

# *Reconstructing the Northern Gulf of California-Salton Trough Oblique Rift*

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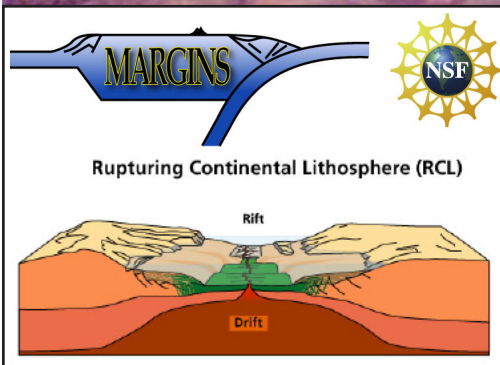
*Paper 3 - 8*

*GSA Cordilleran*

*Section Meeting*

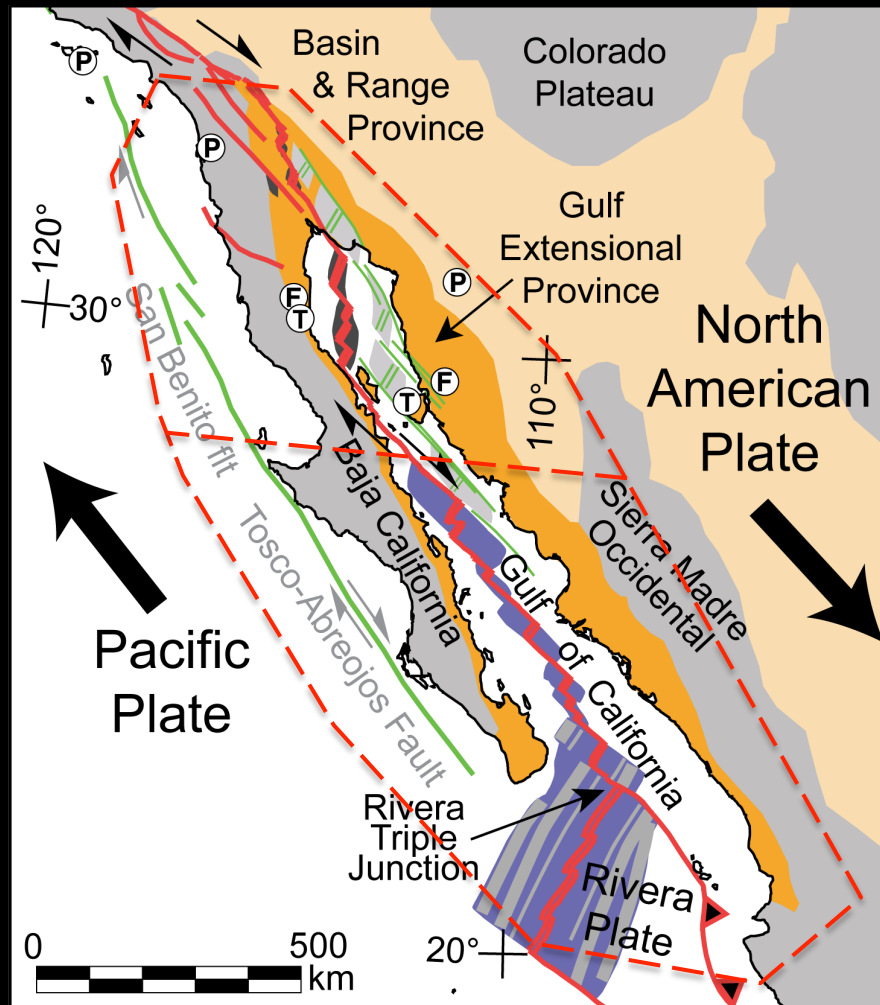
*Queretaro, Mexico*

*April 29, 2012*



**UC DAVIS**  
DEPARTMENT OF GEOLOGY

# Gulf of California-Salton Trough Reconstruction



Oskin & Stock (2003), Arregón-Arreola & Martín-Barajas (2007), Fletcher et al. (2007)

## GOALS

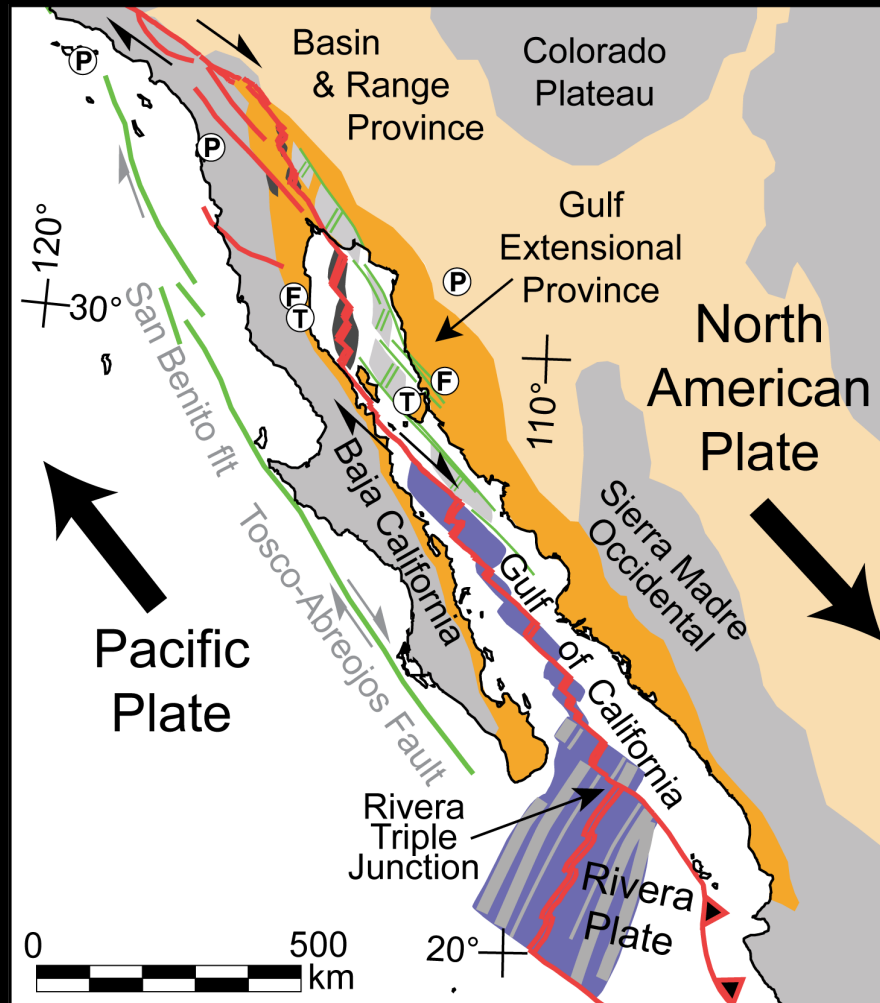
- MARGINS integrative/synthesis activity
- Summarize current state of knowledge for MARGINS focus site
- highlight recent advances in understanding in 4-D strain evolution
- highlight unresolved controversies
- visual tool for Earth Science educators

## METHODS

- GIS-based
- 0 - 2 Ma (every 1 myr)
- 2 - 16 Ma (every 2 myr)

See Skinner et al. poster for Southern Gulf Reconstruction  
Paper 10 - 1, Booth # 38 (This Afternoon)

# Gulf of California-Salton Trough Reconstruction

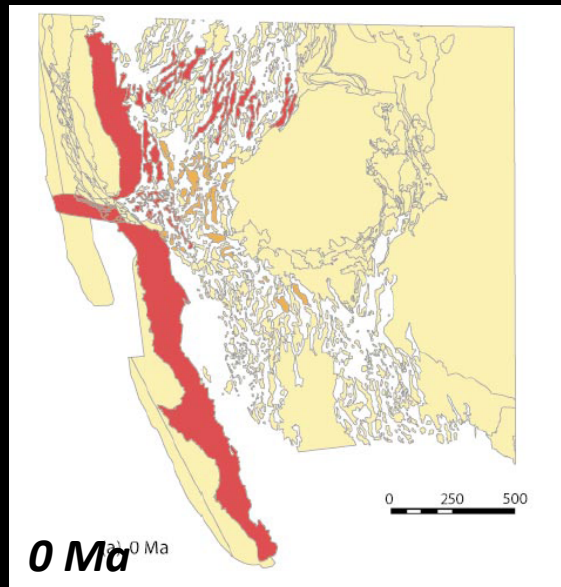


Oskin & Stock (2003), Arregón-Arreola & Martín-Barajas (2007), Fletcher et al. (2007)

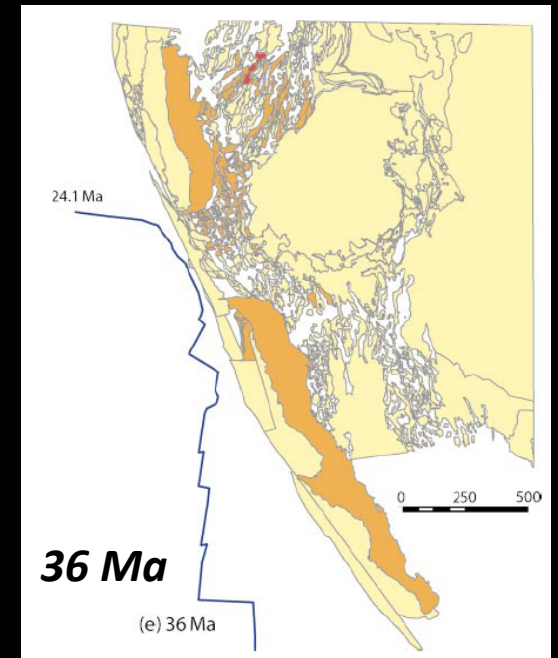
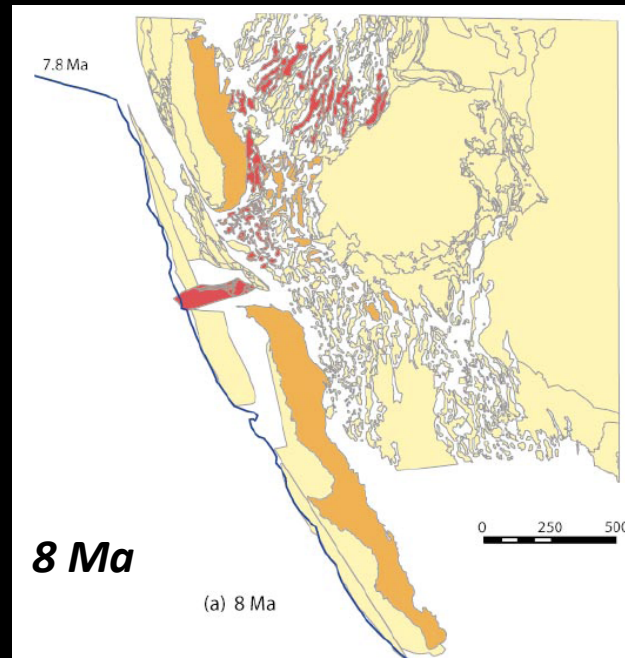
## DATA CONSTRAINTS

- location of major shear zones and extensional basins
- plate boundary studies  
e.g. Atwater & Stock (1998), DeMets (1995)
- geodetic studies  
e.g. Plattner et al. (2007)
- cross-Gulf tie points  
e.g. [T] Oskin et al. (2001)  
[F] Bryant (1986) and Gastil & Krummenacher (1977)  
[P] Poway conglomerate outcrops in NW Sonora and SoCal
- Since ~6.1 Ma, >90% of PAC-NAM motion in GOC  
- similar to modern-day GPS budget
- detailed geologic studies  
e.g. Bennett (2009), Seiler et al. (2010), many others
- Westward Migration of deformation  
e.g. Aragon-Arreola & Martin-Barajas (2007),  
Bennett et al. (submitted, GSABull)

# *Previous Reconstructions*



*McQuarrie & Wernicke (2005)*



# GIS Reconstruction Tool

“Tectonic Reconstruct”  
by Richard Nava (USGS)

GIS v10

Install Add-In File

Excellent  
Reference  
Manual

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## Tectonic Reconstruct for ArcGIS 10 - v1.1



By [rnavasnz\\_12](#)  
★★★★★ (0 rating)  
[di](#) [f](#) [in](#) [i](#) [p](#) [su](#) [t](#) [e](#)

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### Description

Tectonic Reconstruct provides a set of tools for the sequential reconstruction of tectonic features. Polygon or polyline type geometries, populated with rates of movement and directions, are continuously displaced from their present location for different points in time (time slices). Once reconstructed, displacement parameters for each feature in each time-slice may be modified inside an editing environment designed specifically for the recalculation of displacement values through map interaction.

The zip file includes:

- Add-In file for installation
- Reference manual
- Source code

### Access and Use Constraints

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### Comments

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# GIS Reconstruction Tool

“Tectonic Reconstruct” v1.1

Table

Master Layer

| A_RATE_6 | A_AZIM_6 | A_RATE_12 | A_AZIM_12 | A_RATE_18 | A_AZIM_18 | A_RATE_24 | A_AZIM_24 | A_RATE_36 | A_AZIM_36 |
|----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 65.26    | 70       | 50.38     | 70        | 51.14     | 127       | 48.14     | 127       | 40.69     | 70        |
| 49.04    | 70       | 46.3      | 70        | 75.15     | 127       | 59.24     | 127       | 51.29     | 70        |
| 42.68    | 70       | 63.05     | 70        | 71.87     | 127       | 56.07     | 127       | 53.72     | 70        |
| 44.86    | 70       | 41.72     | 70        | 44.54     | 127       | 68.8      | 127       | 54.15     | 70        |
| 52.89    | 70       | 43.76     | 70        | 69.73     | 127       | 63.86     | 127       | 48.74     | 70        |

0 (0 out of 5 Selected)

Master Layer

Tectonic Reconstruct

Input data frame:

Master layer:

Time slice units: Ma

Time slices: 1, 2, 4, 6

Slice prefix: time\_slice

☒ First displacement fields

Rate prefix: A\_RATE

Azimuth prefix: A\_AZIM

☒ Second displacement fields

Rate prefix: B\_RATE

Azimuth prefix: B\_AZIM

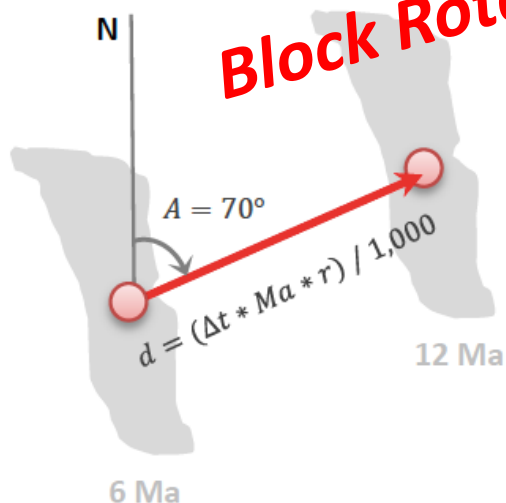
☐ Inherit layer symbology

CONSTRUCT RECONSTRUCT

# GIS Reconstruction Tool

"Tectonic Reconstruct" v1.1

| Master Layer |          |           |           |           |           |           |           |     |
|--------------|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----|
| A_RATE_6     | A_AZIM_6 | A_RATE_12 | A_AZIM_12 | A_RATE_18 | A_AZIM_18 | A_RATE_24 | A_AZIM_24 | A_F |
| 65.26        | 70       | 50.38     | 70        | 51.14     | 127       | 48.14     | 127       |     |
| 49.04        | 70       | 46.3      | 70        | 75.15     | 127       | 59.14     | 127       |     |
| 42.68        | 70       | 63.05     | 70        | 71.87     | 127       |           | 127       |     |



**Block Rotation Coming Soon!**

- Feature centroid
- Displacement vector

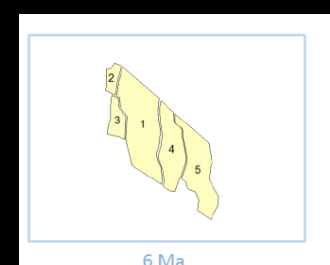
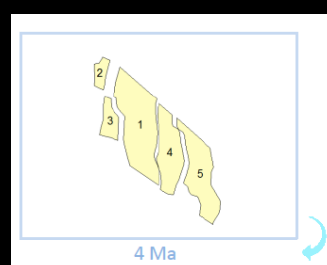
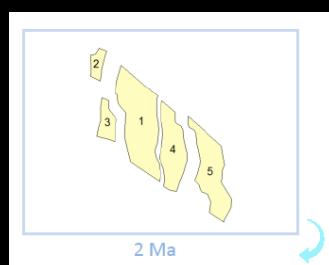
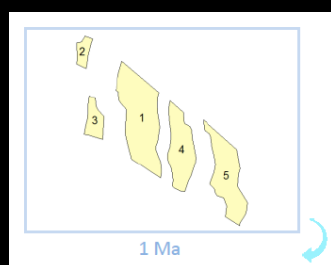
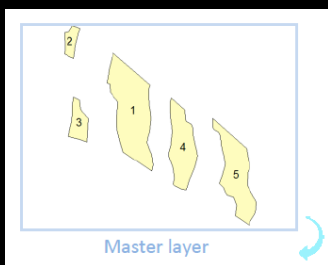
$$\Delta t = \text{slice} - \text{prev slice} = 12 - 6 = 6 \text{ Ma}$$

$$r = 50.38 \text{ mm/a}$$

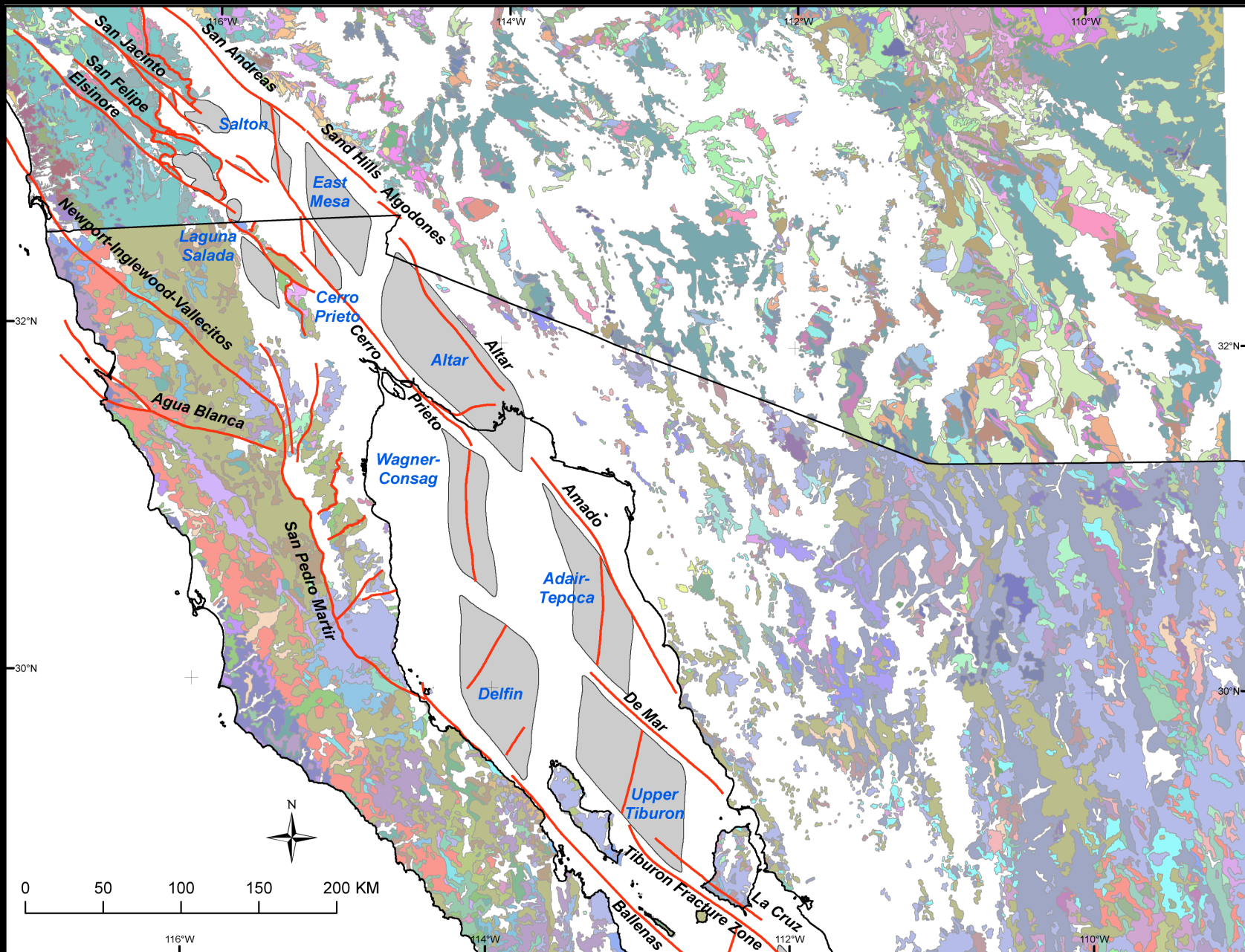
$$Ma = 1,000,000 \text{ a}$$

$$d = (\Delta t * Ma * r) / 1,000$$

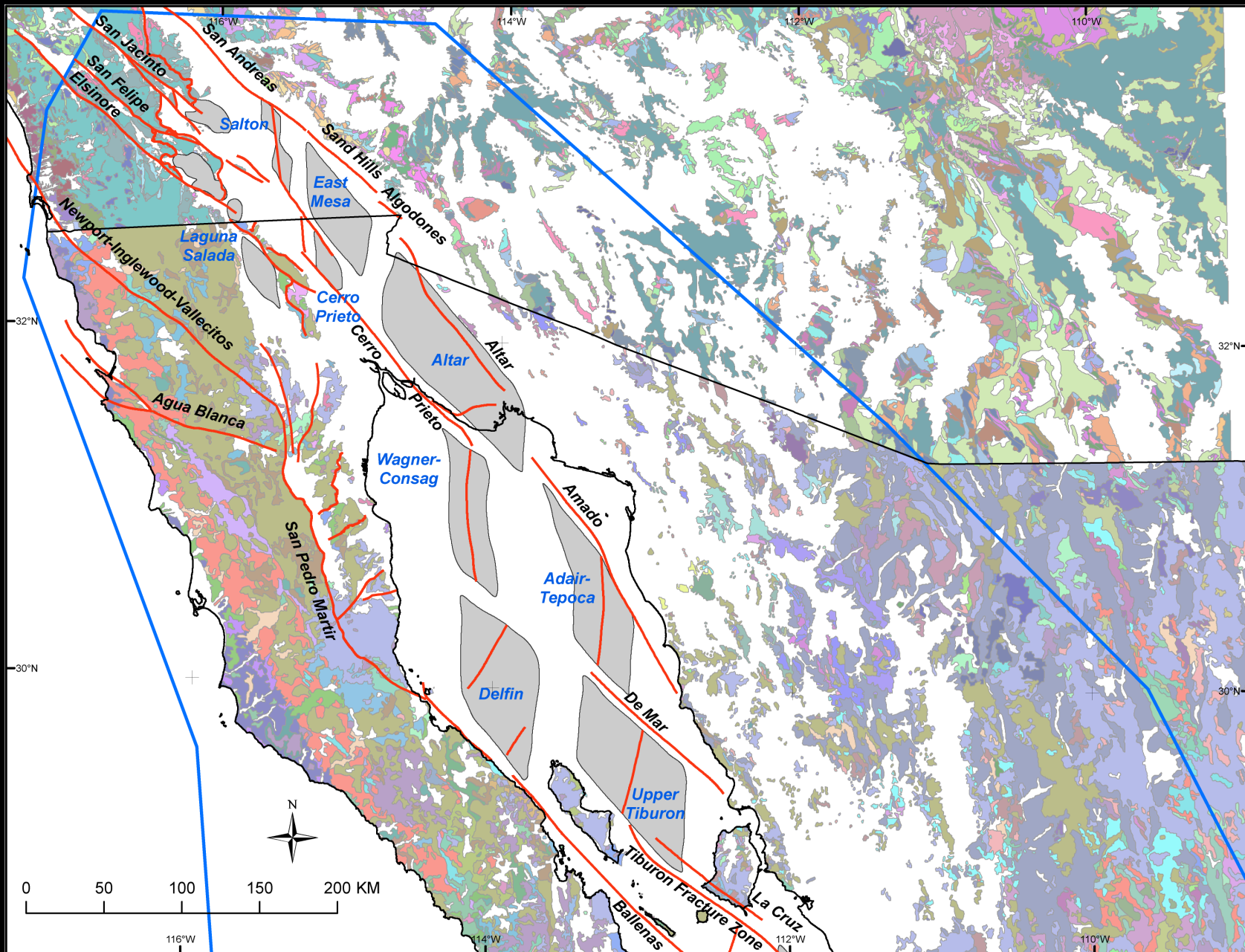
$$d = (6 * 1,000,000 * 50.38) / 1,000 = 30,228 \text{ m}$$



# Present-Day Geology



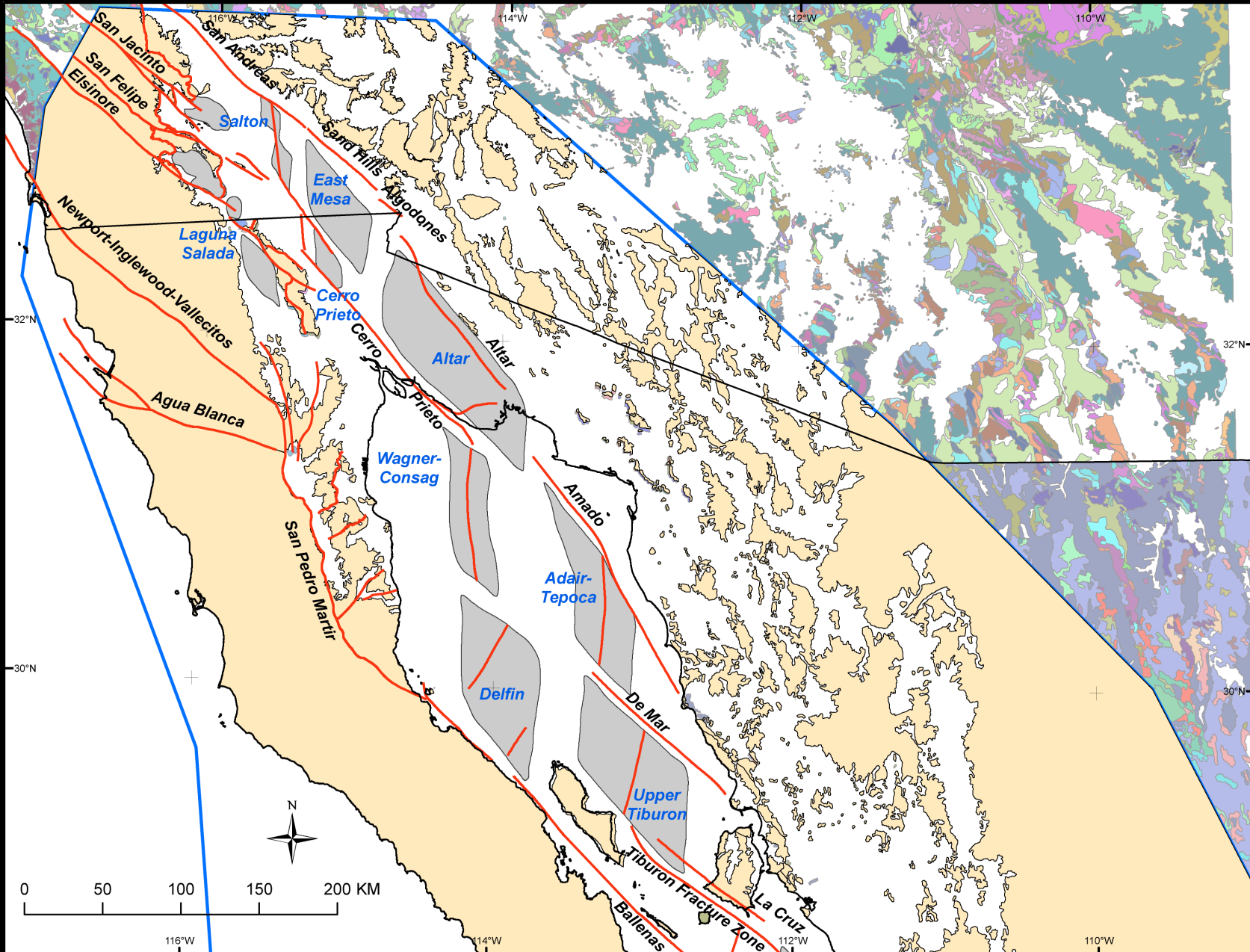
# Present-Day Geology



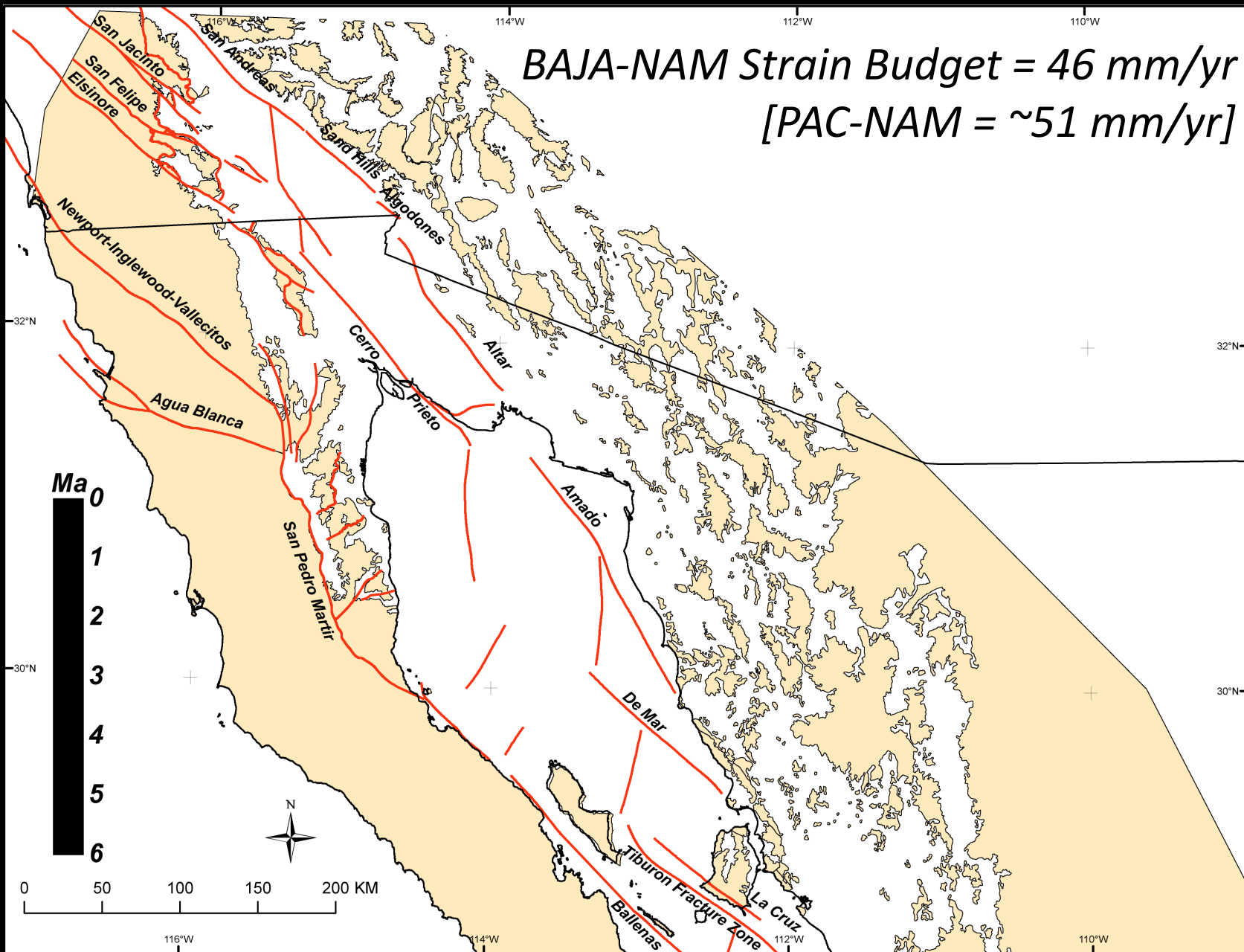
# Present-Day Geology

This geological map of the Baja California Peninsula illustrates the complex tectonic and geological structure of the region. The map is bounded by latitudes 28°N to 33°N and longitudes 110°W to 117°W. Key features include:

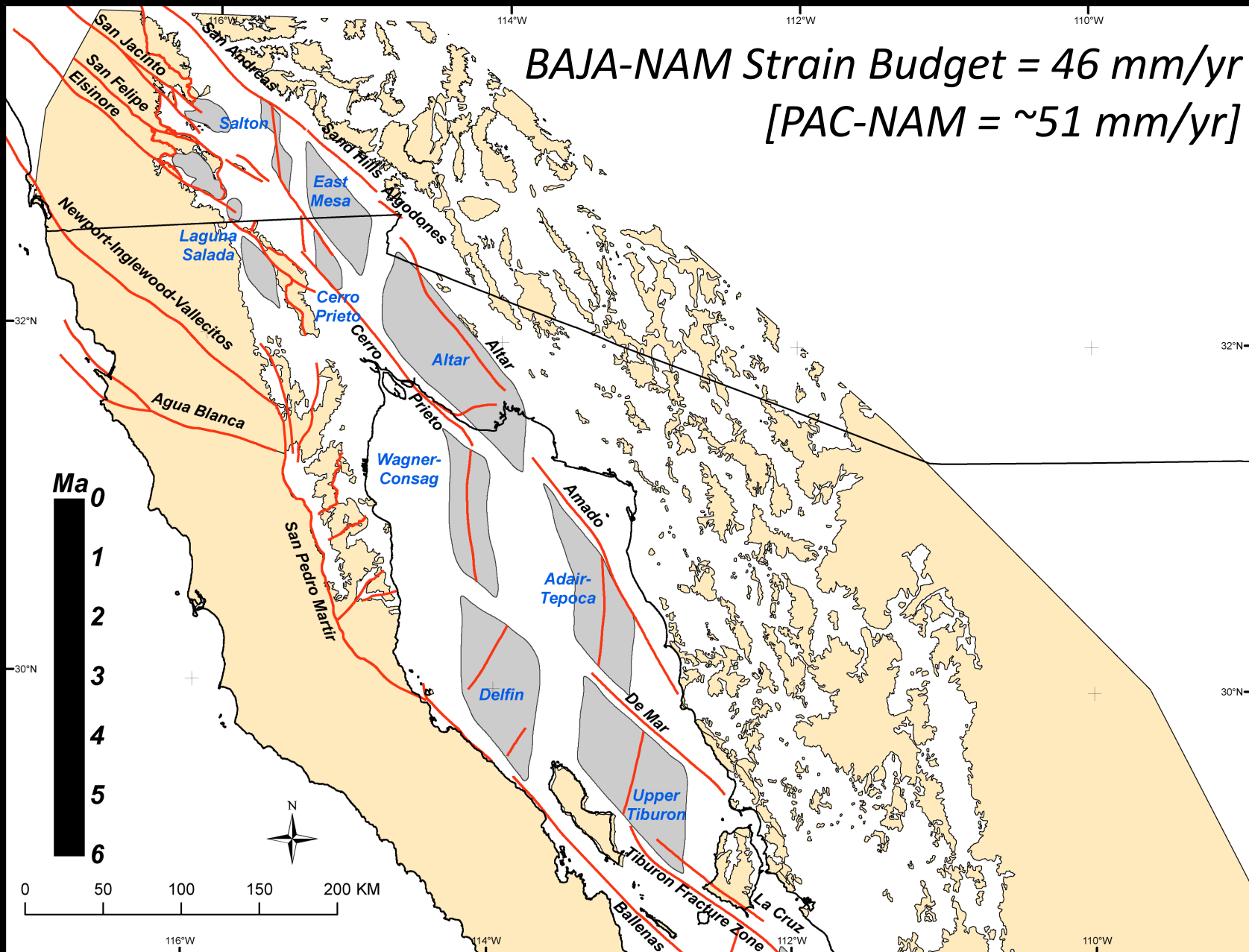
- Tectonic Boundaries:** The San Andreas Fault (SAF) is shown as a major boundary, with the Pacific Plate to the west and the North American Plate to the east. Other significant faults include the San Jacinto, San Felipe, Newport-Inglewood-Vallecitos, Agua Blanca, San Pedro Martir, Cerro Prieto, Altar, Amado, Adair-Tepoca, Delfin, De Mar, Upper Tiburon, and Tiburon Fracture Zone.
- Geological Units:** Various geological units are labeled, including San Jacinto, San Felipe, Elsinore, Salton, East Mesa, Agodones, Laguna Salada, Cerro Prieto, Altar, Wagner-Consag, Amado, Adair-Tepoca, Delfin, De Mar, Upper Tiburon, and Tiburon Fracture Zone.
- Topography and Landmarks:** The map shows the coastline of Baja California, with major cities like San Diego, Tijuana, and Ensenada marked. The Gulf of California is visible to the east.
- Scale and Orientation:** A scale bar at the bottom left indicates distances from 0 to 200 km. A north arrow is located near the center of the map.



*BAJA-NAM Strain Budget = 46 mm/yr*  
*[PAC-NAM = ~51 mm/yr]*



# Present-Day Geology



# 1 Ma

## 0 - 1 Ma SLIP RATES

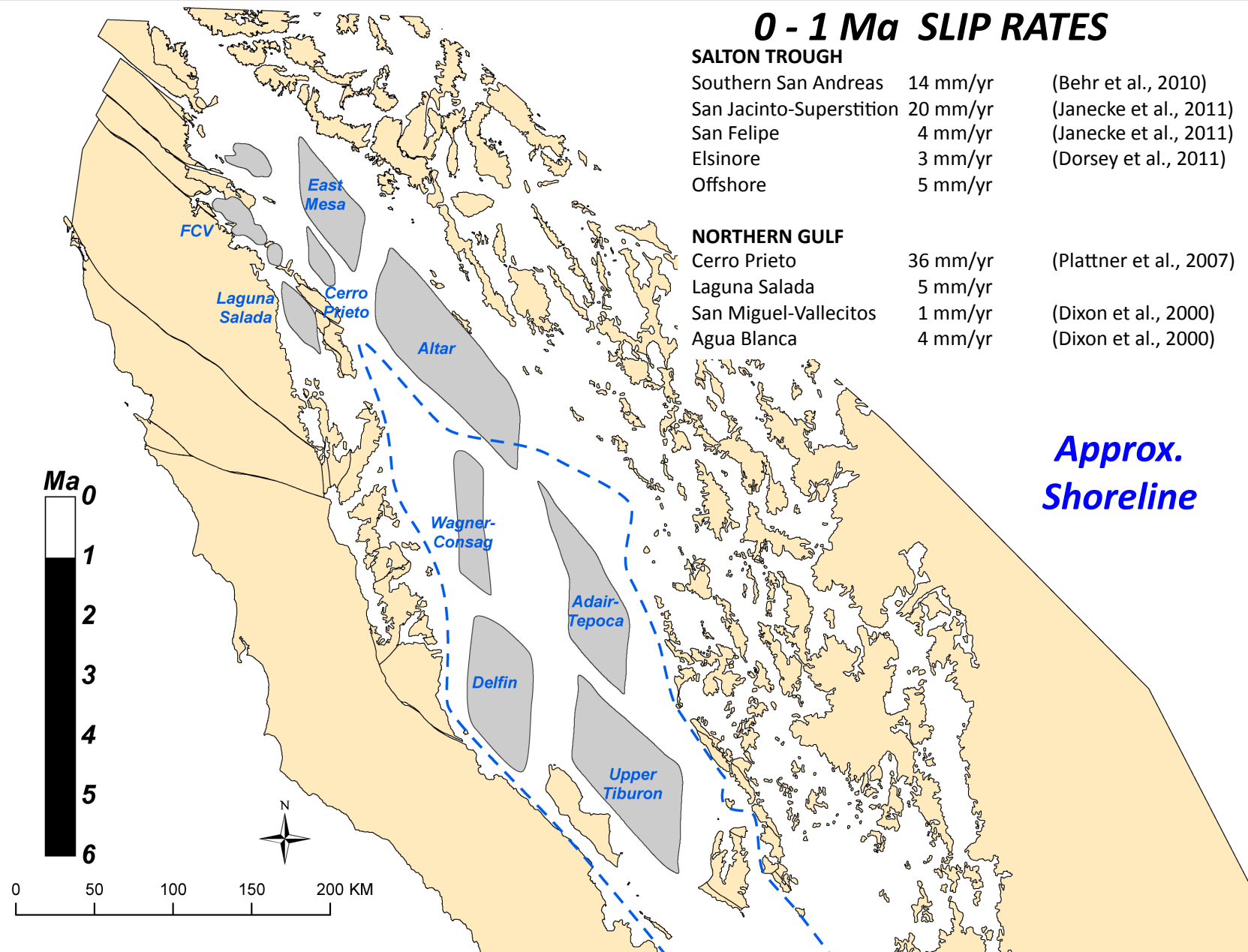
### SALTON TROUGH

|                          |          |                        |
|--------------------------|----------|------------------------|
| Southern San Andreas     | 14 mm/yr | (Behr et al., 2010)    |
| San Jacinto-Superstition | 20 mm/yr | (Janecke et al., 2011) |
| San Felipe               | 4 mm/yr  | (Janecke et al., 2011) |
| Elsinore                 | 3 mm/yr  | (Dorsey et al., 2011)  |
| Offshore                 | 5 mm/yr  |                        |

### NORTHERN GULF

|                       |          |                         |
|-----------------------|----------|-------------------------|
| Cerro Prieto          | 36 mm/yr | (Plattner et al., 2007) |
| Laguna Salada         | 5 mm/yr  |                         |
| San Miguel-Vallecitos | 1 mm/yr  | (Dixon et al., 2000)    |
| Agua Blanca           | 4 mm/yr  | (Dixon et al., 2000)    |

*Approx.  
Shoreline*



# 2 Ma

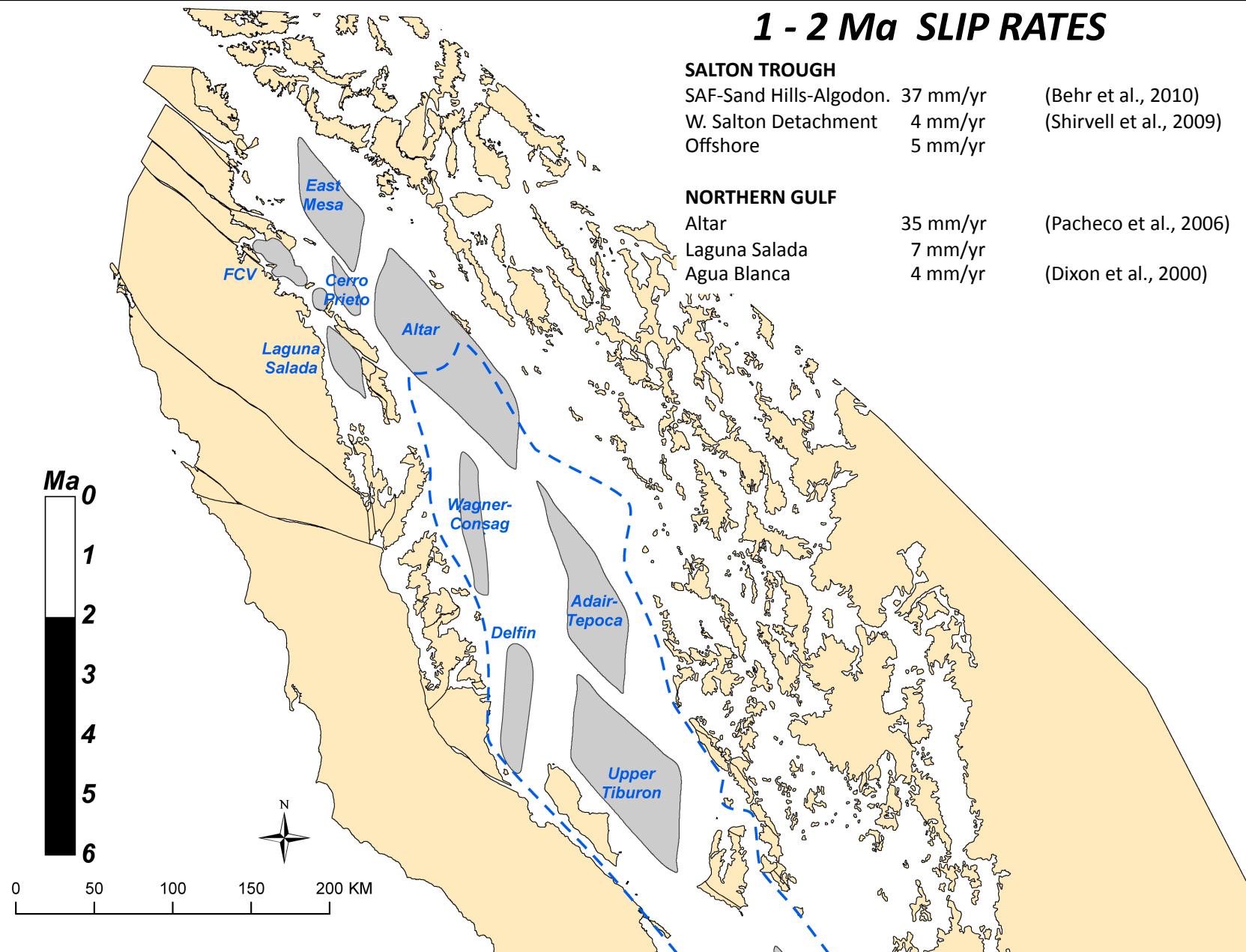
## 1 - 2 Ma SLIP RATES

### SALTON TROUGH

|                         |          |                         |
|-------------------------|----------|-------------------------|
| SAF-Sand Hills-Algodon. | 37 mm/yr | (Behr et al., 2010)     |
| W. Salton Detachment    | 4 mm/yr  | (Shirvell et al., 2009) |
| Offshore                | 5 mm/yr  |                         |

### NORTHERN GULF

|               |          |                        |
|---------------|----------|------------------------|
| Altar         | 35 mm/yr | (Pacheco et al., 2006) |
| Laguna Salada | 7 mm/yr  |                        |
| Agua Blanca   | 4 mm/yr  | (Dixon et al., 2000)   |



# 4 Ma

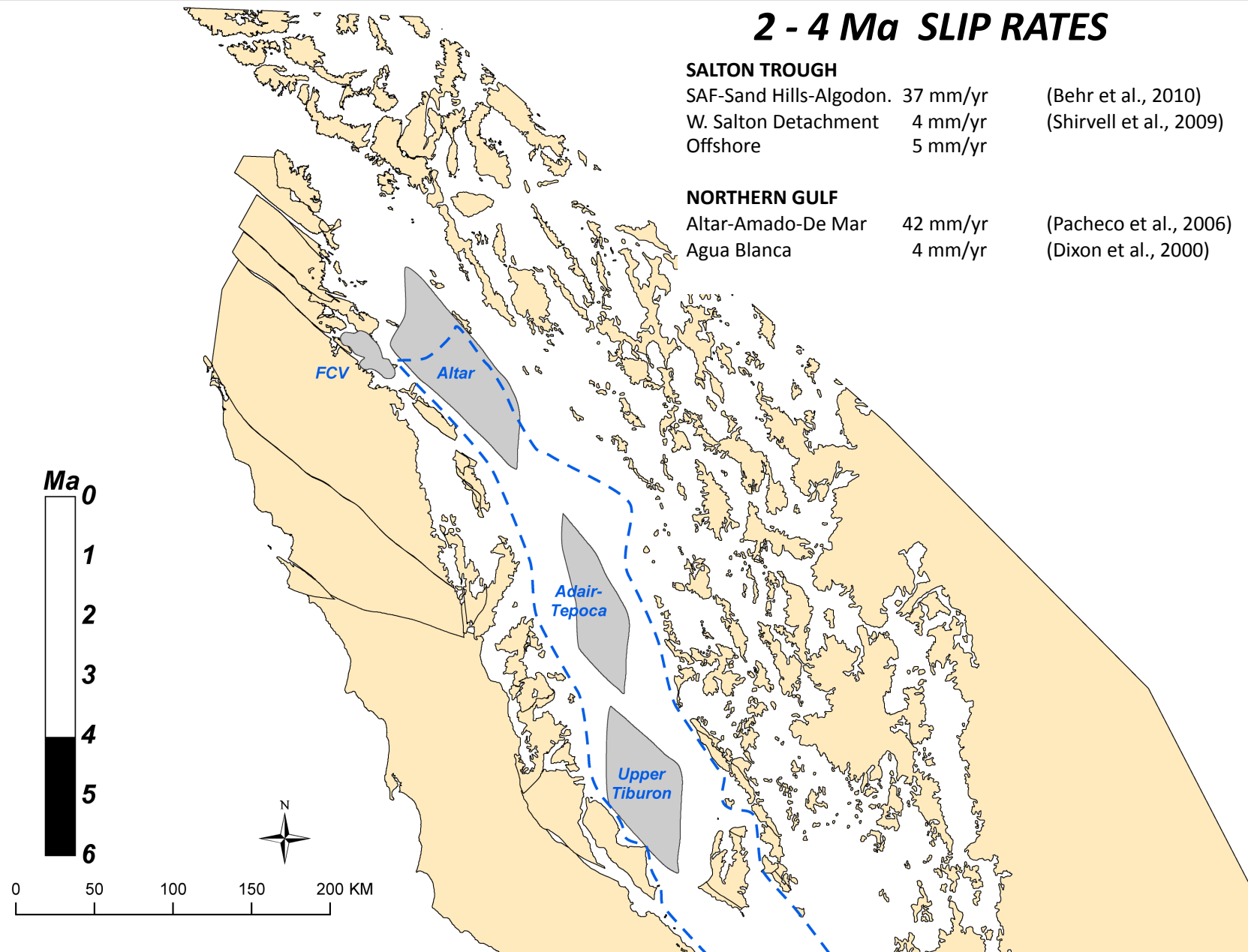
## 2 - 4 Ma SLIP RATES

### SALTON TROUGH

|                         |          |                         |
|-------------------------|----------|-------------------------|
| SAF-Sand Hills-Algodon. | 37 mm/yr | (Behr et al., 2010)     |
| W. Salton Detachment    | 4 mm/yr  | (Shirvell et al., 2009) |
| Offshore                | 5 mm/yr  |                         |

### NORTHERN GULF

|                    |          |                        |
|--------------------|----------|------------------------|
| Altar-Amado-De Mar | 42 mm/yr | (Pacheco et al., 2006) |
| Agua Blanca        | 4 mm/yr  | (Dixon et al., 2000)   |



# 6 Ma

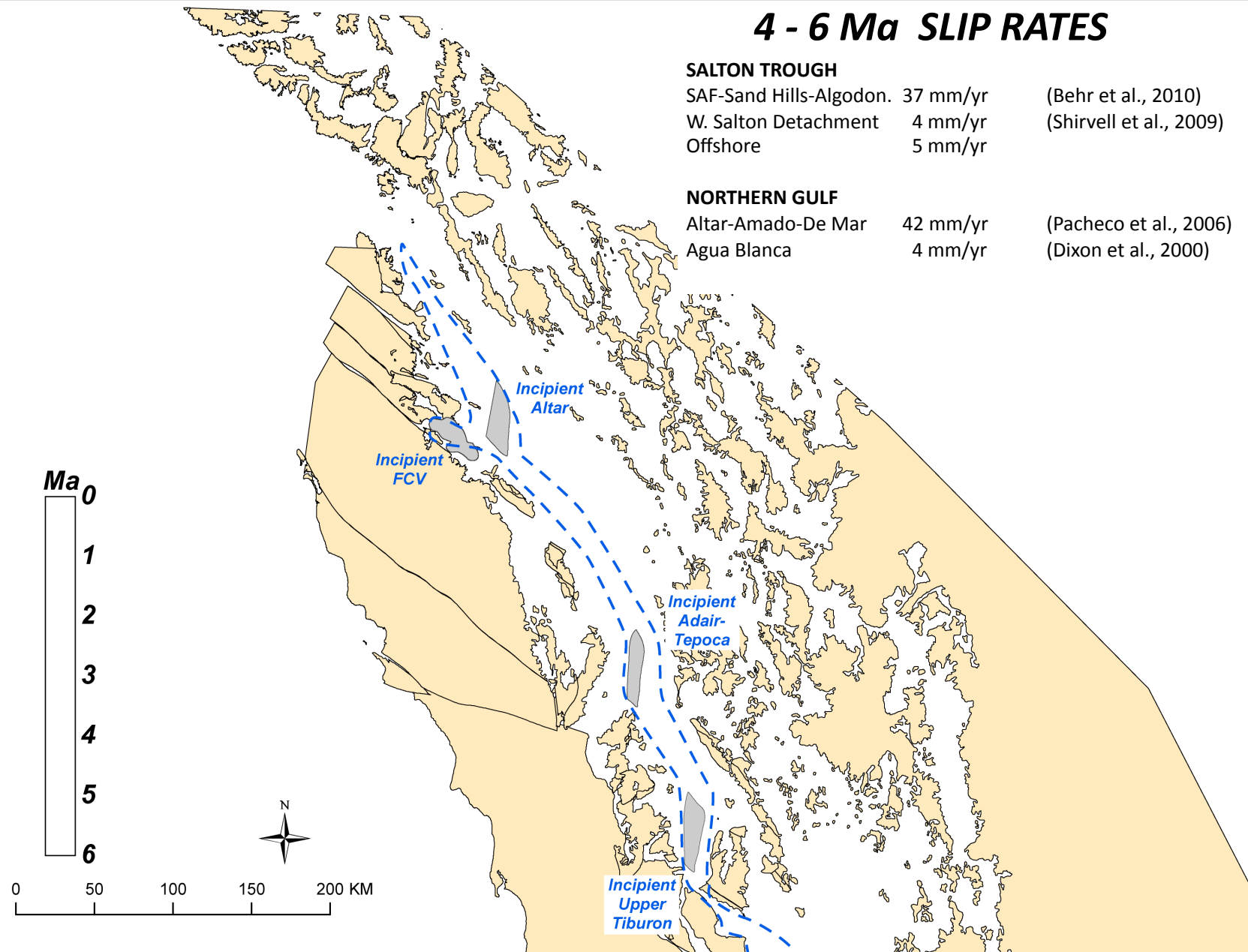
## 4 - 6 Ma SLIP RATES

### SALTON TROUGH

|                         |          |                         |
|-------------------------|----------|-------------------------|
| SAF-Sand Hills-Algodon. | 37 mm/yr | (Behr et al., 2010)     |
| W. Salton Detachment    | 4 mm/yr  | (Shirvell et al., 2009) |
| Offshore                | 5 mm/yr  |                         |

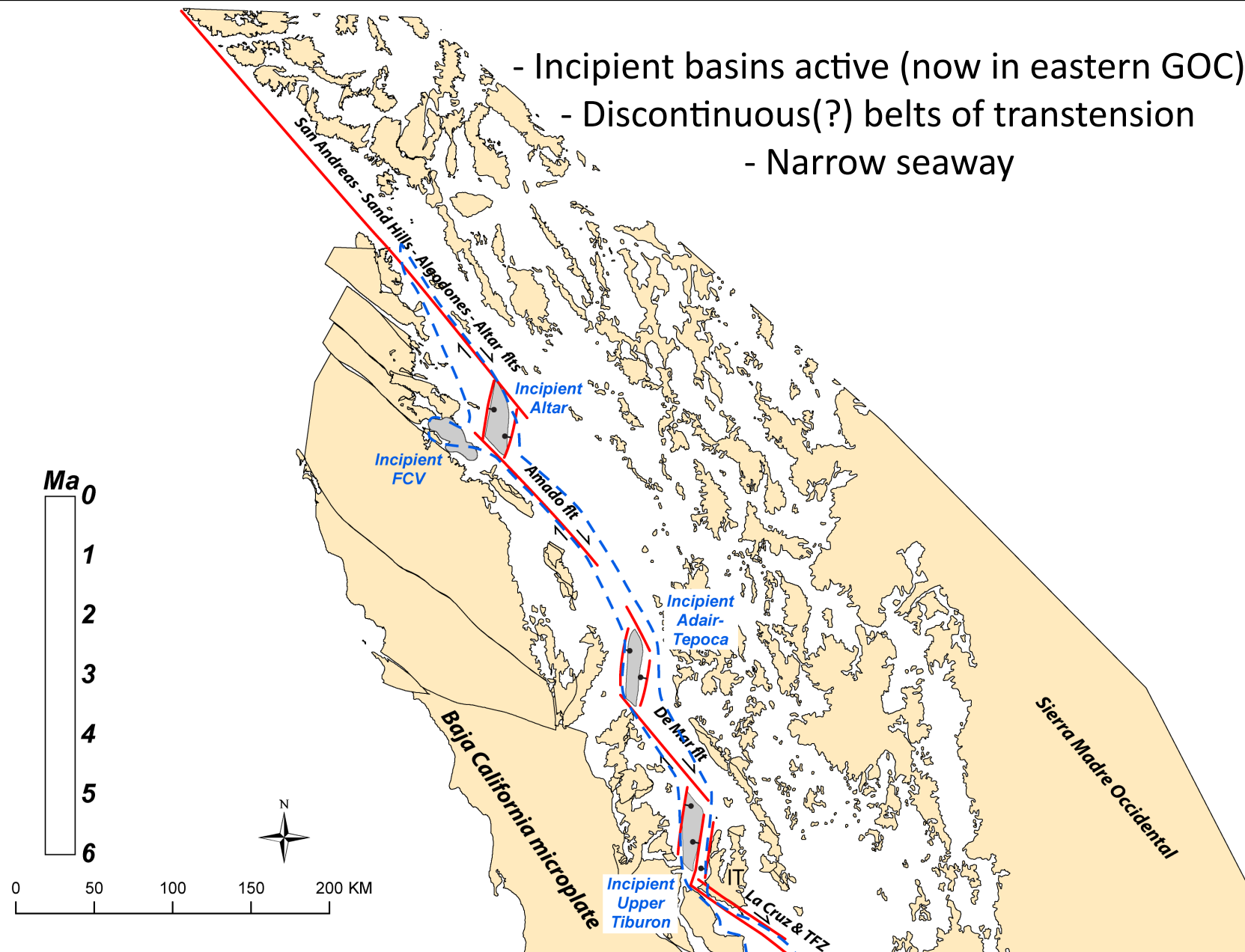
### NORTHERN GULF

|                    |          |                        |
|--------------------|----------|------------------------|
| Altar-Amado-De Mar | 42 mm/yr | (Pacheco et al., 2006) |
| Agua Blanca        | 4 mm/yr  | (Dixon et al., 2000)   |

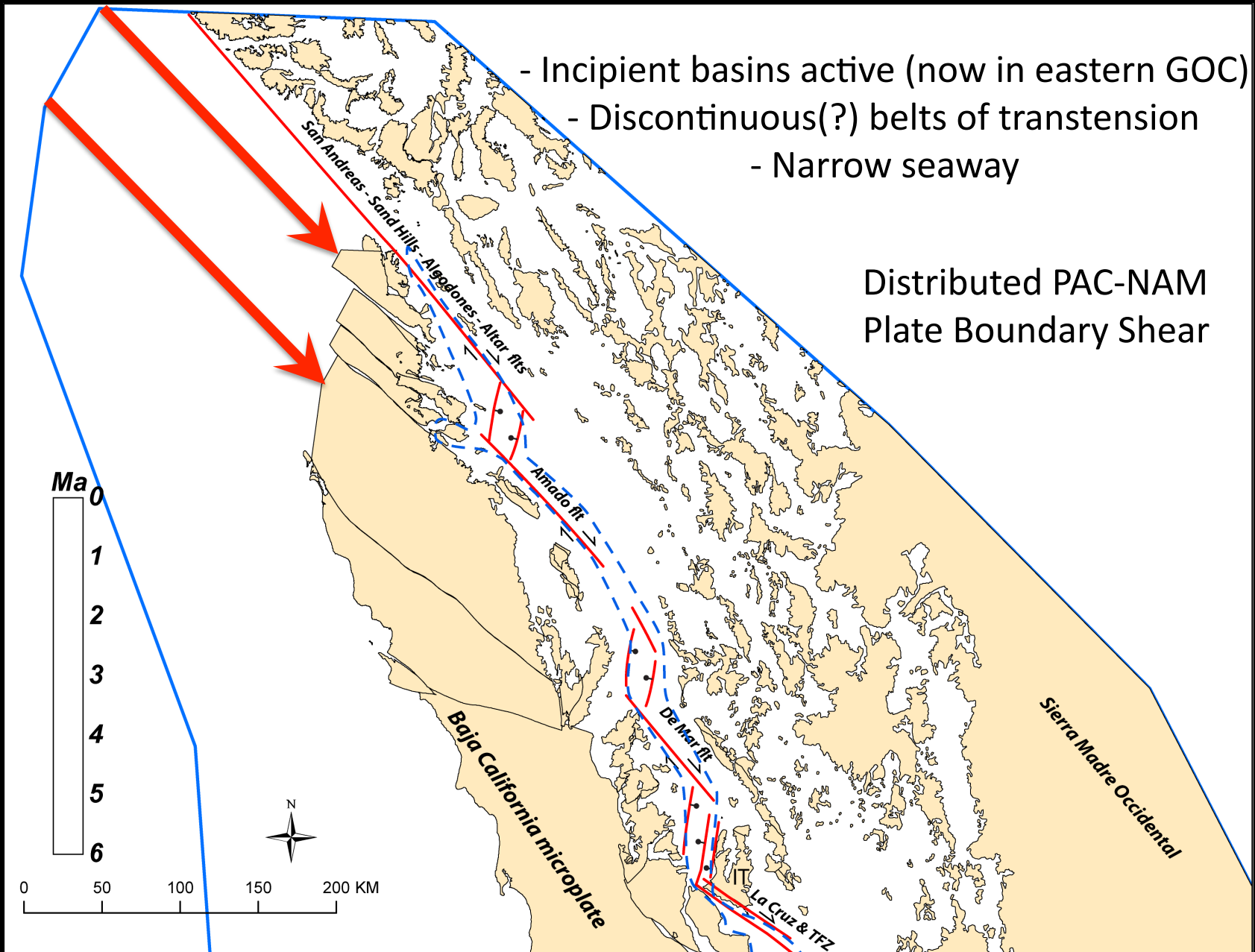


# 6 Ma

- Incipient basins active (now in eastern GOC)
- Discontinuous(?) belts of transtension
- Narrow seaway



# 6 Ma



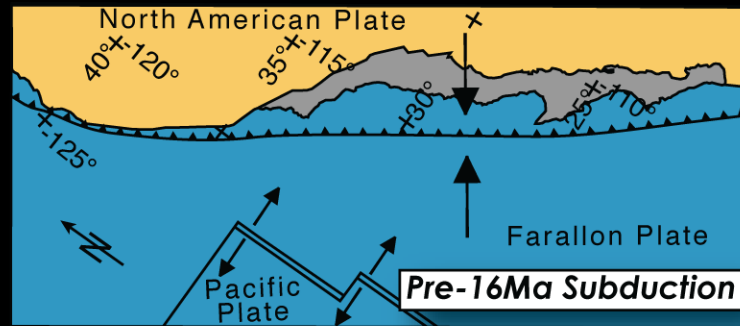
# ***Animation of 0 - 6 Ma Reconstruction***

# *Future Work Plan*

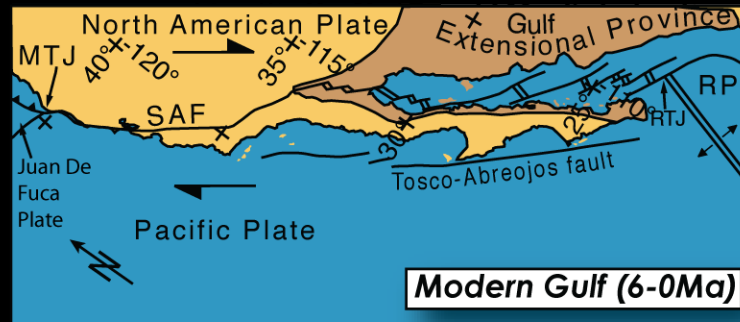
- reconstruction steps 8, 10, 12, 14 Ma
  - 2 sets of Proto-Gulf maps
  - deformation is more diffuse
  - fewer geological constraints
- incorporate offshore faults in all model steps
  - e.g. Tosco-Abreojos fault (full 51 mm/yr)
- publish animations and GIS files of model steps
- merge with McQuarrie & Wernicke (2005)  
animation & GIS files (??)

# Uncertain Strain Evolution

TIME

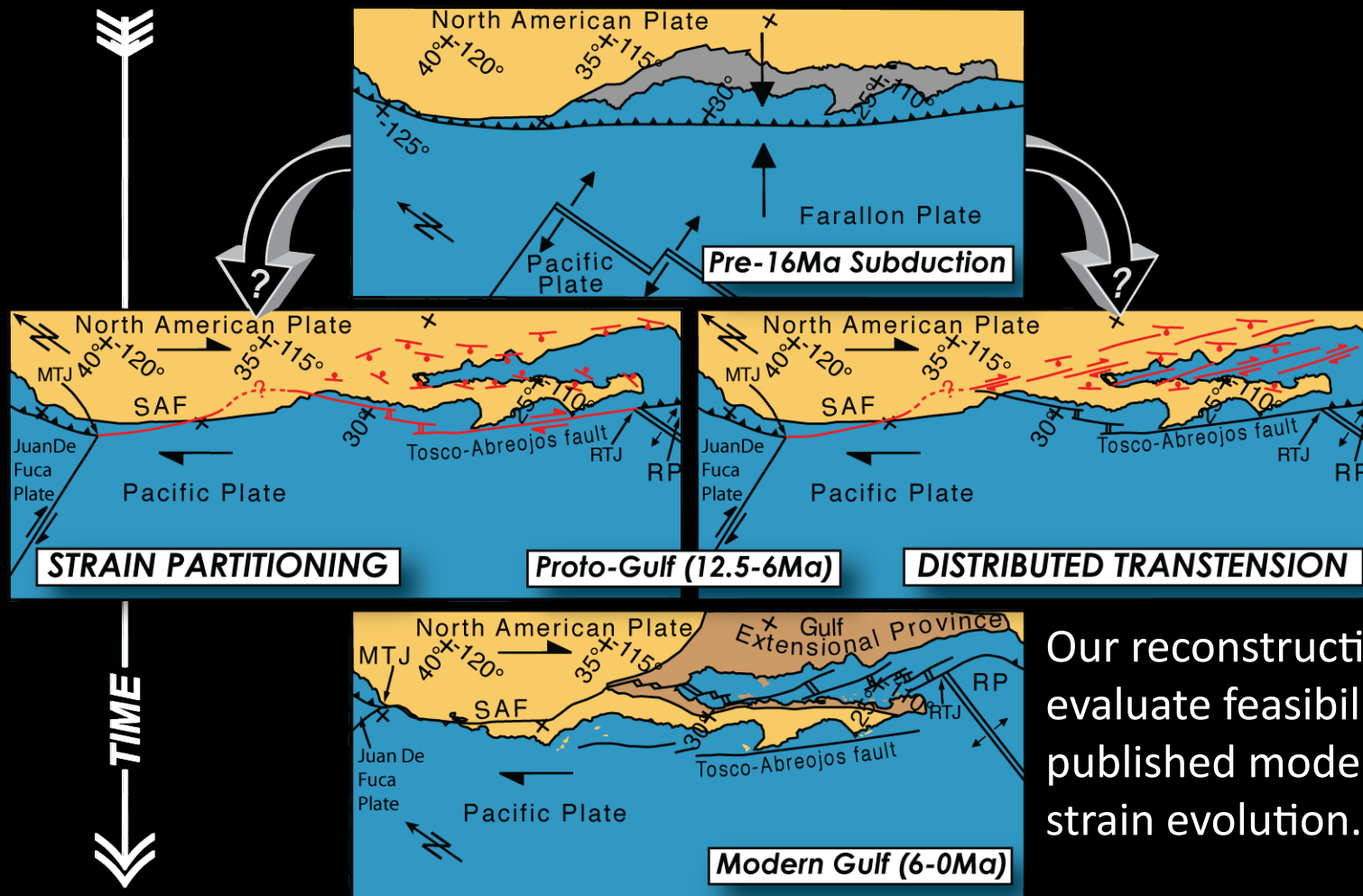


**Proto-Gulf ?**  
**(12.5 - 6 Ma)**



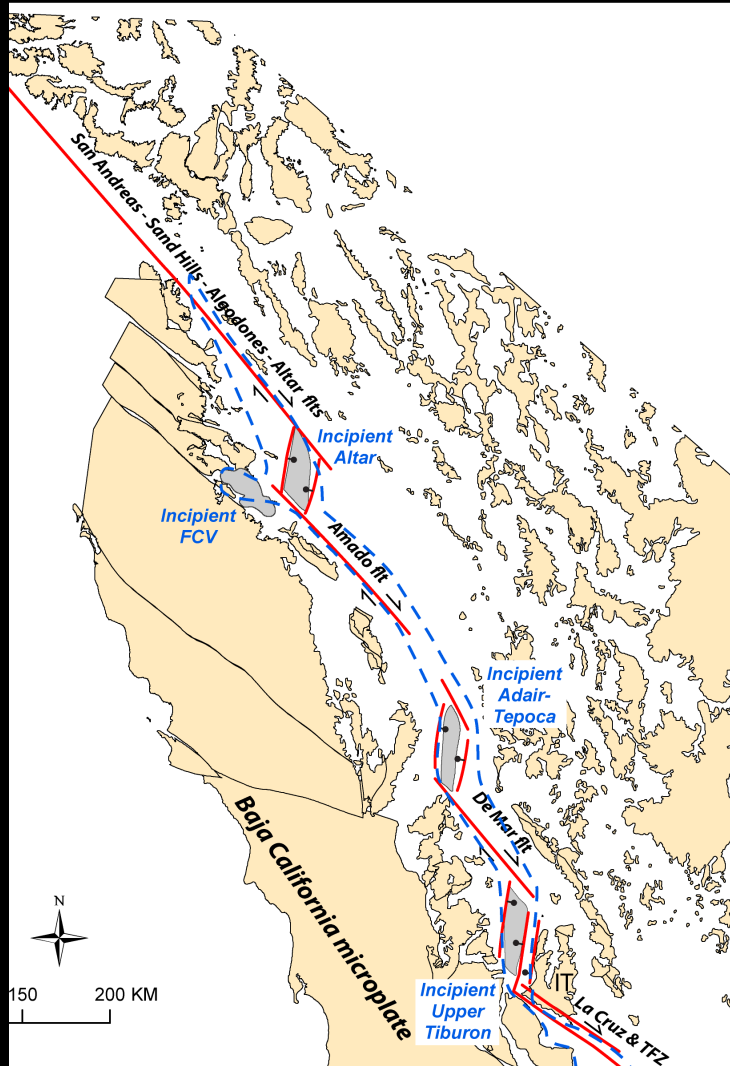
What was the style and distribution of proto-Gulf deformation that preceded plate boundary localization at 6 Ma?

# Uncertain Strain Evolution

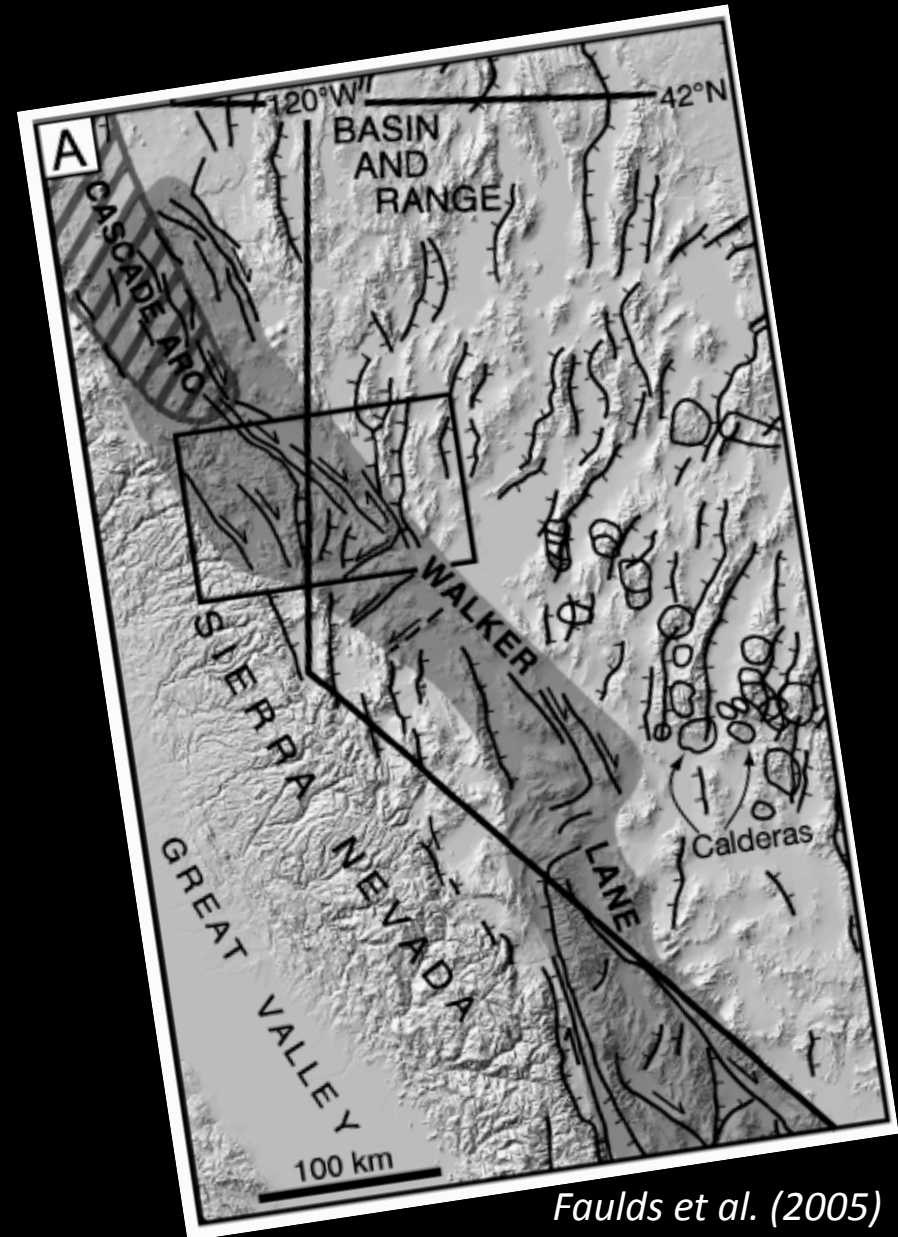


Our reconstruction can evaluate feasibility of published models for strain evolution.

# Modern Analog



*This Study*



*Faulds et al. (2005)*



## ***ACKNOWLEDGMENTS***

- **Richard Nava**
- **Gary Axen**
- **Southern Gulf Reconstruction Team**
  - Paul Umhoefer**
  - Lisa Skinner**
  - Jared Kluesner**



Thank you.