Identification of Lateral Spread Features in the Western New Madrid Seismic Zone

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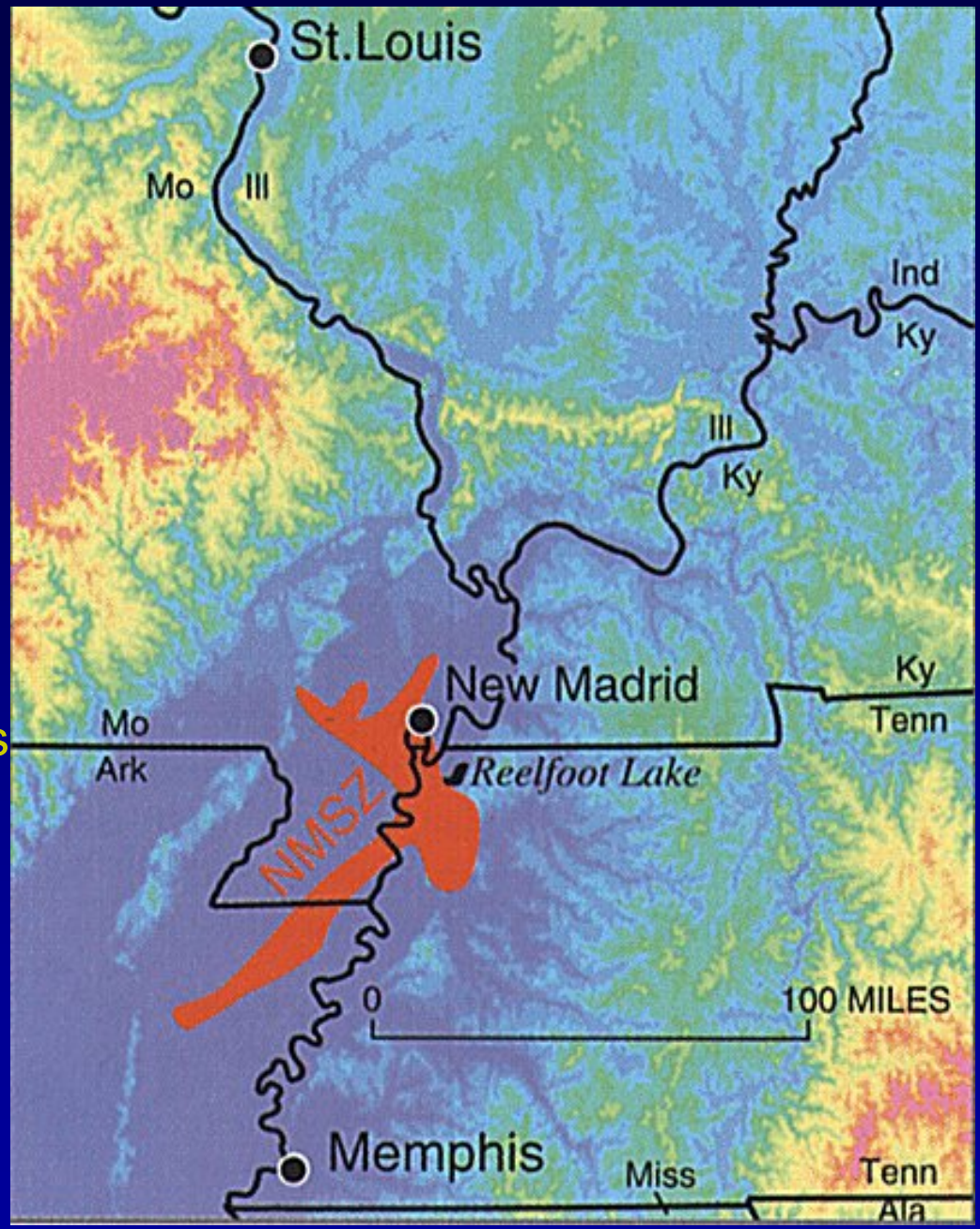
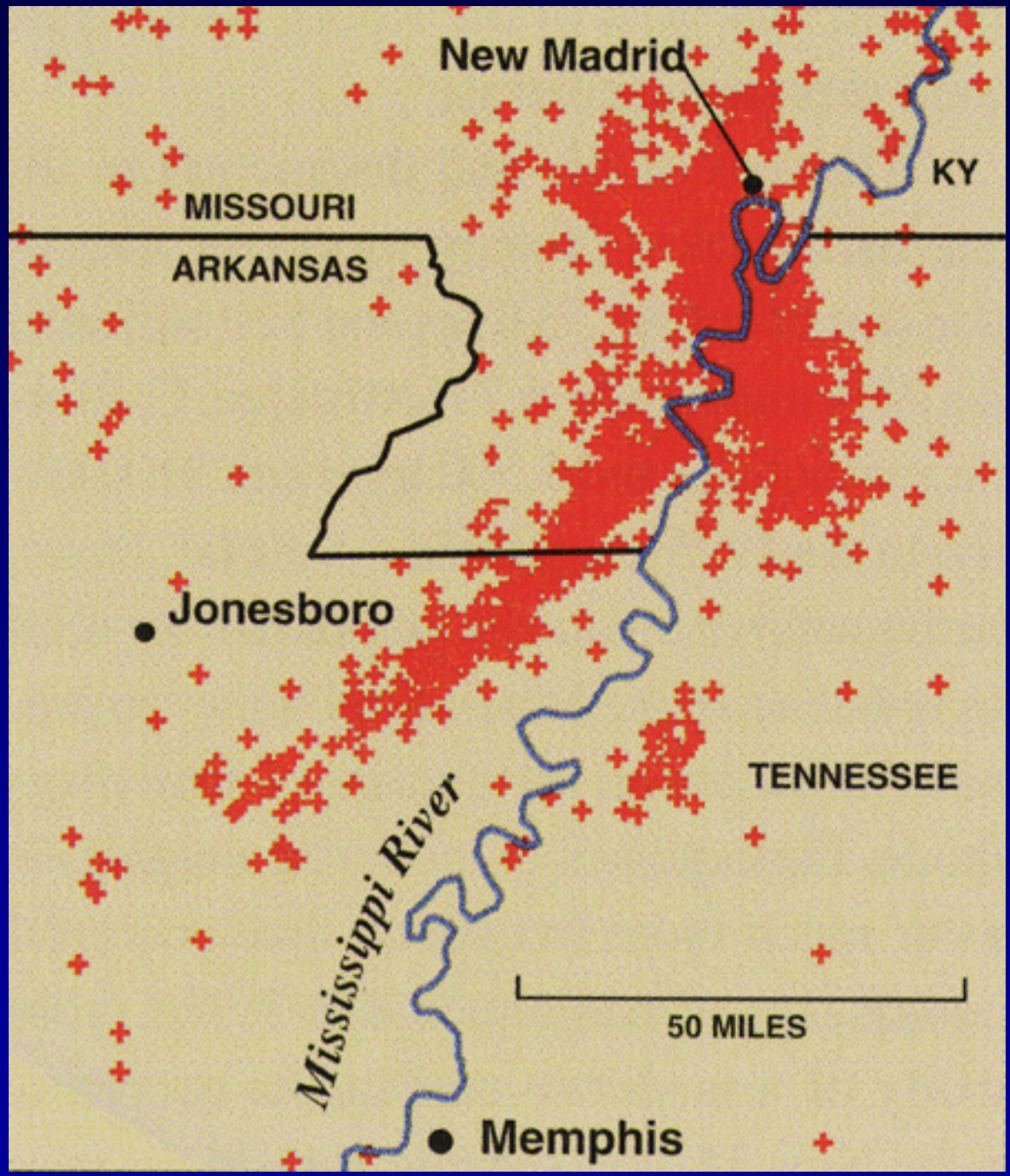
New Madrid Seismic Zone (NMSZ)

- Most seismically active area east of Rocky Mts.
  - Located within Upper Mississippi Embayment
- In 1811-1812
  - Over 2000 felt earthquakes in 4 month period
  - 4 quakes with $M_s \geq 8.0$
- Damage estimates for similar quakes today
  - $10 to $20 billion in Central U.S. (1994)

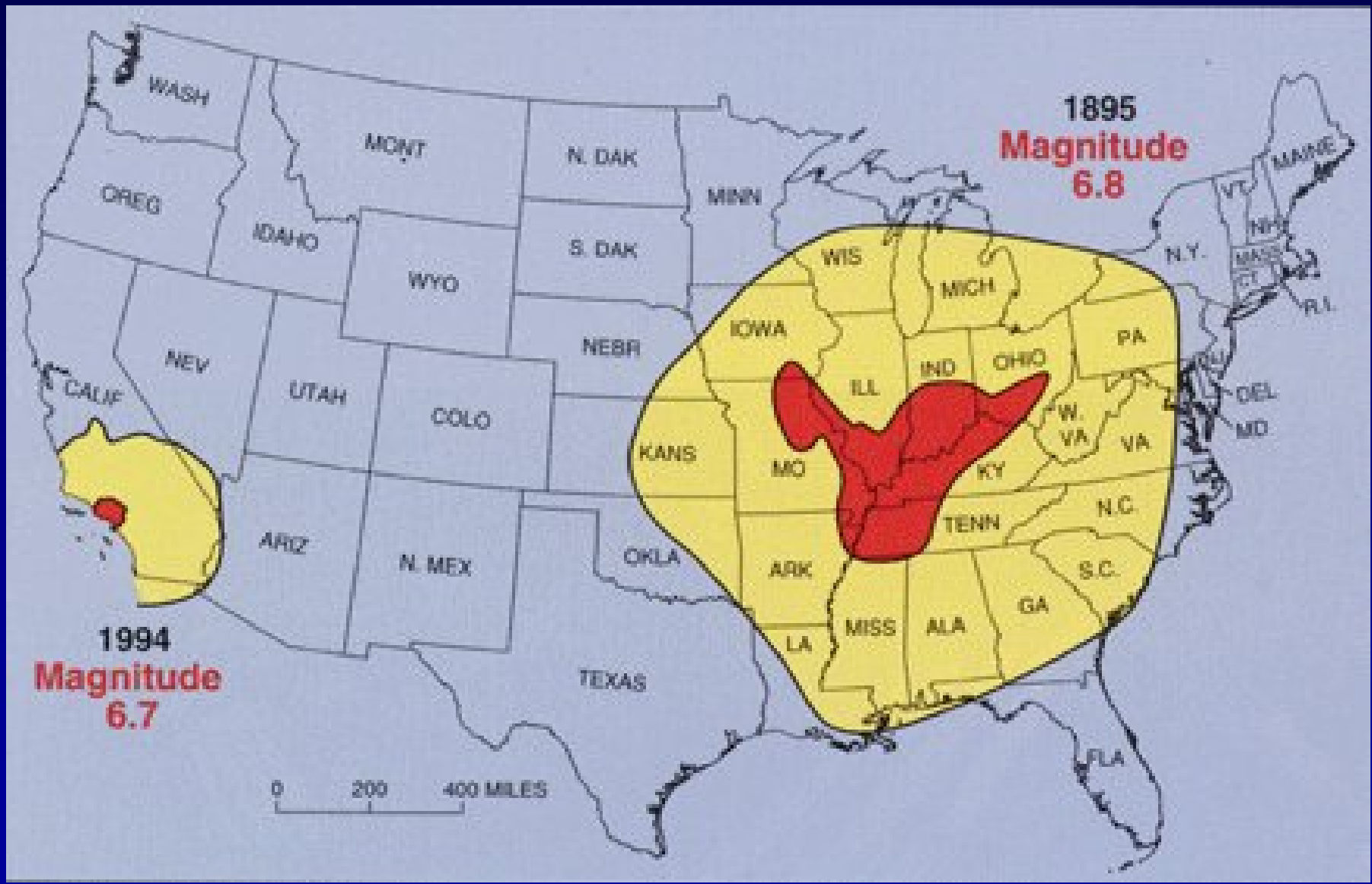


Distribution of Recent Seismicity

- Funding to investigate initiated in the mid-1970s when a nuclear power plant was being considered in the Memphis area
- Locations of earthquakes recorded in the NMSZ from 1974 to 1995



Area affected by a M_s 6.8 Earthquake

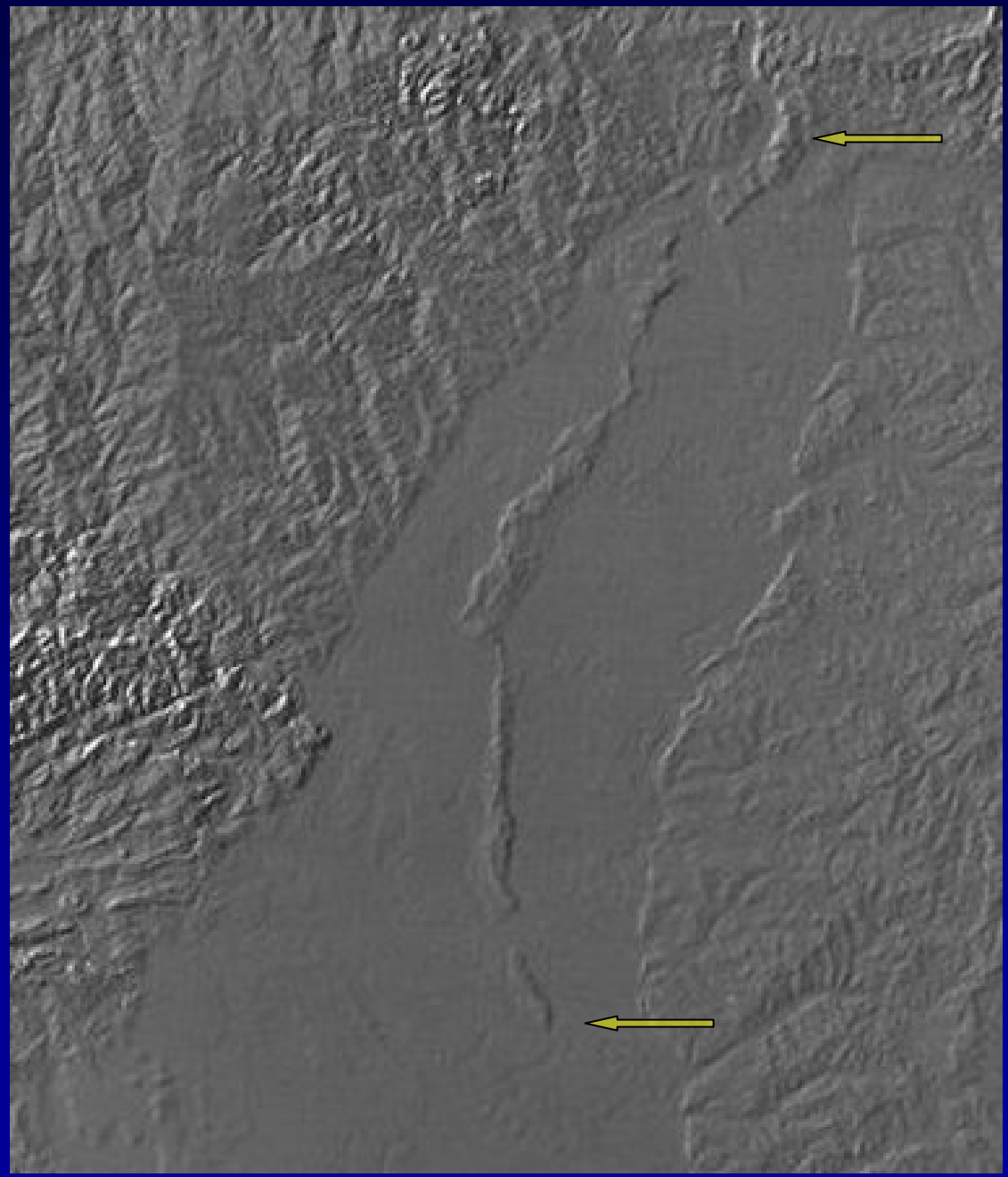


Little Previous Work Evaluating Landslides in the Western NMSZ

- Eastern NMSZ
  - Jibson (1985); Jibson and Keefer (1988,1994)
- Western NMSZ
  - Ding (1991)
    - Mapped at 1:124,000 scale (~1inch to 2 miles)
  - McFarland (1992)
    - Arkansas Geological Commission
- **Previous studies have not identified lateral spreads in the NMSZ**

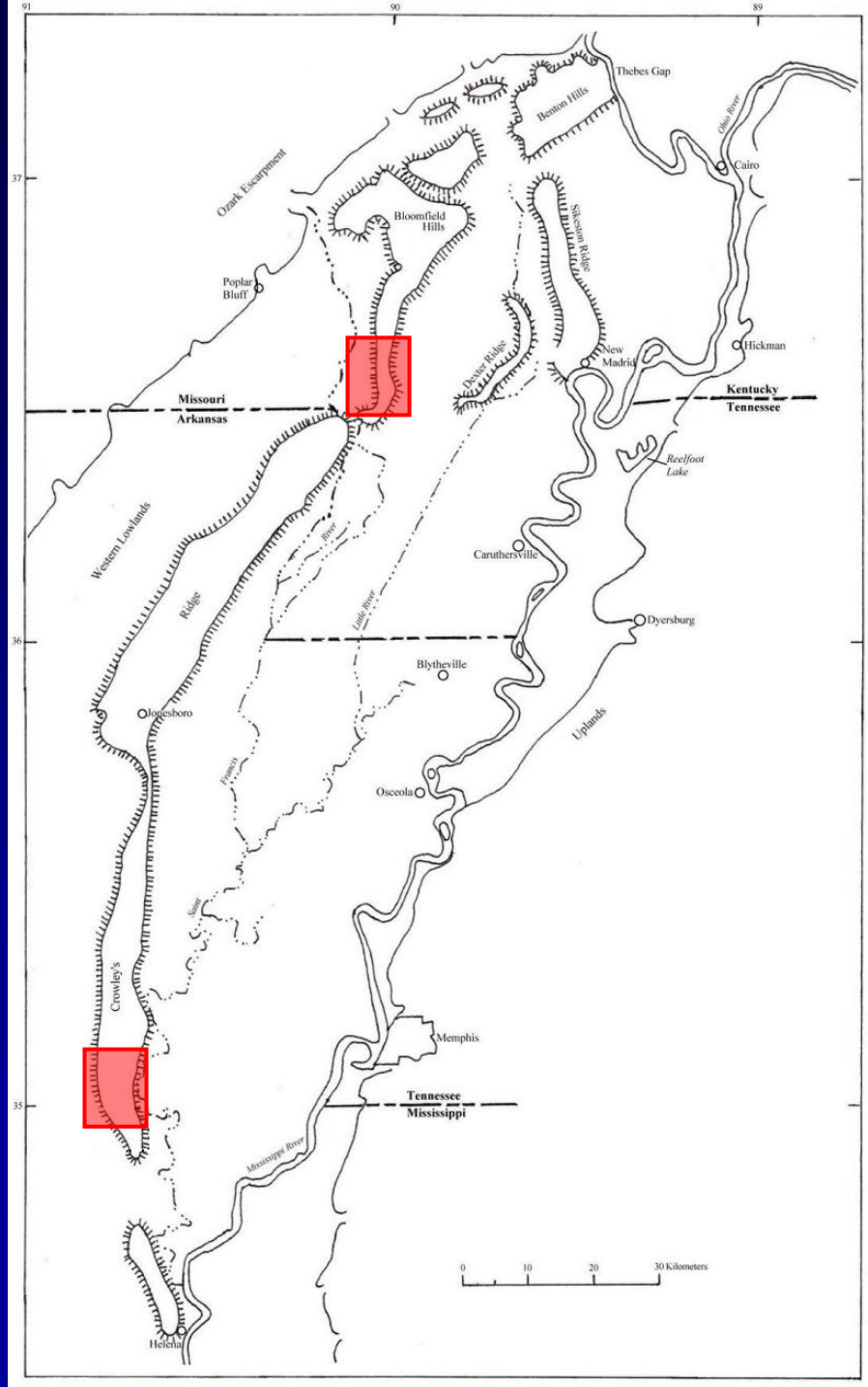
Crowley's Ridge

- Elevated upland within the Mississippi River Embayment, along the NMSZ
- Over 380 km long
- 32 km wide at widest point
- Up to 90 m of relief

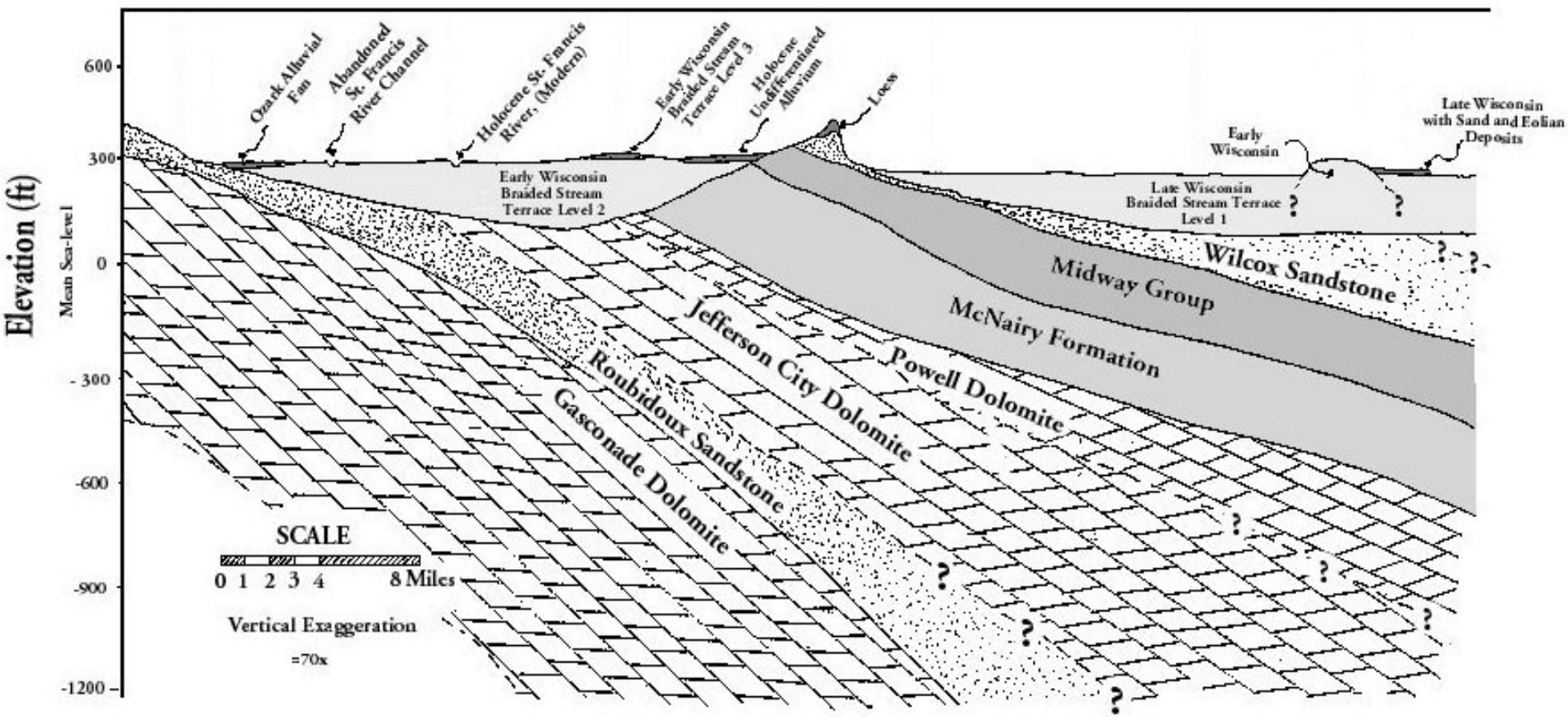


Crowley's Ridge

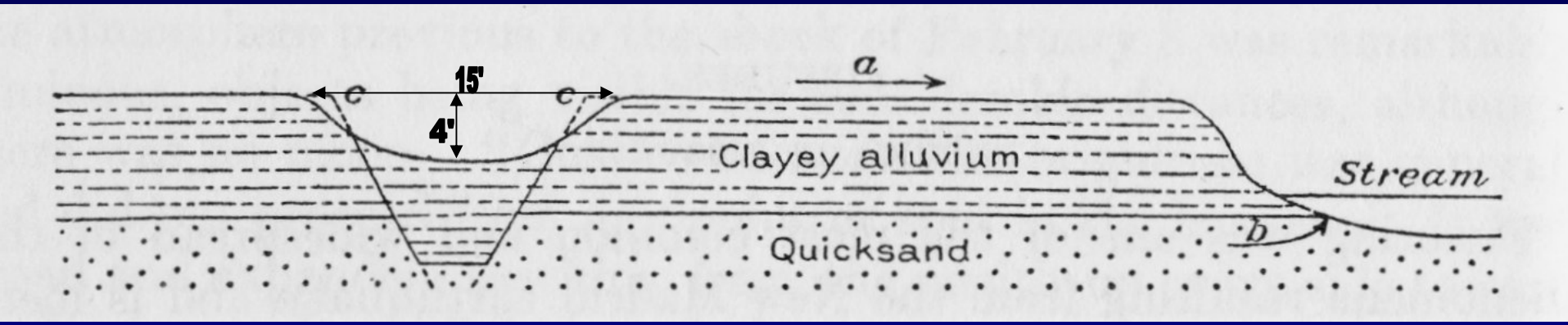
- Likely formed by:
  - erosive processes
  - tectonic processes
    - related to the NMSZ
- 52 quadrangles cover the ridge
- Landslide mapping demonstration quadrangles
  - LaGrange, AR
  - Valley Ridge, MO



Geology Northern Crowley's Ridge



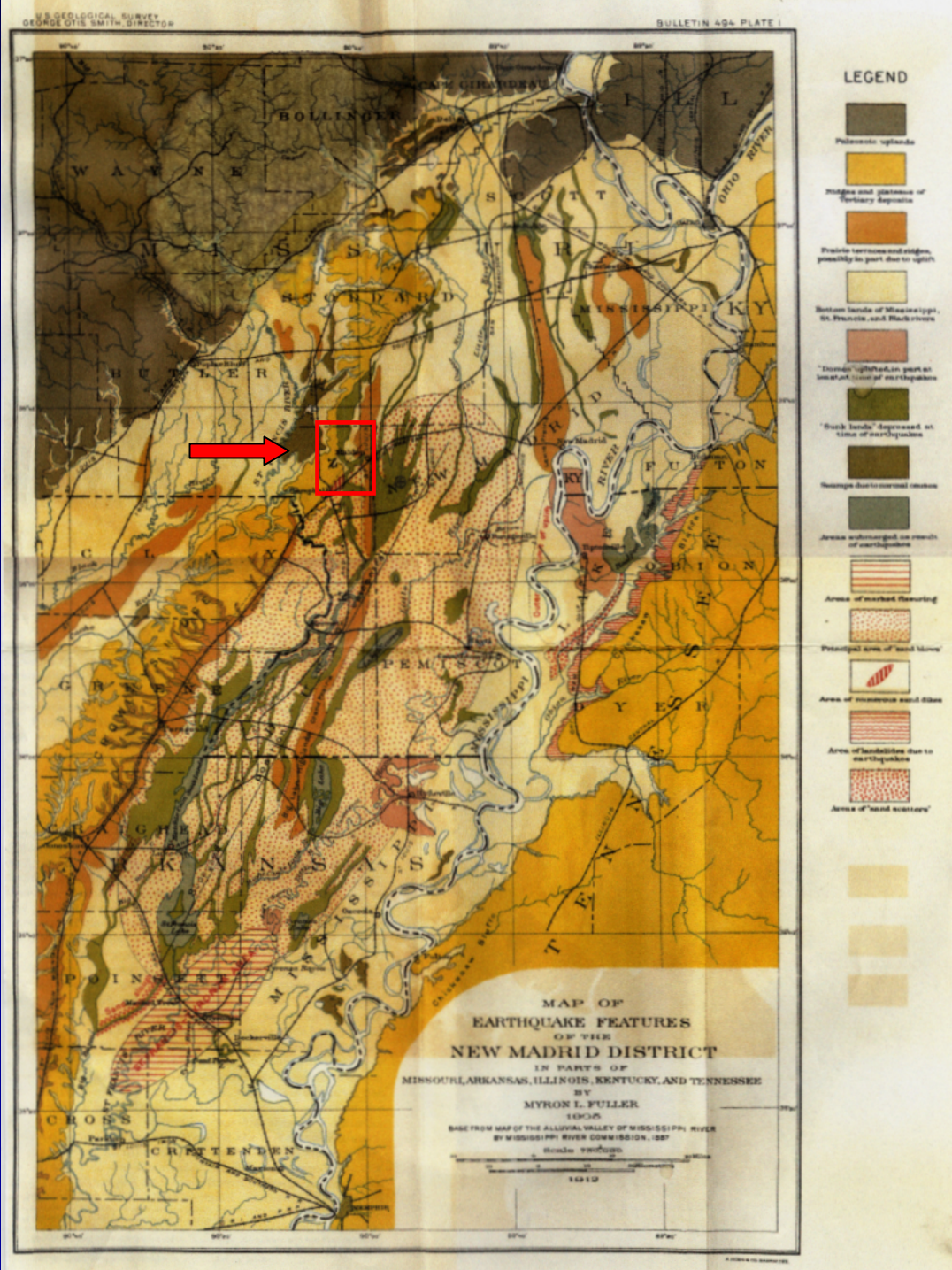
Liquefaction of Discrete Horizons Causes Lateral Spreads



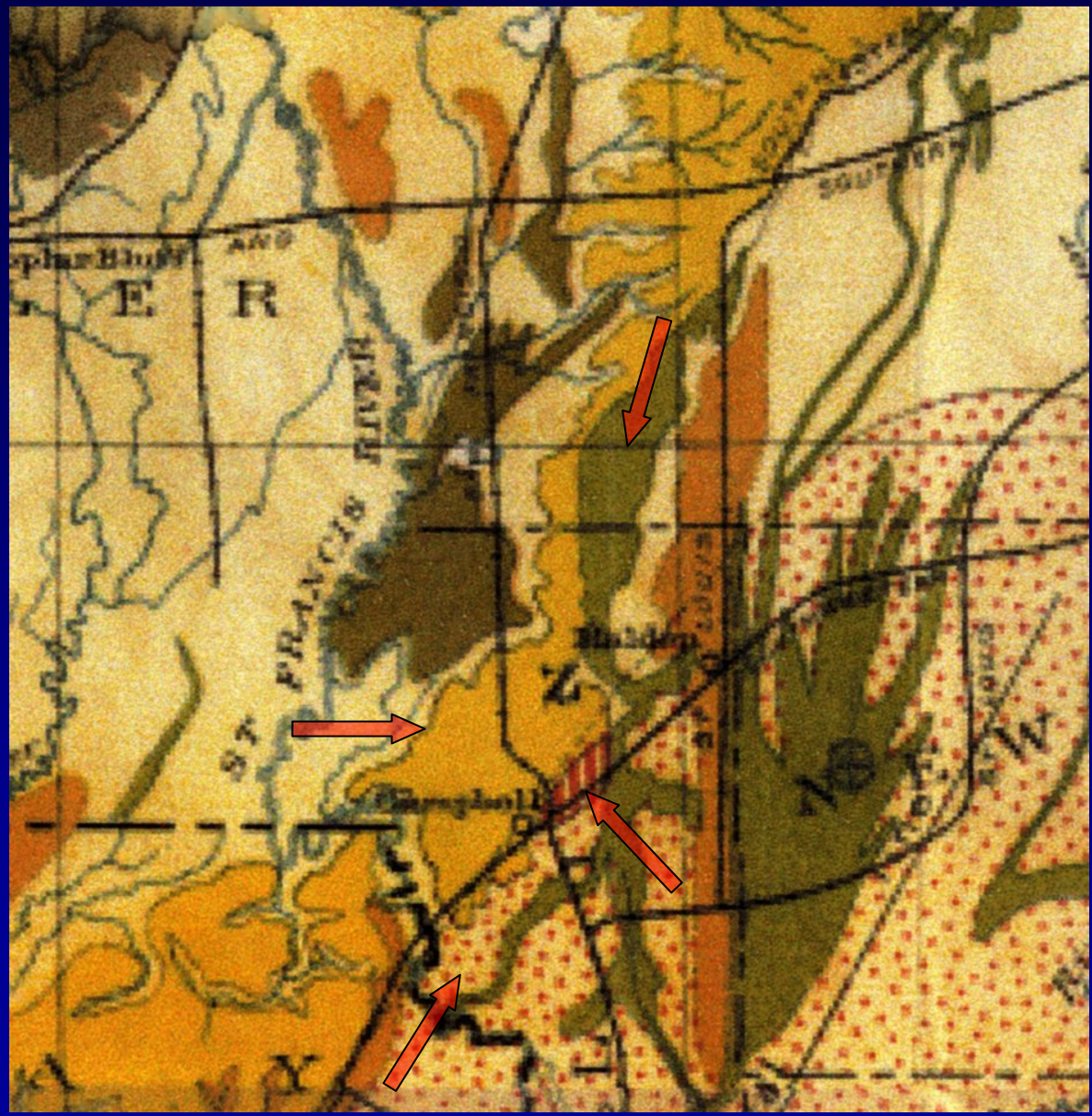
- In 1912 Myron Fuller wrote: “The depth of the openings was not usually very great, probably being in most cases limited to the hard clayey zone extending from the surface down to the **quicksand which usually underlies the surface soil at depths of from 10 to 20 feet**. Few openings probably extended much below the water level, which is apparently nowhere much over 25 feet from the surface.”

Geomorphic Features Associated with the 1811-1812 New Madrid Earthquakes

- Mapped by Myron Fuller in 1905
- Published by the USGS for the 100th anniversary in 1912

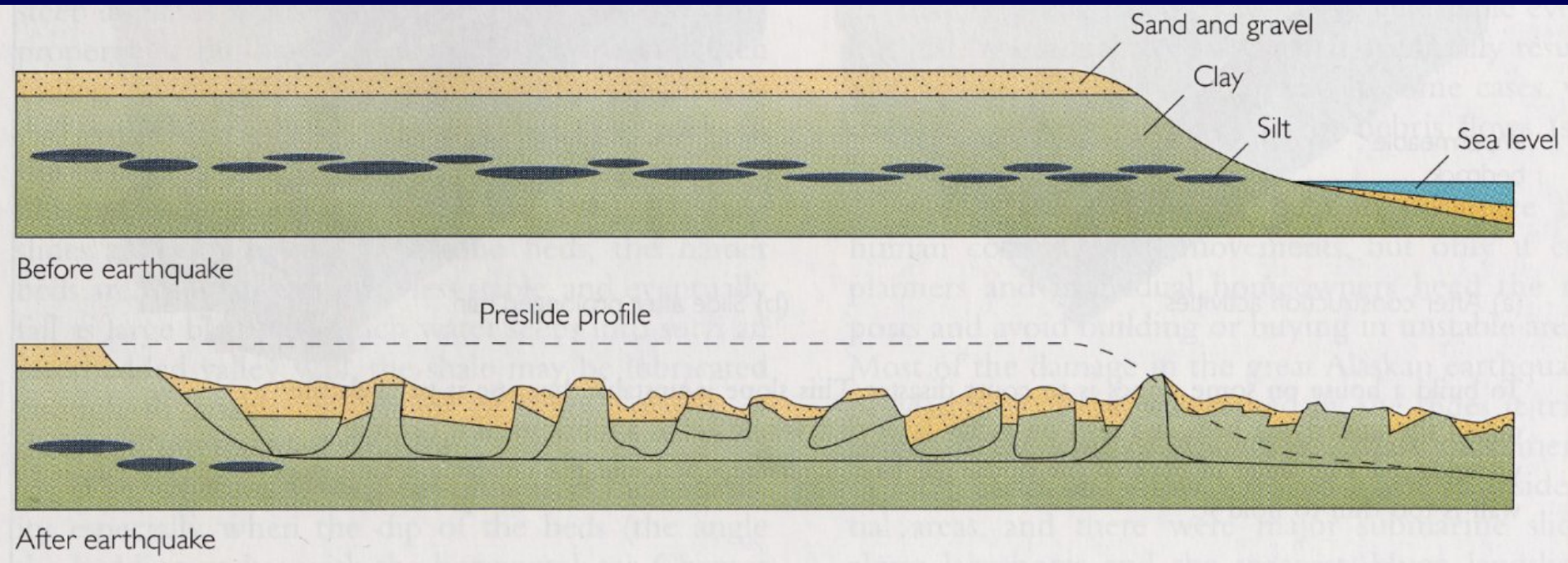


Geomorphic Features of 1811-12 Earthquakes around Valley Ridge quadrangle

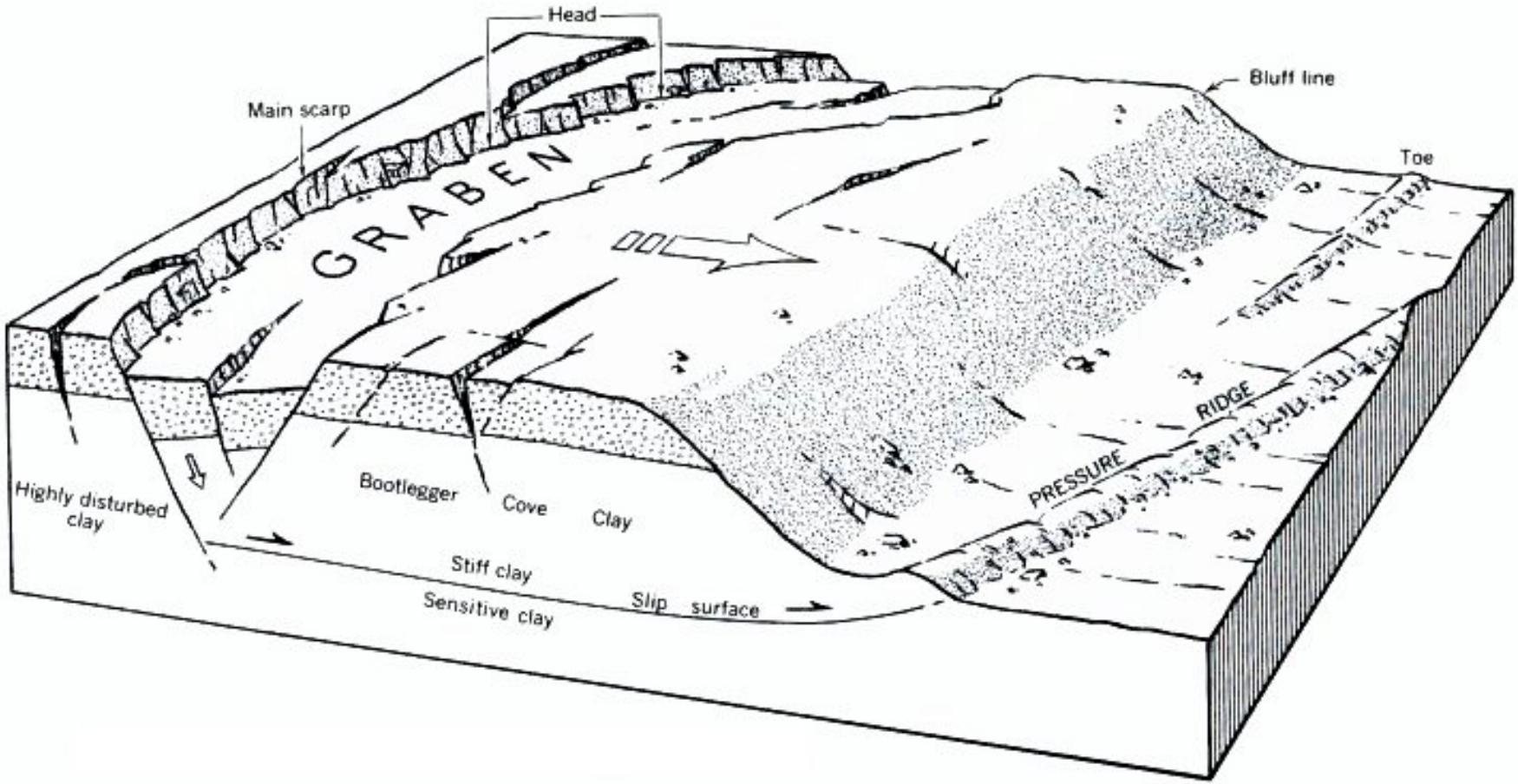


- Elevated terraces
  - Sand blows
  - “Sunk lands”
  - Areas of numerous sand dikes

Lateral Spreading Initially Analyzed after the 1964 Alaska Earthquake



- Stan Wilson and Harry Seed studied the Turnagain Heights Landslide in considerable detail and discovered that discontinuous seams of silt were responsible for the liquefaction that allowed large parcels of ground to be rafted

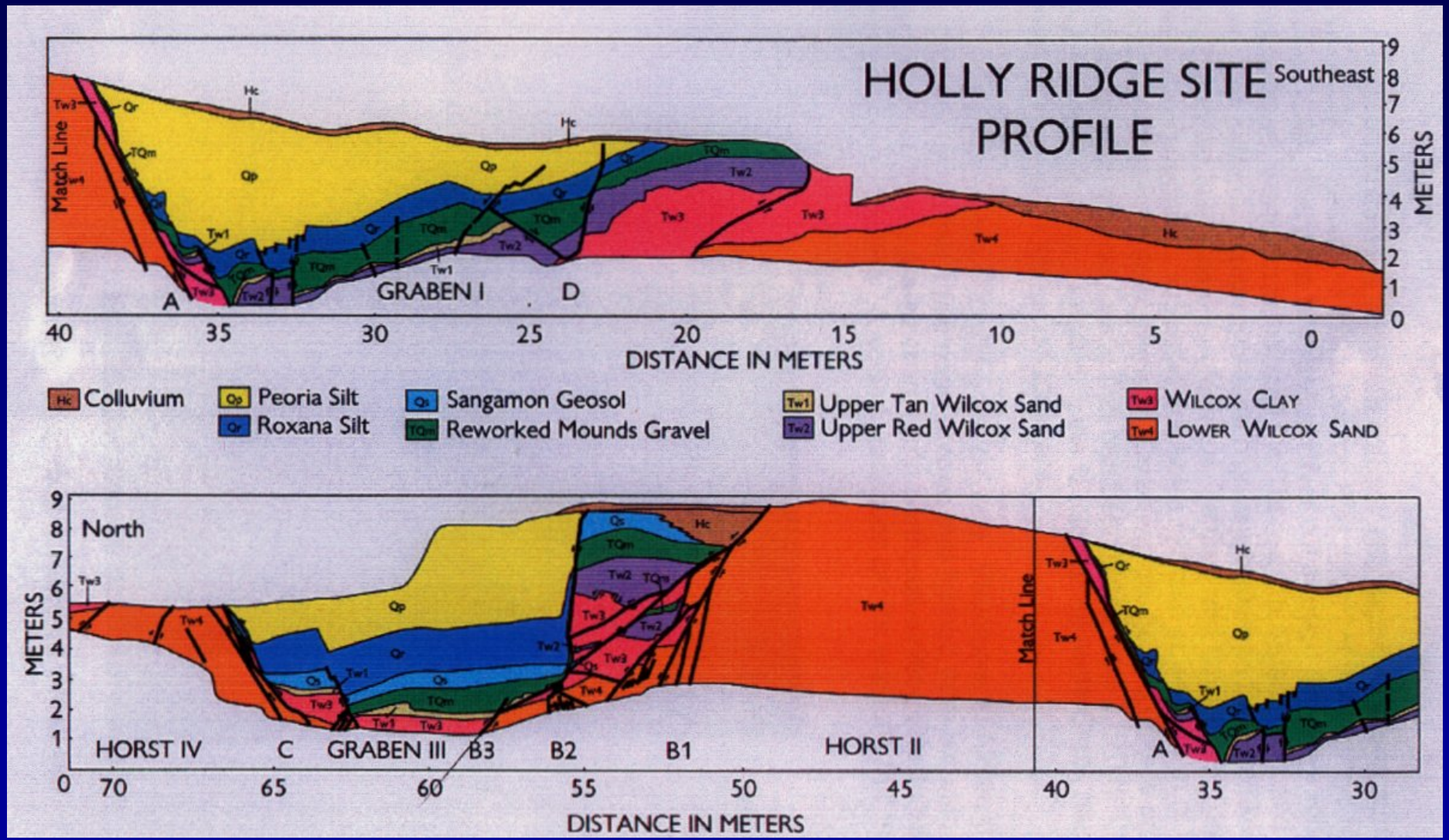


Block diagram of lateral spread which evolved from post-1964 earthquake evaluations in Alaska by Walt Hansen in USGS Professional Paper 542-A (1966)

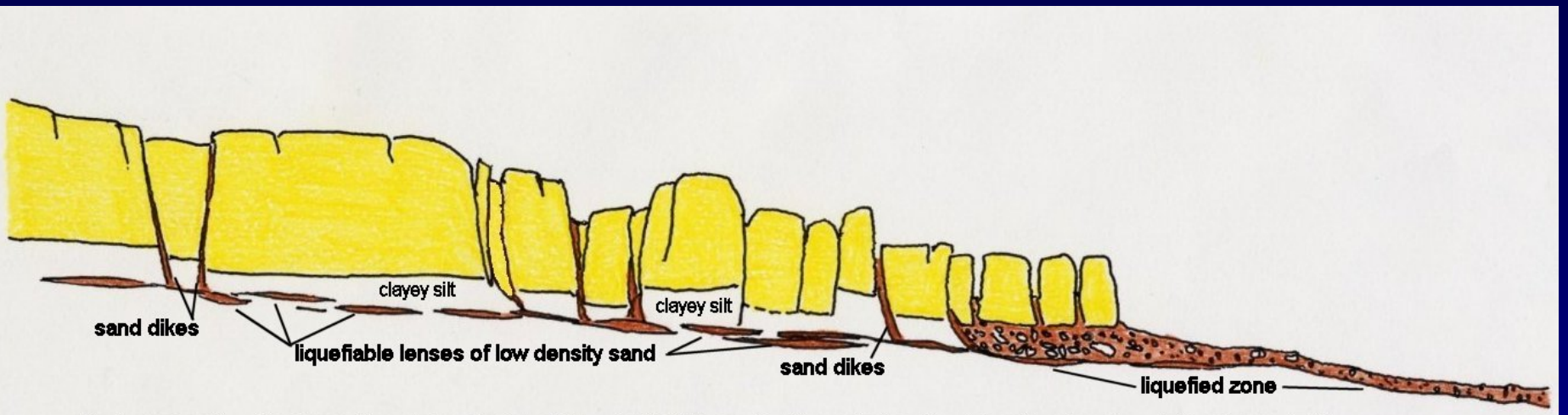
Potential for Lateral Spreads in the NMSZ

- Confined horizons of saturated sands, silty sand and non-cohesive silt, adjacent to channels or other natural depressions:
  - Margins of Crowley's Ridge where river channels come within 3/8 mile
  - Adjacent to sweeping turns of the major river channels
  - Levees and banks of drainage ditches

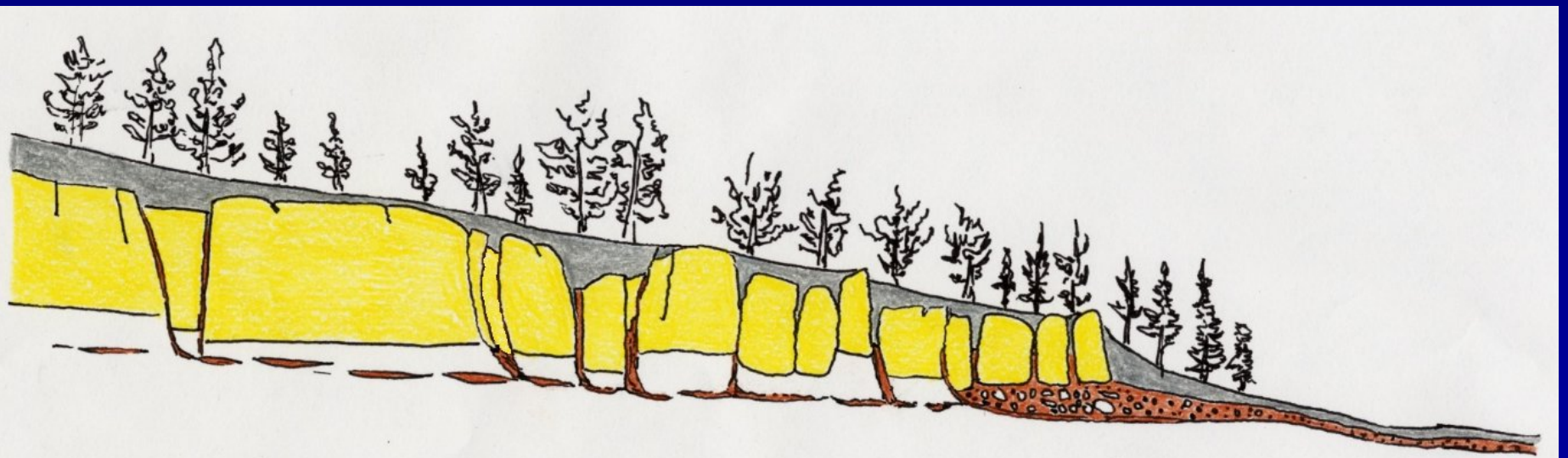
Faulting Recently Observed at Holly Ridge



Lateral Spreads Can Cause Horst and Graben Structures to Form in Their Headscarps

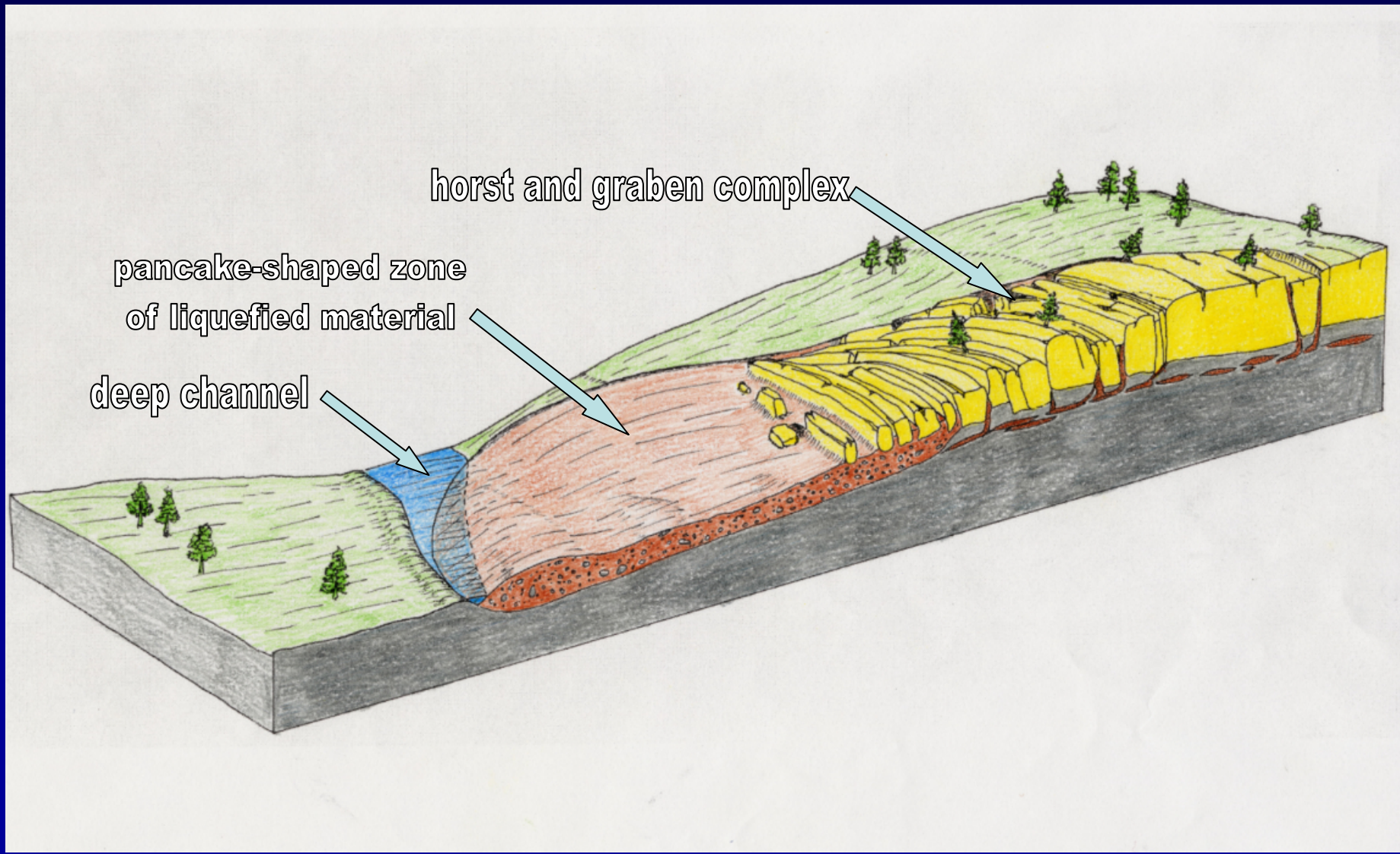


Retrogressive Graben Complex formed by partial liquefaction at shallow depth above a lateral spread



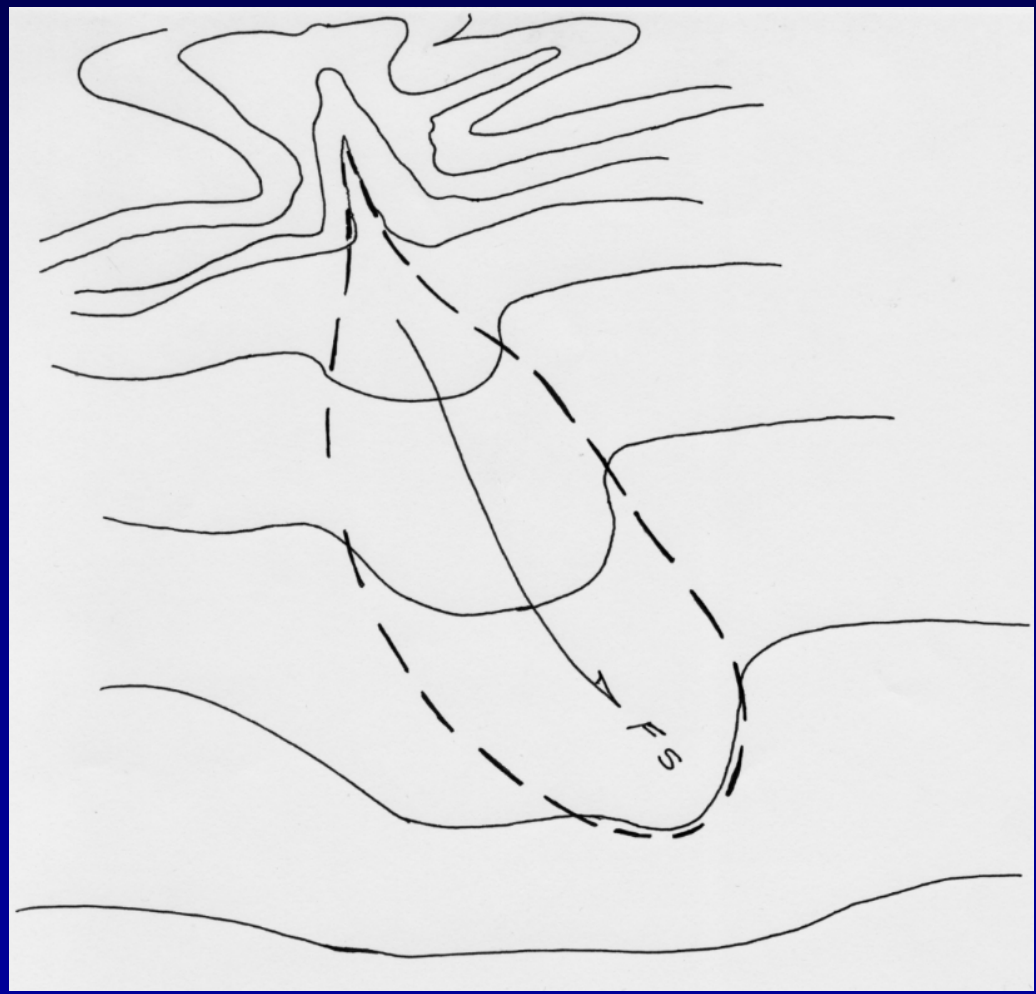
Same graben complex after deposition of Peoria Loess and establishment of vegetation

Classic Features of a Lateral Spread



Topographic Algorithms to Identify Anomalous Geomorphic Features

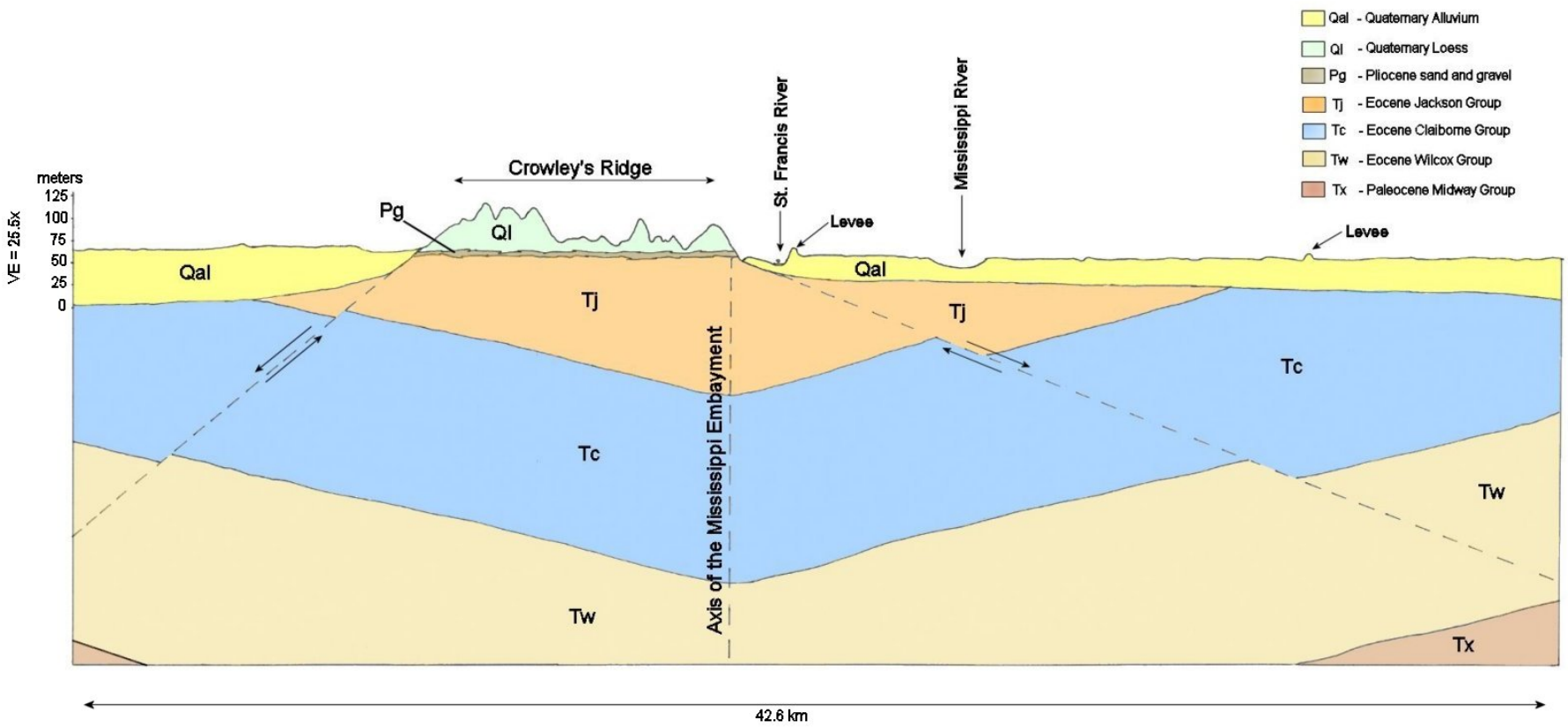
- Drainage patterns and topographic keys useful in identifying anomalous site characteristics typical of landslides
  - Divergent contours
  - Fan-to-drainage area ratios
  - Stepped fan surfaces
  - Theater-shaped headscarps



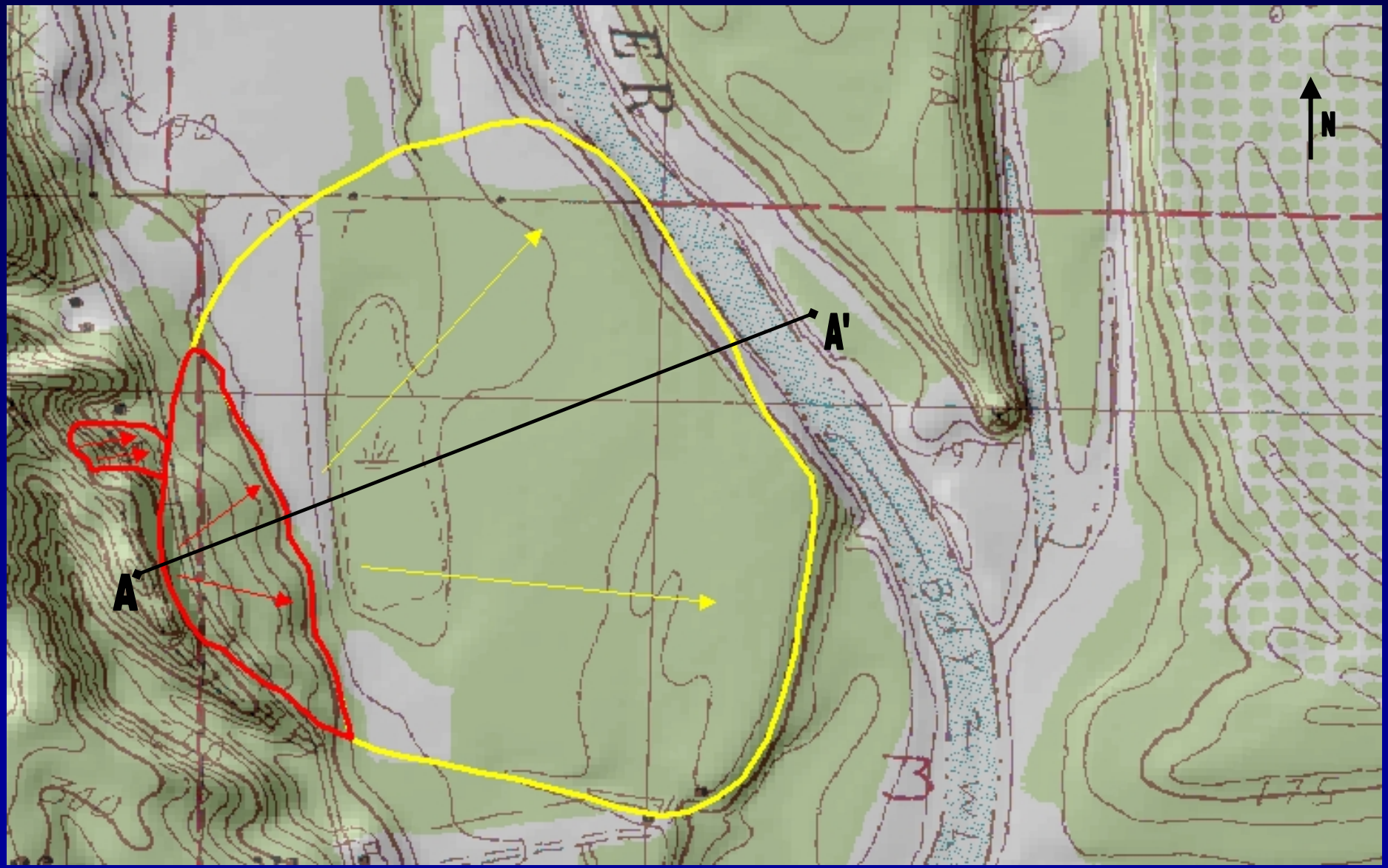
Topographic Algorithms

- Tool of tomorrow for rapid screening of large land areas
- Accuracy depends on quality and scale of topographic maps
- Will likely supplant stereopair aerial photographic methods for reconnaissance mapping of potential landslide hazards
- Following initial identification, detailed field mapping and analyses are used to determine if past landslippage actually occurred and whether or not it was seismically-induced

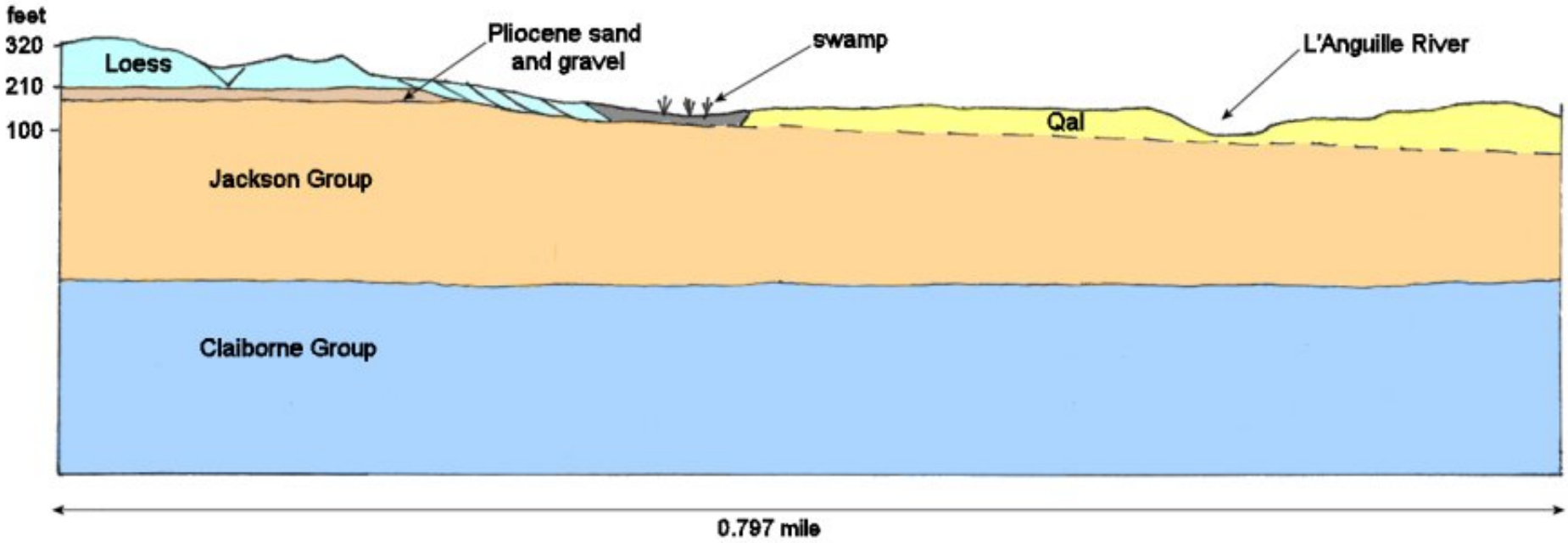
GEOLOGY OF SOUTHERN CROWLEY'S RIDGE

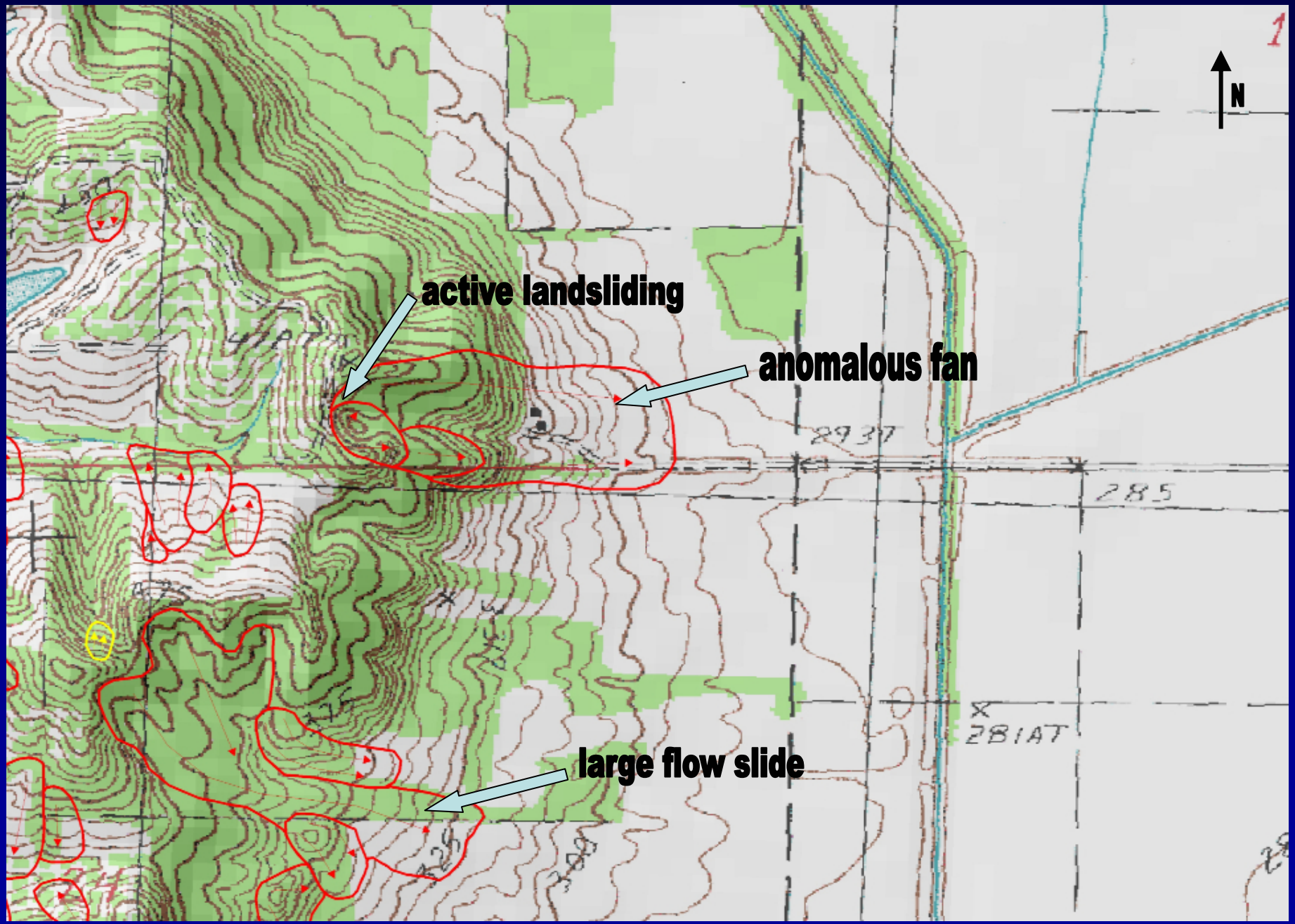


Lateral Spread Mapped Along Crowley's Ridge on LaGrange, Arkansas Quadrangle

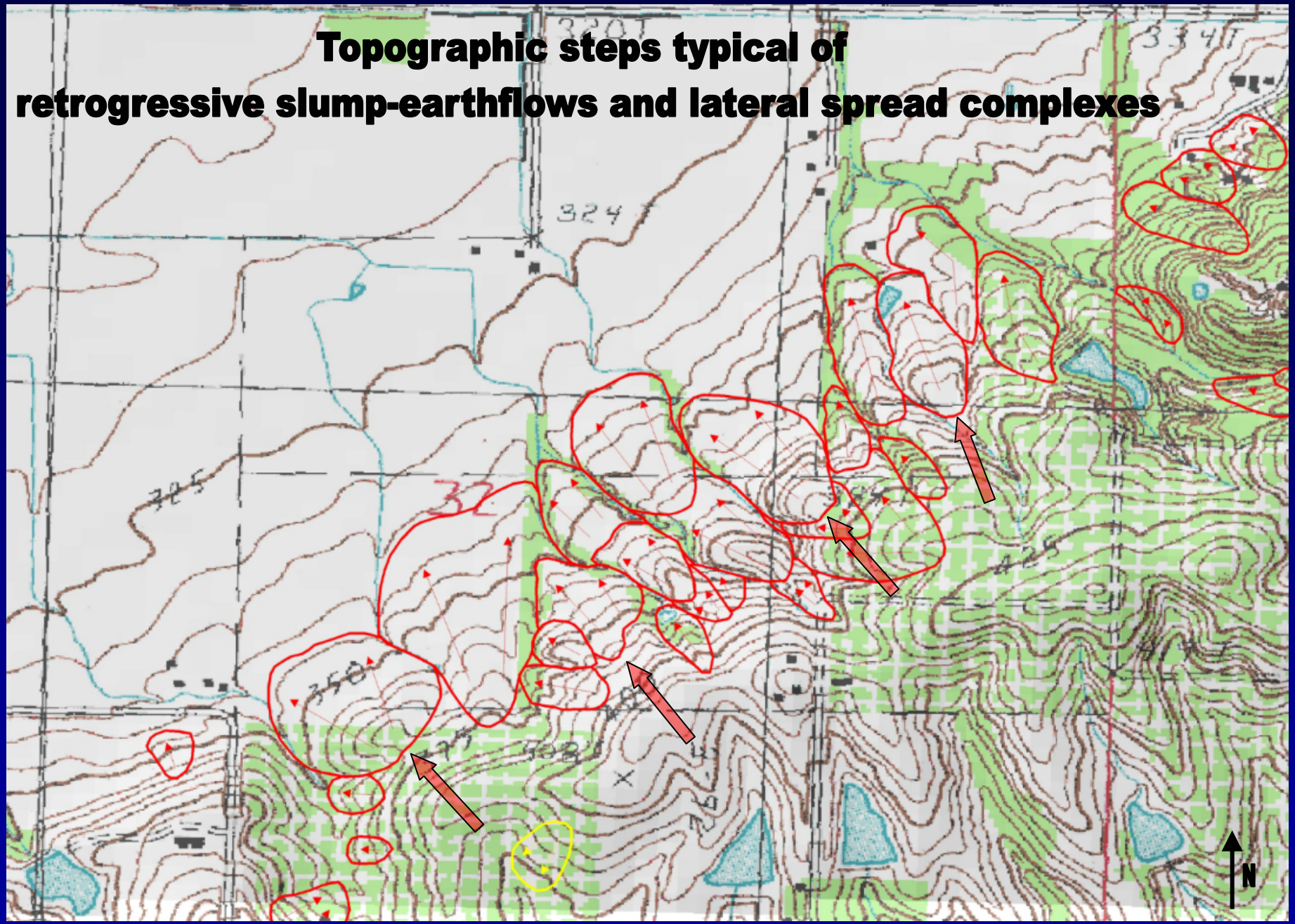


Cross Section Through Lateral Spread Feature Mapped on LaGrange, Arkansas Quadrangle




active landsliding
anomalous fan
large flow slide
N
2937
285
281AT

Topographic steps typical of retrogressive slump-earthflows and lateral spread complexes



Field Identification of Lateral Spreads

- Saturated cohesionless soils capped by low permeability materials
- Proximity to adjacent channels or depressions
- Prominent evacuation grabens because of block movement. These grabens can be infilled
- Stepped topography typical of repeated events causing lurching of selected zones
- Sand dikes filled with liquefied material are most common distinguishing feature, but
- Not all sand dikes are caused by earthquakes

Field Methods to Confirm Lateral Spreads

- Ground Inspection under tree and brush canopy
- Drainage pattern analysis
- Backhoe trenches
- Geophysical techniques very useful
  - Ground Penetrating Radar (GPR)
  - Electrical Resistivity (ER)
  - Induced Polarization (IP)

CONCLUSIONS

1. A great number of seismically-induced landslides and lateral spreads appear to exist within the escarpment formed by Crowley's Ridge within the New Madrid Seismic Zone.
2. These have not previously been recognized west of the Mississippi River
3. Future evaluations of seismic hazards in the NMSZ should include these modes of ground deformation, which may cause extensive damage to transportation, utility and drainage infrastructure

Special Thanks to:

- USGS National Earthquake Hazard Reduction Program (NEHRP)
- University of Missouri Research Board
- Missouri Geological Survey and Resource Assessment Division
- Arkansas Geological Commission
- USGS Mid-Continent Mapping Center
- Kevin James, UMR GE Department