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Glacial Landforms and Deposits in the Uksichan River Valley, Central Kamchatka, Russia

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Abstract In this paper, we provide preliminary data concerned with advance and retreat of large-scale valley glaciers in the late Quaternary age in the lowest part of the Uksichan River Basin, where no remarkable glacier currently exists, even in the uppermost high-altitude area. The Uksichan River, a tributary of the Bystraya River whose drainage basin is distributed in the Sredinny Range, flows from the Uksichan Volcano (1,692 m a.s.l.), approximately 30 km WNW of Esso, the principal town of the Bystrinsky District, central Kamchatka.

Gentle slope surfaces, *i.e.* Surfaces I to VI in descending order, are attached to the valley-side slopes of the broad U-shaped river valley, and the summit level of the low-relief area on the valley bottom is defined as Surface VII. We observed subsurface deposits particularly along a landslide zone, occurring in 1997, where rocks and sediments are better exposed, and in the whole investigated area. From the mode and characteristics of the glacial deposits constituting the respective surfaces, and from micro-landforms in that area, Surfaces II, IV, V, and VI correspond to the advancing stages of the glacier, namely, the Bystraya Stage 2, the Esso Stages 1, 2, and 3, and prior to these stages, a U-shaped valley formed along the Uksichan River in the oldest glacier advancing stage (Bystraya Stage 1). All of these stages certainly date back to the Neoglaciation age (*ca.* 3 ka) on the basis of tephrochronology, especially the presence of SH_3 (1.3-1.4 ka : Shiveluch Volcano origin) and KS_1 (1.7-1.8 ka : Ksudach Caldera origin). Specifically, the glaciers in these stages extended approximately 30 km or more from the Uksichan Volcano and the surrounding mountains, where the accumulation zones were widespread. We presume that the glacier terminus in the Esso Stages 1 to 3, was situated near Esso.

No considerable difference in stratigraphy of the tephra layers, however, can be found even between the surfaces of different levels, whereas it is evident that these surfaces formed in different ages. Thus, other dating methods need

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to be adopted to permit discussion on the detailed periods of glaciation in the Uksichan River area. Moreover, further studies on the sedimentary structures and the deformation of glacial deposits are necessary in order to clarify the detailed glacial environment in each advance stage.

Key words: glaciation, glacial fluctuation, late Quaternary, moraine, glacial till, Uksichan River, Esso, Kamchatka

1. Introduction

During the past two decades, several studies on glacial landforms and Holocene glaciation in the Kamchatka Peninsula have been conducted by geomorphological and tephrochronological methods, mainly in the mountainous areas, where present alpine glaciers occur, *e.g.*, the Koryto Glacier on the coastal side of the Pacific Ocean (Sawaguchi *et al.*, 1999), the Bilchenock Glacier, which flows out of the Ushkovsky Ice Cap and down toward the Central Kamchatka Depression (Yamagata *et al.*, 2002), and the West Ichinsky Glacier in the west of the peninsula (Yamagata *et al.*, 2006). Solomina *et al.* (1995) used lichenometry to clarify the recent glacial fluctuation of several modern glaciers since the Little Ice Age.

Moreover, in river valleys where no remarkable glacier currently exists, even in the uppermost high-altitude area, large-scale valley glaciers were surely present in the previous cold periods, especially in the glacial stages. Zech *et al.* (1997) discussed Pleistocene glaciation in the southwest Kamchatka on the basis of the characteristics of glacial deposits and the relationship between the deposits and marker tephra layers at three localities. Savoskul and Zech (1997) and Sovoskul (1999) made clear the detailed glacial advances since the late Pleistocene in the drainage area of the Avacha River, southern Kamchatka, by tephrochronological and lichenometric methods. Except for these areas, nevertheless, past development of valley-glaciers has not yet been clarified in most of the peninsula.

This paper is aimed at providing preliminary data concerned with the late Quaternary glacial fluctuation in the lowest part of the Uksichan River Basin near Esso, which is the principal town of the Bystrinsky District, central Kamchatka, on the basis of geomorphological and geological fieldwork performed in September 2000, August 2002, and September 2003 for about ten days in total. Esso (55.9°N, 158.7°E, and *ca.* 480 m a.s.l.) is situated at the confluence of the Bystraya River and the Uksichan River (Figs. 1 and 2). The outline of the glacial and periglacial landforms around Esso was also reported by Sone *et al.* (1997).

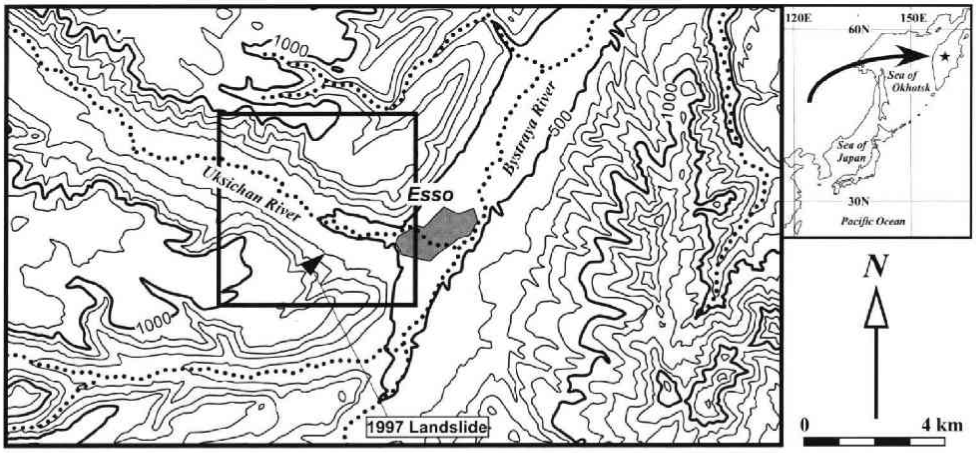

Fig. 1 Investigated area and topography in the vicinity of Esso Rectangle in the figure indicates the investigated area (Fig. 4).

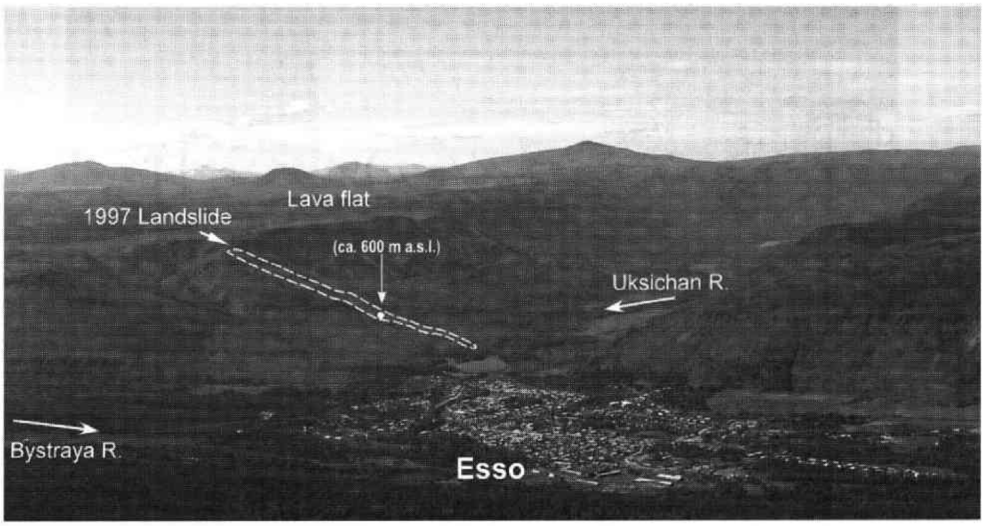

Fig. 2 View of the investigated area taken from the mountains to the east of Esso in August 2002

2. Investigated area

The drainage basin of the Bystraya River is distributed in the Sredinny Range which corresponds to a back-arc volcanic zone, on the west side of the Central Kamchatka Depression. The Uksichan River, a tributary of the Bystraya River, flows from the Uksichan Volcano (1,692 m a.s.l.) and the surrounding mountains, approxi-

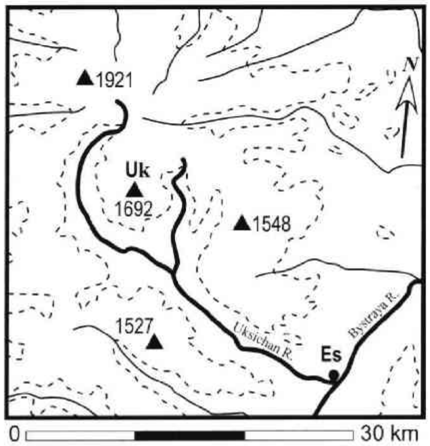

Fig. 3 The Uksichan River basin and the Uksichan Volcano
Principal summits and their altitude are shown by black triangles with numeric values. Solid lines indicate rivers, and dashed lines show the 1000-m contour.
Uk : Uksicahn Volcano, Es : Esso

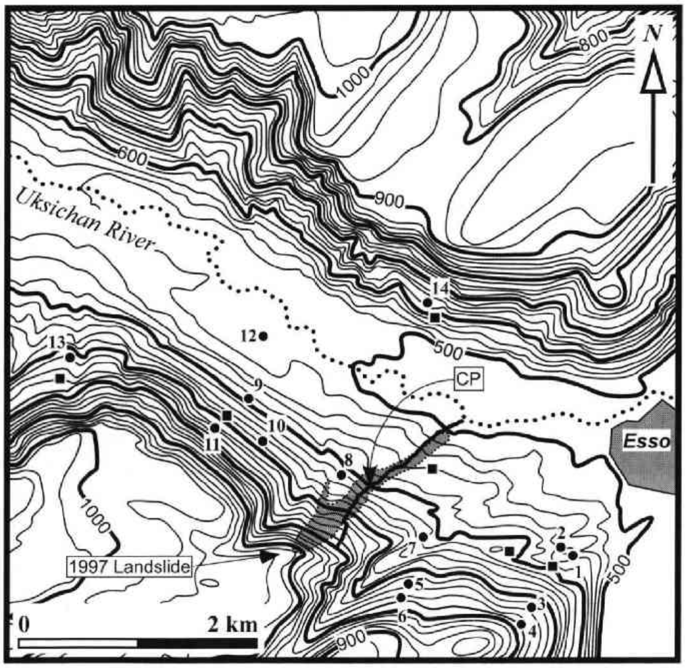

Fig. 4 Topography of the investigated area and the locality of outcrops and test pits
Black squares : outcrop of basement rocks black circles : outcrop of glacial deposits
thick kinked line : topographic measurement line shaded area with dotted margin : 1997 landslide CP : control point of topographic measurement

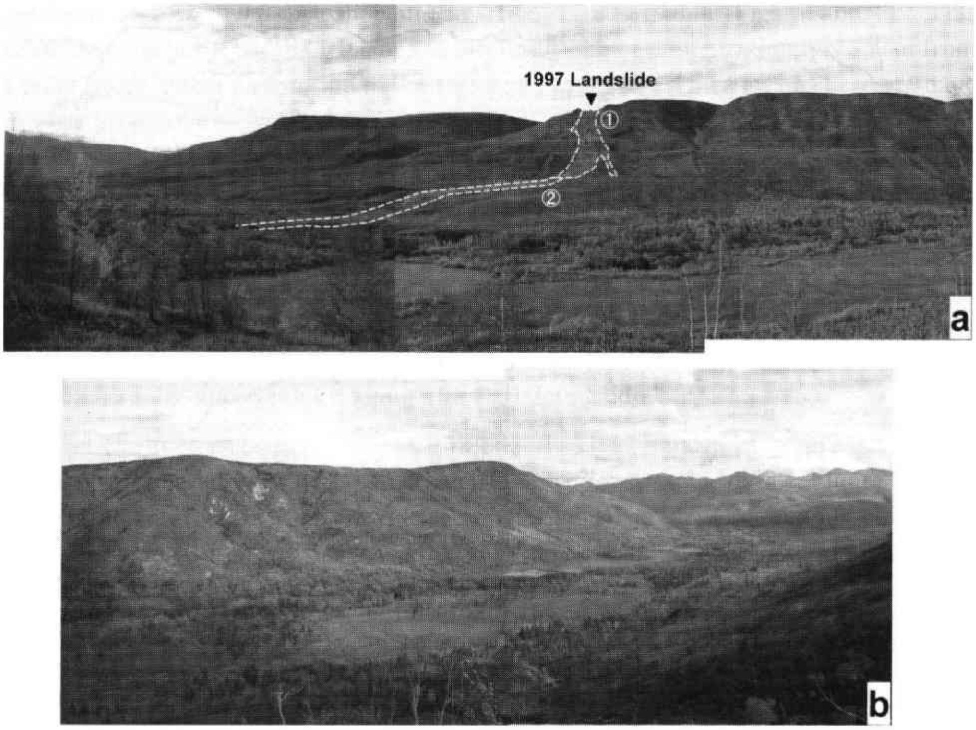

Fig. 5 Valley-side slopes on both banks of the Uksichan River
The right bank slopes are shown in Fig. 5a, and the left in 5b (taken in September 2003). ①: Occurrence and transported areas of the 1997 landslide ②: Deposited area of 1997 Landslide

mately 30 km WNW of Esso (Fig. 3).

The activity of the Uksichan Volcano took place from the late Pliocene to the Holocene, during which time basaltic-andesitic-dacitic volcanic and pyroclastic rocks were widely erupted from the volcano (*e.g.*, Melekestsev *et al.*, 1991 ; Ivanov *et al.*, 2004). In the whole Uksichan River Basin, there is presently no considerable glacier, but glacier landforms are observable as a record of past glacier development, particularly on the body of the Uksichan Volcano.

In the investigated area, the lowest part of the Uksichan River Basin, there is a broad U-shaped river valley, the bottom of which is approximately 500 m in altitude. This valley has a width of 2 to 3 km and a relative height of 450 to 550 m (Figs. 4 and 5). Flat surfaces above the valley-side slopes are 900 to 1,200 m in altitude and are correlated with the depositional surfaces of the volcanic and pyroclastic rocks derived from the Uksichan Volcano. In general, basement rocks and periglacial slope deposits overlying the basement are mainly exposed in the upper half of the valley-side

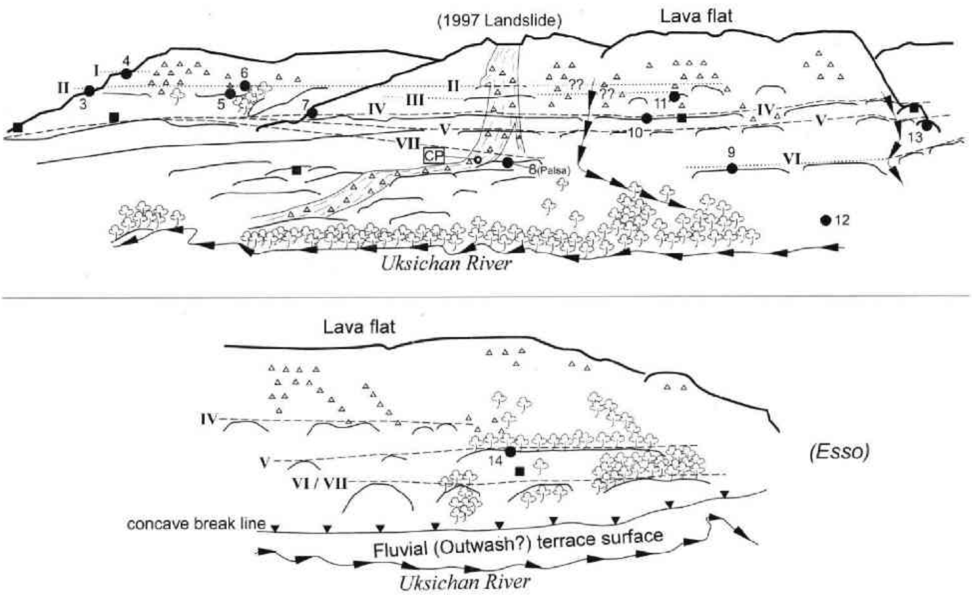

Fig. 6 Sketch of right bank slopes (upper) and left bank slopes (lower)
Gentle slopes and the summit level of low-relief area on valley bottom are divided into Surfaces I to VII on the basis of their height and continuity. Legends showing outcrops and pits are the same as in Fig. 4, but Locs. 1 and 2 are concealed due to being behind small ridges in this figure.

slope, whereas glacial landforms and glacial deposits can be observed in the lower half. Especially in the lower half, we recognized seven specific geomorphic surfaces, which are sporadically distributed but apparently well continuous in height within each surface. Namely, gentle slope surfaces attached to the valley side are correlated with Surfaces I to VI in descending order, and the summit level of the low-relief area on the valley bottom corresponds to Surface VII, as shown by Fig. 6. Surface IV to the south of the Uksichan River exists continuously. In contrast, Surfaces IV to VI are sparsely present on the left bank slopes ; it is, however, difficult to strictly identify the surfaces between the two side slopes. It is inferred that the all of these surfaces originated from glacial landforms and deposits, due to glacial fluctuation in different ages, as stated in the following chapters. A river terrace surface (or a past outwash plain) is distributed close to the present river bed, but not widely so. The study area and surrounding areas are underlain by the discontinuous permafrost ; therefore, Sone *et al.* (2003) reported the degradation palsa at Loc. 8, and Fukui *et al.* (2008) discussed subsurface factor controlling the presence and absence of permafrost on the west of the study area.

On the right bank of the Uksichan River, about 2 km ESE of Esso, a large-scale landform created by a landslide in July 1997 is observable (Figs. 5 and 6). This landslide zone has a width of 100 m and a relative height of approximately 250 m from a point about 600 m a.s.l. to the top of the slope. Its slip surface is considered to have existed at a relatively shallow depth overall, and therefore a rapid slope failure occurred within a short time as local information was obtained. Prior to this, a forest fire took place in 1995 on the slopes of the right bank, including the landslide zone, completely incinerating the trees, *e.g.*, *Larix gmelinii*, *Pinus pumila*, *Betula ermanii*, *etc.*, over a wide area (Yamagata and Sone, 2006). Grassy vegetation in the fire area had somewhat recovered by September 2003.

3. Topography and Geology along the 1997 Landslide

We observed subsurface deposits along the 1997 landslide, where rocks and sediments are better exposed, and obtained detailed topographic data. Figure 7 shows a topographic cross section along most of the landslide slope and the geometry of topographic measurement line, based on our topographic measurements. Such measurements had to be conducted as use of aerial photograph and detailed topographic map is not allowed in Kamchatka. In addition, Fig. 8 shows details of the geomorphological and geological section above the control point, approximately 600 m a.s.l., at which the boundary between the transported and deposited areas of the landslide is situated.

As Fig. 8 shows, four narrow gentle slope surfaces are recognizable along the landslide. Taking into account the distribution of these surfaces in the whole study area, we identified them as Surface II (about 760 m a.s.l.), Surface III (730 m), Surface IV (680 m), and Surface V (645 m), respectively. Surface IV on the right bank is almost continuously traceable, and Surface V to the south of the river also well continues toward the section upstream from the landslide. In contrast, Surfaces II and III are sparsely developed in the study area, and the form of Surface II is relatively obscure, particularly in the landslide zone.

In the landslide zone, dacitic autobrecciated lava or tuff breccia, and welded tuff containing medium-grained hornblende and quartz as phenocrystic minerals are exposed on the slopes of less than 650 m in altitude. Surface V of a gentle slope is recognizable at an elevation of about 645 m. This surface is considered to correspond to the top of a lateral moraine inferred from the spatial continuity of the landform and to consist of the unconsolidated supraglacial till 5, whereas the subsurface deposits could not be observed near the surface.

At an altitude of 660 m, semi-consolidated deposits with subangular to subrounded clasts set within ill-sorted tuffaceous sand to silt, namely, compact diamicton (Fig. 9b), overlies parallel-stratified pumiceous coarse tuff which is several meters thick. The

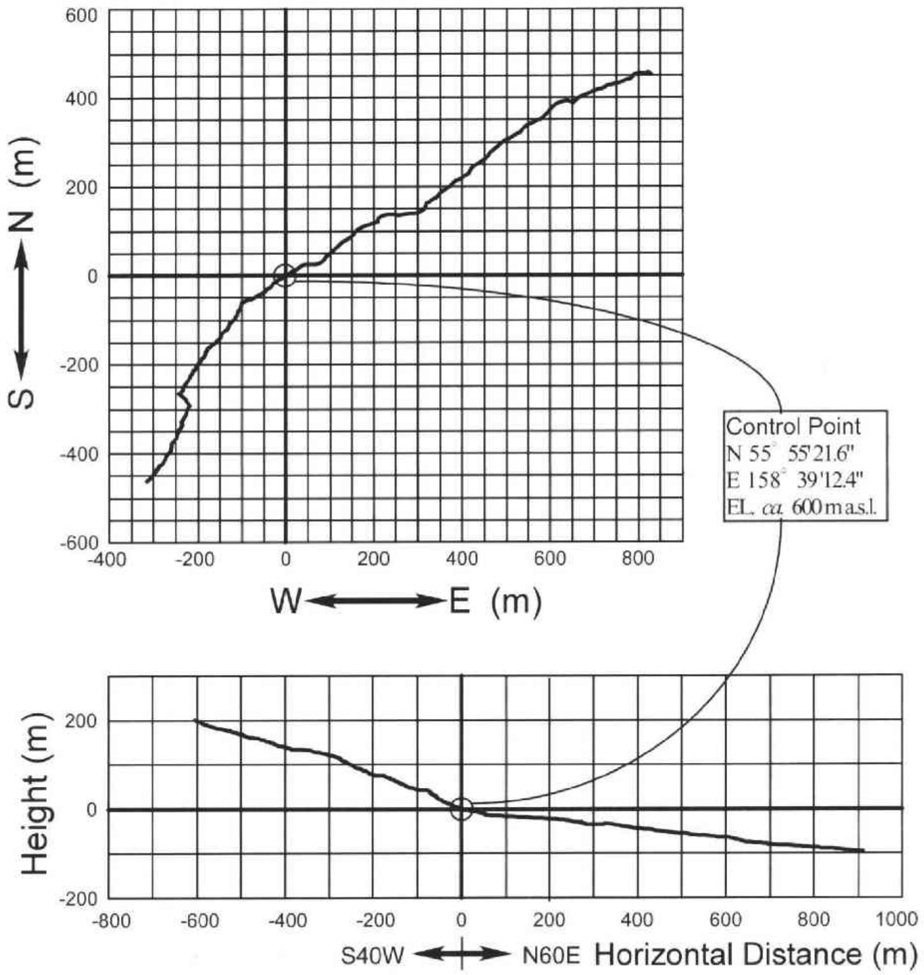

Fig. 7 Topographic measurement of the 1997 landslide slope
The upper figure indicates the horizontal projection of the measurement line and the lower shows the topographic cross section. The direction is shown on the basis of magnetic north (declination : 6 degrees west). Measurement control point is located at the boundary between the transported and deposited areas of the 1997 landslide, and has an altitude of approximately 600 m a.s.l. The cross section is projected to the horizontal line, which strikes N40°E to the southwest of the control point, and N60°E, northeast of the point.

clasts in the deposits are composed of several kinds of volcanic rocks, often containing fresh subrounded pebbles and cobbles. Because of the existence of much debris due to the dryness of the outcrop surface, the original sedimentary structures and deformation of the deposits could not be clarified in detail. Overall, however, we deduce that

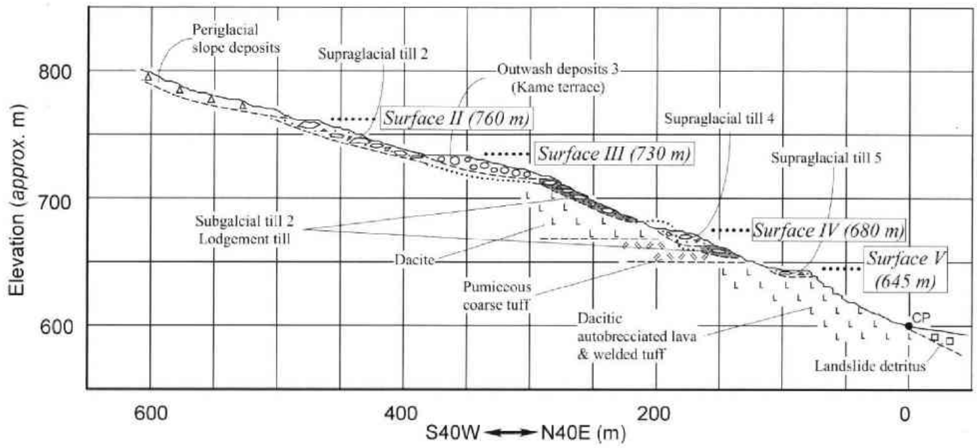

Fig. 8 Geomorphological and geological cross section along the 1997 landslide zone
CP: control point of topographic measurement

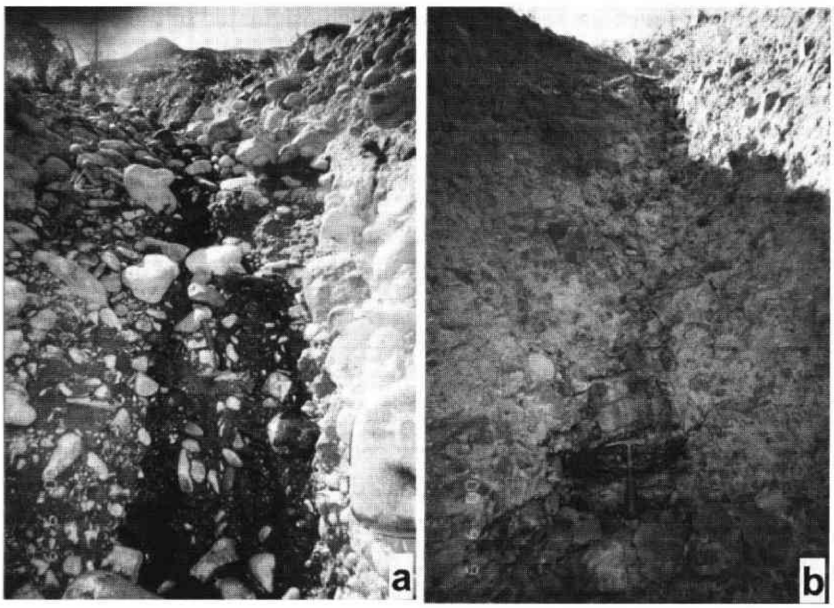

Fig. 9 Outwash deposits and subglacial till (lodgement till) in the 1997 landslide zone
The outwash deposits 3 (Fig. 9a) constitute a kame terrace correlative with Surface III at the 730 m a.s.l. site. The subglacial till 2 (9b) is exposed near the 680 m a.s.l. site and is directly underlain by dacite with fine phenocrysts. Taken in September 2000.

the diamicton is correlated with the subglacial till (subglacial till 2 ; Fig. 8), especially lodgement till, constituting ground moraine from its characteristics, and also in consideration of the lithofacies of underlying coarse tuff, such as glaciotectonite, in which some minor reverse faults are partly observable in the upper part of the tuff. Similarly, the subglacial till 2 with a thickness of about 30 m is also exposed over dacitic to andesitic lava with fine phenocrysts cropping out at the higher site than Surface IV. It is inferred that a supraglacial till connected with the subglacial till 2, should be present above the localities where the subglacial till 2 exposes. As described below, the supraglacial till 2 is thought to exist close to Surface II (Fig. 8).

Upward from about 710 m a.s.l., cobble- to boulder-sized gravel with a relatively high degree of roundness, mainly dominating in subrounded clasts, is continuously present (Fig. 9a). These deposits, in which the sorting of clasts is poor and the matrix materials consist largely of coarse sand with a small amount of fine-grained sediments, are inferred to be fluvioglacial, outwash in origin (the outwash deposits 3), and to constitute a kame terrace whose depositional surface, Surface III, reaches an altitude of approximately 730 m.

Another gentle slope surface, Surface II, is found in the landslide zone near the 760 m site, but is rather indistinct. Much debris which originated in the upper part of the valley-side slopes increases in the area between Surfaces II and III, and accordingly, it is difficult to observe and identify subsurface deposits covered by the debris. We presume that Surface II corresponds to the top of the lateral moraine prior to the formation of Surface III, namely, the outwash plain, because based on topographic data, this gentle slope is not considered to be a landform caused by detritus accumulation locally supplied by surrounding slopes. In other words, the supraglacial till 2 combined with the subglacial till 2, which is slightly eroded by the outwash deposits 3, exists above Surface III.

In the area above Surface II, including the area surrounding the landslide, no specific concave/convex break line is recognizable, except a major convex break just below the lava flat and around the landslide scarp, and there is an almost homogeneous slope. Slope deposits in this part are chiefly composed of subangular boulders with a sand matrix, and therefore it is inferred that the present periglacial deposits thinly cover the basement rock slope.

As stated above, we could not directly observe respective sediments around Surfaces II, IV, and V ; however these surfaces correlated with the tops of lateral moraines of different ages as evidenced by the topographic characteristics and spatial continuity in the whole investigated area. Consequently, the existence of the supraglacial tills 2, 4, and 5 in the landslide zone, can be conjectured as shown in Fig. 8.

4. Distribution of Glacial Deposits in the Investigated Area: Observation Data from Digging Pits and Outcrops

In the investigated area, since the gentle slope surfaces are thought to be highly related to several kinds of glacial deposits, as stated in the previous chapter, we conducted observation of subsurface deposits and micro-landforms, mainly on the gentle slopes. Except for in the 1997 landslide zone, there are very few outcrops of deposits and bedrock on both valley-side slopes of the Uksichan River, particularly in the lower half of the valley, and thus we sought to clarify the existence of such glacial deposits, by excavation of the surface (Fig. 10). As indicated in Fig. 10, tephra layers

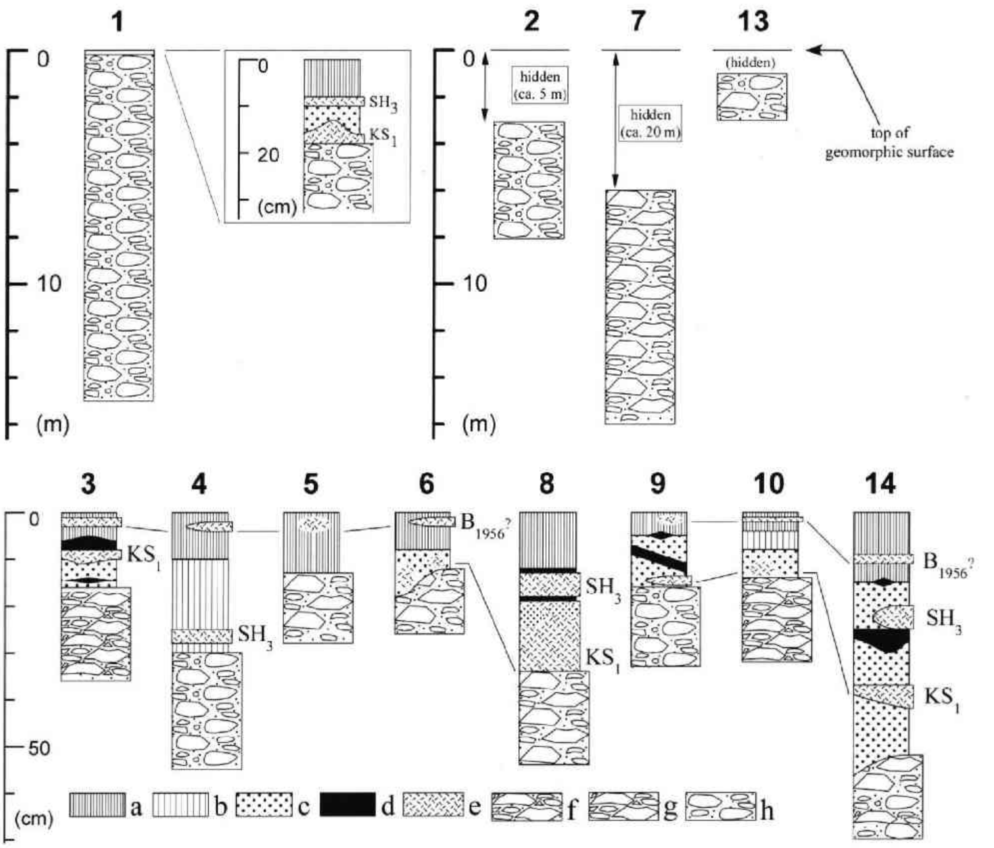

Fig. 10 Columnar section of outcrops and digging pits
a: litter (root litter) b: humic soil c: sand d: charcoal e: tephra f: angular rubble g: angular open-work rubble h: subrounded gravel
Localities are shown in Figs. 4 and 6. Abbreviations of marker tephras are cited from Braitseva *et al.* (1993, 1995, 1997).

overlying the below-mentioned glacial deposits, are megascopically only three, that is, $B_{1956(?)}$ originated in the Bezymianny Volcano (AD 1956 ?), SH_3 (1.3–1.4 ka) derived from the Shiveluch Volcano, and KS_1 (1.7–1.8 ka : Ksudach Caldera origin) (Braitseva *et al.*, 1993, 1995, 1997). In addition, it is inferred that forest fires often took place in this area also before 1995, as evidenced by the existence of some charcoal horizons. The notable characteristics and mode of the glacial deposits at several localities and the respective gentle slope surfaces are described as follows.

At Loc. 4 on Surface I, gravel containing a large amount of subrounded pebbles and cobbles underlies humic soils intercalated with a grayish white volcanic ash layer, SH_3 tephra. The highest gentle slope surface in the study area, Surface I, is considered to consist of fluvioglacial deposits (Fig. 11). On Surface II, a relatively unconsolidated layer of angular rubble is present under the KS_1 tephra (yellowish brown volcanic ash) horizon, *e.g.*, at Locs. 3 and 6. It is difficult to specify all of the deposits constituting Surface II as we could observe only the uppermost part of the gravelly deposits. We assume, however, that Surface II is derived from the top part of the lateral moraine.

Fluvioglacial deposits of Surface III, such as the outwash deposits 3, could not be found anywhere except in the 1997 landslide zone. At Loc. 11, which seems to be situated on Surface III from the viewpoint of elevation, there are faint outcrops of matrix-rich gravelly deposits comprising subangular rubble, in which shape of clasts and grain-size distribution apparently differ from those of Surface III deposits in the landslide zone. Moreover, the deposits at the same locality are covered with thick open-work boulders, namely, talus deposits originating from the huge backward slope ; nevertheless, fluvial deposits were not directly recognizable. On the other hand,

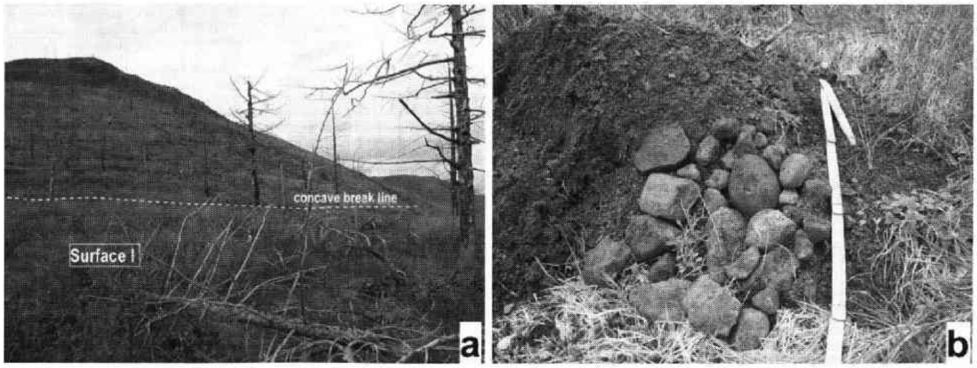

Fig. 11 Topography around Surface I and subrounded cobbles and pebbles in Surface I deposits
Concave break line between the surface and backward slope is recognizable in the center of Fig. 11a. Taken in September 2003.

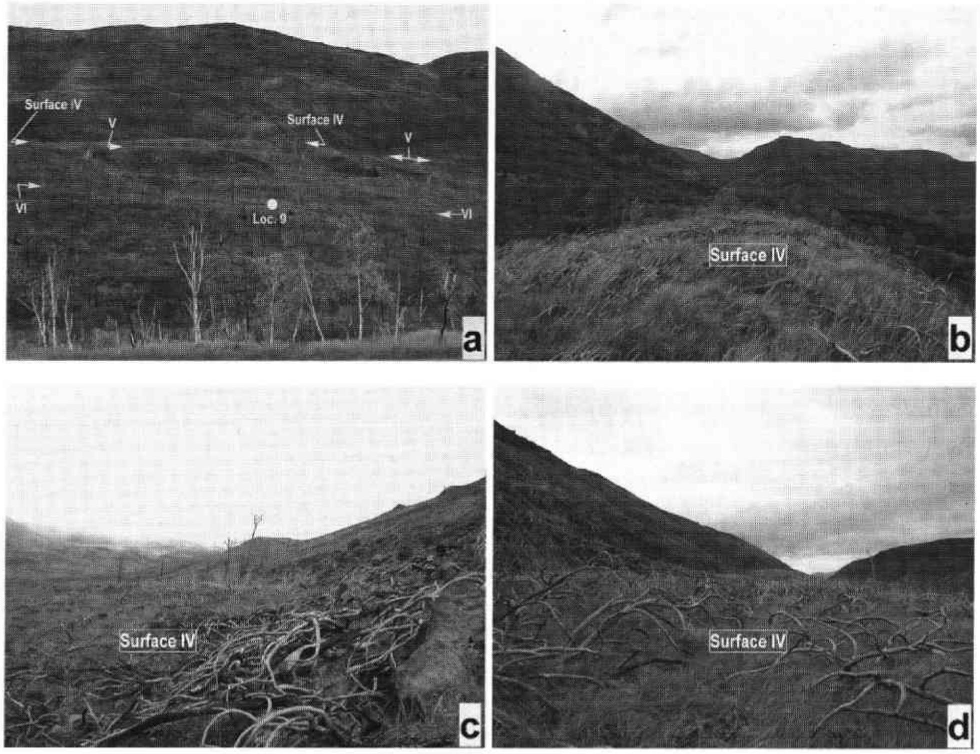

Fig. 12 Topography of Surface IV
a : Surfaces IV, V, and VI on the slopes of the right bank from the valley bottom. b : The top of Surface IV close to the 760 m a.s.l. site near Loc. 13, western margin of the study area. There is a relatively deep depression, connected with the valley-head, on the backward slope side (left side). c : On Surface IV at Loc. 10 (toward upstream). d : On Surface IV at Loc. 10 (toward downstream). All of the photos were taken in September 2003.

relatively loose, ill-sorted angular rubbly deposits, considered to be supra-glacial till, were exposed at Loc. 7, and often contained pebble- to cobble-sized blocks of subglacial till. It seems that the gentle slope behind this locality continues to Surface III, or is situated between Surfaces III and IV. No consistent conclusion about the formation of this gentle slope surface behind Loc. 7, is presently possible.

On Surface IV, only open-work talus deposits from backward scarp are exposed at Loc. 10. At the 760 m a.s.l. site on the western margin of the study area, near Loc. 13 (Fig. 13), as shown by a solid square in Figs. 4, 6, and so forth, there is an outcropping of andesitic lava with plagioclase megacrysts. This site is 5 m below the top of Surface IV, and the presence of glacial till cannot be directly recognized on this surface. Surface IV is, however, extremely well-continuous south of the Uksichan

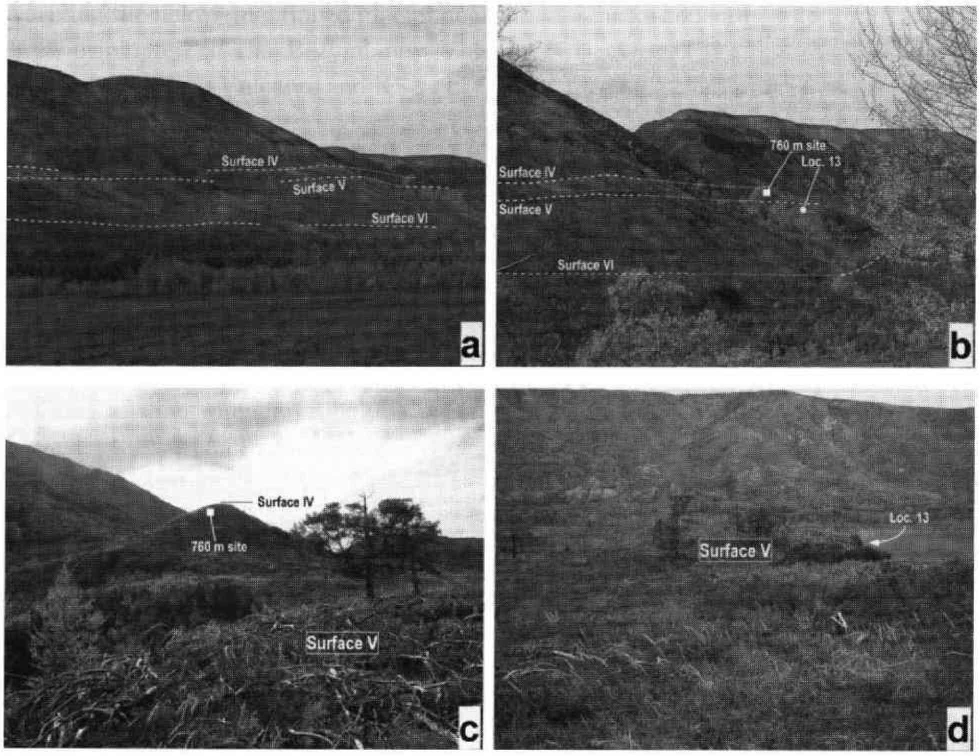

Fig 13 View of Surface V on the western margin of investigated area
a : Surfaces IV, V, and VI on the slopes of the right bank, western margin of the study area. b : Surfaces IV and V near the 760 m a.s.l. site and Loc. 13. c : On Surface V just above Loc. 13. The top of hills, close to the 760 m a.s.l. site, corresponds to Surface IV (Fig. 12b). d : Surface V from the 760 m a.s.l. site. All of the photos were taken in September 2003.

River (*e.g.*, Fig. 12), and it is observable that the top of Surface IV takes the form of a ridge in places, where elongated, sometimes deep, depressions exist close to the concave break line behind the surface. Despite the uncertainty about the existence of the till, from its topographic features, it is concluded that Surface IV arose from a lateral moraine.

As to Surface V, at Loc. 14 of the left bank slope and Loc. 13 of the right bank slope, less consolidated deposits considered to be supraglacial till are present, and consist mainly of angular rubble, partly containing subrounded pebbles and cobbles. Topographically the surface continues well northwestward from the 1997 landslide and maintains an almost constant height difference from Surface IV (Fig. 13). Thus, Surface V is thought to have originated from a lateral moraine as did Surface IV. Surface VI also forms a continuous ridge in the northwest of the study area toward the upstream part of the river. On this surface, deposits composed mainly of subrounded pebbles and cobbles with a matrix of ill-sorted silt to coarse sand are present at Loc. 9. These lithofacies are consistent with the deposits constituting terminal moraine in consideration of the topographical continuity of Loc. 9 to the lateral moraine ridge indicative of Surface VI. The terminus of the glacier when Surface VI formed, therefore, is presumed to have been situated near this locality. From the viewpoint of height, Surface VI also appears to converge with Surface VII at a point southeast of Loc. 9, as mentioned below. Thus, this lateral moraine correlative with Surface VI, disappears in the uppermost part of the investigated area, as shown by comparison with other previously described lateral moraines.

The summit level of low-relief hills, correlated with Surface VII, tends to be in accordance with the altitude in the longitudinal direction of the Uksichan River Valley. In contrast, the change of the hill-top height in the valley-cross-direction differs from the maximum value by approximately 100 m in some places. This surface is inferred to have various properties depending on the age of its components because some moraine ridges, namely, Surfaces IV, V, and VI are convergent with Surface VII in the valley, as shown in Fig. 6. Near Esso, gravel made up mainly of subrounded fine pebbles to boulders is frequently exposed at Locs. 1 and 2, and at some other localities (Figs. 10 and 14). Around these localities, a group of minor ridges and hills composed of these deposits is arranged in multiple semicircular arcs, which are convex toward the downstream side (Fig. 15). From these characteristics of lithofacies and topography, these ridges and hills correspond to a part of the terminal moraine at some stage. The low-relief hills further upstream, also existed as ground moraines at that time and in a more recent age, and underwent modification by outwash at a later time (*e.g.*, Loc. 12 ; Fig. 14).

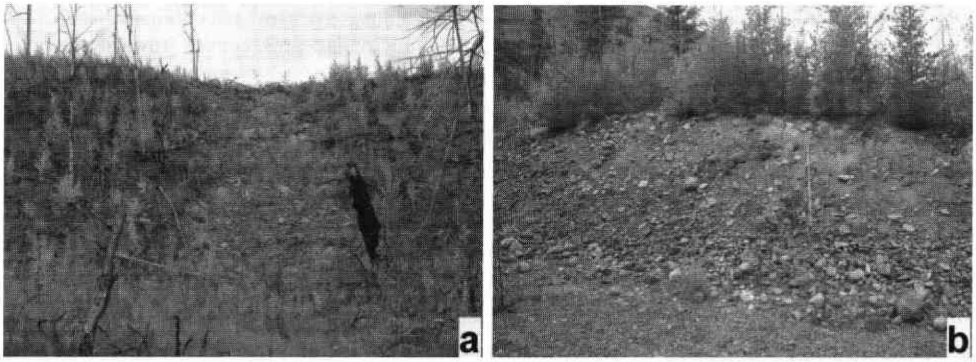

Fig. 14 Surface VII deposits at Locs. 1 and 12
At Loc. 1 (Fig. 14a), 15-m thick subrounded gravel is exposed from the top of hills. Subrounded gravel constituting ground moraine is also observable at Loc. 12 (Fig. 14b). Taken in September 2003.

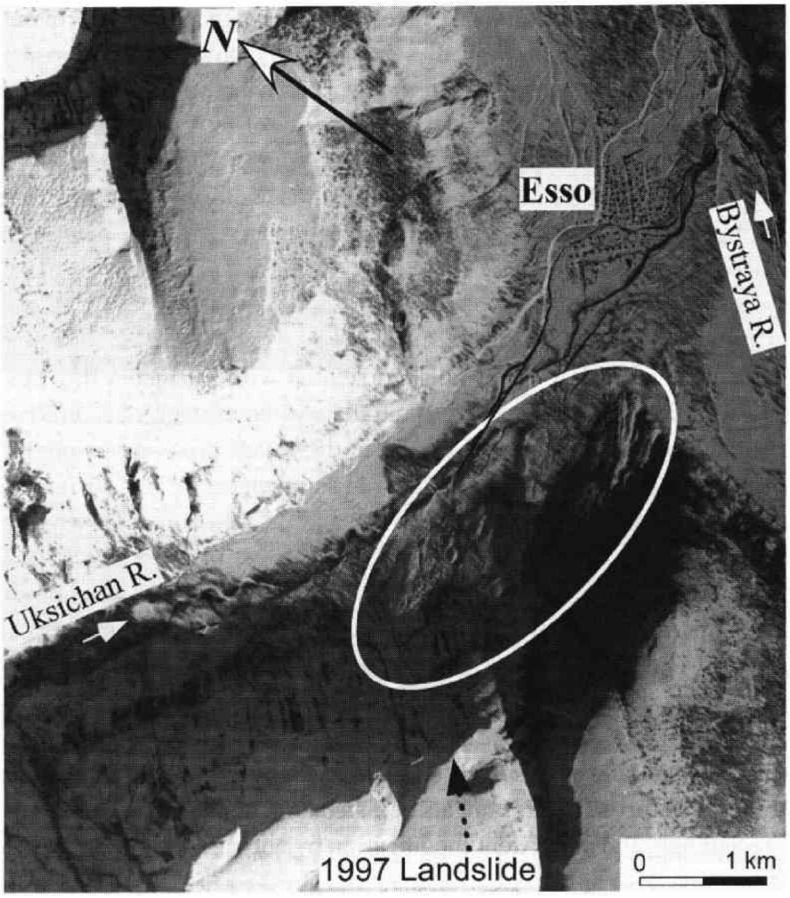

Fig. 15 CORONA satellite image of area around Esso
Small hills belonging to Surface VII, in the white ellipse, are arranged obliquely in the direction of the river valley, and multiple semicircular arcs convex toward the downstream side.

A considerable difference in stratigraphy of the tephra layers is not apparent at all of the localities, even among the surfaces at different levels, whereas it is evident that these surfaces formed in different ages owing to the spatial structures of respective surfaces and subsurface deposits. In addition, the existence of Pleistocene widespread marker tephras have been scarcely reported in Kamchatka, although the volcanic activities of the Pleistocene age are considered to have taken place at roughly the same frequency as those of the Holocene. We postulate that the preservation of tephra layers which existed before the postglacial would have been difficult due to the severe climatic condition, especially in the Last Glacial age. Because of these factors, it is considerably difficult to identify the glacial deposits of different ages by tephrochronological method in the study area.

5. Late Quaternary Glaciation in the Uksichan River Valley

We attempted to reconstruct the late Quaternary glacial fluctuations in the lowest region of the Uksichan River Basin on the basis of the glacial landforms (Fig. 16), though detailed tephrochronological data could not be obtained. The highest Surface I in the above-mentioned surfaces represents the age of glacial retreat, as the deposits comprise fluvioglacial sediments and the surface is inferred to have originated from the outwash plain. Prior to that age, a large-scale valley glacier advanced from the area of the Uksichan Volcano at least once, resulting in the formation of the U-shaped valley along the Uksichan River. In this paper, we define the first advance of the glacier to Esso and toward the downstream of the Bystraya River as the Bystraya Stage 1.

The next oldest glacial advance stage, the Bystraya Stage 2, is represented by the existence of Surface II, derived from the lateral moraine. From the spatial placement of the surface, it is inferred that the glacier in this stage was confluent with the glacier along the present Bystraya River Valley at Esso and that the both flowed down toward

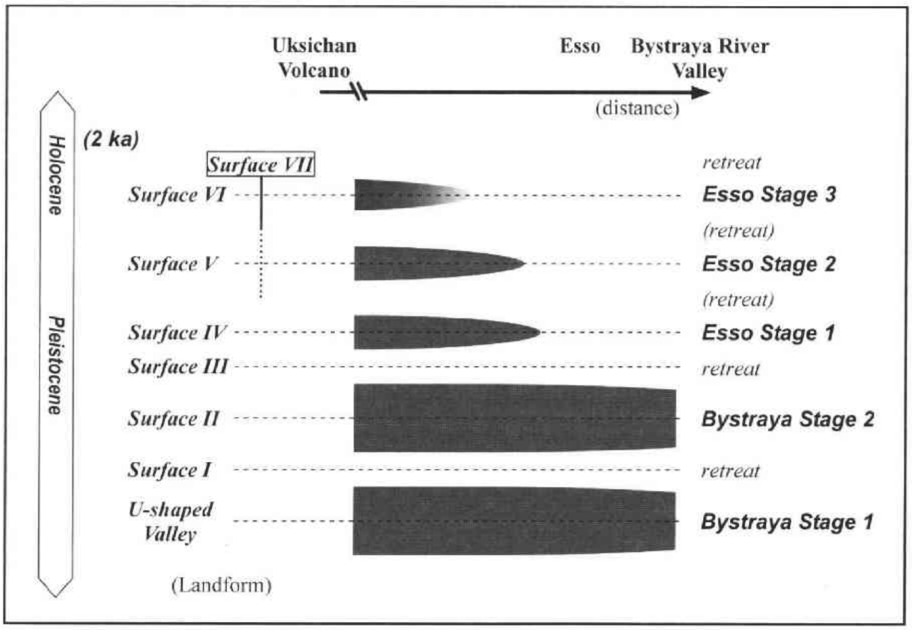

Fig. 16 Late Quaternary glacial fluctuations in the lowest part of Uksichan River Basin

the lower drainage area. Considering the height distribution of the subglacial till 2 (lodgement till) which crops out around Surface IV in the landslide zone, we imagine the thickness of the glacier reached roughly 100 m or more in the investigated area in the Bystraya Stage 2. When the glacier was declining after this stage, fluvioglacial deposits were dispersed and Surface III was brought into being as an outwash plain in the study area.

In the Esso Stage 1, as is indicated by the mostly continuous lateral moraine, Surface IV, the glacier terminus at that time is considered to have reached a point near Esso (Fig. 15). The glacier thickness, however, cannot be estimated because the whole distribution of glacial till, particularly of subglacial till in this stage, is not clear. Surface V, just below Surface IV, also continues well, especially in the west of the investigated area. In general, well-continuous lateral moraine is presumed to have formed in the period of glacier advance (*e.g.*, Hasegawa *et al.*, 2004). According to this, we consider that Surface V is correlated with the independent glacier advance of the Esso Stage 1, that is, the Esso Stage 2. Also, in the Esso Stage 2, it is inferred that the glacier reached its closest point to Esso.

The newest glacier advancing stage in this area, the Esso Stage 3, corresponds to Surface VI, the lowest lateral moraine. The glacier margin in this stage is thought to have been situated between the west end of the study area and Esso. As also described in the previous chapter, the low-relief hills on the valley floor, Surface VII, were formed as ground and terminal moraines in the Esso Stages 1 to 3, and these moraines have been subjected to reshaping by outwash from these stages up to the present. Furthermore, it is inferred that the accumulation zone of the glaciers in the drainage area existed around the Uksichan Volcano and other mountains in respective advance stages and that the whole length of the valley glacier in each stage attained a maximum of approximately 30 km or more, as evidenced by the distance from the mountains to the study area.

All of these five glacial advances certainly date back to the Neoglaciation age of approximately 3 ka, and perhaps before that as indicated by the stratigraphic relationship between the marker tephra layers and the glacial deposits. Although we did not obtain any other data on the ages of respective stages, we have the almost same prospect as Sone *et al.* (1997) that the Esso Stage 1 is presumably correspondent to the Last Glacial age.

6. Concluding Remarks

We conducted preliminary field surveys on glacial landforms and deposits in the lowest part of the Uksichan River Basin, which led to the following conclusions (Fig. 16) :

1) Several specific geomorphic surfaces, consisting mainly of gentle slope surfaces, which are originated from glacier landforms, exist in the investigated area. We subdivided the surfaces into Surfaces I to VII in descending order.

2) From the mode and characteristics of the glacial deposits constituting the respective surfaces, and from micro-landforms in the area studied, Surfaces II, IV, V, and VI correspond to the glacier advancing stages (Bystraya Stage 2, Esso Stage 1, 2, and 3), and prior to these stages, a U-shaped valley formed along the Uksichan River in the oldest glacier advancing stage (Bystraya Stage 1).

3) All of these stages date back to the Neoglaciation age (*ca.* 3 ka) on the basis of tephrochronology. Specifically, the glaciers in these stages extended approximately 30 km or more from the Uksichan Volcano and the surrounding mountains, where the accumulation zones of the glaciers were widespread at those times. We presume that the glacier terminus was situated near Esso in the Esso Stages 1 to 3.

In most of the investigated area, it is relatively easy to find three Holocene marker tephra layers covering the glacial deposits. However, we could not directly estimate the ages of respective advances by the tephrochronological method, and therefore other dating methods need to be adopted to permit discussion on the detailed periods of glaciation in the Uksichan River area. In addition, further studies concerned with the sedimentary structures and the deformation of glacial deposits are necessary in order to clarify the detailed glacial environment in each advance stage, in spite of the absence of outcrops

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