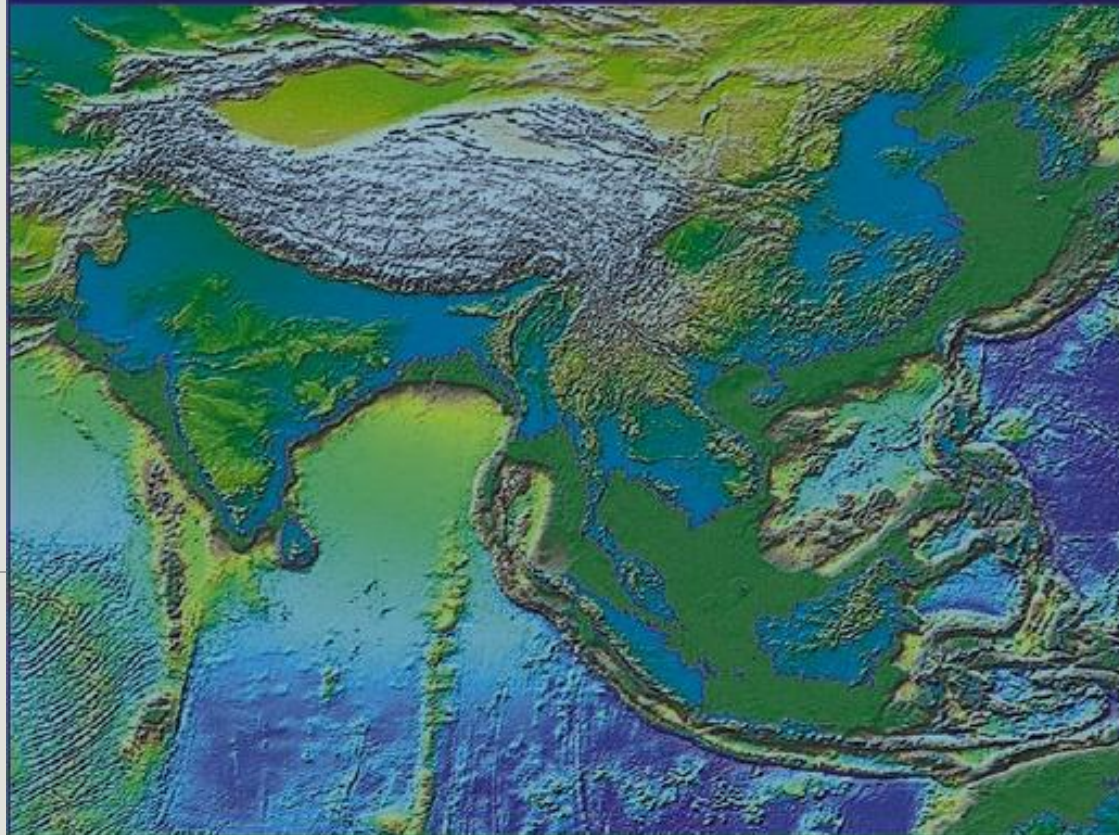


THIRD EDITION

Global Tectonics



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 WILEY-BLACKWELL

Global Tectonics G404 Lecture-4

Instructor
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Chapter 4: Sea Floor Spreading and Transform Faults

4.1 Sea Floor Spreading

Introduction

This chapter bridges continental drift and plate tectonics, showing how oceanic crust forms and moves, while transform faults define plate boundaries.

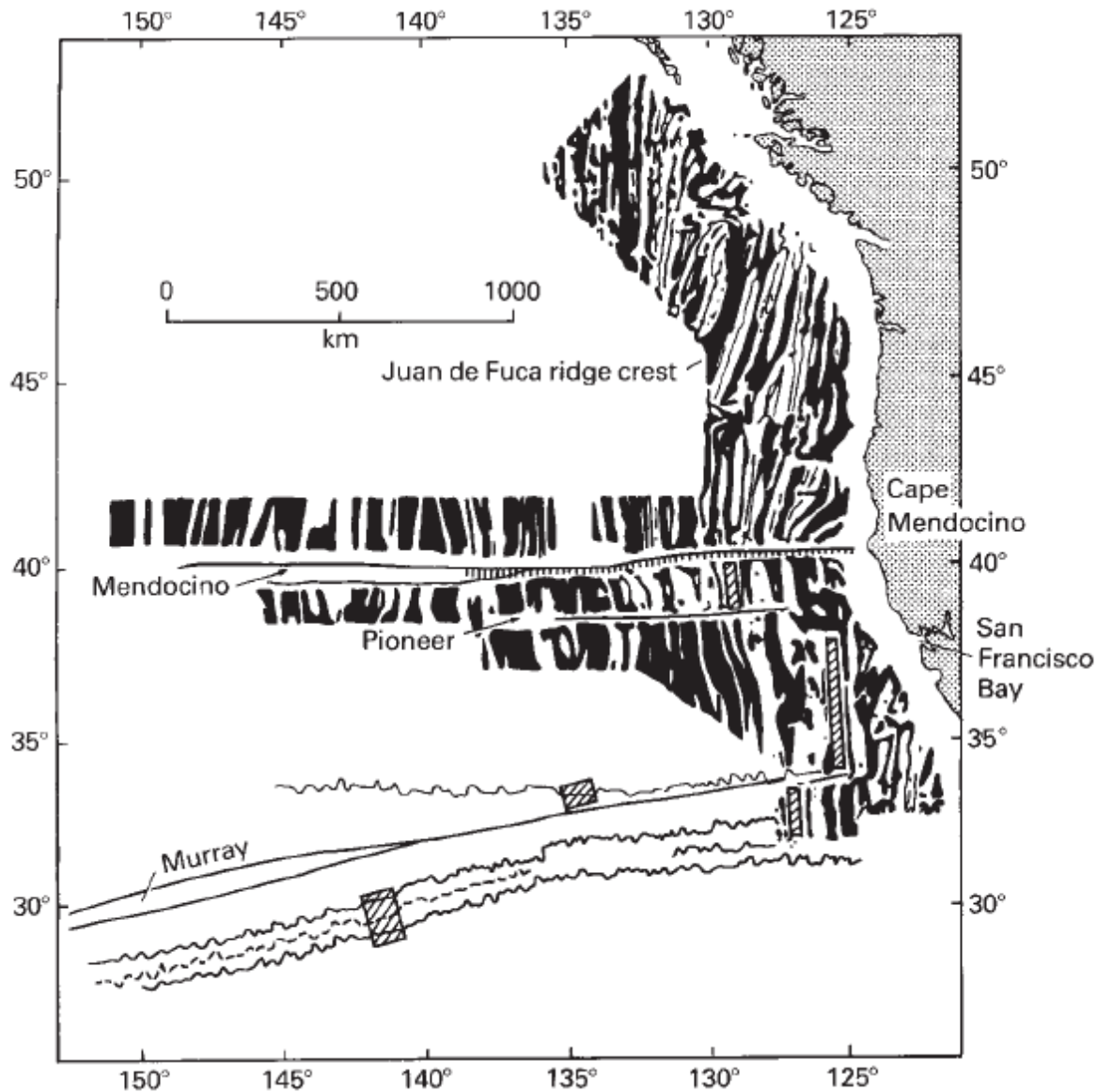
- By the 1950s, evidence for **continental drift** was strong, but the mechanism remained unclear.

- Focus shifted from continents to **ocean basins**, studied via **marine geophysics** (e.g., magnetic surveys).

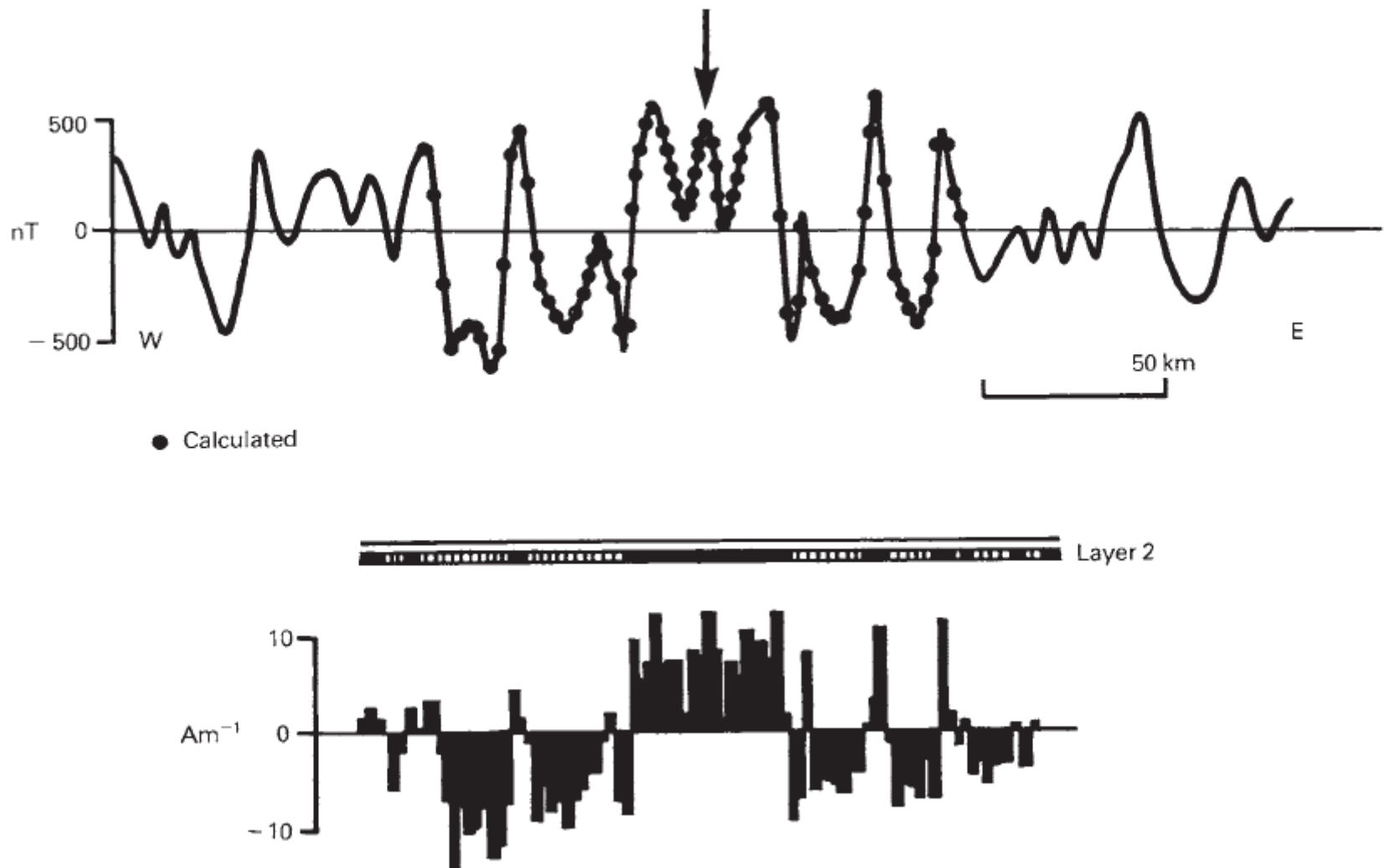
- Magnetic anomalies** revealed unexpected patterns: **linear stripes** parallel to mid-ocean ridges, offset by fracture zones.

Marine Magnetic Anomalies

- Surveys (e.g., Mason & Raff, 1961) showed **magnetic lineations**: alternating high/low magnetic intensity stripes. Source: **Oceanic Layer 2** (basaltic crust), magnetized differently in adjacent blocks due to **geomagnetic reversals**. Example: Juan de Fuca Ridge anomalies modeled with normal/reversed magnetization blocks.



Magnetic anomaly lineation in the northeastern Pacific Ocean. Positive anomalies in black; also shown are the oceanic fracture zones at which the lineation are offset (after Menard, 1964, with permission from the estate of the late Professor H. William Menard).



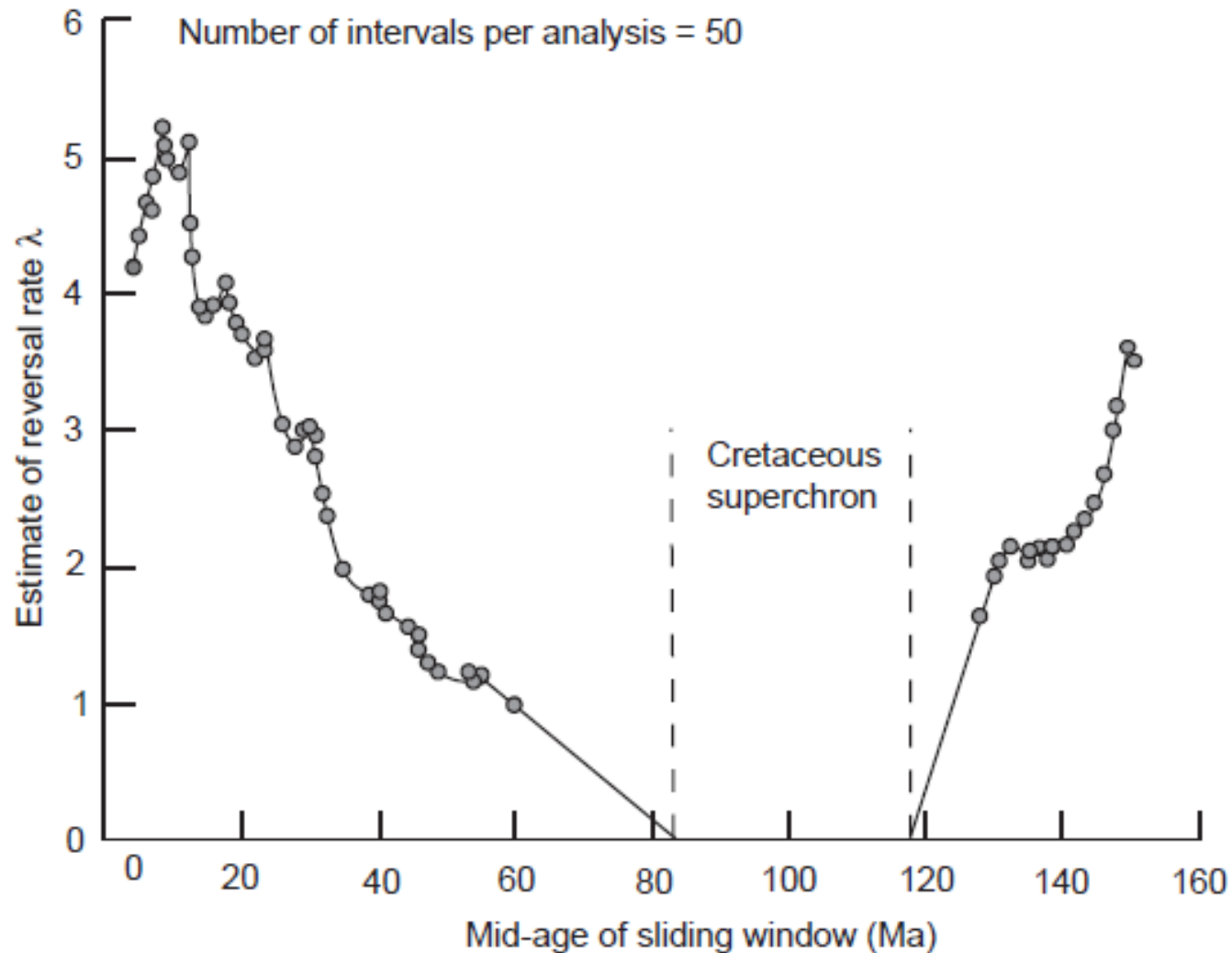
Interpretation of a magnetic anomaly profile across the Juan de Fuca ridge, northeastern Pacific Ocean, in terms of normal and reversed magnetizations of two-dimensional rectangular blocks of oceanic layer 2. The arrow marks the ridge crest (redrawn from Bott, 1967, with permission Blackwell Publishing).

Geomagnetic Reversals

- Earth's magnetic field **reverses polarity** over ~5,000 years, with field strength dropping to 25% before recovering.
- Geodynamo Theory**: Field generated by convection in the **outer core** (a self-sustaining "dynamo" driven by heat/rotation).
- Reversal frequency varies: **Cretaceous Normal Superchron**: No reversals for 35 Ma. **Cenozoic**: Increasing reversal rate. Core-mantle boundary heat flux may influence reversal patterns.

Sea Floor Spreading Hypothesis

- Proposed by **Dietz (1961) and Hess (1962)**: New lithosphere forms at **mid-ocean ridges** via upwelling magma. Continents drift apart as oceans widen; old lithosphere is subducted at trenches. Driven by **mantle convection**



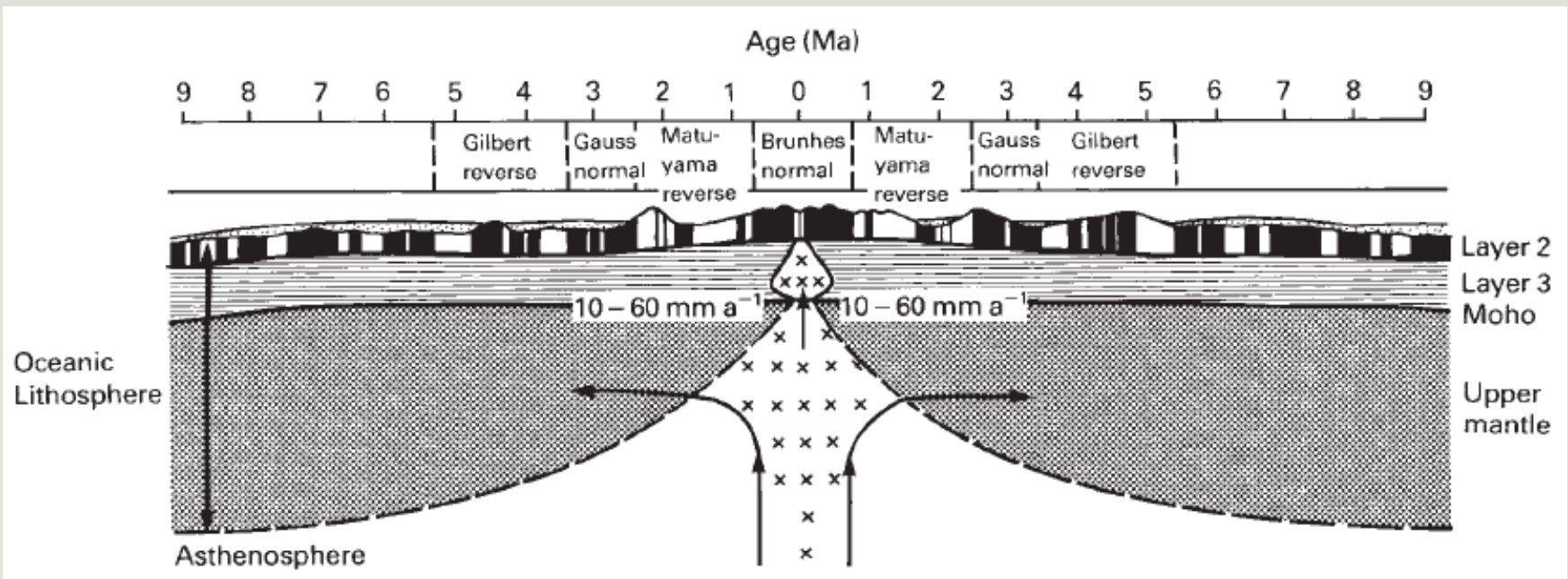
Estimated frequency of geomagnetic reversals over the past 160 Ma (redrawn from Merrill et al., 1996, with permission from Academic Press. Copyright Elsevier 1996).

Vine-Matthews Hypothesis (1963)

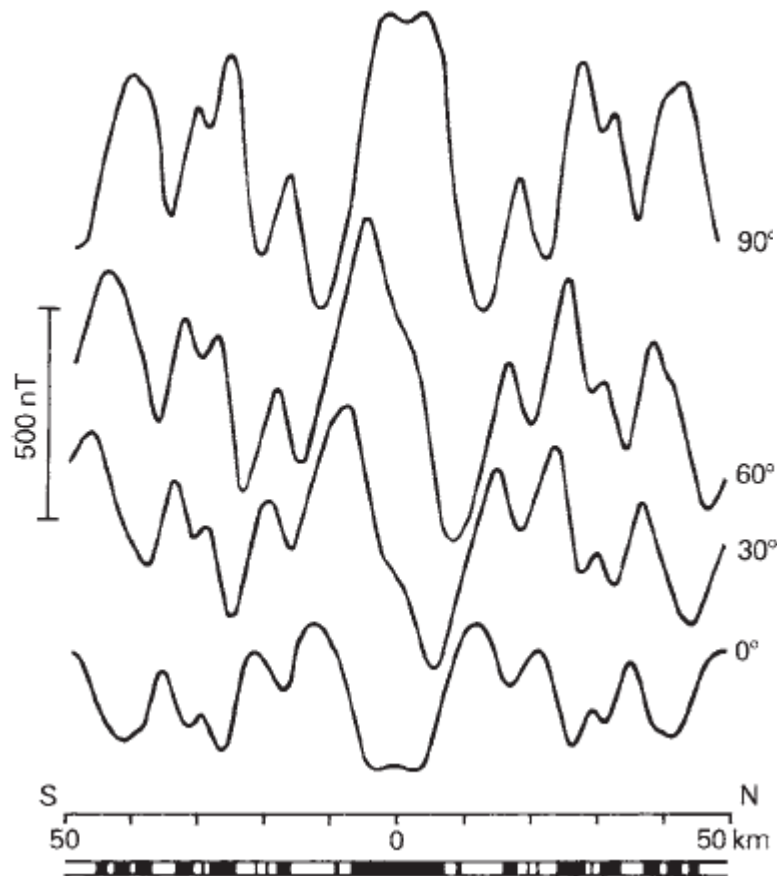
- Combined sea floor spreading with geomagnetic reversals: Magma at ridges cools below the **Curie point**, recording Earth's magnetic field. Reversals create alternating **normal/reversed magnetization stripes**. Mid-ocean ridges act as "**tape recorders**" of geomagnetic history. Anomaly shape varies with **latitude** (steep dips at poles, horizontal at equator) and **ridge orientation**.

Magnetostratigraphy

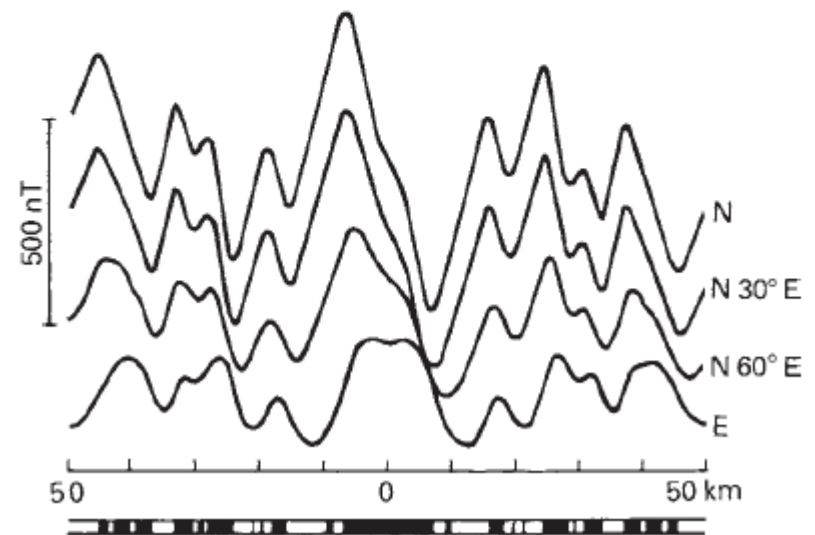
- **Reversal timescale** developed using: Lava flows (dated via K-Ar) and deep-sea cores (microfossil stratigraphy). Key chrons: **Brunhes (normal)**, Matuyama (reversed), Gauss (normal), Gilbert (reversed). **Spreading rates** calculated by matching anomaly patterns to the timescale. Example: South Atlantic spreads at ~20 mm/yr.



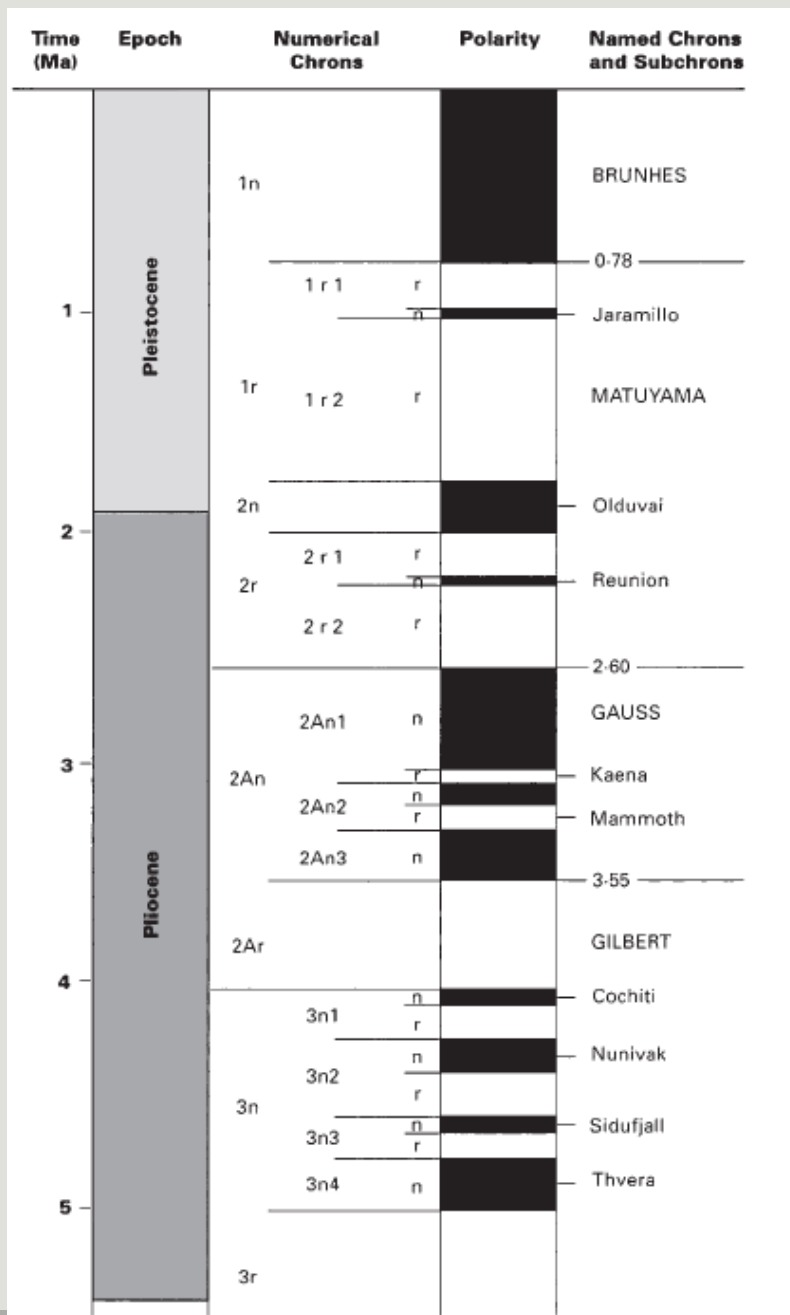
Sea floor spreading and the generation of magnetic lineation by the Vine-Matthews hypothesis (redrawn from Bott, 1982, by permission of Edward Arnold (Publishers) Ltd).



Variation of the magnetic anomaly pattern with the direction of the profile at a fixed latitude. Magnetic inclination is 45° in all cases. No vertical exaggeration.



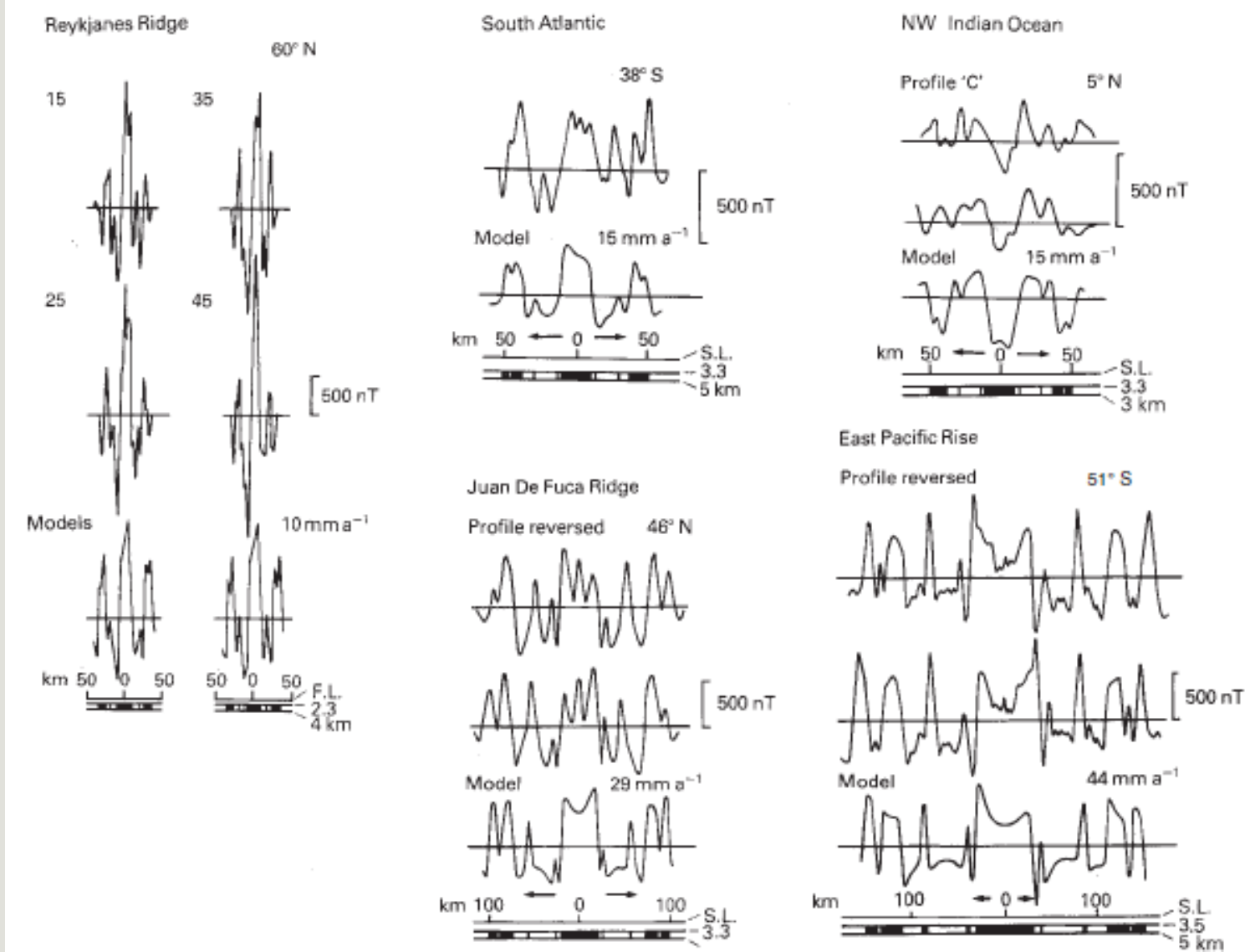
Variation of the magnetic anomaly pattern with geomagnetic latitude. All profiles are north-south. Angles refer to magnetic inclination. No vertical exaggeration.



Geomagnetic polarity timescale for the Plio-Pleistocene (modified from Cande and Kent, 1992, by permission of the American Geophysical Union. Copyright © 1992 American Geophysical Union). Numerical chrons are based on the numbered sequence of marine magnetic anomalies.

<i>Ridge</i>	<i>Latitude</i>	<i>Observed rate (mm a⁻¹)</i>	<i>Predicted rate (mm a⁻¹)</i>
Juan de Fuca	46.0°N	29	†
Gulf of California	23.4°N	25	24.7
Cocos –			
Pacific	17.2°N	37	39.4
Pacific	3.1°N	67	65.4
Galapagos	2.3°N	22	22.0
Galapagos	3.3°N	34	34.6
Nazca –			
Pacific	12.6°S	75	74.2
Chile Rise	43.4°S	31	30.2
Pacific –			
Antarctic	35.6°S	50	49.5
Antarctic	51.0°S	44	44.6
Antarctic	65.3°S	26	29.0
North Atlantic	86.5°N	6	5.7
North Atlantic	60.2°N	9.5	9.2
North Atlantic	42.7°N	11.5	11.9
Central Atlantic	35.0°N	10.5	11.0
Central Atlantic	23.0°N	12.5	12.6
Cayman	18.0°N	7.5	5.9
South Atlantic	38.5°S	18	17.6
Antarctic –			
South America	55.3°S	10	9.3
Africa –			
Antarctic	44.2°S	8	7.4
Northwest Indian Ocean	4.2°N	14	14.6
Northwest Indian Ocean	12.0°S	18.5	17.9
Northwest Indian Ocean	24.5°S	25	24.5
Southeast Indian Ocean	25.8°S	28	28.8
Southeast Indian Ocean	50.0°S	38	37.3
Southeast Indian Ocean	62.4°S	34.5	33.7
Gulf of Aden	12.1°N	8	8.6
Gulf of Aden	14.6°N	12	12.1
Red Sea	18.0°N	10	8.2

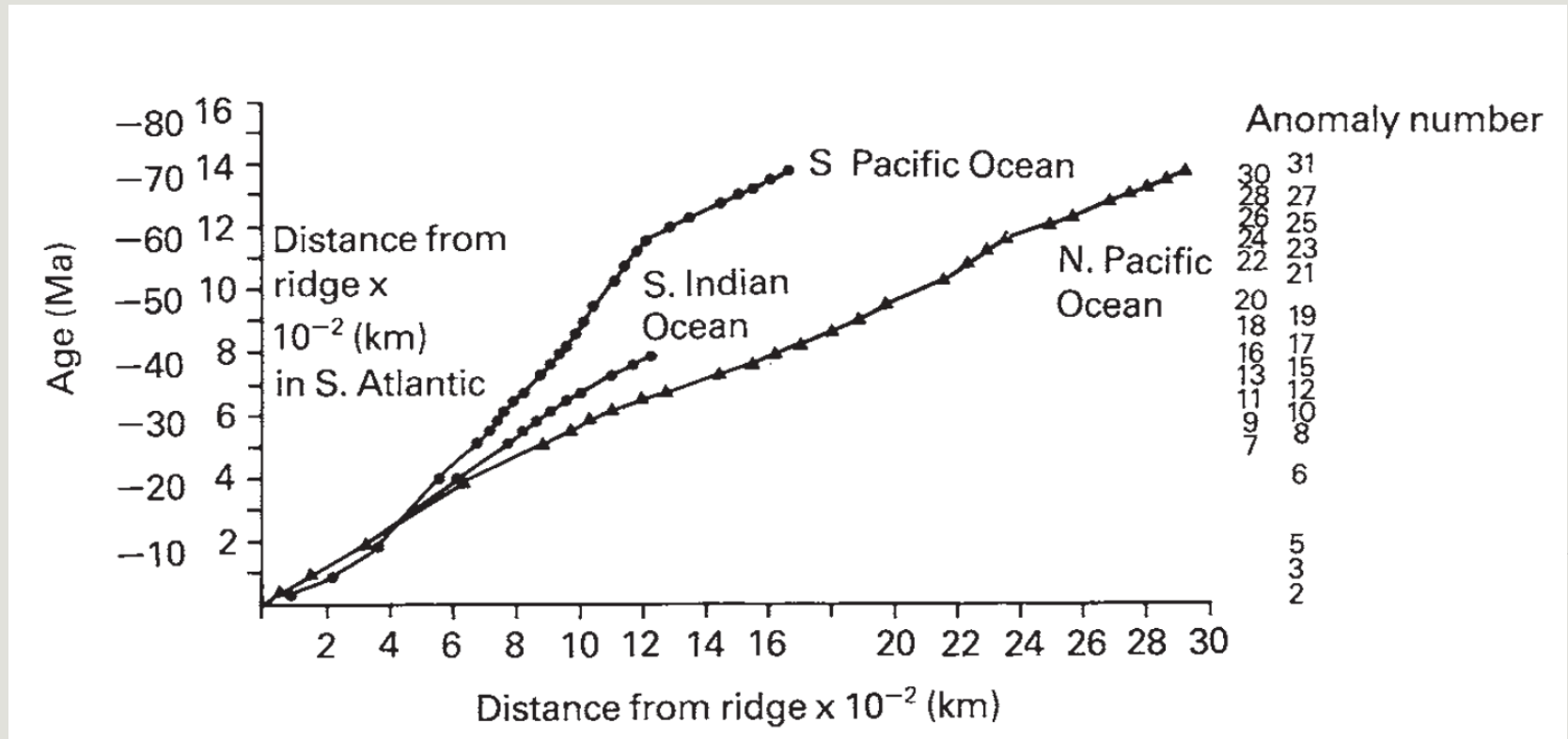
Spreading rates at mid-ocean ridges (“spreading rate” is defined as the accretion rate per ridge flank).



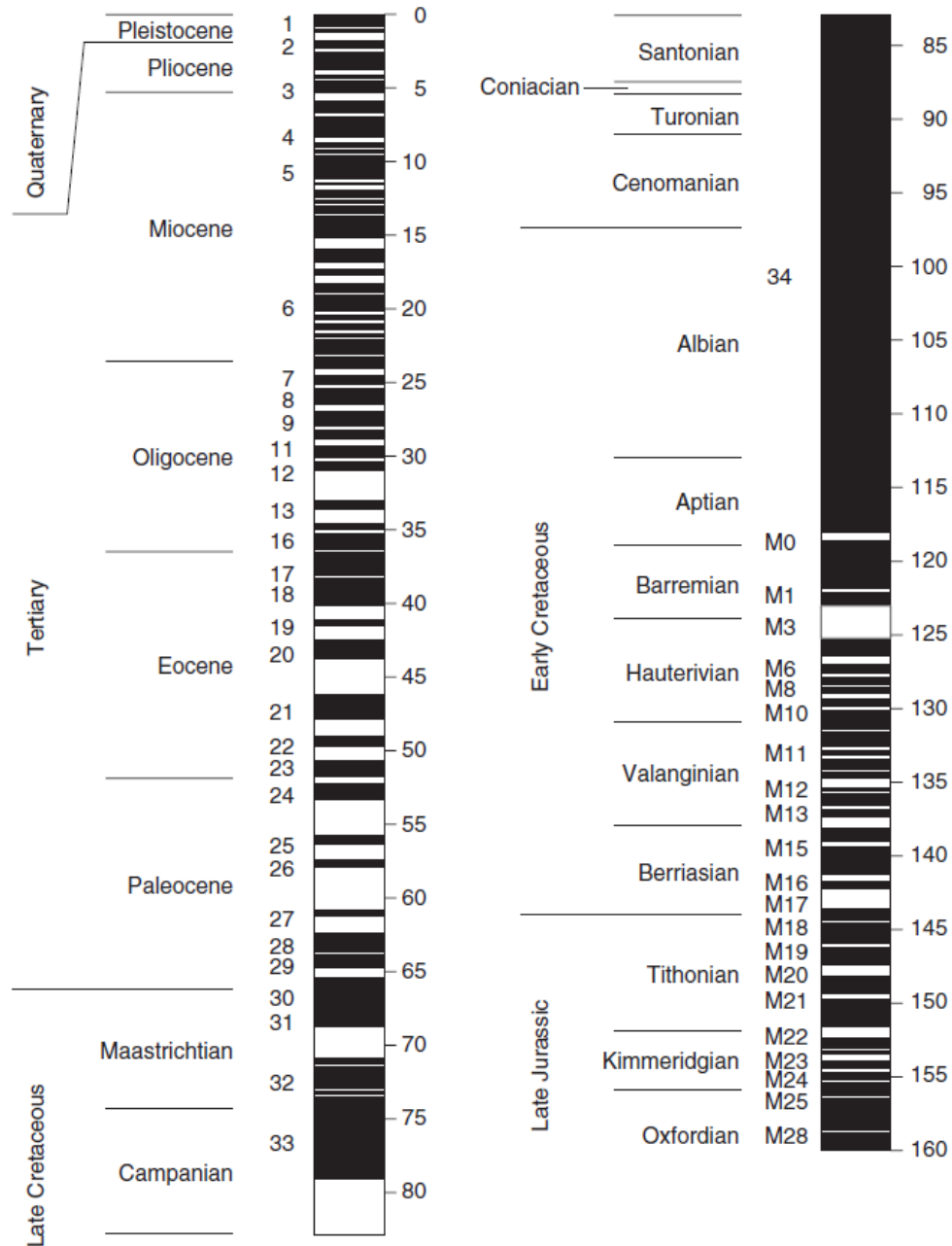
Magnetic anomaly profiles and models of several spreading centers in terms of the reversal timescale (redrawn from Vine, 1966, Science 154, 1405–15, with permission from the AAAS).

Dating the Ocean Floor

Magnetic lineations mapped as **isochrons** (lines of equal age). Oldest oceanic crust: **Jurassic** (~160 Ma). **Cretaceous Quiet Zone**: No reversals (superchron). Reconstructions show ocean basin evolution (e.g., North Atlantic opening).



Relationship between the distance to a given anomaly in the South Atlantic and the distance to the same anomaly in the South Indian, North Pacific and South Pacific Oceans. Numbers on the right refer to magnetic anomaly numbers (redrawn from Heirtzler et al., 1968, by permission of the American Geophysical Union. Copyright © 1968 American Geophysical Union).

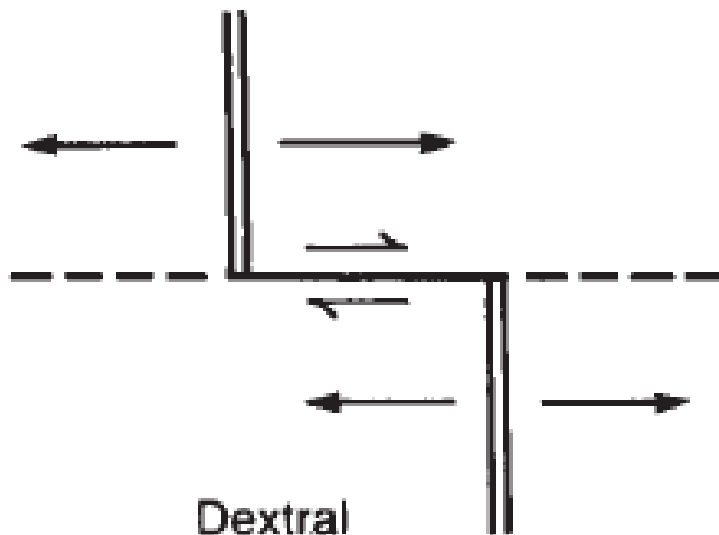


A geomagnetic polarity timescale for the past 160 Ma together with oceanic magnetic anomaly numbers (after McElhinny and McFadden, 2000, with permission from Academic Press. Copyright Elsevier 2000).

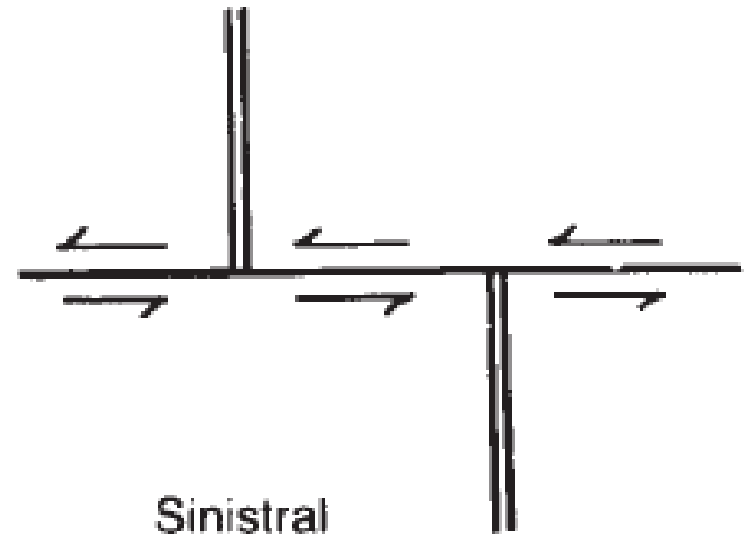
Transform Faults

Transform faults accommodate lateral motion between lithospheric plates. Differ from **transcurrent faults**: Transform faults end at ridges/trenches; displacement is localized between offsets. Example: **Mendocino Fracture Zone** (NE Pacific) offsets anomalies by 1,450 km.

Comparison of transform and transcurrent faults.



(a) Transform fault



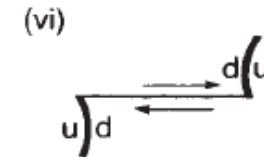
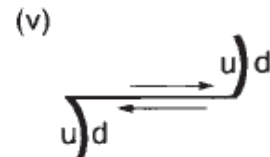
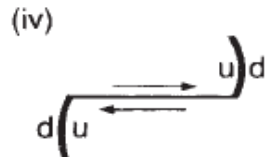
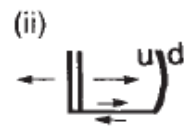
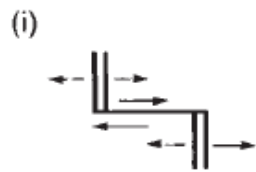
(b) Transcurrent fault

Ridge-Ridge Transform Faults

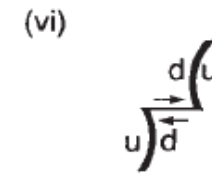
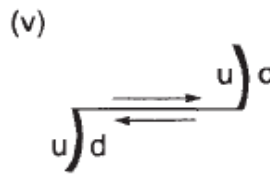
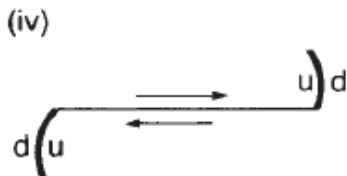
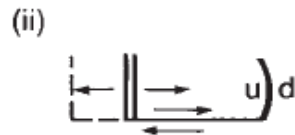
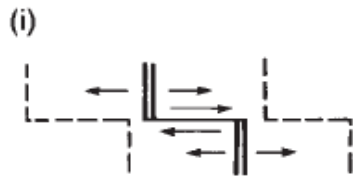
- **Wilson (1965)** identified 6 types (e.g., ridge-to-ridge, ridge-to-trench).
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- **Sykes (1967)** confirmed transform motion via earthquake focal mechanisms

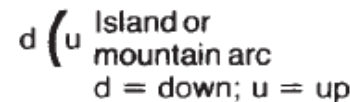
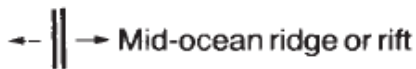
- Strike-slip earthquakes occur **only between ridge segments** (dextral motion).
- Beyond ridges, fracture zones are inactive.



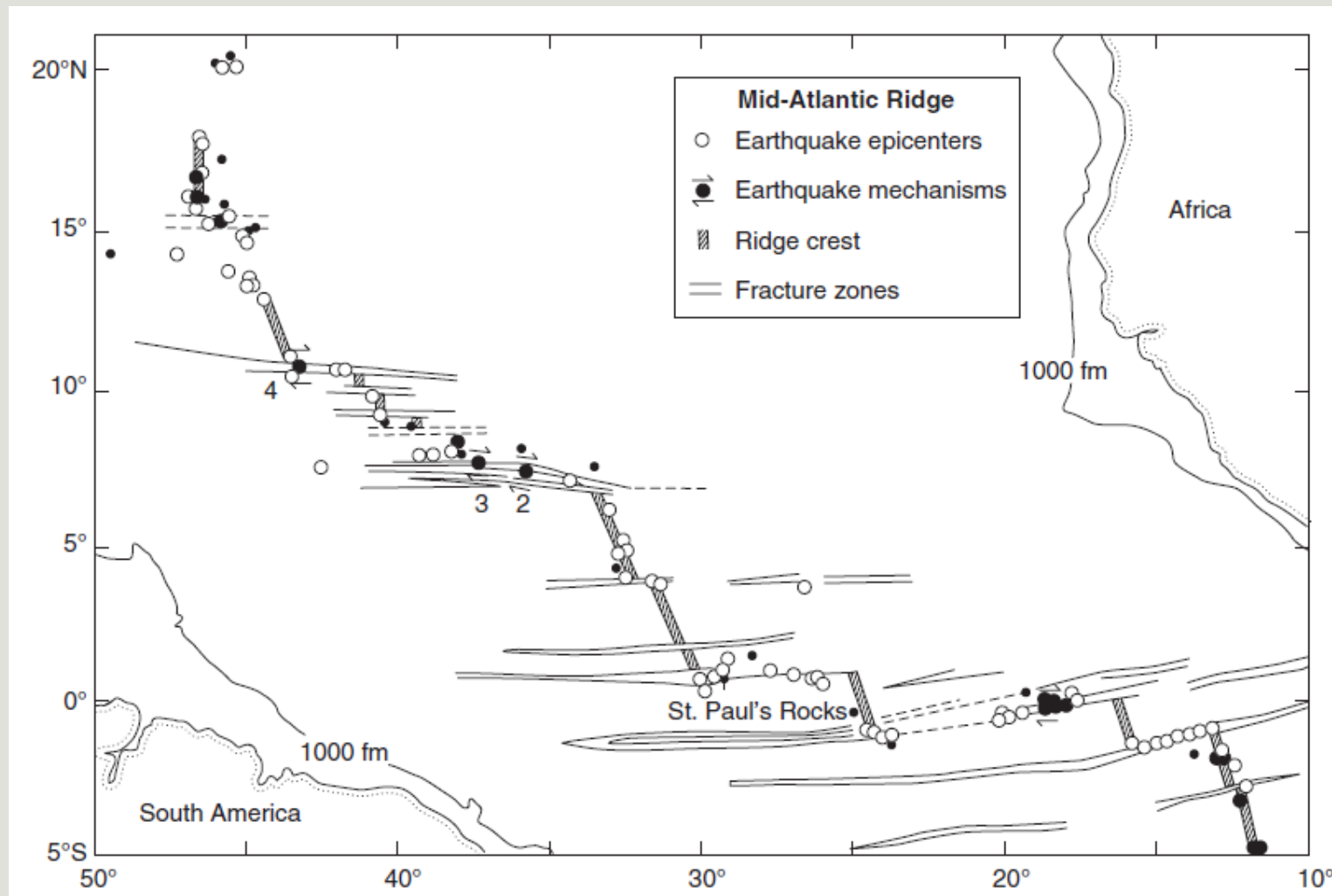
(a)



(b)



(a) Six possible types of dextral transform fault: (i) ridge to ridge; (ii) ridge to concave arc; (iii) ridge to convex arc; (iv) concave arc to concave arc; (v) concave arc to convex arc; (vi) convex arc to convex arc. (b) Appearance of the dextral transform faults after a period of time (redrawn from Wilson, 1965, with permission from Nature 207, 334–47. Copyright © 1965 Macmillan Publishers Ltd).



Epicenters of earthquakes that occurred on the Mid-Atlantic ridge in the equatorial Atlantic between 1955 and 1965. The arrows beside four of the earthquakes indicate the sense of shear and the strike of the fault plane inferred from focal mechanism solutions (modified from Sykes, 1967, by permission of the American Geophysical Union. Copyright © 1967 American Geophysical Union).

Ridge Jumps and Offsets

Ridge jumps: Sudden relocations of spreading centers (e.g., South Atlantic, 98–59 Ma).

Examples: Murray Fracture Zone: Offset reduced by 500 km after a jump. Iceland:

Ridge jumps modified North Atlantic geometry. **Rare but significant:** Most changes occur via **spreading direction shifts** or **ridge propagation**.

Key Concepts:

1. **Sea Floor Spreading:** Oceanic crust forms at ridges, recording geomagnetic reversals as symmetric stripes.
2. **Vine-Matthews Hypothesis:** Links magnetic anomalies to spreading and reversals.
3. **Geomagnetic Reversals:** Driven by core dynamo; frequency varies over geologic time.
4. **Transform Faults:** Plate boundaries where motion is strike-slip, ending at ridges/trenches.
5. **Ocean Floor Age:** Dated via magnetostratigraphy; oldest crust is Jurassic.