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Characteristics of basal till and the discovery of tephra layers in the West Kunlun Mountains

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Abstract

The existing glaciers in the West Kunlun Mountains belong to the extremely continental type of glaciers. Rock debris originating from frost action is very rare and debris are hardly seen on the glacier surface , but the basal till with different thickness often emerges in the lower part of the glacier.

Analysis of grain size of basal till in the region shows that gravel, sand, silt and clay contents are 70.35%, 29.13%, 23.58% and 17.32%, respectively. The clay fraction is even higher than that in maritime glaciers, which may be a result of weaker subglacial melting. The clay content in basal till is also higher than that in other till in the region; the clay contents of superglacial till, meltout till and end moraine are 5.85%, 9.85% and 10.22%, respectively.

The surface texture of quartz sand of basal till of Guliya Ice Cap was studied by Scanning Electron Microscope. The result showed that there were pressure fractures on some particles, but most particulate surfaces show chemical weathering features, melting－coagulation and melt holes comparable with the volcanic ash in the Ashikule Basin. Studies of basal till and tephra layers in the West Kunlun Mountains indicated the close relation among the black muddy sand layer under the north ice flow of Guliya Ice Cap－Alakesayi Glacier, red sandy mud layers below the ice cliff of East Glacier and volcanic eruptions.

1. Introduction

The West Kunlun Mountains region, located south of Hotan and Yutian in Xinjiang, is noted for its volcanic groups and large glaciers. In the summer of 1987, having investigated the Ashikule volcanic groups and large glaciers at the upper reach of the Yurunkax River south of Yutian, we returned via the Xinjiang－Xizang (Tibet) Highway to the south slope and surveyed the glacier north of Gozha Co(Lake) and Guliya Ice Cap near the headwaters of the Keriya River.

Existing glaciers in the West Kunlun Mountains are continental glaciers. Many valley glaciers, 20－30km long, have developed on both sides of the main mountain range. A wide planation surface still exists in the south slope and the head－waters of the Keriya River, and a large ice cap is developed as well (Fig. 1). In spite of the small area of bare bedrock aside the glacier and the low relative elevation, little debris was formed by frozen－weathering. Superglacial debris did not develop well due to the weak erosion on the lower part of glacier. Some scattered superglacial debris are formed by shearing and extrusion. But at the lower part of the ice cliff some layers of subglacial debris were found. These layers, at different depths, were mainly formed by glacial movement. The ash came from the atmosphere.

From the basal till or basal ice layer, we observed and collected some samples to be tested for grain size, minerals, microelement analyses and Scanning Electron Microscope (SEM) observation of surface texture of sand grains, and preliminarily determined that the black sandy mud layer at the north branch of Alake-

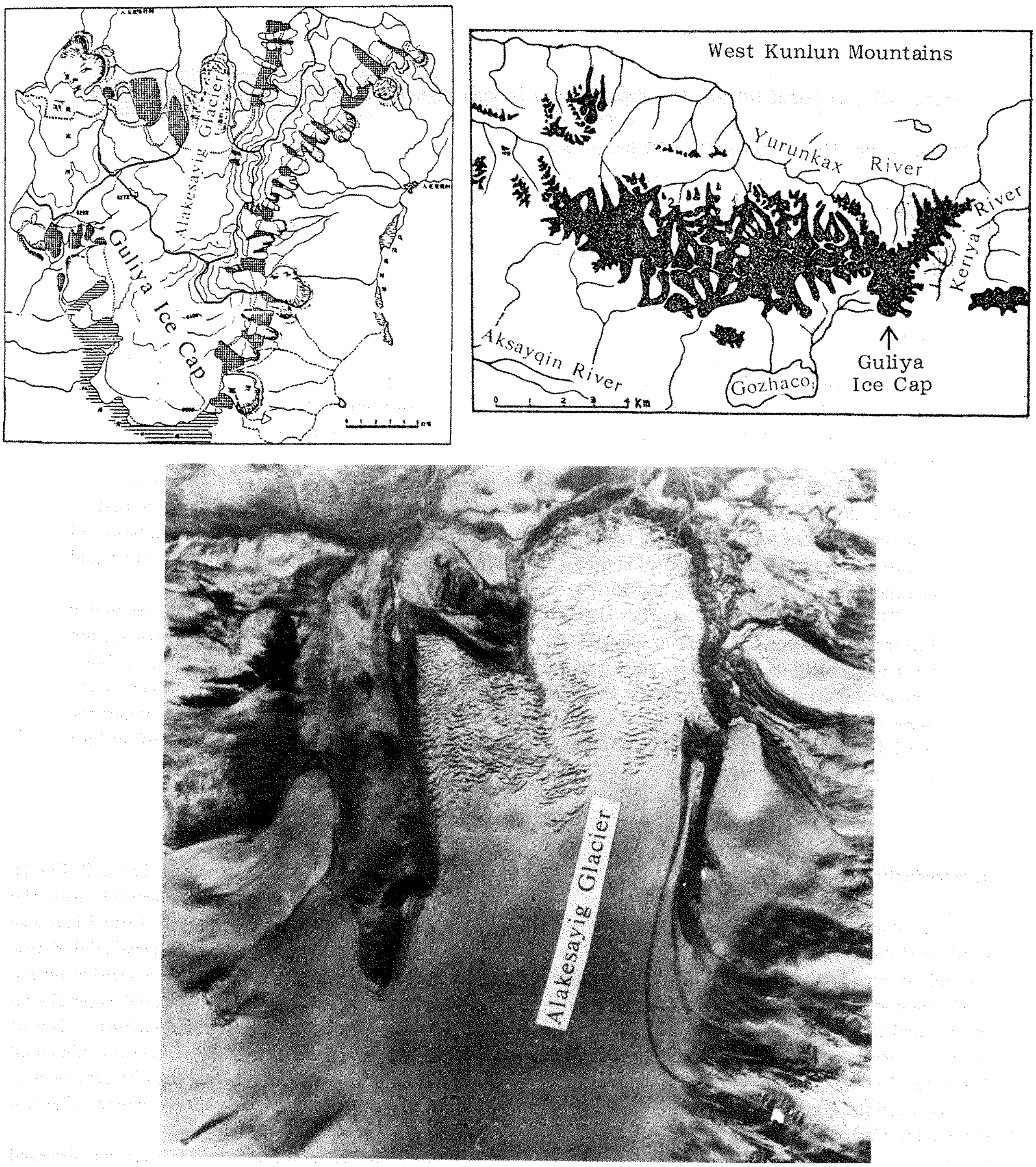

Fig. 1. upper left: Guliya Ice Cap.
upper right: Distribution of glaciers in West Kunlun Mountains.
lower: Alakesayi Glacier – Northern Ice Flow of Guliya Ice Cap (photo).

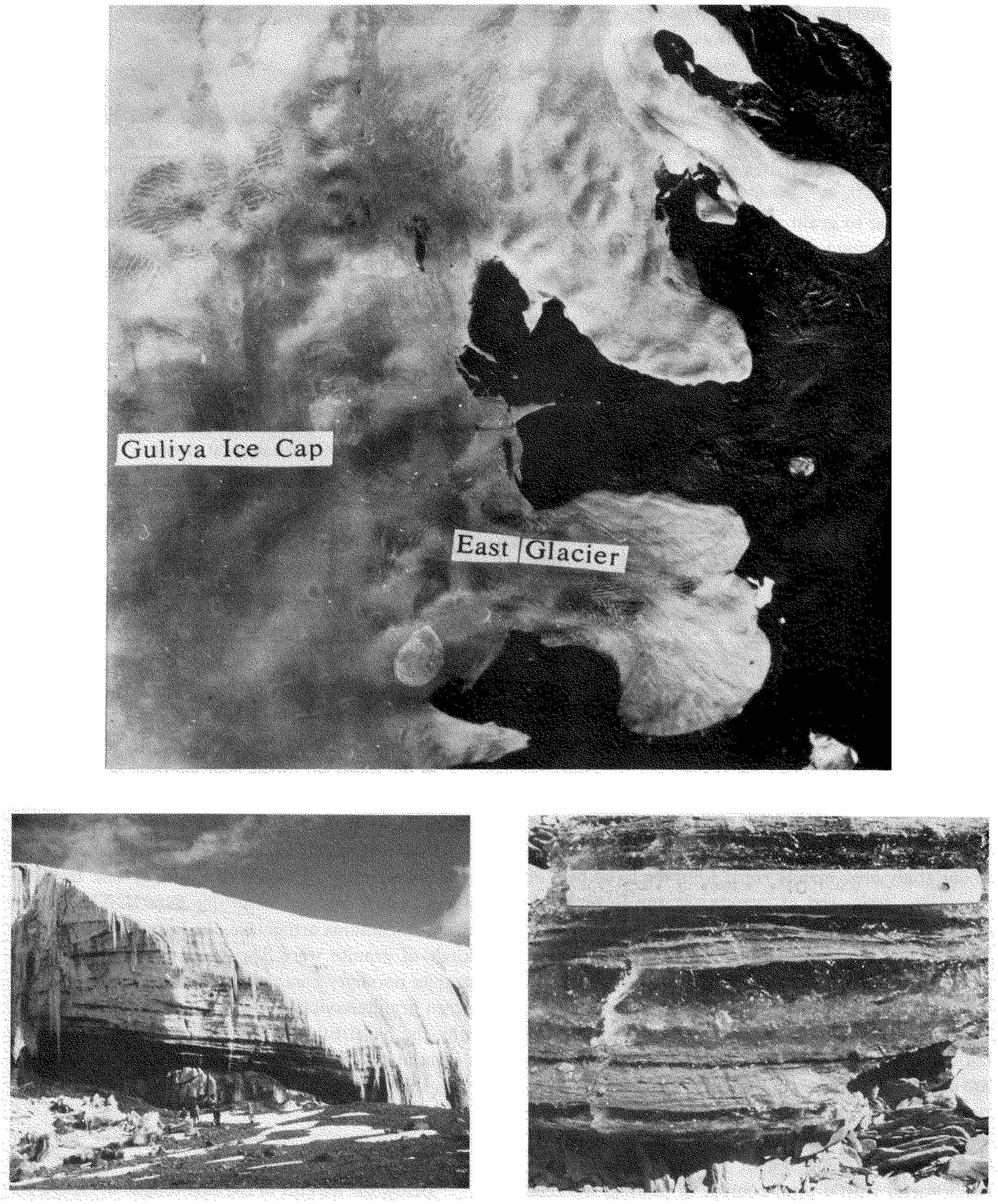

Fig. 2. The Eastern Ice Flow of Guliya Ice Cap (photo).
lower left: Glacier terminus of the Guliya Ice Cap.
lower right: Subglacial ash layers.

sayi Glacier on the Guliya Ice Cap and the red debris sandy mud layer below the East Branch of East Glacier are closely related to volcanic eruptions, (Fig. 2).

2. Grain size characteristics of the basal till

According to grain size analysis of the basal till from several main glaciers, the mean contents of gravel, sand, silt and clay are 30.35%, 29.13%, 25.38% and 17.32% respectively. The clay content is even higher than that of maritime glaciers, because no meltwater washes clay out of the bottom of a continental glacier. The contents of gravel, sand, silt and clay are also higher than those of engalcial debris and lateral moraines in this region, because the abrasion of basal till is more intensive than that of other tills (Tables 1 and 2).

Table 1. Comparison of basal tills of West Kunlun Mountains and other region

Area	Content(%)	Gravel	Sand	Silt	Clay	Glacier Type
West Kunlun Mountains		30.35	29.13	25.38	17.32	extremely continental glacier
Mt. Bogda Tianshan	upper part	69.80	28.85	7.72	3.63	subcontinental glacier
	lower part	46.60	27.63	18.04	7.84	
	total average	58.20	23.19	12.88	5.73	
Mt. Namjiabawa	end moraine	53.37	32.03	12.05	2.55	maritime glacier
	flow till	52.17	23.46	18.70	5.09	

Table 2. Contents of silt and clay in various tills in the study region.

Contents \ Type	Englacial debris	Superglacial Debris	Melt-out Till	End Moraine	Lateral Moraine	Basal Till
Silt	7.16	10.80	20.02	9.11	1.79	23.58
Clay		5.85	9.85	10.22		17.32

3. Petrological and mineral features of basal till

3.1 Heavy minerals

The sources of basal till are related to the lithology of bedrock in the glaciated region. The glaciers in our study area mainly come from the axial part of mountains composed of granite. At the lower part, glaciers flowed over Carboniferous schistose plates. Thus, heavy minerals of the basal tills from various drainage basin are different (Table 3). For example, basal till in the terminus of Alakesayi Glacier has a black metal–tourmaline assemblage ; and contents of both total 80.25%. The next most common minerals are zircon and topaz with contents of 3.00% and 2.75% respectively; so the basal till shows black color. The basal till at the end of the east ice tongue of Guliya Ice Cap is mainly composed of limonite–tourmaline–black metal with a total content of 66.50%, whereas those of muscovite and zircon are 4.00% and 3.75% respectively. But the unstable and stable minerals of the two basal tills mentioned above are similar (Fig. 3).

3.2. Light minerals

In the basal till of the east ice flow of Guliya Ice Cap, quartz content is more than feldspar (25/16.23). In the till layer at the end of Alakesayi Glacier, quartz is less than feldspar (16.50/11.75). Both basal tills contain a large quantity of debris, the former one contains about 56.00% and the latter one 67.50%. The former one also contains orthoclase, the latter does not. Two kinds of granite were discovered in this region: red granite porphyry containing much red orthoclase and green granite containing much cline ; perhaps this is why the basal tills have in different colors. The red debris at the tongue probably has some relationship with the red granite intrusion underneath the glacier.

3.3. Characteristics of the basal till below the east tongue of Guliya Ice Cap

Below the ice cliff of the east tongue of Guliya Ice Cap, there is a red debris sandy mud layer with a thickness of 30m (Fig. 2) which can be divided into 10 layers from top to bottom as follows : (1) Purplish red interlayer of ice and debris; (2) Red interlayer of ice

Table 3. The content of minerals in basal till and ash within glacier of West Kunlun Mountains.

Minerals	Location / Type / Content(%)	Eastern Ice Flow of Guliya Ice Cap			Alakesayi Glacier	Zhongfeng Glacier	Chongce Ice Cap
		general basal till	red volcanic ash	brown-yellow volcanic ash	black basal till	melt-out till	melt-out till
Un-stable Minerals	Augite	2.25	1.42	3.75	0.75	1.00	2.75
	Titanaugite						
	Common Hornblende	2.00	4.27	5.00	1.00		6.25
	Hypersthene						0.25
	Grunerite					0.25	
	Anhydrite						0.25
	Biotite	2.50		4.75	2.00	14.50	1.50
	Idocrase						0.25
	Siderite	2.50		1	0.50		
	Total	9.25	5.69	13.50	4.25	15.75	11.50
Sub-stable Minerals	Diopside	0.25	1.42	0.25		1.00	
	Hedenbergite	0.50		0.50			2.25
	Actinolite	0.25	1.42	0.75	0.50		0.25
	Tremolite	0.75		3.50	0.75		0.50
	Epidote	0.75	2.84	0.50	0.25	3.00	3.75
	Zoisite	0.50				0.75	0.50
	Allanite						0.25
	Chlorite	0.25				0.50	0.25
	Sillimanite						
	Wollastonite	0.25		0.50	0.75		
	Andalusite	1.00		1.25	0.75	0.25	0.25
	Topaz				2.75		
	Total	4.50	5.68	7.50	5.75	5.50	8.00
Stable Minerals	Black metals	20.00	5.70	15.50	57.25	21.00	5.75
	Sphene			0.25		0.25	0.25
	Muscovite	4.00	2.84	7.50	2.00	28.50	18.00
	Total	24.00	8.54	23.25	59.25	49.75	24.00
Most Stable Minerals	Limonite	32.50	47.14	13.75	1.50	0.50	1.00
	Anatase	1.25	7.27	4.25	2.25	0.25	3.50
	Zircon	3.75	2.84	5.00	3.00		1.25
	Tourmaline	24.00	22.84	30.75	23.00	27.50	50.00
	Rutile	0.25					
	Garnet	0.50		1.75	1.00	0.75	0.75
	Total	62.25	80.09	85.75	30.75	29.00	56.5
Light Minerals	Quartz	25.00	3.00	25.00	16.50	34.25	33.50
	Orthoclase	1.50	1.00	2.25	11.75	20.00	6.00
	Plagioclase	15.25	1.25	10.75		18.00	22.50
	others	58.25	94.25	62.25	71.75		

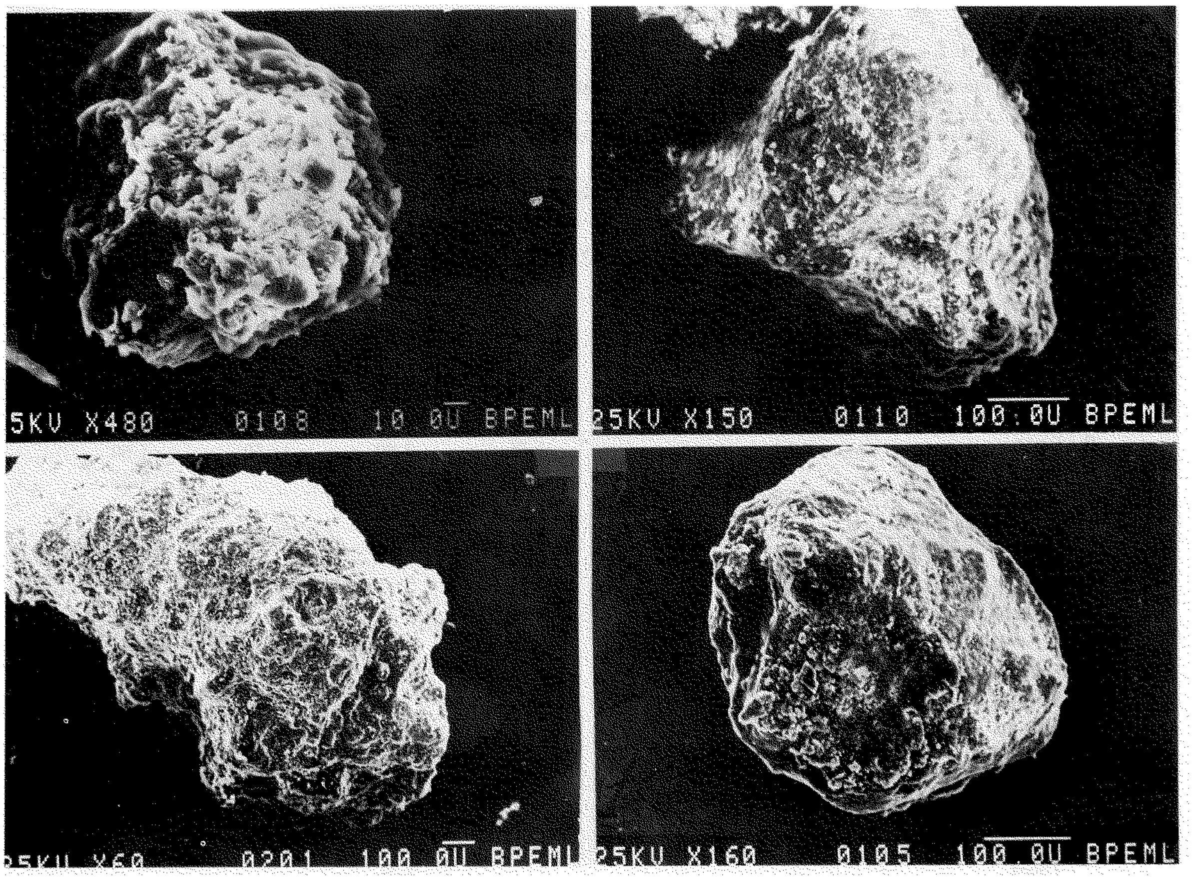

Fig. 3. Characteristics of volcanic ash and sand particles of Eastern Ice Flow of Guliya Ice Cap under scanning electron microscope.

and debris; (3) Red interlayer of ice containing debris; (4) Red interlayer of ice containing debris; (5) Mud–yellow ice layer (containing debris, 12cm in depth, and probably containing volcanic ash); (6) Orange ice layer (containing debris); (7) Grey–blue ice layer; (8) Ice layer (containing debris); (9) Ice layer (containing polluted layer); (10) Grey–yellow ice layer (may be volcanic ash).

We determined the light and heavy minerals in red debris and brown–yellow debris or volcanic ash by microscopic observations. The former is composed of limonite–tourmaline–anatase assemblage with contents of 47.14%, 22.84% and 7.27% respectively; the latter consists of tourmaline–black metal minerals–limonite assemblage with contents of 30.75%, 15.50% and 13.75% repectively. The red volcanic ash contains a little amount of quartz (3%), cline (1.25%) and relatively more orthoclase (1.50%). Otherwise, the brown–yellow ash contains more quartz and cline and less orthoclase, with contents of 25.00%, 10.75% and 2.50% respectively. Maybe this is another reason why the two kinds of debris mentioned above appear in different colors.

4. Microelements in basal till

The basal ice layer below the ice cap of the east ice flow of Guliya Ice Cap is very thick and lined with a red thin interlayer of debris. This red basal till, first found in this region, has folds developed by the glacier movement. The basal till is considered to be related to

Table 4. Microelement analysis of basal till of the East Glacier in Guliya Ice Cap.

Elements	No. of Sample	1	2	3	5	6	7	10
SiO_2		70.36	70.56	68.00	72.96	65.84	64.48	68.20
Fe_2O_3		3.97	3.19	3.94	3.59	4.18	5.51	3.99
Al_2O_3		11.22	6.73	12.24	10.40	11.62	16.31	13.05
K_2O		2.97	2.27	3.33	3.02	2.77	3.56	3.09
Na_2O		0.7	0.15	0.76	0.59	1.43	1.02	0.72
CaO		2.59	5.99	2.87	2.19	4.53	1.45	2.29
MgO		0.12	1.27	1.00	0.69	1.49	1.09	0.86
Ni		0.0211	0.0198	0.0101	0.0183	0.0135	0.0085	0.0102
CO		0.0011	0.0013	0.0018	0.0015	0.0014	0.0024	0.0013
Cu		0.0029	0.0046	0.0037	0.0030	0.0028	0.0043	0.0032
Pb		0.0154	0.091	0.0213	0.0329	0.0279	0.0295	0.0241
Zn		0.0105	0.0072	0.0101	0.0093	0.0086	0.0149	0.0088
Mn		0.0408	0.0752	0.0604	0.0462	0.0416	0.1112	0.0500
Cr		0.0400	0.0364	0.0191	0.0338	0.0147	0.0019	0.0246
V		0.0069	0.0057	0.0086	0.0086	0.131	0.0085	0.0077

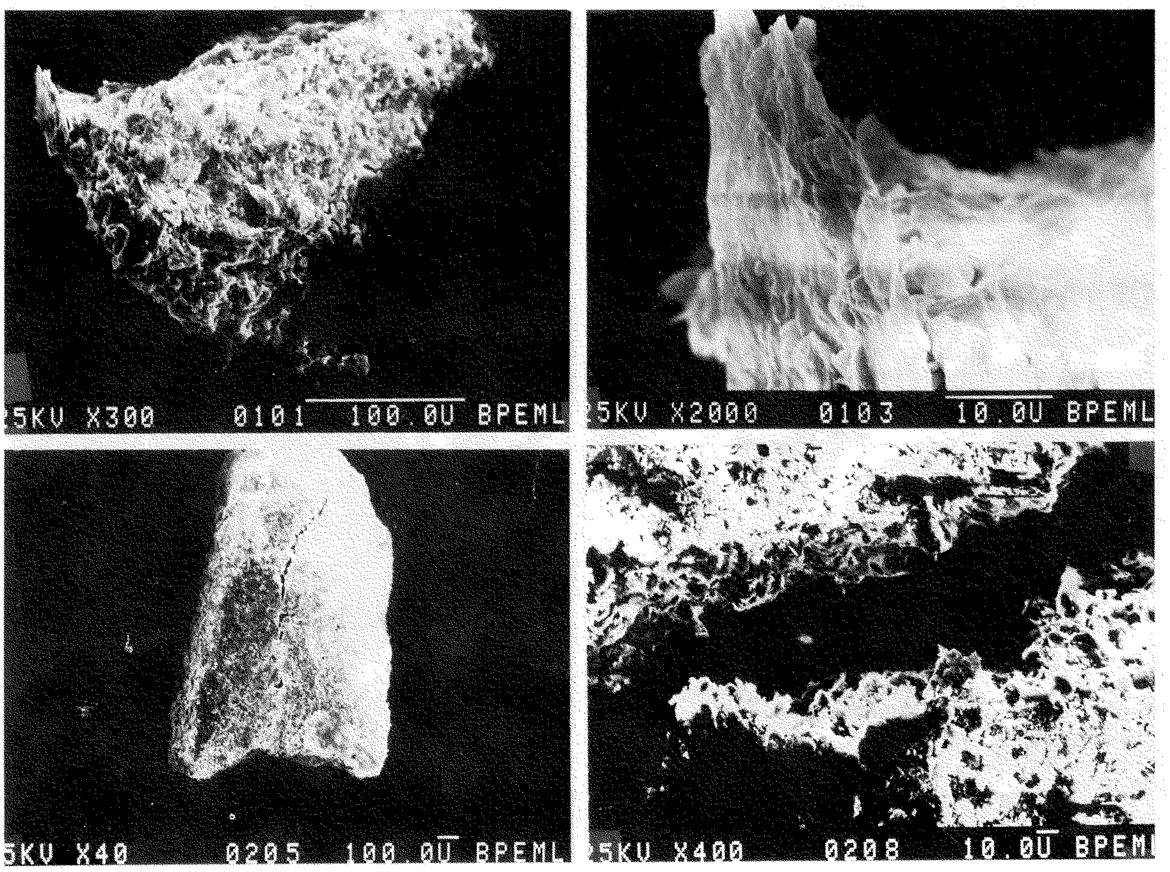

Fig. 4. Shape of particles with edges (upper left) and local enlarging (upper right) under scanning electron microscope. Particles with cracks (lower left) and enlarged cracks (lower right) under scanning electron microscope.

volcanic eruptions in this region. Besides having determined the minerals of two kinds of debris in two colors, we have done microelement analysis of seven samples (Table 4), and revealed that the content of SiO_2 is over 60% (64.48 – 72.96%), the average content of Al_2O_3 is over 10% (6.73 – 16.31%), and those of Fe_2O_3, K_2O, CaO, MgO and Na_2O are 4.05%, 3.00%, 3.13%. 0.93% and 0.77% respectively.

5. Micromorphological characteristics on a surface of particles of basal till and volcanic ash

We have used a scanning electron microscope to study the volcanic ash underneath the ice tongue of Guliya Ice Cap. Glacial striae were not found on particle surfaces (Fig. 3), because these grains are contained in ice layers and not located on a sliding surface. On the contrary, some particles were found with sharp edges and cracks (Fig. 4). Surfaces of most particles were filled with weathered substances or some crystals. Melting – coagulation and melt holes even appeared in particle surfaces. These characteristics may result from the coagulation of fused volcanic ash (Fig. 5) comparable with the volcanic ash in the Ashikule Basin (Fig. 6).

6. Volcanic ash and its age

We have researched the volcanoes and their deposits in the Ashikule Basin on the north flank of the

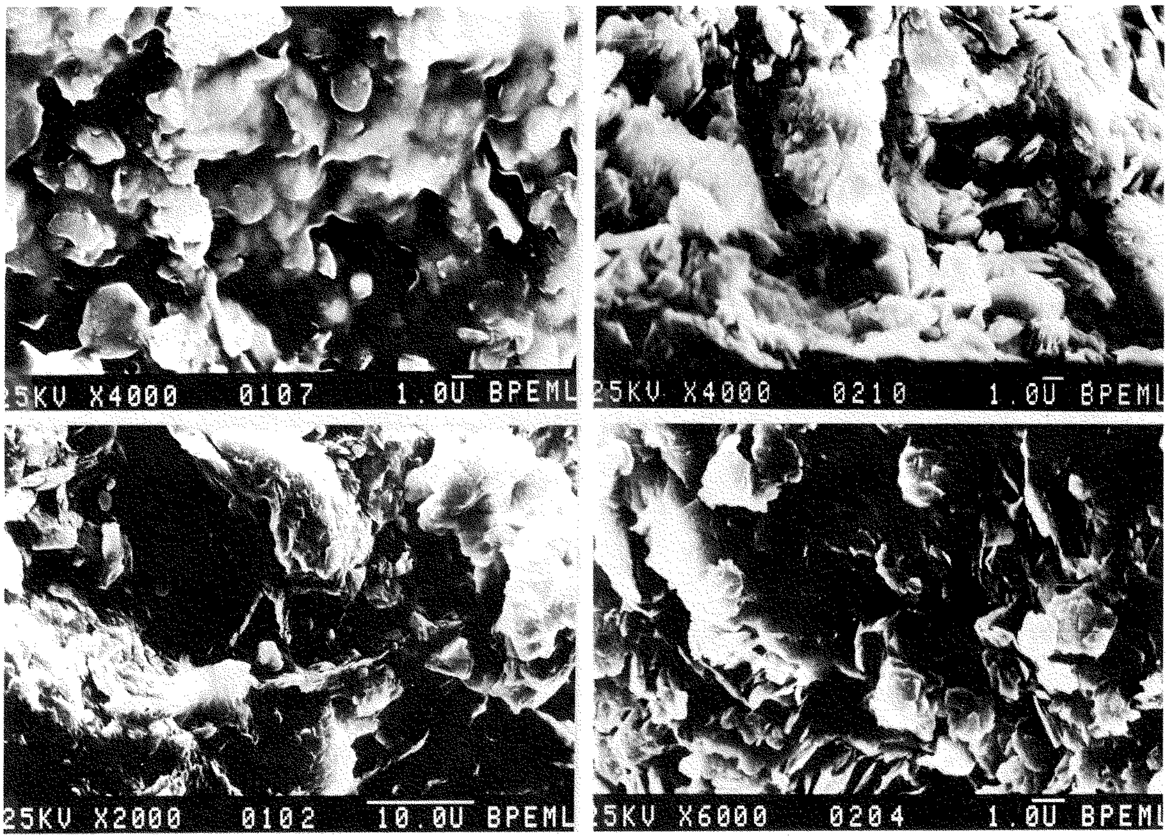

Fig. 5. Micromorphology on the surface of volcanic ash and sand particles under scanning electron microscope.

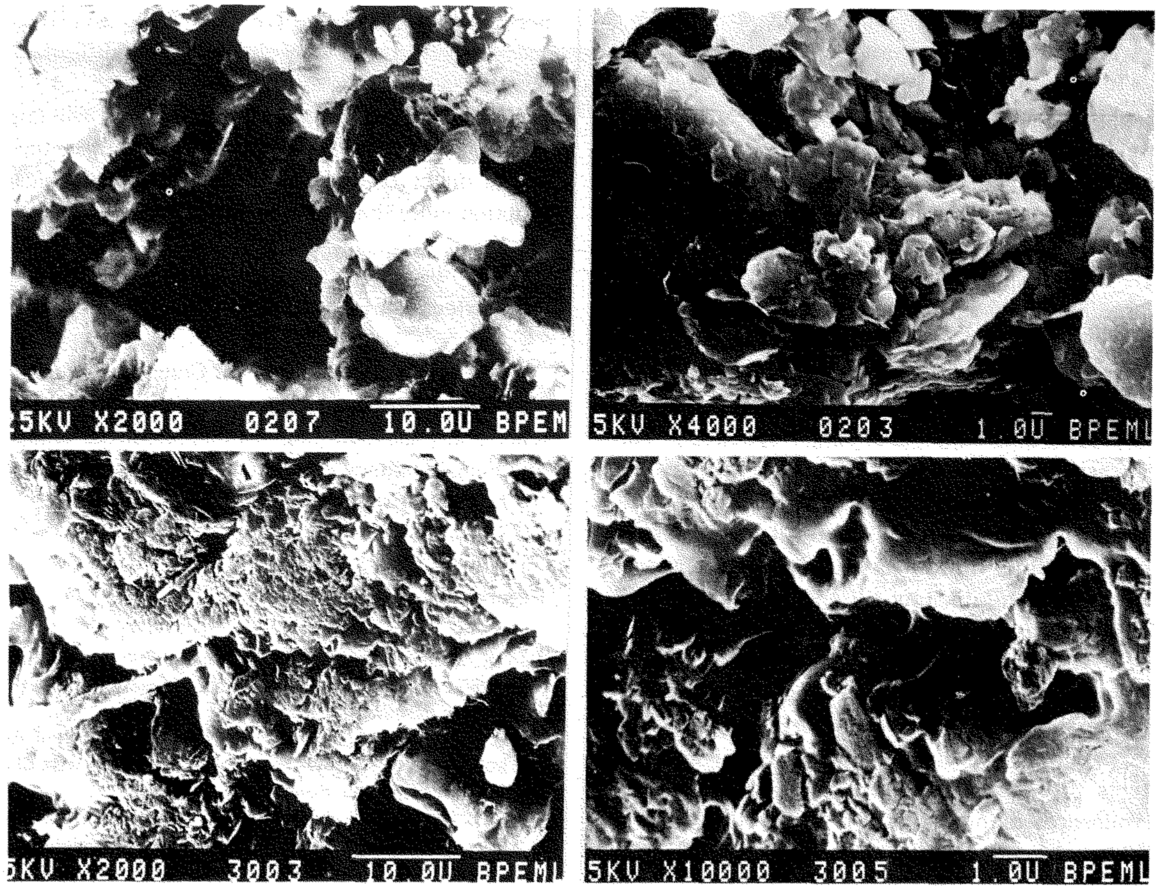

Fig. 6. Micromorphology on the surface of volcanic ash of Ashikule Basin under scanning electron microscope.

West Kunlun Mountains. Ashikule Volcano towers high over a black lava terrace with a relative altitude of 120m and is accumulated by purplish red lava, while the outside of the volcano is completely formed by black lava.

Ashikule Volcano is an active one which erupted on May 27, 1951 (Zhao, 1976). Samples were collected in four various layers on the upper part of the south side of Ashikule Volcano and dated to be about 5,000 yr. B.P., but the age of the northwest wall is about 120,000 yr. B.P., by K−Ar dating (Liu *et al.*, 1989).

According to the field surveys and satellite images, the West Kunlun Mountains are in a region where Quaternary volcanoes are concentrated and some craters are buried. Thus, it is not accidental that the volcanic ash appears in ice layers.

A black sandy mud layer, about 20cm in thickness, was found on the lower part of Alakesayi Glacier. Its C^{14} date is 33,065±585 yr. B.P. This layer must be ash deposited on the glacier in the late stage of the Last Glaciation.

According to stratigraphic observations, there are more than 400 dirt band layers above the ash layer of the east ice flow, Guliya Ice Cap. If the dirt band layer shows an annual layer, the age of the subglacial ash layer is more than 400 years. This ash layer may not be related to the eruption of Ashikule volcano in 1951. So, the definite age of the ash layer should be analyzed in an appropriate way such as the fission track method.

7. Conclusions

The existing glaciers in the West Kunlun Mountains belong to the extremely continental type of glaciers. Only a small area of bedrock is exposed above the glaciers. Thus, morainic materials came mainly from subglacial erosion. Rock debris originating from frost action is very rare and becomes internal moraine in a short period of time. As a result, debris and boulders are hardly seen on the glacier surface. The basal till with different thickness often emerges in the lower part of the glacier terminus.

Analysis of grain size of basal till in the region shows that gravel, sand, silt and clay contents are 70.35%, 29.13%, 23.58% and 17.32%, respectively. The clay fraction is even higher than that in maritime glaciers, which may be a result of weaker subglacial melting. The clay content in basal till is also higher than that in other till in the region; the clay contents of superglacial till, meltout till and end moraine are 5.85%, 9.85% and 10.22%, respectively.

There was a 30m－thick subglacial debris layer at the lower part of the east glacier tongue of Guliya Ice Cap. Samples of ten different debris layers at the lower part were collected for chemical analysis. The contents of 15 chemical elements in this till were determined as follows: SiO_2 (64－72%), Al_2O_3 (6.73－16.31%) and Fe_2O_3 (3.19－5.15%); contents of Ni, Co, Pb, Zn, Mn, Cr and V are all less than 0.1%.

The surface texture of quartz sand (0.1－0.5 mm in diameter) of basal till of Guliya Ice Cap was studied by Scanning Electron Microscope (SEM). The result showed that there were pressure fractures on some particles ,but most particulate surfaces show chemical weathering features ,melting－coagulation and melt holes comparable with the volcanic ash in the Ashikule Basin. Studies of basal till and tephra layers in the West Kunlun Mountains indicated the close relation among the black muddy sand layer under the north ice flow of Guliya Ice Cap－Alakesayi Glacier, red sandy mud layers below the ice cliff of East Glacier and volcanic eruptions.

There may be several tephra (volcanic ash) layers within the basal till of Guliya Ice Cap; these tephra layers might result from an undiscovered volcanic eruption more than 400 years ago.

Acknowledgments

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