PC-29 Pacuan no. 1, Maasin (Text-figs. 7-1, 17; Tables 7-1, 2; Pl. 12, fig. 5)

This survey site is a water well in Pacuan village located about 2 km away to the south of Magsaysay village. This well was bored in 1957 and completed with an iron pipe of 4 inches, and its depth is said to be 49 m. The well produces light brown colored fresh water accompanied with weak gas bubbles. The well once freely flowed out water before, but it stops at present. However, the level of water reaches near the well head and weak gas bubbles are recognized on the surface of water. The Cl^- content of water is 68 mg/l and the gas contains 93.63 vol.% of methane.

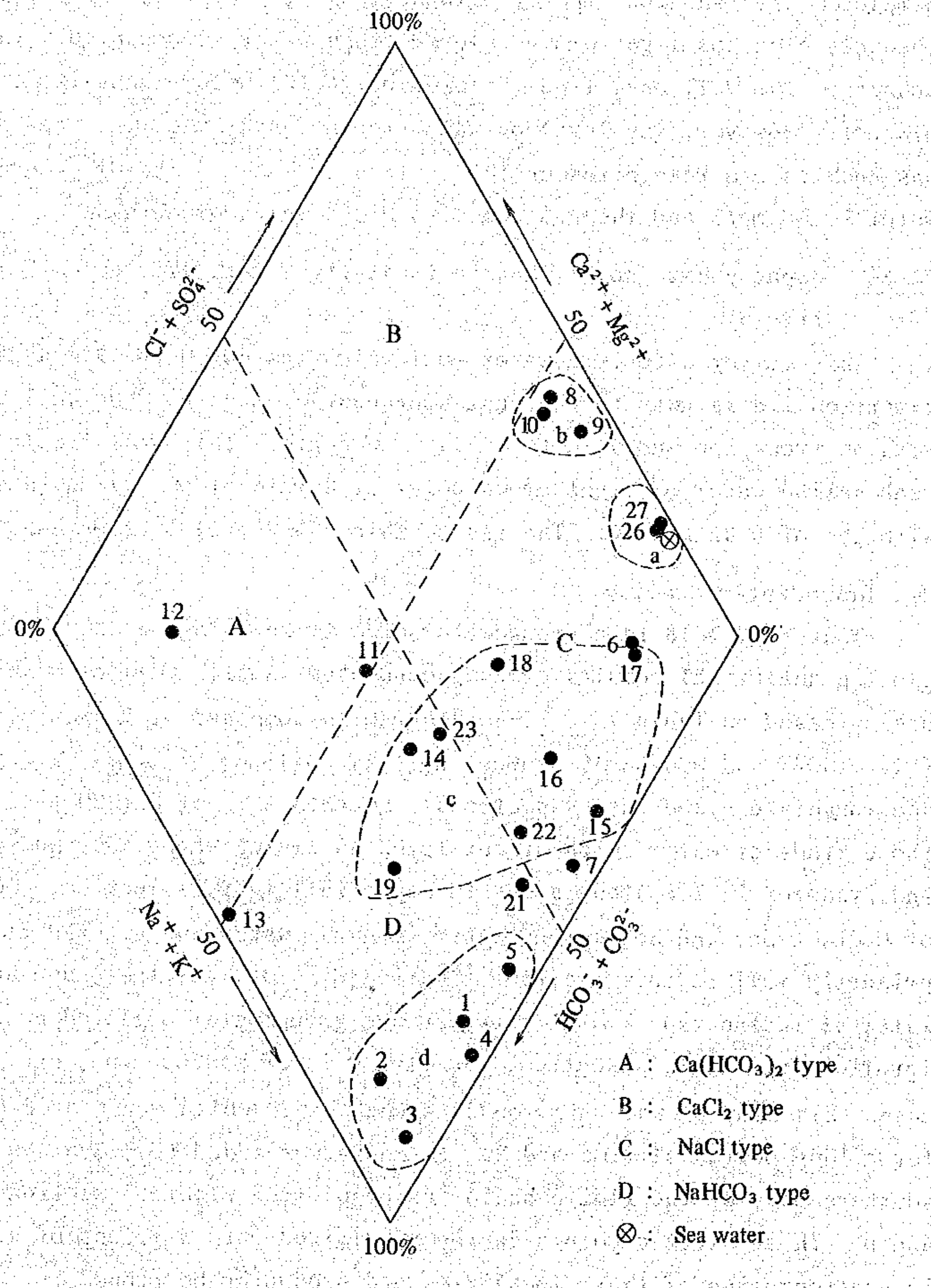
PC-30 Bagacay Ext. no. 1, Maasin (Text-figs. 7-1, 17; Tables 7-1, 2; Pl. 12, fig. 6)

This survey site is a water well which was bored in 1974 at Bagacay Extension 1.5 km away to the east-southeast of Maasin. The well is completed with an iron pipe and said to be 91 m in depth. This well freely flows out weak saline water of light brown color at a rate of 0.5 kl/day accompanied with gas of 0.02 m^3/day. The gas contains 95.89 vol.% of methane.

2) Groundwater quality

Text-fig. 7-18 is a groundwater quality key diagram which has been plotted analytical results of 24 groundwater samples collected in the Iloilo basin, based on Table 7-1. This diagram is composed of 2 axes of anion (Cl^- + SO_4^{2-} and HCO_3^- + CO_3^{2-}) and 2 axes of cation (Ca^{2+} + Mg^{2+} and Na^+ + K^+) and roughly divided into 4 sections. Section A is of $Ca(HCO_3)_2$ type and those kinds of water which are utilized as living water and industrial water and produces in limestone areas in Japan fall in this section. Section B is of $CaCl_2$ type, and hot spring water, mineral water and altered fossil water primarily fall in this section. Section C is of NaCl type, and accompanying water of iodine type kyosui-sei-gasu and groundwater polluted by sea water invation fall in this section. Section D is of $NaHCO_3$ type, and in many cases this kind of water is found in such water which was stored underground for a long period of time and Na^+ in rocks was added to. Groundwaters of the southern part of the Iloilo basin can be plotted within 3 sections of A, C and D. Those plotted points can be subdivided into 4 groups of a through d in consideration of their localities and producing horizons.

NaCl type water samples of the group a (PC-26, 27) were produced from the Guimbal Mudstone, reported by SANTOS (1968), in the vicinity of Maasin (the age of the Mudstone is Late Pliocene around the survey sites).



TEXT-FIGURE 7-18
Key diagram for the groundwater from the Iloilo basin.

These waters are produced from shallow manually dug wells which can be regarded as natural springs, though they contain 11,370 to 14,090 mg/1 of Cl^- and 32.8 to 36.9 mg/1 of I^- and their I^-/Cl^- ratio is high as 2.62 to 2.88. In this connection, if the value of Cl^- is converted to the value of sea water (19,350 mg/1), the value of I^- will be 50.7 to 55.8 mg/1. Since the I^- content of saline water used by Japanese iodine industries as raw material is 30 to 110 mg/1 (some reach 140 mg/1), there is a possibility that iodine type kyosui-sei-gasu deposits are formed in the Guimbal Mudstone.

The groundwater samples of the group b which were collected in the vicinity of Dumangas located in the eastern part of the plain area are close to $CaCl_2$ type (section B) in water quality, and it is considered that those waters are further altered than those of group a. Their I^-/Cl^- ratios are lower than group a, then the potentiality of iodine is considered to be lower than group a. The quality of groundwater is more altered as the age gets older, and according to MOTOJIMA (1972), the groundwater quality in the Pliocene marine deposits in Japan is $NaCl$-HCO_3 and $NaCl$ types, and in the Miocene deposits becomes $CaCl_2$ type, and the I^- content in $CaCl_2$ type of water decreases as the iodine moves into rocks. The waters of group b seem to derive from the Dingle Formation characterized by reefal limestone, and the age of the formation around there is considered as the Late Miocene by the analysis of planktonic foraminifera, therefore it is presumed that the groundwater in the Iloilo basin changes from $NaCl$ type to $CaCl_2$ type (oil field brine type) at the horizon of the Upper/Middle Miocene boundary.

Groundwaters of the group c (PC-14, 15, 16, 17, 18, 19, 22 and 23) were collected from the coastal areas in the southern part of the Iloilo plain including Oton, Alevalo, Mandurriao, Molo, La Paz and Pavia. These waters are produced from shallow water deposits of the Cabatuan Formation covered by a thin Aluvium. As shown in Table 7-1, the Cl^- contents of the waters of this group are generally low and they are within the range of 260 to 2,060 mg/1. Since the depth of wells from which waters were collected is generally shallow as 40 to 100 m, it is considered that the aquifer is affected by flushing of meteoric water. The I^-/Cl^- ratio of 0.9 to 2.0 indicates a possibility that the I^- content will increase to 20 to 40 mg/1 if saline water of which Cl^- content is close to that of sea water can be obtained. However, in view of sedimentary environment, there is less possibility that an iodine type kyosui-sei-gasu deposit with a potentiality exceeding that of underlying Ulian Formation is established in the Cabatuan Formation of this district.

Groundwaters of the group d (PC-1 through 5) of section D ($NaHCO_3$ type) were produced from wells of 34 to 137 m in depth located in the inland area including Zarraga and Sta. Barbara, and are presumed to derive from lagoonal deposits in the Pleistocene Cabatuan Formation. The waters of this group are characterized by the lower content of Cl^- and I^- compared with those of group c.

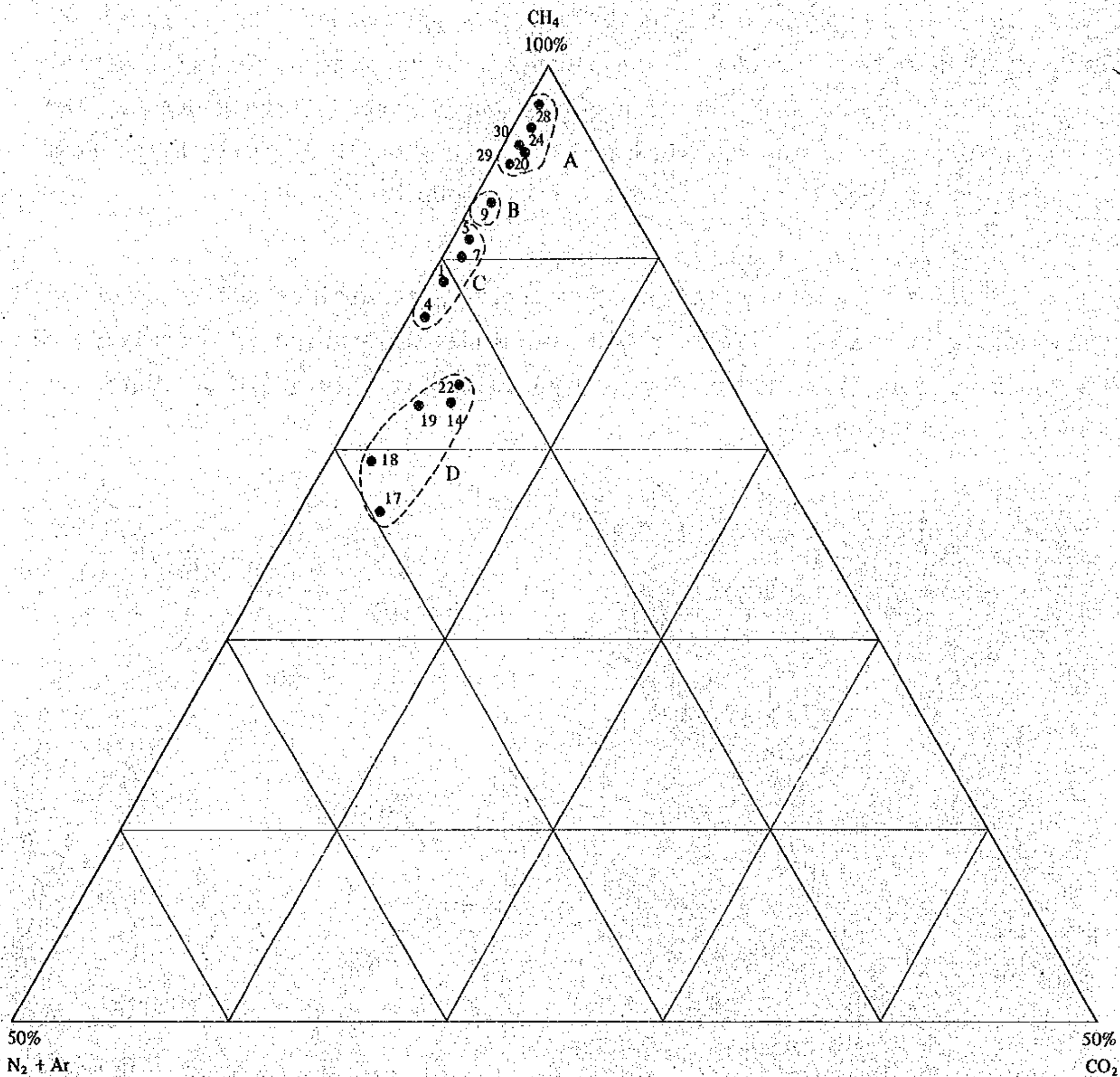
As important sites which do not belong to 4 groups of a through d, there are 2 sites of PC-6 and 7. The waters of these sites derived from the Cabatuan Formation are the same in quality as that of group c, but they are not included in the group c, since they are geographically separated from the localities of group c.

3) Chemical composition of free gas

Text-fig. 7-19 is a triangular net protted the analytical results of free gases collected from 12 free flowing water wells and 2 gas outcrops in the southern part of the Iloilo basin, in accordance with Table 7-2. CH_4, CO_2, and $N_2 + Ar$ are used as the apexes of the triangular net. A remarkable feature to be seen in the diagram is that those points concentrate to the CH_4 and $CH_4 - N_2 + Ar$ areas. In consideration of geological and geographical distribution, these points can be classified into 4 groups of A through D as shown in the diagram.

The gases of the group A (PC-20, 24, 28, 29 and 30) are characterized by high content of CH_4 (93.63 - 98.03 vol.%) and low content of CO_2 (0.07 - 0.60 vol.%). The PC-20 was produced from the Upper Miocene Tubungan Siltstone; PC-24 from the Lower Pleistocene Ulian Formation; other 3 from the Pliocene Guimbal Mudstone. Except PC-24, these gases were produced from relatively older strata than those of other groups.

Gases of the group B have such composition that falls between the groups A and C. The gas of PC-9 belonging to the group B is considered to be originated from the Upper Miocene Dingle Formation. The content of N_2 in PC-9 is relatively high comparing with the group A. This may be attributable to air taken into the gas by flashing of meteoric water. The gas of PC-9 is also characterized by containing helium. It is supposed that helium was not generated in the gas source rocks and reservoirs, but it was generated as a daughter product of radioactive disintegration of uranium (^{235}U) and thorium (^{232}Th) in the basement igneous rocks, rose through fault breccia zone and was dissolved and accumulated in formation water in the Dingle Formation. Consequently, helium is detected in the aquifer near



TEXT-FIGURE 7-19

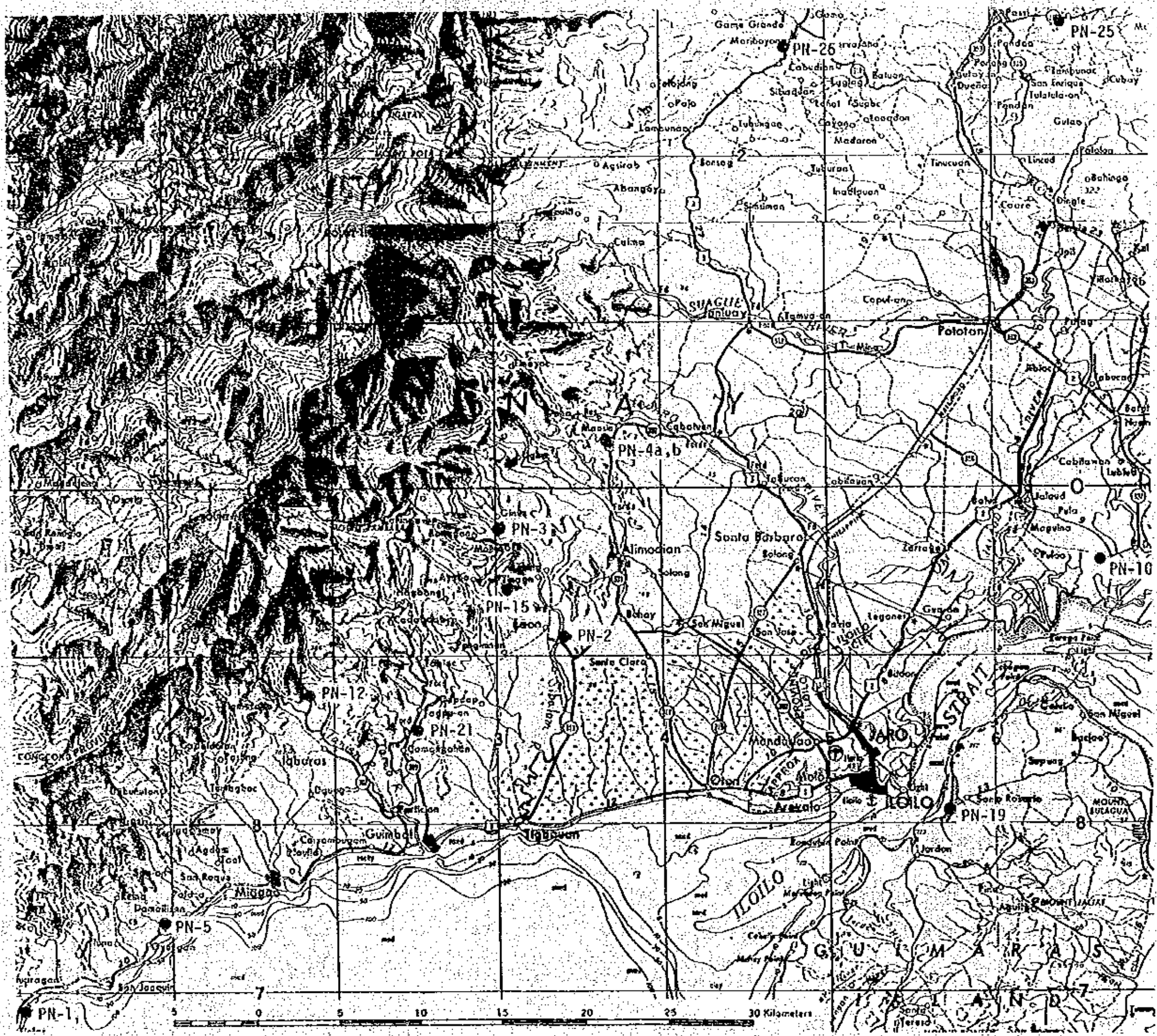
Chemical composition of the free natural gas on the triangular net (vol.%).

fault breccia zone and in relatively older reservoirs.

The gases of the group C (PC-1, 4, 5 and 7) is originated from the Pleistocene Cabatuan Formation at Zarraga, Sta. Barbara and Cabatuan. These gases are composed of 86.95 to 90.87 vol.% of CH_4, 8.00 to 12.55 vol.% of N_2, 0.15 to 0.94 vol.% of CO_2, etc. and they are characterized by their high content of CO_2 and N_2 and low content of CH_4. They resemble to "Quaternary gas" in Japan. The contents of CO_2 and N_2 are generally high in young deposits which maintain activeness for generating gases, or which had preserved activeness up to such geological ages close to the Recent, and they tend to decrease as the age of deposits gets older. These gases are higher than those of group C in the content of CO_2 and N_2 despite they are originated from the same Cabatuan Formation as gases of the group C. The reason for this is presumed that gases of the group D are originated from relatively younger deposits than those of group C.

4) Source rock analysis

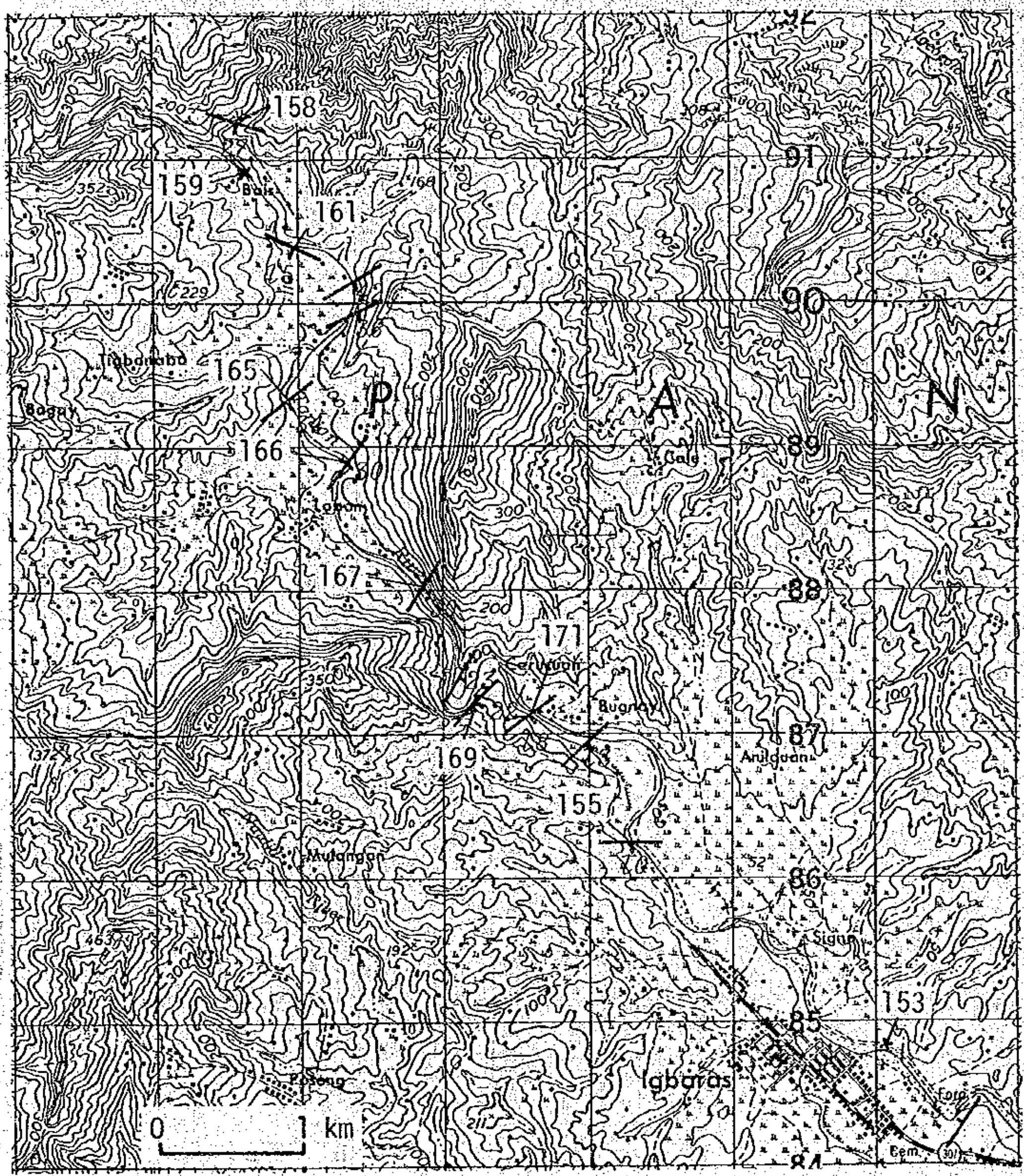
In order to evaluate the gas generation potential of mudstones which are accumulated in the Iloilo basin, the mudstone samples were analyzed on bitumen content (total extractable organic matter by organic solvent) and organic carbon content.



TEXT-FIGURE 7-20

Sample locality map of source rocks in the southern part of Iloilo basin.

Text-fig. 7-20 shows the localities of samples used for the analysis and Table 7-3 shows the result of analysis. The results of analyses of mudstones collected from the Tanian River section 35 km away to the west of Iloilo city and San Joaquin section 47 km away to the west-southwest of the city, reported by ISHIWADA (1971) are referred to herein and shown in Table 7-4. The localities of samples are shown in Text-figs. 7-21 and 22, and collecting horizons are shown in Text-fig. 7-23 respectively.



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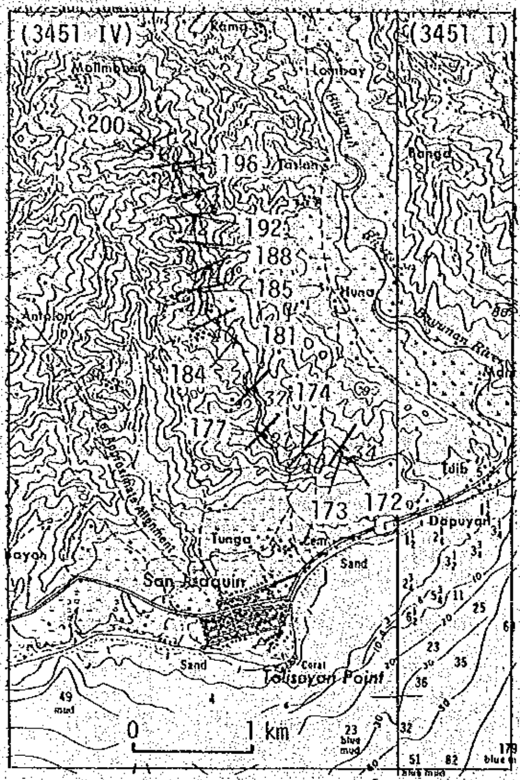
TEXT-FIGURE 7-21

Sample locality map of source rocks in the Tanian River section.



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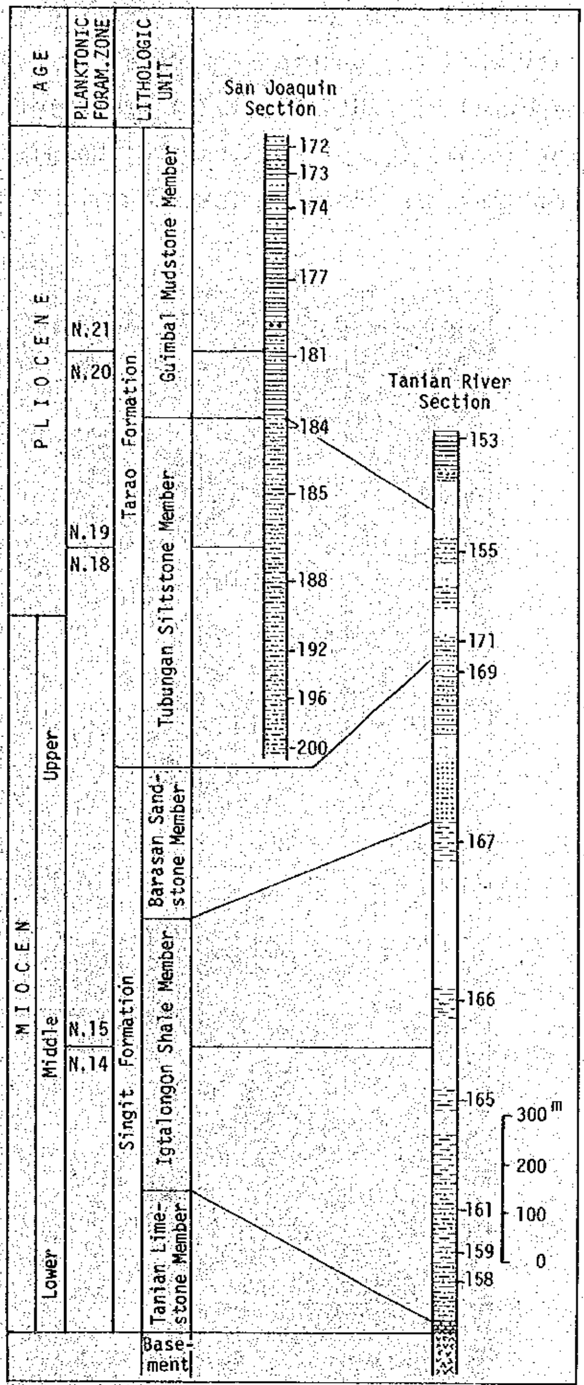
SAN JOAQUIN (Sheet 3451 IV)

TEXT-FIGURE 7-22

Sample locality map of source rocks in the San Joaquin section.



TEXT-FIGURE 7-23

San Joaquin and Tanian River sections showing the horizons of source rock samples.

TABLE 7-3

Organic matters in source rocks from the Iloilo basin (I).

Loc. No.	Lithology	Organic carbon (%)	Extract (%)	Chromatographic separation (%)					Hydro-carbons in rocks (ppm)	Degree of hydrocar-bonization	Extract/ organic carbon ratio (%)	Lithological unit of sam-ple collected	Age
				Paraffin + naphthene	Aromatics	O-N-S compounds	Residue	Hydrocar-bons in extract					
PN-1	Medium greined sandstone	0.20	0.0147	4.88	8.28	21.44	65.40	13.16	19.3	0.0012	7.35	Sewarangan Complex	Up. Olig. - Low. Mio.
2	Bluish green silty sandstone	1.00	0.0481	4.66	8.45	32.92	53.97	13.11	63.0	0.0054	4.81	Tubungan Siltstone	Pliocene
3	Bluish green silty sandstone	0.81	0.0362	6.19	8.29	32.73	52.79	14.48	52.4	0.0056	4.47	Tubungan Siltstone	Up. Mio.
4a	Bluish green siltstone	0.39	0.0201	4.57	6.36	31.98	57.09	10.93	21.9	0.0048	5.15	Guimbal Mudstone	Up. Plio.
4b	Bluish green siltstone	0.69	0.0354	5.08	6.00	20.25	68.67	11.08	39.2	0.0049	5.13	Guimbal Mudstone	Up. Plio.
5	Bluish green silty sandstone	0.27	0.0160	6.24	12.86	19.60	61.30	19.10	30.6	0.0097	5.93	Guimbal Mudstone	Pliocene
10	Bluish green silty sandstone	0.71	0.0303	3.30	11.68	28.63	56.39	14.98	45.4	0.0055	4.27	Dingle Formation	Up. Mio.
12	Bluish green sandy siltstone	0.63	0.0354	4.51	5.53	28.78	61.18	10.04	35.5	0.0048	5.62	Tubungan Siltstone	Up. Mio.
15	Greenish gray sandy siltstone	0.42	0.0284	4.09	5.29	30.89	59.78	9.38	26.6	0.0054	6.76	Tubungan Siltstone	Up. Mio.
19	Bluish gray silty sandstone	0.76	0.0284	2.34	5.00	30.89	61.77	7.34	20.8	0.0024	3.74	Dingle Formation	Up. Mio.
21	Bluish green silty sandstone	0.92	0.1288	5.50	44.19	15.27	35.04	49.69	640	0.0598	14.00	Guimbal Mudstone	Pliocene
25	Dark brown siltstone	0.53	0.0876	3.67	48.42	14.52	33.08	52.10	456	0.0740	16.53	Passi Formation	Up. Mio.
26	Bluish brown siltstone	1.19	0.0732	2.54	31.03	29.72	36.71	33.57	248	0.0179	6.15	Ulian Formation	Low. Pleist.
	Average	0.65	0.0456	4.43	15.50	25.97	54.10	19.92	138	0.0163	7.02		

TABLE 7-4

Organic matters in source rocks from the Iloilo basin (II).

Location No.	Lithology	Extract (%)	Chromatographic separation (%)					Ultimate analysis (%)			Hydro-carbons in rock (ppm)	Hydro carbon/ noncar-bonate carbon ratio
			Paraffin + Naph-thene	Aromatics	O-N-S compounds	Residue	Hydrocar-bons in extract	Total carbon	Carbonate carbon	Noncar-bonate carbon		
153	Bluish grey mudstone	0.030	10.1	5.0	34.5	50.4	15.1	2.45	1.52	0.93	45	0.0042
155	"	0.015	19.0	6.9	36.2	37.9	25.9	2.16	1.53	0.63	39	0.0053
158	"	0.012	5.6	25.0	36.1	33.3	30.6	0.58	0.39	0.19	37	0.0167
159	"	0.005	8.5	8.5	28.8	54.2	17.0	0.67	0.30	0.37	37	0.0086
161	"	0.020	11.3	7.5	35.0	46.2	18.8	1.50	0.77	0.73	38	0.0045
165	Dark grey mudstone	0.022	10.6	7.1	23.5	58.8	17.7	0.60	0.17	0.43	39	0.0078
166	"	0.025	6.1	9.1	36.4	48.4	15.2	1.19	0.48	0.71	38	0.0046
167	"	0.026	6.7	6.7	35.2	51.4	13.4	1.17	0.46	0.71	35	0.0042
169	"	0.081	8.8	7.0	20.1	64.1	15.8	1.33	0.21	1.12	128	0.0098
171	"	0.044	9.1	6.9	34.3	49.7	16.0	1.11	0.10	1.01	70	0.0060
172	"	0.061	11.2	5.5	7.8	75.5	16.7	5.49	0.96	4.53	102	0.0019
173	"	0.054	6.5	8.9	33.1	51.5	15.4	4.58	0.88	3.70	83	0.0019
174	"	0.041	3.7	7.9	34.9	53.5	11.6	2.83	1.85	0.98	48	0.0042
177	"	0.020	12.4	10.8	13.6	63.2	23.2	6.05	4.75	1.30	46	0.0030
181	Bluish grey mudstone	0.049	4.7	6.4	30.6	58.3	11.1	4.33	3.00	1.33	54	0.0035
184	"	0.034	6.7	9.9	30.5	83.4	16.6	4.69	0.05	4.64	56	0.0011
185	"	0.019	4.1	5.4	36.3	54.2	9.5	0.28	0.16	0.12	18	0.0129
188	"	0.021	4.2	5.6	33.1	57.1	9.8	0.25	0.07	0.18	21	0.0100
192	"	0.032	4.4	5.8	30.9	58.9	10.2	1.42	0.69	0.73	33	0.0039
196	"	0.027	4.0	8.0	32.0	56.0	12.0	1.50	0.67	0.83	32	0.0033
200	"	0.021	7.5	10.2	33.4	48.9	17.7	1.80	0.59	1.21	37	0.0026
	Average	0.031	7.9	8.3	30.3	53.5	16.2	2.19	0.93	1.25	49.3	0.0056

(ISHIWADA, 1971)

As shown in Tables 7-3 and 4, percentage of extracts (extracted organic matters: bitumen) of mudstones from the Iloilo basin is within the range of 0.005 to 0.129% and its average is 0.0315% (Table 7-5). The remarkably high values of three samples, namely PN-21 (Guimbal Mudstone, Pliocene), PN-25 (Passi Formation, Upper Miocene) and PN-26 (Ulian Formation, Pleistocene), are noticeable. Comparing with oil and gas fields in Japan, the average of Iloilo basin (0.0315%) is slightly lower than the Kazusa Group's (0.0470%) in Chiba Prefecture and larger than the Miyazaki Group's (0.0264%) in Miyazaki prefecture.

The average (80.4 ppm) of total hydrocarbons (paraffin, cyclo-paraffin and aromatic hydrocarbons) in mudstones is larger than that of Kazusa Group (53 ppm) and that of Miyazaki Group (72 ppm).

The average (1.02%) of organic carbon is larger than values of many fields in Japan including the oil bearing Late Cenozoic sequences along the coastal areas of the Sea of Japan.

The average (0.0097%) of degree of hydrocarbonization (carbon in hydrocarbons/organic carbon = 0.86 × hydrocarbons/organic carbon) is higher than that of Kazusa Group (0.0048%) and lower than that of Miyazaki Group (0.0107%).

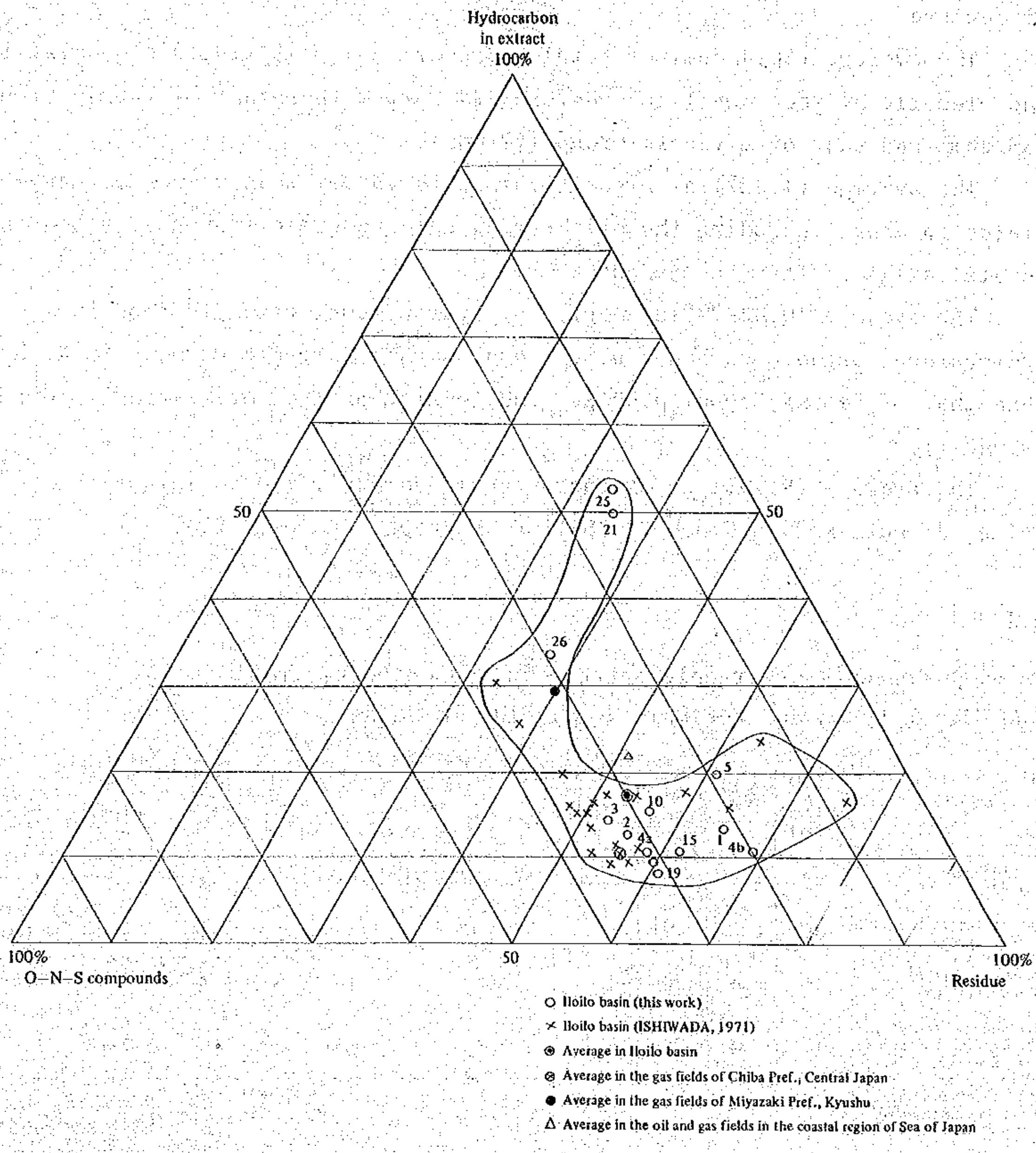
The average (5.19%) of extract/organic carbon ratio is larger than values of both Kazusa Group (4.95%) and Miyazaki Group (4.55%).

TABLE 7-5

Average contents of organic matters in source rocks from the Iloilo basin and the main gas fields in Japan.

Gas fields	Number of analysed samples	Organic carbon (%)	Extract (%)	Chromatographic separation (%)					Hydro-carbons in rocks (ppm)	Degree of hydrocar-bonization	extract/organic carbon ratio(%)
				Paraffin + naphthene	Aromatics	O-N-S compaunds	Residue	Hydrocar-bons in extract			
Iloilo basin, Panay Island	34	1.02	0.0315	6.48	11.05	28.64	53.83	17.53	80.4	0.0097	5.19
Gas fields in Miyazaki Pref., Kyushu	31	0.58	0.0264	17.1	14.5	28.2	40.2	31.6	72	0.0107	4.55
Southern part of Okinawa Island	18	0.58	0.0329	-	-	-	-	-	85	0.0127	5.69
Oil and gas fields in the coastal region of Sea of Japan	415	0.86	0.0970	13.1	8.3	27.4	51.2	21.4	208	0.0208	11.27
Gas fields in Chiba Pref., Central Japan	31	0.95	0.0470	5.8	5.5	33.3	55.4	11.3	53	0.0048	4.95

Text-fig. 7-24 shows a 3-component diagram of total hydrocarbon, O-N-S compounds (hetero organic compounds: oxygen-nitrogen-sulfur compounds) and residue on activated alumina column on which analytical results of rock samples are plotted. From this diagram, it is clearly known that bitumen contents of mudstones from the Iloilo basin concentrate on relatively narrow ranges such as 10 to 20% of hydrocarbons, 20 to 40% of O-N-S compounds and 50 to 70% of residue, and these ranges well conform to those of samples from the kyosui-sei-gasu fields in Japan.

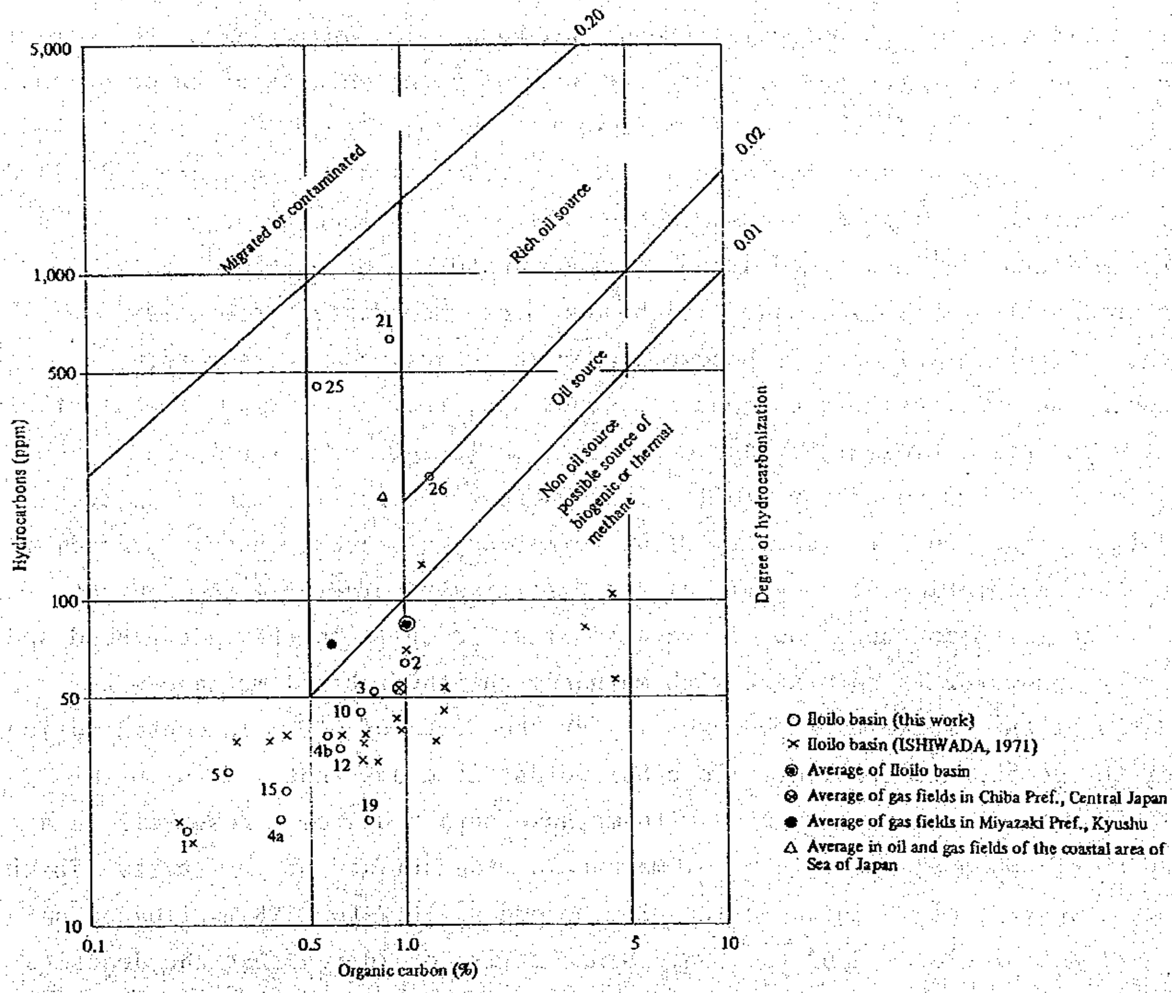


TEXT-FIGURE 7-24

Chemical composition of bitumen in source rocks from the Iloilo basin and the main gas fields in Japan on the triangular net.

Text-fig. 7-25 is a source rock evaluation chart, introduced by KUDO et al. (1976), in which analytical results of organic matters are plotted. In this chart, three samples of PN-21 (Guimbal Mudstone, Pliocene), PN-25 (Passi Formation, Upper Miocene) and PN-26 (Ulian Formation, Pleistocene) are plotted in the section of oil source. These samples contain high percentage of hydrocarbon and present relatively high maturity, therefore they have a low degree of oil generation potential and a high gas generation potential. It is also obvious that other samples have high methane generation potential although they have no heavy hydrocarbon generation potential due to low maturity of organic matters.

From the above results, it is concluded that the mudstones in almost all Late Cenozoic formations of the Iloilo basin have gas generation potential which corresponds to mudstones from the gas fields in Chiba and Miyazaki Prefectures which are representative kyosui-sei-gasu fields in Japan.



TEXT-FIGURE 7-25

Position of source rocks from the Iloilo basin and the main gas fields in Japan on the source rock evaluation chart.

8. Kyosui-sei-gasu deposits

It is presumed that three types of kyosui-sei-gasu deposits are established in the Upper Miocene to Pliocene strata (chiefly Ulian Formation), Miocene Dingle Formation and Pleistocene Cabatuan Formation which lie under the Iloilo plain. The kyosui-sei-gasu deposits in the Upper Miocene to Pliocene must be of iodine type which iodine content in the water is relatively high and their potentiality as economic deposits will be highest among those three types.

1) Kyosui-sei-gasu deposits with iodine in Upper Miocene to Pliocene

Gases produced from gas outcrops and shallow wells in hilly areas at the western and central parts of the Iloilo basin are originated from the Upper Miocene to Pliocene strata and they contain 93.63 to 98.03 vol.% of CH_4, 1.45 to 4.88 vol. % of N_2 and 0.07 to 0.60 vol. % of CO_2 and have total calorific value of 8,914 to 9,332 Kcal/Nm^3. These gas compositions resemble to the high potential kyosui-sei-gasu's in Japan. Among the waters accompaning with the gases, there are some of high contents of chlorine and iodine, namely 11,370 to 14,070 mg/l of Cl^- and 32.8 to 36.9 mg/l of I^- and the I^-/Cl^- ratios are also high as 2.62 to 2.88, although the waters derived from natural springs on the surface of the earth. Since the volume of gas to be dissolved in a fixed amount of groundwater is proportional to hydrostatic pressure, it increases as the depth of groundwater gets deeper. The contents of Cl^- and I^- become higher in the groundwater according to depth where meteoric water does not penetrate, therefore it is expected that high potential kyosui-sei-gasu deposits with iodine are established in the deep reservoirs under the Iloilo plain where the Upper Miocene to Pliocene thick marine deposits (chiefly Ulian Formation) are accumulated. According to the calculation at the time of the preliminary survey, if the content of Cl^- increases to the value of sea water (19,350 mg/l) in the underground and the groundwater is saturated with methane, the theoretical methane-water ratio of the Iloilo basin becomes 1:1 at the depth of 600 m in consideration of the geothermal gradient. In other words, it means that 1 kl of brine similar to sea water saturated with methane obtained from a reservoir at a depth of 600 m produces 1 Nm^3 of methane at the surface of the earth. In this case, content of I^- in the brine will become as 50.7 to 55.8 mg/l based on the I^-/Cl^- ratio of 2.62 to 2.88. Since it is considered that the deposits of plain area were accumulated in deeper sea which were favorable for the concentration of I^- than those of hilly areas, there is a possibility that the I^-/Cl^- ratio in the plane area may exceed the above value. In view of the fact that the I^- content in brine used as raw material by Japanese iodine industries is 30 to 110 mg/l, it is expected that the brine from the Iloilo plane can be used as raw material of iodine industry.

2) Kyosui-sei-gasu deposits in Miocene Dingle Formation

It is expected that kyosui-sei-gasu deposits are established in limestone and sandstone reservoirs of the Lower to Upper Miocene Dingle Formation which is exposed in the eastern part of the Iloilo plain and also lie under the plain.

The gas obtained from a water well (PC-9) of 66 m in depth at the eastern part of the plain contains 93.02 vol.% of CH_4, 5.77 vol.% of N_2 and 0.94 vol.% of CO_2, and it shows the second highest potentiality following that of the Ulian Formation. However, a high potentiality for iodine cannot be expected for its accompanying water since it is altered more than the water of younger formations and it shows NaCl type close to $CaCl_2$ type. According to the data of exploratory drillings, some limestones and sandstones have porosity and permeability which are suitable for reservoirs of kyosui-sei-gasu, and also brine having Cl^- of 16,300 to 17,600 mg/l was confirmed, therefore there is a possibility that kyosui-sei-gasu deposits are established in the upper part of the Miocene Dingle Formation.

3) Kyosui-sei-gasu deposits in Pleistocene Cabatuan Formation

Kyosui-sei-gasu deposits having the features of so called "Quaternary gas" which is characterized by high content of N_2 and CO_2 are established within lagoonal to neritic deposits in the Pleistocene Cabatuan Formation of the plain area. These deposits are distributed within an area of about 250 km^2 including Zarraga, Sta. Barbara, Pavia, Iloilo city and Oton, and it is presumed that their depth varies 100 to 500 m.

PC-1 well of Zarraga bored in this deposits produces gas of more than 9.5 Nm^3/day and water of more than 81.3 kl/day in free flow rate. The gas and water seem to derive from an aquifer of 105.8 to 112.0 m in depth. The water contains 525 mg/l of Cl^-. The gas is composed of 88.83 vol.% of CH_4, 10.29 vol.% of N_2 and 0.15 vol.% of CO_2. Its total calorific value is 8,457 $Kcal/Nm^3$. PC-5 well of Sta. Barbara produces gas of 10.1 Nm^3/day from an aquifer of about 130 m in depth accompanied with water of 45.3 kl/day containing 294 mg/l of Cl^-, and the gas-water ratio is 0.223. The gas is composed of 90.87 vol.% of CH_4, 8.00 vol.% of N_2 and 0.94 vol.% of CO_2 and its total calorific value is 8,651 $Kcal/Nm^3$. Against these, the depth of wells located in the coastal areas including Pavia, Iloilo city, Oton as shallower as 43 to 102 m and gases produced from those wells are composed of 76.51 to 83.54 vol.% of CH_4, 12.06 to 19.87 vol.% of N_2 and 1.77 to 4.01 vol.% of CO_2. Due to these factors, the potentiality of gas reservoirs seems to be lower than that of the above 2 wells. However, the groundwater contains Cl^- of 263 to 2,060 mg/l and I^- of 0.5 to 4.0 mg/l and the I^-/Cl^- ratio is 0.89 to 1.94. As to the potentiality of iodine, the wells in coastal area are higher than inland wells. In consideration of the water quality and gas composition, it is considered that the deposits of inland area are of lagoonal type which is rich in organic matters and those of coastal area are of neritic type which is relatively high in Cl^- and I^- contents and the age of deposits in coastal area is younger than that of inland area.

If the Cl^- content of the groundwater in neritic deposits of the Pleistocene Cabatuan Formation increases the same degree as seawater at the deep underground, the I^- content will increase up to about 40 mg/l and iodine type kyosui-sei-gasu deposits will be established, but the potentiality of such desposits may not be higher than that of deposits expected in the Ulian Formation stated above.

9. Summary

(1) The Late Cenozoic sedimentary succession in the southern part of the Iloilo basin is composed of primarily marine deposits of the Late Oligocene to Pleistocene in age, which are accumulated on the "Basement complex" characterized by andesitic to basaltic volcanic rocks.

(2) In the Leon-Bucari section of the western part of the basin, the Late Cenozoic succession can be divided into A through F formations. The A formation consists of primarily volcanic rocks and composes a part of the "Basement complex." The B formation lies conformably on the A formation with limestone followed by alternating mudstone and sandstone. The C formation begins conformably on the B formation with sandstone facies and its main part is composed of alternating mudstone (predominant) and sandstone. The D formation conformably lies on the C formation and it begins with conglomerates and consists of alternating sandstone and mudstone. The lower part of the E formation is composed of alternating predominant sandstone and lesser mudstone and its upper part consists of primarily mudstone. This formation contacts the underlying and overlaying formations with faults between them. The F formation is composed primarily of conglomerate.

(3) Based on the results of foraminiferal analysis, the sequences from the B formation to the lower part of the E formation are correlative to the Miocene; the upper part of the E formation is to the Pliocene; the F formation is the Early Pleistocene in age.

(4) It is presumed that the Paleobathymetry of the lower part of the B formation was inner neritic, but it became abruptly deeper from the middle part of the formation and turbidite facies were predominant and it became deepest at the stage of deposition of the upper part of the D formation and after that it became gradually shallower.

(5) According to the data of exploratory drillings, the stratigraphic succession of the Iloilo plain in the southern part of the Iloilo basin can be classified into basaltic volcanic rocks (basement), Uppermost Oligocene deposits, Dingle Formation, Ulian Formation and Cabatuan Formation in descending order. The Uppermost Oligocene is composed of reefal limestone, shale, basaltic pyroclastics and it is presumed that there is an unconformity between these deposits and basement rocks. The thickness of the formation is 270 m. The Dingle Formation is composed of reefal limestone, shale, sandstone, and alternating shale and sandstone, and is correlated to the Lower Miocene to Upper Miocene. The thickness of the formation is 1,400 m. This formation contacts with the lower formation unconformably and also two

hiatuses are recognized in the formation. The Ulian Formation is characterized by mudstone and alternating mudstone and sandstone with sandstone and limestone intercalations. This formation is correlated to the upper part of the Upper Miocene to the Lower Pleistocene. The thickness of the formation is 670 m. The Cabatuan Formation is composed of mud, sand and conglomerate and correlative to the Pleistocene. Its thickness is 440 m.

(6) It is presumed that the sedimentary environment of the Dingle Formation is inner to outer neritic, that of the Ulian Formation is outer neritic to bathyal and that of the Cabatuan Formation is lagoonal to neritic, respectively.

(7) The sedimentary facies of the Iloilo basin shows a remarkable contrast between the plain area of the eastern part and the hilly area of the western part. In other words, shelf facies of the Lower to Upper Miocene Dingle Formation characterized by reefal limestone are widely distributed in the plane area, while turbidite facies which indicate relatively deeper sedimentary environment are widely and thickly developed from the middle part of the B formation to the upper part of the D formation in the western hilly area. This relation was inversed at the latter stage of the Late Miocene, that is, the eastern part became deep, and the deep water facies of the Ulian Formation was accumulated, and in the western area, the upper part of the D formation and E formation of relatively shallow water facies were settled. As the Pleistocene age began, the sea in the Iloilo sedimentary basin generally became shallow, and the lagoonal to neritic Cabatuan Formation is deposited in the eastern area and also the paralic to neritic F formation was accumulated in the western fringing area.

(8) It is known by experience that iodine type high potential kyosui-seigasu deposits are established in outer neritic to bathyal deposits in general. Such deposits which conform to these bathymetric conditions in Iloilo basin are the Lower Miocene to Pliocene's (from the middle part of B formation to the E formation) in the western hilly area, and the upperpart of the Upper Miocene to Upper Pliocene's (Tubugan Siltstone Member and Guimbal Mudstone Member of Tarao Formation, upper part of Dingle Formation, Ulian Formation, etc.) in the eastern plain area.

(9) According to the electric logging data of exploratory drillings, the resistivity of the Late Cenozoic deposits in the plain area is within the range between 0.63 and 1.54 Ωm (conductivity, 1,600 - 650 mmhos) and it is recognized that it tends to become low in the central part and high in the fringing areas of the basin. This would indicate that the salinity

of groundwater is relatively high in the central part and low in the fringing areas.

(10) It is presumed from conductivity that the penetrating depth of meteoric water is about 250 m at the inland area and about 370 m at the coastal area.

(11) The porosity of rock samples collected from the surface section of Leon-Bucari is between 49.2% and 12.1% and it decreases as the age of the rock gets older. The horizon of which porosity becomes lower than the minimum porosity of 25% which is required as a reservoir of kyosui-sei-gasu corresponds to the middle part of the E_1 member of the E formation. This horizon also corresponds to the middle part of the Tubungan Siltstone Member and is nearly correlated to the boundary between Miocene and Pliocene.

(12) According to the analysis of sonic logs on exploratory drillings, the porosity of the deposits correlative to Pliocene at a depth of 305 to 1,070 m in the plain area is from 25% to 60%, higher than that of the surface section. This indicates that the degree of compaction of the plain area is lower than that of the Leon-Bucari surface section.

(13) According to the analysis of electric and sonic logs, rocks having a permeability of more than 30 md which is required for the establishment of kyosui-sei-gasu deposits are represented by limestones in the Miocene sequence and by sandstones in the Pliocene and Pleistocene. In the case of the exploratory drillings, the distribution of the Pliocene reservoirs is not necessarily good.

(14) Based on the analysis of seismic profile of the plain area, it is presumed that the area wherein a depth from the ground surface to the limestone in the Dingle Formation exceeds 1,000 m, in other words, the area wherein the thickness of the deposits younger than the middle Late Miocene is more than 1,000 m would exceed 300 km^2.

(15) According to the geochemical survey and data of the exploratory drillings, gas indications are recognized in almost all Late Cenozoic formations distributed in the southern part of the Iloilo basin.

(16) Natural gas in this area is primarily of so-called suiyo-sei-gasu which is dissolved in formation water. There is no record of finding of structural gas, except pocket gases which were found by exploratory drillings of oil.

(17) The result of the analysis of organic matters of gas source rocks shows that the mudstones of Iloilo basin generally have gas generation potential. Especially, Late Miocene Passi Formation, Pliocene Gimbal

Mudstone and Ulian Formation contain source rocks which have a high gas generation potential and a low oil generation potential.

(18) It is expected that iodine type kyosui-sei-gasu deposits of high potentiality are established in the upper part of Upper Miocene to Pliocene deposits (mainly Ulian Formation) which lie in the deep underground of the plain area in the southern part of the Iloilo basin.

(19) It is also expected that kyosui-sei-gasu deposits are established in limestone and sandstone reservoirs in the Lower to Upper Miocene Dingle Formation which is exposed in the eastern part of the Iloilo plane and lies underground of the central to western part of the plane. However, it is presumed that the potentiality of iodine in accompanying water of the gas is not so high as that of the Ulian Formation.

(20) Suiyo-sei-gasu deposits having the feature of so-called Quaternary gas of which methane content is relatively low are established in the lagoonal and neritic deposits in the Pleistocene Cabatuan Formation in the plain area. The distribution area of the gas deposits is about 250 km^2 and the depth of the deposits is presumed to be 100 to 500 m. The potentiality of both gas and iodine of the deposits is not higher than that of the expected deposits in the Pliocene Ulian Formation, but some of the existing groundwater wells are producing gas which can be utilized as fuel for limited areas.

10. Conclusion

(1) It has been revealed by this investigation that the Upper Miocene to Lower Pleistocene marine deposits primarily consisting of mudstones in the southern part of the Iloilo basin include gas of high methane content and brine of high iodine content. The analytical results of organic matters of mudstones show that the deposits have a high gas generation potentiality and also the micropaleontological studies show that the deposits were accumulated under neritic and bathyal sedimentary environment suitable for the concentration of iodine. Since these features resemble to those of the Kazusa Group in Chiba Prefecture and the Miyazaki Group in Miyazaki Prefecture which have representative kyosui-sei-gasu deposits including iodine in Japan, it is expected that the same type of kyosui-sei-gasu deposits is established in the marine deposits of the Iloilo basin. The iodine in water producing with gas is important because it will contribute to the reduction of gas production cost by using it as a raw material of iodine industry.

(2) It is presumed that the kyosui-sei-gasu deposits are formed in reservoirs of coarse grained sediments intercalated in mudstones in the deep underground of the central to western part of the Iloilo plane where the sandstones and mudstones are accumulated thickly. The prospective area on gas includes a corner of Iloilo city in its southeastern part. The city has a population of about 200,000, therefore it is anticipated that the city has a potential demand for city gas. Since this area is located close to the sea, it is easy to discharge saline water from gas production wells. Also this area has a relatively high elevation, therefore it is considered that the influence of ground subsidence can be held minimum.

(3) It is possible to obtain data necessary for practical evaluation, as listed below, of the kyosui-sei-gasu deposits by exploratory drilling: Necessary data are as follows: Depth, thickness and property of reservoirs; potential of gas and iodine; productivity of gas and accompanying water; data on production cost; basis for design of production wells and their interval; basic data for forecast of ground subsidence, etc.

(4) At the first stage of drilling exploration of kyosui-sei-gasu deposits, an emphasis will be placed on a clarification of the vertical features, and measurement and investigation on the stratigraphic succession; geologic age; sedimentary environment; depth, physical properties and effective thickness of reservoirs; gas flow rate; water flow rate;

temperature of water; gas-water ratio; production index; production performance; gas composition; calorific value of the gas; water quality; iodine content, etc. will be conducted.

(5) It is difficult to test multiple reservoirs which are different each other on the depth, internal pressure and productivity by one exploratory drilling, therefore it is desirable that at least two wells will be drilled and deep and shallow reservoirs will be separately tested.

(6) It is necessary that a practical development program will be prepared upon completion of wide and careful investigation on various factors, based on the scale of gas deposits grasped by the exploratory drillings, such as arrangement of production wells; conditions of location and construction cost of gathering, holding and supply facilities; pipelines of gas and water; iodine plant; gas market; method of introduction of gas development, production, control, maintenance and utilization technique and iodine industry technique; policies of economy and mining and industry.

(7) Since so-called Quaternary gas in the Pleistocene lagoonal and neritic deposits is suitable for fuel, although it is low in commerciability, it will be feasible that the "Quaternary gas" producing from some existing wells will be effectively utilized as fuel by surrounding houses.

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