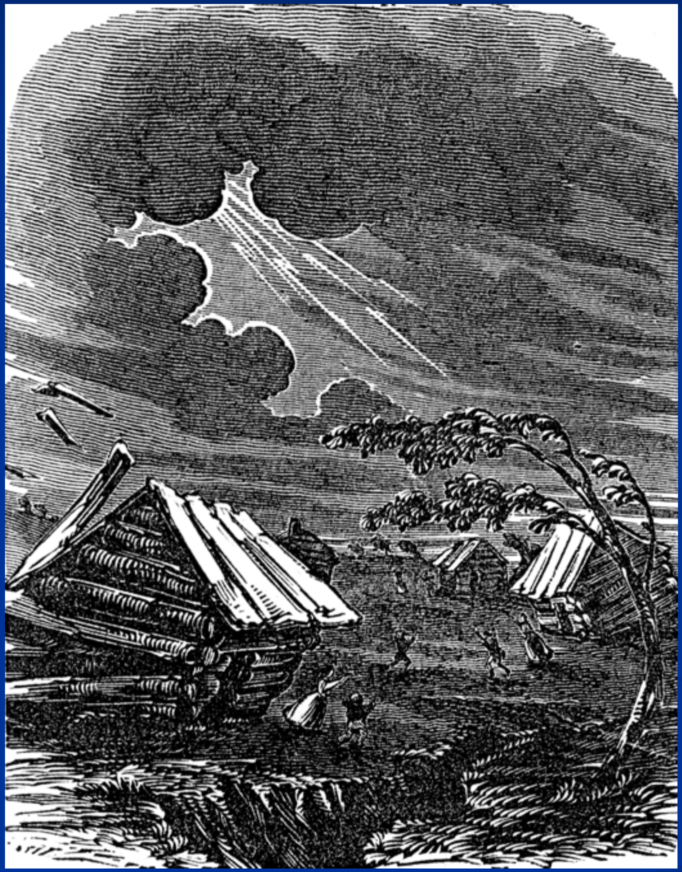
The NMSZ & Evidence of Holocene Displacement in the Jackson Purchase



"The Great New Madrid Earthquake"
From Henry Howe, 1854
Historical Collections of the Great West

M. Tuttle presenting fruits of labor of many investigators and students

Introduction

- The NMSZ has been focus of many paleoseismic studies because of the 1811-1812 earthquake sequence and continued seismicity in the region

- Paleoseismic studies led to recognition of at least three paleoearthquakes, development of Late Holocene earthquake chronology, and estimate of an average recurrence time for New Madrid events

- Studies outside the NMSZ found evidence for activity along other faults of Reelfoot Rift during Holocene and Late Wisconsin

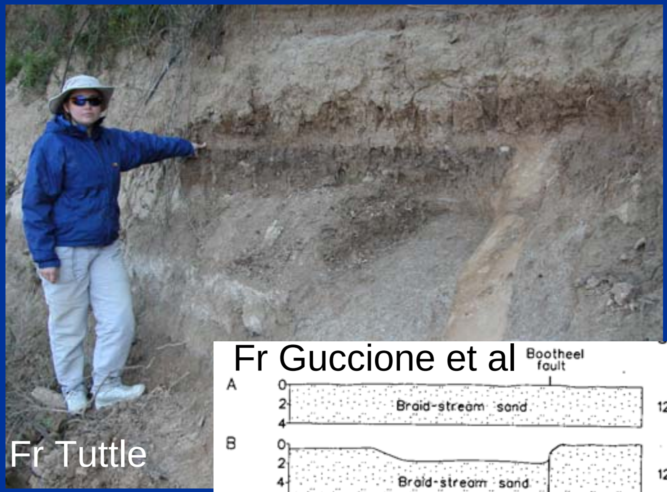
Introduction

- Review the paleoseismic record, as it is currently known, of Reelfoot Rift structures including the New Madrid fault zone, Eastern Margin Reelfoot Rift fault, and Commerce fault zone

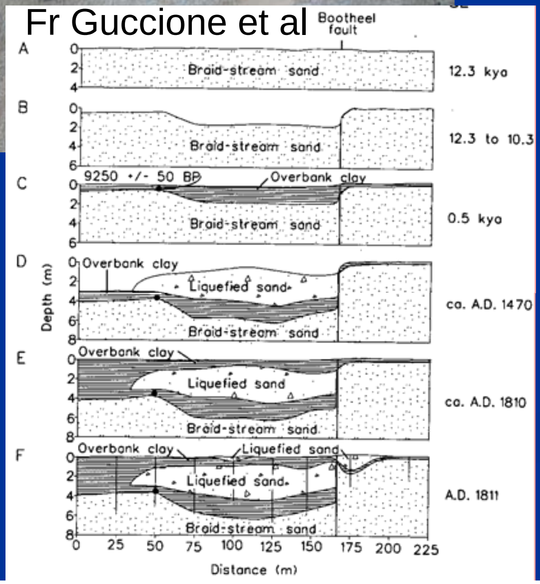
- Discuss some of the implications of the paleoseismic record and outstanding questions regarding earthquake potential of faults in the central US

Paleoseismic Record of Reelfoot Rift

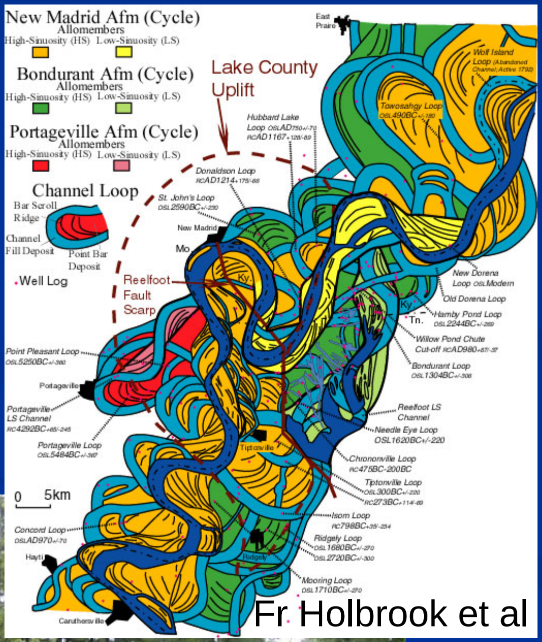
- In NMSZ, multiple and independent lines of evidence - liquefaction features and surface deformation (folding, faulting, uplift, subsidence) and fluvial and biological responses - of strong earthquakes and active faulting



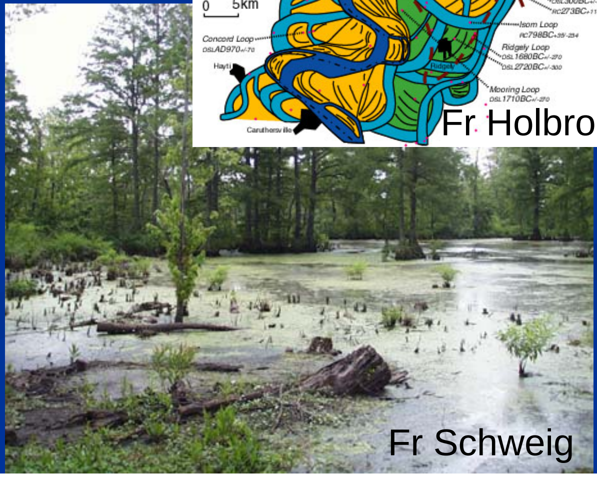
Fr Tuttle



Fr Guccione et al



Fr Holbrook et al



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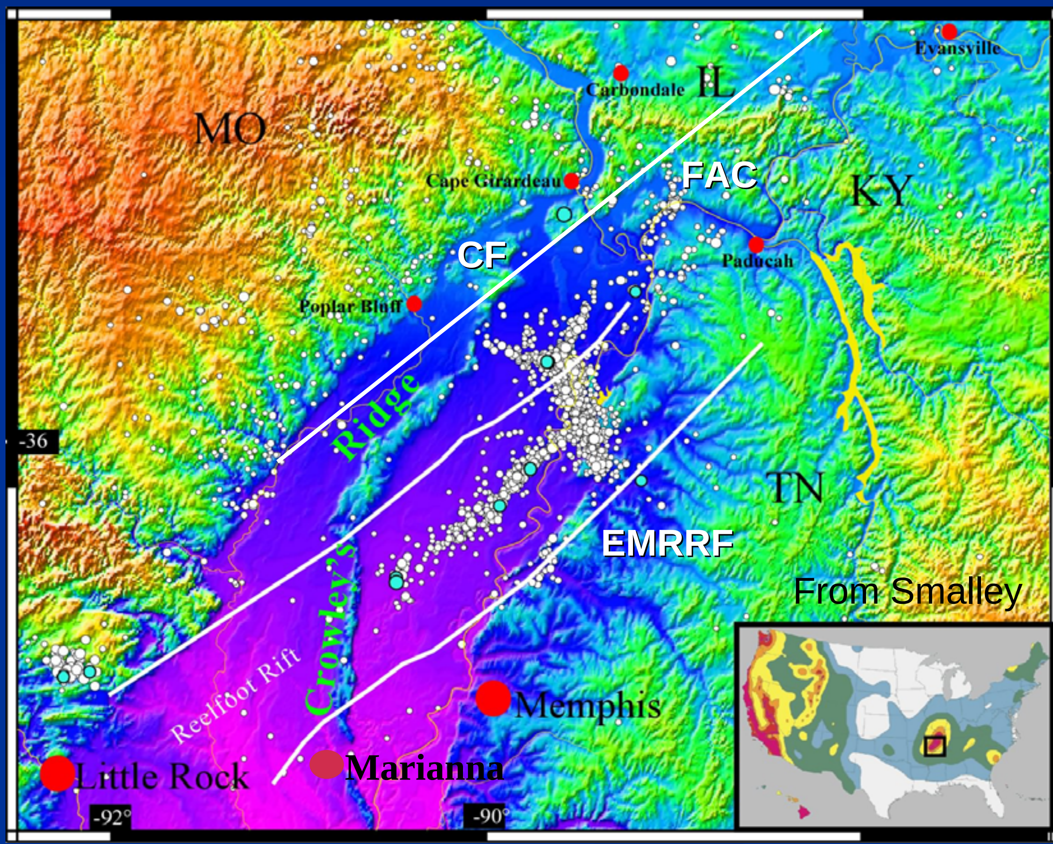
Paleoseismic Record of Reelfoot Rift

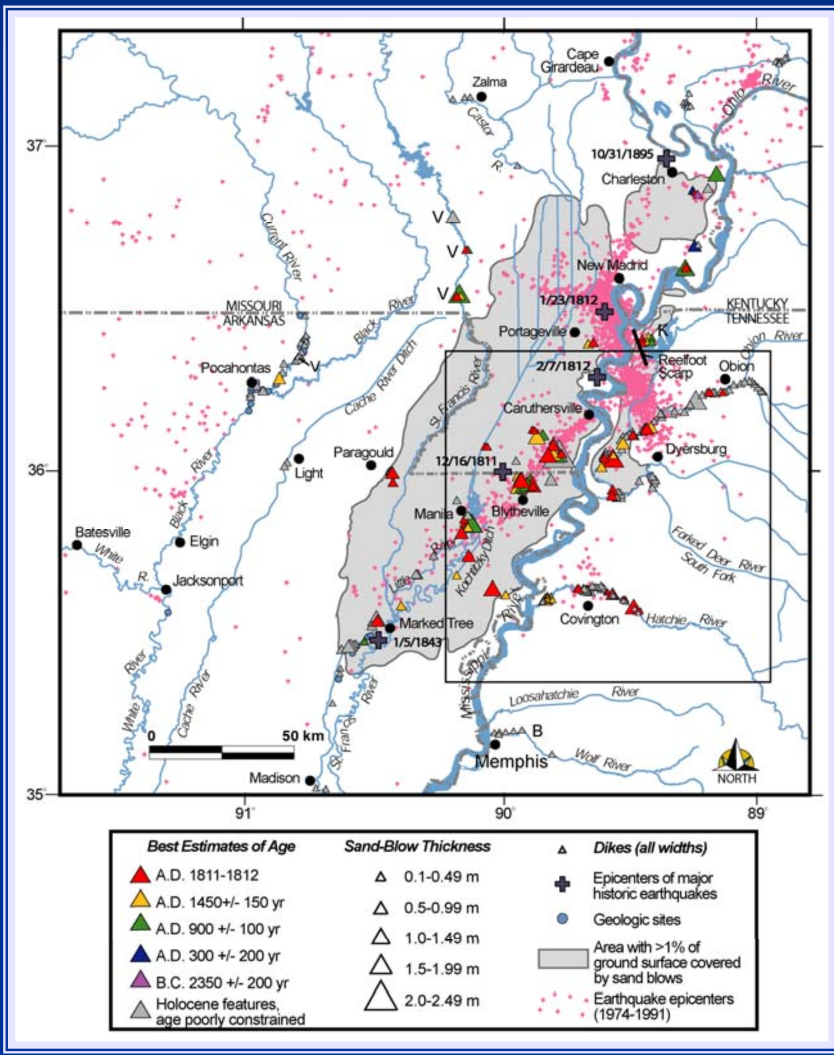
- Along EMRRF, there is evidence of displacement in western TN and earthquake-induced liquefaction associated with fault-parallel lineaments in east-central AR

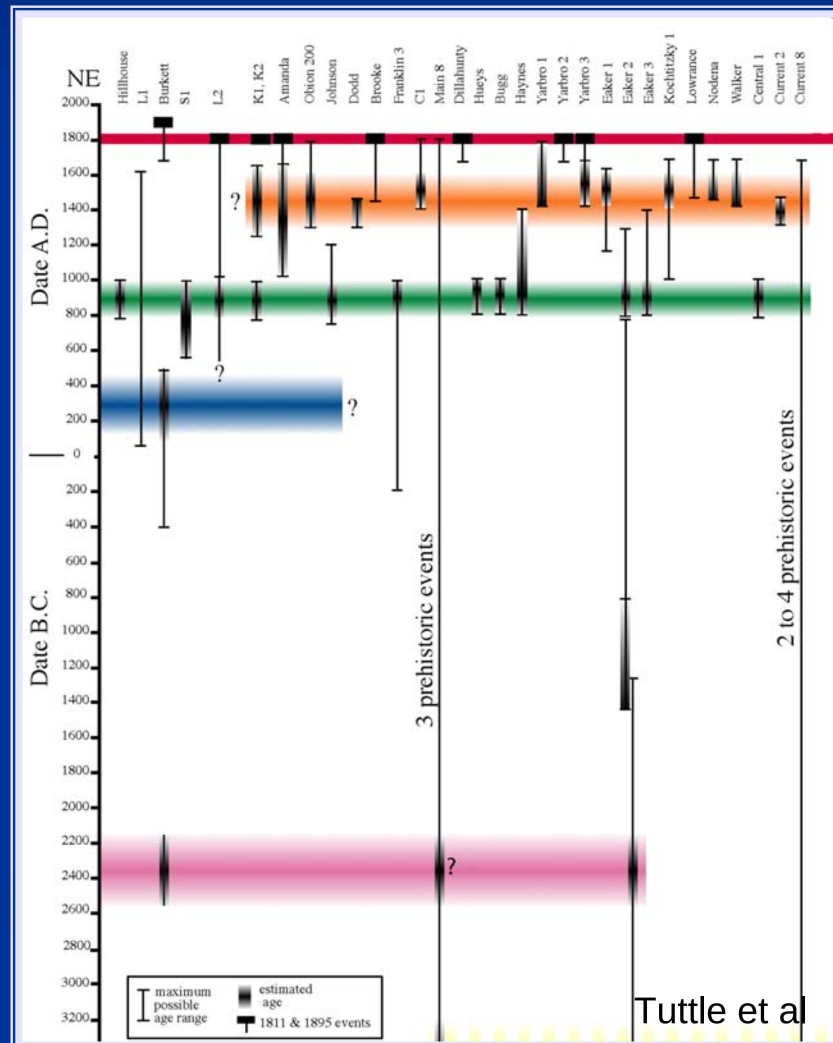


- Along the CF or WMRR, there is evidence of both faulting and earthquake-induced liquefaction

Paleoseismic Record of NMSZ

- **Timing of New Madrid Paleoearthquakes**
  - Significant earthquakes induced liquefaction in AD 1450, AD 900, possibly AD 300, and 2350 BC

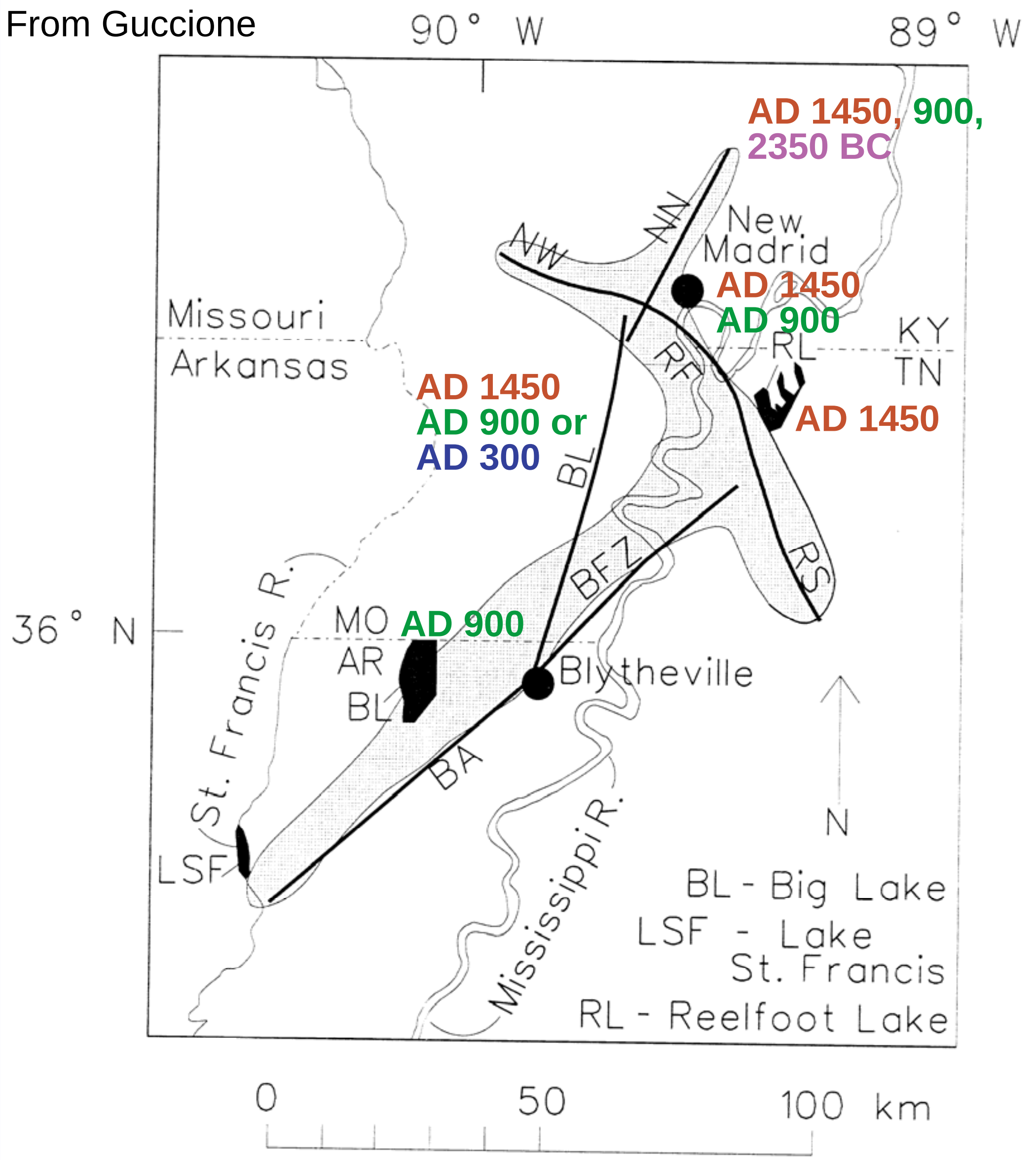




Tuttle et al

Paleoseismic Record of NMSZ

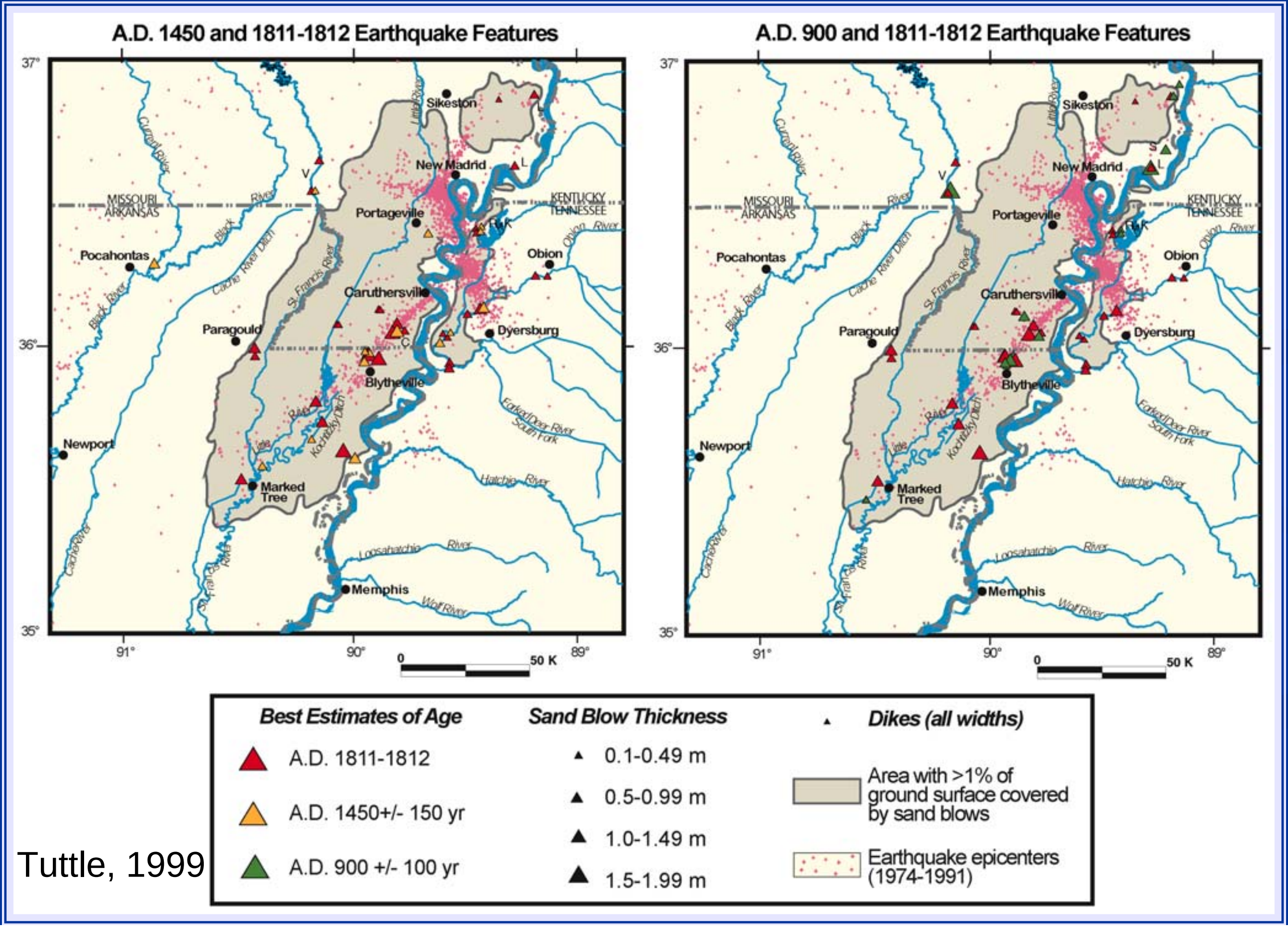
From Guccione



- **Timing of New Madrid Paleoearthquakes**
  - Age estimates supported by dating of deformation along Reelfoot fault, Bootheel fault, at Reelfoot Lake, Big Lake (2 most recent), & by straightening events of Mississippi River northeast of Reelfoot fault (3 events)
  - Other possible events (AD 300, 1100 BC, 3500 BC, 9000 BC) but fewer data; less confidence they are New Madrid-type events

Paleoseismic Record of NMSZ

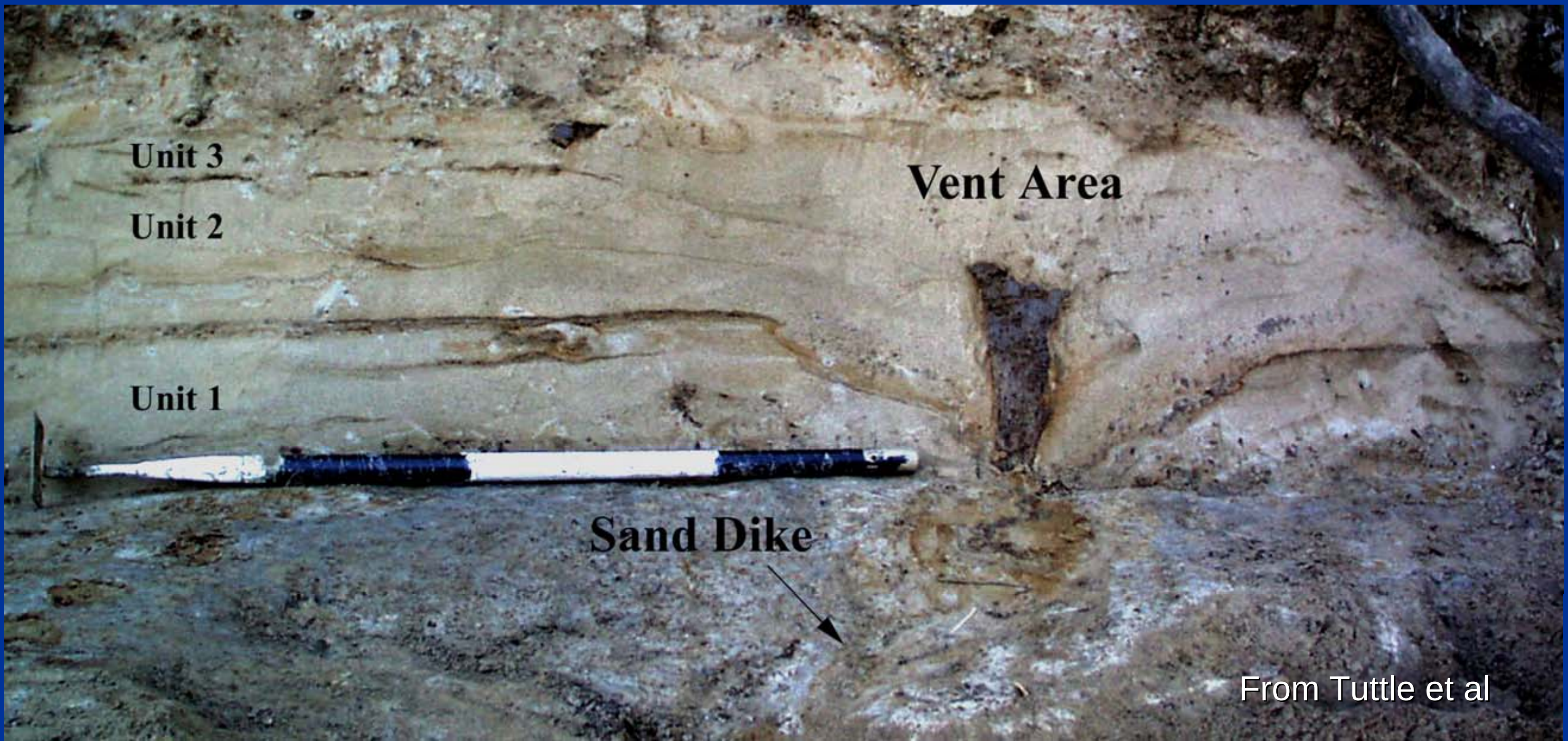
- **Sources of New Madrid Paleoearthquakes**
  - Comparison of size and distribution of prehistoric and historic liquefaction features suggests AD 1450 and AD 900 events were centered also in NMSZ



Tuttle, 1999

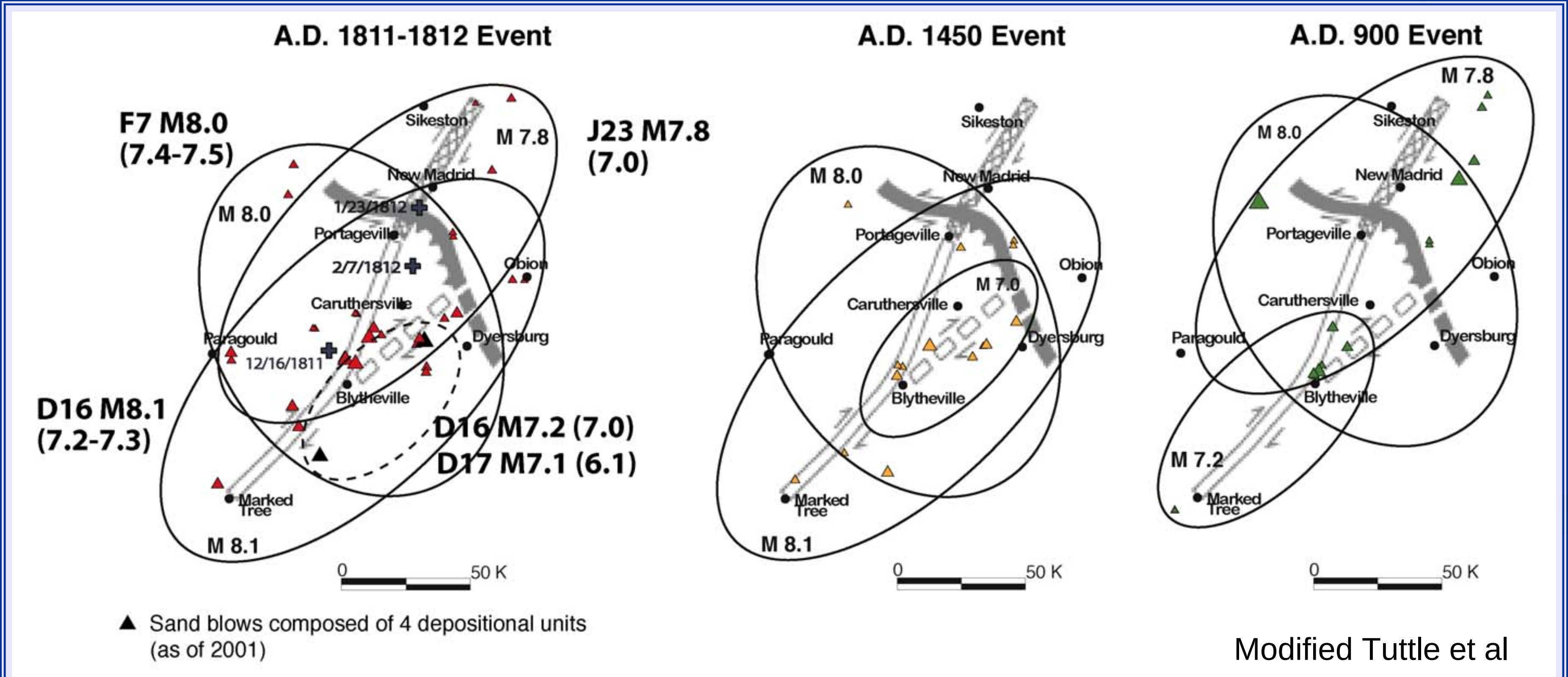
Paleoseismic Record of NMSZ

- **Sources of New Madrid Paleoearthquakes**
  - Historic sand blows composed of multiple units formed during closely timed earthquakes resulting from complex fault rupture (Saucier, 1989)
  - Compound sand blows also formed during the AD 1450, AD 900, and 2350 BC events



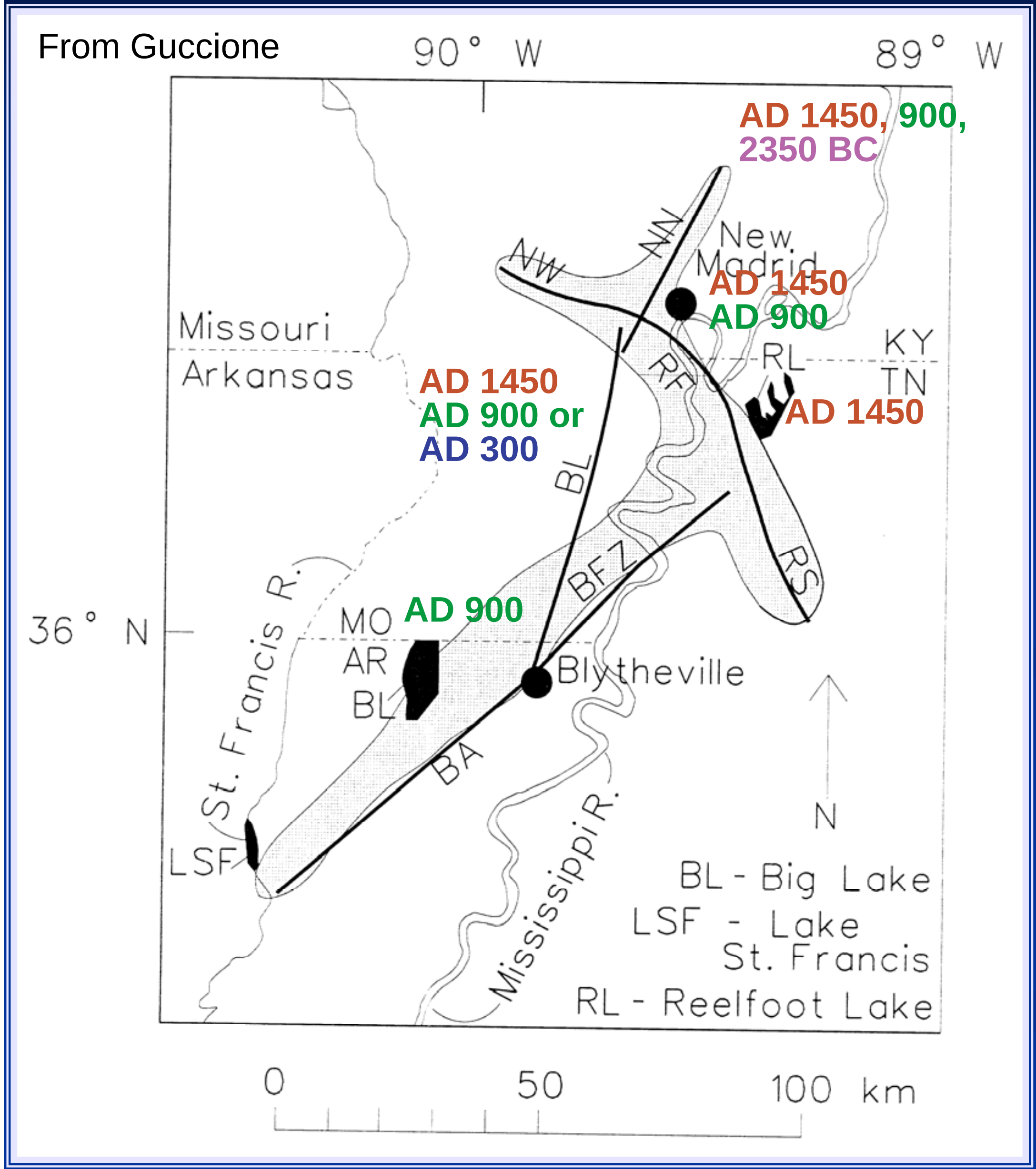
Paleoseismic Record of NMSZ

- **Sources of New Madrid Paleoearthquakes**
  - Sand blow stratigraphy and liquefaction fields suggest Reelfoot fault and Cottonwood Grove fault (or portions of it) were active during AD 1450 and AD 900 events



Modified Tuttle et al

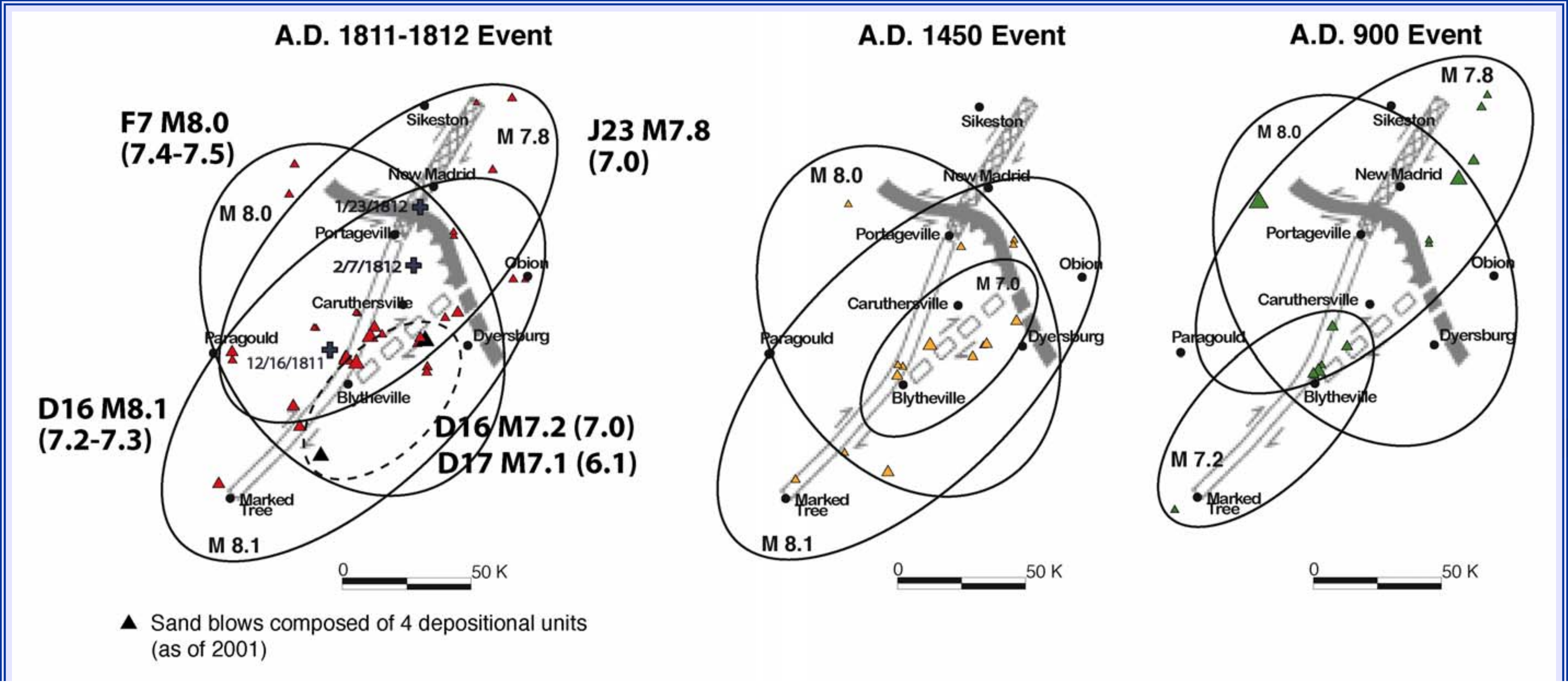
Paleoseismic Record of NMSZ



- **Sources of New Madrid Paleoearthquakes**
  - Deformation and sedimentological records suggest Reelfoot and Bootheel faults as sources of AD 1450 event and Reelfoot and Cottonwood Grove faults as sources of AD 900 event (Kelson et al., 1996; Guccione et al., 2002, 2005; Holbrooke et al., 2006)
  - No evidence of faulting in AD 1450 or AD 900 found in trenches across NMNF (Baldwin et al., 2002)

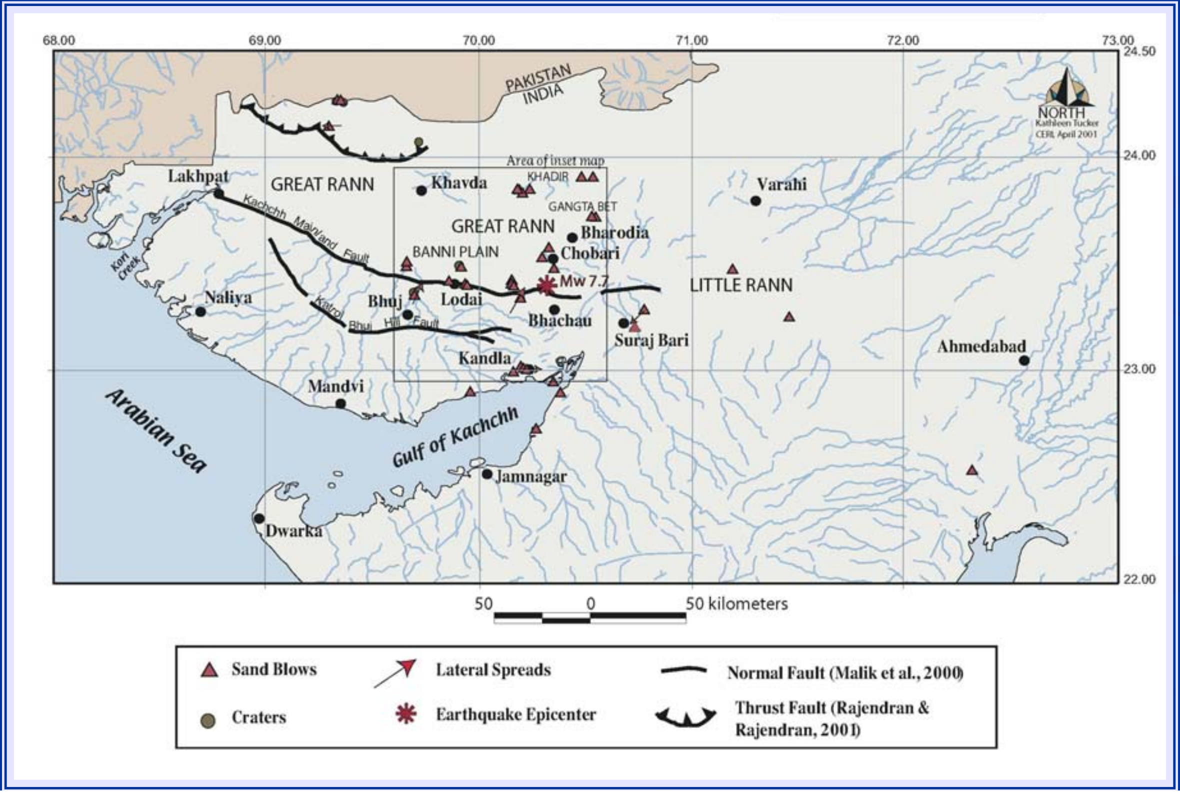
Paleoseismic Record of NMSZ

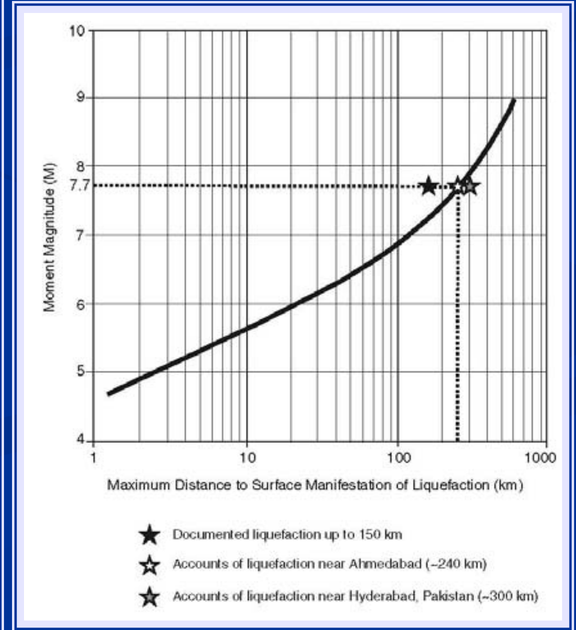
- **Magnitude of New Madrid Paleoearthquakes**
  - Paleoearthquakes similar in magnitude to 1811-1812 event on basis of size and distribution of liquefaction features
  - Geotechnical approach of back-calculating magnitude estimates paleoearthquakes in M 7.5-8 range



Paleoseismic Record of NMSZ

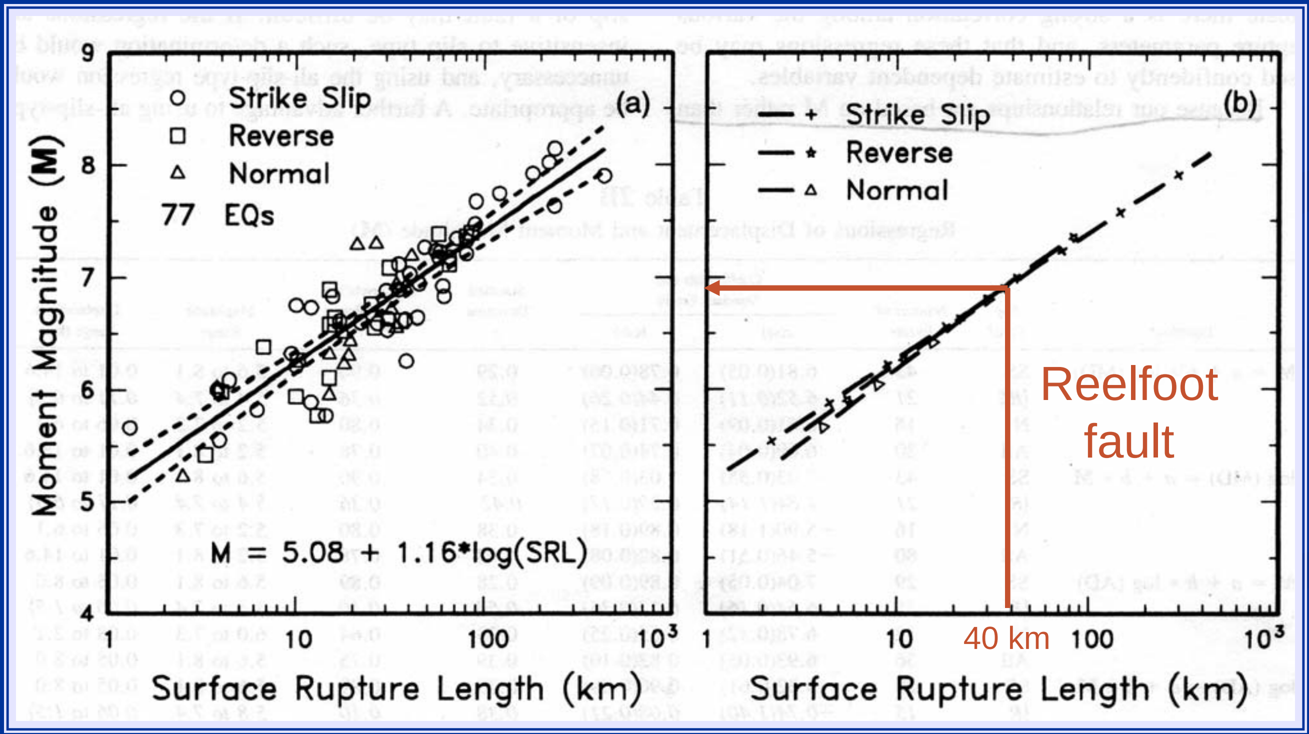
- **Magnitude of Paleoearthquakes**
  - 2001 Bhuj, India eq of M 7.6-7.7 induced liquefaction 240-300 km from epicenter; similar to 1811 NM event and consistent with Ambraseys' relations; given similarity to 1811, paleoearthquakes at least M 7.6





Paleoseismic Record of NMSZ

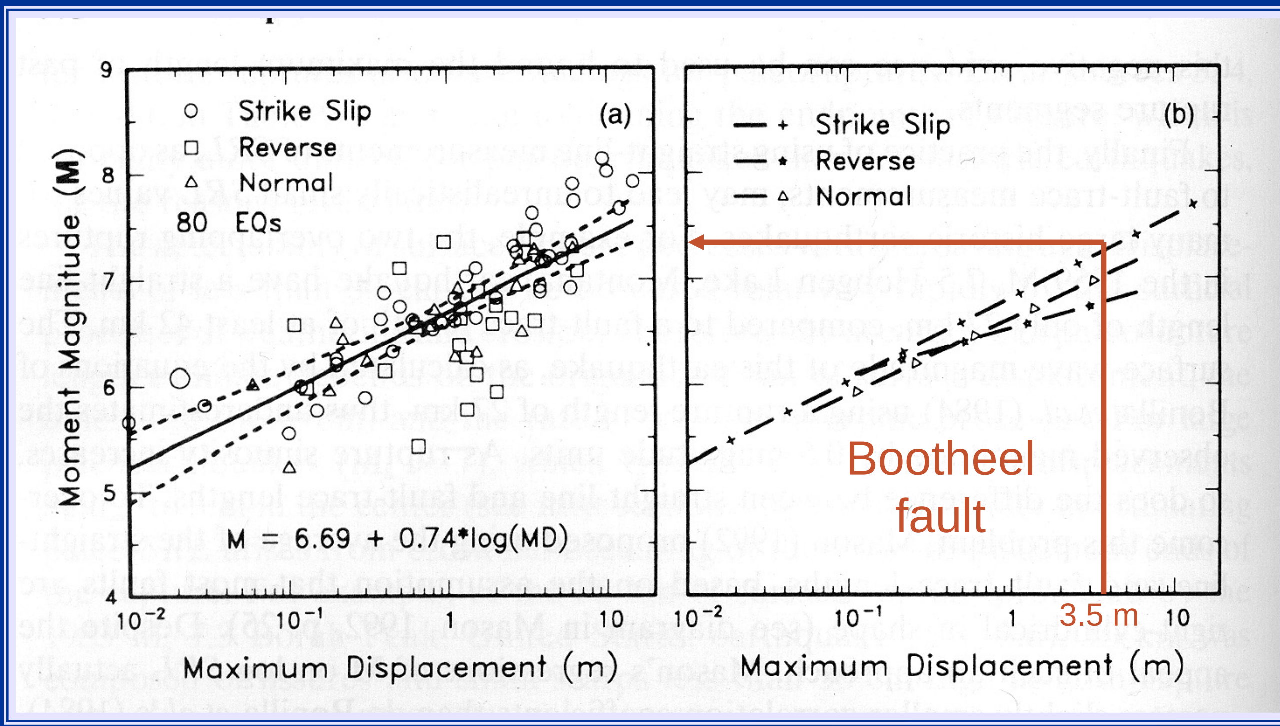
- **Magnitude of Paleoearthquakes**
  - Reelfoot fault - length of 32-40 km and could yield earthquake of M 6.8-7.0; 8 m of uplift most of which formed in second most recent event (AD 1450) (Kelson et al., 1996)



Graphs from McCalpin, 1996

Paleoseismic Record of NMSZ

- **Magnitude of Paleoearthquakes**
  - Bootheel fault - slip rate of 5.4 mm/yr for past 2400 yrs and estimated displacement of 3.5 m/event or M>7 (Guccione et al., 2005)

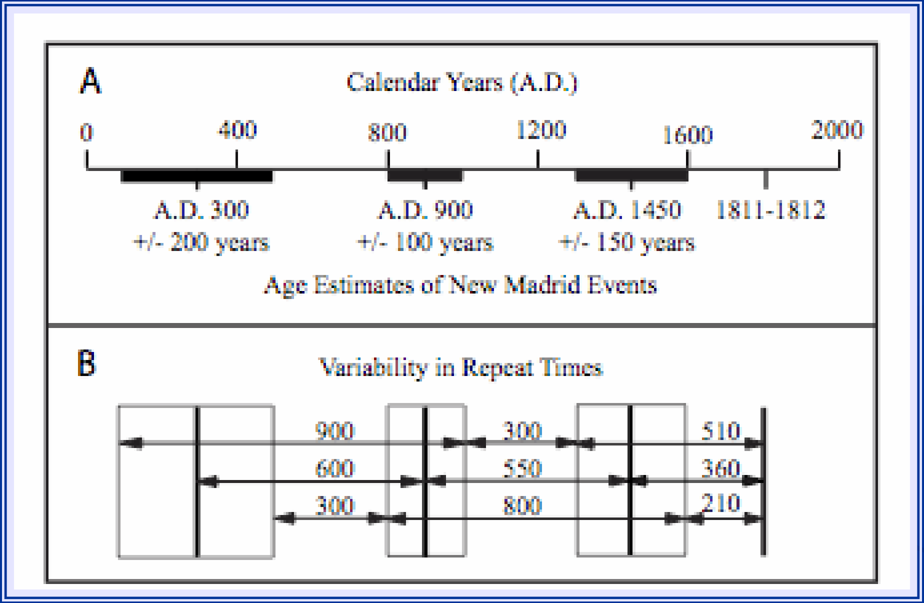


Graphs from McCalpin, 1996

  - Other similar estimates of slip rate for RF and lower estimates for CGF (Mueller et al., 1999)

Paleoseismic Record of NMSZ

- **Earthquake Recurrence**
  - Liquefaction record suggests repeated NM sequences in AD 1450, AD 900, and possibly AD 300; average repeat time 500 yr in 1200-2000 years

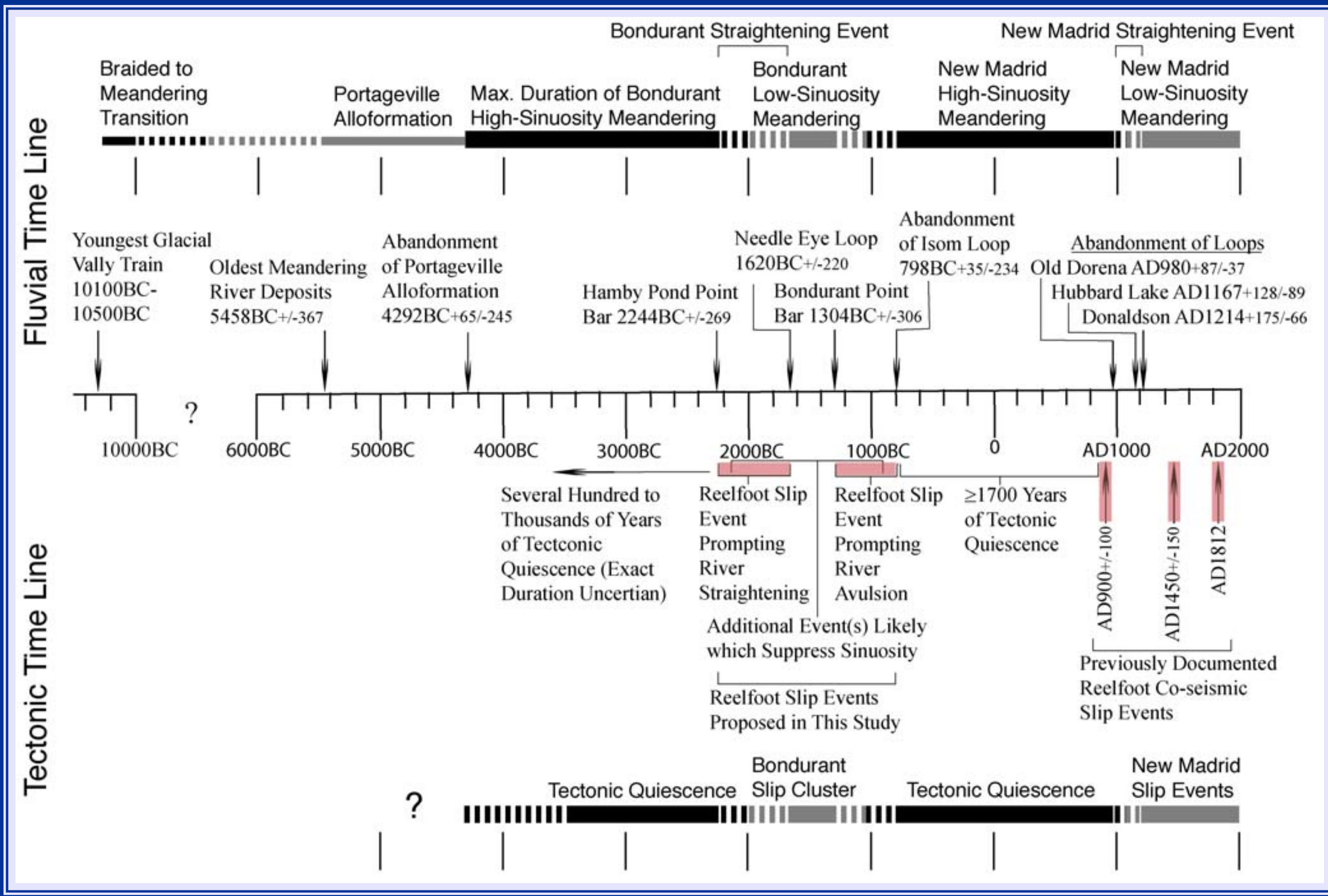


Tuttle et al., 2005

  - Deformation and sedimentological records indicate similar repeat times for ruptures of Bootheel and Reelfoot faults
  - Apparent gap between AD 900 or AD 300 & 2350 BC

Paleoseismic Record of NMSZ

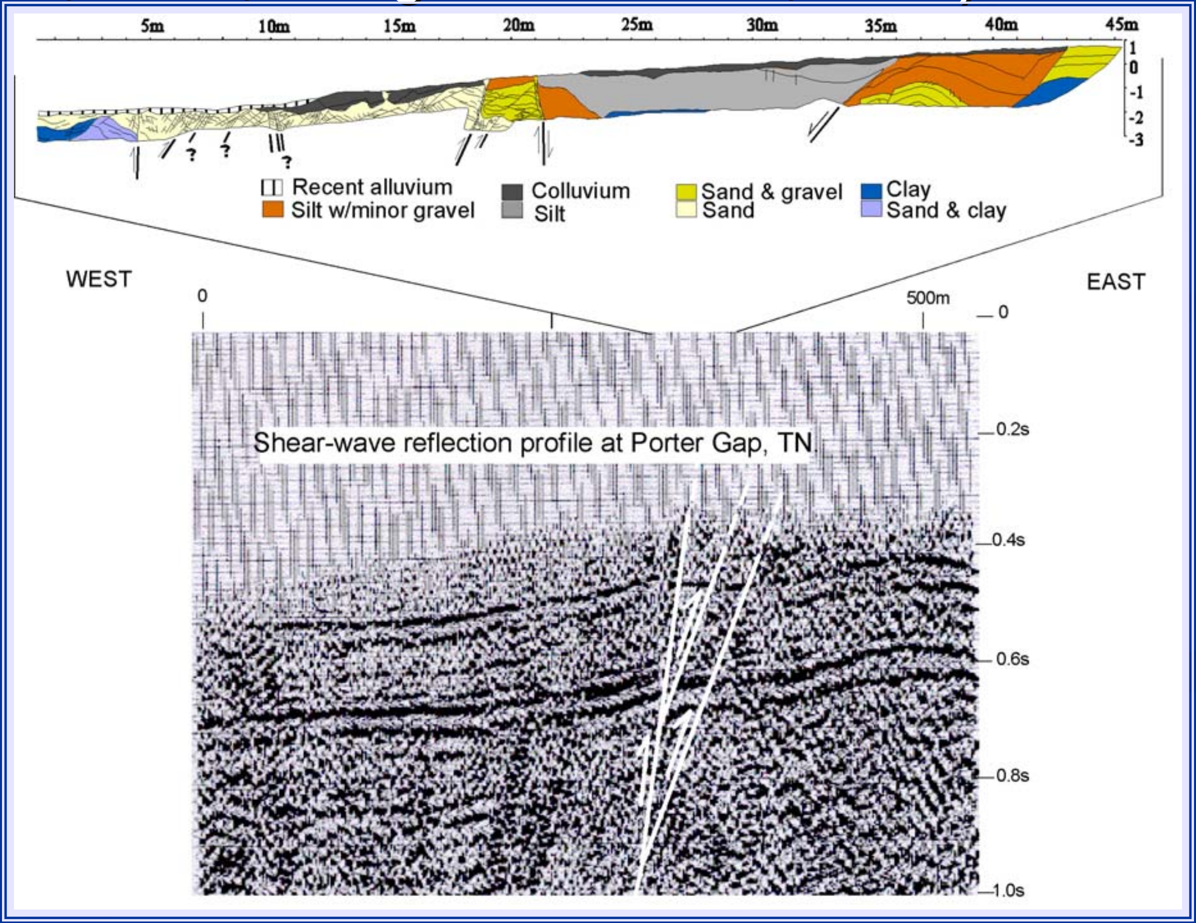
- **Earthquake Recurrence**
  - Mississippi channel straightening events suggests rupture of Reelfoot fault in 2000 BC, 1000 BC, AD 900, AD 1450; grouped as two slip clusters separated by >1700 yr quiescense; RF - active and inactive periods (Holbrook et al., 2006)



Paleoseismic Record of EMRRF

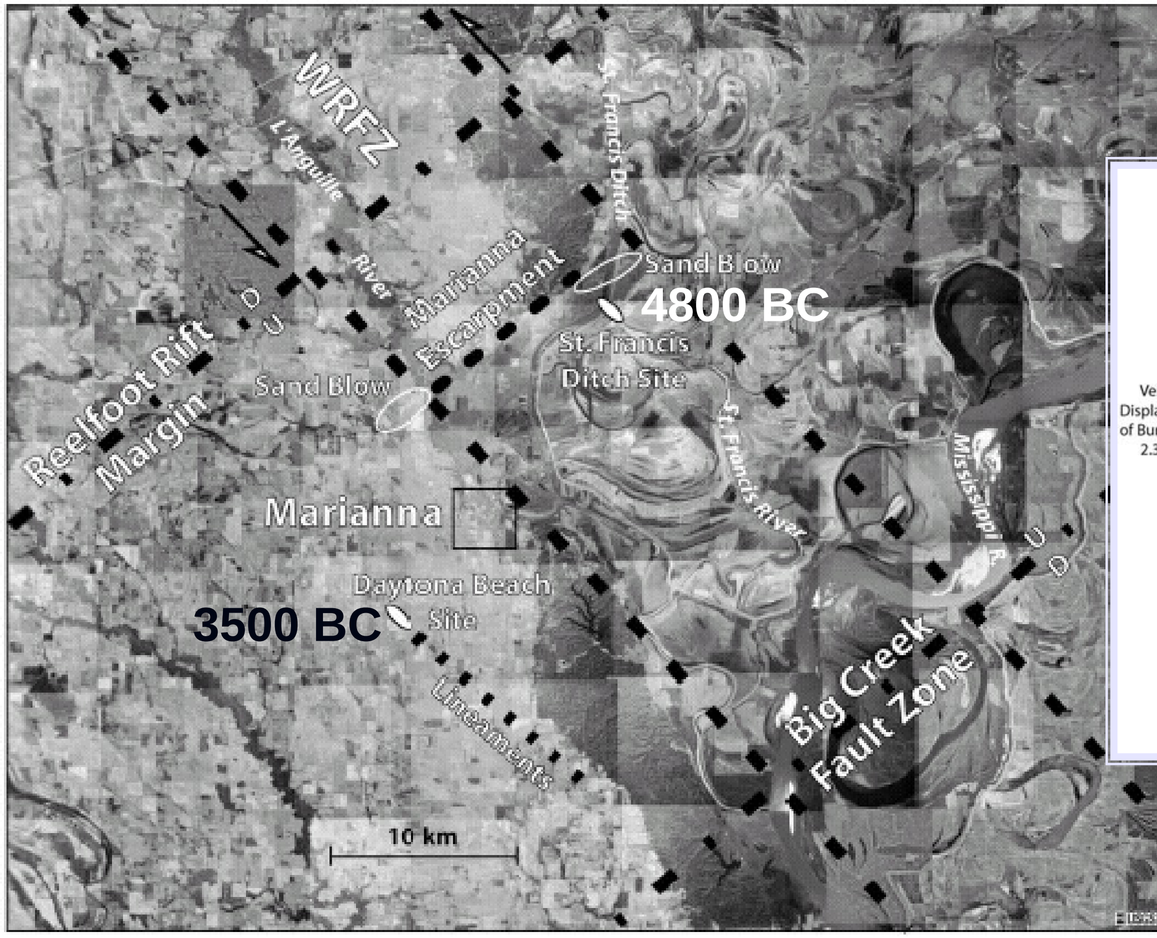
- Western TN - Late Wisconsin-Early Holocene faulting above EMRR; fault coincident with 150 km long lineament (M $\geq$ 7.5); seismicity spatially associated lineament (Chiu et al., 1997; Cox, et al., 2001; Hough and Martin, 2002)

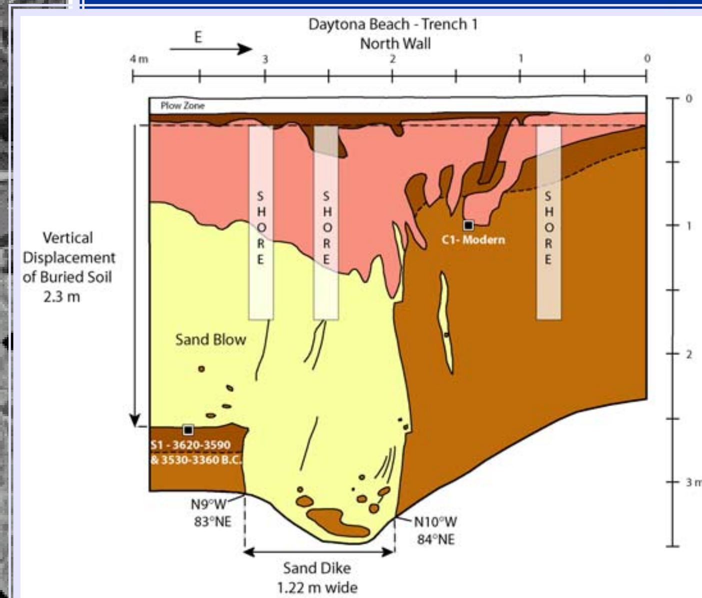
From Cox, et al., 2001



Paleoseismic Record of EMRRF

- Marianna, AR - large Middle Holocene (3,500 B.C. and 4,800 BC) sand blows occur near and along lineaments parallel to mapped trace of EMRRF, suggesting fault produced large eqs during Middle Holocene (Al-Shukri et al., 2006; Tuttle et al., 2006)

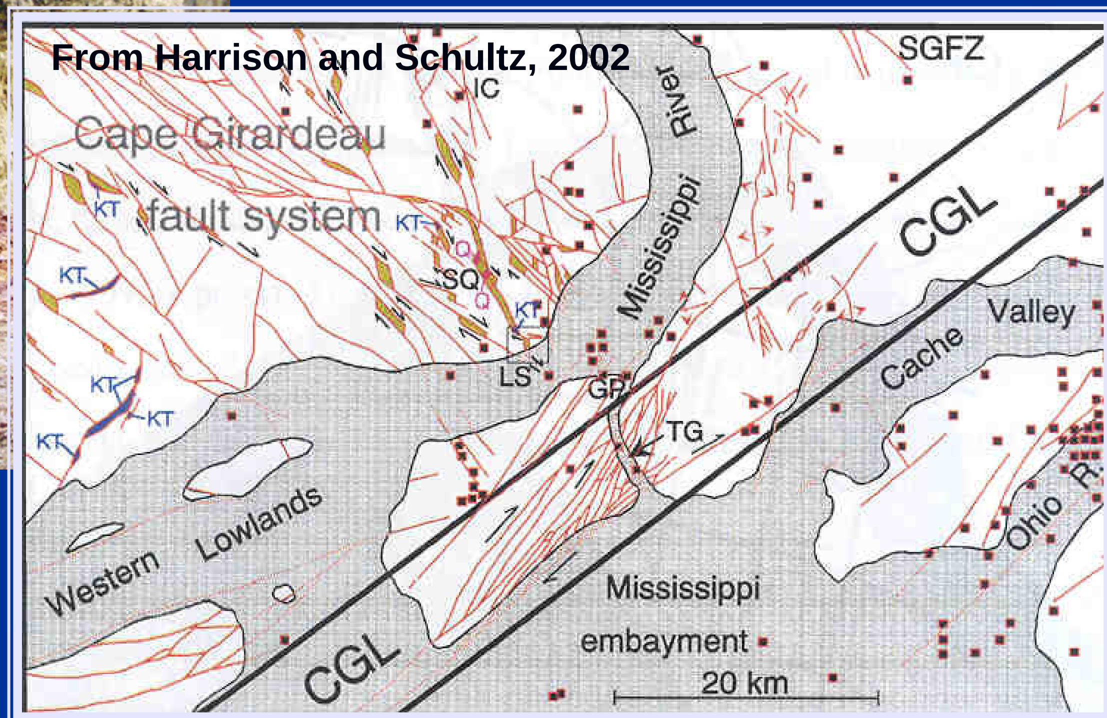




Faults after Fisk, 1944;
Krinitsky, 1950;
Spitz and Schumm, 1997

Paleoseismic Record of Commerce Fault

- Multiple episodes of displacement in 50-60 ka, 25-35 ka, and two episodes during the Holocene (Palmer et al., 1997; Harrison and Schultz, 2002; Baldwin et al., in prep)



Paleoseismic Record of Commerce Fault

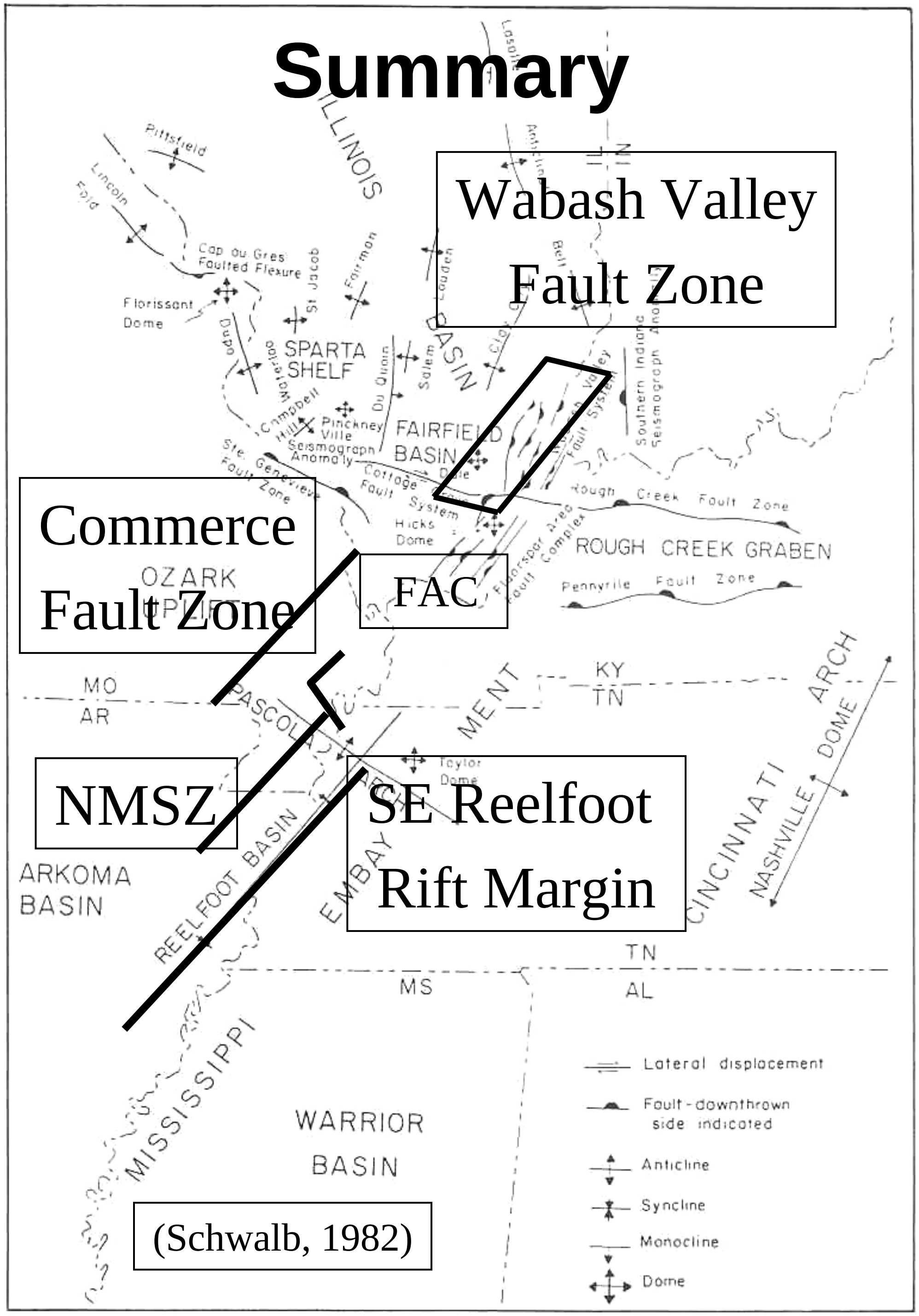
- Early Holocene-Late Wisconsin liquefaction features in Western Lowlands induced by earthquakes produced by local source possibly Commerce fault (Vaughn, 1994)

Summary

Late Wisconsin-Early Holocene;
60-50 ka
35-25 ka
Holocene

Late Holocene
4 ka-present;
5.5 ka and 11 ka?

Middle Holocene
5.5 ka and 6.8 ka



Late Wisconsin
12 ka
Middle Holocene
6 ka

Illinoian at least
55-128 ka

Late Wisconsin-Early Holocene

Modified from Holbrook

Implication of Paleoseismic Record

- Seismicity and active faulting appear to migrate within Reelfoot Rift on time scale of few thousand years

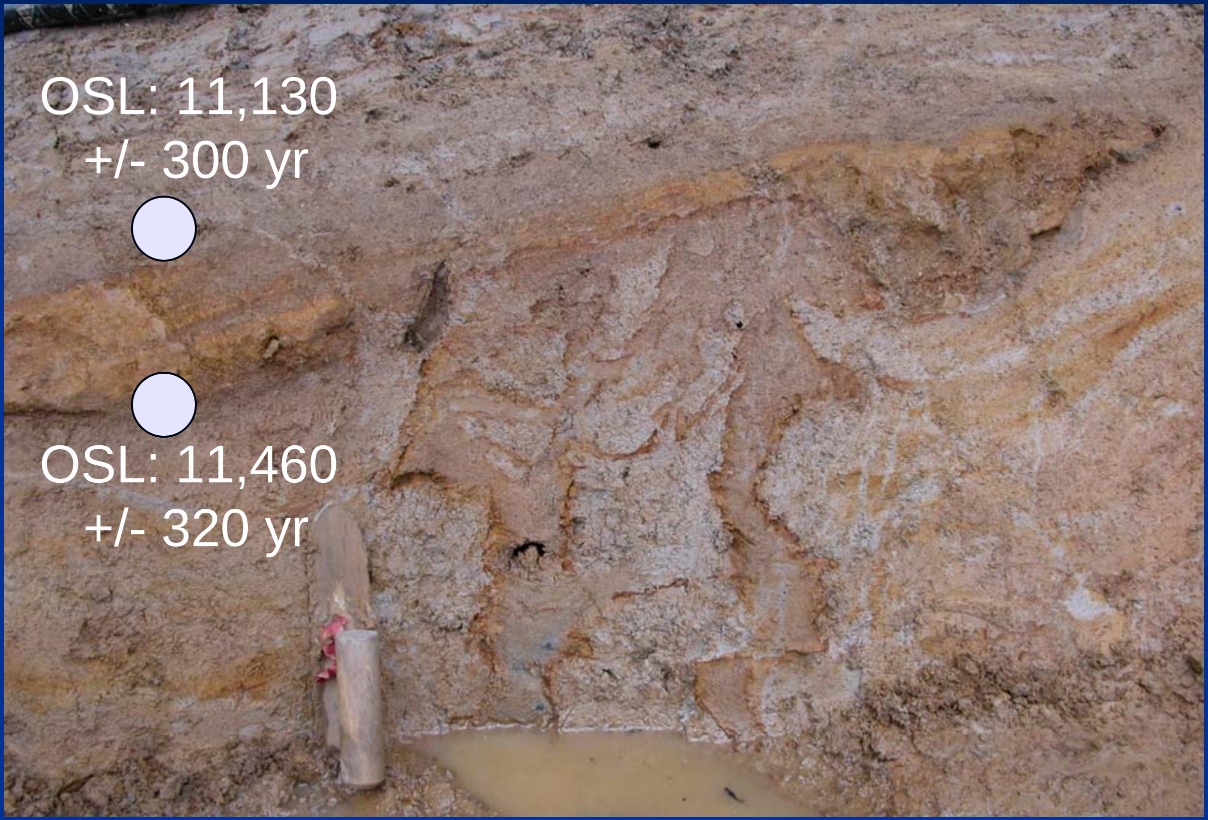
- Paleoseismic record supports shift in locus of largest earthquakes from FAC to other faults within Reelfoot Rift during past several 10,000 yr, most recently to NMFZ (Nelson et al., 1999; McBride et al., 2002)

- Gaps (geographically and temporally) in the paleoseismic record; only snapshots - chronology may be incomplete and all seismic sources may not be known

Outstanding Questions

- Many questions remain about behavior of faults in Jackson Purchase during the Late Quaternary
  - When did the NMFZ become active and is it characterized by active and inactive periods
  - Was displacement along southern EMRRF responsible for Middle Holocene earthquakes near Marianna?
  - Does CFZ provide a kinematic link between Reelfoot Rift and WVSZ?
  - What is relationship between Reelfoot Rift and Rough Creek Graben and has RCG produced large earthquakes during Late Quaternary?

Prehistoric Sand Blow in Western Kentucky



- What's the earthquake source?
  - New Madrid fault zone, Wabash Valley seismic zone, or something else?

Paleoliquefaction

- How to estimate eq source based on liquefaction features alone (no associated fault), especially if similar in age to large distant events?
  - Map size and distribution of similar age features; compare these with modern and historic cases; study sand blow stratigraphy
  - Use empirical relations between earthquake magnitude - liquefaction distance to delineate source area
  - Model scenario events (liquefaction potential analysis, intensity) accounting for factors such as site conditions, directivity, Moho bounce

Paleoseismic Record of Wabash Valley Region

Timing, source areas, and magnitudes of large earthquakes estimated from liquefaction features:

3,800-8,500 yr BP – M 6.2

3,950 yr BP – M 6.3

6,100 yr BP – M 7.1-7.3

12,000 yr BP – M 6.7

20,000 yr BP

Slide Modified from Bauer
Dates: From Munson et al., 1997;
Magnitudes: From Olson et al., 2005