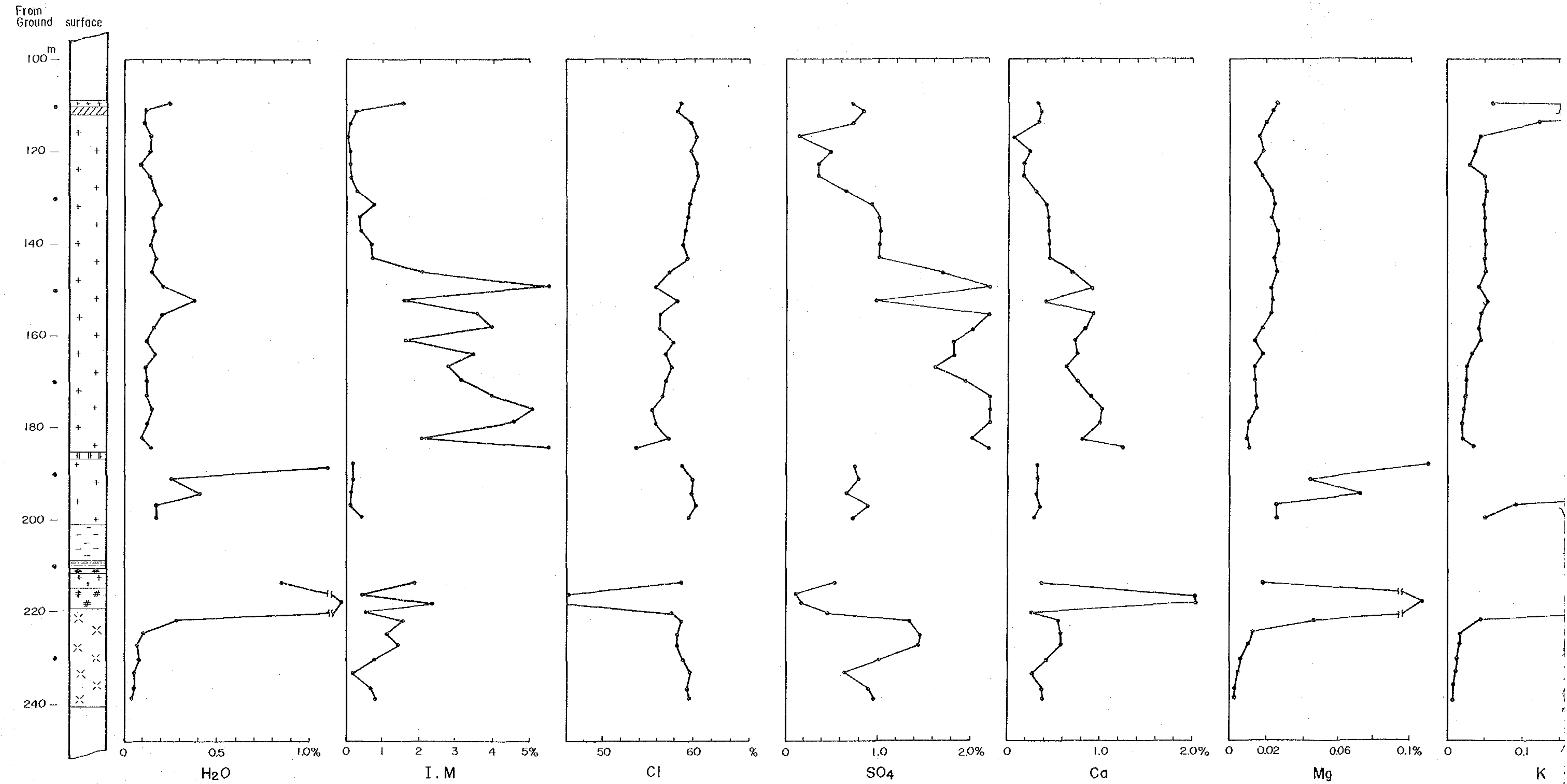
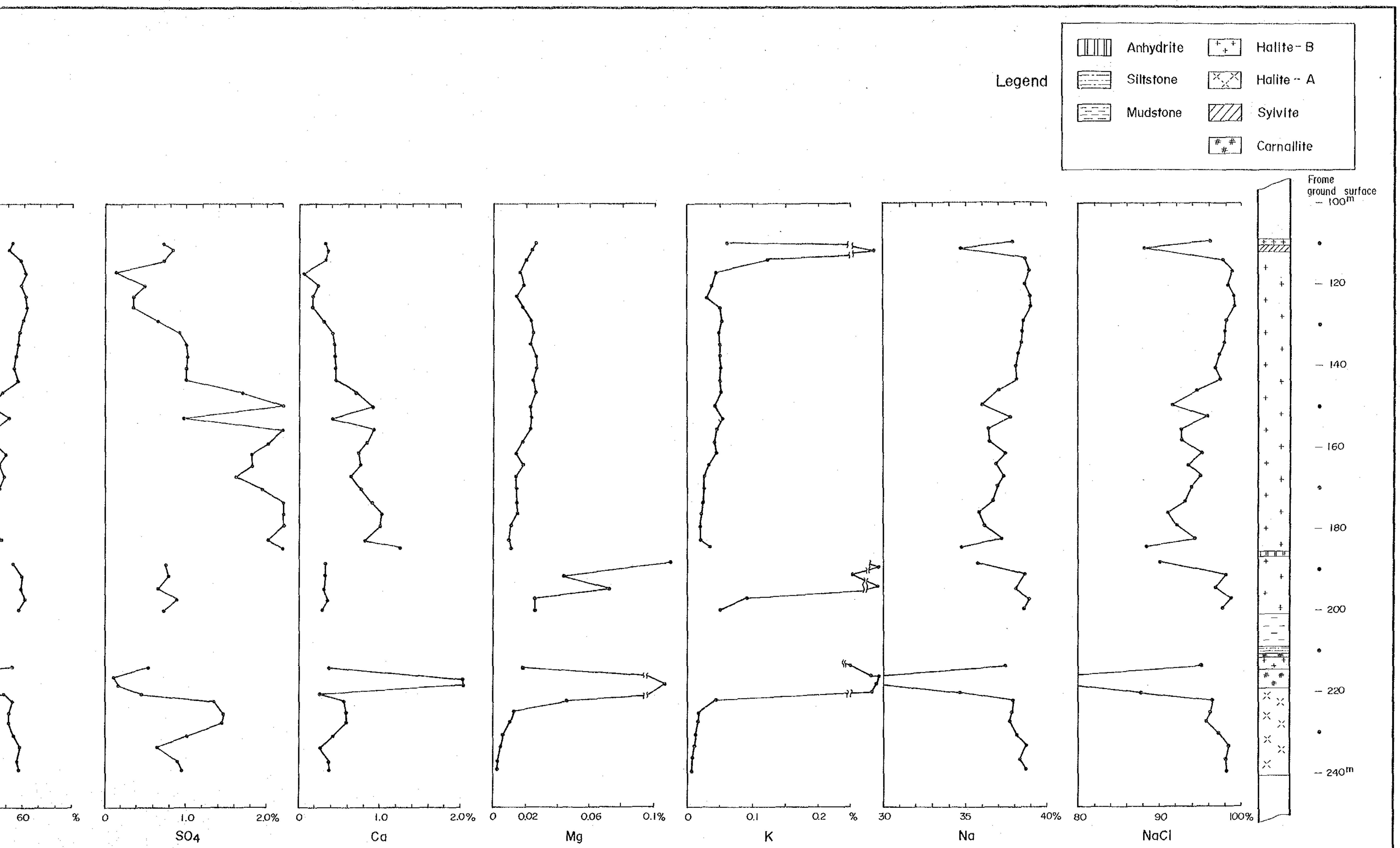


Fig.4·6 (a) Vertical variation of main components of rock salt in the drill hole RS. 18



rock salt in the drill hole RS. 18

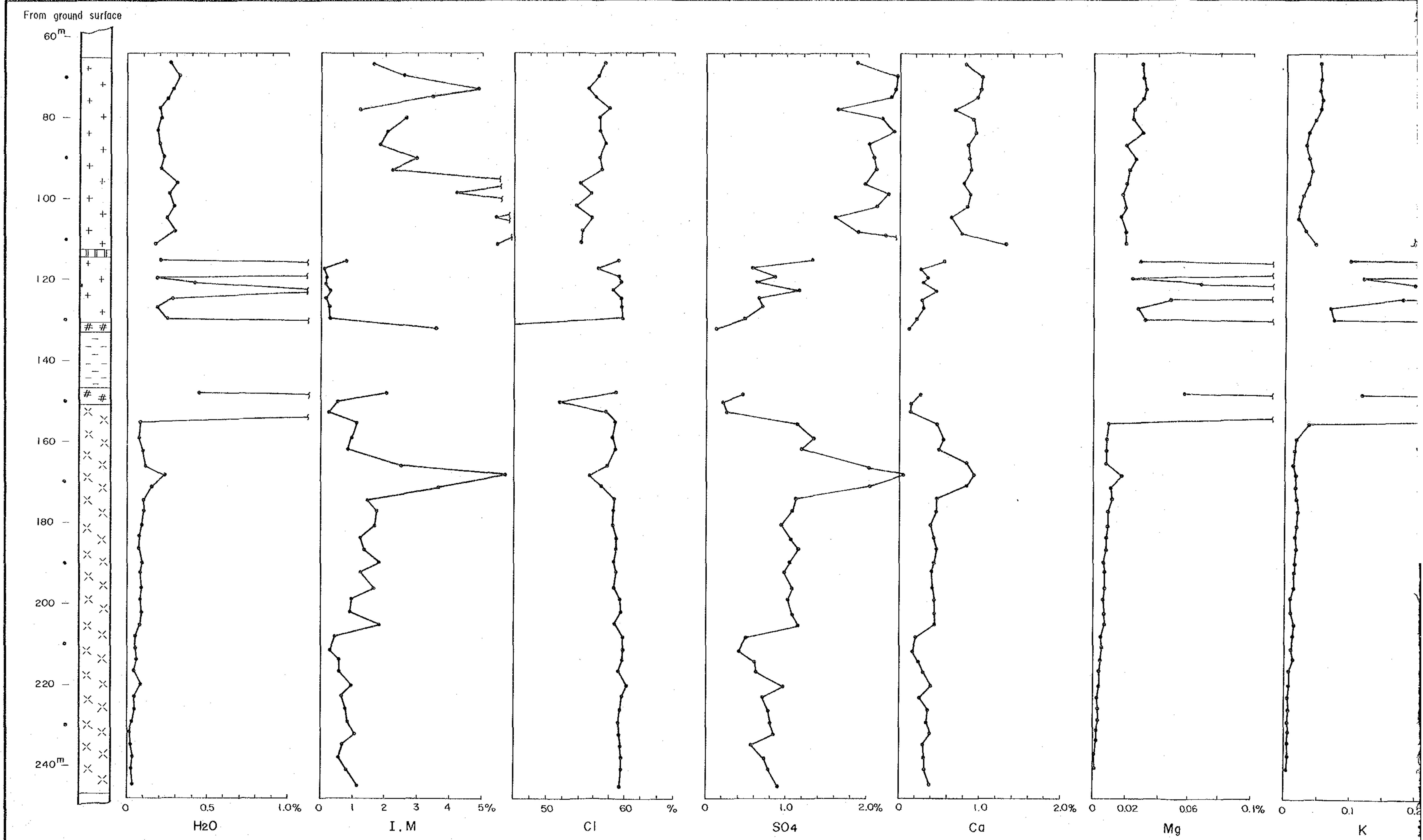
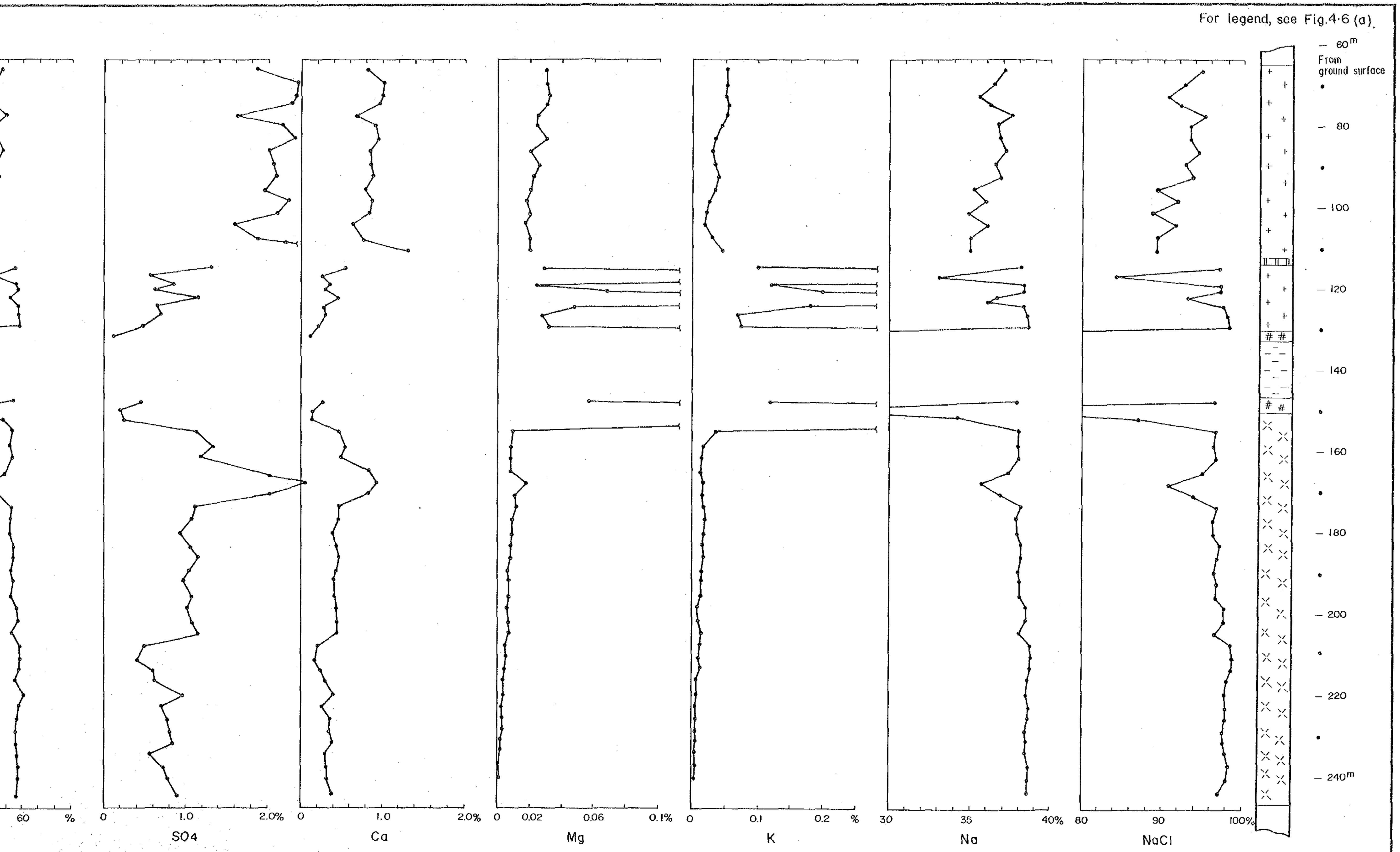


Fig.4·6 (b) Vertical variation of main components of rock salt in the drill hole RS. 19



rock salt in the drill hole RS. 19

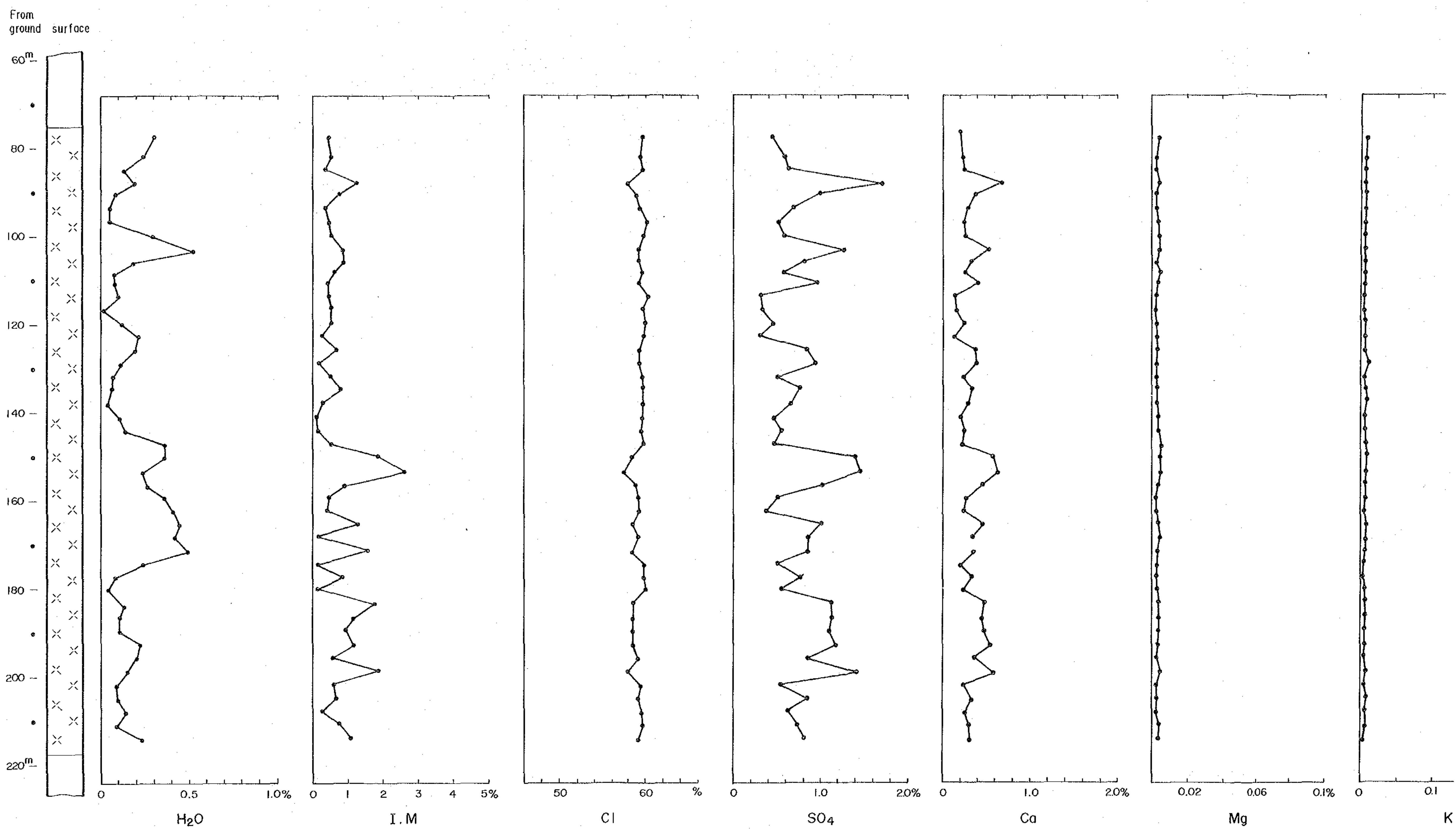
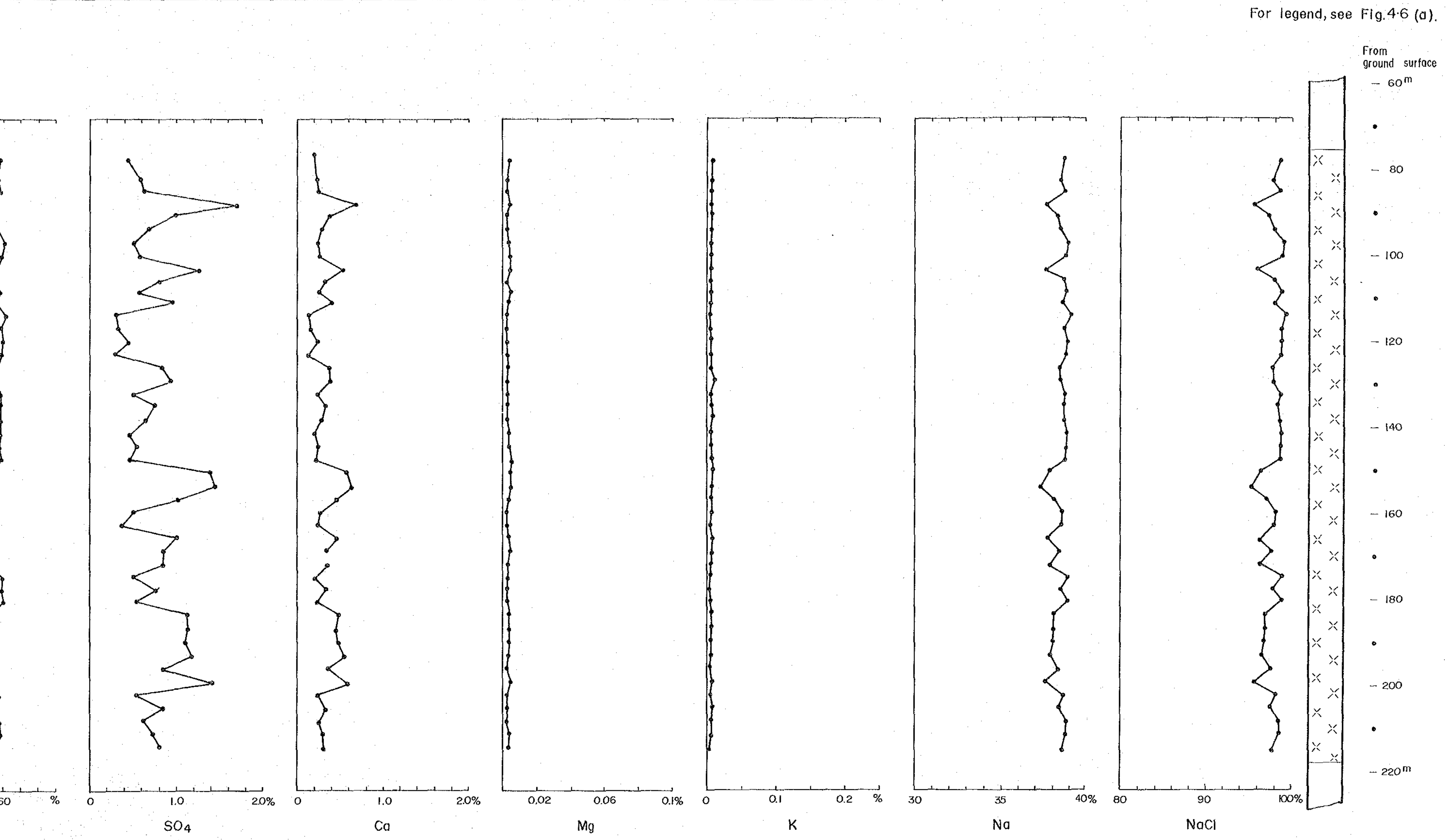


Fig. 4·6 (c) Vertical variation of main components of rock salt in the drill hole RS. 20



ck salt in the drill hole RS. 20

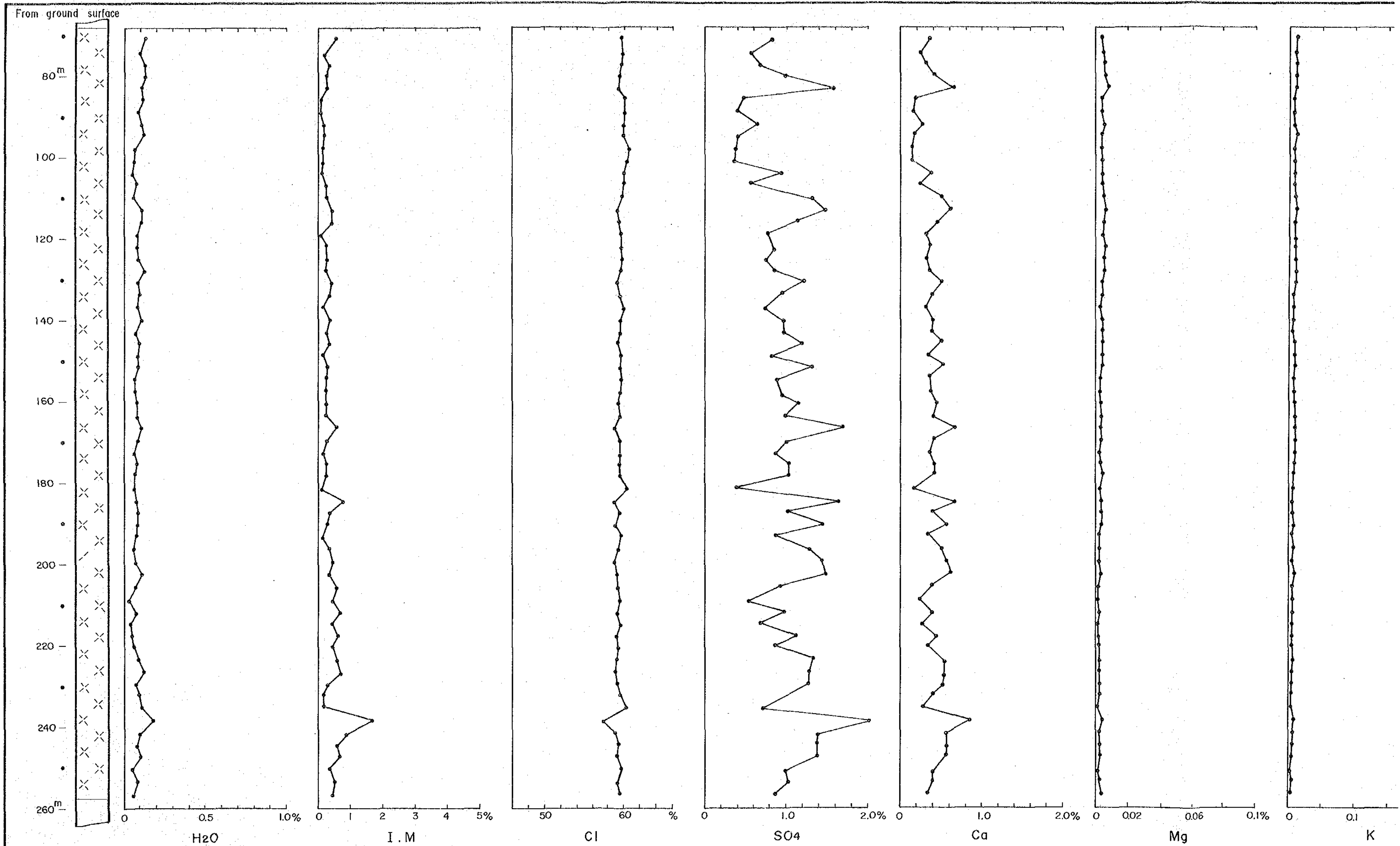
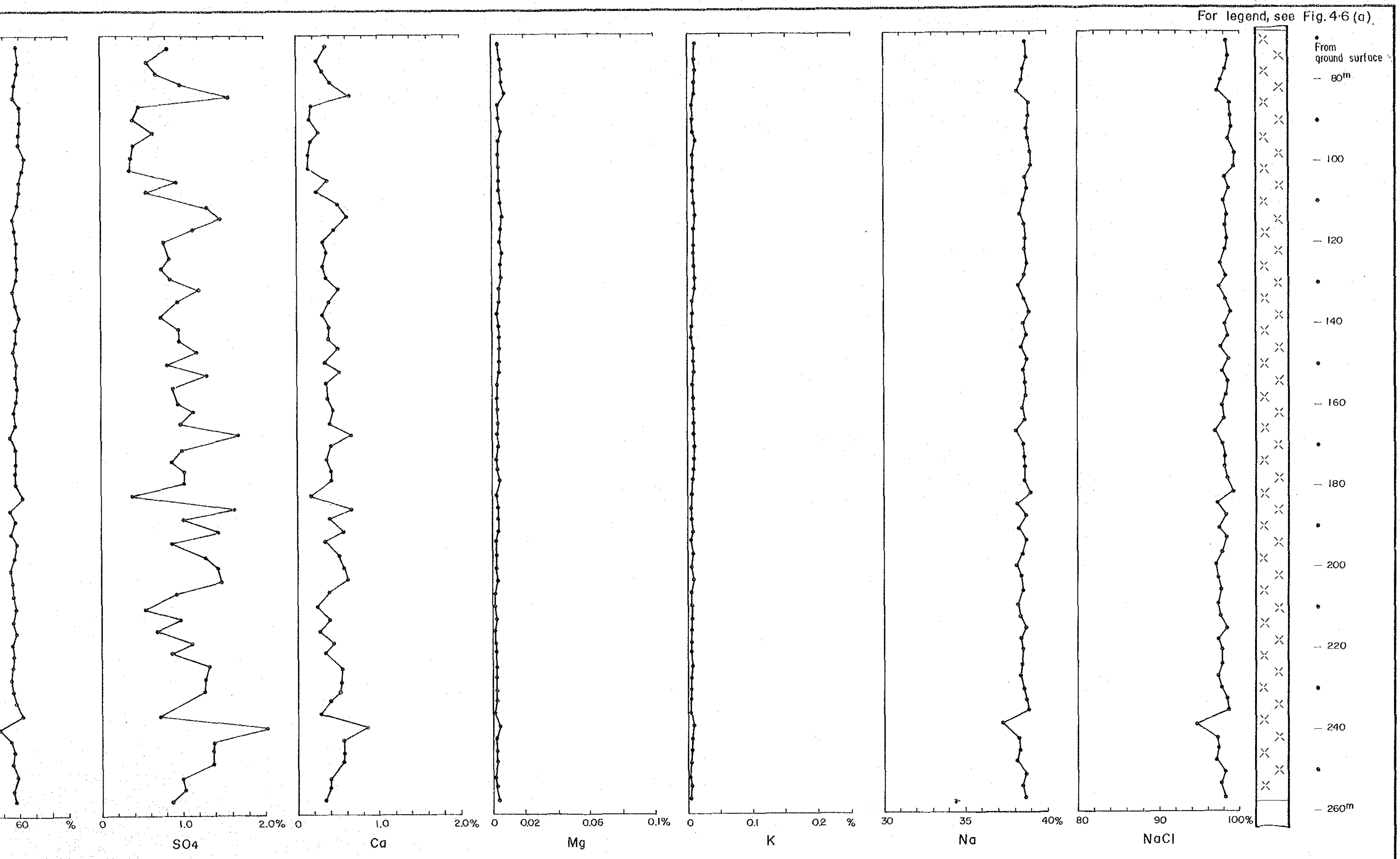


Fig.4·6 (d) Vertical variation of main components of rock salt in the drill hole RS.21



rock salt in the drill hole RS. 21