U. S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

PHOTOGRAPHS OF THE 1989-90 ERUPTIONS OF REDOUBT VOLCANO, ALASKA

by

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INTRODUCTION

This collection of photographs chronicles the 1989-90 eruptions of Redoubt Volcano and illustrates phenomena related to explosive volcanism and associated hazards. Underlined terms are explained in the glossary at the conclusion of the captions. Many of these photographs are also available on the Internet at the Alaska Volcano Observatory home page: http://www.avo.alaska.edu.

Redoubt is a glaciated, active stratovolcano located in Lake Clark National Park and Preserve 170 km (105 miles) southwest of Anchorage, Alaska's largest city and an important transportation hub in the North Pacific (Fig.1). Redoubt is one of about 40 active volcanoes in the Aleutian volcanic arc which stretches some 2,500 km (1550 mi) across the north Pacific.

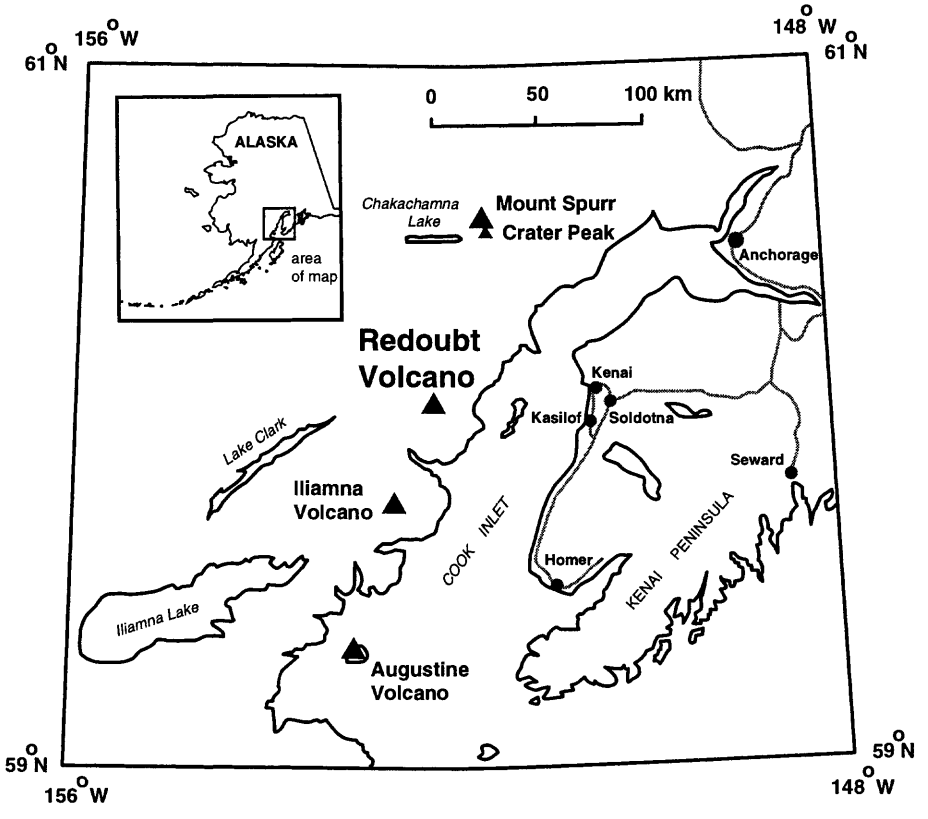


Figure 1. Location of Redoubt Volcano in south central Alaska.

The oldest volcanic rocks known to have erupted from Redoubt are 900,000 years in age (Till and others, 1994). Andesite tephras and pyroclastic deposits are the dominant products from eruptions of the volcano during the last 10,000 years (Riehle, 1985; Till and others, 1994). Two historic eruptions, one in 1902 and another during 1966-1968, occurred prior to the 1989-1990 eruption of Redoubt Volcano.

The 1989-90 eruption is described in detail by Brantley (1990) and Miller and Chouet (1994). To briefly summarize, on December 13, 1989, following a dramatic increase in earthquake activity at Redoubt Volcano, the Alaska Volcano Observatory

issued a warning of the increased likelihood of an eruption. The following day, an explosive eruption sent a column of ash and gas more than 10 km (6 mi) into the atmosphere. Over the next two days, additional explosive eruptions spread ash to the northeast, disrupting airline traffic and other activity throughout south central Alaska. By December 16, the eruption had steadied to a continuous, low-level ejection of ash and steam.

On December 21, 1989, the continuous ash eruption at Redoubt ceased and a large lava dome began to grow in the summit crater. The explosive collapse of this lava dome on January 2, 1990 generated an eruption column with accompanying pyroclastic flows and lahars. A similar cycle of dome emplacement and destruction was repeated twelve more times in the following months until the final lava dome was emplaced on April 21, 1990 (Brantley, 1990; Miller and Chouet, 1994).

The Alaska Volcano Observatory (AVO), a cooperative effort involving the U. S. Geological Survey, the University of Alaska Fairbanks, Geophysical Institute and the Alaska Division of Geological and Geophysical Surveys, is the principal organization responsible for volcanic hazards assessment, eruption notification and monitoring in Alaska. As part of its program, AVO maintains a seismic network at Redoubt and other active Alaskan volcanoes (Wright and Pierson, 1992). Emergency notifications and timely written information releases from AVO transmitt critical hazards information to appropriate federal, state, and municipal agencies as well as other vulnerable parties.

SLIDE CAPTIONS

1. View to the south of Redoubt Volcano, one of the most active volcanoes of the Cook Inlet region in Alaska. The volcano is built upon granite at 1,200-1,500m (4,000-5,000 feet) elevation and rises to 3,108 m (10,197 ft) above sea level. The breached summit crater is drained by Drift glacier, which empties into the Drift River valley forming a piedmont lobe. The topography of the summit crater channeled eruptive material down the Drift River Valley during the 1989 to 1990 eruptions. Further, the interaction of hot pyroclastic materials with glacial ice and snow caused dramatic floods (lahars) and created unusual rock and ice deposits. Photograph by A. Till, U.S. Geological Survey, September 1, 1980.

2. This aerial view, looking southeast, of the summit of Redoubt Volcano was taken just prior to the onset of the 1989 to 1990 eruptions. Melting of the summit crater ice cap caused by heat from rising magma produced a vigorous steam plume. The steam was first noticed by passing pilots on November 20th, 1989 and was visible in Anchorage by December 8th, 1989. Photograph by H. Twitchell, National Park Service, December 14, 1989.

3. On December 14, 1989, Redoubt Volcano erupted sending an eruption column over 10 km (6 mi) into the air. For the next five days, eruptive activity consisted of a series of ash and steam eruptions which eventually settled into a continuous, low-level eruption. This view, looking north, shows a continuous, low-level eruption of steam and ash from the summit of Redoubt. Photograph by W. White, U.S. Geological Survey, December 18, 1989.

4. Beginning December 21, 1989 and continuing through approximately mid-June, 1990, the eruptive style of Redoubt changed to the repeated growth and destruction of a series of lava domes in the summit crater. The lava domes were composed of a highly viscous lava that accumulated in a rubbly pile. The lava domes grew in size until they became oversteepened and collapsed or were explosively destroyed. The avalanches of debris resulting from these collapses produced pyroclastic flows. This view shows the north face of the second largest lava dome, which was later destroyed during an explosive eruption on February 15, 1990. Photograph by R. McGimsey, U.S. Geological Survey, February 2, 1990.

5. This is an aerial view of the highly irregular, steep north face of the final lava dome of the 1989 to 1990 series of eruptions of Redoubt Volcano. The surface consists of blocks of slightly vesicular to dense andesite lava up to 30 m (100 feet) across. Yellow sulfur deposits are visible on a block of lava at center of view. Photograph by C. Neal, U.S. Geological Survey, July 17, 1990.

6. The destruction of a lava dome often results in the generation of pyroclastic flows: hot avalanches of rock and debris. In this view, geologists examine the steaming pyroclastic flow deposits from the March 23, 1990, eruption. The pyroclastic flow came to rest on the margin of the piedmont lobe of Drift glacier. The heat from the deposits melted the underlying glacial ice, generating the steam. Darker patches on the surface are wet areas resulting from this melting. The collapse pits seen here resulted from the funneling of debris into crevasses and holes in the buried surface of the glacier. Photograph by R. McGimsey, U.S. Geological Survey, March 23, 1990.

7. In this view, a geologist examines a thick sequence of 1990 pyroclastic-flow and pyroclastic-surge deposits on the surface of the piedmont lobe of Drift glacier at Redoubt Volcano. Photograph by C. Gardner, U.S. Geological Survey, July 20, 1991.

8. Pyroclastic-flow deposits from the April 15 (lower two thirds of section) and April 21 (upper one third of section), 1990 eruptions of Redoubt Volcano exposed in a gully along the western margin of the piedmont lobe of Drift glacier. The shovel at the base of section shows scale. This material was deposited from hot avalanches of ash and larger rock fragments that raced at high velocity down the canyon on the north side of Redoubt Volcano. The avalanches were initated by sudden failure of the oversteepened front of a lava dome growing in the summit crater of the volcano. Photograph by C. Neal, U.S. Geological Survey, June 7, 1990.

9. Ascending eruption cloud from Redoubt Volcano as viewed to the west from the Kenai Peninsula. The mushroom-shaped plume rose from pyroclastic flows that cascaded down the north flank of the volcano. A smaller, white steam plume rises from the summit crater . As the ash in the eruption cloud was carried downwind, it cooled and fell to the earth - up to 200 km (125 miles) from the volcano. Repeated eruption clouds which formed in this manner distributed ash over much of south-central Alaska. Photograph by R. Clucas, April 21, 1990.

10. Tephra-fall deposits from some of the larger eruptions of Redoubt Volcano between December 15, 1989 and April 21, 1990. An 8 cm (3 in) - thick layer of gravel-sized pumice and lithic lapilli from the December 15, 1989 eruption lies above the dark vegetation mat. This is overlain by about 8 cm (3 in) of coarse ash from several subsequent eruptions in 1990. The ruler, 15 cm (6 in) long, shows scale. This site is located about 10 km (6 mi) from Redoubt Volcano. Photograph by R. McGimsey, U.S. Geological Survey, August 20, 1990.

11. The 1989 to 1990 eruptions of Redoubt Volcano were characterized by repeated growth and destruction of lava domes in the summit crater. Avalanching of hot debris from disintegrating lava domes caused extensive melting of the glacier draining the summit crater and produced deeply incised channels with steep ice walls. View is to the north. Photograph by T. Miller, U.S. Geological Survey, April 7, 1990.

12. Lahars formed during the 1989 to 1990 eruptions of Redoubt Volcano accumulated in the Drift River valley. A lahar is a mixture of water with loose pyroclastic material. The water in lahars is often derived from the melting of glaciers and/or snow. Depending on the amount of solid material they contain, they may flow with the consistency of cement. Lahars have the potential to be extremely destructive as they can travel great distances down-valley from the volcano. The largest lahars, such as this one from the February 15, 1990 eruption, covered the valley floor nearly wall to wall and extended more than 35 km (22 mi) to the Cook Inlet. View is to the west. Photograph by T. Miller, U.S. Geological Survey, February 15, 1990.

13. One of the principal facilities at risk during the 1989 to 1990 eruptions of Redoubt Volcano was the Drift River Oil Terminal located at the mouth of the Drift River, 35 km (22 mi) northeast of the volcano. The February 15, 1990 eruption of Redoubt Volcano produced a lahar that overtopped the containment berm at the Drift River Oil Terminal but did not damage the storage tanks. Photograph by T. Miller, U.S. Geological Survey, February 15, 1990.

14. Large blocks of glacial ice were carried many kilometers downstream by lahars during the 1989 to 1990 eruptions of Redoubt Volcano. Photograph by T. Miller, U.S. Geological Survey, January 5, 1990.

15. This aerial view, looking southwest, shows the Drift River valley following the 1989 to 1990 eruptions of Redoubt Volcano. Two bedrock islands (informally called the "Dumbbell

Hills") are visible at bottom center. Lahar deposits cover the valley floor. Photograph by C. Gardner, U.S. Geological Survey, June 28, 1990.

16. Where exposed by subsequent stream downcutting, lahar deposits from the 1989 to 1990 eruptions of Redoubt Volcano consisted of layers of sand- to boulder-sized debris. This section was exposed in the Drift River valley. The large volume of material deposited by lahars significantly changed the channel geometry of streams in the Drift River Valley. Photograph by R. McGimsey, U.S. Geological Survey, June 15, 1990.

17. Lahars from the 1989 to 1990 eruptions of Redoubt Volcano inundated this structure near the mouth of Drift River, 35 km (22 mi) from the volcano. This dramatic view illustrates the potential dangers posed by lahars to inhabitants near some volcanoes. Photograph by C. Gardner, U.S. Geological Survey, June 1, 1990.

18. Geologists view an unusual flowing mixture of water and ice in the upper Drift River. The flow was produced by a sudden release of impounded water from the upper reaches of the Drift River canyon which drains the summit crater of Redoubt Volcano. Photograph by R. McGimsey, U.S. Geological Survey, March 15, 1990.

19. During the eruption of Redoubt Volcano on December 15, 1989), hot ejecta falling onto the upper flanks of the volcano produced avalanches of snow, ice, meltwater, and pyroclastic debris to form an unusual ice-rock diamict. In this view, the diamict is approximately 4.5-m-thick (15 ft) and caps ice of the piedmont lobe of Drift glacier. Overlying the ice-rock diamict are sand to gravel-sized pyroclastic flow deposits from eruptions between January and March of 1990. Photograph by C. Gardner, U.S. Geological Survey, May 19, 1990.

20. The final lava dome of the 1989 to 1990 series of eruptions of Redoubt Volcano was emplaced in the summit crater by summer, 1990. It measures approximately 350 to 400 m (980 to 1,300 ft) across and represents an estimated 10 million cubic meters (353 million cubic feet) of material. Photograph by C. Neal, U.S. Geological Survey, July 17, 1990.

REFERENCES

Brantley, S., editor, 1990, The eruption of Redoubt Volcano, Alaska, December 14, 1989 - August 31, 1990: U.S. Geological Survey Circular 1061, 33 p.

Miller, T.P., and Chouet, B.A., 1994, The 1989-1990 eruptions of Redoubt Volcano: An introduction: Journal of Volcanology and Geothermal Research, v. 62, p. 1-10.

Riehle, J.R., 1985, A reconnaissance of the major Holocene tephra deposits in the upper Cook Inlet region, Alaska: Journal of Volcanology and Geothermal Research, v. 26, p. 37-74.

Till, A.B., Yount, M.E., and Bevier, M.L., 1994, The geologic history of Redoubt Volcano, Alaska: Journal of Volcanology and Geothermal Research, v. 62, p. 11-30.

Wright, T.L., and Pierson, T.C., 1992, Living with volcanoes: The U.S. Geological Survey's Volcano Hazards Program: U.S. Geological Survey Circular 1073, 57 p.

GLOSSARY OF UNDERLINED TERMS

ash:
Fine fragments (less than 2 millimeters [1/16 in] across) of *lava* or rock formed in an explosive volcanic eruption.

andesite :
Volcanic rock containing about 52 to 63 percent SiO_2, which is an essential constituent of most minerals found in rocks.

diamict:
A general term for a poorly sorted sedimentary rock or deposit.

eruption cloud :
A cloud of gas and *ash* that forms during an explosive volcanic eruption and is carried away from the volcano with the prevailing wind.

eruption column:
The portion of the *eruption cloud* that rises vertically above a volcanic *vent*.

ejecta:
General term for anything thrown into the air from a volcano during an eruption; synonymous with *pyroclast* which means "fire" and "broken piece."

glacier:
Compacted mass of ice formed from accumulation, compaction, and recrystallization of snow. Often moves downslope under the influence of gravity; glaciers are a powerful erosive agent.

granite:
Coarse-grained igneous rock which cools underground and is rich in SiO_2, an essential constituent of most minerals found in rocks.

juvenile:
Material erupted in a molten state as opposed to accidental, older rock fragments that may be ejected from a volcano.

lahar:
A water-saturated mixture of mud and debris that flows rapidly downslope; often formed when hot volcanic material falls on snow and ice or when rain saturates loose volcanic debris on steep slopes.

lapilli:
Fragments of *lava* or rock between 2 and 64 mm (1/16 and 2.5 in) across ejected during a volcanic eruption.

lava:
Molten rock that reaches the Earth's surface.

lava dome:
A steep-sided mass of viscous and often blocky *lava* extruded from a *vent;* typically has a rounded top and roughly circular outline.

lithic:
Synonym for "rock"; in volcanic deposits, it refers to fragments of preexisting rock as opposed to newly erupted *juvenile* material.

magma:
Molten rock beneath the Earth's surface; molten rock that erupts onto the earth's surface is called *lava.*

piedmont lobe:
In referring to *glaciers*, a piedmont lobe occurs where a *glacier* emerges from a valley at the base of a mountain and, no longer constricted, spreads out into a fan.

pumice:
Highly *vesicular* volcanic *ejecta.* It is often buoyant enough to float on water.

pyroclastic:
A general term applied to volcanic products or processes that involve explosive ejection and fragmentation of erupting material.

pyroclastic flow:
A dense, hot, and chaotic avalanche of rock fragments, gas, and *ash* that travels rapidly down the flanks of a volcano.

pyroclastic surge:
A dilute, rapidly moving, hot cloud of rock fragments, gas, and *ash* that travels above the ground away from an explosive eruption.

stratovolcano:
A steep-sided volcano, (also called a *stratocone* or *composite cone*) usually conical in shape, built of *lava* flows and *tephra* from explosive eruptions.

tephra:
A general term for all fragmental volcanic material (for example, *ash* and *bombs*.)

vesicular:
The texture of a volcanic rock characterized by abundant holes or cavities that result from escaping gas (*pumice* is very *vesicular*).

OTHER MULTI-MEDIA PRODUCTS OF INTEREST:

PHOTOGRAPHS OF THE 1992 ERUPTIONS OF CRATER PEAK, SPURR VOLCANO, ALASKA, USGS Open-file Report 93-707, 20 slides, 8 p. text and glossary, by Christina A. Neal, Robert G. McGimsey, Michael P. Doukas, and Inyo Ellersieck, 1993. 20-slide set illustrating aspects of the 1992 eruptions. Includes captions and glossary. Available from:

U.S. Geological Survey ESIC-Open-File Report Section
Box 25286, MS 517
Denver, CO 80225-0046
303-236-7476

VIDEO OF THE AUGUST 18,1992, ERUPTION OF CRATER PEAK VENT ON SPURR VOLCANO, ALASKA", by Robert G. McGimsey and Joseph M. Dorava, 1994, USGS Open-File Report 94-614. This 25-minute, narrated video presents dramatic scenes of the second of three 1992 eruptions of Crater Peak, a satellite vent on Spurr volcano, Alaska. Favorable weather conditions permitted scientists from the Alaska Volcano Observatory to photograph the eruption from a fixed-wing aircraft flying as close as 2 km to the vent. The video includes close-up views of the roiling, 18-kilometer-high eruption column, shockwaves emanating from the column base, ash clouds from pyroclastic flows on the southeast flank, and ash fallout downwind.

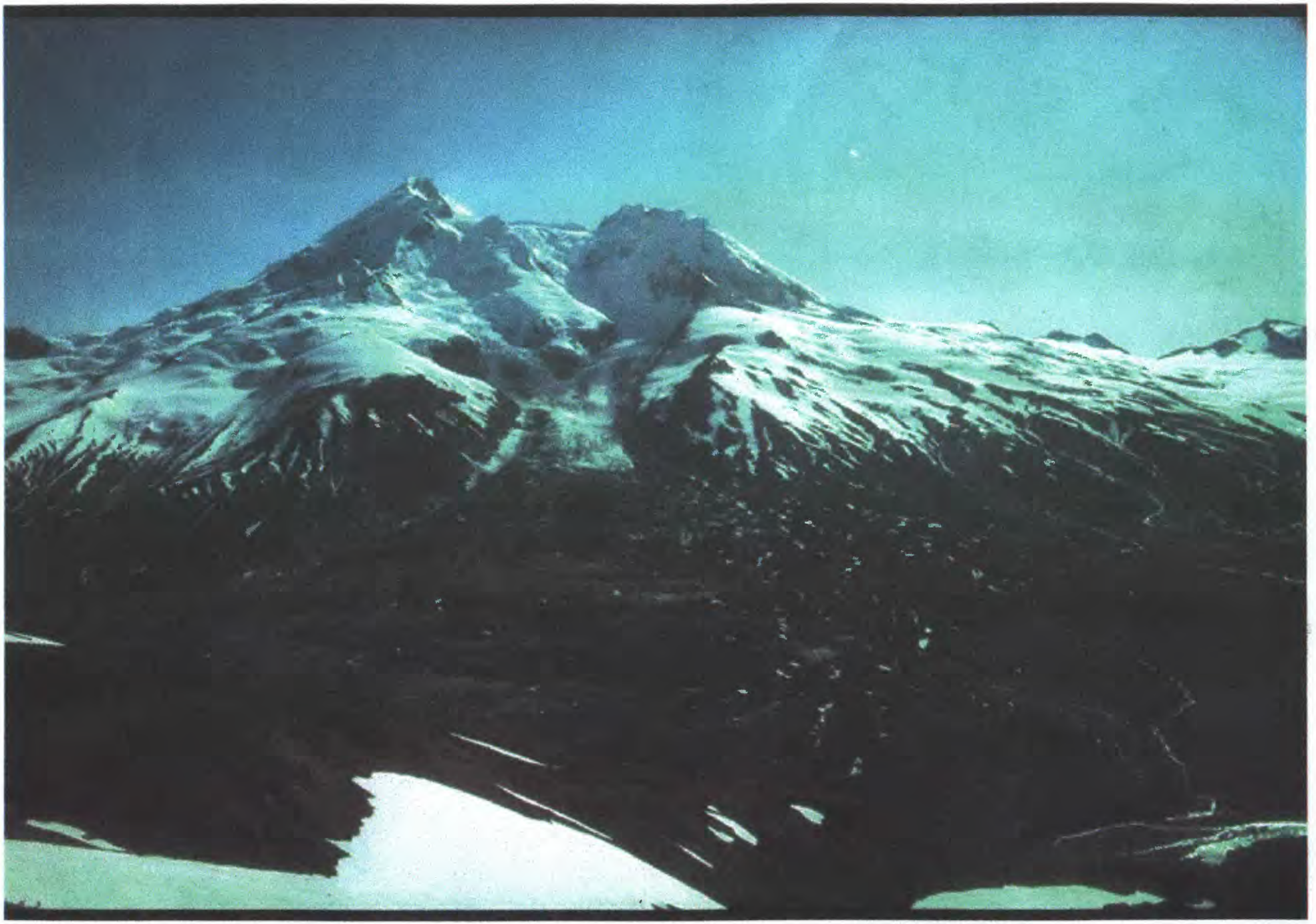
10 YEARS OF VOLCANIC ACTIVITY IN ALASKA: 1983 TO 1992: A VIDEO", by Michael P. Doukas, Robert G. McGimsey, and Joseph M. Dorava, 1995, USGS Open-File Report 95-61. This 28-minute video presents eruption images from eight Alaskan volcanoes during the ten-year period: Veniaminof (1983-84), Augustine (1986), Redoubt (1989-90), Akutan (1991), Bogoslof (1992), Westdahl (1992), Spurr (1992), and Seguam (1992). Classic volcanic phenomena are documented, including meltwater lakes formed when lava flows advanced into an ice-filled caldera (Veniaminof), nighttime views of explosive strombolian activity (Veniaminof), pyroclastic flows descending steep flanks during plinian- and peleean- style eruptions (Augustine), hawaiian-style lava fountaining through glacial ice (Westdahl), island building in the Aleutians (Bogoslof), shock waves and close-up views of a roiling, sub-plinian eruption column rising more than 18 kilometers (Mount Spurr volcano-Crater Peak vent).

The videotapes are available from:

U.S. Geological Survey ESIC-Open-File Report Section
Box 25286, MS 517
Denver, CO 80225-0046
303-236-7476

AND

KAKM Video ATTN: Penny Enders
3877 University Drive
Anchorage, AK 99508
Phone (907) 563-7070
US or Canada 1-800-684-3368
FAX (907) 273-9192
email kakm_video@kakm.pbs.



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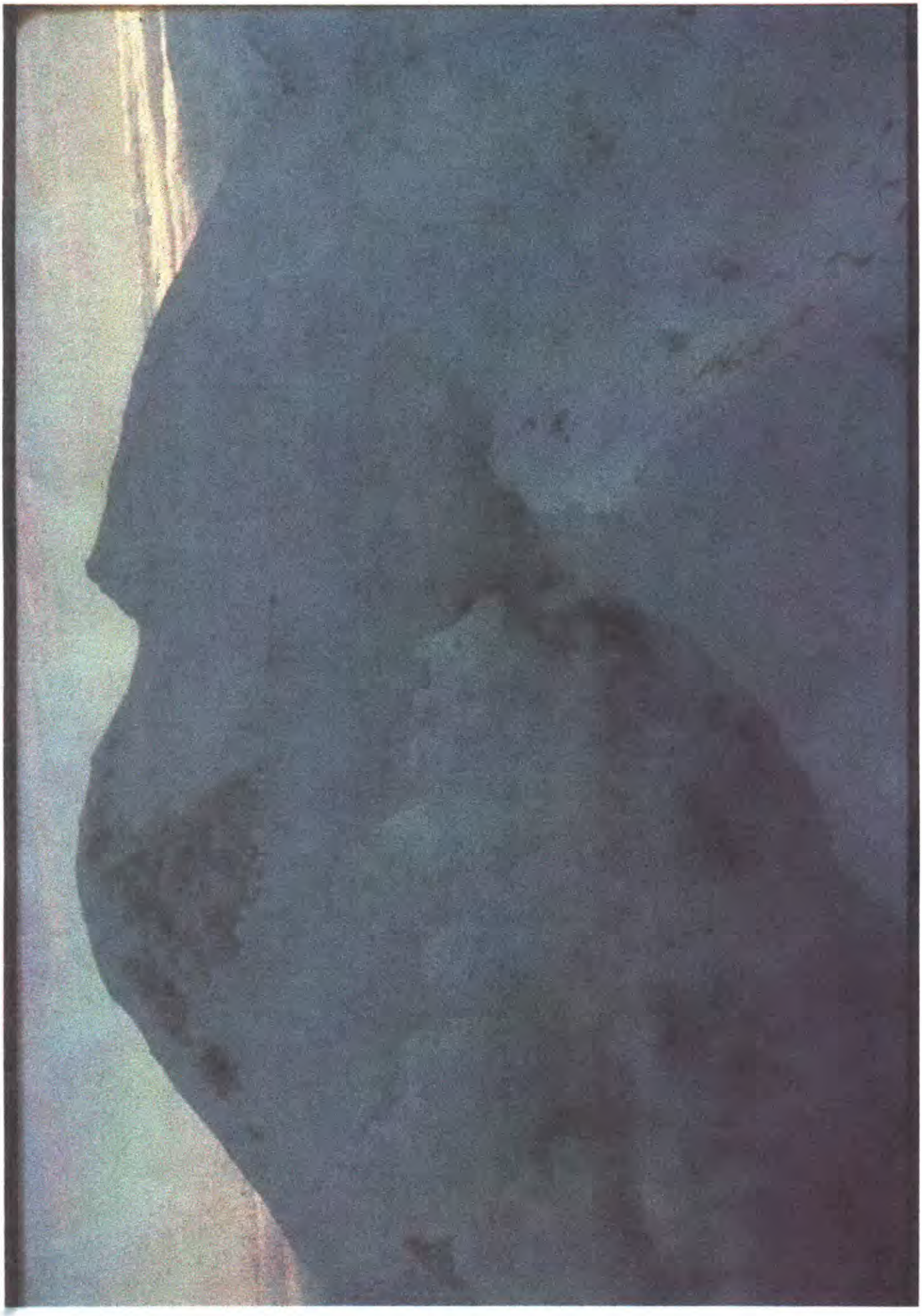

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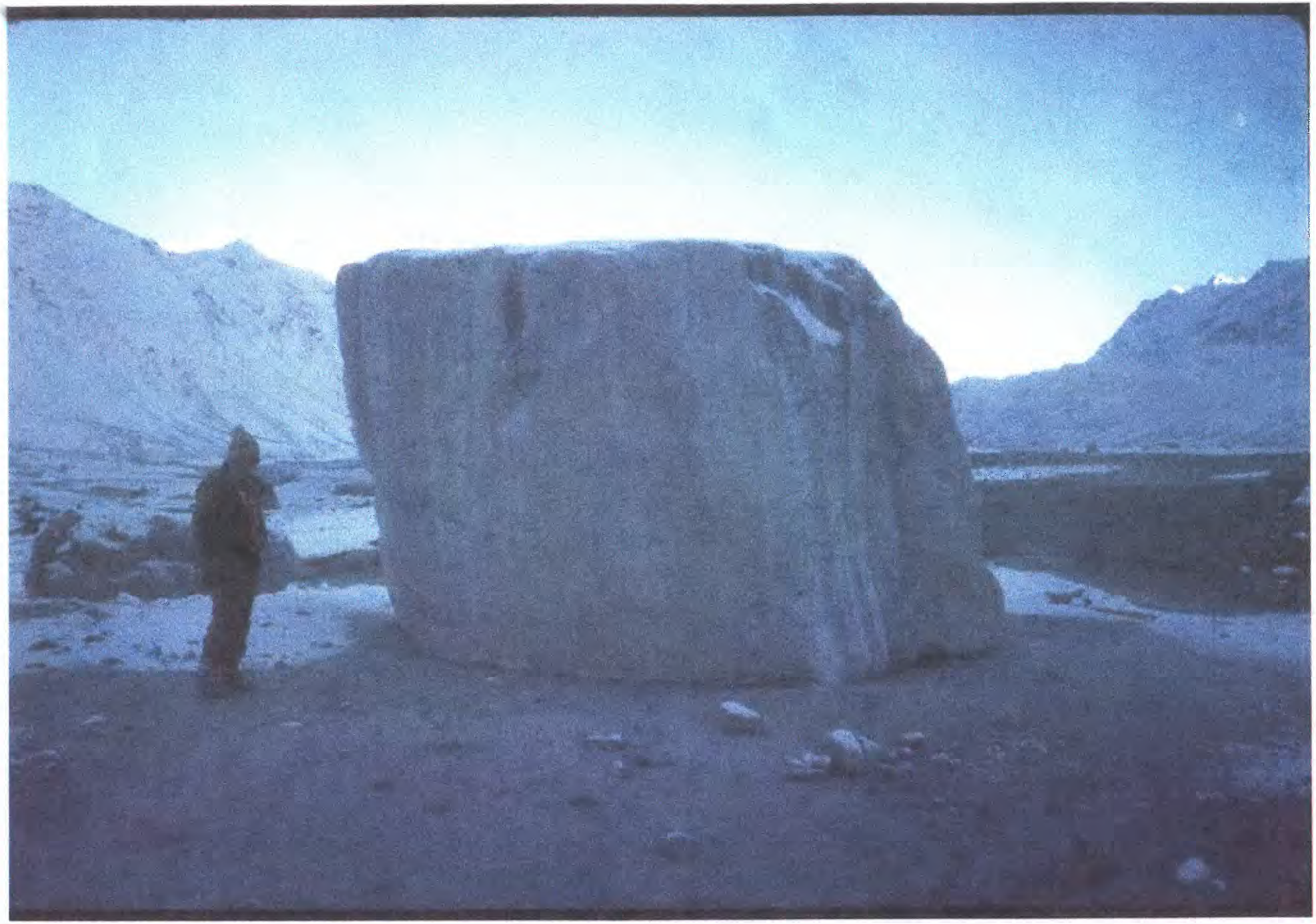

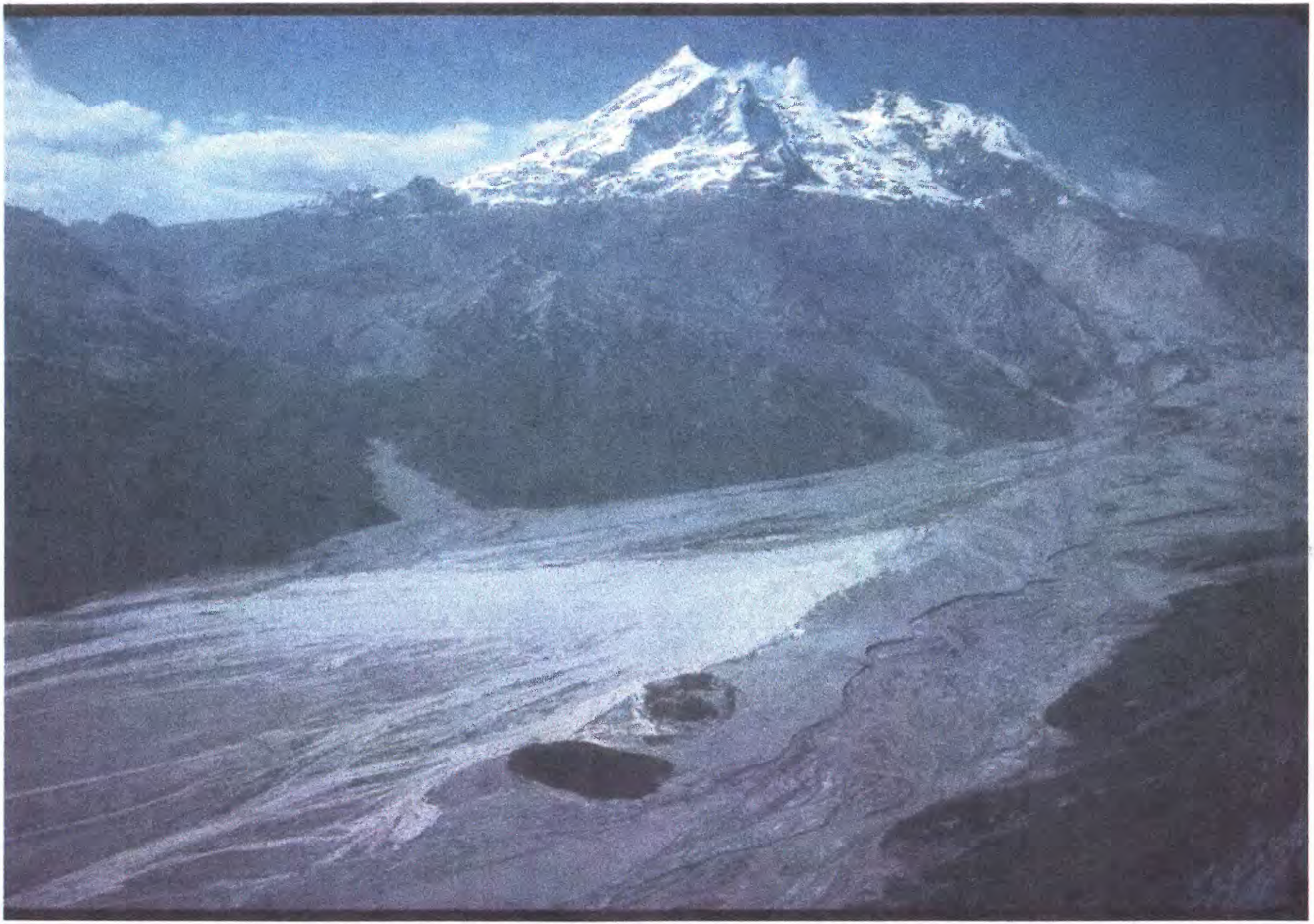

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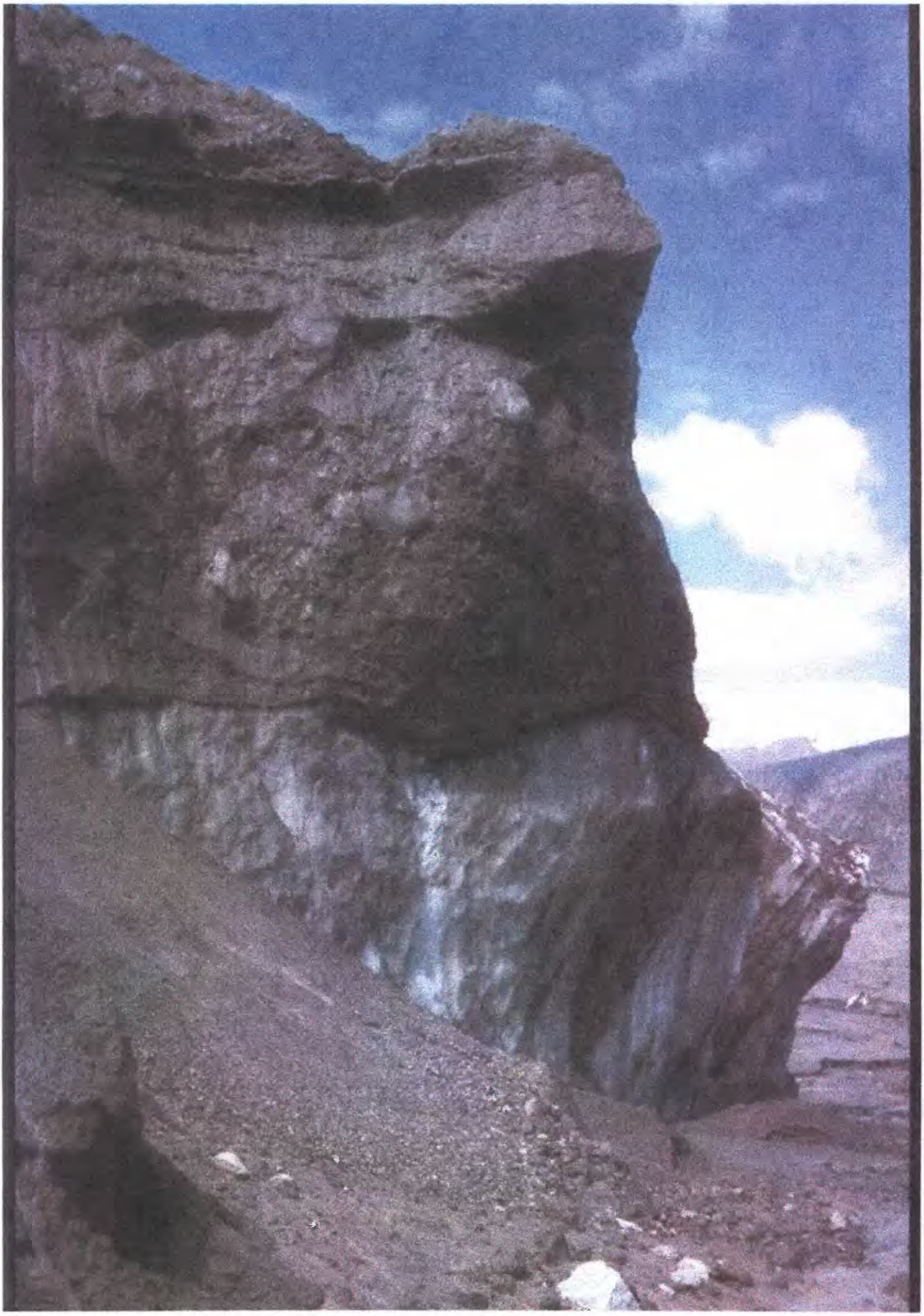


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