Structural Styles and Geotectonic Elements in Northwestern Mississippi: Interpreted from Gravity, Magnetic, and Proprietary 2D Seismic Data

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EXTENDED ABSTRACT

The tectonic history of the southern Laurentian continental margin is characterized by a succession of two complete Wilson cycles. In northwestern Mississippi, the tectonic history and configuration of geotectonic elements associated with the development of the Gulf of Mexico Basin is poorly understood due to a lack of publicly available data and a thick succession of overlying Mesozoic sediments. To more accurately map and define tectonic elements of the region an extensive set of regional geophysical data including: gravity data, magnetic data, and a proprietary set of regional 2D seismic data (the use of which was granted by Seismic Exchange, Inc.). Using these data, and the sparse well control, we define distinct zones of varying structural styles and unique geotectonic elements within the region and provide new insight into the tectonic evolution of the northern margin of the Gulf of Mexico Basin in northwestern Mississippi. Figures 1–4 provide key illustrations.

The Cratonal Zone is defined by the extent of Precambrian basement across the region and is segmented by an orthogonal set of northeast-southwest and northwest-southeast trending faults. A large northeast-southwest trending fault identified in seismic data within the northern study area is interpreted as the southeastern bounding fault of the Reelfoot Rift. East of the Reelfoot Rift, a series of sub-rift-parallel horst and grabens have been identified. Faulting of the horst-graben sequence displaces overlying Paleozoic sediments suggesting the faults either initiated during ~Cambrian rifting and exhibited continued movement during the Paleozoic, or the faults may instead be related to later Paleozoic compressional episodes.

At its southern limit, Precambrian basement material of the Cratonal Zone is dissected by a series of tightly spaced, northwest-southeast trending normal faults displacing the overlying Cambrian-Ordovician carbonate sequence. The southward continuation of the Cratonal Zone is interpreted to align with high angle, down to the south, nor-

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mal faulting that abruptly truncates and displaces Precambrian basement material beneath the limit of seismic data. The timing of northwest-southeast oriented faults along the southern limit of the Cratonal Zone is unknown, but it is proposed that this faulting was likely initiated during late Precambrian–Early Cambrian rifting. However, the primary growth of the faulting was associated with deposition and downwarping across the Paleozoic passive continental margin.

The, now, foreland basin is composed primarily of Cambrian-Devonian shelf carbonates and Carboniferous clastics deposited on top of Precambrian material along the southern continental margin. Cambrian-Ordovician clastic and carbonate sediments that floor the Foreland Basin Zone can be traced to the southern limits of the Cratonal Zone. In the southwestern region of the Foreland Basin Zone, Paleozoic sediments extend beneath north verging frontal thrust structures of the Ouachita Orogenic Belt. Carbonate sediments of the Knox group, and younger, are interpreted to be incorporated within and deformed by foreland vergent thrusts.

The basal Paleozoic sediments in the southwestern region of the Foreland Basin Zone are displaced across faults interpreted to represent inverted normal faults associated with Carboniferous compressional episodes. Middle-Upper Paleozoic sediments in the eastern limits of the study area are shown to drape across northwest-southeast trending normal faults along the southeastern end of the Cratonal Zone. Again, suggesting that northwest-southeast trending faults of the Cratonal Zone were at least pre–Middle Paleozoic.

Divisible into two structural domains, the frontal and allochthonous domains, elements of the Ouachita Zone are completely confined to the subsurface and are visible across western and central Mississippi. Thrust-related structures are only identifiable in seismic data of the western region of the study area. Structures of the Frontal domain in the central portion of the study area are missing due to the emplacement of Jurassic intrusions along the southern limit of the Cratonal Zone.

Corresponding to the limits of the Cratonal Zone, the Frontal domain is characterized by two structural levels separating autochthonous platform and Carboniferous sediments. Extensional basement faults are interpreted to have been reactivated and inverted to form through going thrust structures displacing Paleozoic sediments correlatable across multiple seismic lines.

Carboniferous strata within the upper detachment represent back thrusting of para-autochthonous sediments due to foreland vergent thrust wedging along the lower detachment. The lower detachment follows a ramp-flat type geometry stemming from the basement dislocation at the southern end of the Cratonal Zone. Southward dipping small, imbricate thrusts branching from the detachment surface displace Ordovician through Devonian platform sediments deep into the foreland.

The Allochthonous domain of the Ouachita Zone is characterized by large, southward dipping imbricated thrust sheets branching from a basal detachment. In the western study area, thrust faults continue beneath the limit of seismic data, but are interpreted to sole into a basal detachment. Sediments and structures of the Allochthonous domain are absent in much of the central and eastern regions of the study area due to the presence of large, amalgamated intrusive bodies observed across multiple seismic lines.

The seismically defined limit of the basinal zone corresponds to a linear gravity minima separating Mesozoic rift-related basins to the south from Precambrian and intrusive bodies to the north. Within the basinal zone, seismic and well data confirm the presence of Precambrian crystalline material, Jurassic igneous bodies, and Cretaceous uplifts and intrusions. Syn-rift Triassic clastics confined to grabens paralleling the defined limit of the Basinal Zone are interpreted as evidence for a Mesozoic rift-related transform across Mississippi separating larger rift basins of southwestern Arkansas and southeastern Alabama.

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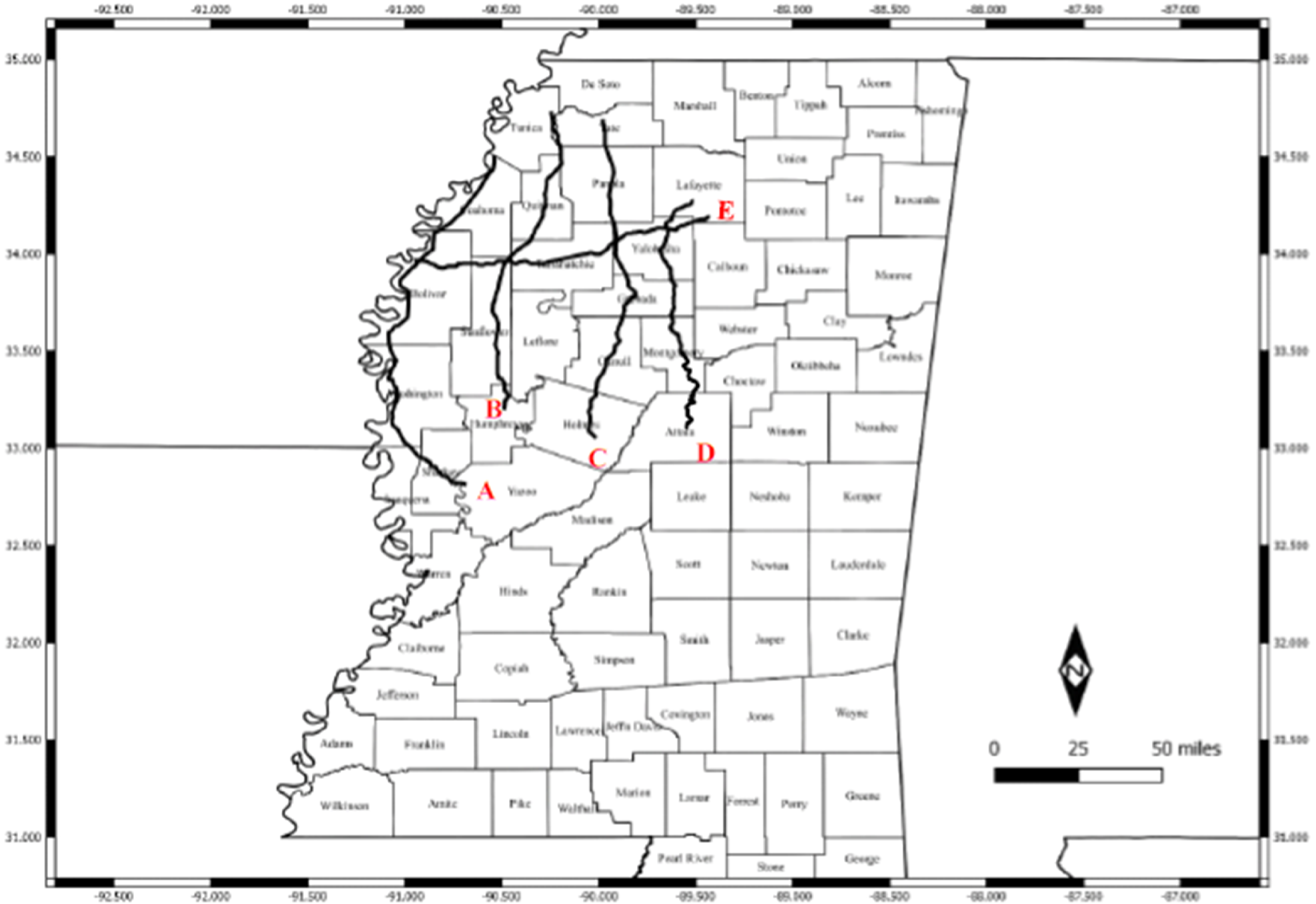


Figure 1: Location of the study area in northwestern Mississippi. Thick black lines represent the surface locations of the five 2-D seismic lines used in this study. Letters refer to how their corresponding seismic lines will be referenced in this text.

These seismic data have an interesting history. They are ‘70s vintage road/vibrator/spec data. They were given to me as paper copies by Western Geophysical in the early 1980s. I tried to get students to work the data several times…however, it was clearly a major project. I asked Nick a few years ago…he took charge. He sought and received permission to utilize and publish the data from Seismic Exchange Incorporated (SEI). He found someone to scan the paper copies which he then incorporated into computer programs where he could interpret on the data and then overlay colors. As an indication or his dedication he has 72 references…this is one of the most comprehensive collections of references for the southern continental boundary/northern Gulf of Mexico boundary that I know of.

I will present only a small part of what he has interpreted and correlated to the work of others. His full thesis will soon be digitally available. I recommend reading it if the structure of the Northern Margin of the Gulf of Mexico Basin interests you.

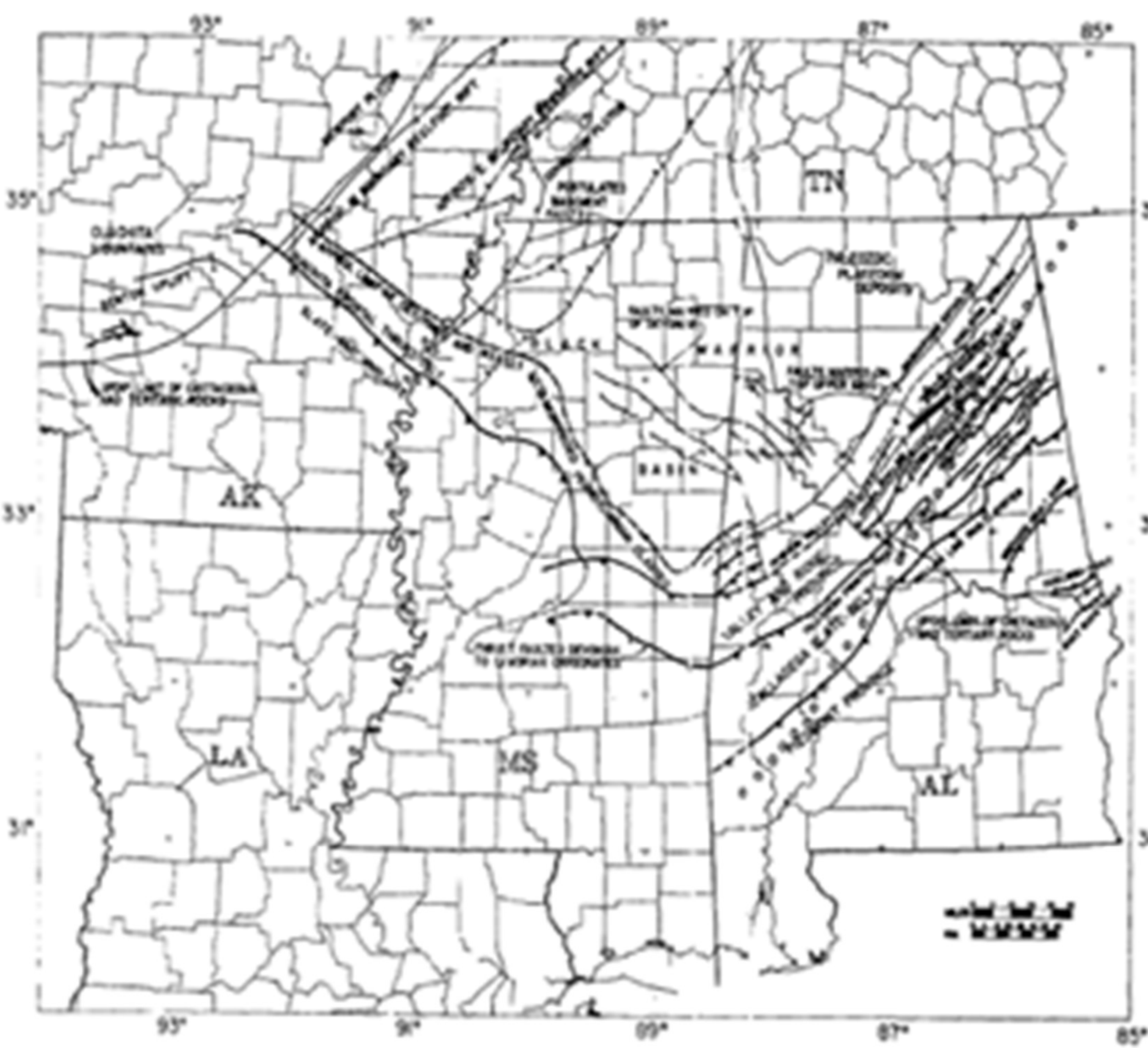


Figure 2: Primary Precambrian and Paleozoic structural features within the northern Gulf Coast region from (from Jurick, 1989).

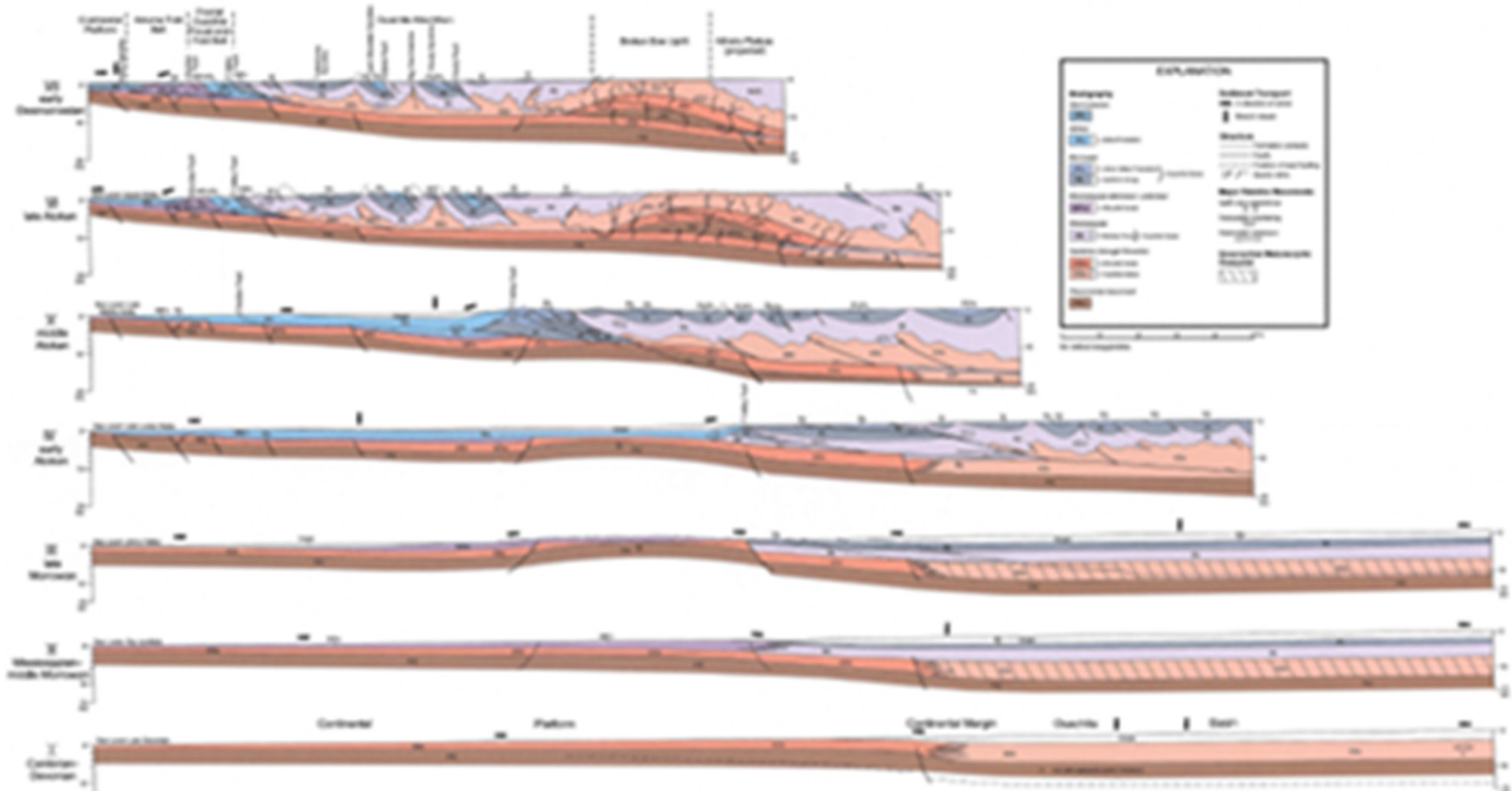
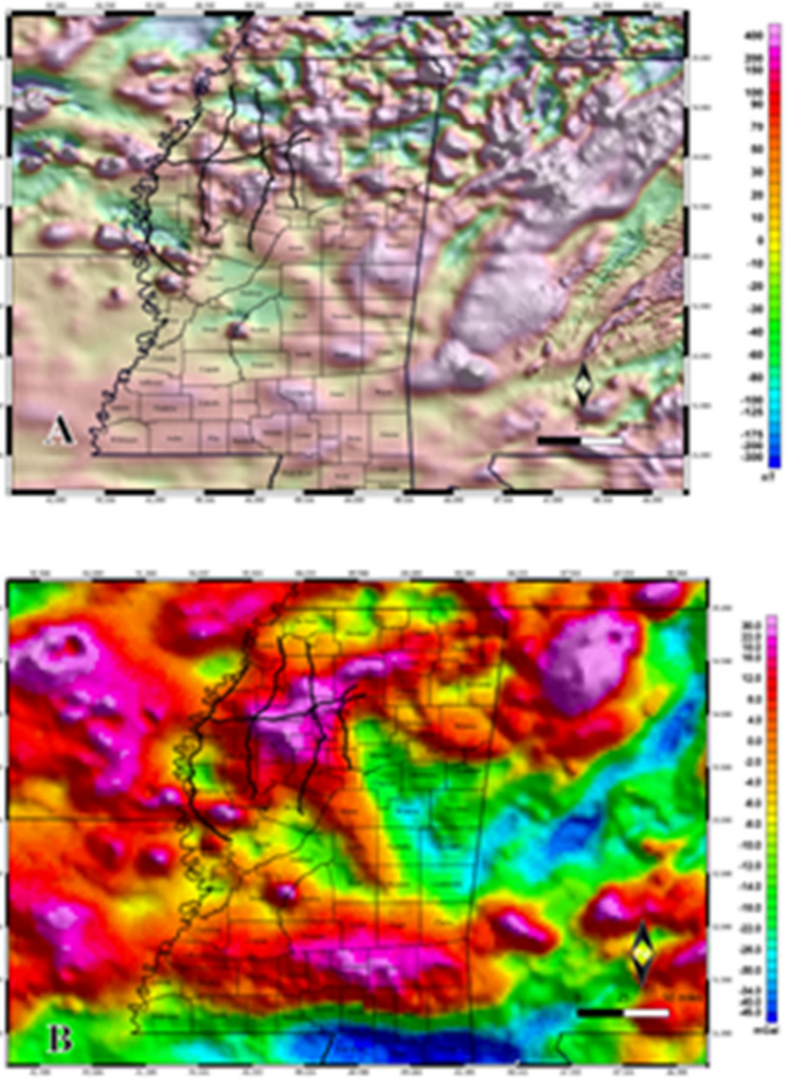


Figure 16: Cross sections from Arbenz (2008) depicting the evolution of Ouachita thrust belt and the division of sediments and structural features.



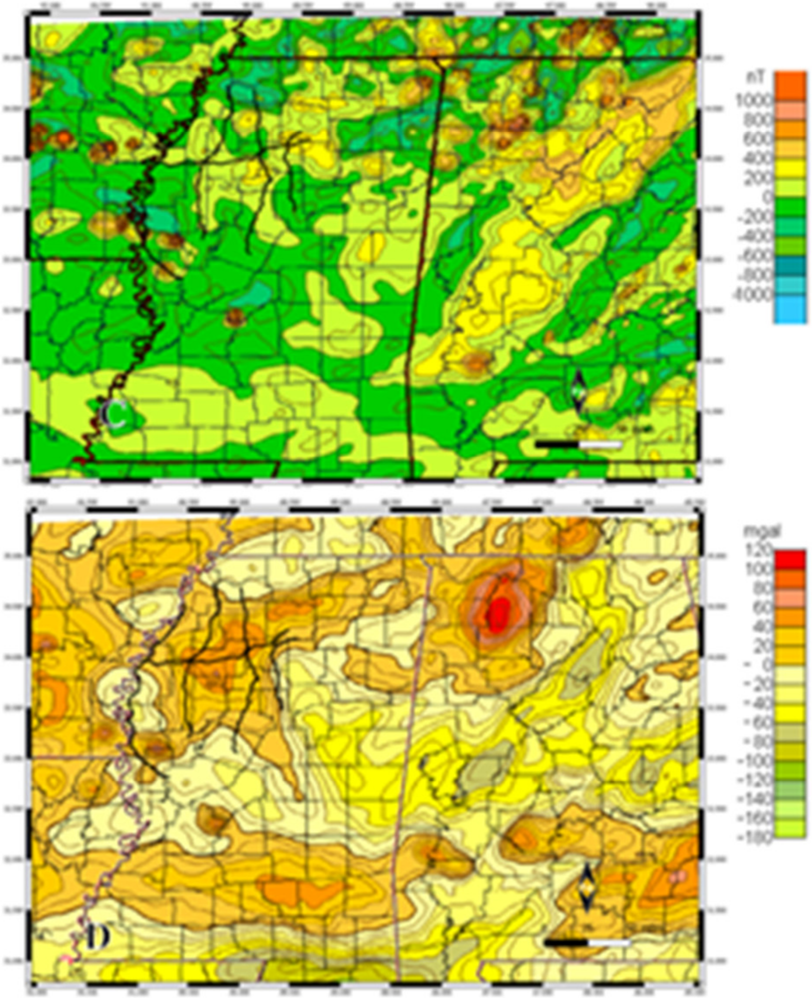


Figure 23: Magnetic anomaly and isostatic gravity maps across the project study area. (A) USGS magnetic anomaly map, (B) USGS isostatic gravity map, (C) contoured magnetic anomaly map modified from Dutch (2014), and (D) contoured isostatic gravity map modified from Dutch (2014).

- Igneous Intrusion (line A, B, C, and E)
- Gulf Coast Plain Mesozoic-Cenozoic Sediments (line A, B, C, D, and E)
- Cretaceous unconformity (line A, B, C, D, E)
- Cretaceous sediments (line A, B)
- Cotton Valley Formation (line A, B)
- Jurassic sediments (Smackover and Haynesville Formations) (line A, B)
- Louann Salt (line A)
- Norphlet Formation (line A, B)
- Werner Anhydrite (line A, B)
- Eagle Mills Formation (line A)
- Allochthonous Ouachita Sediments (line A, B, C, D, and E)
- Carboniferous sediments (Line A, B, C, D, and E)
- Unknown Paleozoic sediments (line A, B)
- Silurian – Devonian sediments (line A, B)
- Cambrian – Ordovician carbonates (line A, B, C, D, and E)
- Cambrian carbonates (line A, B, C, D, and E)
- Cambrian clastic sediments (line A, B, C, D, and E)
- Undifferentiated rift fill sediments (line B)
- Precambrian basement (line A, B, C, D, and E)

Figure 24: List of colors used to describe interpretations of seismic data and the corresponding lines each color is interpreted on.

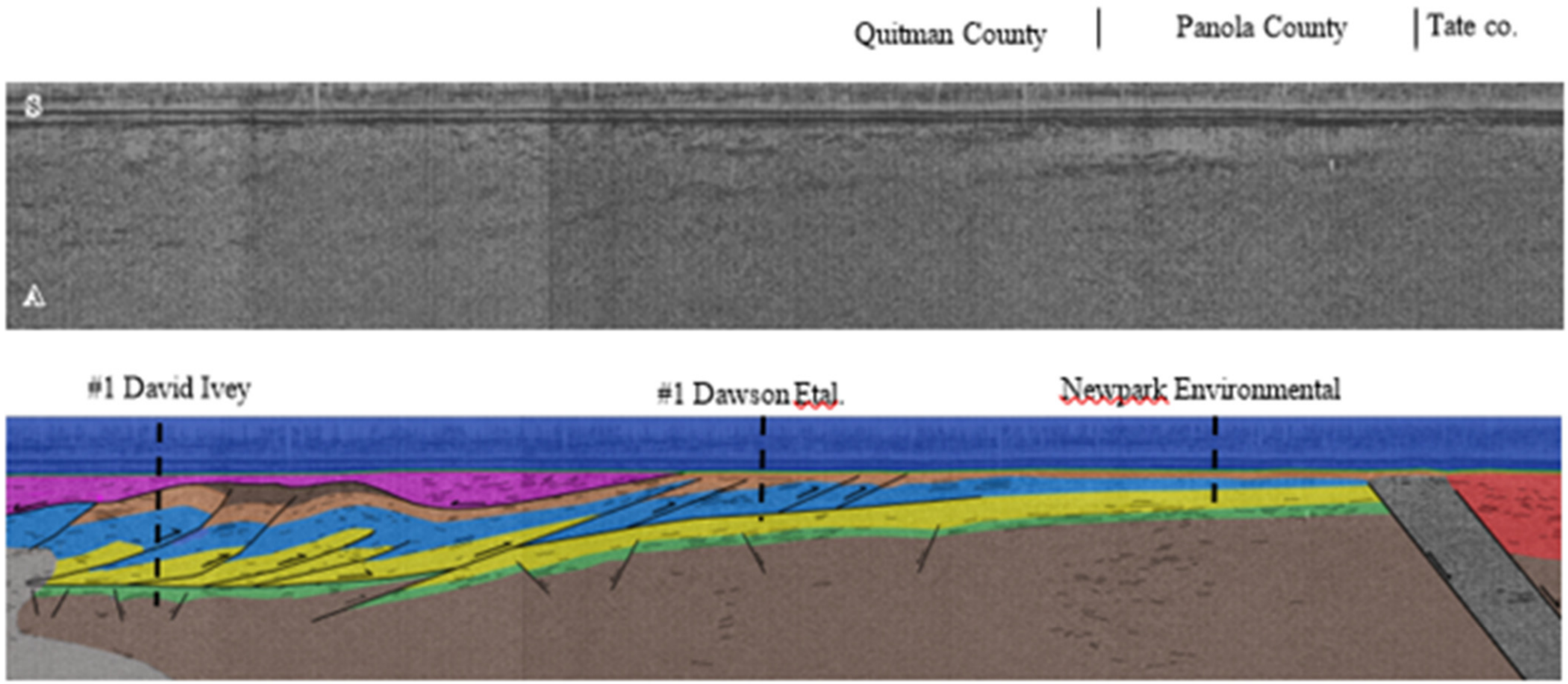


Figure 32: Uninterpreted (A) and interpreted (B) section of the northern portion of line B across basement structures of the Cratonal and Foreland basin zones. Seismic data owned or controlled by Seismic Exchange, Inc.; interpretation is that of Nicholas R. Loundagin.

Bolivar county | Coahoma county

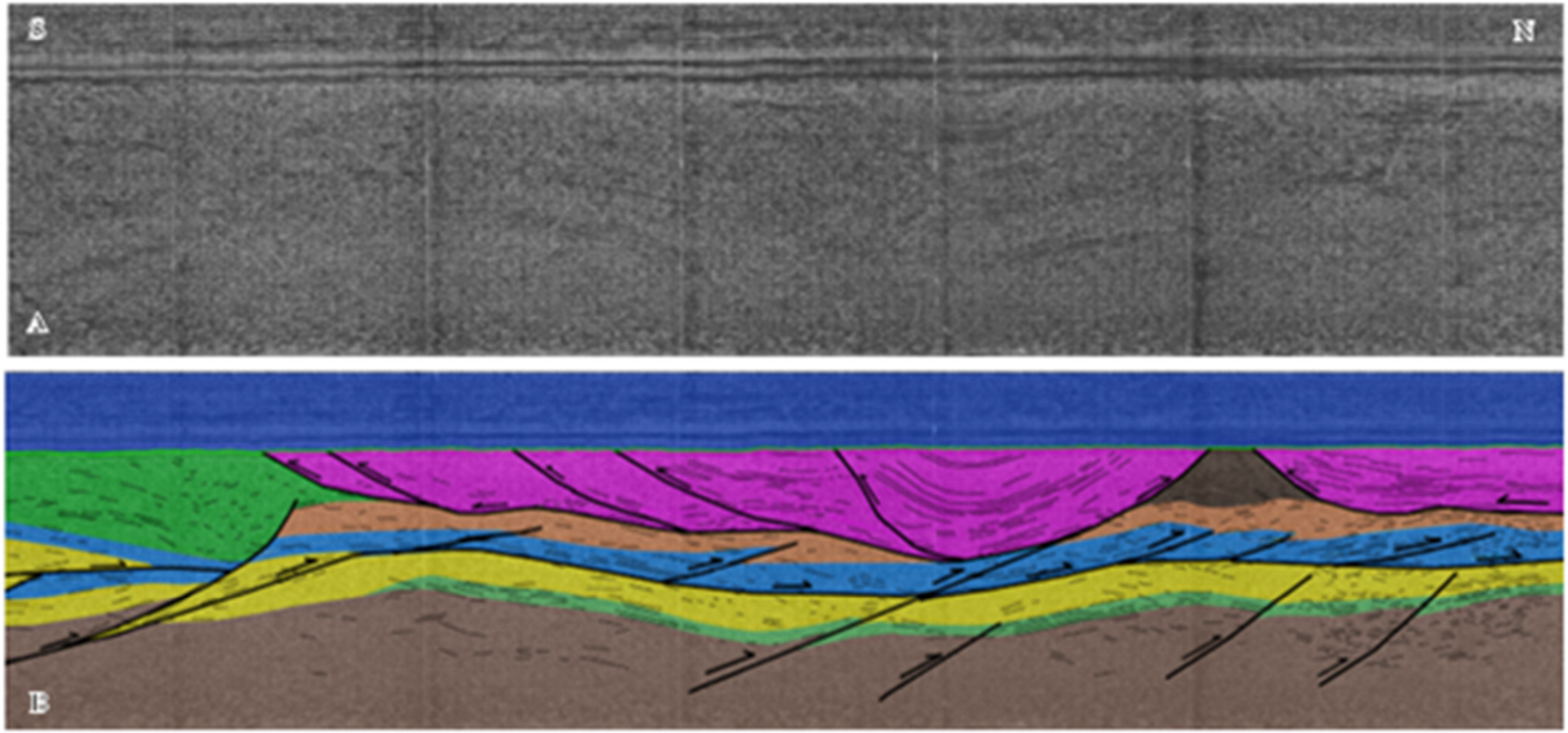


Figure 31: Uninterpreted (A) and interpreted (B) section of the northern portion of line A across basement structures of the Cratonal and Foreland Basin zones. Seismic data owned or controlled by Seismic Exchange, Inc.; interpretation is that of Nicholas R. Loundagin.

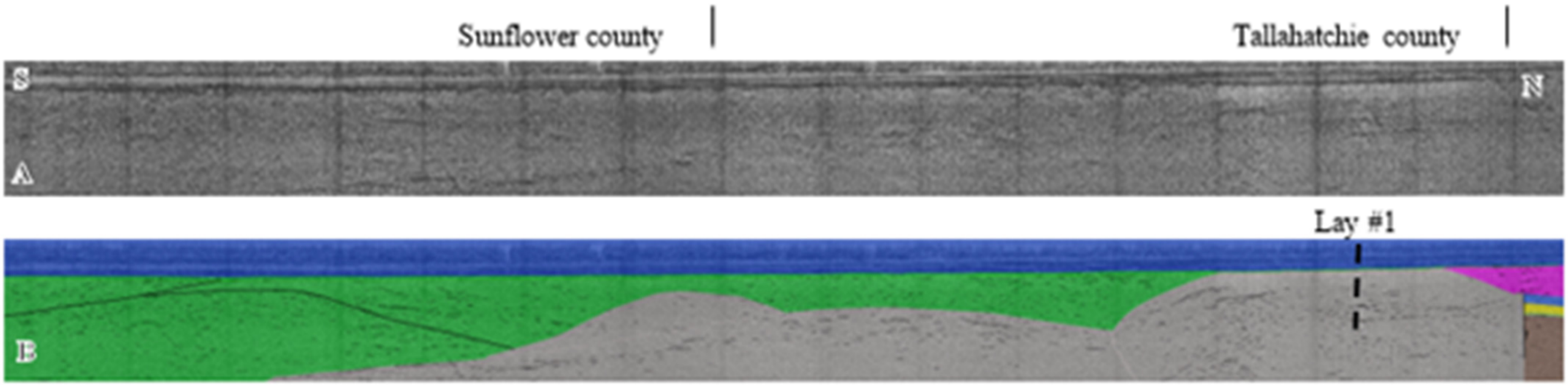


Figure 37: Uninterpreted (A) and interpreted (B) section of line E across the Allochthonous domain. Seismic data owned or controlled by Seismic Exchange, Inc.; interpretation is that of Nicholas R. Loundagin.

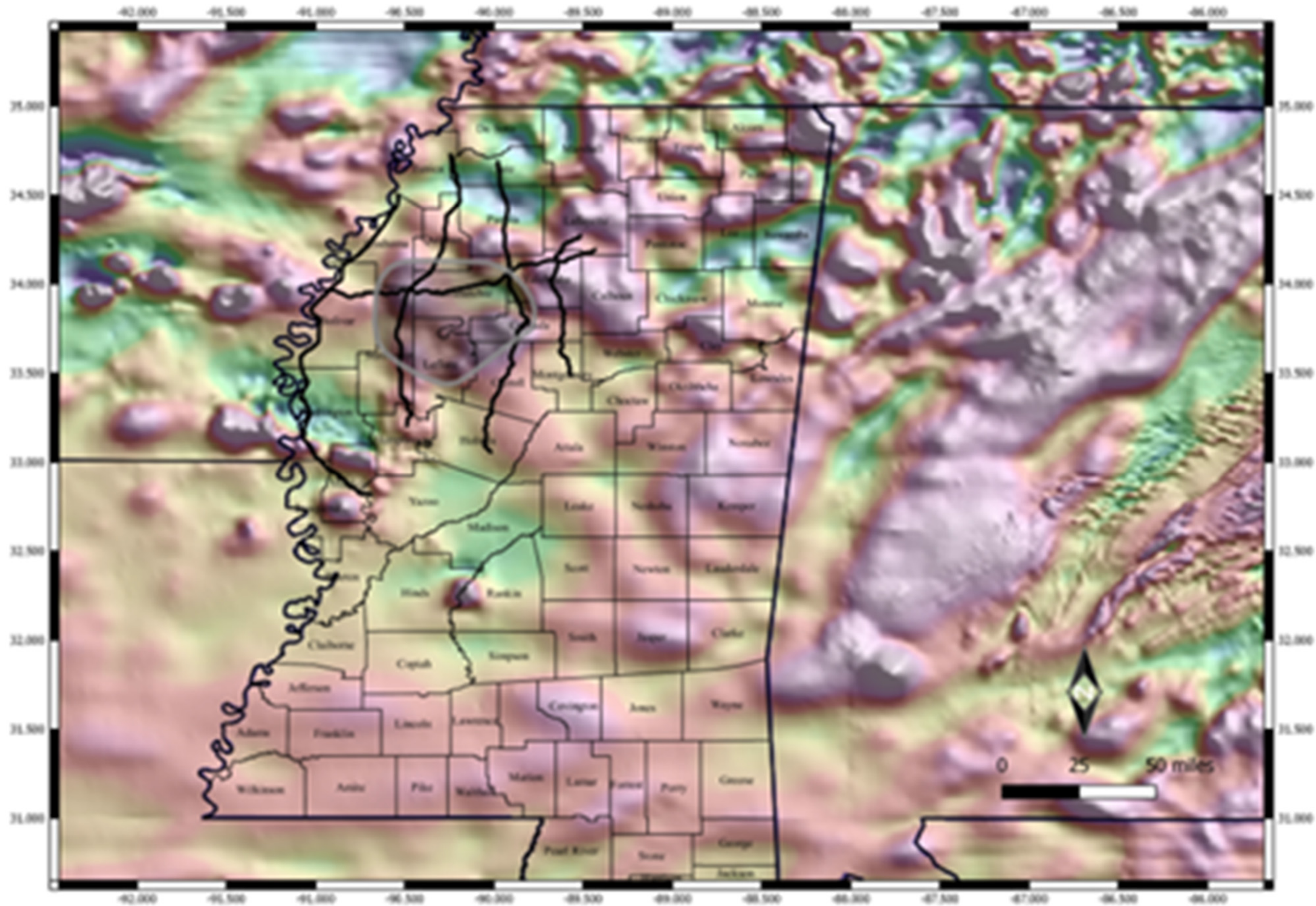


Figure 39: Extent of intrusive body (outlined in gray) as interpreted on seismic data overlaid on USGS magnetic anomaly map.

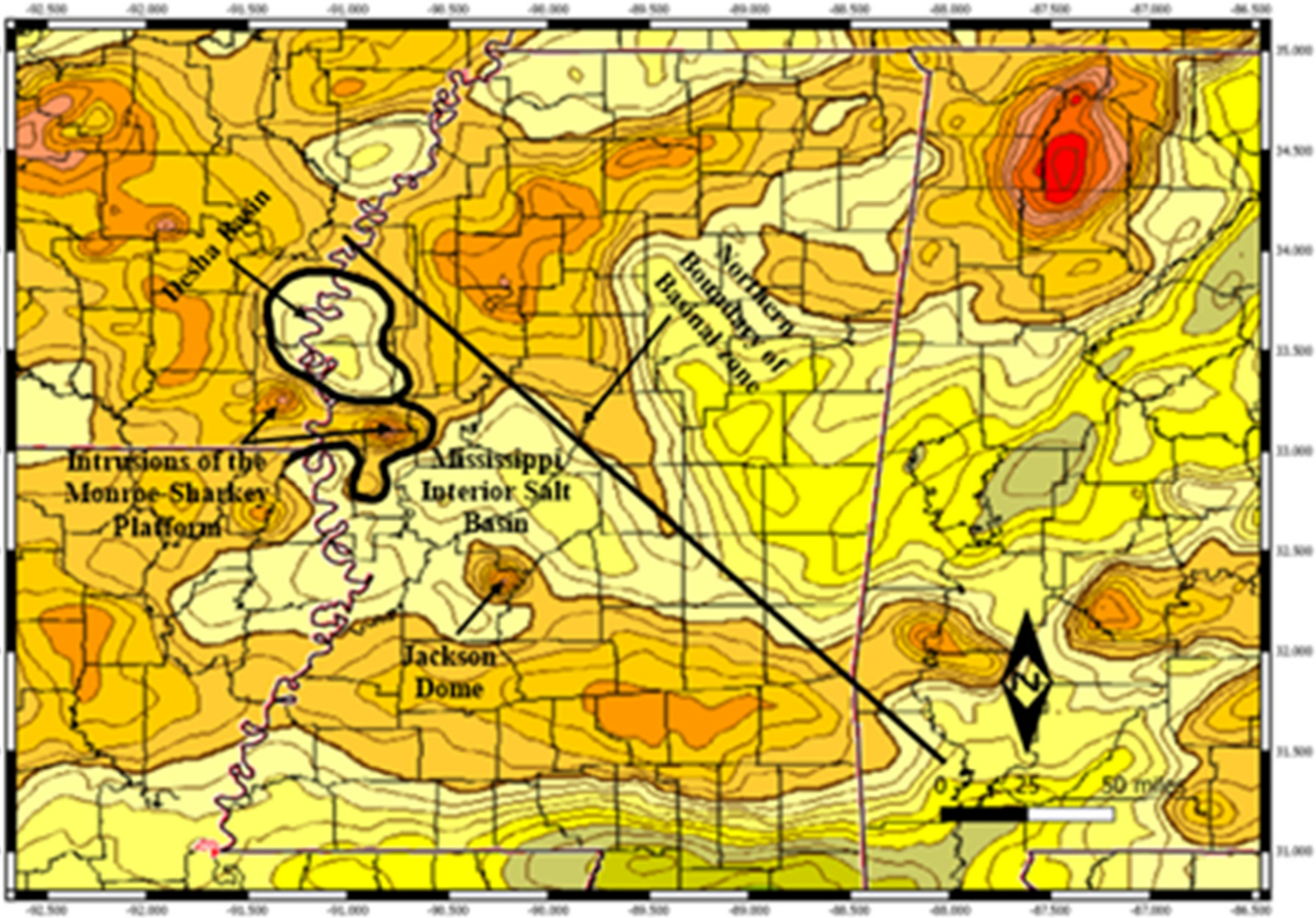


Figure 41: Features of the Basinal zone indicated on a contoured isostatic gravity map based on drilling and seismic data. Modified from Dutch 2014.

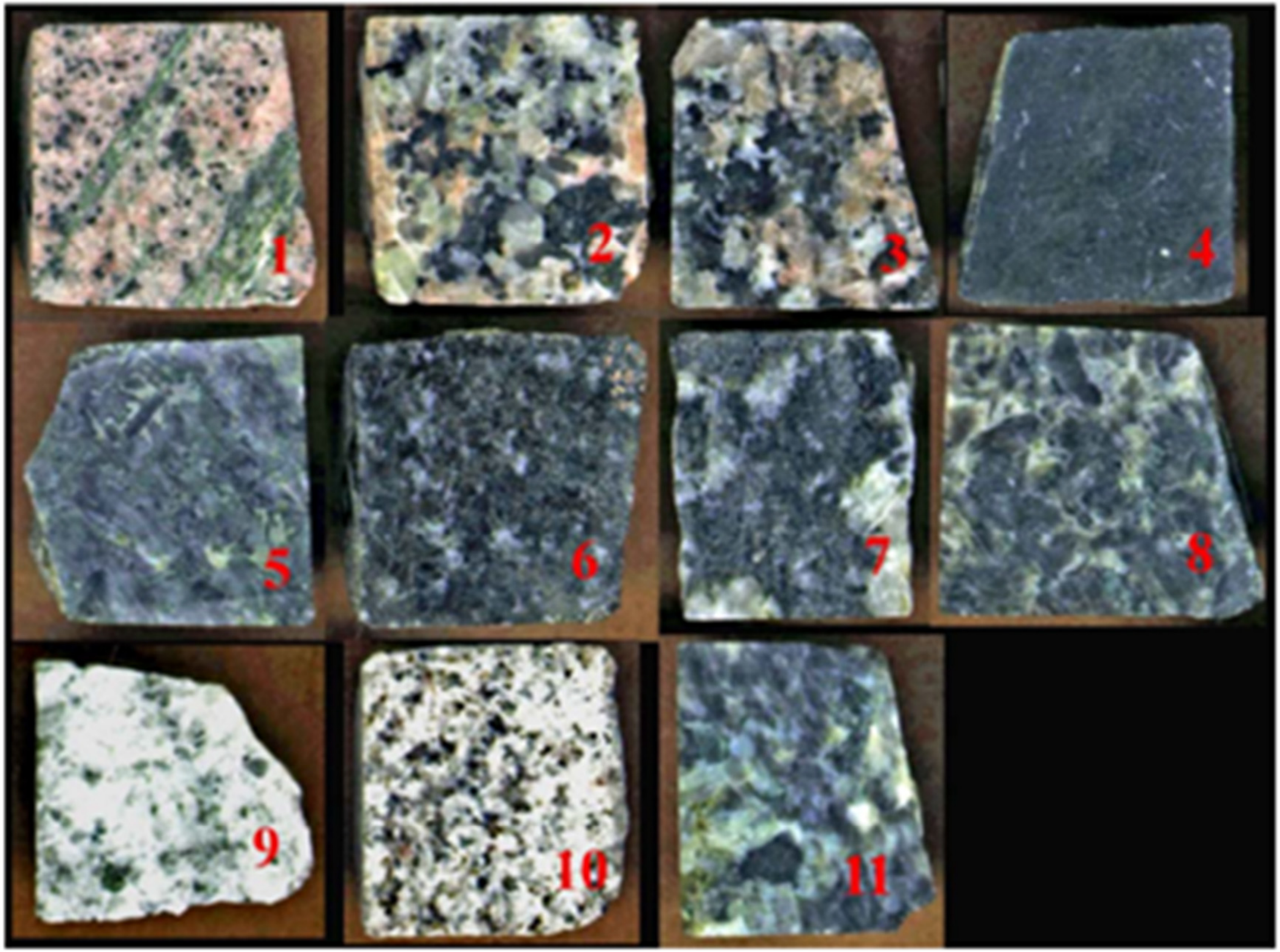


Figure 36: Image of sidewall core samples of igneous rocks from the Marathon Lay #1 well in Tallahatchie County, Mississippi (Figure 2 from Dockery and Thompson, 2010).

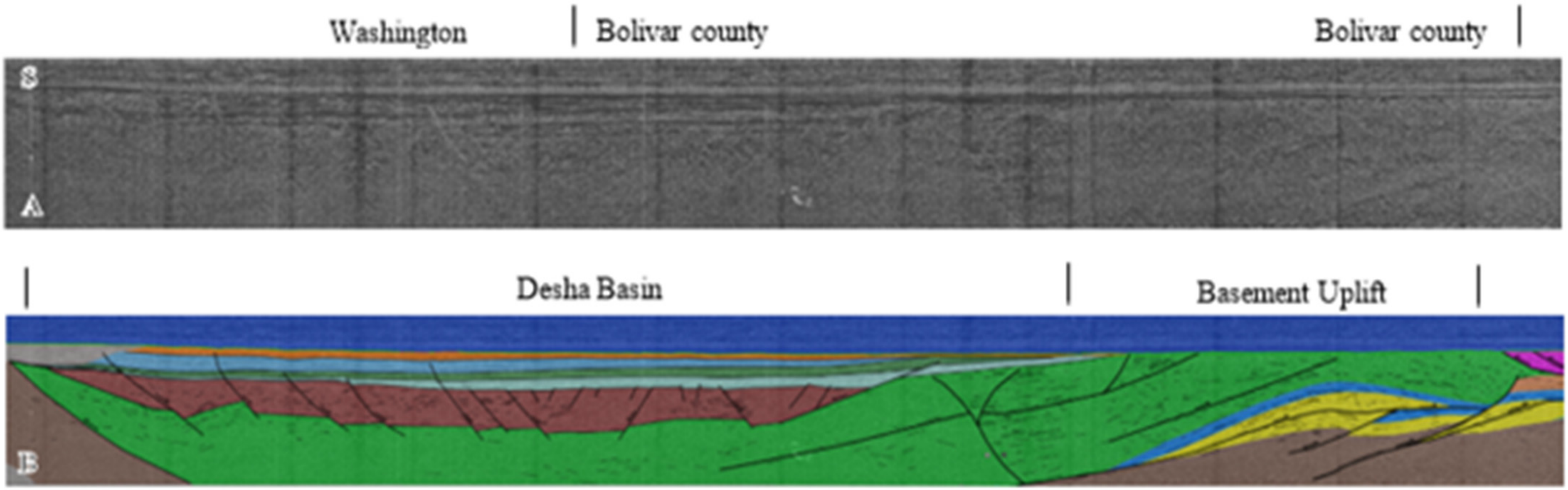


Figure 34: Uninterpreted (A) and interpreted (B) section of line A across the Allochthonous domain and northern Basinal zone. Seismic data owned or controlled by Seismic Exchange, Inc.; interpretation is that of Nicholas R. Loundagin.

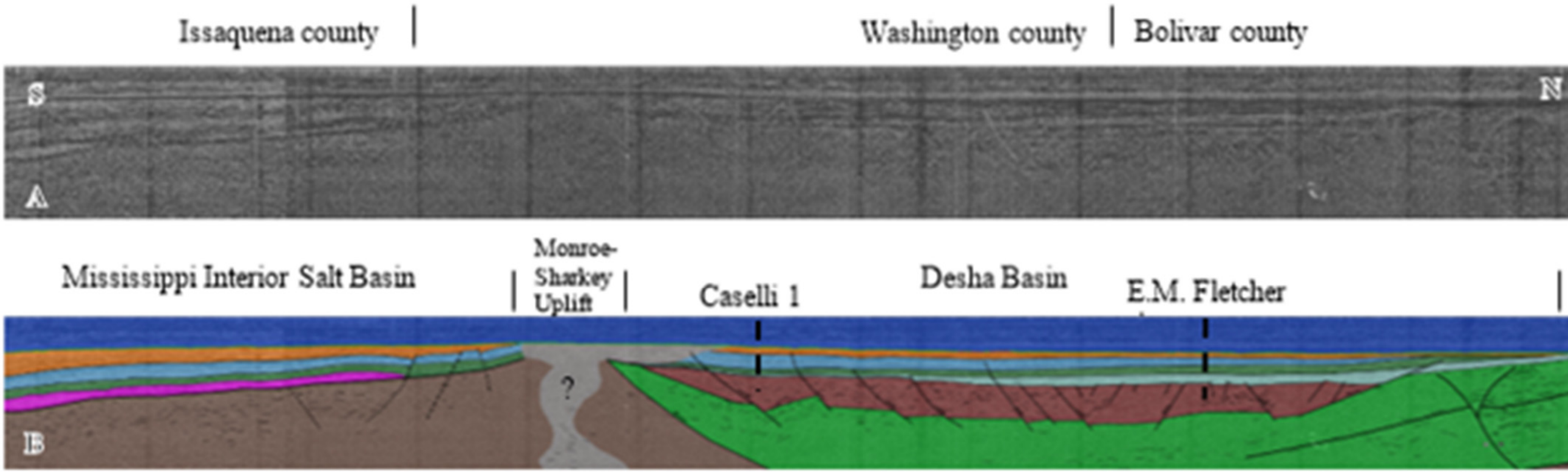


Figure 42: Uninterpreted (A) and interpreted (B) section of line A across the Basinal zone. Seismic data owned or controlled by Seismic Exchange, Inc.; interpretation is that of Nicholas R. Loundagin.

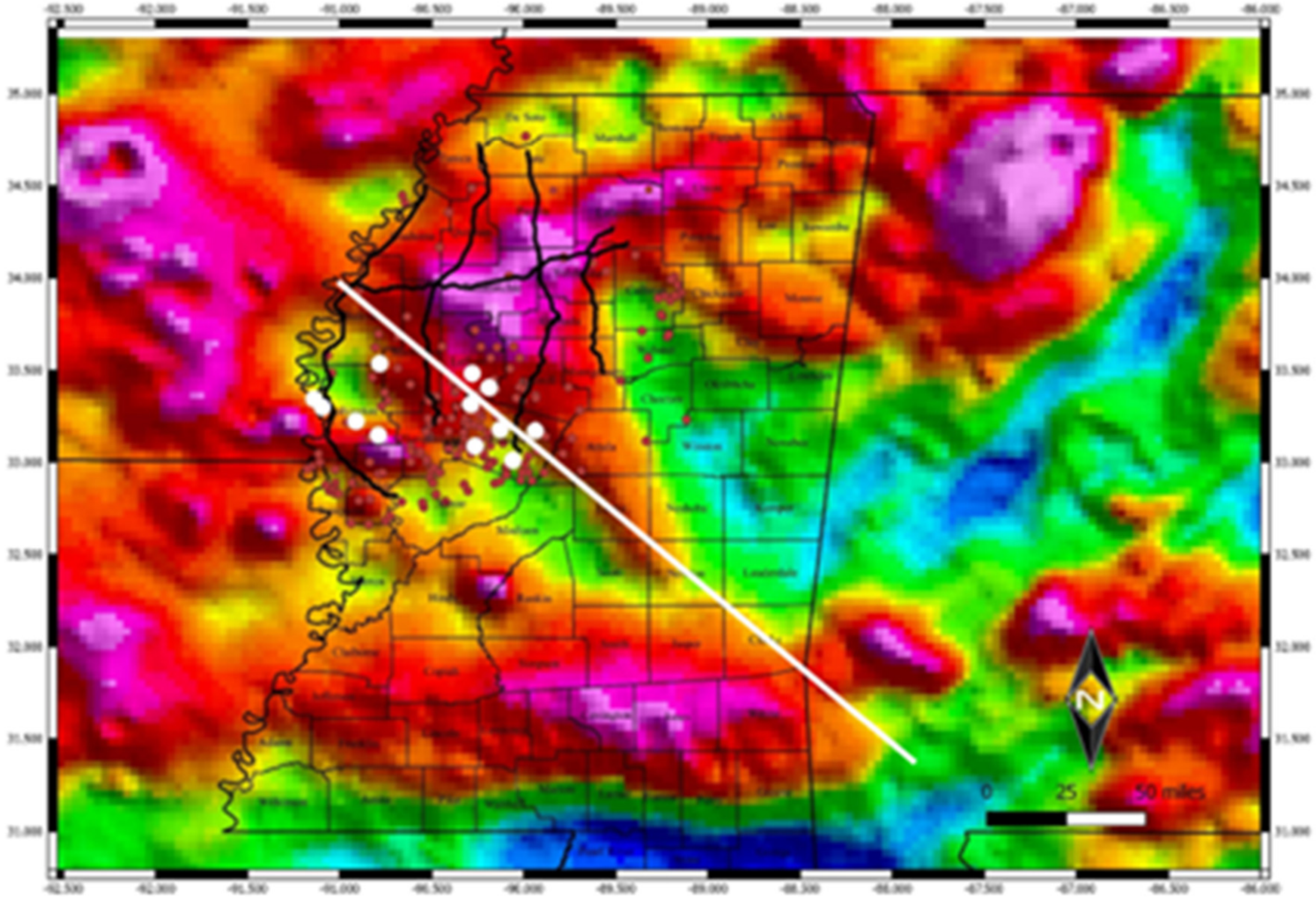
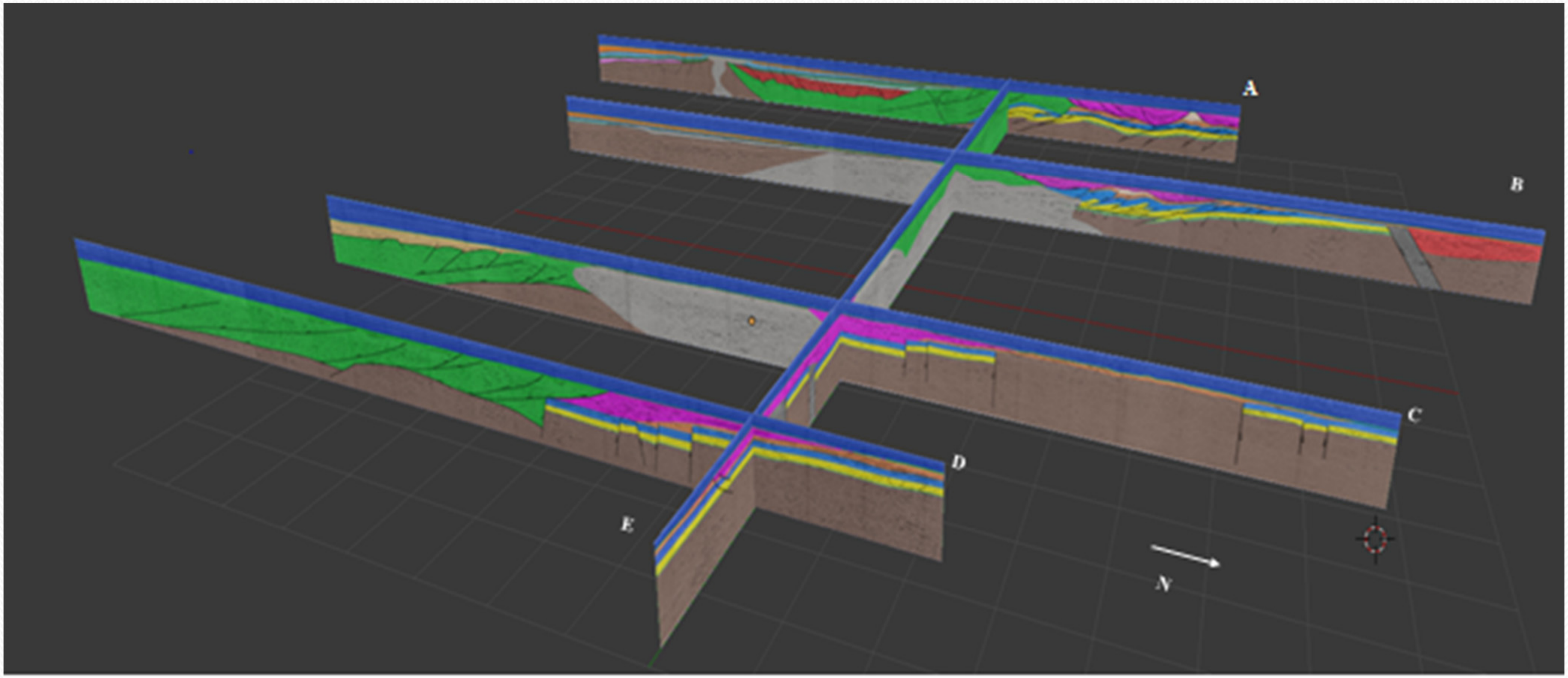


Figure 44: Seismic data, gravity data of the USGS, and well locations in study area. White line = northern margin of basinal zone along linear gravity gradient corresponding to proposed transform margin, white dot= wells encountering eagle mills, black lines=seismic surface trace.


A
B
C
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