ACTIVITIES to accompany the model:
SIMULATION OF PLATE TECTONIC DEFORMATIONS IN SOUTHERN CALIFORNIA AND NORTHERN BAJA CALIFORNIA, 18 MILLION YEARS AGO TO PRESENT

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To view and/or download animations depicting these and other geological processes go to:
http://emvc.geol.ucsb.edu/

Overview: Significant anomalies in the topography of Southern California and northern Baja California and in the bathymetry of their offshore continental shelves. (Refer to the two colored, laminated maps included in this packet)**.**

<u>The topographic map of Southern California</u> and Figure 1C, below, show a very unusual configuration. Most topographic features along the west coasts of the Americas are aligned approximately parallel to their coastlines. By contrast, in southern California there is a group of mountain ranges that are oriented in an east-west direction. These include the Santa Ynez, Topa Topa, and Santa Monica mountains, the Hollywood hills, the partially submerged range that forms the northern Channel Islands, and the east-west coastlines of the Santa Barbara and Malibu-Santa Monica regions. The geographers named these the mountains the “Transverse Ranges” and we call the region they occupy the “Transverse Ranges block” (marked with the locations of Santa Barbara, SB and Oxnard, Ox, on Figure 1A and with SB on the model).

<u>The regional Google map</u> brings out anomalies in the nature of the continental shelves off California and Mexico. Most of the world’s continental shelves look like the shallow, smooth ones shown off mainland Mexico, southern Baja, and central California: they are just submerged extensions of the continental crust that have been smoothed by wave erosion during numerous shifts of the coastlines. In contrast, the continental shelf offshore of southern California and northern Baja California, called the “California Borderland”, is very chaotic. This region is also made of continental crust, but it is all busted up! The offshore islands are edges and corners of the broken pieces that happen to stand above present-day sea level.

The model in this packet was designed to demonstrate the tectonic history that led to these and other unusual features in our region.

Plate Tectonic History of Southern California and Baja California

<u>Simplified plate tectonic history (as scientists have figured it out, so far).</u>

When viewed from the North American plate, the Pacific plate is headed northwestward toward Alaska and the Aleutian Islands. The Pacific plate is also growing wider by sea floor spreading along its eastern edge. By about 25 Ma (Ma = million years ago), the Pacific Plate had grown so wide that its eastern edge began to rub against the western edge of North America.

By 18 Ma, when our model history starts, some coastal pieces of North America have been torn off and have become attached to the Pacific plate.

Between 18 and 6 Ma, the Pacific plate carried these pieces up the coast to the northwest. The Pacific Plate also dragged the southern end of the Transverse Ranges block northwestward, but its other end was stuck, embedded in the continent, so that the block rotated clockwise.

About 6 Ma, Baja California broke off of North America and became attached to the Pacific plate. Since then it has been moving with the Pacific plate, pulling away to the northwest from Mexico and, thus, pulling open the Gulf of California. The other pieces continued up the coast and the Transverse Ranges block continued to rotate. Since Baja began to move, it has been pushing southwestern California ahead of it, causing a continental collision with the Transverse Ranges region.

<u>Make your model enact this history of breakup and drift, as follows:</u>

First set the model to its 18 Ma configuration: Pull the right-hand tab (Baja California) down to its 18 - 6 Ma position (this location has been outlined on the base sheet). Hold it there by pressing your thumb on the tab. Now pull the left-hand tab down until the lower left corner of the Pacific Plate sits on the outline of its 18 Ma position.

The enactment: Keeping the right tab held down, use the left tab to pull the Pacific and its attached continental pieces around to the northwest. Continue to hold Baja (the right tab) in place until 6 Ma, then let go and let it be dragged along as well. Stop when the frames of the pieces match up with the frame on the base (0 Million Years Ago = present day configuration).

Avoid confusion by noticing that the coastlines on the pieces are just their <u>present</u> locations. Past coastline locations were highly variable, reflecting both sea level fluctuations and vertical deformations of the crustal pieces.

Creation of Regional Topographic Features.

As you work the model, find some locations where the model edges are being pulled apart and other locations where edges are running over each other.
(Note that this is the direct result of mismatches between the orientation of the plate boundary and the motion direction of the Pacific Plate past North America.)

Compare these observations to the maps of topography and faults of the region, Figures 1A, 1B, and 1C. (Note: Large versions of Figs. 1A, 1B, and 1C are included in the attached Teacher Resources package.)

Where the continental pieces are being pulled apart, the Gulf of California, the Salton Sea basin (Imperial and Coachella Valleys), the Los Angeles basin, and the offshore borderland basins are being formed. Know that the basement rocks under the Salton Sea and northernmost Gulf of California basins are actually quite deep. They have been filled up with Colorado River mud so that they look shallow. The Los Angeles basin is also quite deep and is also buried in river sediments.

Where the continental pieces are running into one another, the crusts of the Tehachapi mountains, San Bernardino mountains, San Gabriel mountains, and the various Transverse Ranges are all being thickened and elevated.

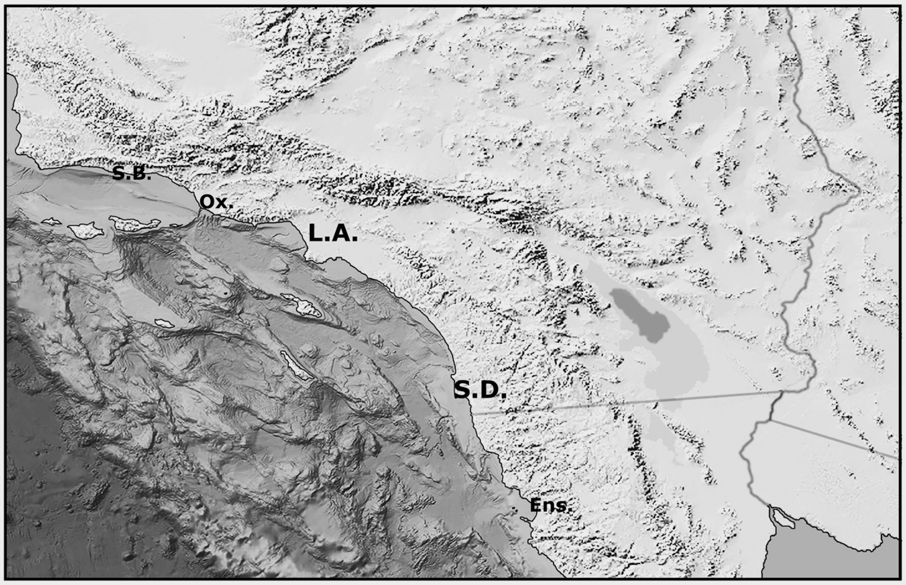

Figure 1A.
Topographic relief in southern California, northern Baja California, and in the offshore continental borderland.

S.B. = Santa Barbara
Ox. = Oxnard
L.A. = Los Angeles
S.D. = San Diego
Ens. = Ensenada

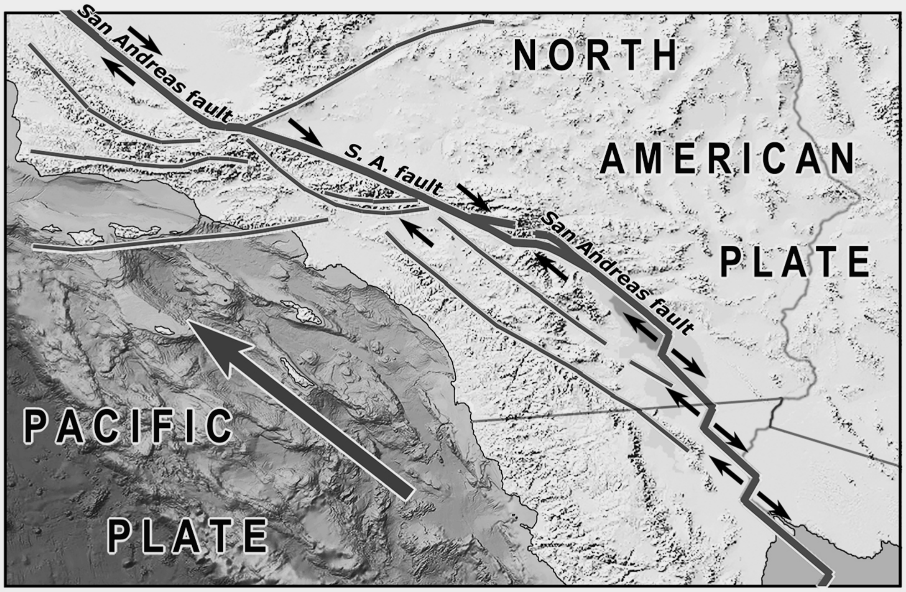

Figure 1B.
Some major faults in the San Andreas fault system.
This is the Pacific - North American plate boundary.

Large arrow = motion of the Pacific plate past the North American plate.

Small arrows = relative motions across fault segments within the system.

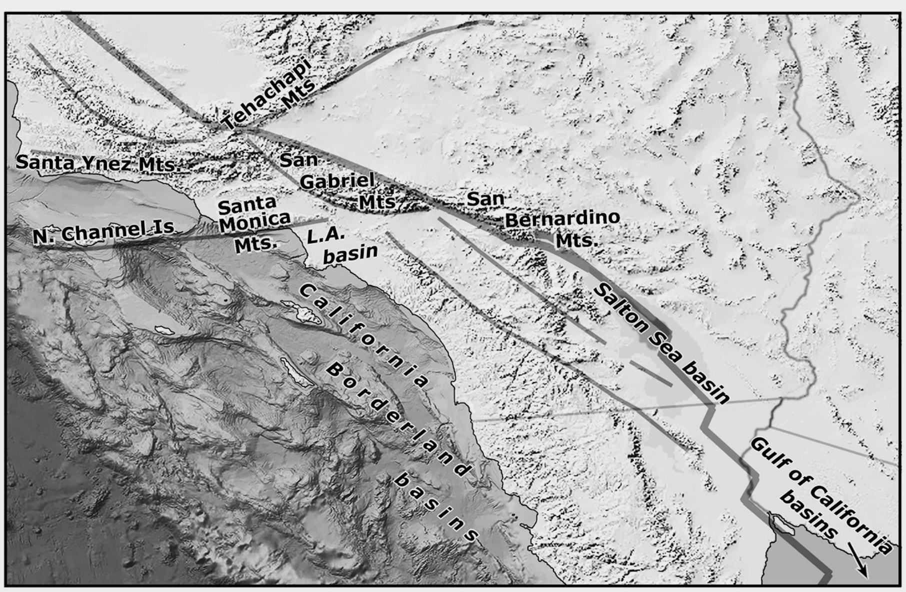

Figure 1C.
Mountain ranges and basins that have formed in response to collisions and pull-aparts along the San Andreas fault.

Rotations of Paleomagnetic Vectors Embedded in the Rocks.

Many rocks, especially lavas, are magnetized when they are first formed. Their internal magnetic vectors are frozen into the rock, pointing (on the average) toward the Earth's north pole at that time. They often retain this record of the original north direction for many millions of years, even after they have been moved and/or rotated.

On the 18 Ma reconstruction, draw or stick on* some arrows pointing north (for example, see figure 2A). Then, work the model and see where they end up pointing. Compare your arrows to those in figure 2B. Figure 2B shows the paleomagnetic vectors that scientists have measured in the rocks that were formed about 18 Ma. These magnetic observations are some of the strongest evidence for the rotation theory illustrated in the model.

*Note: pieces of “post-it” with arrows drawn on them work very well for this.

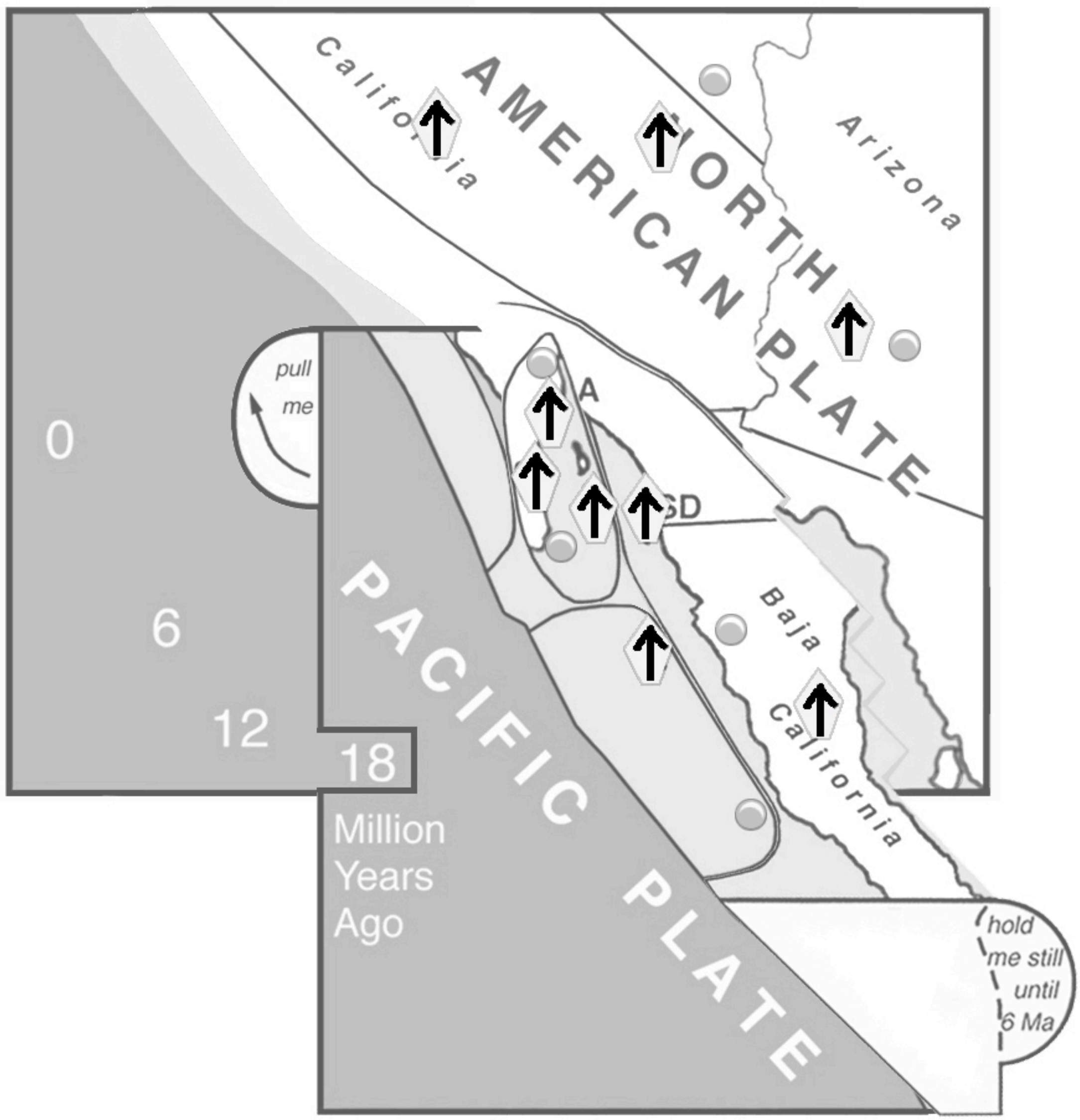

Figure 2A. Example of arrows stuck onto the model to show north directions as they would have been recorded in the rocks 18 million years ago.

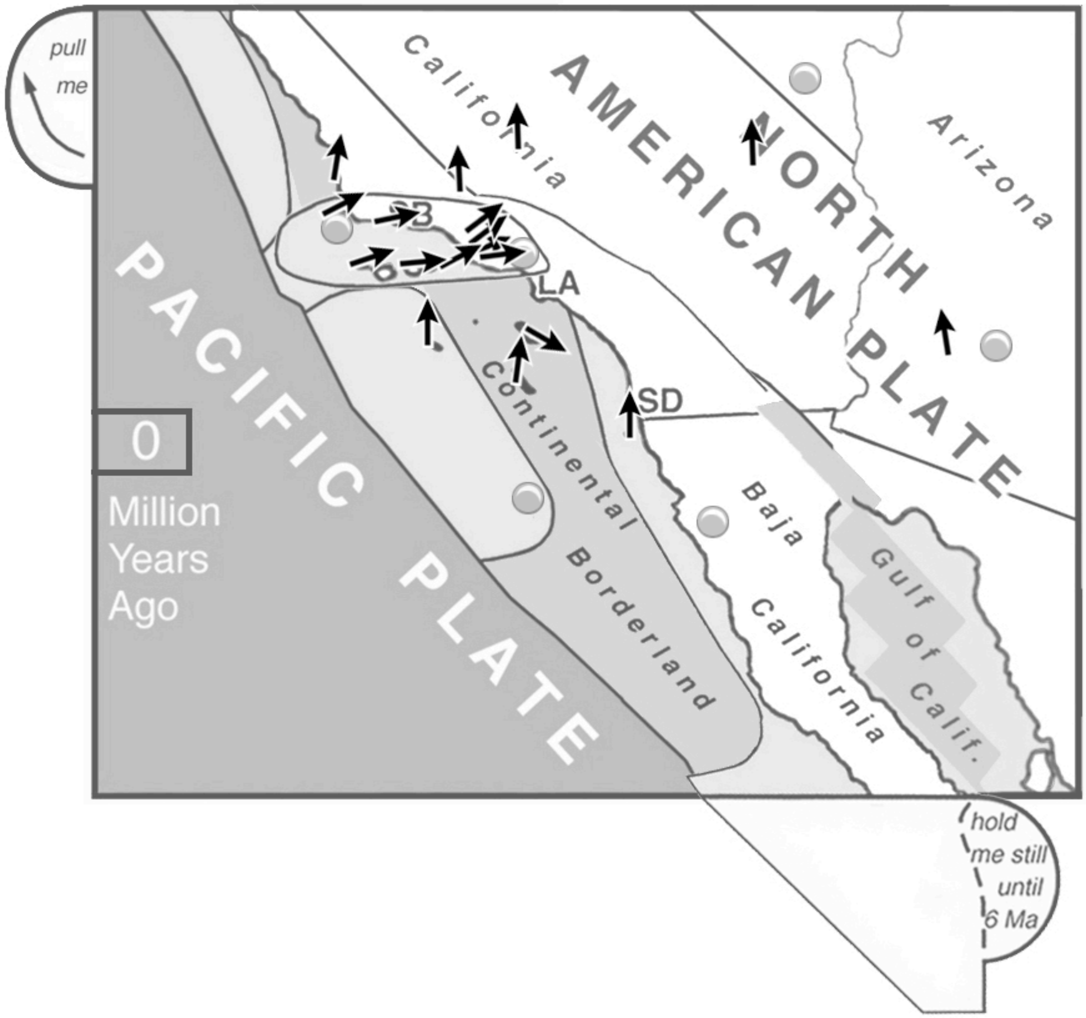

Figure 2B. The scientific observations: paleomagnetic vectors measured in the rocks in their present locations, simplified from various studies by Bruce Luyendyk and colleagues, especially Hornefius 1985, Journal of Geophysical Research, v. 90, p. 12503-12522.

Dispersion of the Poway Conglomerates originally deposited in the Eocene Ballenas River and delta.

In the Jurassic Period, about 155 million years ago, a volcano in Sonora, Mexico, erupted some distinctive purplish-red lavas with white crystals. Over time, the lava flows weathered and broke into pieces. Then, in Eocene time, about 40 million years ago, a big river called the “Ballenas River” rounded the volcanic stones (called the "Poway clasts") and carried them from Sonora to the coast at San Diego. Some of the stones were left behind, buried in the river bed, while others were dumped at the coast or into the sea to form a big delta and submarine sedimentary fan. Some deposits from that old river valley, delta, and fan are found near San Diego, while the toes of the fan are found in the rocks of the northern Channel Islands.

Photographs of some Poway clasts can be found at the web site: emvc.geol.ucsb.edu/

On the 18 Ma reconstruction, draw on the old Ballenas River path** as shown in Figure 3A, then see how the pattern gets torn apart when you work the model. Compare your model at 0 Ma to present day locations of rocks containing those stones (figure 3B). This is strong evidence for the rifting, drifting, and rotation of the pieces.

**It works well to draw the Ballenas River pathway onto 3 judiciously cut "post-it" pieces, as shown below.

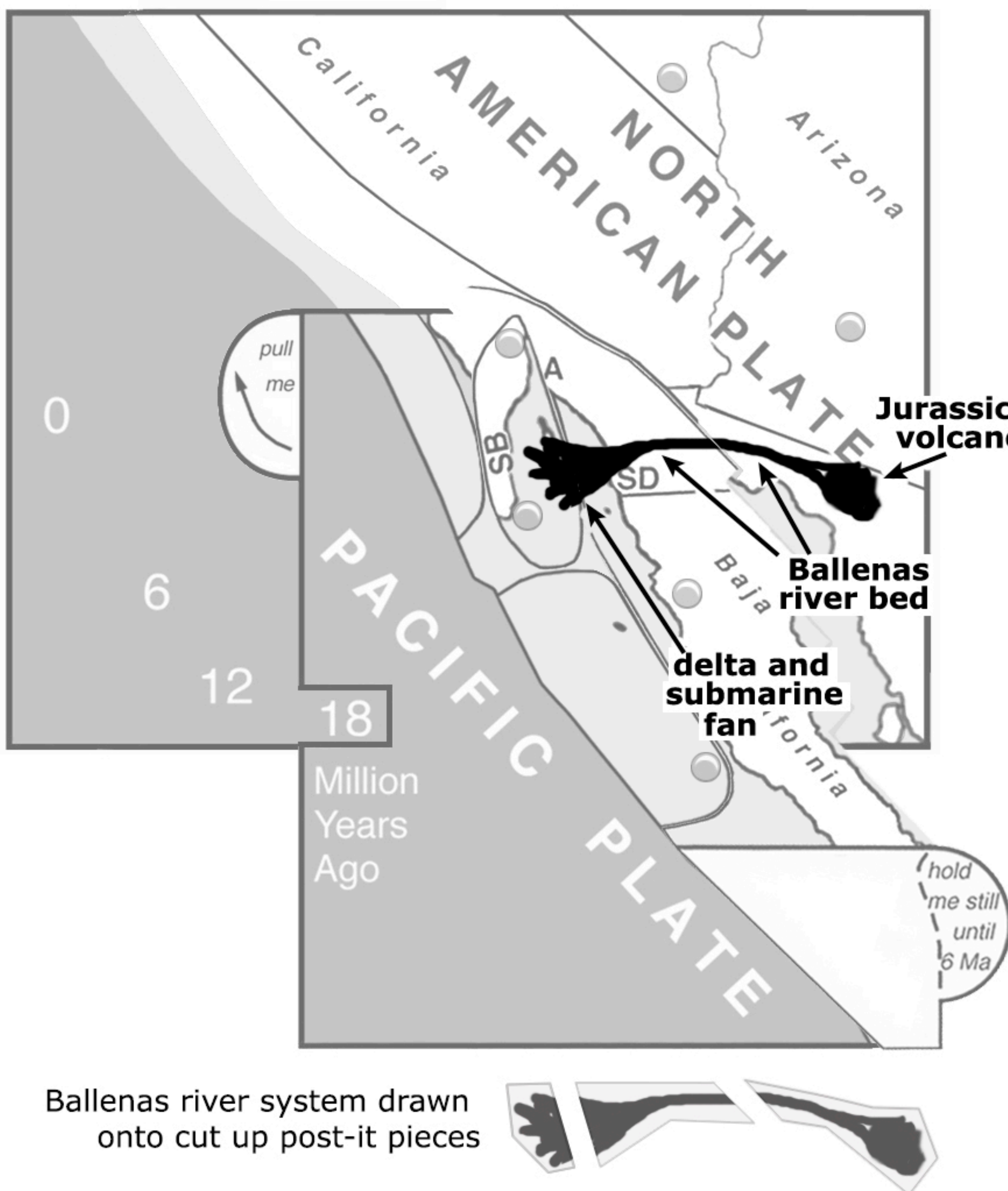

Figure 3A. Example sketch of the Ballenas river system carrying stones from Sonora down the river valley and onto a delta and submarine fan near San Diego.

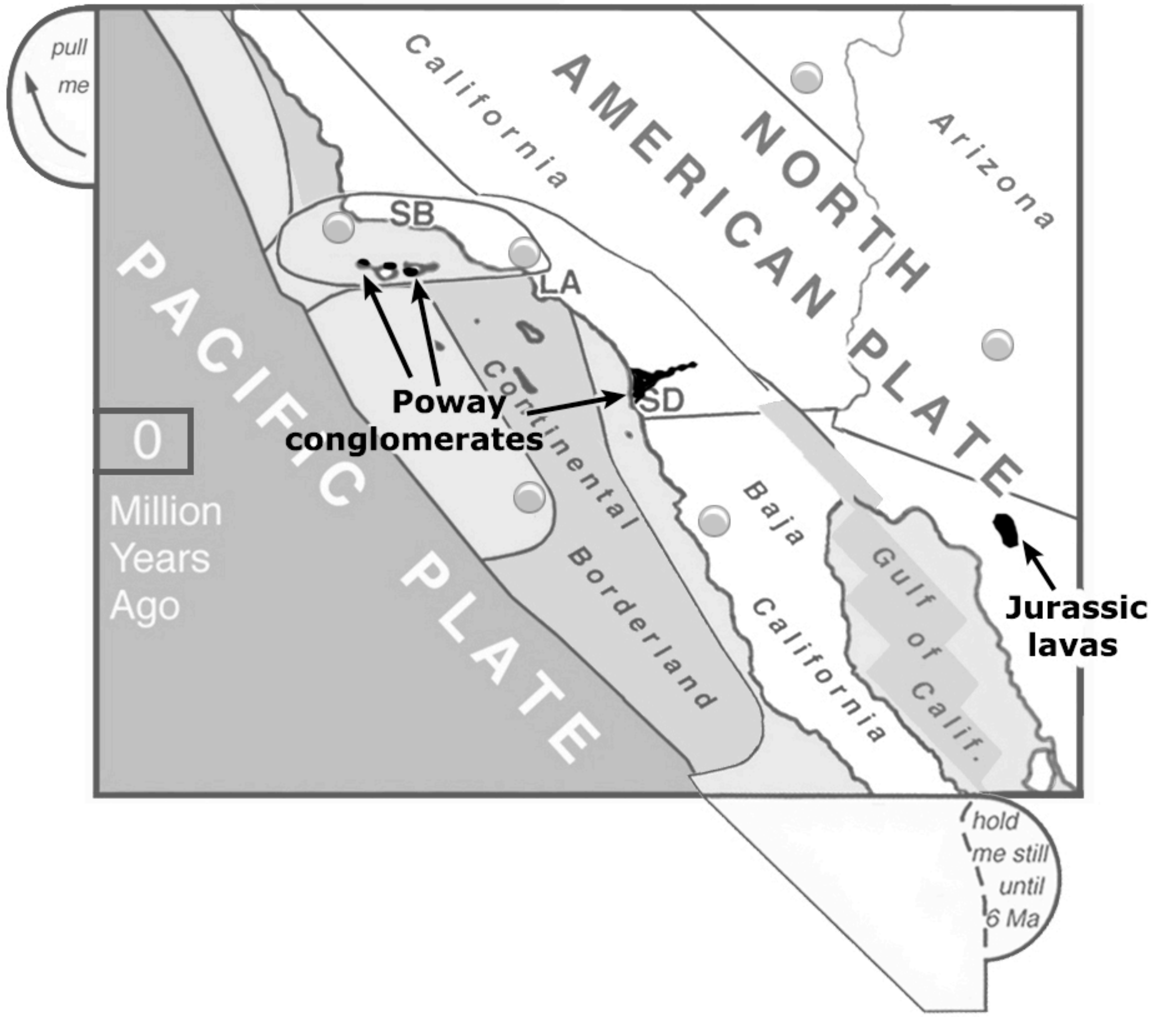

Figure 3B. The scientific observations: sedimentary rocks ("conglomerates") containing Poway stones are presently found on the northern Channel Islands and around San Diego, and matching lavas (the source rocks for the stones) are found in the remains of an old volcano in Sonora, Mexico.

For a description of the Poway rocks and some field guides telling where you can visit them, see Chapter 5 of <u>The Rise and Fall of San Diego</u> by Patrick Abbot, 1999, Sunbelt Publications, Inc., San Diego CA.