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Lemieux landslide of June 20, 1993. This sensitive clay flow occured near the former townsite of Lemieux, Ontario. The failure involved 2.5 to 3.5 Mm^3 of sand, silt, and clay which flowed into the South Nation River valley, inundating 3.3 km of the valley bottom and impounding the South Nation River. GSC 1993-296

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Abstract

Beginning at about 15:30 on June 20, 1993, a sensitive clay flow occurred near the former townsite of Lemieux, Ontario. The failure involved 2.5 to 3.5 Mm^3 of sand, silt, and clay which flowed into South Nation Valley, inundating 3.3 km of the valley bottom and impounding South Nation River. By late June 22, 1993, the river overtopped the dam and again flowed downstream. This paper provides a photographic record of the event and post-failure conditions.

Résumé

Aux environs de 15h30 le 20 juin 1993, une coulée d' argile s' est produite près de l' ancien site de l'agglomération de Lemieux en Ontario. De 2,5 à 3,5 Mm^3 de sable, silt et argile se sont écoulés dans la vallée de la rivère South Nation inondant 3,3 km du fond de la vallée et bloquant ainsi la rivière South Nation. Tard dans la journée du 22 juin 1993, la rivière s' écoulait au-dessus du barrage et en aval de ce dernier. Le présent article fournit un dossier photographique de l' évènement et des conditions subséquentes.

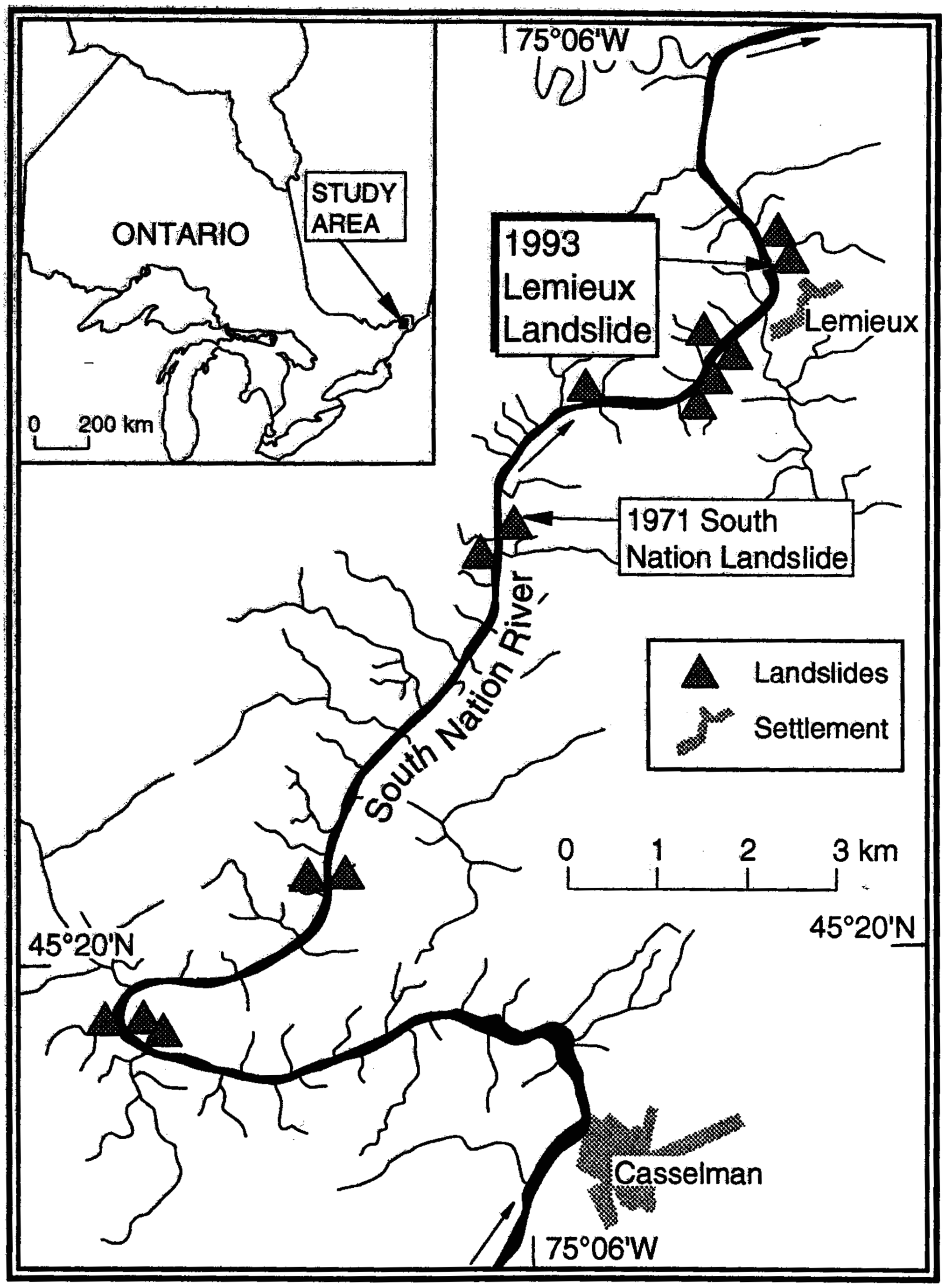

Figure 1. *The June 20, 1993 landslide is located beside the former townsite of Lemieux, Ontario, 50 km east of Ottawa. The Lemieux landslide is the most recent of a long series of sensitive clay flows and retrogressive slides that have occurred along the Casselman-Lemieux reach of South Nation Valley (modified after Richard, 1982).*

Introduction

Mid-afternoon, June 20, 1993, a sensitive clay flow occurred at the former townsite of Lemieux, Ontario, 50 km east of Ottawa (Fig. 1). As documented by Evans and Brooks (in press), the failure involved 2.5 to 3.5 million cubic metres (Mm^3) of sand, silt, and clay which flowed into the valley of South Nation River, inundating 3.3 km of the valley bottom. This spoil impounded South Nation River, eventually flooding the valley bottom upstream as far as Casselman, Ontario (Fig. 1). By late June 22, 1993, South Nation River waters overtopped the landslide dam and again flowed downstream. Fluvial erosion by the restored flow caused a massive increase in water turbidity which adversely affected water quality for farms and communities downstream. River incision into the spoil has proceeded slowly up to at least November 1993, causing the gradual lowering of the impounded waters. There was no loss of life associated with the landslide.

Beginning shortly after 15:30, eyewitnesses at several locations both upstream and downstream of the landslide crater observed a large wave and spoil moving along South Nation Valley. At the bridge on County Road 8, which crosses the South Nation River about 800 m upstream of the landslide, other witnesses first noticed trees moving within the river valley. One person reported a displacement wave about 2 m high moving up the river. This was followed by flowing spoil which eventually filled the valley bottom up to 12m in depth. As observed from the County Road 8 bridge, the movement of the spoil within the river valley occurred over a period of about one half hour. An eyewitness about 2 km downstream of the crater reported a displacement wave 2 to 3 m high, which travelled at "great speed" down the river. Shortly before 16:00, headward regression in the crater reached and severed County Road 16. A motorist proceeding south on this road drove his truck into the crater; he was later rescued. Eyewitnesses reported that, at about 16:30, a last pulse of movement occurred, involving subsidence and translation of sediment. This moved the truck 20 m down the crater while other sections of the road were rafted much further (up to 200 m). Major movement within the crater seems to have been completed by about 16:30.

As discussed by Evans and Brooks (in press), there was no obvious trigger for the slide, although an elevated water table seems to have been an important factor in the failure. Related to this, total precipitation (snow and rainfall) measured at Ottawa International Airport between January 1 and June 20, 1993 was 553.9 mm, exceeding the 47 year January to June mean (406.3 mm) by 36% (Table 1). This January to June 1993 period was the wettest first half year on record since 1947. In June 1993, prior to the landslide, 73.6 mm of rain fell (96% of the total 47 year mean rainfall for June) of which 15.8 mm was received on June 20. Heavy rainfall occurred in the afternoon of June 20, but it is not known how much fell before the landslide. Overall, during the winter of 1993 there was an above normal snowfall with heavy snowfall occurring in March and early April. This fact, combined with a rapid spring melt and heavy spring rainfall resulted in water tables near or at the ground surface. At the time of the landslide, water tables were high in the Lemieux area as was apparent from the widespread occurrence of standing water on the local fields.

The Lemieux landslide is the most recent of a long series of sensitive clay flows and retrogressive slides that have occurred along the Casselman-Lemieux reach of South Nation Valley (Fig. 1). At least 13 historic and prehistoric slide scars are present along the valley; the most recent of these landslides happened on May 16, 1971, 4.5 km upvalley of the Lemieux landslide (see Eden et al., 1971). The potential landslide hazard at Lemieux was recognized by local authorities; the property of most residents was expropriated in 1989/1990.

The occurrences of landslides along South Nation River relates to the presence of a sensitive silty clay, generally referred to as 'Leda clay'. Leda clays are rock flour produced by glacial abrasion. As summarized by Carson and Bovis (1989), the sensitivity generally relates to a high water content within the clay; the flocculated fabric of the clay particles; low electrical attraction between the clay particles; low overburden pressures during deposition of the clays and; the post-depositional leaching of salts from the clays. Upon disturbance or remolding, Leda clays lose most or all of their shear strength. Numerous landslides in the Ottawa Valley-St. Lawrence Lowlands have occurred within Leda clay sediments.

Leda clays are present throughout the Ottawa Valley-St. Lawrence Lowland region having originated from glaciomarine sedimentation in the Champlain Sea during the waning of the Laurentide Glaciation. Along the reach of South Nation Valley that is prone to landslides, the glaciomarine sediments are buried beneath sands of the Russell and Prescott sand plain (Gadd, 1976; Richard, 1982; Chapman and Putnam, 1984). This plain is the remnant of a delta complex that was built into the Champlain Sea by ancestral Ottawa River and its tributaries. The plain was later dissected by streams when relative sea level fell (Gadd, 1987). South Nation River has cut a 23 m deep valley through the sand and into the underlying glaciomarine silt and clay. At Lemieux, a zone of sensitive clay forms the lower portion of the valley sides (Evans and Brooks, in press).

Since June 20, 1993, the site has changed considerably due to erosion of the crater sides, erosion and revegetation of the spoil, and river incision into the spoil. This paper provides general information and serves as a photographic record capturing important characteristics of the landslide which are gradually being lost.

Table 1. *Summary of precipitation; Ottawa International Airport (Source: Environment Canada)*

	Jan.	Feb.	Mar.	Apr.	May	June	Total
Mean Precipitation, 1939-93:	60.0	59.2	66.4	68.9	74.9	76.9	406.3
Precipitation, 1993:	109.0	60.5	86.5	144.1	80.2	*73.6	553.9
Mean Snowfall, 1986-93:	49.6	45.2	32.3	9.1	1.2	0.0	137.4
Snowfall, 1993:	75.8	78.6	92.8	41.6	0.0	0.0	288.8

* June 1993 precipitation covers only the period June 1st to 20th.

Figure 2. Aerial photographs of the Lemieux site a) pre-slide (November 21, 1945; NAPL A9615-91) and b) post-slide (June 22, 1993; CAS 93049-13). This site is along a straight section of South Nation Valley just downstream of the outer bank of a bend (Fig. 1). The 1993 landslide occurred at the site of an earlier retrogressive slide scar; a dashed line delineates the backwall of the earlier scar. This scar forms a terrace along the valley side about 15 m above the pre-slide river channel. Most of the failed area was abandoned farmland with some mixed forest. The failure occurred between two gullies extending eastward from the valley side (A and C). A smaller gully (B) located between these gullies was obliterated by the landslide. The extent of the failure seems to have been restricted by the presence of gully C since the crater roughly follows the upper edge of the gully then begins to curve around behind it (Fig. 2b). The presence of this gully probably allowed sufficient drainage of the immediate area to prevent failure. Note the river bar that coincides approximately with the upstream lip of the crater mouth; it appears on maps and aerial photographs of the site beginning at least in the 1940s.

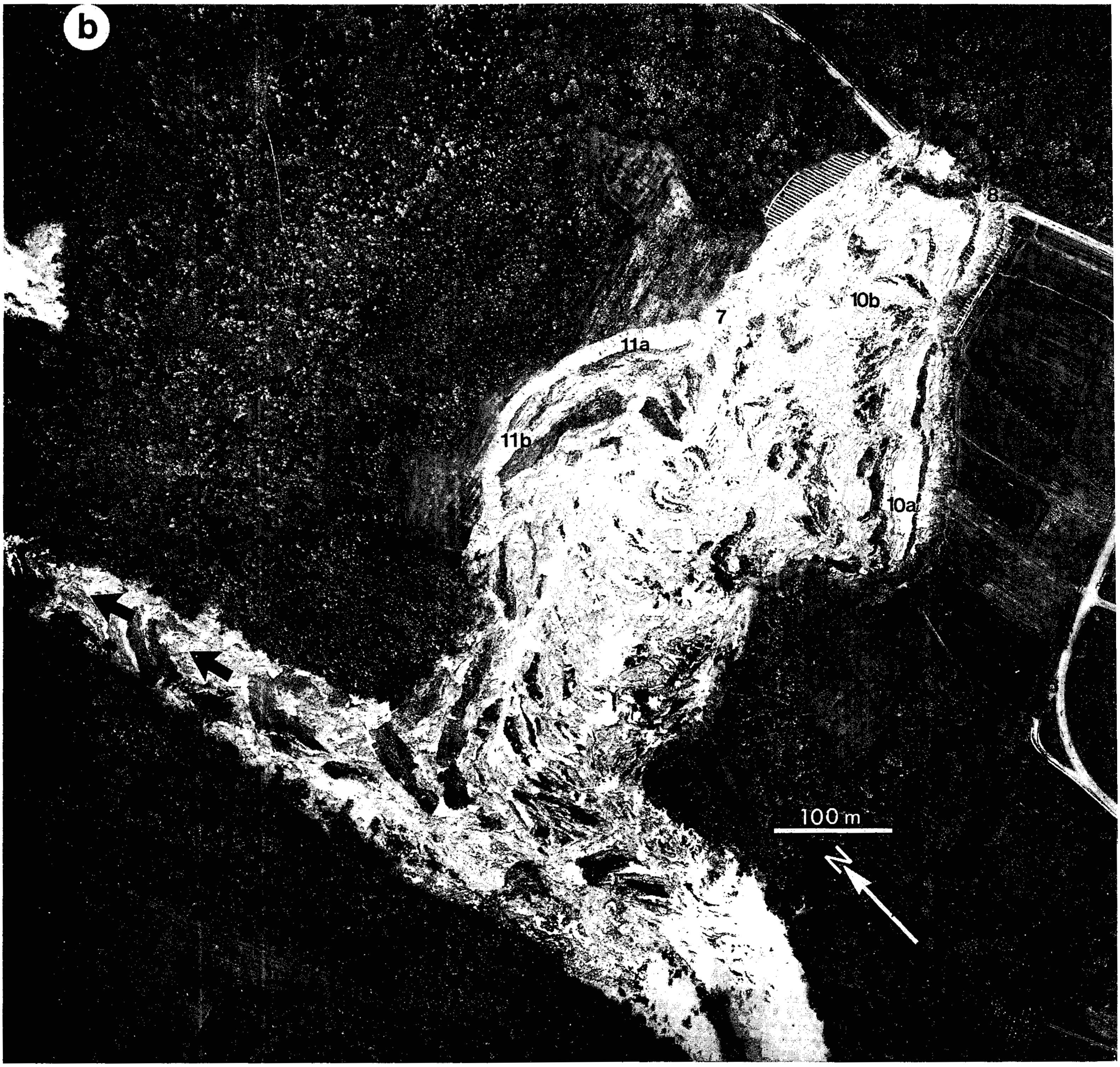

*Photo **b)** was taken two days after the landslide and before the impounded river had overtopped the spoil in South Nation Valley. The landslide crater is 680 m long and up to 320 m wide, covering 17 ha (Evans and Brooks, in press). The elongated shape is not symmetrical; outward embayments extend from both its north and south side. Numbers refer to location of Figures 7, 8, 10a, 10b, 11a, 11b.*

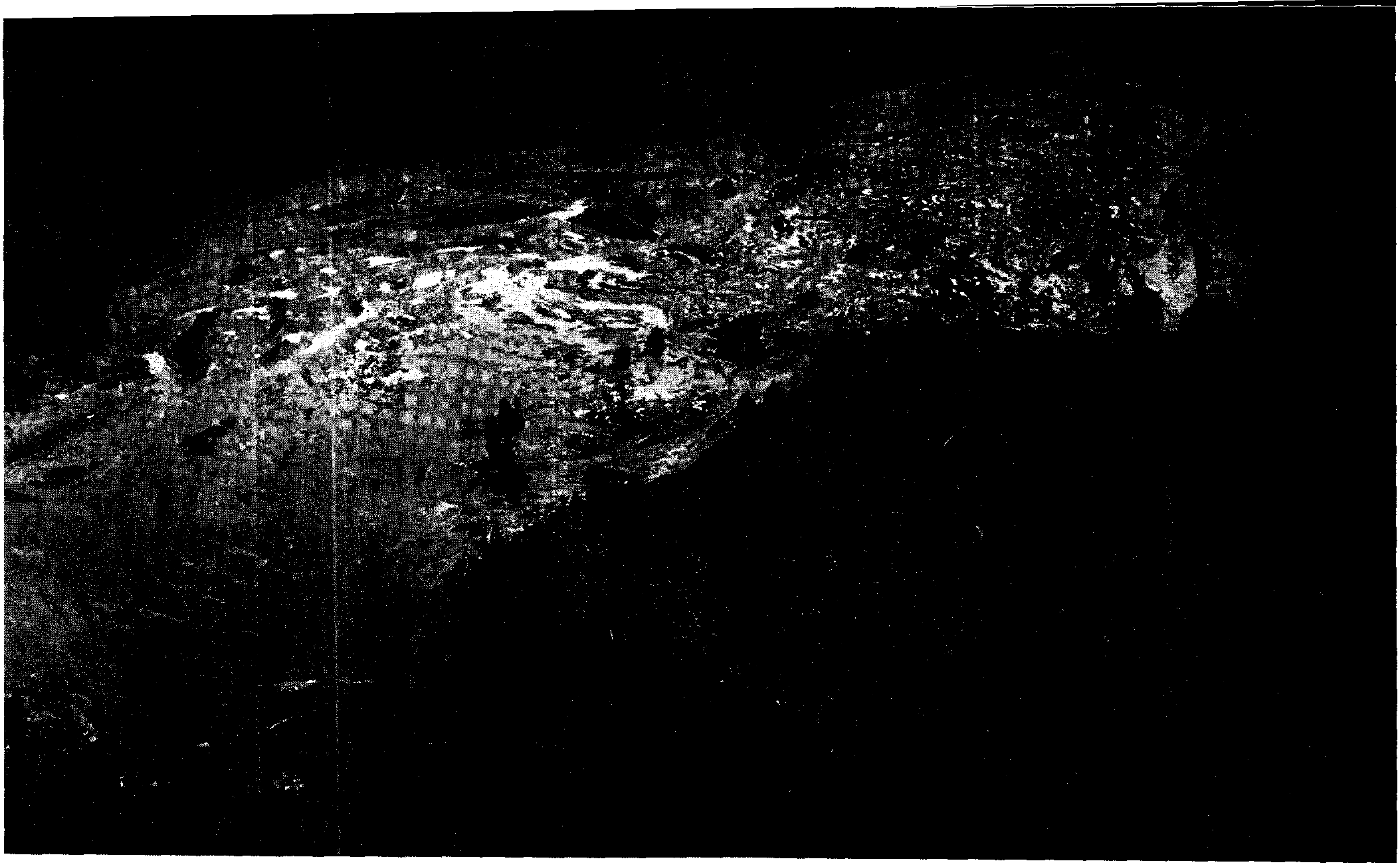

Figure 3. Aerial view of the Lemieux landslide (GSC 1993-254F), late morning Wednesday, June 23, 1993. The landslide involved the failure of 2.5 to 3.5 Mm^3, much of which flowed into South Nation Valley causing the impoundment of the river (foreground). The surface of the crater is up to 12 m below the Russell and Prescott sand plain and slopes gently towards South Nation Valley.

Figure 4. a) Landslide spoil, consisting of rafted blocks of relatively intact material within a matrix of liquefied clay and silt, buried the valley bottom extending about 1.6 km upstream and 1.7 km downstream of the crater mouth. This view is looking downstream towards the County Road 8 bridge which crosses South Nation River about 800 m upstream of the crater, and shows spoil which flowed upstream along the valley bottom. At the bridge, spoil filled the valley to an estimated depth of about 12 m. (photo Ottawa Citizen) b) The accumulation of spoil within South Nation Valley impounded the river upstream of the crater. Immediately after the landslide, river waters rose until they eventually overtopped the spoil. The impounded water reached a maximum height of about 12 m above the pre-slide valley bottom which caused flooding upstream as far as Casselman, Ontario (Fig. 1). This photograph was taken late morning Wednesday, June 23, 1993 at approximately the maximum height of the river impoundment and is looking across the crater mouth upstream into the flooded South Nation Valley (GSC 1993-254B).

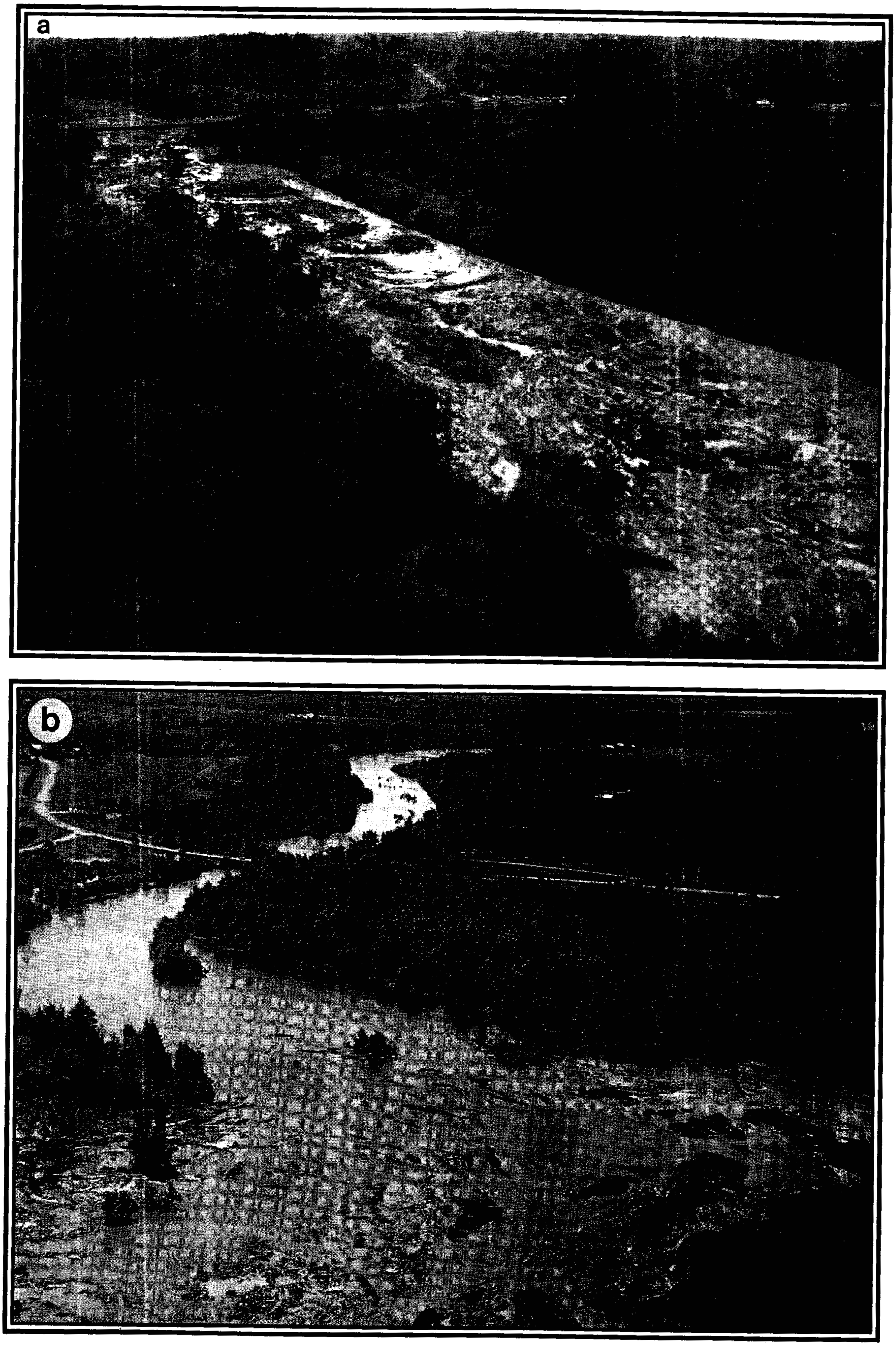
a
b

Figure 5. View downstream across the crater mouth showing the landslide spoil which travelled downstream along the valley bottom (GSC 1993-254A). It was taken late morning Wednesday, June 23, 1993, hours after the impounded river waters overtopped the landslide dam and began flowing downstream. Reflecting a rapid change in water turbidity, water colour changes from dark to light beginning at the mouth of the crater where flow starts to accelerate across the crest of the landslide dam causing erosion and entrainment of the spoil. High levels of water turbidity adversely affected water quality to farms and communities downstream for several days after the river flow was restored.

***Figure 6.** After the overtopping of the landslide dam, the restored flow of South Nation River occurred initially as a broad sheet subdivided by intact sediment blocks and rafted vegetation (cf., Fig. 5). The river gradually incised the spoil (2 m by July 7), reducing the level of the impoundment and creating a relatively narrow, sinuous channel. Comparative photographs of the river reach looking downstream immediately below the lower lip of the crater mouth reveal this change: **a)** taken early afternoon Thursday June 24, 1993 before significant incision (GSC 1993-254I) and **b)** October 11, 1993 after about 5 m of incision. The photographs are taken from the same position; arrows in a) and b) depict a common prominent ridge. (GSC 1993-306)*

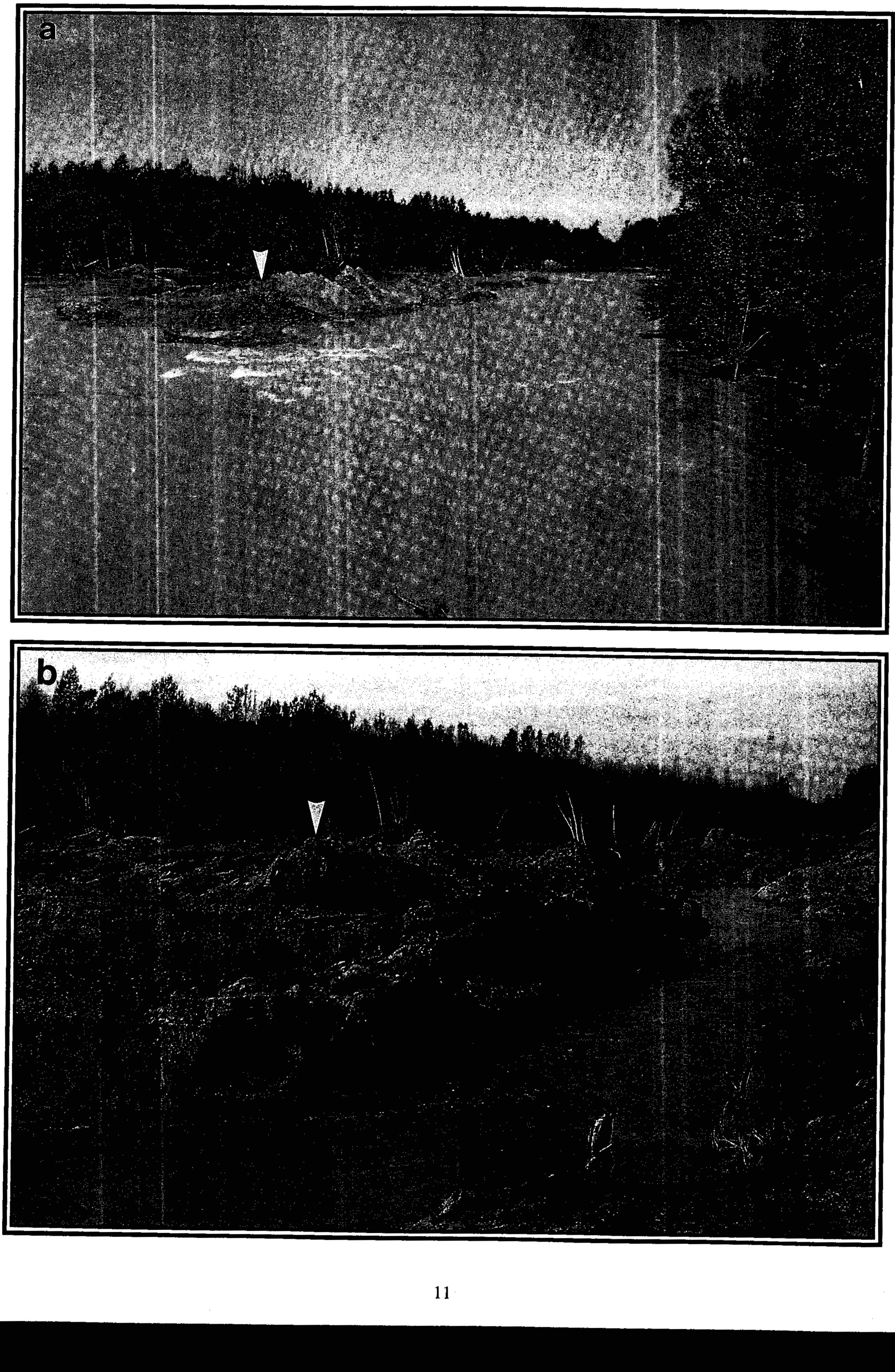
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***Figure 7.** View along north sidewall towards the headwall. Along the reach of South Nation Valley prone to landslides, glaciomarine sediments (silts and clays) are buried beneath deltaic sands. The crater walls reveal a sequence of sediment fining downwards from structureless sand, through interbedded silty sand, laminated fine sand/silt with thin clay layers, to laminated clay with thin silt layers. Deposits in the upper part of the sequence did not remold during the landslide, but rather fractured to form blocks rafted within the spoil. For months after the landslide, water seeped from all coarser laminations in the crater walls. GSC 1993-295A*

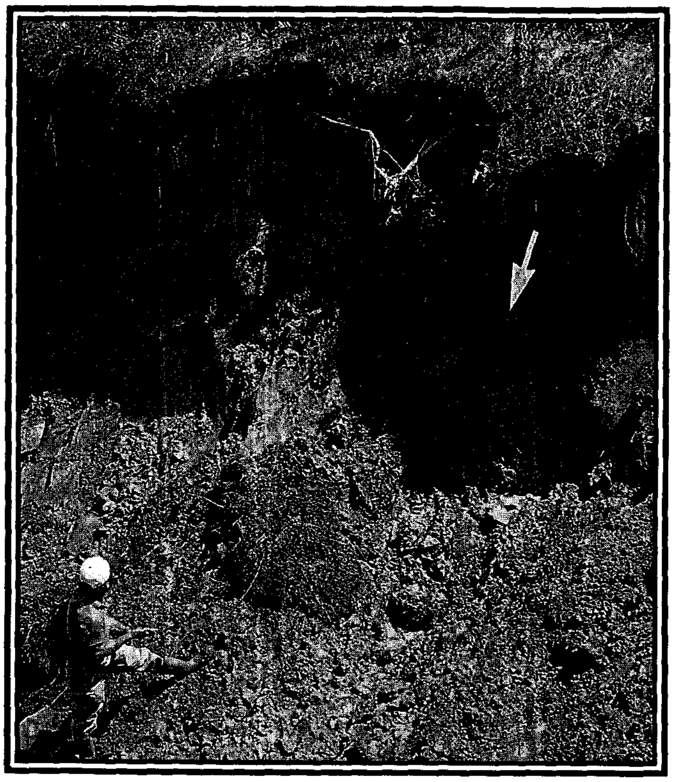


Figure 8. *Indicative of the high water table at the time of the landslide, there was widespread standing water and evidence of drainage into the subsoil on the undisturbed surface around the margin of the crater. After the failure, groundwater seeped from the crater sides, with horizontal pipes being eroded at locations of concentrated flow. Pipe diameter ranged from 0.1-1 m and most were located at a depth of about 2.5 m at the sand/silt interface. The pipe in this photograph was located at the headwall of the crater where eighteen active pipes were observed on Thursday, June 24, 1993. Many of these pipes continued to enlarge in diameter and depth over the summer. GSC 1993-295B*

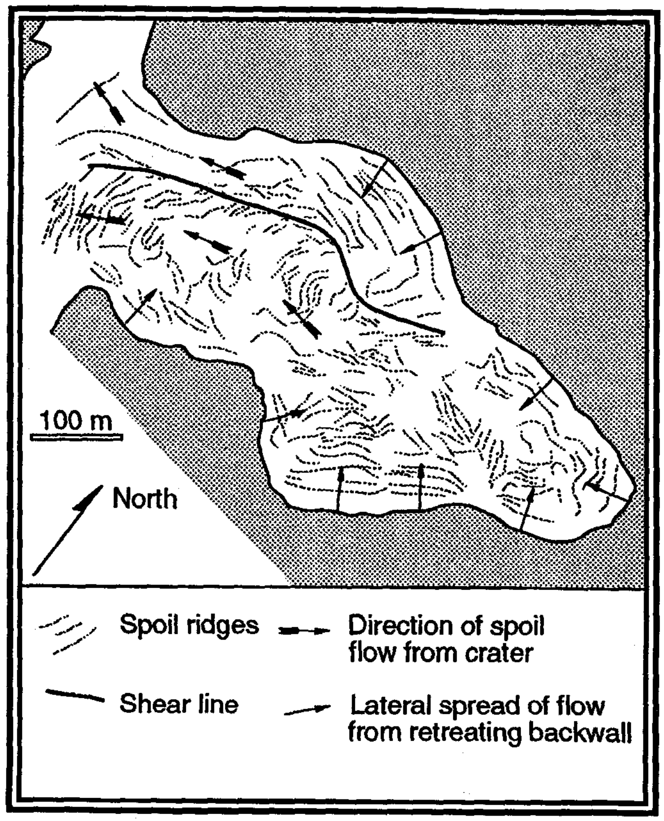


Figure 9. *Within the spoil remaining in the crater are blocks of intact sediment and strips of sod and upright trees that form linear ridges within the remolded clay and ponded water (Fig. 2b). The arrangement of the ridges relates to the pattern of backwall retreat, but since much of the spoil has flowed into the river valley, the pattern of retreat probably relates only to the final stage of the landslide. Assuming that the direction of retreat is perpendicular to the ridges, an outline of the ridges reveals that failure generally has occurred along the crater sides obliquely with respect to the long axis of the crater. This pattern of retreat significantly increased the crater width and has contributed to the formation of an embayment on both the north and south side of the crater. In the lower two-thirds of the crater, there is a lineation running up from the river that appears to be a shear-zone between the flow of spoil in the central portion of the crater and that flowing from the north side embayment.*

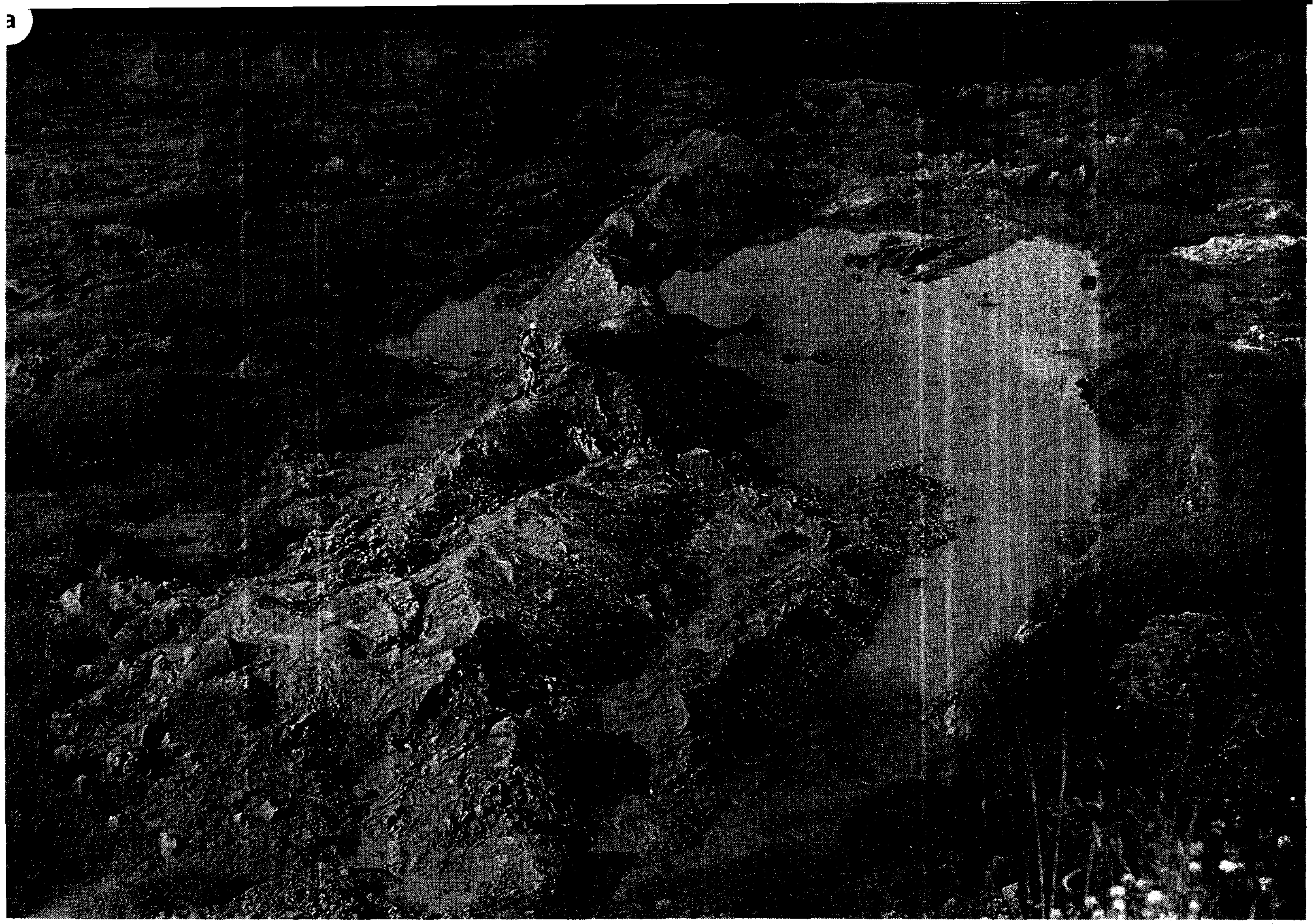
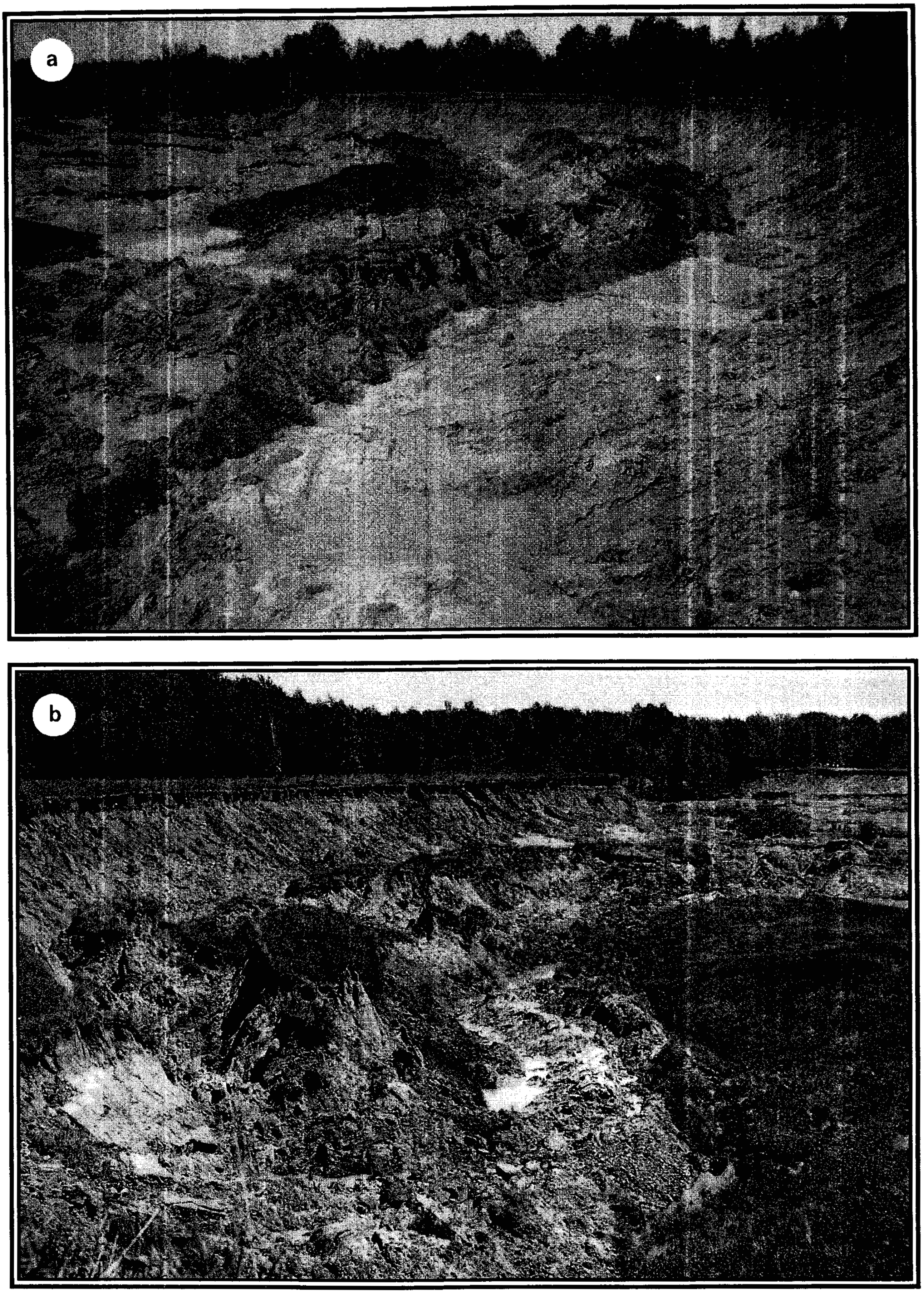


Figure 10. ***a)*** *Sharp-crested ridges and* ***b)*** *prismatic-shaped blocks of intact sediments are prominent features of the spoil particularly within upper part of the crater; note the person for scale. The ridges are composed of horizontal interbeds of clay, silt, and sand which are visible in b). The comparison of the interbeds within the ridges and blocks with the intact deposits of the sidewall suggests that there has been some subsidence as well as translation.*

b

Because of the horizontal nature of the interbeds, these ridges cannot be attributed to rotational failure, but rather to the lateral translation and differential subsidence of the blocks (see Carson, 1977). Between the sharp-crested ridges, the spoil generally consists of disturbed blocks and remolded sediments with the more disrupted and tilted blocks showing evidence of sliding along the interbeds. GSC 1993-295C; GSC 1993-295D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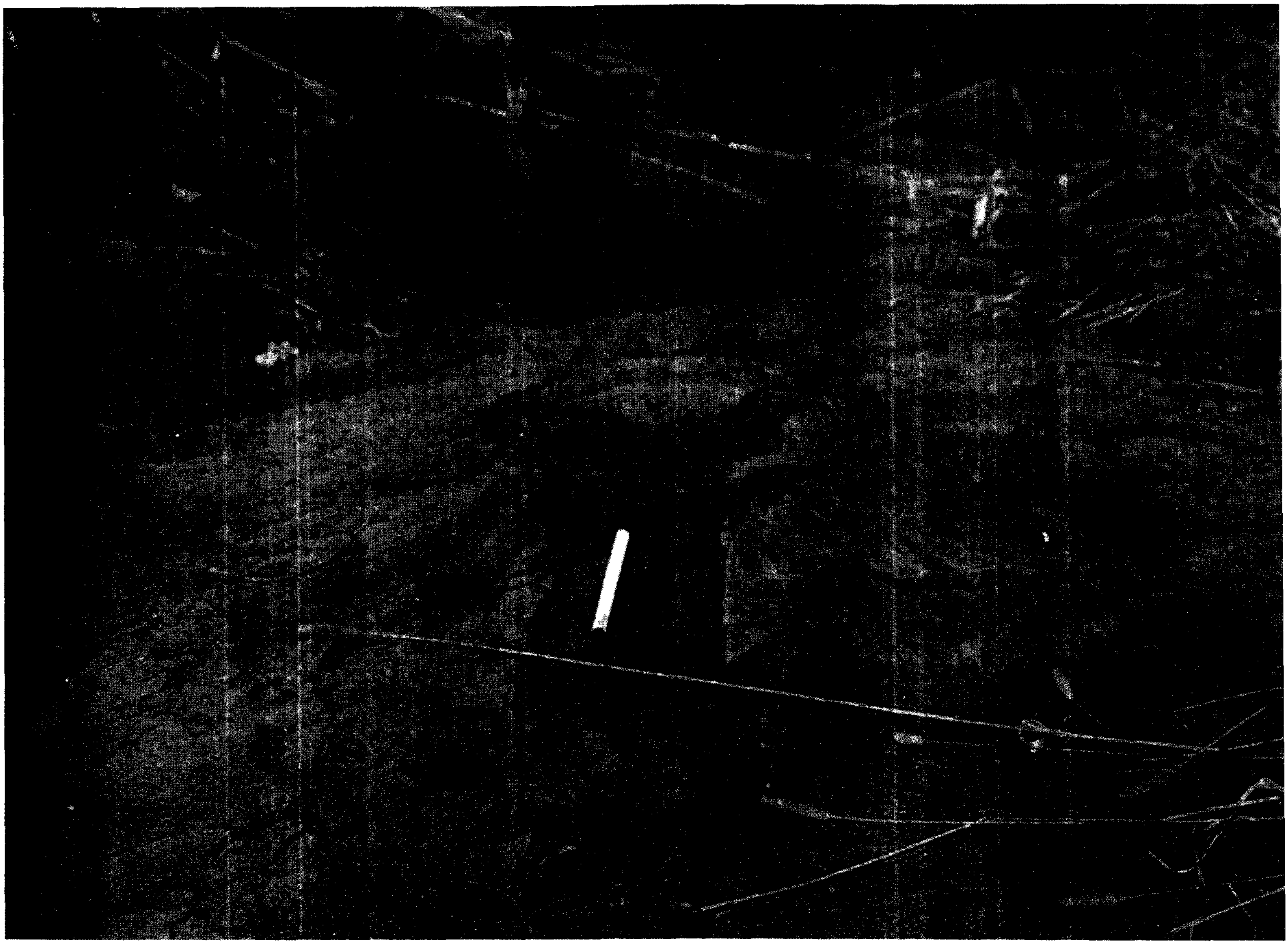

***Figure 12.** In the weeks and months following the landslide, settling of the spoil caused dewatering which produced small mud 'volcanoes' on the surface of the lower part of the crater. GSC 1993-295G*

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***Figure 11. a)** The final stages of failure along the embayment on the north side of the crater occurred as rotational failures rather than subsidence and translation as on the south side. Two rotated blocks are visible in this photograph; their surfaces dip towards the sidewall. Also visible in the photograph at the base of the sidewall are micro-alluvial fans formed by seepage which carried sand and silt from the crater side. Similar fans are common at the base of the sidewall all along the crater margin. GSC 1993-295E **b)** The stiff cap (sod, sand, and silt) of the last rotational block has fractured and some pieces have rotated forward. Grey silty clay was pushed out in front of the last rotational block, lifting the sod of an earlier block. GSC 1993-295F*

Acknowledgments

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