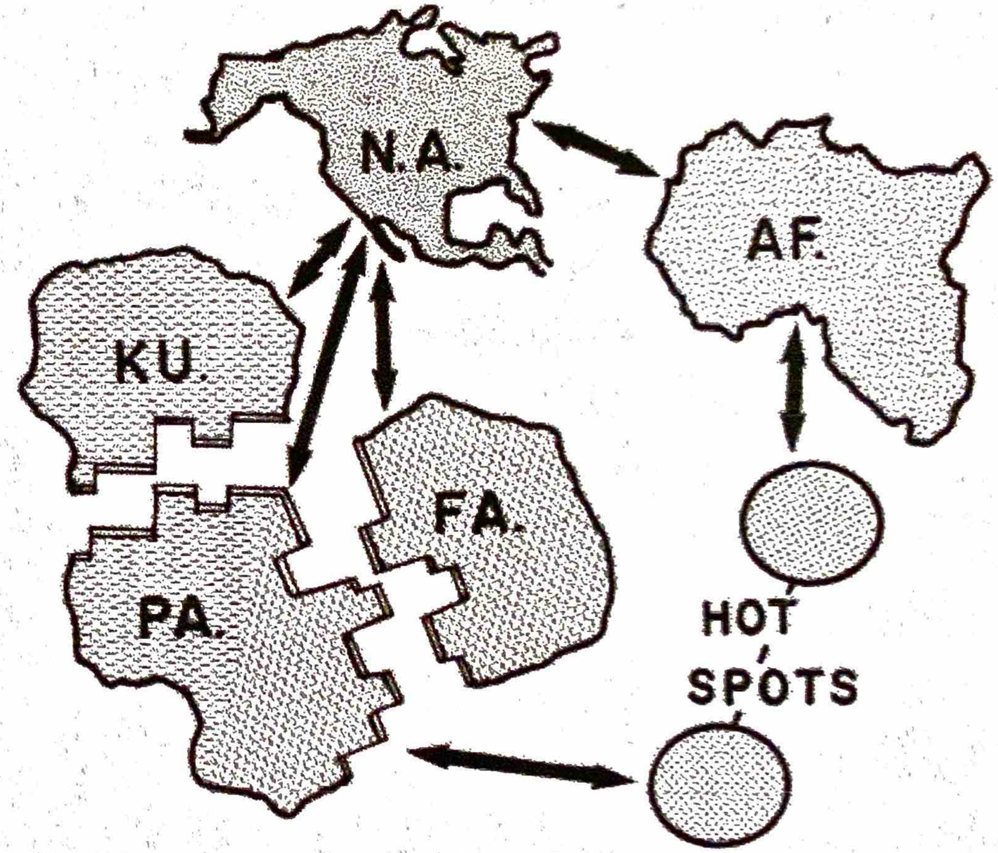
Relative Motions Between Oceanic and Continental Plates in the Pacific Basin

Engebrestson et al., 1985 Geological Society of America Special Paper



Motivation

- Explain cordilleran geology with plate tectonics
  - Need: Euler poles- which describe the former locations of oceanic plates relative to adjacent continents
  - Development of this model allows authors to have the data to discuss some big questions

TABLE 1. Sources of Euler poles used for displacement model.

Age (Ma) From	Age (Ma) To	Latitude °N	Longitude °E	Angle (Deg.)	Reference
PACIFIC-HOTSPOTS					
5	0	56.5	-75.1	4.7	5
28	0	60.8	-71.0	22.8	2
43	0	67.4	-70.5	33.9	2
74	0	52.2	-90.7	49.1	1
100	0	48.8	-81.6	72.7	1
115	0	53.9	-79.8	77.1	1
135	0	56.1	-77.2	86.3	1
145	0	61.1	-78.8	87.3	1
AFRICA-HOTSPOTS					
5	0	50.4	323.1	-1.3	6
9	0	50.4	323.1	-2.4	6
17	0	50.4	323.1	-4.5	6
37	0	40.3	-43.1	-9.8	6
48	0	46.2	-43.1	-12.8	6
65	0	34.7	-56.9	-22.3	6
PACIFIC-FARALLON N.O.M.[11]					
5	0	-19.2	206.5	-3.1	11
9	5	-77.9	69.0	-5.0	11
17	9	-48.0	252.1	-6.5	11
28	17	-80.6	245.1	-7.5	12
37	28	-79.7	31.9	-13.1	12
43	37	-79.7	31.9	-11.0	12
48	43	-79.7	31.9	-8.0	12
56	48	-77.4	358.4	-10.6	12
61	56	-56.0	244.2	-3.8	12
68	61	-56.0	244.2	-3.4	12
74	68	-56.0	244.2	-5.7	12
85	74	-56.0	244.2	-7.5	12
100	85	-61.9	236.0	-13.1	12
119	100	-61.9	236.0	-16.1	12
127	119	-9.2	195.7	-7.4	12
135	127	-9.2	195.7	-7.4	12
145	135	-35.3	227.3	-5.0	12
153	145	-35.3	227.3	-11.3	12

Model

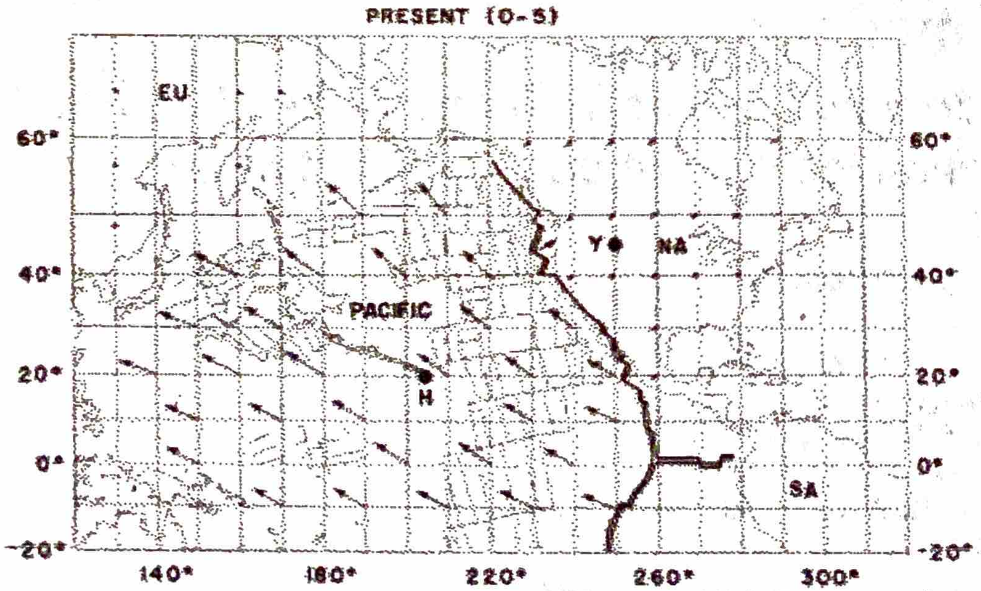
- Relative Motion model methods and assumptions
  - Model based on previously determined reconstructions, calculated movement of plates relative to hotspots to find their motions relative to each other. Assumption: Hot Spots are Fixed
- Reconstructions used to build the model
  - Errors and Uncertainties: Hot spots do move, errors in determining plate hot spot motion; plate plate motion, general location of boundary between oceanic plates

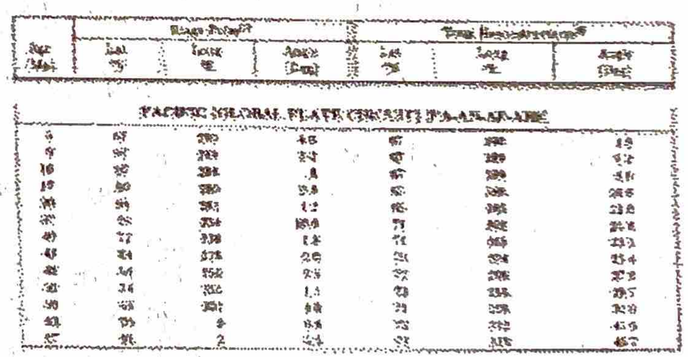
Sources for the reconstruction

References:
(1) Henderson and Gordon (1981); (2) Jarrard and Clague (1977); (3) Klitgord et al. (1982); (4) Koenig (1980); (5) Minster and Jordan (1978); point on error ellipse for Euler pole closest to equator; (6) Morgan (1980); (7) Norton and Sclater (1979); (8) Sibuet and Mascle (1978); (9) Srivastava (1978); (10) Stock and Molnar (1982); (11) Wilson et al. (1982); (12) this paper.

Relative Motion Reconstruction

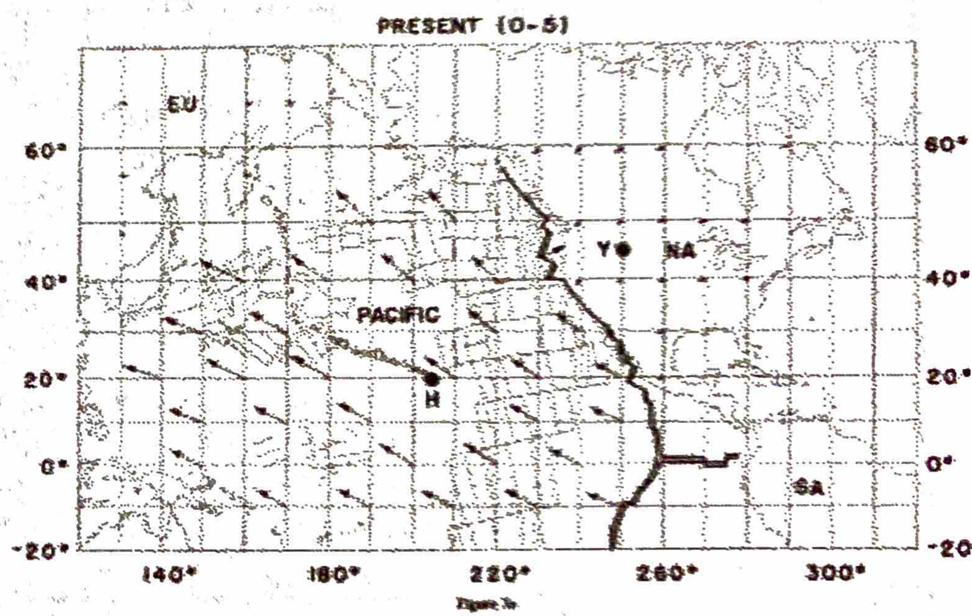
- Reconstructions were generated by rotating magnetic anomalies and fracture zones from their present location back to their earlier locations using the pacific hotspot poles





Reconstruction Details

- Data: Isochrons and fracture zones.
- Isochrons indicate where the ridge was previously
- Arrows show direction and velocity of plate motion; scaled to show the distance the plate would move in 10 my based on stage pole
- Stage pole previously calculated



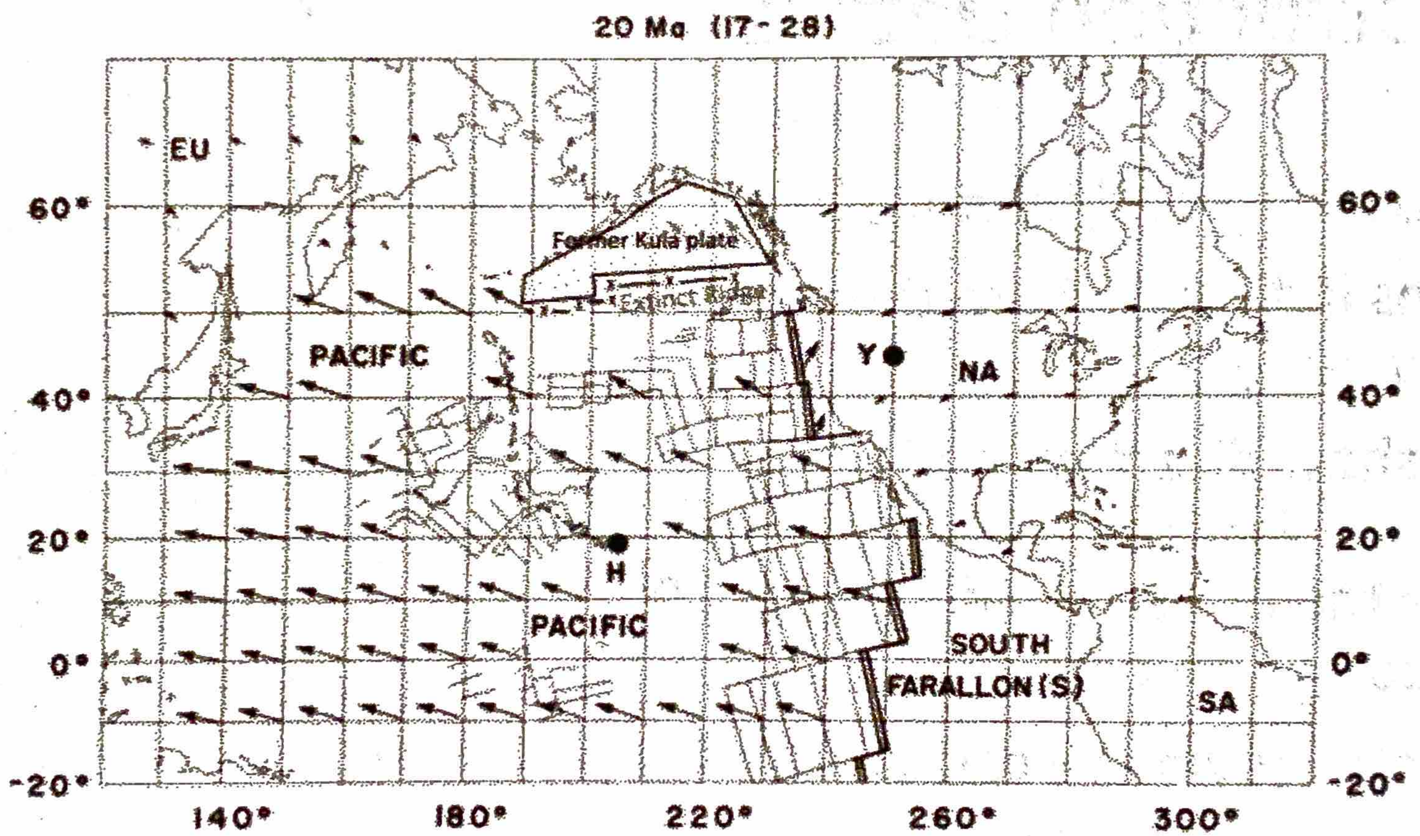

20 Ma (17 - 28)
EU
Former Kula plate
Extinct Ridge
PACIFIC
Y
NA
H
PACIFIC
SOUTH
FARALLON (S)
SA
60°
40°
20°
0°
-20°
140°
180°
220°
260°
300°

Figure 3b

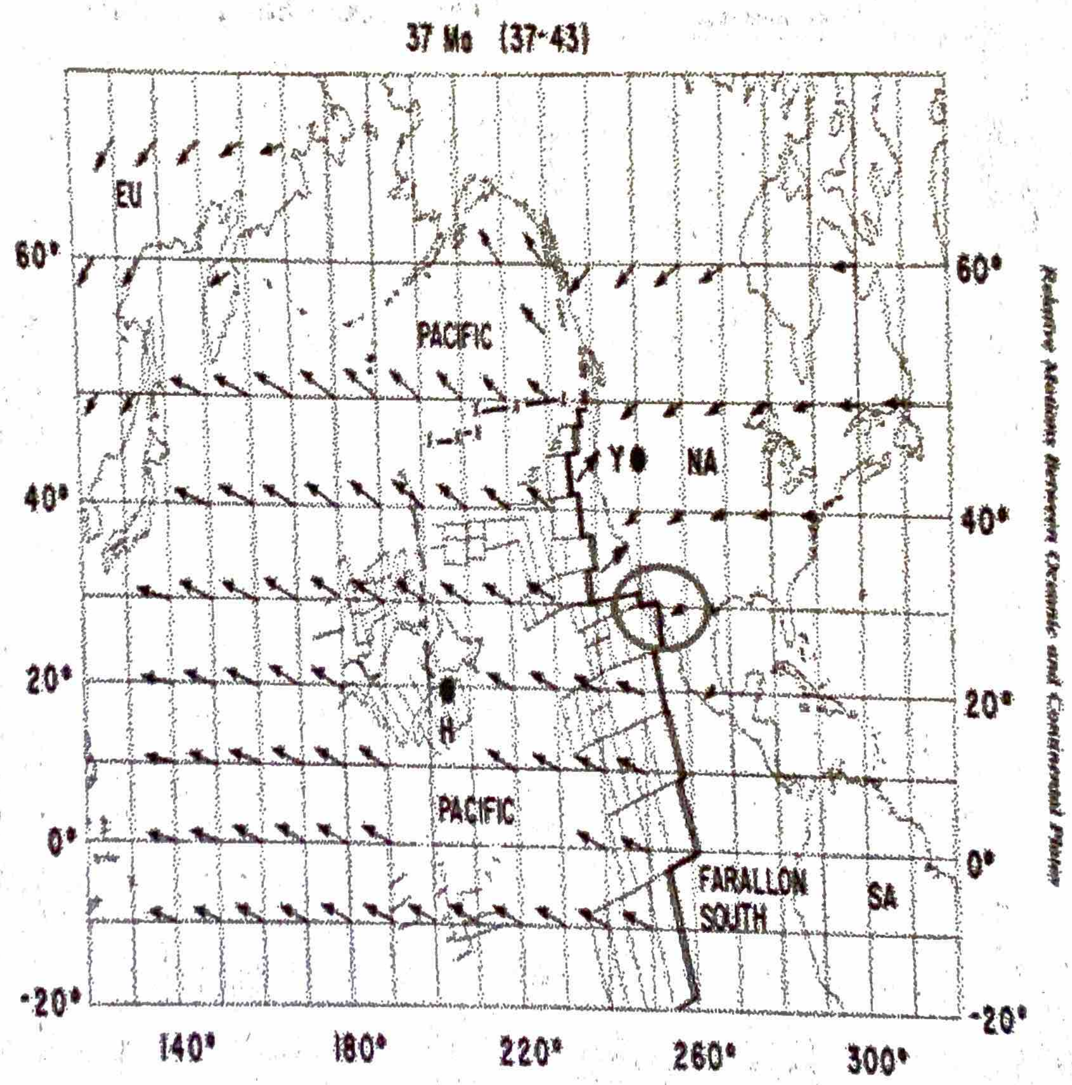
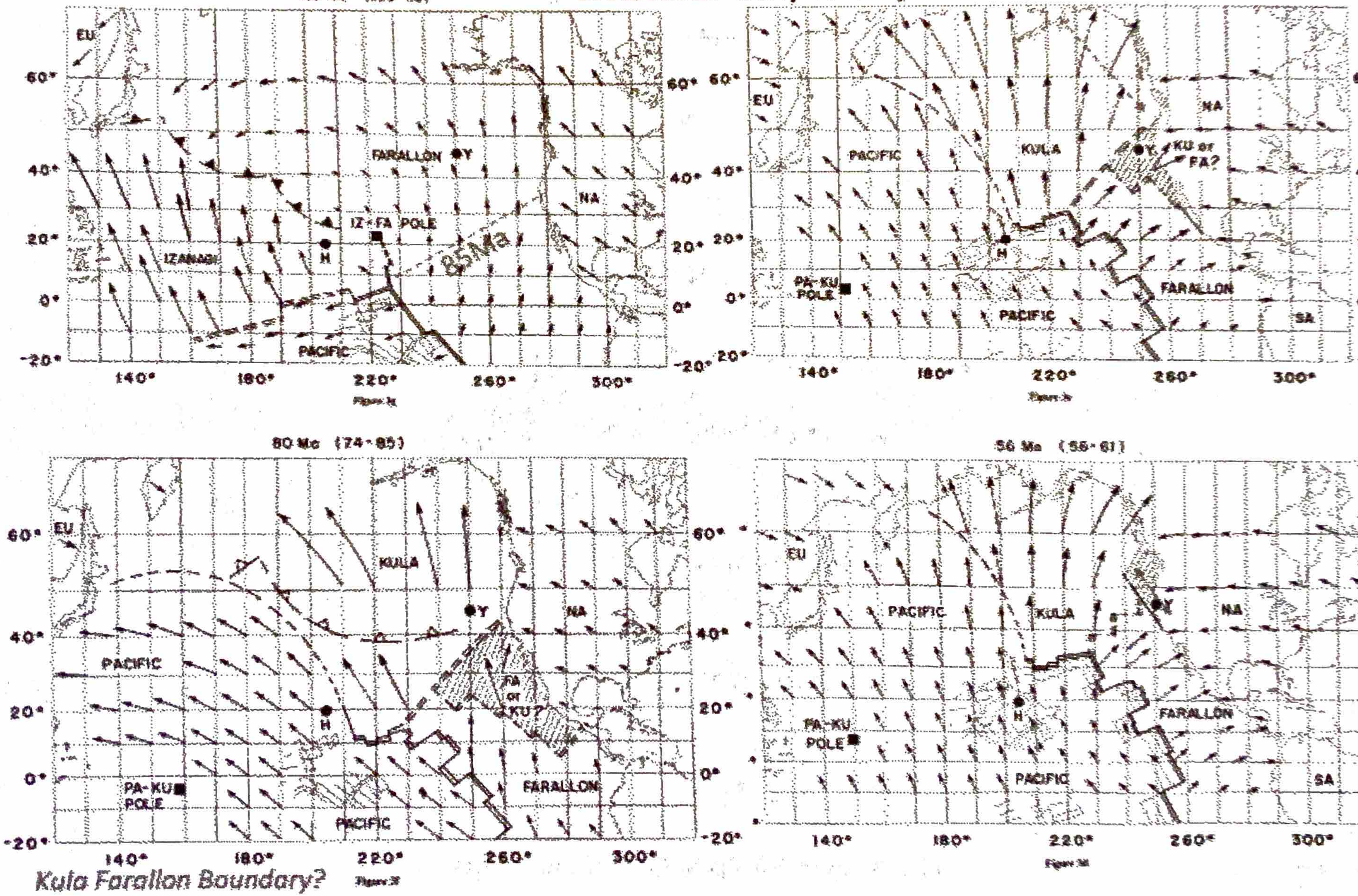


Figure 3c

First Pacific NA Plate Contact @ 37Ma

Cretaceous- Early Tertiary



Kula Farallon Boundary?

NW Faults, Cretaceous Dextral Motion in Washington

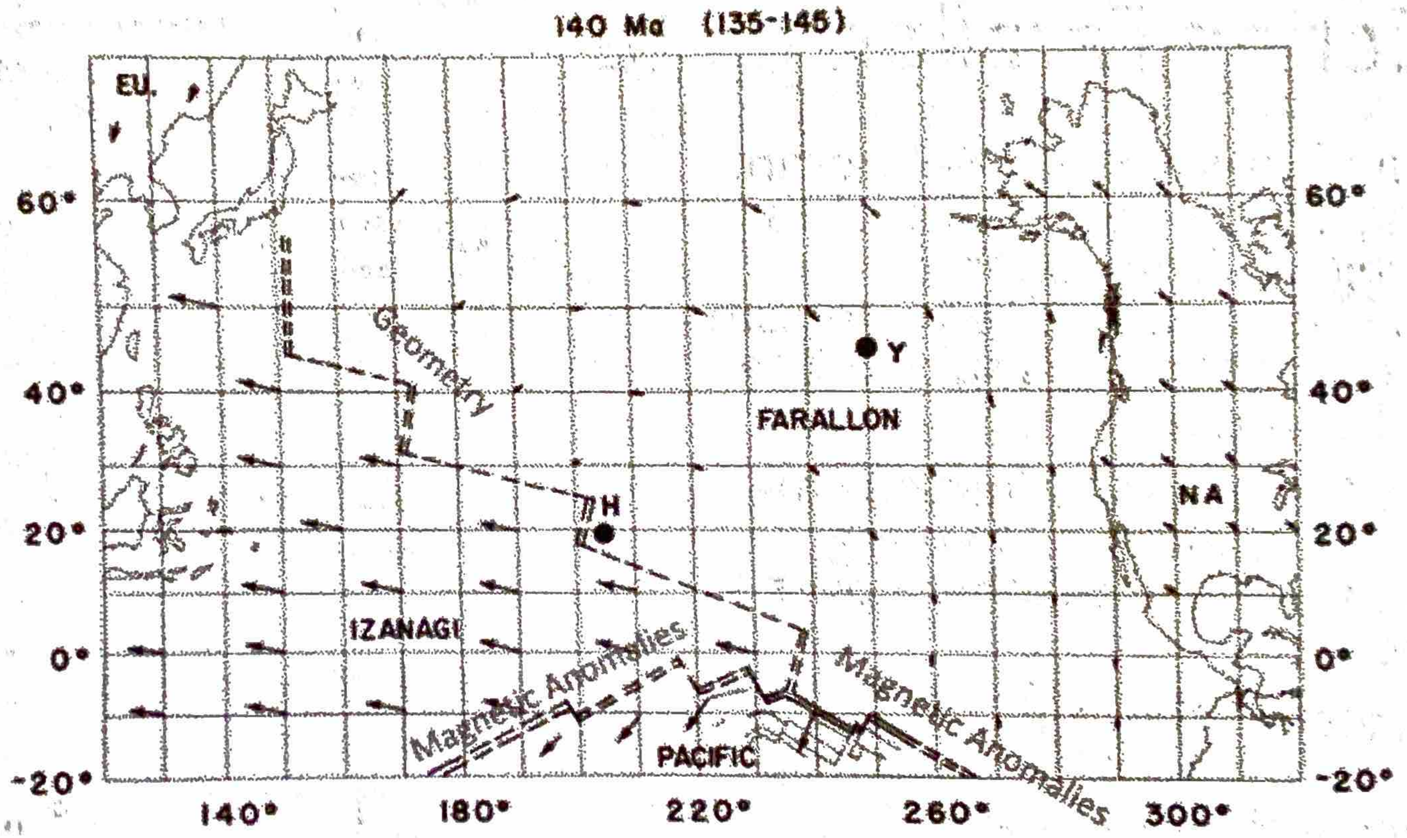
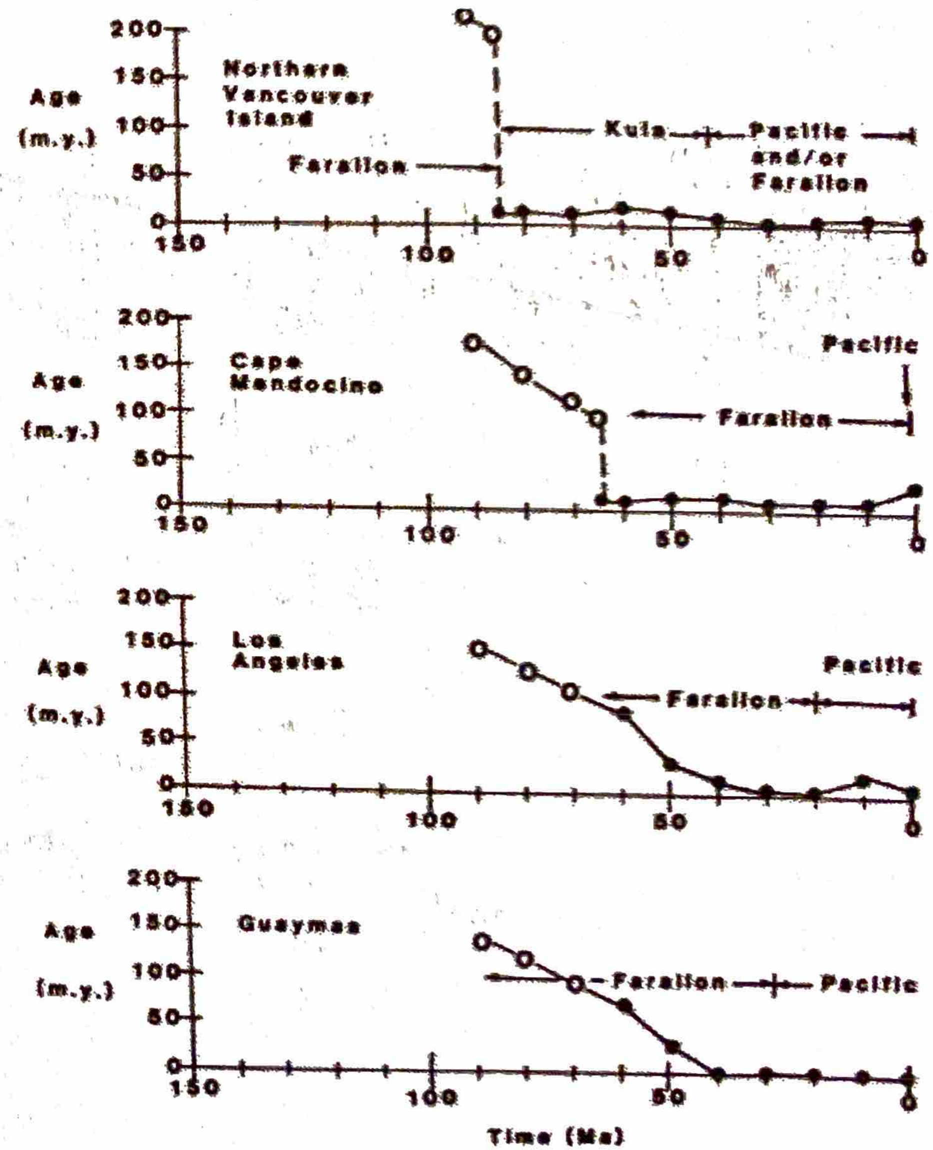

140 Ma (135-145)
EU.
60°
40°
20°
0°
-20°
140°
180°
220°
260°
300°
Geometry
FARALLON
Y
H
NA
IZANAGI
Magnetic Anomalies
PACIFIC
Magnetic Anomalies

Figure 3h

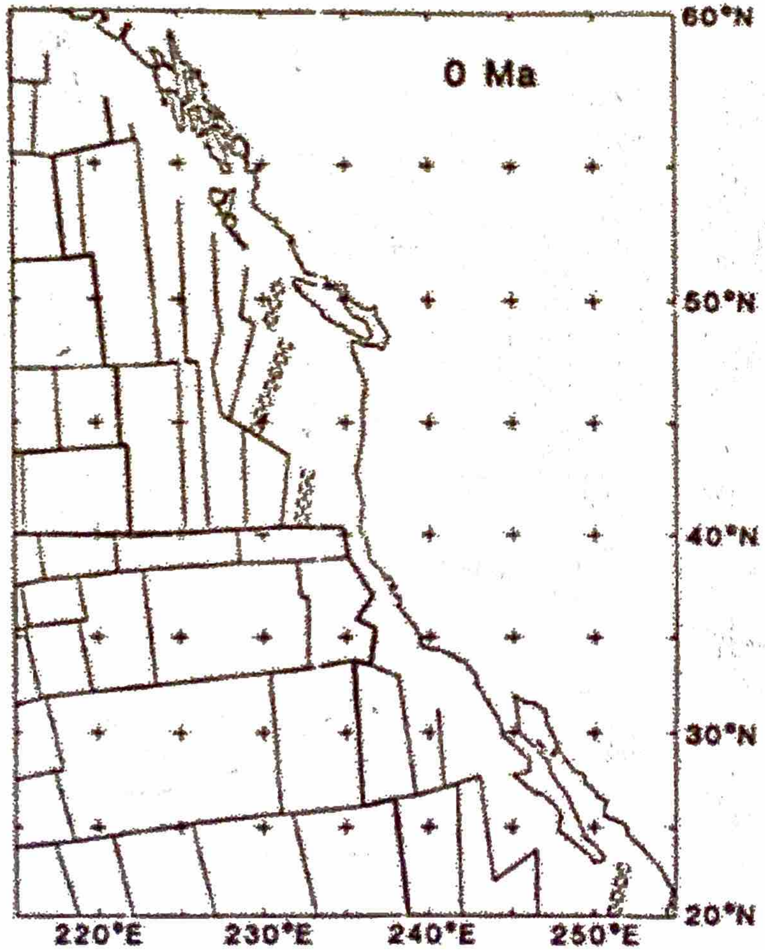
Age and thickness of subducting Farallon plate

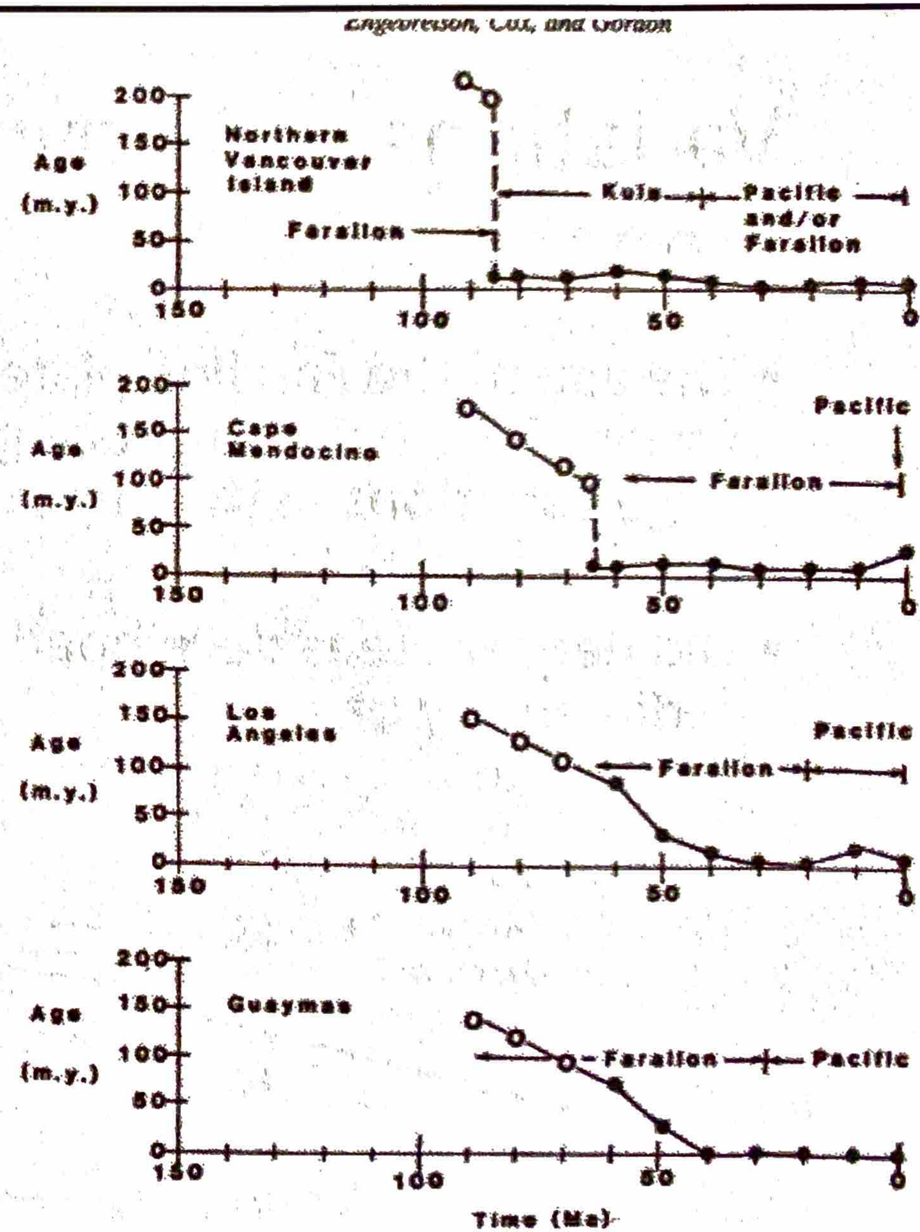
- Molnar and Atwater 1978- Interarc spreading occurs behind trenches subducting old lithosphere; Collision like compressive tectonism occurs behind trenches subducting young lithosphere
- Laramide Compressive Tectonism- Caused by subduction of young buoyant Farallon lithosphere over a long time
- Constructed synthetic Farallon and Kula plates to estimate Farallon age: ~<150 My greater than 50My

Age Estimates for descent into trench



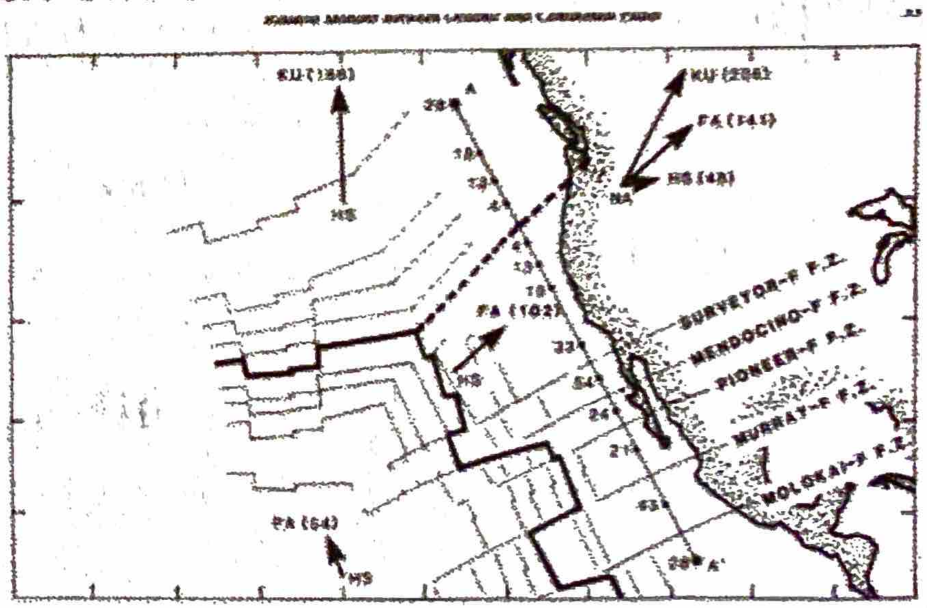
Synthetic Farallon Kula Plate Reconstruction



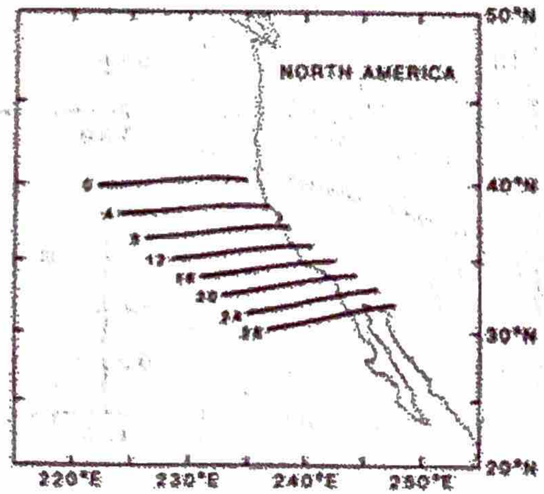


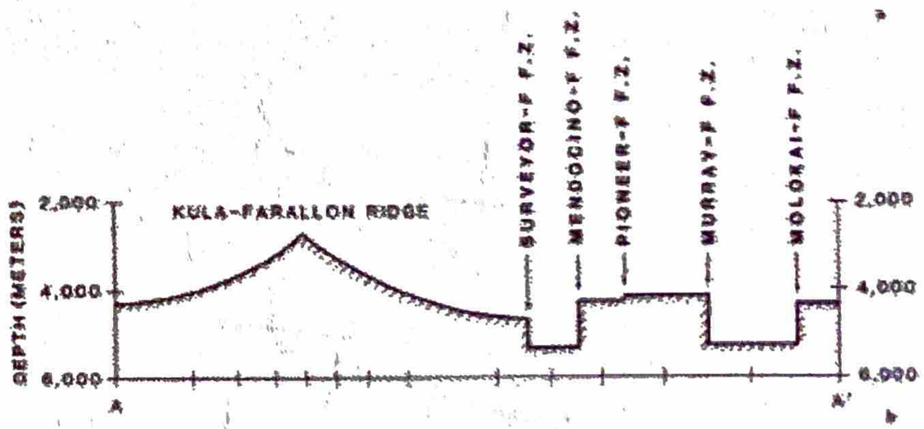
Variations in Bathymetry Parallel to the Trench

- The age of the Farallon plate varies along strike producing large variations in the depth of the Farallon plate
- Old denser areas developed sedimentary basins



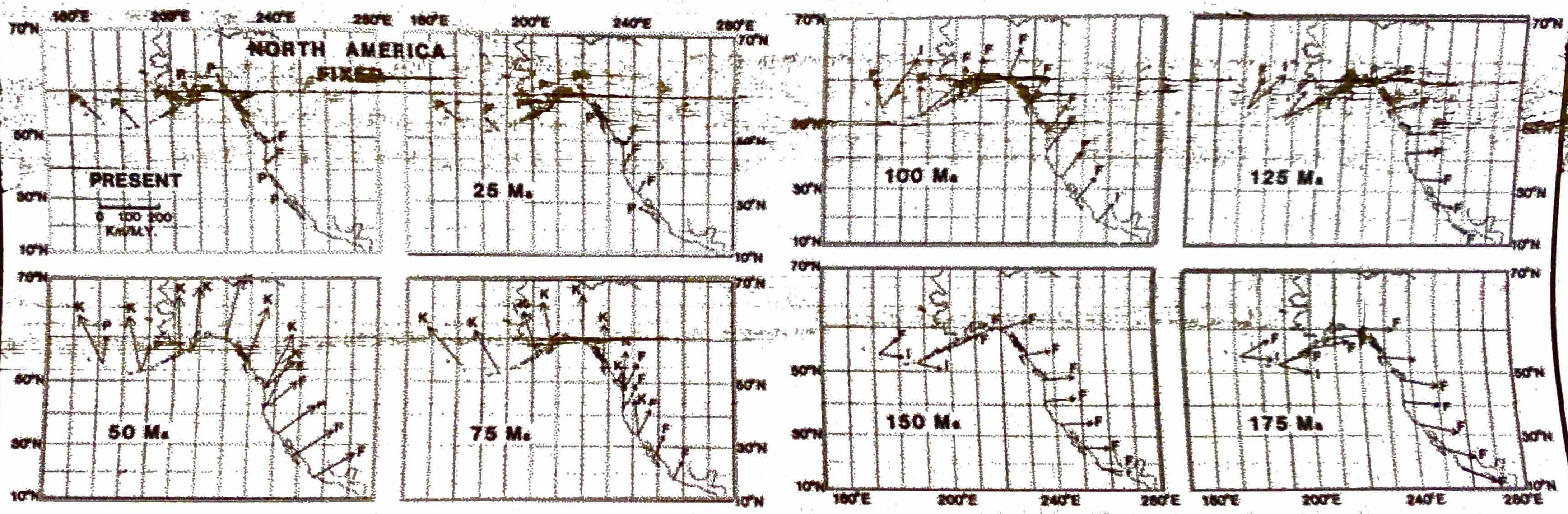
Trace of Mendocino Fracture Zone





Velocity of Convergence

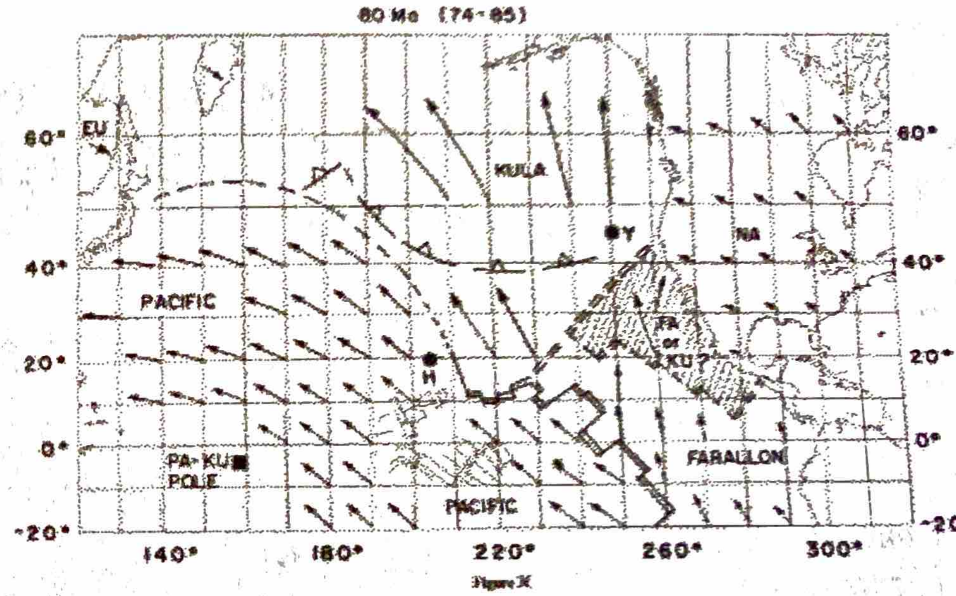
- Calculated convergence velocity vectors of oceanic plates relative to adjacent continental plates

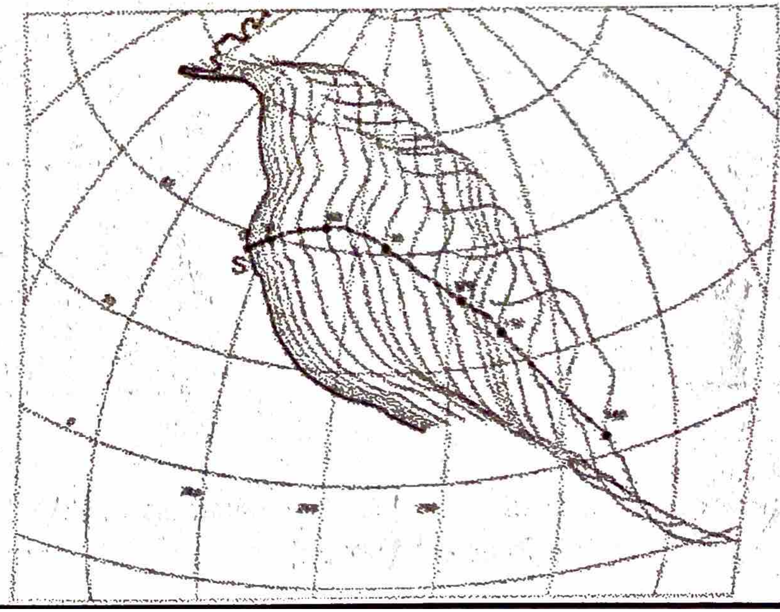


Convergence: Late Jurassic and Early Cretaceous (EW ~100 km/my) -> Late Cretaceous (NE SW oblique) -> Eocene (Oblique Most Rapid) -> Oligocene – Present (Small)

Trajectories of Plates

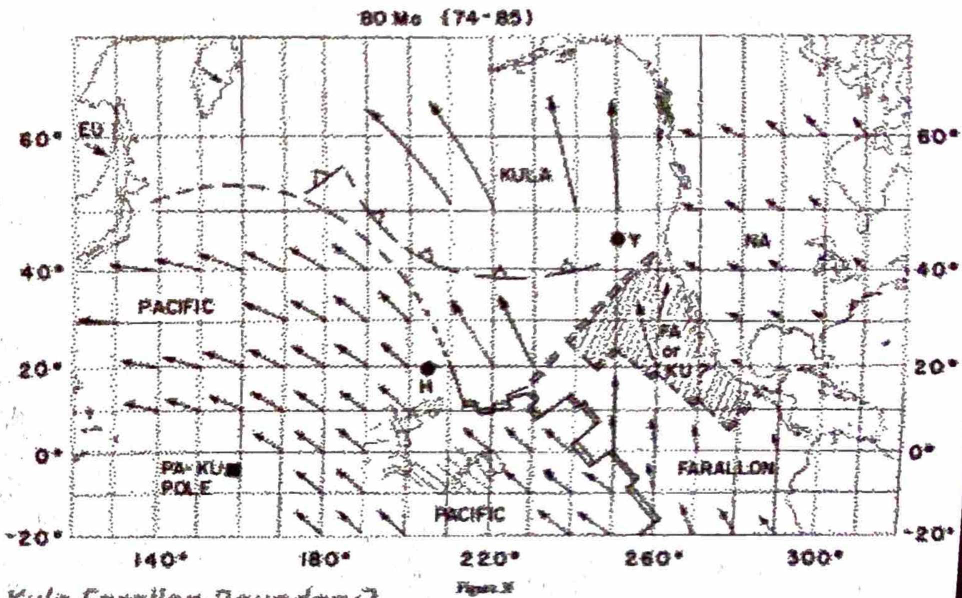
- Kula and Izanagi plates moved to the North
  - Capable of moving terranes North
- Farallon plate swept in Easterly direction
  - Capable of moving terranes West to East
- North American Plate as a Whole
  - Moving to the West, moving faster over a hot spot @60 Ma





Model vs Geologic Events

- Proposed links between plate tectonics and the Laramide orogeny: Change in the absolute motion of North America, decrease in the age of the subducting plate, a change in the rate of convergence, ***a shallowing of the angle of subduction***, and the arrival of allochthonous terranes
- Magmatic lull and increase in the arc trench distance is attributed to anomalously shallow dipping subduction of the Farallon plate beneath North America
- If their model is correct (North Extent of K-F boundary) then southward migration of magmatic lull agrees, but there should be one moving northward too... there isn't



Kula Farallon Boundary?

- Increase in convergence rate before Laramide = evidence for younging and shallowing
  - Increase due to changes in the Pacific-hotspot motion which is seen best when comparing the motion of NA relative to Pacific Hot Spot
- Conclusion: More than one tectonic process produced the Laramide orogeny