P-04-201

Oskarshamn site investigation

Refraction seismic measurements in the water outside Simpevarp and Ävrö and on land on Ävrö

Gustaf Lindqvist, MRM Konsult AB

April 2004

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

ISSN 1651-4416
SKB P-04-201

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Keywords: Refraction seismics, Bedrock velocity, Soil velocity, Overburden, Soil depth, Water depth.

Abstract

This document reports the execution and interpretation of refraction seismics performed in the water outside Simpevarp and Ävrö and on land on Ävrö during December 2003. All measurements were conducted by MRM Konsult AB and GEOMAP a.s.

The objective of the refraction seismic survey was to contribute to the determination of whether the interpreted lineaments are deformation zones or not. The contribution is made by means of interpretation of seismic velocities in the shallow rock and in the overburden. Geometrical information such as thickness of overburden and water depth along the profiles is also obtained.

Twelve profiles with a total length of 3,200 m were measured at sea and two profiles with a total length of 680 m were measured on land. The survey lines were placed to cross over 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, 2,800 m/s up to 4,400 m/s, while the velocity of the sound rock were in the range from 5,000 m/s up to 6,300 m/s with a mean value of 5,562 m/s.

Sammanfattning

Rapporten presenterar utförandet och resultat av tolkningen av refraktionsseismik som genomfördes i vattnet utanför Simpevarp och Ävrö och på land på Ävrö under december 2003. Mätningarna genomfördes av MRM Konsult AB och GEOMAP a.s. Tolkningen genomfördes av MRM Konsult AB.

Syftet med undersökningarna var att undersöka om möjliga tektoniska lineament identifierade med olika geologiska och geofysiska metoder orsakas av deformationszoner i berggrunden eller inte. Undersökningen genomförs genom att tolka seismiska gånghastigheter i den övre berggrunden och ovanliggande jordtäcke. Geometrisk information som tjockleken på överliggande jordtäcke samt vattendjup längs med profilerna erhålls dessutom.

Tolv profiler med en total längd av 3 200 m undersöktes över havet och två profiler med en längd av 680 m mättes på land. Undersökningslinjerna placerades för att korsa tolkade lineament identifierade från flygfotografier och från geofysiska mätningar med helikopter. Huvuddelen av de tolkade lineamenten veriferades som en zon med lägre utbredningshastighet i berget, från 2 800 m/s upp till 4 400 m/s, medan utbredningshastigheten i friskt berg varierade mellan 5 000 m/s upp till 6 300 m/s med ett medelvärde på 5 562 m/s.

Contents

1 Introduction

This document reports the results gained by the measurements and interpretation of refraction seismics performed in the water outside Simpevarp and Ävrö and on land on Ävrö during December 2003, 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 400-03-070 (SKB internal controlling document). In Table 1-1 the controlling documents for performing this activity are listed.

Twelve profiles with a total length of 3,200 m were measured at sea and two profiles with a total length of 680 m were measured on land. The survey lines were placed to cross over lineaments mainly interpreted from air photos or geophysical measurements from helicopter /1, 2, 3/.

The location of the profiles is shown in Figure 1-1.

Table 1-1. Controlling documents for the performance of the activity (SKB internal controlling documents).

Activity plan	Number	Version
Refraktionsseismik i vattnet utanför Simpevarp och Ävrö och på land på Ävrö	AP PS 400-03-070	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för refraktionsseimik	SKB MD 242.001	1.0

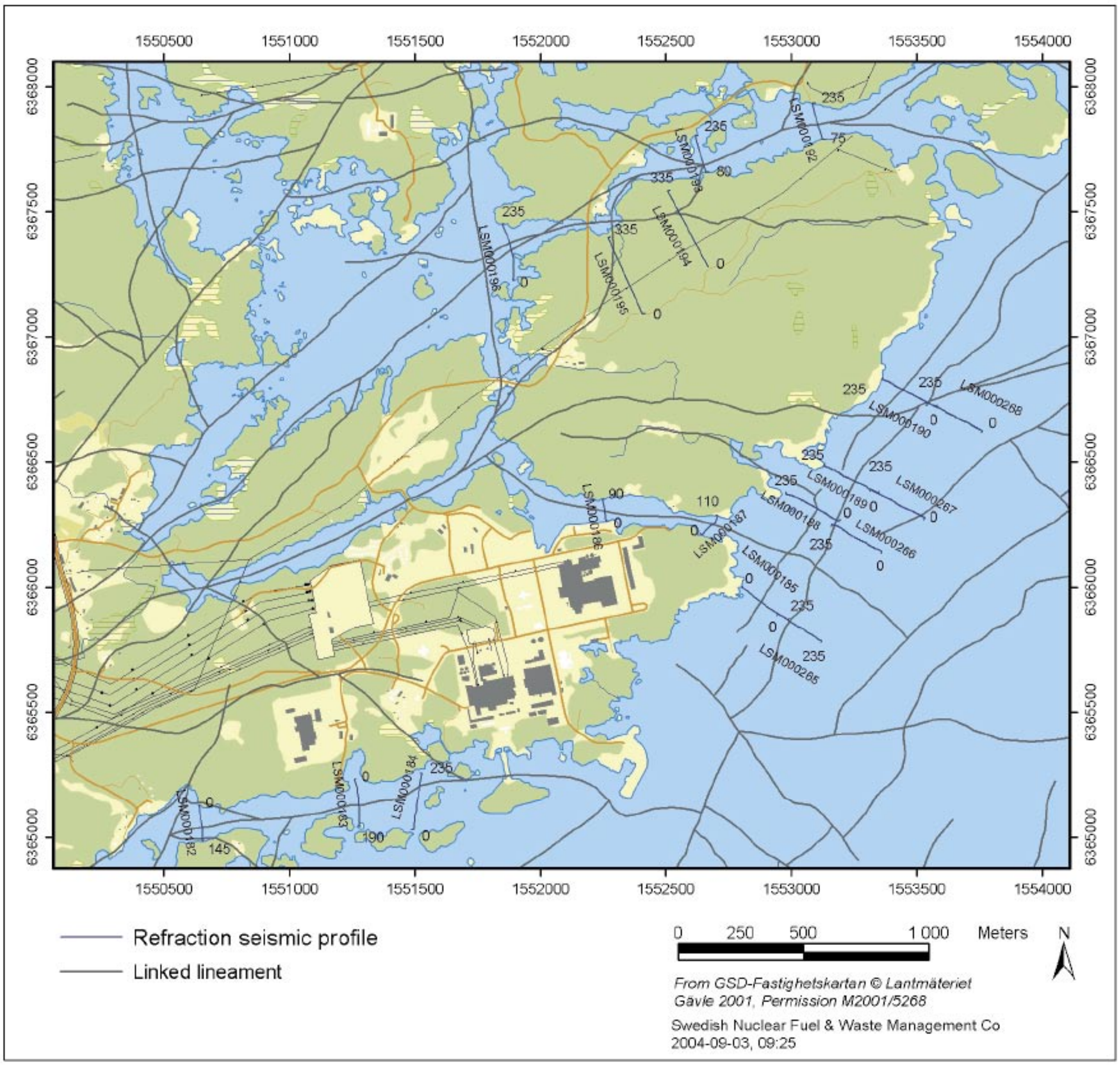

Figure 1-1. *Location of refraction seismic profiles in the sea outside Simpevarp and Ävrö and on Ävrö. Lineaments presented are linked lineaments interpreted from air photos and helicopter airborne geophysics /3/.*

2 Objective and scope

The objective of the refraction seismic survey was to contribute to the determination of whether the interpreted lineaments /1, 2, 3/ are deformation zones or not. The contribution is made by means of interpretation of seismic velocities in the shallow rock and in the overburden. Geometrical information such as thickness of overburden and water depth along the profiles is also obtained. The location of the profiles is shown in Figure 1-1.

3 Equipment

3.1 Description of equipment

3.1.1 Refraction seismic measurements at sea

Boats

The measurement at sea requires one boat to handle the hydrophone cable, Figure 3-1. The recording instrument can be stationed on shore or on another boat. During this survey most of the measurements were carried out with 2 boats. The hydrophone cable is heavy and the boat used for that operation has a hydraulic winch in the front to support when pulling in the cable. The cable operation boat is equipped with a navigation system described below.

Navigation

The equipment consists of a DGPS navigation system working together with a reference signal from a Starfix system satellite. The received coordinates are transformed to the Swedish coordinate system RT90 2.5 gon V by an on board computer. Prior to the seismic measurements the navigation system was checked against a point with known coordinates at the outlet of cooling water from the power station O3. The agreement between the coordinate systems after transformation was within 0.2 m.

Figure 3-1. *Boat with hydrophone cable.*

The navigation data are stored in an event log. The events are trigged manually. Examples of events are planned start and end of profile. Such data are then used to keep the boat along the planned survey line. Normally the positions of the shot points are recorded when the cable is lowered into the water. Every event gives the coordinates for the bow of the boat and also the coordinates for the echo sounder.

Energy source

To generate the sharp impulses needed a normal commercial explosive with trade name Dynamit was used. To ignite the charges a normal type electrical detonator was used. The detonators are of the safety type used in Sweden and the delay was around 20 milliseconds.

Hydrophone cable

The hydrophone cable consists of two separate cables taped together. One cable carries the electrical current to the detonators and dynamite charges placed with 25 m spacing along the cable. The other cable carries the signals from the pressure sensitive hydrophones placed with 5 m separation along the cable. The cable has 48 hydrophones which means that a full spread covers a length of 235 m. The first shot is placed at 7.5 m which gives 10 shots within a full spread. The recording instrument is connected to the active cable by a 200 m long lead cable.

Recording instrument

The signals from the hydrophones are recorded digitally in SEG-2 format by a 48 channel instrument, ABEM Terraloc MK6, Figure 3-2.

Figure 3-2. *The recording instrument, ABEM Terraloc MK6.*

3.1.2 Refraction seismic measurements on land

On land the charges are buried into the ground. The shots are ignited with a separate shot cable. The vibrations in the ground are picked up by geophones, 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 were used which means that a full spread covers 115 m. The same recording instrument, ABEM Terraloc MK6, was used for the measurements on land. The refraction seismic measurements on land was performed according to the method description for refraction seismic SKB MD 242.001 (SKB internal controlling document).

4 Execution

In general the refraction seismic measurements on land was performed according to the method description for refraction seismic SKB MD 242.001 (SKB internal controlling document). Over the sea the procedures was slightly different to the MD 242.001. The description below concentrates on some special procedures for the sea measurements.

4.1 Measurements in water

4.1.1 Position and depth of cable

The final positions of the survey lines was decided out of practical considerations and with the goal to achieve the most information from the survey. When possible, the profiles start and end on rock exposures. In general only small changes of the originally planned program were needed.

The start and end coordinates of the survey lines sometimes was difficult to record because of very shallow water and/or high sea. Each survey line was at first defined by a recorded start and end point. Under ideal conditions the cable should be placed along a straight line between these points. This goal is in practice not always achieved. Every navigation event is supposed to give one depth recording but in some cases high sea or bubbles from the propeller disturbed the echo sounder. The errors in distance between the hydrophones are however always very small.

The position of the cable for the profiles P7–P9 (LSM000188–LSM000190 and LSM000266–LSM000268) was determined by recording the arrival times from shots at ten predetermined points for each hydrophone spread. This gives the position of each hydrophone along the cable. The profile P4 (LSM000185 and LSM000265) was measured under good weather conditions so the positioning of the shots when placing the cable was considered to be good enough.

4.1.2 Water level

With existing recordings of the sea level it was possible to correct for variations of the level during the field work. The recording station is located at the southern side of Äspö. The Table 4-1 shows the profile numbers, the time when cable was put in place and the sea level. As seen in the table the corrections are normally very small.

Table 4-1. Registered sea water level during the field work.

Profile No in AP PS 400-03-070	SKB ID- code	Time	Sea water level
1	LSM000182	2003-12-04 09:30	–0.21
2	LSM000183	2003-12-04 11:30	–0.23
3	LSM000184	2003-12-08 14:50	0
4-1	LSM000185	2003-12-05 10:20	–0.05
4-2	LSM000265	2003-12-05 12:40	–0.08
5	LSM000186	2003-12-04 14:00	–0.27
6	LSM000187	2003-12-05 08:30	–0.06
7-1	LSM000188	2003-12-07 11:10	–0.17
7-2	LSM000266	2003-12-07 13:10	–0.18
8-1	LSM000189	2003-12-09 08:40	0.02
8-2	LSM000267	2003-12-09 11:10	0.02
9-1	LSM000190	2003-12-09 12:50	0.02
9-2	LSM000268	2003-12-09 14:20	0.02
11	LSM000192	2003-12-08 09:00	0.01
12	LSM000193	2003-12-08 10:50	0.04
13	LSM000194	2003-12-06 09:00	On land
14	LSM000195	2003-12-06 13:00	On land
15	LSM000196	2003-12-08 12:40	Inland lake

4.2 Analyses and Interpretation

4.2.1 Data extraction

The arrival times from the different shots were picked using a software built into the recording instrument ABEM Terraloc MK6. The arrival data was used to generate a time-distance plot to be used for the interpretation.

4.2.2 Interpretation

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

4.3 Nonconformities

One planned profile out in the Baltic Sea, P10 (LSM000191) was not measured due to bad weather conditions.

5 Results

The results discussed in the following section are shown as seismic sections in Figures 5-1 to 5-18 in Appendix 1. The seismic sections were delivered in .dwg format in the length scale 1:1000 and depth scale 1:500. 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 to 18 velocities in the uppermost part corresponds to the overburden. Velocities from c 600 up to 1 000 m/s correspond to loose top soil. Velocities from 1 200 up to 2 300 m/s correspond to moraine above the rock surface.

Profile 182 (LSM000182), Figure 5-1 in Appendix 1, shows a water depth of around 2 m. The soil thickness is around 15 m and as a maximum 25 m. The bedrock quality seems to be good with the exception of a low velocity zone between chaining 100 m and 125 m. The low velocity zone can be somewhat narrower but in such a case the sound velocity across the low velocity zone will be even lower than the 2,800 m/s shown.

Profile 183 (LSM000183), Figure 5-2 in Appendix 1, starts and ends on shore. The water depth is around 5 m in the centre part of the line. Between chaining 50 m and 120 m the bedrock level is around –20 m. At chaining 135 m the bedrock is close to –30 m. Looking at the bedrock topography one expects to find low velocity zones around chaining 70 m and chaining 135 m. However, no time loss is found for the signals transmitted through the rock under the local depressions at these locations. The low velocity zones ought to be there but they appear to be narrow since they did not show up in the recordings.

The profile 184 (LSM000184), Figure 5-3 in Appendix 1, is measured from east towards west. The water depth increases from 0 m to around 6 m at chaining 190 m and decreases again to around 3 m at the end of the profile. The bedrock level decreases from 0 m to around –10 m at chaining 30 m and undulates around that level until chaining 130 m where the bedrock dives down towards the lowest level –25 m. at chaining 160 m. The bedrock climbs up to around –15 m at chaining 180 m and is around –12 m at the end of the profile. One low velocity zone in the bedrock is found at chaining 170 m. The velocity of this zone is about 3,700 m/s.

The depressions in the bedrock level around profile 182/110 m, profile 183/135 m and profile 184/160 m are probably caused by the same tectonic lineament according to the strike of this lineament.

Profile 185 (LSM000185), Figure 5-4 in Appendix 1, starts close to land and runs eastward towards the open sea. Profile 265 (LSM000265), Figure 5-5 in Appendix 1, is a continuation of profile 185 with an overlap of about 49 m. The water depth increases from close to 0 m up to 15 m at chaining 120 m. The sea bottom is very flat around –17 m between profile 185 chaining 140 m and profile 265 chaining 90 m. The sea bottom then climbs up to around –13 m at profile 265/120 m. The water depth increases towards the end of the profile to 16–17 m. The soil thickness is zero or very small up to profile 185 chaining 130 m. The soil layer increases thereafter in thickness and varies around 12 m at profile

185 chaining 200 m where the bedrock level reaches –30 m. Moving further towards east the depth decreases and at profile 265 chaining 90 m the soil depth is close to 0 m. Between profile 265 chaining 100 m and profile 265 chaining 140 m the soil is very thin or absent. Further on towards the end of profile 265 the soil thickness is around 3 m and the bedrock level is around –20 m. The sound velocity in the bedrock is generally very high. One minor low velocity zone is found at profile 185 chaining 90 m with a velocity of 3,700 m/s and one broader and more significant low velocity zone is found at profile 185 chaining 200 m with a velocity of 3,900 m/s.

Profile 186 (LSM000186), Figure 5-6 in Appendix 1, starts and ends on rock close to the shoreline. The water depth is 5–6 m. The bedrock level dives down from 0 m. in the beginning of the profile to –25 m at chaining 30 m. The depression in the bedrock seems to be symmetric and the level –10 m is again reached at chaining 60 m. There seems to be a zone with low sound velocity in the bedrock at chaining 35 m, e.g. the centre of the depression. The velocity of the zone is 2,400 m/s.

Profile 187 (LSM000187), Figure 5-7 in Appendix 1, starts on a rock outcrop and ends very close to rock. The water depth is as maximum 7 m at chaining 40 m. The bedrock level is close to 0 m. at the beginning of the profile, sinks down to –14 m at chaining 30 m and climbs up to near 0 m at the end of the profile. A low velocity zone in the bedrock with sound velocity of 4,400 m/s is found between chaining 20 m and 35 m. A broader zone with a somewhat lower than normal velocity of 4,700 m/s is found between chaining 35 m and 65 m. After chaining 65 m the sound velocity in the bedrock is as high as 6,200 m/s, indicating good quality rock. At the end of the profile there is one up to 5 m thick layer of fractured rock on top of the competent bedrock. The sound velocity of that layer is around 3,700 m/s.

Profile 188 (LSM000188), Figure 5-8 in Appendix 1, and profile 266 (LSM000266), Figure 5-9 in Appendix 1, were meant to overlap. Due to bad weather they became a little misplaced. The profiles runs from east towards west. Profile 188 ends at the shoreline (chaining 235 m). The water depth increases from close to 0 m at chaining 235 m to 15 m at chaining 80 m and after that the sea floor is horizontal up to the start of the profile. The soil is thin or absent from land (chaining 235 m) up to chaining 160 m. The soil thickness increases thereafter and a maximum soil depth of around 15 m is found at chaining 30 m. The bedrock level there is close to –30 m. At the beginning of the profile (chaining 0 m) the bedrock level is around –20 m. The sound velocity in the bedrock is generally above 5,300 m/s. A 10 m wide low velocity zone, with a velocity of 4,200 m/s, found at the very end of the profile can be an artefact of the method. There is a possibility that the bedrock is fractured at the surface which can be misinterpreted when the outer shot is too close. At chaining 30 m, where the bedrock level is as lowest, a 20 m wide low velocity zone with the sound velocity of 3,400 m/s is found.

Profile 266 (LSM000266), Figure 5-9 in Appendix 1, ends about 20 m west of the beginning of profile 188. Profile 266 runs from east towards west The sea bottom at the end of the profile is around the level – 15 m. Between chaining 210 m and 160 m outcropping bedrock is forming the sea bottom. The minimum water depth is around 9 m. Further east the water depth increases to 15 m. At the end of the profile the bedrock level is close to –30 m. The bedrock level is around –9 m at chaining 175 m and after that there is a gentle slope towards a level of –20 m at the beginning of the profile. The sound velocity in the bedrock along profile 266 is determined to be 6,300 m/s all the way.

Profile 189 (LSM000189), Figure 5-10 in Appendix 1 and profile 267 (LSM000267), Figure 5-11 in Appendix 1, are measured with a 33 m overlap. The two profile parts are measured from east towards west. The water depth increases from close to 0 m at the shore, at profile 189 chaining 235 m, to close to 14 m at chaining 100 m. The water depth at the beginning of profile 189 up to profile 267 chaining 200 m is about 12 m and increases to 17 m at profile 267 chaining 100 m. The water depth is thereafter constant up to the beginning of the profile 267. The thickness of the soil layer is generally 2–4 m. The lowest bedrock level is around –20 m, a level found at profile 189 chaining 100 m and between profile 267 chaining140 m and 20 m. The sound velocity in the bedrock is 5,300 m/s or higher with the exception of one 25 m wide zone with lower velocity, with a sound velocity of 4,300 m/s found at profile 189 chaining 115 m.

Profile 190 (LSM000190), Figure 5-12 in Appendix 1 and profile 268 (LSM000268), Figure 5-13 in Appendix 1 are measured with a 37 m overlap. The two profiles are measured from east towards west. The water depth close to land at profile 190 chaining 235 m is about 4 m. The water depth increases first slowly and than faster when moving away from land. At profile 190 chaining 100 m the water depth is 12 m. The sea bottom level is around –14 m from profile 190 chaining 80 m up to profile 268 chaining 160 m. The water depth decreases thereafter to around 11 m for the rest of the profile with a local exception at profile 268 chaining 40 m where it is around 13 m. The soil layer is thin from the shore out until the deeper water at profile 190 chaining 100. Between profile 190 chaining 100 and profile 268 chaining 170 the soil layer is 5–8 m thick and the bedrock level is around –22 m in this part. For the rest of profile 268 the soil layer is thin or absent with an exception at profile 268 chaining 35 m where the soil thickness is around 4 m. The sound velocity in the bedrock is 5,400 m/s or higher with a few exceptions. At profile 190 chaining 100 m there is a 35 m wide low velocity zone with a sound velocity of 4,200 m/s and at profile 268 chaining 175 m there is a 10 m wide low velocity zone with a velocity of 3,900 m/s. At profile 268 chaining 35 m there is possibly a minor low velocity zone in the otherwise high velocity rock.

Profile 192 (LSM000192), Figure 5-14 in Appendix 1, starts (75 m) and ends (235 m) on outcropping rock. The water depth increases rapidly from 0 m to around 10 m when moving along the profile from each end. The soil layer is about 50 m in the central parts of the profile. The recorded data suggests that the slope of the bedrock can be even steeper than shown here. At chaining 80 m the bedrock level is calculated to be at –8 m and at chaining 100 m the bedrock level is calculated to be at –40 m. The deepest level, around – 60 m, is found between 130 m to 185 m. At chaining 200 m the bedrock level is around –52 m and at the profile end at 235 m the level is at –1 m. With this dramatic bedrock topography it is difficult to calculate the sound velocity distribution in the bedrock. An estimation is that there is a 20 m wide low velocity zone at chaining 145 m with a sound velocity of 2,500 m/s.

Profile 193 (LSM000193), Figure 5-15 in Appendix 1, starts (80 m) and ends (235 m) very close to outcropping rock above water. The water depth is around 5 m from the beginning of the profile up to the middle of the profile. The water depth decreases thereafter and is small at the end of the profile. The soil layer is around 10 m thick between chaining 110 m and 170 m. Along the other parts of the profile the soil depth is 2–3 m. The bedrock level is around –4 m in the beginning (80 m) and reaches –16 m at 120 m and –12 m at 170 m. Between chaining 180 m and 220 m the level is close to –5 m. In the bedrock one 15 m wide low velocity zone is found at chaining 115 m with a sound velocity of 3,300 m/s.

Profile 194 (LSM000194), Figure 5-16 in Appendix 1, is measured on land. The profile is 345 m long. The soil cover is thin or absent along most of the profile. Between chaining 235 m and 270 m there is a small valley where the soil layer is 3–4 m thick. The bedrock level is around –2 m in this part of the profile. The sound velocity in the bedrock is 5,500 m/s or higher with the exception of two small low velocity zones at chaining 160 m and 235 m. The velocity of these to low velocity zones are 4,000 m/s and 3,700 m/s respectively.

Profile 195 (LSM000195), Figure 5-17 in Appendix 1, is placed on land. The profile is 335 m long. The soil cover is thin or absent along the first half of the profile with exception of a local depression at chaining 90 m where the calculated soil depth is around 4 m. Along the second half of the profile the soil layers are in the range of 3–7 m. The sound velocity in the bedrock is around 5,500 m/s with two 5 m wide low velocity zones, with estimated sound velocities of 3,300 m/s and 3,400 m/s respectively, found at chaining 200 m and 300 m respectively.

Profile 196 (LSM000196), Figure 5-18 in Appendix 1, is located in the lake Borholmsfjärden. The profile starts in the water and ends close to the shore with outcropping bedrock. At chaining 105 m there is a tongue of land with outcropping rock coming from the east side of the profile. The water depth is around 3 m from the profile start up to chaining 105 m where the depth is about 1 m. Further towards the north the water depth is around 8 m at 140 m and a little more than 5 m at 180 m and about 2 m at the end of the profile. The soil layer is mostly 4–7 m thick with the exception of the outcrop at chaining 105 m and at the very end of the profile. The sound velocity in the bedrock is higher than 5,000 m/s with the exception of one 10 m wide low velocity zone at chaining 30 m and one 15 m wide low velocity zone at chaining 140 m. The estimated velocities of the low velocity zones are 3,600 m/s and 3,300 m/s respectively.

5.2 Location of low velocity zones

The location of the low velocity zones is shown in Figure 5-19. Most of the interpreted lineaments were confirmed as a zone with lower seismic velocity, 2,800 m/s up to 4,400 m/s, while the velocity of the sound rock were in the range from 5,000 m/s up to 6,300 m/s with a mean value of 5,562 m/s.

5.3 Data delivery

Data delivered directly after termination of the field activities are:

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

The delivered data have been inserted in the database (SICADA) of SKB. The SICADA reference to the present activity is field note no 200.

Together with this report the following data are delivered:

- Simpevarp_refr_seism.dwg
- Simpevarp_refr_seism_EG170.xls (listing of line coordinates)
- Simpevarp_refr_seism_GP320.xls (results from interpretation)

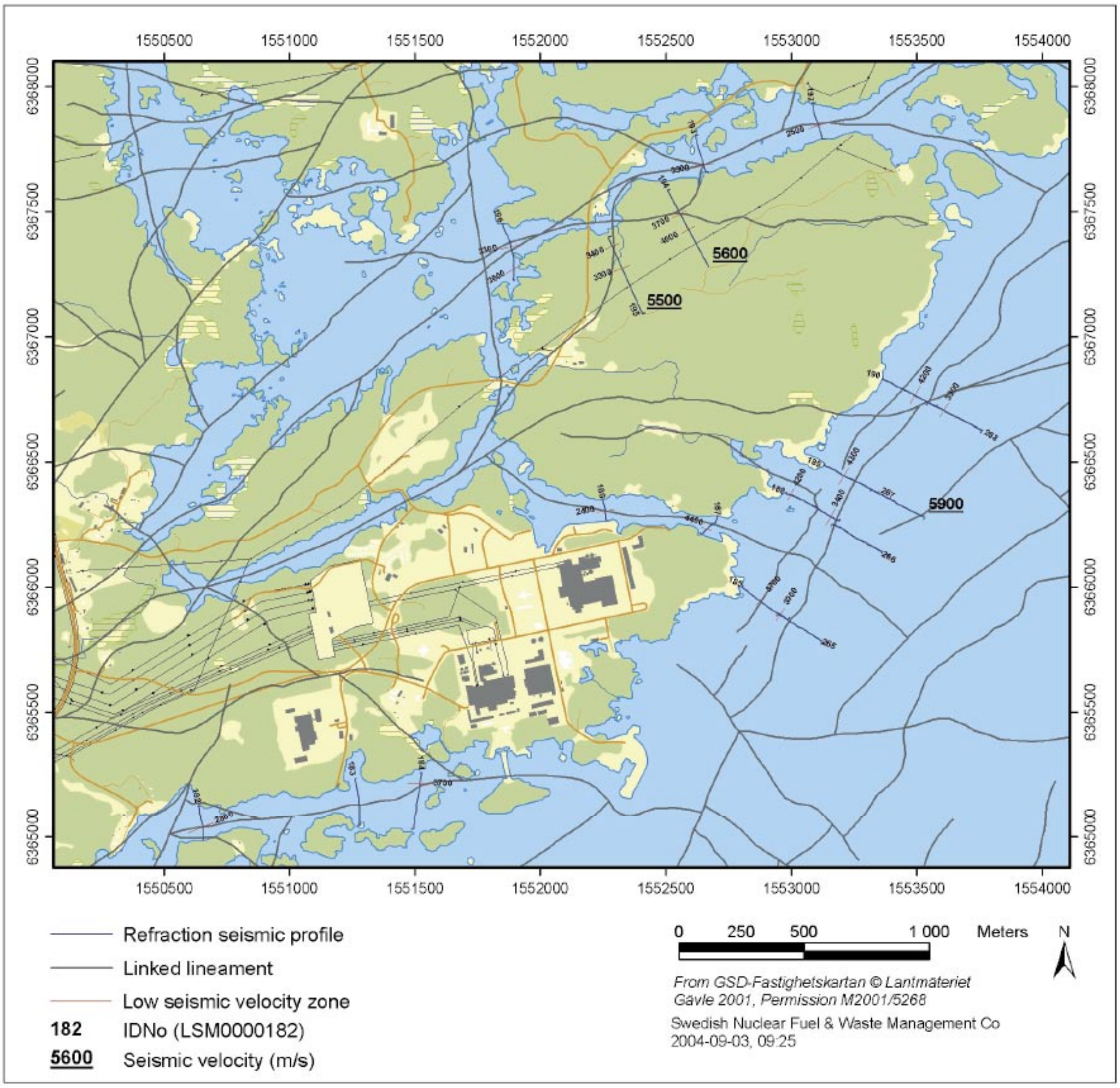

Figure 5-19. *Location of low velocity zones in the bedrock interpreted from this refraction seismic survey. Lineaments presented are linked lineaments interpreted from air photos and helicopter airborne geophysics /3/. The low velocity zones are marked with tic-lines along the profiles.*

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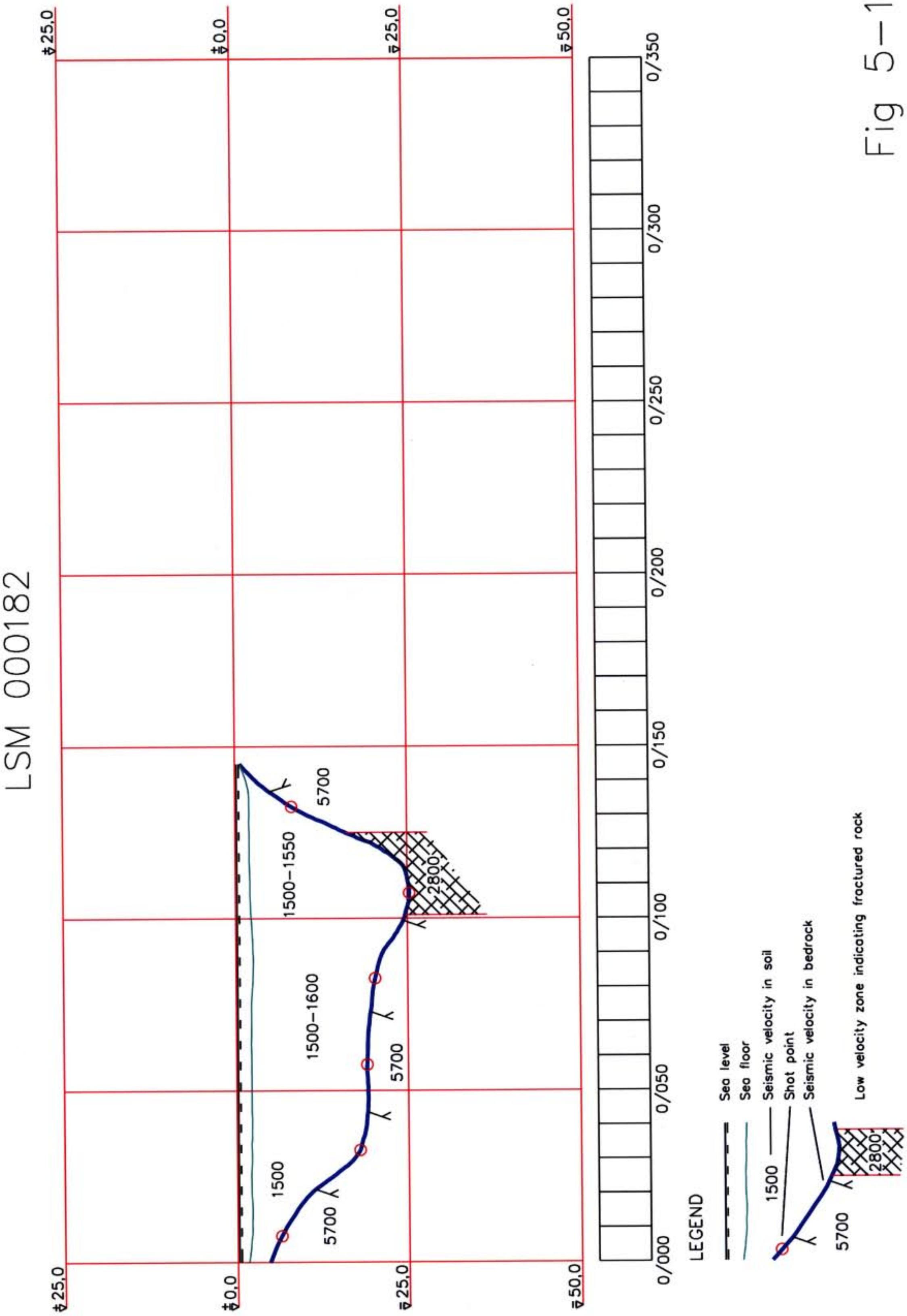
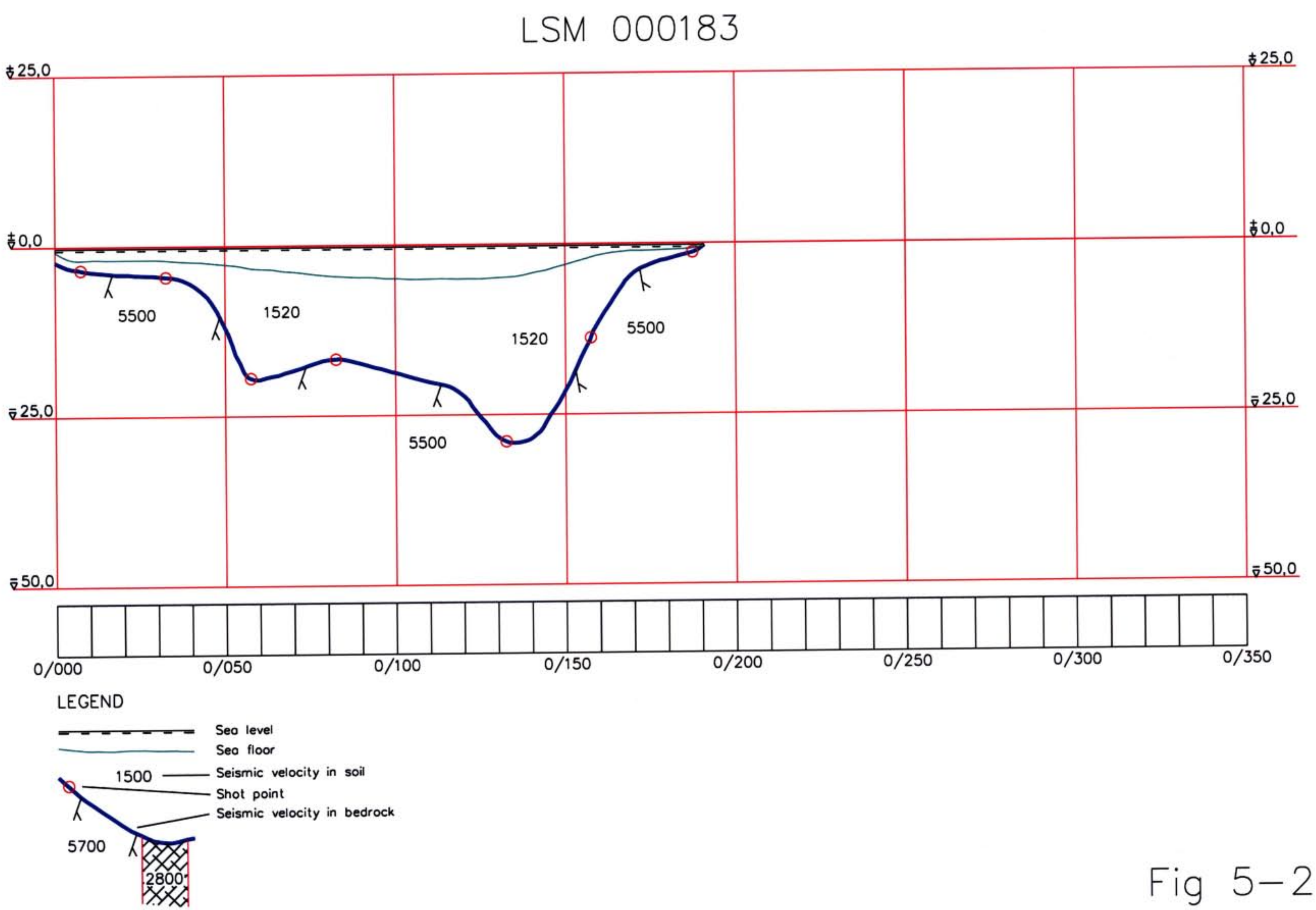
Interpretation of refraction seismic sections in the water outside Simpevarp and Ävrö and on land on Ävrö

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Shot point
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Fig 5–2

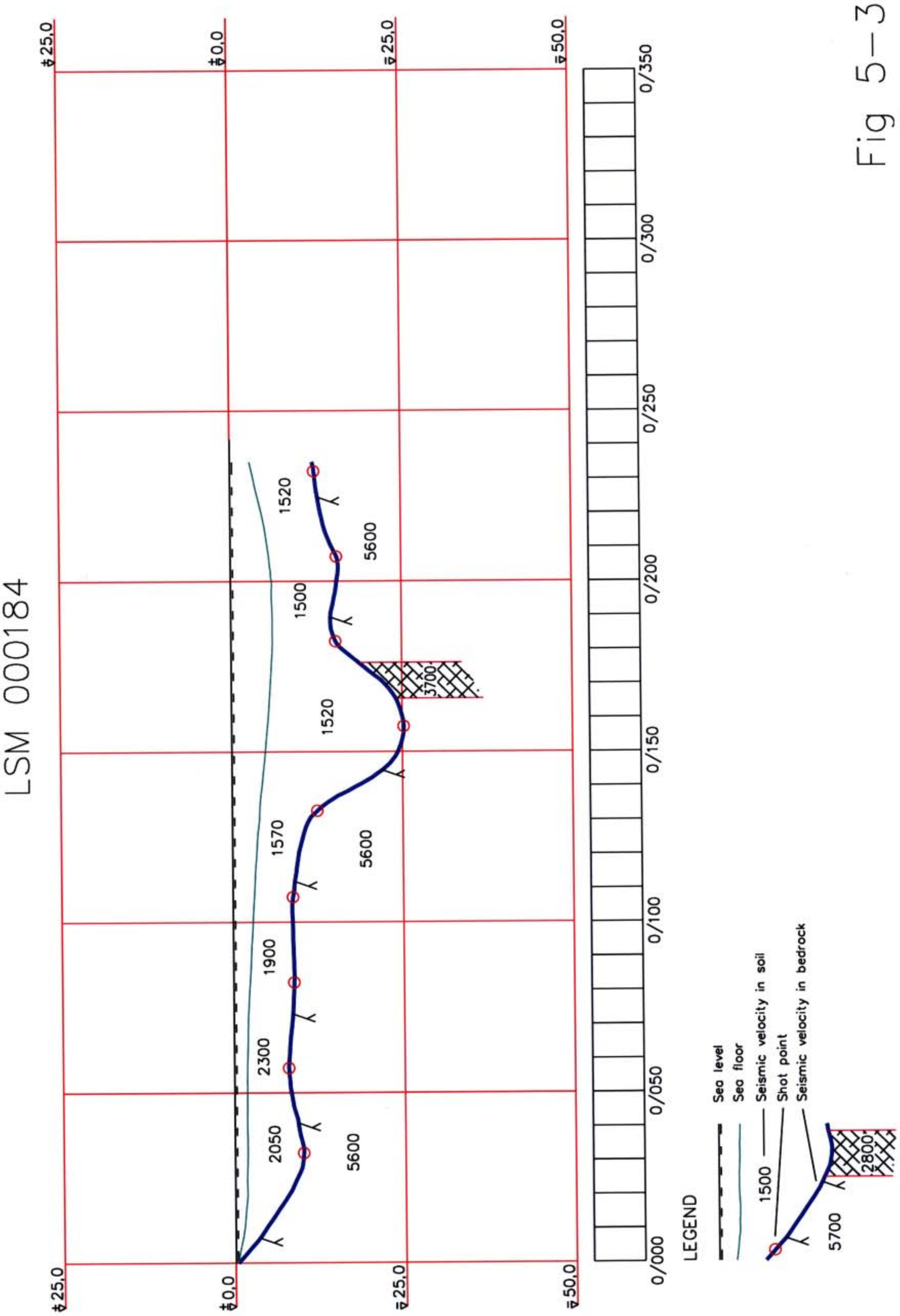
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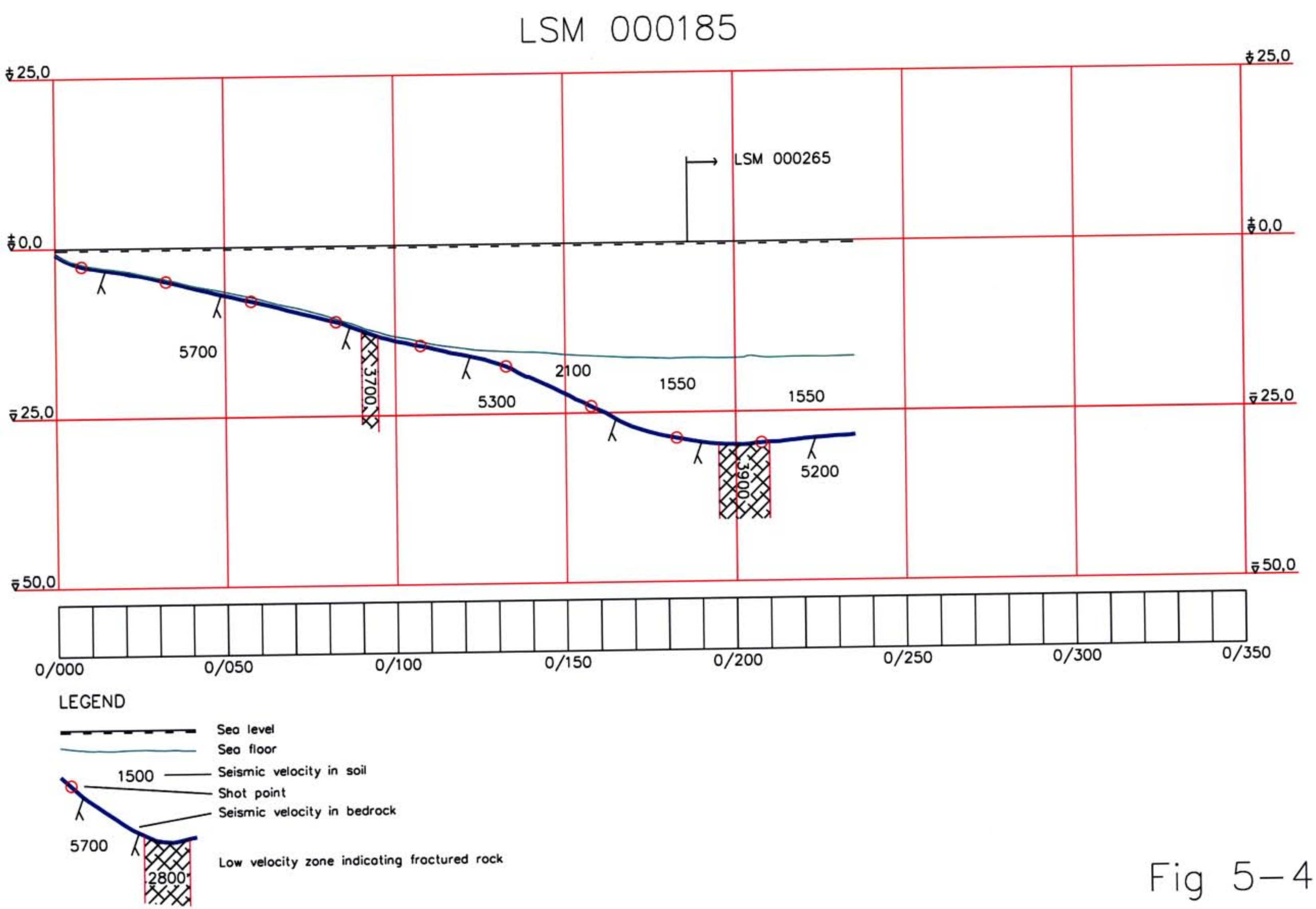
Fig 5–3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0/250
0/300
0/350
LEGEND
Sea level
Sea floor
1500
Seismic velocity in soil
Shot point
Seismic velocity in bedrock
5700
2800
Low velocity zone indicating fractured rock

Fig 5–4

LSM 000265

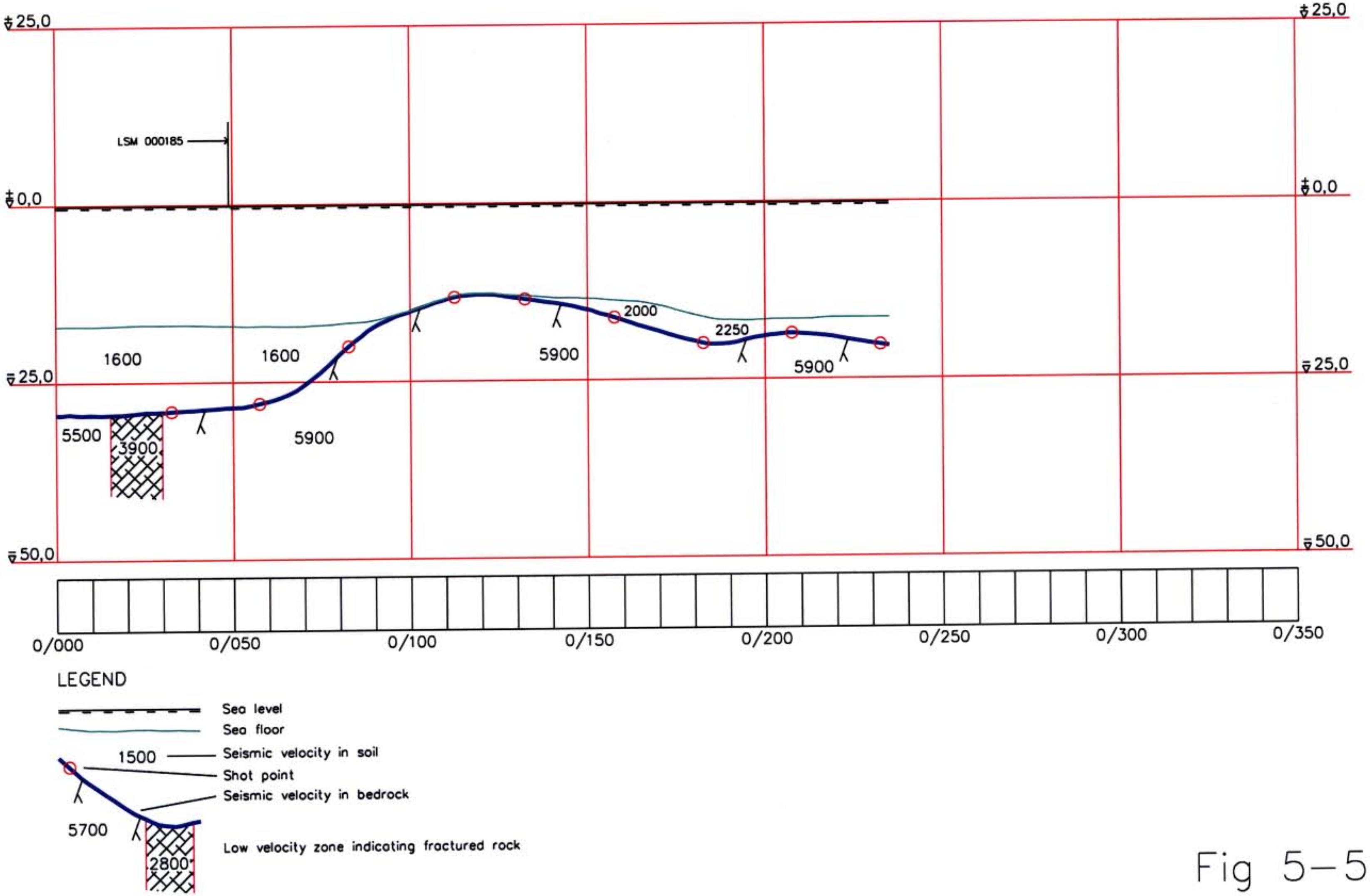


Fig 5–5

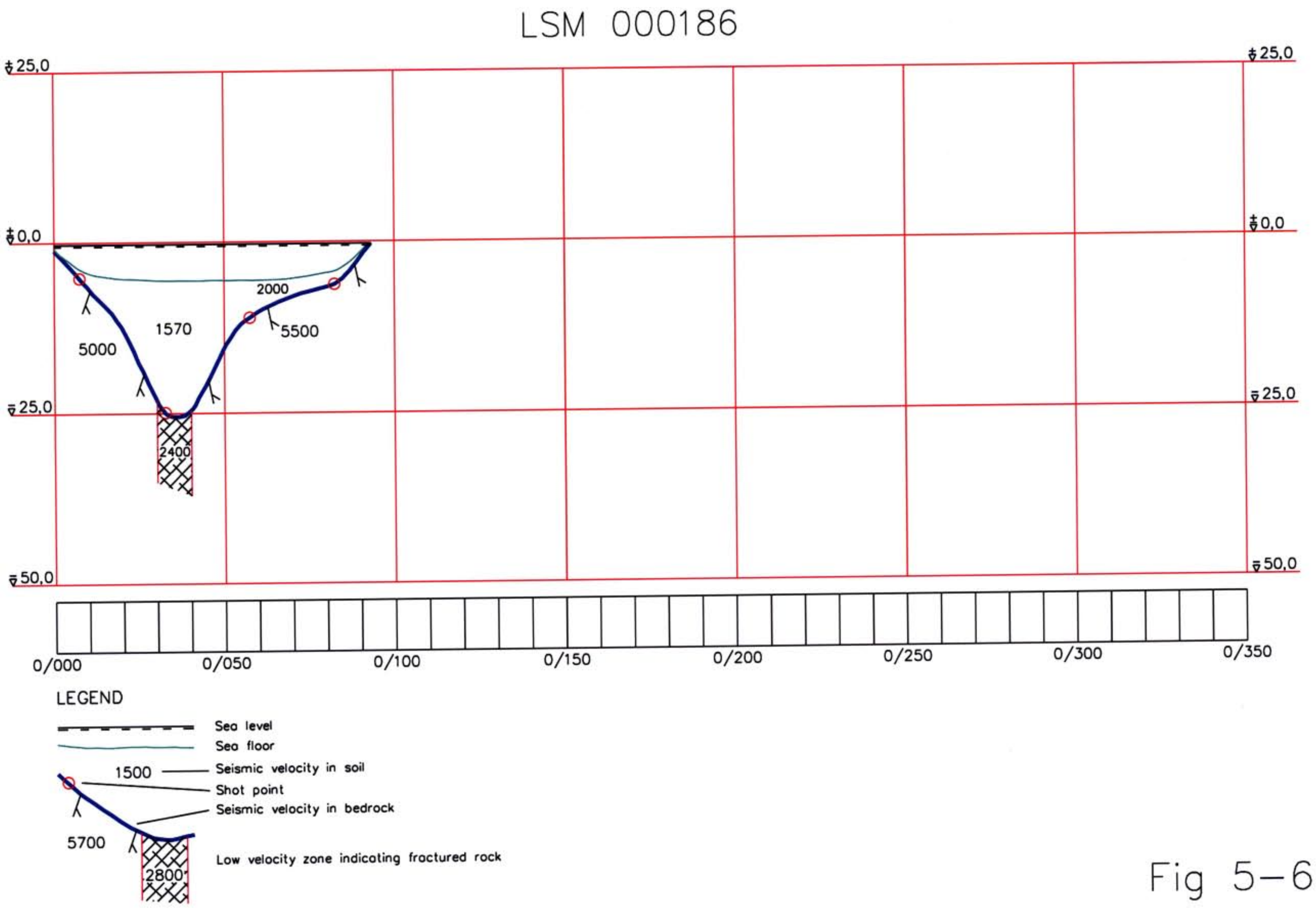

LSM 000186
25,0
0,0
25,0
50,0
2000
1570
5000
5500
2400
0/000
0/050
0/100
0/150
0/200
0/250
0/300
0/350
LEGEND
Sea level
Sea floor
1500
Seismic velocity in soil
Shot point
Seismic velocity in bedrock
5700
2800
Low velocity zone indicating fractured rock

Fig 5–6

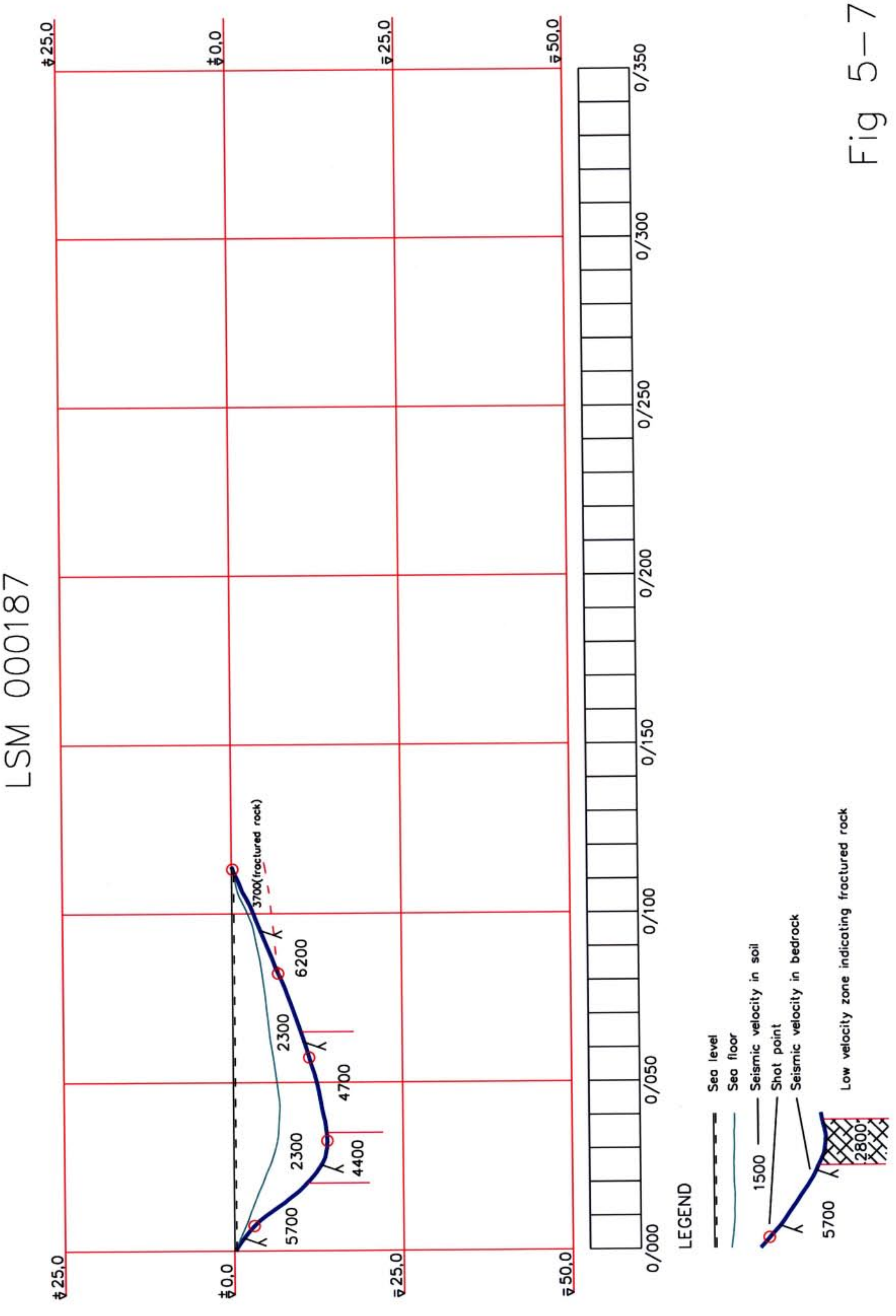

LSM 000187
±25,0
±0,0
∓25,0
∓50,0
0/000
0/050
0/100
0/150
0/200
0/250
0/300
0/350
5700
2300
4400
4700
2300
6200
3700(fractured rock)
LEGEND
Sea level
Sea floor
1500
Seismic velocity in soil
Shot point
Seismic velocity in bedrock
5700
2800
Low velocity zone indicating fractured rock

Fig 5—7

LSM 000188

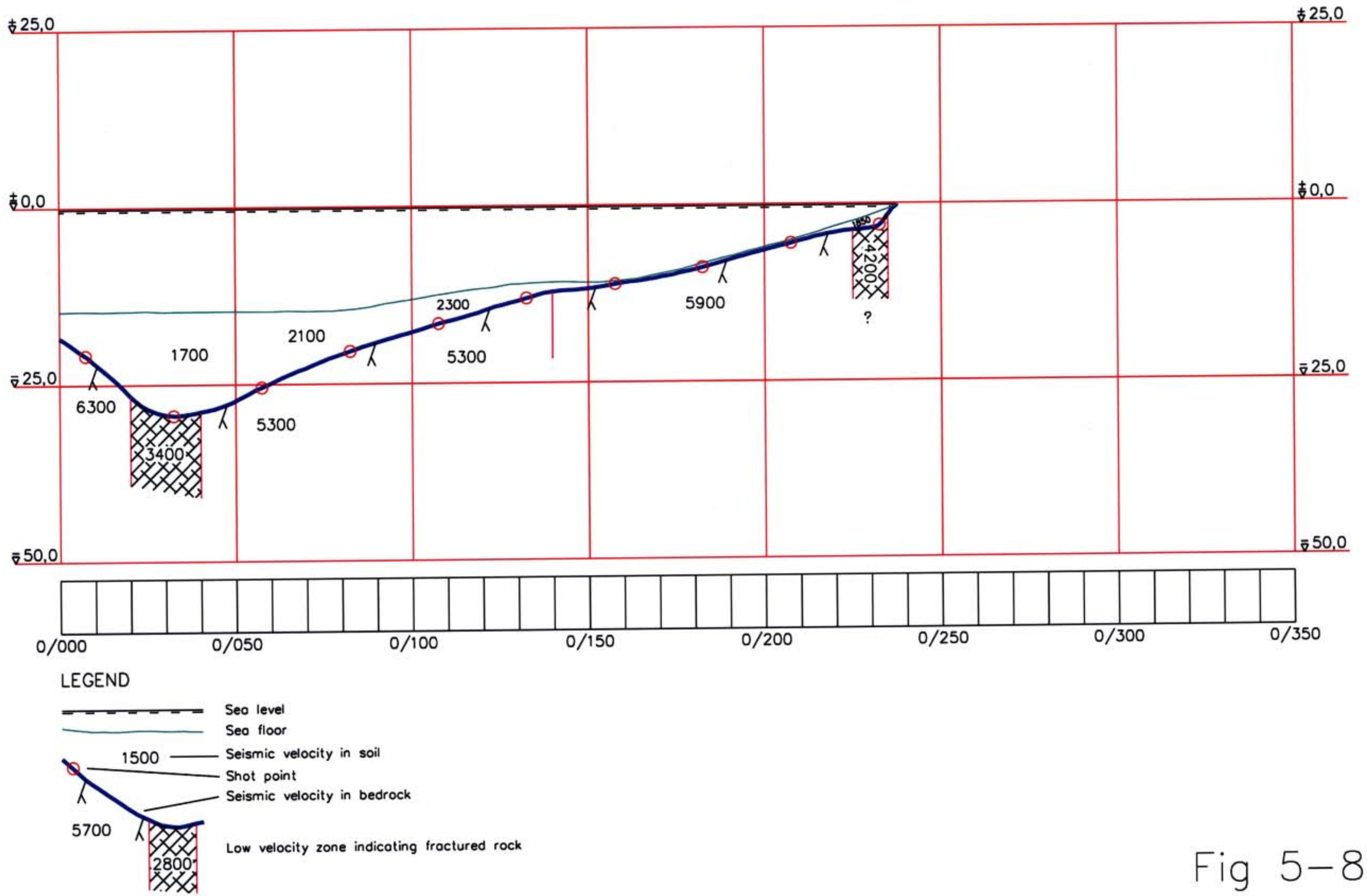


Fig 5–8

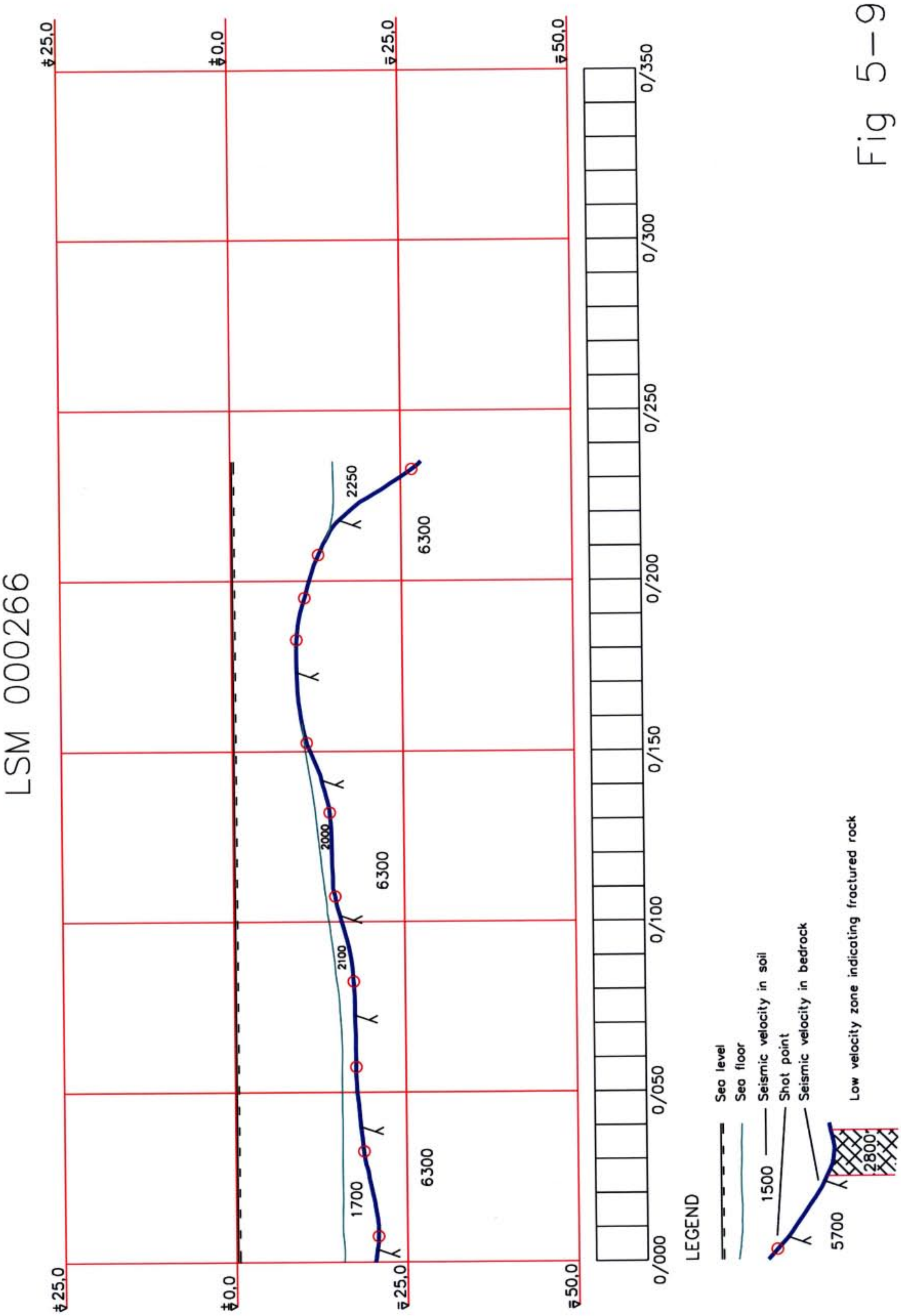
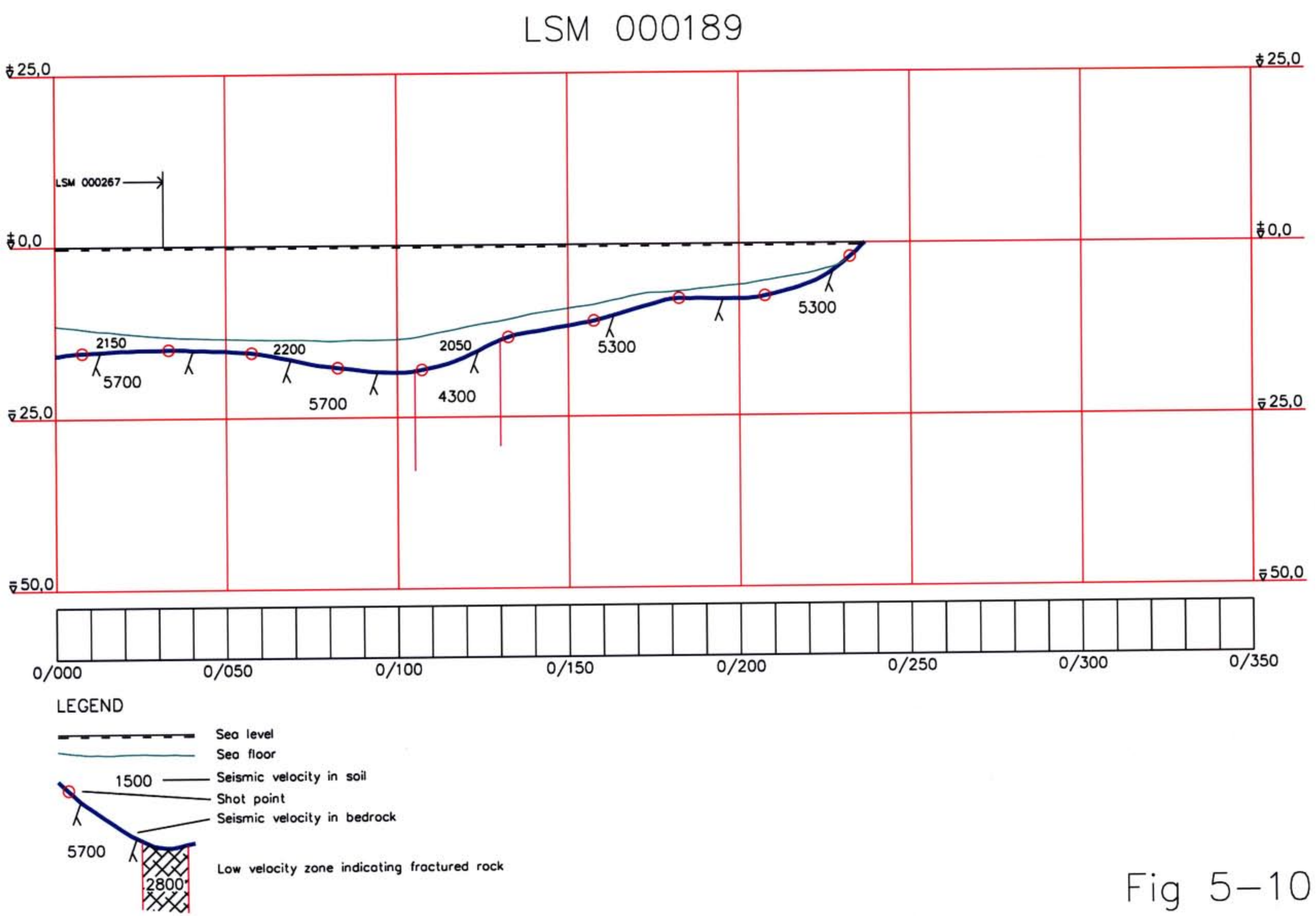
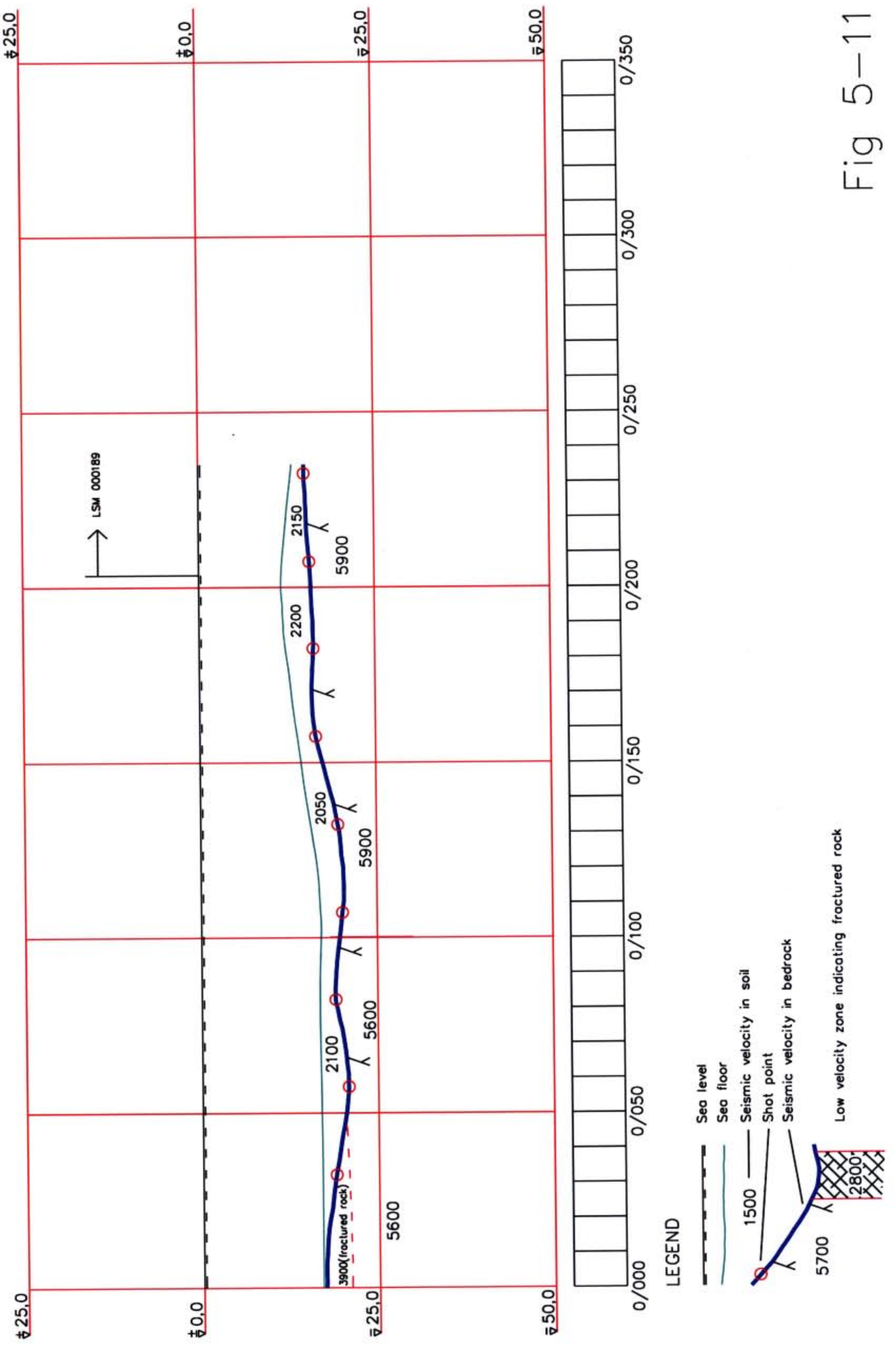

LSM 000266
+25,0
±0,0
-25,0
-50,0
0/000
0/050
0/100
0/150
0/200
0/250
0/300
0/350
1700
2100
2000
2250
6300
6300
6300
LEGEND
Sea level
Sea floor
Seismic velocity in soil
Shot point
Seismic velocity in bedrock
1500
5700
2800
Low velocity zone indicating fractured rock

Fig 5–9



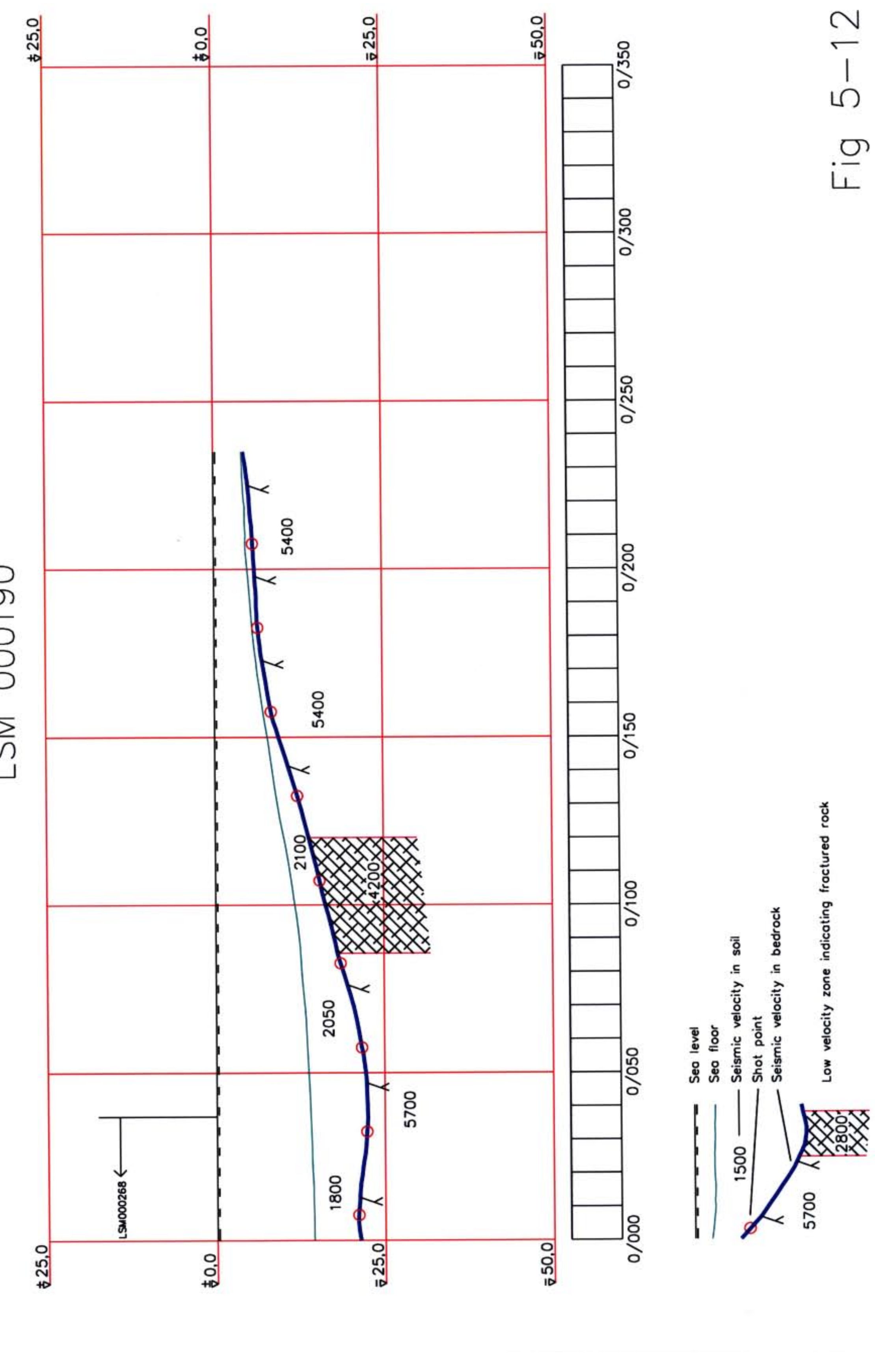
LSM 000189
25,0
0,0
25,0
50,0
LSM 000267
2150
5700
2200
5700
2050
4300
5300
5300
0/000
0/050
0/100
0/150
0/200
0/250
0/300
0/350
LEGEND
Sea level
Sea floor
1500
Seismic velocity in soil
Shot point
Seismic velocity in bedrock
5700
2800
Low velocity zone indicating fractured rock

Fig 5–10



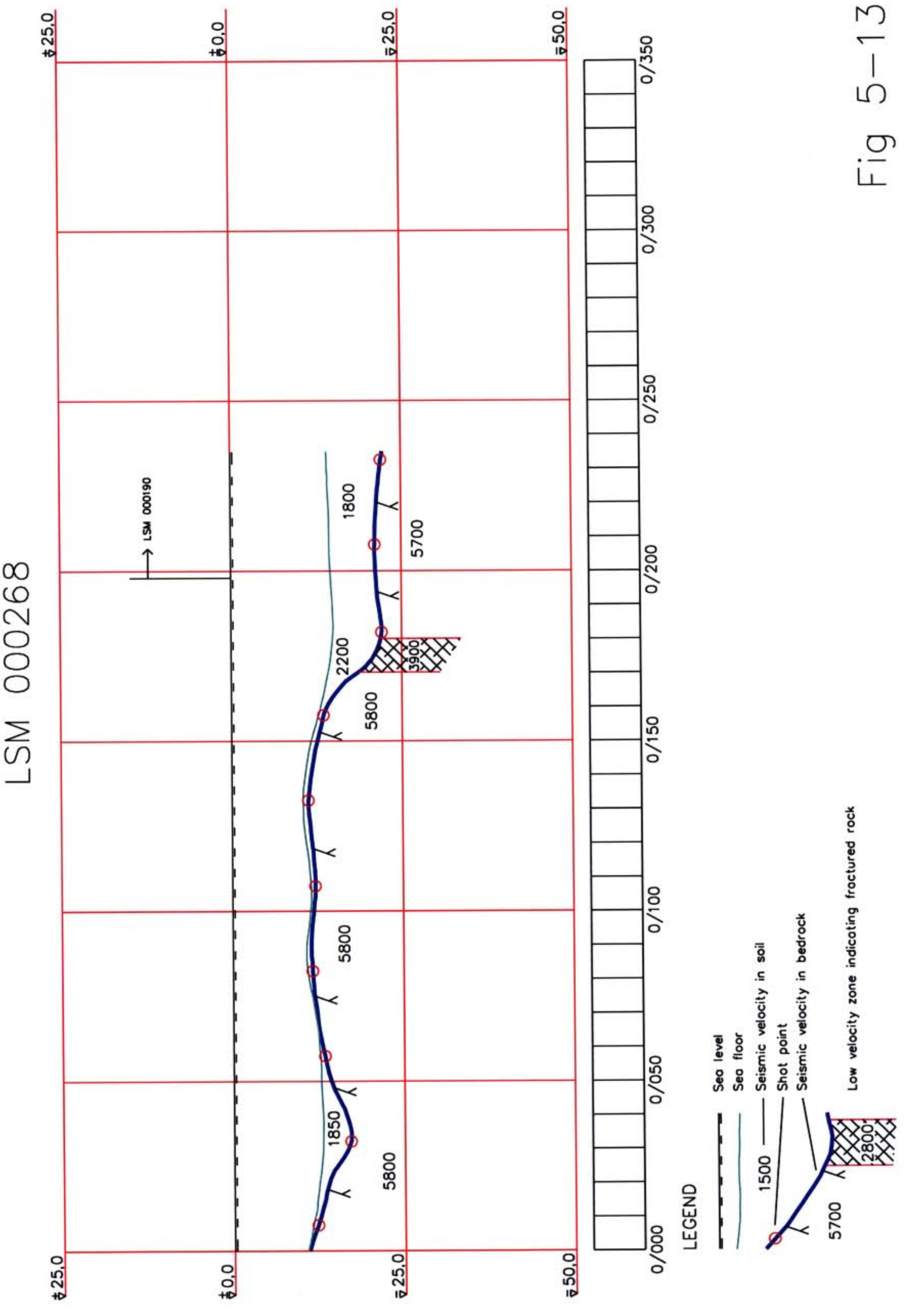
LSM 000267
LSM 000189
+25,0
±0,0
-25,0
-50,0
0/000
0/050
0/100
0/150
0/200
0/250
0/300
0/350
3900(fractured rock)
5600
2100
5600
2050
5900
2200
2150
5900
LEGEND
Sea level
Sea floor
1500
Seismic velocity in soil
Shot point
Seismic velocity in bedrock
5700
2800
Low velocity zone indicating fractured rock

Fig 5—11



LSM 000190
LSM000268
1800
5700
2050
2100
4200
5400
5400
25,0
0,0
25,0
50,0
0/000
0/050
0/100
0/150
0/200
0/250
0/300
0/350
Sea level
Sea floor
1500 — Seismic velocity in soil
Shot point
Seismic velocity in bedrock
5700
2800
Low velocity zone indicating fractured rock

Fig 5–12



LSM 000268
LSM 000190
+25,0
±0,0
-25,0
-50,0
0/000
0/050
0/100
0/150
0/200
0/250
0/300
0/350
1850
5800
5800
2200
5800
3900
1800
5700
LEGEND
Sea level
Sea floor
1500
Seismic velocity in soil
Shot point
5700
Seismic velocity in bedrock
2800
Low velocity zone indicating fractured rock

Fig 5–13

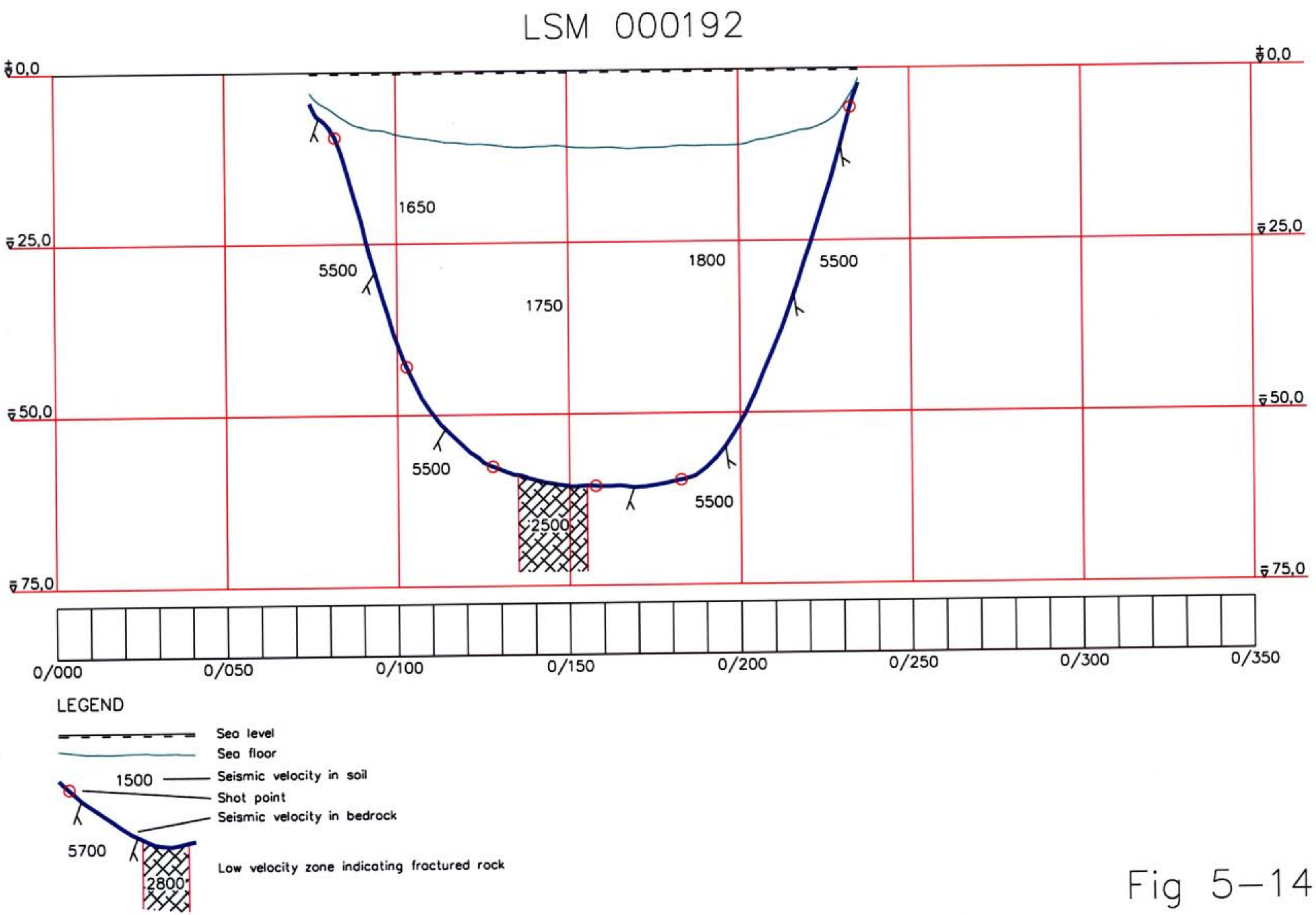

LSM 000192
0,0
25,0
50,0
75,0
1650
1750
1800
5500
5500
5500
5500
2500
0/000
0/050
0/100
0/150
0/200
0/250
0/300
0/350
LEGEND
Sea level
Sea floor
1500
Seismic velocity in soil
Shot point
Seismic velocity in bedrock
5700
2800
Low velocity zone indicating fractured rock

Fig 5–14

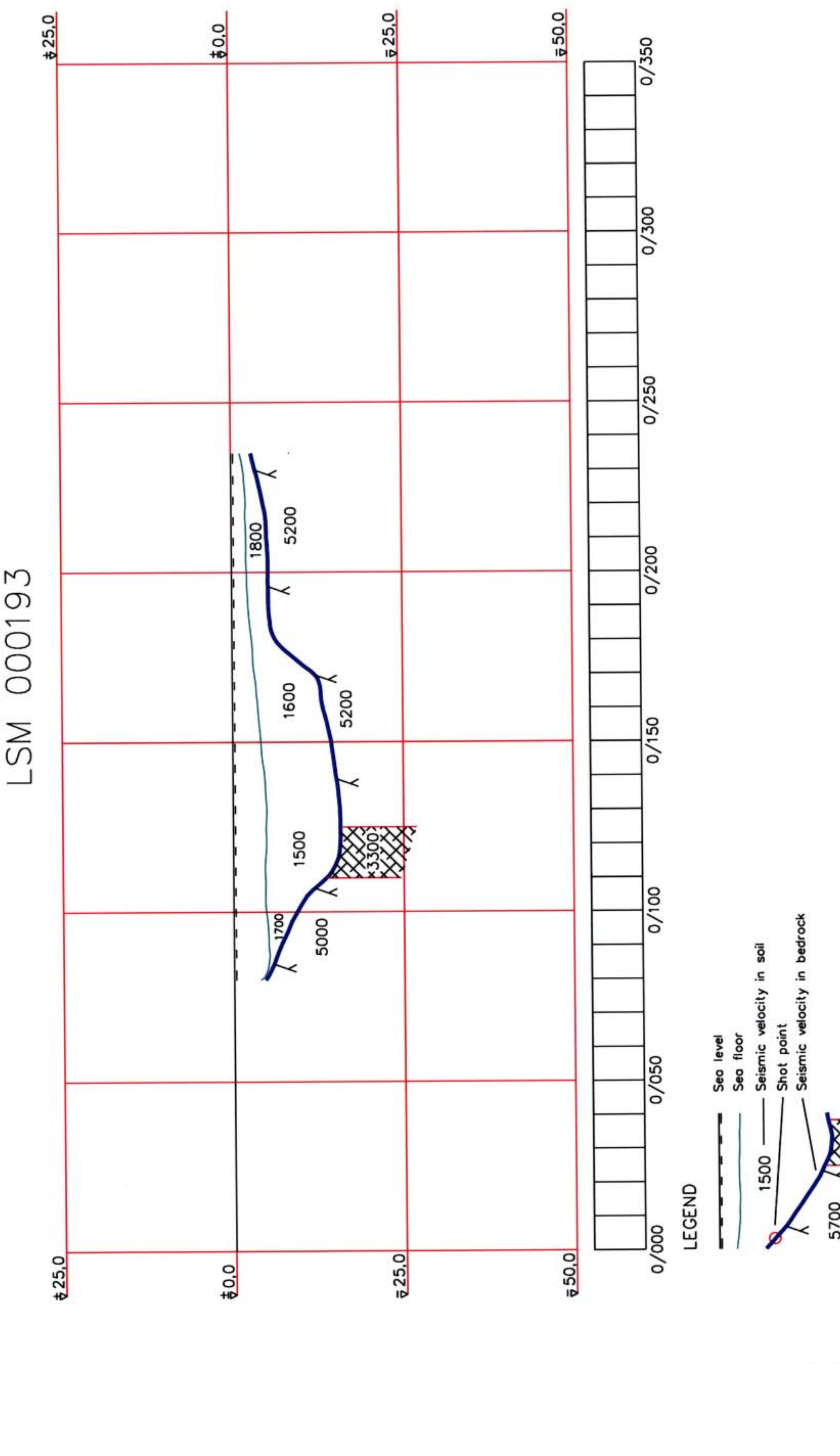

LSM 000193
+25,0
±0,0
-25,0
-50,0
0/000
0/050
0/100
0/150
0/200
0/250
0/300
0/350
1800
5200
1600
5200
1500
3300
1700
5000
LEGEND
Sea level
Sea floor
1500
Seismic velocity in soil
Shot point
5700
Seismic velocity in bedrock
2800
Low velocity zone indicating fractured rock

Fig 5–15

LSM 000194

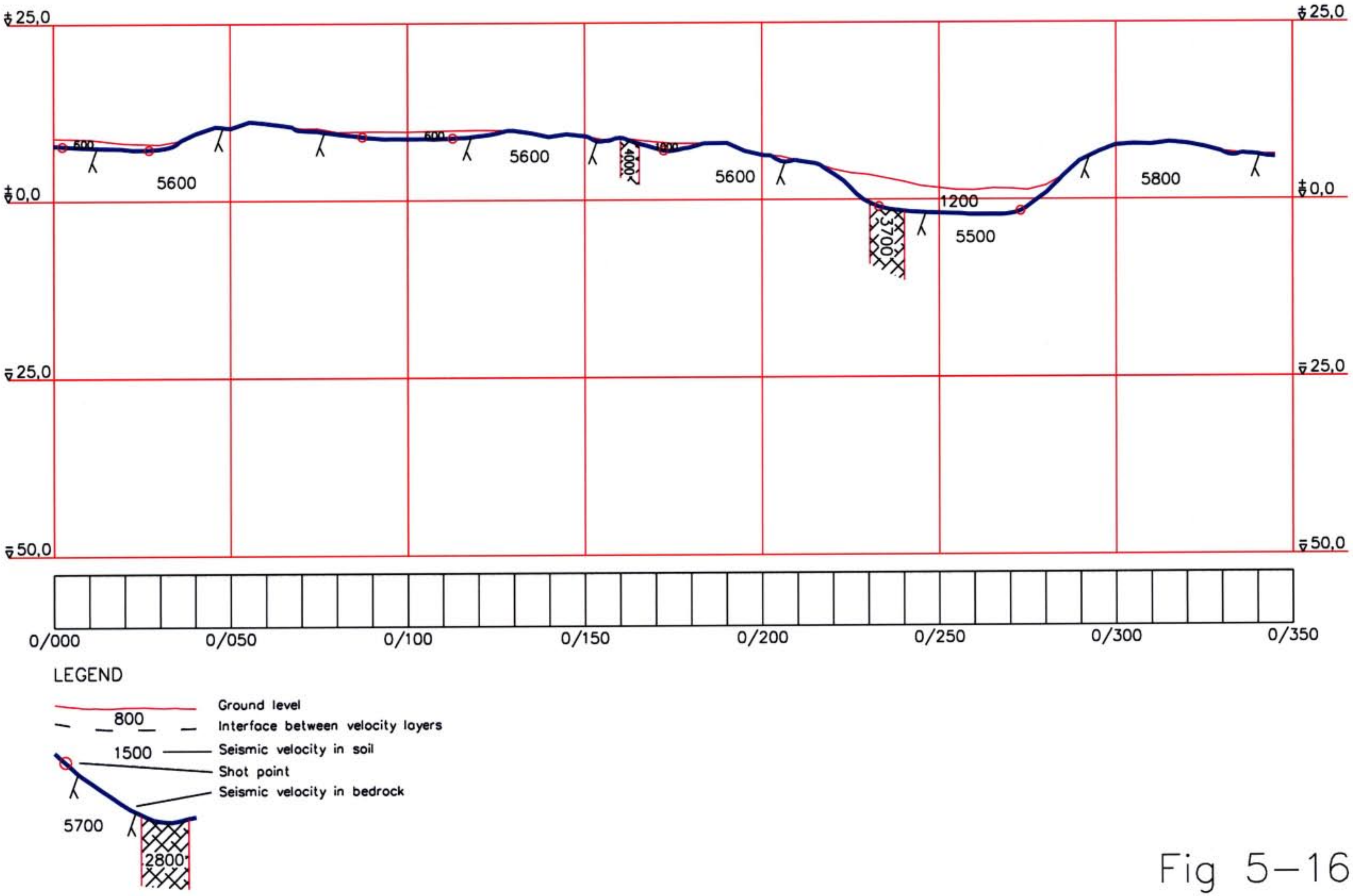


Fig 5–16

LSM 000195

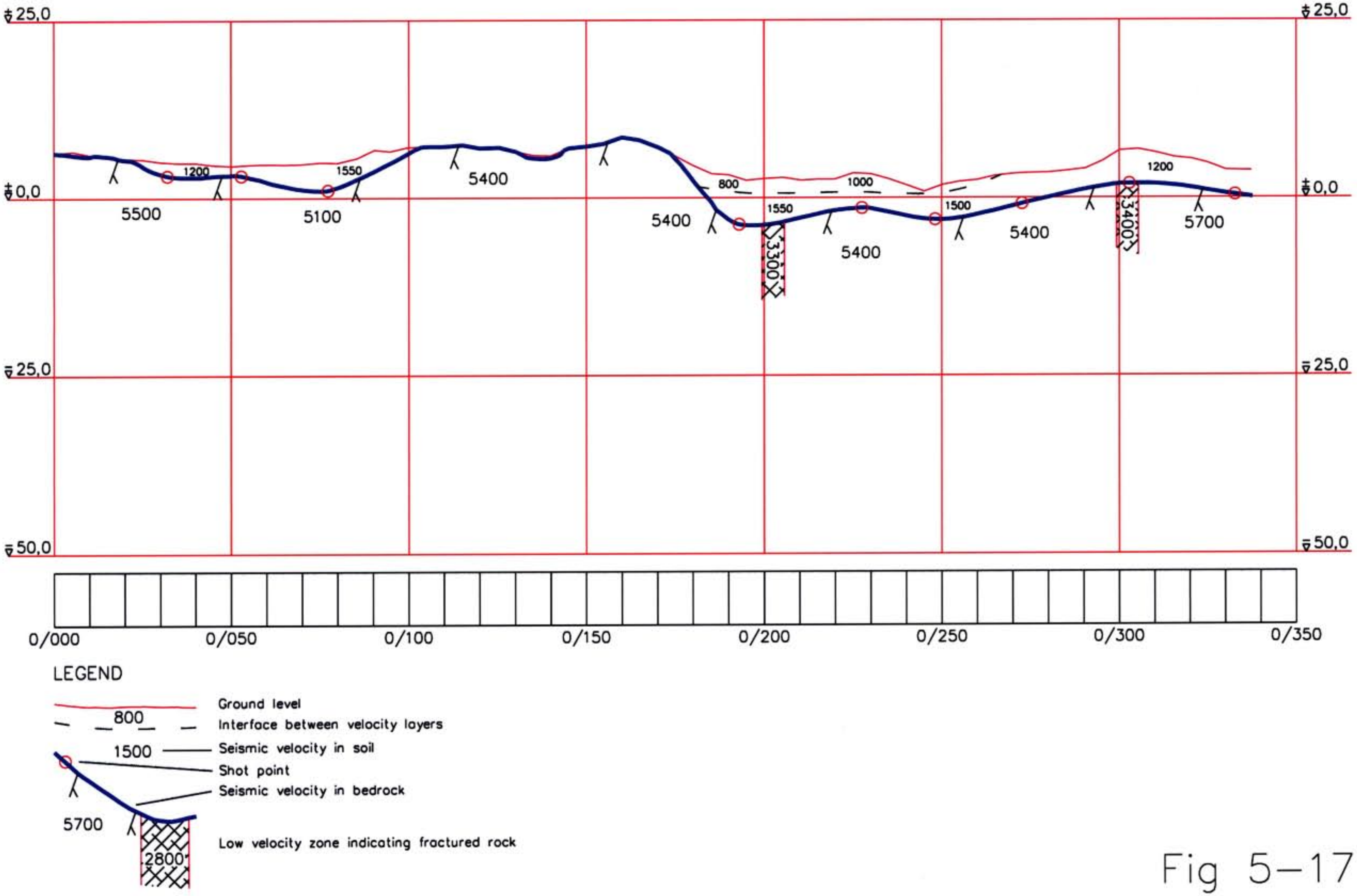


Fig 5–17

LSM 000196

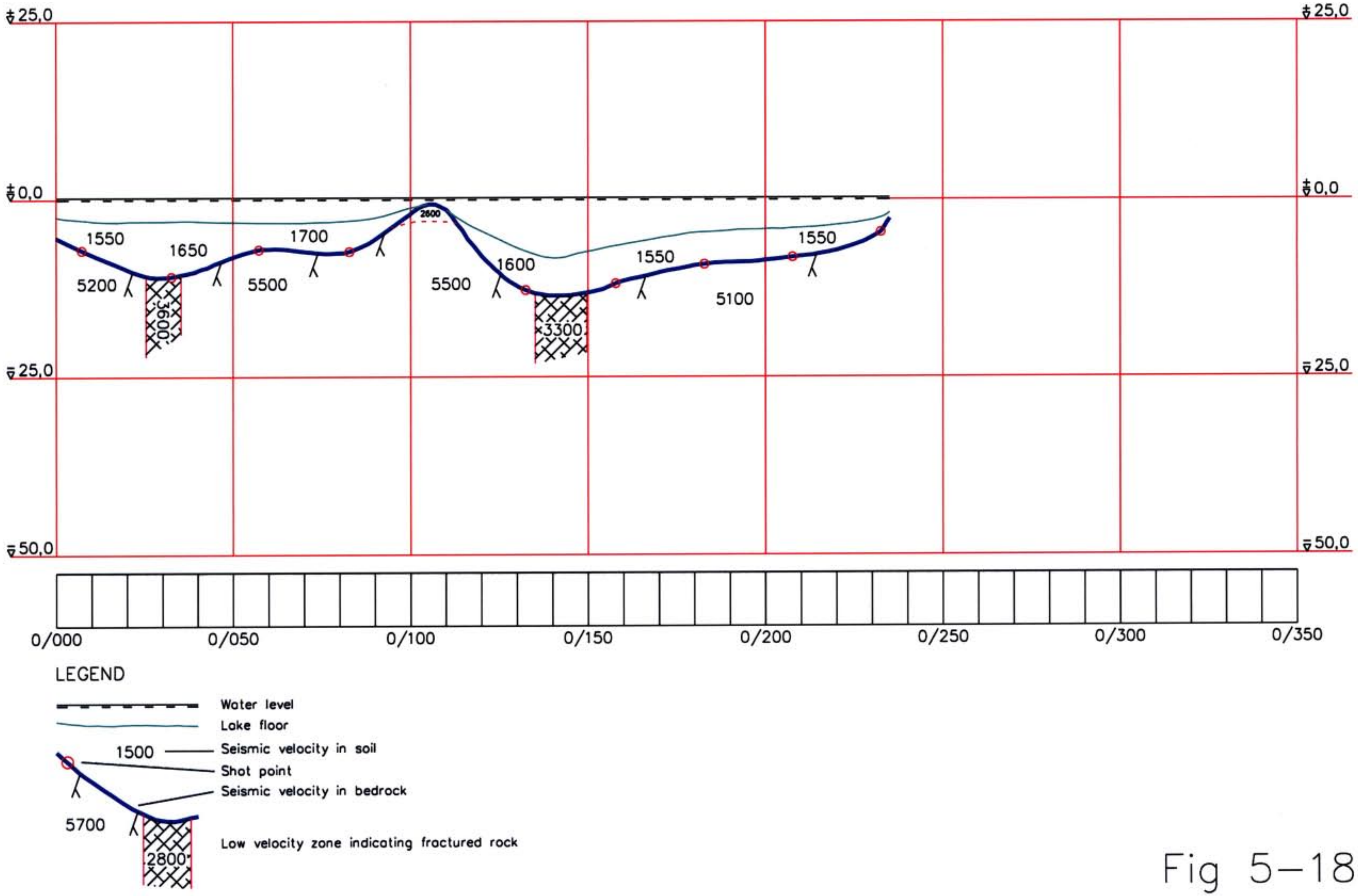


Fig 5–18