R E P O R T

Geophysical survey of the test area of artificial water reservoirs, designed for artificial snowmaking systems in Bakuriani and Gudauri town.

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Contents

1. Research Objective

The report presents geophysical survey results of the test area of artificial water reservoirs, designed for artificial snowmaking systems in Bakuriani and Gudauri.

2. Introduction

2.1. Seismic Prospecting

Study of local physical properties of soils is one of the important tasks of engineering- geological investigations. Wide variety of field and laboratory techniques is available, each with different advantages and limitations with respect to different problems. The selection of testing techniques for measurement of dynamic soil properties requires careful consideration and understanding of the specific problem at hand. Efforts should always be made to use tests or test procedures that replicate the initial stress conditions and the anticipated cycling loading conditions as closely as possible (Kramer 1996).

Field tests allow the properties of the soil to be measured in situ (i.e., in their existing state where complex effects of existing stress, chemical, thermal, and structural conditions are reflected in the measured properties). The measurements of dynamic soil properties by field tests have a number of advantages. Field tests do not require sampling, which can alter the stress, chemical, thermal and structural conditions in soil specimens. Many field tests measure the response of relatively large volumes of soil, thereby minimizing the potential for basing property evaluation upon small, unrepresentative specimens. Many field tests induce soil deformations that are similar to those of problem of interest, particularly for wave propagation.

Our main task was to study of soil structure for study area end assessment of physical-mechanical properties for the identified layers. We have used seismic prospecting methods to assess elastic wave's velocity distribution pattern in the constructed profiles. Shear and Body wave velocities are strongly related to physical-mechanical conditions of soils. Sharp changes in elastic wave's velocities, forms so cold refraction surfaces and well distinguishes major soil layers.

The seismic refraction test allows the wave propagation velocity and thickness of surface layers to be determined from the ground surface. The test involves measurement of the travel times of P and S waves from an impulse source to a linear array points along the ground surface at different distances from the source.

2.2. Electric Resistivity Test

Electric Resistivity Test measures the resistance of the soil to electricity by passing a current through the soil. The purpose of electrical surveys is to determine the subsurface resistivity distribution by making measurements on the ground surface. From these measurements, the true resistivity of the subsurface can be estimated, though more frequently so called apparent resistivity values are used. The ground resistivity is related to various geological parameters such as the mineral and fluid content, porosity and degree of water saturation in the rock.

DC-resistivity methods measure the electrical-resistivity distribution of the subsurface. DC or low-frequency alternating electric current is transmitted into the ground by two electrodes, and the potential difference is measured between a second pair of electrodes. The apparent resistivity of the subsurface is calculated by using Ohm's Law and applying a geometric correction (Telford and others, 1990). The geometrically corrected measurements are apparent resistivities rather than true resistivities, because a resistively homogeneous subsurface is assumed. Subsurface resistivity values are controlled by material resistivity, lithology, and the presence, quality, and quantity of ground water (Haeni and others, 1993). The maximum penetration depth of the resistivity measurement is directly proportional to the electrode spacing and inversely proportional to the subsurface conductivity (Edwards, 1977).

Profiling with 2D dc-resistivity methods is conducted by making measurements along a surface profile using different offsets. The 2D dc-resistivity profiling data are inverted to create a model of resistivity along a section of the subsurface.

3. Equipment and methodology used

Study was done using refracted waves method, at different linear profiles. 46m long profiles were used, with 2 m step between the geophones. Constructed profiles were used to separate different Engineering Geological Layers (EGL) based on different velocities of elastic wave propagation and calculated the physical-mechanical parameters of soils. For this purposes 46m long profiles were used, with vertical and horizontal components of Geophones, to be able detecting body-P waves.

For the registration and processing of longitudinal and shear waves, so called Z-Z and Y-Y blow – registration system was used. Seismic waves were generated using 10 kg hammer hit on the 15 mm thick titanium plate. Relatively large dimensions of the plate enable better transformation of blow energy to elastic vibration energy of rock or soil. S waves were generated using the same hammer hit in horizontal direction – on the wall of 50 cm deep pit.

Typical 5 hit system was used, 2 hits at the beginning and end of the profile, 1 hit at the center point and 2 remote hits. For the recording of seismic waves 24 channel digital engineering seismograph OYO McSeis SX was used, with 10 and 100 Hz geophones (Horizontal as well as vertical components were used).

Allied Tigre 64ch resistivity meter was used, capable to make accurate electrical measurements in the most extreme environments, with following parameters:

- Penetration depths of 700 meters.
- Choice of current settings from 0.5mA to 200mA, with automatic gain steps
- Measurements to be made between 400 Kohm and 0.001 ohm.
- Three square wave frequencies
- Choice of up to 16 cycles per measurement.
- Self-potential monitoring.

Wenner-Schlumberger array was used. The sensitivity plot for the Wenner Alpha array has almost horizontal contours beneath the center of the array. Because of this property, it is relatively sensitive to vertical changes in the subsurface resistivity below the center of the array. However, it is less sensitive to horizontal changes in the subsurface resistivity. In general, the Wenner-Schlumberger array is good in resolving vertical changes (i.e. horizontal structures), but relatively poor in detecting horizontal changes (i.e. narrow vertical structures). Among the common arrays, it has the strongest signal strength. This can be an important factor if the survey is carried in areas with high background noise. ImagerPro 2006 - Windows based acquisition software package was sued. Later for processing and analysis it was also used in conjunction with other processing software such as RES2DINV.

4. Data processing and Interpretation

Seismic data was processed using **WinSysm**(http://www.wgeosoft.ch/software/default2.html). Mainly the ABC method was applied for the interpretation of seismic records. This method, incorporated in WinSism software, allows controlling every stage of data processing and introducing necessary corrections, thus avoiding accidental artifacts and misinterpretation. In other words, ABS method is somehow smoothing the real situation along the profile but well preserves the overall parameters and soil structure. In rare cases GRM and SHP methods were used, due to the limitations in ABS method (in case of high dipping angle of refraction surface), though the resulted profiles were carefully cross-checked and revised.

Compression P waves were picked up mainly according to the first arrivals on the vertical Z-Z component of seismograms for profiles. These waves usually have low amplitudes on horizontal component Y-Y they and attenuate rapidly. So far, their presence on the horizontal components does not affect registration of S wave onsets.

5. Quality Control Procedures

Initial phase of quality control involved assuring the tight fixation of geophones in soil and good electric contacts with strings. Before starting recording reflected waves, usually several test shoots were compiled to ensure reasonable transmission of seismic wave's energy to geophones and their proper functioning.

The main criteria for the quality control of field data (seismograms) are resolution of informative signal. While acquiring the data it was checked that the first onsets should be readable at the beginning, end and middle traces of the record. This criterion was satisfied by increasing the staking number and selecting the adequate source of seismic waves (Hammer or Dropping weight). In any case it was secured, that still the overall wave-front could be readable on the profile and missing onsets could be extended from other channels, taking in to account phase correction. In such cases changes in frequency content due to changes in source to receiver distances were also considered. In case of the remote hits the visibility of first onsets of seismic waves was not the main criteria, as tracing a single phase of the wave through the channels was enough, the same time it was controlled that the informative phase should not be overlaid by other waves.

6 Study and Obtained Results

6.1. Study area of Gudauri town.

Geophysycal survey has been carried using seismic and electric profiling method at Gudauri artificial water reservoir test area.

20 seismic and 6 electrical profiles were made over the study area (see Appendix 1. Schematic map of the line up profiles) (Profile cross-sections See Appendix 2). Based on primary (P wave) wave velocity values from Seimic profiles and preliminary results of the geotechnical studies (LTD "Gvirgvini") with some uncercnities the layers observed on the seismic cross-sections have been identified. We introduced several layers with different physical properties, which are conditionaly considered as engineer – geological elements of different P- wave velocities. Our Investigation at depth showed, that each three layers differ from each other by andesite basalt rock dimensions and concentration.

Our conclusions are based on low velocity values obtained by geophysical studies.Those values are generally less characteristic of basalts, but nevertheless, it is possible that the third layer is represented by a volcanic basalt layers with high permiability and a high degree of weathering. Therefore we may introduce following 3 geotechnical elemets:

EGE 1 – loamy brown plantroots, with small gravel content and moraine gravels andesite basalts and sediments of different-sized pieces of small concentration;

EGE 2 - Andesite basalts moraine sediments are elevated concentrations of different-sized pieces;

EGE 3 – This layer may correspond to the layers of volcanic basalt and high porosity with high degree of weathering or moraine layer and esitebasalts and sediments of the high concentration of different-sized pieces;

Seismic profiles along the longitudinal slot EGE 1 marked 2-7m depth of a wave velocity mainly Vp = 400-800 m /s by-frame, this velocity's relatively low values is observed at profiles # 5, 10, 11 and 12. The bottom layer is norelief characterized.

This layer is bounded by the EGE 2, with the thikness ranges from 5-40 meters, and the velocity Vp = 1000-1300 m / s, this layer is often the velocity of differentiation for each profile within the base relief is crucial to the assumption that the layers apart boulders measures and concentration.

The layers below 3 fixed velocity EGE Vp = 1300-1700 m / s.

Snow cover and frozen powerful electric profiles handling complicated surface layer of the study area. Because some of the high profile of the fixed margin of error - 8.8%.

The top layer is mostly prevalent among sections of the electrical profiles 5-8m. Power and resistance in the range of 6000 - 15000 ohm / m, which is in good agreement with seismic sections of the EGE-1. Here, too, is observed with less relief from bottom (the second layer of the border).

This layer is bounded by a bottom layer 400 - 6000 ohm / m, this layer as well as resistance to seismic sections marked differentiation. Penetration depth of electric profiles is max. 30m, so the most of the profiles has a lack of EGE3 location boundary. And the profiles where this boundary is visible, sharp relief of the basement is also observed.

Coordinates of Seismic and Electric Resistivity profiles are provided below.

Table 1.
Profile Coordinates. Projection - UTM Zone 38(WGS 84 Datum)

Seismic Profiles

NN	1geophone (X, Y)		24geophone (X, Y)	
1	458186.97	4704399.67	458296.76	4704433.88
2	458267.96	4704364.19	458245.04	4704476.88
3	458312.47	4704461.19	458248.64	4704556.85
4	458232.04	4704477.10	458327.79	4704540.80
5	458336.80	4704557.03	458274.71	4704653.83
6	458259.44	4704571.44	458354.97	4704635.47
7	458189.80	4704473.35	458224.21	4704583.08
8	458197.13	4704533.01	458087.60	4704568.04
9	458128.01	4704500.54	458158.60	4704611.39
10	458056.31	4704511.58	458087.80	4704622.18
11	458030.94	4704449.50	457957.80	4704538.24
12	457945.79	4704483.11	458056.25	4704515.11
13	458025.62	4704420.66	458129.85	4704469.27
14	458103.88	4704392.72	458059.91	4704498.98
15	458042.10	4704533.29	457977.35	4704628.34
16	458071.66	4704594.56	457959.41	4704569.56
17	458072.32	4704616.54	457992.16	4704699.00
18	457977.68	4704633.61	458075.90	4704693.43
19	458203.60	4704619.78	458117.65	4704696.18
20	458179.53	4704699.66	458113.96	4704605.18

Electric Resistivity Profiles

NN	start (X, Y)		end (X, Y)	
1	458116.55	4704565.67	458411.15	4704622.33
2	457834.52	4704503.96	458129.13	4704560.62
3	458248.38	4704488.22	457987.46	4704636.28
4	458074.28	4704444.16	458359.25	4704537.94
5	458153.85	4704432.48	457949.71	4704652.32
6	457980.60	4704725.53	458195.33	4704516.03

6.2. Study area of Bakuriani town.

Geophysycal survey has been carried using seismic and electric profiling method at Bakuriani artificial water reservoir area.

10 seismic and 5 electrical profiles were made over the study area (see Appendix 1. Schematic map of the line up profiles) (Profile cross-sections See Appendix 2).

Based on primary (P wave) wave velocity values from Seimic profiles and preliminary results of the geotechnical studies (LTD "Gvirgvini") with some uncercnities the layers observed on the seismic cross-sections have been identified. We introduced several layers with different physical properties, which are conditionaly considered as engineer – geological elements of different P- wave velocities:

EGE 1 – soil and sand;

EGE 2 – sand with sandy gravels;

EGE 3 – clay with boulders.

Seismic profiles along the longitudinal slot EGE 1 marked 3-10m depth of a wave velocity mainly Vp = 400-700 m/s by-frame, this velocity's relatively low values is observed at profiles # 4, 6 and 9. The bottom layer is norelief characterized.

This layer is bounded by the EGE 2, with the thickness ranges from 5-30 meters, and the velocity Vp = 1000-2000 m / s, this layer is often the velocity of differentiation for each profile. Base limit of the layer has relief.

The layer below is EGE 3 fixed velocityVp = 2500-2800 m / s.

The top layer is mostly prevalent among sections of the electrical profiles 5-10m. Power and resistance in the range of 150 - 450ohm / m, which is in good agreement with seismic sections of the EGE-1.

This layer is bounded by a bottom layer 50 – 150 ohm / m, this layer as well as resistance of seismic sections marked differentiation. Penetration depth of electric profiles is max. 20m, so the most of the profiles has a lack of EGE3 location boundary. And the profiles where this boundary is visible, sharp relief of the basement is also observed.

Coordinates of Seismic and Electric Resistivity profiles are providedbelow.

Table 1.
Profile Coordinates. Projection - UTM Zone 38(WGS 84 Datum)

Seismic Profiles

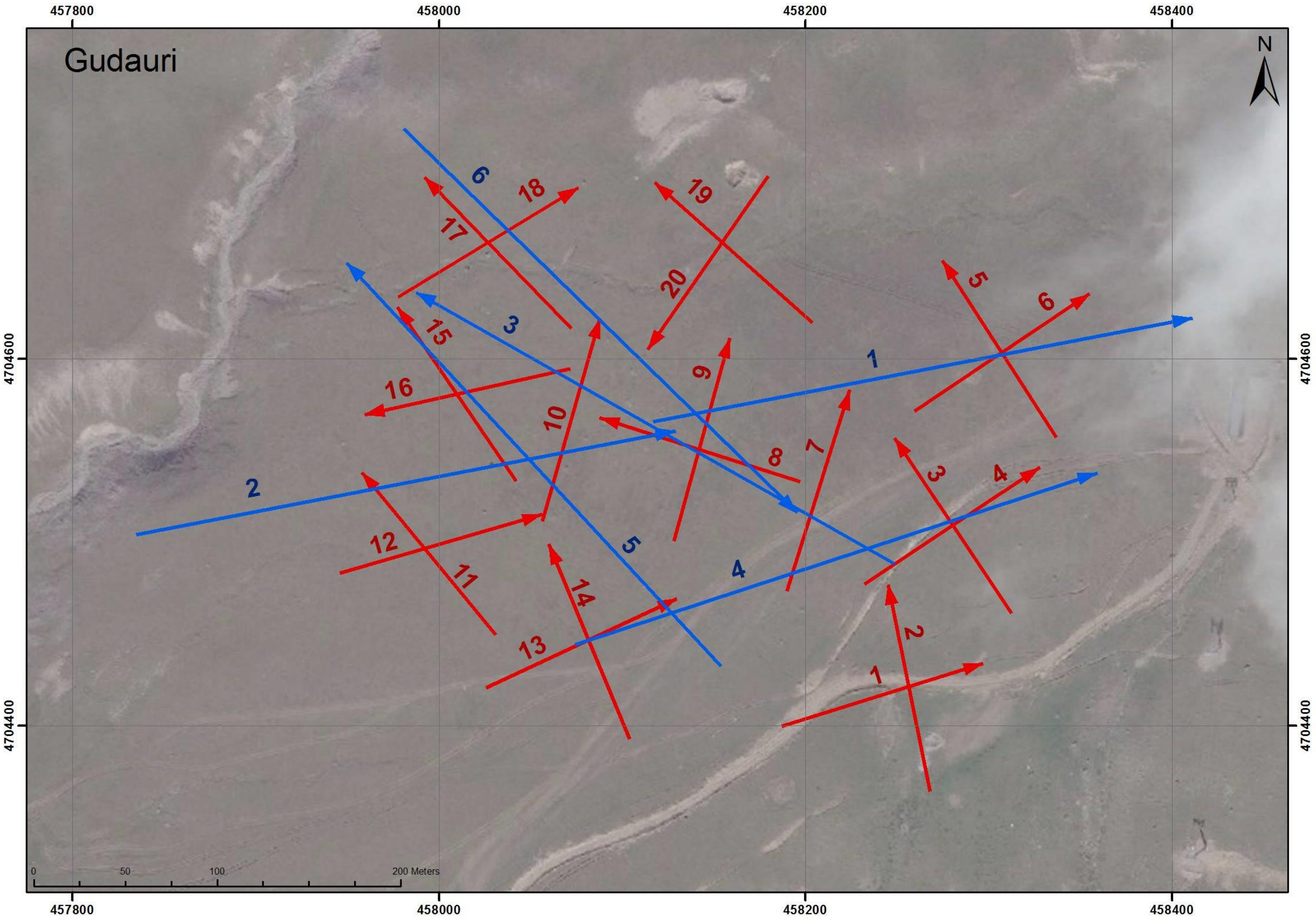
NN	1geophone (X, Y)		24geophone (X, Y)	
1	377637.53	4618250.69	377523.41	4618236.52
2	377584.81	4618192.85	377579.51	4618307.73
3	377560.51	4618311.76	377675.27	4618319.16
4	377636.41	4618260.47	377670.09	4618370.43
5	377555.41	4618206.42	377494.42	4618303.91
6	377469.19	4618237.04	377569.99	4618292.40
7	377490.79	4618309.68	377551.06	4618407.62
8	377521.36	4618382.52	377635.24	4618398.53
9	377558.68	4618323.53	377666.70	4618362.97
10	377596.71	4618226.77	377615.62	4618340.21

Electric Resistivity Profiles

NN	start (X, Y)		end (X, Y)	
1	377635.62	4618385.79	377605.47	4618233.75
2	377586.88	4618356.38	377590.20	4618201.41
3	377729.86	4618330.92	377586.05	4618273.10
4	377627.46	4618297.43	377472.53	4618292.87
5	377646.08	4618409.82	377501.40	4618354.21

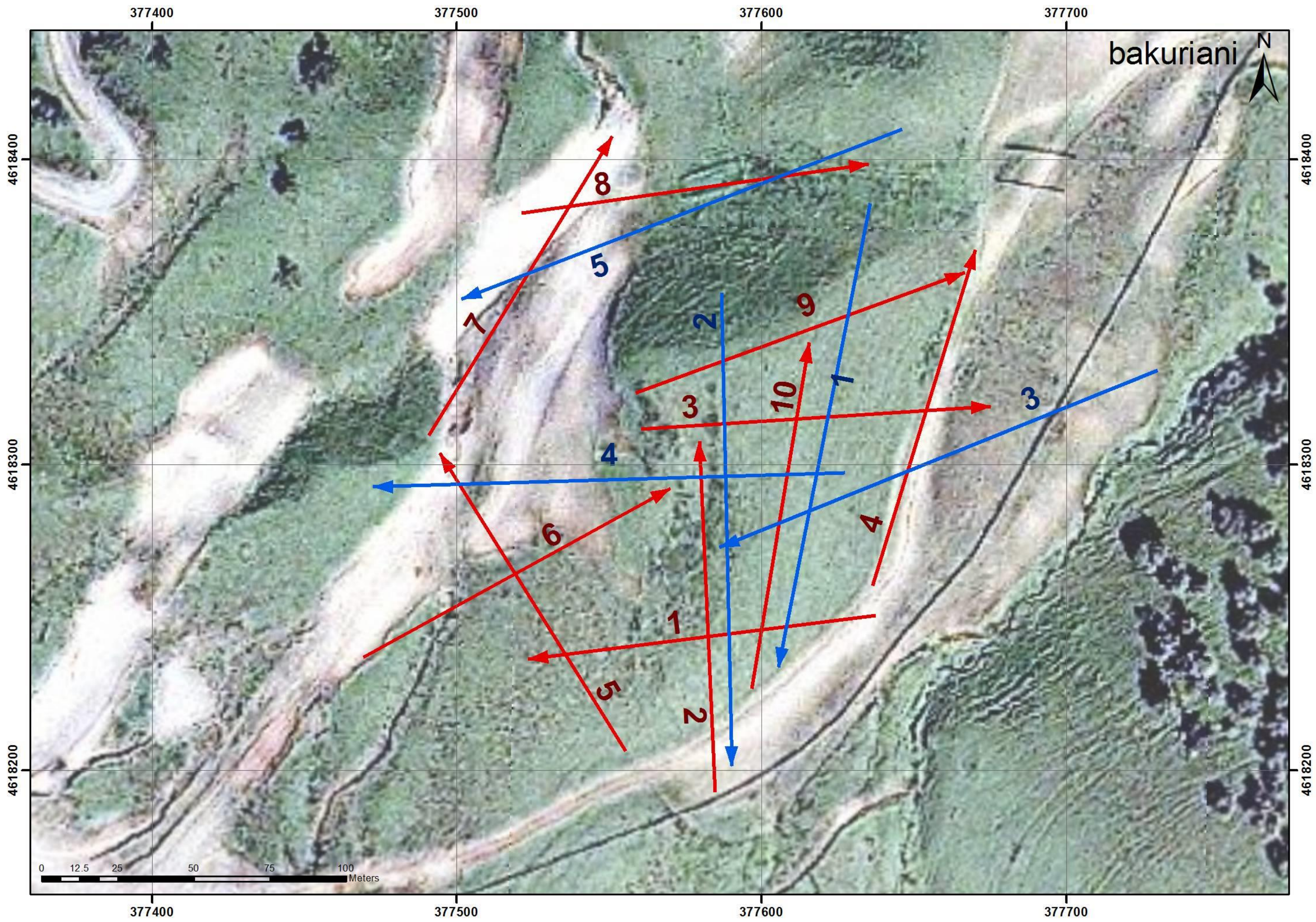
Appendix 1. Schematic map of study area

Gudauri



Locations of Seismic (red) profiles, electrical (black) profiles on the study area.

Bakuriani "Didveli"

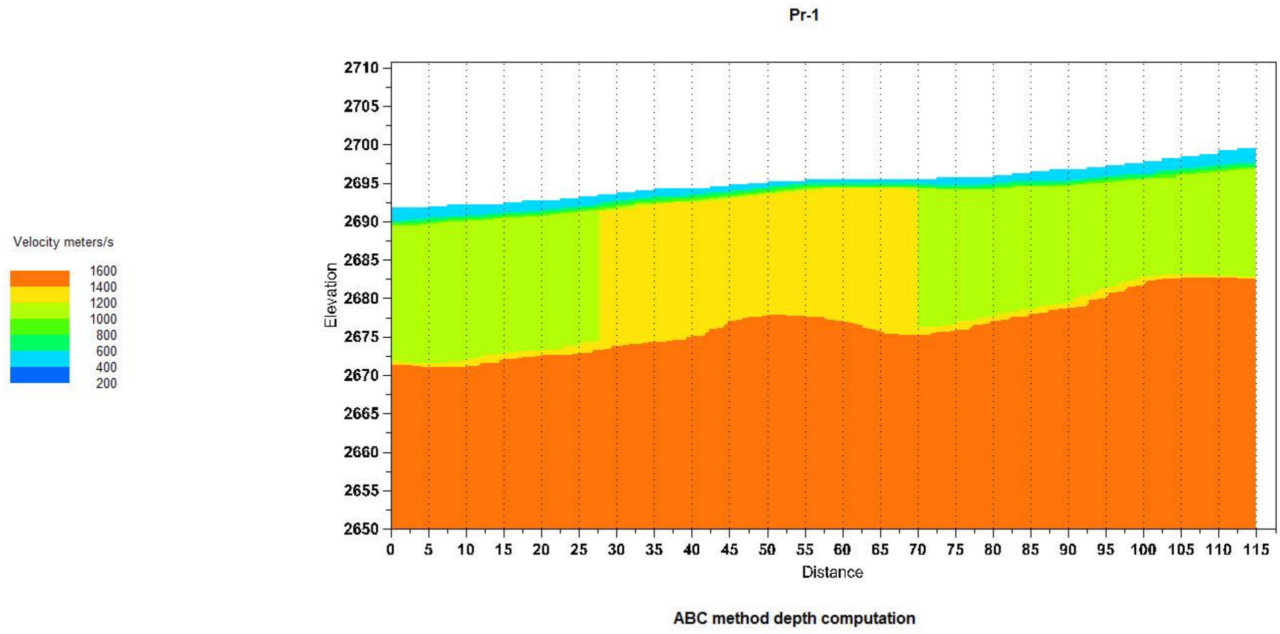


Locations of Seismic (red) profiles,electrical (black) profiles on the study area.

Appendix 2. Seismic refraction profiles

Colors correspond to P-wave velocities

Profile #1



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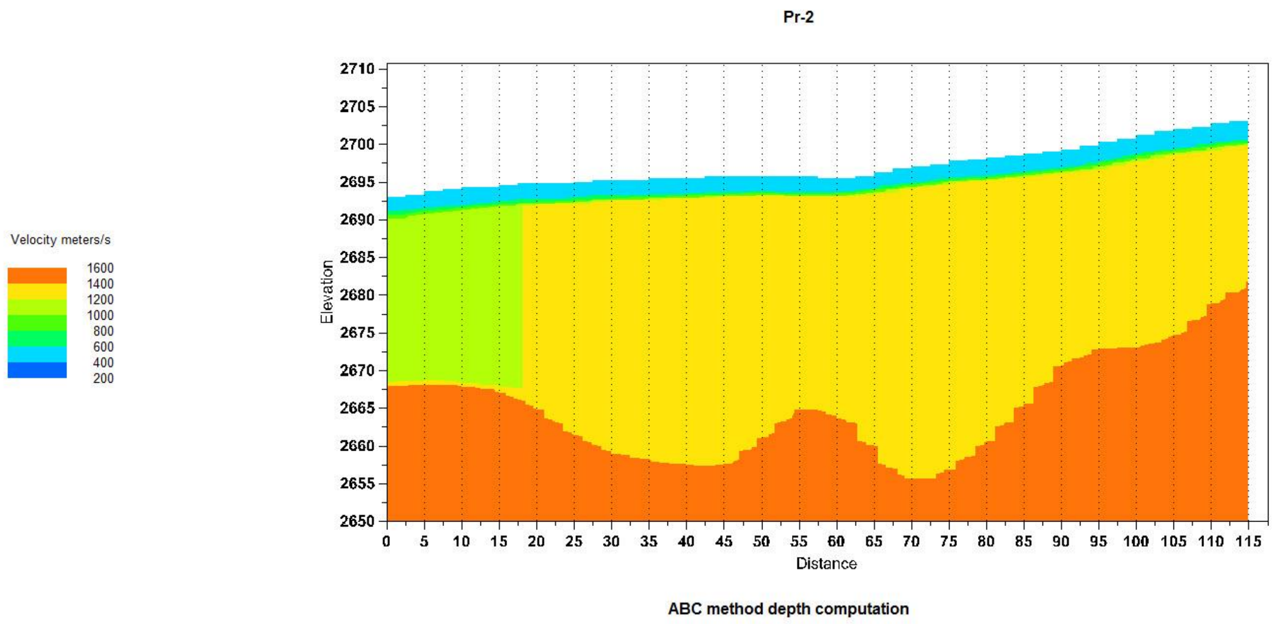
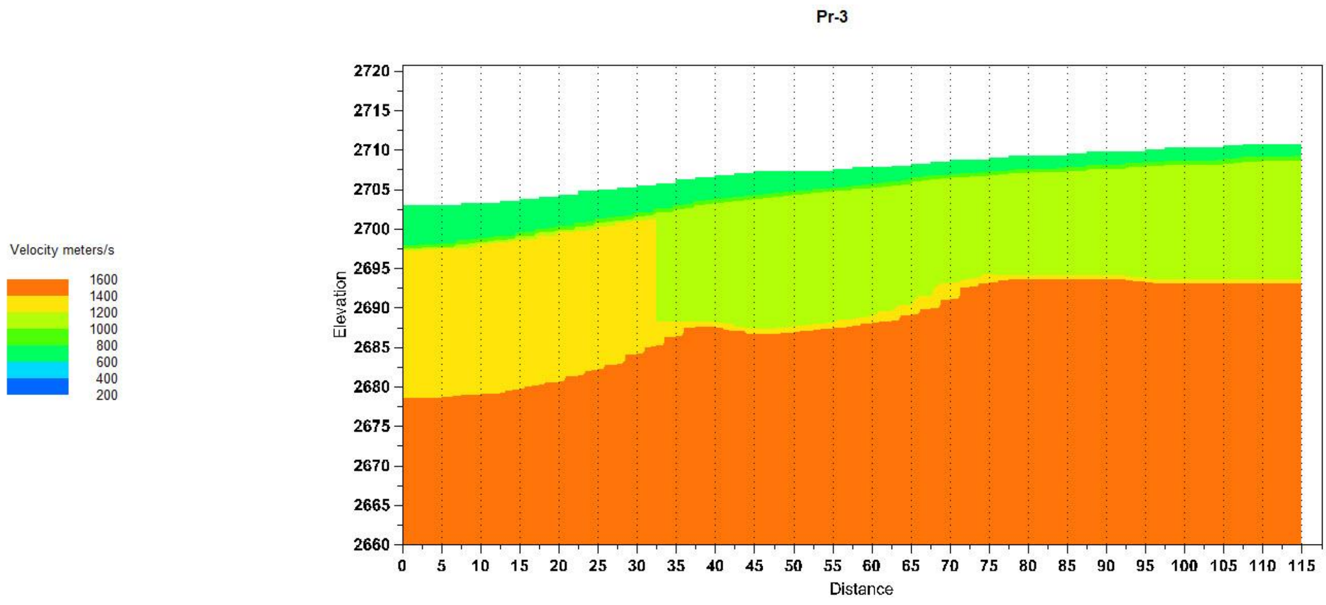
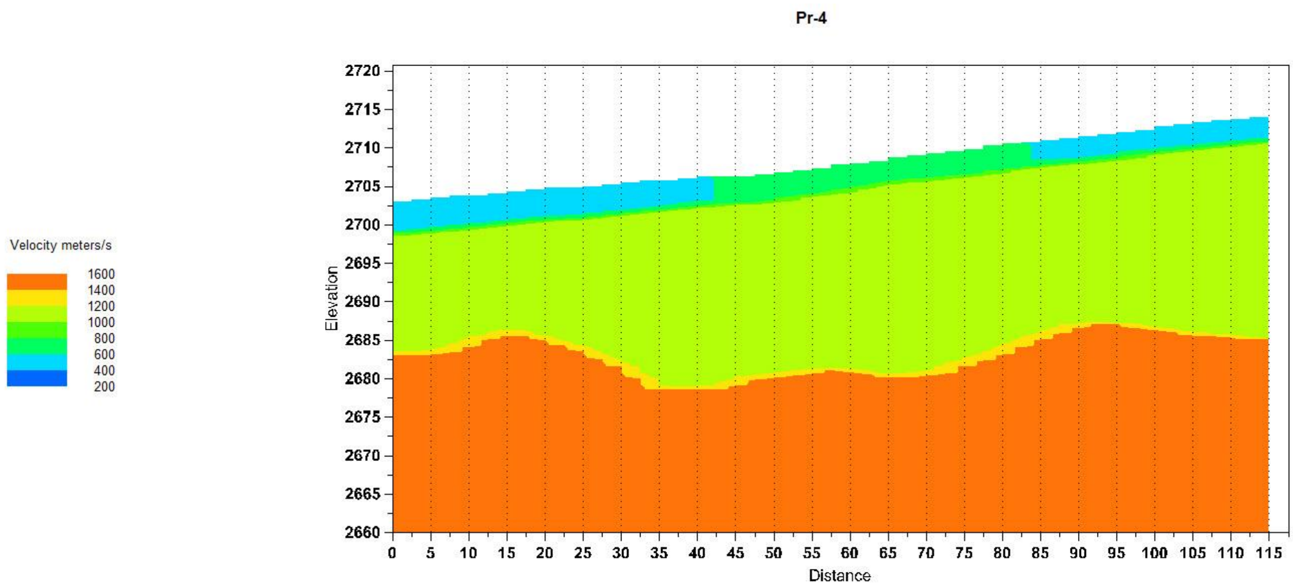


Profile #3



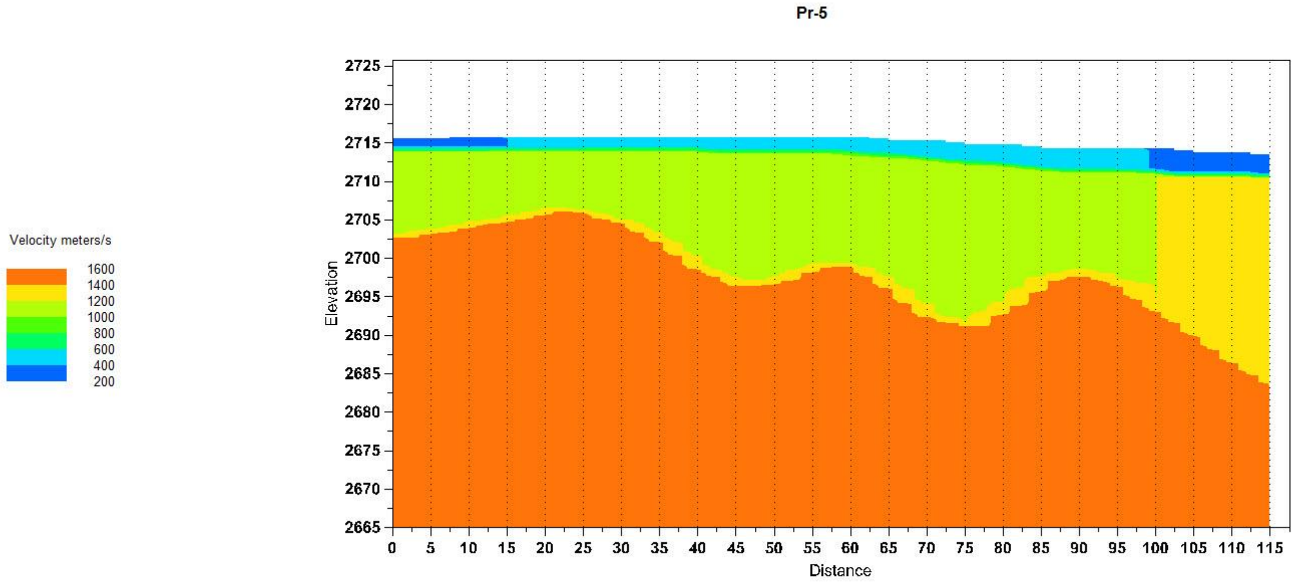
ABC method depth computation

Profile #4



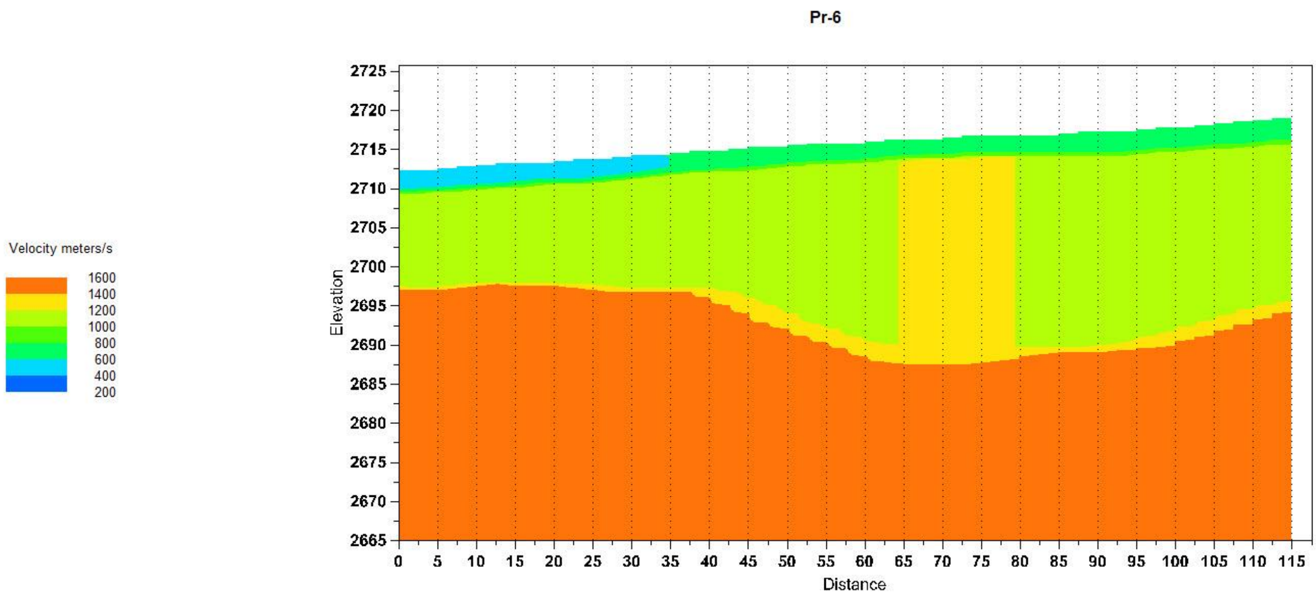
ABC method depth computation

Profile #5



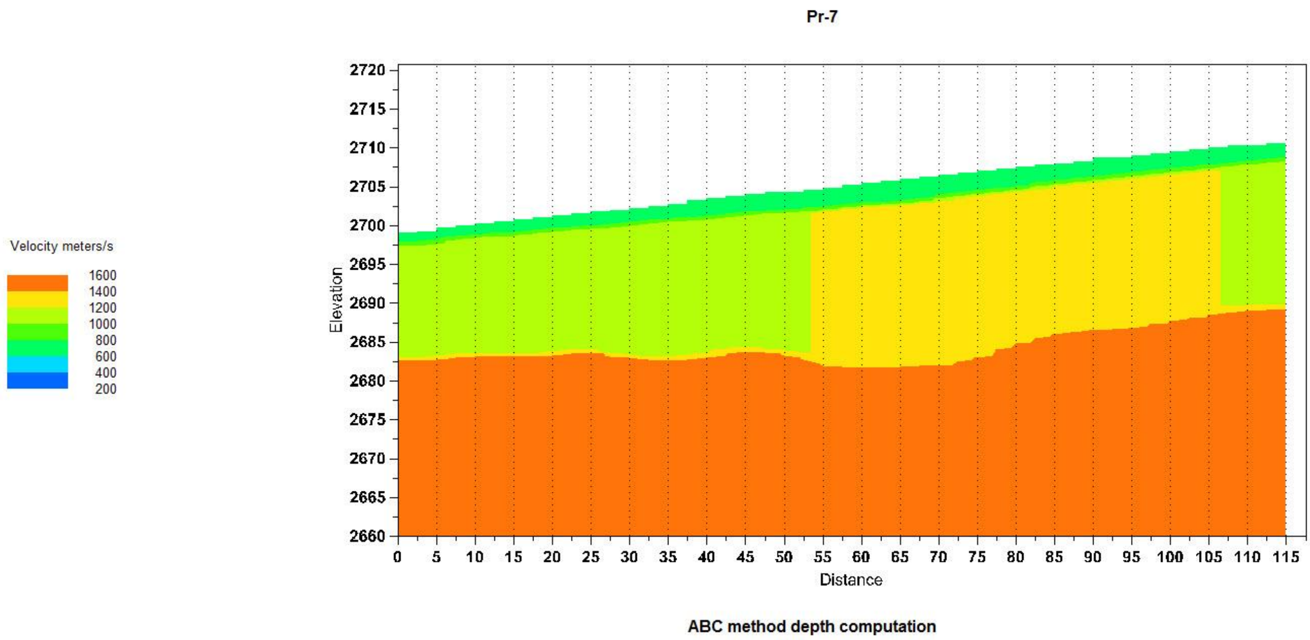
ABC method depth computation

Profile #6

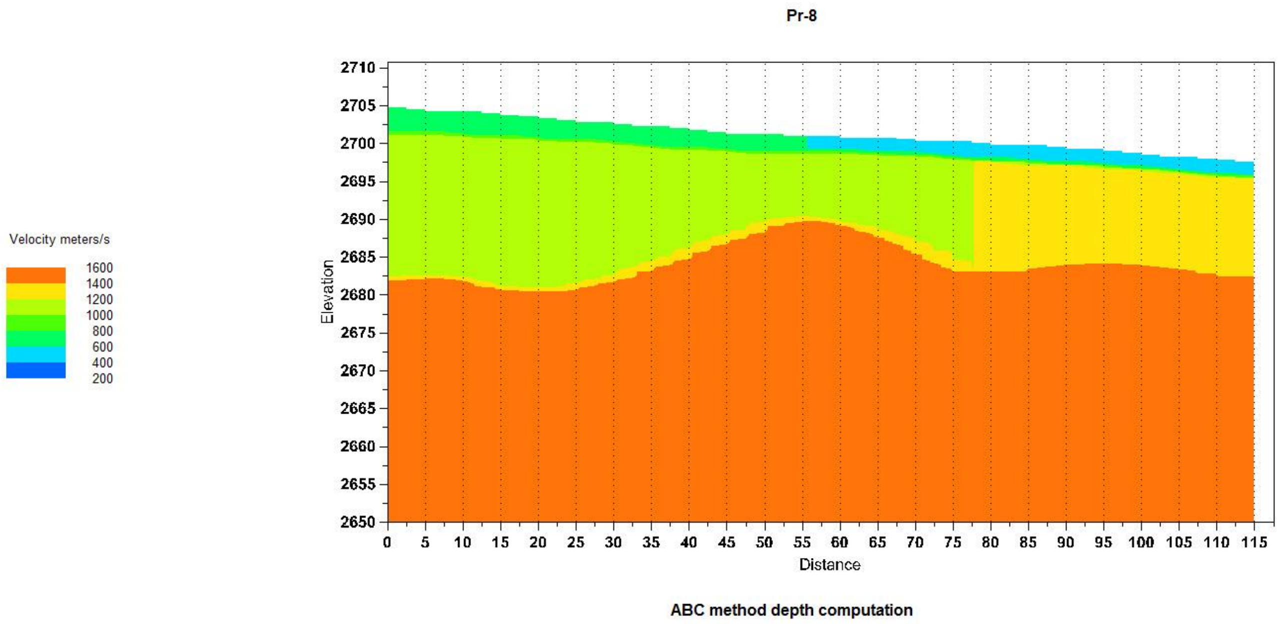


ABC method depth computation

Profile #7



Profile #8



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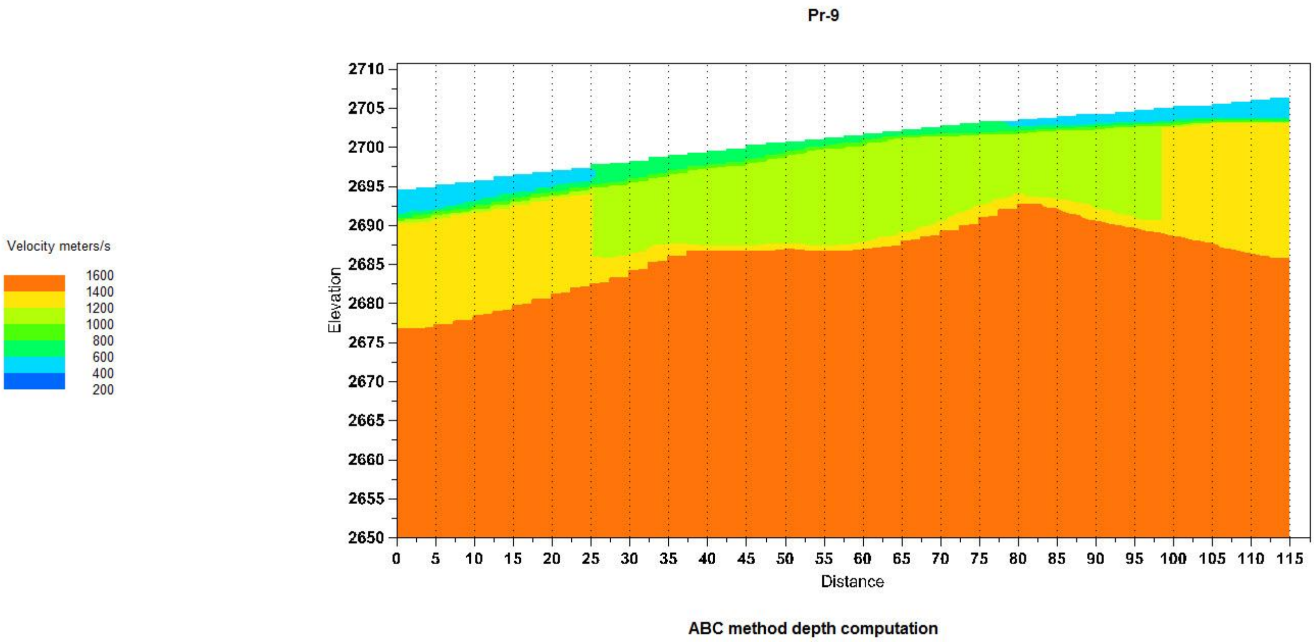
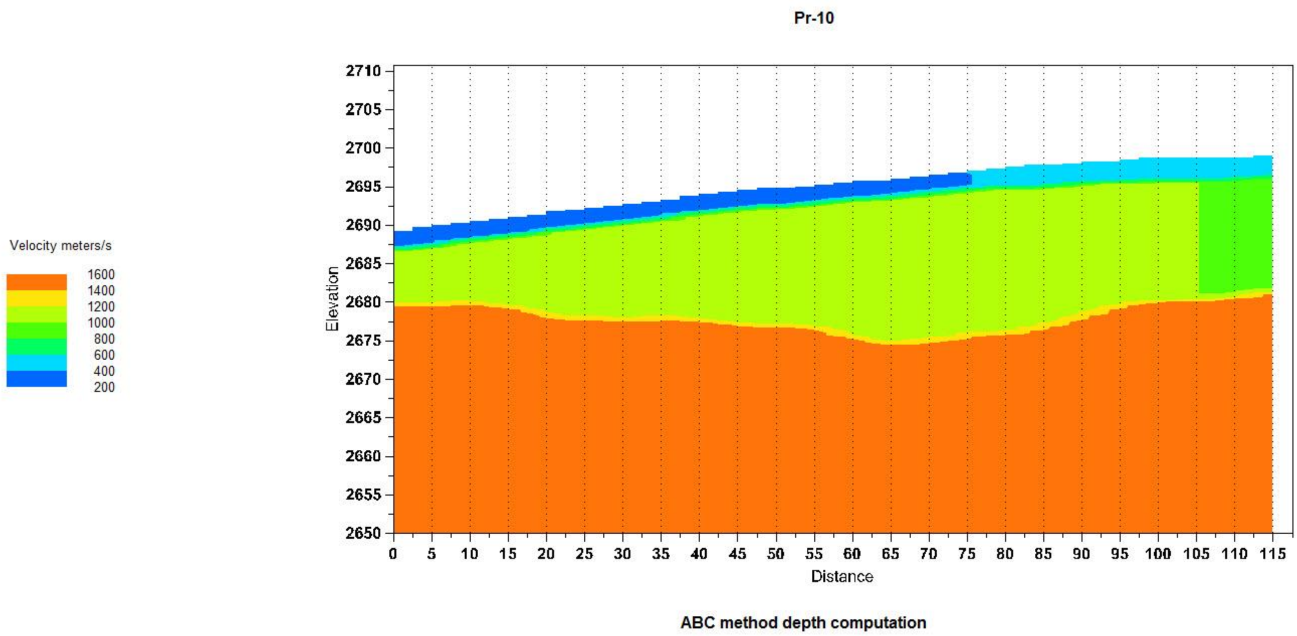


Profile #10



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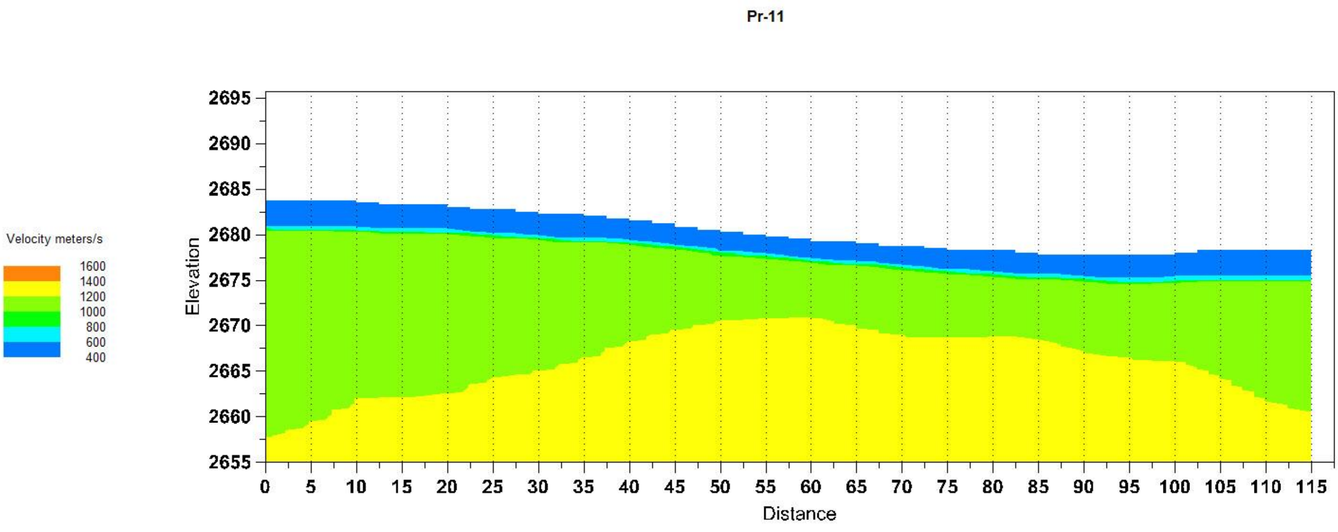
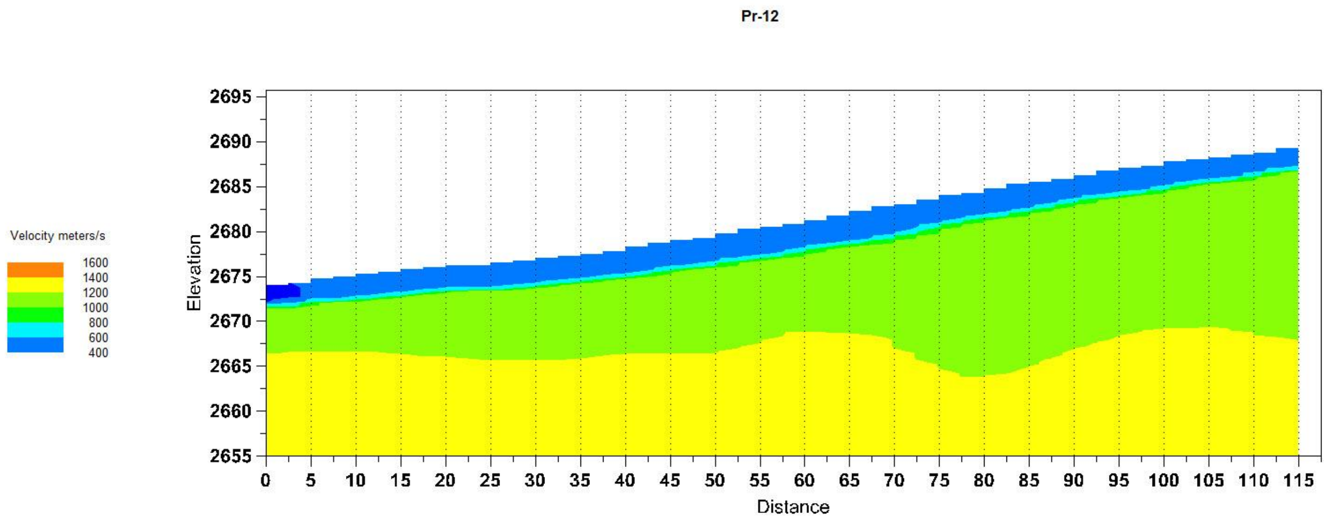


ABC method depth computation

Profile #12



ABC method depth computation

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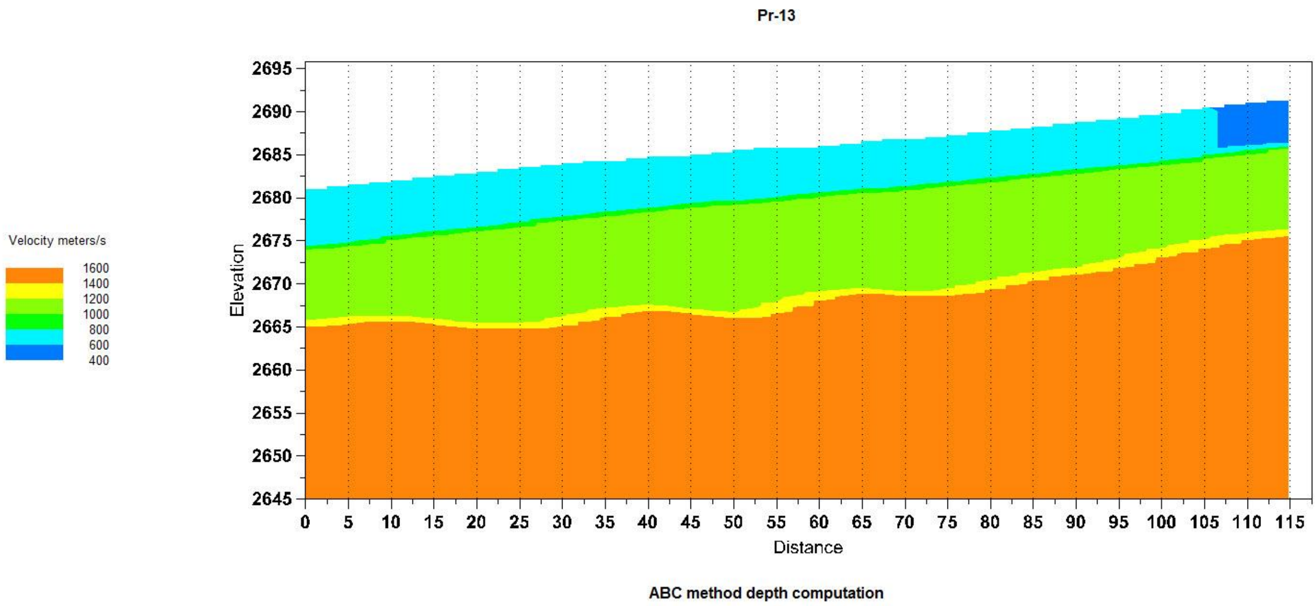

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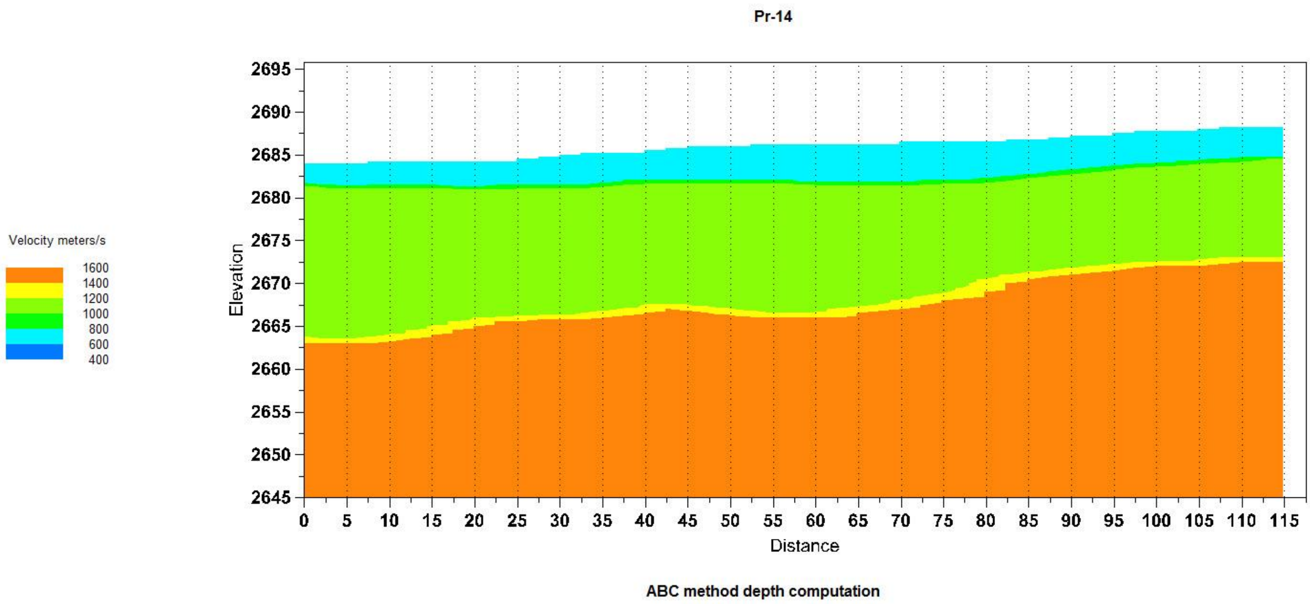

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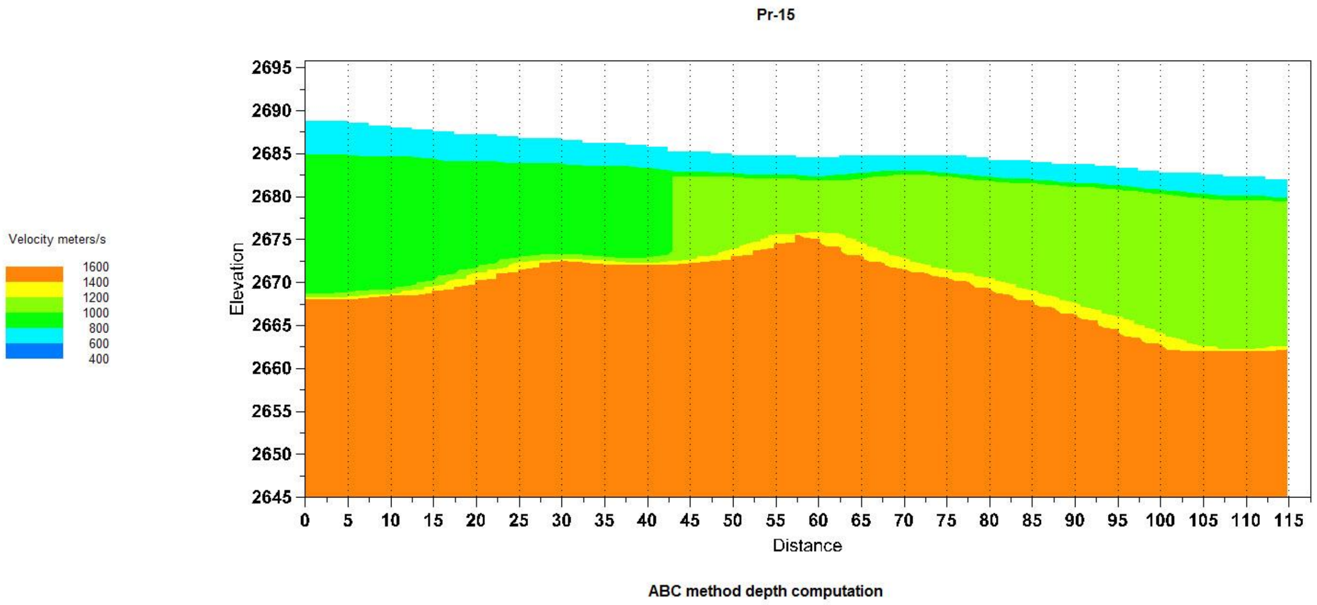

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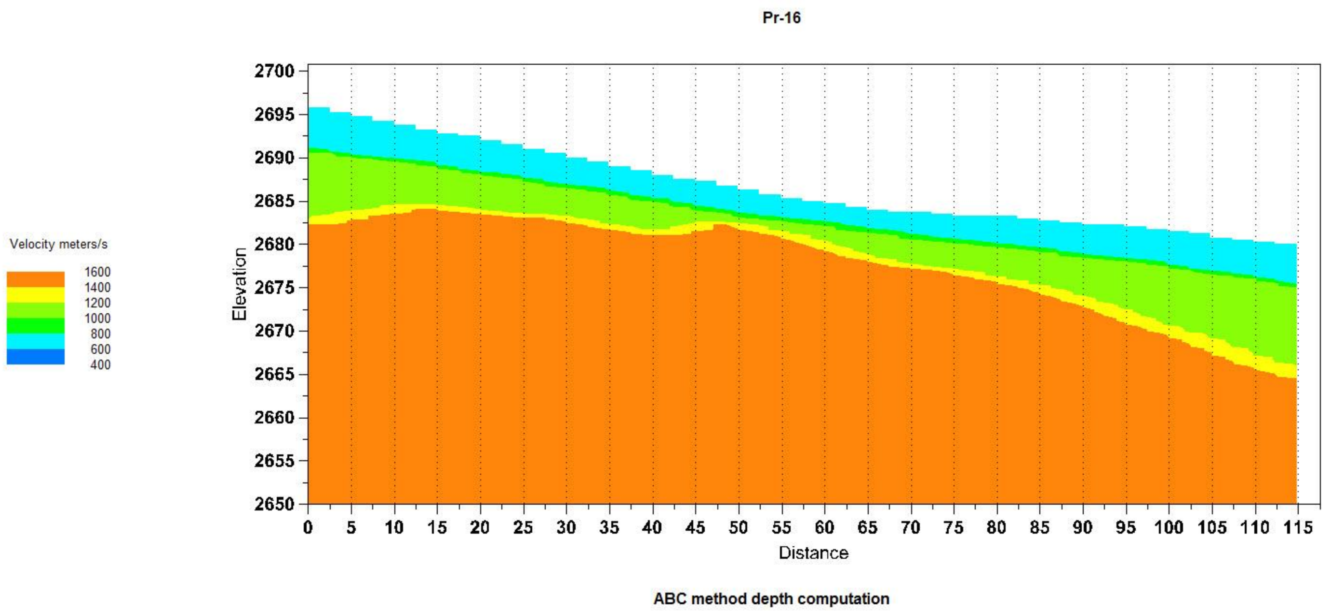

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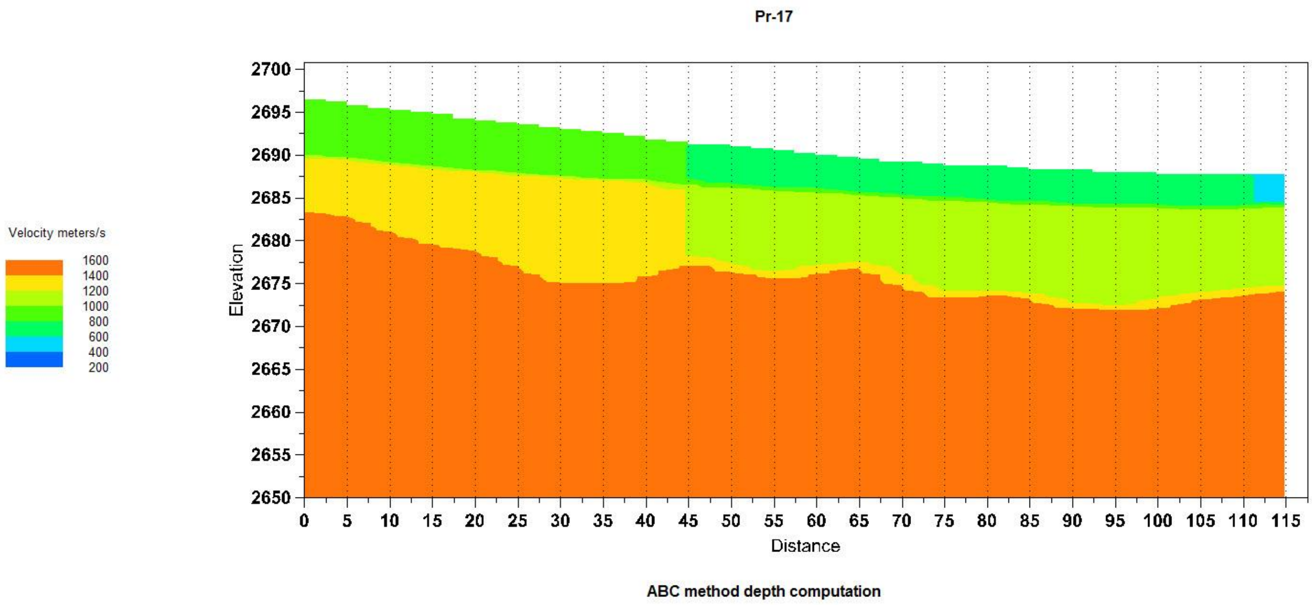

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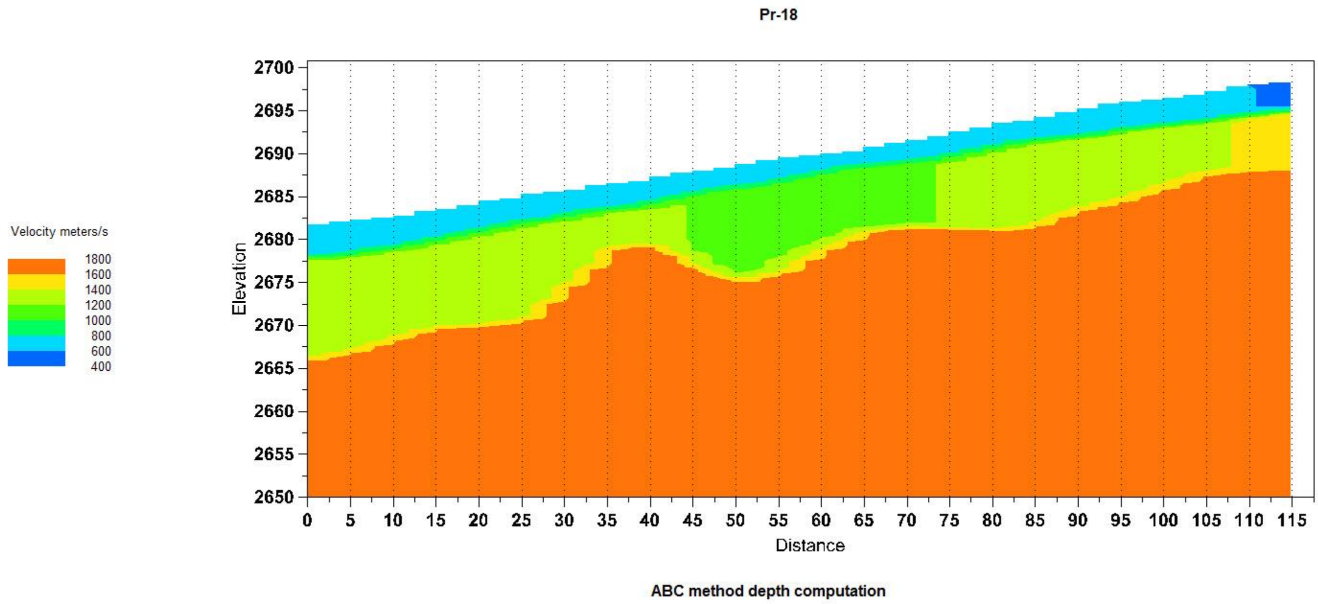

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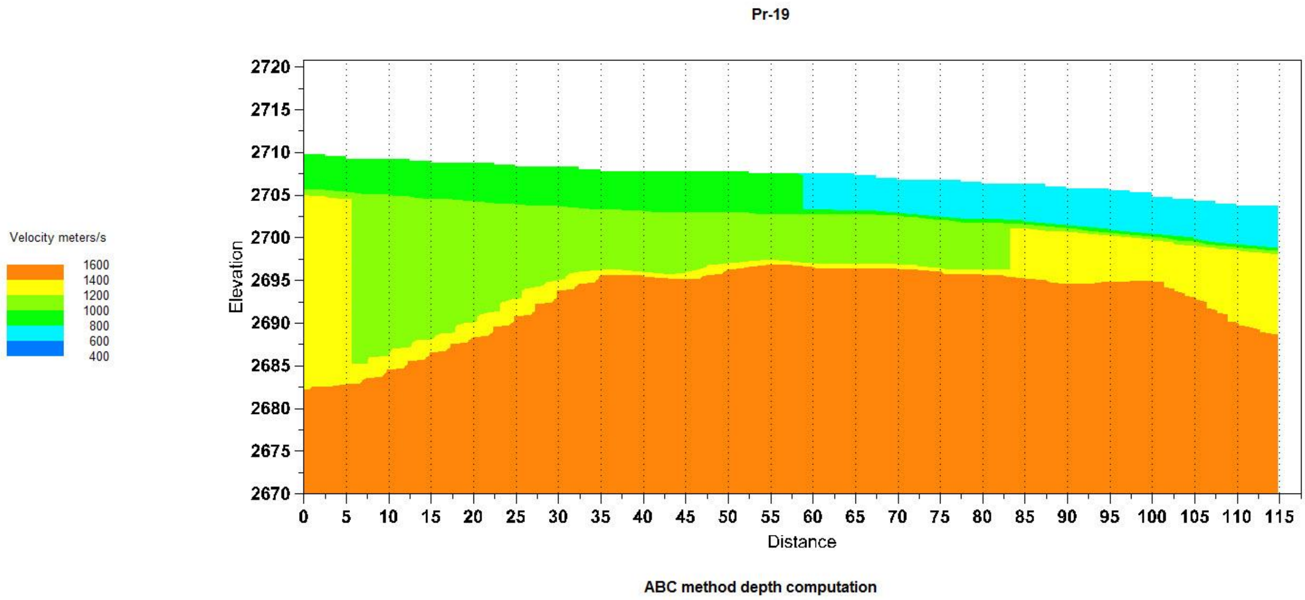

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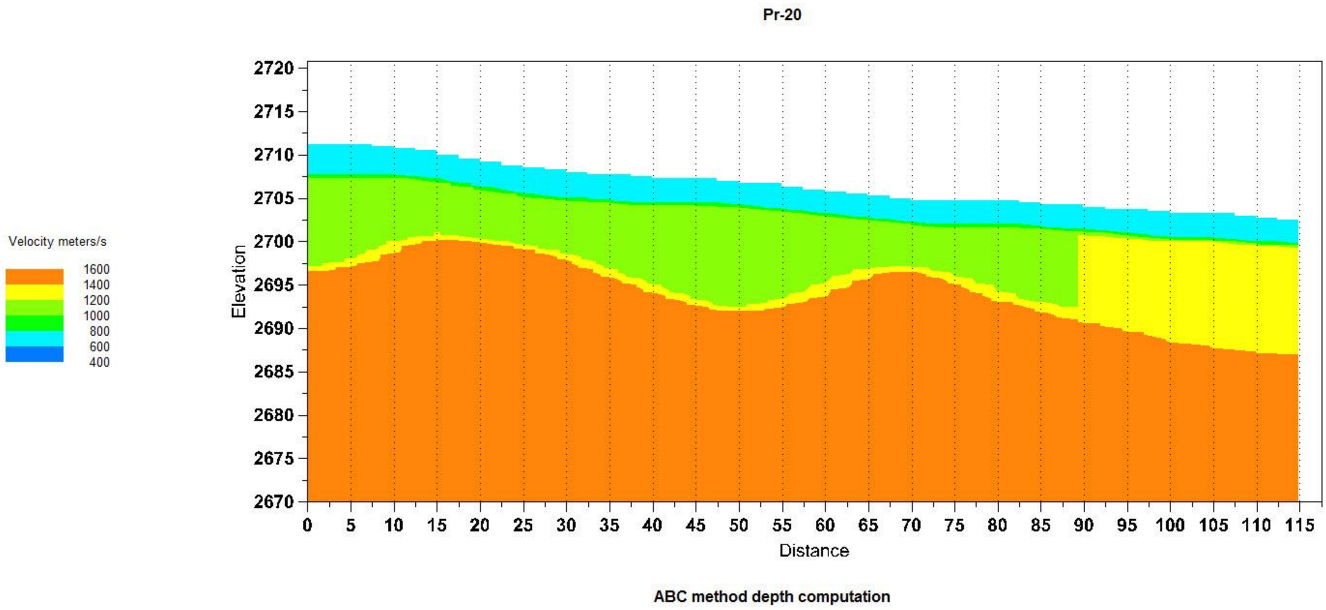
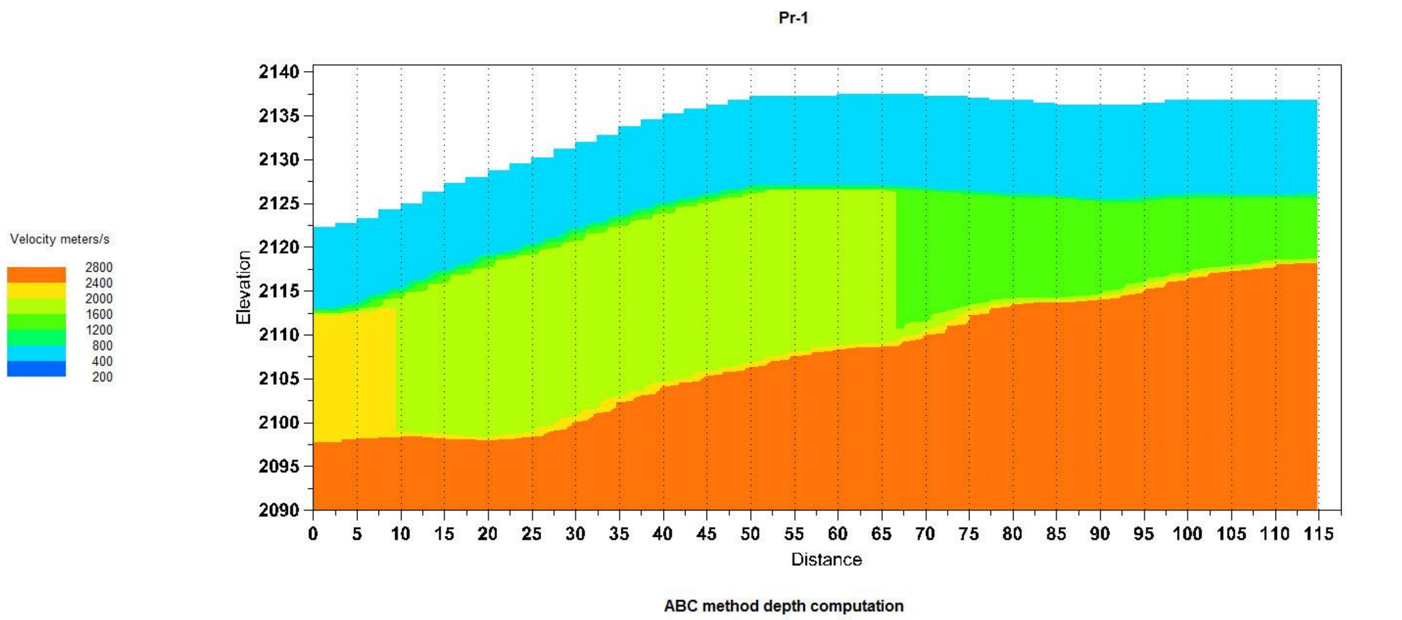


Profile #1



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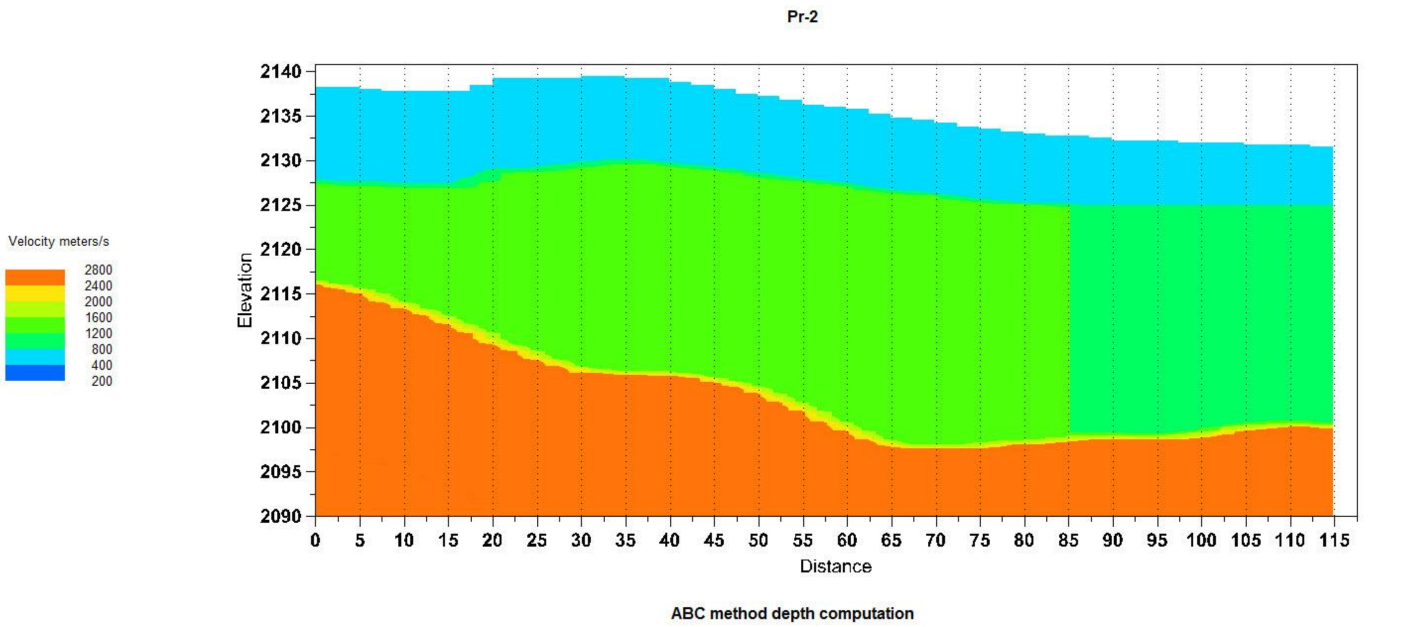

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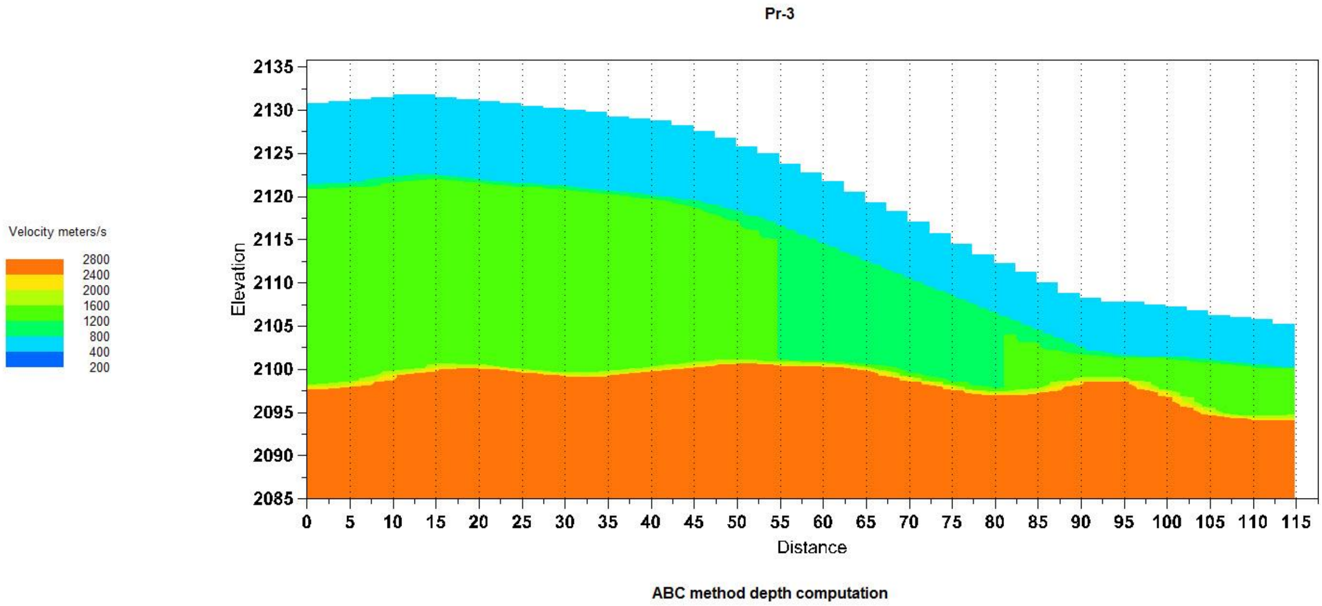

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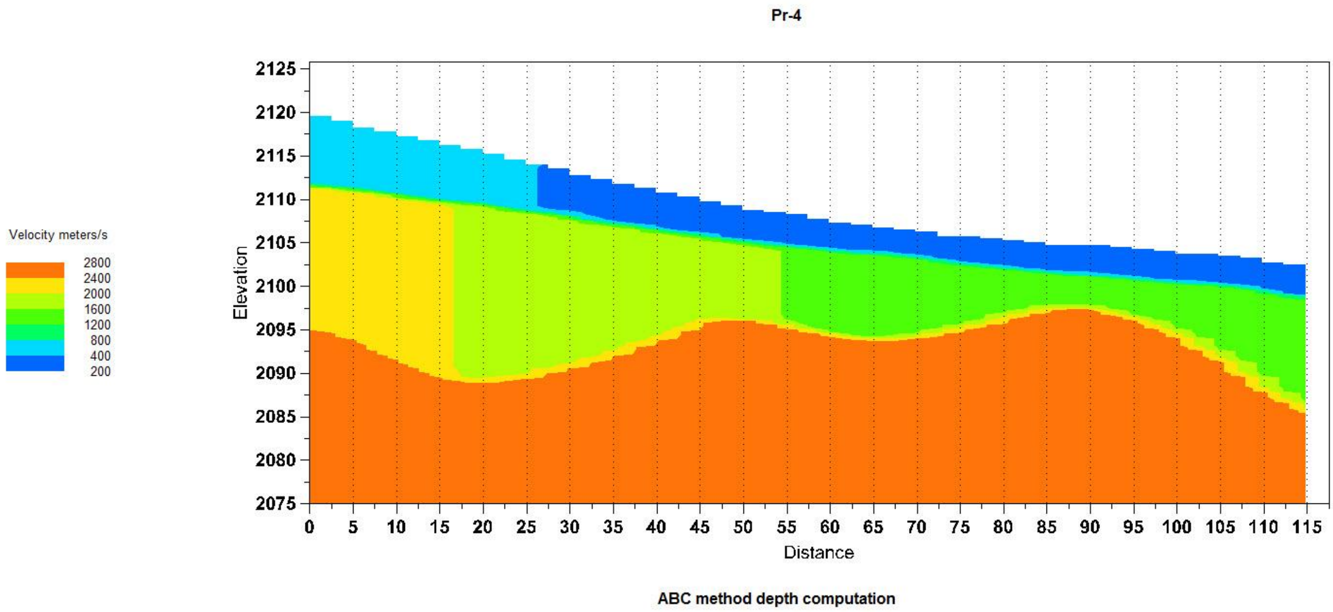

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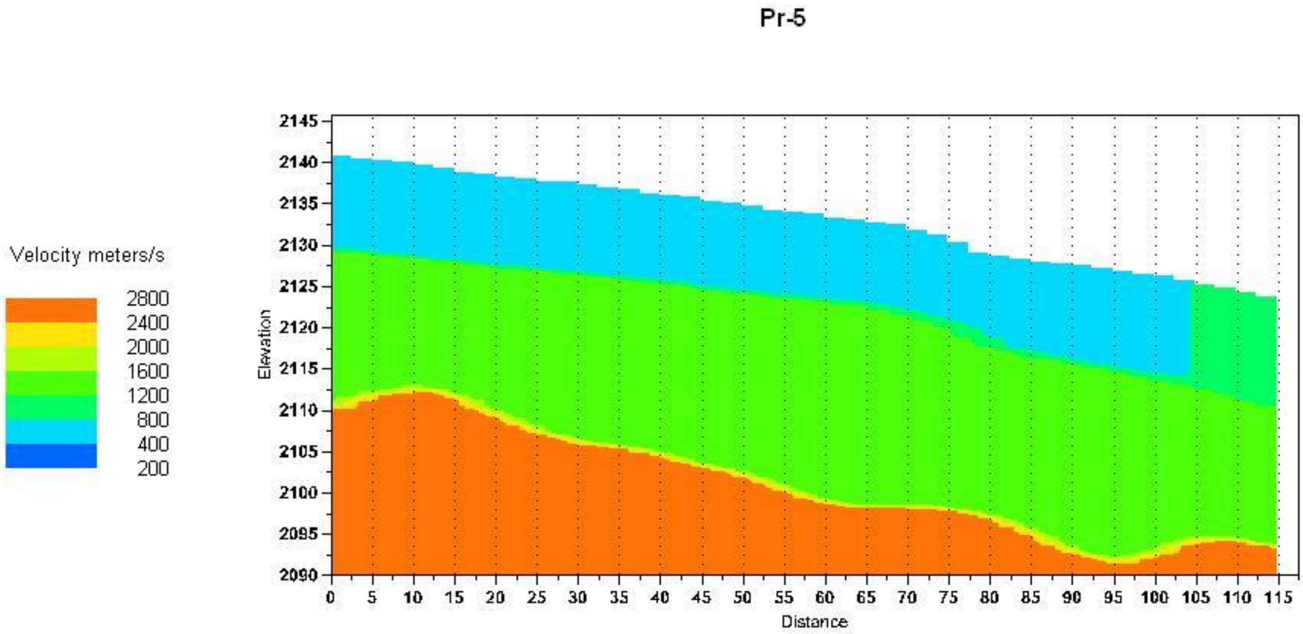
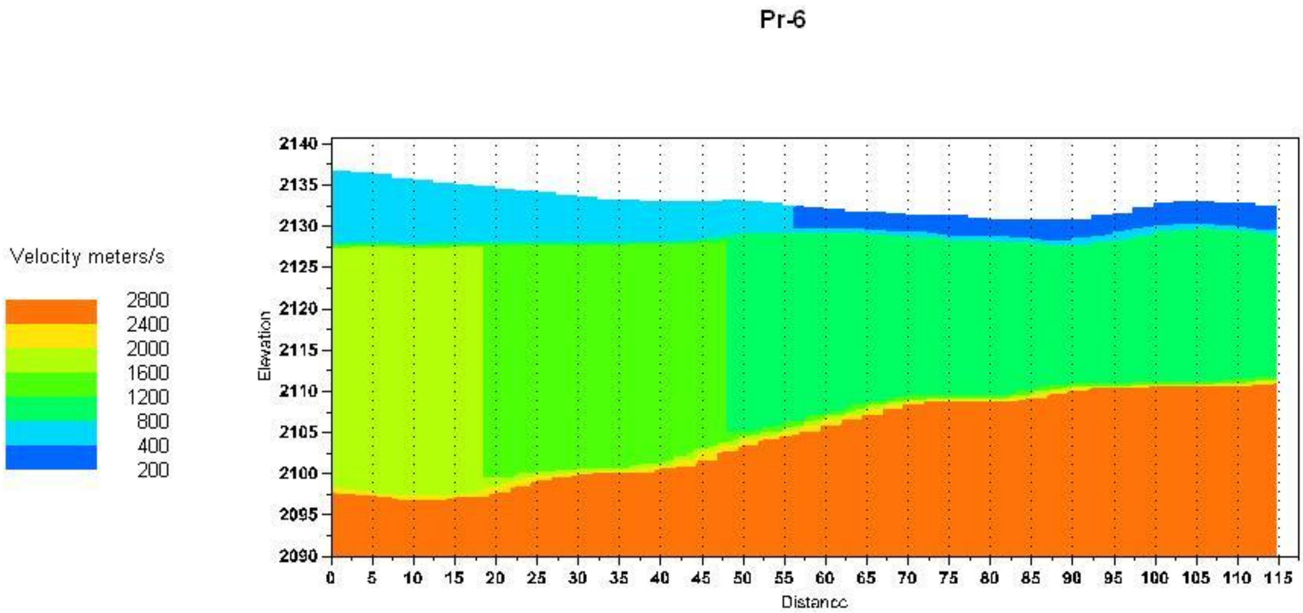


ABC method depth computation

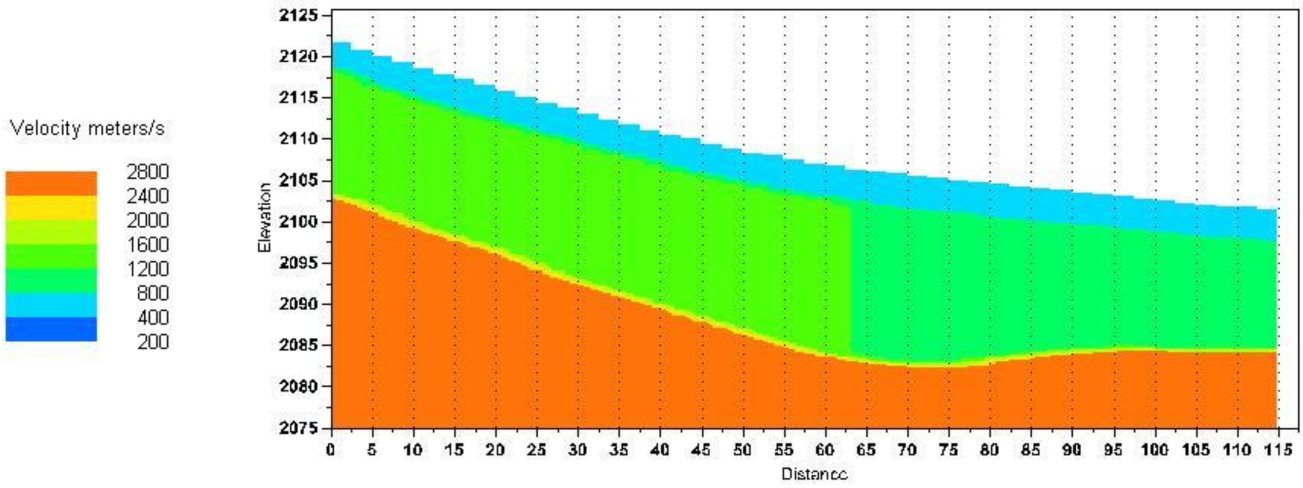
Profile #6



ABC method depth computation

Profile #7

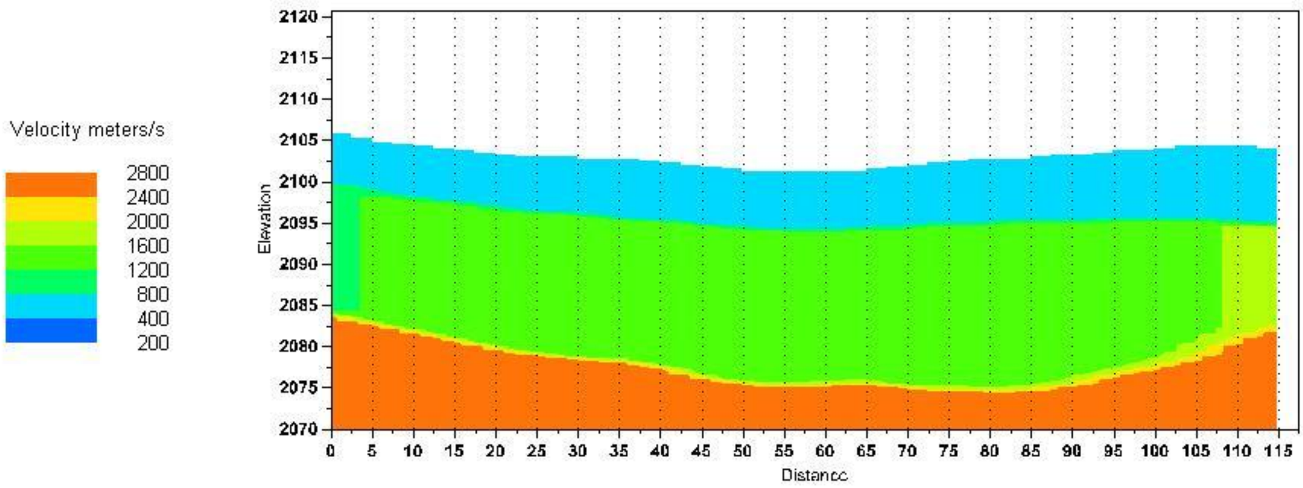
Pr-7



ABC method depth computation

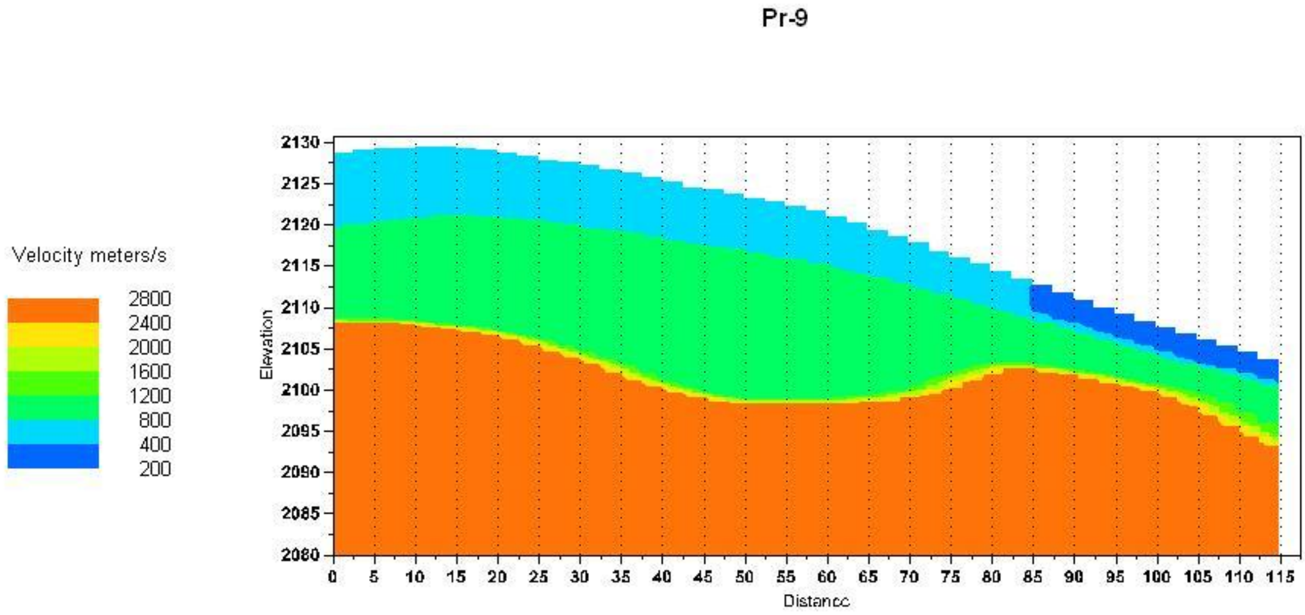
Profile #8

Pr-8



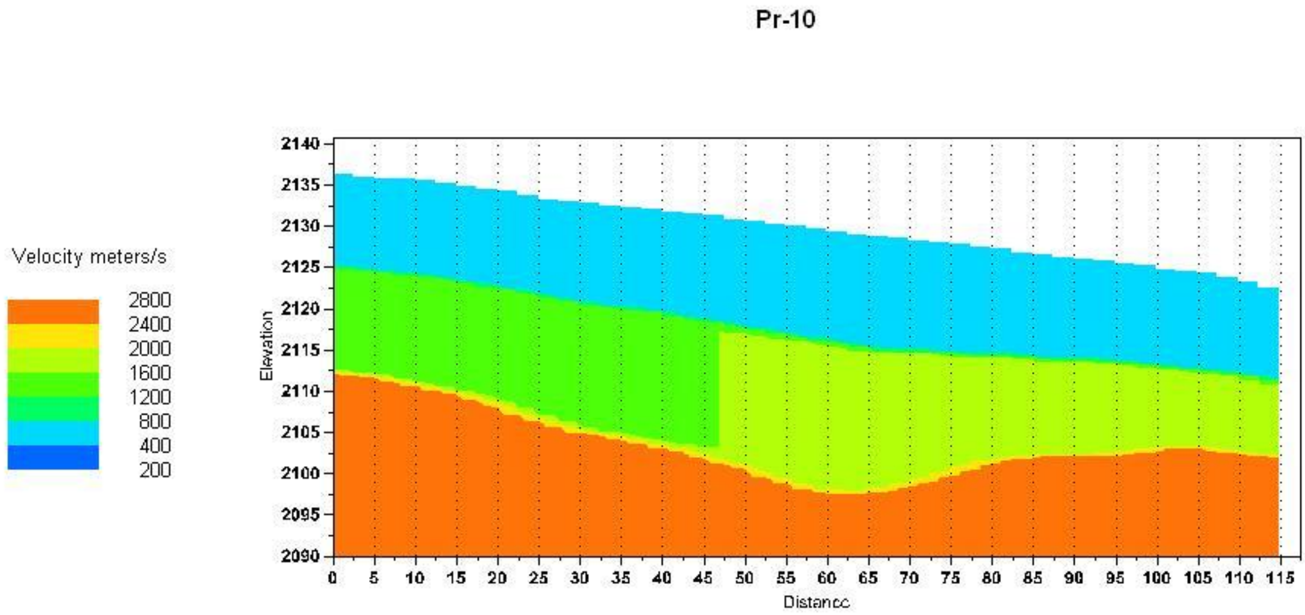
ABC method depth computation

Profile #9



ABC method depth computation

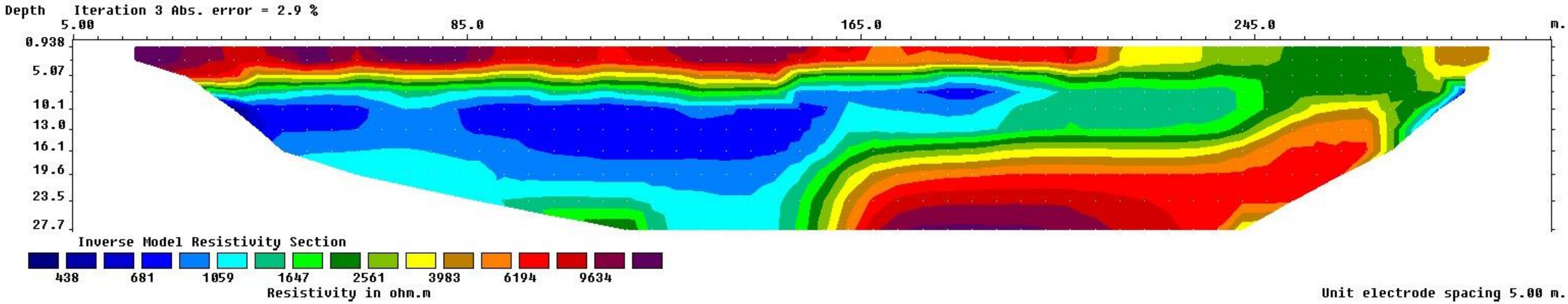
Profile #10



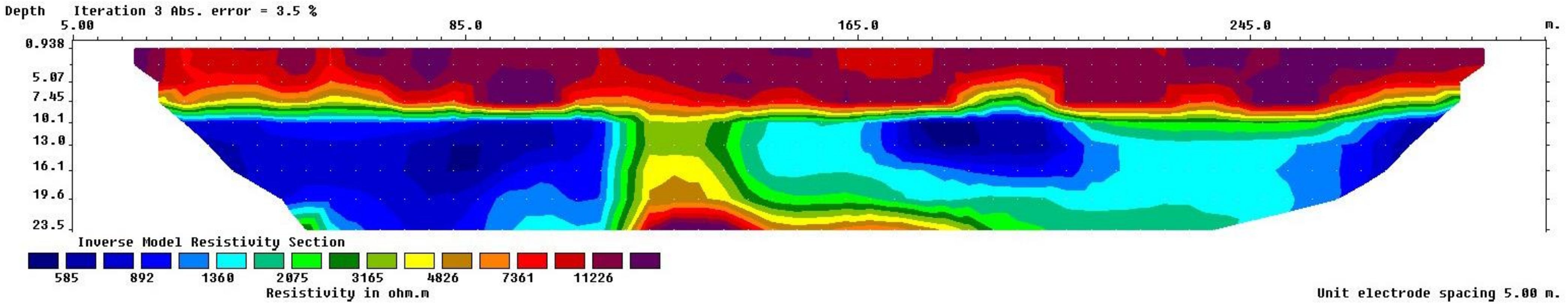
ABC method depth computation

Appendix3. Electrical profiles

Profile #1



Profile #2



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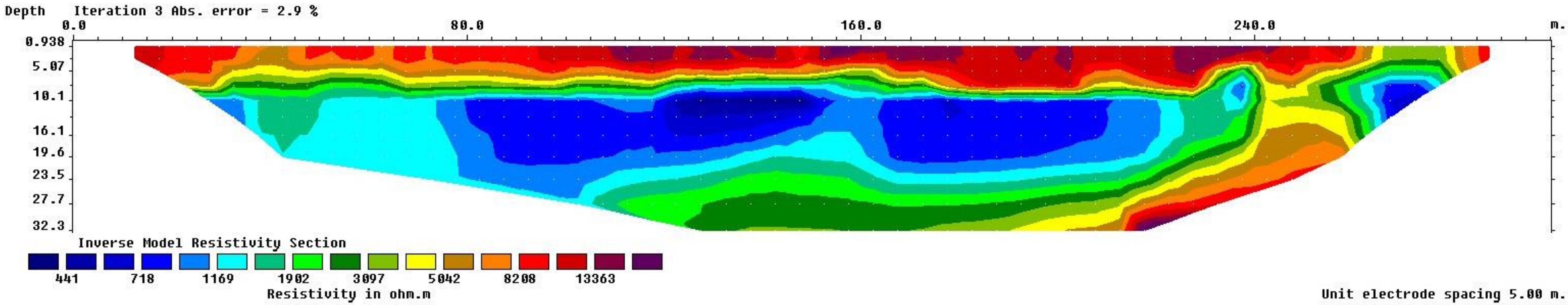
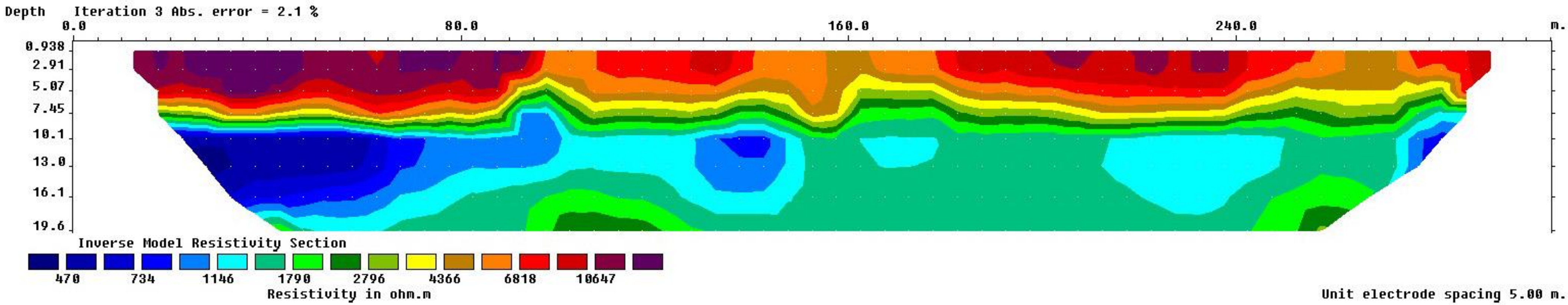


Profile #4



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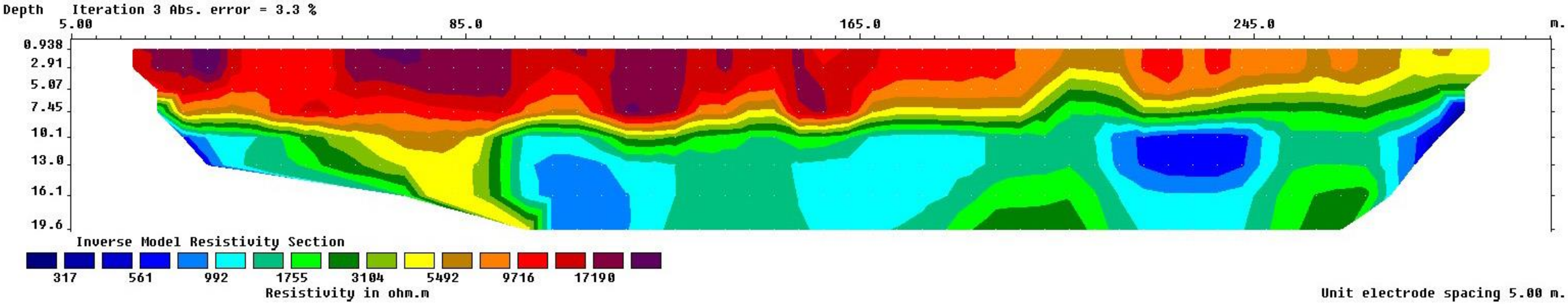

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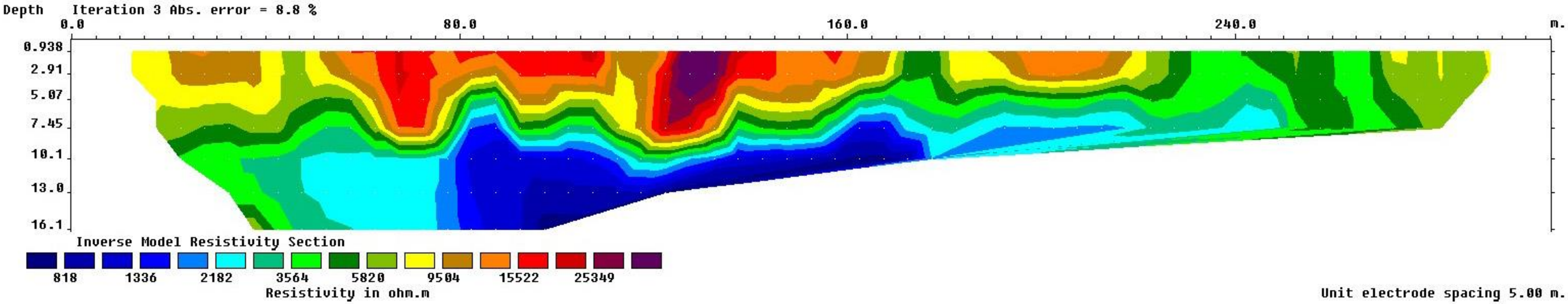

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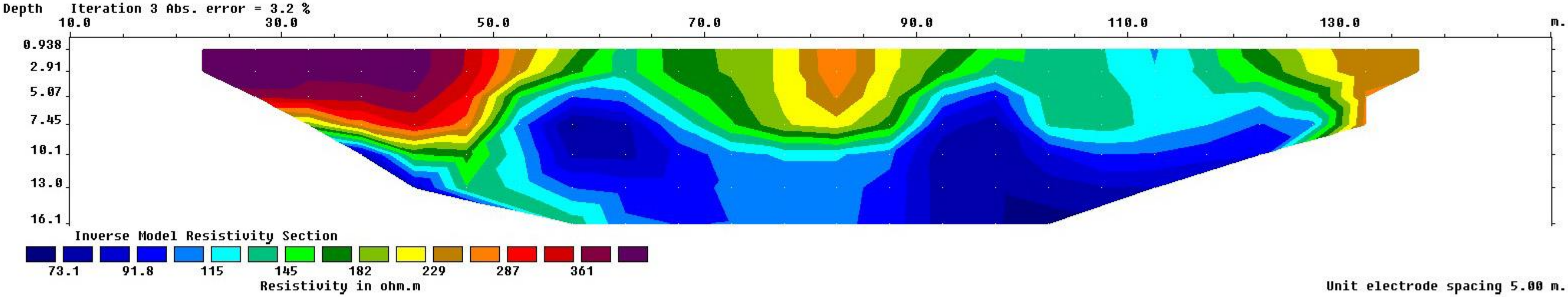

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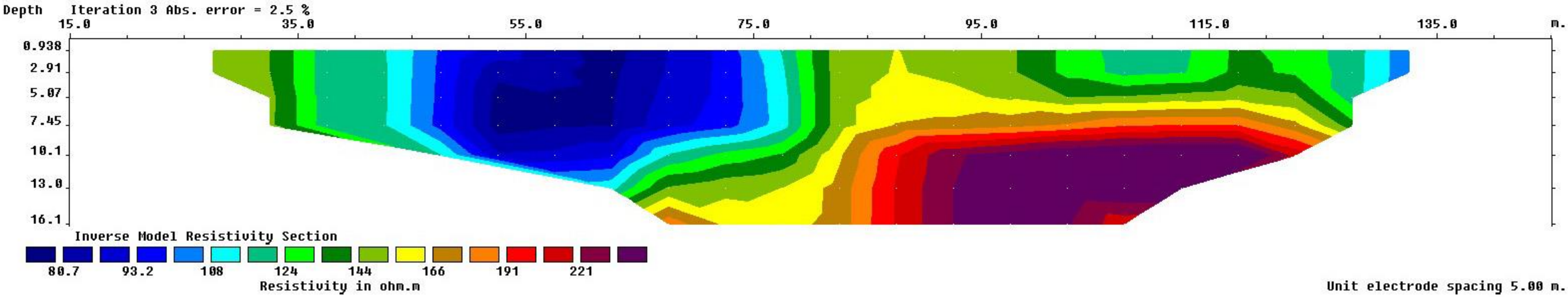

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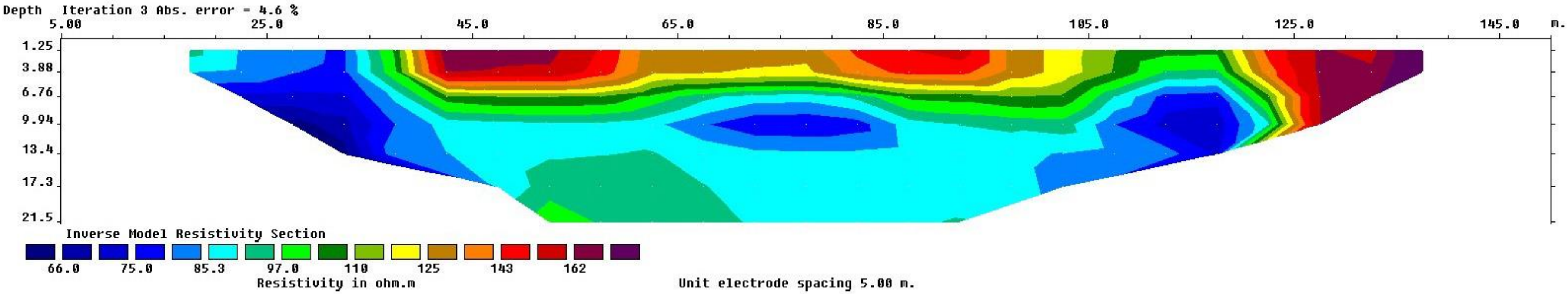

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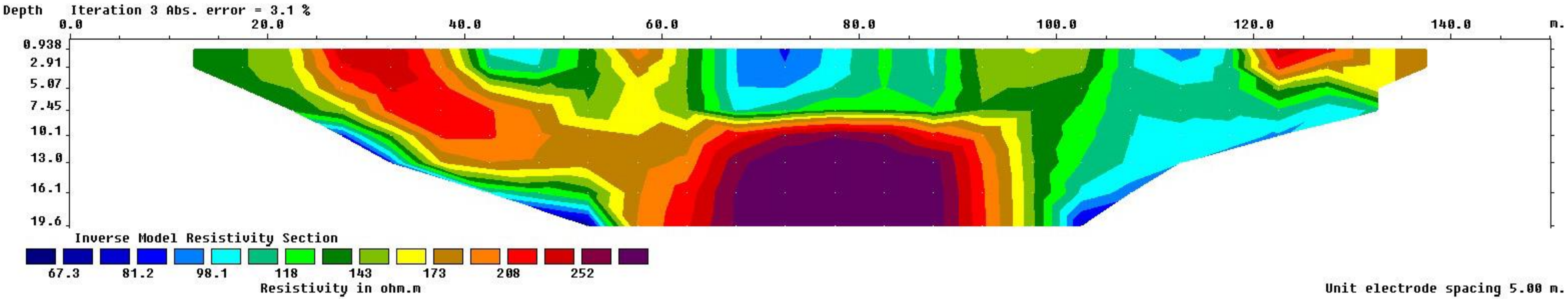

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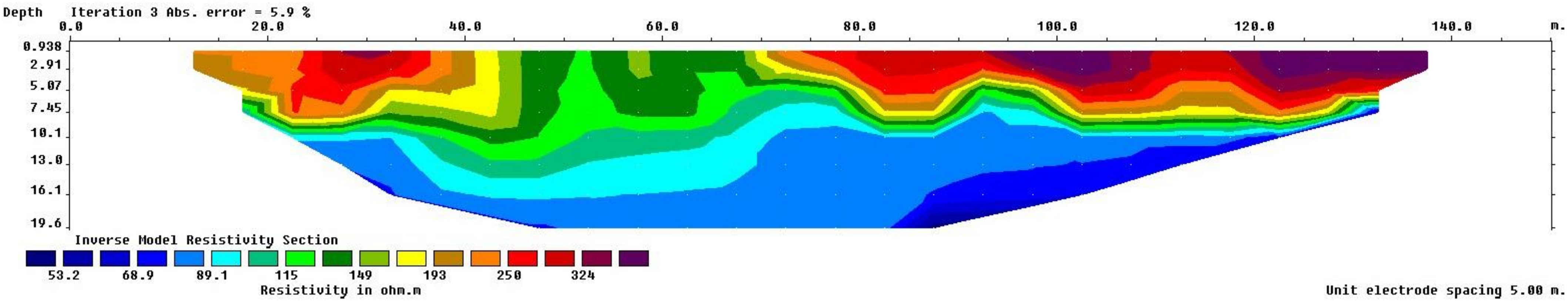
Depth Iteration 3 Abs. error = 5.9 %
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
m.
0.938
2.91
5.07
7.45
10.1
13.0
16.1
19.6
Inverse Model Resistivity Section
53.2
68.9
89.1
115
149
193
250
324
Resistivity in ohm.m
Unit electrode spacing 5.00 m.