Relative Motions Between Oceanic and Continental Plates in the Pacific Basin

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206

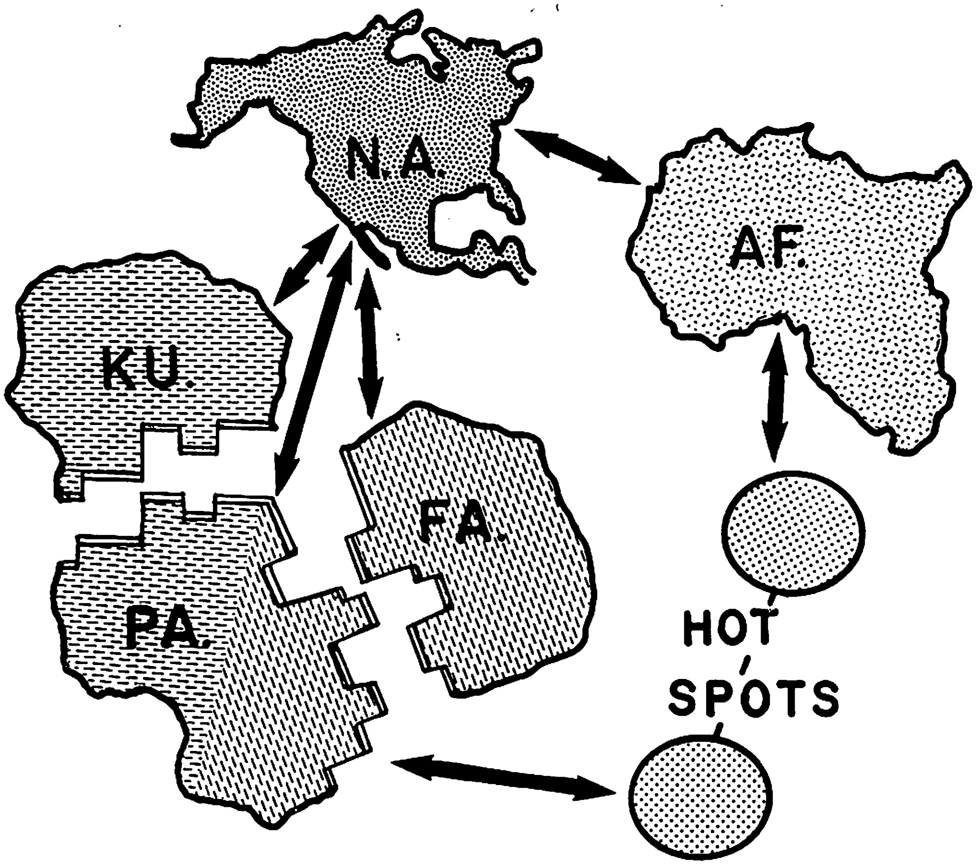


Figure 1. Global plate tectonic model showing the links between the major plates included in our analysis. In addition, the motion of Eurasia (not shown here) was determined from that of North America using the record of the opening of the North Atlantic (Srivastava 1978). South America and Antarctica rotations (not shown here) are included in the tables. PA: Pacific plate. FA: Farallon plate. KU: Kula plate. NA: North America plate. AF: Africa plate. HOT SPOTS: Those in the Pacific and Atlantic basins, here shown schematically, are assumed to have remained at a constant distance from each other.

when hotspots have shifted relative to the rotation axis, hotspots on one side of the globe moved toward the rotation axis and those on the other side moved away, as if the mantle as a whole were moving relative to the rotation axis while the hotspots remained fixed and at the same distance from each other relative to the mantle (Morgan 1981; Gordon and Cape 1981; Gordon 1983; Andrews in press). On balance, hotspots appear to us to form an imperfect but still useful mantle reference frame.

Reconstructions Used to Build the Model

The reconstructions used to build the model come from a variety of sources. The motion of the African plate relative to the Atlantic hotspots (i.e. Africa-hotspot motion) was taken from Morgan (1983). The ages of these reconstructions were adjusted to be consistent with the magnetic reversal time scale of Harland and others (1982), which is used throughout this paper. To obtain the motion of North America relative to hotspots, the Africa–North America relative motion determined by Klitgord and others (1984 and personal communication) was combined with Morgan's Africa–hotspot motion. The motion of Eurasia with respect to the hotspots was then determined from North America–hotspot motion and the Eurasia–North America reconstructions of Srivastava (1978). These reconstructions, as modified by the interpretation of Cande and Kristoffersen (1977), showed that the anomalies Srivastava identified as anomalies 31 and 32 are actually anomalies 33 and 34. The timing of initial rifting of Eurasia–Greenland from North America (~95 Ma) was estimated by extrapolating the spreading rate between anomalies 33 and 34 out to the ocean-continent boundary as determined by Srivastava.

The post-43 Ma Pacific–hotspot motion, that is, the motion of the Pacific plate relative to the hotspots, is generally represented by a single Euler pole (Jarrard and Clague 1977). The possibility that the Pacific plate began to move in a more northerly direction several million years ago is suggested (Cox and Engebretson 1985) by a difference between the Euler pole for the Hawaiian trend (Jarrard and Clague 1977) and the Euler pole for present plate motions, as determined from observations spanning the past several million years (Minster and Jordan 1978). A

TABLE 4. (Continued)

Age (Ma)	Stage Poles[1] Lat °N	Long °E	Angle (Deg)	Total Reconstructions[1] Lat °N	Long °E	Angle (Deg)
66	65	340	4.5	71	288	48.5
67	71	347	1.5	71	290	49.9

(1) Same conventions as in Table 2.
(2) See note (3), Table 2.
(3) See note (1), Table 2.
(4) See note (2), Table 2.

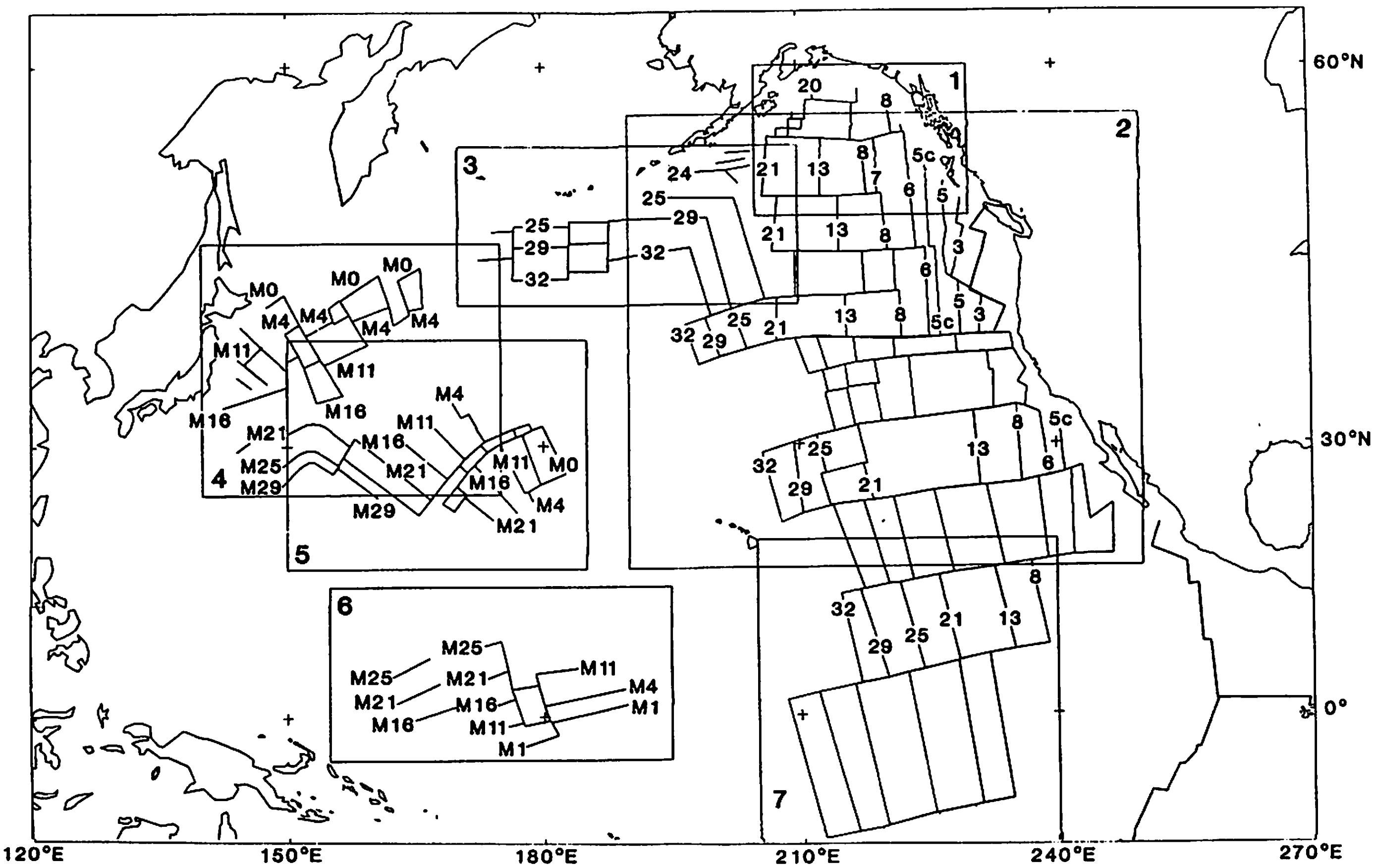


Figure 2. Magnetic lineations discussed in text and shown in subsequent figures. After Figure 1 in Engebretson and others (1984a), which lists the sources of data.

smoothly without ridge jumps. The model proposes that the spreading rate during the Cretaceous normal superchron is similar to that before 118 Ma and after 83 Ma. Picks of chron 34 (85 Ma) on several ship tracks north of the Murray Fracture Zone are consistent with a spreading rate from chron 34 to chron 32b (85–74 Ma) that is the same as that from chron 32b to chron 25 (74–56 Ma). This model requires an eastward jump of the Pacific–Farallon ridge south of the Mendocino Fracture Zone during the normal superchron because the Cretaceous quiet zone on the south side of the Mendocino Fracture Zone is much wider than on the north. This is part of a pattern in which isochrons on opposite sides of the Mendocino Fracture Zone showed very little offset at the time of chron M29 and increasingly large offsets up to and through the Cretaceous quiet zone and chron 32, subsequent to which the offsets show no further systematic increase. If, on the other hand, spreading on the south side of the Mendocino occurred smoothly, without ridge jumping, then the ridge north of the Mendocino Fracture Zone must have jumped during this time and the true Farallon-Pacific spreading rate recorded on the south side was substantially greater than that proposed by our preferred model. The effect of this may be seen by comparing tables labeled "Farallon N.O.M." and "Farallon S.O.M."

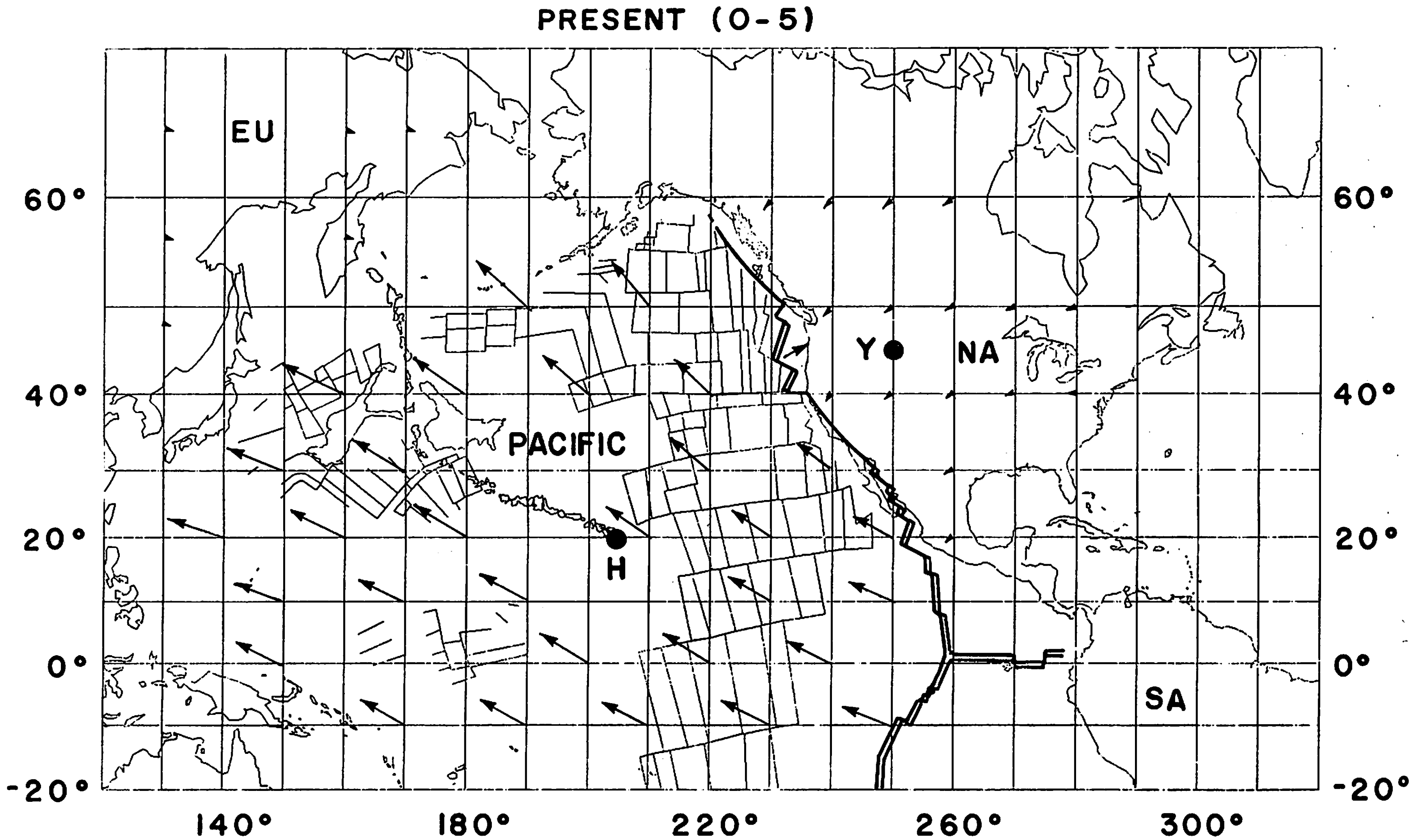


Figure 3a

Figure 3. (this and following pages). Reconstructions in fixed hotspot reference frame. Double heavy lines: ridge boundaries between oceanic plates (dashed where inferred). Single heavy lines: transforms (dashed where inferred). Arrows: motion of plates as determined from stage poles for the time intervals shown in parentheses; arrow length indicates 10 m.y. of motion. Pattern (x-x-x-x-x): abandoned Pacific–Kula ridge. Dots: Yellowstone (Y) and Hawaiian (H) hotspots. Diagonal shading: lithosphere that could be either Farallon or Kula plate. Barbed arcs: island arc inferred from convergence of Farallon and Izanagi velocity vectors—solid barbs when arc was active, open barbs when inactive. Squares: Euler stage poles for oceanic plate pairs shown in present coordinates in fixed hotspot reference frame. SA–South American plate, EU–Eurasian plate. Other abbreviations as in Figure 1.

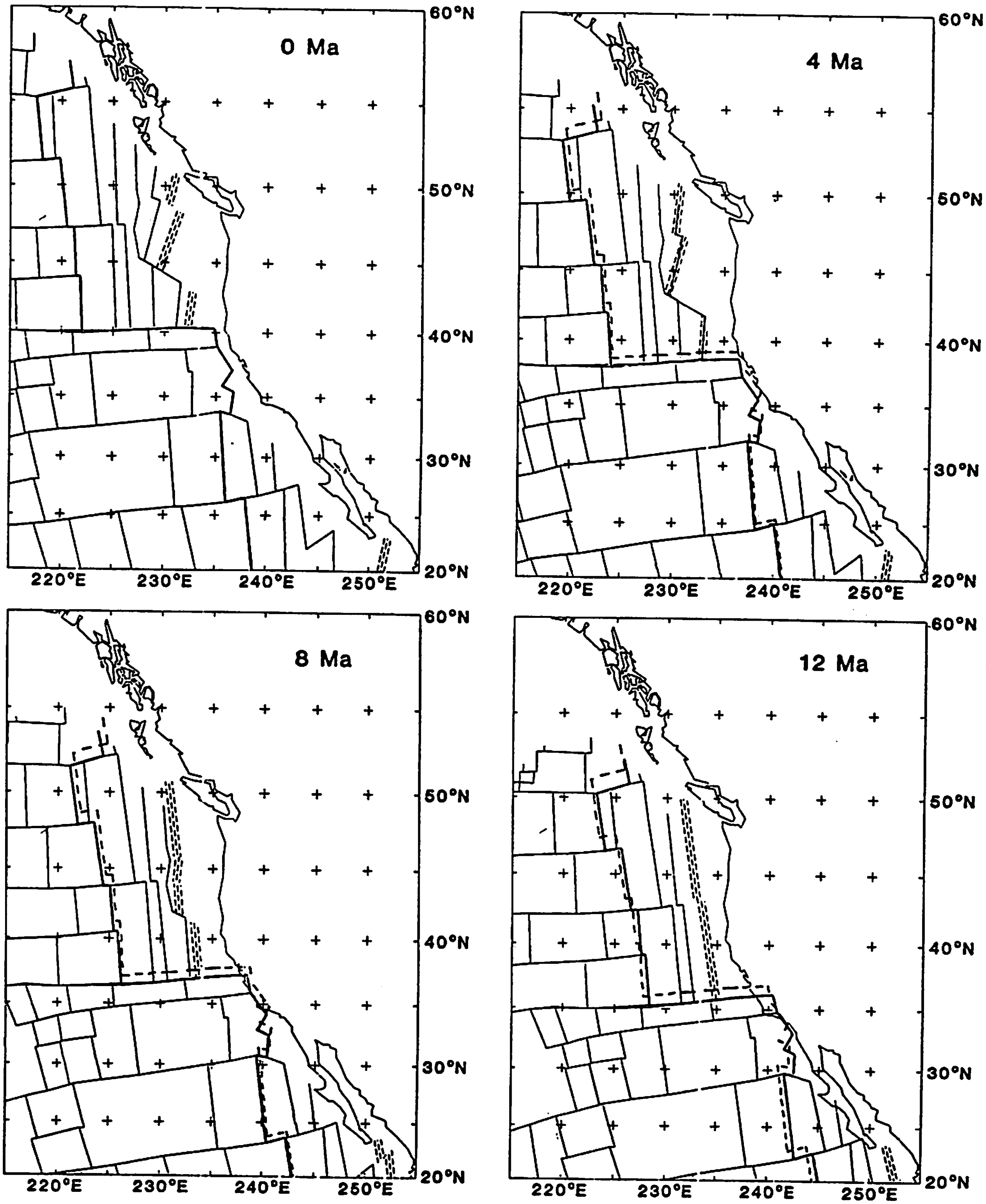
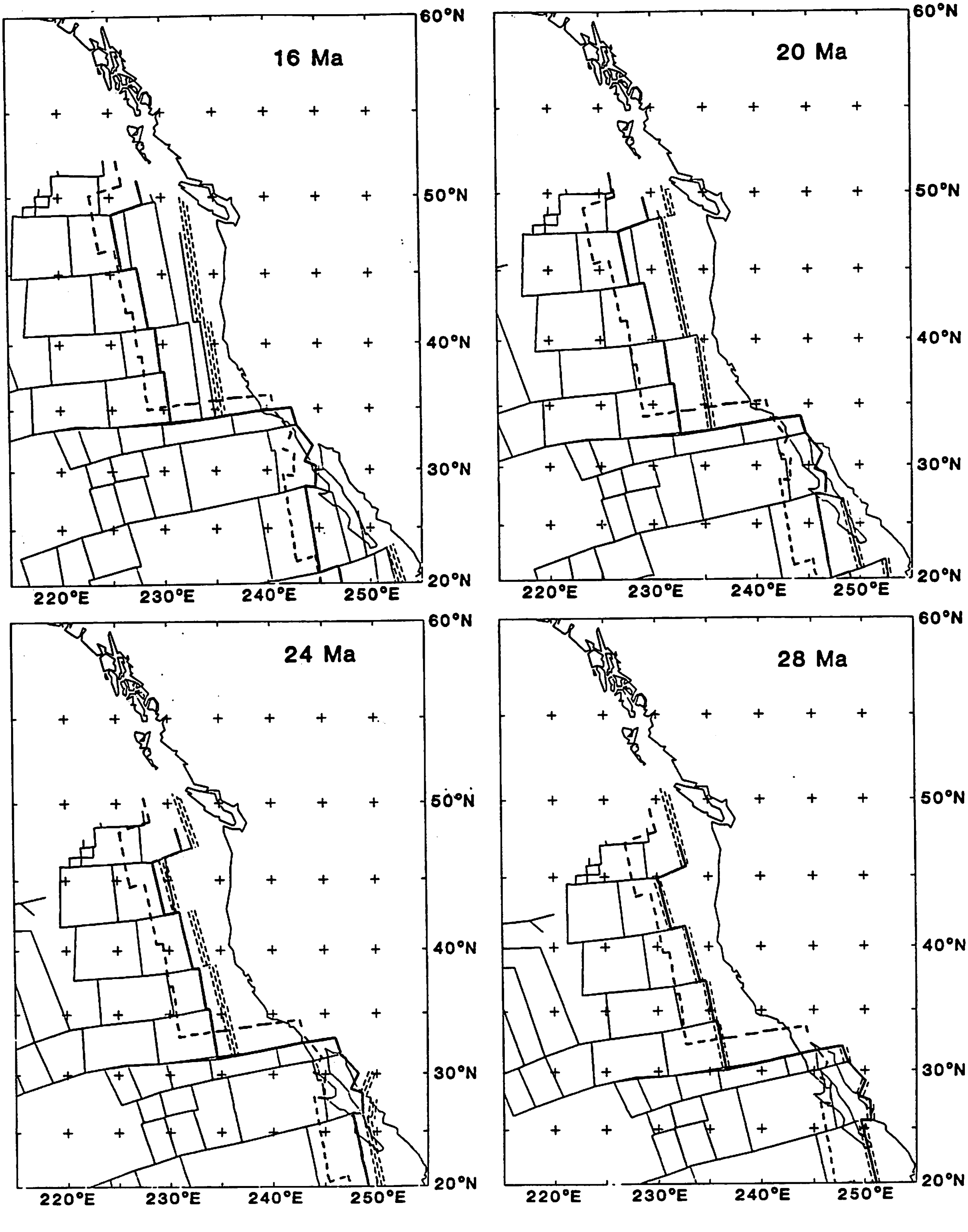


Figure 4 (this and following page). Reconstructions of the Pacific plate relative to a fixed North America plate. Heavy solid line: the chron 8 (28 Ma) Pacific–Farallon isochron obtained using our fixed hotspot model. Heavy dashed line: 28 Ma isochron obtained using the plate circuit through Antarctica. Light dashed band: approximate location of the active ridge at the time of the reconstruction. The rotations used in the global circuit (Table 4) are: North America–Africa, Klitgord and others (1984 and personal communication 1984); Africa–Antarctica, Norton and Sclater (1979); Antarctica–Pacific, Stock and Molnar (1982).


16 Ma
20 Ma
24 Ma
28 Ma
60°N
50°N
40°N
30°N
20°N
220°E
230°E
240°E
250°E

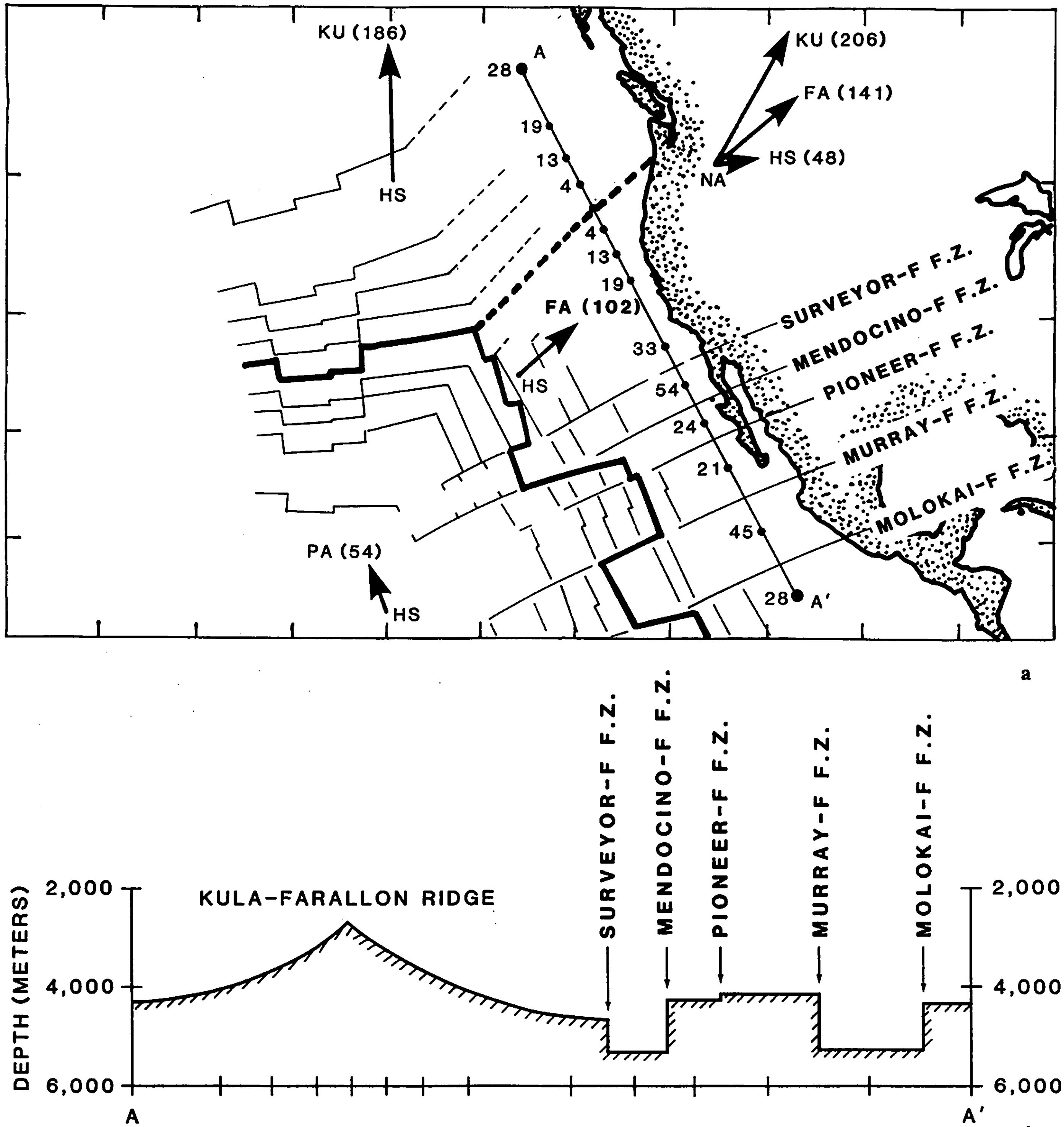


Figure 6. (a) Reconstruction of the plates at 52 Ma showing the age of the Farallon plate along line A–A′. Arrows are linear velocities for the points located at the tails of the arrows. (b) Predicted depth of the Farallon plate along line A–A′ from (a) using the measured depth versus age compilation of Sclater and others (1971).

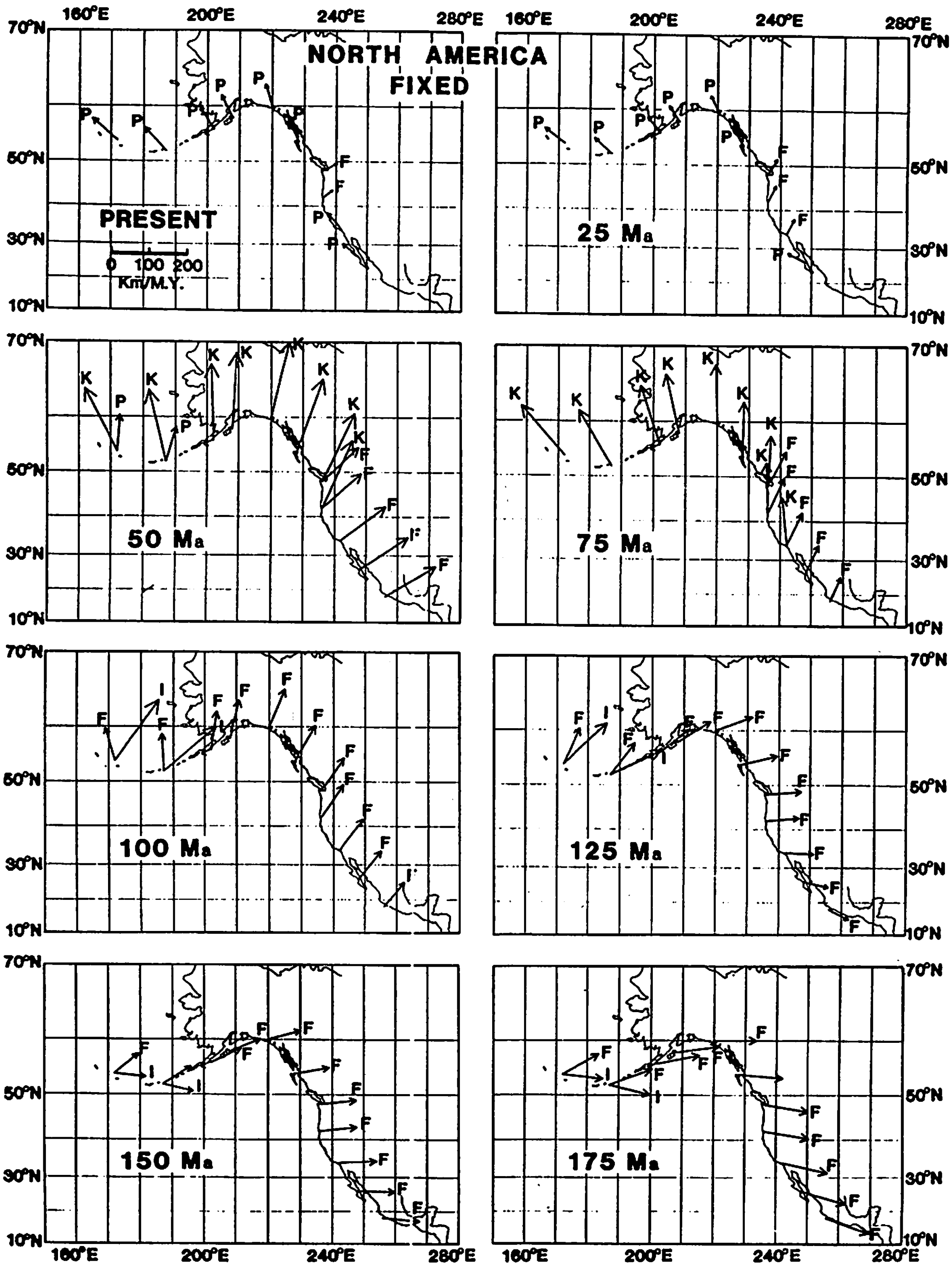
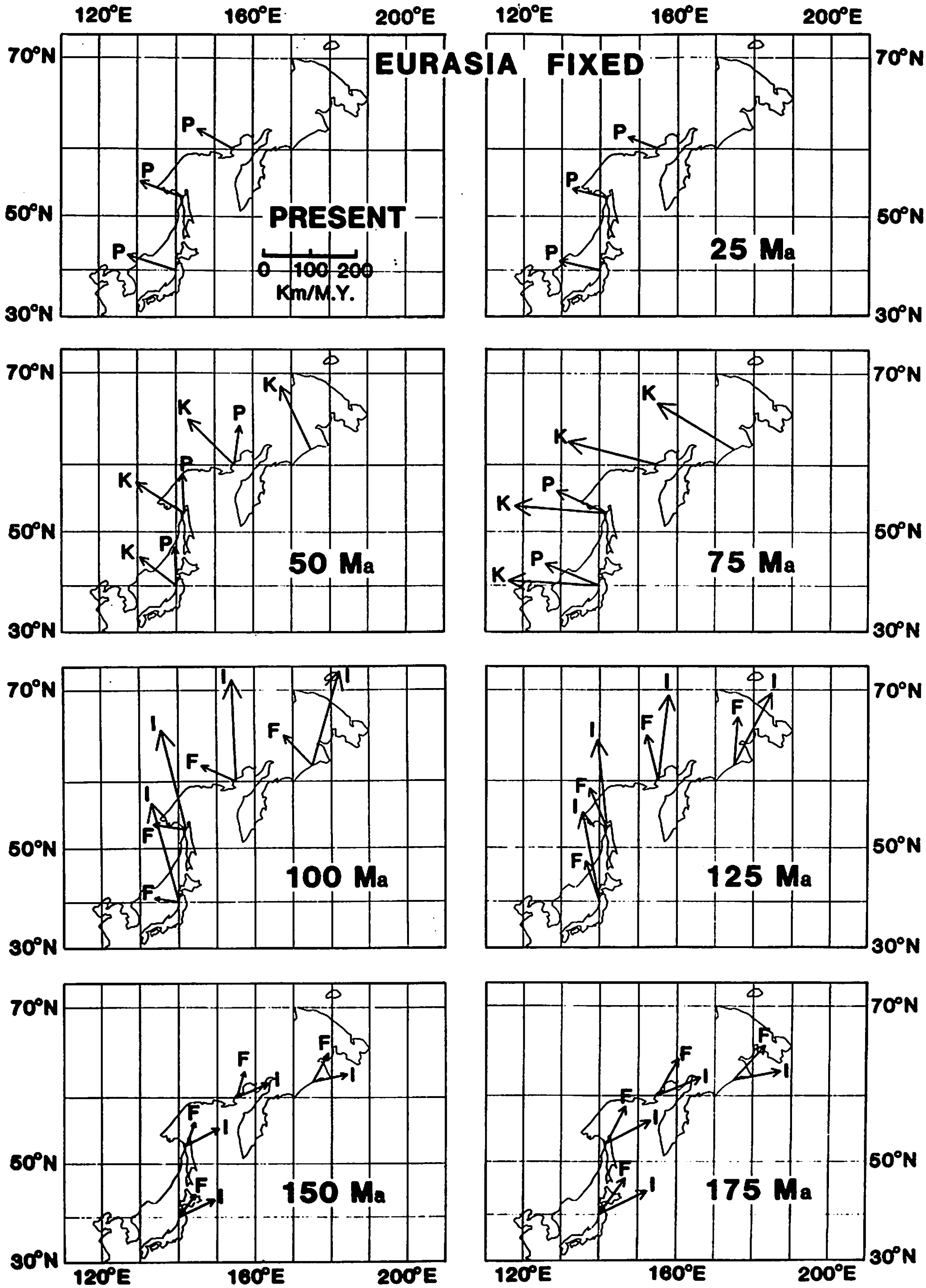


Figure 8 (this and facing page). Convergence velocity vectors of oceanic plates relative to adjacent continental plates. Each arrow at a point along a continental margin shows the convergence velocity of the adjacent oceanic plate at the time indicated, which is between the two times defining the stage used to estimate the velocity vector. Two arrows at certain points show convergence velocities of two oceanic plates when either may have been adjacent to the point. P: Pacific plate. F: Farallon plate. I: Izanagi plate. K: Kula plate. The Izanagi vectors (I) at 175 Ma are based on highly speculative extrapolations of the oldest stage poles for Izanagi–Pacific motion from 145 to 135 Ma. (a) Convergence velocities along North American margin. (b) Convergence velocities along Eurasian margin.


EURASIA FIXED
120°E
160°E
200°E
70°N
50°N
30°N
PRESENT
0 100 200
Km/M.Y.
25 Ma
50 Ma
75 Ma
100 Ma
125 Ma
150 Ma
175 Ma
P
K
F
I