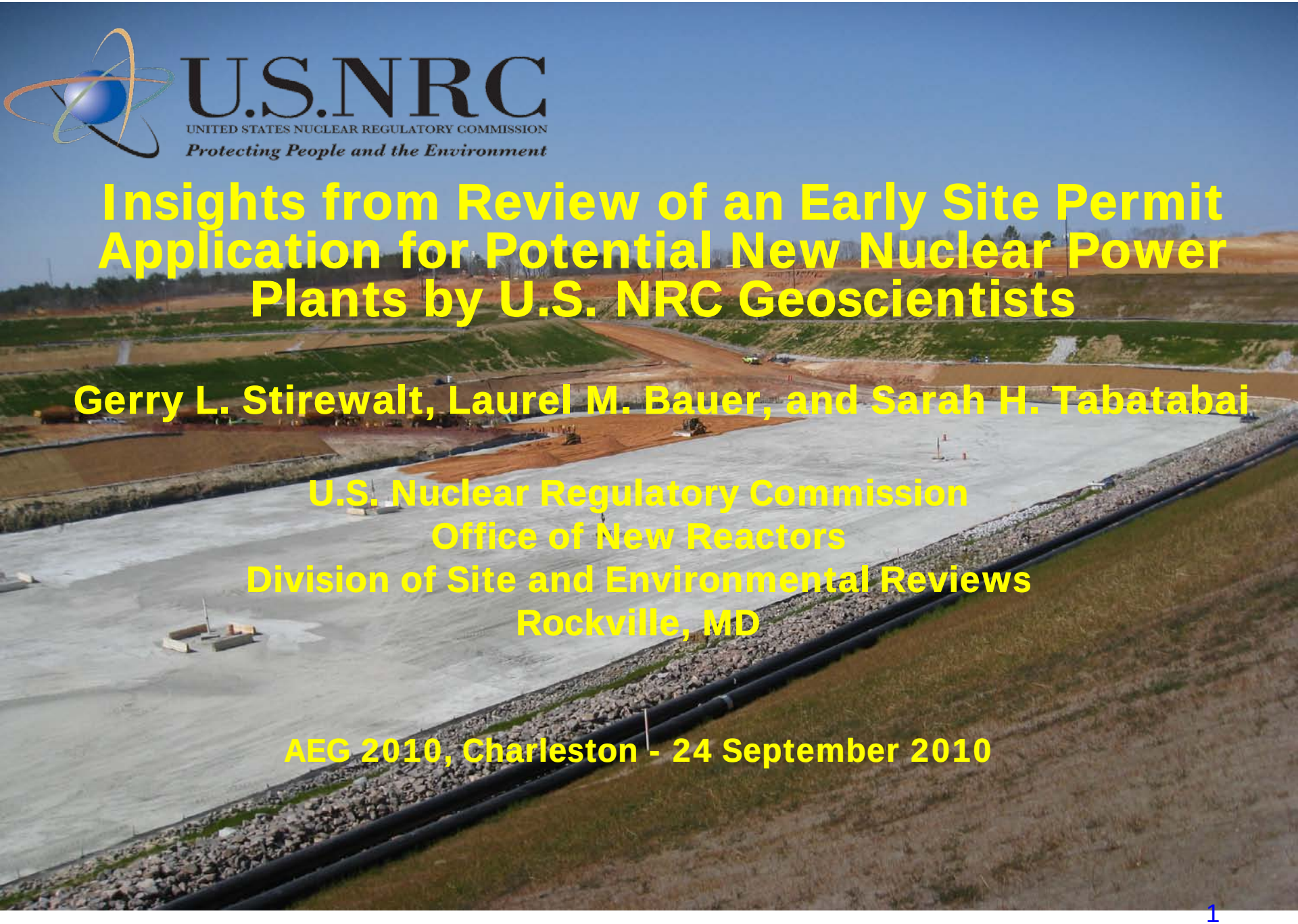

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Insights from Review of an Early Site Permit Application for Potential New Nuclear Power Plants by U.S. NRC Geoscientists

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AEG 2010, Charleston - 24 September 2010

Geoscience and Licensing of New Reactors

Utilities are actively submitting applications to construct new commercial nuclear power facilities. Seismology and geology are fundamental components of the applicant's licensing process for:

(1) Selecting a suitable site for the nuclear power facility.

(2) Designing and constructing the facility to ensure safe operation in light of potential geologic and seismic hazards that may affect the proposed site.

NRC geoscientists follow regulatory requirements and guidelines to ensure that any utility applying for a license to construct a new facility has assessed all potential geologic and seismic hazards for the proposed site. Also document conclusions in a publically-available Site Evaluation Report (SER).

NRC Regulatory Requirements

Regulatory requirements are found in Title 10 of the Code of Federal Regulations (10 CFR).

- 10 CFR Part 52 – "Licenses, Certifications, and Approvals for Nuclear Power Plants"
  - Defines geologic and seismic characteristics of a proposed site that **must** be described by the applicant in a Safety Analysis Report (SAR) as part of the application process.
- 10 CFR Part 100.23 – "Geologic and Seismic Siting Criteria"
  - Further defines principle geologic and seismic factors that **must** be considered for evaluating site suitability and adequacy of design bases in light of geologic and seismic characteristics.

NRC Regulatory Guidelines

Regulatory Guides (RGs) were prepared by NRC technical experts to provide **guidance** to applicants regarding appropriate technical content for an SAR.

- RG 1.132 – "Site Investigations for Foundations of Nuclear Power Plants" (October 2003).
- RG 1.208 – "A Performance-Based Approach to Define Site-Specific Earthquake Ground Motion" (March 2007).
  - Guidance for characterizing geology and seismicity of the site region (320-km [200-mi] radius), vicinity (40-km [25-mi]), area (8-km [5-mi]), and location (1-km [0.6-mi] radius).
  - Defines information needed on earthquake source zone parameters (e.g., recurrence rate and maximum magnitude) for Probabilistic Seismic Hazard Analysis (PSHA).

NRC Review of the Vogtle ESP Application

Information reviewed by NRC geologists and seismologists was submitted by the applicant in SAR Section 2.5 titled "Geology, Seismology, Geotechnical Engineering".

- Applicant proposed two units for the Vogtle site, located along the Savannah River in the Coastal Plain physiographic province of eastern Georgia. Potential technical issues included:
  - Basement rocks underlying Coastal Plain units lie in a seismotectonic terrane affected by Mesozoic extension, a setting known to exhibit increased seismicity compared to more stable continental areas.
  - Meizoseismal area for the 1886 Charleston earthquake lies in the site region, approximately 150 km (85 mi) southeast of the site.
  - The Pen Branch Fault (PBF), a Mesozoic extensional normal fault reactivated as a reverse fault during the Cenozoic, dips beneath proposed Units 2 and 3 based on seismic reflection data.
  - Injected sand dikes indicate liquefaction of Eocene sands at the site.

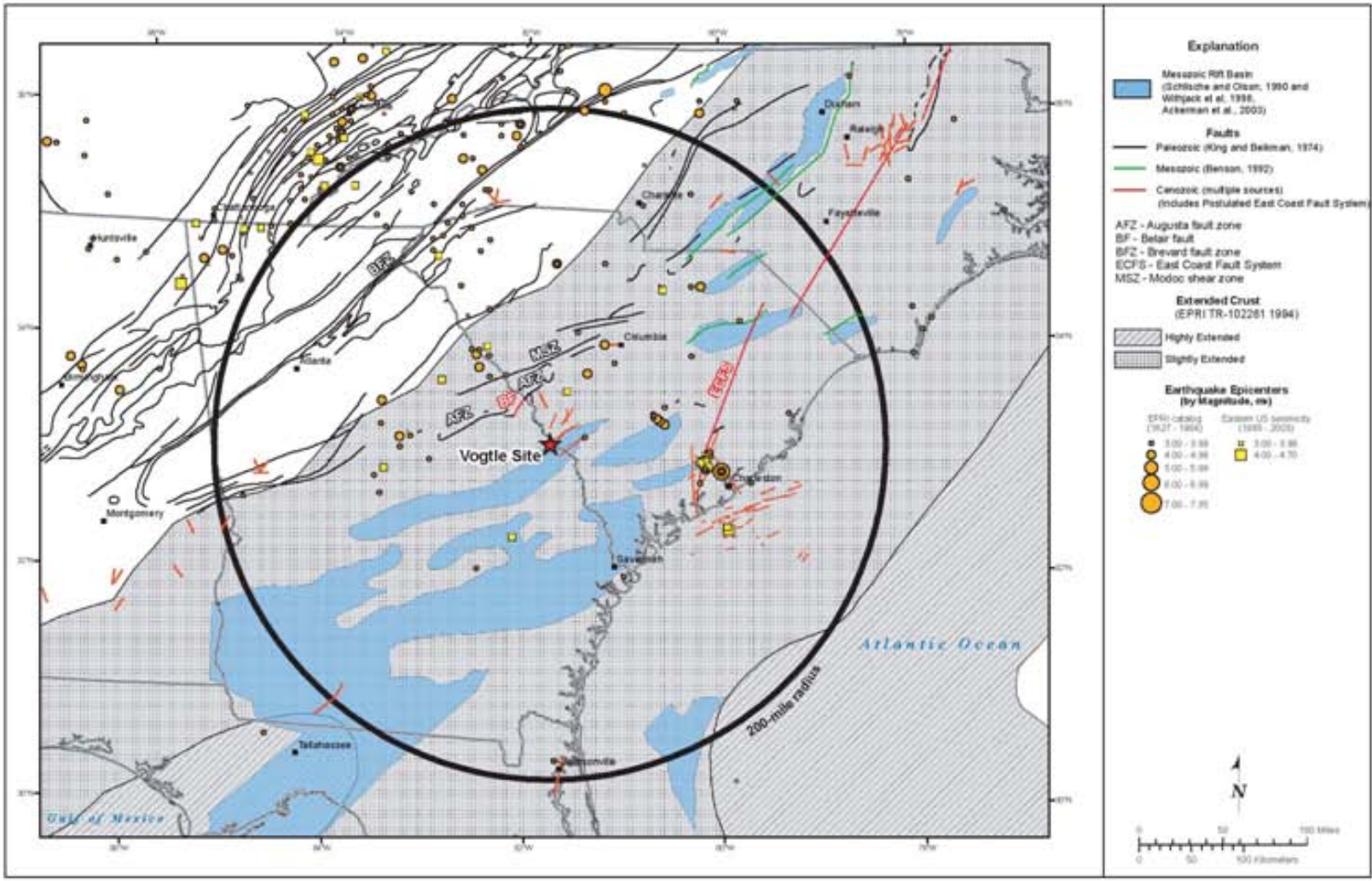


Figure 2.5.1-13 Regional Tectonic Features Map (200-Mile Radius)

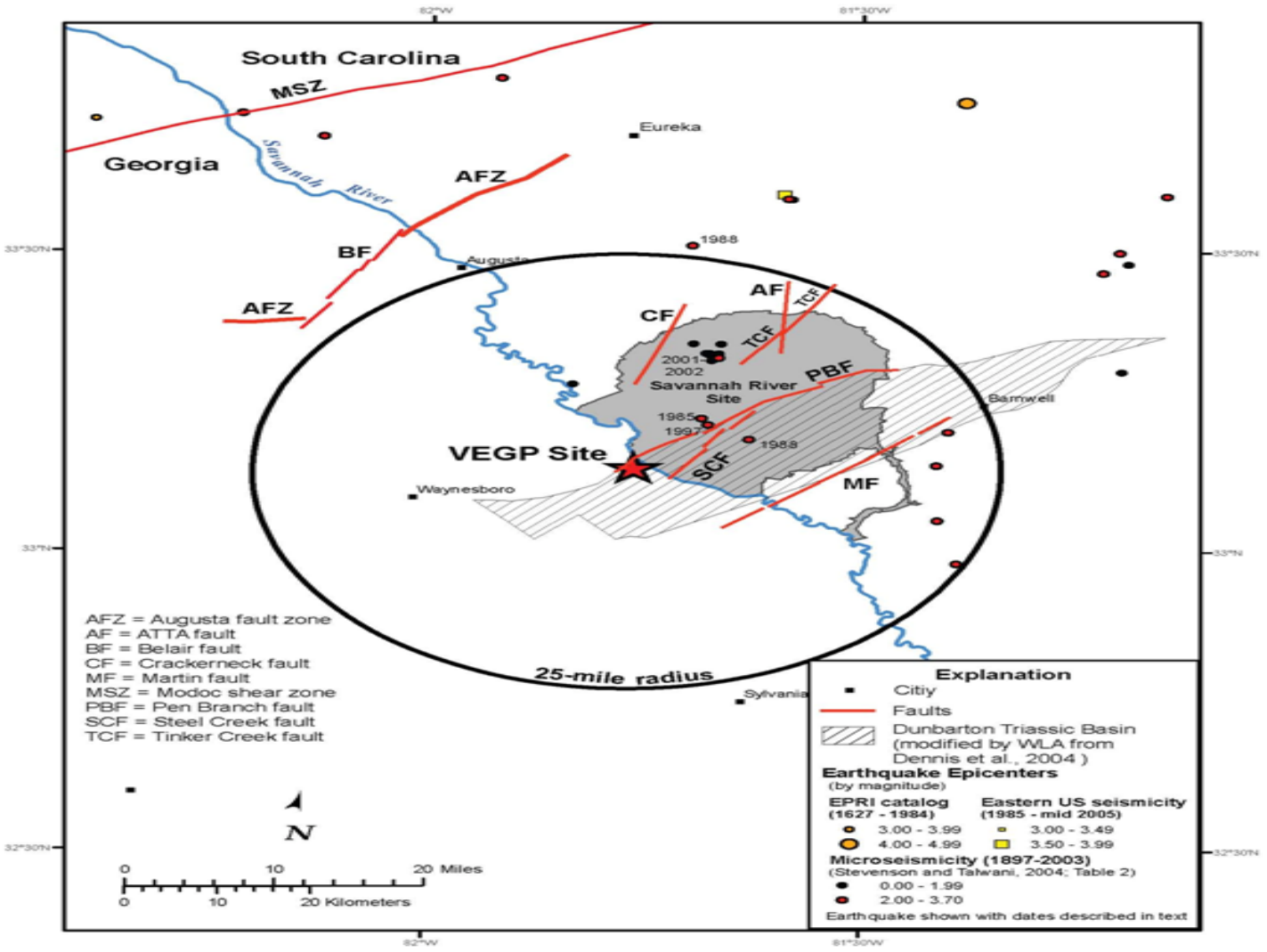


Figure 2.1-16 Site Vicinity Tectonic Features and Seismicity

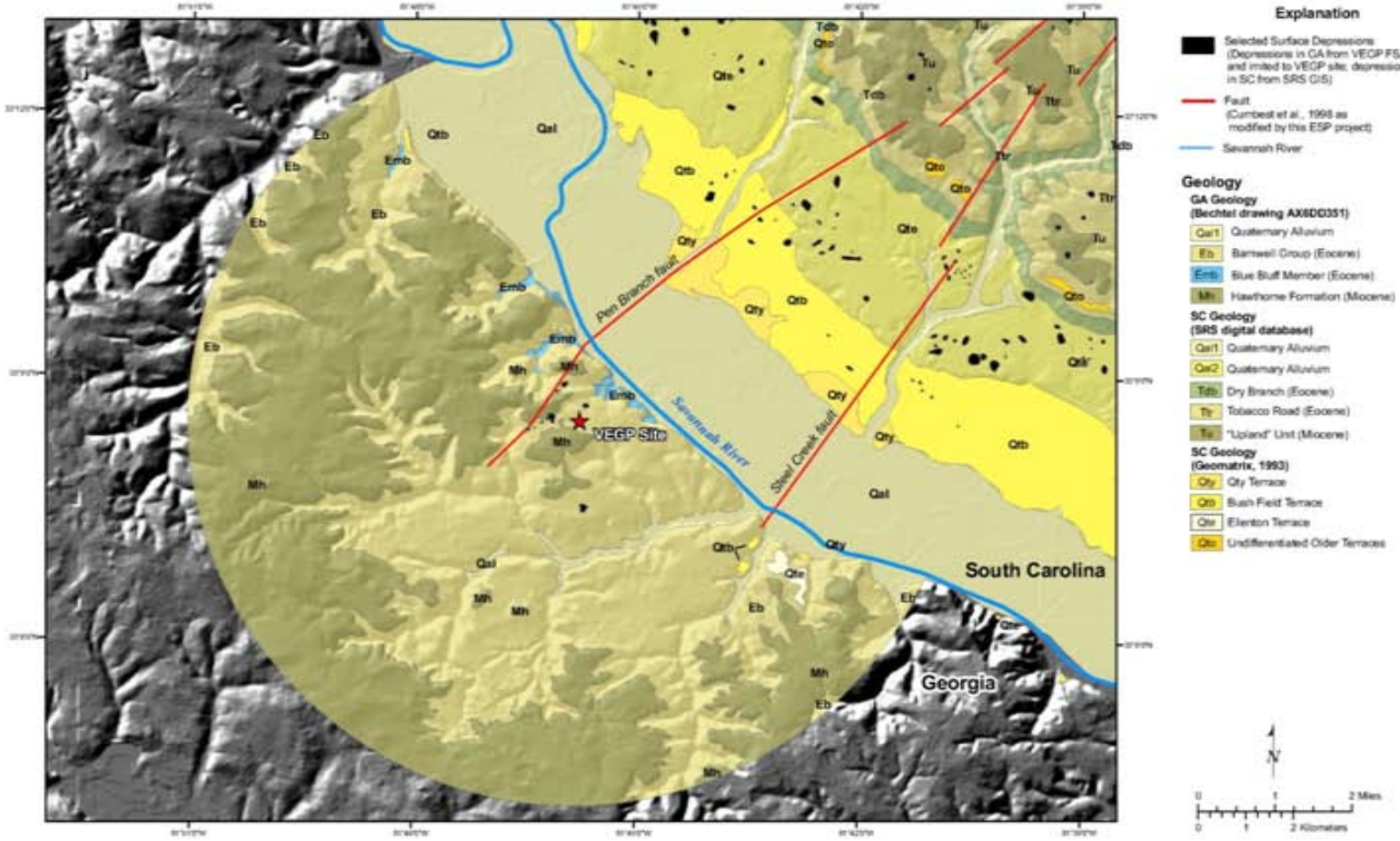


Figure 2.5.1-29 Site Area Geologic Map (5-Mile Radius)

Is the Pen Branch Fault a Capable Tectonic Structure?

NRC geologists assessed information used by the applicant to characterize the PBF.

- Geologic characteristics of the PBF:
  - Northwestern border fault of the Dunbarton Triassic Basin.
  - Originally an extensional normal fault which was reactivated as a reverse fault during the Cenozoic.
  - About 40 km (25 mi) in length, strikes N46-66E, and dips 60-75SE beneath proposed Units 2 and 3 based on seismic reflection data.
  - Exhibits no surface expression or spatially-associated seismicity, so location was defined based on borehole and seismic reflection data.

Applicant's Interpretation of the PBF

Using geologic field data, applicant concluded that the PBF was not a capable tectonic structure (i.e., older than Quaternary, so >2.6 Ma).

- Applicant documented that no stratigraphic evidence indicates any displacement more recent than Eocene (i.e., not <33.9 Ma).
  - Seismic reflection data showed no disruption of sedimentary units younger than Eocene.
  - No tectonic deformation of units overlying the Eocene Blue Bluff Marl (BBM) was observed in trenches crossing the projected surface trace of the PBF, including above a fault-related monoclinal flexure in the BBM.
- Based on 2600 elevation points surveyed atop a Quaternary fluvial terrace which crosses the projected surface trace of the PBF, the applicant documented that the terrace does not show any tectonic deformation due to slip on the PBF.

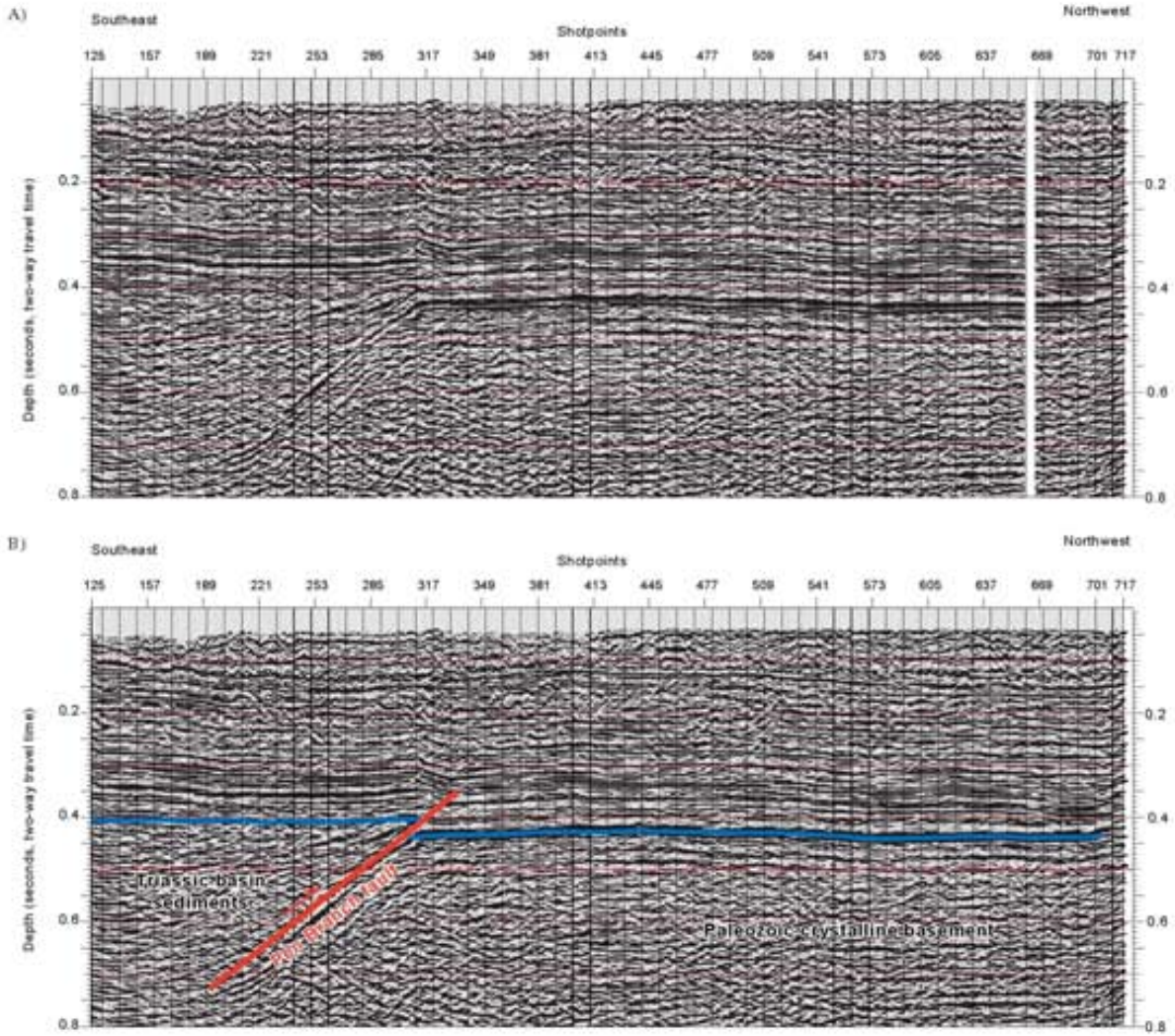


**Figure 2.5.1-37 (A) Seismic Reflection Line 4 (Time Section; Display Velocity = 12,000 fps)
(B) Interpretation (Blue Line Represents Top of Basement)**

Quaternary Fluvial Terrace Crossing Projected Surface Trace of the Pen Branch Fault at SRS

Results of NRC Assessment of the PBF

NRC geologists performed a detailed technical review of data and conclusions presented in the SAR, conducted independent literature research, examined borehole data, and assessed the field evidence for lack of tectonic deformation of the Quaternary fluvial terrace.

- Concluded that the applicant's interpretation of the PBF as a non-capable tectonic structure was correct.
- Applicant was not required to include the PBF in PSHA for determination of ground motion response spectra (GMRS) and analysis of site-specific seismic response.

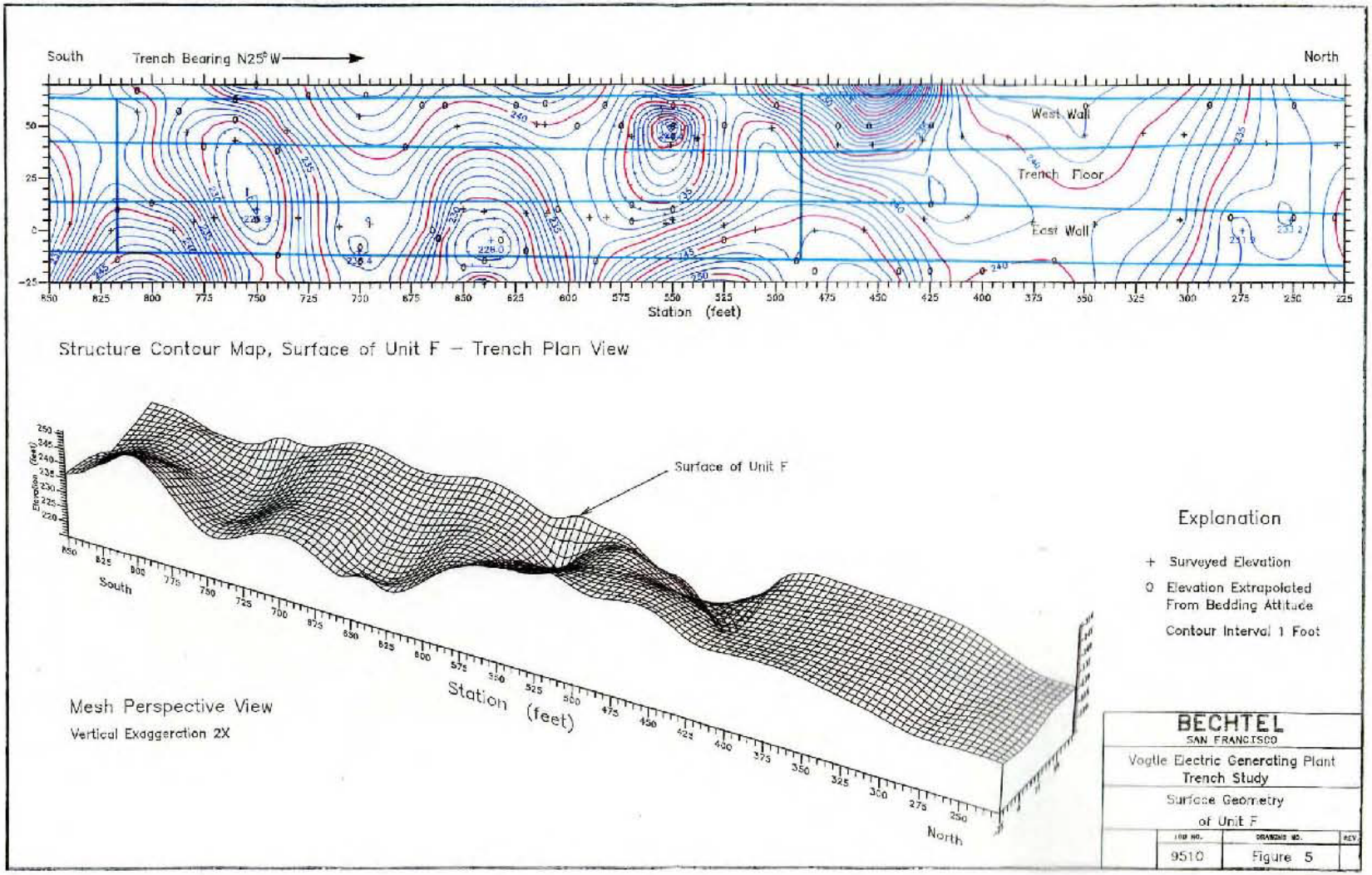
Do Injected Sand Dikes Represent Earthquake-Induced Paleoliquefaction?

NRC geologists/paleoseismologists assessed information used by the applicant to characterize the injected sand dikes.

- Geologic characteristics of the dikes and spatially-related features:
  - Mapped (1984) in a 900-ft long trench cut into Eocene sedimentary units above the projected surface trace of the PBF.
  - Observed only at three locations in the trench and nowhere else on or off the site during ESP site characterization investigations.
  - Show liquefaction of sands overlying the Utley Limestone, which lies atop the BBM (i.e., the foundation unit).
  - Injected dikes confined to a single Eocene horizon, Unit D of the Barnwell Group, which also contains the Utley LS and BBM.
  - Sands were derived from underlying Unit C of the Barnwell Group.

Do Injected Sand Dikes Represent Earthquake-Induced Paleoliquefaction?

- Geologic characteristics of the dikes and spatially-related features (Cont'd):
  - Barnwell sands locally exhibit warped bedding, fractures, and small-scale faults at the same three locations which are spatially associated with depressions related to dissolution of the underlying Utley LS.
  - The localized dissolution depressions to which all deformation features are spatially related, including the injected sand dikes, are defined by an "egg carton" geometry of the surface of Unit F, one of the Barnwell Group units overlying Units C and D.



RAI Figure 2.5.3-2B. Surface Geometry of Unit F Illustrating Localized Nature of Deformation

Dissolution Cavity in Utley LS Overlying the Blue Bluff Marl, Vogtle Unit 3 Excavation

Applicant's Interpretation of Injected Dikes

Using geologic field data, applicant concluded that injected sand dikes formed due to liquefaction and injection resulting from collapse of wet sediments above dissolution features in the Utley LS, rather than from a paleoearthquake.

- Applicant documented the spatial association of local deformation features, including the injected sand dikes, with dissolution collapse depressions in the Utley LS.
  - Data showed deformation features and injected sand dikes occurred at the margins of discontinuous, irregular contoured lows on the surface of Unit F, which defined locations of subsurface dissolution depressions; and the dikes predated a Miocene erosional event (i.e., >5.3 Ma).
  - No liquefaction of sand units was observed at locations other than where spatially associated with dissolution of the Utley LS.

Results of NRC Assessment of Injected Dikes

NRC geologists/paleoseismologists performed a detailed technical review of data and conclusions presented in the SAR, and requested and reviewed additional data related to origin of the injected sand dikes, including the 1984 trench log, to assess field evidence for origin of the injected sand dikes.

- Concluded that the applicant's interpretation of a non-tectonic origin for the injected sand dikes was correct.
- Applicant was not required to represent a local earthquake source for the injected sand dikes in PSHA for determination of the GMRS and analysis of site-specific seismic response.

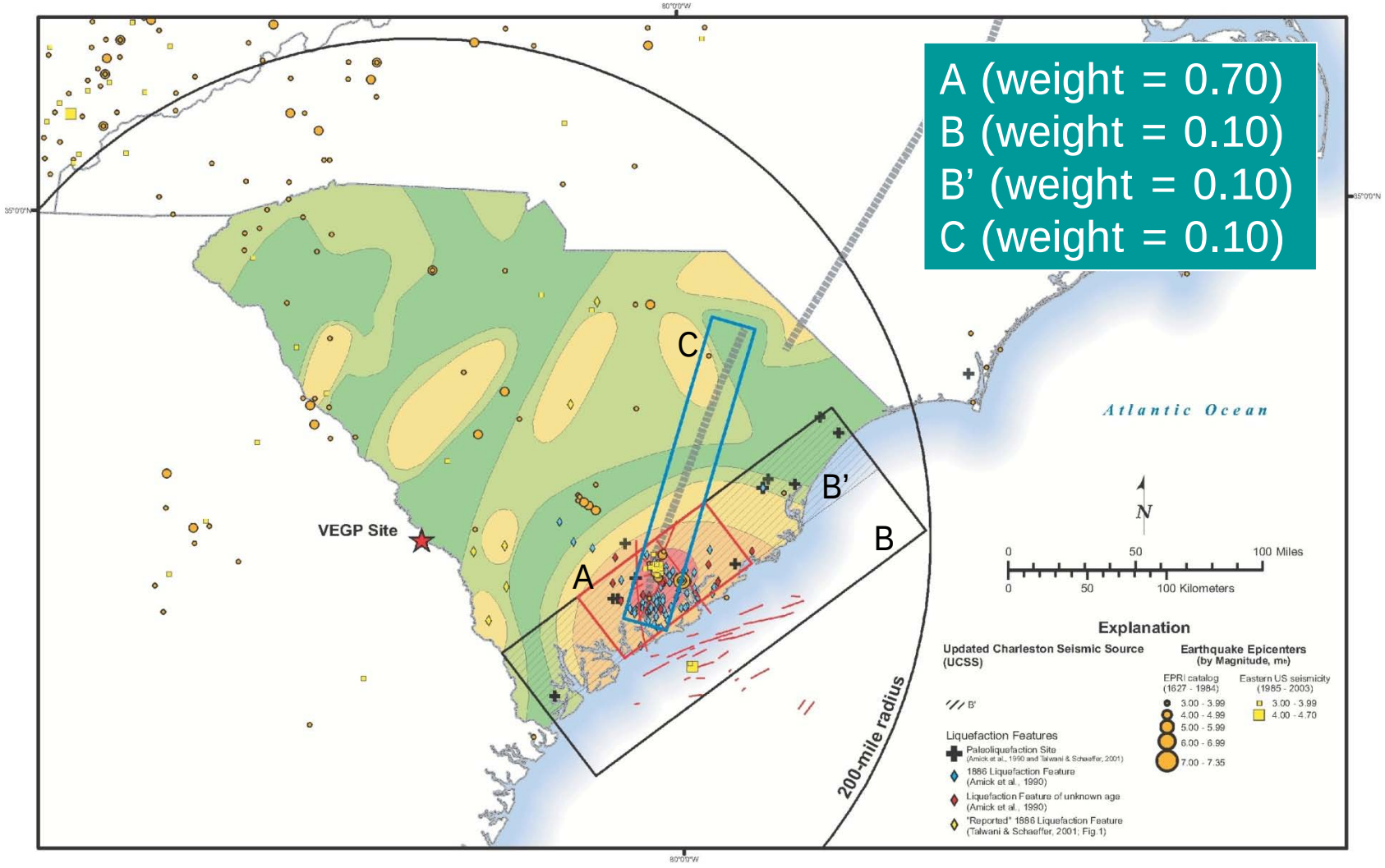
Were Current Data Used to Analyze the Charleston Area Seismic Source?

- Charleston Area Liquefaction Features
  - Liquefaction features resulting from historic and prehistoric earthquakes have been mapped about 209 km (130 mi) northeast and southwest of Charleston along the South Carolina coast and greater than 105 km (65 mi) inland.
  - Applicant documented that inland liquefaction features were characteristic of a localized Charleston earthquake source, rather than a separate inland source.
  - Observed liquefaction features represent 5 earthquakes of similar magnitude, in addition to the 1886 event, during approximately the last 5000 years.

Charleston Seismic Source Zone and Analysis of Site Vibratory Ground Motion

- Updated Charleston Seismic Source (UCSS) Model Parameters
  - Applicant's update of the 1986 EPRI source model for the UCSS model involved changes in source geometry, maximum earthquake magnitude (M_{max}), and recurrence interval.
    - UCSS Geometry "A" (weight = 0.7) is centered on the 1886 Charleston meizoseismal area, includes the majority of inferred fault intersections and most reported 1886 liquefaction features, and envelopes instrumentally-located earthquakes spatially associated with the Middleton Place-Summerville seismic zone.
    - UCSS weighted M_{max} mean magnitude = **M**7.1.

UCSS Zone Geometries A, B, B', C and Distribution of Liquefaction Features



Charleston Seismic Source Zone and Analysis of Site Vibratory Ground Motion

- UCSS Model Parameters (Cont'd)
  - Based on liquefaction features generated by historic and prehistoric earthquakes in the Charleston area, average recurrence interval for M_{max} earthquakes decreased from several thousand, to less than one thousand, years for the UCSS model.

Results of NRC Assessment of the UCSS Model

- NRC seismologists performed a detailed technical review of data and conclusions presented in the SAR and independently assessed all data related to development of the UCSS model.
  - Concluded that the GMRS calculated by the applicant for the Vogtle site using the UCSS model with updated parameters adequately represents regional and local seismic hazard and meets applicable regulatory requirements in 10 CFR Part 52 and 10 CFR Part 100.23.

Role of NRC Geoscientists in Public Hearings

- Testified before a panel of judges in legal public hearings conducted for the Vogtle site, which included working closely with NRC legal staff to prepare for and participate in the hearings.
  - Presented the logic for all conclusions regarding potential geologic and seismic hazards for the Vogtle site, as discussed in the SER.
  - Based on results of the review and assessment of the applicant's SAR, supported the applicant's request for an Early Site Permit (ESP) and a Limited Work Authorization (LWA) to begin foundation excavations for Units 3 and 4.

Vogtle Unit 3 Excavation - Geologists as Scale

Role of NRC Geologists in Examination of Foundation Excavations

- Directly examined the foundation unit (BBM) and sedimentary materials overlying the BBM in excavations for Units 3 and 4, as well as geologic maps and cross sections of excavation walls and floors prepared by the applicant.
  - Assured that no features indicative of capable tectonic structures (i.e., Quaternary faults or earthquake-induced liquefaction) occurred in the excavations.
  - Because the Utley LS overlying the BBM was removed during excavation of Units 3 and 4, NRC geologists did not consider dissolution to pose a geologic hazard for the site.

NRC Geoscientists Fulfilled NRC Mission of Protecting Public Health and Safety and the Environment

- Interfaced with geotechnical engineers, hydrologists, structural engineers, and environmental scientists.

- Determined that the applicant investigated geologic and seismic site characteristics in sufficient detail to:

  - Allow adequate evauation of the site in regard to potential for surface or near-surface faulting.
  - Support analysis of site vibratory ground motion.
  - Permit adequate engineering solutions for potential and actual geologic and seismic hazards at the site.

... and successfully avoided being compressed into excavation backfill ...