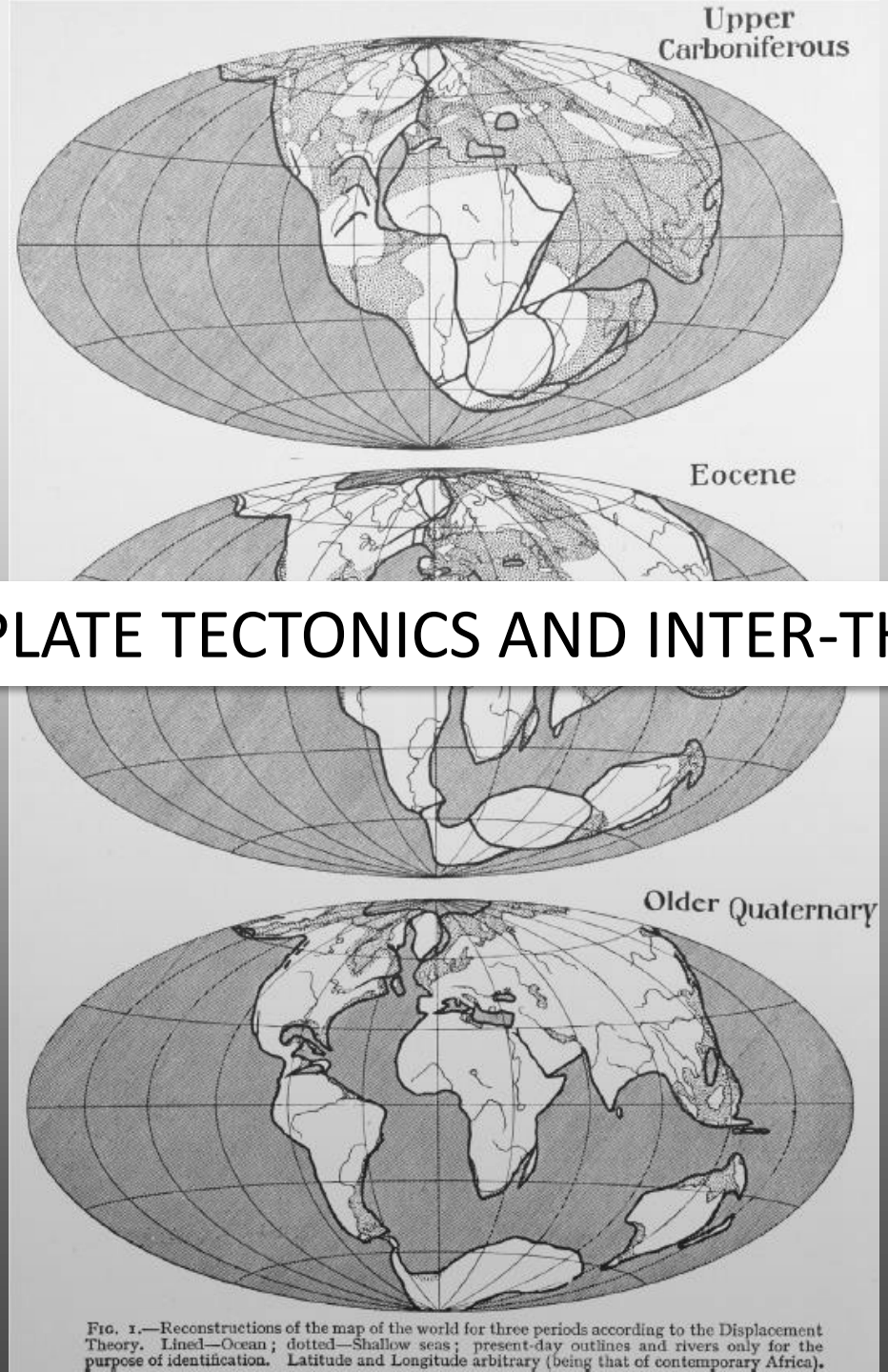


Fig. 1.—Reconstructions of the map of the world for three periods according to the Displacement Theory. Lined—Ocean; dotted—Shallow seas; present-day outlines and rivers only for the purpose of identification. Latitude and Longitude arbitrary (being that of contemporary Africa).

HENRY FRANKEL: PLATE TECTONICS AND INTER-THEORY RELATIONS

Alfred Wegener

Greenland 1912-1913

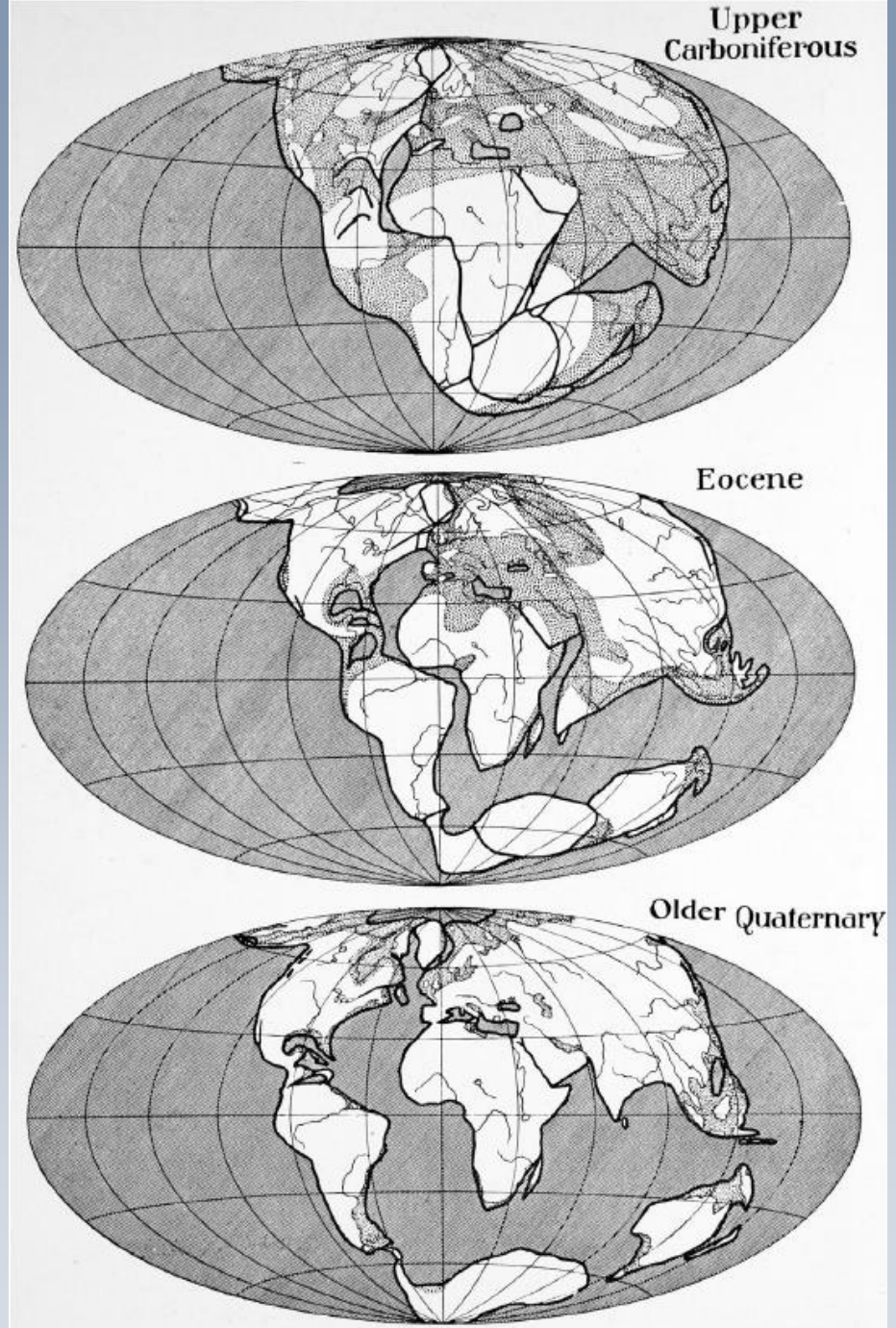

“matching” continents

disjunctive species distributions


mountain ranges

Wegener's solution:

Continents move



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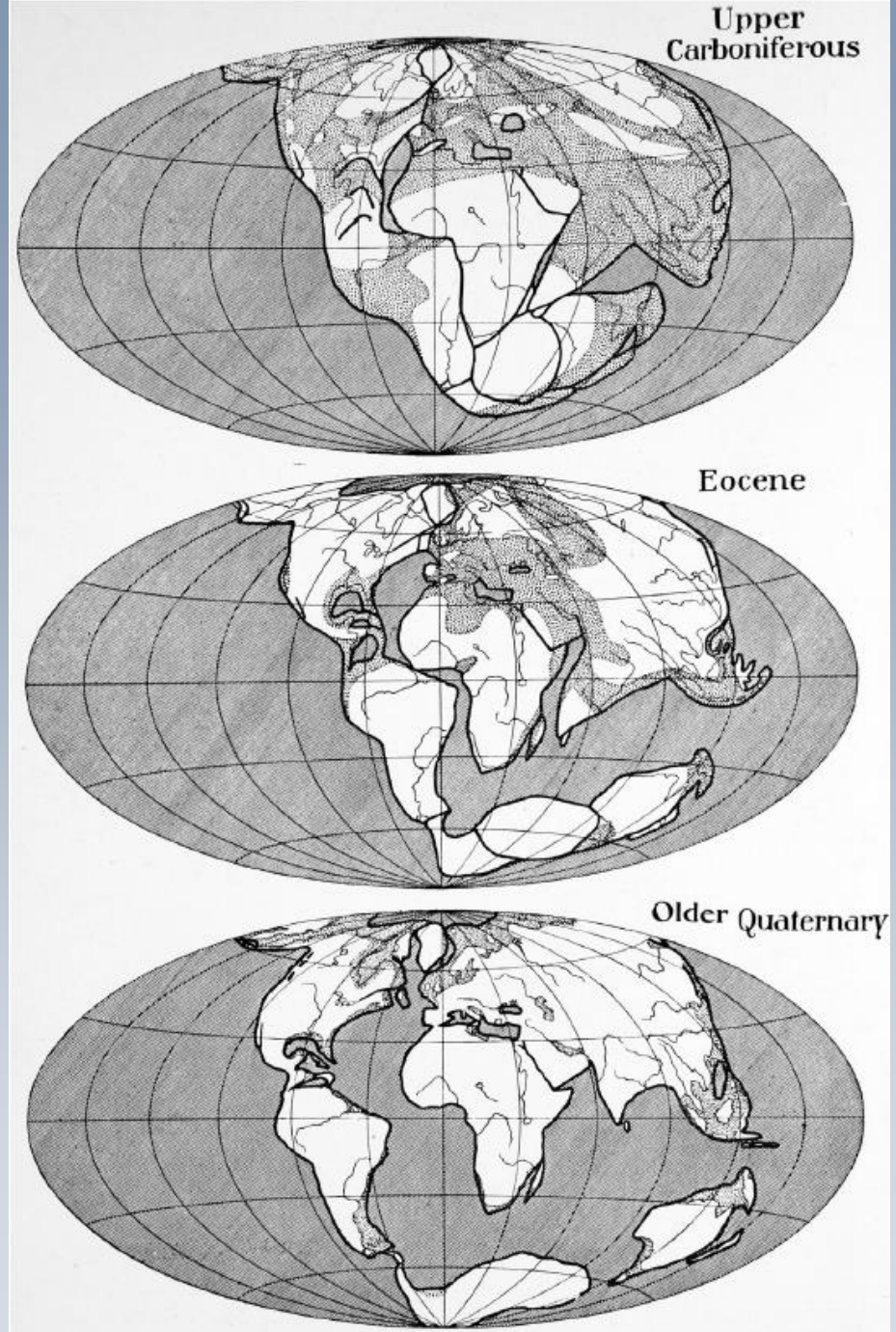
Wegener's solution:

Continents move

Mountains form as continents plow through the seafloor



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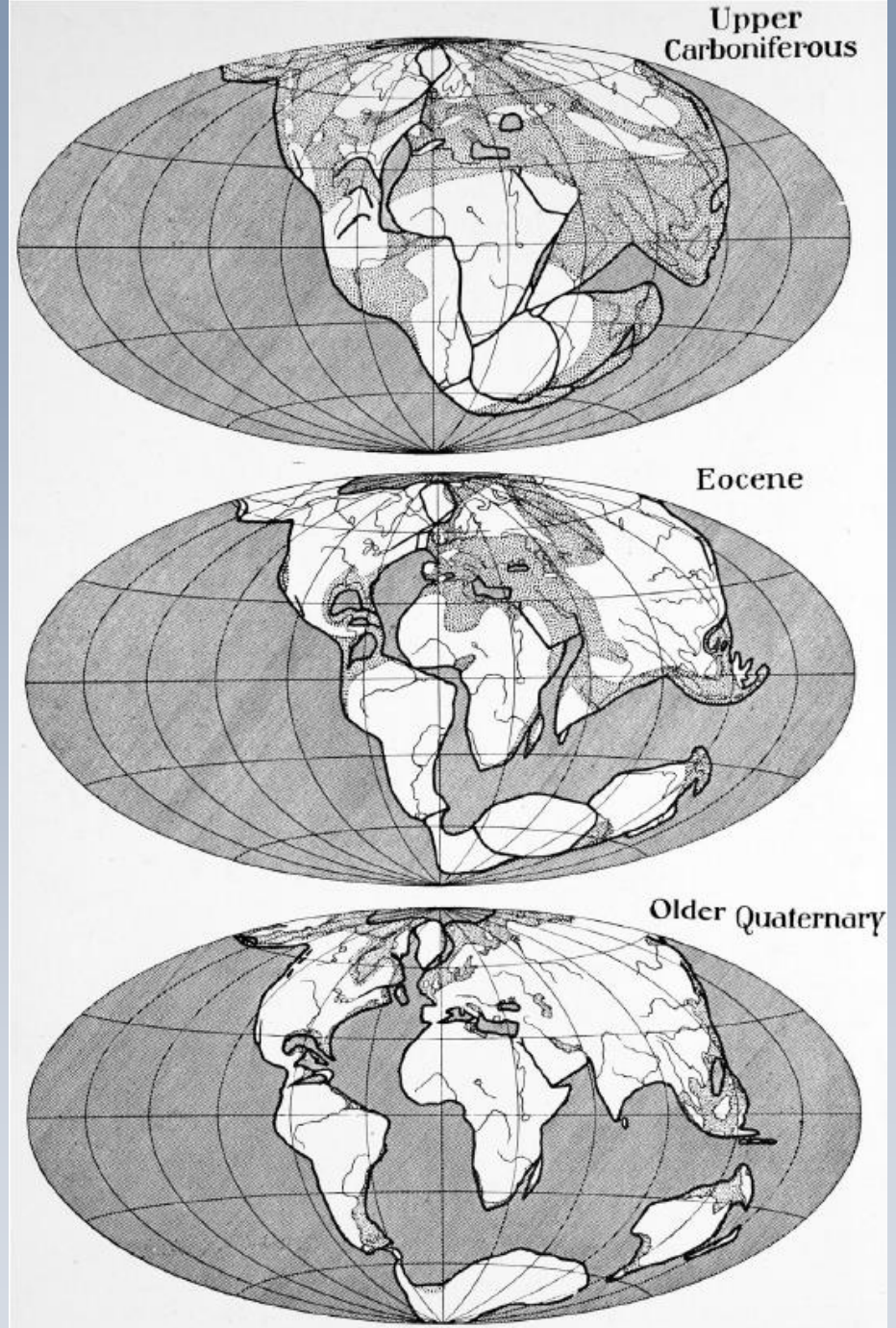

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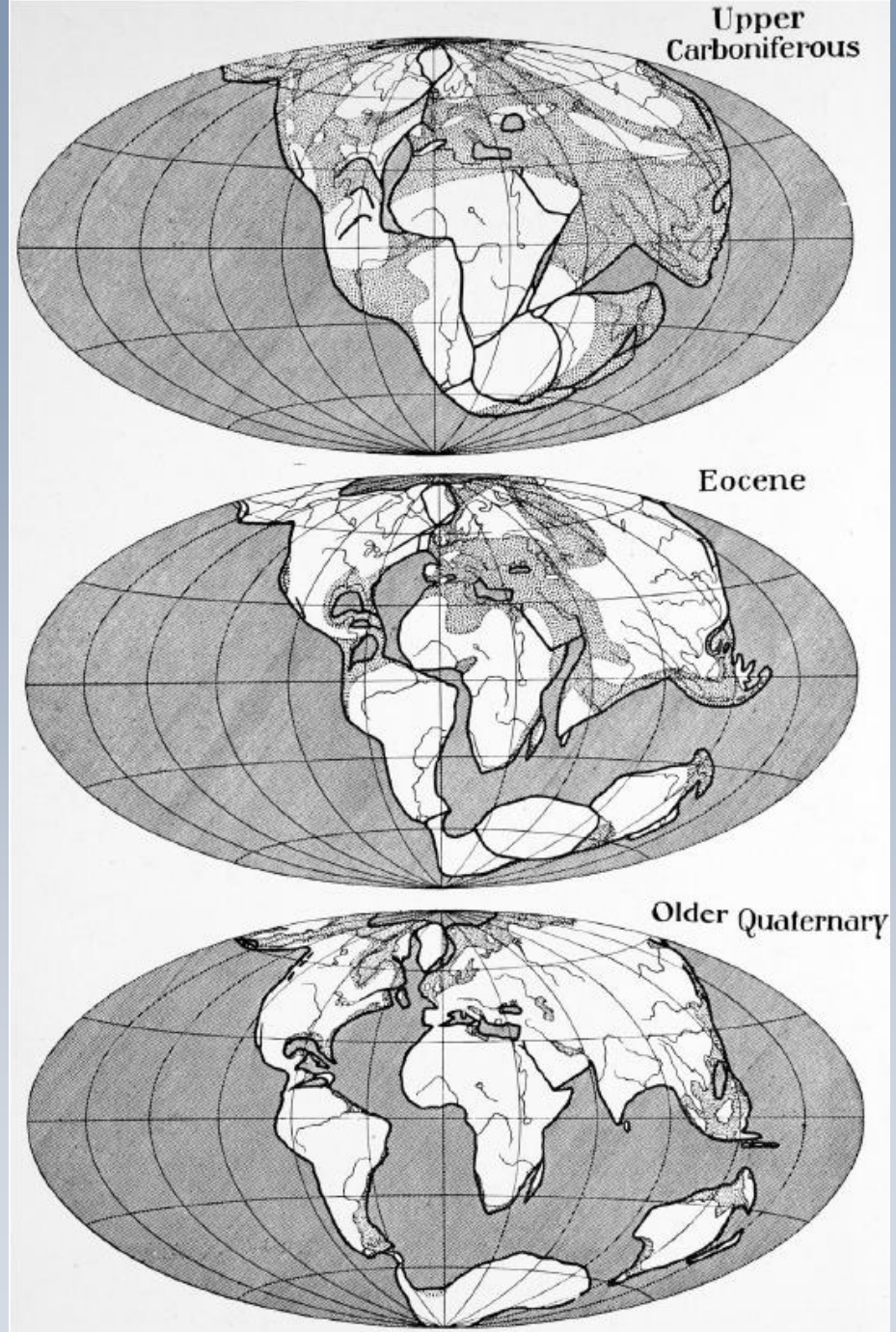
Fixists rebut Wegener:

Land bridges

Wegener's solution:

Continents move

Mountains form as continents plow through the seafloor



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Fixists rebut Wegener:

Land bridges

Lack of mechanism to move continents

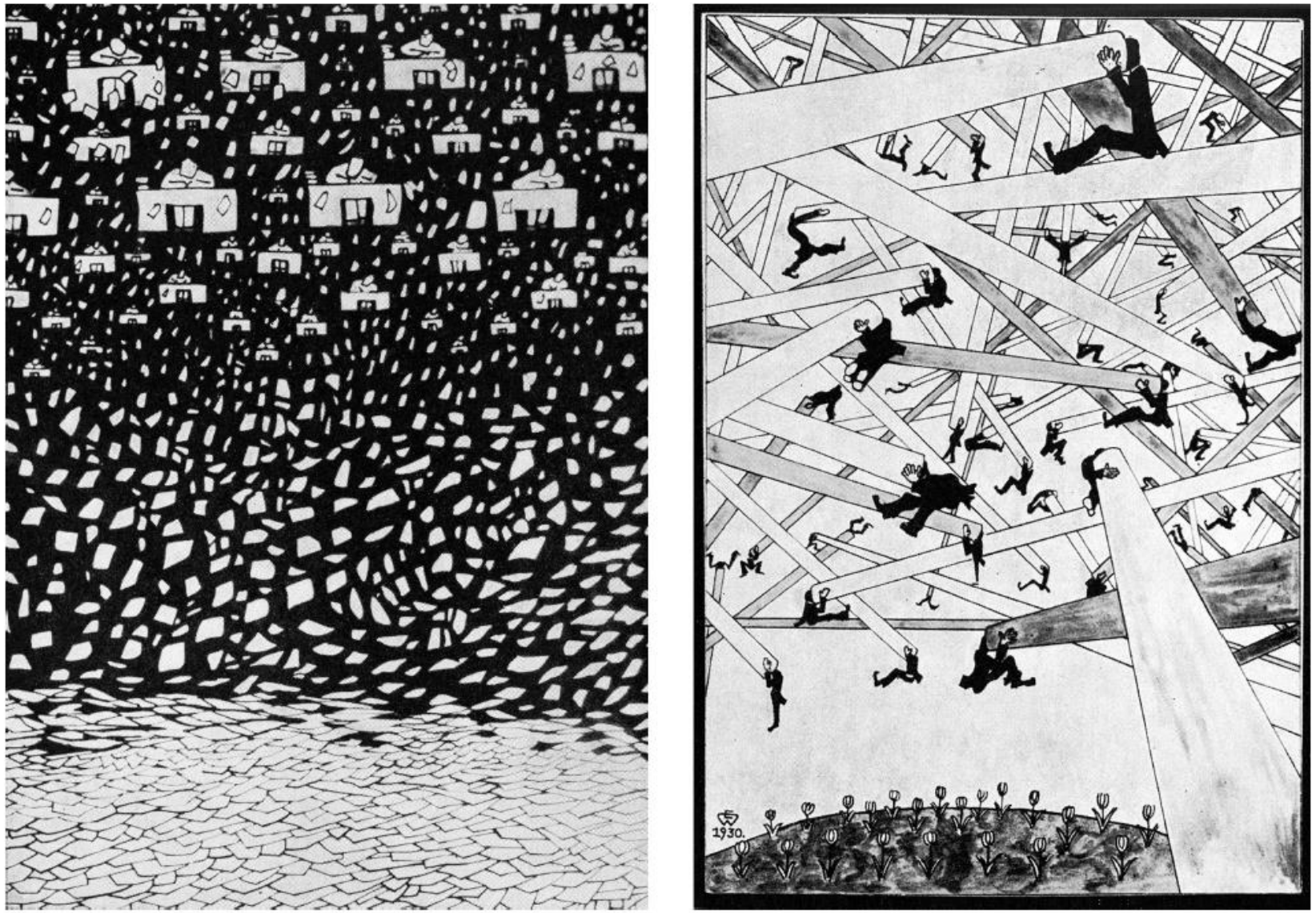


Figure 9.3 Wegmann (1939). The caption of the cartoon on the left is *Die wissenschaftliche Literatur* (The scientific literature); the one on the right is *Die wissenchaftlichen Gesichtspunkte* (The scientific points of view).


Late 50s, early 60s:
developments in marine geology

mid-ocean ridges

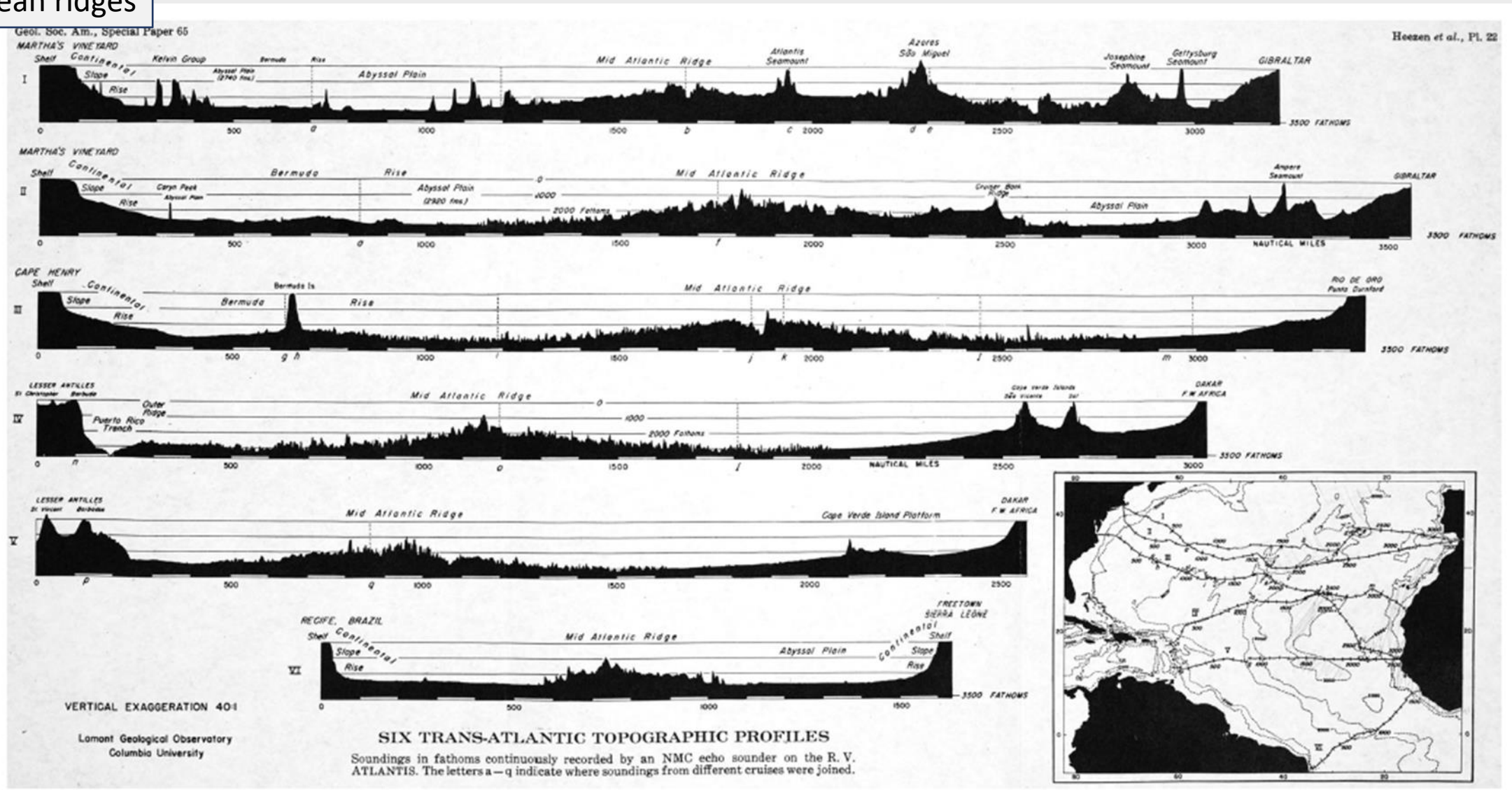


Figure 6.1 Heezen, Tharp, and Ewing's Plate 22 (1959: opposite p. 122) showing Tharp's six trans-Atlantic profiles, which she finished in late 1952 by piecing together sections of data from eight cruises. The rift valley is prominent in the more northerly three profiles but less so in the remaining three.

mid-ocean ridges

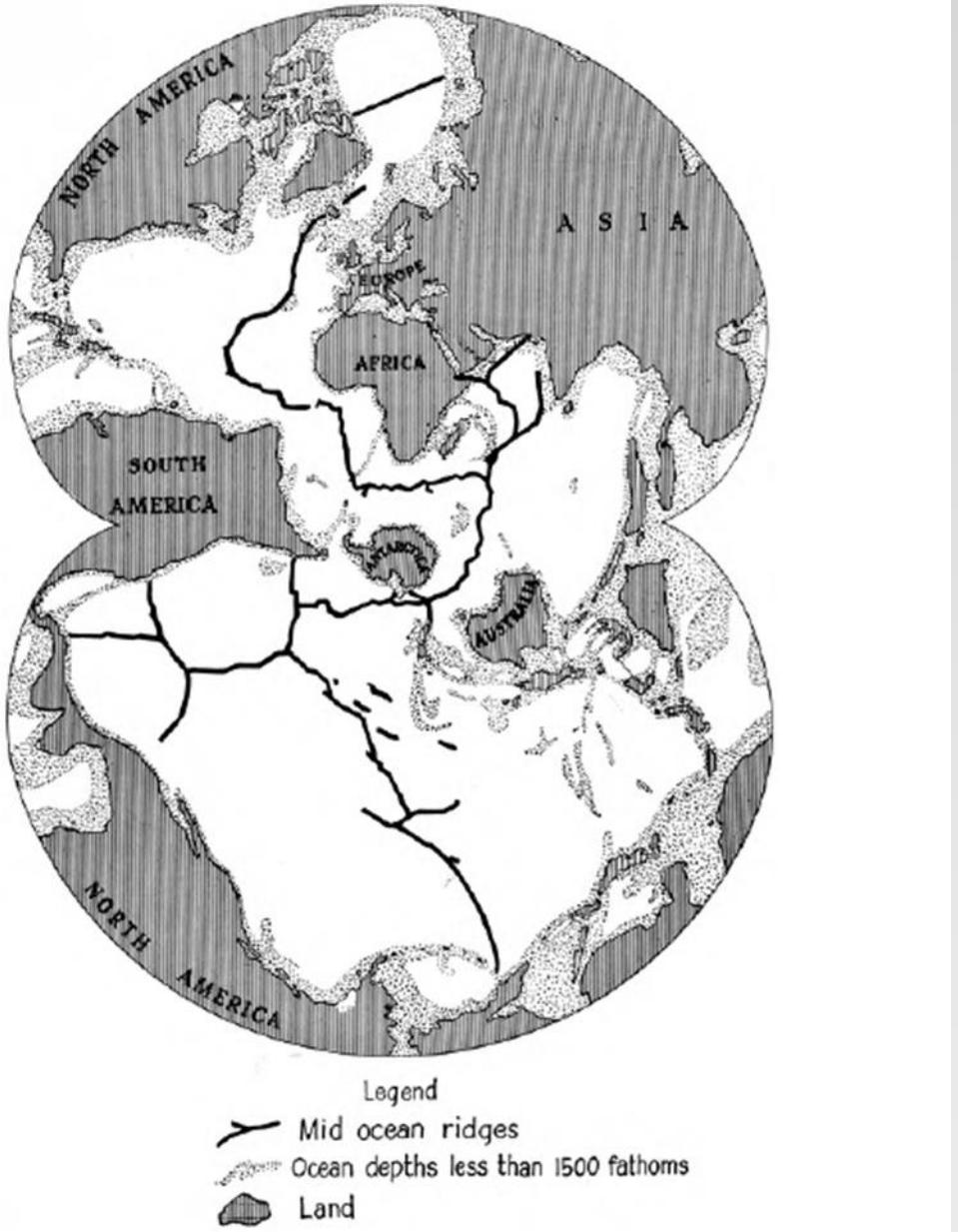
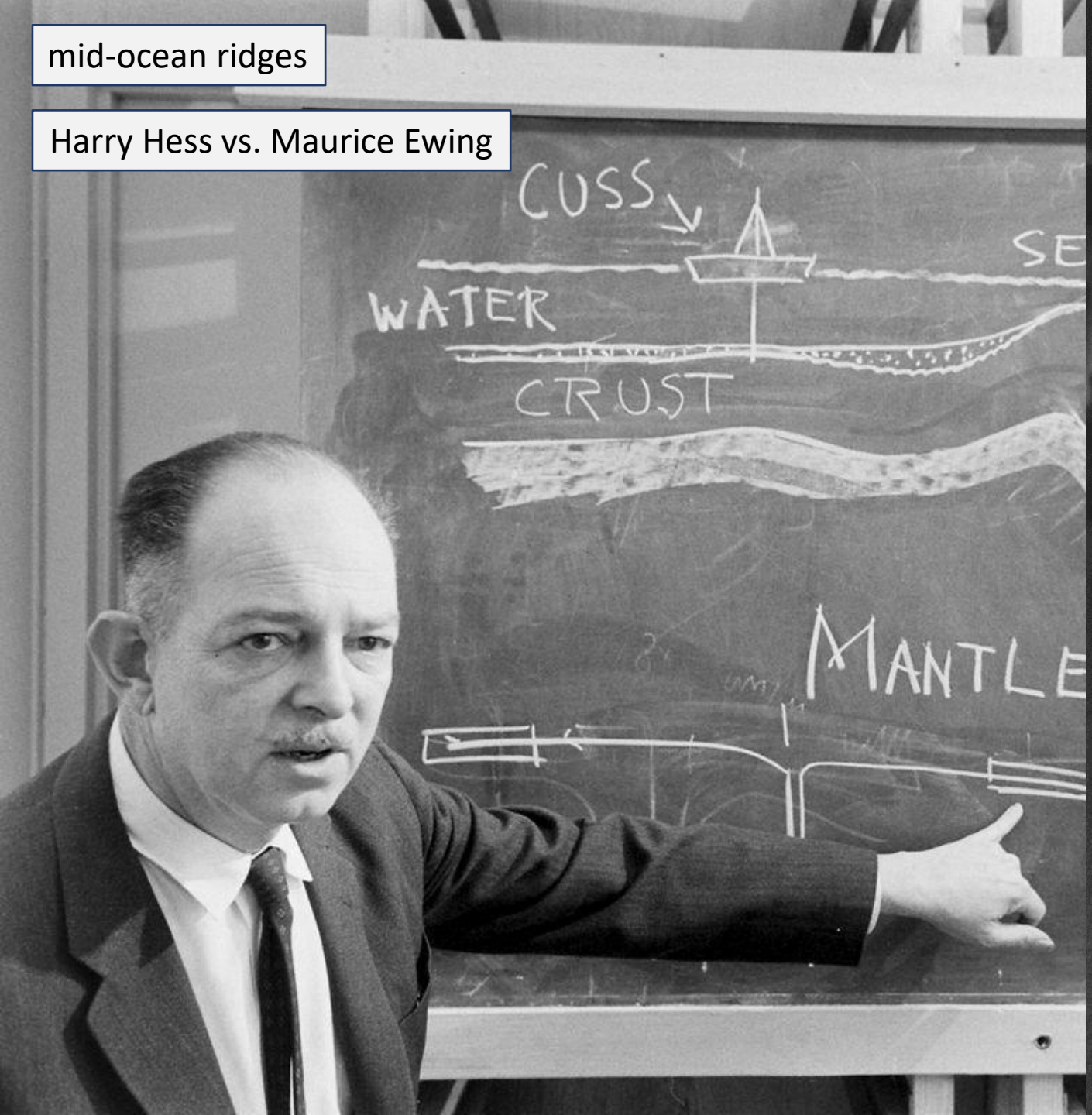


Figure 1.7 Wilson's Figure 2 (1959: Frontispiece, opposite p. 1). His caption reads: "It seems probable that a continuous ridge a few hundred miles wide, from 10 000 to 33 000 feet high and perhaps 40 000 miles long, winds its way across the central ocean floors. The discovery, only two years ago, of the continuity of this, by far the greatest mountain range on Earth, is an interesting commentary upon the state of our knowledge about some parts of the Earth."

mid-ocean ridges

Harry Hess vs. Maurice Ewing



Hess's solution: seafloor spreading

"I shall consider this paper an essay in geopoetry." (1962)

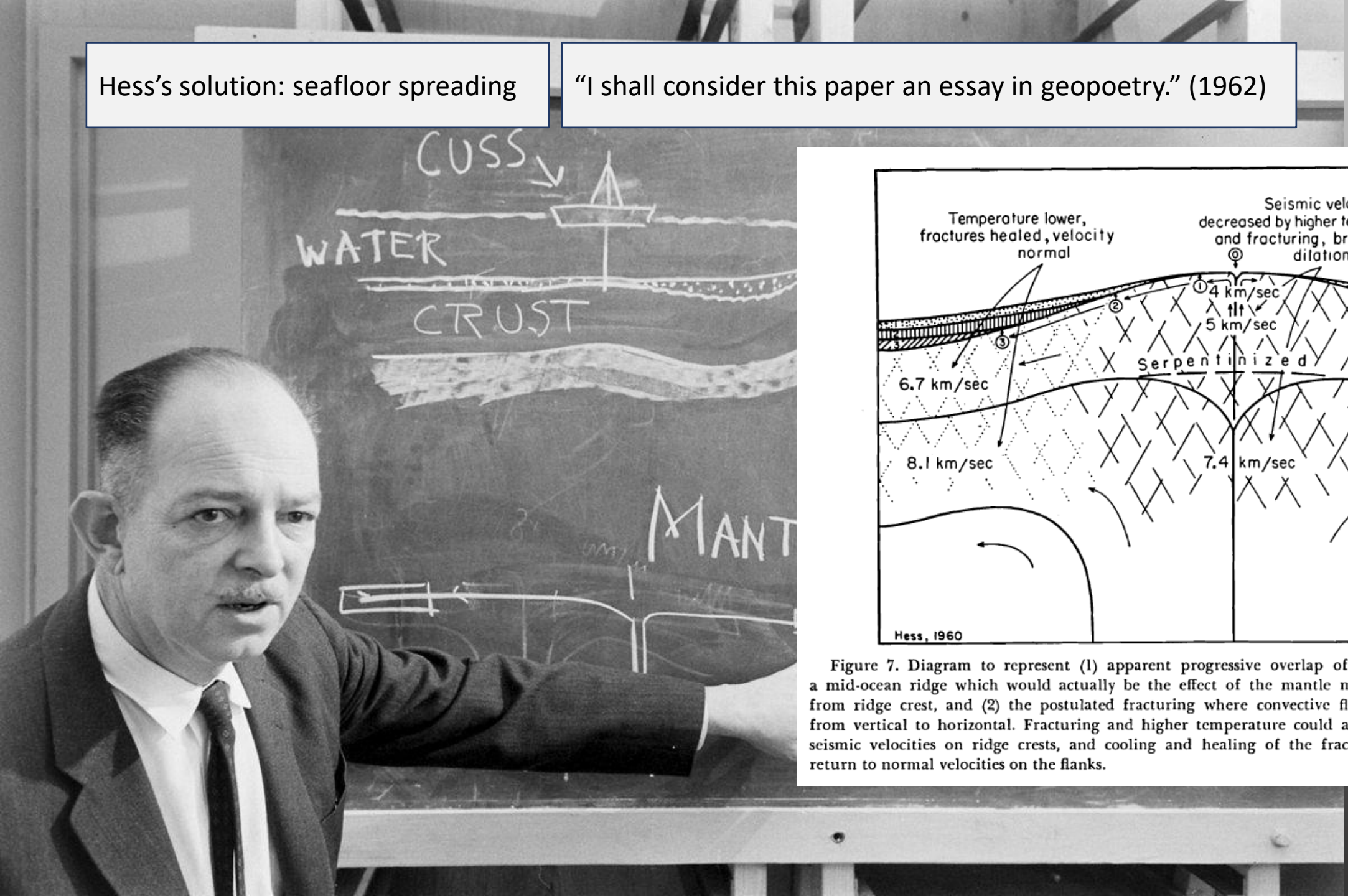


Figure 7. Diagram to represent (1) apparent progressive overlap of ocean sediments on a mid-ocean ridge which would actually be the effect of the mantle moving laterally away from ridge crest, and (2) the postulated fracturing where convective flow changes direction from vertical to horizontal. Fracturing and higher temperature could account for the lower seismic velocities on ridge crests, and cooling and healing of the fractures with time, the return to normal velocities on the flanks.

Hess's solution: seafloor spreading

- Spreading a viable mechanism

"I shall consider this paper an essay in geopoetry." (1962)

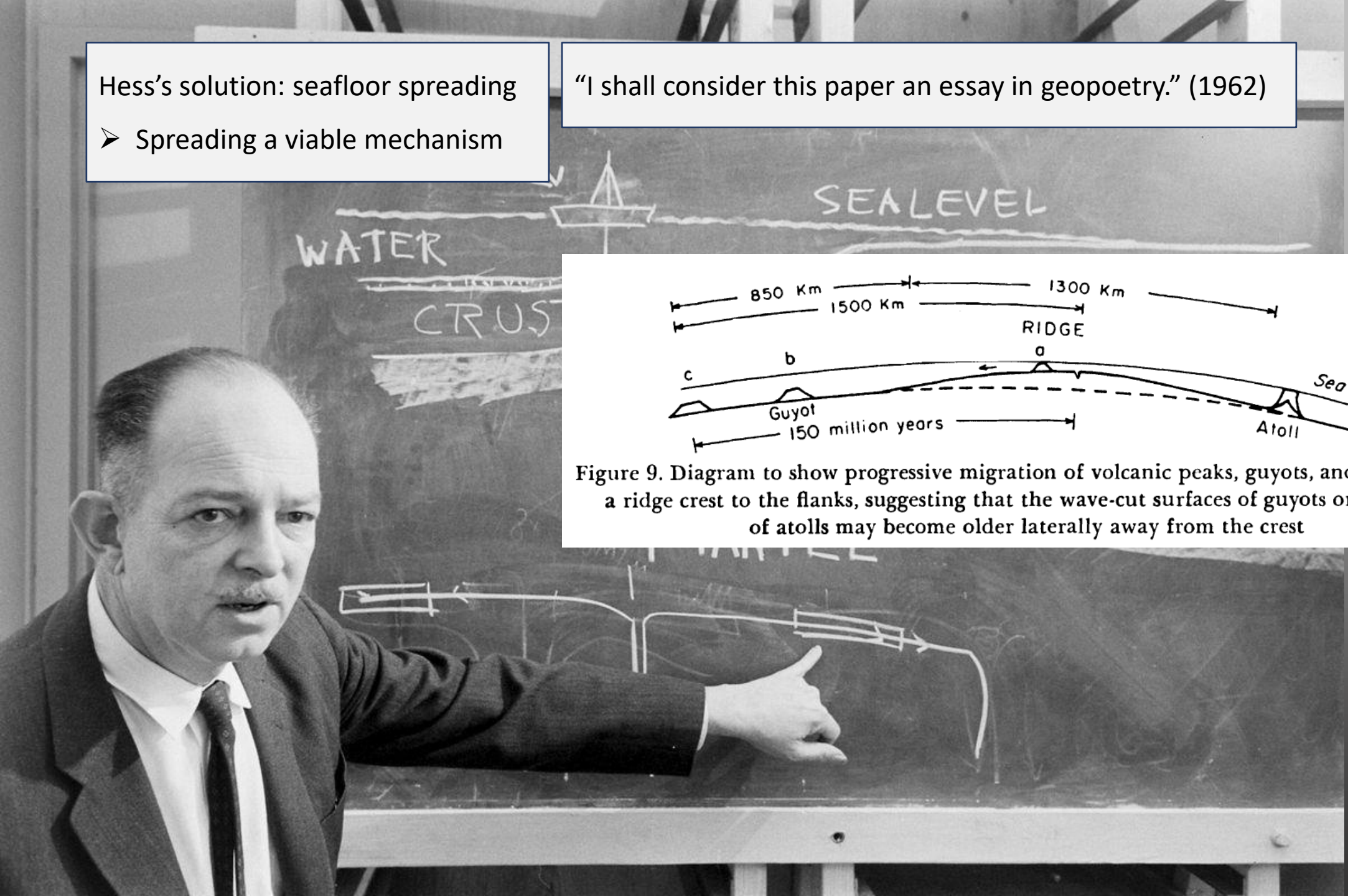


Figure 9. Diagram to show progressive migration of volcanic peaks, guyots, and atolls, from a ridge crest to the flanks, suggesting that the wave-cut surfaces of guyots or the bases of atolls may become older laterally away from the crest

Hess's solution: seafloor spreading

- Spreading a viable mechanism
- Hess converts to drift theory

"I shall consider this paper an essay in geopoetry." (1962)

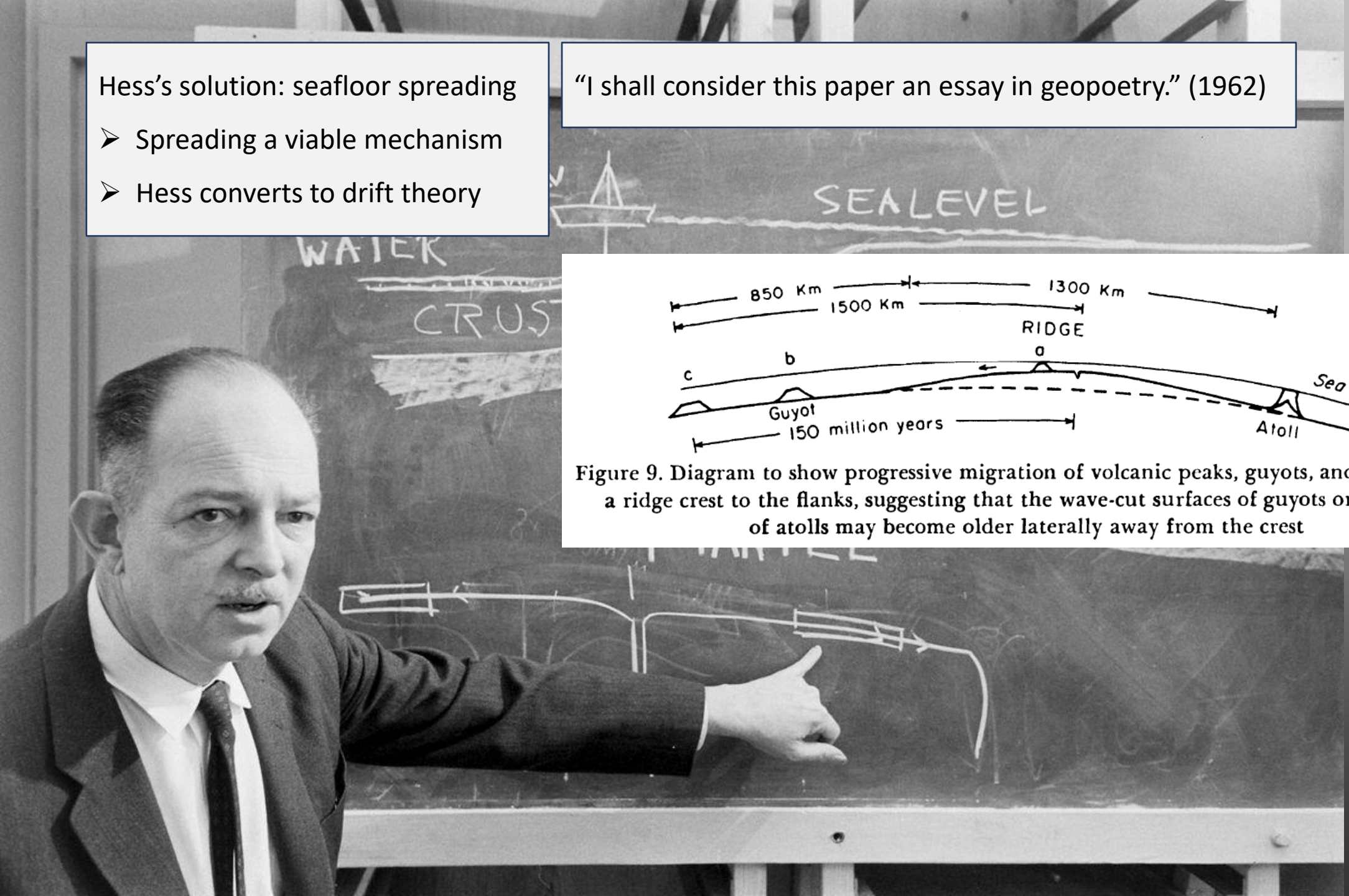


Figure 9. Diagram to show progressive migration of volcanic peaks, guyots, and atolls, from a ridge crest to the flanks, suggesting that the wave-cut surfaces of guyots or the bases of atolls may become older laterally away from the crest

Hess's solution: seafloor spreading

- Spreading a viable mechanism
- Hess converts to drift theory
- Also explains trenches at edges of ocean basins

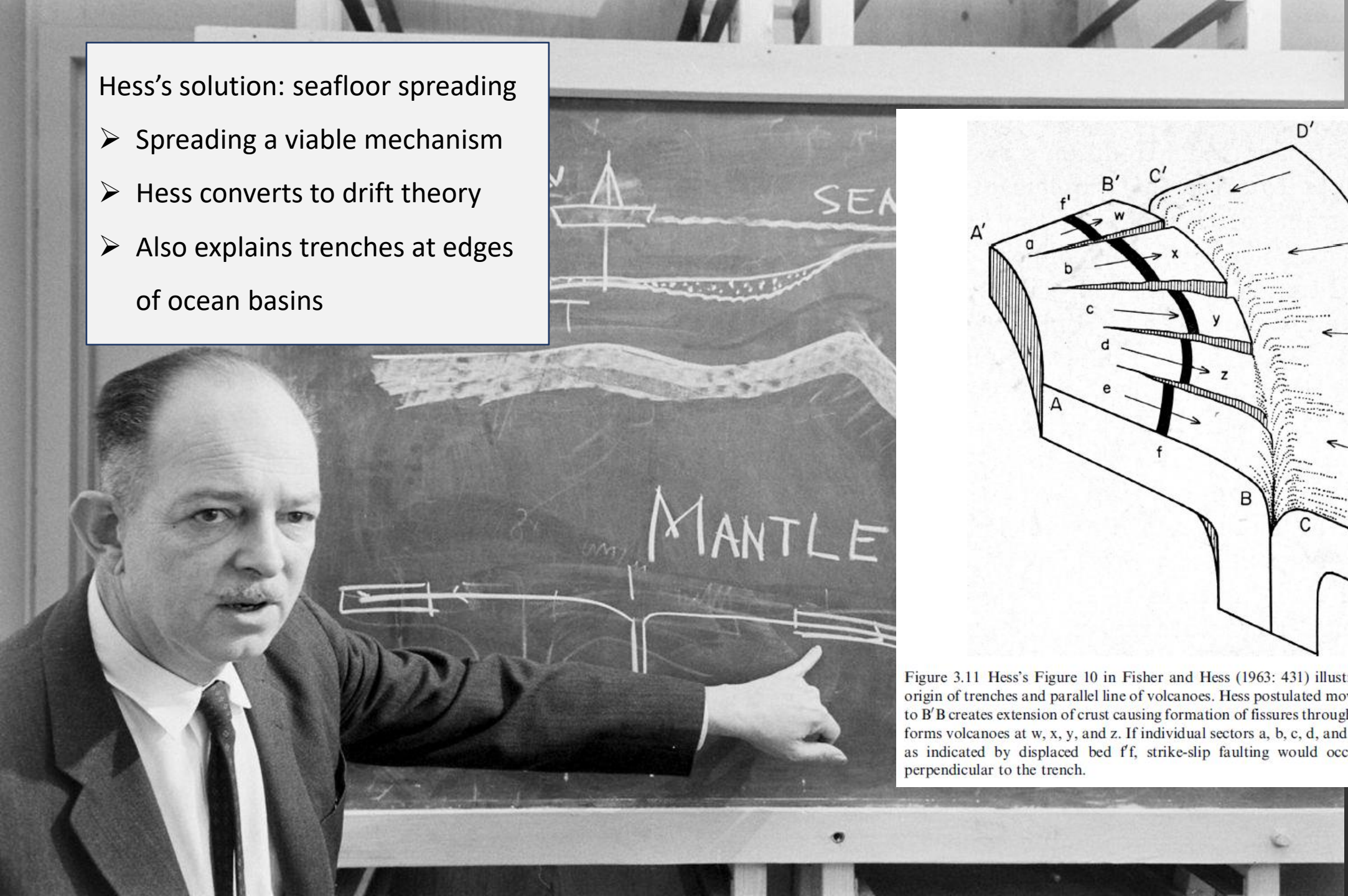


Figure 3.11 Hess's Figure 10 in Fisher and Hess (1963: 431) illustrating his solution to the origin of trenches and parallel line of volcanoes. Hess postulated movement of crust from A′A to B′B creates extension of crust causing formation of fissures through which upwelling magma forms volcanoes at w, x, y, and z. If individual sectors a, b, c, d, and e move at different rates, as indicated by displaced bed f′f, strike-slip faulting would occur along vertical planes perpendicular to the trench.

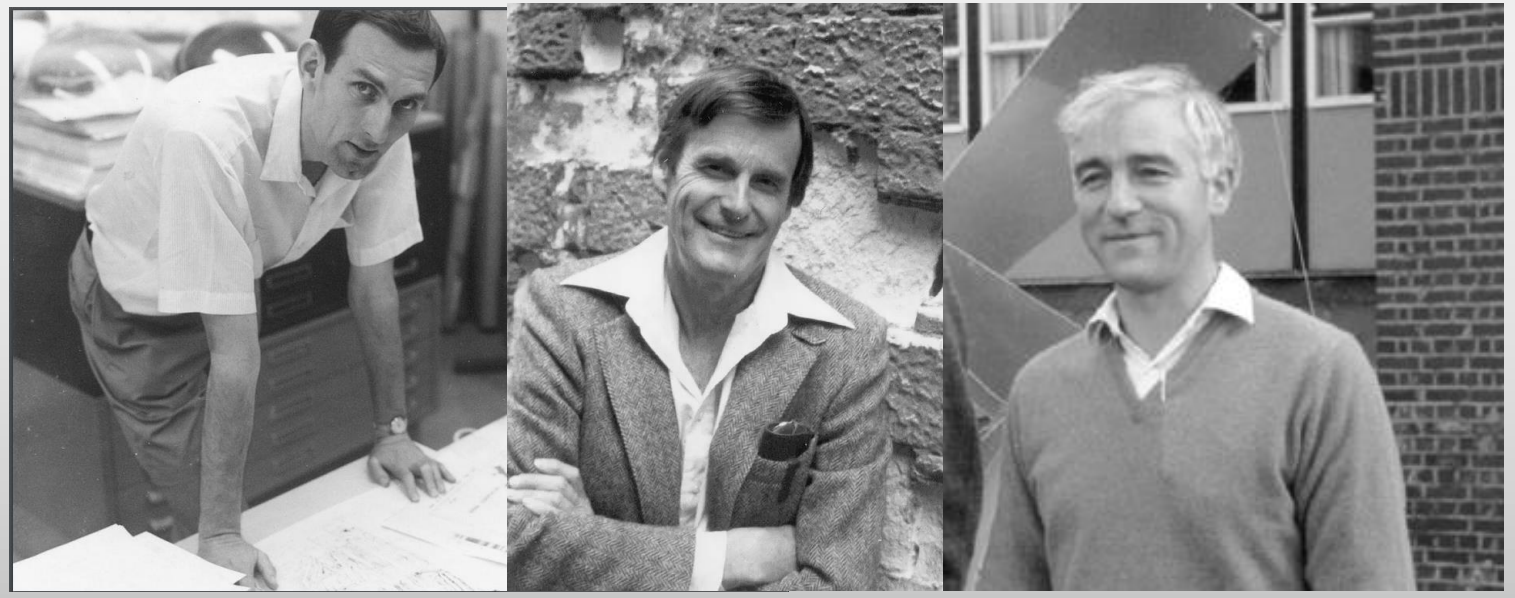
Ewing’s solution: uplift without spreading

- Fixist
- Explained most facts explained by Hess
- Ewing’s theory and Hess’s both sparked interest among geologists; neither attained consensus

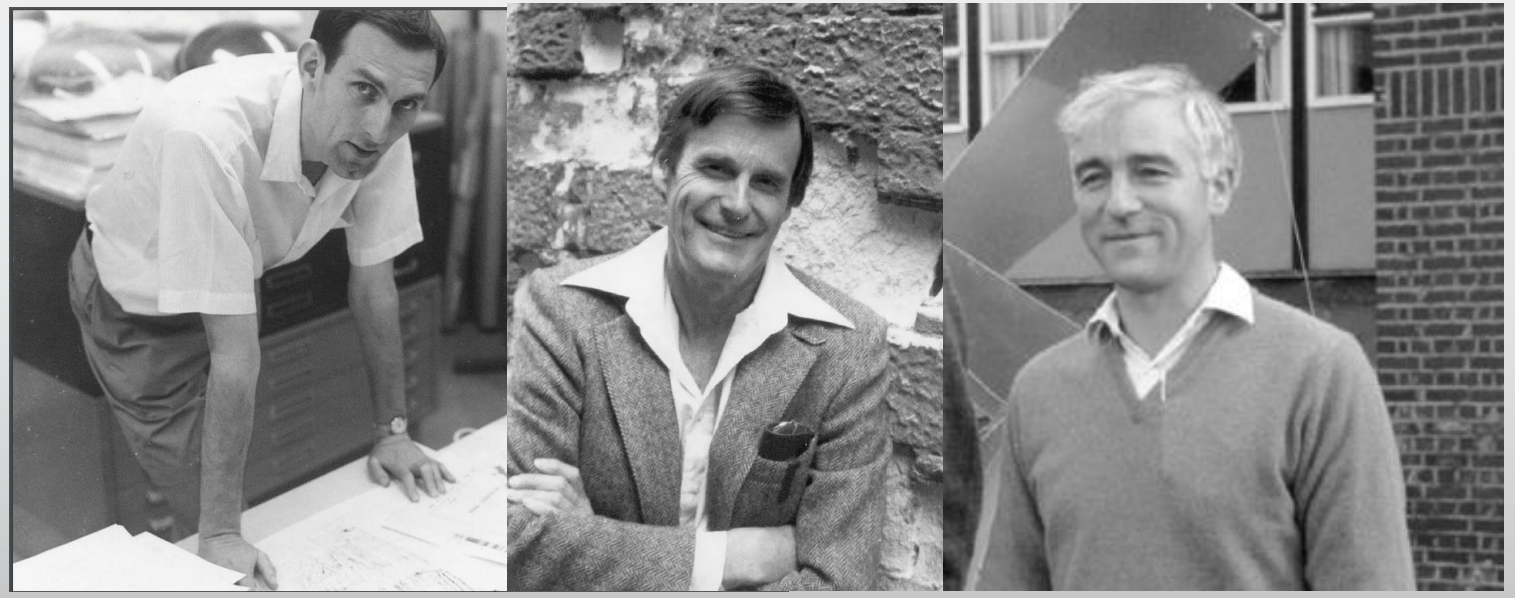
PALEOMAGNETISM

Figure 5.5 Raff and Mason's Figure 1 (1961: 1268). Their caption was simply "Index anomaly map of the total magnetic field. The positive area of the anomalies is shown in black."

"zebra" pattern of magnetic anomalies in ocean basins

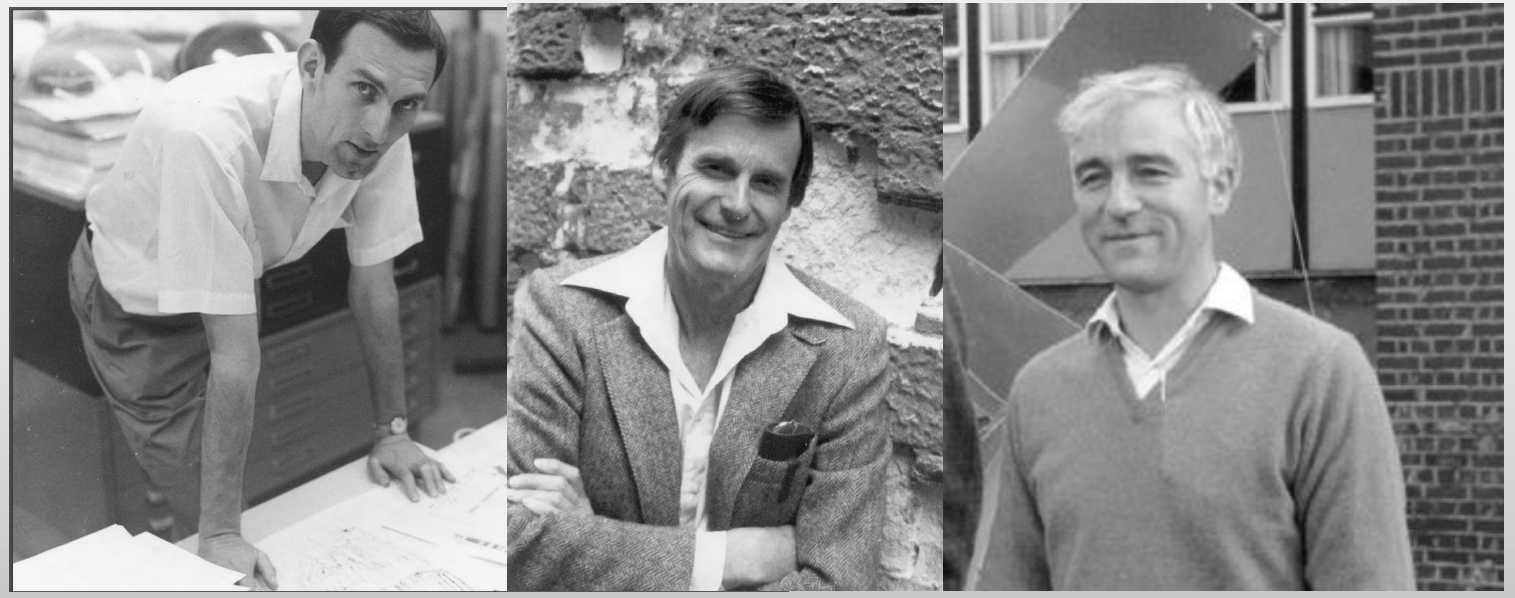


Frederick Vine, Lawrence Morely, Drummond Matthews: VMM (1963)



Frederick Vine, Lawrence Morely, Drummond Matthews: VMM (1963)

- New seafloor becomes magnetized in direction of existing geomagnetic field



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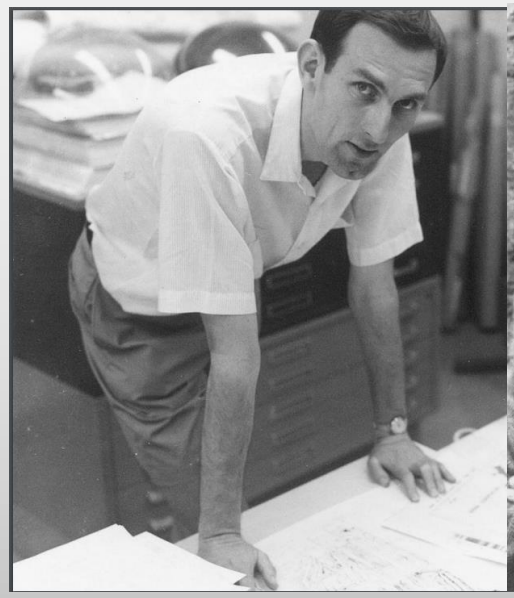
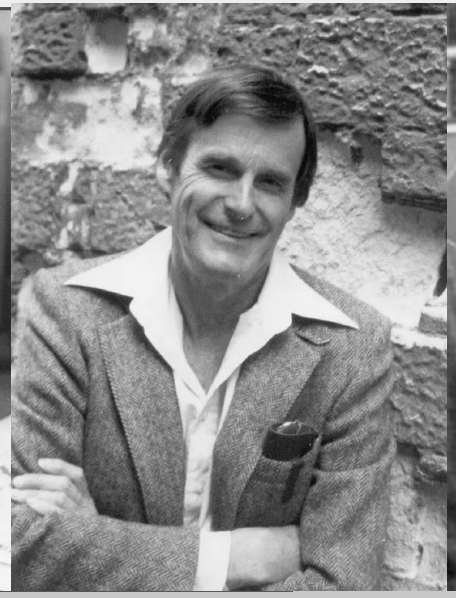
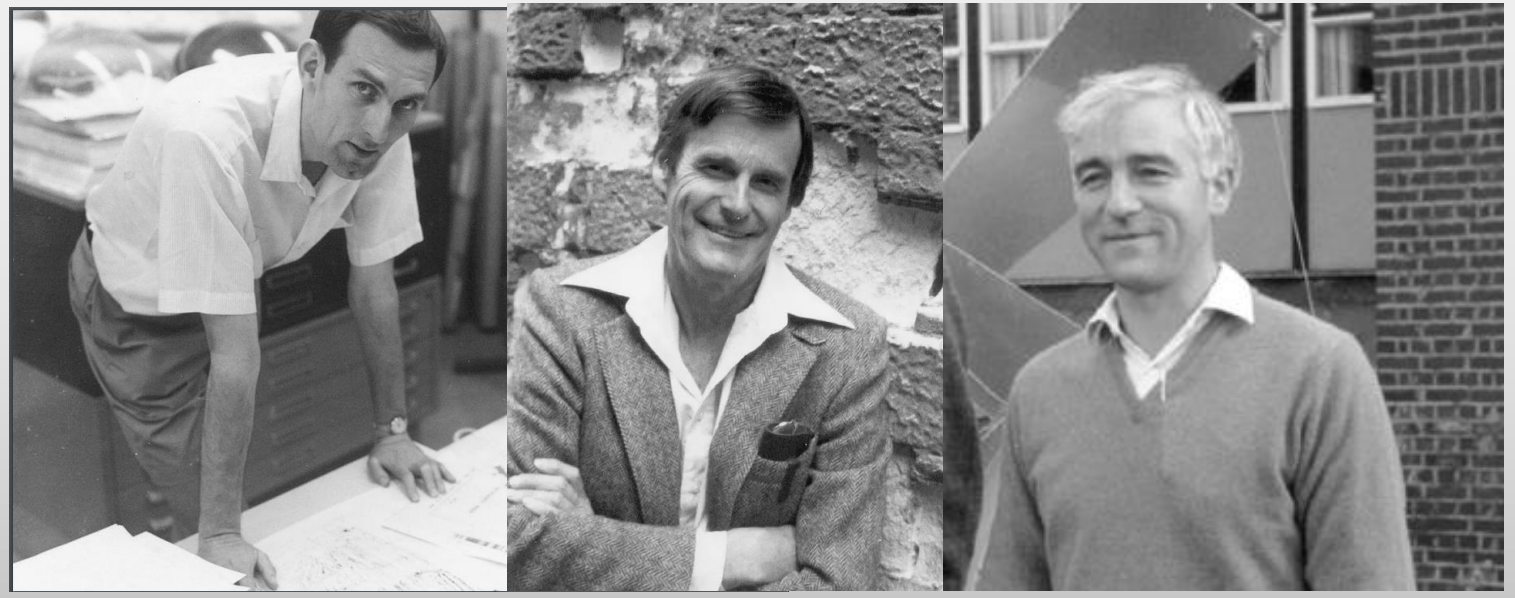
- New seafloor becomes magnetized in direction of existing geomagnetic field
- Repeated reversals in polarity of geomagnetic field explain zebra pattern


Frederick Vine, Lawrence Morely, Drummond Matthews: VMM (1963)

- New seafloor becomes magnetized in direction of existing geomagnetic field
- Repeated reversals in polarity of geomagnetic field explain zebra pattern
- Ewing's group (Lamont researchers) argue magnetic data is unreliable, doesn't match VMM predictions.



Frederick Vine, Lawrence Morely, Drummond Matthews: VMM (1963)

- New seafloor becomes magnetized in direction of existing geomagnetic field
- Repeated reversals in polarity of geomagnetic field explain zebra pattern
- Ewing's group (Lamont researchers) argue magnetic data is unreliable, doesn't match VMM predictions.
- Ewing's group change their minds in 1966-67

Figure 5.5 Raff and Mason's Figure 1 (1961: 1268). Their caption was simply "Index anomaly map of the total magnetic field. The positive area of the anomalies is shown in black."

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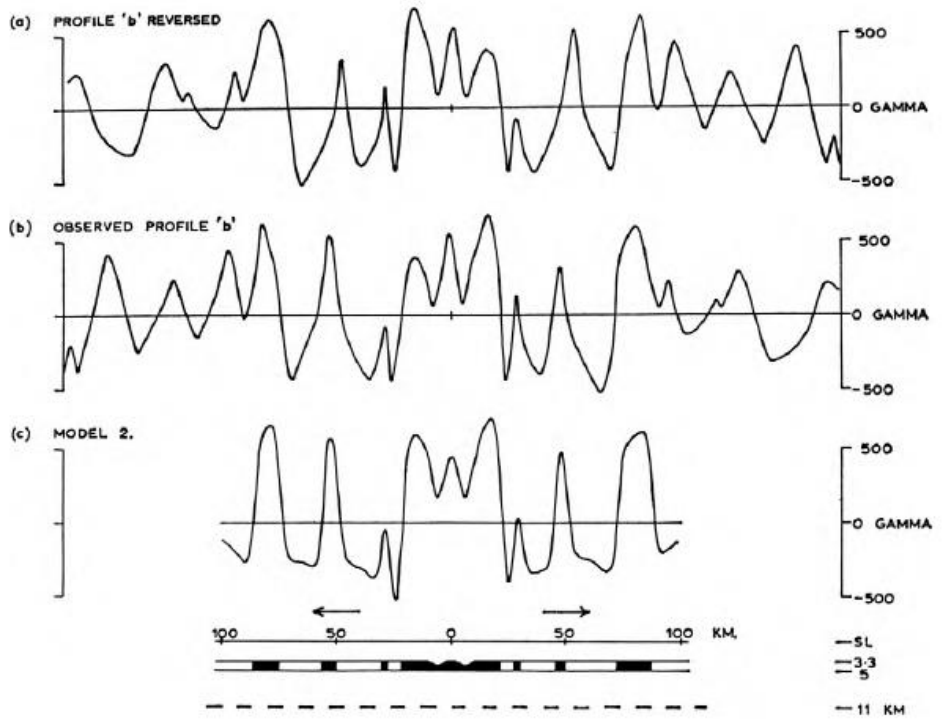

Figure 5.2 Vine and Wilson's Figure 3 (1965: 488) establishing symmetry of magnetic anomalies about the Juan de Fuca Ridge. (b) is a profile as observed over the Juan de Fuca Ridge along dotted line "b" in Figure 5.1; (a) is (b) reversed; (c) is a model of the profile based on Hess's model with the magnetic material being confined to Layer 2, and an effective susceptibility of $+0.02$ for the central block and ± 0.01 for the other blocks.

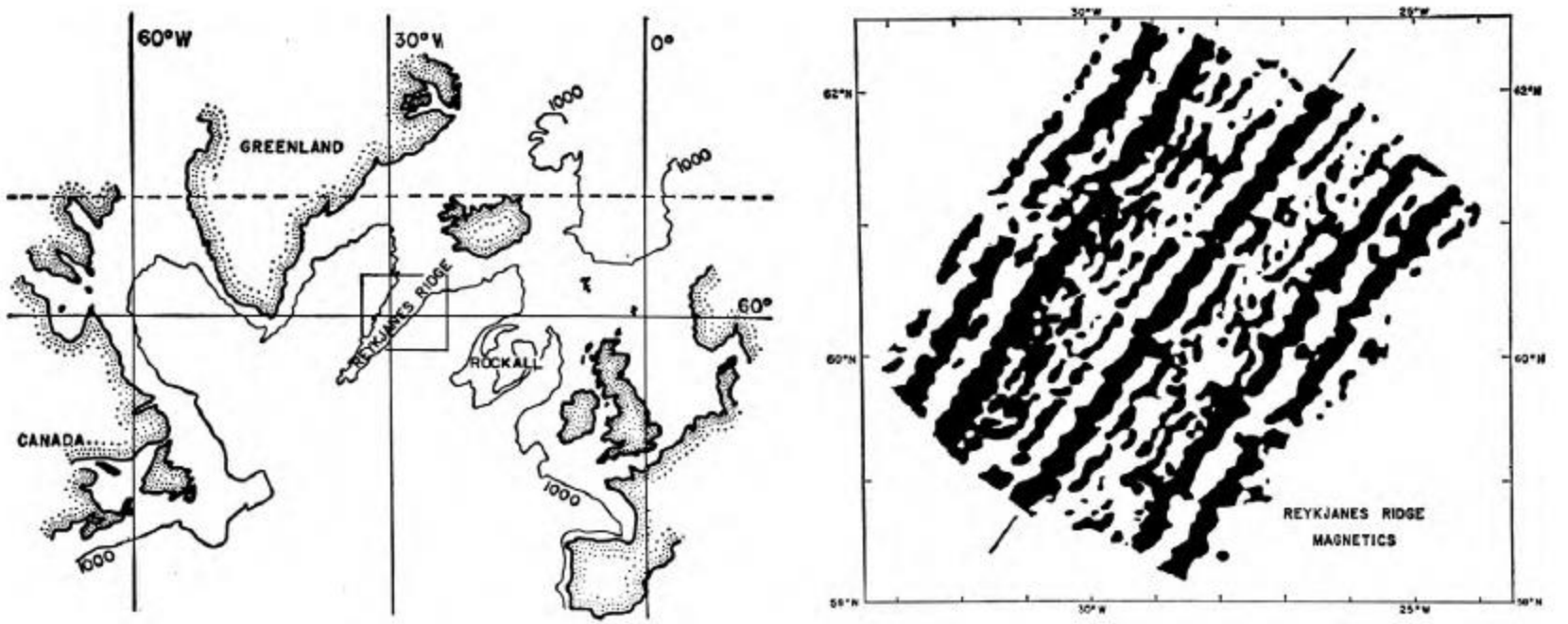

Figure 6.10 Vine's Figures 2 and 3 (1966: 1407). "The location of Reykjanes Ridge, southwest of Iceland" showing the area of the Lamont and US Naval Oceanographic Office aeromagnetic survey. The results are shown in the box on the right; black (white) areas have positive (negative) magnetic anomalies in which the regional field is enhanced (diminished). There is a larger scale anomaly map shown in Figure 5.8.

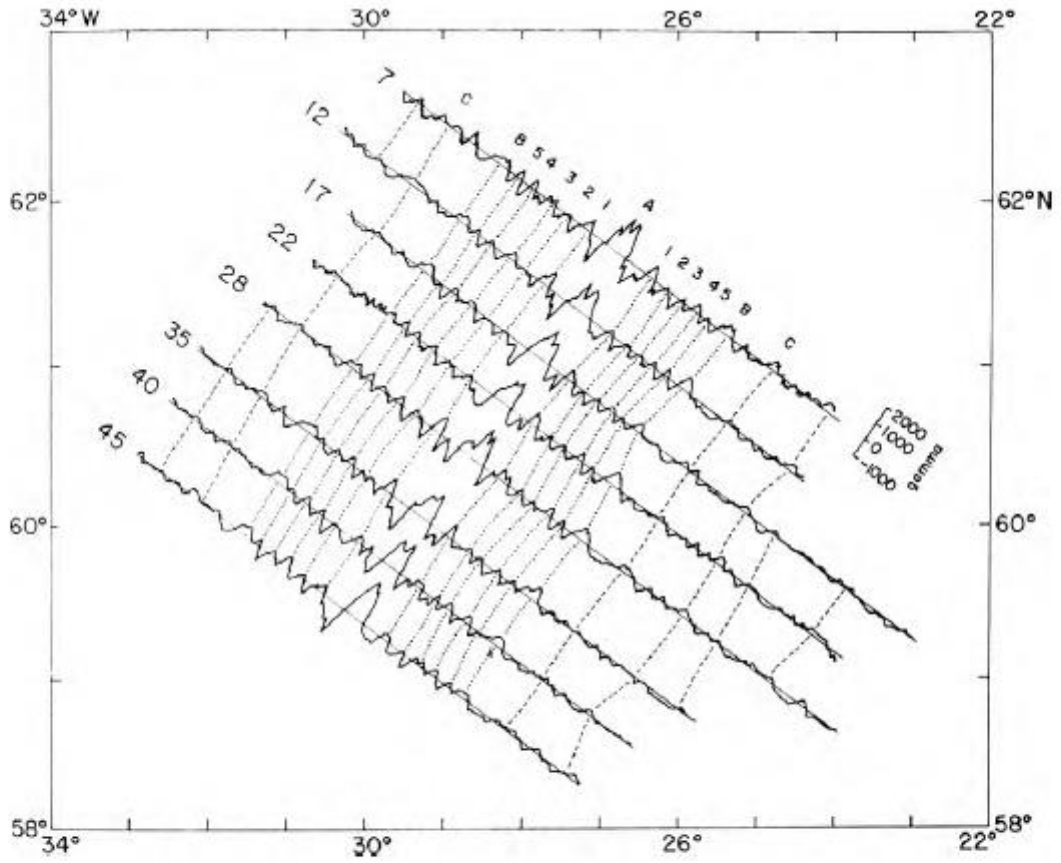

Figure 5.9 Heirtzler *et al.*'s Figure 3 (1966: 431). Eight anomaly profiles from the survey across the Reykjanes Ridge. A is the axial anomaly. The axial zone extends to BB. The thirteen anomalies in the axial zone display definite linearity and the symmetry of the anomalies within the axial zone is striking. The flank anomalies begin with C.

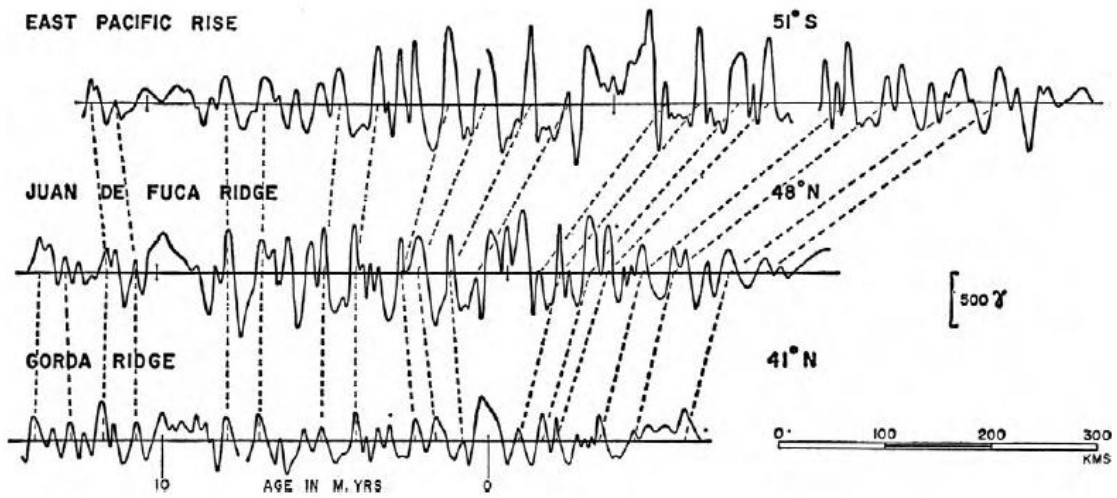

Figure 6.12 Vine's Figure 14 (1966: 1412). His caption reads: "The East Pacific Rise profile *Eltanin*-19 (23) compared with a composite profile across and to the northwest of Juan de Fuca Ridge, and with a profile normal to the strike of the anomalies across and to the west of Gorda Ridge." Reference 23 is to Pitman and Heirtzler (1966).

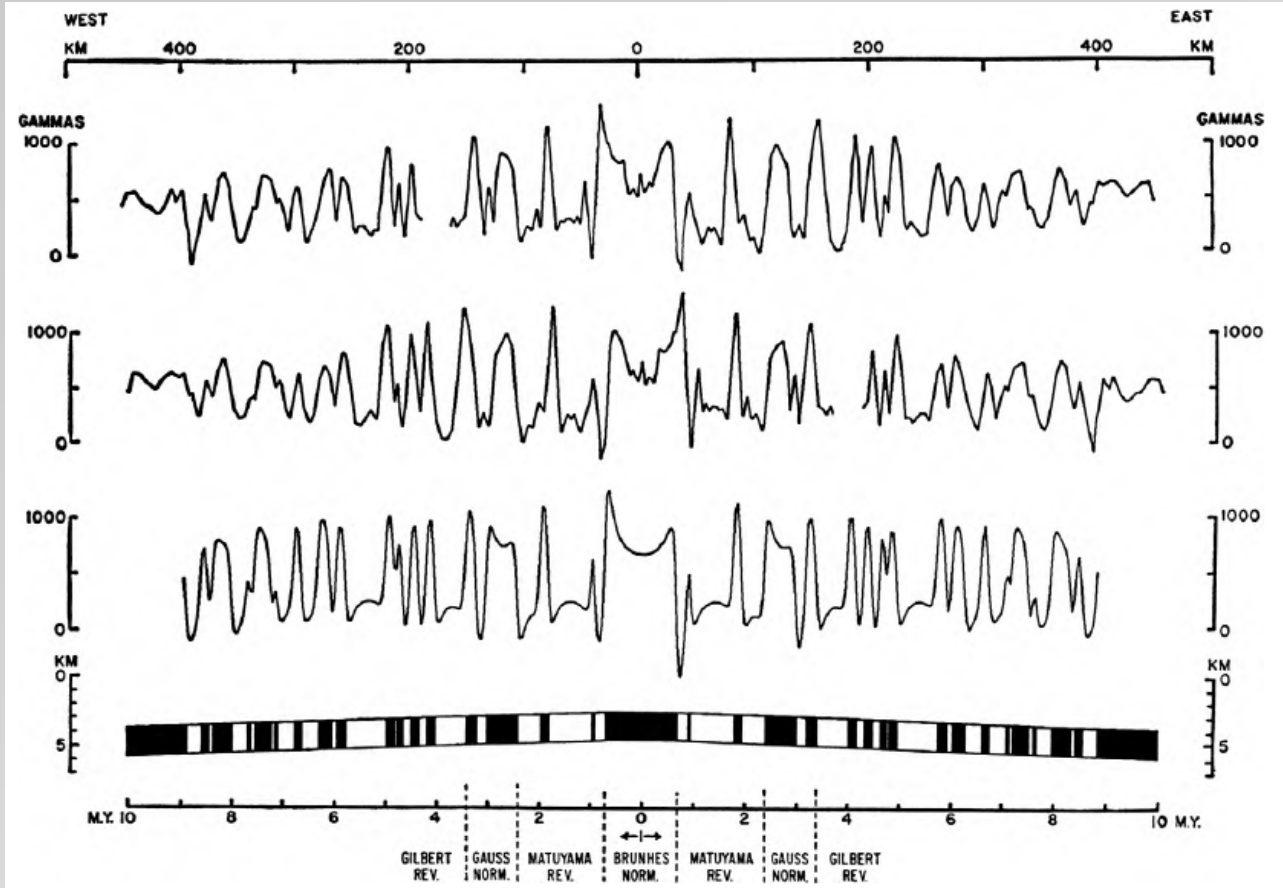

Figure 6.5 Pitman and Heirtzler's Figure 3 (1966: 1166). Their caption reads: "The middle curve is the *Eltanin*-19 magnetic-anomaly profile; east is to the right. The upper anomaly profile is that of *Eltanin*-19 reversed; west is the right. On the bottom is the model for the Pacific-Antarctic Ridge. The time scale (millions of years ago) is related to the distance scale by the spreading rate of 4.5 cm/yr. The previously known magnetic epochs since the Gilbert epoch are noted. The shaded areas are normally magnetized material; unshaded areas, reversely magnetized material. Above the model is the computed anomaly profile." Four Fingers Brown comprises the four positive anomalies within the Gilbert reversed epoch, located approximately 200 km from the ridge axis. They are easily seen on both sides of the computed anomaly profile, on the right side of the top profile, and left side of the middle profile, but are disturbed on the left side of the top profile and right side of the middle profile.

"By 1967 just about everyone who knew and understood what had happened accepted sea-floor spreading. Plate tectonics was developed in 1967."

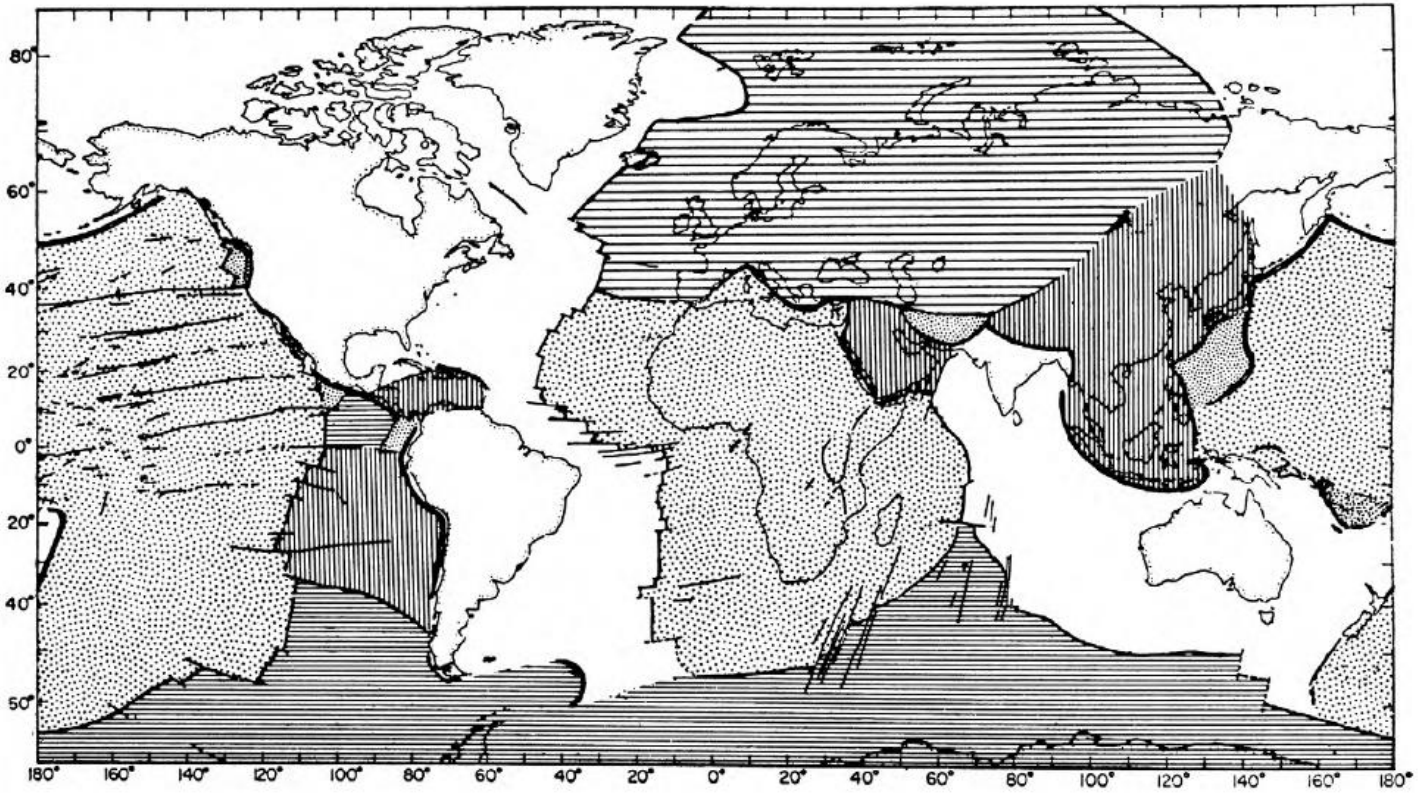

Figure 7.13 Morgan's Figure 1 (1968: 1960). His caption reads: "The crust is divided into units that move as rigid blocks. The boundaries between blocks are rises, trenches (or young fold mountains), and faults. The boundaries drawn in Asia are tentative, and additional sub-blocks may be needed."

Frankel will test the following theses against the history of controversy over continental drift:

T1. Scientists prefer a theory which:

- T1.1. can solve some empirical difficulties confronting its rivals
- T1.2. can solve problems not solved by predecessors

T2. The appraisal of a theory:

- T2.1 depends on its ability to turn counter-examples into solved problems
- T2.2 depends on its ability to solve problems it was not invented to solve

TABLE I.

Particular theses confirmed

Confirmatory instance	Thesis confirmed			
	(T1.1) not solved by rivals	(T2.1) remove counter-example	(T2.2) not designed to solve	(T1.2) predecessors have not solved
1. Wegener's solution to coastline similarities	x			
2. Wegener's solution to the origin of the Permo-Carboniferous ice cap	x			x
3. Wegener's solution to the general problem of disjunctively distributed life forms				x
4. Wegener's solution to origin of Australia's peculiar combination of fauna – particular aspect of disjunctive distribution problem	x			x
5. Fixists' solution to the circum-Pacific aspect of the general problem of disjunctively distributed life forms	x			
6. Fixists' solution to the ice-cap problem [developed after Wegener's solution]		x		x
7. Fixists' attack upon Wegener's solution to the problem of the similarity of coastlines		x		

TABLE I.

Particular theses confirmed

Confirmatory instance	Thesis confirmed			
	(T1.1) not solved by rivals	(T2.1) remove counter-example	(T2.2) not designed to solve	(T1.2) predecessors have not solved
8. Wegener's removal of apparent counter-example raised by fixists to his ice-cap solution		x		
9. Du Toit's removal of apparent counter-example raised by fixists against drift's solution to (3)		x		
10. Fixists' solution to the origin of Australia's peculiar combination of fauna		x		x
11. Paleomagnetic studies during 1950's supportive of continental drift	x		x	x
12. Geodetic studies initially supporting westward drift to Greenland	x		x	x
13. Fixists' attack upon paleomagnetic studies supportive of continental drift		x		
14. Fixists' argument that geodetic evidence about Greenland's drift is unreliable		x		
15. Discoveries which confirmed Hess's sea-floor spreading and VMM	x	x	x	x
16. Discoveries confirming sea-floor spreading and Wilson's transform faults	x		x	x

FRANKEL'S TAKEAWAYS

- Frankel suggests T1.1 (solving problem not solved by rivals) is useful for *convincing members of rival theoretical camps* (and those on the fence).
- T1.2 (solving problem predecessors have not solved) is useful for convincing members of one's *own* camp.
- The correlation between T1.1 and T1.2 in the table may reflect scientists' preference for theories that will convince friends, rivals, and fence-sitters.
- Large number of cases of T2.1 (removing counterexamples) suggests it is easy; most were arguments that rivals' data were unreliable.
- Scarcity of cases of T2.2 (solving problems the theory was not designed to solve) suggests it is difficult.

GEMS

- Lots of history (too much?) packed into short article
- Not whiggish (?)
- Almost exclusively *internal* history
- Takeaways