ANNUAL REPORT 2004

Quantitative Testing of Specific Precarious Rocks Critical for Establishing Constraints on Ground Motion and Source Parameters for Large Earthquakes on the San Jacinto and Elsinore Faults

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INTRODUCTION

In order to develop the appropriate source parameters and estimates of strong ground motion for large earthquakes (M~7) on the San Jacinto and Elsinore faults, we need to have data to constrain proposed parameters. Since there are no near-source strong-motion recordings for large earthquakes on these faults, estimates of source parameters and strong motion for future earthquakes of such types rely on questionable extrapolations from smaller earthquakes at larger distances, and from earthquakes in other regions which may have differing tectonic and geologic environments. Precarious rocks, which have been in place for thousands of years in Southern California, may provide the only existing constraints on ground motions and source parameters. Since a SCEC focus of future research will be toward understanding the physics of large earthquakes, precarious rock data may be a critical constraint for anticipated massive modeling efforts.

PRECARIOUSLY BALANCED ROCK FIELD TESTING

A spectacular band of precariously balanced rocks extends from Riverside, CA, to Aguanga, CA, halfway between the Elsinore and San Jacinto faults (Fig. 1). More than 60 precarious and semi-precarious rocks have been documented along this line (Fig. 2), but none have been found more than a few km closer to either the San Jacinto or Elsinore faults. This fact strongly suggests that the distribution pattern is caused by the attenuation of strong ground motion from numerous large (M~7) events along these two faults (two in historic times, in 1899 and 1918). These rocks can place important constraints on ground motion from such earthquakes (median and standard deviation of attenuation curves).

Nearly a dozen of these rocks were tested for the quasi-static toppling acceleration, toppling directions, and size. Fig. 3 documents our team measuring the quasi-static toppling force for the "Tooth Rock". Table 1 lists the quasi-static toppling accelerations, toppling directions, and the approximate size of the rocks. α's for the "Tooth" and "Nuevo-4" rocks were measured through quasi-static toppling test; α's for the rest of the rocks were determined geometrically (for a detailed description of the methodology see Anooshehpoor et al., 2004 and Shi et al., 1996). The majority of the quasi-static toppling accelerations were between 0.14 g and 0.40 g, which roughly translate into dynamic toppling accelerations between 0.18 g to 0.52 g. The height of the rocks varied from about 1 m to 3 m. Also, preliminary field observations of the larger set of the rocks indicate that nearly 75% of the toppling directions are within $\pm 30^{\circ}$ of the fault-normal direction (40° azimuth). Fig. 4 shows locations of the tested rocks with vectors indicating the approximate direction and magnitude of the quasi-static toppling accelerations. The dynamic toppling accelerations are roughly 30%

higher.

Table 1: Data from the tested precariously balanced rocks.

Rock	Location	Toppling Azimuth	α_1 (rad)	α_2 (rad)	R_1 (cm)	R_2 (cm)	Pedestal Slope (degrees)
Benton	33.59308, -116.92517	90	0.15	0.37	132	135	
Lost Valley	33.37143, -116.57762	130	0.19	0.40	132	160	7
Lost Valley	33.37143, -116.57762	70	0.14	0.23	140	122	5
Mockingbird-1	33.94417, -117.38617	60	0.32	0.36	97	102	
Nuevo-1	33.77985, -117.15380	200	0.35	0.55	58	71	8
Nuevo-2	33.77602, -117.15202	130	0.27	0.45	165	152	
Nuevo-3	33.77715, -117.15132	0	0.21				
Nuevo-3	33.77715, -117.15132	270	0.34				
Nuevo-4	33.77303, -117.15343	280	0.15		51		
Pedley-1	33.98750, -117.46211	75, 255	0.42	0.38	51	51	
Pedley-2	33.98753, -117.46235	30, 210	0.64	0.50	69	69	5
Perris-1	33.78912, -117.24128	110, 290	0.32	0.38	96	93	
Perris-2	33.78807, -117.24363	260	0.21		150		
Perris-3	33.78758, -117.23960	75, 255	0.22	0.38	123	123	
Tooth	33.21650, -116.46507	75	0.18		82		
Tooth	33.21650, -116.46507	255		0.19		82	

NUMERICAL TESTS OF DYNAMIC TOPPLING

Purvance (2004), through a numerical experiment, showed that the probability of toppling generally increases with increasing waveform PGA. In addition, the toppling response has been parameterized in terms of α, R, PGV/PGA, and cross terms. Thus one can define a probability of toppling surface in PGA versus PGV space. These surfaces are shown in Fig. 5 for a subset of the precariously balanced rocks mentioned in Table 1. Of the precariously balanced rocks shown in Fig. 5, “Benton” rock is the tallest. As can be seen, height affects the toppling response at low PGV as PGA increases. Compare this surface with the “Pedley-1” surface, for instance. Even though “Pedley-1” is less precarious (i.e. higher PGAs are required for toppling), as PGA passes a threshold, low PGVs still produce toppling. This is a result is significant since the largest contribution to hazard is at low PGVs, even for high PGAs. See Purvance et al (2004) for details.

REFERENCES

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Figure 1: Examples of precarious rocks found approximately halfway between Elsinore and San Jacinto faults. Clockwise from top left, are Nuevo-2, Tooth, Nuevo-1, and Benton (Table-1).

Figure 2: Geologic map showing locations of precariously balanced rocks between the San Jacinto and Elsinore faults. Note location of Hog Lake where numerous large earthquakes have been documented by fault trenching (Tom Rockwell, personal communication). Also, two historic M~ 7 earthquakes have occurred near the town of San Jacinto.

Figure 3: Field-test to determine the quasi-static toppling acceleration of "Tooth" rock.

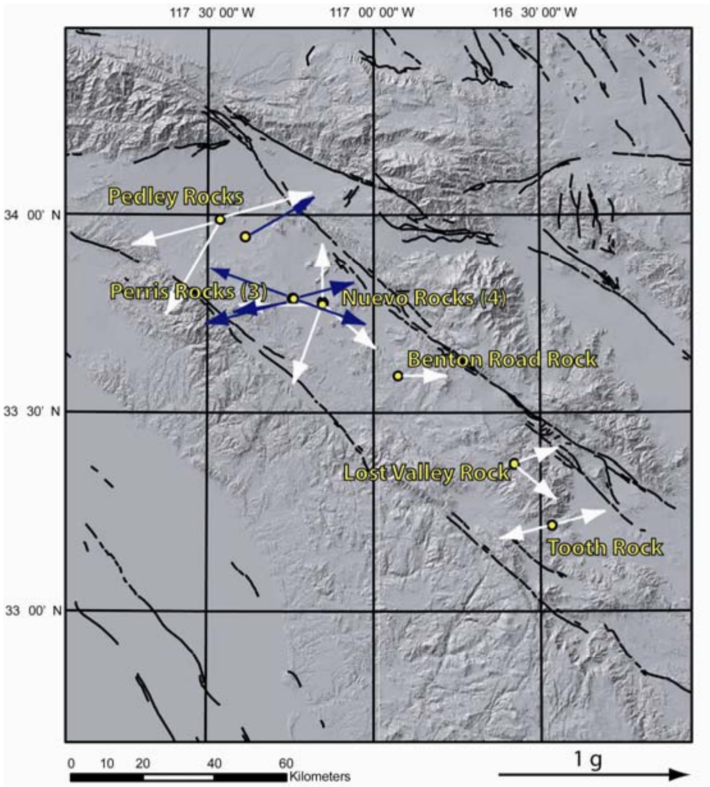

Figure 4: Locations of the tested rocks (Table 1) are shown here. Vectors indicate the approximate direction and magnitude of the quasi-static toppling accelerations. The dynamic toppling accelerations are roughly 30% higher.

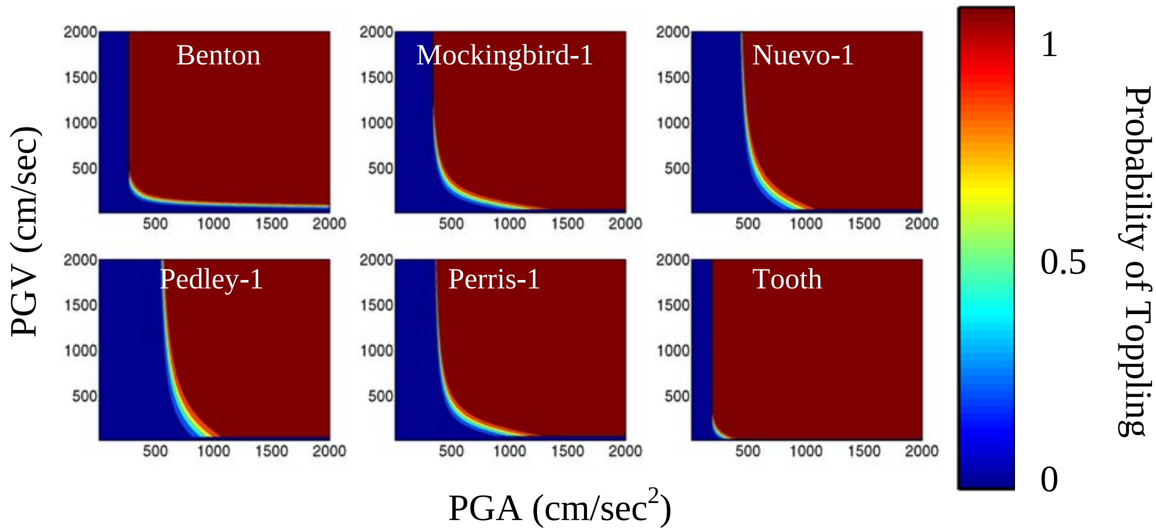

Figure 5: Toppling surfaces in PGV versus PGA space of a subset of precariously balanced rocks between the San Jacinto and Elsinore faults.