Analysis of Fault-Fold Structures along the Newport-Inglewood Rose Canyon Fault System at an unprecedented scale using 3D P-Cable Seismic Reflection Data

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Abstract

The Inner California Borderlands (ICB) is situated off the coast of southern California and northern Baja. The structural and geomorphic characteristics of the area are a middle Oligocene transition from subaerial to submarine fractures along the California coast. Marine stratigraphic evidence shows large-scale extension and rotation accompanied by modern strike-slip deformation. Geologic and geophysical observation indicate that approximately 1.5-2.0° of Pacific-North American relative plate motion is accomodated by offshore strike-slip faulting in the ICB.

The fault-bound fault system, the Newport-Inglewood Rose Canyon (NIRC) fault complex, is a deeply strike-slip system that extends offshore approximately 120 km from San Diego to the San Joaquin Hills near Newport Beach, California. Based on matching and well data, the NIRC fault system has slip rate is 15-20 mm/yr in the south and 4-5.5 mm/yr along its northern extent. Its southeast trending entire length of the system could produce at Mw 7.0 or larger.

West of the main segments of the NIRC fault complex is the San Onofre Fault Trend (SOT), and San Mateo Fault Trend (SMFT) along the continental shelf north where these fault systems are thought to be part of a strike-slip system that eventually merge with the NIRC complex. Others have interpreted these as deformation associated with the Oligocene Blind Fault (OBF) purported to underlie most of the region.

In late 2015, we acquired the first high-resolution 3D P-Cable seismic survey (5,125 m/s) in the resolution of the San Onofre Trend as part of the Southern California Regional Fault Mapping project aboard the R/V New Horizon. Analysis of this data volume provides important new insights and constraints on the origin of the generation and movement of deformation. Based on this new 3D seismic data, we present our interpretation of the San Onofre fault trend is an unseen phenomenon associated with deep zones and right lateral fault strands splashing off the NIRC faults. Such a scenario is consistent with observations from the 100 km along the shelf and upper slopes that shows seaward mapping faults splashing-off the NIRC system.

Methodology

Our 3D data volume was acquired using a “P-Cable” system consisting of 50 km in long streamers, stub 6.25 km apart, with 8 embedded hydrophones each.

Data was collected in 30-50 km/s survey area over the continental shelf (230-700 m in depth) using a single “spreader” qualitatively seismic source (6.25 km in survey interval) with a 2000 m record length and 0.5 ms sample rate. Faults and prominent structural features were imaged by 4.5 km wide swaths at 1/3 km intervals.

Fig. 5

Discussion

Analysis of fault mapping and analysis, we observe a number of highly segmented faults that we can separate into three different trends based on animal.

1. Faults trending from SW to SE parallel to the NIRC faults on the shelf. These faults are not well imaged in the 725 ms time slice (Fig. 1), but can be viewed in the southeast of the 1000 ms time slice (Fig. 2).

2. Faults trending from NW to SE parallel to large segments of NIRC on the shelf. These faults occur at the base of the continental slope, therefore they aren’t well imaged in the 725 ms time slice (figure 1). After fault mapping and analysis, we observe a number of highly segmented faults that we can separate into three different trends based on animal. Faults occurring in the 1000 ms time slice (Fig. 2). These faults occur at the base of the continental slope, therefore they aren’t well imaged in the 725 ms time slice (figure 1). After fault mapping and analysis, we observe a number of highly segmented faults that we can separate into three different trends based on animal. These faults are not well imaged in the 725 ms time slice (Fig. 1), but can be viewed in the southeast of the 1000 ms time slice (Fig. 2).

3. Faults trending from NE to SW orthogonal to NIRC. These segments show a certain amount of possible left-lateral offset. These segments are possibly rotated with the deformation and in some cases we observe linkage between these faults and the large north-south trending segments. We observe a few large faults trending from northwest to the southeast, parallel to large segments of NIRC on the shelf. These faults occur at the base of the continental slope, therefore they aren’t well imaged in the 725 ms time slice (figure 1).

ICB and Survey Area

(Above) Regional 5 km bathymetry and structural map of San Clemente area and San Onofre area. Faults delineated with a pink stippling. The pink stippling is used to indicate a fault zone. These faults are a few large faults trending from northwest to the southeast, parallel to large segments of NIRC on the shelf. These faults occur at the base of the continental slope, therefore they aren’t well imaged in the 725 ms time slice (figure 1).

Fig. 1b a.

Current End-Member Models

There are two end-member models to explain kinematics in this region. A blind thrust-end-member model (left below) suggests that large fault zones such as those on the San Onofre Trend and San Mateo Trend terminate at depth into a low-angle monocline such that has been imaged in the Plateaus and Morelos. This presents a blind thrust fault underlying mostly of the coastal margin represents a considerable seismic hazard for Southern California.

We use a few large faults trending from northwest to the southeast, parallel to large segments of NIRC on the shelf. These faults occur at the base of the continental slope, therefore they aren’t well imaged in the 725 ms time slice (figure 1). After fault mapping and analysis, we observe a number of highly segmented faults that we can separate into three different trends based on animal. These faults are not well imaged in the 725 ms time slice (Fig. 1), but can be viewed in the southeast of the 1000 ms time slice (Fig. 2).

Fig. 1b a.

Our analysis of the 3D seismic data show deformation moving offshore and to the north. We observe predominantly strike-slip trends on the northern and western part of the survey area with mostly strike-slip on the faults to the south. We prefer the strike-slip only-end-member model (right below) where large faults join at depth with the larger Newport-Inglewood Rose Canyon system to the north.

Fig. 1b b.

Conclusions

Our goal when mapping the region was to gain some insight into the character and relationships of these different fault systems. We were especially interested in learning about structures related to interactions between NIRC and SOT/SMFT. In support of our goal, we acquired data over the continental shelf and slope offshore the coast of San Onofre State Park where these fault systems terminate. We then mapped approximately 350 separate fault segments and then characterized them based on deformation and style.

Our observations of large fault segments distributing strain between NIRC and large, but insignificant segments at the base of the continental slope suggest that mapped segments of the SOT/SMFT represent a shear zone accommodating rotation. Large bounding fault segments to the west are possibly sleeping segments of NIRC rather than a separate fault trend.

Our interpretations suggest the site the tectonic and geomorphological setting for the San Onofre trend is strike-slip kinematics and that the P-Cable system allows systematic data collection and analysis. This data collection and analysis provides the opportunity to observe in the volume, please see Hector Perez’s talk on Tuesday at 08:35 am (T101-01).

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Please see the OCS map at the time to download a digital copy of the poster (approximately 4.5 MB).