3.0 REGIONAL TECTONIC AND SEISMIC SETTING

The following two sections provide descriptions of the regional tectonic setting and the associated patterns of earthquake activity in south-central coastal California. The role of the Shoreline fault zone in the tectonic and seismic setting is discussed in Section 4.

3.1 Regional Tectonic Setting

The Shoreline fault zone is located along the coastal margin of the San Luis Range in south-central California near San Luis Obispo. This region of California is characterized by transpressional deformation between the San Andreas fault zone to the east and the San Gregorio–San Simeon–Hosgri system of near-coastal faults to the west (Figure 3-1). Transpressional deformation in the region appears to be driven by three distinct but interacting processes (Lettis et al., 2009): (1) northward left transfer of slip from the San Andreas fault to the Rinconada and West Huasna faults to the Hosgri–San Simeon fault system; (2) clockwise rotation of the western Transverse Ranges domain, which imparts northerly-directed strain in the region; and (3) possible plate-normal convergence across the region.

This transpressional deformation has produced several distinct but interacting crustal domains and tectonic structures (Figure 3-1; PG&E, 1988). The Los Osos domain is a triangular region consisting of northwest-striking reverse, oblique, and strike-slip faults that border uplifted blocks and subsiding basins within the domain. To the west, the Los Osos domain is bordered by the more northerly trending Hosgri–San Simeon fault system that separates the Los Osos domain from the offshore Santa Maria basin. To the south, the Los Osos domain is bordered by the western Transverse Ranges domain. To the northeast, the Los Osos domain is bordered by the Oceanic–West Huasna fault system that separates the Los Osos domain from the more northerly trending Santa Lucia–San Rafael ranges. The northwest-trending structural grain of the Los Osos domain is transitional between the west-trending structural grain in the Transverse Ranges to the south and the north-northwest-trending structural grain of the Santa Lucia–San Rafael ranges to the northeast, and appears to be abruptly truncated to the west by the more northerly trending Hosgri–San Simeon fault system.

The geomorphology and coastal evolution of south-central California within the Los Osos domain reflects the strong influence of late Quaternary tectonic processes. A well-preserved flight of emergent marine terraces along the coast provides an excellent strain gauge from which Hanson et al. (1994, 2004) have assessed the style, rate, and extent of Quaternary deformation in the region. These studies show that the region has undergone late Pleistocene transpressional deformation accommodated by both strike-slip and dip-slip faulting, and by block uplift and subsidence.

The Hosgri and San Simeon fault zones are characterized by 1–3 millimeters per year (mm/yr) of right-lateral slip, with the rate of slip increasing from south to north along the San Gregorio–San Simeon–Hosgri fault system, ultimately to 6–8 mm/yr on the San Gregorio fault zone to the north in the San Francisco Bay area (Hanson et al., 2004). Whereas the Hosgri fault zone is offshore for its total length, the San Simeon fault zone is onshore between Ragged Point and San Simeon Point for part of its length (Hanson and Lettis, 1994; Hall et al., 1994). Focal mechanisms and the distribution of seismicity along the Hosgri fault zone document nearly pure strike-slip on a near-vertical to steeply east-dipping fault to a depth of 12 km (McLaren and Savage, 2001; Hardebeck, 2010).

The DCPP is located on the southwestern slope of the Irish Hills (Figure 3-2) in the northern part of the San Luis Range, a prominent west-northwest-trending topographic and structural high that forms the core of one of the more prominent uplifted structural blocks (the San Luis–Pismo block) in the Los Osos domain (Lettis et al., 1990). The range is uplifting as a relatively rigid crustal block bordered by the northwest-trending Los Osos and Southwestern Boundary zone faults. Elevations and ages of the marine terraces on the southwest side of the San Luis Range show that the range is uplifting at rates of between 0.1 mm/yr to the southeast to 0.2 mm/yr to the northwest, with little or no observable internal deformation. Major geologic structures within the range, including the Pismo syncline, which cores the Irish Hills, and the San Miguelito, Edna, and Pismo faults, do not deform Quaternary deposits or landforms and are not active structures in the contemporary tectonic setting. Previously characterized active fault zones bordering the San Luis–Pismo block to the northeast, southwest, and west are the Los Osos, Southwestern Boundary (including the San Luis Bay fault zone), and Hosgri fault zones, respectively (Figure 3-2). As shown on Figure 3-1, the Shoreline fault zone is located along the southwestern margin of the San Luis–Pismo block.

3.1.1 Los Osos Fault Zone

The northeastern margin of the San Luis Range is bordered by the Los Osos fault zone, which separates the uplifting range from the subsiding or southwest-tilting Cambria block to the northeast. The fault zone has had a complex history of both strike-slip and dip-slip displacement (Lettis and Hall, 1990). The fault zone is a 50 km long, 2 km wide system of discontinuous, subparallel, and en echelon fault traces extending from Estero Bay on the north to an intersection with the West Huasna fault southeast of San Luis Obispo. Along the coast, the fault zone truncates a flight of marine terraces, indicating a vertical rate of separation across the fault zone of about 0.2 mm/yr. Preliminary results from new geomorphic mapping, interpretation of reprocessed seismic-reflection data, analysis of seismicity data, and structural analysis suggest that the fault zone dips steeply to the southeast (45 to 70 degrees or possibly steeper), and may be primarily an oblique-slip fault, with a significant component of dip slip to accommodate uplift of the range.

3.1.2 Southwestern Boundary Fault Zone

The southwestern margin of the San Luis Range is bordered by a complex zone of late Quaternary reverse, oblique-slip, and possibly strike-slip faults. Taken as a whole, these faults separate the San Luis–Pismo block from the subsiding Santa Maria Valley block to the southwest. The zone of faults is collectively called the Southwestern Boundary fault zone and is 4–10 km wide and over 60 km long (Lettis et al., 1990, 2004). The faults generally strike west-northwest and dip steeply to moderately to the northeast. Principal structures within this fault zone include the Wilmar Avenue, San Luis Bay, Pecho, Los Berros, Oceano, and Nipomo faults. The cumulative rate of vertical separation across the fault zone, based primarily on deformation of the marine terrace sequence along the coast and southwest side of the range onshore, ranges from about 0.1 to 0.2 mm/yr; the rate for each fault is generally 0.04–0.1 mm/yr.

3.1.3 San Luis Bay Fault Zone

Within the Southwestern Boundary fault zone, the San Luis Bay fault zone lies closest to the DCPP. The general location of the fault zone is well constrained onshore but is less well constrained offshore both to the east in San Luis Obispo Bay and to the west toward the Hosgri fault zone. Onshore a strand of the fault zone is exposed along Avila Beach Road, where it juxtaposes Franciscan basement over the Squire Member of the Pismo Formation and displaces an overlying marine wave-cut platform and associated marine terrace deposits (PG&E, 1990). A fault strand also displaces fluvial deposits at the mouth of San Luis Obispo Creek before extending offshore to the east into San Luis Obispo Bay. Farther east, the fault zone is interpreted to extend to a location offshore of Mallagh Landing, where it either dies out or intersects the offshore projection of the San Miguelito fault (Plate 1). The fault zone does not extend onshore east of Mallagh Landing, confirming that this is the eastern end of the fault zone.

To the northwest of Avila Beach, the San Luis Bay fault zone crosses a topographic saddle north of Point San Luis where the fault is blind, but beneath the onshore coastal terraces the fault diverges into two distinct traces or zones that deform the marine terraces. The southern trace is named the Rattlesnake fault and has a vertical separation rate of about 0.08 mm/yr. The northern trace is named the Olson fault in the LTSP documents (PG&E, 1990) and the Olson Hill deformation zone in this report (Plate 1). The Olson Hill deformation zone appears to form a monoclinal warp in the marine terraces with a total vertical separation of about 0.06 mm/yr. In contrast to the better-defined Rattlesnake fault, the deformation of marine terraces near Olson Hill cannot be attributed to any specific bedrock fault (Appendix B). The cumulative rate of vertical separation across these two parts of the San Luis Bay fault zone along the outer coast is about 0.14 mm/yr. Offshore to the west, the fault zone is interpreted to extend either to an intersection with the Shoreline fault zone (for a total fault length of 8 km) or across the Shoreline fault zone to an intersection with the Hosgri fault zone (for a total fault length of 16 km) (Appendix B).

3.1.4 Hosgri Fault Zone

The Hosgri fault zone is the southern portion of the larger 410 km long San Gregorio–San Simeon–Hosgri fault system. It is an active transpressional, convergent right-slip fault zone that extends southeastward approximately 110 km from a location 6 km offshore of Cambria to a point 5 km northwest of Point Pedernales (Hanson et al., 2004). The Hosgri fault zone lies offshore for its total length. As described above, the fault zone separates two tectonic domains of contrasting styles and rates of crustal deformation: the offshore Santa Maria basin on the western side of the fault zone and the onshore Los Osos domain on the eastern side (PG&E, 1988, 1990; Lettis et al., 2004). To the east, the fault zone truncates a marine bedrock platform associated with uplift of the San Luis–Pismo block.

The Hosgri fault zone was mapped along its entire length using petroleum industry multichannel seismic-reflection data that imaged the traces to depths of 1.5–3 km beneath the seafloor (PG&E, 1988, 1990). Part of the fault zone is remapped for this study using single-channel, high-resolution USGS sparker data (Appendix H). The USGS data set provides better near-surface resolution of the fault traces and associated structures but with limited depth of penetration. An approximate 33 km long section of the Hosgri fault zone is shown on the geologic map of the

Shoreline fault zone study area (Plate 1). The remainder of the Hosgri fault zone extends both northwest and southeast of the area on Plate 1.

Offshore of DCPP the Hosgri fault zone trends approximately N25°W to N30°W and appears to control the break between the inner and outer continental shelves. It also forms the western termination of the offshore Islay and Santa Rosa reef bedrock shelves (Appendix I) and many of the geologic structures in the Los Osos domain. As mapped from the high-resolution USGS seismic reflection data set, the Hosgri fault zone consists of multiple traces, with individual traces that are continuous for as long as 18 km. The fault zone itself is up to 2.5 km wide and contains both active and inactive traces as well as en echelon conjugate faults and folds. The fault traces appear vertical to steeply dipping in the upper few hundred meters of the sediment section. On the multichannel data, with several seconds of signal penetration, some of the traces dip steeply to the east below about 1 km depth.

3.2 Regional Seismicity Setting

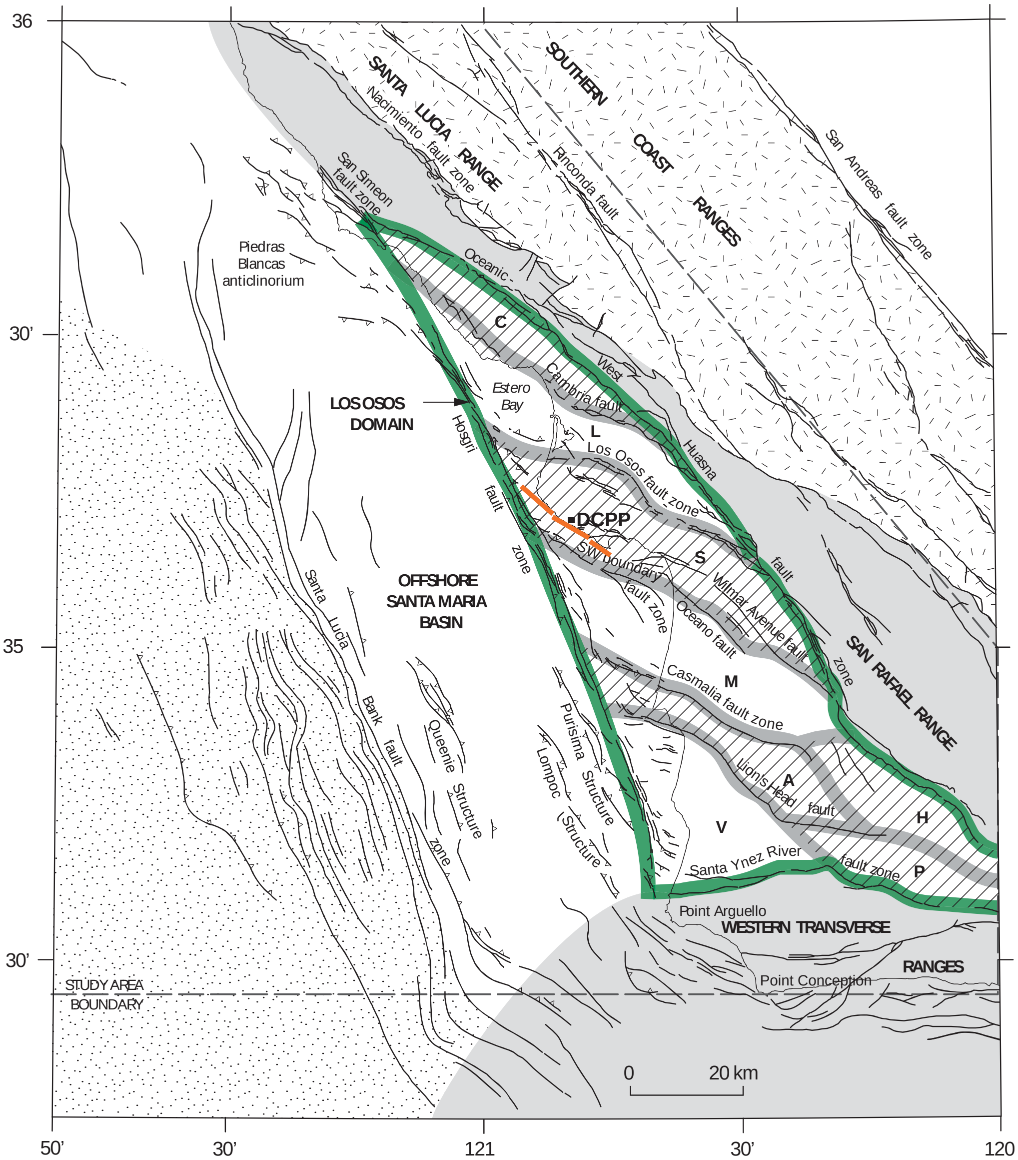
Figure 3-2 shows the regional seismicity patterns (a) and focal mechanisms (b) from 1987 to 2008 from Hardebeck (2010). Earthquake activity west of the San Andreas fault zone is concentrated in several areas: (1) within the Santa Lucia Range: (2) west of the San Simeon area within the active offshore Piedras Blancas anticlinorium; (3) along and east of the Hosgri fault zone within the Los Osos domain; and (4) in the southwestern offshore region, broadly west of Pt. Arguello. The dense cluster of earthquakes along the Santa Lucia Range contains primarily aftershocks from the 2003 M_w 6.5 San Simeon earthquake (McLaren et al., 2008). The San Simeon earthquake is the largest event recorded in the region since the 1927 M_w 7.2 Lompoc earthquake. The Lompoc earthquake occurred in the southern offshore region, southwest of Point Conception.

Within the Los Osos domain, earthquakes occur primarily within the San Luis–Pismo, Casmalia, and western Los Osos blocks (Figures 3-1 and 3-2), and they extend to a depth of 12–15 km. The San Luis–Pismo and Casmalia block activity is consistent with active uplifting blocks. There is a relative lack of seismic activity within the eastern half of the Los Osos block and within the onshore Santa Maria basin. The lower rates of seismic activity in these areas suggest low rates of deformation within the down-dropped blocks of the Los Osos domain. However, the seismic activity in Estero Bay (western half of the Los Osos block) is an exception to this generalization and suggests locally active deformation within this down-dropped block.

Relatively few earthquakes have occurred west of the Hosgri fault zone from about the north end of Estero Bay to Pt. Sal (Figure 3-2a), consistent with its regional role as a significant tectonic boundary. The Hosgri fault zone as a tectonic boundary is also consistent with the truncation of the Los Osos domain by the Hosgri fault zone and the lack of mapped Quaternary faults directly west of the Hosgri.

Focal mechanisms of the region are predominantly reverse and strike-slip (Figure 3-2b) and are consistent with dextral transpressional deformation. Mechanisms beneath the Santa Lucia Range from the San Simeon aftershock zone to the area northeast of the San Simeon fault zone show predominantly reverse motion along west-northwest-trending fault planes. Along and west of the San Simeon fault zone in the Piedras Blancas anticlinorium, mechanisms are predominantly strike-slip. Strike-slip mechanisms are also prevalent south of the San Simeon aftershock zone and along the West Huasna fault zone.

There are numerous strike-slip mechanisms along the Hosgri fault zone between Estero Bay and Pt. San Luis, and directly east of the Hosgri in Estero Bay, along the Shoreline fault zone, and onshore within the Irish Hills. Generally, the Hosgri mechanisms have nodal planes that strike more north-northwesterly compared to the northwesterly striking focal mechanisms directly east of the Hosgri fault zone. Strike-slip mechanisms along the West Huasna fault zone change from nearly north-south-striking nodal planes east of San Luis Obispo to west-northwest-striking nodal planes north of San Luis Obispo to the southern end of the 2003 San Simeon earthquake aftershock zone.



From PG&E, 1988.

Salinian Terrane

Stanley Mountain Terrane

San Simeon Terrane

Patton Terrane

Sur-Obispo Composite (McCulloch, 1987)

Structural blocks within the Los Osos domain

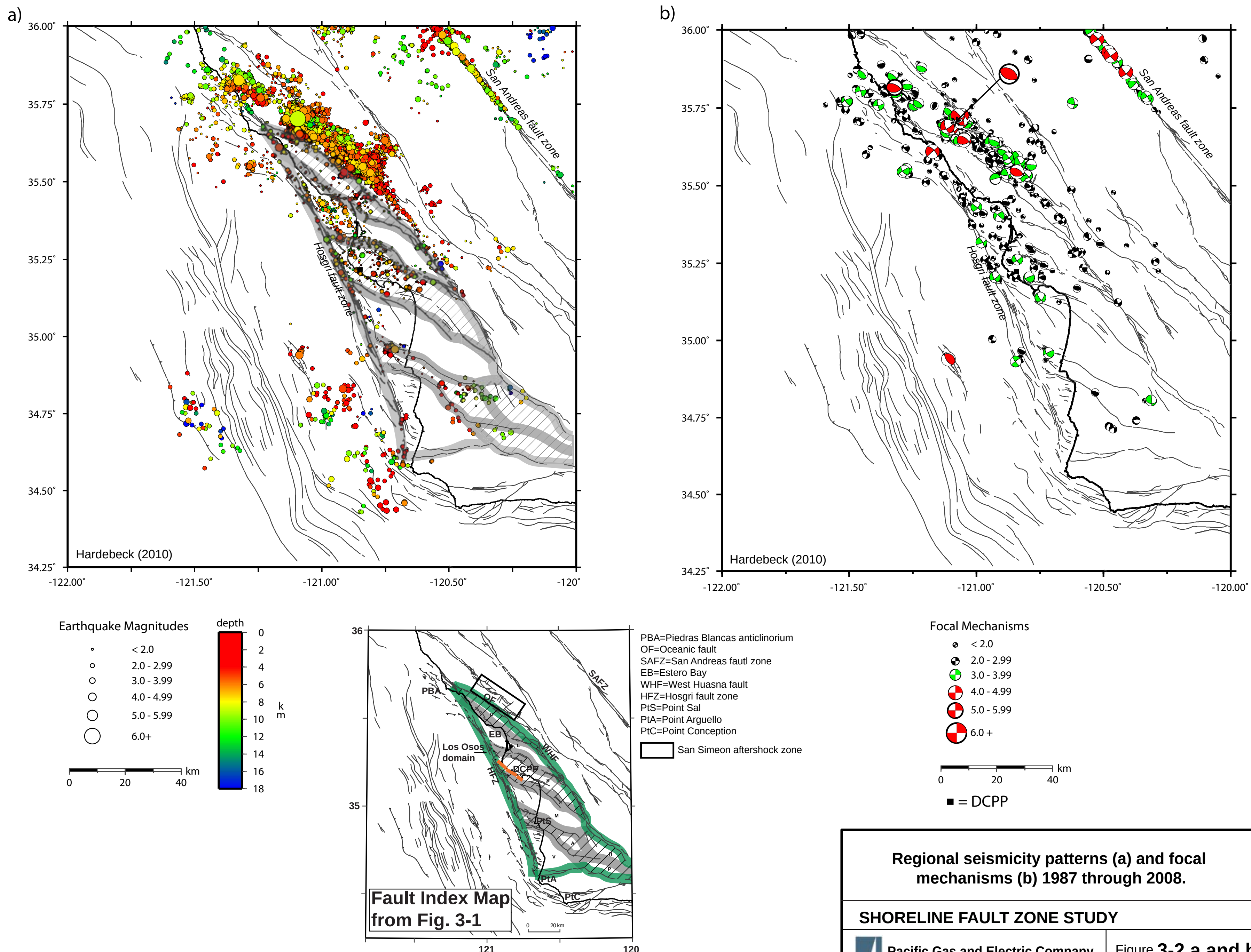
A = Casmalia
C = Cambria
H = Solomon Hills
L = Los Osos
M = Santa Maria Valley
P = Purisima
S = San Luis/Pismo
V = Vandenberg/Lompoc

Note: Orange line is schematic of the Shoreline fault zone.
Green line outlines the Los Osos domain.
Hash marks are uplifted structural blocks within the Los Osos domain.

Los Osos domain

SHORELINE FAULT STUDY

Pacific Gas and Electric Company | Figure **3-1**



Regional seismicity patterns (a) and focal mechanisms (b) 1987 through 2008.

SHORELINE FAULT ZONE STUDY

Pacific Gas and Electric Company | Figure **3-2 a and b**