

# Comparison of Seismicity Rates in the New Madrid and Wabash Valley Seismic Zones

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The Wabash Valley seismic zone in southern Illinois and Indiana is a northeastern extension of the New Madrid seismic zone (Figure 1). Like New Madrid, the Wabash zone is underlain by a failed Precambrian rift, which plays a role in controlling the recent faulting (Braile *et al.* 1986; Sexton *et al.* 1986; Bear *et al.* 1997). Paleoliquefaction deposits indicate the past occurrence of large earthquakes in the Wabash zone (Obermeier 1998) that may have been comparable to those that occurred in the New Madrid zone in 1811–1812 (Hough *et al.* 2000). The two areas seem likely to be mechanically coupled in that stress transfer following large earthquakes in one could affect earthquake occurrence in the other (Mueller *et al.* 2004). Numerical modeling indicates that stress transfer following the 1811–1812 New Madrid earthquakes may be loading faults in the Wabash zone (Li *et al.* 2005; 2007).

Despite their similarities, the two zones have an intriguing difference in seismicity rates (Stein and Newman 2004). This difference is shown in Figure 2A by comparison of frequency-magnitude plots. The plots combine the Center for Earthquake Research and Information (CERI) catalog of seismologically recorded small earthquakes spanning January 1975–June 2010 ([http://www.ceri.memphis.edu/seismic/catalogs/cat\\_nm.html](http://www.ceri.memphis.edu/seismic/catalogs/cat_nm.html)) and the Nuttli catalog of historic earthquakes for 1804–1974 with magnitudes out to magnitude 6.2 (Nuttli 1974).

Both areas show a Gutenberg-Richter distribution of seismicity,  $\log_{10}N = a - bM$ , where the logarithm of the annual number ( $N$ ) of earthquakes above a given magnitude ( $M$ ) decreases linearly with magnitude (Figure 2A). A least squares fit to data from the New Madrid zone (defined as 35–38°N, 88–91°W) yields  $a = 3.45$  and  $b = 0.95 \pm 0.02$ . The Wabash zone (treated here as 37.6–39.7°N, 85.8–88.75°W) yields  $a = 2.13$  and  $b = 0.72 \pm 0.03$ . (These areas, defined as rectangular for simplicity, have a slight overlap.) Hence the New Madrid and Wabash zones have similar numbers of magnitude 5–6 earthquakes, but the larger slope ( $b$ ) indicates that New Madrid has more small earthquakes.

The difference does not appear to result from the limitations of the data, which are common to both zones. The analysis of necessity combines instrumentally determined magnitudes for recent smaller earthquakes with ones inferred from

historical records of older larger earthquakes. The linear trend continues relatively smoothly between the two data types. The results are robust in that they are consistent with those of previous studies combining the historical data with progressively longer instrumental records (Nuttli 1974; Johnston and Nava 1985; Stein and Newman 2004). Catalog incompleteness appears not to be a problem given the lack of a falloff at low magnitudes considered. Thus although the specific  $b$  values derived here (as in any area) depend on the dataset and analysis method used, the difference in  $b$  values between the two seismic zones seems real.

We see two possible causes for this difference. The first is that the Wabash area has a relatively low  $b$  value. A low  $b$  value could indicate high stressing rates on faults (Scholz 1968; Wiemer and Wyss 1997). Hence a low value in the Wabash could mean a higher stressing rate there than in the New Madrid zone for the period spanned by these data, since 1812. This would be consistent with the predicted stress migration following the large 1811–1812 earthquakes (Li *et al.* 2005; 2007).

Alternatively, the New Madrid zone has a relatively high  $b$  value. This situation could arise if many of the earthquakes there are aftershocks of the large 1811–1812 earthquakes (Ebel *et al.* 2000; Stein and Newman 2004; Hough 2009; Stein and Liu 2009). The  $b$  values for many aftershock sequences are higher than those found by including the mainshocks (Frohlich and Davis 1993). This may be the case here, because the data used do not include the three mainshocks, owing to the complexities in assessing their magnitudes (Hough *et al.* 2000).

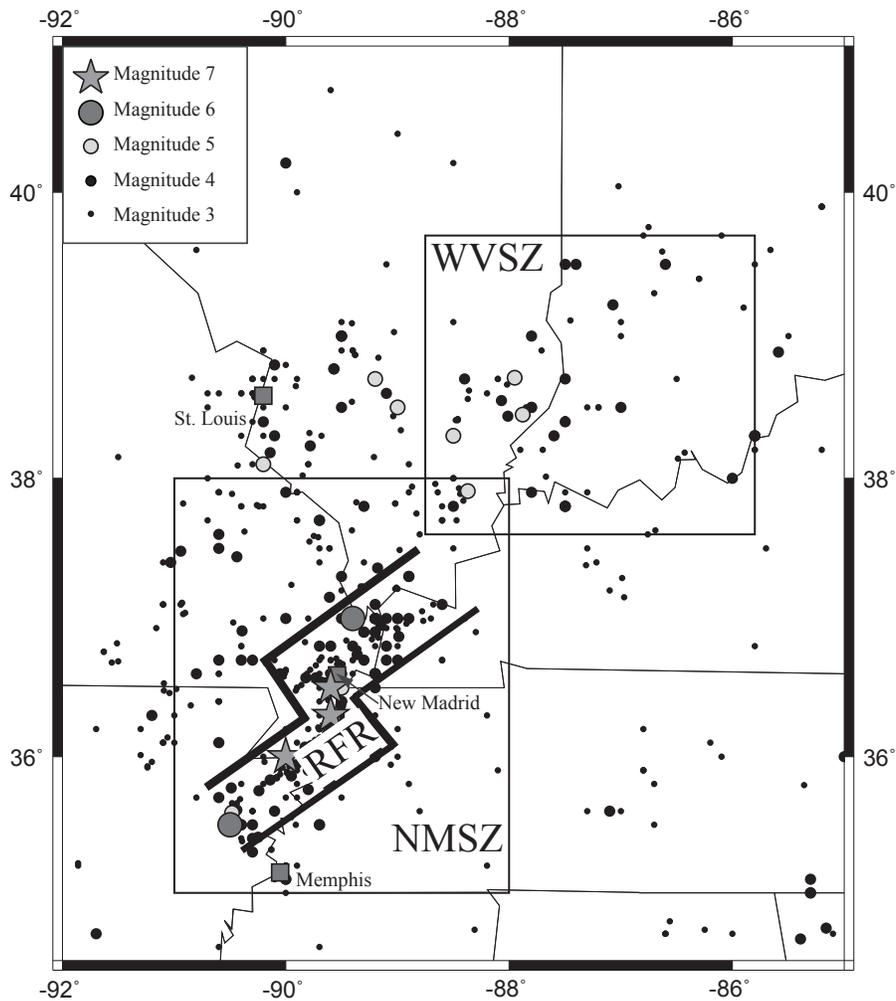
Given that  $b$  values for different areas vary widely, largely between 0.5 and 2.0 (Frohlich and Davis 1993), we assess whether the values for the two areas are “high” or “low” by comparing them to those for the entire central United States, defined here as 34.5–41°N, 85°–92°W (Figure 1). For this region,  $a = 3.57$  and  $b = 0.9 \pm 0.02$  (Figure 2B). However, considering earthquakes in this region but excluding both the New Madrid and Wabash zones yields  $a = 0.9$  and  $b = 0.83 \pm 0.02$ , because most small events are in the New Madrid zone.

Thus the Wabash valley  $b$  value is lower than New Madrid’s but closer to that for the central United States excluding both zones. We hence view the Wabash value as more typical of the central United States, and the New Madrid value as unusually high.

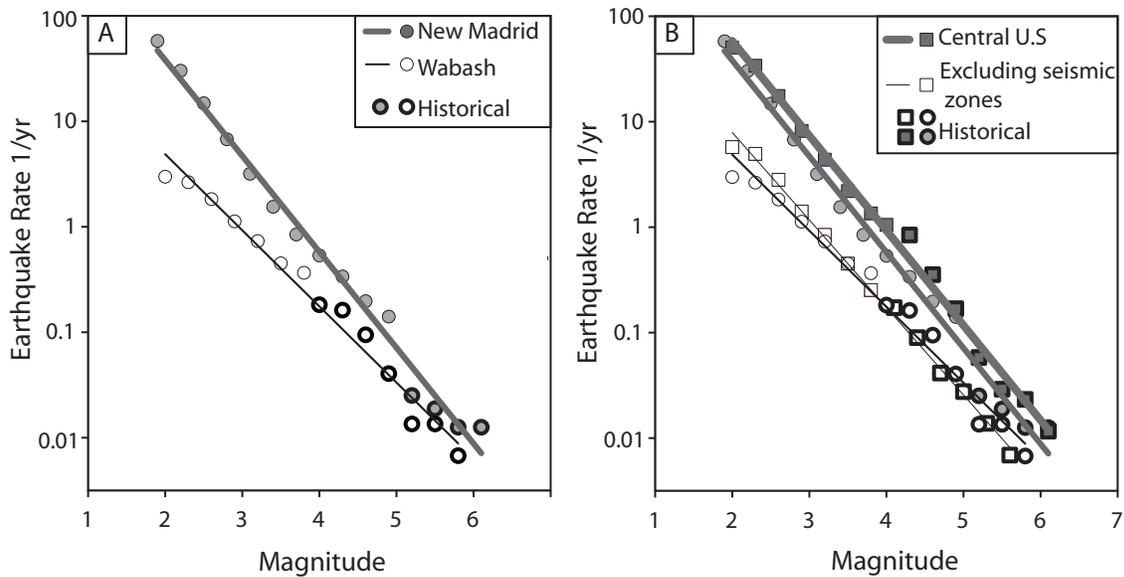
This interpretation is supported by the fact that low  $b$  values are common for intraplate areas. Global compilations of

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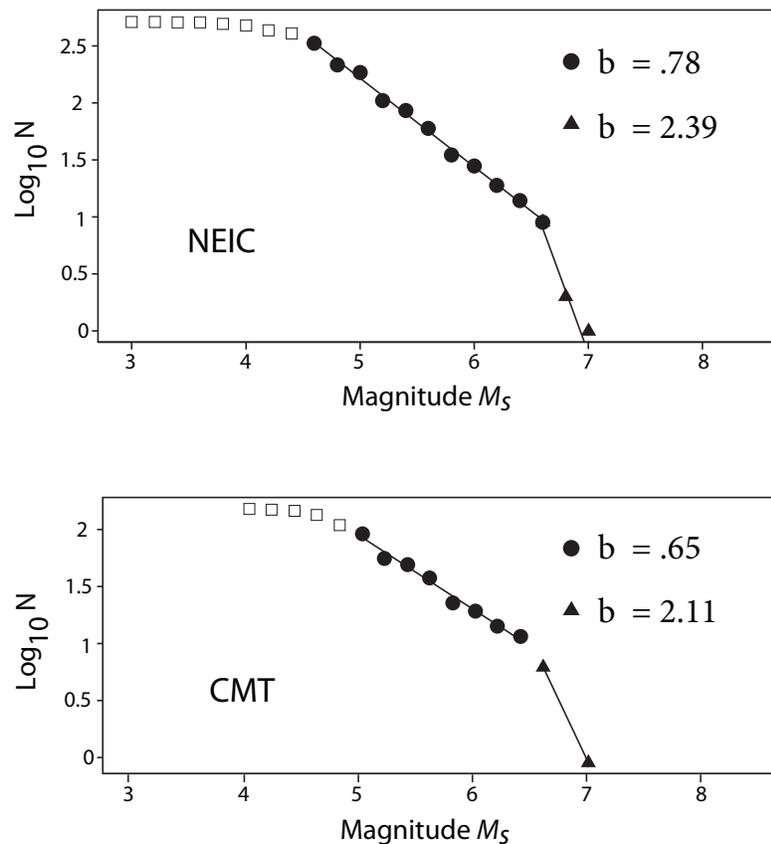


▲ **Figure 1.** Seismicity map of central United States. Main 1811–1812 earthquakes represented by stars. New Madrid Seismic Zone (NMSZ), Wabash Valley Seismic Zone (WVSZ), Reelfoot Rift (RFR).



▲ **Figure 2.** (A) Frequency-magnitude plots for New Madrid and Wabash Valley seismic zones and (B) comparison of these zones with the Central U.S. zones, both including and excluding the New Madrid and Wabash zones.

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▲ **Figure 3.** Frequency-magnitude plots for global intraplate earthquake from Centroid Moment Tensor (CMT) and National Earthquake Information Center (NEIC) datasets. Data denoted by squares were not analyzed due to expected catalog incompleteness. Data for intermediate and large magnitudes were analyzed separately. (Okal and Sweet 2007).

intraplate earthquakes with magnitudes between about 4 and 6.5 yield  $b$  values of 0.6–0.85 (Figure 3). Similar values arise for some specific intracontinental areas (Jaiswal and Sinha 2006; Sykes *et al.* 2008).

Hence the fact that  $b$  is significantly lower than 1 need not indicate that an area's seismicity is anomalous. The instinct that  $b$  should be about 1 reflects the fact that such values usually result from data spanning a broad range of magnitudes including those above 7 (Okal and Romanowicz 1994).

It thus appears that the difference between the New Madrid and Wabash  $b$  values reflects the New Madrid seismicity being dominated by aftershocks of the 1811–1812 earthquakes. Hence the lower Wabash value need not indicate loading by stresses due to these large earthquakes. Thus assessing whether such loading is occurring will require assessing whether the associated strain signal is resolvable in GPS data (Galgana and Hamburger 2010). If so, the strain rate signal will become increasingly apparent with time because GPS velocity precision increases for longer measurement intervals (Stein and Wyssession 2003). ☒

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