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Oskarshamn site investigation

Refraction seismic measurements in Laxemar spring 2005

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Abstract

This document reports the execution and interpretation of refraction seismics performed in Laxemar during April 2005. All measurements were conducted by MRM Konsult AB.

The main objective of the investigation was to investigate possible tectonic lineaments predicted by different geological and geophysical methods. Most of the interpreted lineaments focused for in this investigation were located within or bordering Laxemar subarea in Oskarshamn. A second objective was to obtain geometrical information such as thickness of overburden along the profiles.

Seven profiles with a total length of 9,375 m were measured. The survey lines were placed to cross over interpreted lineaments mainly interpreted from air photos or geophysical measurements from helicopter. Most of the interpreted lineaments were confirmed as a zone with lower seismic velocity, 2,000 m/s up to 4,000 m/s, while the velocity of the sound rock were in the range from 5,000 m/s up to 5, 800 m/s. The mean value of the bedrock velocity for compact rock is 5,400 m/s.

Sammanfattning

Rapporten presenterar utförandet och resultat av tolkningen av refraktionsseismik som genomfördes i Laxemar under april 2005. Mätningarna genomfördes av MRM Konsult AB som också genomförde tolkningen.

Huvudsyftet med undersökningarna var att undersöka möjliga tektoniska lineament identifierade med olika geologiska och geofysiska metoder. Denna undersökning inriktas framförallt på tolkade lineament som ligger i eller omger delområde Laxemar i Oskarshamn. Ett delsyfte med undersökningarna var att bestämma tjockleken på överliggande jordtäcke längs med profilerna.

Sju profiler med en total längd av 9 375 m undersöktes. Undersökningslinjerna placerades för att korsa tolkade lineament identifierade från flygfotografier och från geofysiska mätningar med helikopter. Huvuddelen av de tolkade lineamenten verifierades som en zon med lägre utbredningshastighet i berget, från 2 000 m/s upp till 4 000 m/s, medan utbredningshastigheten i friskt berg varierade mellan 5 000 m/s upp till 5 800 m/s. Medelvärdet på utbredningshastigheten i friskt berg är 5 400 m/s.

Contents

1 Introduction

This document reports the results gained by the measurements and interpretation of refraction seismics in Laxemar subarea, which is one of the activities performed within the site investigation at Oskarshamn. The work was carried out in accordance with activity plan AP PS 400-05-015. In Table 1-1 the controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

Seven profiles with a total length of 9,375 m were measured. The survey lines were placed to cross over interpreted lineaments mainly interpreted from air photos or geophysical measurements from helicopter.

The location of the survey lines is shown in Figure 1-1. The delivered raw and processed data have been inserted in the database of SKB (SICADA) and data are traceable by the activity plan number.

Table 1-1. Controlling documents for the performance of the activity.

Activity plan	**Number**	**Version**
Refraktionsseismik I Laxemar, våren 2005	AP PS 400-05-015	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för refraktionsseimik	SKB MD 242.001	1.0

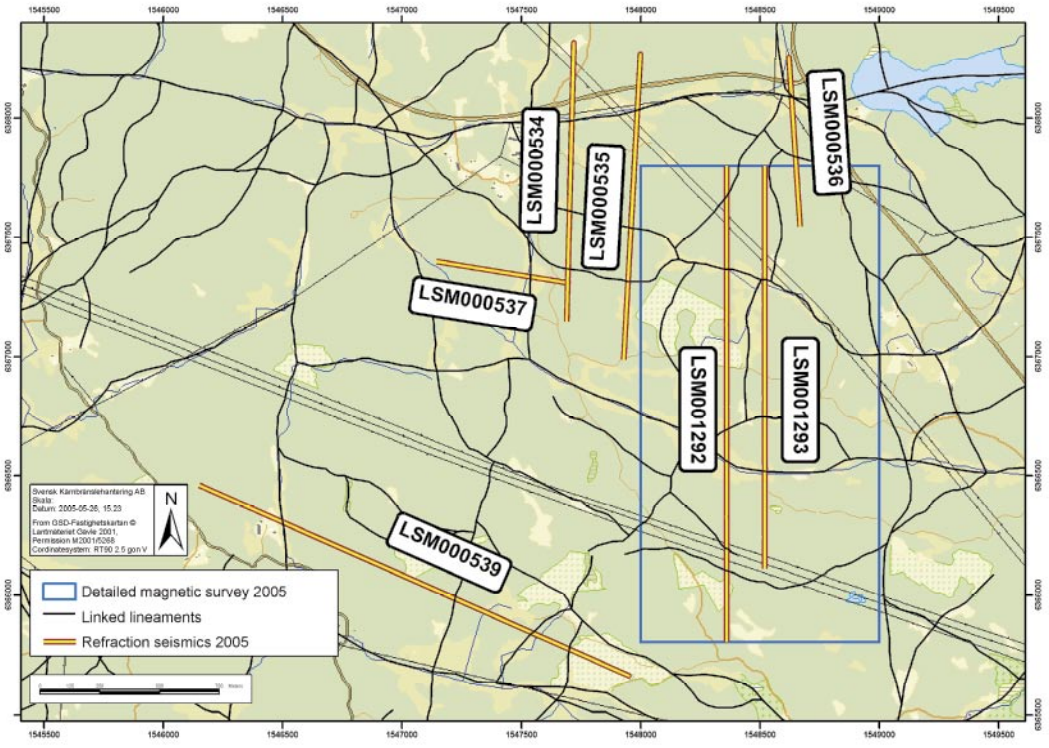

Figure 1-1. *Location of refraction seismic profiles in Laxemar subarea. Grey lines indicate linked lineaments /3/.*

2 Objective and scope

The main objective of the investigation was to investigate possible tectonic lineaments predicted by different geological and geophysical methods /1, 2, 3/. Most of the interpreted lineaments focused for in this investigation were located within or bordering Laxemar subarea in Oskarshamn. A second objective was to obtain geometrical information such as thickness of overburden along the profiles.

Seven profiles with a total length of 9,375 m were measured. The location of the profiles is shown in Figure 1-1.

3 Equipment

3.1 Description of equipment/interpretation tools

3.1.1 Recording instrument

The signals from the geophone cable are recorded digitally in SEG-2 format by a 24-channel instrument, ABEM Terraloc MK6, Figure 3-1.

Figure 3-1. *The recording instrument, ABEM Terraloc MK6.*

4 Execution

4.1 General

The refraction seismic measurements was performed according to the method description for refraction seismic SKB MD 242.001 (SKB internal controlling document).

4.1.1 Refraction seismic measurements

The energy source used was a normal commercial explosive. The charges are buried into the ground. The electrical detonators are ignited with a separate shot cable. The vibrations in the ground are picked up by geophones, Figure 4-1, in this project placed with 5 m spacing along the survey line. The signals from the geophones are carried to the recording instrument by a geophone cable. In this project two cables with a total of 24 outlets was used which means that a full spread covers 115 m in length.

4.1.2 Line survey

Before the seismic measurements the lines were staked and a line survey was performed and the coordinates for geophone points were measured for every 10th of metre. The measurements were performed by a Total station, Figure 4-2 and a GPS/RTK receiver. The resolution in X-, Y- and Z- coordinates is better than 0.1 m in X- and Y- coordinates and better than 0.3 m in Z- coordinates.

Figure 4-1. *Geophones used during the survey.*

Figure 4-2. *Line survey with Total station.*

4.2 Analyses and interpretation

4.2.1 Data extraction

The shot records were visually inspected and subsequently printed on paper. The arrival times from the different shots were picked manually and plotted as time-distance graphs on paper.

4.2.2 Interpretation

The interpretation was carried out manually with conventional methods. These methods are well described by Sjögren /4/.

4.3 Nonconformities

The planned profile LSM000538 was deleted due to land owner restrictions in the interesting section, i.e. part of the profile was on land which not was within the agreed survey area. The profile was replaced by a longer profile, LSM001292, as such that this profile should cover a detailed survey area of 2,000 m length in a north-south direction.

5 Results

The results discussed in the following section are shown as seismic sections in Figures A-1 to A-10 in Appendix 1. The seismic sections are delivered in .dwg format in the length scale 1:1,000 and depth scale 1:200. In Appendix 1 the scale has been reduced according to the layout of the page in the Appendix. The location of the measured lines is shown in Figure 1-1.

5.1 Interpreted results

In the profiles in Appendix 1 velocities in the uppermost part correspond to the overburden. Velocities from 300 up to 700 m/s correspond to loose topsoil. Velocities from 800 up to 2,200 m/s correspond to moraine above or below ground water table.

Profile 534 (LSM000534), shown in Figure A-1 in Appendix 1, starts on outcropping rock in the south and ends on a small arable land towards the north. Most parts of the profile run across very thin soil layer or outcropping rock. One exception is found between chaining 120 m and 240 m where the depth is 3–6 m. The depth under the field at the end of the profile is almost 10 m. One marked feature is the narrow valley between chaining 835 m and 850 m with a sound velocity of 2,800 m/s. The soil depth at the place is uncertain but the zone with low sound velocity in the bedrock is very marked. Besides the above mentioned zone there are four small and narrow zones with somewhat lower sound velocity with sound velocities of 3,500 m/s. Apart from the mentioned zones, the bedrock quality seems to be good or very good with a velocity of 5,100 up to 5,800 m/s with an exception between chaining 295 and 355 which has a sound velocity of 4,800 m/s.

Profile 535 (LSM000535), shown in Figure A-2 in Appendix 1, runs south-north almost parallel to and about 250 m east of profile 534. The soil depth is generally small or non-existent. Between chaining 120 m and 230 m there are some small cultivated fields. The soil depth reaches there a maximum of about 7 m. There are also a couple of narrow zones with low sound velocity in the bedrock at the same place with a sound velocity of 3,800 and 2,800 m/s respectively. Between 280 m and 380 m the soil depth is 5–7 m and also here there are a couple of zones with low sound velocity in the bedrock with a velocity of 3,400 and 3,000 m/s respectively. The narrow valley in profile 534 corresponds here to a wider valley between chaining 1,040 m and 1,080 m. The soil depth is around 6 m close to a low velocity at the same location with a sound velocity of 3,000 m/s. The low velocity zone is however not so pronounced here. Besides the above mentioned zones there are six small and narrow zones with somewhat lower sound velocity with sound velocities of 3,300 up to 3,900 m/s. Apart from the mentioned zones, the bedrock quality seems to be good or very good with a velocity of 5,000 up to 5,900 m/s.

Profile 536 (LSM000536), shown in Figure A-3 in Appendix 1, runs south-north. There is no or almost no soil along most of the profile. Between chaining 490 m and 590 m there is a cultivated field. At chaining 530 m there is a very marked zone with very low sound velocity in the bedrock with a velocity of 2,000 m/s. The calculated depth to rock is close to 20 m at the place. This calculation is however uncertain and it can be much deeper.

A second but minor low velocity zone is found at 320 m with a sound velocity of 3,100 m/s. Apart from the mentioned zones, the bedrock quality seems to be good or very good with a velocity of 5,100 up to 5,700 m/s.

The profile 537 (LSM000537), is shown in Figure A-4 in Appendix 1. The direction is west-east. Up to chaining 350 m the soil cover is thin or absent. In the valley between 350 m and 460 m the maximum depth is around 10 m. Two zones with low sound velocity in the bedrock are also found there with a sound velocity of 3,200 and 3,500 m/s respectively. At the end of the profile large size boulders covers the ground surface. The depth to bedrock is around 5 m along that part of the profile. Apart from the mentioned zones, the bedrock quality seems to be good or very good with a velocity of 5,300 up to 5,600 m/s.

Profile P539 (LSM000539), shown in Figures A-5 and A-6 respectively in Appendix 1, is 1,970 m long and running almost in a west–east direction. The bedrock is outcropping from the beginning up to chaining 310 m. In the valley between 310 m and 405 m a maximum soil depth of about 10 m is found at 390 m. At the same location a marked zone with low sound velocity in the bedrock is found with a velocity of 2,900 m/s. Another minor zone is found at 315 m with a velocity of 3,700 m/s. Outcropping rock between 406 m and 553 m is followed by a marsh up to 640 m. The soil depth across the swamp is as maximum 4 m at the same place as a narrow zone with low sound velocity in the bedrock at chaining 590 m with a velocity of 3,700 m/s. At chaining 830 m there is a small zone with somewhat lower bedrock velocity of 4,000 m/s. After chaining 900 m up to 1,800 m the ground is, with some short exceptions, covered with large boulders. The depth to bedrock is generally around 5 m. The hill at 1,650 m is made up by fractured rock. Low velocity zones in the bedrock are found at chaining 1,290 m, 1,570 m and 1,790 m, with velocities of 2,900, 3,500 and 3,500 m/s. All these low velocity zones are associated with local depressions in the bedrock surface. From chaining 1,800 m up to the end of profile at 1,970 m the bedrock is outcropping with exceptions at 1,850 m and between 1,900 m and 1,940 m. At the latter place the soil depth is more than 5 m and there is also a small zone with somewhat lower bedrock velocity of 4,500 m/s. Apart from the mentioned zones, the bedrock quality seems to be good or very good with a velocity of 5,200 up to 5,800 m/s.

Profile P1292 (LSM001292), shown in Figures A-7 and A-8 in Appendix 1, is 2,000 m long and runs in the south–north direction. The first part up to chaining 600 m has a fairly flat ground surface and a soil depth mostly in the interval 3–5 m. Narrow zones with low sound velocity in the bedrock is found at 12 m, 77 m and 562 m, with sound velocities of 3,500, 3,500 and 3,700 m/s. Between 650 m and 860 m there is a valley. The soil depth under the flat field in the centre of the valley is around 15 m. The upper soil layer, with the low sound velocity of 400–500 m/s, contains probably some organic material which could explain the low velocity. The lower velocity layer is probably caused by clay and sand. Two distinct zones with low sound velocity in the bedrock are found in the valley at chaining 750 and 800 m with velocities of 2,500 m/s. From chaining 950 m up to the end of profile at 2,000 m the soil depth is small or absent. At 1,562 m a minor zone with low sound velocity in the bedrock is found with a velocity of 3,500 m/s. Apart from the mentioned zones, the bedrock quality seems to be good or very good with a velocity of 5,000 up to 5,600 m/s.

Profile P1293 (LSM001293), shown in Figures A-8 and A-9 in Appendix 1, runs in the south–north direction. The measurements were carried out from chaining 310 m up to 2,000 m. The soil cover is small or absent with a few exceptions. At 382 m and 507 m there are minor zones with low sound velocity in the bedrock with velocities of 3,500 m/s. The broad valley in profile P1292 is here much more narrow at chaining 680 up to 800 m.

The ground is flat only between 690 m and 730 m and the soil depth is only around 6 m. Two zones with a low sound velocity in the bedrock are also found under the valley with velocities of 3,500 m/s. At chaining 1,515 m and 1,627 m there are narrow zones with lower than normal bedrock velocity with velocities of 3,500 and 3,700 m/s. They are also associated with local depressions in the bedrock elevation. Besides the above mentioned zones there are twonarrow zones with somewhat lower sound velocity with sound velocities of 4,500 m/s at chaining 960 m and 4,300 m/s at 1,970 m. Apart from the mentioned zones, the bedrock quality seems to be good or very good with a velocity of 5,000 up to 5,500 m/s.

5.2 Location of low velocity zones

The location of low velocity zones is shown in Figure 5-1.

In this survey the sound velocities in the bedrock are generally 5,000 m/s or higher. This indicates solid bedrock. A number of usually 5 m wide zones with lower sound velocity are found. The sound velocity for most of these zones is in the interval 2,000–4,000 m/s. When calculating the sound velocity for the bedrock the lower limit of the width of a low velocity zone is given by the distance between the geophones, in this case 5 m. This means that a zone with fractures that show up during the interpretation can be less than 5 m.

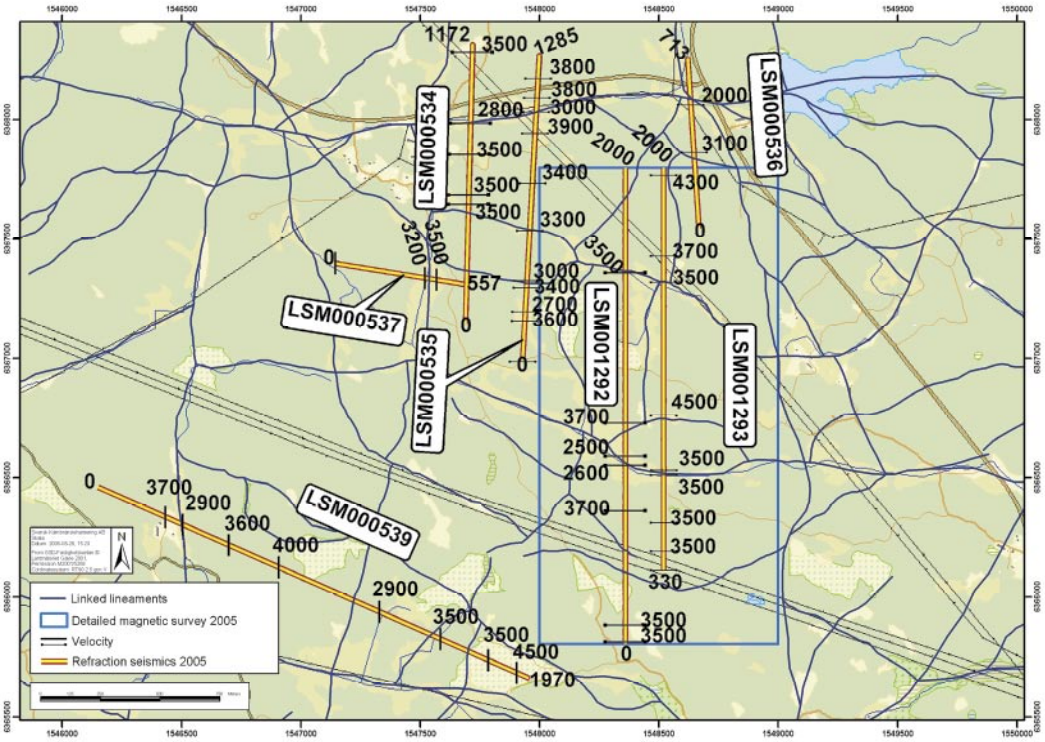

Figure 5-1. *Location of low velocity zones in the bedrock interpreted from this refraction seismic survey. The low velocity zones are marked with tic-lines along the profiles. Grey lines indicate linked lineaments /3/.*

5.3 Data delivery

Raw data from the measurements were delivered directly after the termination of the field activities and the delivered raw and processed data have been inserted in the database of SKB (SICADA) and data are traceable by the activity plan number.

Data delivered directly after termination of the field activities were:

- Field log for record numbers and shot and geophone geometry.
- Seismic raw data recordings in SEG-2 format.

Together with this report the following data are delivered:

- Seismik_Laxemar.dwg (drawings in Appendix 1).
- EG170_Line surveying_Laxemar_Refraktionsseismik_.xls (listing of line coordinates).
- GP320_Refraction seismics_Laxemar_våren_2005.xls.

References

/1/ **Triumf C A, 2003.** Oskarshamn site investigation. Identification of lineaments in the Simpevarp area by the interpretation of topographical data. SKB P-03-99. Svensk Kärnbränslehantering AB.

/2/ **Triumf C A, Thunehed H, Kero L, Persson L, 2003.** Oskarshamn site investigation. Interpretation of airborne geophysical survey data. Helicopter borne survey data of gamma ray spectrometry, magnetics and EM from 2002 and fixed wing airborne survey data of the VLF-field from 1986. SKB P-03-100. Svensk Kärnbränslehantering AB.

/3/ **Triumf C A, 2004.** Oskarshamn site investigation. Joint interpretation of lineaments. SKB P-04-49. Svensk Kärnbränslehantering AB.

/4/ **Sjögren B, 1984.** Shallow refraction seismics. ISBN 0-412-24210-9.

Appendix 1

Interpretation of refraction seismic sections in Laxemar

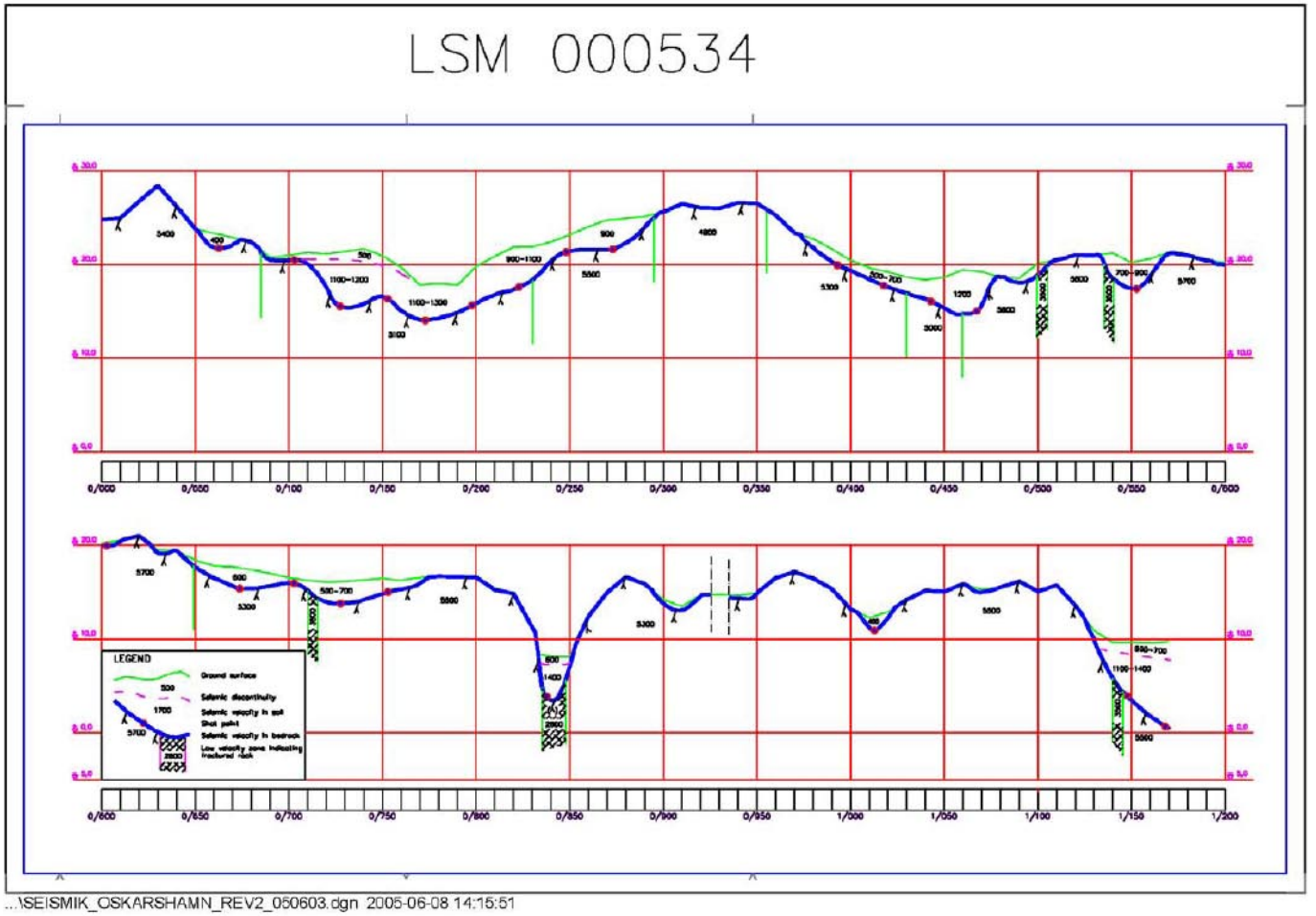

Figure A-1. *Refraction seismics in Laxemar during spring 2005. Profile LSM000534.*

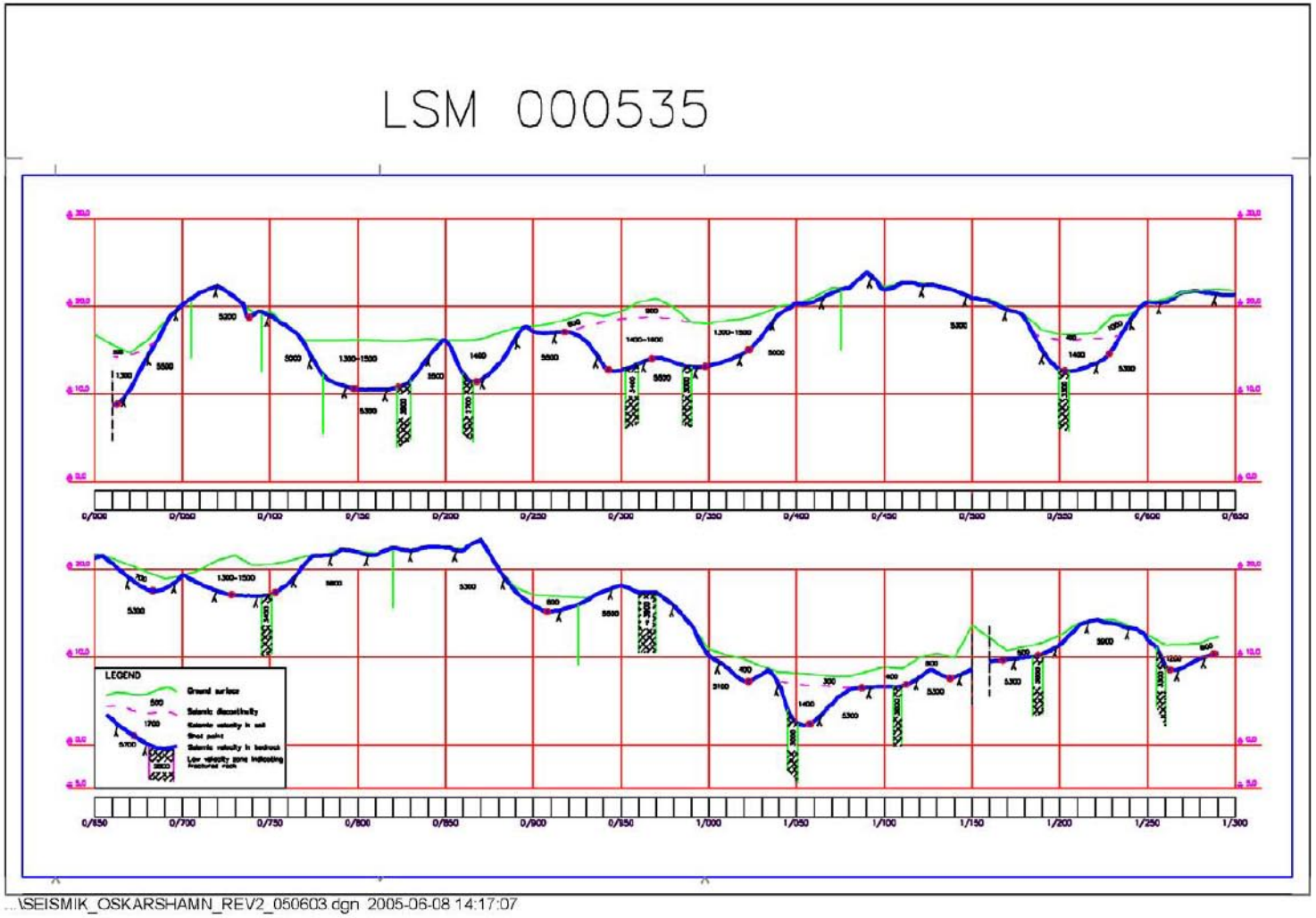

Figure A-2. *Refraction seismics in Laxemar during spring 2005. Profile LSM000535.*

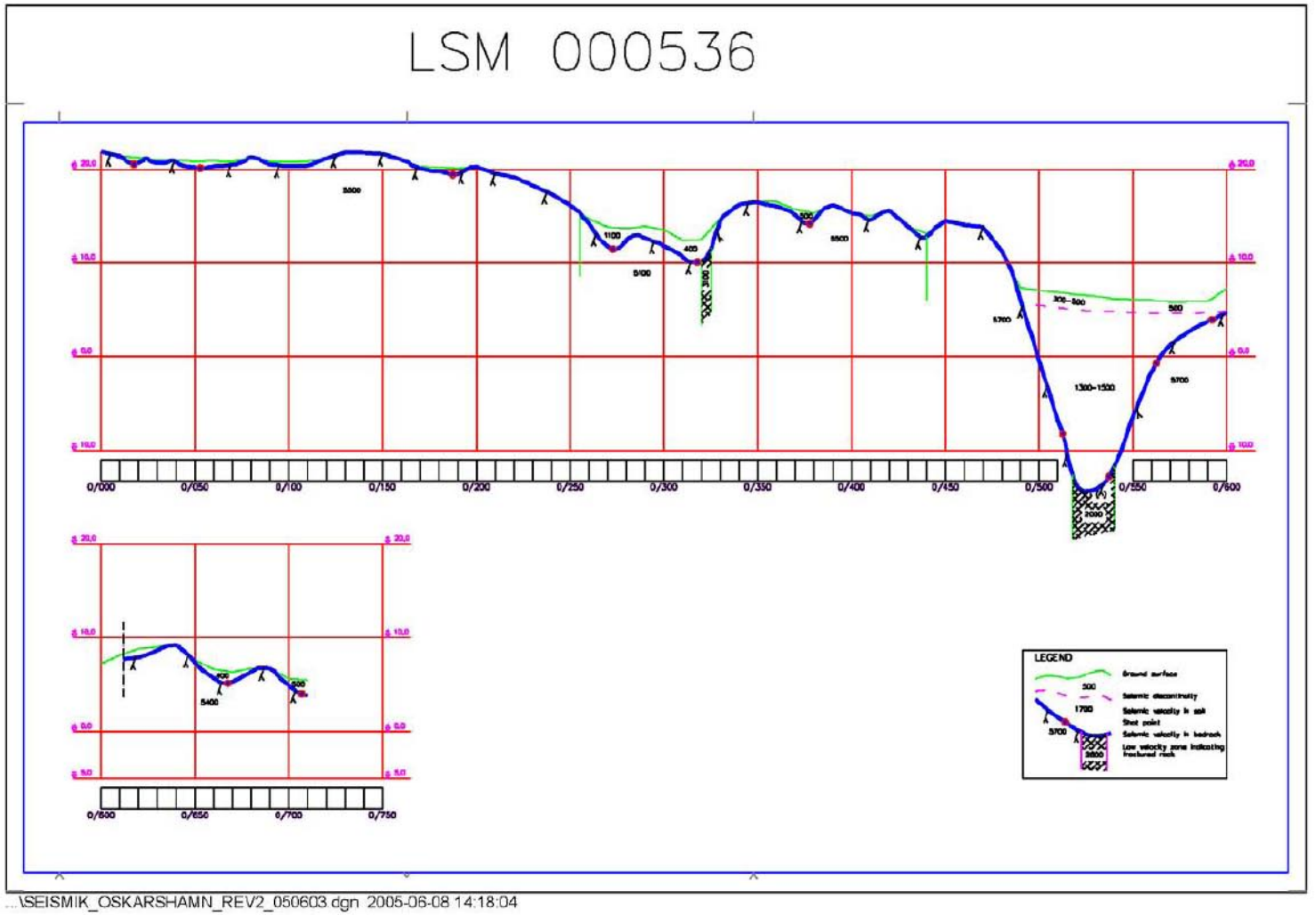

Figure A-3. *Refraction seismics in Laxemar during spring 2005. Profile LSM000536.*

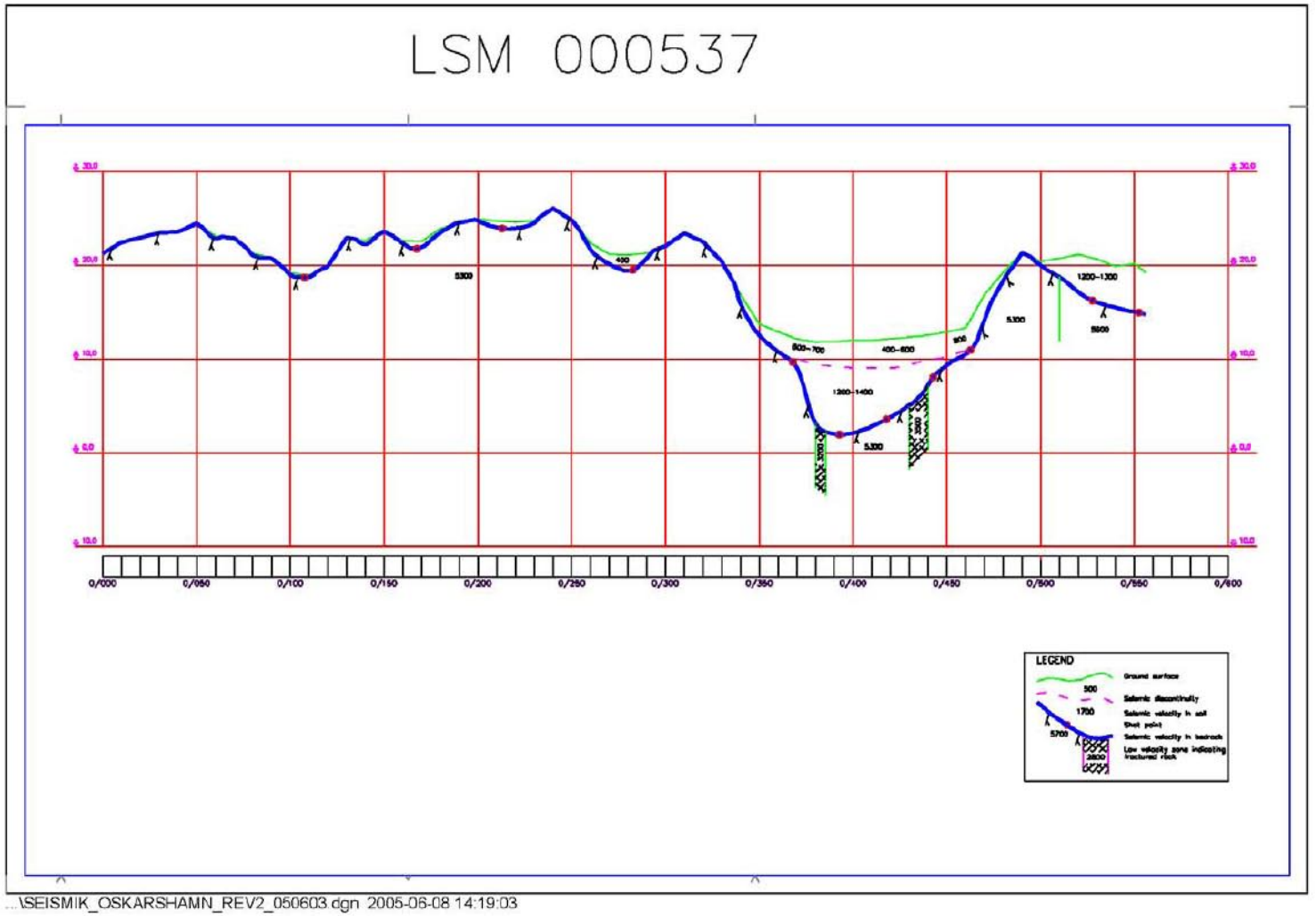

Figure A-4. *Refraction seismics in Laxemar during spring 2005. Profile LSM000537.*

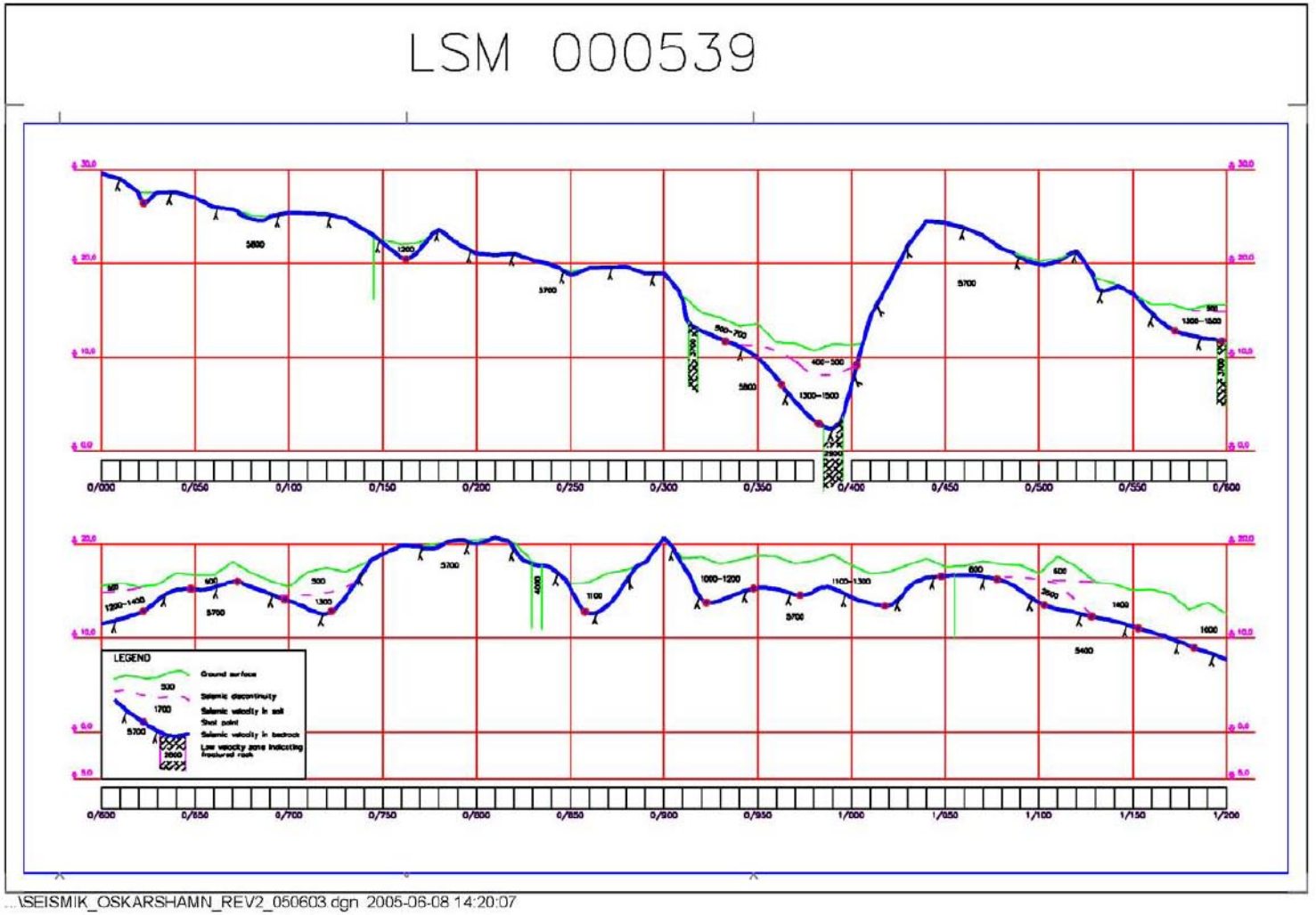

Figure A-5. *Refraction seismics in Laxemar during spring 2005. Profile LSM000539 chaining 0 – 1,200.*

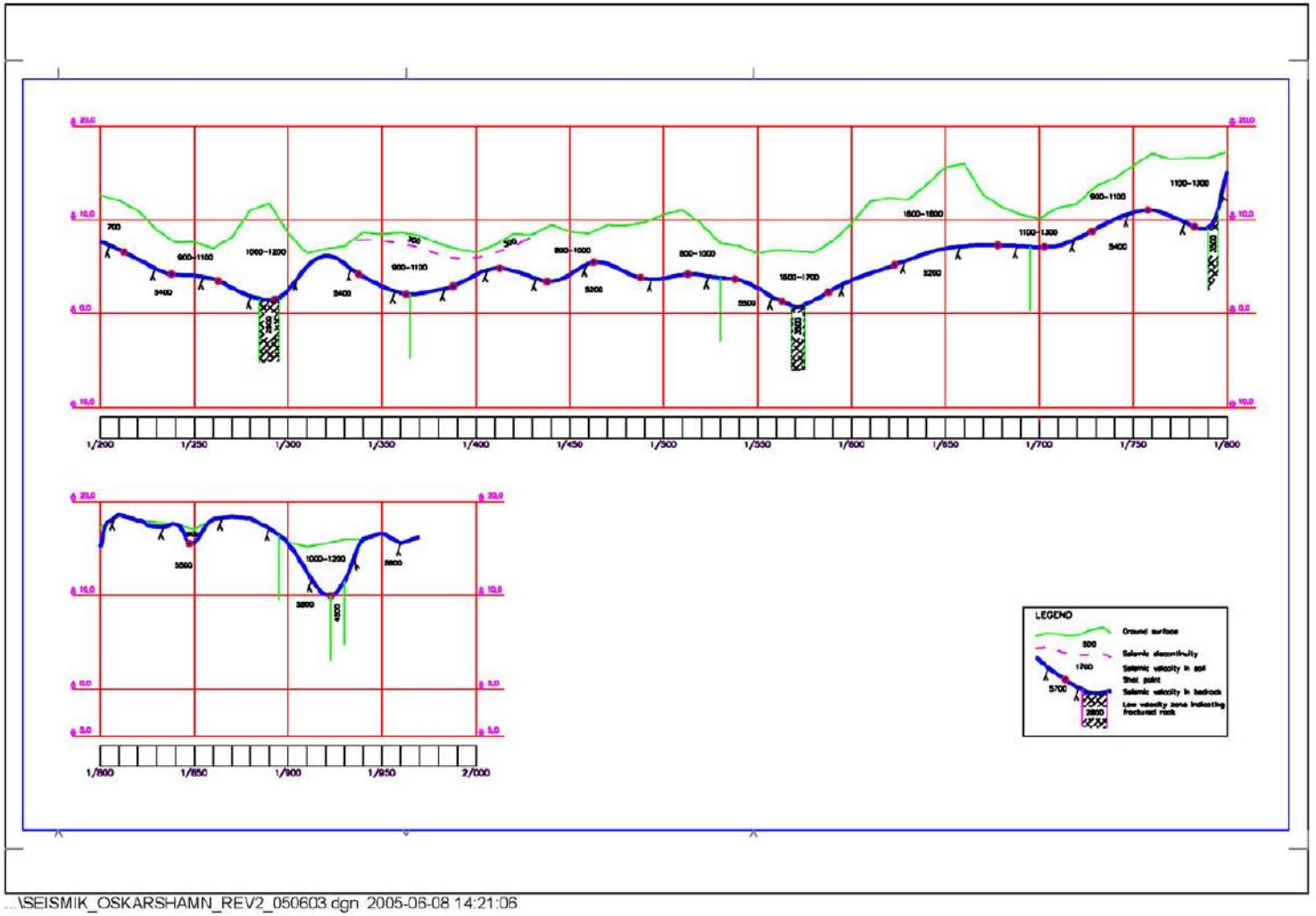

Figure A-6. *Refraction seismics in Laxemar during spring 2005. Profile LSM000539 chaining 1,200 – 1,970.*

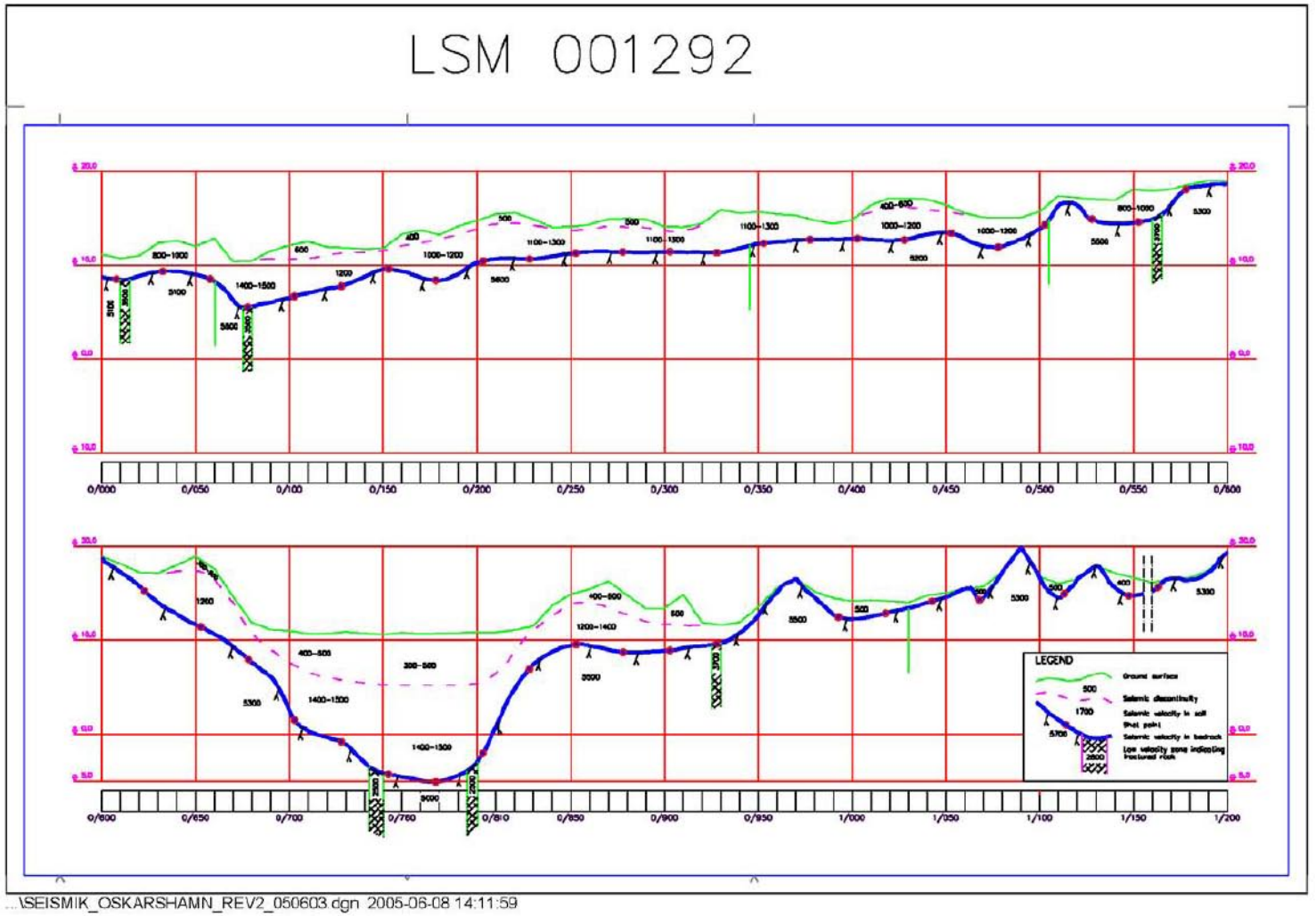

Figure A-7. *Refraction seismics in Laxemar during spring 2005. Profile LSM001292 chaining 0 - 1,200.*

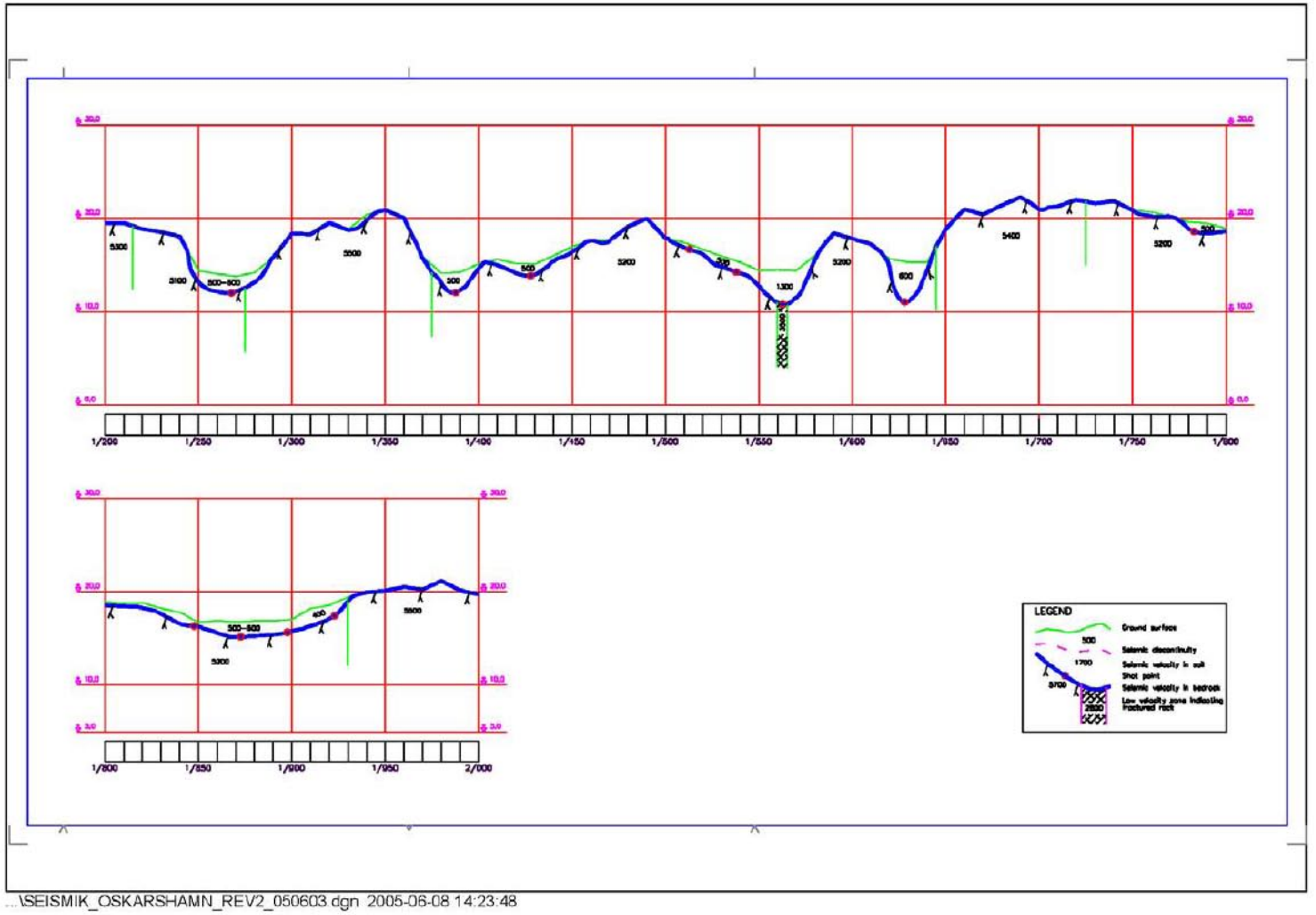

Figure A-8. *Refraction seismics in Laxemar during spring 2005. Profile LSM001292 chaining 1,200 – 2,000.*

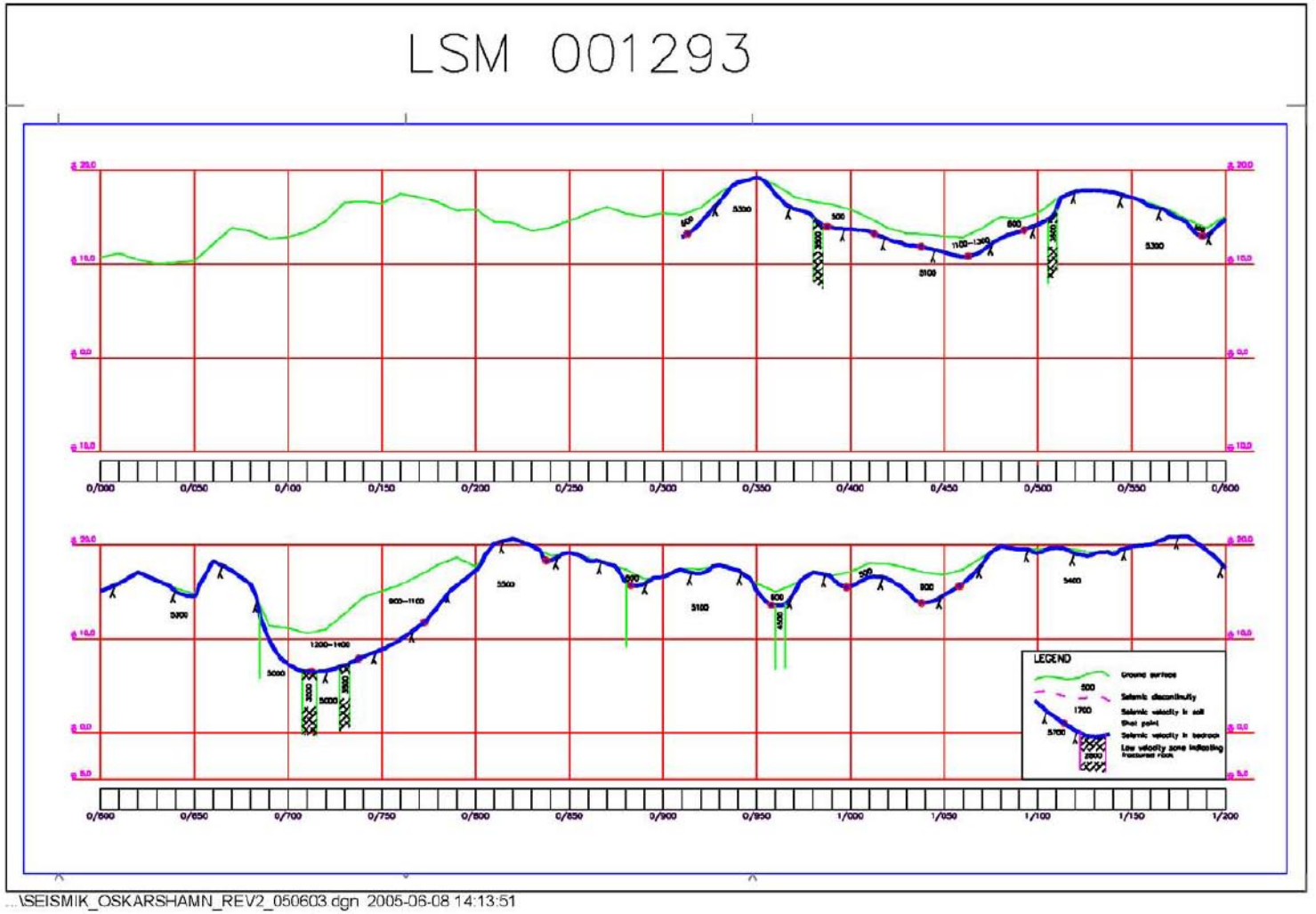

Figure A-9. *Refraction seismics in Laxemar during spring 2005. Profile LSM001293 chaining 310 - 1,200.*

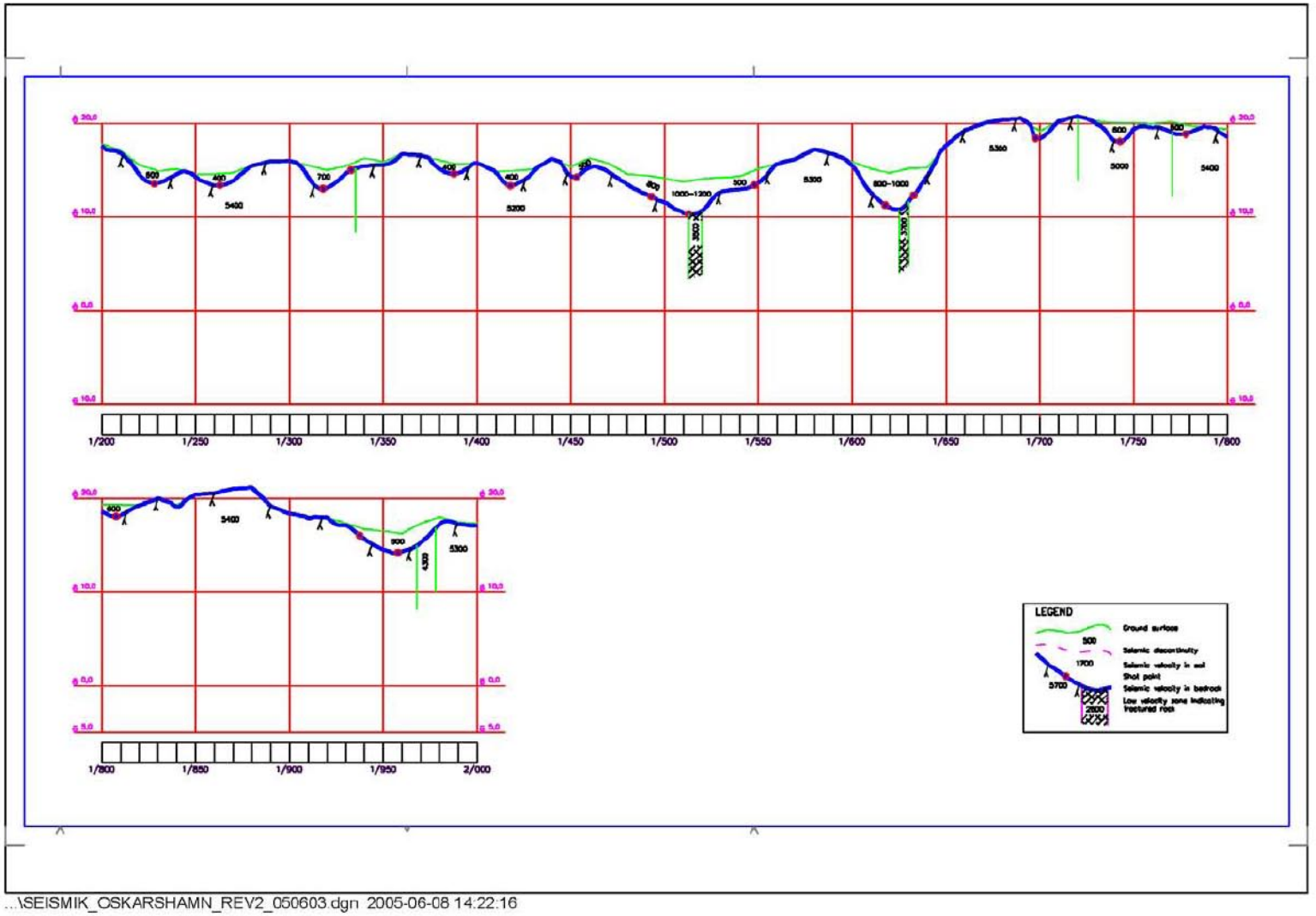

Figure A-10. *Refraction seismics in Laxemar during spring 2005. Profile LSM001293 chaining 1,200 – 2,000.*