Note: Due to file size constraints the rest of the dissertation has been placed in a separate pdf document.

Chapter 5
Analysis

5.1. Major contact reflectors

The twenty eight 2D reflection seismic sections are located in the three domains of the study area. In this section they are described in terms of the seven major contacts that define the eight volumes of the 3D geological model. The seismic sections are displayed in Figure 5.1, inside the red polygons that delineate the boundaries of the three domains. The twenty eight seismic sections are presented in Figures 5.2.1 – 5.2.28. The order of the figures represents the sequence in which the sections were interpreted (listed in Table A1 in the Appendix).

5.1.1. Base of the Karoo Supergroup

The base of the Karoo Supergroup exhibits lower V_p and ρ than the underlying stratigraphy (Section 4.3; V_p and ρ values in Table C in the Appendix). Therefore a strong amplitude reflection is produced at the interface. This reflection is interpreted and imaged beneath the outcrop of the Karoo Supergroup in all three domains. The interpreted interface is particularly well imaged where the Karoo Supergroup is both several hundred meters thick and exhibits an angular contact relationship with underlying reflections. Seismic sections KV-120, OB-41, and OB-74 in Domain 1 exhibit these angular contact relationships in the top 1000m (Figures 5.2.9, 5.2.8, and 5.2.10, respectively).

The seismic data show good delineation of the interface that lies <500m below surface throughout most of Domain 2. In this domain, several seismic sections in these areas exhibit discontinuous, strong amplitude and sub-horizontal reflections. These sections include seismic lines DV-270A, DV-270B, DV-272, BH-268, and BH-269 (Figures 5.2.15, 5.2.14, 5.2.12, 5.2.18, and 5.2.16, respectively). In Domain 3 the interface is well imaged close to surface. The angular contact relationship with underlying seismic stratigraphy is also delineated as a strong seismic marker in several seismic sections, including BH-171A, BH-171B, DE-507, and DE-512B (Figures 5.2.24, 5.2.23, 5.2.28, and 5.2.19, respectively). Several outcrops in Domain 3 provide constraints to the underlying units in adjacent seismic sections.

5.1.2. Pretoria Group – Chuniespoort Group

The interfaces of the Transvaal Supergroup, including the interface between the Pretoria and Chuniespoort groups, are constrained by the surface mapping and boreholes. The interpretations follow guidance from Section 4.3, including the V_p and ρ values displayed in Table C in the Appendix. The contact between the Pretoria and Chuniespoort groups is well imaged by the seismic method due to a significant acoustic impedance contrast between the two stratigraphic units. The seismic interpretation of this interface reasonably correlates across the three domains. The interpretation of the Pretoria Group is constrained by outcrop in the northern half of Domain 1. The outcrop in Domains 2 and 3 are dominated by the relatively thin Karoo Supergroup cover (several hundred meters thick). However several narrow outcrops are mapped in these domains as well.

In Domain 2 the internal reflections of the Transvaal Supergroup are consistent in seismic lines DV-270B, DV-271, DV-272, and DV-274 (Figures 5.2.14, 5.2.13, 5.2.12, and 5.2.11, respectively). In Domain 3 these reflections are dominant across all but three seismic sections (BH-171A, BH-171B, and DE-507). The seismic sections in the southern half of Domain 2 as well as the eastern half of Domain 3 show no evidence of seismic reflections associated with the Transvaal Supergroup. This is confirmed by borehole intersections and the adjacent outcrops. However the quality of the seismic reflections is poor in parts of Domain 3 (e.g., Figure 5.2.21C).

A decrease in V_p and ρ occurs from the Hekpoort Formation to the Timeball Hill Formation (i.e., from 6083 m/s and ~2.83 g/cm^3 to 5513 m/s and ~2.80 g/cm^3). This provides a strong reflection coefficient at the interface. The relative depths of these two formations are highlighted in the seismic sections (e.g., Figures 5.2.4, 5.2.6, 5.2.2 and 5.2.1). The Hekpoort Formation crops out in the northern half of Domain 1 and in several exposures in Domains 2 and 3. Seismic sections in these areas show good internal reflections within the Formation that correlate with the outcrop. In Domain 1 in particular, several seismic sections (KV-117, KV-132, OF-97, OF-98, and OPR-50) correlate well with the outcrop (Figures 5.2.4, 5.2.6, 5.2.2, 5.2.1, and 5.2.3, respectively). The Pretoria Group in seismic section OF-98 is well constrained by borehole 4014246. This borehole is located ~200m from shotpoint 100 in OF-98 and provides the depth extents of the Hekpoort Formation (coinciding well with the interfaces). In Domain 2 the volcanics of the Hekpoort Formation are seismically transparent below the Karoo Supergroup. In Domain 3 the Formation is exposed in outcrop adjacent to seismic sections DE-83, DE-510, and DE-508 (Figures 5.2.25, 5.2.26, and 5.2.27, respectively).

In most sections the Chuniespoort Group is seismically transparent, likely due to the relatively consistent V_p and ρ of the dolomite units. The lateral variations in the amplitude strengths may have been caused by varying chert and shale components because both these lithologies exhibit ρ values that are lower than the dolomite (see Table C in the Appendix). In Domain 1 the interpretation of the seismic sections OF-97, OF-98, and OPR-50 correlate well with the borehole data (Figures 5.2.2, 5.2.1, and 5.2.3, respectively). A few boreholes in Domain 2 intersect the Chuniespoort Group at depths between 1000m and 3000m, and provide constraints to seismic sections DV-270B and DV-272 (Figures 5.2.14 and 5.2.13, respectively). These boreholes are located within 550m of the two sections and importantly they indicate the termination of the Group against the Karoo Supergroup. However boreholes on the southern margin of Domain 3 show the Karoo Supergroup unconformably overlying the Chuniespoort Group. The interface between the Pretoria and Chuniespoort groups in Domain 3 is only provided by one borehole (i.e., 4066142 located adjacent to Hekpoort Formation outcrop).

5.1.3. Black Reef Formation

The Black Reef Formation represents the interface between the Transvaal and Ventersdorp supergroups. The interface is imaged as a strong seismic reflector across all three domains; however the lateral continuity is limited in Domains 2 and 3. In Domain 2 the high resolution imaging of the Black Reef Formation is shown in seismic sections DV-270B, DV-271, DV-272, and DV-274 (Figures 5.2.14, 5.2.13, 5.2.12, and 5.2.11, respectively). In Domain 3, its reflection is consistent across seven of the ten seismic sections, including seismic sections DE-83, DE-506, DE508, DE-510, DE511, DE-512A, and DE512B (Figures 5.2.25, 5.2.22, 5.2.27, 5.2.26, 5.2.21, 5.2.20, and 5.2.19, respectively).

The borehole data provide constraints for the interface between the Malmani Subgroup and the underlying Ventersdorp Supergroup in the northern half of Domain 1. The seismic lines in this area exhibit relatively poor quality of the reflection. Elsewhere in Domain 1, the reflection associated with the base of the Black Reef Formation is robust across seismic sections KV-117, KV-118, KV-120, KV-132, OB-41, and OB-74 (Figures 5.2.4, 5.2.5, 5.2.9, 5.2.6, 5.2.8, and 5.2.10, respectively). The interface exhibits an angular relationship with the underlying seismic stratigraphy (mainly the Ventersdorp Supergroup), and this is confirmed by borehole 4039854 in seismic line KV-120 (Figure 5.2.9).

Borehole 4039854 is located ~600m from shotpoint 450 in KV-120 and intersects the Black Reef Formation from 681.75 to 789.85m downhole. The ~100m thick Black Reef Formation is delineated as a strong seismic reflector due to a significant acoustic impedance contrast at the contact with the underlying volcanics of the Allanridge Formation. The reflection is prominent across seismic section KV-120 to section OB-41.

The Black Reef Formation crops out in the collar rocks of the Vredefort dome. The outcrop coincides with the surface extent of the interface in seismic sections KV-132 and FV-155 (Figures 5.2.6, and 5.2.7, respectively). This extent includes seismic section OPR-50 albeit with relatively poor quality of the reflections.

In Domain 2, the seismic reflections are continuous across seismic lines DV-270B, DV-271, DV-272, and DV-274 (Figures 5.2.14, 5.2.13, 5.2.12, and 5.2.11, respectively). The interface exhibits an angular relationship with the underlying seismic stratigraphy and is constrained by several boreholes. Boreholes 4054356 and 4063523 are located adjacent to shotpoints 730 and 675 in DV-270B, respectively, and borehole 4038363 is ~550m from shotpoint 340 in DV-272.

In Domain 3, the interface is well imaged in seismic section DE-512B (Figure 5.2.19). The borehole intersection on the southern margin of Domain 3 provides the constraints to the Black Reef Formation (at a depth of up to 2060m downhole). Figure 5.2.25C demonstrates a good tie between the borehole data and seismic sections DE-83 and DE-508. The easternmost intersection of the Chuniespoort Group in Domain 3 is reported in borehole 4039847. This borehole, located 4100m east of seismic line DE-511, is shallow and ends at 404.91m downhole; however it does not intersect the Black Reef Formation. The interface of the Black Reef Formation adjacent to the borehole is <700m below surface. It is suggested that if borehole 4039847 was continued a few hundred meters deeper the Black Reef Formation would have been intersected and the footwall lithology would have been confirmed. The Black Reef Formation in this area is interpreted to unconformably overly the Central Rand Group.

The seismic section interpretation of DE-512A is constrained by three boreholes and an outcrop of volcanics of the Klipriviersberg Group (Figure 5.2.20). These boreholes include, (1) 4003241 located ~2000m from shotpoint 350, (2) 4039843 located ~350m from shotpoint 270, and (3) 4066140 located ~400m from shotpoint 370. The volcanics of the Klipriviersberg Group are characterised by strong chaotic reflections in this seismic section. Borehole 4066140 is located in the outcrop and reports volcanics of the Klipriviersberg Group from surface to 1285.95m downhole. Approximately 5000m north of the outcrop the Black Reef Formation is intersected in borehole 4039843 at 258.47m downhole. Approximately 2500m northeast of this borehole, the Klipriviersberg Group crops out ~400m from shotpoint 225 in seismic section DE-512A (and adjacent to seismic line DE-511). Furthermore, borehole 4066139 is located ~6100m from shotpoint 420 in DE-512A (i.e., to the left of the label "DE512A" in Figure 5.1). This borehole reports the Karoo Supergroup unconformably overlying dolomite of the Chuniespoort Group. The interfaces in this part of seismic section DE-512A are repeated, with the geometry illustrated in the interpretation (Figure 5.2.20B).

5.1.4. Ventersdorp Contact Formation (VCF)

The VCF represents the interface between the Ventersdorp and Witwatersrand supergroups, and is imaged as a strong, continuous seismic reflector across the three domains (Section 4.3 V_p and ρ values in Table C in the Appendix). In Domain 2 the interface is not evident in the southernmost seismic sections, including BH-268, FV154, and DV-270A (Figures 5.2.18, 5.2.17.1/2, and 5.2.15, respectively). In Domain 3 the VCF is elevated towards the east and is not evident in the seismic sections (see Figures 5.2.21, 5.2.22, 5.2.23, 5.2.24, and 5.2.26).

Borehole constraints of the VCF reflector in Domain 1 are limited to the north and the southwest margins. These boreholes provide good depth constraints of the contact between the volcanics of the Ventersdorp Supergroup and the quartzites of the Central Rand Group. However, borehole 4039854 is located ~600m from shotpoint 450 in KV-120 and provides the contact with the volcanics of the Crown Formation. In Domains 2 and 3 the borehole coverage is relatively lower than Domain 1, thereby limiting the depth constraints to the adjacent seismic sections. These boreholes provide constraints of <2500m below surface for the volcanics of the Ventersdorp Supergroup. Several boreholes intersect the hangingwall or footwall to the VCF and are important constraints of the adjacent seismic lines.

The V_p and ρ values decrease across the contact between the Klipriviersberg and Central Rand groups (i.e., from ~6300 m/s and ~2.90 g/cm^3, to ~5700 m/s and ~2.76 g/cm^3, respectively). This provides an acoustic impedance contrast across the interface that is reasonably imaged in the seismic data. The VCF is not a stable reflector; discontinuities are common across the seismic sections, possibly indicating a high degree of local fault offsets.

In Domain 3 offsets on the VCF reflector are much less common than in Domains 1 and 2. Seismic section DE-512B provides a good example of the degree of faulting of the VCF reflector (Figure 5.2.19). The interpretation of the Central Rand Group and Ventersdorp Supergroup in Domain 3 is guided by the boreholes as well as the package of strong, closely spaced internal reflections of the West Rand Group.

Furthermore, the interpretation of the VCF reflector in seismic sections DV-270B, DV-271, and DV-272 (Figures 5.2.14, 5.2.13, and 5.2.12, respectively) in Domain 2 is constrained by four boreholes. Two additional boreholes (4202532 and 4063523) are located adjacent to these sections that do not intersect the Ventersdorp Supergroup. Borehole 4202532 is located 50m from shotpoint 710 in seismic section DV-271 (Figure 5.2.13). It intersects the Karoo Supergroup unconformably overlying quartzite of the Kimberley Formation. Borehole 4063523 is located 150m from shotpoint 675 in seismic section DV-270B (Figure 5.2.14). It intercepts the contact between the dolomite of the Chuniespoort Group and quartzite of the Witwatersrand Supergroup.

In the collar rocks of the Vredefort dome in Domain 1, the VCF reflector in seismic section FV-155 is guided by outcrop of the Ventersdorp and Witwatersrand supergroups (Figure 5.2.7). The adjacent boreholes provide additional constraints, for example the Booysens Formation is intersected in the upper 2000m of the section. The Booysens Formation in most seismic lines is relatively poorly imaged, i.e., it is a poor seismic marker. However in adjacent seismic sections OB-74 and DE-512B the Formation is characterized by a seismic reflection within the seismically transparent Central Rand Group (Figures 5.2.10, and 5.2.19, respectively). Outcrops of the Ventersdorp and Witwatersrand supergroups are located ~2800m north of seismic section DV-272 in Domain 2. An outcrop is located ~5000m east of seismic section BH-269 in Domain 2 as well, and exposes volcanics of the Klipriviersberg Group.

In Domain 1 the Central Rand Group is relatively thin in seismic sections KV-120 OB-41, and OB-74 (Figures 5.2.9, 5.2.8, and 5.2.10, respectively). The VCF reflector in these sections is less than 1000m above the Central Rand/West Rand Group interface. In seismic section KV-120 the Central Rand Group is absent in the southwest half. Instead, the VCF is unconformably overlying the West Rand Group. This contact relationship is supported by borehole 4039854, located ~600m from shotpoint 450 in section KV-120. The borehole intersects quartzite and dolomite of the Rietgat Formation that unconformably overlies the West Rand Group (reported as volcanics of the Crown Formation overlying quartzite of the Jeppestown Subgroup).

In Domain 2 the Central Rand Group narrows in seismic sections BH-269, DV-270A and FV-154 (Figures 5.2.16, 5.2.15, and 5.2.17.1, respectively). The VCF reflector is less than 1000m above the Central Rand/West Rand Group interface. The VCF in parts of these sections overlies the West

Rand Group. Adjacent boreholes do not intersect this interface; however they provide the interpretation with good seismic constraints on the overlying units.

In Domain 3, a number of boreholes are located south of seismic section DE-83 and provide constraints of the VCF from 495.91m to >3133.64m downhole. Borehole 4003209 is located ~2400m from shotpoint 870 in section BH-171A (Figure 5.2.14). The borehole reports the intersection of the VCF at 543.00m downhole. Outcrops within 50m of seismic sections BH-171A and BH-171B expose volcanics of the Klipriviersberg Group (Figures 5.2.14 and 5.2.13, respectively). The outcrops provide evidence for the contact of the VCF interface with the package of closely spaced strong seismic reflections that define the West Rand Group.

5.1.5. Central Rand Group – West Rand Group

The interface between the Central Rand and West Rand groups is imaged consistently across all three domains (Section 4.3; Vp and ρ values in Table C in the Appendix). The West Rand Group is characterised by closely spaced, strong amplitude internal reflections. The interface is guided using this signature package. The seismically transparent Central Rand Group further aid the mapping of the interface. The various sedimentary sequences in the West Rand Group are imaged as a 5000 – 10000m wide package of reflections across the three domains. However, in Domain 1 the quality of the seismic reflections of the West Rand Group is relatively poor. Seismic section FV-155, on the other hand, is the exception because it exhibits strong amplitude reflections of the Group (Figure 5.2.7).

Borehole constraints for the seismic interpretation of the Group are limited in all three domains. In Domain 1, only two boreholes intersect the West Rand Group beyond the collar rocks of the Vredefort dome. These two boreholes are 4037657 and 4039854 and are located adjacent to seismic line KV-120. Boreholes in the southern half of Domain 2 intersect the West Rand Group/Central Rand Group contact. The contact in this area is imaged closer to the surface than it is in the north. Seismic sections DV-270B and DV-270A demonstrate this change in depth from north to south (Figures 5.2.14 and 5.2.15, respectively).

In Domain 2, a number of boreholes are not stratigraphically refined. However, some of the intersections provided in these boreholes correlate well with the seismically defined interface. These stratigraphically unrefined boreholes report two shale units at depth. In the adjacent seismic sections, the ~100m thick upper shale unit corresponds to one of the minor internal reflections within the seismically transparent Central Rand Group. The reason for the reflections may be due to a significant acoustic impedance contrast between the quartzite and shale units of the Central Rand Group.

The seismic data also show high resolution imaging of a relatively thinner shale unit at the top of the West Rand Group. The depth location of this shale is well constrained by three boreholes adjacent to the seismic lines. Borehole 4063523 is located ~150m from shotpoint 650 in section DV-270B and intersects the shale unit at 1967.06m downhole at the top of the West Rand Group (Figure 5.2.14). Borehole 4066121 is located ~250m from shotpoint 870 in section BH-268 and intersects the shale unit at 1707.18m downhole (Figure 5.2.18). Borehole 4202051 is located ~170m from shotpoint 470 in section BH-268 and intersects the shale unit from 1530.40 to 1548.68m downhole. The borehole also intersects amygdaloidal lava of the Crown Formation at 1597.15m downhole (Figure 5.2.18), that is part of the strong internal reflectors at the top of the West Rand Group.

In the eastern half of Domain 3, the interface is constrained by several boreholes. The contact between the Central Rand and West Rand groups is intersected at ~1500m downhole. Borehole 4039848 is located ~4300m from shotpoint 490 in section BH-171A (Figure 5.2.24). The borehole reports the Karoo Supergroup unconformably overlying the West Rand Group. Borehole 4003209 is located ~2400m from shotpoint 870 in section BH-171A (Figure 5.2.24). The borehole provides the contact intersection at 1839.86m downhole. Borehole 4039844 is located ~1000m from shotpoint 275 in section DE-511 (Figure 5.2.21). The contact intersection in this borehole is provided at 1975.10m downhole. Borehole 4225646 is located in the gap between seismic sections DE-506, DE-507, DE508, and DE-511 (east of the label "DE508" in Figure 5.1). This borehole also reports the Karoo Supergroup unconformably overlying the West Rand Group.

The interface between the Central Rand and West Rand groups is neither sharp nor defined by a single strong amplitude reflection (as described in Section 4.3). However, the interface is traced as a mostly conformable, undulate seismic horizon across the three domains. In Domain 1, the undulate nature of the interface is best represented in seismic sections KV-117, KV-118, OF-97, and OPR-50 (Figures 5.2.4, 5.2.5, 5.2.2, and 5.2.3, respectively). In Domain 2, this nature is best represented in seismic sections BH-268, DV-270B, DV-271, and DV-272 (Figures 5.2.18, 5.2.14, 5.2.13, and 5.2.12, respectively). The interface across seismic sections DV-270B, DV-271, and DV-272 exhibits reasonable continuation (illustrated in Figure 5.2.14C). In Domain 3, the undulate nature of the interface is evident in seismic section DE-512B (Figure 5.2.19).

The interpreted interface across the three domains also exhibits local offsets. In Domain 1, the faulted seismic sections include OB-41 and OB-74 (Figures 5.2.8 and 5.2.10, respectively). In Domain 2, the seismic sections include BH-269, DV-270A, DV-270B, DV-271, DV274, and FV-154 (Figures 5.2.16, 5.2.15, 5.2.14, 5.2.13, 5.2.11, and 5.2.17.1, respectively). In Domain 3, an offset is evident in seismic section DE-512B (Figure 5.2.19).

5.1.6. West Rand Group – Dominion Group

The interface between the West Rand and Dominion groups is reasonably imaged across all three domains as strong seismic reflector (Section 4.3; Vp and ρ values in Table C in the Appendix). The relatively higher amplitudes of the mafic – intermediate components of the Dominion Group are interpreted in all ten seismic lines of Domain 1. The internal reflections of the Group conform to the overlying reflections, although they also exhibit localised acute orientations. The Dominion Group is seismically better defined in the southern half of Domain 1.

Seismic sections that are characterized by stronger amplitude reflections include KV-120, FV-155, OB41, and OB-74 (Figures 5.2.9, 5.2.7, 5.2.8, and 5.2.10). The Dominion Group crops out in the collar rocks of the Vredefort dome and constrains the interface in seismic section FV-155 (Figure 5.2.7). Seismic sections KV-117 and KV-132 exhibit weaker amplitudes of the Group compared to section FV-155. However, the contact is imaged as a consistent seismic reflector across the two sections (Figures 5.2.4 and 5.2.6, respectively). Offsets and interface terminations of the West Rand and Dominion groups are limited to the south of Domain 1.

The internal reflections of the lower West Rand and Dominion groups in all eight seismic sections of Domain 2 are better defined than the associated interfaces in Domains 1 and 3. The strong reflection associated with the interface between the Government and Hospital Hill subgroups is described in Section 4.3. The interface between these two Subgroups is relatively clear in these eight sections. The interface between the Dominion Group and the Hospital Hill Subgroup is distinct and also exhibits relatively stronger amplitude reflections relative to Domains 1 and 3. These prominent reflections are illustrated in Figure 5.2.13C and demonstrate the continuation of the interfaces between seismic sections DV271 and DV-274.

The internal reflections of the lower West Rand and Dominion groups in Domain 3 are poorly defined in the study area. However, on the eastern margin of Domain 3 the shallower interfaces are better delineated in the seismic data. The interfaces also coincide with Domain 2 in that they are more prominent in the shallower sections than in the deeper sections. The overall trend of the interface is roughly conformable to the overlying seismic stratigraphy. However, several seismic sections in Domains 2 and 3 exhibit laterally terminating reflections. In Domain 2, these sections include BH268, BH-269, FV-154, DV-270A, DV-270B, DV-271 and DV-272 (Figures 5.2.18, 5.2.16, 5.2.17.1, 5.2.15, 5.2.14, 5.2.13, and 5.2.12, respectively). In Domain 3, these sections include BH-171A, BH171B, DE-506, and DE-512B (Figures 5.2.24, 5.2.23, 5.2.22, and 5.2.19, respectively).

5.1.7. Basement Contact

The interface between the Dominion Group and the basement is reasonably imaged as a prominent reflector in seismic sections across all three domains (Section 4.3; Vp and ρ values in Table C in the Appendix). The interpreted Dominion Group exhibits relatively consistent thicknesses of 200 – 800m. The scattered, moderate-amplitude and chaotic reflections of the Group form a reasonably continuous package across the seismic sections. This thin package provides a depth estimate and general topographic morphology of the basement interface. The relatively homogeneous TTG composition of the basement (Poujol et al., 2003) produces a seismically transparent package, delineating the interface with the supracrustal sequences.

In places where faults are interpreted, the interfaces represent the contacts between the TTG suites and the sediments of the West Rand Group. In Domain 2, the seismic sections that show these particular interfaces include BH-268, BH-269, FV-154, DV-270A, DV-270B, and DV-271 (Figures

5.2.18, 5.2.16, 5.2.17.1, 5.2.15, 5.2.14, and 5.2.13, respectively). Similar interfaces in Domain 3 are evident in seismic sections BH-171A, BH-171B, DE-506, DE-507, DE-508, DE-511, and DE512B (Figures 5.2.24, 5.2.23, 5.2.22, 5.2.28, 5.2.27, 5.2.21, and 5.2.19, respectively).

In Domain 1, discrete reflections in the basement package are imaged in several seismic sections, including KV-120, OB-41, and OB-74 (Figures 5.2.9, 5.2.8, and 5.2.10, respectively). Relatively higher amplitude reflections are also imaged in seismic section FV-155, particularly in the dome core rocks (Figure 5.2.7). Unfortunately, the lack of borehole information in the basement rocks adjacent to the seismic section limits the interpretation of the anomalous internal reflections. These reflections may have been caused by thrusting within the basement, or may represent the heterogeneity of the core rocks as suggested by Muundjua et al. (2007). The V_p and ρ characteristics of the various core rocks must be examined to test the association.

In Domain 2, discrete reflections are imaged in several seismic sections, including BH-268, BH-269, FV-154, DV-270A, and DV-271 (Figures 5.2.18, 5.2.16, 5.2.17.1, 5.2.15, and 5.2.13, respectively). Seismic section BH-268 in particular, exhibits a broad cluster of higher-amplitude internal reflections in the basement package (Figure 5.2.18). The cluster extends down to the base of the section at ~18km below surface. The cluster is also detected in the adjacent sections in Domain 3 (i.e., sections DE-506 and DE-507; Figures 5.2.22 and 5.2.28, respectively). The interface with the basement in this area is relatively shallow and is supported, albeit roughly, by borehole 4225646. The borehole is located ~8000m south of the seismic line BH-268, and reports the Karoo Supergroup unconformably overlying the Government Subgroup at 174.50m downhole. The intersection suggests a shallow preservation of the basement package in this area.

Anomalous internal reflections in the basement are detected in two additional seismic sections in Domain 3. These sections include BH-171A and BH-171B (Figures 5.2.24, and 5.2.23, respectively). The anomalous cluster detected in the basement package in these two sections also extends to the base of the sections. However, the strong amplitude reflections are laterally confined, forming a steeply dipping to subvertical column 2500 – 4000m wide.

5.2. Geological Summary

The seismic sections for domains 1, 2, and 3 are displayed in Figures 5.3, 5.4, and 5.5, respectively. The domains are displayed individually because each set highlights certain aspects of the geology. As discussed in Section 4.3, several stratigraphic formations are not preserved, or are unlikely to be preserved. However, the major stratigraphic units are delineated in the seismic sections including the Karoo, Transvaal, Ventersdorp and Witwatersrand supergroups, as well as the Dominion Group and basement TTG suite.

Truncation of the interfaces is observed across the three domains. The major unconformities include the truncation of the VCF through the Central Rand Group, and the truncation of the Black Reef

Formation through all the pre-existing units. Over the extent of the study area, progressive termination of the major supergroups against the Karoo Supergroup is observed in the east.

Two fold systems are interpreted in Domain 1. The first fold system includes an asymmetric syncline with an axial plane that dips towards the dome, possibly associated with the central uplift (Figure 5.3B). The second fold system is interpreted in the Transvaal Supergroup across several seismic sections (Figure 5.3C). The 3D projection of the sections provides the size and orientation of the folds. The folds exhibit wavelengths of ~16000m, amplitudes of ~350m, and subvertical axial planes striking 050° (northeast – southwest). These orientations are oblique to the asymmetric syncline, and therefore associate poorly with the deformation related to the central uplift. The folds interpreted in the Transvaal Supergroup in the seismic sections coincide with the outcrop mapped by Simpson (1978) in the exposed Pretoria Group. The folds adjacent to the dome exhibit decreased wavelengths, down to ~5000m and increased amplitudes, up to ~600m.

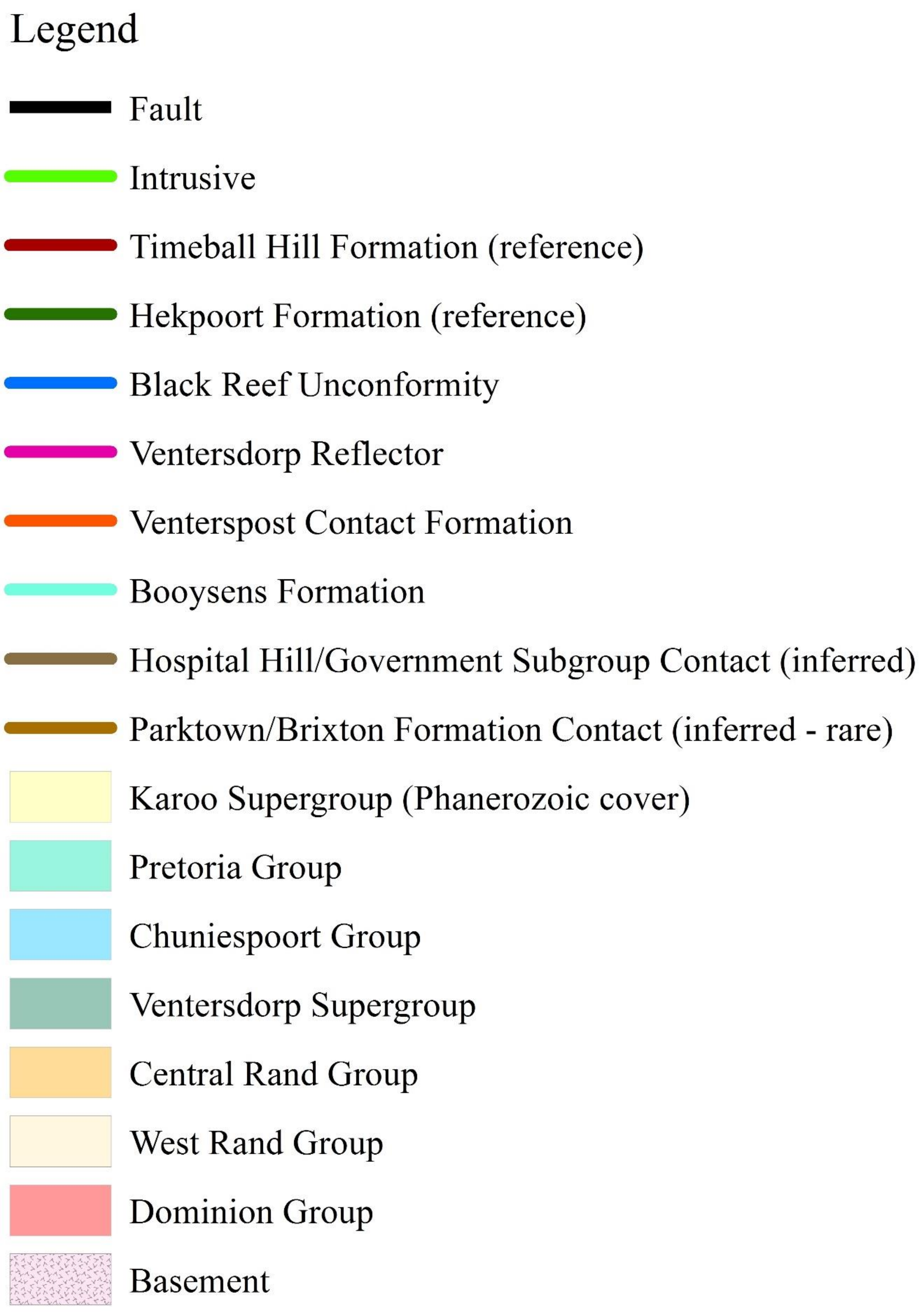
A well-developed listric fault system is interpreted in the southern half of Domain 1 with fault offsets up to 1000m (Figure 5.3C). The floor fault traces across seismic sections KV-120, OB-41, and OB-74 (Figures 5.2.9, 5.2.8, and 5.2.10, respectively). The VCF interface is offset, but the extent of the faults into the seismically transparent Ventersdorp Supergroup is unknown. In addition to the listric system, a low-angle fault is detected adjacent to the interface with the basement. The relationship of the low angle fault to the overlying listric fault system is unknown. Several other offsets are detected in the seismic sections. These include listric fault offsets of the VCF in Domains 2 and 3, and normal/listric fault offsets of the interface between the West Rand and Central Rand groups in Domain 2.

In Domain 2, the Transvaal Supergroup is only detected in the seismic sections in the northern half. The southern half exhibits a relative uplift of ~4000m (Figure 5.4B). The viewing direction of Figure 5.4B is selected as it displays the strike, and dip direction of an interpreted listric fault that forms a sole fault at depth. The structure is delineated across seismic sections DV-270A, DV-270B, and DV-271. 3D projection of these sections provides an estimated orientation for strike (100°) and dip direction (190°) of the extensional feature, i.e., sigma 3 is 190°.

The viewing orientation of Figure 5.4C is important as it displays the strike (035°) of the uplift that is crosscut by the listric fault. It is suggested that the feature represents an asymmetric, gentle, anticlinal fold with a sigma 1 orientation of 125°. The strike of the fold in relation to the listric fault differs by 65° (i.e., 035° versus 100°). The listric fault interpreted in seismic line FV-154 exhibits a second, more complex listric fault system in the supracrustal package. However the orientation of the second listric fault system is not well constrained in 3D so the relationship between the stress regimes of both systems is uncertain.

In Domain 3, the axial plane of the asymmetric synform associated with the central uplift is approximately parallel to the northeast – southwest trending axial plane of the folds in the Transvaal Supergroup. Figure 5.5B displays these features, as well as the change in orientations adjacent to the dome. The orientations shift from upright, steeply dipping units in the west of the dome to upright, shallow dipping units in the east. In addition to the changes in orientation, the interface of the basement is elevated in the east (Figure 5.5C).

Two anomalous zones of strong amplitude reflections in the basement are interpreted in Domain 3 (and in parts of Domain 2). These two anomalies are displayed in Figure 5.5C and are separated by a narrow ‘saddle’. The anomalies indicate an association with areas of relative basement uplift. The broad anomaly is located adjacent to the southeast margin of the Vredefort dome. The narrow, subvertical basement anomaly detected in seismic sections BH-171A and BH-171B is located ~25km southeast of the estimated margin of the Vredefort dome (see Figure 5.2.23). The anomaly underpins an antiformal dome, and due to a pair of outcrops that constrain the Klipriviersberg Group adjacent to the two sections, the deformation can be confined to pre- or syn-Klipriviersberg Group emplacement.



Note, stratigraphic unit colours have been made transparent to highlight the seismic reflections, so the colours are desaturated. The West Rand Group has been made light-brown in these sections and brown in the modelling as these provide better contrasts against respective features and adjacent units.

Figure 5.1 Legend for the 2D reflection seismic section interpretations.

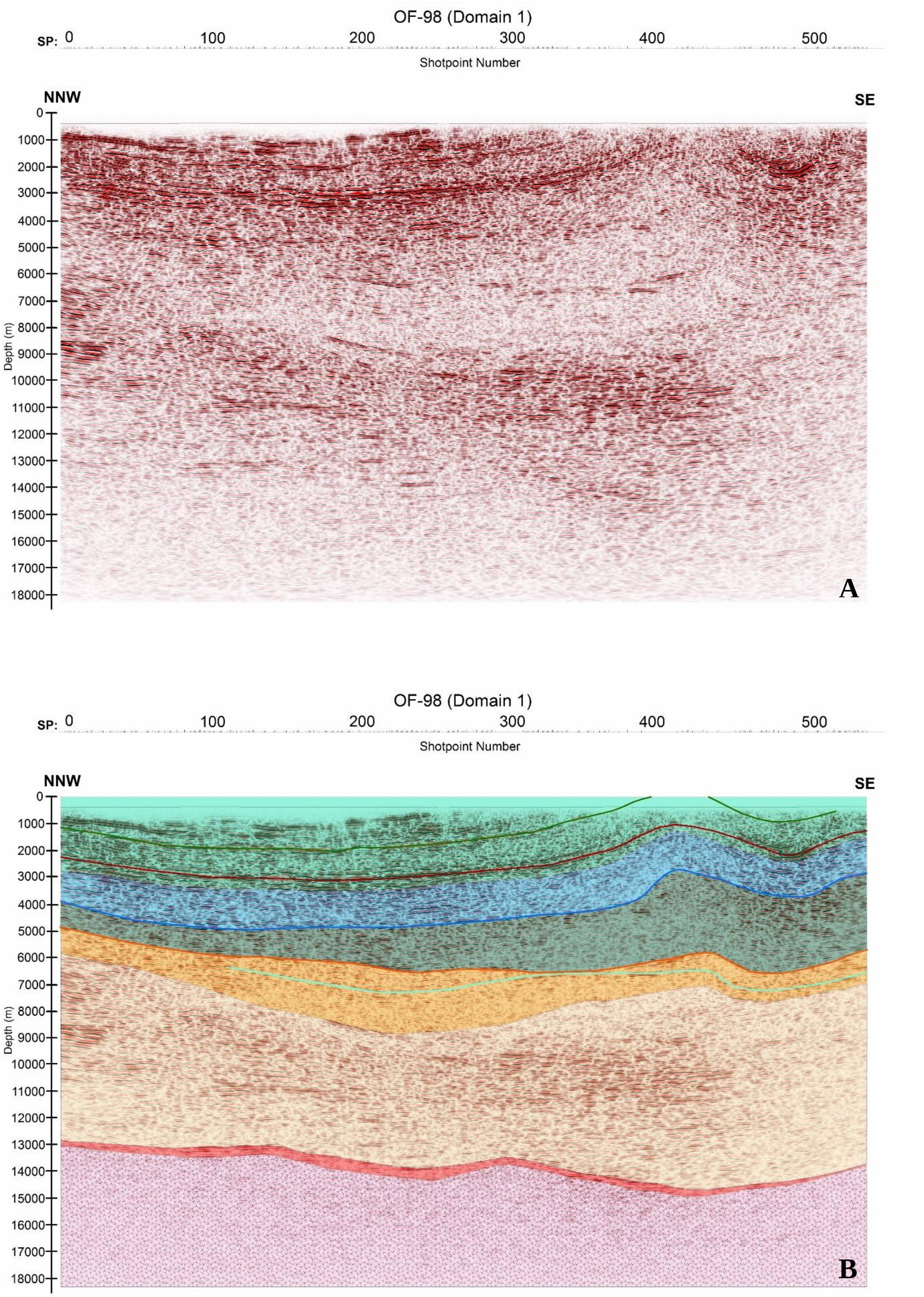
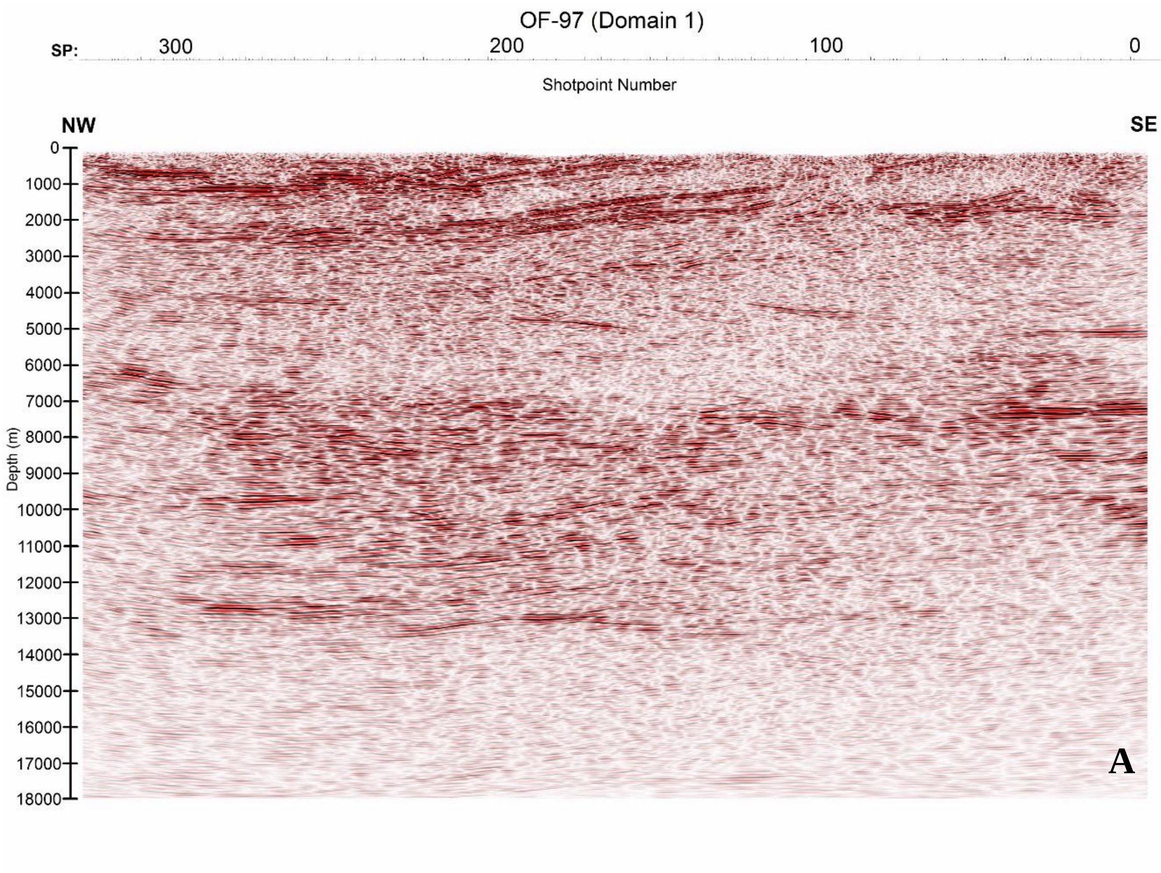


Figure 5.2.1 Line OF-98. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 0.90x.



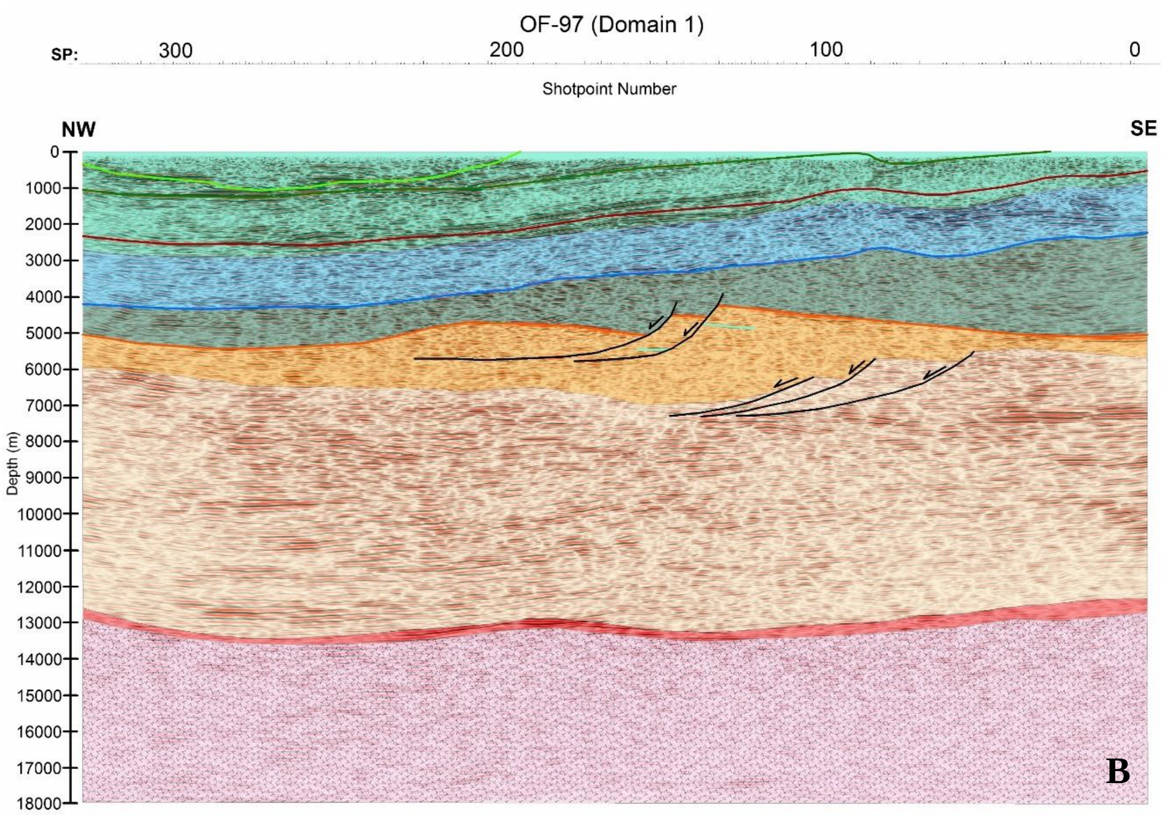
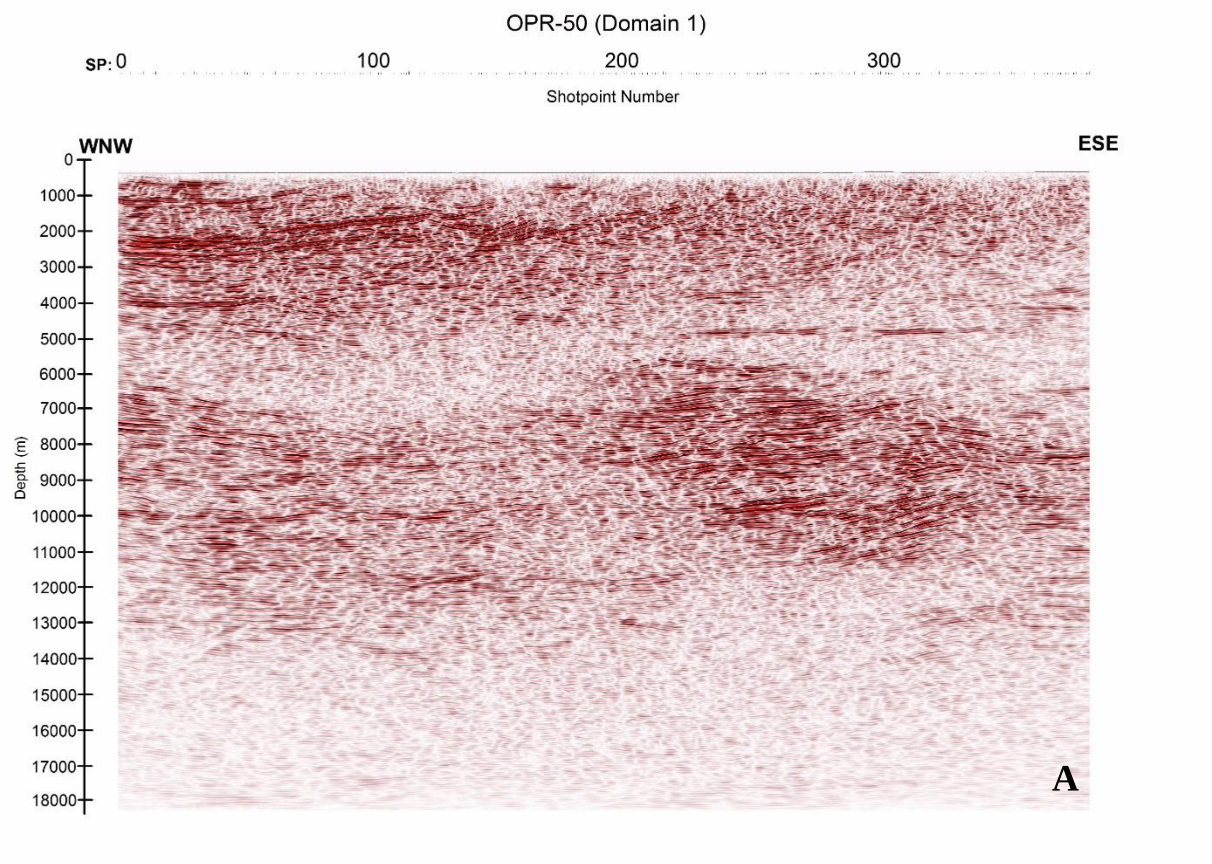


Figure 5.2.2 Line OF-97. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 0.57x.



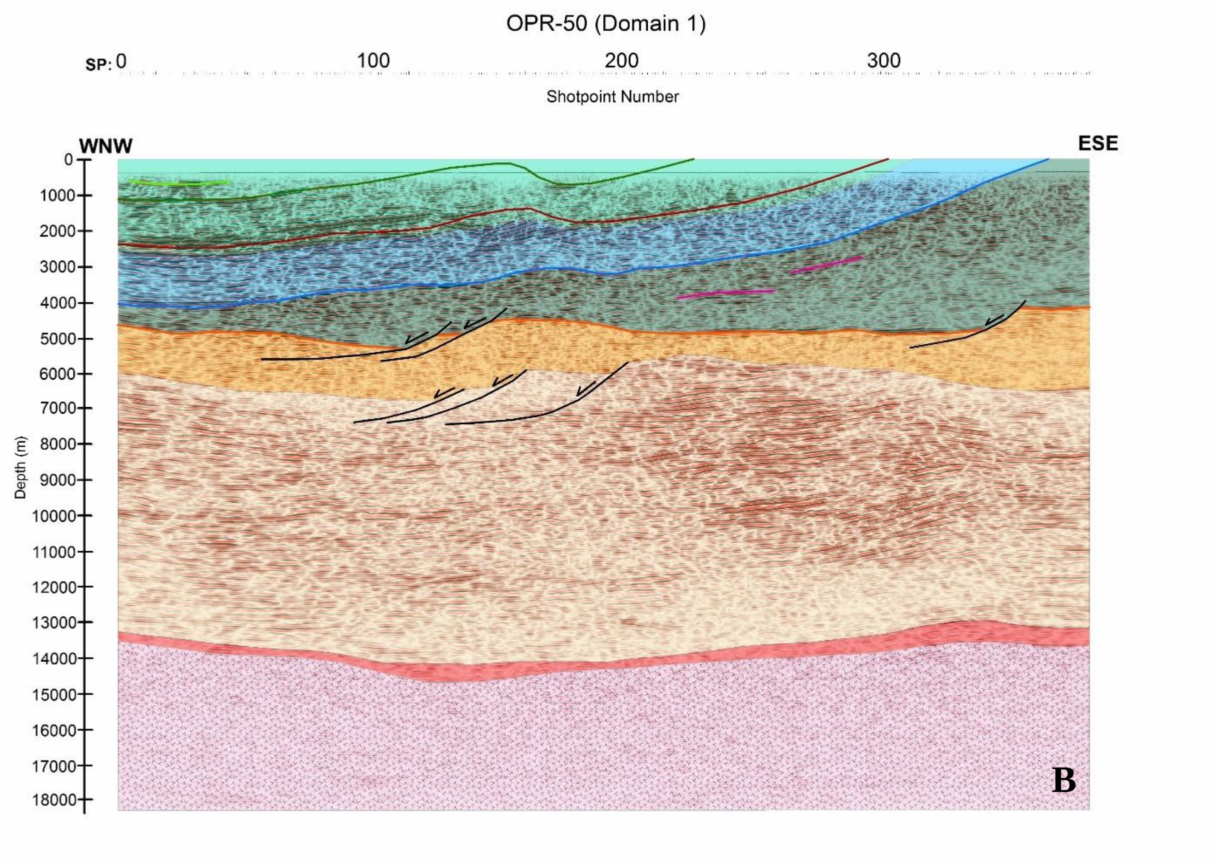


Figure 5.2.3 Line OPR-50. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 0.70x.

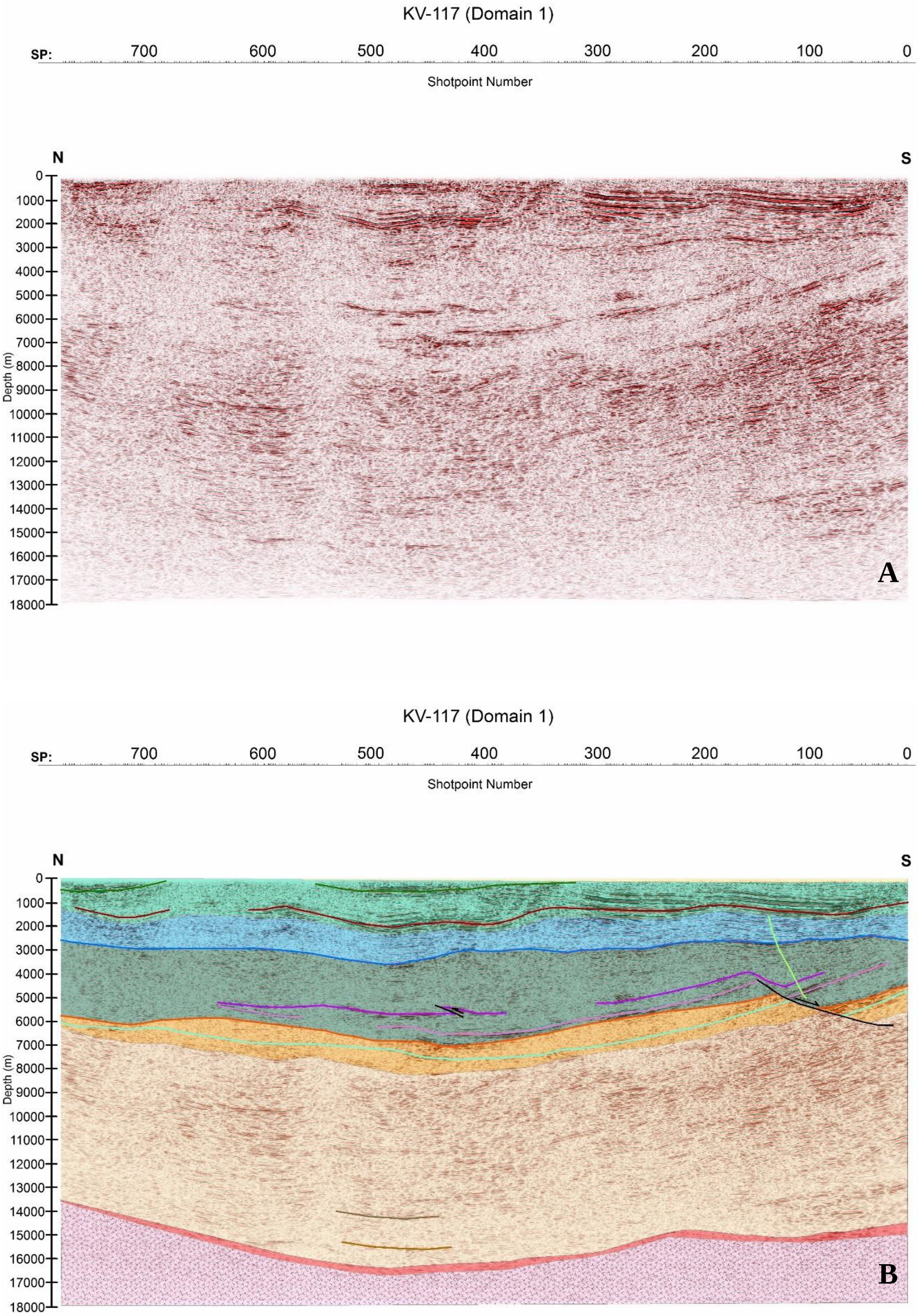


Figure 5.2.4 Line KV-117. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 1.20x.

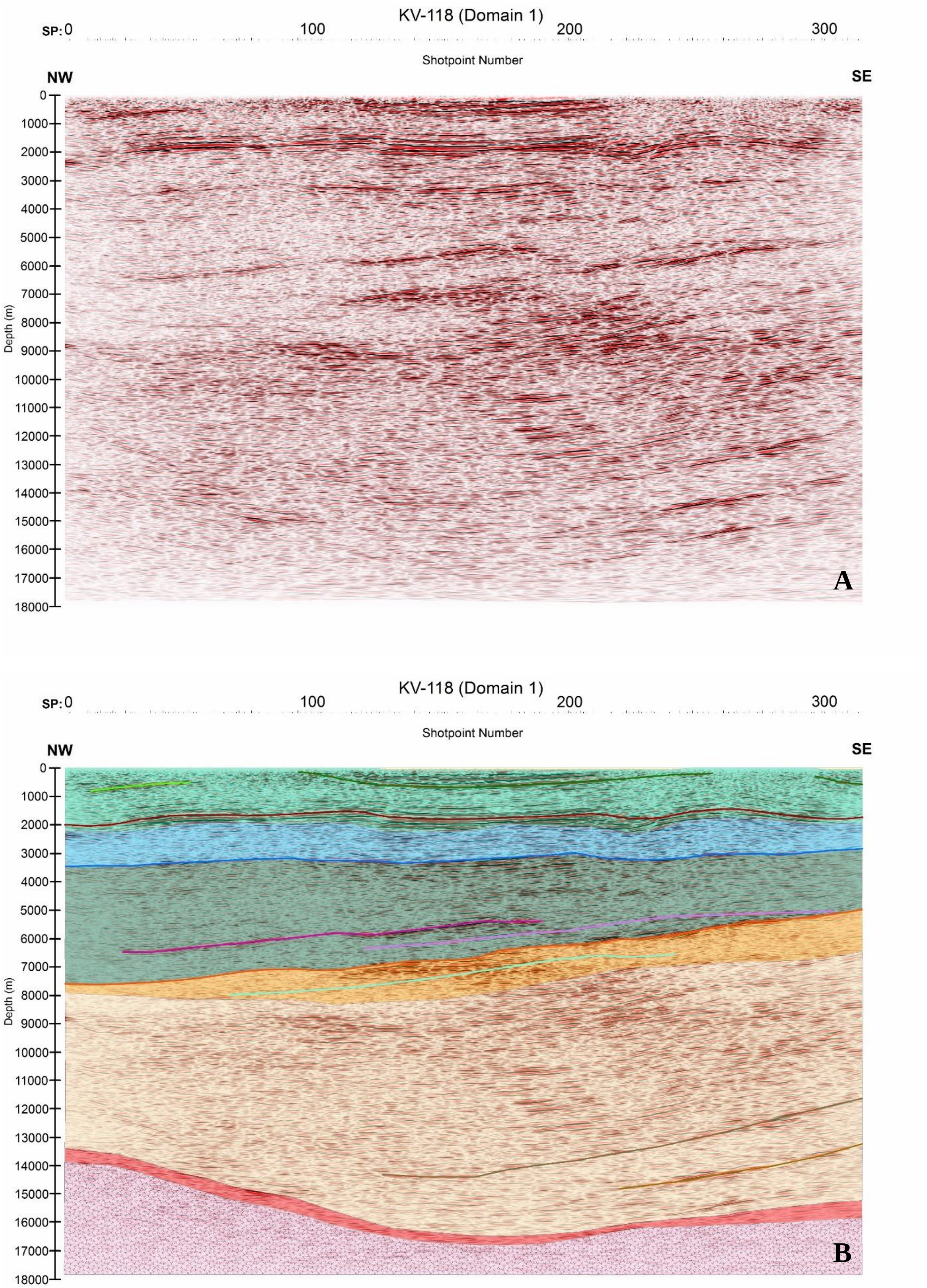
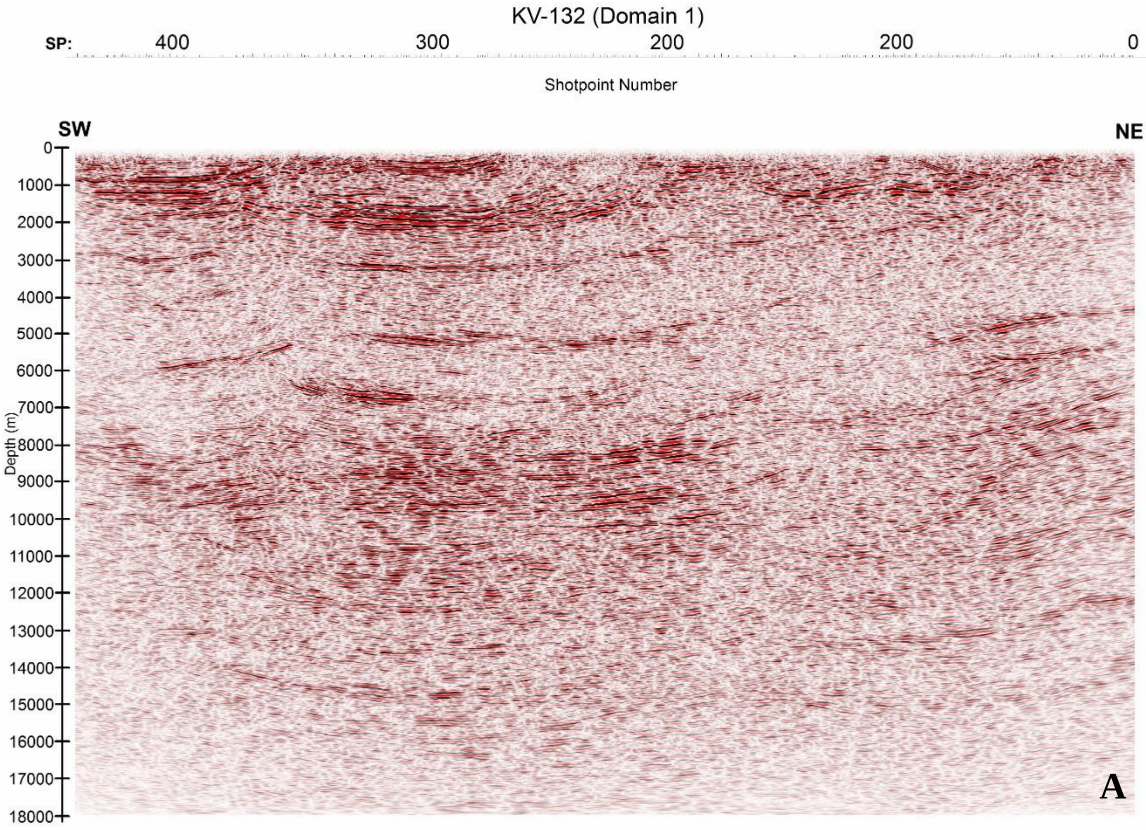


Figure 5.2.5 Line KV-118. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 0.58x.



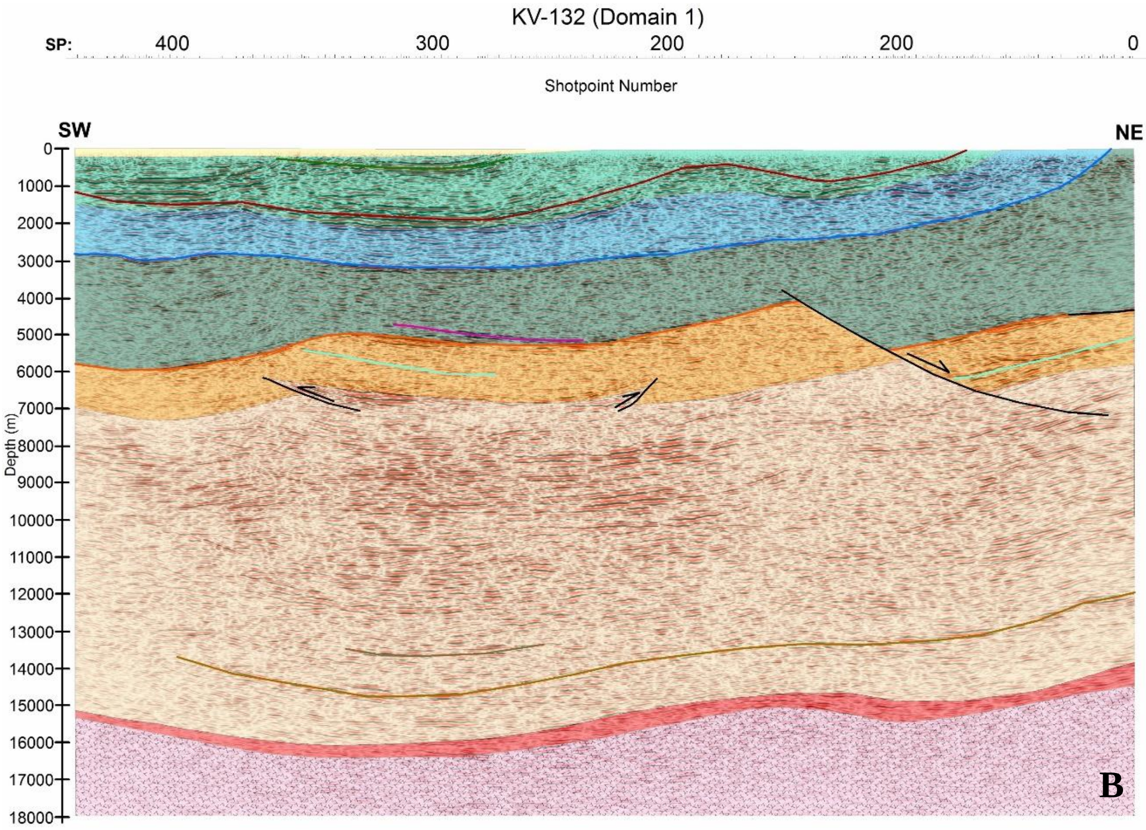


Figure 5.2.6 Line KV-132. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 0.82x.

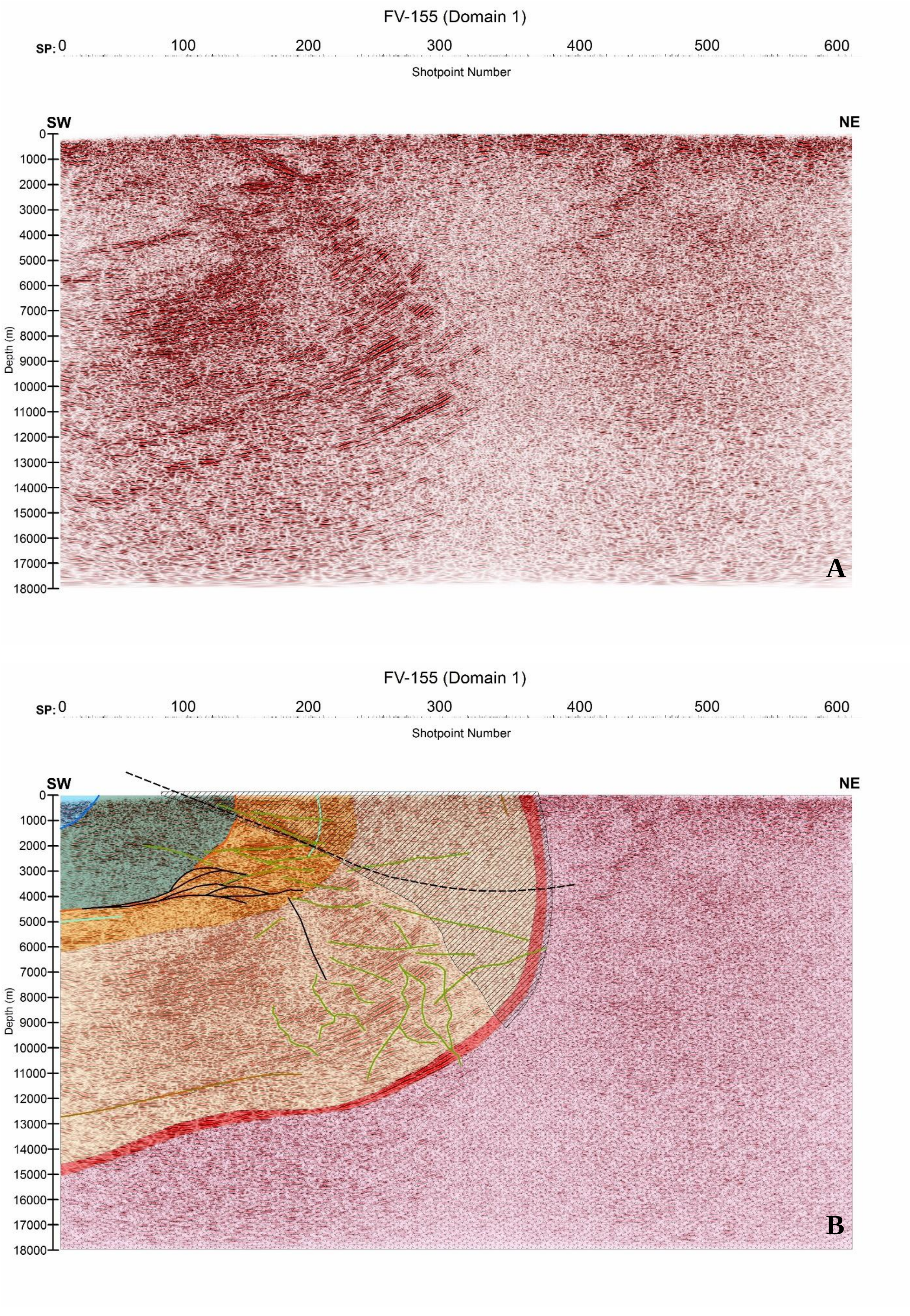
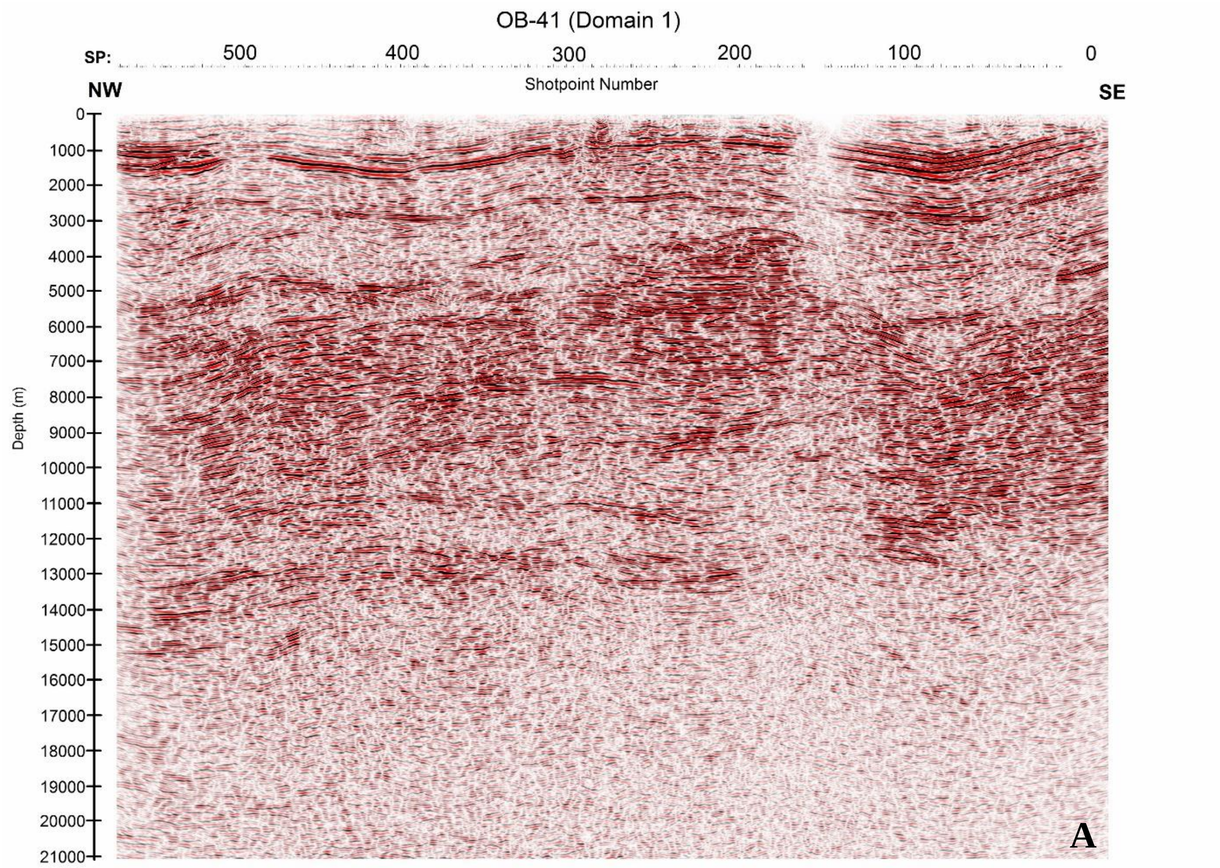


Figure 5.2.7 Line FV-155. A) Un-interpreted seismic section; B) interpreted seismic section. Hatched area represents unresolved subvertical reflections. Fold axial trace of central uplift is also included. Vertical exaggeration is 1.03x.



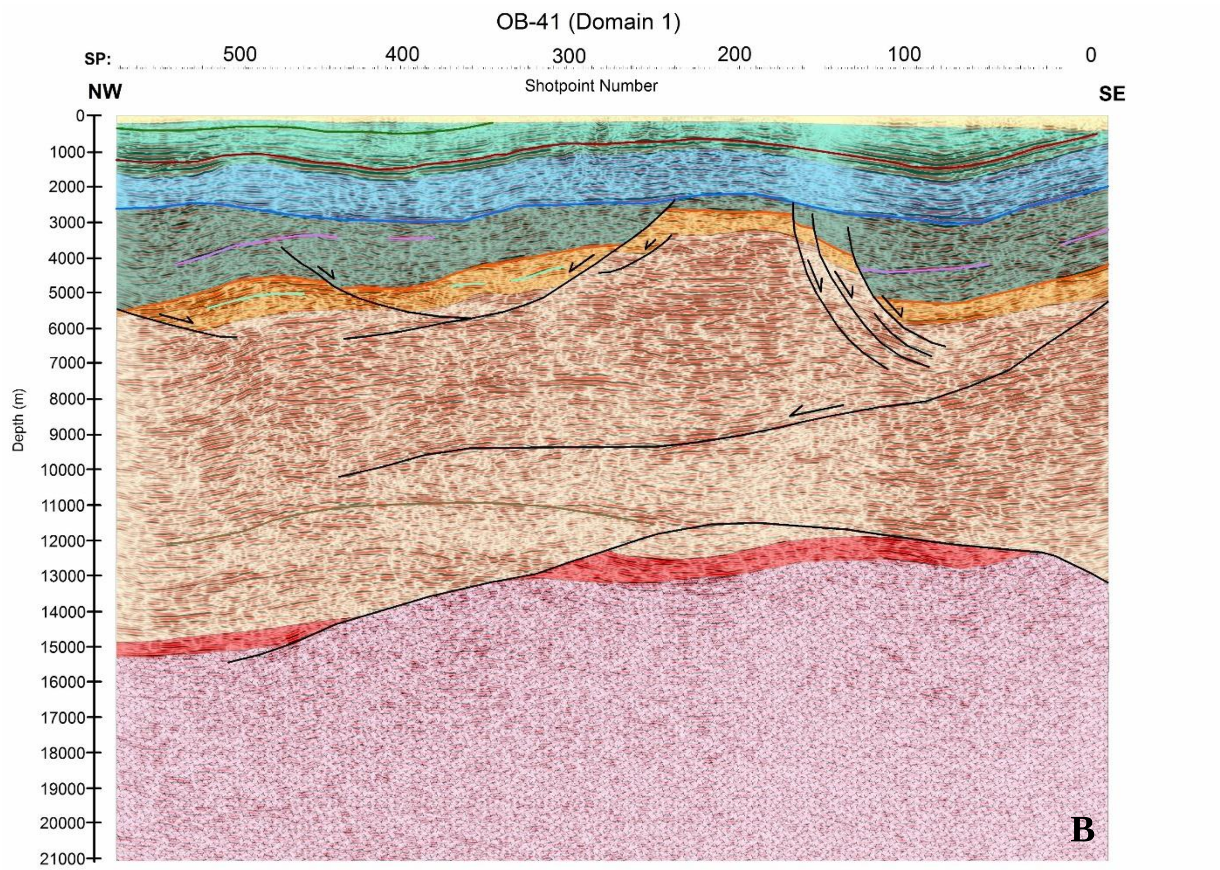


Figure 5.2.8 Line OB-41. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 1.09x.

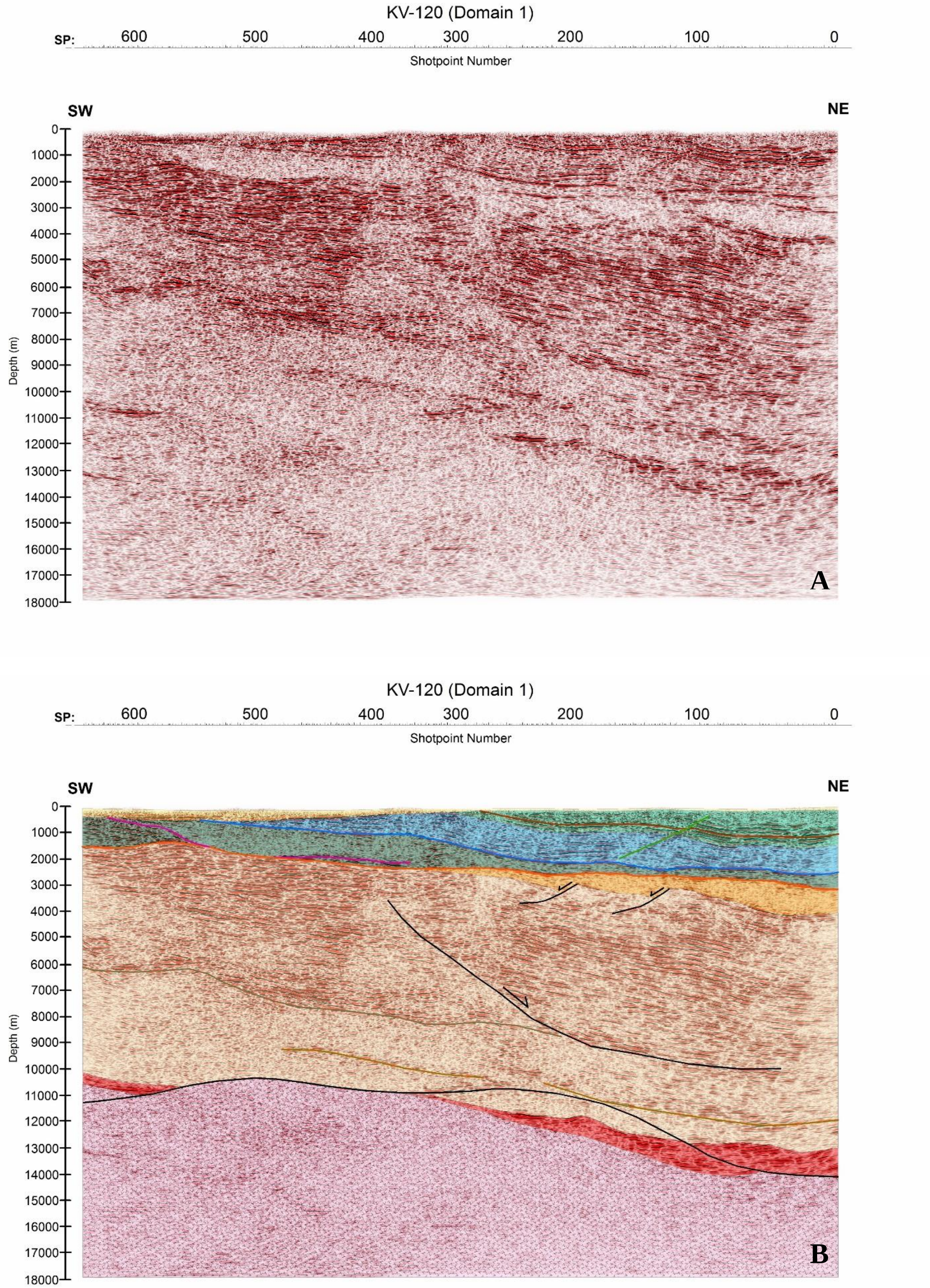
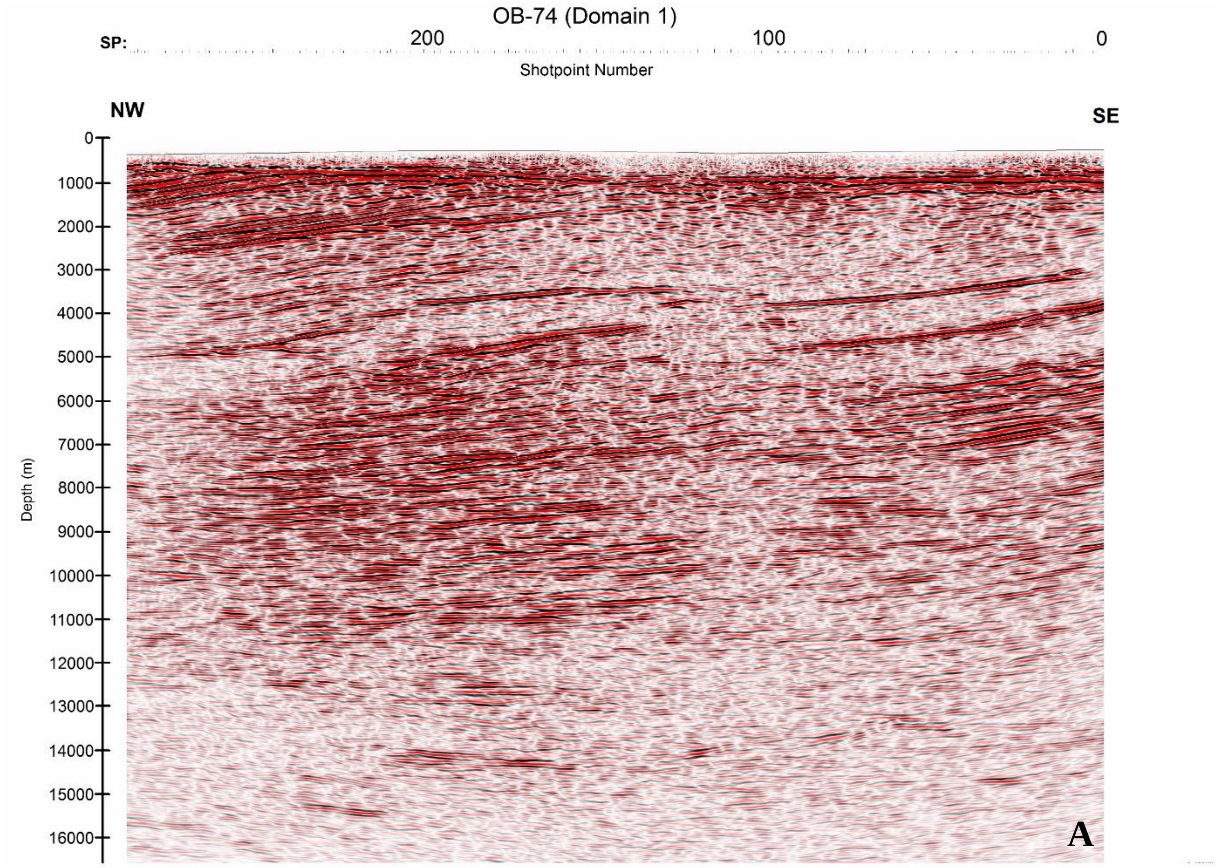


Figure 5.2.9 Line KV-120. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 1.15x.



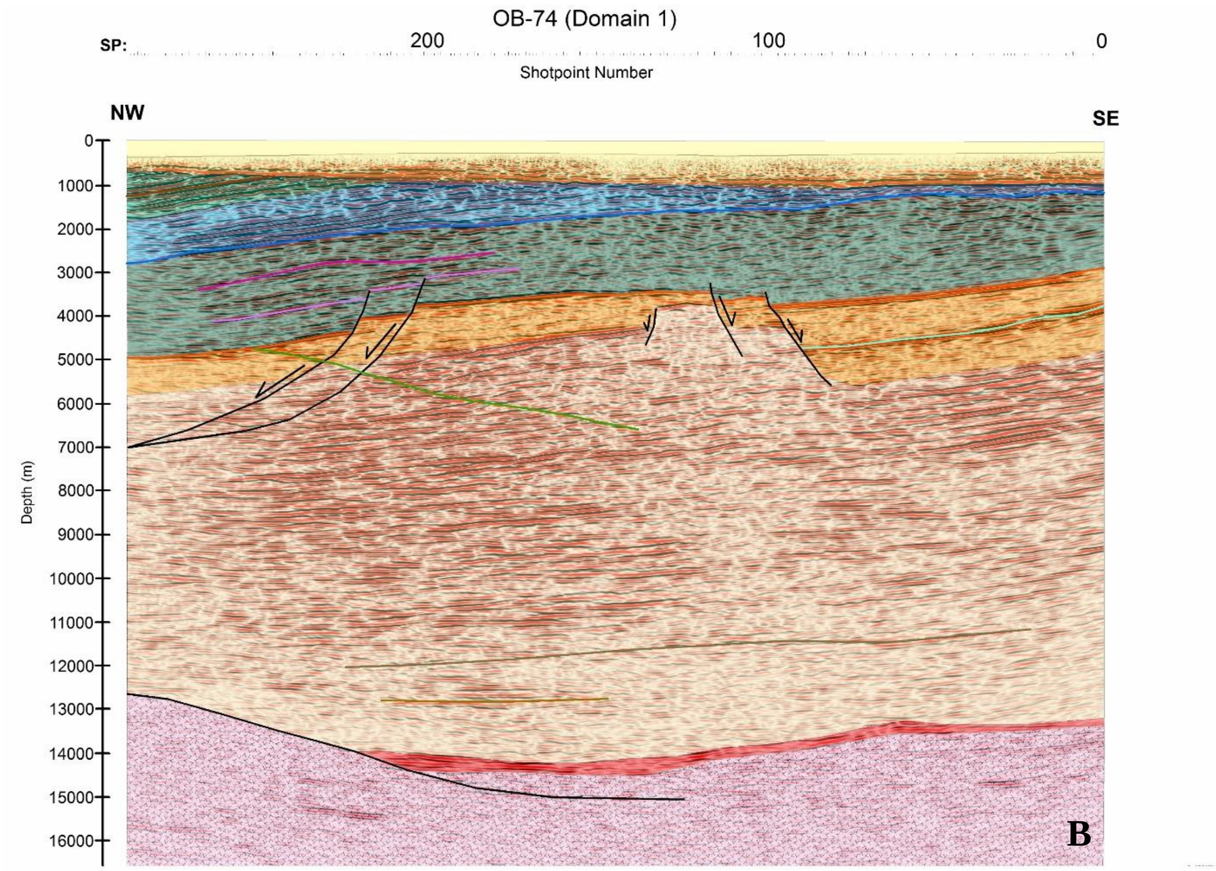
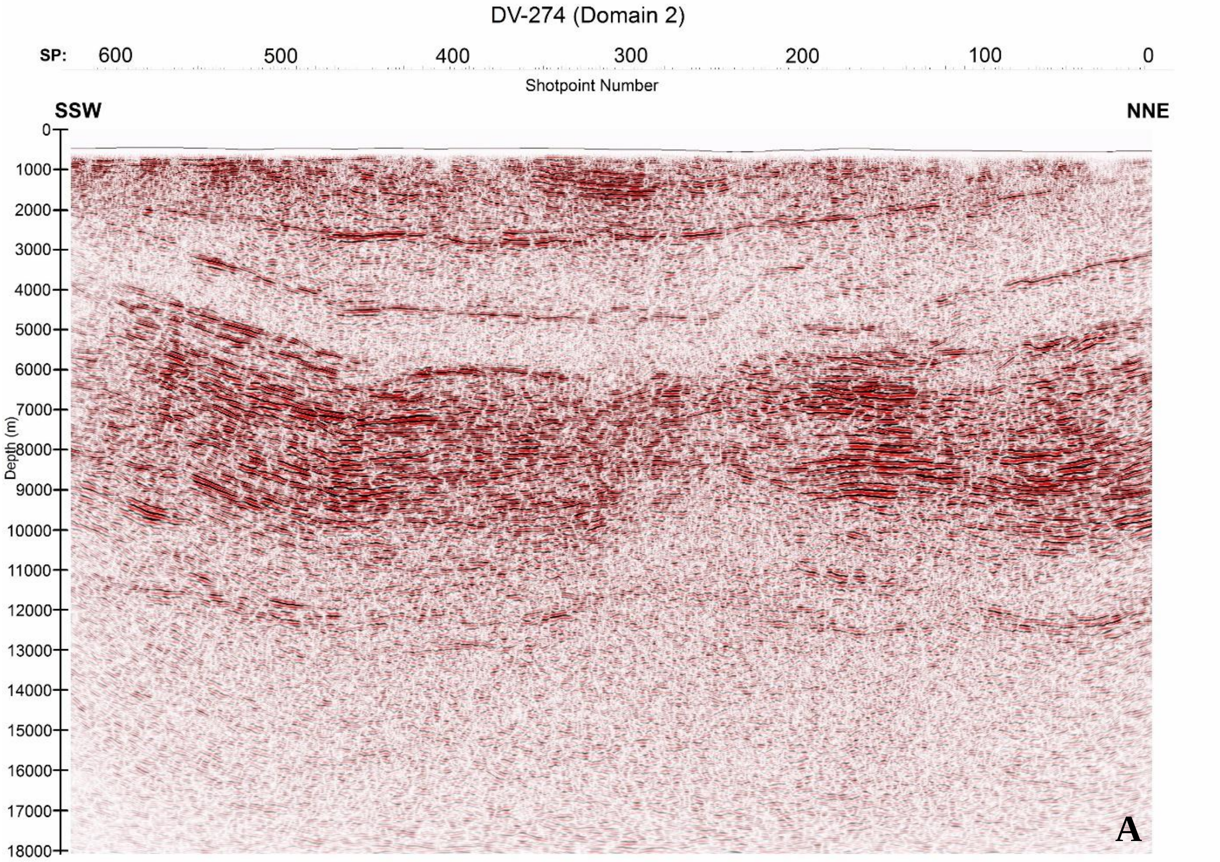


Figure 5.2.10 Line OB-74. Data has a static correction to ~400m. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 0.66x.



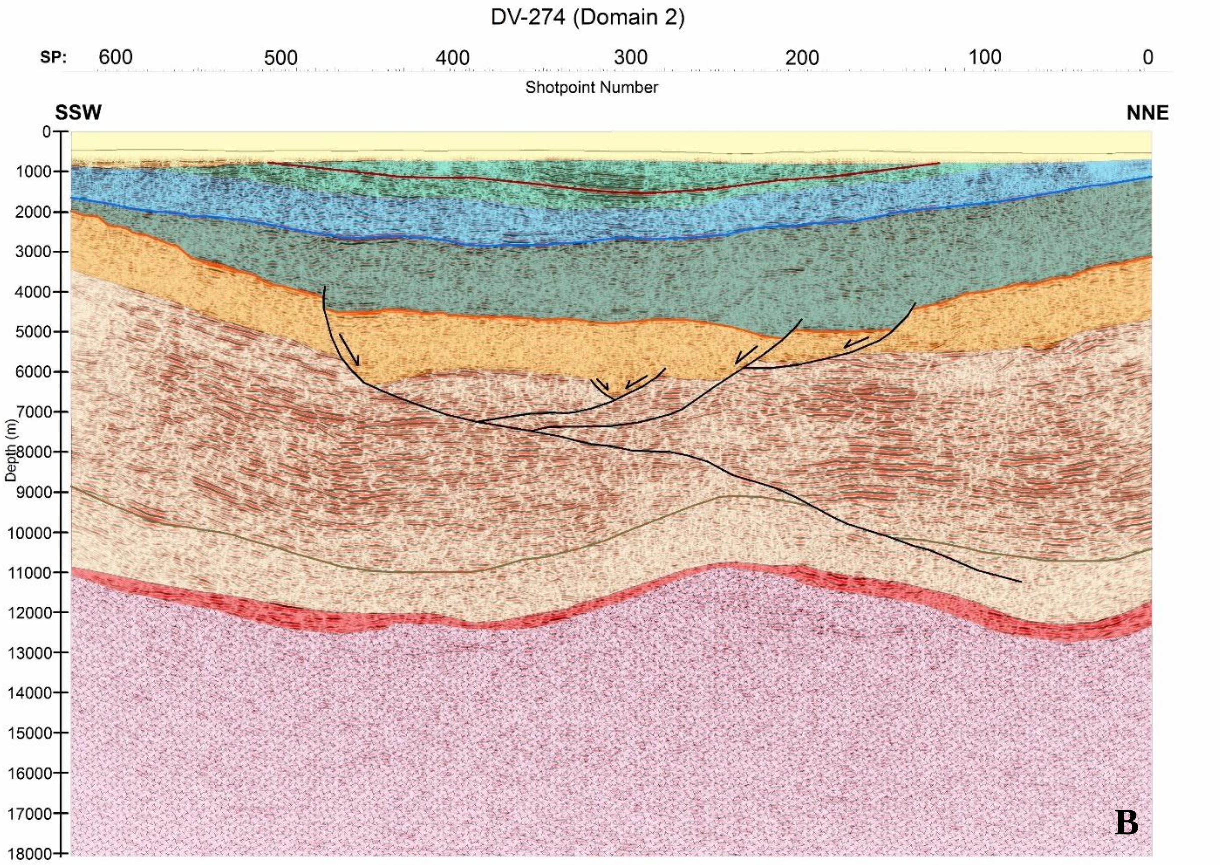


Figure 5.2.11 Line DV-274. Data has a static correction to ~400m. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 1.34x.

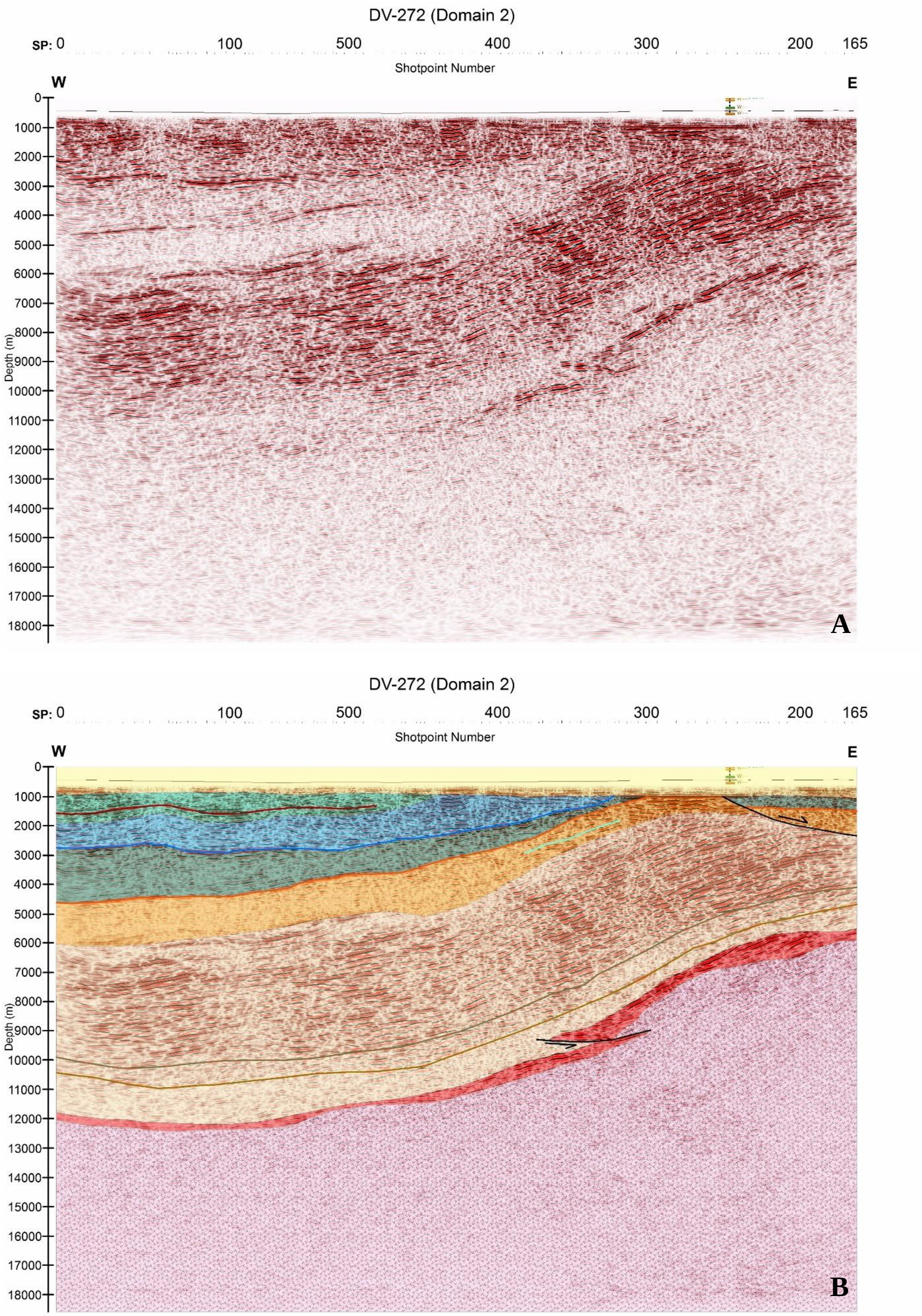


Figure 5.2.12 Line DV-272. Data has a static correction to ~400m. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 0.98x.

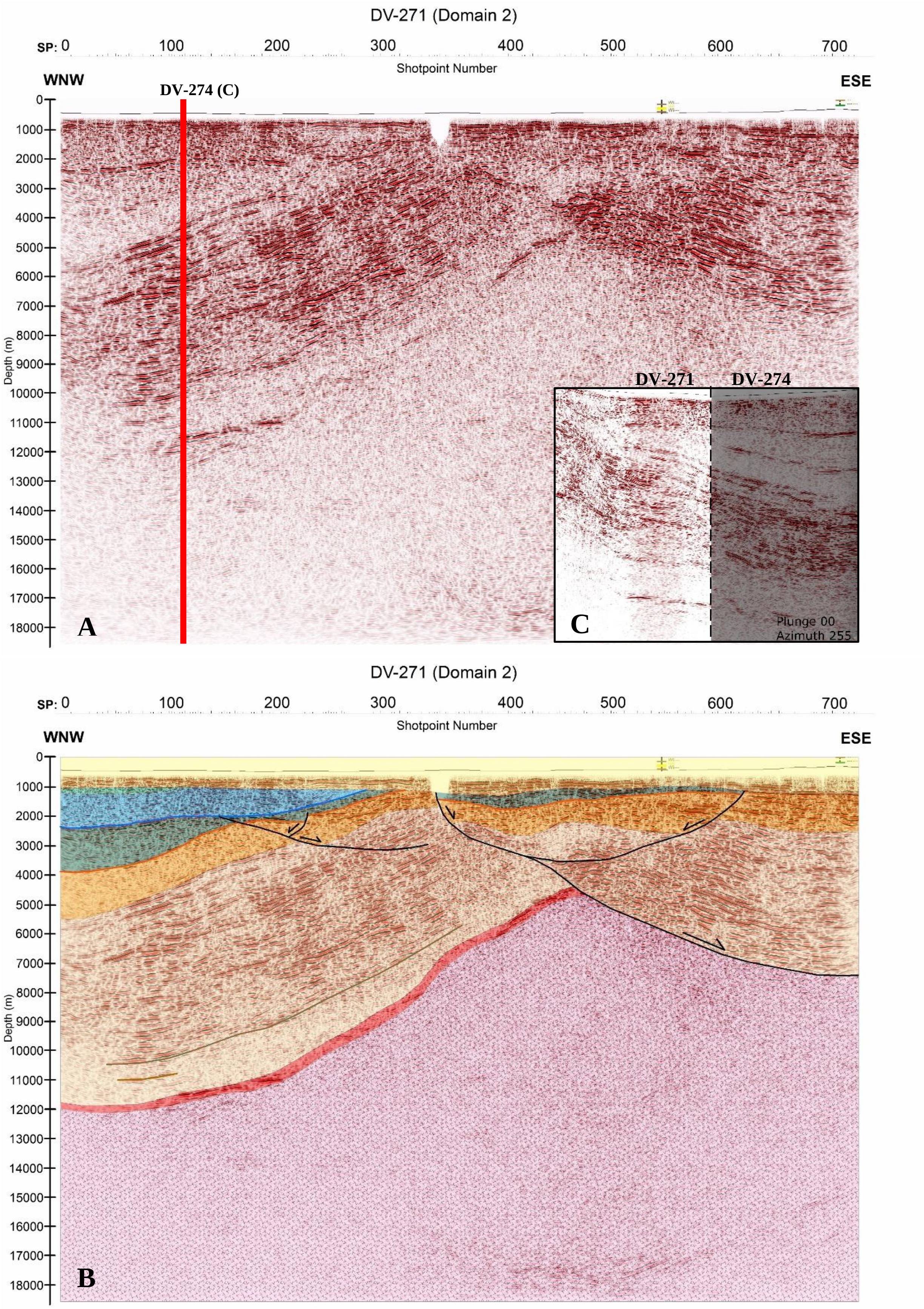


Figure 5.2.13 Line DV-271. Data has a static correction to ~400m. A) Un-interpreted seismic section; B) interpreted seismic section; C) reverse 3D view of the intersection between DV-271 and DV-274, highlighting the continuation of interfaces across the two well resolved seismic sections. Vertical exaggeration in A) and B) is 1.44x.

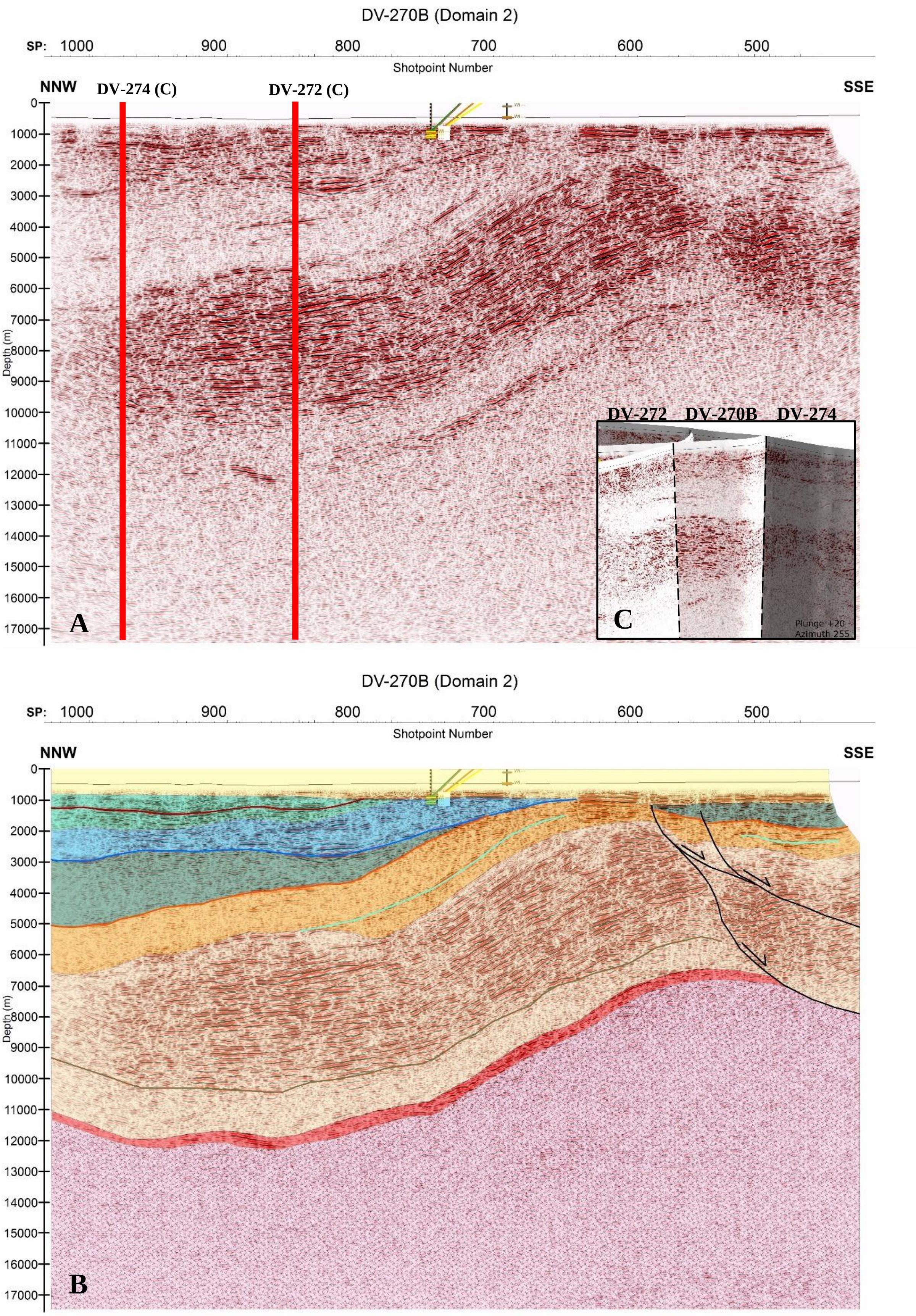


Figure 5.2.14 Line DV-270B. Data has a static correction to ~400m. A) Un-interpreted seismic section; B) interpreted seismic section. C) Reverse 3D view of the intersection between DV-270B, DV-272 and DV-274, highlighting the continuation of the West Rand and Central Rand groups across the three sections. Vertical exaggeration in A) and B) is 1.17x.

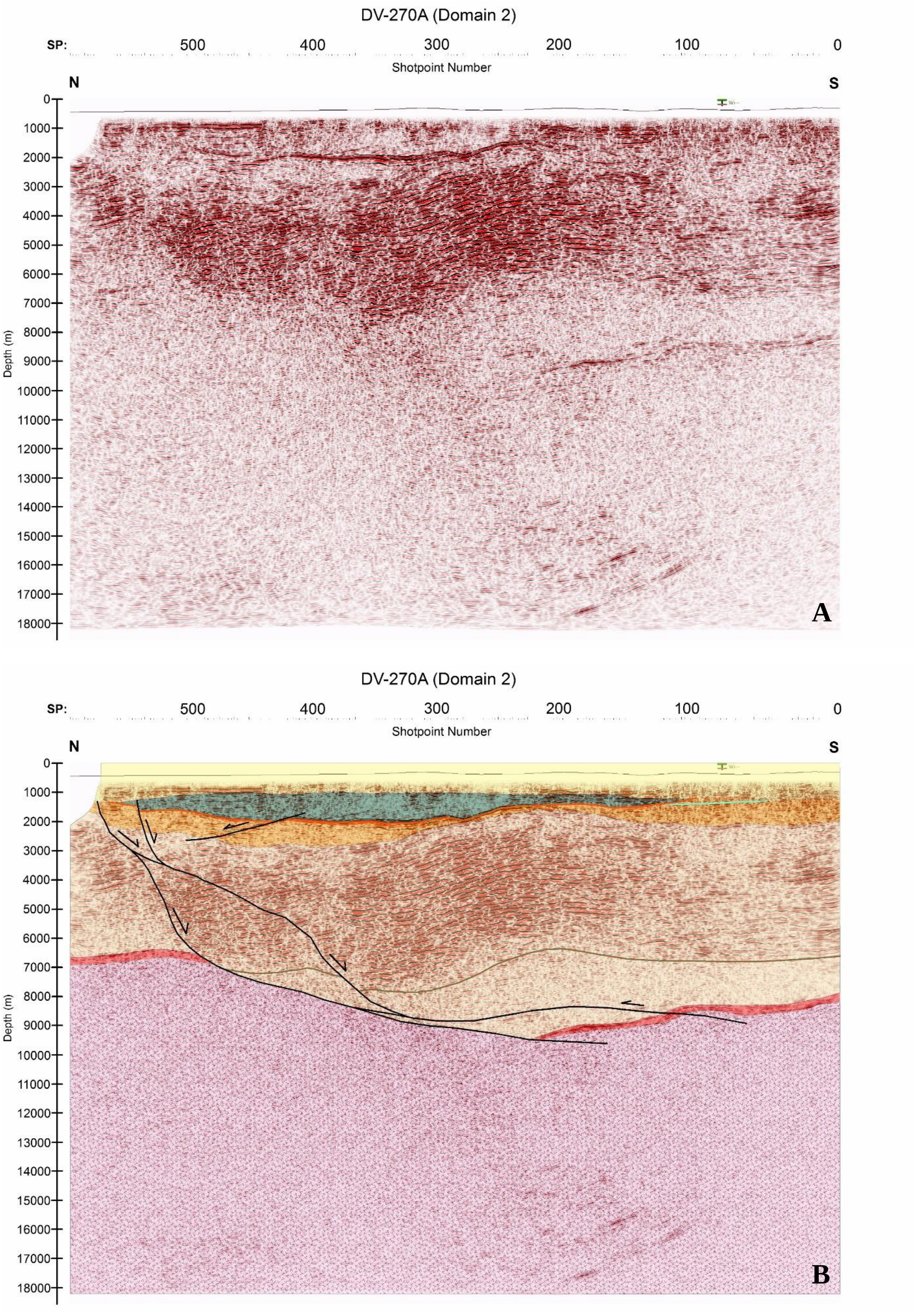


Figure 5.2.15 Line DV-270A. Data has a static correction to ~400m. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 1.19x.

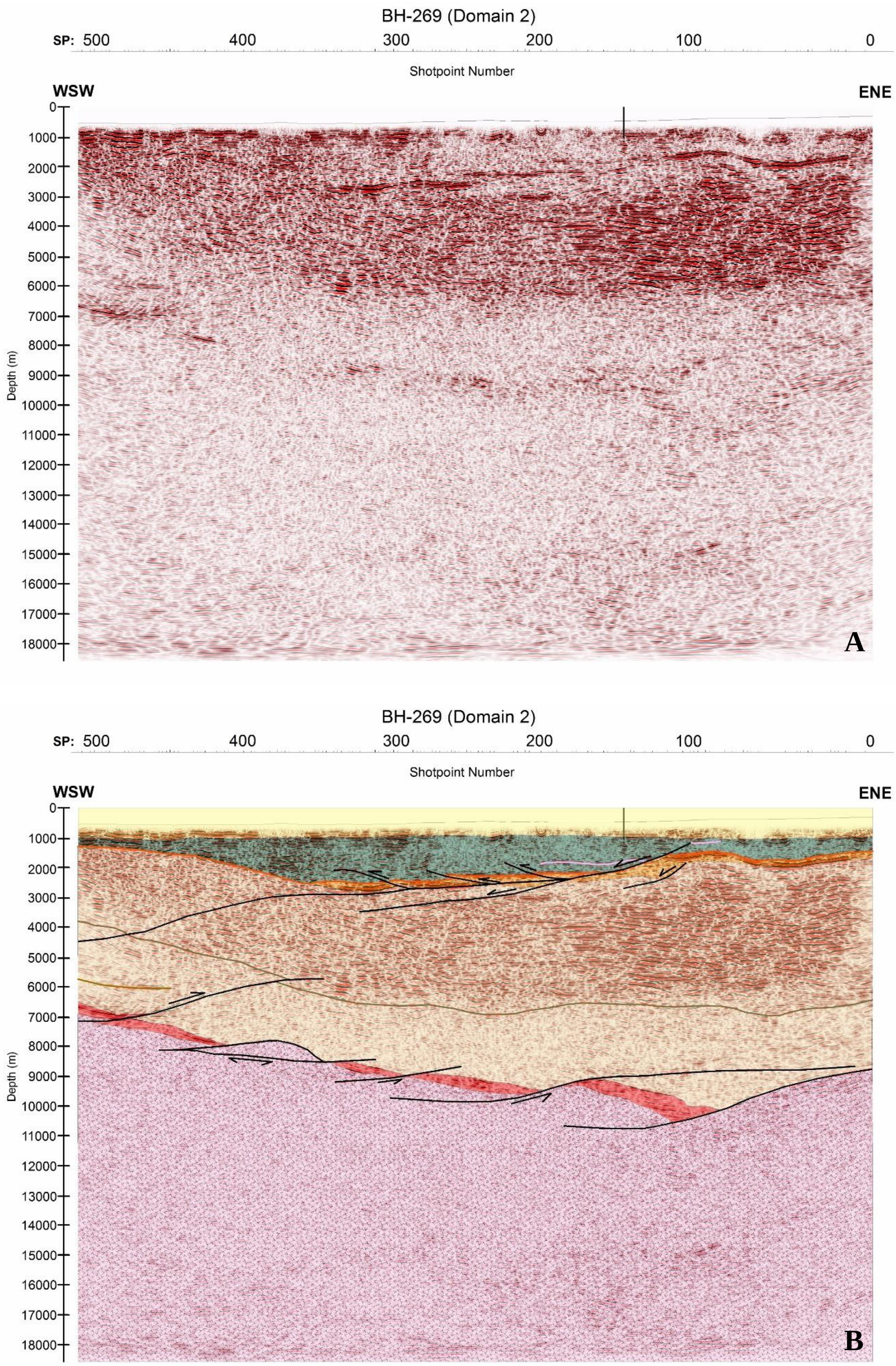


Figure 5.2.16 Line BH-269. Data has a static correction to ~400m. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 0.99x.

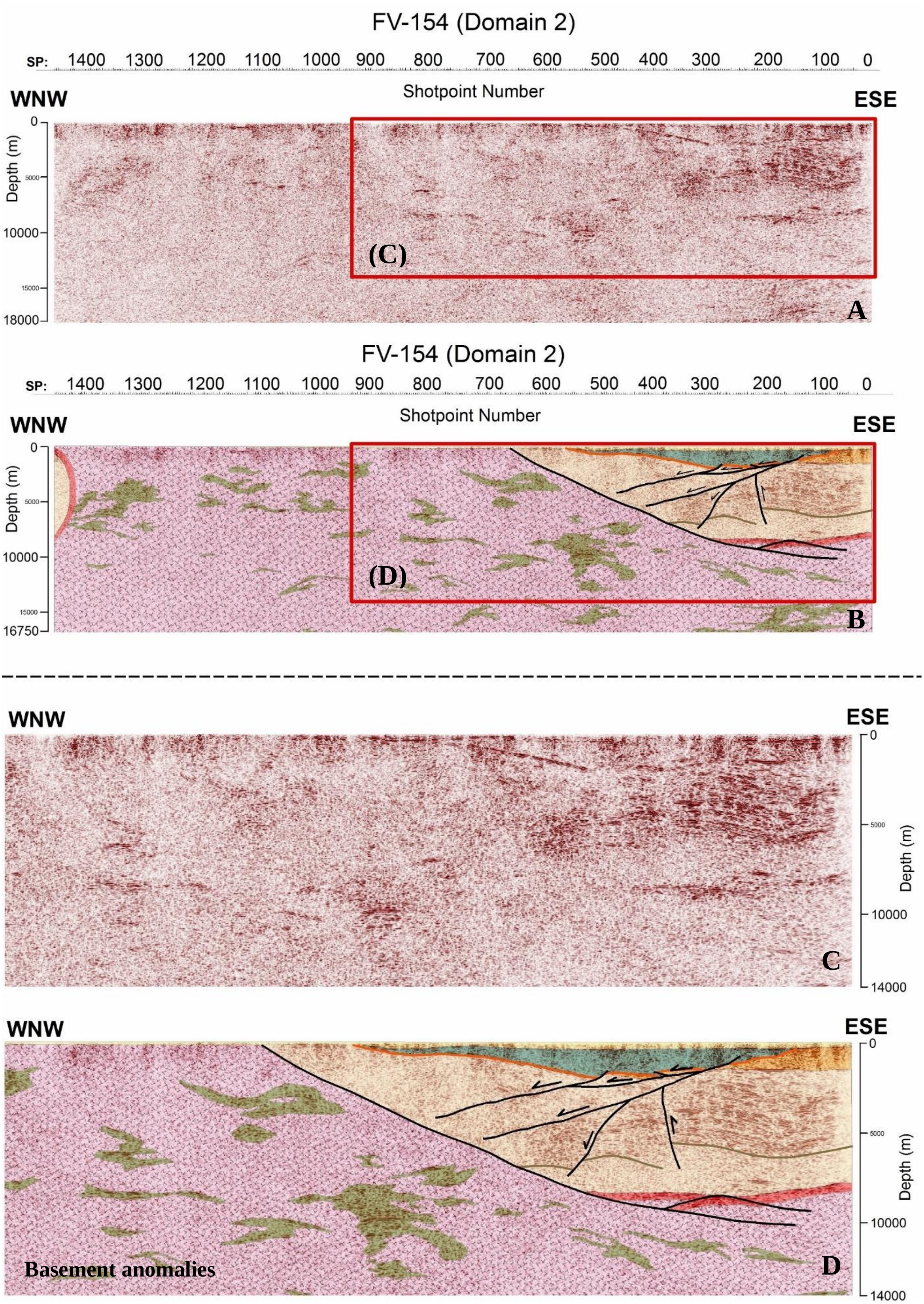


Figure 5.2.17.1 Line FV-154 cropped section. A & C) Un-interpreted seismic section; B & D) interpreted seismic section. Vertical exaggeration is 1.04x.

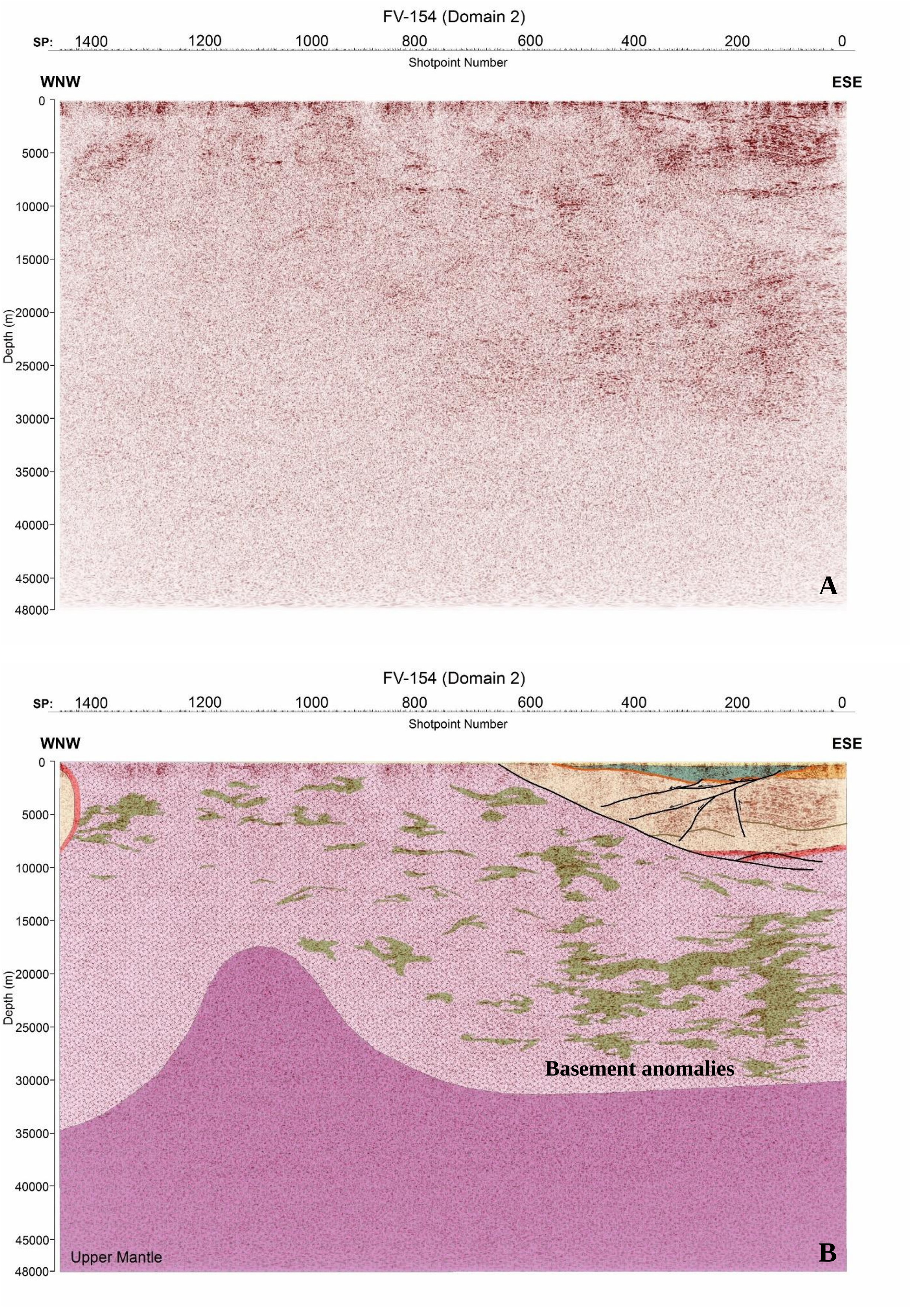
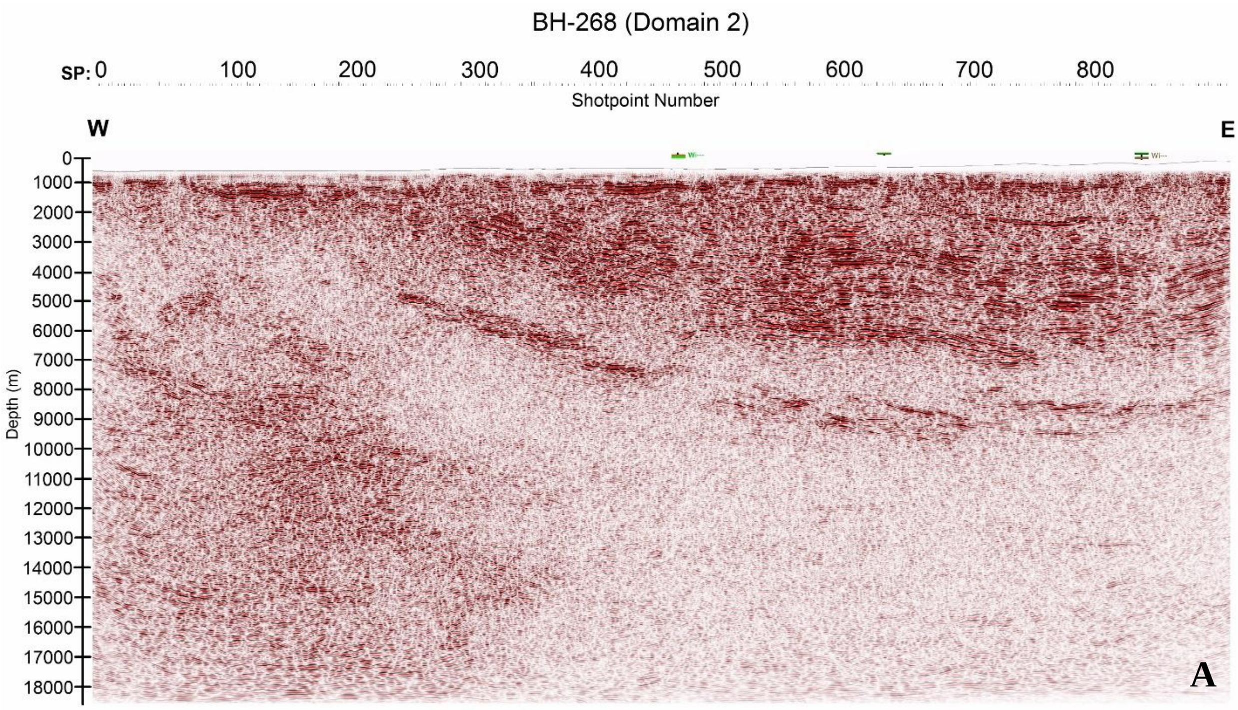


Figure 5.2.17.2 Line FV-154 complete section. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 1.04x.



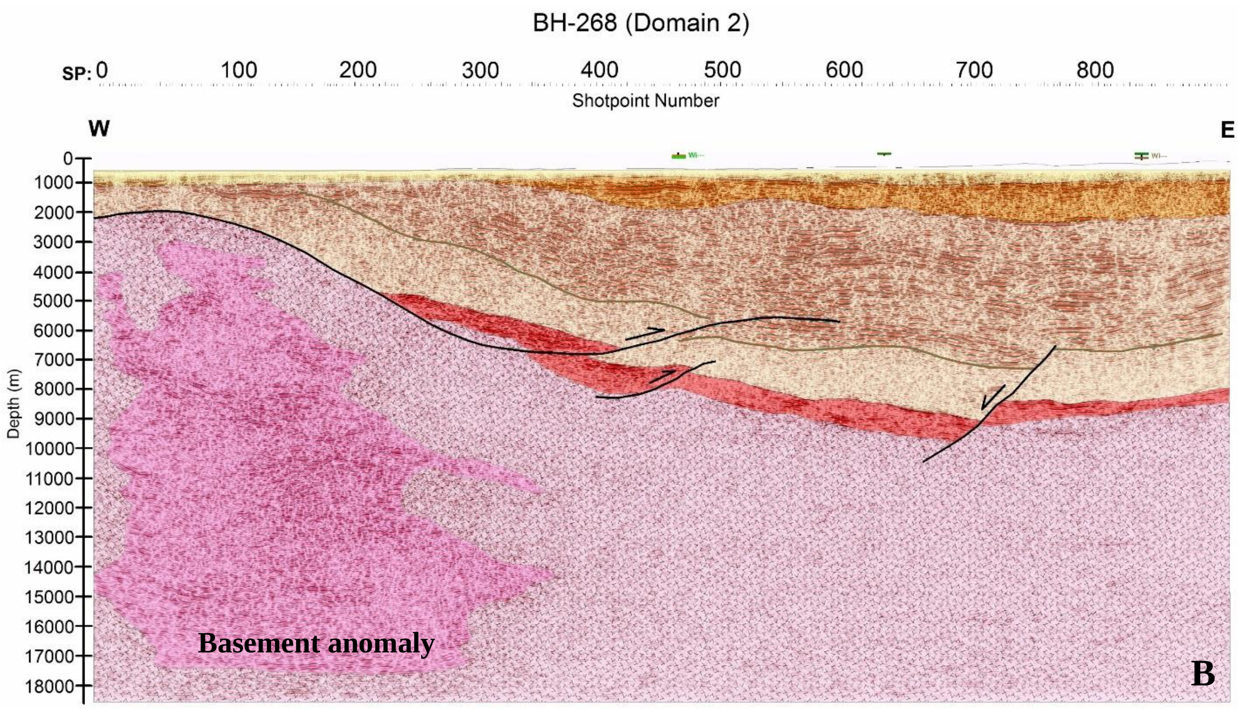
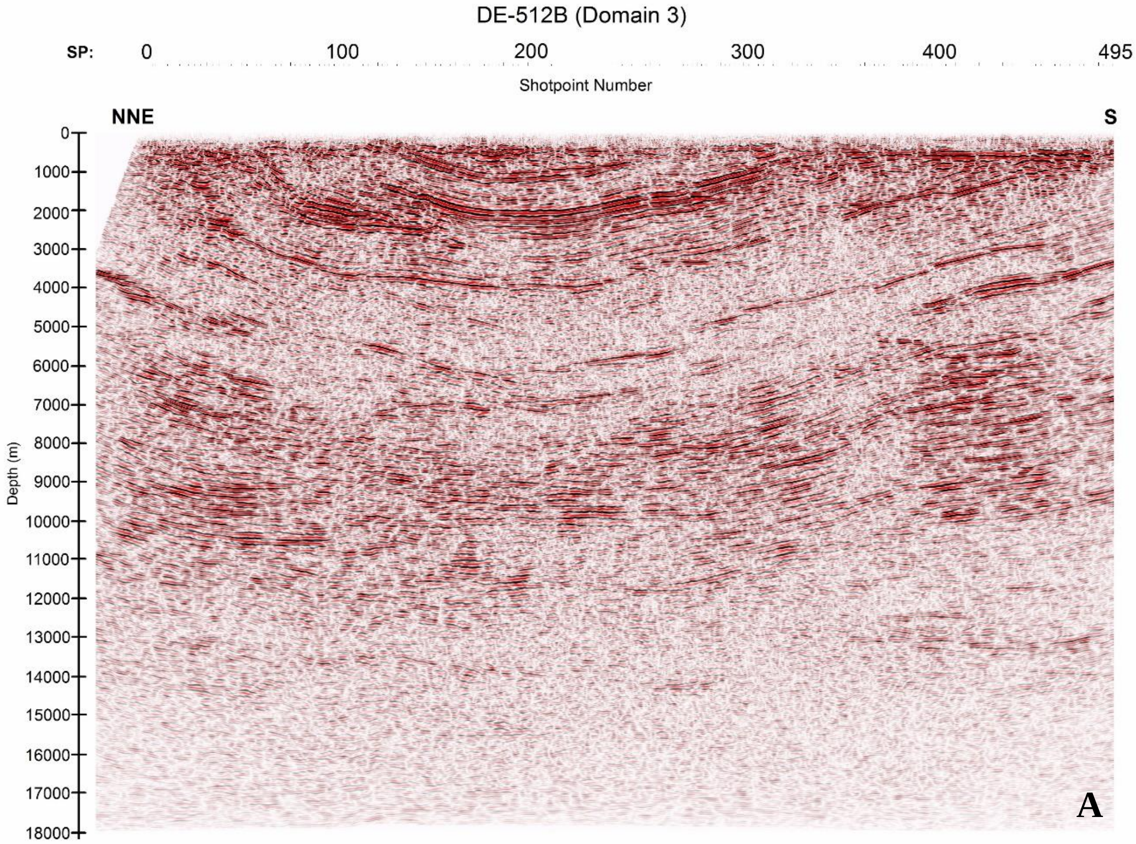


Figure 5.2.18 Line BH-268. Data has a static correction to ~400m. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 1.18x.



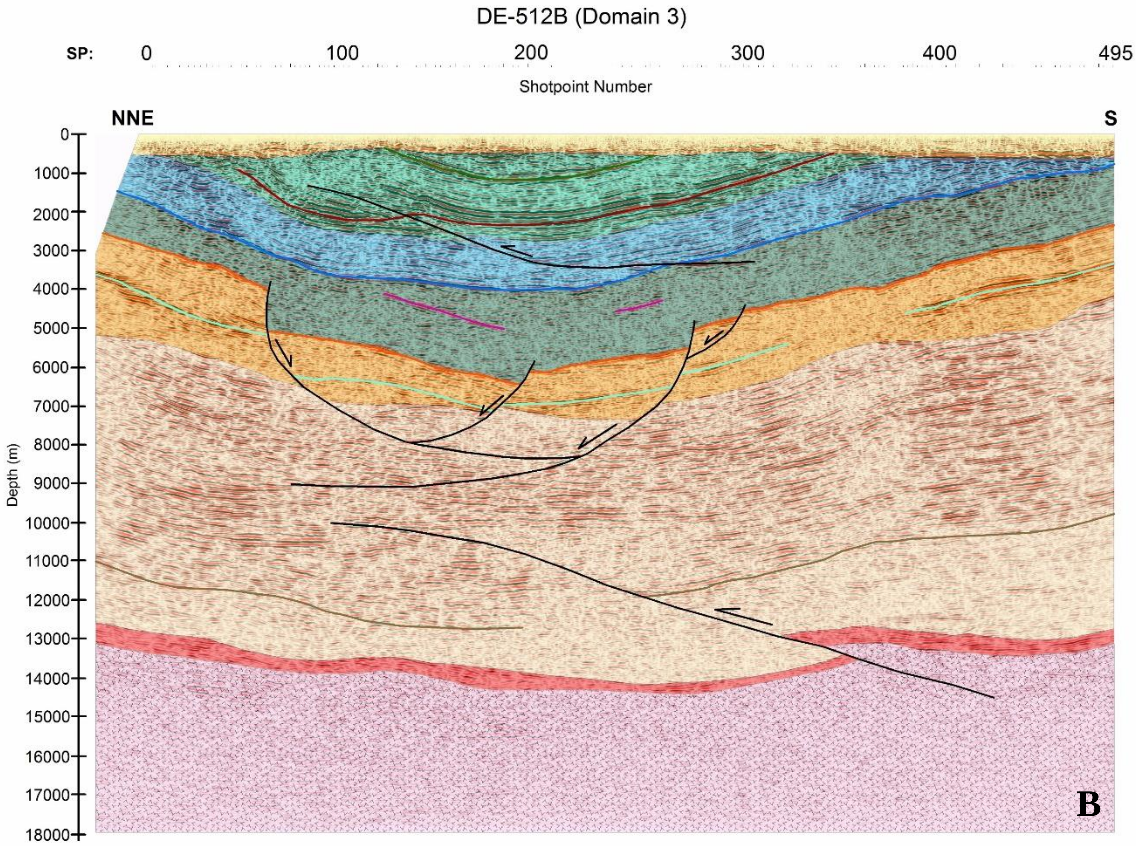
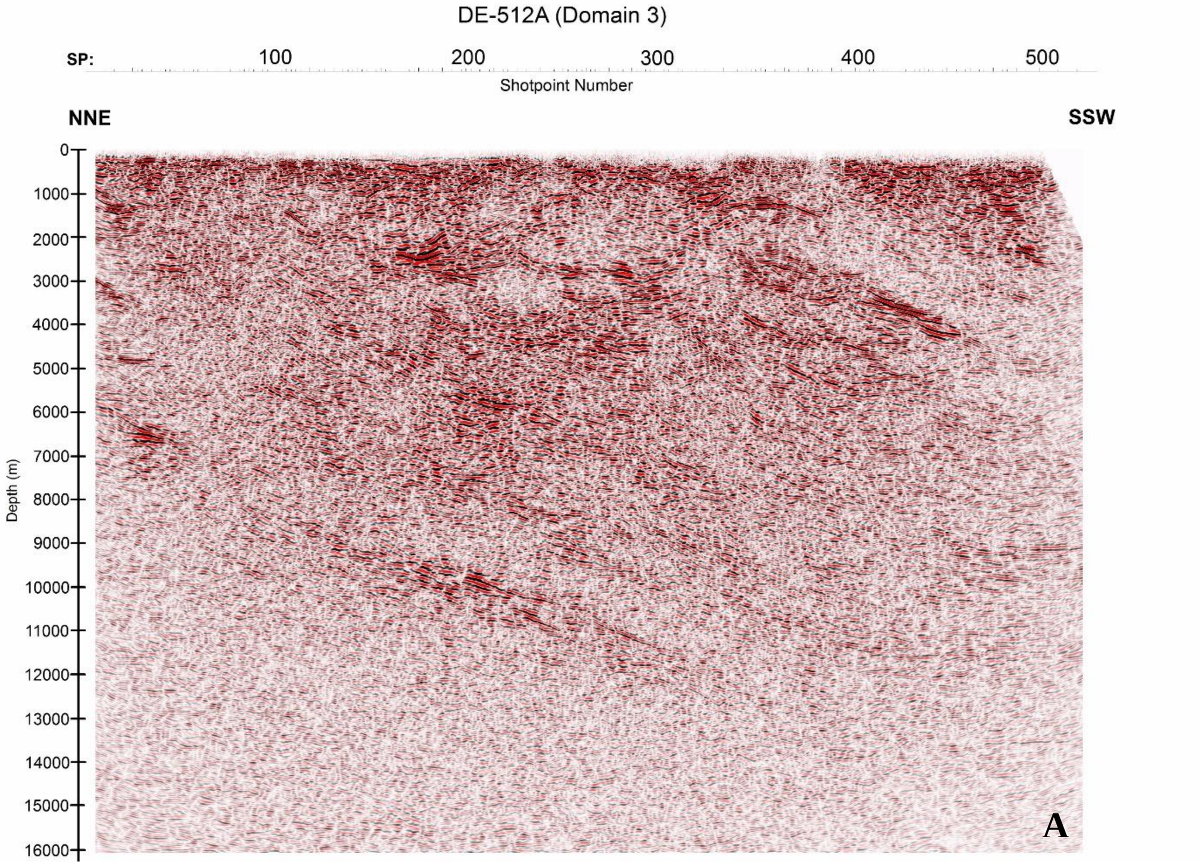


Figure 5.2.19 Line DE-512B. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 0.99x.



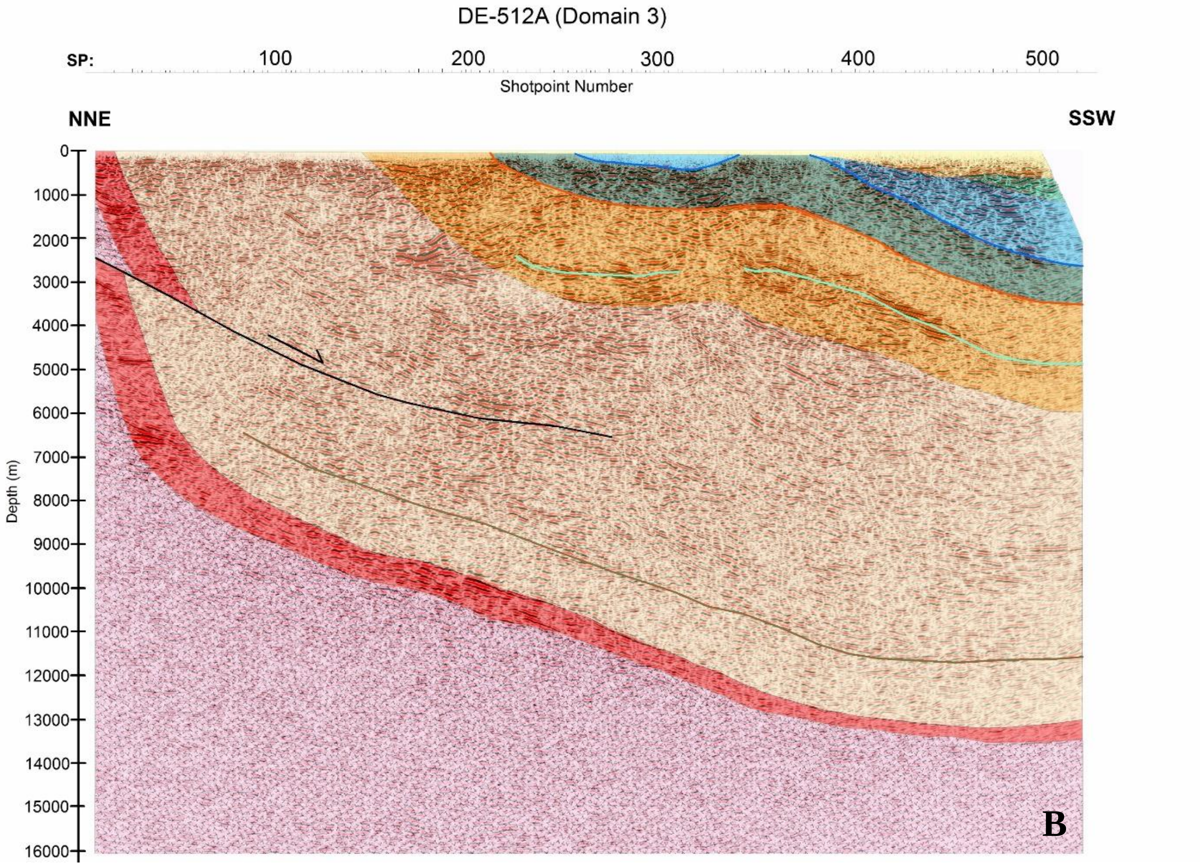


Figure 5.2.20 Line DE-512A. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 1.15x.

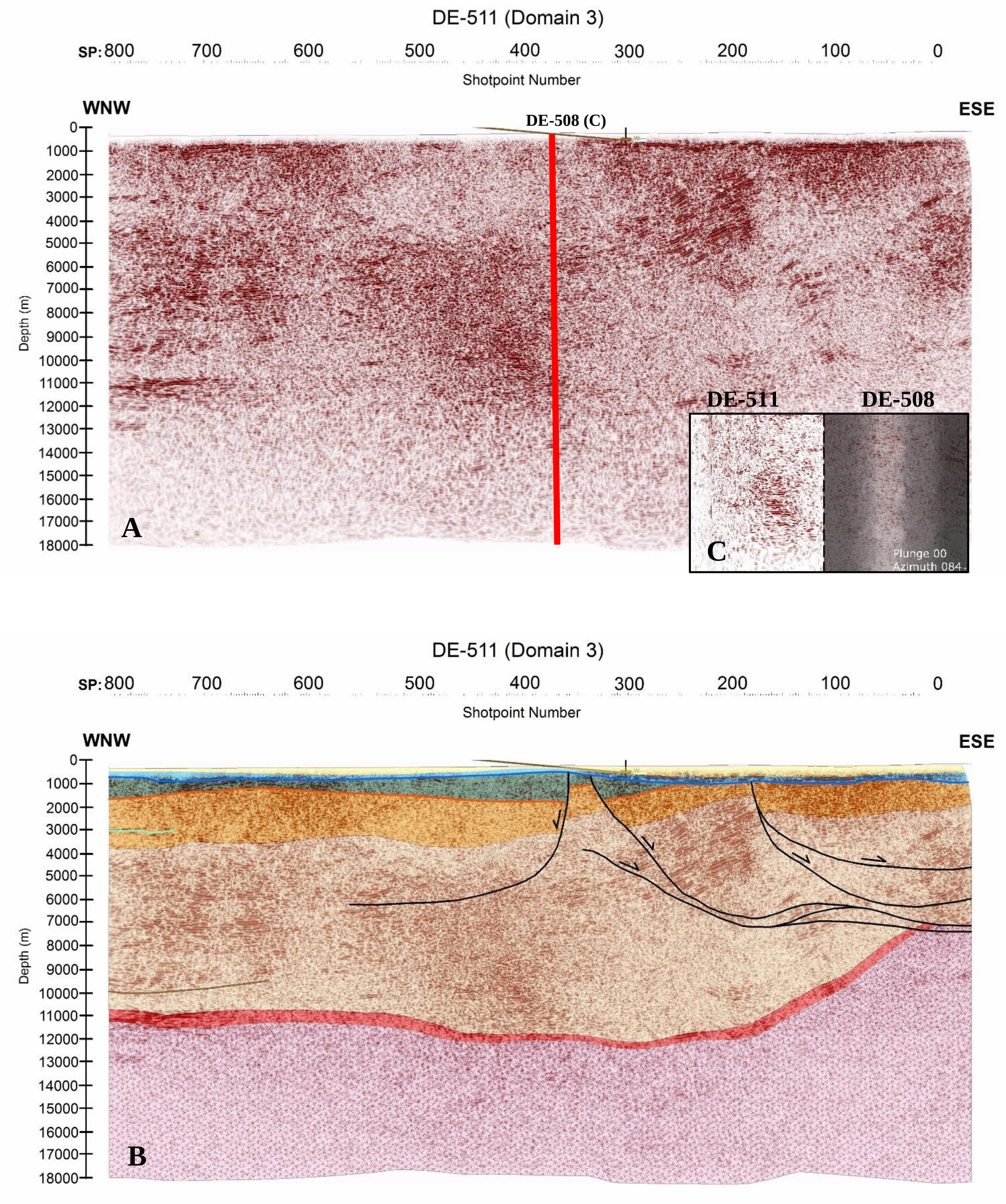
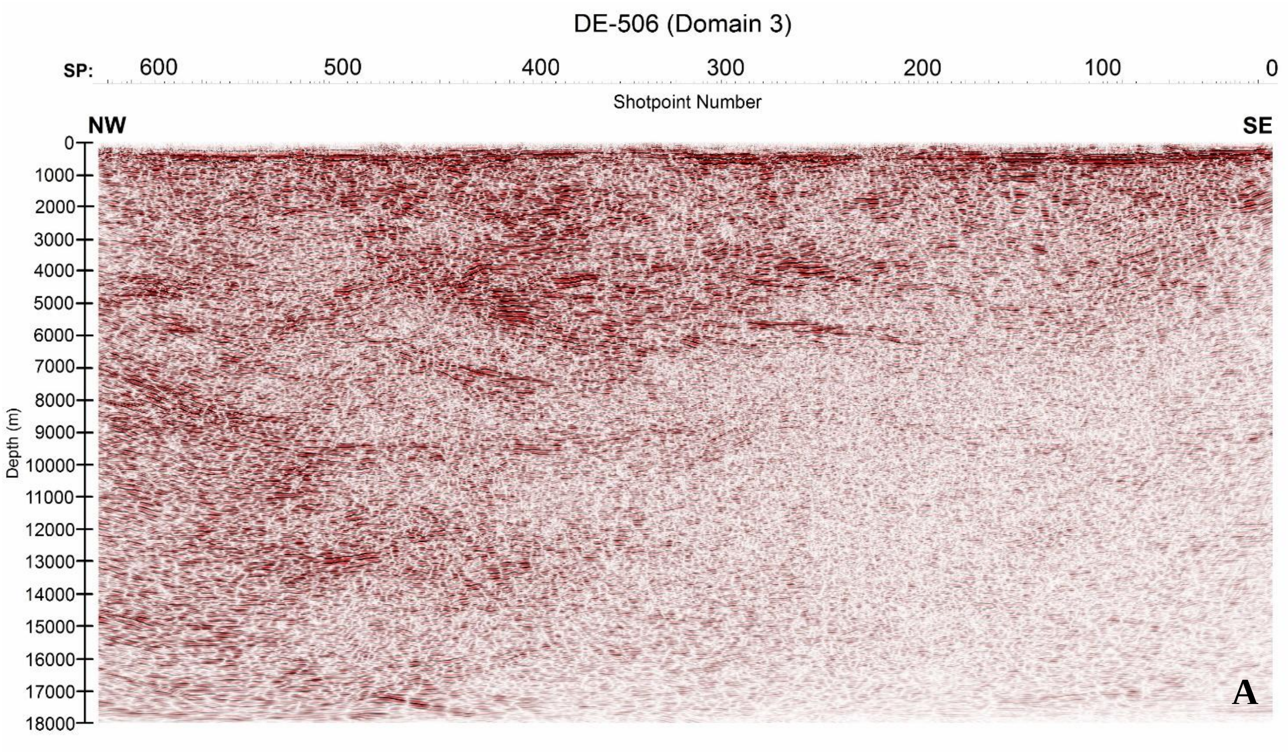


Figure 5.2.21 Line DE-511. A) Un-interpreted seismic section; B) interpreted seismic section. C) 3D view of the intersection between DE-511 and DE-508 highlighting the variation in seismic reflection quality in this part of Domain 3. Vertical exaggeration is 1.11x.



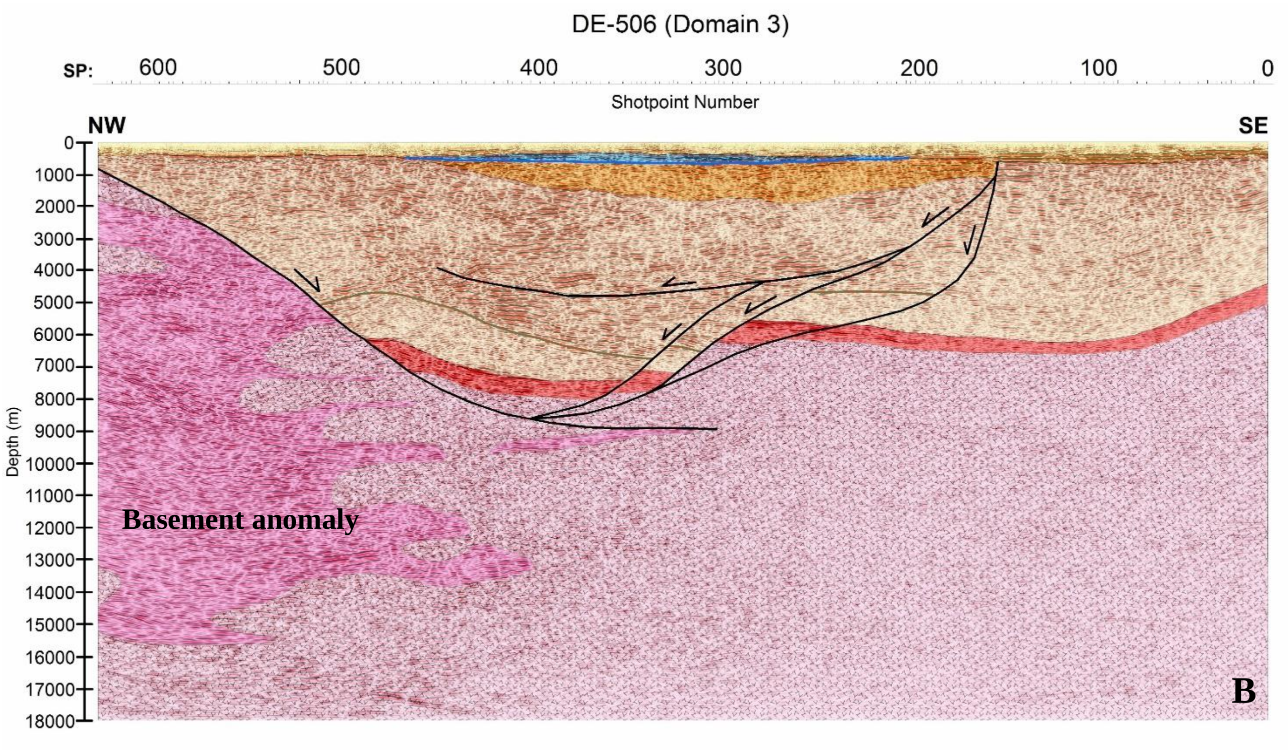


Figure 5.2.22 Line DE-506. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 0.88x.

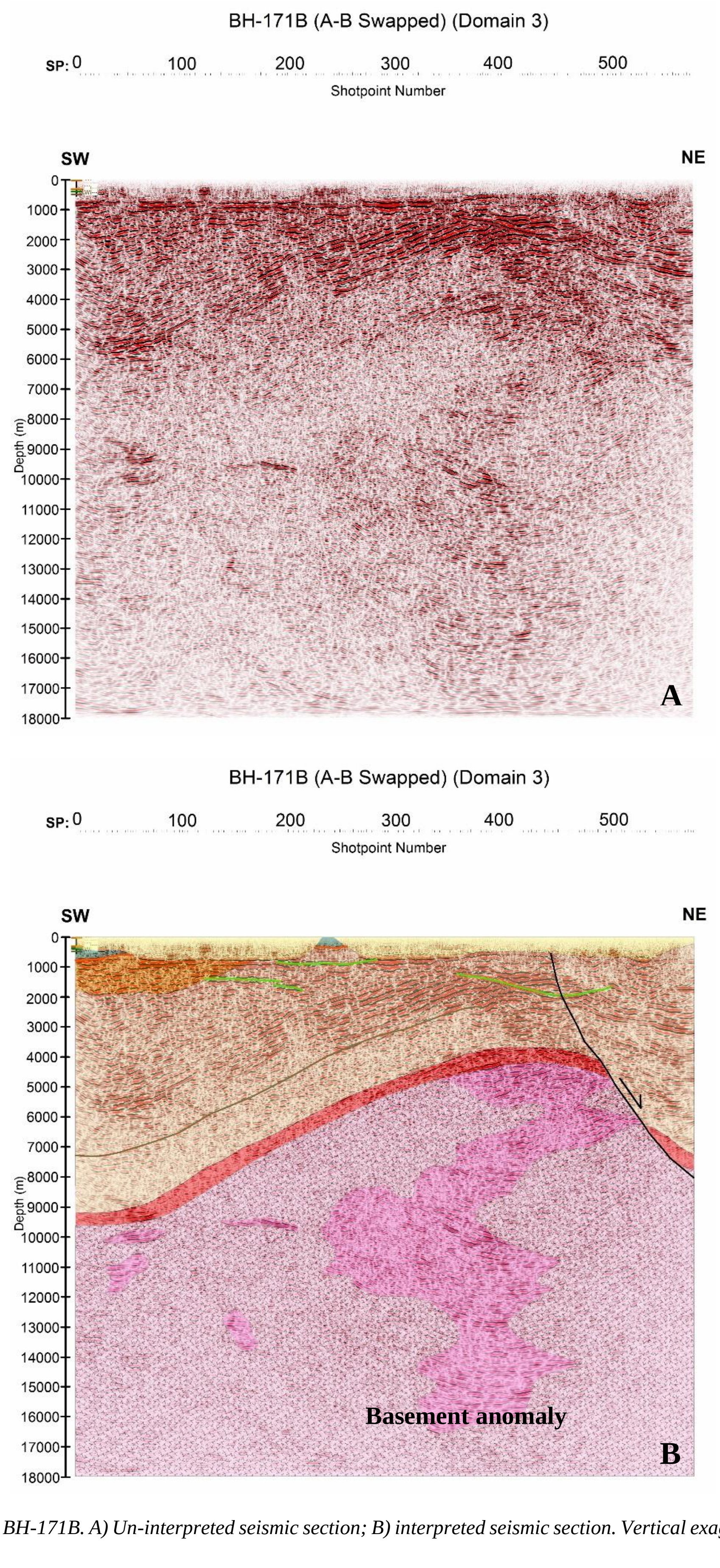


Figure 5.2.23 Line BH-171B. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 1.15x.

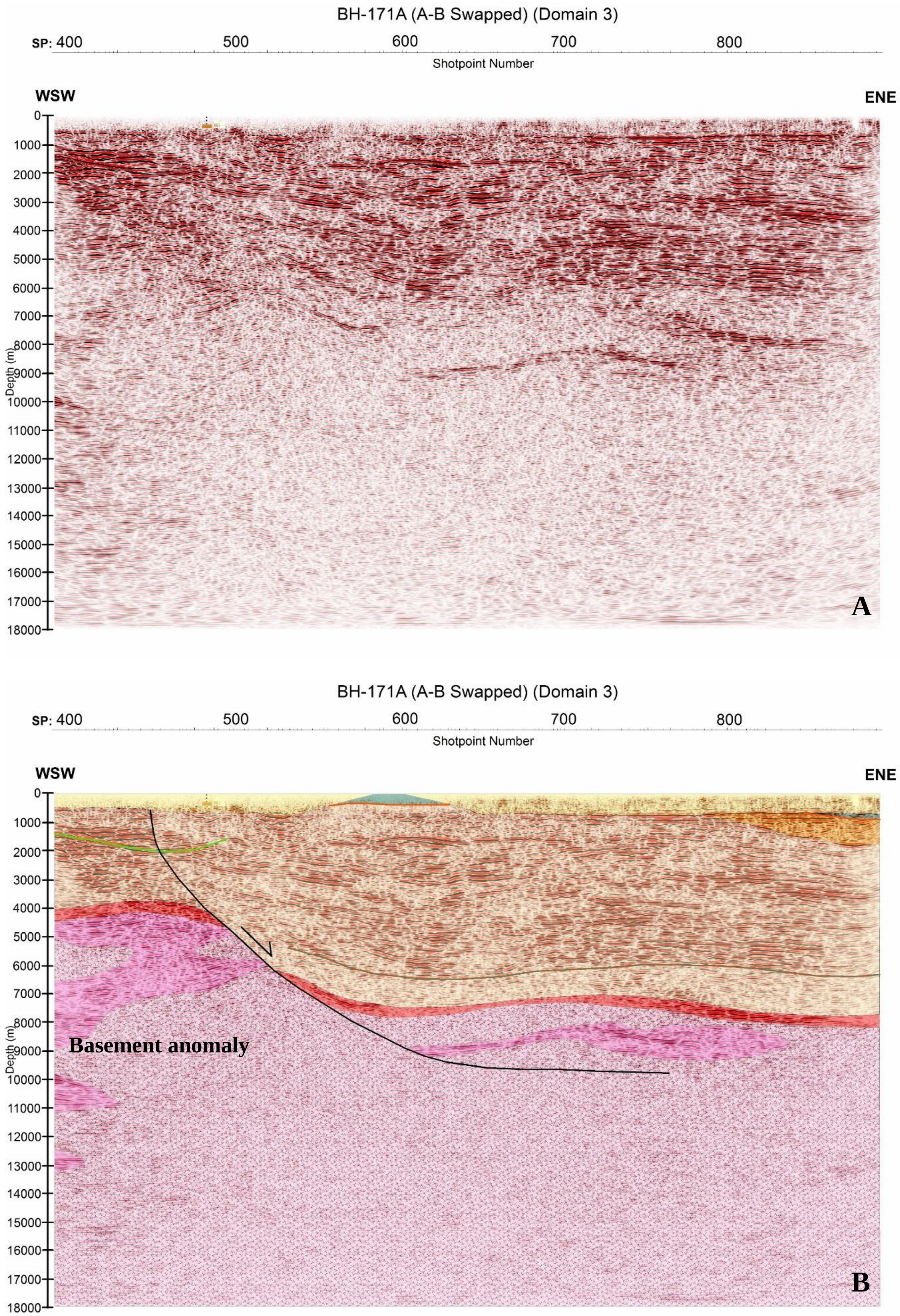
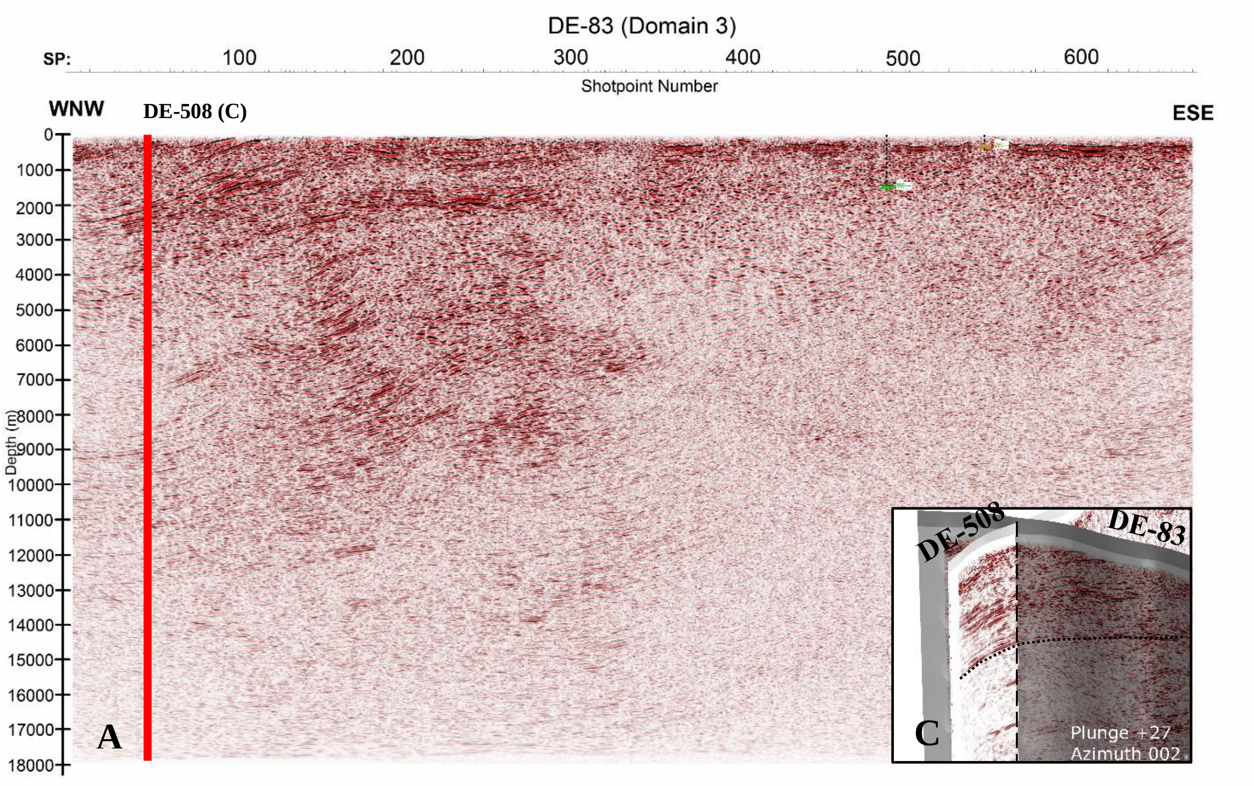


Figure 5.2.24 Line BH-171A. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 0.69x.



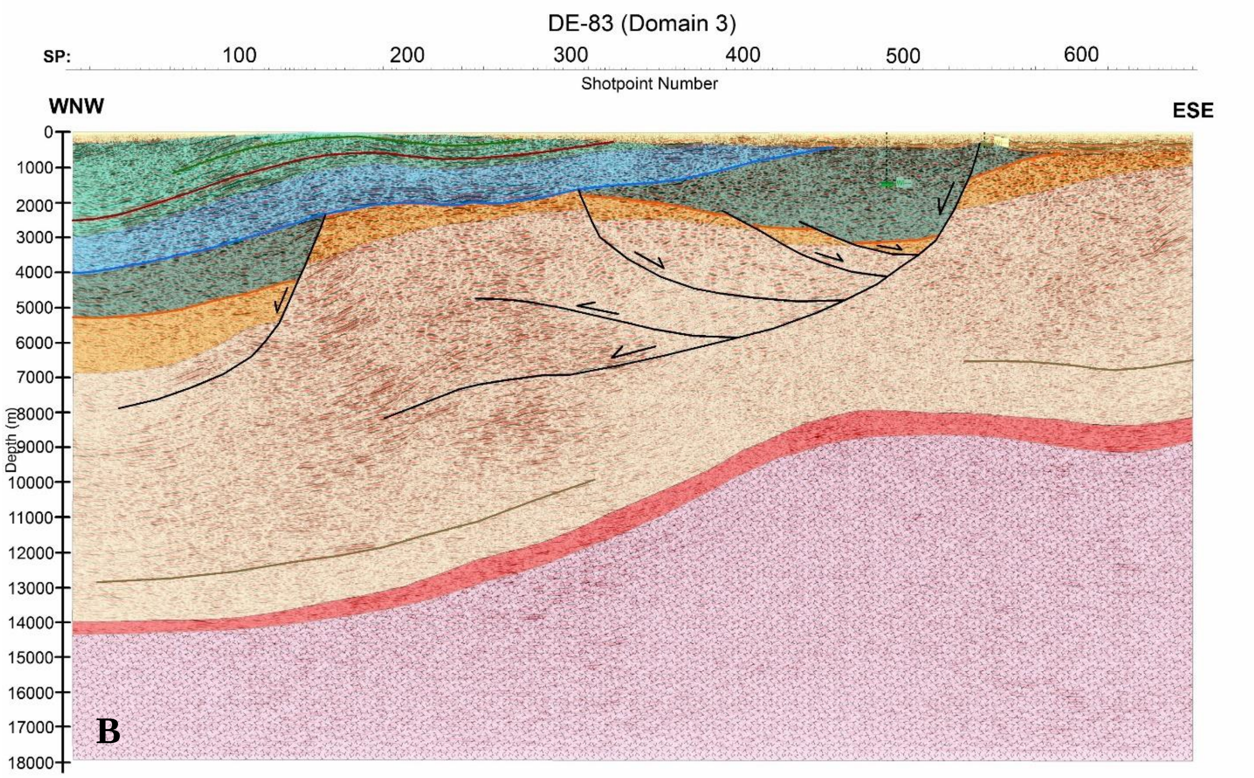


Figure 5.2.25 Line DE-83. A) Un-interpreted seismic section; B) interpreted seismic section. C) 3D view of the intersection between DE-83 and DE-508 highlighting the well matched contact interface of the Black Reef Formation across the two sections (stippled line). Vertical exaggeration is 1.05x.

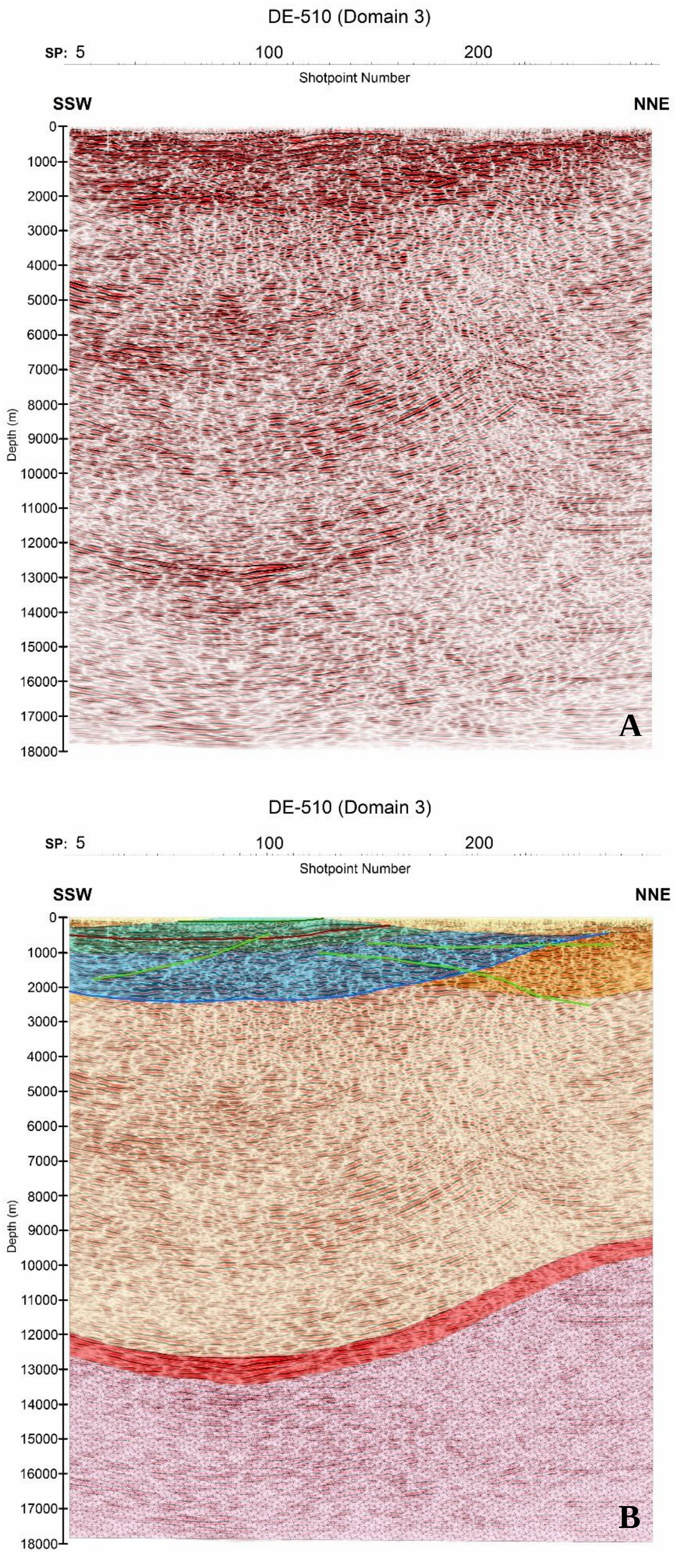


Figure 5.2.26 Line DE-510. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 0.83x.

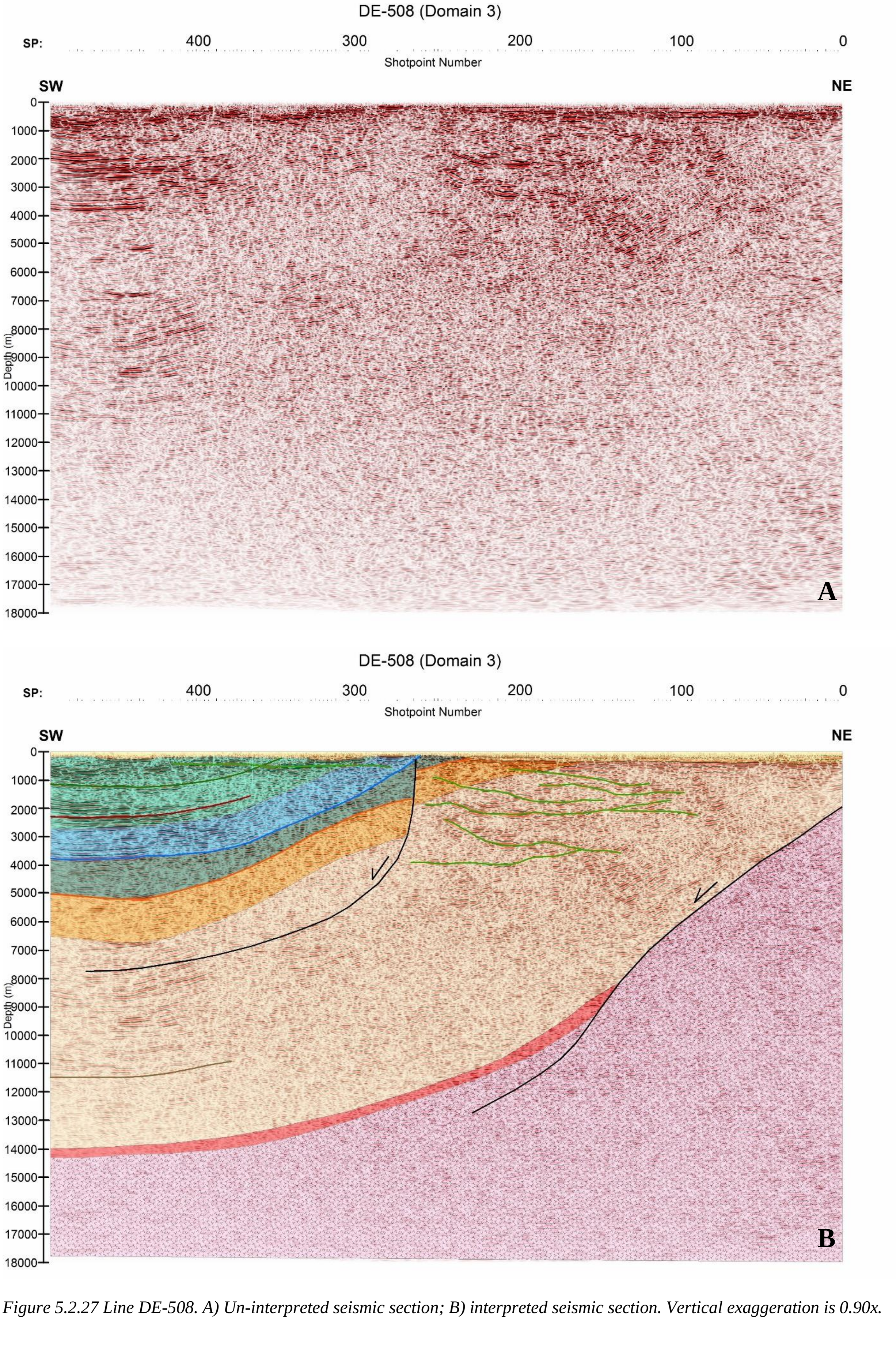
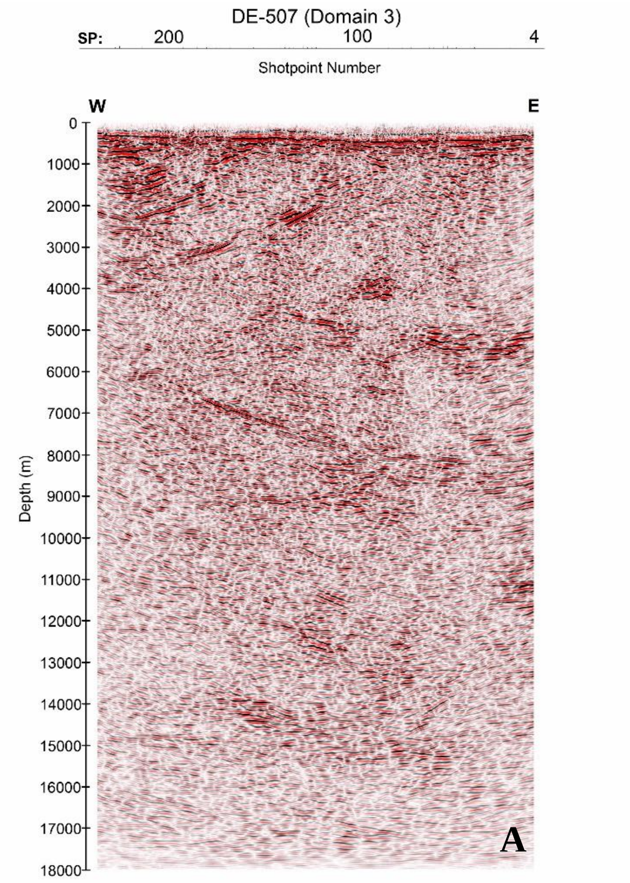


Figure 5.2.27 Line DE-508. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 0.90x.



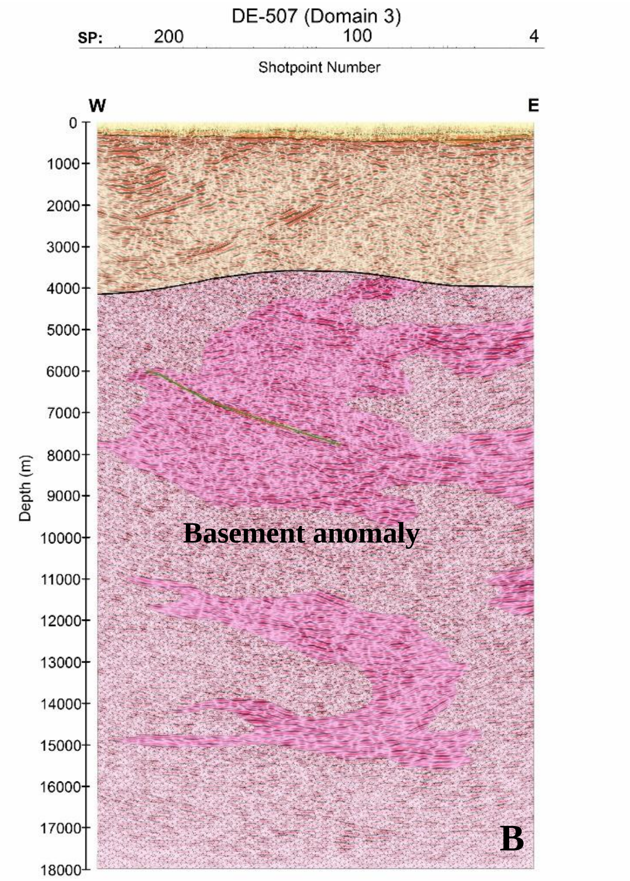


Figure 5.2.28 Line DE-507. A) Un-interpreted seismic section; B) interpreted seismic section. Vertical exaggeration is 1.17x.

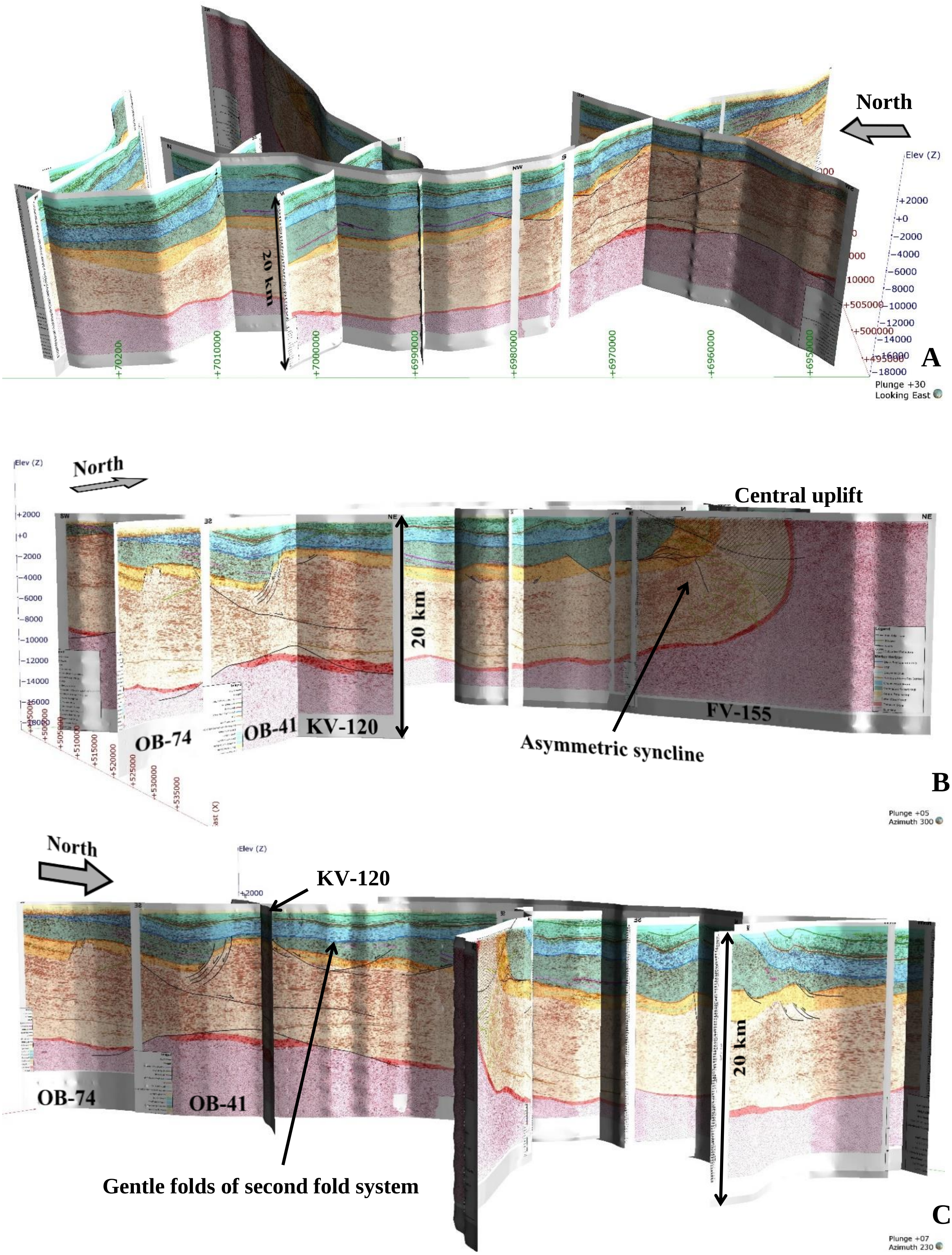


Figure 5.3 Three 3D views of the eight interpreted seismic lines in Domain 1. Note, the plunge angles were used to provide perspective, and do not form part of any structural interpretations. A) Overview of seismic sections, looking east plunging at 30°. B) Looking towards 300° plunging at 05°, highlighting asymmetric syncline related to the central uplift. C) Looking towards 230° plunging at 07°, displaying gentle folds of the second fold system. The orientations are also illustrated in Figure 5.1 to give context with surface geology and boreholes.

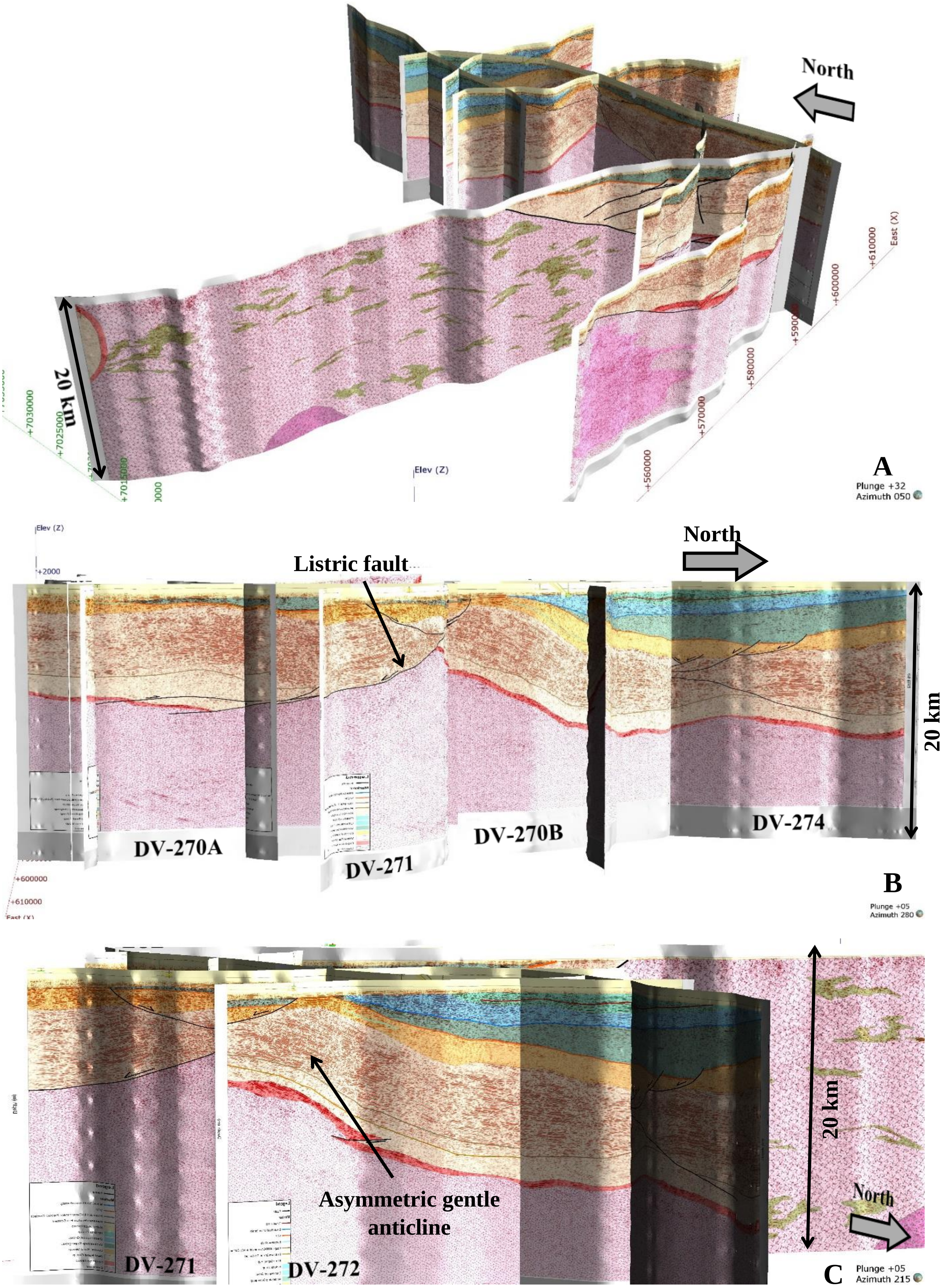
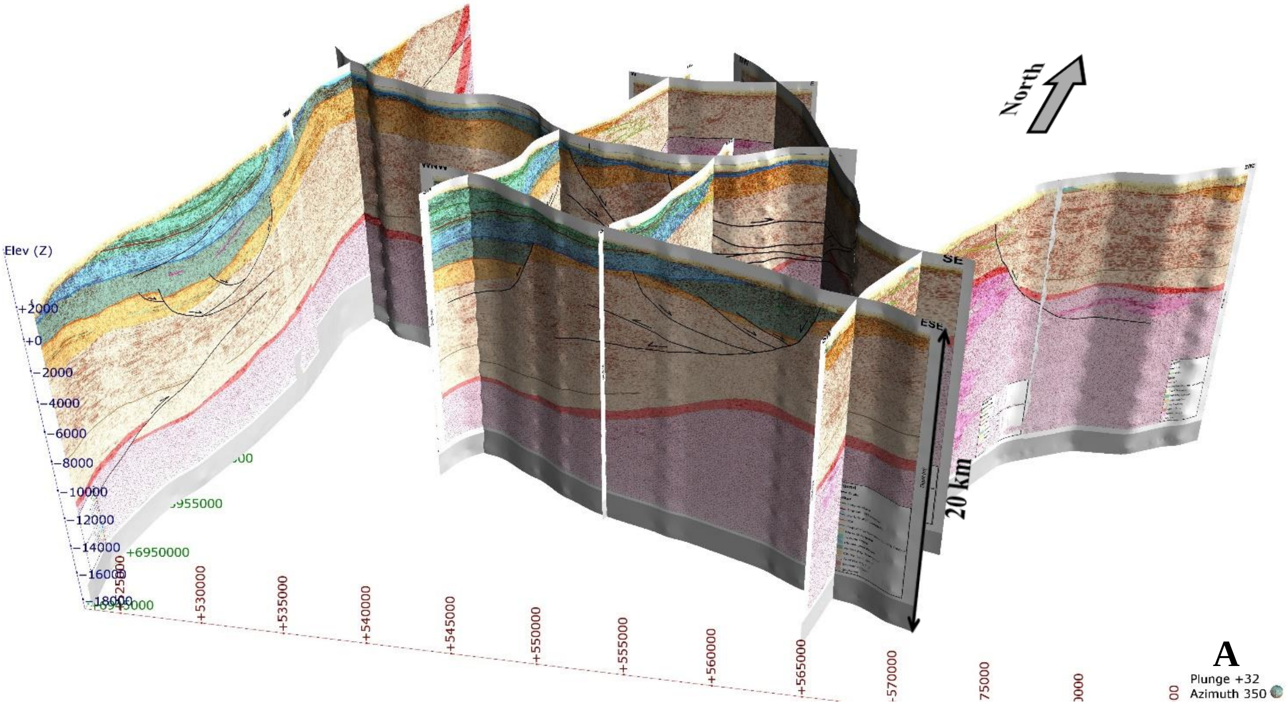
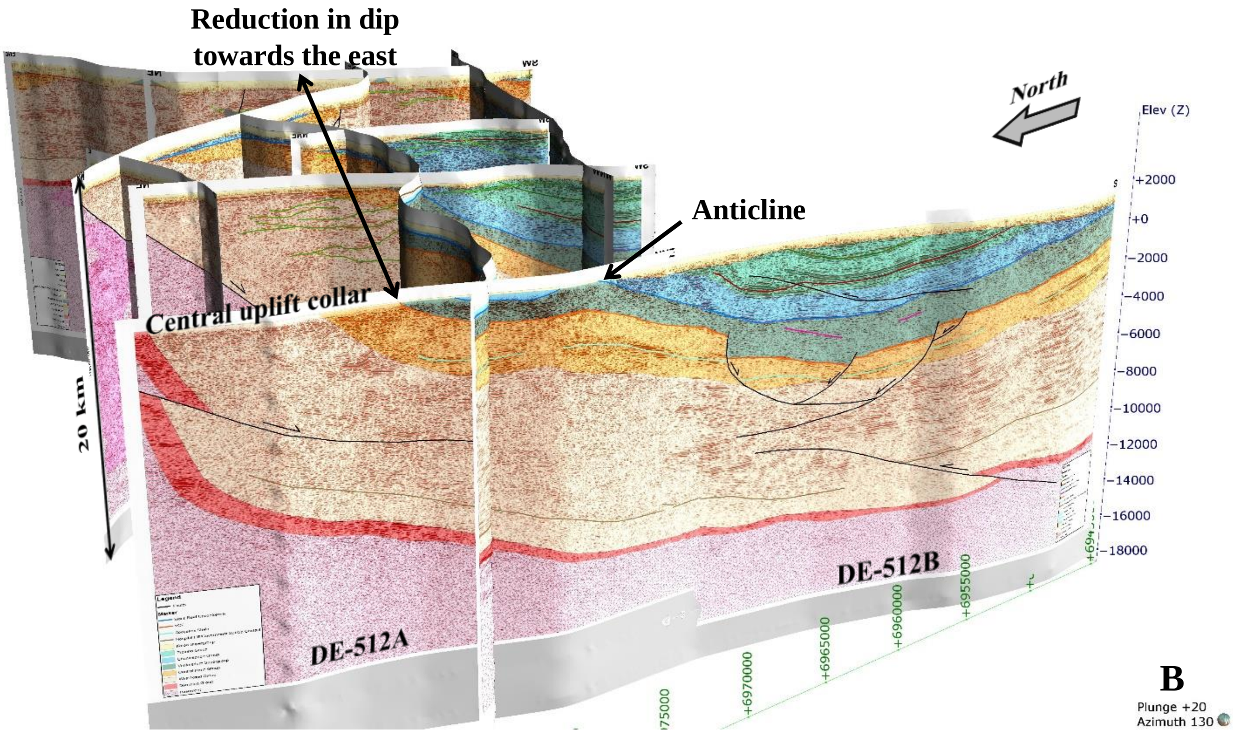


Figure 5.4 Three 3D views of the eight interpreted seismic lines in Domain 2. Note, the plunge angles were used to provide perspective, and do not form part of any structural interpretations. A) Overview of seismic sections, looking towards 050° plunging at 32°. B) Looking towards 280° plunging at 05°, along strike of the listric fault. C) Looking towards 215° plunging at 05°, along strike of the asymmetric, gentle, anticlinal fold. The orientations are also illustrated in Figure 5.1 to give context with surface geology and boreholes.



North
Elev (Z)
+2000
+0
-2000
-4000
-6000
-8000
-10000
-12000
-14000
-16000
-18000
+6950000
+530000
+535000
+540000
+545000
+550000
+555000
+560000
+565000
SE
20 km
A
Plunge +32
Azimuth 350



Reduction in dip
towards the east
North
Anticline
Central uplift collar
Elev (Z)
+2000
+0
-2000
-4000
-6000
-8000
-10000
-12000
-14000
-16000
-18000
20 km
DE-512A
DE-512B
+6970000
+6965000
+6960000
+6955000
B
Plunge +20
Azimuth 130

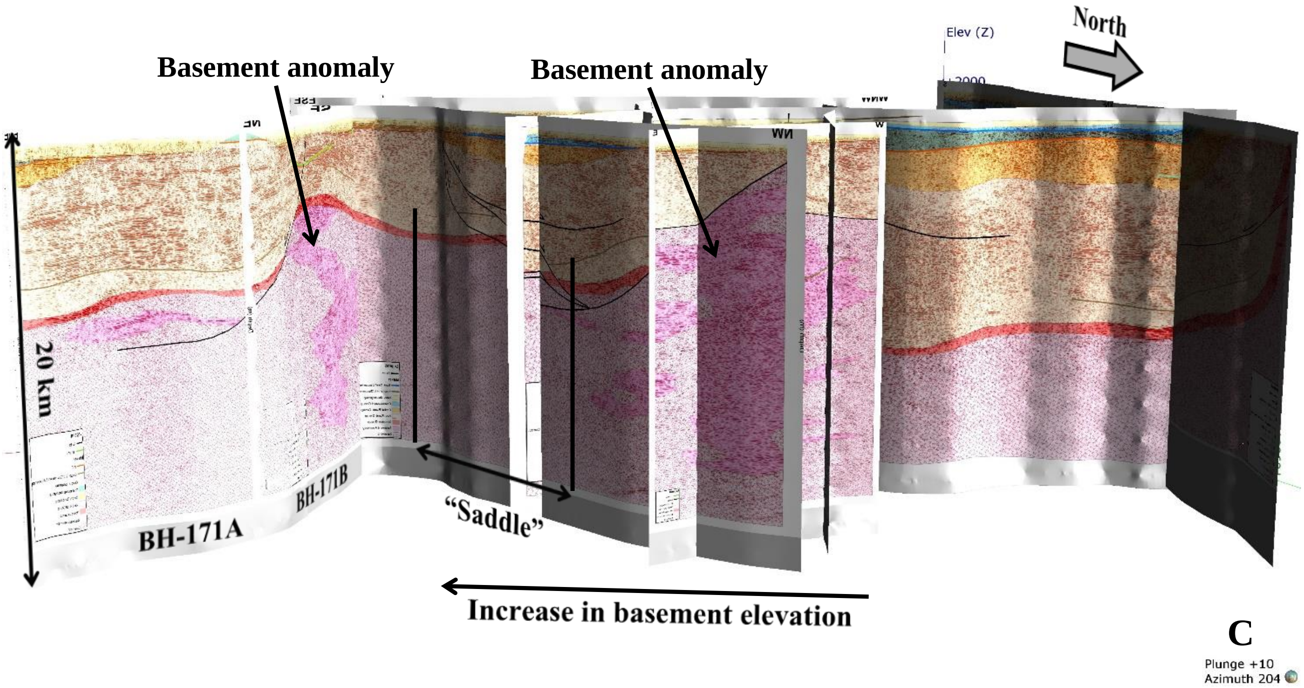


Figure 5.5 Three 3D views of the ten interpreted seismic lines in Domain 3. Note, the plunge angles were used to provide perspective, and do not form part of any structural interpretations. A) Overview of seismic sections, looking towards 350° plunging at 32°. B) Looking towards 130° plunging at 20°, highlighting the asymmetric synform associated with the central uplift, the sub-parallel axial plane of the folds in the Transvaal Supergroup, and the reduction in dip towards the east. C) Looking towards 204° plunging at 10°, highlighting the change in basement elevation across the domain, and the two basement reflection anomalies separated by a narrow 'saddle'. The orientations are also illustrated in Figure 5.1 to give context with surface geology and boreholes.

Note: Due to file size constraints the rest of the dissertation has been placed in a separate pdf document.