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Äspö Hard Rock Laboratory

DECOVALEX

Ultrasonic borehole measurements in the TASQ tunnel (450 m level) at Äspö HRL performed by BGR in November 2006

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April 2007

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Keywords: EDZ, Ultrasonic/seismicborehole measurements, P-wave velocity, S-vawe velocity, Dynamic pseudo elastic parameters

Abstract

This report summarises results from ultrasonic seismic borehole measurements performed between the 27th and 30th of November 2006 in the TASQ tunnel at the Äspö Hard Rock Laboratory, Sweden at depth level 450 m. The measurements aimed at the characterisation of the excavation damaged/disturbed zone (EDZ/EdZ) around the TASQ tunnel.

Eight boreholes in one cross section (horizontal, vertical up, vertical down and 45° inclined upwards) with diameters of 92 mm and lengths of 3 m were used for ultrasonic interval velocity measurements with a mini sonic borehole probe. Between two horizontal boreholes additionally ultrasonic cross hole measurements were performed. Furthermore rotational interval velocity measurements at different depths were done in vertical orientated boreholes.

The quality of the measured data is very good. Very clear seismic P- and SV-wave onsets were determined and different parameters were derived from the data, including seismic P- and SV-wave velocities and in-situ dynamic pseudo elastic parameters like Poisson's Ratio and Young's Modulus.

With the help of different seismic parameter criteria the extents of the EDZ/EdZ were estimated. According to these derived parameters the extents of the EDZ/EdZ determined in the horizontal boreholes (KQ0047B01, KQ0047B02) at the side wall are about 0.25 m at the ESE side of the tunnel and 0.35 m and 0.30 m at the opposite side (WNW side, KQ0047A01, KQ0047A02). In the floor the extent reaches 0.75 m (measured from the concrete slab, KQ0047G01) and in the roof 0.75 m (KQ0047H01) and 0.30 m (KQ0047I01).

Results from interval velocity measurements as well as from rotational interval velocity measurements show several remarkable variations in the derived seismic parameters, e.g. velocity and amplitude variations, which indicating changes in rock parameters. Minima and maxima in the parameter distributions derived from the rotational interval velocity measurements correlate with minor and major principal stress directions. The comparison of results from interval velocity and cross hole measurements shows similarities.

Except for boreholes KQ0047B01 and KQ0047B02 (ESE side of the tunnel) fractures/cracks or hints for their existence could be detected in all other boreholes.

Measurement team: Friedhelm Schulte, Torsten Tietz, Kristof Schuster

Sammanfattning

Den 27 till den 30 november 2006 gjordes seismiska undersökningar i TASQ tunneln på 450 m djup i Äspö Laboratoriet. Mätningarna gjordes för att karakterisera sprängskadezonen runt tunneln.

Det borrades åtta borrhål i en tvärsektion (med riktning: horisontell, vertikalt uppåt, vertikalt nedåt och 45° vinklad uppåt). Deras diameter är 92 mm och de är vardera ca 3 m långa. De användes för intervallmätningar av ljudvågshastigheter, som gjordes med ett seismiskt ultraljudsinstrument konstruerat av BGR (Bundesanstalten für Geowissenschaften und Rohstoffe) kallad mini sonic bore hole probe. Mellan två av de horisontella borrhålen har även en mätning mellan borrhålen gjorts, en sk. cross-hole measurement. Dessutom har intervallmätningar med en rotation av instrumentet gjorts i vertikala borrhål. Dessa mätningar har gjorts på olika djup för att undersöka ljudvågshastigheten i olika riktningar.

Kvaliteten hos mätningarna är mycket hög. Vågfronterna hos både kompressions och den vertikala skjuvvågen var väldigt tydliga, så dess start och bestämningen av parametrar som beror på den kan anses som välgrundade. De parametrar som identifierades och beräknades med resultaten var kompressionsvågshastigheten (P-vågen), skjuvvågshastigheten (S-vågen) och in-situ dynamiska pseudoelastiska parametrar såsom Poissontal och Elasticitetsmodulen.

Med hjälp av olika kriterier för de seismiska parametrarna har utbredningen av sprängskadezonen undersökts. Enligt dessa framräknade parametrar har sprängskadeszonen i de horisontella borrhålen (KQ0047B01, KQ0047B02) i den OSO tunnelväggen bestämts till ungefär 0,25 m och till 0,35 och 0,30 m i den motstående VNV väggen (borrhål KQ0047A01, KQ0047A02). I golvet sträcker sig sprängskadeszonen ner till 0,75 m (mätt från cementplattan, KQ0047G01) och i taket sträcker den sig också 0,75 m ut i bergmassan i ena borrhålet (KQ0047H01) och 0,3 m i det andra (KQ0047I01).

Flera anmärkningsvärda resultat kan skönjas i resultaten från intervallmätningarna liksom i de roterade intervallmätningarna. Det är främst våghastigheterna och amplitudernas variation som påvisar variationer i bergmassans parametrar. Minimum och maximum i parameterfördelningen för rotationsintervallmätningarna korrelerar med spänningsfördelningen i bergmassan. Vid en jämförelse mellan resultaten från intervall- och i den sk cross-hole mätningen hittas stora likheter.

I alla borrhål, förutom borrhål KQ0047B01 och KQ0047B02 (OSO sidan på tunneln), fann man indikationer på sprickor eller anvisningar till sprickor.

Contents

1 Description of Measurements

Within the framework of the project DECOVALEX IV, Task2 (project no: TDF 84 and activity plan: AP-TDF84-06-051) ultrasonic borehole measurements were performed by BGR in eight boreholes and additionally between two boreholes at the Äspö Hard Rock Laboratory, Sweden. These measurements aimed at the detection and characterisation of the excavation disturbed / damaged zone (EdZ/EDZ) with the help of seismic borehole measurements.

In 1996 BGR participated in the ZEDEX-Experiment (EMSLEY, 1997) with ultrasonic borehole measurements.

Measurements took place between the 28th and 30th of November 2006. All tasks of the measurements were performed according to the activity plan for seismic measurements in the TASQ tunnel (BÄCKSTRÖM, 2006).

All boreholes are located in one cross section in the TASQ tunnel at the 450m level. Figure 1 gives an impression of the in-situ measurement conditions in the TASQ tunnel whereas Figure 2 shows the borehole locations in a sketch.

Fig. 1. *Ultrasonic measurements with the BGR mini sonic probe in the TASQ tunnel. View towards the entrance of the tunnel.*

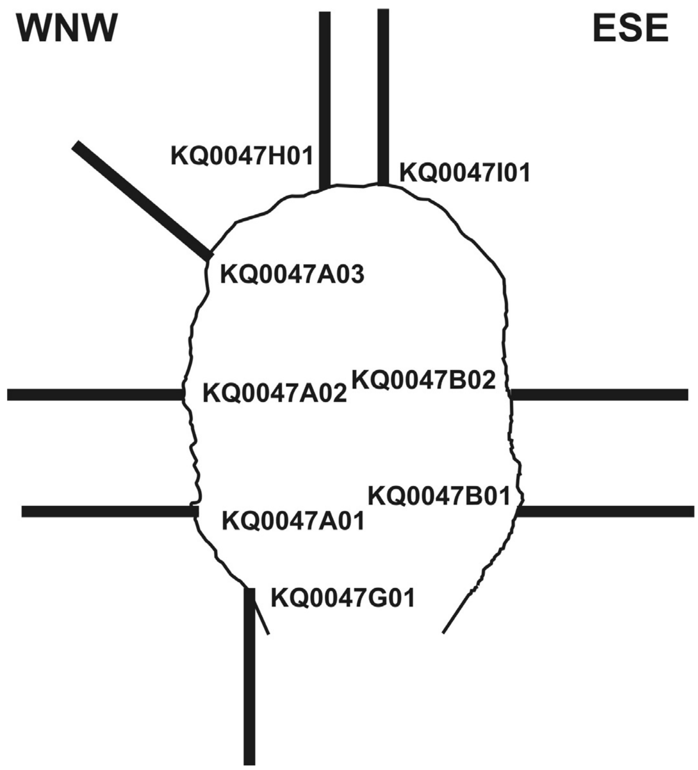


Fig. 2. *Cross section of the TASQ tunnel and locations of the eight boreholes under investigation. Diameters of the boreholes are 92 mm. View from the entrance (SSW) towards the heading face of the tunnel (NNE).*

Borehole coordinates were provided by Svensk Kärnbränslehantering AB (SKB). The diameters of the boreholes are 92 mm. Except for borehole KQ0047G01 (in the floor) all boreholes were dry or only slightly wet. Borehole KQ0047G01 was filled up with water and was pumped out before the measurement.

2 Methods

All applied ultrasonic borehole methods are discussed in detail in SCHUSTER & ALHEID (2002).

Seismic Interval velocity measurements

Measurements of the interval velocity are performed along single boreholes. The seismic velocities are measured along a small borehole interval, typically about 10 cm to 30 cm long. A BGR-borehole probe with one source and three receivers was used. The measurements start at the tunnel's wall. Then the probe is moved progressively down the borehole.

This method reveals the seismic velocity as a function of distance from the tunnel surface. The advantage of this method is that the length of the ray path is independent of the measuring depth. Thus the signal to noise ratio and the frequency content of the signals depend neither on the depth nor on absorbing discontinuities outside the actual interval. Therefore the measurements only reflect the conditions within the measuring interval.

The BGR mini-sonic borehole probe uses a piezoelectric transducer as a seismic source. Three piezoelectric transducers at distances of 10 cm, 20 cm and 30 cm from the source are used as receivers (see Figure 3). The transducers were coupled to the borehole wall by pneumatic cylinders. This method allows strong and reproducible force coupling without using any coupling paste.

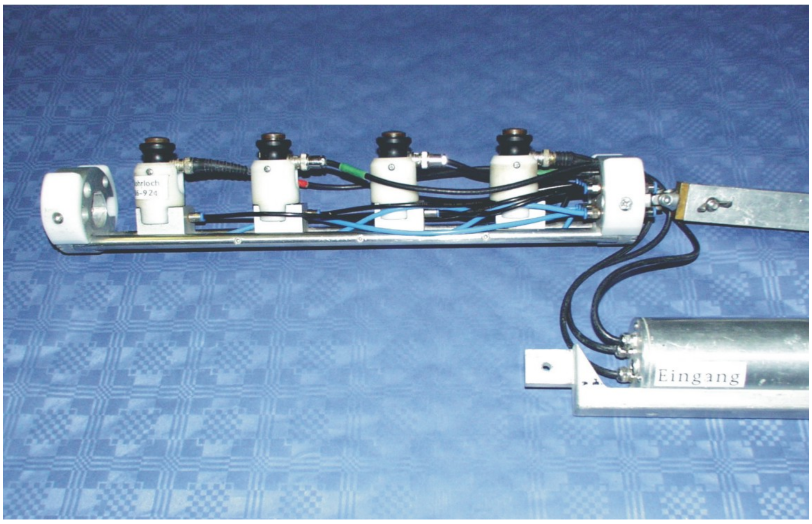


Fig. 3. *BGR-mini-sonic borehole probe.*

The source signal and the three received signals are passed through a signal conditioning unit to a four channel digital storage oscilloscope (Nicolet 440) with a 12 bit dynamic range. The maximum sampling frequency is 10 MHz. In order to increase the signal to noise ratio, 200 single measurements are averaged (stacked). Figure 4 shows a flow chart of the data acquisition system.

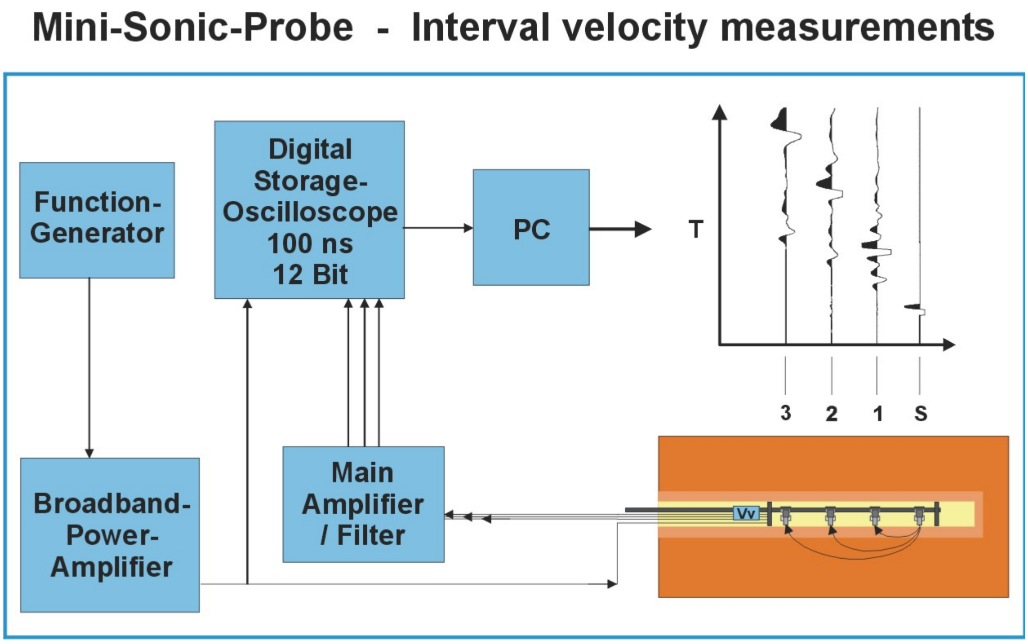


Fig. 4. Flow chart of seismic interval velocity measurements.

Rotational interval velocity measurements

For the seismic interval velocity measurements the borehole probe is moved into the borehole along a certain orientation, e.g. at 12 o'clock position in horizontal boreholes.

For additional, special investigations the ultrasonic probe can be rotated in boreholes at a certain depth from 0° to 360°, e.g. in steps of 30°.

In an isotropic or transversely anisotropic rock (and borehole orientation perpendicular to the bedding) all received signals are expected to be similar. Not in the case of the existence of seismic anisotropy, caused for example by stress redistribution in the rock.

Rotational measurements were done in boreholes KQ0047H01, KQ0047I01 and KQ0047B02 at different depths in steps of 30 degrees.

Seismic Cross hole measurements

After a slight modification the BGR-mini sonic borehole probe can be used for seismic cross hole measurements. Cross hole measurements are carried out between two boreholes. In this case a piezoelectric transducer with an emitting frequency of about 25 kHz as a source is located in one borehole whereas the receivers are located in a second one.

Both, source and receivers are positioned in both boreholes that way, that they are facing each other. In steps of 10 cm both, source and receivers are moved towards the end of the borehole. In this case the assumed ray paths are proximate parallel to the wall of the drift if the distance between the boreholes is not too big. According to the theory, the ray paths not compelling run geometrically the shortest way. Instead they "find" the shortest way in time. In practice the results yield at least a rough model of the velocity distribution. An advantage of course is the fact, that a bigger rock volume is scanned with this method.

Borehole camera inspection

Immediately before the seismic borehole measurements are carried out an inspection of the boreholes is performed with a BGR borehole camera. This inspection aims at the evaluation of the condition of the borehole walls. A relative smooth borehole wall is a precondition for a good coupling of the seismic sensors which leads to a good signal quality.

With a BGR-borehole video camera all boreholes were inspected just before the seismic borehole measurements started. It was found on-site that the walls of the boreholes were in good condition. No borehole breakouts could be observed.

3 Data from interval velocity measurements

The quality of all measured data is very good. Figure 5 shows seismic traces from channel 2 records (distance source – receiver is 20 cm) from ultrasonic interval velocity measurements in boreholes KQ0047B01 and KQ0047B02. Measurements were taken in steps of 5 cm until 1.5 m and in steps of 10 cm till the end of the borehole. Traces are displayed trace normalised. Each trace is normalised individually to the maximum amplitude of this trace. Only a DC-shift was subtracted and travel times were corrected according to the start time of the emitting source signal. In order to display P-wave arrivals and SV-wave onsets simultaneously an automatic gain control (window of 60 µs) was applied to the data. P-wave onsets can be identified very reliable over the total depth range at about 40 µs travel time. SV-wave onsets partly interfere with reverberations from P-wave phases at about 65 µs. This interference is less for channel 3 data.

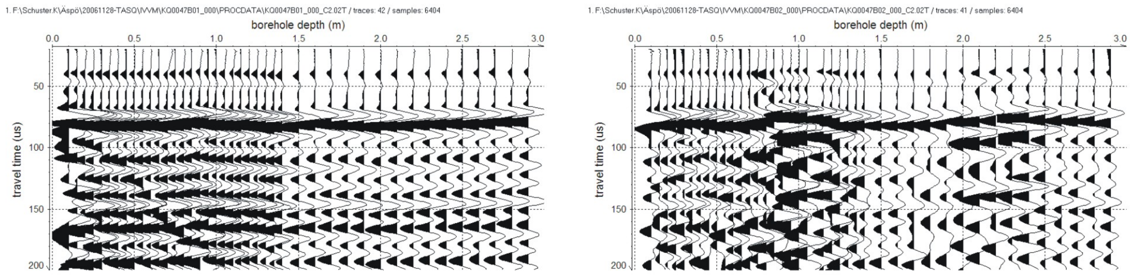


Fig. 5. *Seismic traces from ultrasonic interval velocity measurements (channel 2 data) recorded in boreholes KQ0047B01 (left) and KQ0047B02 (right). Traces displayed trace normalised and with an AGC (window of 60 µs).*

The following Figure 6 shows the same data sets. But in this case the amplitudes are colour coded (violet/red: positive amplitudes, blue/green: negative amplitudes, amber: zero level).

Furthermore the traces for each borehole are normalised over the entire ensemble of traces from this borehole. This allows a relative assessment of the signal strength along the borehole depth.

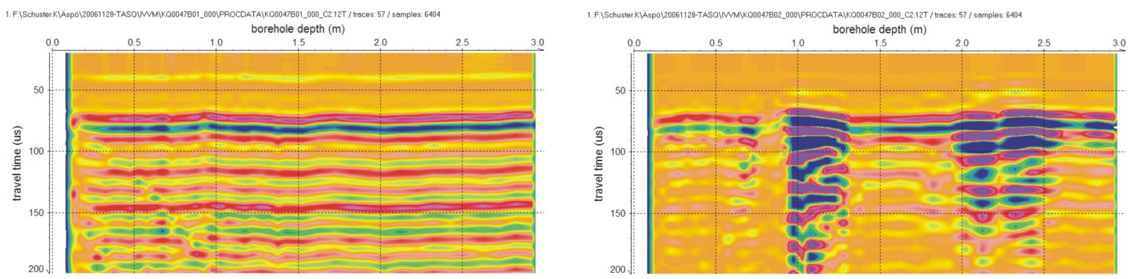


Fig. 6. *Seismic traces from ultrasonic interval velocity measurements (channel 2 data) recorded in borehole KQ0047B01 (left) and KQ0047B02 (right). Traces displayed ensemble normalised and amplitudes are colour coded (violet/red: positive amplitudes, blue/green: negative amplitudes, amber: zero level).*

In both data representations (Fig. 5 and Fig. 6) differences are remarkable. Seismogram sections from borehole KQ0047B01 appear to be smooth or vary only gradually whereas the sections from borehole KQ0047B02 show much more lateral variations in a bigger scale. Small scale variations can be observed in both data sets.

In Figures 7 and 8 for all eight boreholes the data are displayed in a similar way as it was done in Figures 5 and 6. The trace normalised displays (Fig. 7) show very clear that the first arrival phases (P-waves) and the SV-wave onsets can be identified very good in all plots. Figure 8 gives on the other hand a good impression on the variability of the amplitudes (signal strength) which is closely linked to the attenuation properties of the rock mass. Amplitudes are weakest in borehole KQ0047G01 (vertical down in the floor) for comparable borehole orientations (vertical up or vertical down). During the measurements in borehole KQ0047G01 a small problem with the relative sensor orientations occurred. However, a later check showed that the related deviations (travel times and amplitudes) influenced the accuracy of the results only to a negligible extent.

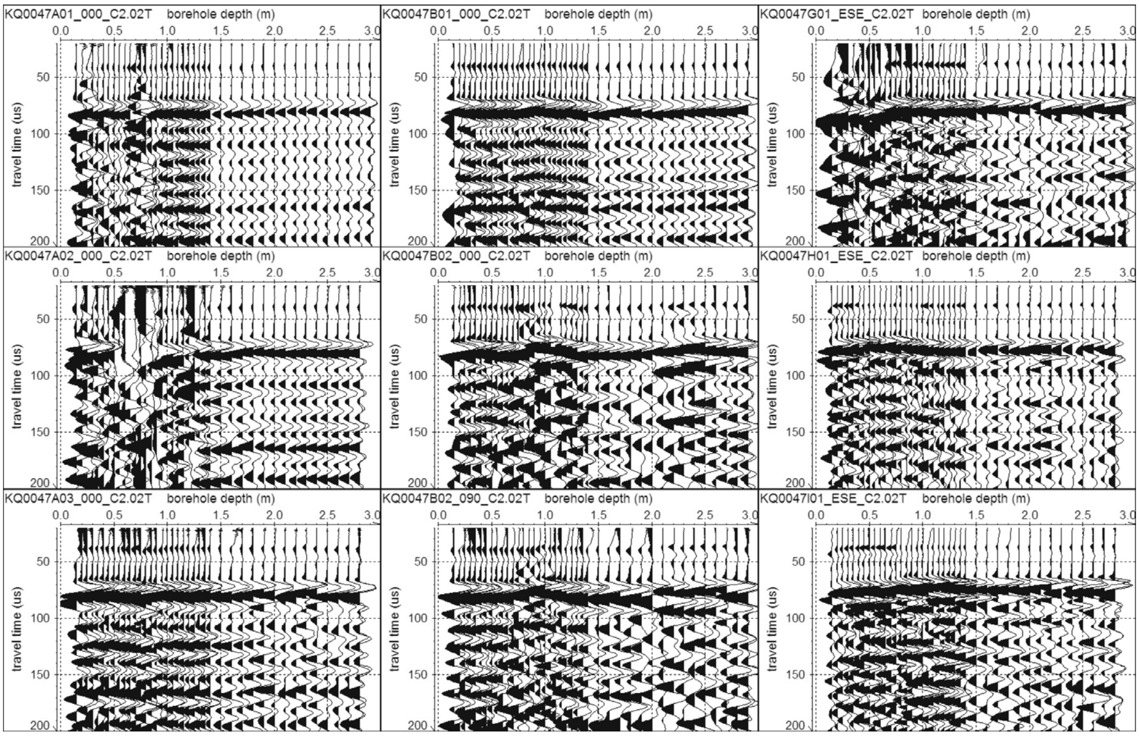


Fig. 7. *Seismic traces from ultrasonic interval velocity measurements (channel 2 data) recorded in eight boreholes KQ0047nnn. Traces displayed trace normalised and with an AGC (window of 60 µs). Borehole names are given in any plot in the left upper corner. Orientation of sensors: …_000_C1: 0°, …_090_C1: 90° and …_ESE_C1: ESE.*

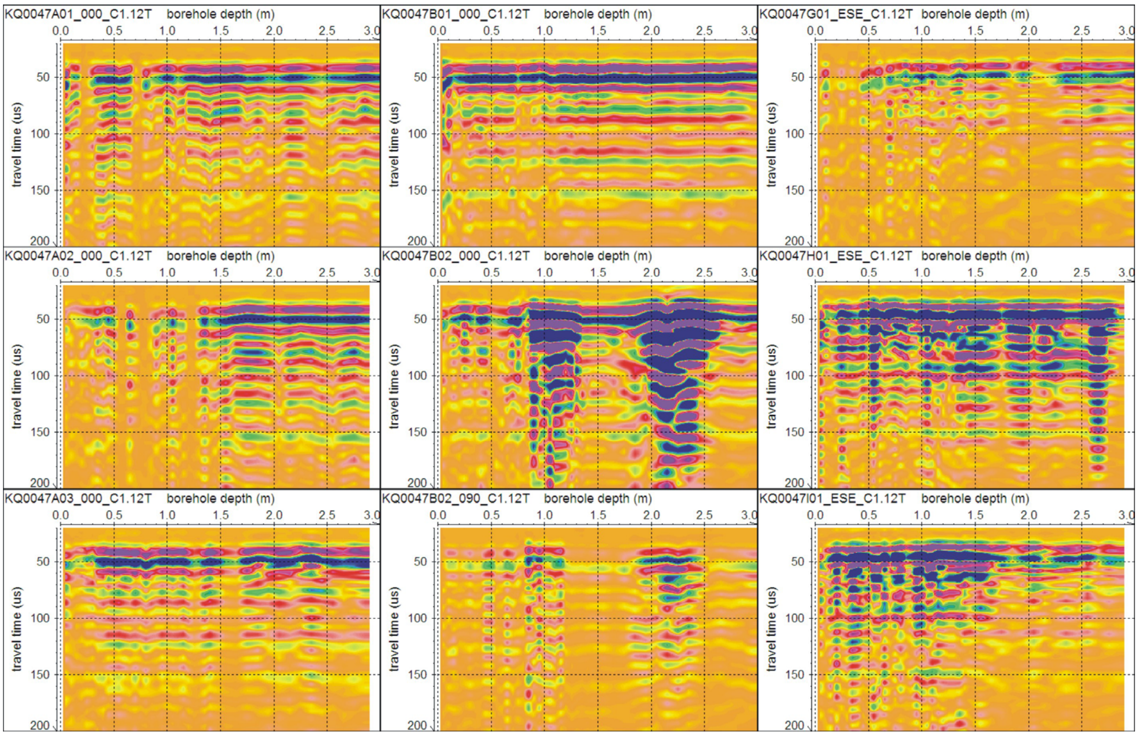


Fig. 8. *Seismic traces from ultrasonic interval velocity measurements (channel 1 data) recorded in eight boreholes (KQ0047nnn). Traces displayed ensemble normalised (over all nine plots) and amplitudes are colour coded (violet/red: positive amplitudes, blue/green: negative amplitudes, amber: zero level). Borehole names are given in any plot in the left upper corner. Orientation of sensors: …_000_C1: 0°, …_090_C1: 90° and …_ESE_C1: ESE.*

4 Interval velocity measurement data - processing and analyses

A detailed description of data processing and analyses can be found in SCHUSTER et al. (2001) and SCHUSTER & ALHEID (2002).

Data are processed with the seismic software ReflexW. Traces sorted according to the CMP-coordinate (Common Mid Point) between source and receiver position. This convention is used for all data plots (traces, velocities, etc.).

4.1 Seismic P-wave velocities

The seismic parameters, first of all the seismic P- and SV-wave velocities (Vp and Vsv), which are derived especially for the characterisation of the EDZ/EdZ, are derived via the travel times between the moment of emission and the first break at each of the three receivers. They are indicated by green (channel 1), red (ch2) and blue (ch3) colours in the appropriate figures. The propagating seismic waves are influenced by the existence of a so called small scale EdZ around the borehole wall. We assume that this small scale EDZ/EdZ has a velocity gradient perpendicular to the borehole axis. This leads to reduced velocities compared to an undisturbed rock. In general we expect that Vp(channel 1) < Vp(ch2) < Vp(ch3). Therefore the values for the seismic velocities for an undisturbed borehole wall will lie above these values.

Average P-wave velocity is a newly introduced parameter which is derived from travel time differences between the first breaks picked at the three receivers. This velocity is less influenced by the small scale EdZ around the borehole wall. Therefore it is more practical for general modelling. This value is in general higher than the velocity values derived from each of the three receivers via the moment of emission. We calculate the average velocity as the average of three values (travel time differences between receiver 2 and receiver 1, between receiver 3 and receiver 2 and between receiver 3 and receiver 1). It can be named as P-wave velocity with minimised influence of the (disturbed) borehole wall.

4.2 Further seismic parameters

Besides the travel time information also absolute and relative amplitude information were extracted from all datasets, mainly for the estimation of the degree and extent of the EDZ/EdZ but also in order to get information about dynamic elastic parameters which could be of interest for geo-mechanical modelling and comparison with parameters derived from core measurements at the laboratory.

The following seismic parameters were derived from all data sets:

- P- and SV-wave (vertical polarised) velocities,
- absolute amplitudes of first arrival (P-wave) and SV-wave onset phases,
- normalised amplitudes of first arrival (P-wave) and SV-wave onset phases,
- apparent frequency of first arrival phases (P-wave) and SV-wave onset phases,
- in-situ dynamic pseudo elastic Poisson's ratio,
- in-situ dynamic pseudo elastic Young's modulus and
- in-situ dynamic pseudo elastic modulus of rigidity.

In Figures 9 to 11 the above mentioned parameters are plotted as a function of the borehole depth exemplarily for data which were measured in borehole KQ0047B02. The corresponding plots for the other boreholes can be found in the Appendix-A. All axes in the different appropriate plots were plotted equally for better comparison. In cases where data points are missing the data quality for picking proper arrival times were not sufficient.

Figure 9 comprises all parameters which are related directly to the seismic P-waves. All three channels (distances between source and receiver of 10 cm, 20 cm and 30 cm) were analysed.

Up to now no detailed S-wave analyses (e. g. differentiating between different S-wave types and polarisation directions) were done. But according to our experiences and regarding the capabilities of our equipment we identify the S-wave as a vertical polarised S-wave (SV).

The data quality for the identification of SV-wave onsets was best for channel 3 records and mainly due to interferences with reverberations from P-wave onsets less precise for channel 2 and cannel 1 data. Therefore the SV-wave onset picking was done only for channel 3 data sets (see Fig. 10). As a consequence all the derived dynamic pseudo elastic parameters result therefore only from channel 3 data sets (see Fig. 11).

All derived dynamic pseudo elastic parameters can not be compared directly with values derived from laboratory testing. Instead of using horizontally polarised S waves for the calculation vertical polarised S-waves are used. Furthermore for the calculation the formulas for isotropic conditions are used and last but not least the in-situ conditions differ very much from the laboratory testing conditions (e.g. orientation to fine bedding, occurrence of micro cracks). Therefore we name these parameters dynamic pseudo elastic parameters. This has to be seen as an approach to get more out from the data.

The knowledge of seismic P- and S-wave velocities along the borehole allows the calculation of the P- to S-wave velocity ratios. These ratios are shown in Figure 11a. Furthermore the Poisson's ratio (ν) was calculated according to:

$$\nu = \frac{V_p^{\,2} - 2V_s^{\,2}}{2\left(V_p^{\,2} - V_s^{\,2}\right)}$$

Results are displayed in Figure 11b.

For the estimation of two further elastic rock parameters, the bulk density (ρ) is necessary.

A density of 2731 kg/m^3 was taken from OLSSON et al. (2004).

The Young's modulus (E_{dyn}) and the modulus of rigidity (G_{dyn}) were calculated along the boreholes depth according to:

$$E_{dyn} = 2 \cdot \rho \cdot V_s^{\,2} \cdot (1 + \nu)$$

and

$$G_{dyn} = \rho \cdot V_s^{\,2} \,.$$

The results are shown in Figures 11c and 11d.

When we consider the fact that P- and also SV-wave velocities which were derived from channel 3 data are in general lesser than the additionally derived P-wave velocity where the influence of the small scale EdZ around the borehole wall is minimised (see above), we have to assume that the ‘true’ values for the derived dynamic pseudo elastic parameters are in general somewhat higher.

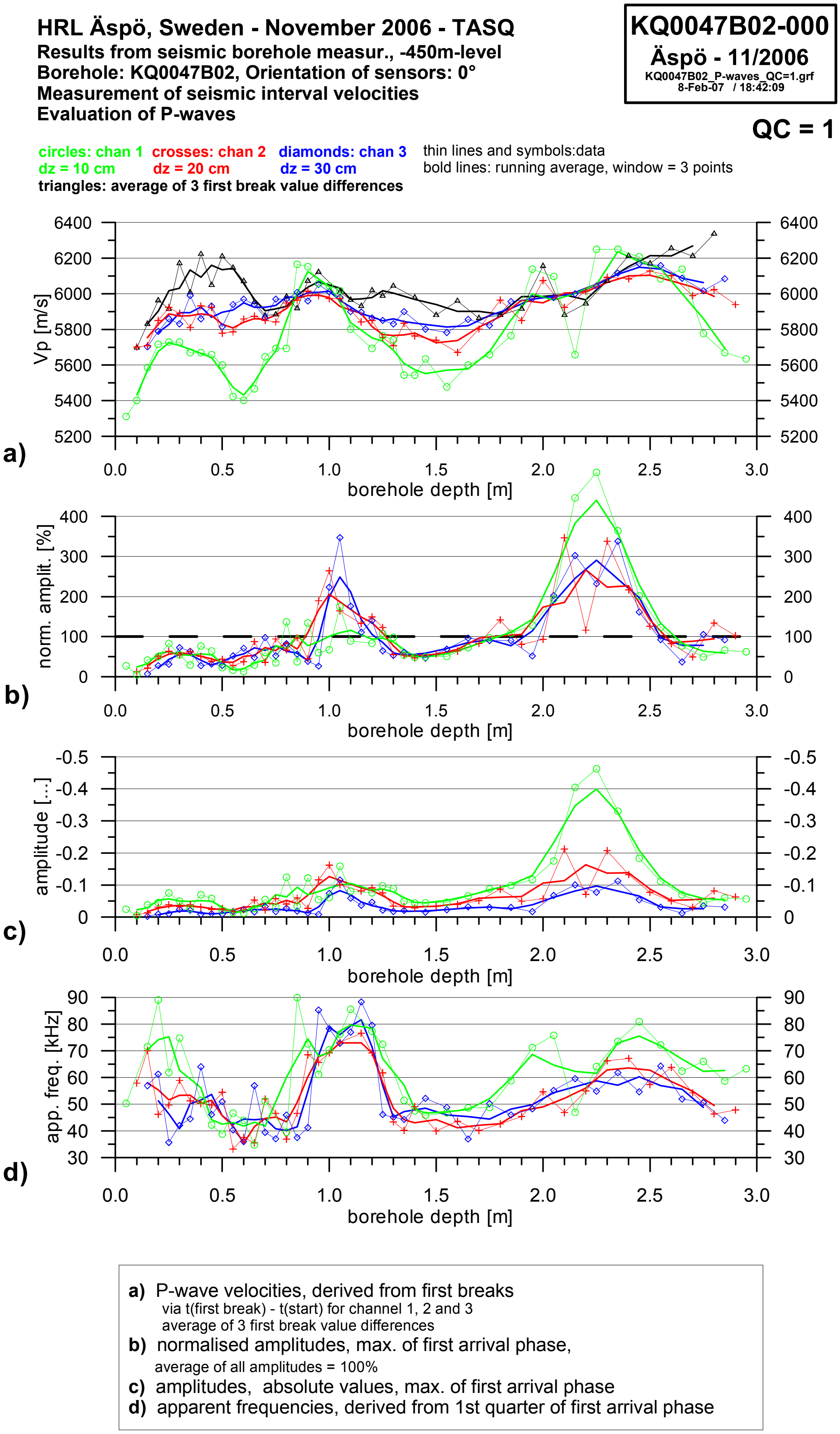
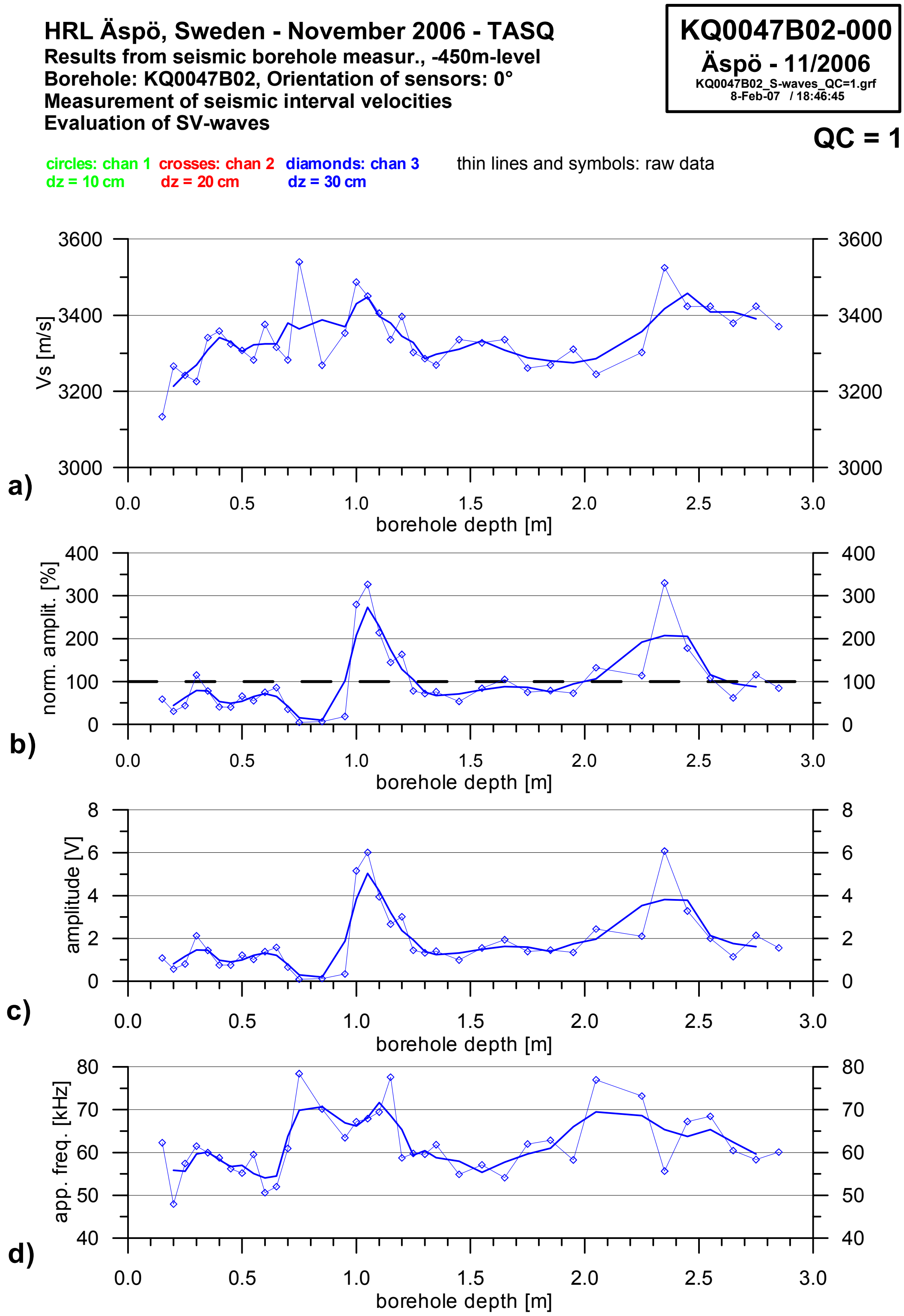


Fig. 9. *Seismic P-wave parameters derived from interval velocity measurements in borehole KQ0047B02.*



a) SV-wave velocities, derived from SV-wave onsets
b) normalised amplitudes, max. of SV-wave onset phases,
average of all amplitudes = 100%
c) amplitudes, absolute values, max. of SV-wave onset phases
d) apparent frequencies, derived from SV-wave onset phase

Fig. 10. *Seismic SV-wave parameters derived from interval velocity measurements in borehole KQ0047B02.*

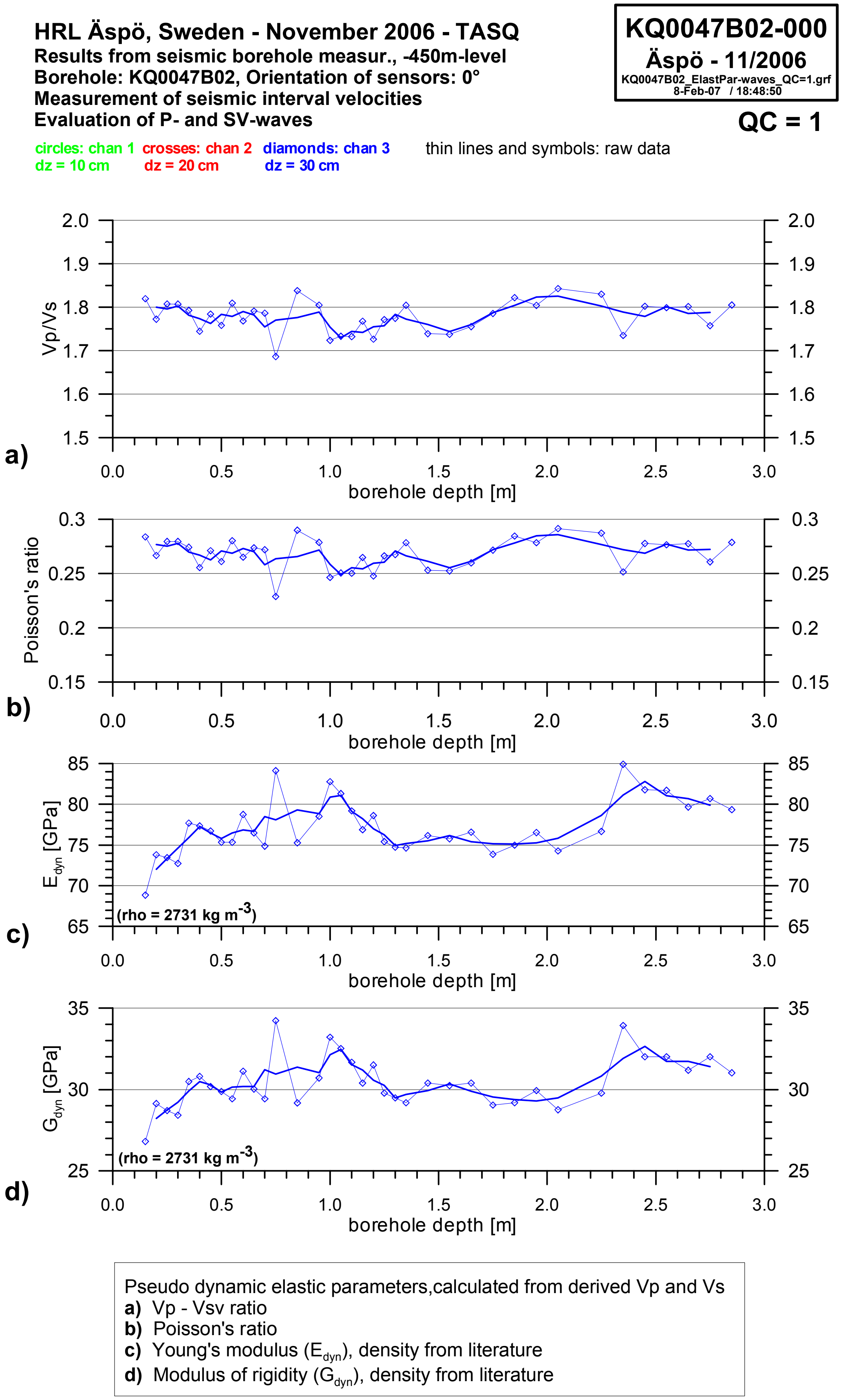


Fig. 11. *In-situ dynamic pseudo elastic parameters derived from interval velocity measurements in borehole KQ0047B02.*

4.3 Uncertainties and errors

For the interval velocity measurements we have to take into account an uncertainty of ± 0.5 to ± 1.0 microseconds for the determination of the onsets of the P-waves and between ± 1 and max. ± 2.5 microseconds for the SV-waves. This results in an uncertainty for P-wave velocities in the range between ± 11 % for channel 1 data and ± 4 % for channel 3 data. For SV-waves the uncertainties in the velocity determination lies between ± 16 % for channel 1 data and ± 6 % for channel 3 data. The mentioned maximum values should be regarded as exceptions which occur only in some parts of the data with low signal quality. Possible errors for the pseudo elastic parameters derived from channel 3 data are in the range of ± 11 % in the worst case.

An error for the determination of the extent of the EDZ can only be estimated roughly. On the basis of our approach for the EDZ/EdZ characterisation it should not exceed ± 10 cm.

In this campaign the picked first arrival times for channel 1 data are less reliable than from channel 2 and channel 3 data. Due to a weak electronic crosstalk from the emitted source signal the first arrival phases from channel 1 data in some cases are superimposed.

4.4 Seismic parameter criteria for the estimation of the extent of the EDZ/EdZ

For the identification and determination of the extent of the EDZ/EdZ reduced P- and SV-wave velocities as well as reduced normalised amplitudes are good indicators (SCHUSTER et al. 2001, SCHUSTER & ALHEID, 2002). These parameters change in general gradually within the EDZ/EdZ until the parameters reach values which stay almost constant with increasing borehole depth. These values are seen as representative for the undamaged and undisturbed rock.

Best conditions for the reliable application of these parameters as a criterion for the characterisation of the EDZ/EdZ is that the measurements take place within one lithological formation. In such cases it can be guaranteed that changes in the derived geophysical parameters are a result of changes in the petro–physical properties of the rock. Within the EDZ such changes are caused mainly by the development of micro cracks due to stress redistributions. In cases where the borehole tool encounters different lithological formations changes in the derived parameters are self-evident. Depending on the relative orientation of the borehole to the interface two extreme cases have to be regarded. When the borehole runs perpendicular or nearly perpendicular through the interface the derived seismic parameters change excursive. In cases where the borehole runs under a steep angle through the interface the derived parameter changes are gradual and the parameters, especially the seismic P-wave velocity, can adulterate the interpretation of the true extent of the EDZ/EdZ. Especially when there is a lithological interface near or within the EDZ/EdZ an interpretation can be ambiguous or even impossible. Several suchlike experiences were made in former measurements in argillaceous clay formations.

Taking also other parameters into account the interpretation can be made more reliable. A visual valuation of the seismogram sections provides additional appropriate information and is used as a further criterion. For these analyses also channel 1 and channel 3 data were taken into account, not all of them are shown in the report. Such seismogram sections for channel 1 and channel 2 data are shown in Figures 6 and 8.

Table 1 summarises the individual parameter related extents of the EDZ/EdZ for the boreholes and the estimated extents of the EDZ/EdZ. The estimation of the extents was made without taking site information into account. According to our information, mainly extracted from the core logs, there are no pronounced changes in lithology/facies along the boreholes. Therefore we have to assume that all substantial deviations in the derived seismic parameters from parameters which can be attributed to an undisturbed rock are caused by the excavation process and the related processes (e.g. stress redistributions, de-saturation).

The column 'estimate' comprises extent values which were chosen as the best representative value among the different parameters. According to our experiences from other sites we gave in this case the criteria 'normalised P-wave amplitudes' and 'seismogram section' the highest priority.

Interpretation and assessment of these results follows in Chapter 5.

Tab. 1. Extent of the EDZ/EdZ (in m) according to analyses of different seismic parameters. The final estimates are given in Chapter 5.

Borehole KQ0047…	Vp	norm. amp. P-waves	Seismogram sections	Vs	norm. amp. S-waves	estimate
…A01	-	0.35	0.3	-	0.35	0.35
…A02	-	-	0.3	-	-	0.30
…A03	-	0.25	0.35	-	-	0.30
…B01	-	0.25	0.25	-	-	0.25
…B02	0.2	0.25	0.25	0.35	-	0.25
…G01	0.75	0.85	0.65	-	-	0.75
…H01	0.15	0.85	0.65	0.35	0.9	0.75
…I01	0.25	0.25	0.3	0.6	-	0.30

5 Results

Main results and remarkable features observed in the data are mentioned and discussed below.

5.1 Extent of the EDZ/EdZ

The derived values for the extents of the EDZ/EdZ which were derived from interval velocity measurements are compiled in Figure 12.

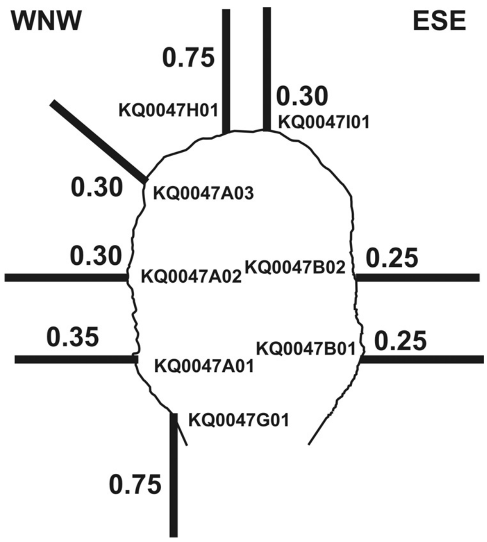


Fig. 12. *Extents of the EDZ/EdZ in meters derived from ultrasonic interval velocity measurements. See also Chap. 5.4.*

According to these results it seems that there is a slight asymmetry in the distribution of the extent values with slightly greater values at the WNW side of the tunnel. These results have to be verified, especially if results from the cross hole measurements are taken into consideration (see Chap. 5.4).

The estimation of the extent of the EdZ in borehole KQ0047H01 was difficult. We estimated it with 0.75 m mainly because of the low P-wave amplitude values and a slightly lower P-wave velocity (channel 3 data), compared to the average values of this data set.

5.2 Variation of derived parameters

The variations of derived parameters are obvious and can be found in all graphs in a small as well as in a greater scale. Figure 13 shows a compilation of P-wave velocities and maximum amplitudes of the first arrival phases derived from channel 3 data as an example.

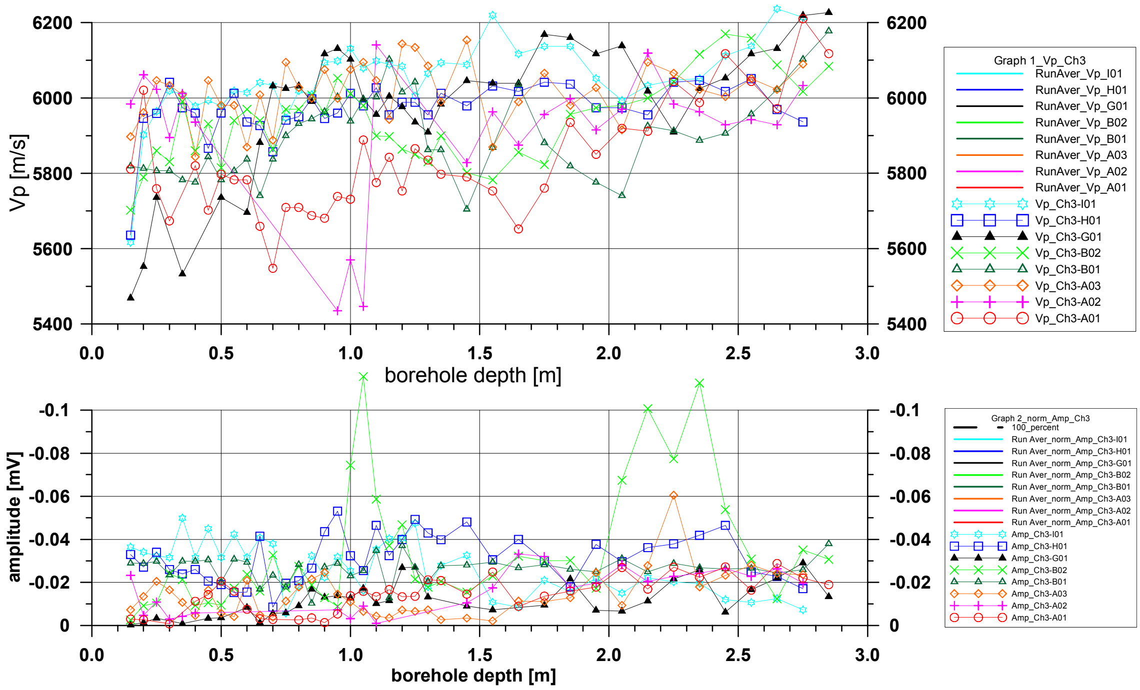


Fig. 13. *Seismic P-wave velocities* ***(above)*** *and maximum amplitudes of first arrival phases* ***(below)*** *derived from ultrasonic interval velocity measurements (channel 3 data) in all eight boreholes. No running average curves are plotted.*

The borehole video analyses showed that no borehole breakouts exist. So we can exclude a direct influence of a damaged borehole wall to the seismic data. For all measurements we had good coupling conditions.

Variations in the parameter distribution can be caused among others by small scale lithological variations, by the existence of small cracks and fractures and of course an uncertainty in the determination of the picked travel times has to be taken into consideration. Poor or changing signal quality and inaccuracies in time picking could be a reason for that. In our case these reasons should be of minor importance due to the relative good signal quality and the experienced staff. In general such variations are more pronounced for channel 1 data.

A strong variation can be found for example in borehole KQ0047B02 (see Fig. 9b,c) where the amplitudes show pronounced maxima at 1 m and 2.2 m whereas the amplitudes drop below the average value after 1.5 m in borehole KQ0047I01 (see Fig. A-22). Both features can be already seen qualitatively in Figure 8.

In the following compilation (see Table 2) we only consider data which were derived outside the EdZ. They were derived from channel 3 records which are still influenced by the existence of a small scale EDZ around the borehole walls, but less than parameters derived from channel 1 and channel 2 data. Nevertheless, the real seismic velocities and consequently also the derived in-situ dynamic pseudo elastic parameters will lie slightly above the listed values.

Tab. 2. Variation of parameters derived from channel 3 records (except Vp-average). Only values outside the EDZ/EdZ are considered.

Variation of derived parameters	
(only outside the EDZ/EdZ)	
P-wave velocity, average of 3 first break value differences [m/s]	5500 – 6500
P-wave velocity [m/s]	5500 – 6200
S-wave velocity [m/s]	3100 – 3700
Dyn. Poisson's ratio [-]	0.21 - 0.29
Dyn. Young's modulus [GPa]	66 – 90
Dyn. Modulus of rigidity [GPa]	26 – 34

5.3 Rotational interval velocity measurements

Rotational interval velocity measurements were performed in boreholes KQ0047H01, KQ0047I01 and KQ0047B02 at different depths in steps of 30 degrees.

In Figure 14 slight variations in travel times for the first arrival phases can be observed. More pronounced are the amplitude variations of this first arrival phases. For example in borehole KQ0047G01 at a depth of 180cm (conf. Fig. 14) the highest amplitudes are between 90° and 150° and again between 330° and 360°. Such an asymmetry can be seen as a hint for the existence of seismic anisotropy.

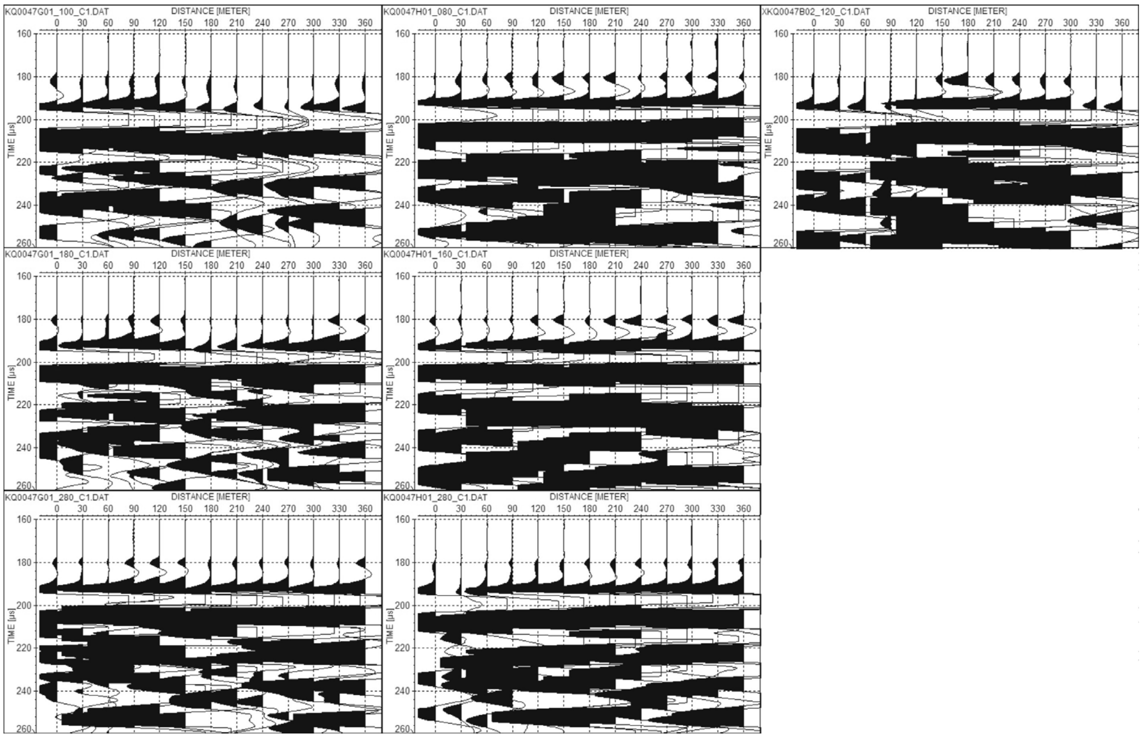


Fig. 14. *Seismic traces (channel 1 data) derived from interval velocity measurements in boreholes KQ0047G01, KQ0047H01 and KQ0047B02. The borehole probe was rotated at different depths clockwise in steps of 30°. Measurements started at 0° what corresponds to the ESE wall of the tunnel for both vertical boreholes. 270° points towards the heading face of the tunnel. For the horizontal borehole 0° corresponds to 12 o'clock.*
Measurement depth for KQ0047G01 – vertical down (left column): 100cm, 180cm and 280cm.
Measurement depth for KQ0047H01 – vertical up (middle column): 80cm, 160cm and 280cm.
Measurement depth for KQ0047B02 – horizontal (right side): 120cm.
(X-axis: Distance (m) corresponds to the rotation angle (degree)

Seismic P- and SV-wave parameters are derived from the rotational interval velocity measurements in the same way as it was done for the interval velocity measurements. In Figures 15 and 16 these parameters are compiled exemplarily for data from borehole KQ0047G01, where the probe was rotated at a depth of 1 m in steps of 30°. Instead of the borehole depth the angle of rotation is plotted on the x-axis. The assignment between measurement directions (given in degrees) and the orientation in the tunnel are plotted on top of the P- and SV-wave velocity graphs. The orientations relative to the tunnel orientation can be found in Figure 2.

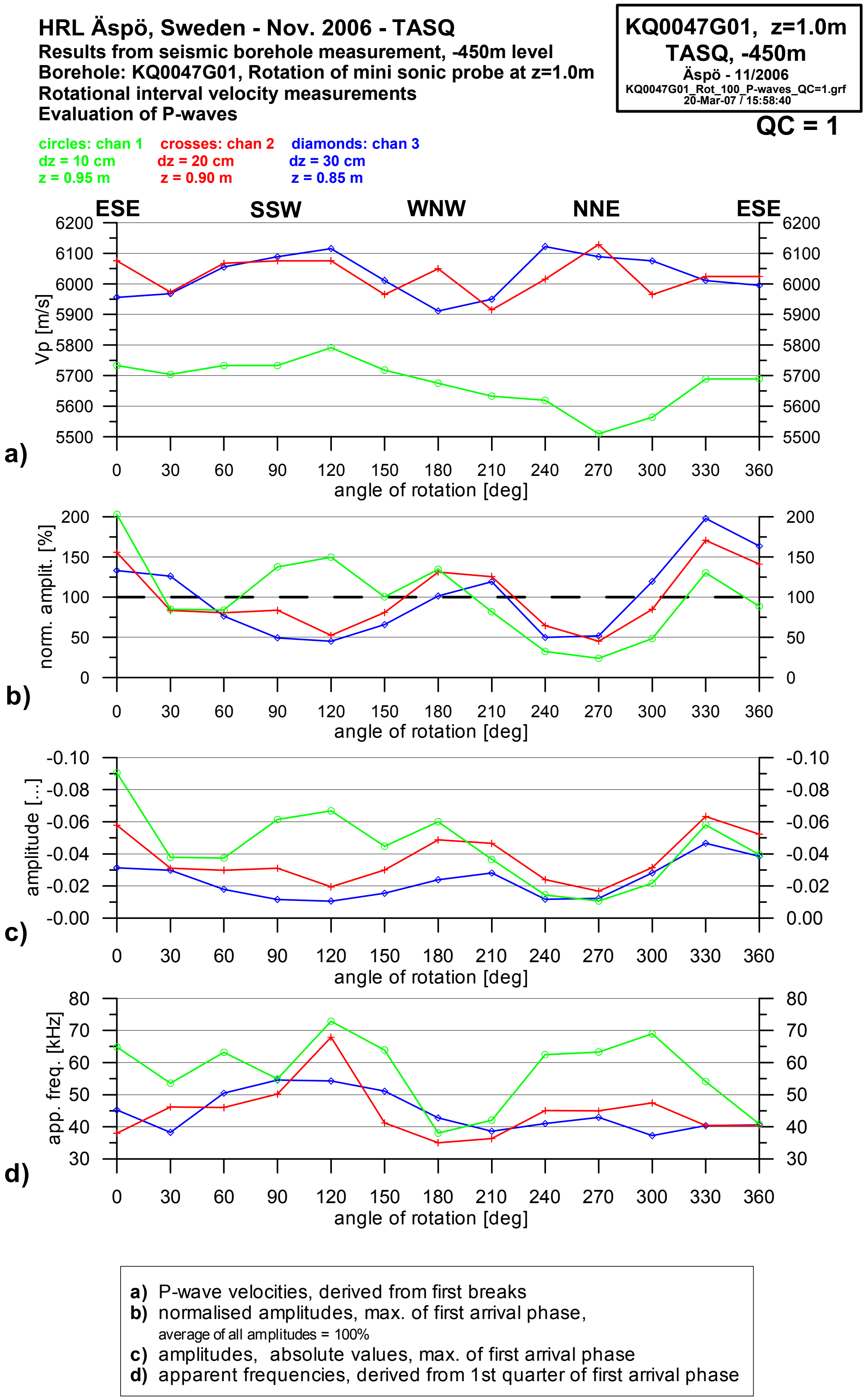


Fig. 15. *Seismic P-wave parameters derived from rotational interval velocity measurements in borehole KQ0047G01 at a depth of 1m.*

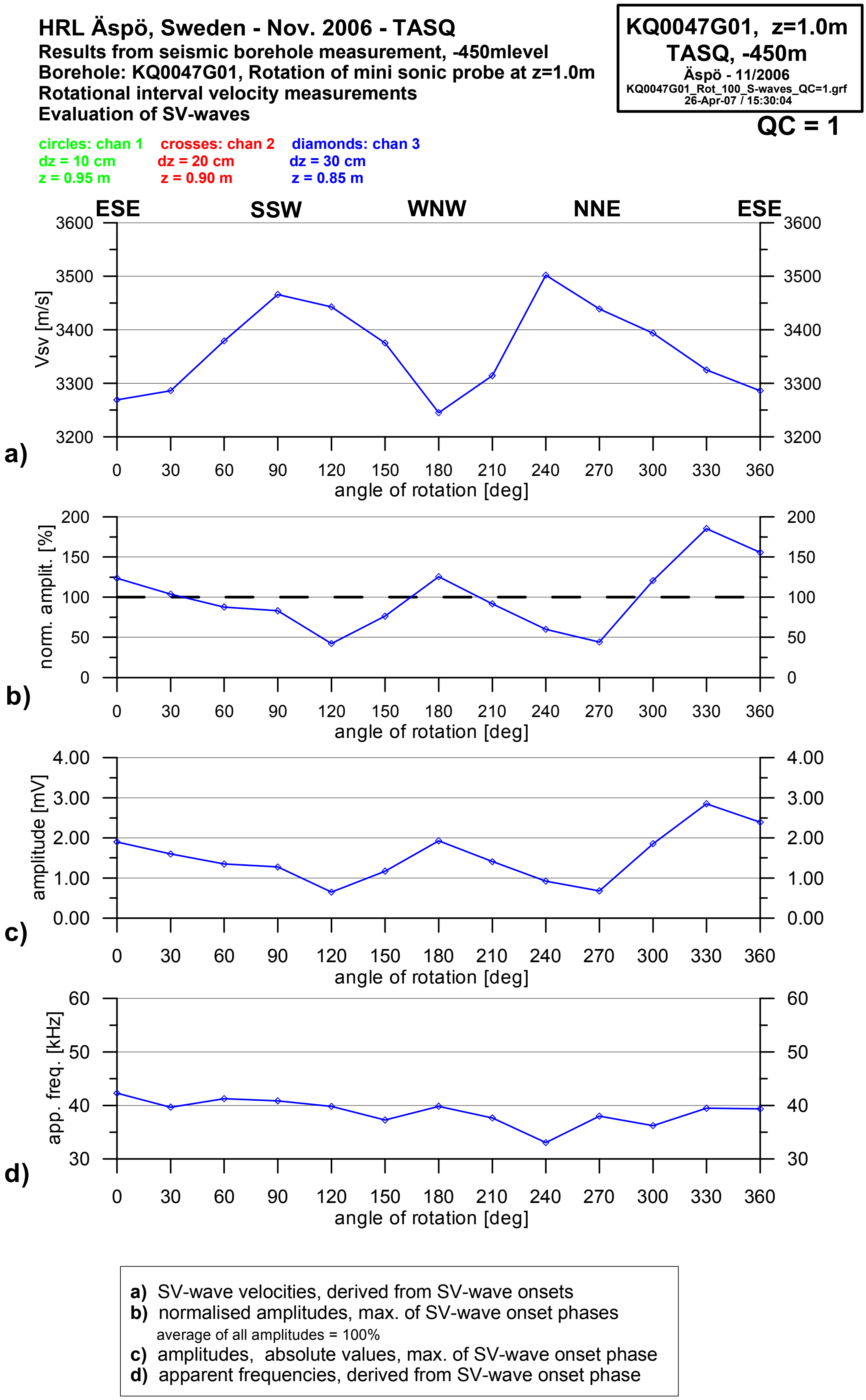


Fig. 16. *Seismic SV-wave parameters derived from rotational interval velocity measurements in borehole KQ0047G01 at a depth of 1m.*

For the P-wave parameters a weak 180°-periodicity with maxima or minima in SSW direction (entrance of the tunnel) and NNE direction (towards the heading face) can be observed. This is the direction of the minor principal stress (OLSSON et al., 2004). For the SV-wave velocity distribution (Fig. 16a) it is more pronounced. The reason for this seismic anisotropy could be related to the minor and major principal stress directions. This should be analysed in more detail.

In many cases the values of parameters derived from measurements at 0° and 360° differ. Under ideal conditions these values should be the same. One reason for these differences could be inaccurateness in positioning the probe. We assume ± 10° as an error, because the positioning in vertical boreholes is done by visual judgement in contrast to horizontal and inclined boreholes where the positioning are made very precisely (± 1°) with the help of a special tool. In combination with small scale inhomogeneities the positioning inaccurateness can be the reason for the differences.

A compilation of the derived P-wave velocities and maximum amplitudes of the first arrival phases from channel 3 data are shown in Figure 17. The corresponding SV-wave parameters are plotted in Figure 18.

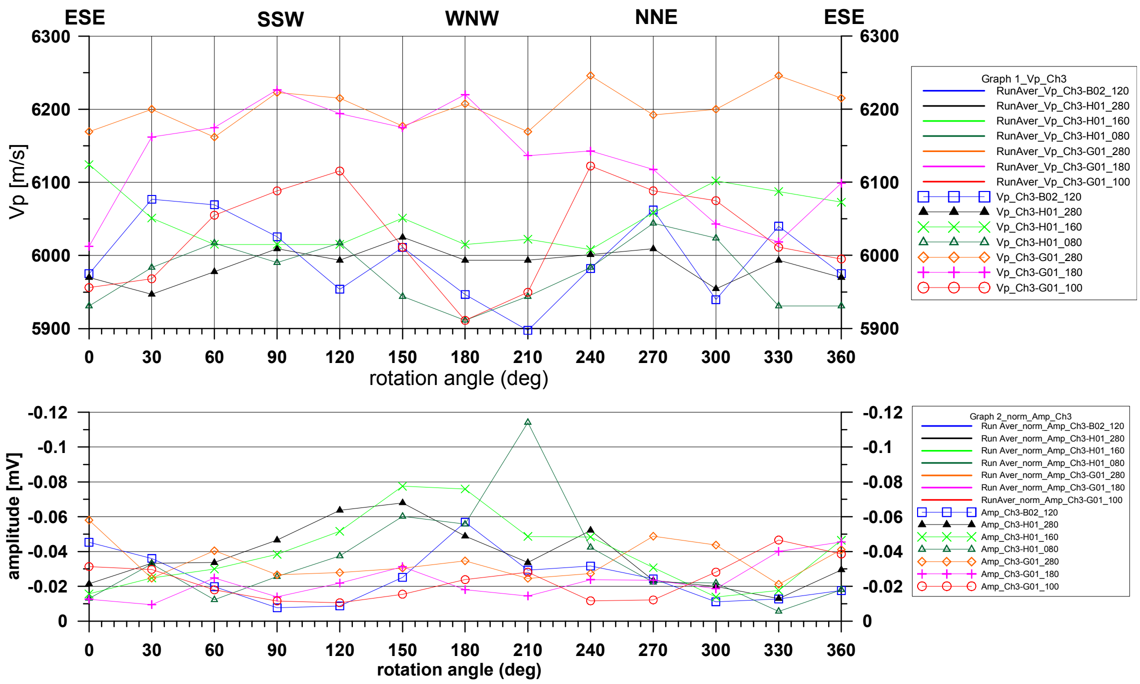


Fig. 17. *Seismic P-wave velocities* ***(above)*** *and maximum amplitudes of first arrival phases* ***(below)*** *derived from ultrasonic rotational interval velocity measurements (channel 3 data) in vertical boreholes KQ0047G01 (measured at depth of 1.0m, 1.8m and 2.8m) and KQ0047H01 (measured at depth of 0.8m, 1.6m and 2.8m). In the horizontal borehole KQ0047B02 measurements at a depth of 1.2m were performed. No running average curves are plotted.*

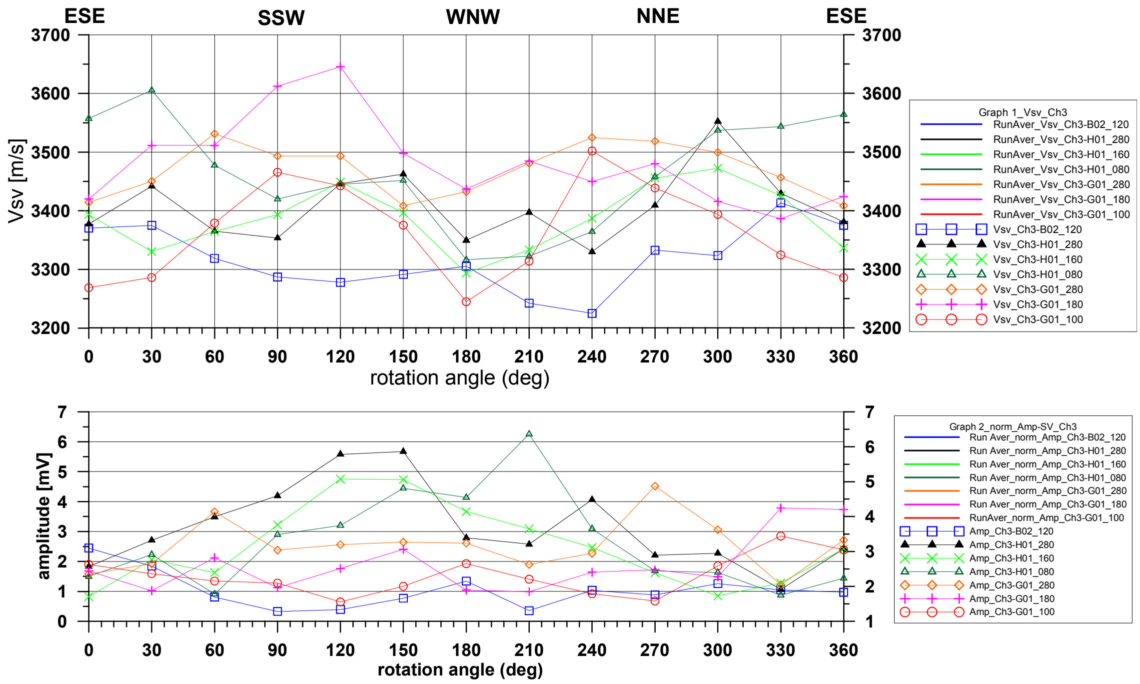


Fig. 18. *Seismic SV-wave velocities **(above)** and maximum amplitudes of first onsets of SV-phases **(below)** derived from ultrasonic rotational interval velocity measurements (channel 3 data) in vertical boreholes KQ0047G01 (measured at depth of 1.0m, 1.8m and 2.8m) and KQ0047H01 (measured at depth of 0.8m, 1.6m and 2.8m). In the horizontal borehole KQ0047B02 measurements at a depth of 1.2m were performed. No running average curves are plotted.*

5.4 Ultrasonic cross hole measurements between boreholes KQ0047B02 and KQ0047B01

Between the horizontal boreholes KQ0047B02 (source) and KQ0047B01 (three receivers) a ultrasonic cross hole measurement was performed. Both, source and receivers were moved successively along the boreholes. The source and receiver 2 were placed perpendicular to each other. The emitted main signal frequency was 25 kHz. The quality of the recorded signals is very good. Figure 19 shows data from channel 2 recordings.

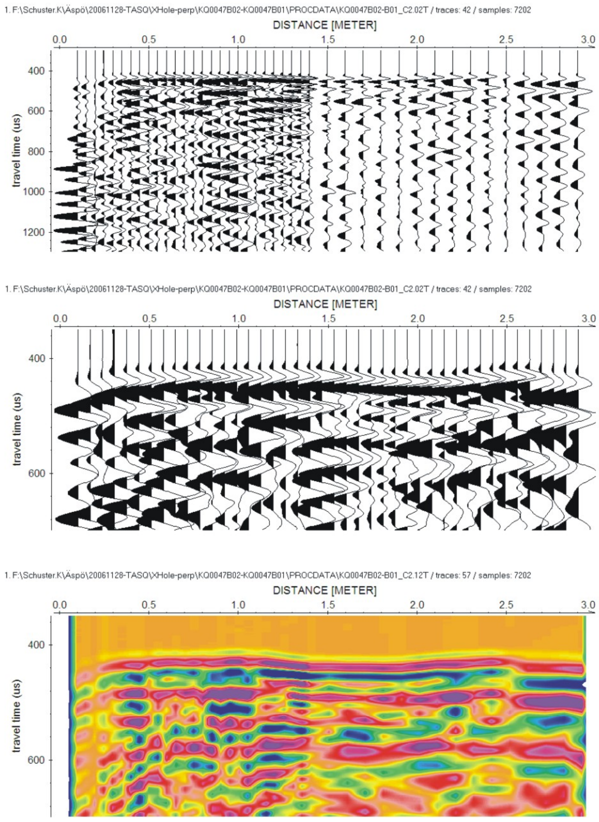


Fig. 19. *Seismic traces from ultrasonic cross hole measurements (channel 2 data) between borehole KQ0047B02 and KQ0047B01.*
Top and Middle: *trace normalised section.*
Below: *Traces displayed ensemble normalised and amplitudes are colour coded (violet/red : positive amplitudes, blue/green : negative amplitudes, amber : zero level).*

The derived P-wave parameters are compiled in Figure 20. The distribution of the normalised amplitudes and the P-wave velocities give reason to assume that a higher attenuation within the first 40 cm to 50 cm of the rock occurs. Results from interval velocity measurements show an extent of the EDZ/EdZ along boreholes KQ0047B01 and KQ0047B02 of 25 cm.

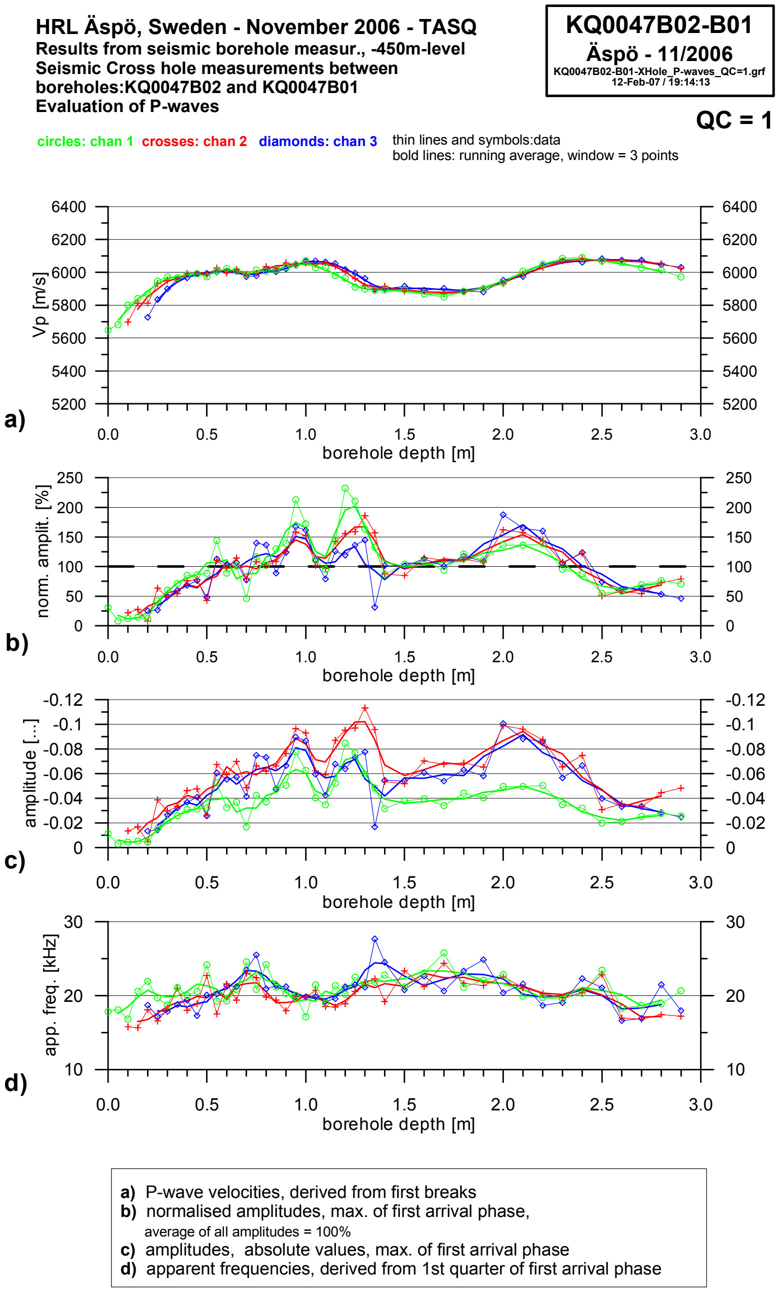


Fig. 20. *Seismic P-wave parameters derived from ultrasonic cross hole measurements between boreholes KQ0047B02 and KQ0047B01.*

5.5 Comparison of results from ultrasonic interval velocity measurements with results from cross hole measurements

In Figure 21 the P-wave distribution derived from cross hole and from interval velocity measurements are compiled in one graph. The trend of both graphs is similar. P-wave velocities from interval velocities are in general lower due to the fact, that they are more influenced by a small scale EdZ around the borehole wall.

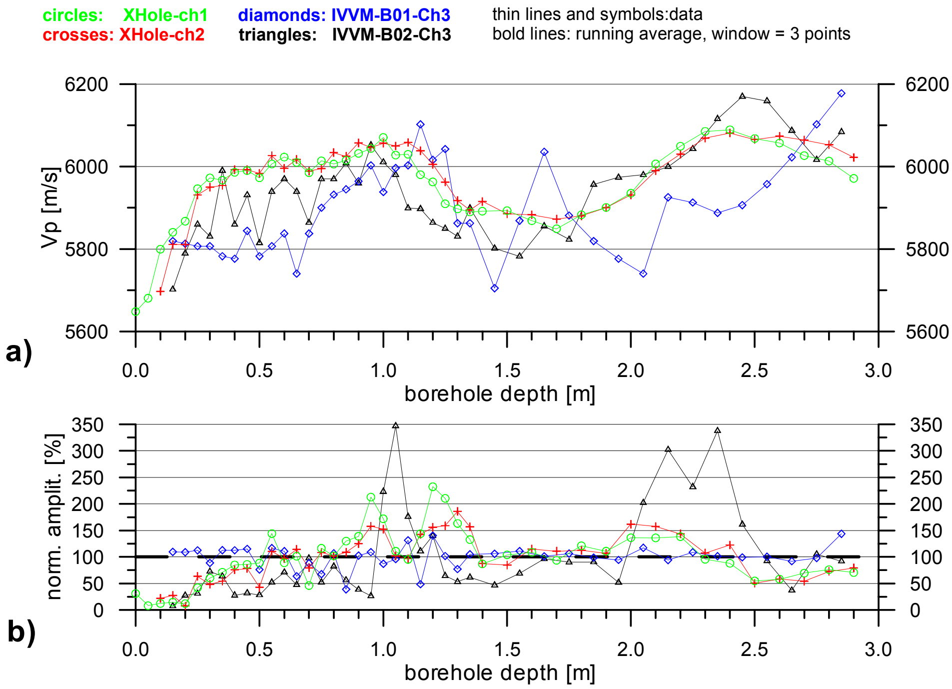


***Fig. 21.** Comparison of seismic P-wave parameters derived from ultrasonic interval velocity measurements with results from cross hole measurements between boreholes KQ0047B02 and KQ0047B01.*
***a):** Seismic P-wave velocities. **b):** Normalised amplitudes of first arrival phases.*

5.6 Detection of fractures and cracks

In some of the derived seismic parameter graphs as well as in the seismogram sections, displayed in varying magnifications, hints for the existence of cracks or fractures can be seen. We assess a loss or a very strong decrease in signal as a hint for the existence of a crack or fracture. Worth mentioning is the fact that no fractures/cracks or hints for their existence are found on the ESE side of the tunnel (boreholes KQ0047B01 and KQ0047B02).

Tab. 3. Possible locations of cracks or fractures according to signal analyses of interval velocity data.

Borehole KQ0047…	**Possible cracks or fracturtes at … cm**
…A01	20-25, 70-75
…A02	55-60, 70-80, 120-125
…A03	(155-165)?
…B01	no
…B02	no
…G01	(15-40)?, 40, (205-215)?
…H01	(10-20)?, (170)?
…I01	5-10, (85-90)?

6 References

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Schuster, K., Alheid, H.-J. & Böddener, D. (2001). Seismic investigation of the Excavation damaged zone in Opalinus Clay, Engng. Geol. 61: 189-197.

Schuster, K. & Alheid, H.-J. (2002). Engineered Barrier (EB) Experiment and Geophysical Characterisation of the Excavation Disturbed Zone (ED-C) Experiment: Seismic Investigation of the EDZ in the EB niche. - Mont Terri Technical Report TR 02-03, swisstopo, Wabern, Switzerland.

Appendix - A

1.) Plots of seismic parameters derived from ultrasonic interval velocity measurements in boreholes:

KQ0047A01

KQ0047A02

KQ0047A03

KQ0047B01

KQ0047B02

KQ0047G01

KQ0047H01

KQ0047I01

(Fig. A-01 – A-24)

2.) Plots of seismic parameters derived from ultrasonic rotational interval velocity measurements in boreholes:

KQ0047G01, depth: 1.0m, 1.8m and 2.8m

KQ0047H01, depth: 0.8m, 1.6m and 2.8m

KQ0047B02, depth: 1.2m

(Fig. A-25 – A-38)

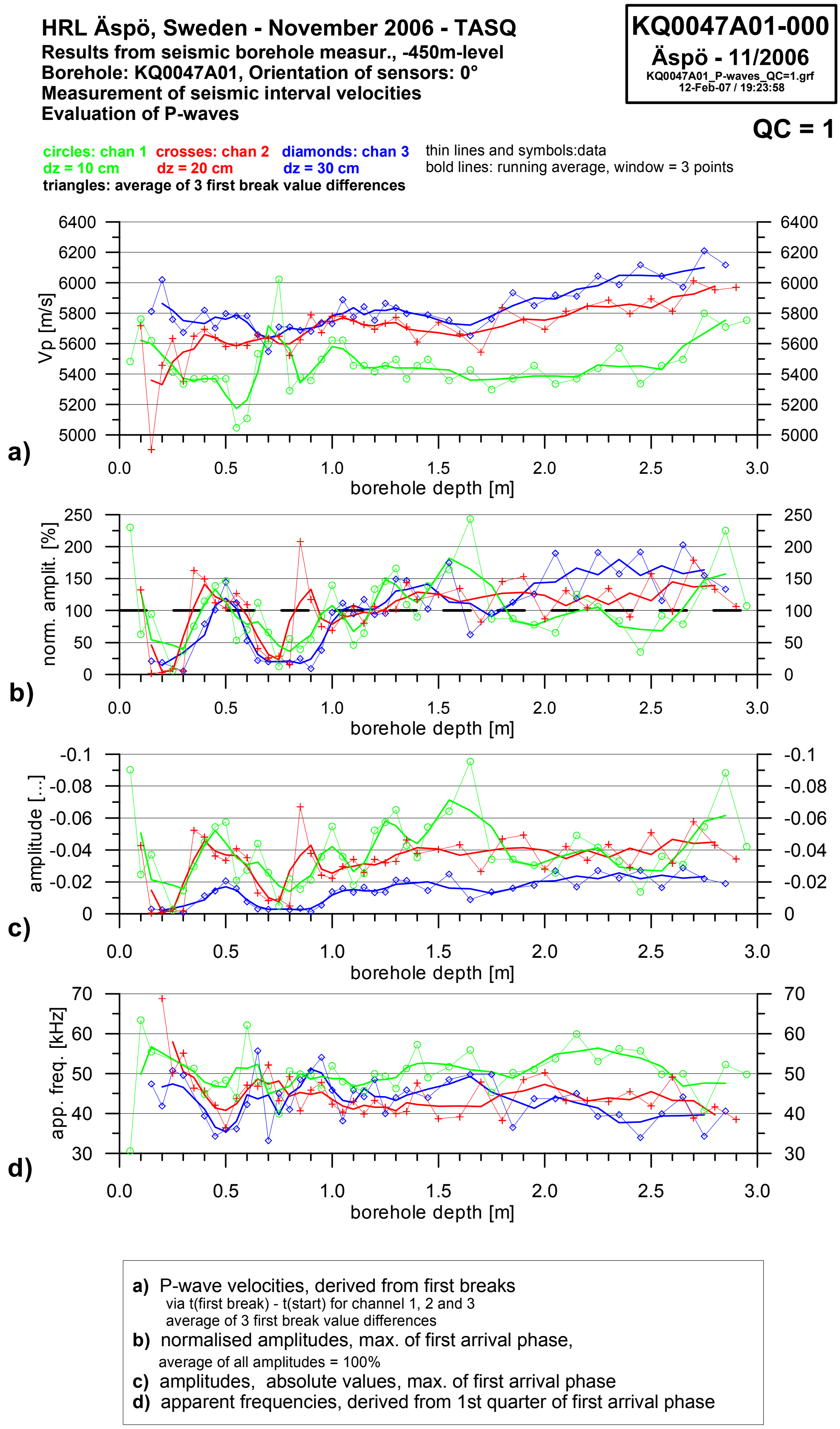


Fig. A-01. *Seismic P-wave parameters derived from interval velocity measurements in borehole KQ0047A01.*

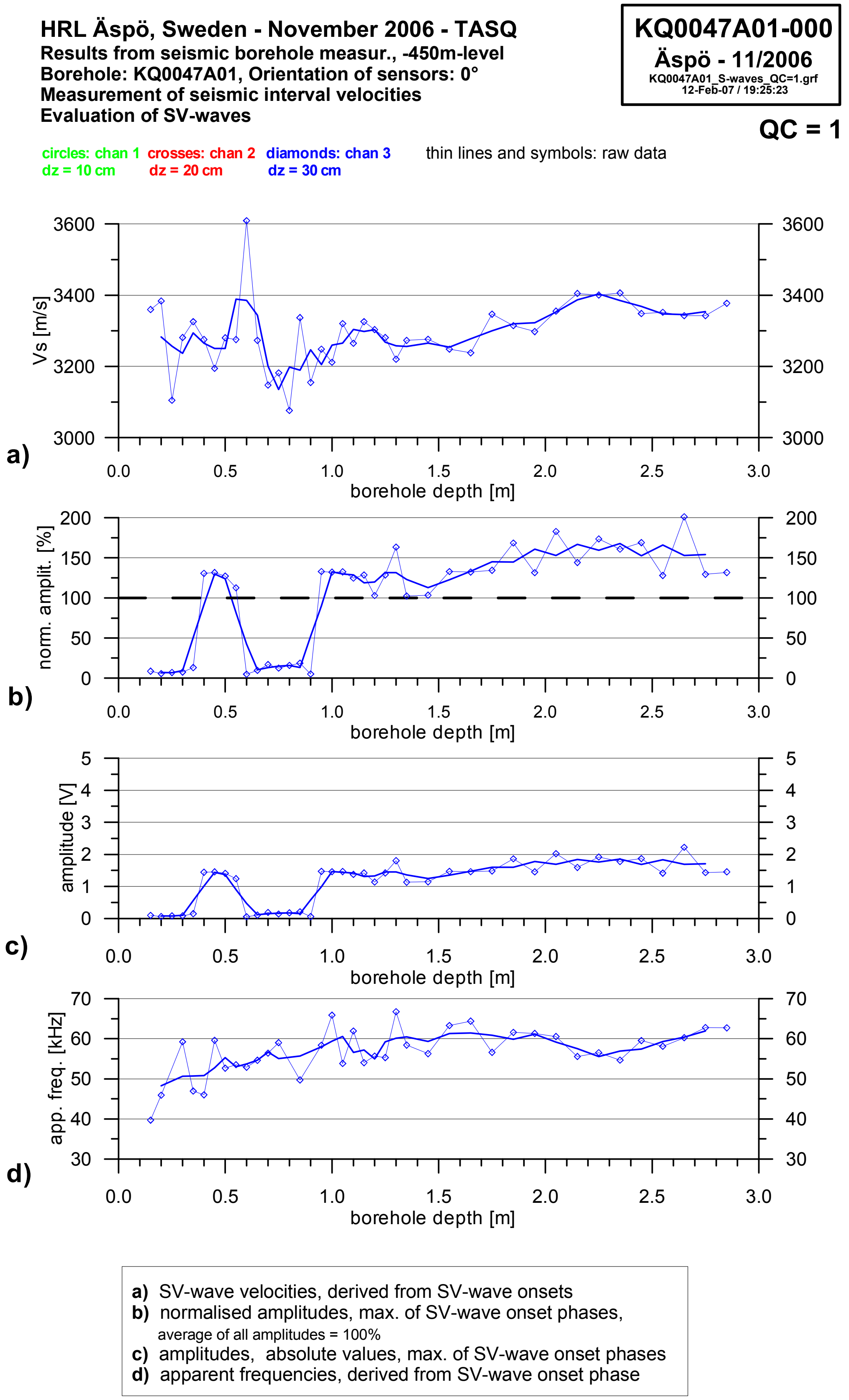


Fig. A-02. *Seismic SV-wave parameters derived from interval velocity measurements in borehole KQ0047A01.*

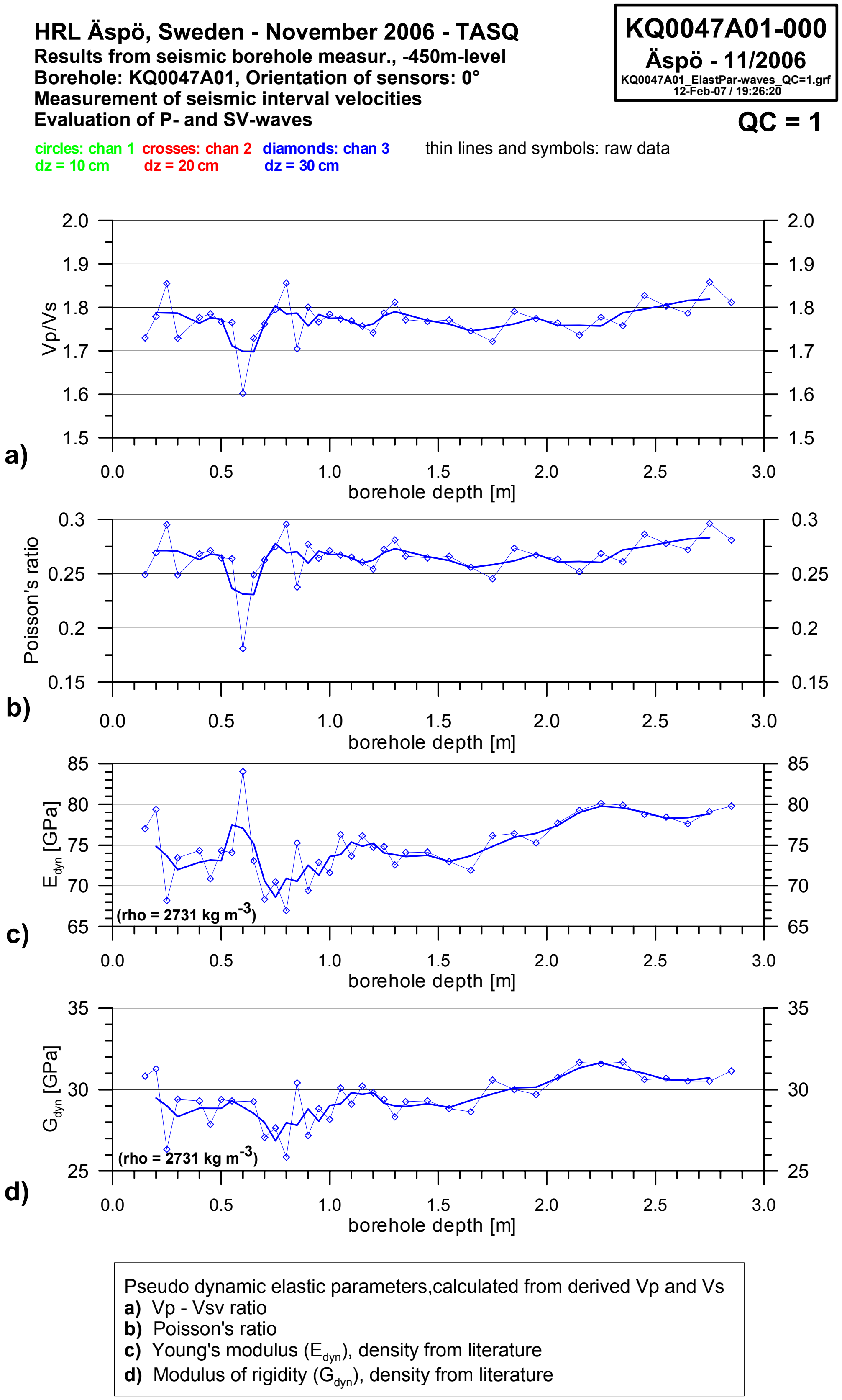


***Fig. A-03.** In-situ dynamic pseudo elastic parameters derived from interval velocity measurements in borehole KQ0047A01.*

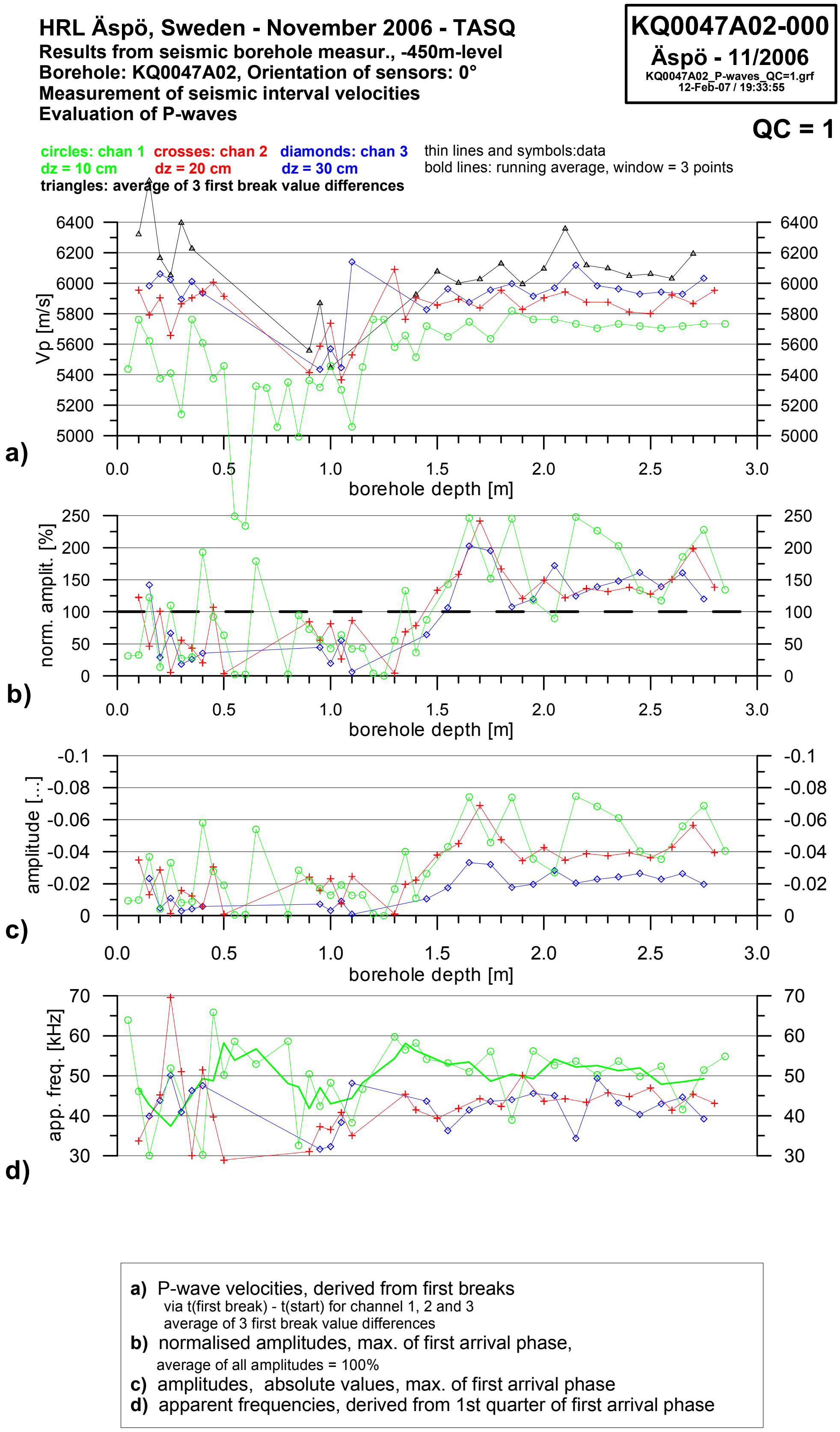


Fig. A-04. *Seismic P-wave parameters derived from interval velocity measurements in borehole KQ0047A02.*

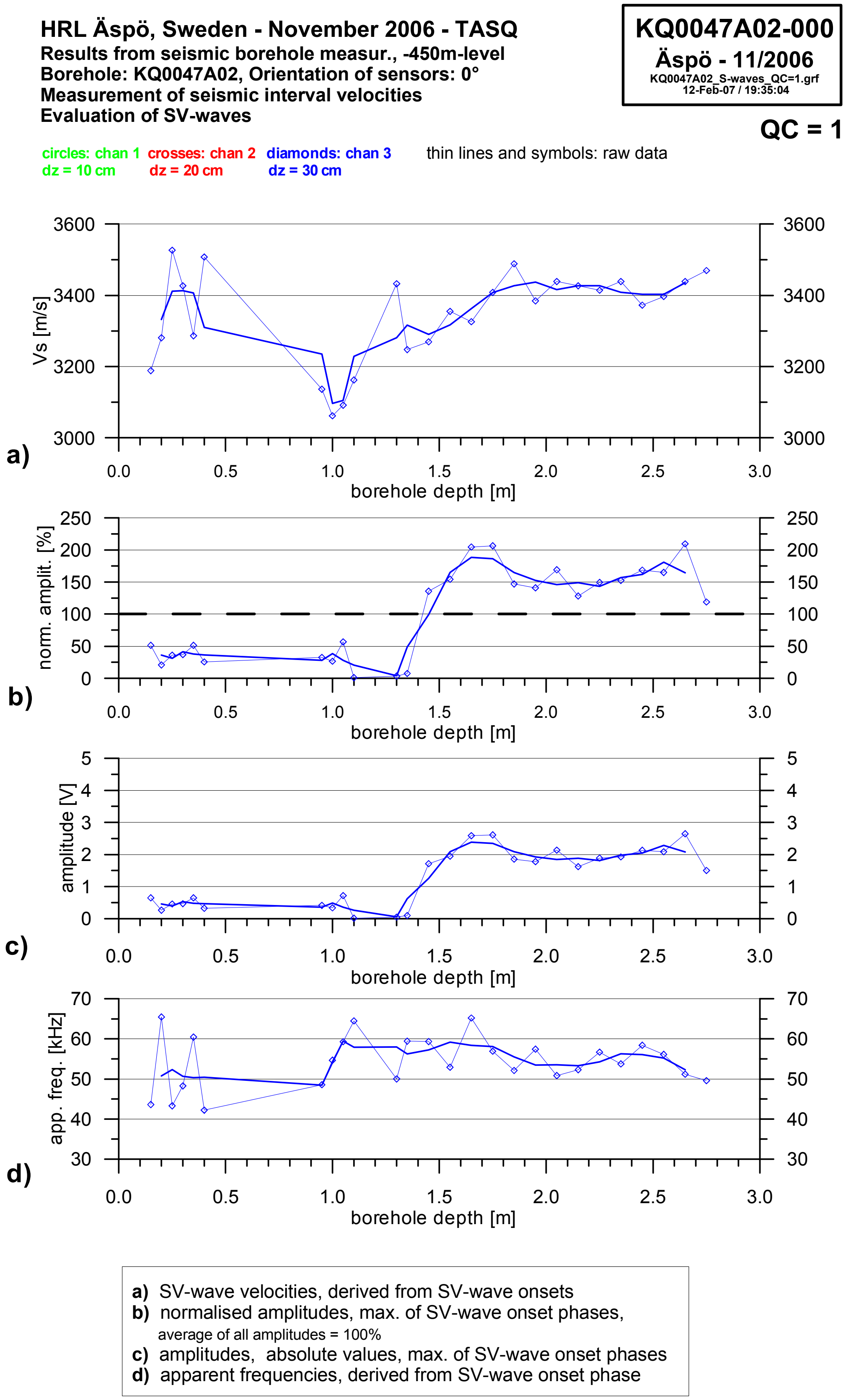


Fig. A-05. *Seismic SV-wave parameters derived from interval velocity measurements in borehole KQ0047A02.*

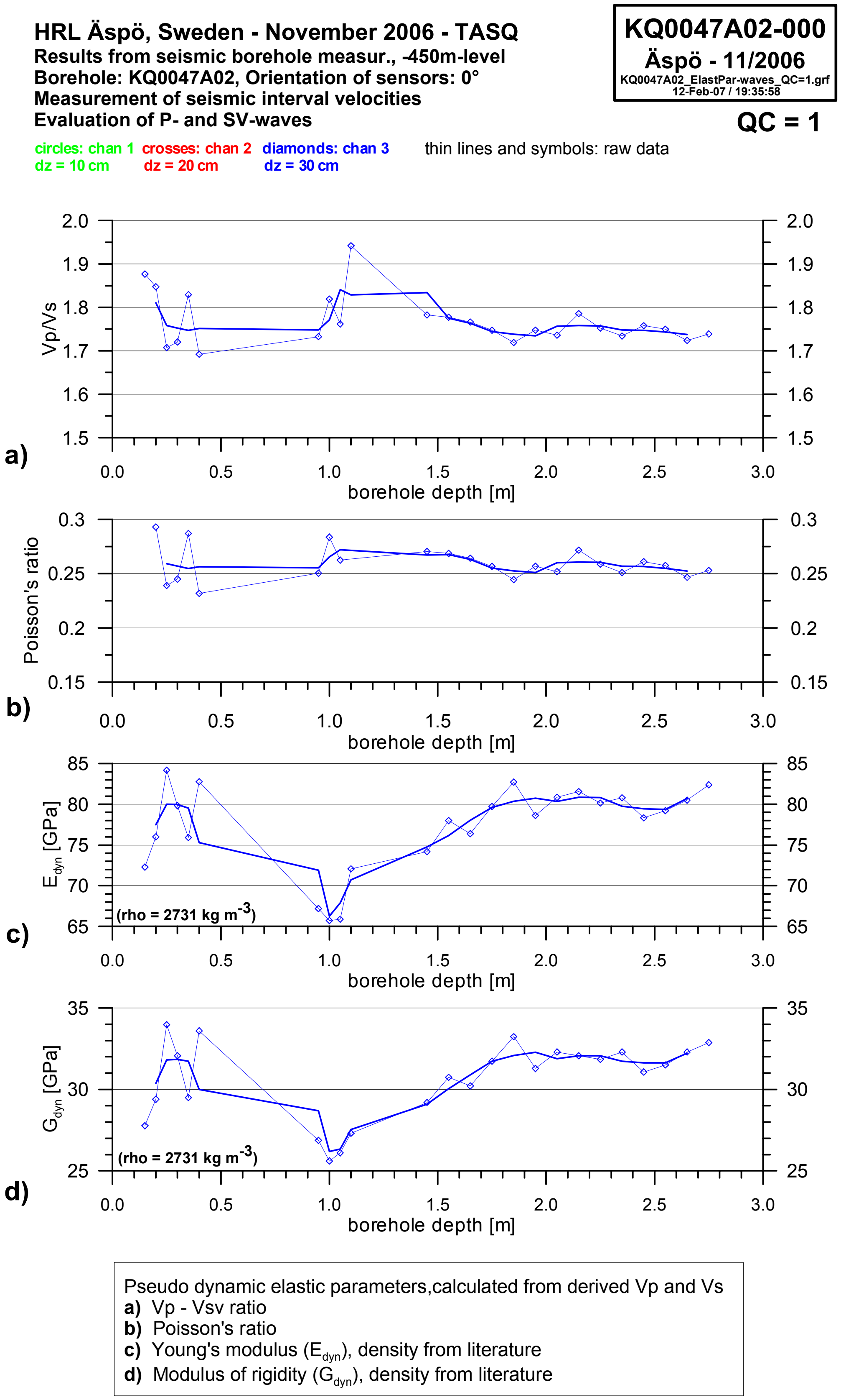


Fig. A-06. *In-situ dynamic pseudo elastic parameters derived from interval velocity measurements in borehole KQ0047A02.*

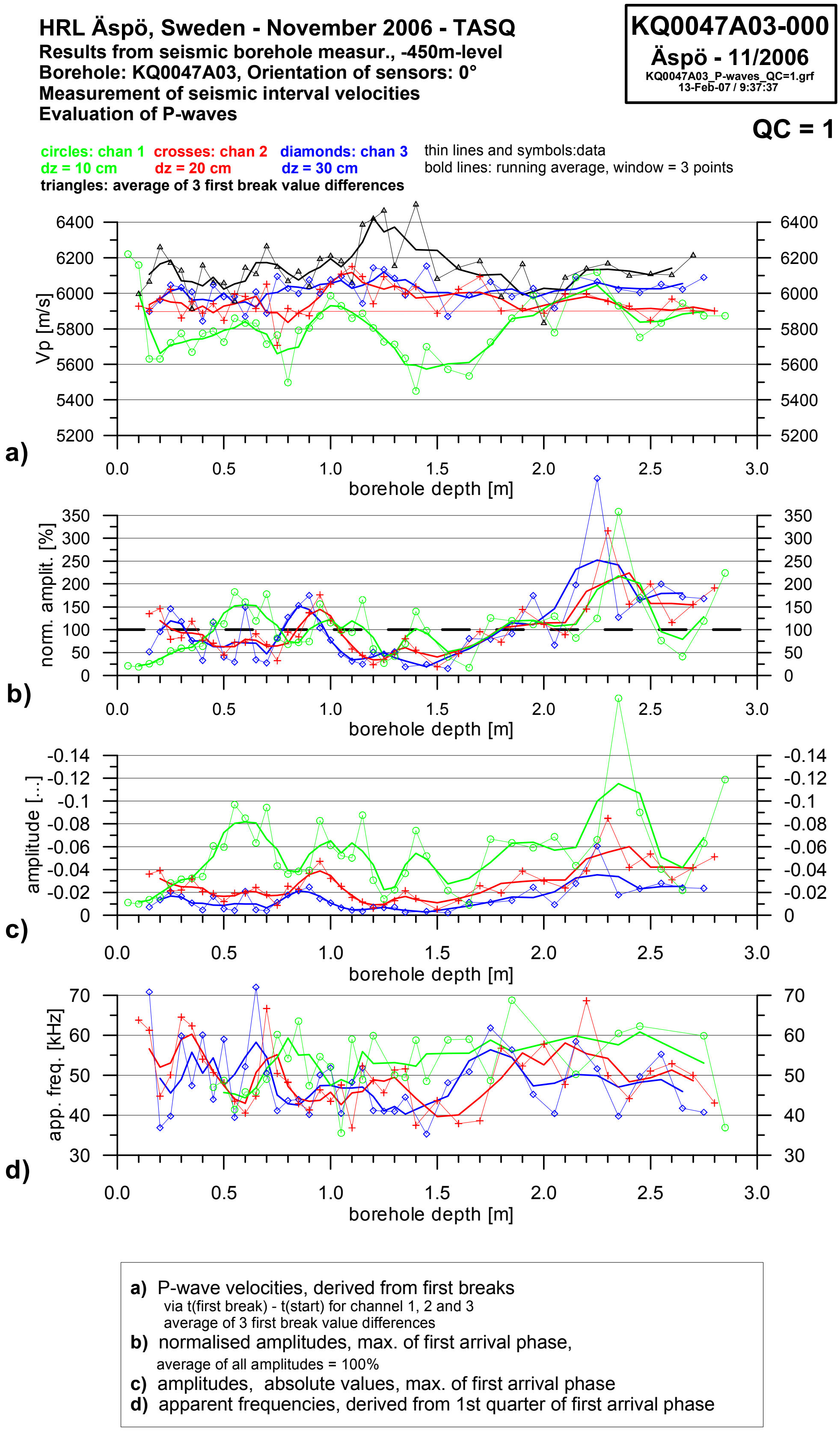


Fig. A-07. Seismic P-wave parameters derived from interval velocity measurements in borehole KQ0047A03.

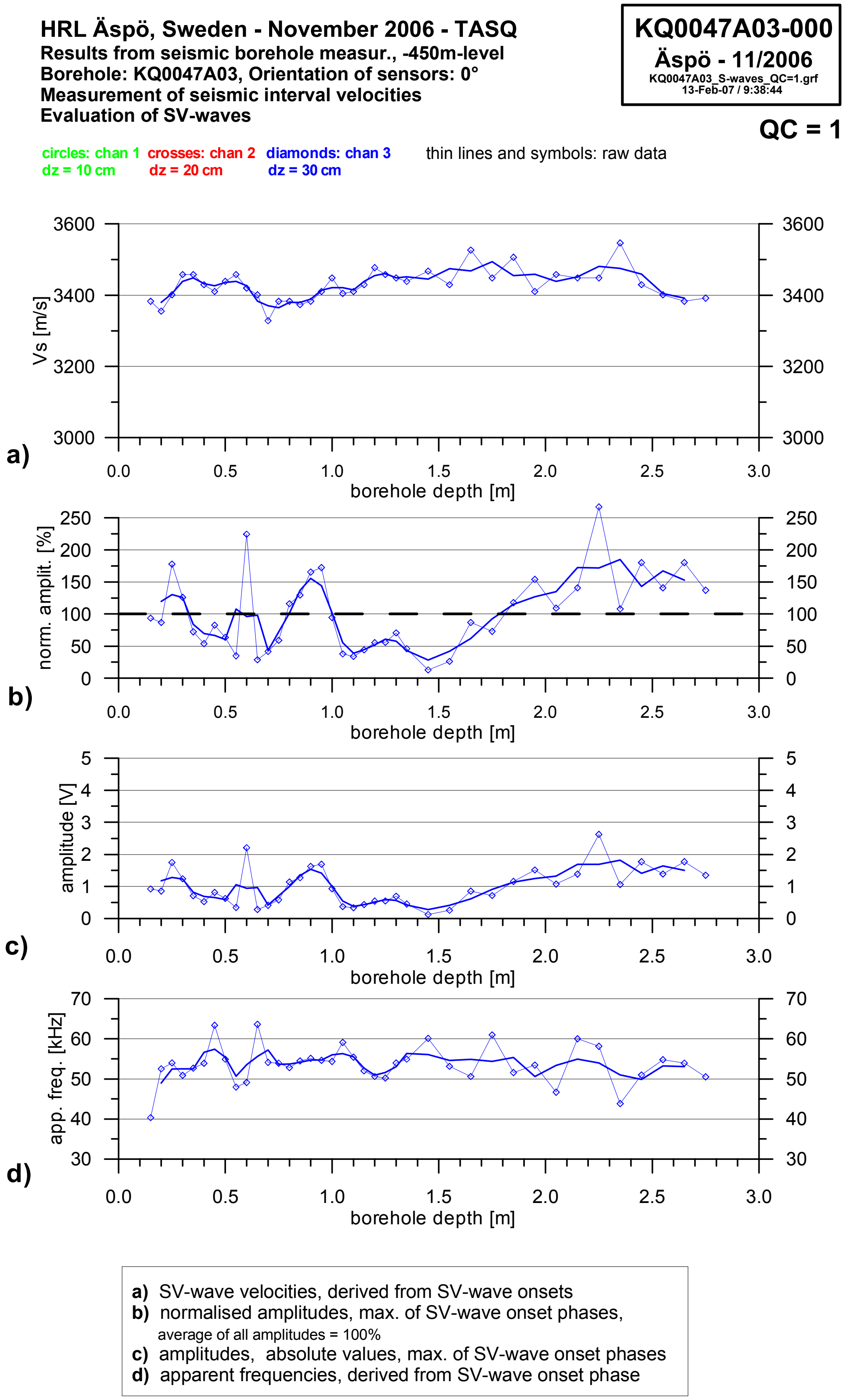


Fig. A-08. *Seismic SV-wave parameters derived from interval velocity measurements in borehole KQ0047A03.*

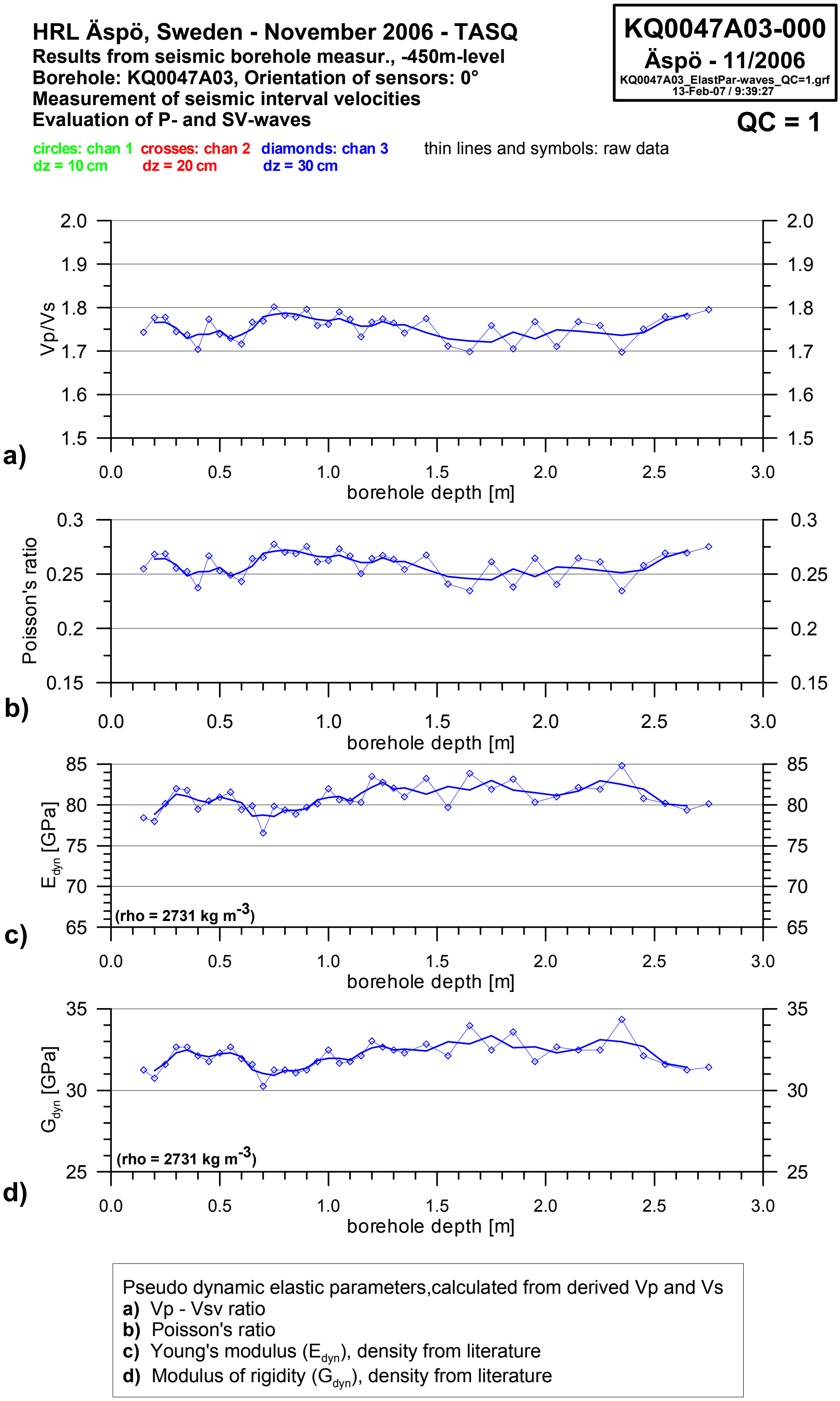


Fig. A-09. *In-situ dynamic pseudo elastic parameters derived from interval velocity measurements in borehole KQ0047A03.*

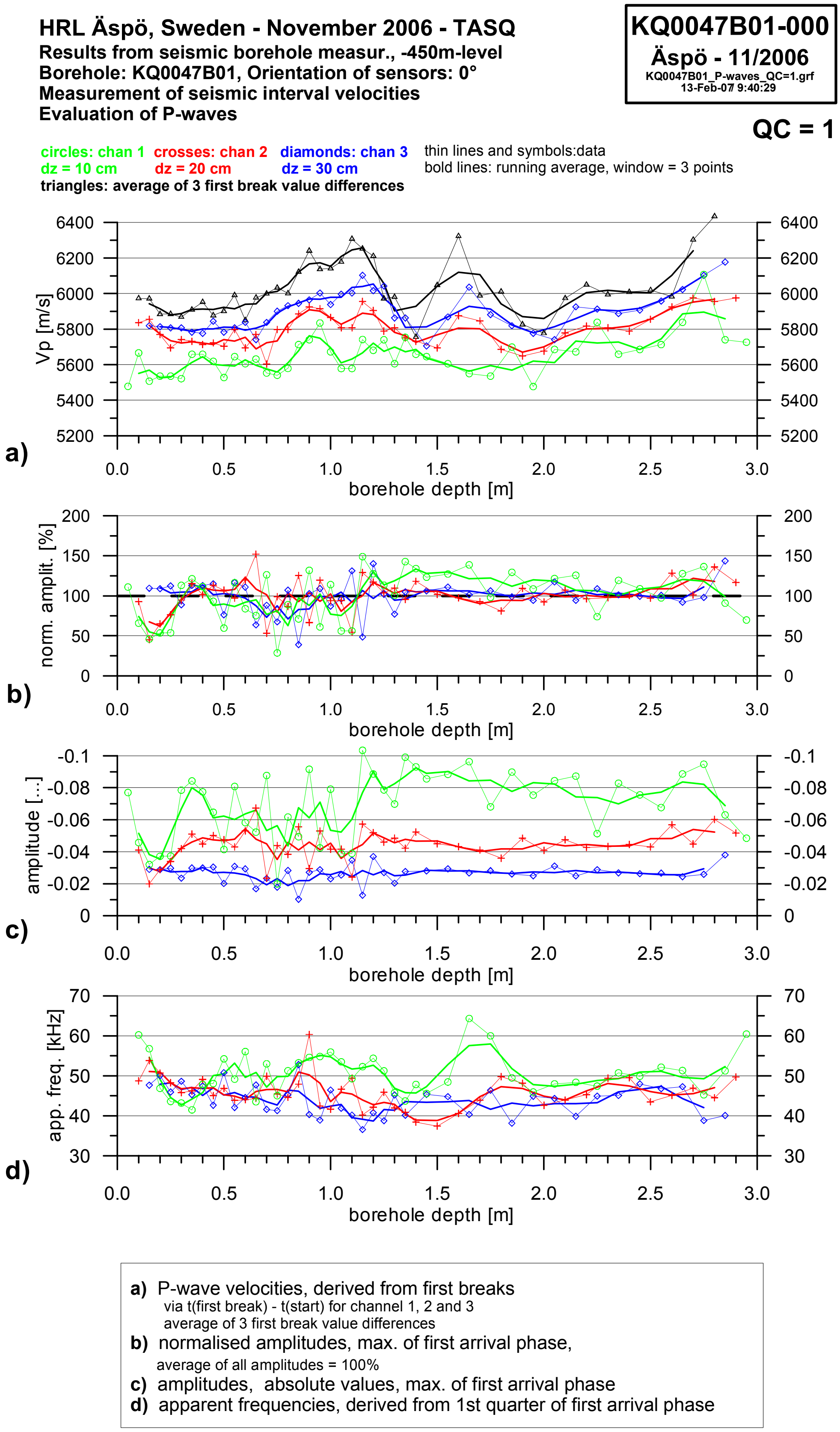


***Fig. A-10.** Seismic P-wave parameters derived from interval velocity measurements in borehole KQ0047B01.*

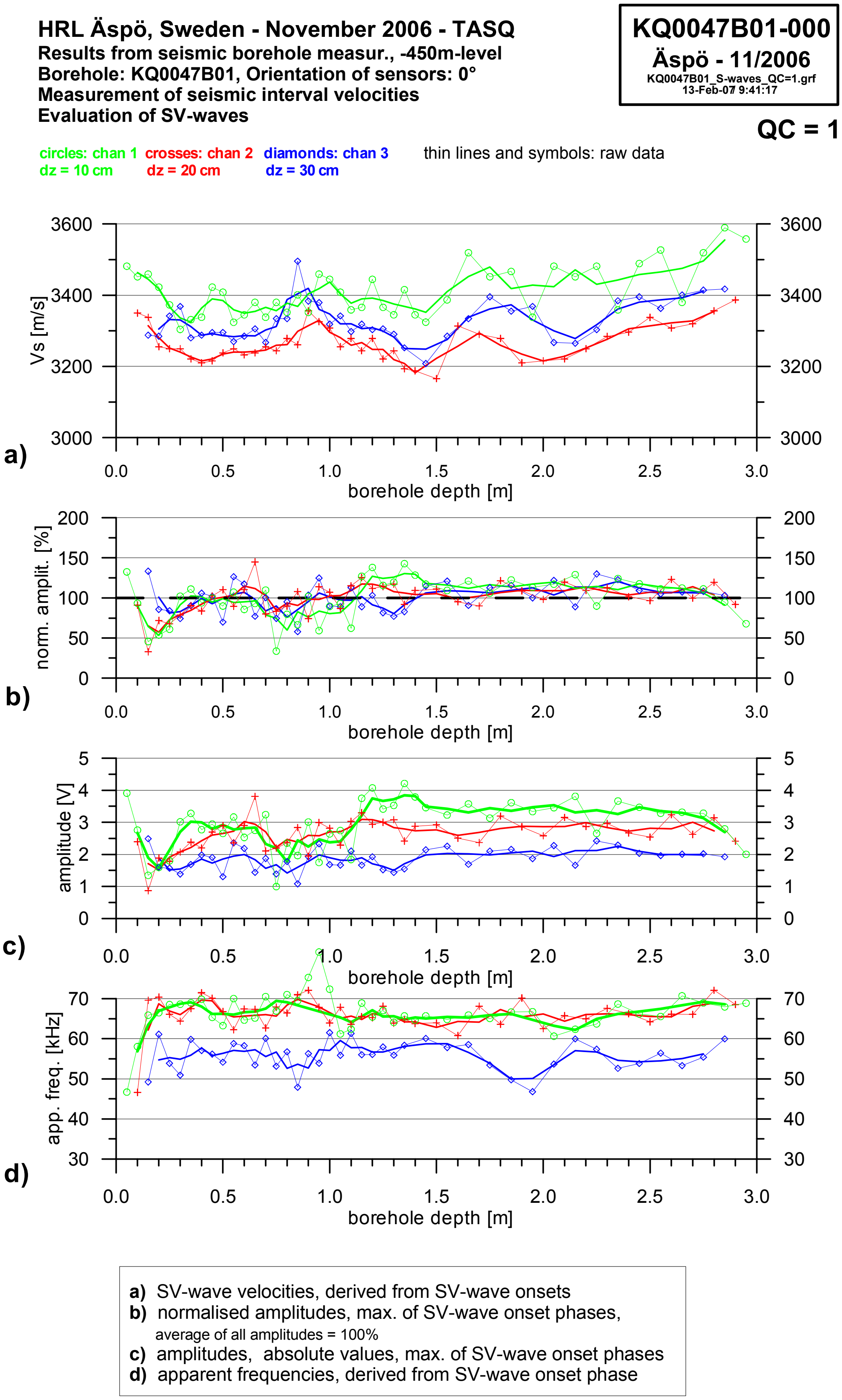


Fig. A-11. *Seismic SV-wave parameters derived from interval velocity measurements in borehole KQ0047B01.*

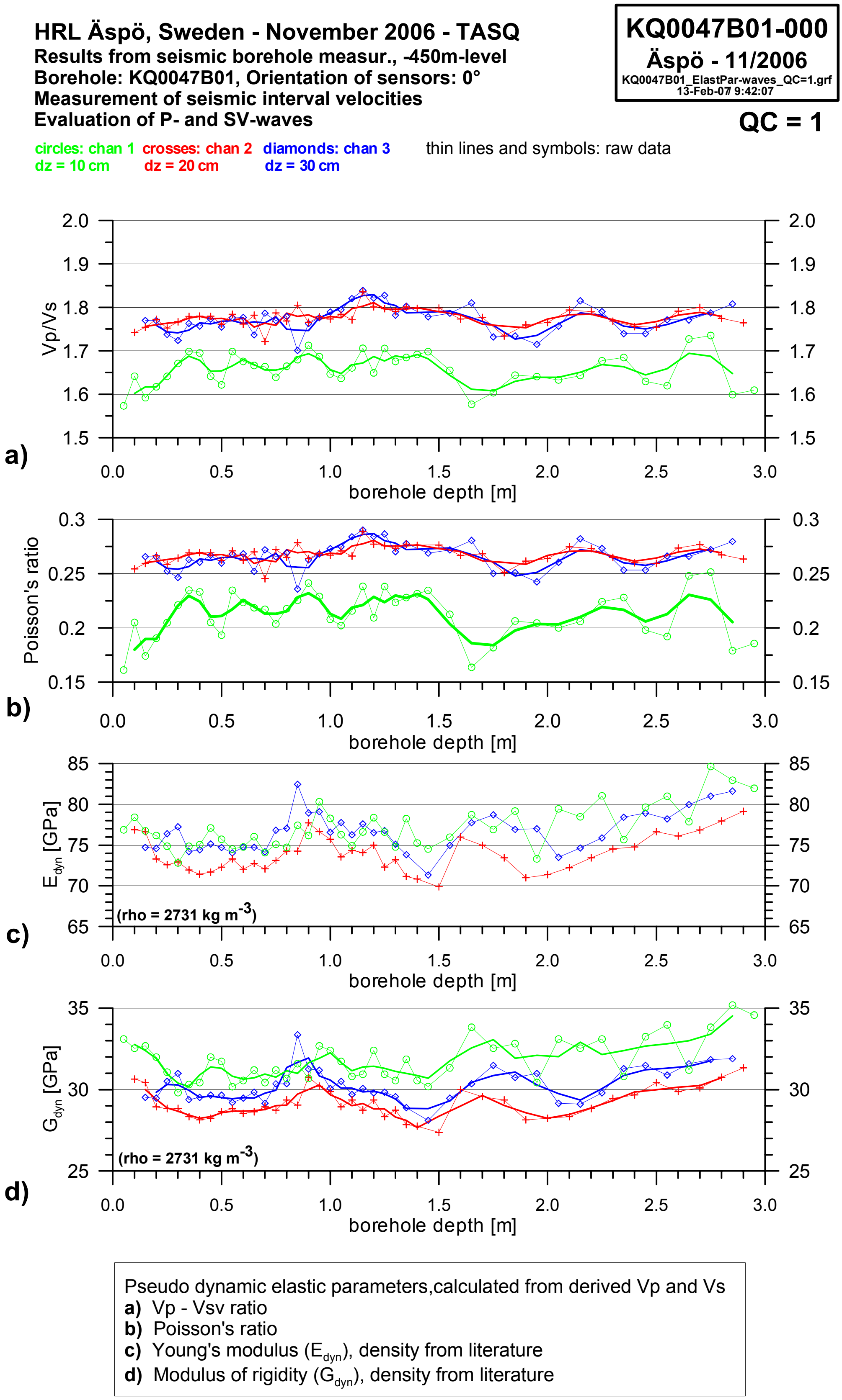


Fig. A-12. In-situ dynamic pseudo elastic parameters derived from interval velocity measurements in borehole KQ0047B01.

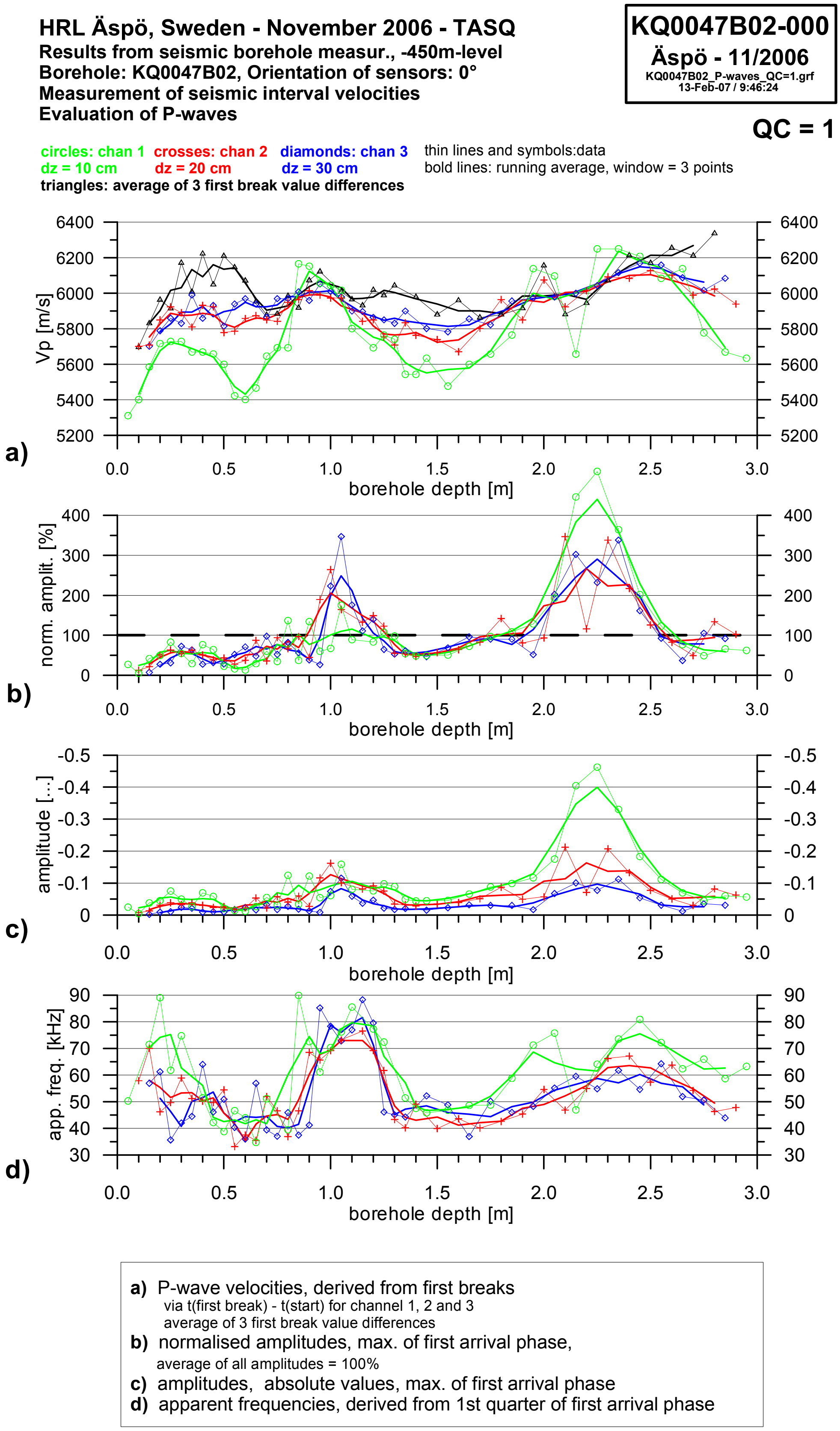


Fig. A-13. Seismic P-wave parameters derived from interval velocity measurements in borehole KQ0047B02.

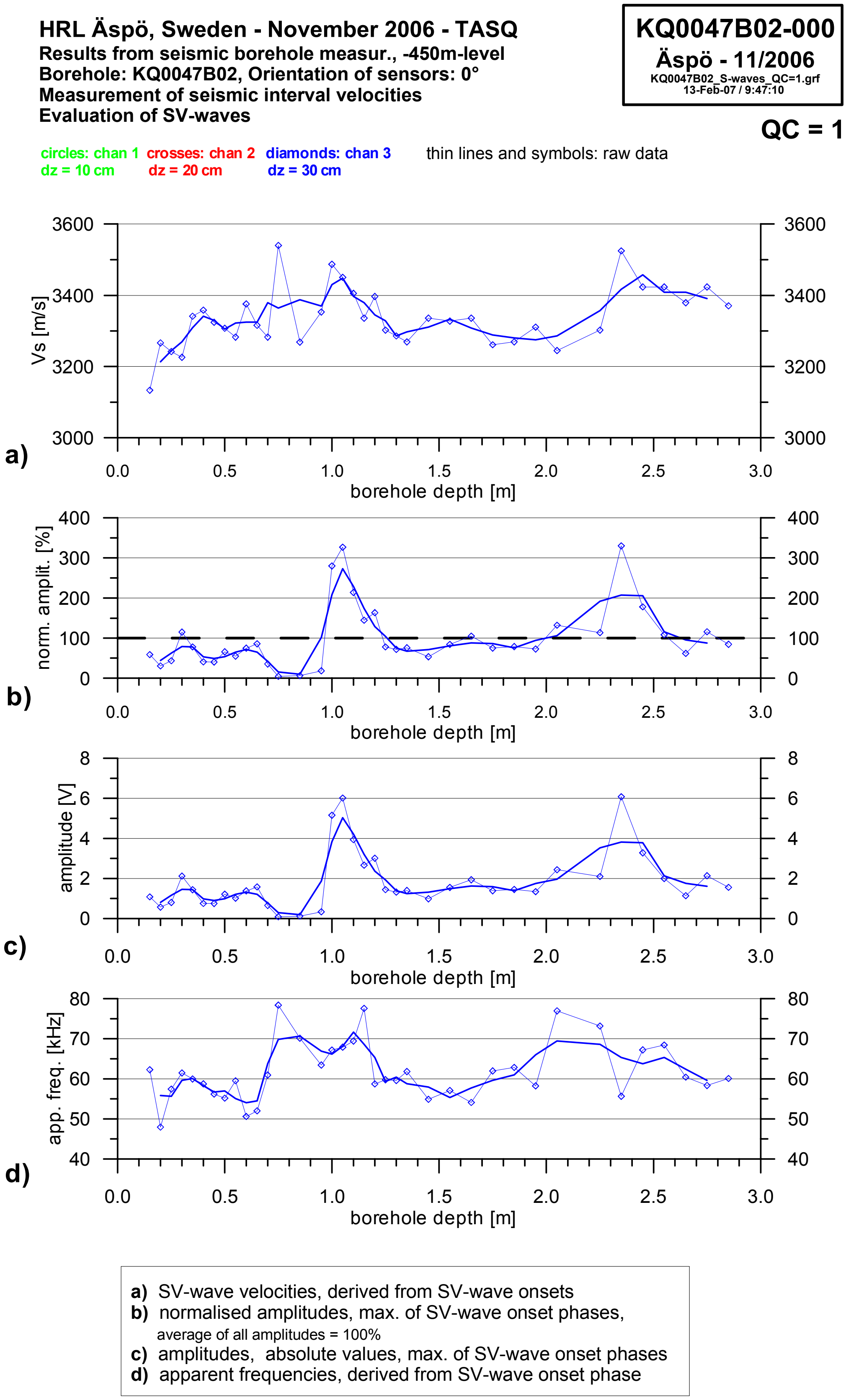


Fig. A-14. *Seismic SV-wave parameters derived from interval velocity measurements in borehole KQ0047B02.*

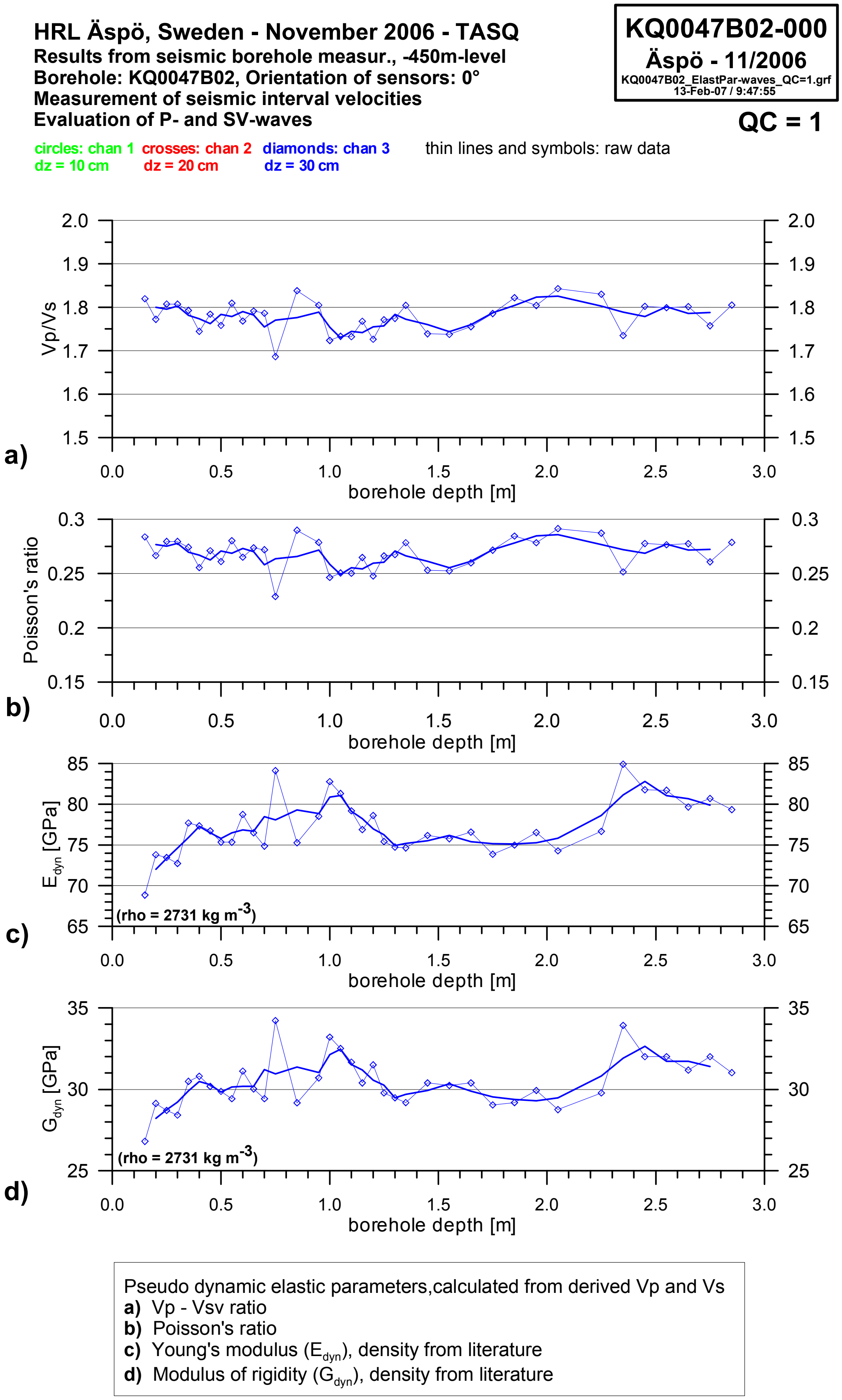


Fig. A-15. *In-situ dynamic pseudo elastic parameters derived from interval velocity measurements in borehole KQ0047B02.*

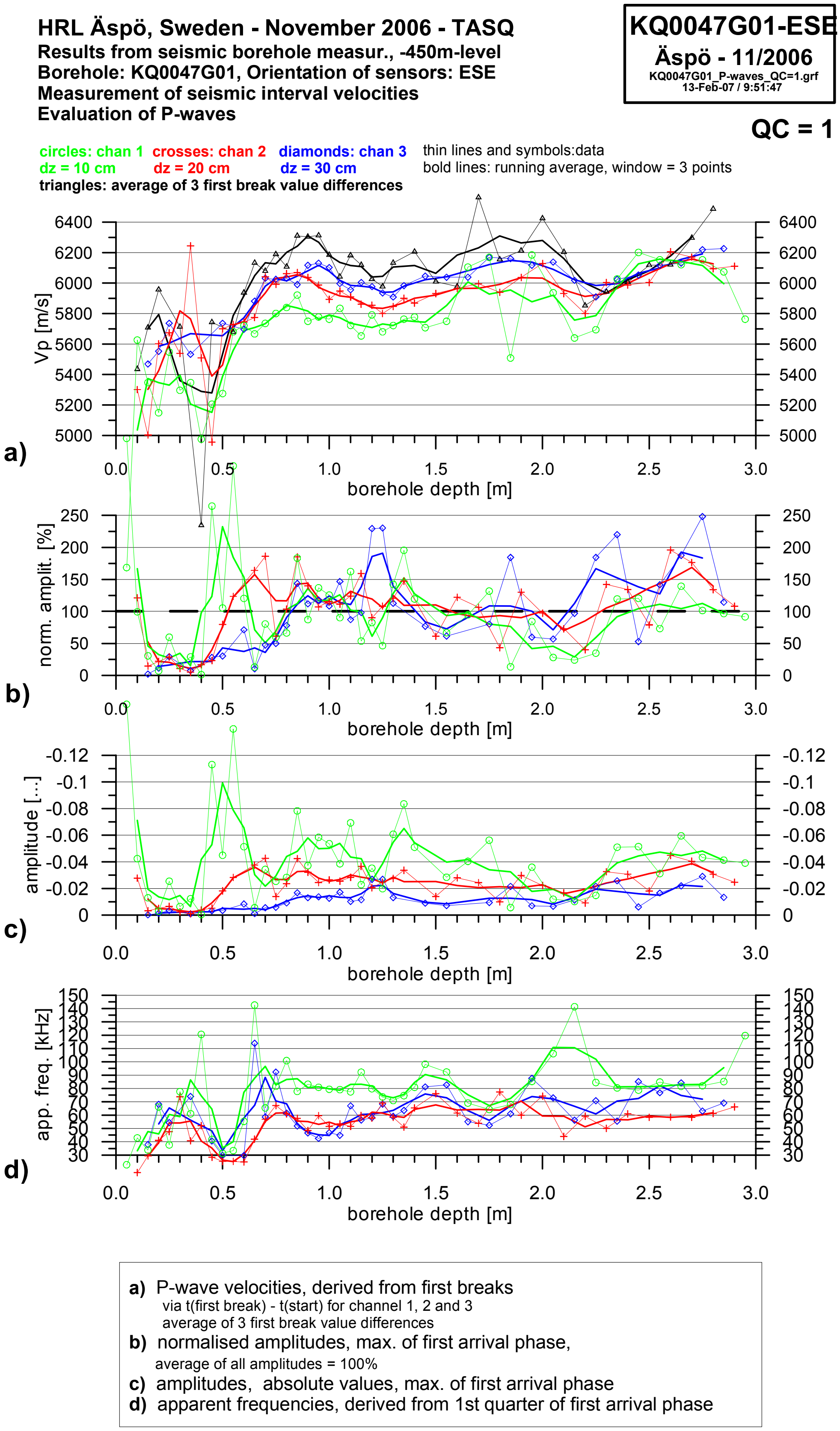


***Fig. A-16.** Seismic P-wave parameters derived from interval velocity measurements in borehole KQ0047G01.*

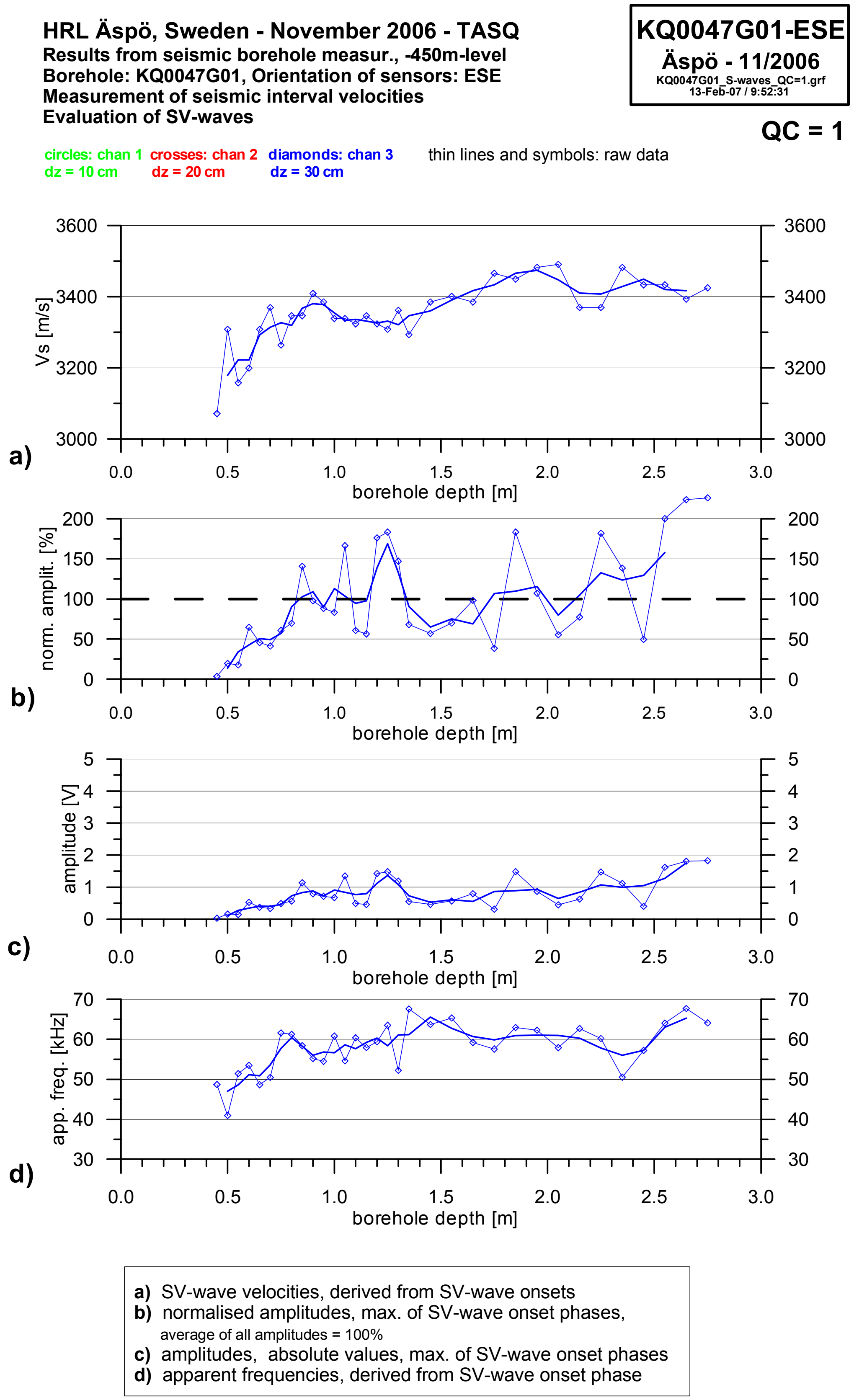


Fig. A-17. *Seismic SV-wave parameters derived from interval velocity measurements in borehole KQ0047G01.*

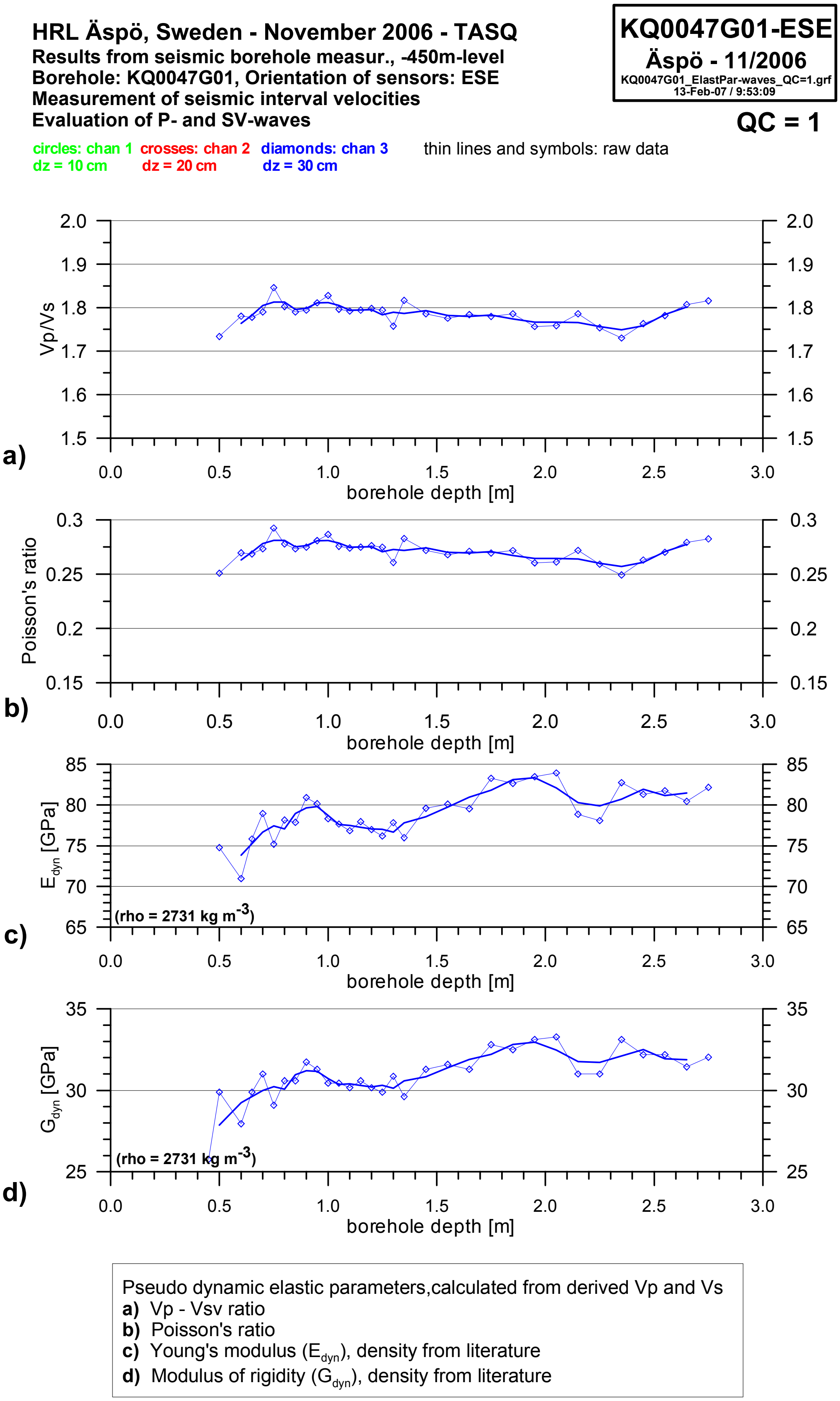


Fig. A-18. *In-situ dynamic pseudo elastic parameters derived from interval velocity measurements in borehole KQ0047G01.*

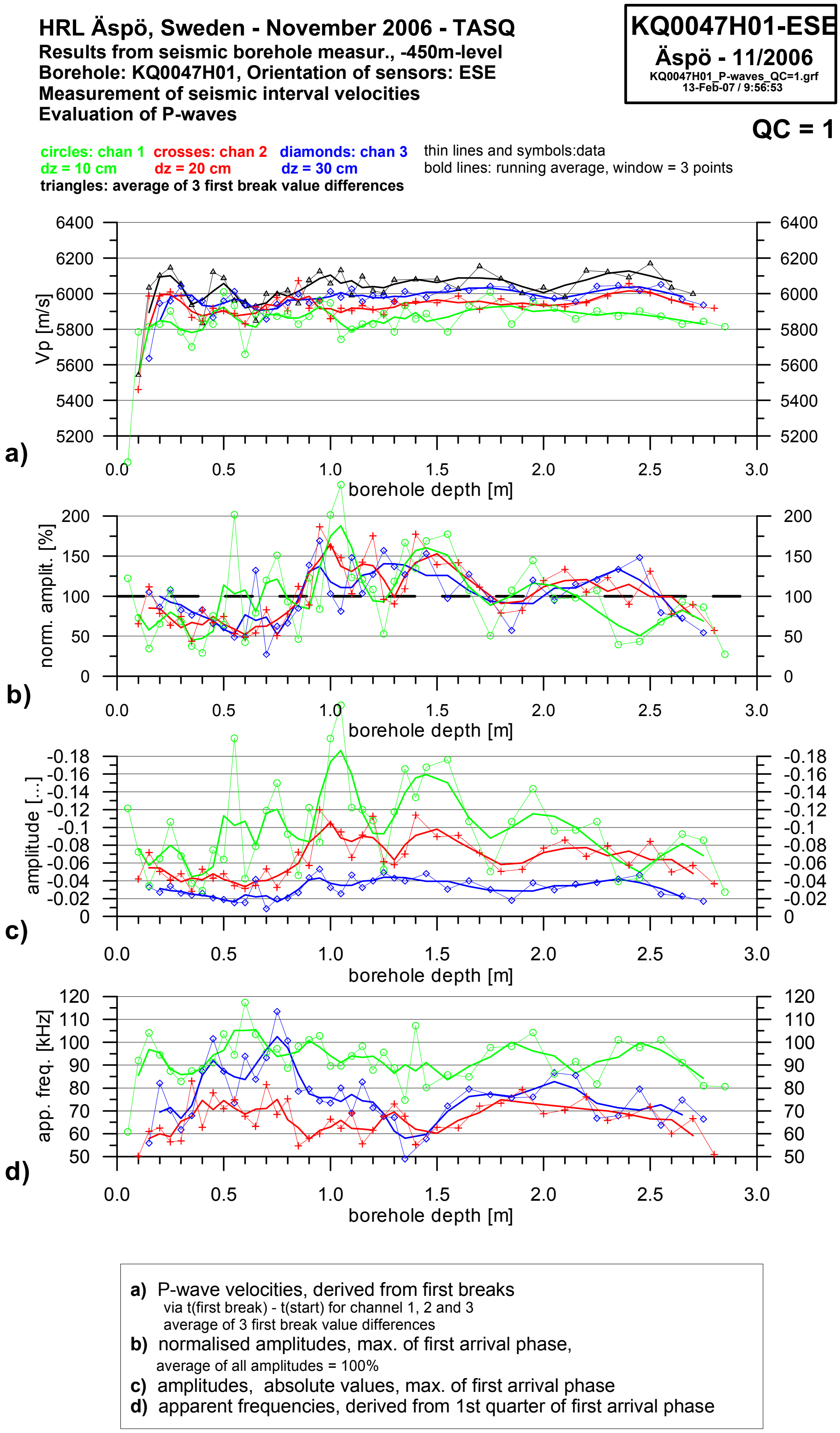


Fig. A-19. Seismic P-wave parameters derived from interval velocity measurements in borehole KQ0047H01.

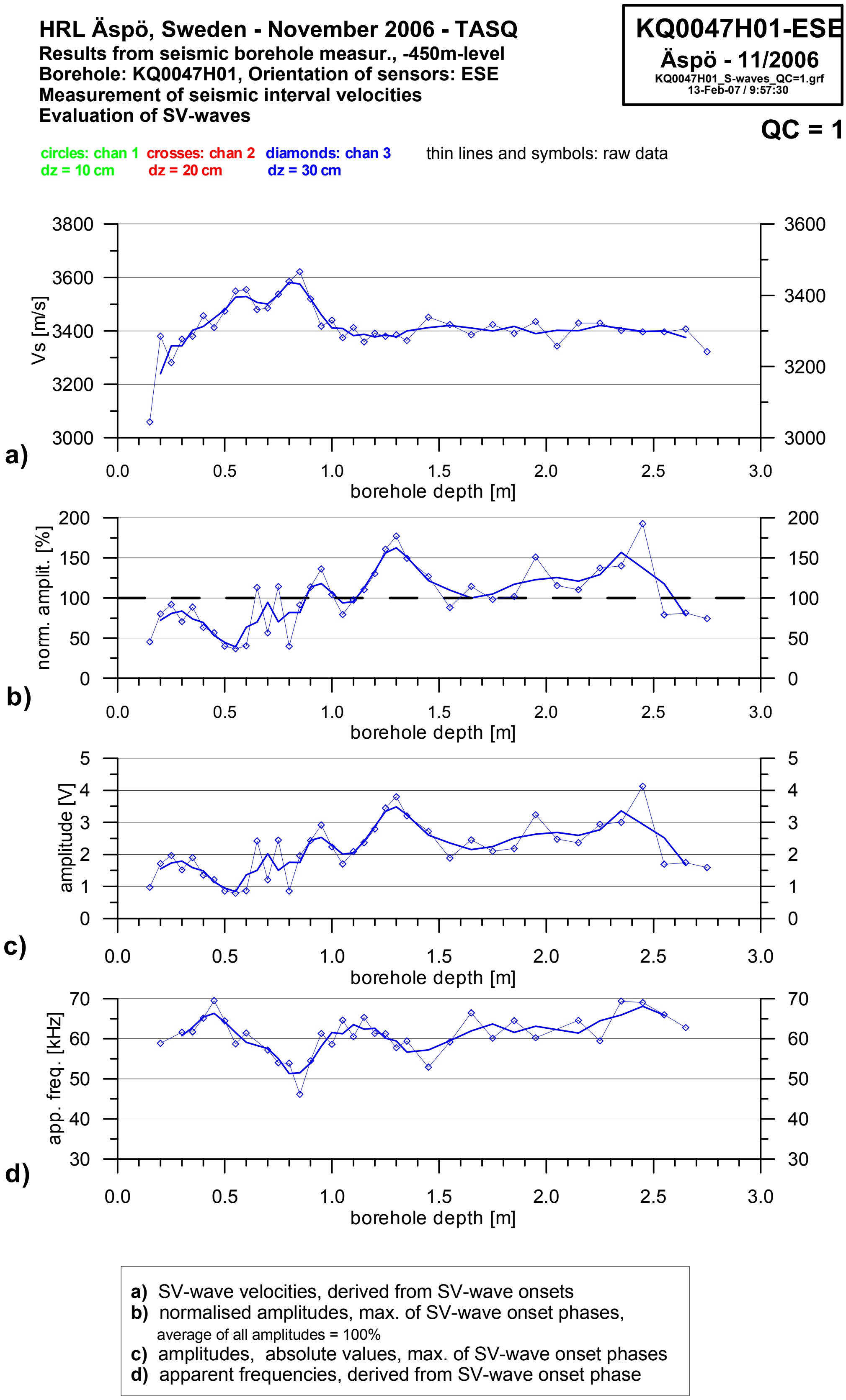


Fig. A-20. Seismic SV-wave parameters derived from interval velocity measurements in borehole KQ0047H01.

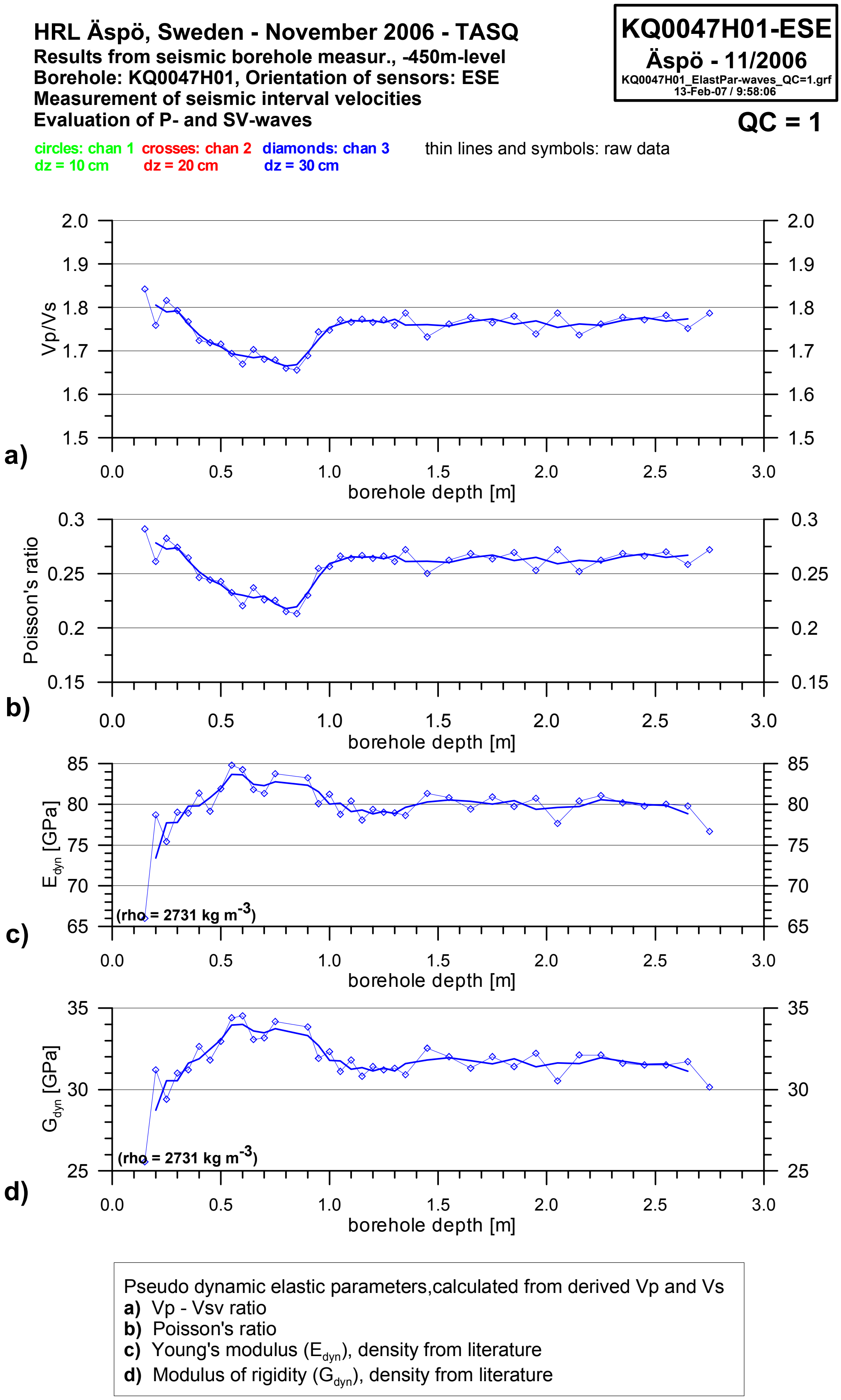


Fig. A-21. In-situ dynamic pseudo elastic parameters derived from interval velocity measurements in borehole KQ0047H01.

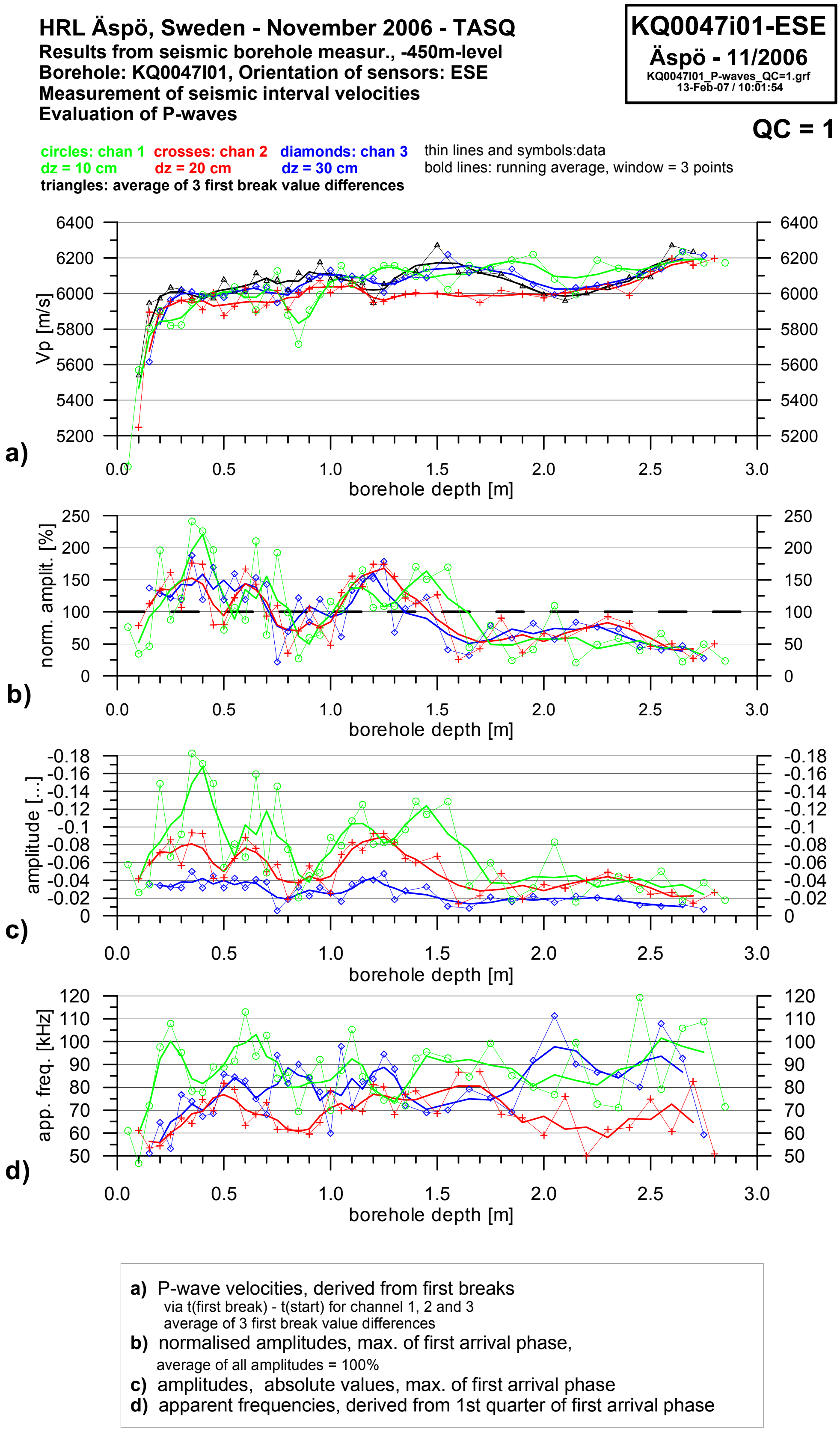


Fig. A-22. Seismic P-wave parameters derived from interval velocity measurements in borehole KQ0047I01.

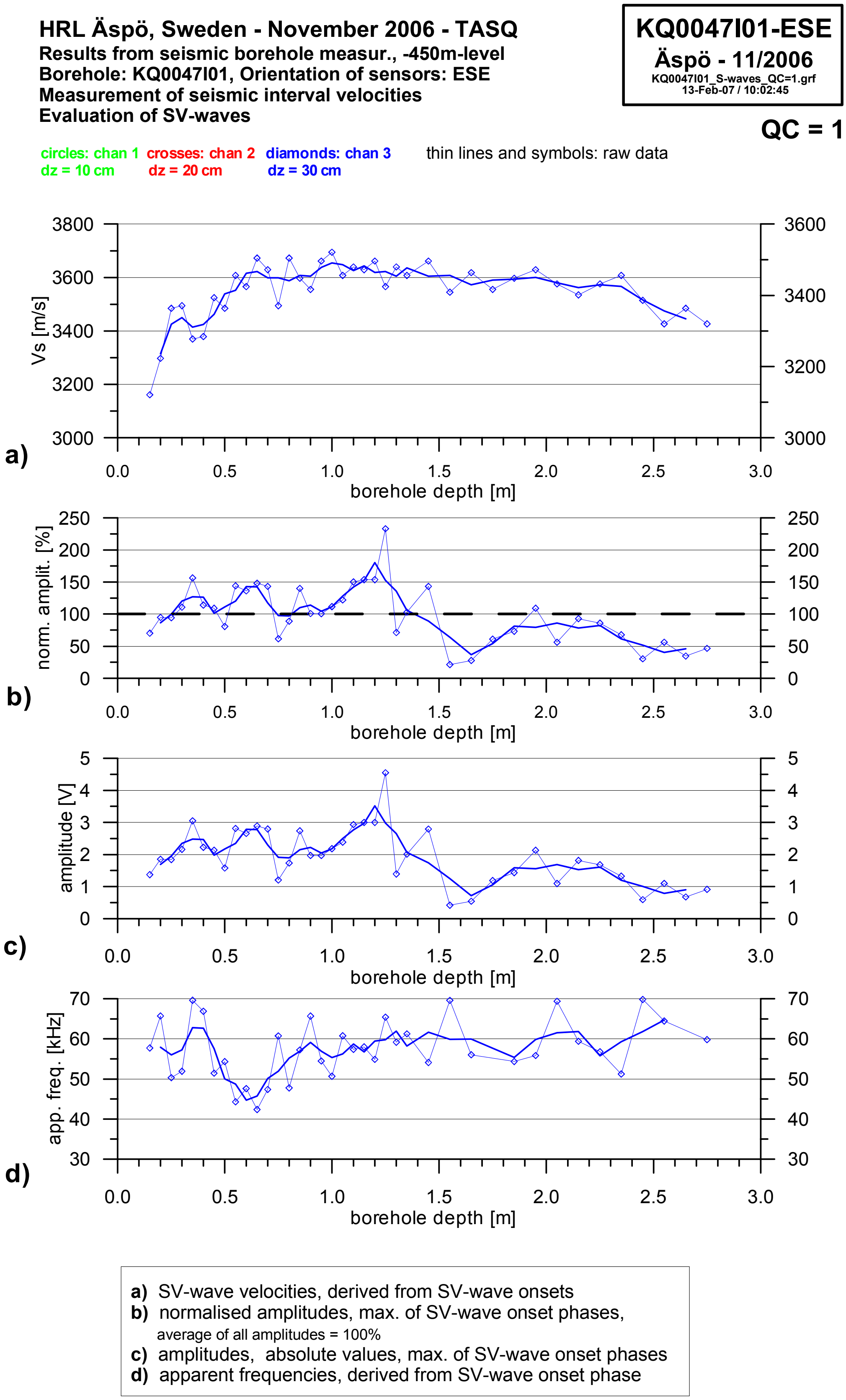


Fig. A-23. *Seismic SV-wave parameters derived from interval velocity measurements in borehole KQ0047I01.*

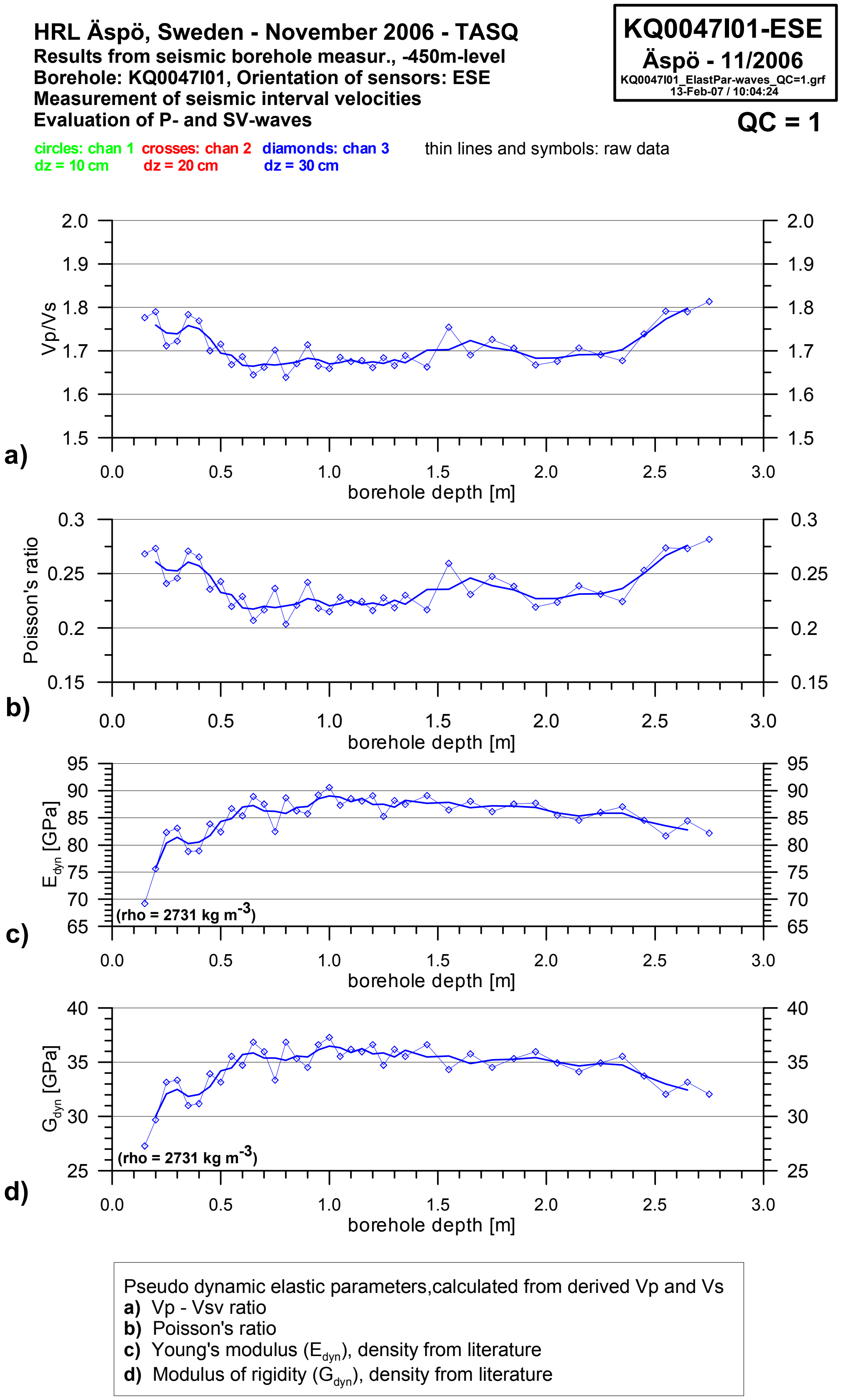


Fig. A-24. *In-situ dynamic pseudo elastic parameters derived from interval velocity measurements in borehole KQ0047I01.*

2.) Plots of seismic parameters derived from ultrasonic rotational interval velocity measurements in boreholes:

KQ0047G01, depth: 1.0m, 1.8m and 2.8m

KQ0047H01, depth: 0.8m, 1.6m and 2.8m

KQ0047B02, depth: 1.2m

(Fig. A-25 – A-38)

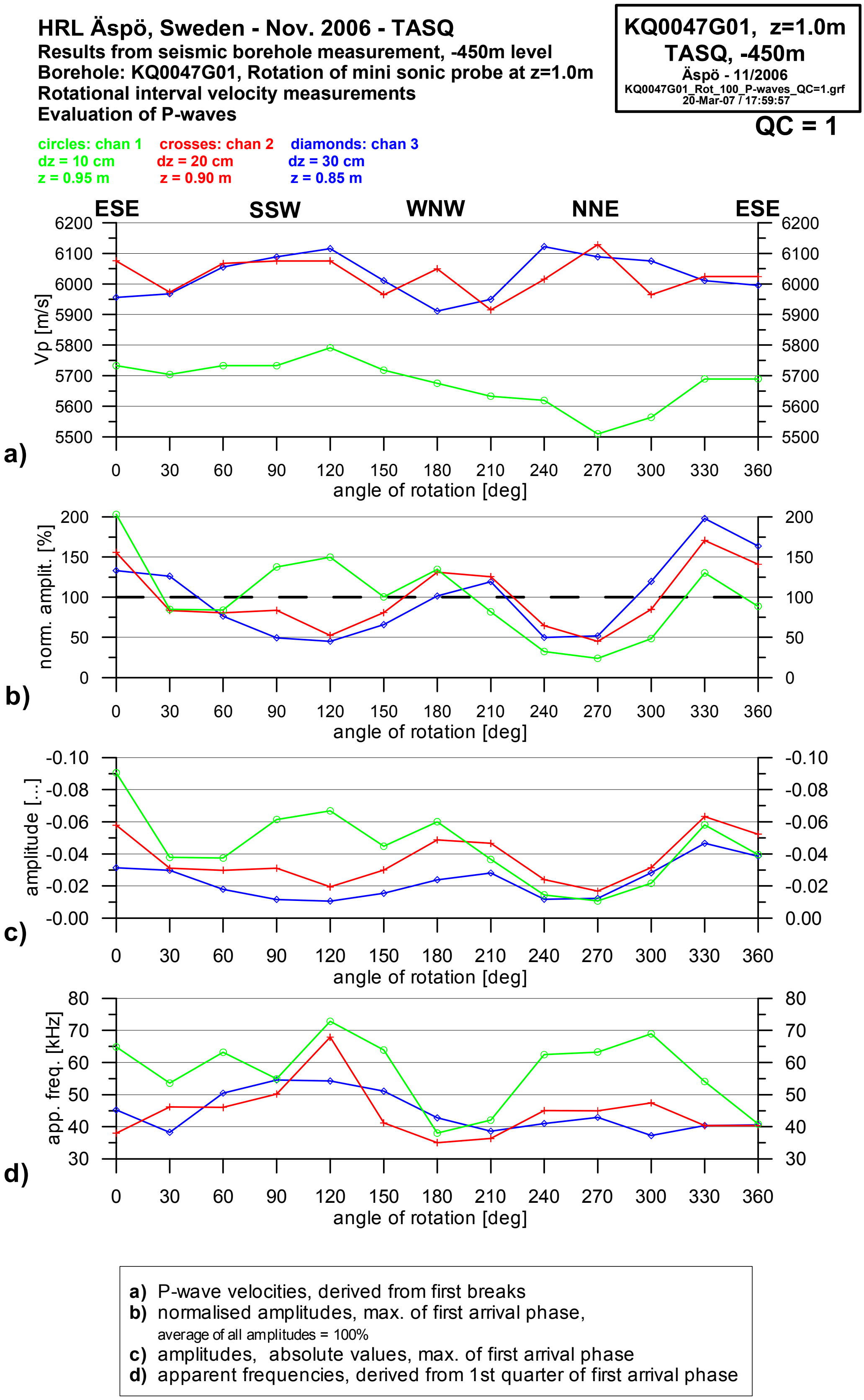


***Fig. A-25.** Seismic P-wave parameters derived from rotational interval velocity measurements in borehole KQ0047G01 at a depth of 1.0 m.*

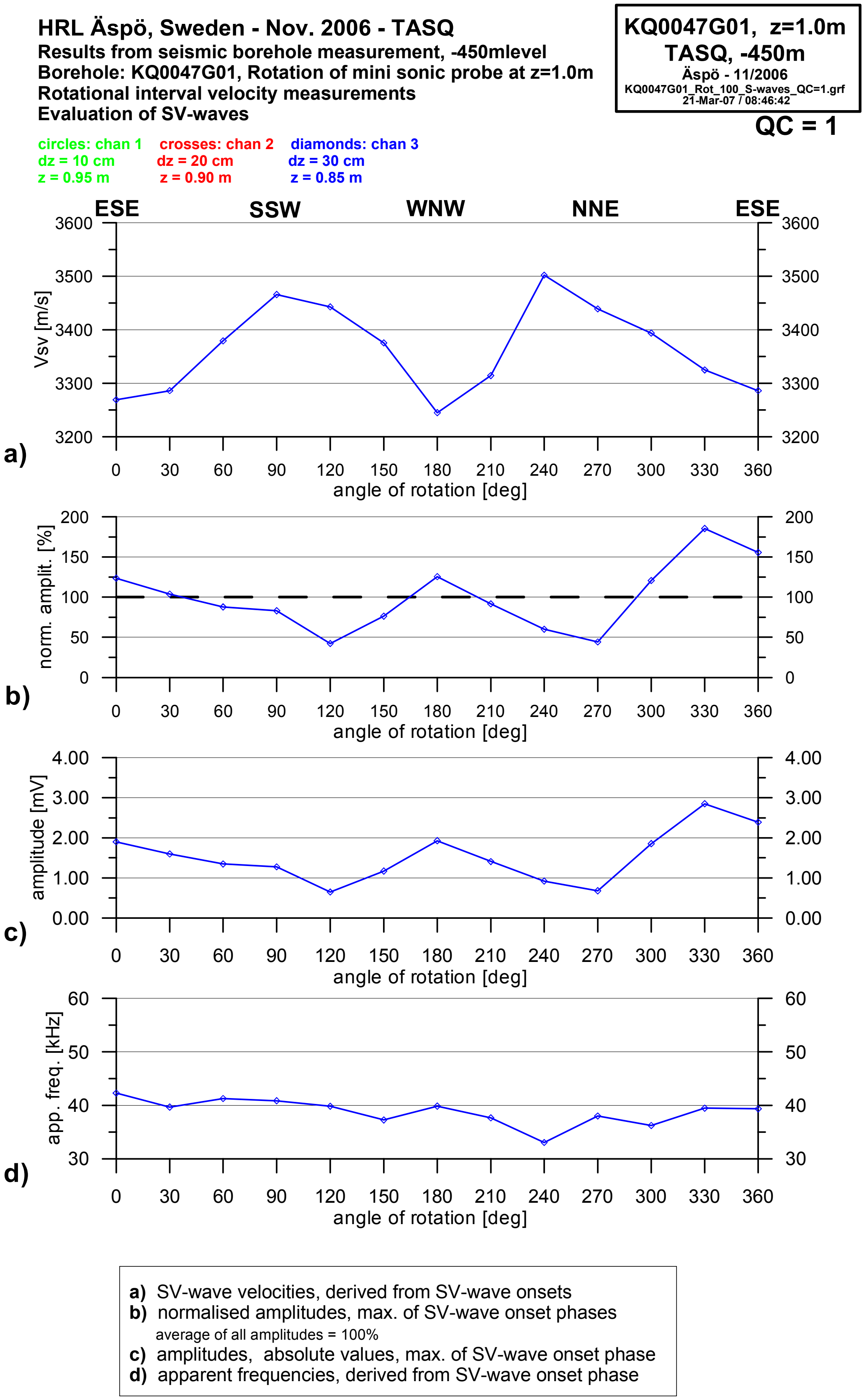


Fig. A-26. *Seismic SV-wave parameters derived from rotational interval velocity measurements in borehole KQ0047G01 at a depth of 1.0 m.*

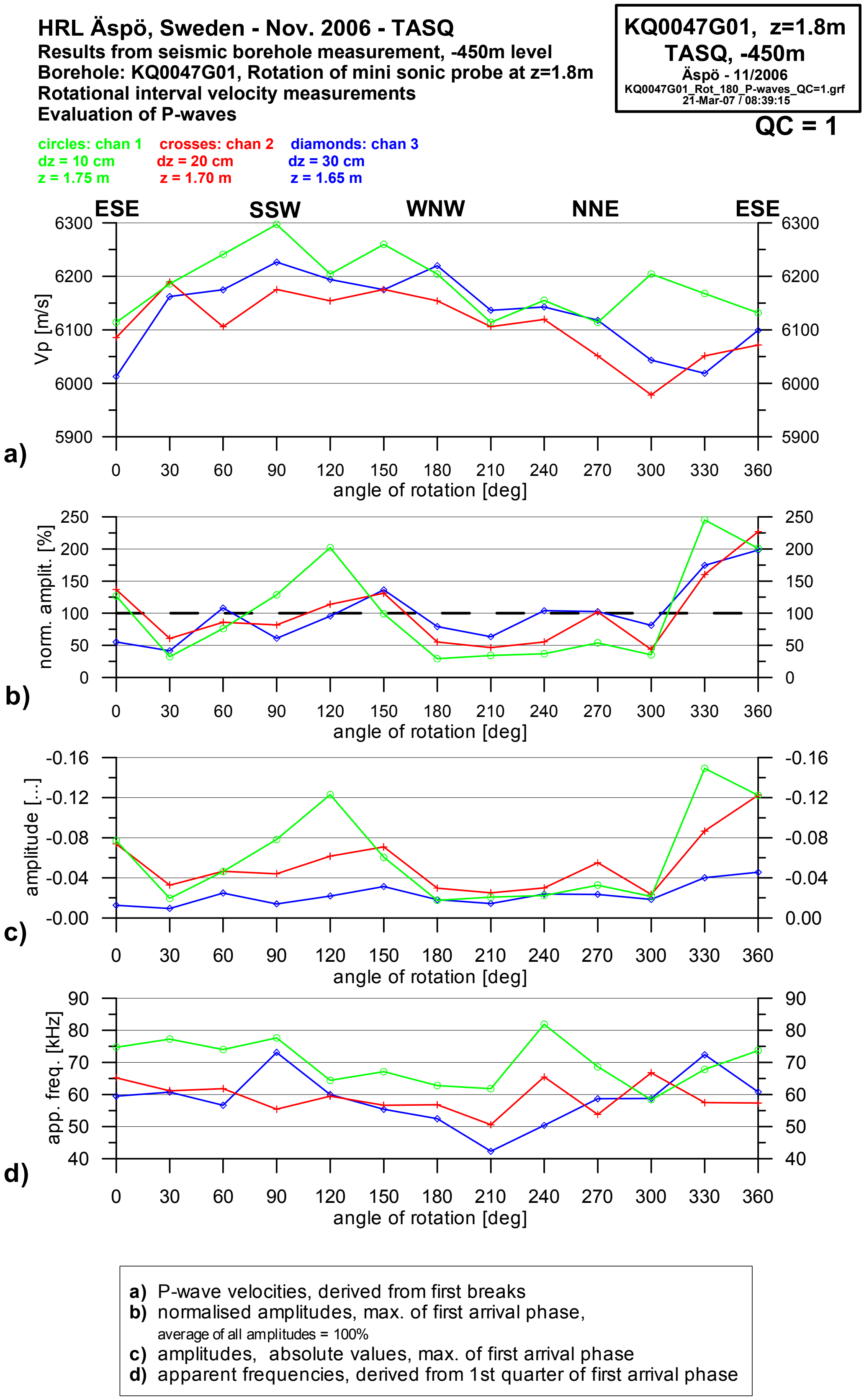


***Fig. A-27.** Seismic P-wave parameters derived from rotational interval velocity measurements in borehole KQ0047G01 at a depth of 1.8m.*

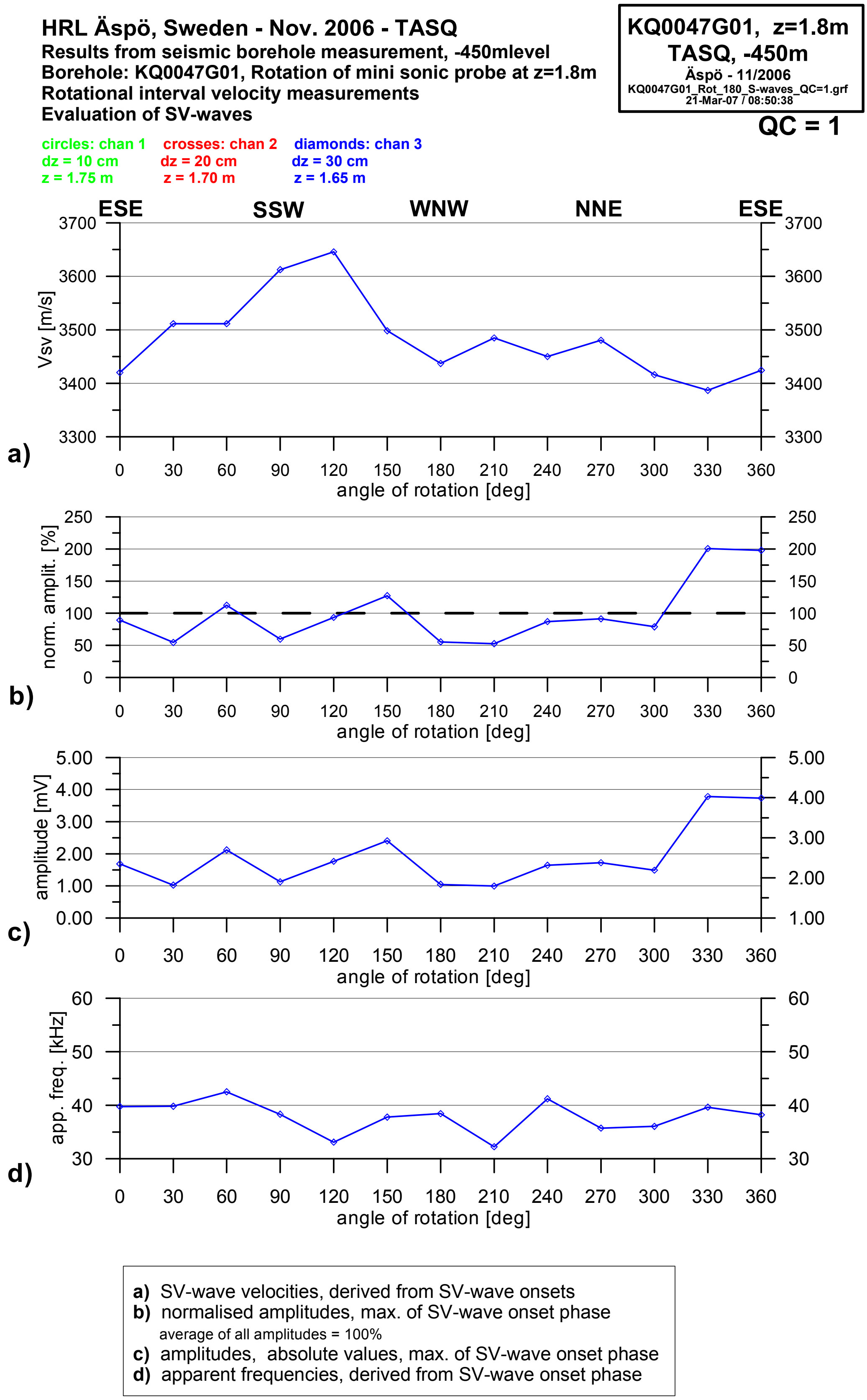


Fig. A-28. Seismic SV-wave parameters derived from rotational interval velocity measurements in borehole KQ0047G01 at a depth of 1.8 m.

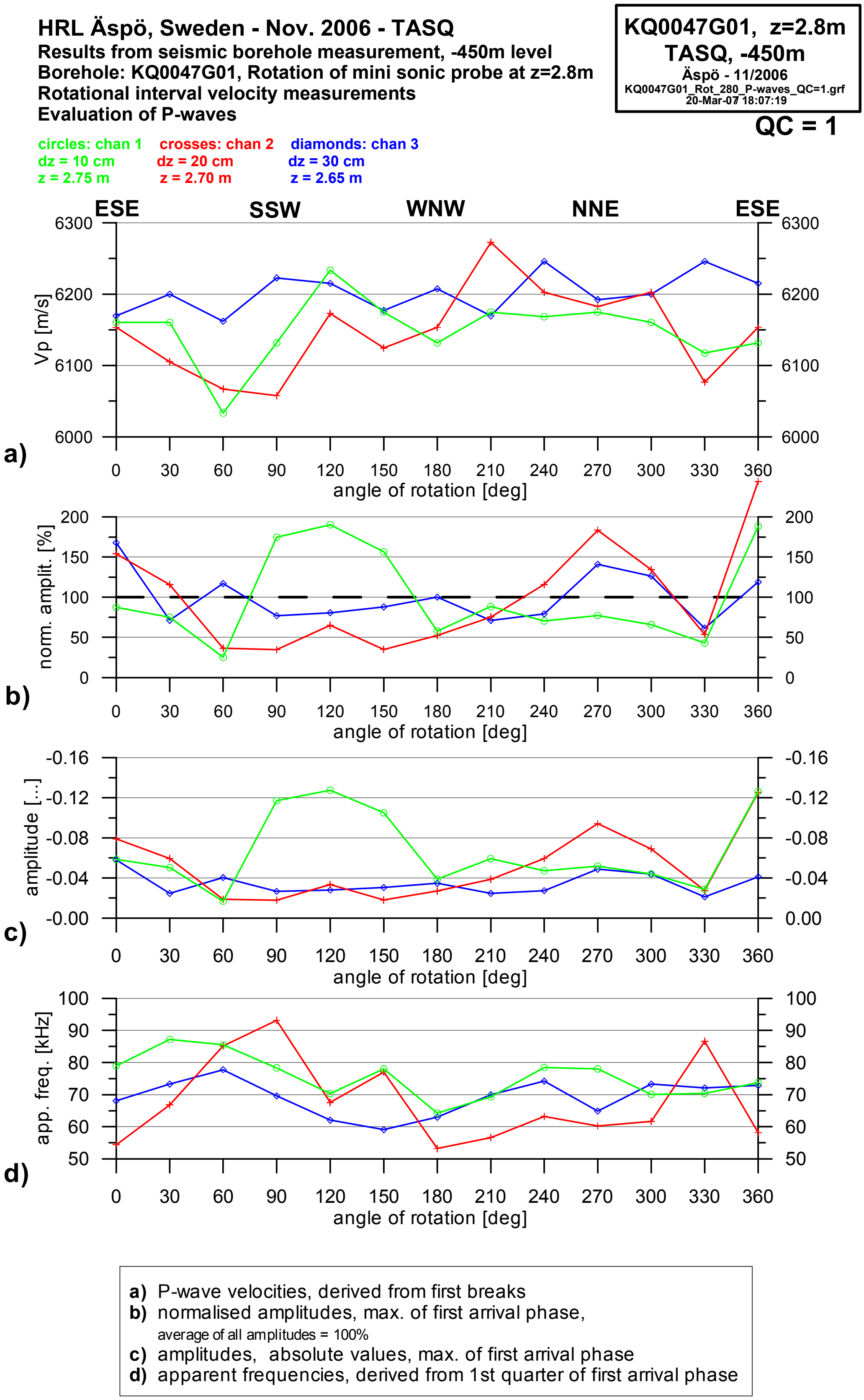


Fig. A-29. *Seismic P-wave parameters derived from rotational interval velocity measurements in borehole KQ0047G01 at a depth of 2.8m.*

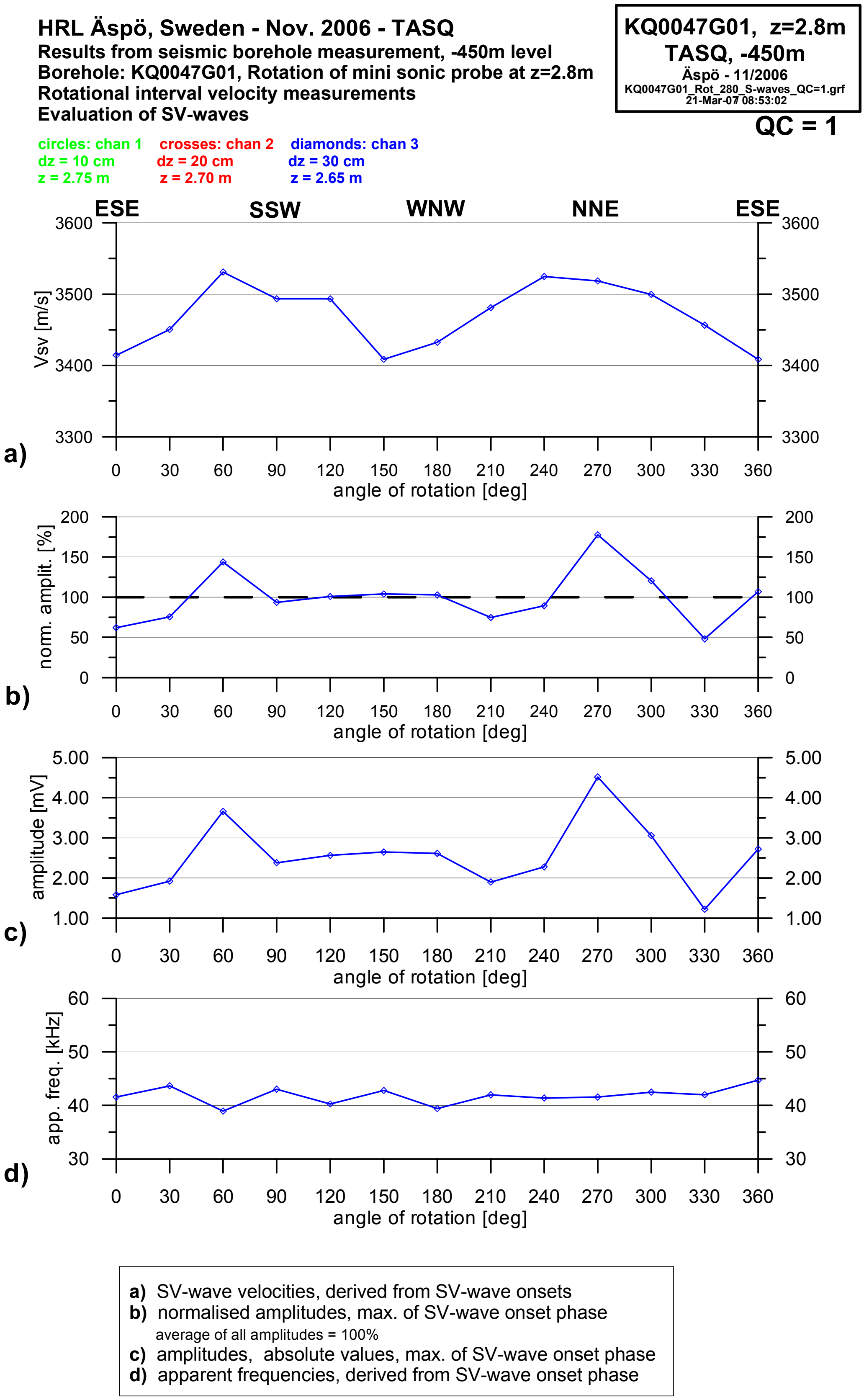
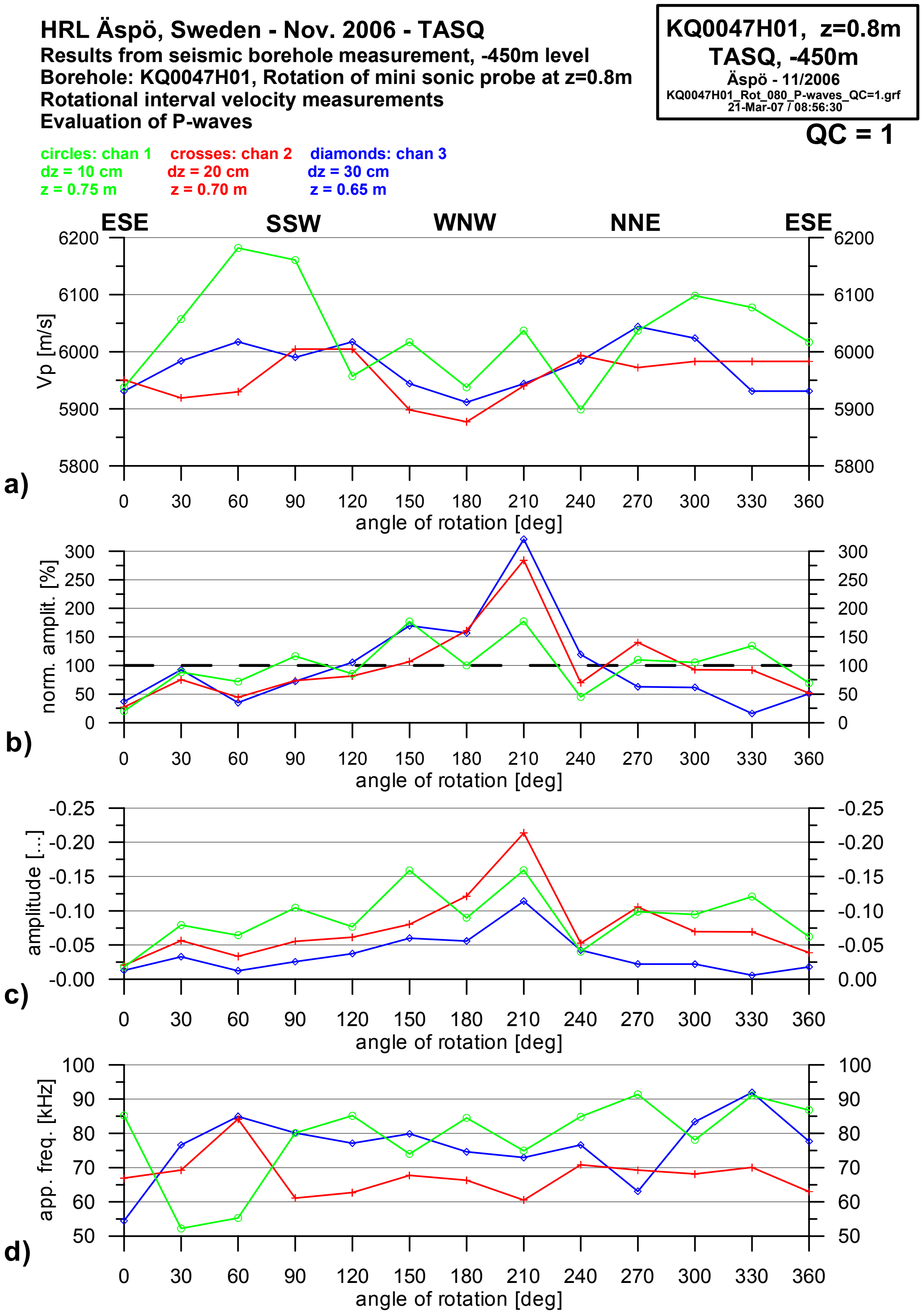


Fig. A-30. *Seismic SV-wave parameters derived from rotational interval velocity measurements in borehole KQ0047G01 at a depth of 2.8 m.*



a) P-wave velocities, derived from first breaks
b) normalised amplitudes, max. of first arrival phase,
average of all amplitudes = 100%
c) amplitudes, absolute values, max. of first arrival phase
d) apparent frequencies, derived from 1st quarter of first arrival phase

Fig. A-31. *Seismic P-wave parameters derived from rotational interval velocity measurements in borehole KQ0047H01 at a depth of 0.8m.*

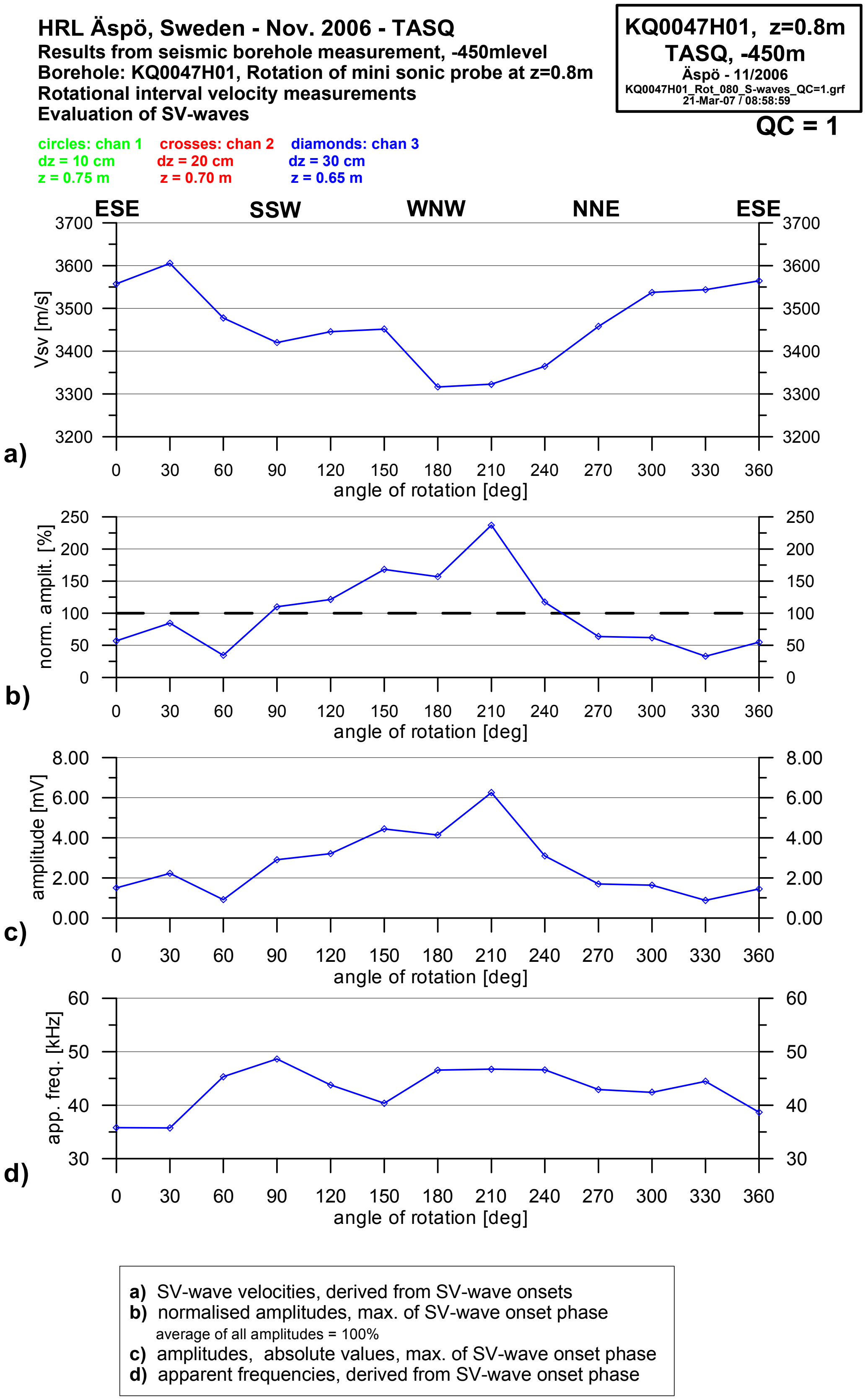


Fig. A-32. *Seismic SV-wave parameters derived from rotational interval velocity measurements in borehole KQ0047H01 at a depth of 0.8 m.*

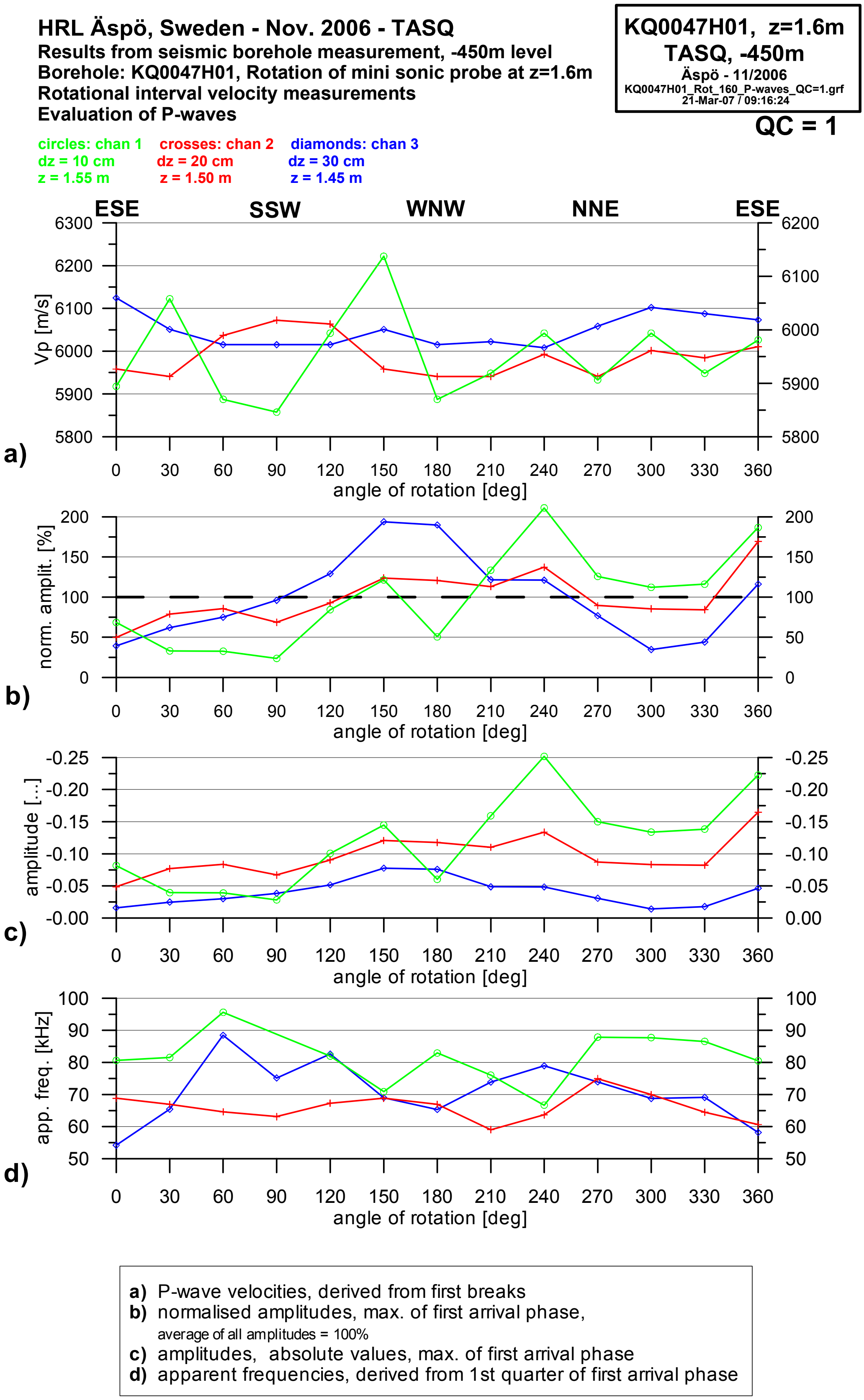


Fig. A-33. Seismic P-wave parameters derived from rotational interval velocity measurements in borehole KQ0047H01 at a depth of 1.6m.

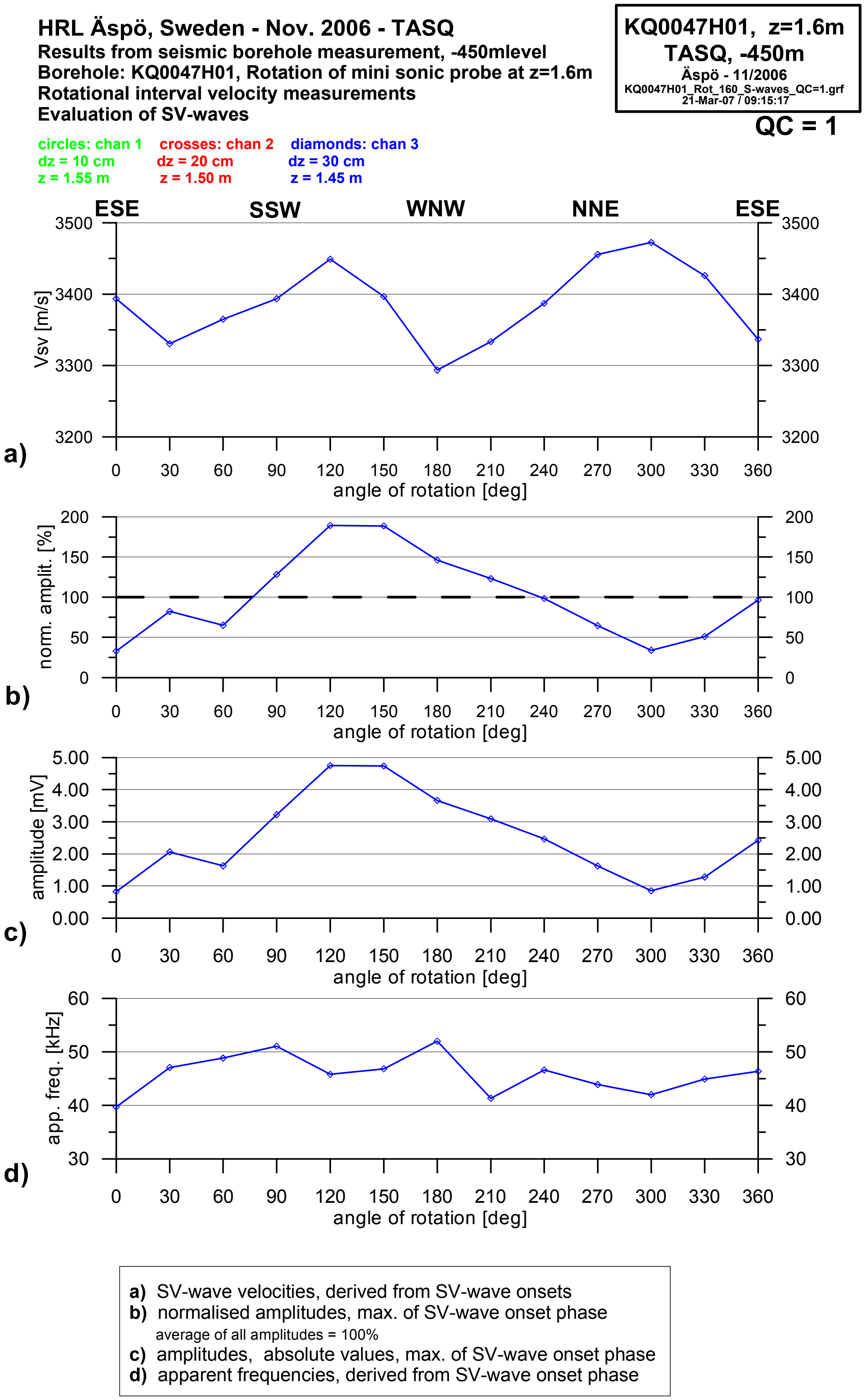


***Fig. A-34.** Seismic SV-wave parameters derived from rotational interval velocity measurements in borehole KQ0047H01 at a depth of 1.6 m.*

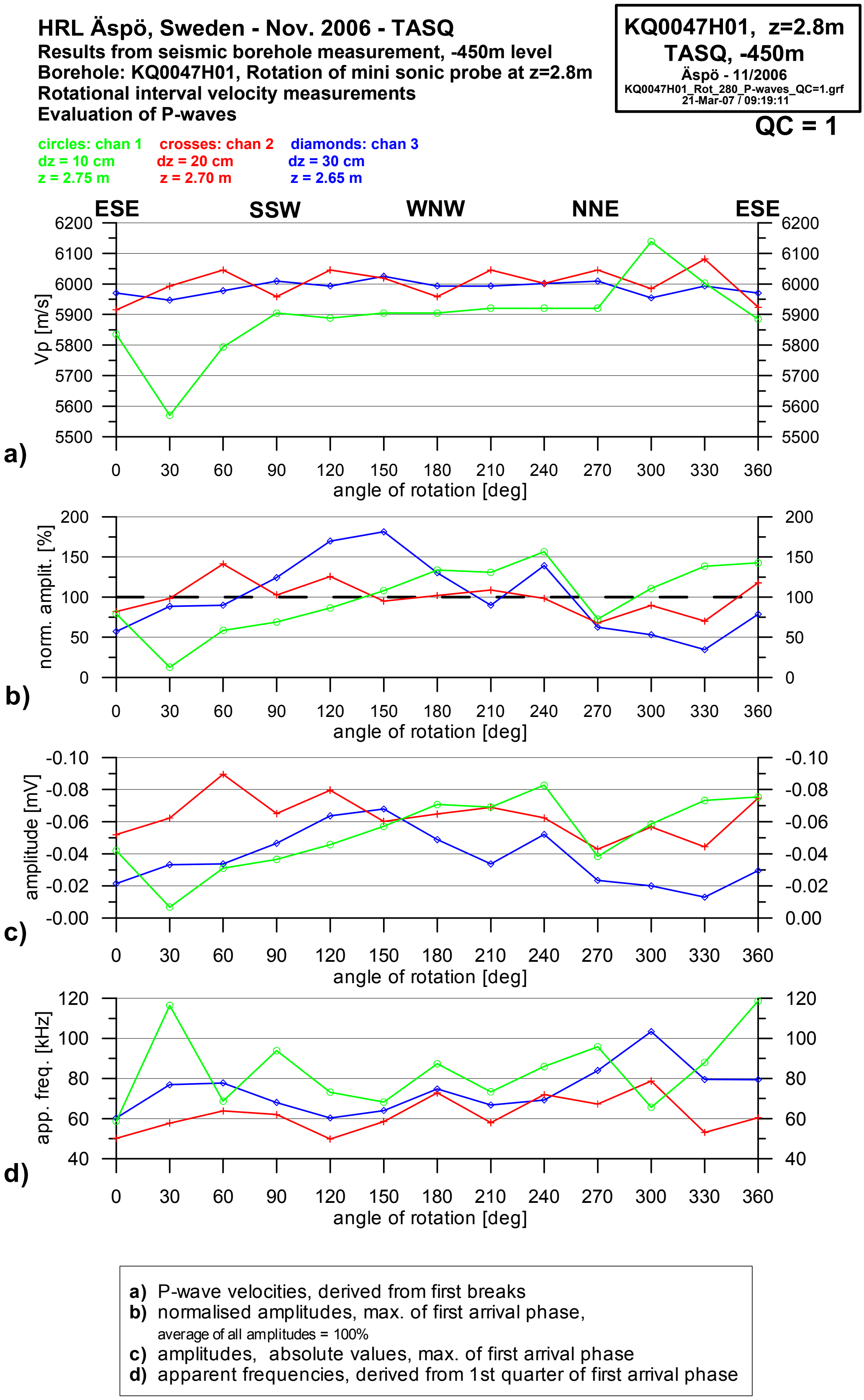


Fig. A-35. Seismic P-wave parameters derived from rotational interval velocity measurements in borehole KQ0047H01 at a depth of 2.8m.

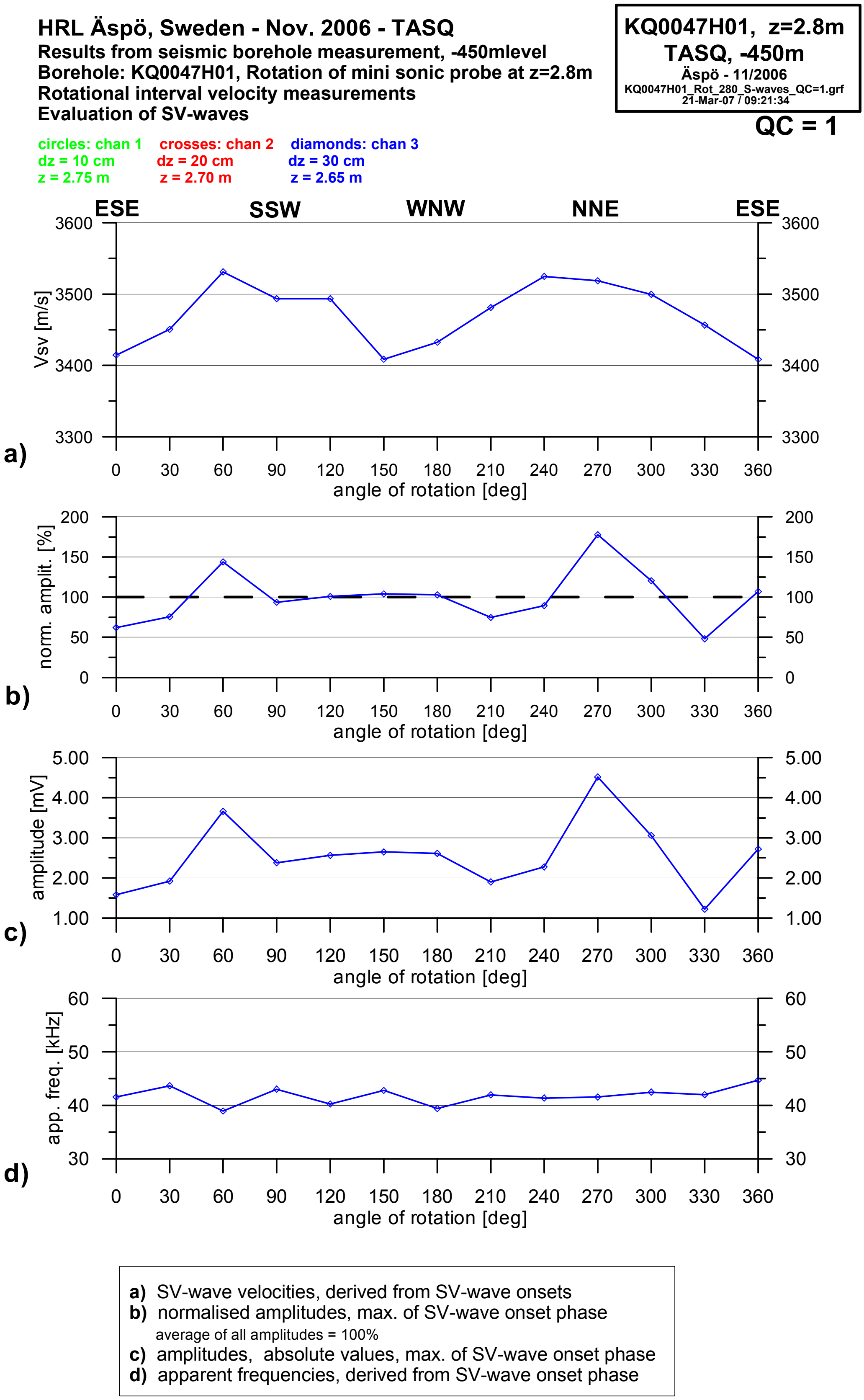


Fig. A-36. *Seismic SV-wave parameters derived from rotational interval velocity measurements in borehole KQ0047H01 at a depth of 2.8 m.*

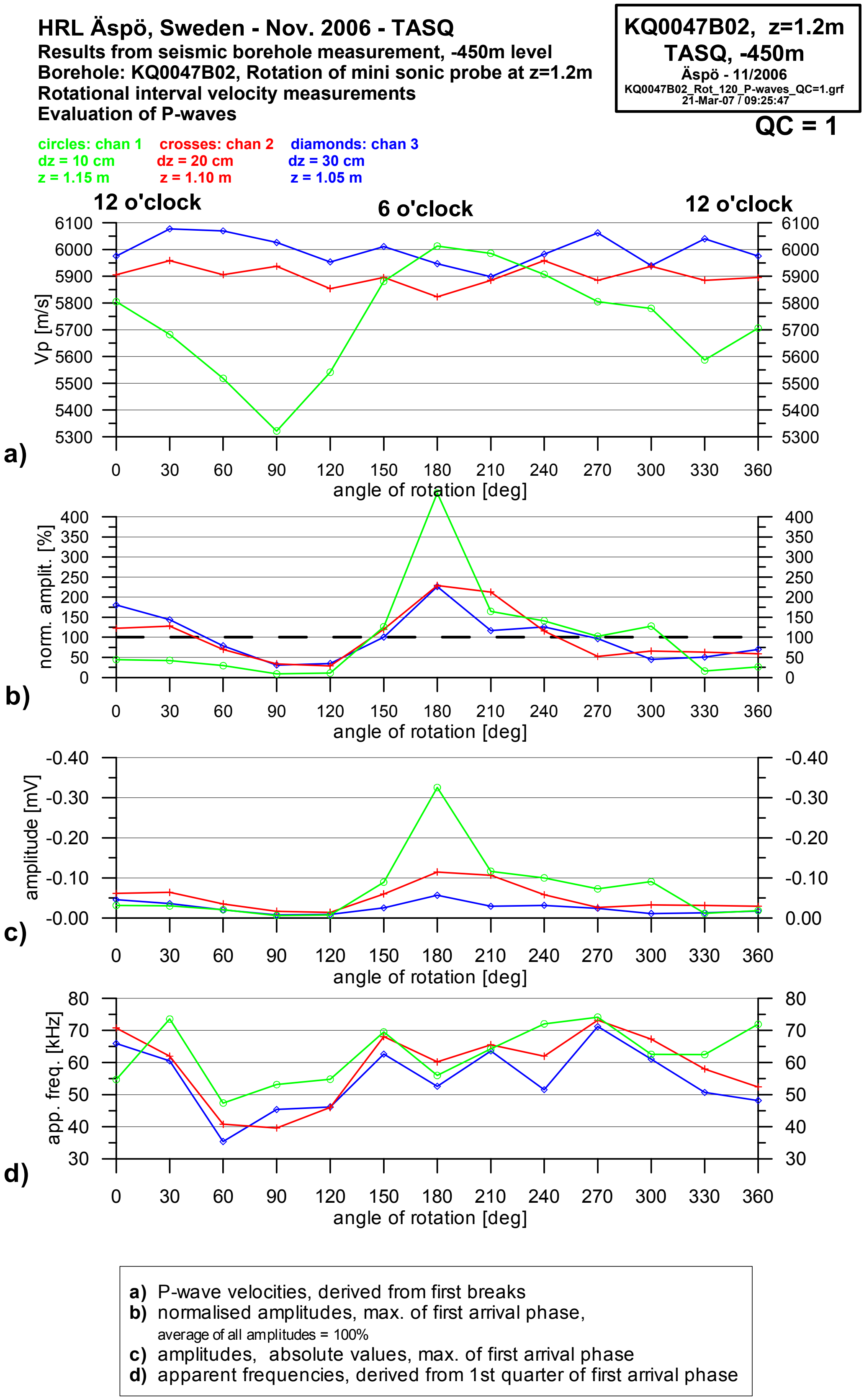


Fig. A-37. Seismic P-wave parameters derived from rotational interval velocity measurements in borehole KQ0047B02 at a depth of 1.2m.

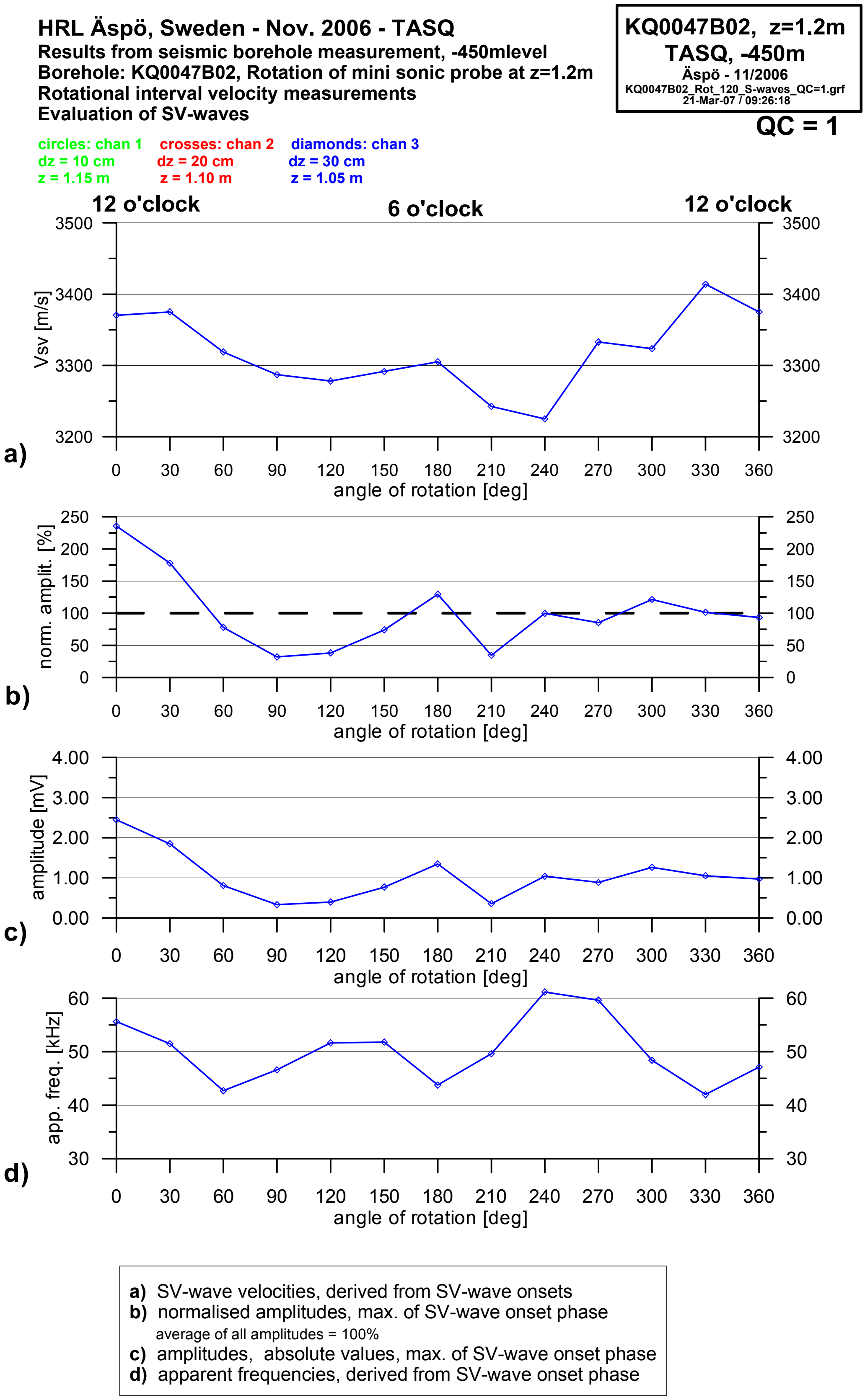


Fig. A-38. Seismic SV-wave parameters derived from rotational interval velocity measurements in borehole KQ0047B02 at a depth of 1.2 m.

Appendix - B

1.) Tabulations of seismic parameters derived from ultrasonic interval velocity measurements in boreholes:

KQ0047A01

KQ0047A02

KQ0047A03

KQ0047B01

KQ0047B02

KQ0047G01

KQ0047H01

KQ0047I01

2.) Tabulations of seismic parameters derived from ultrasonic rotational interval velocity measurements in boreholes:

KQ0047G01, depth: 1.0m, 1.8m and 2.8m

KQ0047H01, depth: 0.8m, 1.6m and 2.8m

KQ0047B02, depth: 1.2m

Borehole: KQ0047A01

Äspö HRL, BGR ultrasonic interval velocity measurements, TASQ tunnel, -450m, borehole: KQ0047A01, sensor orientation: 0°, week 48/2006, (bulk density: 2.731g/cm3)

(distance)	Vp	Vs	Vp/Vs	normAmp_P	normAmp_S	appFreq_P	appFreq_S	Poisson's	temp only for	temp only for	E_dyn [GPa]	G_dyn [GPa]	CMP'	Vp_average
CMP_Pos	if qual >=1	if qual >=1	if QC >= 1	if QC >= 1	if QC >= 1	if QC >= 1	if QC >= 1	ratio	normAmp_P	normAmp_S	if QC>=AW2	if QC>=AX2	for plot	tP01+tP02+tP03)/
[m]	[m/s]	[m/s]		and Amp > 0	and Amp > 0	[kHz]	[kHz]	if QC = 1	Am>0+QC>=	Am<0+QC>=1			[m]	if(QC>=BP2)
channel-1 data														
0,05	5482,69			230,05		30,58			-0,09025				0,10	6071,44
0,10	5761,58			62,78		63,39			-0,02463				0,15	6460,71
0,15	5620,34			94,34		55,46			-0,03701				0,20	6034,55
0,20	not			not		not			not				0,25	5840,87
0,25	5412,09			5,96		73,04			-0,00234				0,30	not
0,30	5334,98			37,11		72,34			-0,01456				0,35	6077,36
0,35	5369,06			75,61		51,28			-0,02966				0,40	6100,64
0,40	5369,06			114,58		44,85			-0,04495				0,45	6217,62
0,45	5369,06			138,64		47,40			-0,05439				0,50	5924,97
0,50	5369,06			146,50		48,31			-0,05747				0,55	5884,49
0,55	5046,72			53,20		43,97			-0,02087				0,60	5499,00
0,60	5108,05			69,77		62,14			-0,02737				0,65	5700,94
0,65	5534,00			112,16		47,80			-0,044				0,70	5895,53
0,70	5595,40			65,66		46,92			-0,02576				0,75	5903,52
0,75	6023,03			12,52		39,94			-0,00491				0,80	5800,08
0,80	5290,22			55,75		50,61			-0,02187				0,85	5710,66
0,85	5380,51			39,43		49,86			-0,01547				0,90	5801,21
0,90	5357,65			54,09		49,65			-0,02122				0,95	5887,65
0,95	5495,95			91,21		46,26			-0,03578				1,00	6132,42
1,00	5622,08			139,61		51,94			-0,05477				1,05	5975,30
1,05	5622,08			91,28		47,96			-0,03581				1,10	6059,13
1,10	5455,15			45,99		46,40			-0,01804				1,15	5892,33
1,15	5455,15			64,57		45,71			-0,02533				1,20	6150,77
1,20	5414,95			133,44		49,93			-0,05235				1,25	6046,11
1,25	5455,15			146,11		49,32			-0,05732				1,30	5967,77
1,30	5495,95			166,05		46,26			-0,06514				1,40	6036,17
1,35	5369,06			109,15		51,28			-0,04282				1,50	5931,72
1,40	5455,15			89,85		57,23			-0,03525				1,60	5848,12
1,45	5495,95			138,54		48,97			-0,05435				1,70	5995,58
1,55	5357,65			163,83		51,71			-0,06427				1,80	6209,49
1,65	5426,83			243,16		55,89			-0,09539				1,90	6147,39
1,75	5297,84			86,90		45,25			-0,03409				2,00	6240,19
1,85	5369,06			87,00		50,25			-0,03413				2,10	6182,45
1,95	5455,15			77,70		51,04			-0,03048				2,20	6312,41
2,05	5334,98			65,23		53,70			-0,02559				2,30	6376,91
2,15	5369,06			125,18		59,88			-0,04911				2,40	6514,16
2,25	5438,53			106,09		53,05			-0,04162				2,50	6364,98
2,35	5570,68			84,22		56,19			-0,03304				2,60	6065,16
2,45	5336,31			34,97		55,68			-0,01372				2,70	6503,73
2,55	5455,15			91,94		49,79			-0,03607				2,80	6318,53
2,65	5495,95			78,66		49,95			-0,03086					
2,75	5799,56			138,92		40,60			-0,0545					
2,85	5709,44			225,08		52,24			-0,0883					
2,95	5754,15			107,14		49,79			-0,04203					
channel-2 data														
0,10	5717,72			132,53		49,79			-0,04272					
0,15	4902,59			1,61		108,45			-0,00052					
0,20	5457,40			2,82		68,79			-0,00091					
0,25	5633,27			8,84		50,03			-0,00285					
0,30	5352,91			5,09		55,10			-0,00164					
0,35	5648,39			162,28		46,37			-0,05231					
0,40	5694,44			149,22		45,64			-0,0481					
0,45	5640,84			112,24		42,06			-0,03618					
0,50	5580,82			103,83		36,43			-0,03347					
0,55	5588,20			126,73		43,78			-0,04085					
0,60	5588,25			109,26		47,08			-0,03522					
0,65	5656,00			40,45		46,82			-0,01304					
0,70	5633,22			25,69		52,12			-0,00828					
0,75	5648,39			28,60		43,17			-0,00922					
0,80	5522,00			15,26		49,20			-0,00492					
0,85	5625,66			207,85		40,66			-0,067					
0,90	5788,72			117,14		45,87			-0,03776					
0,95	5671,34			74,98		47,76			-0,02417					
1,00	5780,75			69,02		42,36			-0,02225					
1,05	5780,75			92,01		40,31			-0,02966					
1,10	5749,01			105,94		43,02			-0,03415					
1,15	5725,52			80,25		39,88			-0,02587					
1,20	5694,44			106,00		43,27			-0,03417					
1,25	5733,35			99,24		41,55			-0,03199					

contd. borehole: KQ0047A01

channel-3 data														
0,15	5811,24	3359,72	1,73	20,91	8,68	47,38	39,68	0,249	-0,00297	0,09583	77,0	30,8		
0,20	6020,72	3383,95	1,78	18,45	5,71	41,86	45,89	0,269	-0,00262	0,06303	79,4	31,3		
0,25	5759,30	3105,10	1,85	not	7,10	50,70	78,27	0,295	not	0,07833	68,2	26,3		
0,30	5673,67	3281,24	1,73	5,21	7,59	49,56	59,20	0,249	-0,00074	0,08376	73,4	29,4		
0,35	not	3325,63	not	not	13,06	not	46,91	not	not	0,14418	not	not		
0,40	5820,11	3275,78	1,78	78,99	130,59	39,34	45,97	0,268	-0,01122	1,44168	74,3	29,3		
0,45	5702,37	3194,52	1,79	101,03	131,69	34,29	59,59	0,271	-0,01435	1,45375	70,9	27,9		
0,50	5797,67	3280,40	1,77	144,33	127,22	35,95	52,65	0,265	-0,0205	1,4044	74,3	29,4		
0,55	5782,80	3275,78	1,77	112,01	112,54	36,12	53,51	0,264	-0,01591	1,24239	74,1	29,3		
0,60	5782,80	3609,36	1,60	52,73	4,75	42,22	52,89	0,181	-0,00749	0,05241	84,0	35,6		
0,65	5659,43	3273,04	1,73	21,97	9,74	55,67	54,59	0,249	-0,00312	0,10748	73,1	29,3		
0,70	5548,03	3147,98	1,76	19,78	16,97	33,21	56,40	0,263	-0,00281	0,18729	68,3	27,1		
0,75	5709,58	3181,79	1,79	not	12,51	44,99	59,01	0,275	not	0,13809	70,5	27,6		
0,80	5709,58	3076,41	1,86	18,09	15,89	41,01	71,56	0,295	-0,00257	0,17543	67,0	25,8		
0,85	5687,98	3336,92	1,70	24,71	18,70	48,48	49,69	0,238	-0,00351	0,20647	75,3	30,4		
0,90	5680,82	3154,91	1,80	9,29	5,19	50,70	78,88	0,277	-0,00132	0,05728	69,4	27,2		
0,95	5738,65	3248,72	1,77	37,74	132,97	54,08	58,35	0,264	-0,00536	1,46794	72,9	28,8		
1,00	5731,35	3211,58	1,78	97,16	132,22	45,82	65,87	0,271	-0,0138	1,4596	71,6	28,2		
1,05	5888,51	3320,02	1,77	111,52	132,64	38,15	53,82	0,267	-0,01584	1,46426	76,3	30,1		
1,10	5775,39	3264,90	1,77	94,91	124,73	45,83	61,93	0,265	-0,01348	1,37692	73,7	29,1		
1,15	5842,73	3325,63	1,76	117,37	128,56	44,22	54,00	0,260	-0,01667	1,41923	76,1	30,2		
1,20	5753,29	3303,29	1,74	93,85	102,96	48,49	55,65	0,254	-0,01333	1,13657	74,7	29,8		
1,25	5865,53	3281,24	1,79	95,40	128,59	39,98	55,28	0,272	-0,01355	1,41955	74,8	29,4		
1,30	5835,17	3220,27	1,81	149,19	163,34	43,95	66,74	0,281	-0,02119	1,80321	72,6	28,3		
1,35	5797,67	3273,04	1,77	146,94	102,35	45,83	58,42	0,266	-0,02087	1,12993	74,1	29,3		
1,45	5790,22	3276,19	1,77	102,58	103,41	43,95	56,28	0,265	-0,01457	1,14163	74,1	29,3		
1,55	5753,29	3248,72	1,77	174,68	132,94	48,49	63,28	0,266	-0,02481	1,46759	73,0	28,8		
1,65	5652,34	3238,02	1,75	62,38	132,25	49,76	64,39	0,256	-0,00886	1,45994	71,9	28,6		
1,75	5760,64	3346,49	1,72	96,03	134,39	49,78	56,60	0,245	-0,01364	1,48356	76,2	30,6		
1,85	5935,00	3314,42	1,79	112,86	168,49	36,48	61,56	0,273	-0,01603	1,85997	76,4	30,0		
1,95	5850,31	3297,75	1,77	125,67	131,60	43,70	61,35	0,267	-0,01785	1,45275	75,3	29,7		
2,05	5919,42	3355,53	1,76	189,46	182,90	43,71	60,52	0,263	-0,02691	2,01909	77,7	30,7		
2,15	5911,66	3405,09	1,74	118,77	144,13	45,02	55,58	0,252	-0,01687	1,59113	79,3	31,7		
2,25	6043,81	3400,38	1,78	190,73	173,59	39,29	56,51	0,268	-0,02709	1,91631	80,1	31,6		
2,35	5987,64	3406,27	1,76	157,43	160,77	39,70	54,65	0,261	-0,02236	1,77484	79,9	31,7		
2,45	6117,59	3348,28	1,83	191,50	168,98	33,96	59,53	0,286	-0,0272	1,8654	78,8	30,6		
2,55	6043,81	3352,29	1,80	115,39	128,02	39,92	58,11	0,278	-0,01639	1,41321	78,4	30,7		
2,65	5971,78	3342,59	1,79	202,63	201,15	44,14	60,26	0,272	-0,02878	2,22062	77,6	30,5		
2,75	6210,26	3342,59	1,86	154,89	129,37	34,28	62,78	0,296	-0,022	1,4282	79,1	30,5		
2,85	6117,59	3377,03	1,81	133,42	131,73	40,58	62,70	0,281	-0,01895	1,45425	79,8	31,1		

Borehole: KQ0047A02

Äspö HRL, BGR ultrasonic interval velocity measurem., TASQ tunnel, -450m, week 48/2006, borehole: KQ0047A02, sensor orientation: 0°, (bulk density: 2.731g/cm3)

(distance) CMP_Pos [m]	Vp if qual >=1 [m/s]	Vs if qual >=1 [m/s]	Vp/Vs if QC >= 1	normAmp_P if QC >= 1 and Amp > 0	normAmp_S if QC >= 1 and Amp > 0	appFreq_P if QC >= 1 [kHz]	appFreq_S if QC >= 1 [kHz]	Poisson's ratio if QC = 1	temp only for normAmp_P Am>0+QC>=	temp only for normAmp_S Am<0+QC>=1	E_dyn [GPa] if QC>=AW2	G_dyn [GPa] if QC>=AX2	CMP' for plot [m]	Vp_average 01+tP02+tP03 if(QC>=BP2)
channel-1 data														
0,05	5437,95			31,13		63,93			-0,00938				0,10	6322,07
0,10	5762,23			32,55		46,11			-0,00981				0,15	6672,69
0,15	5622,53			122,35		30,07			-0,03687				0,20	6165,61
0,20	5374,94			13,64		103,33			-0,00411				0,25	6052,86
0,25	5410,51			109,97		51,89			-0,03314				0,30	6397,05
0,30	5140,74			27,01		79,40			-0,00814				0,35	6227,88
0,35	5763,35			29,17		72,49			-0,00879				0,40	not
0,40	5608,93			192,90		30,23			-0,05813				0,45	not
0,45	5374,94			91,92		65,87			-0,0277				0,50	not
0,50	5458,24			63,38		50,21			-0,0191				0,55	not
0,55	4471,86			1,89		58,57			-0,00057				0,60	not
0,60	4408,13			2,09		73,11			-0,00063				0,65	not
0,65	5325,56			179,13		52,94			-0,05398				0,70	not
0,70	5313,36			not		72,88			not				0,75	not
0,75	5056,70			not		80,02			not				0,80	not
0,80	5351,13			2,32		58,63			-0,0007				0,85	not
0,85	4993,05			94,38		32,59			-0,02844				0,90	5558,04
0,90	5363,60			72,71		50,45			-0,02191				0,95	5869,94
0,95	5317,49			56,21		42,41			-0,01694				1,00	5447,89
1,00	5458,24			42,51		48,27			-0,01281				1,05	not
1,05	5301,22			63,75		72,75			-0,01921				1,10	not
1,10	5058,39			42,11		38,28			-0,01269				1,15	not
1,15	5450,73			43,27		46,70			-0,01304				1,20	not
1,20	5763,35			3,85		75,24			-0,00116				1,25	not
1,25	5763,35			0,07		75,24			-0,00002				1,30	not
1,30	5581,93			55,15		59,74			-0,01662				1,40	5924,66
1,35	5657,93			132,87		56,49			-0,04004				1,50	6077,10
1,40	5515,55			36,30		58,20			-0,01094				1,60	6002,32
1,45	5719,60			87,34		54,16			-0,02632				1,70	6027,35
1,55	5649,92			142,93		53,18			-0,04307				1,80	6128,48
1,65	5747,95			246,20		50,99			-0,07419				1,90	5994,76
1,75	5636,19			151,72		56,08			-0,04572				2,00	6096,36
1,85	5820,08			245,30		38,95			-0,07392				2,10	6358,71
1,95	5763,35			117,87		56,19			-0,03552				2,20	6118,42
2,05	5763,35			89,63		52,64			-0,02701				2,30	6097,12
2,15	5733,74			247,89		53,66			-0,0747				2,40	6049,83
2,25	5705,53			226,58		50,27			-0,06828				2,50	6061,50
2,35	5733,74			202,73		53,66			-0,06109				2,60	6031,69
2,45	5719,60			133,57		49,84			-0,04025				2,70	6194,65
2,55	5705,53			117,44		52,38			-0,03539					
2,65	5719,60			185,80		41,55			-0,05599					
2,75	5733,74			228,05		51,45			-0,06872					
2,85	5733,74			134,30		54,83			-0,04047					
channel-2 data														
0,10	5955,11			122,42		33,71			-0,03485					
0,15	5792,32			46,09		72,01			-0,01312					
0,20	5904,63			100,57		45,22			-0,02863					
0,25	5657,58			4,92		69,57			-0,0014					
0,30	5864,86			55,47		51,04			-0,01579					
0,35	5904,63			43,31		30,02			-0,01233					
0,40	5944,94			20,30		51,46			-0,00578					
0,45	6006,46			107,00		39,67			-0,03046					
0,50	5914,66			3,34		28,91			-0,00095					
0,55	not			not		not			not					
0,60	not			not		not			not					
0,65	not			not		not			not					
0,70	not			not		not			not					
0,75	not			not		not			not					
0,80	not			not		not			not					
0,85	not			not		not			not					
0,90	5414,09			84,55		31,02			-0,02407					
0,95	5588,25			55,43		37,25			-0,01578					
1,00	5737,66			81,21		36,54			-0,02312					
1,05	5366,31			26,31		40,77			-0,00749					
1,10	5529,66			86,24		35,06			-0,02455					
1,15	not			not		not			not					
1,20	not			not		not			not					
1,25	not			not		not			not					
1,30	6091,32			3,90		90,37			-0,00111					

contd. borehole: KQ0047A02

channel-3 data														
0,15	5983,99	3188,52	1,88	141,73	51,43	39,90	43,58	0,302	-0,02324	0,64966	72,3	27,8		
0,20	6061,36	3280,75	1,85	28,66	20,70	43,81	65,48	0,293	-0,0047	0,2615	76,0	29,4		
0,25	6022,73	3526,76	1,71	66,54	35,99	50,11	43,27	0,239	-0,01091	0,45454	84,2	34,0		
0,30	5895,05	3426,49	1,72	18,05	36,79	40,92	48,25	0,245	-0,00296	0,46469	79,8	32,1		
0,35	6011,89	3286,34	1,83	25,86	51,44	46,31	60,44	0,287	-0,00424	0,64971	75,9	29,5		
0,40	5935,77	3507,52	1,69	35,31	25,54	47,54	42,22	0,232	-0,00579	0,32256	82,8	33,6		
0,45	not	not	not	not	not	not	not	not	not	not	not	not		
0,50	not	not	not	not	not	not	not	not	not	not	not	not		
0,55	not	not	not	not	not	not	not	not	not	not	not	not		
0,60	not	not	not	not	not	not	not	not	not	not	not	not		
0,65	not	not	not	not	not	not	not	not	not	not	not	not		
0,70	not	not	not	not	not	not	not	not	not	not	not	not		
0,75	not	not	not	not	not	not	not	not	not	not	not	not		
0,80	not	not	not	not	not	not	not	not	not	not	not	not		
0,85	not	not	not	not	not	not	not	not	not	not	not	not		
0,90	not	not	not	not	not	not	not	not	not	not	not	not		
0,95	5435,23	3136,66	1,73	44,34	32,35	31,63	48,53	0,250	-0,00727	0,40868	67,2	26,9		
1,00	5570,27	3061,95	1,82	19,45	26,53	32,29	54,67	0,283	-0,00319	0,33506	65,7	25,6		
1,05	5446,71	3091,40	1,76	55,01	56,84	38,34	59,27	0,262	-0,00902	0,71793	65,9	26,1		
1,10	6140,77	3162,38	1,94	5,85	1,05	48,13	64,48	0,320	-0,00096	0,01326	72,1	27,3		
1,15	not	not	not	not	not	not	not	not	not	not	not	not		
1,20	not	not	not	not	not	not	not	not	not	not	not	not		
1,25	not	not	not	not	not	not	not	not	not	not	not	not		
1,30	not	3432,59	not	not	3,45	not	50,00	not	not	0,04359	not	not		
1,35	not	3247,59	not	not	7,54	not	59,43	not	not	0,09521	not	not		
1,45	5828,42	3269,62	1,78	64,16	135,73	43,64	59,32	0,270	-0,01052	1,71448	74,2	29,2		
1,55	5963,23	3354,95	1,78	106,24	154,23	36,28	52,90	0,268	-0,01742	1,94818	78,0	30,7		
1,65	5874,90	3326,02	1,77	202,54	204,73	41,42	65,22	0,264	-0,03321	2,58599	76,4	30,2		
1,75	5956,34	3408,32	1,75	195,10	206,49	43,60	56,92	0,257	-0,03199	2,60821	79,7	31,7		
1,85	5997,91	3488,48	1,72	107,58	146,90	43,99	52,09	0,244	-0,01764	1,85556	82,7	33,2		
1,95	5915,34	3384,39	1,75	119,66	140,87	45,58	57,45	0,257	-0,01962	1,77938	78,6	31,3		
2,05	5970,13	3438,71	1,74	172,10	169,02	45,05	50,83	0,252	-0,02822	2,13498	80,8	32,3		
2,15	6118,90	3426,49	1,79	124,47	128,22	34,38	52,29	0,272	-0,02041	1,61959	81,5	32,1		
2,25	5983,99	3414,36	1,75	138,93	149,58	49,35	56,68	0,259	-0,02278	1,88942	80,1	31,8		
2,35	5963,23	3438,71	1,73	147,89	152,49	43,17	53,75	0,251	-0,02425	1,92615	80,8	32,3		
2,45	5928,94	3372,56	1,76	161,13	168,74	40,32	58,40	0,261	-0,02642	2,13138	78,3	31,1		
2,55	5942,61	3396,32	1,75	138,99	164,91	42,98	56,11	0,257	-0,02279	2,08301	79,2	31,5		
2,65	5928,94	3438,71	1,72	160,58	209,52	44,64	51,18	0,247	-0,02633	2,64647	80,5	32,3		
2,75	6033,00	3469,65	1,74	119,84	118,94	39,23	49,56	0,253	-0,01965	1,50235	82,4	32,9		

Borehole: KQ0047A03

Äspö HRL, BGR ultrasonic interval velocity measurem., TASQ tunnel, -450m, week 48/2006, borehole: KQ0047A03, sensor orientation: 0°, (bulk density: 2.731g/cm3)

(distance)	Vp	Vs	Vp/Vs	normAmp_P	normAmp_S	appFreq_P	appFreq_S	Poisson's	temp only for	temp only for	E_dyn [GPa]	G_dyn [GPa]	CMP'	Vp_average
CMP_Pos	if qual >=1	if qual >=1	if QC >= 1	if QC >= 1	if QC >= 1	if QC >= 1	if QC >= 1	ratio	normAmp_P	normAmp_S	if QC>=AW2	if QC>=AX2	for plot	01+tP02+tP03
[m]	[m/s]	[m/s]		and Amp > 0	and Amp > 0	[kHz]	[kHz]	if QC = 1	Am>0+QC>='	Am<0+QC>=1			[m]	if(QC>=BP2)
channel-1 data														
0,05	6220,81			21,03		148,60			-0,01115				0,10	5995,65
0,10	6159,37			18,73		143,81			-0,00993				0,15	6065,64
0,15	5631,04			25,67		128,78			-0,01361				0,20	6258,85
0,20	5631,04			30,29		122,47			-0,01606				0,25	6171,90
0,25	5721,44			53,46		75,26			-0,02834				0,30	6127,57
0,30	5774,42			59,48		100,72			-0,03153				0,35	5911,91
0,35	5669,43			61,23		72,22			-0,03246				0,40	6156,08
0,40	5774,42			63,87		96,82			-0,03386				0,45	6058,45
0,45	5787,81			114,50		46,97			-0,0607				0,50	6057,86
0,50	5725,52			112,58		48,69			-0,05968				0,55	5954,49
0,55	5860,02			182,69		41,42			-0,09685				0,60	6143,51
0,60	5832,62			160,25		45,83			-0,08495				0,65	6108,08
0,65	5832,62			119,39		45,83			-0,06329				0,70	6264,01
0,70	5714,00			177,87		49,03			-0,09429				0,75	6148,63
0,75	5765,22			81,40		60,17			-0,04315				0,80	6068,13
0,80	5498,37			68,12		54,20			-0,03611				0,85	6121,42
0,85	5791,99			72,51		63,54			-0,03844				0,90	6036,74
0,90	5805,47			74,04		47,39			-0,03925				0,95	6192,96
0,95	5873,82			156,13		54,64			-0,08277				1,00	6209,65
1,00	5986,59			115,37		52,13			-0,06116				1,05	6180,60
1,05	5929,67			98,47		35,53			-0,0522				1,10	6058,86
1,10	5860,02			94,62		59,03			-0,05016				1,15	6387,21
1,15	5887,68			165,30		48,87			-0,08763				1,20	6419,02
1,20	5805,47			57,84		59,88			-0,03066				1,25	6465,47
1,25	5727,05			26,81		70,64			-0,01421				1,30	6153,72
1,30	5712,41			41,95		50,06			-0,02224				1,40	6499,92
1,35	5634,99			69,17		49,47			-0,03667				1,50	6081,60
1,40	5450,32			139,89		58,79			-0,07416				1,60	6145,32
1,45	5699,36			97,88		48,50			-0,05189				1,70	6180,67
1,55	5572,06			40,69		58,85			-0,02157				1,80	5979,43
1,65	5534,97			17,00		59,01			-0,00901				1,90	6163,27
1,75	5725,52			125,67		48,69			-0,06662				2,00	5833,15
1,85	5860,02			119,67		68,77			-0,06344				2,10	6088,08
1,95	5986,59			111,39		75,85			-0,05905				2,20	6139,19
2,05	5778,57			129,57		92,78			-0,06869				2,30	6168,11
2,15	6088,87			81,96		50,24			-0,04345				2,40	6099,35
2,25	6118,74			124,61		74,48			-0,06606				2,50	6107,95
2,35	5929,67			358,35		60,45			-0,18997				2,60	6103,36
2,45	5751,93			169,85		62,27			-0,09004				2,70	6212,97
2,55	5832,62			76,25		90,74			-0,04042					
2,65	5943,79			41,24		100,98			-0,02186					
2,75	5873,82			119,05		59,88			-0,06311					
2,85	5873,82			224,16		36,90			-0,11883					
channel-2 data														
0,10	5927,40			not		63,79			not					
0,15	5913,96			134,94		61,25			-0,03616					
0,20	5968,10			145,99		44,73			-0,03912					
0,25	6023,25			79,26		50,05			-0,02124					
0,30	5860,78			82,40		64,52			-0,02208					
0,35	5954,47			118,41		62,32			-0,03173					
0,40	5887,25			77,21		54,02			-0,02069					
0,45	5940,91			70,57		50,66			-0,01891					
0,50	5847,64			44,89		48,09			-0,01203					
0,55	5995,55			72,17		43,54			-0,01934					
0,60	5981,80			72,77		40,55			-0,0195					
0,65	5913,96			90,94		44,79			-0,02437					
0,70	6051,21			67,36		66,69			-0,01805					
0,75	5706,85			32,50		50,46			-0,00871					
0,80	5913,96			94,82		48,25			-0,02541					
0,85	5887,25			84,34		42,89			-0,0226					
0,90	5873,99			137,14		41,31			-0,03675					
0,95	6023,25			176,14		46,34			-0,0472					
1,00	6051,21			120,27		43,49			-0,03223					
1,05	6107,91			94,26		47,57			-0,02526					
1,10	6151,14			57,92		36,84			-0,01552					
1,15	6093,64			43,59		52,31			-0,01168					
1,20	5940,91			23,44		48,68			-0,00628					
1,25	6093,64			34,74		45,63			-0,00931					
1,30	6037,20			47,39		51,31			-0,0127					

contd. borehole: KQ0047A03,

channel-3 data

0,15	5897,30	3382,77	1,74	51,78	93,58	70,84	40,30	0,255	-0,00727	0,92018	78,4	31,3		
0,20	5961,74	3355,38	1,78	95,80	86,82	36,88	52,49	0,268	-0,01345	0,85375	78,0	30,7		
0,25	6046,68	3401,28	1,78	145,73	177,78	39,77	53,98	0,269	-0,02046	1,74814	80,2	31,6		
0,30	6033,42	3458,03	1,74	117,74	126,14	59,85	50,88	0,255	-0,01653	1,24037	82,0	32,7		
0,35	6008,63	3458,03	1,74	76,35	72,32	47,42	52,66	0,252	-0,01072	0,71108	81,8	32,7		
0,40	5843,57	3429,42	1,70	32,76	53,74	60,07	53,89	0,237	-0,0046	0,5284	79,5	32,1		
0,45	6046,68	3410,61	1,77	117,02	82,58	43,97	63,37	0,267	-0,01643	0,81197	80,5	31,8		
0,50	5980,41	3438,91	1,74	40,24	63,65	59,02	54,91	0,253	-0,00565	0,62585	80,9	32,3		
0,55	5980,41	3458,03	1,73	29,34	34,88	39,46	47,95	0,249	-0,00412	0,34298	81,6	32,7		
0,60	5869,96	3419,99	1,72	149,43	224,37	52,17	49,09	0,243	-0,02098	2,20622	79,4	31,9		
0,65	6008,63	3401,28	1,77	34,26	28,63	72,01	63,59	0,264	-0,00481	0,28154	79,9	31,6		
0,70	5888,21	3328,44	1,77	27,49	41,71	50,50	54,10	0,265	-0,00386	0,41009	76,6	30,3		
0,75	6094,93	3382,77	1,80	80,77	58,88	41,13	53,91	0,277	-0,01134	0,57901	79,8	31,3		
0,80	6027,60	3382,77	1,78	127,21	116,00	43,64	52,77	0,270	-0,01786	1,14064	79,4	31,3		
0,85	5999,19	3373,59	1,78	153,06	129,62	43,91	54,46	0,269	-0,02149	1,27461	78,9	31,1		
0,90	6075,54	3382,77	1,80	175,00	165,34	40,18	55,10	0,275	-0,02457	1,62583	79,7	31,3		
0,95	5999,19	3410,61	1,76	103,77	172,32	50,07	54,60	0,261	-0,01457	1,69442	80,1	31,8		
1,00	6075,54	3448,44	1,76	77,42	94,54	51,85	54,34	0,262	-0,01087	0,92963	82,0	32,5		
1,05	6094,93	3405,09	1,79	46,37	37,74	40,46	59,09	0,273	-0,00651	0,37109	80,6	31,7		
1,10	6046,68	3410,61	1,77	31,27	34,11	48,21	55,41	0,267	-0,00439	0,33541	80,5	31,8		
1,15	5943,18	3429,42	1,73	24,86	44,15	51,85	52,02	0,250	-0,00349	0,43411	80,3	32,1		
1,20	6143,95	3477,38	1,77	51,14	55,31	41,18	50,59	0,264	-0,00718	0,54387	83,5	33,0		
1,25	6134,09	3458,03	1,77	46,72	55,91	41,03	50,19	0,267	-0,00656	0,54974	82,8	32,7		
1,30	6085,22	3448,44	1,76	51,71	70,59	40,98	53,95	0,263	-0,00726	0,69414	82,1	32,5		
1,35	5989,79	3438,91	1,74	18,95	45,93	44,53	54,91	0,254	-0,00266	0,45164	81,0	32,3		
1,45	6153,85	3467,68	1,77	24,07	12,87	35,28	60,08	0,267	-0,00338	0,12652	83,2	32,8		
1,55	5869,96	3429,42	1,71	15,03	26,10	48,15	53,12	0,241	-0,00211	0,25669	79,7	32,1		
1,65	5989,79	3526,69	1,70	80,56	86,74	50,87	50,57	0,235	-0,01131	0,85289	83,9	34,0		
1,75	6065,89	3448,44	1,76	79,34	72,96	61,83	60,97	0,261	-0,01114	0,71746	81,9	32,5		
1,85	5980,41	3506,80	1,71	91,60	117,73	56,35	51,55	0,238	-0,01286	1,15764	83,2	33,6		
1,95	6027,60	3410,61	1,77	174,64	154,01	45,22	53,44	0,265	-0,02452	1,51438	80,3	31,8		
2,05	5915,57	3458,03	1,71	66,52	109,18	40,41	46,66	0,240	-0,00934	1,07356	81,0	32,7		
2,15	6094,93	3448,44	1,77	198,01	140,76	58,43	59,99	0,265	-0,0278	1,3841	82,1	32,5		
2,25	6065,89	3448,44	1,76	431,13	266,95	51,62	58,14	0,261	-0,06053	2,62497	81,9	32,5		
2,35	6022,64	3546,81	1,70	127,28	107,89	39,76	43,83	0,235	-0,01787	1,06093	84,8	34,4		
2,45	6003,71	3429,42	1,75	165,67	180,00	49,69	50,96	0,258	-0,02326	1,76994	80,8	32,1		
2,55	6051,27	3401,28	1,78	200,00	140,97	55,27	54,77	0,269	-0,02808	1,38612	80,2	31,6		
2,65	6022,64	3382,77	1,78	171,79	180,01	41,75	53,91	0,270	-0,02412	1,77008	79,4	31,3		
2,75	6089,86	3392,00	1,80	168,16	137,19	40,73	50,50	0,275	-0,02361	1,34899	80,1	31,4		

Borehole: KQ0047B01

Aspö HRL, BGR ultrasonic interval velocity measurem., TASQ tunnel, -450m, week 48/2006, borehole: KQ0047B01, sensor orientation: 0°, (bulk density: 2.731g/cm3)

(distance) CMP_Pos [m]	Vp if qual >=1 [m/s]	Vs if qual >=1 [m/s]	Vp/Vs if QC >= 1	normAmp_P if QC >= 1 and Amp > 0	normAmp_S if QC >= 1 and Amp > C	appFreq_P if QC >= 1 [kHz]	appFreq_S if QC >= 1 [kHz]	Poisson's ratio if QC = 1	temp only for normAmp_P Am>0+QC>=	temp only for normAmp_S Am<0+QC>=1	E_dyn [GPa] if QC>=AW2	G_dyn [GPa] if QC>=AX2	CMP' for plot [m]	Vp_average (tP01+tP02+tP03)/3 if(QC>=BP2)
channel-1 data														
0,05	5478,11			110,89		75,25			-0,07702				0,10	5972,85
0,10	5666,20			65,81		60,22			-0,04571				0,15	5972,09
0,15	5507,31			46,07		56,77			-0,032				0,20	5884,78
0,20	5535,53			53,49		46,86			-0,03715				0,25	5885,09
0,25	5535,53			53,76		43,59			-0,03734				0,30	5868,90
0,30	5521,38			113,02		43,19			-0,0785				0,35	5909,95
0,35	5658,64			121,28		41,47			-0,08424				0,40	5952,91
0,40	5658,64			111,49		47,82			-0,07744				0,45	5877,52
0,45	5618,71			93,06		48,06			-0,06464				0,50	5901,25
0,50	5527,70			59,62		54,24			-0,04141				0,55	5991,36
0,55	5645,27			116,34		49,15			-0,08081				0,60	5850,15
0,60	5605,53			83,82		56,05			-0,05822				0,65	5976,72
0,65	5631,96			75,25		43,52			-0,05227				0,70	6000,26
0,70	5553,40			126,21		52,98			-0,08766				0,75	6032,83
0,75	5540,52			28,62		45,04			-0,01988				0,80	6001,57
0,80	5579,34			88,83		51,26			-0,0617				0,85	6122,04
0,85	5712,77			71,07		53,24			-0,04936				0,90	6240,89
0,90	5740,22			131,81		54,60			-0,09155				0,95	6137,15
0,95	5834,54			61,03		54,82			-0,04239				1,00	6140,57
1,00	5672,08			113,91		55,93			-0,07912				1,05	6178,73
1,05	5578,41			55,99		53,49			-0,03889				1,10	6307,15
1,10	5578,41			56,06		49,27			-0,03894				1,15	6252,79
1,15	5741,50			148,88		52,27			-0,10341				1,20	6211,42
1,20	5681,10			127,56		54,37			-0,0886				1,25	5972,17
1,25	5740,22			113,22		51,24			-0,07864				1,30	5980,71
1,30	5605,53			100,51		45,78			-0,06981				1,40	5756,30
1,35	5754,05			142,66		43,70			-0,09909				1,50	6046,81
1,40	5658,64			133,95		47,82			-0,09304				1,60	6323,35
1,45	5645,27			123,23		45,57			-0,08559				1,70	5988,63
1,55	5605,53			127,24		48,45			-0,08838				1,80	6010,81
1,65	5549,75			138,62		64,33			-0,09628				1,90	5826,43
1,75	5535,53			98,00		59,98			-0,06807				2,00	5777,08
1,85	5699,14			129,29		49,47			-0,0898				2,10	5973,87
1,95	5477,01			108,57		45,94			-0,07541				2,20	6049,70
2,05	5685,57			121,50		47,97			-0,08439				2,30	5995,42
2,15	5672,08			125,60		48,36			-0,08724				2,40	6008,58
2,25	5838,43			73,90		47,42			-0,05133				2,50	6019,12
2,35	5658,64			119,25		50,73			-0,08283				2,60	5983,39
2,45	5685,57			108,74		49,88			-0,07553				2,70	6303,00
2,55	5712,77			97,37		52,13			-0,06763				2,80	6434,97
2,65	5838,43			127,62		51,31			-0,08864					
2,75	6107,09			136,36		45,24			-0,09471					
2,85	5740,22			90,72		51,24			-0,06301					
2,95	5726,46			69,77		60,43			-0,04846					
channel-2 data														
0,10	5836,46			92,76		48,71			-0,04111					
0,15	5855,92			45,01		53,80			-0,01995					
0,20	5769,38			64,98		50,67			-0,0288					
0,25	5694,57			76,44		48,27			-0,03388					
0,30	5741,10			94,74		45,76			-0,04199					
0,35	5731,73			115,32		46,24			-0,05111					
0,40	5713,09			101,35		49,09			-0,04492					
0,45	5722,40			113,20		45,05			-0,05017					
0,50	5703,82			107,20		46,85			-0,04751					
0,55	5797,94			97,20		43,82			-0,04308					
0,60	5694,57			119,63		44,02			-0,05302					
0,65	5769,38			151,96		44,37			-0,06735					
0,70	5603,75			53,09		49,90			-0,02353					
0,75	5797,94			98,87		45,41			-0,04382					
0,80	5797,94			86,48		44,60			-0,03833					
0,85	5885,34			125,36		47,92			-0,05556					
0,90	5925,04			66,52		60,31			-0,02948					
0,95	5915,07			119,43		42,46			-0,05293					
1,00	5865,69			93,88		41,64			-0,04161					
1,05	5807,52			93,95		46,63			-0,04164					
1,10	5807,52			54,47		49,39			-0,02414					
1,15	5955,17			128,99		40,22			-0,05717					
1,20	5905,13			117,17		42,15			-0,05193					
1,25	5788,39			103,63		45,89			-0,04593					

contd. borehole: KQ0047B01

channel-3 data														
0,15	5819,41	3287,65	1,77	109,47	133,38	47,63	49,19	0,266	-0,02897	2,48663	74,7	29,5		
0,20	5813,28	3285,11	1,77	108,87	85,74	50,06	61,10	0,265	-0,02881	1,59849	74,6	29,5		
0,25	5807,16	3341,99	1,74	112,38	84,08	45,96	53,84	0,252	-0,02974	1,56746	76,4	30,5		
0,30	5807,16	3368,51	1,72	88,80	74,23	48,64	50,90	0,246	-0,0235	1,3839	77,3	31,0		
0,35	5782,81	3280,03	1,76	112,91	90,20	45,27	59,84	0,263	-0,02988	1,68152	74,2	29,4		
0,40	5776,76	3287,65	1,76	112,80	106,00	47,46	57,05	0,260	-0,02985	1,97615	74,4	29,5		
0,45	5844,07	3295,31	1,77	115,14	102,16	42,62	56,15	0,267	-0,03047	1,90453	75,1	29,7		
0,50	5782,81	3295,31	1,75	76,22	69,87	50,79	54,12	0,260	-0,02017	1,30263	74,7	29,7		
0,55	5807,16	3269,93	1,78	116,73	126,46	42,09	58,82	0,268	-0,03089	2,35751	74,0	29,2		
0,60	5837,88	3285,11	1,78	110,79	117,18	44,55	58,25	0,268	-0,02932	2,18448	74,8	29,5		
0,65	5740,70	3305,57	1,74	63,63	77,04	47,70	53,42	0,252	-0,01684	1,43616	74,7	29,8		
0,70	5837,88	3267,41	1,79	88,08	100,28	41,59	60,09	0,272	-0,02331	1,86949	74,2	29,2		
0,75	5900,32	3334,12	1,77	67,41	74,38	41,29	53,12	0,265	-0,01784	1,38656	76,8	30,4		
0,80	5932,03	3334,12	1,78	107,02	95,29	45,23	56,74	0,269	-0,02832	1,77648	77,1	30,4		
0,85	5944,82	3495,26	1,70	38,96	58,03	52,79	47,88	0,236	-0,01031	1,08189	82,5	33,4		
0,90	5964,10	3383,43	1,76	102,63	103,52	40,33	56,27	0,263	-0,02716	1,92984	79,0	31,3		
0,95	6003,03	3379,23	1,78	109,02	124,90	38,91	53,88	0,268	-0,02885	2,32855	79,1	31,2		
1,00	5938,42	3318,49	1,79	87,10	90,00	46,46	61,50	0,273	-0,02305	1,67775	76,6	30,1		
1,05	5996,51	3341,99	1,79	96,02	89,33	41,87	55,85	0,275	-0,02541	1,66539	77,8	30,5		
1,10	6003,03	3297,87	1,82	131,24	112,94	40,16	61,33	0,284	-0,03473	2,10547	76,3	29,7		
1,15	6102,63	3318,49	1,84	48,56	89,05	36,55	56,00	0,290	-0,01285	1,66015	77,6	30,1		
1,20	6016,12	3303,00	1,82	140,08	103,33	40,76	56,10	0,284	-0,03707	1,92633	76,5	29,8		
1,25	6042,48	3305,57	1,83	101,80	81,52	38,75	57,96	0,286	-0,02694	1,51966	76,8	29,8		
1,30	5862,70	3290,20	1,78	77,09	77,02	45,22	55,90	0,270	-0,0204	1,4358	75,1	29,6		
1,35	5862,70	3252,40	1,80	104,82	82,89	40,13	58,33	0,278	-0,02774	1,54526	73,8	28,9		
1,45	5705,08	3208,16	1,78	106,00	114,81	45,33	60,07	0,269	-0,02805	2,14035	71,3	28,1		
1,55	5868,93	3285,11	1,79	110,95	120,94	44,78	57,80	0,272	-0,02936	2,25464	75,0	29,5		
1,65	6035,87	3334,12	1,81	101,20	90,65	40,34	58,51	0,280	-0,02678	1,69002	77,7	30,4		
1,75	5881,45	3395,44	1,73	106,37	112,73	46,36	53,41	0,250	-0,02815	2,10165	78,7	31,5		
1,85	5819,41	3355,20	1,73	98,70	115,71	38,18	49,73	0,251	-0,02612	2,15708	76,9	30,7		
1,95	5776,76	3368,51	1,71	94,32	100,13	44,90	46,77	0,242	-0,02496	1,86664	77,0	31,0		
2,05	5740,70	3267,41	1,76	117,29	121,89	44,31	53,65	0,260	-0,03104	2,27236	73,5	29,2		
2,15	5925,66	3264,90	1,81	94,13	88,91	39,85	59,95	0,282	-0,02491	1,65749	74,6	29,1		
2,25	5912,96	3303,00	1,79	108,79	129,81	44,93	57,38	0,273	-0,02879	2,42001	75,9	29,8		
2,35	5887,72	3384,62	1,74	101,31	122,77	45,07	52,59	0,253	-0,02681	2,28879	78,4	31,3		
2,45	5906,63	3395,44	1,74	99,31	109,19	47,99	53,79	0,253	-0,02628	2,03552	78,9	31,5		
2,55	5957,66	3363,17	1,77	100,52	104,97	46,78	56,41	0,266	-0,0266	1,957	78,2	30,9		
2,65	6022,69	3400,88	1,77	92,05	107,44	47,27	53,25	0,266	-0,02436	2,00304	80,0	31,6		
2,75	6102,63	3414,56	1,79	98,02	108,13	38,81	55,40	0,272	-0,02594	2,01586	81,0	31,8		
2,85	6177,79	3417,30	1,81	143,48	103,11	40,07	59,96	0,280	-0,03797	1,92223	81,6	31,9		

Borehole: KQ0047B02

Aspö HRL, BGR ultrasonic interval velocity measurem., TASQ tunnel, -450m, week 48/2006, borehole: KQ0047B02, sensor orientation: 0°, (bulk density: 2.731g/cm:

(distance) CMP_Pos [m]	Vp if qual >=1 [m/s]	Vs if qual >=1 [m/s]	Vp/Vs if QC >= 1	normAmp_P if QC >= 1 and Amp > 0	normAmp_S if QC >= 1 and Amp > 0	appFreq_P if QC >= 1 [kHz]	appFreq_S if QC >= 1 [kHz]	Poisson's ratio if QC = 1	temp only for normAmp_P Am>0+QC>=	temp only for normAmp_S Am<0+QC>=1	E_dyn [GPa] if QC>=AW2	G_dyn [GPa] if QC>=AX2	CMP' for plot [m]	Vp_average (tP01+tP02+tP03)/3 if(QC>=BP2)
channel-1 data														
0,05	5311,19			27,26		50,28			-0,02474				0,10	5697,81
0,10	5401,67			5,06		135,61			-0,00459				0,15	5830,42
0,15	5585,65			41,89		71,49			-0,03802				0,20	5963,10
0,20	5716,90			49,88		89,03			-0,04527				0,25	5914,96
0,25	5728,83			82,87		61,81			-0,07522				0,30	6172,06
0,30	5728,83			54,77		74,75			-0,04971				0,35	6007,45
0,35	5669,71			29,24		115,76			-0,02654				0,40	6222,69
0,40	5669,71			76,67		51,41			-0,06959				0,45	6049,71
0,45	5658,03			64,24		42,19			-0,05831				0,50	6209,42
0,50	5600,35			22,70		38,80			-0,0206				0,55	6146,13
0,55	5423,45			16,18		46,63			-0,01469				0,60	6071,47
0,60	5402,12			13,42		43,95			-0,01218				0,65	5953,99
0,65	5466,62			29,35		34,74			-0,02664				0,70	5878,58
0,70	5646,40			60,56		51,13			-0,05497				0,75	5883,87
0,75	5693,21			34,64		111,85			-0,03144				0,80	5984,23
0,80	5693,21			136,88		39,46			-0,12424				0,85	5918,64
0,85	6166,03			37,38		89,86			-0,03393				0,90	6072,52
0,90	6152,23			134,35		72,55			-0,12194				0,95	6121,64
0,95	6057,27			60,06		61,11			-0,05451				1,05	6008,42
1,00	6043,94			67,34		70,33			-0,06112				1,10	5966,32
1,05	6017,46			175,08		76,18			-0,15891				1,15	5931,03
1,10	5801,42			89,04		85,52			-0,08082				1,20	6018,52
1,20	5693,21			83,50		77,27			-0,07579				1,25	5988,71
1,25	5764,89			107,69		72,39			-0,09774				1,30	6043,85
1,30	5740,80			98,31		93,25			-0,08923				1,40	5978,99
1,35	5543,84			54,18		51,42			-0,04918				1,50	5880,38
1,40	5543,84			48,54		47,51			-0,04406				1,60	5960,34
1,45	5634,82			49,37		45,84			-0,04481				1,70	5863,74
1,55	5477,52			50,67		46,79			-0,04599				1,80	5879,82
1,65	5600,35			72,67		48,60			-0,06596				1,90	5915,91
1,75	5658,03			96,98		48,77			-0,08802				2,00	6155,76
1,85	5764,89			108,79		58,77			-0,09874				2,10	5882,66
1,95	6138,48			128,63		71,24			-0,11675				2,20	5944,91
2,05	6097,60			193,06		75,76			-0,17523				2,30	6072,36
2,15	5658,03			445,92		46,94			-0,40473				2,40	6213,88
2,25	6250,21			509,79		64,09			-0,4627				2,50	6170,58
2,35	6250,21			364,11		73,52			-0,33048				2,60	6255,82
2,45	6207,84			201,84		80,87			-0,1832				2,70	6211,97
2,55	6084,10			122,96		72,18			-0,1116				2,80	6337,07
2,65	6138,48			76,62		62,35			-0,06954					
2,75	5777,02			49,07		65,96			-0,04454					
2,85	5669,71			66,12		58,65			-0,06001					
2,95	5634,82			62,32		63,24			-0,05656					
channel-2 data														
0,10	5701,49			12,70		57,85			-0,00778					
0,15	5709,13			21,34		70,06			-0,01307					
0,20	5850,14			51,09		46,19			-0,03129					
0,25	5923,29			63,53		49,65			-0,03891					
0,30	5890,56			54,26		58,86			-0,03323					
0,35	5810,28			62,94		51,25			-0,03855					
0,40	5931,53			50,89		50,18			-0,03117					
0,45	5923,29			38,71		49,65			-0,02371					
0,50	5778,77			43,37		54,46			-0,02656					
0,55	5786,62			27,38		33,17			-0,01677					
0,60	5858,18			37,29		37,54			-0,02284					
0,65	5874,32			87,45		35,44			-0,05356					
0,70	5850,14			35,95		51,94			-0,02202					
0,75	5842,12			94,39		46,59			-0,05781					
0,80	5948,08			66,47		36,90			-0,04071					
0,85	5964,73			96,81		46,56			-0,05929					
0,90	6015,22			44,71		68,47			-0,02738					
0,95	5989,87			189,48		65,61			-0,11605					
1,00	5973,09			264,30		69,13			-0,16187					
1,05	5973,09			164,60		73,18			-0,10081					
1,15	5842,12			132,78		76,55			-0,08132					
1,20	5850,14			149,19		69,20			-0,09137					
1,25	5755,37			122,80		61,73			-0,07521					
1,30	5709,13			55,33		43,34			-0,03389					
1,35	5834,13			53,44		40,20			-0,03273					

contd. borehole: KQ0047B02

channel-3 data														
0,15	5702,21	3133,27	1,82	7,59	58,75	56,93	62,24	0,284	-0,00253	1,08187	68,8	26,8		
0,20	5789,56	3266,22	1,77	27,52	30,73	61,24	47,93	0,267	-0,00917	0,56593	73,8	29,1		
0,25	5860,03	3241,95	1,81	31,21	43,42	35,68	57,43	0,279	-0,0104	0,7995	73,5	28,7		
0,30	5830,75	3225,96	1,81	72,65	115,04	42,03	61,47	0,279	-0,02421	2,11829	72,7	28,4		
0,35	5990,39	3341,28	1,79	63,95	77,93	44,49	59,95	0,274	-0,02131	1,43499	77,7	30,5		
0,40	5860,03	3358,43	1,74	27,88	40,67	64,01	58,73	0,255	-0,00929	0,74881	77,3	30,8		
0,45	5931,23	3324,31	1,78	31,78	40,41	46,12	56,17	0,271	-0,01059	0,74401	76,7	30,2		
0,50	5815,09	3307,50	1,76	28,33	65,81	50,92	55,17	0,261	-0,00944	1,21176	75,3	29,9		
0,55	5939,70	3282,61	1,81	52,12	54,99	40,37	59,49	0,280	-0,01737	1,01253	75,3	29,4		
0,60	5969,96	3375,76	1,77	71,15	74,79	35,98	50,58	0,265	-0,02371	1,37719	78,7	31,1		
0,65	5939,70	3315,88	1,79	47,74	85,56	56,92	52,00	0,274	-0,01591	1,57549	76,5	30,0		
0,70	5864,30	3282,61	1,79	97,82	35,39	39,41	60,94	0,272	-0,0326	0,6516	74,9	29,4		
0,75	5969,96	3540,14	1,69	52,33	4,60	37,05	78,39	0,229	-0,01744	0,08466	84,1	34,2		
0,80	5969,96	not	not	82,46	not	45,88	not	not	-0,02748	not	not	not		
0,85	6008,37	3268,51	1,84	56,41	6,31	37,48	70,14	0,290	-0,0188	0,1162	75,3	29,2		
0,90	5959,80	not	not	38,62	not	41,24	not	not	-0,01287	not	not	not		
0,95	6052,54	3353,07	1,81	26,59	18,39	85,21	63,42	0,279	-0,00886	0,33864	78,5	30,7		
1,00	6010,97	3487,09	1,72	223,31	279,86	78,34	67,17	0,246	-0,07442	5,15308	82,8	33,2		
1,05	5980,16	3450,32	1,73	346,88	326,53	72,80	67,88	0,251	-0,1156	6,0124	81,3	32,5		
1,10	5899,54	3405,42	1,73	176,05	213,75	76,96	69,43	0,250	-0,05867	3,93583	79,2	31,7		
1,15	5897,58	3335,97	1,77	111,09	144,76	88,29	77,57	0,265	-0,03702	2,66548	76,9	30,4		
1,20	5864,30	3396,58	1,73	140,13	163,27	79,54	58,72	0,248	-0,0467	3,0063	78,6	31,5		
1,25	5850,24	3302,30	1,77	64,49	78,01	46,13	59,76	0,266	-0,02149	1,43651	75,4	29,8		
1,30	5830,75	3285,71	1,77	53,23	71,91	45,06	59,56	0,267	-0,01774	1,32406	74,7	29,5		
1,35	5899,54	3269,30	1,80	61,45	75,94	44,26	61,81	0,278	-0,02048	1,39832	74,6	29,2		
1,45	5801,76	3335,97	1,74	46,57	53,60	52,18	54,87	0,253	-0,01552	0,98688	76,2	30,4		
1,55	5782,59	3327,49	1,74	68,87	84,09	48,83	57,08	0,252	-0,02295	1,54845	75,7	30,2		
1,65	5856,04	3335,97	1,76	96,38	105,06	36,92	54,08	0,260	-0,03212	1,93448	76,6	30,4		
1,75	5823,23	3261,15	1,79	90,26	75,04	50,18	61,96	0,272	-0,03008	1,38172	73,9	29,0		
1,85	5956,72	3269,30	1,82	90,47	78,57	45,98	62,84	0,284	-0,03015	1,44665	75,0	29,2		
1,95	5973,84	3310,65	1,80	51,79	72,65	48,25	58,23	0,278	-0,01726	1,33774	76,5	29,9		
2,05	5980,16	3244,98	1,84	202,37	132,08	55,14	76,95	0,291	-0,06744	2,43196	74,3	28,8		
2,15	5999,70	not	not	302,17	not	59,56	not	not	-0,1007	not	not	not		
2,25	6043,31	3302,30	1,83	232,17	113,87	54,85	73,16	0,287	-0,07737	2,09663	76,7	29,8		
2,35	6115,99	3524,66	1,74	337,82	329,81	61,76	55,63	0,251	-0,11258	6,07292	84,9	33,9		
2,45	6169,88	3423,24	1,80	161,35	177,93	54,62	67,20	0,278	-0,05377	3,27623	81,8	32,0		
2,55	6159,03	3423,24	1,80	92,57	108,30	64,25	68,42	0,276	-0,03085	1,99415	81,7	32,0		
2,65	6087,55	3379,04	1,80	37,09	61,75	51,88	60,41	0,277	-0,01236	1,13704	79,7	31,2		
2,75	6017,07	3423,24	1,76	105,21	115,93	50,59	58,32	0,261	-0,03506	2,13474	80,7	32,0		
2,85	6084,10	3370,34	1,81	92,12	84,51	43,93	60,07	0,279	-0,0307	1,5561	79,3	31,0		

Borehole: KQ0047G01

Äspö HRL, BGR ultrasonic interval velocity measurem., TASQ tunnel, -450m, week 48/2006, borehole: KQ0047G01, sensor orientation: ESE, (bulk density: 2.731g/cı

(distance) CMP_Pos [m]	Vp if qual >=1 [m/s]	Vs if qual >=1 [m/s]	Vp/Vs if QC >= 1	normAmp_P if QC >= 1 and Amp > 0	normAmp_S if QC >= 1 and Amp > 0	appFreq_P if QC >= 1 [kHz]	appFreq_S if QC >= 1 [kHz]	Poisson's ratio if QC = 1	temp only for normAmp_P Am>0+QC>=·	temp only for normAmp_S Am<0+QC>=1	E_dyn [GPa] if QC>=AW2	G_dyn [GPa] if QC>=AX2	CMP' for plot [m]	Vp_average (tP01+tP02+tP03)/3 if(QC>=BP2)
channel-1 data														
0,05	4132,95			370,33		22,72			-0,15821				0,10	5436,56
0,10	5626,44			99,32		42,91			-0,04243				0,15	5708,25
0,15	5346,79			30,48		33,80			-0,01302				0,20	5957,90
0,20	5149,03			7,02		66,16			-0,003				0,25	not
0,25	5547,31			59,62		37,62			-0,02547				0,30	5714,58
0,30	5296,56			15,17		77,64			-0,00648				0,35	not
0,35	5346,79			28,93		61,02			-0,01236				0,40	4411,49
0,40	4975,82			1,12		120,59			-0,00048				0,45	5743,27
0,45	5205,66			264,48		41,74			-0,11299				0,50	not
0,50	5275,28			105,22		31,28			-0,04495				0,55	5678,65
0,55	5680,45			327,24		33,35			-0,1398				0,60	5937,17
0,60	5721,65			120,27		55,28			-0,05138				0,65	6132,73
0,65	5666,85			12,97		142,57			-0,00554				0,70	6080,05
0,70	5735,52			80,29		65,36			-0,0343				0,75	6190,07
0,75	5800,80			59,50		81,67			-0,02542				0,80	6107,86
0,80	5840,51			66,20		100,88			-0,02828				0,85	6311,25
0,85	5921,60			183,26		77,82			-0,07829				0,90	6305,10
0,90	5749,45			87,12		83,14			-0,03722				0,95	6313,69
0,95	5777,52			136,72		80,87			-0,05841				1,00	6185,66
1,00	5763,45			125,49		79,38			-0,05361				1,05	6043,54
1,05	5834,50			90,28		79,10			-0,03857				1,10	6182,77
1,10	5722,97			162,17		77,48			-0,06928				1,15	6119,38
1,15	5653,32			53,58		92,21			-0,02289				1,20	6027,17
1,20	5791,66			82,49		79,78			-0,03524				1,25	5977,41
1,25	5680,45			46,44		73,62			-0,01984				1,30	6132,71
1,30	5721,65			142,20		70,97			-0,06075				1,40	6206,88
1,35	5763,45			195,43		74,64			-0,08349				1,50	6010,16
1,40	5777,52			119,33		80,87			-0,05098				1,60	5978,52
1,45	5707,85			not		98,19			not				1,70	6563,04
1,55	5749,45			66,66		92,35			-0,02848				1,80	6155,54
1,65	6105,43			94,59		69,04			-0,04041				1,90	6212,73
1,75	6169,09			131,64		64,27			-0,05624				2,00	6425,62
1,85	5508,57			13,41		68,02			-0,00573				2,10	6203,92
1,95	6185,21			84,22		85,25			-0,03598				2,20	5853,33
2,05	5936,95			27,97		106,10			-0,01195				2,30	5943,41
2,15	5639,84			23,99		141,32			-0,01025				2,40	6006,68
2,25	5694,12			34,71		84,49			-0,01483				2,50	6118,14
2,35	6027,68			119,33		80,39			-0,05098				2,60	6121,13
2,45	6201,42			120,43		78,75			-0,05145				2,70	6297,88
2,55	6153,05			73,08		84,81			-0,03122				2,80	6487,24
2,65	6121,22			139,32		81,61			-0,05952					
2,75	6153,05			101,35		82,02			-0,0433					
2,85	6074,09			96,60		85,13			-0,04127					
2,95	5763,45			91,48		119,65			-0,03908					
channel-2 data														
0,10	5301,29			121,26		16,81			-0,0278					
0,15	5003,16			14,39		29,32			-0,0033					
0,20	5601,71			21,98		41,01			-0,00504					
0,25	5673,16			28,70		47,65			-0,00658					
0,30	5538,94			10,73		73,70			-0,00246					
0,35	6244,50			4,84		40,73			-0,00111					
0,40	5509,71			16,71		52,08			-0,00383					
0,45	4957,10			22,99		28,44			-0,00527					
0,50	5700,35			79,65		25,22			-0,01826					
0,55	5729,72			123,31		25,27			-0,02827					
0,60	5744,52			not		24,79			not					
0,65	5774,34			163,92		41,92			-0,03758					
0,70	6040,97			185,99		56,91			-0,04264					
0,75	5992,14			60,94		67,15			-0,01397					
0,80	6061,68			103,46		60,89			-0,02372					
0,85	6069,95			185,12		57,46			-0,04244					
0,90	6037,00			139,89		48,35			-0,03207					
0,95	5988,24			107,13		59,51			-0,02456					
1,00	5893,04			115,37		51,42			-0,02645					
1,05	5948,20			111,32		53,46			-0,02552					
1,10	5908,69			124,01		51,53			-0,02843					
1,15	5861,97			159,16		59,78			-0,03649					
1,20	5854,26			89,90		57,65			-0,02061					
1,25	5800,82			108,13		69,02			-0,02479					

contd. borehole: KQ0047G01

channel-3 data														
0,15	5469,06	not	not	2,05	not	37,83	not	not	-0,00024	not	not	not		
0,20	5552,83	not	not	11,42	not	68,06	not	not	-0,00134	not	not	not		
0,25	5736,04	not	not	29,16	not	54,36	not	not	-0,00342	not	not	not		
0,30	not	not	not	not	not	not	not	not	not	not	not	not		
0,35	5532,89	not	not	7,42	not	73,99	not	not	-0,00087	not	not	not		
0,40	not	not	not	not	not	not	not	not	not	not	not	not		
0,45	4598,16	3071,10	1,50	28,13	3,54	40,61	48,67	0,097	-0,0033	0,02862	56,5	25,8		
0,50	5736,04	3308,26	1,73	30,18	19,38	29,74	40,95	0,251	-0,00354	0,15654	74,8	29,9		
0,55	not	3157,65	not	not	17,62	not	51,41	not	not	0,14232	not	not		
0,60	5696,07	3199,26	1,78	71,10	64,79	29,65	53,48	0,270	-0,00834	0,52328	71,0	28,0		
0,65	5881,59	3308,26	1,78	10,40	45,61	113,98	48,66	0,269	-0,00122	0,36836	75,8	29,9		
0,70	6032,10	3369,48	1,79	47,57	41,30	58,60	50,47	0,273	-0,00558	0,33356	79,0	31,0		
0,75	6025,13	3263,78	1,85	49,87	60,78	92,30	61,58	0,292	-0,00585	0,49085	75,2	29,1		
0,80	6032,10	3346,26	1,80	78,01	69,71	61,48	61,25	0,278	-0,00915	0,56305	78,1	30,6		
0,85	5990,52	3346,26	1,79	143,66	140,82	51,86	58,39	0,273	-0,01685	1,13735	77,9	30,6		
0,90	6117,01	3408,91	1,79	111,69	97,75	46,67	55,18	0,275	-0,0131	0,7895	80,9	31,7		
0,95	6131,40	3385,14	1,81	117,65	88,28	42,58	54,45	0,281	-0,0138	0,713	80,2	31,3		
1,00	6102,69	3338,59	1,83	108,27	83,30	46,80	60,79	0,286	-0,0127	0,6728	78,3	30,4		
1,05	5997,41	3338,59	1,80	146,64	166,74	44,82	54,59	0,275	-0,0172	1,3467	77,7	30,4		
1,10	5956,31	3323,35	1,79	86,96	60,67	66,97	60,35	0,274	-0,0102	0,49	76,9	30,2		
1,15	6004,32	3346,26	1,79	98,04	56,48	56,36	57,94	0,275	-0,0115	0,4562	78,0	30,6		
1,20	5976,79	3323,35	1,80	229,34	176,28	58,06	59,40	0,276	-0,0269	1,4237	77,0	30,2		
1,25	5935,97	3308,26	1,79	230,19	183,56	68,29	63,48	0,275	-0,027	1,4825	76,2	29,9		
1,30	5909,07	3361,70	1,76	112,54	147,24	59,09	52,24	0,261	-0,0132	1,1892	77,8	30,9		
1,35	5983,65	3293,30	1,82	not	67,96	63,52	67,55	0,283	not	0,5489	76,0	29,6		
1,45	6046,09	3385,14	1,79	76,73	56,95	81,14	63,70	0,272	-0,009	0,45995	79,6	31,3		
1,55	6039,09	3400,95	1,78	61,38	70,08	82,68	65,29	0,268	-0,0072	0,566	80,1	31,6		
1,65	6039,09	3385,14	1,78	not	98,19	54,98	59,18	0,271	not	0,793	79,5	31,3		
1,75	6168,55	3465,68	1,78	80,14	38,36	52,45	57,54	0,269	-0,0094	0,30985	83,3	32,8		
1,85	6160,37	3449,27	1,79	184,15	183,67	60,95	62,91	0,272	-0,0216	1,4834	82,6	32,5		
1,95	6117,01	3482,25	1,76	59,68	107,21	87,52	62,26	0,260	-0,007	0,8659	83,5	33,1		
2,05	6138,61	3490,60	1,76	56,70	55,43	72,91	57,91	0,261	-0,00665	0,4477	83,9	33,3		
2,15	6018,18	3369,48	1,79	96,77	77,38	56,17	62,70	0,272	-0,01135	0,62495	78,9	31,0		
2,25	5909,07	3369,48	1,75	184,15	182,03	70,81	60,18	0,259	-0,0216	1,4702	78,1	31,0		
2,35	6025,13	3482,25	1,73	219,96	138,66	55,45	50,52	0,249	-0,0258	1,1199	82,7	33,1		
2,45	6053,11	3433,01	1,76	52,86	49,63	85,07	57,21	0,263	-0,0062	0,4008	81,3	32,2		
2,55	6117,01	3433,01	1,78	141,52	200,31	76,77	64,05	0,270	-0,0166	1,6178	81,8	32,2		
2,65	6131,40	3393,02	1,81	187,56	224,01	84,13	67,69	0,279	-0,022	1,8092	80,4	31,4		
2,75	6219,15	3424,94	1,82	248,09	226,26	63,10	64,08	0,282	-0,0291	1,8274	82,2	32,0		
2,85	6226,57	not	not	114,24	not	69,07	not	not	-0,0134	not				

Borehole: KQ0047H01

Aspö HRL, BGR ultrasonic interval velocity measurem., TASQ tunnel, -450m, week 48/2006, borehole: KQ0047H01, sensor orientation: ESE, (bulk density: 2.731g/c

(distance) CMP_Pos [m]	Vp if qual >=1 [m/s]	Vs if qual >=1 [m/s]	Vp/Vs if QC >= 1	normAmp_P if QC >= 1 and Amp > 0	normAmp_S if QC >= 1 and Amp > 0	appFreq_P if QC >= 1 [kHz]	appFreq_S if QC >= 1 [kHz]	Poisson's ratio if QC = 1	temp only for normAmp_P Am>0+QC>='	temp only for normAmp_S Am<0+QC>=1	E_dyn [GPa] if QC>=AW2	G_dyn [GPa] if QC>=AX2	CMP' for plot [m]	Vp_average tP01+tP02+tP03)/3 if(QC>=BP2)
channel-1 data														
0,05	5053,19			122,29		60,82			-0,12144				0,10	5543,22
0,10	5785,82			72,93		92,03			-0,07242				0,15	6034,62
0,15	5814,69			34,59		104,07			-0,03435				0,20	6101,86
0,20	5829,23			65,51		94,52			-0,06505				0,25	6146,09
0,25	5903,04			107,04		87,43			-0,10629				0,30	6053,58
0,30	5785,82			68,31		82,88			-0,06783				0,35	5936,63
0,35	5700,91			37,67		87,45			-0,03741				0,40	5833,90
0,40	5858,01			29,17		88,36			-0,02897				0,45	6122,48
0,45	5829,23			75,35		91,07			-0,07483				0,50	6088,01
0,50	6009,58			64,53		103,60			-0,06408				0,55	5960,63
0,55	5933,10			201,67		94,50			-0,20027				0,60	5954,01
0,60	5659,38			42,61		117,36			-0,04231				0,65	5847,21
0,65	5888,13			79,32		103,45			-0,07877				0,70	5998,51
0,70	5888,13			119,76		95,54			-0,11893				0,75	5998,71
0,75	5873,29			150,94		97,13			-0,14989				0,80	6017,89
0,80	5889,03			93,21		88,67			-0,09256				0,85	5944,57
0,85	5829,23			46,37		98,23			-0,04605				0,90	6075,58
0,90	5873,29			123,07		101,06			-0,12221				0,95	6125,44
0,95	5963,46			83,81		102,83			-0,08323				1,00	6057,38
1,00	5948,24			201,34		89,66			-0,19994				1,05	6132,03
1,05	5743,05			239,08		89,68			-0,23741				1,10	5989,58
1,10	5800,22			123,22		94,01			-0,12236				1,15	6096,78
1,15	5829,23			120,71		98,23			-0,11987				1,20	6016,76
1,20	5829,23			108,45		87,87			-0,10769				1,25	6004,68
1,25	5888,13			52,88		95,54			-0,05251				1,30	6077,06
1,30	5785,82			118,53		88,77			-0,1177				1,40	6080,62
1,35	5933,10			166,88		74,73			-0,16572				1,50	6082,81
1,40	5858,53			134,76		107,26			-0,13382				1,60	6026,31
1,45	5888,13			168,94		80,21			-0,16776				1,70	6153,96
1,55	5785,82			177,33		85,72			-0,17609				1,80	6083,99
1,65	5933,10			107,43		84,88			-0,10668				1,90	6002,80
1,75	6009,58			50,73		97,66			-0,05038				2,00	6033,88
1,85	5829,23			107,32		98,23			-0,10657				2,10	5981,59
1,95	5951,77			144,55		104,24			-0,14354				2,20	6129,63
2,05	5918,03			96,75		86,13			-0,09608				2,30	6122,03
2,15	5858,53			97,87		91,55			-0,09719				2,40	6092,38
2,25	5903,04			107,19		81,71			-0,10644				2,50	6169,50
2,35	5873,29			39,56		101,06			-0,03928				2,60	6034,29
2,45	5903,04			43,55		97,67			-0,04325				2,70	5999,07
2,55	5873,29			67,99		101,06			-0,06752					
2,65	5829,23			93,19		91,07			-0,09254					
2,75	5843,84			86,16		80,96			-0,08556					
2,85	5814,69			27,45		80,59			-0,02726					
channel-2 data														
0,10	5461,33			65,53		50,21			-0,04207					
0,15	5987,42			111,63		61,03			-0,07167					
0,20	5987,42			78,60		62,55			-0,05046					
0,25	6010,58			63,72		56,49			-0,04091					
0,30	5987,42			74,65		56,86			-0,04793					
0,35	5866,85			43,88		83,05			-0,02817					
0,40	5844,79			82,47		62,79			-0,05295					
0,45	5919,00			66,73		77,87			-0,04284					
0,50	5904,01			74,69		70,93			-0,04795					
0,55	5889,09			53,57		74,88			-0,03439					
0,60	5830,17			48,69		67,65			-0,03126					
0,65	5926,53			53,97		63,24			-0,03465					
0,70	5911,49			83,16		81,50			-0,05339					
0,75	5979,74			50,70		68,42			-0,03255					
0,80	5904,01			77,58		75,19			-0,04981					
0,85	6073,23			112,13		54,72			-0,07199					
0,90	5919,00			89,05		58,00			-0,05717					
0,95	5964,44			186,63		59,98			-0,11982					
1,00	5859,48			161,46		66,36			-0,10366					
1,05	5919,00			147,72		62,34			-0,09484					
1,10	5904,01			103,11		68,97			-0,0662					
1,15	5934,07			142,24		55,60			-0,09132					
1,20	5911,49			175,27		61,46			-0,11253					
1,25	5881,66			96,02		67,64			-0,06165					
1,30	5956,82			90,45		72,99			-0,05807					

contd. borehole: KQ0047H01

channel-3 data														
0,15	5636,04	3059,20	1,84	104,97	45,40	55,91	80,36	0,291	-0,03295	0,97185	66,0	25,6		
0,20	5945,99	3380,25	1,76	86,37	80,09	82,08	58,84	0,261	-0,02711	1,71449	78,7	31,2		
0,25	5959,30	3281,32	1,82	108,35	91,79	70,25	75,98	0,282	-0,03401	1,96499	75,4	29,4		
0,30	6041,70	3369,56	1,79	82,80	70,65	61,80	61,65	0,274	-0,02599	1,51241	79,0	31,0		
0,35	5974,17	3380,25	1,77	76,27	88,67	67,86	61,75	0,265	-0,02394	1,89826	78,9	31,2		
0,40	5959,90	3457,06	1,72	82,93	63,19	87,30	65,11	0,246	-0,02603	1,35277	81,4	32,6		
0,45	5866,46	3412,75	1,72	65,63	56,63	101,55	69,50	0,244	-0,0206	1,2124	79,2	31,8		
0,50	5959,90	3473,98	1,72	60,56	39,90	87,30	64,43	0,243	-0,01901	0,85419	81,9	33,0		
0,55	6012,57	3549,23	1,69	48,74	36,79	73,43	58,72	0,233	-0,0153	0,7875	84,8	34,4		
0,60	5936,26	3555,15	1,67	49,44	40,28	93,87	61,41	0,220	-0,01552	0,86228	84,2	34,5		
0,65	5926,86	3479,65	1,70	132,15	113,09	83,81	70,88	0,237	-0,04148	2,42102	81,8	33,1		
0,70	5857,28	3485,35	1,68	27,27	56,46	93,22	57,16	0,226	-0,00856	1,20864	81,3	33,2		
0,75	5940,98	3537,44	1,68	62,51	114,25	113,47	54,00	0,225	-0,01962	2,44578	83,8	34,2		
0,80	5950,42	3585,07	1,66	66,26	39,85	100,67	53,89	0,215	-0,0208	0,8532	85,3	35,1		
0,85	5998,12	3621,65	1,66	84,84	91,53	78,51	46,12	0,213	-0,02663	1,95937	86,9	35,8		
0,90	5945,70	3519,90	1,69	138,77	113,67	79,53	54,48	0,230	-0,04356	2,43344	83,3	33,8		
0,95	5959,90	3418,23	1,74	169,17	136,24	74,33	61,31	0,255	-0,0531	2,91669	80,1	31,9		
1,00	6012,57	3440,31	1,75	103,12	104,41	73,43	58,61	0,257	-0,03237	2,23523	81,2	32,3		
1,05	5978,95	3374,90	1,77	81,21	79,41	80,03	64,62	0,266	-0,02549	1,69991	78,8	31,1		
1,10	6027,10	3412,75	1,77	148,11	97,59	68,97	60,53	0,264	-0,04649	2,08911	80,4	31,8		
1,15	5955,16	3358,93	1,77	103,41	110,39	82,69	65,31	0,267	-0,03246	2,36314	78,1	30,8		
1,20	5988,52	3391,02	1,77	127,18	130,39	71,34	61,34	0,264	-0,03992	2,79148	79,4	31,4		
1,25	5988,52	3380,25	1,77	156,87	160,82	67,49	61,24	0,266	-0,04924	3,44276	79,0	31,2		
1,30	5955,16	3385,63	1,76	137,02	177,32	67,14	57,75	0,261	-0,04301	3,79599	79,0	31,3		
1,35	6012,57	3364,24	1,79	126,83	149,53	48,98	59,41	0,272	-0,03981	3,20119	78,6	30,9		
1,45	5978,95	3451,46	1,73	153,08	127,01	57,82	52,90	0,250	-0,04805	2,71895	81,3	32,5		
1,55	6031,96	3423,72	1,76	97,26	88,17	72,15	59,18	0,262	-0,03053	1,88747	80,8	32,0		
1,65	6017,41	3385,63	1,78	127,30	114,41	79,50	66,45	0,268	-0,03996	2,44924	79,4	31,3		
1,75	6041,70	3423,72	1,76	96,05	98,12	77,04	60,13	0,263	-0,03015	2,10045	80,9	32,0		
1,85	6036,82	3391,02	1,78	57,22	101,96	75,64	64,50	0,270	-0,01796	2,18284	79,7	31,4		
1,95	5974,17	3434,76	1,74	120,04	151,10	76,13	60,22	0,253	-0,03768	3,23482	80,7	32,2		
2,05	5974,17	3343,12	1,79	94,59	115,42	86,69	76,06	0,272	-0,02969	2,47091	77,7	30,5		
2,15	5955,16	3429,23	1,74	115,17	110,37	85,51	64,58	0,252	-0,03615	2,36285	80,4	32,1		
2,25	6041,70	3429,23	1,76	120,65	137,47	66,75	59,46	0,262	-0,03787	2,94293	81,1	32,1		
2,35	6046,58	3401,85	1,78	133,45	140,14	67,84	69,38	0,268	-0,04189	3,00011	80,2	31,6		
2,45	6017,41	3396,42	1,77	148,11	192,73	79,50	69,00	0,266	-0,04649	4,12602	79,8	31,5		
2,55	6051,47	3396,42	1,78	79,42	79,12	63,69	65,97	0,270	-0,02493	1,69387	80,0	31,5		
2,65	5969,41	3407,29	1,75	72,51	81,32	74,77	62,76	0,258	-0,02276	1,74084	79,8	31,7		
2,75	5936,26	3322,26	1,79	54,38	74,33	66,43	71,45	0,272	-0,01707	1,59133	76,7	30,1		

Borehole: KQ0047I01

Aspö HRL, BGR ultrasonic interval velocity measurem., TASQ tunnel, -450m, week 48/2006, borehole: KQ0047I01, sensor orientation: ESE, (bulk density: 2.731g/c

(distance) CMP_Pos [m]	Vp if qual >=1 [m/s]	Vs if qual >=1 [m/s]	Vp/Vs if QC >= 1	normAmp_P if QC >= 1 and Amp > 0	normAmp_S if QC >= 1 and Amp > 0	appFreq_P if QC >= 1 [kHz]	appFreq_S if QC >= 1 [kHz]	Poisson's ratio if QC = 1	temp only for normAmp_P Am>0+QC>=	temp only for normAmp_S Am<0+QC>=1	E_dyn [GPa] if QC>=AW2	G_dyn [GPa] if QC>=AX2	CMP' for plot [m]	Vp_average tP01+tP02+tP03)/3 if(QC>=BP2)
channel-A51 data														
0,05	5025,81			76,16		60,94			-0,05769				0,10	5538,75
0,10	5570,31			34,43		46,75			-0,02608				0,15	5944,93
0,15	5806,20			46,12		71,90			-0,03493				0,20	5972,22
0,20	5903,42			196,16		97,63			-0,14858				0,25	6033,37
0,25	5819,89			87,47		107,87			-0,06625				0,30	6023,08
0,30	5822,94			120,96		95,18			-0,09162				0,35	5971,17
0,35	5949,27			241,38		78,34			-0,18283				0,40	5980,09
0,40	5992,61			225,98		77,81			-0,17117				0,45	5972,15
0,45	5992,61			196,62		88,88			-0,14893				0,50	6077,85
0,50	5992,61			71,68		88,88			-0,05429				0,55	6010,78
0,55	6036,59			106,60		91,43			-0,08074				0,60	6005,92
0,60	5992,61			87,19		112,98			-0,06604				0,65	6113,60
0,65	5906,56			210,43		93,64			-0,15939				0,70	6070,93
0,70	6036,59			63,85		102,70			-0,04836				0,75	6077,17
0,75	6126,50			192,29		83,96			-0,14565				0,80	6017,84
0,80	5878,42			98,65		86,55			-0,07472				0,85	6114,89
0,85	5715,06			26,93		69,40			-0,0204				0,90	6074,55
0,90	5906,56			59,34		84,18			-0,04495				0,95	6174,70
0,95	5992,61			63,67		92,16			-0,04823				1,00	6078,66
1,00	6051,39			116,13		69,93			-0,08796				1,05	6087,13
1,05	6157,07			104,17		87,46			-0,0789				1,10	6066,36
1,10	6051,39			140,91		105,27			-0,10673				1,15	6057,94
1,15	6081,21			165,06		84,58			-0,12502				1,20	5947,82
1,20	6126,50			106,58		78,68			-0,08073				1,25	6052,75
1,25	6157,07			108,60		74,44			-0,08226				1,30	6074,34
1,30	6157,07			108,60		74,44			-0,08226				1,40	6125,09
1,35	6126,50			128,08		71,89			-0,09701				1,50	6270,69
1,40	6096,23			170,16		92,72			-0,12889				1,60	6118,91
1,45	6141,75			150,57		95,49			-0,11405				1,70	6119,86
1,55	6021,86			169,48		92,80			-0,12837				1,80	6108,44
1,65	6157,07			44,15		84,50			-0,03344				1,90	6039,78
1,75	6141,75			78,50		99,29			-0,05946				2,00	5994,27
1,85	6187,94			24,03		85,05			-0,0182				2,10	5959,26
1,95	6219,13			41,13		80,11			-0,03115				2,20	6000,62
2,05	6081,21			109,45		76,78			-0,0829				2,30	6031,69
2,15	5992,61			20,54		99,49			-0,01556				2,40	6090,36
2,25	6187,94			49,01		72,68			-0,03712				2,50	6089,96
2,35	6141,75			58,68		71,06			-0,04445				2,60	6270,95
2,45	6096,23			39,37		119,25			-0,02982				2,70	6234,29
2,55	6157,07			66,30		79,15			-0,05022					
2,65	6234,84			21,97		105,88			-0,01664					
2,75	6172,47			49,32		108,74			-0,03736					
2,85	6172,47			23,32		71,45			-0,01766					
channel-2 data														
0,10	5248,42			78,50		61,08			-0,04158					
0,15	5895,15			112,51		53,49			-0,05959					
0,20	5881,85			133,73		54,38			-0,07083					
0,25	5955,74			161,14		59,26			-0,08535					
0,30	5962,55			106,81		66,54			-0,05657					
0,35	5969,38			176,11		64,17			-0,09328					
0,40	5908,50			174,28		74,62			-0,09231					
0,45	6003,74			79,47		69,69			-0,04209					
0,50	5875,22			80,75		81,73			-0,04277					
0,55	5928,66			121,66		78,98			-0,06444					
0,60	6031,52			166,73		63,44			-0,08831					
0,65	5895,15			143,19		68,05			-0,07584					
0,70	5935,40			93,32		73,45			-0,04943					
0,75	6017,60			109,35		61,51			-0,05792					
0,80	5908,50			35,40		61,72			-0,01875					
0,85	6003,74			69,82		61,16			-0,03698					
0,90	6024,55			105,88		59,49			-0,05608					
0,95	6073,67			74,82		64,58			-0,03963					
1,00	6003,74			47,84		78,43			-0,02534					
1,05	6038,50			129,73		69,85			-0,06871					
1,10	6066,60			155,55		70,77			-0,08239					
1,15	6024,55			139,26		69,40			-0,07376					
1,20	5948,95			174,30		81,15			-0,09232					
1,25	5955,74			174,30		80,15			-0,09232					
1,30	5983,07			155,25		68,08			-0,08223					

contd. borehole: KQ0047I01

channel-3 data														
0,15	5616,35	3161,22	1,78	137,06	70,23	51,18	57,71	0,268	-0,03641	1,37059	69,2	27,3		
0,20	5902,08	3297,27	1,79	128,10	94,80	64,59	65,72	0,273	-0,03403	1,85027	75,6	29,7		
0,25	5964,55	3484,75	1,71	121,89	94,35	53,16	50,31	0,241	-0,03238	1,84142	82,3	33,2		
0,30	6019,16	3494,69	1,72	118,65	110,65	76,71	51,90	0,246	-0,03152	2,15948	83,1	33,4		
0,35	6009,99	3369,79	1,78	187,81	156,33	73,90	69,63	0,271	-0,04989	3,05111	78,8	31,0		
0,40	5978,16	3379,08	1,77	118,69	114,09	67,25	66,87	0,265	-0,03153	2,22667	78,9	31,2		
0,45	5993,69	3524,83	1,70	169,29	109,24	68,54	51,42	0,236	-0,04497	2,13203	83,9	33,9		
0,50	5978,11	3484,75	1,72	118,62	80,72	85,71	54,32	0,243	-0,03151	1,57549	82,4	33,2		
0,55	6019,16	3607,83	1,67	159,42	144,06	84,48	44,27	0,220	-0,04235	2,81165	86,7	35,5		
0,60	6014,57	3565,85	1,69	118,84	136,11	82,75	47,57	0,229	-0,03157	2,65643	85,4	34,7		
0,65	6040,76	3672,69	1,64	153,51	148,11	74,91	42,35	0,207	-0,04078	2,89072	88,9	36,8		
0,70	6032,97	3629,20	1,66	142,86	143,24	68,06	47,37	0,216	-0,03795	2,79555	87,5	36,0		
0,75	5947,34	3494,69	1,70	21,49	61,63	94,08	60,72	0,236	-0,00571	1,20279	82,5	33,4		
0,80	6019,16	3672,69	1,64	68,89	88,93	81,72	47,73	0,203	-0,0183	1,7357	88,7	36,8		
0,85	6009,30	3597,24	1,67	121,85	140,14	90,01	57,25	0,221	-0,03237	2,73503	86,3	35,3		
0,90	6093,55	3555,51	1,71	84,13	100,89	84,24	65,67	0,242	-0,02235	1,96905	85,8	34,5		
0,95	6098,26	3661,72	1,67	119,60	100,77	77,99	54,47	0,218	-0,03177	1,96663	89,2	36,6		
1,00	6131,44	3694,83	1,66	95,54	111,76	59,93	50,67	0,215	-0,02538	2,18122	90,6	37,3		
1,05	6079,46	3607,83	1,69	61,10	122,20	97,90	60,76	0,228	-0,01623	2,38497	87,3	35,5		
1,10	6098,26	3639,97	1,68	133,15	150,17	71,31	57,35	0,223	-0,03537	2,93083	88,5	36,2		
1,15	6088,85	3629,20	1,68	151,86	153,72	82,52	57,99	0,224	-0,04034	3,00016	88,1	36,0		
1,20	6084,15	3661,72	1,66	151,86	153,72	83,57	54,87	0,216	-0,04034	3,00016	89,1	36,6		
1,25	6005,41	3565,85	1,68	178,66	233,16	94,52	65,41	0,228	-0,04746	4,55054	85,3	34,7		
1,30	6065,44	3639,97	1,67	67,80	71,32	88,05	59,15	0,219	-0,01801	1,39199	88,2	36,2		
1,35	6093,55	3607,83	1,69	105,03	103,01	72,10	61,25	0,230	-0,0279	2,0105	87,5	35,5		
1,45	6088,58	3661,72	1,66	122,53	143,13	68,92	54,08	0,217	-0,03255	2,79345	89,1	36,6		
1,55	6219,87	3545,22	1,75	40,54	21,39	70,08	69,60	0,259	-0,01077	0,41748	86,5	34,3		
1,65	6117,17	3618,48	1,69	31,85	27,74	79,17	56,02	0,231	-0,00846	0,54139	88,0	35,8		
1,75	6137,16	3555,51	1,73	79,01	60,87	75,36	71,28	0,247	-0,02099	1,18801	86,1	34,5		
1,85	6137,16	3597,24	1,71	58,84	73,36	69,11	54,35	0,238	-0,01563	1,43167	87,5	35,3		
1,95	6051,48	3629,20	1,67	81,99	109,20	91,73	55,83	0,219	-0,02178	2,13122	87,7	36,0		
2,05	5993,69	3576,25	1,68	56,69	56,15	111,24	69,38	0,224	-0,01506	1,09584	85,5	34,9		
2,15	6032,97	3535,00	1,71	83,68	92,92	90,15	59,38	0,239	-0,02223	1,81357	84,5	34,1		
2,25	6046,84	3576,25	1,69	76,15	85,96	86,59	56,78	0,231	-0,02023	1,67777	86,0	34,9		
2,35	6051,48	3607,83	1,68	73,26	67,96	85,46	51,22	0,224	-0,01946	1,32634	87,0	35,5		
2,45	6112,43	3514,73	1,74	45,21	30,33	80,14	69,82	0,253	-0,01201	0,59199	84,5	33,7		
2,55	6137,16	3426,31	1,79	40,20	56,22	107,88	64,44	0,274	-0,01068	1,09732	81,7	32,1		
2,65	6236,68	3484,75	1,79	47,02	34,68	92,68	81,45	0,273	-0,01249	0,67681	84,4	33,2		
2,75	6213,54	3426,31	1,81	27,33	46,74	59,27	59,81	0,282	-0,00726	0,91224	82,2	32,1		

Borehole: KQ0047G01, depth: 1.0 m

Äspö HRL, BGR ultrasonic rotational interval vel. meas., TASQ tunnel, -450m, week 48/2006, borehole: KQ0047G01, depth: 1.0m, (bulk density: 2.731g/cm3)

rotational angle [deg]	Vp if qual >=1 [m/s]	Vs if qual >=1 [m/s]	Vp/Vs if QC >= 1	normAmp_P if QC >= 1 and Amp > 0	normAmp_S if QC >= 1 and Amp > 0	appFreq_P if QC >= 1 [kHz]	appFreq_S if QC >= 1 [kHz]	Poisson's ratio if QC = 1	temp only for normAmp_P Am>0+QC>=	temp only for normAmp_S Am<0+QC>=1	E_dyn [GPa] if QC>=AW2	G_dyn [GPa] if QC>=AX2
channel-1 data												
0,00	5732,59			203,06		64,84			-0,09058			
30,00	5703,74			84,90		53,56			-0,03787			
60,00	5732,59			83,89		63,20			-0,03742			
90,00	5732,59			137,71		54,87			-0,06143			
120,00	5791,18			149,84		72,84			-0,06684			
150,00	5718,13			100,39		63,91			-0,04478			
180,00	5675,18			134,67		38,00			-0,06007			
210,00	5632,87			81,83		42,04			-0,0365			
240,00	5618,91			32,33		62,45			-0,01442			
270,00	5509,64			23,85		63,29			-0,01064			
300,00	5563,74			48,54		68,94			-0,02165			
330,00	5689,42			130,27		54,07			-0,05811			
360,00	5689,42			88,73		40,83			-0,03958			
channel-2 data												
0,00	6075,77			155,90		37,98			-0,05781			
30,00	5973,30			83,46		46,15			-0,03095			
60,00	6067,09			80,47		46,00			-0,02984			
90,00	6075,77			83,71		50,18			-0,03104			
120,00	6075,77			52,45		67,89			-0,01945			
150,00	5964,91			80,85		41,18			-0,02998			
180,00	6049,82			131,33		35,01			-0,0487			
210,00	5915,10			125,56		36,29			-0,04656			
240,00	6015,57			64,56		45,02			-0,02394			
270,00	6128,33			45,20		44,93			-0,01676			
300,00	5964,91			84,81		47,43			-0,03145			
330,00	6024,10			170,76		40,32			-0,06332			
360,00	6024,10			140,93		40,32			-0,05226			
channel-3 data												
0,00	5956,22	3268,89	1,82	133,23	123,71	45,19	42,28	0,284	-0,03136	1,90024	66,2	25,8
30,00	5968,17	3286,17	1,82	126,30	103,86	38,27	39,66	0,282	-0,02973	1,59527	66,8	26,0
60,00	6055,09	3379,05	1,79	76,34	87,70	50,46	41,26	0,274	-0,01797	1,34703	70,1	27,5
90,00	6088,34	3465,70	1,76	49,45	83,07	54,56	40,86	0,260	-0,01164	1,27596	73,0	28,9
120,00	6115,57	3442,67	1,78	45,03	42,24	54,25	39,81	0,268	-0,0106	0,6488	72,4	28,6
150,00	6011,32	3375,38	1,78	65,81	76,23	51,08	37,25	0,270	-0,01549	1,17091	69,7	27,5
180,00	5911,29	3245,00	1,82	101,45	125,54	42,74	39,84	0,284	-0,02388	1,92832	65,2	25,4
210,00	5949,76	3314,20	1,80	119,42	91,63	38,59	37,65	0,275	-0,02811	1,40749	67,5	26,5
240,00	6122,39	3502,04	1,75	49,75	60,01	40,99	33,03	0,257	-0,01171	0,92179	74,3	29,6
270,00	6088,42	3438,86	1,77	51,92	44,21	42,91	37,99	0,266	-0,01222	0,67908	72,1	28,5
300,00	6074,94	3393,81	1,79	119,68	120,71	37,22	36,22	0,273	-0,02817	1,85403	70,7	27,8
330,00	6011,32	3324,83	1,81	197,89	185,47	40,36	39,46	0,280	-0,04658	2,84882	68,2	26,6
360,00	5995,27	3286,17	1,82	163,73	155,62	40,58	39,34	0,285	-0,03854	2,39026	66,9	26,0

Borehole: KQ0047G01, depth: 1.8 m

Äspö HRL, BGR ultrasonic rotational interval vel. meas., TASQ tunnel, -450m, week 48/2006, borehole: KQ0047G01, depth: 1.8m, (bulk density: 2.731g/cm3)

rotational angle [deg]	Vp if qual >=1 [m/s]	Vs if qual >=1 [m/s]	Vp/Vs if QC >= 1	normAmp_P if QC >= 1 and Amp > 0	normAmp_S if QC >= 1 and Amp > 0	appFreq_P if QC >= 1 [kHz]	appFreq_S if QC >= 1 [kHz]	Poisson's ratio if QC = 1	temp only for normAmp_P Am>0+QC>=	temp only for normAmp_S Am<0+QC>=1	E_dyn [GPa] if QC>=AW2	G_dyn [GPa] if QC>=AX2
channel-1 data												
0,00	6113,93			126,77		74,76			-0,07715			
30,00	6185,94			32,19		77,30			-0,01959			
60,00	6241,08			76,00		74,03			-0,04625			
90,00	6297,20			128,60		77,64			-0,07826			
120,00	6204,21			202,03		64,40			-0,12295			
150,00	6259,67			99,22		67,12			-0,06038			
180,00	6204,21			29,00		62,78			-0,01765			
210,00	6113,93			34,15		61,82			-0,02078			
240,00	6154,96			36,84		81,89			-0,02242			
270,00	6113,93			53,93		68,61			-0,03282			
300,00	6204,21			35,10		58,39			-0,02136			
330,00	6167,78			245,15		67,81			-0,14919			
360,00	6131,77			201,04		73,71			-0,12235			
channel-2 data												
0,00	6085,27			136,91		65,21			-0,07398			
30,00	6189,28			60,72		61,18			-0,03281			
60,00	6105,79			86,05		61,82			-0,0465			
90,00	6175,21			81,57		55,40			-0,04408			
120,00	6154,22			114,07		59,50			-0,06164			
150,00	6175,21			131,04		56,66			-0,07081			
180,00	6154,22			55,15		56,79			-0,0298			
210,00	6105,79			46,47		50,56			-0,02511			
240,00	6119,55			55,46		65,48			-0,02997			
270,00	6051,38			101,80		53,77			-0,05501			
300,00	5978,12			43,60		66,76			-0,02356			
330,00	6051,38			160,41		57,48			-0,08668			
360,00	6071,67			226,75		57,34			-0,12253			
channel-3 data												
0,00	6012,51	3420,06	1,76	55,12	89,21	59,47	39,74	0,261	-0,01265	1,68395	71,1	28,2
30,00	6162,00	3511,36	1,75	41,53	54,32	60,76	39,80	0,260	-0,00953	1,02537	74,9	29,7
60,00	6174,79	3511,36	1,76	108,10	112,43	56,62	42,51	0,261	-0,02481	2,12239	74,9	29,7
90,00	6226,50	3612,39	1,72	60,96	59,61	73,12	38,31	0,246	-0,01399	1,12521	78,4	31,4
120,00	6194,08	3645,76	1,70	95,51	93,40	60,00	33,08	0,235	-0,02192	1,76308	79,1	32,0
150,00	6174,79	3498,02	1,77	136,38	127,38	55,37	37,77	0,264	-0,0313	2,4045	74,5	29,5
180,00	6219,99	3437,09	1,81	79,00	55,48	52,43	38,41	0,280	-0,01813	1,04727	72,9	28,5
210,00	6136,57	3484,78	1,76	63,27	52,51	42,28	32,23	0,262	-0,01452	0,99128	73,9	29,3
240,00	6142,91	3449,96	1,78	103,83	87,07	50,37	41,18	0,270	-0,02383	1,64357	72,8	28,7
270,00	6117,63	3480,39	1,76	102,57	91,27	58,67	35,71	0,261	-0,02354	1,72286	73,6	29,2
300,00	6043,05	3415,83	1,77	81,09	78,82	58,74	36,04	0,265	-0,01861	1,48779	71,2	28,1
330,00	6018,59	3386,52	1,78	174,55	200,53	72,37	39,64	0,268	-0,04006	3,78544	70,1	27,6
360,00	6098,82	3424,30	1,78	198,08	197,97	60,83	38,19	0,270	-0,04546	3,73704	71,8	28,3

Borehole: KQ0047G01, depth: 2.8 m

Äspö HRL, BGR ultrasonic rotational interval vel. meas., TASQ tunnel, -450m, week 48/2006, borehole: KQ0047G01, depth: 2.8m, (bulk density: 2.731g/cm3)

rotational angle [deg]	Vp if qual >=1 [m/s]	Vs if qual >=1 [m/s]	Vp/Vs if QC >= 1	normAmp_P if QC >= 1 and Amp > 0	normAmp_S if QC >= 1 and Amp > 0	appFreq_P if QC >= 1 [kHz]	appFreq_S if QC >= 1 [kHz]	Poisson's ratio if QC = 1	temp only for normAmp_P Am>0+QC>=	temp only for normAmp_S Am<0+QC>=1	E_dyn [GPa] if QC>=AW2	G_dyn [GPa] if QC>=AX2
channel-1 data												
0,00	6160,45			87,38		78,93			-0,05853			
30,00	6160,45			75,13		87,19			-0,05033			
60,00	6033,28			25,15		85,46			-0,01685			
90,00	6131,73			174,68		78,34			-0,11701			
120,00	6233,45			190,25		70,27			-0,12744			
150,00	6174,92			156,64		77,99			-0,10493			
180,00	6131,73			57,79		64,24			-0,03871			
210,00	6174,92			88,42		69,34			-0,05923			
240,00	6168,36			70,40		78,41			-0,04716			
270,00	6174,92			77,20		77,99			-0,05171			
300,00	6160,45			65,76		70,08			-0,04405			
330,00	6117,47			42,93		70,36			-0,02876			
360,00	6131,73			188,26		73,72			-0,12611			
channel-2 data												
0,00	6153,52			154,09		54,37			-0,07908			
30,00	6105,23			115,63		66,82			-0,05934			
60,00	6067,14			36,50		85,16			-0,01873			
90,00	6057,69			34,67		93,14			-0,01779			
120,00	6173,05			64,97		67,55			-0,03334			
150,00	6124,45			35,04		77,07			-0,01798			
180,00	6153,52			52,44		53,21			-0,02691			
210,00	6272,59			75,33		56,62			-0,03866			
240,00	6202,58			115,86		63,21			-0,05946			
270,00	6182,86			183,48		60,20			-0,09416			
300,00	6202,58			134,37		61,65			-0,06896			
330,00	6076,61			53,59		86,60			-0,0275			
360,00	6153,52			244,04		58,16			-0,12524			
channel-3 data												
0,00	6169,52	3414,51	1,81	167,90	62,13	68,05	41,53	0,279	-0,05806	1,57914	71,9	28,1
30,00	6199,91	3450,50	1,80	71,23	75,59	73,27	43,65	0,276	-0,02463	1,92147	73,2	28,7
60,00	6161,97	3531,13	1,75	117,04	143,93	77,78	38,94	0,256	-0,04047	3,65853	75,5	30,1
90,00	6222,90	3493,45	1,78	76,98	93,63	69,62	43,01	0,270	-0,02662	2,37978	74,7	29,4
120,00	6215,22	3493,45	1,78	80,77	100,85	62,01	40,24	0,269	-0,02793	2,56347	74,7	29,4
150,00	6177,09	3408,58	1,81	87,97	104,04	59,05	42,78	0,281	-0,03042	2,64458	71,7	28,0
180,00	6207,55	3432,41	1,81	100,12	102,82	62,94	39,38	0,280	-0,03462	2,61338	72,7	28,4
210,00	6169,52	3481,07	1,77	71,05	74,68	69,95	41,95	0,266	-0,02457	1,89823	74,0	29,2
240,00	6246,06	3524,80	1,77	79,12	89,40	74,19	41,36	0,266	-0,02736	2,27244	75,8	29,9
270,00	6192,28	3518,48	1,76	141,04	177,68	64,89	41,54	0,262	-0,04877	4,51623	75,3	29,8
300,00	6199,91	3499,68	1,77	126,43	120,38	73,27	42,45	0,266	-0,04372	3,05978	74,7	29,5
330,00	6246,06	3456,57	1,81	61,42	47,97	72,05	41,99	0,279	-0,02124	1,21936	73,7	28,8
360,00	6215,22	3408,58	1,82	118,92	106,90	72,86	44,70	0,285	-0,04112	2,71728	72,0	28,0

Borehole: KQ0047H01, depth: 0.8 m

Äspö HRL, BGR ultrasonic rotational interval vel. meas., TASQ tunnel, -450m, week 48/2006, borehole: KQ0047H01, depth: 0.8m, (bulk density: 2.731g/cm3)

rotational angle [deg]	Vp if qual >=1 [m/s]	Vs if qual >=1 [m/s]	Vp/Vs if QC >= 1	normAmp_P if QC >= 1 and Amp > 0	normAmp_S if QC >= 1 and Amp > 0	appFreq_P if QC >= 1 [kHz]	appFreq_S if QC >= 1 [kHz]	Poisson's ratio if QC = 1	temp only for normAmp_P Am>0+QC>='	temp only for normAmp_S Am<0+QC>=1	E_dyn [GPa] if QC>=AW2	G_dyn [GPa] if QC>=AX2
channel-1 data												
0,00	5937,56			20,09		85,19			-0,01804			
30,00	6057,21			88,22		52,18			-0,07921			
60,00	6181,78			71,68		55,27			-0,06436			
90,00	6160,66			116,39		80,10			-0,10451			
120,00	5957,17			85,23		85,12			-0,07653			
150,00	6016,79			177,00		73,97			-0,15893			
180,00	5937,56			100,02		84,51			-0,08981			
210,00	6036,93			177,30		74,96			-0,1592			
240,00	5898,72			44,95		84,83			-0,04036			
270,00	6036,93			109,94		91,40			-0,09871			
300,00	6098,17			105,36		78,09			-0,0946			
330,00	6077,62			134,52		91,04			-0,12078			
360,00	6016,79			69,30		86,81			-0,06222			
channel-2 data												
0,00	5950,78			27,11		66,88			-0,0204			
30,00	5919,07			75,13		69,23			-0,05654			
60,00	5929,60			44,41		84,15			-0,03342			
90,00	6004,39			73,45		61,11			-0,05528			
120,00	6004,39			81,56		62,64			-0,06138			
150,00	5898,11			106,70		67,74			-0,0803			
180,00	5877,31			161,15		66,30			-0,12128			
210,00	5940,17			284,20		60,52			-0,21389			
240,00	5993,59			69,89		70,80			-0,0526			
270,00	5972,11			140,46		69,23			-0,10571			
300,00	5982,83			92,48		68,10			-0,0696			
330,00	5982,83			92,04		70,01			-0,06927			
360,00	5982,83			51,44		62,96			-0,03871			
channel-3 data												
0,00	5931,01	3557,31	1,67	36,79	56,83	54,46	35,80	0,219	-0,01307	1,49993	74,4	30,5
30,00	5983,69	3605,53	1,66	92,48	84,43	76,60	35,73	0,215	-0,03285	2,22855	76,1	31,3
60,00	6017,09	3477,59	1,73	34,71	34,46	84,97	45,32	0,249	-0,01233	0,90947	72,8	29,1
90,00	5990,34	3420,10	1,75	72,12	109,85	80,14	48,62	0,258	-0,02562	2,89938	70,9	28,2
120,00	6017,09	3445,42	1,75	105,51	121,44	77,11	43,75	0,256	-0,03748	3,20532	71,9	28,6
150,00	5944,09	3451,80	1,72	169,47	168,46	79,88	40,36	0,246	-0,0602	4,4463	71,5	28,7
180,00	5911,49	3316,55	1,78	156,88	156,75	74,60	46,54	0,270	-0,05573	4,13727	67,3	26,5
210,00	5944,09	3322,46	1,79	321,31	236,98	72,89	46,70	0,273	-0,11414	6,25486	67,7	26,6
240,00	5983,69	3364,49	1,78	119,33	117,20	76,60	46,58	0,269	-0,04239	3,09341	69,2	27,3
270,00	6044,09	3458,21	1,75	62,86	63,93	63,06	42,92	0,257	-0,02233	1,68727	72,4	28,8
300,00	6023,82	3537,04	1,70	61,76	61,92	83,40	42,43	0,237	-0,02194	1,63426	74,6	30,2
330,00	5931,01	3543,77	1,67	15,96	33,07	91,97	44,47	0,222	-0,00567	0,87283	74,0	30,3
360,00	5931,01	3564,12	1,66	50,81	54,70	77,68	38,68	0,217	-0,01805	1,44385	74,5	30,6

Borehole: KQ0047H01, depth: 1.6 m

Äspö HRL, BGR ultrasonic rotational interval vel. meas., TASQ tunnel, -450m, week 48/2006, borehole: KQ0047H01, depth: 1.6m, (bulk density: 2.731g/cm3)

rotational angle [deg]	Vp if qual >=1 [m/s]	Vs if qual >=1 [m/s]	Vp/Vs if QC >= 1	normAmp_P if QC >= 1 and Amp > 0	normAmp_S if QC >= 1 and Amp > 0	appFreq_P if QC >= 1 [kHz]	appFreq_S if QC >= 1 [kHz]	Poisson's ratio if QC = 1	temp only for normAmp_P Am>0+QC>=1	temp only for normAmp_S Am<0+QC>=1	E_dyn [GPa] if QC>=AW2	G_dyn [GPa] if QC>=AX2
channel-1 data												
0,00	5917,73			68,52		80,60			-0,08168			
30,00	6122,45			33,03		81,52			-0,03938			
60,00	5887,45			32,64		95,61			-0,03891			
90,00	5857,47			23,70		107,40			-0,02825			
120,00	6042,06			84,42		81,98			-0,10064			
150,00	6221,79			121,44		70,87			-0,14477			
180,00	5887,45			50,53		82,93			-0,06024			
210,00	5948,33			133,53		76,02			-0,15918			
240,00	6042,06			211,22		66,68			-0,2518			
270,00	5932,99			125,81		87,87			-0,14998			
300,00	6042,06			112,25		87,74			-0,13381			
330,00	5948,33			116,18		86,55			-0,1385			
360,00	6026,23			186,72		80,49			-0,22259			
channel-1 data												
0,00	5958,14			49,89		68,82			-0,04859			
30,00	5940,94			78,96		66,93			-0,0769			
60,00	6036,77			85,79		64,60			-0,08355			
90,00	6072,39			68,62		63,07			-0,06683			
120,00	6063,45			92,85		67,29			-0,09043			
150,00	5958,14			123,90		68,82			-0,12067			
180,00	5940,94			120,84		66,93			-0,11769			
210,00	5940,94			113,22		59,03			-0,11027			
240,00	5992,83			137,33		63,67			-0,13375			
270,00	5940,94			89,44		74,96			-0,08711			
300,00	6001,57			85,46		69,92			-0,08323			
330,00	5984,12			84,44		64,46			-0,08224			
360,00	6010,33			169,24		60,62			-0,16483			
channel-1 data												
0,00	6124,30	3393,54	1,80	39,26	32,83	54,17	39,69	0,278	-0,01569	0,82411	71,0	27,8
30,00	6051,10	3330,42	1,82	62,11	82,18	65,41	47,08	0,283	-0,02482	2,06268	68,6	26,7
60,00	6015,15	3364,84	1,79	74,95	64,91	88,47	48,82	0,272	-0,02995	1,62915	69,4	27,3
90,00	6015,15	3393,54	1,77	96,04	128,43	75,17	51,04	0,267	-0,03838	3,22362	70,3	27,8
120,00	6015,15	3449,10	1,74	129,15	189,34	82,62	45,78	0,255	-0,05161	4,75239	72,0	28,7
150,00	6051,10	3396,75	1,78	193,94	188,81	69,02	46,81	0,270	-0,0775	4,739	70,6	27,8
180,00	6015,15	3293,66	1,83	189,91	146,04	65,34	52,00	0,286	-0,07589	3,66562	67,2	26,1
210,00	6022,31	3333,52	1,81	121,69	123,16	73,85	41,31	0,279	-0,04863	3,09137	68,5	26,8
240,00	6008,01	3387,12	1,77	121,07	98,33	78,95	46,60	0,267	-0,04838	2,46812	70,1	27,6
270,00	6058,34	3455,75	1,75	76,90	64,66	73,93	43,90	0,259	-0,03073	1,62307	72,5	28,8
300,00	6102,15	3472,51	1,76	34,73	33,87	68,74	41,99	0,261	-0,01388	0,85012	73,3	29,1
330,00	6087,48	3426,00	1,78	44,04	50,98	69,09	44,91	0,268	-0,0176	1,2797	71,7	28,3
360,00	6072,87	3336,62	1,82	116,21	96,45	58,14	46,34	0,284	-0,04644	2,42096	68,9	26,8

Borehole: KQ0047H01, depth: 2.8 m

Äspö HRL, BGR ultrasonic rotational interval vel. meas., TASQ tunnel, -450m, week 48/2006, borehole: KQ0047H01, depth: 2.8m, (bulk density: 2.731g/cm3)

rotational angle [deg]	Vp if qual >=1 [m/s]	Vs if qual >=1 [m/s]	Vp/Vs if QC >= 1	normAmp_P if QC >= 1 and Amp > 0	normAmp_S if QC >= 1 and Amp > 0	appFreq_P if QC >= 1 [kHz]	appFreq_S if QC >= 1 [kHz]	Poisson's ratio if QC = 1	temp only for normAmp_P Am>0+QC>=	temp only for normAmp_S Am<0+QC>=1	E_dyn [GPa] if QC>=AW2	G_dyn [GPa] if QC>=AX2
channel-1 data												
0,00	5834,94			79,33		58,66			-0,04193			
30,00	5570,25			12,77		116,41			-0,00675			
60,00	5793,84			58,69		68,68			-0,03102			
90,00	5904,45			69,04		93,86			-0,03649			
120,00	5888,39			86,47		73,15			-0,0457			
150,00	5904,45			108,09		68,24			-0,05713			
180,00	5904,45			133,75		87,30			-0,07069			
210,00	5920,59			130,80		73,32			-0,06913			
240,00	5920,59			156,49		85,92			-0,08271			
270,00	5920,59			72,64		95,79			-0,03839			
300,00	6138,83			110,80		65,61			-0,05856			
330,00	6002,67			138,55		88,01			-0,07323			
360,00	5885,07			142,58		118,60			-0,07536			
channel-2 data												
0,00	5915,33			82,03		50,10			-0,05197			
30,00	5992,83			98,23		57,78			-0,06224			
60,00	6045,64			141,34		63,80			-0,08955			
90,00	5958,14			102,72		62,00			-0,06508			
120,00	6045,64			125,82		49,82			-0,07972			
150,00	6019,12			95,06		58,51			-0,06023			
180,00	5958,14			102,18		72,83			-0,06474			
210,00	6045,64			108,73		57,89			-0,06889			
240,00	6001,57			98,46		71,93			-0,06238			
270,00	6045,64			67,79		67,24			-0,04295			
300,00	5984,12			89,71		78,66			-0,05684			
330,00	6081,36			70,06		53,05			-0,04439			
360,00	5923,84			117,87		60,41			-0,07468			
channel-3 data												
0,00	5970,11	3377,24	1,77	57,23	58,25	60,25	40,42	0,265	-0,02144	1,83196	69,5	27,5
30,00	5946,91	3441,94	1,73	88,70	86,08	76,84	38,05	0,248	-0,03323	2,70737	71,3	28,6
60,00	5977,89	3365,38	1,78	89,88	111,03	77,76	46,48	0,268	-0,03367	3,49193	69,2	27,3
90,00	6009,19	3353,60	1,79	124,29	133,43	68,00	54,09	0,274	-0,04656	4,19644	69,1	27,1
120,00	5993,50	3446,07	1,74	169,96	177,49	60,30	45,69	0,253	-0,06367	5,58233	71,7	28,6
150,00	6024,97	3462,67	1,74	181,33	180,36	63,98	45,20	0,253	-0,06793	5,67257	72,4	28,9
180,00	5993,50	3349,70	1,79	130,40	88,70	74,72	52,41	0,273	-0,04885	2,78965	68,8	27,0
210,00	5993,50	3397,20	1,76	89,91	81,85	66,74	43,89	0,263	-0,03368	2,57422	70,3	27,8
240,00	6001,33	3330,29	1,80	139,18	129,26	69,23	58,02	0,278	-0,05214	4,06536	68,3	26,7
270,00	6009,19	3409,29	1,76	62,49	70,21	83,99	50,99	0,263	-0,02341	2,20809	70,7	28,0
300,00	5954,62	3552,53	1,68	53,25	72,27	103,35	39,52	0,224	-0,01995	2,27305	74,4	30,4
330,00	5993,50	3429,62	1,75	34,68	33,76	79,47	43,00	0,257	-0,01299	1,06191	71,2	28,3
360,00	5970,11	3381,22	1,77	78,69	77,30	79,37	42,83	0,264	-0,02948	2,43112	69,6	27,6

Borehole: KQ0047B02, depth: 1.2 m

Äspö HRL, BGR ultrasonic rotational interval vel. meas., TASQ tunnel, -450m, week 48/2006, borehole: KQ0047B02, depth: 1.2m, (bulk density: 2.731g/cm3)

rotational angle [deg]	Vp if qual >=1 [m/s]	Vs if qual >=1 [m/s]	Vp/Vs if QC >= 1	normAmp_P if QC >= 1 and Amp > 0	normAmp_S if QC >= 1 and Amp > 0	appFreq_P if QC >= 1 [kHz]	appFreq_S if QC >= 1 [kHz]	Poisson's ratio if QC = 1	temp only for normAmp_P Am>0+QC>=	temp only for normAmp_S Am<0+QC>=1	E_dyn [GPa] if QC>=AW2	G_dyn [GPa] if QC>=AX2
channel-1 data												
0,00	5804,69			44,34		54,67			-0,03141			
30,00	5681,82			42,46		73,53			-0,03008			
60,00	5518,29			29,29		47,36			-0,02075			
90,00	5321,37			8,81		53,10			-0,00624			
120,00	5541,07			10,85		54,78			-0,00769			
150,00	5881,00			126,19		69,52			-0,0894			
180,00	6012,73			459,38		55,95			-0,32546			
210,00	5985,92			164,62		64,20			-0,11663			
240,00	5906,88			141,21		72,03			-0,10004			
270,00	5804,69			102,56		74,13			-0,07266			
300,00	5779,69			127,90		62,53			-0,09061			
330,00	5587,20			16,08		62,47			-0,01139			
360,00	5705,97			26,32		71,90			-0,01865			
channel-2 data												
0,00	5905,72			122,34		70,73			-0,06134			
30,00	5958,52			128,26		61,96			-0,06431			
60,00	5905,72			69,85		40,75			-0,03502			
90,00	5937,29			34,01		39,59			-0,01705			
120,00	5853,85			28,54		46,00			-0,01431			
150,00	5895,27			119,81		68,04			-0,06007			
180,00	5823,15			229,23		60,18			-0,11493			
210,00	5884,86			212,63		65,54			-0,10661			
240,00	5958,52			115,58		61,96			-0,05795			
270,00	5884,86			52,37		73,22			-0,02626			
300,00	5937,29			65,86		67,30			-0,03302			
330,00	5884,86			62,79		57,94			-0,03148			
360,00	5895,27			58,74		52,36			-0,02945			
channel-3 data												
0,00	5975,17	3370,37	1,77	180,25	235,56	65,92	55,62	0,267	-0,04528	2,44892	69,4	27,4
30,00	6076,88	3375,13	1,80	143,47	178,03	60,49	51,47	0,277	-0,03604	1,85086	70,1	27,5
60,00	6069,50	3318,95	1,83	78,98	77,91	35,35	42,70	0,287	-0,01984	0,80996	68,3	26,5
90,00	6025,60	3287,03	1,83	30,85	31,85	45,35	46,59	0,288	-0,00775	0,33115	67,1	26,0
120,00	5953,82	3278,03	1,82	34,99	38,12	46,19	51,64	0,283	-0,00879	0,39631	66,4	25,9
150,00	6011,11	3291,55	1,83	100,28	74,09	62,62	51,77	0,286	-0,02519	0,77031	67,2	26,1
180,00	5946,74	3305,19	1,80	226,43	129,48	52,61	43,73	0,277	-0,05688	1,34612	67,2	26,3
210,00	5897,62	3242,49	1,82	116,72	34,31	63,58	49,61	0,283	-0,02932	0,35668	65,0	25,3
240,00	5982,33	3225,01	1,85	126,04	99,59	51,52	61,15	0,295	-0,03166	1,03534	64,9	25,1
270,00	6062,14	3332,82	1,82	96,74	85,24	71,17	59,62	0,283	-0,0243	0,8862	68,7	26,8
300,00	5939,67	3323,56	1,79	44,51	121,25	61,09	48,38	0,272	-0,01118	1,26052	67,7	26,6
330,00	6040,16	3413,65	1,77	50,72	101,11	50,68	41,95	0,265	-0,01274	1,05116	71,1	28,1
360,00	5975,17	3375,13	1,77	70,02	93,47	48,15	47,11	0,266	-0,01759	0,97171	69,5	27,5

Appendix - C

Description of ultrasonic borehole data
recorded by BGR at Äspö URL in November 2006

Ultrasonic interval velocity measurements
Rotational ultrasonic interval velocity measurements
Ultrasonic cross hole measurements

All raw data are delivered separately as SG2-files on a CD

Description of ultrasonic borehole data recorded by BGR at Äspö URL in November 2006

Organisation: Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Hannover, Section B2.2

Location: Äspö HRL, Sweden, TASQ tunnel, -450 m level

Mesurement team: Friedhelm Schulte, Torsten Tietz, Kristof Schuster

Date: 27.11. – 01.12.2006

Method: Ultrasonic interval velocity measurements, rotational ultrasonic interval velocity measurements and ultrasonic cross hole measurements

Tool: BGR mini ultrasonic probe

General:

Measurements of interval velocities were performed along single boreholes. A BGR mini ultrasonic borehole probe with one source and three receivers was used. The seismic velocities are measured along a small borehole interval, typically between 10 cm and 30 cm. The measurements start at the tunnel surface. Then the probe was moved progressively down the borehole in steps of 5 cm (up to 1.5 m) and then in steps of 10 cm up to the end of the borehole. Additionally the tool was rotated in three boreholes at several depths in steps of 30 degrees (Rotational interval velocity measurements).

Between boreholes KQ0047B02 and KQ0047B01 ultrasonic cross hole measurements were performed.

The source signal and the three received signals were passed through a signal conditioning unit to a four channel digital storage oscilloscope (Nicolet 440) which uses a special data format (Nicolet Oscilloscope 440). Data are transformed via the seismic processing software REFLEXW into the internal data format of this software. **Data are converted from this internal REFLEXW-format into the international SEG2 Format for this raw data report.** Data are sorted according to the CMP-coordinate (Common Mid Point) between source and receiver position.

Each data set for one borehole consists of four files, one file for each channel:

C1: channel 1, source - receiver - distance: 10 cm
(~ 2.5 m for cross hole measurements)

C2: channel 2, source - receiver - distance: 20 cm
(~ 2.5 m for cross hole measurements)

C3: channel 3, source - receiver - distance: 30 cm
(~ 2.5 m for cross hole measurements)

41: channel 4, source signal

Recording parameters for channels 1 - 3 are (same for all recordings):

Preamplification: 100

Amplification: 100

Frequency of source signal: ~ 60 kHz (~ 25 kHz for cross hole measurements)

Bandpass filter: 0.1 - 300 kHz

No. of samples: 8000

No. of stacks: 200

Time increment: 100 ns (500 ns for cross hole measurements)

Please note: The year 1986 is stored in all files instead of 2006
(2k / millennium problem)

All raw data are delivered separately as SG2-files on a CD.

Ultrasonic interval velocity measurement

Location: Äspö HRL, TASQ tunnel, borehole: **KQ0047A01**

Filename: CH 4: KQ0047A01_000_C4.SG2
CH 1: KQ0047A01_000_C1.SG2
CH 2: KQ0047A01_000_C2.SG2
CH 3: KQ0047A01_000_C3.SG2

Time increment: 100 ns

Orientation of sensors: 0° (12 o'clock)

Start at: 0.10 m (source position), **end at:** 3.0 m (source position)

Date and time for the beginning of measurement: 28.11.2006, 14:18

Location: Äspö HRL, TASQ tunnel, borehole: **KQ0047A02**

Filename: CH 4: KQ0047A02_000_C4.SG2
CH 1: KQ0047A02_000_C1.SG2
CH 2: KQ0047A02_000_C2.SG2
CH 3: KQ0047A02_000_C3.SG2

Time increment: 100 ns

Orientation of sensors: 0° (12 o'clock)

Start at: 0.10 m (source position), **end at:** 2.9 m (source position)

Date and time for the beginning of measurement: 28.11.2006, 15:39

Location: Äspö HRL, TASQ tunnel, borehole: **KQ0047A03**

Filename: CH 4: KQ0047A03_000_C4.SG2
CH 1: KQ0047A03_000_C1.SG2
CH 2: KQ0047A03_000_C2.SG2
CH 3: KQ0047A03_000_C3.SG2

Time increment: 100 ns

Orientation of sensors: 0° (12 o'clock)

Start at: 0.10 m (source position), **end at:** 2.9 m (source position)

Date and time for the beginning of measurement: 29.11.2006, 08:40

Location: Äspö HRL, TASQ tunnel, borehole: **KQ0047B01**

Filename: CH 4: KQ0047B01_000_C4.SG2
CH 1: KQ0047B01_000_C1.SG2
CH 2: KQ0047B01_000_C2.SG2
CH 3: KQ0047B01_000_C3.SG2

Time increment: 100 ns

Orientation of sensors: 0° (12 o'clock)

Start at: 0.10 m (source position), **end at:** 3.0 m (source position)

Date and time for the beginning of measurement: 29.11.2006, 16:45

Location: Äspö HRL, TASQ tunnel, borehole: **KQ0047B02**

Filename: CH 4: KQ0047B02_000_C4.SG2
CH 1: KQ0047B02_000_C1.SG2
CH 2: KQ0047B02_000_C2.SG2
CH 3: KQ0047B02_000_C3.SG2

Time increment: 100 ns

Orientation of sensors: 0° (12 o'clock)

Start at: 0.10 m (source position), **end at:** 3.0 m (source position)

Date and time for the beginning of measurement: 29.11.2006, 15:10

Location: Äspö HRL, TASQ tunnel, borehole: **KQ0047B02**

Filename: CH 4: KQ0047B02_090_C4.SG2
CH 1: KQ0047B02_090_C1.SG2
CH 2: KQ0047B02_090_C2.SG2
CH 3: KQ0047B02_090_C3.SG2

Time increment: 100 ns

Orientation of sensors: 90° (3 o'clock)

Start at: 0.10 m (source position), **end at:** 3.0 m (source position)

Date and time for the beginning of measurement: 30.11.2006, 13:20

Location: Äspö HRL, TASQ tunnel, borehole: **KQ0047G01**

Filename: CH 4: KQ0047G01_ESE_C4.SG2
CH 1: KQ0047G01_ESE_C1.SG2
CH 2: KQ0047G01_ESE_C2.SG2
CH 3: KQ0047G01_ESE_C3.SG2

Time increment: 100 ns

Orientation of sensors: ESE

Start at: 0.10 m (source position), **end at:** 3.0 m (source position)

Date and time for the beginning of measurement: 30.11.2006, 08:57

Location: Äspö HRL, TASQ tunnel, borehole: **KQ0047H01**

Filename: CH 4: KQ0047H01_ESE_C4.SG2
CH 1: KQ0047H01_ESE_C1.SG2
CH 2: KQ0047H01_ESE_C2.SG2
CH 3: KQ0047H01_ESE_C3.SG2

Time increment: 100 ns

Orientation of sensors: ESE

Start at: 0.10 m (source position), **end at:** 2.9 m (source position)

Date and time for the beginning of measurement: 29.11.2006, 09:50

Location: Äspö HRL, TASQ tunnel, borehole: **KQ0047I01**

Filename: CH 4: KQ0047I01_ESE_C4.SG2
CH 1: KQ0047I01_ESE_C1.SG2
CH 2: KQ0047I01_ESE_C2.SG2
CH 3: KQ0047I01_ESE_C3.SG2

Time increment: 100 ns

Orientation of sensors: ESE

Start at: 0.10 m (source position), **end at:** 2.9 m (source position)

Date and time for the beginning of measurement: 29.11.2006, 10:57

Rotational ultrasonic interval velocity measurement

Location: Äspö HRL, TASQ tunnel, borehole: **KQ0047G01 (100cm)**

Filename: CH 4: KQ0047G01_100_C4.SG2

CH 1: KQ0047G01_100_C1.SG2

CH 2: KQ0047G01_100_C2.SG2

CH 3: KQ0047G01_100_C3.SG2

Time increment: 100 ns

Measured at depth: 100 cm

Start at: 0° (ESE), **end at:** 360° (ESE)

Date and time for the beginning of measurement: 30.11.2006, 11:07

Location: Äspö HRL, TASQ tunnel, borehole: **KQ0047G01 (180cm)**

Filename: CH 4: KQ0047G01_180_C4.SG2

CH 1: KQ0047G01_180_C1.SG2

CH 2: KQ0047G01_180_C2.SG2

CH 3: KQ0047G01_180_C3.SG2

Time increment: 100 ns

Measured at depth: 180 cm

Start at: 0° (ESE), **end at:** 360° (ESE)

Date and time for the beginning of measurement: 30.11.2006, 10:50

Location: Äspö HRL, TASQ tunnel, borehole: **KQ0047G01 (280cm)**

Filename: CH 4: KQ0047G01_280_C4.SG2

CH 1: KQ0047G01_280_C1.SG2

CH 2: KQ0047G01_280_C2.SG2

CH 3: KQ0047G01_280_C3.SG2

Time increment: 100 ns

Measured at depth: 280 cm

Start at: 0° (ESE), **end at:** 360° (ESE)

Date and time for the beginning of measurement: 30.11.2006, 10:31

Location: Äspö HRL, TASQ tunnel, borehole: **KQ0047H01 (80cm)**

Filename: CH 4: KQ0047H01_080_C4.SG2
CH 1: KQ0047H01_080_C1.SG2
CH 2: KQ0047H01_080_C2.SG2
CH 3: KQ0047H01_080_C3.SG2

Time increment: 100 ns

Measured at depth: 80 cm

Start at: 0° (ESE), **end at:** 360° (ESE)

Date and time for the beginning of measurement: 29.11.2006, 13:46

Location: Äspö HRL, TASQ tunnel, borehole: **KQ0047H01 (160cm)**

Filename: CH 4: KQ0047H01_160_C4.SG2
CH 1: KQ0047H01_160_C1.SG2
CH 2: KQ0047H01_160_C2.SG2
CH 3: KQ0047H01_160_C3.SG2

Time increment: 100 ns

Measured at depth: 160 cm

Start at: 0° (ESE), **end at:** 360° (ESE)

Date and time for the beginning of measurement: 29.11.2006, 14:10

Location: Äspö HRL, TASQ tunnel, borehole: **KQ0047H01 (280cm)**

Filename: CH 4: KQ0047H01_280_C4.SG2
CH 1: KQ0047H01_280_C1.SG2
CH 2: KQ0047H01_280_C2.SG2
CH 3: KQ0047H01_280_C3.SG2

Time increment: 100 ns

Measured at depth: 280 cm

Start at: 0° (ESE), **end at:** 360° (ESE)

Date and time for the beginning of measurement: 29.11.2006, 14:33

Location: Äspö HRL, TASQ tunnel, borehole: **KQ0047B02 (120cm)**

Filename: CH 4: KQ0047B02_120_C4.SG2

CH 1: KQ0047B02_120_C1.SG2

CH 2: KQ0047B02_120_C2.SG2

CH 3: KQ0047B02_120_C3.SG2

Time increment: 100 ns

Measured at depth: 120 cm

Start at: 0° (12 o'clock), **end at:** 360° (12 o'clock)

Date and time for the beginning of measurement: 30.11.2006, 14:57

Ultrasonic cross hole measurements

Location: Äspö HRL, TASQ tunnel, borehole: KQ0047B02 (source) and KQ0047B01 (receivers)

Filename: CH 4: KQ0047B02-B01_C4.SG2

CH 1: KQ0047B02-B01_C1.SG2

CH 2: KQ0047B02-B01_C2.SG2

CH 3: KQ0047B02-B01_C3.SG2

Time increment: 500 ns

Orientation of sensors: KQ0047B02: 180° (6 o'clock) and KQ0047B01: 0° (12 o'clock)

Start at: 0.0 m (source position), **end at:** 2.9 m (source position)

Date and time for the beginning of measurement: 30.11.2006, 16:49