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SURVEY FOR NEW PRECARIOUS ROCKS IMPORTANT FOR TESTING CYBERSHAKE, NGA, AND HAZARD MAPS

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Introduction: PBRs and Seismic Hazard

It has become clear that precariously balanced rocks (PBRs) provide important constraints on ground motion attenuation curves and seismic hazard. Because obtaining a statistically sufficient number of near-source recordings form very large earthquakes in a variety of tectonic environments may take many decades, precariously balanced rocks which have been in place thousands of years provide important constraints on such ground motion attenuation curves and seismic hazard.

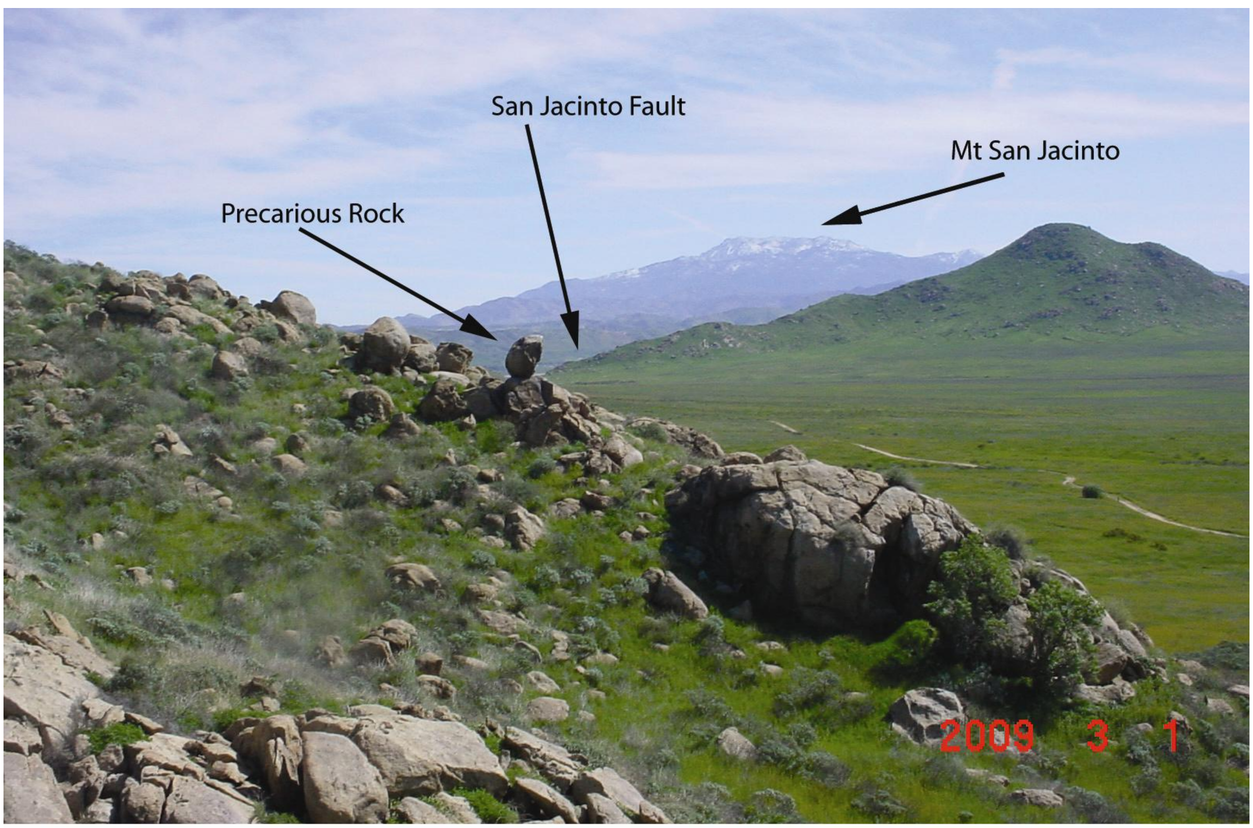

Figure 1

Hundreds of useful rocks have been documented in several papers published with SCEC and NEHRP funding. Additional papers have quantified the constraints from both the age and mechanical points of view. New attenuation curves (NGA) are more consistent with PBRs than the older attenuation curves, but the validity of the NGA curves remains in question. Also, it has become clear that some of the statistical assumptions in PSHA give physically unreasonable answers when extrapolated to very low probabilities, a conclusion supported by precarious rock constraints. The new 2008 Seismic Hazard maps for 2% in 50 year probabilities appear to be inconsistent with many PBRs. Recently it has become accepted that future hazard maps will have to take into account the effect of an erroneous assumption about the connection between the spatial scatter of strong motion data, and the temporal scatter at a particular spatial site (the so-called ergodic assumption, Anderson and Brune, 1999). Determining how to make the correction will require verification from constraints on maximum low probability ground motion, such as constraints provided by precarious rocks. Support for the old age of the rocks has been provided by cosmogenic age dating (Rood et al., SCEC Annual Meeting Abstracts. 2008). Our results are strong evidence that PBRs provide important constraints for all of the new tools for estimating earthquake hazard.

In 2008 the PI and assistant (Richard Brune) continued to locate and document new PBRs in areas critical for constraining results of the new seismic hazard tools in the Cybershake Platform, an element of the Community Modeling Environment (CME) of the Southern California Earthquake Center (SCEC). Comparison of ground motion predictions of Terrashake with precarious rocks near Banning and Beaumont, suggests that recent large earthquakes may have nucleated in San Gorgonio Pass (Olsen and Brune, 2007). PBRS have suggested a possible correlation with trans-tensional step-overs and with direction of rupture. Groups of precarious rocks have been reported near extensional step-overs on strike-slip faults in Southern California and Nevada (Brune, 2003) and thus suggest that the ground motion at these sites may be anomalously low because stress levels are low, or because the fault ruptures tend to nucleate at, and propagate away from extensional step-overs. Brune, Biasi, and Brune, SCEC ABS., 2007, suggested that this low stress may be one of the reasons for low ground motions in the vicinity of San Bernardino. Rood et al., (SCEC Annual Meeting Abstracts, 2008) have confirmed the great age of these rocks.

Silverwood Lake-Grass Valley-San Bernardino

Since San Bernardino is next to the San Andreas Fault, various investigators have suggested that a typical scenario earthquake on the Southern San Andreas Fault, would cause extreme damage. If the precarious rocks can place a constraint on ground motion in rocks surrounding San Bernardino, this may lead to improved estimation of ground motion in the sedimentary basin on which most of the city is located. During 2008 we located and documented new precarious rocks south of Beaumont and Banning which will be valuable in constraining the hazard around San Bernardino.

Precariously balanced rocks are generally not found closer than about 15 km from the southern San Andreas Fault. Previous exceptions have been noted in San Gorgonio Pass just south of Banning and Beaumont. Olsen and Brune (2007) suggested two possible explanations: (1) Most large earthquakes in the area (including possibly the 1857 earthquake) nucleate in San Gorgonio Pass and rupture away from there, so that directivity focuses the energy away, and/or (2): the faulting in San Gorgonio Pass is thrust faulting with the energy concentrating in the hanging wall and decoupling energy from the foot wall, where Banning and Beaumont are located.

Last year we discovered a number of precariously balanced rocks at Silverwood Lake, about 7 km northeast of the San Andreas Fault in Cajon Pass, where offsets of several meters were documented for the 1812 earthquake. The preliminary toppling accelerations for these rocks are 0.2 to 0.3, unexpectedly low to have survived an earthquake with such a large offset. The hazard indicated in the 2002 PHSA maps suggests 2% in 50 yr hazard of 0.7 g. The rocks are formed in relatively soft granitic materials, and thus could have formed relatively recently compared to other balanced rocks in the Mojave region. Nevertheless they probably are at least 1000 yrs old, and thus survived the 1812 earthquake (and also the 1857 earthquake), and probably several prior earthquakes. Further study will be required to verify the distribution, toppling accelerations, and ages of the rocks, however we feel our preliminary assessments warrant speculation on possible explanations.

During 2008 we found some new rocks in the Grass Valley region and helped in the study of several previously located rocks. These rocks are at a distance of about 11 km from the San Andreas Fault and very close to the Cleghorn Fault. The pedestals were confirmed to be more than 10 ka old (Rood et al. SCEC 2008 abstract). The results indicate the Cleghorn Fault is not active, as previously thought (Behr et al, SCEC 2008 abstracts).

The nucleation point suggestions of Olsen and Brune (2007) seem somewhat less likely to apply to the Silverwood Lake and Grass Valley rocks. They are on the hanging wall side of the faults in San Gorgonio Pass. Also, it may be difficult to locate nucleation points which would explain low accelerations at points as far apart as Silverwood Lake and Banning. Other possible explanations include:

(1) Ground accelerations are unexpectedly low even though the offsets may be large -- possibly a result of the lack of any nearby strong asperity, a local low stress drop anti-asperity, or other causes for local extreme deviation of the ground motions from the expected median.

(2) The intersection of the San Andreas Fault with the San Jacinto fault NW of Silverwood Lake creates a regional trans-tensional releasing-bend geometry. Precariously balanced rocks have previously been documented unusually near other trans-tensional step-overs in strike slip faults (Brune, 2003).

(3) The rocks are located in some special as yet unknown geologic situation that somehow isolates them from strong ground motions.

Joshua Tree National Monument

Several zones of granitic outcrops previously located from satellite images, have been surveyed during 2008. PBRs found provide important constraints on the hazard from the Southern San Andreas Fault, the Calico fault, the Vernon fault, and, perhaps most importantly, the Eureka Peak fault, likely source of the 1992 Joshua Tree earthquake. We found a number of semi-precarious rocks at the eastern part of Joshua Tree National Park, but as we moved west the rocks appeared more shaken down until we reached the western edge of the park, near the Eureka Peak fault, where the rocks were intensely shaken down. This result may indicate that the activity on the Pinto Mountain Fault deflects to the south near Morongo Valley (onto the Morongo Valley Fault). This might explain the fact that the precarious rocks near Pioneertown, next to the Pinto Mountain Fault, suggest that that section of the fault is inactive.

TRANS-TENSIONAL STEP-OVER IN THE SAN JACINTO VALLEY.

Earlier studies of precarious rocks south of Beaumont, CA, suggested that the trans-tensional step-over in the San Jacinto strike-slip fault might be associated with relatively low ground motions (Brune, 2003). This suggested that we document any precarious rocks on the southwest side of the

San Jacinto Fault. In 2008 we carried out three surveys that confirmed that this was indeed the case. An example of one of the rocks is shown in figure 1. This rock is located about 7 km from the San Jacinto fault shown in the intermediate distance. San Jacinto Peak is shown in the far background. Further studies of these rocks by rupture modeling may explain why trans-tensional step-overs are associated with low ground motions.

PRECARIOUS ROCKS ON THE UC RIVERSIDE CAMPUS.

In 2008 we located a couple of new precarious rocks on the UC Riverside campus. These rocks are being used as part of a study of seismic hazard on the UCR campus by a graduate student, Corrie Neighbors (supervised by Elizabeth Cochran). The rocks are anomalously close to the San Jacinto Fault and may be influenced by the San Jacinto fault trans-tensional step-over described above.

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