Determining the Geometry of the San Joaquin Hills Blind Thrust: Implications for Earthquake Source Characteristics

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Introduction: This report presents results of work completed in 1998 on offshore subsurface structures which may be related to uplift of the San Joaquin Hills, in northern Orange County. We examined seismic reflection datasets which extend in offshore regions from Oceanside to Huntington Beach. These include two surveys (2D and 3D - mapped by Rivera and Shaw) and profiles from other surveys (mapped by Mueller), available from the Minerals Management Service, Bohannon and Geist (1998) and Crouch and Suppe (1993). Available offshore data strongly support work by Grant and others (submitted) that active uplift is occurring along a fold trend that includes the San Joaquin Hills and offshore regions to the south.

Regional Extensional Fault Systems: Offshore seismic data are interpreted to image a major, east-dipping low-angle normal fault, the Oceanside detachment, that is responsible for exhumation in Miocene time of high-grade metamorphic rocks now exposed on Catalina Island (Crouch and Suppe, 1993; Bohannon and Geist, 1998). This east-dipping detachment is imaged as fault plane reflectors on numerous seismic profiles; preliminary mapping indicates it dips less than 9^{o} and lies at ~ 8km depth beneath the coastline at a latitude midway between San Clemente and Oceanside. The eastward extent of the detachment is undefined. However if projected along the 9^{o} dip defined offshore, the detachment would cross the base of the seismic crust (~17km) in the center of the Perris Plain, midway between the Elsinore and San Jacinto faults. Steeper dips would support the detachment crossing the base of the seismogenic crust further west. Structures defined on seismic data within the hangingwall of the Oceanside Detachment include a large west-dipping rollover anticline, interpreted to result from normal-sense slip, based on the geometry and age of Miocene growth strata. Other extensional features include highly rotated, west-dipping fault blocks above the detachment, which are bounded by east-dipping (synthetic) normal faults. Reflectors in the footwall of the detachment are discontinuous and interpreted to define layering in metamorphic rocks. Fault plane reflectors are not evident beneath the detachment.

Compressive Thrusts and Folds: Numerous compressive fault-related folds and thrusts are imaged in the hangingwall of the Oceanside detachment. At least three contractile folds appear to be formed above reactivated, steeply west-dipping thrusts that originated as synthetic normal faults above the Oceanside detachment. Forelimbs above the reactivated thrusts dip steeply, and are consistent with the development of fault-propagation folds. The seafloor above these folds on the continental slope is deformed where their crests lie 50-150 msec above adjacent areas. The most likely candidate for a blind thrust responsible for uplift of the San Joaquin Hills is a 5-6km wide, east-vergent fault-bend (?) fold formed beneath the modern shelf-slope break (in fact it forms the modern shelf-slope break at this latitude). The crest of the fold trends parallel to the coastline (~6km offshore) between Dana Point and a point ~35 km to the south. The continental shelf above the crest and forelimb of the fold slopes gently westward and does not mimic the geometry of shallow folded strata, implying significant erosion of the upper part of the fold during sea level low stands at ~60 to 120m water depth. The backlimb of the fold defines a relatively steeper gradient in the continental slope above ~150m water depth. The width of the east-dipping forelimb is ~ 900m, which we relate to the amount of fault slip on an east-vergent blind thrust, which dips between 19 and 25^{o} west.

Structural Solution: We interpret the east-vergent blind thrust to transfer slip from the underlying east-dipping Oceanside detachment as part of a wedge thrust structure (Mueller and others, 1998). Based on uplift rates derived from U-series dating of marine terrace deposits in the Newport Bay area (0.21-0.27mm/yr in the last 122Ka) we calculate a slip rate on a 19-25^o dipping thrust of 0.50 - 0.84 mm/yr. For earthquakes originating at the base of the seismogenic crust on the detachment, a large fault area is indicated given its shallow dip in offshore regions (e.g. 10^3 km^2). We do not calculate potential rupture area and earthquake magnitude due to uncertainties in the dip of the detachment in onshore areas (i.e. its downdip "area" in the seismogenic crust). We do not consider the east-vergent blind thrust responsible for uplift of the San Joaquin Hills as a significant source of future earthquakes, based on its relatively shallow intersection (e.g. 5 km) with the underlying detachment. Work completed in offshore areas is consistent with previous blind thrust models proposed to underlie the San Joaquin Hills based on the geometry and age of folded marine terraces (Mueller and others, 1998; Grant and others, in review). These models suggest east-vergent fault-bend folding above a relatively low-angle blind thrust. Future efforts in offshore areas will be directed at more complete mapping of the Oceanside detachment and structures in its hangingwall, which we hope to tie with the onshore geometry of the San Joaquin Hills.

References Cited

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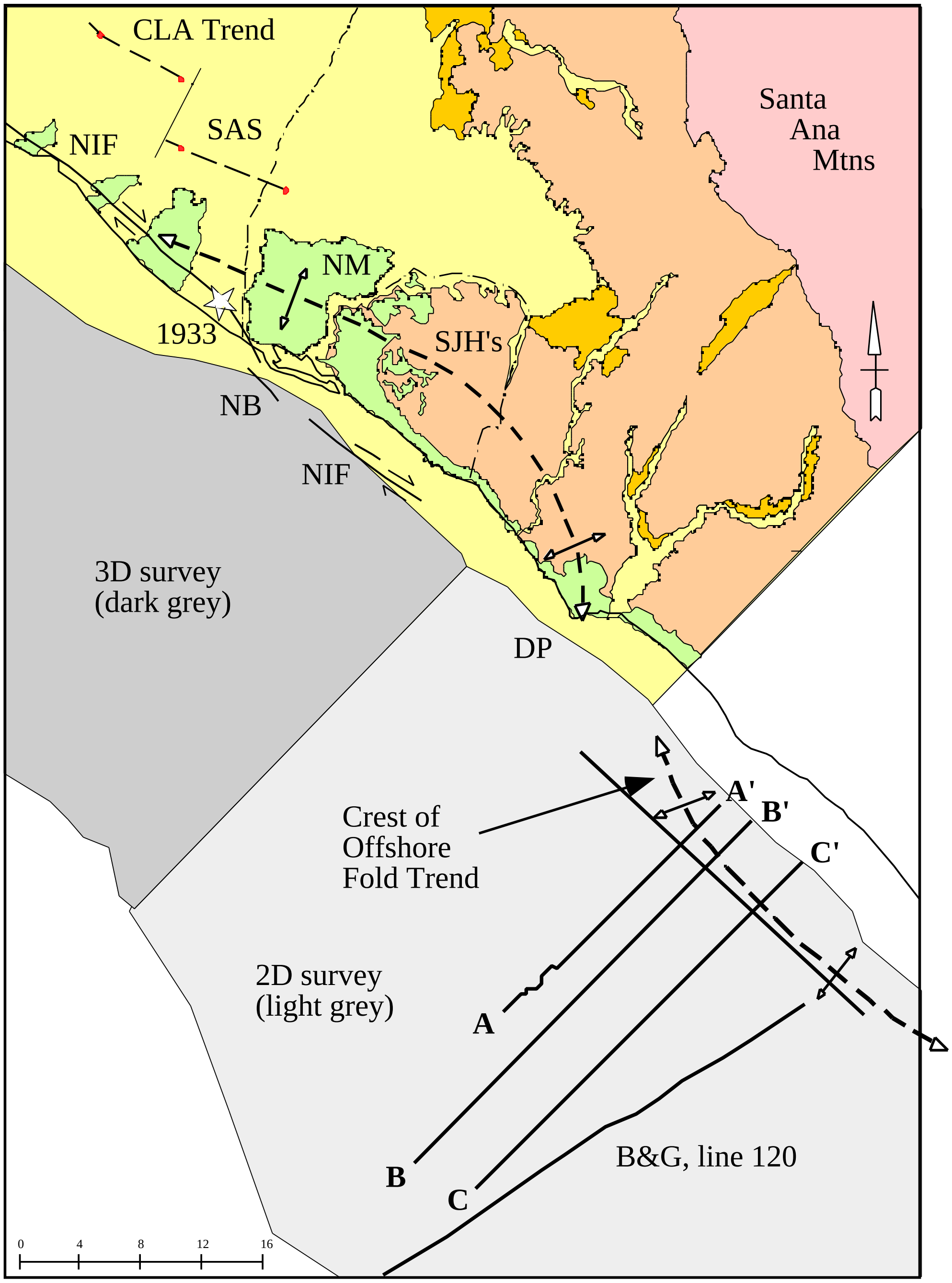

Figure 1 Map of simplified onshore geology of Orange County. CLA, Compton-Los Alamitos trend, SAS, Santa Ana segment, NIF, Newport-Inglewood Fault, NM, Newport Mesa, SJH, San Joaquin Hills, NB, Newport Beach, DP, Dana Point, B&G, Bohannon and Geist line 120, A-A', B-B', C-C',. selected profiles from Harvard dataset. Profile C-C' shown as Figure 2.

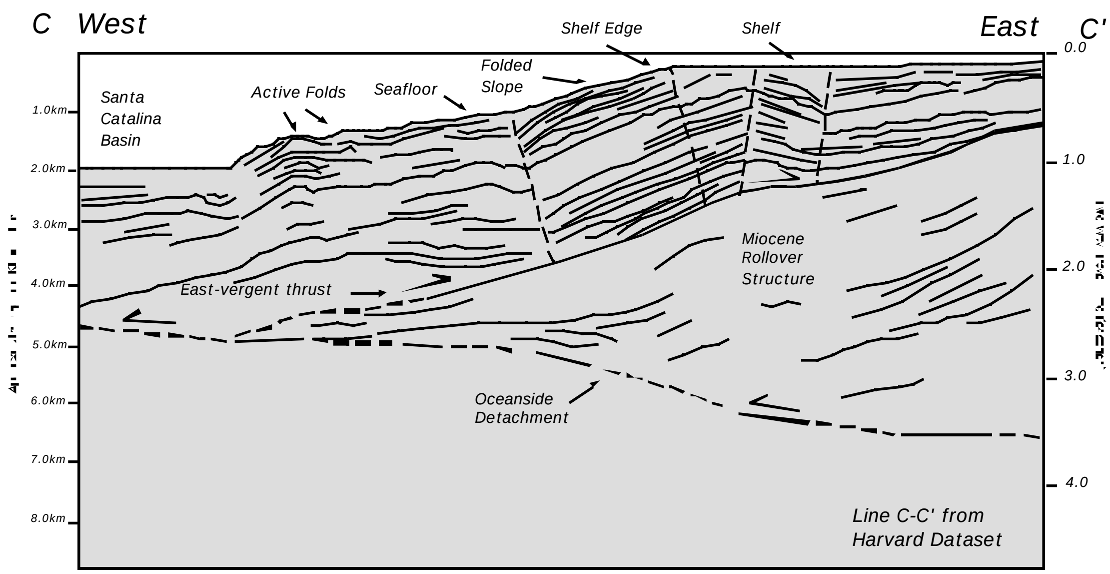

Figure 2 Interpreted seismic line C-C' from Harvard 2D dataset. Note the Oceanside detachment and the blind thrust in its hangingwall which we interpret to be related to the southern extension of the San Joaquin Hills anticline. These form a wedge-thrust structure which is formed by west vergent slip on the detachment. Note the narrow east-facing forelimb formed above the upper blind thrust; underlying reflectors define fold geometry related to rollover on the detachment and compressive fault-related folding. Note also where the continental slope appears folded by the back limb of the upper fold, which we interpret to indicate its currently active nature. Erosion during sea level low stands may have eroded the crest of the fold on the shelf.