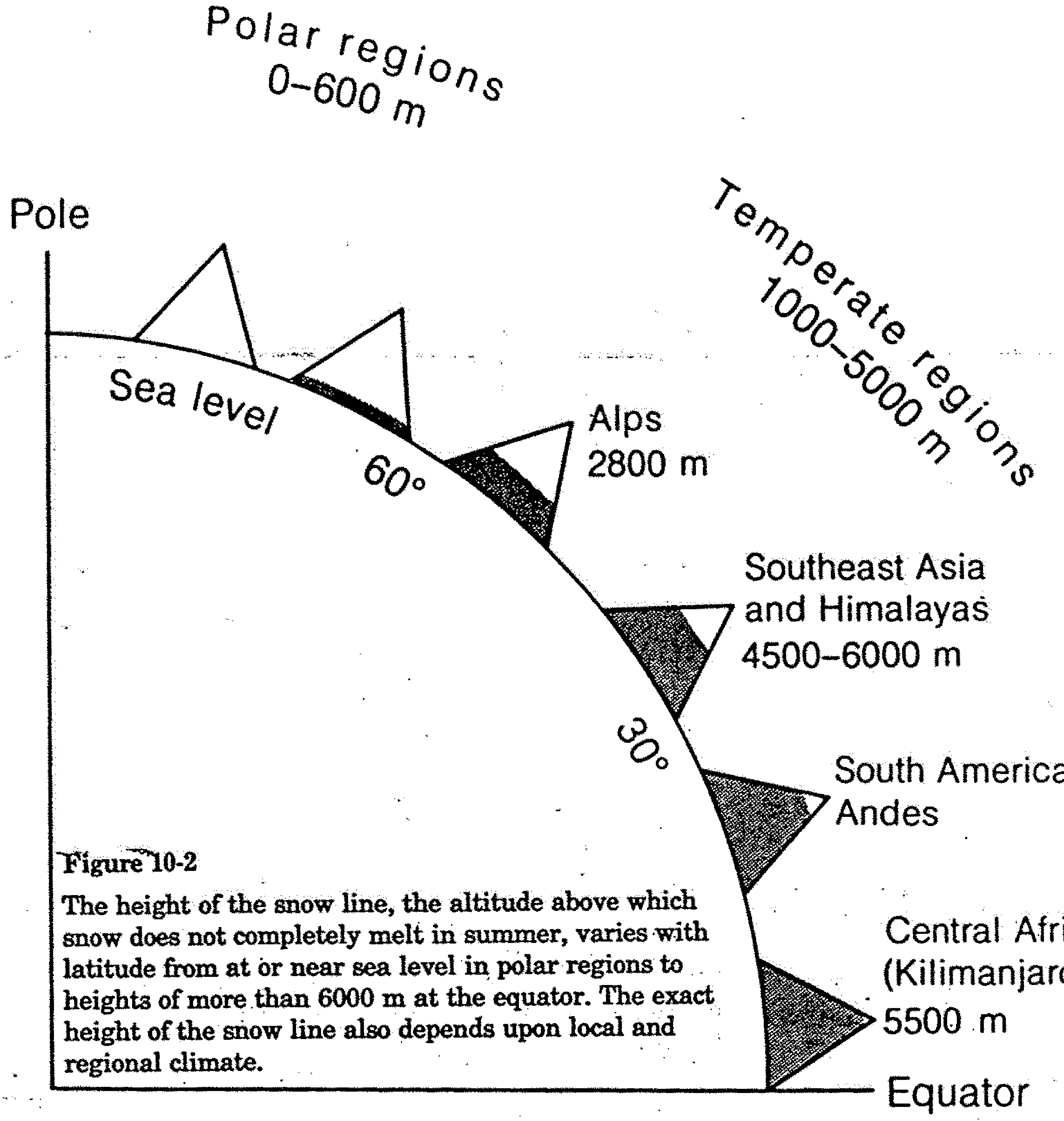


Figure 10-2

The height of the snow line, the altitude above which snow does not completely melt in summer, varies with latitude from at or near sea level in polar regions to heights of more than 6000 m at the equator. The exact height of the snow line also depends upon local and regional climate.

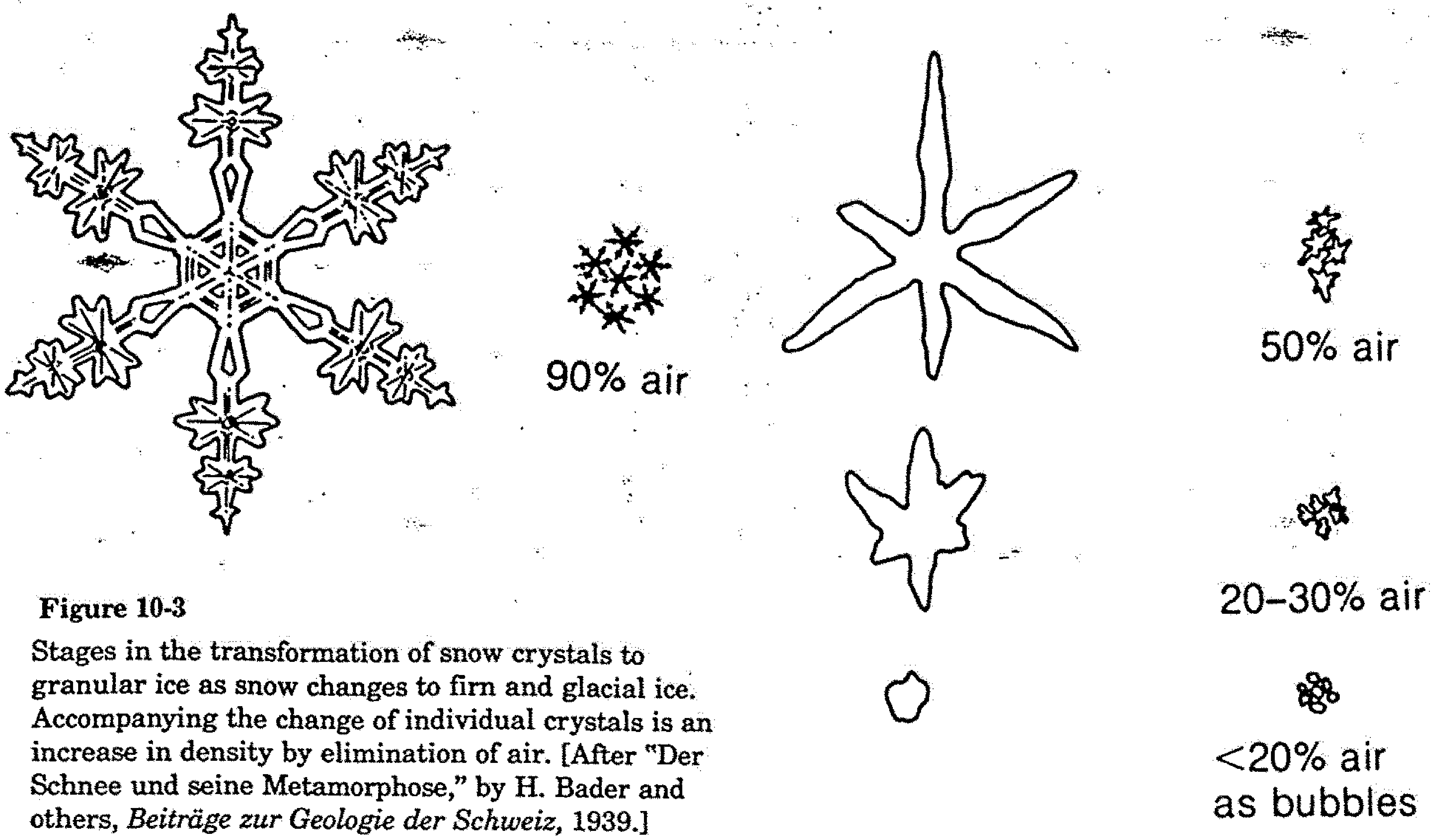
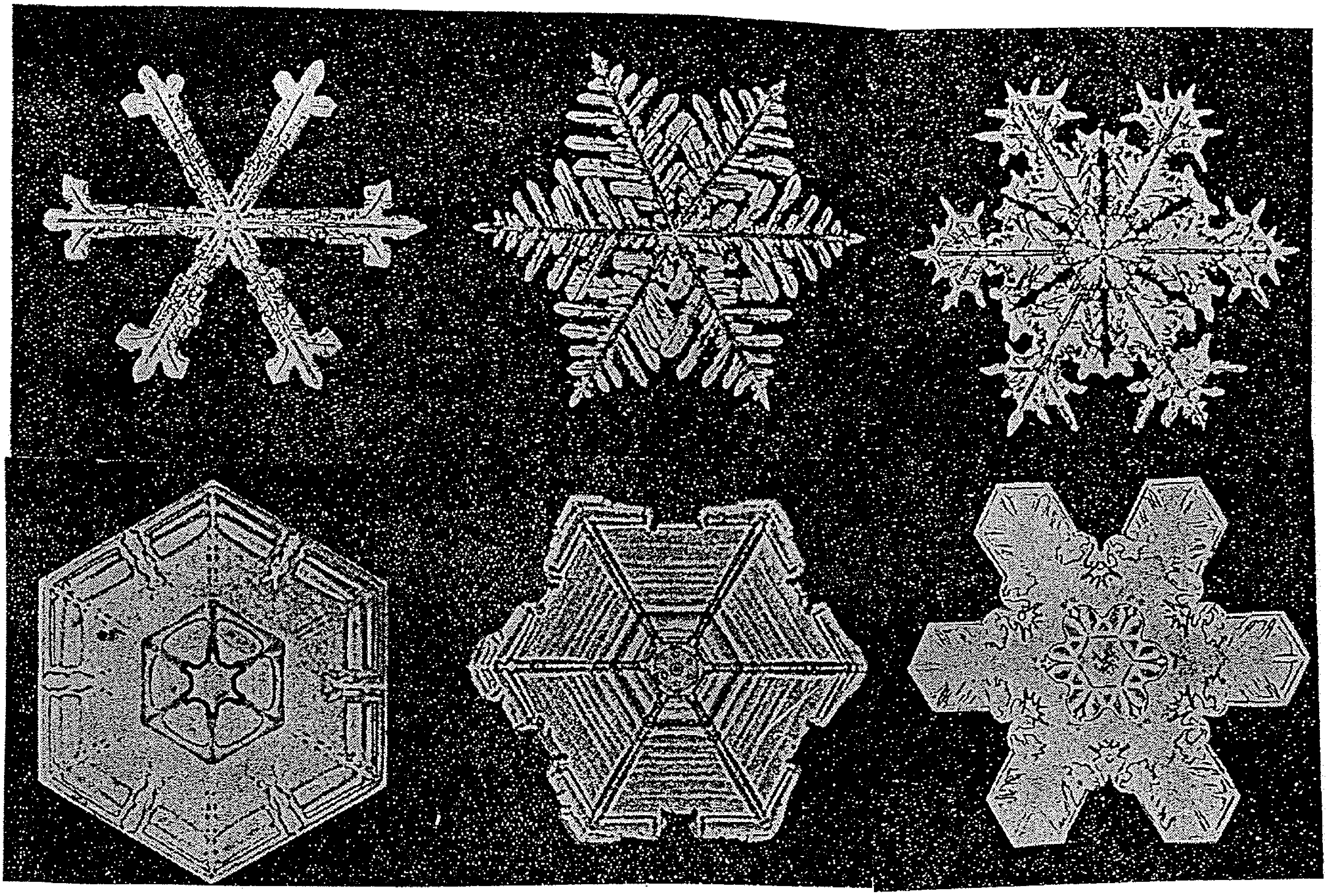


Figure 10-3

Stages in the transformation of snow crystals to granular ice as snow changes to firn and glacial ice. Accompanying the change of individual crystals is an increase in density by elimination of air. [After "Der Schnee und seine Metamorphose," by H. Bader and others, *Beiträge zur Geologie der Schweiz,* 1939.]



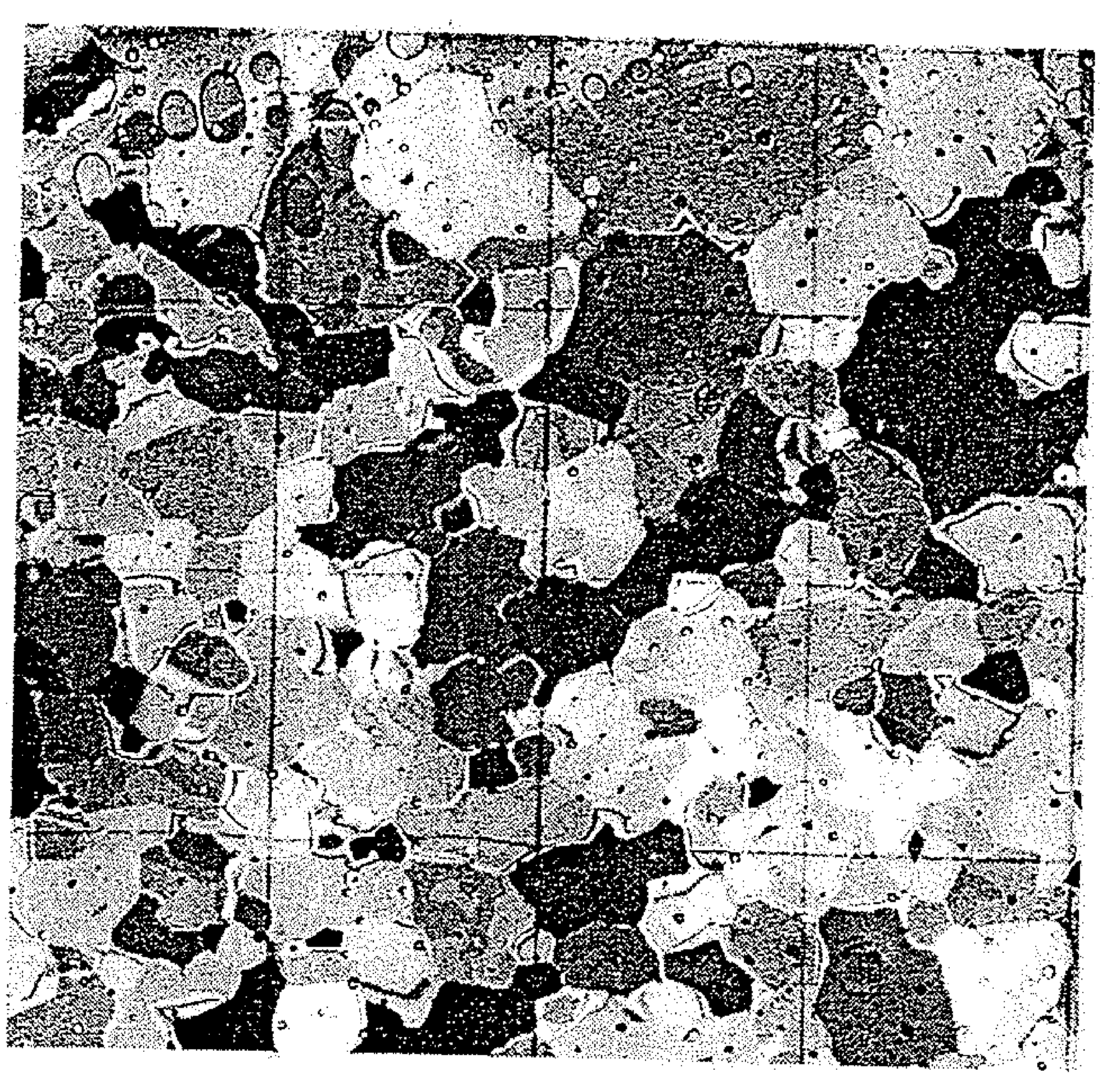


Figure 10-6

Photomicrograph of typical crystalline mosaic of glacier ice. Sample is from the Antarctic ice sheet, depth 193 m, Byrd Station, Antarctica. Each grid measures 1.0 cm. Each small area of uniform white, gray, or black is a single crystal as seen in polarized light. The tiny circular and tubular spots are bubbles of air. Geochemists can analyze these air bubbles to measure the amounts of carbon dioxide and other gases in the atmosphere when the ice formed. [From A. J. Gow, U.S. Army Cold Regions Research and Engineering Laboratory.]

Fig. 275. Photograph of a compound valley glacier fed by many tributary ice streams with moraines. (After Sharp 1960)

Abb. 5. Zernagte Oberfläche tauenden *Firns* am Mount Rainier im Staate Washington (USA). (Nach National Parks Folio.)

Obr. 25. *Kry (séracs) na povrchu ledovce Taschach-Ferner v Oetztálských Alpách v Tyrolsku.* (Foto JUDr FRANT. JAKUBEC.)

15.6 Crevassed surface of the Columbia glacier, Chugach Mountains, Alaska. [Austin Post, University of Washington.]

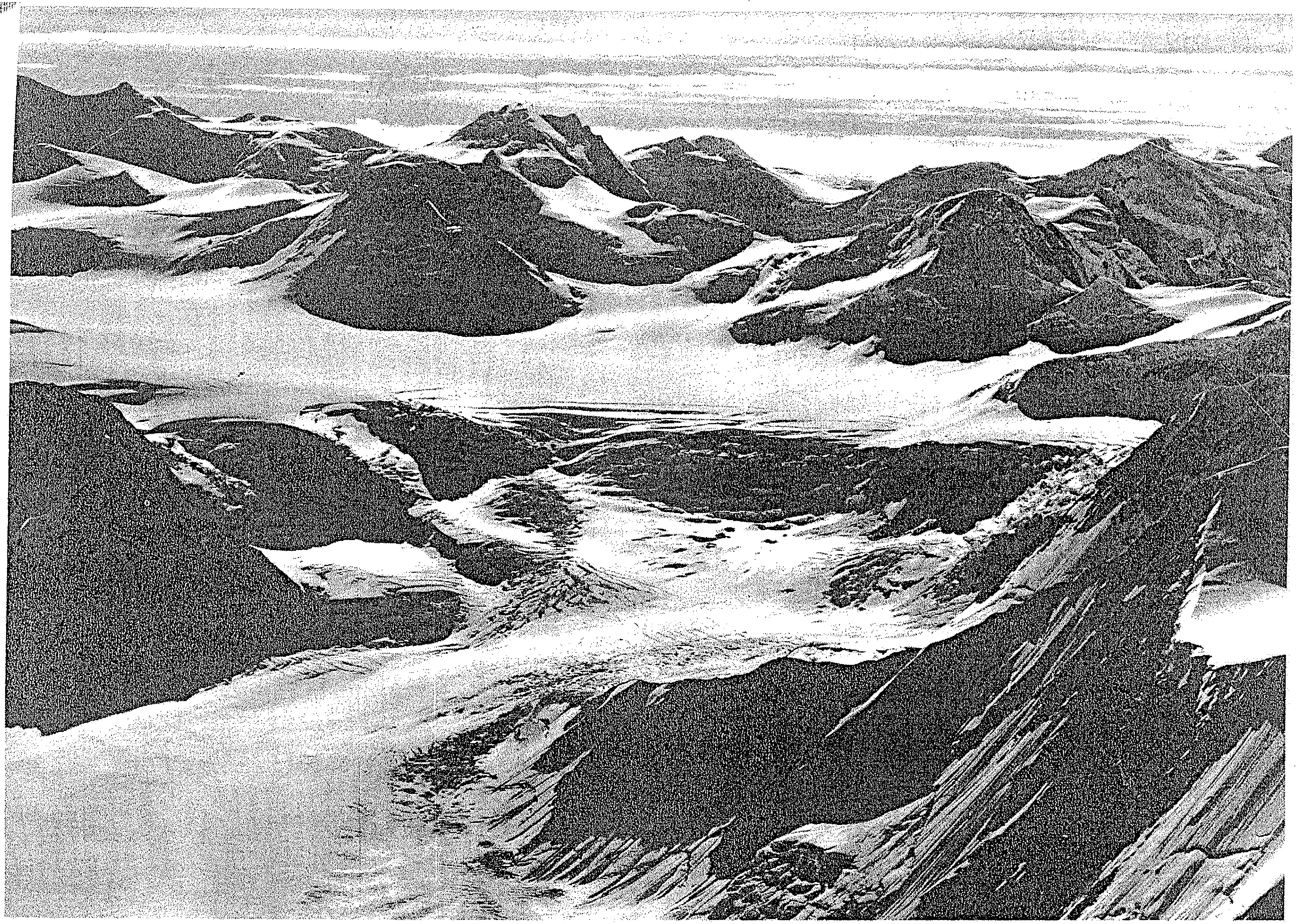
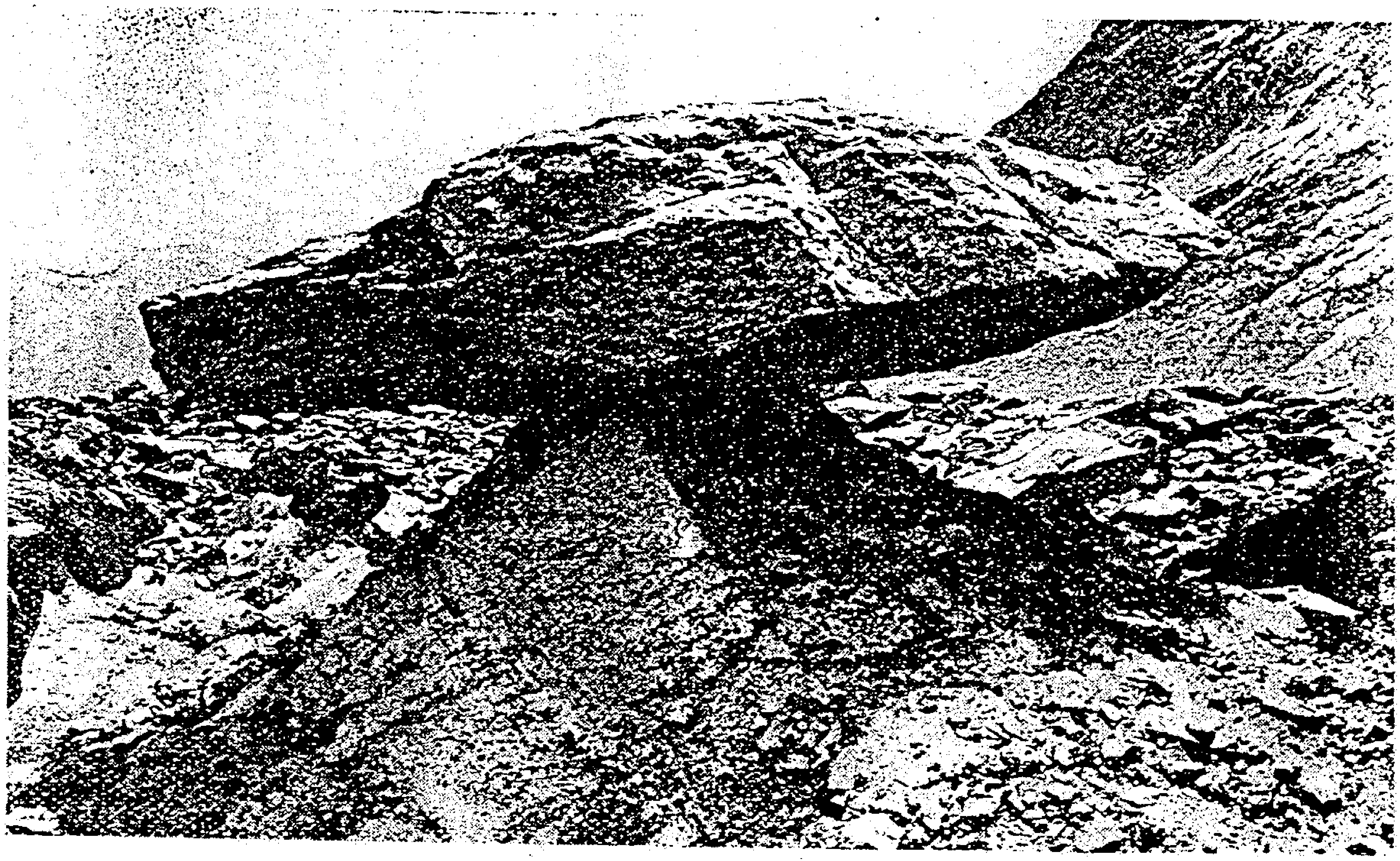
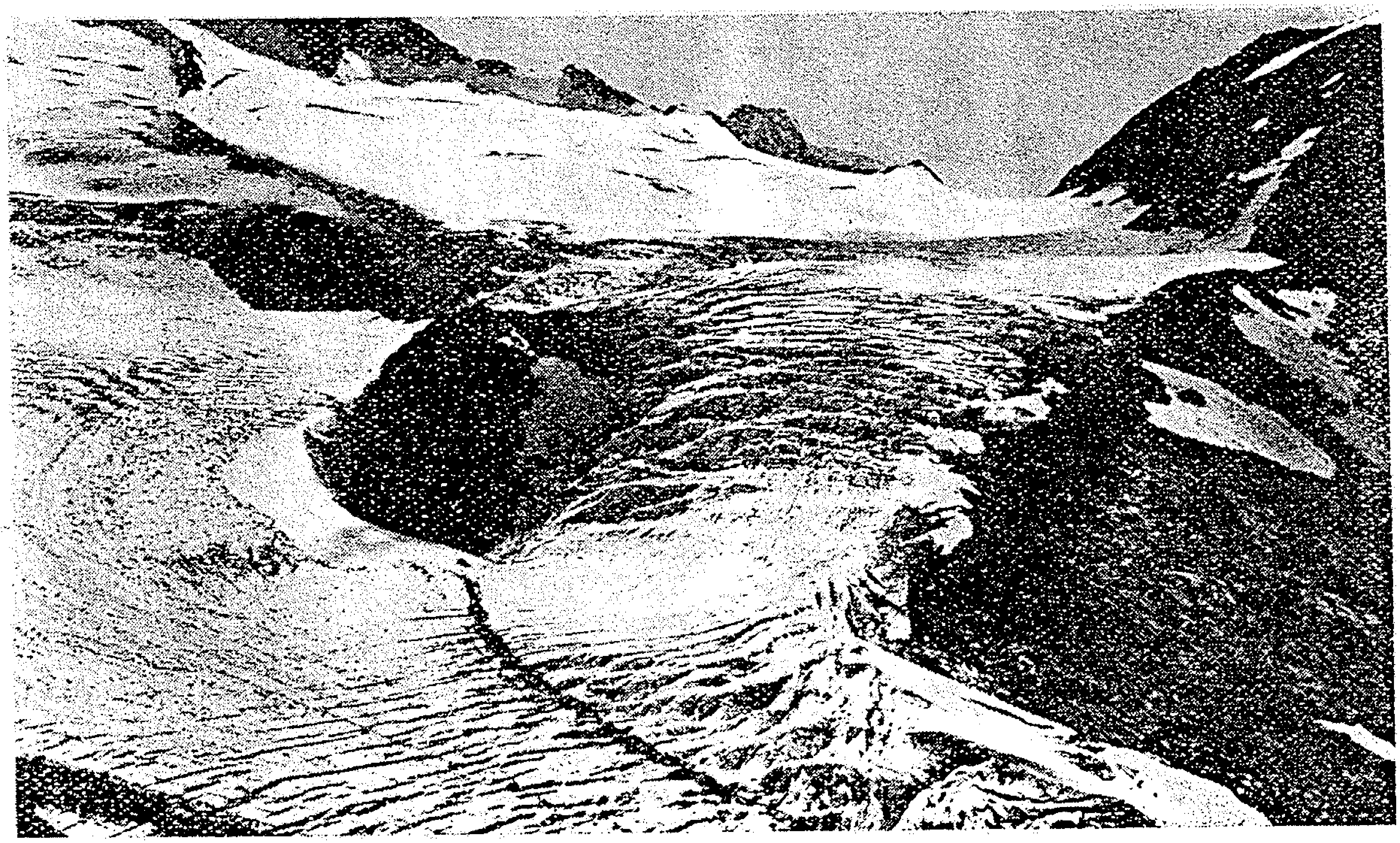


FIGURE 13–2 *Snowfields above the head of a valley glacier in Alaska. Clearest relations are at right foreground and left background: much of the flat in mid-distance is a snowfield, but it merges into moving ice—becoming a glacier below the crevasses that mark the head of a steep slope.*



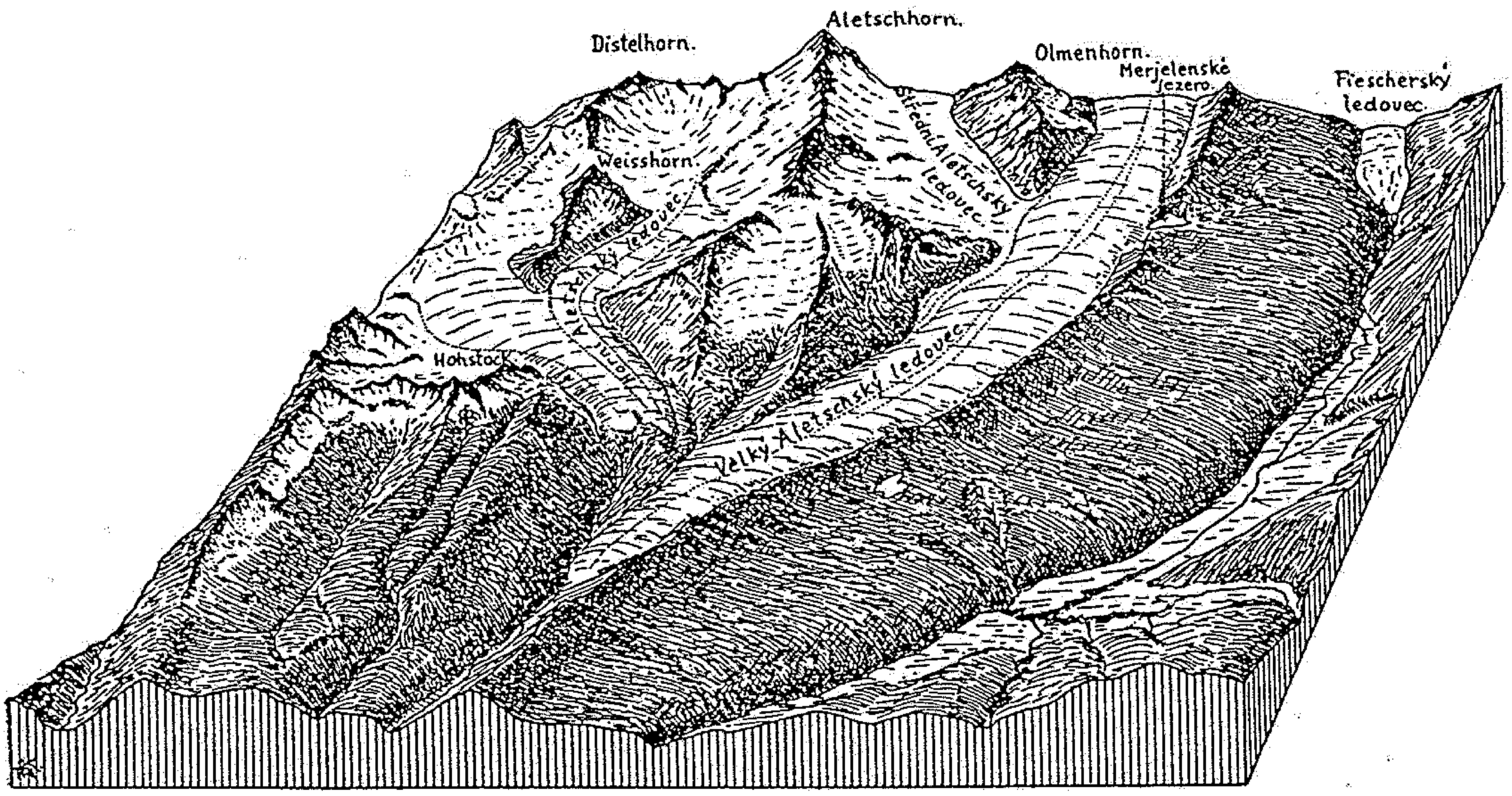
Obr. 68. *Ledovcový stůl.* (Podle LUISE TRENKERA.)



Obr. 66. *Hornosulzbašský ledovec (Ober Sulzbachkees) sestupující do Krimmler Törl v záp. Solnohradsku. Na obrázku je vidět firnoviště, pod ním sestupující splaz roztrhaný v kry a rozdělený malým nunatakem; černé pruhy v přední části splazu jsou střední morény.* (Foto MYLIUS.)

Figure 10-19

Forks of Susitna glacier, Alaska, showing how lateral moraines (dark bands), formed at the valley walls of the tributaries, coalesce to become medial moraines in the merged stream of ice. Irregular distortion and folding of bands reflects differential deformation of ice as it flows. [Photo by B. Washburn.]



Obr. 7. *Blokdiagram Aletschského ledovce v Bernských Alpách.* (Podle A. K. LOBECKA.)

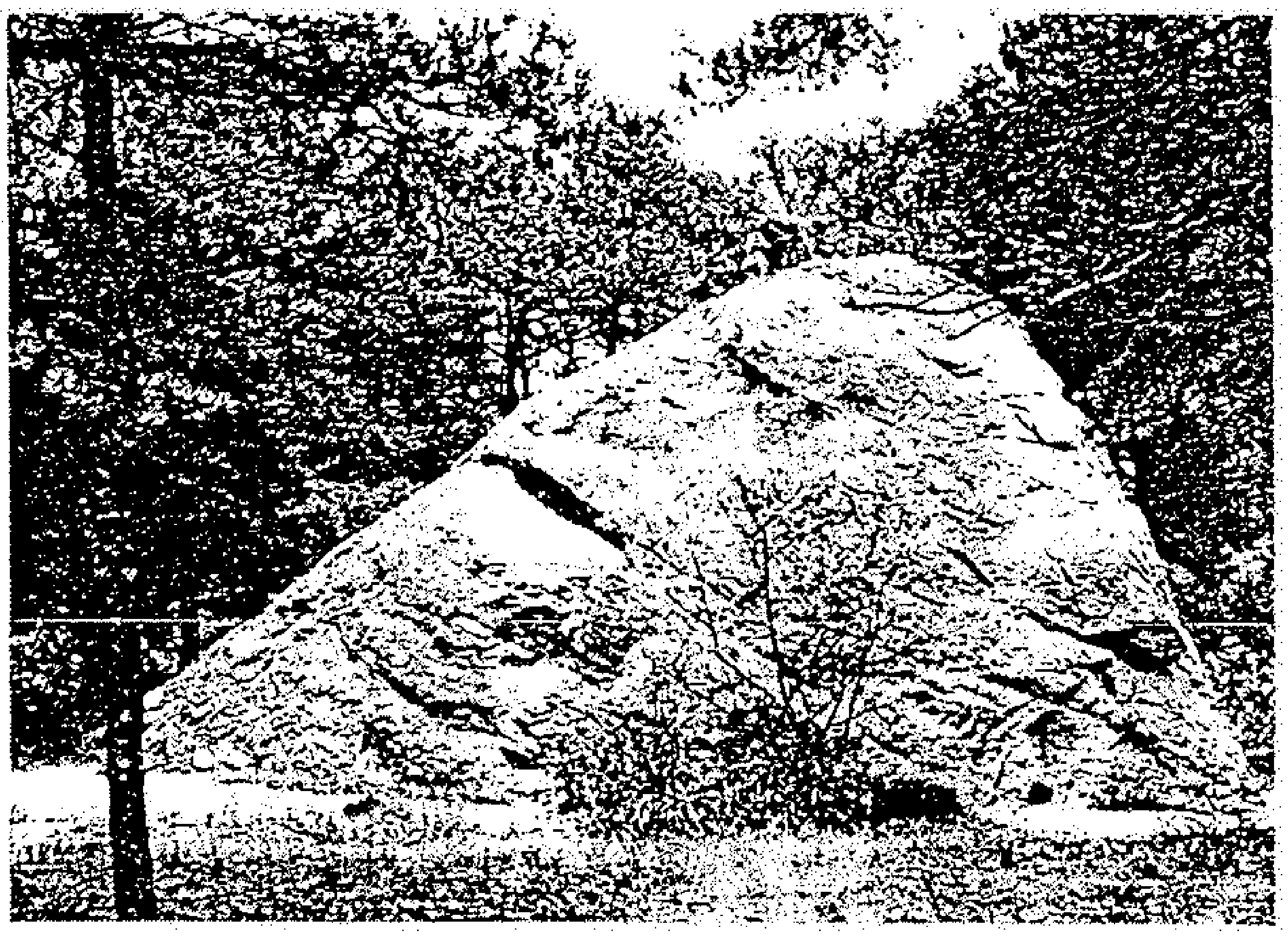


Figure 10-17

A huge erratic boulder carried to Cape Cod during the Pleistocene glaciation. The boulder is a metamorphic rock type typical of areas in southern New Hampshire, 150 km to the northwest. Doan Rock, Eastham, Massachusetts. [Photo by R. Siever.]

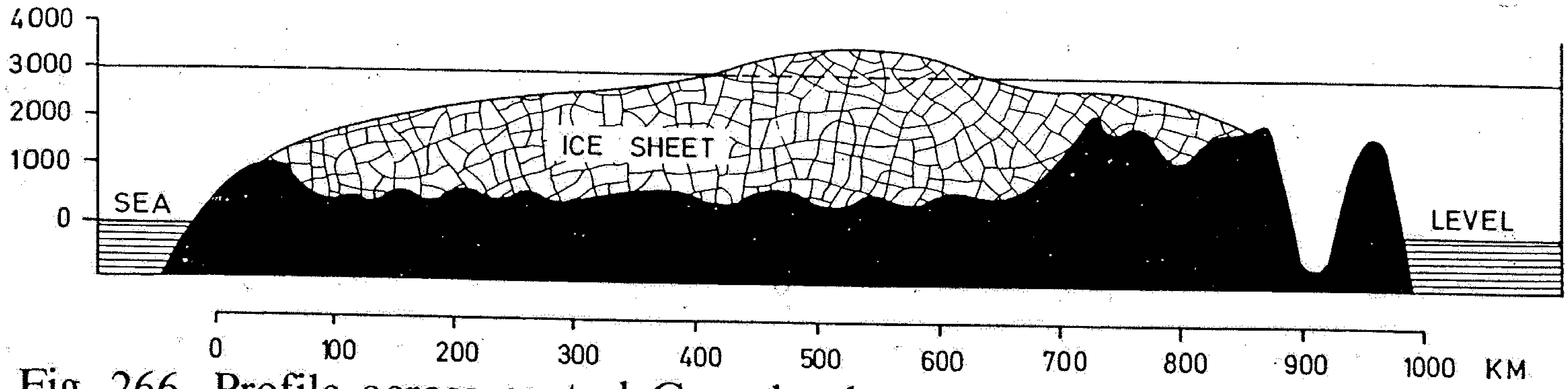


Fig. 266. Profile across central Greenland showing the ice sheet. (Modified after Holmes 1965)

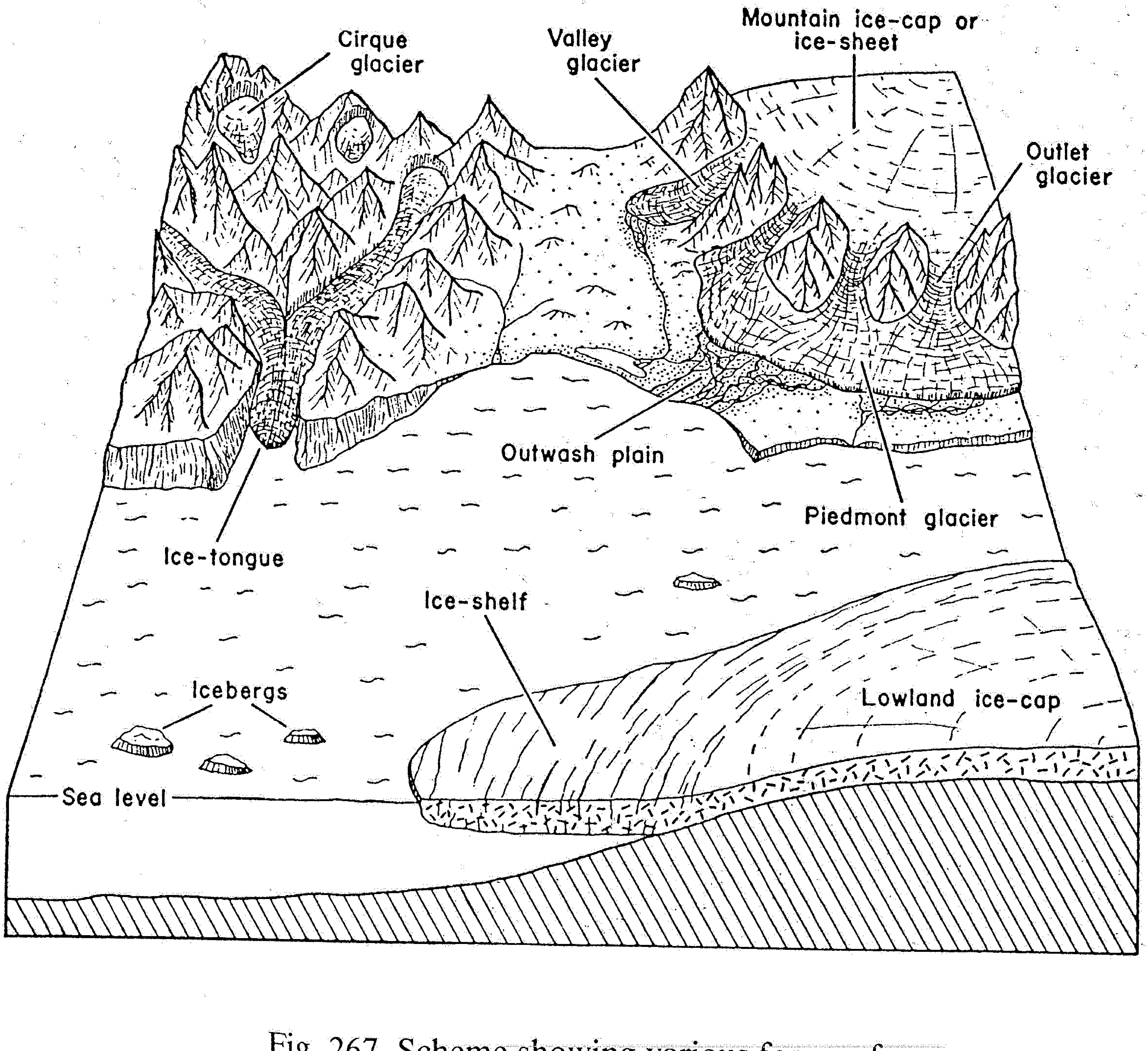
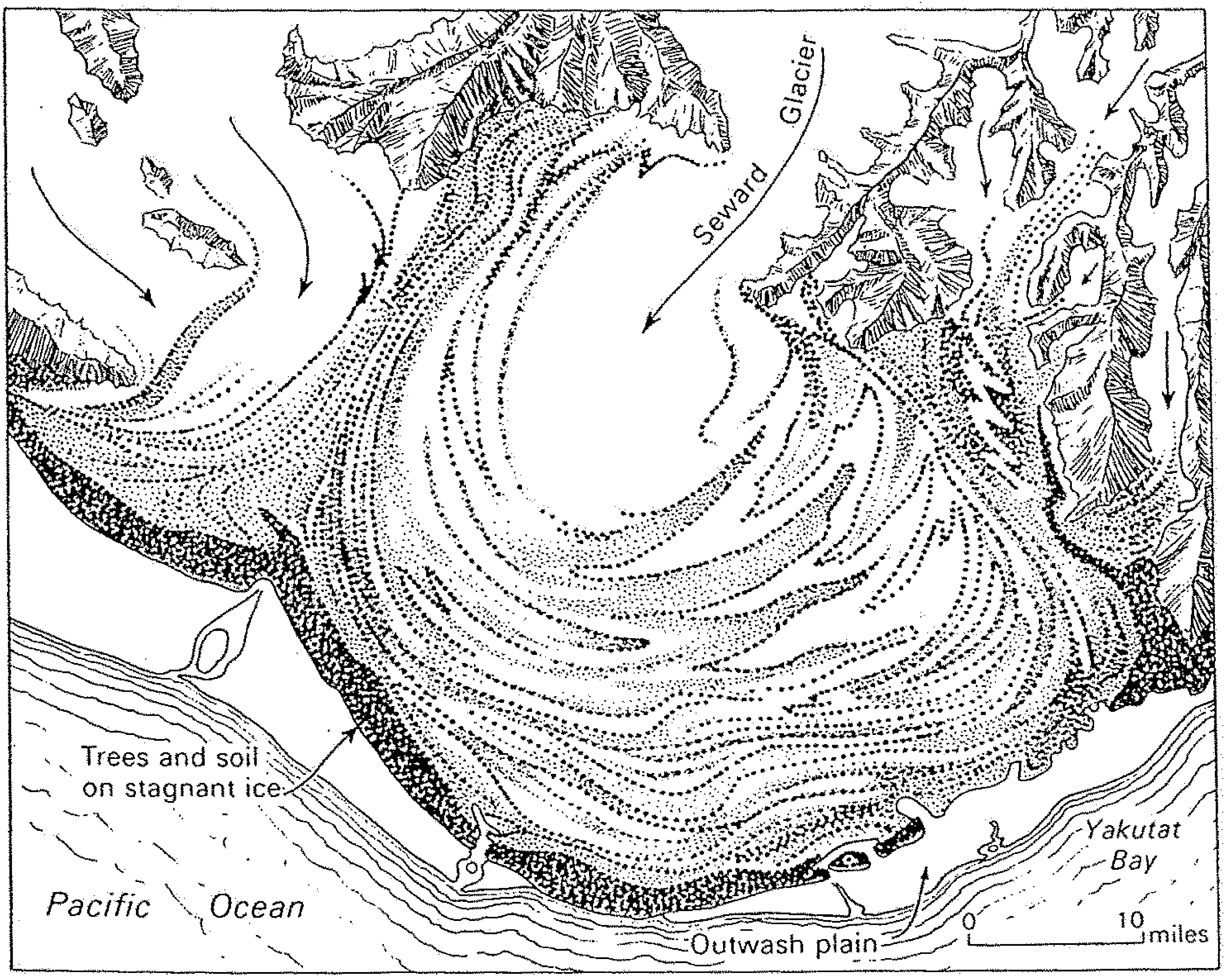


Fig. 267. Scheme showing various forms of occurrence of glacial ice. (After Allen, 1970).

Map of the Malaspina glacier, Alaska. The arrows indicate the flow of the valley glaciers that feed the Malaspina. (After R. S. Tarr and Laurence Martin, 1914.)



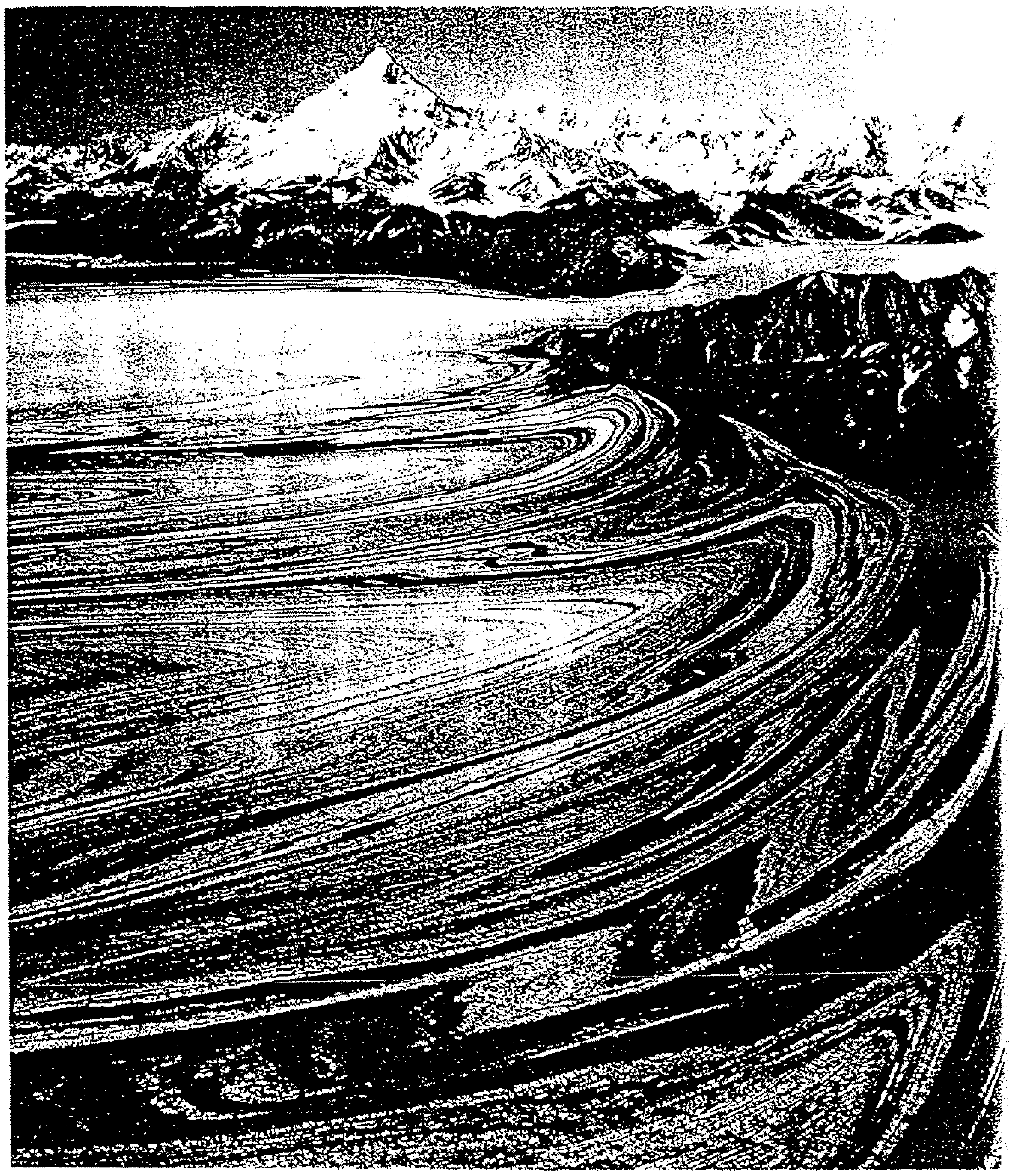
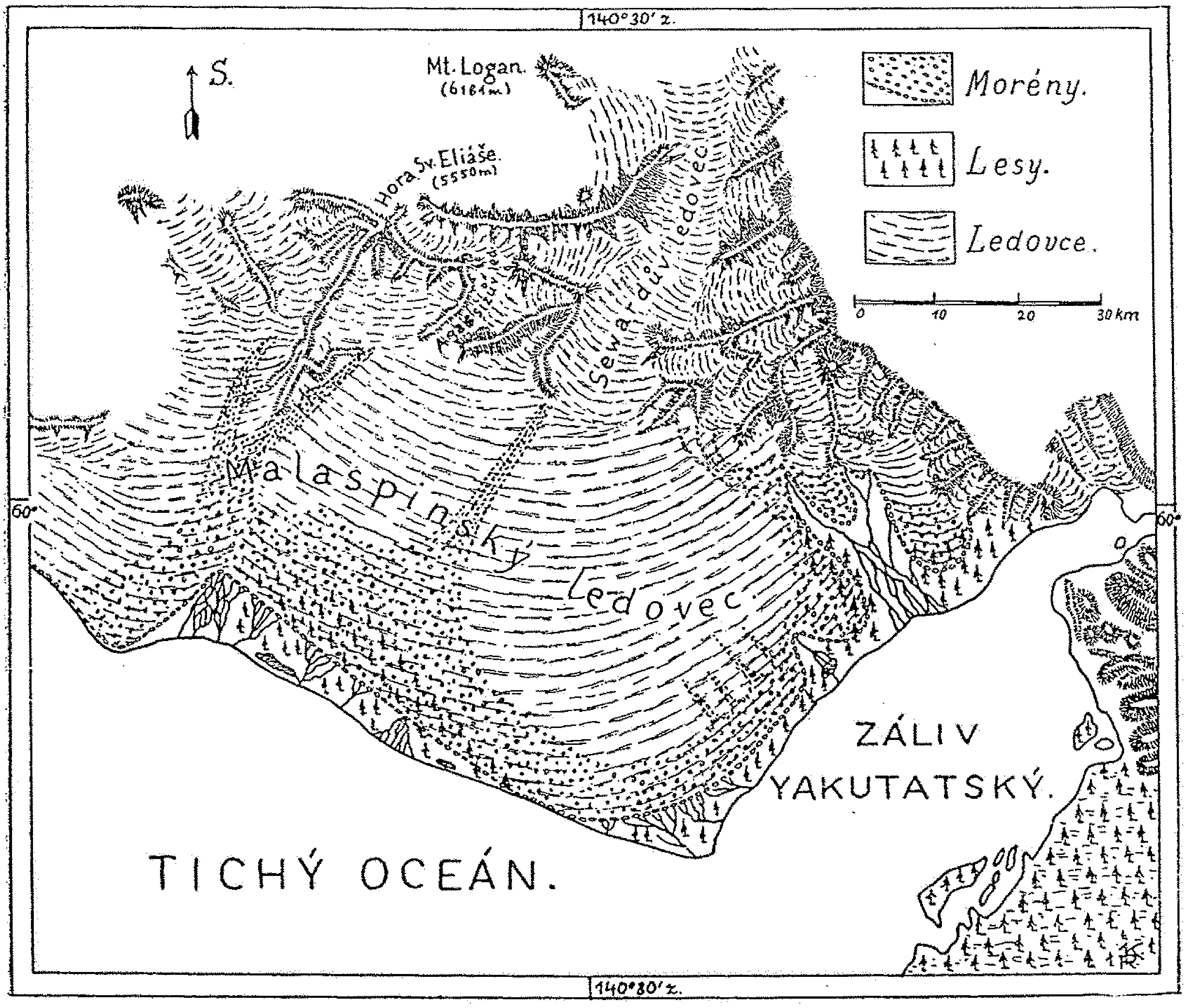


FIGURE 13-12 *Folds in the Malaspina glacier, Alaska. Seward glacier in right rear. The scale of folding is in miles, in places as much as 10 miles. (Photo by Austin Post, U.S. Geological Survey.)*



Obr. 12. *Malaspinský ledovec v Aljašce. Nejlepší příklad piedmontního (podhorského, úpatního) ledovce nynější doby.* (Podle J. C. Russella.)

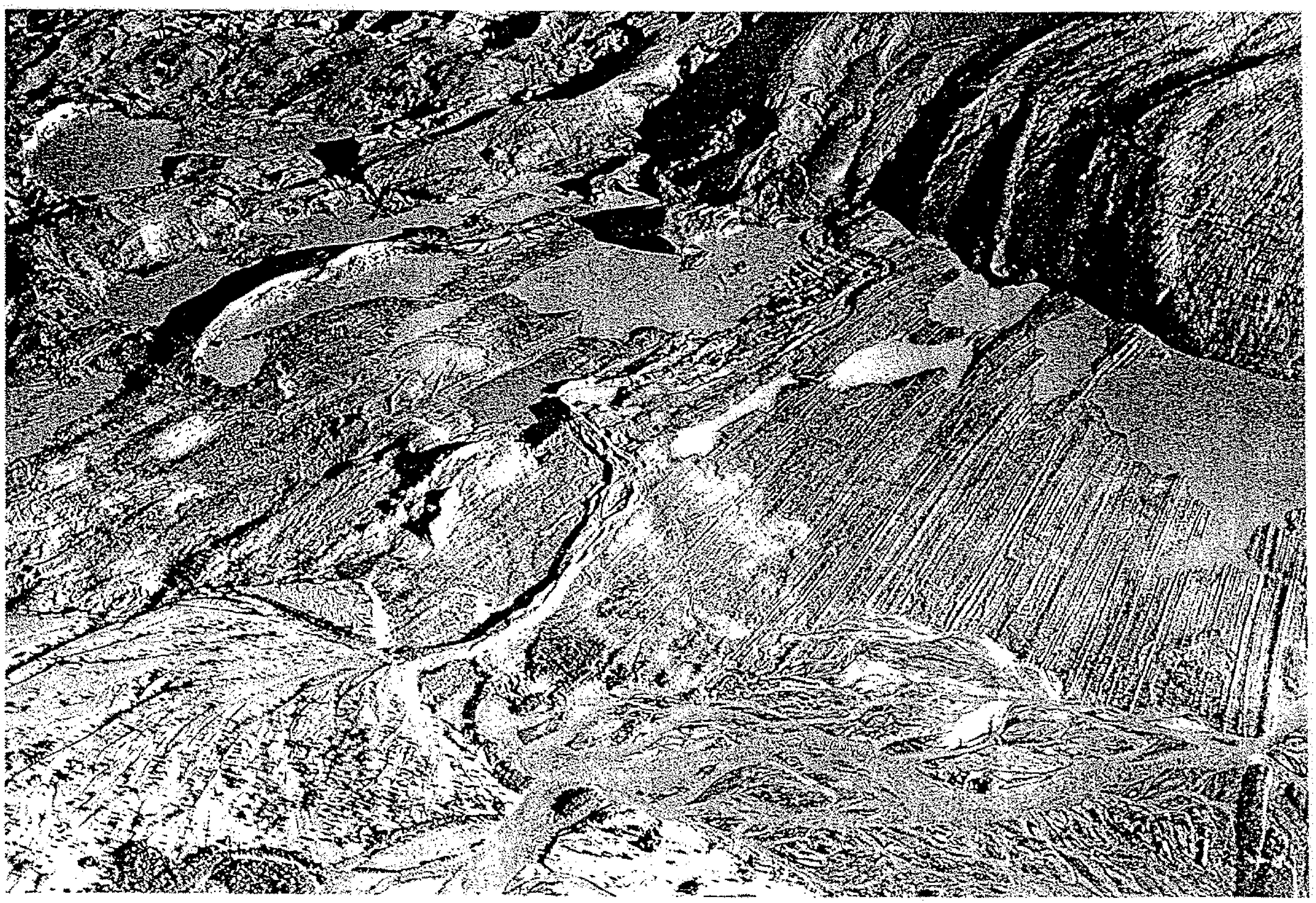
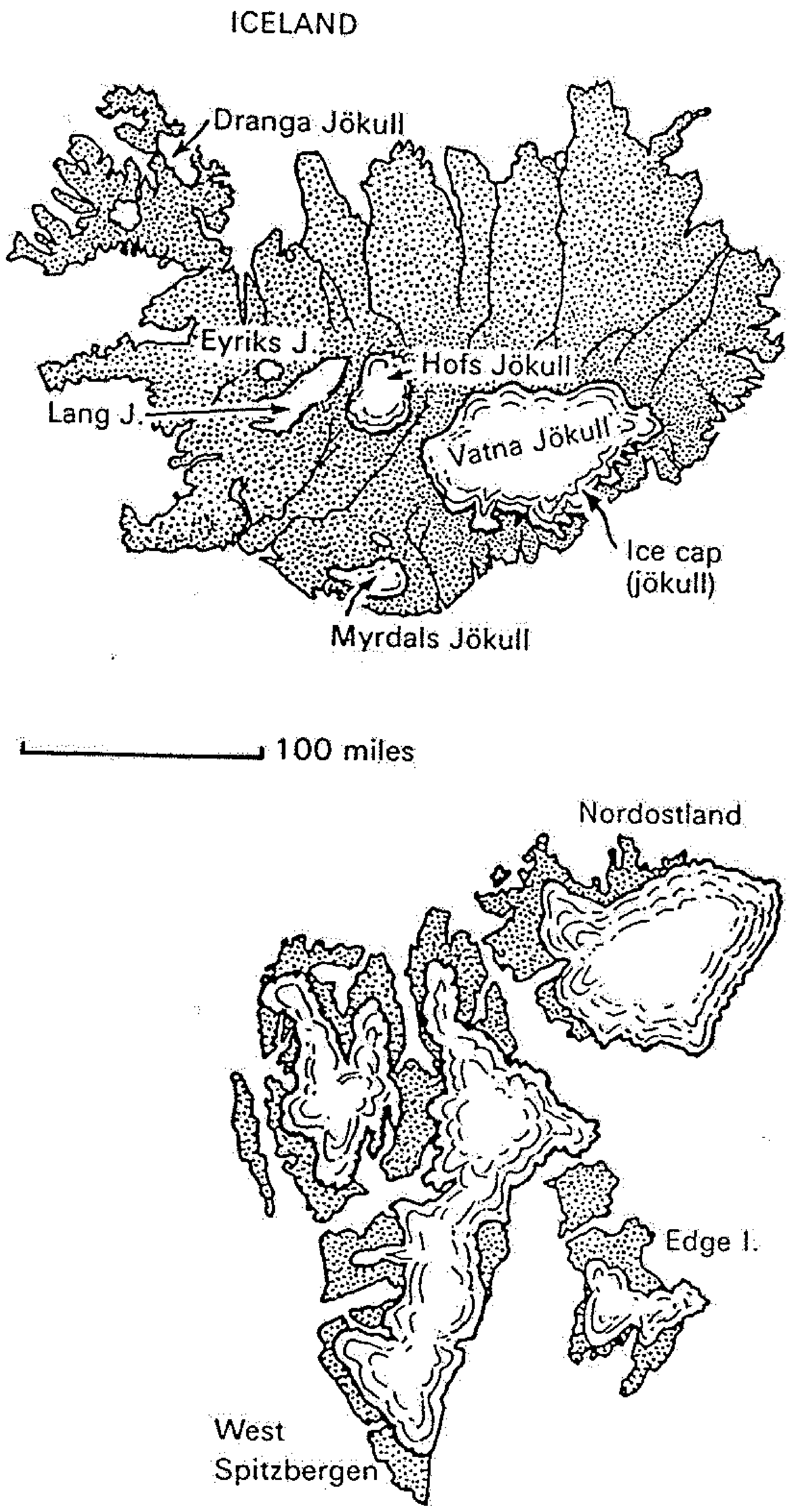


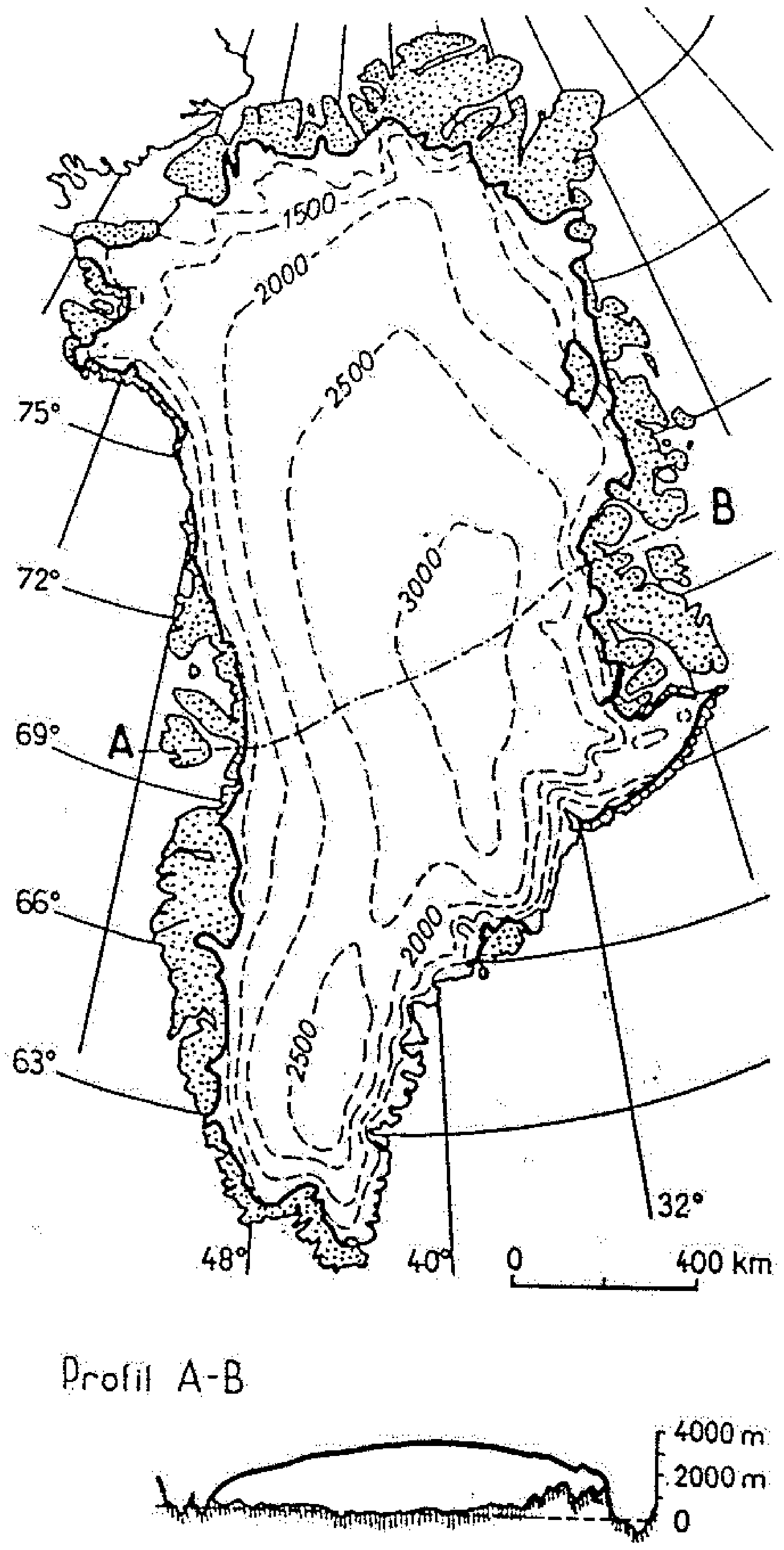
Figure 10-26

Retreat of the ice margin has revealed an esker formed by a stream that ran under the glacier. The esker is the winding ridge of sand and gravel running from upper right to lower left. The grooves at right are in soft glacial sediment and are not bedrock striations. [Photo by B. Washburn.]

FIGURE 13–14

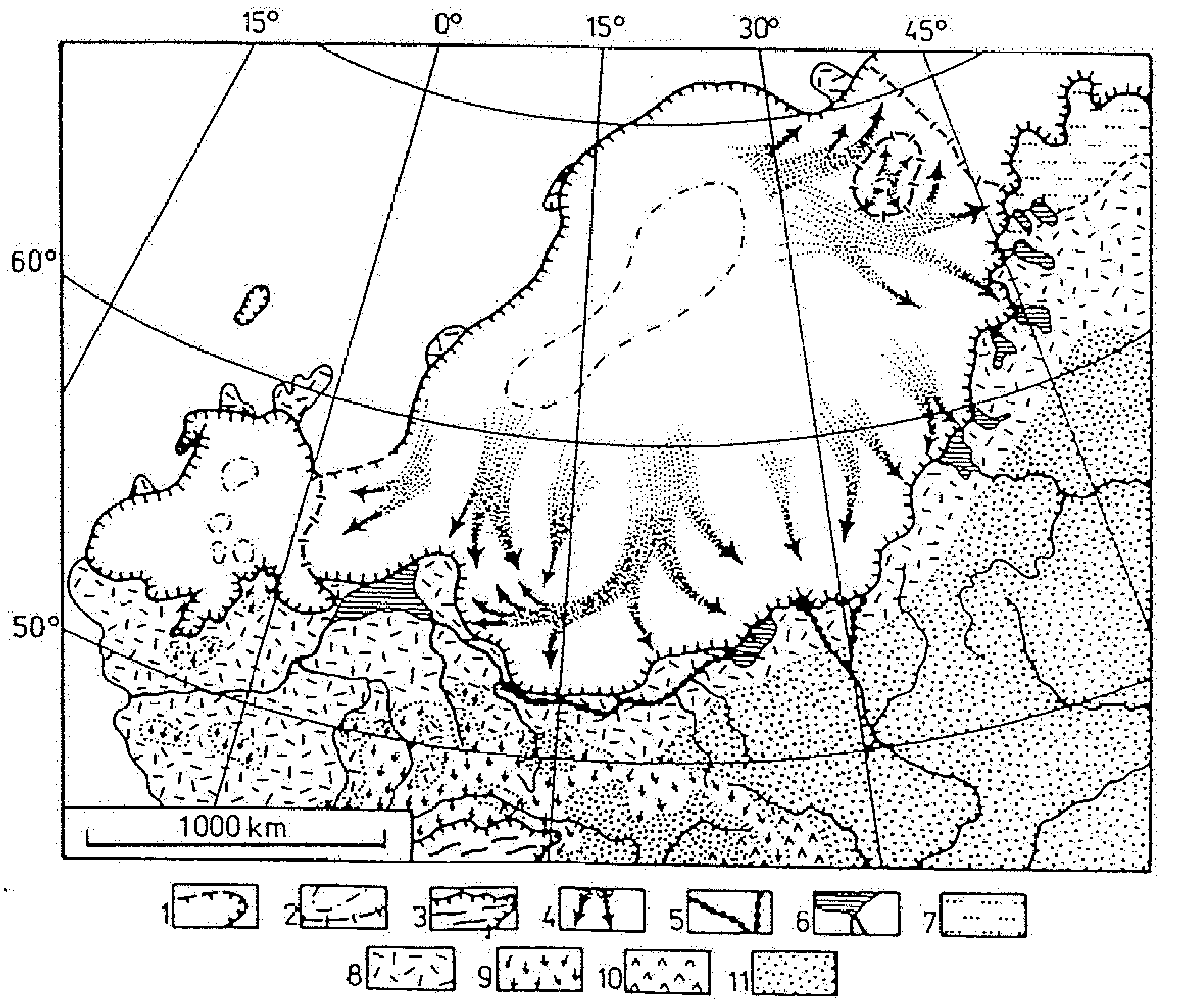
Ice caps of Iceland and Spitzbergen. (After Stieler's Atlas.)





Obr. 22.2. Dnešní kontinentální zalednění Grónska a řez ledovcem ukazující jeho mocnost v profilu A—B (podle R. F. Flinta)

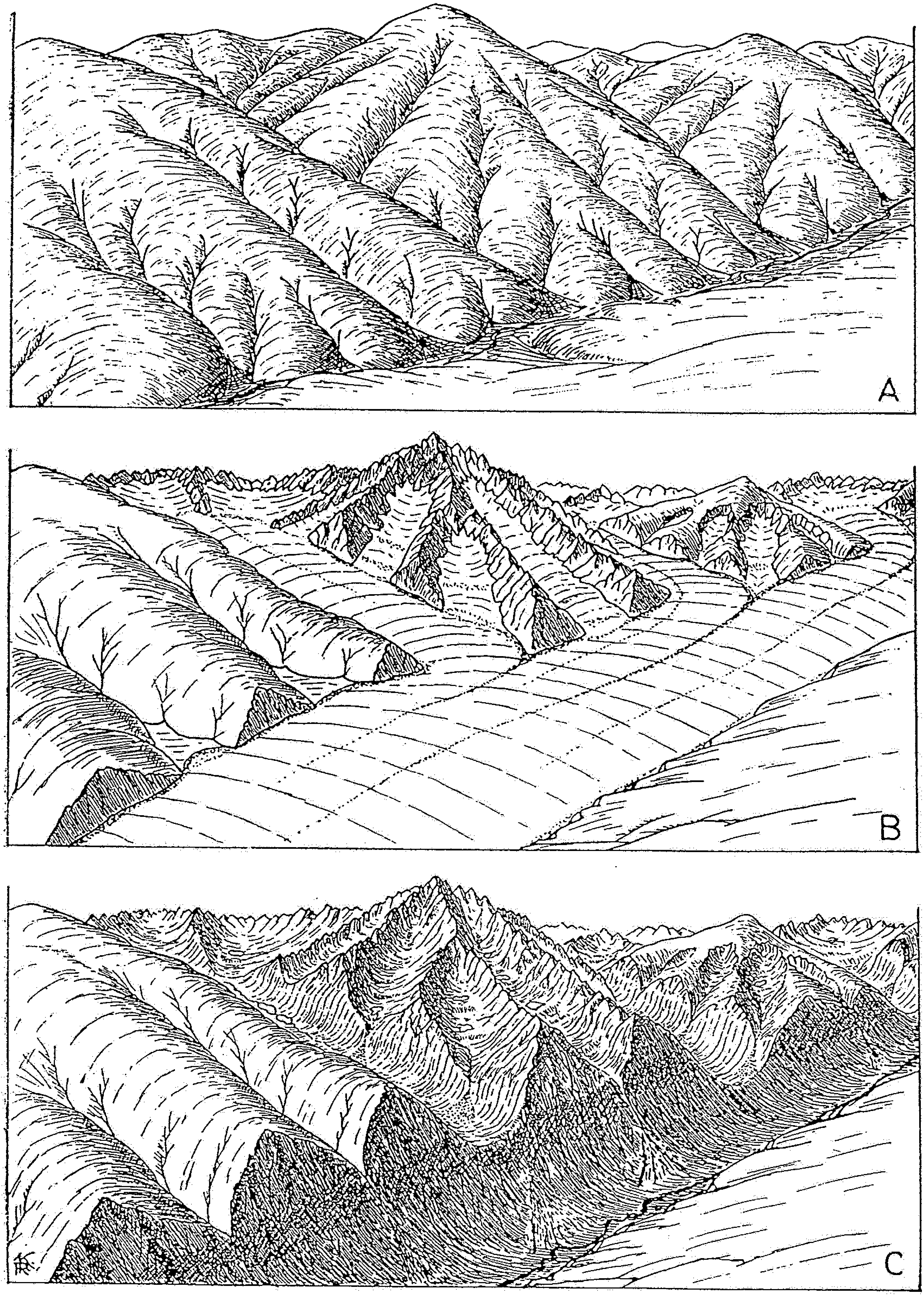
tečkovaně — pevnina nekrytá ledovcem;
bíle — dnešní kontinentální zalednění



Obr. 106 Severní Evropa v době největšího rozsahu posledního zalednění: 1 - okraj zalednění, 2 - centra tvorby ledu a hranice okrsků živených z jednotlivých center, 3 - horské zalednění, 4 - hlavní směry pohybu ledu, 5 - řeky živené zaledněním, 6 - příledovcová jezera, 7 - polární pustiny, 8 - tundra (příledovcová vegetace), 9 - horské tundry a alpinské hole, 10 - lesy/tajga, 11 - chladné stepi (podle I. P. Gerasimova a sp. 1965)

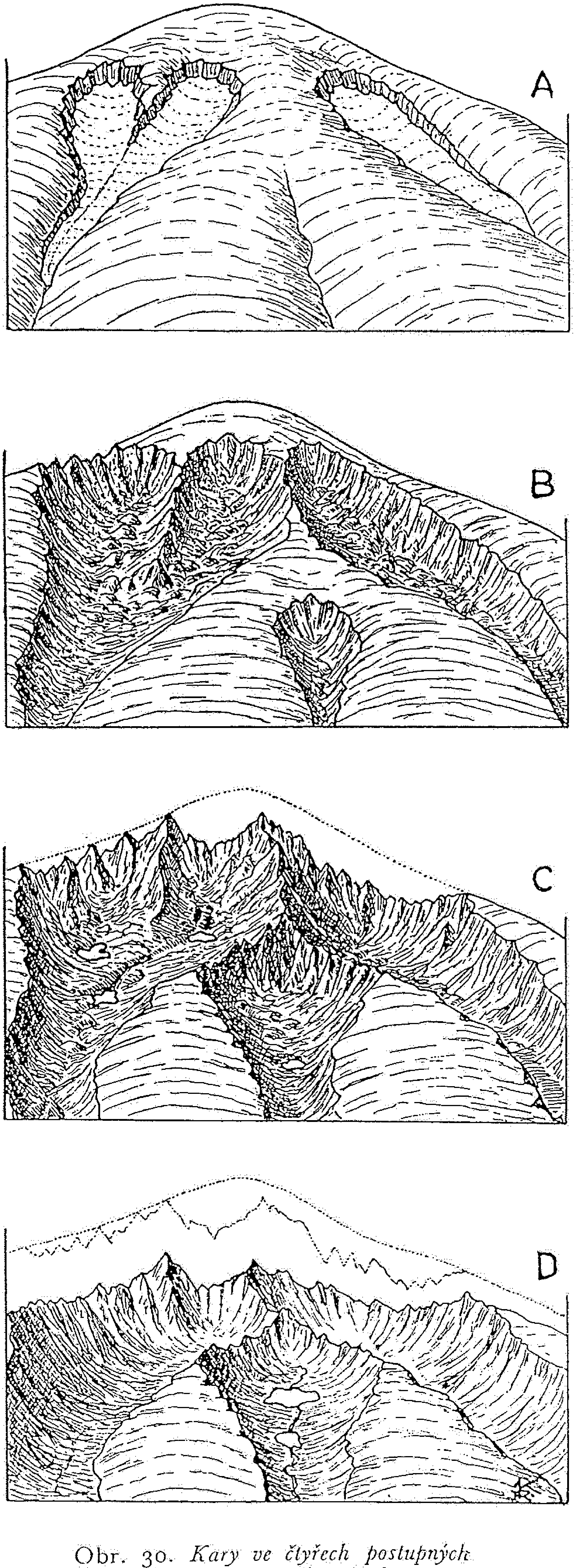
Randspalten und Schmelzwässer am Rand des Inlandeises in Nordostgrönland

Abb. 2. Schematischer Schnitt durch einen Eisschild. In der Mitte des Eisschildes bewegt sich das Eis zunächst senkrecht nach unten und weicht dann unter dem wachsenden Druck seitlich aus. Am Rand des Eisschildes können Randgebirge den Eisschild als Nunataks durchragen. Das Eis durchströmt als Auslaßgletscher das Randgebirge, die Eisbasis liegt z. T. unter dem Meeresspiegel. Wo das Eis in das Meer fließt, entwickelt sich Schelfeis, von dem große Tafeleisberge abbrechen.

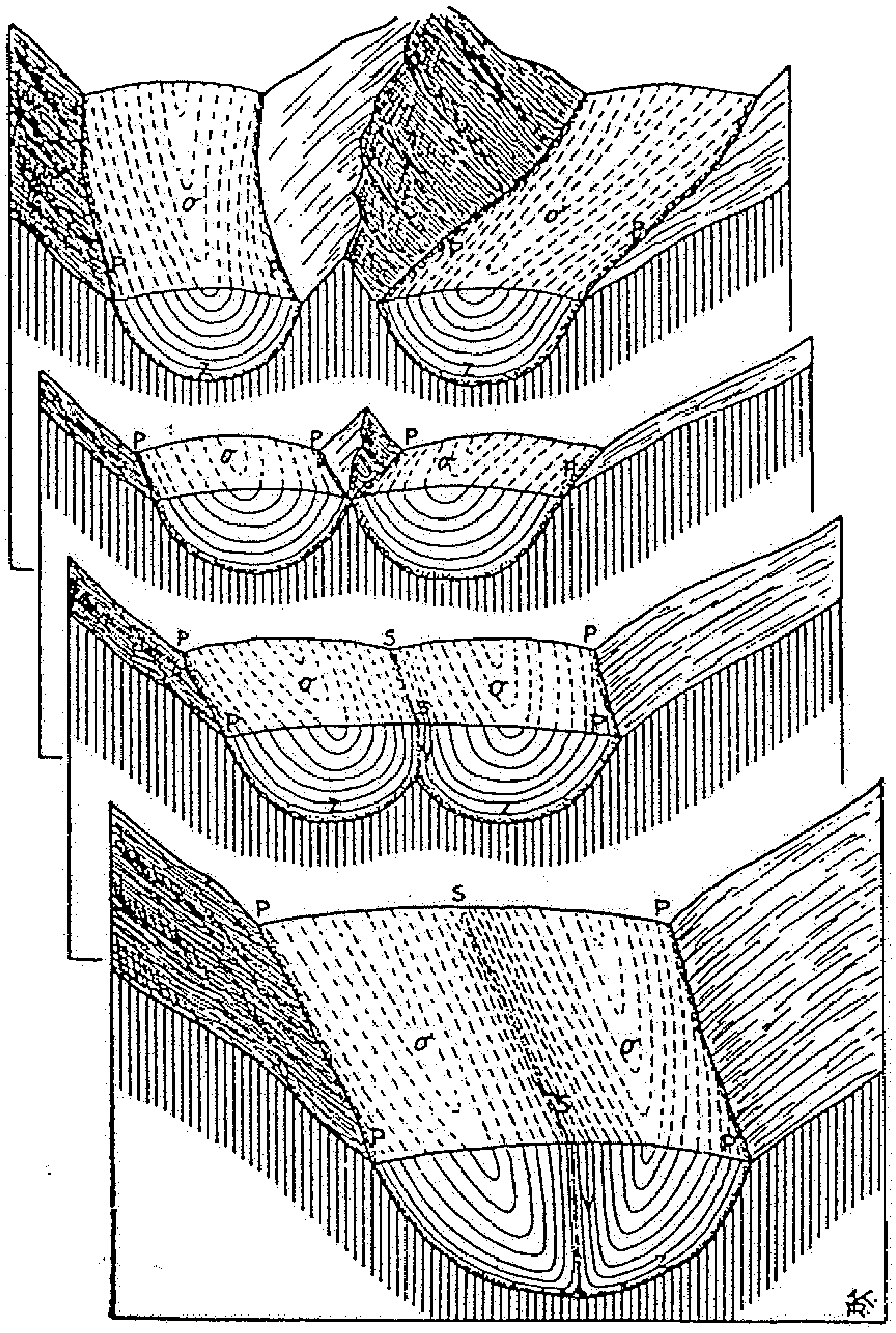


Obr. 39. *Přeměna reliefu pohoří účinkem ledovcové erose. A. Pohoří před zaledněním, rozryté normální vodní erosí. B. Totéž pohoří v době zalednění. C. Relief téhož pohoří po zmizení ledovců. Vidíme široká, neckovitá údolí v podobě písmene U; postranní údolí jsou visutá. V horských karech jsou četná cirkusová jezírka.* (Upraveno podle W. M. Davise.)

Abb. 9. Fluviale und glaziale Talbildung. Nach WAGNER 1960: 223.
1) Praeglaziales Kerbtal. 2) Vergletscherung, Vertiefung und Verbreiterung des Tales. Entstehung der U-Form. 3) Postglazial, steile Talflanken mit Schliffgrenze (S), Stufenmündung kleiner Seitentäler (Hängetal).



Obr. 30. *Kary ve čtyřech postupných obdobích tvarového vývoje.* (Podle W. M. Davise.)



Obr. 22. *Spojení dvou splazů v jeden větší ledovec znázorněné ve čtyřech úsecích a ukazující vnitřní stavbu (texturu) ledovce. o = obloukovité pruhování ledovce (ogivi), p = postranní moréna, s = střední moréna, v = vnitřní moréna, z = spodní neboli základní moréna.* (Originál.)

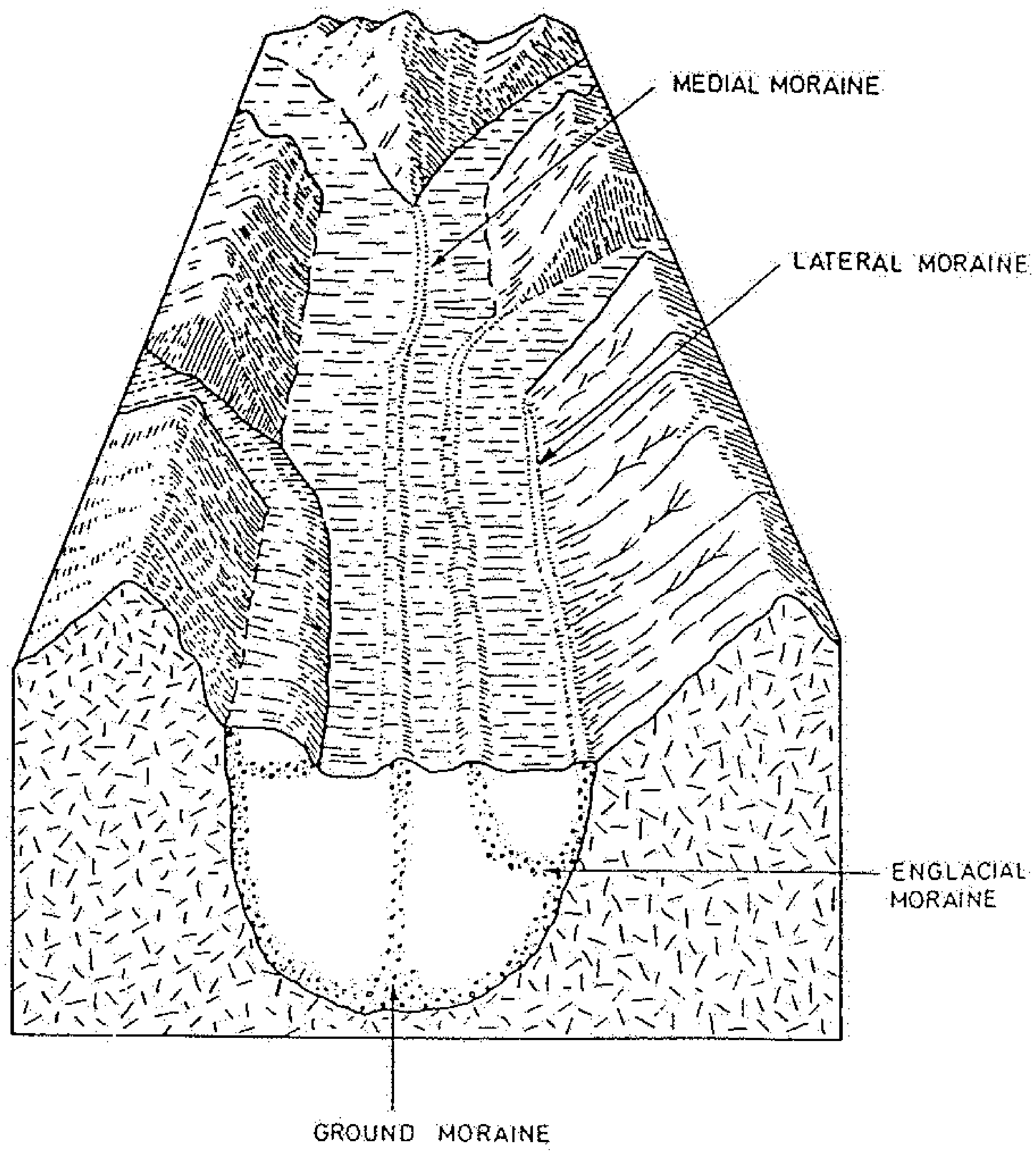
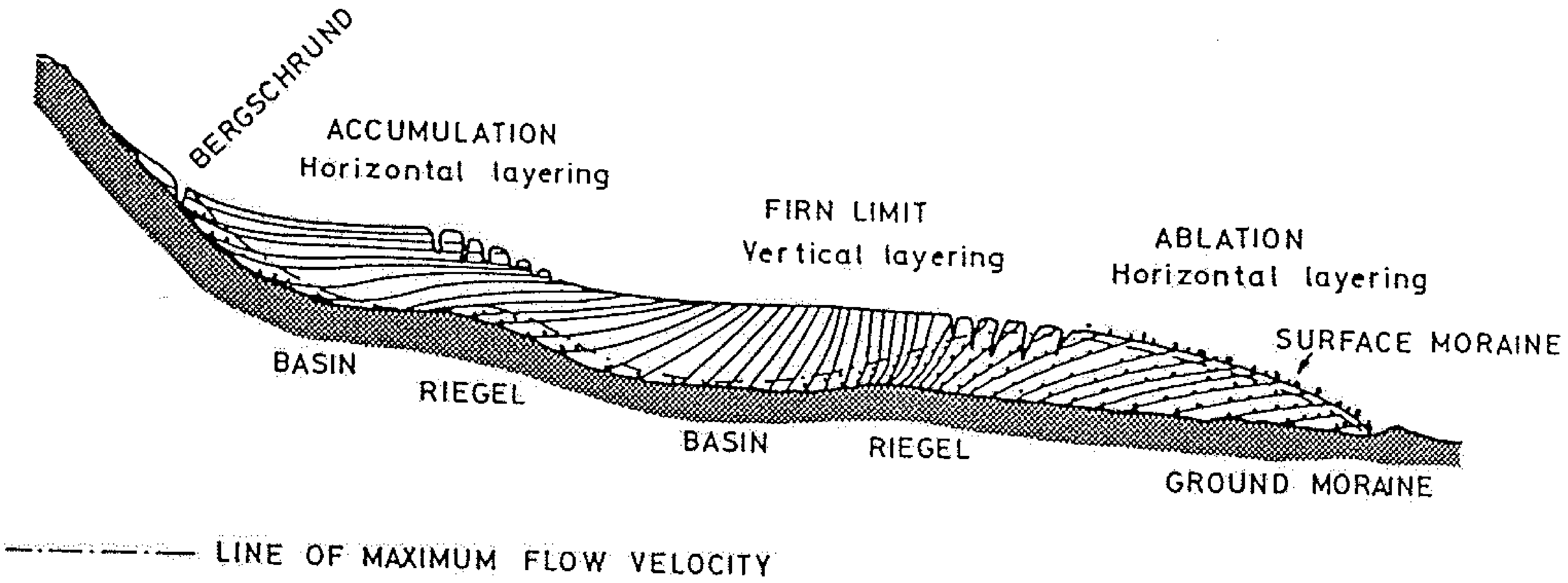
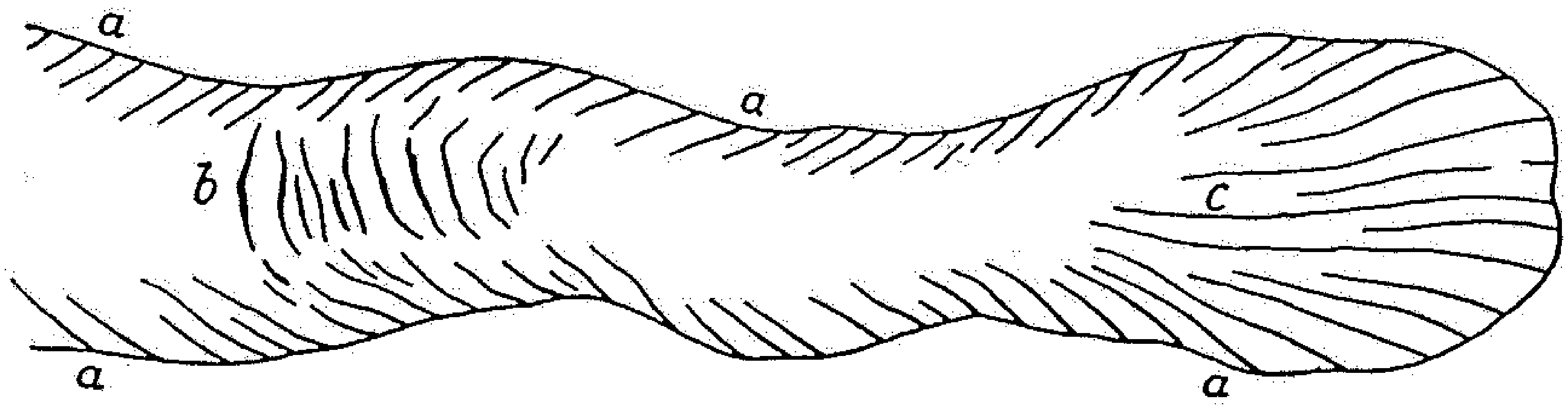
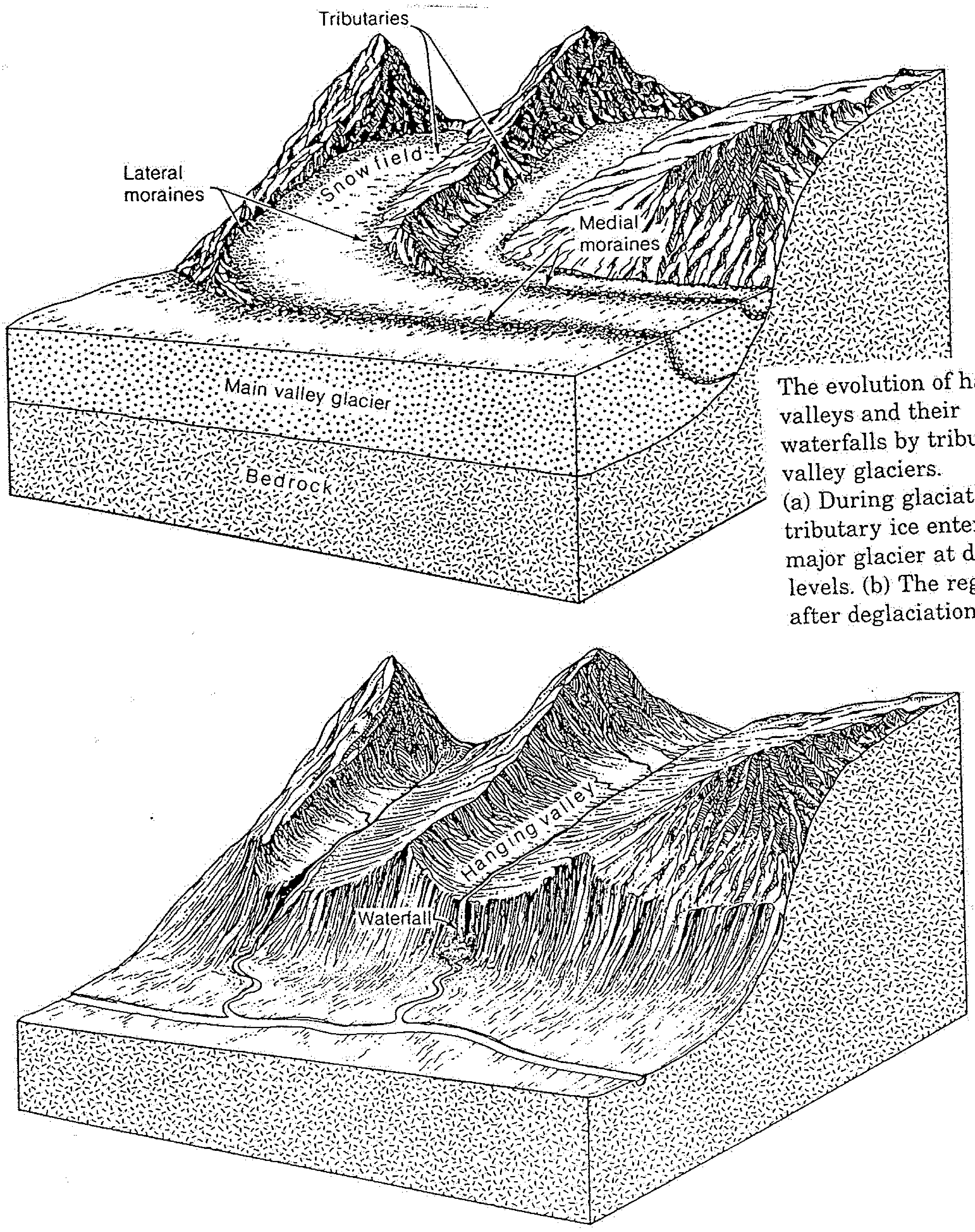


Fig. 274. Diagram illustrating various modes of transport of glacial material and various types of sediment load. (Modified after Sharp 1960)





Obr. 23. *Trhliny v ledovcovém splazu. a = trhliny okrajní, b = trhliny příčné, c = trhliny podélné (v čele splazu).* (Podle Em. Kaysera.)



The evolution of hanging valleys and their waterfalls by tributary valley glaciers. (a) During glaciation, tributary ice enters a major glacier at different levels. (b) The region after deglaciation.

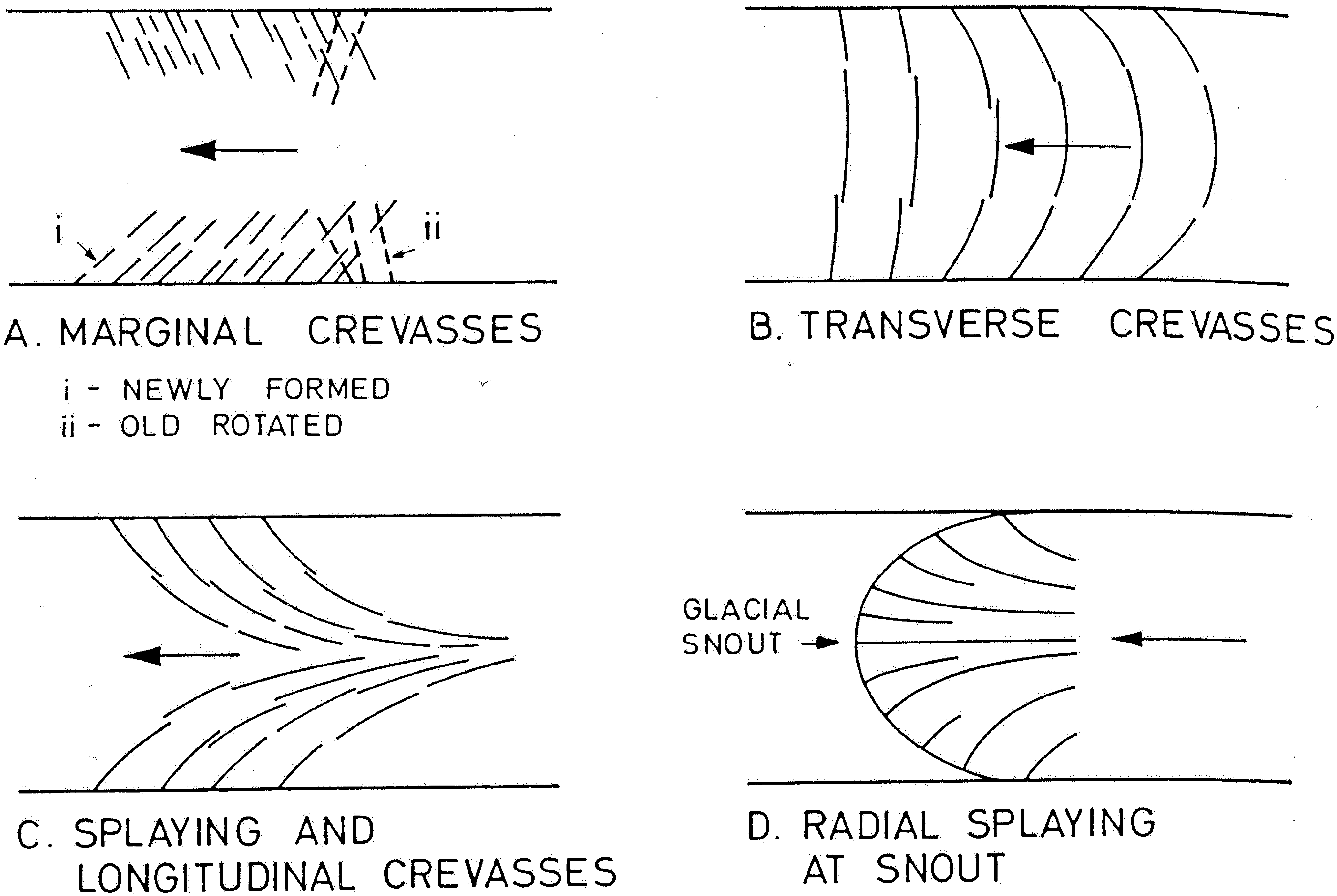
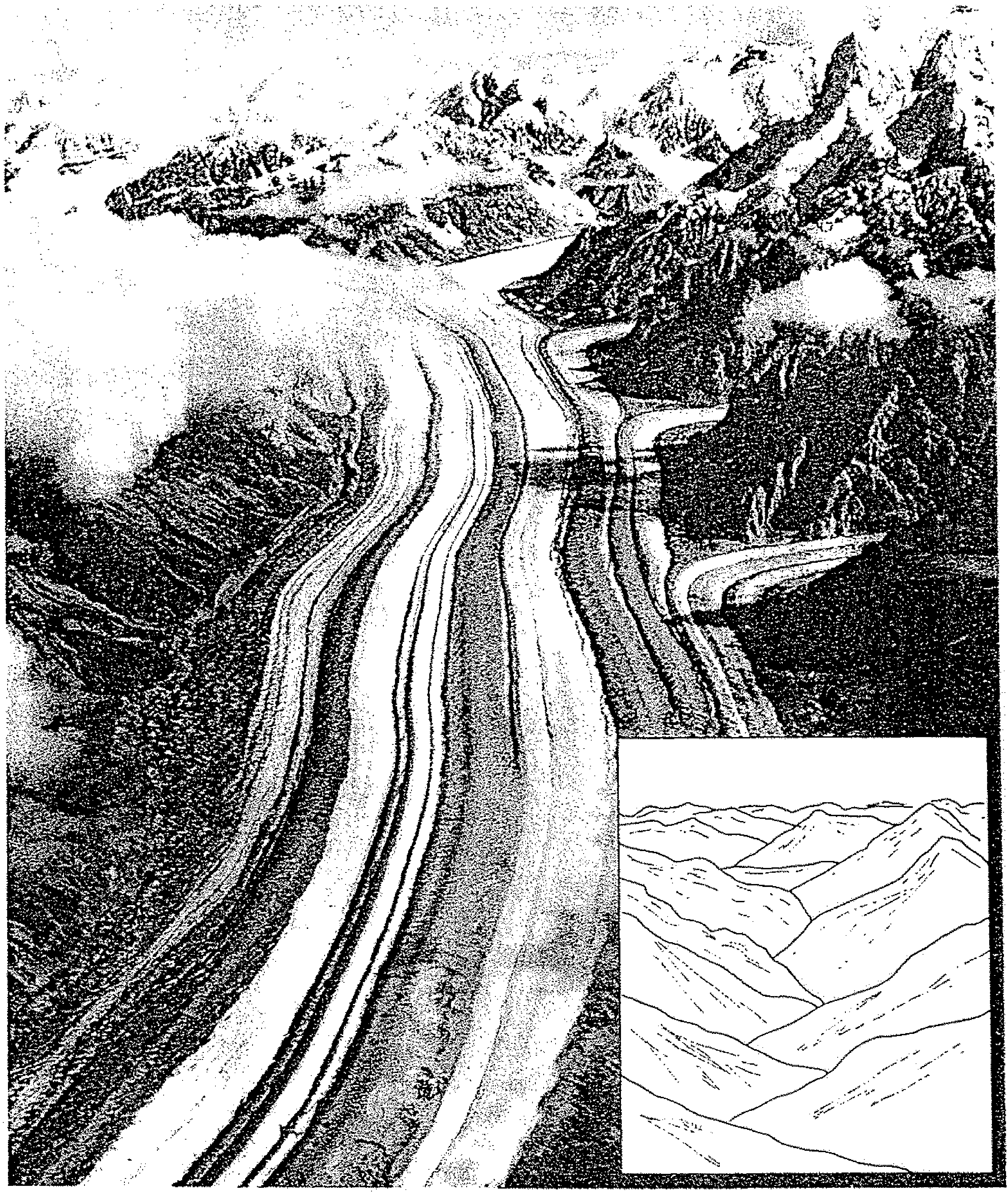
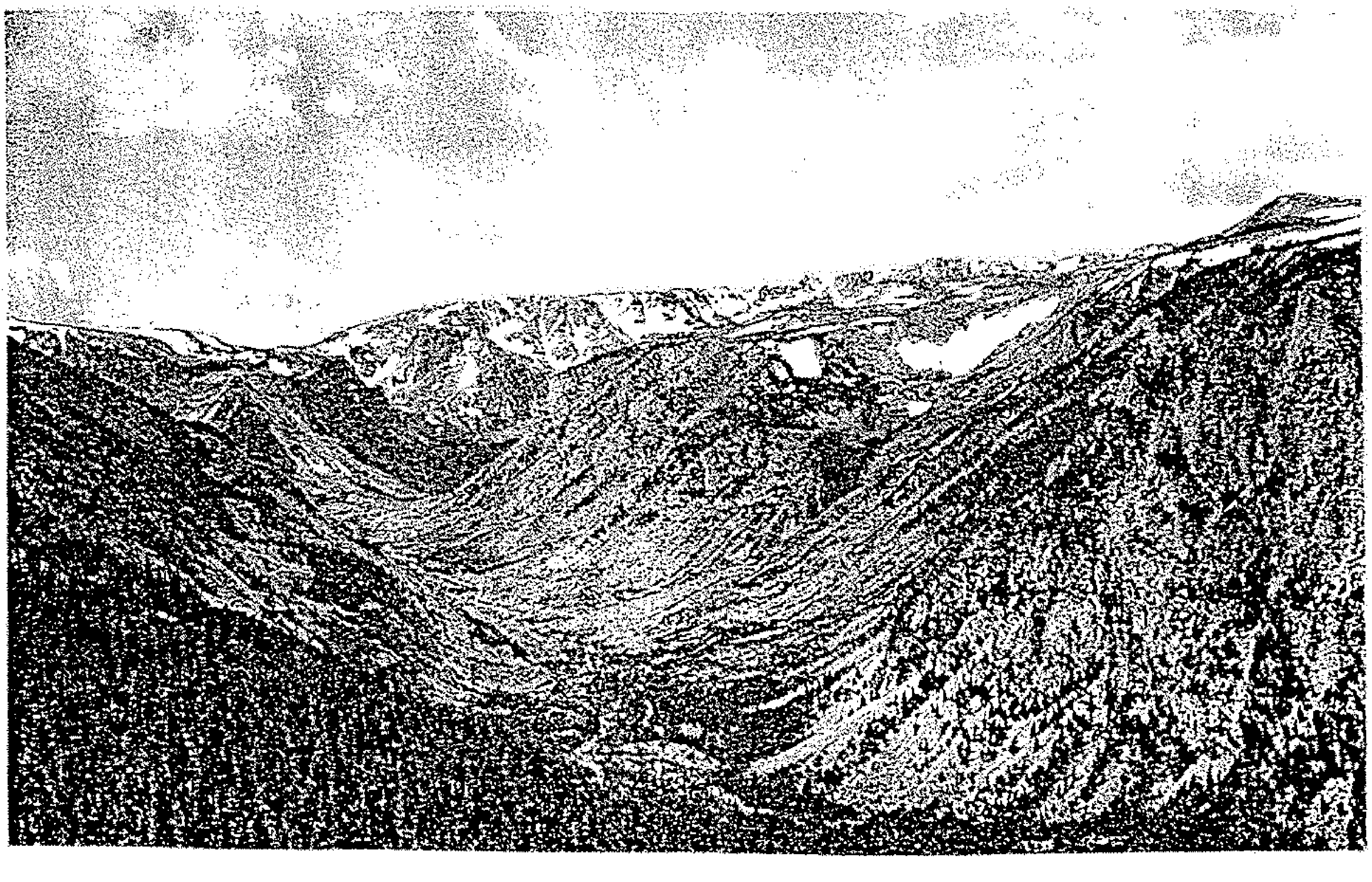


Fig. 264. Scheme showing various types of crevasses in a glacier. (Modified after Sharp 1960)



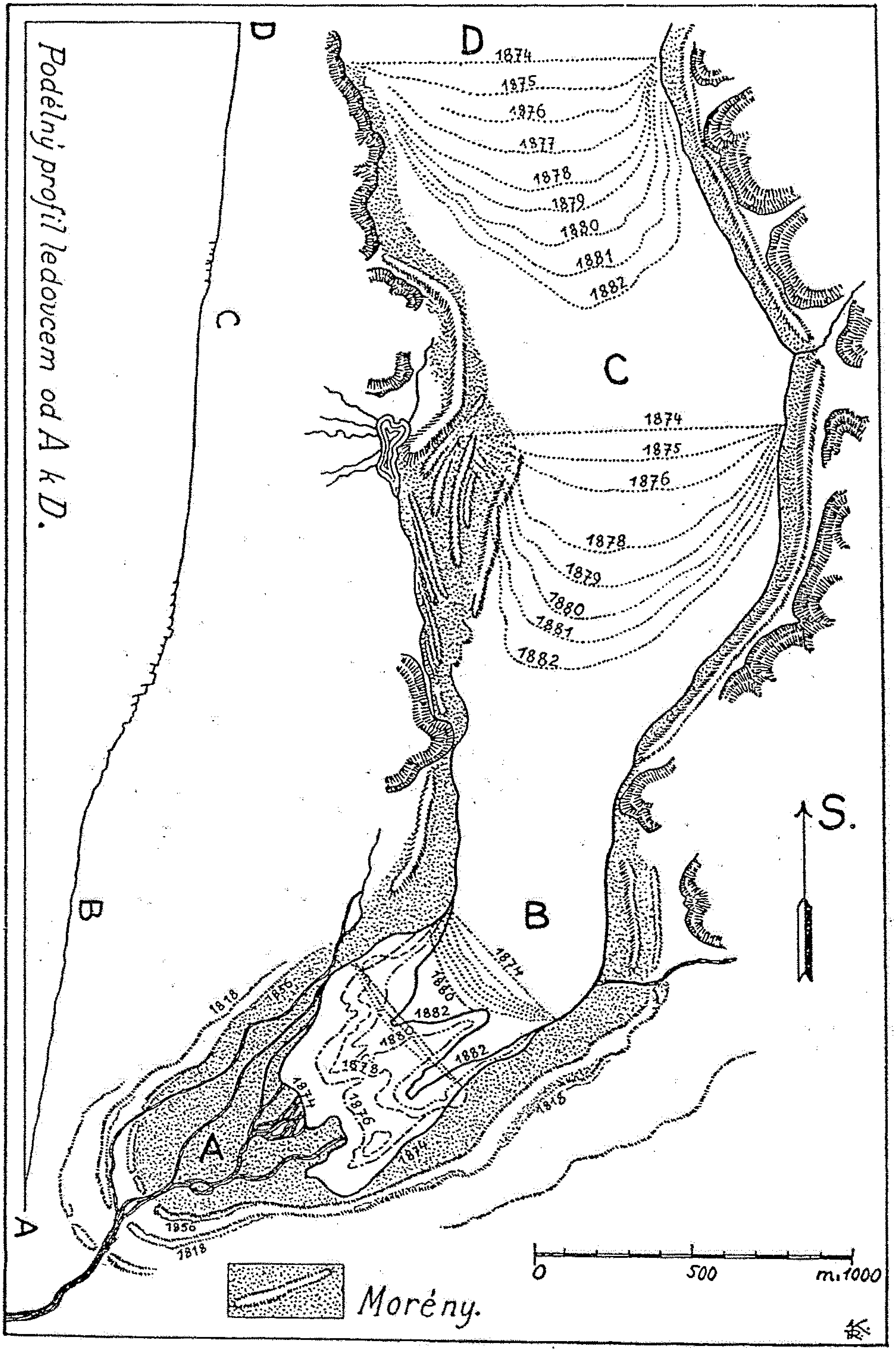
14.20

The Barnard glacier and its tributaries in Alaska flow in a valley system first formed by normal stream and slope processes. What the topography might have looked like in that earlier stage is suggested in the inset sketch. (Photograph by Austin Post, U.S. Geological Survey)

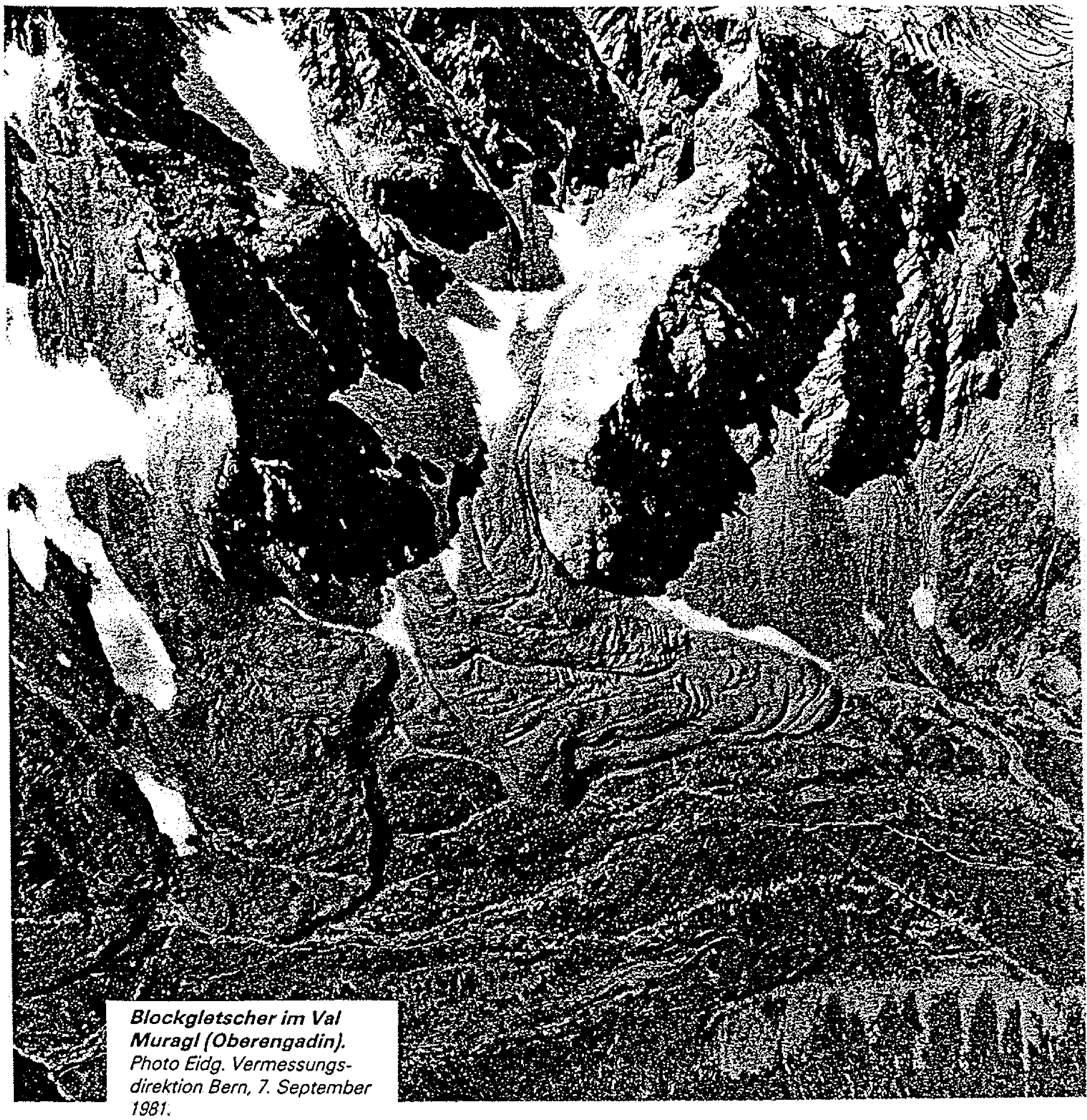


14.21

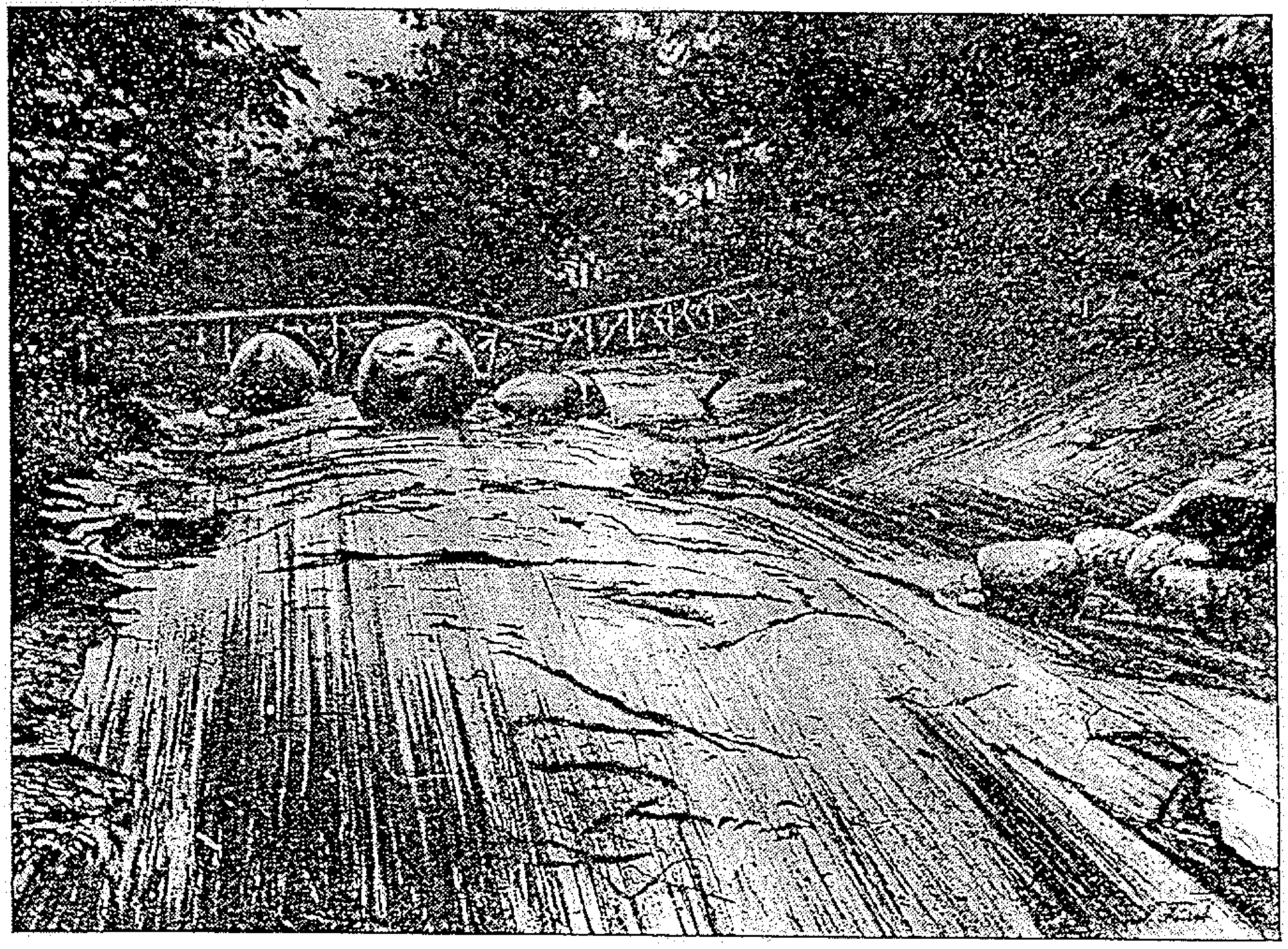
Several times in the Pleistocene glacier ice flowed down Rock Creek Valley in Montana's Beartooth Mountains. In the process it snubbed off valley spurs and widened a V-shaped valley to a U-shaped glacial valley. See also Figure 14.20. (Photograph by Sheldon Judson)



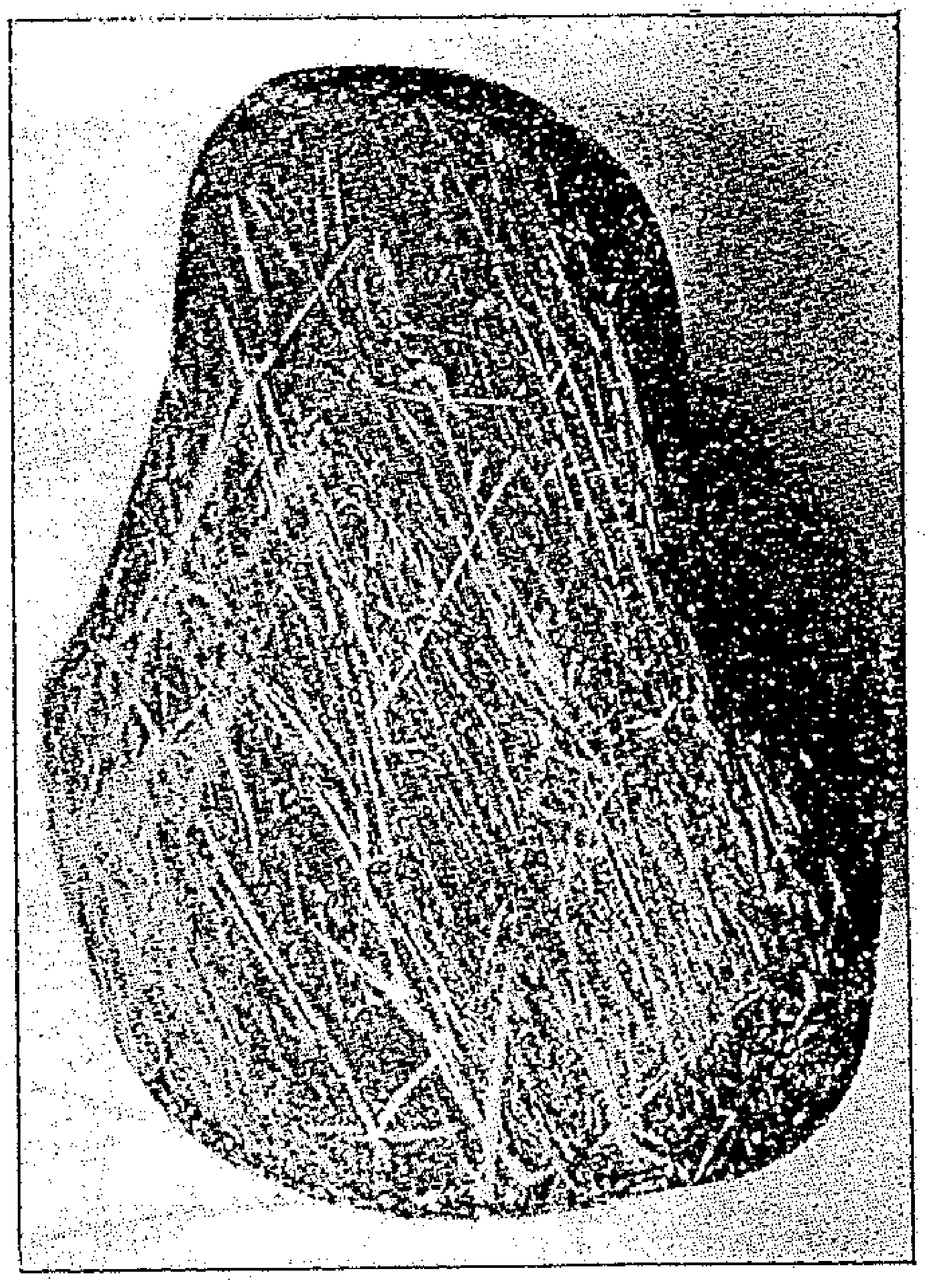
Obr. 18. *Mapa znázorňující různou rychlost pohybu Rhônského ledovce ve středu a při okrajích splazu. Mapa ukazuje též ustupování čela ledovce v letech 1874 až 1882.* (Podle Alb. Heima.)



Blockgletscher im Val Muragl (Oberengadin).
Photo Eidg. Vermessungsdirektion Bern, 7. September 1981.



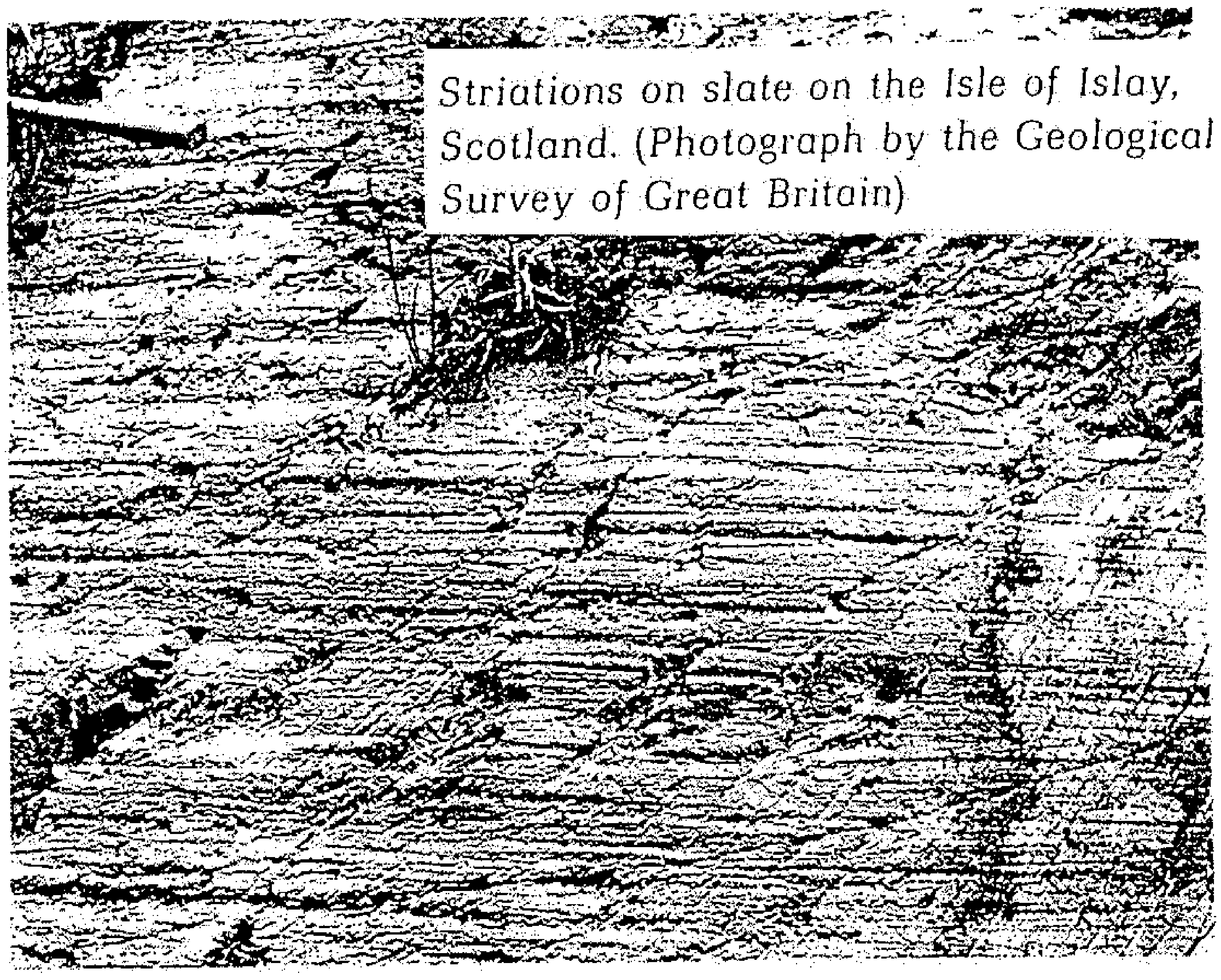
Obr. 291. *Ledovcem ohlazený a zrýhovaný skalní podklad s několika bludnými balvany* v „ledovcové zahrádce“ v Luzernu (Švýcarsko). (Podle W. Flaiga.)



Ledovcovým obrusem poškrábaný souvek.
G. Wagnera.)

Grooves with striations near the Parliament Buildings, Victoria, British Columbia. Glacier flow away from observer. (Photograph by Sheldon Judson)

FIGURE 13–18
Glacially polished columnar basalt, Devil's Postpile, California. (Photo by Tad Nichols, Tucson, Arizona.)



Striations on slate on the Isle of Islay, Scotland. (Photograph by the Geological Survey of Great Britain)

Lunate chatter marks on the back of a roche moutonée, near the lower end of Florence Canyon, Sierra Nevada, California. (Photo by François Matthes, U.S. Geological Survey.)

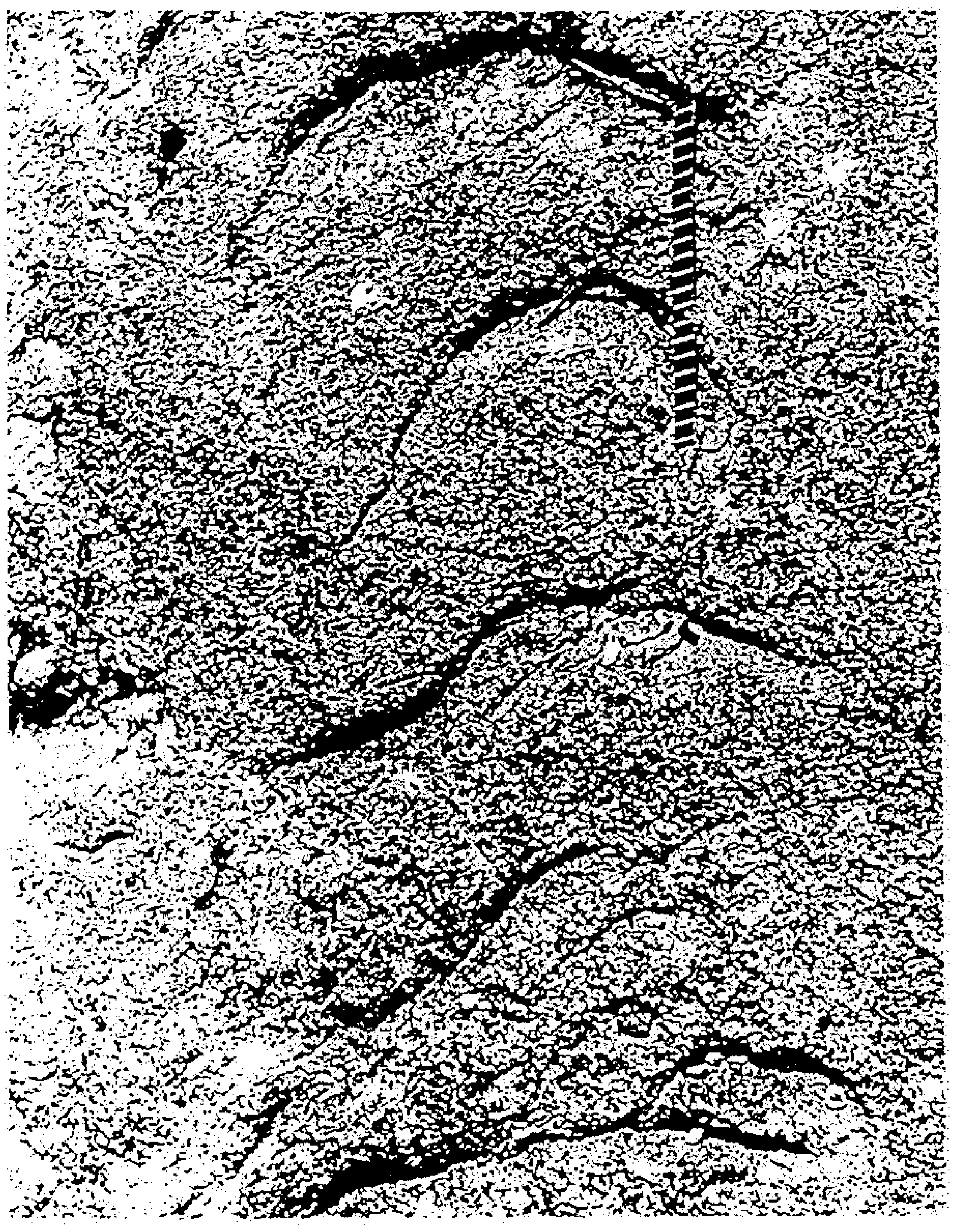
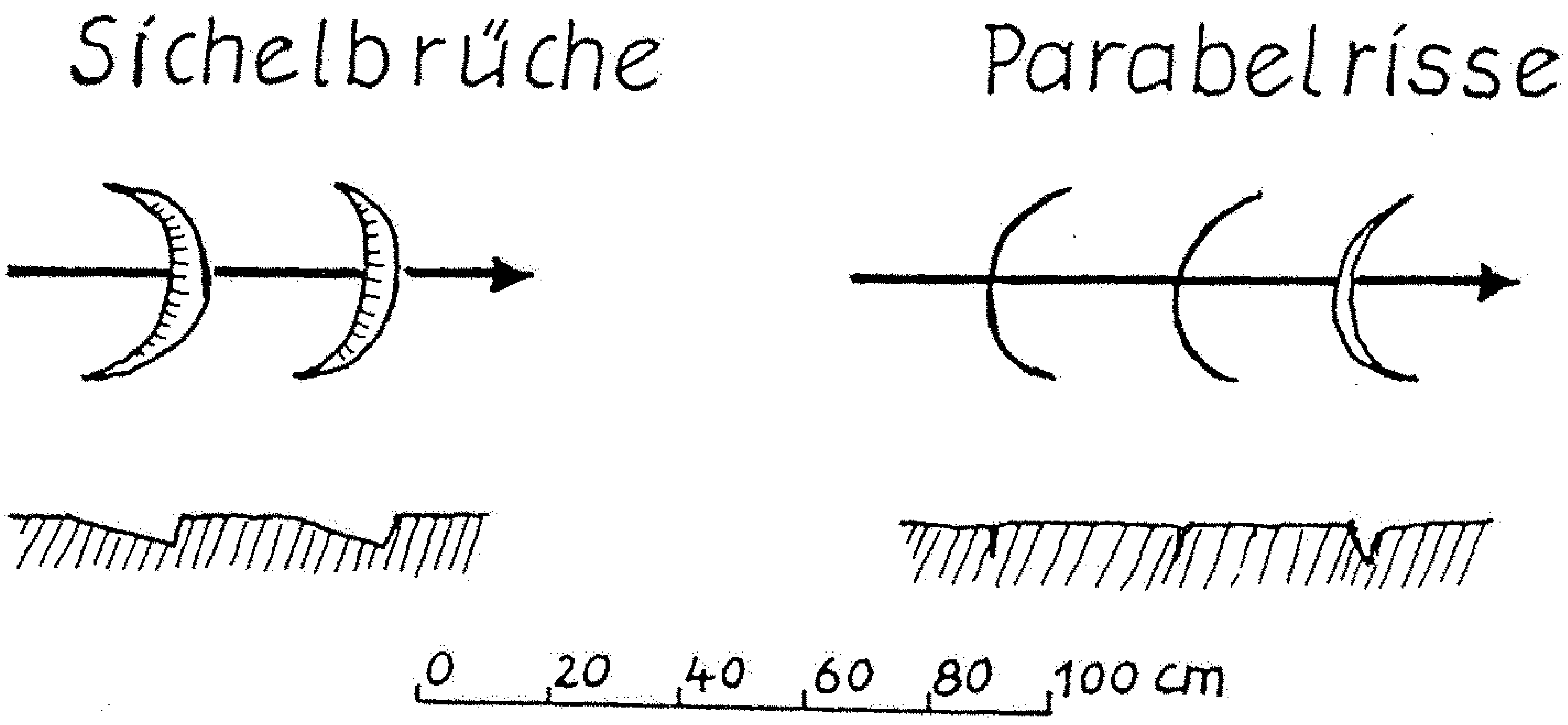
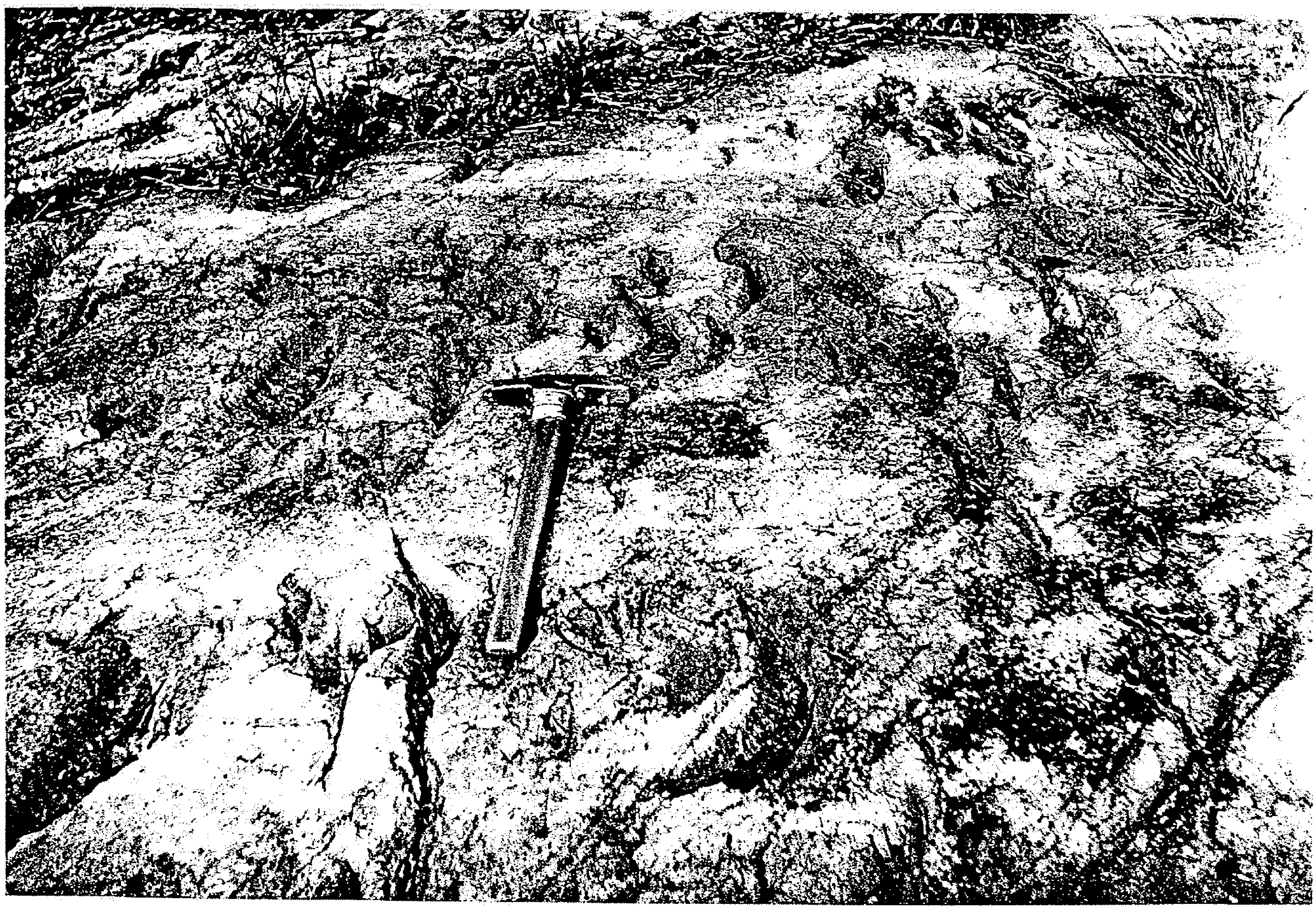


Fig. 272. Crescentic fractures of variable shapes. Southern Norway

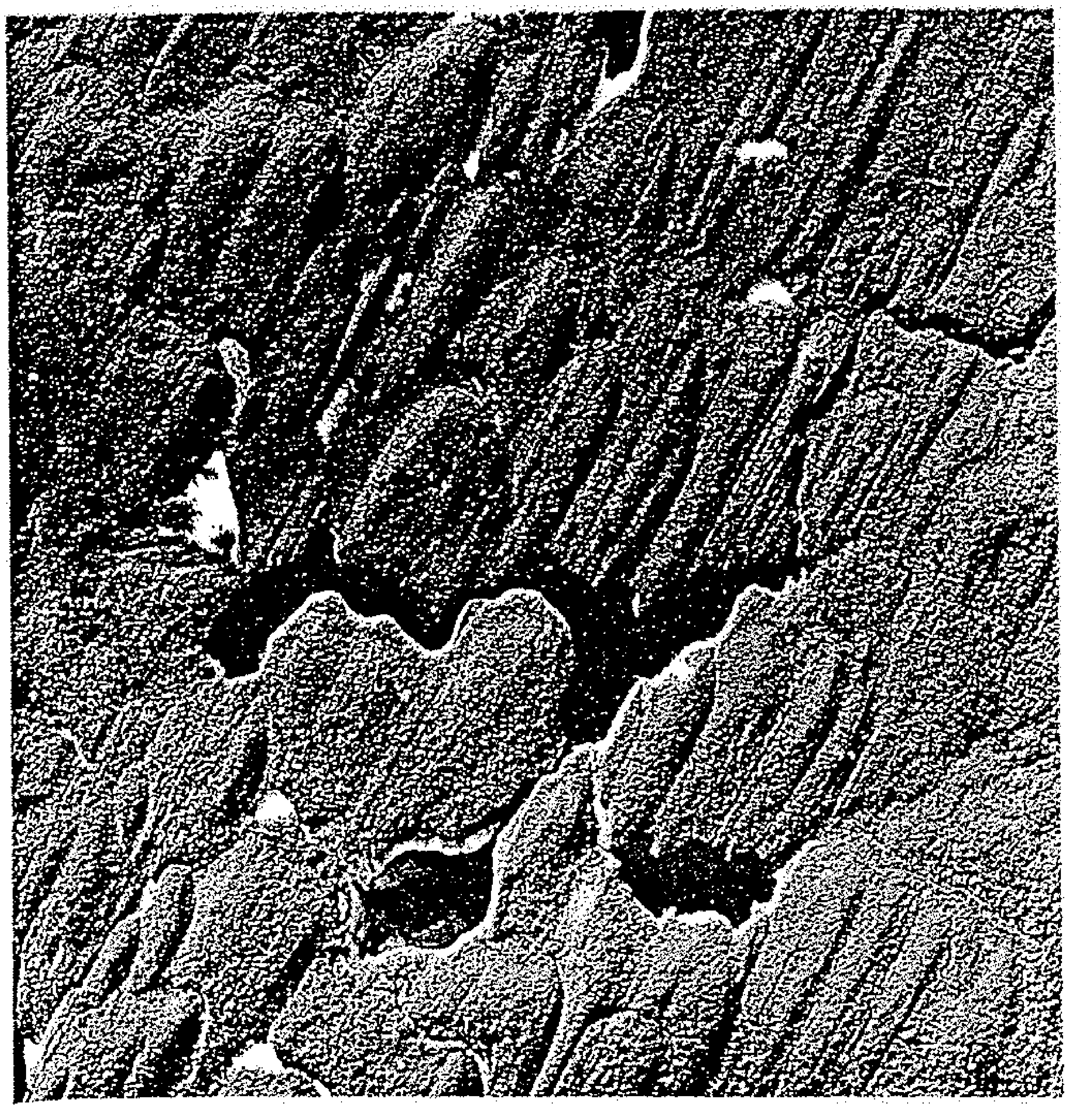
Fig. 272. Crescentic fractures of variable shapes. Southern Norway





14.16

Glacier ice has left this high polish on the granitic bedrock of the Sierra Nevada Mountains, California. Subsequent weathering has destroyed a part of the polish leaving a rough and irregular surface. (Photograph by U.S. Geological Survey)



15.23 This drumlin field shows the streamlined form of these ice-molded features. Ice movement was from upper right to lower left. Near Carp Lake, north-central British Columbia; width of view is about 10 km. [U.S. Army Air Force.]

Figure 10-18

Glacial polish, striations, and grooves formed on a fine-grained granite surface, Sequoia National Park, California. The direction of ice movement was diagonally toward the right and away from the camera. Since the glaciation, the rock has been disrupted into angular blocks by repeated frost action. [Photo by F. E. Matthes, U.S. Geological Survey.]

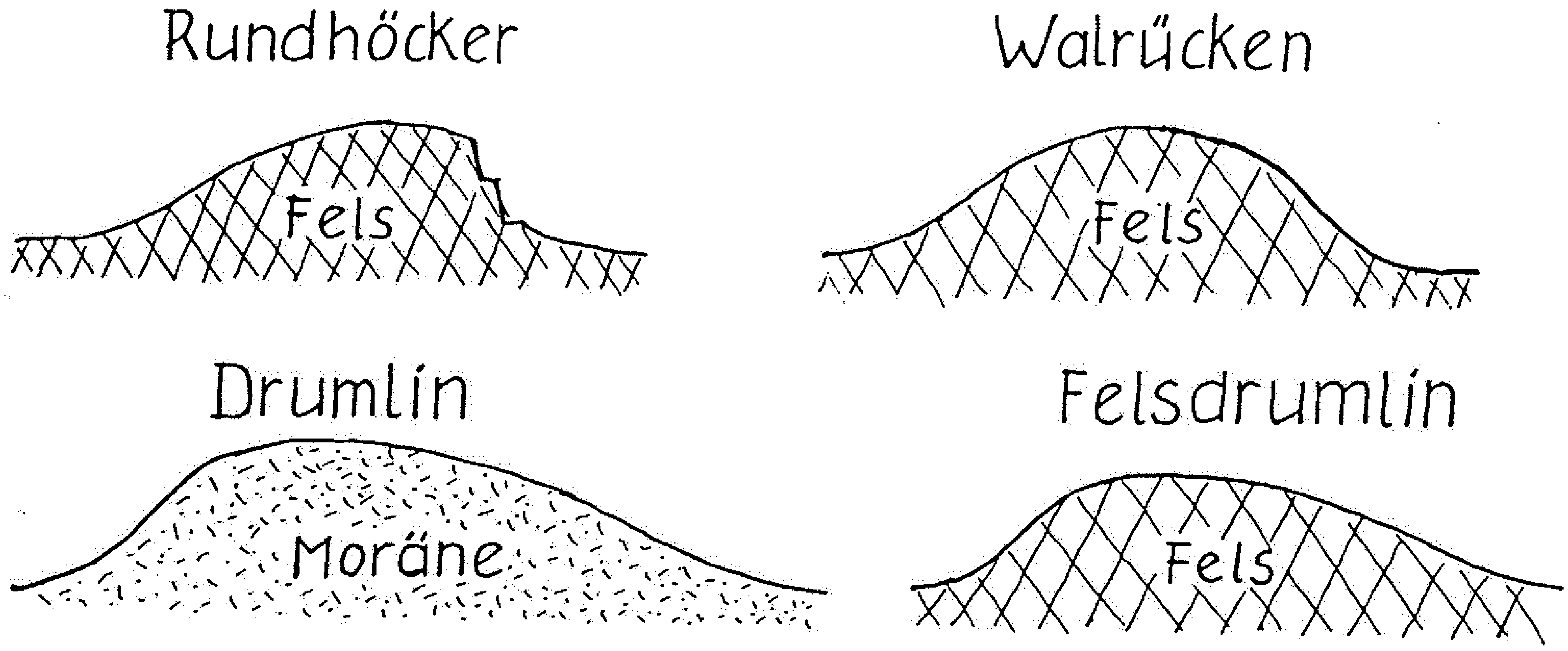


Abb. 7. Rundhöcker, Wallrücken, Drumlin, Felsdrumlin.

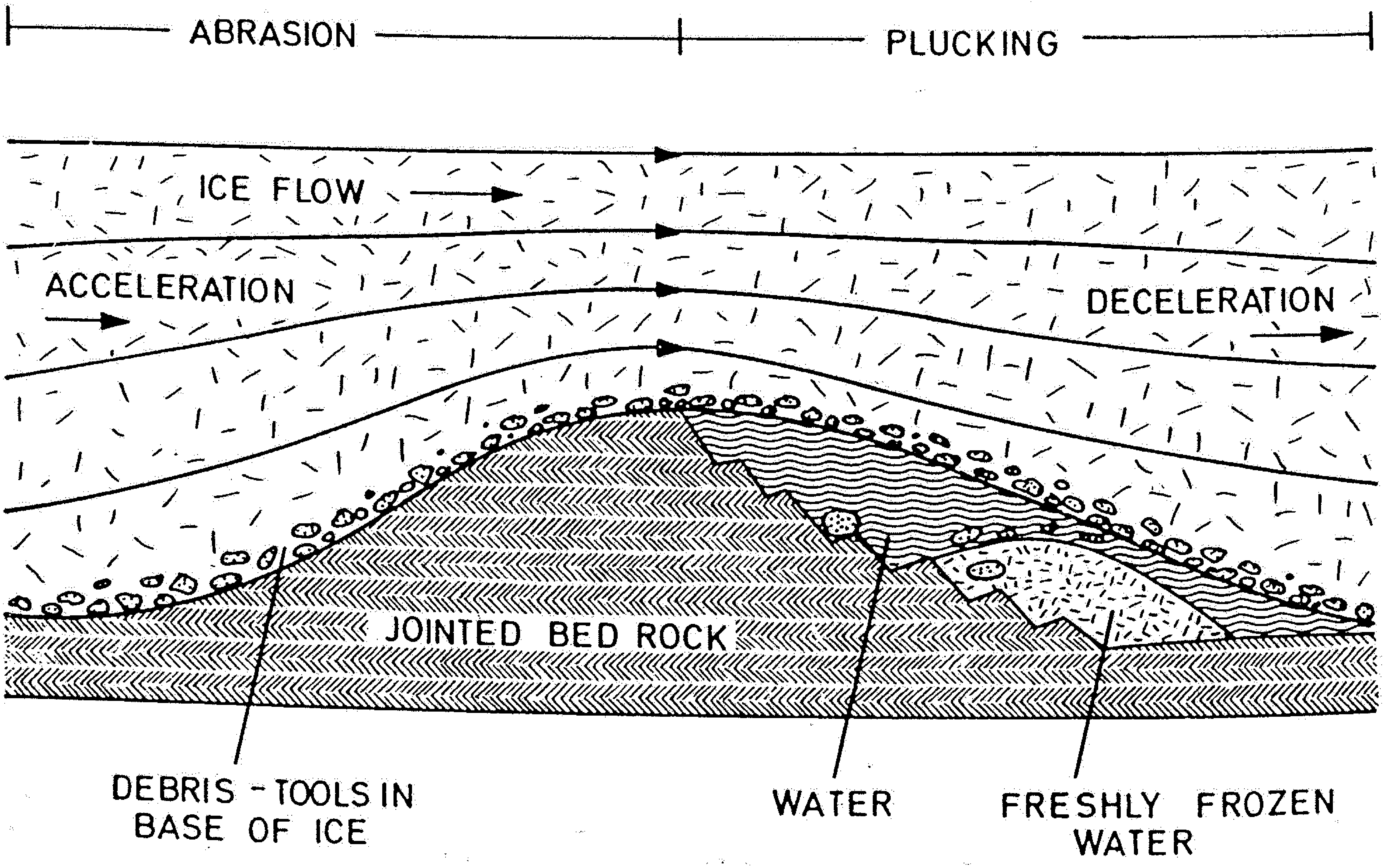
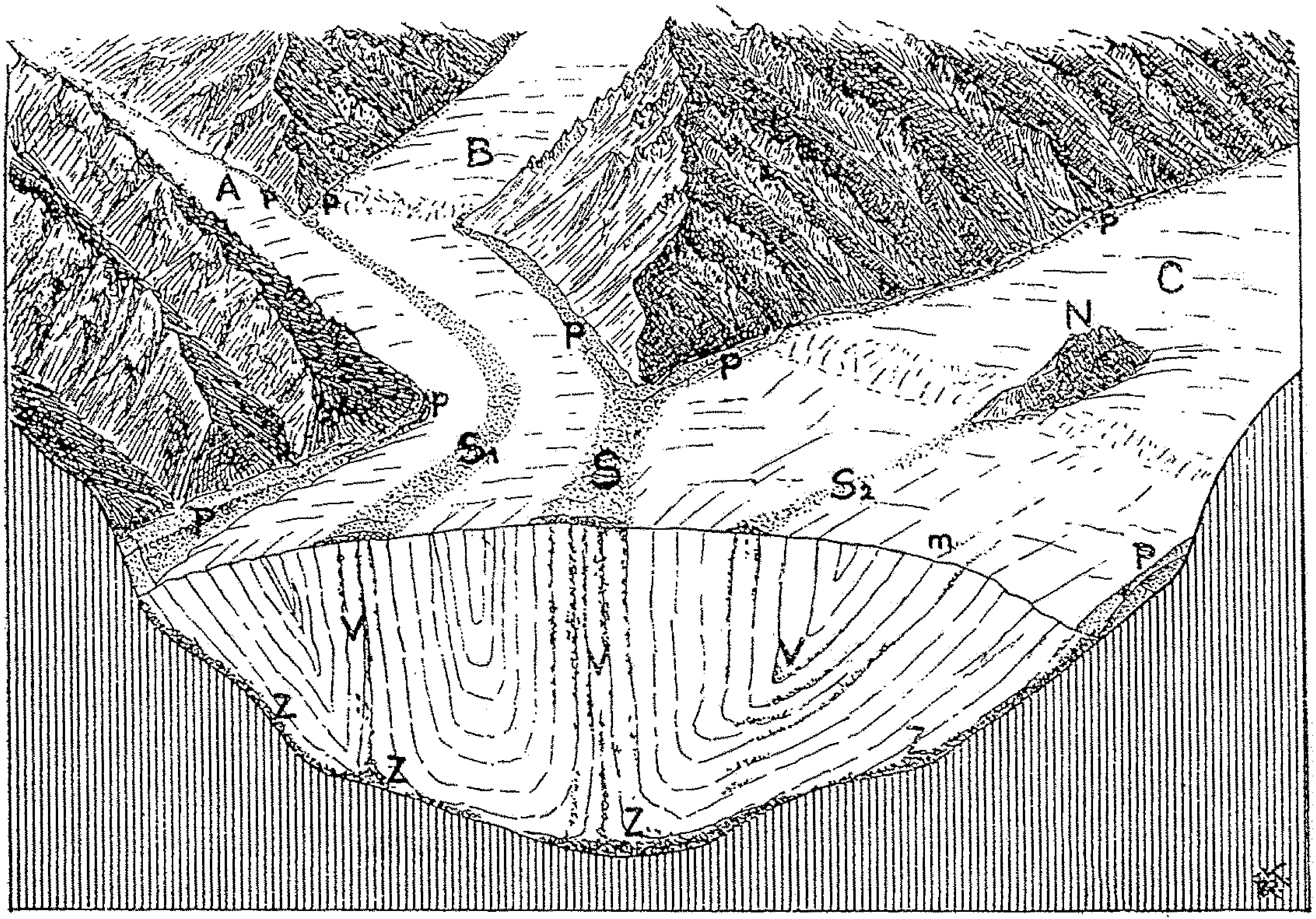
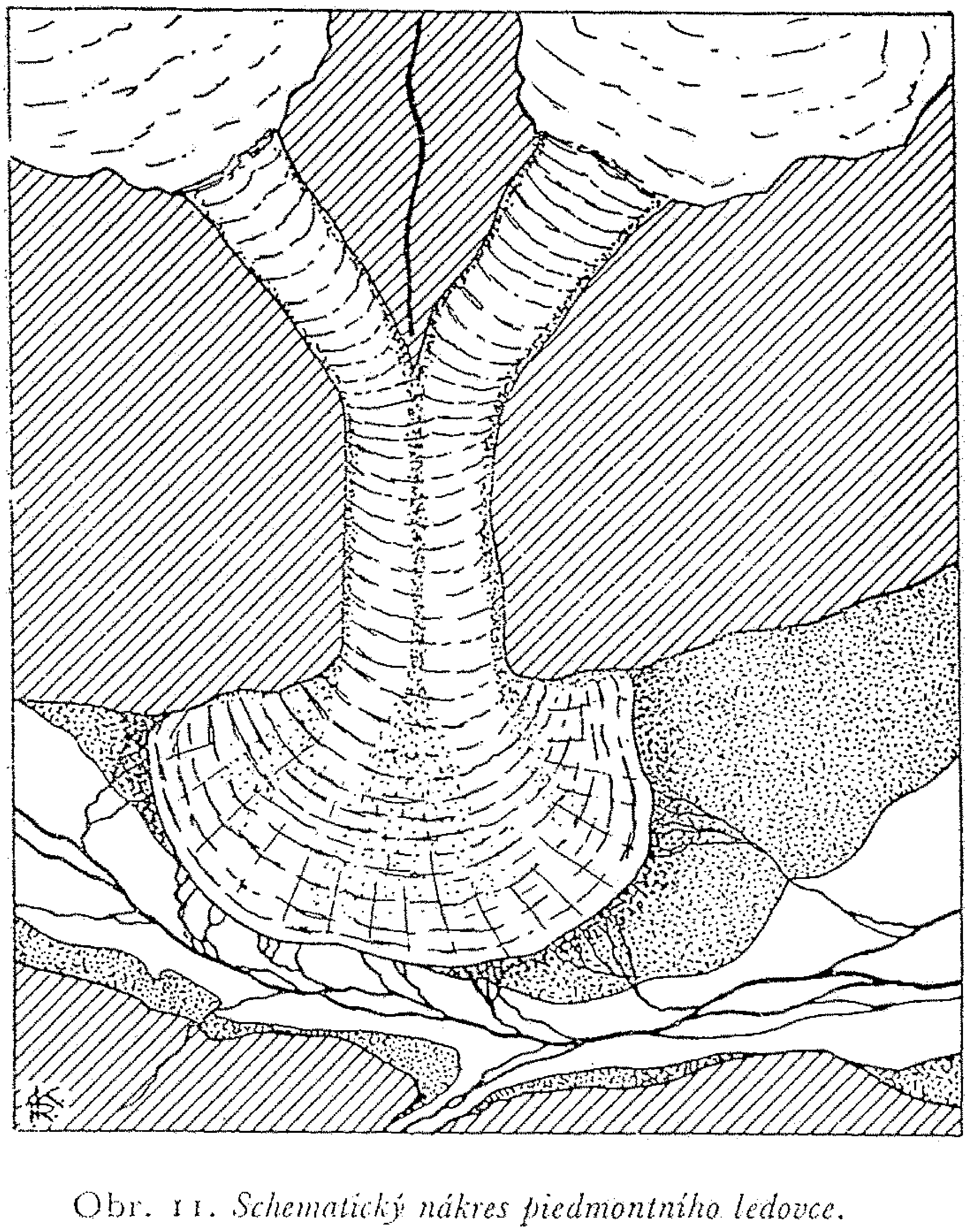


Fig. 268. Schematic representation of the process of plucking and abrasion on the bedrock of a glacier. (Modified after Allen 1970)

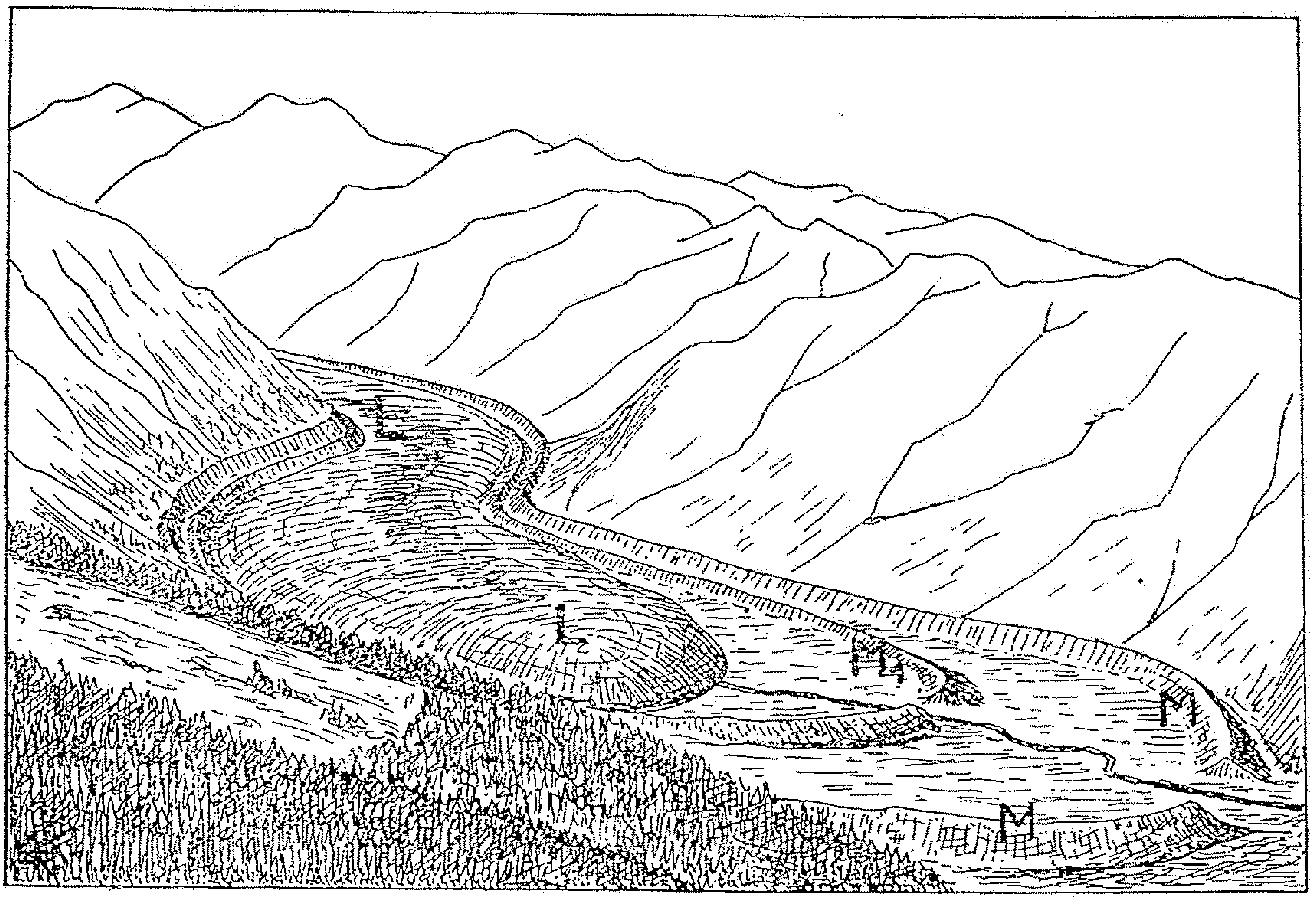


Obr. 35. *Perspektivní pohled na údolní ledovec vzniklý spojením tří menších ledovcových splazů A, B, C a schematický průřez ledovcem. P = morény postranní; S, S_1 = morény střední vzniklé spojením postranních morén dvou splývajicích splazů; S_2 = střední moréna tvořící se z nunataku N, skalky, jež vyčnívá ze skalního podkladu nad povrch splazu C; V = morény unitřní; Z = moréna spodní neboli základní; m = střední moréna vznikající ablací (roztáváním) ledovce z morény vnitřní. V příčném řezu ledovcem vidíme obloukovité pruhování (ogivi) ukazující na splynutí ledovce ze tří splazů.* (Upraveno podle E. de Martonna.)



Obr. 11. *Schematický nákres piedmontního ledovce.*

FIGURE 13–8 *Steele glacier, Yukon Territory, Canada. A surging glacier.* (*Photo by Austin Post, U.S. Geological Survey.*)



Obr. 38. *Schematické znázornění ustupujícího údolního ledovce L zanechávajícího vedle čelní (koncové) morény M ústupovou morénu M_1.* (Podle F. E. MATTHESE.)

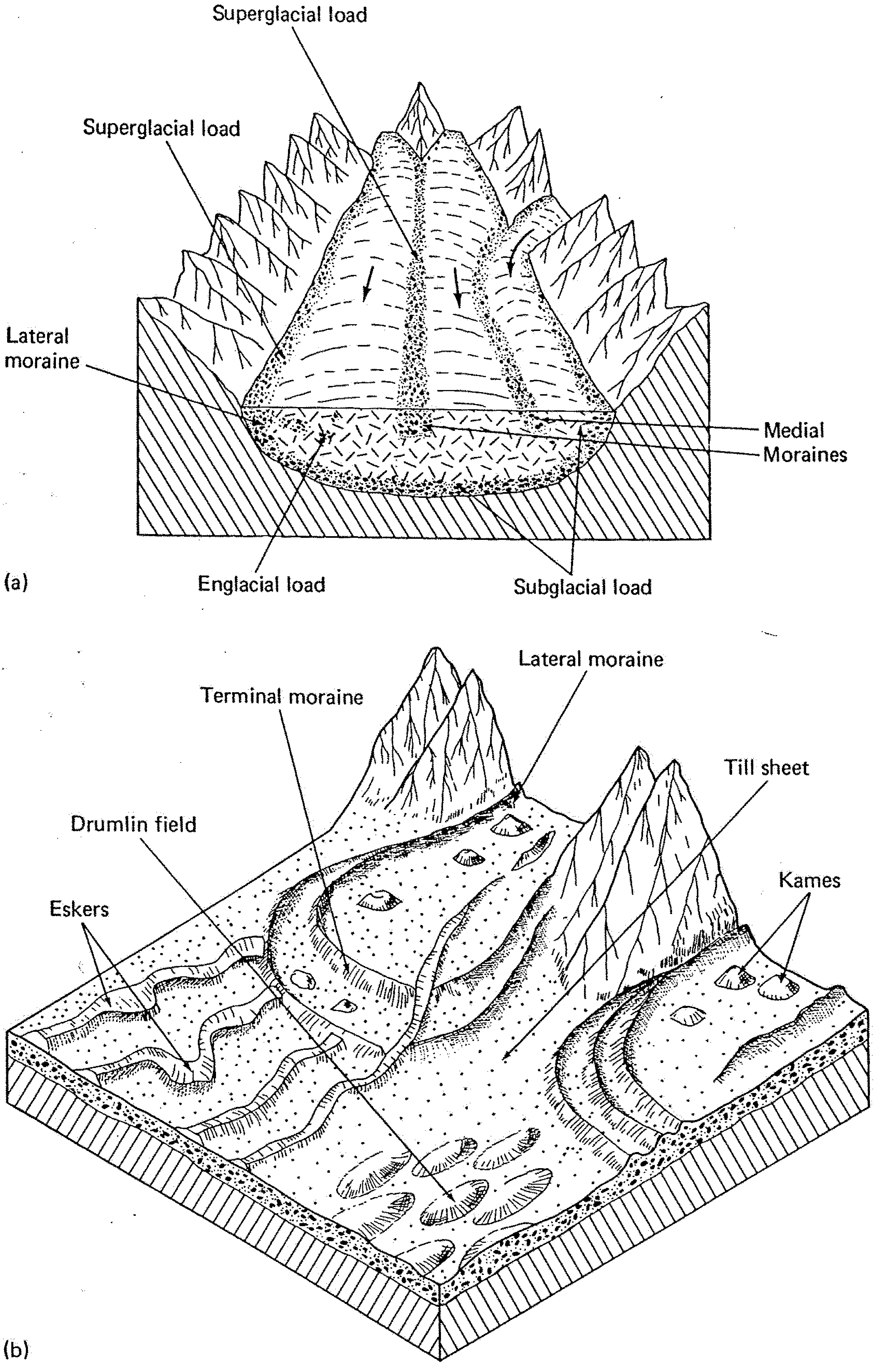
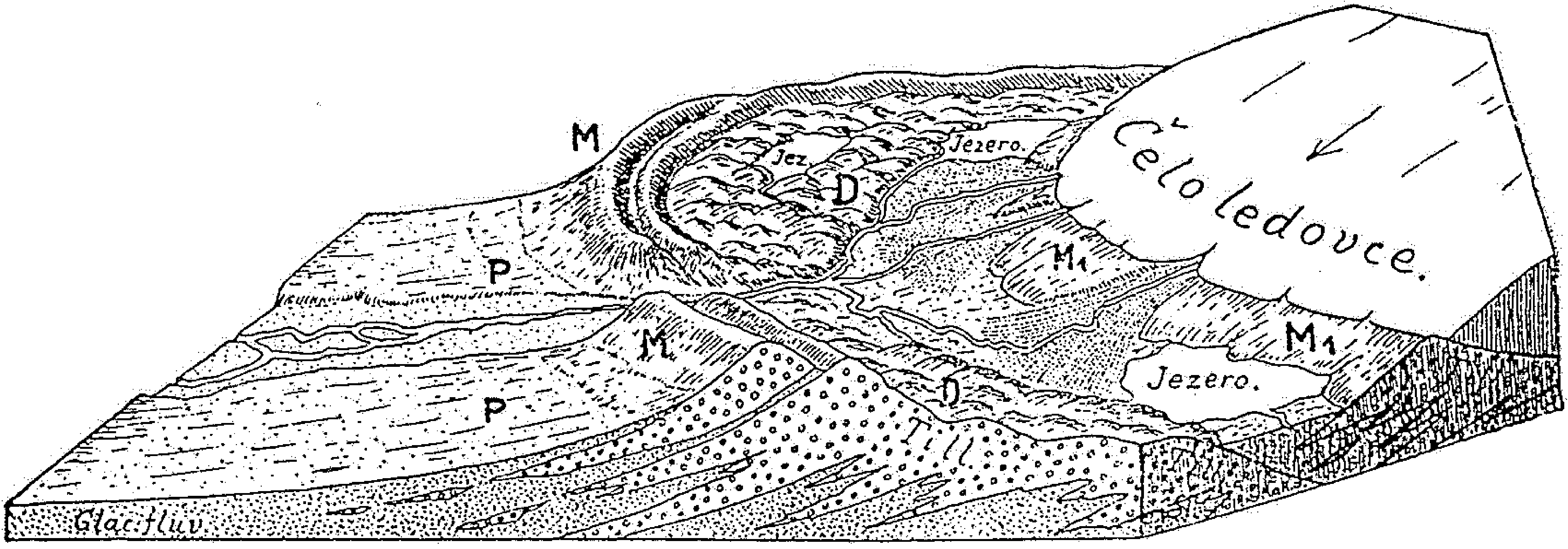


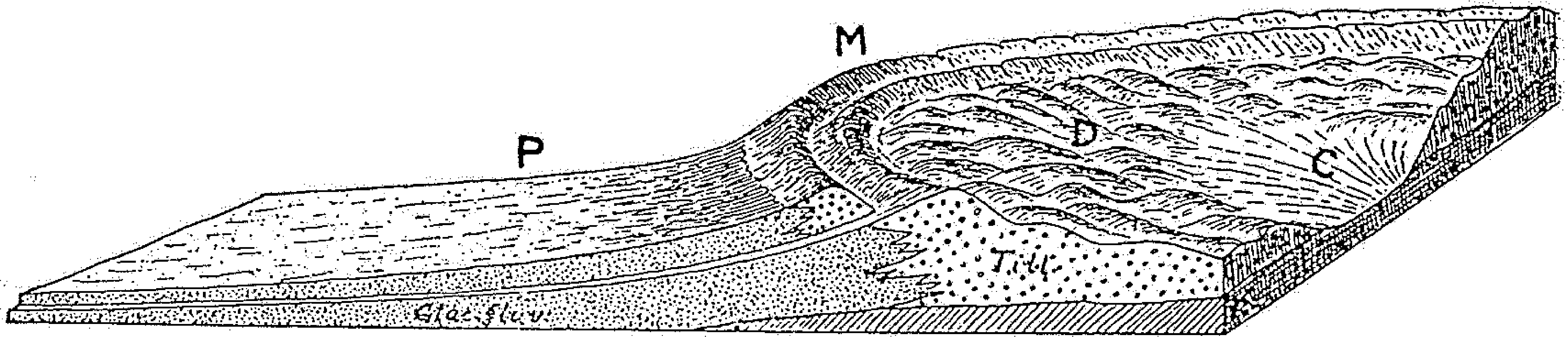
Figure 7–7 Schematic diagrams showing (a) where sediment is entrained in a glacier and (b) the location and geometry of sediment bodies. (After Allen, 1970a, pp. 228–229.)

Figure 10-16

Moraines of the Northern Iliamna glacier, Alaska. In the middle background is the present ice margin, and in the foreground a series of semicircular terminal moraines, called recessional moraines, deposited as the ice melted back from its farthest extent. [Photo by B. Washburn.]



Obr. 37. *Schema ústupu údolního ledovce. Vlevo dvojitý val starší, koncové morény M složený z tillu, za ním spodní neboli základní moréna s drumliny D. Vpravo těsně u ledovce se tvoří mladší, ústupová moréna M_1. Ledovcový potok se proerodoval valem čelní morény a pokračuje dále v uloženinách glaciálního výplavu P.* (Podle G. Wagnera.)



Obr. 36. *T. zv. glaciální serie, jak se jeví po ústupu údolního ledovce. C = pánev splazová, D = spodní neboli základní moréna s drumliny, M = val čelních, koncových morén, P = přechodní kužel glaciálního výplavu tvořený glaciofluviálními nánosy.* (Podle A. Pencka a E. Brücknera.)

Abb. 34. Glaziale Serie nach PENCK & BRÜCKNER (1909: 16) und GERMAN (1968: 715) erweitert: SF 1 u. SF 2 – Schotterfelder von Endmoräne Em 1 und Em 2 ausgehend, S – Schotter, E – Endmoräne des weitesten Vorstoßes, eS – eisrandnahe Schmelzwassersedimente, T – Toteislöcher, V – Grundmoräne des weitesten Vorstoßes, Gm 1 u. Gm 2 – Grundmoräne zu Em 1 u. Em 2, VS – Vorstoßschotter, gs 1, 2 u. 3 – glazilakustrine Sedimente, th – Sedimente aus dem vorangegangenen Thermal, aM – Moräne der vorangegangenen Eiszeit, Tf – Torf, U – praequartärer Untergrund.

FIGURE 13–20
Till deposited by a valley glacier, West Walker River, Nevada. The largest boulders are nearly half a meter in diameter. (Photo by Eliot Blackwelder, Stanford University.)

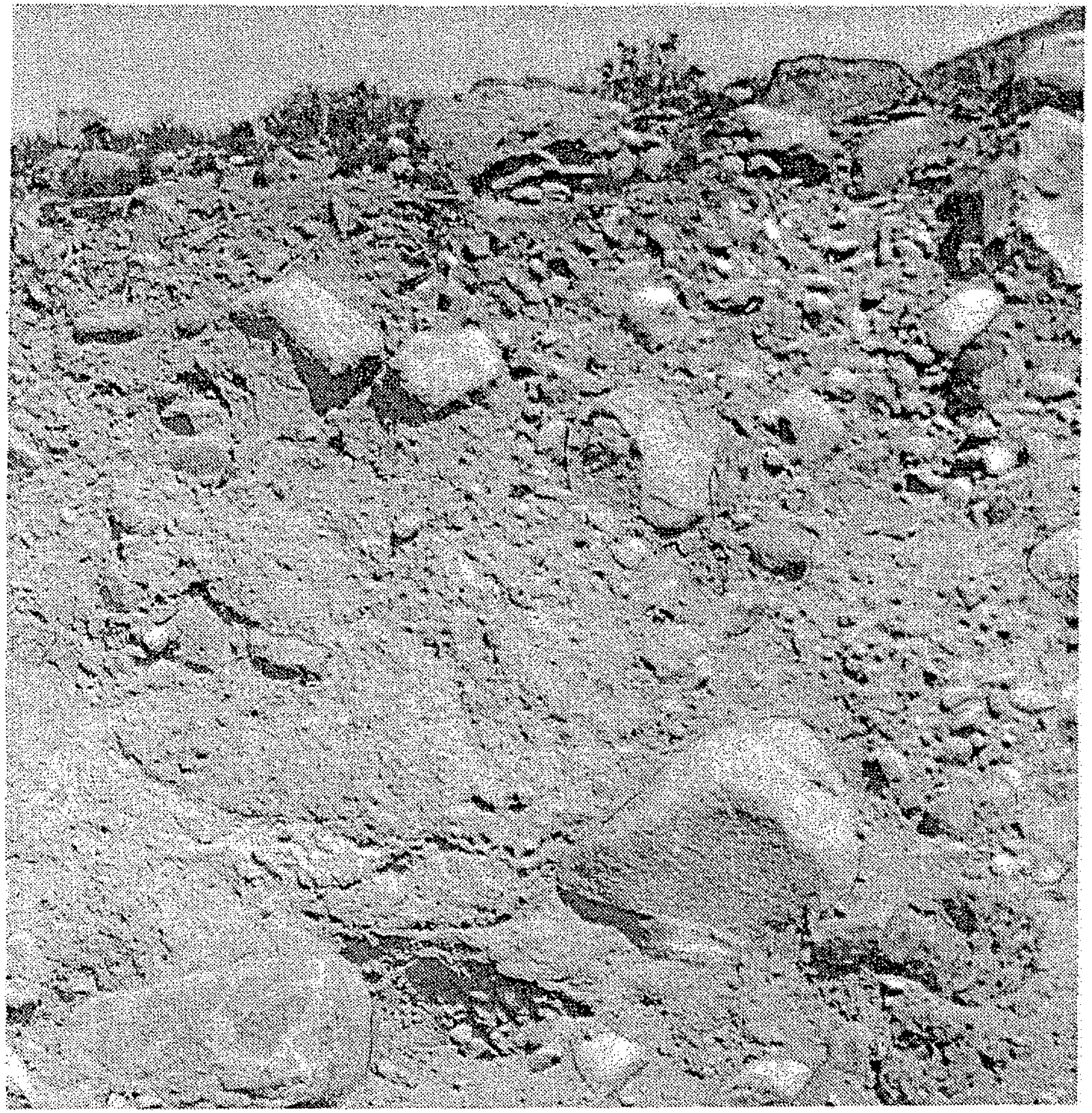
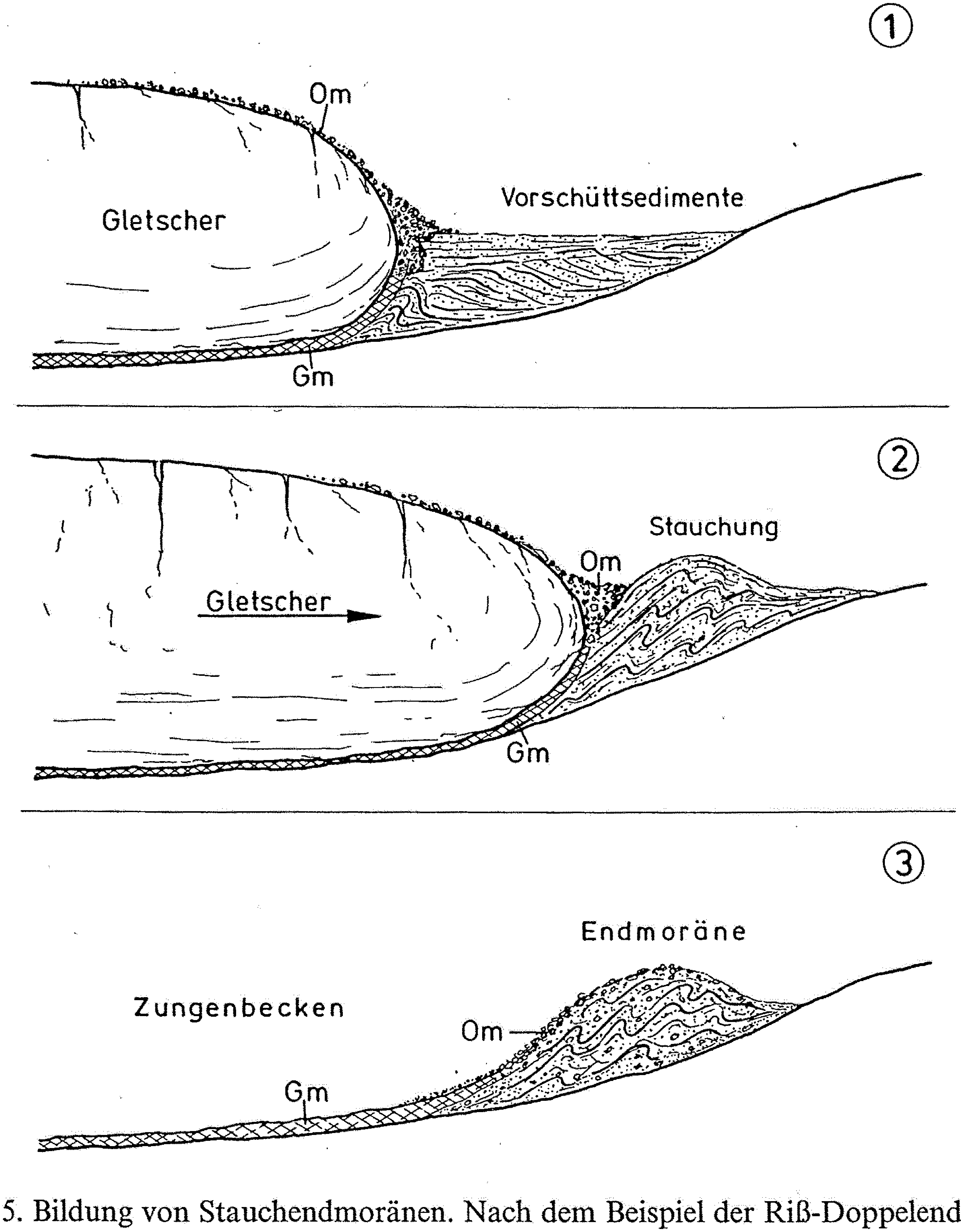


FIGURE 13–21
Silt-laden stream emerging from an ice tunnel in the front of a glacier, Tanana district, Alaska. (Photo by S. R. Capps, U.S. Geological Survey.)

FIGURE 13–25
Map of drumlins and sketch of ground moraine near Weedsport, New York. (From Weedsport quadrangle, New York, U.S. Geological Survey.)



bb. 15. Bildung von Stauchendmoränen. Nach dem Beispiel der Riß-Doppelendmoräne ei Bad Wurzach (Rheingletschergebiet) und nach Gripp (1929: 191).
) Ablagerung von Schotter und Sedimenten vor dem Gletscher; 2) Vorrücken des letschers und Stauchung der Sedimente, Bildung von Schollen und Falten, darüber bermoräne; 3) Nach dem Zurückschmelzen des Gletschers
M – Grundmoräne, OM – Obermoräne.

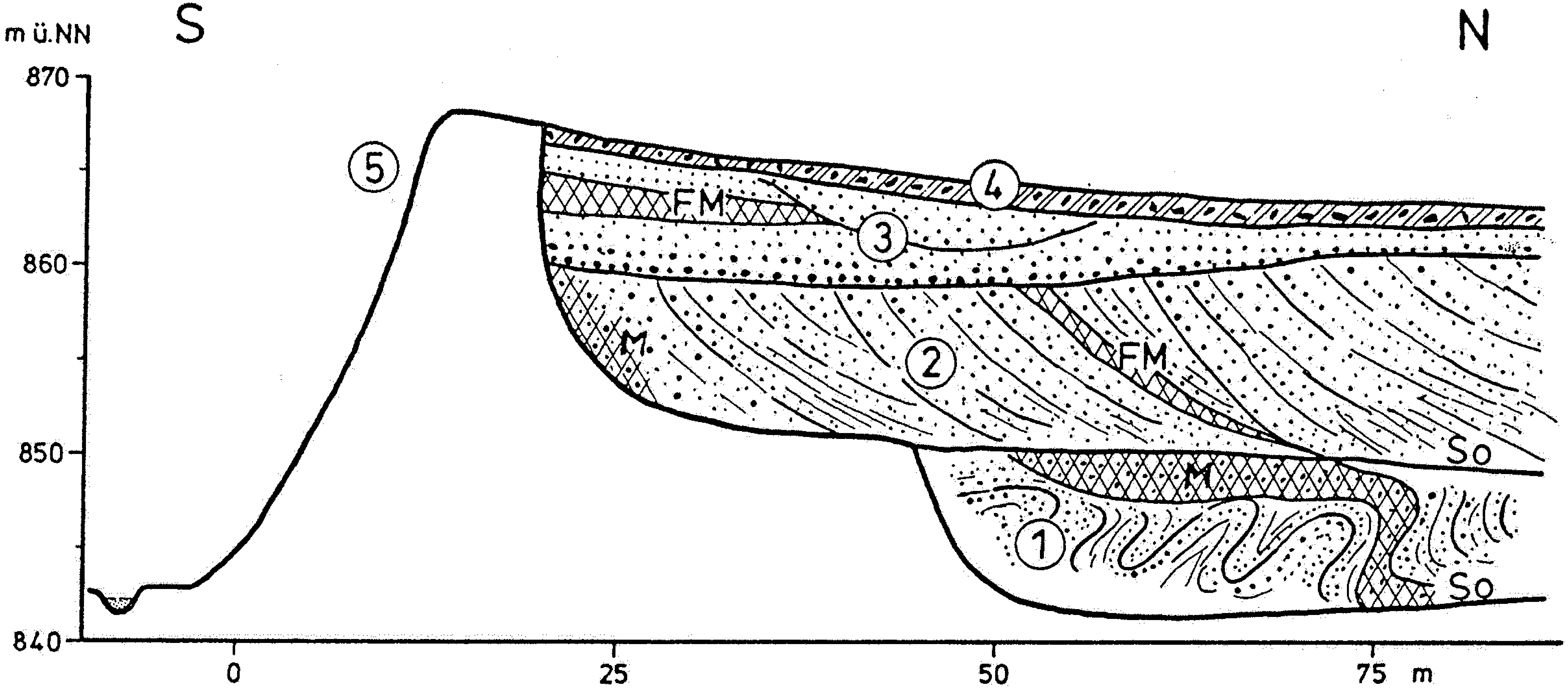
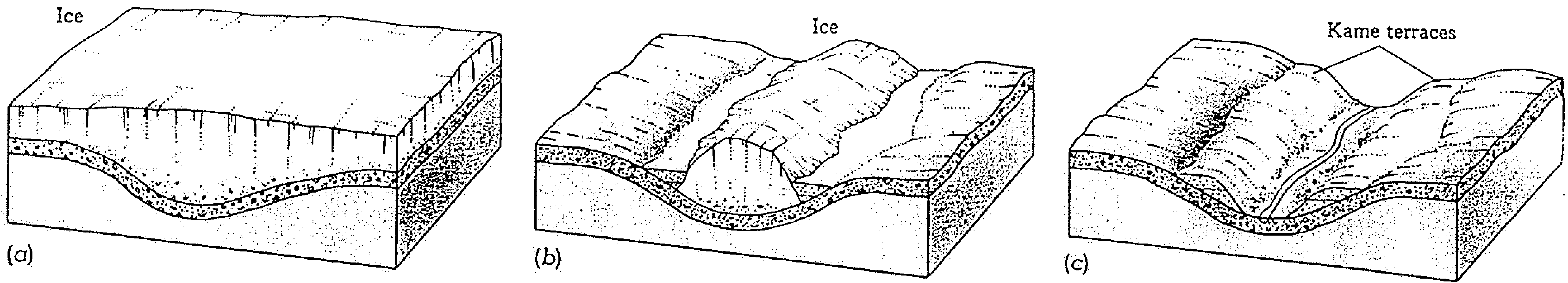
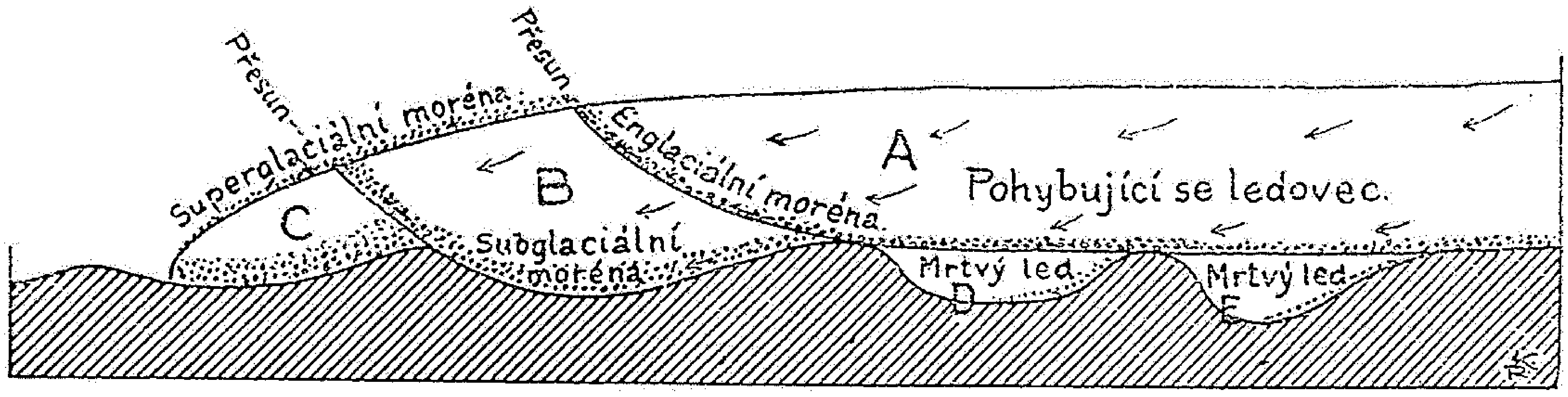


Abb. 26. Kames-Delta, Südteil der Kiesgrube Langenordnach bei Neustadt im Hochschwarzwald (Würm-Hochstand). So – Sohlen der Kiesgrube.
1) Stauchmoräne eines ersten, weiteren Vorstoßes. Sand und Kies mit Moräne (M); 2) Schräge Deltaschichtung (forset beds) aus Kies, Sand und Silt mit einer Lage aus Fließmoräne (FM), im S Moräne (M), vielleicht Grundmoräne? 3) Horizontale Deltaschichten (topset beds) aus Grobkies mit einer Lage aus Fließmoräne (FM); 4) Periglaziale Fließerde; 5) Steilhang = ehemaliger Gletscherrand (Eiskontakt).



15.29 The sequence in the development of a kame terrace. (*a*) Ice wasting from an irregular topography lingers longest in the valleys. (*b*) While the ice still partially fills one of these valleys, outwash may be deposited between it and the valley walls. (*c*) The final disappearance of the ice leaves the outwash in the form of terraces along the sides of the valley.



Obr. 42. *Vznik vnitřní (englaciální) a svrchní (superglaciální) morény v čele pevninského ledovce. Ledovec se v čele roztrhává v kry, které se přes sebe přesunují. Některé, vmáčklé do nerovného podkladu (D, E), zůstávají ležet jako mrtvý led. Materiál spodní (subglaciální) morény se dostává při přesunu ker dovnitř a na povrch ledovce.* (Podle F. T. Thwaitese.)

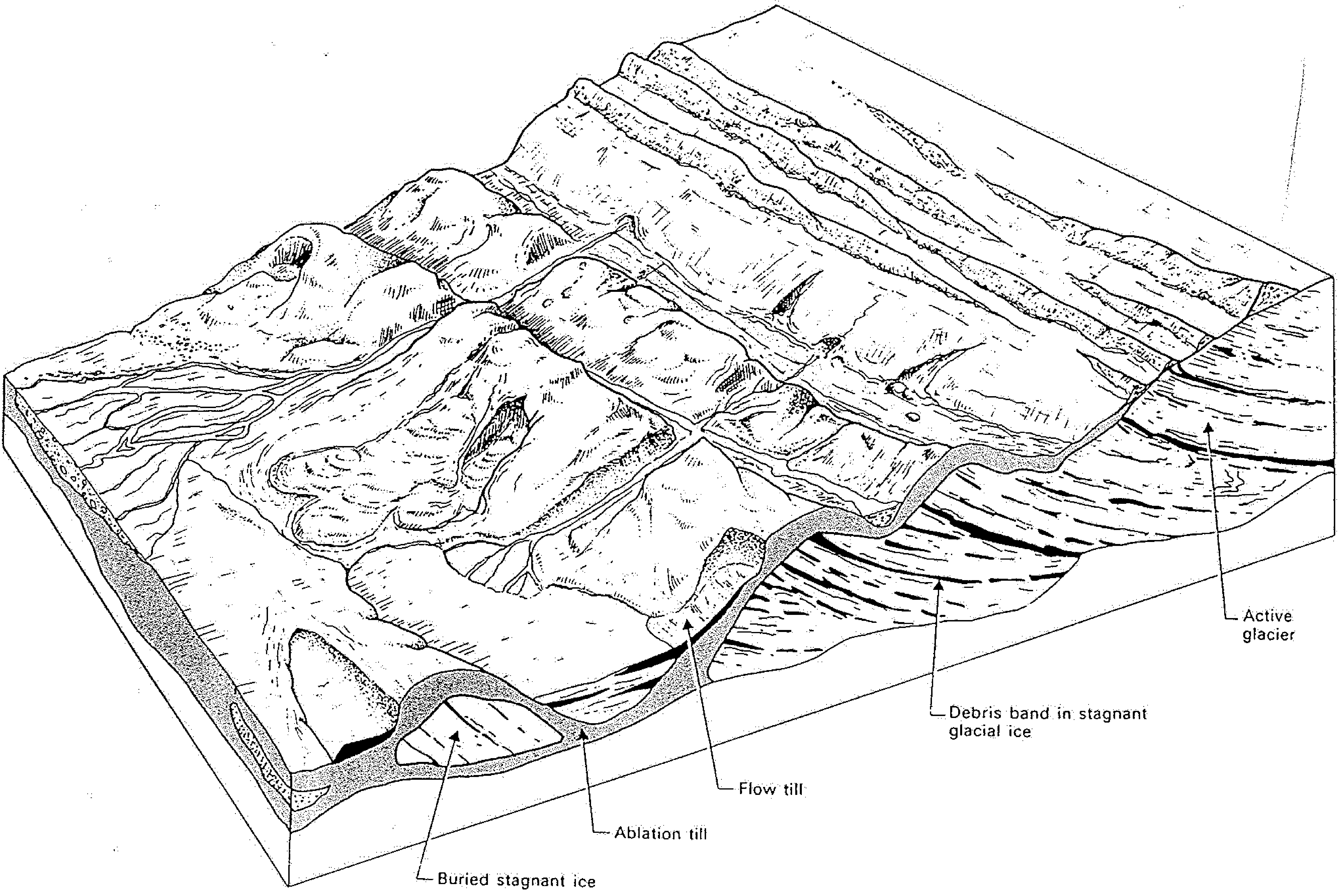
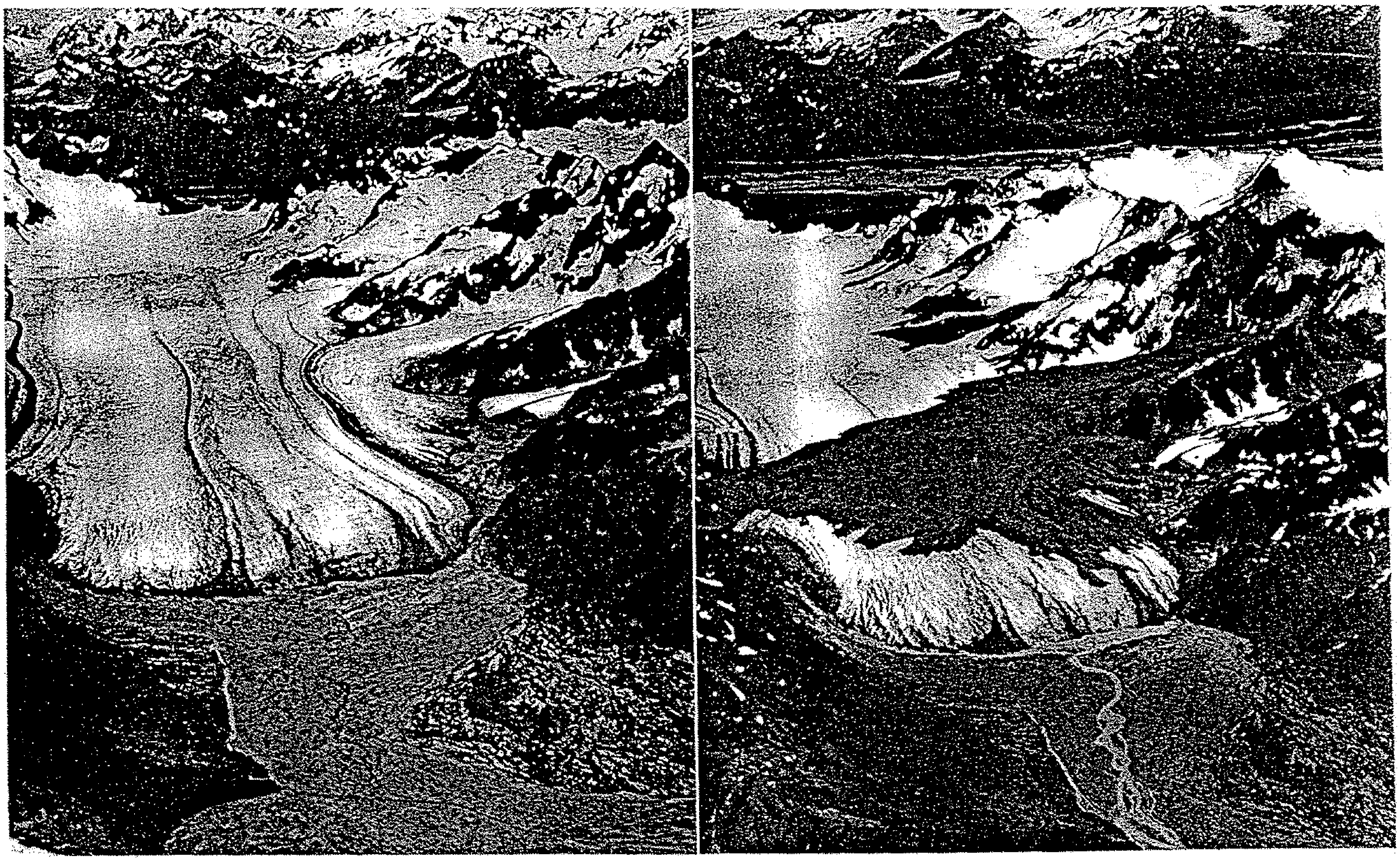


Fig. 13.3. Supraglacial to ice-contact proglacial zones of a glacier whose margin is gradually retreating, and which is thermally cold at the margin. Subglacial material is brought into the glacier by basal freezing and thrusting. This material is released at the surface as ablation till, as the enclosing glacial ice gradually melts. Ablation till is reworked by flowing meltwater, and may slump downslope to form flow tills. Beds of flow till can be intercalated with proglacial stream or lake deposits, and may be extensively reworked (modified from Boulton, 1972).



Sherman Slide

(*a*) before (*b*) after

12.1 (*a*) On August 26, 1963, 7 months before the Good Friday earthquake in southern Alaska, the Sherman glacier appeared like this in the camera of Austin Post of the U.S. Geological Survey. (*b*) The earthquake of March 24, 1964, set off a number of major rock slides, one of which occurred across the Sherman glacier. Post's photograph of August 24, 1964, shows the slide as a 4-km-long tongue of dark debris against the bright background of the glacier.

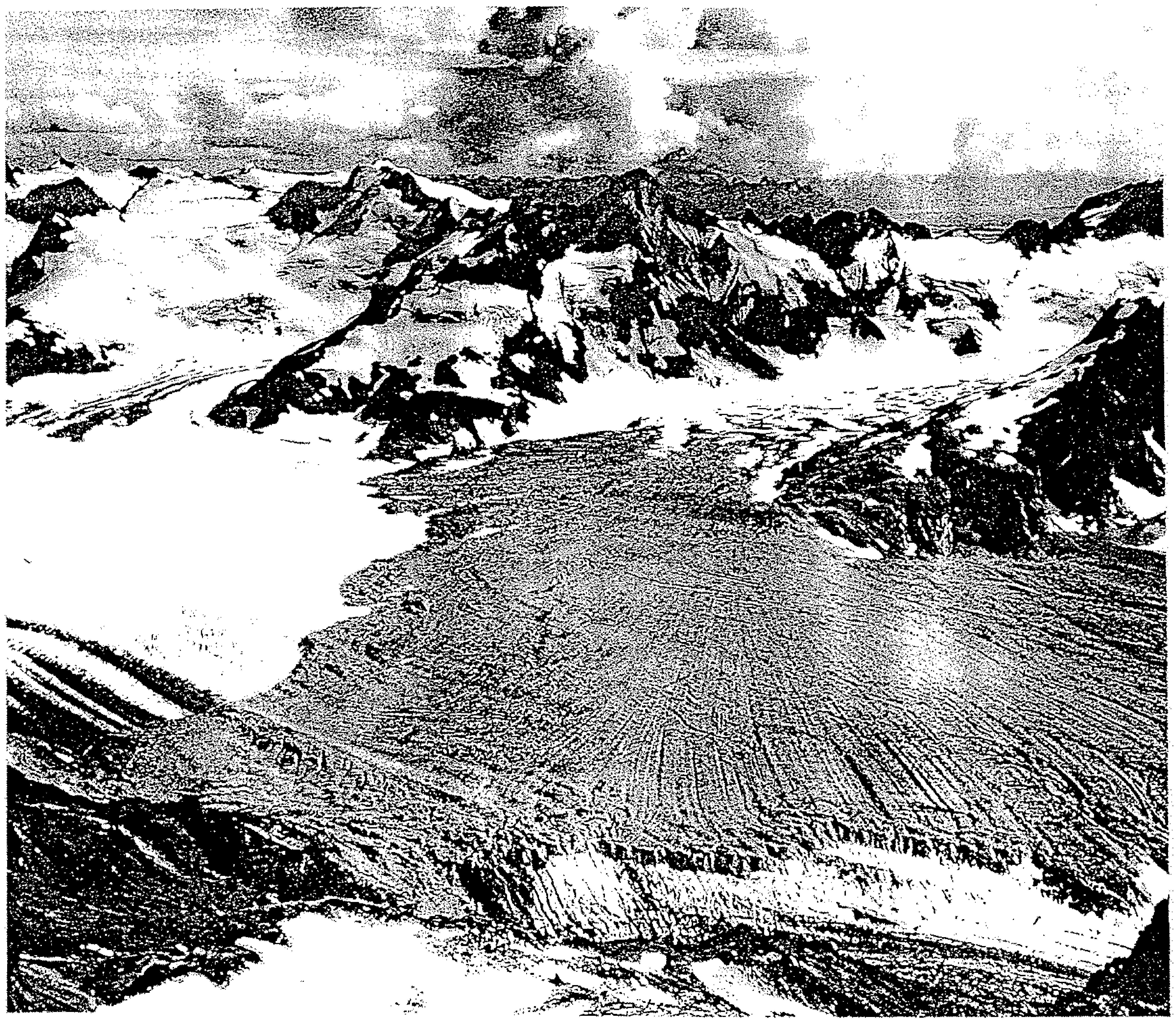


Figure 8.15 Beginning of a snow avalanche, set off by the slight disturbance of a skier passing over an unstable patch of snow. Photograph by Ludwig, courtesy of U.S. Forest Service/USGS Photo Library, Denver, CO.

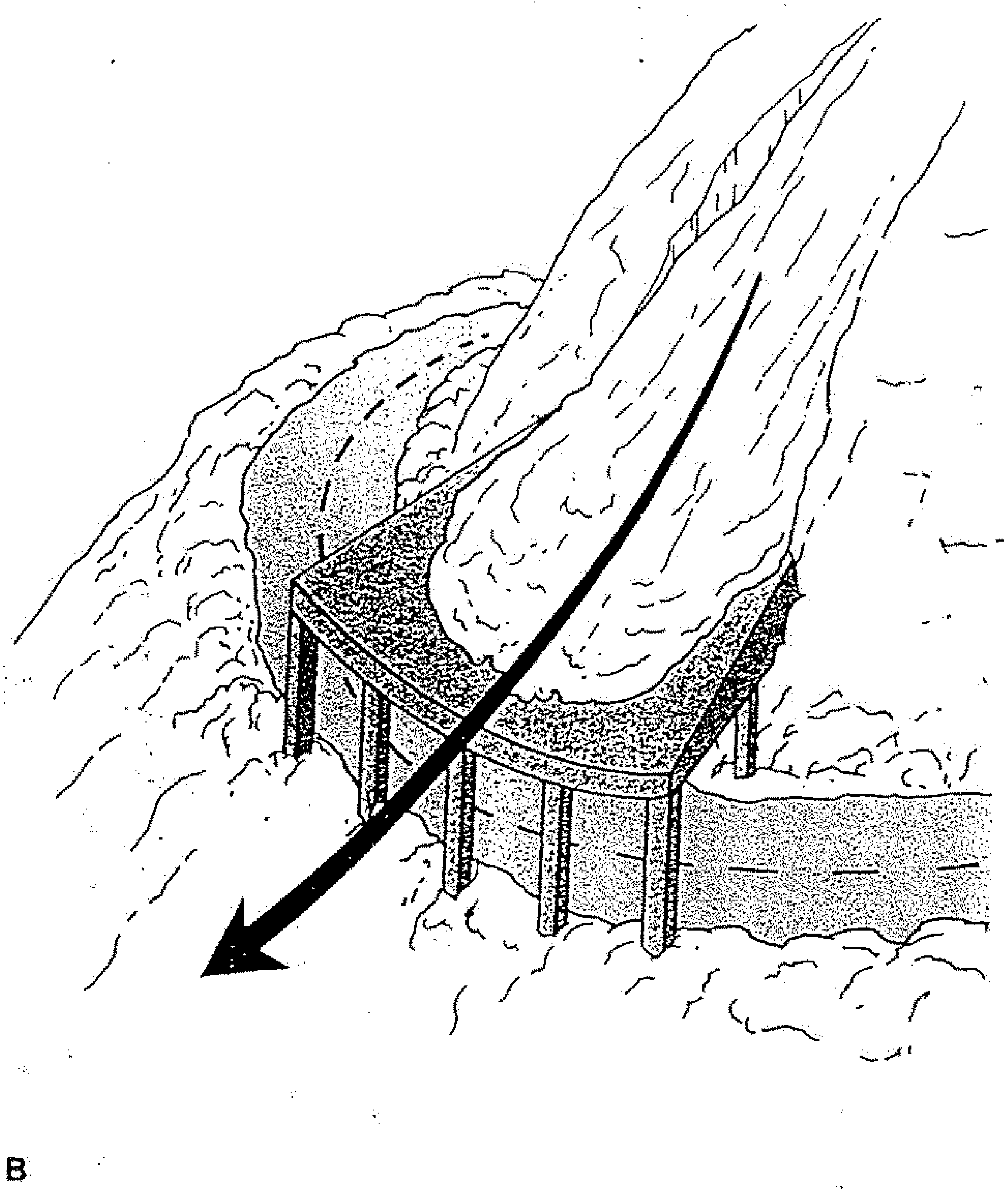


Figure 8.19 Measures to reduce the consequences of slope instability. (*A*) Chain-link fencing draped over roadcut to protect road from rockfall. (*B*) Shelter built over railroad track or road in snow avalanche area.

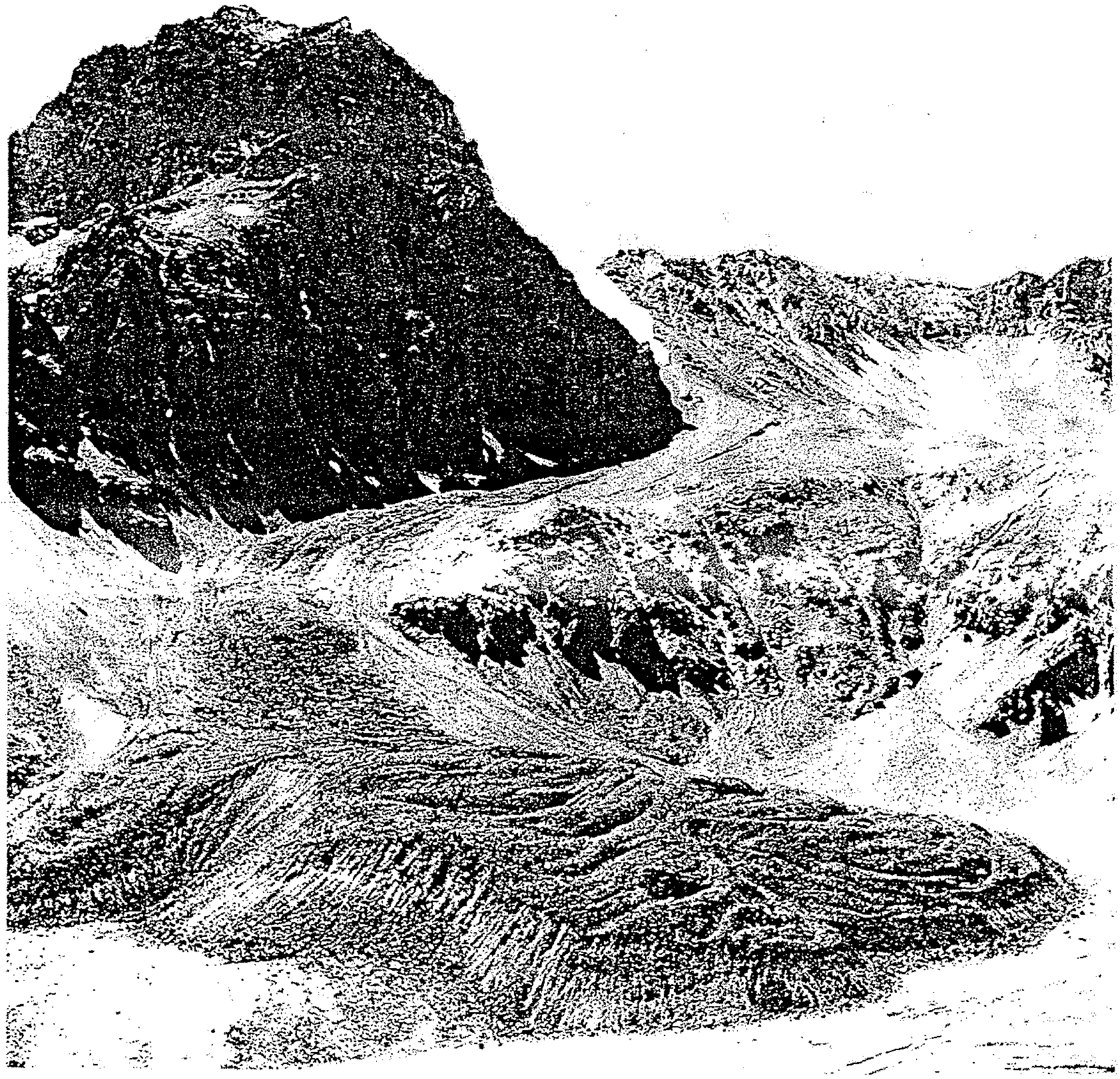


FIGURE 11–13 *Rock glacier on Cerro del Plomo, Andes of Chile. Note the smooth talus at* [illegible]

Fig. 276 Possible flow paths of supraglacially and subglacially derived debris through a glacier transporting system. On the left are the clast shape and textural characteristics of the debris types which form the primary source for the various til
Processes during the depositional phase frequently p
secondary modification of the texture. (After Boulton 1

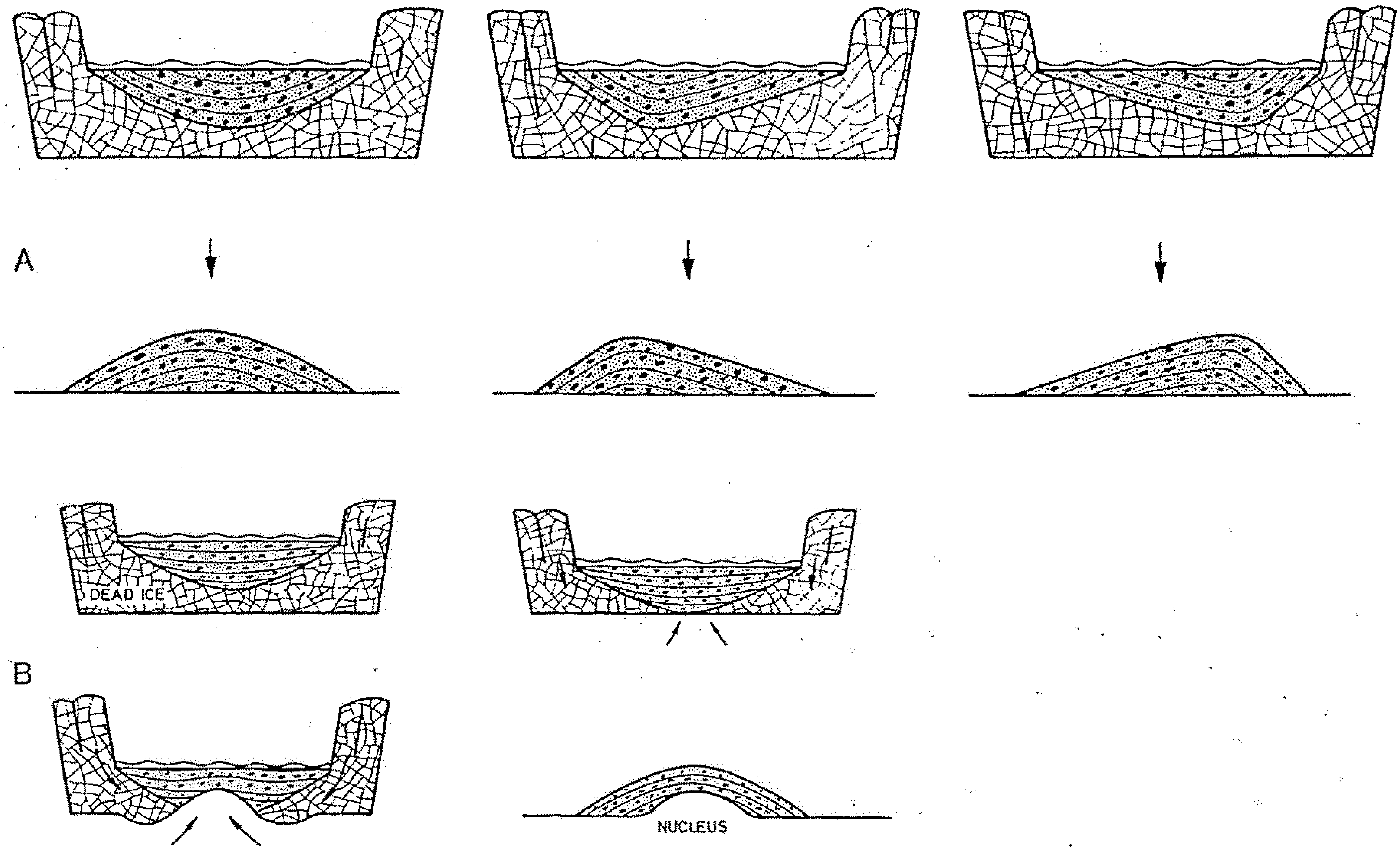


Fig. 283. Scheme showing the formation of kames. A Development of kames without a nucleus in dead ice. B Development of kames with a nucleus. (Modified after Keller 1952)

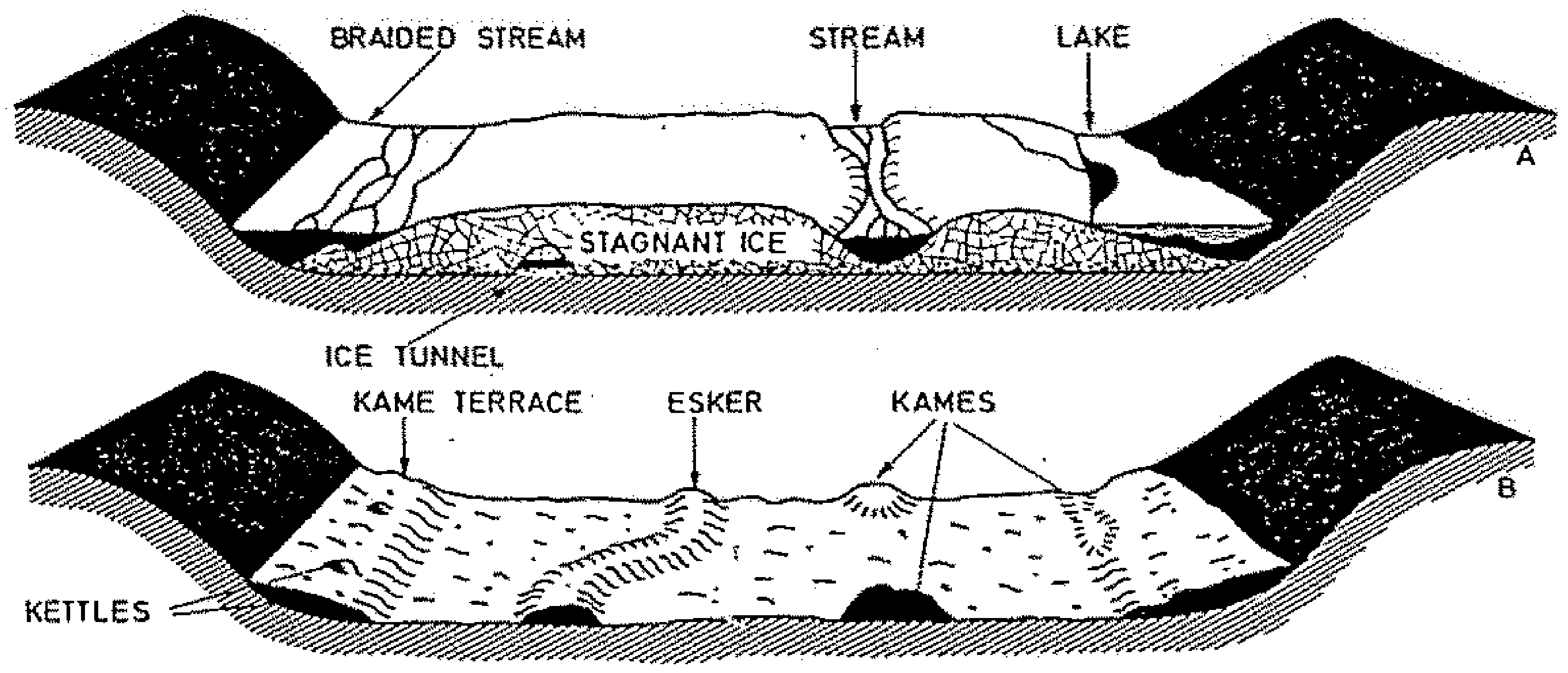


Fig. 284. Genesis of various kinds of bodies made in an ice-contact stratified deposit. (Modified after Flint 1957)

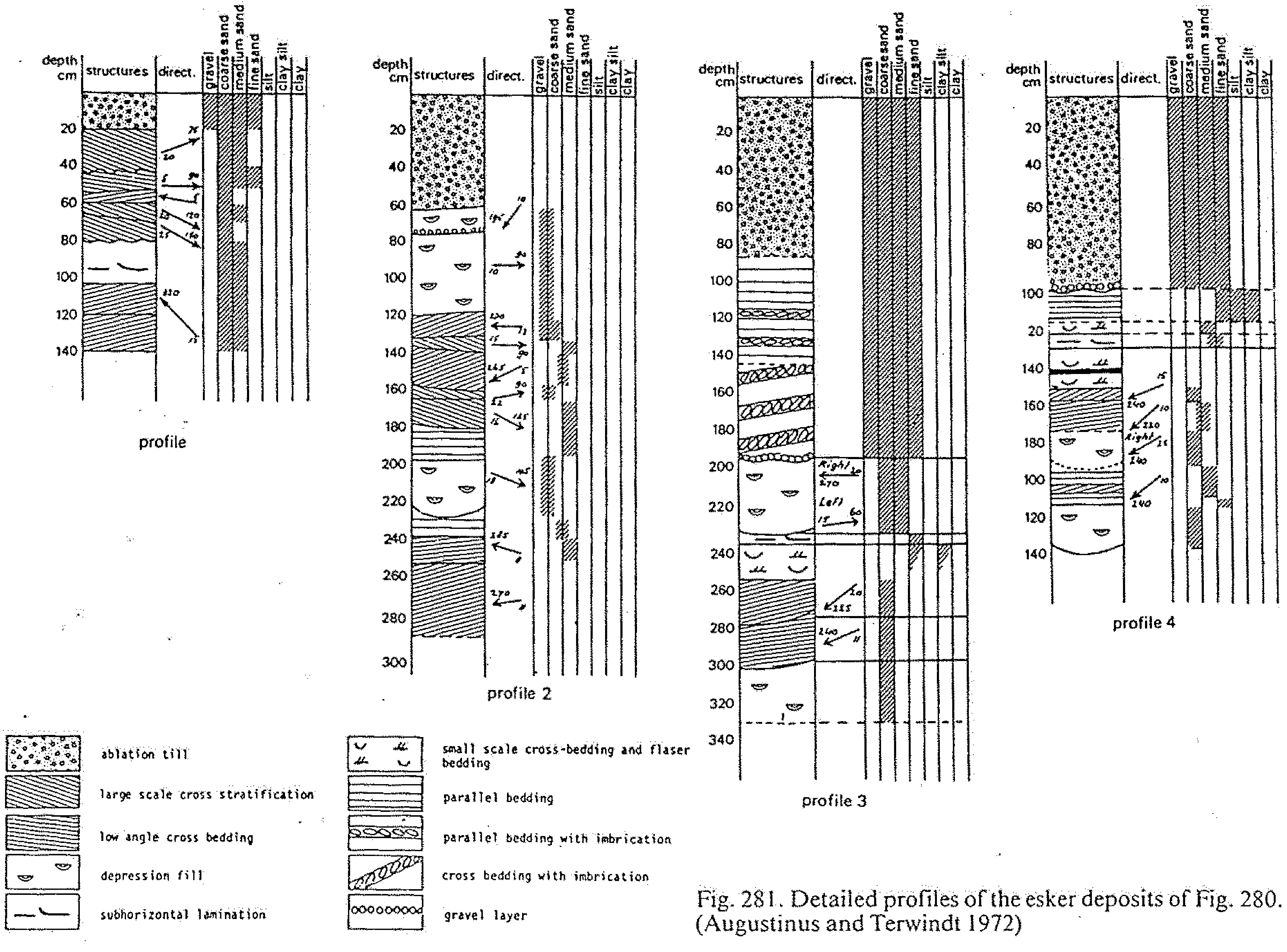


Fig. 281. Detailed profiles of the esker deposits of Fig. 280. (Augustinus and Terwindt 1972)

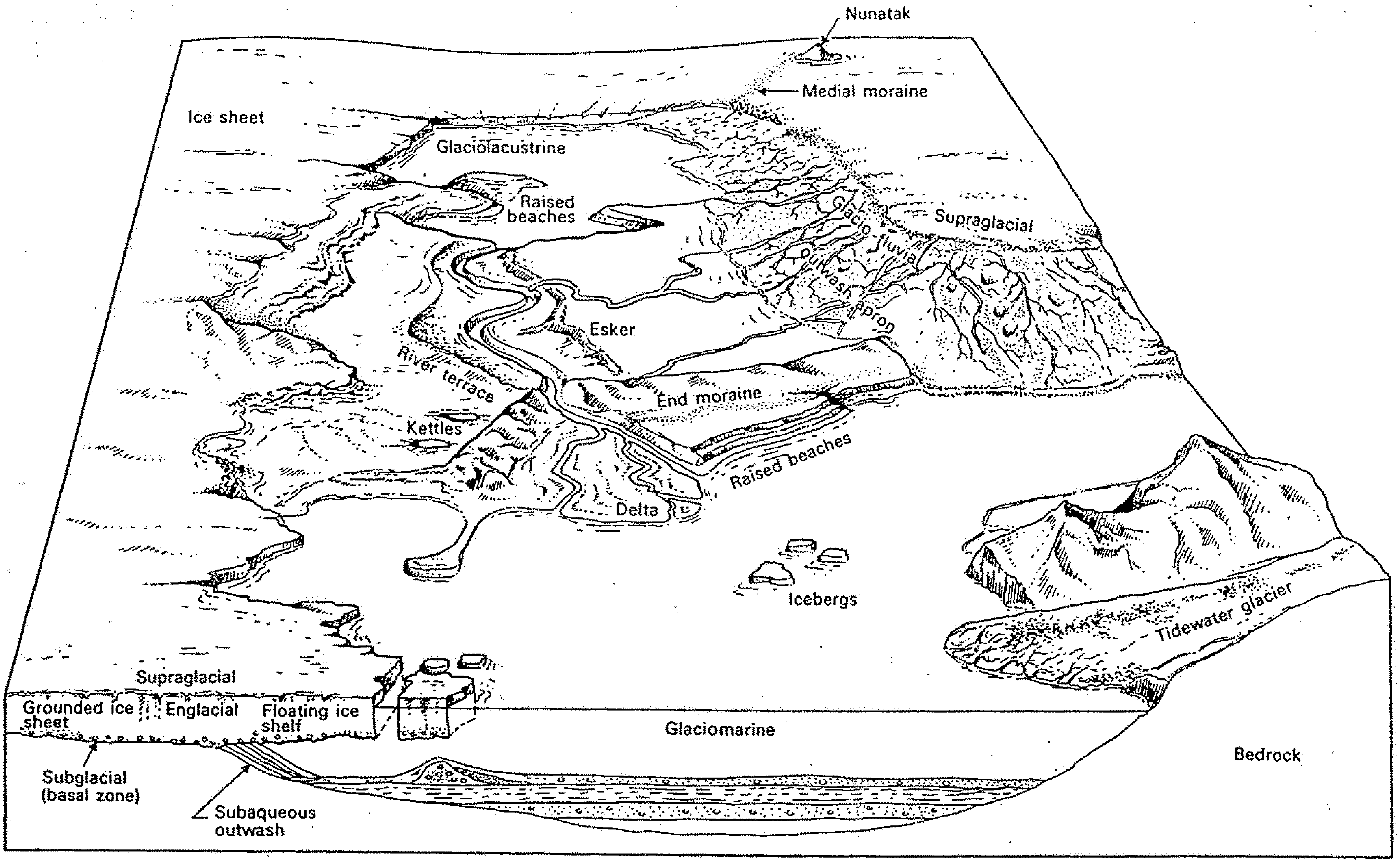
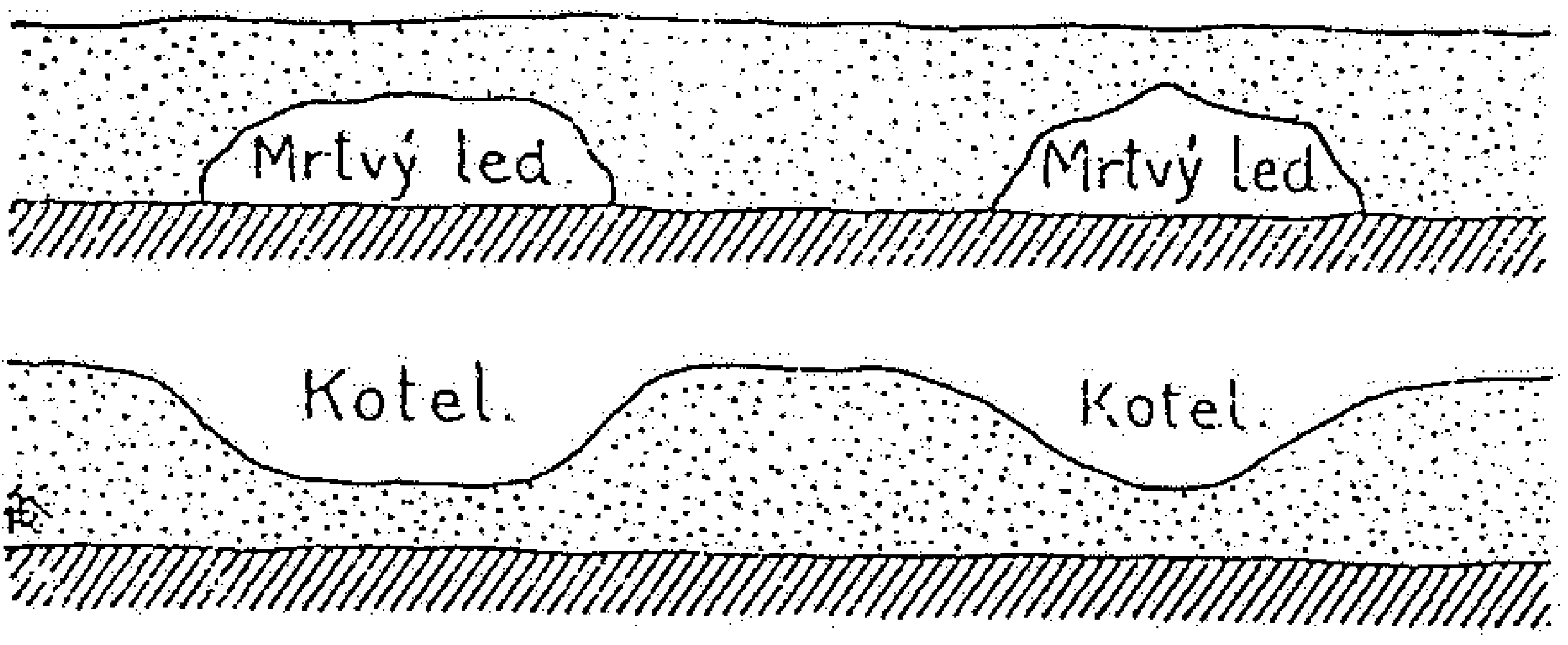
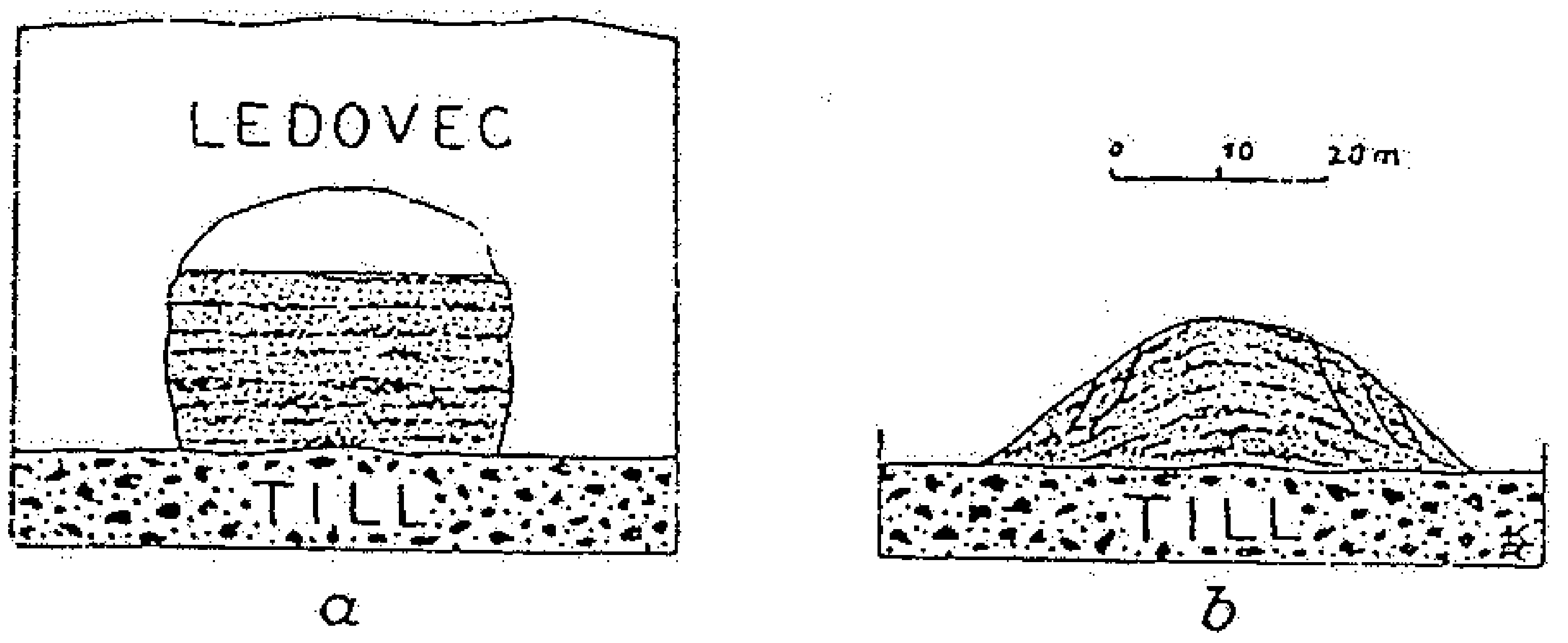


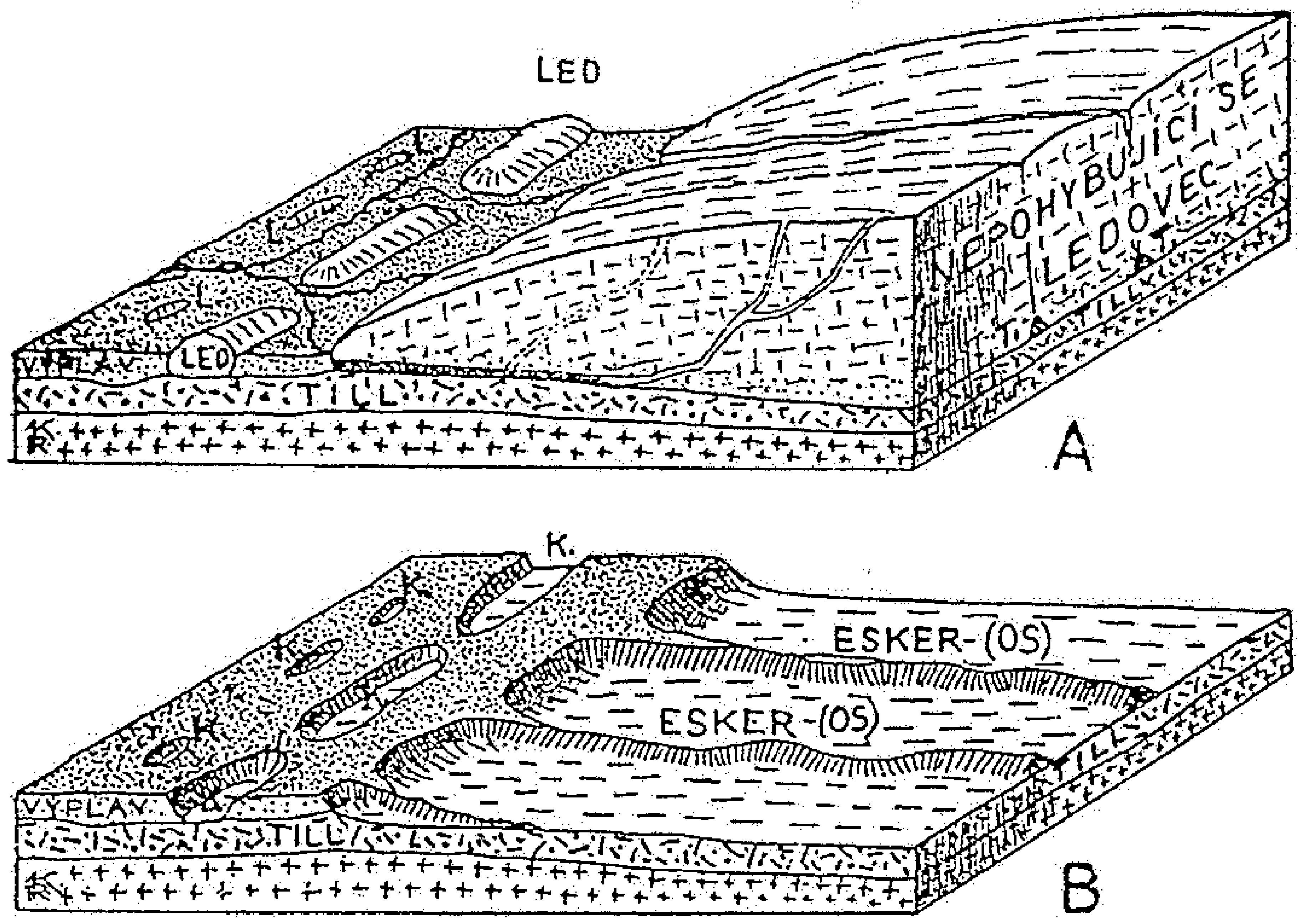
Fig. 13.2. Glacial environments and associated landforms typical of glaciated areas, including glaciofluvial outwash fan, ice-contact end moraine, glacial lake- and sea-bottom deposits, raised beaches and marine delta.



Obr. 46. *Vznik kotlů (sollů, kettles) po roztání kusů mrtvého ledu, které byly pohřbeny v glaciálních, po příp. glaciofluviálních uloženinách.* (Podle K. Keilhacka.)



Obr. 47. *Schematické znázornění vzniku eskeru (osu). a) Tunel v ledovci vytvořený podledovcovými vodami je vyplněn glaciofluviálními nánosy písku a štěrku. b) Po roztání ledovce tyto nánosy tvoří podélný val.*



Obr. 48. *Vznik eskerů (osarů) a kotlů (kettles). A. Čelní oblast nepohybujícího se pevninského ledovce. V ledovci vidíme kanály, kterými se dostává tavná voda s povrchu ledovce na jeho spodinu a vytváří zde v něm tunely (T). Před ledovcem spočívá v ledovcovém výplavu několik ker mrtvého ledu oddělených od roztávajícího pevninského ledovce. B. Táž oblast po zmizení ledovce. V tunelech podledovcových vod vznikly glaciofluviální nánosy, které vyčnívají z obnaženého podloží ledovce nad okolními nánosy tillu jako dlouhé valy eskery neboli osary. Roztáním kusů a ker mrtvého ledu vznikají v ledovcovém výplavu dolíky a jámy, t. zv. kotle (K).* (Podle F. T. Thwaitese.)

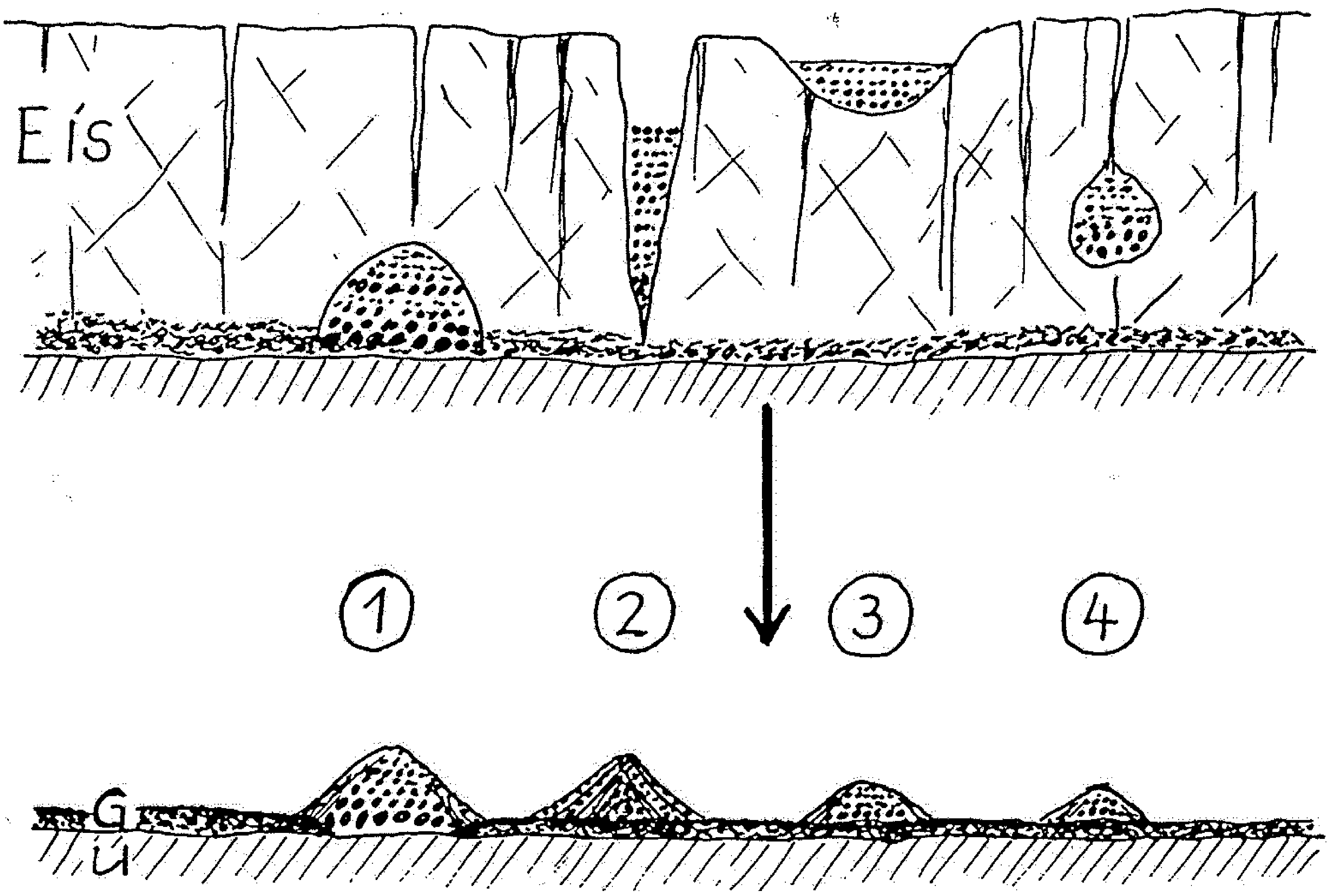


Abb. 29. Entstehung von Oosern:
1) subglazial, 2) Spaltenfüllung, 3) supraglazial, 4) inglazial, G – Grundmoräne, UT – Untergrund.

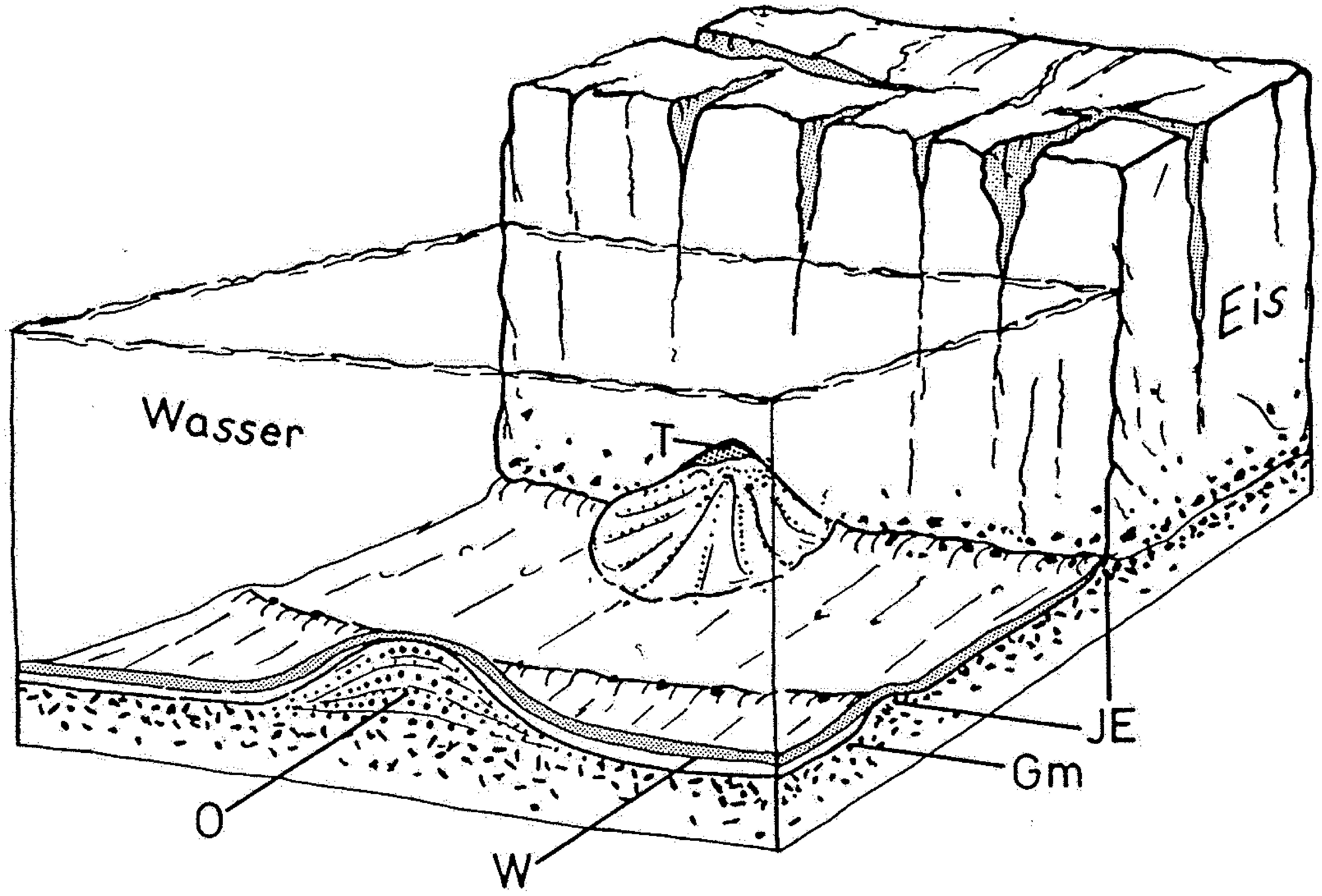


Abb. 30. Bildung eines Gletschertor-Oosers. Nach Magnusson, Granlund & Lundquist 1949: 256.
O – Oos, T – Gletschertor, Gm – Grundmoräne, JE – Jahresendmoräne, W – Warven (Jahresschichten).

Abb. 27. Oben: Bildung einer Kamesterrasse (KT), E Eis, OM Obermoräne, Fm – Fließmoräne, Gm – Grundmoräne. Rechts: Nach dem Abschmelzen des Eises. V Versturz, der auch erodiert werden kann. Unten: Entstehung eines Kames- oder Toteisfeldes. Links: Überschotterte Toteisblöcke (E). Rechts: Nach dem Abschmelzen der Toteisblöcke. Die glazifluvialen Schichten streichen in die Luft aus und sind besonders am Rand der Hügel durch Nachsacken gestört. Unter den Toteisblöcken z. T. Grundmoräne.

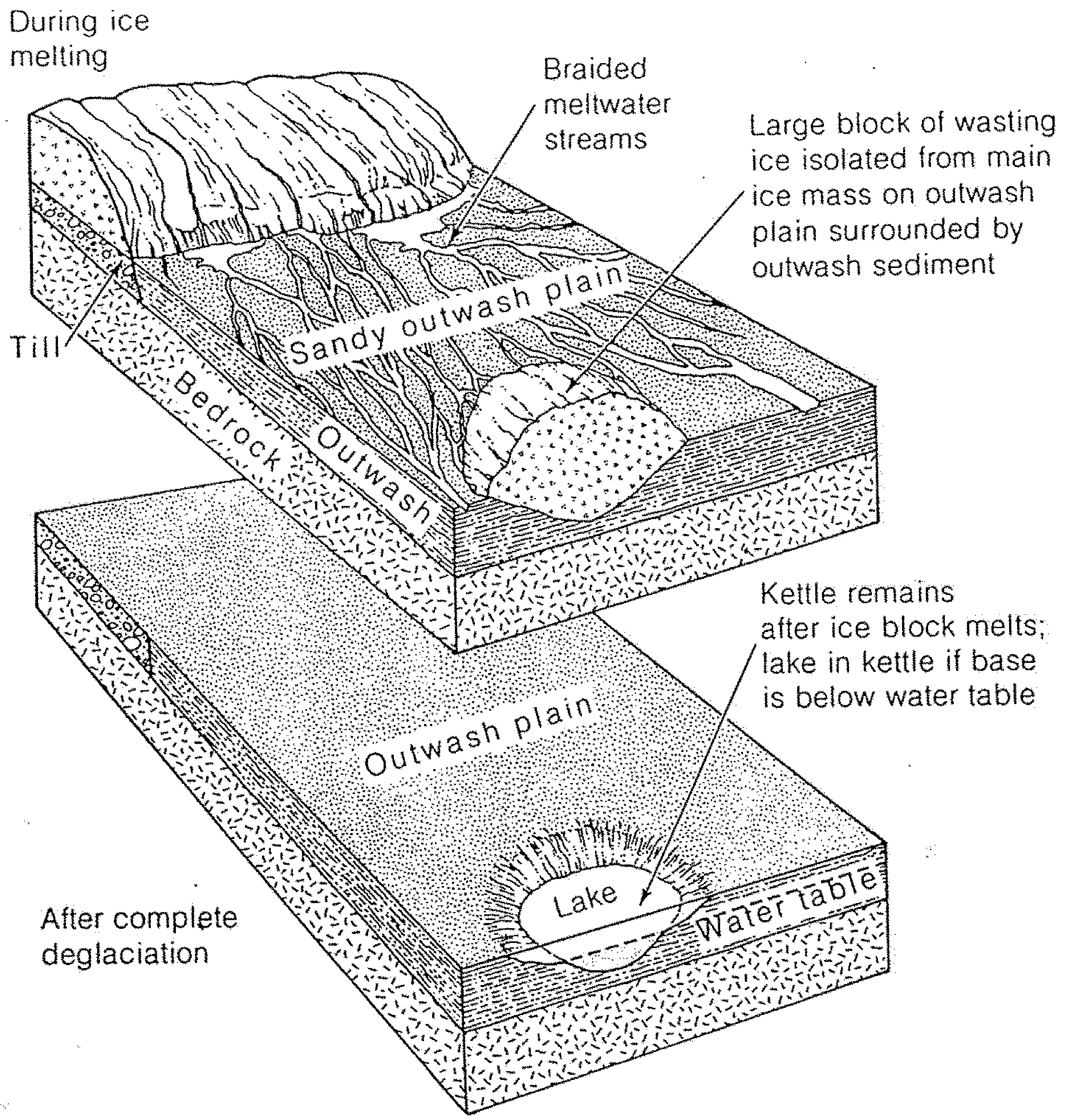
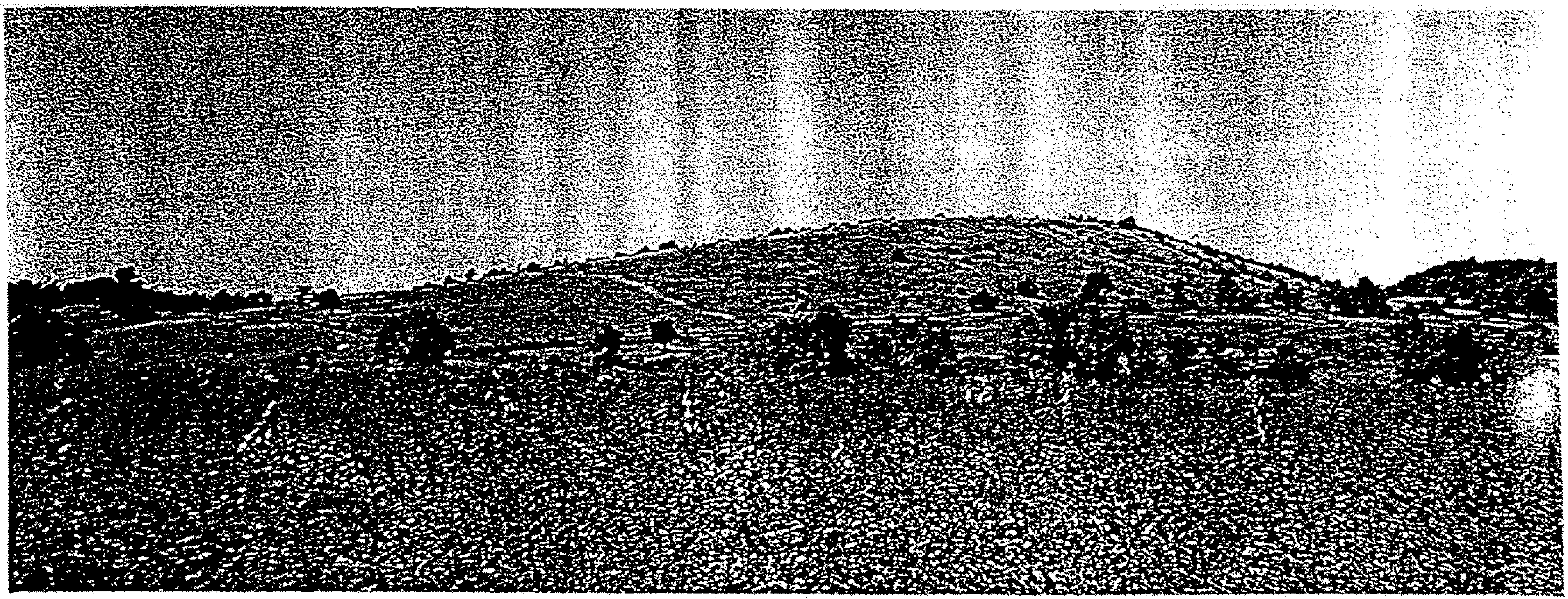
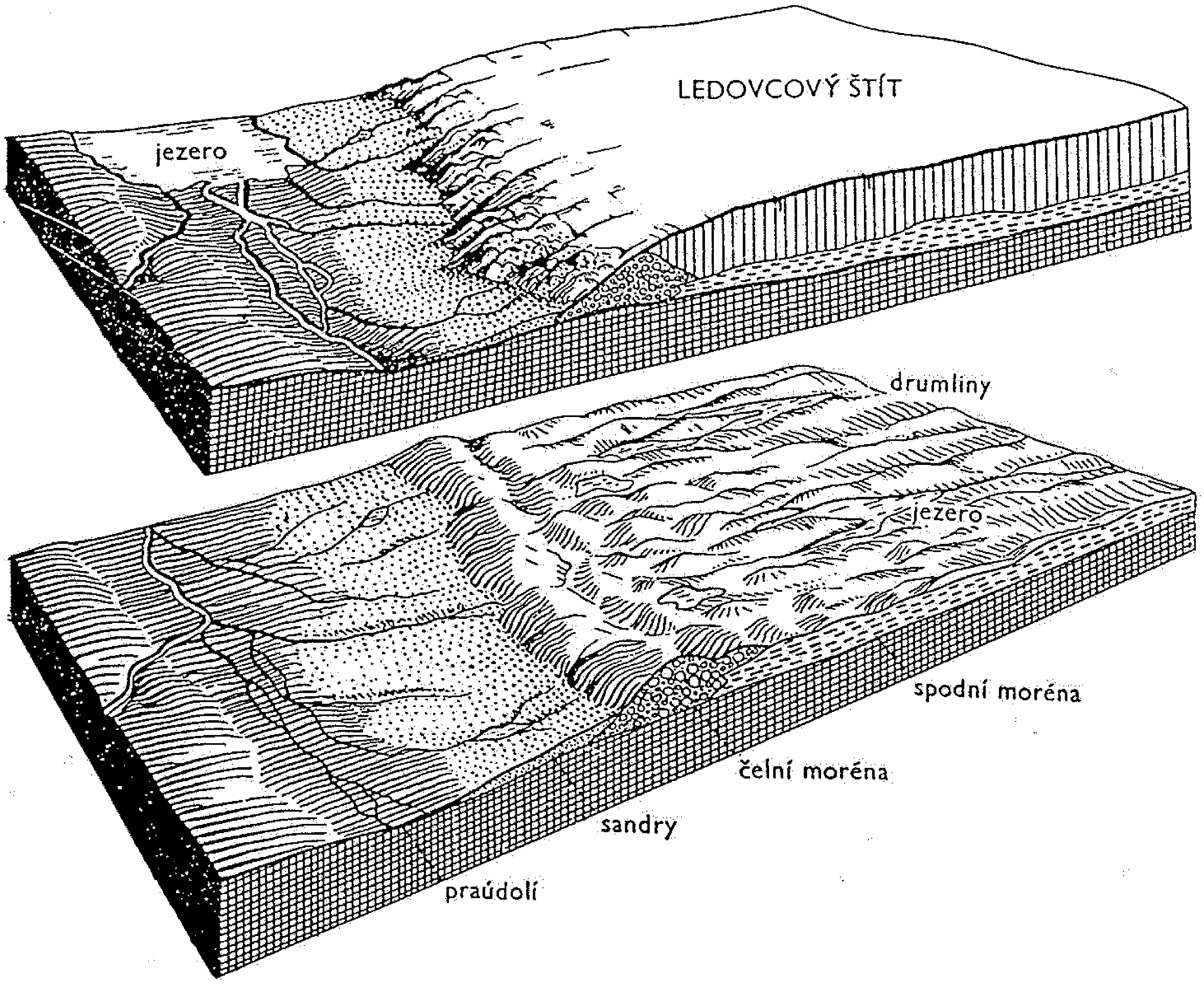


Figure 10-25

Evolution of an outwash kettle. As a glacier retreats, it may leave behind large blocks of wasting ice that are gradually buried by outwash from the receding ice front. After the front has retreated far enough from the region, outwash sedimentation stops, the ice block melts, and a depression remains, filled with water if it is deep enough to intersect the groundwater table.



15.21 A drumlin near Elbridge in central New York State. The blunt end of the asymmetric long profile faces north, the direction from which the glacier advanced.



Obr. 297. *Schematický blokdiagram krajiny v době pleistocénního zalednění* (nahoře) *a dnes, po ústupu ledovcového štítu* (dole). (Podle Hirta.)

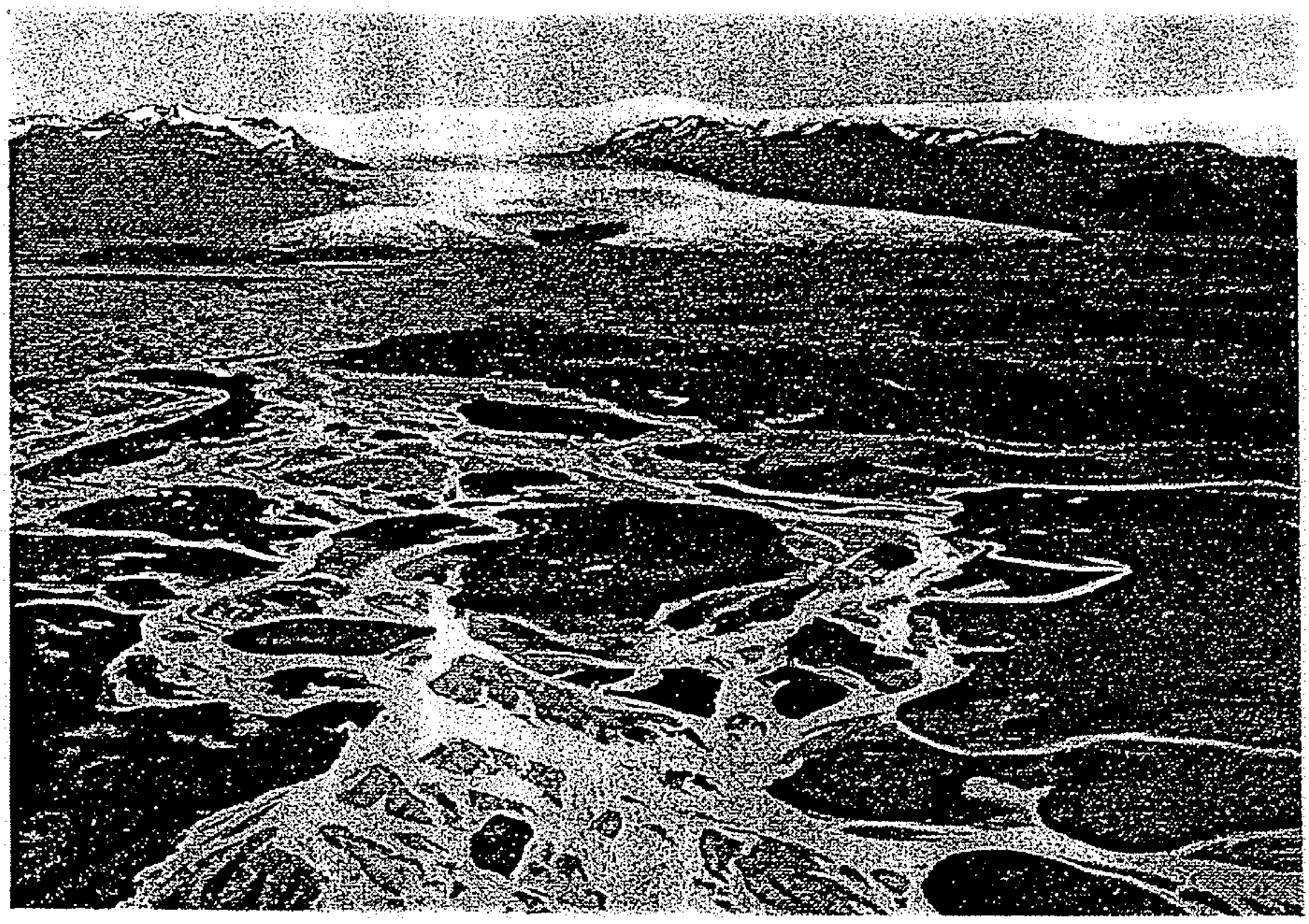
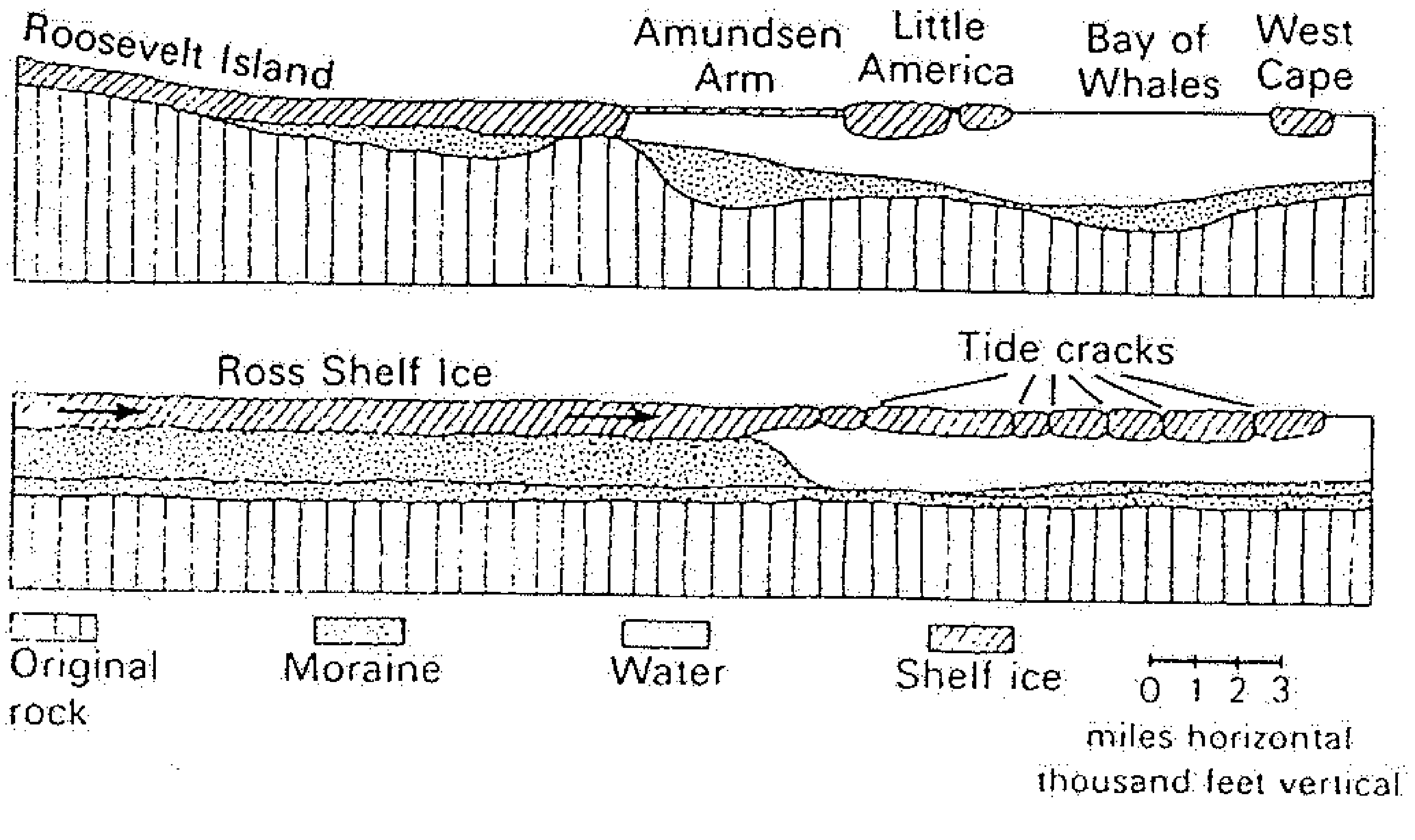


Abb. 31. Sandrebene vor dem Inlandeis. Vatnajökull (Südisland), (Luftbild)



Bottom: *Sections through the Ross Shelf Ice and Bay of Whales. The thickness of the ice has been determined by seismic methods, described in Chapter 19. (After T. C. Poulter, Stanford Research Institute.)*

Figure 12.34
Depositional features in front of a receding ice sheet.

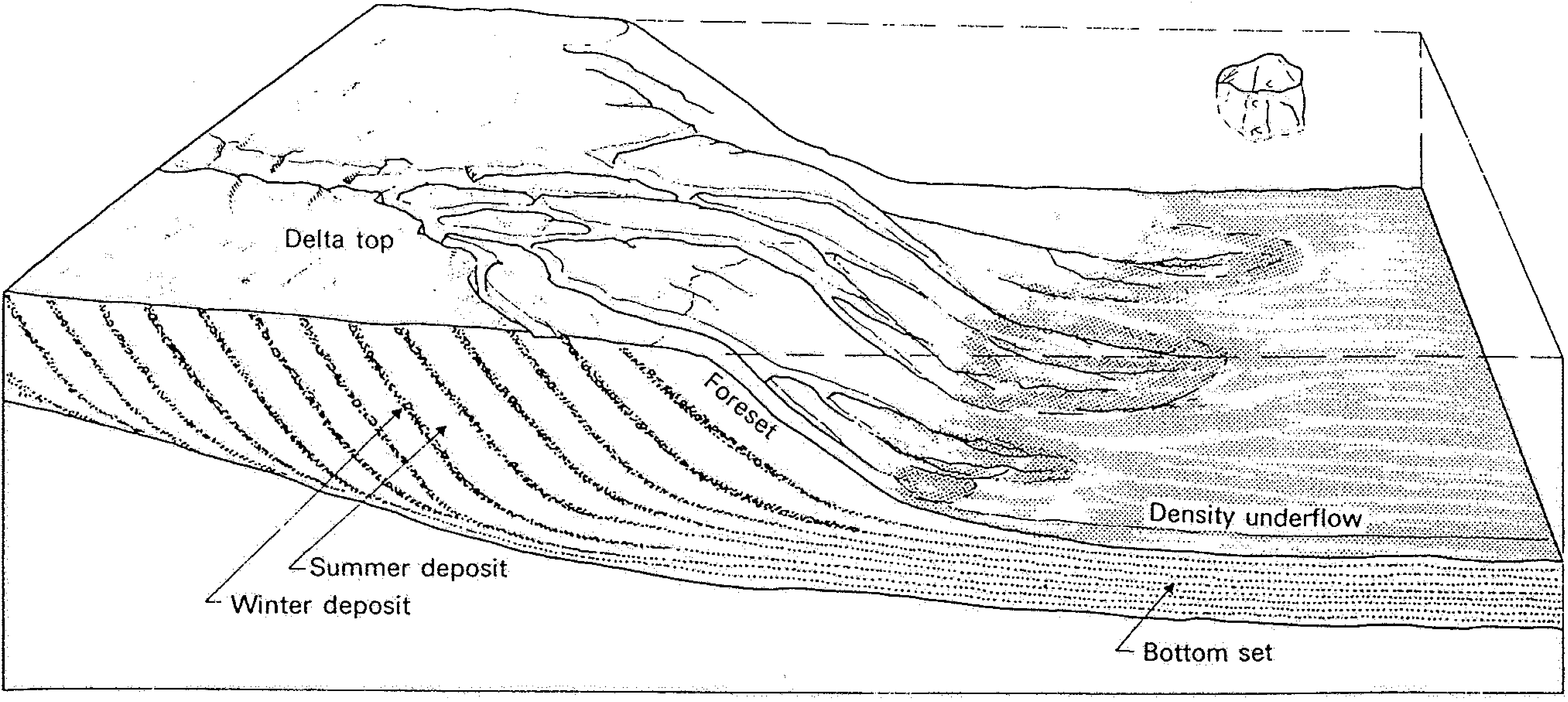


Fig. 13.4. Sedimentation in a glacial lake. During the summer, mainly climbing ripple-laminated sand is deposited on a prograding delta, while thin silt layers are deposited by a density underflow on the lake bottom. During the winter, these areas are covered with a clay drape. Icebergs, and shore and river ice may raft coarse sediment into the lake during the spring thaw and summer.

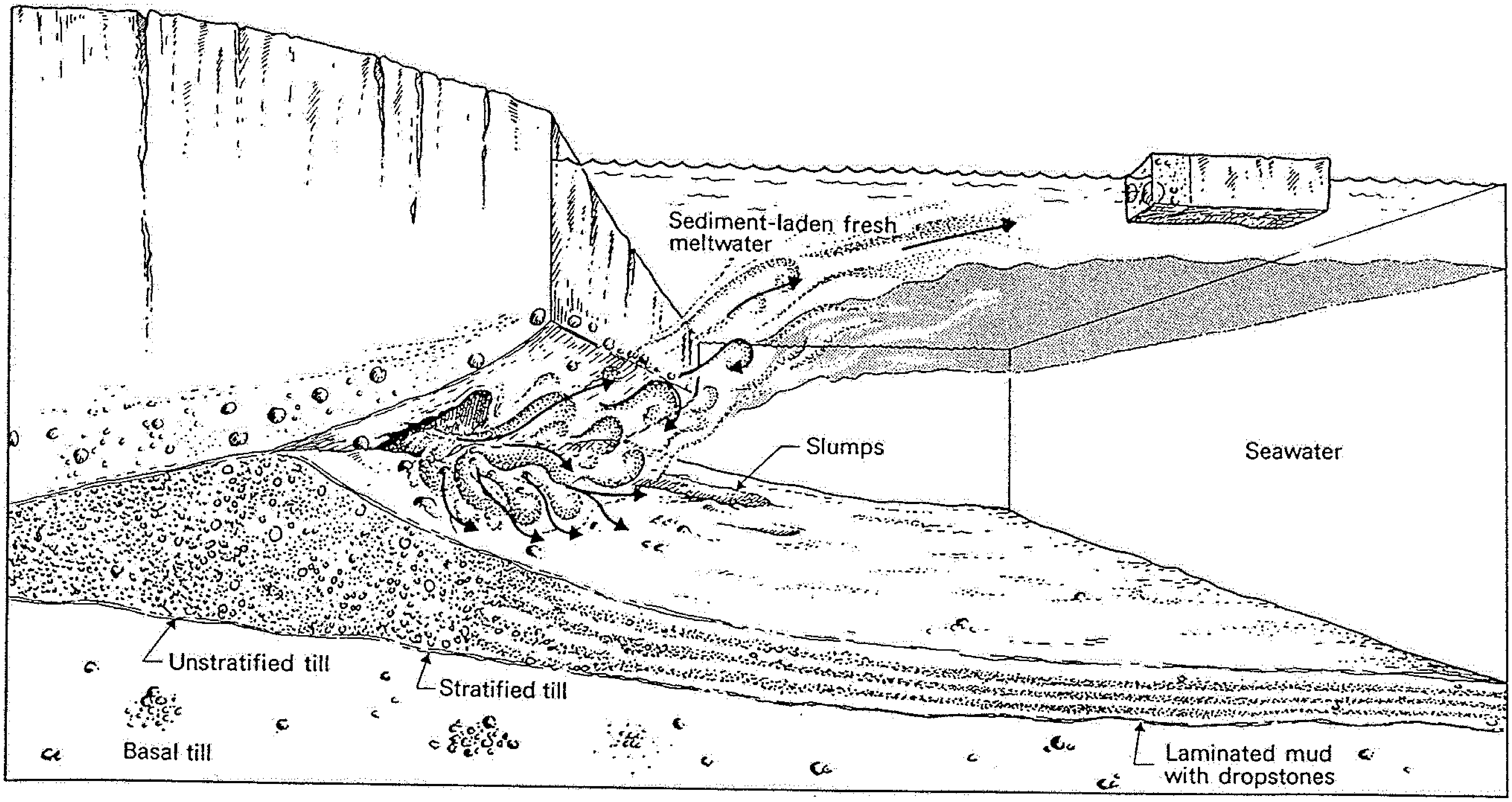


Fig. 13.5. Hypothetical model of glaciomarine sedimentation adjacent to a wet-based tidewater glacier, based on observations of Pleistocene subaqueous outwash and considerations of current dynamics of modern marine deltas. Most of the fresh glacial meltwater rises to the surface of the sea as a low density overflow layer. This layer gradually mixes with sea water while being driven by winds and currents. Silt and flocculated clays gradually fall out of suspension. Rapid mixing of fresh water and sea water adjacent to tunnel mouths may produce a high density underflow capable of transporting sand-grade sediment and occasionally coarser material.

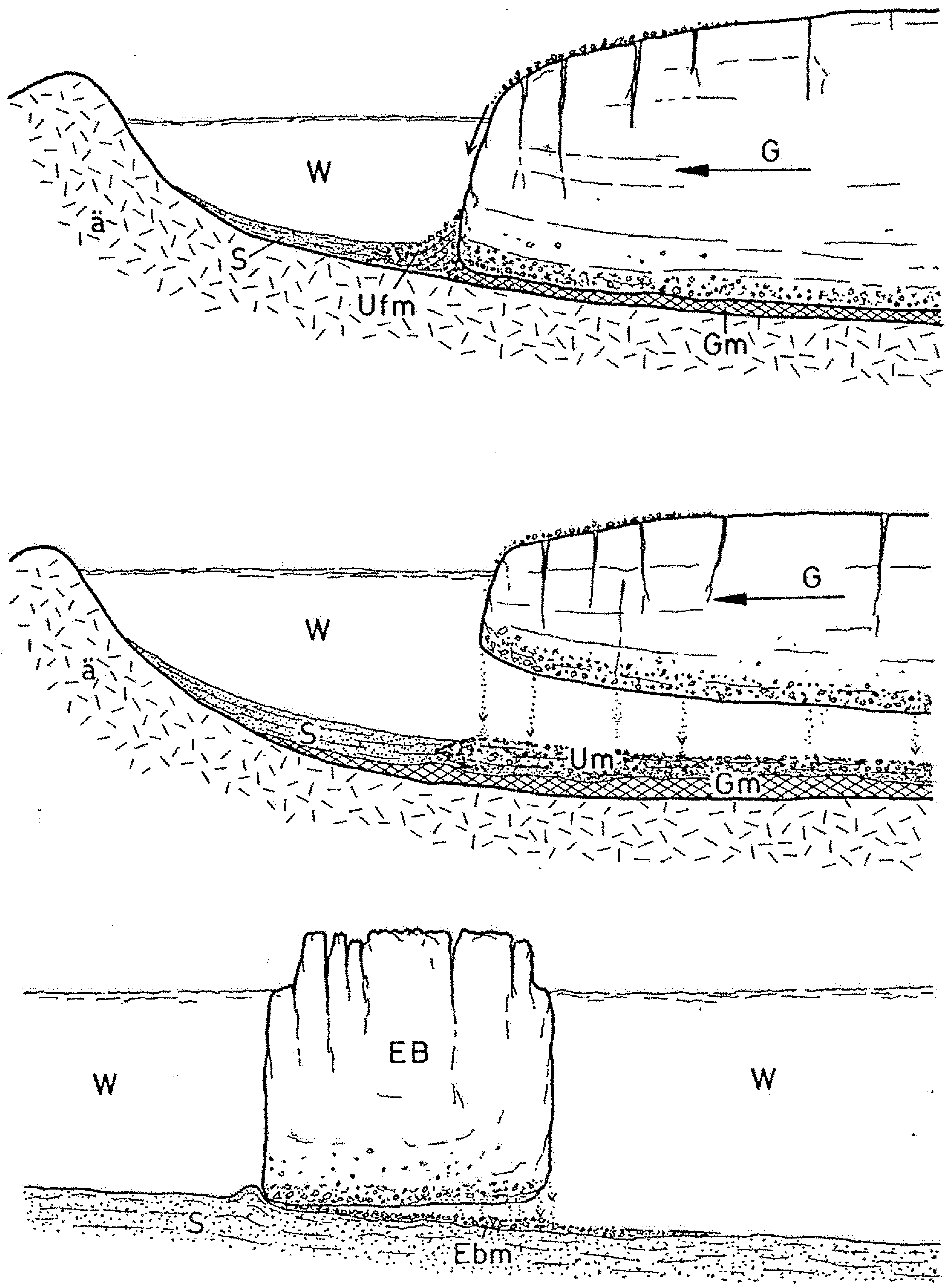
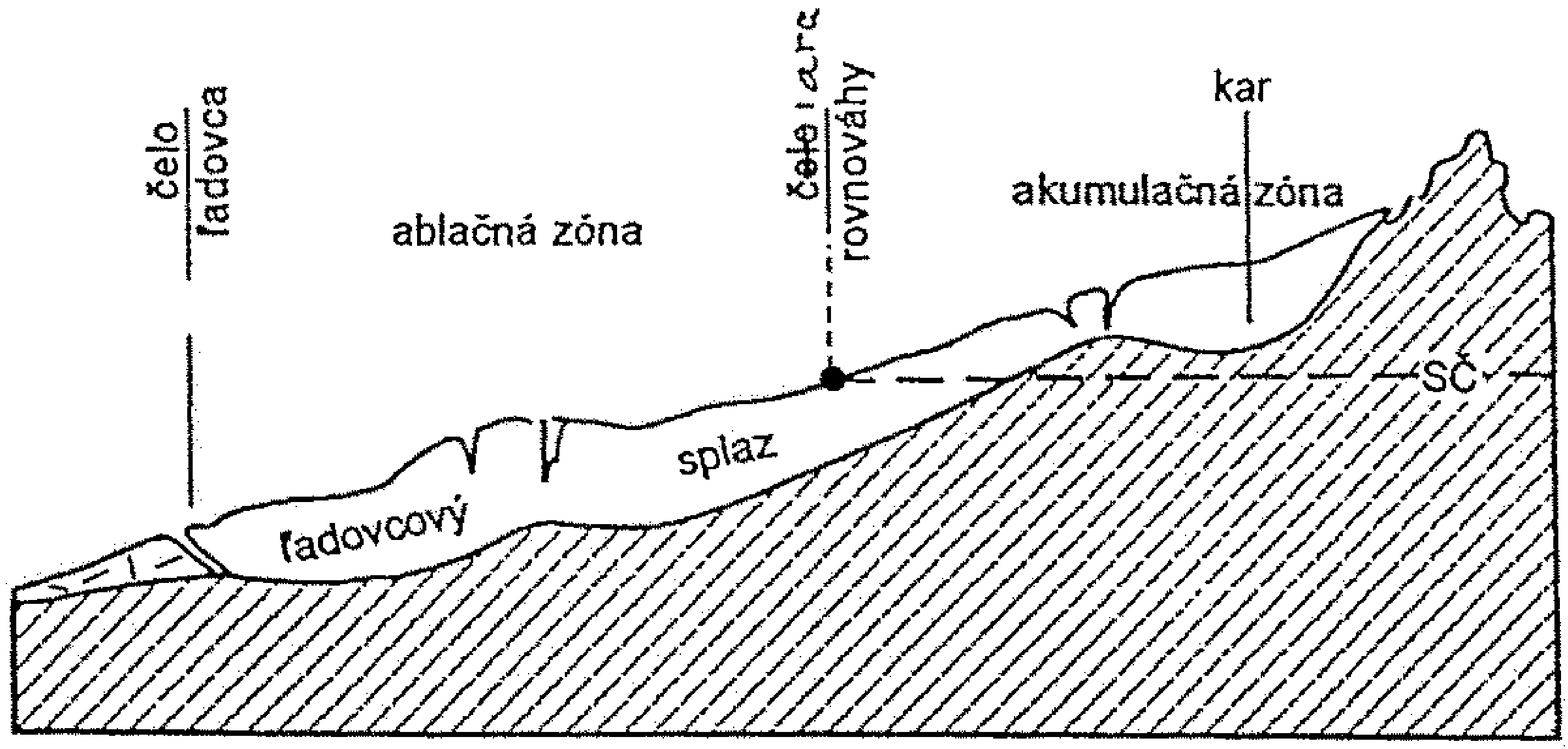
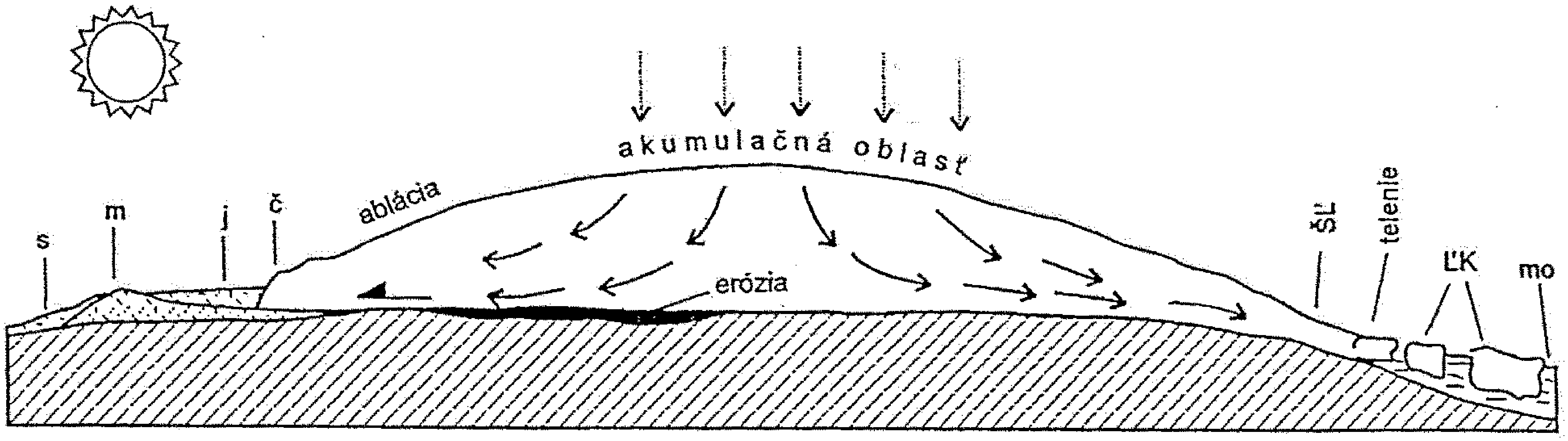


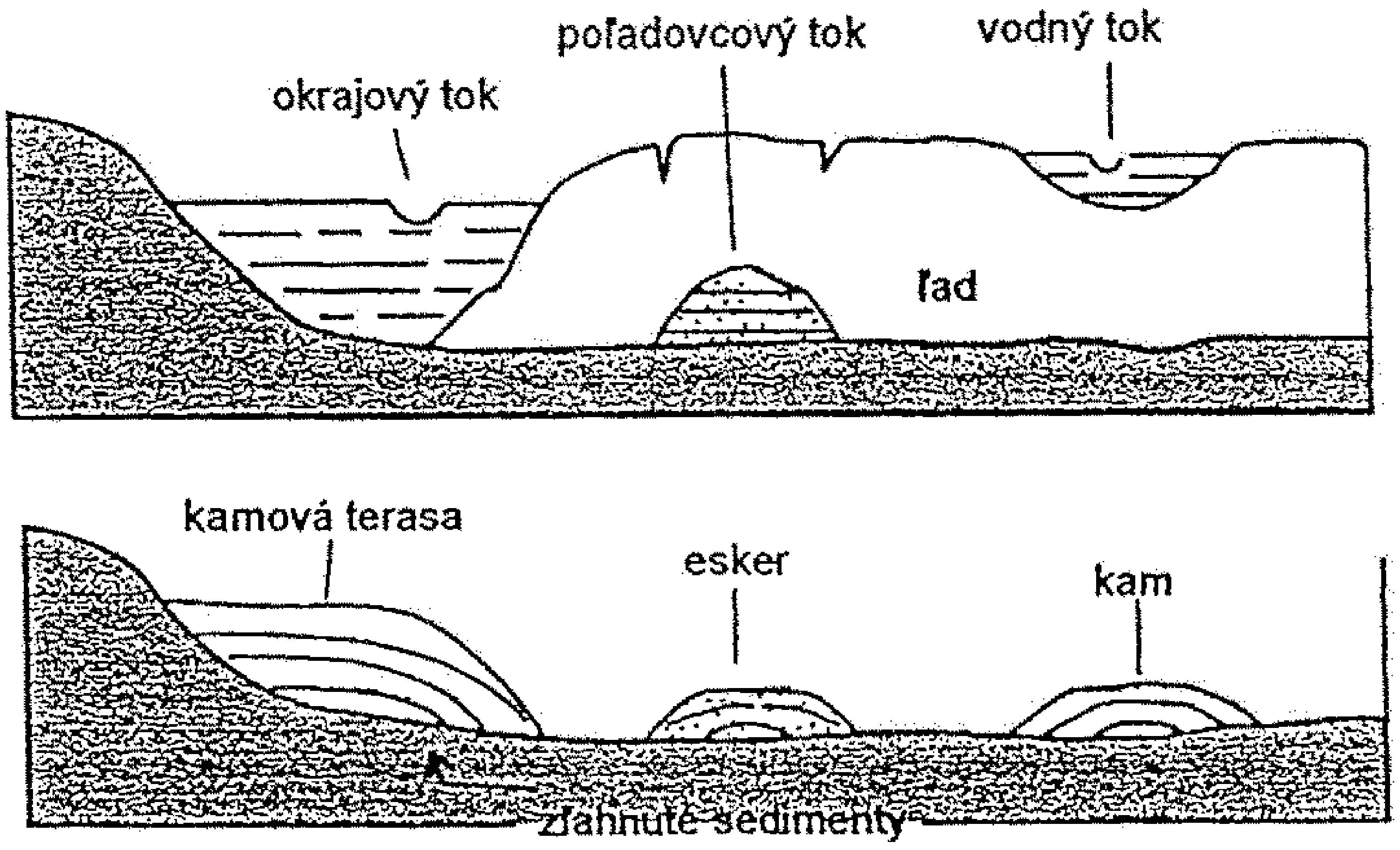
Abb. 17. Unterwassermoränen (waterlain tills) nach Dreimanis (1979), verändert.
Oben und Mitte: Am westlichen Bodensee. Oben: Mächtiger Gletscher liegt auf dem Seegrund; am Rand Unterwasserfließmoräne (UFM) mit Seesedimenten verzahnt. Mitte: Abgeschmolzener, dünner Gletscher, schwimmt. Ablagerung von Unterwassermoräne (UM), die sich mit Seesedimenten verzahnt. Unten: Eisberg (EB) lagert Eisbergmoräne (EBM) ab, die sich mit Seesedimenten verzahnt.
W – Wasser, GM – Grundmoräne, G – Gletscher mit Fließrichtung, ä – ältere Ablagerungen.



19.9 Bilancia na ľadovci. Línia rovnováhy má charakter vrstevnice na povrchu ľadovca a oddeľuje zónu ablácie od akumulačnej zóny a je vo výške snežnej čiary (sč).



19.8 Prierez ľadovcovým štítom. V ľavej časti ľadovec s teplou bázou eroduje, v pravej časti so studenou bázou sa pohyb uskutočňuje vnútri ľadovca (neeroduje podklad). Pohybom cez šelf (ako šelfový ľadovec -ŠĽ) sa dostáva do mora (mo), kde sa ulamujú ľadovcové kry (ĽK) -telenie ľadovca. Vysvetlivky: s - sandry, m - moréna., j - priľadovcové jazero, č - čelo ľadovca.



19.22 Sedimenty povrchových a podľadovcových vodných tokov pred a po deglaciácii (eskery, kamy a kamové terasy).

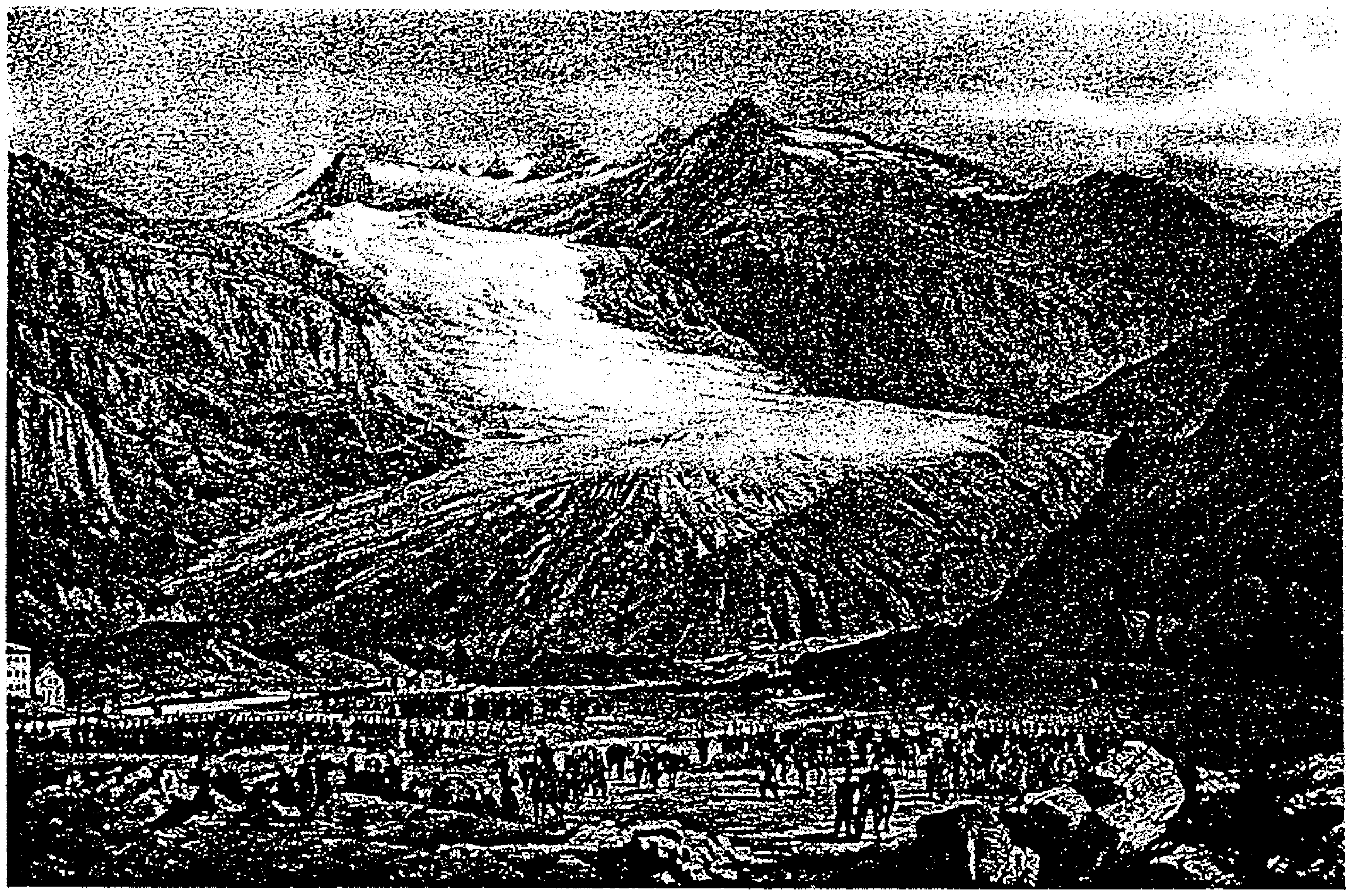


Abb. 2
Rhonegletscher 1861, im flachen Talboden auf ca. 1780 m stirnend. Marschhalt der Ersten Brigade anlässlich von Gebirgsmanövern am 20. August 1861.
Nach der Natur gezeichnet von Eugen Adam. Eidg. Militärbibliothek Bern.

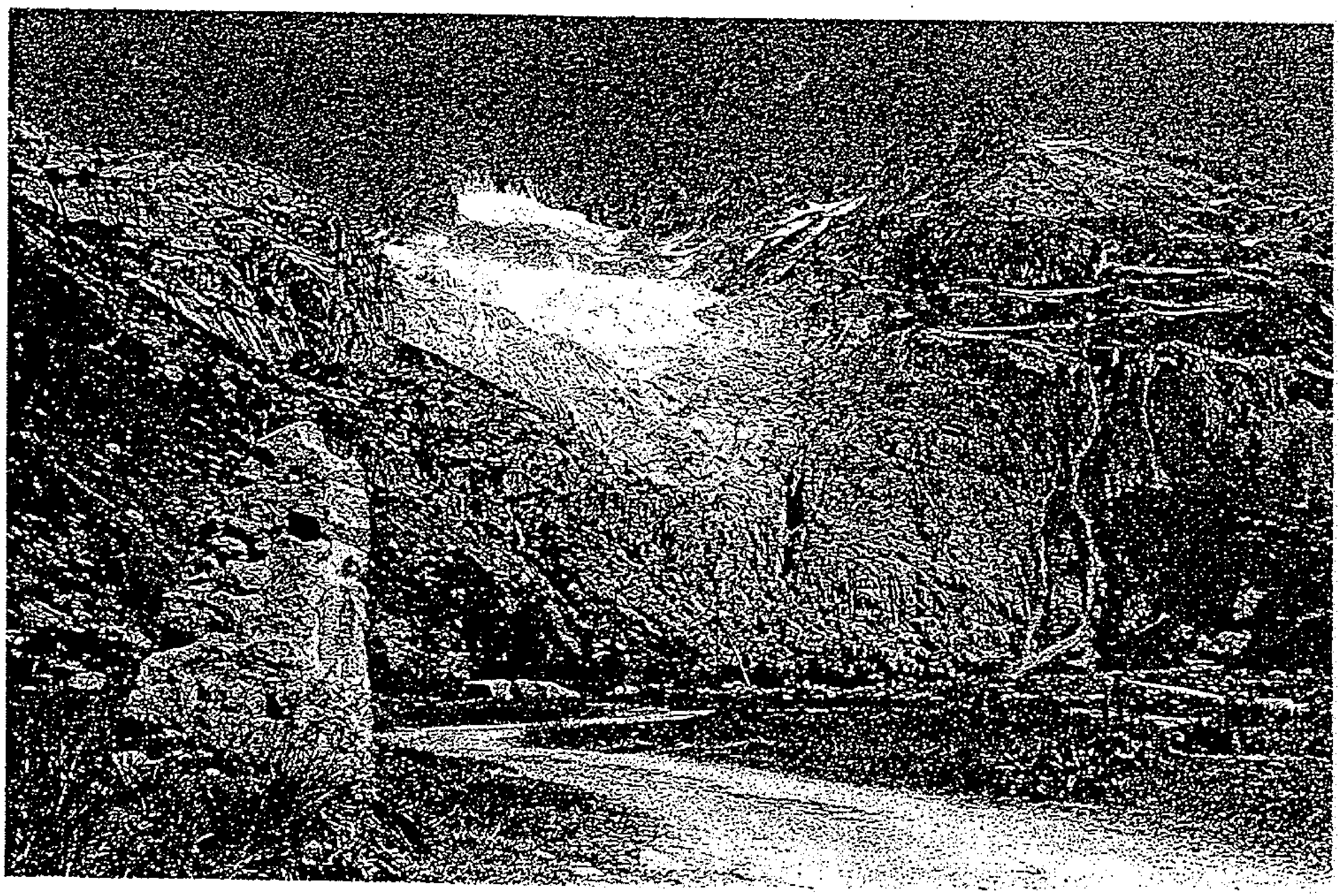


Abb. 3
Rhonegletscher 1984, auf dem glattgescheuerten Granit auf ca. 2250 m stirnend. Links im Vordergrund: Erinnerungsstein an den Gletscherstand von 1856.

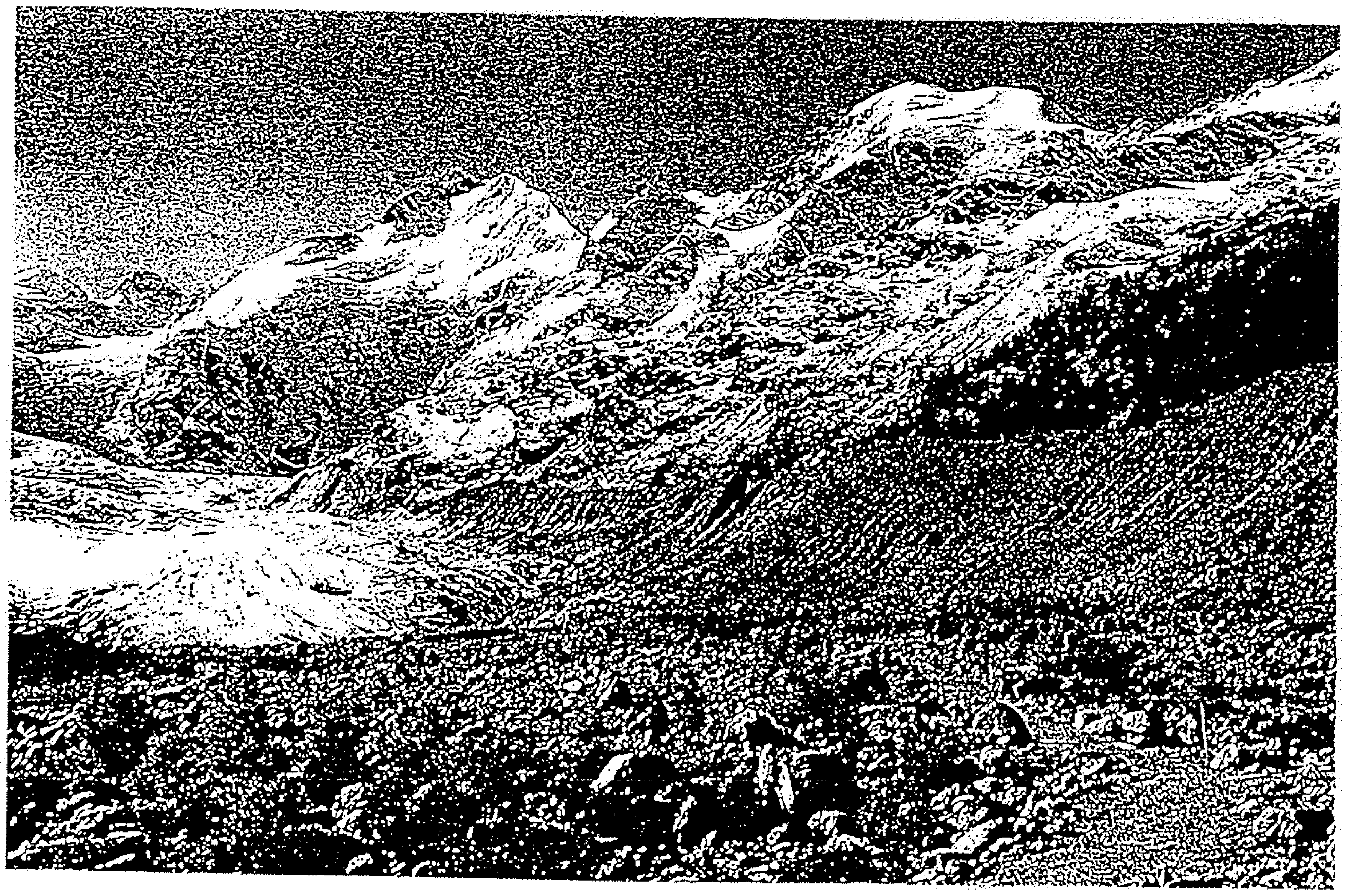


Abb. 1
Gletschervorfeld Morteratschgletscher (Oberengadin), ca. 2000 m ü. M. 1984. Im Vordergrund Pioniervegetation aus Erlen, Lärchen und Weiden auf dem seit ca. 1950 eisfrei gewordenen blockübersäten Gelände. Im Mittelgrund rechts die unbewachsene Seitenmoräne des Maximalstandes von 1850. Im Hintergrund Piz Bernina 4049 m mit Biancograt, rechts Piz Morteratsch.

Abb. 5.37
Jungpaläozoischer Tillit im östlichen Australien, der als Grundmoräne entstanden ist. Charakteristisch sind die extrem unterschiedliche Rundung der einzelnen Geschiebe, die markante Durchmischung feiner bis sehr grober Korngrößen sowie die große Heterogenität der eingearbeiteten Gesteinstypen.

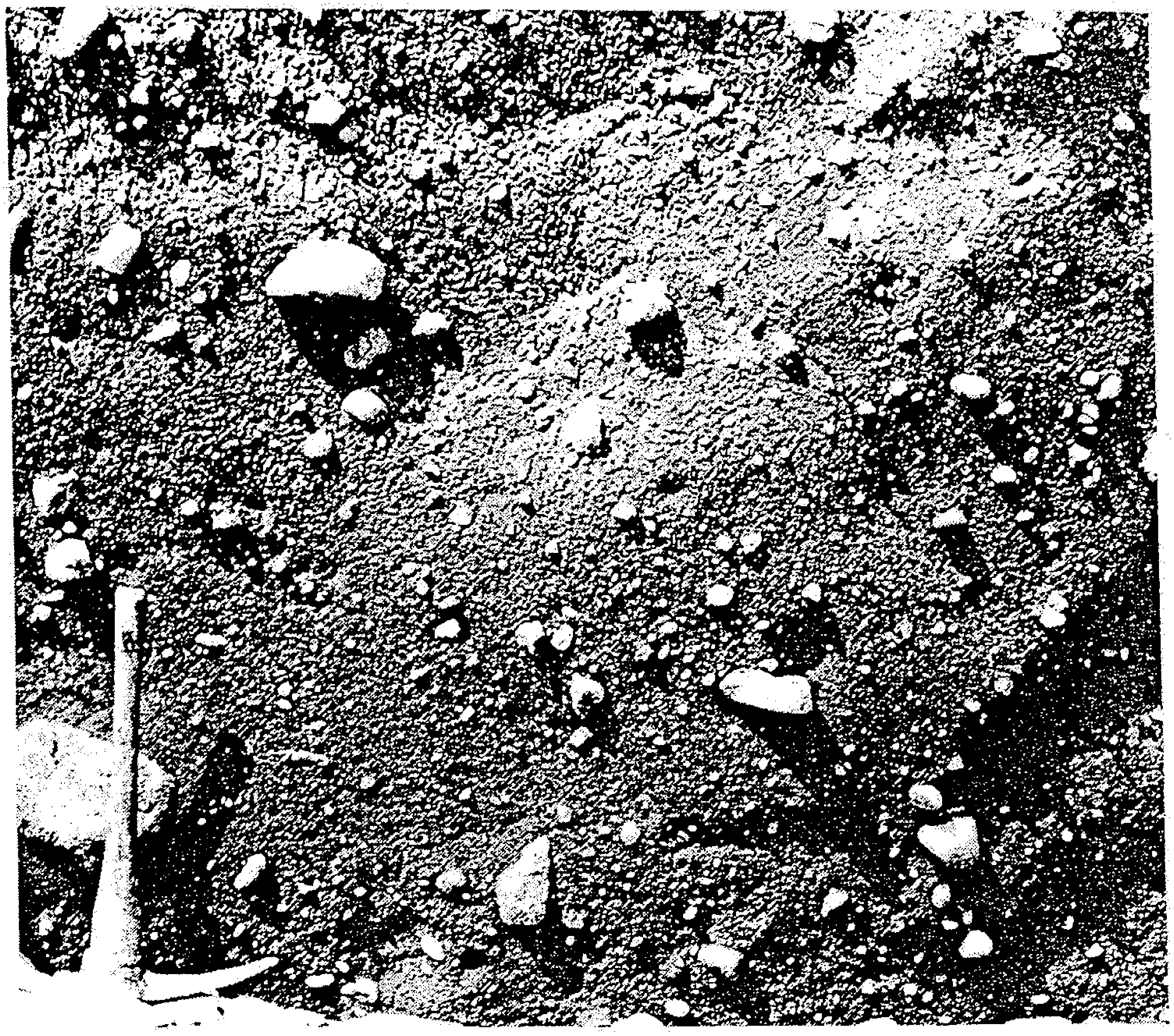
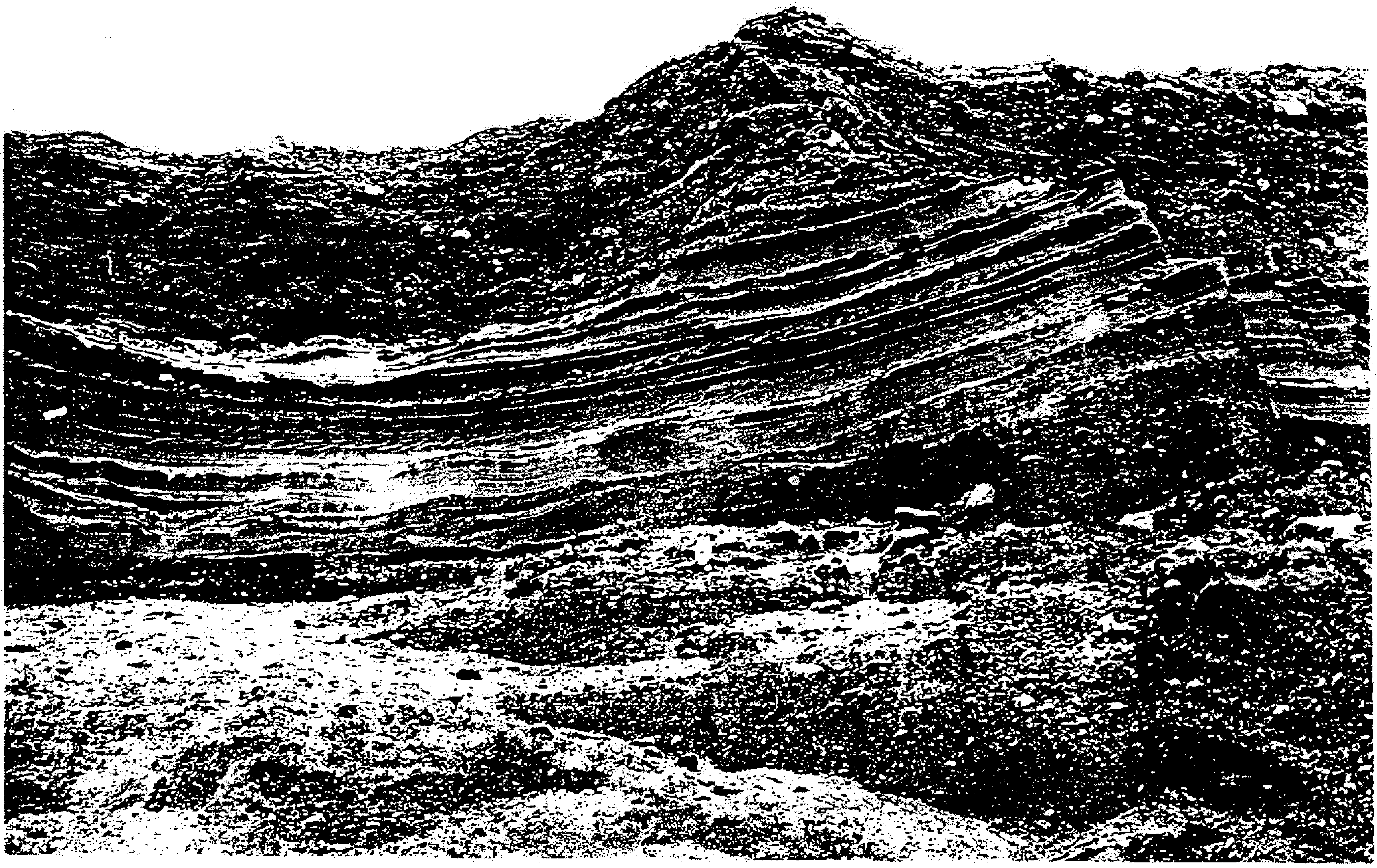


Figure 9-33 *Till exposed in coastal cliff. Montauk Till (Pleistocene) near Montauk Point, Long Island, New York. (R. G. LaFleur.)*



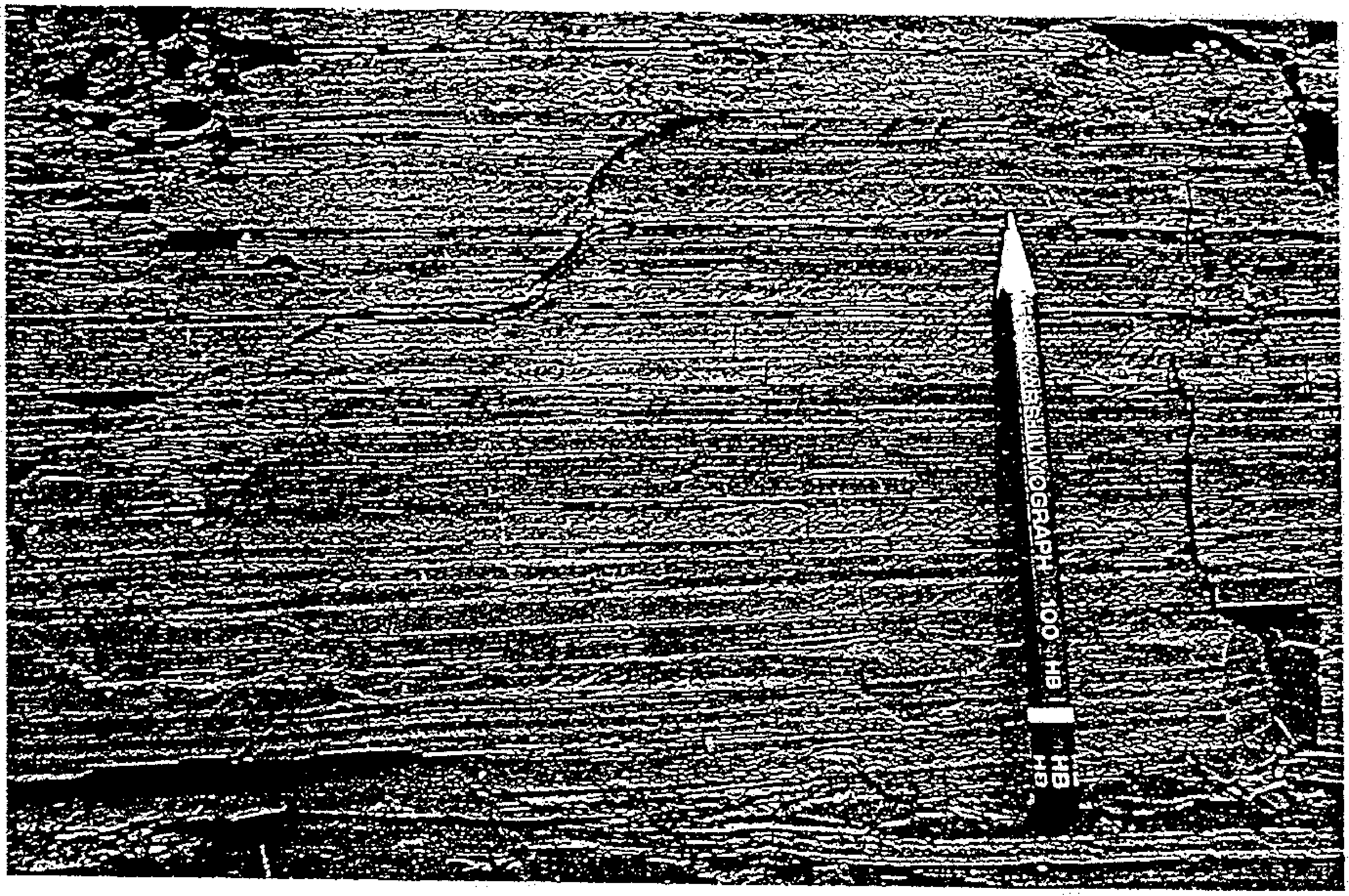


Abb. 5.39
Jahreszeitlich geschichtete Bändertone der jungpaläozoischen Vereisung in Südamerika, Paraná-Becken, Brasilien.

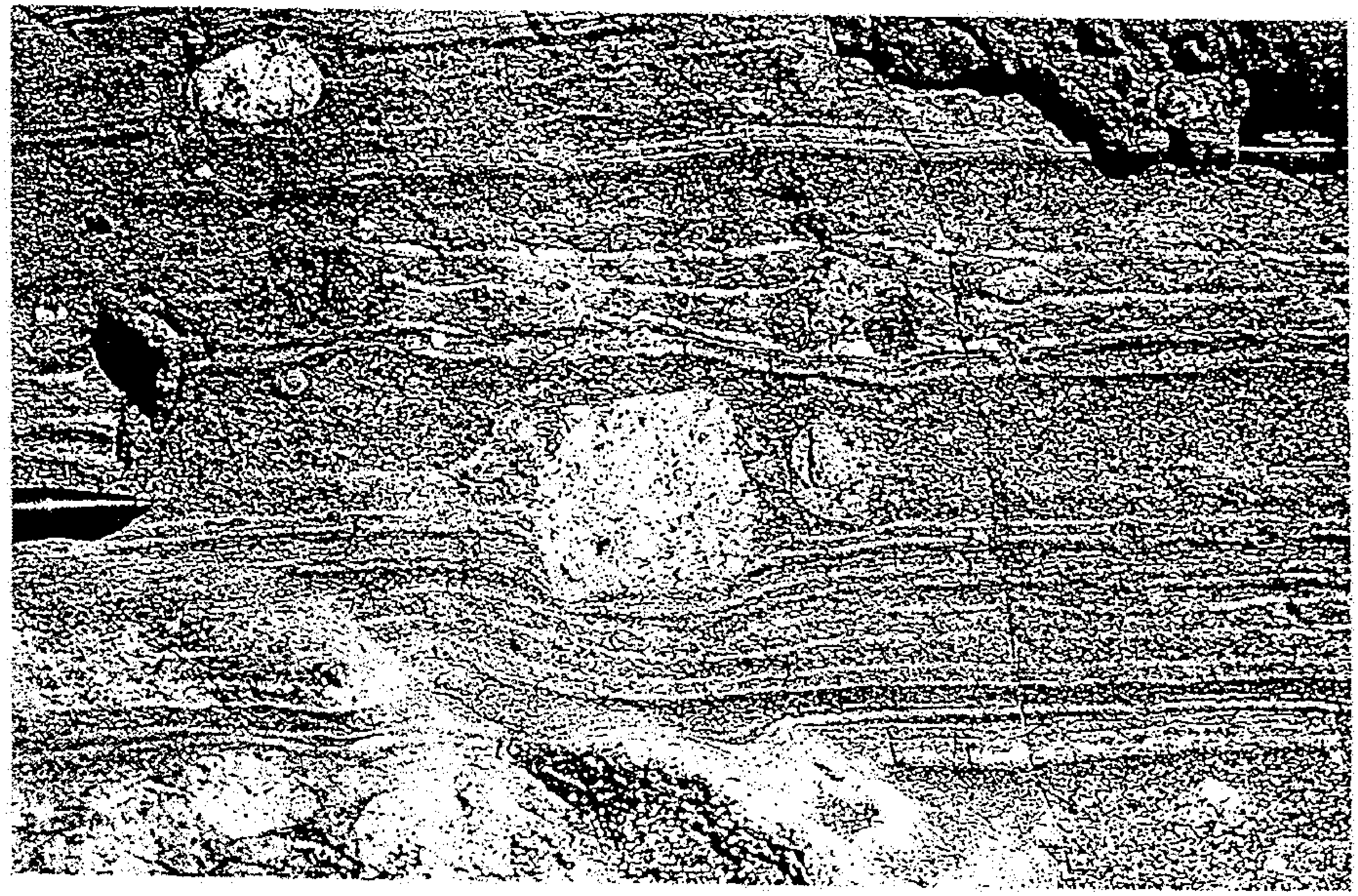


Abb. 5.40
Granitische Dropstones in einem jungpaläozoischen Tillit im östlichen Australien. Die vom umgebenden Sediment abweichende Lithologie der Dropstones tritt hervor, ebenso wie die durch den Aufprall unter dem Klast herabgebogenen Sedimentlaminae. Die Verbiegung der Laminae ist allerdings durch die spätere Setzung des Sedimentes noch betont.

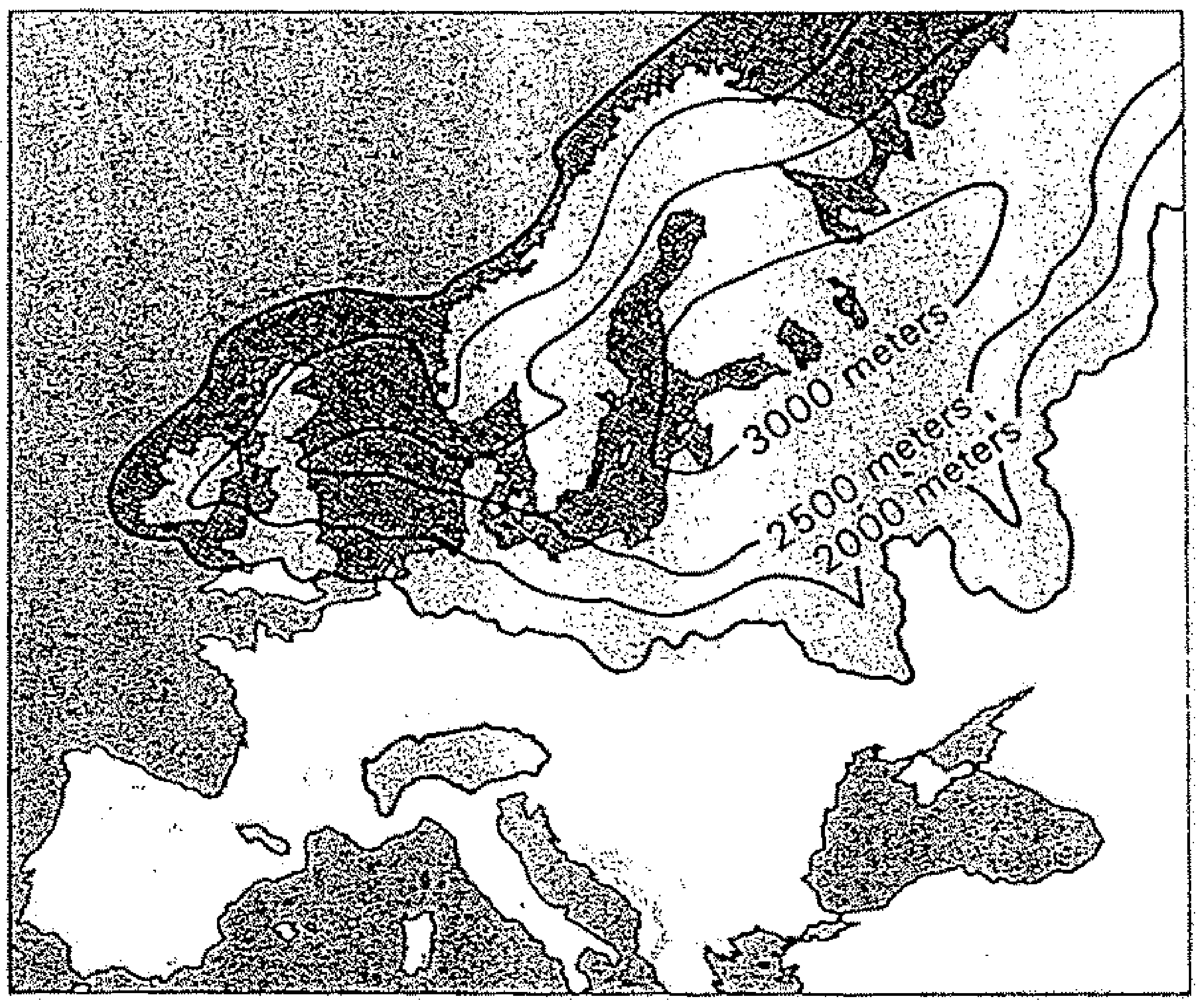
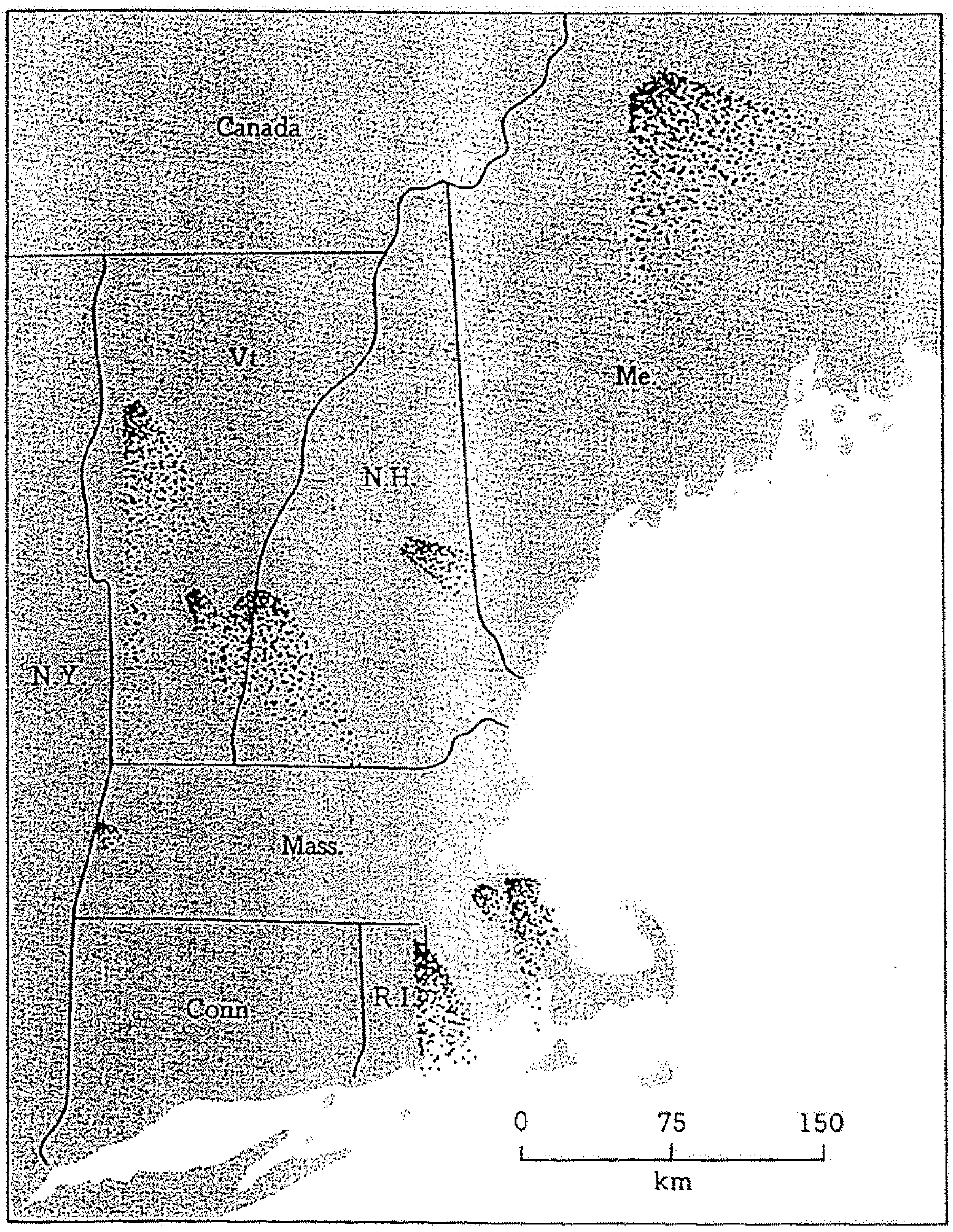
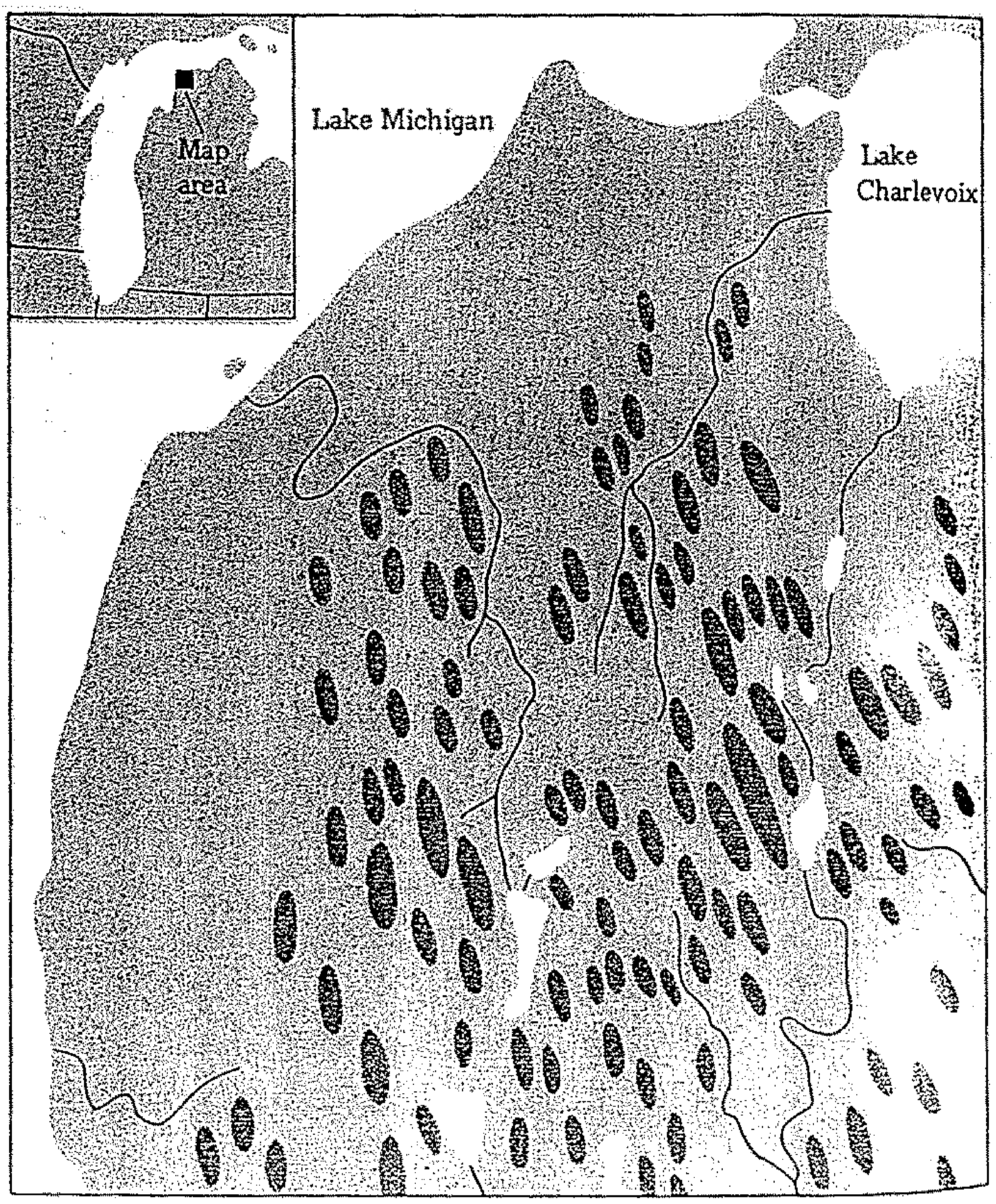


FIGURE 13–45
Reconstruction of the European ice sheets at their maximum extent. The contours are based on analogy with the slopes of the present Greenland and Antarctic ice sheets. (After G. de Q. Robin, Science Journal, *1966.)*

FIGURE 13–46
Postglacial uplift in Fennoscandia. The heavy lines connect points of equal uplift in meters, of the highest strand line of the sea that flooded the area just after the melting of the glacier. (After R. A. Daly, The Changing World of the Ice Age, *Yale University Press, 1934.)*



15.24 The boulder trains plotted on this map indicate the general direction of ice movement across New England. The apex of the fan indicates the area from which the boulders were derived; the fan itself covers the area across which they were deposited. [After J. W. Goldthwait in R. F. Flint, "Glacial Map of North America," *Geol. Soc. Am. Spec. Paper 60,* 1945.]



15.22 Map of part of the drumlin-field area south and east of Charlevoix, Michigan. Ice moved toward the south-southeast. [After Frank Leverett and F. B. Taylor, "The Pleistocene of Indiana and Michigan and the History of the Great Lakes," *U.S. Geol. Surv Monog. 53,* p. 311, 1915.]

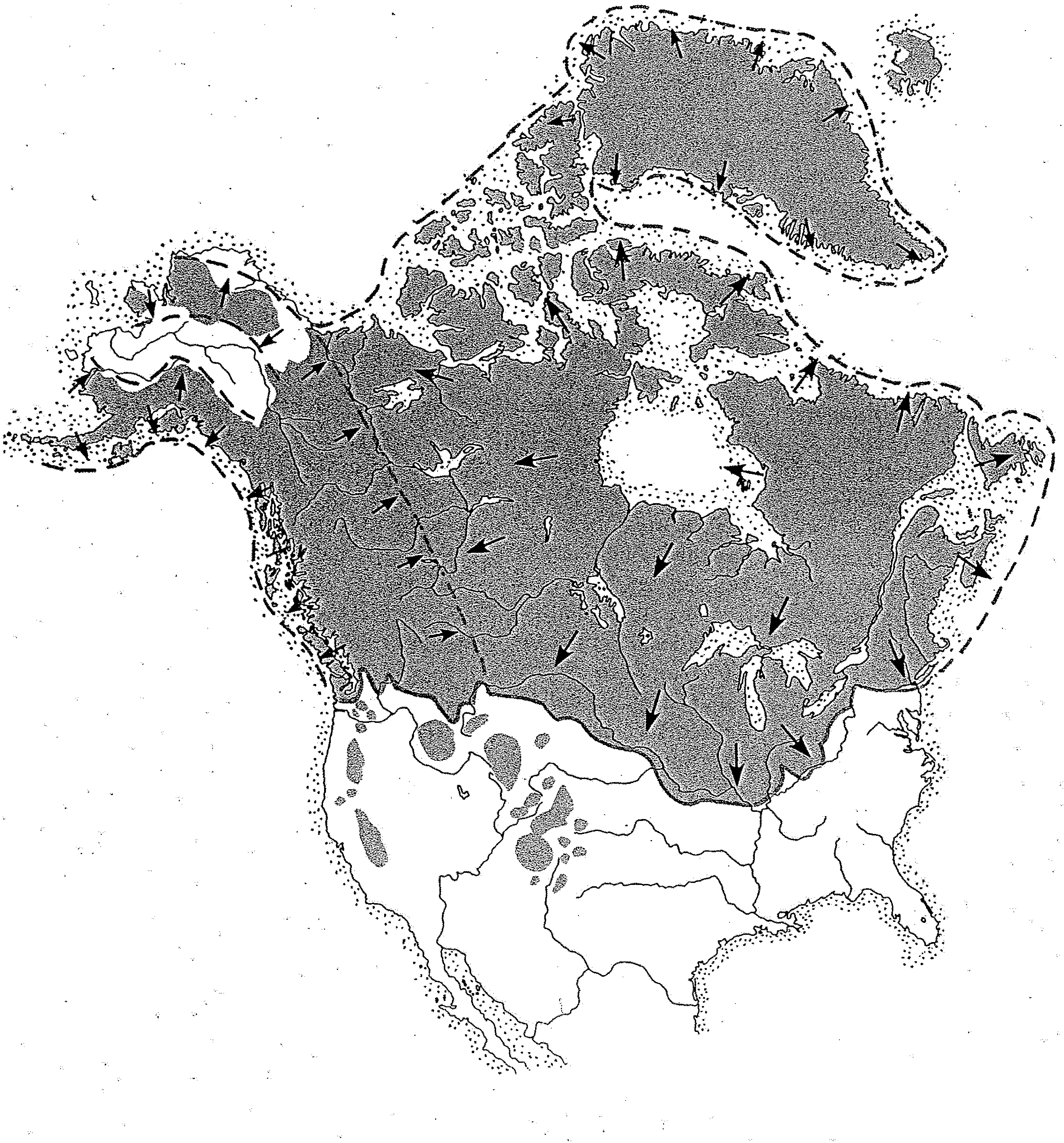


Figure 9.11 Extent of glaciation in North America during the Pleistocene epoch. Arrows show the direction of ice movement.
Source: After C. S. Denny, *National Atlas of the United States*, U.S. Geological Survey.

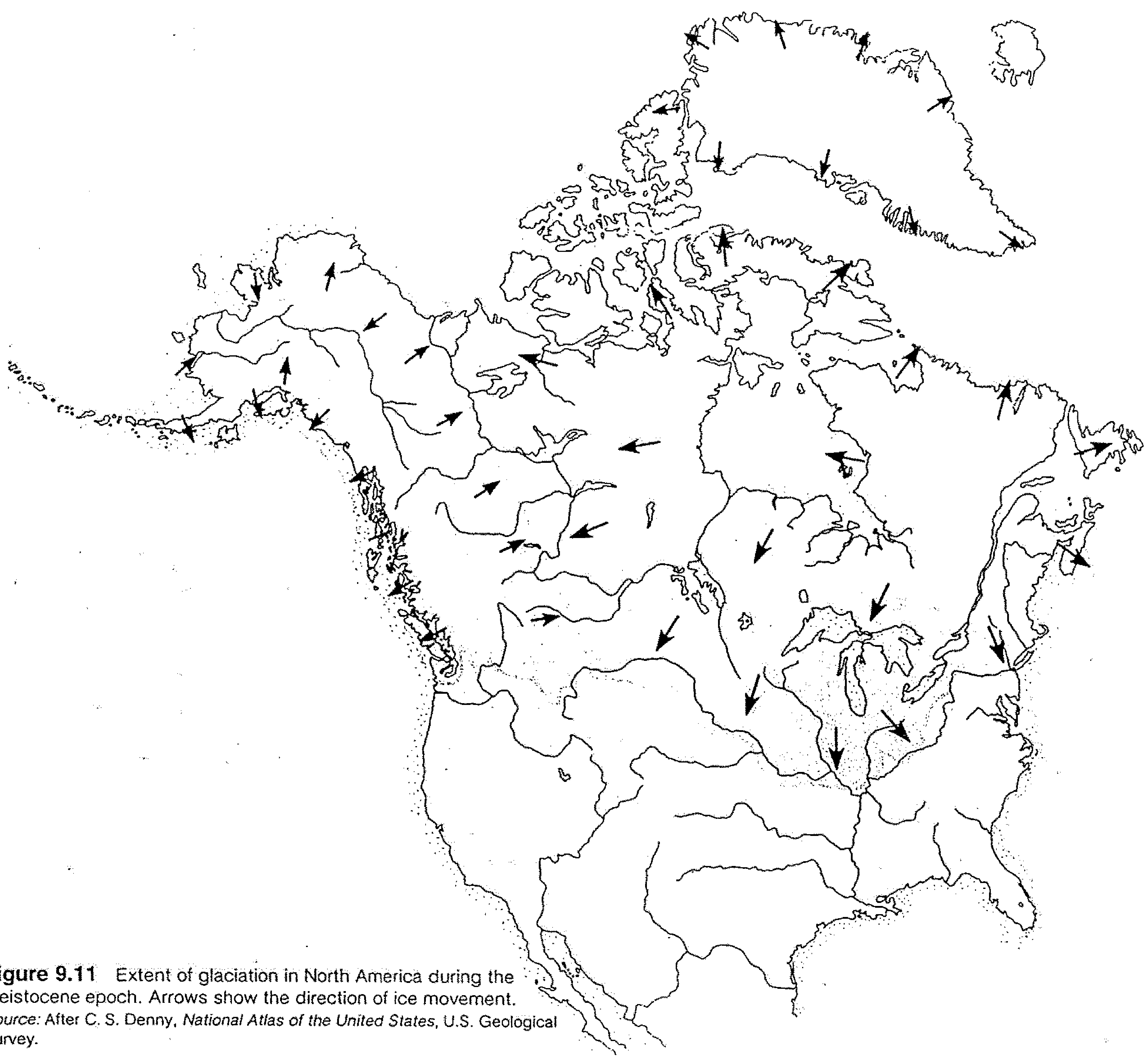


Figure 9.11 Extent of glaciation in North America during the Pleistocene epoch. Arrows show the direction of ice movement.
Source: After C. S. Denny, *National Atlas of the United States*, U.S. Geological Survey.

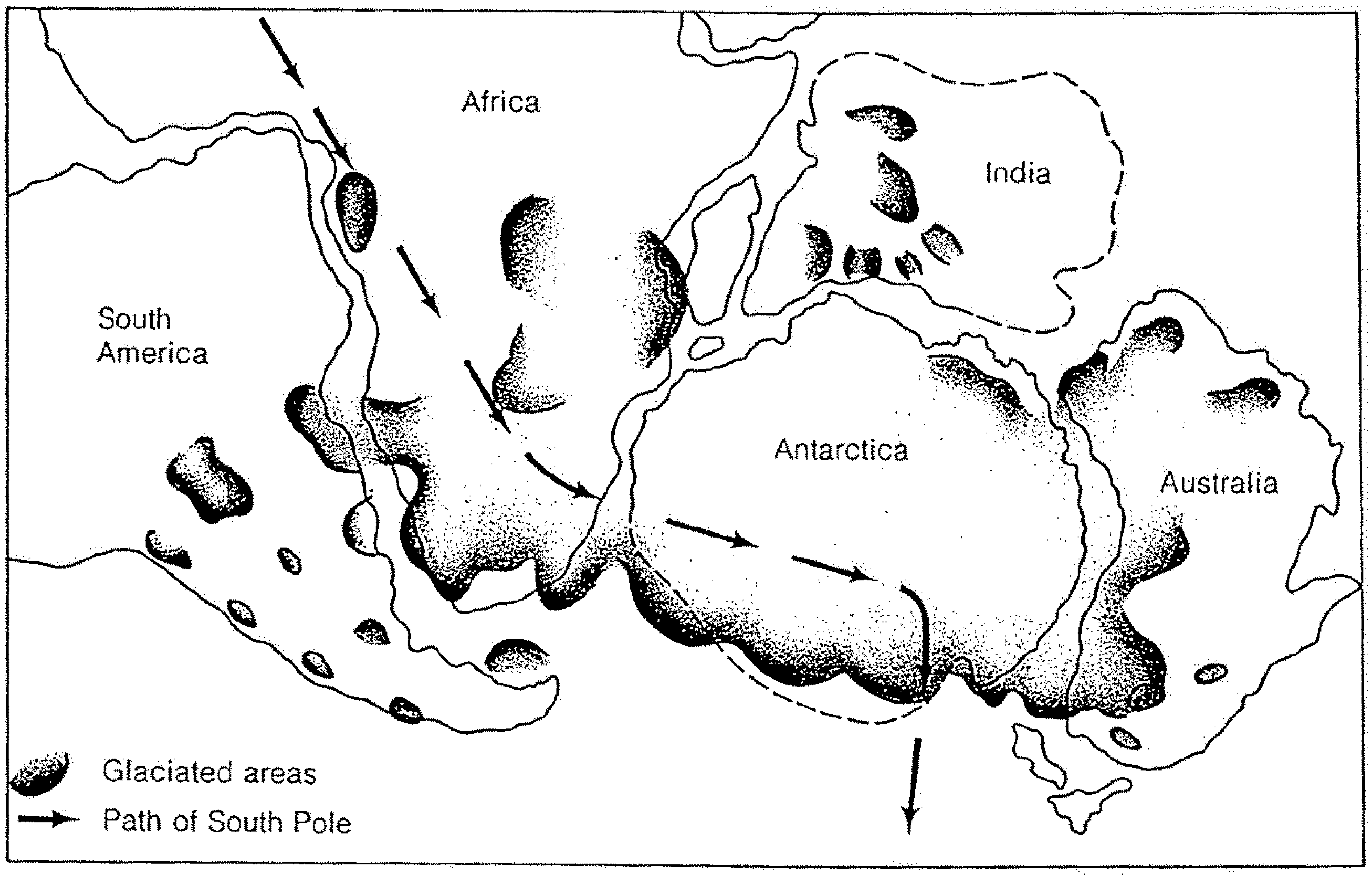


Figure 10-31

Late Paleozoic glaciated areas of Gondwanaland, the southern continent that formed in the Late Paleozoic Era. These continental glaciers, inferred from glacial deposits and striated bedrock, waxed and waned irregularly for about 90 million years from Late Mississippian to Middle Permian times, not all areas flourishing at the same time. The path of the South Pole is reconstructed from paleomagnetic data of M. W. McElhinny. [After J. C. Crowell, "Gondwanan Glaciation, Cyclothems, Continental Positioning, and Climate Change," *American Journal of Science,* v. 278, p. 1346, 1978.]

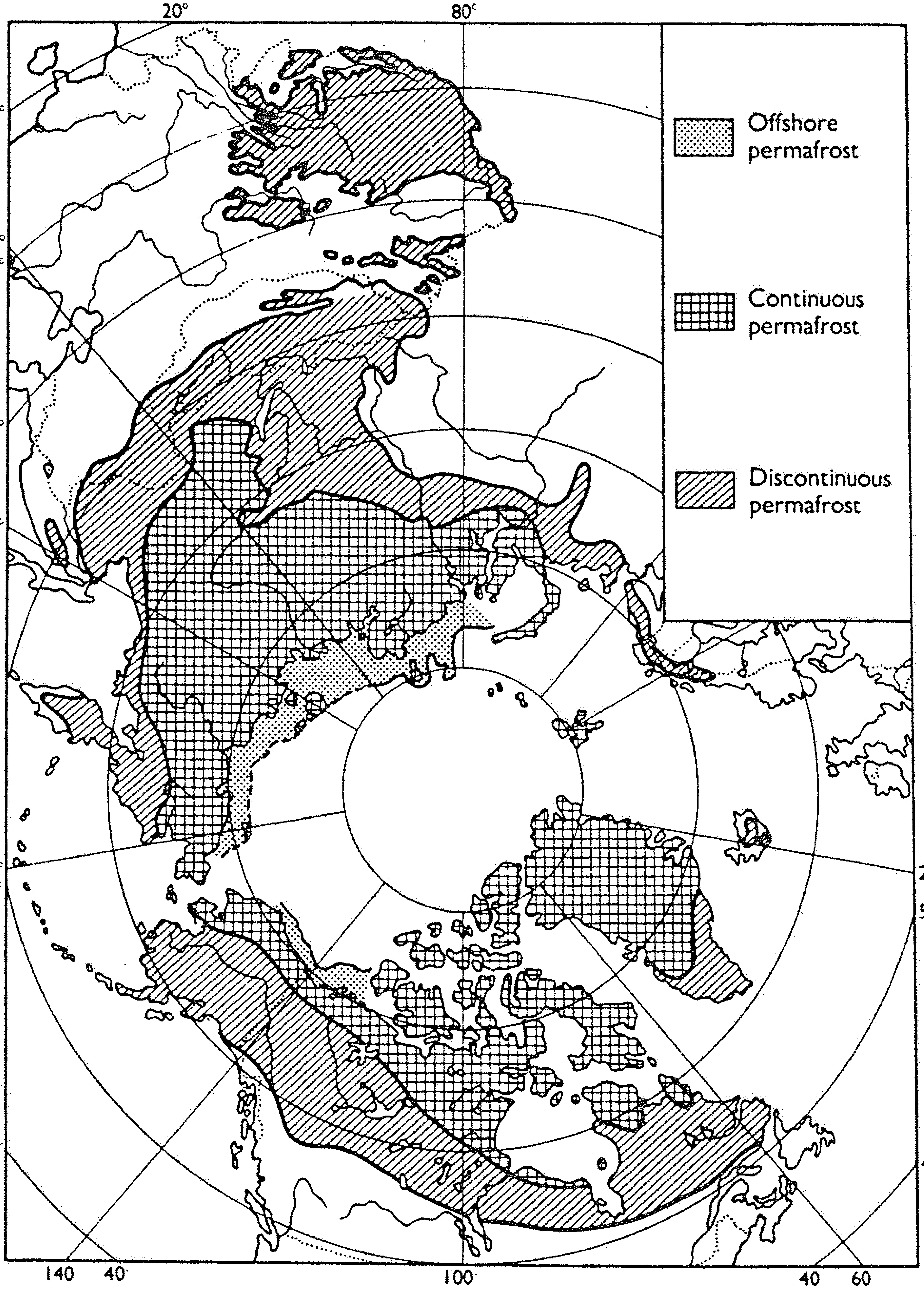
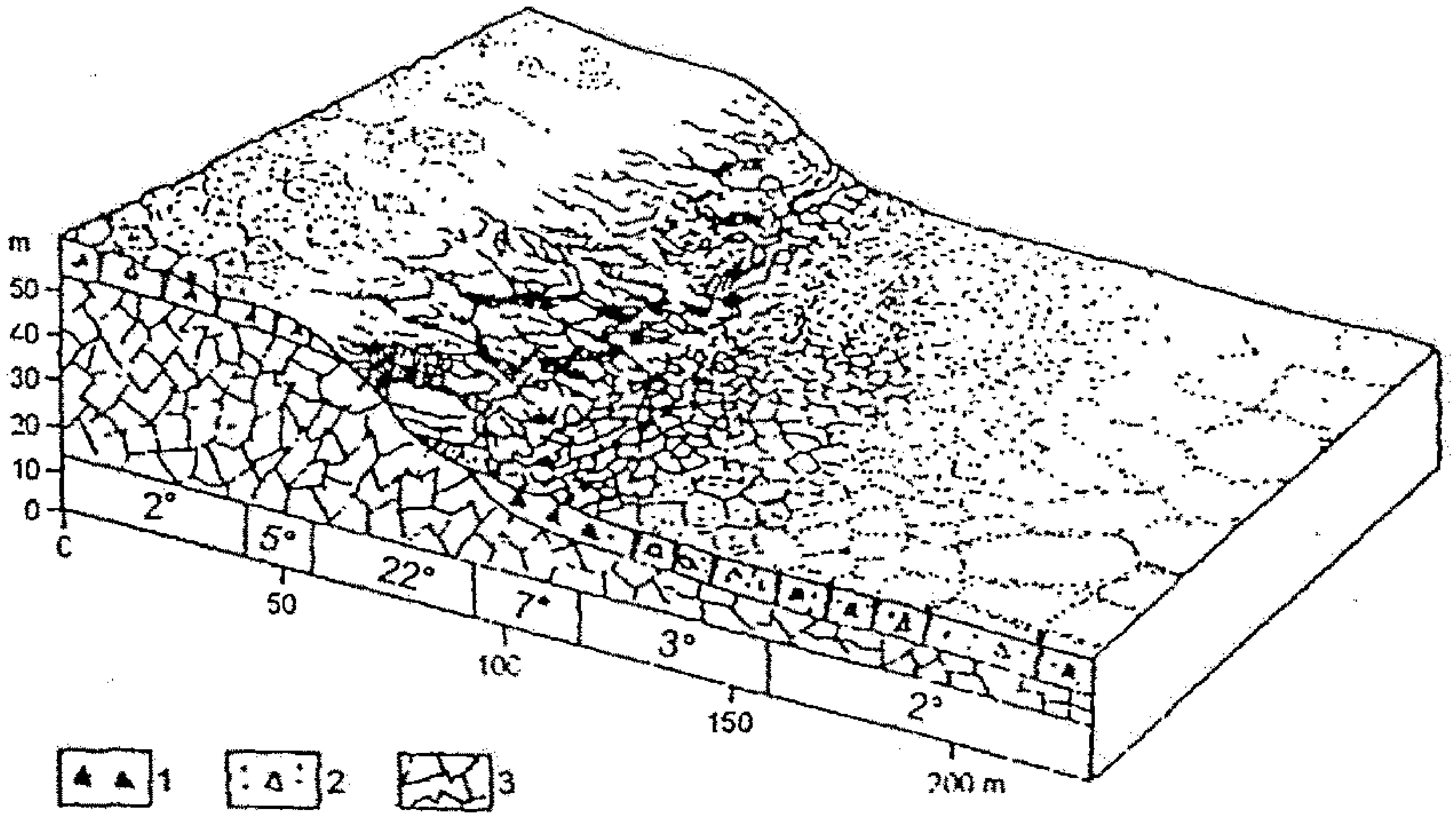
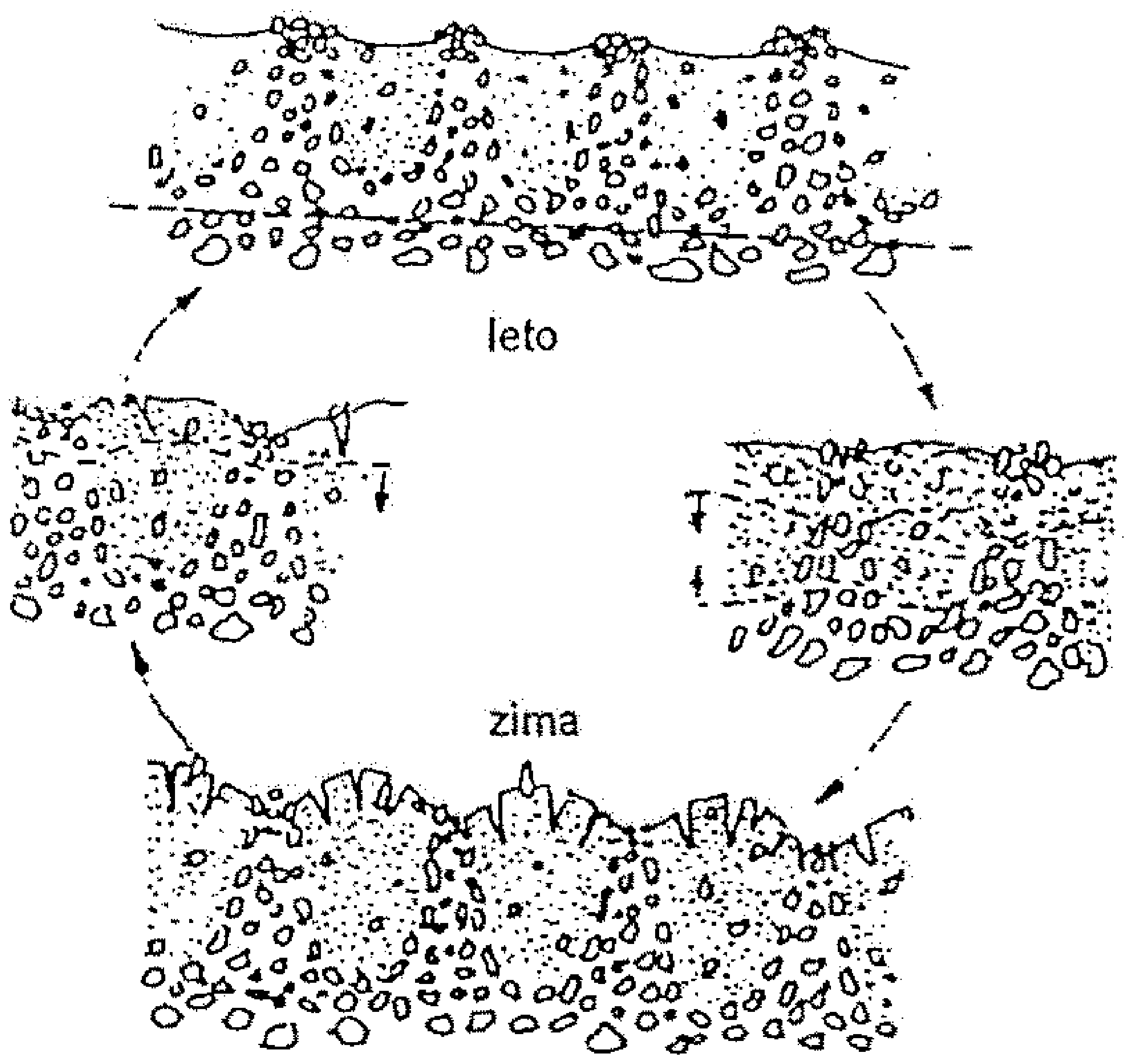


Abb. 38. Verbreitung von Permafrost auf der Nordhalbkugel. Nach WASHBURN 1979: 23.

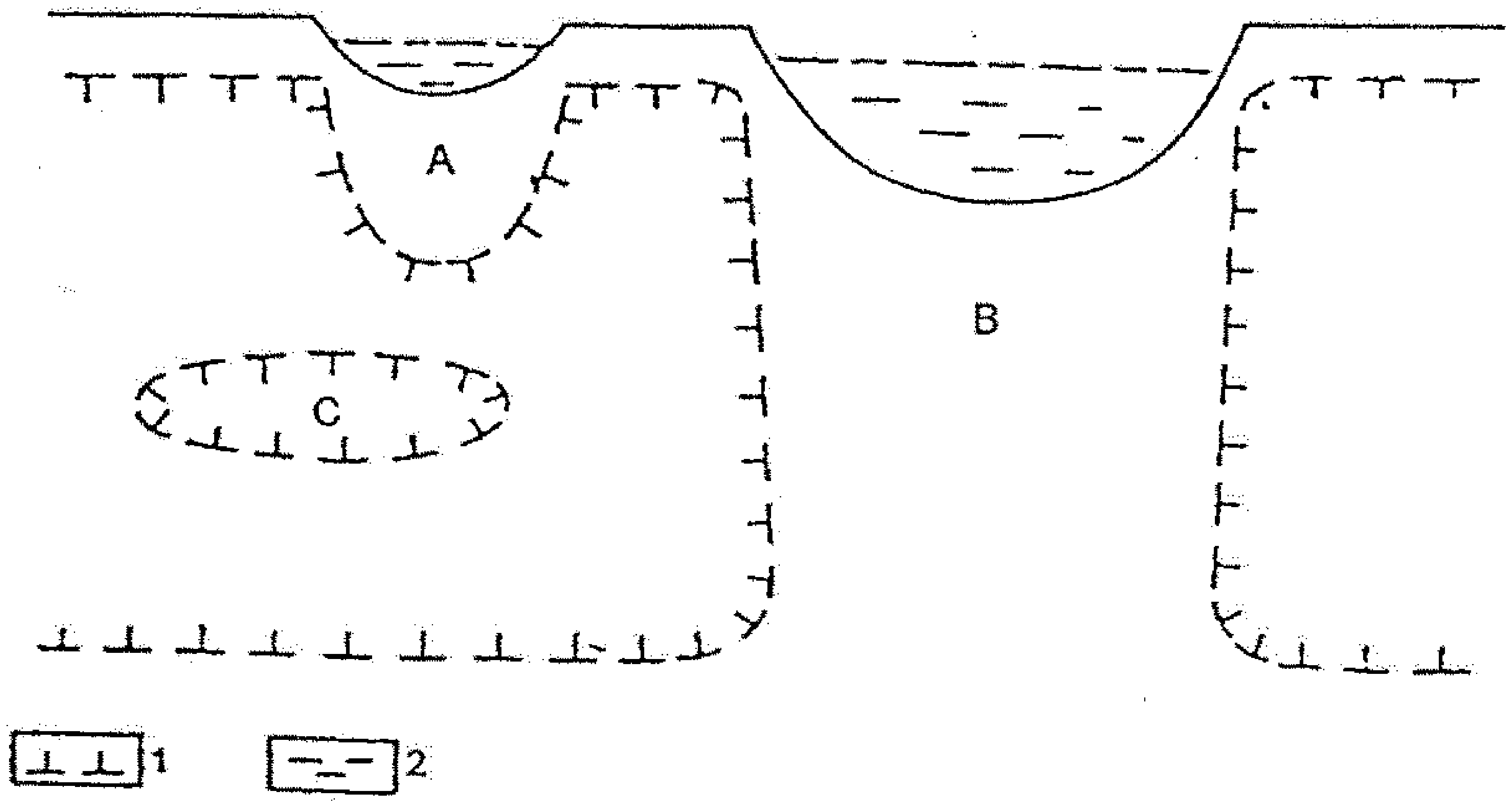
19.3 Kryoturbáciou zvírené pôdy (činná vrstva) sa na povrchu prejavujú vznikom kamenných polygónov a vencov s jemnozemou uprostred.

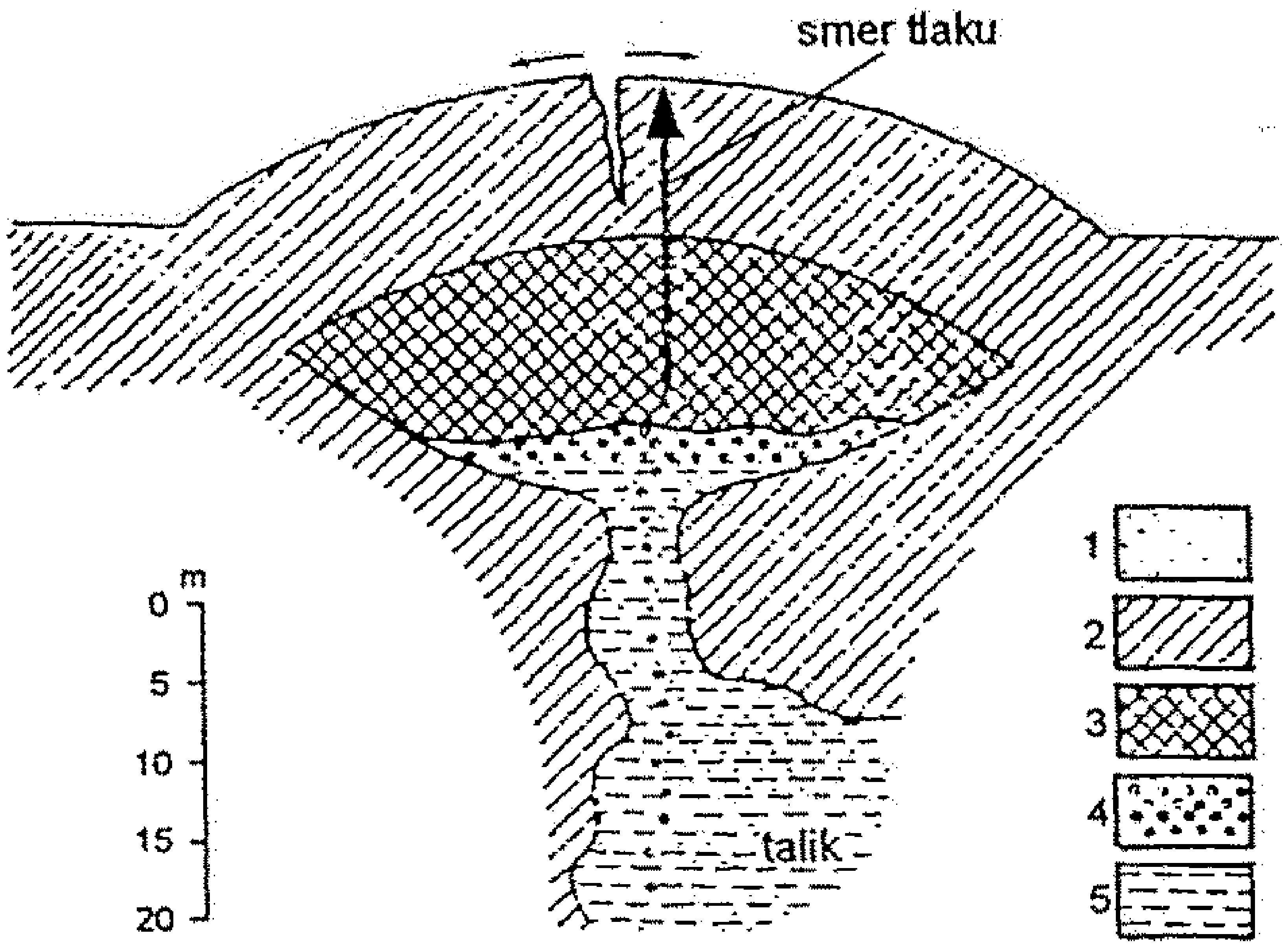




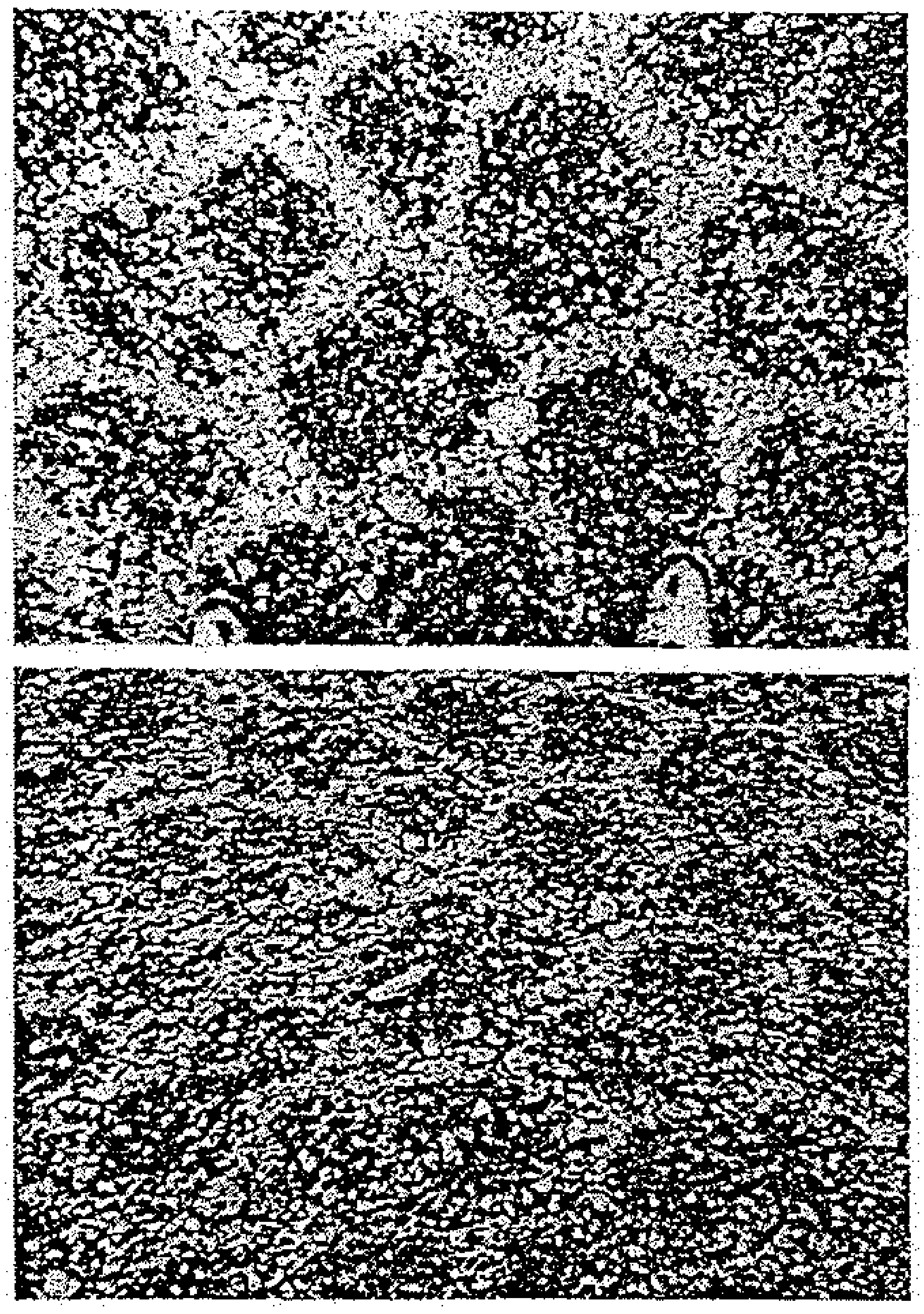
Kryoplanačné terasy oddelené nivačným zrubom. Vysvetlívky: 1 – ostrohranná suť, 2 – jadra kamenných polygónov, 3. skalné podložie

Typy talikov: A– uzavretý podjazerný talik, B– otvorený podjazerný talik, C– vnútorný talik 1– hranice permafrostu, 2– voda





19.5 Profil pingom. 1– piesok, 2– permafrost, 3– ľadová šošovka z doby vzniku pinga, 4– plyn, 5– podzemná voda v taliku



1 Steinringe (Polygonboden), Kleinformen; Island

2 Streifenfrostboden am Mt. Kema in 4300 m Höhe

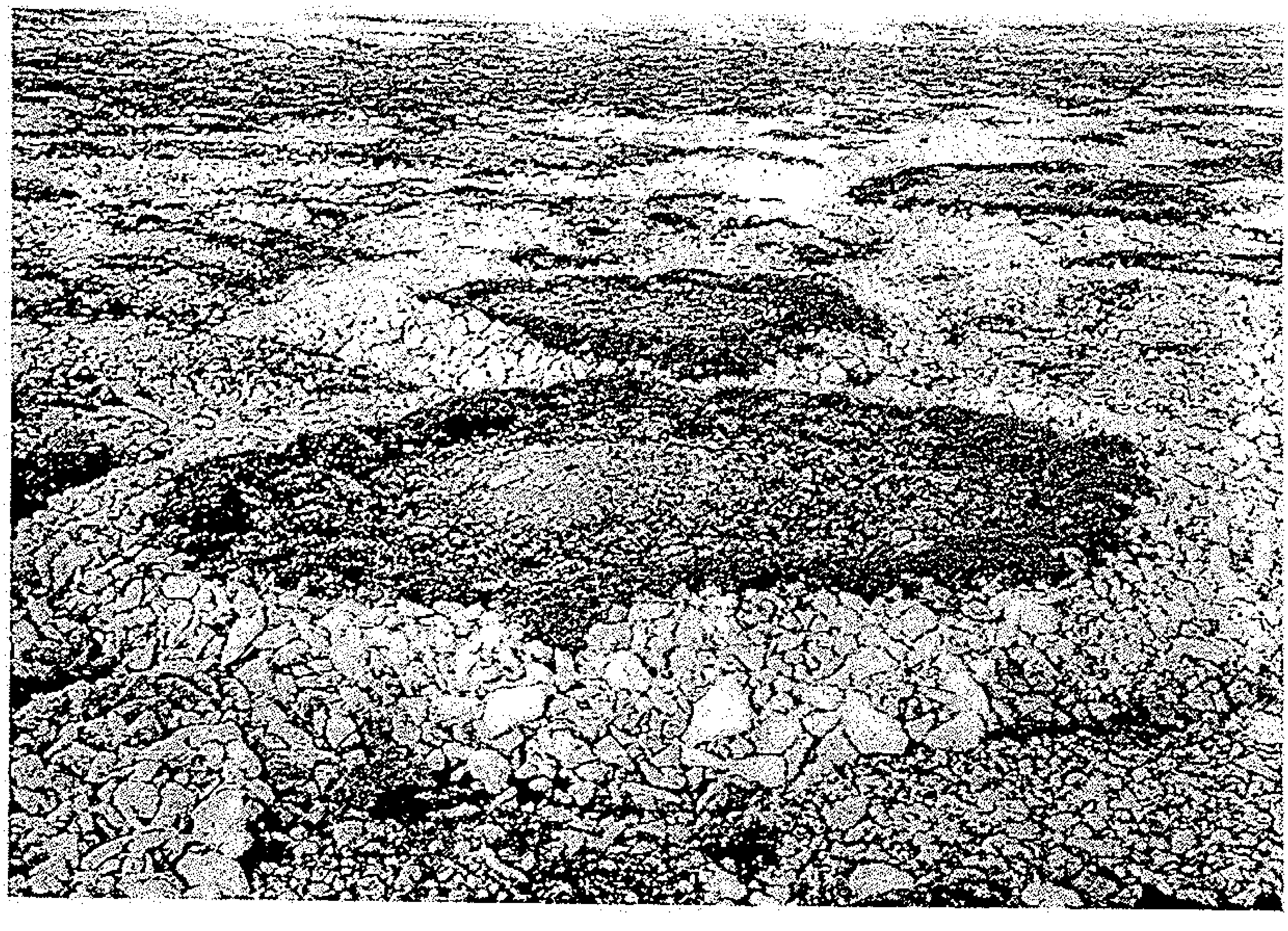
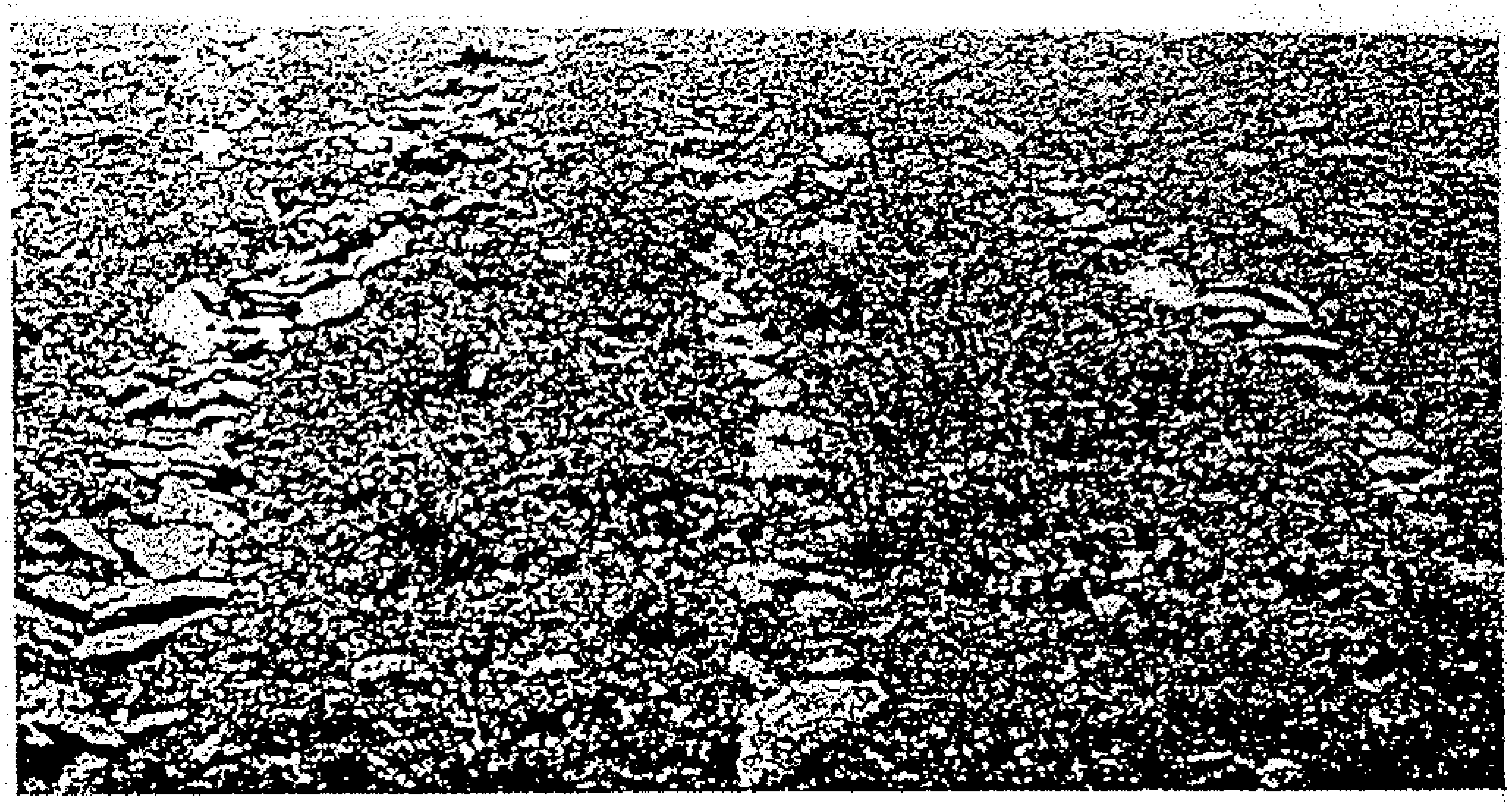
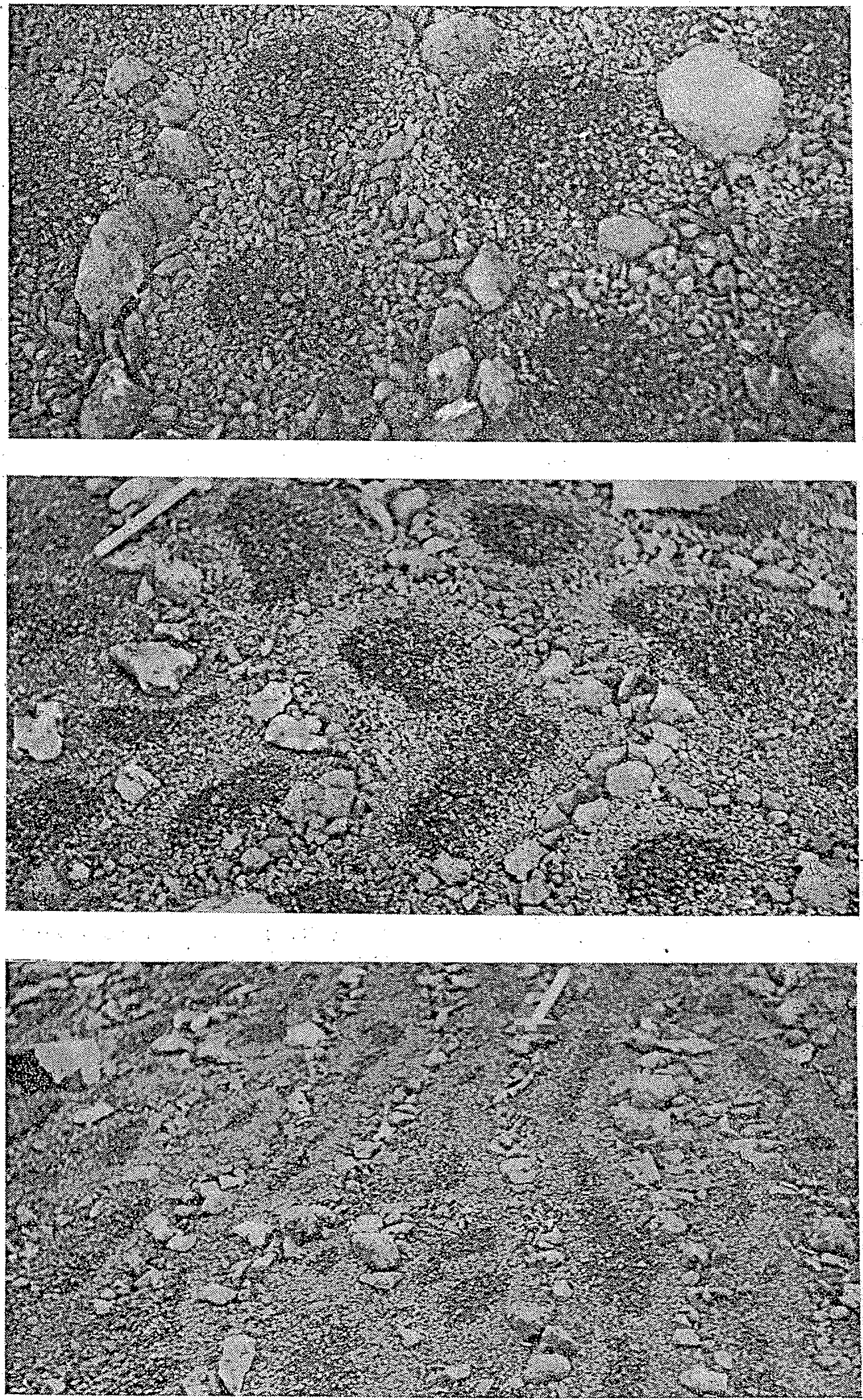


Abb. 32 Polarer Steinnetzboden. Steinringe mit Feinerde im Kern. Königsbucht, Spitzbergen (nach *F. Mattick*)

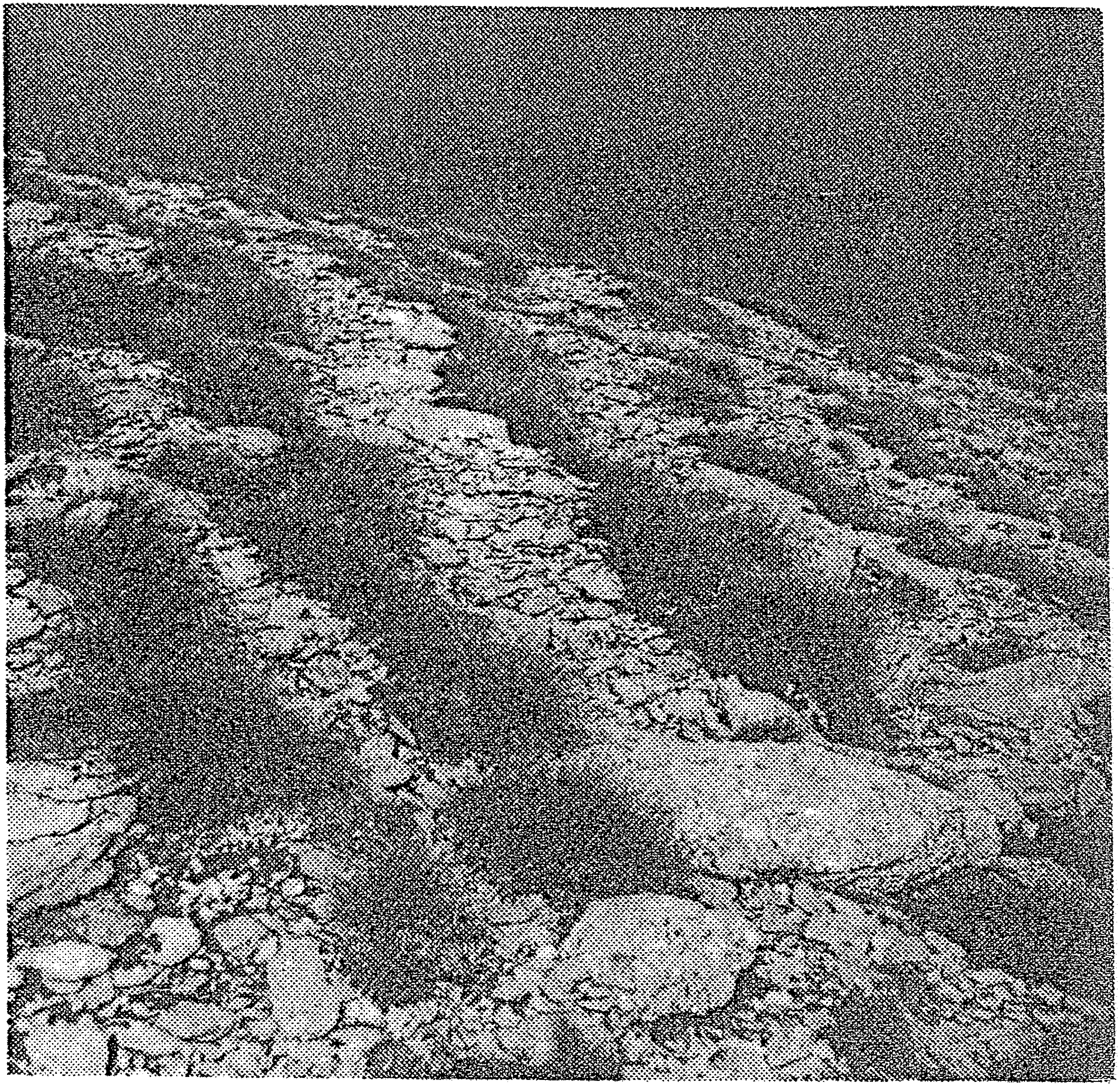


1 Steinstreifenboden in Nordschottland

Obr. 134. *Blokdiagram, znázorňující deformaci políčkované (polygonové) půdy soliflukcí na svazích. Šipky značí směr soliflukce. V předním profilu vidíme průřezy ledových klínů.* (Podle C. F. Sharpea.)



Obr. 241. *Polygonální půdy na Faerských ostrovech vzniklé soliflukcí. Nahoře: Pravidelná, okrouhle šestiboká políčka na vodorovném povrchu. Uprostřed: Na mírném svahu se políčka protahují. Dole: Na příkřejším svahu se protáhlá políčka mění v pruhy.* (Foto: prof. Dr JOSEF KUNSKÝ.)



Girlandové půdy na Bujačím vrchu, Belianske Tatry. (Foto J. Rubín.)

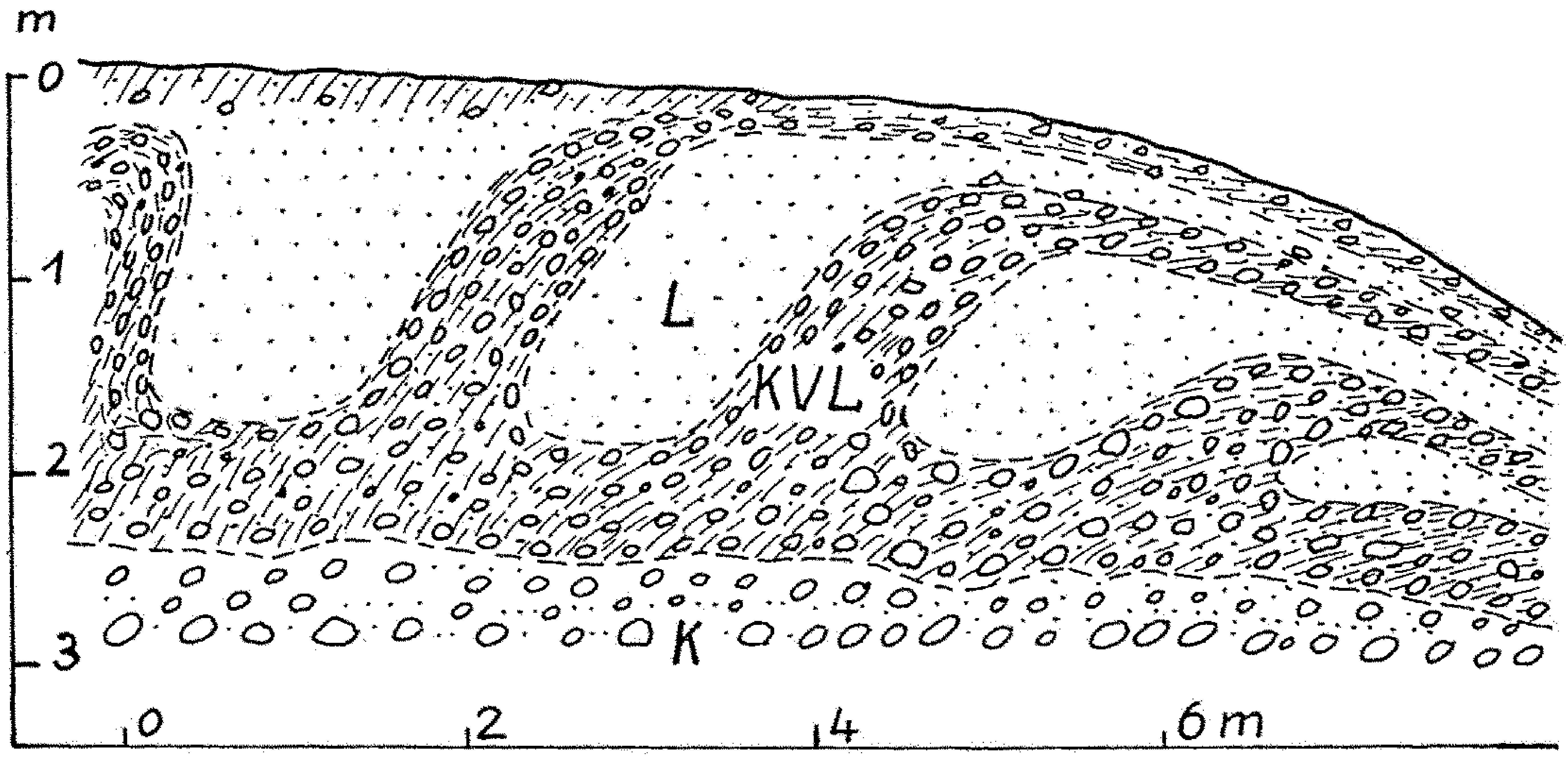


Abb. 49. Taschenboden, am Hang in Fließerde übergehend. Auf Schottern der Rißeiszeit nördlich Biberach, bei Attenweiler.
L – Lößlehm, oben humos und mit einzelnen Geröllen, KVL – Kiesverwitterungslehm, kalkfrei, K – Kies, kalkreich.
Der Lößlehm lag zunächst horizontal auf dem verwitterten Kies. Der Kies ist rißzeitlich, dann Verwitterung zwischen Riß und Würm. Löß-Aufwehung in der Würmeiszeit, dann Kryoturbation, wobei die Lößdecke eingefaltet wurde. Danach Gelifluktion in den oberen Lagen.

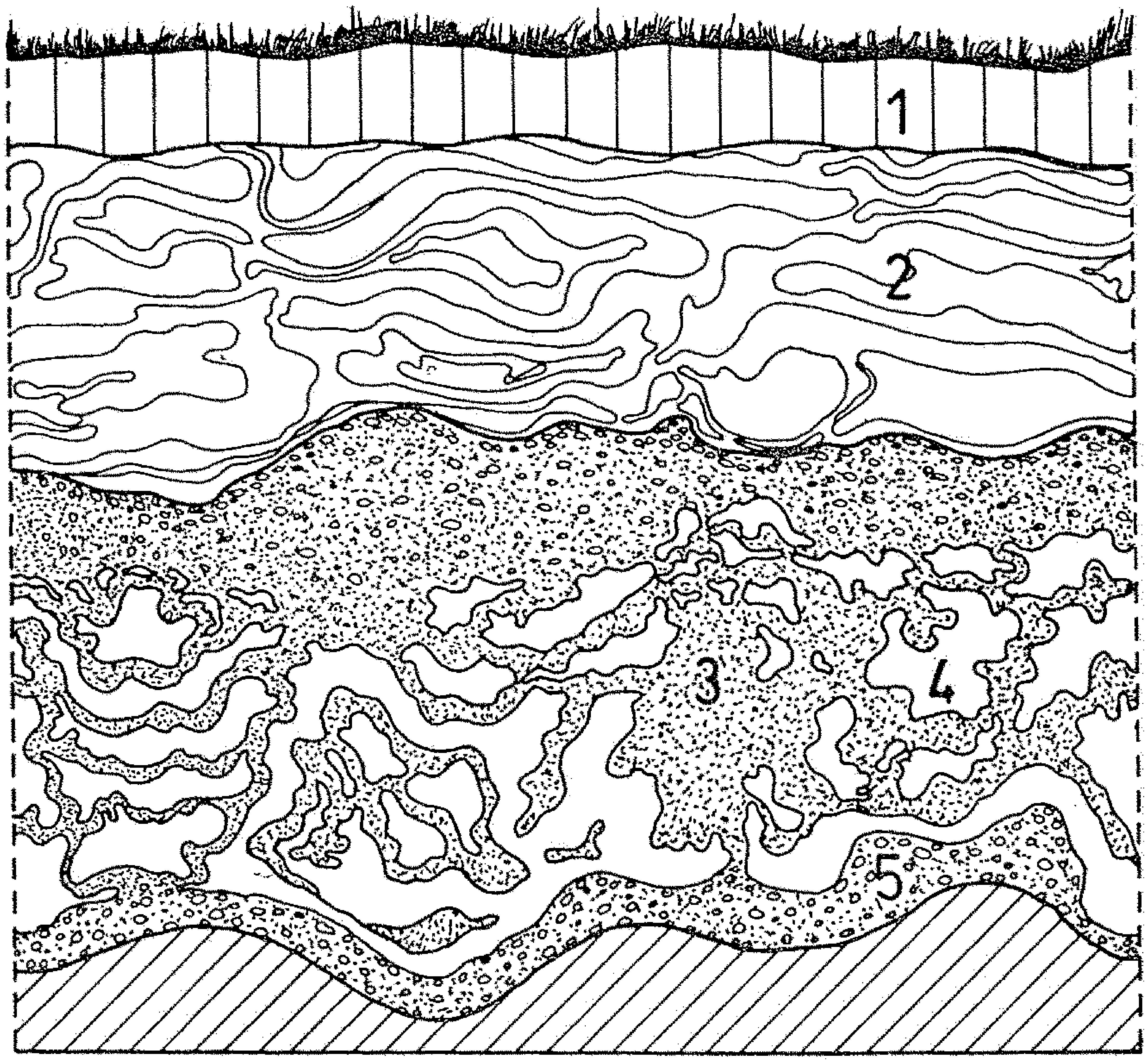
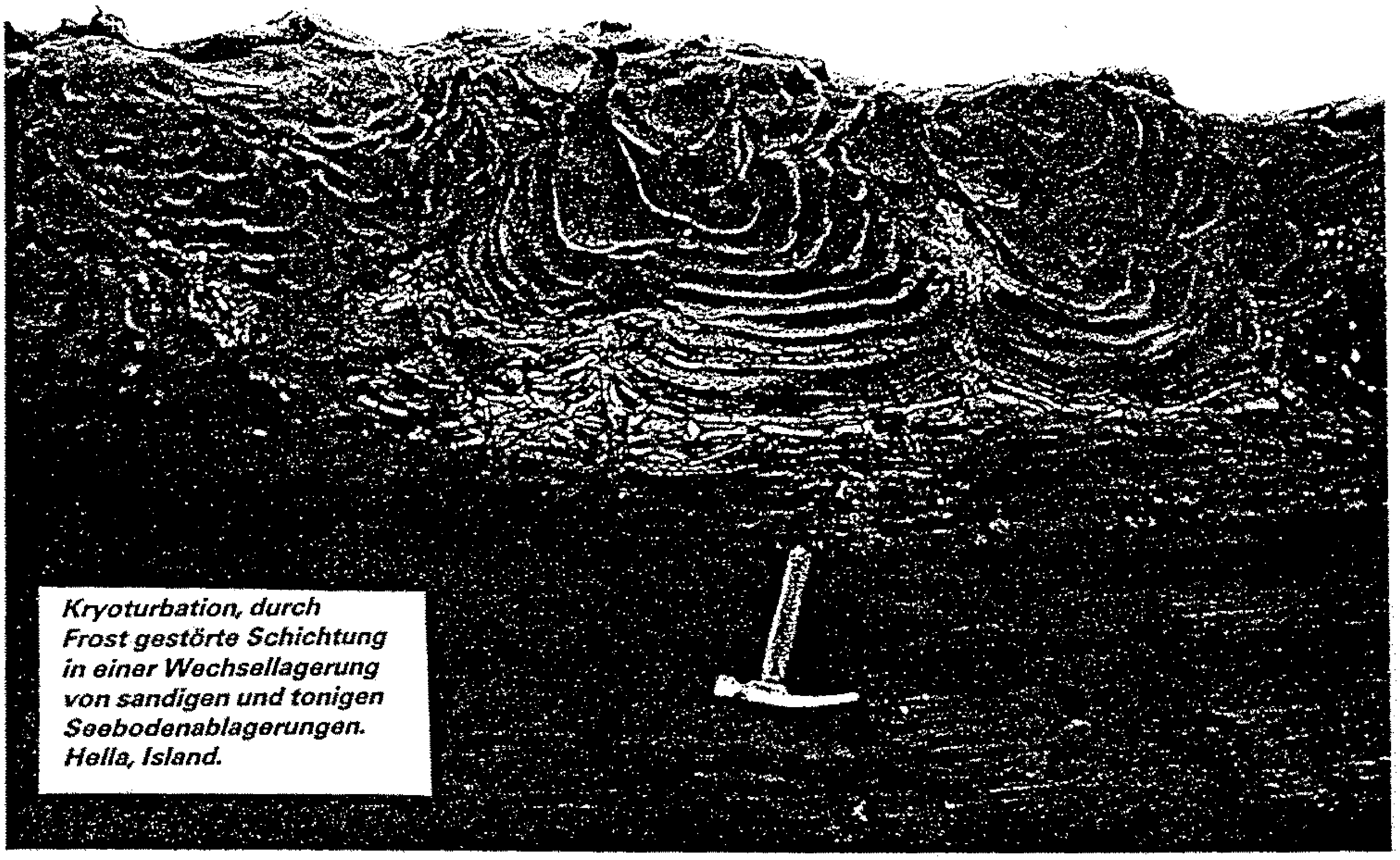


Abb. 50. Würgeboden in der Mittelterrasse am Niederrhein. Steeger 1944, Abb. 7.
1) Auffüllung, 2) geschichtete lößartige Feinsande, 3) Feinsand, z. T. kiesig, 4) toniger Feinsand, 5) Kies.



Kryoturbation, durch Frost gestörte Schichtung in einer Wechsellagerung von sandigen und tonigen Seebodenablagerungen. Hella, Island.

Abb. 31 Kryoturbates Gefüge durch Frostschub. Pleistozäne Pelite, Enger Grund, Karwendelgebirge

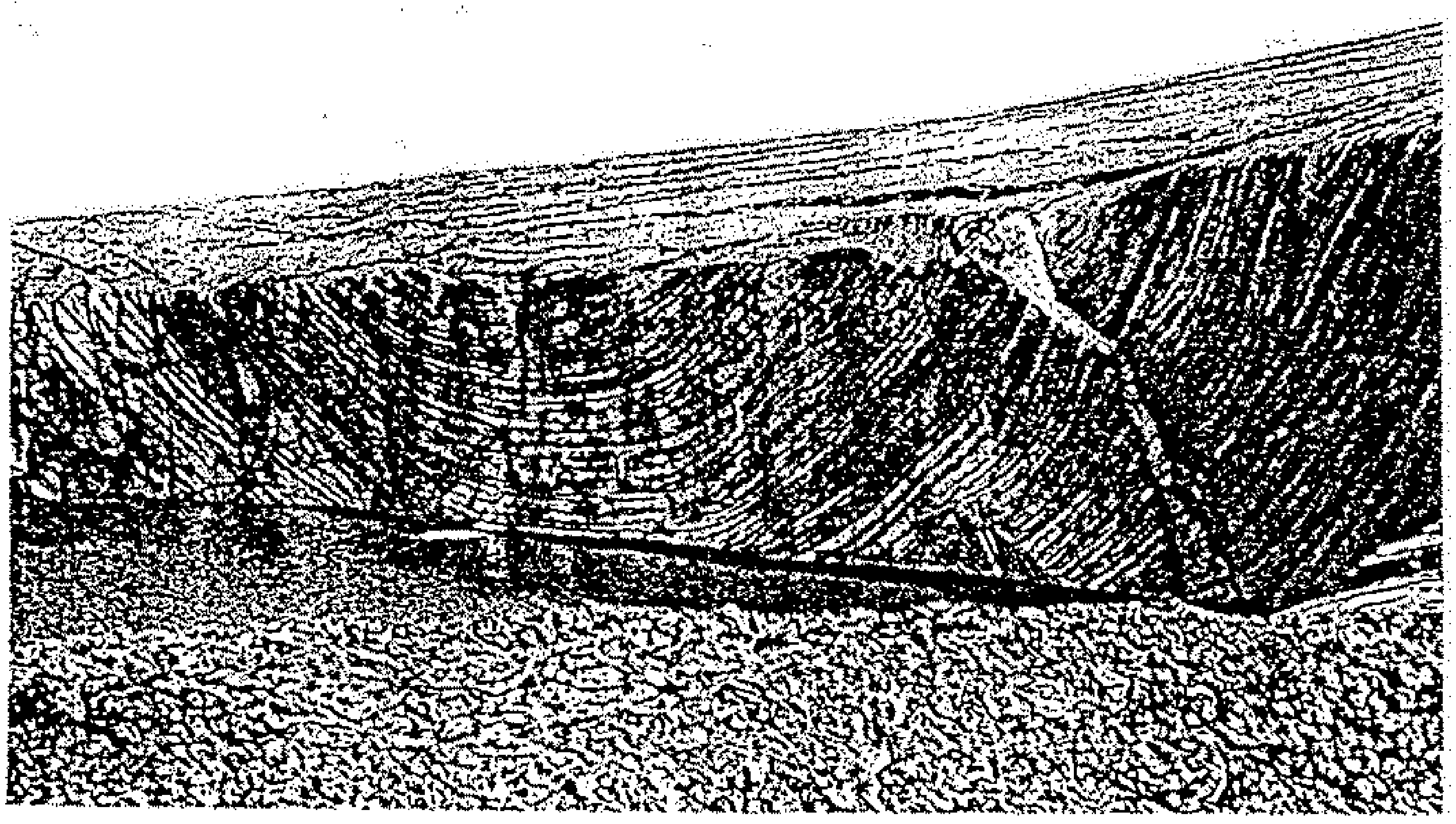
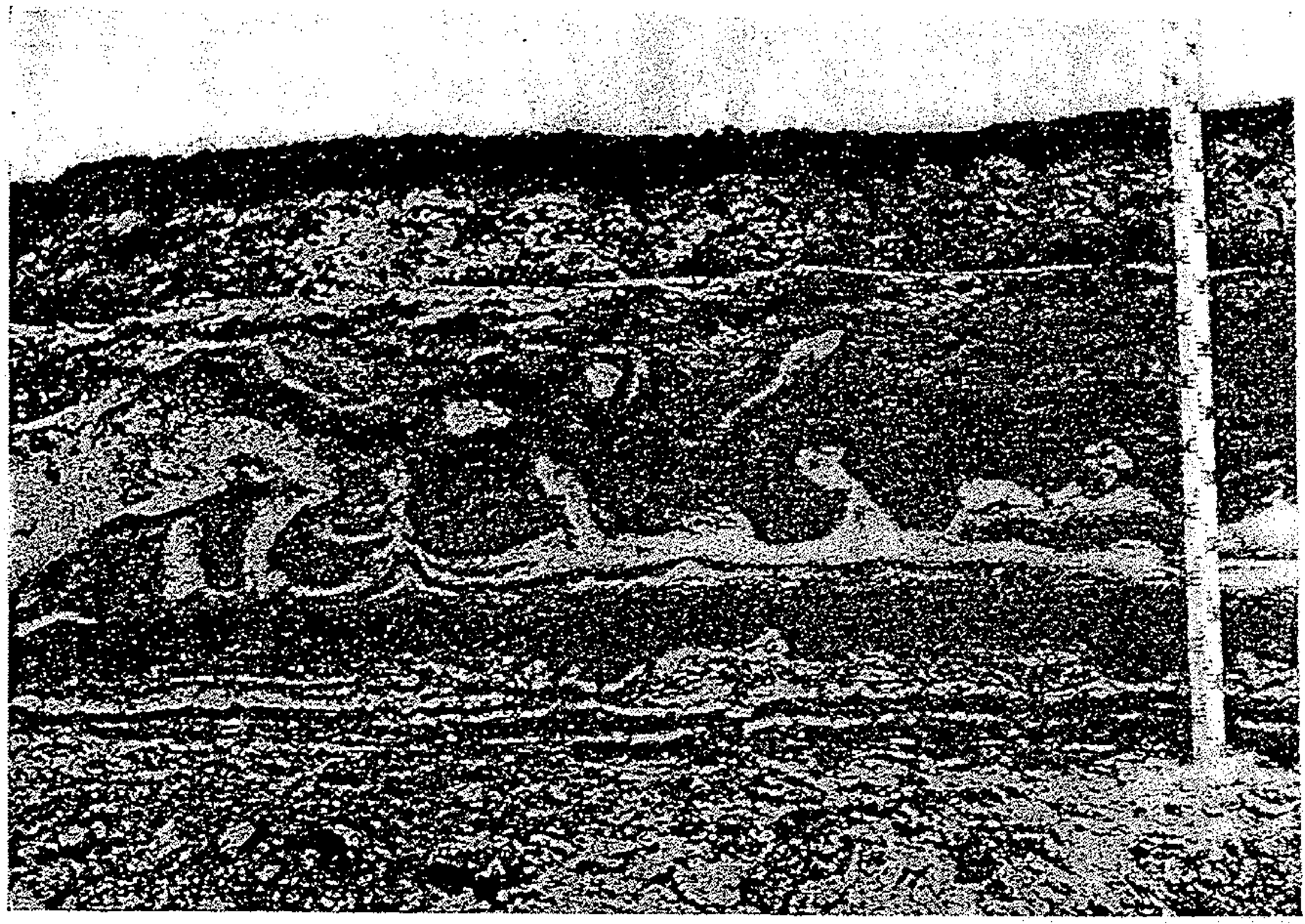
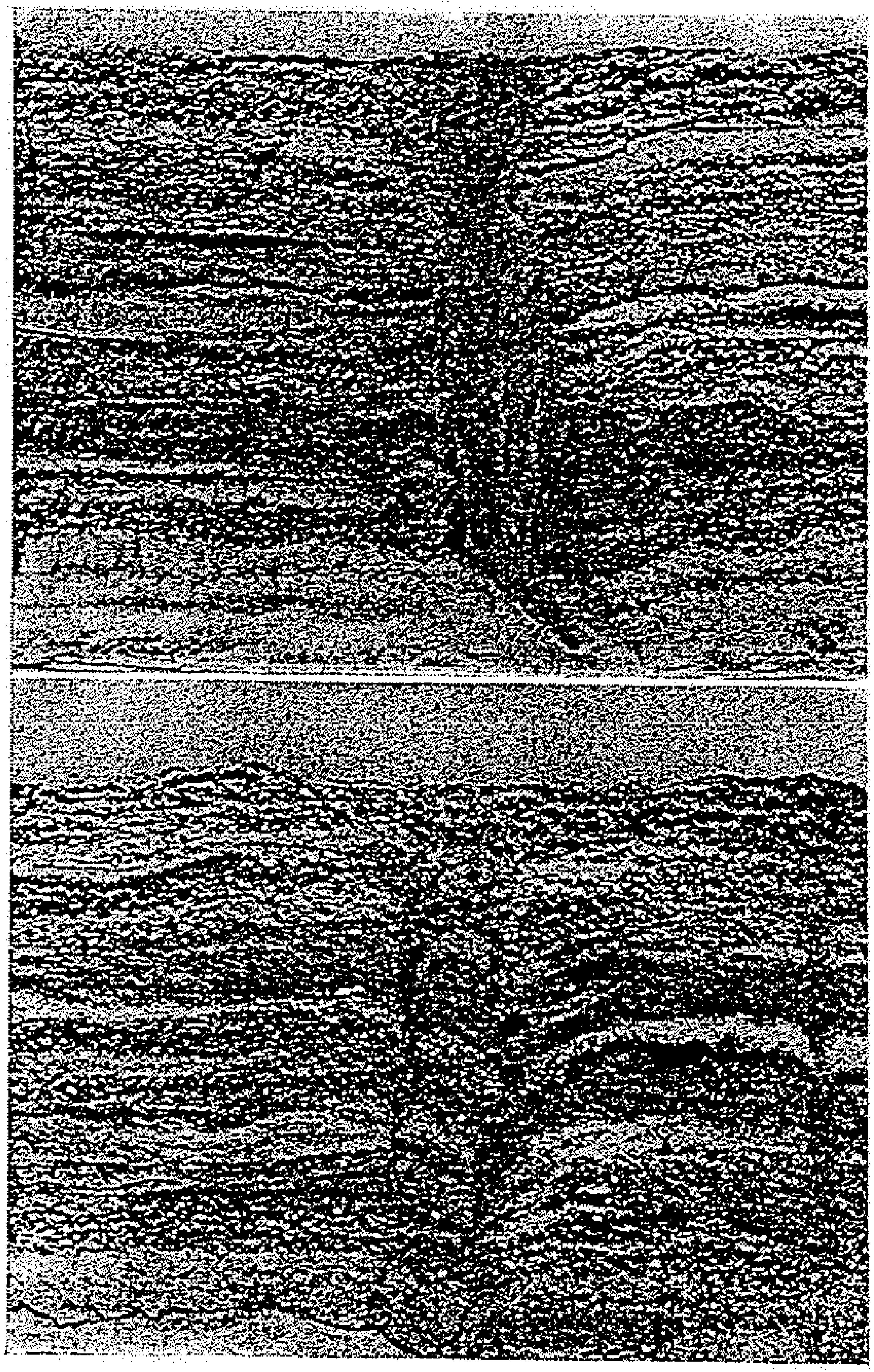


Abb. 24 Muldenförmig verbogenes Blaublattgefüge. Lischanna-Gletscher, Unterengadin



2 Eiszeitlicher Brodelboden im Deckgebirge der Braunkohle; Grube Marga, Lausitz



1 Schottergefüllte Keilspalten in den interglazialen Flußschottern der Salzke zwischen Bennstedt und Langenbogen, westlich von Halle

oben: einzelne Keilspalte

unten: doppelte Keilspalte

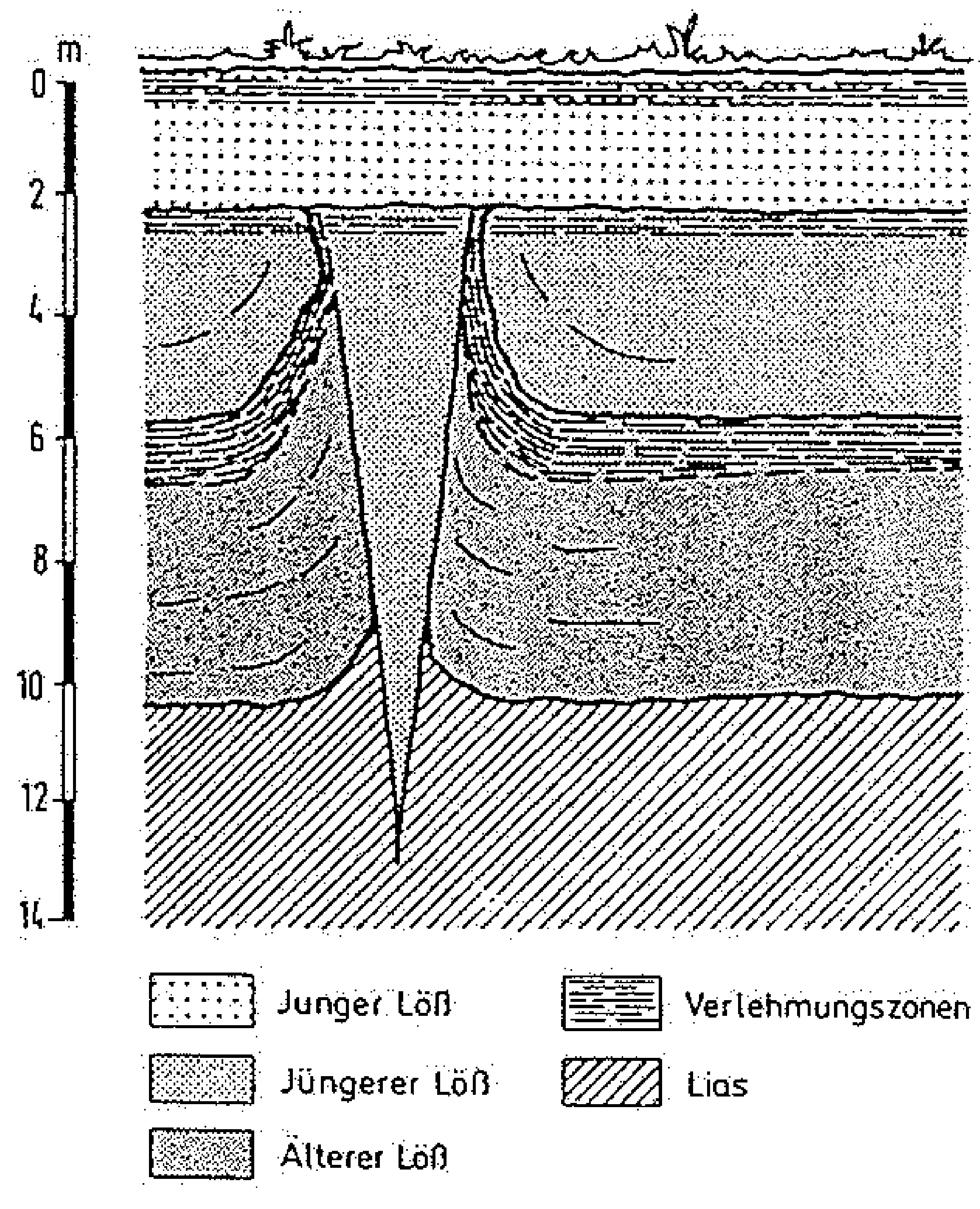
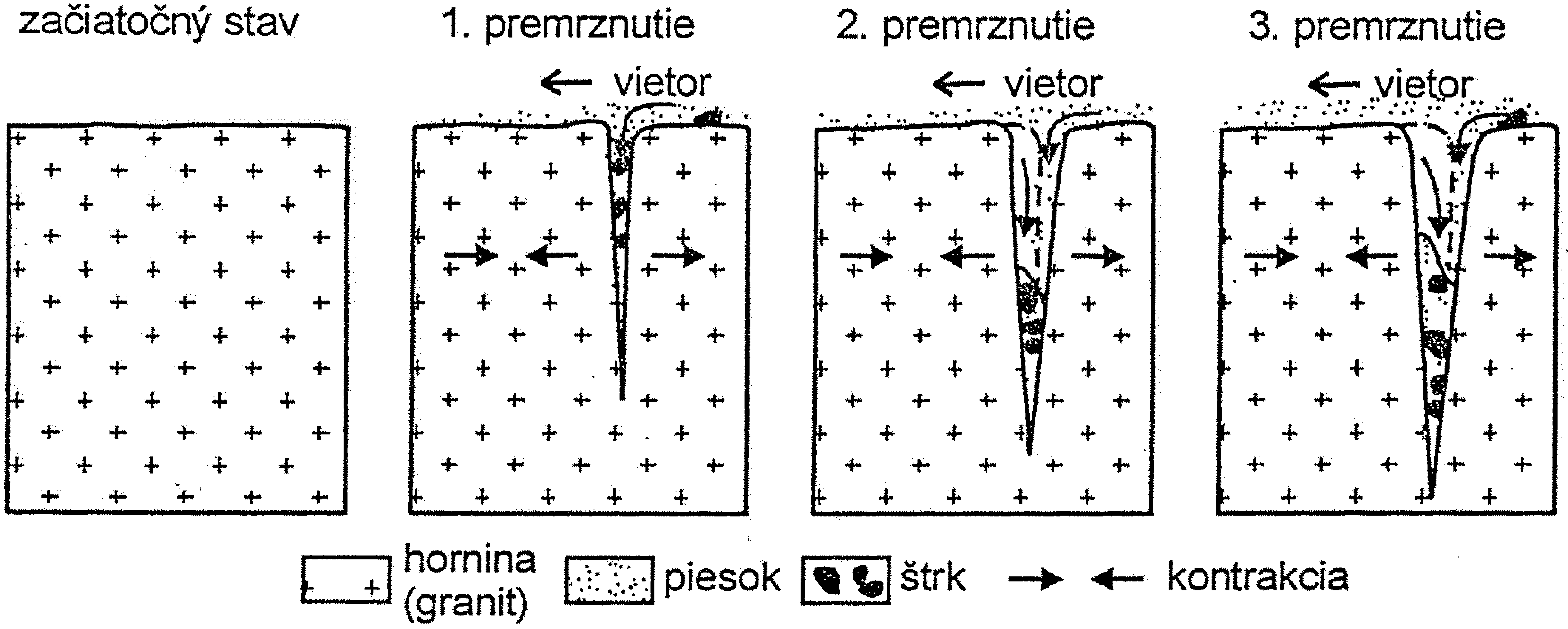
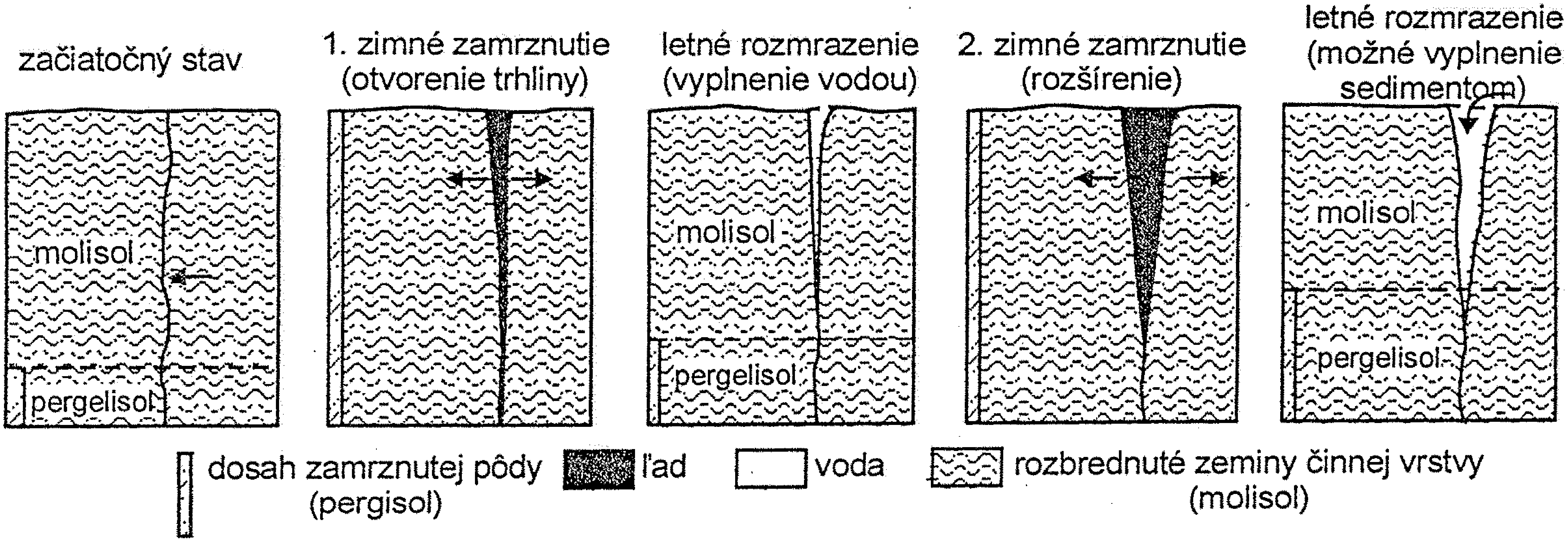


Abb. 33 Eiskeilspalte im Älteren Löß der Riß-Eiszeit und Jüngeren Löß 1 der frühen Würm-Eiszeit. Durch Gefrieren des Wassers unter Stauchung erweitert, später gefüllt und von Jüngerem Löß 2 der späten Würm-Eiszeit überdeckt. Göttingen (nach *G. Selzer*)

a) pieskový (mrazový) klin vzniká kontrakciou hornín v chladnom a suchom podnebí



b) ľadový klin vzniká tlakom zamŕzajúcej vody v trhline v chladnom a vlhkom podnebí



Obr. 19.2. Vznik a vývoj a – pieskového (mrazového) klinu, b – ľadového klinu. (podľa Campyho – Macaira 1989)

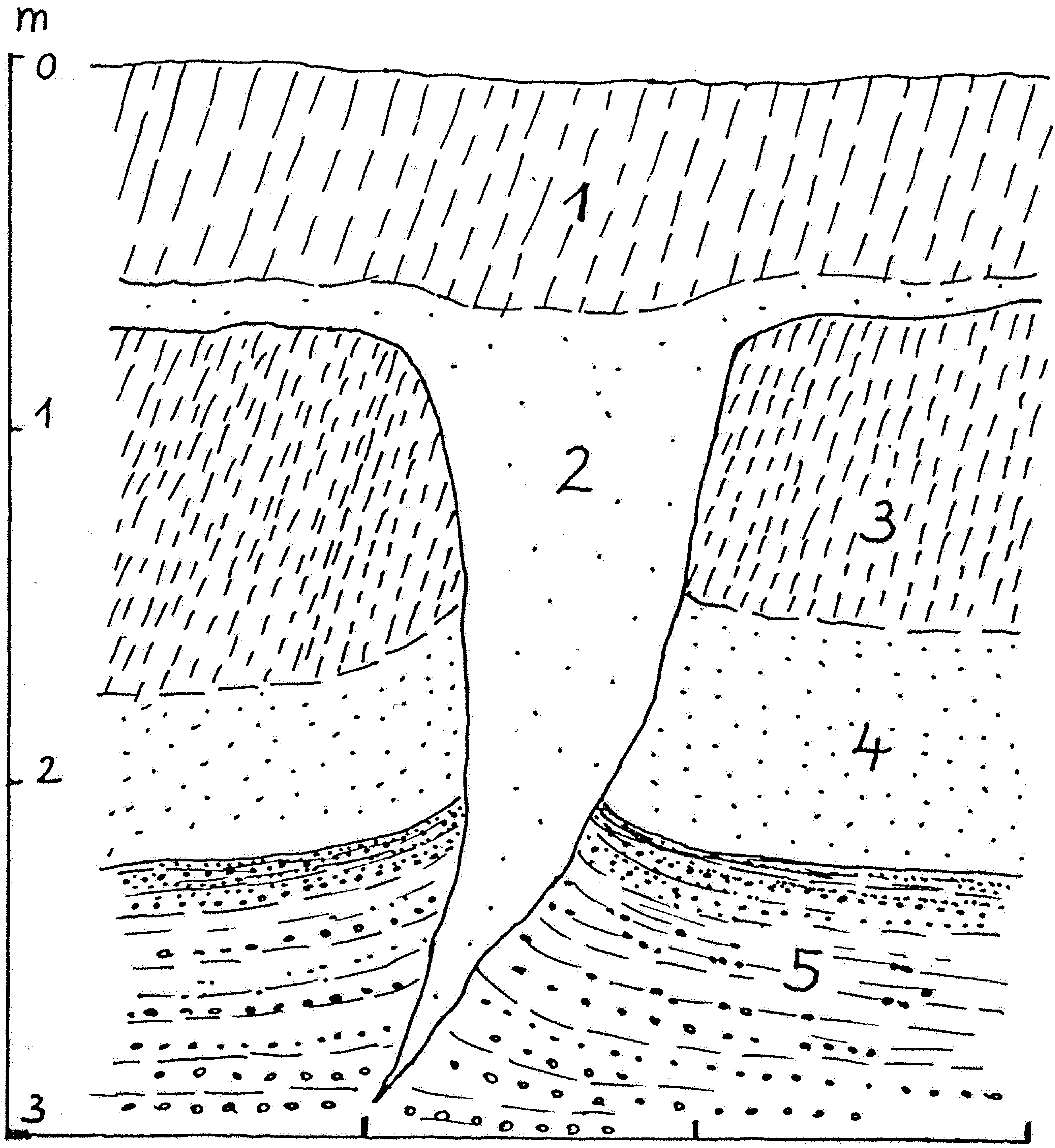


Abb. 42. Eiskeilfüllung:
1) Lößlehm, Bodenbildung aus 2, 2) Löß, 3) älterer Lößlehm, Bodenbildung aus 4, 4) älterer Löß, 5) siltiger Sand und Kies, geschichtet.

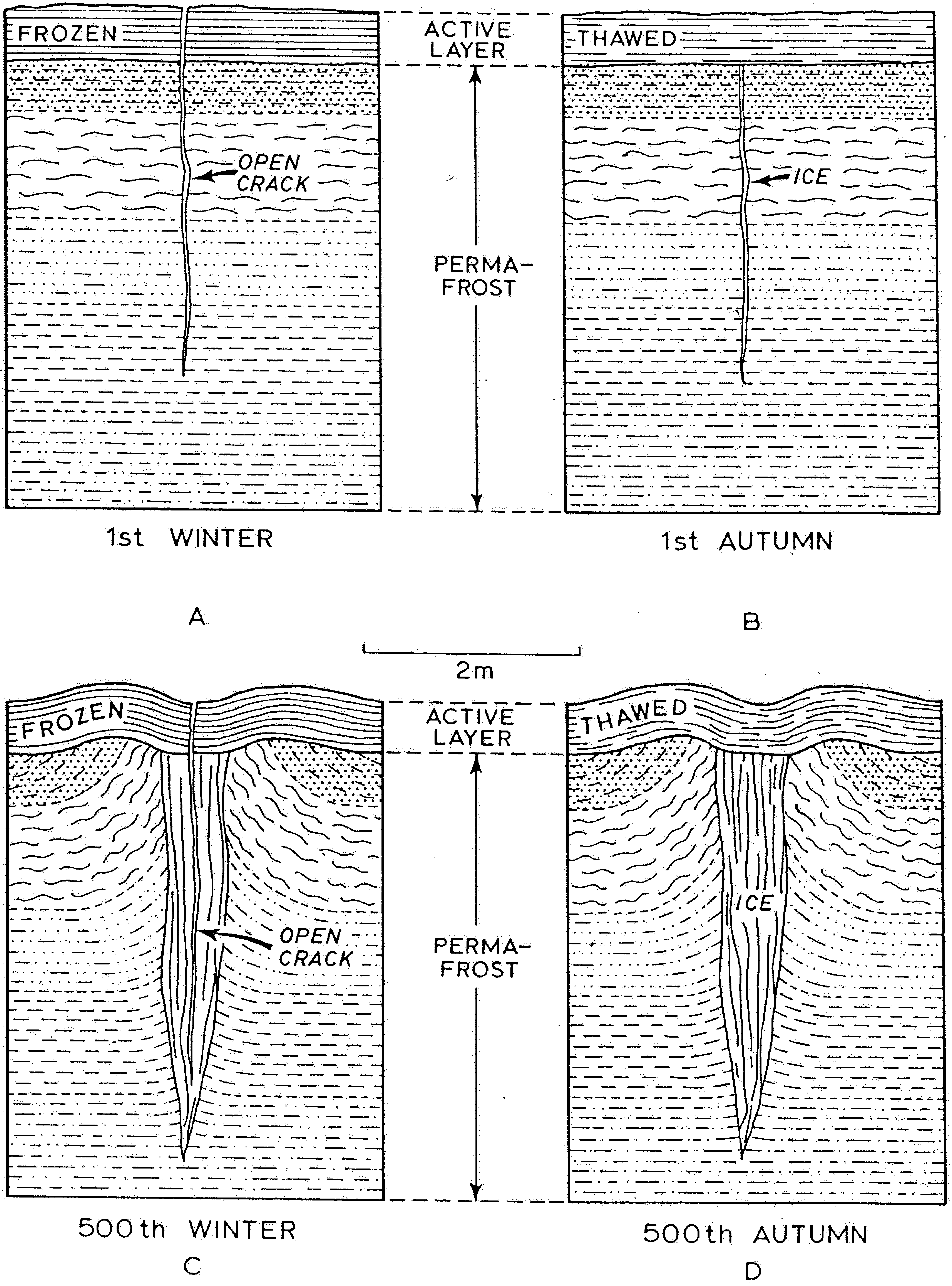


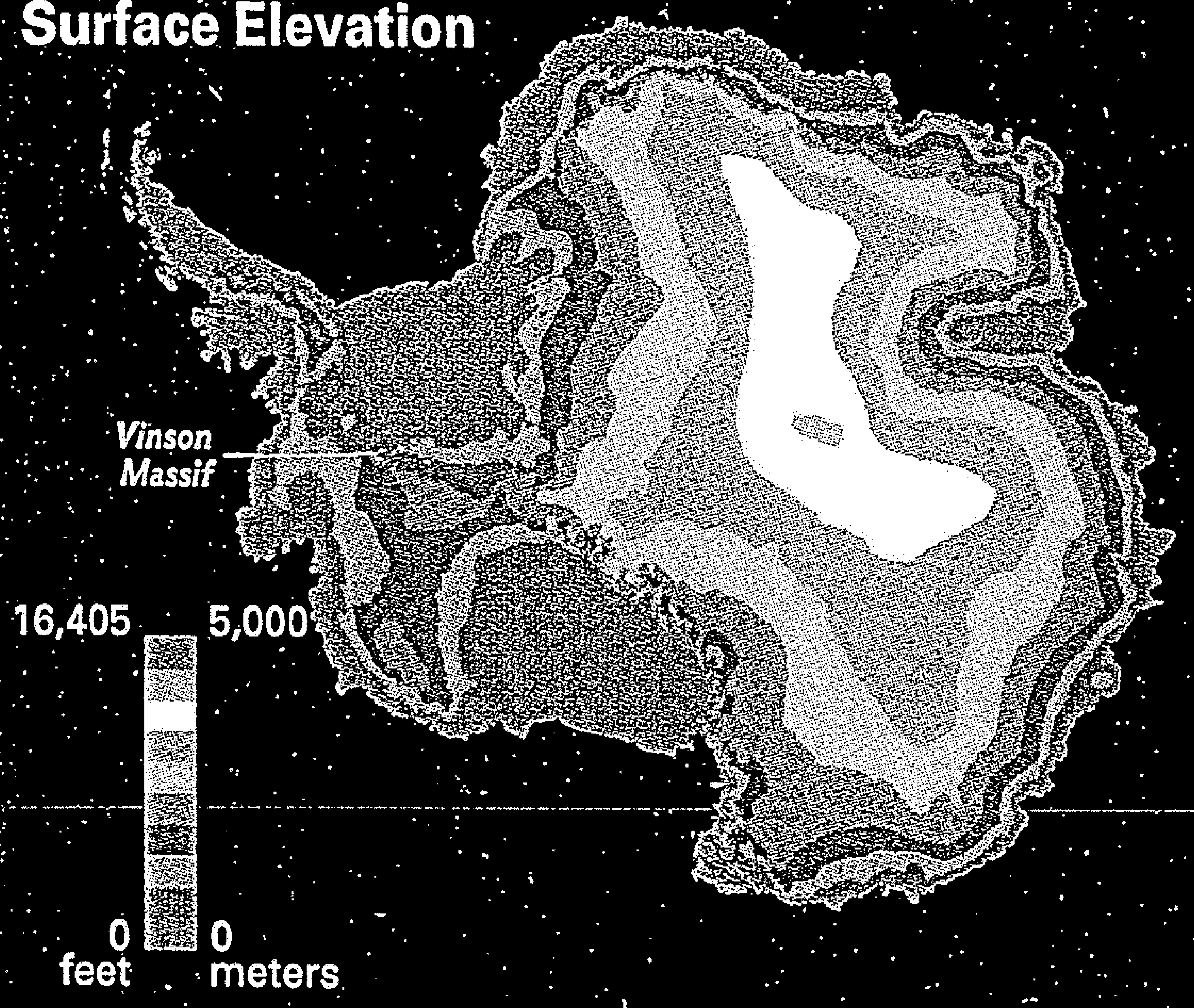
Abb. 41. Entstehung eines Eiskeils nach der Kontraktionstheorie von LACHENBRUCH 1962. Aus EMBELTON & KING 1975, Fig. 2.7.

Obr. 132. *Hákování vrstev. Vlevo: V souvrství příkře do svahu skloněných břidličných a pískovcových vrstev ohýbají se pod pláštěm svahové ssuti břidličné vrstvy po svahu, lavice křehkých pískovců se trhají v kry, které se posunují po svahu. Vpravo: Příkře po svahu skloněné vrstvy se pod pláštěm svahové ssuti ohýbají do překocené polohy; žíly vyvřelých hornin, prorážejících souvrstvím, se pod ssutí trhají v kry, které se posunují po svahu dolů.* (Originál.)

Obr. 172. *Hákování vrstev hlubočepských vápenců a stará soliflukce v odkopu na staveništi na Žvahově u Hlubočep.* (Foto prof. Q. ZÁRUBA.)

Obr. 136. *Stará soliflukce pod nánosem spraše v odkopu pod Šafránkou v Motole ve Velké Praze.* 1 = *spraš v původní poloze s holocenní černozemí na povrchu;* 2 = *svezlá půda, přemístěné křídové jíly perucké, na povrchu s balvany železitých pískovců;* 3 = *rozložené ordovické břidlice bohdalecké* ($d\varepsilon_2$) *vyvlečené soliflukcí.* (Podle Dr Q. Záruby.)

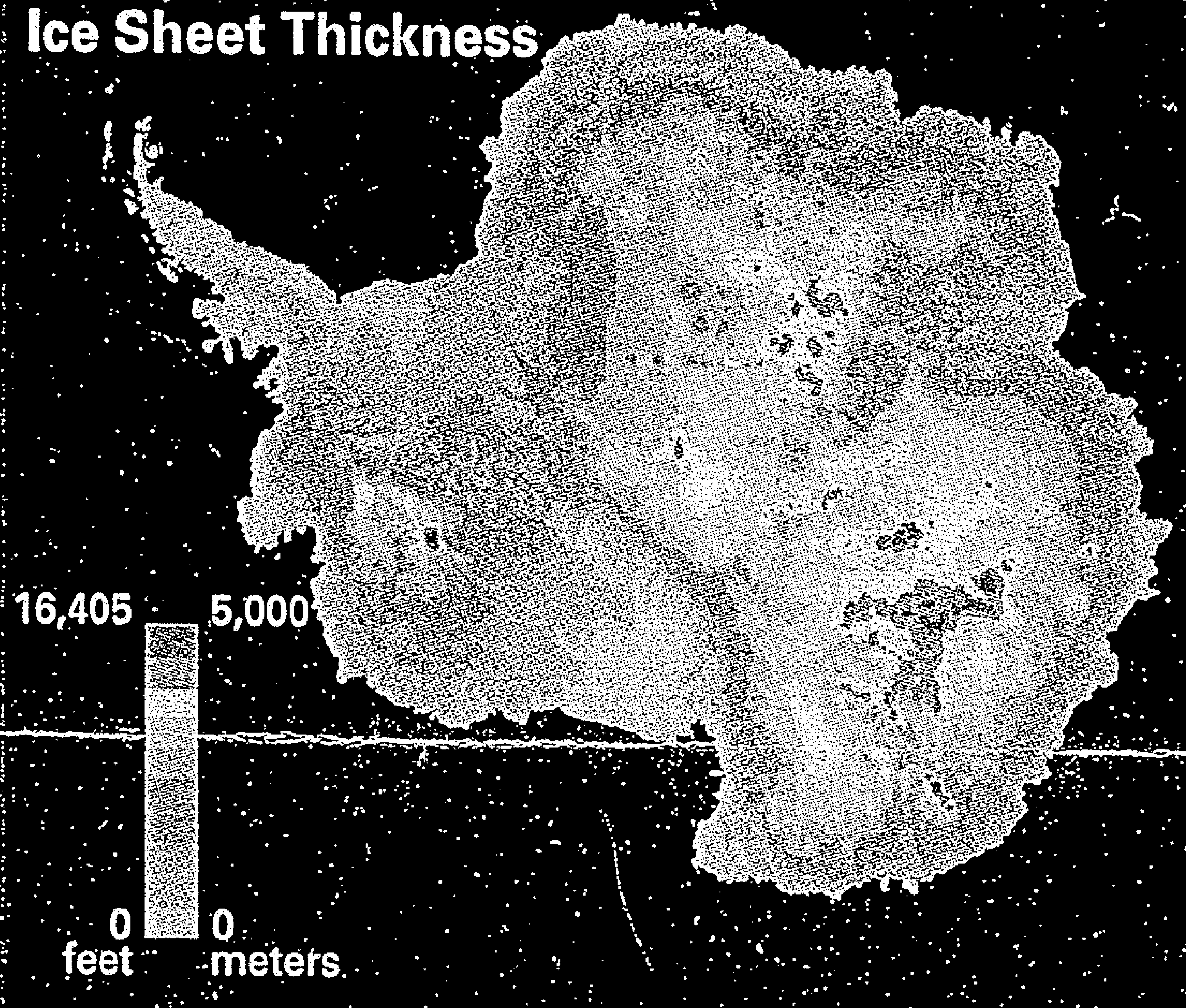

Supplement to NATIONAL GEOGRAPHIC, February 2002
SOUTH ATLANTIC OCEAN
INDIAN OCEAN
SOUTH PACIFIC OCEAN
SOUTH AMERICA
AUSTRALIA
ANTARCTICA
ANTARCTIC CIRCLE
South Pole
Weddell Sea
Ross Sea
Drake Passage
Bird Island U.K.
South Georgia U.K.
Laurie Island
Macquarie Island Australia
New Zealand
Maximum extent of sea ice
Minimum extent of sea ice
Year-round by 2003
Scale varies in this perspective.
30°W
0°
30°E
60°
90°
30°
60°
120°
150°E
180°
150°W
120°
90°
Research Stations
□ Year-round
□ Summer only
△ Automatic weather station


Surface Elevation

BYRD POLAR RESEARCH CENTER, OHIO STATE UNIVERSITY

ELEVATION OF THE ICE SHEET

Many mountaintops rise higher than Antarctica's highest point—Vinson Massif, 16,067 feet—but with an average elevation of 8,000 feet, the continent ranks as Earth's highest. Asia, its closest competitor, averages 3,000 feet. Roughly dome shaped, the ice sheet conceals much of the bedrock relief below. The 1,800-mile-long Transantarctic Mountains rival the Rockies in height, but only the peaks break through the ice.


Ice Sheet Thickness

BEDMAP PROJECT

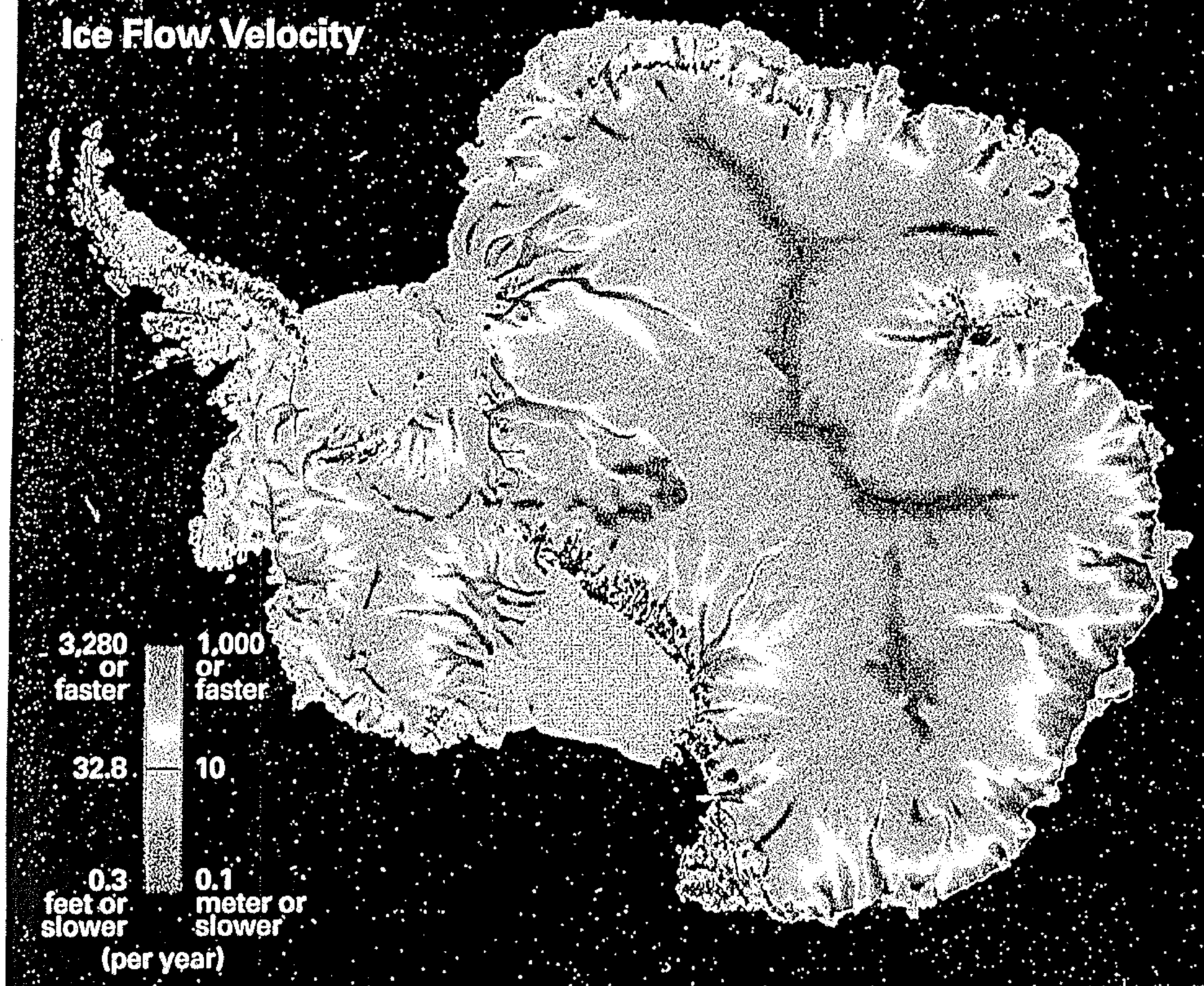
MEASUREMENTS OF A PARADOX

Ninety percent of the world's ice and 70 percent of the world's fresh water are found here, yet most of Antarctica is truly a desert. The snow equivalent of less than three inches of rain—a precipitation rate close to that of the Sahara—falls over the high interior of the continent each year. But snow and ice have been slowly accumulating on Antarctica for millions of years. More than 15,600 feet deep at its thickest, the mean depth of the ice exceeds 6,600 feet.

feet meters

6,600 feet.

BEDMAP PROJECT



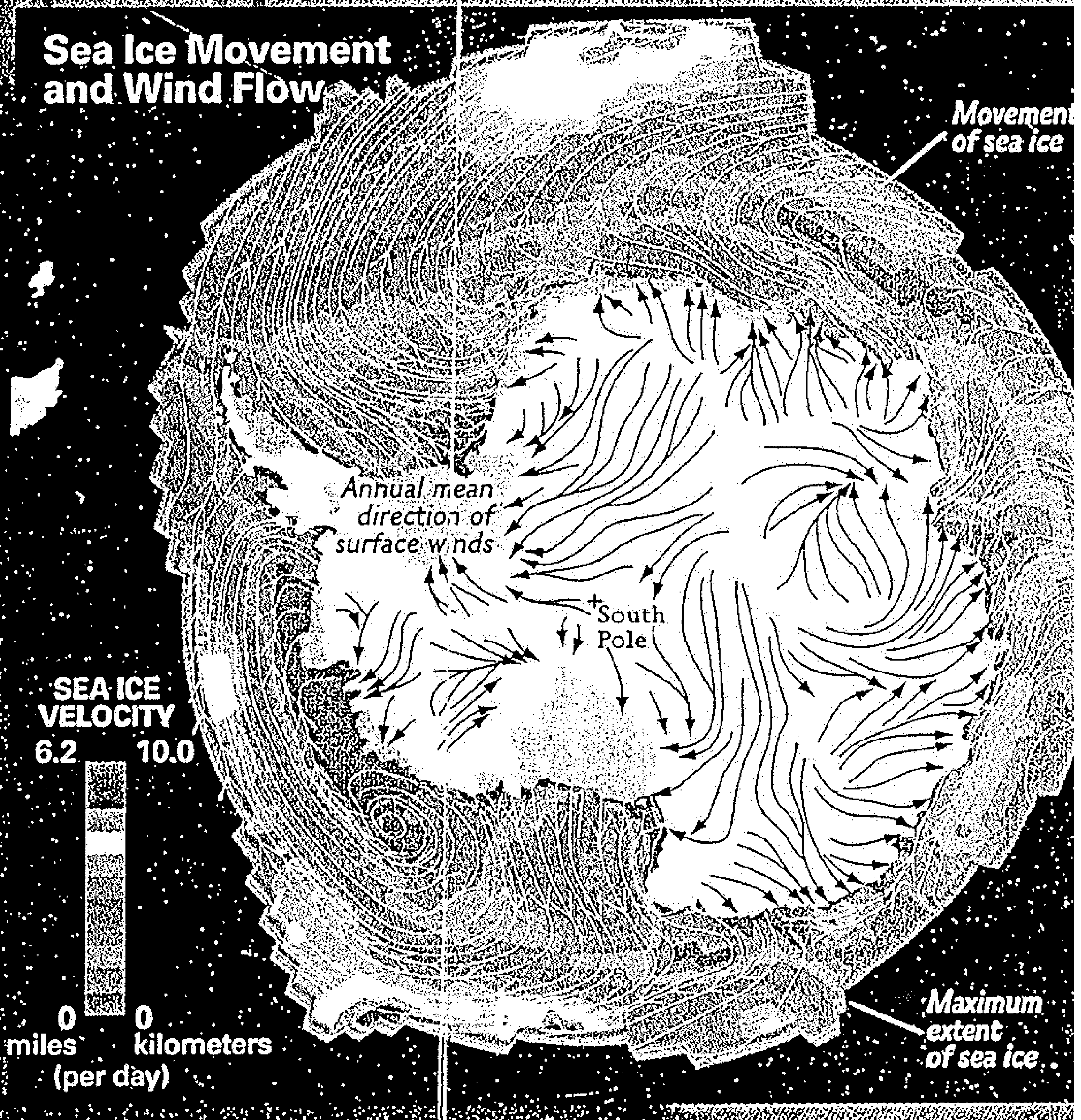
MODELED ICE VELOCITIES: ROLAND WARNER, ANTARCTIC COOPERATIVE RESEARCH CENTRE

◀ICE ON THE MOVE

Glaciologists once thought that ice motion in Antarctica's interior was slow and relatively uniform, with just a few fast-moving outlet glaciers and ice streams drawing ice from the interior down to the sea. A computer model based on new satellite data suggests a more intricate ice-movement pattern (left). Like rivers, coastal ice flows appear to be fed by complex systems of tributaries that penetrate hundreds of miles into major drainage basins.

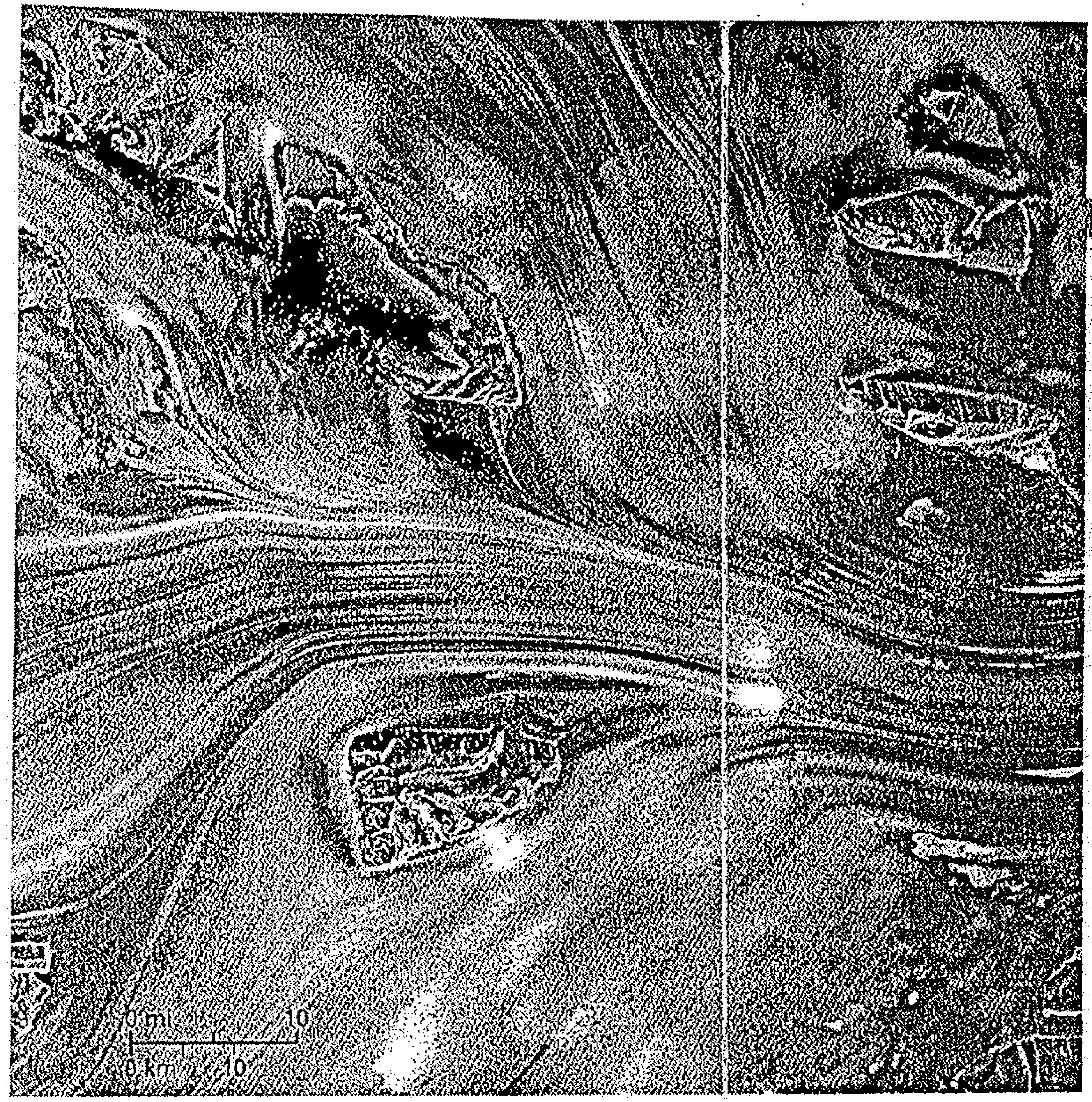
ULTIMATE WINDS▶

Katabatic winds—cold air pouring down glacial slopes—often blow at 80 miles an hour and can exceed 180 miles an hour. Offshore, circumpolar winds and currents push against sea ice that rings Antarctica each winter, driving the frozen ocean counterclockwise around the continent.



SEA ICE VELOCITY DATA: MARK R. DRINKWATER, EUROPEAN SPACE AGENCY. SURFACE WINDS BASED ON DATA FROM DAVID H. BROMWICH, OHIO STATE UNIVERSITY, AND THOMAS R. PARISH, UNIVERSITY OF WYOMING.


popular with penguins and other
seabirds, including gulls, skuas, and
petrels and provides important
habitat for several species of seals.
S E A
Snow Hill I.
Trinity Peninsula
James Ross Island
Cape Longing
Robertson I.
ANTARCTIC
PENINSULA
LARSEN
ICE SHELF
Oscar II Coast
Vernadsky (Ukraine)
Palmer
Beascochea Bay
BISCOE
Renaud I.
Lavoisier I.
ISLANDS
Liard I.
Adelaide Island
Bowman Coast
San Martín (Argentina)
Rothera (United Kingdom) (Laboratory destroyed by fire September 2001)
Marguerite Bay
Fleming Glacier
Dyer Plateau
8530 ft 2600 m
PALMER LAND
Mt. Jackson
Lassiter Coast
A-44
A-43B
A-43A
Gould Bay
COAST
FILCHNER ICE SHELF
Recovery Gl.
Shackleton Range
Holmes Summit
6152 ft 1875 m
Slessor Gl.
4888 ft 1490 m
BERKNER ISLAND
3202 ft 976 m
RONNE ICE SHELF
Bowman Pen.
Dodson Peninsula
Latady Mts.
Seward Mts.
George VI Sound
Henry Ice Rise
735 ft 224 m
PENSACOLA MOUNTAINS
Mt. Stephenson
9800 ft 2987 m
ALEXANDER ISLAND
LeMay Range
Sweeney Mts.
Mt. Edward
Korff Ice Rise
Lazarev Bay
Wilkins Ice Shelf
Bach Ice Shelf
Beethoven Peninsula
Mt. Becker 5059 ft 1542 m
Evans Ice Stream
Zumberge Coast
Charcot Island
Latady I.
Ronne Entrance
Stange Sound
Spaatz Island
Smyley Island
Carroll Inlet
Eltanin Bay
Fletcher Promontory
Rutford Ice Stream
Carlson Inlet
Vinson Massif 16050 ft 4892 m
ELLSWORTH MOUNTAINS
ELLSWORTH LAND
BELLINGSHAUSEN
SEA
Venable Ice Shelf
Fletcher Pen.
Farwell Island
WEST
ANTARCTICA
8763 ft 2671 m Mt. Woollard
Whitmore Mts.
Mt. Seelig
ABBOT ICE SHELF
Jones Mountains
Pine Island Glacier
HOLLICK-KENYON PLATEAU
Peter I Island
THURSTON ISLAND
Noville Pen.
Sherman
Peacock Sd.
Pine Island Bay
Canisteo Pen.
Thwaites Gl.
WALGREEN COAST
MARIE BYRD LAND
ROCKEFELLER PLATEAU
3963 ft 1208 m
50°



ASA/OHIO STATE
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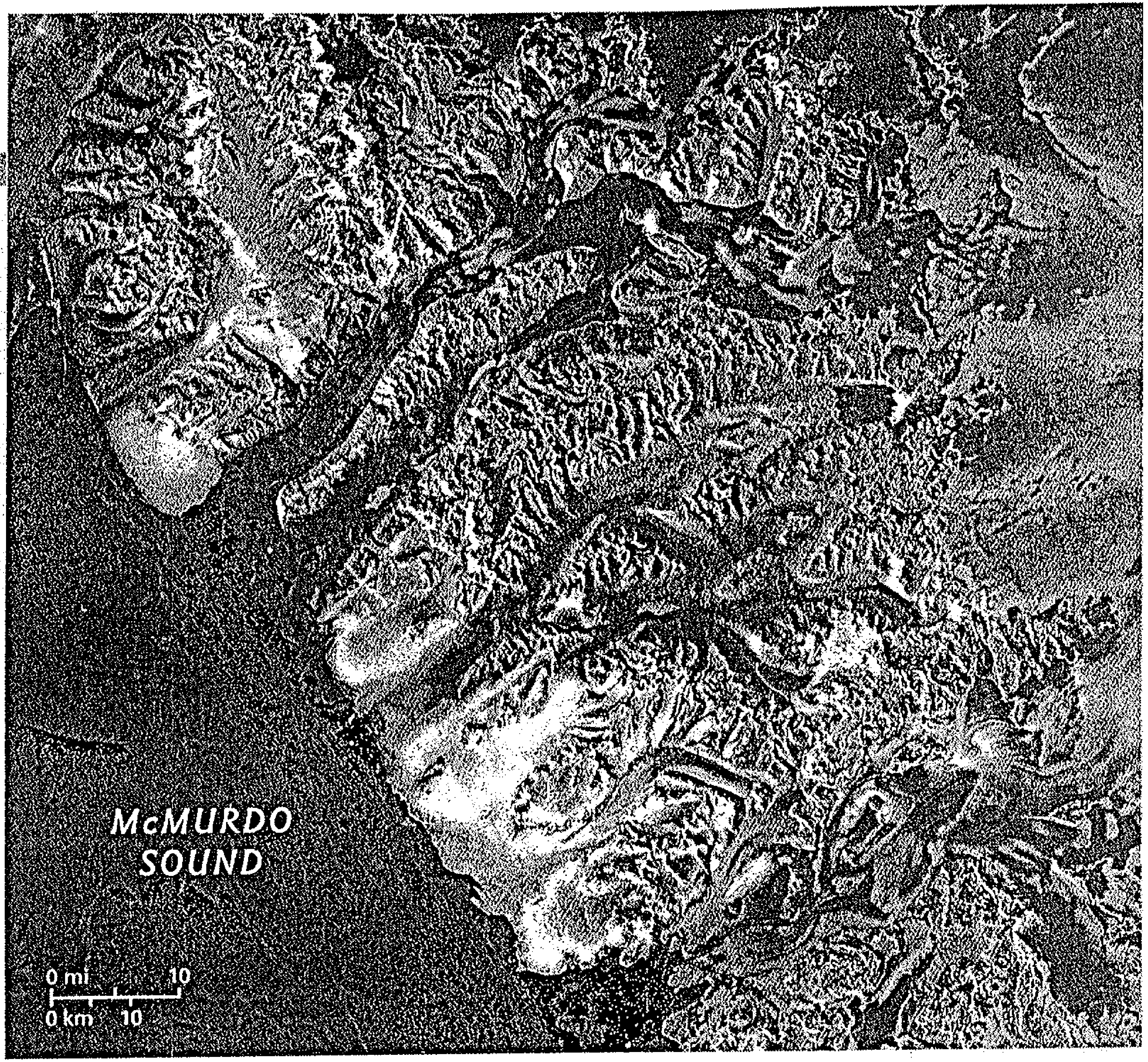
③ Multiple tributaries funnel into Lambert Glacier (above), draining 350,000 square miles of East Antarctica. Emptying into the Amery Ice Shelf, Lambert is 25 miles wide and nearly 250 miles long—one of the largest ice streams on Earth.

④ Like a reservoir behind a dam, the East Antarctic ice sheet runs up to the steep ridge of the Transantarctic Mountains (right). Between the mountains and McMurdo Sound lie the Dry Valleys, where desert-like conditions and blasting winds keep some 1,500 square miles of rock and soil free from snow buildup.

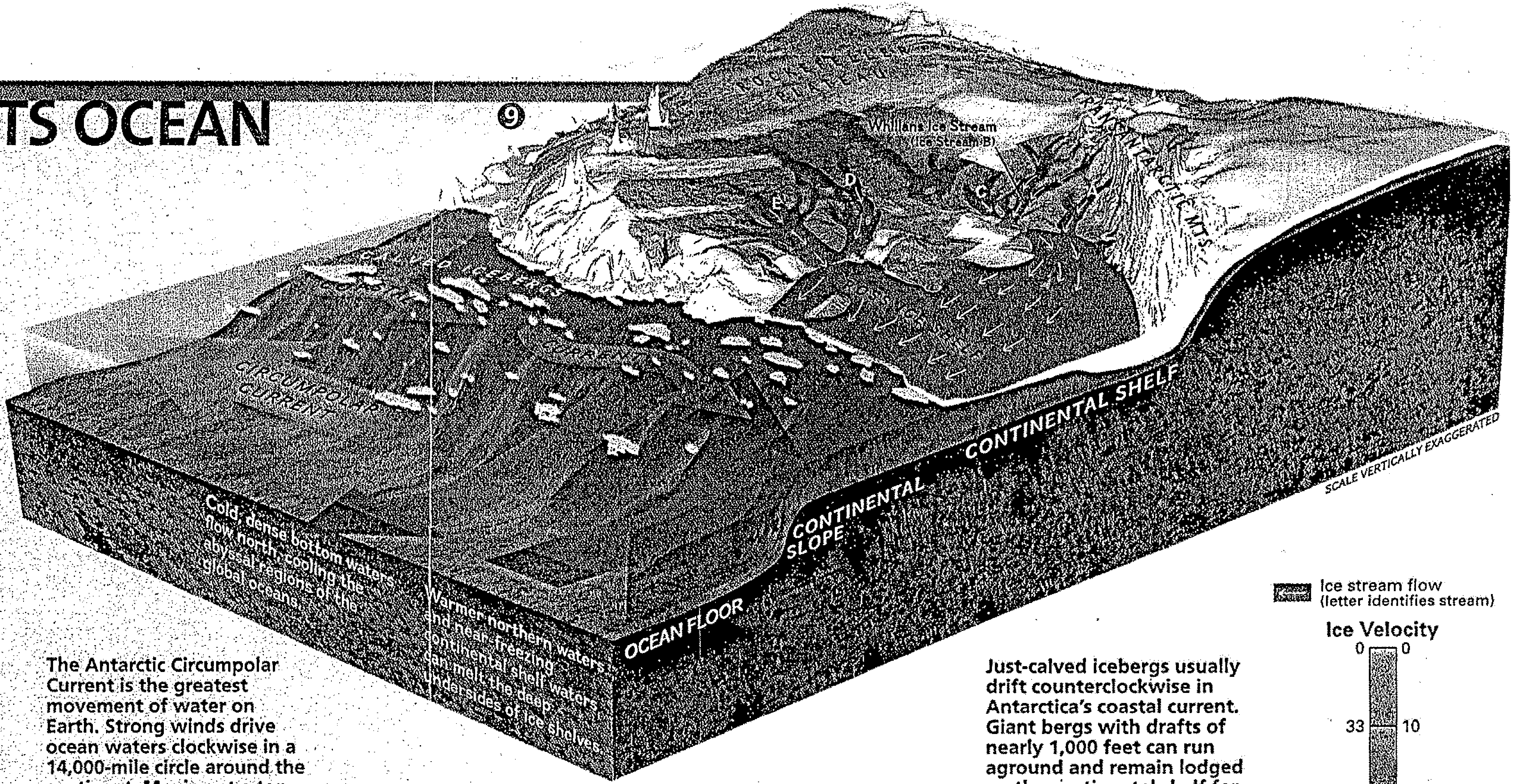


CSA/NASA/OHIO STATE UNIVERSITY

WHERE ICE MEETS OCEAN

Antarctica's ice sheet and surrounding oceans form a kind of giant conveyor belt. Moisture from the oceans falls on the continent as snow. Centuries of pressure and cold turn snow into ice, which moves—at first imperceptibly slowly, then gaining speed—down the long curves of the ice sheet. Complex systems of tributary glaciers flow into enormous riverlike ice streams (white arrows on glaciers, right), some of which move up to a mile and a half a year. Fed by this network of ice streams, ice shelves grow past the grounding line—the last contact point between ice and bedrock—and spread a thick layer of floating ice over the ocean. Ice turns to water again as warm ocean currents melt the underside of ice shelves and as shelf edges calve icebergs into the sea.

Most experts think this ice-ocean system is near equilibrium, with ice accumulation balancing ice shelf losses by melting and iceberg calving. Climate warming could shift the balance, however, and accelerated melting could raise sea level worldwide.



Cold, dense bottom waters flow north, cooling the abyssal regions of the global oceans.

Warmer northern waters and near-freezing continental shelf waters can melt the deep undersides of ice shelves.

The Antarctic Circumpolar Current is the greatest movement of water on Earth. Strong winds drive ocean waters clockwise in a 14,000-mile circle around the continent. Moving at a top speed of nearly 200 feet a minute, the current flows through a band of ocean more than 600 miles wide and can extend all the way to the ocean bottom.

Just-calved icebergs usually drift counterclockwise in Antarctica's coastal current. Giant bergs with drafts of nearly 1,000 feet can run aground and remain lodged on the continental shelf for years. Once free they sometimes break up into smaller icebergs that can move north and menace ship traffic.

▨ Ice stream flow (letter identifies stream)

Ice Velocity

feet per year	meters per year
0	0
33	10
328	100
3,280	1,000

WEIGHT OF THE ICE SHEET
The ice mass covering Antarctica is so heavy that it depresses the Earth's crust more than 3,000 feet. Ice-free continental shelves actually tilt in toward the land, rather than sloping away toward the deep seafloor.

SOUTH POLE
Ice movement is gradual but inexorable. The exact location of the geographic South Pole must be marked annually because the ice over the Pole shifts about 30 feet every year.

AMERY ICE SHELF
While ice shelves on the Antarctic Peninsula have retreated dramatically in recent decades, others—including Amery Ice Shelf, fed by the massive Lambert Glacier—have grown larger.

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SUBGLACIAL MOUNTAINS
The Gamburtsev highlands rise some 9,500 feet above sea level—higher than the Appalachian Mountains of eastern North America—but they are completely buried by ice.

TRANSANTARCTIC MOUNTAINS
The 1,800-mile-long Transantarctic range divides East and West Antarctica. Exposed peaks called nunataks offer geologists and paleontologists access to unaltered sedimentary deposits more than 500 million years old.

MOUNT EREBUS
Almost always observed with a vapor cloud issuing from its large summit crater, 12,448-foot-tall Erebus is an active volcano. A deep inner crater discovered in 1972 holds a bubbling lava lake.

CONTINENTAL SHELVES
Antarctica's continental shelves lie under an average of 1,300 feet of ocean—three times deeper than the mean shelf depth elsewhere in the world. Gouges and sediment deposits record the advance and retreat of coastal glacier tongues.

PROBING VOSTOK'S MYSTERIES

Lake Vostok tantalizes scientists. How did the 170-mile-long, 30-mile-wide lake form? What keeps it liquid? What life-forms might have adapted to its cold, dark, high-pressure depths? New technologies will be required to penetrate the ice cover, explore the lake, and collect study samples—all without contaminating this unique environment. Space researchers hope that tools developed for Vostok could someday be used to explore liquid seas under the frozen surface of Europa, one of Jupiter's giant moons.