2014 SCEC Annual Report

Fragile Geologic Features in Southern California: Statistical Remnants and Representative Fragility

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SUMMARY OF 2013 WORK

Our 2013 SCEC-funded work has been focussed on undertaking the first stages of a field review of fragile geologic features (FGFs) at the Lovejoy Buttes site in the Mojave Desert of southern California. The Lovejoy Buttes site is recognised as one of the most significant FGF sites in southern California due to its location close to the San Andreas Fault (about 20km). The few rare FGFs observed at Lovejoy Buttes (precariously-balanced rocks) are estimated to be of the order 10,000 years in age based on cosmogenic dating (Bell et al. 1998; Stirling and Rood, 2012), and imply non-exceedance of peak ground accelerations (PGAs) of 0.3g for that time period, despite repeated large-to-great San Andreas earthquakes (Brune, 1999). The national seismic hazard model (Petersen et al. 2008) also indicates high hazard for return periods equivalent to the age of the rare FGFs (PGA~1g). The toppling accelerations for the FGFs are field estimates based on the geometry of the FGFs, and are quasi static (Brune, 1999).

The objective of our 2013 work has been to address the hypothesis that the few rare FGFs focused on in the previous Lovejoy Buttes studies may not provide realistic constraints on ground motions because they are rarities (statistical remnants). In support of our hypothesis we observed semi FGFs (i.e. less fragile) to be abundant at Lovejoy Buttes, suggesting they may provide more realistic constraints on San Andreas motions than the FGFs (Stirling and Rood, 2012). Semi FGFs, like FGFs, were identified on the basis of being disconnected from the surrounding country rock and showing obvious signs of fragility (Fig. 1). We did not consider large stable boulders or resistant outcrops in our field survey as these would provide meaninglessly high fragility estimates.

Our brief field survey of the Lovejoy Buttes site in September 2013 allowed us to obtain quasi static estimates of toppling accelerations (peak ground acceleration or PGA) for 20 semi FGFs that ranged from 0.3 to 0.8g, with the main population being at 0.35-0.6g (Fig. 2). Furthermore, we are confident that many more semi FGFs are present at Lovejoy Buttes than we had time to include in our short field review. While it is difficult to imagine how the rare FGFs could remain standing in earthquake motions well beyond their toppling acceleration estimates, the concept could perhaps be understood by using the analogue of a cemetery that has been shaken by repeated earthquakes over time, with significant damage to tombstones in each event. Despite the repeated strong shaking and associated damage, some delicate structures will remain standing. Furthermore, OConnell et al (2007) suggested that uncertainties in FGF age, site conditions and seismic hazard are collectively large enough to allow for consistency between FGFs and seismic hazard estimates.

Figure. 1. Example of a semi FGF observed at Lovejoy Buttes.

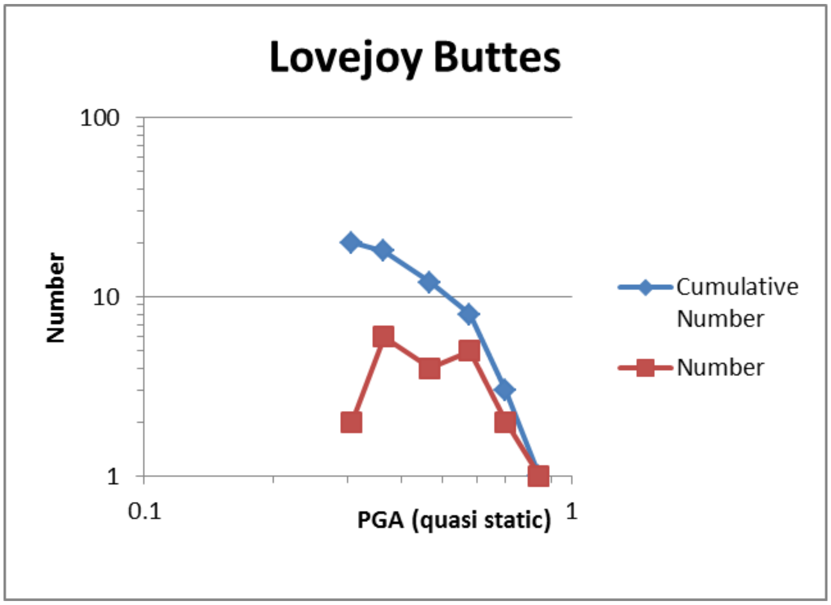

Figure. 2. Graph of the number of semi FGFs plotted as a function of the quasi-static estimate of PGA required to topple the FGF (fragility) at Lovejoy Buttes. The reddish curve labeled "Number" shows the number of FGFs of a given fragility, whereas the blue curve labeled "Cumulative Number" shows the number of FGFs with a given fragility greater than or equal to a given value. Note that the 0.3g estimates are based on the two known FGFs at the site, and therefore define the lower limit of fragility. The upper limit of fragility is based on features that still give the overall appearance of fragility, rather than being (e.g.) resistant outcrops which would provide meaninglessly high fragility estimates.

Our initial observations of rare FGFs and more plentiful semi FGFs (Fig. 2) indicate that 0.35-0.6g may be a more realistic estimate of maximum PGA at Lovejoy Buttes. While this is still considerably less than the 10,000 year return period PGA estimates for the site from the US national seismic hazard model (~1g; Petersen et al. 2008), the discrepancy is less than that indicated from previous interpretations of the few FGFs (Brune, 1999). If funded, our 2014 work will focus on: (1) greatly increasing the number of quasi static toppling acceleration estimates for semi FGFs at Lovejoy Buttes to obtain a more statistically robust result than that shown in Figure 2, and; (2) comparing the distribution of toppling acceleration estimates to estimates of PGA expected from the USA national seismic hazard model for return periods equivalent to the 10,000 year age of the dated FGFs (Bell et al. 1998; Stirling and Rood 2012). This will enable us to more substantially review the degree of discrepancy originally reported between the national seismic hazard model and the few FGFs (Brune 1999). Comparisons between the toppling acceleration estimates and the national seismic hazard model will be made by the Points in Hazardspace approach (Abrahamson, 2008; Anderson and Brune 1999).

We consider our project to be both important and timely, given that we are now at a time when the most fragile of FGFs in Southern California are being used to constrain estimates of seismic hazard in the SCEC Cybershake project, and specific rupture segmentation scenarios are being defined to reconcile the presence of FGFs near major active faults (Grant Ludwig in prep). In short, we consider interpretations limited to the most fragile FGFs may underestimate the hazard for SCEC. Finally, it is worthwhile to mention that we are taking a similar approach to estimating representative fragilities from FGFs and semi FGFs in New Zealand and coastal California to contribute to commissioned seismic hazard studies in those two regions. This represents the first industry-funded FGF-related work to have taken place since cancellation of the Yucca Mountain project some years ago.

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