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Oskarshamn site investigation

Refraction seismic measurements in Laxemar spring 2006

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Abstract

This document reports the execution and interpretation of refraction seismics performed in Laxemar during April 2006. 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 Laxemar subarea in Oskarshamn. A second objective was to obtain geometrical information such as thickness of overburden along the profiles.

Thirteen profiles with a total length of 3,970 m were measured. The geophone spacing was 2.5 m for all profiles except one where the geophone spacing was 5 m. The survey lines were placed to cross over lineaments mainly interpreted from laser data and detailed geophysical measurements from ground surface. A number of (52) usually 2.5 m wide zones with lower sound velocity, from 2,000 m/s up to 4,000 m/s with a mean value of 3,500 m/s were found. The sound velocity of the compact rock varied between 4,900 m/s and 5,900 m/s. The mean value of the sound velocity for compact rock was 5,500 m/s.

Sammanfattning

Rapporten presenterar utförandet och resultat av tolkningen av refraktionsseismik som genomfördes i Laxemar under april 2006. 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 delområde Laxemar i Oskarshamn. Ett delsyfte med undersökningarna var att bestämma tjockleken på överliggande jordtäcke längs med profilerna.

Tretton profiler med en total längd av 3 970 m undersöktes. Avståndet mellan geofonerna var 2,5 m för alla mätlinjer med undantag av en där avståndet var 5 m. Undersökningslinjerna placerades för att korsa lineament tolkade från laserdata samt från detaljerade geofysiska mätningar från markytan. Ett antal (52) i huvudsak 2,5 m breda zoner med lägre utbredningshastighet, från 2 000 m/s upp till 4 000 m/s med ett medelvärde på 3 500 m/s hittades. Utbredningshastigheten i friskt berg varierade mellan 4 900 m/s upp till 5 900 m/s. Medelvärdet på utbredningshastigheten i friskt berg var 5 500 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 400-06-043. 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.

Thirteen profiles with a total length of 3,970 m were measured. The geophone spacing was 2.5 m for all profiles except one where the geophone spacing was 5 m. The survey lines were placed to cross over interpreted lineaments mainly interpreted from laser data and detailed geophysical measurements from ground surface.

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 våren 2006 Laxemar	AP PS 400-06-043	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för refraktionsseimik	SKB MD 242.001	1.0

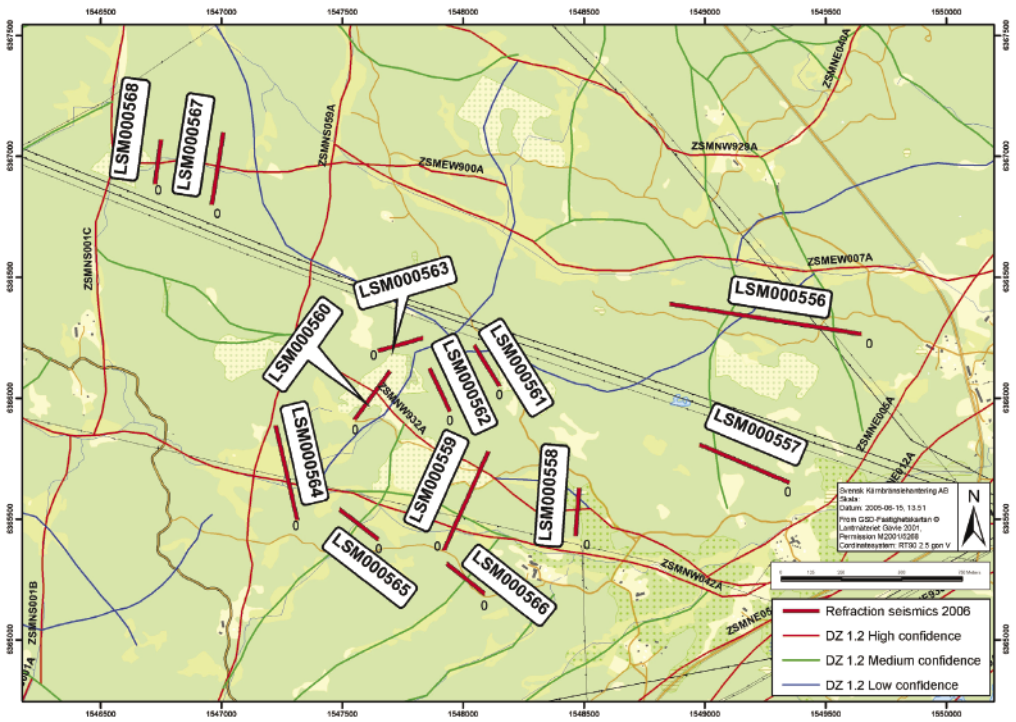

Figure 1-1. *Location of refraction seismic profiles in Laxemar subarea. Interpreted deformation zones with high, medium and low confidence from the preliminary site description of Laxemar are shown with red, green and blue lines respectively /3/.*

2 Objective and scope

The main objective of the investigation was to investigate possible tectonic lineaments interpreted from laser data and detailed geophysical measurements from ground surface /1/, /2/, /3/. Most of the interpreted lineaments focused for in this investigation were located within Laxemar subarea in Oskarshamn. A second objective was to obtain geometrical information such as thickness of overburden along the profiles.

Thirteen profiles with a total length of 3,970 m were measured. The geophone spacing used was 2.5 m for all profiles except LSM000566, for which 5 m was used. 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 normally placed with 2.5 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 were used which means that a full spread covers 57.5 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 calculated from the adjusted digital terrain model. 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.

Figur 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 profile LSM000558 was shortened from the planned 200 m down to 155 m due to deep water in a pond.

5 Results

The results discussed in the following section are shown as seismic sections in Figures A-1 to A-6 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 2,400 m/s correspond to moraine above or below ground water table.

Profile LSM000556, shown in Figure A-1 in Appendix 1, runs from east to west with start in east. The soil depth is generally small. For the parts of the profile with higher elevation, between chaining 210 m and 500 m and between 580 m and 710 m, the rock is mostly outcropping. Along the first 200 m the soil depth is 2–3 m and similar soil depths are found locally around chaining 520 m, 565 m and 720 m. Generally the sound velocity in the bedrock is 5,100 m/s or higher indicating competent bedrock. A number of zones with low sound velocity were found during the interpretation. The two most significant ones are found at 210 m and 320 m.

Profile LSM000557, shown in Figure A-2 in Appendix 1, runs almost east-west with start in east. The soil depth is less than 3 m along the first 140 m. Along the rest of the profile the soil depth is 3–8 m. Four minor zones with lower than normal sound velocity in the bedrock are found.

Profile LSM000558, shown in Figure A-2 in Appendix 1, runs south-north with start in south. The profile was shortened from the planned 200 m down to 155 m due to deep water in a pond. The soil depth is 5–8 m. The sound velocity in the soil indicates that the soil is a moraine. Only one minor low velocity zone in the bedrock was found.

The profile LSM000559, is shown in Figure A-3 in Appendix 1. The direction is SSW-NNE with start in SSW. The first 85 m is situated south of a small stream which divides the profile into two parts. The soil depth is 3–8 m all the way up to chaining 300 m. At 300 m the indicated depth is around 2 m. I can be that the soil at that place consists of fractured surface rock. From chaining 320 m up to the end of the profile there is outcropping rock or small soil depth. Between 50 m and 175 m there are agricultural fields. The soil in the surface is silty-sandy but around chaining 60 m there can be some clay. The interpretation at that place was complicated by some frozen soil at the surface. The normal sound velocity in the bedrock is 5,200 m/s or higher. Under the agricultural land there are four zones with lower than normal sound velocity in the bedrock. Three less significant zones are found along the rest of the profile

Profile LSM000560, shown in Figure A-3 in Appendix 1, is running SSW-NNE with start in SSW. The soil is 3–6 m thick along the first 160 m of the profile. Between 165 m and 180 m the bedrock is outcropping. At 185 m the sound velocity indicates fissured rock at the surface. From 195 m up to the end of profile at 255 m the soil depth is in the range 4–8 m.

The sound velocity in the bedrock is 5,500 m/s or higher with exception of the part between 25 m and 70 m where the velocity is around 4,900 m/s. Five narrow zones with lower than normal velocity are found. The most significant ones are found at 145 m and 215 m.

Profile LSM000561, shown in Figure A-4 in Appendix 1, is 200 m long and runs SE-NW with start in SE. The soil depth is generally 4–6 m. At the end of the profile the bedrock is close to the ground. The sound velocity in the bedrock is normally 5,500 m/s or higher. Six zones with low velocity are found. The most significant one is found at chaining 180 m.

Profile LSM000562, shown in Figure A-4 in Appendix 1, is placed about 200 m SW of LSM000561 and runs parallel to the same with start in SE. The soil depth is in the range of 5–10 m. The soil is probably a sandy moraine. The sound velocity in the bedrock is around 5,600 m/s. Three narrow zones with low sound velocity are found.

Profile LSM000563, shown in Figure A-4 in Appendix 1, runs almost west-east with start in west. The profile begins on outcropping rock and between chaining 5 m and 29 m there is a depression in the bedrock which seems to be filled with a soil of high organic content. After outcropping rock between chaining 29 m and 42 m the soil layer is thin up to 100 m. Along the second half of the profile the soil depth is 4–6 m. The sound velocity in the bedrock is around 5,500 m/s. Four thin low velocity zones are found, in most cases associated with depressions in the bedrock surface.

Profile LSM000564, shown in Figure A-5 in Appendix 1, is running SSE-NNW with start in SSE. The profile is crossing a stream at chaining 140 m. The profile starts on a small hill with big boulders. The soil depth varies between 1 m and 5 m along the first 80 m of the profile. Between chaining 85 m and 110 m there is a hill with outcropping rock. On the north side of the stream there is another hill with a thin soil cover. The depth to bedrock is 4–5 m at the stream. Between chaining 200 m and 320 m there is a agricultural field where the surface soil seems to contain some organic material. Deeper down the soil consists of clay on top of probably silt/sand. The soil depth between chaining 240 m and 310 m is 9–13 m. From chaining 330 m up to the end of the profile at 405 m the soil depth is 4–7 m. The sound velocity in the bedrock is about 5,300 m/s. Three out of the four low velocity zones found are connected with depressions and rapid changes of the bedrock elevation.

Profile LSM000565, shown in Figure A-5 in Appendix 1, is running in the ESE-WNW direction with start in ESE. The topography is rather dramatic along the profile. The soil layer is thickest, around 8 m, under the hill at chaining 45 m and under the last part of the profile where the depth is in the range 6–9 m. The sound velocity in the bedrock is generally around 5,600 m/s. Four zones with lower than normal velocity are found. The most significant one is situated in the valley at chaining 97 m.

Profile LSM000566, shown in Figure A-6 in Appendix 1, is running SE-NW with start in SE. The profile was measured with 5 m geophone distance. The soil layer is generally thin. The sound velocity in the bedrock is around 5,600 m/s with the exception of two narrow zones with lower velocity.

Profile LSM000567, shown in Figure A-6 in Appendix 1, runs close to S-N with start in S. The soil layer is either very thin or absent along the whole profile. At the shot point 157.5 m the calculated depth is 2.8 m. This is probably an underestimation because the distance between the outcrop to the south and the outcrop to the north is less than 20 m. The sound velocity in the bedrock is 5,300 m/s or higher except between chaining 110 m and 150 m where the sound velocity is 4,900 m/s. Three zones with lower velocity are found. The one at 152 m is most significant.

Profile LSM000568, shown in Figure A-6 in Appendix 1, is placed about 250 m W of LSM000567 and runs parallel to the same with start in S. The soil is thin or absent up to chaining 60 m. Thereafter the soil thickness is in the range 3–8 m except at the end of the profile where the rock again is close to the surface. The sound velocity in the bedrock is around 5,600 m/s. Three zones with low velocity are found. The one at 175 m is most significant and is associated with a marked depression in the bedrock surface.

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 varied between 4,900 m/s up to 5, 900 m/s. The mean value of the bedrock velocity for compact rock was 5,500 m/s. This indicates solid bedrock. A number of (52) usually 2.5 m wide zones with lower sound velocity were found. The sound velocity for most of these zones was in the interval 2,000–4,000 m/s with a mean value of 3,500 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 2.5 m. This means that a zone with fractures that show up during the interpretation can be less than 2.5 m. One final remark regarding low velocity zones in the bedrock is that a 2.5 m wide zone with a sound velocity of 3,500 m/s corresponds to an extra delay of the signal with about 0.25 milliseconds which is close to or even lower than the resolution for the method, see method description MD 242.001.

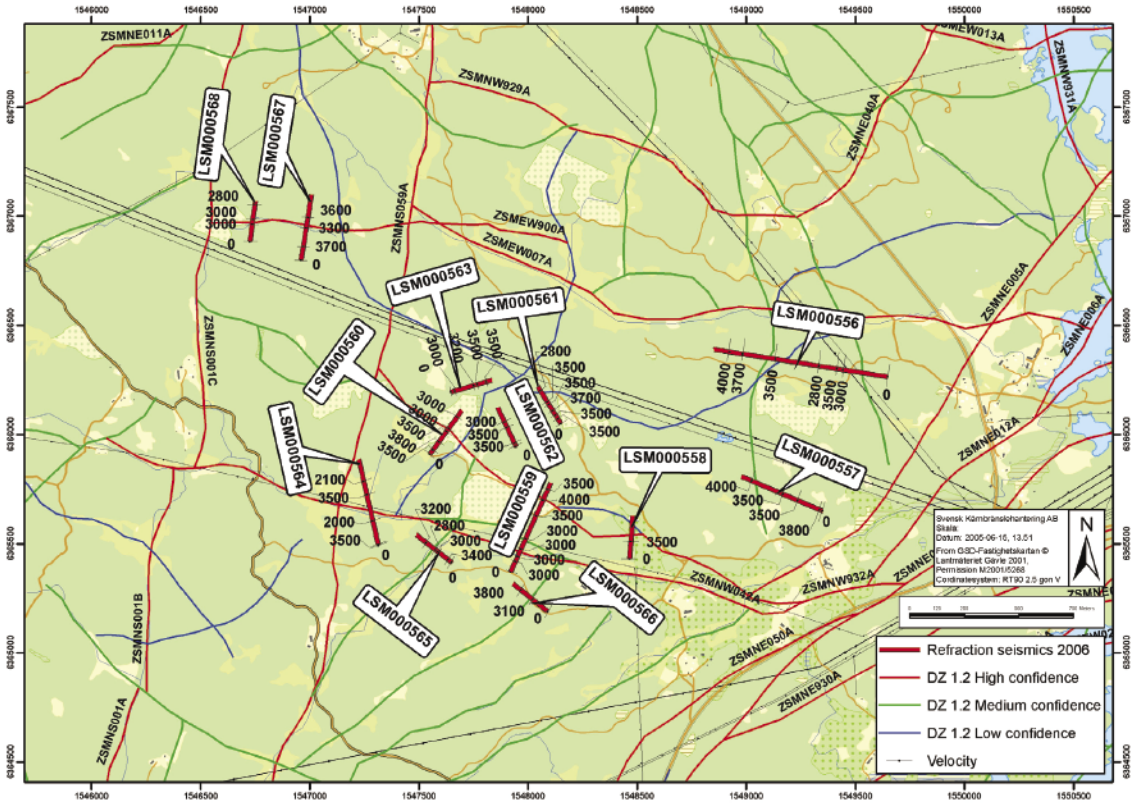

Figure 5-1. *Location of low velocity zones in the bedrock interpreted from this refraction seismic survey. The low velocity zones are marked with tic-lines along the profiles. Interpreted deformation zones with high, medium and low confidence from the preliminary site description of Laxemar are shown with red, green and blue lines respectively /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 våren 2006.dwg (drawings in Appendix 1).
- EG170_Line surveying_Laxemar_Refraktionsseismik_2006.xls (listing of line coordinates).
- GP320_Refraction seismics_Laxemar_våren_2006.xls.

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/1/ **Berglund J, Nyborg M, Triumf C A and Thunehed H, 2006**. Oskarshamn site investigation. Coordinated presentation of topographic and geophysical lineaments in selected areas, including field assessment – Laxemar area. SKB P-06-15. Svensk Kärnbränslehantering AB.

/2/ **Triumf C A and Thunehed H, 2006.** Oskarshamn site investigation. Detailed ground geophysics at Laxemar, autumn/winter 2005/2006 (in press). Svensk Kärnbränslehantering AB.

/3/ **SKB, 2006**. Preliminary site description. Laxemar subarea – version 1.2. SKB R-06-10. Svensk Kärnbränslehantering AB.

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

Interpretation of refraction seismic sections in Laxemar

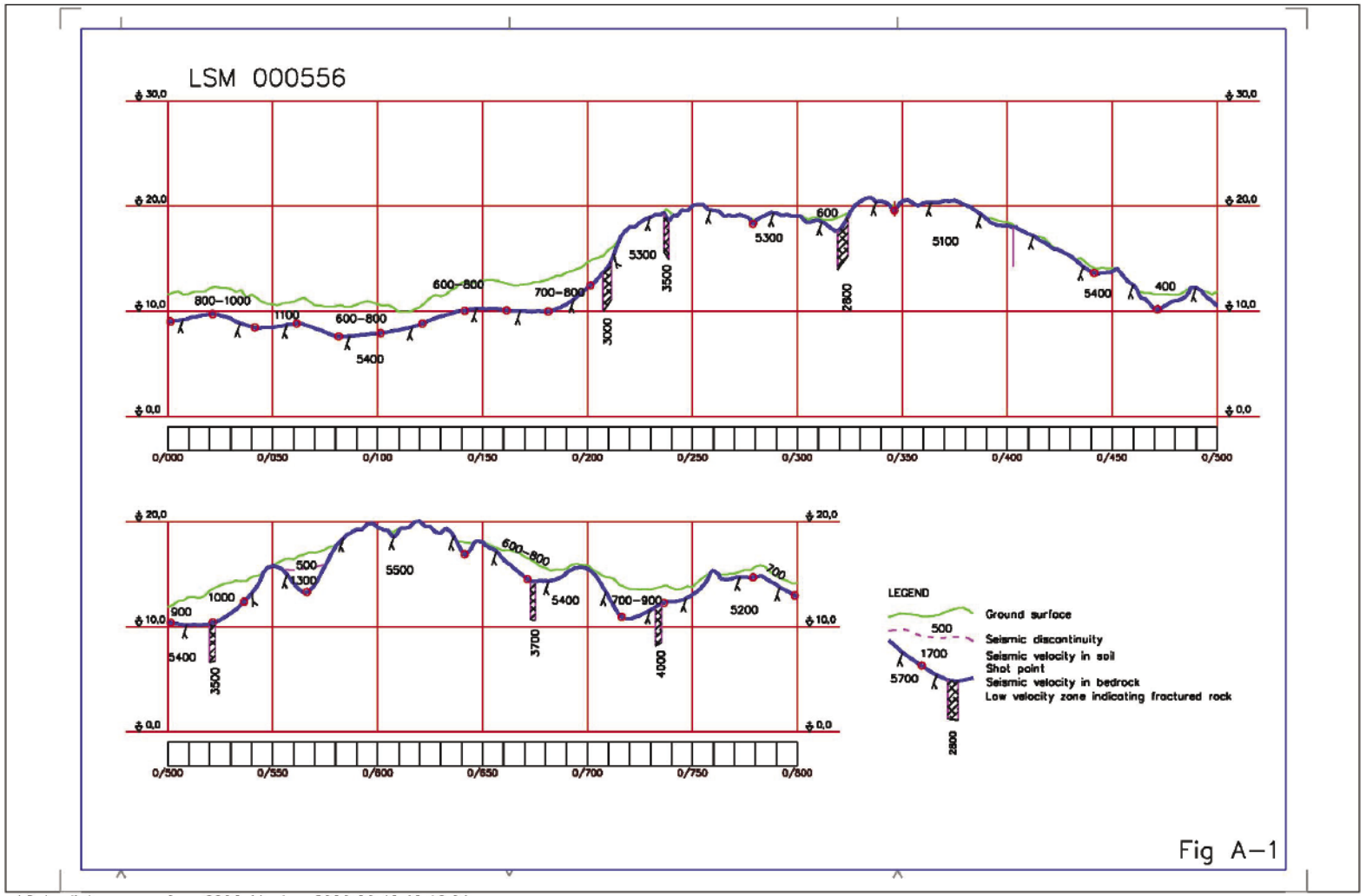

Figure A-1. *Refraction seismics in Laxemar during spring 2006. Profile LSM000556.*

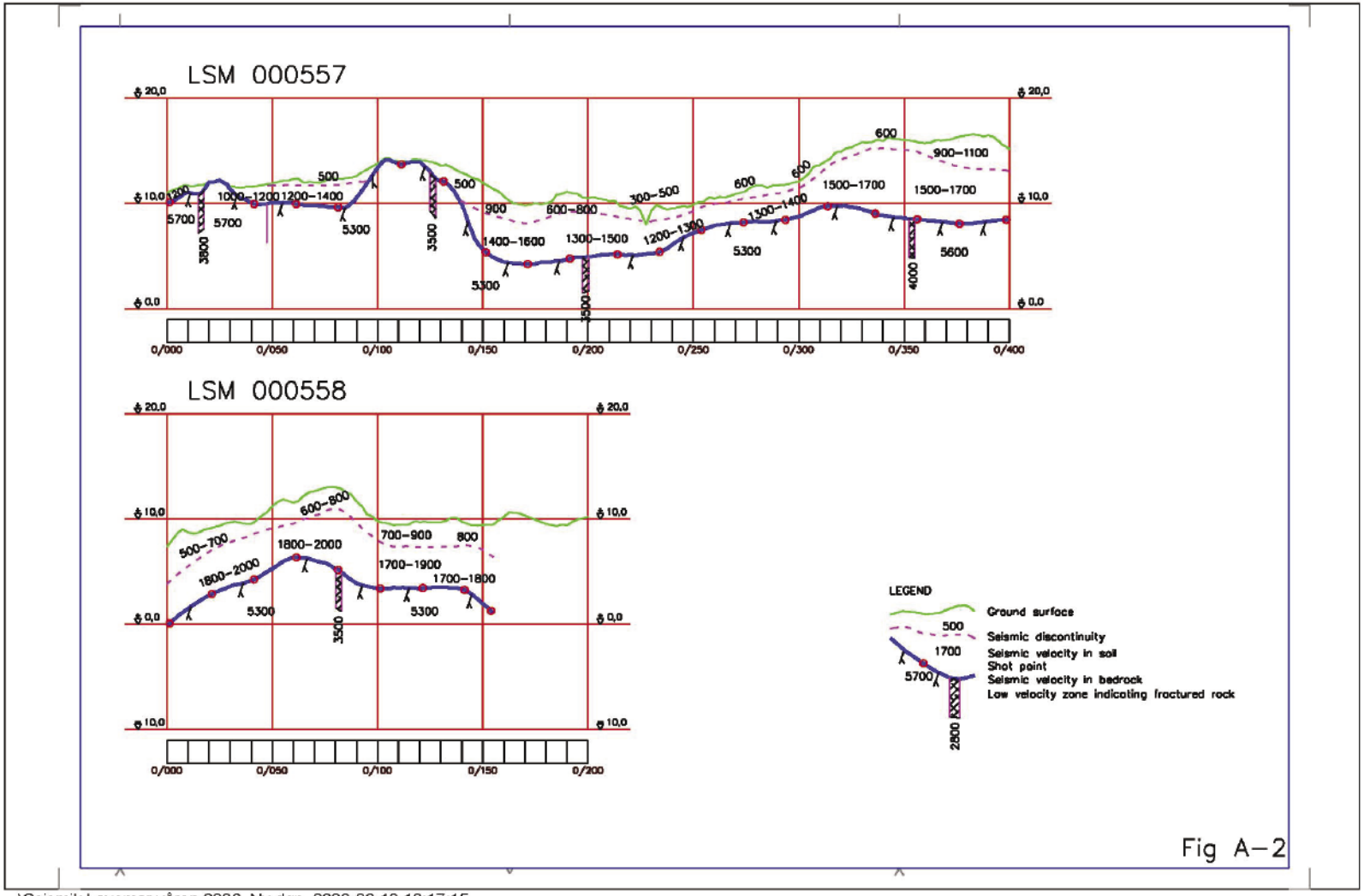

Figure A-2. *Refraction seismics in Laxemar during spring 2006. Profile LSM000557 and LSM000558.*

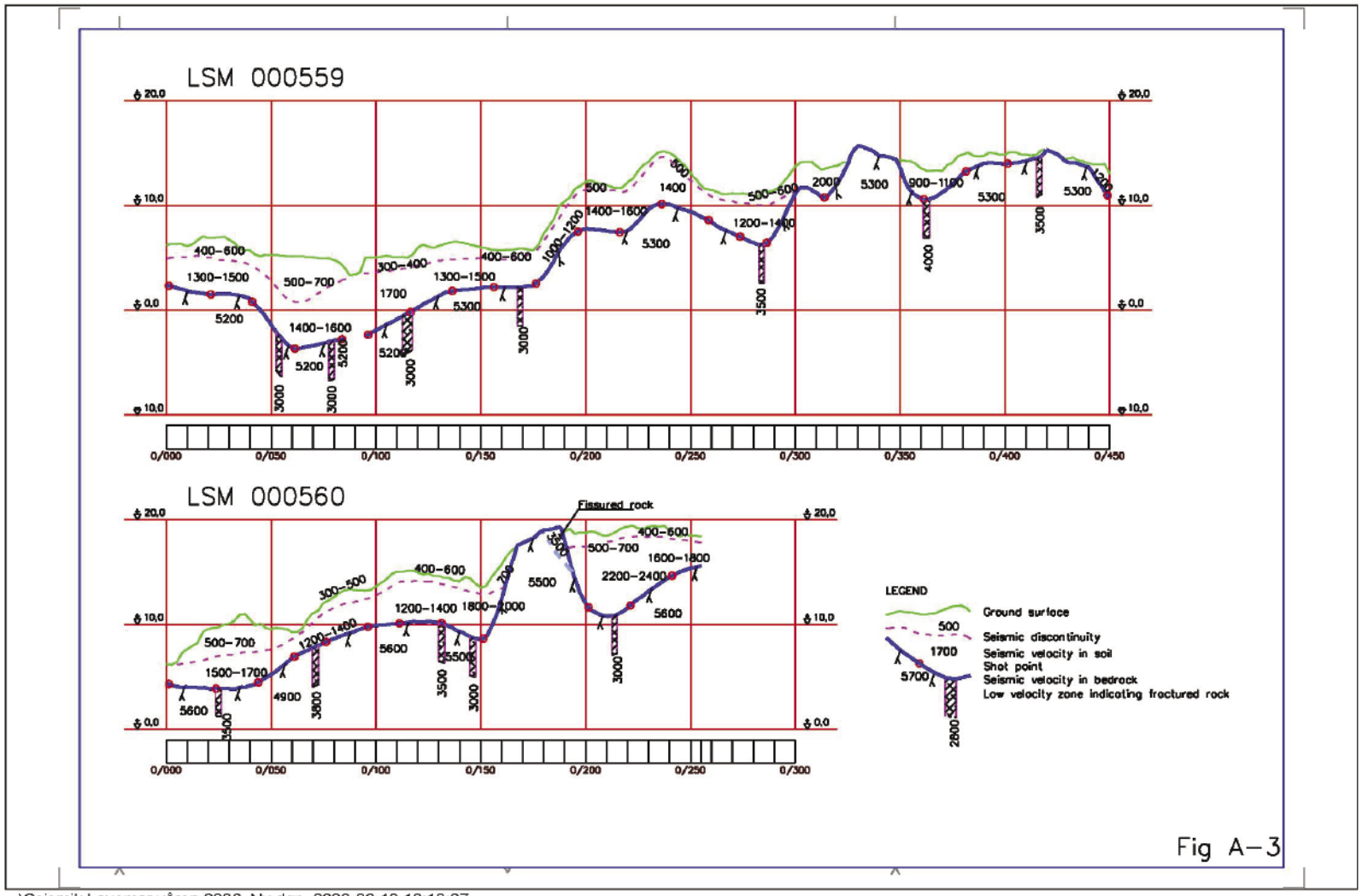

Figure A-3. *Refraction seismics in Laxemar during spring 2006. Profile LSM000559 and LSM000560.*

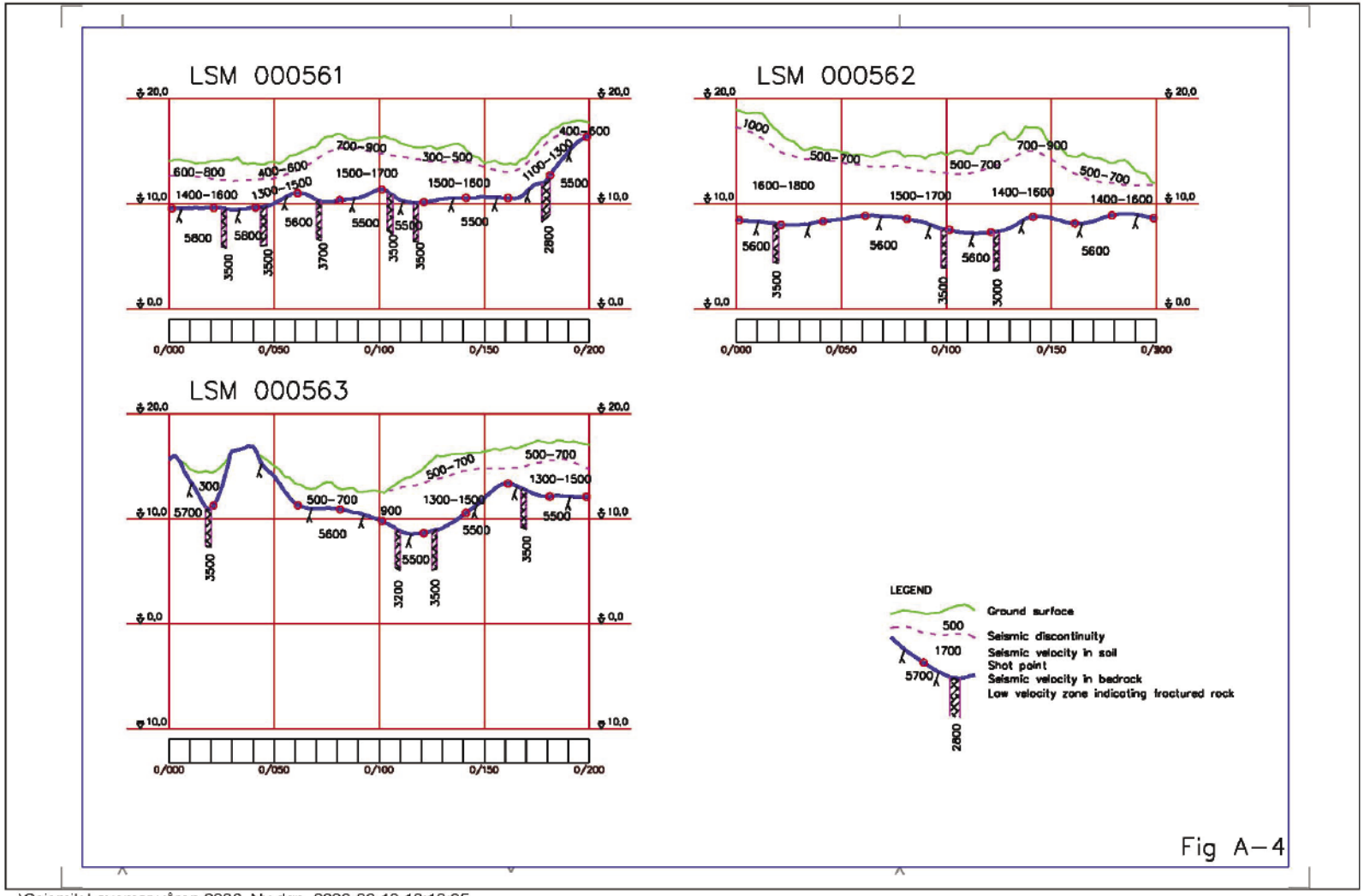

Figure A-4. *Refraction seismics in Laxemar during spring 2006. Profile LSM000561, LSM000562 and LSM000563.*

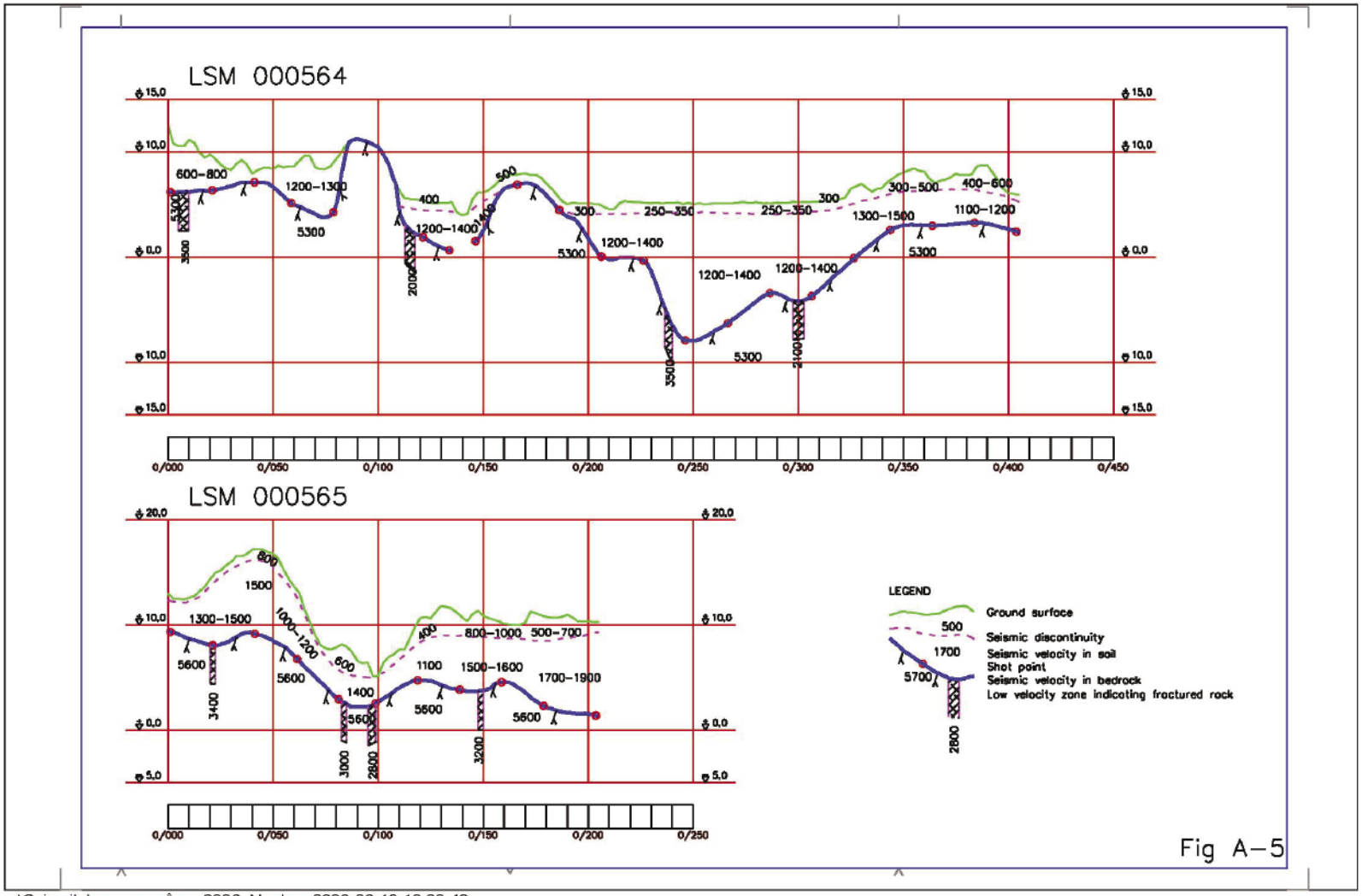

Figure A-5. *Refraction seismics in Laxemar during spring 2006. Profile LSM000564 and LSM000565.*

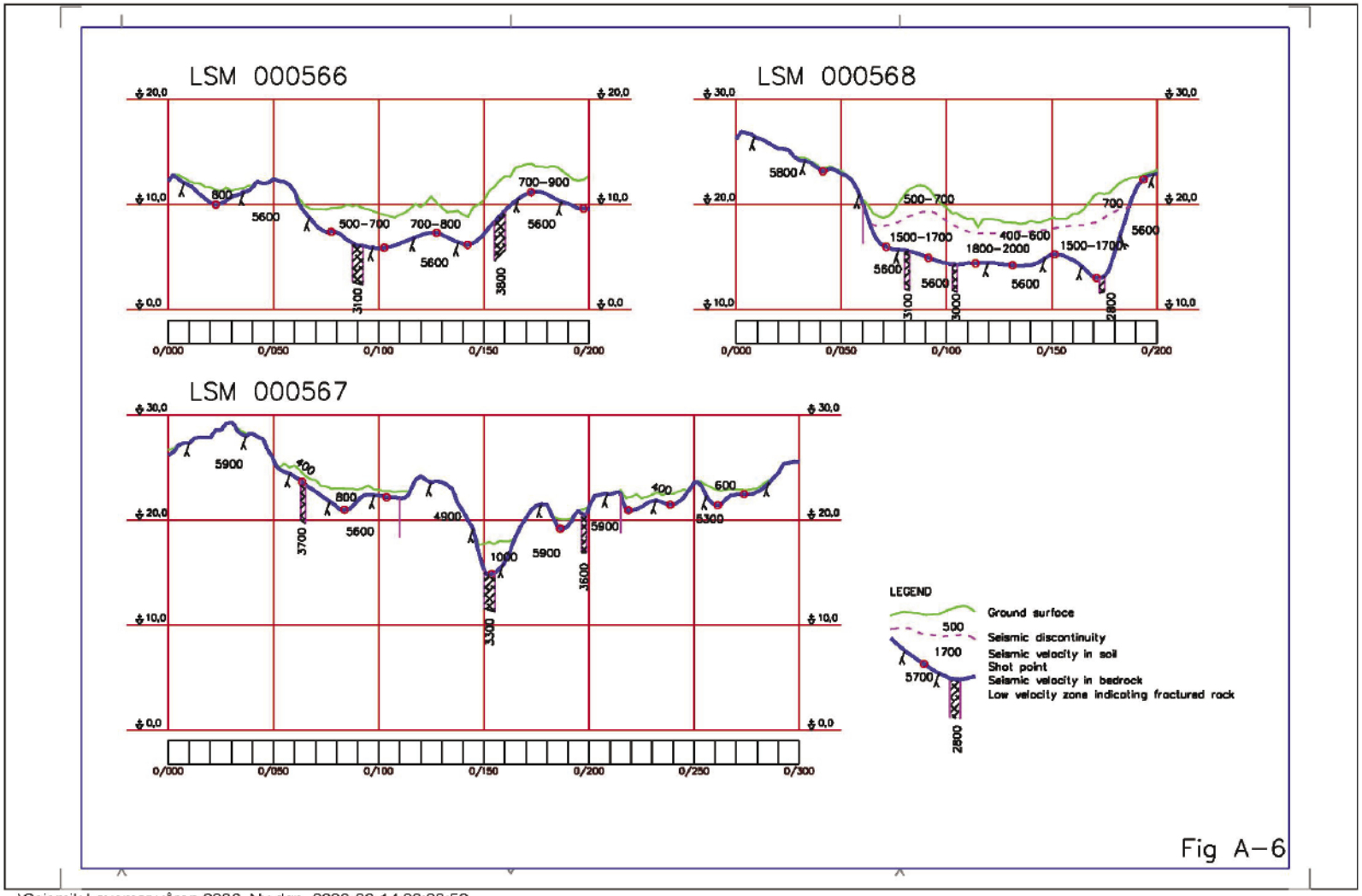

Figure A-6. *Refraction seismics in Laxemar during spring 2006. Profile LSM000566, LSM000567 and LSM000568.*