FEASIBILITY STUDY REPORT

ON

THE LAKE TENGGANO

BAUXITE RESOURCES DEVELOPMENT PROJECT

IN

THE SOLOMON ISLANDS

AUGUST, 1982

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of Solomon Islands, the Government of Japan decided to conduct a survey on THE FEASIBILITY STUDY FOR THE LAKE TENGGANO BAUXITE RESOURCES DEVELOPMENT Project and entrusted the survey to the Japan International Cooperation Agency (JICA). The JICA sent to Solomon Islands a survey team headed by Mr. Noboru Tsukahara from 18th October to 17th December 1981.

The team exchanged views with the officials concerned of the Government of Solomon Islands and conducted a field survey in the Lake TeNggano area, Rennell Island, Solomon Islands. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

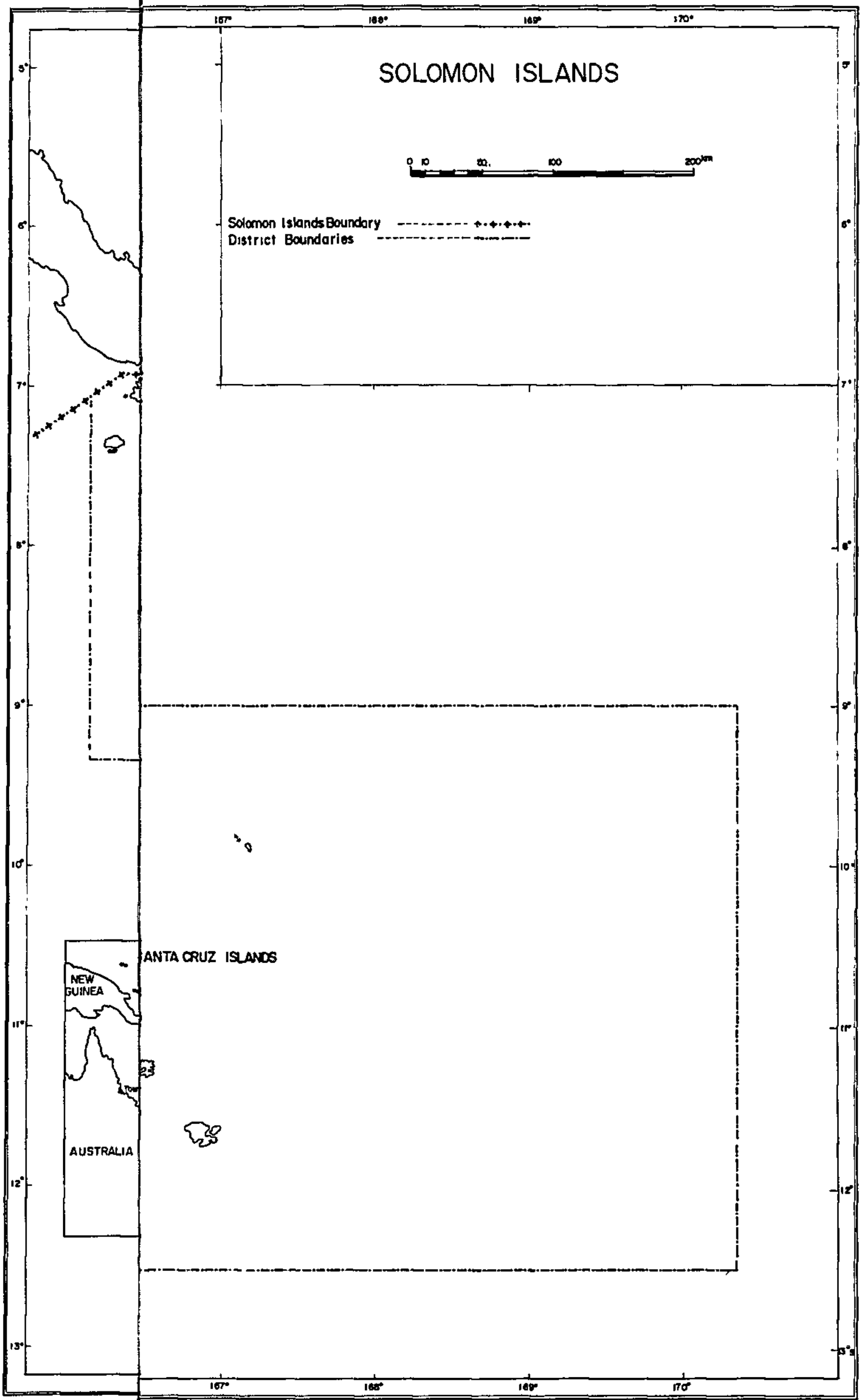
I wish to express my deep appreciation to the officials concerned of the Government of Solomon Islands for their close cooperation extended to the team.

Tokyo, AUGUST, 1982

Keisuke Arita

Keisuke Arita
President
Japan International Cooperation Agency

CONTENTS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Solomon Islands Boundary
District Boundaries
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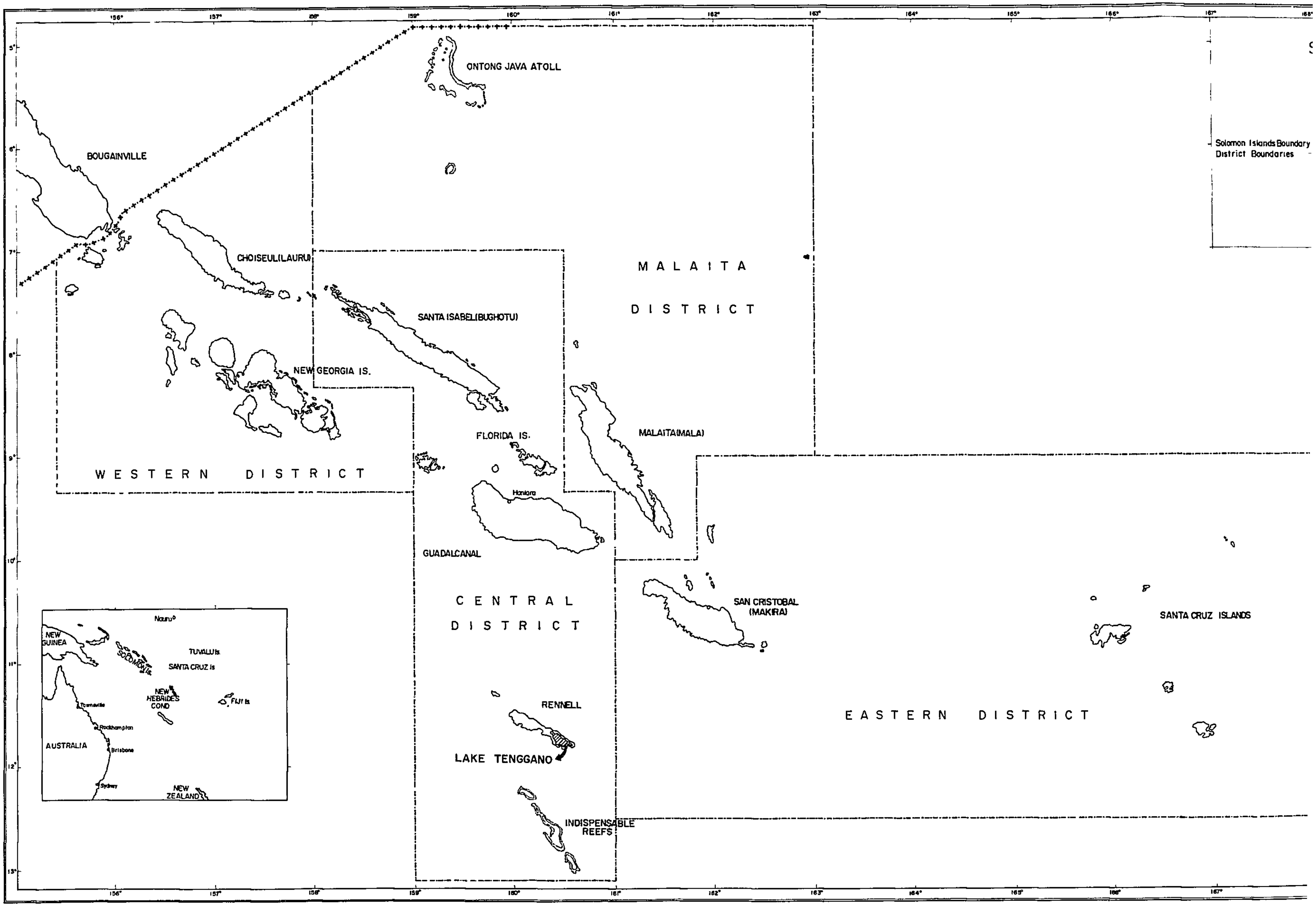

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SANTA ISABEL(BUGHOTU)
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FLORIDA IS.
Honiara
WESTERN DISTRICT
GUADALCANAL
CENTRAL
DISTRICT
SAN CRISTOBAL
(MAKIRA)
SANTA CRUZ ISLANDS
RENNELL
LAKE TENGGANO
EASTERN DISTRICT
INDISPENSABLE
REEFS
Solomon Islands Boundary
District Boundaries
NEW
GUINEA
Nauru
TUVALU Is
SOLOMON Is
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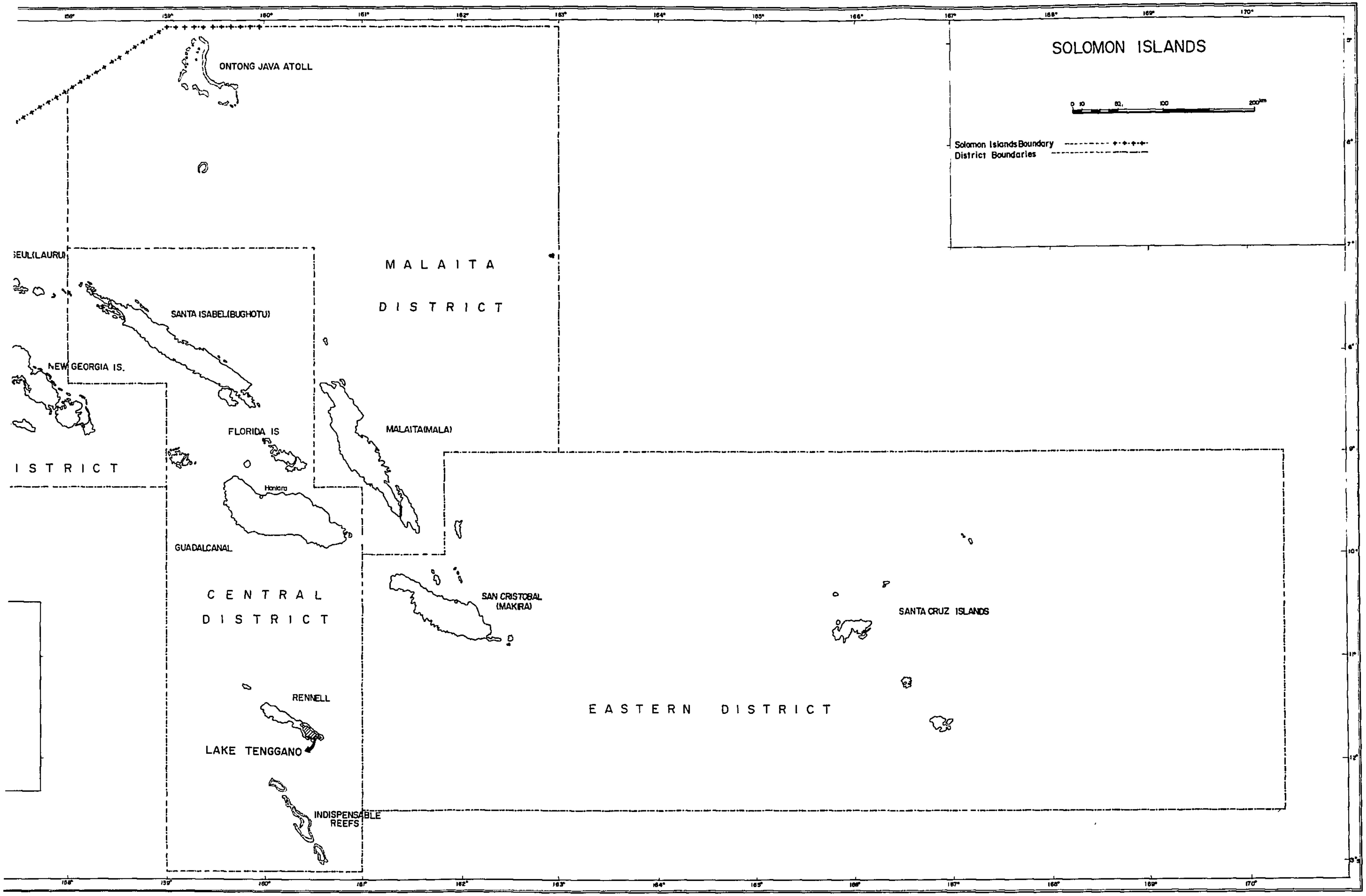

SOLOMON ISLANDS
Solomon Islands Boundary
District Boundaries
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MALAITA
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NEW GEORGIA IS.
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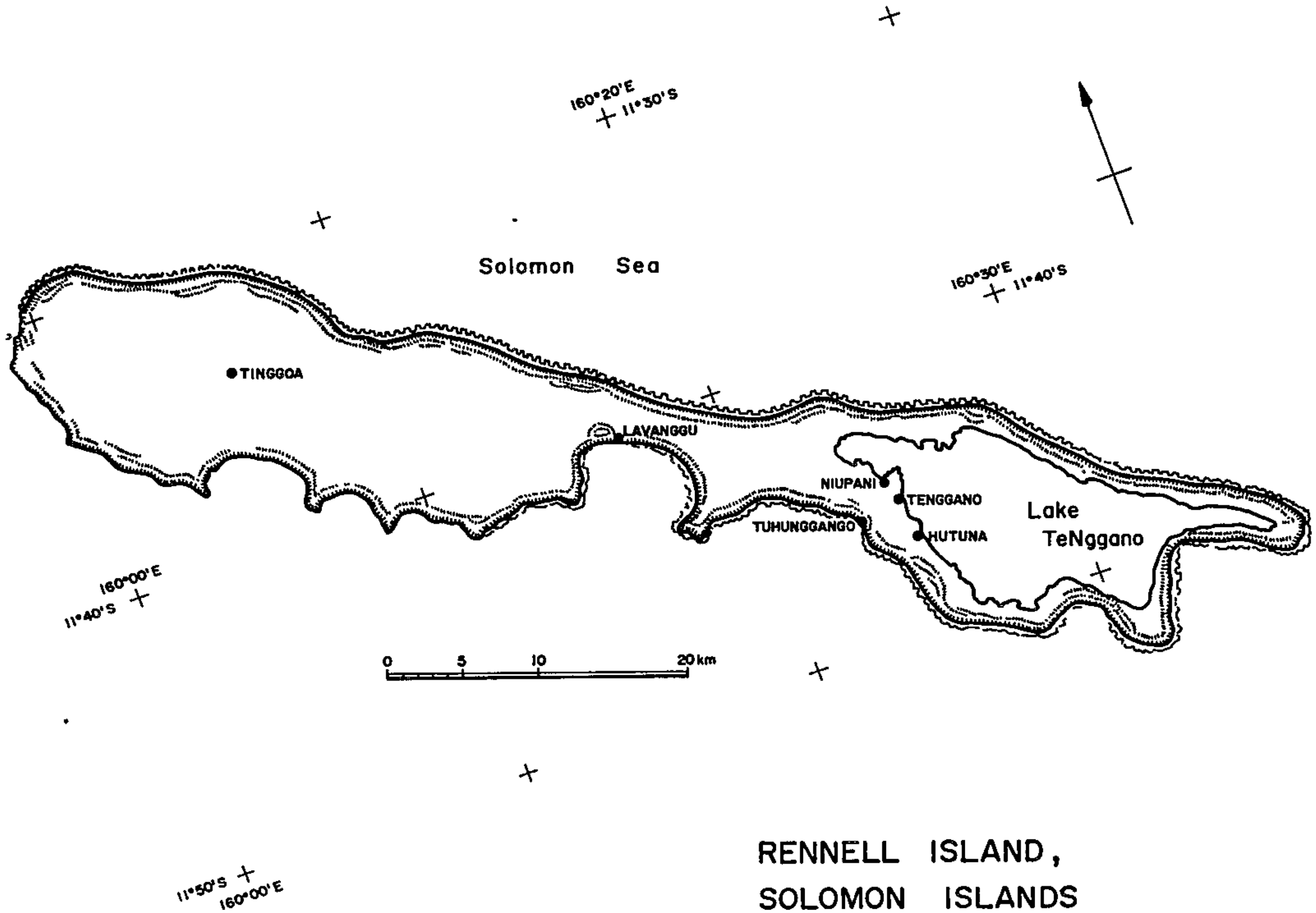

160°20'E
11°30'S
Solomon Sea
160°30'E
11°40'S
TINGGOA
LAVANGGU
NIUPANI
TENGGANO
HUTUNA
TUHUNGGANGO
Lake
TeNggano
160°00'E
11°40'S
0
5
10
20 km
11°50'S
160°00'E
RENNELL ISLAND,
SOLOMON ISLANDS

ONE SUMMARY

1-1 The Solomon Islands is situated in the south-western part of the Pacific Ocean and the Rennell Island is located in the southern part of the Solomon Islands. The Lake TeNggano occupies the eastern quarter of the Rennell Island. Occurrences of the bauxitic clay sediments on the Lake TeNggano floor have been so far known. Based on the previous data of geological research, the Solomon Islands Government has requested to the Japanese Government, in February 1979, to carry out outlined geological and geophysical survey works of the Lake TeNggano floor sediments and to make a brief appraisal of the bauxitic clay sediments from the stand point of mineral resources. In response to the request of the Solomon Islands Government, the Japan International Cooperation Agency has dispatched the Japanese Survey Team, organized by six members, to the Solomon Islands, led by N. Tsukahara, to be involved in the field survey works in Rennell Island from 18th October 1981 to 17th December 1981.

1-2 Field survey works are comprised of as follows:

a) Sub-bottom Profiling of the lake floor, Lake TeNggano, by using a Sub-bottom Profiler and an Echo-sounder.
   35 traverse lines, totalling 169 kilometres, were tripped loaded on a survey-catamaran.

b) Collecting 65 lake sediment samples from 48 locations on the Lake TeNggano by using a Piston Corer equipped with a 2 metre-long inner tube of acrylic resin and man-hands by using a 1 metre-long acrylic resin tube, sticking into the sediment in the lake water.

1-3 The Japanese Survey Team has been engaged in the laboratory and mapping works in Japan after completion of the field survey works in the Solomon Islands. The major works are comprised of as follows:

a) Mapping tracks of the survey-catamaran.
b) Mapping isopachs of the lake sediments.
c) Mapping lake floor topography.
d) Mapping isobaths of the lake sediment surface.
e) Mapping isobaths of bed-rock limestone surface.
f) Chemical analyses of 37 samples, clay and other sediments.
g) X-ray powder diffractions of 37 samples, clay and other sediments.

1-4 Major results of the field and laboratory works are summarized as follows:

a) The lake sediments of the Lake TeNggano are geologically divided into five sediments – four horizons as Sediments A and/or B, Sediment C, Sediment D and Sediment E in ascending order based on the water depth, on which they occur. General water depths of the sediment occurrences are as follows:

Sediments A and/or B	:	28 metres to 34 metres below lake water level
Sediment C	:	18 metres to 22 metres below lake water level
Sediment D	:	8 metres to 15 metres below lake water level
Sediment E	:	2 metres to 11 metres below lake water level

b) The lake sediments of the Lake TeNggano are mainly composed of grayish green to grayish brown jelly, reddish brown jelly and mud or jellied mud associated with plant fragments. Bauxitic gray clay sediments are observed on the horizons of Sediments C, D and E. None of clay beds were encountered in Sediments A and/or B during the course of the current survey works.

c) Sediments A and/or B are widely distributed on the lake floor in the central part of the lake. Sediments C, D and E are distributed limitedly in shallow water areas close to the lake shore.

d) It is considered that the major occurrences of the bauxitic gray clay are distributed in the Sediment E. The bauxitic clay is overlain by jelly sediment or by nothing and is observed directly under the lake water. The bauxitic clay is also underlain by bed-rock limestone or by jelly sediment in some places. It is very sticky and gray.

e) The minor occurrences of the bauxitic gray clay are observed in the Sediments C and D. They probably show very limited extents of occurrence in the area.

f) The aluminium mineral of the bauxitic clay, observed in the Sediments C, D and E in the Lake TeNggano area, is gibbsite. Boehmite is associated with gibbsite in the TINGOA clay occurrence in the eastern end of the Lake TeNggano. The thickness of the bauxitic clay occurrence is ranging from 0.2 to 0.4 metre in general. The NIUPANI occurrence, the thickest among them is more than 1.2 metres thick. Raw clay generally contains from 33% to 41% moisture. After removing moisture by drying in air bath at 80°C for 40 hours, it generally contains from 43% to 46% Al_2O_3, 49.86% the highest, 20.12% the lowest. SiO_2 content is generally low, less than 0.30% and TiO_2 content is also generally low, less than 1.85%. It generally contains from 0.4% to 1.4% P_2O_5, more than 3.5% in some occurrences. Anatase and crandallite are discernible as titanium and phosphorus minerals.
Pyrite is widely observed in bauxitic clay, marcasite and siderite are also discernible in some occurrences. Fe_2O_3 content, converted from the total iron content value, generally shows from 12% to 18%.

g) The major facies of the Sediments A and/or B, C and D are grayish green jelly and mud or jellied mud associated with plant fragments, which generally contain more than 90% moisture. After removing moisture by drying in air bath at 80°C for 40 hours, they contain from 5% to 8% Al_2O_3 in general. Al_2O_3 content is originated from gibbsite identified by X-ray power diffraction. It is considered that gibbsite shows very dispersive wide distribution throughout in jellied lake sediments.

h) Sticky, bauxitic gray clay in the Sediment E generally shows patchy occurrences, filling up sink-holes of the bed-rock limestone. The average diameter of the sink-hole is ranging from 0.2 metre to 0.4 metre. It is estimated that the general extent of the clay-filled sink-holes is to be less than 30 metres by 30 metres on plan in an occurrence in general.
The NIUPANI clay occurrence, intersected by piston coring holes 29/1 and 29/3, 150 metres apart approximately, is inferred to be showing some extent of occurrence, however, lateral continuation of the clay is still obscure due to a thick cover of reddish brown jelly, about 1 metre thick. No clay was intersected by Hole 29/2, 350 metres apart from Holes 29/1 and 29/3.

i) The bauxitic gray clay, observed in the Lake TeNggano area, shows patchy occurrences in the limited areas and is very sticky. The clay is overlain by jelly sediment or by nothing and is observed directly under the lake water. The clay is also underlain by bed-rock limestone or by jelly sediment in some places.
It is considered that limited areal extent and quality of the bauxitic gray clay in the Lake TeNggano area make unlikely the possibilities for large – to moderate – scale mining operation of bauxite, and likely for the beneficiation as raw material of local ceramic use or modelling clay of education material in school.

TWO BACKGROUND AND OBJECTIVES OF THE SURVEY WORKS

The Solomon Islands is located in the north-western part of the Melanesian arcs of Circum-Pacific Orogenic Belt. It is also situated in the young orogenic zone, emerged by an upheaval of the welt type after the Tertiary age and forms an islands country, which lies on the Circum-Pacific Metallogenetic Belt. Strenuous exploration works by using modern exploration technology have been carried out up to date mainly for porphyry copper, phosphate, lateritic nickel and bauxite deposits in the Solomon Islands, however, none of the known mineral deposits are currently of economic size.

Honiara, the capital of the Solomon Islands, is in Guadalcanal Island and the Rennell Island is located 180 kilometres southwards from Guadalcanal Island. A regional aerial geophysical survey by the United Nations Development Programme has been carried out over the Rennell Is. in 1965. The UNDP survey was remarkably responsible for the new discovery of the bauxite deposit in western Rennell Is. by a detection of a radiometric anomaly. The geological type of the bauxite deposit in western Rennell is similar to that of the "terra rossa" type, which overlies the limestone bed of the Rennell atoll. Aggressive exploration works and feasibility studies have been carried out by the Metal Mining Agency of Japan and the Mitsui Mining & Smelting Co. Ltd., Japan, during 1969 to 1974.

Occurrences of the bauxitic clay sediments on the Lake TeNggano floor have been so far known and the cruise survey by the Committee for Coordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas, Economic and Social Commission for Asia and the Pacific, United Nations, was carried out in 1977.

Based on these achievements, the Solomon Islands Government has requested to the Japanese Government, in Feb. 1979, to carry out an outlined geological and geophysical survey for the Lake TeNggano floor sediments on the basis of governmental technical cooperation. The Japan International Cooperation Agency has dispatched the representative survey team to the Solomon Islands in November 1979 to set up the general exploration programmes after completion of field survey in Rennell Island and to make general discussions with Solomon Islands Government.

The Japan International Cooperation Agency then organized the survey team of six members, led by N. Tsukahara, in 1981 and dispatched the team to the Rennell Island to carry out field survey works of the Lake TeNggano floor sediments.

The major objectives of the survey works are to carry out outlined investigations of the occurrence of the lake floor sediments of the Lake TeNggano and to make a brief appraisal of the bauxitic clay sediments from the stand point of mineral resources.

THREE MEMBERS OF THE SURVEY TEAMS AND FIELD WORK PROGRESS

The members of the Japanese Survey Team of the Bauxite Resources Feasibility Study in the Rennell Island are as follows. The Counterpart Team as follows, by the Geology Division, Ministry of Land, Energy and Natural Resources has jointed with the Japanese Team to be involved in the field work in the Rennell Island to give full supports and cooperations to the Japanese Team.

Japanese Team	N. TSUKAHARA,	Team Leader, geologist
	A. SUGIYAMA,	Deputy Leader, geologist
	Y. AKAZAWA,	Surveyor
	F. AKIMOTO,	Surveyor
	S. SASAKI,	Oceanographer
	M. KONDO,	Assist. Geophysicist
Geology Division	F. I. COULSON,	Chief Geologist
Team, S.I.	S. DANITOFEA,	Geologist
	P. DIAU,	
	A. BANA,	
	R. ANISI,	
	W. GARAEMA,	
	P. ISRAEL,	
	R. TAFUSELO,	
	W. ZAMA,	
	A. ALE,	
	J. POLOSO,	

The Japanese Survey Team left Japan on 18th Oct. 1981 and arrived in Honiara on 20th Oct. 1981. The Team stayed in the Rennell Island 36 days during 2nd Nov. 1981 to 7th Dec. 1981 to be involved in the field survey works. The Japanese Team left Honiara on 15th Dec. 1981 and returned to Japan on 17th Dec. 1981. The details of the itinerary of the field survey works in Rennell Island are shown in ANNEX 4.

FOUR AN OUTLINE OF FIELD SURVEY WORKS

The field survey works for the lake sediments in the Lake TeNggano, Rennell Island, were carried out from 20th October 1981, after an arrival of the Japanese Team, to 15th December 1981 as shown in ANNEX 4. The Team stayed in the Rennell Island 36 days from 2nd November to 7th December for the survey works.

The major objectives of the field survey works are to elucidate general geological occurrences of the lake sediments and bauxitic clay distributed on the lake floor of the Lake TeNggano, by acoustic sub-bottom profiling and sediment sampling work.

4-1 Area of the Field Work

The whole area of the Lake TeNggano, Rennell Island, was covered by the current survey works. The Lake TeNggano is situated in the eastern quarter of the Rennell coral atoll, 28 kilometres long northwest – southeast directionally and 10 kilometres wide northeast – southwest directionally. It shows a harmonic shape to the out-line of the eastern Rennell Island and many small islands are scatteringly distributed in it, particularly in the northwestern bay of the lake. It also has a much indented lake shore line. The Lake water of the Lake TeNggano shows semi-saline.

The field camp of the Teams was based in TeNggano Village, northwestern shore of the lake.

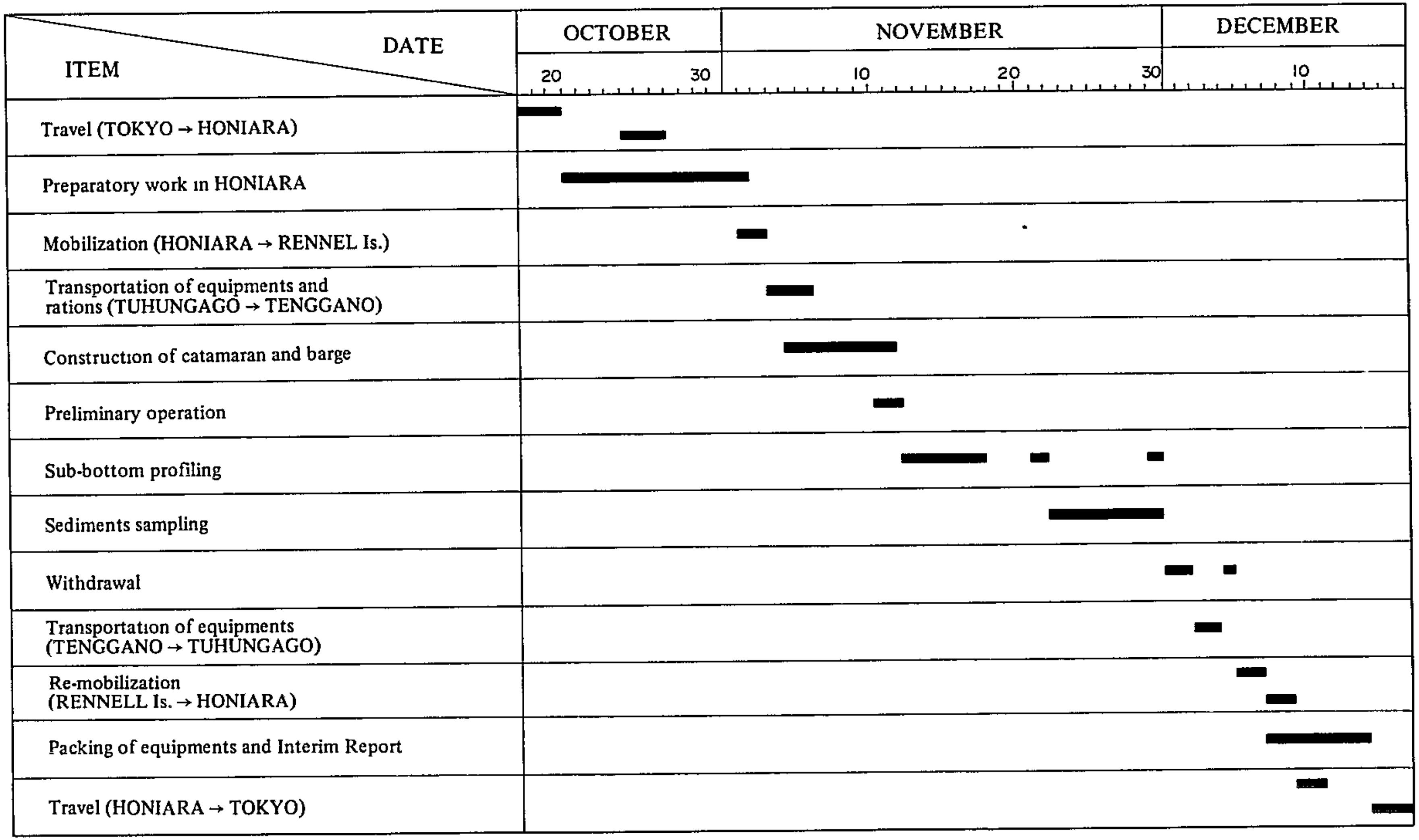
4-2 General Progress

General progress of the field works is shown in Table 1.

The major equipments for the survey work were sent from Tokyo by air and sea cargos to Honiara. After completion of the preparatory works in Honiara, all the equipments, fuel, and rations were shipped to Tuhunggango shore, eastern Rennell, by the cargo boat, the Bulawa, provided by the Geology Division. The whole of the equipments, fuel and rations were carried piecemeal through a rough path by man-power of local labours to the base camp, some 4 kilometres apart from the shore, which was one of the strenuous efforts during the course of the field work.

Prior the commencement of the field works, constructions of the survey-catamaran and the barge, an observation of the fluctuation of the lake water level and adjustments of the survey equipments were successfully implemented. The survey-catamaran was constructed by jointing two glass-fibre canoes, provided by the Geology Division, 6.55 metres long and 1.2 metres wide each and 0.6 metre apart. They were jointed in TeNggano Village by timbers and bolts, decked by plywoods in central part of the catamaran, where the sub-bottom profiler, echo-sounder and other equipments were loaded as shown in Figure 1. A 35 Horse Power outboard engine was equipped. The barge was initially constructed in Tulagi, by the National Fisheries Developments Ltd. under the supervision of M. KITANO, who has been dispatched to the National Fisheries Developments Ltd. by the Japan International Cooperation Agency as a

Table 1 Survey Work Progress



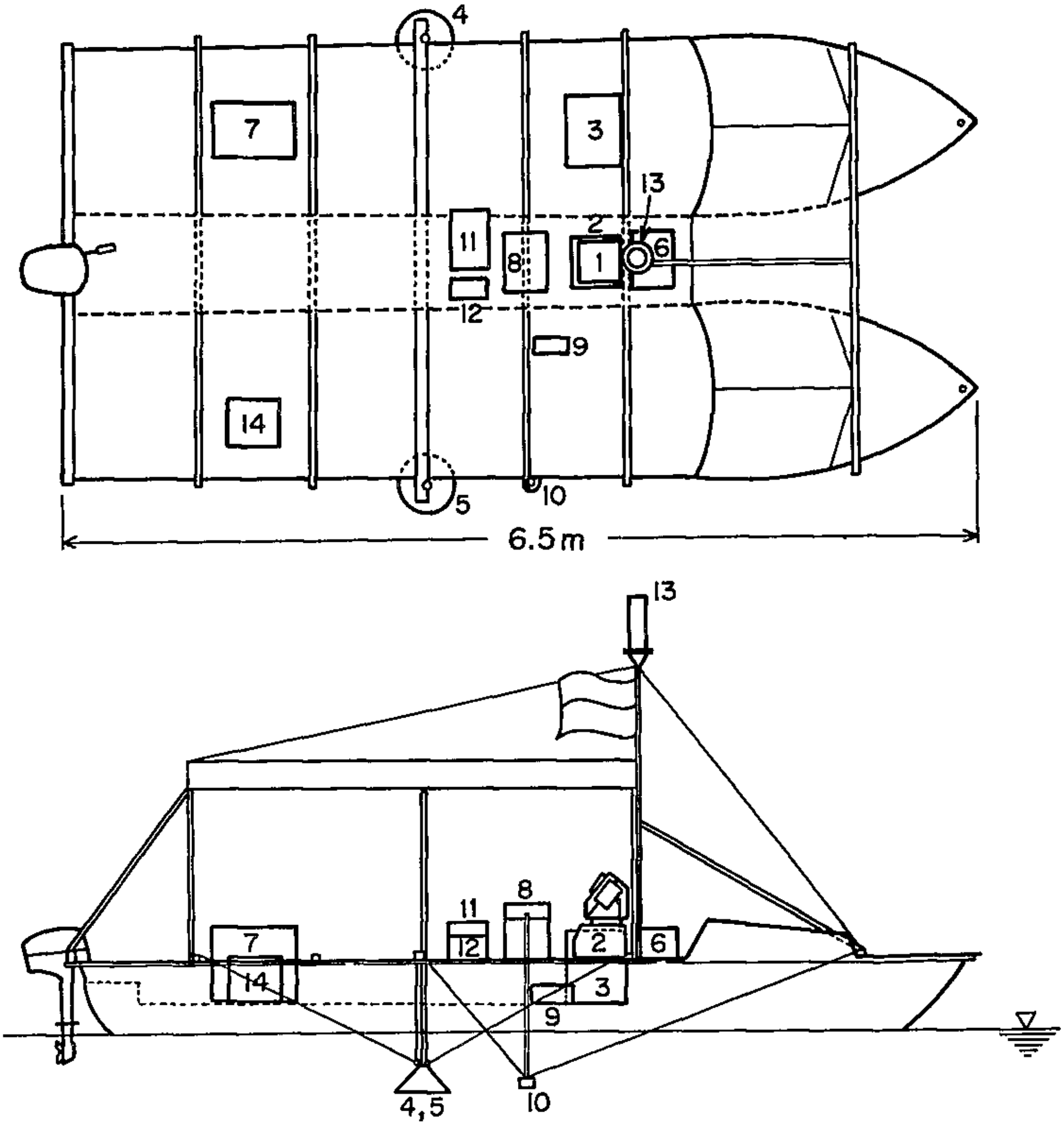


Figure 1 Catamaran

Sub-bottom Profiler

1. Recorder
2. Receiver
3. Transmitter
4. Transmitting Transducer
5. Receiving Transducer
6. Power Supply Unit
7. Generator

Echo Sounder

8. Recorder
9. Battery
10. Transducer

Automatic Distance Meter

11. Main Unit
12. Printer
13. Antenna Unit
14. Generator

Japanese Expert. It was transported to the base camp disjointedly and reassembled in TeNggano Village as shown in Figure 2, prior to the commencement of the field works. It was 6 metres by 5.5 metres in size, framed by timbers 0.8 metre high and was buoyed by 36 petrol drums. It was wholly decked by timbers, except the central portion, through where the core barrels were operated. A-frame of aluminum pipes was equipped to hang on the piston coring barrels. A winch and an engine were also equipped on the barge.

The barge was taken in towing by the survey-catamaran, using a 20 metre-long rope. The two accessory glass-fibre canoes, provided by the Geology Division, were normally used for the mobilization of survey crew on the lake, and sometimes for a complementary service of towing the barge under wild weather.

Field survey works on the lake were carried out from 13th November to 30th November as shown in ANNEX 4. The work during the first half was seriously troubled by strong wind, by which sub-bottom profiling work had to be curtailed to some 68 per cent of initial programme. Sampling work was performed successfully in the later half as scheduled.

After completion of the field survey works, all the member of the Teams and equipments were withdrawn from TeNggano Village to the Tuhunggango shore by the same way to the coming in and were loaded on the cargo boat, the Thomas E, provided by the Geology Division, to be sent to Honiara. A wireless telecommunication system between the base camp and Honiara was scrupulously provided by the Geology Division, by which daily communication was easily enabled.

On 11th December, after returning to Honiara, the Japanese Team made an interim report on the major results of the field survey works in the Lake TeNggano area to the Solomon Islands Government in Honiara.

4-3 Major Equipments

One set of automatic radio distancemetre, one echo-sounder, one sub-bottom profiler, one set of piston corer with core barrels and tools, two theolites, four transceivers, generators, miscellaneous tools and etc. were used for the field survey works. General specifications of the major equipments are tabulated in Table 2.

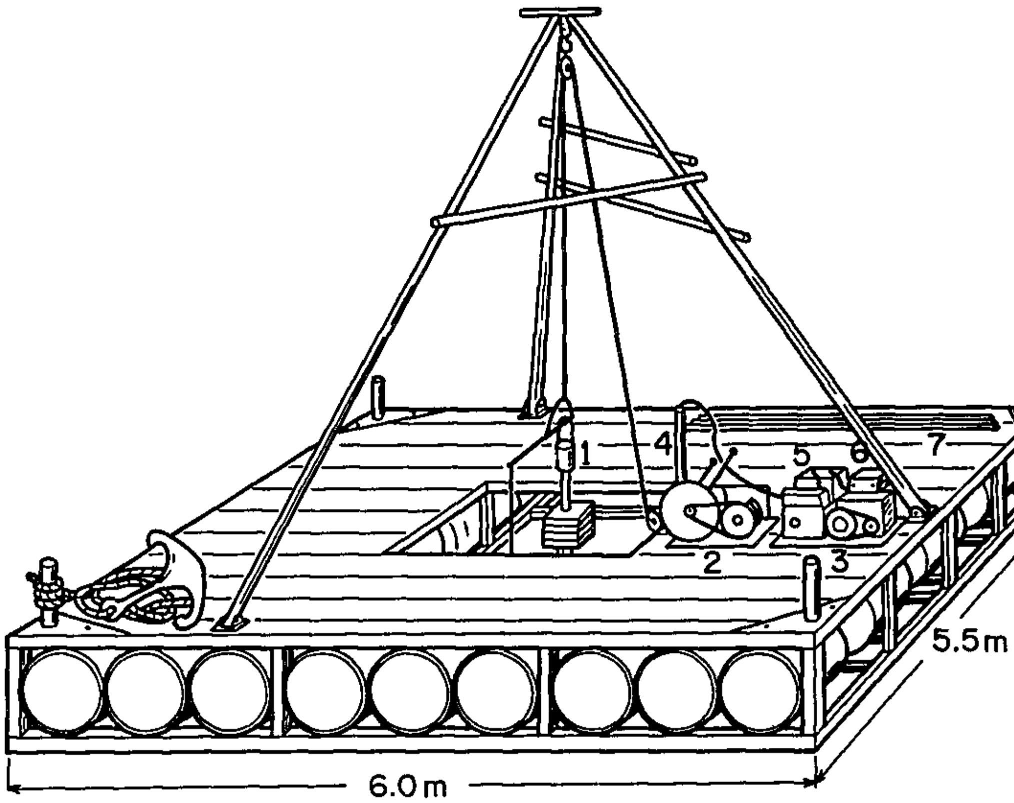


Figure 2 Barge

1. Piston Corer
2. Winch
3. Engine of Winch
4. Transducer of Echo Sounder
5. Battery
6. Recorder of Echo Sounder
7. Inner Tubes

Table 2 Specifications of Major Equipments

Specifications		
Automatic Distance Meter	Maker	Shimada Rika Kogyo Co., Ltd.
	Type	AUDISTER 9D010
	Max. measurable distance	20km
	Measurement distribution error	±1m
	Measurement tolerance	0.1m
	Carrier frequency	8.5 ~ 9.3 GHz
	Antenna output power	0.3W
	Antenna directivity M.S.	Horizontal. 360°, Vertical: 15°
	Antenna directivity S.S.	Horizontal: 30°, Vertical: 15°
	Measurement rate	Once/sec.
Echo Sounder	Maker	Rasa Denshi Co., Ltd.
	Type	RS-61
	Range	0 ~ 61m
	Accuracy	±3cm ±water depth x 1/1000
	Chart	Dry paper, Width: 130mm
	Chart speed	60 mm/min.
	Frequency	200 kHz
	Beam width	About 3°
Sub-bottom profiler	Maker	Kaijyo Denki Co., Ltd.
	Type	SP
	Range	0 ~ 50m
	Chart	Dry paper, Width: 150mm
	Chart speed	40mm/min.
	Frequency	8 kHz
	Beam width	About 30°
	Oscillation	180/min.
Piston Corer	Type	KOKUSAI
	Length of core barrel	2m
	Diameter of inner-tube	Outside: 65mm, Inside: 59mm
	Weight	Max. 100 kg
	Lifting	Electric winch
Distance Meter	Maker	HEWLETT PACKARD
	Type	HP Model 3800B
	Max measurable distance	3 km
	Accuracy	±(5mm + 7mm per km)
Theodolite	Maker	Tamaya Co., Ltd.
	Type	TM-10C
	Accuracy	10"
Theodolite	Maker	Nihon Kogaku Co., Ltd.
	Type	NT-2
	Accuracy	20"
Walkie Talkie	Maker	SONY
	Type	SONY ICB-680
	Channel	8

FIVE GENERAL METHODS OF FIELD SURVEY WORKS

General methods applied to the field survey works are described as follows and are composed of the preparatory works and field works on the lake.

5-1 Preparatory Works

a) Preparation of Topographical Map of Eastern Rennell Island

A topographical map of the Eastern Rennell Island covering the Lake TeNggano, one to 25,000 scale approximately, was produced by using the air photographs provided by the Geology Division, Solomon Islands, prior to the commencement of the field survey works.

It was very helpful for the works to maintain improved efficient progresses and also to fix up the positions of the control points on land, which were used for the positioning of the survey-catamaran, on a standard acccuracy.

Contact-printed air photographs, scale of which was one to 50,000 approximately, were provided by the Geology Division. They were composed of 22 sheets by 2 flights and were photographed by the Camera, Type RC-8, made by WILD-HEERBRUGG Co. Ltd., Switzerland.

An expedient mean was applied to produce a topographical map in this occasion due to a lack of air-photo signals images on the photographs. This is, to fix up the sea water level on the photographs as zero metre datum level. It will present no problems to produce contour lines in every ten-metre as the tidal difference in the area was presumed to be several ten centimetres: and to fix up the scale of air-photographs as one to 50,000 approximately. A topographical map, scale of which was tentatively one to 25,000, was produced by doubling the air-photographs. The precise scale will be obtained after a measurement in the field: The PLANICOMP C-100 System of an analyzing stereo plotter, Zeiss Co. Ltd., West Germany made, was used for the plotting.

b) Survey of Control Points

Four control points, Points A, B, C and D, to be used for positioning of the survey-catamaran, were provided in the Lake TeNggano area by the Geology Division prior to the commencement of the field survey works. Additional Point E was provided by the Joint Team to assure the clear view within the field.

The co-ordinate values by the Universal Transverse Mercator Projection of Points A, B, C and D, provided by the Geology Division, Solomon Islands, are tabulated in Table 3 and are plotted in Figure 3.

The survey of the Point E was made by the Japanese Team by using an automatic distancemetre. Result of the survey is tabulated in Table 4. The co-ordinate value of the Point E was obtained after the survey by establishing

Table 3 Co-ordinates Value of Control Points

Control point	North in metres	East in metres
A	8,701,307.57	656,251.50
B	8,692,424.72	664,900.12
C	8,697,765.56	667,452.26
D	8,695,333.79	672,953.69
E	8,703,282.15	663,101.31

Table 4 Result of Measurement at Point A
Distance is shown in metres

	Time	Distance between A and C	Distance between A and E
Result	12.09.42	11760.6	07136.7
	12.09.22	11760.4	07136.7
	12.09.02	11760.5	07136.7
	12.08.42	11760.6	07136.2
	12.08.22	11760.6	07136.8
	12.08.02	11760.4	07136.9
	12.07.42	11760.4	07136.7
	12.07.22	11760.4	07135.9
	12.07.02	11760.6	07136.7
	12.06.42	11760.4	07136.7
	12.06.22	11760.4	07136.8
	12.06.02	11760.3	07136.5
	12.05.42	11760.3	07136.9
	12.05.22	11760.6	07136.6
	12.05.02	11760.7	07136.7
	Mean Value	11,760.5	7,136.6
	Measured Angle between C and E 33° 37′ 45″		

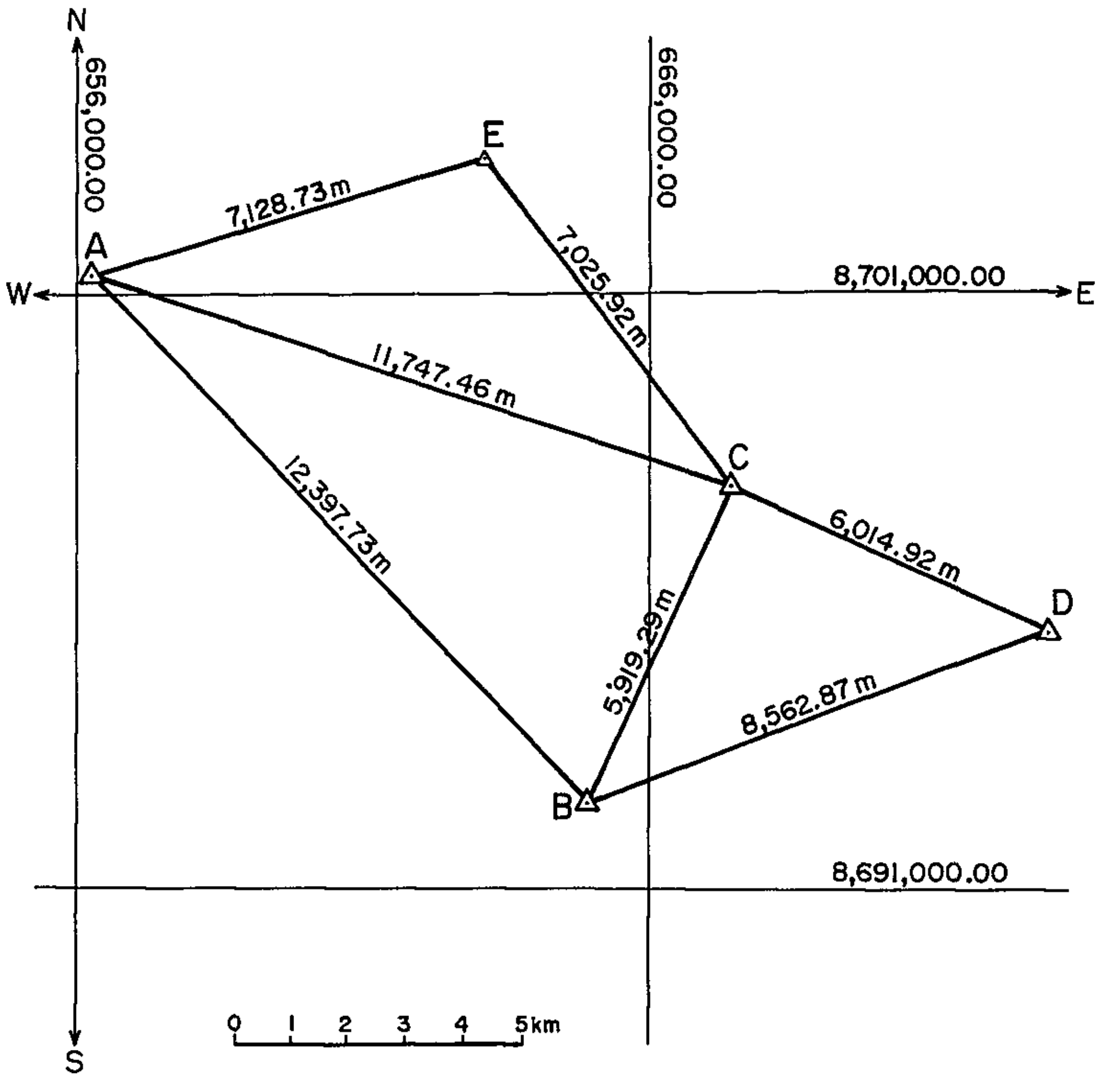


Figure 3 Interrelation of five Control Points A, B, C, D and E

the Master station on the Point A and two Slave stations on the Points C and E. The distances between A and C, A and E, and also the angle between A-C and A-E were surveyed. The distance difference of 13.02 metres between Point A and C was obtained if a comparison of the results by using the co-ordinate value by Geology Division and that by the Japanese Team's survey is made. The latter showed the results showing the longer distance. It is considered that this difference largely exceeds the probable error by the automatic distancemetre, however, detailed close re-examination of the distance difference was not made, because the range of error obtained there was considered to be negligible to maintain the accuracy required for the current works.

c) Observation of Lake Water Level Fluctuation

The Rennell Island is an up-lifted coral atoll and many caves and sink-holes are observed throughout the whole island. The water flow between the lake and the Pacific Ocean was anticipated prior to the commencement of the field works. Observation of the fluctuation of lake water level was made every one hour from 8 am to 6 pm, by using water level gauge, on 7th, 13th and 14th November, 1981 in TeNggano Village shore, however, negligibly small fluctuations were recorded as shown in Table 5. It should be concluded that the water level of the Lake TeNggano may show no fluctuation. It is estimated by air photograph mapping that the lake water level is four to five metres higher than that of sea water level circumscribing the Rennell Island.

d) Mounting Equipments

The equipments used for positioning, an Echo-sounder and a Sub-bottom profiler were loaded on the survey-catamaran as shown in Figure 1. The survey catamaran has a gunwale only some 0.3 metre high and an insufficient decking cover of plywoods by a makeshift. Strenuous efforts have been made under the inclement weather and a high-speed cruise for the safety maintenances of the survey equipments.

A piston corer, a winch with an engine and various gears for sediment sampling work were loaded on the barge as shown in Figure 2. The transducer of the echo-sounder was loaded on the barge in the opening in the centre of the deck, to watch the activities of the corer in the lake water, lake floor topography and lake water depth at the location, where sediment sampling work was operated.

The barge was taken in tow by the survey-catamaran, which was equipped with a 35 Horse Power-outboard engine, by using a 20 metre-long rope. Two accessory glass-fibre canoes, provided by the Geology Division, were sometimes used for a complementary service of towing the barge under wild weather.

The survey-catamaran was constructed in TeNggano Village by jointing two glass-fibre canoes, provided by the Geology Division, Solomon Islands. The barge was initially constructed by the National Fisheries Developments Ltd., Tulagi, Solomon Islands and was reassembled in TeNggano Village.

Table 5 Fluctuation of lake water level, Lake TeNggano

Figures show the water level difference from the Datum Level in centimetre every one hour.

Date / Time hours	Nov. 7	Nov. 13	Nov. 14
7		Datum Level	
8	Datum Level	0.0	Datum Level
9	0.0	0.0	-0.5
10	+0.25	0.0	-0.5
11	0.0	0.0	-0.5
12	+0.5	0.0	-0.5
13	0.0	0.0	-0.5
14	+0.5	0.0	-0.5
15	0.0	0.0	-0.5
16	+0.75	0.0	+0.5
17	0.0	0.0	+0.5
18	+0.75	0.0	+0.5

5-2 Survey Works on the Lake

a) Positioning of survey-catamaran

Positioning of the survey-catamaran was operated by both of distance measuring method by using the automatic distancemetre and straight-line method by using two theodolites.

The master station of the automatic distancemetre was operated on the survey-catamaran. Two slave stations were operated simultaneously against the master station on land. They were arbitrarily selected from the five control points, A, B, C, D and E, which had been prepared to be used for a slave station, depending on the allocation of the traverse line of the survey-catamaran on that day on the lake.

The survey-catamaran was led by one theodolite on straight-line on the lake and the positioning was made by another theolite. Straight-line method was used to substitute the automatic distancemetre when it was out of order. Transceivers were used for the connection between them. Table 6 shows the control points, by which positioning works were operated for each traverse line.

Three points method by using sextants was applied in the north-western bay of the lake and along Hutuna shore and a water-way to Hutuna Village, where water-depth was very shallow.

b) Echo-sounding

The echo-sounder, Type RS-61, capable of 61 metre-deep measurement, was used for the current survey, based on the previous reports, by which maximum water depth of the Lake TeNggano was reported as to be less than 50 metres. Figure 4 shows allocation of tracks of sub-bottom profiling by survey-catamaran on the lake as specified in Table 6.

35 traverse lines, totalling 169 km, were tripped on the lake. The initial programme of 250 kilometre-cruise of sub-bottom profiling had to be curtailed to 169 kilometres due to the inclement weather and some mechanical troubles.

c) Acoustic sub-bottom profiling

The sub-bottom profiler, Type SP, capable of 8 kHz-frequency, a magnetic distortion type, was used for the current survey. Type SP is characterized by being equipped with light-weight transducers with a high dissolution availability and is considered to be fit in the work for thin-accumulated sediment, such as a lagoonal sediment, similar to that of the Lake TeNggano.

The acoustic sub-bottom profiler was mostly operated simultaneously with the echo-sounder, however, some of the traverse lines were operated by the echo-sounder only, due to inclement weather on the lake. It is believed that the operation by the echo-sounder only, produces no any serious problems for the survey of limestone surface, because general thickness of the sediments in the Lake TeNggano is small and also an attenuation of acoustic energy inside the sediment is very small.

Table 6 Survey Traverses

Δ : by Acoustic Profiler only

Date	Line Number	Slave Station		Direction	Fixed Point Number	Time hours	Distance in km	
		R1	R2					
Nov. 13	L-13.1	C	D	–	1-16	15:20 – 15:50	3.1	
Nov. 14	L-14.1	C	D	–	1-50	9:58 – 11:36	7.2	
do.	L-14.2	C	D	–	51-90	12:24 – 13:42	6.3	
do.	L-14.3	C	D	–	91-114	13:57 – 14:43	4.7	

Date	Line Number	Leading Station	Position-ing Station	Direction	Fixed Point Number	Time Hours	Distance in km	
Nov. 15	L-15.1	–	–	C → A	1-31	9:50 – 10:50	11.5	
do.	L-15.2	E	A	A286°-15'	1-50	15:13 – 16:30	11.1	Δ
Nov. 16	L-16.1	C	E	A342°-30'	1-41	9:20 – 10:36	9.2	
do.	L-16.2	C	E	A312°-30'	1-42	10:50 – 11:48	9.4	
do.	L-16.3	C	E	A324°-00'	43-59	13:00 – 13:47	3.0	
do.	L-16.4	C	E	A333°-00'	60-82	14:00 – 14:40	3.5	
do.	L-16.5	C	E	A351°-30'	83-131	15:02 – 15:37	5.1	
do.	L-16.6	C	E	A7°-00'	132-162	15:50 – 16:37	3.9	
Nov. 17	L-17.1	B	C	C334°-40'	1-46	9:30 – 11:18	8.1	
do.	L-17.2	B	C	C64°-45'	47-76	11:30 – 12:28	6.0	
do.	L-17.3	B	C	C75°-00'	77-97	13:50 – 14:50	5.3	
do.	L-17.4	B	C	C82°-00'	98-120	15:30 – 16:35	5.2	
do.	L-17.5	B	C	C94°-00'	121-133	16:47 – 17:20	3.5	
Nov. 18	L-18.1	–	–	B → C	1-25	13:35 – 14:23	5.7	Δ

Table 6 – cont'd.

*: by Echo-Sounder only

Date	Line Number	Leading Station	Position-ing Station	Direction	Fixed Point Number	Time hours	Distance in km	
Nov. 19	L-19.1	B	D	C 10°-00'	1-8	11:45 – 12.07	1.2	
do.	L-19.2	B	D	C 22°-00'	9-19	12:15 – 12:58	1.5	
do.	L-19.3	B	D	C 30°-50'	20-33	13:20 – 14:02	1.6	
do.	L-19.4	–	–	D → Tingoa	1-21	15:20 – 16:50	6.5	Δ
Nov. 22	L-22.1	–	–	–	1-15	8:13 – 8:40	2.9	*
do.	L-22.2	–	–	–	16-24	8:43 – 9:00	2.0	*
do.	L-22.3	–	–	–	25-29	9:03 – 9:10	1.0	*
do.	L-22.4	–	–	–	30-42	9:26 – 9:50	2.8	*
do.	L-22.5	–	–	–	43-50	10:32 – 10:45	1.7	*
do.	L-22.6	–	–	–	51-61	10:55 – 11:15	2.3	*
do.	L-22.7	–	–	–	62-72	11:17 – 11:35	2.3	*
do.	L-22.8	–	–	–	73-80	14:22 – 14:50	1.3	*
do.	L-22.9	–	–	–	81-92	15:55 – 16:17	3.0	*
Nov. 30	L-30.1	E	C	A → E	1-30	10:07 – 10:58	6.8	*
do.	L-30.2	E	C	A335°-00'	31-74	11:00 – 11:45	7.1	*
do.	L-30.3	E	C	A309°-00'	75-139	13:03 – 13:56	8.6	*
do.	L-30.4	E	C	A16°-00'	140-158	15:00 – 15:40	4.6	*

d) Piston Coring and Sampling

The locations of the piston coring sampling were selected based on the results of sub-bottom profiling, by which lake floor topography and general distribution of the lake sediment were elucidated. Careful attentions were paid to the selection of weight of the corer and the hight, at which the corer was dropped down, because general thickness of the sediment was less than 5 metres, limestone surface was frequently undulated and also sediment was soft and limestone was hard. Activities of the corer were carefully watched by the echo-sounder, equipped in an opening in the centre of the barge-deck. 65 sediment samples from 48 locations on the lake were collected as shown in Figure 5.

The length of the core barrel was 2 metres long, having a 2 metre-long inner tube of acrylic resin, 65 millimetres outside diameter, and 59 millimetres inside diameter, which was limited by the height of A-frame and a size of the barge. Piston-coring was effective for the sampling of very wet jelly, which was the major material of the Lake TeNggano sediment. 60 kilogramme-weight was used for the work. Some of the work were operated without a piston, to collect the sediment skipping over the overlying sediment.

In very shallow-water areas, to where the barge was inaccessible, samples were collected by diving and man-hands, sticking a 1 metre-long acrylic resin tube in the sediment.

Collected samples were arranged on vinyl chloride tray to be photographed and sketched. Sufficient amounts of sample were collected in the sample receptacles to be sent to laboratory.

Geological logs of the sediments by piston-coring and man-hands are shown in ANNEX 2.

SIX RESULTS OF THE SURVEY WORKS AND INTERPRETATIONS

6-1 Echo-sounding

It is generally required to make ordinary corrections of the original echo-sounding records, which are tidal level correction, draft correction and sound speed correction, to produce the accurate measurement of water depth. Tidal level correction was unnecessary for the current survey procedure, as no fluctuation of lake water level was observed as noted in 5-1, c). Draft correction, to correct the distance between lake water surface and the transducer of the echo-sounder, was made by adopting the correction value as 0.5 metre and/or 0.4 metre. Sound speed correction, which is required for the error correction caused by water temperature, salinity of lake water and water pressure, was made by the Bar-check method. Bar-check was made by dropping down the bar onto 28 metres below lake water level. Correction value was obtained by making a Bar-check correction graph.

Figure 6, Lake Floor Topography, was delineated based on the bathymetric map, which was plotted on the track chart, after draft and sound speed corrections were applied to the original echo-sounding records.

As shown in Figure 7, Cross Sections of Lake Floor, the general lake floor topography in the area, where lake sediments are overlying the bed-rock, is mostly gentle and shows frequent steep undulations inversely in the area, where bed-rock limestone underlies directly under the lake water.

The general features of the lake floor topography, Lake TeNggano, are considered to be as follows;

a) The area, which is circumscribed by the 30 metre – isobath below lake water level, is located in the eastern half of the lake. The deepest portion in this area is 31 metres deep below lake water level.

b) The lake floor in the area, where water depth is deeper than 20 metres to 25 metres, normally shows a mostly gentle topography and it is inversely rich in undulations, where water depth is more shallow than 20 metres. The former coincides with the area, where the lake floor is covered by sediments and the latter the area, where bed-rock limestone underlies directly under the lake water.

c) The lake floor topography along the lake shore area is mostly undulated. The bigger inclination gradient of lake floor toward lake bottom is observed along the north-eastern shore than that along the south-western shore.

d) The water depth in the north-western bay of the Lake TeNggano is mostly less than 5 metres and a narrow depression of 5 metres to 10 metres deep is observed along the northern half of the bay.

6-2 Sub-bottom Profilling and Sediment Sampling

a) Removing disturbance from the Sub-bottom Profiling Records

The principal characteristics of the materials, related to the acoustic reflection, such as observable difference of tones and patterns, are recorded by Sub-bottom profiler on recording-paper. Disturbed records, which are not to be caused by the difference of original characters of the materials, are normally included in the total records. It is required to remove the disturbance factor from the original data, and after that accurate interpretations of the sub-bottom profiling will be produced. The major disturbance factors related to the acoustic reflection are as follows;

Multi-reflection: Acoustic multi-reflection is normally caused by the double acoustic reflection or more from the lake floor or from the boundary surface of the sediments, which has not been received by the receiving transducer after single reflection. Multi-reflection patternes, superimposed patterns, which are same to that of the primary single reflection, are recorded on the depth two to three times deeper position than that, where the primary single reflection record is obtained. The records of the multi-reflection of later arrivals gradually tend to get obscure and dull.

Scattering: Scattering is normally caused by the scattering of acoustic wave in every direction from the secondary sound source body, which was initially struck by the primary acoustic wave. Scattering is frequently observed if lake floor and sediment surface is steeply undulated. Peaked topography, like a pinnacle, normally produces more expanded record pattern than the reality and depressed topography inversely produces more shallow pattern. Acoustic reflection from the underlying sediment is frequently covered by scattering if pebbles, shells or gas bubbles are contained in overlying sediment.

Side reflection: Side reflection is normally caused by the acoustic reflection from the protruded fabrics or topographical prominence if the directivity of transmitted acoustic wave from the transmitting transducer is insufficient. It normally shows a superimposed double pattern. It is frequently observed that the geological boundary of lake sediment and bed-rock limestone, which is steeply undulated, is obscure by scattering. The scattering is reported to be caused by the materials, which are on the sediment surface and/or in the sediment itself. Scattering observed during the current survey work is considered to be mainly caused by plant fragments. Side reflection is also observed as shown in ANNEX 1, revealing reverse-stood tea-cup shadow in the sediment pattern by surrounding peaks of bed-rock limestone.

b) Dividing sediments

Principally, general geology of the Lake TeNggano area is divided into two

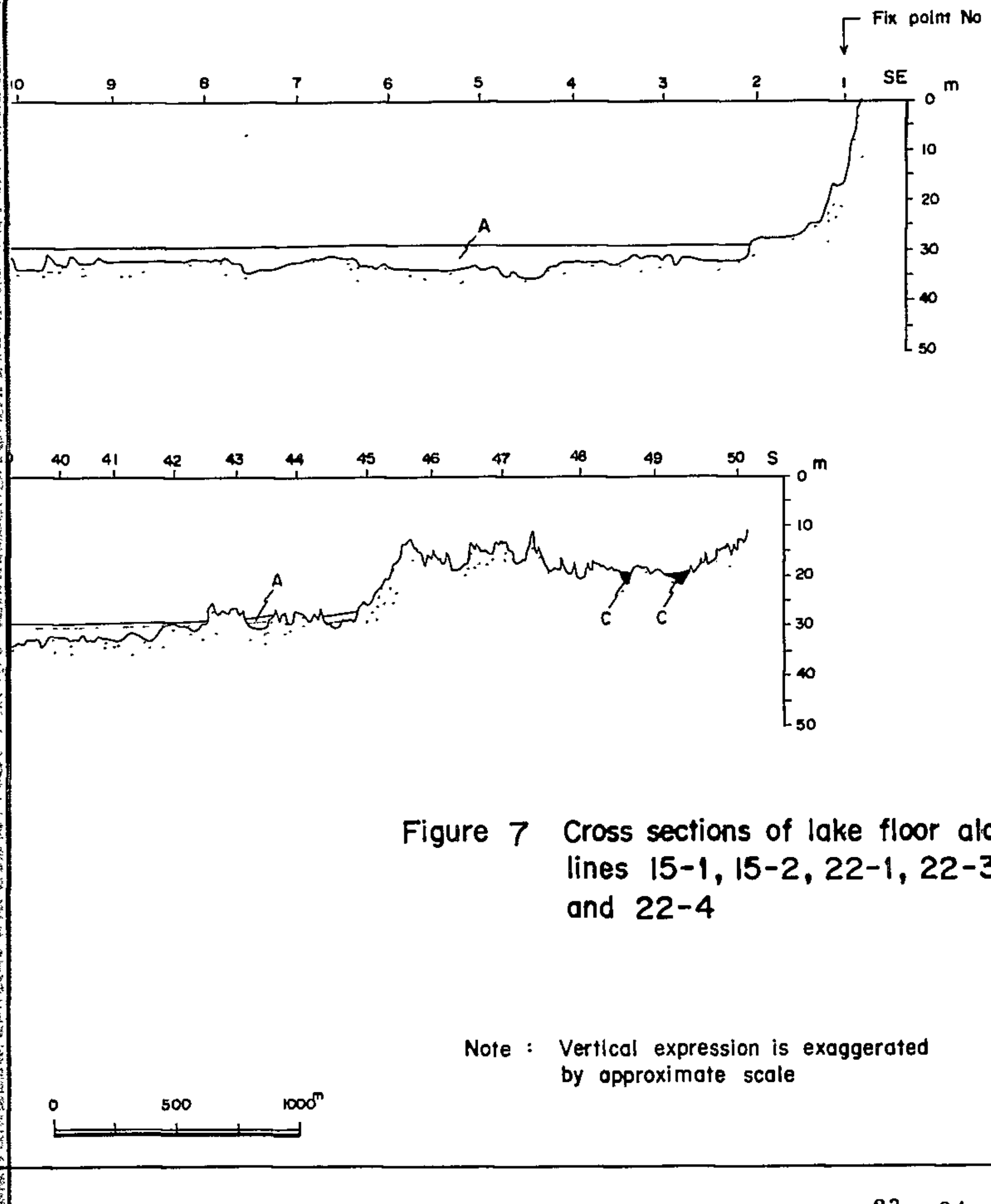
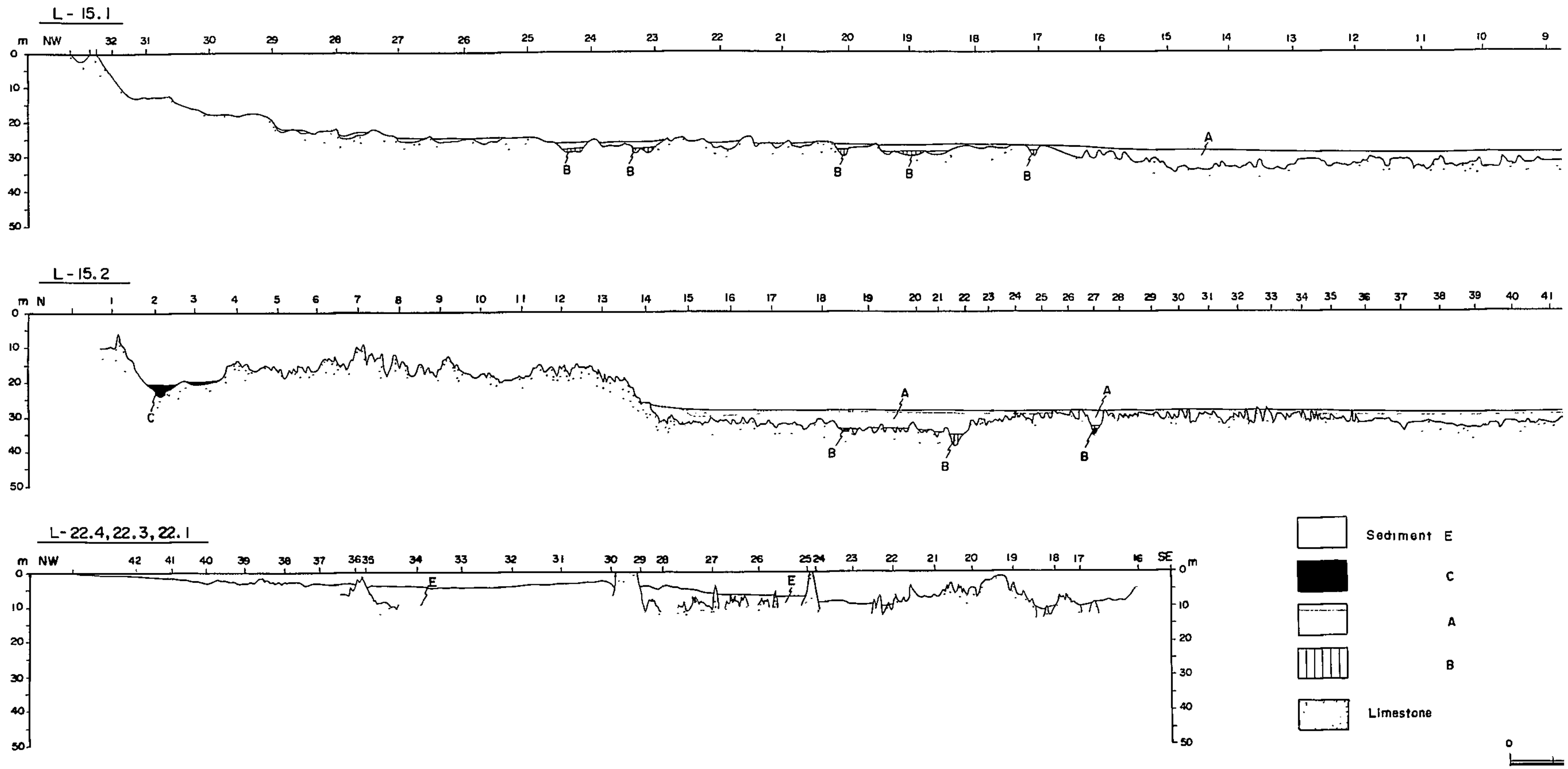


Figure 7 Cross sections of lake floor along lines 15-1, 15-2, 22-1, 22-3 and 22-4

Note : Vertical expression is exaggerated by approximate scale



L-15.1
L-15.2
L-22.4, 22.3, 22.1
NW
N
SE
m
A
B
C
E
Sediment E
C
A
B
Limestone

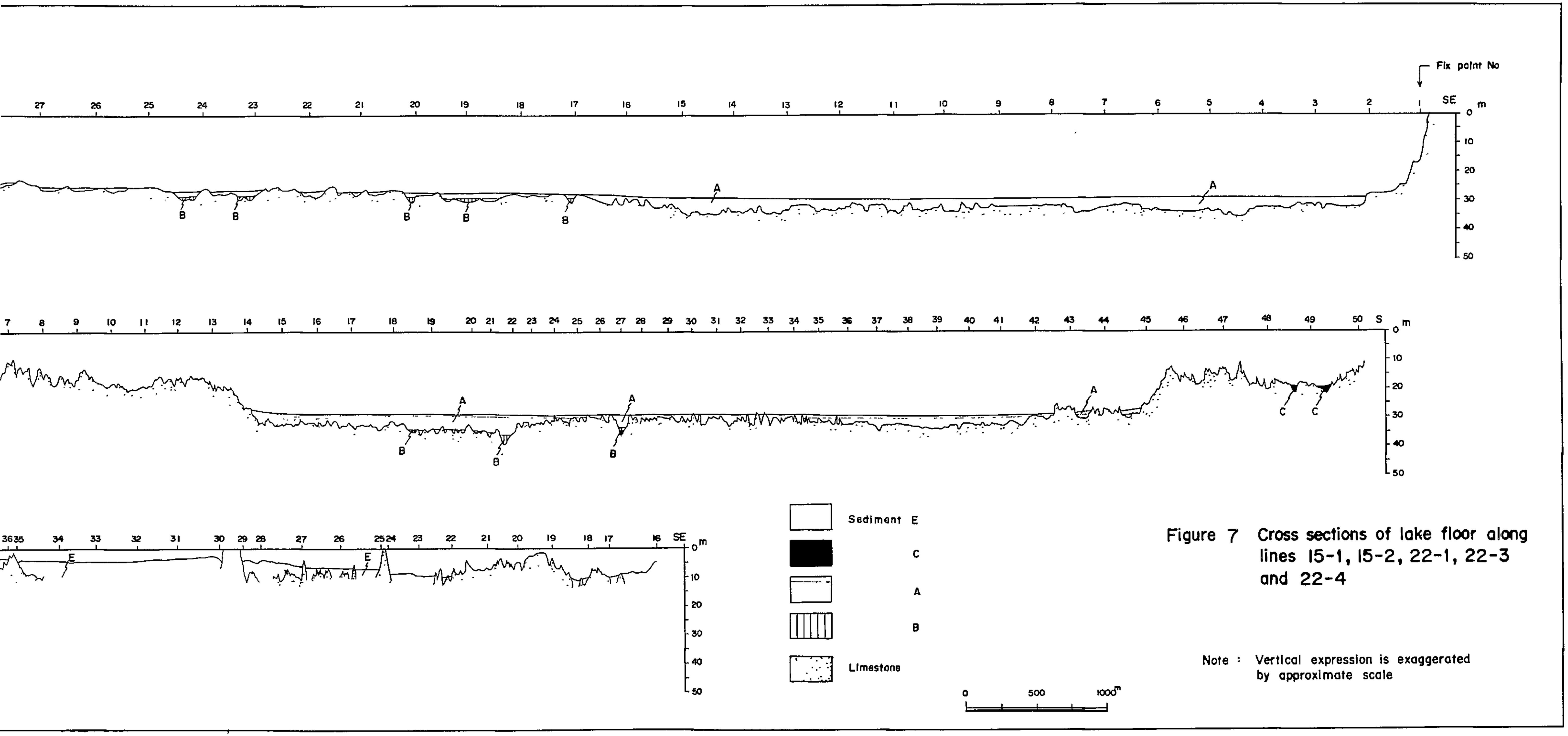


Figure 7 Cross sections of lake floor along lines 15-1, 15-2, 22-1, 22-3 and 22-4

units, bed-rock limestone and overlying sediments. A distinct difference of acoustic reflection intensity between limestone and overlying sediment is also observed by sub-bottom profiling. The bed-rock limestone shows frequent topographical undulations and reveals distinct dark patterns of acoustic reflection, due to a precipitous decrease in acoustic energy inside the limestone. The sediments on the Lake TeNggano floor normally have flat surface and show a small decrease in acoustic energy inside the sediments, however, sediments show some different acoustic reflection patterns in parts and geological distributions. The sediments distributed on the lake floor, Lake TeNggano, are divided into five sediments – four horizons based on the results of sub-bottom profiling and sediment sampling work. They are Sediment A and/or B, Sediment C, Sediment D and Sediment E. Figure 8 shows a schematic profile of the sediments based on the geological occurrence related to the water depth, on which they occur. Geological logs of the sediment sampling by piston coring are shown in ANNEX 2. X-ray powder diffraction charts of clay and sediment are attached in ANNEX 3.

Sediment A: The Sediment A is widely distributed on the lake floor of the central portion of the Lake TeNggano. The surface of the sediment is generally observed on 28 metres to 30 metres below lake water level, 31 metres is the deepest in the eastern portion of the lake, 22 metres is the most shallow in the western portion.

The records of the acoustic profiling generally show wholly whitish patterns, which are normally caused by the homogeneous and soft materials. Partial internal reflection is occasionally observed. A weak, parallel acoustic reflection to that of the Sediment A is frequently observed on some 2 metres higher horizon from the surface of the Sediment A as shown in ANNEX 1. It is presumed that the weak reflection is caused by fine and suspended materials close to the surface of the Sediment A, which is not included in a part of the Sediment A, as it is occasionally obscure and ocassionally disappears and is considered to be a semi-liquidal accumulation.

The Sediment A is generally 5 metres to 6 metres thick and 8 metres in maximum.

It is mainly composed of grayish green to grayish brown jelly. It generally contains fine plant fragments – leaf and fibrous fragments –, however, it is homogeneous in some places. The Sediment A is observed in Piston Coring Holes 23/1, 23/2, 23/3, 24/2 and etc., as shown in ANNEX 2. Jelly associated with the Sediment A, which is very wet material, contains 90% to 92% moisture. After drying the sample in air bath by 80°C-40 hours, it contains 4.5% to 8% Al_2O_3, which is originated from gibbsite, as shown in Tables 7 and 8. Ankerite, calcite and a small amount of pyrite are observed. Halite is discernible as an evaporation product of the semi-saline lake water, Lake TeNggano.

Sediment B: The Sediment B is distributed overlying depressions of the

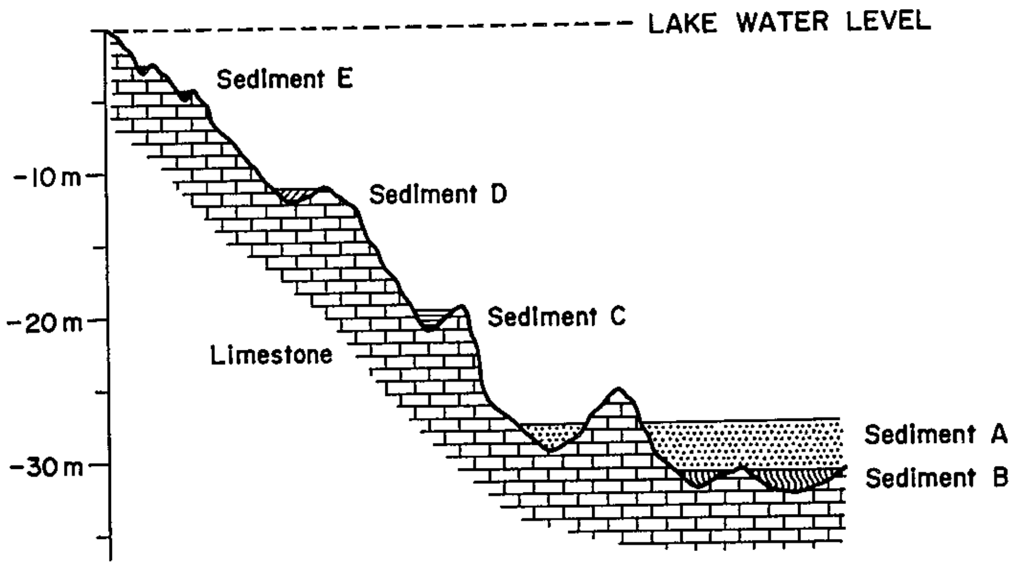


Figure 8 Schematic Profile of the lake sediments, Lake TeNggano

Table 7 Chemical analyses of lake sediments, Lake TeNggano

Horizon and material		A - jelly					B - mud		C - clay		C - jelly	C - mud	D - jelly
Sample number		23/3	24/3A	25/1	27/5	28/4A	24/3B	28/4B	26/5B	27/4B	27/6	28/1	27/3
Thickness of sampling in metre		2.0	0.5	2.0	2.0	1.0	1.5	0.5	0.3	0.15	2.0	2.0	0.8
Moisture	%	89.80	90.68	91.10	91.58	91.79	86.62	85.11	72.81	66.42	91.04	91.27	93.14
Al_2O_3	%	7.10	5.98	4.42	4.74	8.16	5.60	5.67	29.84	20.12	7.88	5.98	6.85
SiO_2	%	0.18	0.15	1.59	0.70	0.09	0.12	0.07	0.23	0.28	0.22	0.32	0.20
TiO_2	%	0.62	0.26	0.26	0.27	0.38	0.27	0.20	1.32	0.97	0.34	0.20	0.32
Total Fe as Fe_2O_3	%	2.60	2.60	2.00	1.90	2.70	2.50	2.40	10.78	10.38	3.29	1.70	2.20
P_2O_5	%	0.57	0.50	0.50	0.50	0.55	0.25	0.27	1.35	3.78	0.64	0.46	0.57
Loss by ignition	%	80.38	72.13	79.78	81.95	64.34	55.66	58.12	43.88	39.67	60.87	62.02	66.74
Total	%	91.45	81.62	88.55	90.06	76.22	64.40	66.73	87.40	75.20	73.24	70.68	76.88
Remarks		Abbreviations of "Horizon and material" A: Sediment A B: Sediment B C: Sediment C D: Sediment D E: Sediment E							Moisture: Weight loss after drying 80°C for forty hours. Loss by ignition: Weight loss after ignition 1,150°C for one hour.				

Table 7 – Cont'd. -2

Horizon and material		D - clay		E - clay										
Sample number		28/2B	28/2C	25/7A	25/7B	26/1	29/1A	29/1B	29/1C	29/3A	29/3B	29/3C	29/6A	29/6B
Thickness of sampling in metre		0.25	0.30	0.20	0.25	0.35	0.40	0.40	0.40	0.20	0.30	0.30	0.20	0.30
Moisture	%	51.88	46.97	36.16	35.01	36.24	41.43	32.92	34.44	50.13	36.03	32.54	40.44	41.33
Al_2O_3	%	35.20	39.56	46.10	40.50	45.54	42.05	43.36	45.10	42.74	46.07	45.14	45.23	42.92
SiO_2	%	0.40	0.54	0.20	0.15	0.13	0.26	0.21	0.20	0.19	0.16	0.14	0.24	0.21
TiO_2	%	1.32	1.38	1.80	1.75	1.83	1.73	1.60	1.77	1.73	1.72	1.77	1.75	1.85
Total Fe as Fe_2O_3	%	13.97	15.37	17.56	18.58	16.37	17.77	17.87	14.61	15.87	12.63	14.43	15.47	15.50
P_2O_5	%	3.37	3.00	3.57	3.62	3.57	0.69	0.57	0.69	1.23	1.05	0.87	0.44	0.48
Loss by ignition	%	36.54	34.69	24.37	25.80	29.62	35.25	35.48	34.73	35.38	35.73	35.41	36.76	36.13
Total	%	90.80	94.54	93.60	90.40	97.06	97.75	99.09	97.10	97.14	97.36	97.76	99.89	97.09
Remarks		SOUTHERN HUTUNA clay		TINGOA clay			NIUPANI clay			NIUPANI clay			NORTHERN NIUPANI clay	

Table 7— Cont'd. - 3

Horizon and material	E - clay								E - aragonite sand			
Sample number	30/1	30/2	30/3	30/4	30/5	30/6	30/7	30/8	29/4A	29/4B	29/5A	29/5B
Thickness of sampling in metre	0.20	0.20	0.40	0.50	0.20	0.20	0.50	0.40	0.60	0.50	0.25	0.85
Moisture %	36.52	35.15	36.59	36.99	67.12	42.54	50.64	58.67	51.85	79.02	72.90	80.60
Al_2O_3 %	49.86	46.05	41.67	40.11	37.91	43.24	47.10	34.89	0.03	0.13	0.10	0.16
SiO_2 %	0.18	0.20	0.18	0.21	0.15	0.16	0.09	0.13	0.11	0.06	0.04	0.08
TiO_2 %	1.57	1.68	1.73	1.82	1.67	1.80	1.58	1.63	tr.	tr.	tr.	0.23
Total Fe as Fe_2O_3 %	11.34	14.11	18.39	19.79	15.60	16.00	13.57	15.77	tr.	0.04	0.04	0.06
P_2O_5 %	0.48	0.46	0.64	0.64	0.41	0.55	1.08	1.42	0.02	0.07	0.05	0.08
Loss by ignition %	35.45	35.24	34.39	33.94	42.99	34.69	34.71	36.84	42.10	48.98	48.90	49.38
Total %	98.88	97.74	97.00	96.51	98.73	96.44	98.13	90.68	42.26	49.28	49.13	49.99
Remarks	S.D.A. SCHOOL BAY clay (30/1–30/2)		HUTUNA clay (30/3–30/4)						tr.: trace			

Table 8 Mineral assemblage of lake sediments by X-ray power diffraction, Lake TeNggano

Horizon and material	A - jelly					B - mud		C - clay		C - jelly	C - mud	D - jelly	D - clay SOUTHERN HUTUNA clay		E - clay TINGOA clay			E - clay NIUPANI clay		
Sample number	23/3	24/3A	25/1	27/5	28/4A	24/3B	28/4B	26/5B	27/4B	27/6	28/1	27/3	28/2B	28/2C	25/7A	25/7B	26/1	29/1A	29/1B	29/1C
Boehmite	–	–	–	–	–	–	–	–	–	–	–	–	–	–	◎	◎	◎	–	–	–
Gibbsite	○	○	○	△	○	△	○	◎	◎	○	△	○	◎	◎	◎	◎	◎	◎	◎	◎
Anatase	–	–	–	–	–	–	*	*	*	–	–	–	*	*	*	*	*	○	○	○
Ankerite	△	○	○	○	○	○	◎	–	◎	◎	◎	◎	○	–	–	–	–	–	–	–
Aragonite	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Calcite	△	○	△	△	◎	◎	–	○	△	◎	◎	◎	–	–	–	–	–	–	–	–
Crandallite	–	–	–	–	–	–	△	△	○	–	–	–	○	○	○	○	○	–	–	*
Geothite	–	–	–	–	–	–	–	△	–	–	–	–	–	–	–	–	–	–	–	–
Gypsum	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Halite	◎	◎	◎	◎	◎	◎	△	○	–	◎	◎	○	△	△	*	*	○	*	*	*
Marcasite	–	–	–	–	–	–	–	–	△	–	–	–	–	△	–	–	–	–	–	*
Pyrite	△	△	△	△	△	△	○	○	○	△	△	○	◎	◎	○	○	○	○	◎	○
Rhodochrosite	–	–	–	–	–	–	–	–	–	–	–	–	–	–	*	△	–	*	–	–
Siderite	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Remarks	Abbreviations of "Horizon and material"; A: Sediment A, B: Sediment B, C: Sediment C, D: Sediment D, E: Sediment E ◎ Abundant, ○ Medial, △ Modicum, * Inferred, – Absent																			

Table 8 – Cont'd.

Horizon and material	E - clay													E - aragonite sand			
	NIUPANI clay			NORTHERN NIUPANI clay		SDA SCHOOL BAY clay		HUTUNA clay									
Sample number	29/3A	29/3B	29/3C	29/6A	29/6B	30/1	30/2	30/3	30/4	30/5	30/6	30/7	30/8	29/4A	29/4B	29/5A	29/5B
Boehmite	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Gibbsite	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	–	–	–	–
Anatase	*	△	△	△	△	△	△	△	△	△	△	*	*	–	–	–	–
Ankerite	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Aragonite	–	–	–	–	–	–	–	–	–	–	–	–	–	◎	◎	◎	◎
Calcite	–	–	–	–	–	–	–	–	–	○	△	–	△	–	△	*	△
Crandallite	△	△	*	–	–	–	–	*	*	–	–	△	△	–	–	–	–
Goethite	–	–	–	–	–	–	–	–	–	–	–	△	–	–	–	–	–
Gypsum	–	–	–	–	–	–	–	–	–	–	–	–	△	–	–	–	–
Halite	*	*	*	–	△	*	*	–	*	*	–	*	*	–	–	–	–
Marcasite	△	–	△	–	–	–	–	–	–	–	△	–	–	–	–	–	–
Pyrite	○	○	○	◎	◎	○	○	○	○	○	○	○	○	–	–	–	–
Rhodochrocite	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Siderite	–	–	–	–	–	△	○	○	○	–	–	–	–	–	–	–	–
Remarks	Abbreviations of "Horizon and Material"; A: Sediment A, B: Sediment B, C: Sediment C, D: Sediment D, E: Sediment E ◎ Abundant, ○ Medial, △ Modicum, * Inferred, – Absent																

bed-rock limestone and is overlain by the Sediment A. The surface of the Sediment B is, consequently, on 28 metres to 34 metres below lake water level, deeper than that of the Sediment A.

The records of the acoustic profiling generally show uniformly dark to semi-dark patterns, by which it is easily distinguished from the Sediment A. Geological boundary of the Sediment B and bed-rock limestone is obscure in some places caused by the scattering on the surface or inside of the Sediment B.

It is generally 1 metre to 3 metres thick, 4 metres in maximum.

It is mainly composed of jellied brown mud and is frequently associated with plant fragments, by which internal acoustic reflection is caused. It is observed in lower parts of Piston Coring Holes 24/3, 28/4 and etc.. Jellied mud, associated with the Sediment B, which is very wet material, contains 85% to 87% moisture. After drying the raw sample in air bath by 80°C-40 hours, it contains 5.6% Al_2O_3 approximately, which is originated from gibbsite as shown in Tables 7 and 8. General chemical and mineralogical characters of the Sediment B is similar to that of the Sediment A and is also associated with ankerite, calcite and a small amount of pyrite. Halite is discernible as an evaporation product of the semi-saline lake water, Lake TeNggano.

Sediment C: The Sediment C is distributed in shallow-water area, generally on 18 metres to 22 metres below lake water level and directly overlies bed-rock limestone. It is laterally discontinuous to the Sediments A and/or B.

The records of the acoustic profiling are generally similar to that of the Sediment B, however, occasionally to that of the Sediment A.

It is generally less than 2 metres thick.

It is mainly composed of grayish green to grayish brown jelly or jellied muddy sediment, associated with a large amount of plant fragments. It is observed in Piston Coring Holes 26/5, 27/4, 27/6, 28/1 and etc.. Bauxitic gray to yellow brown clay occurrences are observed in lower parts of Holes 26/5 and 27/4. Jelly or jellied muddy sediment associated with the Sediment C, which is very wet material, contains 91% moisture approximately. After drying the raw sample in air bath by 80°C-40 hours, it contains 6% to 8% Al_2O_3, which is originated from gibbsite, as shown in Tables 7 and 8. Ankerite and calcite are outstandingly observed and are associated with a small amount of pyrite. Halite is discernible as an evaporation product of the semi-saline lake water, Lake TeNggano. Clay, intersected by Holes 26/5 and 27/4, is mainly composed of gibbsite and is associated with ankerite, calcite, crandallite, anatase, pyrite and marcasite, as shown in Table 8. The clay shows a some high phosphorus content among the clay samples observed in the Lake TeNggano area, 1.35% to 3.78% P_2O_5. Phosphorus is originated from crandallite. Al_2O_3 contents, after drying raw clay samples of Holes 26/5 and 27/4 are as follows;

Hole number	Thickness in metre	Al_2O_3 per cent	Overlain/Underlain
26/5	more than 0.30	29.84	Grayish green jelly /Unknown
27/4	more than 0.15	20.12	Yellowish brown jelly/Unknown

They show low SiO_2 content, 0.23% to 0.28%, and low TiO_2 content, 0.97% to 1.32%.

Sediment D: The Sediment D is distributed in shallow-water area, more shallow than that of the Sediment C, and is on 8 metres to 15 metres below lake water level. It directly overlies bed-rock limestone and is laterally discontinuous to the Sediments A, B and C.

The records of the acoustic profiling generally show dark patterns, similar to that of the Sediment B, and is characterized by frequent scattering.

It is generally less than 2 metres thick.

It is mainly composed of jellied brown soft mud, associated with a large amount of fibrous plant and fine wooden fragments, by which frequent acoustic scattering is caused. It is observed in Piston Coring Holes 27/3 and 28/2. A sticky, bauxitic clay occurrence, which is under the name of "SOUTHERN HUTUNA clay" in the report was encountered in lower part of the Hole 28/2, 0.55 metre thick between 11.15 metres to 11.70 metres below lake water level. Jellied brown mud in the Sediment C, which is very wet material, contains 93% moisture approximately. After drying raw sample in air bath by 80°C-40 hours, it contains 6.85% Al_2O_3, which is originated from gibbsite, as shown in Tables 7 and 8. It is mainly composed of ankerite and calcite, associated with a small amount of pyrite. Halite is discernible as an evaporation product of the semi-saline lake water, Lake TeNggano. "SOUTHERN HUTUNA clay" is mainly composed of gibbsite and is associated with ankerite, crandallite anatase, pyrite and marcasite. Al_2O_3 content of the clay after drying in air bath by 80°C-40 hours is as follows;

Occurrence	Hole number	Thickness in metre	Al_2O_3 per cent	Overlain /Underlain
SOUTHERN HUTUNA	28/2	0.55	37.58	Jellied mud /Limestone

It contains 0.48% SiO_2, 1.35% TiO_2 and 3.17% P_2O_5, which is characterized by some high phosphorus content.

Sediment E: The Sediment E is distributed in the limited and very shallow-water areas and is generally observed on 2 metres to 11 metres below lake water level, more shallow than that of the Sediment D. It directly overlies bed-rock limestone.

Only the limited number of records of echo-sounding operation were obtained by the current work due to inaccessibilities of survey boat into the shallow-water areas. It is considered that the lake water depth to the surface of the Sediment E in the north-western bay of the Lake TeNggano near Tebaitahe, where the sediment surface shows frequent gentle undulations, is to be 5 metres approximately.

The major bauxitic gray clay occurrences in the Lake TeNggano area are observed in the Sediment E. They are generally distributed on 2 metres to 5 metres below lake water level.

The Sediment E is mainly composed of grayish green to reddish brown jelly and brown muddy sediment and is sparsely associated with bauxitic gray clay. Aragonite sand bed, creamy white to pale pinkish brown, is remarkably observed in the end portion of the north-western bay of the lake. Bauxitic sticky, gray clay shows patchy occurrences in the Sediment E. It is generally overlain by grayish green to reddish brown jelly and occasionally by nothing directly under the lake water. It is occasionally underlain by bed-rock limestone directly and occasionally by brown muddy sediment. It is very sticky. Geological occurrences of bauxitic gray clay are shown in ANNEX 2 and major chemical compositions and mineral assemblage are tabulated in Tables 7 and 8. Al_2O_3 contents of bauxitic gray clay in the Lake TeNggano area, collected by the current survey are as follows. Al_2O_3 contents are shown in the values after the raw samples are dried in air bath by 80°C-40 hours;

Occurrence	Name	Hole number	Thickness in metre	Al_2O_3 per cent	Overlain /Underlain
Eastern end of L. TeNggano	TINGOA	25/7	0.45	42.99	none/ Brown mud
Eastern end of L. TeNggano	TINGOA	26/1	0.35	45.54	none/ Limestone
Southern shore of L. TeNggano	S.D.A. SCHOOL BAY	30/1	0.20	49.86	Green jelly/ Limestone
Southern shore of L. TeNggano	S.D.A. SCHOOL BAY	30/2	more than 0.20	46.05	Green jelly/ Unknown
Southern shore of L. TeNggano	HUTUNA	30/3	0.40	41.67	Green jelly/ Brown mud
Southern shore of L. TeNggano	HUTUNA	30/4	0.50	40.11	Green jelly/ Brown mud
Southern shore of L. TeNggano	–	30/5	0.20	37.91	Green jelly/ Limestone
Southern shore of L. TeNggano	–	30/6	0.20	43.24	none/ Brown mud
Southern shore of L. TeNggano	NIUPANI	29/1	more than 1.20	43.50	Reddish brown jelly/ Unknown

Occurrence	Name	Hole number	Thickness in metre	Al_2O_3 per cent	Overlain /Underlain
Southern shore of L. TeNggano	NIUPANI	29/3	0.80	44.89	Red jelly/ Limestone
Northern shore of L. TeNggano	NORTHERN NIUPANI	29/6	0.50	43.84	none/ Limestone
Northern shore of L. TeNggano	–	30/7	more than 0.50	47.10	Green jelly/ Unknown
Northern shore of L. TeNggano	–	30/8	more than 0.40	34.89	Green jelly/ Unknown

Clay samples by the current survey were collected by both of piston coring and man-hands by diving.

As shown in Table 7, raw samples of the bauxitic gray clay generally contain 33% to 41% moisture. After removing off the moisture by drying 80°C-40 hours in air bath, they generally show 43% to 46% Al_2O_3, 49.86% the highest and 34.89% the lowest. They contain 0.09% to 0.26% SiO_2, 1.57% to 1.85% TiO_2, very low. They also contain 0.46% to 1.42% P_2O_5 in general, except TINGOA clay, which shows 3.60% P_2O_5. Iron content in the form of Fe_2O_3 generally shows 12% to 18% Fe_2O_3.

As shown in Table 8 and ANNEX 3, bauxitic gray clay are composed of gibbsite, except TINGOA clay, which is a mixture of gibbsite and boehmite. TiO_2 and P_2O_5 are originated from anatase and crandallite. Silica mineral is not discernible by X-ray power diffraction. Pyrite is widely observed, sparsely associated with marcasite. Siderite is discernible in S.D.A. SCHOOL BAY clay and HUTUNA clay. Gypsum in Hole 30/8-clay, goethite in Hole 30/7 are discernible. Rhodochrosite is discernible in TINGOA clay, which is also inferred to be in NIUPANI clay. Calcite is observed in Holes 30/5-, 30/6- and 30/8-clay.

The bauxitic gray clay occurrences show patchy distributions, filling up small pocket-like sink-holes of bed-rock limestone, mainly on 2 metres to 4 metres below lake water level. It is considered that the NIUPANI clay, intersected by Holes 29/1 and 29/3, which are 150 metres apart, has some extensive occurrence, however, lateral continuation of the clay is still unknown due to a thick cover – 0.8 metre to 1.2 metres – between them. Clay is not encountered by Hole 29/2, 350 metres apart from Holes 29/1 and 29/3. Diameter of the sink-hole of bed-rock limestone, filled up by bauxitic gray clay in the area, is 0.2 to 0.4 metre in general. The distribution of clay-filled sink-holes are scatteredly obsevered. It is presumed that the lateral extent of clay-filled sink-holes does not exceed 30 metres by 30 metres in an occurrence in general.

c) Water Depth to Sediment Surface

Figure 9 shows isobaths of the lake sediment surface in the Lake TeNggano to interprete the sedimentation mechanism and dislocation after sedimentation.

The major characters of the sediment distribution in the area are as follows;

Sediment A: The surface of the Sediment A is mostly flat in wide area, however, it is slightly heaved up in the marginal portion of the lake, which is resulted in a slightly shallow-water-depth occurrence of the sediment surface. Water depth of the sediment surface is 28 metres to 30 metres in wide area, 31 metres in the eastern portion of the lake is the deepest, 26 metres in northern margin, and 22 metres in southern margin.

Sediment C: The Sediment C is mainly distributed in the south-eastern portion of the lake and near the Station E. It shows a flat surface, generally on 18 metres to 22 metres below lake water level.

Sediment D: The Sediment D is mainly distributed along the southern Hutuna shore, near the Station E and the water-way to the north-western bay of the lake. It shows a flat surface, generally on 8 metres to 15 metres below lake water level.

Sediment E: The Sediment E shows limited distributions in shallow-water area near the lake shore. Gentle undulations of the sediment surface are observed in the end part of the north-western bay, where remarkable aragonite sand bed is clearly observed by showing pinkish creamy colour. Aragonite sand bed mentioned above shows a tongue-like distribution, south-west to north-east directional, near Tebaitahe. Grayish green jelly and brown muddy sediment of the Sediment E is considered to be having flat surface in general. It is generally distributed on 2 metres to 11 metres below lake water level.

d) Water depth to Bed-rock Limestone Surface

Figure 10 shows isobaths of the bed-rock limestone surface to elucidate the distribution of major sedimentation basins. The limestone-surface shows a very undulated and irregular topography, of which major characters are as follows;

1) General inclination of the limestone surface in the area, where water depth is larger than 25 metres to 30 metres, is generally gentle, however, it is more steep in the area, where water depth is smaller than the above.

2) General inclinations of limestone surface in the areas, where water depth is 5 metres to 10 metres, 15 metres to 20 metres, and 20 metres to 25 metres below lake water level, frequently show some large topographical gradient.

3) The largest water depth to the limestone surface in the Lake TeNggano is 39 metres in the eastern part of the lake.

e) Isopachs of the Sediments

Figure 11 shows isopachs of the sediments observed in the Lake TeNggano to elucidate the general form of the sedimentation. It is synthesized by a combination of lake floor topography and isobaths of the bed-rock limestone. Isobaths have every 2-metre intervals. The major characters of isopachs of the sediments in the Lake TeNggano are as follows;

1) The sediments widely cover the bed-rock limestone in the central part of the lake and generally have flat sediment surface, of which thickness is directly influenced by the surface topography of the bed-rock limestone. The thicker sediment cover is observed in the area, where the water depth to the bed-rock surface is larger, which is 8 metres in maximum in the area.

The area, where bed-rock limestone is directly distributed under the lake water, occupies some 35% of the whole area of the lake.

3) Delineating of isopachs in the north-western bay of the lake have been omitted due to poorly obtainable data on the water depth to the limestone surface. However, a wide lift of the bed-rock limestone, which separates the sedimentation basins of northwestern bay and the central part of the lake, is remarkable.

4) Sediments C, D and E, which directly overlie the bed-rock limestone, show scattered, patchy and limited distributions. Similar occurrences of the sediments to above are inferred ın the area, where the traverse lines of the current survey do not cover.

SEVEN CONCLUSIONS AND APPRAISAL

7-1 The lake floor sediments in the Lake TeNggano area are divided into five sediments – four horizons as follows based on the results of acoustic sub-bottom profiling, echo-sounding and sediment sampling works;

Sediments A and/or B	: 28 metres to 34 metres below lake water level
Sediment C	: 18 metres to 22 metres below lake water level
Sediment D	: 8 metres to 15 metres below lake water level
Sediment E	: 2 metres to 11 metres below lake water level

7-2 Bauxitic gray clay occurrences are observed in the Sediments C, D and E. No clay occurrence has ever been observed in the Sediments A and/or B.

7-3 Major occurrences of the bauxitic gray clay are observed in the Sediment E. They normally occur on 2 metres to 5 metres below lake water level.

7-4 Bauxitic gray clay is very sticky. It normally shows scattered and patchy occurrences, filling up small pocket-like sink-holes of the bed-rock limestone. The average diameter of sink-holes is ranging from 0.2 metre to 0.4 metre and a lateral extent of the clay-filled sink-holes is estimated to be less than 30 metres by 30 metres in an occurrence in general.

It is, however, considered that the NIUPANI clay, which is distributed near the lake shore of NIUPANI Village, and is encountered by Piston Coring Holes 29/1 and 29/3, 150 metres apart, is estimated to be having some extent. It is located on 2.8 metres to 3.7 metres below lake water level and is more than 0.8 metre to 1.2 metres thick, 43% to 45% Al_2O_3. Lateral extent of the NIUPANI clay occurrence is still obscure due to a thick cover of reddish brown jelly. No clay has been intersected by Hole 29/2, 350 metres apart from Holes 29/1 and 29/3.

7-5 Bauxitic gray clay in the Sediment E is covered by jelly in some places and lies directly under the lake water in another places.

It is underlain by bed-rock limestone in some places and by jelly in another places.

7-6 Raw sample of bauxitic gray clay generally contains 33% to 41% moisture, some 60% occasionally. After removing off moisture by drying in air bath at 80°C for 40 hours, it generally contains 43% to 46% Al_2O_3, 49.86% is the highest and 20.12% is the lowest. It is inferred that it has a tendency, which shows high Al_2O_3 content is obtained in clay in the Sediment E, getting lower Al_2O_3 content in clay in the Sediment D and the lowest content in clay in the Sediment C.

It generally contains less than 0.30% SiO_2, less than 1.85% TiO_2, very low. It also generally contains 0.46% to 1.42% P_2O_5, some 3.8% in some places. Total iron content, as shown in the form of Fe_2O_3, is 12% to 18% Fe_2O_3.

7-7 Aluminium mineral observed in bauxitic gray clay in the Lake TeNggano area is gibbsite. TINGOA clay, occurs in the eastern end of the lake, is a mixture of gibbsite and boehmite.
TiO_2 is originated from anatase, P_2O_5 is from crandallite. Pyrite is widely observed, minorly associated with marcasite and siderite. Rhodochrosite, calcite, ankerite, gypsum and goethite are sparsely observed. Silica mineral is not discernible by X-ray powder diffraction.

7-8 The Sediments A and/or B, C, D and E are mainly composed of grayish green jelly and jellied muddy sediment, which are very wet materials and contain 90% moisture approximately. After removing the moisture by drying in air bath at 80°C-40 hours, they normally contain 5% to 8% Al_2O_3, originated from gibbsite.
It is clarified that gibbsite is widely dispersed and scattered throughout in jelly and muddy sediments. Ankerite and calcite are also widely observed.

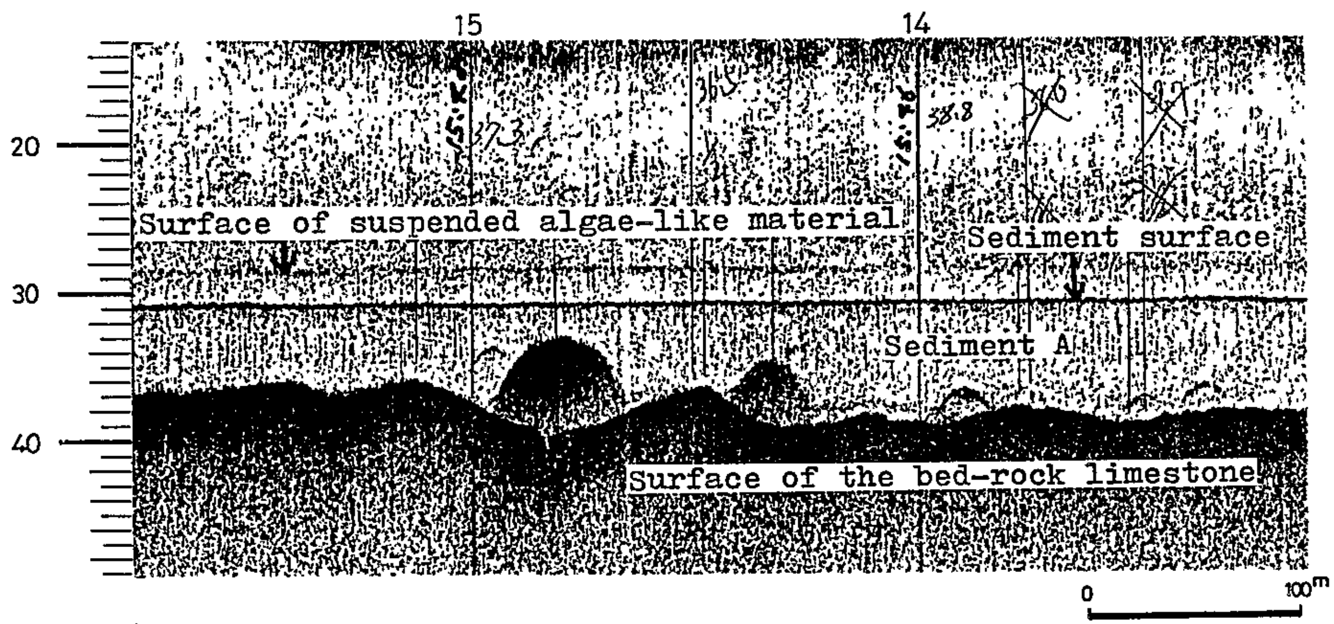
7-9 It is considered that the limited areal extent and quality of the bauxitic gray clay in the Lake TeNggano area make unlikely the possibilities for large- to moderate-scale mining operation of bauxite, and likely for the beneficiation as raw material of local ceramic use or modelling clay of education material in school.

ANNEX 1

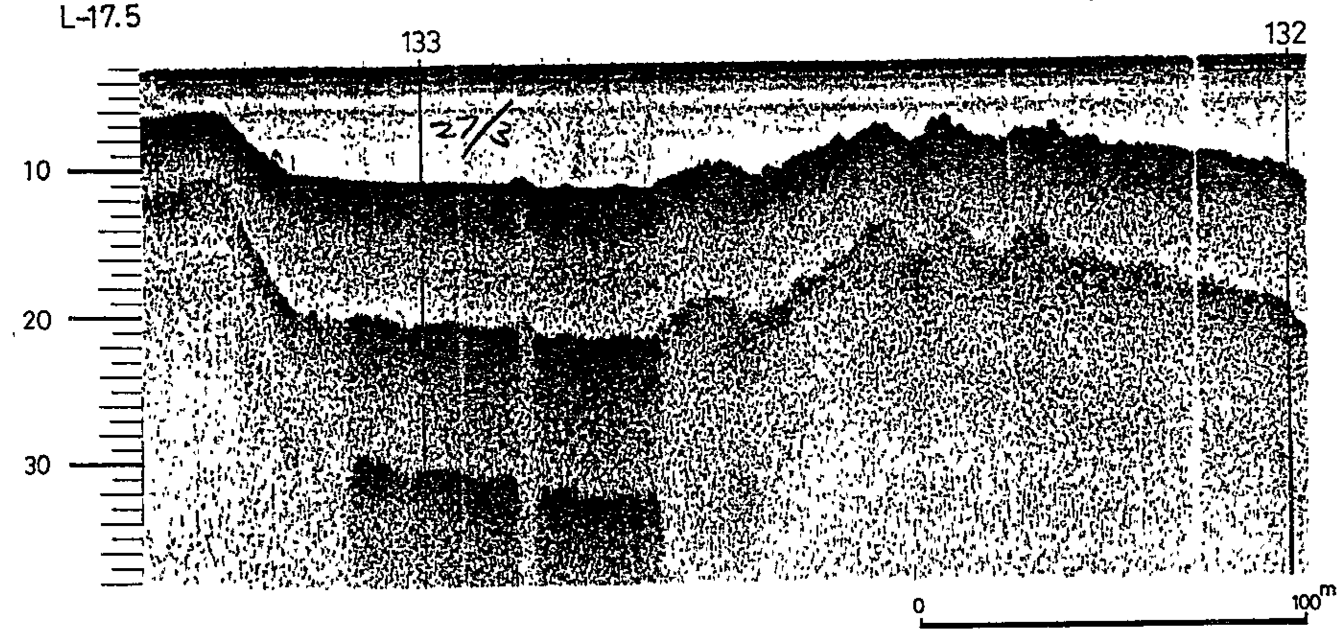
ANNEX 1

RECORDS BY ACOUSTIC PROFILING AND ECHO-SOUNDING,

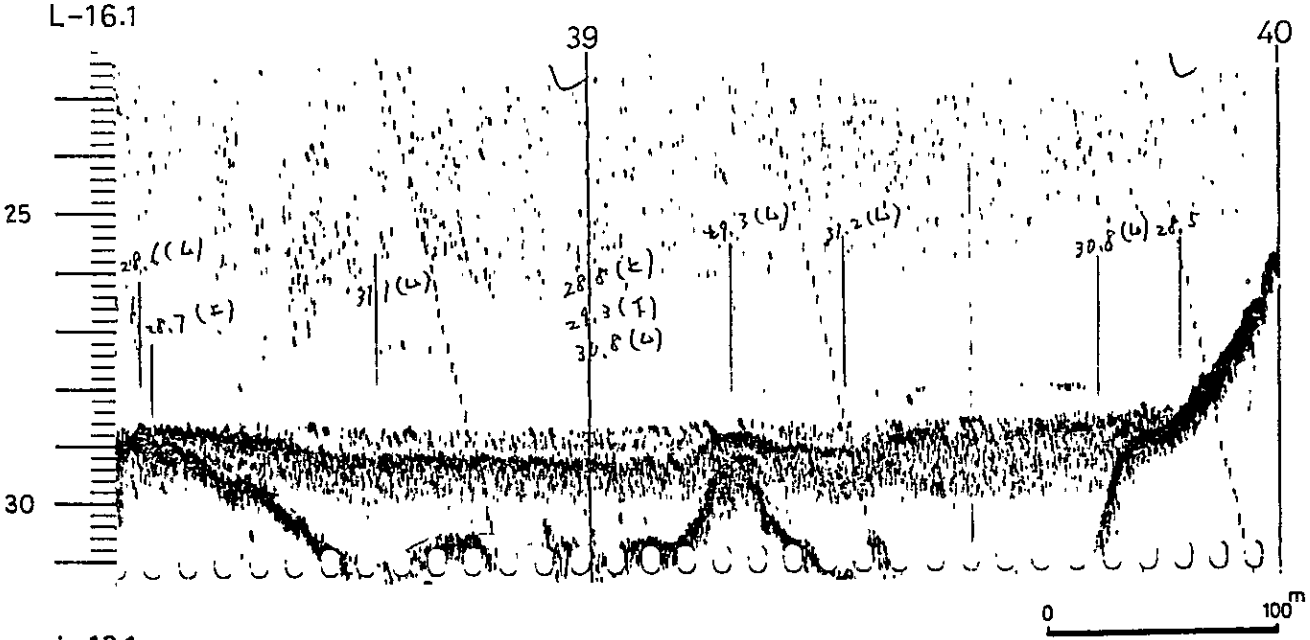
LAKE TENGGANO, RENNELL IS., SOLOMON IS.



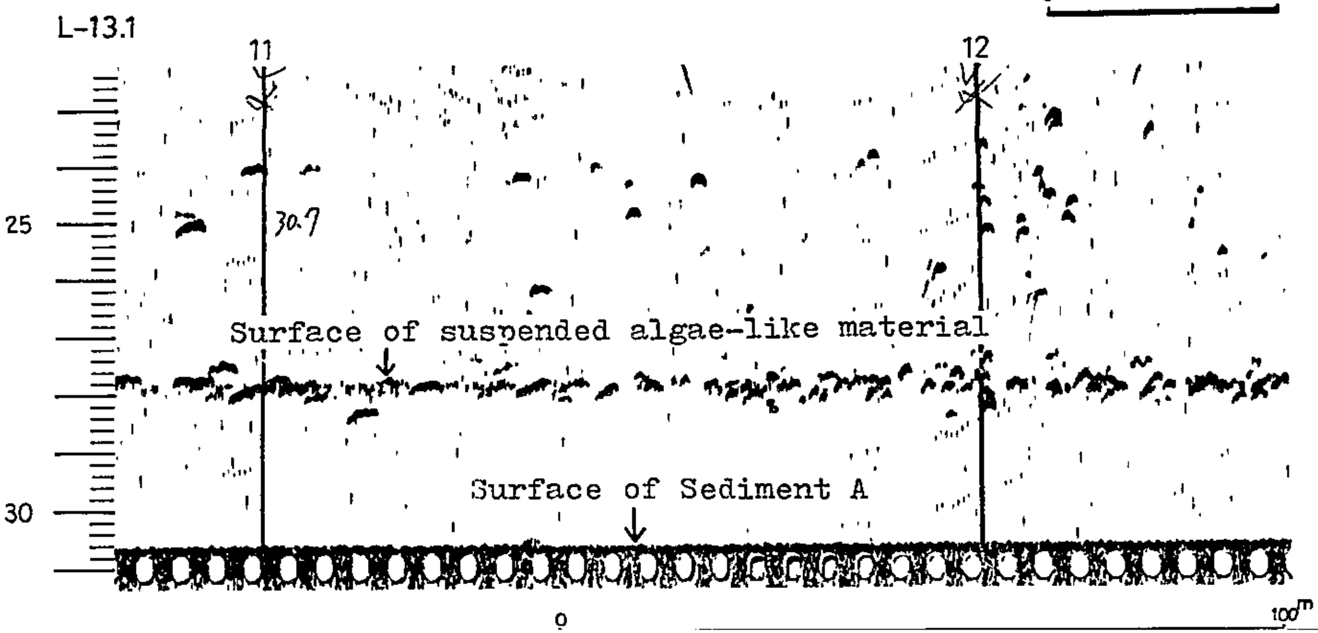
Side reflection pattern by pinnacl
of bed-rock limestone.



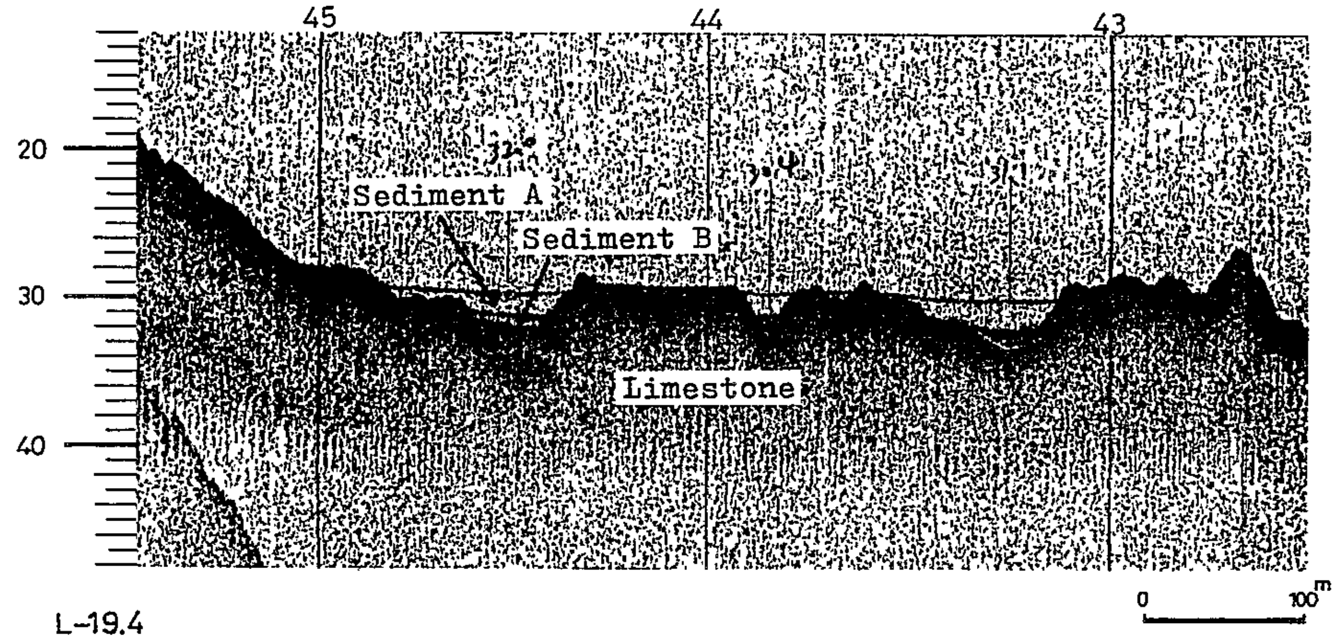
Scattering pattern at the surface
of Sediment D.



Surface of the bed-rock limestone overlain by Sediment A, observed by echo sounder



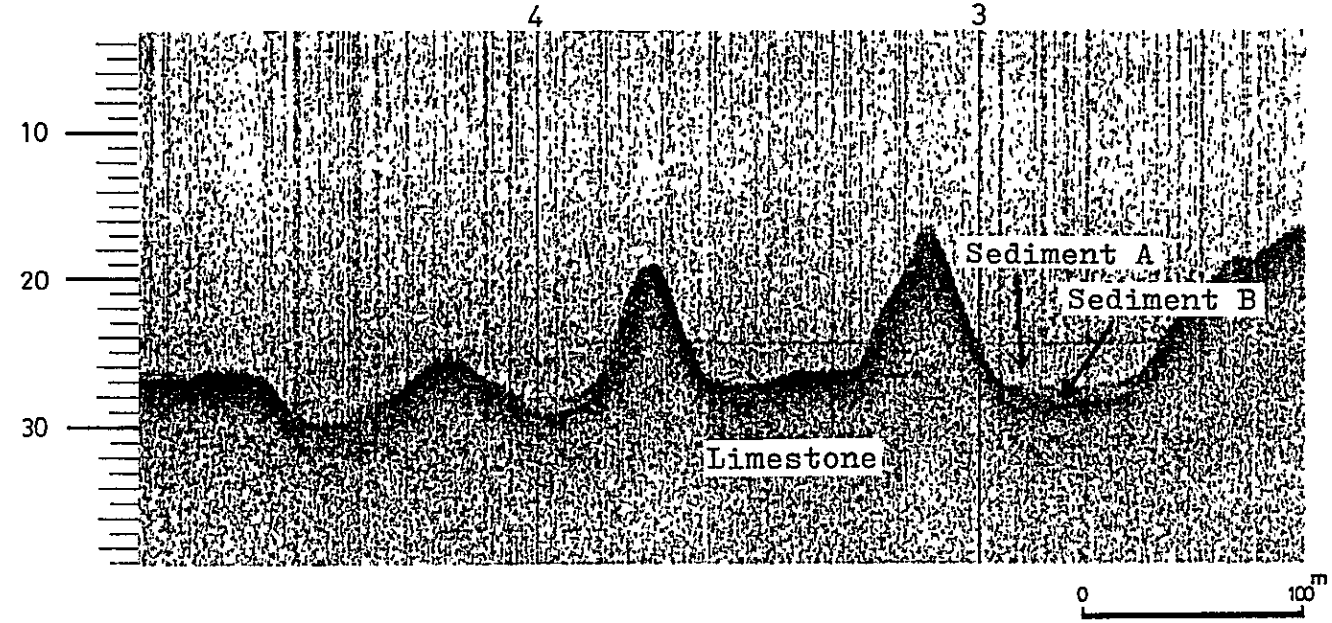
Surface of suspended algae-like material



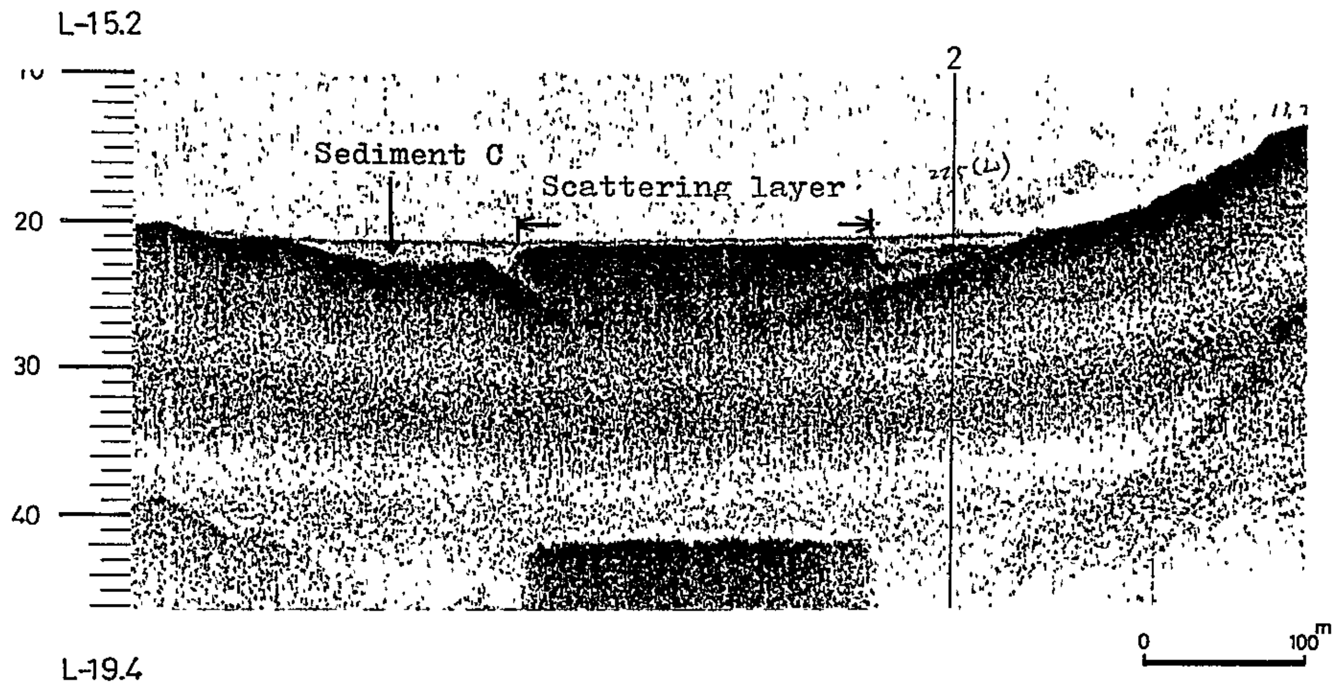
Sediments A and B filling up hollows of the bed-rock limestone

3

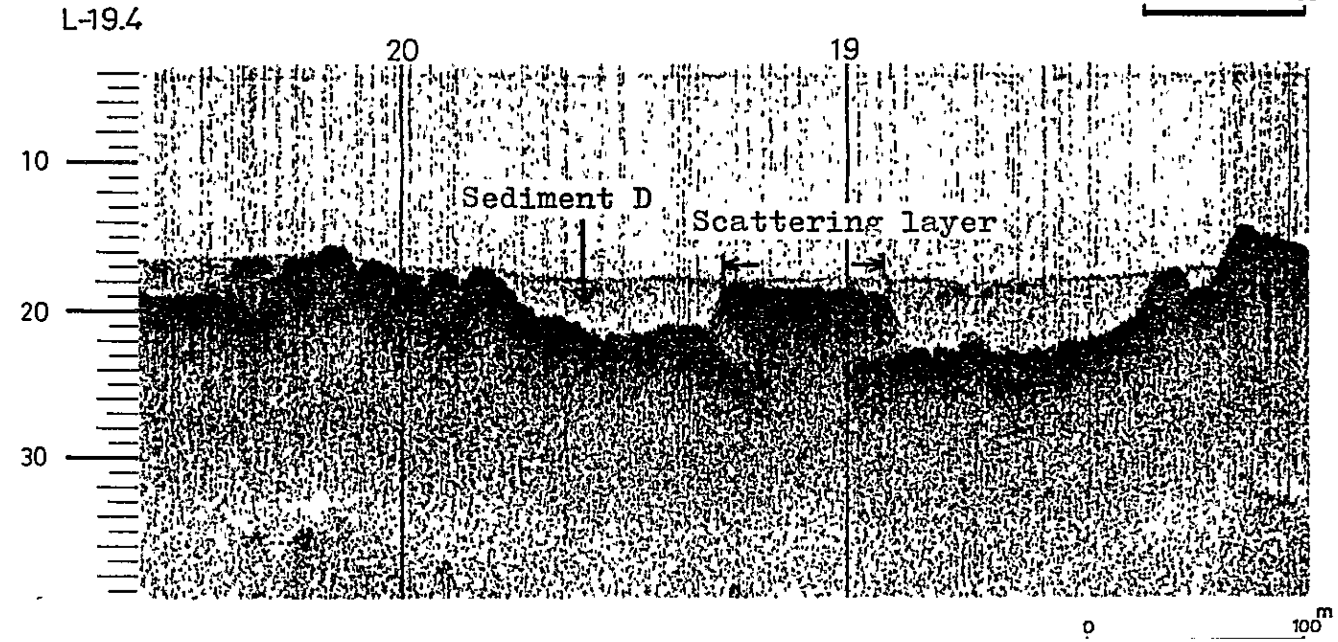
L-19.4



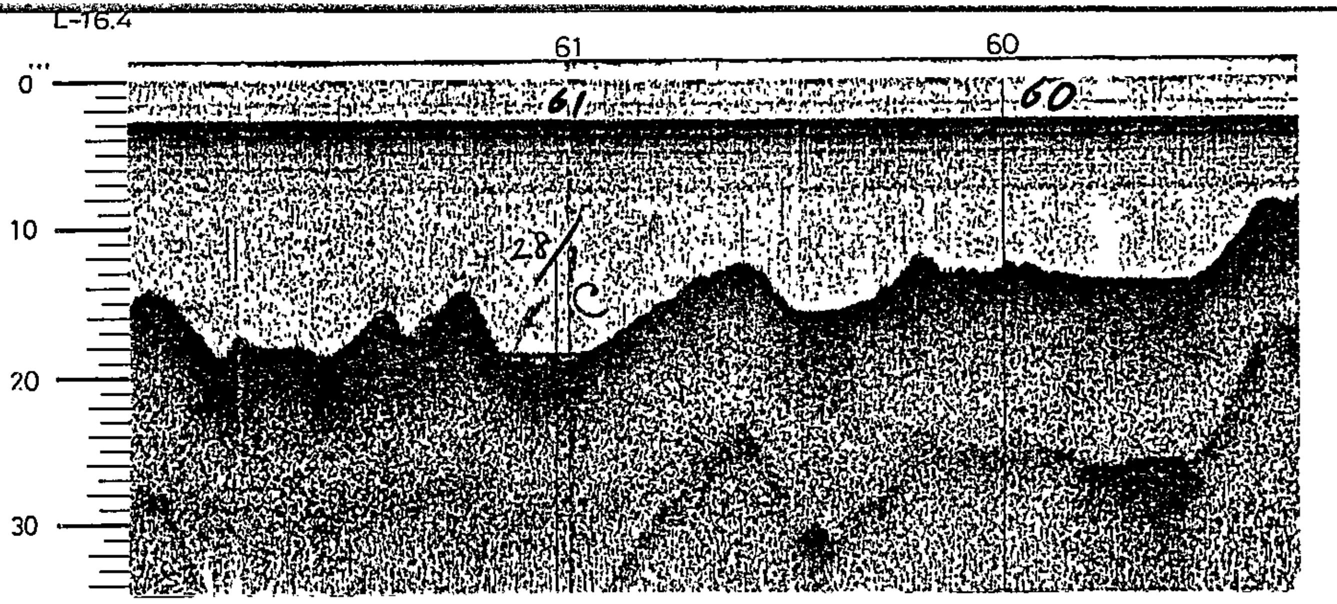
Do.



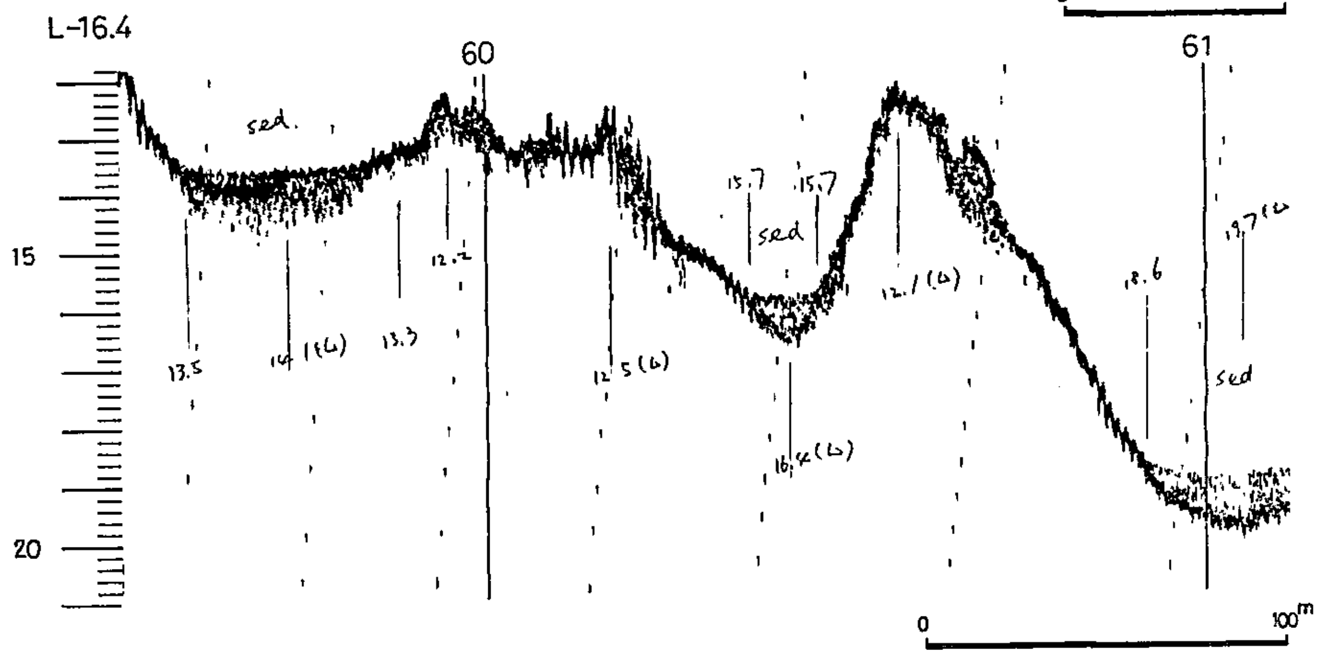
Sediment C and its scattering pattern



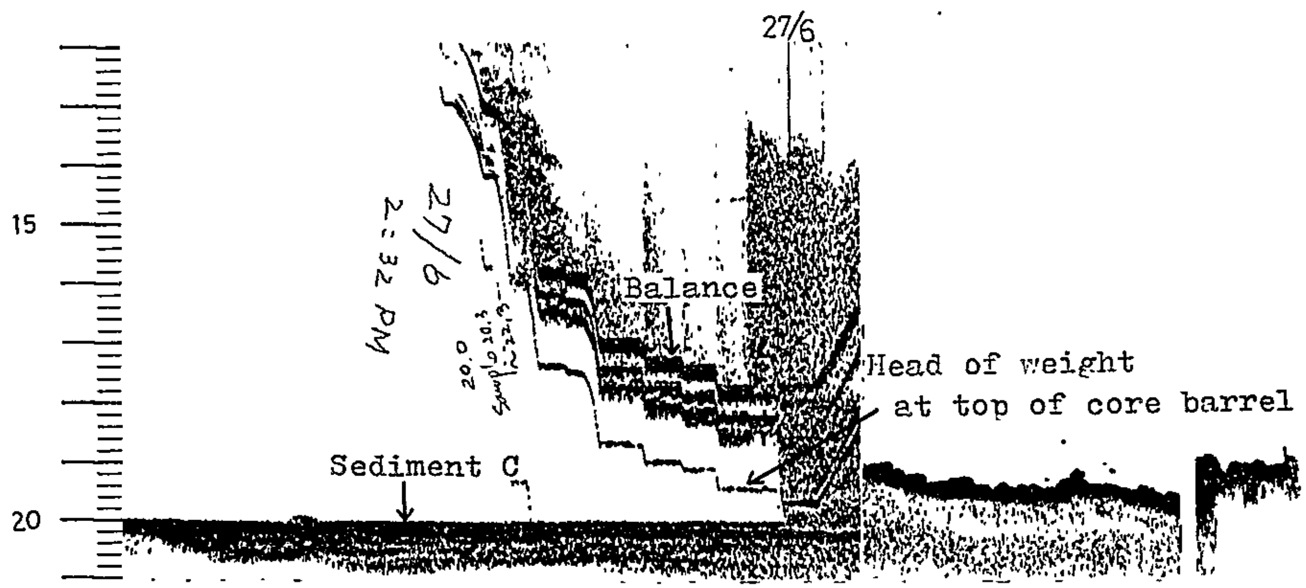
Sediment D and its scattering pattern



Sediment D by acoustic profiler
at Pts, 60-61, L-16.4



Sediment D by echo-sounder
at Pts. 60-61, L-16.4



Movement of piston-corer during dropping to intersect to sediment, observed by echo-sounder.

ANNEX 2

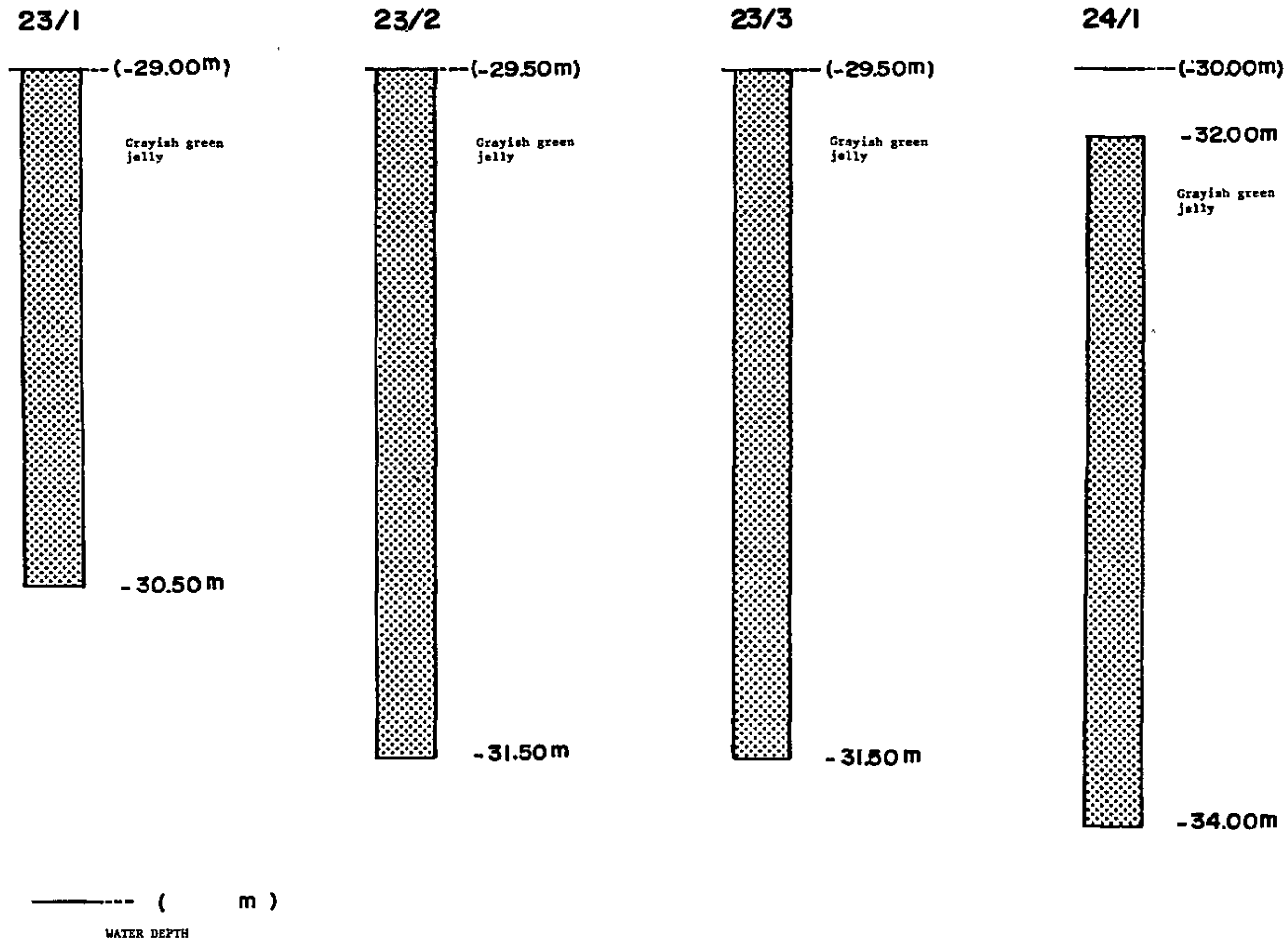
ANNEX 2

GEOLOGICAL LOGS BY PISTON CORING

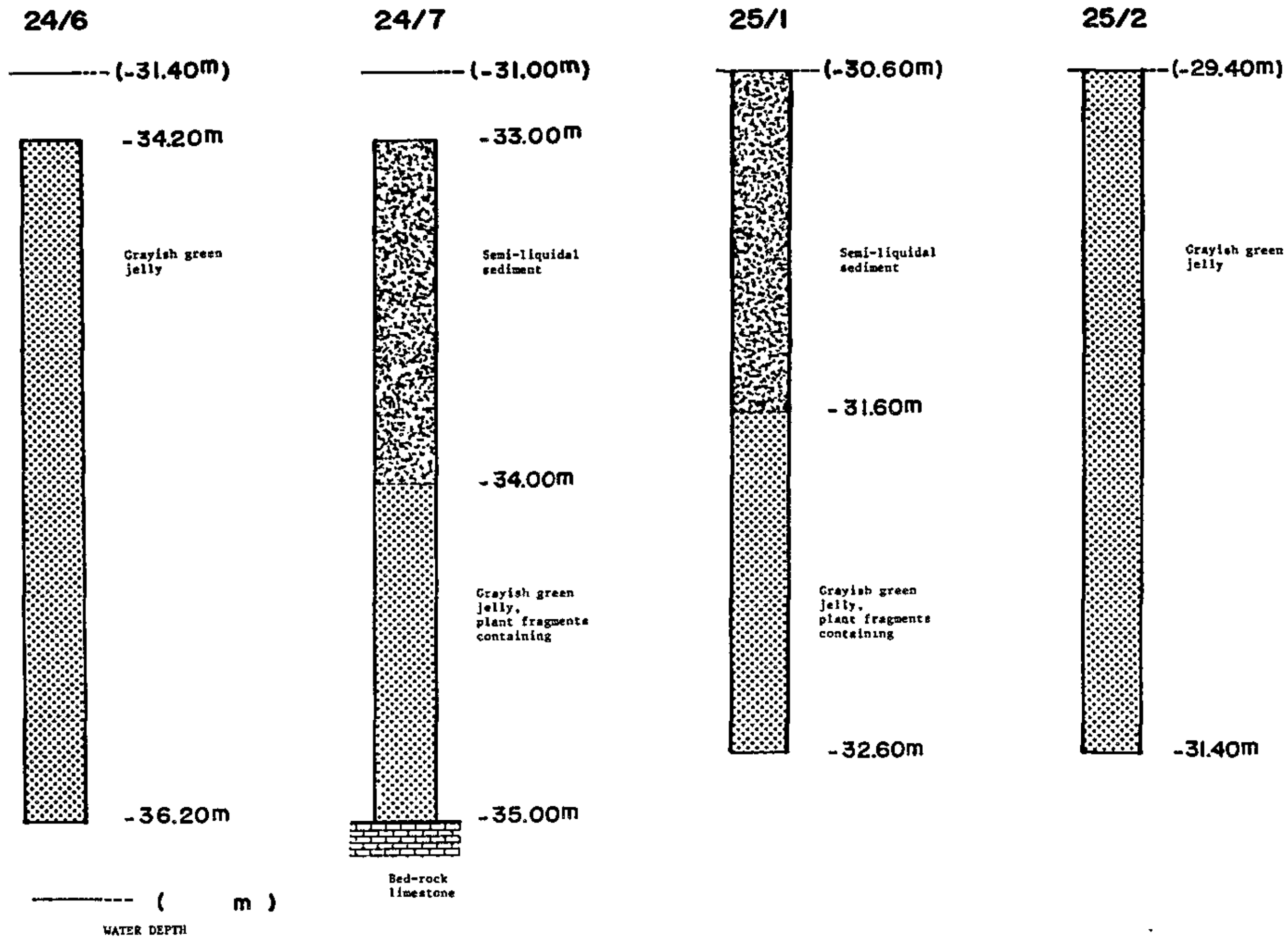
OF

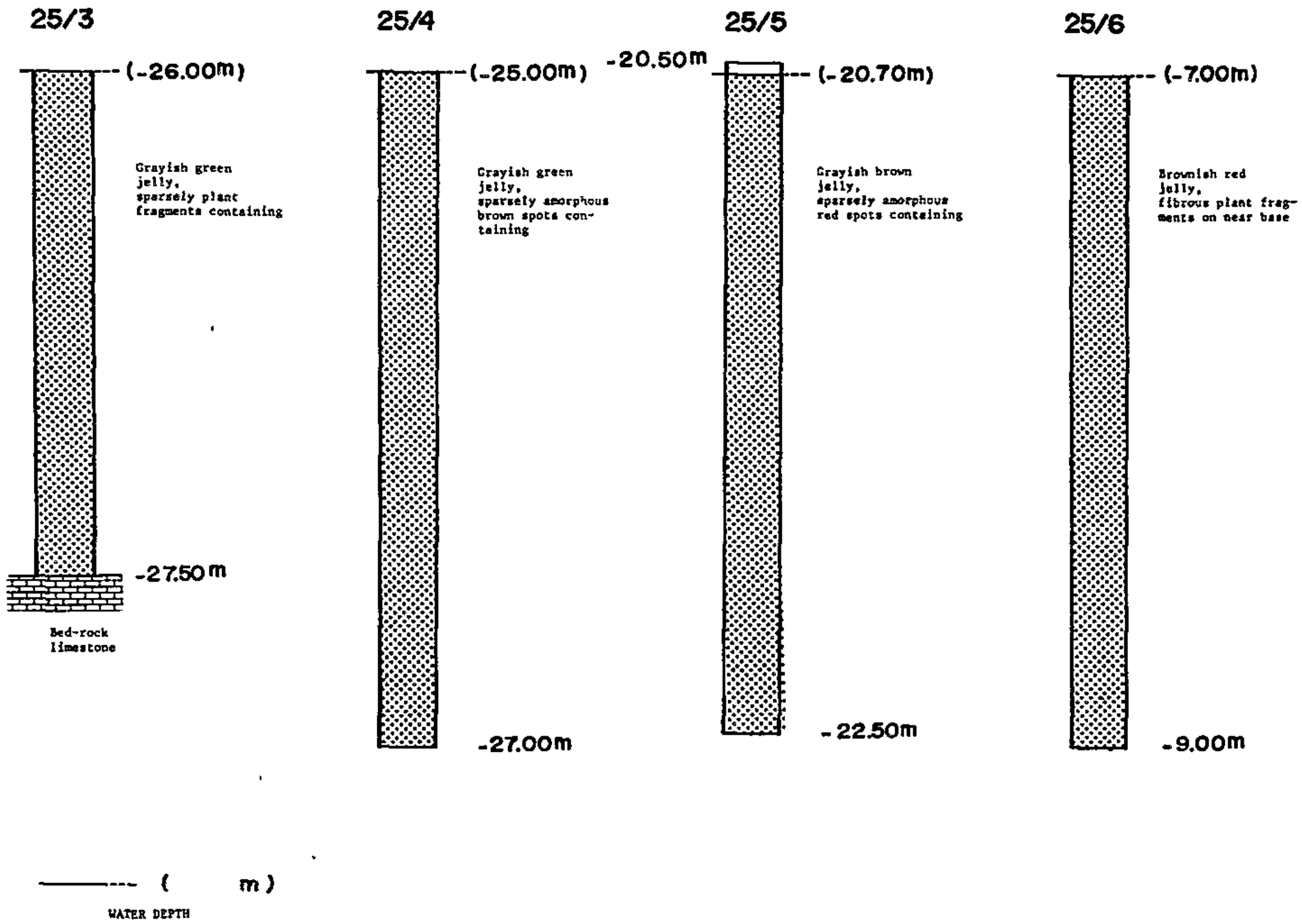
THE LAKE FLOOR SEDIMENTS, RENNELL IS., SOLOMON IS.

23/1, 23/2 and etc. show the hole numbers of piston coring, locations of which are to be referred to Figure 5.

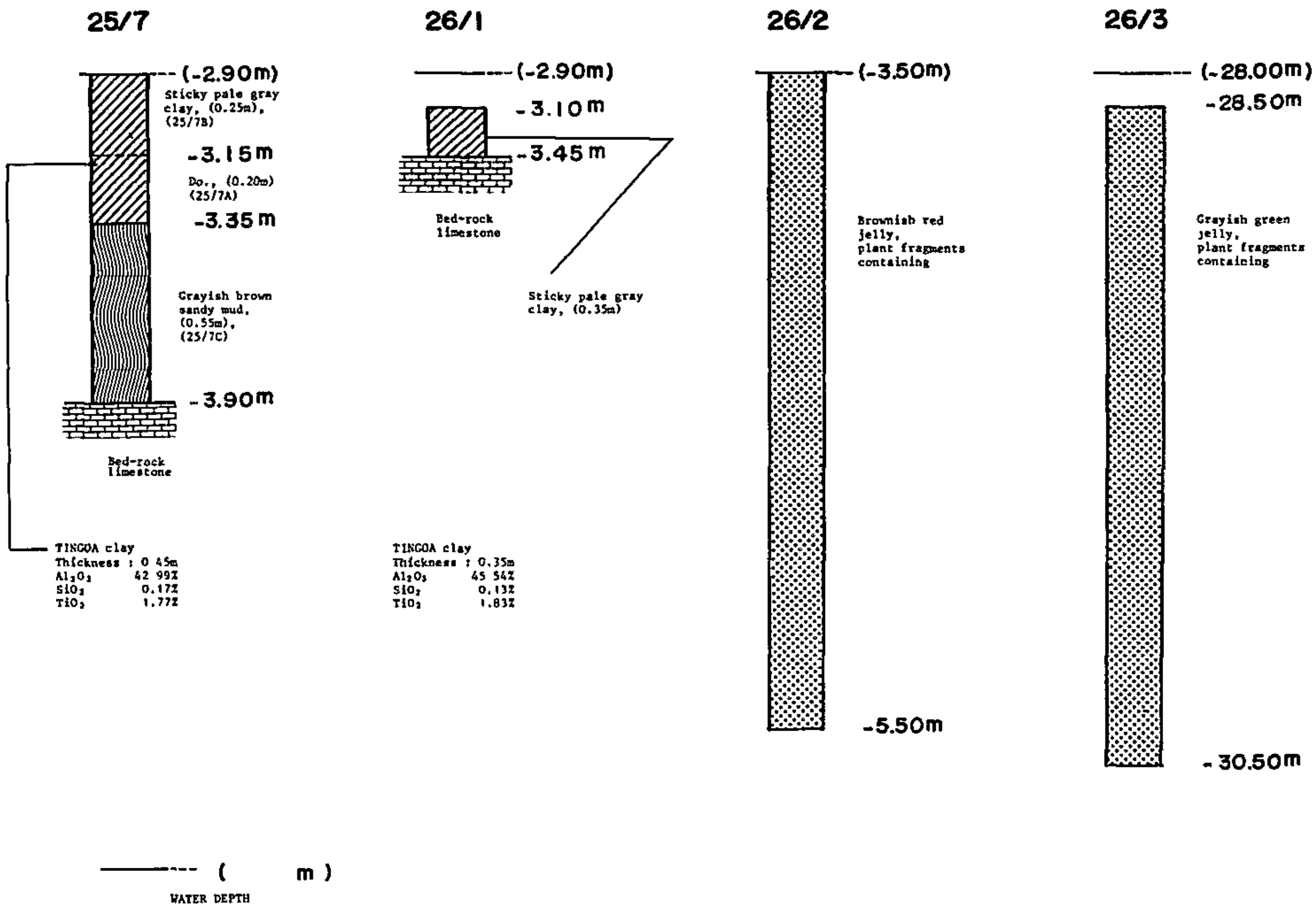

23/1
(-29.00m)
Grayish green jelly
-30.50m
23/2
(-29.50m)
Grayish green jelly
-31.50m
23/3
(-29.50m)
Grayish green jelly
-31.50m
24/1
(-30.00m)
-32.00m
Grayish green jelly
-34.00m
(m)
WATER DEPTH

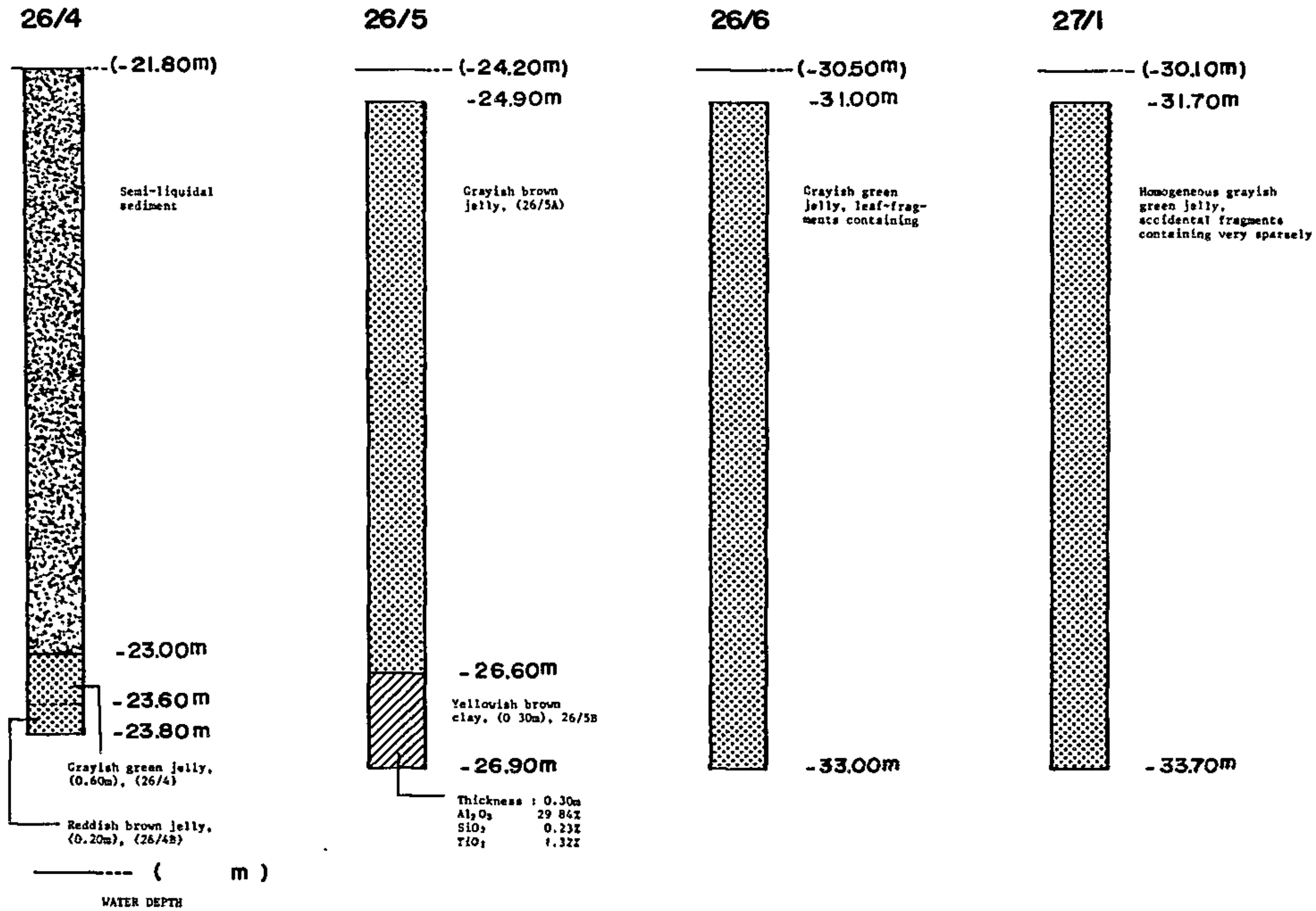
24/5
(-27.20m)
-27.50m
Semi-liquidal sediment
-28.50m
Grayish green jelly
-29.50m
24/4
(-23.00m)
Semi-liquidal sediment
-23.70m
Grayish green jelly, leaf and small shell fragments containing
-25.00m
24/3
(-30.00m)
-31.50m
Grayish green jelly (24/3A)
-32.00m
Brown muddy sediment, plant fragments containing (24/3B)
-33.50m
24/2
(-30.40m)
-31.00m
Grayish green jelly
-33.00m
(m)
WATER DEPTH


24/6
(-31.40m)
-34.20m
Grayish green jelly
-36.20m
24/7
(-31.00m)
-33.00m
Semi-liquidal sediment
-34.00m
Grayish green jelly, plant fragments containing
-35.00m
Bed-rock limestone
25/1
(-30.60m)
Semi-liquidal sediment
-31.60m
Grayish green jelly, plant fragments containing
-32.60m
25/2
(-29.40m)
Grayish green jelly
-31.40m
(m)
WATER DEPTH

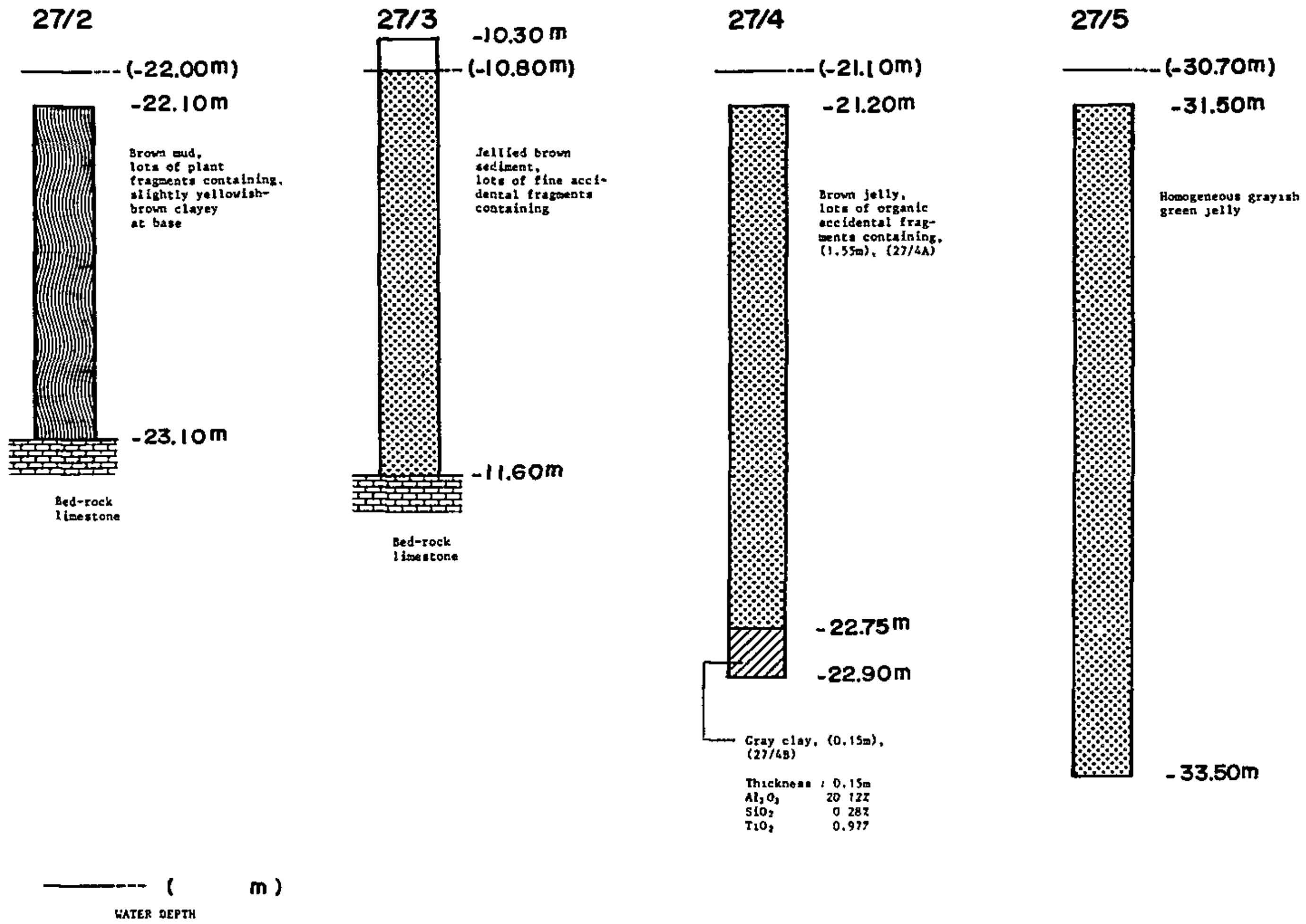


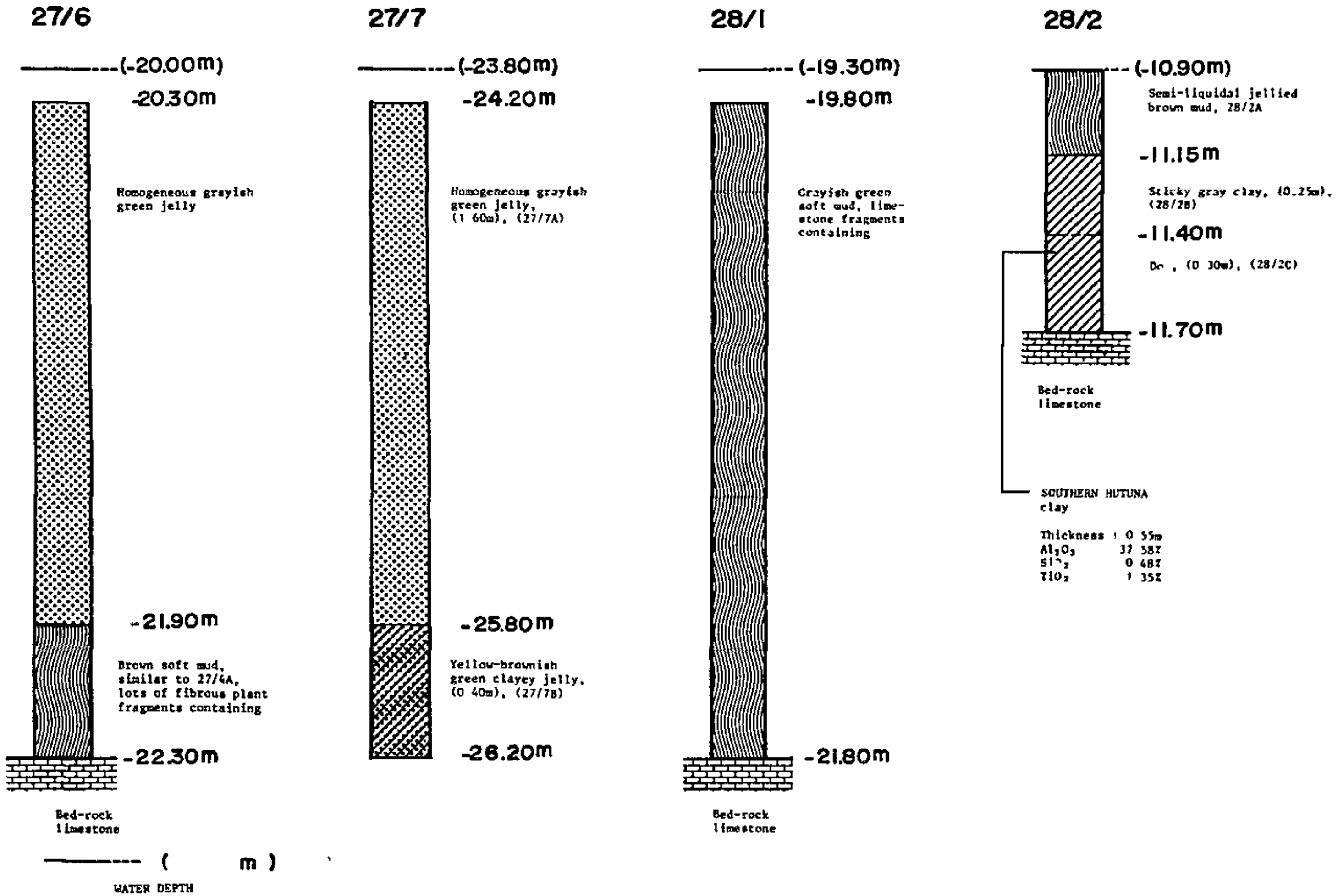
25/3
(-26.00m)
Grayish green jelly, sparsely plant fragments containing
-27.50m
Bed-rock limestone
25/4
(-25.00m)
Grayish green jelly, sparsely amorphous brown spots containing
-27.00m
-20.50m
25/5
(-20.70m)
Grayish brown jelly, sparsely amorphous red spots containing
-22.50m
25/6
(-7.00m)
Brownish red jelly, fibrous plant fragments on near base
-9.00m
(m)
WATER DEPTH

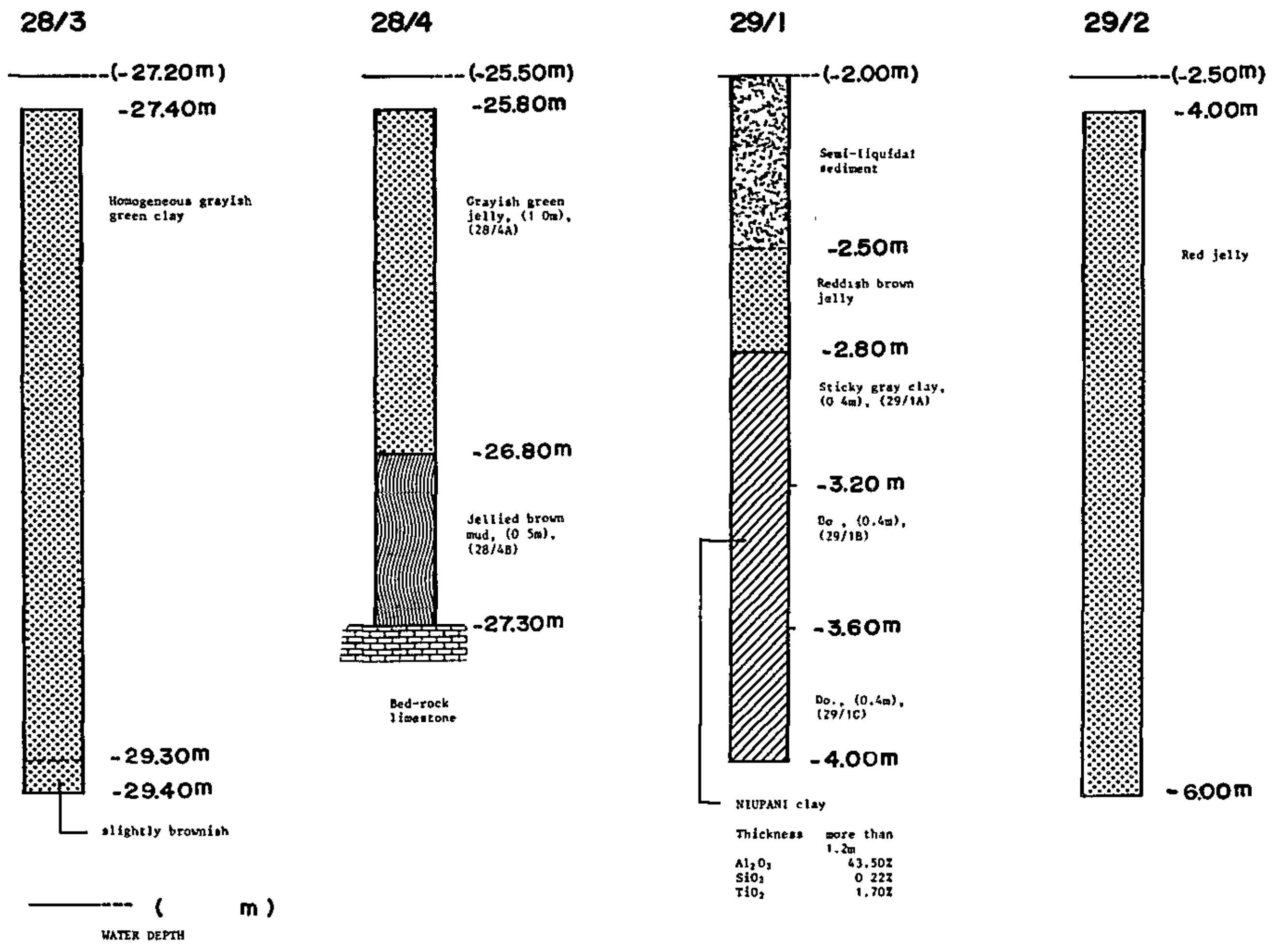

25/7
(-2.90m)
Sticky pale gray clay, (0.25m), (25/7B)
-3.15m
Do., (0.20m) (25/7A)
-3.35m
Grayish brown sandy mud, (0.55m), (25/7C)
-3.90m
Bed-rock limestone
TINGOA clay
Thickness : 0.45m
Al2O3 42.99%
SiO2 0.17%
TiO2 1.77%
26/1
(-2.90m)
-3.10m
-3.45m
Bed-rock limestone
Sticky pale gray clay, (0.35m)
TINGOA clay
Thickness : 0.35m
Al2O3 45.54%
SiO2 0.13%
TiO2 1.83%
26/2
(-3.50m)
Brownish red jelly, plant fragments containing
-5.50m
26/3
(-28.00m)
-28.50m
Grayish green jelly, plant fragments containing
-30.50m
(m)
WATER DEPTH

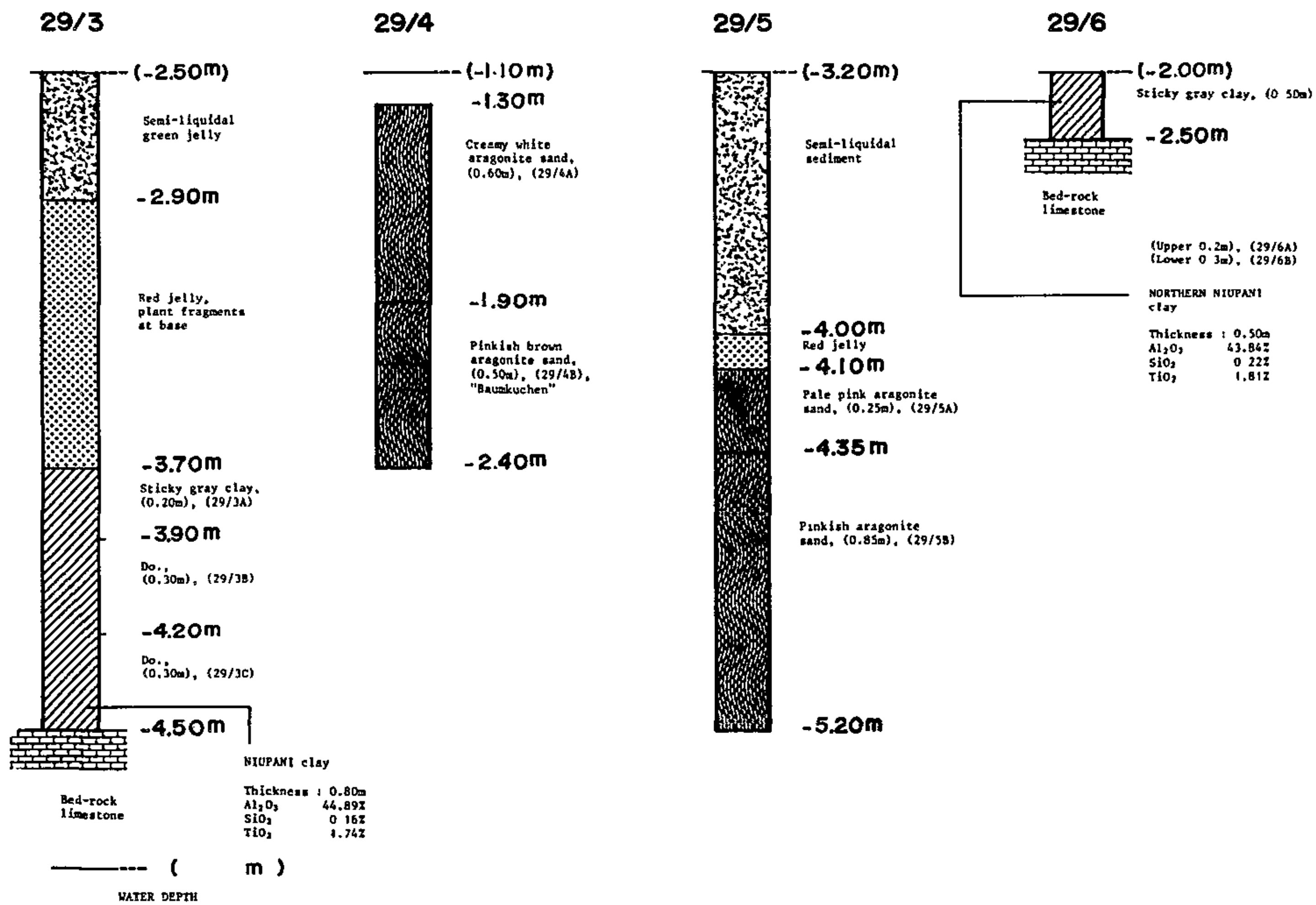


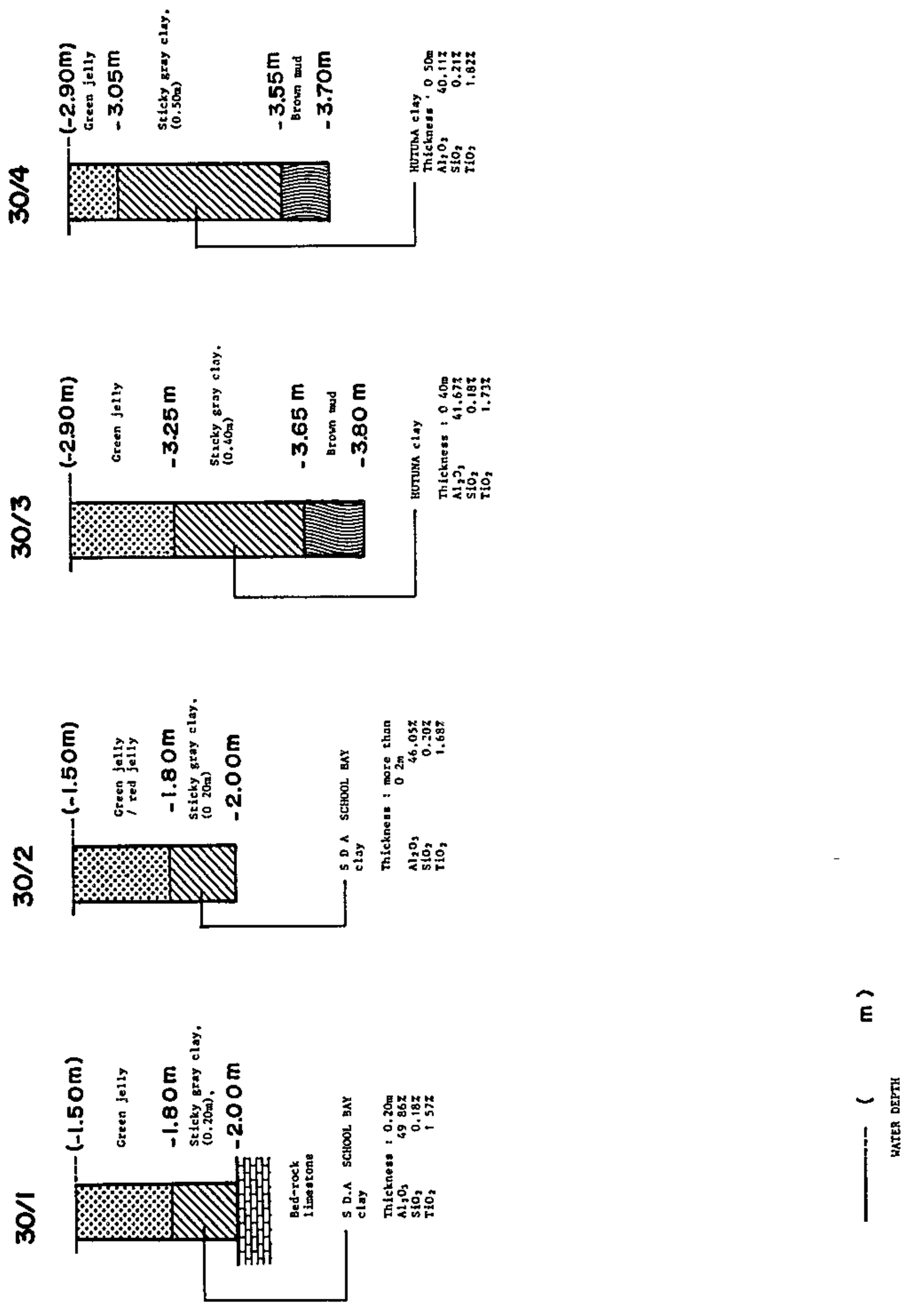
26/4
(-21.80m)
Semi-liquidal sediment
-23.00m
-23.60m
-23.80m
Grayish green jelly, (0.60m), (26/4)
Reddish brown jelly, (0.20m), (26/4B)
(m)
WATER DEPTH
26/5
(-24.20m)
-24.90m
Grayish brown jelly, (26/5A)
-26.60m
Yellowish brown clay, (0 30m), 26/5B
-26.90m
Thickness : 0.30m
Al_2O_3 29.84%
SiO_2 0.23%
TiO_2 1.32%
26/6
(-30.50m)
-31.00m
Grayish green jelly, leaf-fragments containing
-33.00m
27/1
(-30.10m)
-31.70m
Homogeneous grayish green jelly, accidental fragments containing very sparsely
-33.70m

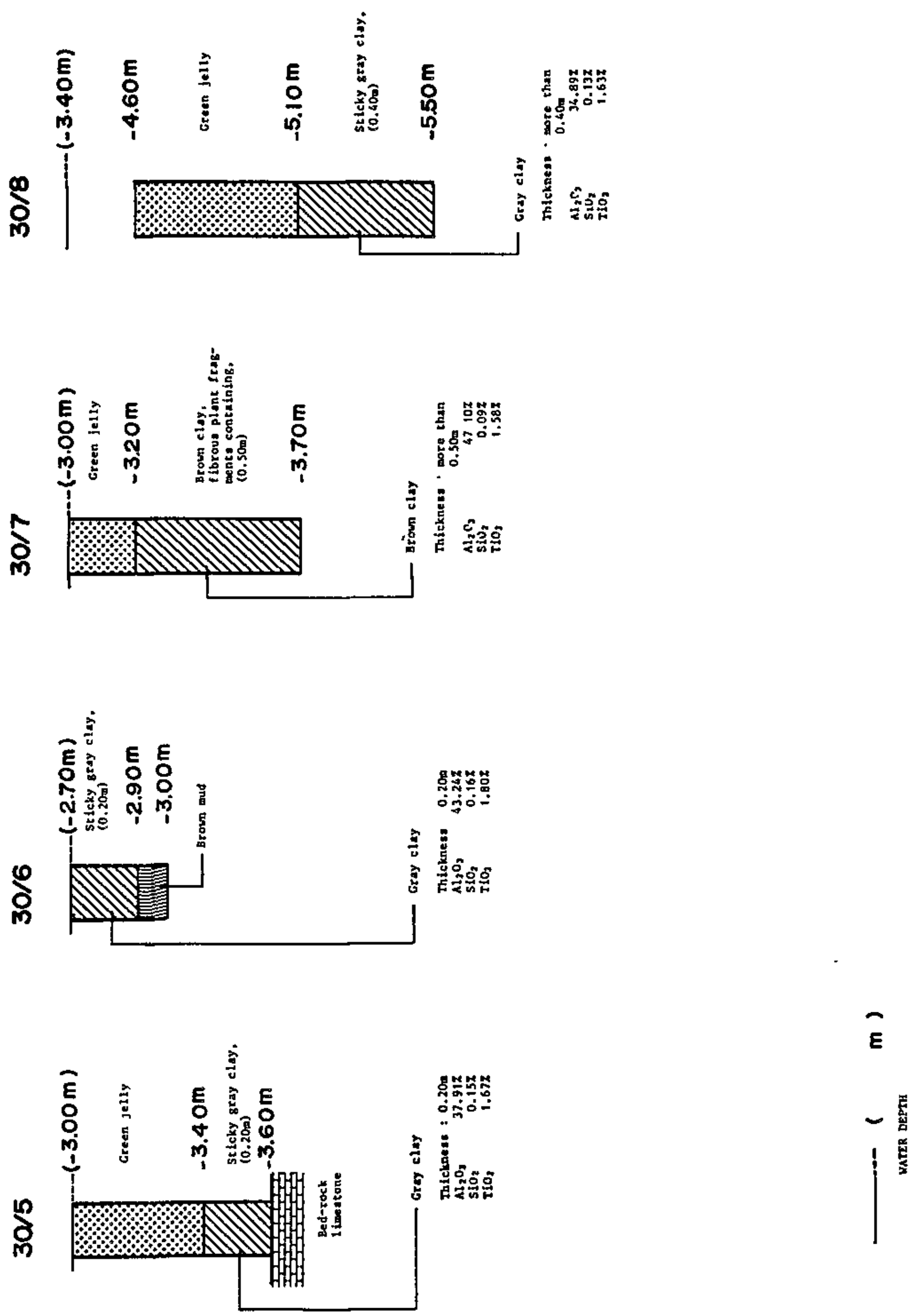

27/2
(-22.00m)
-22.10m
Brown mud, lots of plant fragments containing, slightly yellowish-brown clayey at base
-23.10m
Bed-rock limestone
27/3
-10.30 m
(-10.80m)
Jellied brown sediment, lots of fine accidental fragments containing
-11.60m
Bed-rock limestone
27/4
(-21.10m)
-21.20m
Brown jelly, lots of organic accidental fragments containing, (1.55m), (27/4A)
-22.75m
-22.90m
Gray clay, (0.15m), (27/4B)
Thickness : 0.15m
Al_2O_3 20 12%
SiO_2 0 28%
TiO_2 0.97%
27/5
(-30.70m)
-31.50m
Homogeneous grayish green jelly
-33.50m
(m)
WATER DEPTH


27/6
(-20.00m)
-20.30m
Homogeneous grayish green jelly
-21.90m
Brown soft mud, similar to 27/4A, lots of fibrous plant fragments containing
-22.30m
Bed-rock limestone
(m)
WATER DEPTH
27/7
(-23.80m)
-24.20m
Homogeneous grayish green jelly, (1 60m), (27/7A)
-25.80m
Yellow-brownish green clayey jelly, (0 40m), (27/7B)
-26.20m
28/1
(-19.30m)
-19.80m
Grayish green soft mud, limestone fragments containing
-21.80m
Bed-rock limestone
28/2
(-10.90m)
Semi-liquidal jellied brown mud, 28/2A
-11.15m
Sticky gray clay, (0.25m), (28/2B)
-11.40m
Do , (0 30m), (28/2C)
-11.70m
Bed-rock limestone
SOUTHERN HUTUNA clay
Thickness : 0 55m
Al_2O_3 37 58%
TiO_2 1 35%


28/3
(-27.20m)
-27.40m
Homogeneous grayish green clay
-29.30m
-29.40m
slightly brownish
28/4
(-25.50m)
-25.80m
Grayish green jelly, (1 0m), (28/4A)
-26.80m
Jellied brown mud, (0 5m), (28/4B)
-27.30m
Bed-rock limestone
29/1
(-2.00m)
Semi-liquidal sediment
-2.50m
Reddish brown jelly
-2.80m
Sticky gray clay, (0 4m), (29/1A)
-3.20 m
Do , (0.4m), (29/1B)
-3.60m
Do., (0.4m), (29/1C)
-4.00m
NIUPANI clay
Thickness more than 1.2m
Al2O3 43.50%
SiO2 0 22%
TiO2 1.70%
29/2
(-2.50m)
-4.00m
Red jelly
-6.00m
(m)
WATER DEPTH


29/3
(-2.50m)
Semi-liquidal green jelly
-2.90m
Red jelly, plant fragments at base
-3.70m
Sticky gray clay, (0.20m), (29/3A)
-3.90m
Do., (0.30m), (29/3B)
-4.20m
Do., (0.30m), (29/3C)
-4.50m
Bed-rock limestone
NIUPANI clay
Thickness : 0.80m
Al_2O_3 44.89%
SiO_2 0 16%
TiO_2 4.74%
(m)
WATER DEPTH
29/4
(-1.10m)
-1.30m
Creamy white aragonite sand, (0.60m), (29/4A)
-1.90m
Pinkish brown aragonite sand, (0.50m), (29/4B), "Baumkuchen"
-2.40m
29/5
(-3.20m)
Semi-liquidal sediment
-4.00m
Red jelly
-4.10m
Pale pink aragonite sand, (0.25m), (29/5A)
-4.35m
Pinkish aragonite sand, (0.85m), (29/5B)
-5.20m
29/6
(-2.00m)
Sticky gray clay, (0 50m)
-2.50m
Bed-rock limestone
(Upper 0.2m), (29/6A)
(Lower 0 3m), (29/6B)
NORTHERN NIUPANI clay
Thickness : 0.50m
Al_2O_3 43.84%
SiO_2 0 22%
TiO_2 1.81%


30/1
(-1.50m)
Green jelly
-1.80m
Sticky gray clay, (0.20m),
-2.00m
Bed-rock limestone
S D.A SCHOOL BAY clay
Thickness : 0.20m
Al_2O_3 49 86%
SiO_2 0.18%
TiO_2 1 57%
30/2
(-1.50m)
Green jelly / red jelly
-1.80m
Sticky gray clay, (0 20m)
-2.00m
S D A SCHOOL BAY clay
Thickness : more than 0 2m
Al_2O_3 46.05%
SiO_2 0.20%
TiO_2 1.68%
30/3
(-2.90m)
Green jelly
-3.25 m
Sticky gray clay, (0.40m)
-3.65 m
Brown mud
-3.80 m
HUTUNA clay
Thickness : 0 40m
Al_2O_3 41.67%
SiO_2 0.18%
TiO_2 1.73%
30/4
(-2.90m)
Green jelly
-3.05m
Sticky gray clay, (0.50m)
-3.55m
Brown mud
-3.70m
HUTUNA clay
Thickness : 0 50m
Al_2O_3 40.11%
SiO_2 0.21%
TiO_2 1.82%
(m)
WATER DEPTH


30/5
(-3.00m)
Green jelly
-3.40m
Sticky gray clay, (0.20m)
-3.60m
Bed-rock limestone
Gray clay
Thickness : 0.20m
Al2O3 37.91%
SiO2 0.15%
TiO2 1.67%
30/6
(-2.70m)
Sticky gray clay, (0.20m)
-2.90m
-3.00m
Brown mud
Gray clay
Thickness 0.20m
Al2O3 43.24%
SiO2 0.16%
TiO2 1.80%
30/7
(-3.00m)
Green jelly
-3.20m
Brown clay, fibrous plant fragments containing, (0.50m)
-3.70m
Brown clay
Thickness : more than 0.50m
Al2O3 47.10%
SiO2 0.09%
TiO2 1.58%
30/8
(-3.40m)
-4.60m
Green jelly
-5.10m
Sticky gray clay, (0.40m)
-5.50m
Gray clay
Thickness : more than 0.40m
Al2O3 34.89%
SiO2 0.13%
TiO2 1.63%
(m)
WATER DEPTH

ANNEX 3

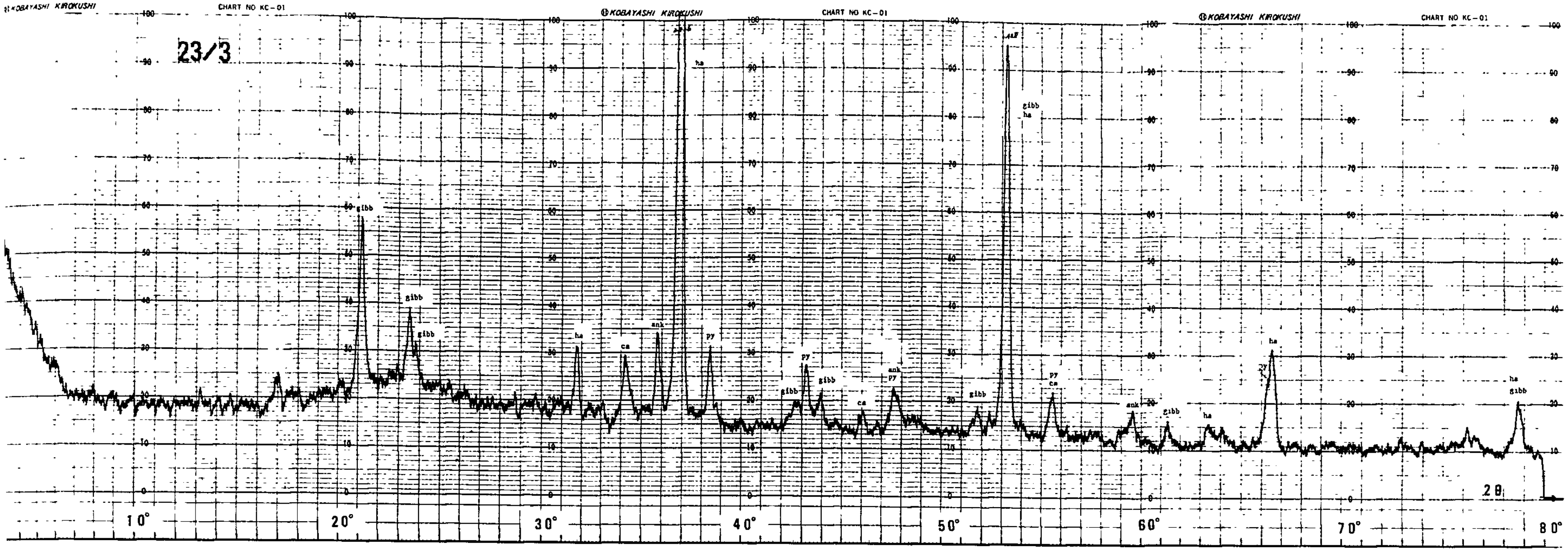
ANNEX 3

X-RAY POWDER DIFFRACTION CHARTS

Diffractometer	:	Type RAD – 2A RIGAKU DENKI Co., Ltd.	
Specifications	:	Target/Filter	Cobalt/Iron
		Voltage/Current	30 kV/10 mA
		Count Full Scale	400 cps.
		Time Constant	2 sec.
		PHA	050 – 200
		Div. slit/Rec. slit	1 deg/0.3 mm
		Scan Speed	2 deg/min
		Chart Speed	2 cm/min

Abbreviation of mineral names:

anat	:	anatase	goe	:	goethite
ank	:	ankerite	gyp	:	gypsum
ara	:	aragonite	ha	:	halite
boe	:	boehmite	ma	:	marcasite
ca	:	calcite	py	:	pyrite
crn	:	crandallite	rhod	:	rhodochrosite
gibb	:	gibbsite	si	:	siderite


KOBAYASHI KIROKUSHI
CHART NO KC-01
23/3
gibb
ha
ca
ank
py
2θ
10°
20°
30°
40°
50°
60°
70°
80°

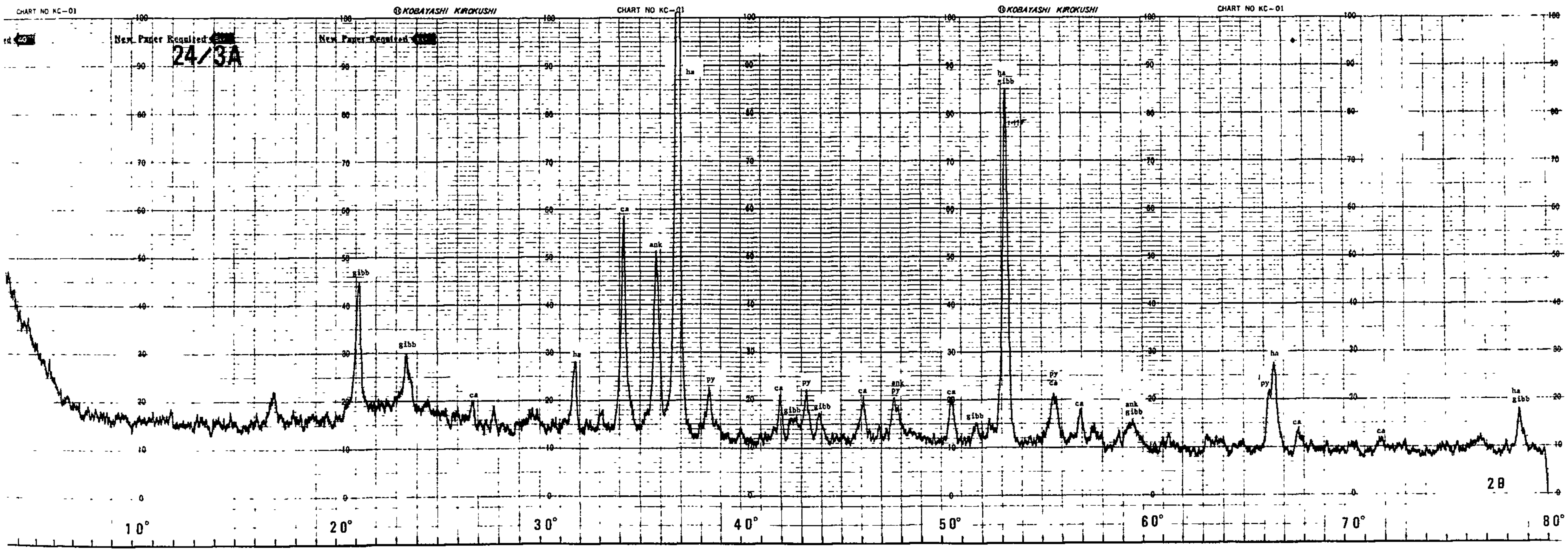
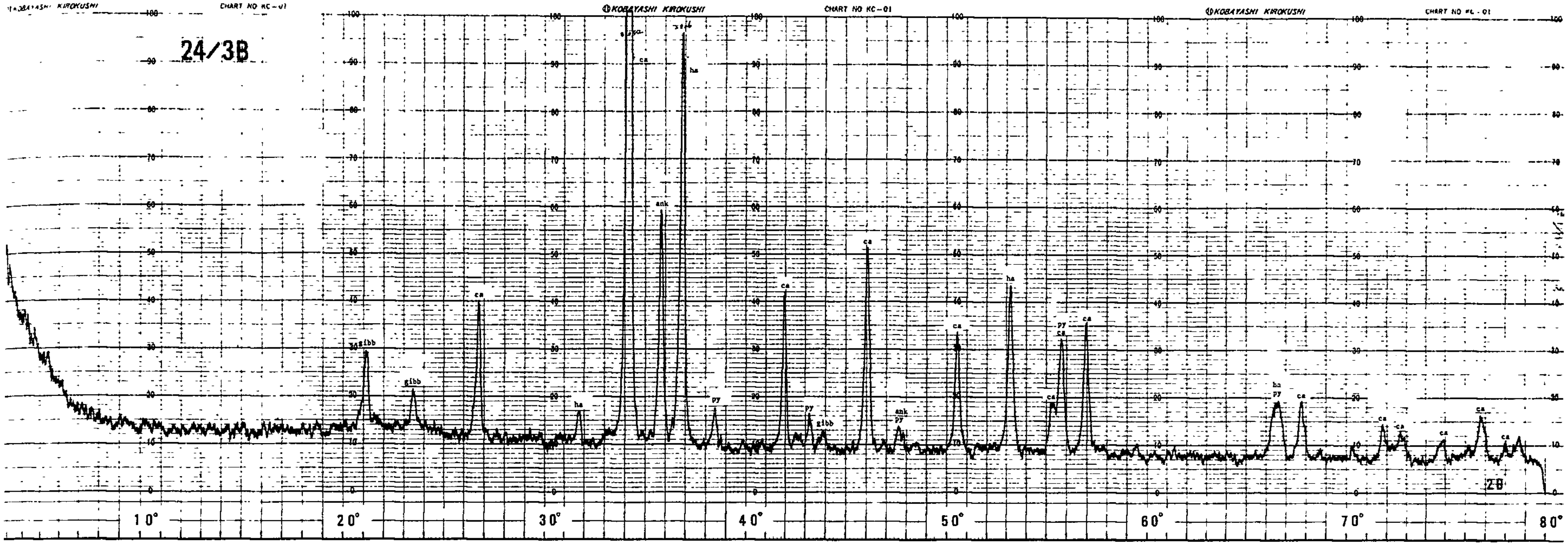
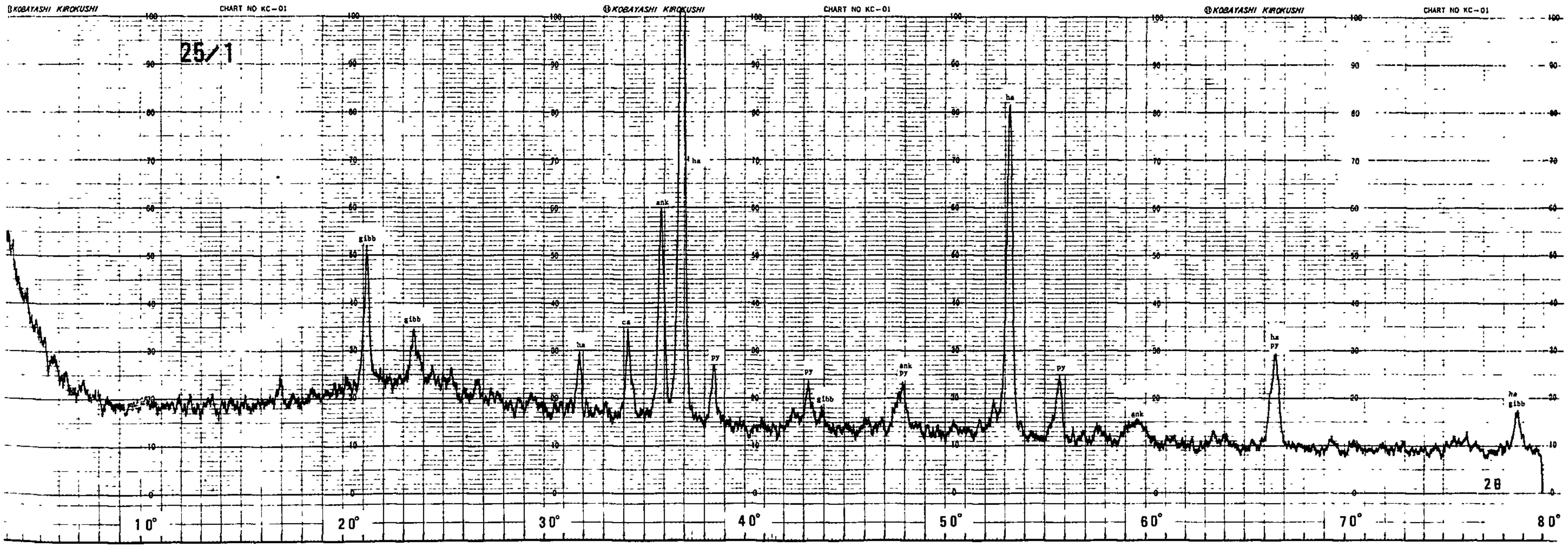


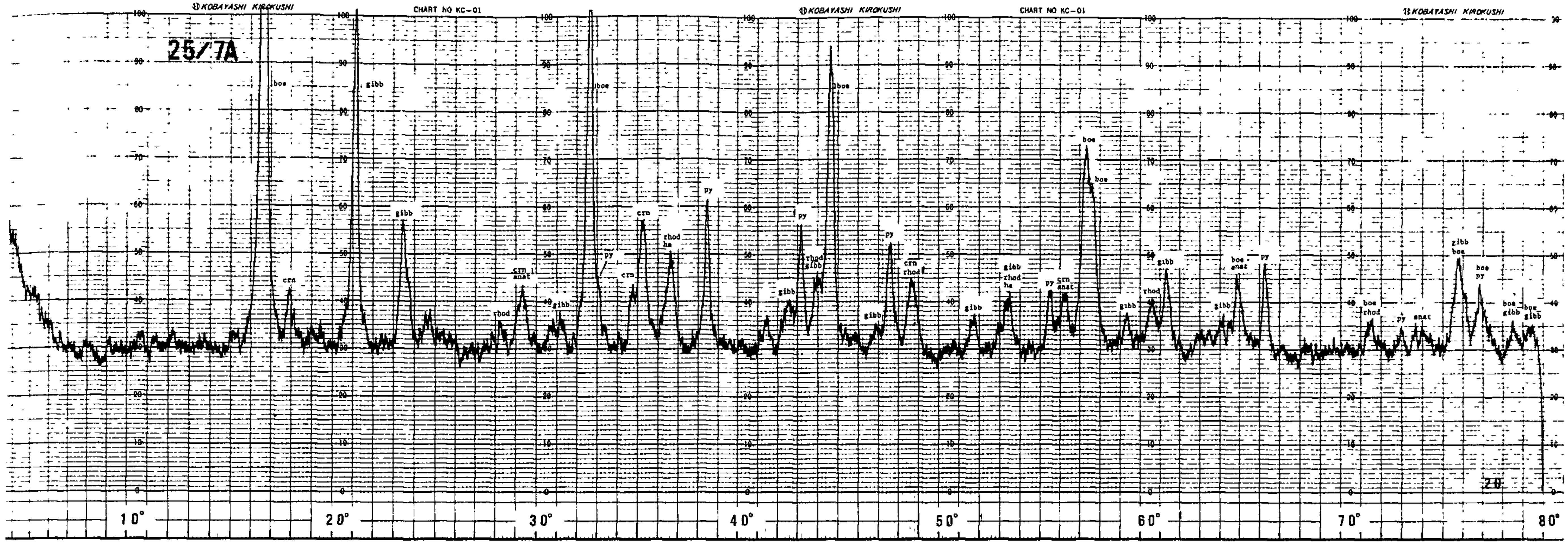
CHART NO KC-01
KOBAYASHI KIROKUSHI
New Paper Required
24/3A
gibb
ha
ca
ank
py
2θ
10°
20°
30°
40°
50°
60°
70°
80°

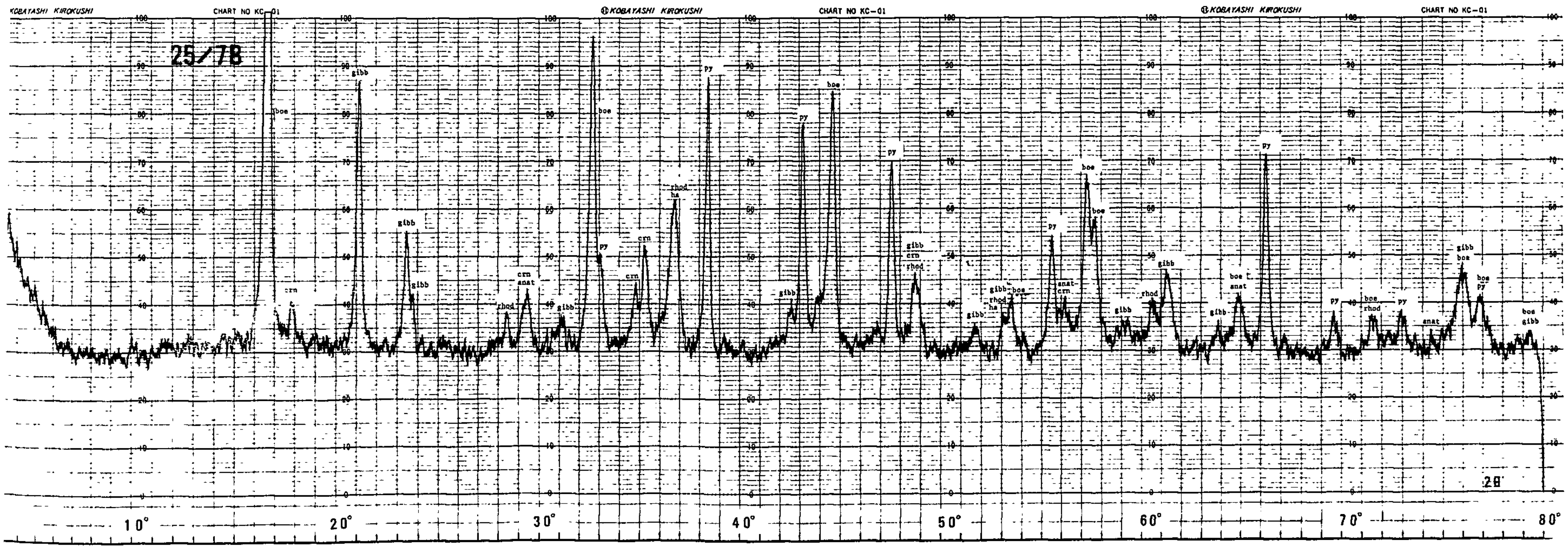


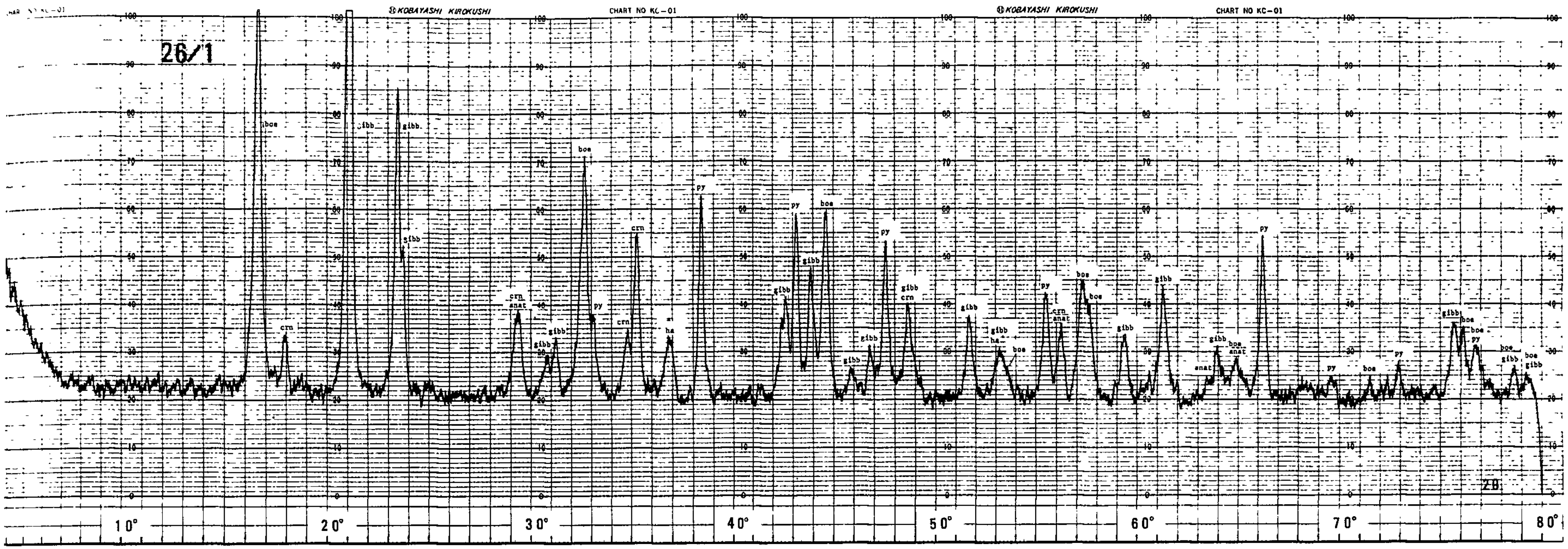
KOBAYASHI KIROKUSHI
CHART NO KC-01
24/3B
gibb
gibb
ca
ha
ca
ank
ha
py
ca
py
gibb
ca
ank
py
ca
ha
py
ca
ca
ca
ha
py
ca
ca
ca
ca
ca
ca
2θ
10°
20°
30°
40°
50°
60°
70°
80°

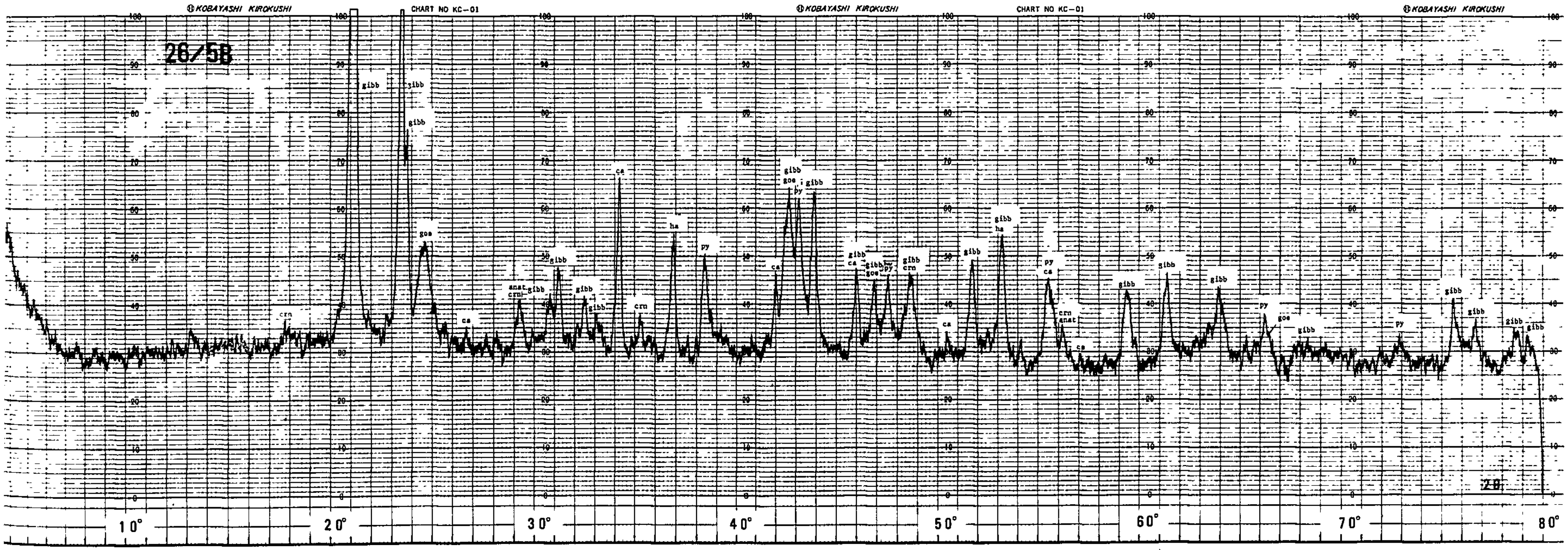


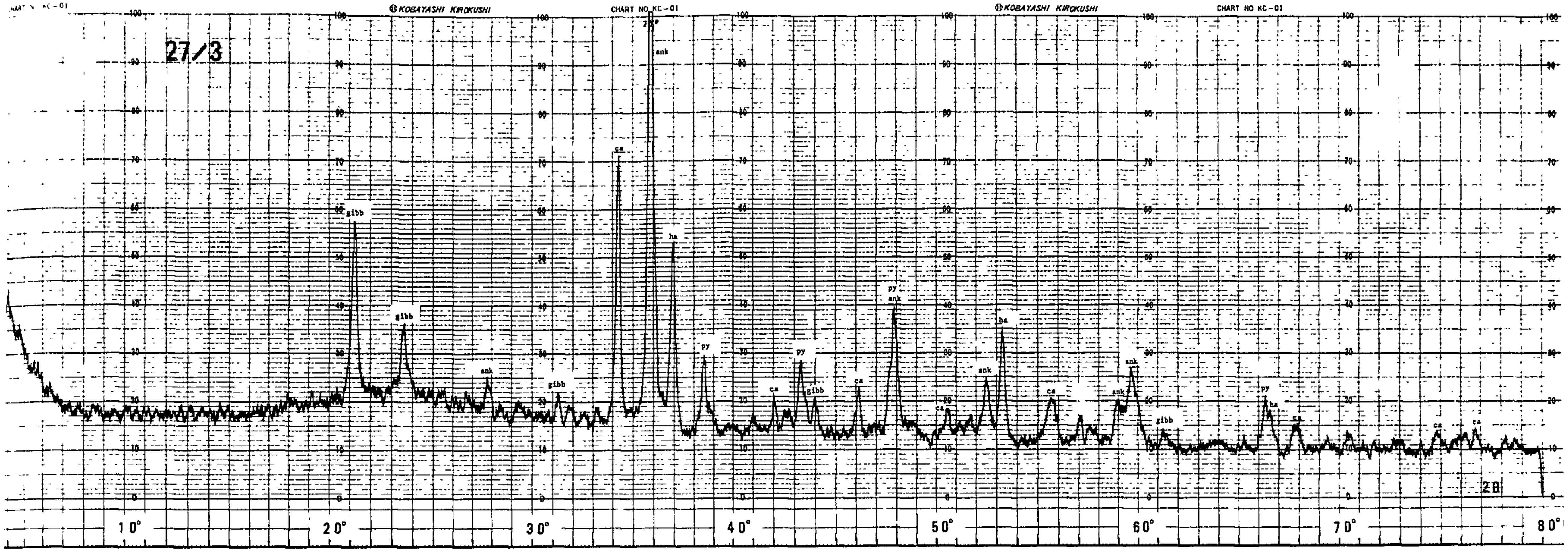
KOBAYASHI KIROKUSHI
CHART NO KC-01
25/1
gibb
gibb
ha
ca
ank
ha
py
py
gibb
ank
py
ha
py
ank
ha
py
ha
gibb
2θ
10°
20°
30°
40°
50°
60°
70°
80°

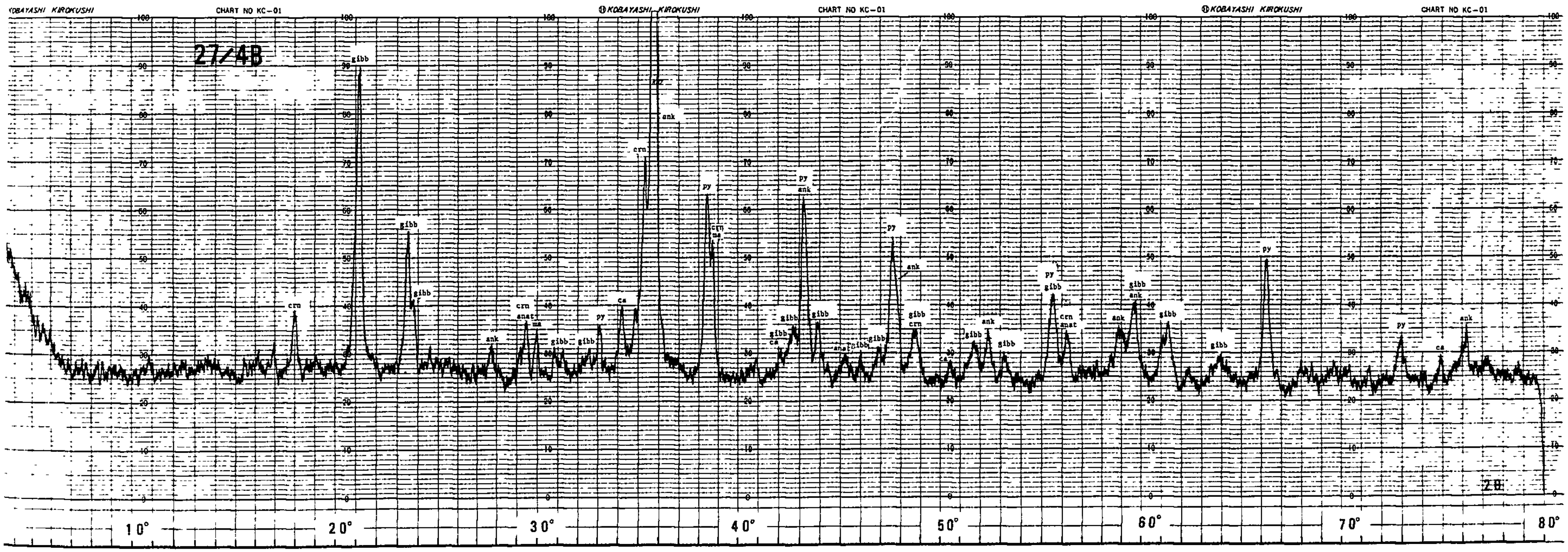

25/7A
KOBAYASHI KIROKUSHI
CHART NO KC-01
boe
gibb
crn
anat
rhod
ha
py
2θ
10°
20°
30°
40°
50°
60°
70°
80°

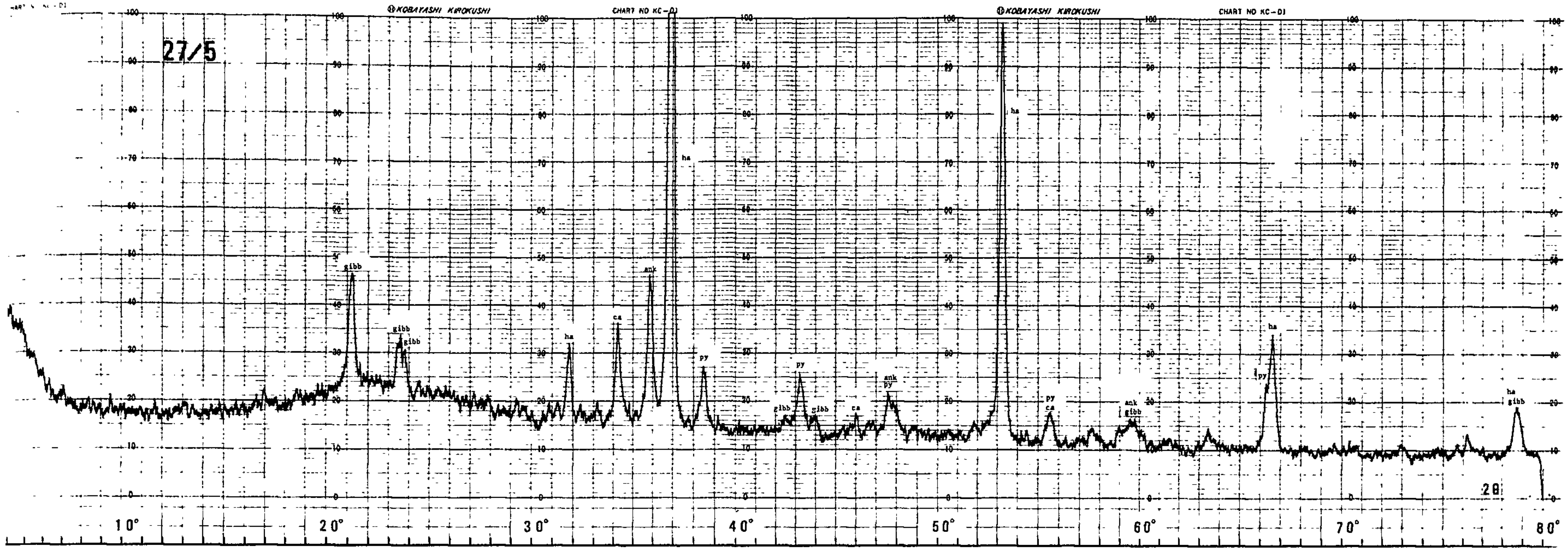

25/7B
KOBAYASHI KIROKUSHI
CHART NO KC-01
boe
gibb
crn
anat
rhod
ha
py
2θ
10°
20°
30°
40°
50°
60°
70°
80°

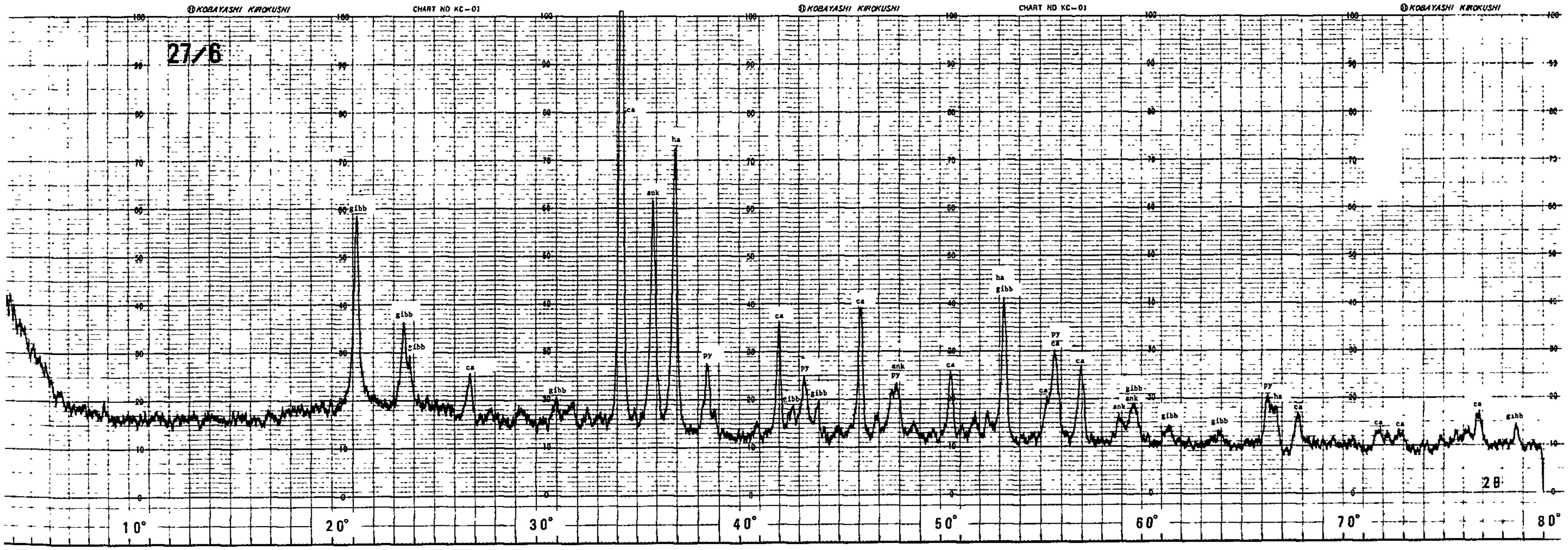

26/1
KOBAYASHI KIROKUSHI
CHART NO KC-01
boe
gibb
crn
anat
py
ha
2θ
10°
20°
30°
40°
50°
60°
70°
80°

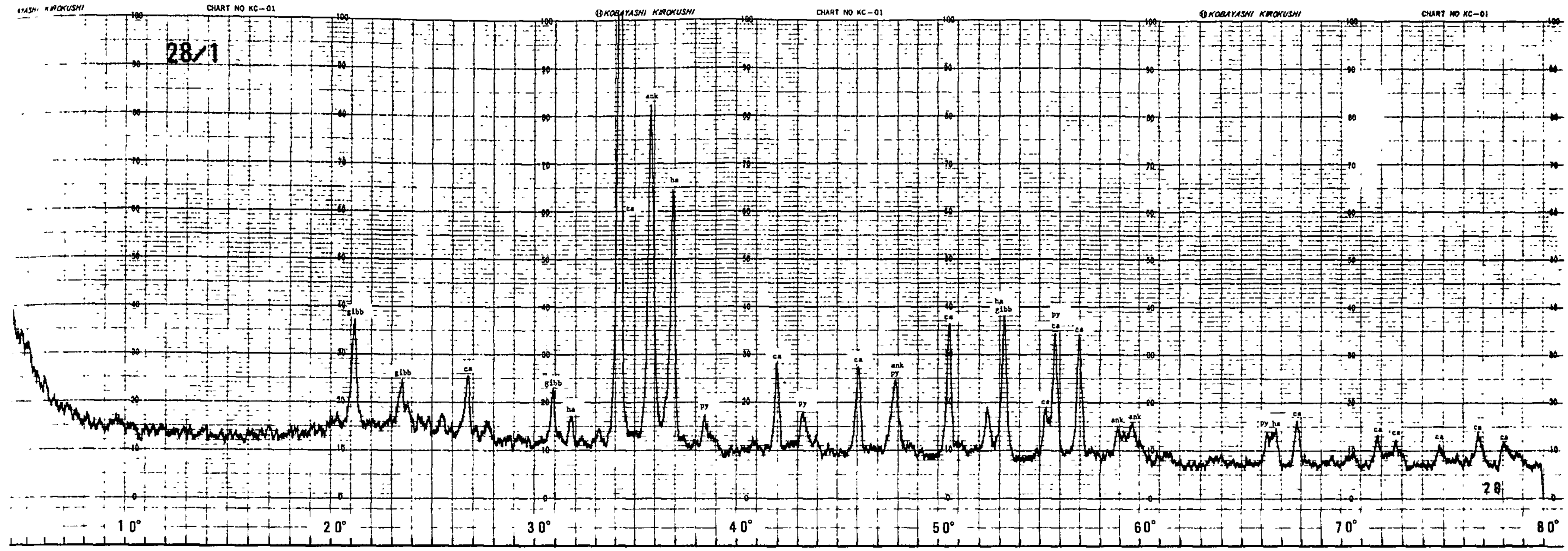

26/5B
KOBAYASHI KIROKUSHI
CHART NO KC-01
gibb
goe
crn
anat
ca
ha
py
2θ
10°
20°
30°
40°
50°
60°
70°
80°

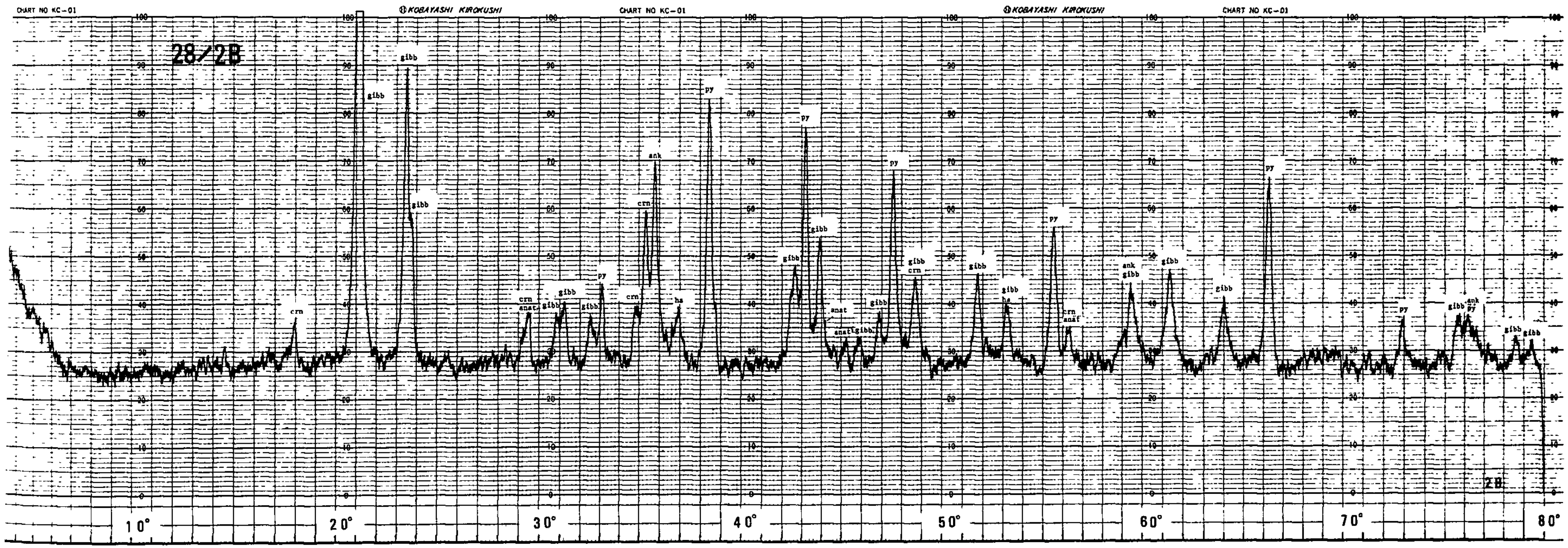

27/3
KOBAYASHI KIROKUSHI
CHART NO KC-01
gibb
ca
ank
ha
py
10°
20°
30°
40°
50°
60°
70°
80°
2θ


27/4B
KOBAYASHI KIROKUSHI
CHART NO KC-01
gibb
crn
ank
py
ca
anat
10°
20°
30°
40°
50°
60°
70°
80°
2θ


KOBAYASHI KIROKUSHI
CHART NO KC-01
27/5
gibb
gibb
ha
ca
ank
ha
py
py
ank
py
ha
py
ca
ank
gibb
ha
py
ha
gibb
2θ
10°
20°
30°
40°
50°
60°
70°
80°


KOBAYASHI KIROKUSHI
CHART NO KC-01
27/6
gibb
gibb
gibb
ca
ca
ank
ha
py
ca
py
ca
ank
py
ha
gibb
py
ca
ca
gibb
ank
py
ha
ca
ca
gibb
2θ
10°
20°
30°
40°
50°
60°
70°
80°


28/1
10°
20°
30°
40°
50°
60°
70°
80°
2θ


28/2B
10°
20°
30°
40°
50°
60°
70°
80°
2θ