ELECTRONIC SUPPLEMENT

Repeated Large Magnitude Earthquakes in the Marianna Area of East-Central Arkansas during the Middle-Early Holocene and Possibly the Late Pleistocene

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This supplement presents data for six sites of earthquake-induced liquefaction — the Daytona Beach Southeast 2 (DBSW2), Daytona Beach Northwest 2 (DBNW2), Daytona Beach Northwest 3 (DBNW3), Daytona Beach Northwest 5 (DBNW5), Daytona Beach Northwest 7 (DBNW7), and Daytona Beach Northwest 8 (DBNW8) — including the following: (1) a map showing ages and sizes of sand blows at the study sites along the Daytona Beach lineament (DBL) and locations of two seismic reflection profiles with interpreted fault zones projected to the surface, (2) site investigation summaries including satellite images, geophysical profiles, and trench logs for the sites, (3) tabulated results of radiocarbon (^{14}C) and optically-stimulated luminescence (OSL) dating for samples collected at the sites, and (4) a list of cited references.

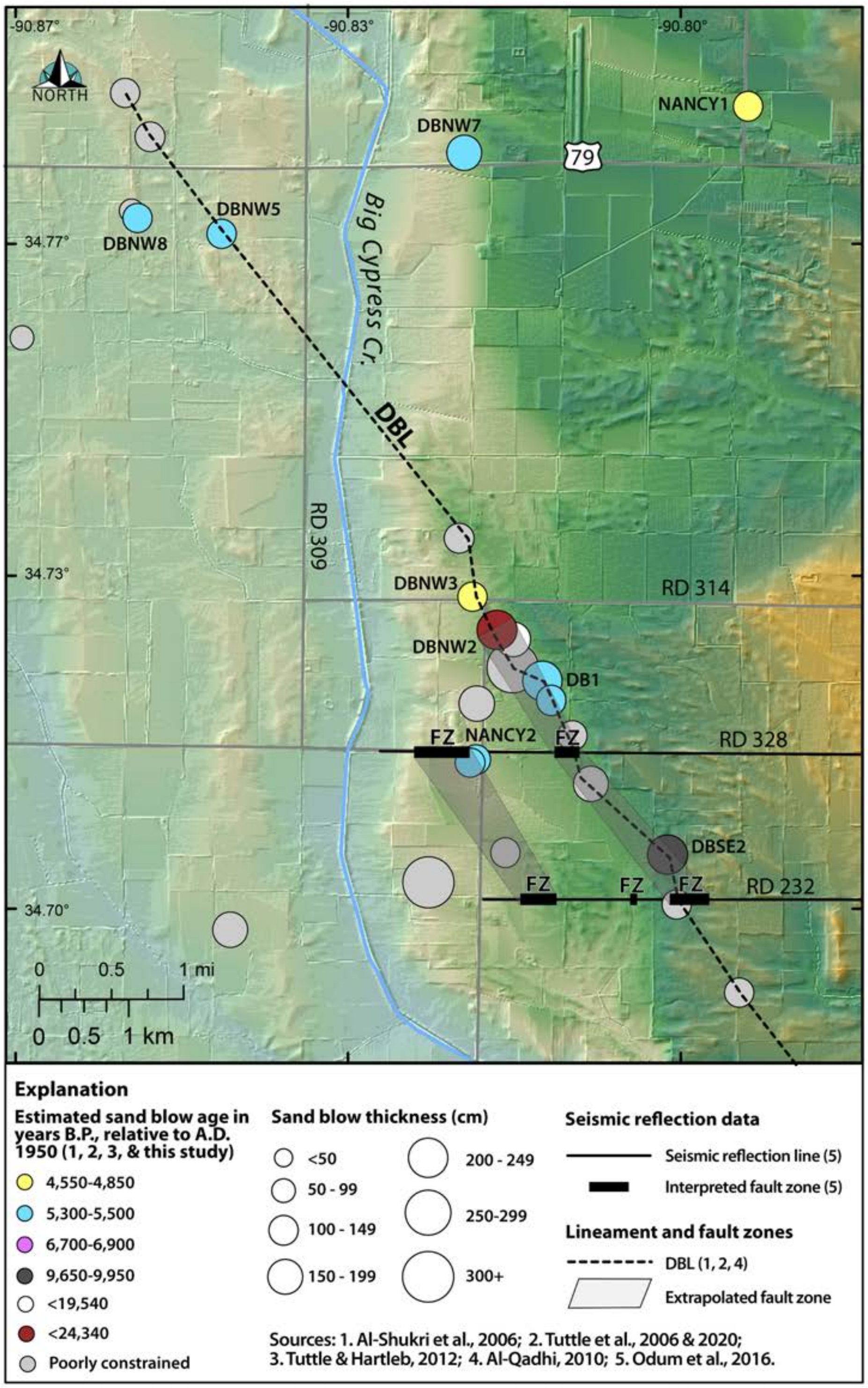

Figure S1. Map of portion of the Marianna study area (delineated on Figure 2 with black rectangle), showing study sites along the DBL with estimated ages and measured sizes of sand blows investigated during this and previous studies. Also shown are the seismic reflection lines and interpreted fault zones from Odum et al. (2016) projected to the surface and extrapolated between DBSE2 and DBNW2 where soft-sediment faults (SSFs) were observed. Sources of information are listed in the Explanation.

SITE INVESTIGATION SUMMARIES

Daytona Beach Southeast 2 Site (DBSE2)

GPS Location, Triple Crown trench: 34.7051° N, 90.8011°W

Observations from Google Earth (GE) satellite image and geophysical profiles (Figures S2–S3)

Width of Sand Blow: 60 m

Length of Sand Blow: 140 m

Observations from Triple Crown trench (Figures S4 and S5):

Width of Sand Blow: 56+ m

Thickness of Sand Blow: 2.2 m including plow zone

Width of Sand Dikes: 7–130 cm, possibly up to 5+ m

Weathering Characteristics: Weathering, including iron-staining and formation of redoximorphic features (aka mottles) and few Fe-Mn nodules, occurs throughout entire thickness of sand blow, but is especially pronounced in the upper 1 m; soil lamellae had formed along margins of dikes; also, fines had accumulated in the lower part of the sand blow above the buried soil and in several of the dikes.

Other Notable Features: A SSF occurs adjacent to the western margin of a sand dike and is subparallel to the Daytona Beach lineament (DBL). Soil lamellae appear to have been dragged along and offset across the fault (Figure S5). Apparent vertical offset of soil lamellae and mismatch of lamellae thickness across the fault suggest reverse and strike-slip components of displacement.

Constraining Ages (Figure S4; Tables S1 and S2):

^{14}C dating of sample C1 of charred material collected from the top of the soil buried by the large sand blow yielded an age of 9,680–9,910 yr B.P. This represents a close maximum constraining age for the sand blow, indicating that it formed about 9.8 ka. OSL dating of sample OSL1 collected from the buried soil near sample C1 and within 5 cm of the base of the sand blow yielded an age of 11,940 ± 1,000 yr B.P. The age for sample OSL1 is consistent with the younger age for C1 collected higher in the buried soil.

Age Estimate: 9.8 ka (range 9,680–9,910 yr B.P.)

Reference: Al-Shukri, H., Mahdi, H., Al-Qadhi, O., and Tuttle, M.P., 2009, Spatial and temporal characteristics of paleoseismic features in the southern terminus of the New Madrid seismic zone in eastern Arkansas, Final Technical Report, Prepared for U.S. Geological Survey award 1434-07HQGR0069, 24 p.

Figure S2. Esri World Imagery (2018) displayed in ArcGIS Pro, showing the light-colored sand blow at site DBSE2 (dashed black polygon), GPR profiles including profiles 39 and 114 (yellow lines), the resistivity profile (blue line), paleoseismic trenches (thick red lines), and the location of the main sand dikes (white lines) as observed in the southern paleoseismic trench.

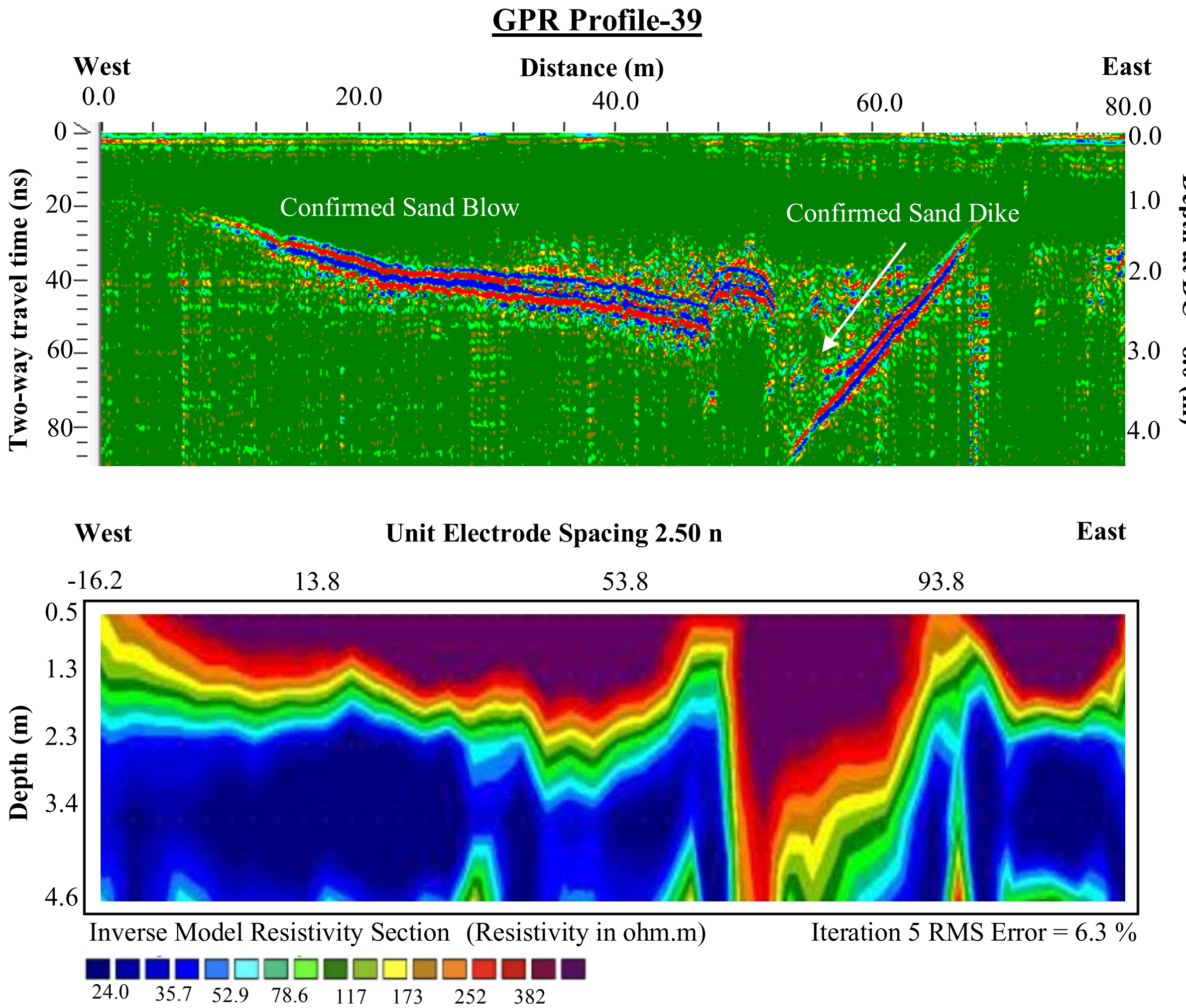

Figure S3. (Upper) Segment of southernmost GPR profile 39 collected at site DBSE2; (Lower) resistivity profile collected adjacent to the southern trench (Al-Qadhi, 2010). High resistivity values correspond to the sand blow and associated sand dikes. The prominent subvertical anomaly aligns with the large sand dike identified in the GPR profile and observed in the paleoseismic trench.

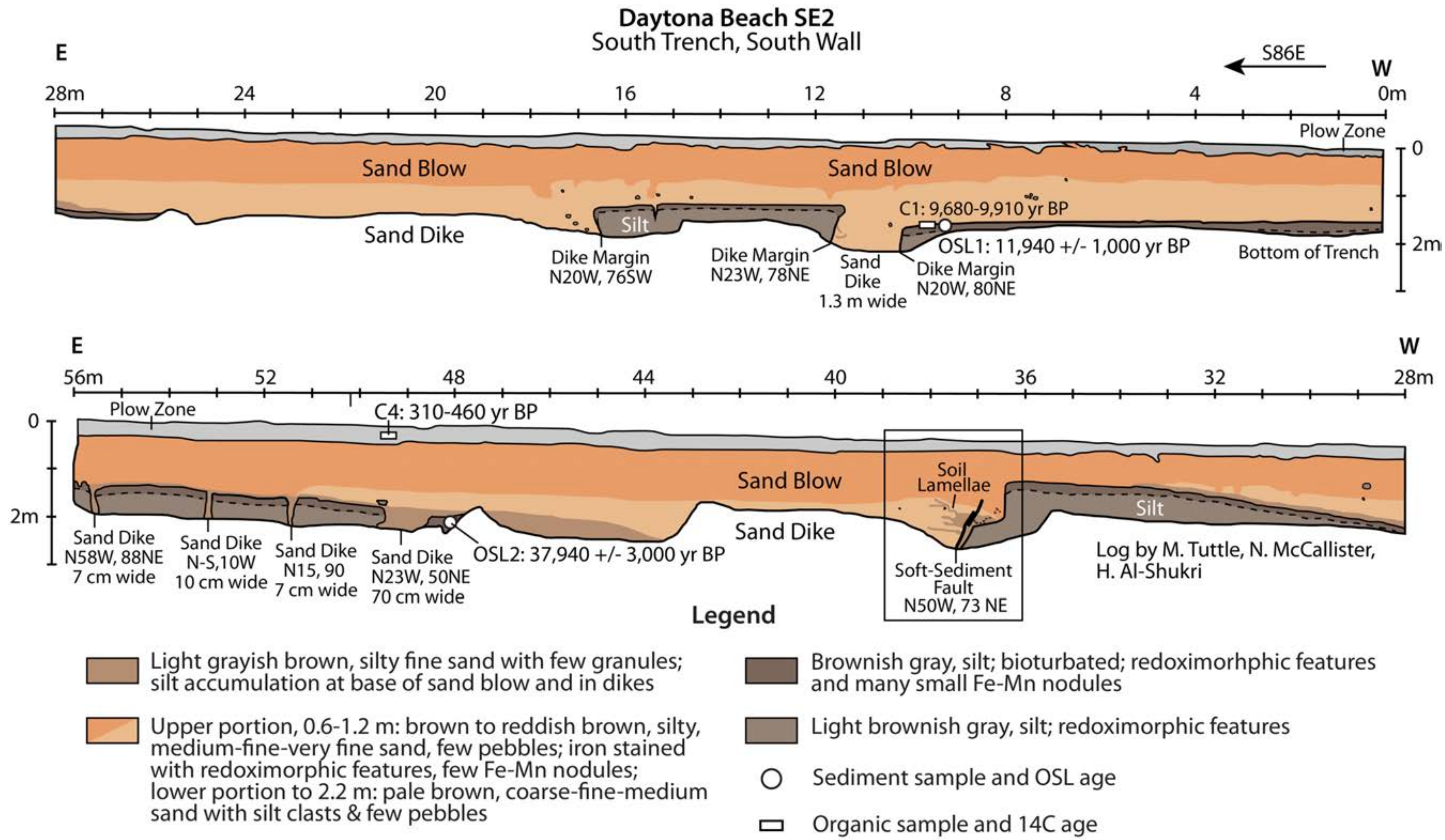

Figure S4. Log of the south wall of the Triple Crown trench excavated at site DBSE2 showing a cross-section of the sand blow, sand dikes, and buried soils, as well as the positions of samples collected for ^{14}C and OSL dating. Dating of the buried soil provides close maximum constraining ages for the sand blow and related dikes, indicating that they formed about 9.8 ka. Note that the upper 0.6–1.2 m of the sand blow is very weathered (indicated by reddish brown shading), that silt has accumulated along the bottom of the sand blow, and that soil lamellae have formed in the sand dikes. Location of the trench is shown on Figure S2.

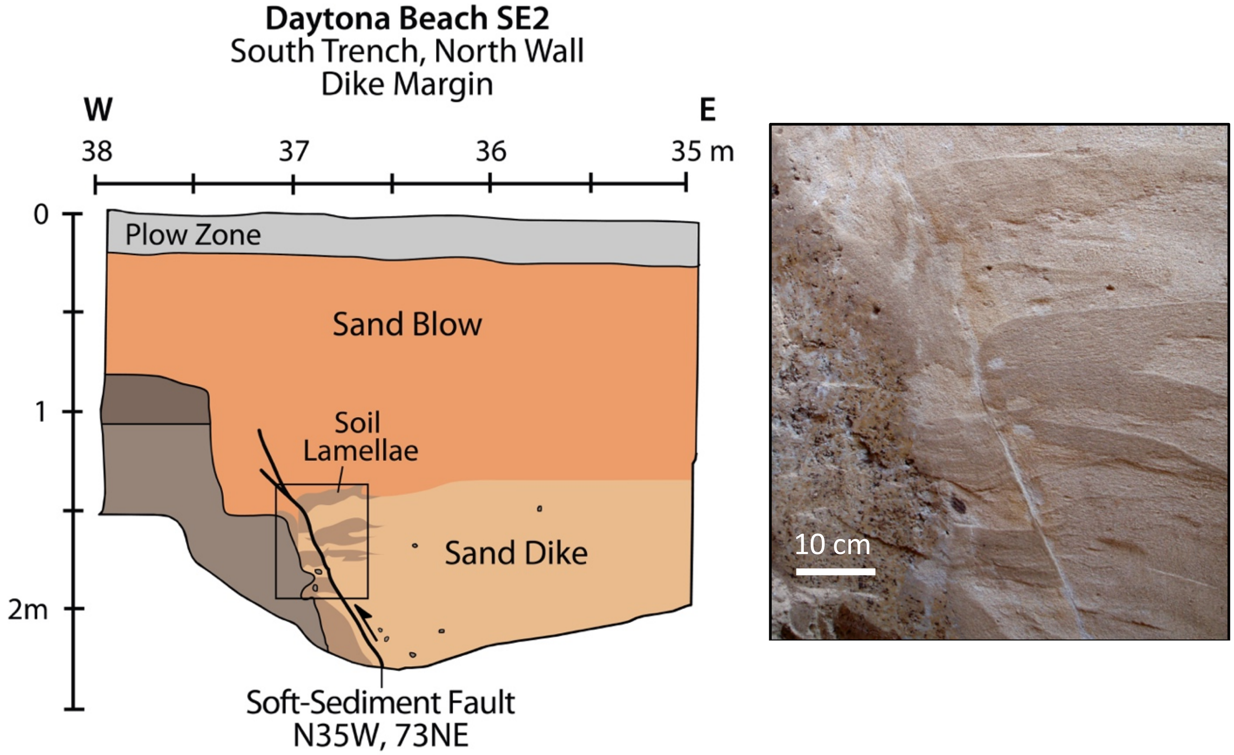

Figure S5. (Left) Portion of log of the north wall of Triple Crown trench at site DBSE2, showing the western margin of a sand dike along which soil lamellae appear to have been dragged along and offset by a SSF with a strike and dip of N35°W, 73°NE. The dike margin and fault were traced across the trench floor to the south wall of the trench and are outlined on Figure S4 with a rectangle (also see Figure S4 for unit descriptions). The SSF parallels the DBL. (Right) Photograph of SSF along which soil lamellae are dragged and offset. Vertical offset of soil lamellae and mismatch of lamellae thickness across the fault suggest reverse and strike-slip components of displacement. Area of the photograph is outlined on the adjacent log with a rectangle.

Daytona Beach Northwest 2 Site (DBNW2)

GPS Locations:

South trench: 34.7271° N, 90.8176°W
North trench: 34.7274° N, 90.8181°W

Observations from GE satellite image and geophysical profiles (Figures S6 and S7):

Width of Sand Blow: 100+ m

Length of Sand Blow: 300+ m

Observations from South trench (Figure S8):

Width of Sand Blow: 13+ m; sand blow extends >7 m west of dike

Thickness of Sand Blow: 1.6 m including plow zone

Width of Sand Dike: 6.4 m

Weathering Characteristics: The upper 0.5 m of the sand blow is very weathered, including redoximorphic features and manganese staining. Silt has accumulated and a few soil lamellae formed along the eastern margin of the dike.

Other Notable Features: The soil below the large sand blow, which represents the event horizon, is displaced downward about 1.5 m on the west side of the dike.

Constraining Ages of Sand Blow from South trench (Figure S8 and Table S3):

OSL dating of samples OSL1 and OSL2 collected from the buried soil below the sand blow yielded ages of 15,040 ± 4,540 yr B.P. and 19,540 ± 1,010 yr B.P., respectively. The samples were collected from the same context and their ages overlap at the one sigma error range. However, the age for OSL2 has a much smaller error (3%) at one sigma compared to that for OSL1 (30%). Therefore, the age of 19.54 ka for OSL2 is preferred. The overdispersion value is high (33%) for OSL2, suggesting that the soil may not have been completely reset prior to burial by the sand blow or may include older sediment mixed in from above or below. Therefore, the OSL age is interpreted as a maximum constraining age, suggesting that the liquefaction event is younger than ca. 19.5 ka.

Observations from North trench (Figure S9):

Width of Sand Blow: 14+ m as observed in trench; sand blow extends >7 m west of dike

Thickness of Sand Blow: 2.4 m including plow zone

Width of Sand Dike: 4.5 m

Weathering Characteristics: The entire sand blow is extremely weathered, including iron-staining and formation of redoximorphic features, especially for the upper 1 m of the sand blow. Silt accumulated along the base of the sand blow above the buried soil and a 1.5-m-thick section of soil lamellae formed along the eastern margin of the large dike.

Other Notable Features: Flow structure occurs in the sand blow above the dike. The soil below the large sand blow is displaced downward about 1.2 m on the west side of the dike. Two SSFs, adjacent to the eastern margin of a sand dike, appear to offset the section of soil lamellae. In addition, several domains of relatively unweathered, loose sand appear to have been injected along the faults. These observations suggest that a second event, including faulting and earthquake-induced liquefaction, occurred thousands of years after the first event responsible for the formation of the large sand blow and dike.

The second event may be the same event responsible for the large sand blow in the nearby South trench.

Constraining Ages of Sand Blow from North trench (Figure S9 and Table S3):

OSL dating of samples OSL1 and OSL2 collected from the buried soil below the sand blow yielded ages of 32,440 ± 1,880 yr B.P. and 24,340 ± 1,790 yr B.P., respectively. Although the samples were collected from the same context, their ages differ by at least 4,430 yr. Overdispersion values are modest (29%) for OSL1 and high (41%) for OSL2. The age for OSL1 may reflect the age of the parent material of the soil; whereas, OSL2 may have been mixed sediment or poorly bleached. These ages are not well constrained but represent maximum limiting ages, suggesting the event is younger than ca. 24.3 ka.

Age Estimates: <19.5 ka (maximum constraining age: 19,540 ± 1,010 yr B.P.) sand blow in south trench; <24.3 ka (maximum constraining age: 24,340 ± 1,790 yr B.P.) sand blow in north trench. The two trenches are about 50 m apart and both cross the northwest trend of the large sand dikes. The sand blows documented in the two trenches appear to have formed along the same structure but during two different events separated by thousands of years. The site was revisited to collect additional samples to better constrain the age of the sand blows. Unfortunately, the site had been excavated and the sand blows removed for building material.

Reference: Al-Shukri, H., Mahdi, H., Tuttle, M. P., Dyer-Williams, K., 2015, Geophysical and paleoseismic investigations of large sand blows along a northwest-oriented lineament near Marianna, Arkansas, Final Technical Report, Prepared for U.S. Geological Survey award G12AP20093, 31 p.

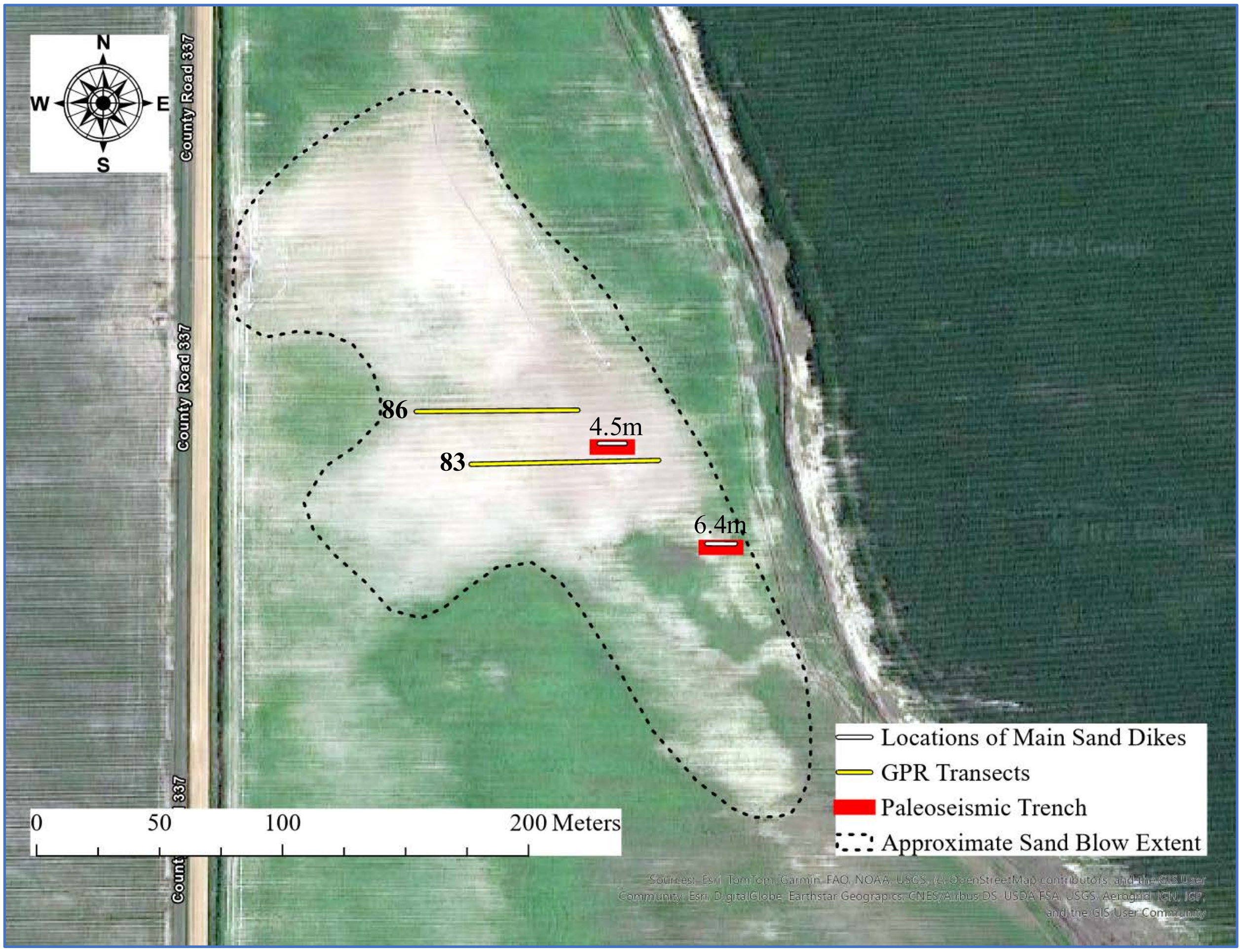

Figure S6. Google Earth imagery (2016) imported into ArcGIS Pro, showing the very large sand blows (light-colored soils) at site DBNW2 (dashed black polygon), the locations of GPR profiles 83 and 86 (yellow lines), the southern and northern paleoseismic trenches (thick red lines), and the location of the main sand dikes (white lines) as observed in the paleoseismic trenches.

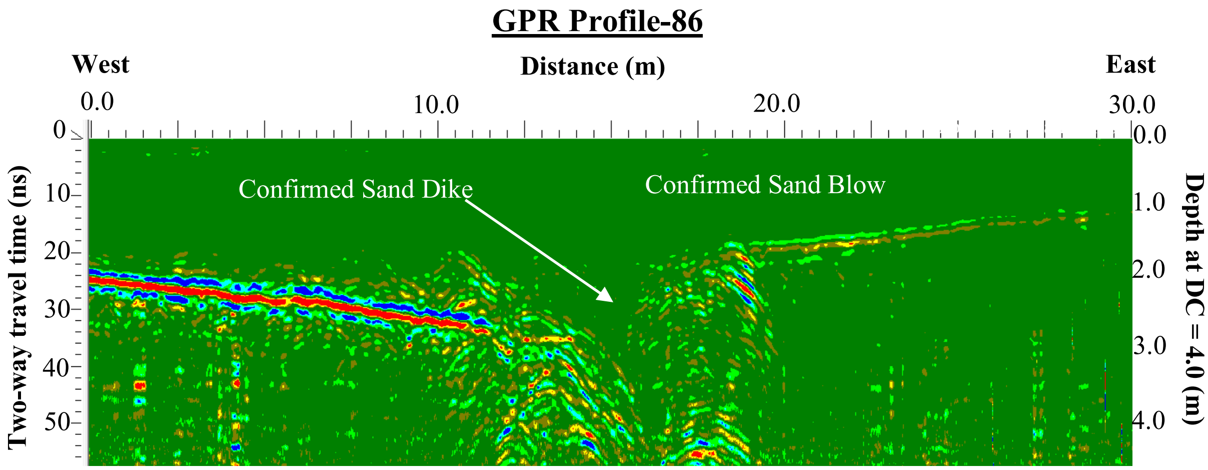

Figure S7. Eastern portion of GPR profile 86 shows deformation of a strong reflector (red and blue bands) which represents the contact between the sand blow above and buried silty soil below. A 6.4 m-wide discontinuity in the contact is due to a large dike that crosscuts the soil.

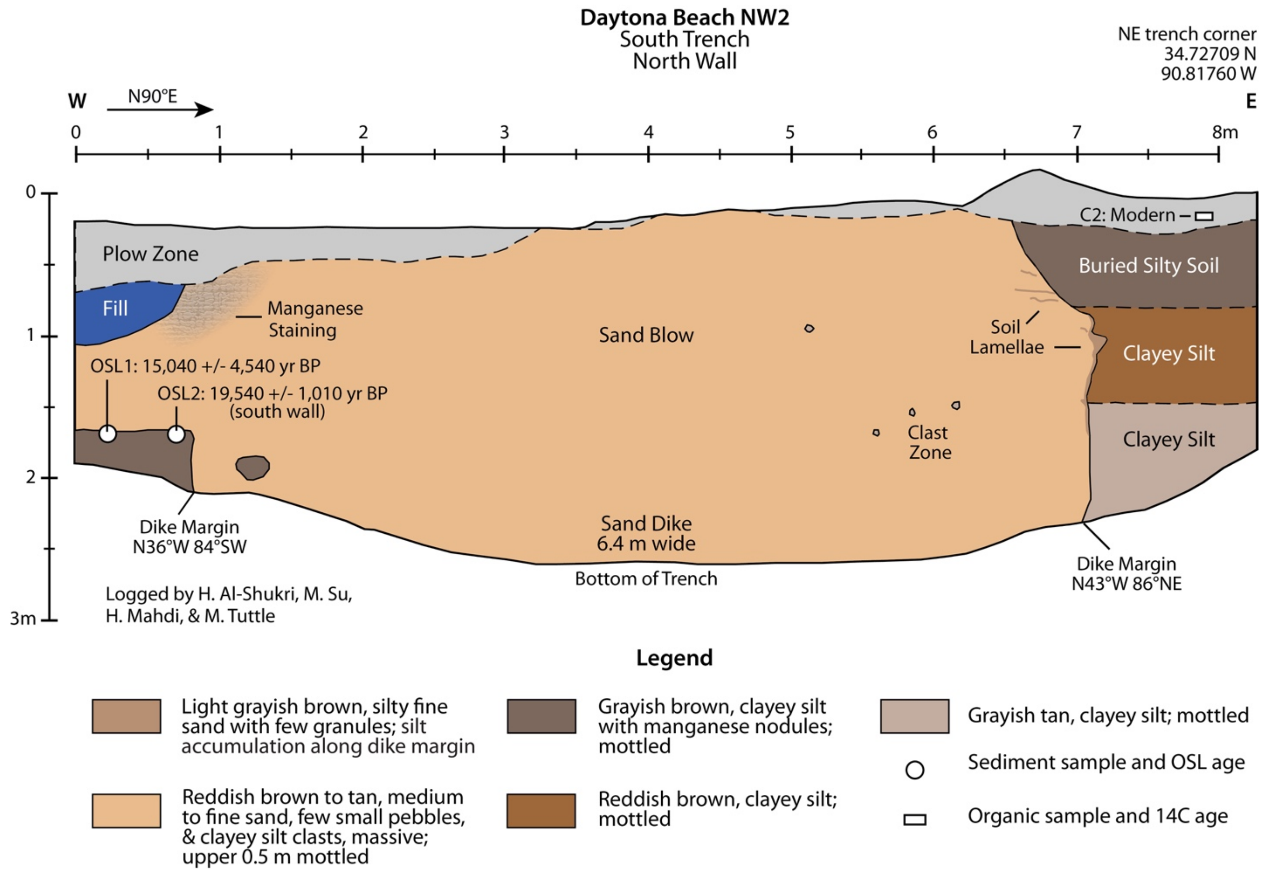

Figure S8. Log of the north wall of the southern trench at site DBNW2. This sand blow and dike exhibit iron staining, silt accumulation, and formation of soil lamellae. However, they are less weathered than the sand blow and dike in the northern trench, suggesting that they may be younger in age. OSL2, has a much smaller one sigma error (5%) than does OSL1, and therefore its age of 19.54 ka is preferred. However, OSL2 has a fairly high overdispersion value (33%) suggesting that it may be mixed or not completely reset prior to burial. Therefore, OSL2 provides a maximum constraining age, suggesting that the liquefaction event is younger than ca. 19.5 ka.

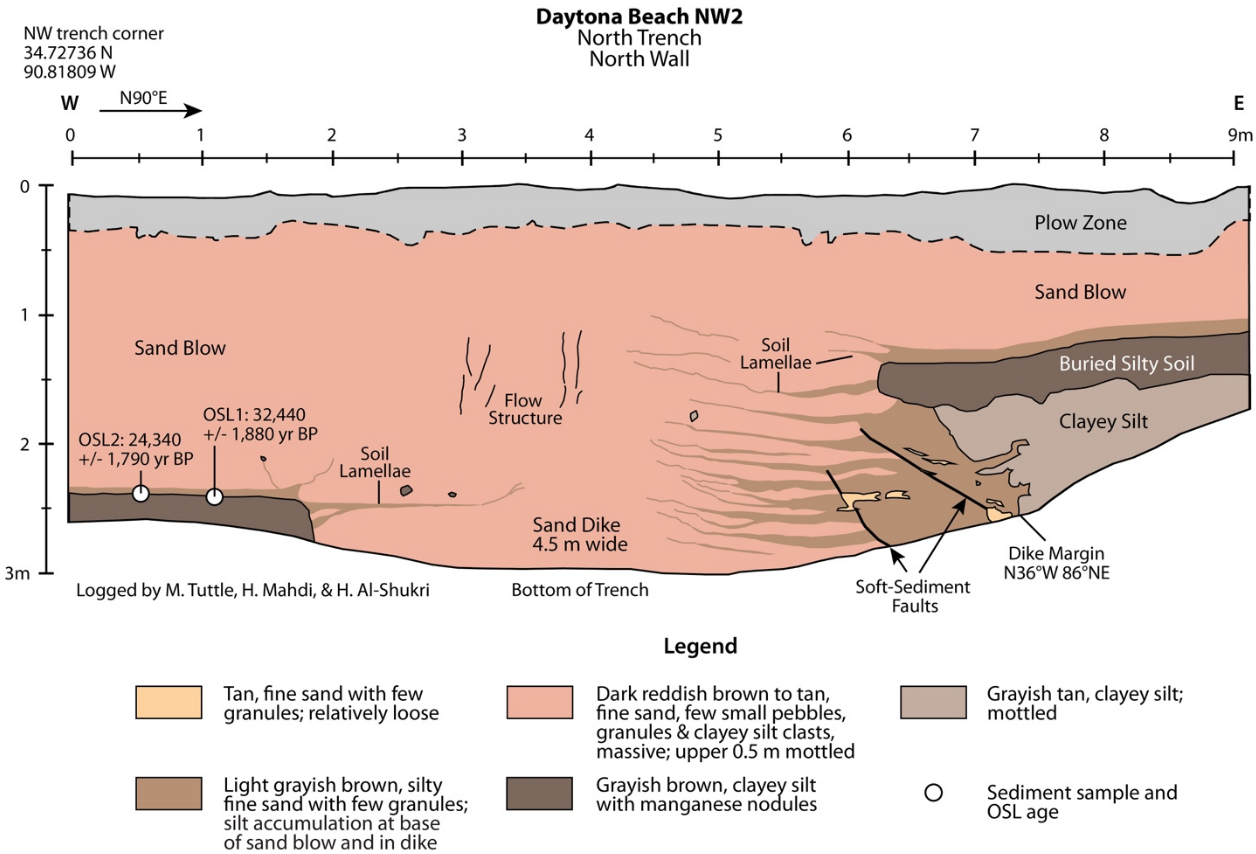

Figure S9. Log of the north wall of the northern trench at site DBNW2. This sand blow and dike are extremely weathered with silt accumulation above the buried soil and formation of a thick section of soil lamellae within the dike. The lamellae appear to be offset by SSFs along which dikes of loose fine sand may have been injected, suggesting a subsequent event. Even though OSL1 and OSL2 were both collected from the buried soil below the sand blow, their ages differ by at least 4,430 yr. Overdispersion values are modest (29%) for OSL1 and high (33%) for OSL2. The OSL ages are not well constrained but represent maximum limiting ages, suggesting the liquefaction event is younger than ca. 24.3 ka.

Daytona Beach Northwest 3 Site (DBNW3)

GPS Locations:

North trench: 34.7312° N, 90.8206°W
South trench: 34.7311° N, 90.8205°W

Observations from GE satellite image and geophysical profiles (Figures S10 and S11):

Width of Sand Blow: 52 m from GPR survey
Length of Sand Blow: 85 m from GPR survey

Observations from North trench (Figure S12):

Thickness of Sand Blow: 75 cm including plow zone

Width of Sand Dikes: 17 cm and 4 cm

Weathering Characteristics: Iron staining in upper 55–65 cm of sand blow and upper 15–25 cm of sand dike; also, several Fe-Mn nodules and soil lamellae had formed in upper 50 cm of sand blow.

Other Notable Features: The buried soil below the large sand blow is inclined such that it is 40 cm lower at the east end of the trench than at the west of the trench. The buried soil may be displaced downward about 10 cm on the east side of the dike.

Constraining Ages of Sand Blow from North trench (Figure S12 and Table S1 and S4):

^{14}C dating of sample C1 of charred material from the buried soil about 13 cm below the sand blow yielded an age of 4,573–4,805 yr B.P. This represents a fairly close maximum constraining age of 4.7 ka for the sand blow. OSL dating of sample OSL1 collected from the buried soil 3-5 cm below the sand blow yielded an age of 4,710 ± 215 yr B.P. This age is consistent with the ^{14}C age of C1 and supports the age estimate of 4.7 ka for the sand blow. Sample OSL3 collected from the subsoil 33-38 cm below the sand blow yielded an age of 13,310 ± 540 yr B.P. Given that it had fairly low overdispersion value, the OSL age probably reflects the age of the parent material of the soil.

Observations from South trench (Figure S13):

Thickness of Sand Blow: 100 cm including plow zone

Width of Sand Dike: 72 cm in north wall; 100 cm in south trench

Weathering Characteristics: Iron staining in upper 70–90 cm of sand blow and upper 15 cm of sand dike; also, several Fe-Mn nodules and soil lamellae had formed in upper 50 cm of sand blow.

Other Notable Feature: The soil below the large sand blow is displaced downward about 40 cm on the east side of the dike.

Constraining Ages of Sand Blow from South trench (Figure S13 and Table S4):

Sample OSL1 collected from the subsoil 32–37 cm below the sand blow yielded an age of 12,500 ± 405 yr B.P., very similar to the age of OSL3 collected from a similar context in the northern trench. Again, the OSL age had fairly low overdispersion value suggesting that the sediment was not mixed and reflects the age of the parent material.

Age Estimate: 4.7 ka; (range 4,573–4,805 yr B.P.; 4,495–4,925 yr B.P.). The two trenches are about 10 m apart and both cross the northwest trend of a through-going sand dike. The sand blow documented in the two trenches is one and the same and formed during one event about 4.7 ka.

Reference: Tuttle M. P., Al-Shukri, H, and Mahdi, H., 2020, Geophysical and paleoseismic investigations of large sand blows along a northwest-oriented lineament near Marianna, Arkansas, Final Technical Report, U.S. Geological Survey award G18AP00083, 31 p.

Figure S10. Esri World Imagery (2018) displayed in ArcGIS Pro, showing the northwest–southeast elongated sand blow (light-colored soils) at site DBNW3 (dashed black polygon), the locations of GPR profiles 21–25 (yellow lines), two paleoseismic trenches (thick red lines), and the location of the main sand dike (white lines) as identified on the GPR profiles 22 and 23 and confirmed in the paleoseismic trenches.

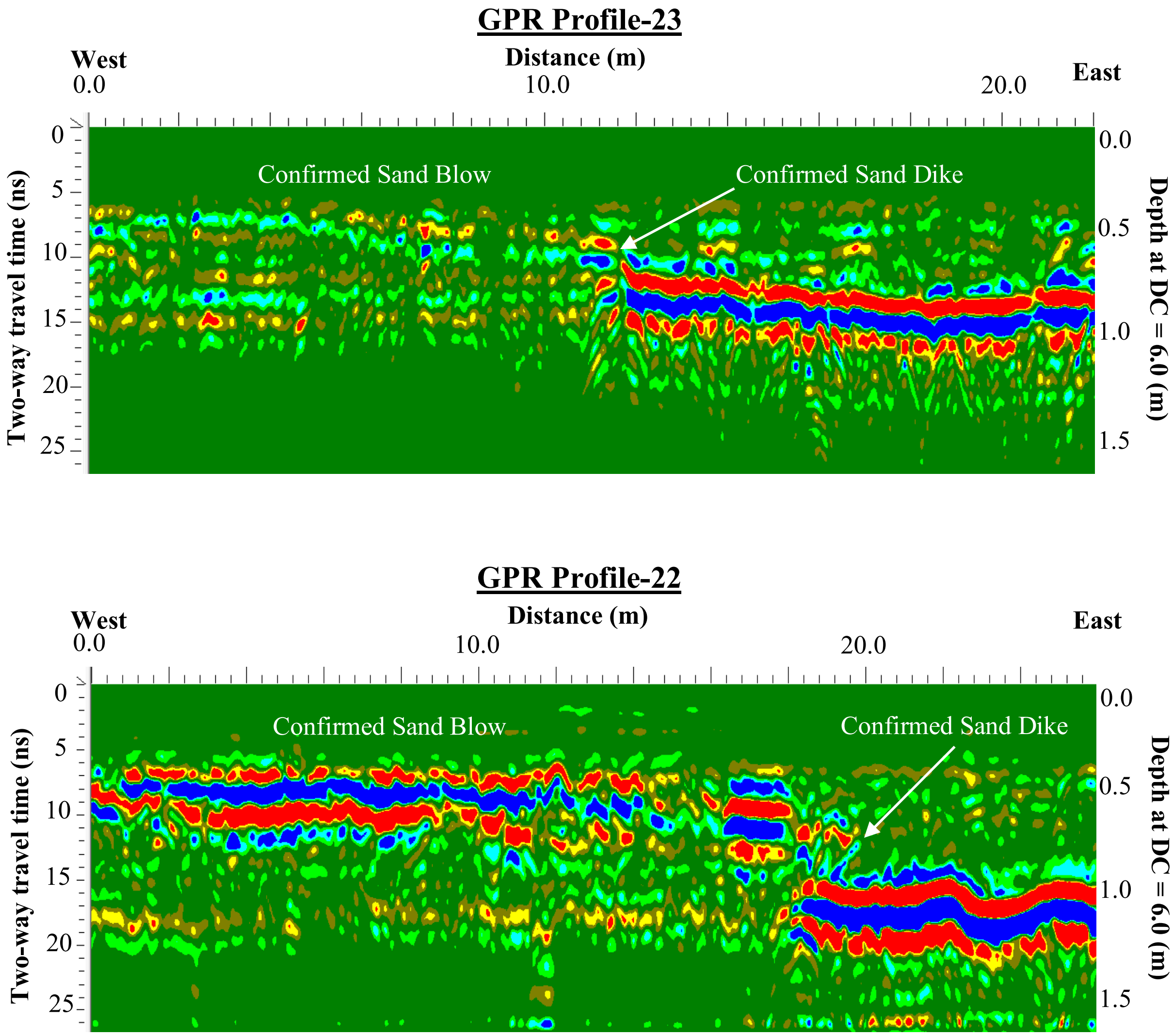

Figure S11. GPR profiles 23 (upper) and 22 (lower) show deformation of a strong reflector (red and blue bands) which represents the contact between the sand blow above and buried silty soil below (Hussein, 2020). Discontinuities in the contact are related to ground failure and dike emplacement.

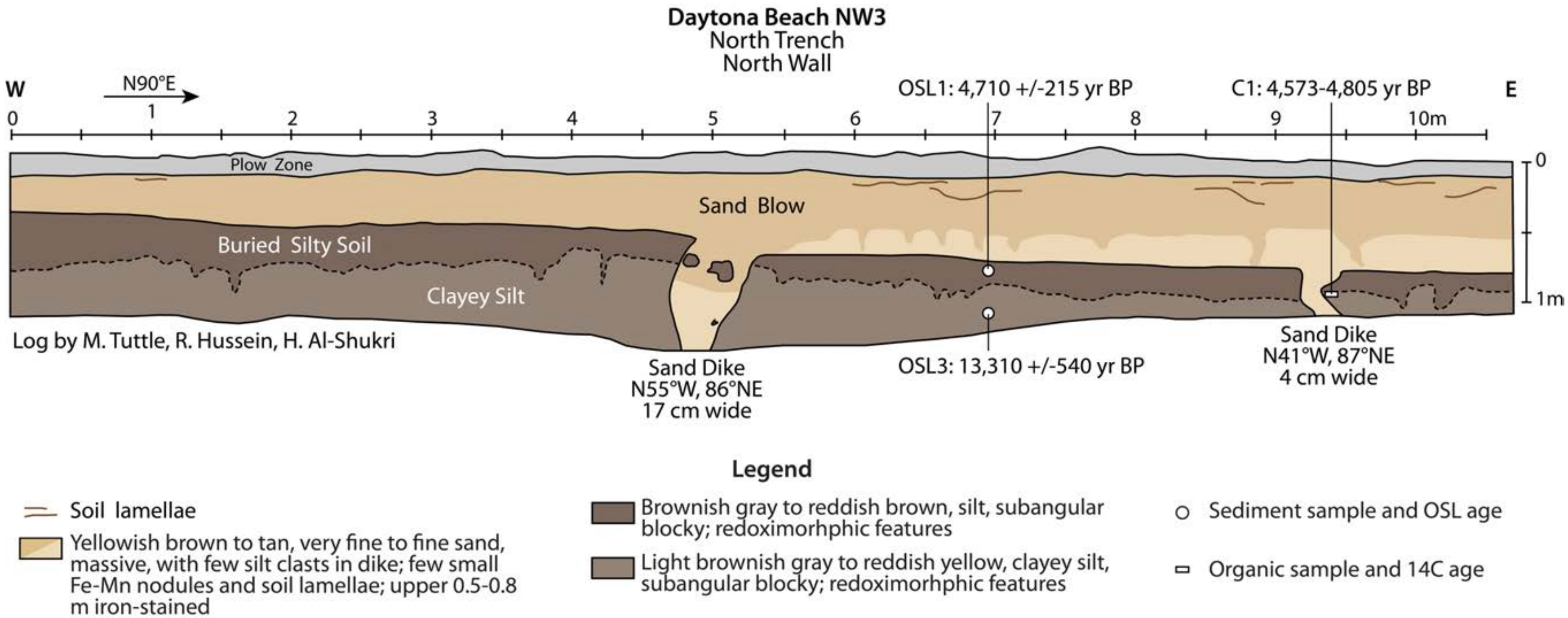

Figure S12. Log of the north wall of the northern trench excavated in the sand blow at site DBNW3. The trench was excavated along the transect of GPR profile 23 (see Figures S10 and S11) and shows a cross-section of the sand blow, sand dikes, and buried soils, as well as the positions of OSL and ^{14}C samples. ^{14}C and OSL dating of the buried soil provides fairly close maximum constraining ages for the sand blow and related sand dikes and indicates that they formed about 4.7 ka. Note that the upper 0.5–0.8 m of the sand blow is weathered (indicated by light brown shading) and includes small Fe-Mn nodules and soil lamellae.

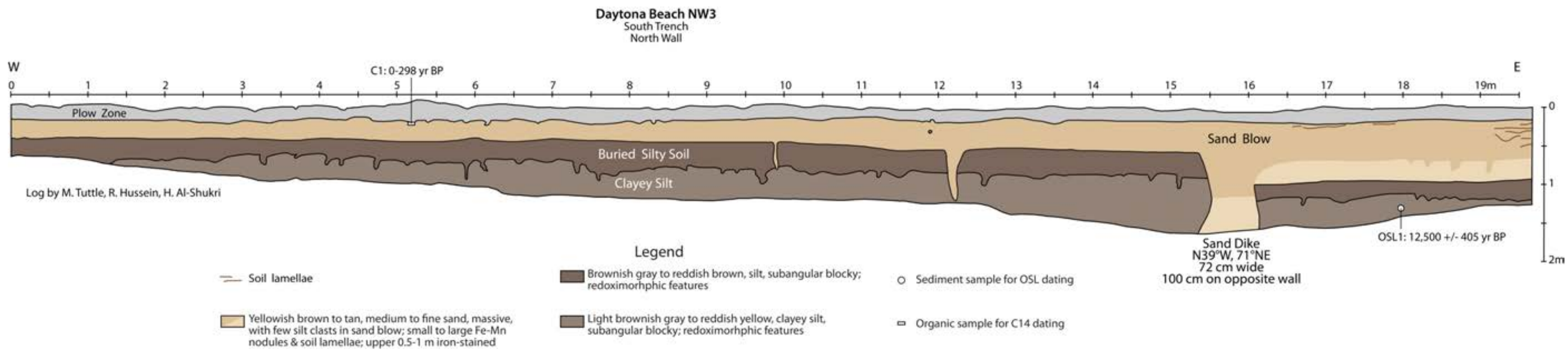

Figure S13. Log of the north wall of the southern trench excavated in the sand blow at site DBNW3. The trench was excavated along the transect of GPR profile 22 (see Figures S10 and S11) and shows a cross-section of the sand blow, sand dike, and buried soils, as well as the position of OSL and ^{14}C samples. OSL date of the buried subsoil (OSL1) agrees with the date of the buried subsoil (OSL3) in the northern trench. The organic sample (C1) collected immediately below the plow zone from the upper part of the sand blow is very young and probably was from a root recently grown into the sand blow from above. As in the northern trench, the upper 0.5–0.8 m of the sand blow is weathered (indicated by light brown shading) and includes small Fe-Mn nodules and soil lamellae.

Daytona Beach Northwest 5 Site (DBNW5)

GPS Location:

South trench: 34.7679°N, 90.8461°W

North trench: Collapsed due to flooding during two tropical storms

Observations from GE satellite image and geophysical profiles (Figures S14 and S15):

Width of Sand Blow: 36 m from GPR survey

Length of Sand Blow: 64 m from GPR survey

Observations from South trench (Figure S16):

Thickness of Sand Blow: 1.4 m including plow zone

Width of Sand Dike: 2.7 m measured perpendicular to strike of the dike

Weathering Characteristics: Sand blow is very weathered; iron staining and formation of small to medium Fe-Mn nodules in upper 40 cm and large nodules above basal contact with buried soil.

Other Notable Features: The buried soil is displaced downward ~1.1 m on the northeast side of the dike. Large clasts of clayey silt occur in the sand blow above large sand dike.

Constraining Ages of Sand Blow from South trench (Figure S16; Tables S1, S4, and S5):

^{14}C dating of organic-rich sediment samples SL1 and SL2 from the top of the buried soil on either side of the large dike provide fairly close maximum constraining ages of 5,474–5,577 yr B.P. and 5,327–5,476 yr B.P., respectively. Giving preference to the younger ^{14}C age, the sand blow formed about 5.4 ka.

OSL dating of sample OSL 3 from the top of the buried soil provides a close maximum constraining age of 5,110 ± 120 yr B.P. and OSL 4 from 16 cm below the top of the buried soil provides a maximum constraining age of 7,475 ± 235 yr B.P. The OSL age of sample OSL 3 is in fairly close agreement with the ^{14}C ages of SL1 and SL2. The OSL age of sample OSL 4 is consistent with the younger age of OSL3 collected higher in the buried soil. OSL3 and OSL4 are more deeply buried and have lower overdispersion values than OSL1 and OSL 2 suggesting that they are less likely to be mixed (Tables S4 and S5).

Age Estimate: 5.4 ka (range 5,327–5,476); preference given to fairly close maximum constraining age from ^{14}C dating.

References: Tuttle M. P., Al-Shukri, H, and Mahdi, H., 2020, Geophysical and paleoseismic investigations of large sand blows along a northwest-oriented lineament near Marianna, Arkansas, Final Technical Report, U.S. Geological Survey award G18AP00083, 31 p.

Tuttle M. P., Al-Shukri, H, Mahdi, H., Hussein, R. Ameen, T., and Tucker, K., 2025, Geophysical and paleoseismological investigations of the Marianna earthquake source in east-central, Arkansas, Final Technical Report, U.S. Geological Survey award G22AP00335, 39 p.

Figure S14. Esri World Imagery (2018) displayed in ArcGIS Pro, showing a large sand blow (light-colored soils) at site DBNW5 (dashed black polygon), the locations of GPR profiles 43–47 (yellow lines), two paleoseismic trenches (thick red lines), and the location of the main sand dike (white line) as identified on GPR profile 43 and in the southern paleoseismic trench.

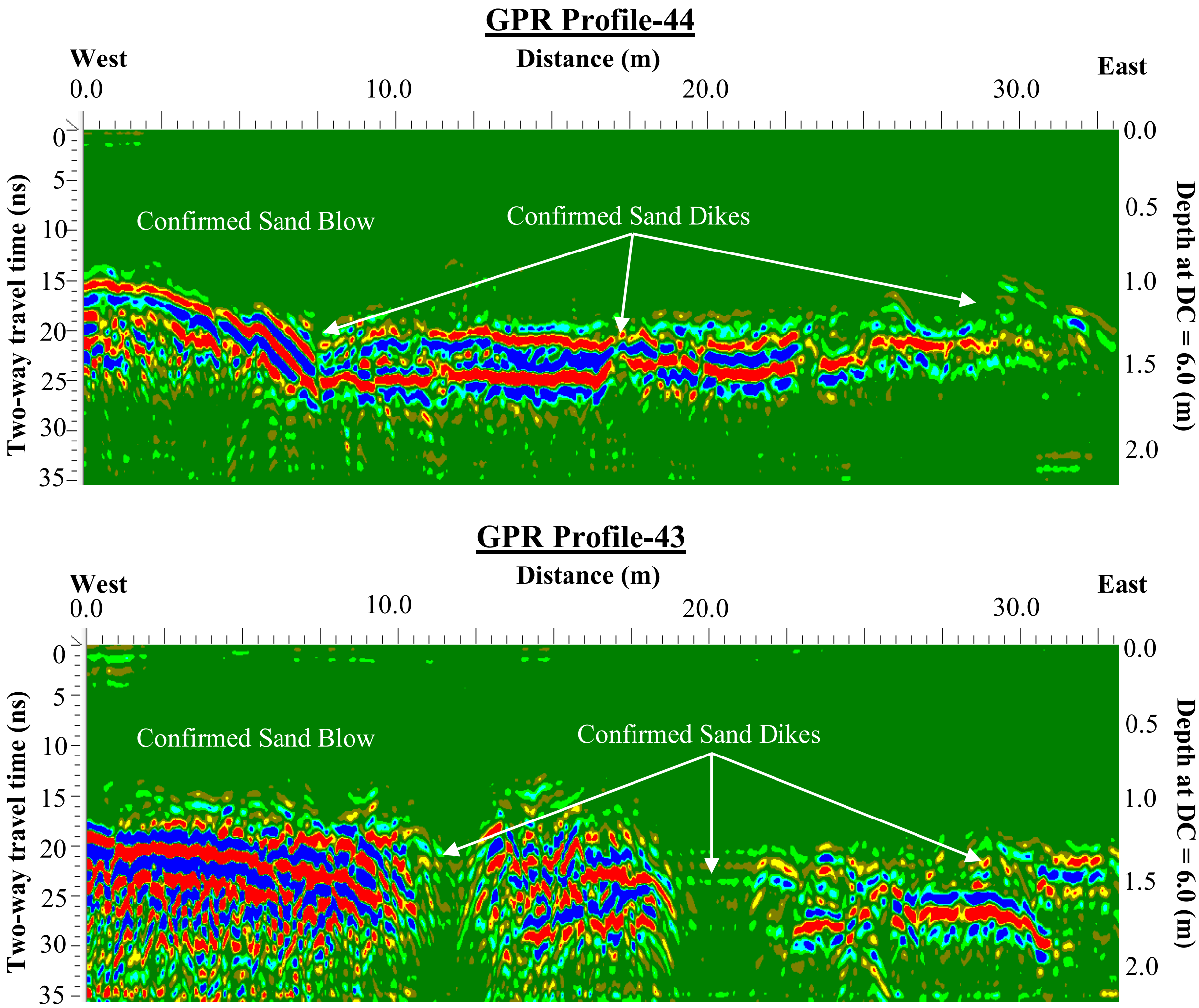

Figure S15. Western portions of GPR profiles 44 (upper) and 43 (lower) show deformation of a strong reflector (red and blue bands) which represents the contact between the sand blow above and buried silty soil below (Hussein, 2020). Discontinuities in the contact are related to ground failure and sand dike emplacement.

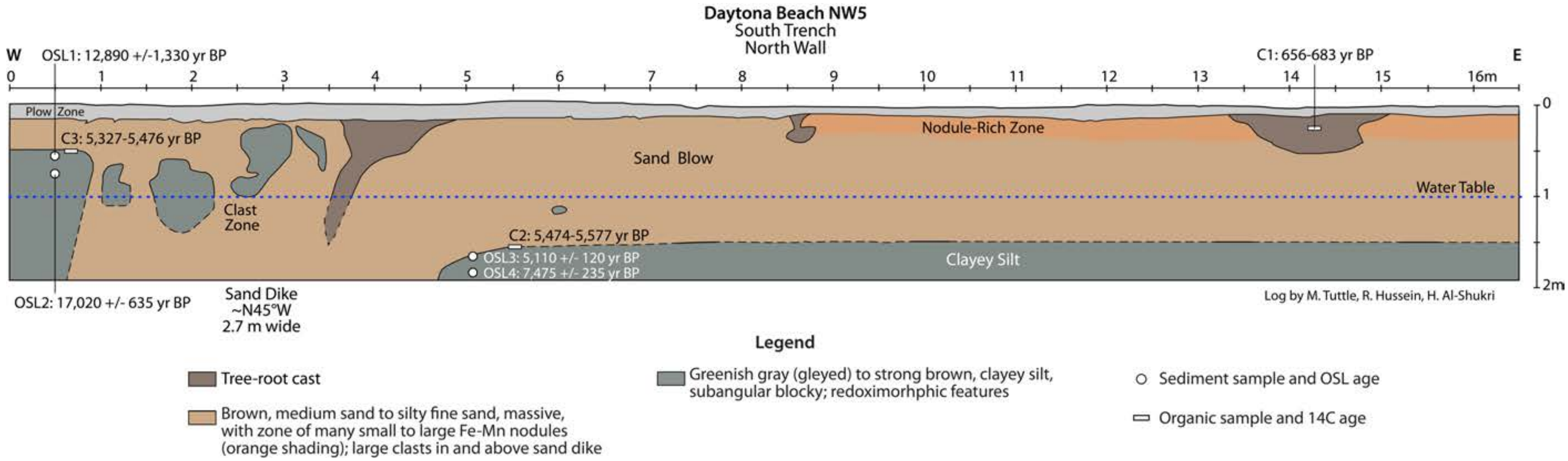

Figure S16. Log of the north wall of the southern trench excavated in the sand blow at site DBNW5. The trench was excavated along the transect of GPR profile 43 (see Figures S14 and S15) and shows a cross section of the large sand blow, large sand dike, and buried soil, as well as the positions of ^{14}C and OSL samples. Large clasts of the silty clay soil were concentrated in the sand blow above the large sand dike. The sand blow was very weathered and included a zone of small Fe-Mn nodules in the upper part of the sand blow and also large nodules towards the bottom of the sand blow. It rained during logging of the sand blow and the trenches filled with water and partially collapsed. Following the storm, the high-water table (dotted blue line) and buttressed trench walls made it difficult to log the contact between the sand blow and underlying soil (dashed where inferred). The site was revisited in 2023 and additional samples collected for dating. ^{14}C and OSL dating of the buried soil adjacent to the dike provides fairly close maximum constraining ages for the liquefaction features and indicate that they formed during an event about 5.4 ka.

Daytona Beach Northwest 7 Site (DBNW7)

GPS Location of trench: 34.7761°N, 90.8216°W

Observations from GE satellite image and geophysical profiles (Figures S17 and S18):

Width of Sand Blow: 45 m from GPR survey

Length of Sand Blow: 60 m from GPR survey

Observations from trench (Figure S19):

Thickness of Sand Blow: 1.5 m including plow zone

Width of Sand Dike: 49 cm

Weathering Characteristics: Sand blow is very weathered with redoximorphic features throughout and few areas of intense iron staining with small Fe-Mn nodules.

Other Notable Features: Few clasts of clayey silt occur in sand blow. Vent structure above the dike crosscuts the sand blow and is filled with silty, very fine sand (final phase of venting). The buried soil is displaced downward about 0.5 m on the east side of the dike.

Constraining Ages of Sand Blow from trench (Figure S19; Tables S1 and S5):

^{14}C dating of sample C2 of charred material collected near the tip of a root cast that extended through the sand blow and into the buried soil provides a minimum constraining age of 1,179 yr B.P.

The contact of the buried soil was bioturbated, especially west of the sand dike, making it difficult to sample an undisturbed portion of the buried soil. Therefore, samples of the buried soil were collected east of the dike. OSL2 collected from the upper 5 cm of the buried soil yielded an age of 41,445 ± 2,060 yr B.P. Its overdispersion value (24 ± 3%) is modest, suggesting that the OSL age may reflect the age of the parent material of the soil, rather than the time of burial of the surface by this sand blow.

OSL3 collected 15 cm below the top of the buried soil, where bioturbation was less severe, yielded an age of 7,200 ± 180 yr B.P. Its uncertainty range is relatively small and overdispersion value low, lending confidence in the age. Given the similarity in the age of OSL3 with that of OSL4 (7,475 ± 235 yr B.P.) collected at site DBNW5 16 cm below the top of the buried soil, the sand blow and dike at DBNW7 are interpreted to have formed at the same time as the liquefaction features at DBNW5 or about 5.4 ka.

OSL1 and OSL4 were collected from the upper portion of the sand blow and yielded ages of 16,285 ± 1,395 yr B.P. and 17,205 ± 1,350 yr B.P., respectively. OSL4 had a low overdispersion value (4 ± 1%). The ages of OSL4 sand OSL1 suggest that the vented sand is much older than the buried soil and reflects the age of the source layer that liquefied. It would seem that the luminescence of the sand was not reset during venting perhaps as a result of rapid deposition of the sand blow.

Age Estimate: 5.4 ka (range 5,327–5,476); based on dating at DBNW7 and nearby DBNW5

Reference: Tuttle M. P., Al-Shukri, H, Mahdi, H., Hussein, R. Ameen, T., and Tucker, K., 2025, Geophysical and paleoseismological investigations of the Marianna earthquake source in east-central, Arkansas, Final Technical Report, U.S. Geological Survey award G22AP00335, 39 p.

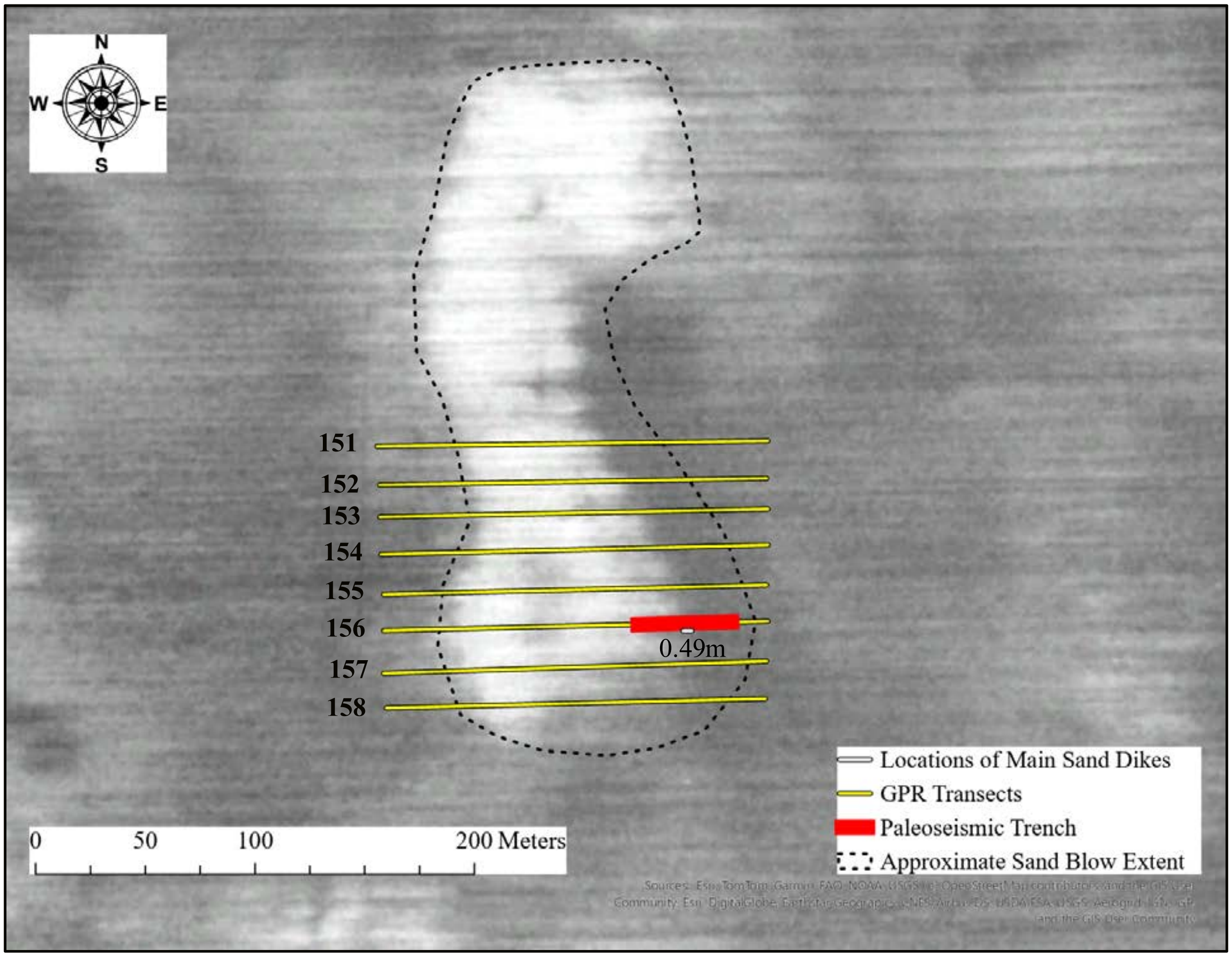

Figure S17. Google Earth imagery (2001) imported into ArcGIS Pro, showing a very large sand blow (light-colored soils) at site DBNW7 (dashed black polygon), the locations of GPR profiles 151–158 (yellow lines), one paleoseismic trench (thick red line), and the location of the main sand dike (white line) as observed in the trench.

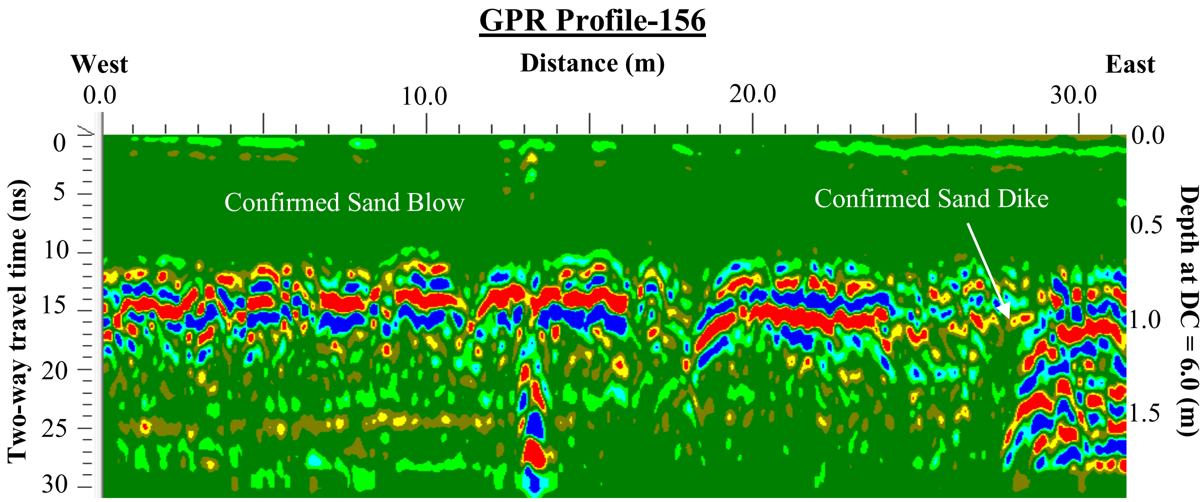

Figure S18. Portion of GPR profile 156 shows deformation of a strong reflector (red and blue bands) which represents the contact between the sand blow above and buried silty soil below. A sand blow and related sand dike (identified towards east end of the profile) were confirmed in the paleoseismic trench excavated along GPR profile 156.

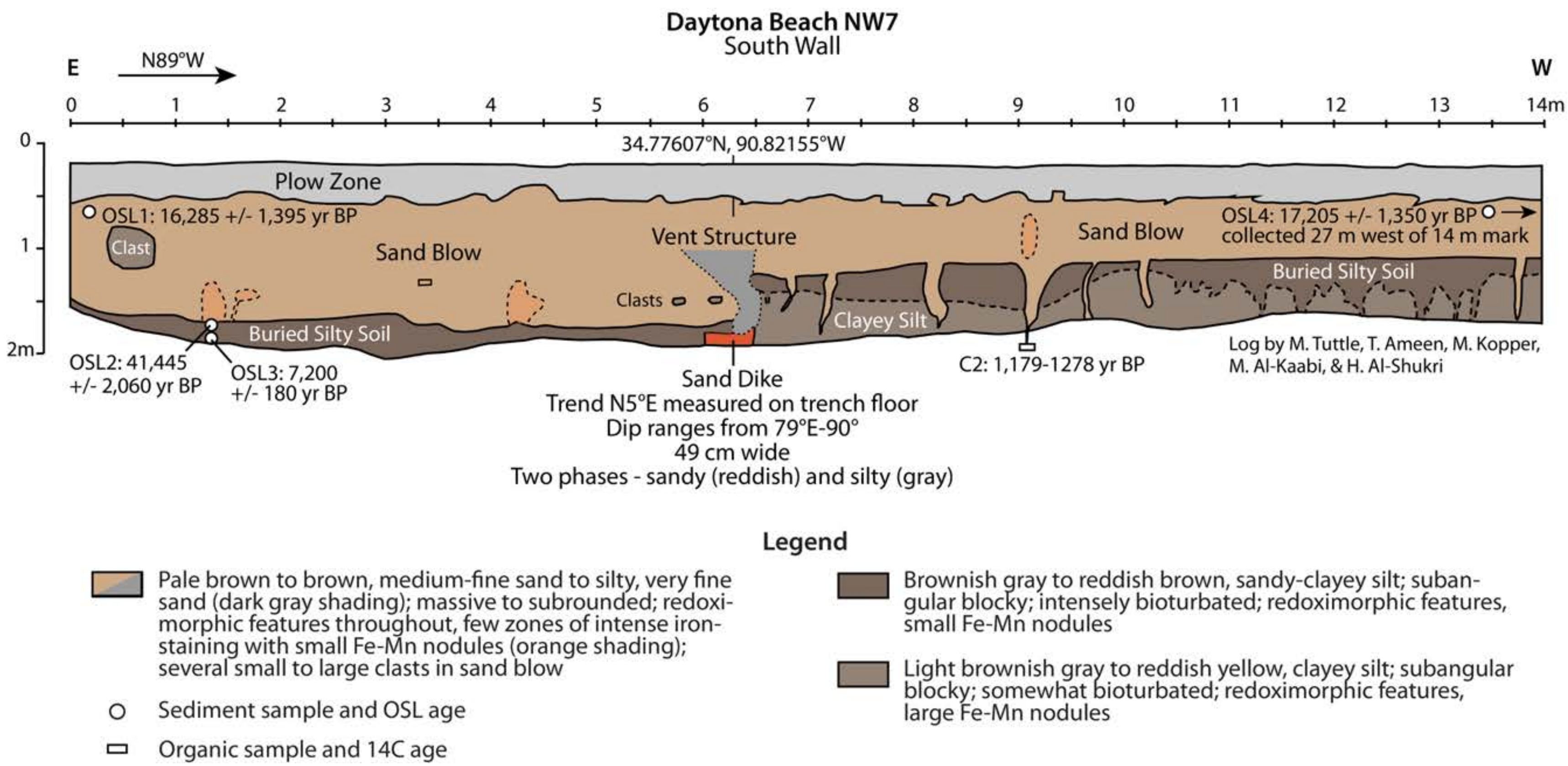

Figure S19. Log of south wall of the eastern 14 m of the 41-m-long trench excavated in the sand blow at site DBNW7. The trench was excavated along the transect of GPR profile 156 (see Figures S17 and S18) and shows a cross section of the sand blow, sand dike, buried soils, and the positions of ^{14}C and OSL samples. The sand blow and sand dike were very weathered. C2 collected from a root cast grown through the sand blow and into the buried soils provides a minimum constraining age of about 1,179 yr B.P. OSL3 collected 15 cm below the top of the buried soil provides a maximum constraining age of 7,200 ± 180 yr B.P. for the liquefaction features. The age of OSL3 is similar to that of OSL 4 from nearby site DBNW5 collected 16 cm below the buried soil. Therefore, it seems likely that the liquefaction features at DBNW7 formed during the same event as the liquefaction features at DBNW5 or about 5.4 ka.

Daytona Beach Northwest 8 Site (DBNW8)

GPS Location of trench: 34.7695°N, 90.8546°W

Observations from GE satellite image and geophysical profiles (Figures S20 and S21):

Width of Sand Blow: 65+ m

Length of Sand Blow: 75 m

Observations from trench (Figure S22):

Thickness of Sand Blow: 1.05 m including plow zone

Width of Sand Dikes: western dike: 54 cm; eastern compound dike: 50 cm and 16 cm

Weathering Characteristics: Sand blow is very weathered with redoximorphic features common and few areas of intense iron staining. Few soil lamellae developed in sand blow.

Other Notable Features: Few clasts of clayey silt in and above sand dikes. Flow structure in and above eastern sand dike. Compound sand dike: earlier phase composed of coarse-medium-fine sand; later phase composed of silty, medium-fine sand. The buried soil is displaced downward about 0.3 m on the west side of the eastern dike.

Constraining Ages of Sand Blow from trench (Figure S22; Table S5):

OSL dating of sample OSL5 collected about 8 cm below the top of the buried soil yielded an age of 6,335 ± 150 yr B.P., which represents a maximum constraining age for the sand blow and related sand dikes. There is confidence in the age estimate for OSL5 given its small uncertainty and low overdispersion value of 4 ± 1%. Similarly, there is confidence in the age estimate of 14,985 ± 365 yr B.P. for sample OSL6 collected 30 cm below OSL5 from the subsoil.

At nearby site DBNW5, OSL3 (5,110 ± 120 yr B.P.) and OSL4 (7,475 ± 235 yr B.P) were collected at the top of the buried soil and 16 cm below the sand blow, respectively. At site DBNW8, sample OSL5 was collected 8 cm below the top of the buried soil, or at a depth about halfway between OSL3 and OSL4 at DBNW5. Therefore, it seems likely that the sand blow at DBNW8 formed during the same event or about 5.4 ka.

OSL dating of samples OSL1 and OSL4 collected from the upper part of the sand blow yielded ages of 18,375 ± 495 yr B.P. and 18,605 ± 1,345 yr B.P. and had high overdispersion values of 40 ± 8 and 36 ± 6, respectively. Like the samples collected from the upper part of the sand blow at DBNW7, these ages are older than the soil buried by the sand blow. This suggests that the luminescence of the sand vented to the ground surface may not have been solar reset. This may be due to rapid deposition of the sand blow.

Age Estimate: 5.4 (range 5,327–5,476); based on dating at DBNW8 and nearby DBNW5)

Reference: Tuttle M. P., Al-Shukri, H, Mahdi, H., Hussein, R. Ameen, T., and Tucker, K., 2025, Geophysical and paleoseismological investigations of the Marianna earthquake source in east-central, Arkansas, Final Technical Report, U.S. Geological Survey award G22AP00335, 39 p.

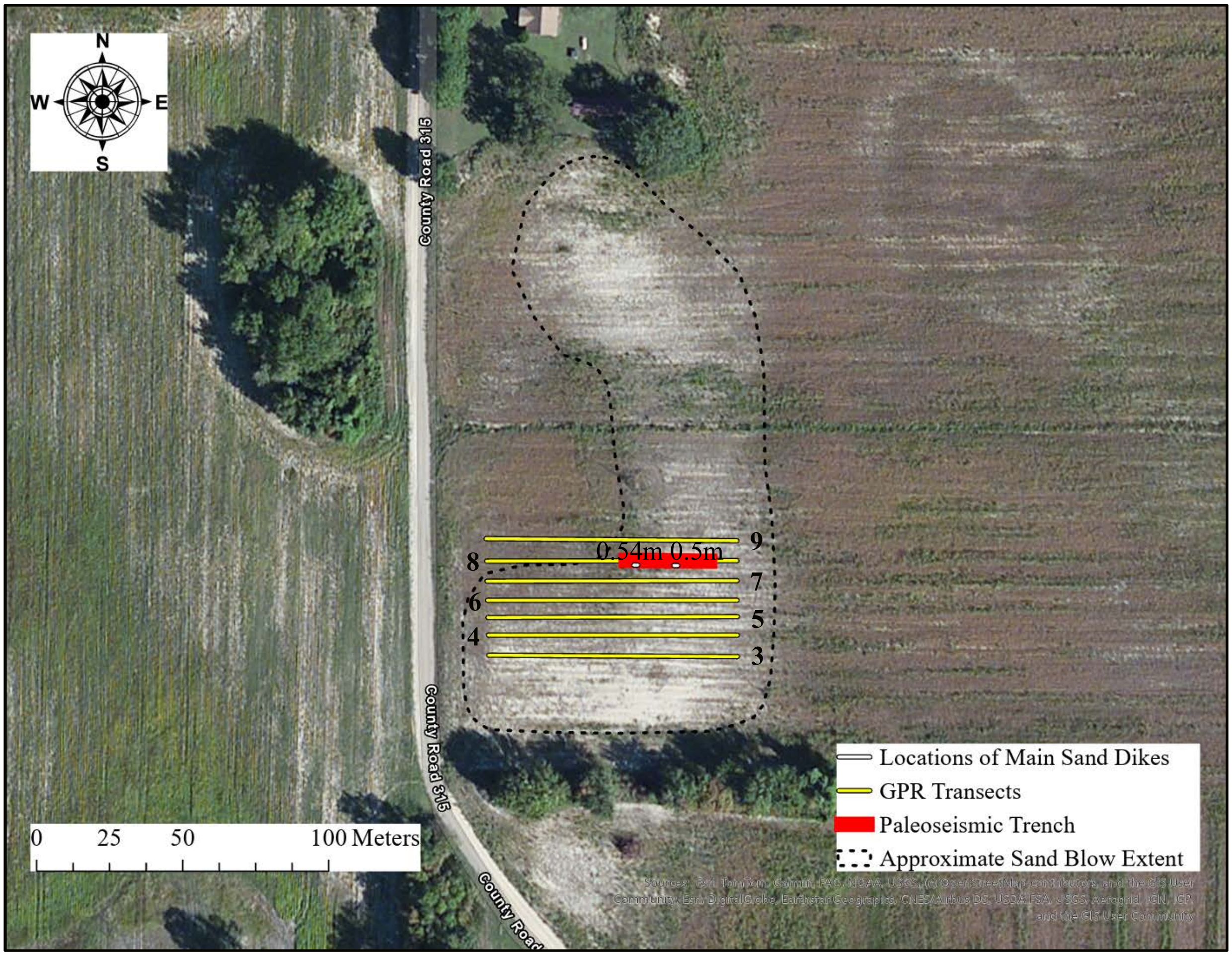

Figure S20. Esri World Imagery (2014) displayed in ArcGIS Pro, showing a very large sand blow (light-colored soils) at site DBNW8 (dashed black polygon), the locations of GPR profiles 3–9 (yellow lines), one paleoseismic trench (thick red line), and the locations of main sand dikes (white lines) as observed in the trench.

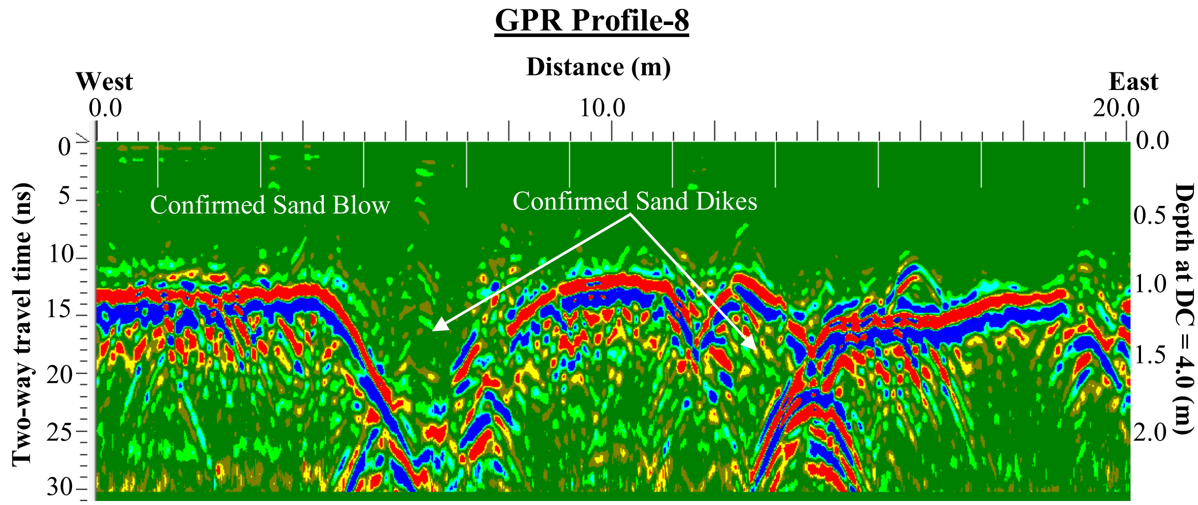

Figure S21. Eastern portion of GPR profile 8 shows deformation of a strong reflector (red and blue bands) which represents the contact between the sand blow above and buried silty soil below. A sand blow and two related sand dikes were confirmed in the paleoseismic trench excavated close to GPR profile 8.

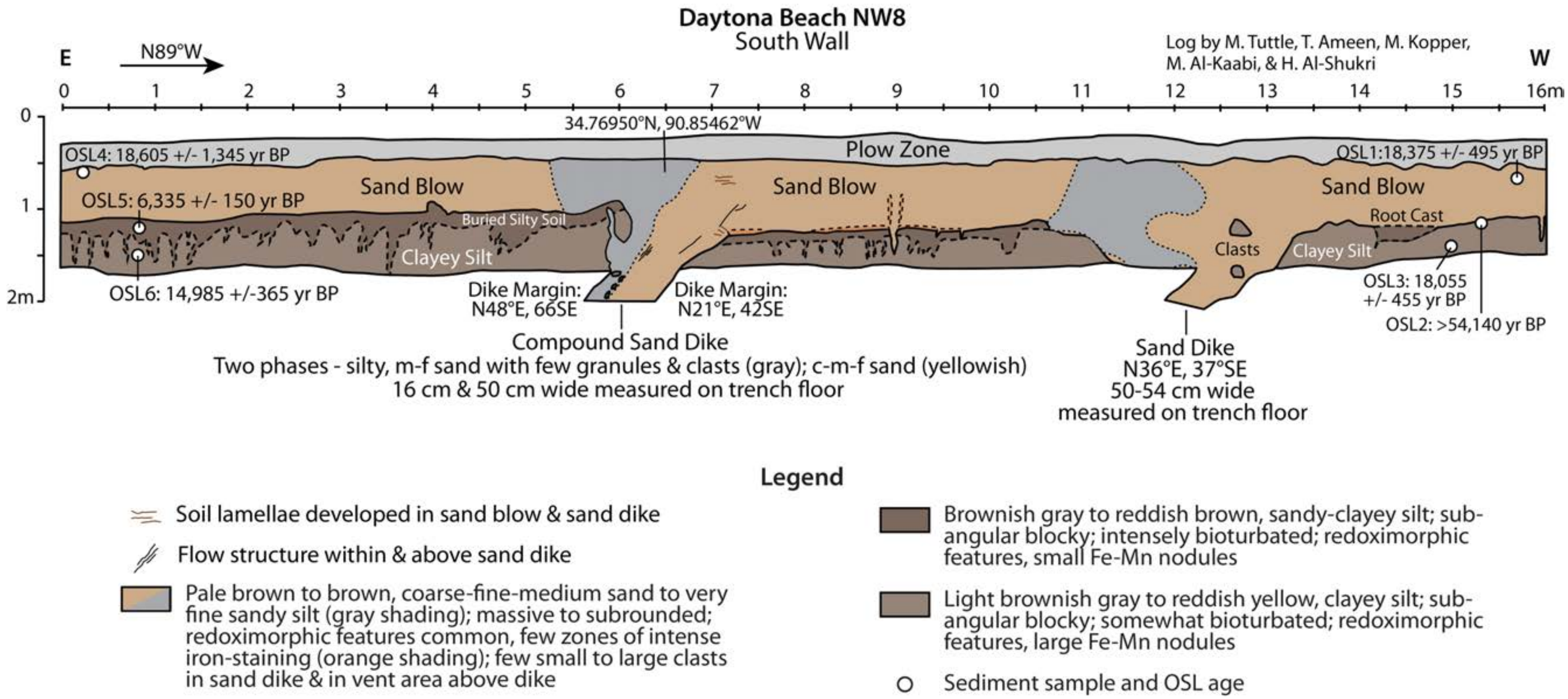

Figure S22. Log of the south wall of the trench excavated in the sand blow at site DBNW8. The trench was excavated close to the transect of GPR profile 8 (see Figures S20 and S21) and shows a cross section of the sand blow, sand dikes, and buried soils, as well as the positions of OSL samples. The sand blow and sand dikes were very weathered. OSL5 collected 8 cm below the top of the buried soil provides a maximum constraining age of 6,485 yr B.P. for the liquefaction features. Given the age and depth of OSL5 below the top of the buried soil, it seems likely that the liquefaction features at this site formed during the same event as the liquefaction features at nearby site DBNW5 or about 5.4 ka.

DATING RESULTS

Table S1. Results of Radiocarbon Dating of Charred Material and Organic Sediment Associated with Sand Blows (2010-2023).

Trench Sample # Beta #	$^{13}C/^{12}C$ Ratio*	Conventional ^{14}C Age Yr B.P.†	Calibrated Age Yr B.P.‡ 1-sigma	Calibrated Calendar Date‡ 1-sigma	Prob. %	Calibrated Age Yr B.P.‡ 2-sigma	Calibrated Calendar Date‡ 2-sigma	Prob. %	Sample Description§
SITE DBSE2									
Triple Cr. C1 252610	NA	8780 ± 60	9680-9910	7730-7960 BC	68	9560-9960 9990-10150	7610-8010 BC 8040-8200 BC	95	Charred material, buried soil below sand blow
Triple Cr. C4 276429	NA	320 ± 40	310-460	AD 1640-1490	68	290-490	AD 1660-1460	95	Charred material, base of plow zone above sand blow
SITE DBNW3									
North C1 546853	-24.1	4120 ± 30	4573-4647 4760-4805 4674-4696	2624-2698 BC 2811-2856 BC 2725-2747 BC	36.7 21.3 10.2	4528-4726 4753-4815	2579-2777 BC 2804-2866 BC	70.3 25.1	Charred material, buried soil, collected ~13 cm below sand blow
South C1 546854	-23.8	210 ± 30	150-185 272-298 Post BP 0-10	AD 1800-1765 AD 1678-1652 Post AD 1950-1940	33 25 10.2	144-216 266-304 Post BP 0-21	AD 1806-1734 AD 1684-1646 Post AD 1950-1929	50.5 30.8 14.1	Charred material, near the contact of the plow zone and sand blow
SITE DBNW5									
South C1 546855	-24.3	710 ± 30	656-683	AD 1294-1267	68.2	644-694 565-588	AD 1306-1256 AD 1385-1362	84.8 10.6	Charred material, tree root cast in upper part of sand blow
South SL1 681253	-18.0	4760 ± 30	5507-5577 5474-5485	3558-3628 BC 3525-3536 BC	59.7 8.5	5460-5585 5355-5377 5331-5348	3511-3636 BC 3406-3428 BC 3382-3399 BC	87.8 4.2 3.4	Organic sediment, upper 0.5 cm of buried sand blow; near OSL3
South SL2 681254	-17.8	4710 ± 30	5327-5388 5445-5476 5395-5400	3378-3439 BC 3496-3527 BC 3446-3451 BC	44.9 21.1 2.2	5322-5417 5438-5438 5525-5575 5510-5520	3373-3468 BC 3489-3534 BC 3576-3626 BC 3561-3571 BC	54.8 24.1 14.9 1.6	Organic sediment, upper 0.5 cm of buried sand blow; near OSL1
SITE DBNW7									
Tr C2 681255	-25.1	1290 ± 30	1179-1214 1244-1278	AD 771-736 AD 706-672	35.2 33.0	1176-1291	AD 774-659	95.4	Charred material, 175 cm BS near tip of root cast that extends thru sand blow into buried soil

* NA – not applicable.

† Conventional radiocarbon ages in years B.P. or before present (A.D. 1950) determined by Beta Analytic, Inc. Errors represent 1 standard deviation statistics or 68% probability.

‡ Calibrated age ranges and calendar dates as determined by Beta Analytic, Inc., using the high probability density range method (Bronk Ramsey, 2009) and INTCAL20 (Reimer et al., 2020). 1-sigma error ranges represent 68.2% probability and 2-sigma ranges represent 95.4% probability.

§ Abbreviations: OSL – optically stimulated luminescence sample; BS – below surface.

Table S2. Results of Optically-Stimulated Luminescence Dating of Soils Buried by Sand Blows (2010).

Trench Sample #	H_20 (%)*	K (%)†	U (ppm)†	Th (ppm)†	Cosmic Dose Additions (Gy/ka)‡	Total Dose (Gy/ka)	Equivalent Dose (Gy)	n §	OSL Age (Yr)‖	OSL Age Yr. B.P. (AD 1950)	Sample Description
					SITE DBSE2						
Triple Cr. OSL1	15 (45)	1.70 ± 0.07	2.25 ± 0.10	7.26 ± 0.2	0.17 ± 0.02	2.56 ± 0.06	30.6 ± 1.83	19 (20)	12,000 ± 1,000	11,940 ± 1,000	Buried soil at contact with sand blow above
Triple Cr. OSL2	12 (35)	1.73 ± 0.08	2.27 ± 0.13	7.26 ± 0.2	0.16 ± 0.01	2.65 ± 0.08	103 ± 3.61	19 (20)	38,000 ± 3,000	37,940 ± 3,000	Buried soil 20 cm below contact with sand blow above
Double Cr. OSL3	16 (30)	1.73 ± 0.07	2.17 ± 0.17	7.26 ± 0.2	0.16 ± 0.01	2.52 ± 0.07	103 ± 3.61	19 (20)	52,000 ± 3,000	51,940 ± 3,000	Buried soil at contact with sand blow above

* Field moisture, with figure in parentheses indicating the complete sample saturation %. Ages calculated using approximately 30% of saturation values.

† Analyses obtained using low-resolution gamma spectrometry (NaI detector).

‡ Cosmic doses and attenuation with depth were calculated using the methods of Prescott and Hutton (1994).

§ Number of replicated equivalent dose (De) estimates used to calculate the mean. Figures in parentheses indicate total number of measurements made including failed runs with unusable data.

‖ Dose rate and age for fine-grained 125-90 um quartz sand. Linear + exponential fit used on age, errors to one sigma, weighted mean used. Datum year assumed to be AD 2010.

OSL ages determined by U.S. Geological Survey, Denver, CO.

Table S3. Results of Optically-Stimulated Luminescence Dating of Soils Buried by Sand Blows (8/31/2015).

Trench Sample #	H_20 (%)*	K (%)†	U (ppm)†	Th (ppm)†	Total Dose (Gy/ka)‡	Equivalent Dose (Gy)	n§	Scatter (%)ǀ	OSL Age (Yr)#	OSL Age Yr. B.P. (AD 1950)	Sample Description
SITE DBNW2											
North OSL1	12 (26)	1.34 ± 0.03	1.30 ± 0.04	4.50 ± 0.14	2.03 ± 0.06	65.9 ± 3.34	3 (15)	29	32,500 ± 1,880	32,440 ± 1,880	Buried soil at contact with sand blow above
North OSL2	12 (21)	1.01 ± 0.04	0.91 ± 0.11	2.94 ± 0.26	1.54 ± 0.08	37.5 ± 1.97	2 (15)	41	24,400 ± 1,790	24,340 ± 1,790	Buried soil at contact with sand blow above
South OSL1	12 (33)	1.30 ± 0.03$	0.90 ± 0.03$	3.56 ± 0.18$	1.82 ± 0.05	27.5 ± 0.42	2 (14)	42	15,100 ± 4,540	15,040 ± 4,540	Buried soil at contact with sand blow above
South OSL2	13 (21)	1.25 ± 0.03$	0.60 ± 0.02$	2.80 ± 0.14$	1.70 ± 0.04	33.3 ± 1.51	2 (7)	33	19,600 ± 1,010	19,540 ± 1,010	Buried soil at contact with sand blow above

* Field moisture, with figure in parentheses indicating the complete sample saturation %. Ages calculated using 25% of the saturated moisture (i.e., 12 (26): 26 * 0.25 = 6).

† Analyses obtained using high-resolution gamma spectrometry (Ge detector).

‡ Includes cosmic doses and attenuation with depth calculated using the methods of Prescott and Hutton (1994). Cosmic doses varied from 0.16 to 0.18 Gy/ka.

§ Number of replicated equivalent dose (De) estimates used to calculate the equivalent dose. Figures in parentheses indicate total number of measurements included in calculating the represented equivalent dose and age using the minimum age model (MAM). Single grain and single aliquot readings are combined.

ǀ Defined as "over-dispersion" of the De values. Obtained by the "R" factor program. Values >35% are considered to be poorly bleached or mixed sediment.

\# Dose rate and age for fine-grained 250-180 microns quartz. Exponential + linear fit used on equivalent dose, errors to one sigma. Datum year assumed to be AD 2010. OSL ages determined by U.S. Geological Survey, Denver, CO.

$ Analyses obtained using inductively coupled plasma mass spectrometry (ICP-MS). All errors were obtained with calibration standards.

Table S4. Results of Optically-Stimulated Luminescence Ages on Quartz Grains from Soils Buried by Sand Blows (4/30/2020).

Sample Lab No. Depth (m)	Aliquots*	Grain Size (µm)	Equivalent Dose (De) (Gy)†	Over-dispersion (%)‡	U (ppm)§	Th (ppm)§	K (%)§	H_20 (%)	Cosmic Dose Rate (mGray/yr)ǁ	Dose Rate (mGray/yr)	OSL Age (Yr)#	OSL Age Yr. B.P. (AD 1950)	Sample Description
SITE DBNW3													
NTR-OSL1 BG4884 0.7	40/40	38-63	12.84 ± 0.5	9 ± 1	2.61 ± 0.01	7.00 ± 0.01	1.86 ± 0.01	10 ± 2	0.18 ± 0.02	2.69 ± 0.06	4,770 ± 215	4,710 ± 215	Buried silty soil collected 3-5 cm below sand blow
NTR-OSL3 BG4885 1.1	39/40	38-63	41.39 ± 1.29	13 ± 1	2.85 ± 0.01	9.10 ± 0.01	1.63 ± 0.01	10 ± 2	0.17 ± 0.02	2.69 ± 0.07	13,370 ± 540	13,310 ± 540	Clayey silty subsoil collected 33-38 cm below sand blow
STR-OSL1 BG4886 1.3	40/40	38-63	39.73 ± 0.95	9 ± 1	3.33 ± 0.01	10.55 ± 0.01	1.63 ± 0.01	10 ± 2	0.17 ± 0.02	3.16 ± 0.07	12,560 ± 405	12,500 ± 405	Clayey silty subsoil collected 32-37 cm below sand blow
SITE DBNW5													
OSL1 BG4894 0.53	20/20	250-355	38.89 ± 1.14	11 ± 2	2.17 ± 0.01	5.87 ± 0.01	1.74 ± 0.01	20 ± 3	0.21 ± 0.02	3.15 ± 0.03	13,950 ± 1,330	12,890 ± 1,330	Buried silty soil collected 3-5 cm below sand blow
OSL2 BG4895 0.77	20/20	150-250	45.28 ± 1.67	15 ± 3	3.20 ± 0.01	8.62 ± 0.01	1.68 ± 0.01	20 ± 3	0.19 ± 0.02	3.41 ± 0.08	17,080 ± 635	17,020 ± 635	Silty subsoil collected 25-30 cm below sand blow

* Aliquots measured and used to define De population by Central Age or Minimum Age Model (Galbraith and Roberts, 2012).

† Equivalent dose calculated on a pure quartz fraction with ultra-small aliquots with 20-80 grains/aliquot and analyzed under blue-light excitation (470 ± 20 nm) by Single Aliquot Regeneration protocols (SAR; Murray & Wintle, 2003; Wintle & Murray, 2006). Equivalent dose (De) was calculated by Central Age or Minimum Age model when overdispersion values are < 20% (at two sigma) and >20% (at two sigma) and assuming a normal data distribution (Galbraith and Roberts, 2012; Liang and Forman, 2019).

‡ Overdispersion values reflects precision beyond instrumental errors; values of ≤ 20% (at 1 sigma limit) indicate low dispersion in equivalent dose values and defines a unimodal distribution. Values > 20% are associated with mixed equivalent dose signature reflecting multiple grain populations or partial solar resetting.

§ U, Th, and K content analyzed by inductively coupled plasma-mass spectrometry by ALS Laboratories, Reno, NV; and includes dose contribution from Rb.

ǁ Includes a cosmic dose rate calculated from parameters in Prescott and Hutton (1994) and includes soft components (Liang and Forman, 2019).

\# Systematic and random errors calculated in a quadrature at one standard deviation by the Luminescence Dating and Age Calculator (LDAC) at https://www.baylor.edu/geosciences/index.php?id=962356 (Liang and Forman, 2019). Datum year is AD 2010. OSL ages determined at Geoluminescence Dating Research Laboratory, Dept. of Geosciences, Baylor University, Waco, TX, USA.

Table S5. Results of Optically-Stimulated Luminescence Ages on Quartz Grains from Sediment Associated with Sand Blows (4/30/2020).

Sample Lab No. Depth (m)	Aliquot*	Grain Size (µm)	Equivalent Dose (De) (Gy)[†]	Over-dispersion (%)[‡]	U (ppm)[§]	Th (ppm)[§]	K (%)[§]	Rb (ppm)	H20 (%)	Cosmic Dose Rate (mGray/yr)[ǀ]	Dose Rate (mGray/yr)	OSL Age (Yr)[#]	OSL Age Yr. B.P. (AD 1950)	Sample Description
SITE DBNW5														
OSL3 BG5807 1.65	25/25	32-63	16.27 ± 0.16	6 ± 1	3.53 ± 0.01	10.45 ± 0.01	2.11 ± 0.01	110.0 ± 0.1	15 ± 2	0.175 ± 0.017	3.14 ± 0.06	5,170 ± 120	5,110 ± 120	Top of soil buried by sand blow
OSL4 BG5808 1.78	20/20	32-63	22.74 ± 0.28	5 ± 1	3.44 ± 0.01	10.70 ± 0.01	2.09 ± 0.01	103.5 ± 0.1	15 ± 2	0.172 ± 0.017	3.12 ± 0.06	7,535 ± 235	7,475 ± 235	Clayey silt, 13 cm below OSL3
SITE DBNW7														
OSL1 BG5803 0.46	50/50	250-355	31.98 ± 2.70	44 ± 4	1.26 ± 0.01	4.31 ± 0.01	1.72 ± 0.01	55.5 ± 0.1	10 ± 2	0.220 ± 0.022	1.96 ± 0.05	16,345 ± 1,395	16,285 ± 1,395	Upper portion of sand blow
OSL2 BG5804 1.56	30/32	150-250	120.98 ± 5.44	24 ± 3	3.21 ± 0.01	8.94 ± 0.01	2.06 ± 0.01	79.2 ± 0.1	10 ± 2	0.177 ± 0.018	2.91 ± 0.06	41,505 ± 2,060	41,445 ± 2,060	Top of soil buried by sand blow
OSL3 BG5805 1.68	20/20	32-63	22.74 ± 0.28	5 ± 1	3.21 ± 0.01	9.18 ± 0.01	2.14 ± 0.01	84.2 ± 0.1	10 ± 2	0.174 ± 0.017	3.01 ± 0.06	7,260 ± 180	7,200 ± 180	Clayey silt, 12 cm below OSL2
OSL4 BG5806 0.45	29/30	150-250	35.26 ± 0.21	4 ± 1	1.26 ± 0.01	4.09 ± 0.01	1.78 ± 0.01	56.3 ± 0.1	10 ± 2	0.221 ± 0.022	2.04 ± 0.05	17,265 ± 1,350	17,205 ± 1,350	Upper portion of sand blow
SITE DBNW8														
OSL1 BG5797 0.42	20/20	150-250	39.63 ± 0.46	40 ± 8	1.52 ± 0.01	4.67 ± 0.01	1.80 ± 0.01	59.0 ± 0.1	10 ± 2	0.223 ± 0.022	2.15 ± 0.05	18,435 ± 495	18,375 ± 495	Upper portion of sand blow
OSL2 BG5798 0.92	21/25	150-250	>130	NC	2.23 ± 0.01	5.99 ± 0.01	1.88 ± 0.01	61.2 ± 0.1	10 ± 2	0.1986 ± 0.019	2.4 ± 0.05	>54,200	>54,140	Top of soil buried by sand blow
OSL3 BG5799 1.10	20/20	32-63	59.32 ± 0.79	5 ± 1	3.30 ± 0.01	10.60 ± 0.01	2.12 ± 0.01	92.2 ± 0.1	10 ± 2	0.186 ± 0.019	3.27 ± 0.07	18,115 ± 455	18,055 ± 455	Clayey silt, 18 cm below OSL2
OSL4 BG5800 0.34	24/24	150-250	40.75 ± 2.87	38 ± 6	1.54 ± 0.01	4.81 ± 0.01	1.82 ± 0.01	56.2 ± 0.1	10 ± 2	0.229 ± 0.023	2.18 ± 0.05	18,665 ± 1,345	18,605 ± 1,345	Upper portion of sand blow
OSL5 BG5801 0.95	20/20	32-63	20.12 ± 0.21	4 ± 1	3.57 ± 0.01	9.35 ± 0.01	1.98 ± 0.01	81.9 ± 0.1	10 ± 2	0.185 ± 0.018	3.14 ± 0.07	6,395 ± 150	6,335 ± 150	Buried soil, 8 cm below sand blow

OSL6 BG5802 1.25	23/23	32-63	21.88 ± 1.60	4 ± 1	3.44 ± 0.01	11.20 ± 0.01	1.96 ± 0.01	85.6 ± 0.1	10 ± 2	0.183 ± 0.018	3.18 ± 0.07	15,045 ± 365	14,985 ± 365	Clayey silt, 30 cm below OSL5

* Aliquots measured and used to define De population by Central Age or Minimum Age Model (Galbraith and Roberts, 2012).

† Equivalent dose calculated on a pure quartz fraction with ultra-small aliquots with 20-80 grains/aliquot and analyzed under blue-light excitation (470 ± 20 nm) by Single Aliquot Regeneration protocols (SAR; Murray & Wintle, 2003; Wintle & Murray, 2006). Equivalent dose (De) was calculated by Central Age or Minimum Age model when overdispersion values are < 20% (at two sigma) and >20% (at two sigma) and assuming a normal data distribution (Galbraith and Roberts, 2012; Liang and Forman, 2019).

‡ Overdispersion values reflects precision beyond instrumental errors; values of ≤ 20% (at 1 sigma limit) indicate low dispersion in equivalent dose values and defines a unimodal distribution. Values > 20% are associated with mixed equivalent dose signature reflecting multiple grain populations or partial solar resetting.

§ U, Th, Rb and K content analyzed by inductively coupled plasma-mass spectrometry by ALS Laboratories, Reno, NV.

‖ Includes a cosmic dose rate calculated from parameters in Prescott and Hutton (1994) and includes soft components (Liang and Forman, 2019).

Systematic and random errors calculated in a quadrature at one standard deviation by the Luminescence Dating and Age Calculator (LDAC) at https://www.baylor.edu/geosciences/index.php?id=962356 (Liang and Forman, 2019). Datum year is AD 2010. OSL ages determined at Geoluminescence Dating Research Laboratory, Dept. of Geosciences, Baylor University, Waco, TX, USA.

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