

Some Properties of Brackish Sediments along the Chao Phraya River of Thailand

by

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Takaya found two Quaternary brackish clay beds in the lower reaches of the Chao Phraya river through the field survey of outcrops (Takaya, 1971). The matrix color of sediments and the existence of basic ferric sulphate (jarosite) which gives a characteristic yellow color, and gypsum needles were used as the field criteria of the brackish clays. To clarify what chemical properties are connected with these criteria, electric conductivity and salt composition of water extracts from the sediments, existence of oxidizable sulphur, etc. were examined by the present author. Consequently, it was confirmed that the two brackish clay beds were further subdivided. In this report the author wishes to present a stratigraphy based on the result of the chemical analyses and to try to correlated it with Takaya's stratigraphy.

I Morphology of Surveyed Outcrops and Sampled Substrata

Rough positions of surveyed outcrops are shown in Fig. 1. Their geomorphological settings and layer sequences are given in Fig. 2 and Table 1. The author adopted the same locality numbers as used by Takaya in his previous report (Takaya, 1971) for the convenience of comparison. But several localities are added with such suffixes as *a* and *b*. These denote outcrops which were not described by Takaya but have similar profiles to those having the corresponding numbers. For the detailed descriptions of the layer sequences, Takaya's report should be referred to, though a concise picture is given in Fig. 2.

II Analytical Methods and Results

On air dried soils, pH, water soluble cations and anions, (such as Ca, Mg, Na, Cl and SO₄), electric conductivity and exchangeable bases (when the conductivity was low) were determined based on the methods described by Kawaguchi and Kyuma

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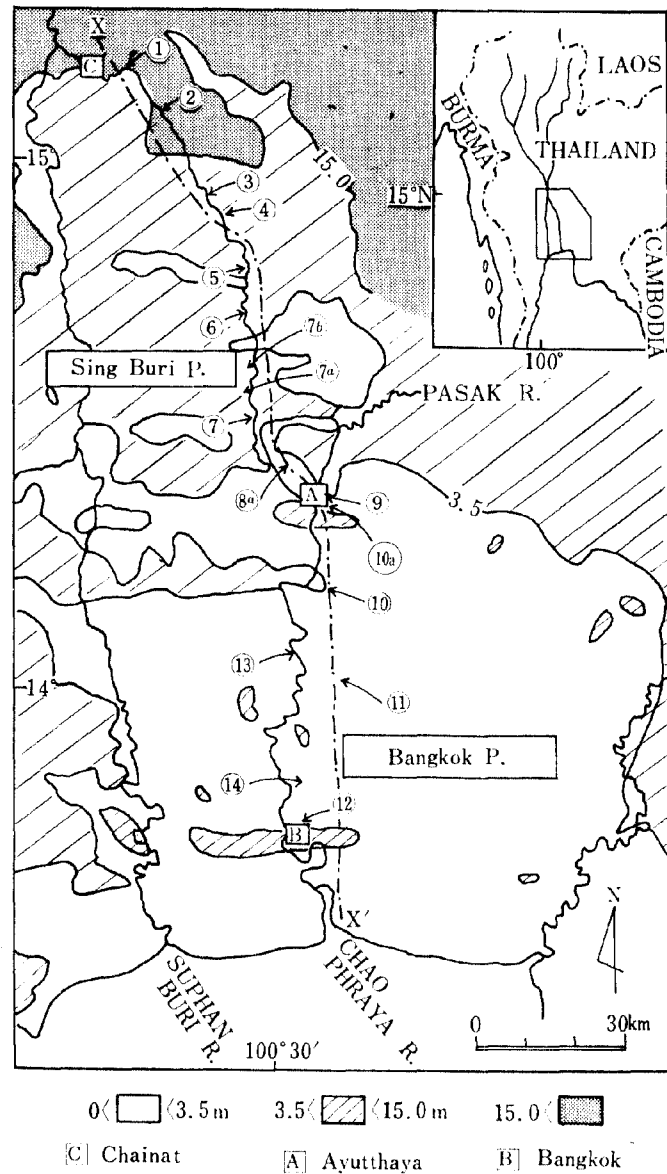


Fig. 1 Index map of the lower reach of the Chao Phraya River, with localities of sampling outcrops

(Kawaguchi and Kyuma, 1968). Electric conductivity was measured at 20°C on water extracts or soil suspensions which have the soil water ratio of 1:5. For the detection of oxidizable sulphur, the pH values were determined by glass electrode pH-meter on soil suspensions which were treated with hydrogen peroxide. When the pH values were below 3.8, the samples were considered to contain oxidizable sulphur, according to Murakami's experience (Murakami, 1961).

To determine the weathering degrees of sediments, the clay mineral compositions

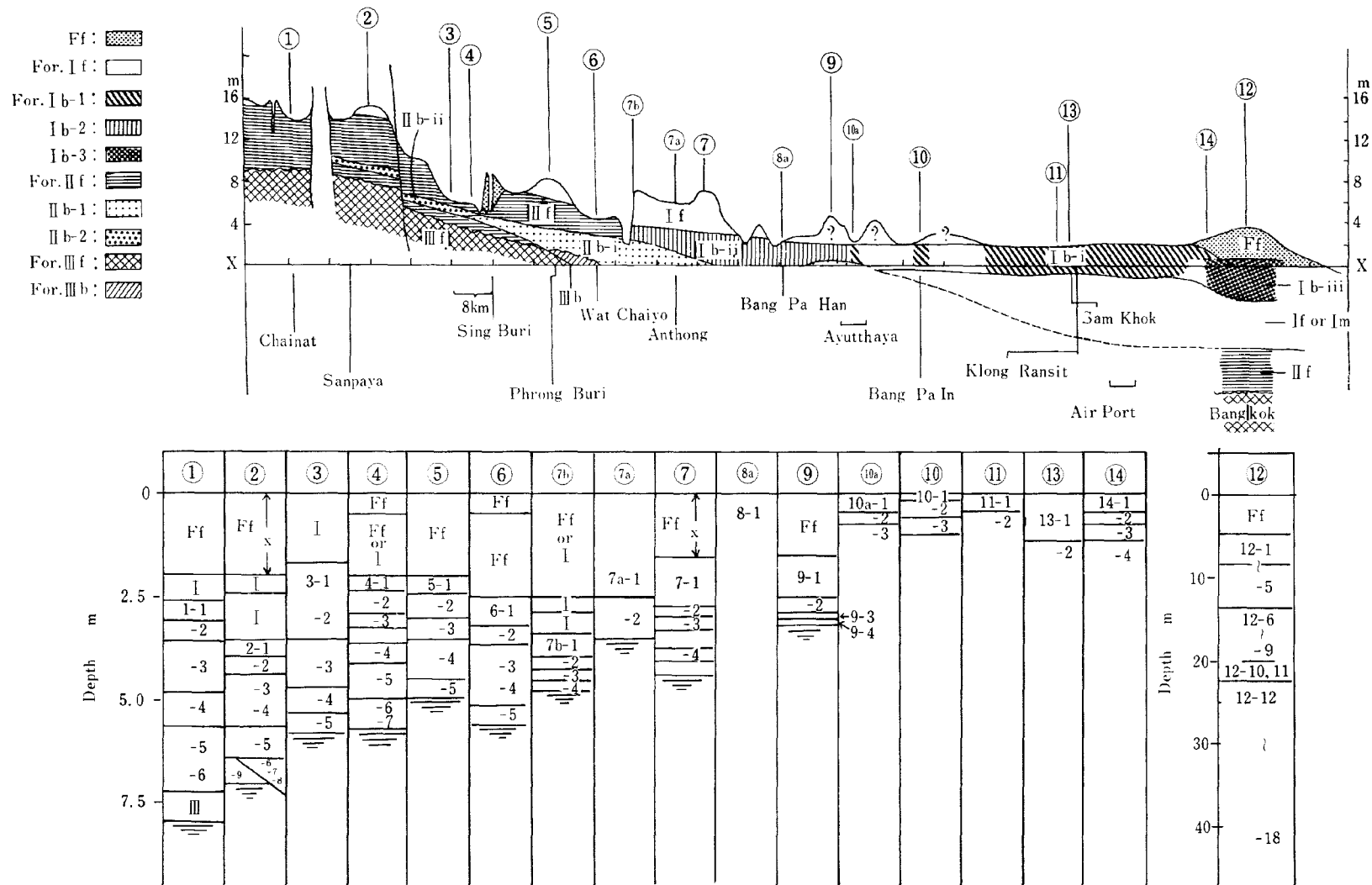


Fig. 2 N-S profile along the Chao Phraya River showing the localities of sampling outcrops and sampling layers in outcrops

Table 1 Layer Sequences of Surveyed Outcrops and Correlation between Sample Substrata and Takaya's Identified Formations and Substrata

Sample Number	Takaya's identified		Sample Number	Takaya's identified		
	For.	layer		For.	layer	
1 — 1	I	Loc. 1 2.6 ~ 3.1m	9 — 1	I b	Loc. 9 4) 5) 6) 7)	
2	II		2	I b		
3	II		3	I b		
4	II		4	II b		
5	II		5.7 ~ 7.2			
6	II		7.2 ~ 7.4			
2 — 1	I	Loc. 2 4) 5) 6) 7) 8) 9) 10)	10 a — 1	I b	Loc. 10 0 ~ 0.1m 0.1 ~ 0.6 0.6 ~ 0.9	
2	I		2	I b		
3	II b		3	I b		
4	II b		10 — 1	I b	Loc. 10 0 ~ 0.1m 0.1 ~ 0.6 0.6 ~ 0.9	
5	II b		2	I b		
6	II		3	I b		
7	II		11 — 1	I b	Loc. 11 0 ~ 0.1m 0.1 ~ 0.5	
8	II		2	I b		
9	III					
3 — 1	I		Loc. 3 1.7 ~ 2.5m	13 — 1	F p	
2	I	2		I b		
3	II	2.5 ~ 3.5				
4	II	3.5 ~ 4.7				
5	III	4.7 ~ 5.3 5.3 ~ 5.9				
4 — 1	I	Loc. 4 3) 4) 5) 7) 8) 10) 11)	14 — 1	F p	Loc. 12 2)	
2	I		2	F p		
3	I		3	F p		
4	II b		4	I b		
5	II b		12 — 1		Loc. 12 — 2)	
6	II		2			
7	II		3	I		
		4				
		5				
5 — 1	I?	Loc. 5 2.0 ~ 2.4m	6		Loc. 12 — 3)	
2	I?		7			
3	II b?		8	II		
4	II?		9			
5	III		4.5 ~ 4.9 4.9 ~ 5.2			
6 — 1	I?	Loc. 6 3) 4) 5) 6) 7)	10		Loc. 12 — 4)	
2	II b		11	II		
3	II b					
4	II b					
5	III					
7 b — 1	I	Loc. 7 1.0 ~ 1.7m	12		Loc. 12 — 5), 6), 7)	
2	I		13			
3	I		14			
4	I b		15	III		
		1.0 ~ 1.7 1.0 ~ 1.7 1.7 ~ 2.4	16			
			17			
			18			
7 a — 1	I	Loc. 7 1.0 ~ 1.7m	Loc. 7 b	Right bank of Chao Phraya, Ca. 7 km N of Anthonng,		
2	I b		1.7 ~ 2.4	Loc. 7 a	Right bank of Chao Phraya, Anthonng Bridge G. H. Ca.	
7 — 1	I	Loc. 7 1.0 ~ 1.2m	Loc. 8 a	Ca. 4 km S of Amphoe Bang Pa Han		
2	I		1.2 ~ 1.7	Loc. 10 a	East of Ayutthaya	
3	I		1.4 ~ 1.7	Loc. 13	Left bank of Chao Phraya, Amphoe Samkok	
4	I b		2.1 ~ 2.4	Loc. 14	Ca. 3 km West of Bang Khen	
8 a — 1	I b	Loc. 8 1.0 ~ 1.5m				

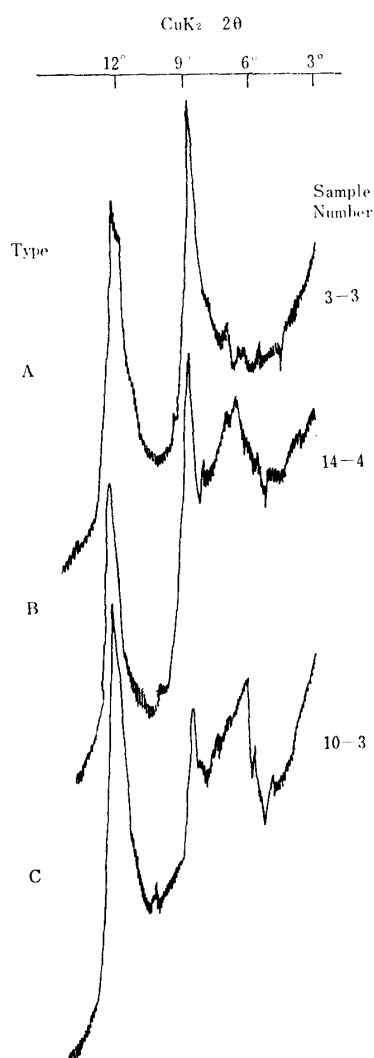


Fig. 3 Types of X-ray Diffraction Diagrams of K-AD Clay Specimens

were examined by a method reported previously by the author (Hattori,1967). The result of the X-ray diffraction analyses made on K-air dried oriented specimens revealed that the specimens could be grouped into three types: types A, B and C, each being characterized by dominant Vermiculite, montmorillonite and Al-interlayered minerals, respectively, as shown in Fig. 3. Some intermediate types were also found and they were expressed by combined letters such as types AB, BC and etc. in which the former letter indicates the main component.

The results obtained are given in Table 2.

III Discussion

According to the soil survey in the Chao Phraya basin conducted by the Department of Land Development of Thailand, the parent materials of alluvial soils in the basin are classified into three kinds: riverine, brackish and marine alluvium. And it is said that the marine alluvium contains much sodium, magnesium and chloride ions when they are not leached severely, and brackish ones contain not only the above ions but also oxidizable sulphur or sulphate ions and sometimes gypsum needles when calcium ions are supplied. On the other hand riverine ones contain many calcium ions and less sodium ions

and contain almost no chloride and sulphate ions. Marine alluvial soils may become similar to riverine alluvial soils as the leaching proceeds, but, brackish alluviums transform to a characteristic soil which is called acid sulphate soil. The acid sulphate soil may be used for both cases whether oxidizable sulphur is already oxidized to form basic ferric sulphate (and/or gypsum) or is present intact. The former is called cat clay and the latter mud clay. (Moorman, 1963)

Subdivision of acid sulphate soils in the Chao Phraya basin

From the data listed in Table 2, we can distinguish four sediments deposited in marine and brackish waters. The first group (which is termed group 1 in this paper) appears very much like the cat clay in its field occurrence producing common gypsum

Table 2 Some Chemical Properties and Clay Mineral Composition of Substrata

Sample Number	pH(1:5)		Water Extracted			Exchangeable			Clay Mineral Composition					
	non-treat	H ₂ O ₂ treat	EC $\mu\Omega$	Cl	SO ₄	meq/100g Ca Mg Na			Relative Intensity of each peak 7Å 10Å 12-15Å			Type of X-ray diffractions diagram of K-AD clay specimen		
1 —	1	8.4	71					12.3	3.74	10.20	45	20	35	AB
	2	8.6	79					9.30	1.70	10.20	60	15	25	AB
	3	9.2	43					7.10	1.53	5.07	50	20	30	AB
	4	8.4	51					10.4	1.94	6.47	45	20	35	AB
	5	7.9	31					5.54	1.11	3.49	60	25	15	A
	6	8.1	20					6.25	1.53	3.49	55	20	25	AB
2 —	1	7.0	5.1	7				15.2	4.86	1.87	40	25	35	AB
	2	6.6	5.3	20				13.9	3.47	1.58	45	25	30	AB
	3	7.1	5.9	35				23.4	4.02	2.51	40	20	40	AB
	4	7.5	6.0	20				19.1	2.22	2.30	50	10	40	AC
	5	8.8	8.4	40				25.2	1.70	1.79	60	10	30	AC
	6	9.0	8.6	15	—	—		19.5	1.53	1.11	40	5	55	ABC
	7	8.3	8.2	27	—	+		19.0	1.67	1.57	40	10	50	ABC
	8	8.3	8.4	14				16.6	1.53	1.23	35	10	55	ABC
	9	7.3		3				10.5	1.11	0.26	45	20	35	A
3 —	1	6.6	6.0	5				14.3	4.31	0.34	45	20	35	AB
	2	6.7	5.6	13				10.3	2.78	0.56	45	25	30	AB
	3	6.9	5.9	19				20.0	4.31	1.40	45	25	30	AC
	4	7.5	6.9	25	±	+		12.6	2.08	1.32	60	10	30	AC
	5	7.8	7.8	26	—	+		21.2	3.61	1.96	60	15	25	A
4 —	1	6.1		3				11.6	3.89	0.17	40	25	35	AC
	2	6.3	5.2	4				10.7	3.61	0.17	40	35	25	AC
	3	6.1	5.0	4				10.5	3.47	0.13	35	30	35	AC
	4	5.0	4.0	24	—	—		11.8	2.50	0.17	40	30	30	AC
	5	5.9	4.8	13	—	—		10.1	2.64	0.17	30	25	45	AC
	6	6.0	5.4	9				12.4	4.58	0.17	40	20	40	AC
	7	5.5		6				20.2	6.94	0.26	45	15	40	AB
5 —	1	7.3	5.7	69				18.1	5.00	4.77	40	25	35	AB
	2	7.5	7.4	80	++	±	0.20 0.13 3.69				45	30	25	AC
	3	7.4	6.9	68	++	+	0.69 0.43 3.15				50	20	30	ABC
	4	7.1	7.2	116	++	+	0.83 0.47 4.35				50	15	35	ABC
	5	7.8	7.4	76	+	±	0.22 0.22 2.39				55	15	30	AC
6 —	1	6.6	5.7	23				12.6	2.92	0.89	45	30	25	A
	2	7.2	6.6	22				9.70	2.08	0.81	50	30	20	A
	3	7.1	7.1	68	±	++	2.58 2.10 0.69				45	25	30	ABC
	4	7.1	6.8	77	+	+	0.61 0.58 0.98				40	20	40	ABC
	5	7.1	6.6	90	+	+	1.41 0.63 2.18				50	20	30	AB
7 b—	1	6.8	4.8	29				28.4	9.16	3.10	45	25	30	AB
	2	7.5	6.2	6				8.02	3.75	0.72	40	25	35	AB
	3	7.3	6.7	4				8.02	3.61	0.68	40	25	35	A
	4	4.3	3.2	118	+	+	0.92 0.72 3.70				45	30	25	ABC
7 a—	1	6.7	5.7	12				11.4	4.16	0.77	45	30	25	AC
	2	4.3	3.5	48	++	+		20.0	6.11	0.77	45	20	35	AC
7 —	1	6.8	6.0	84				15.8	9.16	3.19	45	30	25	AB
	2	4.8	3.9	192	##	##	1.12 1.59 4.35				40	30	30	ABC
	3	4.5	3.4	170	##	##	0.83 1.46 2.75				40	30	30	AC
	4	4.3	3.1	150	##	##	4.14 2.17 3.92				45	20	35	AC
8 a—	1	3.9	3.2	301	++	##	13.72 3.71 3.37				50	20	30	AB

Sample Number	pH(1:5)		Water Extracted				Exchangeable			Clay Mineral Composition						
	non-treat	H ₂ O ₂ treat	EC μΩ	Cl	SO ₄	meq/100g Ca Mg Na			meq/100g Ca Mg Na			Relative Intensity of each peak 7Å 10Å 12-15Å			Type of Xray diffractions diagram of K-AD clay specimen	
9 —	1	7.0	3.3	175	##	##	1.46	1.41	6.53				40	20	40	AC
	2	6.7	5.7	275	##	##	3.68	3.00	6.85				55	20	25	ABC
	3	6.7	6.6	265	##	##	5.36	1.73	8.36				60	15	25	ABC
	4	7.1	7.1	280	##	+	0.81	1.70	7.71				50	15	35	ABC
10 a —	1	5.2	3.6	27	—	±				31.4	7.91	0.47	40	15	45	AC
	2	4.4	3.4	80	—	##	2.71	0.94	0.55				40	20	40	AC
	3	4.1	3.5	70	—	##	3.78	1.01	0.52				40	20	40	ABC
10 —	1	4.3	3.2	101	—	##	2.94	2.44	2.50				55	15	30	AC
	2	4.4	3.2	96	—	##	7.39	1.76	2.50				45	20	35	CA
	3	4.2	3.3	56	—	+	0.22	0.29	0.72				40	20	40	ABC
11 —	1	4.0	2.9	42	—	+				6.47	4.02	0.64				AC
	2	3.7	3.0	43	—	+				4.01	2.50	0.72				AC
13 —	1	6.0	5.0	22	±	±				11.0	3.61	0.38	45	20	35	AB
	2	4.6	3.7	12	—	±				5.34	1.67	0.08	45	20	35	AB
14 —	1	6.3	5.3	36	±	+				8.58	9.72	3.10	40	25	35	AB
	2	6.6	6.9	23	±	+				8.57	11.23	0.72	40	25	35	AB
	3	6.9	5.7	21	—	±				5.91	7.08	0.68	30	20	50	BA
	4	4.8	2.5	454	##	##	6.62	10.6	8.05				40	25	35	BA
12 —	1	3.7		304	##	##							35	20	45	BA
	2	4.1		454	##	##							35	20	45	BA
	3	8.2		70	##	—							35	20	45	BA
	4	8.7		39	##	—							35	20	45	BA
	5	7.5		51	##	—							35	20	45	AB
	6	5.2		73	##	—							40	20	40	AB
	7	7.3		41									40	20	40	AB
	8	8.0		40									40	20	40	AB
	9	7.2		20									30	10	60	BA
	10	5.6											50	20	30	A
	11	5.1											50	25	25	A
	12	5.1											30	20	50	AB
	13												40	15	45	AB
	14												40	15	45	AB
	15												40	20	40	AB
	16												30	20	50	AB
	17												25	15	60	AB
	18												20	15	60	AB

needles, but the reaction is neutral and no oxidizable sulphur is found. The lower parts of outcrops of Locs. 5, 6 and 9 produce this group of acid sulphate soil. The second group (group 2) is a near cat clay. This has the all the nature of the cat clay but yields many sodium chlorides. The lower parts of outcrops of Locs. 7 b, 7 a, 7 and 8a belong to this group. The third group (group 3) is acidic cat clay which yields a small amount of exchangeable bases and water soluble chloride ions. This is seen in the outcrops of Locs. 10, 10 a, 11 and 13. The fourth one (group 4) is mud clay laid under the fresh water sediments and observed in the outcrops of Locs. 12 and 14.

Table 3 is a kind of correlation chart between the stratigraphical positions and the characteristics of substrata. Stratigraphically the substrata from which the specimens were collected are divided into the flood plain deposits (the youngest deposit), Formation I (Recent in age), Formation II (upper Pleistocene in age) and probably Formation III (provisionally of middle Pleistocene) based on the sediments' weathering degree. And each formation is further divided into substrata of marine, brackish and fresh water origins based on the chemical properties. Formation Ib-i, Ib-ii, Ib-iii and Iib-i correspond to soil groups 2, 3, 4 and 1 respectively. The table, however, should be read with reference to the following explanations. First, the analytical data do not show the evidence that the Formation Iib-ii is of brackish origin, but this unit is interpreted as brackish by the author because 1) its stratigraphical position can be correlated to Formation Iib-i which is of brackish origin, 2) gypsum needles are detected in it by the naked eye though the amount is very low, 3) it shows apparently higher conductivity than those of the upper and the lower substrata. The second is; the lowest layers of outcrops of Locs. 5 and 6 which are classified as Formation III are temporarily coded as IIIb, implying their brackish origin, because of their resemblance to their overlying beds which are identified to be Formation Iib-i. But it is quite doubtful whether they were deposited in a brackish water. They may be riverine alluvial soils which were secondarily contaminated by chloride and sulphate released from the overlying beds. Anyway, Table 3 indicates that the result of the chemical analyses shows a good agreement with Takaya's stratigraphy.

A drilling core ca. 40 m long, which was obtained in Bangkok (Loc. 12), can be mineralogically divided into three layers based on the clay mineral composition of eighteen core samples. The interesting thing is that each layer has its equivalent formation in the outcrop areas. The correlation is shown in Fig. 2.

The analyses also revealed that the clays belonging to the so-called mud clay are rich in montmorillonite while those belonging to the cat clay yield more or less Al-interlayered minerals. The difference may be ascribed to the difference in degree of oxidation and leaching.

Table 3 Correlation between Stratigraphical Position and Characteristics of Substrata

Stratigraphical Position*	Soil Grouping	Acidity	EC	SO ₄ ⁻⁻ or (Gypsum)	Fe ₂ S	Cl ⁻	Calcite	Kaol. %	Main Type of 14Å Mineral	Author's Grouping	Loc. 12	Takaya's Grouping
Ff	1	slightly acidic	low	±	-	-	-	30~45	AB	13-1, 14-1, 2, 3		13-1. 14-1, 2, 3
Ib	i	acidic	low	+	+	-	-	40~55	CA~AC	10a-1, 2, 3 10-1, 2, 3 11-1, 2, 13-2	12-1, 2	7b-4. 7a-1. 7-4. 8a-1. 9-1, 2, 3. 10a- 1, 2, 3. 10-1, 2, 3. 11-1, 2. 13-2. 14-4
	ii	acidic	high	+	+	+	-	40~50	AC	7b-4. 7a-2. 7-2, 3, 4. 8a-1. 9-1		
	iii	acidic	high	+	+	+	-	40	BA	14-4		
If		neutral	low	-	-	-	-	40~50	various type	1-1, 2, 2-1, 2, 3-1, 2, 3 5-1. 6-1, 2, 7b-1, 2, 3 7a-1. 7-1. 4-1, 2, 3	(12-3, 4, 5) **	1-1. 2-1, 2. 3-1, 2. 4-1, 2, 3. 5-1?, 2? 6-1?, 7b-1, 2, 3. 7a-1. 7-1, 2, 3
IIb	i	neutral	high	+	-	+	+	40~60	ABC	5-2, 3, 4. 6-3, 4 9-2, 3, 4		2-3, 4, 5. 3-3, 4. 4-4, 5. 6-2, 3, 4. 9-4. 5-3?, 4?
	ii	slightly acidic~ neutral	low	±	-	-	+ or -	30~60	AC	2-3, 4, 5. 3-4 4-4, 5		
IIf		slightly acidic~ alkaline	low	-	-	-	+ or -	40~60	AB	1-3, 4, 5, 6 2-6, 7, 8 4-6, 7	12-6**, 7, 8, 9 12-10, 11	1-2, 3, 4, 5, 6. 2-6, 7, 8. 4-6, 7
IIIb		neutral	high	+	-	+	+	50~55	AB~AC	5-5. 6-5	12-12	5-5. 6-5
IIIf		alkaline	low	-	-	-	+	45~60	A	2-9. 3-5	~ -18	2-9. 3-5

* F : flood plain sediments, I : For. I, II : For. II, III : For. III, f : fresh water sediments, b : brackish water sediments

** slightly affected by marine water

Regional distribution of acid sulphate soils

The regional distribution of the acid sulphate soils are summarized as follows;

Formation IIb-ii is found to the north of Sing Buri. This locality is situated on the northern upper part of the Sing Buri Plain which is supposed to be the upper Pleistocene deltaic plain by Takaya (Takaya, 1969).

Formation IIb-i and Formation IIIb are found in an area between Sing Buri and 8 km south of Wat Chaiyo. The area occupies a portion of the southern part of the Sing Buri Plain.

Formation Ib-ii is found in an area between 8 km north of Anghong and 10 km north of Ayutthaya. The area coincided with the Bam Phraek trough which is supposed to be a fossil valley of old Recent age by Takaya (Takaya, 1969).

Formation Ib-i is found in the area between Ayutthaya and Bangkok. The area forms the heart of the Recent deltaic plain.

Formation Ib-iii is found to the south of Bangkok. This is the latest born area in the Bangkok plain.

The outline of the distribution can be seen on a profile shown in Fig. 2.

Summary

Classification of the brackish clays which develop along the lower reaches of the Chao Phraya river was made with reference to the quantity and quality of the water soluble salts and the existence of oxidizable sulphur, and the clay mineralogical composition. And then the classified clays were correlated with Takaya's stratigraphy as follows:

The author's classification	Takaya's classification	
	Stratigraphy	Age
Flood Plain deposit	Flood Plain deposit	
Formation If	non brackish Formation I	
Formation Ib-i (cat clay without Cl')		Recent
Formation Ib-ii (cat clay with Cl')	brackish Formation I	
Formation Ib-iii (mud clay)		
unconformity		
Formation IIIf	non brackish Formation II	upper
Formation IIb-i (fossil cat clay without oxidizable sulphur)		Pleistocene
Formation IIb-ii	brackish Formation II	
unconformity		
Formation IIIf	Older Formation	middle
Formation IIIb	(corresponding to Formation III)	Pleistocene ?

The positional relations of the clays are visualized on a profile as shown in Fig. 2.

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