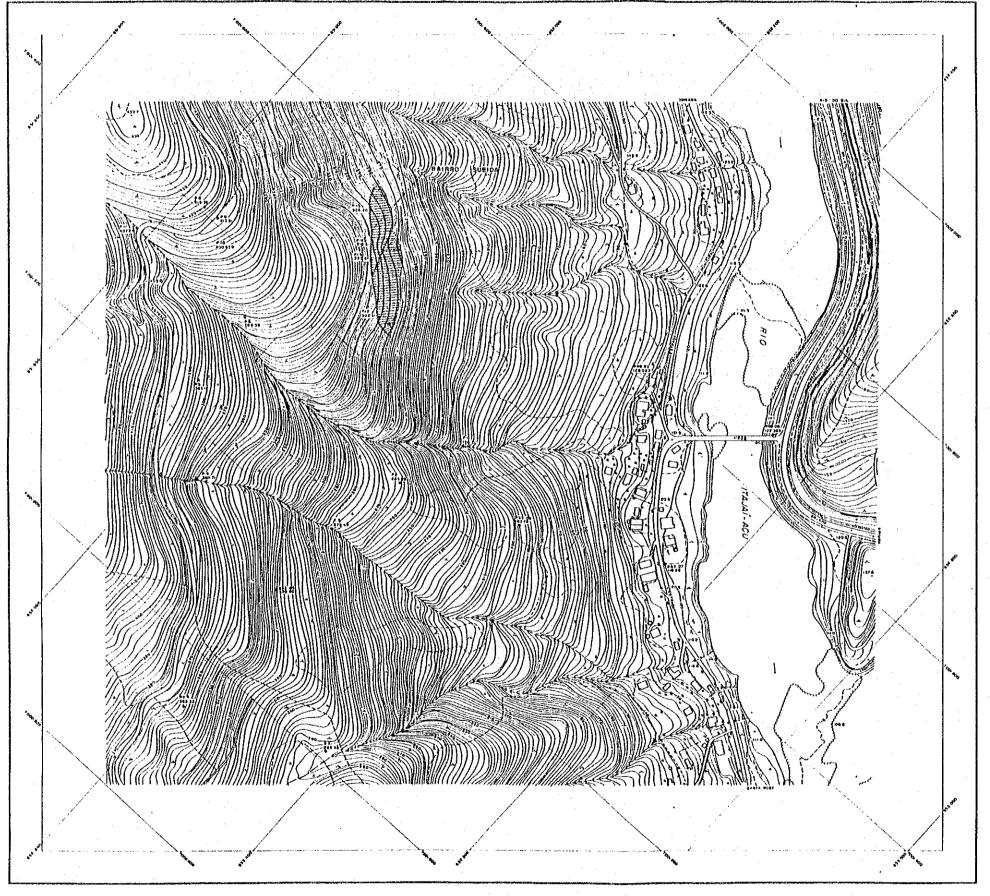


# THE SALTO PILÃO HYDROELECTRIC POWER DEVELOPMENT PROJECT POWER STATION SITE





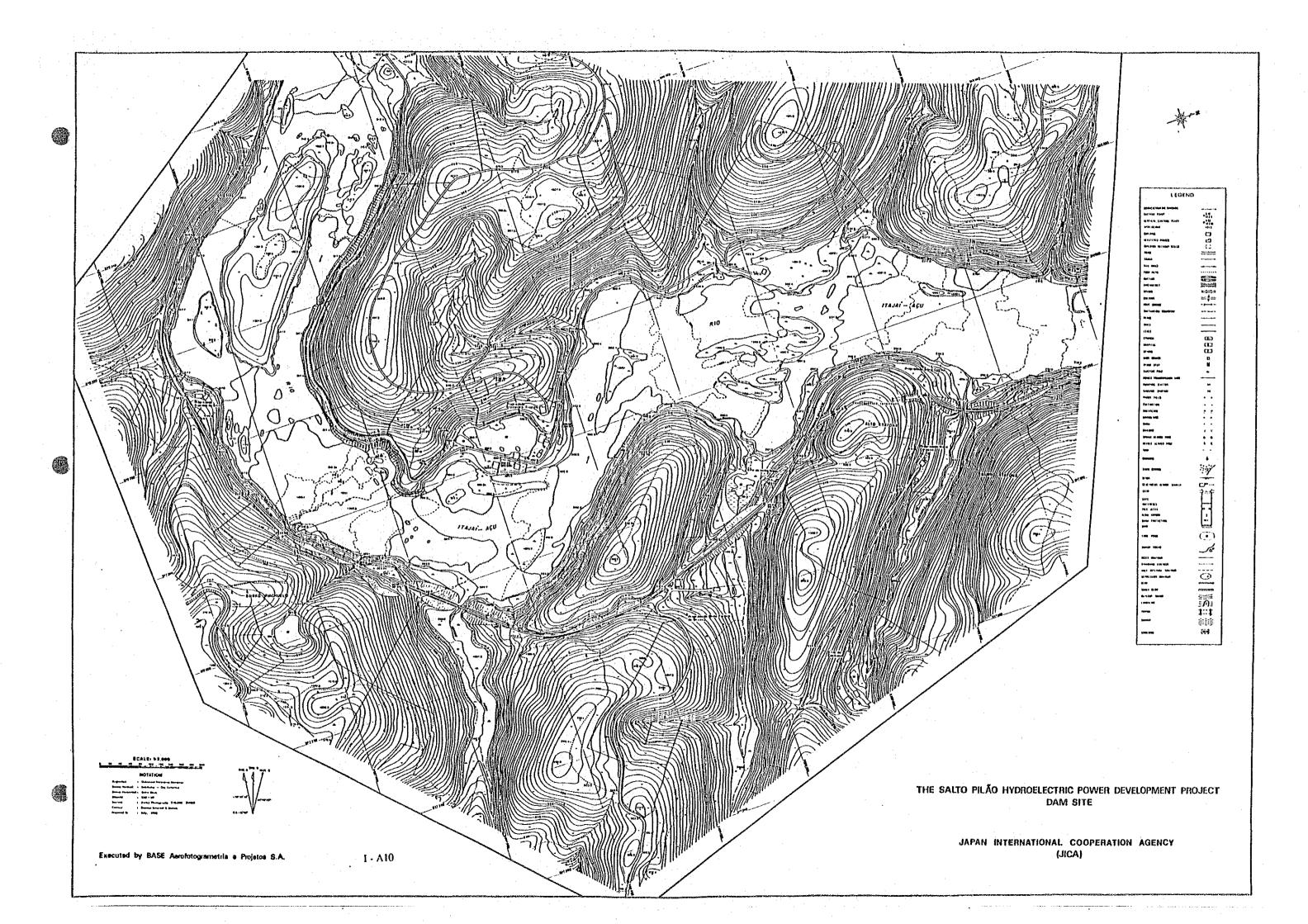
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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



# ANNEX II GEOLOGICAL INVESTIGATION

## ANNEX II GEOLOGICAL INVESTIGATION

## TABLE OF CONTENTS

		Page
1.	INTRODUCTION	II - 1
2.	GEOLOGICAL MAPPING	II - 1
	2.1 Geological Maps and Sections	II - 1
	2.2 Geological Interpretation	II - 1
3.	FIELD INVESTIGATION	II - 2
	3.1 Core Boring	II - 2
	3.2 In-sites Permeability Test	II - 3
4.	LABORATORY ROCK TEST	II - 4
	LIST OF TABLES	
		Page
II.3.1	•	
II.3.2		
II.4.1	Result of Laboratory Rock Test	II - T3
	LIST OF FIGURES	
	DIOI OF TIGORIES	
		Page
11.2.1	Geological Map of Project Area	II - Fl
II.2.2	Geological Section along Tunnel Route from Dam Axis B	II - F2
11.2.3	Geological Map Dam Area	II - F3
II.2.4	Geological Section along Dam Axis B, C, and D	.II - F4
11.2.5	Geological Map of Powerhouse Area	II - F5
11.2.6	Geological Section along Penstock to Powerhouse	
	(Proposed Site)	II - F6
II.2.7	Geological Section along Penstock to Powerhouse	

	(Alternative Site)	II - F7
11.2.8	Section of Quarries A and B	.II - F8
II.3.1	Drill Logs (Present Investigation)	II - F9
II.3.2	Drill Logs (by Canambra E.C.)	II - F21
11.3.3	Results of Permeability Test	II - F24
II.4.1	Result of Alkali Reactivity Test	II - F26

#### 1. INTRODUCTION

The geological investigation in the present study consists core boring, in-situ permeability test, laboratory rock test and geological mapping of the project area. Their work quantities are as follows:

1) Geological Mapping : 2 areas

2) Field Investigation

- Core boring : 10 holes
- In-situ permeability test : 14 points
3) Laboratory rock test : 23 samples

The works 2) and 3) were entrusted to the local expert firm (SPT Sondagens). The works were carried out from June to August 1993.

Previous investigations carried out by Canambra E. C. (1969) and by JICA (1990) concentrated on the axis B of the damsite and upstream site of powerhouse. The present investigation were executed mainly on the dam axis C and downstream alternative site for powerhouse. Because, the dam axis C was recommended in the previous Hydro Inventory Study - 1991 and the downstream powerhouse site was considered attractive on the topographic point of view.

#### 2. GEOLOGICAL MAPPING

#### 2.1 Geological Maps and Sections

Surface geology of the project area, especially of the dam area and powerhouse area, was investigated by a geologist of JICA team. The results were indicated on the maps prepared in the present study. Fig. II.2.1 shows the overall geological map of the project area and Fig. II.2.2 shows the geological section between dam site (axis B) and powerhouse along headrace tunnel.

Detailed geological maps and geological sections of damsites and powerhouse site (proposed upstream site) are shown in Figs. II.2.3 to II.2.6. Geological section of alternative penstock route and alternative powerhouse site (downstream site) is shown in Fig. II.2.7.

#### 2.2 Geological Interpretation

As shown on Fig. II.1, the dam and most part of headrace tunnel are situated in the granite body which is called Subida Series. This is normally classified as an intrusive rock with 70 km<sup>2</sup> of area, which is in a discordant contact with the surrounding volcanic and sedimentary rocks of Itajai Group. In some places, the relationship between these two units is dubious. It can be supposed in principle that the granite is actually intrusive, but

the analysis of specific places shows the granite being cut by other lithologies of effusive sequence.

Generally, the Subida granite is composed of leucogranites, with a reddish-brown colour, with hypidiomorphic granular texture, medium to coarse grain size, isotropic and homogeneous. The essential composition contains alkali-potassium feldspars (mainly orthoclase), quartz and iron-magnesium silicate, with high sodium proportion (sodium amphiboles and pyroxenes). The micaceous minerals are also lacking. The age is about 530 and 550 million years.

The northeast part of the project area including surge tank and powerhouse site show volcanic lithologies from Campo Alegre Formation. In this region were found two kinds of igneous rocks:

- Acid microcrystalline rocks, probably effusive, here classified as rhyolites. They are felsic, with also the same mineralogical composition of the granite, but with imperceptible crystals by naked eye;
- Basic rocks with fine grain size, classified as diabases. They are essentially composed of pyroxenes and calcium-alkali feldspars, containing probably olivine, sulphides and garnet. The colour is dark grey.

#### 3. FIELD INVESTIGATION

#### 3.1 Core Boring

Core boring of 10 holes or 300 m in total length was undertaken. Location of the holes are shown in Fig. II.2.1. Length and ground elevation of each hole are tabulated below:

Hole	Length	Ground		
No.	(m)	Height (m)		Site
B93-1	40	338.37	Dam axis - C	Left abutment
2	25	305.97	Dam axis - C	River bed
3	40	321.56	Dam axis - C	Right abutment
4	20	331.31	Dam site	Diversion Tunnel
5	45	320.0	Surge Tank	Downstream alternative
6	40	193.78	Penstock	Downstream alternative
7	20	119.69	Powerhouse	Downstream alternative
8-1	25	360.0	Quarry - A	
8-2	20	384.0	Quarry - B	*
8-3	25	306.0	Quarry - B	
rotal 10	300	,		
holes	·			

Drill logs of the holes are shown in Fig. II.3.1. In classification of rock grade, the two standards were referred: (1) Japanese rock classification standard as shown in Table II.3.1 and (2) Brazilian rock classification index as shown in Table II.3.2.

#### 3.2 In-situ Permeability Test

The field permeability tests on rock layer were executed inside the holes drilled for core boring with numbers of 93-1 to 93-5. The test was made in a section of 5 m length at the selected depth. In each test section, the quantity of injected water was counted at 10 - minute intervals.

From the data obtained during the tests, the P-Q graphs are prepared as shown in Fig. II.3.2. The Lugeon value (lit/min/m at 10 kg/cm<sup>2</sup>) is obtained from these graphs.

Exceptionally, in order to check the permeability of overburden soil, water leakage test without pressurization was executed at the right bank of damsite (Hole No. 93-3) at the depth between 0 to 5 m.

The following table shows the results of in-situ permeability tests.

Location	Hole No.	Depth (m)	Rock Type *1	Lugeon Value
Dam site C, Left Abutment	B93-1	25-30	Gr	5,2
Do	B93-1	30-35	Gr	4
Do	B93-1	35-40	Gr	1
Dam site C, River bed	B93-2	10-15	Gr	2.2
Do	B93-2	15-20	Gr	0.8
Do	B93-2	20-25	Gr	4.5
Dam site C, Right Abutment	B93-3	00-05	$\mathbf{D}\mathbf{s}$	$k = 3.1^{-4}$ cm/s *2
Do	B93-3	20-25	Gr	0.5
Do	B93-3	25-30	Gr	0.2
Do	B93-3	30-35	Gr	0.1
Do	B93-3	35-40	Gr	5
Dam site C, Diversion	B93-4	15-20	Gr	0.5
Surge Tank	B93-5	30-35	Ry	0.4
Do	B93-5	35-40	Ry	3

Notes: \*1 Gr = Granite, Ds = Soil, Ry = Rhyolite

\*2 k = Permeability coefficient

#### 4. LABORATORY ROCK TEST

In order to examine the engineering properties of rocks at dam foundation and tunnel and rocks for concrete aggregate, the laboratory rock tests were carried out on samples taken from drilled cores and outcrops in the existing quarry and in the existing tunnel. The sampling in the existing tunnel of abandoned railway near the quarry A was made aiming to represent rock of the headrace tunnel which passes in the similar granite mass. Locations of sampling are listed below:

Sample	Rock	Sampling	Depth	Type of Sample	Nos. of
No.	Type	Location	(m)	•	Piece
Dam & Waterway		<del></del>			
Dam - 1	Granite	B93-1	38.3	Boring core	1
- 2	- Do -	B93-1	38.6	- Đo -	1
- 3	- Do -	B93-1	39.0	- Do -	1
- 4	- Do -	B93-1	39.3	- Do -	1
<b>-</b> 5	- Do -	B93-2	22.3	- Do -	1
- 6	- Do -	B93-2	24.0	- Do -	1
- 7	- Do -	B93-3	25.0	- Do -	1
- 8	- Do -	B93-3	30.0	- Do -	1
- 9	- Do -	B93-3	33.0	- Do -	1
- 10	- Do -	B93-3	35.0	- Do -	1
Tunnel - 1	- Do -	<b>Existing Tunnel</b>		Angular Blocks	2
- 2	- Do -	- Do -		Angular Blocks	2
- 3	- Do -	- Do -		Angular Blocks	2
- 4	Rhyolite	B93-6	28.5	Boring core	1
- 5	- Do -	B93-6	29.5	- Do -	1
- 6	- Do -	B93-6	37.0	- Do -	1
- 7	- Do -	B93-5	25.0	- Do -	1
- 8	- Do -	B93-5	27.0	- Do -	1
- 9	- Do -	B93-5	28.0	- Do -	1
- 10	- Do -	B93-5	30.0	- Do -	1
Concrete					
Aggregate Quarry					
Quarry - 1	Granite	Existing quarry *		Angular Blocks	2
Quarry - 2	- Do -	- Do -		Angular Blocks	2
Quarry - 3	- Do -	- Do -		Angular Blocks	2
Total: 23		· · · · · · · · · · · · · · · · · · ·		<del></del>	<del></del>

<sup>\*:</sup> Upstream portal of the existing tunnel near quarry-A.

The rock pieces sampled were tested at the laboratory in São Paulo on the following test items.

Test Item	Test Specification (ASTM)
1) Specific gravity	C-29-76
2) Water absorption	C-29-76
3) Void ratio	C-29-76
4) Dynamic elastic modulus	D-2845-89
(Velocity of super sonic wave)	
5) Unconfined compressive strength	C-109-70
6) Los Angeles abrasion test	C-241-51
7) Potential alkali reactivity	C-289-81
(Chemical Method)	

The test item 7) was applied only to 3 test samples for concrete aggregate. The other test items were applied to all test samples.

The test results are summarized in Table II.4.1. The results of the potential alkali reactivity test is shown in Fig. II.4.1.

Characteristic engineering properties revealed by these tests are as follows:

- As to granite in dam site, dynamic elastic modulus is 65 GPa on an average, unconfined compressive strength ranges from 210 MPa to 140 MPa (average 170 MPa). These figures present that the rock is excellent.
- Granite in relation to headrace tunnel also has very good condition; dynamic elastic modulus and unconfined compressive strength, respectively 62.7 GPa and 150 MPa on an average.
- As to rhyolite in relation to penstock tunnel, dynamic elastic modulus shows nearly equal value 68~70 GPa, average 69 GPa. However there is a large difference in unconfined compressive strength: minimum 73 MPa, maximum 240 MPa and average 170 MPa.
- Granite in quarry site has a sufficient strength; unconfined compressive strength 150 MPa. However the rate of abrasion loss is relatively large; 32% in index of Los Angeles Abrasion. Reaction to alkali aggression is low and quite innocuous.

## Table

Table II.2.1 Japanese Rock Classification

Rock Class	Characteristics
A	Hard and fresh rocks. Rock-forming minerals are fresh and not weathered or altered. Joints and cracks are closed tightly, no weathering on their planes. Clear sound is emitted when hammered.
æ	Hard and fresh rocks. Rock forming minerals are weathered slightly or partially altered. Joints and cracks are closed tightly, without weathering. Clear sound is emitted when hammered.
Æ	Fairly hard and slightly weathered rocks. Rock-forming minerals, except quartz, are weathered or altered. Tightness of joints and cracks is slightly reduced and each block is apt to be exfoliated along joints and cracks which sometimes contain clay and other materials, stained by limonite. Slightly dull sound is emitted when hammered.
CM	Slightly soft and moderately weathered rock. Rockfarning minerals, except quartz, are weathered or altered. Exfoliation occurs along joint and cracks by hammering. Joints and cracks sometimes contain clay and other materials. Slightly dull sound is emitted when hammered.
CC	Soft and weathered rocks. Rock minerals are weathered. Exfoliation occurs easily along joints and cracks by hammering. Joints and cracks contain clay and other materials. Dull sound is emitted when hammered.
Д	Very soft, highly weathered, fractured and/or altered rocks. Rock-forming minerals are highly weathered. Joints and cracks are very loose, easily collapse by weak hammering, which contain clay and other materials. Very dull sound is emitted when hammered.

Rock Class	Compressive	Modulus of	Modulus of	Seismic	Poisson's
	Strength (qu :	Elasticity	Deformation	Velocity	Ratio
and the Charles	kg/cm <sup>2</sup> )	(Es:kg/cm²)	(Ed: kg/cm <sup>2</sup> )	(km/sec)	
A&B	more than	more than	more than	more than	less than
	800	80,000	50,000	3.7	0.2
₽	800 to 200	80,000 to	50,000 to	3.7 to 3	0.2 to 0.3
		40,000	20,000		
3	400 to 200	40,000 to	20,000 to	3 to 1.5	02 to 03
		15,000	5,600		
덩	less than 200	less than	less than	less than	more
	:	15,000	5,000	1.5	than 0.3
Ω	less than 100	less than	less than	less than	more
a. ·		2,000	5,000	1.5	than 0.3

					0
Borchole test	Modulus of Elasticity: ES (kg/cm <sup>2</sup> )	more than 100,000	150,000 to 60,000	60,000 to 10,000	less than 15,000
Borch	Modulus of Deformation (kg/cm <sup>2</sup> )	more than 50,000	60,000 to 15,000	20,000 to 3,000	less than 6,000
	Internal Friction Angle (degree)	. 55 to 65	40 to 55	30 to 45	15 to 35
	Cohesion (kg/cm²)	more than 40	40 to 20	20 to 10	less than 10
	Rock Class	A&B	æ	CM	CL&D

Notes:

- Compressive strength shows the result of rock piece test.
- Modulus of elasticity and deformation show the results of in-situ plate loading tests. 333
  - Es means static modulus of elasticity.

Source ; Standard of Central Research Institute of Electric Power Industry of Japan

Table II.3.1 Brazilian Rock Classification

Ha	rdness		Alteration	Fractureness		Fractures		,	
							Orientation Conditions		Conditions
	Very		Solid		0 to 1		0°		
HI	Hard	Al	Rock	Fl	по	H	Horizontal	SI	Rough
					Fissured				
	Hard		Little		2 to 5		0° to 20°		
H2	•	A2	Altered	F2	Little	SH	Sub	S2	Little
				1	Fissured	1 1	Horizontal		Rough
	Moderately		Moderately		6 to 10		20° to 70°	1	
Н3	Hard	A3	Altered	F3	Moderately	T	Inclined	S3	Smooth
					Fissured	] [			
	Soft		Very		11 to 20	T	70° to 90°		
H4		A4	Altered	F4	Very	SV	Sub	\$4	Granular
					Fissured	1. 1	Vertical		Filling
	Very				20	T	****		
H5	Soft	A5	Saprolite	F5	Extremely	V	Vertical	S5	Clayey
					Fissured				Filling

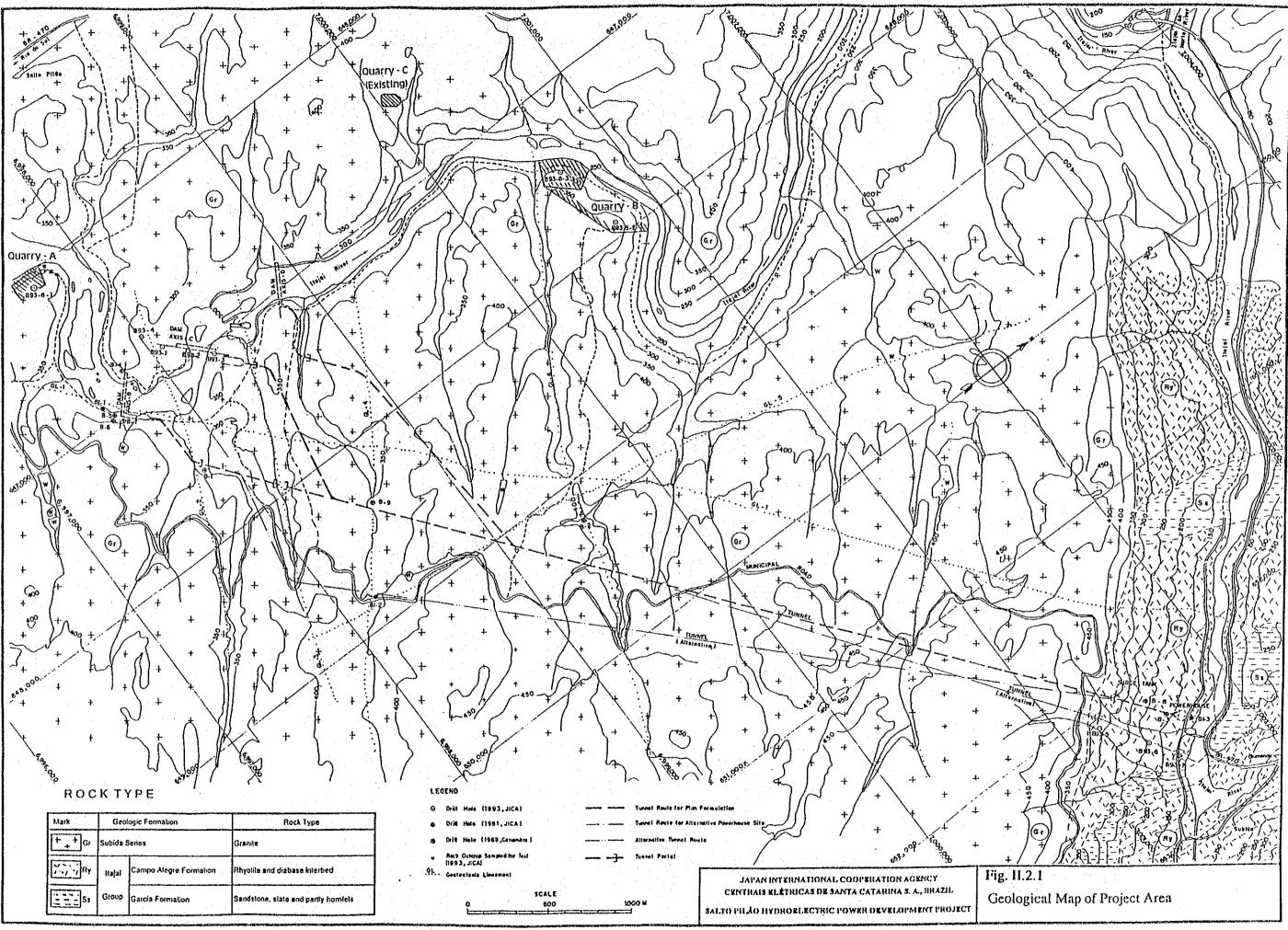
Table II.4.1 Result of Laboratory

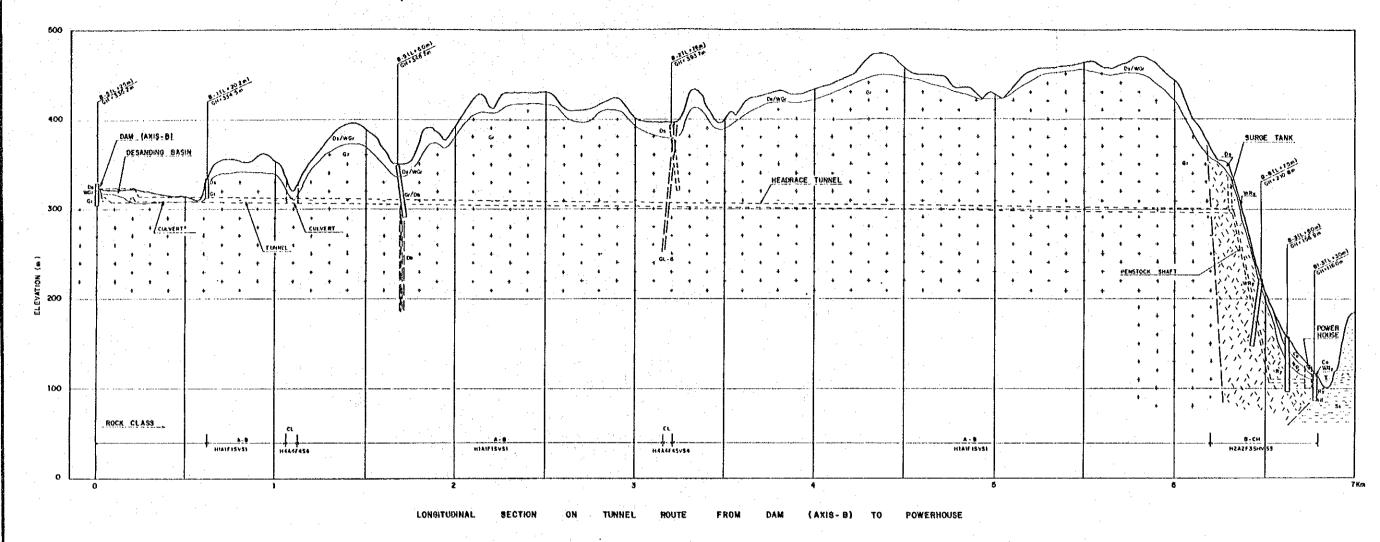
Gravity (g/cm3)         Absorption (g/cm3)         Ratio (GPa)         Compressive Abrasion (PA)         Dissolved (m Mole/L) (m Mole/L)           (g/cm3)         (%)         (%)         Modulus (MA)         Strength (PA)         (m Mole/L) (m Mole/L)           2.596         0.07         0.19         66.37         144.84		Depth Rock Specific	1		Dynamic	Dynamic Unconfined Los Angeles	Los Angeles	Potenti	Potential Alkali Reactivity	ctivity
(%) (%) Modulus Strength (%) Silica of Alka (GPa) (MPa) (MPa) (MPa) (m MoleLL) (m MoleLD) (m MoleCD) (m MoleCD		Gravi		ion Ratio	Elastic	Compressive .	Abrasion	Dissolved	Reduction	Result
CPa   CPa   CMPa   CMPa   Cm Mole/L   Cm		(g/cm		<u>8</u>	Modulus	Strength	8		of Alkalinity	
0.07         0.19         66.37         144.84         -					(GPa)	(MPa)		(加 Mole/L)	(m Mole/L)	
0.07         0.19         68.92         155.13         -         -           0.07         0.17         64.61         175.03         -         -         -           0.08         0.20         67.98         195.31         -         -         -           0.08         0.20         67.98         195.31         -         -         -           0.09         0.22         60.17         188.06         -         -         -           0.09         0.25         55.49         186.00         -         -         -           0.09         0.25         55.49         186.00         -         -         -           0.09         0.25         55.49         186.00         -         -         -           0.28         0.72         58.68         209.23         -         -         -           0.23         0.82         64.01         137.30         -         -         -           0.24         0.59         59.05         166.31         -         -         -           0.25         0.58         61.69         144.84         -         -         -           0.27         0.58	38.3 Gr	2,5				144.84		1		•
0.07         0.17         64.61         175.03         -         -           0.10         0.25         61.62         168.27         -         -           0.08         0.20         67.98         195.31         -         -           0.09         0.23         60.17         188.06         -         -         -           0.09         0.25         55.49         186.00         -         -         -           0.09         0.25         55.49         186.00         -         -         -           0.09         0.25         55.49         186.00         -         -         -           0.14         0.36         60.88         140.04         -         -         -           0.28         0.72         58.68         209.23         -         -         -           0.29         0.89         144.84         -         -         -         -           0.20         0.59         59.05         166.31         -         -         -         -           0.20         0.58         61.69         144.84         -         -         -           0.21         0.56         69.93	38.6 Gr	2.¢				155.13	•	-	_	•
0.10         0.25         61.62         168.27         -         -           0.08         0.20         67.98         195.31         -         -           0.08         0.20         67.98         195.31         -         -           0.12         0.31         63.23         42.53         -         -           0.09         0.22         60.17         188.06         -         -           0.09         0.25         55.49         186.00         -         -           0.14         0.36         60.88         140.04         -         -         -           0.28         0.72         58.68         209.23         -         -         -         -           0.28         64.01         137.30         -	39.0 Gr	2.¢				175.03	-	•	•	•
0.08         0.20         67.98         195.31         -         -           0.12         0.31         63.23         42.53         -         -           0.09         0.22         60.17         188.06         -         -           0.09         0.25         55.49         186.00         -         -           0.09         0.25         55.49         186.00         -         -           0.14         0.36         60.88         140.04         -         -         -           0.28         0.72         58.68         209.23         -         -         -         -           0.29         0.59         59.05         166.31         -         -         -         -           0.21         0.58         61.69         144.84         -         -         -         -           0.22         0.58         61.69         144.84         -         -         -         -           0.21         0.56         69.93         206.68         -         -         -         -           0.21         0.56         69.93         206.68         -         -         -         -           0	39.3 Gr	2.5					. 1	•	1	
0.12         0.31         63.23         42.53         -         -           0.09         0.22         60.17         188.06         -         -           0.09         0.25         55.49         186.00         -         -           0.14         0.36         60.88         140.04         -         -           0.28         0.72         58.68         209.23         -         -           0.23         0.59         59.05         166.31         -         -           0.23         0.59         59.05         166.31         -         -           0.23         0.59         59.05         166.31         -         -           0.23         0.59         59.05         166.31         -         -           0.23         0.59         59.05         166.31         -         -           0.24         0.5         69.05         144.84         -         -         -           0.25         6.8         61.69         144.84         -         -         -           0.27         0.56         69.93         206.68         -         -         -           0.14         0.39         6	22.3 Gr	2.¢					•		_	
0.09         0.22         60.17         188.06         -         -         -           0.09         0.25         55.49         186.00         -         -         -           0.14         0.36         60.88         140.04         -         -         -           0.28         0.72         58.68         209.23         -         -         -           0.23         0.82         64.01         137.30         -         -         -           0.23         0.59         59.05         166.31         -         -         -           0.23         0.58         61.69         144.84         -         -         -           0.24         0.58         61.69         144.84         -         -         -           0.20         0.15         68.76         191.98         -         -         -         -           0.17         0.47         72.29         141.51         -         -         -         -           0.10         0.26         65.73         148.96         -         -         -         -           0.14         0.29         66.78         154.84         32         16.79 <td>24.0 Gr</td> <td>2.5</td> <td>-</td> <td></td> <td></td> <td></td> <td>•</td> <td>:</td> <td>-</td> <td>•</td>	24.0 Gr	2.5	-				•	:	-	•
0.09         0.25         55.49         186.00         -         -         -           0.14         0.36         60.88         140.04         -         -         -           0.28         0.72         58.68         209.23         -         -         -           0.23         0.82         64.01         137.30         -         -         -           0.23         0.58         61.69         144.84         -         -         -           0.22         0.58         61.69         144.84         -         -         -           0.06         0.15         68.76         191.98         -         -         -           0.21         0.56         69.93         206.68         -         -         -         -           0.17         0.47         72.29         141.51         -         -         -         -         -           0.06         0.17         69.10         241.96         -         -         -         -         -           0.14         0.29         66.78         190.61         -         -         -         -         -         -         -         -         -	25.0 Gr	2.5				188.06	•	1	-	1
0.14         0.36         60.88         140.04         -	30.0 Gr	5.					•	•	-	•
0.28         0.72         58.68         209.23         -         -           0.32         0.82         64.01         137.30         -         -         -           0.23         0.59         59.05         166.31         -         -         -           0.22         0.58         61.69         144.84         -         -         -           0.06         0.15         68.76         191.98         -         -         -           0.21         0.56         69.93         206.68         -         -         -           0.17         0.47         72.29         141.51         -         -         -           0.06         0.17         69.10         241.96         -         -         -         -           0.07         0.20         65.73         148.96         -         -         -         -           0.10         0.29         66.78         190.61         -         -         -         -           0.10         0.29         66.78         154.84         32         2.50         -           0.10         0.26         60.70         164.54         32         9.16	33.0 Gr	2.5					•	-		1
0.32         0.82         64.01         137.30         -         -           0.23         0.59         59.05         166.31         -         -         -           0.22         0.58         61.69         144.84         -         -         -           0.06         0.15         68.76         191.98         -         -         -           0.21         0.56         69.93         206.68         -         -         -           0.17         0.47         72.29         141.51         -         -         -           0.06         0.17         69.10         241.96         -         -         -         -           0.07         0.20         65.73         148.96         -         -         -         -           0.14         0.39         66.88         190.61         -         -         -         -           0.12         0.56         61.50         154.84         32         2.50         -           0.10         0.26         61.50         164.54         32         167.9           0.16         0.41         59.81         150.53         32         9.16	35.0 Gr	2.5				209.23	•			-
0.23         0.59         59.05         166.31         -         -           0.22         0.58         61.69         144.84         -         -         -           0.06         0.15         68.76         191.98         -         -         -           0.21         0.56         69.93         206.68         -         -         -           0.17         0.47         72.29         141.51         -         -         -           0.06         0.17         69.10         241.96         -         -         -         -           0.07         0.20         65.73         148.96         -         -         -         -           0.14         0.39         66.88         190.61         -         -         -         -           0.10         0.29         66.78         71.93         -         -         -         -           0.10         0.26         61.50         154.84         32         16.79           0.10         0.26         60.70         164.54         32         16.79           0.16         0.41         59.81         150.53         32         9.16	Outcrop (Tunnel)* - Gr	2.					•		_	1
0.22         0.58         61.69         144.84         -         -           0.06         0.15         68.76         191.98         -         -         -           0.21         0.56         69.93         206.68         -         -         -           0.17         0.47         72.29         141.51         -         -         -           0.06         0.17         69.10         241.96         -         -         -           0.07         0.20         65.73         148.96         -         -         -           0.14         0.39         66.88         190.61         -         -         -           0.10         0.29         66.78         71.93         -         -         -           0.10         0.26         61.50         154.84         32         2.50           0.10         0.26         60.70         164.54         32         16.79           0.16         0.41         59.81         150.53         32         9.16	Outcrop (Tunnel)* - Gr	7.					•	1	1	•
0.06         0.15         68.76         191.98         -	Outcrop (Tunnel)* - Gr	2.0					•	•	1	•
0.21         0.56         69.93         206.68         -         -         -           0.17         0.47         72.29         141.51         -         -         -           0.06         0.17         69.10         241.96         -         -         -           0.07         0.20         65.73         148.96         -         -         -         -           0.14         0.39         66.88         190.61         -         -         -         -         -           0.10         0.29         66.78         71.93         -	28.5 Db	2.0					•	•	•	
0.17         0.47         72.29         141.51         -         -           0.06         0.17         69.10         241.96         -         -         -           0.07         0.20         65.73         148.96         -         -         -           0.14         0.39         66.88         190.61         -         -         -         -           0.10         0.29         66.78         71.93         -         -         -         -           0.22         0.56         61.50         154.84         32         2.50         -           0.10         0.26         60.70         164.54         32         16.79           0.16         0.41         59.81         150.53         32         9.16	29.5 Ry	2.0					•	•	•	•
0.06         0.17         69.10         241.96         -         -         -           0.07         0.20         65.73         148.96         -         -         -         -           0.14         0.39         66.88         190.61         -<	37.0 Db	2.					•		_	
0.07         0.20         65.73         148.96         -	25.0 Db	2.					•	•	-	_
0.14         0.39         66.88         190.61         -	27.0 Db	2.						-	•	ŧ
0.10     0.29     66.78     71.93     -     -     -       0.22     0.56     61.50     154.84     32     2.50       0.10     0.26     60.70     164.54     32     16.79       0.16     0.41     59.81     150.53     32     9.16	28.0 Ry	2.					•			-
0.22         0.56         61.50         154.84         32         2.50           0.10         0.26         60.70         164.54         32         16.79           0.16         0.41         59.81         150.53         32         9.16	30.0 Ry	2.					•		_	•
0.10         0.26         60.70         164.54         32         16.79           0.16         0.41         59.81         150.53         32         9.16	Outcrop (Quarry)** - Gr	2.:					32	2.50	75.25	Inoffensive
0.16 0.41 59.81 150.53 32   9.16	Outcrop (Quarry)** - Gr	2.					32	16.79	37.65	Inoffensive
	Outcrop (Quarry)** - Gr	2				150.53	32	9.16	37.65	Inoffensive

Inside of existing tunnel of abandoned railway near Drill hole B93-8-1.
Existing quarry at upstream portal of the above existing tunnel.
Gr : Granite

: Rhyolite : Diabase 9 % g

## Figure





#### **ROCK PROPERTIES**

Mark	Geologic	Formation	Rock Type	Rock Cia	suffication	Engineering Properties
				(1)	(2)	
Gr	Subida S	ienes	Granite	A-8	HIAIFISVSI	Very hard. Measure, Joints closed tightly and spaced only with 3 to 5 m.
WGr			Weathered Grande	CL	113A4F45VS5	Stained into brown, Fregite and soft.
Ry			Rhyolds	В - Сн	H1A1F2SVS3	Complex of rhyokie, rhyodacie, Interbedded with diabase. Very hard but cracky. Joints develop in some places.
WRy	Itajai Group	Campo Alegre Formation	Weathered Rhyolds	CM - CL	H3A3F4SVS4	Colour aftered. Stained. Moderately hard. Many open cracks with day film.
Ob			Diabase	СН	H2A2F35V53	Intrusive rock. Hard but cracky,
Ħ		Garcia Formation	Homiels	СН	H2A2F3SVS3	Hard. Thermo-meternorphic. Joints develop with spacing of 10 cm:

Note: Rock Classification (1): Japanese classification Rock Classification (2): Brazikan index

Al: Aliunium, Clayer Soil

Co: Collumium, Clayer Soil with Boulders
De: Clay, Soit Decomposed Rock

Fr. Granie

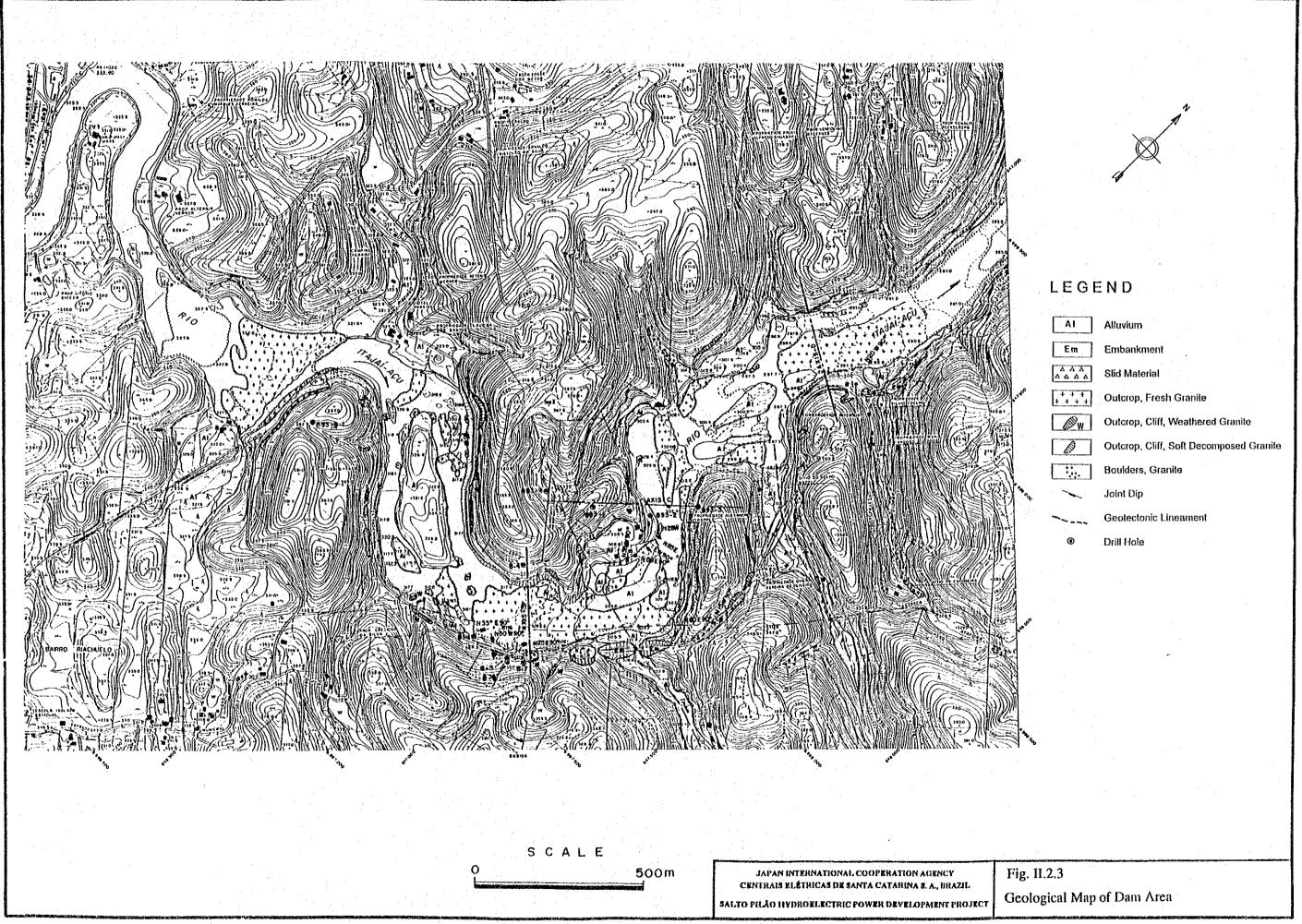
Ry: Rhyolite with Diabare Interbed

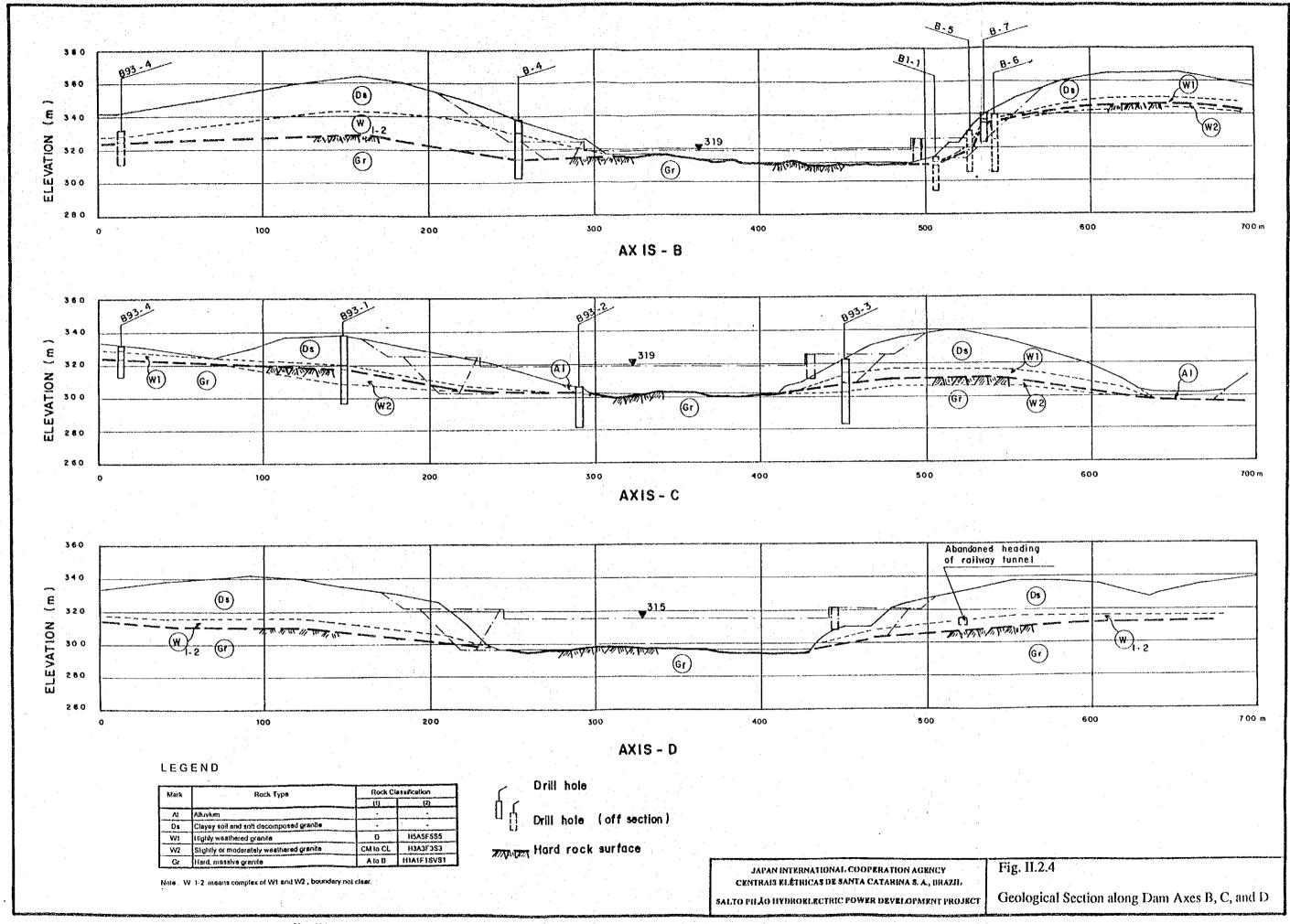
Db: Diabase Intrusion

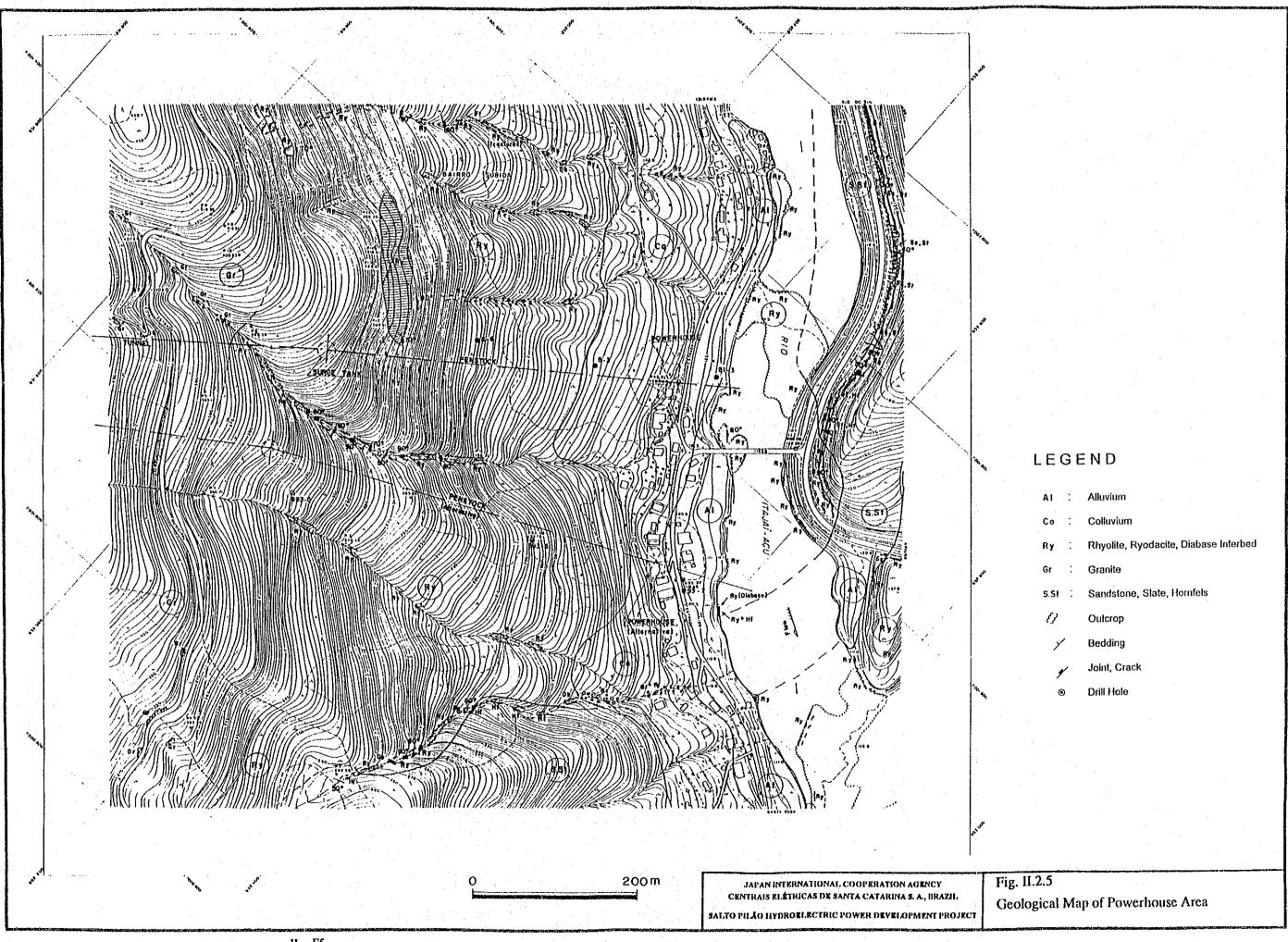
No. B-: by Canambra, 1969
Ho. B1-: by JICA, 1991
No. B93-: by JICA, 1993

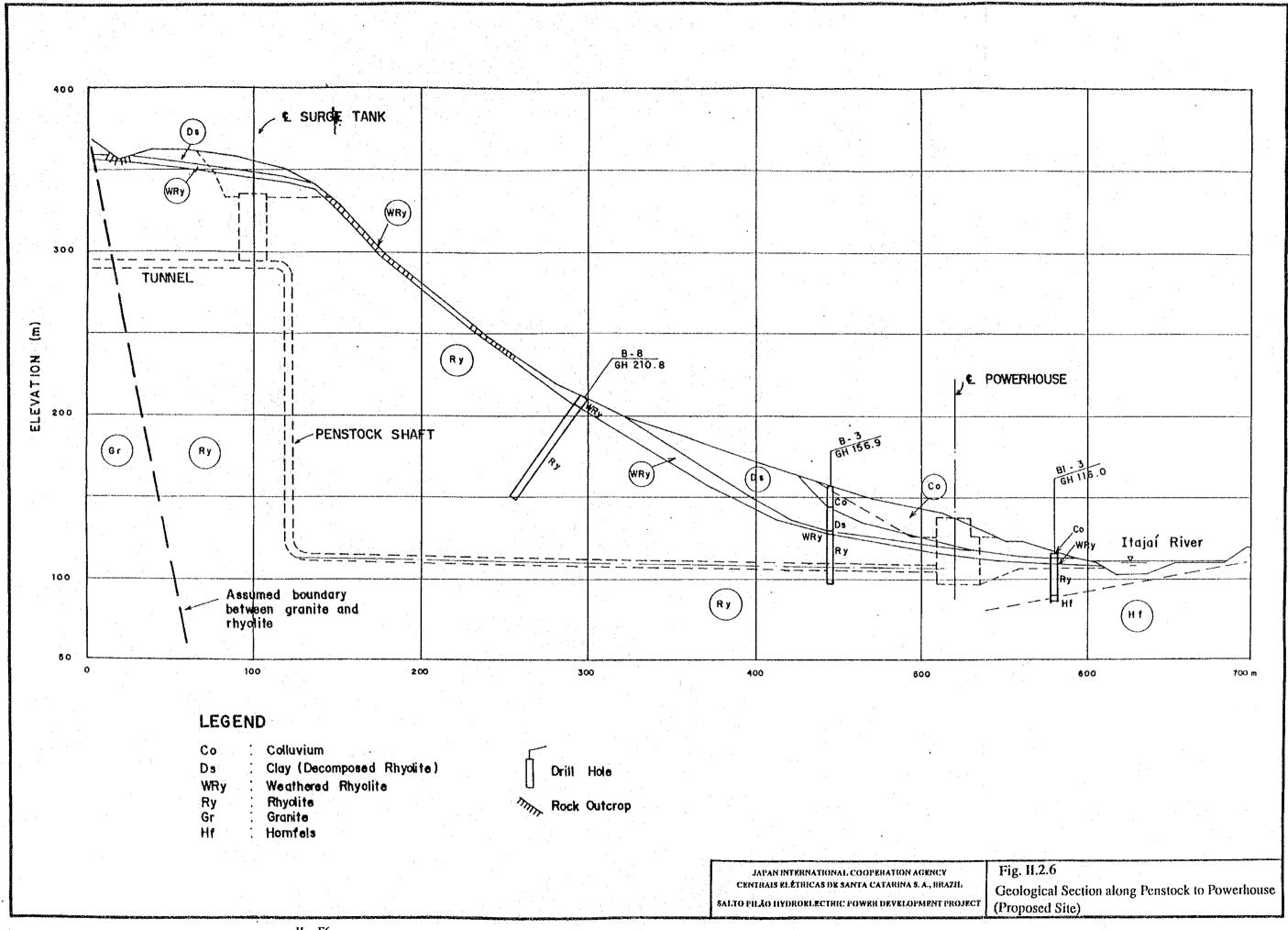
JAPAN INTERNATIONAL COOPERATION AGENCY
CENTRAIS REÉTRICAS DE SANTA CATARINA S. A., BRAZIL
SALTO PILÃO HYDROBLECTRIC POWER DEVELOPMENT PROJECT

Fig. II.2.2
Geological Section along Tunnel Route
from Dam Axis B









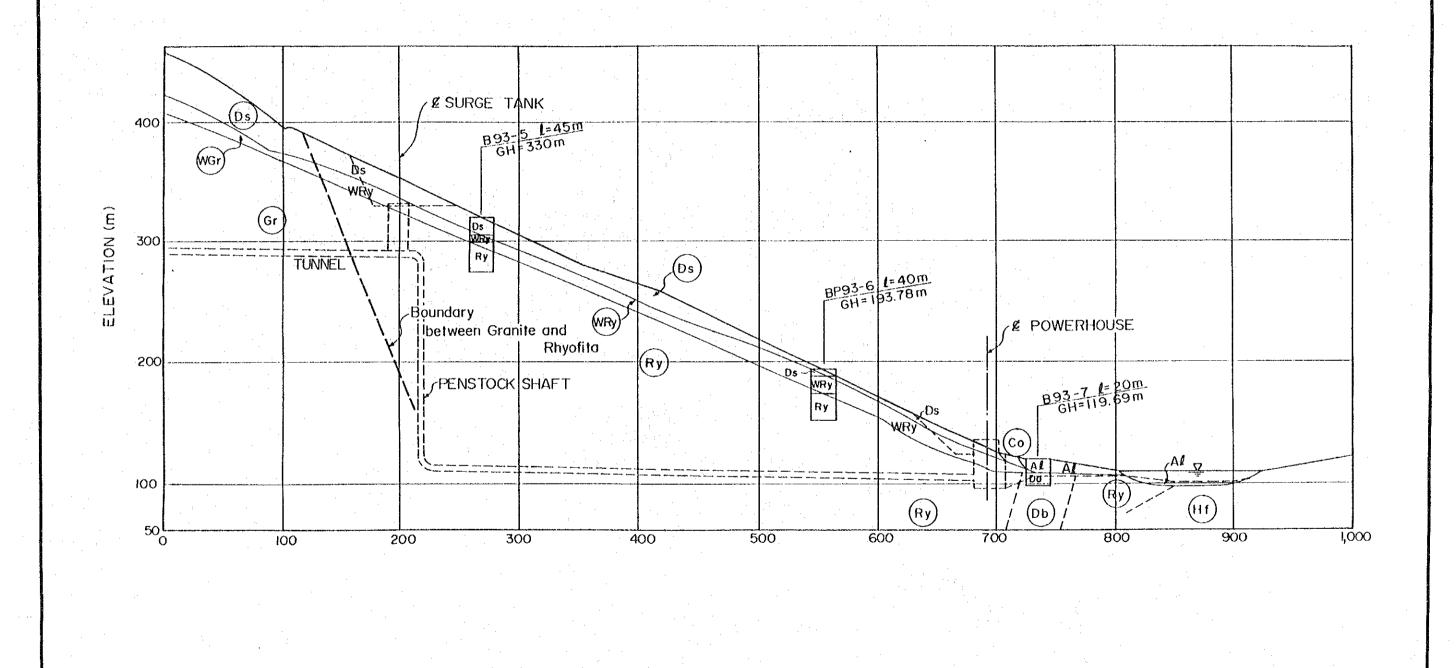


Fig. II.2.7

(Alternative Site)

Geological Section along Penstock to Powerhouse

JAPAN INTERNATIONAL COOPERATION AGENCY
CENTRAIS ELÉTRICAS DE SANTA CATARINA S. A., BRAZIL

SALTO PHÃO HYDROELECTRIC POWER DEVELOPMENT PROJECT

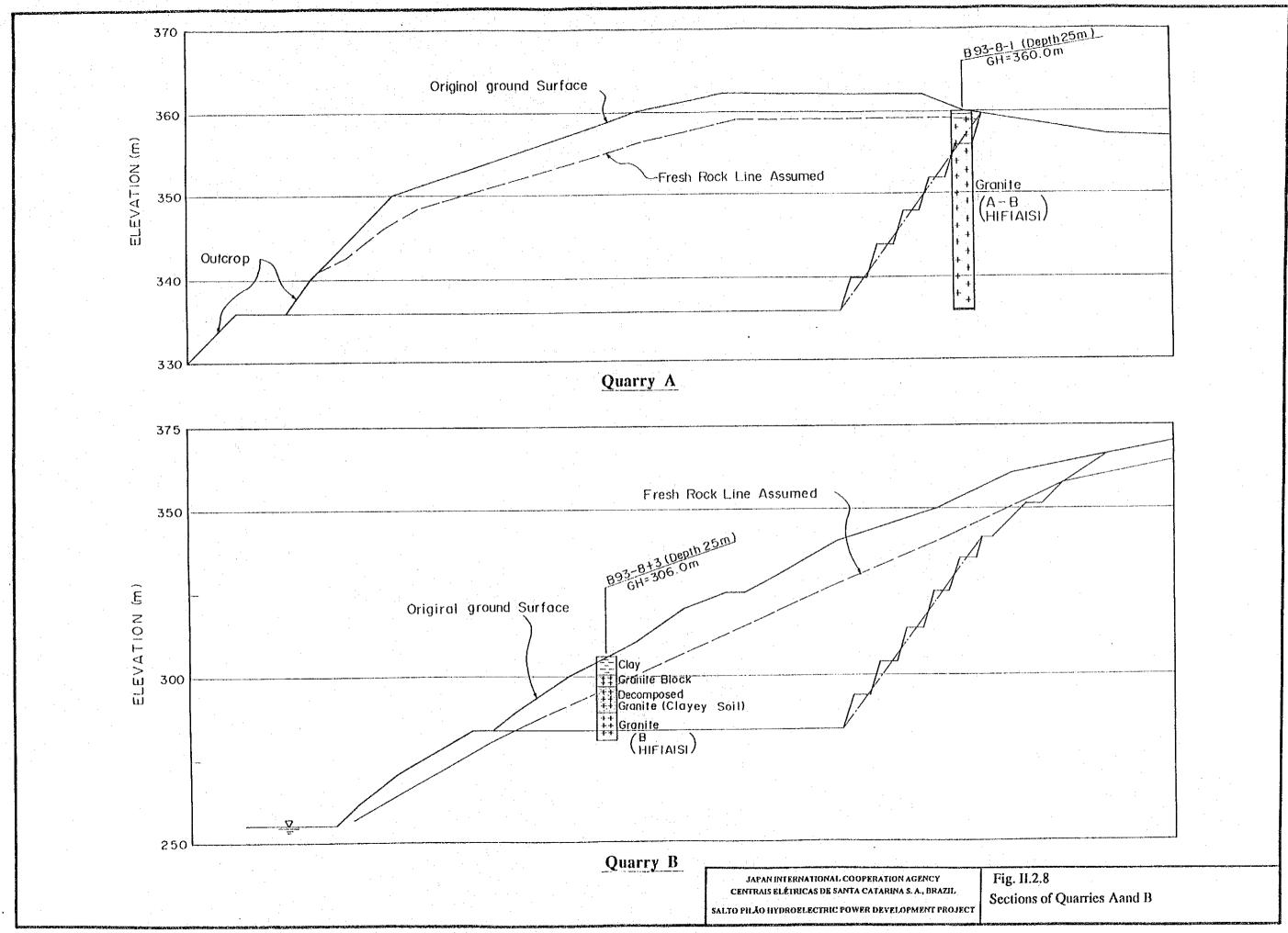


Fig. II.3.1 Drill Logs (Present Investigation) 1/12

DRILL LOG

HOLE NO. 93-1 SHEET NO. 1 OF 1

WROD is Red Quality Designation. B.Q for Class ( ) Brasil Standard,
WLUGEON VALUE is trainer under injection mater pressure of 100g/cm |
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WLUGEON VALUE is trainer under injection mater pressure of 100g/cm |
WLUGEON VALUE is trainer under injection mater pressure under injection under injection under injection under injec

Fig. II.3.1 Drill Logs (Present Investigation) 2/12

PROJECT Salto Pilão Hydroelectric Power Development Project (Brazil)  SITE Damsits, Axis - C, River bed / COORDINATE : : : : NCLEATION -90°  AVERAGE CORE RECOVERY 100% DATE FROM 30, May TO 10 Jun '93 DRILLED J. Arvez  BY ST	ELEVATION 305,97 m DRILL RIG LOGGED S. Ikeda Lugeon Value (Lu) 10 20 30 40 50
SITE Damsite, Asis - C, River bed COORMNATE : BECLEVIUM - 90°  AVERAGE CORE 100% DATE FROM 30 May1010 Jun '93 DRILLED J. Arvez  RECOVERY OR FORMATION SECTION DESCRIPTION LET BECOVERY FOR Alluvial Soil.  Alluvial Soil Clay and Clayey silt.  High plasticity	DRILL RIG LOGGED S. Ikeda Lugeon Value (Lu) 10 20 30 40 50
ACREAGE CORE 100% DATE FROM 30 May17010 Jun'93 DRILLED J. Arvez RECOVERY RECOVERY OR FORMATION SECTION DESCRIPTION	Lugcon Value (Lu)
ROCK TYPE OR FORMATION SECTION  DESCRIPTION  Alluvial soil.  Clay and Clayey slit.  High plasticity  A-B  A-B  A-B  A-B  A-B  A-B  A-B  A-	10 20 30 40 50
Alluvial soll. Clay and Clayey silt. High plasticity  4.0 301.97  4.0 301.97  4.0 301.97  4.0 25.0 Granite. Kdlifelsper rich./ Pink colour. Medium to coarse in grain size. Massive, rarely cracked. Sufficiently hard and tight. Interval of joint spaced at 3 to 5 m  4. Sufficiently loint.  95 Horizontal joint.	
12.5 ~ 12.8  Horizontal joint.  13.5 Vertical joint.  19.5 Joint 45° dip.	

<sup>)</sup> Brasil Standard

LCS FORM-B

Fig. II.3.1 Drill Logs (Present Investigation) 3/12

DRILL LOG

HOLE NO. 93-3 SHEET NO. 1 OF 1

P	ROJEC	ī	Salto Pilão Hyd	roelectric	Power I	)evelopment	Project (Braz	il)		DEPTH	40 m	ELEVATION	321.56m	7
TUE	SITE	2056	Domsite, Axis	s ~ C,Rigi	t Bank	COORDINATE	:			DICLETATION	-90m	DRILL RIG		
R	RĂGE ECOVE	RY	10	00%		DATE	FROM JO. Jul	7 337 33.		DRILLED	J. Arvez	LOGGED	3. Ikeda	
OMTE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	COLUMN SECTION		DESCRIPT	ION	BIT & DIAMETER	Rock Class	CORE RECOVERY RQD % cm	0	•	alue (Lu) 30 40 50	ОБЕРТИ
արջարգ					Clay	Soil.								National Assessment
d 			Cloyey			te origin, pletely deco oil,							# H 133 F 23 M 23 S 1 1 1 3 3 5 5 5	السيسال
Reduca Tring		· •	Soil Heavily	+\f\ \f\ \f\ -		ly weather			D /H5A5/					<u> </u>
Scale Firms	15 <sup>0</sup>	316.5	W'ed Granite	**************************************	remain	te Rock te s. Very soi			F5S5 (H4A4) (F4S5)	, ,				
81			Granite	400040					HBA3 F3SV S4	,				الكاسية كالسابة
11			or damo	, , , , , , , , , , , , , , , , , , ,	Medi Massi	um grain	size.							M
3		:	LABO ROCK	+ +	Joint Hard	interval 3 and tight.	10 5m.							] 
25			O TEST SAMPLE WNo Dam7	+ +	_	0.0 Ily Weathe / loose,	red.						2 1	, ¥5, market
7			Granite	+ +	Belov	r 20. <sup>0</sup> hard and	fow.		<b>A</b>		Į, į	10		7 8
3C			SAMPLE	+	Craci ,	18,			HIAI FISV SI				\$	9
1			No Dom 8	* +				-				was:	a a	HOLE HOLE
3			No Dam 9	+ +									4	NO.
1.6		٠.		* */_ +		jont 80°	đip						3 6	183
7 8				<b>√</b> -		ay film. - water lea 40. <sup>0</sup>	ik,					<b>9</b> 3		77
9 	40.0	281,56	5	+ _ +		ntal joint	spaced						9	,

Fig. II.3.1 Drill Logs (Present Investigation) 4/12

	PROJE											NO. 1 OF		
ì	(1) F.M. (2)						Project (Braz	il)		DEPTH	20 m	ELEVATION	331,31 m	
TA.	SITE PERAGE RECOVI	CORE	Damsite, Left		VT)	COORDINATE DATE	FROM 23. Jun	; TO 10	FP¹ lul.	DRILLE		LOGGED	S. Ikeda	
DATE	рерти	ELEVATION	ROCK TYPE OR	COLUMN SECTION		DESCRIPT		BIT &		CORE RECOVERY	0. 21 42		/alue (Lu)	ОЕРТН
	0 14 5 6 7 8 9 20°	327.81	Clay & Boulder  Diabase Canite		O°~3.5 Clay. Grant Complete so 3.5 ~ 7. Clay Weath  7.3 ~ 20 Grant: Kalife pink co Medic grain s Mass Joint 3 to 5 Hard 7.3 ~ 10 Slight 9.3 Dial 40 cm perfect	te origin. letely deco il.  and Boulde mered Gran  blour. interval at m. and tight of y Weather base intert thick, cont ly tight with	results in see in cout enough.	CH CH B		RCOVERY RQD Some				10 10 10 10 10 10 10 10 10 10 10 10 10 1
المستارين اوروز ويتالينا ويوزيونا ويودا														للسرا بساسيا ساسيا سياسية سيار

ORQD is Rock Quality Designation. RQD= (Total length of cylindric cores longer than 10 cm1/(Total core length) = 100%.

#LUCEON VALUE in Fraining under injection mater pressure of long/cm?

#II - F12

#HAMETER is in millimeter

Fig. II.3.1 Drill Logs (Present Investigation) 5/12

DRILL LOG HOLE NO. 93-5 SHEET NO. 1 OF 2 (0 to 30m) Salto Pilao Hydroelectric Power Development Project (Brazil) 45m ELEVATION 320.0 m DEPTH PROJECT Surge Tank, (alternative) -90m COORDINATE SECLETATION DRILL NIG SITE AVERAGE CORE RECOVERY 100% DATE FROM10.Jul TO 27. Jul '93/ DRILLED J. Arvez LOGGED S. Ikeda BIT & DIAMETER ROCK TYPE CORE DEPTH COLUMN Rock Class Lugeon Value (Lu) RECOVERY DESCRIPTION ΩR SECTION ROD FORMATION 0. ~ 20.0 Clayey Soil. Rhyclite origin. Completely decomposed into soit. Rock texture can be seen Weathered rocks like dice are found in some places. Clayey Soil 16.5 303.5 16<sup>5</sup> ~20<sup>0</sup> Weathered Rhyolite 8 Weathered Heavily weathered cracked Rhyolite into dice. H5A4 F4HV S5 20.0 300.0 20,0 30.0 CM l,v Rhyolite F354 GWL Gray colour appears CH Rhyotite Rhyodacite. H2A2 F2\$3/ Fine and compact. SAMPLE. No Hard rock. Ð Tun1-7 ν Joints develop at interval of 10 to 50 cm. Tun1-8 HIAI FISV Tun1 - 9 200~ 240 \sı Vertical joint at interval of 50 cm.

Conitue to SHT No 2

٧

LOG FORM-B

<sup>#</sup> DEPTH and ELEVATION are to meter

<sup>#</sup>DIAMETER is in millimeter

DRILL LOG

HOLE NO. 93-5 SHEET NO. 2 OF 2 (30-45m)

ſ	p	ROJEC	Ť		ito Pilão Hyd		Power I	Dev :lopmen	t Project (Braz	il)		DEPT	н 4.	5 m	ELEVATION	320.0 m	
		SITE			rge Tank. (			COORDINATE		:		DICLUTAT		90°	DRILL RIG		
Į	AVE	AGE ECOVE	CORE RY		10	0%		DATE	FROM 10.Jul	******	Jul '93	DRILL	ED	J. Arvez	LOGGED	S. Ikeda	-
	DATE	DEPTH	ELEVATION	Ì	ROCK TYPE OR FORMATION	COLUMN SECTION		DESCRIP	TION	BIT & DIAMETER	Rock	CORE RECOVE ROD %			10 20	/alue (Lu) 30 40 :	о Бертн
	X անումայի 3 այն հայտնականի ավարիականի անաստանական արդանում անում անում անում անում անականական անականական անում			S S S S S S S S S S S S S S S S S S S	FORMATION PLE No	ツママママママママママママママママママママママママママママママママママママ	30° ~ Rhyo Hard some 30° ~ Diag spaces cracke 34.3 J cracke 37.0 J into di 37.3 ~ Vert interve Crac Belo	inue from 45.0  Alte.  I rock, joi places. 32.0  and and h d with 20 c dd.  oint 70° d ce.  40.5  ical joint, al.	SHT No 1  nt develop in  orizontal joint  m, and  dip and  ip cracked  10 to 20 cm  box size.		CM (H2A3) CH-B (H2A1) S2 CM (H2A2) CH-B (H2A1) CH-B (H2A1) F2SV S2 CL CM CH CM CH CM CH CM	ROP %					
																	m

RRQD in Rock Quality Designation. RQD=(Total length of sylindric cores longer than 16 cm)/(Total core length) x 100%
#LUGEON VALUE is Undaten nader injection water presents of folig/cm!
#DEPTH and ELEVATION are in meter
#DIAMETER in milliocter

Fig. II.3.1 Drill Logs (Present Investigation) 7/12

DRILL LOG HOLE NO. 93-6 SHEET NO. 1 OF 2 (0-30m) Salto Pilho Hydroelectric Power Development Project (Brazil) 40 m ELEVATION 193.78 m DEPTH PROJECT DRILL RIG COORDINATE MCLOUTER -90\* SITE Penstock FROM 11 Jun AVERAGE CORE LOGGED DATE TO 30. Jun '93 DRILLED J. Arvez S. Ikeda 100% BIT & DIAMETER ROCK TYPE COLUMN Rock Class Lugeon Value (L1) RECOYER DESCRIPTION OR SECTION ROD FORMATION o.° ~ 3.° Top Soil. Clayey Clayey soll. Soil 3 3.2 ~ 20.2 Weathered Rhyolite Minerals and matrix are ٧ discoloured into brown. 6 ٧, Open joints and cracks develop at interval CM CM of 5 to 10 cm. H3 A3 Space of crack are filled wifh clay. F3 Weathered In hordness moderate however cracked in many Rhyolite places.  $11^{5} - 12^{0}$ ,  $13^{2} - 13^{5}$ Clay filled in open crack. 14.8 N 15.5 CM Vertical joint and fractured. 16.0 ~ 16.5 Clay filled in open crack. ٥ 173 ~ 18 E CL Fractured with clay, D 181 - 202 20.2 173.58 Fractured into dice. A2 CH H2A2 20.5~ Fresh Rhyolite Interbedded with dark grey CH-B И rhyolite (diabass). H2A1 H2HV Rhyolite S2 / Sufficiently hard. CL ΑŠ Joint Interval 30 to 50 cm. СН bedded HV Diabase Open cracks a few. CL 25,3 - 260, 265 - 270 CH-B SAMPL E H2A1 No Locally fractured. Tunl FEHV Continued to Sheet 2

<sup>#</sup>R.Q.D is Rock Quality Besignation, R.Q.D.™ (Total length of cylindric cares longer them 18 ami/i Total core longth) × 177%

<sup>@</sup>LUGEON VALUE is I/min/m under infration mater presents of 10kg/cul

MCEPTH and ELEVATION are in meter WDI AMETER Is in millimeter