Exelon.
Generation

NP-11-0037
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10 CFR 52, Subpart A

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Subject: Exelon Nuclear Texas Holdings, LLC
Victoria County Station Early Site Permit Application
Response to Request for Additional Information Letter No. 07
NRC Docket No. 52-042

Attached are responses to NRC staff questions included in Request for Additional Information (RAI) Letter No. 07, dated April 8, 2011, related to Early Site Permit Application (ESPA), Part 2, Sections 02.04.06, 02.05.02, and 11.02. NRC RAI Letter No. 07 contained twenty Questions. This submittal comprises the final partial response to RAI Letter No. 07, and includes response to the following three (3) Questions:

02.05.02-3 a, b, c

When a change to the ESPA is indicated by a Question response, the change will be incorporated into the next routine revision of the ESPA, planned for no later than March 31, 2012.

Of the remaining seventeen (17) RAIs associated with RAI Letter No. 07, responses to seven (7) Questions were submitted to the NRC in Exelon Letter NP-11-0016, dated May 5, 2011, responses to seven (7) Questions were submitted to the NRC in Exelon Letter NP-11-0020, dated May 23, 2011, response to one (1) Question was submitted to the NRC in Exelon Letter NP-11-0025, dated June 17, 2011, and responses to two (2) Questions were submitted to the NRC in Exelon Letter NP-11-0028, dated June 30, 2011. This submittal completes the Exelon response to NRC RAI Letter No. 07, dated April 8, 2011.

No new regulatory commitments are contained in this submittal. If any additional information is needed, please contact David J. Distel at (610) 765-5517.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 4th day of August, 2011.

Respectfully,

Marilyn C. Kray

Marilyn C. Kray
Vice President, Nuclear Project Development

Attachments:
1. Question 02.05.02-3 a, b, c

cc: USNRC, Director, Office of New Reactors/NRLPO (w/Attachments)
USNRC, Project Manager, VCS, Division of New Reactor Licensing (w/Attachments)
USNRC Region IV, Regional Administrator (w/Attachments)

RAI 02.05.02-3 a, b, c:

Question:

In SSAR Section 2.5.2.2, the applicant discussed the EPRI-SOG model seismic source characterizations used in the PSHA for the VCS site. In accordance with 10 CFR 100.23, the staff requests the applicant provide additional information regarding its seismic source characterizations.

(a) As shown in SSAR Figure 2.5.2-5, the boundary of the Dames and Moore New Mexico source (67) appears to include a reentrant that loops northwestward from the northern boundary of the Quachitas Fold belt through southeastern New Mexico and back. This feature does not appear to be represented by any of the Dames and Moore sources but encloses the January 2, 1992, and April 14, 1995, earthquakes [magnitudes (Emb) 5.0 and 5.6, respectively]. Please discuss this source's contribution to the VCS site hazard in light of this reentrant feature.

(b) SSAR Figure 2.5.2-7 demonstrates that the Rondout background 50 zone encloses the January 2, 1992, and April 14, 1995, earthquakes [magnitudes (Emb) 5.0 and 5.6, respectively]. These magnitudes are greater than m_b 4.8, the smallest value in the Mmax distribution for the Rondout zone (SSAR Table 2.5.2-10). Please explain why the Rondout background 50 zone was not updated to reflect these two recent earthquakes.

(c) SSAR Section 2.5.2.4.3 describes the applicant's interpretation of the tectonic environment that produced the moderate-sized (Emb 5.6) earthquake on April 14, 1995 in Western Texas. The applicant created a new seismic source to accommodate potential hazard that results from the Rio Grande Rift (RGR). Please discuss how the applicant reached the conclusion that the April 14, 1995 earthquake is tectonically related to the RGR system. Please also provide further information on how the hazard calculated at the VCS site would be impacted if the applicant updated the EPRI source model parameters that encompass the earthquake rather than attributing the event to an eastward extension of the RGR.

Response:

(a) As described in SSAR Section 2.5.2.2.1 and 2.5.2.2.1.2, SSAR Figure 2.5.2-5 shows the EPRI-SOG source zones for the Dames & Moore Earth Science Team (EST) that are within 200 miles of the VCS site. The "reentrant" in SSAR Figure 2.5.2-5 that is noted in the RAI question as not having a source zone is over 250 miles from the VCS site, and therefore the source zone for that region was not included in the figure. This "reentrant" region is filled by the Delaware Basin (zone 26), the Delaware Aulacogen (zone 27), and the default zone for zones 26 and 27 (zone 26b) (Figure 1) (EPRI, 1989). The general approach used to select potential source zones to be included in the source model is based on guidance discussed in Section 5.5.1 of the EQHAZARD Primer (EPRI, 1989) titled "*Selection of Seismic Sources-Development of Source Files*", which states:

> "The first step in the application of EQPARAM is to select, from the seismic sources identified by each Team, the sources that may contribute to earthquake hazard at the site. Typically, one must include all sources within

100 km of the site and highly active sources within 200 km – a simpler criterion is to include all sources within 200km of the site." (p. 5-11).

Based on this guidance, all sources within 200 miles (320 kilometers) of the VCS Site were included in the seismic source model (which is a greater distance than the 200 kilometer distance suggested by the EQHAZARD Primer). Thus, zones 26, 26b, and 27 were screened out of the seismic hazard calculations because they are over 250 miles from the VCS site.

Source zones 26, 27 and 26b were considered in the sensitivity analysis that is discussed in part (c) of this response (see Tables 1 and 2). See part (c) for a detailed discussion. The results of this sensitivity analysis—which incorporated a modified Mmax distribution larger than both the January 2, 1992 5.0 and the April 14, 1995 5.6 earthquakes—demonstrated that the potential impact (in percent difference in rock UHRS values) of the updated characterization is not significant.

The impact of the April 14, 1995 earthquake is discussed separately in response to part (c) of this RAI.

(b) Rondout zone 50 (also referred to as the Grenville Province, zone C02) is described within the EPRI-SOG documentation as having a Mmax distribution, with weights in parentheses, of mb 4.8 (0.2), 5.5 (0.6), and 5.8 (0.2) (SSAR Table 2.5.2-10). The Mmax values for this zone were not updated to take into account the January 2, 1992 Emb 5.0 earthquake because the earthquake is located 2.5 kilometers outside of Rondout Zone 50. Therefore, there is no need to update the Mmax distribution for zone 50.

Rondout zone 50 (C02) was considered in the sensitivity analysis discussed as part (c) of this response (see Tables 1 and 2). As part of this sensitivity analysis the Mmax distribution for zone 50 (C02) was updated with a minimum Mmax distribution of mb 5.8. The results of this sensitivity analysis demonstrated that the potential impact (in percent difference in rock UHRS values) of the updated characterization is not significant.

The basis for not updating Rondout zone 50 due to the April 14, 1995 Emb 5.6 earthquake (i.e., the Alpine earthquake) is described in the response to part (c) of this RAI.

(c) This RAI question asks for: (1) information supporting the conclusion that the April 14,1995 earthquake (the Alpine earthquake) is related to the Rio Grande Rift (RGR), and (2) information on how rejecting this interpretation would impact the seismic hazard at the VCS site. The response to these two requests is divided into several parts. First, the seismotectonic setting of the Alpine earthquake is discussed, and it is demonstrated that the most widely held interpretation is that the Alpine earthquake is related to Rio Grande Rift (RGR) seismotectonics. Second, the EPRI-SOG source zones that contain the Alpine earthquake are reviewed, and it is demonstrated that the EPRI-SOG earth science teams (ESTs) did not intend for these source zones that contain the Alpine earthquake to characterize regions associated with the RGR. Based on this information, it is concluded that it is not appropriate to use the Alpine earthquake as a basis for updating the parameters for these source zones. Despite the conclusion that the EPRI-SOG sources should not be updated to account for the Alpine earthquake, the third and fourth parts presented below describe how the Alpine earthquake could potentially be used to conservatively modify the EPRI-SOG source characterizations and how these updates would impact the VCS UHRS. This analysis demonstrates that the impacts of these conservative potential updates on the site hazard are not significant. For example, the greatest percentage difference in the mean rock UHRS over the values presented in the SSAR at annual probabilities of exceedance of 10^{-4}, 10^{-5}, and 10^{-6} are 0.26% at 25 Hz, 0.09% at 1 Hz, and 0.03% at 2.5 Hz, respectively. Therefore, the conservative and alternate interpretation of the Alpine earthquake does not have an impact on the VCS site.

Seismotectonic Setting of the Alpine Earthquake

To complement the information presented within the SSAR documenting that the Alpine earthquake is related to the RGR (see SSAR Section 2.5.2.4.4.3), a detailed review of published information regarding the seismotectonic setting of the region surrounding the Alpine earthquake was conducted. This review mirrors that which was conducted in response to an RAI received as part of the Comanche Peak COL application (RAI 02.05.02-24, Accession Number ML 102370659). The results of these efforts, summarized below, support the conclusion of the SSAR that the Alpine earthquake is associated with the RGR.

Background

The 14 April 1995, Emb 5.6 Alpine earthquake was felt over an area of approximately 760,000 km^2 and had a maximum intensity of MMI VI (Frohlich and Davis, 2002). Figure 2 shows the general setting of the 1995 Alpine earthquake in relation to physiographic provinces (Fenneman and Johnson, 1946) and the terrain of western Texas, faults from the USGS Quaternary fault and fold database (USGS, 2006), and historical earthquakes (see SSAR Section 2.5.2.1). The CMT focal mechanism for the Alpine earthquake indicates normal slip on moderately dipping nodal planes (Global CMT Project, 2007). It is the second largest earthquake recorded in Texas (the 1931 Valentine earthquake was Emb 5.8). Many small landslides were triggered in the mountains surrounding the epicentral region (Frohlich and Davis, 2002), but no fault-related surface deformation has been identified. Also, the earthquake has not been associated with a causative fault.

Published Studies Related to the 1995 Alpine Earthquake

There are no published studies specifically related to the source characteristics and setting of the Alpine earthquake. The earthquake location, magnitude, and source parameters were routinely catalogued by the USGS. Frohlich and Davis (2002) describe the general setting as well as effects and felt reports of the Alpine earthquake. The Alpine earthquake was recorded on seismic networks worldwide, and several geophysical studies were conducted using those recordings (Das and Nolet, 1998; Melbourne and Helmberger, 1998; Rodgers and Bhattacharyya, 2001; Xie, 1998). The primary focus of these studies was on continental-scale lithospheric structure and seismic wave propagation, not the Alpine earthquake.

Overview of Tectonic History in the Region of the 1995 Alpine Earthquake

The Alpine earthquake was located adjacent to or astride several tectonic boundaries spanning several tectonic episodes. The epicentral region of the Alpine earthquake lies near the southwest margin of the North American craton where Proterozoic rifting separated the North and South American Plates (Figure 3). This rifting is proposed to have created structural trends (primarily northwest and northeast trends) that were reactivated in subsequent stages of tectonism (Page, et al., 2008; Poole, et al., 2005). Following this rifting, four to five distinct Phanerozoic tectonic episodes are generally recognized (Figure 4) as reflected in the regional geologic structure. These tectonic episodes are discussed separately below.

The first major tectonic event was intense deformation within the Marathon Basin (the region directly south of the Alpine earthquake) that resulted from the late Paleozoic collision of the North and South American Plates along the Ouachita-Marathon-Sonora orogen (Poole, et al., 2005) (Figure 5). The deformation included reactivation of some northwest- to north-striking Proterozoic faults (e.g., Ross, 1986). However, the thick Permian Basin deposits to the north and east of the area overlap these faults indicating that the region was relatively stable during that time period (Ross, 1986).

Through the early Mesozoic (Figure 4) the region experienced minor deformation associated with renewed rifting between North and South America, which ultimately led to the opening of the Gulf of Mexico (Page, et al., 2008) and a complex array of basins to the west (Haenggi and Muehlberger, 2005). During this time, the Alpine-Marathon region was part of the Diablo Platform, a relatively high region east of the subsiding Chihuahua Trough (Figures 6 and 7).

The late Cretaceous to early Tertiary Laramide orogeny represented a shift to east-northeast shortening in the region (Ewing, 1991a, b). The eastern edge of the fold-thrust belt represented by the Chihuahua Trough (called the Chihuahua Tectonic belt) was about 200 km to the west of the Alpine earthquake, but basement-cored structures of Laramide age extend inland to east of the Alpine-Marathon area (Figures 8 through 10). Southwest of the Alpine area, this orogeny is recorded as northwest-trending folds in Cretaceous units shown on the Tectonic Map of Texas (Figure 11a) (Texas BEG, 1997).

The late stages of subduction of the Farallon plate triggered major episodes of middle Tertiary volcanism and plutonism and development of the Trans-Pecos volcanic field in the region (also called the Trans-Pecos Igneous Province) (Figures 4 and 12) (Henry, et al., 1991). The 1995 Alpine earthquake occurred within this field (Figures 13 and 14). Although the major preserved outcrops of this volcanism lie to the west of the Alpine earthquake epicenter, small remnants of similar intrusive rocks are mapped just to the east of the epicenter (Figure 15). The northeastern extent of these rocks is near the Brewster and Pecos County line, northeast of the Alpine-Marathon area. This boundary continues along the same southeast trend into Mexico (see Figure 11).

Normal faulting related to Basin and Range and RGR extension began in the Alpine-Marathon region about 25 Ma (Figure 4) and is marked by an episode of predominantly basaltic volcanism (Henry and Price, 1986) that peaked about 20 Ma, but eruptions continued to about 10 Ma (Henry, 2010). Unmapped basaltic dikes thought to be of this age are present in the Glass Mountains (C. Henry, pers. comm., 2010), near the epicentral region of the 1995 Alpine earthquake. Neogene normal faulting associated with extension is distributed in a broad region across west Texas and extends several kilometers east of the epicentral region of the 1995 Alpine earthquake (Figures 15 and 16) (Henry and Price, 1986; Muehlberger, 1980).

Evaluation of Alpine Earthquake Seismotectonic Setting
Five explicit criteria are useful in evaluating the seismotectonic setting of the Alpine earthquake. These criteria, and conclusions with respect to the criteria, are presented below.

1. Neogene and Quaternary faulting

No Quaternary faults have been identified in the vicinity of the epicenter of the 1995 Alpine earthquake. The closest Quaternary faults identified in the USGS Quaternary Fault and Fold Database (USGS and BEG, 2006) are: an unnamed fault near Santiago Peak 50 km south of the epicenter, the West Lobo Valley fault about 120 km to the northwest of the epicenter, unnamed faults near Ruidosa about 120 km southwest of the epicenter, and the West Wyle fault about 140 km northwest of the epicenter (Figure 2). However, available literature does not fully document the extent and detail of Quaternary faults in the region closer to the earthquake epicenter. Muehlberger et al. (1978) map a belt of northwest-striking late Cenozoic extension-related faults that extends as far east as Marathon, TX. The northeastern edge of this belt of faulting is near the epicentral area of the 1995 earthquake (Figure 16). Dickerson and Muehlberger (1994) describe this faulting as being related to RGR extension. In addition, Henry and Price (1985) include the area of the 1995 earthquake within the extent of Basin and Range faulting in west Texas (Figure 15).

Based on the information discussed above, there is existing geologic evidence that the Alpine earthquake occurred within a region that is dominated by Cenozoic seismotectonics related to the RGR.

2. Extent of Basaltic Volcanism

Mafic intrusive and extrusive rocks related to late Cenozoic extension are shown on existing maps within a few kilometers to the west and northwest of the 1995 Alpine Earthquake epicenter (Figure 15)(Henry and Price, 1985; Henry and Price, 1986). In addition, unpublished mapping (C.Henry, pers. comm., 2010) indicates that basaltic dikes related to late Cenozoic extension are present in the Glass Mountains near the epicentral area.

The presence of this late Tertiary volcanism related to RGR extension near the Alpine earthquake is strong evidence that RGR-related extension was the latest major tectonic event impacting the region of the earthquake, and thus the earthquake is likely related to modern RGR extension.

3. Region of Recurrent Deformation

As discussed above, the Alpine earthquake lies within a belt of recurrent late Mesozoic to Cenozoic tectonic activity in western Texas. This region is tectonically distinct from the stable craton region of Texas to the east and south of the Alpine earthquake (e.g., Figure 12). The earthquake lies with a belt of silicic volcanism, as evident in the extensive outcrops of mid-Cenozoic silicic volcanic rocks of the Trans-Pecos volcanic field within ~15 km of the epicenter (Figure 12 and 15). Related intrusive rocks, preserved as sills, laccoliths, necks, and plugs also are scattered through the region in a belt that extends at least 15 km east of the epicenter (Figures 11 and 15).

These repeated tectonic episodes provide evidence that the seismotectonic setting of the region surrounding the Alpine earthquake is significantly different than that of the central and south-central Texas.

4. Comparisons to Regional Seismicity

The style of faulting, and kinematic indicators of the state of stress from earthquakes in west Texas (e.g., 1931 Valentine earthquake, Alpine earthquake), are all indicative of extensional or trans-tensional mechanisms (Figure 17) (Doser, 1987; Doser, et al., 1992; Frohlich and Davis, 2002). This region of west Texas also experiences higher rates of seismicity than observed in central Texas (Frohlich and Davis, 2002) (see SSAR Figure 2.5.2-1).

These observations support the hypothesis that the region surrounding the Alpine earthquake is seismologically distinct from the region of central and south-central Texas and is likely related to the seismotectonics of the RGR as opposed to the stable continental interior of central and south-central Texas.

5. Regional Stress Maps and Models

The Alpine earthquake was located along the western boundary of the Southern Great Plains stress province of Zoback and Zoback (Zoback, 1992; Zoback and Zoback, 1980; Zoback and Zoback, 1989), defined as a transitional zone between active extension of the Western US and compressional stress of the midcontinent. The current compilation of the World Stress Map (Reinecker, et al., 2008) includes the 1995 earthquake focal mechanism as a normal fault mechanism (i.e. extensional) as discussed above, but does not define stress provinces or boundaries. At the continental scale, the 1995 Alpine earthquake lies within the western US extensional region defined by Humphries and Coblentz (2007).

These observations suggest that the region surrounding the Alpine earthquake is within a stress domain that is different from that of central and south-central Texas and is likely related to the RGR seismotectonics.

Expert interviews
As part of the response to RAI 02.05.02-24 for the Comanche Peak COLA addressing a similar issue regarding the Alpine earthquake (Accession Number ML 102370659), 10 interviews were conducted with technical experts in an effort to more accurately document the opinion of the informed technical community with respect to the appropriate characterization of the Alpine earthquake. The 10 interviewees were:

Expert	Background
M. Machette	Retired USGS geologist specializing in Quaternary fault studies and the RGR
C. Frohlich	Seismologist at Univ. Texas specializing in Texas earthquakes
D. Doser	Seismologist at Univ. Texas El Paso specializing in Texas earthquakes
C. Henry	Volcanologist previously at Texas Bureau of Economic Geology specializing in volcanism in Texas
I. Wong	Seismic hazard consultant at URS with extensive experience in characterizing seismic hazard of RGR
S. Olig	Seismic hazard consultant at URS with extensive experience in characterizing seismic hazard of RGR
J. Pulliam	Geophysicist at Baylor Univ. with experience in RGR lithospheric structure and tectonics
S. Harmsen	Geophysicist at the USGS with experience in central US seismicity
E. Collins	Geologist at Texas Bureau of Economic Geology specializing in earthquake and geologic hazard evaluations for Texas
R. Wheeler	Seismologist at the USGS responsible for earthquake hazard evaluations throughout the central and eastern US

The results of these interviews are broadly summarized below. For a more detailed description of the interview results, see Table 1 of the response to RAI 02.05.02-24 for the Comanche Peak COLA (Accession Number ML 102370659).

Each expert was asked a series of questions that included the following:

1. Are you familiar with the 1995 Alpine, Texas earthquake?
2. Have you conducted any specific investigations or studies related to this earthquake?
    a. Other earthquakes or tectonic features in the region?
3. Our data review has found relatively few studies of this earthquake. Are you aware of any unpublished or pending investigations or evaluations of this earthquake?
4. Our initial evaluations have considered this earthquake related to Rio Grande Rift/Basin and Range extensional tectonics.
    a. Do you consider this a defensible characterization of the 1995 earthquake?
    b. Are there alternative characterizations that should be considered?
    c. In your view, what might be the eastern extent of extensional tectonics in west Texas at the latitude of Alpine?
    d. Is the Alpine EQ plausibly related to tectonic regimes of central Texas?
5. In your view, what is the appropriate tectonic characterization of the 1995 Alpine Texas earthquake?
    a. What are the key data or factors on which that characterization is based?
    b. Are there large uncertainties in this conclusion, or gaps in available data that might influence characterization of this earthquake?
6. Are there other experts that you would recommend we contact who might be knowledgeable regarding this earthquake?

The general conclusions based on the interviews are that: (1) experts with more direct knowledge of the earthquake and familiarity with geologic data in the surrounding region have more strongly held opinions that the earthquake is related to RGR extension and not the seismotectonics of central Texas (e.g., Henry, Doser); (2) experts with less familiarity of the earthquake or those with opinions based on more regional data are more open to alternate characterizations of the earthquake (e.g., Wong, Harmsen); (3) the predominant expert opinion is that the Alpine earthquake is related to the extensional tectonics of the RGR (e.g., only one of the ten experts gives significant weight [50%] to the interpretation that the earthquake could be related to the seismotectonics of central Texas).

Conclusion Regarding Seismotectonic Setting of the Alpine Earthquake
Based on the review of the available geologic, geophysical, and seismological information presented in this RAI response and in the SSAR (see SSAR Section 2.5.2.4.4.3) and the interviews with technical experts familiar with the Alpine earthquake and/or the seismotectonic setting of the region surrounding the Alpine earthquake, it is concluded that the best characterization of the Alpine earthquake is that it is related to the extensional tectonics of the RGR and not the tectonic setting of central or south-central Texas. As with all scientific inquiries there is some uncertainty in this conclusion. However, the strongest evidence and the majority opinion of the experts is that the earthquake is related to the RGR.

EPRI-SOG ESTs' Tectonic Characterization of the Alpine Earthquake Region
The Alpine earthquake occurs within 5 EPRI-SOG source zones (Figure 18). In general, the EPRI-SOG ESTs defined and characterized source zones based on their evaluations of tectonic features (EPRI, 1986-1989). The tectonic characteristics used by each EST to define their respective source zones that contain the Alpine earthquake are summarized below. Based on the descriptions of the source zones it is clear that they were not intended to represent the seismotectonic setting of the RGR, and, therefore, updating the characterizations of these source zones (e.g., maximum magnitude and probability of activity [Pa] values) based on the Alpine earthquake is conservative with respect to the seismic hazard at the VCS site.

Dames & Moore
The Alpine earthquake occurs within Dames & Moore zone 26b (default zone for Delaware basin [zone 26] and Delaware aulacogen [zone 27]). As indicated by the zone names, these zones were designed to characterize the Delaware basin and aulacogen, a Permian basin associated with the thrust-loading of the Ouachita orogenic belt and a hypothesized failed rift arm associated with the early Paleozoic rifting of Rodinia, respectively (e.g., Denison, 1989; Ewing, 1991b; Walper, 1977; Whitmeyer and Karlstrom, 2007). Based on the descriptions of these tectonic features and the resulting seismic source zones by the Dames & Moore EST (EPRI, 1986-1989, vol. 6, p. A-19, A-93, and B-24), it is clear that the zones are not meant to characterize the RGR seismotectonic region.

Law
The Alpine earthquake occurs within Law zone 124 (New Mexico – Texas Block). The Law EST explicitly states that the western boundary of this zone was defined by the "north-south magnetic trend of the Rio Grande-Colorado Front Ranges", a region that was explicitly excluded from their source characterizations (EPRI, 1986-1989, vol. 7, p. B-8 and 5-8). Based on these descriptions of the zone, it is clear that the zone was not meant to characterize the RGR seismotectonic region. In addition, the largest earthquake within zone 124 that was known to the Law EST during their characterization of the zone was the August 16, 1931 Emb 5.8 Valentine earthquake in west Texas. This earthquake has a larger magnitude than the Alpine earthquake, but the lower-bound Mmax for the zone is less than this magnitude (mb 4.9) (SSAR Table 2.5.2-9). There is no explanation within the Law EST volume (EPRI, 1986-1989, vol. 7) for why the lower-bound Mmax is less than the magnitude of this earthquake. Given the similarity in location and magnitude between the Valentine and Alpine earthquakes, however, it is reasonable to assume that the Alpine earthquake would not have served as motivation for the Law EST to update zone 124.

Rondout
The Alpine earthquake occurs within Rondout zone C02 (Grenville Crust). The Rondout EST states that this zone is defined by areas of the central and eastern US that were: (1) not within source zones that were characterized based on tectonic features, and (2) were of Grenville age (EPRI, 1986-1989, vol. 10, p. B-19 to B20). Based on the description of this source zone, it is clear that the zone was not intended to represent the RGR seismotectonic region.

Weston
The Alpine earthquake occurs within Weston zone 37 (Delaware basin) and zone 109 (Southwest [background zone for 37]). The Weston EST does not provide a basis for either zone 37 and 109. However, the Weston EST does provide a source zone meant

to describe the RGR (zone 38) (EPRI, 1986-1989, vol. 5, p. 5-10). The eastern boundary of this zone is coincident with the western boundary of the zone 37 and is therefore only approximately 6 km from the location of the Alpine earthquake. Based on Weston's inclusion of a zone intended to represent the RGR and the proximity of that zone to the Alpine earthquake, it is reasonable to conclude that zone 37 and 109 should not be updated to account for the Alpine earthquake.

Updated EPRI-SOG Source Characterizations

Despite the conclusion that the EPRI-SOG sources described above should not be updated based on the Alpine earthquake, a sensitivity analysis has been performed to investigate the potential impact of the Alpine earthquake on the EPRI-SOG source zones. The updates to these source zones have been made following the original methodology of the EPRI-SOG study as closely as possible (EPRI, 1986-1989). This section describes these updates, and a summary of all of the updates is presented in Table 1.

Dames & Moore

The Alpine earthquake occurs in Dames & Moore zone 26b, the default zone for the Delaware basin (zone 26) and the Delaware aulacogen (zone 27). These three zones are mutually exclusive interpretations of the seismicity in the region of the zones. The Pa values for 26, 26b, and 27 are 0.15, 0.72, and 0.13, respectively (EPRI, 1989). Because the Alpine earthquake only occurred in an area covered by zone 26b, and because the previous largest magnitude earthquake in the zone was an Emb 3.9, the Pa values of zones 26, 26b, and 27 would need to be updated to 0.0, 1.0, and 0.0.

The original weighted Mmax distribution for zone 26b was: mb 5.2 (0.8) and mb 7.2 (0.2). Because the lower-bound Mmax of this distribution is less than the magnitude of the Alpine earthquake (Emb 5.6), the Mmax distribution needs to be updated. The Dames & Moore methodology for defining Mmax used two "base" values: mb 7.2 and an estimate based on the observed seismicity rate within a zone (EPRI, 1986-1989, vol. 6, p. 6-4). For zone 26b the rate-based estimate is mb 5.2 (EPRI, 1986-1989, vol. 6, p. 6-9). Because this estimate is less than the magnitude of the Alpine earthquake, the Dames & Moore methodology cannot accurately describe the Mmax for the zone. Therefore the observed magnitude of the Alpine earthquake was used as the lower bound Mmax for the zone and retain the existing weights. The updated Mmax distribution for the zone is thus: mb 5.6 (0.8) and mb 7.2 (0.2).

Law

The Alpine earthquake occurs within Law zone 124 (New Mexico – Texas Block). This zone is a background zone with a weighted Mmax distribution of: mb 4.9 (0.3), mb 5.5 (0.5), and 5.8 (0.2) (EPRI, 1989). As previously described, the maximum observed earthquake in this zone, and the largest earthquake within the zone known to the Law EST, is the 1931 Valentine earthquake with magnitude Emb 5.8. Because this earthquake is larger than the Alpine earthquake (Emb 5.6), the 5.8 magnitude will be used as the basis for updating the Mmax distribution of the zone despite the fact that the Law EST knew of the event during their original characterization of the source zone.

Law based their Mmax distribution on three different estimates of Mmax (EPRI, 1986-1989, vol. 7, p. 6-8 to 6-14):

- Mhist – the historical maximum observed earthquake in the zone;

- Mbmax – a judgment-based estimate chosen from one of six options; and
- Mb1000 – the magnitude associated with a 1000-year return period.

The Mhist value for the zone is mb 5.8 based on the Valentine earthquake. The Mb1000 value is mb 5.74 based on the seismicity within the zone. Magnitude mb 6.8 is an appropriate Mbmax for the zone based on options 1b and 2 from the Law guidance on determining Mbmax (EPRI, 1986-1989, vol. 7, p. 6-9). The basis for this conclusion is that:

- Option 1a does not seem appropriate because the majority of the zone is not a rift and does not end in oceanic or extensional crust;
- Option 1b describes rift structures that are surrounded by continental crust;
- Option 1b is conservative for zones with Mb1000 << 6.8; and
- Option 2 describes regions where earthquakes are associated with significant thicknesses of brittle crust where features are poorly defined.

According to the Law methodology, the Mmax weights are based on the relative magnitudes of the three estimates. For example, if Mbmax>Mb1000>Mbhist, the weights on these three estimates should be 0.3, 0.5, and 0.2 (EPRI, 1986-1989, vol. 7, p. 6-14). The methodology also states that if any estimates are within 0.1 magnitude units, the weights of these estimates should be combined and the higher magnitude should be used. In this case Mb1000 and Mbhist are within 0.1 magnitude units, so the updated Mmax distribution is: mb 5.8 (0.7) and mb 6.8 (0.3).

Rondout
The Alpine earthquake occurs within Rondout zone C02 (Grenville Crust). Zone C02 is a background zone with a Mmax distribution of: mb 4.8 (0.2), mb 5.5 (0.6), and mb 5.8 (0.2) (EPRI, 1989). Because the lower-bound Mmax of this distribution is less than the magnitude of the Alpine earthquake (Emb 5.6), the Mmax distribution needs to be updated. The Rondout methodology defines Mmax by classifying zones into one of several classes based on the size of expected earthquakes (EPRI, 1986-1989, vol. 10, p. 5-4 to 5-6). The Rondout volume states that zones capable of moderate earthquakes (e.g., the Alpine earthquake) have Mmax values between 5.8 and 6.8, so the updated Mmax distribution is given a range between 5.8 and 6.8 with weights taken from similar zones as reported in the EQHAZARD Primer (EPRI, 1989). The updated distribution is then: mb 5.8 (0.15), mb 6.5 (0.6), and mb 6.8 (0.25).

Weston
The Alpine earthquake occurs within Weston zone 37 (Delaware basin) and zone 109 (Southwest; the background zone for 37). Because the Alpine earthquake is larger than the maximum observed earthquake in the zone from the EPRI-SOG study (Emb 4.6), and because that earthquake is less than mb 5.0, the Pa of zone 37 needs to be reevaluated. Also, the original Mmax distribution for zone 37 and 109 is 5.4 (0.33), 6.0 (0.49), and 6.6 (0.18). Because the lower-bound value of this distribution is less than the magnitude of the Alpine earthquake (Emb 5.6), the Mmax distribution for both zones 37 and 109 need to be updated.

The Pa values for Weston source zones were developed by evaluating the probability of activity of tectonic features using what the Weston EST referred to as a matrix of physical characteristics. The details of the methodology are presented within the Weston EST volume (EPRI, 1986-1989, vol. 5, section 4), but a brief outline of the methodology is presented below.

The basis for the Pa value for a given zone is weights given to the applicability of three characteristics for each source zone, where the sum of the weights for each characteristic is 1.0. The characteristics are:

- The zone's association with seismicity. This characteristic was evaluated for moderate to large earthquakes (mb ≥ 5.0), small earthquake only (mb < 5.0), and no seismicity.
- How favorably oriented tectonic features are within the zone relative to the dominant stress direction. This characteristic was described as either favorable or not favorable.
- Whether the zone is associated with tectonic features that have a deep crustal expression. This characteristic was described as: (1) having a deep expression and a barrier to extension of the feature, (2) having a deep expression without a barrier, and (3) only having a shallow expression.

The weights of these characteristics are then applied to the matrix of physical characteristics to develop a Pa value.

The Weston EST evaluated the characteristics of zone 37 as follows (weights are in parentheses) (EPRI, 1986-1989, vol. 9, p. 4-55 to 4-56):

- Association with seismicity – moderate to large (0.7), small (0.3), none (0.0);
- Geometry – favorable (0.7), unfavorable (0.3); and
- Deep crustal association – deep with barrier (0.5), deep without barrier (0.5), shallow (0.0).

Applying these evaluations to the matrix of physical characteristics gives a Pa of 0.81, the Pa value for zone 37 from the EPRI-SOG study (EPRI, 1989).

Inclusion of the Alpine earthquake would require updating the Pa evaluation for zone 37 because the largest observed earthquake in the zone prior to the Alpine earthquake was less than 5.0. Therefore, the weight that the zone is associated with moderate to large seismicity needs to be increased from the original value of 0.7. The Weston EST methodology does not provide enough information to determine how the occurrence of the Alpine earthquake would impact that ESTs evaluation of association with seismicity, so a conservative change is made to the weights by increasing the association with moderate to large earthquakes to 1.0 and by decreasing the association with small earthquakes to 0. Applying these changes results in a conservative updated Pa for zone 37 of 0.865.

The Weston EST methodology for the original Mmax distribution of zone 37 was based on developing a cumulative probability of activity distribution for earthquakes, dependent on their mb magnitude, from Pa evaluations made at several magnitudes using matrices of physical characteristics (EPRI, 1986-1989, vol. 5, section 4). From this cumulative distribution, a discrete probability density function (PDF) describing the probability that a given Mmax value is appropriate for the source zone was determined. The final Mmax distribution was then calculated by truncating the PDF at the lowest magnitude of the discrete PDF that was greater than or equal to the largest observed earthquake within the zone and renormalizing the PDF.

The occurrence of the Alpine earthquake potentially impacts this methodology of determining Mmax in two ways. Firstly, the occurrence of the Alpine earthquake may change some of the Pa evaluations that were used in developing the cumulative probability of activity distribution. However, this sensitivity analysis did not update these evaluations because: (a) the Weston EST volume does not present enough information to be able to evaluate how the Alpine earthquake would change the cumulative probability of activity distribution, and (b) if updating the cumulative probability of activity distribution could be done following the Weston methodology, the change in the mean Mmax for both zones 37 and 109 would be less than mb 0.1. The second impact of the Alpine earthquake is that it changes the magnitude at which the PDF for both zones 37 and 109 should be truncated. The Mmax distributions were updated to account for this impact. The updated Mmax distributions for zone 37 and 109 are: 37 – mb 6.0 (0.68), mb 6.6 (0.29), mb 7.2 (0.03); 109 – mb 6.0 (0.76), mb 6.6 (0.21), mb 7.2 (0.03).

Sensitivity Study for Impact of Potential Changes to Site GMRS
To investigate the impact of these potential changes to the EPRI-SOG source characterizations on the seismic hazard at the VCS site, a sensitivity analysis was conducted with the updated source characterizations presented in Table 1. The updated characterizations were used with the other contributing source zones identified within the SSAR (SSAR Tables 2.5.2-7 through 2.5.2-12, and Table 2.5.2-19) to calculate the rock UHRS following the same procedure as described in SSAR Subsection 2.5.2.4.7. The results of these calculations are shown in Table 2 as the percent difference in mean rock UHRS compared to the values presented within the SSAR (see SSAR Table 2.5.2-24). As described in SSAR Subsection 2.5.2.5, the site GMRS is calculated from the UHRS at annual probabilities of exceedance of 10^{-4} and 10^{-5} by taking into account the seismic wave transmission characteristics of the site, but, given the low percentage increases in UHRS, the new UHRS values can be used as a proxy for determining the impact of the sensitivity study on the seismic hazard and insignificant impact on the GMRS (see Table 2).

As can be seen in the percent difference in rock UHRS values, the potential impact of the updated EPRI-SOG characterizations in light of the Alpine earthquake are not significant, especially considering: (1) the fact that many of the potential Pa and Mmax changes are made using conservative assumptions, and (2) the conclusion that the parameters of the EPRI-SOG sources should not be updated in response to the Alpine earthquake because it is related to the RGR. As an alternative to updating the EPRI-SOG source zones, it is also not necessary to develop a new characterization of the RGR for the VCS site because: (1) the lower bound Mmax value (6.3) for hypothetical RGR faults is considerably larger than the Alpine earthquake and (2) initial sensitivity analyses of the RGR faults indicate that it is unlikely any RGR source would contribute to the seismic hazard at the site (see SSAR subsection 2.5.2.4.7).

Associated ESPA Revisions:

No ESPA revision is required as a result of this response.

Source Zone	Mmax (mb)	Weight	Pa
Rondout Grenville Province Background (50 or C02)	5.8 6.5 6.8	0.15 0.60 0.25	No change
Weston Delaware Basin (37)	6.0 6.6 7.2	0.68 0.29 0.03	0.865
Weston Southwest (109)	6.0 6.6 7.2	0.76 0.21 0.03	Background for WGC-37. Updated to be consistent with revised P* for WGC-37
Law New Mexico – Texas Block (124)	5.8 6.8	0.7 0.3	No change
Dames & Moore Default for Delaware Basin and Delaware Aulacogen (26B)	5.6 7.2	0.8 0.2	1.0
Dames & Moore Delaware Basin (26)	No change		0.0
Dames & Moore Delaware Aulacogen (27)	No change		0.0

Table 1: Summary of EPRI-SOG changes from Alpine earthquake.

Freq. (Hz)	Percent Increase in Mean UHRS Rock Amplitude		
	10^{-4}	10^{-5}	10^{-6}
100/PGA	0.16%	0.00%	0.00%
25	0.26%	0.03%	0.00%
10	0.19%	0.00%	0.01%
5	0.12%	0.05%	0.00%
2.5	0.06%	0.00%	0.03%
1	0.03%	0.09%	0.00%
0.5	0.00%	0.00%	0.00%

Table 2: Potential impact of updating EPRI-SOG sources for the Alpine earthquake on the site UHRS.

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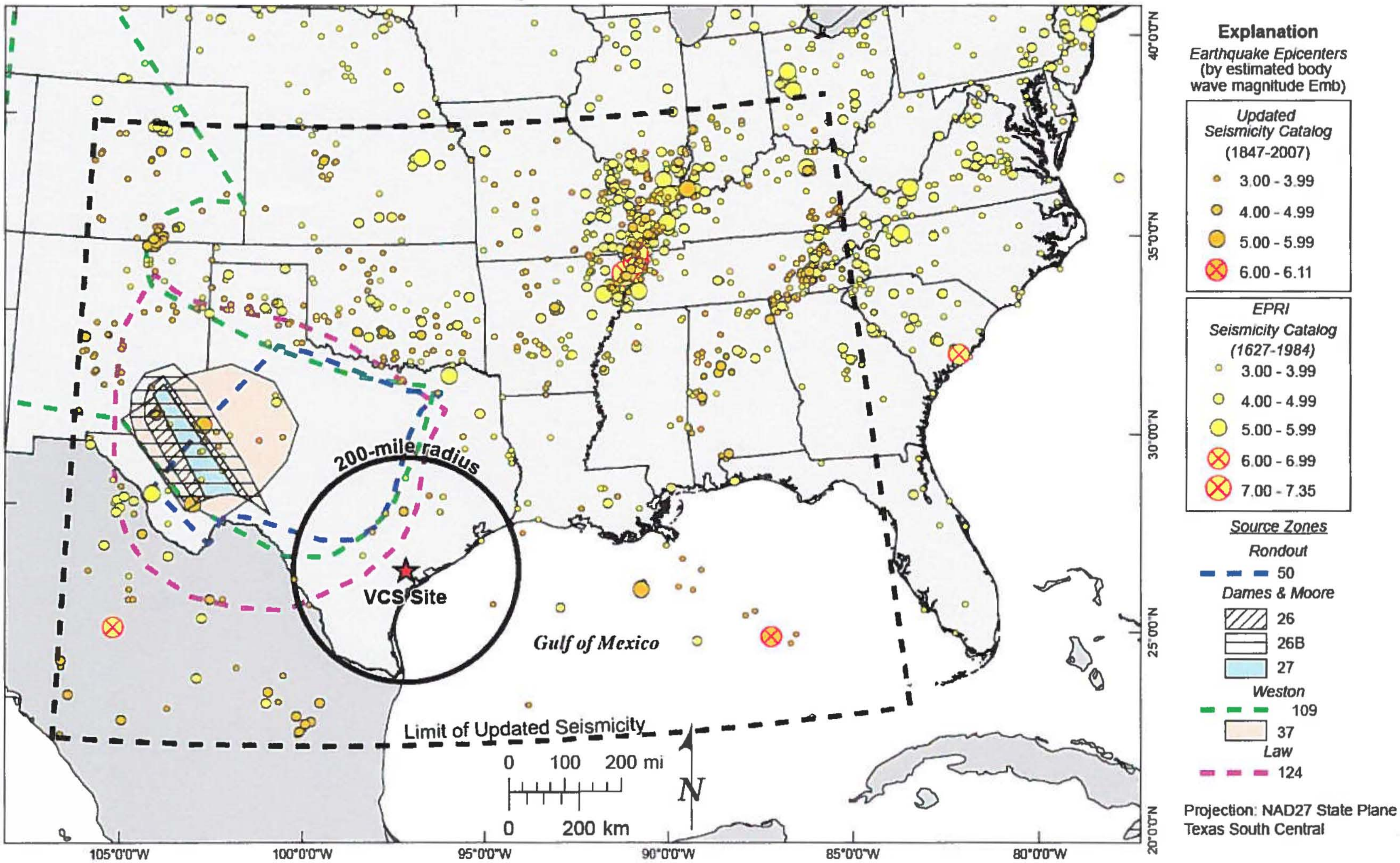


Figure 1: Location of Dames & Moore Zones 26, 26b, and 27.

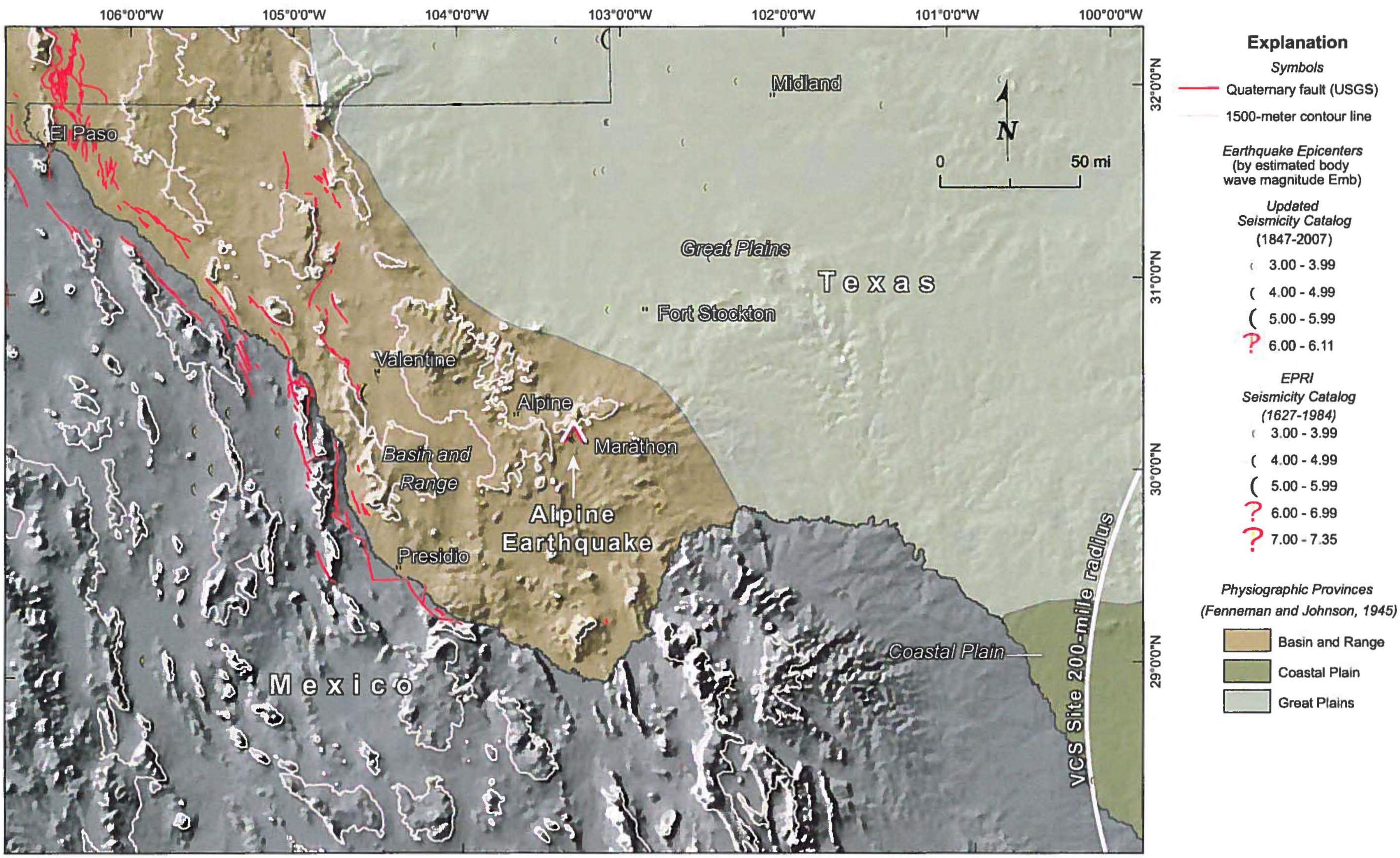
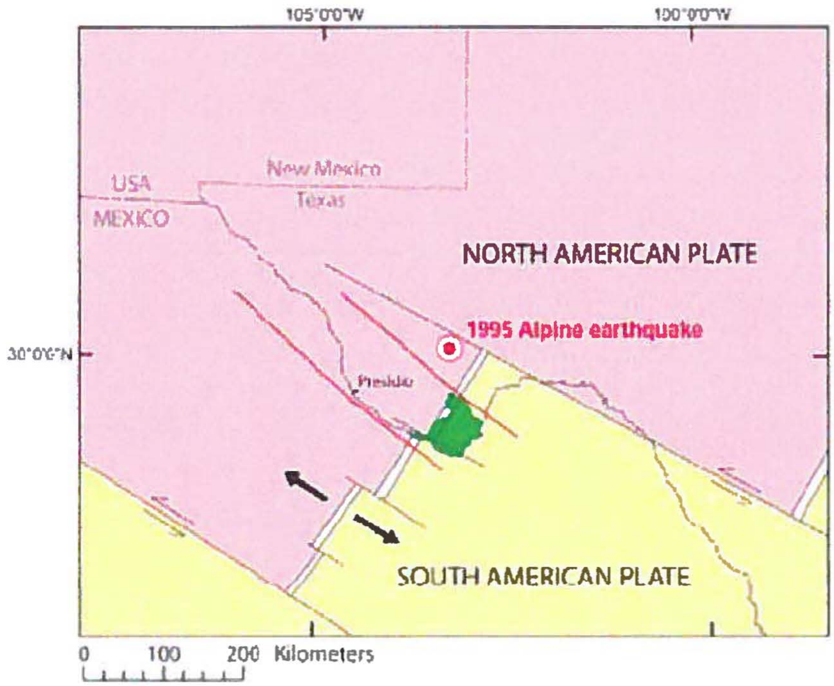


Figure 2: Location of Alpine earthquake.



Index map showing transform faults and lineaments related to Proterozoic rifting along the southern edge of North America. Solid black lines are Neoproterozoic continental transform faults. Arrows show relative motion of continental plate offset; gray double-banded line is main rift zone between North and South American plates; solid red lines are Texas lineament; and dark green line is Big Bend National Park.

Figure 3: Proterozoic structure from Page et al. (2008)

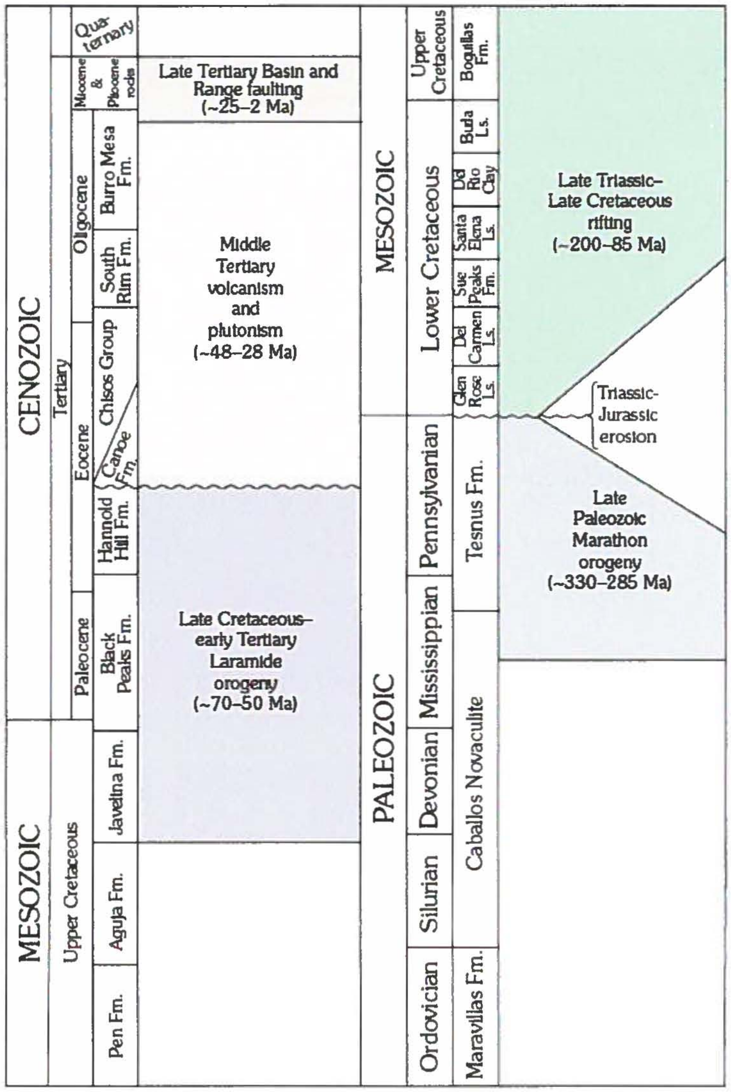
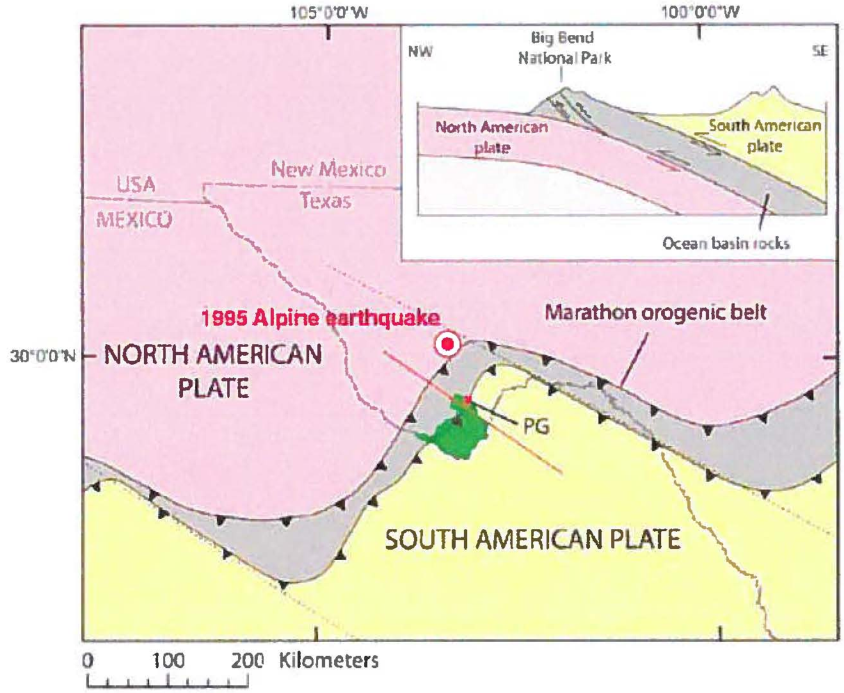
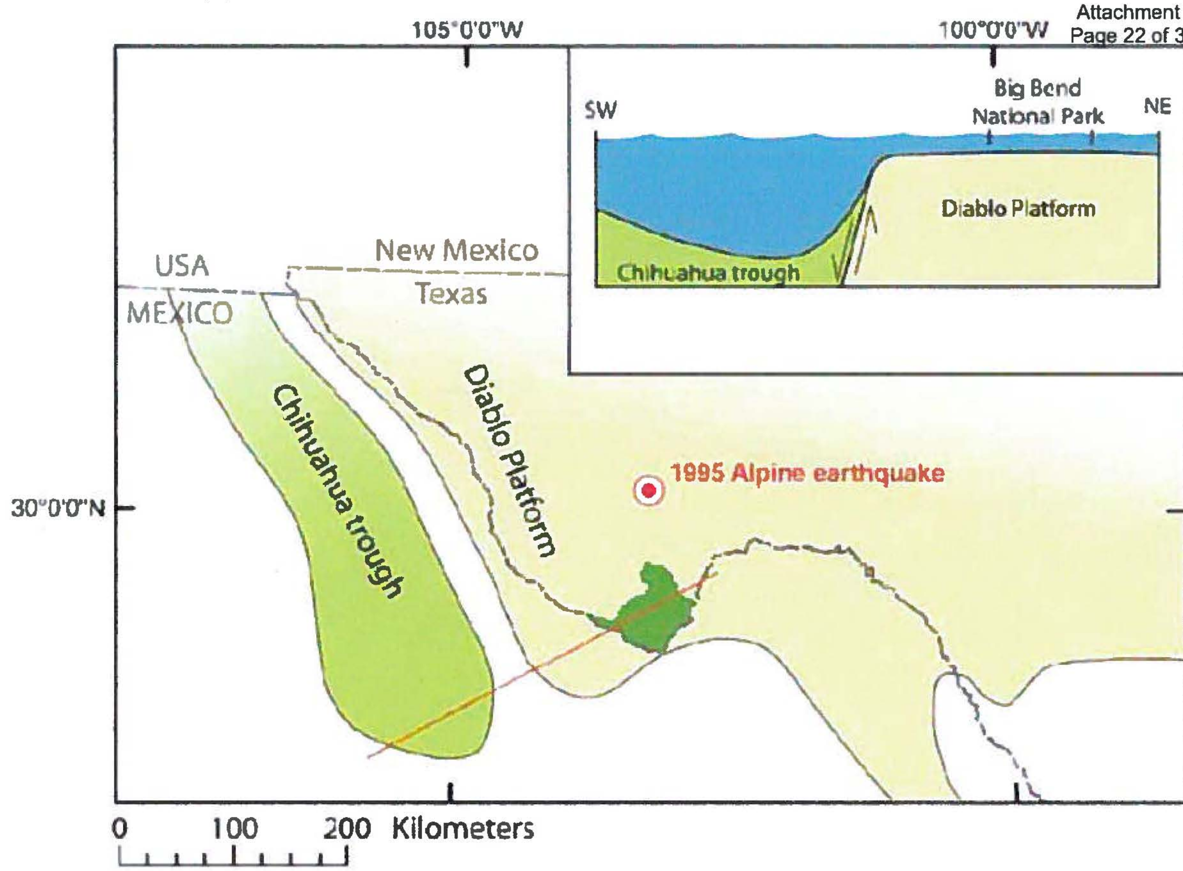


Figure 4: Phanerozoic tectonic events from Page et al. (2008)



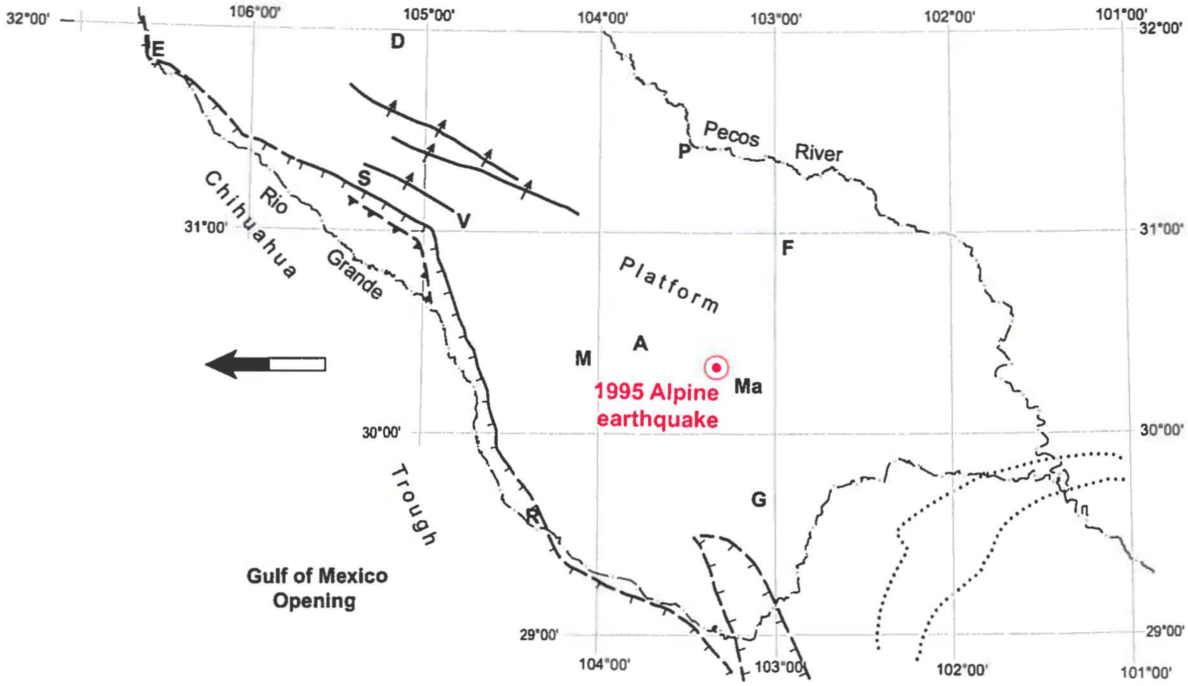
Map showing location of Marathon orogenic belt and subduction zone (inset figure) formed from collision between the North and South American plates. Dotted black lines are traces of transform faults shown in Figure 3; short red line represents approximate line of section for inset figure; dark green area is Big Bend National Park; PG = Persimmon Gap.

Figure 5: Map of Marathon orogenic belt from Page et al. (2008)



Map showing location of Diablo Platform and Chihuahua trough, features that formed in the Big Bend during Late Triassic through Late Cretaceous rifting between North and South America. Solid red line is approximate line of section for inset figure.

Figure 6: Map of Chihuahua Trough and Diablo Platform from Page et al. (2008)



Known mid-Mesozoic (Gulf of Mexico opening) faults. The principal feature is the prominent fault separating the subsiding Chihuahua Trough from the platform; reentrant into the south tip of the Big Bend is based on shapes of structures (tight asymmetrical folds) compared to those on either side. The dotted lines in the southeast corner of the map mark the boundaries of the mid-Cretaceous (Washita and Fredericksburg) reef. The landward kink lies along the northern border of the Texas Lineament as used in this paper. Small arrows point toward down side of monocline. Large arrow shows approximate sense of motion of Mexico relative to Texas.

Figure 7: Map of Chihuahua Trough and Diablo Platform modified from Muehlberger (1980).

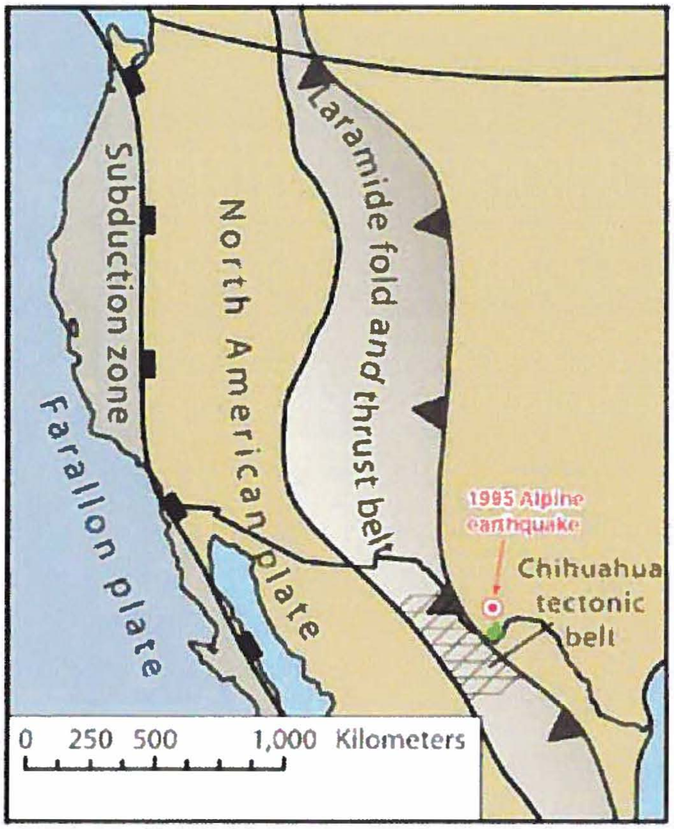
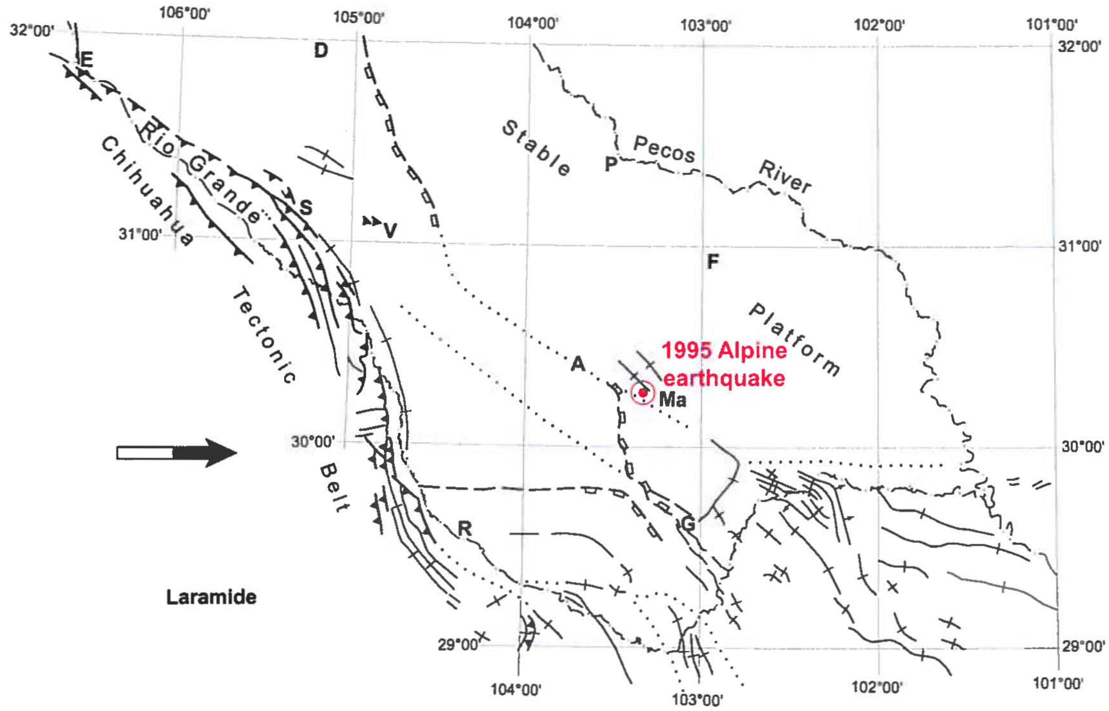
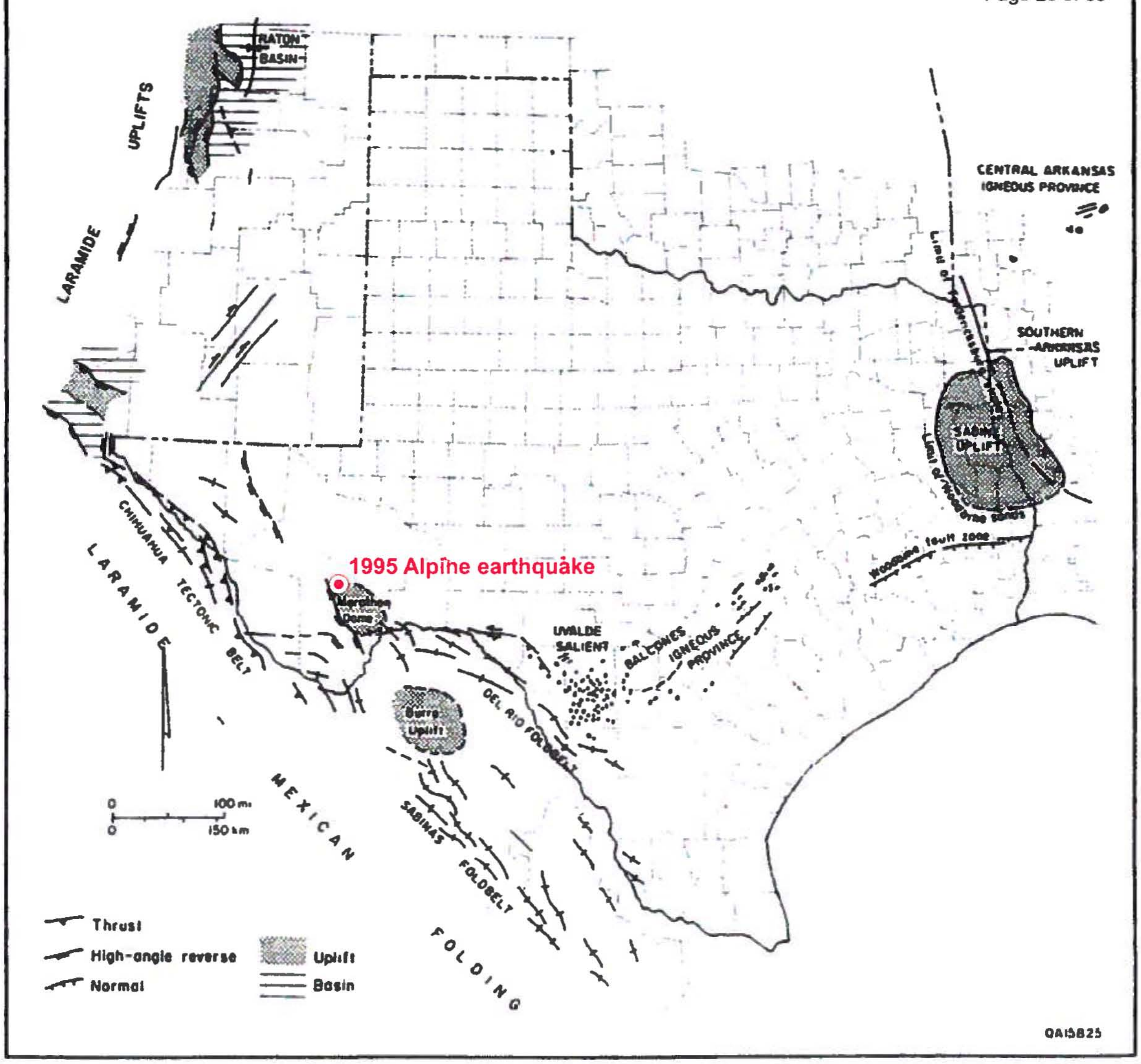


Figure 8: Extent of Laramide fold and thrust belt from Page et al. (2008).



Known Laramide faults and folds. Short bar across fine line = anticline (open folds in Texas, mainly monoclines in Mexico); open rectangles = upthrown side of faulted monoclines. Large arrrow shows approximate sense of motion of overthrust sheets and of Mexico relative to Texas.

Figure 9: Laramide faults and folds in the Alpine-Maraqthon region modified from Muehlberger (1980).



Map of mid-Cretaceous to Eocene tectonic elements of Texas: uplifts, volcanic centers, and faults of Late Cretaceous age in the Gulf Coast Basin: folds and faults of Laramide age (latest Cretaceous, Paleocene, and early Eocene) in West Texas and Mexico.

Figure 10: Mid-Cretaceous to Eocene tectonic features from Ewing (1991b).

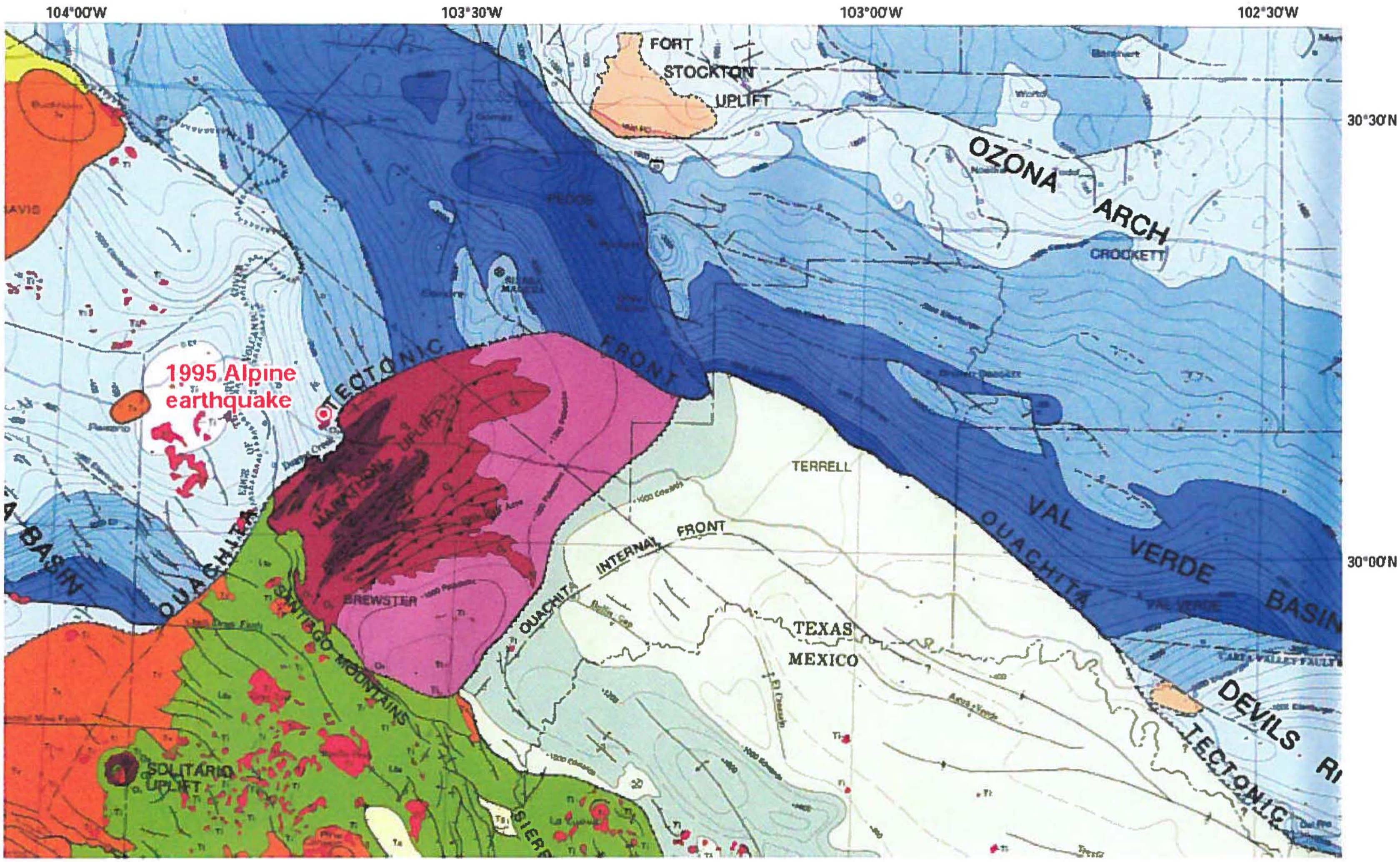


Figure 11a: Tectonic map of Texas in the Alpine-Maraton region (Ewing, 1990)

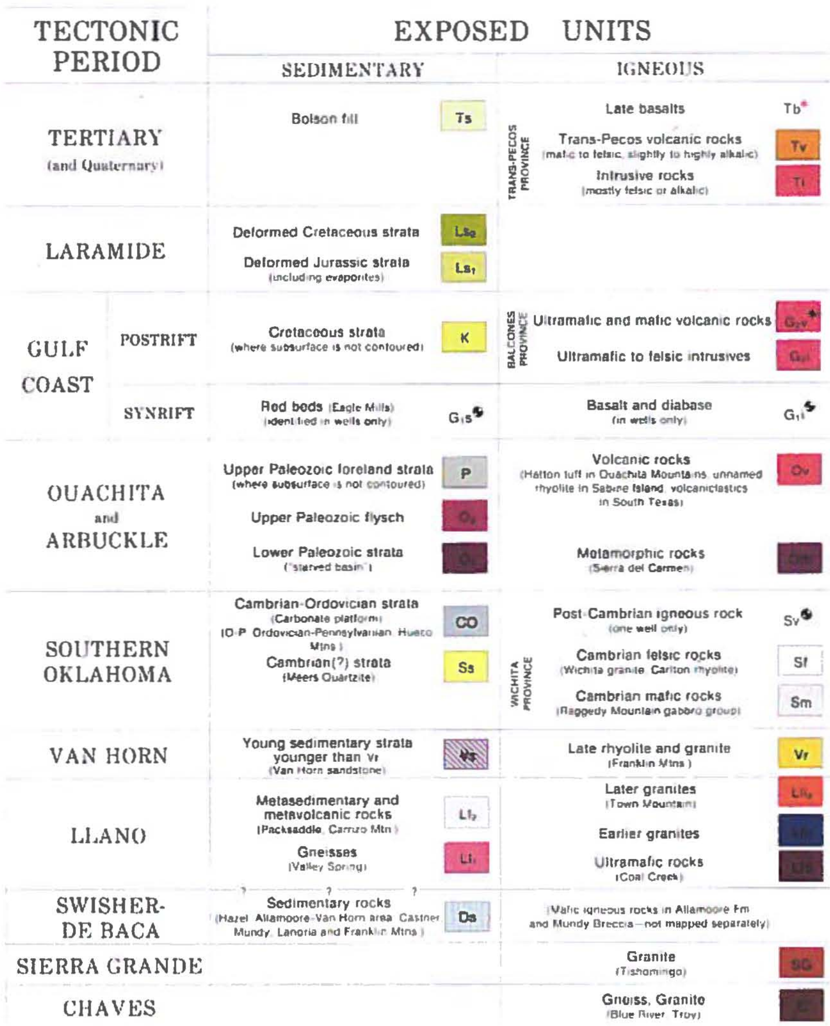
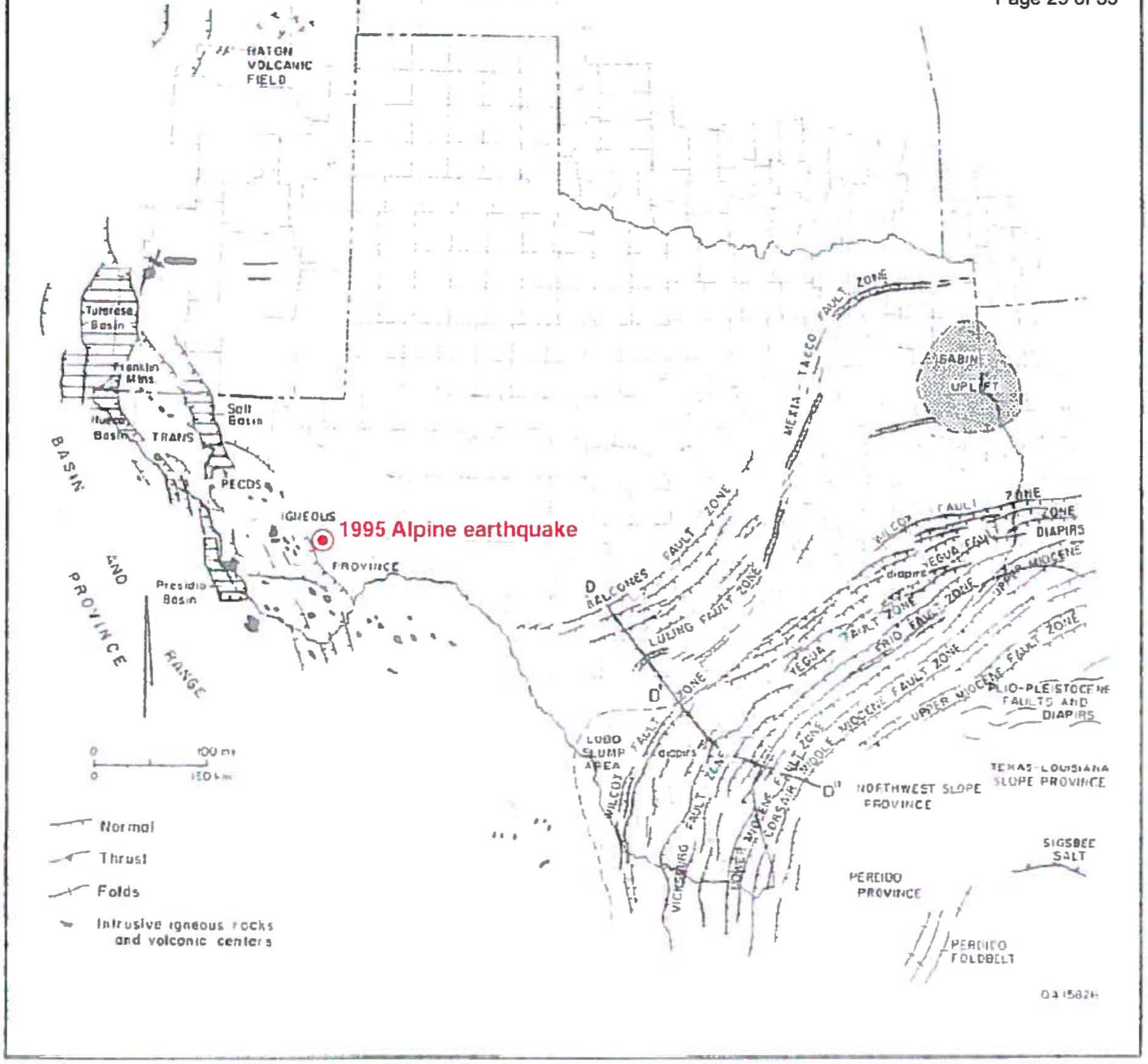


Figure 11b: Explanation for the Tectonic map of Texas (Ewing, 1990).



Map of Cenozoic tectonic elements of Texas: shelf-margin growth faults in the Gulf Coast; Basin and Range tectonic elements in West Texas; and Balcones faults.

Figure 12: Cenozoic tectonic features of Texas from Ewing (1991b). Note igneous bodies and faults of the Trans-Pecos volcanic field.

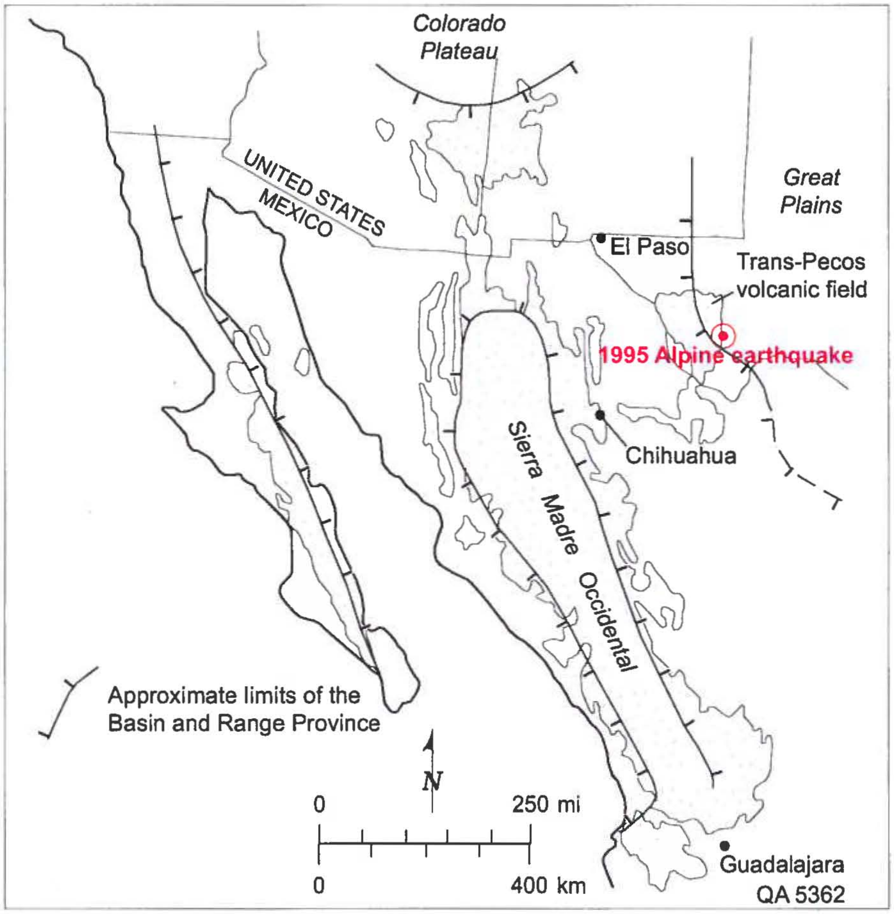
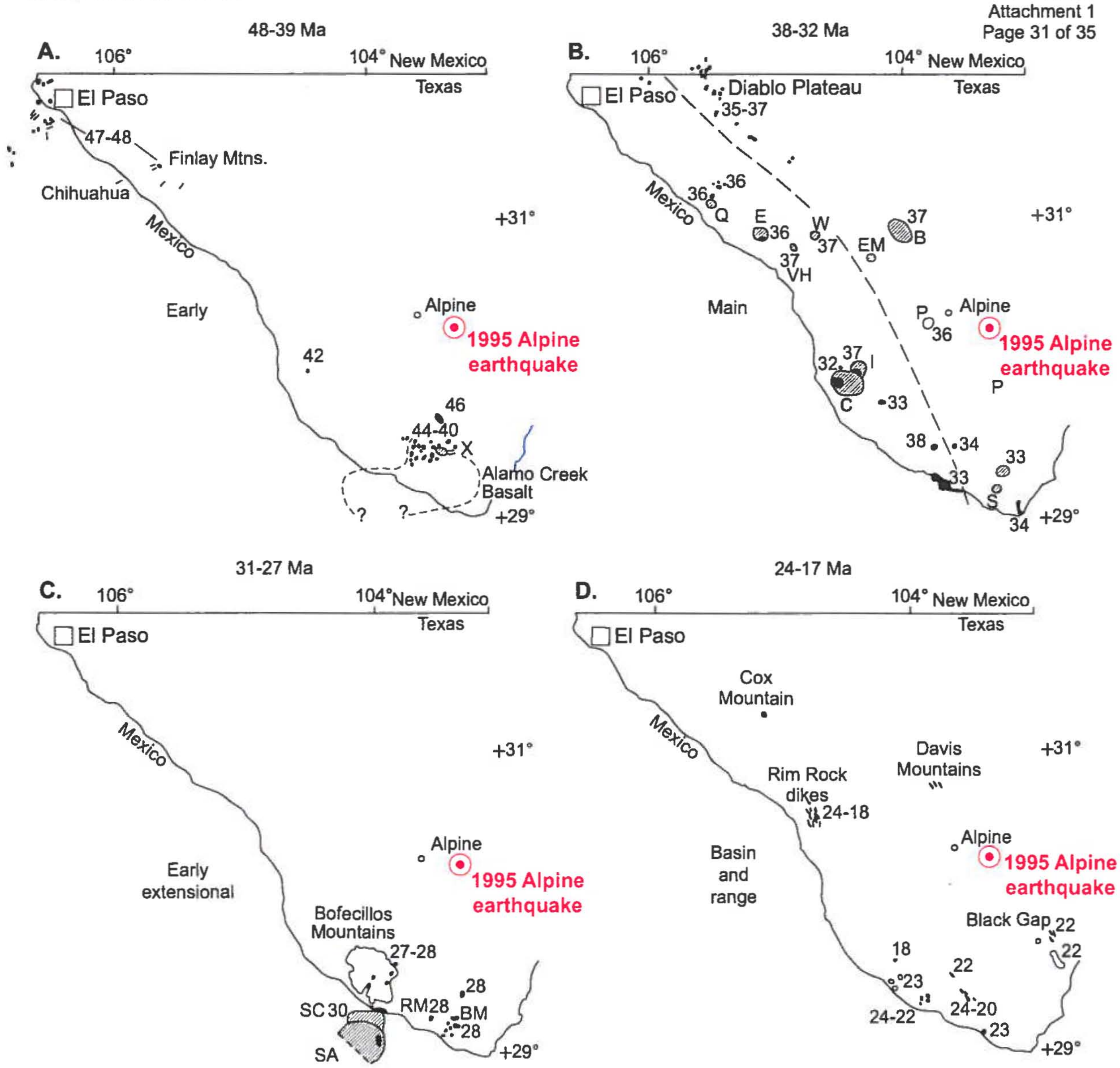


Figure 13: Extent of the Trans-Pecos volcanic field modified from Henry et al. (1991).



Distribution of magmatism through time in Trans-Pecos Texas. Numbers indicate times of major activity of individual centers or areas of magmatism. Ruled areas are calderas and solid areas are major intrusions. (a) Initial encroachment of volcanic arc (48-39 Ma). Moderate volumes of magma were emplaced in northern and southern Trans-Pecos Texas. (b) Main continental arc phase (38 to 32 Ma). Large volumes of magma were emplaced, mostly from caldera complexes, throughout Trans-Pecos. AC and A denote western alkalicalcis and eastern alkalic belts. (c) Initial extensional phase (31-27 Ma). Moderate volumes of magma were emplaced exclusively in southern Trans-Pecos Texas and Chihuahua, contemporaneous with initial east-northeast extension. (d) Main Basin and Range phase (24-17 Ma). Small volumes of magma were emplaced throughout Trans-Pecos Texas contemporaneous with major Basin and Range faulting. EP, El Paso. Letters next to calderas: X, Christmas Mountains caldera complex; Q, Quitman Mountains caldera; E, Eagle Mountains caldera; VH, Van Horn Mountains caldera; W, Wylie Mountains caldera; B, Buckhorn caldera; EM, El Muerto caldera; P, Paisano volcano; I, Infiernito caldera; C, Chimati Mountains caldera; PC, Pine Canyon caldera; S, Sierra Quernada caldera; SC, San Carlos caldera; Sa, Santana caldera.

Figure 14: Temporal evolution of Trans-Pecos volcanism modified from Henry et al. (1991).

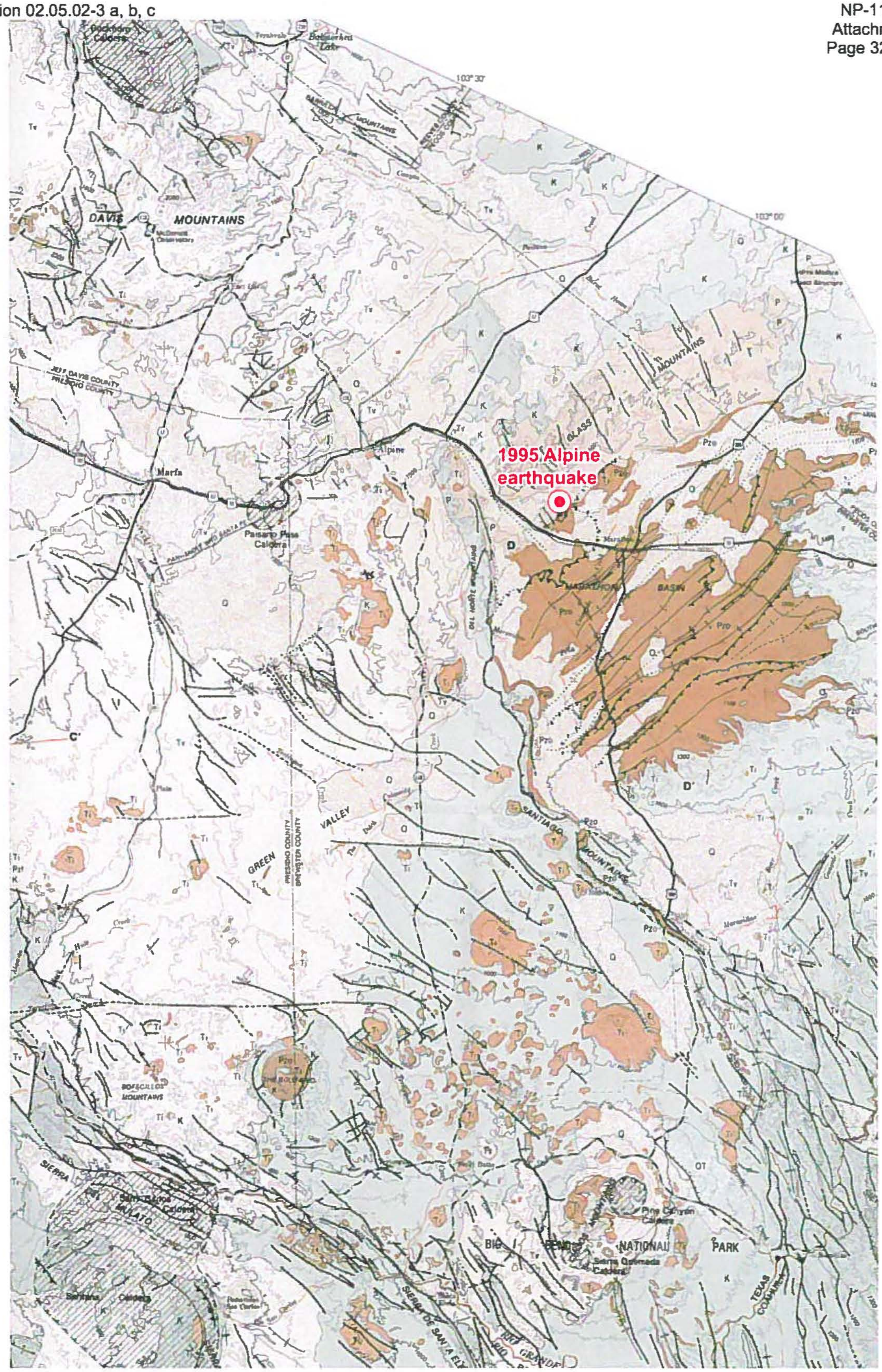


Figure 15a: Geologic map of the Alpine earthquake region from Henry and Price (1985).

Q — Alluvium, thin, mostly Quaternary; mapped only where nature of underlying bedrock is uncertain

QT — Basin fill, early Miocene to Holocene age, thick sedimentary accumulations within normal-fault-bounded basins; lighter pattern in areas of thin basin fill (generally less than 100 m) occurring mostly at margins of basins and gradational to thick basin fill

Ti — Intrusive rocks, late Eocene to Miocene age

Tv — Volcanic rocks and volcaniclastic sediments, late Eocene to Miocene age, almost all pre-Basin and Range faulting

K — Mesozoic to early Eocene age sedimentary rocks; includes all post-Paleozoic rocks affected by Laramide folding; mostly Cretaceous with some Jurassic in Malone Mountains, and Paleocene and early Eocene in Big Bend National Park (Je, Jurassic evaporite, shown separately on cross sections B-B′ and C-C′)

P — Permian sedimentary rocks, post-late Paleozoic deformation of Marathon region

Pz — Pre-Permian, Paleozoic sedimentary rocks involved in Late Paleozoic deformation. Divided into Pzo, allochthonous Ouachita facies rocks in Marathon area and Solitario, and Pzf, autochthonous foreland facies rocks in rest of Trans-Pecos

pC — Precambrian rocks, exclusively around Van Horn, on Diablo Plateau, and in Franklin Mountains. Divided into pCv (Van Horn Sandstone), pCt (Thunderbird Group, Red Bluff Granite, and rhyolite in Pump Station Hills), pCh (Hazel and Allamoore Formations of Van Horn area and presumably correlative Lanoria Quartzite, Mundy Breccia, and Castner Limestone of Franklin Mountains), and pCc (Carrizo Mountain Group)

Contact, dashed where approximately located

Normal fault, hachures on downthrown side, dashed where approximately located, dotted where covered

Normal fault with Quaternary displacement

Thrust fault, barbs on upper plate, dashed where approximately located, dotted where covered

High-angle reverse fault, dashed where approximately located, dotted where covered

Strike-slip fault showing relative motion, dashed where approximately located

Anticline showing direction of plunge, dashed where approximately located, dotted where covered

Overturned anticline, dashed where approximately located

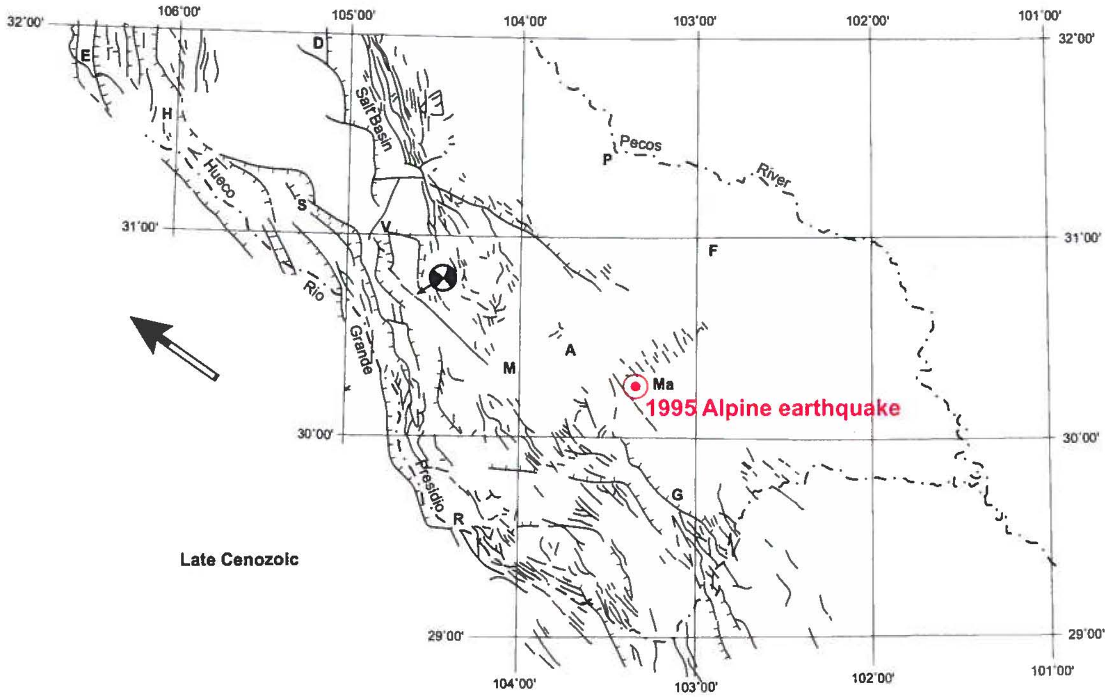
Syncline showing direction of plunge, dashed where approximately located, dotted where covered

Overturned syncline, dashed where approximately located

Monocline, dashed where approximately located, dotted where covered

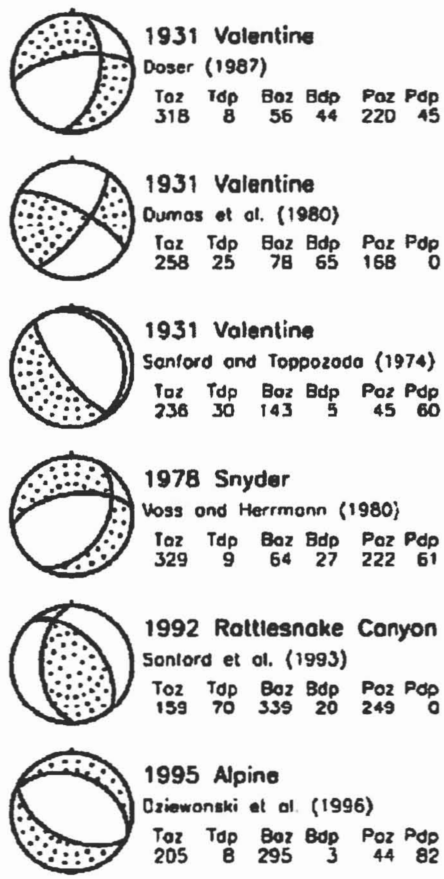
Caldera, dashed where approximately located

Figure 15b: Explanation for the geologic map of the Alpine earthquake region from Henry and Price (1985).



Known Late Cenozoic faults. Tick marks on major graben border faults. Main sources: Geologic Atlas of Texas - Van Horn - El Paso, Pecos, Marfa, Ft. Stockton, and Emory Peak-Presidio sheets. Also show is first-motion diagram for Valentine earthquake; shaded quadrants-compression; arrow from diagram points to the Valentine fault, the fault assumed to have moved during the August 16, 1931, Valentine earthquake.

Figure 16: Cenozoic faults in the Alpine-Marathon region modified from Muehlberger (1980).



Summary of published focal mechanisms for Texas earthquakes. The text at right of lower-hemisphere focal plots indicates the year and location of the earthquake, the source reference for the mechanism, and the azimuth and plunge of the principal axes, labeled T (tension), B (null), and P (pressure) axes. Except for the 1995 Alpine earthquake, the referenced sources either did not present numerical information for the azimuth and dip of the principal axes, or the numerical values persented were such that the T and P axes were not perpendicular. Thus we obtained the focal plots and numerical values here by fitting focal plots presented in the refernced sources.

Figure 17: Focal mechanisms of west Texas earthquakes from Frolich and Davis (2002).