A STUDY ON LITHOLOGY AND SHAPE CHARACTERISTICS OF MORAINE AND MARINE PEBBLES IN THE LÜTZOW-HOLM BAY REGION

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Abstract: A statistical study on lithology and shape characteristics of moraine and marine pebbles was carried out in the Lützow-Holm Bay Region, East Antarctica. 5128 moraine and 2808 marine pebbles −5 and −4 in phi scale were selected from 20 sites to determine the lithology. Granitoid rocks were the most predominant among the pebbles. Jaspilite, basalt, hornfels and serpentine pebbles were also found, though they are not exposed in the vicinity of the study area. Composition of pebble lithology suggests that a large proportion of both moraine and marine pebbles were not derived from the adjacent ice-free area but were transported from the inland ice-covered area.

4220 moraine and 1681 marine pebbles of granitoid rocks were selected for shape analysis. Measurement of roundness, flatness and sphericity were performed. The average roundness was quite low in both moraine and marine pebbles. The elevated beaches have less rounded pebbles than those of the present tidal zone. This indicates that the pebbles of elevated beaches have been weathered by frost action since the beaches emerged. Pebbles of marine deposits can be distinguished from those of moraine, the former being flatter than the latter. The sphericity index is greater in moraine than in marine pebbles.

1. Introduction

It is difficult to elucidate the geology of the area covered with thick ice sheet in the Antarctic region. The moraine and marine deposits of the Lützow-Holm Bay Region are composed of various kinds of rocks which have been derived not only from the adjacent ice-free area but also from the ice-covered area. Lithology of moraine and marine deposits has rarely been surveyed in this region, while geological investigations have advanced in the ice-free area (YOSHIDA *et al.*, 1971; ISHIKAWA, 1976; YOSHIDA, 1977). Identification of pebble lithology was carried out in this area to estimate the geology under the ice sheet.

The analysis of pebble shape is important in interpreting the mechanisms of deposition and transportation of pebbles (KING, 1966). Measurement of pebble roundness, flatness and sphericity was also done in the same area to understand glacial abrasion and marine process in the arctic environment.

2. Study Area and Methods

The study area is shown in Fig. 1 and the outline of sampling sites is given in Table 1. At each locality, pebbles of 64 to 32 mm (−5 in phi scale) and 32 to 16 mm (−4 in phi scale) in medium diameter were collected in squares of 1 by 1 meter. 5128 pebbles were picked up from 13 moraine sites, 2297 from 6 elevated beaches, and 511 from a present tidal zone. All the pebbles were grouped by the respective lithology.

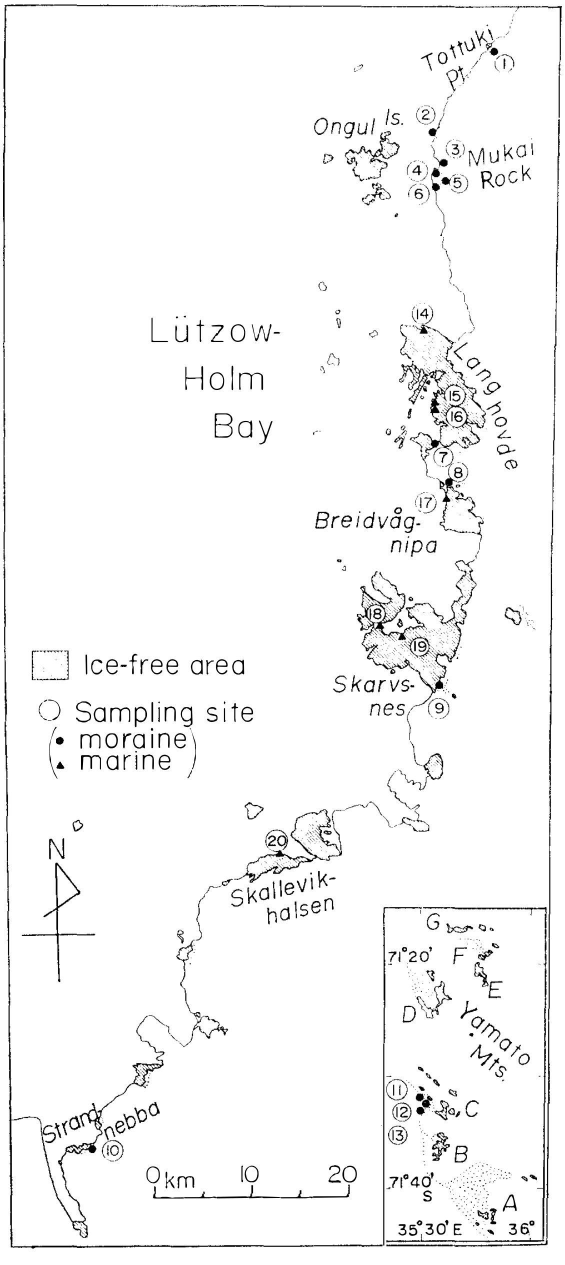


Fig. 1. Study area and sampling sites.

Table 1. General remarks on the topology and geology of the sampling sites.

Sample No. and location	Origin	Geology of the adjacent outcrops						
		Metabasite	Marble	Pyroxene Gn.	Hornblend Gn.	Garnet Gn.	Garn. Biot. Gn.	Granitoid rocks
1. Tottuki Point	Shear Moraine	Unknown						
2. Moraine opposite to the Ongul Islands	Shear Moraine	Unknown						
3, 4, 5 and 6. Mukai Rock	Shear Moraine	Unknown						
7. Hamna Icefall	Lateral Moraine	X	X	R	P	X	R	R
8. Breidvågnipa	Shear Moraine	O	P	R	X	X	R	R
9. Skarvsnes	Shear Moraine	X	X	R	X	X	P	R
10. Strandnebba	Shear Moraine	P	X	X	R	X	X	R
11, 12, and 13. C gr., Yamato Mts.	Shear Moraine	P	X	X	X	X	X	R
14. Kominato Inlet, Langhovde	Terrace 8 m a.s.l.	O	P	R	X	P	R	O
15. Yatude Valley, Langhovde	Terrace 15 m a.s.l.	O	X	O	P	R	R	R
16. Yatude Valley, Langhovde	Terrace 12 m a.s.l.	O	X	O	P	R	R	R
17. Breidvågnipa	Tidal zone 0 m a.s.l.	P	O	R	X	X	R	R
18. Kizahasi Beach, Skarvsnes	Terrace 5 m a.s.l.	P	X	R	X	O	R	O
19. South to Osen, Skarvsnes	Terrace 7 m a.s.l.	P	X	R	O	P	R	P
20. Skallevikhalsen	Terrace 5 m a.s.l.	O	R	X	R	O	X	R

(R: Rich, O: Ordinary, P: Poor, X: Lack or unknown)

Geology is based on YOSHIDA *et al.*, 1976, ISHIKAWA *et al.*, 1976, 1977, SHIRAISHI *et al.*, 1978 and author's survey.

Nos. 3 to 6 were collected in the moraine field of the Mukai Rock to check the local variance in the same area. No. 14 was on the raised beach in the Kominato Inlet which represented see level of 23830±910 Y.B.P. (MORIWAKI, 1974). Nos. 15 and 16 were of marine terrace deposits composed of coarser materials, presumably fluvio-glacial origin. No. 19 was collected on the raised beach which represented see level of 5010±80 Y.B.P.

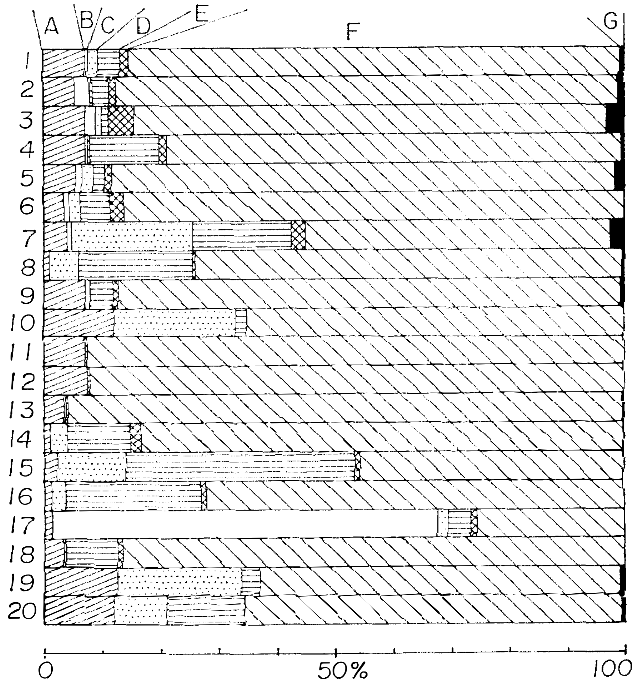
Length (l), width (w) and height (t) in the principal plane of pebble were measured to obtain indices of shape characteristics. Roundness index was represented by visual comparison chart of KRUMBEIN (1941). Flatness was defined as follows (NAKAYAMA, 1963);

$$F=\frac{w-t}{w}$$

Sphericity index was determined by Krumbein's visual figure using *w/l* and *t/w* (KRUMBEIN and PETTIJOHN, 1938).

3. Lithology of Moraine and Marine Pebbles

The composition of pebble lithology at each sampling site is shown in Fig. 2. Granitoid rocks including granite gneiss, gneissose granite, migmatite and pegmatite are the most predominant pebbles, although pyroxene, hornblend and garnet gneisses are most extensively exposed, occupying 90 percent of the ice-free area of the Lützow-Holm Bay region (YANAI, 1973).



A: Metabasite. B: Marble. C: Pyroxene and hornblend gneisses. D: Garnet and garnet-biotite gneisses. E: Jaspilite. F: Granitoid rocks. G: Other rocks.

Fig. 2. Composition of pebble lithology.

Among the moraine sites, Nos. 1 to 6 and 9 are quite similar in composition consisting largely of pebbles of granitoid rocks with several percent of metabasite and gneisses. Marble pebbles are frequently contained in these samples. No outcrops of marble beds have been found in the area to the north of Langhovde. However, they are exposed in the Langhovde, Breidvågnipa and Skallen regions. This suggests that marble bedrocks exist under the ice field of this area close to the coast. Jaspilite, hornfels, basalt and serpentine pebbles, though in small amounts, are also noticeable because there are no outcrops of them in the vicinity of the Lützow-Holm Bay region.

Compositions of sample Nos. 7, 8 and 10 which are rather rich in gneiss pebbles coincide with the distribution of outcrops in the ice-free area.

Distinct difference in composition is recognized between the moraine pebbles in the coastal region and those in the Yamato Mountains region. In Nos. 11 to 13, most of pebbles are of granitoid rocks containing abundunt pink microcline which are vastly exposed in the Yamato Mountains. Only three pebbles of garnet-biotite gneiss and one each of marble and syenite are found in these sites.

In the samples from marine deposits, the proportion of granitoid pebbles is smaller than that in moraine. A large amount of marble pebbles in sample No. 17 is ascribed to the exposures of the marble vein locating some 10 meters inland from the coast of Breidvågnipa. On the other hand, marble pebbles were rarely found on the beach of Skallevikhalsen as shown in sample No. 20, though exposures of marble bedrocks extensively spread in this ice-free area.

It is generally understood that composition of pebble lithology can not necessarily coincide with geology of ice-free area. In the present study area, a large proportion of both moraine and marine deposits was transported by glaciers from the inland ice-covered region.

4. Shape Characteristics of Moraine and Marine Pebbles

It is important for shape analysis that all the pebbles should be of the same lithology, as pebbles of different lithology tend to have different characteristic shapes. Granitoid pebbles were selected in this study because they were most predominantly distributed. A total of 4220 pebbles from moraine deposits, 1551 from the elevated beach deposits and 130 from the present tidal deposits was used for shape analysis. Mean values of roundness, flatness and sphericity at each sampling site are calculated in Table 2. Roundness of pebbles ranges from 0.1 in minimum to 0.6 in maximum, flatness from 0 to 0.9 and sphericity from 0.5 to 0.9 in the present area.

Pebbles of moraine deposits are poorly rounded in this area. DRAKE (1972) mentioned that 70 percent of pebbles possessed a roundness of 0.1 at the time when glaciers plucked them from their bedrock source. Poorly rounded pebbles of the present moraine deposits indicate that glaciers caused no changes in pebble roundness during the transport.

Beaches of polar region have poorly rounded pebbles (NICHOLS, 1961), though roundness of marine pebbles is greater than 0.5 in nonpolar climate (NAKAYAMA, 1968). In the present area, most of them are angular and sub-angular.

Pebbles of sample No. 17 collected from the tidal zone marked the greatest in roundness. The elevated beaches have less rounded pebbles than those of the present tidal zone. This indicates two alternatives: (1) The pebbles have been weathered since the beaches emerged. (2) The marine erosion before the beaches emerged had been less active than at present.

Table 2. Mean values of roundness, flatness and sphericity of the granitoid rocks.

	Number		Roundness		Flatness		Sphericity	
	$-\phi 5$	$-\phi 4$	$-\phi 5$	$-\phi 4$	$-\phi 5$	$-\phi 4$	$-\phi 5$	$-\phi 4$
1	125	390	0.155	0.171	0.320	0.289	0.727	0.719
2	135	217	0.141	0.134	0.348	0.299	0.714	0.713
3	93	203	0.133	0.128	0.306	0.292	0.722	0.691
4	113	185	0.128	0.131	0.384	0.295	0.717	0.688
5	82	245	0.138	0.137	0.349	0.318	0.710	0.694
6	98	180	0.133	0.124	0.301	0.283	0.728	0.718
7	29	36	0.165	0.181	0.299	0.225	0.779	0.724
8	83	239	0.147	0.215	0.327	0.291	0.725	0.723
9	129	185	0.132	0.134	0.340	0.290	0.728	0.687
10	72	325	0.199	0.191	0.304	0.288	0.744	0.723
11	100	207	0.131	0.128	0.360	0.300	0.709	0.706
12	113	206	0.136	0.124	0.323	0.323	0.721	0.697
13	132	298	0.190	0.136	0.339	0.309	0.708	0.694
14	69	142	0.157	0.150	0.460	0.400	0.664	0.641
15	39	110	0.251	0.184	0.370	0.361	0.713	0.685
16	65	223	0.137	0.149	0.392	0.341	0.711	0.684
17	43	87	0.372	0.375	0.609	0.474	0.618	0.643
18	129	209	0.114	0.119	0.415	0.390	0.694	0.685
19	71	234	0.128	0.135	0.474	0.415	0.656	0.663
20	60	200	0.173	0.189	0.350	0.335	0.724	0.705

The first alternative is preferred by the author because most of pebbles in the elevated beaches are found to possess partial or complete rugged and weathered rims, probably by frost shattering.

Regarding flatness, marine deposits can be distinguished from moraine as shown in Fig. 3, where marine pebbles are much greater in flatness than moraine. The average value of 0.3 to 0.35 is considered the equilibrium state for flattening of moraine pebbles. This figure also shows that pebbles of -5ϕ are always flatter than those of -4ϕ.

The histogram of flatness for each sample is given in Fig. 4 to understand the distribution pattern. The variances of the frequency distribution were tested by F ratio test to compare the histograms. The result suggests that the significant difference at 0.001 probability dose not apply to all the histograms. This means that all the samples were picked up from the same population and that no differences were found among the patterns of histogram. The only difference between the flatness of moraine sample and that of marine was the mean value as a result of t ratio test.

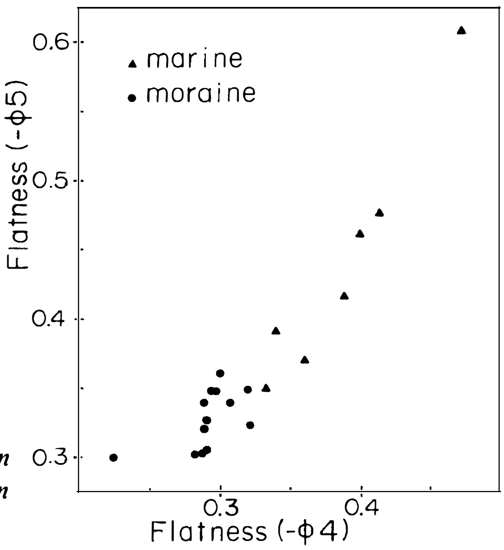


Fig. 3. Flatness correlation between pebbles of −5 and of −4 in phi scale.

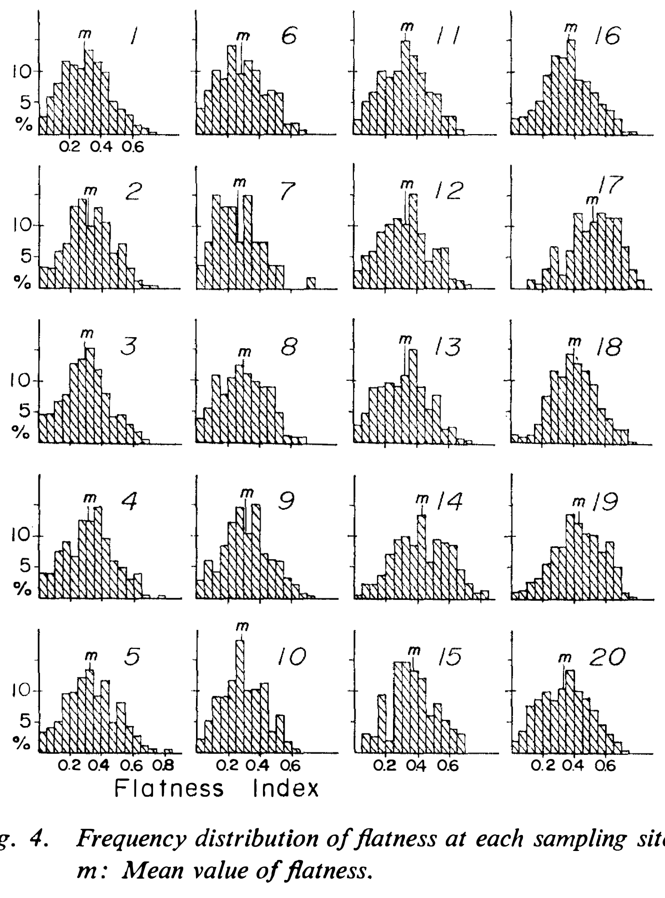


Fig. 4. Frequency distribution of flatness at each sampling site. m: Mean value of flatness.

Sphericity of moraine pebbles was greater than that of marine, and pebbles of -5ϕ showed greater sphericity than of -4ϕ.

5. Conclusion

Lithology of pebbles in the Lützow-Holm Bay region suggests that most of moraine and marine deposits were of glacial origin and were transported from the ice-covered area. Granitoid rocks are considered most predominant among bedrocks of the inland area covered with thick ice. Bedrocks of jaspilite, basalts, hornfels and serpentine presumably exist in the ice-covered area, though they have never been found in the study area.

Roundness is quite low in both moraine and marine pebbles of this area. The pebbles collected from the elevated beaches are less rounded than those from the present tidal zone because they have been weathered by frost shattering since the beaches emerged. Flatness index of pebbles is quite useful to distinguish between marine and moraine deposits. The former is apparently flatter than the latter. The value of sphericity is greater in moraine than in marine pebbles.

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