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Geology and Geophysics
Subsurface Exploration Non-Destructive Evaluation

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via Email (Pages 1-6/Figures 1-5)

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Attention: Mr. Judd J. King, PE, GE
Mr. Gresham D. Eckrich, PE, CEG

Final Report
Seismic Reflection and Refraction Surveys
Harbor Terrace Development
Avila Beach, California

INTRODUCTION

This report presents the results of the seismic reflection and refraction surveys completed along two surveys line designated as “Lines 1 and 2” positioned across the referenced site as shown in Figure 1. The data from these surveys was used to prepare seismic reflection and refraction velocity profiles showing images of subsurface geologic layering. These profile images were evaluated to interpret structural and stratigraphic conditions beneath the site.

The following sections summarize our field data recording procedures and methods of computer data processing and display. A concluding section discusses our current geologic evaluation of the seismic profiles along Lines 1 and 2. This evaluation incorporates recent geologic data made available from Yeh and Associates.

SURVEY PROCEDURES

Advanced Geoscience mobilized a survey crew from Torrance, California to conduct the seismic reflection and refraction surveys along Lines 1 and 2. The field surveys were conducted on October 9 through 12, 2017.

The positioning of Lines 1 and 2 was based on our discussions with Yeh and Associates. Line 1 was positioned along a straight-line, 888-foot long, north-south traverse. Line 1 was set up on a mostly homoclinal sloping surface, avoiding the steeper embankments separating the terraced areas at this site (Figure 1). Line 2 was positioned to the east of Line 1 along a northeast to southwest, 688-foot long traverse. Line 2 had to be set up to avoid buildings and trailers and follow a pathway through trees and thicker plant cover. Line 2 also had to cross a steeper embankment separating terraced areas.

Survey stakes were first positioned on Lines 1 and 2 to establish distance stationing. A global positioning survey was later performed by Yeh and Associates to measure the coordinates and elevations of these survey stakes.

Data Recording Procedures

A Seistronix, Ltd. EX-6, 132-channel data recording system was used to record the seismic data. The EX-6 system was connected to geophone receiver arrays setup along Lines 1 and 2. Each geophone array consisted of 40-Hertz (cut off frequency) geophones spaced 8-feet apart. The total length of geophone coverage set up along Line 1 was 888 feet (using 112 channels). The total length of geophone coverage set up along Line 2 was 688 feet (using 87 channels).

The seismic waves were transmitted into the ground at 8-foot intervals along Lines 1 and 2. The energy source points were positioned between the geophones. The seismic waves generated at each source point were recorded by the EX-6 system into all geophone channels.

The seismic energy source was mostly generated by a man-portable, 60-pound weight drop impacting a steel plate placed on the ground surface. A 20-pound sledge hammer was later used to record part of Line 2. Multiple impacts were made with both energy sources to sum together from eight to fifteen recordings to enhance the coherent seismic wave patterns and minimize the amplitude of background noise.

A total of 111 field records were recorded for Line 1 and 85 field records for Line 2. Each field record was recorded with a 0.8-second record length and 0.25-millisecond sampling rate with 24 bit analog-to-digital resolution.

Data Processing and Display

The seismic data processing procedures were performed by Advanced Geoscience with consideration given to the area's geologic conditions.

The field records from selected source points spaced 24 to 48-feet apart along Lines 1 and 2 were input into the RAYFRACT seismic refraction tomography software developed by Intelligent Resources, Inc. (www.rayfract.com). RAYFRACT was used to generate seismic compressional-wave velocity profiles along Lines 1 and 2.

The field records were input into RAYFRACT to graphically pick first arrival times ("first breaks") for refracted waves traveling through the surface layer and into deeper higher-velocity layers. These time-distance data were used together with geophone station coordinates and elevations to conduct refraction tomography imaging of seismic velocity layering. RAYFRACT first generated an initial velocity-depth model using the 1D gradient method. This initial model was then refined to produce a closer fit to the arrival time data using the Wavepath Eikonal Traveltime tomographic inversion method with 60 iterations with a maximum velocity 4,000 m/sec. The best-fit velocity-depth model was then gridded and color contoured with SURFER (written by Golden Software, Inc.) to show estimated vertical and lateral velocity variations. The resulting seismic compressional-wave velocity profiles for Lines 1 and 2 are shown in Figures 2 and 4.

Advanced Geoscience used the Visual_SUNT seismic reflection processing software developed by W_Geosoft (www.wgeosoft.ch) to prepare seismic reflection profiles for Lines 1 and 2. The field records were input into this computer program together with the measured geophone coordinates and elevations to perform a specialized sequence of data editing, digital filtering, trace sorting, velocity corrections, and trace summation procedures to prepare common midpoint (CMP)-stacked (summed), reflection time profiles. Several sequences of data processing were performed and evaluated and modified until a set of processing parameters was arrived at that provided the clearest images of geologic structure and stratigraphy. The resulting "un-migrated" reflection time profiles for Lines 1 and 2 are shown in Figures 2 and 3.

The variations in ground surface elevation along Lines 1 and 2 were also accounted for in the reflection data processing by applying "elevation statics" corrections. After the CMP-stacking, the CMP traces were shifted to a horizontal datum elevation positioned just above the highest point on the north end the survey lines (Line 1- 225 feet and Line 2- 140 feet). The time shifts introduced by this step were calculated using a replacement velocity of 3,000 ft/sec for the material between the ground surface and horizontal datum. This step effectively reduced the reference time (t=0) on the reflection time profiles to the horizontal datum elevations.

The reflection time profiles were then converted to approximate depth profiles using smoothed seismic velocity-time grids generated from the refraction velocity profiles. In making this conversion the interval summation calculation Dij=Vij x Tij was performed on each sample of each trace with the replacement velocity 3,000 ft/sec used for the time window associated with the elevation statics. The resulting approximate reflection depth profiles for Lines 1 and 2 are shown in Figures 4 and 5.

Figures 2 through 5 show the reflection and refraction profiles with same horizontal scale and positioning relative to one another. The profiles are all displayed with a horizontal scale of 1 inch=60 feet. The elevation scale for the refraction profile is also 1 inch=60 feet. However, the elevation scale for the reflection depth profiles is 1 inch=80 feet (showing 0.75x vertical reduction). This vertical scale reduction was used to provide better depth imaging with less waveform stretching due the rapidly increasing subsurface velocity gradient. It is noted that these reflection depth profiles are only approximate images of the true depth profile.

DISCUSSION OF RESULTS

Geologic Evaluation

The following interpretation of the seismic reflection profiles along Lines 1 and 2 is based on our current understanding of the geologic structure and stratigraphy of this area, which is based on the mapping of geologic units outcropping near these survey lines shown in Figure 1 and the borehole contacts shown on various cross sections prepared by Yeh and Associates. It is emphasized that additional subsurface geologic data from deeper boreholes (and possibly additional seismic survey lines) is needed to finalize this interpretation.

The seismic profiles in Figures 2 through 5 show our current interpretation of subsurface geologic stratigraphy and the orientations of major bedrock fault planes beneath Lines 1 and 2. These features on the seismic reflection profiles were first identified on the reflection time profiles (which provided a sharper imaging of subsurface layering) and then transferred to the same reflection patterns shown on the reflection depth profiles. The reflection depth profiles show the more correct orientation of these features. Due to the higher subsurface velocity gradients in this area, these approximate depth profiles reveal geologic layering to a depth of beyond 1,000 feet.

A pattern of reflections from the geologic units mapped on the surface and encountered in the boreholes was first interpreted on Line 1. Based on the alignments of sharper vertical separations within these reflection patterns and the associated diffraction patterns, various fault plane orientations were interpreted on Line 1. This pattern of faulting is shown by the fault plane orientations for Faults A, B, C, and D in Figures 2 and 3. The north-dipping Fault A which separates Cretaceous Atascadero Formation sedimentary units (Kas) to the north from Franciscan Formation (KJf) units to the south appears to be the pre-Tertiary age reverse fault shown on the geologic mapping in Figure 1. Faults B and C appear to be en-echelon faults associated with Fault A.

A pattern of similar reflections from the geologic units in this area was interpreted on Line 2. Fault plane orientations similar to those on Line 1 were also interpreted on Line 2. The reverse faults identified as Faults A and D appear to extend to the northeast to intersect Line 2 as shown on Figures 4 and 5. The interpretation of the trend of Fault D is based on the geologic mapping in Figure 1 which infers a fault contact between Franciscan Melange (KJfm) and Atascadero (Kas) units along the southeast part of the site.

Faults E and F were also interpreted on Line 2. However, these faults appear to show less vertical separation than the faults located to the north.

It is emphasized that this interpretation of subsurface faulting on the seismic reflection profiles cannot be used to establish the age and recency of faulting in this area. Direct geologic observations from trenching and other means of subsurface exploration are required to establish this.

The seismic refraction velocity profiles (in Figures 2 and 4) also provide data on the hardness of the upper bedrock materials in this area. Based on the correlation of these velocity profiles to the Caterpillar, Inc. seismic-velocity-versus-rippabilty charts for metamorphic rock, it appears that beneath both Lines 1 and 2 most of the upper 30 to 40 feet of weathered bedrock near the ground surface is rippable with velocities generally less than 6,500 ft/sec (the lower limit for a Caterpillar D9R). However, beneath Line 1 there are isolated areas where velocities exceeding 6,500 ft/sec could be shallower than this.

Advanced Geoscience appreciates this opportunity to be of service to Yeh and Associates and the Harbor Development Project. Please contact the undersigned if you have any questions or additional requests concerning these seismic surveys.

Sincerely,

Advanced Geoscience, Inc.

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MARK G. OLSON
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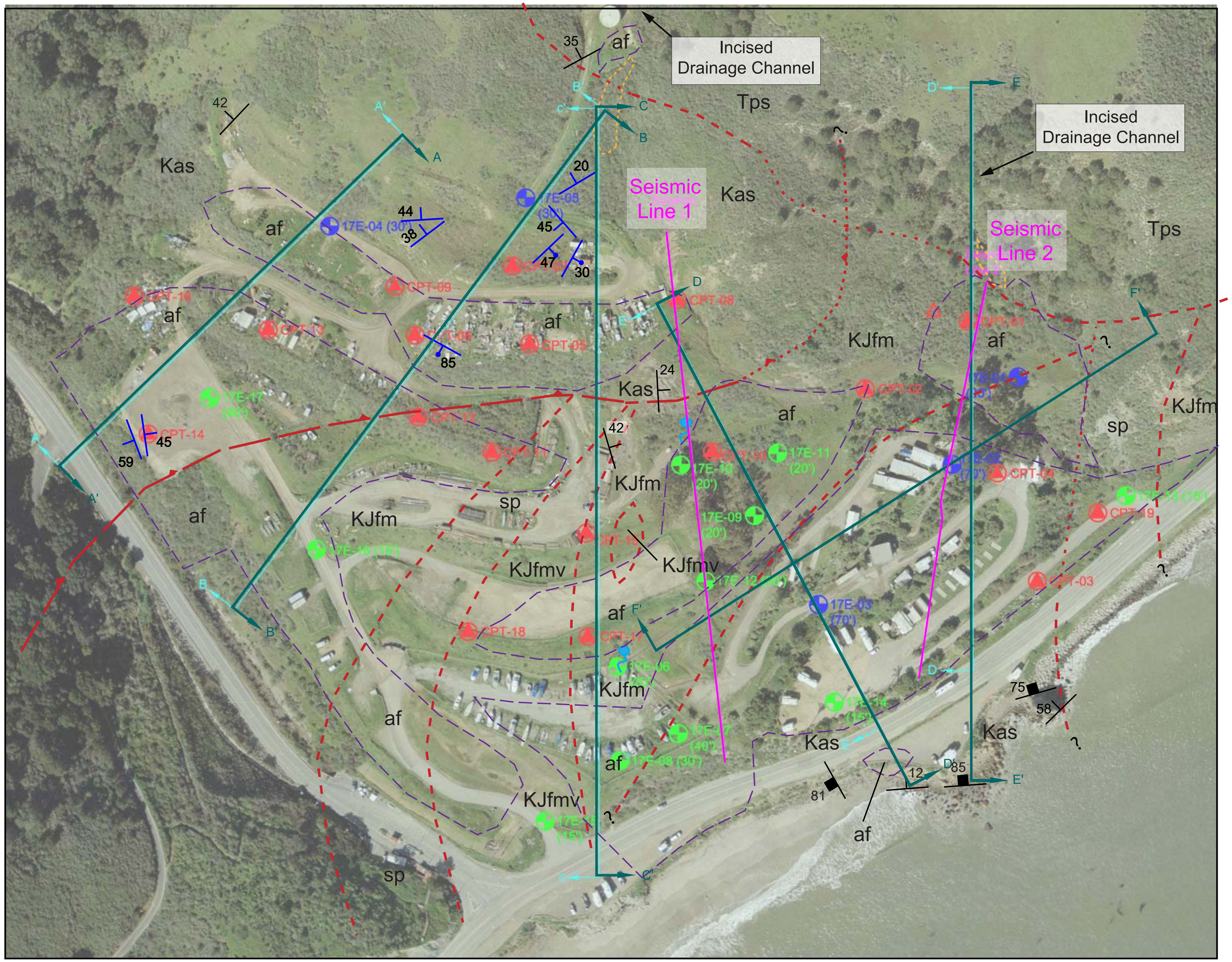
Mark G. Olson, PGp, PG, CHG
Principal Geologist and Geophysicist

List of Attachments:

Figure 1- Site Map Showing Locations of Lines 1 and 2
Figure 2- Line 1 Seismic Refraction Velocity and Reflection Time Profiles
Figure 3- Line 1 Seismic Refraction Velocity and Reflection Depth Profiles
Figure 4- Line 2 Seismic Refraction Velocity and Reflection Time Profiles
Figure 5- Line 2 Seismic Refraction Velocity and Reflection Depth Profiles



LEGEND:

Approximate Fill (af) Limits

Approximate Debris Flow Deposit Limits

Contact Between Bedrock Units, based on Hall (1979); dashed where approximately located or inferred; dotted where concealed

Tps - Pismo Formation Squire member (Tertiary age)
Kas - Atascadero Formation (Cretaceous age; named Unnamed Sedimentary Rocks by Hall, 1979)
Franciscan Complex (Cretaceous to Jurassic age)
KJfm - Melange
KJfmv - Metavolcanic Rocks
sp - Serpentinite (Cretaceous to Jurassic age)

Approximate Pre-Tertiary age Thrust or Reverse Fault Mapped by Hall (1973, 1979); dashed where approximately located or inferred; dotted where concealed and inferred; queried where concealed or doubtful; sawteeth on upper block

58 Strike and Dip of Bedding Plane (this study)

81 Strike and Dip of Bedrock Discontinuity (this study)

21 FBL (1971) Strike and Dip of Bedding

30 FBL (1971) Strike and Dip of Fault Plane

Spring Observed in July 2017

F F' Cross Sections

North

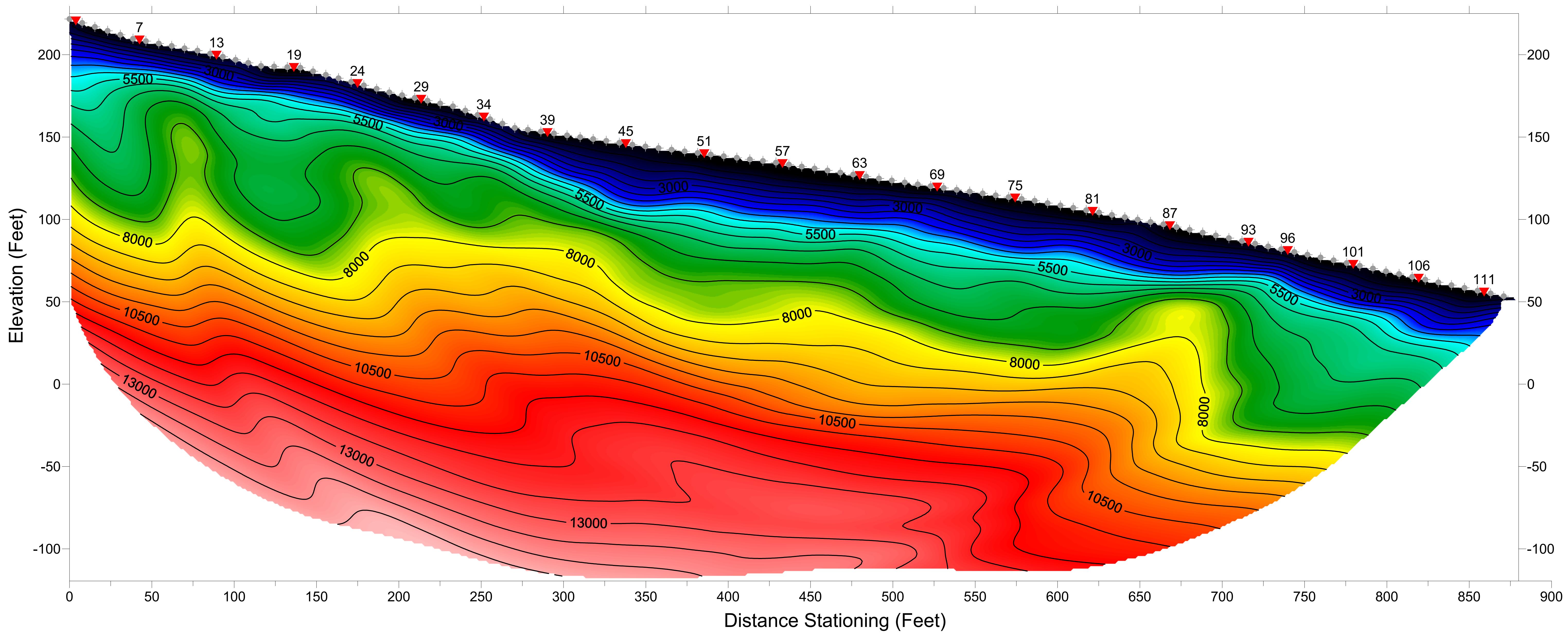
0 200 feet

Site Map Showing Geologic Mapping and Locations of Seismic Lines 1 and 2	
Harbor Terrace Development Project	
Avila Beach Drive Avila Beach, California	Figure 1

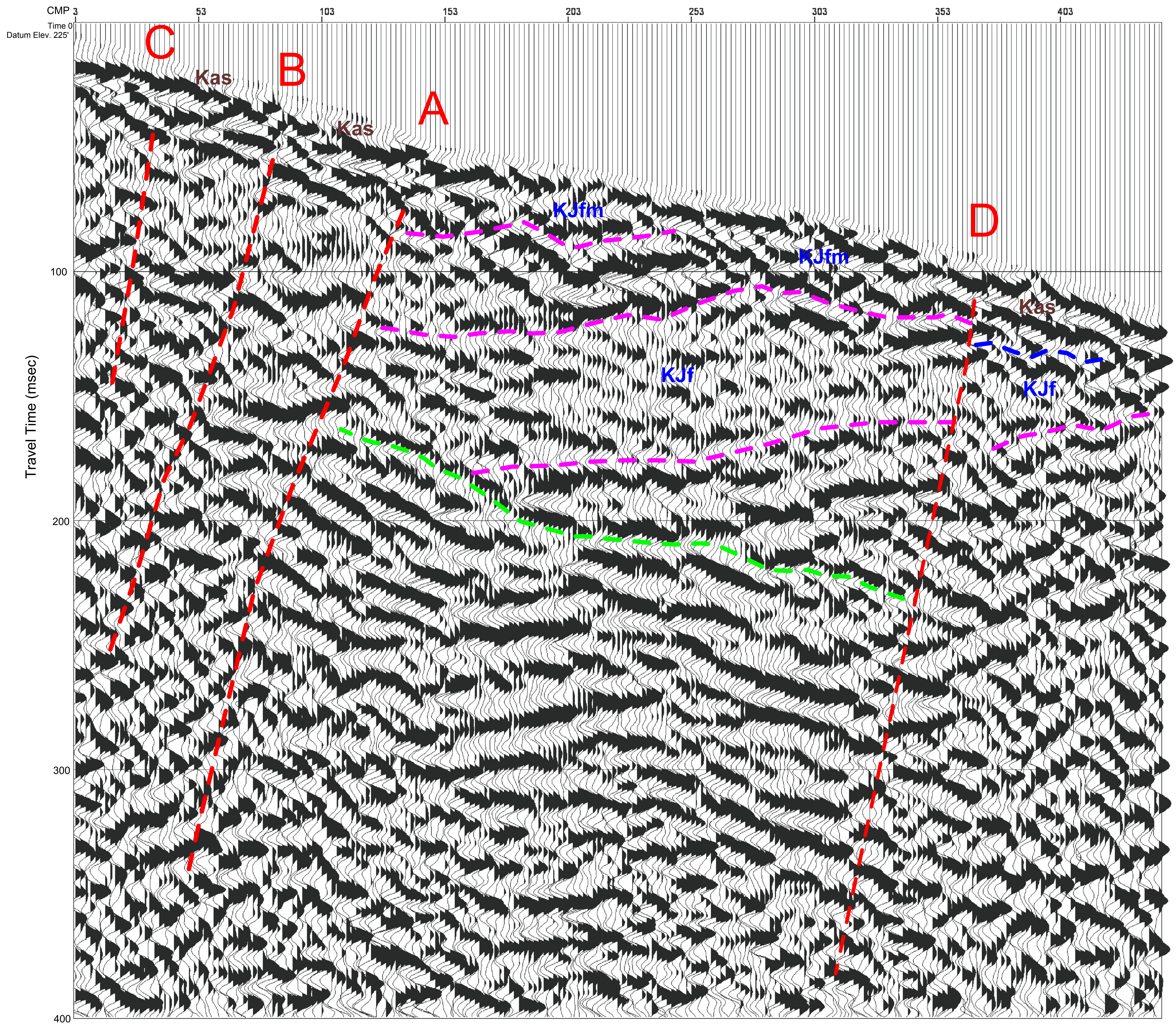
North

South

Line 1- Seismic Refraction Velocity Depth Profile



Line 1- Seismic Reflection Time Profile



Explanation of Geologic Interpretation:

- Major Bedrock Fault Planes Orientations Interpreted
- Upper Surface of Franciscan Formation (KJf)
- Lithologic Contacts within Franciscan Formation
- Deeper Unconformity Surface within Franciscan Formation
- **Kas** Cretaceous Atascadero Formation
- **KJfm** Franciscan Formation Melange

Seismic Refraction Velocity Based on RAYFRACT Seismic Refraction Tomography
Seismic Compressional-Wave Velocity Contour Interval 500 ft/sec
Horizontal and Vertical Scale 1 inch= 60 feet

Seismic Reflection Based on Visual_SUNT Processing
Horizontal Scale 1 inch= 60 Feet Vertical Time Scale 400 msec

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Figure 2
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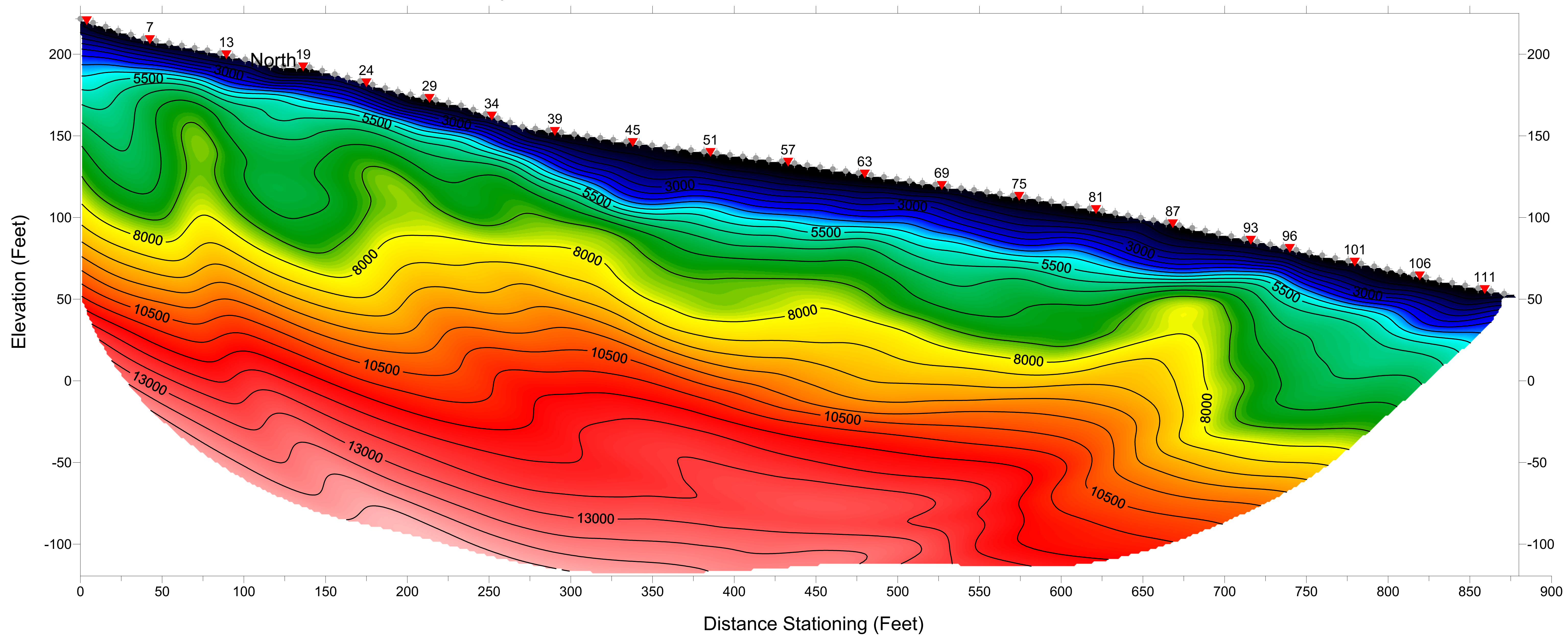
North South

Line 1- Seismic Refraction Velocity Depth Profile



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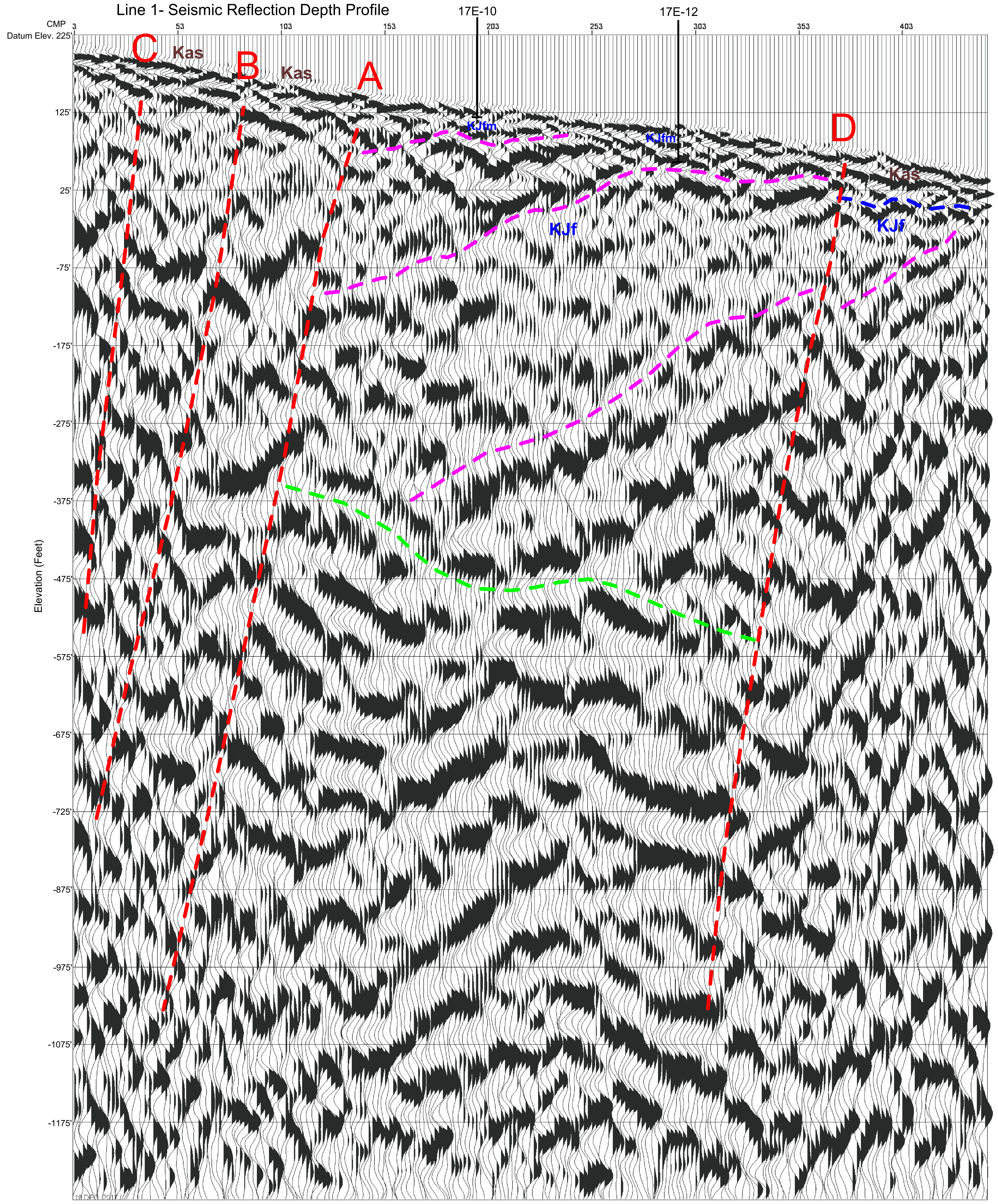

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Figure 3
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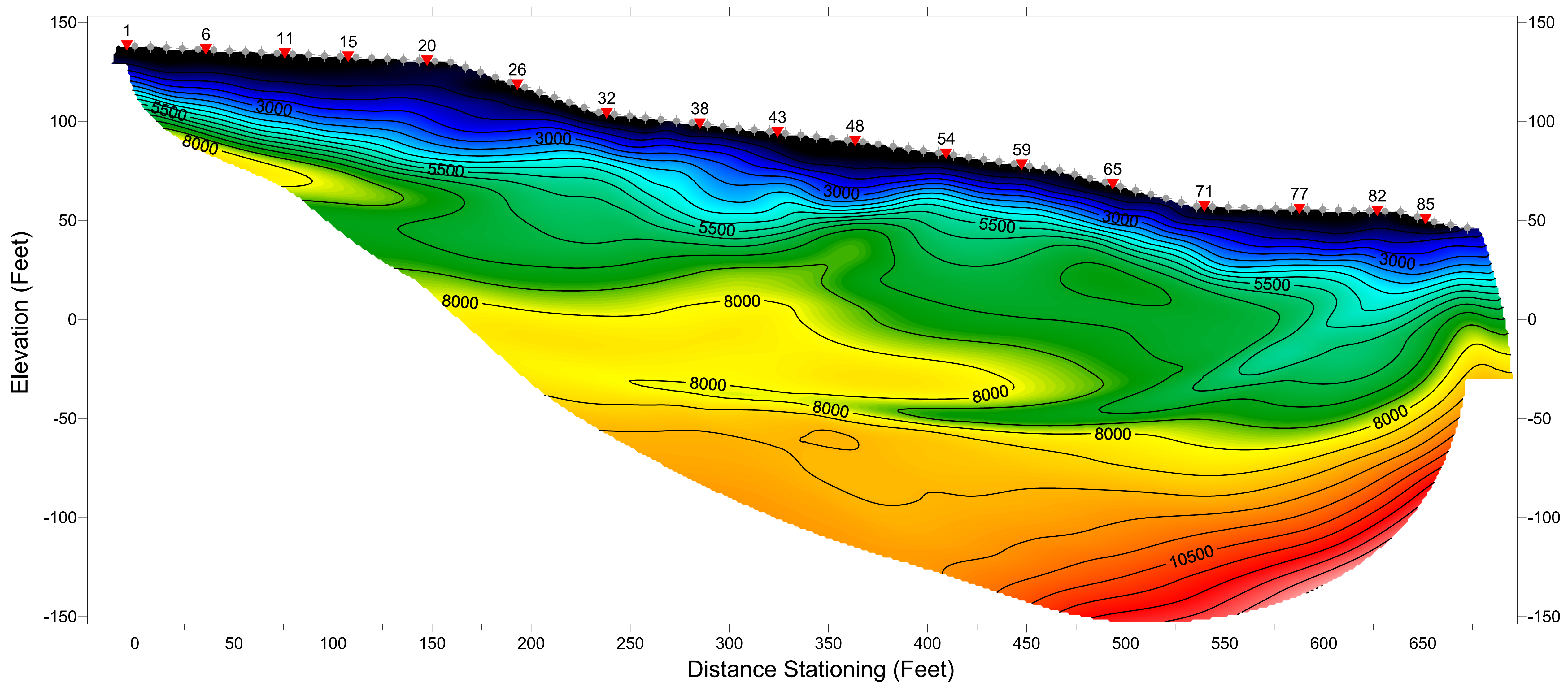
North

South

Line 2- Seismic Refraction Velocity Depth Profile



Line 2- Seismic Reflection Time Profile

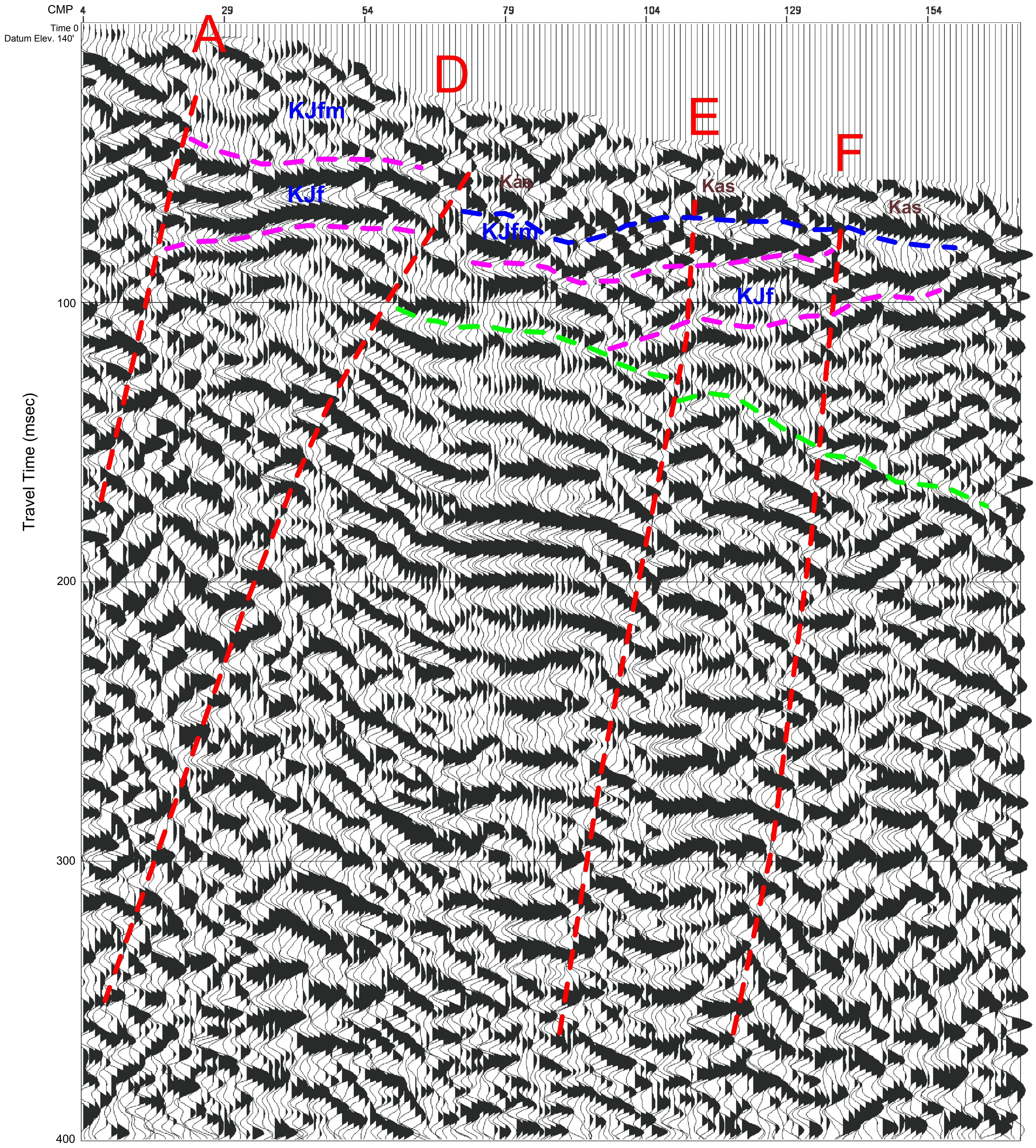


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Figure 4
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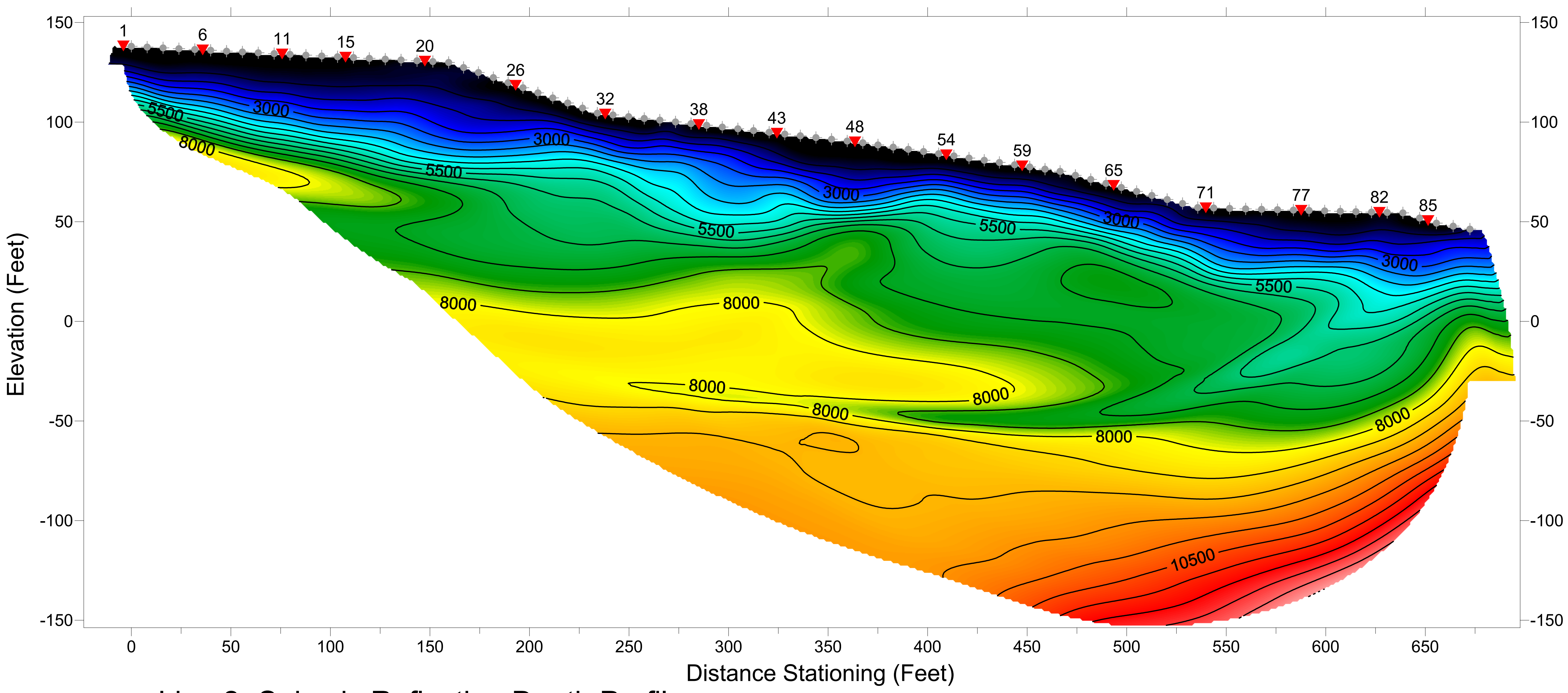
North

South

Line 2- Seismic Refraction Velocity Depth Profile



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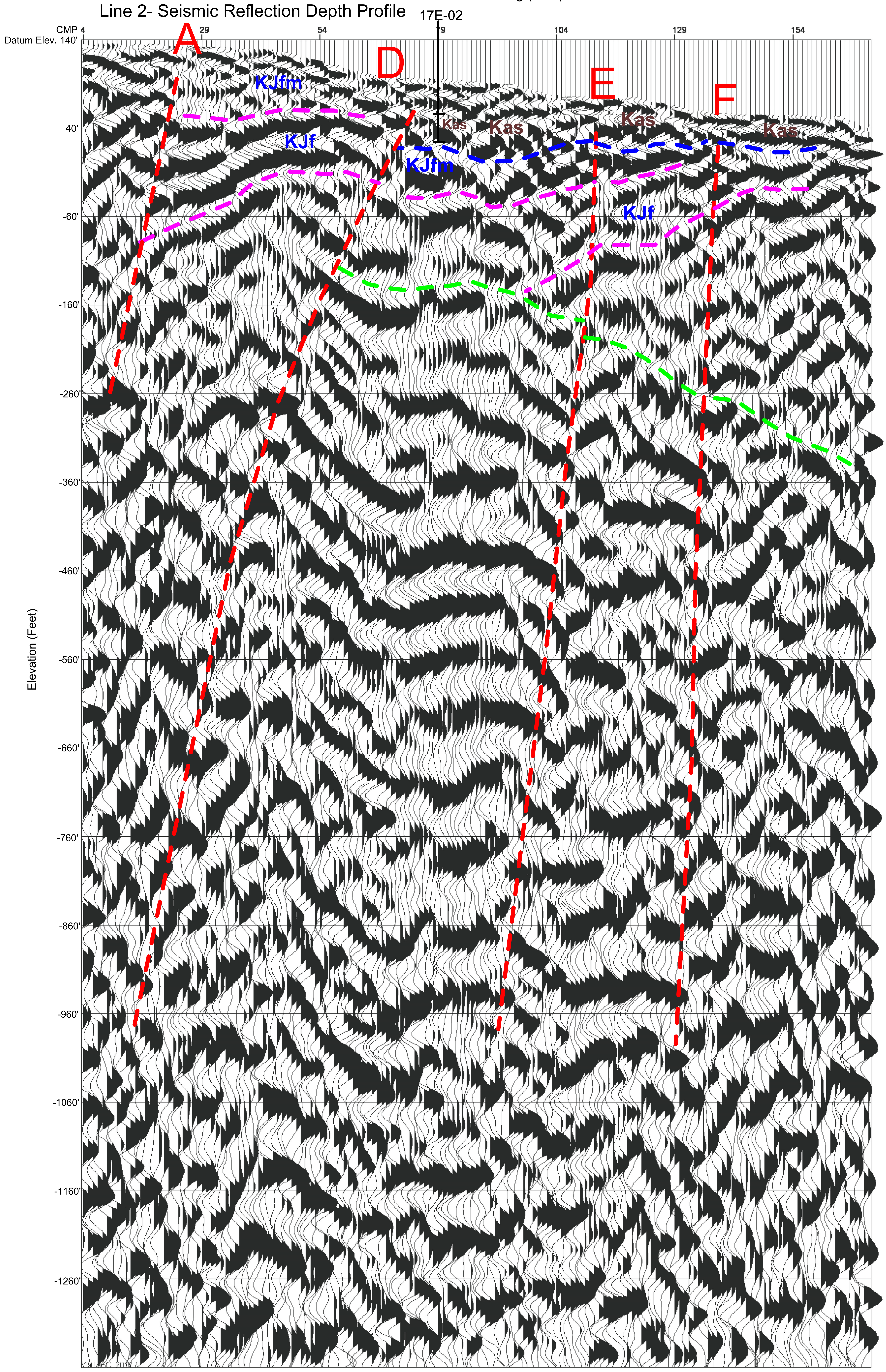

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Figure 5
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