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Formation of dirt layers and surface dust by micro-plant growth in Yala (Dakpatsen) Glacier, Nepal Himalayas

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Abstract

Biological observation and analysis of surface dust and dirt layer dust particles in glacial strata was carried out at Yala (Dakpatsen) Glacier, Langtang region, Nepal Himalayas, in the 1985 monsoon season. Micro-plants such as blue-green algae and bacteria, the main components of these dust materials, are thought to grow on and in the glacial strata during the period when melt-water and sun light are available there, and have an important role in dirt layer formation. In the monsoon season, considerable surface dust, containing micro-plants, so much as to cover the glacier surface, were observed in the ablation area. The growth of these micro-plants seemed to change the surface albedo of this glacier and accelerate glacier ablation in this season.

1. Introduction

Since the glacier has long been believed to be an almost non-biological environment, all components of surface dust and dust particles contained in the glacial strata have unanimously been believed to be airborne materials (Grove 1960, Orheim 1975). However, recently, variovs cold-tolerant animals and micro-plants which spend their entire lives in the glacier were discovered in Himalayan and Patagonian glaciers (Kohshima 1984a, 1985). The present author showed in the previous research on Yala Glacier, carried out in the post-monsoon season of 1982, that a new species of cold tolerant insect (a wingless midge, *Diamesa* sp., Chironomidae) inhabits this glacier, feeding on micro-plants growing there (Kohshima 1984a) and that these micro-plants are main components of the surface dust and dust particles contained in the ice core samples taken by full depth boring in the accumulation area, suggesting the biological origin of these materials for the first time (Kohshima 1984b). The present research aimed to clarify the growth condition of these micro-plants in the monsoon season, their estimated main growth season.

2. Field description and study period

The research was carried out on Yala (Dakpatsen) Glacier (5,100–5,700 m altitude) in the Langtang region of Nepal (Fig. 1) between July 27 and September 28 1985, from the monsoon season to the beginning of the post-monsoon season.

This glacier is plateau-shaped glaglacier, without a debris covered area, and has many flat terraced plateaus divided by ice cliffs and crevasses (Fig. 2). The research was concentrated on three plateaus termed P1, P2, P3 (*ca.* 5,130m, 5,200 m, 5,400 m altitude respectively). The equilibrium line of the glacier in the study period was between P2 and P3 (*ca.* 5,300 m altitude). Though the accumulation area was covered with snow during the study period, the ablation area was a bare ice area without snow cover before the snowfall of September 10. After that snowfall, the glacier was completely covered with thick snow.

3. Dirt layers and dust particles

3. 1. Structure and content of dirt layers and dust particles

To investigate structure and condition of the new dirt layers, the surface snow strata of the accumu-

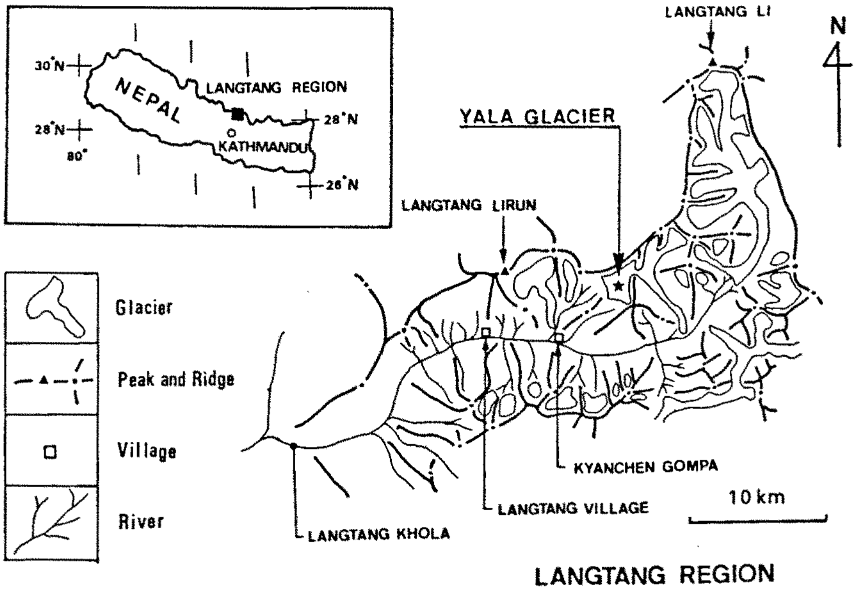

Fig. 1. Map of Langtang region Nepal, showing the location of Yala Glacier.

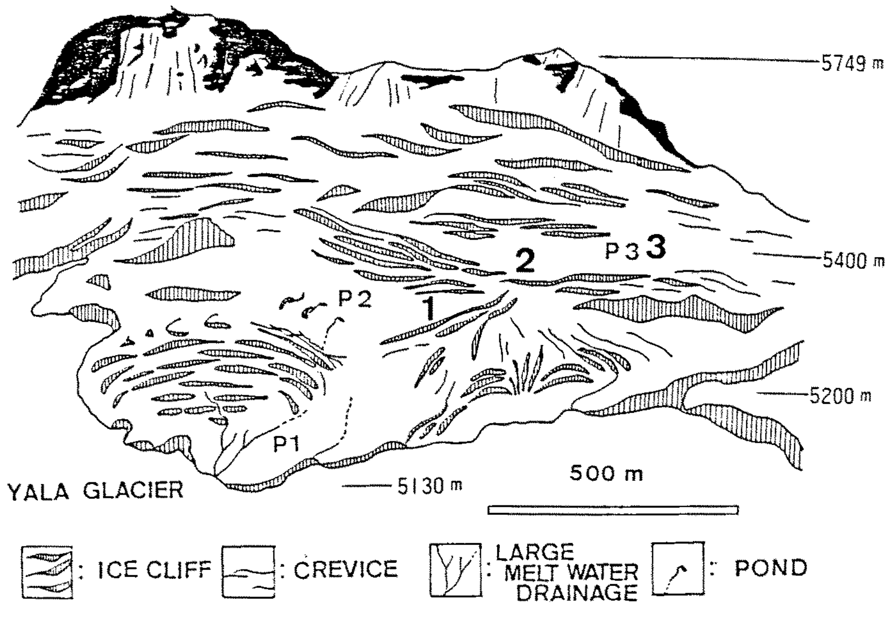

Fig. 2. Outline of Yala Glacier showing the location of the study sites.

lation area were observed and dust particles were collected at 3 sites on P3.

Fig. 3 shows the surface snow strata recorded at Site 2 on August 7 1982. There were two obvious dirt layers (snow or ice layers containing dust particles) in the strata. The upper one (DL1) is thought to have been formed in 1985, and the lower one (DL2) in 1984. The structure of the surface snow strata did not differ among the three study sites on P3 in the study period.

New dirt layers (DL1, DL2 in Fig. 3) consisted of horizontally arranged large granular ice grains (2–8 mm in diameter) with many small vertical cavities between them which seemed to be formed by melt-water percolation. Individual dust particles tended to

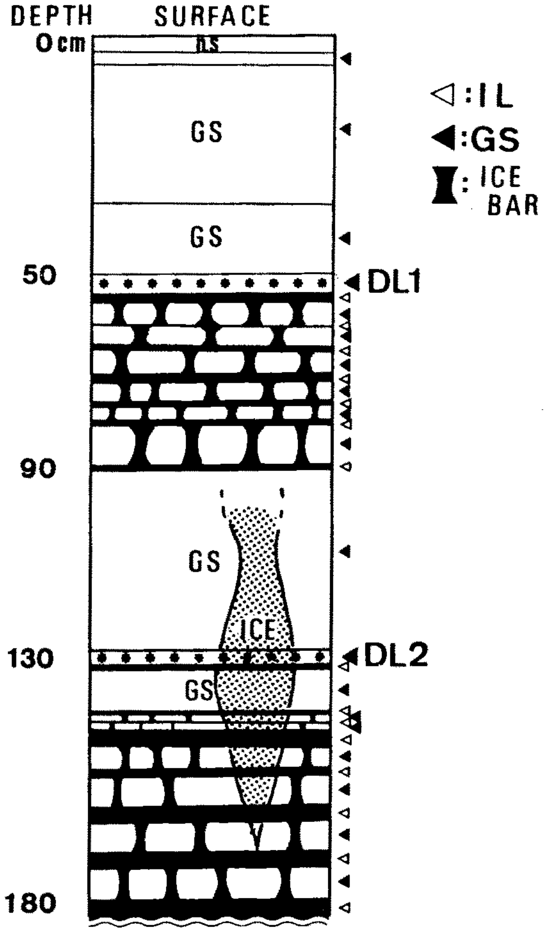

Fig. 3. Structure of the surface snow strata at Site 2 recorded on August 7 1985. GS: granular snow. IL: Ice layer. DL: Dirt layer. Small dots: Dust particles.

be separated in these cavities. The characteristic granular form (0.1–0.5 mm in diameter) of dust particles seemed to be formed in these cavities by melt-water. Fig. 4 is a microscopic photograph of a dust particle contained in DL1 formed in 1986, collected at Site 2. Main components are filamentous blue-green algae (*Phormidium* spp.) and bacteria (unidentified, Kohshima 1984b). This photograph was taken after ultra-sonication of the particle to unfasten the tight aggregation of algae and dark colored bacteria and to clarify the volume of the algae. It is difficult to believe that all these micro-plants are airborne accumulation. Rather, it is more reasonable to think that airborne fragments of these micro-plants grew on the glacier. In this research, small insects (Collembola) living in the dirt layer snow cavities and feeding on the dust particles were newly found.

3. 2. Formation of dirt layers

The wet granular snow layers on DL1 are thought to be snow of this monsoon season (1985) and indicate melt-water percolation in this season (Fig. 3). Snow temperature of the surface snow strata was constantly 0 ℃ throughout the study period. In this stratum, there are many ice layers with ice bars and granular snow grains between them, located just under the dirt layers. This suggests that these dirt layers began to be formed in the pre-monsoon season, when these structures were formed by melt-wfter percolation and refreezing (Iida *et al.* 1987), and fragments of micro-plants as well as other airborne materials might be accumulated on the stable glacier surface in the dry season with scarce snowfall.

After this "first process", the micro-plants might grow in the dirt layer using melt-water and nutrients accumulated in the same layer, and make the dirt layer more obvious ("second process"). However, because sufficient sun light for algal growth cannot reach the dirt layer under the 50 cm monsoon snow cover, photosynthetic algal growth in the dirt layer of this site is thought to have occurred during a period when this site was covered with thinner monsoon snow cover. At Site 1, near the lower end of the accumulation area, where this monsoon snow cover was thinner (26 cm on August 4 and 5 cm on August 17), the snow of the dirt layer was tinted green by much algal growth in the middle of August. The monsoon snow cover at Site 2 and Site 3 also decreased during the study period until the snowfall of September 10 (16 cm at Site 2 on August 25).

Algae in the dirt layer are thought to grow during when the sufficient melt-water and sun light are available in the dirt layer. Such a condition sufficient for algal growth in the dirt layer might be available mainly in the pre-monsoon and monsoon seasons.

However, formation of dirt layer is not limited to the pre-monsoon and monsoon seasons. One dirt layer was observed in snow strata accumulated on P1 and on the ground near the glacier terminus in the winter (Iida *et al.* 1987 and personal communication). That dirt layer was located between the snow layer accumulated at the end of the monsoon season and the winter snow layer. This suggests that this dirt layer was formed in the post-monsoon season. Analysis of the dust particles of this "fall dirt layer" revealed that these dust particles contained different species of micro-plants from those in the "summer dirt layers".

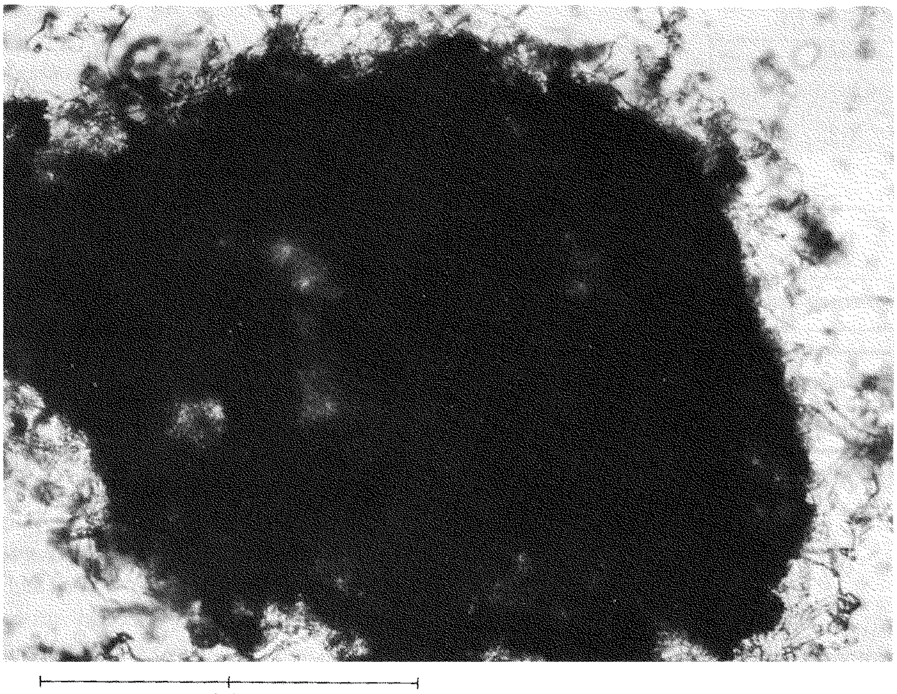

Fig. 4. Microscopic photograph of a dust particle collected at DL1 in Fig. 3. This photograph was taken after ultra-sonication of the particle to unfasten the tight aggrregation of algae and dark colored bacteria and to clarify the volume of the blgae.

Amount of micro-plants contained in the dust particles of the fall dirt layer was very small compared with that of the summer dirt layers, and dust particles of the fall dirt layer did not take granular form. These results suggest that the "first process" of this fall dirt layer formation occurred in the post-monsoon season (dry season) and period of "second process" was very short because, in winter, melt-water and sun light were not sufficient for micro-plant growth.

4. Surface dust in the ablation area.

4. 1. Formation of surface dust by micro-plant growth

In the monsoon season, the ablation area of this glacier (P1 and P2) was a dirty bare ice area with blackish mud-like materials (surface dust) on the surface (Fig. 5). The surface dust had a characteristic granular form (0.2–3.0 mm in diameter, Fig. 6). The main components of these "mud-like granules" were filamentous blue-green algae (*Phormidium* spp.) and bacteria (unidentified), just like the dust particles of the accumulation area (Kohshima 1984b).

These mud-like granules seemed to be formed at the bottom of small pit structures of the glacier surface (1–5 mm in diameter, 0.5–3 cm in depth, Fig. 6). The surface ice of this area contained numerous pit structures of various sizes with blackish mud-like granules at the bottom, which seemed to be formed by solar radiation heating blackish materials on the ice and melting the ice under them. This pit structure seems to offer good condition for growth of aquatic micro-plants by providing melt-water and by gathering nutrients. Because many micro-plants such as aquatic blue-green algae (*Phormidium* spp.) have glutinous materials around them, these micro-plants might get together with such airborne materials as soil particles and plant flagments *etc.* at the bottom of the pits and form mud-like granules. These mud-like granules seem to be carried and gathered by melt-water flow and form large pit structures where they are deposited. In these large pits, numerous wingless midge larvae (*Diamesa* sp.) and newly found copepods (Crustacea) were found to live feeding on these granules (Kohshima unpublished).

Some part of these micro-plants contained in the mud-like granules should come from the accumulation area. The micro-plants growing in the dirt layer are

Fig. 5. Yala Glacier in the monsoon season. The ablation area (lower part) is covered with dark colored surface dusts containing many micro-plants.

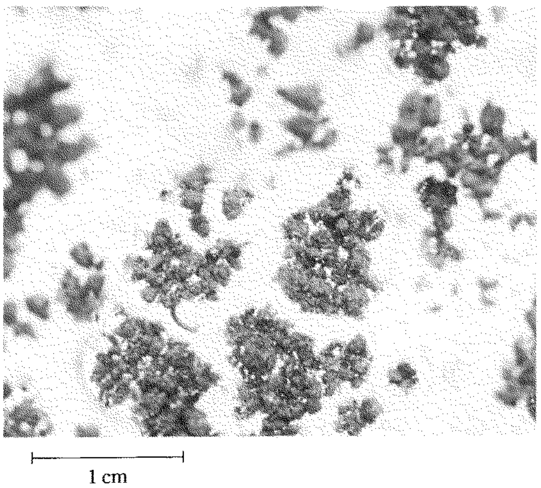

Fig. 6. Mud-like granules (surface dusts) and small pit structures on the ablation area surface ice.

stocked in the glacier ice annually, and are carried by glacier movement to the ablation area. These micro-plants should be concentrated on the surface of the ablation area as surface ablation proceeds. In fact, at many places of the ablation area, dirt layers releasing dust particles to the surface were observed. By this process and partly by material transport of melt-water flow, the ablation area is so enriched in micro-plants that the surface of this area has a dirty color in the monsoon season.

4. 2. Effect of micro-plant growth on surface albedo and ablation speed.

These surface dusts (mud-like granules) considerably affected the ablation area surface albedo in the monsoon season. A preliminary experiment was carried out on P1 to examine the effect of surface dust on surface ice ablation speed. In this experiment, the height of the gap between a small clean ice area (50 cm square) with surface dust scratched off and control area with surface dusts intact was measured afterward. The experiment started at 09 : 20 on September 8. The results were as follows. Sept. 8 15 : 33, 3.0 cm. Sept. 9 08 : 55, 5.5 cm. 15:40, 10.6 cm. Sept. 10 09:40, 12. 0 cm.

The results show that surface dust accelerated the ablation speed by about 6 cm per day in this case.

The results of this report suggest the importance of biological factors on this glacier.

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