ESTIMATION OF THE MAGNITUDES OF 1811-1812 NEW MADRID EARTHQUAKES USING LIQUEFACTION DATA AND EXTENDED-SOURCE GROUND-MOTION MODELS

Principal Investigator: Dr. Gabriel R. Toro, Risk Engineering, Inc.

4155 Darley Avenue, Suite A, Boulder, Colorado 80305
Phone #:303-499-3000, Fax #: 303-499-4850, e-mail address: toro@riskeng.com

Contributions from
Walter J. Silva
Pacific Engineering and Analysis Co.

US Geological Survey Grant O1HQGRO153

ABSTRACT

This study utilizes refined approaches for the estimation of ground-motions, site response, and liquefaction, together with the abundant liquefaction data from the 1811-1812 New Madrid earthquakes, to estimate the magnitudes of the 1811-1812 earthquakes. The model for groundmotion model considers extended-source effects. The model for site response considers the mechanical properties of Mississippi-embayment soils and the thick soil column, whose thickness varies geographically. The probabilistic liquefaction model considers the natural scatter of liquefaction data. The scatter in the liquefaction model is combined in a rigorous manner with the scatter of ground-motion and site-response models to obtain a rigorous probabilistic model that can be used in a formal statistical comparison to the liquefaction data, which comes mainly from the Obermeier (1989) compilation of liquefaction evidence from the 1811-1812 events. This approach differs from previous practice used to infer the magnitudes of past earthquakes from liquefaction data (e.g., Obermeier and Pond, 1999) in the use of a more sophisticated model for source and path effects, in the consideration of regional soil characteristics affecting site response, and in the explicit consideration of uncertainty. This approach uses information from the entire geographical pattern of liquefaction, rather than on the maximum distance to a liquefaction feature.

Estimates of the moment magnitude-stress drop combinations for the 1811-1812 main shocks, and the associated uncertainties, as determined from the liquefaction data, are as follows. The 1st event of 16 December 1811 was most likely M=8 with a medium stress drop (-100 bars) or M=7.75 with a high stress drop (-140 bars). It is unlikely that the magnitude was as low as 7.5. The 2nd event of 23 January 1812 was most likely M=7.75 or 8. It is unlikely that the magnitude of this event was as low as M=7.5. It was not possible to resolve a stress drop estimate for this earthquake. The 3`d New Madrid event of 7 February 1812 is difficult to resolve because of ambiguity in assigning Obermeier's liquefaction observations to a causative event. These results indicate that liquefaction observations in the Mississippi embayment are consistent with M 7'/a - 8, a fault rupture length of -100 km, and low strain rates.

The maximum magnitude that can occur in the New Madrid faults, which is generally taken as the magnitude of the largest 1811-1812 New Madrid main shock, has important implications on the seismic hazard for Memphis, St. Louis, and other locations near the New Madrid faults, particularly for low-frequency structures such as long-span bridges, high-rise buildings, and large tanks. The magnitude and stress drop estimates from this study will result in more accurate seismic-hazard maps and site-specific seismic hazard results.

This study demonstrates an improved methodology for inferring the magnitude of a past earthquake from liquefaction data. Two important advantages of this approach are (1) the explicit consideration of rupture size, and (2) use of the entire pattern of liquefaction rather than the most distant liquefaction feature. The latter advantage uses a probabilistic/statistical treatment and provides more stable results). This approach will be useful in other regions such as Charleston, Wabash, and the Pacific Northwest, where maps of paleo-liquefaction features are becoming available