Bringing MARGINS data to the classroom: Rupturing Continental Lithosphere

Relative plate motion in the Gulf of California

The Gulf of California (GC), located between Baja California and mainland Mexico, is a body of water occupying an oblique rift zone. In this exercise, you will 1) examine the pattern of relative plate motion between the Baja Microplate and the North American Plate; 2) evaluate the relationship between GC rift zone fault segments and relative plate motion by estimating opening and strike slip rates; and 3) relate the relative plate motion and slip rates to the geologic evolution of the region, expressed by the network of faults throughout the region.

An Euler pole description of relative plate motion

Two types of data serve as the backbone for this exercise: fault maps and Euler poles. The fault maps contain the latitude and longitude of fault traces within the GC rift zone and are divided by faulting style: `GCAST_Normal.kmz`, `GCAST_Rift.kmz`, and `GCAST_strikeslip.kmz` contain off-rift normal faults, rift segments proper, and transform faults, respectively. ("GCAST" stands for Gulf of California And Salton Trough.) The Euler pole is specified by its latitude, longitude, and rotation rate, shown in `BC-NA Euler Pole.kmz`.

Using the Euler pole, you are to generate contours of relative plate motion velocity. Rearrange the equation

$$v = \Omega r = \Omega \, \mathrm{R} \sin \delta,$$

where v is the linear relative plate motion velocity, Ω is the Euler pole rotation rate (given in °/Myr, but you should convert to radians per year), R is the radius of Earth (6371 km), and δ is the angular distance between the Euler pole and a point at which you are measuring relative plate motion velocity, to determine the angular distance, δ, between the given Euler pole and small circles of relative plate motion at 1 mm/yr intervals from 40 to 50 mm/yr (11 circles total).

To plot the "isorate" small circles, you can use a web-based Google Earth circle generator, which will create a downloadable `.kml` file for each of the 11 circles. The generator accepts coordinates of the center of the circle and a point on its circumference. Create, download, and display in Google Earth all 11 circles. You may wish to manually change the color of the circles to distinguish them.

Relating relative plate motion to plate boundary structure

With the direction and rate of velocity calculated and shown by the colored small circles, you can investigate the relationship between the relative plate motion described by the Euler pole and the faults that comprise the GC plate boundary region in several ways:

1. Describe the changes in the relative plate speed along the margin. Does this make sense given the relative geographic locations of the margin and the Euler pole? How does the speed compare between an individual transform segment and an adjacent rift segment?

2. Choose at least one rift segment and strike-slip segment in the southern, central, and northern GC. Using the *Heading* feature of the Google Earth *Ruler* tool, determine a) the strike of the faults and b) the local direction of relative plate motion (as close to your selected segments as possible). Using these measurements, calculate the components of velocity parallel (strike-slip) and perpendicular (opening/closing) to each fault segment.

   What is the relationship between the rate of opening on rift segments (northeast strike) and the rate of strike-slip on transform segments (southeast strike)? What is the sign convention for the opening/slip rates (i.e., does a positive rate describe divergence or convergence? Left-lateral or right-lateral)? Opening is expected along the rift segments, but does the dominantly right-lateral strike-slip make sense? Are there examples of closing (convergence) or left-lateral faulting, and how can you reconcile those "opposite" senses of deformation with the overall tectonics?

3. Determine the variation along the GC in the rift obliquity angle, α. The obliquity angle is defined as the difference between the relative plate motion direction and the direction perpendicular to rift segment strike. Determine an average angle for three sections of the GC: north (30º–33ºN latitude), central (26.5º–30ºN) and south (23º–26.5ºN). Along with the mean strike of the segments, calculate the mean direction of relative plate motion within these regions, yielding a single α value for each region.

   Based on your α calculations, is there a correlation between the obliquity of opening and the style of off-margin deformation? Examine the total width of mapped faults across the region, the orientations of off-axis normal faults, and the relative lengths and abundances of rift segments and strike-slip faults. Consult the Discussion section of *Dorsey and Umhoefer* [2012] (p. 220–221) for more details on the faulting styles along the Gulf.

References

Dorsey, R. J., and P. J. Umhoefer (2012), Influence of sediment input and plate-motion obliquity on basin development along an active oblique-divergent plate boundary: Gulf of California and Salton Trough, in *Tectonics of Sedimentary Basins: Recent Advances*, edited by C. Busby and A. Azor, pp. 209-225, Wiley-Blackwell.