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to the Southern California Earthquake Center

Survey for Precarious Rocks on the Foot Wall of Major Earthquakes Involving Thrust Motion

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Working Group B - Ground Motion Modeling
Task B1

Technical Description

Last year funding was received for a reconnaissance survey for precarious rocks on the foot-wall of the Banning thrust to provide upper bound constraints for foot-wall ground motion for very large thrust earthquakes. Such a thrust earthquake is being considered as one of the most hazardous scenarios for an earthquake in the Los Angeles Basin.

Recent studies using foam rubber (Brune, 1996b), lattice modeling (Shi et al.1998), and finite element modeling (Ogelsby et al.1998) have suggested extremely intense ground motions on the near surface hanging wall of thrust faults. Allen et al.(1998) have found clear evidence of such extreme motions in the 1971 San Fernando Earthquake, confirming earlier evidence by Oldham (1889), Nason (1973) and Iida (1985). The modeling studies indicate much lower ground motions in the foot wall. In the foam rubber model studied by Brune (1996b), which exhibits clear fault separation near the surface, the ground motions are about a factor of 5 lower in the foot wall than in the hanging wall. For some of the scenarios for very large thrust earthquakes on the frontal thrust fault at the foot of the San Gabriel Mountains, the Los Angeles Basin would be on the foot wall of a major thrust, and thus it is important to confirm whether or not there are relatively low ground motions on the foot wall of such thrusts.

The potential usefulness of the precarious rock methodology has been recognized by reviewers of previous studies, and by grants from NSF and NEHRP. In 1998 a grant from SCEC was funded to test precarious rocks along a transect perpendicular to the Mojave section of the San Andreas fault. These studies have provided upper bound estimates of ground motion which are critical in testing PSHA models (Brune, 1999, SRL; Anderson and Brune, 1999, SRL).

Generally the foot-wall block of active thrusts is covered with thick sediments (e.g., in the LA Basin and Southern San Joaquin Valley) and thus the precarious rock methodology is not applicable. There are two exceptions to this -- the San Gorgonio Pass in Southern California--where slip along the San Andreas Fault has caused the crystalline rocks of the San Jacinto Mountains to be the foot-wall block of the Banning Thrust, and the northeast half of the White Wolf Fault, site of the M=7.6 Kern County thrust earthquake of 1952 (USGS-NEHRP reviewers has approved a project to study the precarious rock constraints on ground motion for the White Wolf fault, funding level $60K--the research proposed here will complement that study by providing an additional example for statistical confidence).

The Banning Thrust has had a major earthquake in the last thousand years (McGill et al., 1998) and probably several in the Holocene. The crystalline rocks of the San Jacinto Block south of the Banning Fault are ideal for producing precarious rocks. This rock type extends from about 4 km from the fault to more than 20 km. The center of the San Jacinto Block is far enough from both the San Jacinto and San Andreas Faults that the main contribution to the hazard is from the Banning Thrust.

Reconnaissance surveys in 1999 have confirmed that there are many rocks in this region that potentially can provide important constraints on ground motion. One example has been published in Brune (1996a, Fig 2-m). The pedestal age of this rock was 13 ka (Bell et al., 1998). This rock, and several nearby semi-precarious rocks, was the object of a field trip at the 1999 annual SCEC meeting, attended by more than 50 persons.

The results of the 1999 reconnaissance surveys are summarized in Fig. 1. Semi-precarious rocks (toppling accelerations of about 0.5-0.3 g, as defined by Brune, 1996) exist on the south side (foot-wall side) of the Banning fault, starting at a distance of about 3 km. Farther south, at a distance of about 15 km there exist precarious rocks (toppling accelerations of about 0.2-0.3 g). Farther east or west sites are closer to strike-slip faults (San Andreas and San Jacinto), and thus confuse the constraint on ground motion from the Banning thrust. Thus for preliminary interpretation we concentrate on the rocks about halfway between the strike-slip faults, i.e., around the area just south of Banning (see Fig. 1). The preliminary estimate of bounds on ground motion decrease from about 0.5 g at a distance of 3 km to about 0.3 g at a distance of about 15 km. Theses values are significantly less than median values predicted by recent regression curves for oblique and thrust fault earthquakes of Campbell (1998),- -for M=8 about 0.65 g at 4 km and 0. 45 g at 15 km. They are also significantly lower than the USGS-CDMG 2% in 50 yr. hazard map values for this area, which vary from about 1.0 g to about 0.7 g in the same distance range(these values are amplified by the ergodic assumption, i.e., random variation which predicts that occasionally very large values will occur, considerably greater than the median). These preliminary results tend to confirm the suggestion from the modeling evidence cited above, that the

ground motion on the foot-wall of major thrust faults is much lower than for the hanging wall, a result also consistent with values from the recent Chi-Chi, Taiwan earthquake which recorded considerably smaller ground motions foot-wall side, even though the stations there were primarily on sedimentary fill. If this asymmetry is verified for thrust faults in general, it has important implications for seismic hazard from thrust faults in the Los Angeles Basin.

The results of more quantitative field testing (proposed for funding from year 2000 funds) will provide important constraints on the foot wall ground motion from the Banning Thrust. This in turn will provide important information for assessing the foot wall ground motion potential for the San Gabriel Mountain Frontal Thrust System in the Los Angeles Basin.

References

Allen, C.R., J.N. Brune, L.S. Cluff, and A.G. Barrows, Jr. (1998). Evidence for unusually strong near-field ground motion on the hanging wall of the San Fernando Fault during the 1971 earthquake, Seism. Res. Lett., Vol. 69, No. 6.

Anderson, J.G., and J.N. Brune (in press 1999). Probabilistic seismic hazard analysis without the ergodic assumption, Seism. Res. Lett., Vol.70, No. 1

Bell, J. W., J. N. Brune, T. Liu, M. Zreda, and J. C. Yount (1998). Dating precariously balanced rocks in seismically active parts of California and Nevada, Geology 26, 495-498.

Brune, J.N., (1996a): Precariously Balanced Rocks and Ground Motion Maps for Southern California, Bull. Seism. Soc. Amer., Vol. 86, No. 1A, 43-54.

Brune, J.N. (1996a). Particle motion in a foam rubber model of thrust faulting, Seism. Res. Lett. 67(2), 34.

Brune, J.N. (1996b). Particle motions in a physical model of shallow thrust faulting, Proc. Indian Acad. Sci., Earth and Plan. Sci. 105, L197-L206.

Brune, J.N. (1999). Precarious rocks along the Mojave section of the San Andreas Fault, California: Constraints on ground motion from great earthquakes, Seism. Res. Lett., Vol. 70, No. 1

Campbell, Kenneth W.(1997). Empirical Near-Source Attenuation Relationships for Horizontal and Vertical Components of Peak Ground Acceleration, Peak Ground Velocity, and Pseudo-Absolute Acceleration Response Spectra, Seis. Res. Lett., Vol 68, Number 1.

Iida, K. (1985). Damage and intensity distribution of the January 13, 1945 Mikawa earthquake [in Japanese], in History and Damage by Earthqakes and Tsunamis in the tokai District: Selected Scientific Papers of Prof. Kumiji Iida, Disaster Prevention Res. Lab., Fac. Eng., Aichi Eng. Univ., 570-668.

McGill, S.F., D. Grant, and S.G. Wells (1998). Partial paleoseismic record of the San Andreas Fault at City Creek, near San Bernardino, California, Southern Calif. Earthquake Ctr. Annual Meeting abstracts, 76-77.

Nason, R.D. (1973). Increased seismic shaking above a thrust fault, San Fernando, California, Earthquake of February 9, 1971, 3, Washington, U.S. Dept. of Commerce, 123-126.

Ogelsby, D.D., R.J. Archuleta, and S.B. Nielsen (1998). Earthquakes on dipping faults: The effects of broken symmetry, Science 280, 1055-1059.

Oldham, R.D. (1899). Report of the great earthquake of 12th June 1897, Geol. Survey India Mem. 29, 379 pp.

Shi, B., J.N. Brune, A. Anooshehpoor, and Y. Zeng (1998). Dynamics of thrust faulting: 2-D lattice model, Bull. Seism. Soc. Am., Vol. 88, No. 6, 1484-1494.

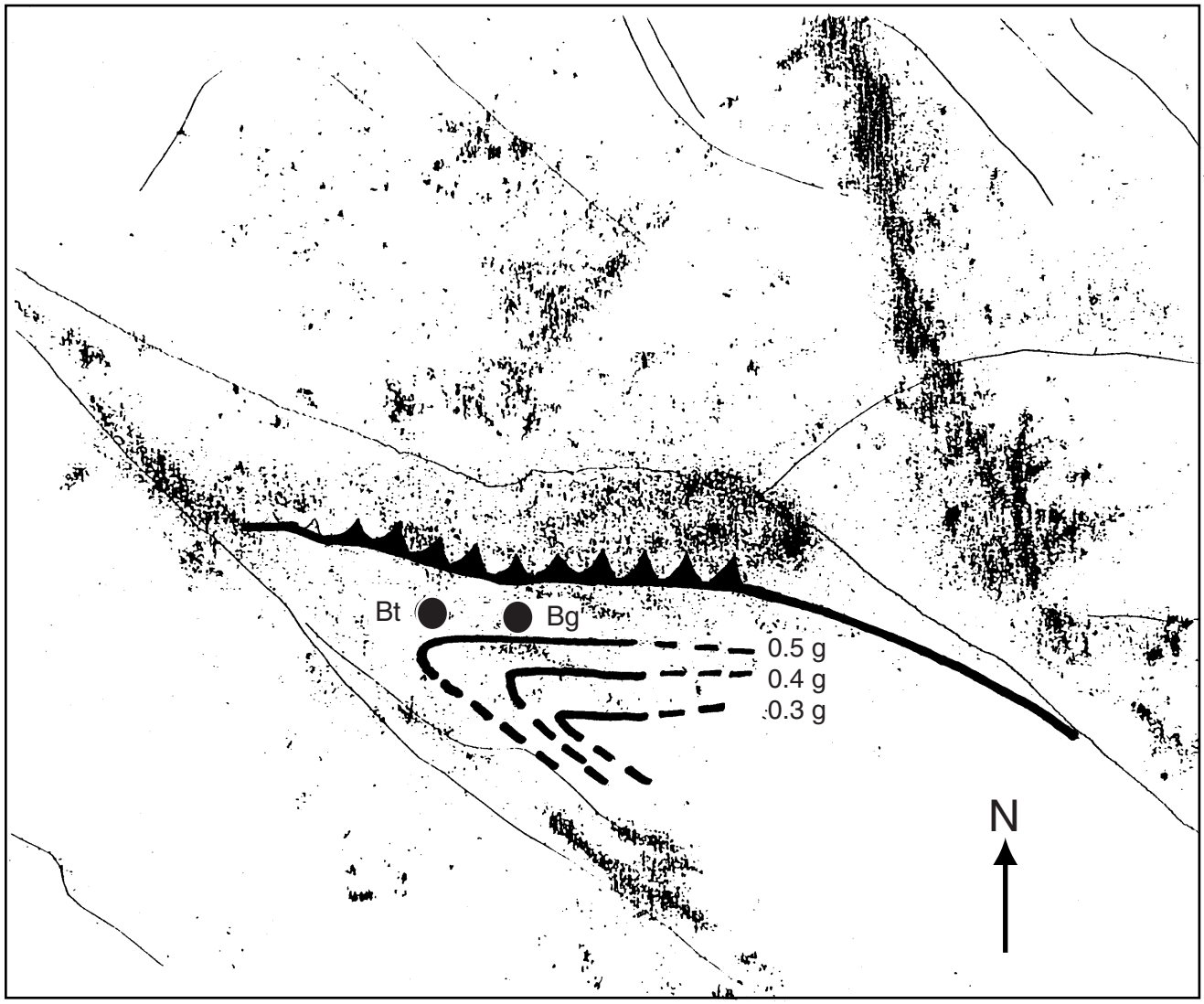

Figure 1: Map showing approximate contours of bounds on peak ground acceleration estimated from preliminary studies of precarious rocks south of the Banning Fault branch of the San Andreas Fault System in Southern California. The Banning Fault is shown by the dark line indicating a thrust fault dipping to the north. The solid circles indicate the approximate locations of the towns of Beaumont (Bt) and Banning (Bg), California. The region of semi-precarious rocks and precarious rocks proposed for study is the region between the solid contours for 0.5 g and 0.3 g extending about 15 km south of Banning (not the dashed parts of the contours). Light lines indicate other faults in the region. Shaded areas consist of dots corresponding to locations of small earthquakes.