Handout 4.1– Classroom Reading Exercise:

The instructor should distribute the following handout to the students as it outlines how seismic hazards are determined in certain regions where few earthquakes have occurred, little is known about the actual potential for damaging earthquake (intraplate regions, etc.) sources, and where the historical record does not provide an accurate picture of the seismicity. This information is scientific in nature, and the instructor and students may not be familiar with this work. However, the main purpose is to provide "color" and pique interest. Depending upon the comfort level of the instructor with this material (i.e., based on Internet research, etc.), an excellent discussion on the subject of paleoseismology, which as been used in many areas to provide earthquake data extending far back into prehistoric times, could occur. However, a class discussion is not necessarily required as this material is covered on the accompanying homework assignment.

In case the instructor chooses to present the material as electronic visuals (as opposed to a black and white handout copy), cues for electronic visuals are provided for the accompanying file: Session 4 – Electronic Visuals.ppt. Alternatively, the instructor may wish to post the file below electronically on the Internet for the students to download.

Handout 4.1 - Examples of Paleoseismic Analysis:

- Examining exposed faults and determining the ages of movements from weathering rates (UT, ID).

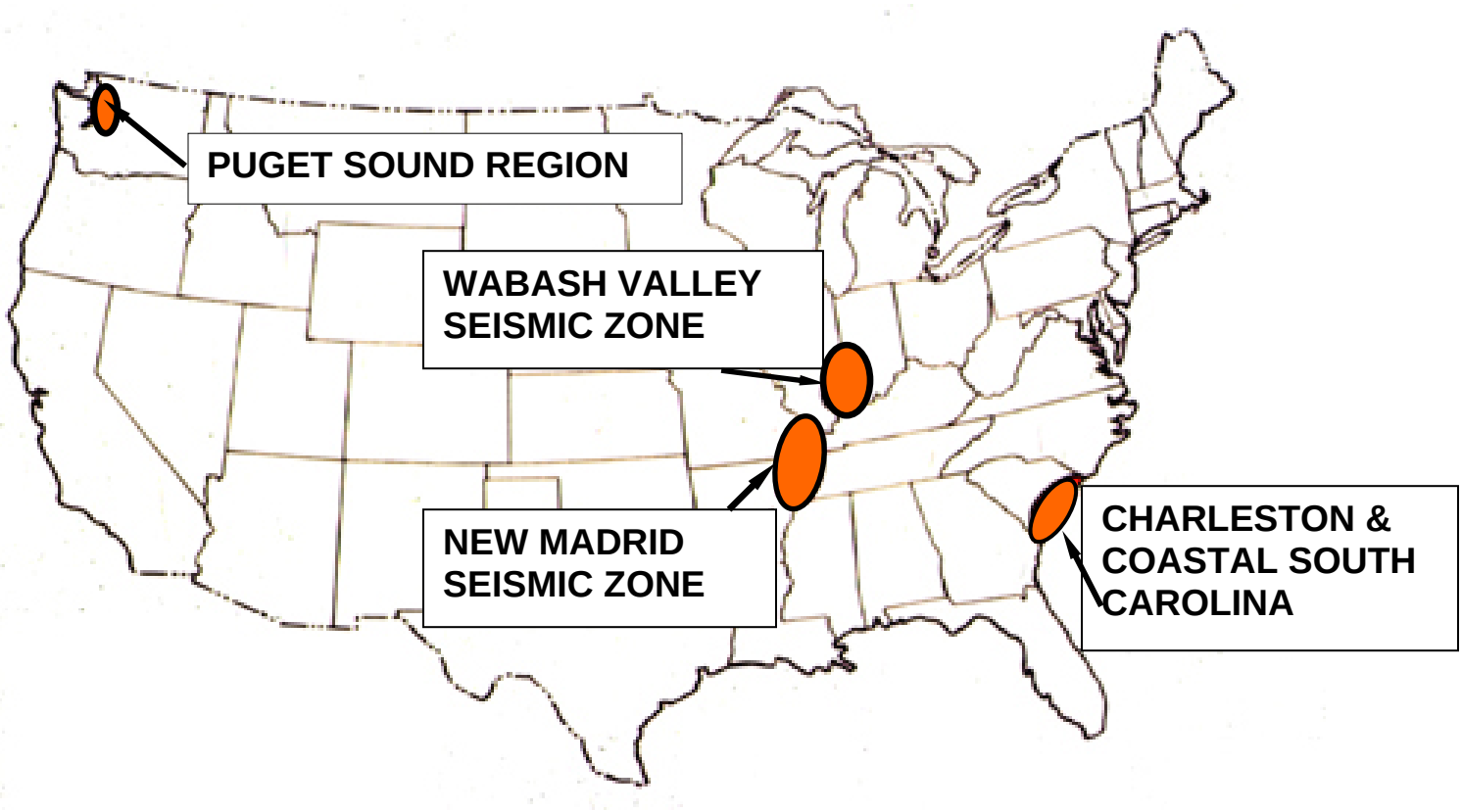
- Dating old earthquake-induced landslides (MO, WA).

- Dating earthquake-induced land subsidence (coastal area of OR, WA).

- Studying liquefaction evidence such as ancient sand boils produced by earthquakes (SC, central U.S.) – this technique is termed paleoliquefaction analysis.

Locations where paleoliquefaction studies have been recently performed in the U.S. are shown in Visual 4.8:

[*Electronic Visual 4.8*]



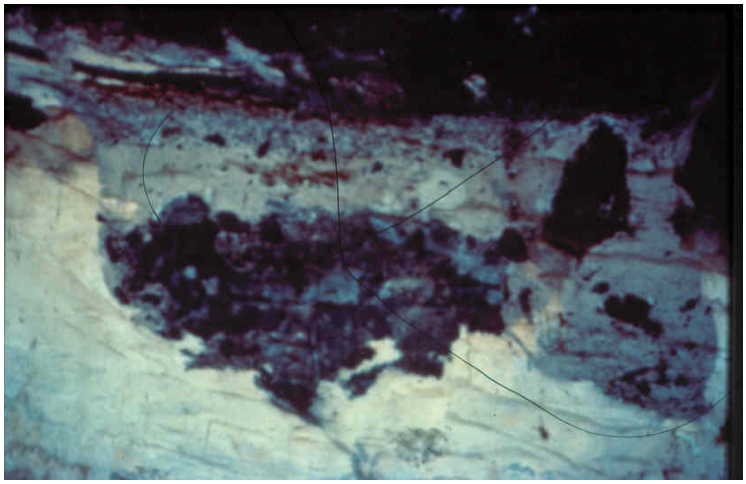
Visual 4.8 Locations where paleoliquefaction studies have been recently performed in the U.S..

- Recent paleoliquefaction studies in the central U.S. and southeast indicate recurring large prehistoric earthquakes – this has increased the seismic hazard and the changes are reflected in revised USGS maps (from the early 1990s) that reflect higher earthquake motions.

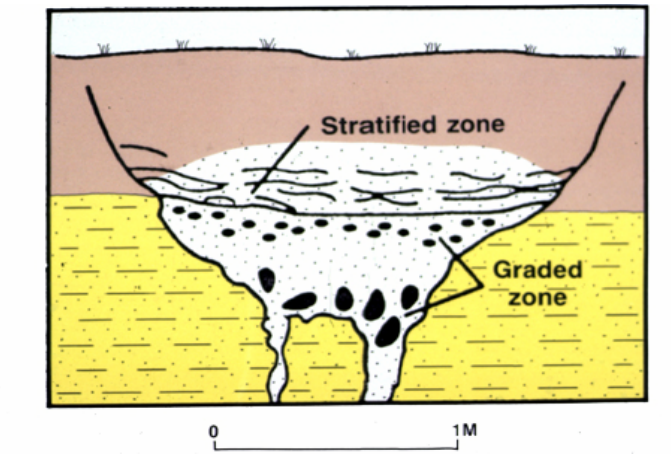
- Paleoliquefaction studies in the Pacific Northwest have been less comprehensive than those in other regions.

An example of paleoliquefaction project in coastal SC is shown in Visual 4.9 and 4.10.
[*Electronic Visuals 4.9 and 4.10*]

Visual 4.9: Photo of liquefaction feature produced the 1886 Charleston, SC earthquake. Such features occur in abundance in sandy areas where the water table is high and a strong earthquake (> M5.5) occurs. Credit: USGS



Visual 4.10: Photo of "fossilized" liquefaction feature found in a SC ditch. The features such as those in the previous photo are preserved in the soil profile for thousands of years. When these features are found in excavations, they indicate the occurrence of a large earthquake in the past. The dark material typically contains organic matter such as leaves and twigs that can be carbon dated. Photo credit: S. Obermeier, USGS.



Visual 4.11: Schematic illustrating a typical ancient liquefaction feature. The dark material represents organic-rich soil that can usually be dated to determine when the feature was formed. Credit: S. Obermeier, USGS.

- A recent paleoliquefaction study in the Charleston, SC area surprisingly found many liquefaction features that were much older than the 1886 event. This indicated that a series of large earthquakes occurred in the region, as shown in the table below. These findings significantly upgraded the seismic hazard estimate for the Charleston, SC region (Obermeier, 1998; Talwani and Schaeffer, 2001).

[*Electronic Visuals 4.11 and 4.12*]

Ages of Liquefaction Features Found in Charleston, SC Region*

600 ybp

1250 ybp

3250 ybp

5150 ybp

>5150 ybp

(* YBP = years before present)

*Obermeier, 1988; USGS

Visual 4.12: Table showing the ages of liquefaction features found in Charleston, SC. Tens to hundreds of features were found across a widespread area for each of the generations shown, indicating large, recurring earthquakes. Data credit: S. Obermeier, USGS.

- Similar studies and findings have been performed in the Central U.S. and Pacific Northwest.

References Utilized:

Martin, J.R., and G.W. Clough, 1994. "Seismic Parameters from Liquefaction Evidence," *Journal of Geotechnical Engineering, ASCE*, August, 1994, pp. 1345-1361.

Martin, J.R., and E.C. Pond 1993, "Seismic Analysis of Relict Liquefaction Features in Regions of Infrequent Seismicity," *Transportation Research Board Record No. 1411,* National Research Council, January, 1993, pp. 53-60.

Obermeier, S. F. 1998. "Seismic Liquefaction Features: Examples from Paleoseismic Investigations in the Continental United States," *Open-File Report,* 98-488, U.S. Geological Survey.

Obermeier, S. F., Weems, R. E., and R. B. Jacobson. 1987. "Earthquake-Induced Liquefaction Features in the Coastal South Carolina Region," *Open File Report, 87-504*, U.S. Geological Survey.

Obermeier, S.F., Munson, P.J., Munson, C.A., Martin, J.R., Youd, T.L., and N.K. Bluer. 1992. "Liquefaction Evidence for a Strong Holocene Earthquake in the Wabash Valley of Indiana-Illinois," *Seismological Research Letters, Journal of the Eastern Section of the Seismological Society of America*, Vol. 63, No. 3, July-September, 1992, pp. 321-335.

Pond, E. and J. R. Martin. 1997. "Estimated Magnitudes and Ground Motions Characteristics Associated with Prehistoric Earthquakes in the Wabash Valley Region of the Central United States," *Journal of Seismological Research Letters, Seismological Society of America (Eastern and Central U.S.),* Vol. 68, No. 4, pp. 611-623.

Talwani, P., and W. Schaeffer, 2001. "Recurrence Rates of Large Earthquakes in the South Carolina Coastal Plain Based on Paleoliquefaction Data." *Journal of Geophysical Research (JGR)*, 106, pp. 621-642.

US Geological Survey (USGS), data and various figures from website at:
http://quake.wr.usgs.gov/prepare/factsheets/RiskMaps/