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COASTAL PHENOMENA AND ISOSTATIC UPLIFT AROUND FILDES PENINSULA OF KING GEORGE ISLAND, SOUTH SHETLAND ISLANDS, ANTARCTICA

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Abstract After a field work on recently raised coastal features in South Shetland Islands, we conclude that there are three kinds of recent coastal features, i.e, fragmental coast, rock coast, and ice cliff coast. The processes and forms of the fragmental cost formed by wave action with floating ice are studied. Systematic study of the raised coasts enables us to distinguish two groups of the coasts by an elevation of 20m a.s.l. The raised coasts above 20m a.s.l. belong to older group and those below 20m a.s.l. belong to younger group. Mean uplift rate of coast in this area is 6.7 mm/a.
Key words Coastal phenomena, isostatic uplift, Fildes Peninsula.

Introduction

South Shetland Islands are located at latitude 61°45′ — 63°21′S, longitude 57°30′ — 62°50′W. The major islands are covered by cap glacier, and only small ice free areas occur on the margins of the islands. On the South Shetland Islands, the annual mean temperature ranges from —2.6 to —9.0℃, the maximum wind velocity can be 61 — 68 m/s, and the annual mean precipitation is 415mm. The field work was conducted during the summer of the Southern Hemisphere in 1987 — 1988 on Fildes Peninsula of King George Island, Harmony Cove of Nelson Island and Adelie Island. The coastal features in these areas are typical in geomorphology of the region. So it is necessary to be deeply considered.

The Types and Characteristics of the Recent Coast

From May to October, there are 6 to 7 months when the sea around the coast of the South Shetland Islands is frosted every year, meanwhile, the wave action seases. This is

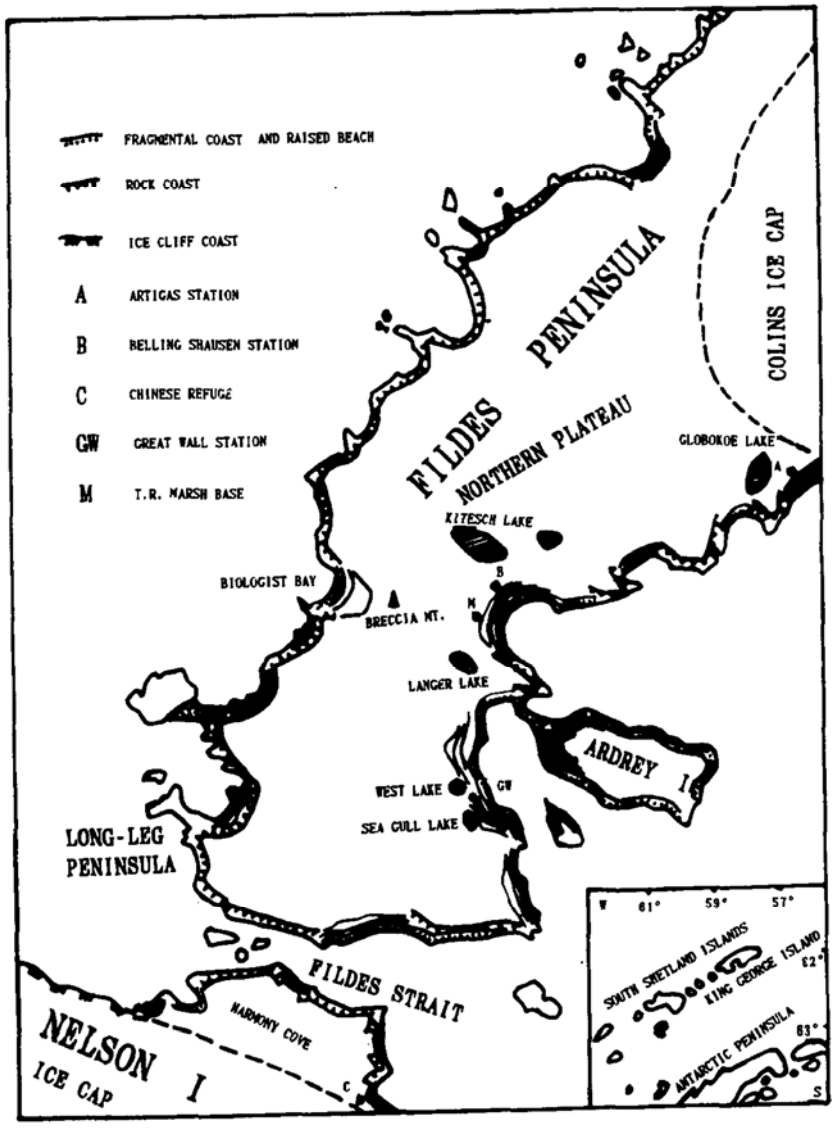

Fig. 1. Map showing distribution of three types of coasts in the area investgated.

one of the characteristic geomorphologal processes for the Antarctic coast. The maximum tidal range is 2. 28m and the tide in this area is an unregular semidiurnal tide. Storm added by high tide can lead to storm surge which can greatly affects on fragmental coast. In the melting season, great quantity of ice blocks accumulate along the coast, act by wave, they push, polish and dash against the coast.

1. Fragmental coast

Fragmental coast consists of sand and gravel. The fragmental coast mainly belongs

to gravel coast. The coastal gravels take the rounded oblate shape with flat plane inclined seaward, and long axis parallel to the coast. The coastal gravels are mainly subrounded, and subangular gravels are also common. There is few rounded gravels. At the back of high tidal line, there exist backshore surge. Small part of the fragmental coast consists of sand, for example, the beaches at Chinese Glacial Survey Refuge Bay of Nelson Island, Biology Bay and Glacial River Bay of Fildes Peninsula. The sand coast of small bay is depositional. Sands and gravels can block small bay due to wave action to form laguna. For example, the laguna at the front of Great Wall Station on King George Island and north—west of Harmony Cove of Nelson Island. The bars are formed around the Long—leg Peninsula, Flat Top Volcano of King George Island, between Adelie Island and King George Island, and north—west of Spray Island.

A strong storm surge can significantly affect fragmental coast. A strong storm surge, occurring on the 3rd Jan. 1988, causes the backshore terrace in front of Great Wall Station to raise up 3—10cm. And a great quantity of sand and stone moved over the back shore terrace and deposited.

Floating ice play a very important role in coastal features. The floating ices along the sand and gravel coast act on tideland and shallow sea floor by pushing, polishing and dashing of the waves. The common features are pavements formed by push and press of floating ice (Plate 1), linear gravel ridges along coast in front of backshore, channels sided by coarser gravels (plate 2) and irregular crisscross gravel network structures (Araya and Herve, 1990a).

Linear gravel ridges are located in front of backshore along the coast and consists of gravels larger than 20cm in diameter continuously or discontinuously. This feature is very common on the beaches of by wave action with floating ice pushed the gravels in front of backshore.

Pavement is one of the most common features on fragmental coasts and occurs on low slope gravel tideland. Closely fitted and inlaid gravels with upward maximum flat plane, form a flat surface of tideland. The pavement developes most typically on tideland with slope lower than 5° and gravel diameter of 15 to 50 cm. Gravels on tideland, pushed and pressed by floating ice loaded by wave, change their way to drift and than to rest in a stable or balanced state. Finally, the gravels are pushed together and show an inlaid contact, the upward flat planes of gravels form a smooth surface. Then, floating ice only causes the gravels to move a little or remain in situ. Floating ice mainly exerts polishing effect on gravel top of pavement. The gravel tops of pavement south of Great Wall Station have polished surfaces and a few of them with stria by floating ice. It is shown that pavement structure is in stable state by the fact that there exists seaweed in seams between gravels.

Channals vertical to coast were formed by big floating ice that was pushed up to high tidal line by waves. There is a channal 15m in length, 2.5m in width, and 0.3—0.4m in depthin the north of Great Wall Station.

The gravel pit surrounded by coarser gravels was formed on tideland with less sorted sediments. It has a lower and finer floating ice (more than 1 m in diameter) can be stranded when high tide occurs. The stranded ice, rocking or swaying in situ. After the floating ice melted completely, a gravel pit was formed.

Many times large number of floating ice stranded on tideland, forms a network strcture, which consists of crisscross features of gravel ridges and pits. As every accumulation the floating ice on tideland, the network changes its features. So the network strcture is in unstable state and a tends to become a stable state of pavement strcture. Some coarser gravels are pushed to backshore and form linear gravel ridge along coast.

2. *Rock coast*

After the last glaciation, as the raised coast features show, this area has undergone slow uplift. The erosion of wave on raising shore gives rise to sea cliffs with a height of 35—45 m a. s. l. and flat top. Wave acting on base of cliff creates wave—cut caves, tors, grooves and platforms. There is a wave—cut bridge at Half Three Point of Fildes Peninsula. The above—mentioned features from a type of rock coast. The portion of rock coast is larger at the western side of Fildes Peninsula than at the east side. Thus the western side of Fildes Peninsula shows a landform of cliffs and reefs (Plate 3). It is suggested that these feathers were created by coast erosional retreat due to strong estward wind—wave action. The width of undersea platform above a depth of 100m at the western side of Fildes Peninsula ranges from 10 to 15km, but only several hundred meters to 5km at its eastern side, that also shows the western side has undergone stronger erosional progress.

3. *Ice cliff coast*

The coast of South Shetland Islands mainly consists of ice cliffs (plate 4), which are a peculiar feature in areas of high altitude. Ice comes from cap glaciers on the islands to shore and collapses from glacier to sea. The collapses ice becomes floating ice and reduces gradually in sea. The height of ice cliff ranges from several meters to several hundred meters. The base of ice cliff sometimes grounds on sea floor and sometimes floats on sea. Wave has two effects on ice cliff, i. e. the mechanical dashing and slapping and the thermaly ablation. Therefore in the development of ice cliff, the thermal ablation is very important. We found thermo—melting caves 2 to 3 meters in ice cliff in the north of Fildes Peninsula and Harmony Cove of Nelson Island.

The themaly ablation undoubtedly leads the ice cliff to be unstable and accelerates the collapes rate of ice cliff coast. The frequent loss of ice is compensated by the flowing glacier to the coast. Therefore material on ice cliff coast is in dynamical balance by glacier. It is necessary to point out that ice—bergs and floating ice don't belong to coastal category after they break away from glacier, but they have not finished act as a geomorphological feature. The reasons are mentioned below. They have effective dashing and polishing action on the coast when they flow to shore. They move as ice raft carrying rock fragments that come from bedrock under original glacier and drop down to sea floor when the ice melted out. Therefore it is considered that the ice cliff coast is one of the special coastal types and has distinctive geomorphological signficance and progress. Ice cliff coast is the exit from which rock fragments are transported.

In general, the coast of South Shetland Islands can be diveded into three types fragmental coast, rock coast and ice cliff coast. In tideland with slope lower than 5°, and gravel diameter of 15 to 50cm have linear gravel ridges along coast, gravel channels and ridges vertical to coast, gravel pits surrounded by coarser material, pavements and gravel network structures. They were formed by wave with floating ice. Ice cliff coast holds dynamic balance. The thermal ablation of sea water is very important in the development of ice cliff coast. Gravels on modern beaches are low rounded, indicating that they have not undergone sufficient polishing and rounding. Modern coasts only exist in a short time. Also, it is suggested that the low rounded gravels are partly due to the limited wave action in winter period.

The Raised Coast and Isostatic Compensation Uplift

The evidence for sea level change in South Shetland Islands area from Tertiary to Quaternary is a 9m seqence of marine conglomerate which is exposed at 45m a. s. l. in the south—east of King George Island (Adie, 1963). From fossil evidence, the rock was depoisted in an environment near the sea. From late Pleistocene to present, many traces of sea level change are maintained on the Islands (Fuenzalida, 1963; Araya and Herve, 1970b; Birkenmajer, 1981; Xie, 1988). It is suggested that the raised coast is related with glacier advance and retreat due to climatic change in Late Pleistocene. The coast rises when glacier retreats and isostatic uplift occurs.

1. Distribution, altitude and time of raised coast

NELSON ISLAND Raised beaches are distributed at 1. 5—2. 0, 4. 0, 7. 0—7. 5, 9. 0 and 14. 0m a. s. l. They consist of subrounded flat gravels. The wave cut phenomena, such as wave cut caves and platforms, occur at 4, 9 , 14, 20 and 35m a. s. l.

LIVINGSTON ISLAND Raised beaches were found at 2.4—3.0, 5.4—6.1, 7.6, 10.6—12.2m a.s.l. Wave cut phenomena were found at 2.4—3.0, 7.6, 15.2, 23, 45—53m a.s.l. (Adie, 1963).

ADELIE ISLAND Raised beaches were found at 2.0, 5.0, 6.6, 9.0 , 13.0, 18.0m a.s.l. There is a raised laguna behind a beach at 18m a.s .l. Wave cut caves, tors and platforms occur at 2.0, 5.5, 9.0 and 35m a .s.l.

FILDES PENINSULA of KING GEORGE ISLAND Detailed field work was conducted on Fildes Peninsula. Below 20 m a.s. l. , well maintained raised beaches were found at 1.5—2.0, 3.0—5.0, 6.5—7.5, 9.0—10.0, 12.0—14.0 and 16.5—18.0 m a.s.l. In additon, Rounded gravels are scattered at 35, 45 and 55 m a.s.l. , but no remarkable beach was found. It is suggested that these gravels have been distributed on fossil beaches according to their shape. Raised lagunas occur at 7.0—8.7, 13—14 and 18 m a.s.l. They are supplied with fresh water from melting snow. Wave cut phenomena were found at 3.0, 6.0—7.0, 10.0, 18.0—20. 0, 35—40, 45—55 and 90—99 m a.s.l. The wave cut features below 20m a.s.l. are distributed along recent coast. Wave cut features above 20m a. s. l. are wave cut caves, grooves and platforms scattered on the peninsula. For example, there is a wave cut cave at 38.0 m found on Half—Side Mt. which is surrounded by scattered littoral gravels. A fresh water lake in front of the cave is considered to be a raised laguna. An eastward depression of the lake were filled with fragments and some rounded gravels. The western coast of Fildes Peninsula consists mainly of wave cut platform or sea cliff with height from 45 to 55 m a.s.l. In the protruded parts of the cliff exist wave cut caves at different height. Wave cut caves and grooves were found on Northern Plateau and Breccia Mt . which are at altitude of 90—99m a.s.l. (plate 5,6,7). At the 99m a. s .l. on Breccia Mt. we found many wave cut feature, such as caves, grooves and pits. A few rounded gravels in the grooves on Briccia Mt. may be preserve marine gravels.

From the preservation degree, the raised coastal features around South Shetland Islands can be distinguished to be of two period. The coastal feature below 20m a.s. l. are well preserved. The raised beaches hold their original ridge, and gravels a beach were weathered by frost—thawing and their primary occurrence. Stone circles were found on some higher beaches (20 m a.s.l.). Gravels on raised beached were partly cracked by frost action. It can be that the raised beaches and wave cut features below an elevation of 20 m a.s. l. have been rising continuously. Above the elevation of 20m a.s.l. wave cut features and raised beaches are sporadically preserved, the marine features are most wave cut platforms, caves and grooves, but no obvious beach. A great many glacial forms, such as stria, straited surfaces and boulders, were found on platforms above the elevation of 35 m a. s. l. From the above mentioned phenomena, it is suggested that there was a

glaciation after the marine features had formed and the glacier covering the marine features. As the glacier retreats, the previous marine feature which had not been destroyed appeared again, meanwhile the marine features below 20 m a. s. l. were formed gradually due to uplift of isostatic compensation. It is suggested that the marine features above 20 m were formed during the last interglacier stage, and the marine features below elevation of 20m a. s. l. were formed post—glacial period. How to divide the marine features above 20m a. s. l. remains a problem to be further studied.

2. The rate of uplift

Fossil shells were collected for radiocarbon dating at three sites on Fildes Peninsula of King George Island. The elevation of sampling sites are 9, 10 and 14 m a. s. l, and their radiocarbon ages are 1,310+95a, 1,310+110a and 2,180+95a B. P., respectively, the mean uplift rates are 7. 0, 7. 6, and 6. 5mm/a, respectively. Xie (1988) obtained samples from lacustrine deposits of West Lake near Great Wall Station. The elevation of the samples is 18 m a. s. l. and the radiocarbon age is 3200 a B. P. mean uplift rate is 5. 6mm/yr. From the above—mentioned data, the mean uplift rate in this area is 6. 7mm/yr. Table 1 shows the elevation, age and mean uplift rate of the coast of South Shetland Islands and the marginal areas of Antarctic Continent. From the data in Table 1, we conclude that the Antarctic area has been being in an uplift condition since glacier retreat in Holocene. The uplift rate in maritime area is higher than that in the continental area of Antarctica. It may reflect that during post—glacial stage, the recession of glacier decreased from lower to higher latitudes, and the amount of isostatic uplift decreased from lower to higher latitudes.

Basing on the above analysis we deduce that the raised coasts of South Shetland Islands can be distinghuished into older group which is above the elevation of 20 m and younger group which is below 20m a. s. l. The well preservd younger group has a mean uplift rate of 6. 7 mm/a. There was a glaciation after the older group. The younger group formed during post—glacial stage and the older formed during the last interglacial stage or earlier. The uplift rate in South Shetland Islands area is larger than that of marginal coast of Antarctic Continent. The uplift rate of the former is more than 6 . 7mm/a.

Conclusions

(1) The recent coasts of South Shetland Islands can be disinghuished to be of types

Table 1. The elevation, age and uplift rate of the coasts in Antarctic region.

	Location	Elevation m a.s.l.	Age a.B.P.	Mean uplift rate mm/a	Note
Maritime area of Antarctica	Fildes Peninsula of King George Island, South Shetland Island	9	1,310	7.0	the authors, 1988
		10	1,310	7.6	
		14	2,180	6.4	
		18	3,200	5.6	Xie, 1988
	Admiralty Bay of King George Island, South Shetland Islands	2	250	8.0	Birkenmajer, 1981
		6	550	10.9	
		10	800	12.5	
		14	1,000	14.0	
		45	5,000	9.0	Tatur, 1986
	South Georgia Island	2.5	200	12.5	Clapperton, 1971
Antarctic Continent	East Orgul Island	3.5	3,840	1.0	Meguro, 1963
	Luzow—Holm Bay	9.5	7,730	1.2	Moriwaki, 1974 1976
		1.5	4,300	0.35	
		—	—	2.5	Yoshida, 1979
	Vestfold Hills	6—15	6,000—7,600	1.0—2.0	Zhang, 1985
	Windwill Island	23	6,040	3.9	Cameron, 1961
	McMurdo Sound	13	4,450	2.9	Nichols, 1968

fragmental coast, rock coast and ice cliff coast.

(2) There are many peculiar high latitude coastal phnomena formed on fragmental coast by waves with floating ice. They are linear gravel ridges near backshore terrace, vertical gravel channels and ridges, pavements, gravel pits and network structure on tideland. The typical features appear on tideland with gravel 15—50 cm diameter and slope lower 5°.

(3) Wave action is very important in ablation of ice cliff coast and can accelerate collapse of ice cliff.

(4) The raised coasts were divided into two groups, the older group above 20 m a.s.l. and the younger group below below 20 m a.s.l.. There was a glaciation between the two groups. The youger group is considered to have been forming during post—glaciation and the older group in last interglacial stage or earlier.

(5) The average uplift rate of South Sheland Islands coasts is 6.7 mm/a, which is larger than that of the coasts on marin of Antarctic Continent. The uplift of the coasts were due to isostatic compensation of the crust after glaciation.

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Plate 1. Pavement at Fildes Peninsula.

Plate 2. Gravel pits at fragmental coast in Adelie Island.

Plate 3. West coast of Fildes Peninsula.

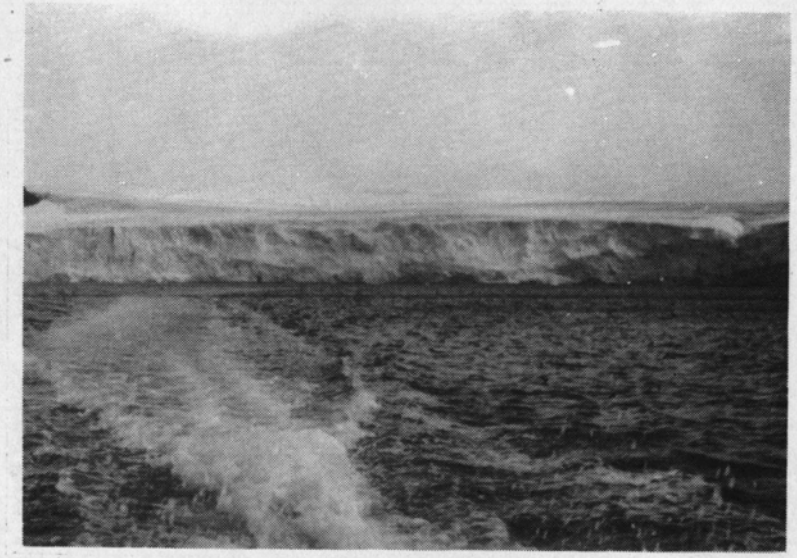

Plate 4. Ice cliff coast at Nelson Island.

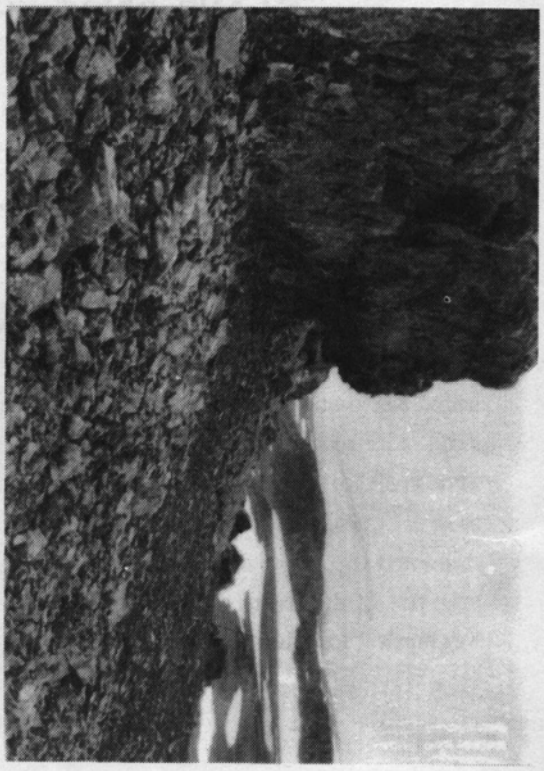

Plate 5. Wave cut cave on Northern Plateau in Fildes Peninsula.

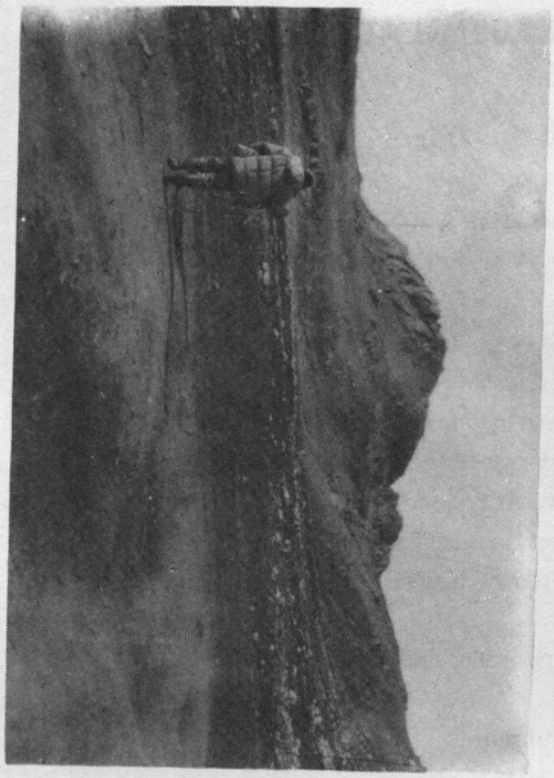

Plate 6. The Breccia Mt..

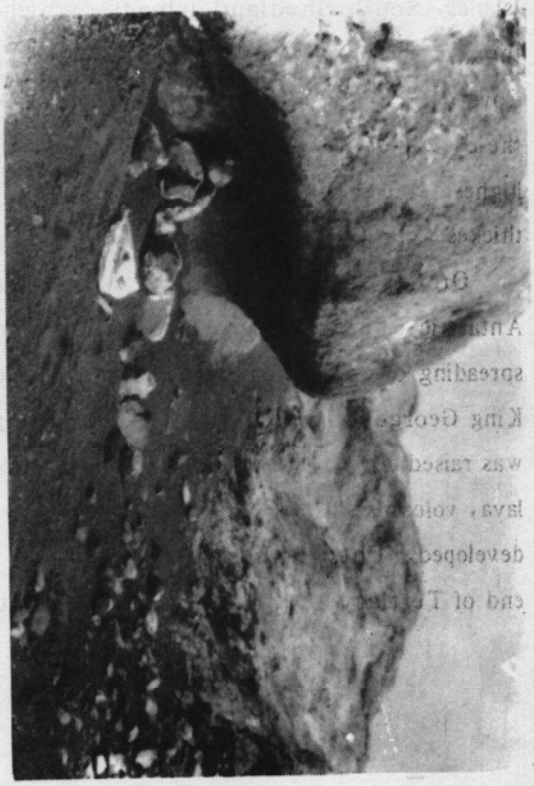

Plate 7. Wave cut goove on Breccia Mt..