On the Size and Specific Gravity of Seashore Sand.

By

Yosirô IKEDA, Mituo ARAMATA and

Katuhiko YONETA.

In order to study the motion of sand, it is necessary that sands should be distinctly specified. Sand is an assemblage or granular mass composed of particles which are complex in their components as well as their forms and sizes. To simplify the research on dynamical properties, first, the chemical components are not considered, and secondly, the hardness and the conditions of surface of the particles are not discussed. The specific gravity and size only, which are important to the dynamical study, are taken into consideration. Accordingly, it is desired that materials with specified physical properties should be chosen for quantitative research either from natural sand or by means of crushing and selection with sieves. Although the latter is easily realized, the results studied by making use of sand selected by such a method may not be applicable in the natural phenomena. There arises, therefore, the question whether sand having specified physical properties may or may not be obtained from natural sand.

In the course of research on the cause of dune formation, the physical properties of sands were investigated by making use of samples from sandy beaches which were kindly sent by many graduates of the Technical Department of Hokkaido Imperial University who are distributed everywhere in Nippon. From Honsyu, Hokkaidô and Karahuto, samples were obtained almost sufficient in number (something over two hundred). Of course even in a sandy beach the sands have not uniform physical properties and components, depending upon the spot from which the collection is made, that is, the percentage of iron-sand and the size may be various according to the spot or to the depth from the surface. Although, thus, even sand from a sandy beach is not strictly specified, it is remarkable that the sizes of the seashore sands are almost limited within a certain range in spite of different components. This fact may be comprehended by the following. The sand particles transported through a river to the sea, being crushed, polished and selected by natural force, are raised upon a beach by means of sea waves. Thus, the sand of the seashore has specified physical properties, subjected to natural selections or dynamical conditions. Therefore, if the matter be further precisely investigated, there might be discovered some relations between the differences of their physical properties and the natural forces such as the strength and direction of predominant winds, the violence of waves and surrounding topography.

1. Physical properties of individual sand.

The diameter d by means of magnifying-glass with scale is measured along the direction of scale. Let 100 grains be taken at random from the sample in question and from the 100 grains let the number of grains be counted which lie between d and $d+\Delta d$. ($\Delta d = 0.05$ mm.) The frequency curve whose abscissa indicates the diameter and the ordinate the number of grains, is shown in Fig. 1. n_{max} is the maximum point of the curve and d_{max} the diameter which corresponds to n_{max}. When a point d, the area of the domain limited by the frequency curve, is divided into two equal parts, such d is denoted by d_{av}. If the frequency curve is symmetrical, d_{max} is equal to d_{av}. In practice, the frequency curve is distorted slightly from the symmetrical curve, therefore d_{max} is nearly equal to d_{av}. Considering stability, the average horizontal length of a laid body is a little larger than its average vertical length. But at present the discrepancy due to it may be neglected. The sands of Takaômori, Hakodate and Syari, Hokkaidô are adopted as examples of these frequency curves. Fig. 2 shows the results of measurements of the sand from Hakodate measured by 4 persons, and Fig. 3 shows those from Syari measured by 2 persons. Although the samples are separately taken from a bottle, the results measured nearly agree with each other, indicating a character such as seen in Gauss's error curve. Although among the sand of Takaômori, there exist grains having rather black appearance due to a larger

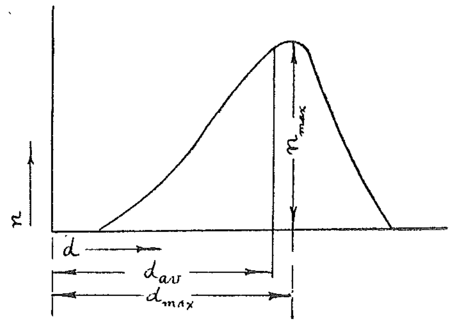

Fig. 1.

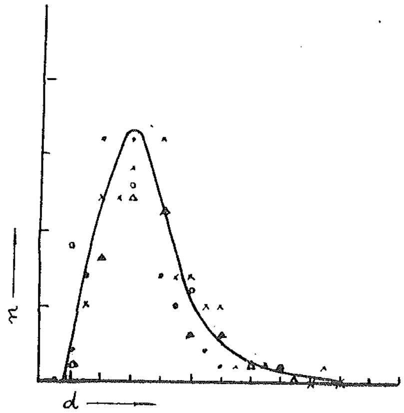

Fig. 2.

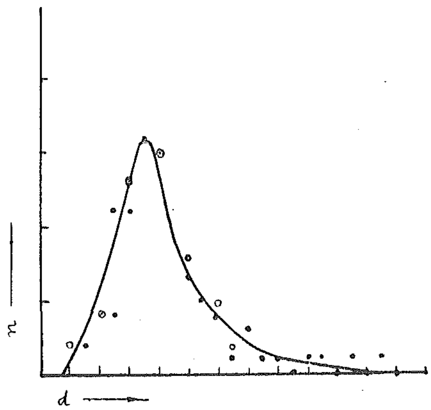

Fig. 3.

content of iron, this sample makes the usual appearance. From these curves, it is judged that the sand should be composed of comparatively regular particles, the sizes being near of an average. On the contrary, the sands of lakes, swamps or rivers are very miscellaneous and the curves showing the size and percentage of number of particles has many max. and min. Next for the sand of Takaômori specific gravity is 3.5, the apparent specific gravity is 1.83 and the porosity is 0.48, and for the one from Syari, the true and apparent specific gravity and porosity are respectively 3.0, 1.55 and 0.48. The porosity seems to be related to the height of distribution curves, though with some exceptions. Specific gravity is much influenced by the percentage of iron-sand included. Although the physical properties of sand differ from spot to spot even at the same beach, yet the specific gravity of seashore sand does not seem to be smaller than 2.3 nor larger than 3.8, and many of samples have a specific gravity of about 2.7. Therefore, the dynamical properties common to all sands may be considered when the motion of sands of sandy beaches is studied. In Tables 1, 2 and 3 the diameter, true and apparent specific gravities and porosity are summarized for the collected sands.

Table 1.

Sea	Locality	No. of place
Mamiya Strait		1-18
Aniwa Bay	Karahuto	19-25
Sea of Okhotsk		26-30

Table 1.—(*Continued*)

Sea	Locality	No. of place
Sea of Japan	Hokkaido	31-60
Tugaru Strait		61-67
Volcano Bay		68-75
Pacific Ocean		76-92
Nemuro Strait		93-95
Sea of Okhotsk		96-101
	The Kuriles	102-105
Sea of Japan	Akita prefecture	106-112
	Niigata ,,	113-129
	Toyama ,,	130-134
	Hyogo ,,	135-136
	Kyoto urban prefecture	137
	Tottori prefecture	138-144
	Simane prefecture	145-149
Pacific Ocean	Iwate prefecture	150-151
	Miyagi ,,	152
	Hukusima ,,	153
	Ibaragi ,,	154
	Tiba ,,	155-158
	Kanagawa ,,	159
	Sizuoka ,,	160-162
	Mie prefecture	163-170
	Wakayama ,,	171-186
Inland Sea	Hyôgo prefecture	187-192
	Hirosima ,,	193-205
	Kôti ,,	206

Table 2.

No.	Place	No.	Place	No.	Place
1	Kitanayosi	11	Maoka	21	Utisa
2	Esutoru	12	Honto	22	Uryu
3	Motake	13	Utihoro	23	Hamamiti
4	Tinnai	14	Moziro	24	Merei
5	Kusyunnai	15	Minaminayosi	25	Yamitu
6	Nayoro	16	Togusi	26	Tomunai
7	Tomarioru	17	Sozin Cape	27	Sakaihama
8	Nisititoru	18	Siranusi	28	Maguntan
9	Nitasu	19	Tisiya	29	Higasisirutoru
10	Habomai	20	Sonsi	30	Tirie

Table 2.—(*Continued*)

No.	Place	No.	Place
31	Zenibako village, Otaru district	66	Siriuti River, Siriuti village, ditto
32	Isikari village, Isikari district	67	Nezaki, Zenigame, Kameda district
33	Atuta village, Atuta district	68	Mori town, Kayabe district
34	Hamamasu village. Hamamasu dist.	69	Yagumo town, Yagumo district
35	Kawasimo village, ditto	70	Osyamanbe. Yamakosi district
36	Rumoe village, Rumoe district	71	Toyoura, Abuta district
37	Kotanhama, ditto (No. 1.)	72	Abuta village, Abuta district
38	Segosihama, ditto (No. 2.)	73	Usu, Usu district
39	Mouth of Onišika River, ditto	74	Nisihama-mati, Date town, Usu district
40	Hutakosi, Osima, Matumae dist.	75	Sikabe, Sikabe district.
41	Toyobe, Esasi, Hiyama dist.	76	Tomakomai town, Yûhutu district
42	Kumaisi, Esi dist.	77	Yûhutu, Yûhûtu district
43	Hiratanai, Kutô dist.	78	Higasi-Sizunai, Sizunai district
44	Setana, Setana dist.	79	Urakawa, Urakawa district
45	Higasi-Simamaki village, Simamaki dist.	80	Hunke, Hiroo district
46	Nisi-Simamaki village, ditto	81	Ôtu village
47	Tarugisi, Suttu dist.	82	Mouth of Tokati River, Ôtu village
48	Iwanai, Iwanai dist.	83	Ôtu, Ôtu village
49	Tomari village, Furuu dist.	84	Sinkusiro River, Kusiro city
50	Notuka, Irihune village, Syakotan dist.	85	Kusiro River, ditto
51	Tisaki, Bikuni, ditto	86	Benten-ga-hama, ditto
52	The coast at Bikuni, ditto	87	Sireto, ditto
53	Mouth of Bikuni River, ditto	88	Sinhuzi, ditto
54	Okoppe, Yoiti dist. (No. 1.)	89	Lake Harutori, ditto
55	,, (No. 2.)	90	Lake Akan
56	,, (coarse sand)	91	Sinryu, Akkesi dist.
57	,, (medium sand)	92	Monsizu, ditto.
58	,, (fine sand)	93	Inside the harbour of Nemuro
59	The coast at Otaru	94	Sibetu River
60	Zenibako, Otaru dist.	95	Rausu River
61	Sunayama, Takaomori, Hakodate city	96	Syari, Syari dist.
62	The bank of Sinkawa, ditto	97	Yanbetu, Yanbetu dist.
63	The beach at the mouth of Sinkawa, ditto	98	Mouth of Yûbetu River, Monbetu dist.
		99	Yûbetu River, ditto
64	The bottom of Sinkawa, ditto	100	Simoyûbetu, ditto
65	Kuneri, Kamiiso district	101	Simosyokotu, ditto

Table 2.—(*Continued*)

No.	Place	No.	Place
102	Rubetu, Yetorup Island Kuriles	139	A place between Koyama and Suetune (B)
103	Naipo, ditto	140	ditto (C)
104	Tosimoe, ditto	141	ditto (D)
105	Iririhusi, ditto	142	Tomiura
106	Araya, Kawabe dist.	143	Hamamura, Seizyo town, Kedaka district
107	Simohama, Yuri dist.	144	Yodoe town, Seihaku district
108	Kitahama, ditto	145	Hukumitu village, Nima district
109	Seki, Kamihama, ditto	146	Iwami-Fukumitu, ditto
110	Detomati, Honzyo town, ditto	147	Nozi, ditto
111	Mouth of Yonesiro River (No. 1.)	148	A place between Tunozu and Namiko, Naka district
112	ditto (No. 2.)	149	A place detween Orii and Miho-Misumi, ditto
113	Ryotu town, Sado dist.	150	Sokei town, Simo-Hei district
114	Naoetu town, Nakakubiki dist. (No. 1.)	151	Matubara, Takata, Kesen district
115	ditto (No. 2.)	152	Itikagesima, Kisennuma, Motoyosi district
116	Teratomari, Santô dist.	153	Taira, Iwaki district
117	Kasiwasaki, Kariha dist.	154	Ôta town, Kuzi district
118	Itoigawa town, Nisikubiki dist.	155	Makuhari, Tiba district
119	Iwahune town, Iwahune dist.	156	Kanaya, Kimizu district
120	ditto (No. 1, a)	157	Hunabasi, Tiba district (on the surface)
121	ditto (No. 1, b)	158	ditto (30 cm. below the surface)
122	ditto (No. 2, a)	159	Kita-Sitaura, Miura district
123	ditto (No. 2, b)	160	Lake Hamana, Hamana district
124	ditto (No. 3, a)	161	Mouth of Abe River, Abe dist.
125	ditto (No. 3, b)	162	Usami, Tagata dist.
126	Aikawa, Sado district	163	Kuwana, Kuwana dist.
127	Takati, ditto	164	The left side of the mouth of Suzuka River, Yokkaiti
128	The inlet at Ogi town, ditto	165	The left side of Horikiri River, Sirako town, Kawage dist.
129	Ogi town, ditto	166	Akogiura, Tu city
130	Simao, Miyata, Himi district (No. 1)	167	Tu city
131	ditto (No. 2)	168	Takasara, Ida village, Minami-Muro dist.
132	Husiki, Imizu district (No. 3)	169	Hirasima, Udono village, ditto
133	Sinminato, ditto (No. 4)	170	Mizunomoto, Adawa village, ditto
134	Uozu, Simo-Niigawa district		
135	Igumi, Nisihama, Mikata district		
136	Kasumi, Kisaki district		
137	Amano-Hasidate, Yosa district		
138	A place between Koyama and Suetune (A)		

Table 2.—(*Continued*)

No.	Place	No.	Place
171	Mouth of Kumano River, Singû city	188	A place near the 6th brerkwater at Kobe
172	Simo-Kumano, ditto	189	Sioya, Akasi dist.
173	Ôhama, ditto	190	Akasi, ditto
174	Singû city	191	Asiya, Muko dist.
175	Ôura, Nisimukai town, Higasimuro dist.	192	Sikama, Sikama dist.
176	Urati, ditto	193	Tatanomi, Toyota dist.
177	Takasiba, Simosato town, Higasimuro dist.	194	Kosaki, ditto
178	Konosiro, Tamanoura, ditto	195	Sunami, ditto
179	The beach near Nati station, ditto	196	Itukaiti town, Saeki dist.
180	Mouth of Nati River, Nati town, ditto	197	Ôtake town, ditto
181	Ukui, Ukui village, ditto	198	Ôno town, ditto
182	Esumi village, Nisimuro dist., ditto	199	Mihara-mati, Mihara city
183	Hosino, ditto	200	Itosaki-mati, ditto
184	Mirotu, Esu village, ditto	201	Aga-mati, Kure city
185	Tonda village, ditto	202	Takehara town, Kamo dist.
186	Sirahama, Setokanayama village	203	Tomo town, Numakuma dist.
187	Kôroen, Nisinomiya	204	The coast at Hukuyama Bay
		205	The coast at Matunaga Bay
		206	Kudô village, Hata dist.

Table 3

No.	Specific gravity	Apparent specific gravity	Porosity	Average diameter
1	2.7	1.64	0.39	0.55
2	2.5	1.59	0.36	0.3
3	2.6	1.58	0.39	0.3
4	2.8	1.54	0.45	0.25
5	2.7	1.73	0.36	0.6
6	2.7	1.52	0.44	0.25
7	2.8	1.55	0.45	0.3
8	2.7	1.53	0.43	0.3
9	3.3	1.92	0.42	0.3
10	2.7	1.50	0.44	0.25
11	2.7	1.47	0.46	
12	2.7	1.59	0.41	0.55
13	2.6	1.58	0.39	0.5

Table 3.—(*Continued*)

No.	Specific gravity	Apparent specific gravity	Porosity	Average diameter
14	2.7	1.54	0.43	0.25
15	3.0	1.54	0.49	0.35
16	2.7	1.48	0.45	0.25
17	2.7	1.53	0.43	0.3
18	2.5	1.43	0.43	0.25
19	2.7	1.61	0.40	0.7
20	2.7	1.62	0.40	0.45
21	2.7	1.53	0.43	
22	2.8	1.55	0.45	0.3
23	2.7	1.53	0.43	0.25
24	2.7	1.56	0.42	0.5
25	2.7	1.62	0.40	0.5
26	2.7	1.64	0.39	0.6
27	2.8	1.64	0.41	0.55
28	2.7	1.56	0.42	0.75
29	2.7	1.56	0.42	0.3
30	2.7	1.60	0.21	0.6
31	2.7	1.36	0.50	
32				
33	2.7	1.50	0.45	0.65-0.75
34	3.1	1.83	0.40	0.45
35	3.0	1.80	0.40	0.4
36	2.9	1.71	0.41	1.0-0.8
37	3.0	1.56	0.48	0.6
38	2.8	1.64	0.42	1.0-0.8
39	3.0	1.55	0.48	0.35
40	3.0	1.69	0.44	0.5
41	2.8	1.58	0.44	0.45
42	2.7	1.49	0.45	0.9
43	3.0	1.56	0.48	0.3-0.35
44	3.0	1.56	0.48	0.35-0.4
45	3.0	1.52	0.49	0.7
46	2.7	1.45	0.43	0.5
47	3.0	1.56	0.48	0.35
48	3.7	1.65	0.56	0.4
49	3.0	1.59	0.47	0.4-0.45
50	2.8	1.46	0.48	0.55
51	2.8	1.51	0.46	0.35-0.4

Table 3.—(*Continued*)

No.	Specific gravity	Apparent specific gravity	Porosity	Average diameter
52	2.8	1.51	0.46	0.45
53	2.8	1.54	0.45	0.35
54	2.6	1.38	0.47	0.4
55	2.6	1.40	0.46	0.5
56	2.8	1.32	0.53	0.75-0.8
57	2.5	1.40	0.44	0.5
58	3.0	1.38	0.54	0.4
59				
60				0.25-0.3
61	3.5	1.83	0.48	0.3
62	3.0	1.68	0.44	0.5-0.55
63	2.8	1.72	0.39	0.55
64	3.0	1.59	0.47	0.4-0.45
65	2.6	1.53	0.41	0.3
66	3.0	1.52	0.49	0.6
67	3.0	1.62	0.46	0.35
68	2.7	1.54	0.43	0.4
69	3.0	1.40	0.53	0.3
70	2.5	1.45	0.42	0.45-0.5
71	2.8	1.53	0.45	0.35-0.4
72	2.3	1.47	0.36	0.4-0.45
73	2.3	1.01	0.56	0.2-0.25
74	2.5	1.35	0.46	0.25
75	3.0	1.56	0.48	0.8
76	2.8	1.72	0.39	0.6
77	3.0	1.60	0.47	0.4-0.45
78	2.5	1.63	0.35	2.5
79	2.8	1.66	0.41	0.8-0.85
80	2.8	1.61	0.42	0.5-0.55
81	2.7	1.61	0.40	0.35-0.4
82	3.0	1.44	0.52	0.25
83	3.0	1.61	0.46	0.5-0.55
84	3.0	1.69	0.44	0.4
85	2.5	1.41	0.44	0.35
86	3.0	1.60	0.47	0.45
87	2.5	1.65	0.34	
88	2.8	1.66	0.41	0.55-0.6
89	3.0	1.64	0.45	0.95-1.0

Table 3.—(*Continued*)

No.	Specific gravity	Apparent specific gravity	Porosity	Average diameter
90	2.5	1 31	0.48	
91	2.7	1.65	0.39	
92	2.7			
93	2.7	1.74	0.36	0.3-04
94	2.8	1.73	0.38	0.4-0.45
95	3.0	1.36	0.55	0.4
96	3.0	1.55	0.48	0.35
97	3.0	1.58	0.47	0.5-0.55
98	2.7	1.63	0.40	1.2
99	3.0	1.63	0.46	0.6-0.7
100	2.8	1.58	0.44	0.7-0.8
101	2.6	1.63	0.37	0.5
102	3.0	1.64	0.45	0.45-0.5
103	3.0	1.56	0.48	0.5
104	3.0	1.59	0.47	0.35-0.45
105	2.9	1.60	0.45	0.45
106	3.0	1.52	0.49	0.35
107	2.6	1.51	0.42	0.3
108	3.0	1.61	0.46	0.85
109	2.8	1.49	0.48	0.45
110	2.8	1.58	0.44	0.85
111	3.0	1.51	0.50	0.35-0.4
112	2.8	1.59	0.43	0.8-0.85
113	2.8	1.62	0.42	1.0
114	3.0	1.52	0.49	0.3-0.35
115	2.7	1.53	0.46	0.3-0.35
116	2.8	1.53	0.45	0.6
117	2.8	1.56	0.44	0.5
118	3.0	1.59	0.47	0.4
119	2.7	1.59	0.41	1.2
120	2.7	1.46	0.46	0.35-0.4
121	2.7	1.51	0.44	0.35-0.4
122	2.8	1.56	0.44	0.45
123	2.8	1.58	0.44	0.45
124	3.0	1.59	0.47	0.35
125	2.9	1.69	0.42	0.35
126	2.8	1.62	0.42	0.95
127	2.7	1.43	0.47	0.3

Table 3.—(*Continued*)

No.	Specific gravity	Apparent specific gravity	Porosity	Average diameter
128	2.7	1.10	0.59	0.25
129	2.7	1.27	0.53	0.25
130	2.7	1.50	0.45	0.4
131	2.7	1.45	0.43	
132	2.5	1.32	0.47	0.3-0.35
133	3.0	1.55	0.48	0.7-0.75
134	3.0	1.55	0.48	0.45-0.5
135	2.7	1.29	0.52	0.25
136	2.7	1.56	0.42	1.05
137	2.7	1.48	0.45	0.85
138	2.6	1.41	0.46	0.3
139	2.7	1.48	0.45	0.3
140	2.7	1.56	0.42	
141	2.7	1.53	0.43	0.3
142	2.8	1.34	0.52	0.25
143	2.8	1.49	0.46	0.5
144	3.0	1.41	0.53	0.35
145	2.7	1.30	0.52	0.3
146	2.7	1.30	0.52	0.2
147	2.7	1.49	0.45	0.25
148	2.7	1.47	0.46	0.5
149	3.0	1.59	0.47	0.25
150	3.0	1.50	0.50	0.45-0.5
151	2.8	1.64	0.48	0.3
152	2.7	1.24	0.54	0.45-0.5
153	3.0	1.56	0.48	1.0
154	2.7	1.47	0.46	0.35
155	2.9	1.58	0.45	0.5
156	3.0	1.59	0.47	
157	2.3	1.42	0.38	0.05
158	2.8	1.45	0.48	
159	3.7	1.94	0.48	0.4
160	2.7	1.49	0.45	0.4-0.45
161	2.7	1.52	0.44	0.55
162	3.0	1.75	0.42	
163	2.7	1.38	0.49	0.3
164	2.7	1.56	0.42	
165	2.6	1.45	0.44	0.3

Table 3.—(*Continued*)

No.	Specific gravity	Apparent specific gravity	Porosity	Average diameter
166	2.7	1.41	0.48	0.3
167	2.7	1.40	0.45	0.3
168	2.7	1.61	0.41	0.6
169	2.7	1.59	0.41	
170	2.7	1.62	0.40	
171	2.7	1.53	0.43	0.35
172	2.7	1.59	0.41	
173	2.8	1.68	0.4	1.45
174	2.7	1.48	0.45	0.35
175	3.0	1.80	0.4	0.35-0.4
176	2.7	1.66	0.38	1.1
177	3.0	1.65	0.45	0.55
178	2.9	1.51	0.48	0.25
179	2.8	1.56	0.43	0.45
180	2.9	1.55	0.47	0.35
181	2.7	1.56	0.42	0.4
182	2.7	1.64	0.39	
183	2.7	1.54	0.43	0.6
184	2.7	1.62	0.40	
185	2.7	1.66	0.38	1.25
186	2.8	1.48	0.47	
187	2.7	1.41	0.48	1.2
188	2.7	1.44	0.47	0.3
189	2.7	1.44	0.47	0.25
190	2.7	1.51	0.42	1.05
191	2.8	1.49	0.47	0.65
192	2.6	1.29	0.50	0.2
193	2.8	1.44	0.49	
194	2.5	1.48	0.41	0.6
195	2.7	1.46	0.46	0.7
196	2.7	1.41	0.48	0.65
197	2.5	1.49	0.40	0.5
198	2.7	1.39	0.45	0.5
199	2.7	1.38	0.49	0.5
200	2.6	1.44	0.45	0.6
201	2.6	1.46	0.44	
202	2.5	1.45	0.42	1.15
203	2.6	1.48	0.43	0.6

Table 3.—(*Continued*)

No.	Specific gravity	Apparent specific gravity	Porosity	Average diameter
204	2.5	1.53	0.39	0.6
205	2.6	1.43	0.45	0.3
206	2.9	1.51	0.48	0.25

2. Frequency curve of d_{max}.

Values of d_{max} obtained from the data of all samples are summarized in Table 4, and indicated by a frequency curve shown in Fig. 4. Judging from the result, almost every d lies between 0.25 and 0.45 mm.

Table 4. Frequency of d_{max} of Sand Grains.

d_{max} in mm.	N			
	Honsyû	Hokkaido	Karahuto	Sum Total
0.075	0	0	0	0
0.175	9	0	1	10
0.275	25	13	14	52
0.375	26	31	2	59
0.475	12	13	4	29
0.575	10	4	5	19
0.675	3	3	0	6
0.775	2	3	0	5
0.875	2	3	0	5
0.975	1	0	0	1
1.075	0	0	0	0

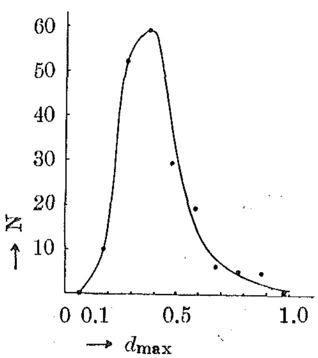

Fig. 4.

3. Frequency curve of the specific gravity.

Let the specific gravity be denoted by ρ and the number of grains which lie between ρ and $\rho+\Delta\rho$ ($\Delta\rho = 0.10$) by N. The data thus obtained are summarized in Table 5. The frequency curve whose abscissa is the specific gravity and ordinate the number is drawn as shown in Fig. 5.

Table 5. Frequency of Specific Gravity of Sand.

Specific gravity	N										
	Honsyû				Hokkaido					Karahuto	Sum Total
	Pacific Ocean	Sea of Japan	Inland Sea	Sum	Pacific Ocean	Sea of Japan	Sea of Okhotsk	etc.	Sum		
2.0	0	0	0	0	0	0	0	0	0	0	0
2.1	0	0	0	0	0	0	0	0	0	0	0
2.2	0	0	0	0	0	0	0	0	0	0	0
2.3	1	0	0	1	0	0	0	2	2	0	3
2.4	0	0	0	0	0	0	0	0	0	0	0
2.5	0	1	4	5	4	1	0	2	7	2	14
2.6	1	2	5	8	0	2	1	1	4	2	14
2.7	20	18	8	46	3	3	1	2	9	20	75
2.8	5	11	2	18	4	7	1	13	15	4	35
2.9	3	1	0	4	0	1	0	0	1	0	5
3.0	6	10	0	16	7	10	3	7	27	1	44
3.1	0	0	0	0	0	1	0	0	1	0	1
3.2	0	0	0	0	0	0	0	0	0	0	0

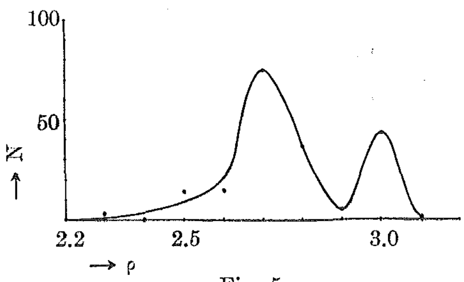

Fig. 5.

There occur two maxima, that is, the points at 2.7 and 3.0. The former corresponds to the specific gravity of quartz and feldspar and the latter is considered to be affected by iron-sand.

4. Frequency curve of porosity.

Let the porosity of the sand be denoted by p and the number of samples which lie between p and $p+\varDelta p$ ($\varDelta p = 0.02$) by N. The data obtained are summarized in Table 6. The frequency curve thus obtained is shown in Fig. 6. It shows that the number increases gradually at first

Table 6. Frequency of Porosity of Sand.

Porosity	N									
	Honsyû				Hokkaido				Kara-huto	Sum Total
	Pacific Ocean	Sea of Japan	Inland Sea	Sum	Pacific Ocean	Sea of Japan	etc.	Sum		
0.315	0	0	0	0	0	0	0	0	0	0
0.335	0	0	0	0	1	0	0	1	1	2
0.355	0	0	0	0	1	0	2	3	0	3
0.375	1	0	0	1	0	0	1	1	2	4
0.395	6	0	2	8	3	1	3	7	6	21
0.415	6	7	1	14	2	3	2	7	8	29
0.435	4	8	4	16	3	4	3	10	6	32
0.455	6	10	4	20	1	6	5	12	5	37
0.475	9	8	5	22	5	8	7	20	0	42
0.495	4	3	2	9	0	1	2	3	1	13
0.515	0	4	0	4	1	0	0	1	0	5
0.535	1	2	0	3	0	2	1	3	0	6
0.555	0	0	0	0	0	1	2	3	0	3
0.575	0	0	0	0	0	0	0	0	0	0
0.595	0	1	0	1	0	0	0	0	0	1
0.615	0	0	1	1	0	0	0	0	0	1
0.635	0	0	0	0	0	0	0	0	0	0

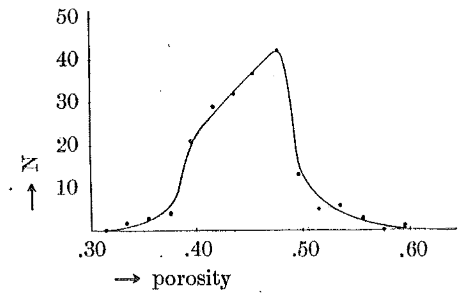

Fig. 6.

and after reaching its maximum decreases suddenly. It is remarkable that the maximum point of the porosity is nearly to the maximum porosity given by an assemblage of spheres of equal diameter.

5. The relation between n_{max} and porosity.

From 2 above it can be seen that when n_{max} is large, the greater number of grains is arranged within a narrow range of diamater, and inversely when n_{max} is small, the size of grains is widely distributed: in such a case the small grains fill the vacant space which is made when the large grains alone are filled up and consequently the porosity is low in this case. Indeed the relation between n_{max} and porosity is indicated by the set of points shown in Fig. 7 and the points are limited to a narrow space.

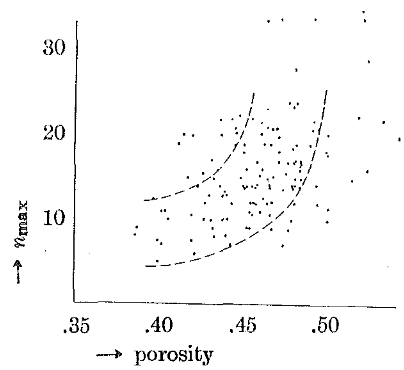

Fig. 7.