Anomalous Seismicity in the San Diego Coastal Region

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Abstract

This short note documents recent seismic activity in the coastal region adjacent to San Diego. Seismic activity in the region has increased dramatically since 1983 when compared with previous historic activity. Similar increases in seismicity, that occurred prior to significant earthquakes in California, are also documented. It is speculated that the tectonic style in the continental borderland off of San Diego is very similar to that in the Basin and Range province.

Introduction

Despite the fact that large linear bathymetric features in the continental margin of southernmost California have long been suspected to be related to major active faults (Clarke et al., 1985), earthquake activity in the vicinity of San Diego has historically been very low. However this situation has changed rather dramatically in the last several years. A magnitude 5.3 earthquake, commonly referred to as the Oceanside earthquake, occurred at 13:46 GMT, 13 July 1986 about 70 km northwest of San Diego along the northern end of a major northwest-trending escarpment known as the Thirty-Mile Bank (see Figure 1). This earthquake was preceded by over a year of increased activity in the epicentral region and the aftershock sequence has also been quite strong. In addition to the Oceanside sequence, San Diego has also experienced a sequence of five earthquakes in the magnitude 4 range that have occurred both in San Diego Bay and slightly offshore within the last year and a half. For long-time residents of San Diego, this earthquake activity has certainly seemed unusual. What is the significance of these sequences; are they likely to continue; and what is the prospect for even larger earthquakes within the next several years?

Recent Seismicity

Recent seismicity in the San Diego region is shown for the periods 1978 through 1984 and 1985 to Sept. 1986 in Figures 1 and 2, respectively. A time-distance plot of seismicity as projected onto the line C-D is shown in Figure 3 for the period from 1978 through Sept. 1986. A number of clusters of activity can be distinguished; one large one to the north (Oceanside earthquake), and two (maybe more) clusters in the San Diego region. Clearly, the rate of seismicity since 1983 is far higher than that from 1978 to 1983. There are several indications that these clusters may be temporally related on several time scales. The most obvious correlation is the appearance of these clusters within a two-year period. A second temporal coincidence can be seen on a time scale of days. For instance, the Oceanside earthquake in July 1986 was preceded by three hours by a magnitude 3 earthquake
in San Diego Bay. Within the next week, clusters of seismicity were active about 10 km west of San Diego. A similar coincidence in June 1985 prompted an official notification from the USGS to the State of California of a potential geologic hazard. In that case, a M 3.9 earthquake in the Oceanside region was followed within two days by a sequence of earthquakes in San Diego Bay having magnitudes of 3.9, 4.0, and 3.8. Although it may be that these coincidences are merely fortuitous, they are certainly disconcerting when experienced in real time.

The recent activity in the San Diego coastal region can be viewed from a broader perspective in Figure 4. All seismicity located using the Caltech-USGS seismic network since 1978 is shown. The recent clusters of activity appear to lie along and to define a rather broad seismicity lineation running from the San Miguel fault in northern Baja to the Santa Monica Bay. A second broad seismicity lineation can be seen to the west running from Ensenada to Santa Barbara. At this point, I am unaware of any mapped throughgoing fault systems that parallel these apparent seismicity lineations and it may be that the lineations are caused by a fortuitous alignment of earthquake clusters. Focal mechanisms for the 13 July 1986 M 5.3 earthquake and for the M 3.8 earthquake that occurred in the San Diego sequence of June 1985 are shown in Figure 5. Focal mechanisms for the San Diego earthquake appear to be consistent with right-lateral faulting on northerly-trending faults. These mechanisms would be consistent with the orientation of the Rose Canyon fault system. The focal mechanism of the Oceanside earthquake is somewhat problematic; the focal mechanism from local readings from the southern California network yields oblique-right-lateral slip on a north-trending plane (Egill Hauksson and Lucy Jones, personal communication). However, long-period teleseismic P-waves seem to be more consistent with a N46W-striking, 52E-dipping, thrust fault (John Nabelek, personal communication). Furthermore, many of the aftershocks for which mechanisms have been determined using local array data also have significant thrust components (Lucy Jones, personal communication). Thirty-Mile Bank, the major bathymetric feature of the area, trends to the northwest. At this time, the orientation of the Oceanside earthquake is unresolved.

Time-distance plots of seismicity projected onto the line A-B of Figure 4 and for the periods 1932 to present (magnitude > 3.8) and 1978 to present (all magnitudes) are shown in Figures 6 and 7, respectively. A noticeable paucity of significant seismicity in the San Diego region can be seen for a period from the mid 50's through the mid 70's. The onset of activity seen in Figure 6 is due to events to the southeast of San Clemente island. The persistent clustering nature of the recent seismicity can be seen in Figure 7.
Comparison to Other Regions

One of the most disconcerting features of the recent San Diego seismicity is its persistence and its increasing rate with time. When experienced in real time, it is far easier to get excited by increasing seismicity than by seismic quiescences. However, there are several clear examples in which persistent, increasing seismicity over the time scale of months has been accompanied by potentially damaging earthquakes. A number of rectangular subregions of California are defined in Figure 8. In Figure 9, the cumulative number of earthquakes larger than magnitude 3.5 is given as a function of time since 1932 for each region. This same function is also plotted for the entire Caltech catalog. Although a careful study of the procedures used to construct this catalog would be necessary to assess the completeness of the catalog, I believe that the catalog is reasonably complete at the magnitude 3.5 level (Hileman, 1978). Clear changes in the seismicity rate can be seen in 1952 and 1979 for the entire catalog. I am not aware of any procedural changes that would have produced the lower overall seismicity rate for the period from 1952 to 1979, and one speculation is that this change is physically related to the occurrence of the M 7.7 1952 Kern County earthquake (Raleigh et al., 1982). The overall catalog seismicity rate increased again in the period 1979 to present principally because of earthquake sequences in Imperial Valley, Long Valley, Coalinga, and most recently, North Palm Springs and Oceanside.

Inspection of the cumulative seismicity plots for selected subregions (Figure 9) reveals that periods of increasing seismicity have preceded several significant earthquakes. Very clear seismicity increases can be seen in both the Mammoth and Coso regions (Boxes A and C, respectively). Three magnitude 6 earthquakes occurred in 1980 in the Mammoth region following a period of increasing activity that began in 1978 (Ryall and Ryall, 1981). The recent increase in activity in the Mammoth box is distributed over a very large region and high levels of seismicity have persisted in this region at least until the present. Seismicity in the Coso box also experienced a steady increase during the period from 1981 through 1983. The largest events in this region have been in the magnitude 5 range and were preceded by about a year of increased seismic activity.

Seismic activity in the Imperial Valley region (Box F) was also clearly higher for a period of about 5 years before the magnitude 6.5 Imperial Valley earthquake in 1979 (Johnson, 1979). Finally there was a noticeable increase in seismic activity in the area of the 1983 M 6.5 Coalinga earthquake (Box B) and a magnitude 5.5 earthquake occurred just to the north of and six months prior to the Coalinga mainshock (Eaton, 1985). The seismicity in the San Diego region (Box G) shows a very clear seismicity increase that began in about 1983. This increase is very similar to the increased seismicity that was experienced in the Mammoth and Coso regions.

Although I have shown several examples in which seismicity increased over the time scale of months to years before several significant earthquakes, there are also many examples of larger
earthquakes for which seismicity increases did not occur. There is no evidence that seismicity increased before the M 6.5 San Fernando earthquake in 1971 (Box D) or before the M 6.5 Borrego mountain earthquake on the San Jacinto fault in 1968 (Box E).

Discussion

With the exception of the Coalinga earthquake, the previous examples of increased seismicity occurred in regions of strike-slip faulting that are accompanied by crustal spreading. A natural question arises; is the recent seismicity in the San Diego region also related to strike-slip faulting in a region of crustal spreading? Inspection of the bathymetry in the continental margin south of the Los Angeles Basin and north of Ensenada, Mexico reveals a very broad region (more than 200 km wide) of northwest-trending basins and ranges. In fact, the physiography of this region is very similar to that of the Owens Valley, Panamint Valley, and Death Valley. The vertical relief seen within this continental margin is as much as 2,000 meters and the physiography of this margin is unique when compared with any other continental margin. Humphreys and Weldon (1986) have suggested that approximately 5 to 10 mm/yr of northwest-trending, right-lateral shear deformation is occurring in the continental borderland. This shear deformation may also be accompanied by an undetermined amount of crustal spreading (Gene Humphreys, personal communication).

There are indications that the Basin and Range province of eastern California and Nevada have a distinctive style of seismicity in which regions undergo long periods of seismic quiescences (hundreds or thousands of years) that are interrupted by periods of high regional seismicity (Wallace, 1985). If this is also the case for the continental margin off of San Diego, then we may be seeing the beginning of a prolonged period of higher seismicity. Although I have not been able to quantitatively give any prospects for future activity, I believe that there is an even chance that we have not seen the last of the seismic activity in this region.

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References


Figure 1. All events in the Caltech catalog from Jan. 1985 through Aug. 1986. Many events after the 13 July 1986 earthquake are not yet included in the catalog. Seismicity northeast of the Elsinore fault is not plotted. Time-distance plot for seismicity in the box and projected onto the line C-D is found in Figure 3.
Figure 2. Same as Figure 1, except for the time period from Jan. 1978 through Dec. 1984.
Figure 3. Time-distance plot of seismicity in the box given in Figure 1 for the time period from Jan. 1978 through Aug. 1986. The Oceanside earthquake is at the top of the plot (about distance 20 km) and the San Diego seismicity is near the bottom (about distance 90 km).
Figure 4. All events in the Caltech catalog from Jan. 1985 through June 1986 (about 100,000 events). Time distance plots for seismicity in the box are given in Figures 6 and 7.
Figure 5. Focal mechanisms of the 13 July 1986 M 5.3 Oceanside earthquake and the 17 June 1985 M 3.8 San Diego earthquake from first-motion data from the Caltech-USGS telemetered array (Lucy Jones and Egill Hauksson, personal communication). Long-period teleseismic P-waves indicate a thrust mechanism for the Oceanside earthquake (dotted line; John Nabelek, personal communication).
Figure 6. Time-distance plot of seismicity in the box of Figure 4 and for the period from 1932 to 1986. Only earthquakes larger than magnitude 3.8 are plotted. The Oceanside earthquake is at about distance 320 km.
Figure 7. Same as Figure 6, but for all earthquakes since Jan. 1978.
Figure 8. Definition of boxes used in Figure 9 together with seismicity in the Caltech catalog from Jan. 1978 to June 1976.
Figure 9. Cumulative number of earthquakes larger than magnitude 3.5 plotted versus time since 1932. The entire Caltech catalog is plotted in the upper left and the other subregions are defined in Figure 8.