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Forsmark site investigation

Seismic velocity analysis in excavated trenches

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Abstract

This report presents the results of seismic velocity measurements performed in October 2004 in the Forsmark area by IMPAKT GEOFYSIK AB. The intention of the investigation was to establish the velocity distribution in bedrock material as measured directly upon the excavated bedrock surface. This was done at two specific sites, referred to as the western and the eastern trench. At the western trench an occurrence of highly compressed bottom moraine was identified, the velocity of this moraine was also measured in accordance with the bedrock measurements.

The results indicate high p-wave velocities in the bedrock material (> 5,000 m/s) and extremely high velocities in the compact moraine (2,300–2,560 m/s).

Sammanfattning

På uppdrag av SKB i Forsmark utfördes under oktober 2004 en mätning av seismiska hastigheter i undersökningsområdet. Mätningarna skedde på avtäckt berg i två grävda diken, västra gropen resp. östra gropen. Dessutom mättes hastigheter i framschaktad bottenmorän i den västra gropen. Mätningarna syftade till att verifiera de resultat som erhållits vid mätningar tidigare på hösten.

Resultaten visar på höga hastigheter i bergmaterialet > 5 000 m/s samt mycket höga hastigheter i den kompakta bottenmoränen 2 300–2 500 m/s.

Contents

1 Introduction

This document reports the results gained by seismic velocity measurements, which is one of the activities performed within the site investigation at Forsmark. The work was, in applicable parts, carried out in accordance with the activity plan AP PF 400-04-77. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

The field measurements of the seismic velocity survey was performed in October 2004 at two target areas referred to as the eastern and the western trench, see Figure 1-1.

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

Activity plan	Number	Version
Refraktionsseismik 2004	AP PF 400-04-77	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för refraktionsseismik	SKB MD 242.001	1.0

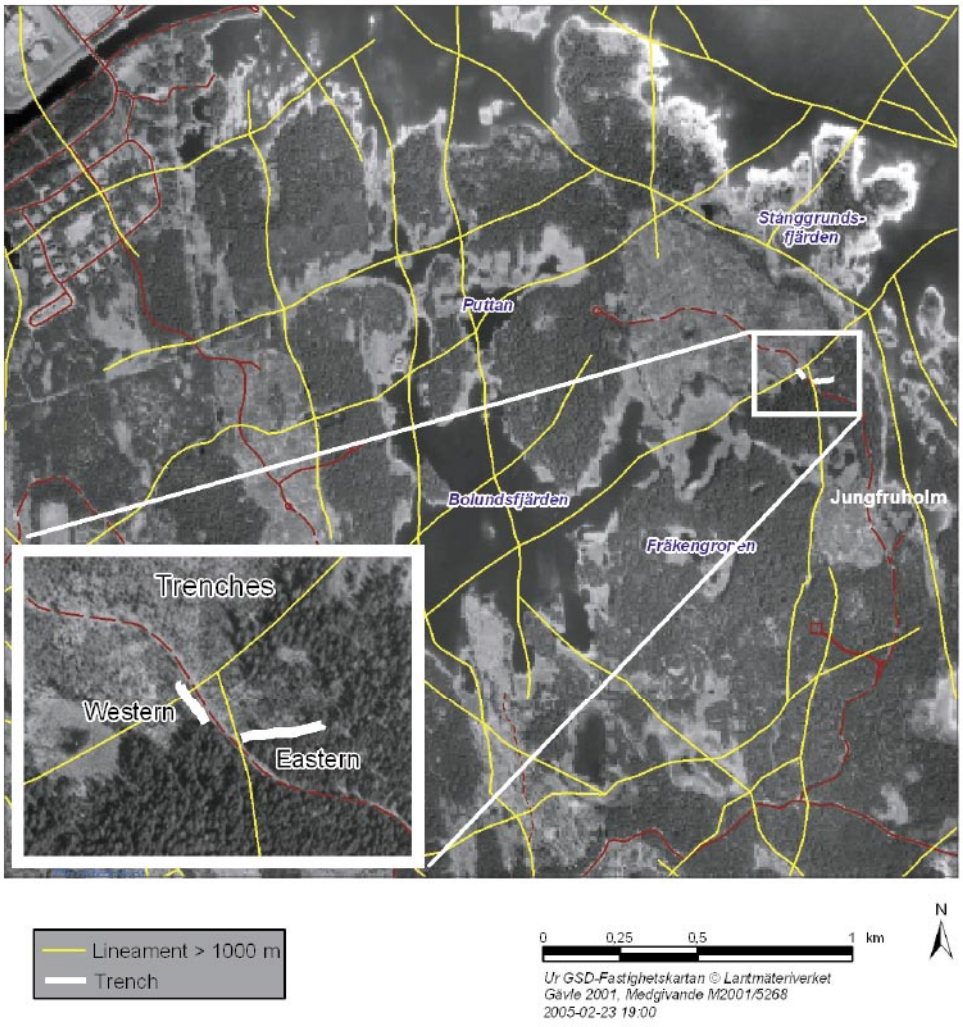


Figure 1-1. *Location of the two trenches where velocity analysis was performed.*

2 Objective and scope

The purpose of the seismic velocity measurements was to determine the velocity distribution as measured directly in the actual material, in this case, the exposed and cleaned bedrock surface and the excavated top surface of the compact bottom moraine.

The geophones were placed in holes, drilled to a depth of 5 cm, in the bedrock surface using a pneumatic drilling equipment.

The obtained seismic velocities contains only information derived from the propagation of the compression energy (the P-wave velocity).

3 Equipment

3.1 Description of equipment/interpretation tools

The seismic data was collected and recorded using a 24 channel ABEM Terraloc MK6 seismograph, see Figure 3-1, equipped with 18–bit +3-bit IFP A/D converters. The data is stored primarily in an internal hard disk in SEG-2-format. The signals were registered using vertical 10 Hz geophones connected to specially designed seismic cables. The energy source used was primarily a handheld sledgehammer. Small dynamite charges were also fired at the end of each investigation profile.

The collected data was copied onto stationary computers, stored and backed up on CD-media.

The calibration of the seismic data collecting system (the ABEM seismograph) is a matter of testing the performance of the A/D converters. Comparing a known analogue input signal of suitably wide spectrum to the digital output of the system does this. Hereby the internal noise and crosstalk also can be monitored. Geophone system impedance can be displayed for each channel using built-in software.

Figure 3-1. *The seismograph used for refractions seismics.*

4 Execution

4.1 General

The seismic velocity measurements was in applicable parts performed in accordance with the method description: “Metodbeskrivning för refraktionsseismik”, SKB MD 242.001, SKB internal document.

4.2 Preparations

Prior to the start of data acquisition, all functions tests were carried out with satisfying results.

4.3 Execution of field work

Before starting the measurements, the two sites were excavated so that the bedrock surface was exposed in two trenches, approximately 50 and 80 m long respectively.

In the western trench, the geophone spacing selected was 1 m, and 5 cm deep holes, wide enough to make sure that there was a tight connection to the geophone spikes, were drilled using a pneumatic drill hammer. The same procedure was applied at the eastern trench where the geophone spacing was set to 2 m. The total lengths of the investigated lines were 22 m and 44 m, respectively.

In the western trench, velocity measurements were also made in an excavated portion of bottom moraine, see Figure 4-1. This section, in which the moraine was thick enough to avoid refracted influence from the underlying bedrock, was measured with 1 m geophone separation and 10 geophones were used, giving a total length of 9 m.

The source of energy was primarily a hand operated sledgehammer. At each end of the two bedrock profiles a shot with a small amount of explosives was fired.

4.4 Data handling/post processing

The collected data was stored in SEG-2 format. Each file represent the information from a specific shot point. The file identifier refers to a unique shot number that is included in the filename. The file consists of a header, holding, for example, information of acquisition date, time, parameters as recording time, sample rate, number of used channels, and specifies the format for the binary 32 bit data fields where the registered data from each geophone are located.

The data files are transferred to an interpretation computer where the first arrival time of the first arriving compression energy wave is determined, using an interactive technique providing manual check of each trace.

From geometries of geophones and shot points together with the obtained arrival times, a statistic evaluation of the velocity distribution in the measured objects were made.

Figure 4-1. *Execution of refraction seismic measurements on top of the compact moraine that occurs in the western trench. The geophone separation is 1 m.*

4.5 Non-conformities

The survey was conducted in correspondence with the Activity plan and the Method description. No non-conformities that affect the results were identified.

5 Results

The results of the seismic velocity measurements are presented as time-distance plots together with corresponding statistics.

In the western trench, the bedrock velocities varied between 5,200–5,700 m/s indicating a homogeneous material of igneous type with no detectable zones of open fractures.

The result of the velocity analysis in the compact moraine material in the western trench shows very high velocities 2,300–2,500 m/s, which indicates an extremely compact bottom moraine. For comparison, the loose morain that occurs from the ground surface down to the compact moraine display a velocity of 400–1,500 m/s as measured in an earlier survey (Toresson 2005, SKB P-05-12).

The Eastern trench also shows high p-wave velocities for the bedrock, ranging between 4,800–5,200 m/s.

The presented velocities represent the mean velocities calculated over the entire measured profile. In the time distance-plots (see Appendix 1) there are also observable small scale variations in the velocity distribution along the investigated lines, originating more from surface irregularities, than from actual zones of lower velocities.

There is also an indication of somewhat lower velocities in the uppermost 1–2 m of the bedrock material.

Presentation of data and results.

All collected raw data was delivered to SKB after the termination of the field activities.

All results have been reported as drawing files (.dwg) and in a data file containing coordinates and velocities (.xls).

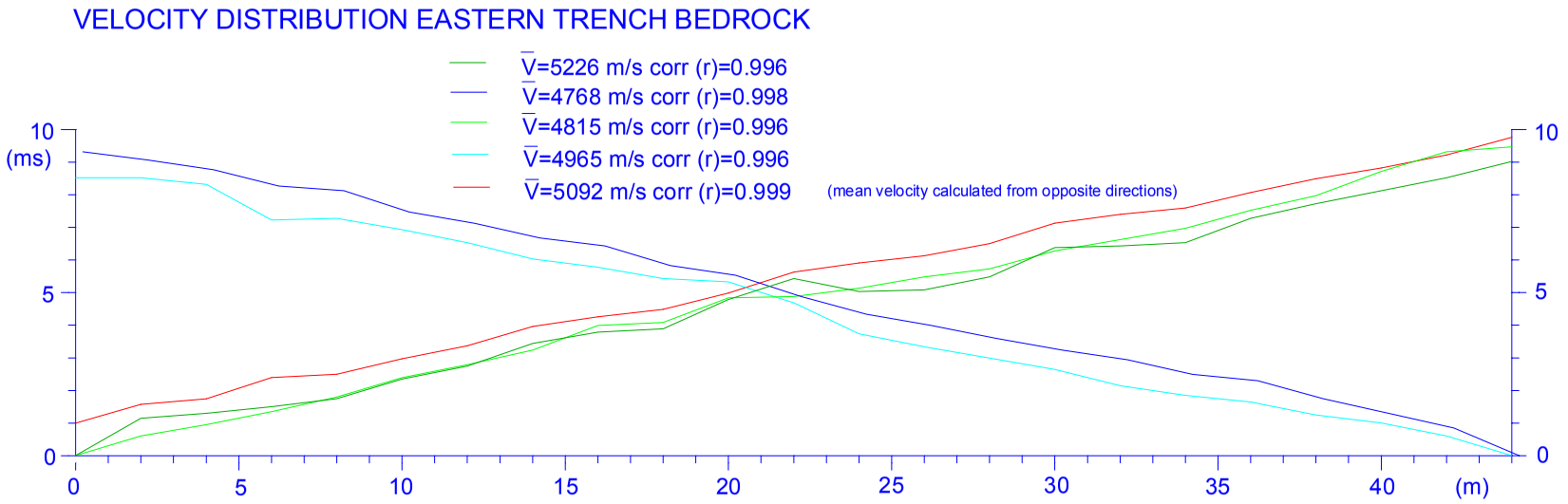
Output data has been prepared and stored according to SICADA format.

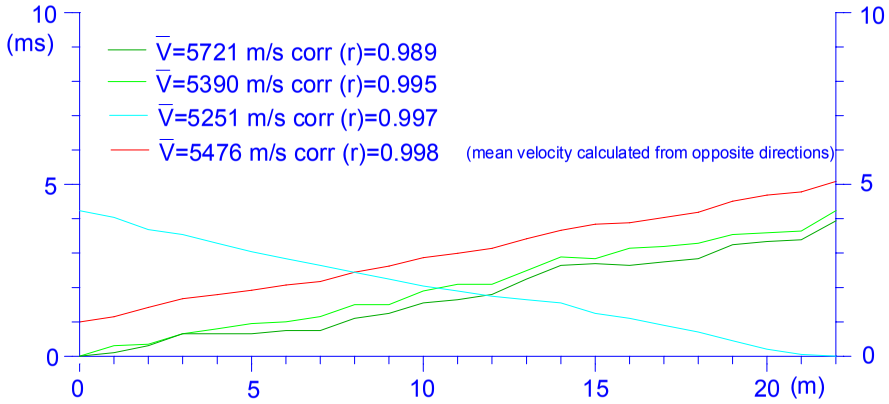
Object	File name	No of files	Data Format
Raw data	F08800.sg2 – F08809.sg2	10	SEG-2
Drawing	Forsmark_seis042.dwg	1	dwg

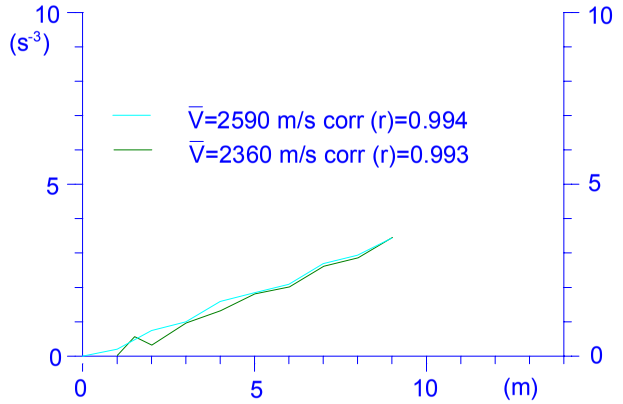
Appendix

Presentation of the seismic sections

The seismic sections (next page) presents the velocity distribution in the bedrock from the eastern trench (44 m) and the western trench (22 m) together with the velocity in the compact moraine in the eastern trench (14 m).


VELOCITY DISTRIBUTION EASTERN TRENCH BEDROCK
V̄=5226 m/s corr (r)=0.996
V̄=4768 m/s corr (r)=0.998
V̄=4815 m/s corr (r)=0.996
V̄=4965 m/s corr (r)=0.996
V̄=5092 m/s corr (r)=0.999
(mean velocity calculated from opposite directions)
10
(ms)
5
0
0
5
10
15
20
25
30
35
40
(m)


VELOCITY DISTRIBUTION WESTERN TRENCH BEDROCK
V̄=5721 m/s corr (r)=0.989
V̄=5390 m/s corr (r)=0.995
V̄=5251 m/s corr (r)=0.997
V̄=5476 m/s corr (r)=0.998
(mean velocity calculated from opposite directions)
10
(ms)
5
0
0
5
10
15
20
(m)


VELOCITY DISTRIBUTION EASTERN TRENCH MORRAINE
V̄=2590 m/s corr (r)=0.994
V̄=2360 m/s corr (r)=0.993
10
(s-3)
5
0
0
5
10
(m)