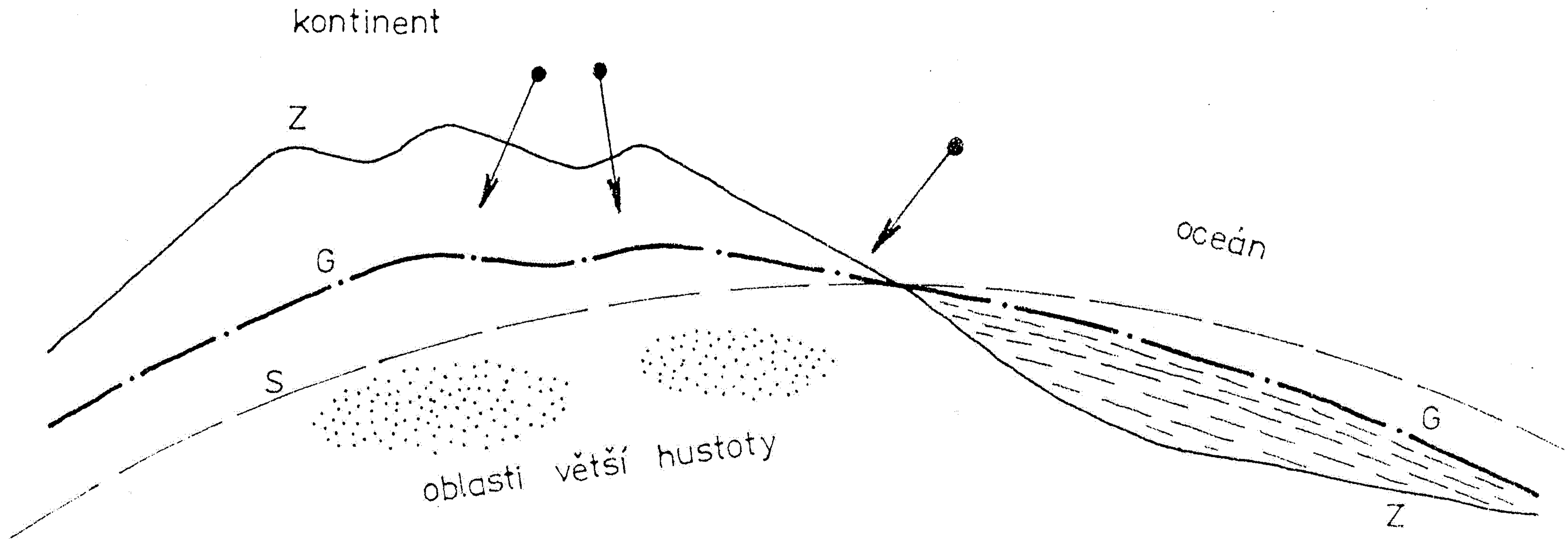


**GFZ
Potsdam**

Abb. 9.16

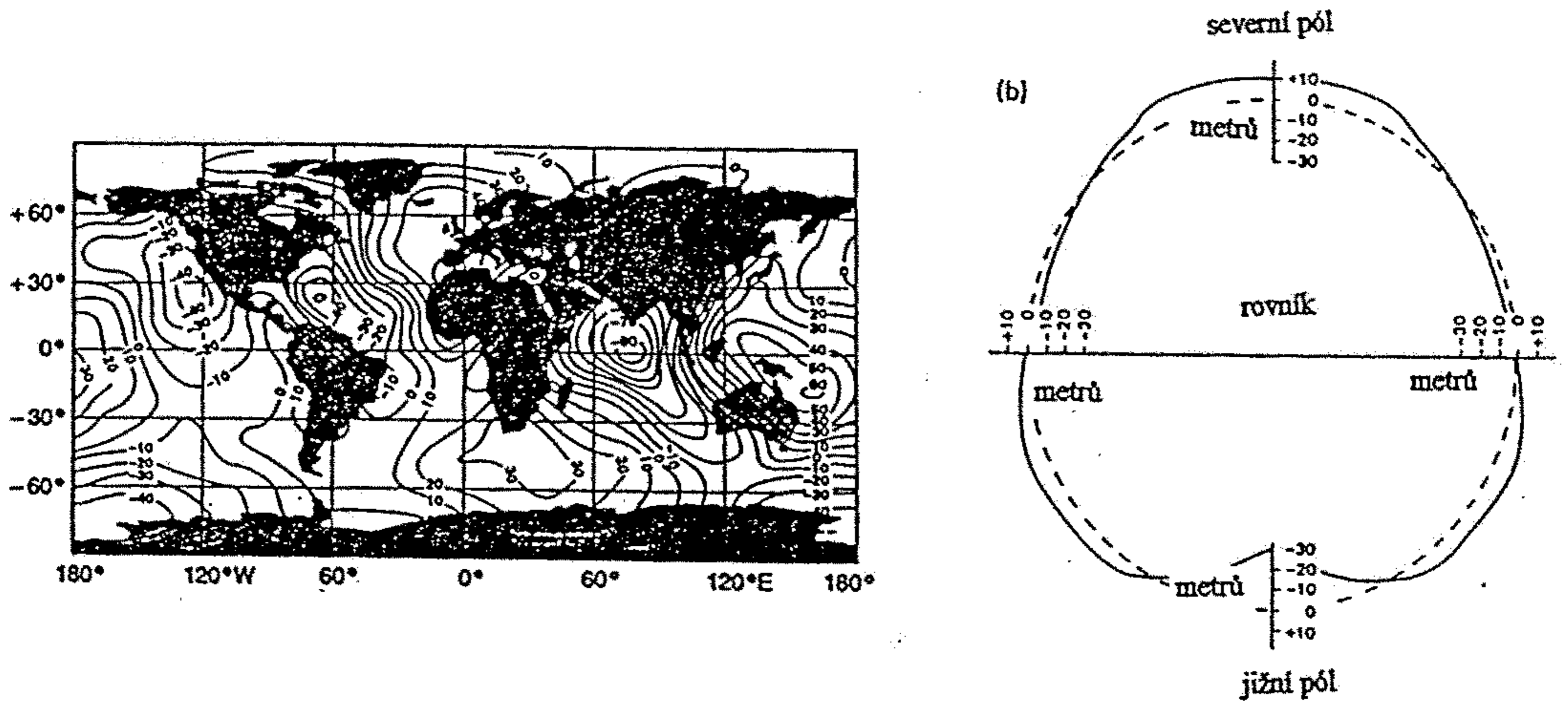
Die Meeresoberfläche entspricht als Gleichgewichtsfläche in erster Näherung dem Geoid. Die durch Masseninhomogenitäten im Erdinnern verursachten „Beulen“ der Meeresoberfläche betragen bis zu 100 m (hier stark überhöht dargestellt). Die Tiefseerinnen der zirkumpazifischen Subduktionszonensysteme zeigen eine langgezogene negative Anomalie. Über den Kontinenten wird das Geoid aus terrestrischer

Gravimetrie abgeleitet und bildet die Bezugsfläche für die topographischen Höhen. Das globale Geoidmodell ist am GeoForschungsZentrum, Potsdam (Projekt ERS-1/2 (D-PAF, Oberpfaffenhofen)), aus Satellitenbahnbeobachtungen, terrestrischer Gravimetrie und Altimeter-Meßdaten des Europäischen Fernerkundungssatelliten ERS-1 abgeleitet worden (mit frdl. Genehmigung von C. REIGBER).



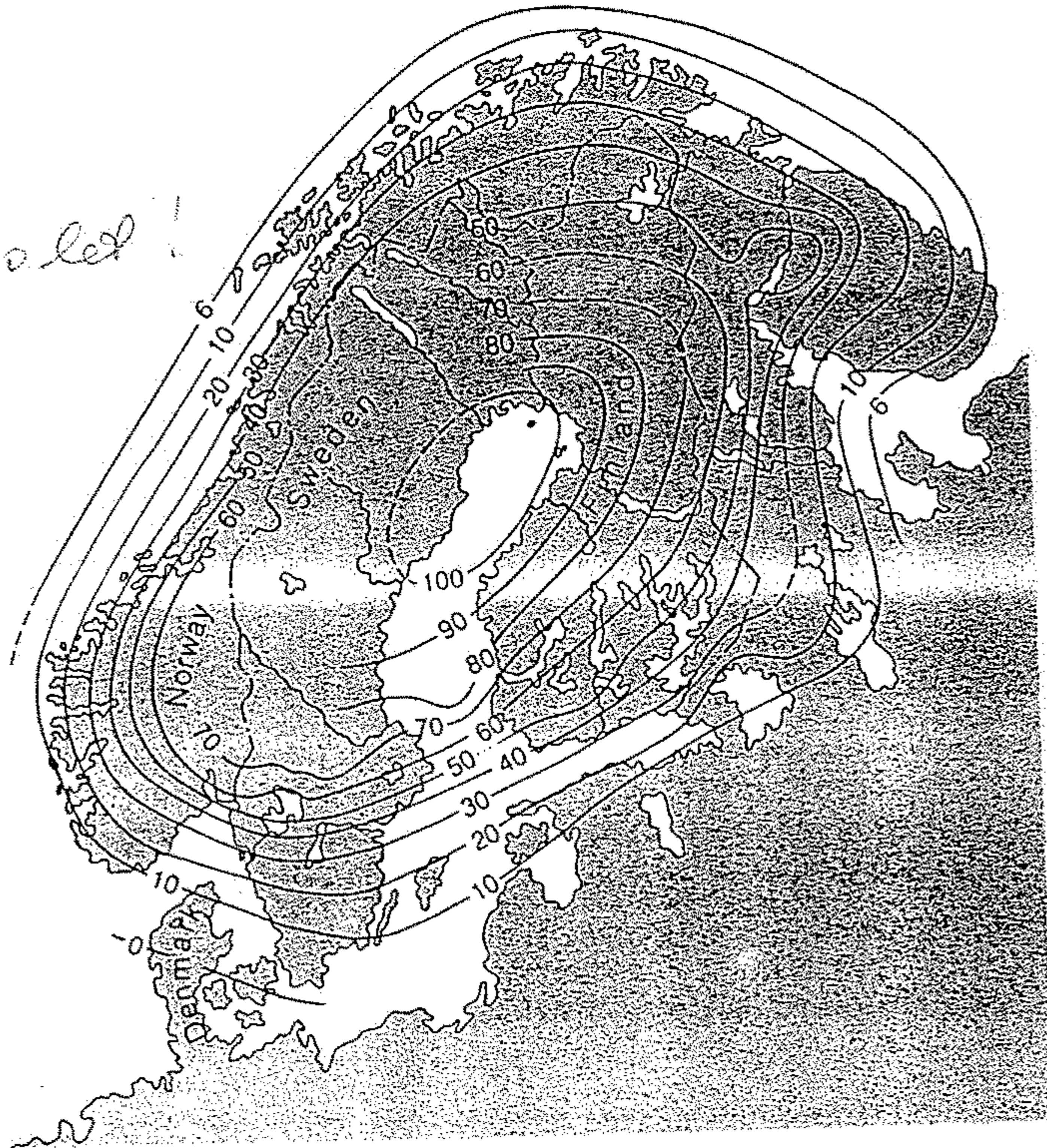
Obr. 11. Schematické znázornění průběhu sféroidu a geoidu. Podle *Milničuka a Arabadžiho* (1979)

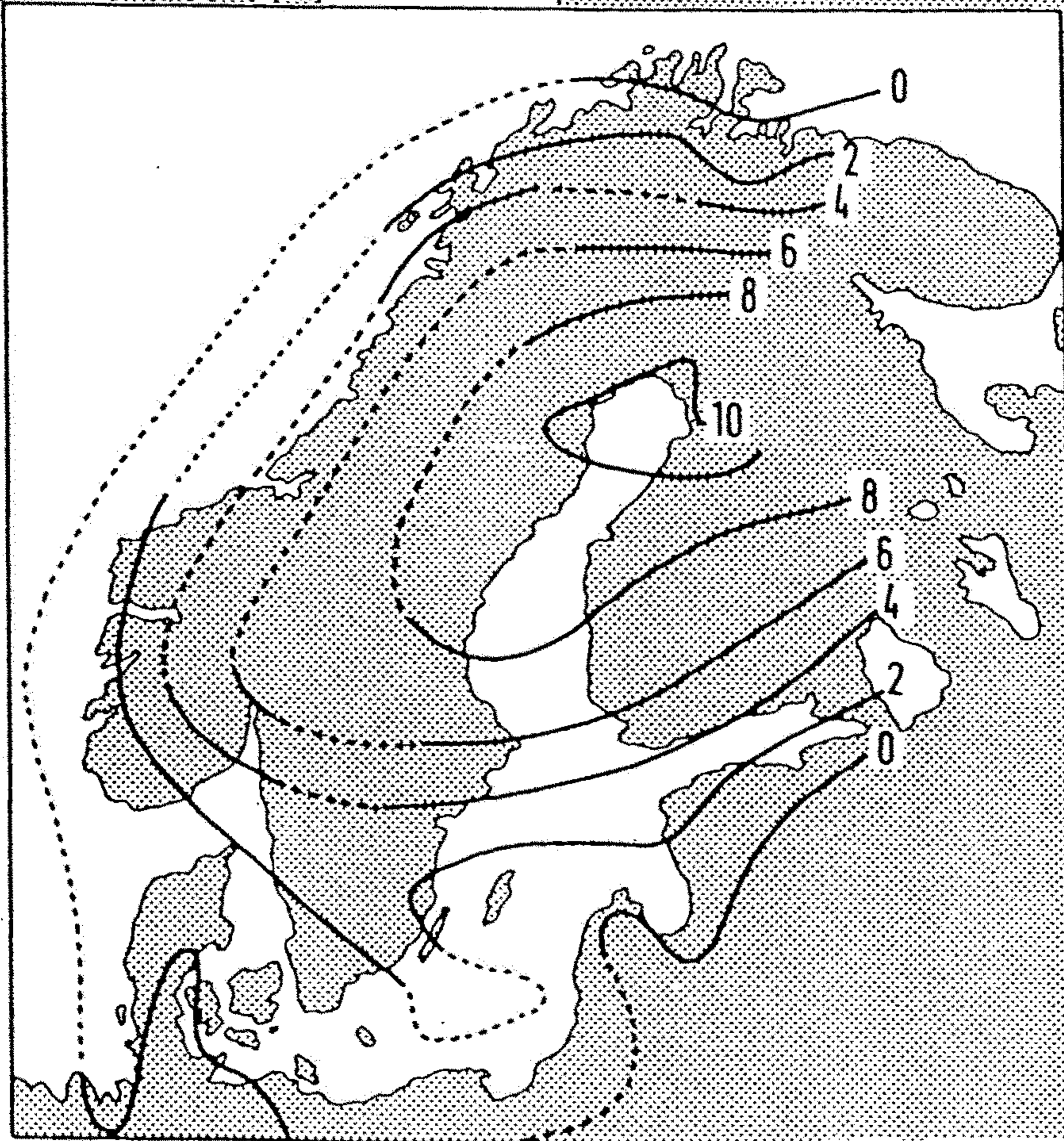
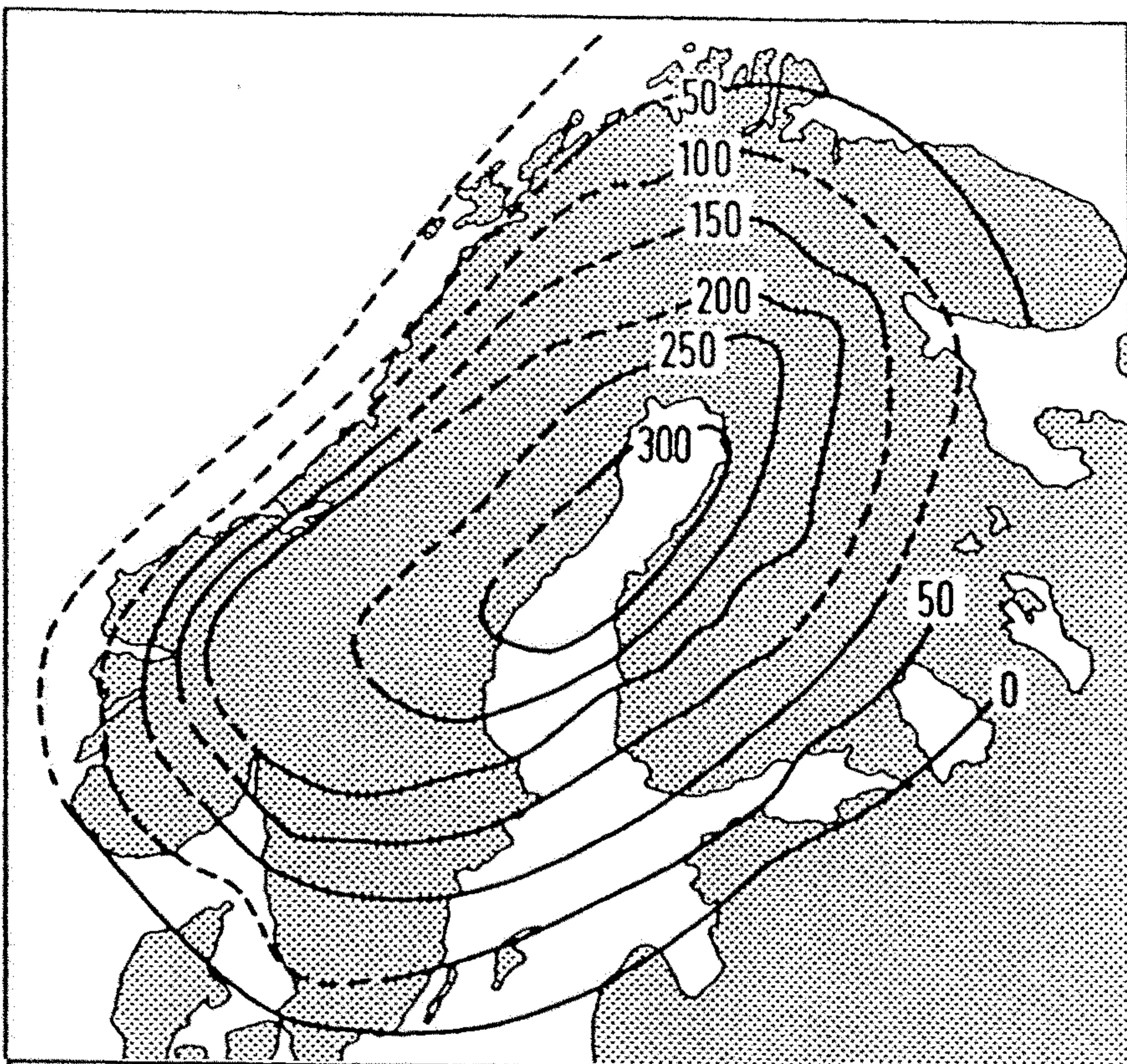
Vztah mezi povrchem Země (Z), geoidu (G) a sféroidu (S)



Obr. 27: Vlevo: Výškové anomálie geoidu vůči ideálnímu sféroidu (v metrech). Pozitivní anomálie jsou způsobeny přítomností těžkých hmot v blízkosti povrchu. Deprese geoidu reprezentují pravděpodobně rozsah výskytu lehčích hmot v plášti. Vpravo: Tvar Země za předpokladu, že je Země symetrická vzhledem ke své rotační ose (plná čára), srovnaný s tvarem sféroidu (podle King-Hele 1969, Anderson 1992).

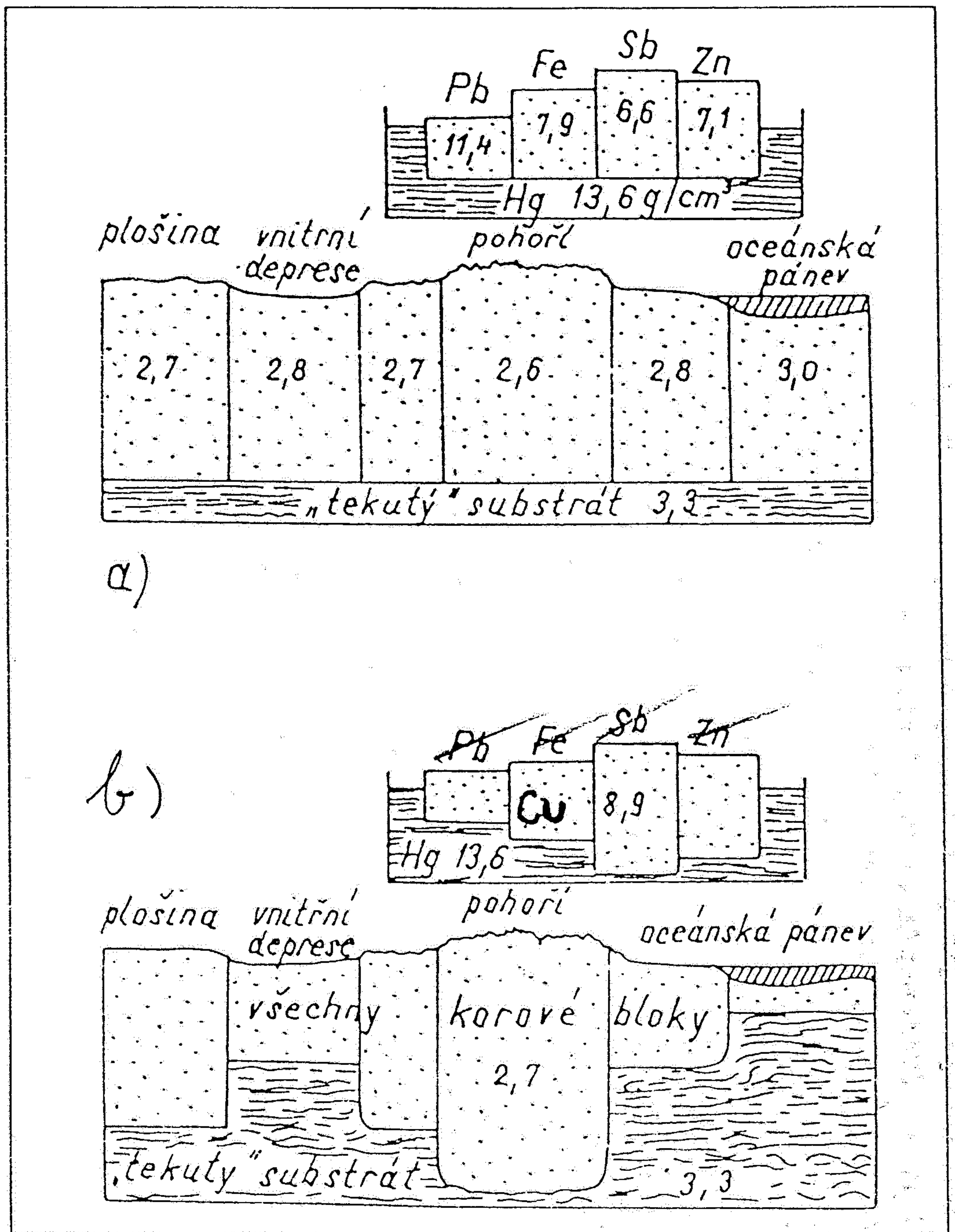
*Výzdvič za
předvětr 5000 let!*





Skandinavien war während der letzten Eiszeit von einem dicken Eispanzer bedeckt. Nach dem Abschmelzen des Eises vor 10 000 Jahren hat sich das Zentrum Skandinaviens um über 300 m gehoben (linkes Bild). Diese

isostatische Bewegung der Lithosphäre hält noch heute mit bis zu 10 mm/Jahr an (rechtes Bild); die Linien gleicher Hebung werden als Isobasen bezeichnet (gestrichelt: vermutet) (aus ZEIL, 1990).



Obr. 28: a) Prattovo pojetí izostáze, vycházející z rozdílných hustot jednotlivých krustálních segmentů, b) Airyho teorie vycházející z představy různé hloubky izostatické kompenzační hladiny (podle různých pramenů in Tonika 1985)

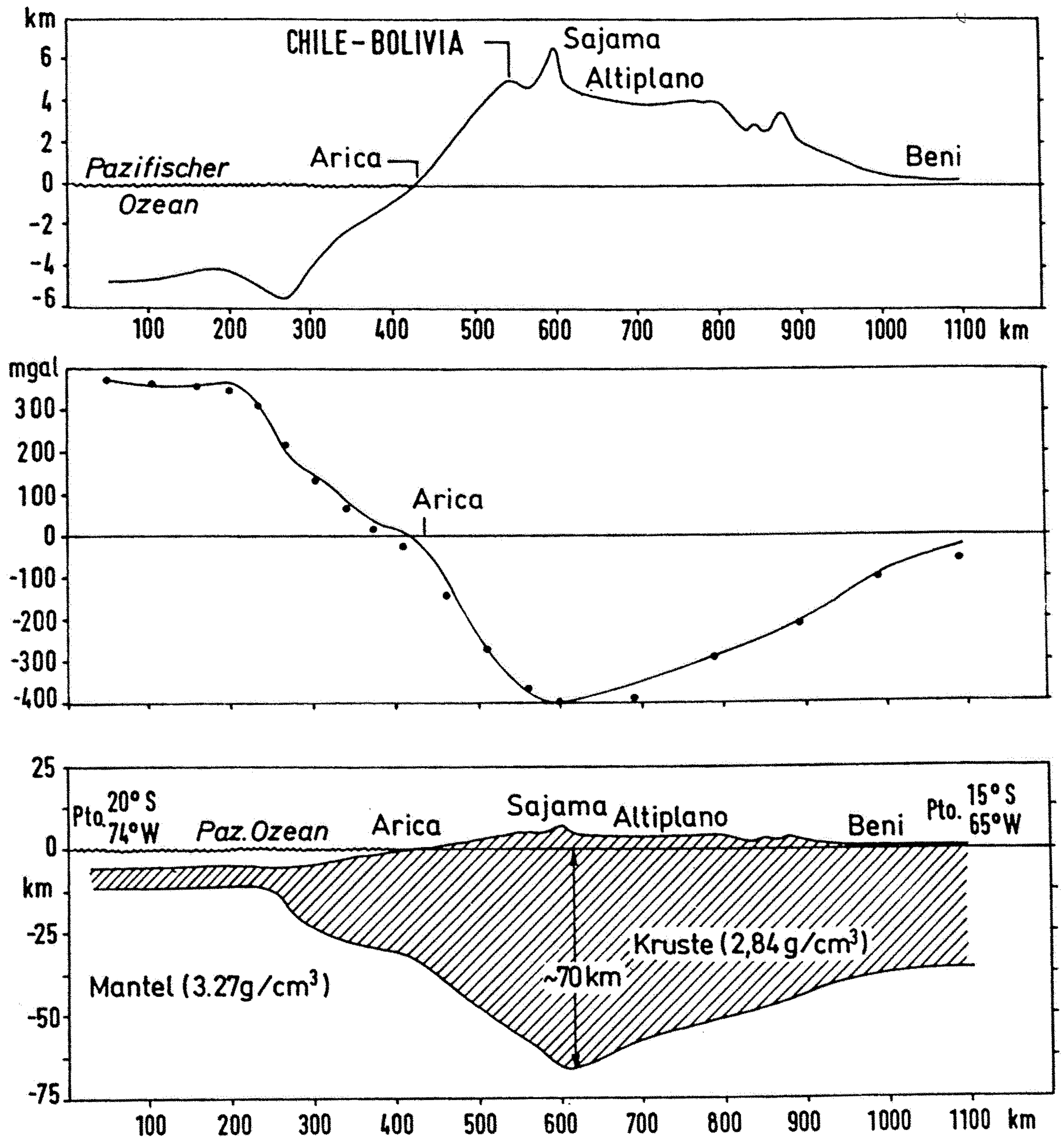


Abb. 216 Morphologie, Schwereanomalien und Ergebnisse seismischer Messungen an zwei Profilen durch die Anden (nach Dragicevic 1970)

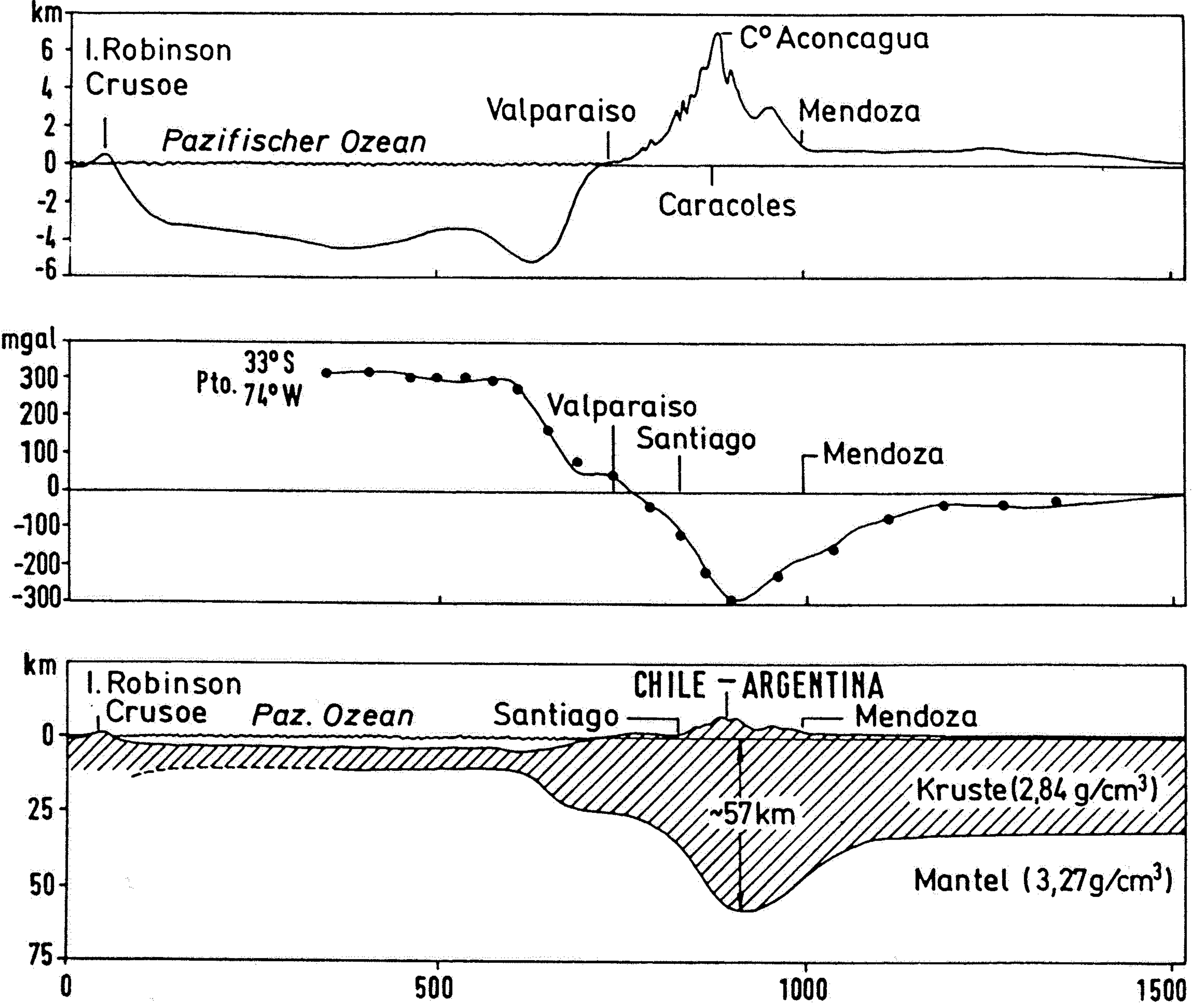
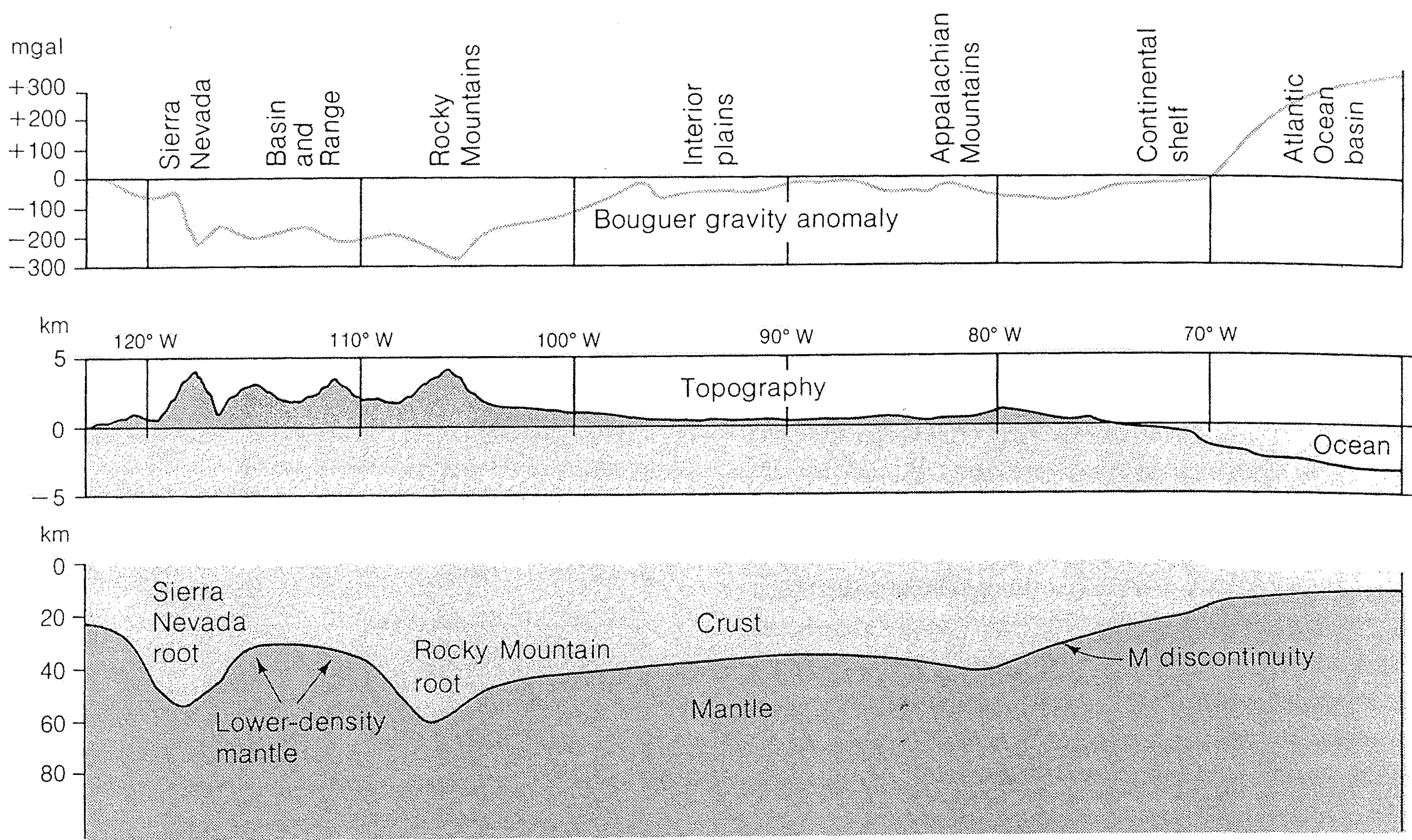


Abb. 216 Morphologie, Schwereanomalien und Ergebnisse seismischer Messungen an zwei Profilen durch die Anden (nach Dragicevic 1970)



Transcontinental gravity survey from the Pacific Ocean to the Atlantic Ocean. The negative gravity anomalies over the mountainous regions, the near-zero values at low elevations, and the positive values over

deep oceans, mirroring the topography, demonstrate the role of isostatic compensation in shaping Earth's surface features.

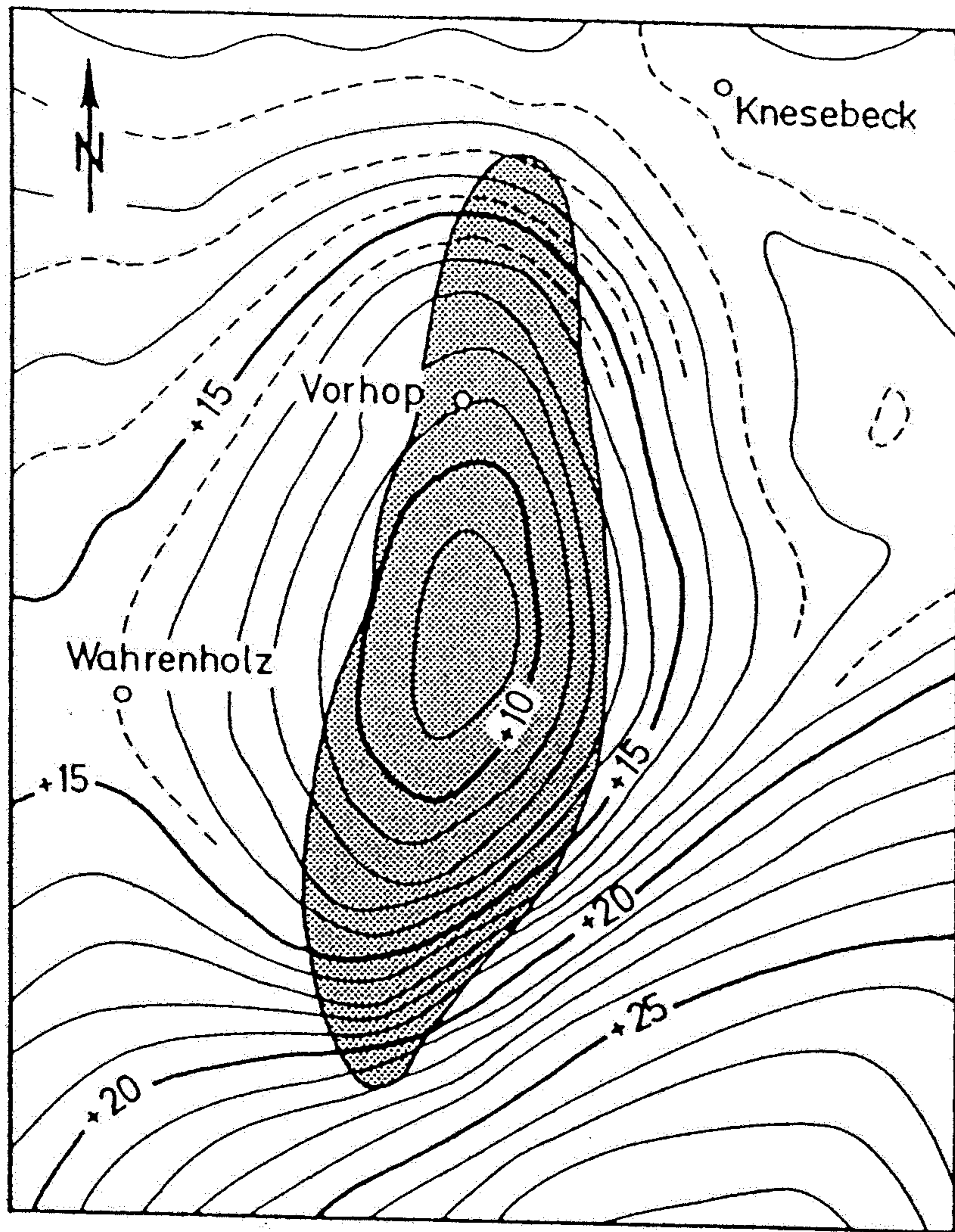
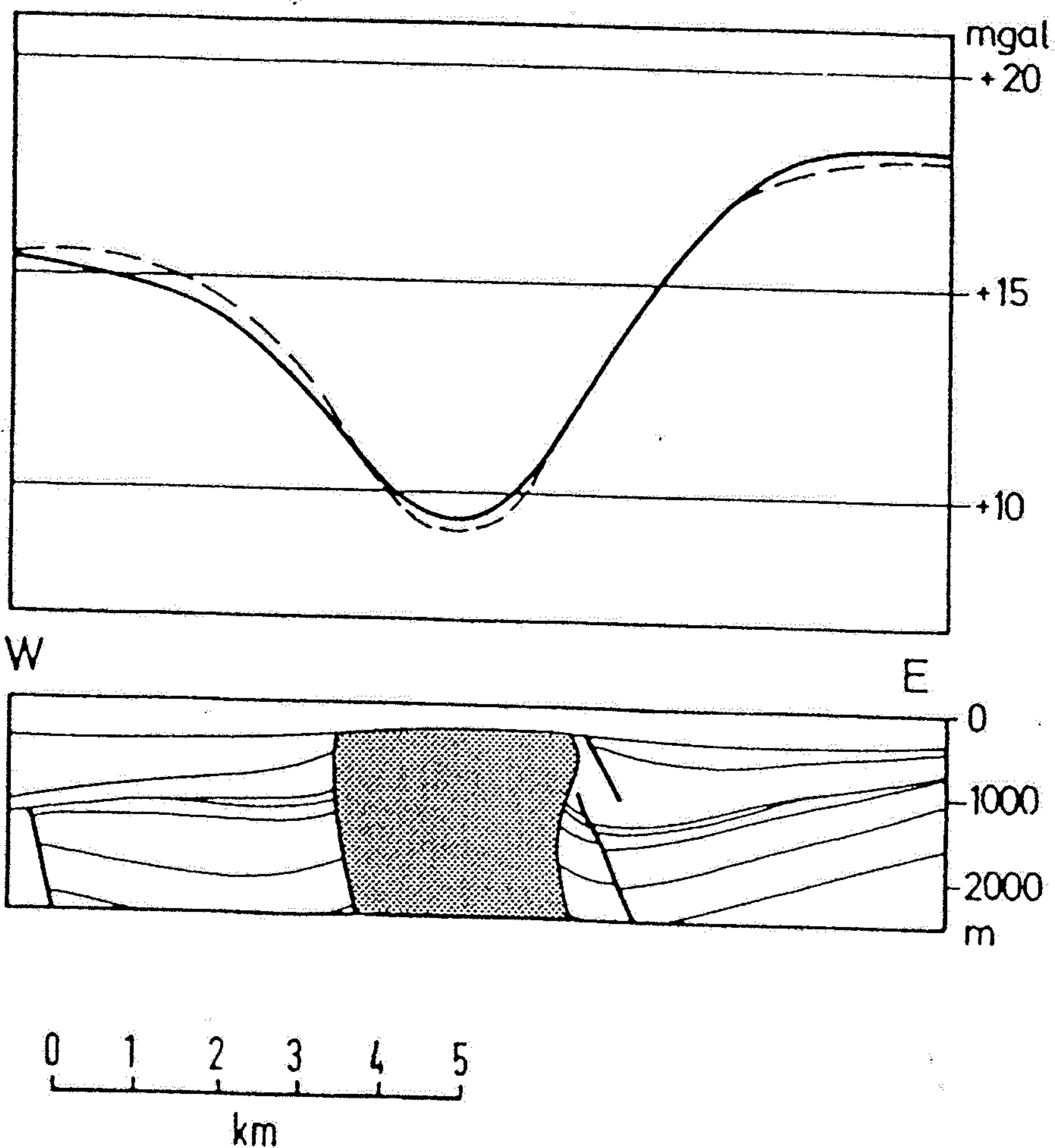


Abb. 9.14

Schwere-Anomalie des Salzstocks Vorhop, Ostthannover; links Isanomalenkarte (Linien gleicher Schwere) und Grundriß des Salzstocks (grau); (1 Gal = $0,01 \text{ m s}^{-2}$, benannt nach Galileo Galilei); rechts: geologisches Profil des Salzstocks und seiner Umgebung, darüber das Schwereprofil gemessen (-) und berechnet (- -): Das leichte Steinsalz (Tab. 9.2) nahe der Erdoberfläche verursacht eine negative Schwereanomalie in einem Gebiet mit positiver Schwere (Messungen PRAKLA SEISMOS, Auswertung Preussag, Gew. ELWERATH, aus ZEIL, 1990).



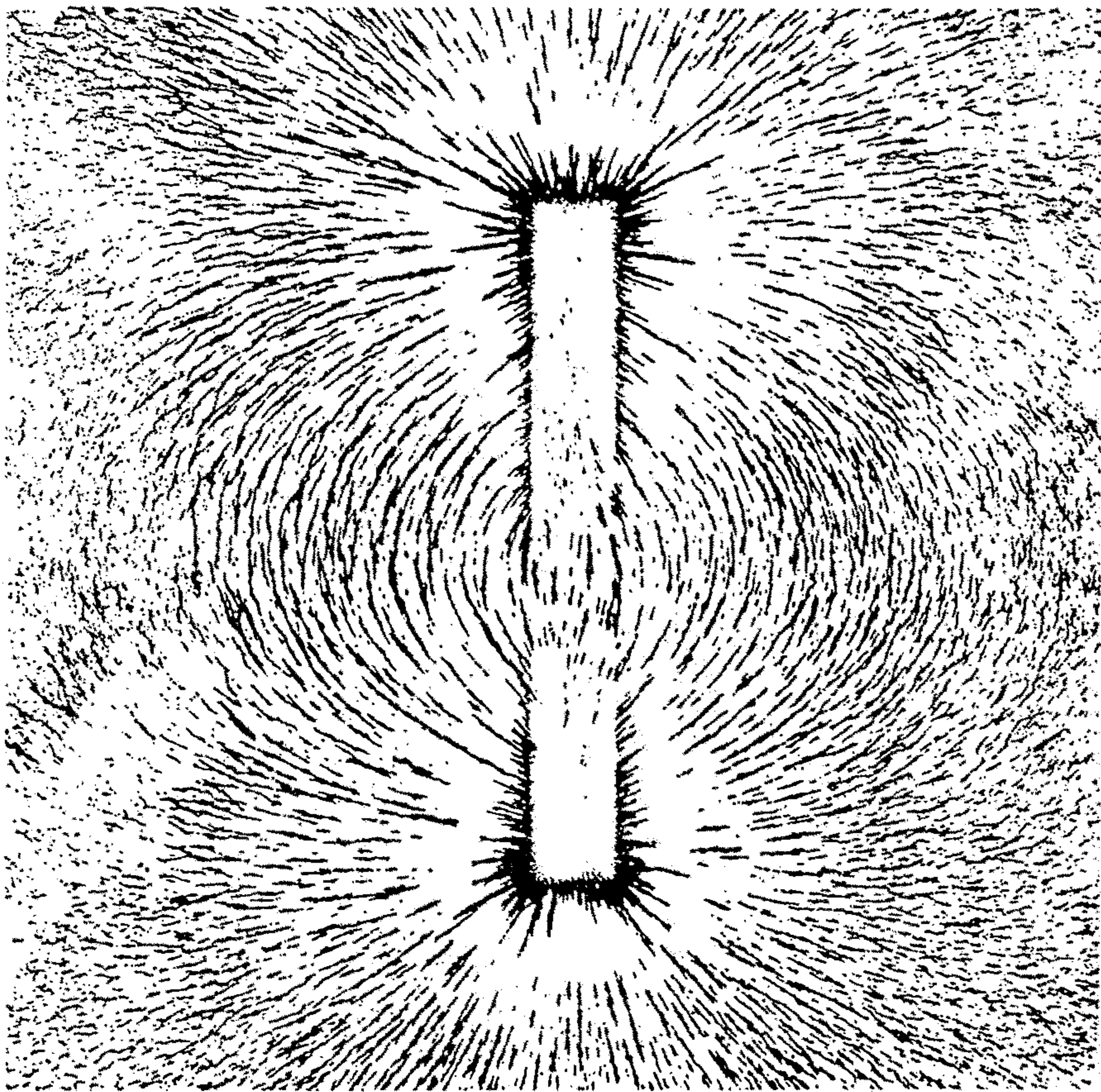
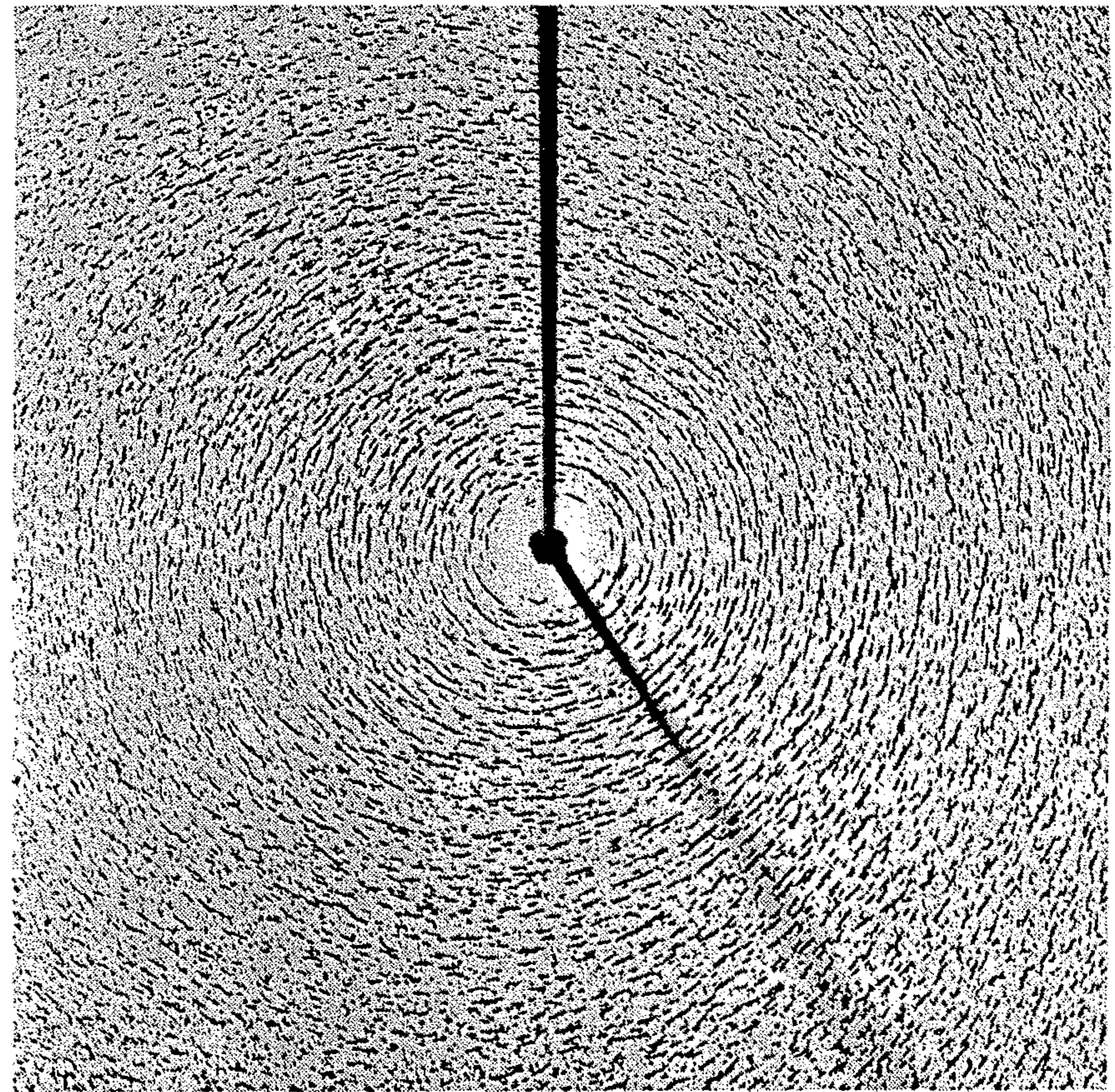
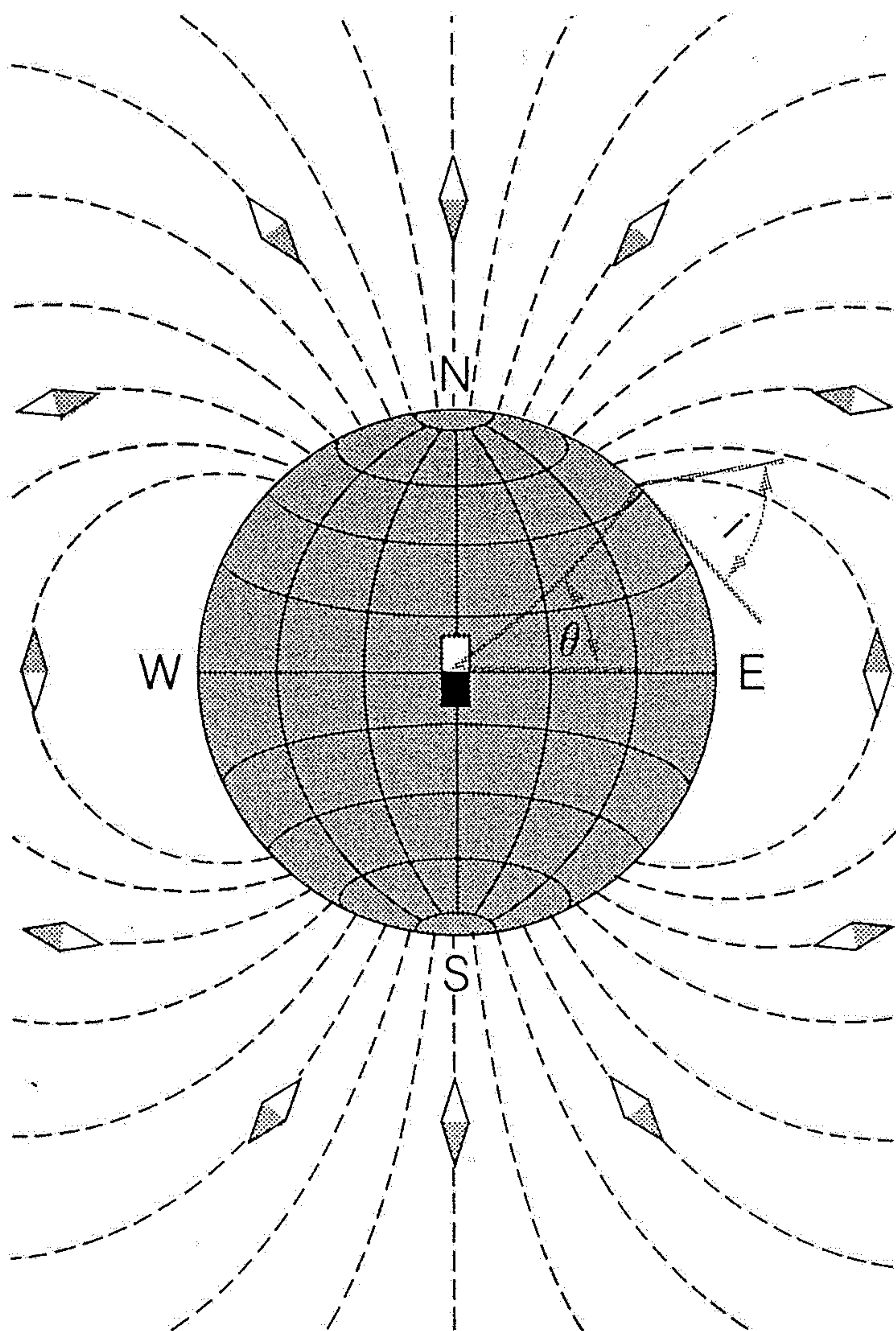
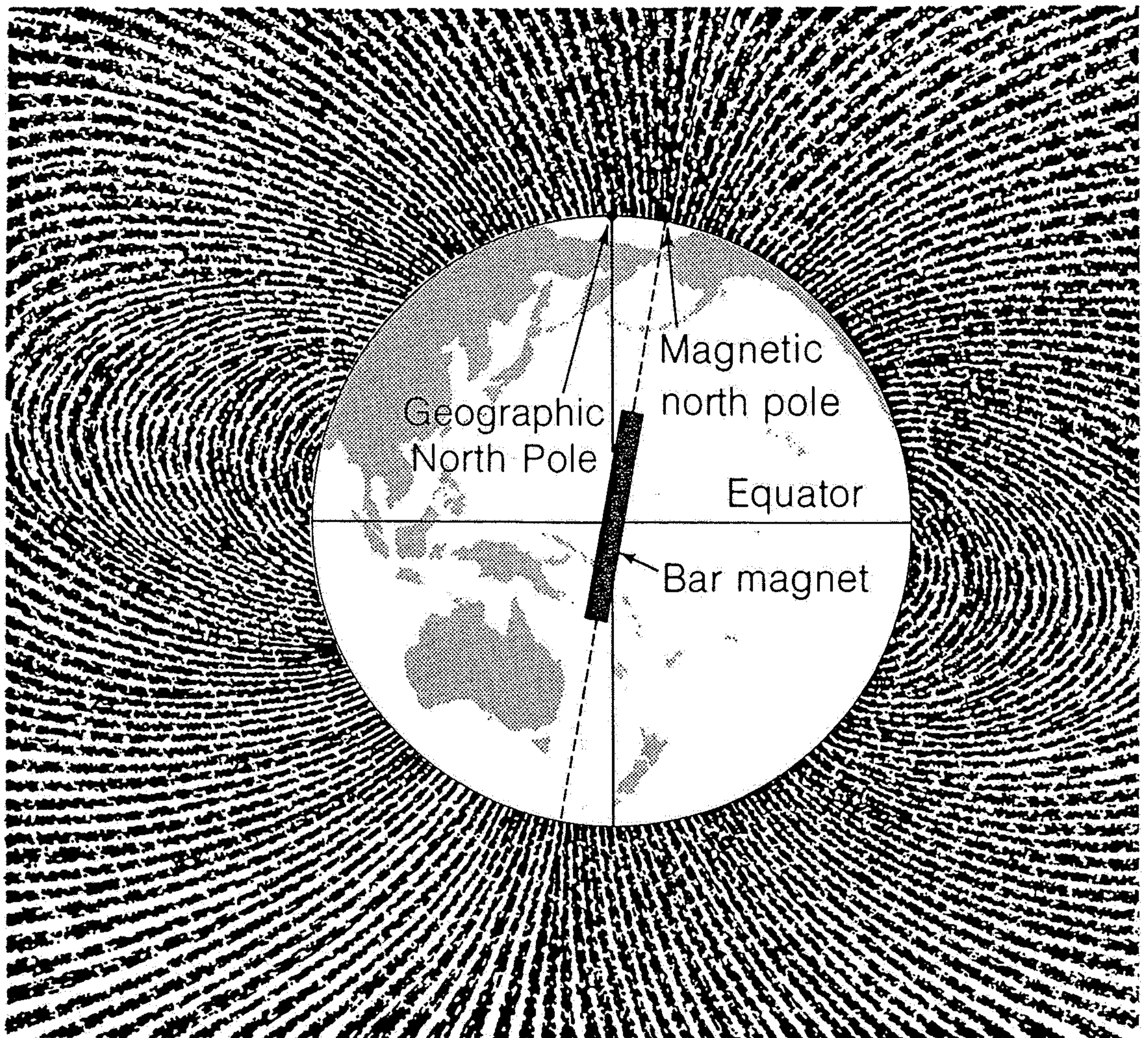


Figure 19-2

Magnetic fields of a bar magnet and of a wire carrying an electric current, made evident by the alignment of iron filings on paper. The filings are



aligned parallel to the magnetic field lines. [From *PSSC Physics*, 3rd ed. Copyright © 1971 by D. C. Heath and Co. Reprinted by permission of the publisher.]



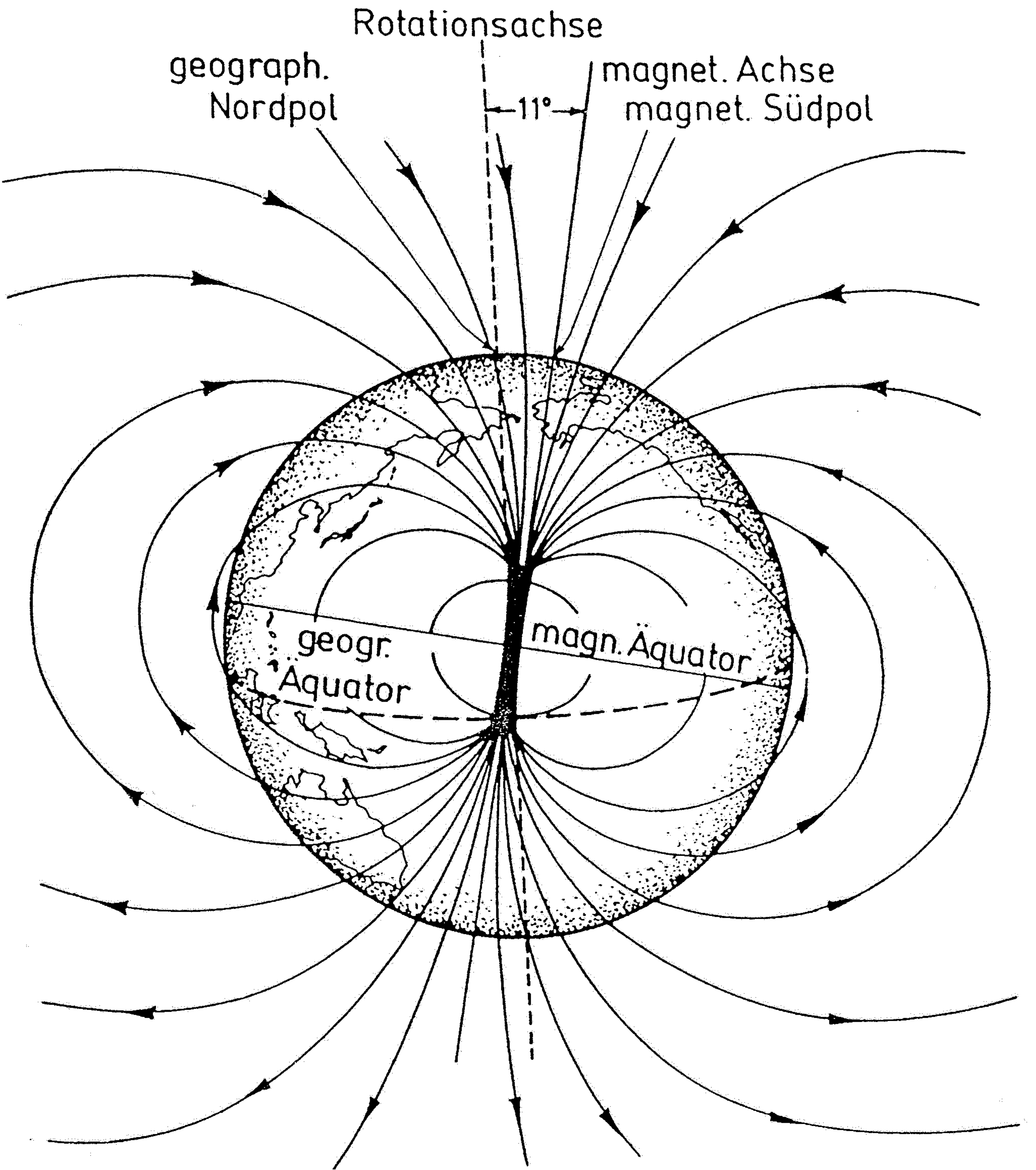
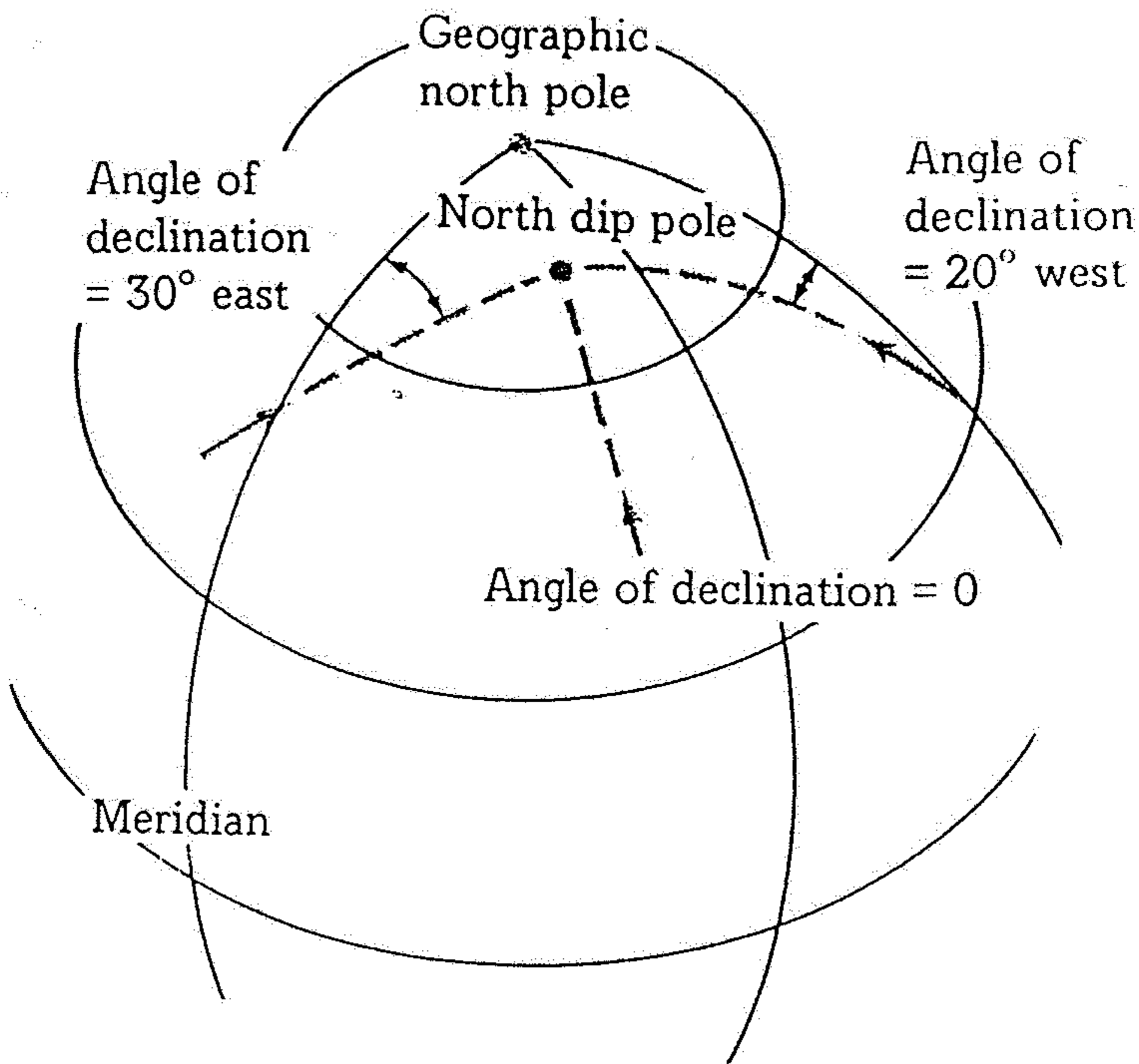
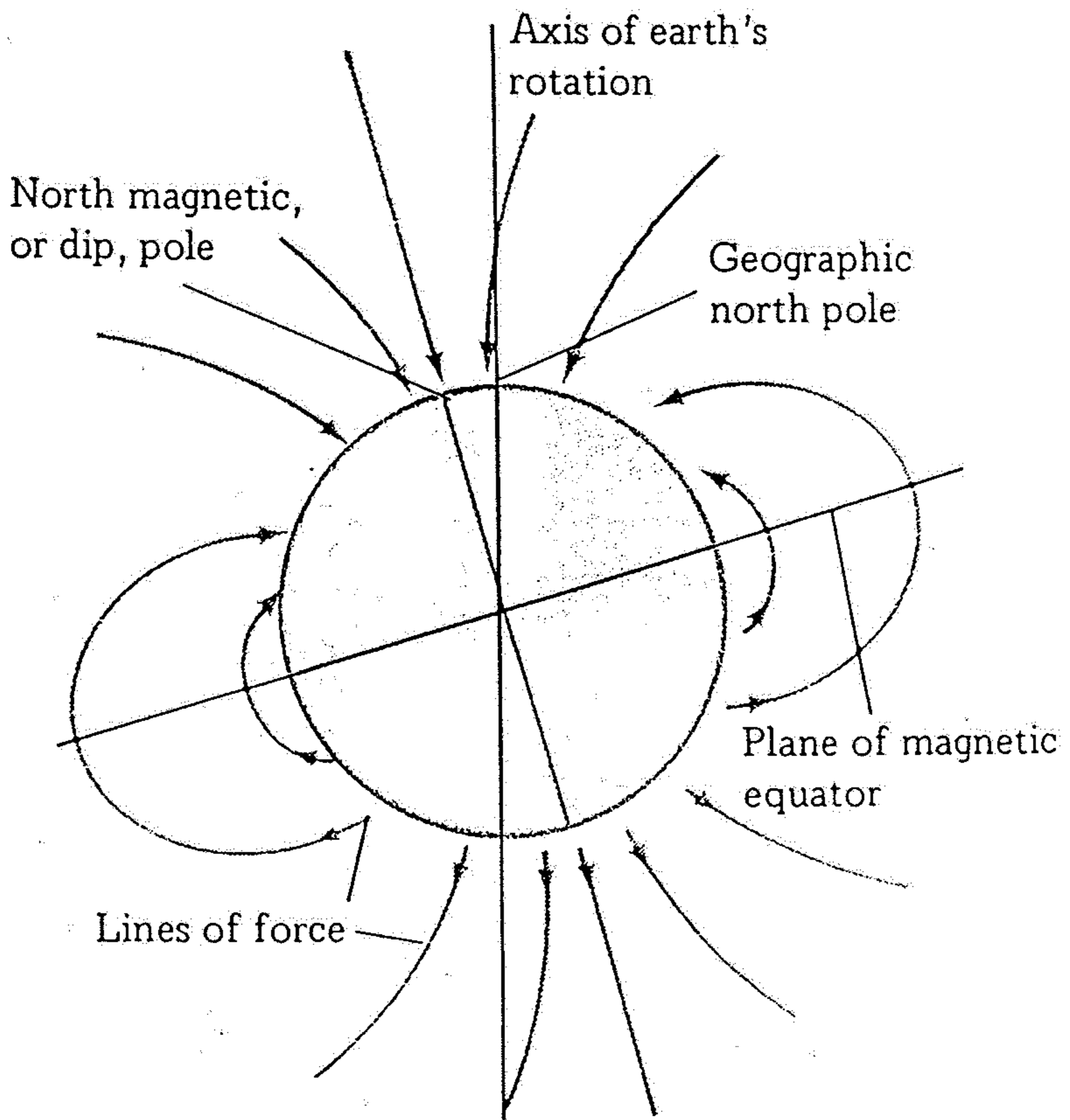


Abb. 10.10

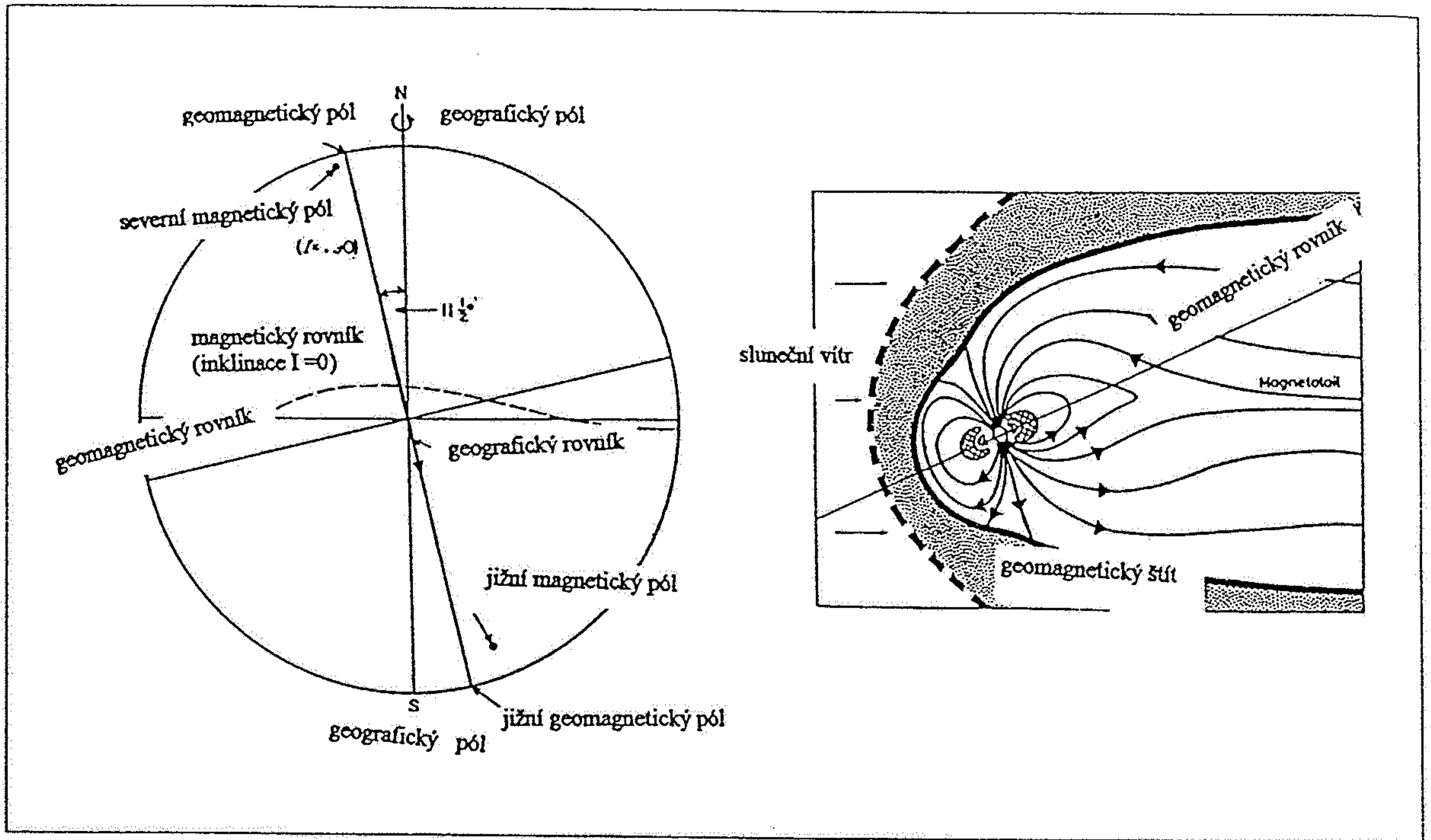
Geographischer und magnetischer Pol weichen z.Zt. um ca. 11° von einander ab. Der Verlauf der Magnetfeldlinien des im äußeren Kern erzeugten Magnet-

feldes entspricht in erster Näherung dem eines großen, ins Erdinnere gedachten, Dipolmagneten. Der Eintauchwinkel der Feldlinien in die Erdoberfläche wird als Inklination bezeichnet.

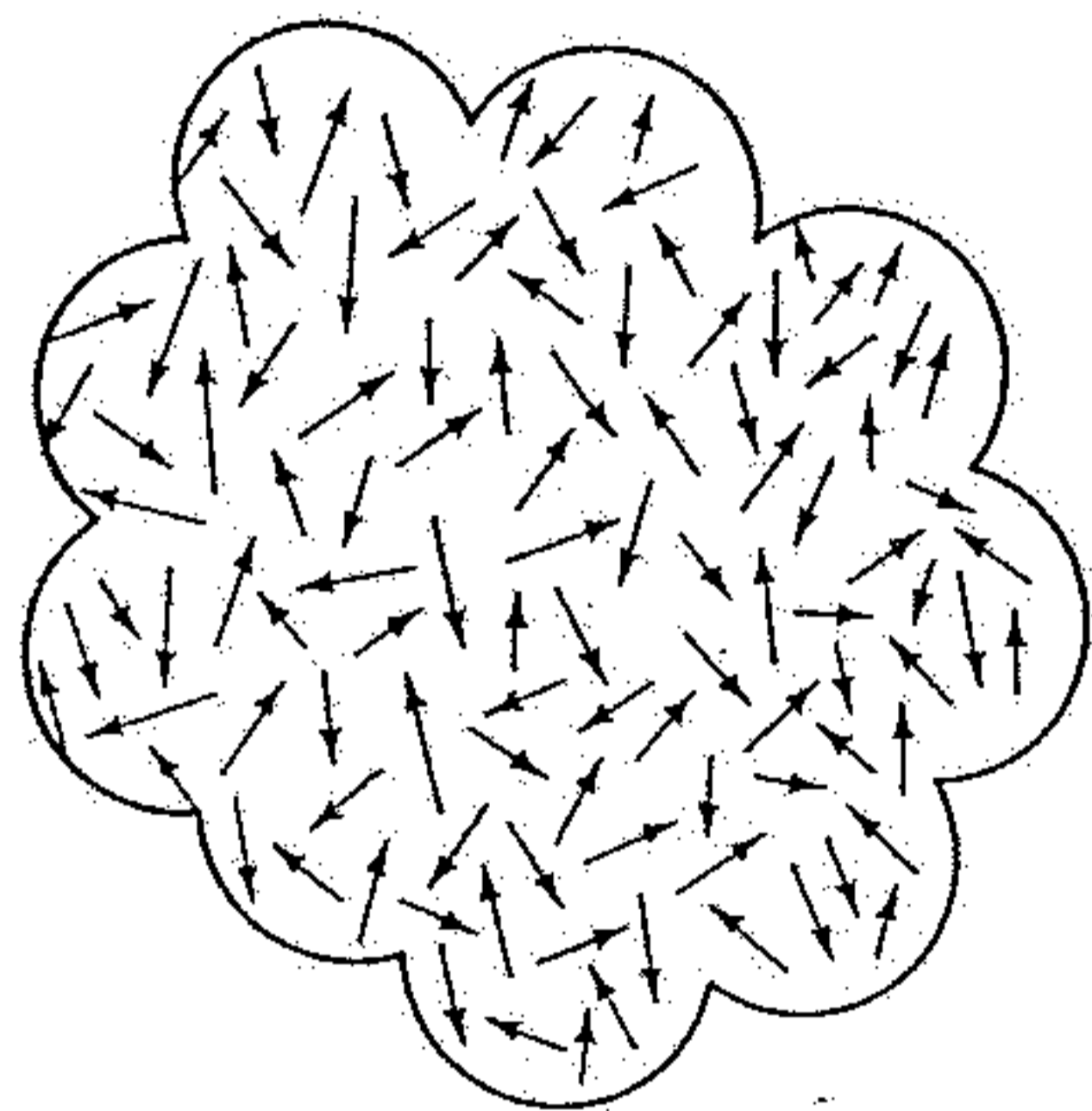
11.7 The Earth's magnetic field can be pictured as a series of lines of force. The arrows indicate positions that would be taken by a magnetic needle free to move in space and located at various places in the Earth's field. The magnetic, or dip, poles do not coincide with the geographic poles, nor are the north and south magnetic poles directly opposite each other.



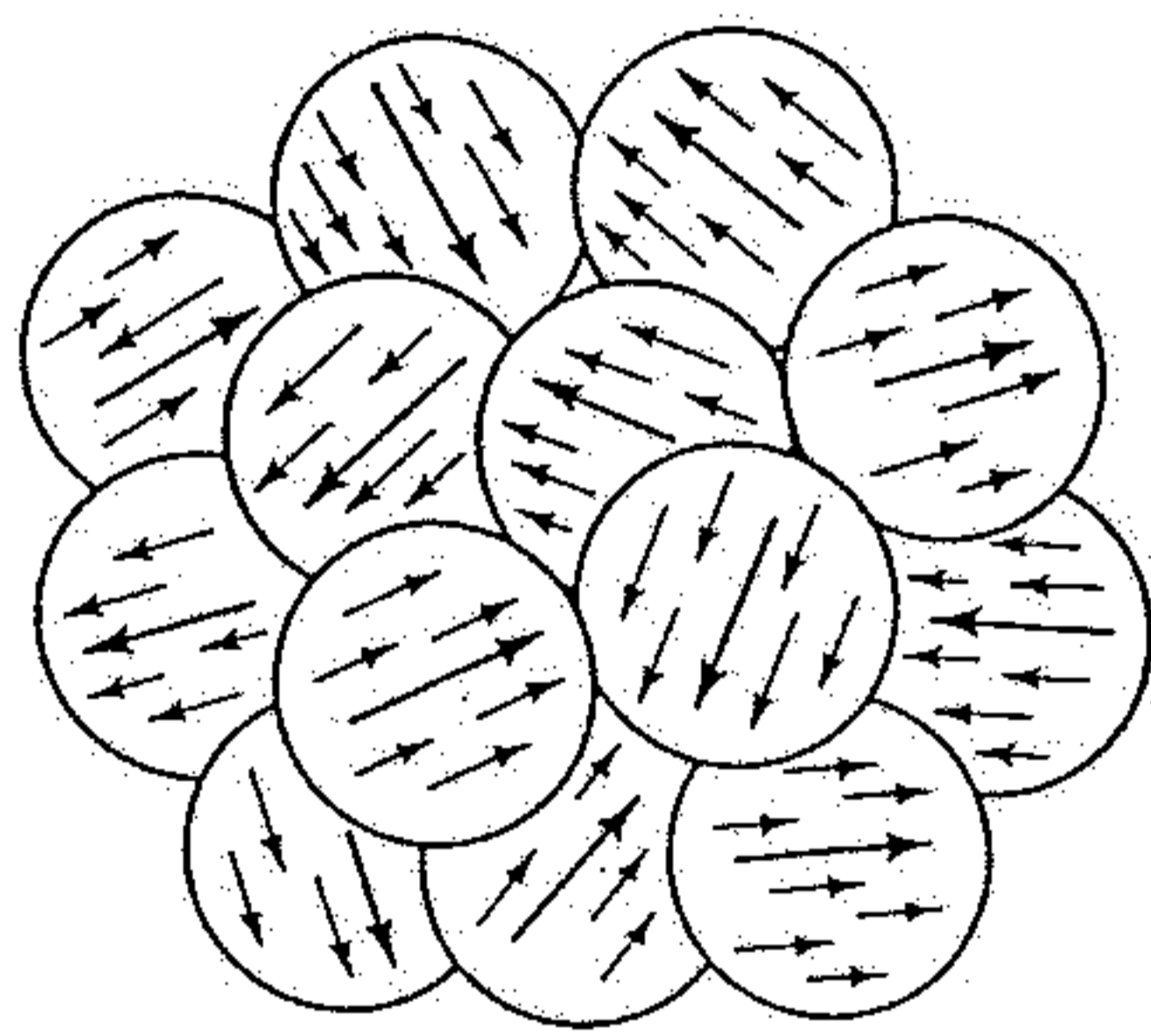
11.8 Because the dip poles and geographic poles do not coincide, the compass needle does not point to true north. The angle of divergence of the compass from the geographic pole is the declination and is measured east and west of true north.



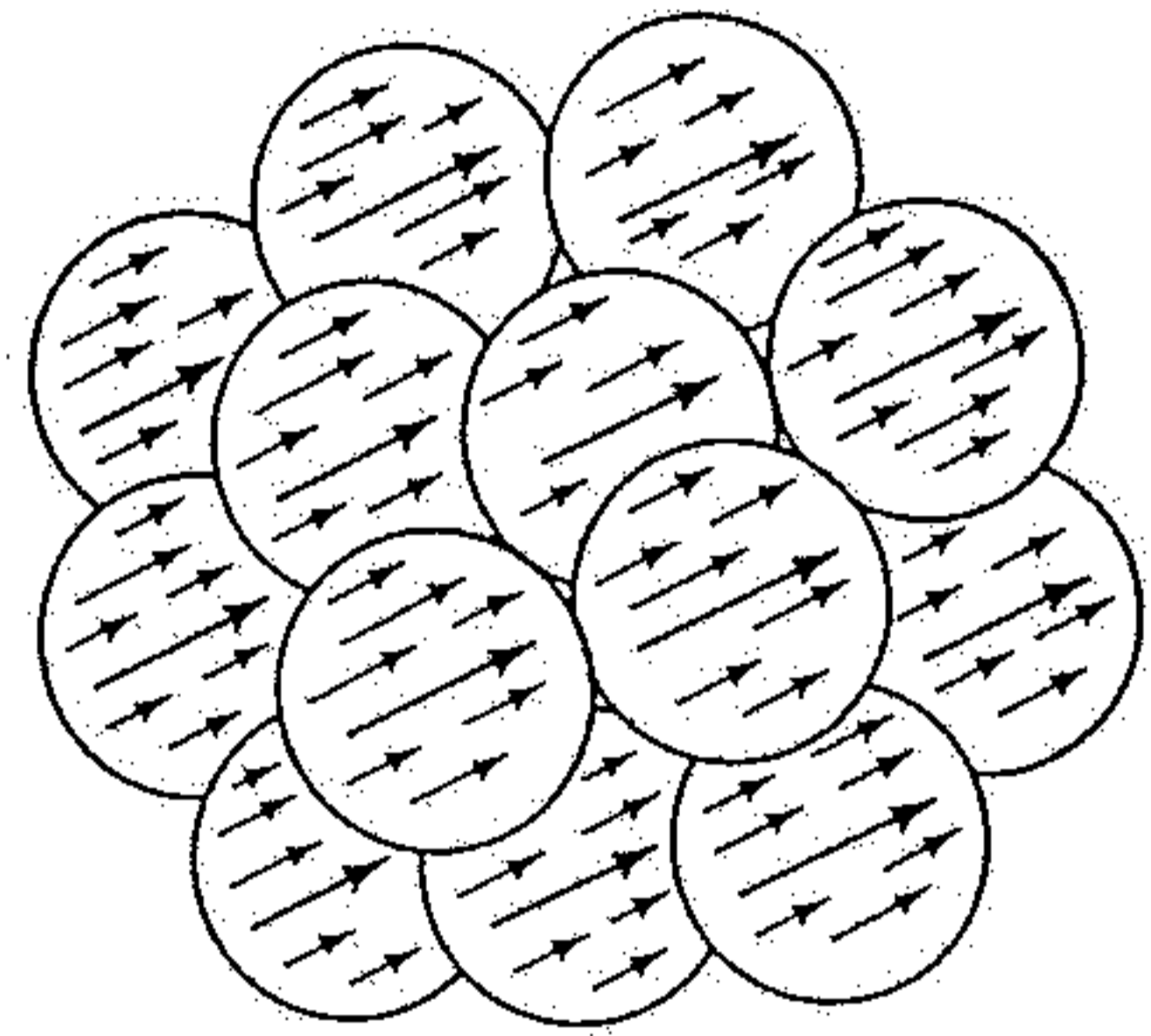
Obr: 25: Zemské magnetické pole (podle Mc Elhinny 1973)



(a) Above the Curie point, atoms take random directions



(b) Below the Curie point, atoms become parallel within domains



(c) Below the Curie point, in the presence of an external magnetic field, domains line up

Figure 19-9

Magnetic properties of magnetizable material. (a) At temperatures above the Curie point, heat agitates the atoms; they take random directions, and their randomly oriented magnetic fields cancel. (b) Below the Curie point, domains form in which the atoms line up, giving each domain a definite magnetization

represented by the larger arrows. (c) If the material cools below the Curie point in the presence of an external magnetic field, the domains line up parallel to the external field, and the material becomes permanently magnetized.

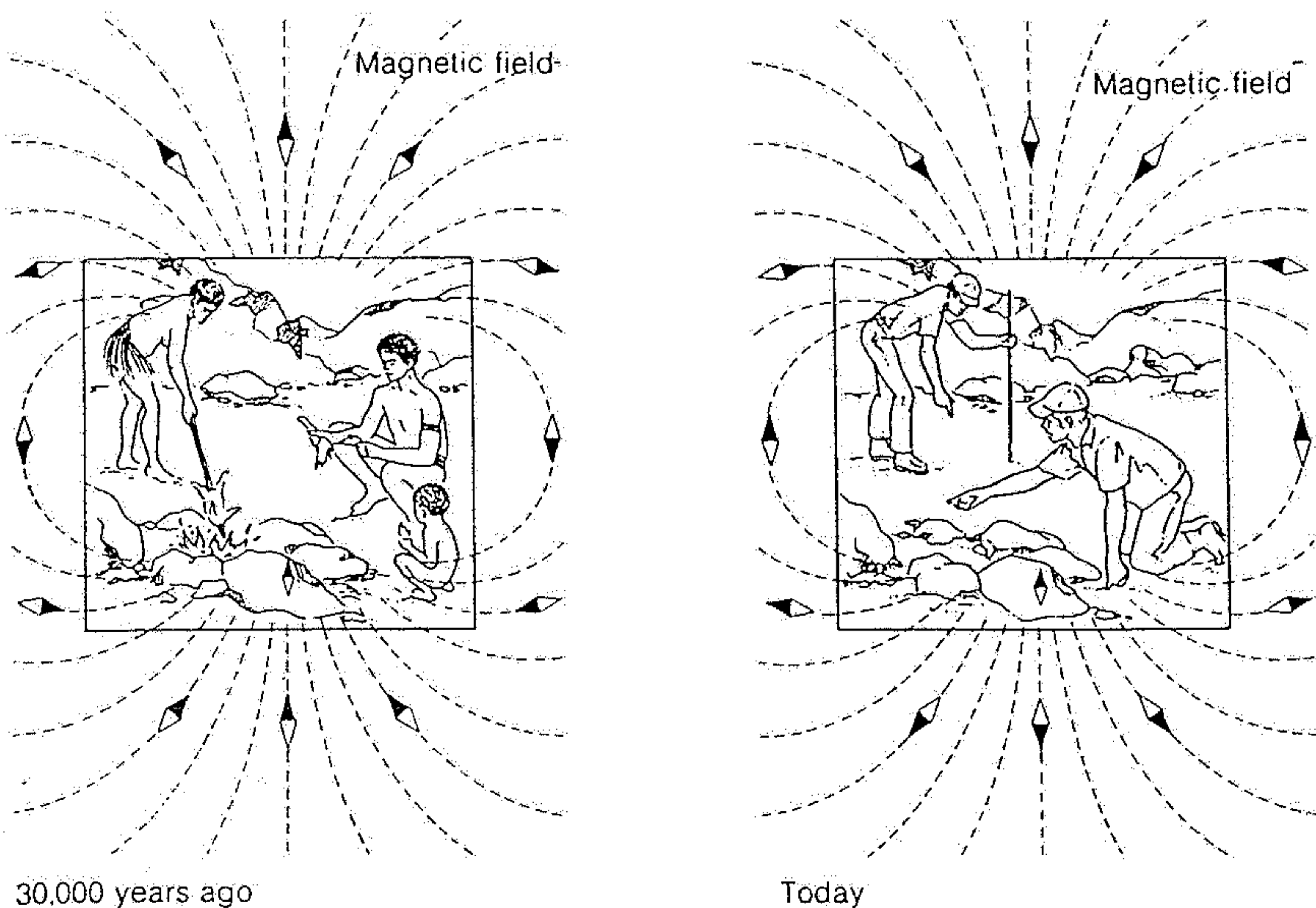


Figure 19-8

Earth's magnetic field 30,000 years ago was the reverse of today's. We know this from the discovery of reversely magnetized rocks found in the fireplace of an ancient campsite. The rocks, cooling after the last fire, became magnetized in the direction of the ancient magnetic field, leaving a permanent record of it, just as a fossil leaves a record of ancient life.

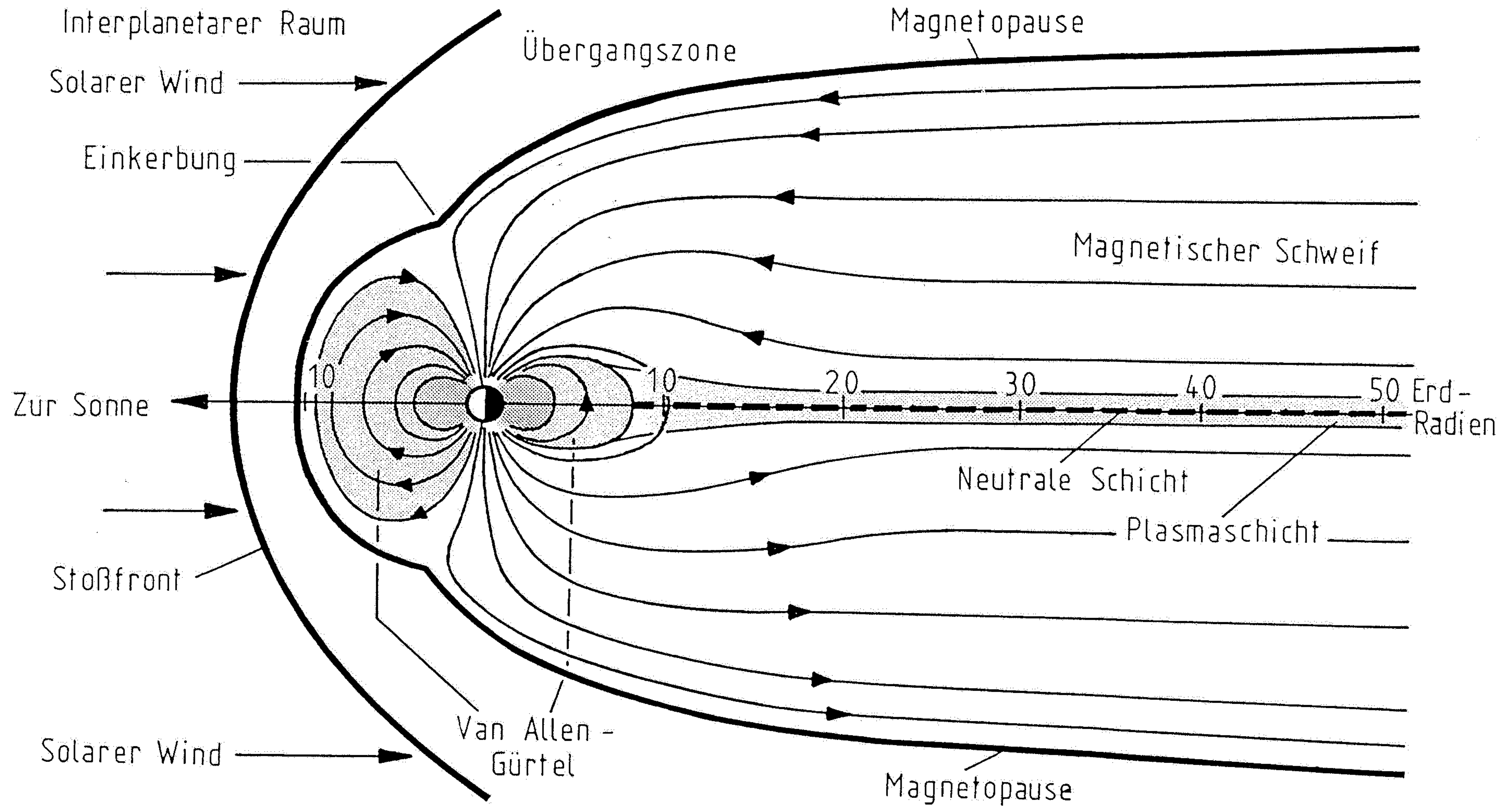


Abb. 8.2. Die Magnetosphäre der Erde. Schattiert: Van-Allen-Strahlungsgürtel und Plasmaschicht. Nähere Beschreibung im Text.

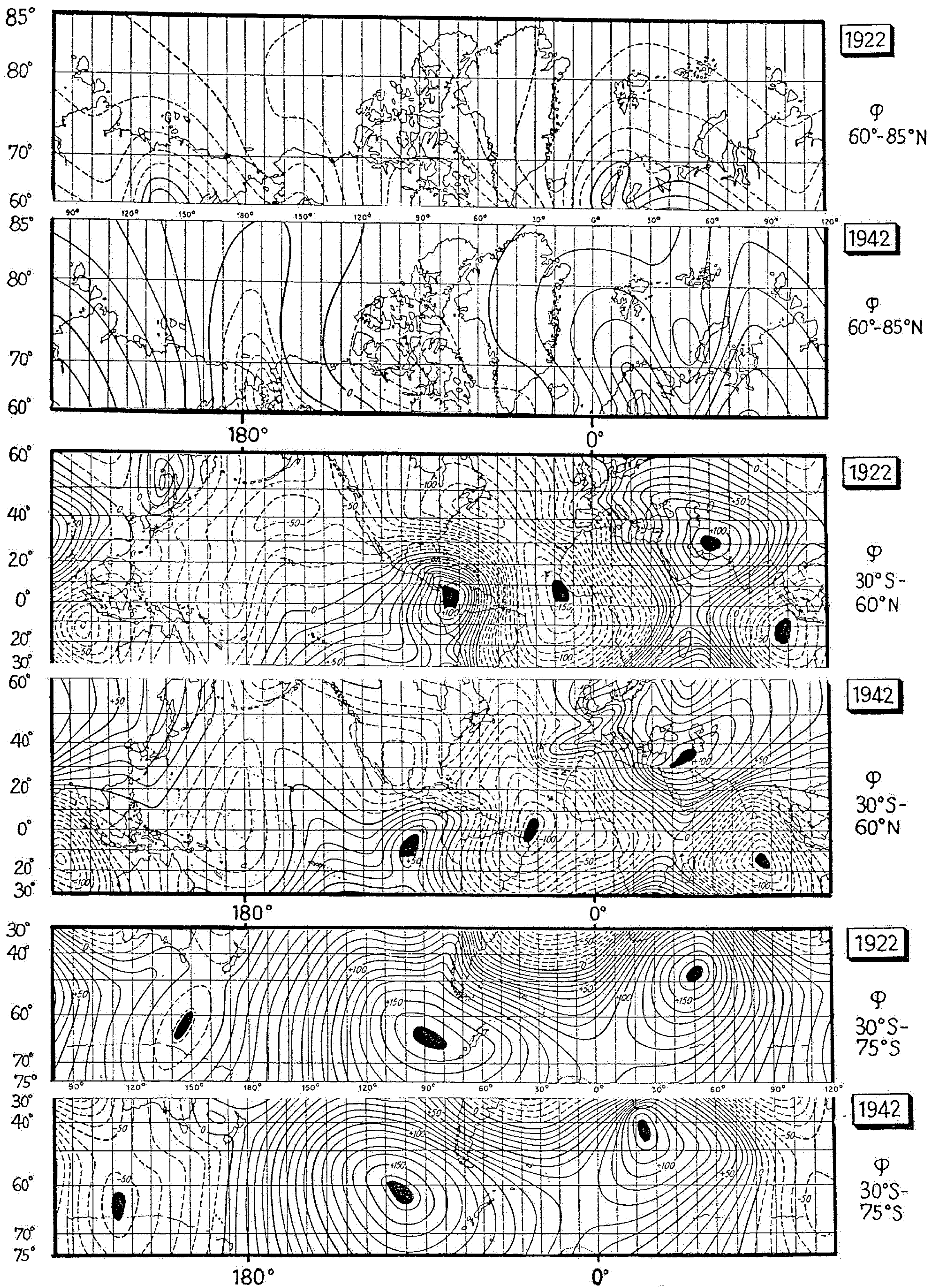


Abb. 8.4. Weltkarten der erdmagnetischen Säkularvariation. Die Karten zeigen die Linien gleicher zeitlicher Änderung des Feldes und die Isoporezentren (schwarze Flecken) jeweils für 1922 und 1942. Zum bequemen Vergleich wurden die Karten in drei Breitenzonen zerschnitten und die Zonen von 1922 und 1942 jeweils paarweise übereinander angeordnet. Oberes Paar: Nördliche Breiten. Hier sind kaum Isoporezentren erkennbar. Mittleres Paar: Äquatorzone. Deutlich ist die Wanderung der Isoporezentren nach Westen zwischen 1922 und 1942 sichtbar. Das gleiche erkennt man im unteren Paar für die Südhalbkugel. Nach VESTINE (1947).

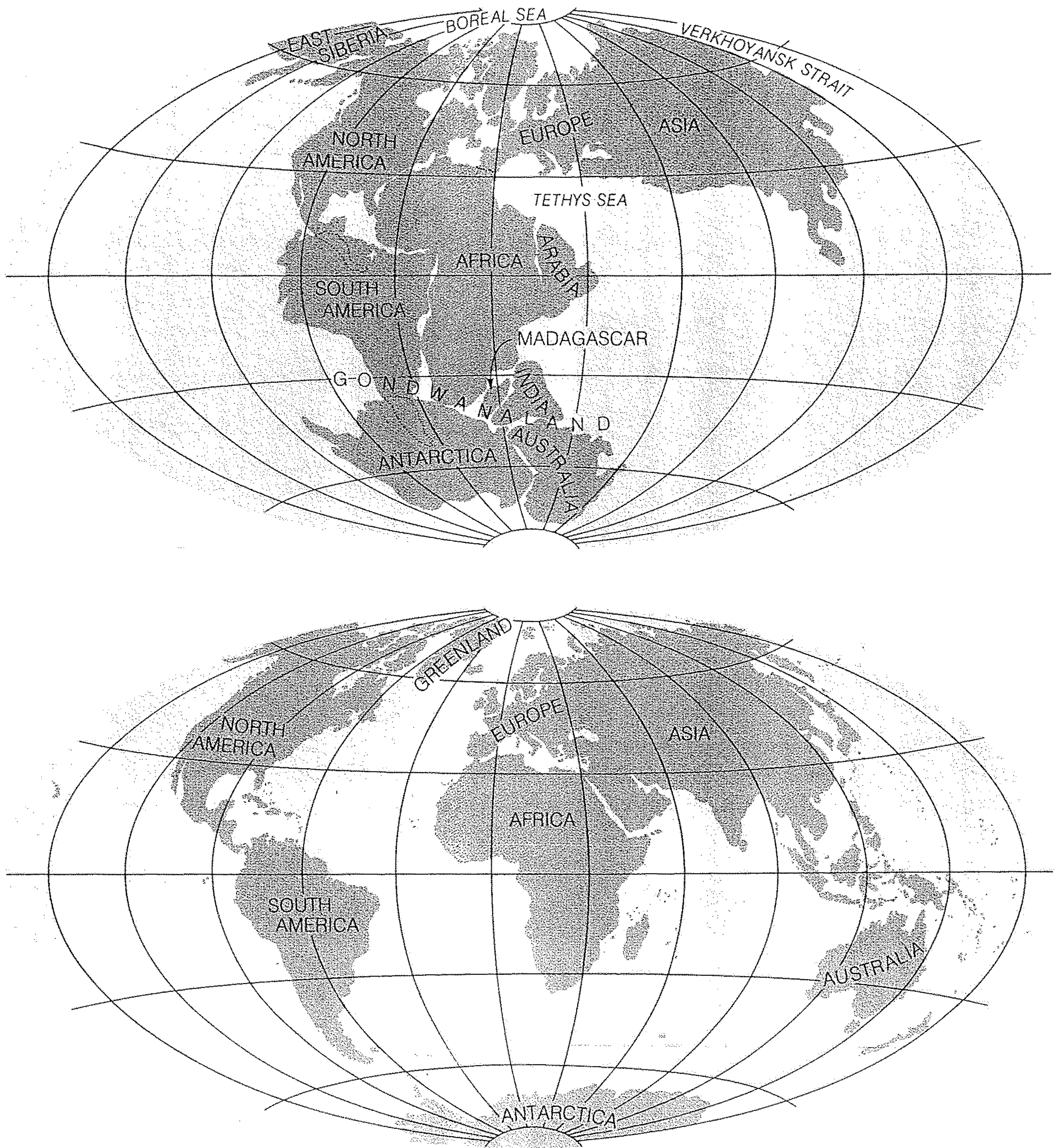
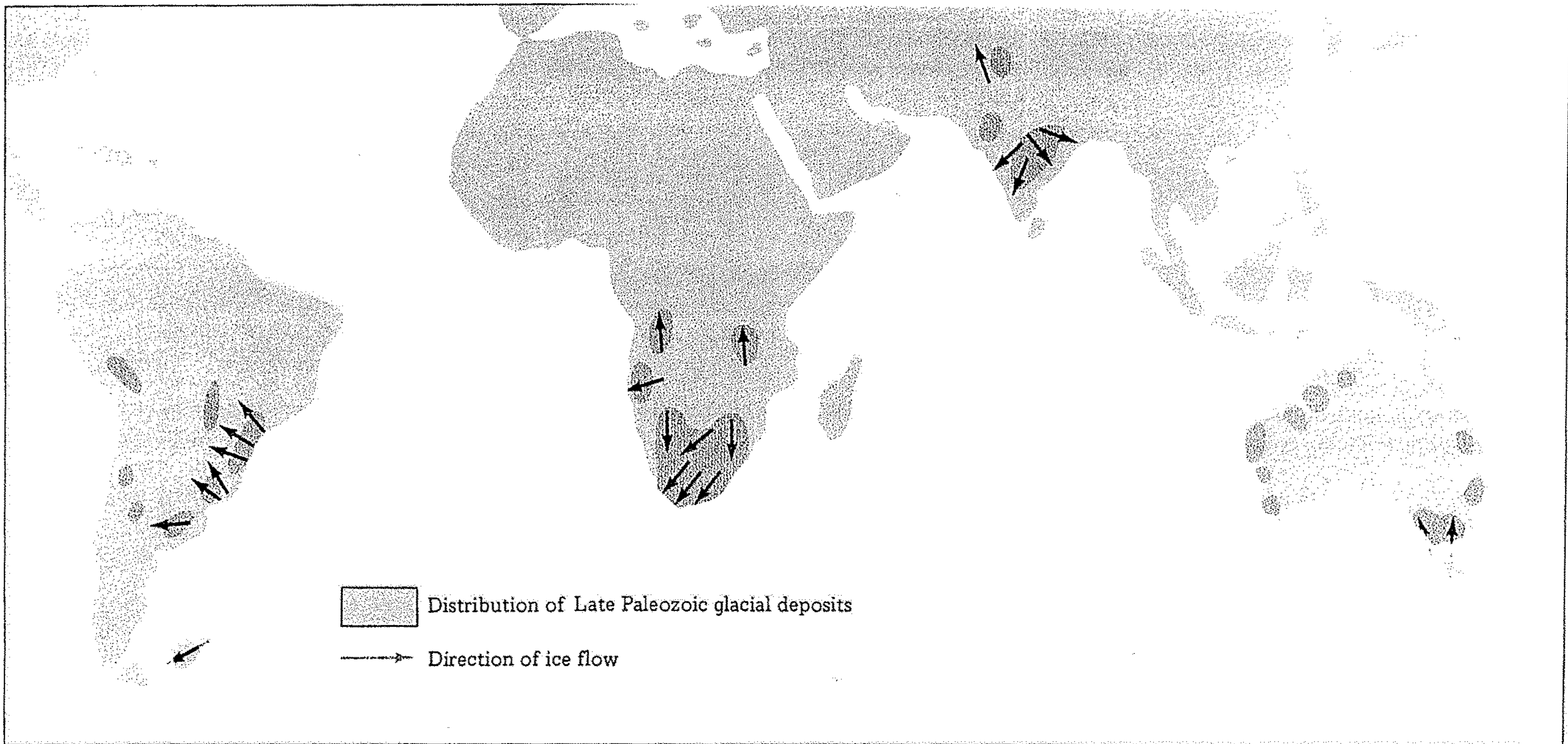


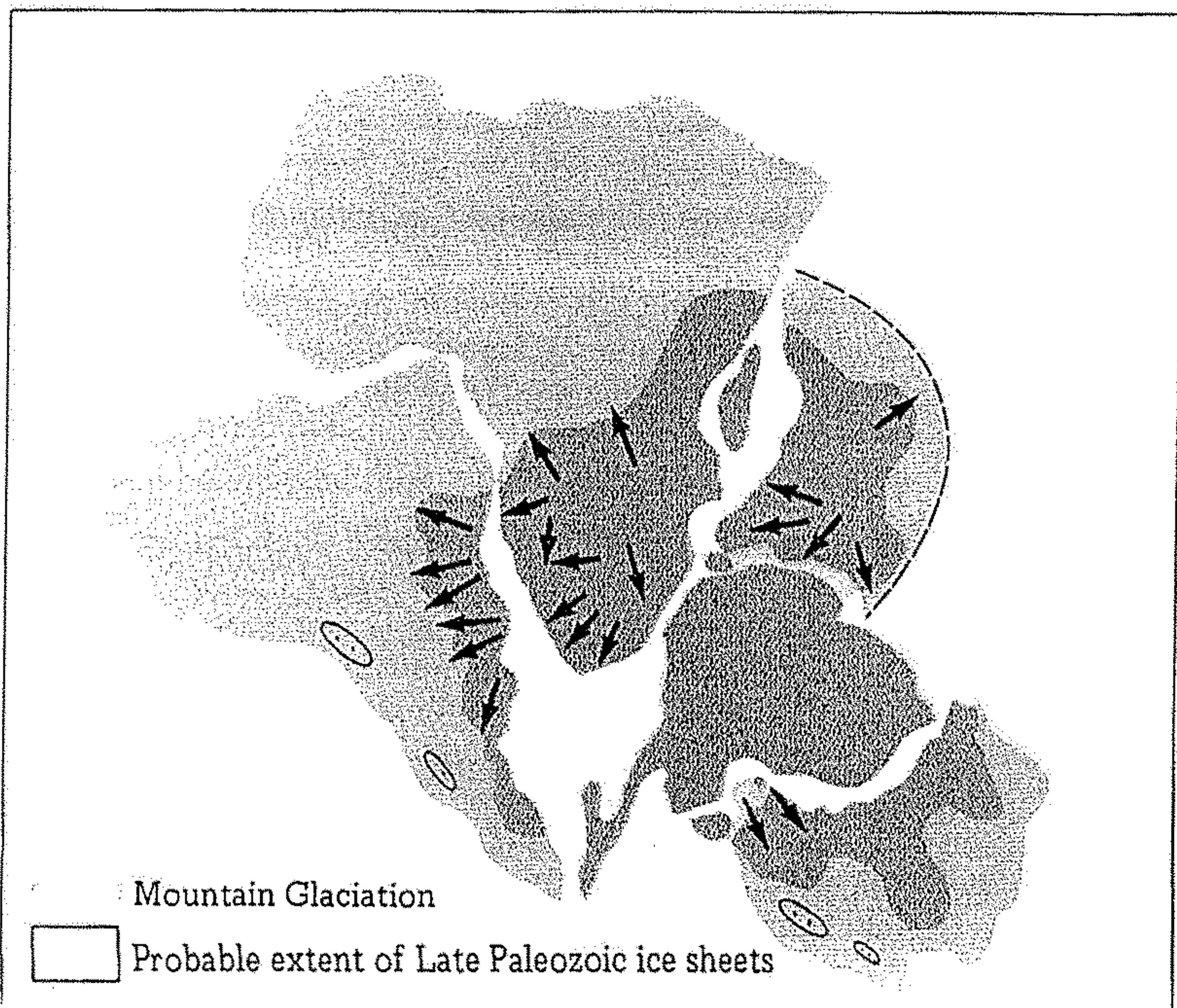
Figure 1-14

Single supercontinent of Pangaea, made up of all present continents, existed 200 million years ago [After "Continental Drift" by J. Tuzo Wilson. Copyright © 1963 by Scientific American, Inc. All rights reserved.]

erized by earthquake activity and volcanism. The void between the receding plates is filled by molten, mobile material that rises from below the lithosphere. The material solidifies in the crack, and the plates grow as they separate. Since new oceanic floor is created, this part of the process is called **oceanic floor spreading**.



(a)

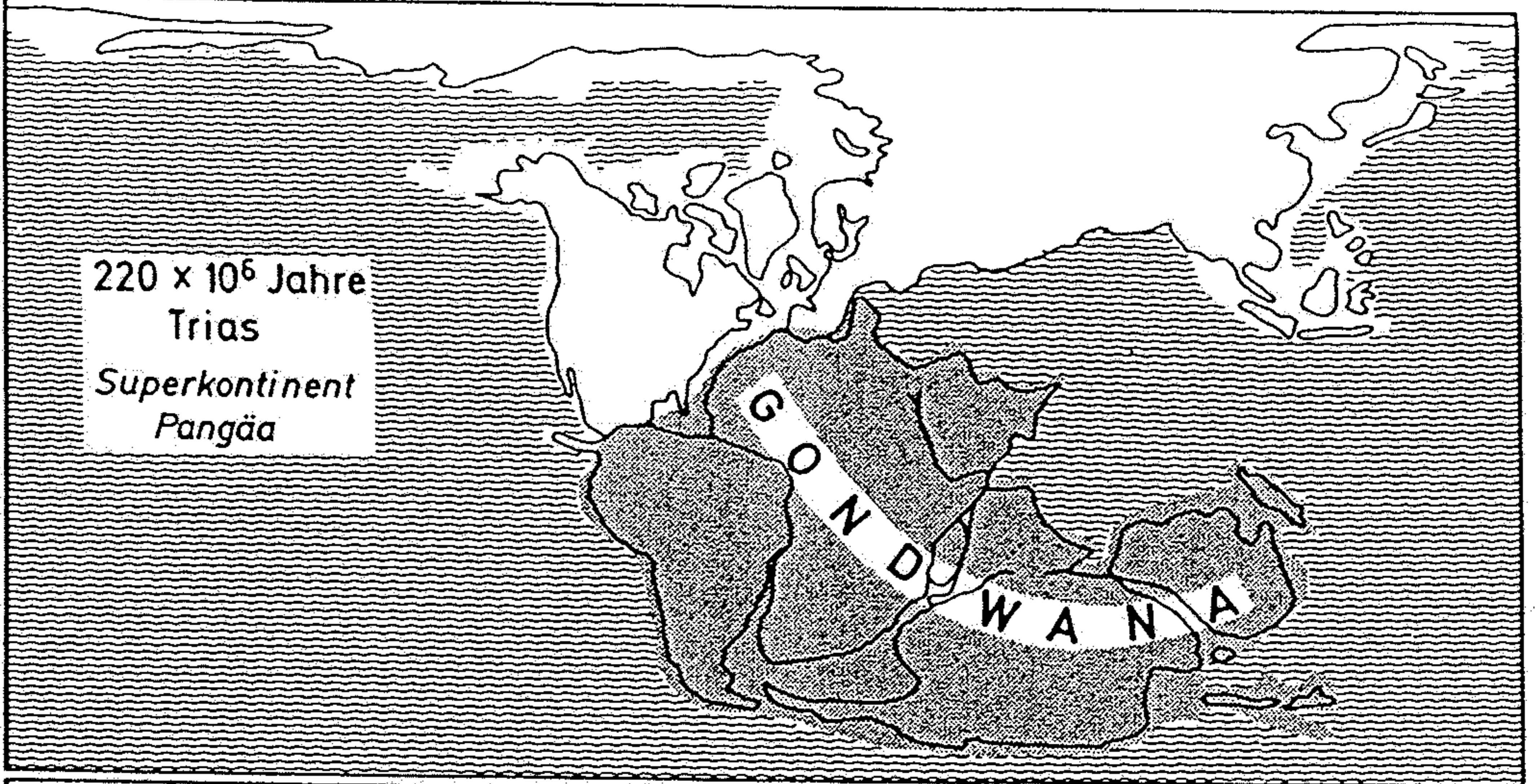


11.3 (a) Direction of movement of late Paleozoic glaciers and distribution of some known late Paleozoic tillites. (b) If we fit the Gondwana continents back together, the directions of the striations suggest a generally outward direction of flow of ice on the late Paleozoic landmass. If the Gondwana continents are restored to their Carboniferous positions, the glacial striations fit an understandable pattern, with movement out from a common center.

corals mark a climate shifting geographically through time. Today true coral reefs are restricted to warm, clear marine waters between 30° north and 30° south of the equator. If we assume that ancient reef-forming corals had similar restrictions, then plotting their distribution in the past should show the distribution of tropical waters of the past and the location of the past equator. When we do this, we find that reef-forming corals did not approximate their present distribution until halfway through the Mesozoic Era. Prior to that time, they lay south of the present equator.

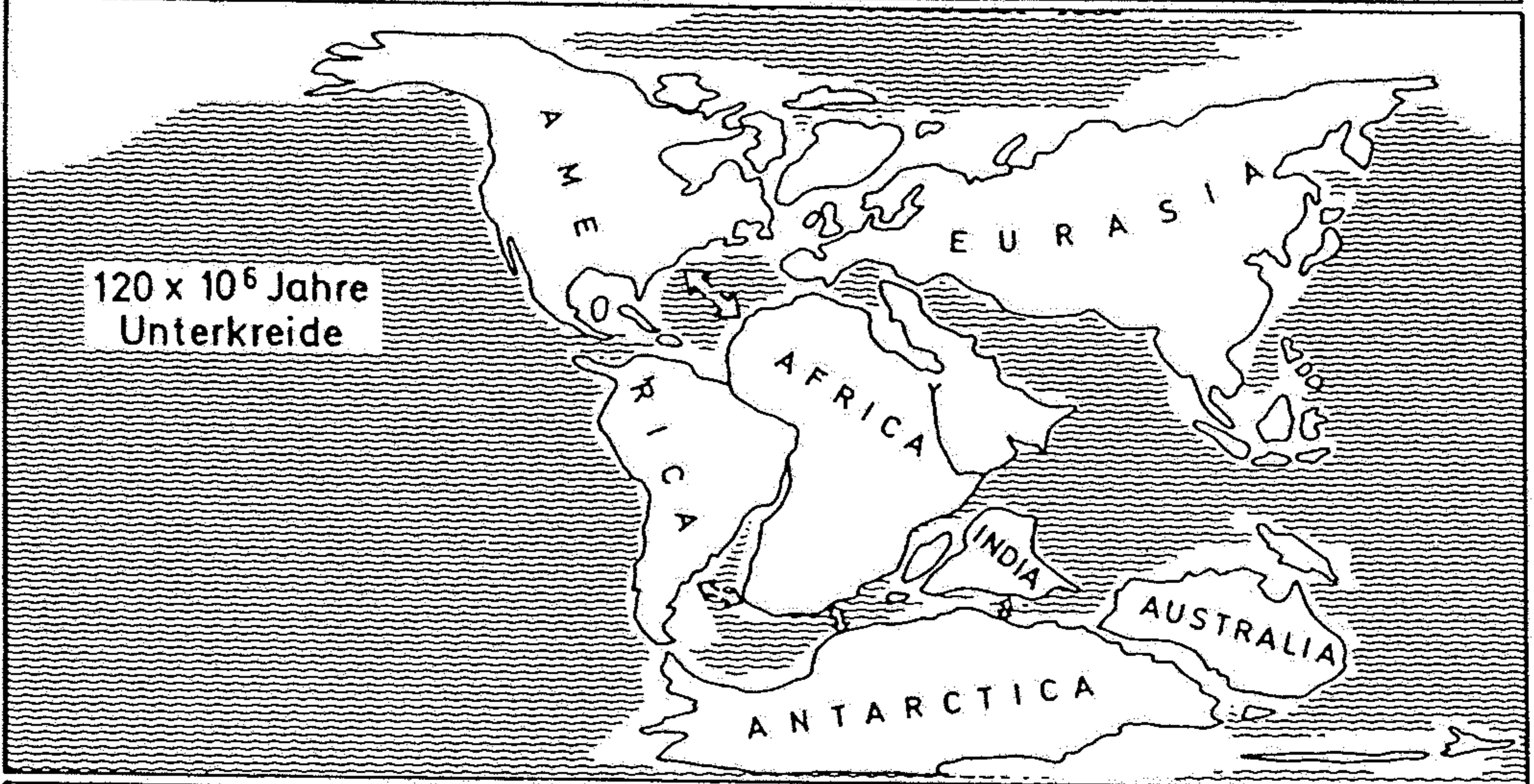
*Trias
Carin*

220 x 10⁶ Jahre
Trias
Superkontinent
Pangäa



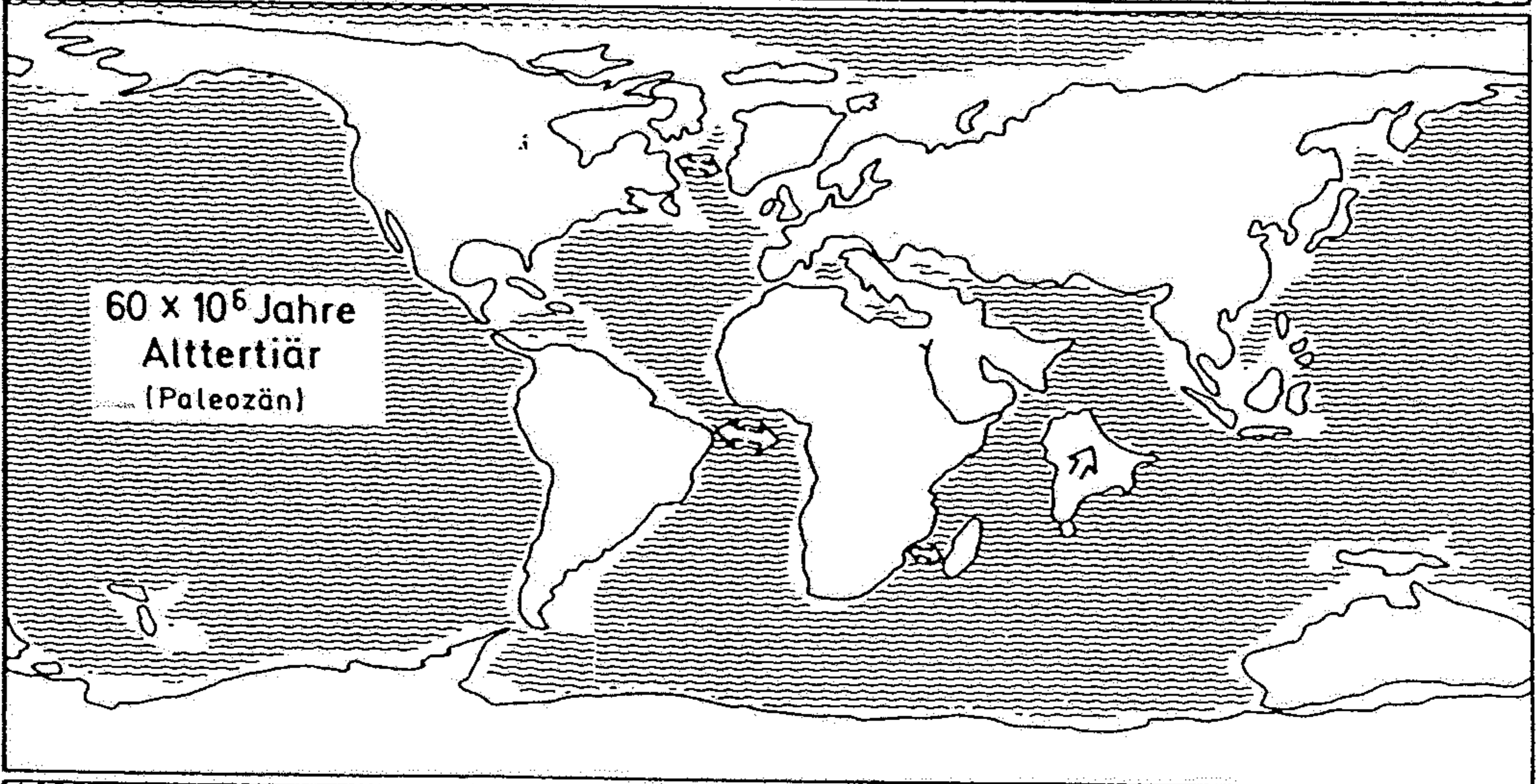
*Unterkreide
apt*

120 x 10⁶ Jahre
Unterkreide



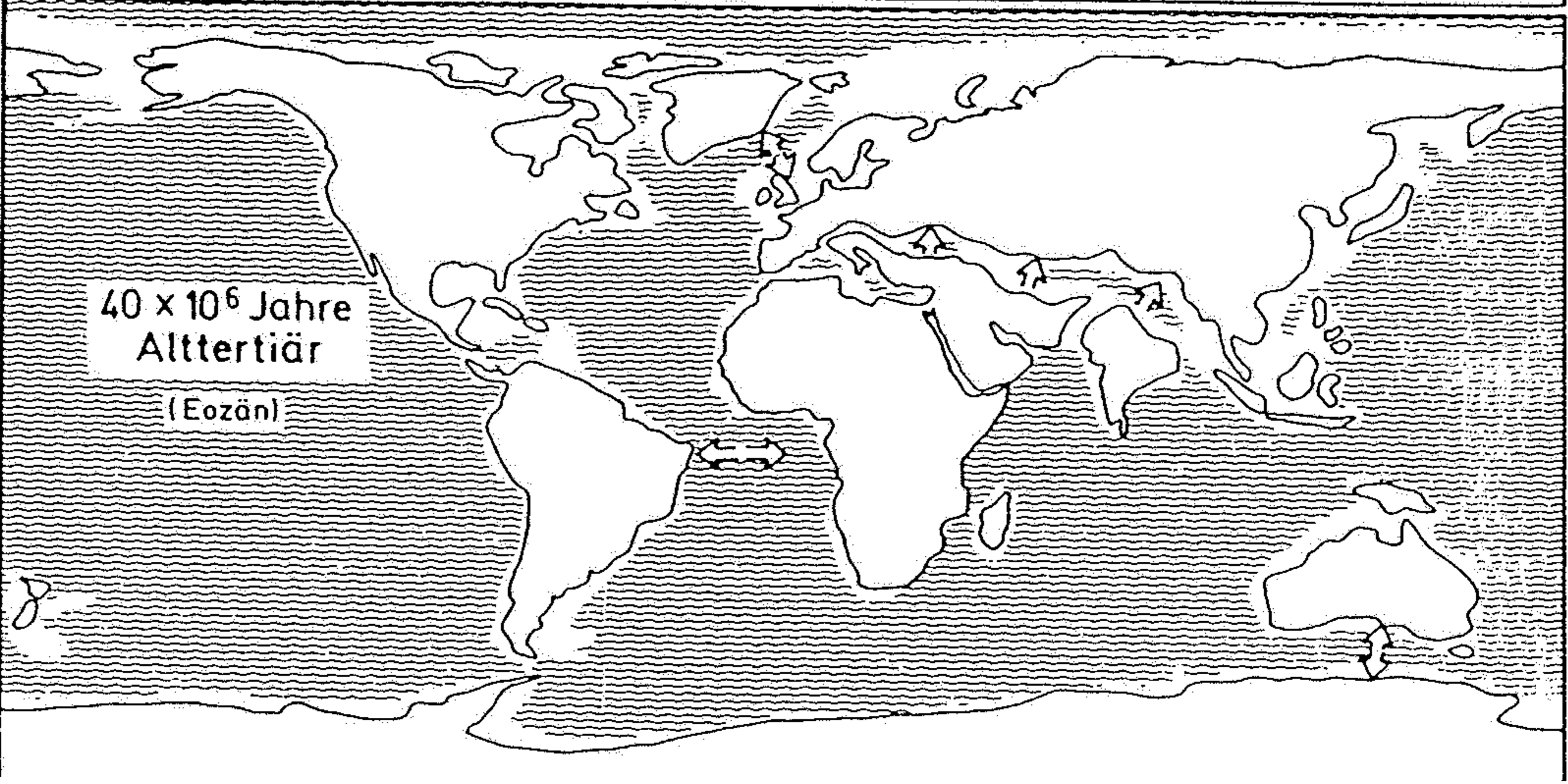
*Alttertiär
Pliozän*

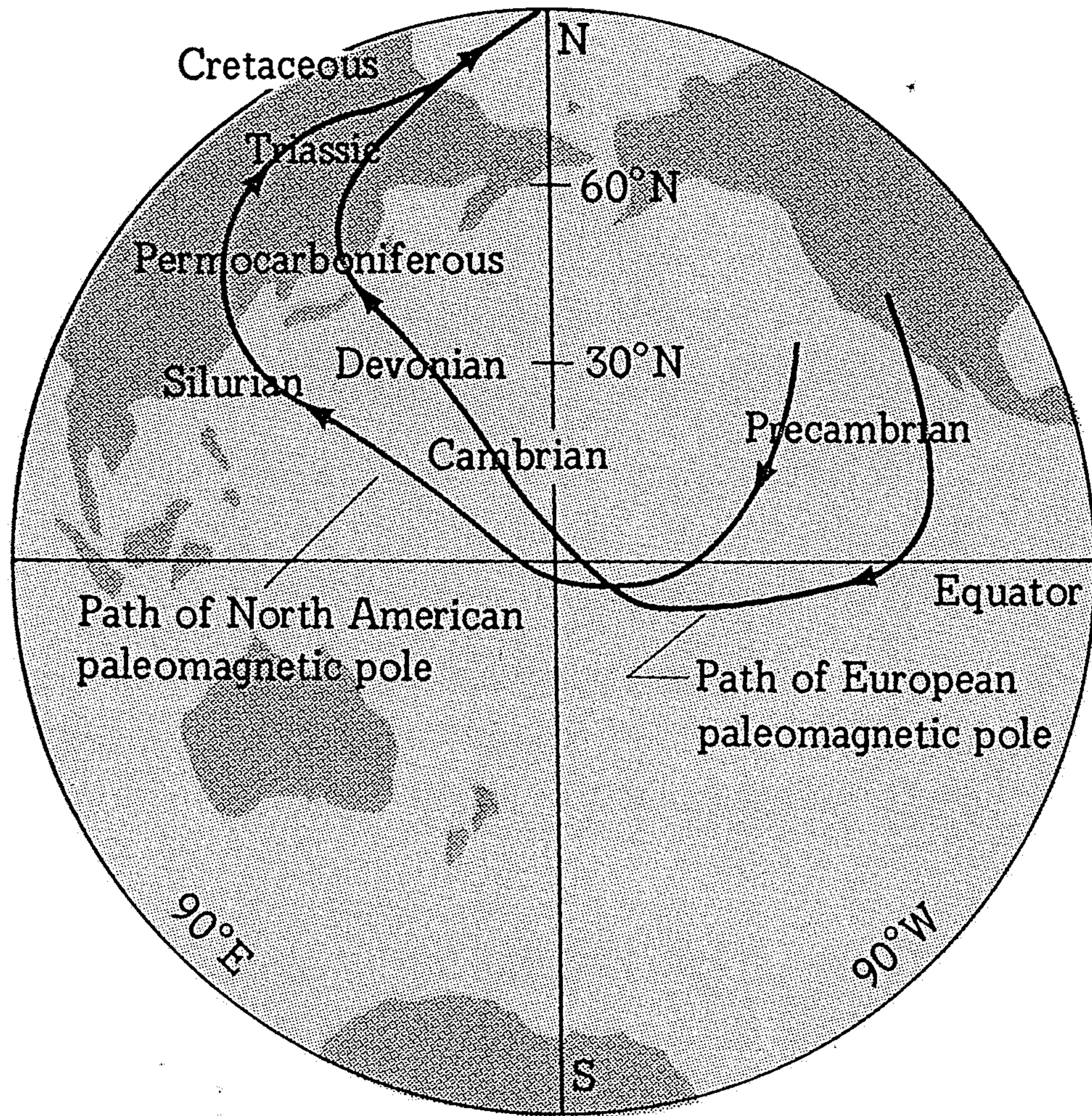
60 x 10⁶ Jahre
Alttertiär
(Paleozän)



*Alttertiär
Eozän*

40 x 10⁶ Jahre
Alttertiär
(Eozän)





11.13 "Wander curves" of rocks from North America and Europe show the paths followed by the magnetic poles of these two continents from Precambrian times to the present. [After Allan Cox and R. R. Doell, "Review of Paleomagnetism," *Bull. Geol. Soc. Am.*, vol. 71, p. 758, 1960.]

THE EARTH'S MAGNETISM AND GRAVITY

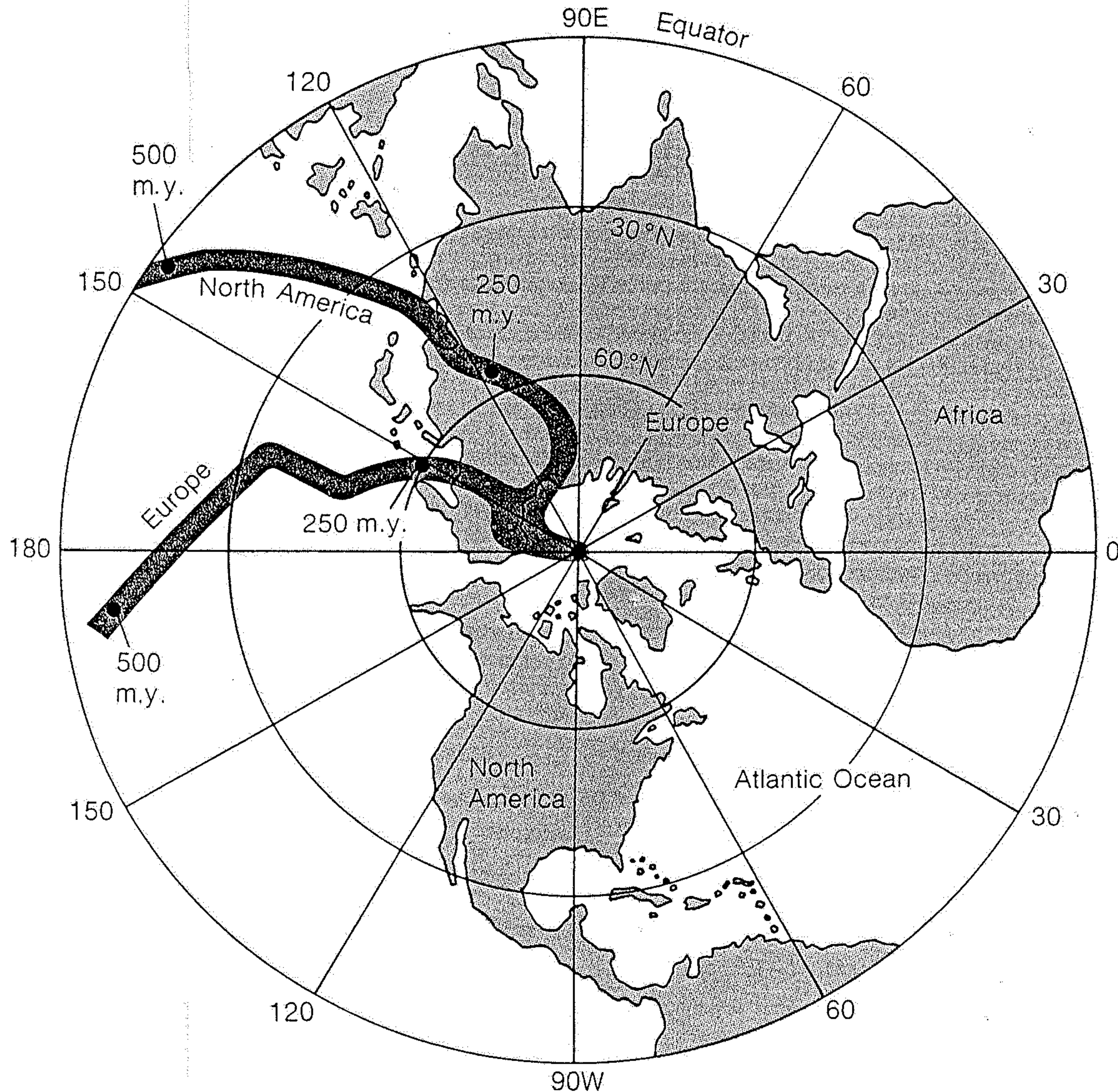


Figure 19-11

Apparent polar-wandering curves based on North American and European paleomagnetic data showing apparent positions of the magnetic pole from the present to 500 million years ago. Most geophysicists believe that the pole didn't actually wander, as the figure implies; it remained fixed, close to the geographic pole, while the "map"—that is, the outer layers of the Earth—drifted over the interior. If the Atlantic had not opened and continental drift had not occurred, the European and North American polar-wandering curves would coincide prior to Triassic time. Thus the polar-wandering curves really indicate the simultaneous northward drift of these continents and the east-west opening of the Atlantic Ocean. The polar-wandering curve, though fictitious, is a convenient way of summarizing paleomagnetic data.

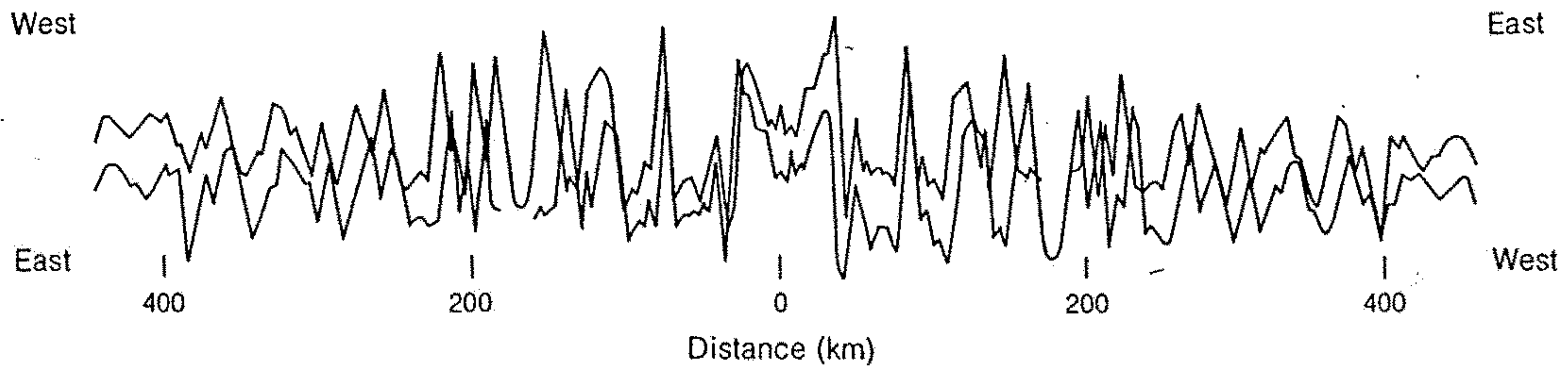


Figure 19-16

Symmetry of the magnetic anomaly of sea-floor rocks on both sides of the ridge axis is demonstrated by reversing a record covering about 900 km of both flanks (brown) and superposing it on the record as

ordinarily shown (black). [After "Sea-Floor Spreading" by J. R. Heirtzler. Copyright © 1968 by Scientific American, Inc. All rights reserved.]

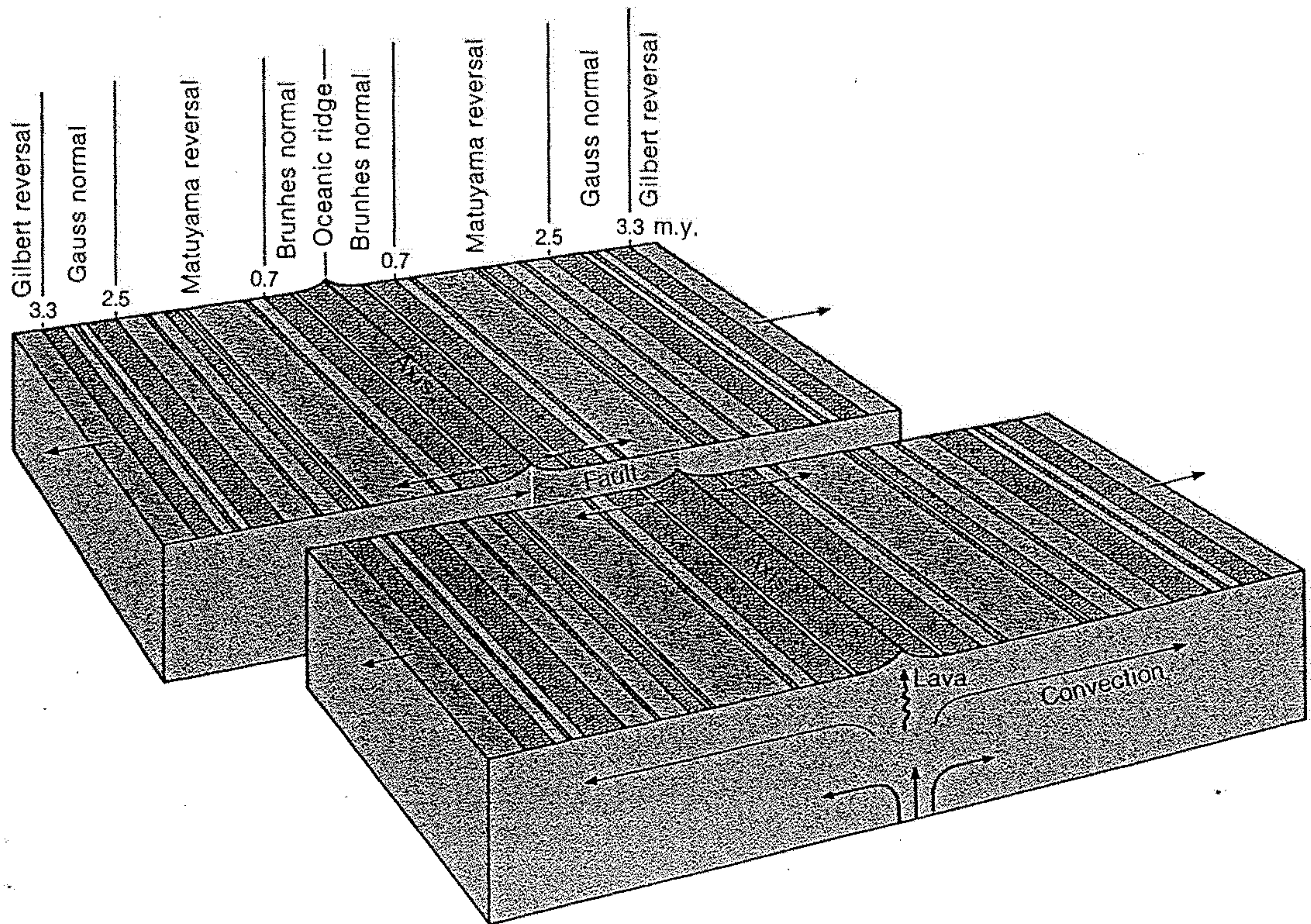
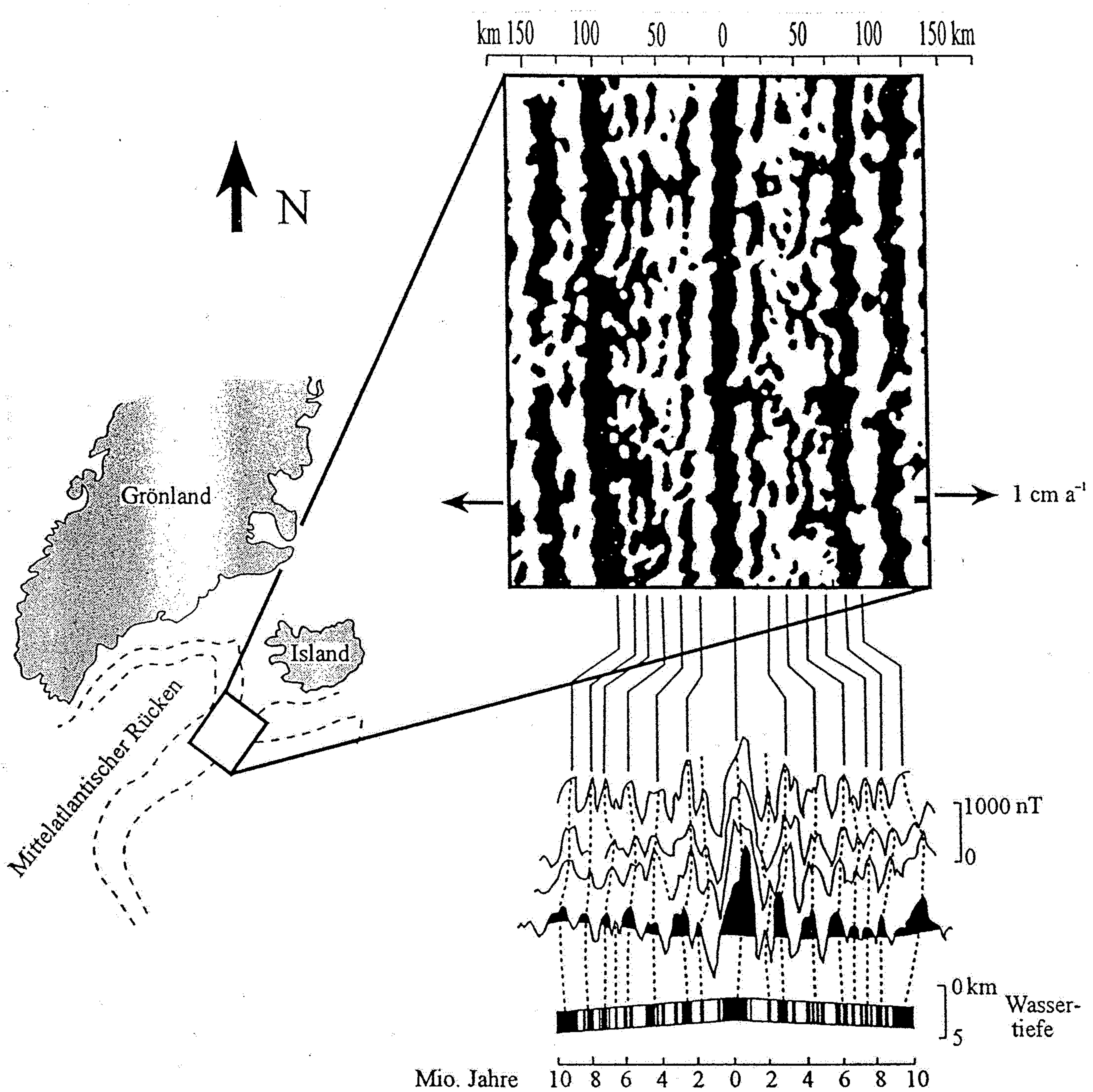


Figure 19-17

The succession of normal and reversed magnetic anomalies on the sea floor provides strong support for the concept of sea-floor spreading. Rocks of normal, or present-day, polarity are shown in dark shades; rocks of reversed polarity are in light shades. The symmetry of the magnetic stripes and the correlation with the time scale of reversals worked out from lava flows on land suggest that molten rock upwelling along the

ridge axis became magnetized as it cooled, was pushed out on both sides, and gradually moved outward with the separating plates. The separation of the two blocks represents a transform fault. The diagram is based on the studies of many scientists. [After "The Confirmation of Continental Drift" by P. M. Hurley. Copyright © 1968 by Scientific American, Inc. All rights reserved.]

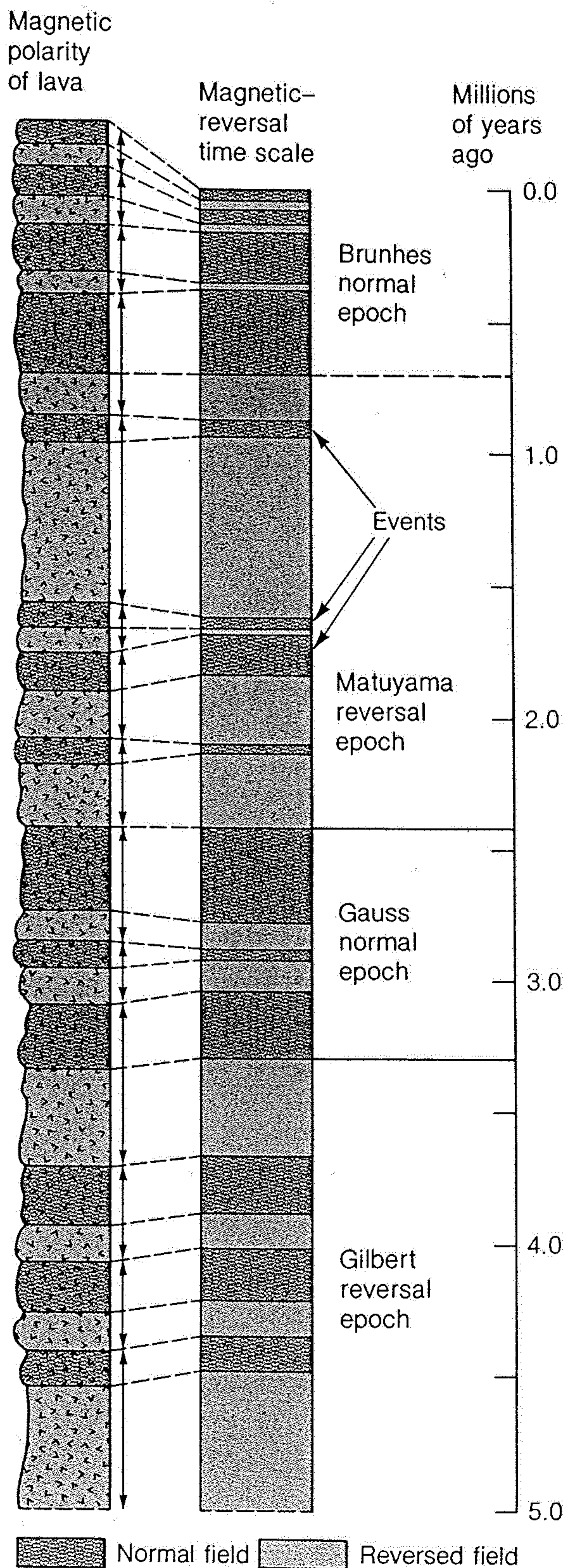


Variation der magnetischen Feldstärke des Meeresbodens beiderseits des Reykjanes-Rückens südlich von Island (zur Position vgl. Abb. 10.1). Bereiche mit positiver Anomalie sind schwarz eingezeichnet. Die Magmatite dieser Bereiche sind in Zeiten mit normaler Polarität des Erdmagnetfeldes entstanden. Unten sind die Schwankungen der Feldstärke entlang von drei Profilen über den Mittelozeanischen Rücken hinweg und ein theoretisches Krustenprofil dargestellt. Ganz unten ist die Korrelation

mit der Zeitskala der magnetischen Umpolungen gezeigt (siehe Abb. 10.12). Die auffällige Spiegelsymmetrie der magnetischen Streifung beiderseits des Mittelozeanischen Rückens, die hier und an vielen anderen MOR-Abschnitten beobachtet wurde, war ein entscheidender Beweis für das Sea floor spreading. Die unregelmäßigen Umrisse der magnetischen Streifen haben ihre Ursache in der komplexen räumlichen und zeitlichen Anordnung der magmatischen Prozesse am MOR (nach STROHBACH, 1991).

Figure 19-13

Lava beds preserve the record of reversals of the Earth's magnetic field. The modern flow at the top shows the direction of the field today. Earlier flows record the directions of ancient fields that existed when the lavas cooled.



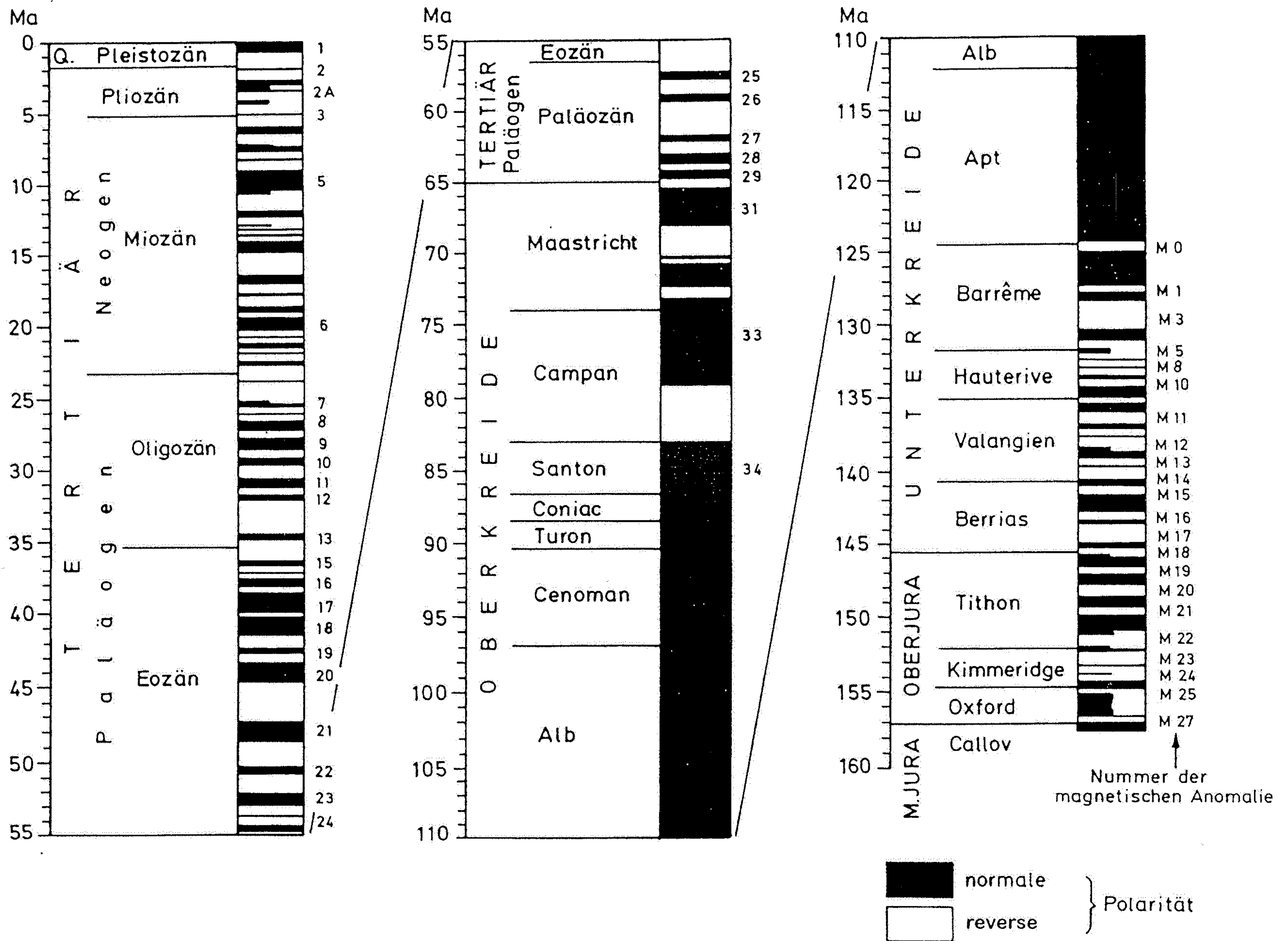


Abb. 10.12

Zeitskala der Magnetfeldumkehr. Schwarz = normale Polarität, wie heute; die Skala beruht i.w. auf Magnetfeldmessungen der ozeanischen Kruste und radiometrischen Altersbestimmungen ihrer Gesteine und reicht daher nur bis in den Jura (Abb. 10.9, vgl. auch Abb. 7.8). Die Umpolungen finden in unregelmäßigen Abständen von einigen hunderttausend Jahren statt. Daneben kommen kurzfristige Ereignisse vor, die vermutlich „mißglückte“ Umpolungen ohne ausreichende Stabilität darstellen dürften. Die außergewöhnlich lange Periode mit normaler Polarität in der Kreide (Nr. 34) wird als Magnetic quiet zone bezeichnet (nach HARLAND et al. 1990).

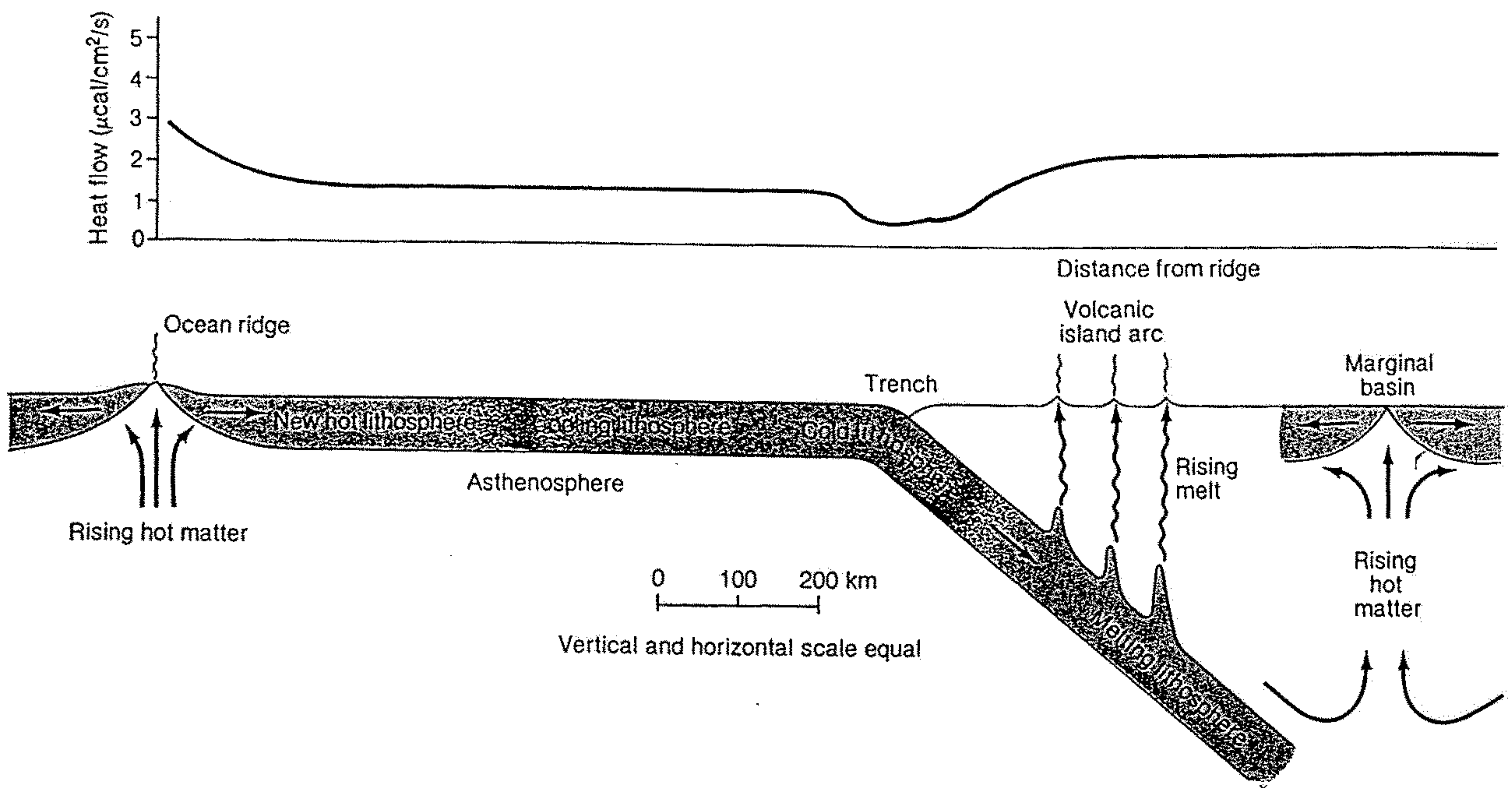
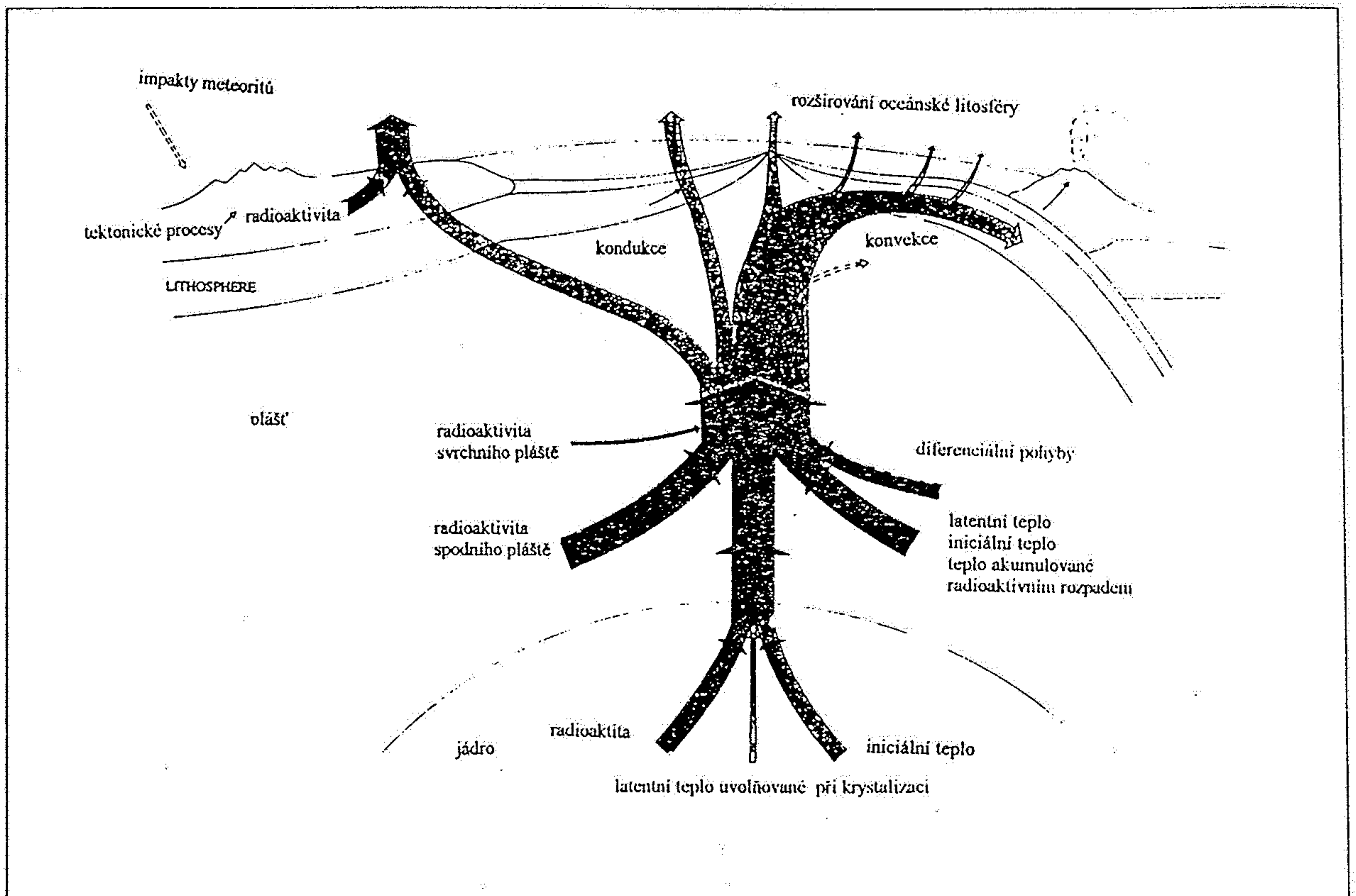


Figure 14-8

The pattern of heat flow out of the sea floor. High values are observed over mid-ocean ridges. As the sea floor spreads and cools, less heat reaches the surface. On the side of deep-sea trenches where the lithosphere plunges into the asthenosphere, rising magma from the melting lithosphere produces higher heat-flow

values. A small region of secondary spreading may develop in a marginal basin behind the subduction zone. The Sea of Japan, which separates the Japanese island arc from the Asian continent, is an example of such a region.



Obr. 12: Energetická bilance vnitřních obalů Země. Šíře šipek není vždy proporcionální množství energie dodávané z jednotlivých zdrojů (podle Le Pichon, Lliboutry, Le Mouel, Sclater in Caron et al. 1989)

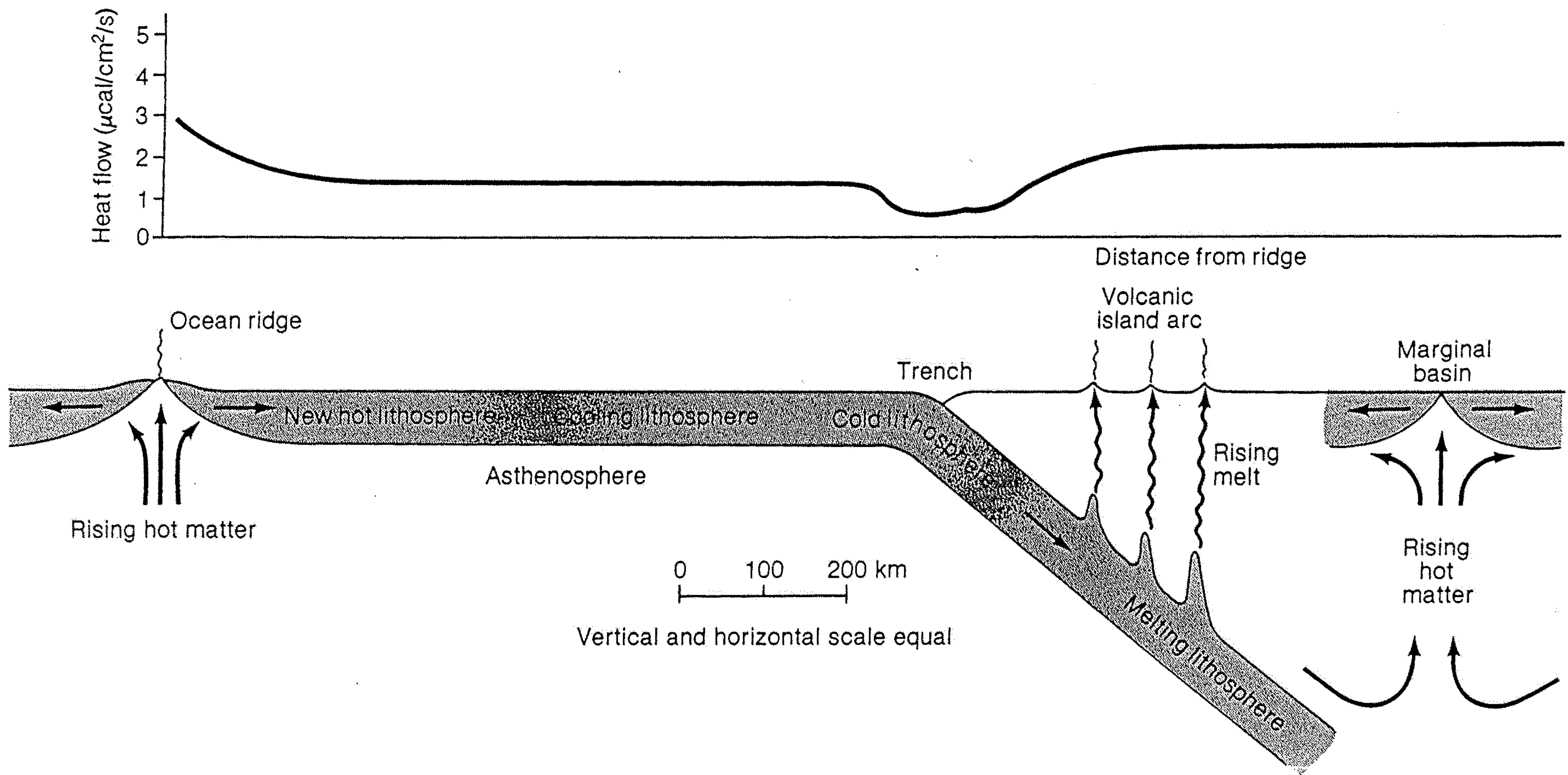
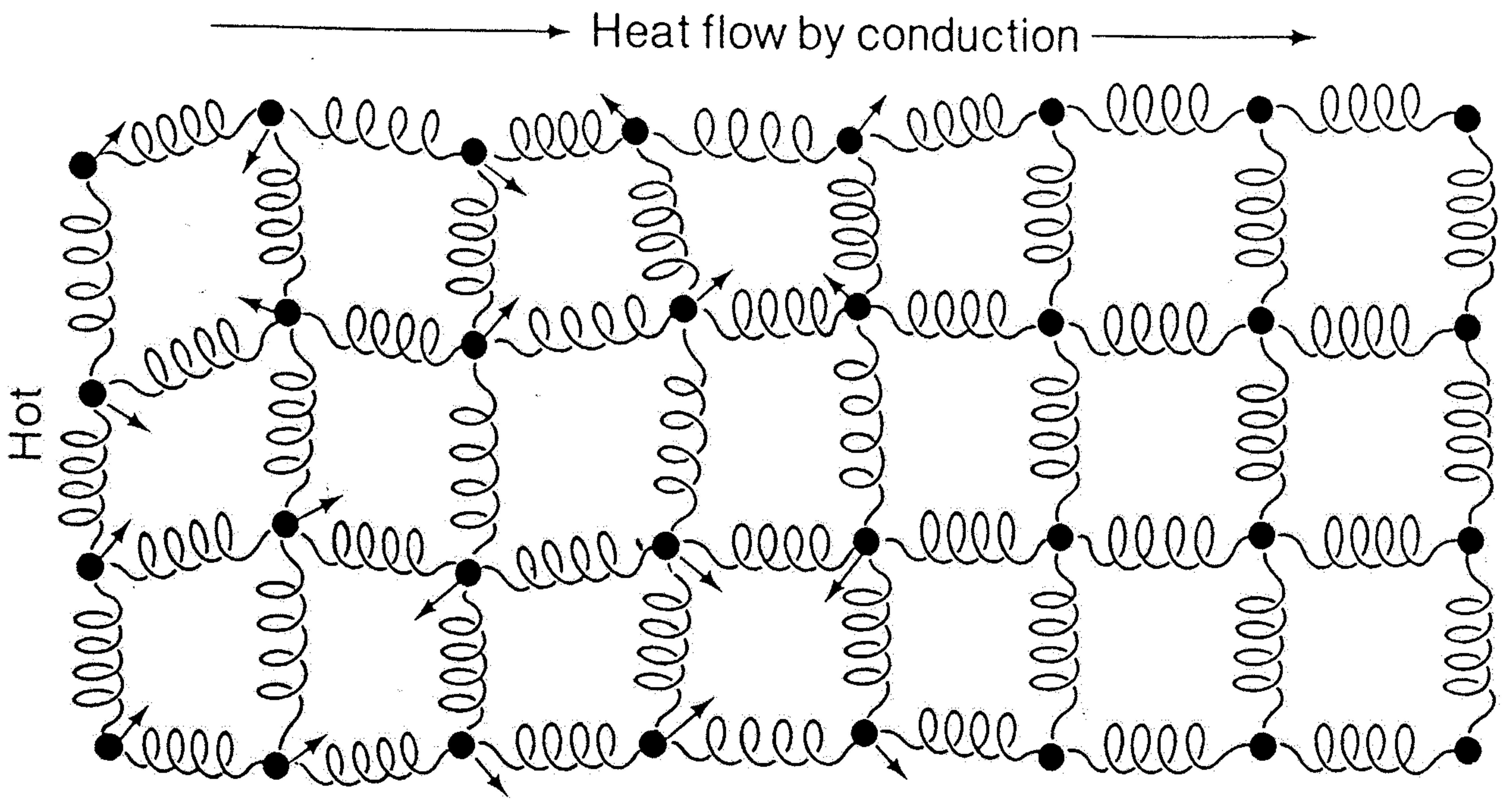


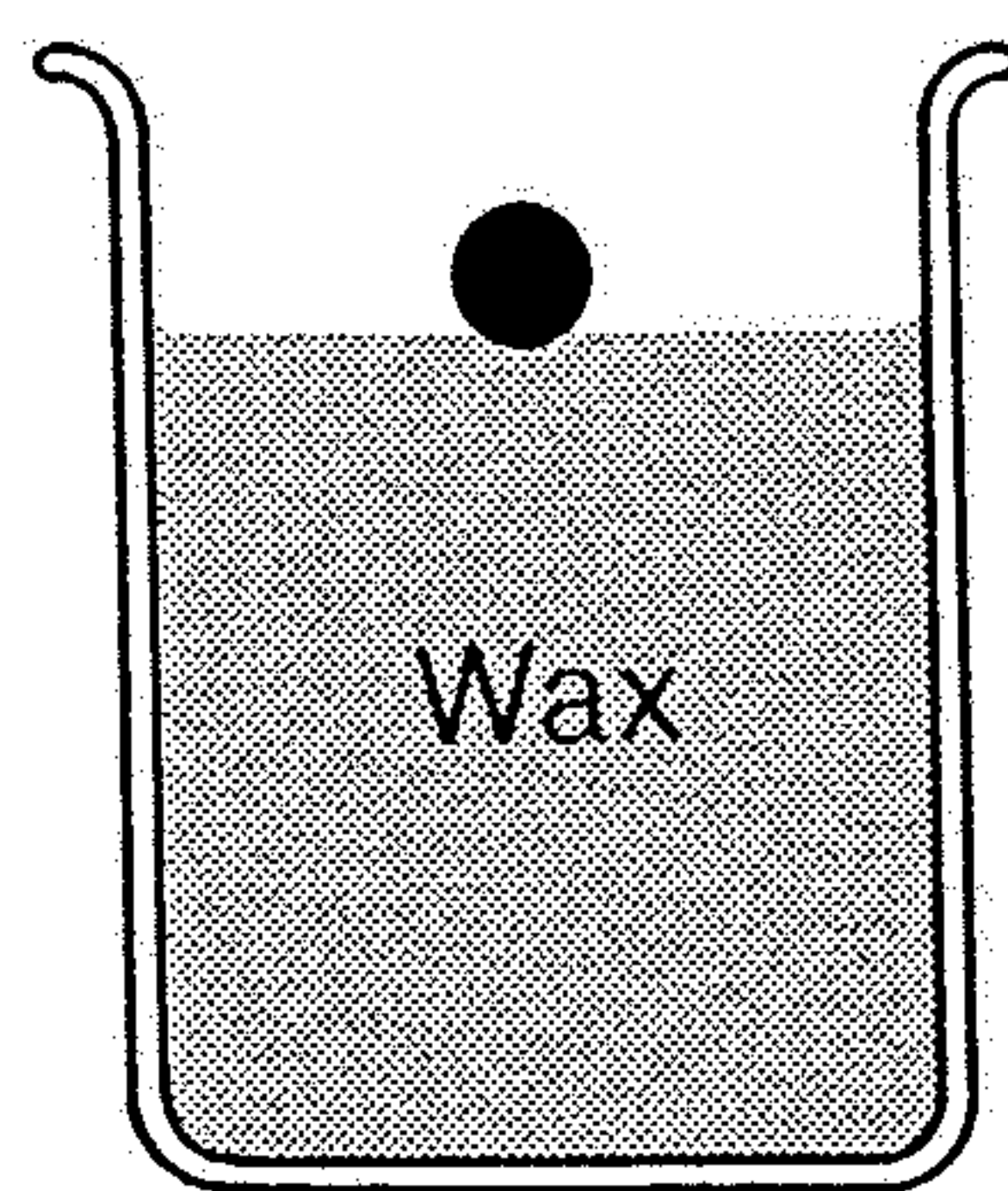
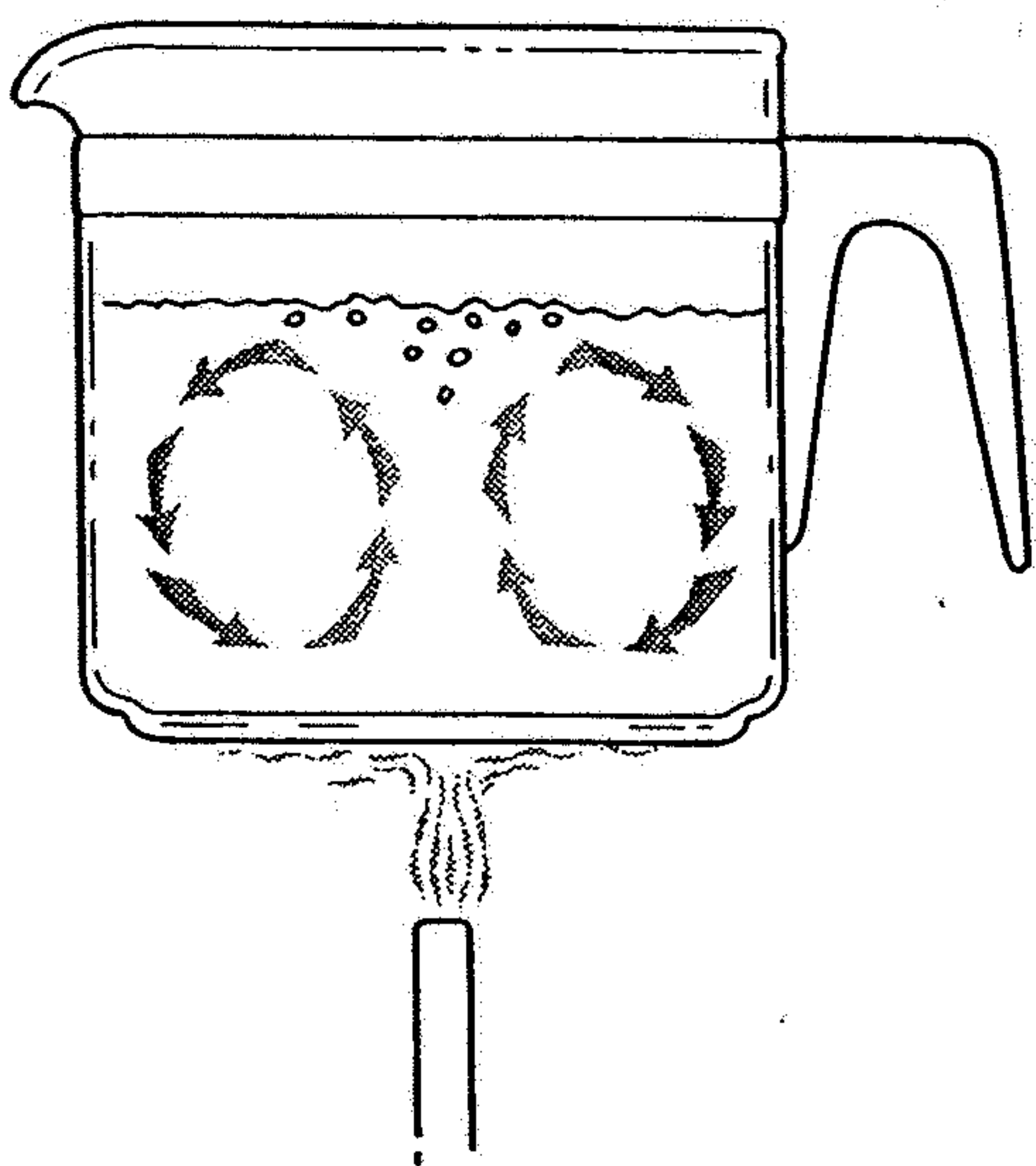
Figure 14-8

The pattern of heat flow out of the sea floor. High values are observed over mid-ocean ridges. As the sea floor spreads and cools, less heat reaches the surface. On the side of deep-sea trenches where the lithosphere plunges into the asthenosphere, rising magma from the melting lithosphere produces higher heat-flow

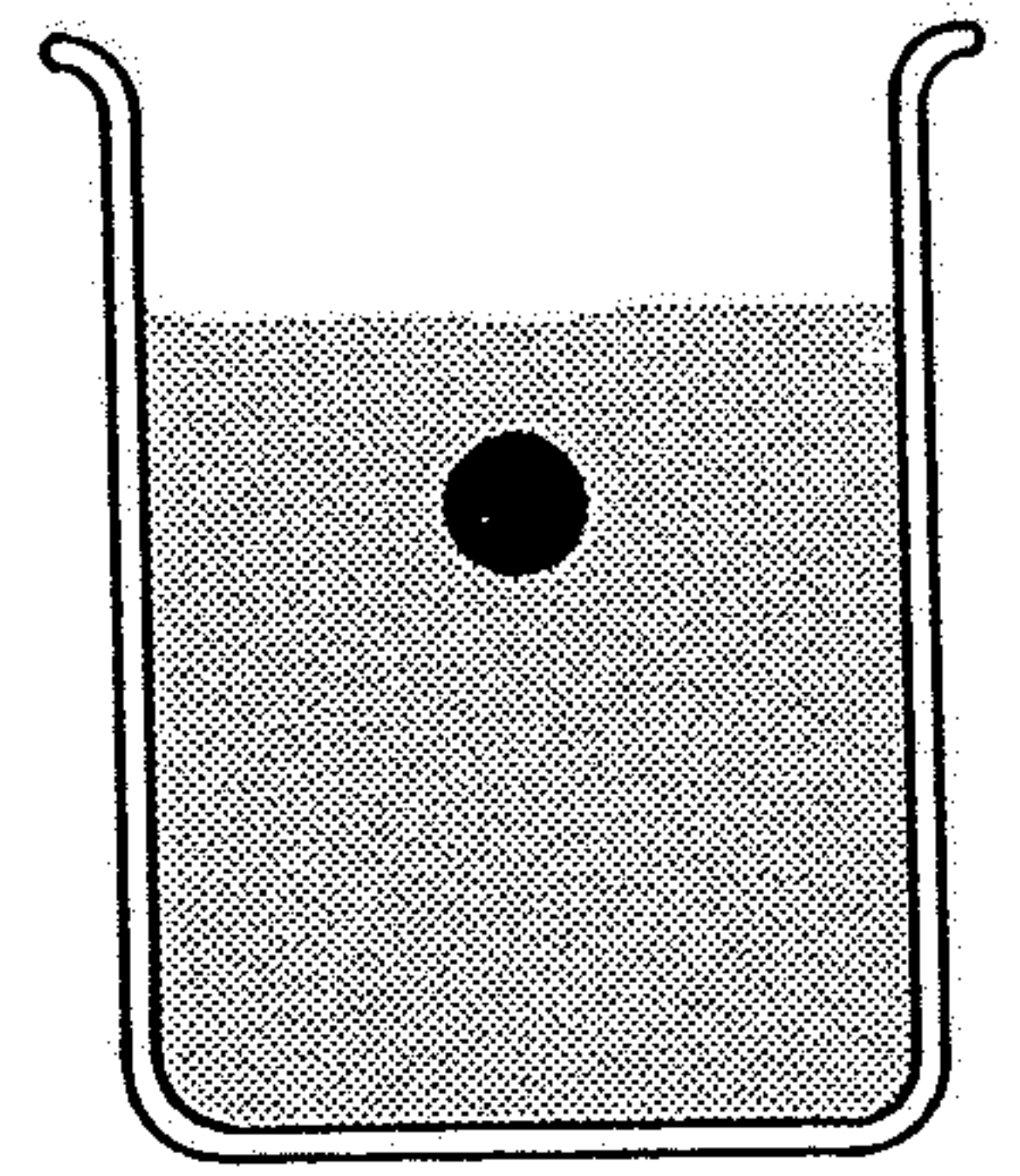
values. A small region of secondary spreading may develop in a marginal basin behind the subduction zone. The Sea of Japan, which separates the Japanese island arc from the Asian continent, is an example of such a region.



Schematic representation of heat flow by conduction through a solid. Interatomic forces that bind atoms to each other are indicated by springs. Heat applied at the left induces thermal agitation of the atoms. Heat is conducted as the vibrations gradually spread to the right.

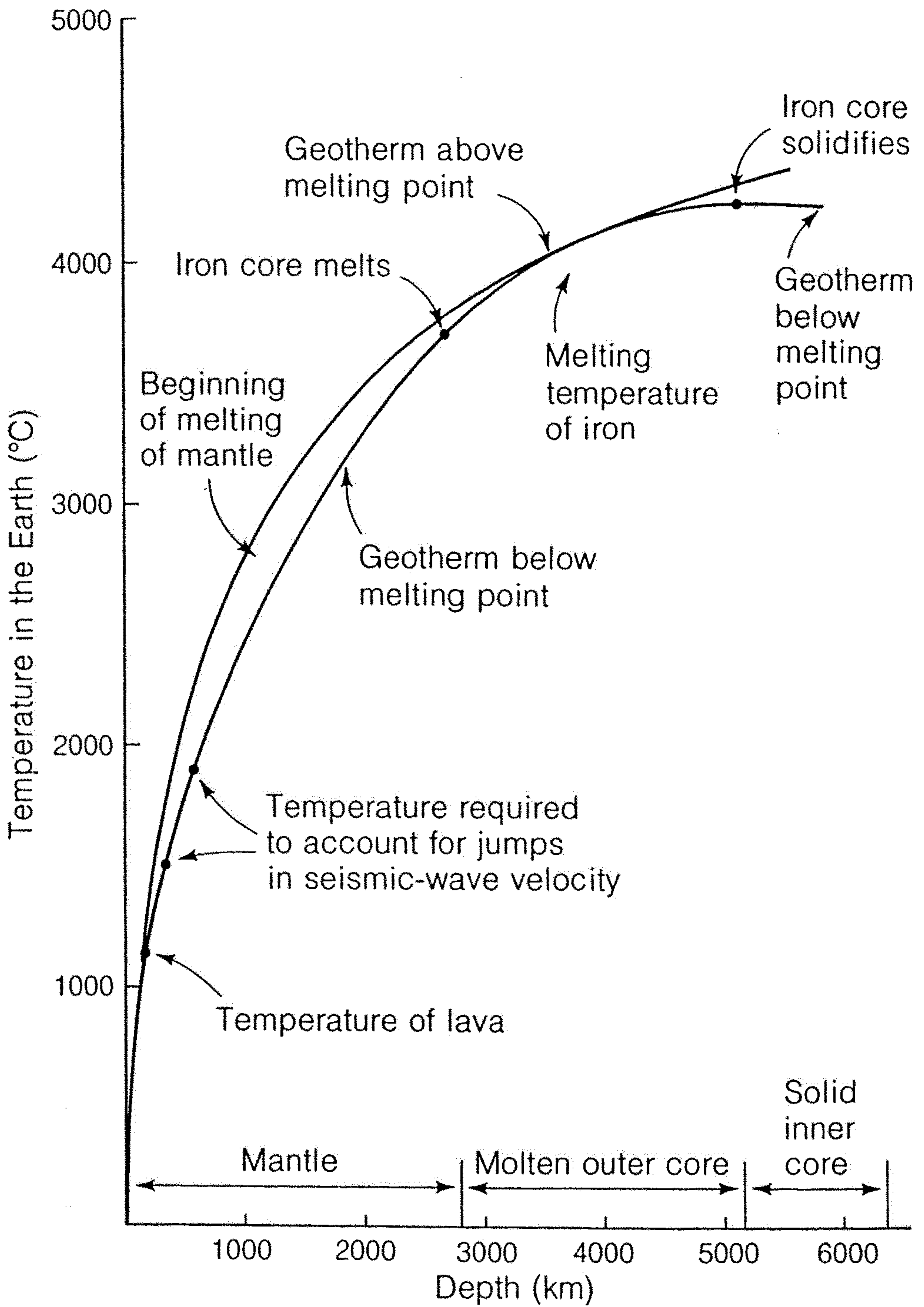


Lead weight placed on top of wax



Many hours or days later, lead sinks into the viscous material

Materials can behave as solids over short times and as viscous fluids over long intervals. Cold wax is a solid, but a lead ball placed on top of the wax slowly sinks into the interior in a few hours or days, as if the wax were a viscous fluid. Earth's mantle is supposed to show this dual behavior, permitting slow convection to occur.



A geotherm (black curve) showing how temperature may increase with depth from the surface to the center of the Earth. The probable melting-point temperature in the mantle and core is depicted by the brown curve. Where the geotherm is below the melting point, as in most of the mantle or the inner core, the material is solid. Where the geotherm is at the melting point, at depths of 100–300 km, the upper mantle is partially molten. The outer iron core is hot enough to be fully molten. Temperatures at Earth’s center reach about 4300°C.

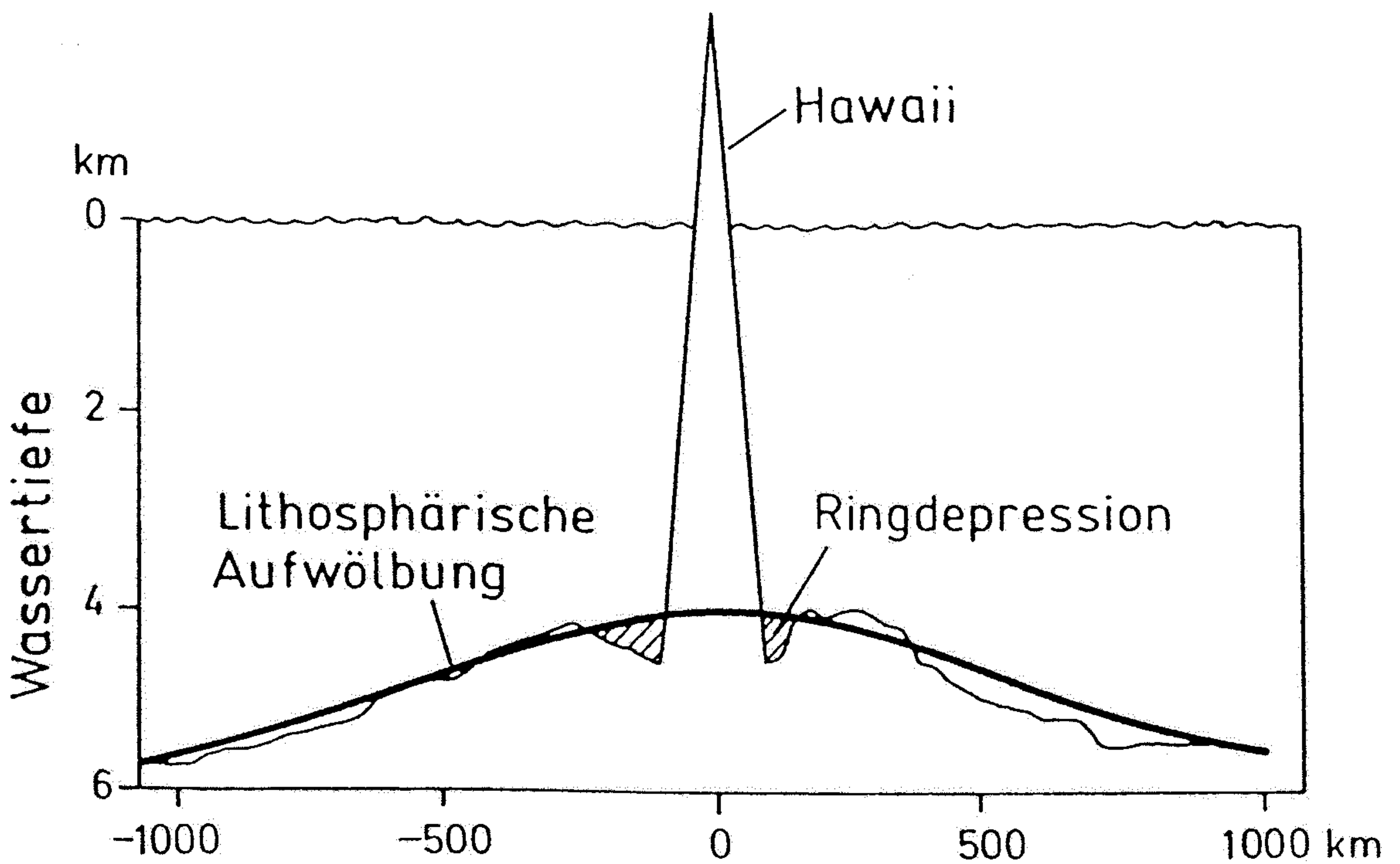


Abb. 9.13

Die Topographie des Meeresbodens rund um Hawaii reflektiert das thermische und elastische Verhalten der ozeanischen Lithosphäre. Die Aufheizung durch Mantelmagma führt zu einer Dichteverringern und Ausdehnung der Lithosphäre oberhalb des Magmenherdes und damit zum „Aufschwimmen“. Dies hat eine Aufwölbung des Meeresbodens um bis zu 1500 m in einem Umkreis von rund 1000 km um Hawaii bewirkt. Das fast 9 km hohe Vulkangebäude der Insel Hawaii hat durch seine Last eine isostatische Eindellung der Lithosphäre verursacht, die in einem Umkreis von ca. 250 km zu beobachten ist. Die so entstandene Ringdepression ist bei vielen anderen Vulkaninseln durch vulkanische und vulkanosedimentäre Ablagerungen zugeschüttet (vereinfacht nach WATTS & DALY, 1981).



Abb. 9.4
 Wärmeflußdichte in Mitteleuropa; eine besonders hohe Wärmeflußdichte ist in den vulkanisch aktiven Gebieten Italiens meßbar (nach HURTIG & ROCKEL, 1993).

Hydrothermal
resource

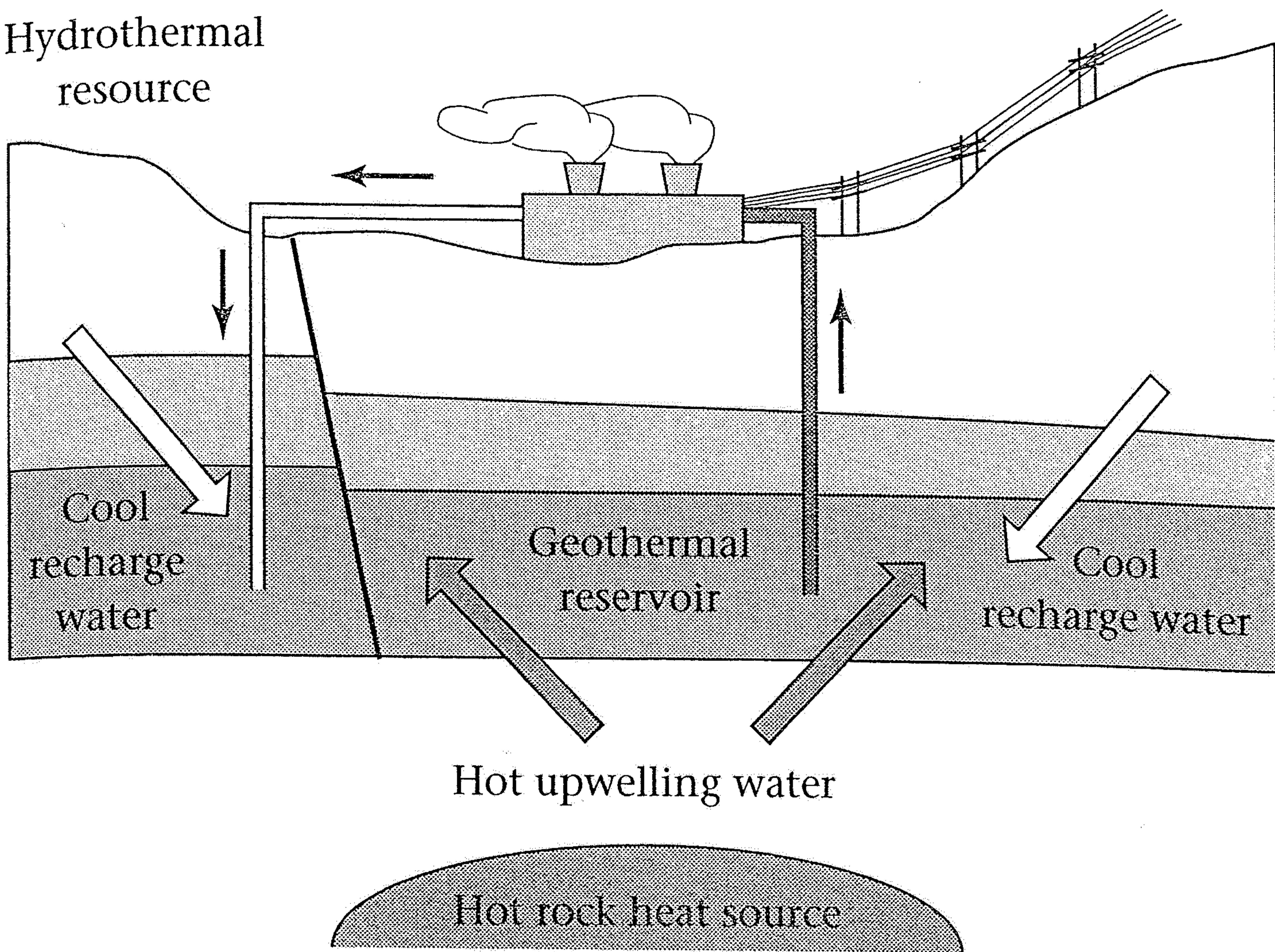


Figure 24.19. A high-temperature water geothermal system. The reservoir consists of porous rock and contains water that is heated by conduction from a magma heat source. Although the reservoir is surrounded by solid rock, hot water can escape to the surface as steam through fissures. This steam can be used to run turbines and produce electricity. (*Source:* Adapted from Earth Science Laboratory, *Geothermal energy*, University of Utah Research Institute, 1992.)