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Charleston liquefaction features (Class A) No. 2657

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Synopsis	The evidence for Quaternary faulting at this locale in central coastal South Carolina consists of (1) eyewitness reports of widespread liquefaction during an earthquake in 1886 of moment magnitude M 7.3 and intensity MMI X (Bollinger, 1977 #1966; Johnston, 1996 #1842), (2) middle to late Holocene craters, sand blows, and sand fissures produced by large, prehistoric earthquakes, and (3) the recognition that the liquefaction and paleoliquefaction features are attributable to strong shaking caused by seismic faulting (Obermeier and others, 1987 #2050; Obermeier, 1996 #2256). These liquefaction features are evidence of strong shaking, but they do not identify the specific fault or faults that caused an earthquake or earthquakes. Because individual Quaternary faults remain unidentified, it is not possible to define and measure specific attributes (azimuth, length, dip, etc.) for the Charleston liquefaction features.

Name comments	
County(s) and State(s)	CHARLESTON COUNTY, SOUTH CAROLINA DORCHESTER COUNTY, SOUTH CAROLINA BERKELEY COUNTY, SOUTH CAROLINA
Physiographic province(s)	COASTAL PLAIN
Reliability of location	Poor Compiled at 1:2,000,000 scale. *Comments:* The liquefaction was recognized as being caused by strong ground motion (Obermeier, 1996 #2256), and the strong motions are presumed to be caused by slip on one or more preexisting faults. However, the causative fault or faults have not been identified, and the locations and sizes of the liquefaction features provide poor constraints on the exact location, dimension, and orientation of the source or sources of the shaking.
Geologic setting	The land surface is flat and near sea level, and the water table is near or at the surface (Obermeier, 1996 #2256). Five to 25 m of Quaternary beach, marine, and fluvial deposits overlie 500-1100 m of Tertiary and Cretaceous Coastal Plain strata, which in turn overlie Triassic and Jurassic basalt and rift basins and Paleozoic metamorphic and igneous rocks (Ackermann, 1983 #1961; Daniels and others, 1983 #1962; McCartan and others, 1990 #1969). The Charleston area is part of a seismically active region that spans most of South Carolina (Bollinger, 1973 #1798; Bollinger and others, 1991 #2005). Seismicity in the region surrounding the 1886 earthquake has been higher than typical for the southeastern U.S. as a whole since 1886, but was markedly lower during the preceding half century than it has been since 1886 (Bollinger and Visvanathan, 1977 #1967; Armbruster and Seeber, 1984 #1790). McCartan and others (1990 #1969) reported that no faults are known to offset Quaternary deposits. However, study of paleoliquefaction features has yielded a chronology of large, prehistoric earthquakes that spans at least the latter half of the Holocene (Amick and Gelinas, 1991 #1787; Talwani, 1994 #1977; Talwani, 1996 #2234; Obermeier, 1996 #2256, and

	preceding reports summarized by these authors). Amick and Gelinas (1991 #1787) and D. Amick (oral commun., 1998) noted that ground-water level in the area was lower before 3 ka than at present, and still lower before 5 ka. Low water tables can suppress liquefaction (Obermeier, 1996 #2256). Thus, earthquakes older than 3-5 ka. and large enough to cause liquefaction may be underrepresented in the South Carolina earthquake chronology, and their magnitudes may be underestimated. Despite considerable geological, seismological, and other geophysical work conducted during more than two decades, the fault or faults that produced the 1886 earthquake remain unknown (for example Rankin, 1977 #1970; Gohn, 1983 #1964; Dewey, 1985 #2030; Talwani, 1990 #2013). Geomorphic and geodetic anomalies in and near the meizoseismal area of the 1886 earthquake have not yet been clearly linked to seismogenic faulting, partly because many kinds of neotectonic evidence cannot demonstrate that prehistoric deformation of the ground surface occurred suddenly (Rhea, 1989 #1886; Talwani, 1990 #2013; Marple and Talwani, 1993 #1857; Talwani and others, 1997 #2058; Talwani and Marple, 1997 #2236).
Length (km)	km.
Average strike	
Sense of movement	No data *Comments:* The 1886 earthquake is known only from reports of damage, shaking, lateral spreading, and liquefaction. The prehistoric earthquakes are known only from the locations and geological dating of the liquefaction. No surface ruptures or other types of tectonic deformation are known from any of the earthquakes. Single-earthquake focal mechanisms and hypocenter locations that were calculated with corrected polarities and a three-dimensional velocity structure (Shedlock, 1987 #1982) have not yielded constraints on the sense of movement for the 1886 earthquake.
Dip	No data *Comments:* The causative fault or faults remain unidentified and uncharacterized.

Paleoseismology studies	Obermeier and others (1985 #1871) and Talwani and Cox (1985 #1902) first reported pre-1886 liquefaction features of the type produced by prehistoric earthquakes. Obermeier and others (1987 #2050; 1989 #2218), Weems and Obermeier (1989 #2241), and Amick and others (1990 #1788) described criteria for recognizing and dating prehistoric liquefaction features throughout coastal South Carolina. Amick and Gelinas (1991 #1787), Rajendran and Talwani (1993 #1882), and Talwani (1994 #1977; 1996 #2234) reported results that contributed to an evolving chronology of large earthquakes. Interpretations of the number of large Charleston earthquakes are complicated by the fact that the main source at Charleston appears to be flanked on both sides by secondary sources of liquefaction, approximately 100 km to the northeast near Georgetown, South Carolina (structure #2659), and approximately 100 km to the southwest near Bluffton, South Carolina (structure #2658). Each secondary source is described separately in this compilation. Approximately synchronous liquefaction at two adjacent sources or at all three sources could be caused by a single large earthquake at one of the sources, or by smaller, coeval earthquakes at each source. Additional complications arise because a prehistoric liquefaction-inducing earthquake can be assigned to one source or another depending on the number and size of liquefaction features of appropriate ages that have been found near each source. However, continuing fieldwork has led to the recognition of additional paleoliquefaction features and to revisions in the estimated age of large earthquakes. Thus, for example, Amick and Gelinas (1991 #1787) reported evidence of a liquefaction-inducing earthquake near the Charleston source 580?104 years ago. Rajendran and Talwani (1993 #1882) revised the estimated location of this earthquake to the Bluffton area and the estimated time to 500?180 years ago. The results of subsequent studies returned the most likely location to the Charleston area and revised the estimated age to 546?17 years ago (Talwani, 1996 #2234, and S.F. Obermeier, written commun., 1998). The following chronology of large, liquefaction-causing earthquakes follows Talwani (1996 #2234), who applied dendrochronological corrections to all previous age estimates (P. Talwani, oral communs., 1998). Eight large earthquakes have occurred in coastal South Carolina, the1886 event and prehistoric

	earthquakes at 0.55 ka, 1.00 ka, 1.64 ka, 1.96 ka (1754-2177 yr B.P.), 3.55 ka, 5.04 ka, and 5.80 ka. The first two and last three age estimates directly correspond to estimates reported by earlier workers. The earthquake at 1.00 ka corresponds to the events dated between 1.13 ka and 1.25 ka by Amick and Gelinas (1991 #1787), Obermeier (1996 #2256), Rajendran and Talwani (1993 #1882), and Talwani (1994 #1977). The earthquake at 1.64 ka corresponds to the events dated at 1.72 ka (Amick and Gelinas, 1991 #1787) and 1.80 ka (Talwani, 1994 #1977). Paleoliquefaction features attributed to the 1.64 ka earthquake have, thus far, only been reported from the Georgetown source area. The earthquake at 1.96 ka corresponds to the events dated at 2.35 ka (Rajendran and Talwani, 1993 #1882) and 2.20 ka (Talwani, 1994 #1977). Evidence for the 1.96 ka earthquake has, thus far, only been reported from the Bluffton source area. Amick and Gelinas (1991 #1787) and Obermeier (1996 #2256) argued that the prehistoric earthquakes were larger than M 5, were probably larger than M 5.5, and that some might have exceeded the magnitude of the 1886 shock based on the size of the prehistoric liquefaction features compared to those that formed in 1886 and elsewhere in the world, the geographic distribution of features of a particular age, the source sand compactness, the water-table depth, and other relevant factors. Amick and Gelinas (1991 #1787) and D. Amick (oral commun., 1998) noted that ground-water level was lower before 3 ka than at present, and still lower before 5 ka. Thus, large earthquakes older than 3-5 ka might be underrepresented in the South Carolina earthquake chronology, and their magnitudes might be underestimated.
Geomorphic expression	Some of the numerous sandblows that formed in 1886 may still be expressed as shallow craters as much as several meters wide. However, all craters of prehistoric sandblows are filled with sediment, so the prehistoric craters lack geomorphic expression and are recognized only in excavations (Obermeier, 1996 #2048).
Age of faulted surficial deposits	The liquefaction features formed in Quaternary deposits (McCartan and others, 1990 #1969). Most areas searched for liquefaction features are those underlain by deposits 80,000-250,000 years old because older deposits have low liquefaction susceptibility and because, in younger deposits, the water table is too high to permit searches of excavations (Obermeier, 1996 #2048).

Historic earthquake	
Most recent prehistoric deformation	latest Quaternary (<15 ka) *Comments:* The most recent prehistoric earthquake at the Charleston source that was large enough to cause liquefaction occurred at 0.55 ka (Amick and Gelinas, 1991 #1787; Obermeier, 1996 #2048; Talwani, 1996 #2234)
Recurrence interval	0.44 or 0.46 k.y. (< 3.2 ka) *Comments:* There are two proposed earthquake scenarios for the Charleston source. As noted above under "Paleoseismological studies", eight earthquakes that caused liquefaction occurred at approximately 0.11, 0.55, 1.00, 1.64, 1.96, 3.55, 5.04, and 5.80 ka (Talwani, 1996). Talwani and others (1999 #7588) provide an update to the following chronology. One scenario has all of the earthquakes occurring in the Charleston source area, and the second scenario has the 1.64 ka earthquake occurring at or near Georgetown and the 1.96 ka earthquake occurring at or near Bluffton (P. Talwani, oral communs., 1997, 1998). In addition, as noted above under "Geologic setting", the water table was lower than at present before 3 ka, and still lower prior to 5 ka (Amick and Gelinas, 1991 #1787, and D. Amick, oral commun., 1998). Lower water tables could result in an incomplete record of large prehistoric earthquakes in middle Holocene time. If all eight earthquakes occurred in the Charleston source area, then the resulting seven recurrence intervals would have a mean value of 0.81 k.y. If the 1.64 and 1.96 ka earthquakes occurred at or near Georgetown and Bluffton, respectively, then the resulting five intervals would have an average recurrence interval of 1.14 k.y. If the two earthquakes that occurred before 5 ka are excluded, when the water table was lowest, then the resulting recurrence estimates are 0.69 k.y. (5 intervals) if all earthquakes were in the Charleston source area, and 1.15 k.y. (3 intervals) if the 1.64 and 1.96 ka earthquakes occurred at or near Georgetown and Bluffton. If all three earthquakes that occurred before 3 ka are excluded, when the water table was lower than at present, then the resulting recurrence estimate is 0.46 k.y. (4 intervals) if all earthquakes were in the Charleston source area, and 0.44 k.y. (2 intervals) if the 1.64 and 1.96 ka earthquakes were at or near Georgetown and Bluffton. The last two estimates, 0.44 and 0.46 k.y., are preferred and use only earthquakes younger than 3 ka. The five earthquakes

	since 3 ka occurred 0.32-0.64 k.y. apart, whereas the three before 3 ka occurred 0.76-1.59 k.y. apart. Two possible explanations for this decrease in recurrence intervals are that (1) lower water tables before 3 ka produced an incomplete paleoseismological record of liquefaction, and (2) the record is complete and recurrence intervals decreased markedly between 3.55 and 1.96 ka. In either case, earthquakes since 3 ka probably best represent the current and continuing behavior of the Charleston source. Note that whether the earthquakes at 1.64 and 1.96 ka occurred at Charleston, or at Georgetown and Bluffton, has a negligible effect on the estimated recurrence interval for the Charleston source.
Slip-rate category	Insufficient data *Comments:* No causal fault, surface rupture, or dated fault offset is known. Talwani (1999 #2235) showed that a slip rate estimated from Global Positioning System data could produce an 1886-sized earthquake in approximately the recurrence interval given above ("Recurrence interval").
Date and Compiler(s)	1999 Russell L. Wheeler, U.S. Geological Survey, Emeritus
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