2012 SCEC Annual Report

Fragile Geologic Features in New Zealand and Southern California: New Age Constraints and Comparison to Seismic Hazard Models

Principal Investigators:

Mark W. Stirling

GNS Science (Institute of Geological & Nuclear Sciences)
P.O. Box 30368, Lower Hutt, New Zealand

Dylan H. Rood

AMS Laboratory

Scottish Universities Environmental Research Centre

East Kilbride G75 0QF UK

Introduction

Our 2012 SCEC funding $US4000 was used on attending the SCEC annual meeting, and to undertake a field reconnaissance of “well studied” sites of precariously-balanced rocks (PBRs) in Southern California. The objective was to take a “stand back” review of the PBRs, data and interpretations, identify the strengths and issues of the work, and where effort should be concentrated in the future. The following is a short field log of the places visited over the time period 5-9 September, with key field observations, interpretations and issues identified.

Field Reconnaissance of Fragile Geologic Features in Southern California

1. Morro Bay Area
   Our first area of field reconnaissance was Morro Bay and surrounds. Morro Bay is located on the California coast to the south of Monterey, and is immediately north of the Diablo Canyon nuclear power plant land. Identification and review of fragile geologic features (FGFs) in the area will therefore be potentially useful for review of probabilistic seismic hazard (PSH) models for Diablo Canyon.

   We visited the prominent wave cut platform to the south and north of Morro Bay to see if we could identify any abandoned sea stacks preserved on the approximately 10m a.s.l. wavecut platform. Since abandoned sea stacks are no longer being actively modified by the sea, the age and fragility of the sea stack is set by the timing of abandonment (presumably earthquake uplift). We only observed two abandoned sea stacks to the north of Morro Bay (Fig. 1), and these were weathered and in a state of semi-fragility. By semi-fragility, we mean that strong motions of 1g or greater would be expected to damage or destroy the features. Near-total damage to an active sea stack in New Zealand (Shag Rock) was observed during motions of about 1g in the M6.2, 22 February 2011 Christchurch earthquake, and this serves as a reality check of shaking-induced damage of sea stacks. Unfortunately no other examples of sea stacks were observed in the area.

   We also scanned hillslope outcrops in Morro Bay State Park looking for any FGFs, but did not see anything of note. We did see areas of suitable outcrops for development of such features, but none were observed. Aside from the two abandoned sea stacks to the south of Morro Bay, the general area appears to have limited potential for study of FGFs. However, assessment of the age and fragility of these two sea stacks may have potential for constraining the ground motions from near-field large earthquakes on the Hosgri Fault.

2. Hanging wall of White Wolf Fault: A full day was spent observing granitic corestone outcrops, and undertaking photogrammetry of the PBR WW26, also named Kent (Fig. 2). The PBR was subjected to load testing several years back by Jim Brune and colleagues, with the interest in constraining hanging wall motions from the White Wolf Fault. The fault produced the M7.3 1952 Kern County earthquake. The Garlock Fault is also close enough (c.30km) to be capable of producing strong motions at the site.

The area shows generally stable granitic outcrops and rare PBRs (only one observed). It is difficult to know whether or not the granite outcrops are conducive to PBR formation, or whether PBRs have been formed but then destroyed by strong ground motions. Our feeling is that this one PBR, while able to constrain ground motions at the actual PBR site for fragility age of the rock (fragility age is the time span of the present fragility of the PBR), cannot be used to constrain ground motions for the general area with confidence without observing many more similarly fragile features in the area.

3. Kern Canyon – Lake Isabella: We visited PBR LI1 (also named Izzy) within granitic outcrops located on a hillslope less than 1km downstream of the right abutment of the Lake Isabella Dam site (Fig. 3). This large earth dam is also bisected by the active Kern Canyon Fault, so studies of PBRs in the area are potentially valuable for constraining near-field ground motions at the dam site. The PBR is spectacular, but we consider that the absence of other PBRs in the area again brings into question the wider applicability of PBR-derived ground motion constraints to the dam site. During our visit we discussed the "statistical remnant" hypothesis, in which PBRs might be remnants of former populations of PBRs destroyed by strong shaking. Because fragility functions typically allow significant probabilities of non-toppling (i.e. 1-toppling probability), one can work out the probability of a PBR surviving from a former population of n PBRs, given the PBR age, PSH estimates for the site, and the fragility function. We will be revisiting the work of O'Connell et al (BSSA) to explore this aspect in more detail, as we feel that the statistical remnant hypothesis has not been sufficiently examined in the work programmes and literature to date.

4. Red Rock Canyon Hoodoos: We visited the Red Rock Canyon area, just north of the Garlock Fault on HW14, to observe HooDoos developed in 10my sandstones. The area is a classic badlands landscape, where columnar jointing and strong lithological and sedimentary contrasts in the sediments have resulted in formation of the spectacular hoodoos. We could see that the most spectacular hoodoo was narrowest at its base (Fig. 4), presumably where the most rainwater flows on the hoodoo shaft (all water flow travels downwards), and where saltation processes would be most strongly felt. The hoodoos are definitely fragile geologic features, but the difficulty surrounds the age of the features. They may be very young features given the soft sediments in the area, and may not be particularly useful for constraining ground motions for long return periods.

5. Lovejoy Buttes, Mojave Desert: We visited the Lovejoy "big rock" PBR, a very large PBR in the headwaters of a canyon in the center of the butte (Fig. 5). Two smaller PBRs were also located nearby, and the surrounding granitic terrain showed literally hundreds of semi-fragile features (open-jointed fragile outcrops and semi PBRs). The granitic outcrop landscape is generally in a semi-precarious state, in that there are hundreds of landforms that would be shaken down if strong ground motions shook the area. We also noticed that hardly any debris is present at the base of the slopes, suggesting no strong

ground motions for a very long time in the butte. The presence of a mid-slope saprolite also indicates incomplete erosion and exhumation of the granitic landscape. Given that Lovejoy Buttes is about 14km from the San Andreas Fault (SAF), it is a potentially important site for constraining PSH for near-SAF sites. While the PBRs provide ground motion constraints for the actual PBR sites, the general fragility of the granitic rockmass may provide more realistic constraints on the PSH, as the constraints would be derived from a large number of semi-precarious landforms. We also discussed the statistical remnant hypothesis in the context of Lovejoy Buttes, and concluded that a former population of PBRs might not have ever existed, as the complexities of the geomorphology is consistent with variable rates of outcrop exposure (and therefore corestone exposure) across the rockmass.

6. Roundtop PBR site, between Elsinore and San Jacinto Faults: We viewed the large Roundtop PBR and surrounding ridge top granitic outcrops from the main road (Fig. 6). Roundtop PBR is apparently the only PBR on the ridge top, but there is an additional PBR in a neighbouring area (Beaumont PBR). Both of these PBRs are apparently old c.f. Lovejoy Buttes (c. 25-30kyr c.f. 10kyr at Lovejoy Buttes). Again our impression is that the PBRs are rare features in the area, and the representative fragility may be a lot less than that of the PBRs.

7. Pioneer PBR site, Pioneer Town Area, Yucca Valley: We observed abundant grantic corestone topography from the road side in the vicinity of the Pioneer PBR site (Fig. 7). Again, like Lovejoy Buttes, the granitic outcrops appear to have a representative fragility, with abundant semi precarious outcrops and semi PBRs visible across the hillsides.

Discussion and Conclusions

PBRs appear to be rare, well-studied features. In all sites visited, the PBRs appear to be no more than a few in number (usually just one), yet the surrounding rockmass is of suitable form (morphology, joint spacing etc) for formation of such features. We instead saw abundant semi-precarious outcrops and semi PBRs in these areas, and could therefore see a “representative fragility” in these landforms. In other words we saw hundreds of landforms that indicated higher accelerations required for modification of the outcrops/semi PBRs than the accelerations required for destruction of the most fragile PBRs.

Our recommendation is that that the rare, isolated PBRs should not be used for constraining PSH models and physics based seismic hazard analyses (e.g. Cybershake) unless the PBR areas contain tens to hundreds of PBRs. Since no such site exists (to our knowledge), we consider that these rare PBRs may be less meaningful for constraining the upper bounds of ground motions than the abundant semi fragile landforms that exist across the outcrops. Constraining seismic hazard models to fit the rare fragile PBRs may result in serious underestimation of the hazard. Conversely, the detailed work that has gone into providing age estimates for PBRs would still be valuable for developing the dating constraints for the semi fragile landforms. Future work should be focussed on assessment of fragility and age of abundant semi-fragile PBRs in suitable terrains, and the rare fragile PBRs should not be overinterpreted through constraining of major hazard modeling efforts like UCERF, NSHMP and Cybershake.

Figure 1. Abandoned sea-stacks in Morro Bay area, California.

Figure 2. Precariously-balanced rock (PBR) “Kent” in the vicinity (hanging wall) of the White Wolf Fault, Kern County.

Figure 3. PBR "Izzy", with the Kern Canyon Fault and Lake Isabella dam Site in the middle distance.

Figure 4. Hoodoo, Red Rock Canyon.

Figure 5. “Big Rock” PBR, Lovejoy Buttes. Numerous semi-PBRs are present on the surrounding hillslopes, and these provide a more representative fragility for the butte than do the rare PBRs.

Figure 6. “Round top” PBR site, between the San Jacinto and Elsinore Faults.


Figure 7. Granitic corestone topography near Pioneer Town, Yucca Valley.