EARTHQUAKE CONTEXTS IN THE NEW MADRID SEISMIC ZONE NORTHEAST ARKANSAS AND SOUTHEAST MISSOURI

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ABSTRACT

The New Madrid earthquakes of 1811-1812 included three very large earthquakes, at least one larger than magnitude 7.5. Geoarchaeological investigations conducted at 23 sites over the past 20 years have identified and dated large sand blows resulting from this historical earthquake sequence and at least three similar prehistoric earthquake sequences. The sand blows are horizon markers, similar to the Mount Mazama Ash in the Great Basin. The geoarcheological investigations have contributed to estimating the timing of the prehistoric New Madrid earthquakes. The archeological contexts of some of these sand blows are described and the implications for prehistoric archaeology in the region are discussed.

INTRODUCTION

The New Madrid Seismic Zone is located in the Lower Mississippi River Valley, in adjacent parts of Arkansas, Missouri, Illinois, Tennessee, and Kentucky. Its location in the center of the North American Continental Plate is not explained by current Plate Tectonic Theory. Fuller (1912: 11-13) studying the effects of the 1811-1812 earthquakes noted several lines of evidence suggesting that there had been similar prehistoric events. Inquiries into the earthquake potential of the region resumed in the early 1970s, when the U. S. Geologic Survey (USGS) began actively searching for sites that would allow dating of the prehistoric earthquakes that were thought to have occurred in the New Madrid Seismic Zone. It is very important to know the frequency of large earthquakes to be able to assess earthquake hazard so that buildings and other installed facilities can be constructed in such ways that they will not be badly damaged or destroyed during an earthquake. This is of major concern with facilities such as nuclear reactors or gas pipelines, because of the potential impact a failure could have on people and the

environment for miles around as demonstrated by the accident at Japan's Fukushima Dai'ichi nuclear power plant in 2011. Dave Russ (1979) found faults, folds, and liquefaction features in trenches excavated across the Reelfoot scarp in northwestern Tennessee and attributed them to two Late Holocene earthquakes that pre-dated the 1811-1812 New Madrid earthquakes. In the 1990s, Jim Price and Roger Saucier found paleoliquefaction features including a large sand blow under Mound A at Towosahgy State Park (Beckwith's Fort; Saucier 1990). Since 1992, when several prehistoric sand blows were found at Eaker Air Force Base and in drainage ditches from Birdseye to Blytheville, Arkansas, our team has dated and documented prehistoric sand blows at 23 prehistoric sites.

New Madrid Earthquakes (A. D. 1811-1812) Historic Accounts

The three largest of the 1811-12 earthquakes were incredibly violent, estimated to have been between moment magnitude 7-8. Several observers actually saw waves being propagated through the ground. Lesieur noted that: "The earth was observed to roll in waves a few feet high with visible depressions between. By and by these swells burst throwing up large volumes of water, sand and coal."(Lesieur 1888 in Fuller 1912:31)

Louis Bringier, a well known engineer in the Mississippi Valley during the early nineteenth century, described the terrifying violence of one of the many aftershocks of the December mainshock:

> It [liquefied sand] rushed out in all quarters, bringing with it an enormous quantity of carbonized wood, reduced mostly into dust, which was ejected to a height of from ten to fifteen feet, and fell back in a black shower, mixed with the sand which its rapid motion had forced along; at the same time, the roaring and whistling produced by the impetuosity of the air escaping from its confinement, seemed to increase the horrible disorder of the trees which everywhere encountered each other, being blown up, cracking and splitting, and falling by

> thousands at a time. In the meantime, the surface was sinking, and a black liquid was rising up to the belly of my horse, who stood motionless, struck with terror.
>
> These occurrences occupied nearly two minutes; the trees, shaken in their foundation kept falling here and there, and the whole surface of the country remained covered with holes, which, to compare small things with great, resembled so many craters of volcanoes, surrounded with a ring of carbonized wood and sand, which rose to a height of about seven feet.
>
> I had occasion, a few months after, to sound the depth of several of these holes, and found them not to exceed twenty feet; but I must remark the quicksand had washed into them. The country here was formerly perfectly level, and covered with numerous small prairies of various sizes, dispersed through the woods. Now it is covered with slaches [ponds] and sand hills or monticules (Bringier in Williams 1989:123-124 and Fuller 1912:76).

The 1811-12 events destroyed thousands of acres of farmland by cratering and covering the surface with sterile ejected sand. The large sand blows are very well-drained and still have an adverse effect on crops. It was the first time that the United States Government provided relief to a natural disaster. The towns of New Madrid and Little Prairie (located where Caruthersville now is) were totally destroyed. The road from New Madrid to Little Prairie was destroyed requiring a detour of more than 100 miles. Hundreds of thousands of acres of timber were destroyed and over 90% of the boats near New Madrid were sunk or thrown up on shore by a 15-20 foot high river tsunami (Fuller 1912:43). There was a sulfurous smell from the ejected coal and methane. The aerosols and fine dust enveloped the epicenter for hours after each major event. Ejected coal is reported to have been used as a fuel source for many years.

The 1811-1812 events had a number of reported phenomena associated with it that are not well understood. There were explosions and lights described as lightning discharges. It is now thought that the lightning was caused by the piezoelectric effect (Stewert 1995).

Liquefaction Features

In the Mississippi Valley one of the most visible and widespread phenomena remaining on the landscape and in the archaeological record that uniquely came from earthquakes are liquefaction features, especially sand dikes and related sand blows.

Earthquake-induced liquefaction can result in geysers of water and entrained sand reaching up to 10 meters into the air. The water and sand fall back to the earth forming a volcanic-cone-like deposit, with a crater in the center. Sand blows occur in several different environments and can provide telltale signs of past earthquakes. Often several aligned sand volcanoes or sand blows and sand fissures form along the edges of abandoned meander channels and along the crests of buried point bar deposits (see Tuttle and Barstow, 1996) where sands are naturally deposited in a relatively loose density. Sand fissures are often related to lateral spreading, a type of mass movement that occurs on nearly flat ground as the result of liquefaction of underlying sediments.

The very large (i.e. moment magnitude ~7-8) 1811-12 New Madrid earthquakes and earlier ones have produced vents as wide as 2-3 m and subsidence of 3 meters over four hectares (10 acres) of surface. The Yarbro sand pit, located within several kilometers of the estimated epicenter of the very large 16 December 1811 earthquake is one of these (Tuttle, 1999). The New Madrid sand blows are world class geological features.

Fuller, who compiled the official USGS report one century after the event, saw many of these earthquake effects in the first decade of the 20th century while much of the area was forested and still had standing, earthquake-killed trees. In 1905, Fuller saw fissures 1-2 feet deep (Fuller 1912:51). In 1846 Sir Charles Lyell described fissures west of the rebuilt town of New Madrid as being “only 5-6 feet deep and noted that many of the smaller ones were already filled

(Lyell 1847:235). The development of mechanical agriculture and land leveling during the 20th century have homogenized the plow zone making the surface indications of liquefaction features more subtle than they were a century ago.

Prehistoric Chronology Methods

The geoarchaeological work conducted in the past 20 years has documented and dated three prehistoric events at twenty-three different sites. We have been successful by targeting archeological sites that have abundant carbon, and sampling the deposits above and below the sand blows. Our general excavation procedure has been to collect surface artifacts to locate cultural features, to excavate test units to verify the presence of a sand blow, to employ geophysical techniques, especially resistivity and conductivity, and to locate the feeder dike of the sand blow. An ~1m wide trench is laid out so that it will intersect the feeder dike, a diagnostic characteristic of sand blows. We use a backhoe to strip the plow zone and watch for cultural features that may occur just below the plow zone and have been excavated into the top of the sand blow. The stripping is done above the designated trench location. If there are features intruding into the sand blow then these are excavated by trowel, documented, and the contents floated. The sand blow is then cross sectioned with the backhoe. The contact between the sand blow and buried soil is carefully examined for artifacts and charcoal, and if any are found they are collected for analysis and dating purposes. If artifacts or cultural features are found in the buried soil, they too are excavated by trowel, documented, and the contents floated. Where possible, carbon samples are point plotted as taken. Priority for dating is given to annuals closest to the sand blow, particularly to fragile annuals such as corn kernels and leaves. Point plotted samples and flotation samples are first analyzed and identified by an ethnobotanist prior to radio carbon dating.

In addition to the 1811-12 earthquakes, which have been dated at more than 20 sites, this work, along with complementary work at more than 230 liquefaction sites along ~800 km of rivers and drainage ditches (see Tuttle and Hartleb, 2012 for extensive reference list), has dated two major earthquake events that occurred during the past millennium. Major earthquakes that induced liquefaction over a large area are now known to have taken place during the Late Mississippian and at the Late Woodland/ Early Mississippian transition. Another earthquake has been identified in the Late Archaic period (Figure 2). This and possibly other earthquakes are not as well constrained temporally nor have they been identified at sites across the whole region. We do not believe that all prehistoric New Madrid earthquakes have yet been identified prior to AD 800.

The Late Mississippian Event (A.D. 1447 +/- 8)

The Late Mississippian event is dated to 1447 +/- 8 in the Common Era. This tight temporal constraint is based on a statistical analysis of the dated samples above and below the liquefaction features at 8 archaeological sites as well as 5 other liquefaction sites across the region. The statistical analysis of the age estimates was performed by Bob Youngs as part of the Central and Eastern US Seismic Source Characterization Project; the age estimates of all sand blows were reassessed by Tish Tuttle as part of the development of the CEUS paleoliquefaction database (Tuttle and Hartleb 2012). The Dodd site is an important representative site.

At the Dodd site (Frakes, 23PM46), two possible generations of sand blows were identified on aerial photographs and verified in soil pits at the site. Subsequently, a soil resistivity survey conducted by Lorraine Wolf of Auburn University imaged the sand blow as a long linear feature about 10 meters wide and at least 80 meters long (Tuttle et al., 1999). A backhoe trench opened across this feature revealed that a graben had formed and dropped down

~1 m between two sand dikes and that ejected sand filled in the graben covering pristine cultural deposits. Pre-earthquake features and soil horizons yielded calibrated dates of A.D. 1290-1410 and A. D. 1220-1300. Associated artifacts included Nodena arrow points and pottery with the Memphis beveled rims with notching and appliqués. There was also an earlier Mississippian component at this site as evidenced by Varney Red filmed pottery. A portion of a wall trench -- uncovered on the last day of field work -- had been dug into the upper part of the sand blow. The wall trench was excavated. An AMS date on a corn kernel recovered from this feature had a calibrated date of A.D. 1405-1455.

At the Dodd site, one house had been built on the sand blow, but there is not substantial midden there or artifacts in the plow zone. Though our sample of sites in the northern part of the NMSZ with this event is still small, we are not seeing much occupation after the earthquake on top of these sand blows. By A. D. 1500, or a little before, Southeast Missouri was abandoned. We believe that this earthquake or sequence of earthquakes was a factor in causing the vacant quarter. This might be partially testable by finding and dating Middle to early Late Mississippian components under sand blows.

In 2005 we excavated a sweat lodge located 0.8 km southeast of Tyronza at the East Site (3PO610) in Poinsett County. The sweat lodge was buried by a sand blow. Five radiocarbon dates placed the sweat lodge between A. D. 1250 and 1430. The dates of the sweat lodge below the sand blow and two radiocarbon dates, from 5-10 cm above the sand blow, constrained the age of the sand blow between A. D. 1250 and 1650. The sweat lodge was tilted up to 22 degrees toward the southeast, in the assumed direction of the main feeder dike of the sand blow. This ground failure was caused by subsidence of the ground surface as water and sand from the liquefied layer at depth vented to the surface. The tilting had thrown the underlying midden

deposits out of level. These deposits that were excavated on level cross cut all of the strata. Understanding the effect of earthquake-related ground failure on the site prior to excavation would have made it possible to restore the displaced cultural stratigraphy to its pre-event configuration for proper interpretation (Lafferty et al 2008; Tuttle et al 2011).

In 1541 De Soto was in Pacaha, estimated by Childs and McNutt to have been in the Blytheville area (2009). He sent a reconnaissance party, apparently under the command of the expedition's Factor, Luys Hernandez de Biedma, who reports:

> Some incursions were made to capture Indians who might give us the information; particularly was one undertaken to the northwest, where we were told there were large settlements, through which we might go. We went in that direction eight days, through a wilderness which had large pondy swamps, where we did not find even trees, and only some wide plains, on which grew a plant so rank and high, that even on horseback we could not break our way through (Biedma in Milanich 1991:272).

Pondy swamps are precisely the characterization of the area around New Madrid after the 1811-1812 event.

Late Woodland/Early Mississippian Event (A. D. 840 +/- 40)

Dates at 10 different archaeological sites (as well as 3 other liquefaction sites) in the region have helped to estimate the timing of a major event at the Late Woodland / Early Mississippian transition at A. D. 840 +/- 40.

The first documented site of this event was at 3MS560 on Eaker Air Force Base (Eaker 3 Tuttle and Schweig, 1995; Tuttle 1999:123-128; Lafferty and Cande 1994). There were two events separated by a clay lens covering 40 m of the profile. The clay would have settled out of suspension from ponded water shortly after the first event. The second event happened before much organic matter accumulated on the bottom of the pond. The buried midden was tested with

a 2 m x 50 cm test unit, and recovered an assemblage of shell-tempered and sand-tempered sherds from the black midden under the sand blow.

3MS557, also on Eaker Air Force Base, had three generations of sand blows and related feeder dikes that was probably utilized during all the events. A prehistoric feature penetrated the latest sand blow. This pit and occupation is dated ca. 1300 - 1400 by four carbon dates. The feature produced a typical Mississippian botanical assemblage dominated by corn. Also exposed in this profile were two earlier liquefaction events, the earliest sand blow probably formed between 3340 and 1690 B. C., possibly during the same event that produced the compound sand blow at Burkett site about 2350 B.C. +/- 200 yr.

A backhoe trench was opened at Huey's House (3MS306; Tuttle et al 1998:53-68) to the base of the plow zone, exposing an unplowed sand blow. Stripping of the plow zone adjacent to the trench revealed intact cultural features below the plow zone but above the sand blow. A .5 x 2 meter test unit was excavated through the post event deposits and into part of the pre event midden. An additional 1 x 1 meter test unit was excavated through the pre eruption midden. The midden deposits were screened and trowel cut. A 20 x 20 cm flotation column was recovered from each excavated level.

The artifacts recovered in the pre-sand blow midden indicate typical changes one would expect at the Late Woodland-Early Mississippian transition. Shell-tempered pottery increased in frequency and size in the upper levels, at the expense of sand-tempered Barnes pottery. One projectile point, a Table Rock Stemmed, a Late Woodland type, was recovered in the third excavation level. The presence of a mud dauber nest in the top level and daub in the upper levels indicate the presence of a structure. The carbon date from this midden of A.D. 880-1040 is consistent with the ceramic assemblage when compared to those of other large dated features

from Zebree, Mangrum, and the Priestly sites (respectively Morse and Morse 1980; Klinger 1982, Benn 1990).

Four features were excavated in relation to the sand blow. Three of these (F: 2, 3, and 4) were cultural overlaying the sand blow and the other (F-1) was the upper part of the sand blow. Feature 1 was a very dark stain sitting directly on the sand blow, that, when excavated, turned into a lens-shaped root cast with much lignite in it.

Feature 2 was an amorphously shaped pit in Trench 1 that intruded into the sand blow material for 7 cm. Feature 2 was truncated by the clay of Feature 3 and Feature 4. Feature 3 was a clay hearth overlaying coarse sand and Feature 4. The center of the Feature 3 clay had been reddened by firing; although this was not intensive enough to take an archaeomagnetic sample. The contact with the sand was abrupt. Feature 4 was a second clay lens that was under the coarse sand and above the fine earthquake sand and terminated abruptly at the edge of Feature 2. Fine earthquake sand with lignite was present across the width of the test unit. There were no micro dikes in the cultural features, which supports their post earthquake deposition. Micro dikes were present in the midden under the features.

The recovered artifacts indicate a Late Woodland-Early Mississippian (AD. 600-1000) event. All of the red filmed pottery is interior slip, characteristic of Varney Red Filmed. The mixed temper ceramics, shell and either grog or sand, have sparse shell, which contrasts with the later Mississippian wares that have much more shell. These mixed tempers, occurring as they do in the middle of the levels, is exactly what one expects at the cusp of this technological transformation. The two points, either diminutive dart points or very large arrow points, are also characteristic of this time period. These appear to be diminutive Steuban/Rice Side Notched points, suggesting a possible cultural continuity.

The time of this event was firmly pinned down at the Hillhouse site in Mississippi County, Missouri. Feature 331 was a lateral spread fissure which in-filled with a particular rich accumulation of artifacts between AD 880 and circa 1100 (Lafferty 2002; Tuttle et al. 1998).

Two radiocarbon dates, one from a clast of midden in the sand, and the other from overlaying midden, had virtually identical curves with mid points at 885 and 880 A. D. Two archeological dates from the middle of the overlaying midden had dates of AD 920 from Depositional Stratum III (These are numbered sequentially from bottom to top) and 1015 A. D from ten centimeters above in Depositional Stratum V. The ceramics recovered from the midden are all grog tempered Baytown Plain, Mulberry Creek Cord Marked, weathered decorated (probably worn-down cord-marked), with a smattering of incised and punctuated sherds.

In summary, the liquefaction features from these two earthquakes form temporal horizon markers similar to the Mt. Mazama Ash in the Great Basin. These are region-wide markers and span a very short period of time. At the present time both markers are more precisely dated than individual carbon dates and with additional data we can expect this precision to increase. Also, the soils in these liquefaction features from these two earthquakes are more highly developed than those present in the 1811-12 liquefaction features.

Much more research needs to be carried out with respect to the liquefaction features in the NMSZ. The surface deformation documented at the East site should be a caution to archaeologists working in the region. These deformations often make the archaeological deposits rather strange. It would behoove all archaeologists working in the region to learn to recognize these features and know when to call in the paleoseismologists to get the most out of the

exposures. Needed work includes the better spatial and temporal definition of other earlier sand blows as well as more spatially extensive dating of the two above defined horizon markers. Finding and dating more Mississippian components in Southeast Missouri under the 1447 sand blows would add credence to the earthquake being a causal factor of the Vacant Quarter.

At least five liquefaction features are known to be under mounds and I suspect that there are more because it seems likely that some of the mound construction took place where it did because of the liquefaction/sand blows at those locations. There are other locations where the natives built fires in the crater (i.e. 3MS304; Tuttle 1999:131-133). With the eruptions from below and lightning discharges from above, these locations may have been seen as powerful places by the Native Americans. Finally, at some sites we can expect to see direct adverse effects such as burying the still occupied site. Think Pompeii.

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