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Forsmark site investigation

Overcoring rock stress measurements in borehole KFM07C

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Summary

Overcoring stress measurements were conducted in borehole KFM07C at the Forsmark site. The equipment used for the measurements was the three-dimensional Borre probe. Measurements were planned to be conducted at five measurement levels in borehole KFM07C, but in the end, measurements were attempted at six levels. At the first four levels measurements useable for stress determination were obtained but the two last levels suffered from ring disking to such an extent that no reliable results were achieved.

The successful measurements showed that the obtained maximum horizontal stress is 24.8 MPa orientated N-S and with minor horizontal stress equal to 13.3 MPa at Level 1 (98.76 to 108.42 m borehole length). The measured vertical stress is 3.9 MPa, which can be considered as in fair agreement or only slightly high compared with theoretically calculated vertical stress at this depth.

Maximum horizontal stress for Level 2A (158.28 to 162.69 m borehole length) is in the same magnitude (22.8 MPa) as for the previous measurement level but orientated in E-W, and with a minor horizontal stress equal to 19.2 MPa. The obtained vertical stress is 3.0 MPa, which is considered in fair agreement with the vertical overburden load.

At Level 2B (174.60 to 177.65 m borehole length), the obtained maximum horizontal stress is 24.9 MPa, orientated in N-S and with minimum horizontal stress equal to 18.2 MPa. Measured vertical stress is 7.9 MPa, which is somewhat high in comparison with the overburden pressure. The corresponding results for Level 3 (192.47 to 197.28 m borehole length) is 20.4 MPa (maximum horizontal stress), 17.2 MPa (minor) and 11.2 MPa for the vertical stress. The mean orientation for the maximum horizontal stress is WNW-ESE.

A maximum horizontal stress equal to 30.2 MPa was obtained at Level 4 (238.05 to 258.73 m borehole length) and a minor horizontal stress of 18.6 MPa. The orientation for the maximum horizontal stress is N-S. The vertical stress was measured to 12.1 MPa, which is twice as high as the theoretically determined vertical stress due to overburden.

Transient strain analysis was conducted on all strain results from successful or partly successful installations. The majority of the calculations indicated tensile stress high enough to cause tensile damages in overcore samples.

Samples of pilot cores were tested uniaxially to obtain values on elastic parameters. The obtained values of the Young's modulus from the uniaxial test were in agreement with the corresponding results from biaxial tests results. Obtained results for Poisson's ratio obtained from biaxial tests were slightly higher compared to corresponding results from the uniaxial tests for all measurement levels, but the biaxial tests gave somewhat higher Poisson's ratio for Level 4 compared to the previous levels.

P-wave measurements were conducted on chosen overcore samples to investigate if any development of microcracks could be detected. The P-wave measurements gave higher P-velocity for samples from Level 1 and much less scattered results compared to the deeper measurement levels. Potential sources for these differences between the measurement levels can be lithological variations and variations in the amount of microcracks.

The strain measurements clearly indicated a temperature effect from drilling on the core sample and thereby, also, on the strain gauges. It is not quantified to what extent this affects strain response. In the analysis, efforts were made to minimize the effects on the resulting state of stress. It is suggested that a more detailed investigation is performed to, if possible, quantify the temperature effects in overcoring.

Sammanfattning

Bergspänningsmätningar med överborrningsmetoden har genomförts i borrhål KFM07C i Forsmark. Vid mätningarna användes Borre-cellen, vilken är en tredimensionell mätmetod. Mätningarna avsågs att utföras på fem mätnivåer i borrhålet, men totalt kom mätningar att utföras på sex nivåer. De fyra första mätnivåerna gav användbara mätresultat medan mätningarna på de två sista nivåerna drabbades av ”ring disking” och sprickplan parallella med borrhålet i så stor utsträckning att inga tillförlitlaga mätresultat erhölls.

Sammanfattningsvis, utifrån de lyckade mätningarna, erhölls på mätnivå 1 (98,76–108,42 m borrhålslängd) en största horisontalspänning med en magnitud på 24,8 MPa (medelvärde) och orientering i N-S och en minsta horisontalspänning med magnitud 13,3 MPa (medel). Den uppmätta vertikalspänningen är 3,9 MPa vilket kan anses vara endast något högt i jämförelse med den teoretiskt bestämda vertikalspänningen på detta djup.

Största horisontalspänning för mätnivå 2A (158,28 till 162,69 m borrhålslängd) var av samma magnitud (22,8 MPa) som ovanliggande nivå men med en orientering i O-V-lig riktning och med en minsta horisontalspänning på 19,2 MPa. Den uppmätta vertikalspänningen är 3,0 MPa vilket kan anses rimligt överrensstämma med teoretiskt beräknad vertikalspänning.

På nivå 2B (174,60 till 177,65 m borrhålslängd) är största uppmätta horisontalspänning 24,9 MPa, orienterad N-S, och minsta horisontalspänning 18,2 MPa. Uppmätt vertikalspänning är 7,9 MPa vilket är högt jämfört med teoretiskt beräknad vertikalspänning. Motsvarande resultat för nivå 3 (192,47 till 197,28 m borrhålslängd) är 20,4 MPa (största horisontalspänning), 17,2 MPa (minsta horisontalspänning) och 11,2 MPa för vertikalspänningen. Orienteringen (medel) för största horisontalspänningen är VNV-OSO.

På mätnivå 4 (238,05 till 258,73 m borrhålslängd) uppmättes en största (medel) horisontalspänning på 30,2 MPa och motsvarande minsta horisontalspänning på 18,6 MPa. Orienteringen på största horisontalspänningen är N-S. Vertikalspänningen uppmättes till 12,1 MPa vilket är dubbelt så högt som motsvarande teoretiskt beräknade vertikalspänning.

Transientanalyser utfördes på alla mätdata från mätförsök som bedömts som lyckade eller delvis lyckade. Det stora flertalet beräkningar indikerade förekomst av höga dragspänningar som kan orsaka skador i överborrad kärna.

Enaxiella tryckförsök utfördes också på pilotkärnor i syfte att bestämma värden på de elastiska parametrarna. Erhållna värden på elasticitetsmodulen från de enaxiella tryckförsöken sammanföll med motsvarade värden från biaxialförsöken. Värden på tvärkontraktionstalet erhållna från biaxialförsöken visade sig något högre än värden från enaxiella tryckförsök på kärnor från samtliga mätnivåer, men med större skillnad mellan mätmetoderna på kärnor från mätnivå 4.

P-vågsmätningar utfördes också på utvalda bergprover från överborrningskärnor för att utröna huruvida eventuell mikrosprickbildning kunde detekteras. P-vågsmätningarna visade på de högsta hastigheterna vid mätningar på prover från Nivå 1 för att sedan både få lägre hastighet och betydligt större spridning av resultaten från mätningar på kärnor från de efterkommande mätnivåerna. Detta kan bero på variationer i geologi (bergart och foliation) och/eller ökad förekomst av mikrosprickor.

Töjningsmätningarna vid överborrningarna visar på en temperaturpåverkan från borrningen på bergkärnorna och därmed också trådtöjningsgivarna. I vilket utsträckning detta påverkar töjningarna har inte kvantifierats i detta mätuppdrag, men däremot har åtgärder vidtagits vid spänningsanalysen för att motverka effekten. Det föreslås här att vidare studier bör göras för att, om möjligt, kvantifiera temperatureffekten från borrningen på töjningsdata.

Contents

1 Introduction

This document reports the data gained from three-dimensional overcoring rock stress measurements in borehole KFM07C, which is one of the activities within the site investigation at Forsmark. The borehole is located in the Forsmark candidate area as shown in Figure 1-1.

The borehole was planned to be drilled subvertically (at approximately 85° dip) from the ground surface down to a length of 500 metres. The hole is of “telescope” type with varying diameter (339–86 mm) down to 98 m hole length and with 75.8 mm diameter, down to 500 m length corresponding to a vertical depth of c 498 m. The borehole section 0–c 85 m is cased with an inner diameter of 200 mm. A short section between 428 and 430 m has a hole diameter of 84 mm. Overcoring rock stress measurements were planned to be conducted at approximately 90, 150, 200, 250 and 300 m borehole length, during drilling of the hole. During the measuring campaign it was decided to perform measurements at an additional, sixth level, at approximately 420 m borehole length.

Controlling documents for performance of the activity are listed in Table 1-1. Both Activity Plan and Method description are SKB’s internal controlling document.

The original data from the present study are stored in the primary data base Sicada, where they are traceable by the Activity Plan number (AP PF 400-05-123). Only data in SKB’s data bases are accepted for further interpretation and modelling. The data presented in this report are regarded as copies of the original data. Data in the database may be revised, if needed. However, such revisions will not necessarily result in a revision of the P-report, although the normal procedure is that major data revisions entail a revision of the P-report. Minor data revisions are normally presented as supplements available at www.skb.se.

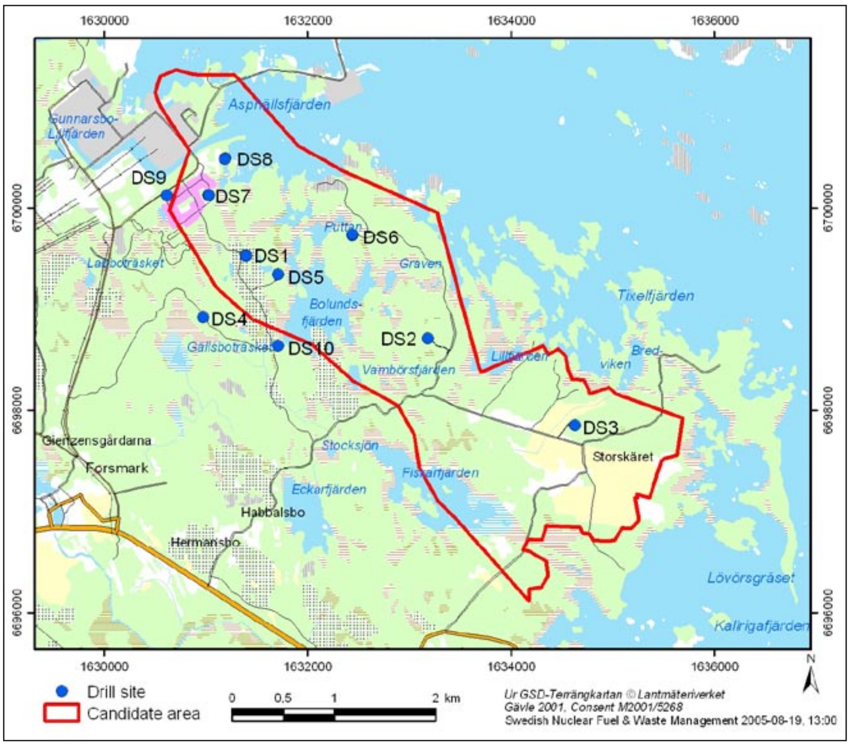

Figure 1-1. *Location of drill sites (DS) 1–10 within the Forsmark area. The telescopic hole KFM07C is located at DS7.*

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

Activity Plan	Number	Version
Kärnborrning av och Bergspänningsmätningar i KFM07C	AP PF 400-05-123	1.0
Method Description		
Method Description for Rock Stress Measurements with the Overcoring Method	SKB MD 181.001	1.0

2 Objective and scope

The objectives of the overcoring rock stress measurements were to: (i) determine the stress gradient through the fractured shallow rock mass to the rock mass almost devoid of open fractures at greater depth, (ii) decrease the uncertainty in stress magnitude at larger depth, and (iii) collect more data about when ring disking occurs. This was to be achieved by 3–4 successful test results from each level at 85–100, 150–160, 190–210, 240–250 and 300 m borehole length and with a later, additional measuring level at 420 m borehole length.

All measurements were conducted using the three-dimensional Borre probe for overcoring (developed and used by Vattenfall Power Consultant AB). The method is described in detail in Chapter 3 of this report. Field measurements were done in six periods during 2006, see Table 2-1.

Execution of field measurements and data analysis is presented in Chapter 4 of this report. In addition to conventional analysis of overcoring data, a laboratory test program comprising uniaxial compression tests and P-wave determination was performed, in order to obtain and verify (compared to biaxial tests) values on the elastic constants and to verify any presence of microcracks in the cores.

All measurement results are presented in Chapter 5, along with a brief discussion of the test results. Measurement and analysis data from the tests are reported in Appendices A through H.

All stresses presented in this report are denoted using a geomechanical sign convention with compressive stresses taken as positive. Compressive strains are, however, defined as negative. All stress orientations are given with respect to geographic North (based on borehole orientation measurements), using a right-hand rule notation. Measurement positions are given as the hole length at the gauge position of the measurement probe.

The presentation of this report is restricted to the work done and the results obtained, as such. It is neither attempted to put the data into a geological/tectonic context, nor to discuss the implications of the results for future work.

Table 2-1. Duration of field measurement periods during 2006.

Level no	From	To	Period no
1	March 30	April 10	1
2	April 21	May 1	2
3	April 21	May 1	2
4	May 21	June 1	3
5	June 5	June 18	4
6	June 20	June 30	5
Summer shut-down	July 1	July 30	–
6	July 31	August 8	6

3 Equipment

3.1 The overcoring method

Three-dimensional overcoring rock stress measurements are based on measuring strains when a sample of rock is released from the rock mass and the stresses acting upon it. The in situ stresses can be calculated from the measured strains and with knowledge of the elastic properties of the rock. The complete, three-dimensional, stress tensor is determined from a single measurement, under the assumption of continuous, homogeneous, isotropic and linear-elastic rock behaviour /Leeman and Hayes 1966, Leeman 1968/.

3.2 Description of field equipment

The Borre probe /Sjöberg and Klasson 2003/ is owned and used by Vattenfall Power Consultant AB for stress measurements in deep, water-filled boreholes. The equipment for overcoring rock stress measurements using the Borre probe comprises:

- pilot hole drilling equipment for wireline core drilling, including planing tool,
- inspection tool (test probe) with built-in borehole cleaning brush,
- Borre probe with built-in data logger,
- set of strain gauges (to be mounted on the Borre probe),
- glue (for bonding strain gauges to the borehole wall),
- cell adapter (installation tool),
- biaxial test equipment including load cell, pressure gauge, hydraulic pump and strain indicator,
- portable computer.

A new pilot hole wireline drilling equipment was recently developed for use with two of the major wireline systems utilized in Sweden – the Hagby WL76 Metric Thinwall Wireline System, and the Atlas Copco CORAC N3/50 System. Both systems produce a c 76 mm overall hole diameter (albeit with slight differences in drill bit diameter for the two systems), whereas the obtained pilot hole diameter is 36 mm using the developed pilot hole equipment. In this project, the Atlas Copco CORAC N3/50 equipment was used for drilling.

The developed wireline pilot hole equipment is fitted to the wireline drill string. Thrusting of the pilot hole drill is controlled through water pressure in the drill string, whereas rotation is transferred through the drill string itself. The unique design of the equipment ensures that the pilot hole is always drilled for a length of 75 cm. The pilot core is recovered through the wireline drill string in the normal fashion for wireline systems. The drilling equipment also includes a planing tool attached to the wireline equipment, which is used to grind the base of the borehole to ensure that it is planar. Overcoring equipment includes a specially manufactured, thinwall, core barrel and coring bit producing a nominal core diameter of 61.7 mm, i.e. equal to that produced by using conventional Craelius T2-76 equipment. The latter is a requirement for being able to fit overcored samples into the biaxial test cell.

The most vital part of the equipment is the Borre probe, which is shown in Figure 3-1. The instrument carries nine electrical resistance strain gauges mounted in three rosettes. Each rosette comprises three strain gauges oriented (i) parallel (axial or longitudinal gauges), (ii) perpendicular (circumferential or tangential gauges), and (iii) at a 45° angle, to the borehole axis, respectively, see Figure 3-2. The strain-gauge rosettes are bonded to three plastic cantilever arms at the lower end of the probe, which is the only part of the instrument that enters into the pilot hole. The arms are located 120° apart with a known orientation to the main body of the instrument. Thus, the nine strain gauges of the Borre probe form an array representing seven spatially different directions. All strain gauges are mounted at a depth of 160 mm in the pilot hole. The temperature sensor is located inside the front end (metal shell) of the Borre cell.

The strain gauges are connected to a data logger inside the probe. The probe also measures the temperature in the borehole to assess the temperature effects on the readings during the overcoring phase. An extra wire is used, which is wired directly into the wheatstone measuring bridge, thus providing automatic temperature compensation for wire resistance during actual strain recording.

The present version of the logger is termed Borre III and has two recording modes – sparse and dense recording. Sparse recording – every 15 minutes – is conducted from the time of activation to a selected start time for dense recording. The sparse recording provides a quality check of glue hardening and possible disturbances prior to overcoring. Dense recording is done in user-specified intervals of between 3 and 60 seconds, from the pre-set start time (set to just before anticipated start of actual overcoring) until the core is recovered and logging terminated. The data logger is programmed through connection to a portable computer before installation of the probe in the borehole. No further connection to the ground surface is required after this programming.

Description of the details of the Borre probe and other components of the equipment is further presented in /Sjöberg and Klasson 2003/ and in SKB MD 181.001 (SKB internal controlling document).

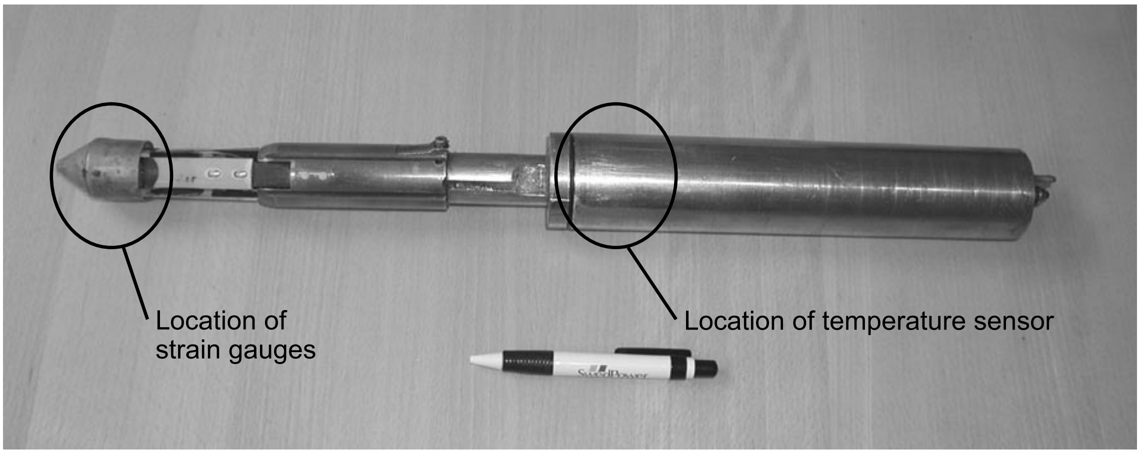

Figure 3-1. *The Borre probe.*

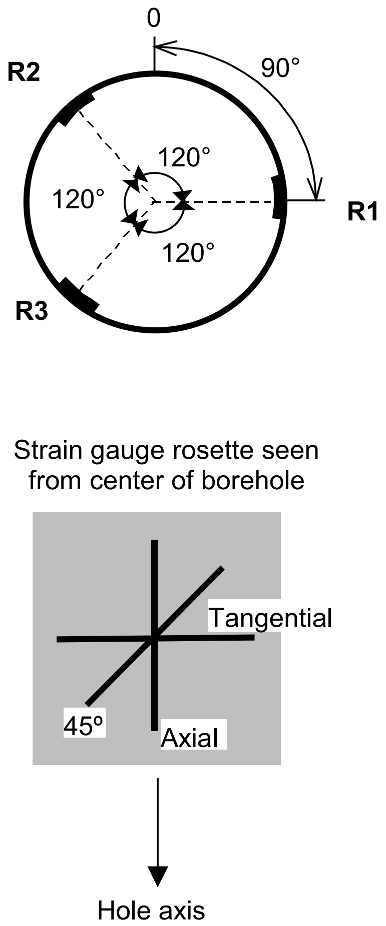

__Figure 3-2.__ Strain gauge configuration of the Borre probe. Axial strain gauges are denoted L1, L2, and L3 (gauge nos. 1, 4, 7), tangential gauges are denoted T1, T2, and T3 (gauge nos. 2, 5, 8), and inclined gauges are denoted 45-1, 45-2, and 45-3 (gauge nos. 3, 6, 9).

4 Execution

4.1 General

In the following, the execution of overcoring measurements is briefly described. Measurements were conducted in accordance with extensive quality operating procedures for the method used. A list of the constituent procedures is given in Appendix I, see also SKB MD 181.001 (SKB internal controlling document).

4.2 Borehole data

The details of the core drilling of borehole KFM07C are not covered in this report. However, a brief description is given below.The borehole was drilled with 339 mm diameter to a length of 6.23 m, and from there with stepwise decreasing diameter down to 98.42 m length. For the remainder of the hole, a 75.8 mm hole diameter applies (final hole length of 500.34 m). A section between 430.28 and 430.40 m borehole length has 84.0 mm hole diameter. This section is supplied with a reinforcing steel plate. Steel casing with an inner diameter of 200 mm was installed down to a borehole length of 84.79 m below which there is a stainless steel transition cone to the narrower part of the borehole at 98.39 m. The gap between the casing and the borehole wall was grouted with a total of 1,548 kg (1,505 l) cement ("Aalborg Portland Cement/ microsilica") down to 85.10 m hole length. This was carried out on January 17, 2006, i.e. well in advance of the commencement of the overcoring campaign.

4.3 Preparations

Preparations before measurement start include (according to the method description):

- functional checks of strain gauges and data logger in the probe,
- calibration of biaxial test equipment,
- glue test on every new glue purchase,
- functional checks of drilling and installation equipment.

4.4 Execution of measurements

Overcoring stress measurement using the Borre probe involves:

1. Pilot hole drilling and examination.
2. Preparation and installation of the Borre probe.
3. Overcoring and recovery of the probe.
4. Biaxial testing of the overcore sample.

The procedure for stress measurement using the Borre probe is briefly summarized in Figure 4-1. Each stage is succinctly described below.

4.4.1 Pilot hole drilling

The 76 mm borehole is advanced to the target test depth, specified in advance. Once at this depth, a decision as to whether attempt pilot hole drilling is made. The main criterion for attempting a pilot hole is that the 76 mm drill core shall carry homogeneous rock close to the hole bottom. Discrete fractures may be accepted if the overall fracture frequency and/or orientation of discontinuities indicate that the pilot hole core shall be homogeneous and free of open fractures. If these requirements are not met, the 76 mm borehole is extended another 1–3 m.

Once a decision on pilot hole drilling is taken, the bottom of the 76 mm hole is grinded to ensure that it is planar. Using wireline pilot hole drilling, a 0.75 m long pilot hole is drilled. The borehole is flushed and the return water checked for cleanness (free of debris). The retrieved pilot core is inspected to determine whether the hole location is suitable for testing. The criteria on the pilot hole core for the decision to go on with the test are the following:

- 3–25 cm: (length) Continuous core, mechanical fractures accepted. No healed fracture that can be extrapolated to cross close to the gauge position at 16 cm during the subsequent overcoring process.
- 15–17 cm: (length) No larger and/or different mineral crystals than elsewhere on the core shall be present around 16 cm. Pegmatite shall be avoided if possible.
- Any direct or indirect information on core damage (ring disking, microcracking, etc) on the pilot core surface is an evidence of non-linear and inelastic behaviour, which renders the core unacceptable.

As the hollow overcored core is more vulnerable to core damage, there is no reason to proceed with measurement if there is any core damage or any features present as described above.

If these criteria are not met, but conditions appear to be better at a slightly deeper location in the pilot hole, planing and grinding of the bottom of the 76 mm hole may be performed to reach a more suitable location for the strain gauges (always installed 16 cm from the bottom of the 76 mm hole). Planing of up to 10 cm can normally be achieved in practice. If planing is not possible within the above limits, a new pilot hole is instead drilled.

If the pilot hole is judged acceptable for installation, a test probe is lowered down the borehole to check that the pilot hole is open and free from debris.

4.4.2 Preparation and installation

If the conditions for a suitable pilot hole are satisfied, and the pilot hole is open and free from debris, the Borre probe is prepared for installation into the pilot borehole. The preparations include:

- attaching strain gauges to the probe and connecting them to the logger,
- programming of the data logger with start time and sampling interval,
- attaching the probe and the compass to the installation tool,
- mixing and applying glue to the strain gauges.

The probe is then installed into the pilot hole, as shown in Figure 4-1. The probe is left in the hole for a minimum of 8 hours (usually overnight) for proper bonding of strain gauges to the pilot hole wall.

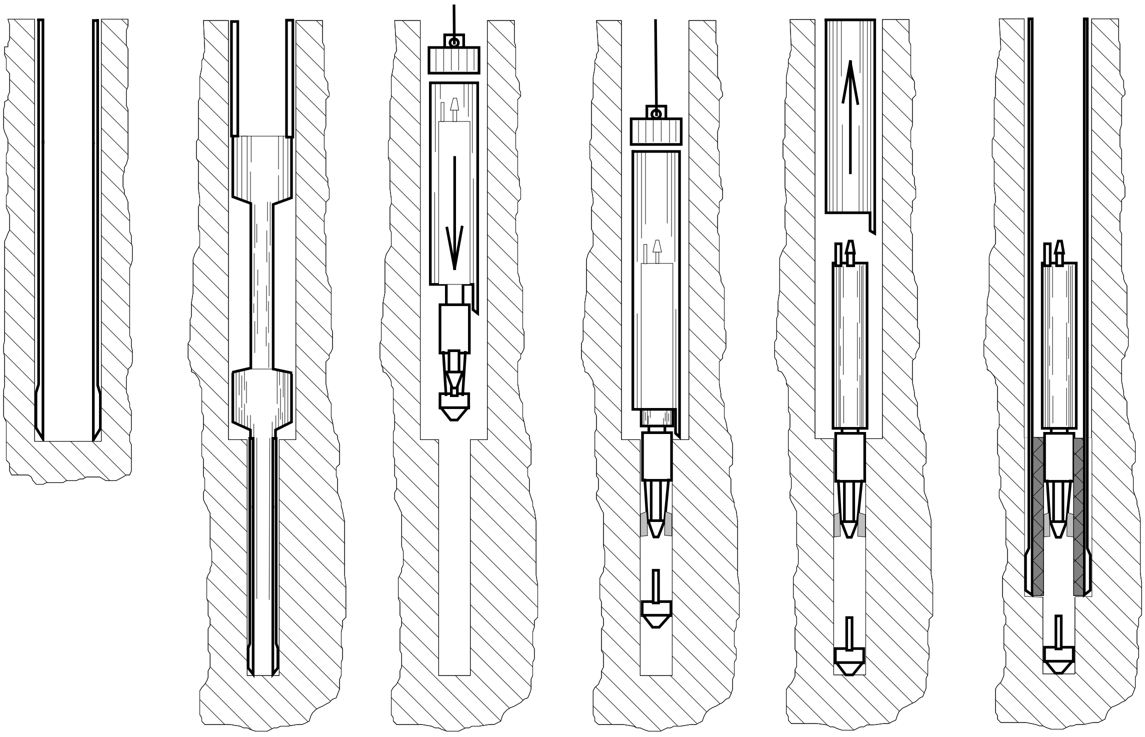

Figure 4-1. *Installation and measurement procedure with the Borre probe:*

1. *Advance 76 mm-diameter main borehole to measurement depth. Grind the hole bottom using the planing tool.*
2. *Drill 36 mm-diameter pilot hole and recover core for appraisal. Flush the borehole to remove drill cuttings.*
3. *Prepare the Borre probe for measurement and apply glue to strain gauges. Insert the probe in installation tool into hole.*
4. *Tip of probe with strain gauges enters the pilot hole. Probe releases from installation tool through a latch, which also fixes the compass, thus recording the installed probe orientation. Gauges bonded to pilot hole wall under pressure from the nose cone.*
5. *Allow glue to harden (usually overnight). Pull out installation tool and retrieve to surface. The probe is bonded in place.*
6. *Overcore the Borre probe and record strain data using the built-in data logger. Break the core after completed overcoring and recover in core barrel to surface.*

4.4.3 Overcoring

Overcoring of the probe involves flushing before and after overcoring, to stabilize temperatures. A checklist is followed to control drilling rate, rotational speeds, flushing, etc (according to the method description). Coring advance is done at a specified constant rate (normally 3 cm/min). In practice, it is difficult for the drilling contractor to maintain a constant rate throughout the overcoring process; hence, variations are almost always present. The coring advance was registered manually using a watch and markers on the drill string for every 4th cm up to 32 cm overcoring length, after as well as before completed overcoring (normally 100 cm length).

The borehole is left with only flushing continued and no other on-going activity for approximately 15 minutes after completed overcoring. After flushing stop the borehole is left completely without on-going activities before the core is broken loose from the hole. This procedure ensures that sufficient strain data are recorded to assess temperature effects, possible non-ideal rock behaviour, etc, which may affect strain readings and measurement results adversely.

After overcoring, the probe is recovered with the overcore sample inside the core barrel. Strain data are transferred from the data logger to a portable computer. The overcore sample is then mapped with respect to length, concentricity, gauge positions, lithology, structures, microcracks and other possible defects.

4.4.4 Biaxial testing

Biaxial testing of the overcored specimens is conducted to determine the elastic constants of the rock at the measurement position. Testing is carried out on-site as soon as possible after overcoring, using the equipment shown in Figure 4-2. The overcore sample must be at least 24 cm long, without fractures, for biaxial testing to be possible.

The test sequence comprises both loading and unloading in order to study possible inelastic behaviour of the rock. The sample is loaded to a maximum radial pressure of 10 MPa, in increments of 1 MPa, and then unloaded in the same manner. The strains induced in the overcore sample are monitored by the strain gauges installed by the Borre probe, using the built-in data logger of the probe. After completed test sequence, the Borre probe is disconnected from the overcore sample. Supplementary logging of the core is performed to check for potential new fractures. Inner and outer core diameter, as well as the annular thickness of the overcore sample, are also measured.

4.5 Data handling

The raw data include overcoring strain data files, biaxial strain data files, and completed check-lists and QA Report Forms from measurements. Routine data processing of measurement data involves importing the strain data file from overcoring into an in-house developed Microsoft Excel application for presenting overcoring strain response. Graphing of the strain response is performed automatically by the software application, and strain differences calculated based on input start- and stop-times for the overcoring process.

Similarly, the strain data file from biaxial testing is imported into the corresponding Excel application for presentation of biaxial test response and automatic calculation of elastic constants (Young's modulus and Poisson's ratio).

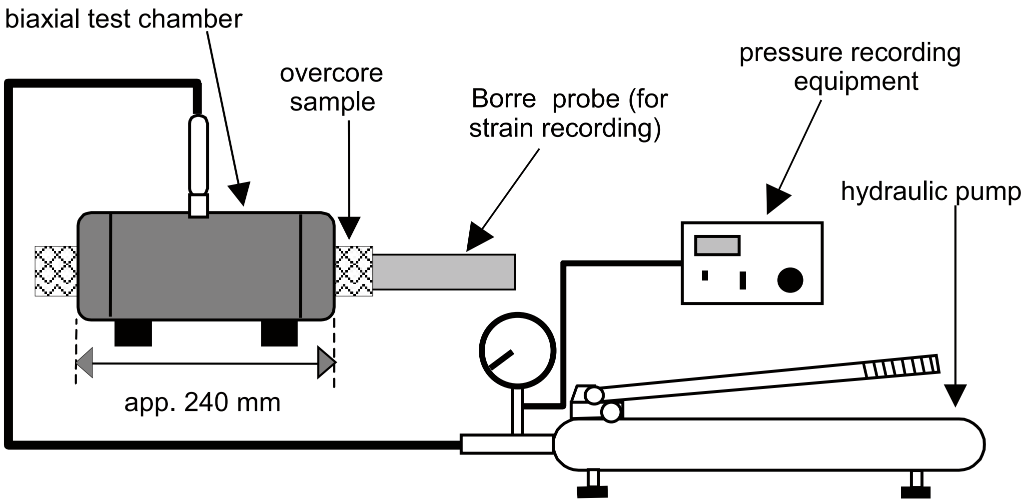

Figure 4-2. Schematic drawing of the biaxial load cell with pressure generator and recording equipment.

Calculation of stresses is carried out using another in-house developed Microsoft Excel application, with input in the form of strain differences, values on elastic constants, and borehole and recorded strain gauge orientation from the probe installation. The stress calculations are based on the theory presented by /Leeman 1968/. Calculation is performed for a single measurement, or for several successive measurements on one or several test levels, with automatic calculation of mean stresses for each level.

The primary data reported from the overcoring stress measurements are:

- magnitudes of the three principal stresses,
- orientations of the three principal stresses (bearing and dip),
- magnitudes and orientations of the stresses acting in the horizontal and vertical planes,
- values on elastic constants from biaxial testing.

4.6 Data analyses

4.6.1 Classical overcoring analysis and stress calculation

The Borre probe is a "soft" stress cell, which means that the stiffness of the strain gauges is negligible in comparison to the stiffness of the rock. Thus, only the strains induced by overcoring and the elastic constants of the rock, in addition to the orientation of the probe in the borehole (including borehole orientation), are required to determine the complete stress tensor. Calculation of stresses from strain is done under the assumption of continuous, homogeneous, isotropic, and linear-elastic rock behaviour /Leeman 1968/. The stress relief is identical in magnitude to that produced by the in situ stress field but opposite in sign.

The analyses of obtained test data comprise (i) analysis of overcoring strain data, (ii) analysis of biaxial test data, and (iii) stress calculation, using data from the first two tasks. For each task, quality control checks and data assessments are included. Detailed descriptions of each step are given in SKB MD 181.001 (SKB internal controlling document), and are briefly summarized below.

The recorded strain gauge response and temperature are plotted vs. recorded time, and the strain differences due to overcoring and stress relief are calculated for each strain gauge for later use as input to the stress calculation. The overcoring strain change is normally determined as the difference between (i) recorded strain after completed overcoring with flushing on, and (ii) recorded strain at the start of overcoring with flushing on. It is important that all conditions, except the overcoring stress relief itself, are as similar as possible for these two instances (e.g. flushing, water pressures, temperatures, etc). Furthermore, the strain values should be stable (little or negligible strain drift) at these instances. In some cases, stable and ideal strain response can be observed during the first portion (typically 20–30 cm) of the overcoring process, whereas significant strain drifts occur during the rest of the overcoring. In theory, practically all of the strain relief takes place during the first 24 cm of overcoring (with gauge positions at 16 cm), see e.g. /Hakala et al. 2003/. For such cases, strain differences may be determined from stable values of this portion of the strain response curve (corresponding to approximately 20–30 cm drill bit position or more). However, temperature effects (heating of the rock due to drilling) are more prevalent at this stage, which must be considered. It should also be noted that small changes in strains (a few µstrains), which may arise from choosing slightly different start- and stop-times for the overcoring, have very small influence on the calculated magnitudes and orientations of the in situ stress state.

Recorded strain and pressure data from biaxial testing are plotted and examined. Elastic constants are determined from recorded strain and pressure data from the biaxial testing. For this, the theory for an infinitely long, thick-walled circular cylinder subjected to uniform external pressure is employed, see e.g. /KTH 1990/. Since the Borre probe incorporates three pairs of circumferential and axial strain gauges, three pairs of elastic property-values are obtained from each biaxial test. The aim is to obtain rock parameters that apply to the relaxation experienced by the rock during overcoring. Therefore, the values of E (Young's modulus) and ν (Poisson's ratio) are taken to be secant values, calculated from strain data obtained during unloading of the core specimen. Usually, the secant values between the pressures of 8 and 3 MPa are calculated and averaged for the three strain rosettes. However, elastic constants may be calculated for other pressure intervals, if recorded strain readings are significantly unstable and/or display notable non-linearity for certain pressures.

Calculation of stresses from measured strains is based on the classical theory by /Leeman 1968/. The details of the formulation can also be found in e.g. /Amadei and Stephansson 1997/ and are not repeated here. Strain measurements from at least six independent directions are required to determine the stress tensor (which has six components). When all nine gauges of the Borre probe function properly during a measurement, redundant strain data are obtained. A least square regression procedure is used to find the solution best fitting all the strain data, from which the stress tensor components are calculated. For each test, one tangential or inclined gauge and/or two axial gauges may be rejected or recalculated without impairing the determination of the stress tensor. Recalculation is only performed if evidence of malfunctioning gauges exists, see also /Sjöberg and Klasson 2003/ and SKB MD 181.001 (SKB internal controlling document). Subsequently, the magnitude and orientation vector of each of the three principal stresses are calculated, as well as the stresses acting in the horizontal and vertical planes.

For the case of several measurements on one test level, the mean stress state is calculated. This is conducted by first taking the stress tensor components for each of the measurements (defined in a common coordinate system, e.g. the site coordinate system), and averaging each of the stress tensor components. From these mean values, the mean principal stresses, as well as the mean horizontal and vertical stresses, are determined. All calculated data are stored in Sicada, traceable by the Activity Plan number.

4.6.2 Transient strain analysis

A methodology for transient strain analysis of overcoring data was presented by /Hakala et al. 2003/. The methodology involves calculating the theoretical strains corresponding to a given stress field (by using pre-calculations from a three-dimensional numerical model). The theoretical strain response is calculated for the entire overcoring process and can thus subsequently be compared to the actual recorded strain response from the overcoring measurement.

The analysis can be used to assess whether the measured strain differences and calculated stresses are compatible. Larger deviations in terms of measured vs. calculated (theoretical) strains are indications of imperfect conditions at the time of measurements, e.g. debonding, microcracking, heterogeneities, anisotropy, etc. The analysis cannot, however, be used to detect systematic measurement errors.

Transient strain analysis was carried out using the computer code and methodology developed by /Hakala et al. 2003/, and described in more detail in /Hakala 2004, 2006/. For each test (measurement point), the reported stress state and accompanying field parameters were input to the transient strain analysis program. Transient and final strains were calculated and the final strains compared with the measured final strains. The strain differences (measured vs. calculated strains) were evaluated and the maximum difference calculated for each strain gauge as follows:

$$M\_diff_i = \frac{|(\varepsilon_i - \varepsilon\_calc_i)|}{\varepsilon\_amp_i}$$

$\varepsilon\_amp_i = \varepsilon_{i,max} - \varepsilon_{i,min}$

where

M_diff_i = maximum strain difference for one of the strain gauges (i=1, 2,..9) (%),

ε_i = measured strain for one of strain gauges (i=1, 2,..9),

ε_calc_i = back-calculated strain from the calculated stress state for one of the strain gauges (i=1, 2,..9),

ε_amp_i = amplitude for the calculated transient strain curve for one of strain gauges (i=1, 2,..9),

$\varepsilon_{i,max}$ = maximum recorded strain value for one of strain gauges (i=1, 2,..9),

$\varepsilon_{i,min}$ = minimum recorded strain value for one of strain gauges (i=1, 2,..9).

In addition, the amount of unexplained strain was calculated using the program. Initially, the strain differences from the measurement are used to calculate stresses, using the least-square regression procedure described in Section 4.4.1. The resulting stresses were then used to back-calculate the corresponding strains for each of the strain gauges of the probe. The amount of unexplained strain was defined as the sum of absolute differences between measured and calculated strains divided by sum of calculated strains, i.e. /Hakala et al. 2003/:

$$AUS = \frac{\sum_{i=1}^{9} |(\varepsilon_i - \varepsilon\_calc_i)|}{\sum_{i=1}^{9} \varepsilon\_calc_i}$$

where

AUS = amount of unexplained strain (%),

ε_i = measured strain for each of the strain gauges (i=1, 2,..9),

ε_calc_i = back-calculated strain from the calculated stress state for each of the strain gauges (i=1, 2,..9).

A higher value on *AUS* indicates larger difference between measured and theoretical strain values. This value can thus be used to estimate the heterogeneity, anisotropy, reliability, or successfulness of measurements.

The stress path developing during the overcoring process was also calculated, including the maximum tensile stress acting on the overcore sample. A high value on the tensile stress is an indicator of high possibility of tensile damage of the rock during overcoring.

At this stage, no strength values have been presented from borehole KFM07C. Previously in the site investigation program, indirect tensile tests have been performed in campaigns on samples from borehole KFM01A /Eloranta 2004, Jacobsson 2004/, obtaining an average tensile strength of around 14 MPa and standard deviation of about 2 MPa. These values of the tensile strength are also presented valid for the dominating rock mass in the area in the Site descriptive modelling, Forsmark stage 2.1 /SKB 2006/.

For illustrative purposes, a uniaxial compressive strength of 231 MPa and a uniaxial tensile strength of 14 MPa were assumed to define a failure criterion.

It should be noted that only linear-elastic analysis is conducted; hence, very high tensile stresses can develop, which, in reality, would be limited as the strength of the rock is exceeded. The post-peak process and associated stresses and strains can, obviously, not be studied with this computer program.

Finally, the developed code has the capability to solve the in situ state of stress based on the measured transient or final strains /Hakala et al. 2003/, following the method presented by /Fouial et al. 1998/. This inverse solution enables, in theory, stresses to be determined from the early, pre-overcoring, strain response. The inverse solution is exact if calculated strain values and coring advance are exact. In reality, there are always errors associated with the measurements. /Hakala et al. 2003/ stated that for the inverse solution to be useful, coring advance must be measured with an accuracy of ± 1 mm, or better. This is clearly difficult to achieve in practice. During overcoring measurements in borehole KFM07C, overcoring was attempted at a constant rate for the different measurements. Manual registration of the coring advance was conducted for every 4th cm up to 32 cm overcoring length. However, the coring rate often proved to be varying due to practical constraints (variations in rock type, drill string extension, etc), thus resulting in a varying error in the determination of coring advance. Consequently, in most cases, the local maxima and minima of the measured and theoretical strains, respectively, did not match perfectly. For such cases, the measured strain response curves were corrected to match the theoretical strains with respect to position/core advance, thus resulting in an improved inverse solution. The inverse solution was applied to selected measurements in KFM07C, as described in the following.

4.7 Additional uniaxial compression tests on pilot core samples

The additional uniaxial test program was performed in order to obtain and verify values on elastic constants of the rock mass and to compare these results with the results from conducted biaxial tests.

4.7.1 Samples

Samples, comprising pilot cores representing various measurements were chosen by the responsible field engineer for the measurement campaign. Samples for uniaxial testing were collected from pilot cores between about 100 and 420 mbl (m borehole length) in borehole KFM07C. The spatial depth distribution between samples varied from about 5 to 104 mbl. The samples tested are composed of metagranitic to granodioritic rocks. The testing strategy was to measure the elastic properties, Young's Modulus (E) and Poisson's Ratio (ν), from one or two test depths at each measurement level where overcoring and biaxial testing had been conducted. Moreover, a group of three samples were taken from each test depth to provide a measure of the possible variability. The samples were taken so that one sample was centralized over the corresponding depths to those of the strain rosettes of hollow overcore. In total, uniaxial tests were conducted on 28 samples from nine test depths and six levels within borehole KFM07C. The pilot core samples had a diameter (d) of about 22 mm, and a height (h) of 55 mm, i.e. $h \approx 2.5 \cdot d$.

The test samples fulfilled all requirements of the ISRM suggested methods /ISRM 1979/ and /ASTM SM (D 3148-72), 1993/ with three exceptions. First, the sample diameter was significantly smaller than in the standards (≈ 22 mm instead of ≥ 50–54 mm). Second, because of limited length of the pilot core, three samples were taken from each test depth. This is less than what is recommended in the ISRM and ASTM SM. Third, the samples had been stored openly in their core box for longer than 30 days, which has resulted in that the sample was dehydrated. The latter deviation from the standards is considered to be of minor importance because of the nature of the crystalline rocks, i.e. low porosity and low water content.

4.7.2 Test equipment

The elastic properties *E* and ν were determined by generally following the ISRM SM /Brown 1981/ and /ASTM SM (D 3148-72), 1993/. Measurements were conducted in the COMPLAB laboratory at Luleå University of Technology. The main components of the equipment are:

- Load frame with digital controller. The frame is a stiff Instron 4.5 MN servo-hydraulic loading frame. The static load capacity has been reduced to 2 MN by an internal load cell. The frame has a travel of +/– 35 mm, and is controlled by a Dartec 9,500 digital controller that has additional amplifiers in a stand-alone rack.
- Data acquisition system including a data logger and computer. Data was recorded at 5 Hz. A total of nine channels were recorded, including time (s), load (kN), stroke (mm), and six strain channels (µstrain). The computer program Catman was used to collect data.
- The axial and radial deformation of the specimen is measured with two X-Y-45° strain gauges that are glued to the opposite sides of the sample. The strain gauges were manufactured by KYOWA, type KFG-10-120-D17-11L1M2S (120 Ω). Gauges had an amplification factor of 3 mV/V that result in a maximum strain of about 7,500 µstrains, and strain gauge factors of 2.10 ± 1% or 2.11 ± 1%.
- Disc-shaped steel platens with Rockwell hardness ≥ Rc 58. The diameter of the platens was 23 mm, i.e. within the ISRM and/or ASTM SM.
- Spherical seat with diameter of 23 mm. The spherical seat is placed below the sample, which is a minor deviation to the ISRM and/or ASTM SM.
- External 200 kN load cell. The external load cell is used to improve the load accuracy. The anticipated stress range is within the lowermost range of the internal load cell, which is considered to have too poor resolution for the current project.

The sample dimensions were measured using a micrometer with an accuracy of 1/1,000 mm.

4.7.3 Test procedure

The elastic properties were determined using two strain gauges that were mounted on opposite sides of the sample. In general, this followed the ISRM SM /Fairhurst and Hudson 1999, Brown 1981/ and /ASTM SM (D 3148-72), 1993/, with two exceptions. An additional unloading – reloading cycle was performed before the sample was run to failure. The tests were run in stroke control, using a stroke rate that leads to failure within 5–10 minutes for the load cycle. The complete loading-unloading-reloading cycle takes about 10 to 15 minutes to complete. Furthermore, because of the small sample size and initial instability of the test set up, the spherical seat was placed below the sample rather than on top of the sample. The test procedure is summarized below.

- Drive specimen manually near to contact. No axial force is allowed.
- Reset readings of actuator displacement and axial force.
- Drive specimen to force contact to seat and centralize the sample.
- Photograph sample in the test set-up.
- Start computer program Catman.
- Subject sample to loading at constant stroke rate of 0.0008 mm/mm/s to an axial stress of about 100 MPa.
- Subject sample to unloading at constant stroke rate of –0.0008 mm/mm/s to an axial stress of about 5 MPa.
- Subject sample to loading at constant stroke rate of 0.0008 mm/mm/s until failure.

- Stop test manually, turn off Catman program.
- Photograph sample after failure.
- Collect the remains of the sample in a plastic bag, tag the bag with sample ID.

4.7.4 Calculations

The load (P), stroke, and axial (ε_a), radial (ε_r) and 45°-inclined strains were recorded during testing. For all calculations, the average values of the two opposite strain readings have been used. The variations in ε_r was used to calculate the variation in cross sectional area (A) of the sample during the test, which in turn, was used to calculate the axial stress according to $\sigma_a = P/A$.

Young's Modulus (E) and Poisson's Ratio (ν) were obtained following calculation instructions given by ISRM SM /Fairhurst and Hudson 1999, Brown 1981/ and /ASTM SM (D 3148-72), 1993/.

Four types of Young's Modulus (E) and Poisson's Ratio (ν) were calculated in Kalediagraph 4.0, a plot- and statistics program:

- Initial tangent E and ν. The slopes of the stress-strain and strain-strain curves were determined over the axial stress range from 0 to 10 MPa.
- Tangent E and ν at an axial stress level of 50% of the uniaxial compressive strength. The slopes of the stress-strain and strain-strain curves were determined for the stress interval ± 50 MPa of 50% of the peak strength.
- Tangent E and ν for the unloading curve. The slopes of the stress-strain and strain-strain curves were determined.
- Secant E and ν from minimum axial stress to 50% of the maximum axial stress of the unload curve (i.e. ≈ 50 MPa) were determined.

4.8 Additional P-wave measurements on overcore samples

The additional P-wave measurement program was performed in order to, if possible, verify any presence of microcracks in cores subjected to rock stress measurements at different levels of the borehole.

4.8.1 Samples

Samples, comprising hollow cores representing various measurements, were chosen by the responsible field engineer for the measurement campaign. Samples for P-wave measurements were collected between about 100 and 420 mbl (m borehole length) in borehole KFM07C. The samples tested are composed of metagranitic to granodioritic rocks. The testing strategy was to measure the P-wave velocity from one to two tests at each measurement level where overcoring and biaxial testing had been conducted. Moreover, a group of three samples were collected from each test depth. The samples were taken so that one sample was centralized over the positions of the strain rosette positions from the overcoreing measurements. A reference line was marked on all cores from the overcoring at the position for the reference mark from the overcoring measurements. It was done so all test samples could be orientated versus North. In total, P-wave velocity was measured on 39 samples from 12 test depths and six levels of borehole KFM07C. The internal and external diameters of the hollow samples were 36.6 and 61.6 mm, respectively, and their length was about 40 mm. Detailed descriptions of the samples are available from the detailed core log by SKB.

4.8.2 Test equipment

The travel time of P-wave through the sample was measured using the recommendations for laboratory testing given by the ISRM suggested methods for determining sound velocity /ISRM 1978/. Measurements were conducted at the division of Mining and Geotechnical Engineering at Luleå Technical University. The main components of the equipment are /Eitzenberger 2003/:

- LeCroy 9424 Quad 350 MHz Oscilloscope.
- Pulse generator PUNDIT, generates 10 pulses per second.
- Two cylindrical videoscan transducers from Panametrics (V103-RM), which can be used both as transmitters and receivers. The transducers have an eigenfrequency of 1 MHz and a diameter of 13 mm.
- A clamp, marks and angle-iron ensure that the transducers are attached diametrically opposite to each other.

To obtain good acoustic contact between the transducers, distilled water was used as couplant.

The sample thickness was measured at the same points as the travel time measurements using a micrometer with an accuracy of 1/1,000 mm.

4.8.3 Test procedure

The samples were oriented versus North using the marked reference line as described earlier. Then, a position for each 30° was marked along the periphery on the top of each test sample (viewed along the core centre axis), i.e. 12, positions were marked on top of each test sample. A line was also drawn between the top and bottom mark for each position. The P-wave test was performed from the top down to the bottom of test sample, following the centre axis of the core, i.e. parallel to the axis of the borehole. One test was performed at each position, i.e. 12 tests per sample. At cases were the positions for the strain gauges not coincided with any of the marked positions (coincided with the drawn lines), the positions for the strain gauges were marked in the same manner as the other test positions and three additional tests were performed, totally 15 tests per test sample. The following procedure is used when performing the tests:

1. The test equipment is assembled and calibrated.
2. The sample is inserted into the test rig so that the transducers are placed opposite to each other. The zero travel time (t_0) is read once every day.
3. The sample is inserted into the test rig so that the transducers are centralized over the side of the hollow sample cylinder.
4. Water is applied to the surfaces of the transducers and sample to increase the coupling effect and a small stress is applied to hold the sample in place and to obtain good coupling.
5. The travel time (t) is measured with the oscilloscope. The travel time is taken as the average of 20 readings by the oscilloscope.
6. The sample height (z) is measured using the micrometer.
7. The actual P-wave velocity is calculated by subtracting the zero time from the measured travel time according: $V_p = \dfrac{z}{(t - t_0)}$.

Steps 3 to 7 were repeated for every test, whereas step 1 only was performed at the start of the test series, and step 2 was made once per day.

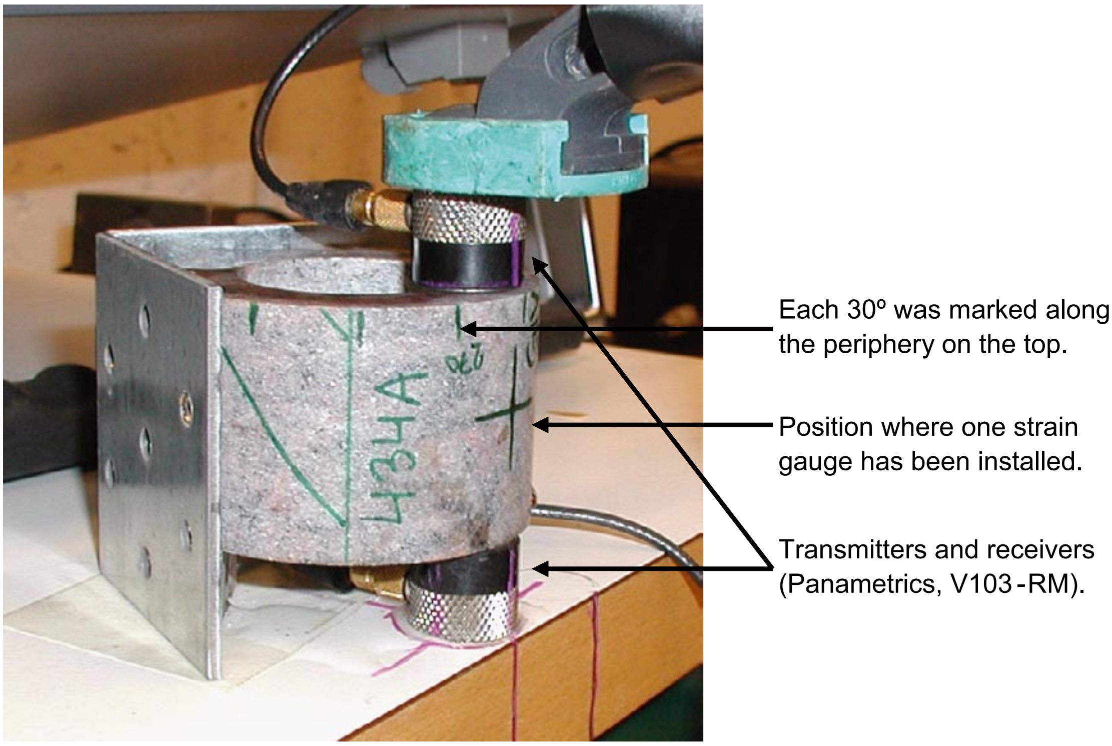

Figure 4-3. *Photo of test set up for the cylinder at the position of the strain gauges at test no 4:3:4. Exact positions where the strain gauges have been installed are marked as well as the position for each 30° along the periphery on the top.*

5 Results

5.1 Overview

Measurements were planned to be conducted at five measurement levels in borehole KFM07C. However, measurements were performed at six levels, out of which four measurement levels could be judged as completed successfully. Level 1 included measurements between 98 and 110 m borehole length. For Level 2, measurements were attempted between 158 and 179 mbl and for Level 3 between 192 and 198 mbl. Level 4 commenced with measurements at 239 mbl and stopped at 263 mbl. For Levels 5 and 6, measurements were attempted between 304 and 322, and between 419 and 426 mbl, respectively.

A brief summary of conducted measurements is given in Table 5-1. All tests have been numbered as follows: *measurement level : test no. : pilot hole no.*. Thus, e.g. test 2:5:3 denotes measurement Level 2, test (or measurement) no. 5 at that level, and pilot hole no. 3 (to reach an acceptable measurement location for this test). Each test is presented with a rating reflecting successfulness and reliability of that particular measurement. Ratings were assigned per the following criteria:

Rating	Description and criteria
a	**Successful test**
	• Geometrical conditions achieved (strain gauges at correct position, etc).
	• Stable strain response prior to, and during, overcoring with minimal strain drift (strain change less than 10 µstrains per 15 min for undisturbed conditions).
	• No fractures and/or ring disking observed in the overcore sample (at least 24 cm intact core).
	• Linear and isotropic (20–30% deviation acceptable) strain response during biaxial testing. Minor hysteresis (< 100 µstrains) accepted.
	• Stress calculation possible with classical analysis (Section 4.6.1). Values on elastic constants may be assumed from nearby tests if biaxial test data are lacking, and all other criteria above are satisfied.
b	**Partly successful test**
	• Signs of debonding but fairly stable strain response up until peak value (typically at 24–30 cm drill bit position).
	• Stress calculation possible with classical analysis (Section 4.6.1) but results judged uncertain and/or less reliable.
	• Additional stress determination may be conducted using inverse solution of transient strain analysis (Section 4.6.2).
c	**Failed test**
	• Installation failed or incomplete.
	• Debonding of strain gauges and/or large strain drift.
	• Fractures/joints detected in overcore sample.

Table 5-1. General test data from measurements in borehole KFM07C, Forsmark.

Test no. (pilot hole no. *)	Hole length [m]	Vertical depth [m] **)	Overcoring	Biaxial testing	Transient strain analysis	Rating	Comments
1:1:5	98.76	98.29	Yes	No	Yes	a	Successful installation, but biaxial test failed due to cable failure. Stable strain response during overcoring. Some gauges responded somewhat on the flush stop.
1:2:4	104.53	104.03	Yes	Yes	Yes	b	Successful installation. Stable strain response during overcoring, some gauges responded to flush stop.
1:3:2	107.53	107.01	Yes	No	No	c	Installation failed, rock fragment affected the gauges.
1:4:1	108.42	107.90	Yes	Yes	Yes	b	Successful installation and overcoring. Stable strain response during overcoring. Some gauges responded somewhat on the flush stop.
1:5:1	109.46	108.93	Yes	No	No	c	Installation failed, rock fragment prevented the gauges holder from entering the pilot hole.
2:1:3	158.28	157.46	Yes	Yes	Yes	b	Successful installation and stable strain response during overcoring. Unstable biaxial response. Some gauges responded some-what on the flush stop.
2:2:1	159.32	158.50	Yes	No	No	c	Successful installation, but biaxial test failed. Stable strain response during overcoring. Horizontal crack at 8 cm.
2:3:1	160.37	159.54	Yes	Yes	Yes	b	Successful installation. Stable strain response during overcoring. Horizontal crack at 58 cm. Some gauges responded somewhat on the flush stop.
2:4:1	162.69	161.85	Yes	Yes	Yes	a	Successful installation. Stable strain response during overcoring. Some gauges responded somewhat on the flush stop. A response on the strain gauges at 09:45 due problems with drill equipment.
2:5:3	166.81	165.94	Yes	No	No	c	Ring disking before installation depth on WL cores. Drill bit broke while overcoring. No data could be acquired.
2:6:1	168.12	167.25	Yes	No	No	c	Drill bit broke while over-coring. No data could be acquired.

Test no. (pilot hole no. *)	Hole length [m]	Vertical depth [m] **)	Overcoring	Biaxial testing	Transient strain analysis	Rating	Comments
2:7:3	173.56	172.65	Yes	Yes	No	c	Successful installation. Stable strain response during overcoring. Biaxial response somewhat unstable. Lot of drill cuttings or cement in the pilot hole and at strain gauges, 17 cm at the bottom and filled protective cone. Varying rock condiotions before suitable rock mass for installation.
2:8:1	174.60	173.69	Yes	Yes	Yes	b	Successful installation. Stable strain response during overcoring. Some gauges responded some-what on the flush stop.
2:9:1	175.62	174.70	Yes	Yes	Yes	b	Successful installation. Stable strain response during overcoring towards position for strain gauges, afterwards some strain drift. Some gauges responded somewhat on the flush stop.
2:10:1	176.65	175.72	Yes	Yes	Yes	b	Successful installation. Stable strain response during overcoring towards position for strain gauges, afterwards some strain drift. Some gauges responded somewhat on the flush stop.
2:11:1	177.65	176.72	Yes	Yes	Yes	b	Successful installation. Stable strain response during overcoring towards position for strain gauges, afterwards some strain drift. Some gauges responded somewhat on the flush stop.
2:12:1	178.67	177.73	Yes	Yes	No	c	Successful installation. Some unstable strain response during overcoring. Some gauges responded somewhat on the flush stop. Biaxial test response unstable.
3:1:1	192.47	191.46	Yes	Yes	Yes	b	Successful installation and stable strain response during overcoring. Some strain gauges showed drift after the drill bit having passed the position for strain gauges and relative unstable biaxial response. Some gauges responded somewhat on the flush stop.
3:2:1	193.23	192.21	Yes	No	No	c	Successful installation, somewhat unstable strain response during overcoring and unstable biaxial response.

Test no. (pilot hole no. *)	Hole length [m]	Vertical depth [m] **)	Overcoring	Biaxial testing	Transient strain analysis	Rating	Comments
3:3:1	194.36	193.33	Yes	No	No	c	Successful installation, somewhat unstable strain response during overcoring. Biaxial test failed due to cable malfunction. Additional biaxial testing was performed.
3:4:1	195.31	194.28	Yes	Yes	Yes	b	Successful installation and stable strain response during overcoring. Less strain drift after corebit passing the position for strain gauges. Some gauges responded some-what on the flush stop. Relative stable biaxial response.
3:5:1	196.37	195.33	Yes	Yes	No	c	Successful installation but unstable strain response during overcoring and unstable biaxial response.
3:6:1	197.28	196.23	Yes	Yes	Yes	a	Successful installation and stable strain response during overcoring but unstable biaxial response. Some gauges responded somewhat on the flush stop. Ring disking at the top the overcored core.
4:1:2	238.05	236.93	Yes	Yes	Yes	b	Large grains near the strain gauges. The gauges are well glued to the rock surface. Some gauges responded somewhat on the flush stop. Very unstable strain response in the biaxial test.
4:2:3	242.70	241.40	Yes	Yes	Yes	b	Fractures between the earlier installation and this one. Strain gauges glued extremely well. Some gauges responded somewhat on the flush stop. Very unstable strain response in the biaxial test.
	~244 to ~253	High amount of broken rock core, ring disking on WL-cores (hollow), quartz, pegmatite.					
4:3:4	255.53	254.17	Yes	Yes	No	c	Strain gauges glued only fair. Some ring disking on WL cores (hollow).
4:4:2	258.73	257.35	Yes	Yes	Yes	b	Strain gauges glued extremely well. Some gauges responded some-what on the flush stop. Tendencies to ring disking on the core.
4:5:1	259.63	258.24	Yes	No	No	c	Strain gauges glued extremely well. Ring disking over entire overcoring core.

Test no. (pilot hole no. *)	Hole length [m]	Vertical depth [m] **)	Overcoring	Biaxial testing	Transient strain analysis	Rating	Comments
4:6:2	263.14	261.73	Yes	No	No	c	Strain gauges glued well. Ring disking in the top of the core and tendencies of ring disking at the position of strain gauges.
5:1:1	304.15	302.52	Yes	No	No	c	Very unrealistic strain response, large ring disking in the core.
5:2:3	312.72	311.05	Yes	No	No	c	Very unrealistic strain response, large ring disking in the core.
5:3:4	316.25	314.56	Yes	Yes	Yes	b	Stable strain response but tendecies of ring disking on top of the core.
5:4:1	317.64	315.94	Yes	Yes	No	c	Unrealistic strain response, steeply dipping fracture at outer boundary of the core, parallel with core axis.
5:5:2	322.28	320.56	Yes	No	No	c	Very unrealistic strain response, steeply dipping fracture at outer boundary of the core, parallel with core axis.
6:1:2	419.35	417.12	Yes	No	No	c	Very unrealistic strain response, core damaged on the top and down ~8 cm and with tendencies to more damages.
6:2:1	420.50	418.27	Yes	Yes	No	c	Unstable strain response before overcoring, biaxial test gave very unstable response.
6:3:1	422.58	420.33	Yes	No	No	c	Unstable strain response, and ring disking along the whole core.
6:4:1	423.77	421.52	Yes	No	No	c	Unstable strain response, and ring disking along the whole core.
6:5:2	425.55	423.29	Yes	No	No	c	Ring disking along the whole core.

*) numbering scheme: *(measurement level : test no. : pilot hole no.),*

**) vertical depth (below ground surface) interpolated from borehole orientation measurements (every three metres).

At some measurements there is a strain response at flush stop, which is most probably caused by the relative change in physical conditions for the strain gauges that occur when hard flushing suddenly stops.

Borehole orientations for the measurement depths in question are shown in Table 5-2, as measured after completed drilling of the hole. Inclination, bearing and vertical depth at measuring points are calculated from given borehole orientation data measured with the "Flexit"-unit, data given to Vattenfall Power Consultant in January 2007. These orientation data were used in the stress calculations described below, together with the recorded orientations of the installed Borre probe.

Table 5-2. Borehole orientation for overcoring measurement points in borehole KFM07C. Orientations taken from nearest (3 metre) measured section.

Level no.	Test no. (pilot hole no. *)	Hole length [m]	Borehole bearing [°] **)	Borehole dip [°] ***)
1	1:1:5	98.76	153.83	83.66
1	1:2:4	104.53	154.30	83.68
1	1:3:2	107.53	154.31	83.71
1	1:4:1	108.42	154.29	83.72
1	1:5:1	109.46	154.25	83.72
2	2:1:3	158.28	154.18	83.85
2	2:2:1	159.32	154.16	83.85
2	2:3:1	160.37	154.14	83.85
2	2:4:1	162.69	154.02	83.85
2	2:5:3	166.81	153.63	83.86
2	2:6:1	168.12	153.61	83.86
2	2:7:3	173.56	153.55	83.86
2	2:8:1	174.60	153.55	83.86
2	2:9:1	175.62	153.56	83.86
2	2:10:1	176.65	153.57	83.86
2	2:11:1	177.65	153.41	83.86
2	2:12:1	178.67	153.16	83.85
3	3:1:1	192.47	152.34	83.89
3	3:2:1	193.23	152.38	83.90
3	3:3:1	194.36	152.45	83.90
3	3:4:1	195.31	152.51	83.90
3	3:5:1	196.37	152.58	83.90
3	3:6:1	197.28	152.64	83.90
4	4:1:2	238.05	150.07	84.22
4	4:2:3	242.70	153.27	83.98
4	4:3:4	255.53	152.66	84.02
4	4:4:2	258.73	152.78	84.02
4	4:5:1	259.63	152.78	84.03
4	4:6:2	263.14	152.79	84.04
5	5:1:1	304.15	152.31	84.10
5	5:2:3	312.72	151.93	84.10
5	5:3:4	316.25	151.95	84.12
5	5:4:1	317.64	151.96	84.12
5	5:5:2	322.28	151.96	84.12
6	6:1:2	419.35	149.62	84.17
6	6:2:1	420.50	149.64	84.17
6	6:3:1	422.58	149.48	84.19
6	6:4:1	423.77	149.32	84.19
6	6:5:2	425.55	149.03	84.19

*) numbering scheme: *(measurement level : test no. : pilot hole no.),*
**) clockwise from geographic north,
***) positive downward from the horizontal.

5.2 Overcoring test data

Results from all tests with rating *a* and *b* in Table 5-1 are presented in the following and in Appendices A through G. Key measurement data (recorded times for borehole activities) for these tests are presented in Appendix A. Furthermore, core logs and photos are presented in Appendices F and G. The core logs were conducted during the field campaign.

The strain response for each test is shown in Appendix B. Each test is presented with two plots displaying (i) the complete strain record (from activation of probe to core recovery), and (ii) the strain response from overcoring start to end of strain registration (core recovered from borehole). The latter was used to define strain differences for later input to stress calculation. The times for which the strain differences have been determined are shown in Appendix A, activity "OC Start" and "OC Stop". The actual times for which the overcoring has been performed ("OC Start" and "OC Stop") is shown together with time for drill bit passing position for strain gauges and core break in the Figures in Appendix B.

5.2.1 Measurement Level 1

A total of five installations were attempted at the first measurement level in borehole KFM07C. During installation and overcoring of all tests, no exceptional events were observed. Out of these measurements, one successful test (1:1:5) and two partially successful tests (1:2:4 and 1:4:1) were obtained. Both test nos. 1:3:2 and 1:5:1, failed due to rock fragments (in the borehole) preventing proper installation. All successful and partly successful tests at this level displayed stable strain response during overcoring and successful biaxial tests, except test no. 1:1:5 where the biaxial test failed. The measured temperature increased in the probe during overcoring with 1–2.5°C but returned to pre-overcoring temperature after completed overcoring and flushing.

5.2.2 Measurement Level 2

In total, 12 measurements were performed at this level. No exceptional events were observed during installation and overcoring except for test 2:4:1. Shortly after overcoring started, very high water pressure was observed. The drill string was pulled and with the equipment at surface it was found that the new core barrel was 4 mm longer than normal, which prevented proper water flow. This was adjusted and the overcoring could continue without any effects on the test performance and quality. At this level one successful test (2:4:1) and six partially successful tests (2.1.3, 2:3.1, 2:8:1, 2:9:1, 2:10:1 and 2:11:1) were obtained. For these six tests, the main reason for not having *a*-rating is strain drift after the drill bit having passed the strain gauges. The unsuccessful tests (2:2:1, 2:5:3, 2:6:1, 2:7:3 and 2:12:1) suffered mainly from drilling problems (drill bite failure), fractures, or drill cuttings preventing good bonding. At this level the measured temperature increased in the probe during overcoring between 3–4.5°C, but returned to 0.5–1.5°C above pre-overcoring temperature after completed overcoring and flushing.

5.2.3 Measurement Level 3

Six measurements were attempted, and one test (3:6:1) was judged successful and two partly successful (test nos. 3.1:1 and 3.4:1). For test 3:6:1, the biaxial test gave unstable response but suffered also from ring disking at the top of the core sample (one ring disk). The partly successful tests displayed some strain drift after the drill bit having passed the position for the strain gauges and during the biaxial test. The main reason for these tests not having an *a*-rating is strain drift after the drill bit passed the strain gauges. At this level the measured temperature increased in the probe during overcoring between 2.5–4.5°C but returned to 1–1.5°C above pre-overcoring temperature after completed overcoring and flushing.

5.2.4 Measurement Level 4

At this level, six measurements were performed. Three partly successful tests were obtained (4:1:2, 4:2:3 and 4:4:2) and all three were bonded very hard against the rock wall. The main reason for these tests not having an *a*-rating is strain drift after the drill bit passed the strain gauges, as well as difficulties of achieving completely successful biaxial tests. For test 4:1:2 large grains were attached on the strain gauges. Fractures before the position of test 4:2:3 and a larger zone of fractured rock with high contents of quartz and pegmatite and occurrence of ring disking after test no 4:2:3 gave an unfavourable situation for stable strain response. For test 4:4:2 there were tendencies of ring disking on the core. For the remaining unsuccessful tests (4:3:4, 4:5:1 and 4.6:2) they all suffered from various degrees of ring disking. At this level the measured temperature increased in the probe during overcoring between 2.5–4.5°C but returned to 1°C above pre-overcoring temperature after completed overcoring and flushing.

5.2.5 Measurement Level 5

Totally five installations were performed but only one was judged as partly successful (5:3:4). This test showed stable strain response but gave unrealistic, very low horizontal stresses, 0 and 7 MPa, for the minor and major horizontal stress, respectively, and the vertical stress –7.5 MPa. For the first two tests nos. (5.1:1 and 5:2:3) ring disking occurred in the overcore sample and for the last two tests (nos. 5:4:1 and 5:5:2), a long steeply dipping fracture followed the core axis on the outer boundary of the core. For test no 5:3:4 the temperature increased in the probe with 4.5°C during overcoring but returned to 2°C above pre-overcoring temperature after completed overcoring and flushing.

5.2.6 Measurement Level 6

Five installations were conducted, but all tests were judged unsuccessful due to fracture and core damages on the two first tests (6:1:2 and 6:2:1) and extensive ring disking on the following tests (6:3.1. 6:4:1 and 6:5:2). Since ring disking occurred in such amount at this level and had been present at Level 4 and to a high extent at Level 5, SKB decided to terminate the measurement campaign.

5.3 Biaxial test data

All suitable overcore rock samples were tested in the biaxial cell to determine the elastic properties. Two tests (nos. 1:1:5 and 3:3:1) failed due to cable malfunction. At the upper levels (Level 1 and 2) the majority of the successful installations also had successful biaxial test. For Level 1, test nos. 1:2:4 and 1:4:1 had stable and linear strain response. For Level 2, test nos. 2:8:1 and 2:10:1 also gave stable results using all gauges while tests nos. 2:1:3, 2:3:1, 2:4:1, 2:9:1 and 2:11:1 gave stable and linear results when one strain rosette was excluded. The rosette that was excluded varied from test to test and the main reason for exclusion was unstable strain response.

Biaxial tests from measurements at Level 3 had less successful response. For test no. 3:6:1, all rosettes gave relative stable and linear response and were used for determining the elastic properties. For test nos. 3:1:1 and 3:4:1, one rosette had to be excluded to obtain reliable results from the biaxial test. At Level 4 the amount of unstable and non-linear behaviour of the gauges increased. The results from test no. 4:1:2 could not be used due to non-linear response from the gauges. This behaviour could possibly be due to the presence of larger grains in the sample. Test no. 4:2:3 gave usable results when excluding rosette no. 3, even if the response from remaining strain gauges had some hysteresis. The most stable and linear result at Level 4 came from test no. 4:4:2 after excluding different gauges at different strain rosettes. The results from the biaxial tests on overcore rock samples from tests with rating *a* and *b* are shown in Table 5-3. The scatter of the Young's modulus is relatively low as well as for Poisson's ratio for all levels, with few exceptions. Test no. 2:11:1 gave low values whereas tests nos. 2:9:1, 3:6:1, 4:2:3 and 4:4:2 gave very high, which can be an indication of core damages.

Table 5-3. Results from biaxial testing on *a* and *b* rated overcore samples from borehole KFM07C.

Level no.	Measurement no. (pilot hole no. *)	Hole length [m]	Young's modulus, *E* [GPa]	Poisson's ratio, ν
1	1:2:4	104.53	63.4	0.30
1	1:4:1	108.42	72.7	0.30
1	**Mean**	**–**	**68.0**	**0.30**
2	2:1:3	158.28	71.3	0.32
2	2:3:1	160.37	58.5	0.31
2	2:4:1	162.69	63.5	0.30
2	2:8:1	174.60	67.0	0.23
2	2:9:1	175.62	80.9	0.36
2	2:10:1	176.65	69.2	0.28
2	2:11:1	177.65	56.4	0.16
2	**Mean**	**–**	**66.7**	**0.28**
3	3:1:1	192.47	78.3	0.24
3	3:4:1	195.31	68.5	0.26
3	3:6:1	197.28	76.1	0.41
3	**Mean**	**–**	**74.3**	**0.30**
4	4:1:2[1)]	238.05	N/A	N/A
4	4:2:3[2)]	242.70	81.7	0.40
4	4:4:2[3)]	258.73	72.2	0.42
4	**Mean**	**–**	**76.9**	**0.41**

*) numbering scheme: *(measurement level : test no. : pilot hole no.)*,
[1)] very unstable strain response; values not usable,
[2)] unstable strain response; values usable,
[3)] unstable strain response; using linear fit at the loading stage.

5.4 Results from uniaxial testing of pilot core samples

Three uniaxial samples (A–C) were taken from pilot cores at selected depths, see Table 5-4, to represent each corresponding biaxial test. Sample A was taken 3 cm above the exact position of the strain gauges for the corresponding test. Sample B was taken at the exact location, and sample C 3 cm below the position of the strain gauges on the overcore sample. A mean value and standard deviation were then determined for each group (A–C samples) representing elastic properties for corresponding measurement. The results used in the comparison with the results from biaxial tests are shown in Table 5-4 and determined using the secant values to be comparable to the biaxial tests. All available results from the uniaxial compression testing are shown in Appendix J.

The results from the uniaxial testing program may differ when compared to those from the biaxial tests due to local discrepancies in geology. But the test samples for the uniaxial tests have been chosen to represent similar rock mass as those of the rock cores subjected to biaxial testing. There is also a difference in load direction towards any foliations in a uniaxial test compared to a biaxial test, which can influence the result. In addition, there is a difference of the thickness of the tested specimen between uniaxial and biaxial tests. Nevertheless, there is only a minor difference between the values of Young's modulus determined from the biaxial tests and uniaxial tests. For example at Level 1, the uniaxial tests gave a Young's modulus (E) = 72 GPa and Poisson's ratio (ν) = 0.23, compared to results from biaxial tests where measured E (mean value) = 68 GPa and ν = 0.30. The largest differences between results from uniaxial and biaxial tests were obtained for Level 3, where uniaxial tests gave E = 62 GPa and Poisson's ratio (ν) = 0.19 to be compared with the results from biaxial tests, which provided E (mean value) = 74.3 GPa and ν = 0.30.

Table 5-4. Results from uniaxial test on pilot cores from borehole KFM07C.

Level no.	Measure-ment no.*	Hole length [m]	Young's modulus, *E* [GPa]	Standard deviation, *E* [GPa]	Poisson's ratio, ν	Standard deviation, ν
1	1:1:5	98.76	71.2	2.3	0.21	0.01
1	1:2:4	104.53	72.3	2.2	0.23	0.00
2	2:2:1	159.32	66.1	2.0	0.23	0.01
2	2:8:1	174.60	68.7	2.1	0.22	0.01
3	3:4:1	195.31	62.1	1.6	0.19	0.00
4	4:1:2	238.05	69.5	1.9	0.22	0.01
4	4:2:3	242.70	71.9	1.3	0.24	0.01
5	5:3:4	316.25	70.3	1.6	0.22	0.01
6	6:2:1	420.50	71.3	1.9	0.23	0.01

*) numbering scheme: *(measurement level : test no. : pilot hole no.)*.

Due to the discussed differences between the two test types, sample size, geology, etc, the difference in the results can be considered as negligible, especially for Young's modulus. Poisson's ratio obtained from biaxial tests, however, differed some compared to the values obtained from uniaxial tests. The biaxial tests gave higher Poisson's ratio compared to uniaxial tests, for Level nos. 1, 2 and 3. The differences in results from the biaxial and uniaxial tests were relatively small for Level nos. 1, 2 and 3. Though, for Level 4 the biaxial tests gave higher values compared to the previous levels and compared to values obtained from uniaxial tests on pilot cores from Level 4.

Due to the small difference in Young's modulus for all levels and Poisson's ratio for the upper three levels (nos. 1 through 3), it was decided to use the results obtained from biaxial tests, since these results are obtained from loading conditions similar to the load conditions at overcoring. The small differences gave negligible differences in the determination of he stress state. The results from the uniaxial tests are instead used for this measurement campaign as a quality control of the results obtained from the biaxial tests.

5.5 In situ stress state

The in situ stress state was calculated using: (i) the measured strain response (difference between strain gauge readings after and prior to overcoring), (ii) recorded orientation of strain gauge rosettes in the borehole, and (iii) values on elastic constants determined from biaxial testing. Strain differences were determined from stable strain values before overcoring vs. stable values after completed overcoring. For tests with post-overcoring response with strain drift, the final strain values were taken at the end of the flushing period (just before core break) to minimize the possible influence of temperature on the strain readings (cf. Appendix A in which the times for which strain differences were calculated are given by the activity "OC Start" and "OC Stop", respectively).

The mean stresses were calculated from all successful (rating *a*) and partly successful (ratings *b*) measurements at Level 1, 2, 3 and 4. At Level 5, one test (5:3:4) gave strain response that was stable but the other tests at Level 5 and 6 yielded unstable or gave unrealistic strain response. The strain response curves were either very unstable or gave very small overcoring strain change, corresponding to principal stresses between 2 to –2 MPa. A majority of the cores at Level no. 5 and 6 also suffered from ring disking and/or fractures sub-parallel to the borehole axis. For this reason, no stress calculation was performed at Level nos. 5 and 6.

In the stress calculation, Level 2 is divided into Level 2A and 2B due to a relatively large distance between the first group of measurements (2A) and the second (2B) due to drilling problems and a 10 m wide zone of disturbed geology. The distance between these two groups is the same as the distance between Level 2B and Level 3. Also, the results indicated a general change in stress orientation between Level 2A and 2B. Level 4 is also extended over a longer distance in the borehole and intersected by a zone of disturbed geology between tests nos. 4:2:3 and 4:4:2. Unfortunately, it was not possible to obtain more successful tests at Level 4 due to ring disking.

There is a difference in the strain response between Level 1 and Levels nos. 2 through 4. From Level 2 and downwards in the borehole there is a general strain drift in the post-overcoring response from the strain gauges. After completed overcoring and during the following flushing period, this general strain drift decreases and stands stable before the flushing period is over. It is also observed that there is a difference in measured temperature increase during overcoring at Level 1 compared to Levels nos. 2 through 4.

Based on this, strain values have been taken from ordinary start-stop time of overcoring (normal procedure) for Level 1. Due to what seems to be a temperature influence on the measurements, the strain values for determining the stresses for Level nos. 2 through 4 have been selected from an extended time interval. The start values for determining the stresses ("OC Start") have been chosen slightly before the start of overcoring but after start of flushing, and the stop values ("OC Stop") have been chosen after completed overcoring but slightly before the end of flushing. This was done in order to use start-stop values for determining the strain differences for constant physical conditions and with as small effect as possible from the temperature increase related to drilling.

The resulting stresses for each test, as well as the mean values for Level 1, 2, 3 and 4 are shown in Appendix D, and in Table 5-5, Table 5-6, and Table 5-7. All orientations are given relative to geographic North. Orientations of the principal stresses are also shown in Figure 5-1 to Figure 5-5 for Level 1, 2, 3 and 4. All original data are stored in the SKB database Sicada.

The calculated mean horizontal stresses for Level 1 were high but with small individual scatter between the measurements. The only exception is the minor horizontal stress for test no 1:1:5. The determined vertical stress for Level 1 is somewhat high but in fair agreement with the theoretical vertical stress determined from overburden weight and with only a minor scatter between the individual tests.

For Level 2A, the scatter is large for the major horizontal stress and its direction between test no. 2:4:1 and test nos. 2:1:3 and 2:3:1. For the minor horizontal stress, the measured results also show a large scatter. Test nos. 2:3:1 and 2:4:1 have similar vertical stress (although high compared to the theoretical vertical stress) whereas test 2:1:3 gave negative values for the vertical stress. The results from Level 2B show very similar magnitudes for the major horizontal stress for test nos. 2:9:1, 2:10:1 and 2:11:1, but the tests at Level 2B demonstrated different major directions for the major horizontal stress which could be divided into two major orientations. The first major orientation was obtained by test nos. 2:8:1 and 2:9:1 and the second by test nos. 2:10:1 and 2:11:1. This grouping can also be done with respect to the vertical stress. The first group resulted in a vertical stress in good agreement with theoretical while the second group gave a somewhat high vertical stress compared to the theoretical vertical stress due to overburden weight.

The measurements at Level 3, test nos. 3:1:1 and 3:4:1, resulted in similar major, minor and vertical stress between the tests, both in magnitude and orientations. Test no 3:6:1 showed diverging results from the other two successful tests, especially in orientation of horizontal stresses. This test was also subjected to some ring disking on top of the core. All measurements resulted in similar vertical stress, though twice the magnitude of the theoretical vertical stress.

Table 5-5. Magnitudes of principal stress as determined by overcoring in borehole KFM07C.

Level no.	Measurement no. (pilot hole no. *)	Hole length [m]	σ_1 [MPa]	σ_2 [MPa]	σ_3 [MPa]
1	1:1:5	98.76	28.0	22.0	1.5
1	1:2:4	104.53	26.2	12.1	1.3
1	1:4:1	108.42	24.5	12.8	–2.4
1	**Mean**	**–**	**24.8**	**14.5**	**2.6**
2A	2:1:3	158.28	22.4	5.6	–10.2
2A	2:3:1	160.37	27.9	13.0	6.8
2A	2:4:1	162.69	39.6	21.3	8.5
2A	**Mean**	**–**	**22.9**	**19.5**	**2.6**
2B	2:8:1	174.60	38.5	17.4	5.1
2B	2:9:1	175.62	23.5	8.8	4.1
2B	2:10:1	176.65	26.3	13.1	8.3
2B	2:11:1	177.65	26.8	19.7	12.2
2B	**Mean**	**–**	**24.9**	**18.2**	**7.8**
3	3:1:1	192.47	27.2	10.8	9.4
3	3:4:1	195.31	22.6	9.8	7.2
3	3:6:1	197.28	31.2	16.1	11.8
3	**Mean**	**–**	**20.4**	**17.2**	**11.1**
4	4:1:2	238.05	27.1	9.3	–0.7
4	4:2:3	242.70	47.1	26.9	17.3
4	4:4:2	258.73	32.9	15.6	7.3
4	**Mean**	**–**	**31.0**	**18.6**	**11.3**

*) numbering scheme: *(measurement level : test no. : pilot hole no.).*

Table 5-6. Orientations of principal stress as determined by overcoring in borehole KFM07C.

Level no.	Measurement no. (pilot hole no. *)	Hole length [m]	σ_1 Trend/Plunge [°]	σ_2 Trend/Plunge [°]	σ_3 Trend/Plunge [°]
1	1:1:5	98.76	175/03	084/21	272/68
1	1:2:4	104.53	170/09	263/22	059/66
1	1:4:1	108.42	010/24	109/21	236/58
1	**Mean**	**–**	**354/02**	**085/18**	**258/72**
2A	2:1:3	158.28	282/04	014/26	184/63
2A	2:3:1	160.37	139/01	049/09	233/81
2A	2:4:1	162.69	215/02	305/11	117/79
2A	**Mean**	**–**	**286/04**	**017/08**	**167/81**
2B	2:8:1	174.60	355/08	085/01	185/82
2B	2:9:1	175.62	176/02	266/03	057/87
2B	2:10:1	176.65	051/05	143/25	310/65
2B	2:11:1	177.65	270/06	001/07	141/80
2B	**Mean**	**–**	**009/04**	**279/00**	**186/86**
3	3:1:1	192.47	116/16	024/08	269/72
3	3:4:1	195.31	326/22	081/46	219/36
3	3:6:1	197.28	222/06	313/10	103/79
3	**Mean**	**–**	**304/01**	**034/06**	**206/84**
4	4:1:2	238.05	208/05	299/10	093/79
4	4:2:3	242.70	324/18	072/43	217/41
4	4:4:2	258.73	003/11	103/41	260/47
4	**Mean**	**–**	**354/11**	**086/05**	**200/78**

*) numbering scheme: *(measurement level : test no. : pilot hole no.).*

Table 5-7. Horizontal and vertical stress components calculated from measured principal stresses in borehole KFM07C.

Level no.	Measurement no. (pilot hole no. *)	Hole length [m]	σ_H [MPa]	σ_h [MPa]	σ_v [MPa]	Trend σ_H [°]
1	1:1:5	98.76	27.9	19.2	4.3	177
1	1:2:4	104.53	25.7	10.5	3.4	168
1	1:4:1	108.42	21.1	10.1	3.8	178
1	**Mean**	**–**	**24.8**	**13.3**	**3.9**	**173**
2	2:1:3	158.28	22.2	2.5	–6.9	101
2	2:3:1	160.37	27.9	12.9	7.0	139
2	2:4:1	162.69	39.6	20.8	9.0	035
2A	**Mean**	**–**	**22.8**	**19.2**	**3.0**	**103**
2	2:8:1	174.60	37.9	17.4	5.7	175
2	2:9:1	175.62	23.5	8.7	4.1	176
2	2:10:1	176.65	26.1	12.3	9.3	050
2	2:11:1	177.65	26.6	19.6	12.5	090
2B	**Mean**	**–**	**24.9**	**18.2**	**7.9**	**009**
3	3:1:1	192.47	25.9	10.8	10.8	116
3	3:4:1	195.31	20.7	8.2	10.7	144
3	3:6:1	197.28	31.0	15.9	12.1	042
3	**Mean**	**–**	**20.4**	**17.1**	**11.2**	**124**
4	4:1:2	238.05	26.9	9.0	–0.2	028
4	4:2:3	242.70	44.7	21.9	24.8	140
4	4:4:2	258.73	32.1	11.8	11.9	00
4	**Mean**	**–**	**30.2**	**18.6**	**12.1**	**174**

*) numbering scheme: *(measurement level : test no. : pilot hole no.).*

The results from Level 4 displayed a large scatter in terms of both magnitude and orientation of the stresses despite the fact that all tests exhibited good bonding. However, extensive ring disking occurred at this level. The vertical stresses determined from the partly successful measurements gave unrealistically high values compared to the theoretical vertical stress.

Confidence intervals were calculated for the measurement results using the methodology proposed by /Walker et al. 1990/ and a newly developed computer code (described in /Lindfors et al. 2005/). Confidence intervals were determined for both magnitudes and orientations of the principal stresses at Level 1 to 4 , as well as for the horizontal and vertical stress components. In this report, only the 90%-confidence intervals are presented, see Appendix H.

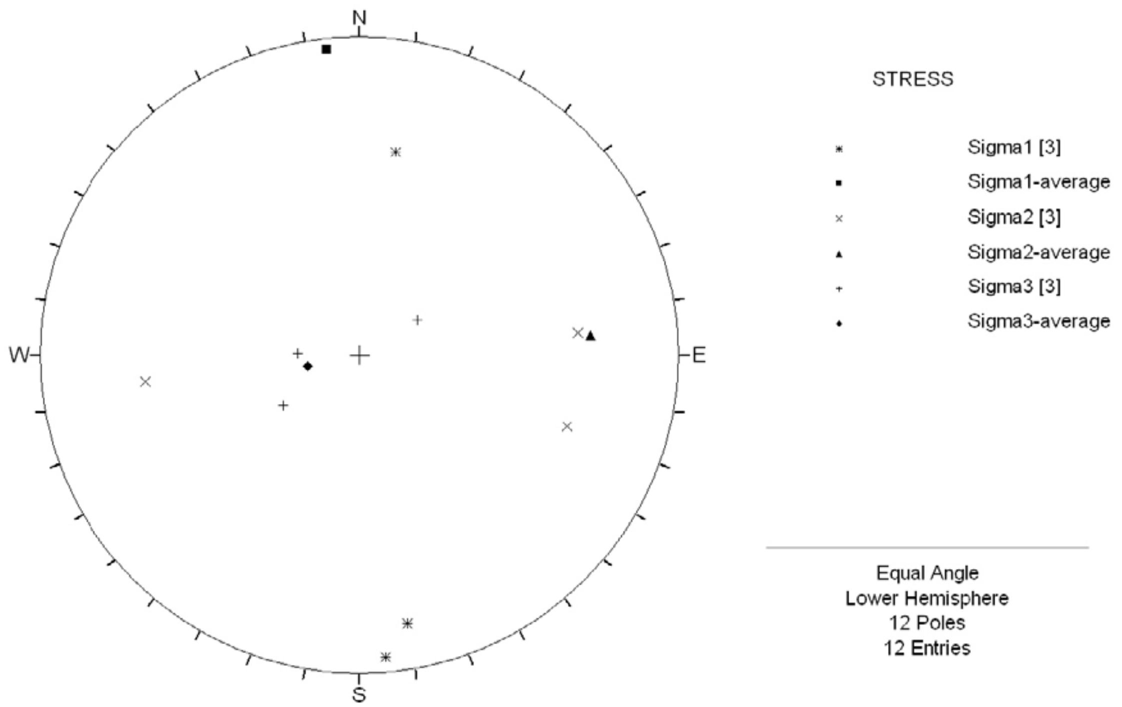

Figure 5-1. *Orientations of measured principal stresses in borehole KFM07C, Level 1, shown in a lower hemisphere projection (all measurements with ratings a and b; only one measurement with rating a, cf. Table 5-1).*

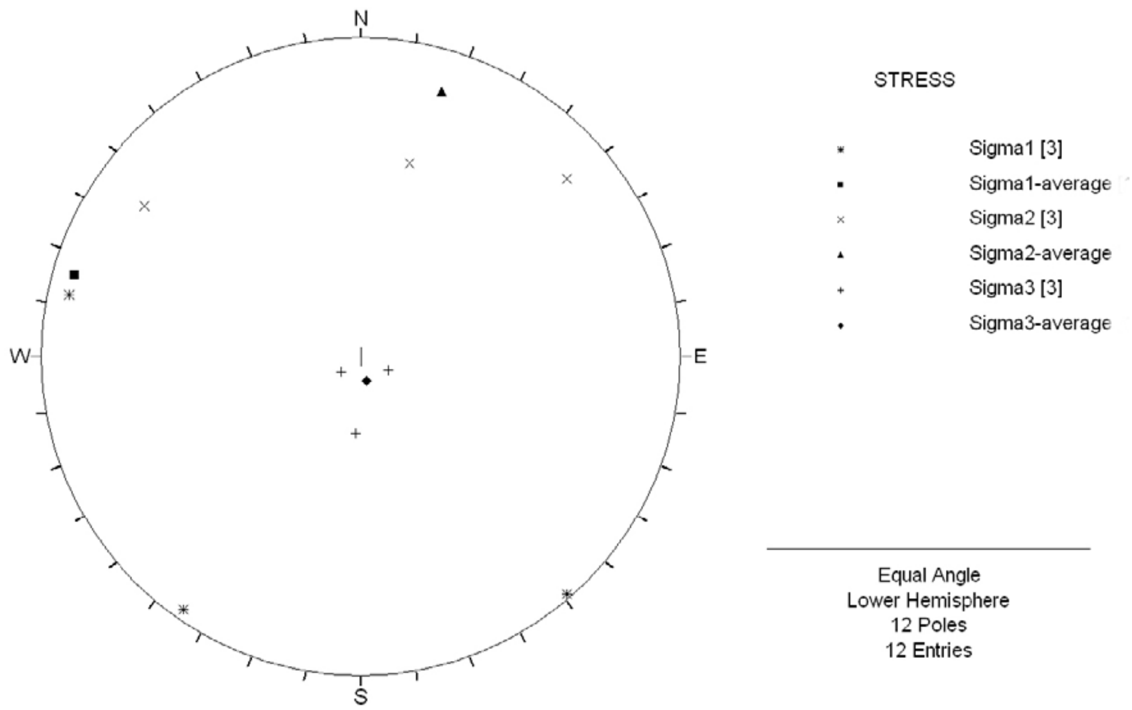

Figure 5-2. *Orientations of measured principal stresses in borehole KFM07C, Level 2A, shown in a lower hemisphere projection (all measurements with ratings a and b; only one measurement with rating a, cf. Table 5-1).*

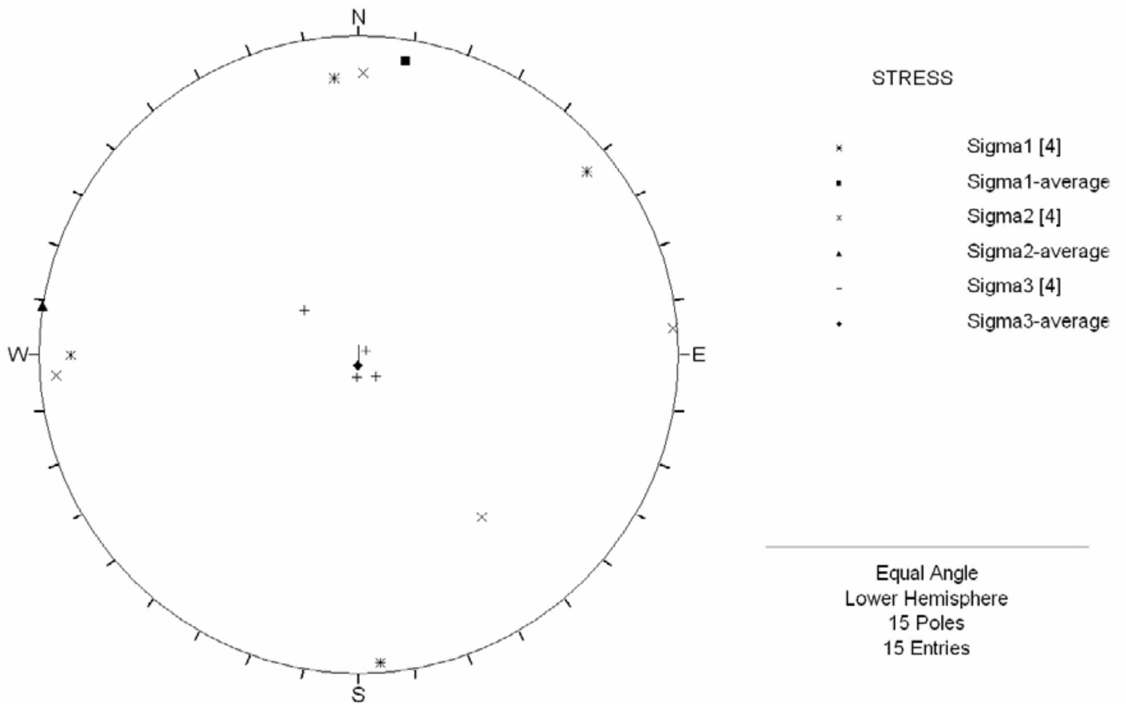

Figure 5-3. *Orientations of measured principal stresses in borehole KFM07C, Level 2B, shown in a lower hemisphere projection (all measurements with ratings a and b; only one measurement with rating a, cf. Table 5-1).*

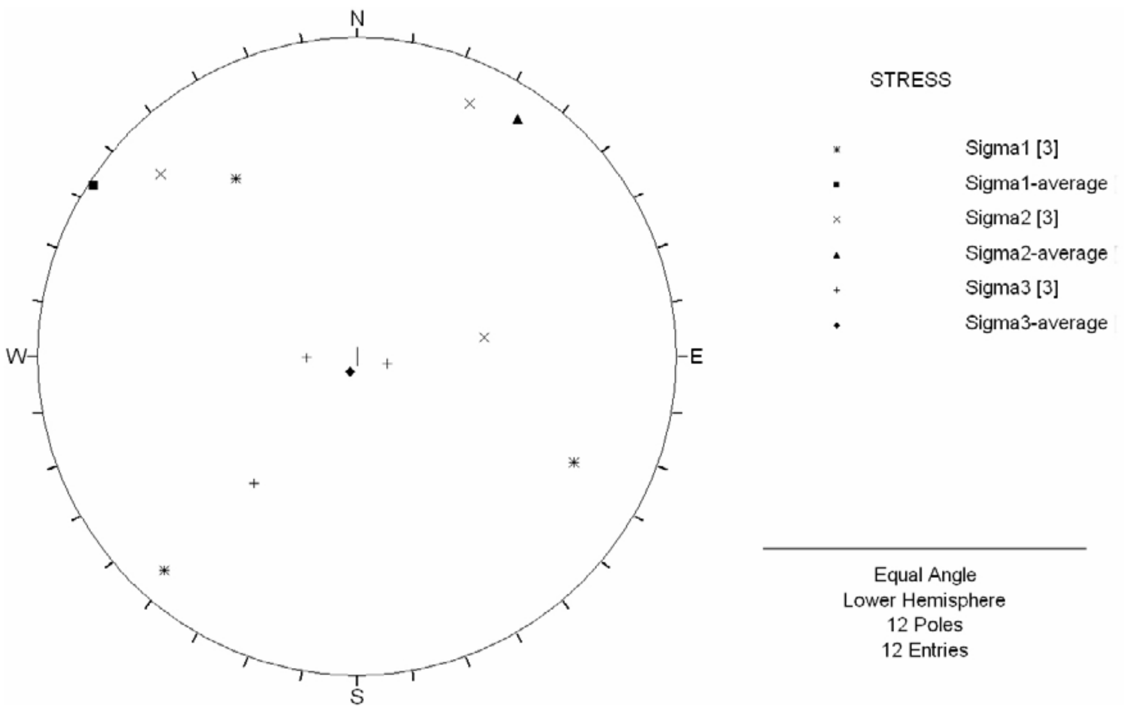

Figure 5-4. *Orientations of measured principal stresses in borehole KFM07C, Level 3, shown in a lower hemisphere projection (all measurements with ratings a and b; only one measurement with rating a, cf. Table 5-1).*

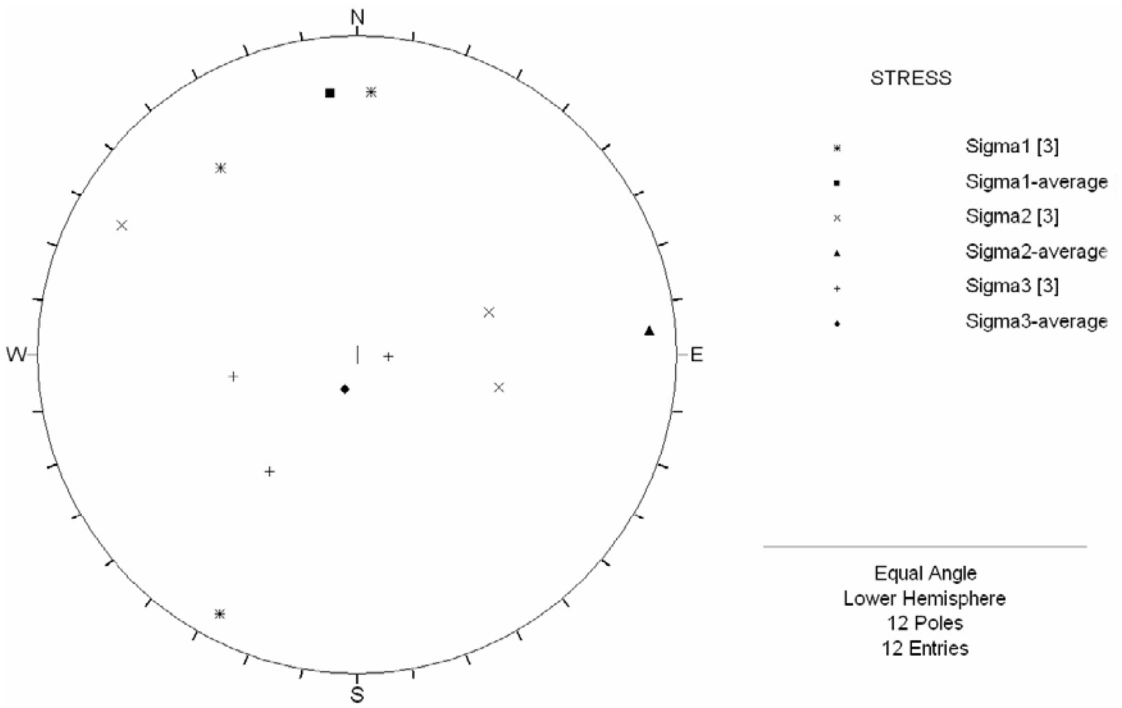

Figure 5-5. *Orientations of measured principal stresses in borehole KFM07C, Level 4, shown in a lower hemisphere projection (all measurements with ratings a and b; only one measurement with rating a, cf. Table 5-1).*

5.6 Transient strain analysis

5.6.1 Transient strain response

Transient strain analysis was conducted for all tests with ratings *a* and *b* from Levels 1, 2, 3, 4, and 5 (see Table 5-1). The resulting calculated strain differences (compared to measured strains), amount of unexplained strain, and maximum tensile stress are shown in Appendix E. The amount of final unexplained strains was found to be high for all levels (> 20%). Only at test no. 1:1:5 the amount can be judged as low (5%).

For test no 1:1:5, the agreement between measured and theoretical strains is in general fair to good (see Figure 5-6 through Figure 5-8), but for remaining tests the results show larger deviations.

The transient strain analysis also gave high maximum tensile stress, between 26 to 35 MPa for Level nos. 1 and 2A and 17 to 31 MPa for Level nos. 2B and 3. For Level 4 the corresponding values vary between 35 to 45 MPa.

The calculated values of the maximum tensile stress at all levels except for Level 5 is high enough to cause tensile damages in overcore samples in the dominating rock types at the site.

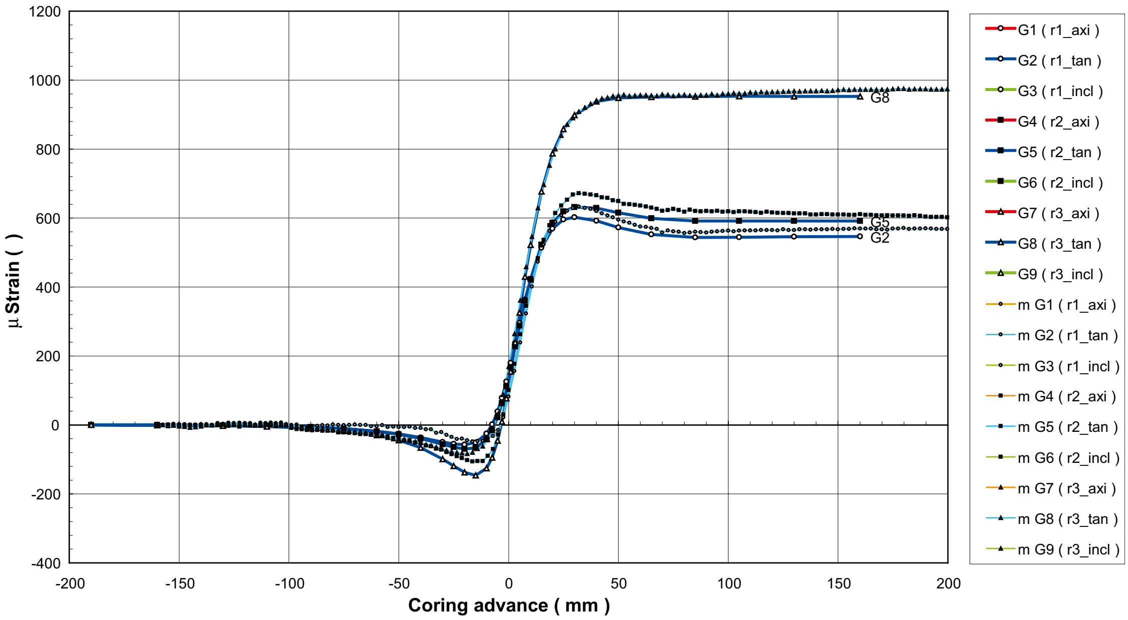

Figure 5-6. *Calculated vs. measured strain response during overcoring as a function of coring advance (gauge position at 0 mm) for test no. 1:1:5 and all tangential gauges.*

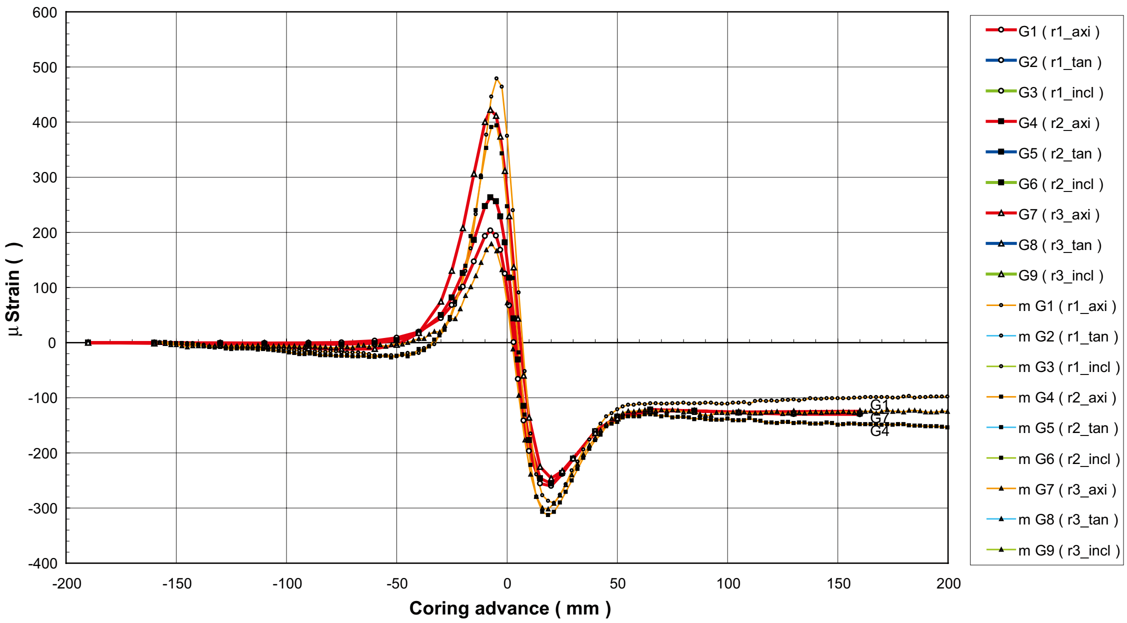

Figure 5-7. *Calculated vs. measured strain response during overcoring as a function of coring advance (gauge position at 0 mm) for test no. 1:1:5 and all axial gauges.*

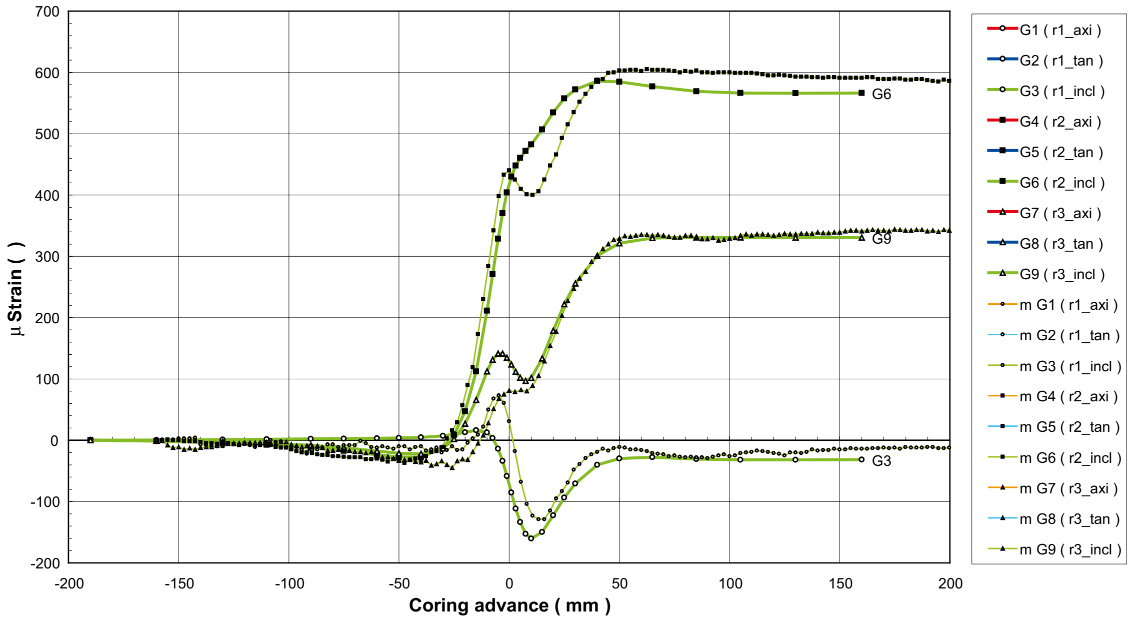

Figure 5-8. *Calculated vs. measured strain response during overcoring as a function of coring advance (gauge position at 0 mm) for test no. 1:1:5 and all inclined gauges.*

5.6.2 Inverse solution stress estimate

It was attempted to use the inverse solution to complement the stress determination from classical analysis. The inverse solution is a tool to theoretically determine the stresses, and is normally used if difficulties to determine the stresses from measurement occur, e.g. malfunctioning gauges, extensive core damage and/or ring disking, etc.

The inverse solution was attempted using the early (transient) strain response from overcoring to assess whether this would provide improved reliability in the estimation of the stress state. Generally, the stresses calculated with the inverse solution vary significantly with coring advance. To obtain a reliable stress estimate, the calculated stresses must be relatively constant over some distance during the early overcoring phase. This requires that (i) the overcoring response during the first few minutes (before passing the strain gauges at 16 cm position) is stable and, (ii) the coring advance is accurate. Unfortunately, these two conditions are seldom satisfied simultaneously. Calculations rendering unrealistic values, for example negative stresses, have been rejected. The result from the inverse solution is further used in comparison with stresses determined using classical analysis, to indicate possible effects of microcracking or other problems during overcoring. Water pressure was not included in the analysis.

Unfortunately, the above requirements were not fulfilled, causing unstable stress values at different drill bit positions during early overcoring, see also Figure 5-9. It is therefore impossible to determine the stresses with any reliability and, consequently, the stress state could not be determined unambiguosly for any of the measurements levels.

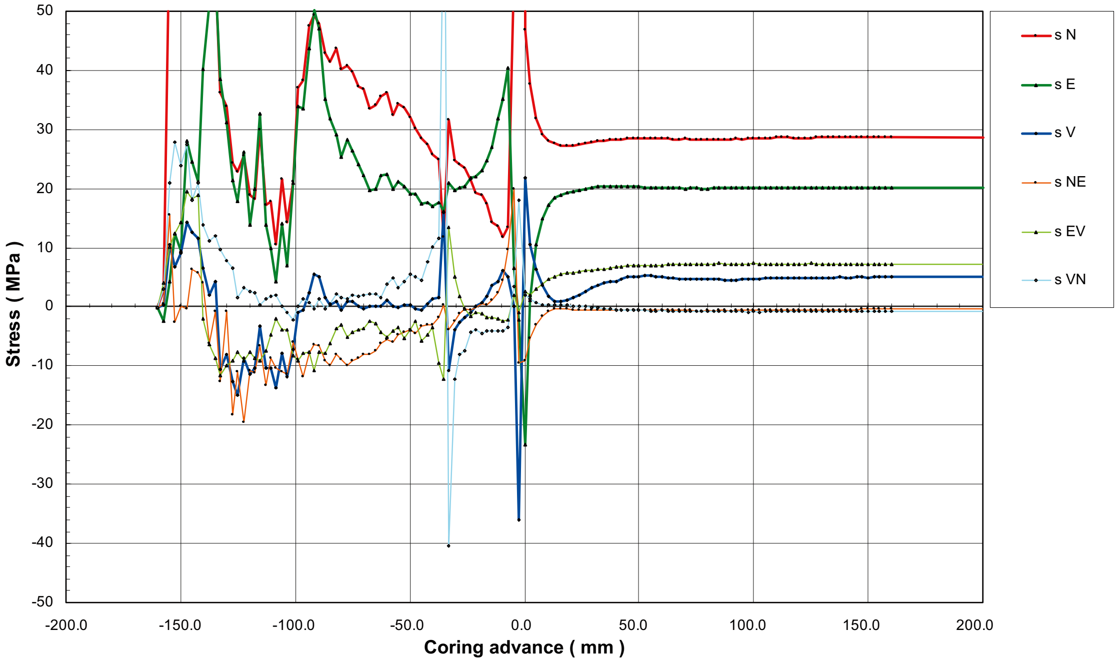

Figure 5-9. *Example of inverse stress solution for test no. 1:1:5 (no stable pre-overcoring values found).*

5.7 Results from P-waves on overcore samples

The P-wave velocity was measured on test samples from the following hollow overcored samples 1:2:4, 1:4:1 (Level 1), 2:1:3, 2:4:1, 2:8:1, 2:9:1 (Level 2), 3:4:1, 3:5:1 (Level 3), 4:2:3, 4:3:4, 4:4:2 (Level 4), 5:3:4 (Level 5), and 6:2:1 (Level 6). Between 12 to 15 measurements were performed on each core and three cores were used for each overcoring test, which gave 36 to 45 P-wave tests for each overcoring test.

Figure 5-10 shows all P-wave measurements plotted versus depth where it can be noted that the P-wave velocity varies from 4,400 to 6,019 m/s. The figure reveals decreasing P-wave velocities from 5,800 m/s for Level 1 to 4,400 m/s for Level 3. Below this depth there is a gradual increase in P-wave velocity to the maximum value 6,019 m/s at Level 6. Figure 5-10 also shows how the width of scatter in P-wave velocity values varies at individual samples and at each level. Level 1 has a very small scatter, while the lower levels display a large scatter, especially Level 2. Plots of angular variation of P-wave velocity of each individual tests for all test samples are showed in Appendix K**.**

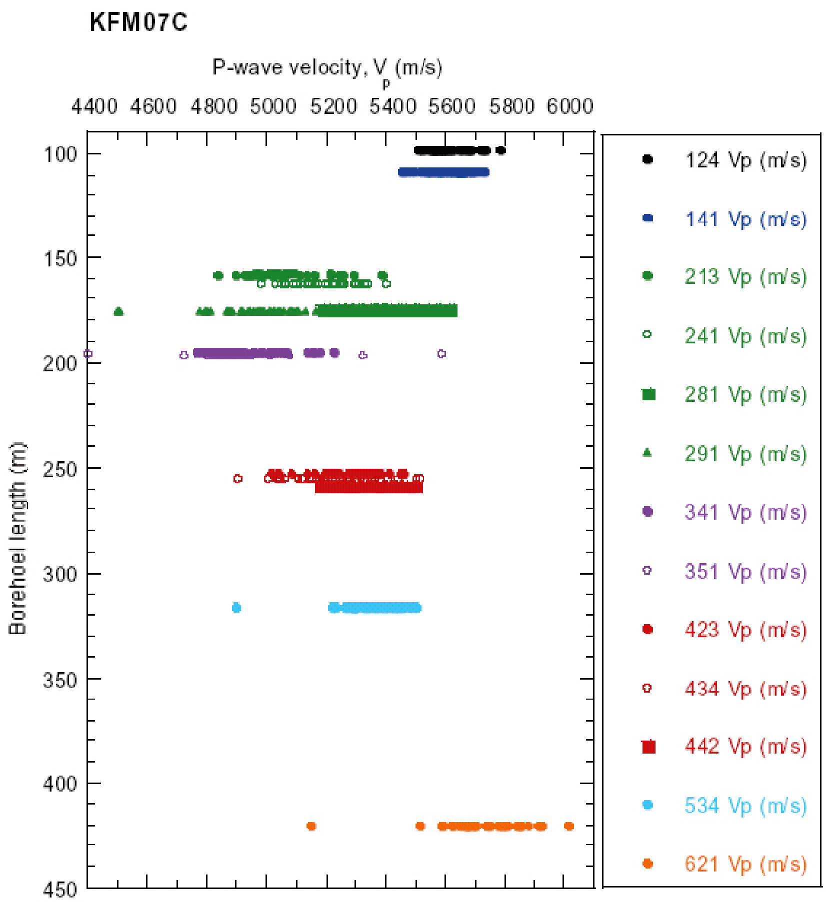

Figure 5-10. *P-wave velocity of all individual test pieces taken from cores from overcoring stress measurements plotted versus depth. 124 V_p is equal to measured P-velocity from test pieces taken from hollow cylinder from overcoring test no. 1:2:4.*

5.8 Summary results and discussion

The overcoring measurements in borehole KFM07C were largely successful, though problems with fractures sub-parallel with the borehole axis and ring disking occurred. The latter was most frequently occurring at lower measurement levels. Ring disking also prevented any realistic results at all from Level nos. 5 and 6.

The obtained stress state from the measurements at Level 1 (approximately 100 m vertical depth) is characterised by stress magnitudes with a mean value equal to 24.8 MPa for measured major principal, horizontally oriented stresses. The mean calculated major horizontal stress has a magnitude of 24.8 MPa and is oriented N-S and the minor horizontal mean stress is 13.3 MPa, which can be considered as high values for both major and minor stresses. The mean vertical stress component is 3.9 MPa, which is only slightly elevated compared to the theoretical value corresponding to the overburden weight. Variations between the individual measurements are small, with respect to both orientation and magnitude, as manifested by the calculated confidence intervals (Appendix H). Only test no. 1:4:1 differs to some extent due to the orientation of the principal stresses.

The results from the measured stresses at Level 2 are divided into two sub-groups, Level 2A and 2B, divided by a 10 to 12 m wide span, as described earlier. The results from Level 2A gave similar magnitudes for the major principal stress as for Level 1 and is as well horizontally orientated. Mean calculated major horizontal stress is equal to 22.8 MPa. The orientation is, however, E-W. Minor horizontal stress is determined to 19.2 MPa. The mean vertical stress is determined to be 3.0 MPa, which is in fair agreement with the theoretical value corresponding to the overburden pressure. At this level (2A), there is a large scatter between the tests.

At Level 2B the mean value for the major horizontal stress is 24.9 MPa and the minor horizontal stress is 18.2 MPa, which is more or less equal to the magnitudes measured from Level 1 and 2A. The orientation of maximum horizontal stress for Level 2B is N-S. The distinct change of orientation may be explained by the presence of a larger section of disturbed rock mass between Level 2A and 2B, though, the major principal stress is also here horizontal. The vertical stress is determined to have a mean value of 7.9 MPa, which is high compared to the theoretical vertical stress. Among the four successful installations at Level 2B, two tests have very similar orientation (N-S) of the major principal stress whereas two tests show a large scatter.

For Level 3, the mean major horizontal stress is somewhat lower (20.4 MPa) compared to the previous levels (nos. 1, 2A and 2B). It must be noted that the depth difference between Level 2B and Level 3 is roughly 12 m. The magnitude for this level is, with respect to its depth, considered as moderate and with an orientation WNW-ESE. The minor horizontal stress is 17.2 MPa. The mean vertical stress determined from the tests is 11.2 MPa, which is twice the magnitude of the overburden stress. The first two tests (nos. 3:1:1 and 3:4:1) gave quite similar results in terms of both magnitude and orientation of the major principal stress (NNW-SSE), while the third successful measurement provided higher stresses and an orientation almost perpendicular to the orientation indicated in first two tests (NNE-SSW). It should be observed that this last measurement (3:6:1) suffered from ring disking on the top of the core.

For level 4, the mean magnitude of the principal stresses was higher compared to the previous level (Level 3). However, the scatter in the magnitudes among the individual measurements was large, ranging from 27 to almost 47 MPa, giving a mean value for the major horizontal stress equal to 30.2 MPa and 18.6 MPa for the minor. The mean orientation was determined to be N-S. Also at this level, the measurements were divided by a larger zone (~ 10 m) of disturbed rock mass (pegmatite veins, fractures etc). The mean vertical stress measured is 12.1 MPa, which is almost twice the theoretical vertical stress. It should be observed that ring disking occurred to a relatively large extent and prevented more successful measurements at this level.

Due to fractures sub-parallel to the borehole axis and occurrence of ring disking, no successful stress measurements could be obtained at Level 5 and 6.

The comparison between the obtained results from biaxial tests and uniaxial compression tests showed that the difference in the results for Young's modulus can be considered as negligible. Poisson's ratio obtained from biaxial tests differed some compared to the values obtained from uniaxial tests. Biaxial tests gave slightly higher Poisson's ratio compared to uniaxial tests for Level nos. 1, 2 and 3. For Level 4, the biaxial tests gave higher values compared to the results from biaxial tests on samples from the previous levels and also compared to the results from uniaxial tests on pilot cores from Level 4.

Viewing these differences in physical condition etc, the used values from biaxial tests seem reliable. The possible effect of the small difference in elastic properties between the two methods is not of vital importance for determining the stresses. Furthermore, since the loading conditions of the biaxial tests are identical to those from overcoring, the values from biaxial tests are considered more representative. The results from the uniaxial tests are used as a quality control of the results obtained from the biaxial tests.

The results from the P-wave measurements showed a large scatter in P-wave velocity from Level 2A and further downwards in the borehole. There is a distinct difference between Level 1 and the remaining levels due the scatter of test results. There is also a decrease in velocity, going from Level 1 down to Levels 2 and 3. At Level 4 the velocity seems to slowly increase. For Level 6 the measured velocity is in the same magnitude as at Level 1. Potential sources for these results can be lithological variations (e.g. type of rock, degree of anisotropy) and variation in (microcracking induced) porosity.

Some test samples showed angular dependency in P-wave velocity, wheareas others revealed more homogenous and scattered values, respectively. This could reflect that the degree of acoustic velocity varies for individual levels.

Transient strain analysis was conducted for all tests with ratings *a* and *b* at all levels. For the large majority of tests, the amount of unexplained stress was considered high (> 20%). Also, high maximum tensile stresses were obtained from the calculations. All tests showed tensile stress higher than 14 MPa. These values are high enough to cause tensile damages in overcore samples in the dominating rock types at the site.

Stress determination using the inverse solution was attempted on all tests subjected to transient strain analysis.

However, it was not possible to obtain stable stress values during the pre-overcoring phase. Therefore, stresses could not be determined with any reliability and the stress state could not be unambiguosly determined for any of the measurements levels.

It appears likely that there is a temperature effect on the strain gauges from the drilling. The effect is clearly visible from overcoring start and during varying time periods of the post-peak strain behaviour. The phenomenon is also visible in a late stage of overcoring strain data, see for example strain response from tests nos. 3:4:1 and 3:6:1 (Appendix B). The temperature effects appear to be more prominent than in previous overcoring measurements at the site, see e.g. /Sjöberg 2004/. It is not possible to solve this issue within the present work, only to minimize and avoid any effects on the determination of the stress field. This is done by carefully selecting strain input data for stress calculations. It is suggested that a more detailed investigation is performed to quantify possible temperature effects in overcoring.

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Appendix A

Key measurement data

Table A-1. Key measurement data for test no. 1:1:5, 98.76 m borehole length.

Activity	Date [yy-mm-dd]	Time [hh:mm:ss]
Activation time	2006-04-03	16:02:00
Mixing of glue	2006-04-03	16:27:00
Application of glue to gauges	2006-04-03	16:32:00
Probe installation in pilot hole	2006-04-03	16:41:00
Start time for dense sampling (5 s interval)	2006-04-04	07:00:00
Adapter retrieved	2006-04-04	07:41:30
Adapter on surface	2006-04-04	07:46:00
Drill string fed down the hole	2006-04-04	08:00:00
Drill string in place	2006-04-04	08:20:00
Flushing start	2006-04-04	08:21:00
Rotation start	2006-04-04	08:50:00
Overcoring start	2006-04-04	08:51:00
Overcoring 4 cm	2006-04-04	08:52:20
Overcoring 8 cm	2006-04-04	08:53:45
Overcoring 12 cm	2006-04-04	08:55:05
Overcoring 16 cm	2006-04-04	08:56:30
Overcoring 20 cm	2006-04-04	08:57:45
Overcoring 24 cm	2006-04-04	08:59:05
Overcoring 28 cm	2006-04-04	09:00:30
Overcoring 32 cm	2006-04-04	09:01:45
Overcoring stop (71 cm)	2006-04-04	09:14:50
Flushing off	2006-04-04	09:30:00
Core break	2006-04-04	09:45:15
Core retrieval start	2006-04-04	10:15:00
Core & probe on surface	2006-04-04	10:23:00
End of strain registration	2006-04-04	10:56:05
Calculation of strain difference: OC Start	2006-04-04	08:50:55
Calculation of strain difference: OC Stop	2006-04-04	09:15:00
Overcoring advance	Overcoring rate [cm/min]	
0 – 16 cm	2.9	
16 – 32 cm	3.0	
32 cm – overcoring stop	3.0	

Table A-2. Key measurement data for test no. 1:2:4, 104.53 m borehole length.

Activity	Date [yy-mm-dd]	Time [hh:mm:ss]
Activation time	2006-04-05	16:15:00
Mixing of glue	2006-04-05	16:20:00
Application of glue to gauges	2006-04-05	16:24:00
Probe installation in pilot hole	2006-04-05	16:33:00
Start time for dense sampling (5 s interval)	2006-04-06	07:00:00
Adapter retrieved	2006-04-06	07:37:30
Adapter on surface	2006-04-06	07:40:00
Drill string fed down the hole	2006-04-06	08:01:00
Drill string in place	2006-04-06	08:21:30
Flushing start	2006-04-06	08:22:30
Rotation start	2006-04-06	08:28:15
Overcoring start	2006-04-06	08:51:20
Overcoring 4 cm	2006-04-06	08:52:50
Overcoring 8 cm	2006-04-06	08:54:20
Overcoring 12 cm	2006-04-06	08:55:40
Overcoring 16 cm	2006-04-06	08:57:00
Overcoring 20 cm	2006-04-06	08:58:20
Overcoring 24 cm	2006-04-06	08:59:45
Overcoring 28 cm	2006-04-06	09:01:05
Overcoring 32 cm	2006-04-06	09:02:25
Overcoring stop (100 cm)	2006-04-06	09:22:20
Flushing off	2006-04-06	09:38:00
Core break	2006-04-06	10:02:35
Core retrieval start	2006-04-06	10:25:00
Core & probe on surface	2006-04-06	10:44:00
End of strain registration	2006-04-06	10:58:40
Calculation of strain difference: OC Start	2006-04-06	08:51:20
Calculation of strain difference: OC Stop	2006-04-06	09:22:55
Overcoring advance	Overcoring rate [cm/min]	
0 – 16 cm	2.8	
16 – 32 cm	3.0	
32 cm – overcoring stop	3.4	

Table A-3. Key measurement data for test no. 1:4:1, 108.42 m borehole length.

Activity	Date [yy-mm-dd]	Time [hh:mm:ss]
Activation time	2006-04-08	17:21:00
Mixing of glue	2006-04-08	17:36:00
Application of glue to gauges	2006-04-08	17:39:00
Probe installation in pilot hole	2006-04-08	17:47:00
Start time for dense sampling (5 s interval)	2006-04-09	07:00:00
Adapter retrieved	2006-04-09	07:45:00
Adapter on surface	2006-04-09	07:47:20
Drill string fed down the hole	2006-04-09	08:00:00
Drill string in place	2006-04-09	08:13:45
Flushing start	2006-04-09	08:54:00
Rotation start	2006-04-09	09:14:20
Overcoring start	2006-04-09	09:14:25
Overcoring 4 cm	2006-04-09	09:16:20
Overcoring 8 cm	2006-04-09	09:17:50
Overcoring 12 cm	2006-04-09	09:19:25
Overcoring 16 cm	2006-04-09	09:21:40
Overcoring 20 cm	2006-04-09	09:23:05
Overcoring 24 cm	2006-04-09	09:24:25
Overcoring 28 cm	2006-04-09	09:26:00
Overcoring 32 cm	2006-04-09	09:27:20
Overcoring stop (90 cm)	2006-04-09	09:46:15
Flushing off	2006-04-09	10:01:00
Core break	2006-04-09	10:18:35
Core retrieval start	2006-04-09	10:19:50
Core & probe on surface	2006-04-09	10:55:00
End of strain registration	2006-04-09	11:12:10
Calculation of strain difference: OC Start	2006-04-09	08:48:25
Calculation of strain difference: OC Stop	2006-04-09	10:17:30

Overcoring advance	Overcoring rate [cm/min]
0 – 16 cm	2.2
16 – 32 cm	2.8
32 cm – overcoring stop	3.1

Table A-4. Key measurement data for test no. 2:1:3, 158.28 m borehole length.

Activity	Date [yy-mm-dd]	Time [hh:mm:ss]
Activation time	2006-04-22	15:30:00
Mixing of glue	2006-04-22	15:58:00
Application of glue to gauges	2006-04-22	16:02:00
Probe installation in pilot hole	2006-04-22	16:15:05
Start time for dense sampling (5 s interval)	2006-04-23	07:00:00
Adapter retrieved	2006-04-23	07:43:40
Adapter on surface	2006-04-23	07:48:40
Drill string fed down the hole	2006-04-23	07:56:30
Drill string in place	2006-04-23	08:25:45
Flushing start	2006-04-23	08:26:05
Rotation start	2006-04-23	08:51:00
Overcoring start	2006-04-23	08:58:20
Overcoring 4 cm	2006-04-23	09:00:15
Overcoring 8 cm	2006-04-23	09:02:35
Overcoring 12 cm	2006-04-23	09:04:55
Overcoring 16 cm	2006-04-23	09:07:10
Overcoring 20 cm	2006-04-23	09:09:30
Overcoring 24 cm	2006-04-23	09:11:15
Overcoring 28 cm	2006-04-23	09:13:55
Overcoring 32 cm	2006-04-23	09:16:10
Overcoring stop (98 cm)	2006-04-23	09:27:45
Flushing off	2006-04-23	09:46:00
Core break	2006-04-23	10:00:20
Core retrieval start	2006-04-23	10:23:15
Core & probe on surface	2006-04-23	10:50:00
End of strain registration	2006-04-23	12:08:20
Calculation of strain difference: OC Start	2006-04-23	08:44:20
Calculation of strain difference: OC Stop	2006-04-23	09:44:45

Overcoring advance	Overcoring rate [cm/min]
0 – 16 cm	1.8
16 – 32 cm	1.8
32 cm – overcoring stop	5.7

Table A-5. Key measurement data for test no. 2:3:1, 160.37 m borehole length.

Activity	Date [yy-mm-dd]	Time [hh:mm:ss]
Activation time	2006-04-24	17:01:00
Mixing of glue	2006-04-24	17:26:00
Application of glue to gauges	2006-04-24	17:33:00
Probe installation in pilot hole	2006-04-24	17:41:15
Start time for dense sampling (5 s interval)	2006-04-25	07:00:00
Adapter retrieved	2006-04-25	07:34:40
Adapter on surface	2006-04-25	07:37:50
Drill string fed down the hole	2006-04-25	07:50:20
Drill string in place	2006-04-25	08:24:00
Flushing start	2006-04-25	08:25:15
Rotation start	2006-04-25	08:46:20
Overcoring start	2006-04-25	08:47:30
Overcoring 4 cm	2006-04-25	08:49:10
Overcoring 8 cm	2006-04-25	08:50:30
Overcoring 12 cm	2006-04-25	08:51:10
Overcoring 16 cm	2006-04-25	08:53:05
Overcoring 20 cm	2006-04-25	08:54:25
Overcoring 24 cm	2006-04-25	08:55:55
Overcoring 28 cm	2006-04-25	08:57:15
Overcoring 32 cm	2006-04-25	08:58:45
Overcoring stop (100 cm)	2006-04-25	09:22:50
Flushing off	2006-04-25	09:37:25
Core break	2006-04-25	09:55:50
Core retrieval start	2006-04-25	10:12:15
Core & probe on surface	2006-04-25	10:40:00
End of strain registration	2006-04-25	10:58:50
Calculation of strain difference: OC Start	2006-04-25	08:45:30
Calculation of strain difference: OC Stop	2006-04-25	09:35:50

Overcoring advance	Overcoring rate [cm/min]
0 – 16 cm	2.9
16 – 32 cm	2.8
32 cm – overcoring stop	2.8

Table A-6. Key measurement data for test no. 2:4:1, 162.69 m borehole length.

Activity	Date [yy-mm-dd]	Time [hh:mm:ss]
Activation time	2006-04-26	15:40:00
Mixing of glue	2006-04-26	00:00:00
Application of glue to gauges	2006-04-26	00:00:00
Probe installation in pilot hole	2006-04-26	16:06:30
Start time for dense sampling (5 s interval)	2006-04-27	07:00:00
Adapter retrieved	2006-04-27	07:41:40
Adapter on surface	2006-04-27	07:44:00
Drill string fed down the hole	2006-04-27	08:42:00
Drill string in place	2006-04-27	09:30:15
Flushing start	2006-04-27	12:25:00
Rotation start	2006-04-27	12:41:30
Overcoring start	2006-04-27	12:41:50
Overcoring 4 cm	2006-04-27	12:43:40
Overcoring 8 cm	2006-04-27	12:45:20
Overcoring 12 cm	2006-04-27	12:46:55
Overcoring 16 cm	2006-04-27	12:47:50
Overcoring 20 cm	2006-04-27	12:49:05
Overcoring 24 cm	2006-04-27	12:50:30
Overcoring 28 cm	2006-04-27	12:51:50
Overcoring 32 cm	2006-04-27	12:53:10
Overcoring stop (100 cm)	2006-04-27	13:16:15
Flushing off	2006-04-27	13:32:00
Core break	2006-04-27	13:52:30
Core retrieval start	2006-04-27	14:12:00
Core & probe on surface	2006-04-27	14:30:30
End of strain registration	2006-04-27	14:55:25
Calculation of strain difference: OC Start	2006-04-27	12:34:50
Calculation of strain difference: OC Stop	2006-04-27	13:31:15
Overcoring advance	Overcoring rate [cm/min]	
0 – 16 cm	2.7	
16 – 32 cm	3.0	
32 cm – overcoring stop	2.9	

Table A-7. Key measurement data for test no. 2:8:1, 174.60 m borehole length.

Activity	Date [yy-mm-dd]	Time [hh:mm:ss]
Activation time	2006-05-06	17:00:00
Mixing of glue	2006-05-06	17:15:00
Application of glue to gauges	2006-05-06	17:20:00
Probe installation in pilot hole	2006-05-06	17:28:00
Start time for dense sampling (5 s interval)	2006-05-07	07:00:00
Adapter retrieved	2006-05-07	07:37:50
Adapter on surface	2006-05-07	07:41:50
Drill string fed down the hole	2006-05-07	07:52:45
Drill string in place	2006-05-07	08:23:00
Flushing start	2006-05-07	08:23:30
Rotation start	2006-05-07	08:44:15
Overcoring start	2006-05-07	08:44:35
Overcoring 4 cm	2006-05-07	08:46:20
Overcoring 8 cm	2006-05-07	08:47:40
Overcoring 12 cm	2006-05-07	08:49:00
Overcoring 16 cm	2006-05-07	08:50:20
Overcoring 20 cm	2006-05-07	08:51:40
Overcoring 24 cm	2006-05-07	08:53:00
Overcoring 28 cm	2006-05-07	08:54:20
Overcoring 32 cm	2006-05-07	08:55:45
Overcoring stop (100 cm)	2006-05-07	09:07:35
Flushing off	2006-05-07	09:24:40
Core break	2006-05-07	09:43:45
Core retrieval start	2006-05-07	09:58:45
Core & probe on surface	2006-05-07	10:26:00
End of strain registration	2006-05-07	10:48:15
Calculation of strain difference: OC Start	2006-05-07	08:38:15
Calculation of strain difference: OC Stop	2006-05-07	09:23:35
Overcoring advance	Overcoring rate [cm/min]	
0 – 16 cm	2.8	
16 – 32 cm	3.0	
32 cm – overcoring stop	5.7	

Table A-8. Key measurement data for test no. 2:9:1, 175.62 m borehole length.

Activity	Date [yy-mm-dd]	Time [hh:mm:ss]
Activation time	2006-05-07	16:45:00
Mixing of glue	2006-05-07	16:56:00
Application of glue to gauges	2006-05-07	17:01:00
Probe installation in pilot hole	2006-05-07	17:11:00
Start time for dense sampling (5 s interval)	2006-05-08	07:00:00
Adapter retrieved	2006-05-08	07:35:10
Adapter on surface	2006-05-08	07:39:40
Drill string fed down the hole	2006-05-08	07:43:55
Drill string in place	2006-05-08	08:15:05
Flushing start	2006-05-08	08:18:00
Rotation start	2006-05-08	08:38:05
Overcoring start	2006-05-08	08:38:30
Overcoring 4 cm	2006-05-08	08:40:10
Overcoring 8 cm	2006-05-08	08:41:35
Overcoring 12 cm	2006-05-08	08:42:55
Overcoring 16 cm	2006-05-08	08:44:15
Overcoring 20 cm	2006-05-08	08:45:35
Overcoring 24 cm	2006-05-08	08:46:55
Overcoring 28 cm	2006-05-08	08:48:15
Overcoring 32 cm	2006-05-08	08:49:35
Overcoring stop (101 cm)	2006-05-08	09:01:25
Flushing off	2006-05-08	09:17:45
Core break	2006-05-08	09:32:40
Core retrieval start	2006-05-08	09:49:35
Core & probe on surface	2006-05-08	10:16:40
End of strain registration	2006-05-08	11:24:15
Calculation of strain difference: OC Start	2006-05-08	08:38:30
Calculation of strain difference: OC Stop	2006-05-08	09:16:25
Overcoring advance	Overcoring rate [cm/min]	
0 – 16 cm	2.8	
16 – 32 cm	3.0	
32 cm – overcoring stop	5.8	

Table A-9. Key measurement data for test no. 2:10:1, 176.65 m borehole length.

Activity	Date [yy-mm-dd]	Time [hh:mm:ss]
Activation time	2006-05-08	17:10:00
Mixing of glue	2006-05-08	17:26:00
Application of glue to gauges	2006-05-08	17:35:00
Probe installation in pilot hole	2006-05-08	17:50:50
Start time for dense sampling (5 s interval)	2006-05-09	07:00:00
Adapter retrieved	2006-05-09	07:37:50
Adapter on surface	2006-05-09	07:40:20
Drill string fed down the hole	2006-05-09	07:46:10
Drill string in place	2006-05-09	08:35:00
Flushing start	2006-05-09	08:17:40
Rotation start	2006-05-09	08:37:30
Overcoring start	2006-05-09	08:37:50
Overcoring 4 cm	2006-05-09	08:39:15
Overcoring 8 cm	2006-05-09	08:40:40
Overcoring 12 cm	2006-05-09	08:42:00
Overcoring 16 cm	2006-05-09	08:43:20
Overcoring 20 cm	2006-05-09	08:44:40
Overcoring 24 cm	2006-05-09	08:45:55
Overcoring 28 cm	2006-05-09	08:47:15
Overcoring 32 cm	2006-05-09	08:48:40
Overcoring stop (99 cm)	2006-05-09	09:11:50
Flushing off	2006-05-09	09:29:15
Core break	2006-05-09	09:45:45
Core retrieval start	2006-05-09	10:08:05
Core & probe on surface	2006-05-09	10:40:00
End of strain registration	2006-05-09	10:40:00
Calculation of strain difference: OC Start	2006-05-09	08:37:50
Calculation of strain difference: OC Stop	2006-05-09	09:28:50
Overcoring advance	Overcoring rate [cm/min]	
0 – 16 cm	2.9	
16 – 32 cm	3.0	
32 cm – overcoring stop	2.9	

Table A-10. Key measurement data for test no. 2:11:1, 177.65 m borehole length.

Activity	Date [yy-mm-dd]	Time [hh:mm:ss]
Activation time	2006-05-09	17:30:00
Mixing of glue	2006-05-09	17:54:00
Application of glue to gauges	2006-05-09	17:58:00
Probe installation in pilot hole	2006-05-09	18:06:00
Start time for dense sampling (5 s interval)	2006-05-10	07:00:00
Adapter retrieved	2006-05-10	07:44:30
Adapter on surface	2006-05-10	07:47:45
Drill string fed down the hole	2006-05-10	07:55:55
Drill string in place	2006-05-10	08:45:05
Flushing start	2006-05-10	08:27:15
Rotation start	2006-05-10	08:45:30
Overcoring start	2006-05-10	08:48:30
Overcoring 4 cm	2006-05-10	08:50:00
Overcoring 8 cm	2006-05-10	08:51:20
Overcoring 12 cm	2006-05-10	08:52:45
Overcoring 16 cm	2006-05-10	08:54:10
Overcoring 20 cm	2006-05-10	08:55:30
Overcoring 24 cm	2006-05-10	08:56:50
Overcoring 28 cm	2006-05-10	08:58:05
Overcoring 32 cm	2006-05-10	08:59:30
Overcoring stop (100 cm)	2006-05-10	09:11:40
Flushing off	2006-05-10	09:30:20
Core break	2006-05-10	09:58:55
Core retrieval start	2006-05-10	10:15:40
Core & probe on surface	2006-05-10	10:45:00
End of strain registration	2006-05-10	11:12:00
Calculation of strain difference: OC Start	2006-05-10	08:42:30
Calculation of strain difference: OC Stop	2006-05-10	09:29:40
Overcoring advance	Overcoring rate [cm/min]	
0 – 16 cm	2.8	
16 – 32 cm	3.0	
32 cm – overcoring stop	5.6	

Table A-11. Key measurement data for test no. 3:1:1, 192.47 m borehole length.

Activity	Date [yy-mm-dd]	Time [hh:mm:ss]
Activation time	2006-05-12	14:15:00
Mixing of glue	2006-05-12	14:30:00
Application of glue to gauges	2006-05-12	14:34:00
Probe installation in pilot hole	2006-05-12	14:42:40
Start time for dense sampling (5 s interval)	2006-05-13	07:00:00
Adapter retrieved	2006-05-13	07:40:30
Adapter on surface	2006-05-13	07:43:30
Drill string fed down the hole	2006-05-13	07:50:30
Drill string in place	2006-05-13	08.27:00
Flushing start	2006-05-13	08:18:00
Rotation start	2006-05-13	08:40:05
Overcoring start	2006-05-13	08:40:25
Overcoring 4 cm	2006-05-13	08:42:05
Overcoring 8 cm	2006-05-13	08:43:25
Overcoring 12 cm	2006-05-13	08:44:45
Overcoring 16 cm	2006-05-13	08:45:05
Overcoring 20 cm	2006-05-13	08:46:25
Overcoring 24 cm	2006-05-13	08:47:45
Overcoring 28 cm	2006-05-13	08.48:10
Overcoring 32 cm	2006-05-13	08:51:40
Overcoring stop (90 cm)	2006-05-13	09:11:20
Flushing off	2006-05-13	09:27:00
Core break	2006-05-13	09:44:10
Core retrieval start	2006-05-13	10:03:10
Core & probe on surface	2006-05-13	10:29:00
End of strain registration	2006-05-13	10:45:55
Calculation of strain difference: OC Start	2006-05-13	08:23:30
Calculation of strain difference: OC Stop	2006-05-13	09:29:40
Overcoring advance	Overcoring rate [cm/min]	
0 – 16 cm	3.4	
16 – 32 cm	2.4	
32 cm – overcoring stop	2.9	

Table A-12. Key measurement data for test no. 3:4:1, 195.31 m borehole length.

Activity	**Date [yy-mm-dd]**	**Time [hh:mm:ss]**
Activation time	2006-05-15	16:15:00
Mixing of glue	2006-05-15	16:40:00
Application of glue to gauges	2006-05-15	16:43:00
Probe installation in pilot hole	2006-05-15	16:51:50
Start time for dense sampling (5 s interval)	2006-05-16	07:00:05
Adapter retrieved	2006-05-16	00:07:42
Adapter on surface	2006-05-16	07:45:00
Drill string fed down the hole	2006-05-16	07:51:00
Drill string in place	2006-05-16	08:23:30
Flushing start	2006-05-16	08:23:40
Rotation start	2006-05-16	08:50:30
Overcoring start	2006-05-16	08:56:45
Overcoring 4 cm	2006-05-16	08:58:40
Overcoring 8 cm	2006-05-16	09:00:00
Overcoring 12 cm	2006-05-16	09:01:30
Overcoring 16 cm	2006-05-16	09:02:40
Overcoring 20 cm	2006-05-16	09:04:05
Overcoring 24 cm	2006-05-16	09:05:25
Overcoring 28 cm	2006-05-16	09:06:45
Overcoring 32 cm	2006-05-16	09:08:15
Overcoring stop (100 cm)	2006-05-16	09:31:40
Flushing off	2006-05-16	09:55:15
Core break	2006-05-16	10:14:10
Core retrieval start	2006-05-16	10:34:10
Core & probe on surface	2006-05-16	11:04:00
End of strain registration	2006-05-16	11:43:45
Calculation of strain difference: OC Start	2006-05-16	08:48:45
Calculation of strain difference: OC Stop	2006-05-16	09:53:40
Overcoring advance	Overcoring rate [cm/min]	
0 – 16 cm	2.7	
16 – 32 cm	2.9	
32 cm – overcoring stop	2.9	

Table A-13. Key measurement data for test no. 3:6:1, 197.28 m borehole length.

Activity	Date [yy-mm-dd]	Time [hh:mm:ss]
Activation time	2006-05-17	18:00:00
Mixing of glue	2006-05-17	19:48:00
Application of glue to gauges	2006-05-17	19:50:00
Probe installation in pilot hole	2006-05-17	19:59:55
Start time for dense sampling (5 s interval)	2006-05-18	07:00:00
Adapter retrieved	2006-05-18	07:41:20
Adapter on surface	2006-05-18	07:45:20
Drill string fed down the hole	2006-05-18	07:56:45
Drill string in place	2006-05-18	08:30:35
Flushing start	2006-05-18	08:30:40
Rotation start	2006-05-18	08:55:30
Overcoring start	2006-05-18	08:56:00
Overcoring 4 cm	2006-05-18	08:57:35
Overcoring 8 cm	2006-05-18	08:58:50
Overcoring 12 cm	2006-05-18	09:00:10
Overcoring 16 cm	2006-05-18	09:01:30
Overcoring 20 cm	2006-05-18	09:02:50
Overcoring 24 cm	2006-05-18	09:04:10
Overcoring 28 cm	2006-05-18	09:05:30
Overcoring 32 cm	2006-05-18	09:06:55
Overcoring stop (85 cm)	2006-05-18	09:25:20
Flushing off	2006-05-18	09:45:20
Core break	2006-05-18	10:04:40
Core retrieval start	2006-05-18	10:27:25
Core & probe on surface	2006-05-18	11:04:50
End of strain registration	2006-05-18	11:29:15
Calculation of strain difference: OC Start	2006-05-18	08:56:00
Calculation of strain difference: OC Stop	2006-05-18	09:43:20
Overcoring advance	Overcoring rate [cm/min]	
0 – 16 cm	2.9	
16 – 32 cm	3.0	
32 cm – overcoring stop	2.9	

Table A-14. **Key measurement data for test no. 4:1:2, 238.05 m borehole length.**

Activity	Date [yy-mm-dd]	Time [hh:mm:ss]
Activation time	2006-05-21	16:49:00
Mixing of glue	2006-05-21	16:49:00
Application of glue to gauges	2006-05-21	16:52:00
Probe installation in pilot hole	2006-05-21	17:05:00
Start time for dense sampling (5 s interval)	2006-05-22	07:00:00
Adapter retrieved	2006-05-22	07:43:10
Adapter on surface	2006-05-22	07:48:10
Drill string fed down the hole	2006-05-22	07:50:00
Drill string in place	2006-05-22	08:55:50
Flushing start	2006-05-22	08:38:30
Rotation start	2006-05-22	08:53:30
Overcoring start	2006-05-22	09:10:30
Overcoring 4 cm	2006-05-22	09:12:15
Overcoring 8 cm	2006-05-22	09:13:35
Overcoring 12 cm	2006-05-22	09:14:55
Overcoring 16 cm	2006-05-22	09:16:20
Overcoring 20 cm	2006-05-22	09:17:40
Overcoring 24 cm	2006-05-22	09:19:00
Overcoring 28 cm	2006-05-22	09:20:20
Overcoring 32 cm	2006-05-22	09:21:40
Overcoring stop (100 cm)	2006-05-22	09:44:25
Flushing off	2006-05-22	09:59:35
Core break	2006-05-22	10:18:00
Core retrieval start	2006-05-22	10:35:05
Core & probe on surface	2006-05-22	11:15:00
End of strain registration	2006-05-22	11:35:35
Calculation of strain difference: OC Start	2006-05-22	09:10:30
Calculation of strain difference: OC Stop	2006-05-22	09:57:25

Overcoring advance	Overcoring rate [cm/min]
0 – 16 cm	2.7
16 – 32 cm	3.0
32 cm – overcoring stop	3.0

Table A-15. Key measurement data for test no. 4:2:3, 242.70 m borehole length.

Activity	Date [yy-mm-dd]	Time [hh:mm:ss]
Activation time	2006-05-23	15:00:00
Mixing of glue	2006-05-23	15:27:00
Application of glue to gauges	2006-05-23	15:31:00
Probe installation in pilot hole	2006-05-23	15:40:45
Start time for dense sampling (5 s interval)	2006-05-24	07:00:00
Adapter retrieved	2006-05-24	07:45:50
Adapter on surface	2006-05-24	07:49:30
Drill string fed down the hole	2006-05-24	07:56:00
Drill string in place	2006-05-24	08:57:50
Flushing start	2006-05-24	08:24:25
Rotation start	2006-05-24	08:54:00
Overcoring start	2006-05-24	08:55:30
Overcoring 4 cm	2006-05-24	08:56:15
Overcoring 8 cm	2006-05-24	08:57:30
Overcoring 12 cm	2006-05-24	08:59:45
Overcoring 16 cm	2006-05-24	09:00:10
Overcoring 20 cm	2006-05-24	09:01:30
Overcoring 24 cm	2006-05-24	09:02:50
Overcoring 28 cm	2006-05-24	09:04:05
Overcoring 32 cm	2006-05-24	09:05:40
Overcoring stop (82 cm)	2006-05-24	09:22:55
Flushing off	2006-05-24	09:30:00
Core break	2006-05-24	09:46:05
Core retrieval start	2006-05-24	10:11:00
Core & probe on surface	2006-05-24	10:46:00
End of strain registration	2006-05-24	11:03:20
Calculation of strain difference: OC Start	2006-05-24	08:49:30
Calculation of strain difference: OC Stop	2006-05-24	09:31:55

Overcoring advance	Overcoring rate [cm/min]
0 – 16 cm	3.4
16 – 32 cm	2.9
32 cm – overcoring stop	2.9

Table A-16. Key measurement data for test no. 4:4:2, 258.73 m borehole length.

Activity	Date [yy-mm-dd]	Time [hh:mm:ss]
Activation time	2006-05-28	16:15:00
Mixing of glue	2006-05-28	16:43:00
Application of glue to gauges	2006-05-28	16:46:00
Probe installation in pilot hole	2006-05-28	16:57:00
Start time for dense sampling (5 s interval)	2006-05-29	07:00:00
Adapter retrieved	2006-05-29	07:43:20
Adapter on surface	2006-05-29	07:47:40
Drill string fed down the hole	2006-05-29	07:59:00
Drill string in place	2006-05-29	08:49:30
Flushing start	2006-05-29	08:30:00
Rotation start	2006-05-29	08:50:20
Overcoring start	2006-05-29	08:50:50
Overcoring 4 cm	2006-05-29	08:52:30
Overcoring 8 cm	2006-05-29	08:53:50
Overcoring 12 cm	2006-05-29	08:55:10
Overcoring 16 cm	2006-05-29	08:56:30
Overcoring 20 cm	2006-05-29	08:57:50
Overcoring 24 cm	2006-05-29	08:59:10
Overcoring 28 cm	2006-05-29	09:00:30
Overcoring 32 cm	2006-05-29	09:01:50
Overcoring stop (80 cm)	2006-05-29	09:19:45
Flushing off	2006-05-29	09:40:30
Core break	2006-05-29	10:01:00
Core retrieval start	2006-05-29	10:17:00
Core & probe on surface	2006-05-29	10:52:00
End of strain registration	2006-05-29	11:26:55
Calculation of strain difference: OC Start	2006-05-29	08:44:50
Calculation of strain difference: OC Stop	2006-05-29	09:37:45

Overcoring advance	Overcoring rate [cm/min]
0 – 16 cm	2.8
16 – 32 cm	3.0
32 cm – overcoring stop	2.7

Table A-17. Key measurement data for test no. 5:3:4, 316.25 m borehole length.

Activity	Date [yy-mm-dd]	Time [hh:mm:ss]
Activation time	2006-06-11	14:15:00
Mixing of glue	2006-06-11	14:52:00
Application of glue to gauges	2006-06-11	14:56:00
Probe installation in pilot hole	2006-06-11	15:07:00
Start time for dense sampling (5 s interval)	2006-06-12	07:00:00
Adapter retrieved	2006-06-12	07:39:05
Adapter on surface	2006-06-12	07:43:10
Drill string fed down the hole	2006-06-12	07:57:40
Drill string in place	2006-06-12	08:40:00
Flushing start	2006-06-12	08:34:10
Rotation start	2006-06-12	08:58:20
Overcoring start	2006-06-12	08:58:25
Overcoring 4 cm	2006-06-12	08:59:30
Overcoring 8 cm	2006-06-12	09:00:55
Overcoring 12 cm	2006-06-12	09:02:15
Overcoring 16 cm	2006-06-12	09:03:30
Overcoring 20 cm	2006-06-12	09:05:00
Overcoring 24 cm	2006-06-12	09:06:20
Overcoring 28 cm	2006-06-12	09:07:45
Overcoring 32 cm	2006-06-12	09:09:00
Overcoring stop (100 cm)	2006-06-12	09:32:10
Flushing off	2006-06-12	09:48:40
Core break	2006-06-12	10:06:20
Core retrieval start	2006-06-12	10:25:00
Core & probe on surface	2006-06-12	11:07:10
End of strain registration	2006-06-12	11:20:00
Calculation of strain difference: OC Start	2006-06-12	08:55:25
Calculation of strain difference: OC Stop	2006-06-12	09:46:10

Overcoring advance	Overcoring rate [cm/min]
0 – 16 cm	3.1
16 – 32 cm	2.9
32 cm – overcoring stop	2.9

Overcoring strain data and graphs

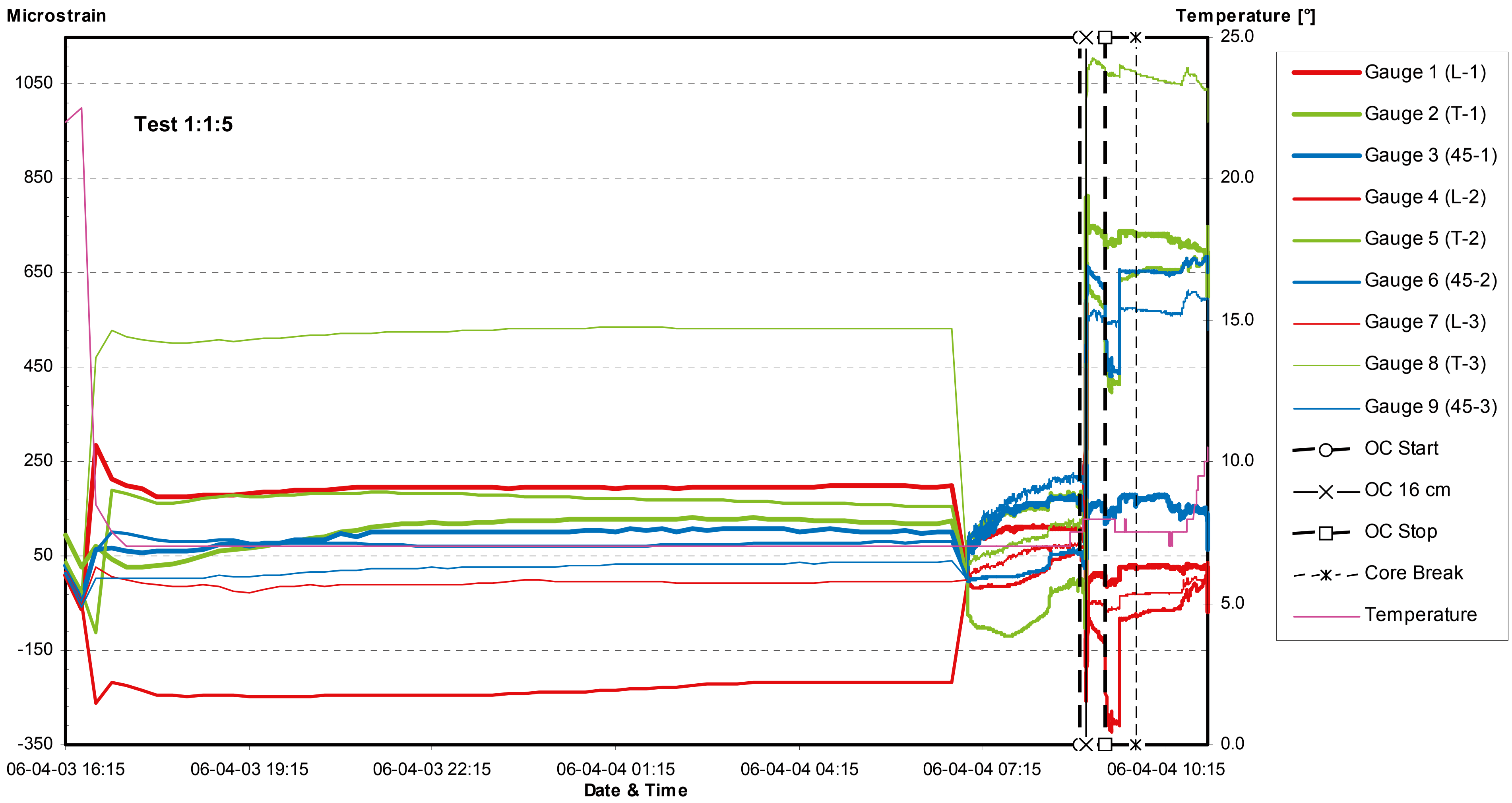


Figure B-1. *All recorded strain data and temperature from activation of probe to recovery from borehole for test no. 1:1:5, 98.76 m borehole length.*

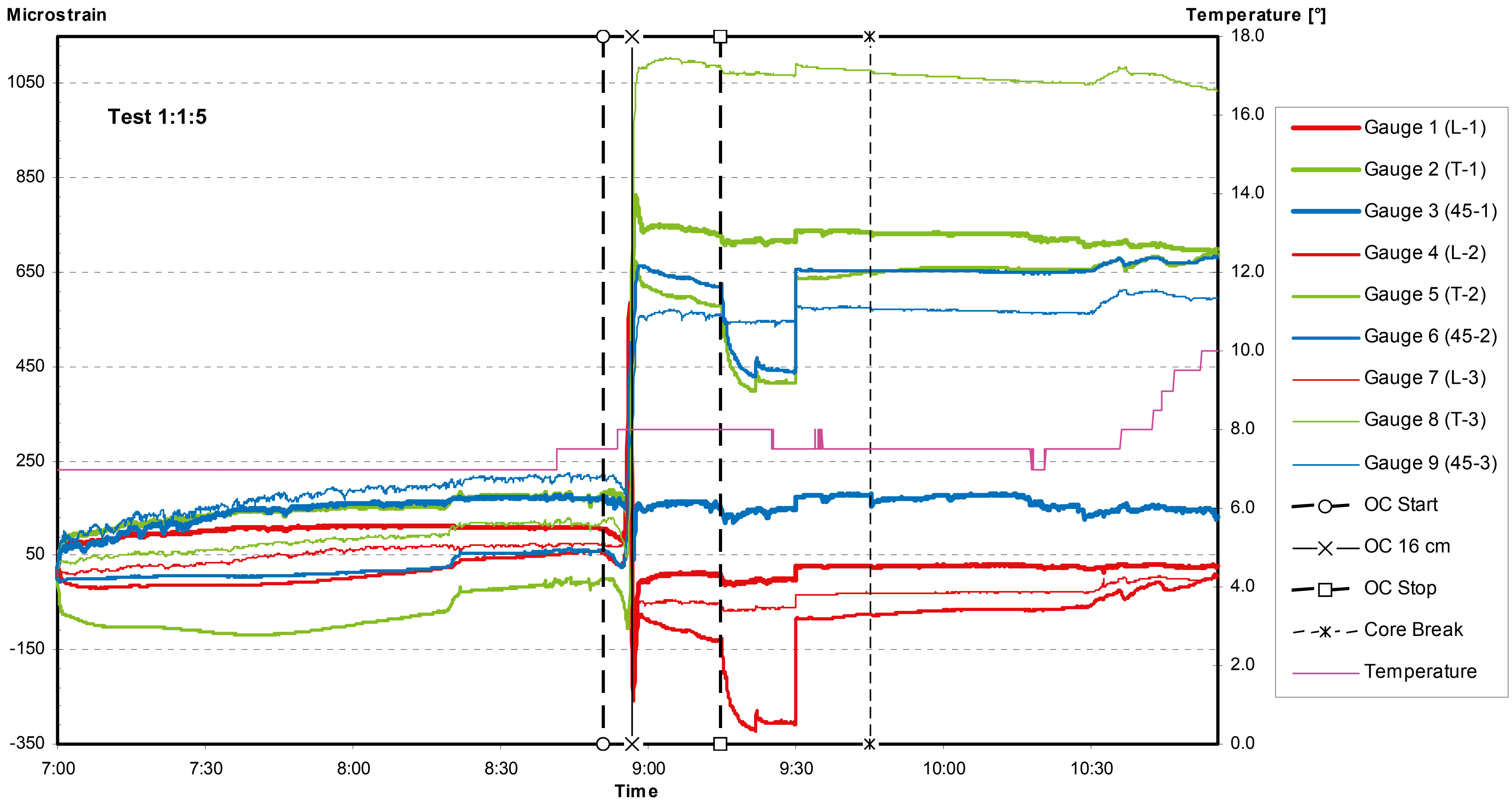


Figure B-2. Recorded strain data and temperature during overcoring (from start to stop) for test no. 1:1:5, 98.76 m borehole length. Strain values reset to zero at 07:00.

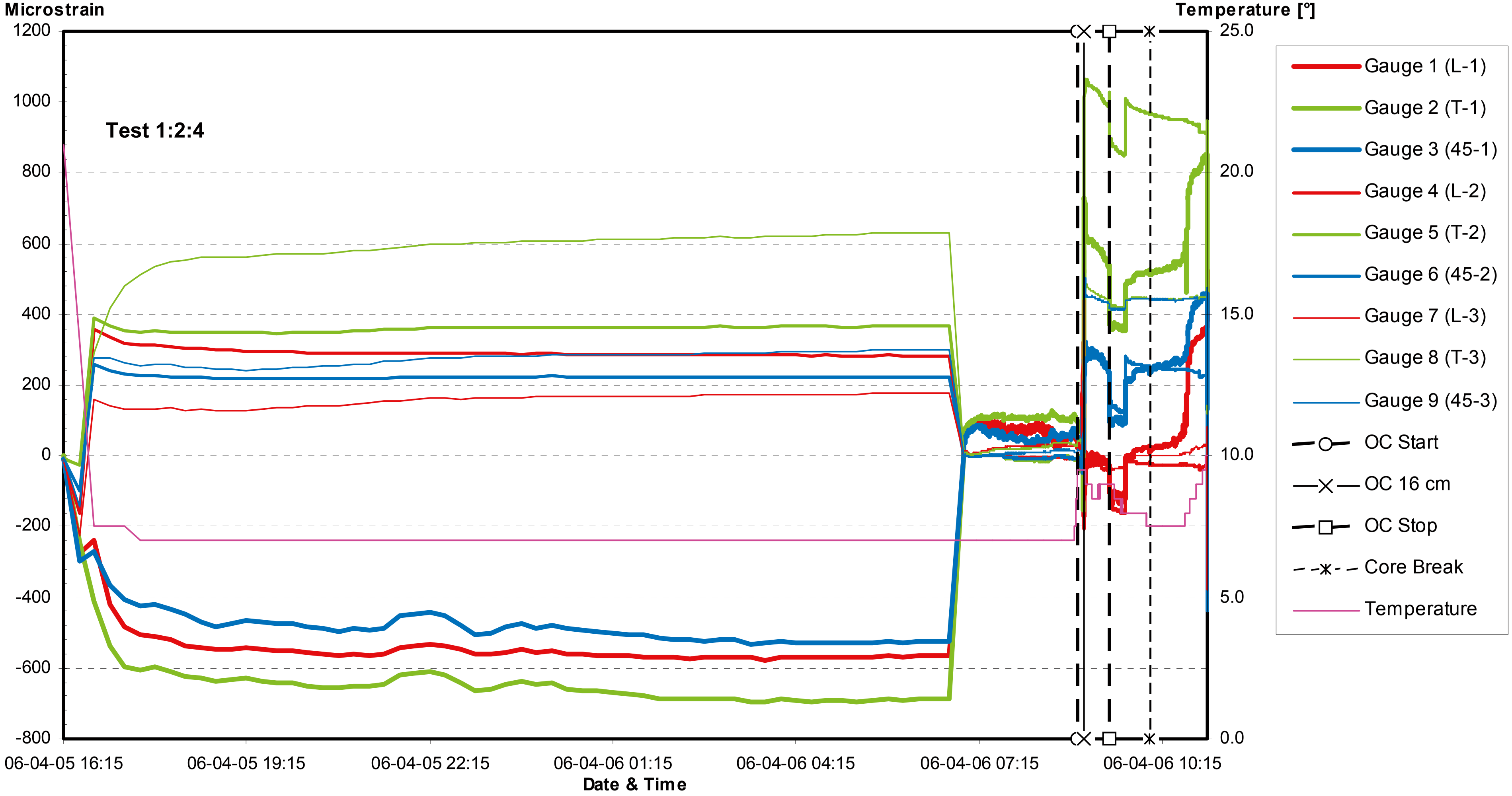


Figure B-3. *All recorded strain data and temperature from activation of probe to recovery from borehole for test no. 1:2:4, 104.53 m borehole length.*

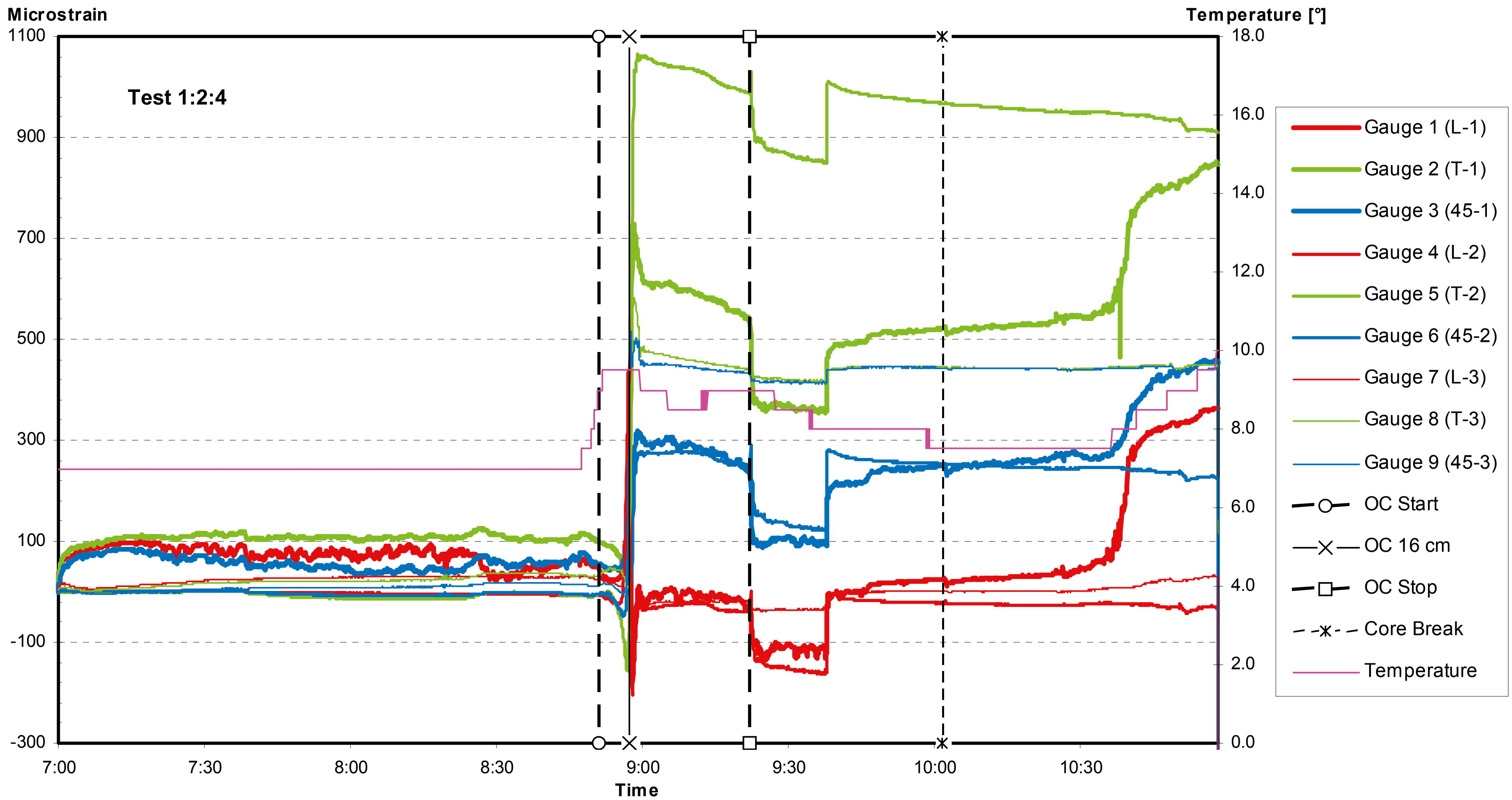


Figure B-4. *Recorded strain data and temperature during overcoring (from start to stop) for test no. 1:2:4, 104.53 m borehole length. Strain values reset to zero at 07:00*

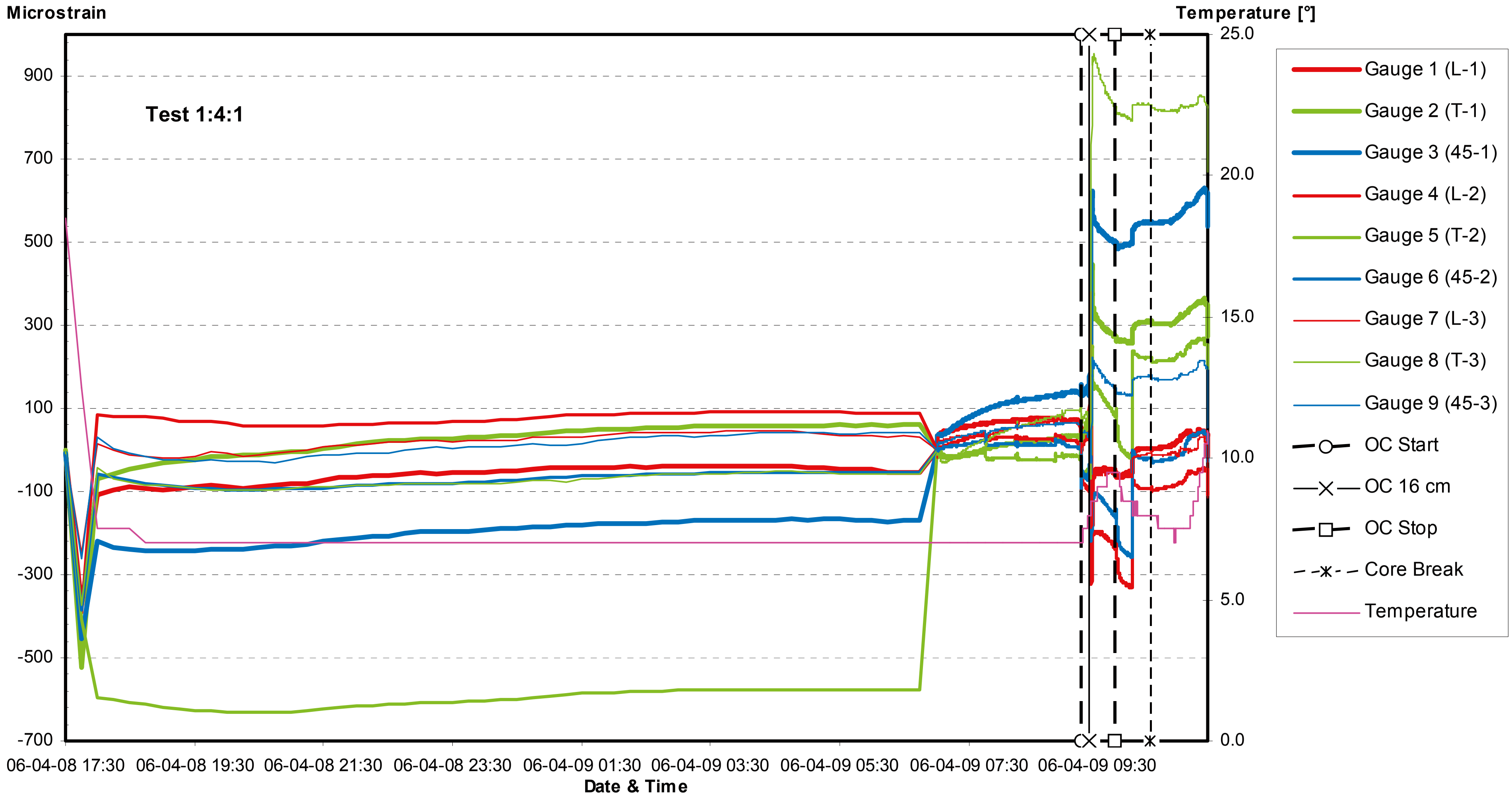


Figure B-5. *All recorded strain data and temperature from activation of probe to recovery from borehole for test no. 1:4:1, 108.42 m borehole length.*

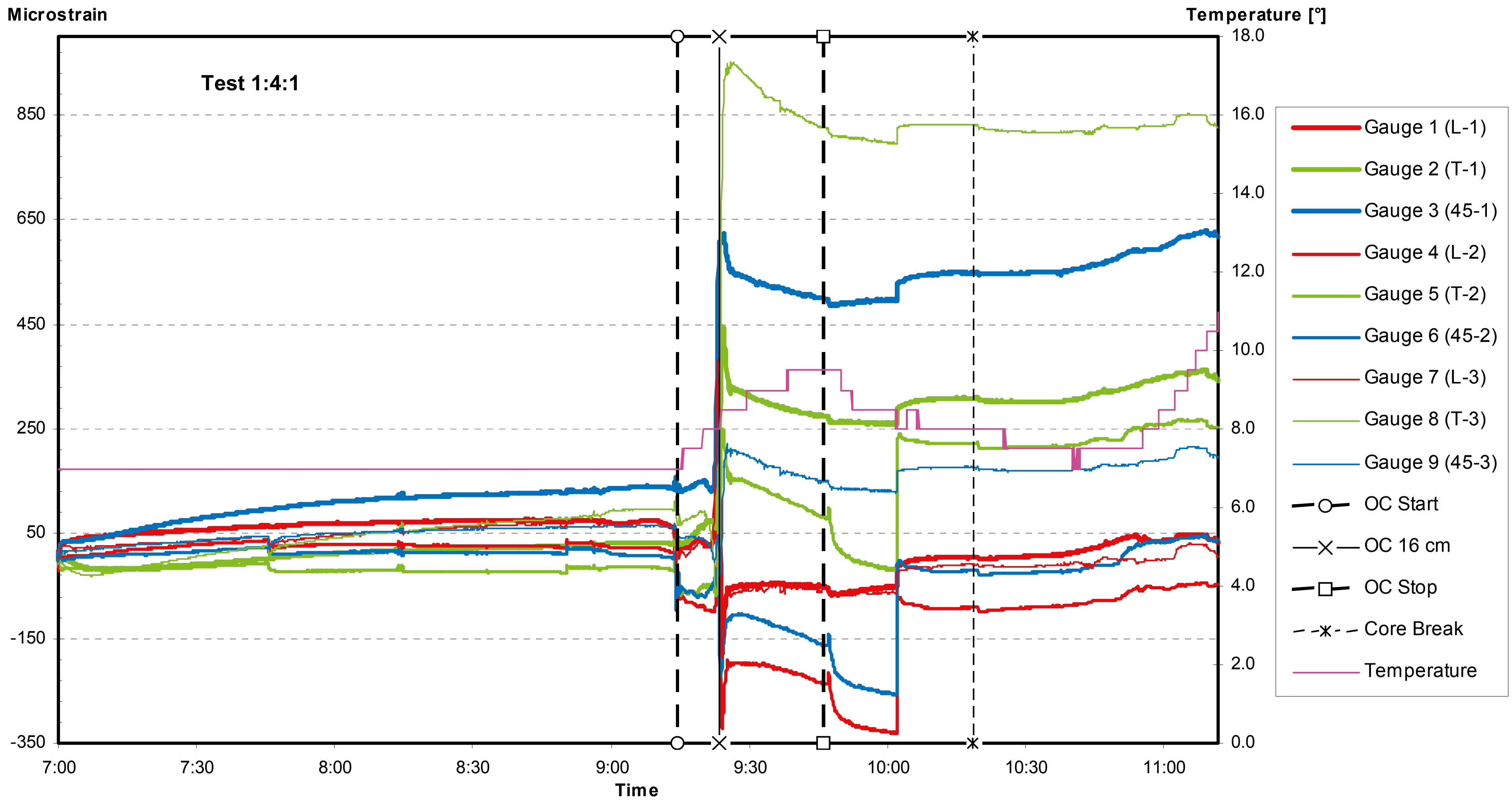


Figure B-6. *Recorded strain data and temperature during overcoring (from start to stop) for test no. 1:4:1, 108.42 m borehole length. Strain values reset to zero at 07:00.*

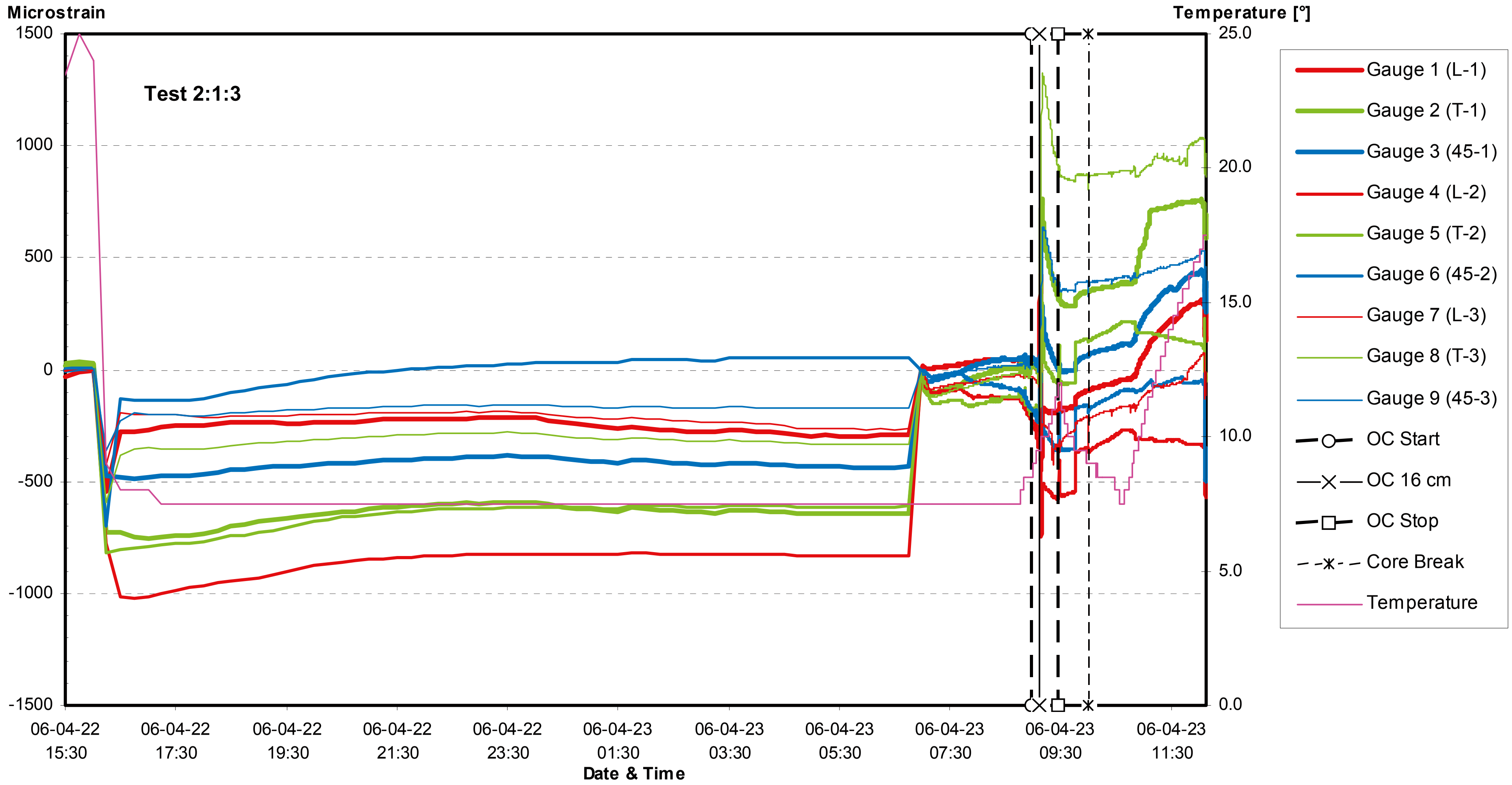


Figure B-7. *All recorded strain data and temperature from activation of probe to recovery from borehole for test no. 2:1:3, 158.28 m borehole length.*

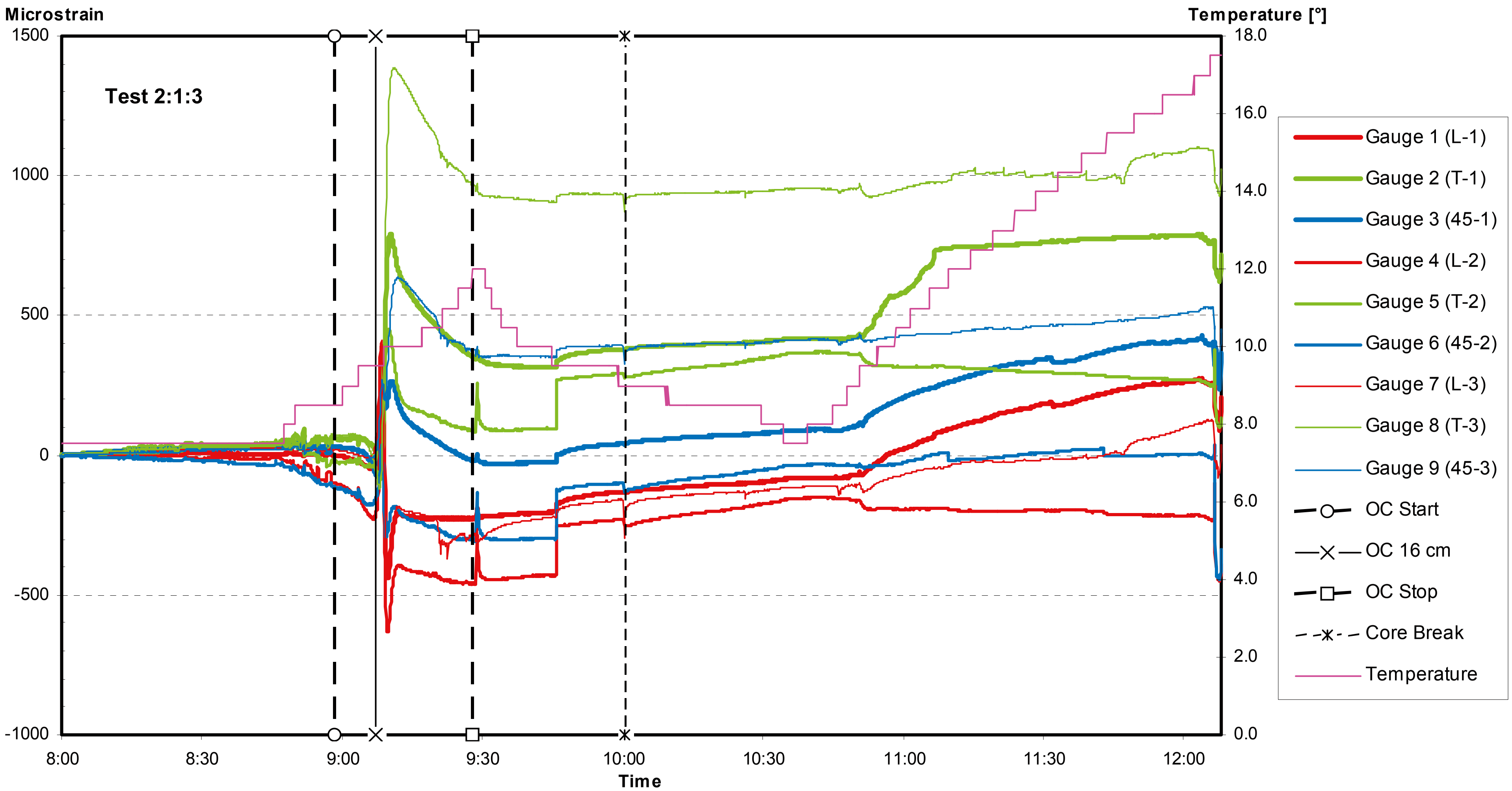


Figure B-8. *Recorded strain data and temperature during overcoring (from start to stop) for test no. 2:1:3, 158.28 m borehole length. Strain values reset to zero at 08:00.*

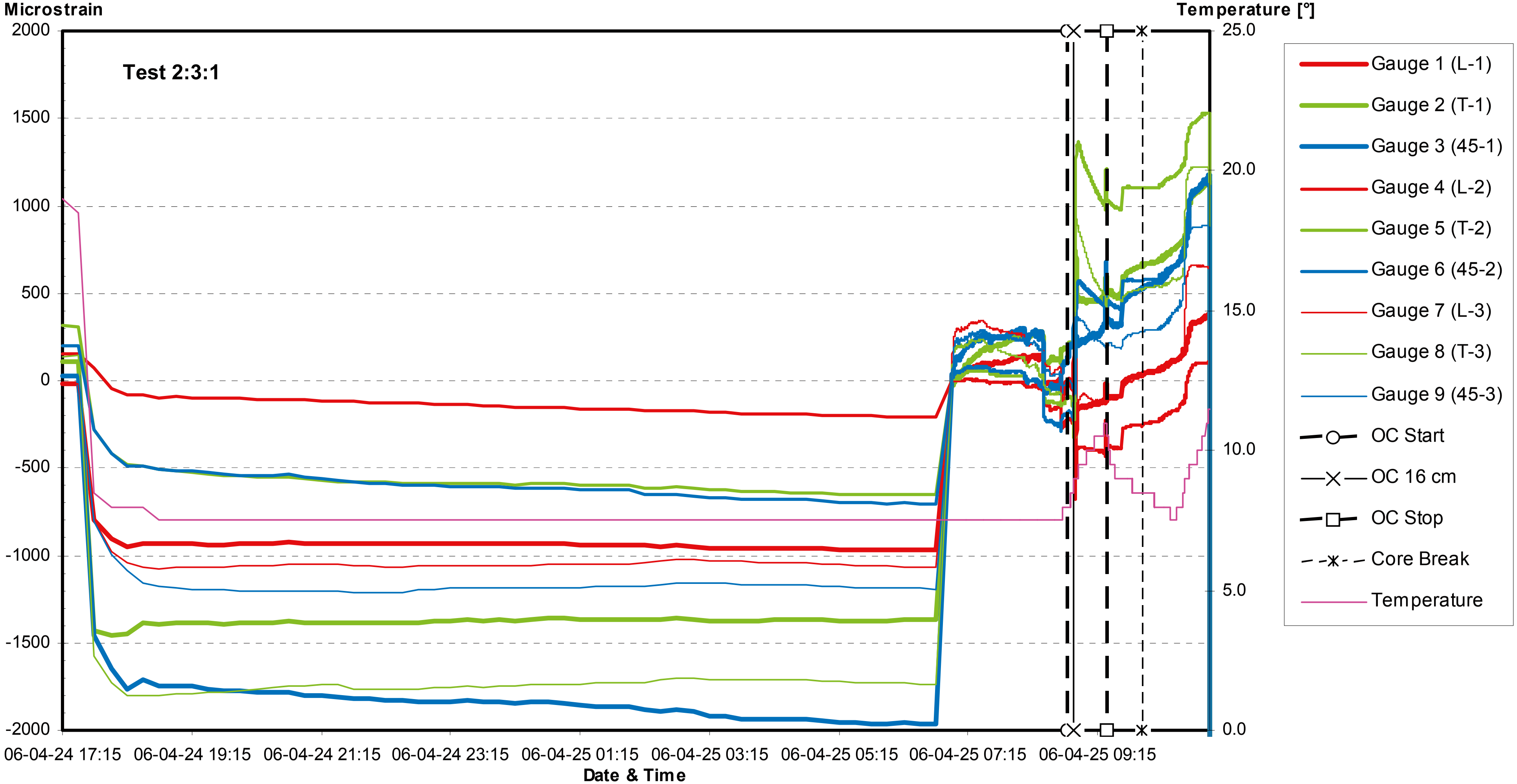


Figure B-9. *All recorded strain data and temperature from activation of probe to recovery from borehole for test no. 2:3:1, 160.37 m borehole length.*

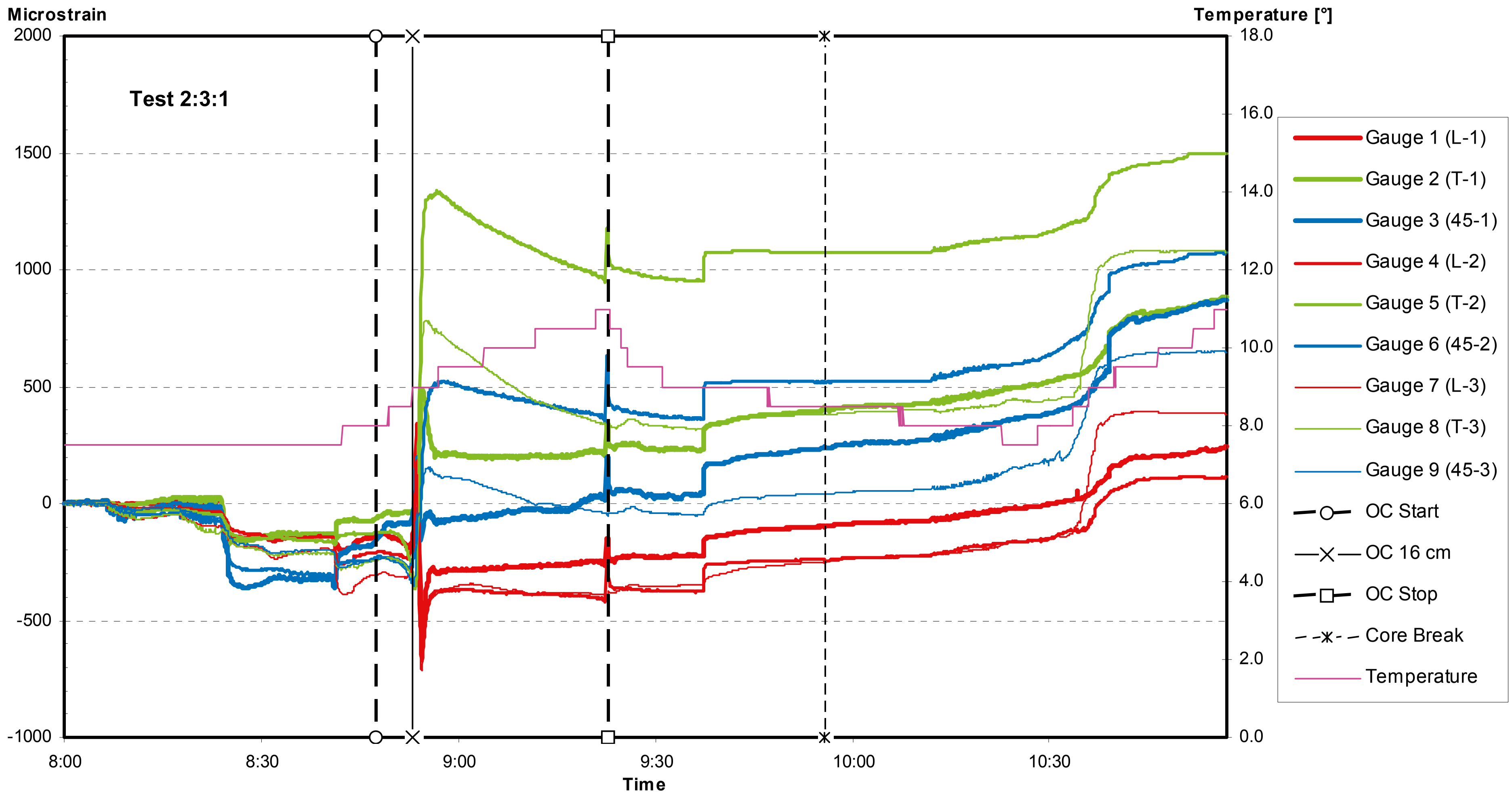


Figure B-10. *Recorded strain data and temperature during overcoring (from start to stop) for test no. 2:3:1, 160.37 m borehole length. Strain values reset to zero at 08:00.*

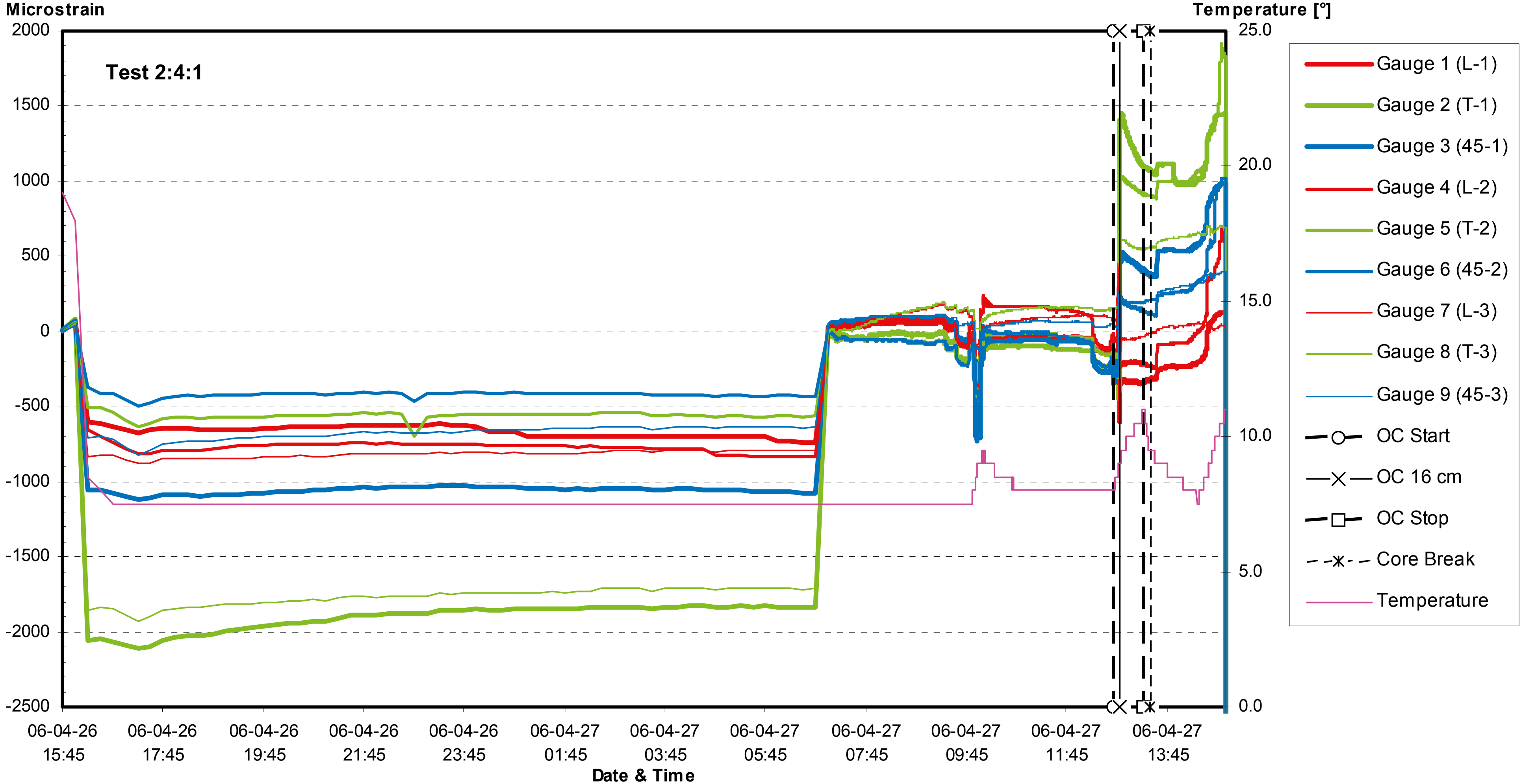


Figure B-11. *All recorded strain data and temperature from activation of probe to recovery from borehole for test no. 2:4:1, 162.69 m borehole length.*

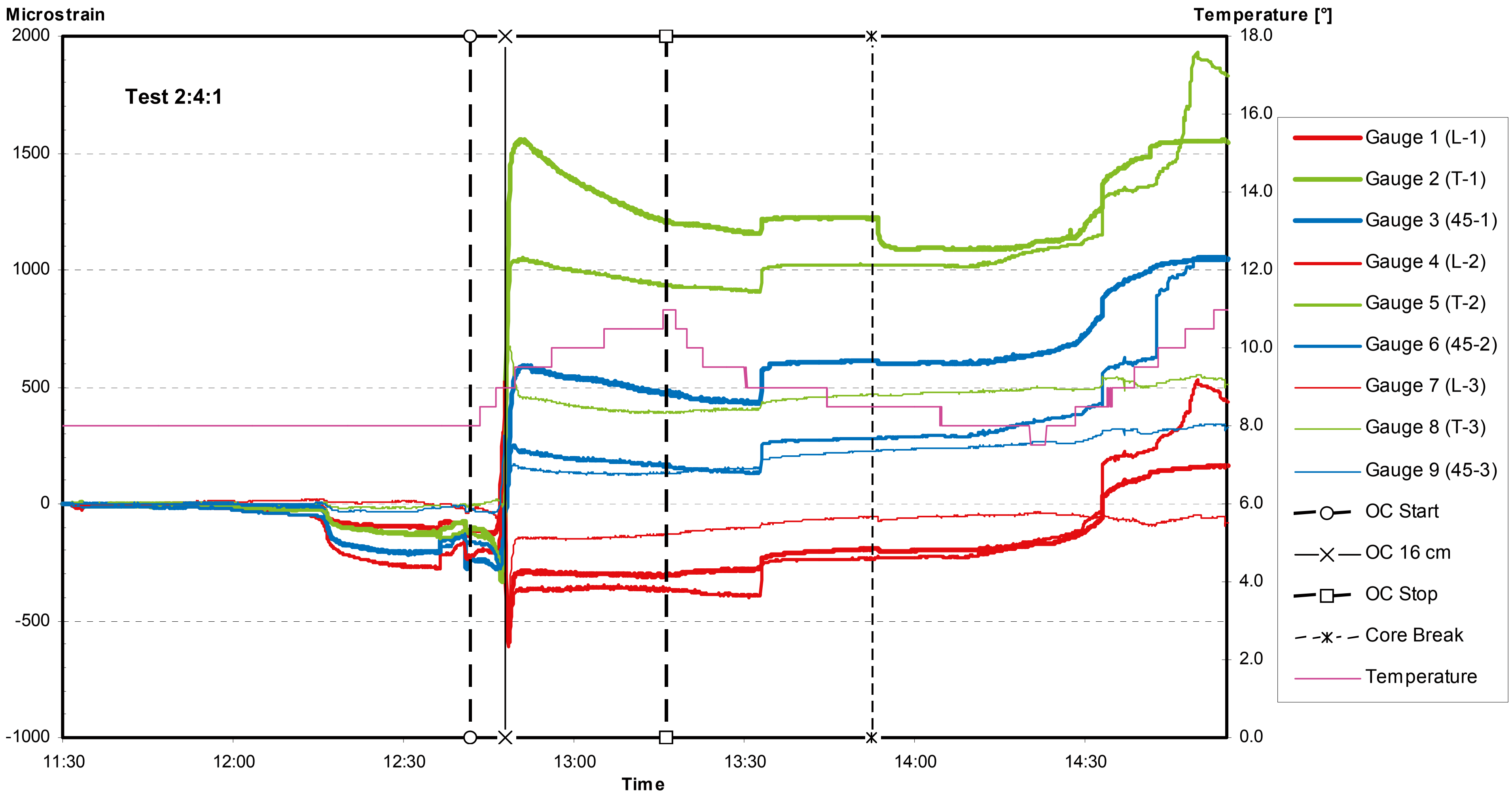


Figure B-12. *Recorded strain data and temperature during overcoring (from start to stop) for test no. 2:4:1, 162.69 borehole length. Strain values reset to zero at 11:30.*

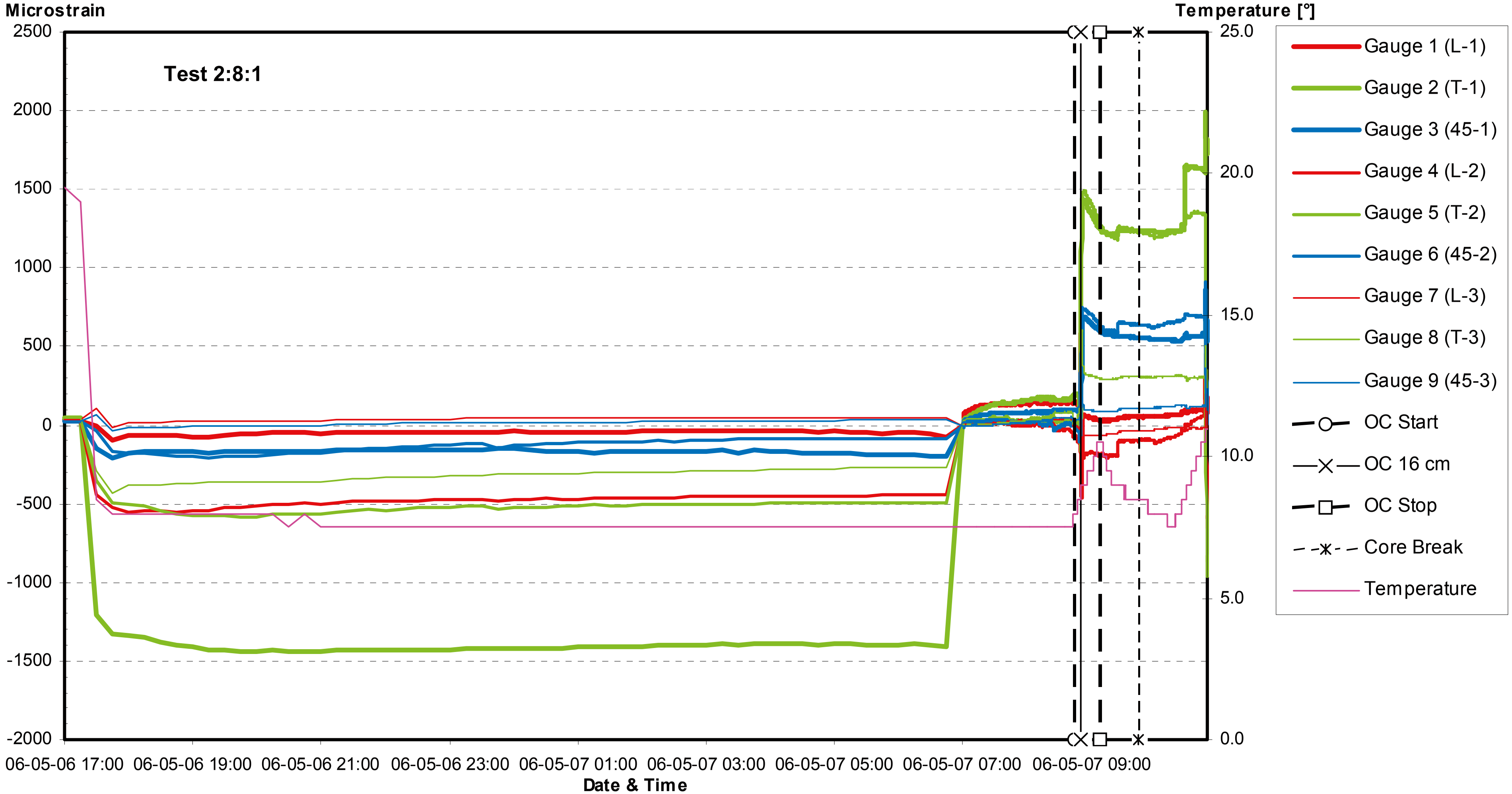


Figure B-13. *All recorded strain data and temperature from activation of probe to recovery from borehole for test no. 2:8:1, 174.60 m borehole length.*

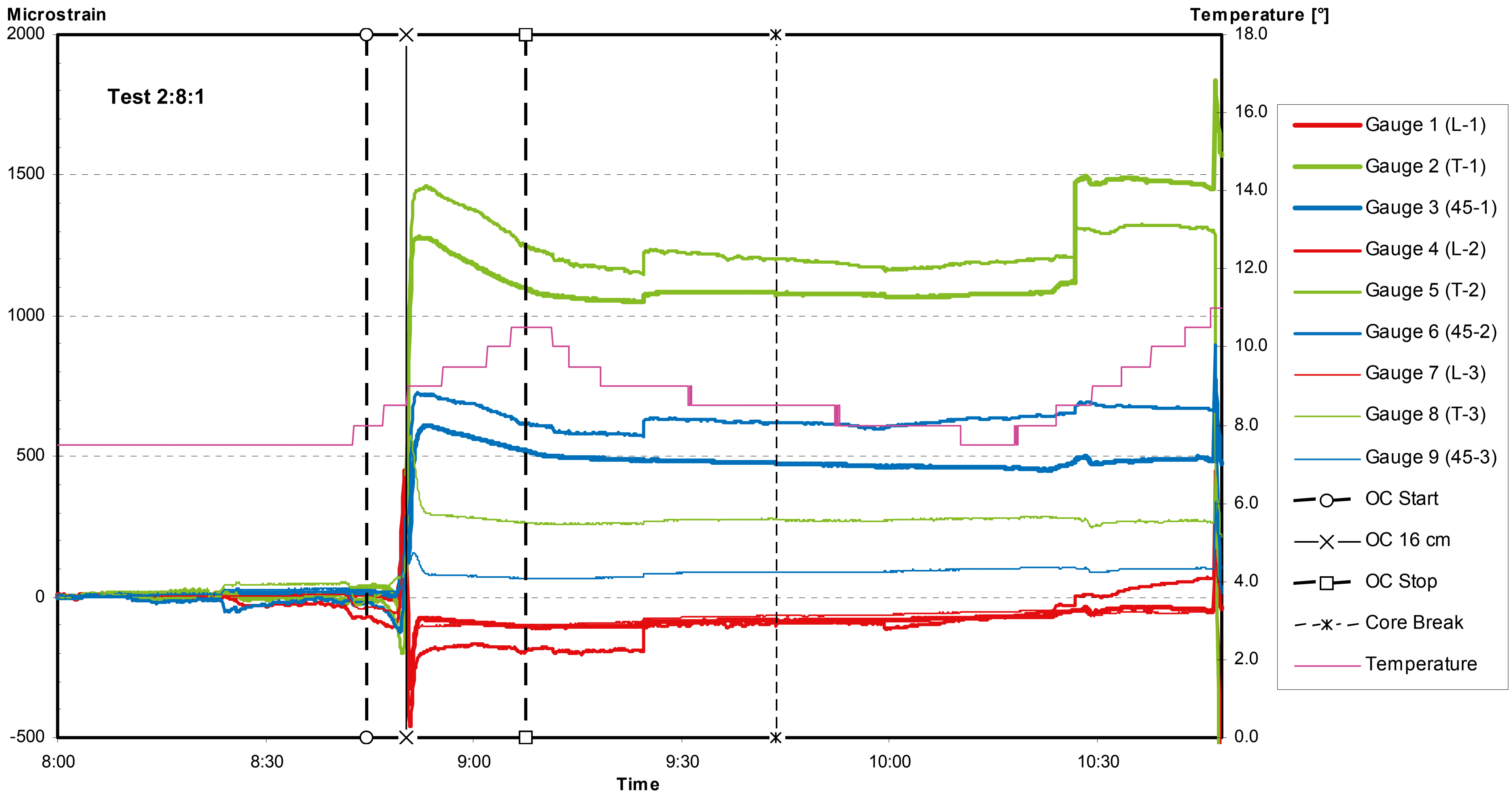


Figure B-14. *Recorded strain data and temperature during overcoring (from start to stop) for test no. 2:8:1, 174.60 borehole length. Strain values reset to zero at 08:00.*

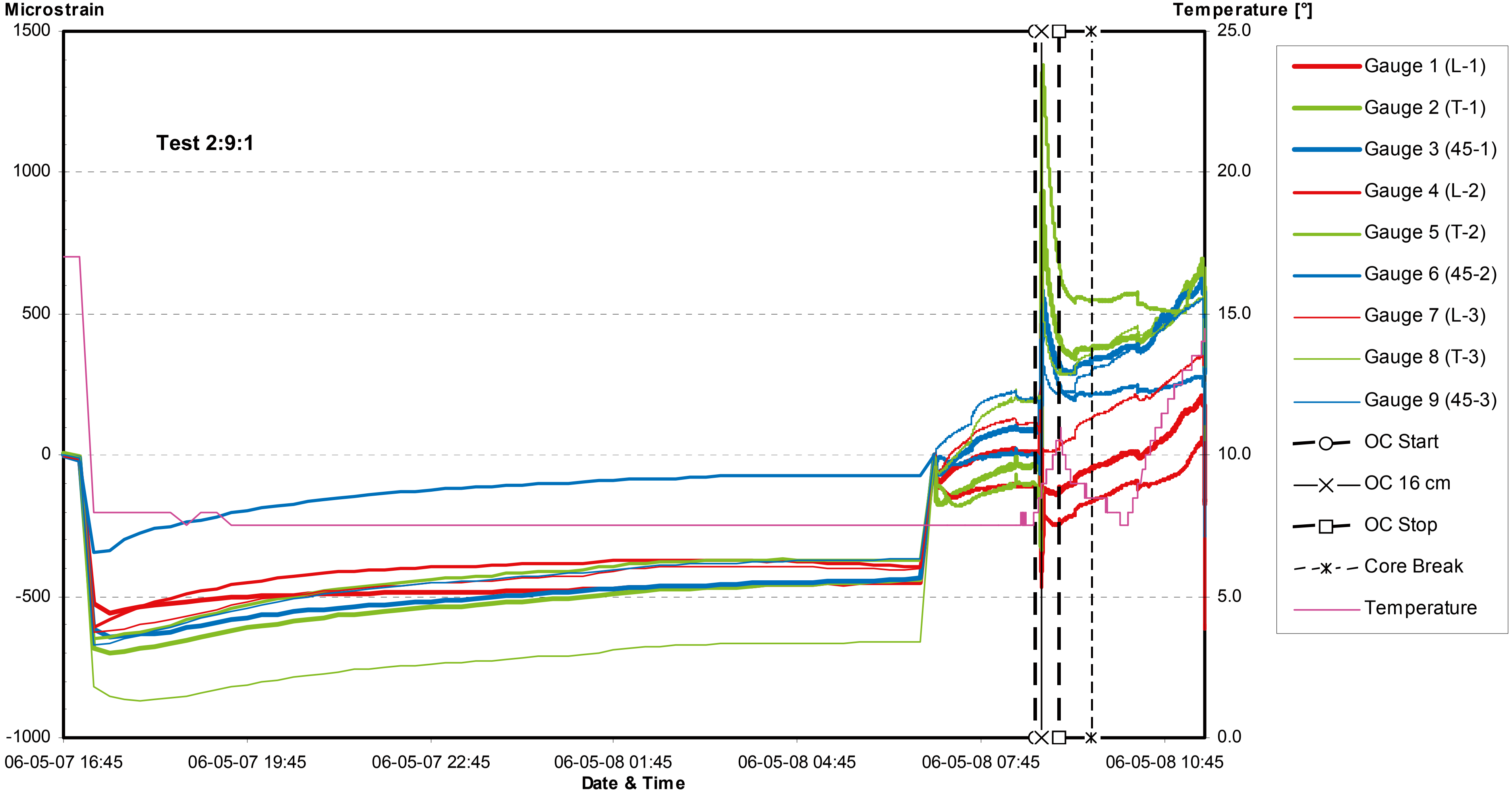


Figure B-15. *All recorded strain data and temperature from activation of probe to recovery from borehole for test no. 2:9:1, 175.62 m borehole length.*

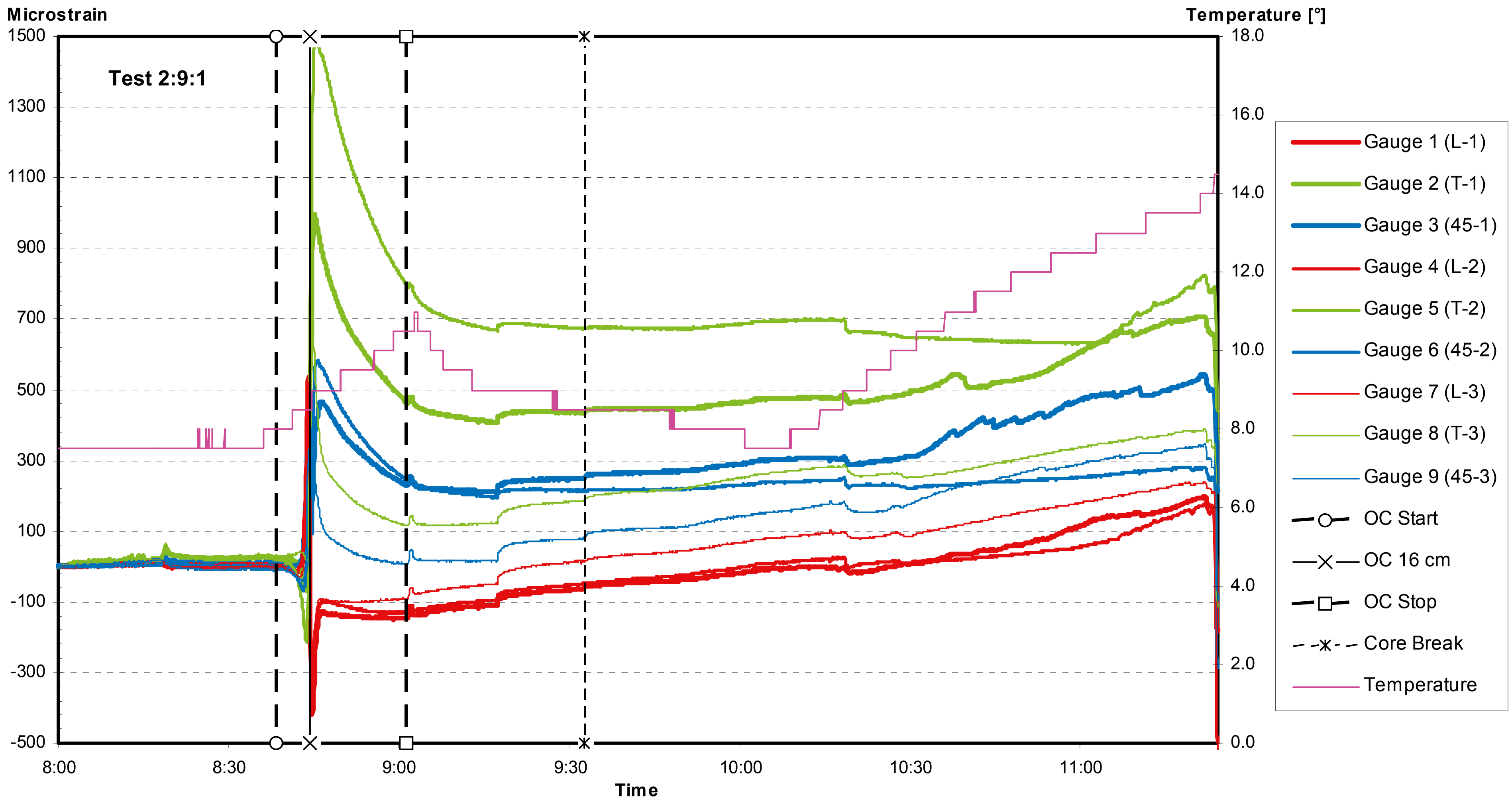


Figure B-16. *Recorded strain data and temperature during overcoring (from start to stop) for test no. 2:9:1, 175.62 borehole length. Strain values reset to zero at 08:00.*

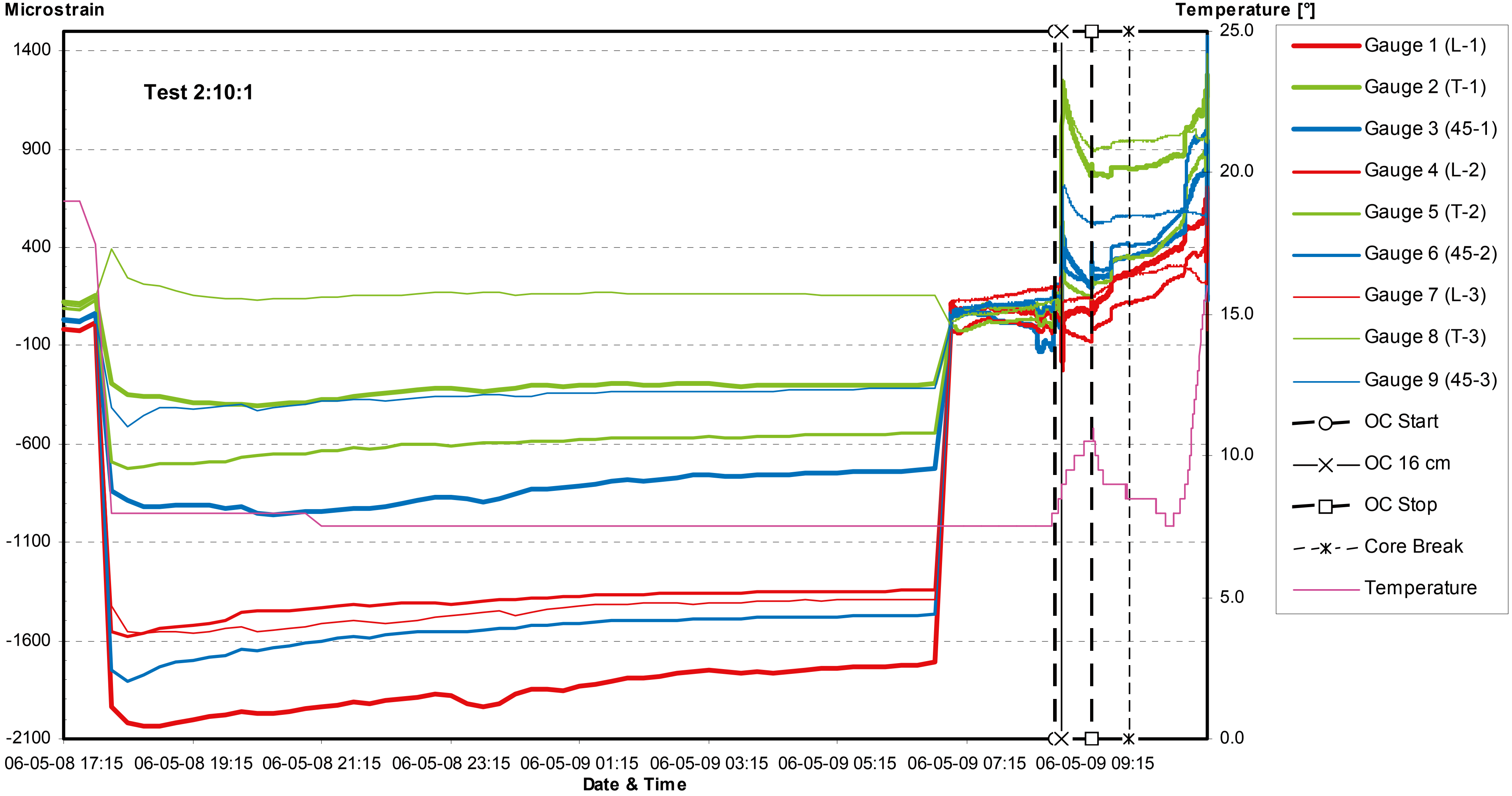


Figure B-17. *All recorded strain data and temperature from activation of probe to recovery from borehole for test no. 2:10:1, 175.65 m borehole length.*

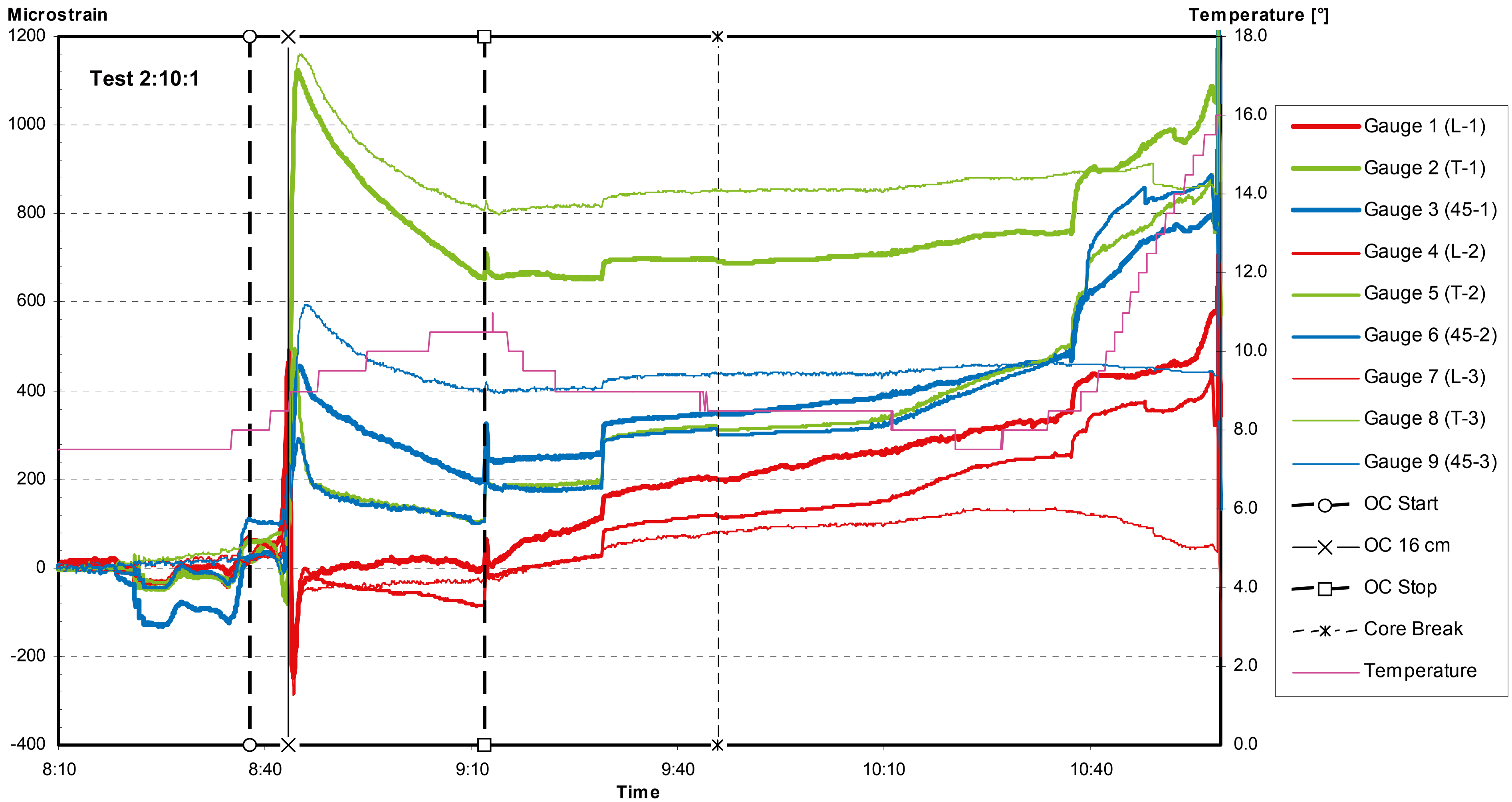


Figure B-18. *Recorded strain data and temperature during overcoring (from start to stop) for test no. 2:10:1, 175.65 borehole length. Strain values reset to zero at 08:10.*

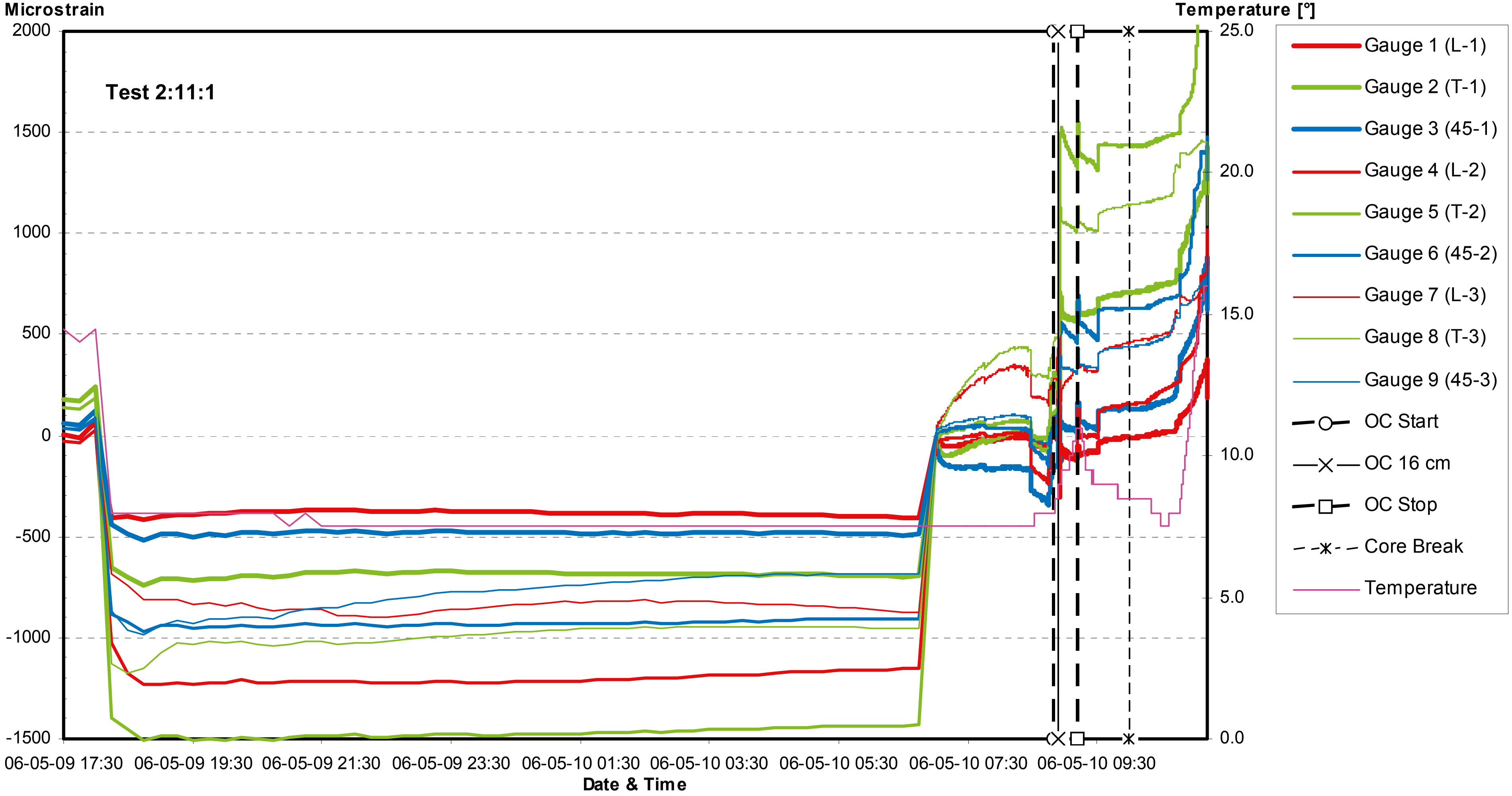


Figure B-19. *All recorded strain data and temperature from activation of probe to recovery from borehole for test no. 2:11:1, 177.65 m borehole length.*

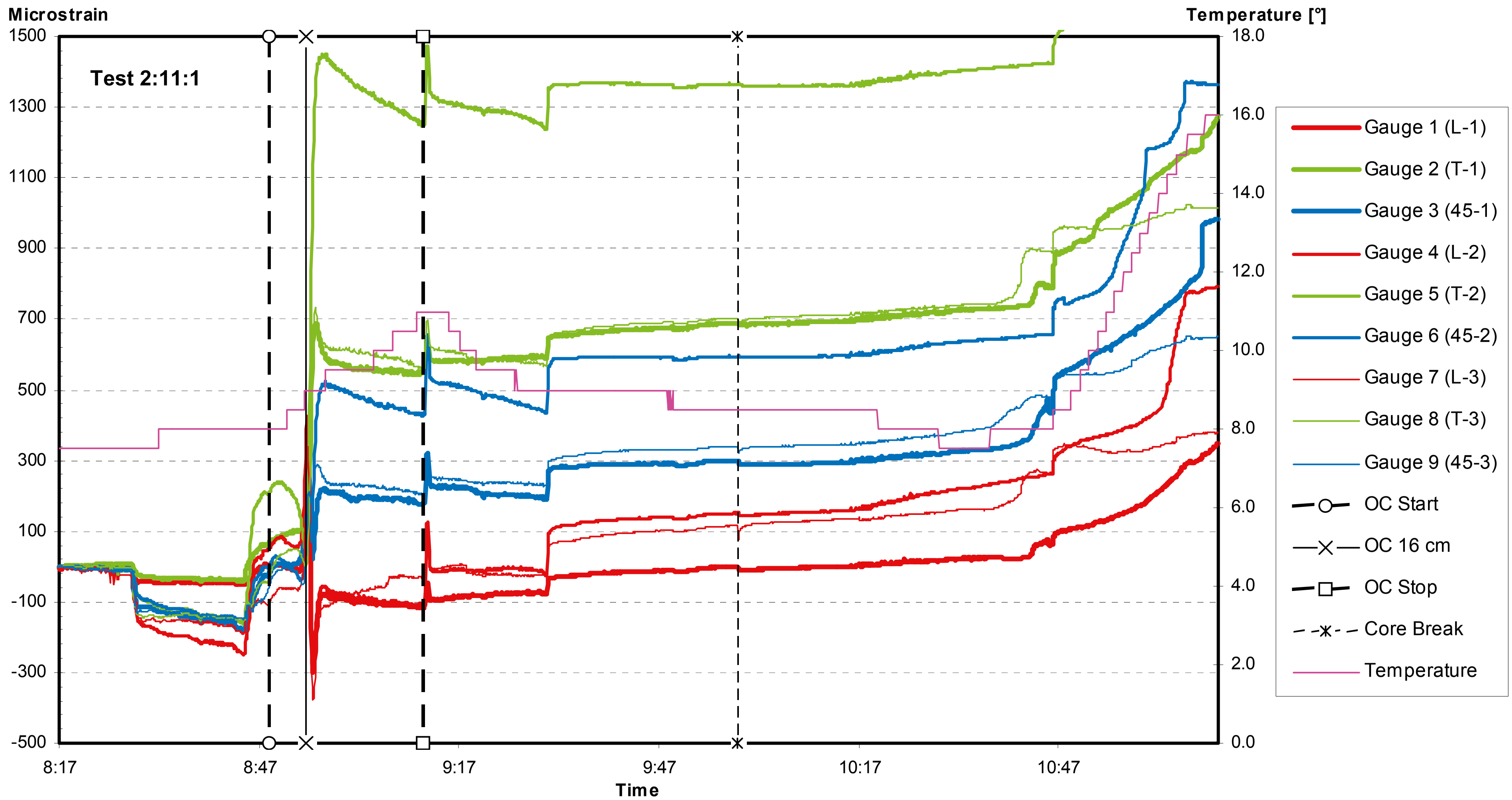


Figure B-20. *Recorded strain data and temperature during overcoring (from start to stop) for test no. 2:11:1, 177.65 borehole length. Strain values reset to zero at 08:17.*

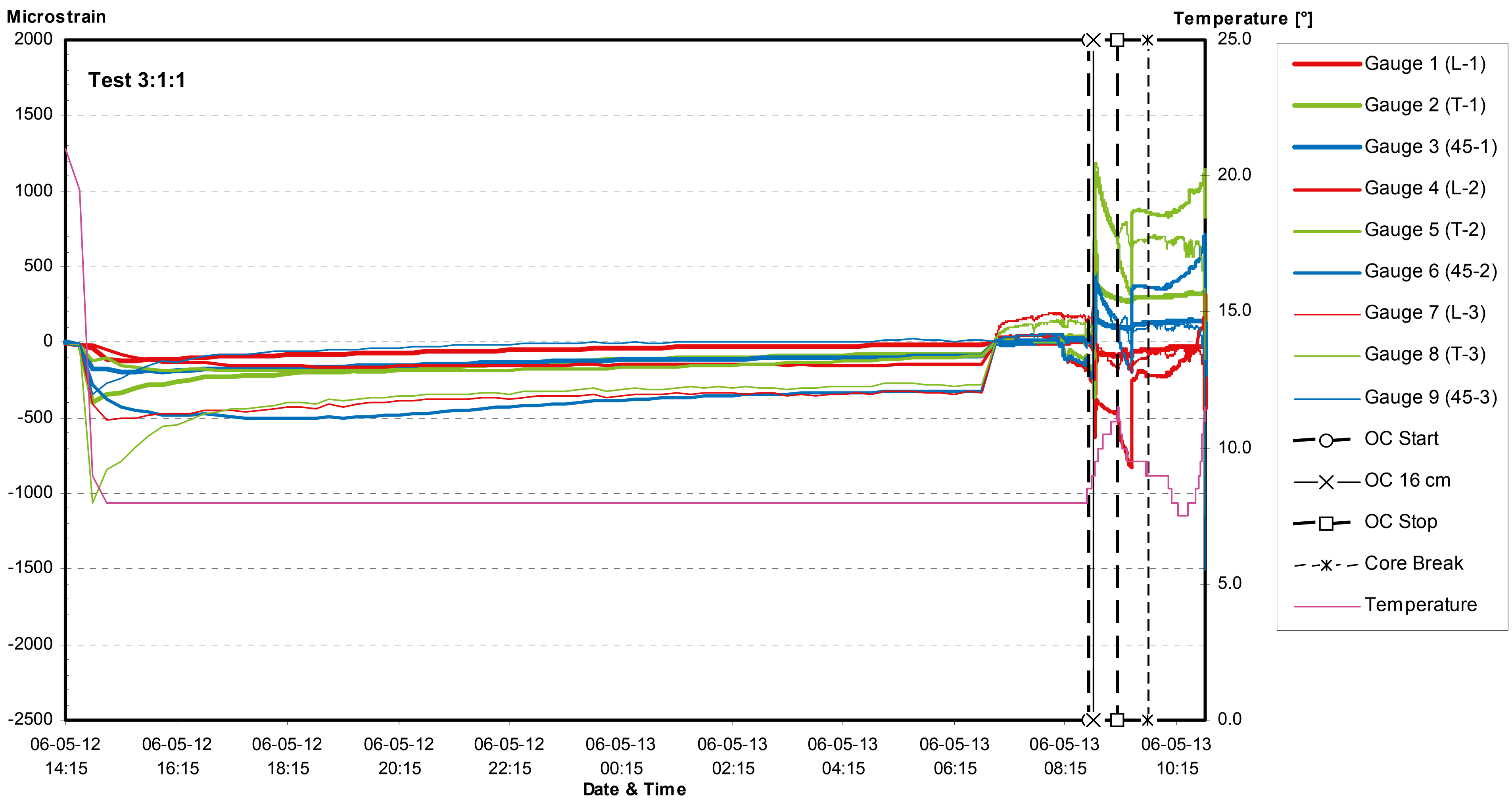


Figure B-21. *All recorded strain data and temperature from activation of probe to recovery from borehole for test no. 3:1:1, 192.47 m borehole length.*

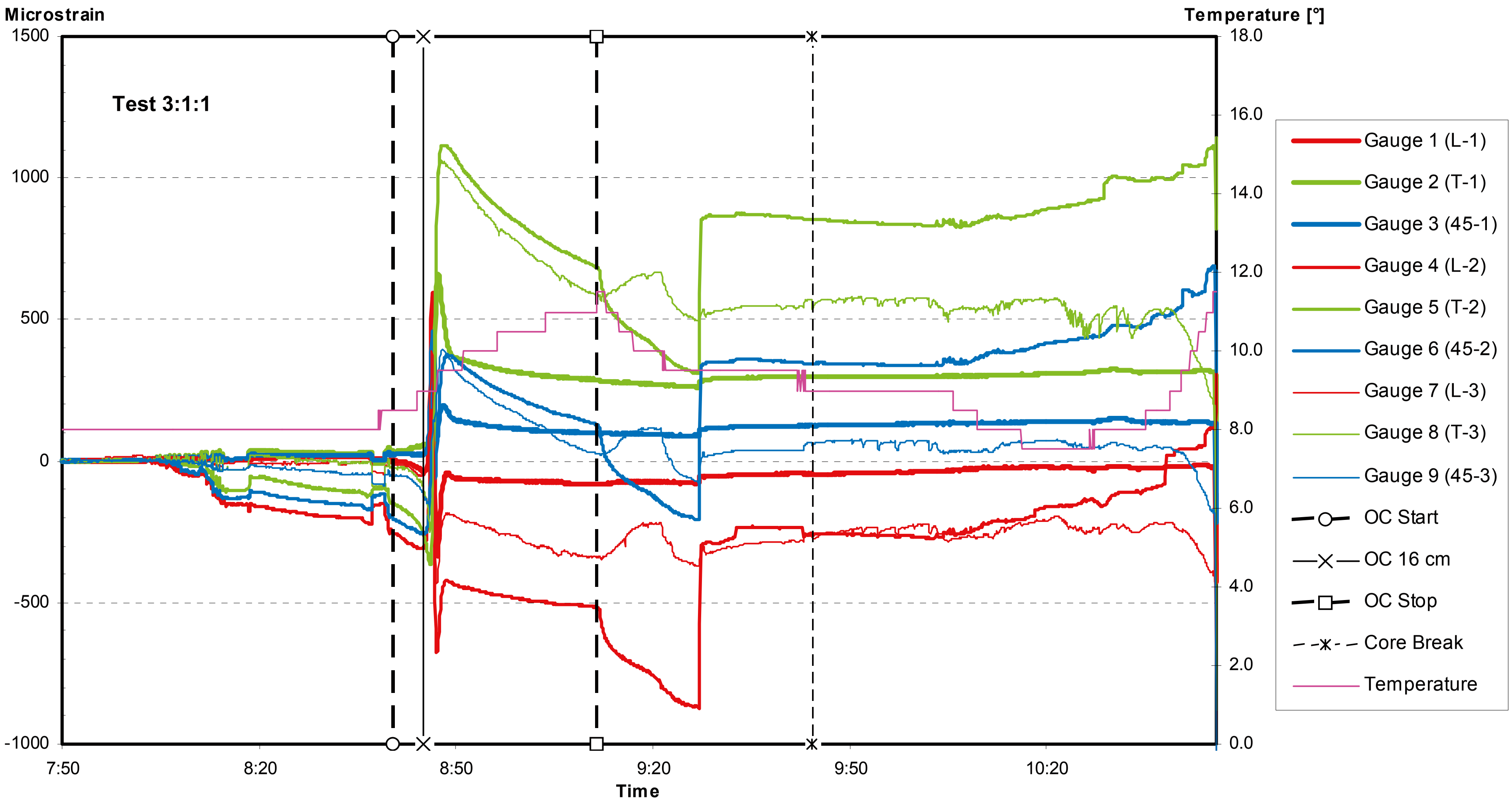


__Figure B-22.__ Recorded strain data and temperature during overcoring (from start to stop) for test no. 3:1:1, 192.47 borehole length. Strain values reset to zero at 07:50.

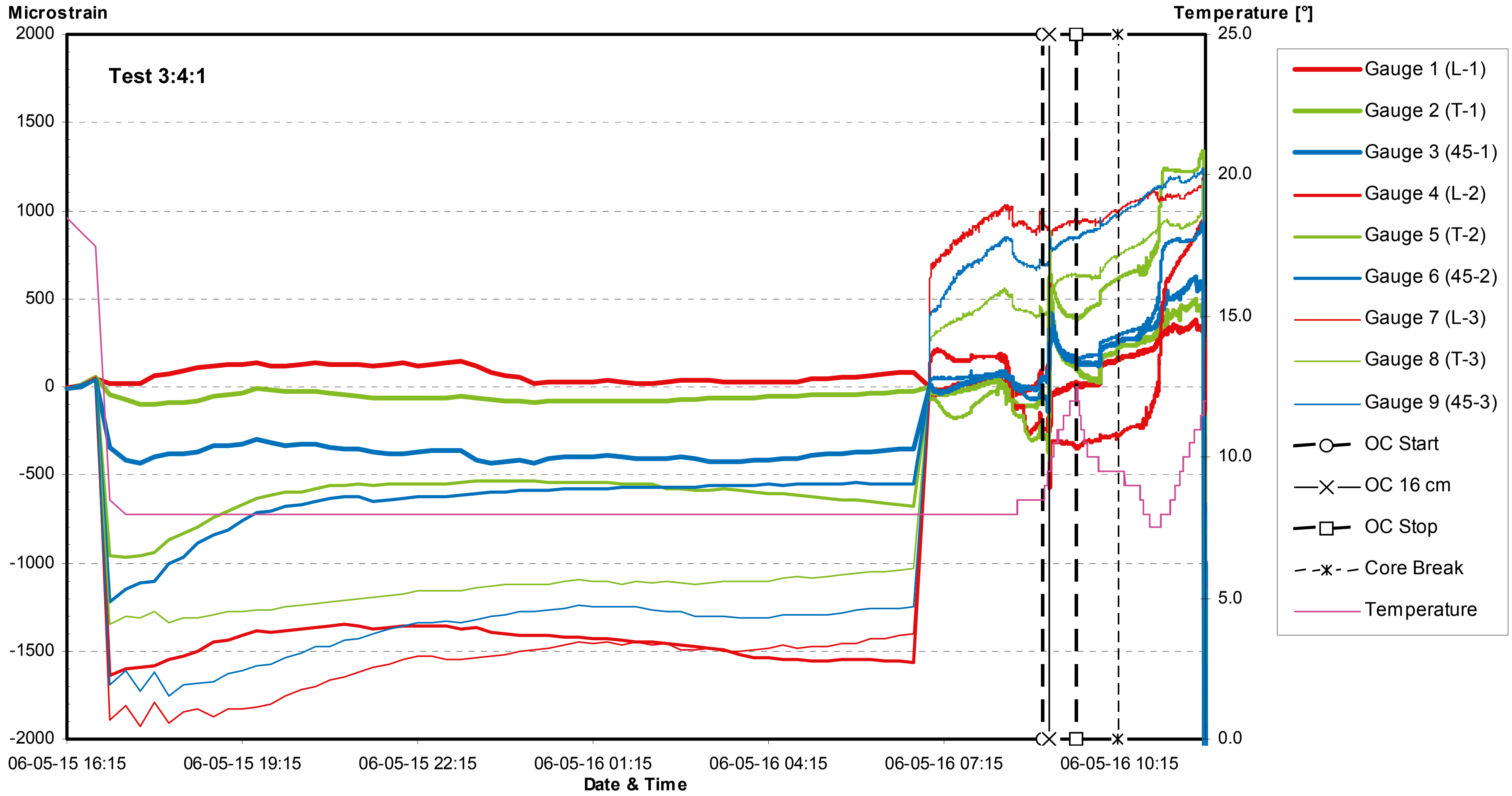


Figure B-23. *All recorded strain data and temperature from activation of probe to recovery from borehole for test no. 3:4:1, 195.31 m borehole length.*

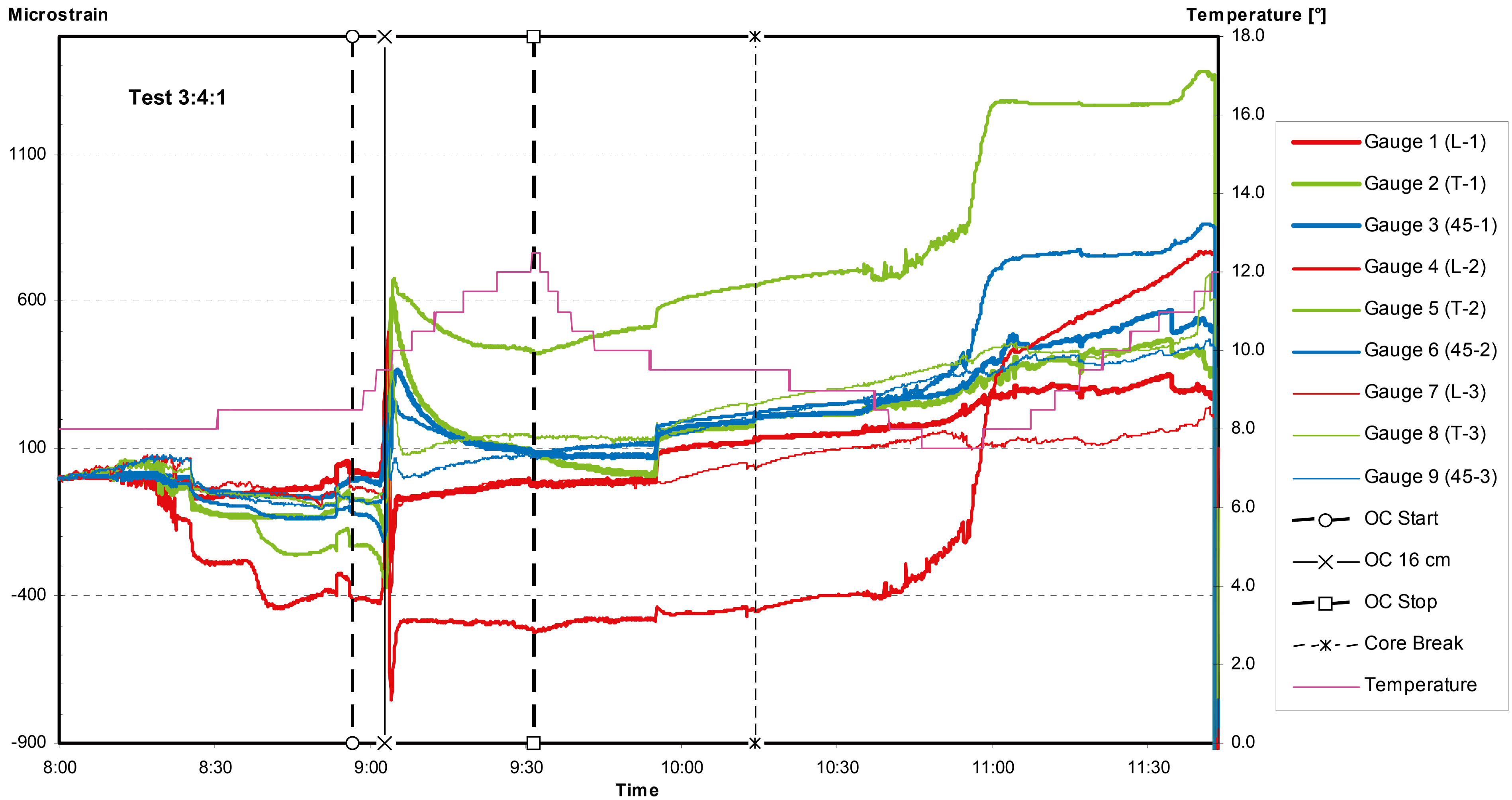


Figure B-24. *Recorded strain data and temperature during overcoring (from start to stop) for test no. 3:4:1, 195.31 borehole length. Strain values reset to zero at 08:00.*

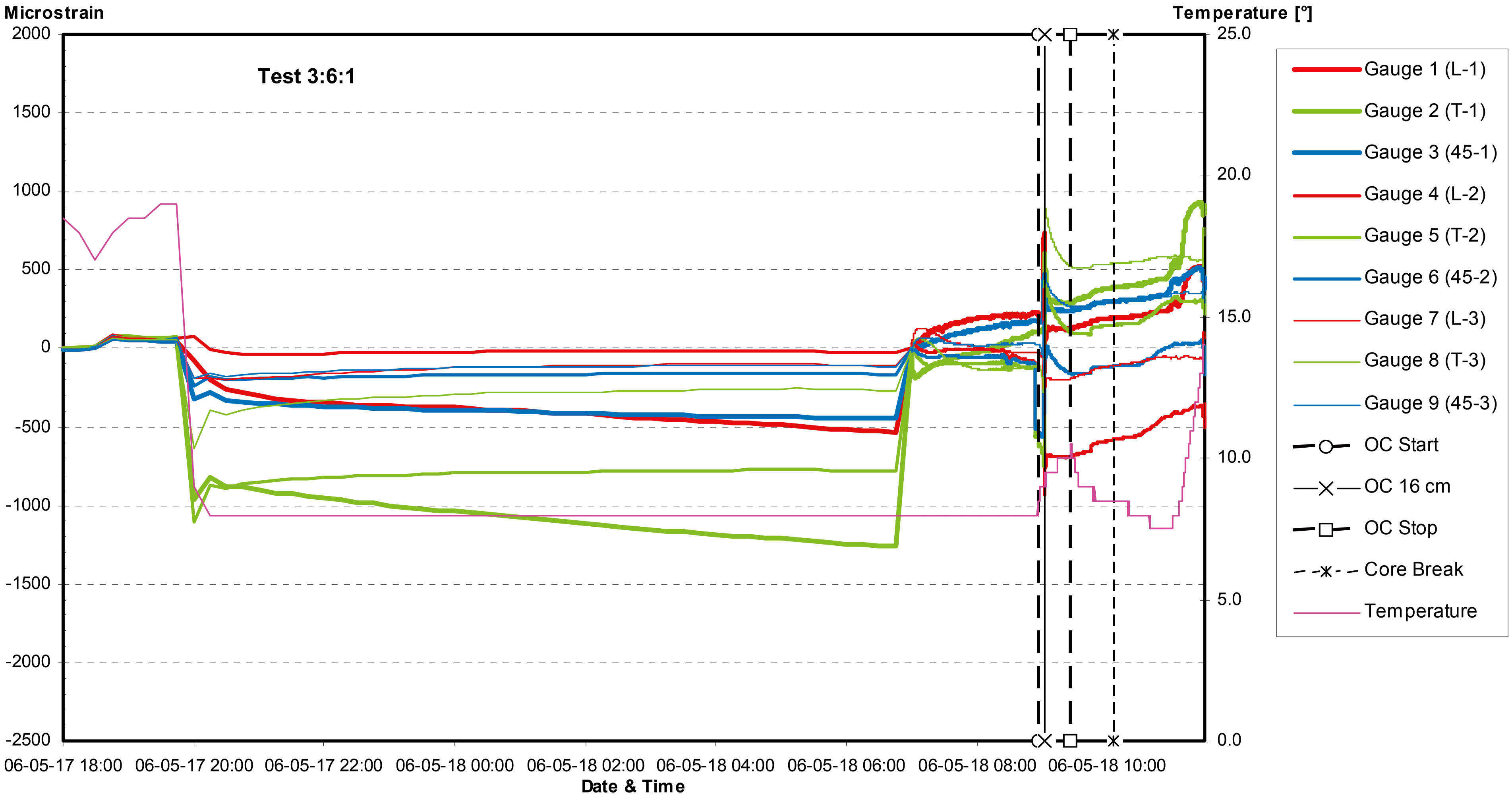


Figure B-25. *All recorded strain data and temperature from activation of probe to recovery from borehole for test no. 3:6:1, 197.28 m borehole length.*

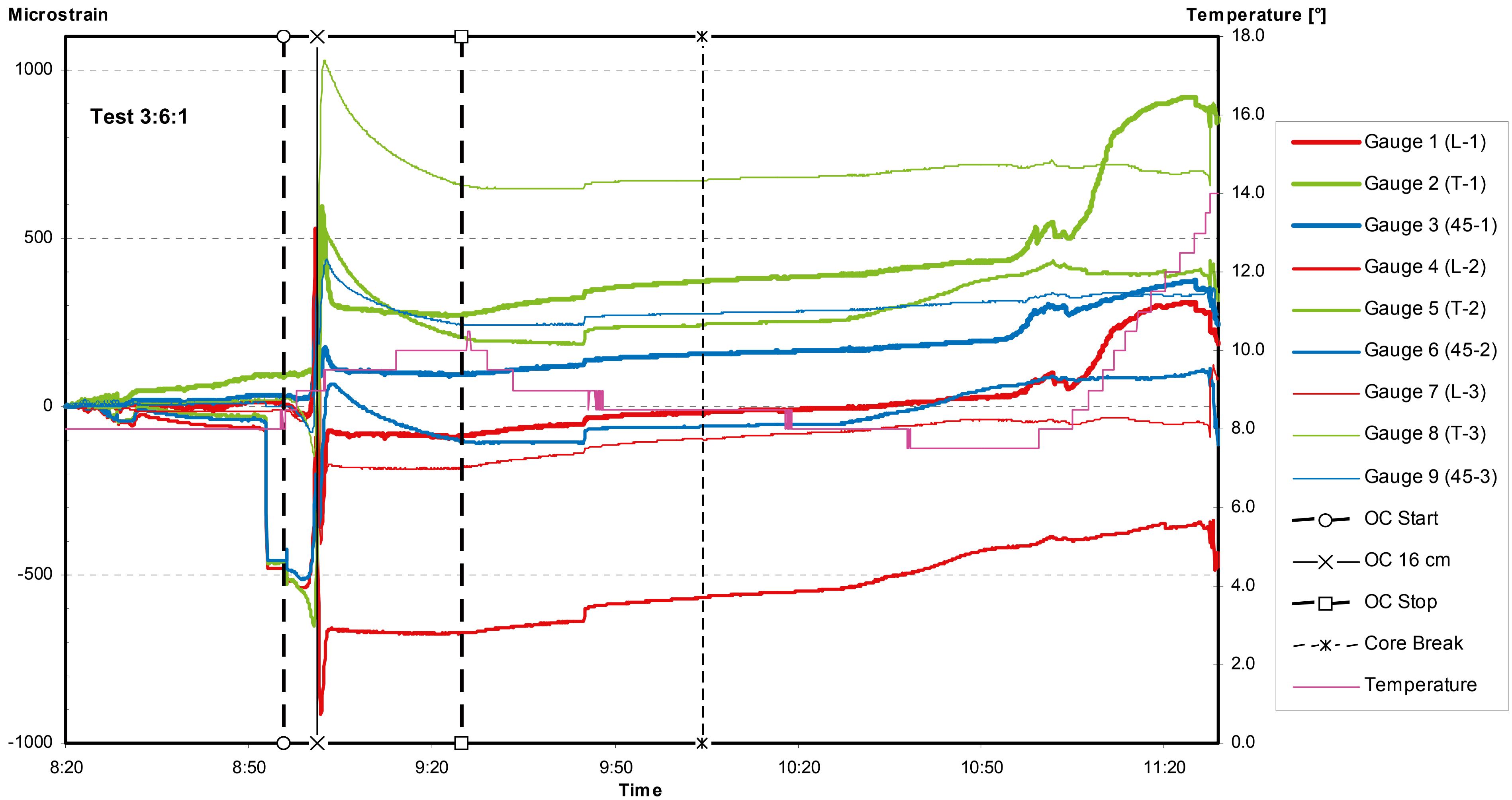


Figure B-26. *Recorded strain data and temperature during overcoring (from start to stop) for test no. 3:6:1, 197.28 borehole length. Strain values reset to zero at 08:20.*

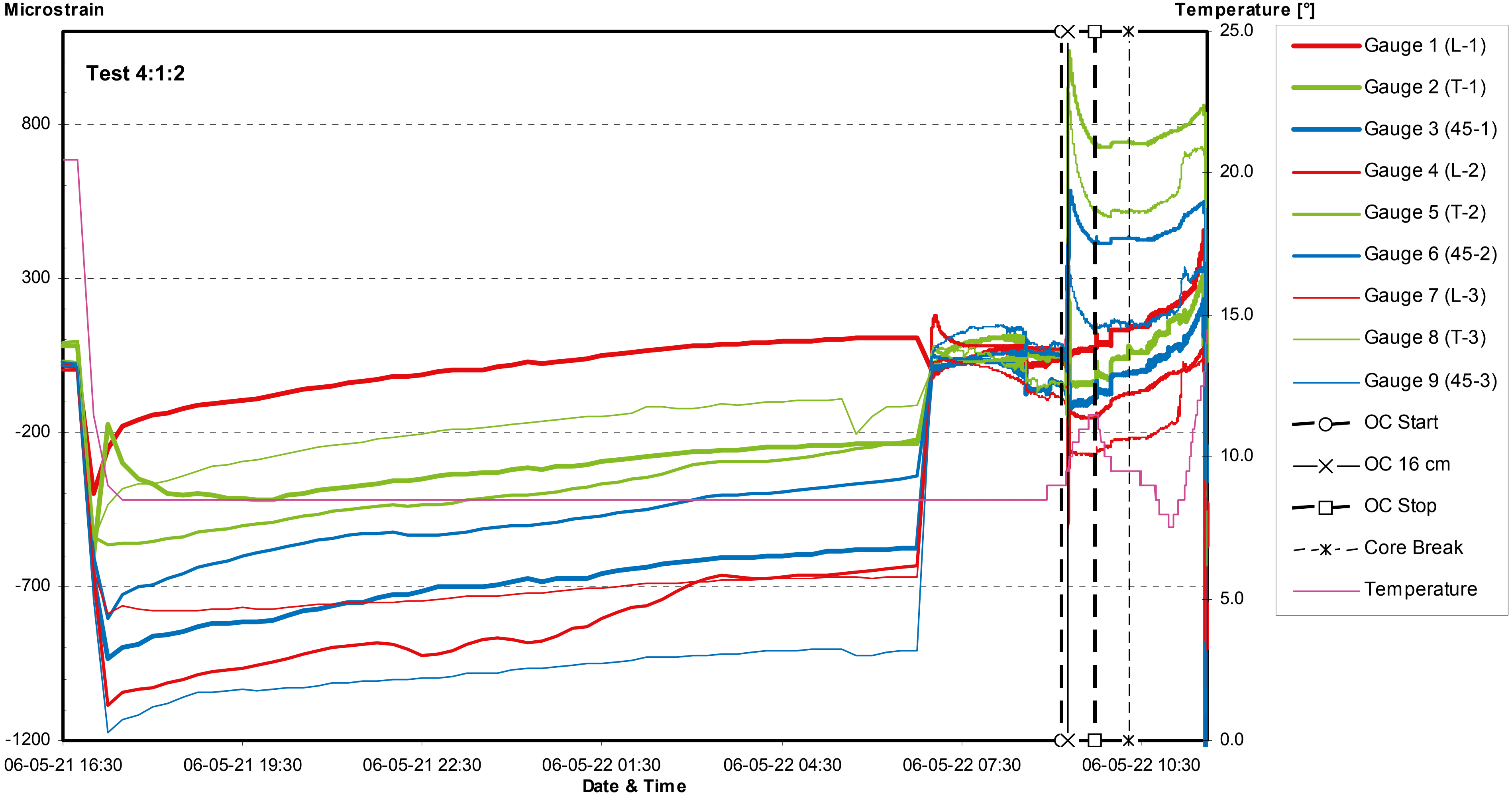


Figure B-27. *All recorded strain data and temperature from activation of probe to recovery from borehole for test no. 4:1:2, 238.05 m borehole length.*

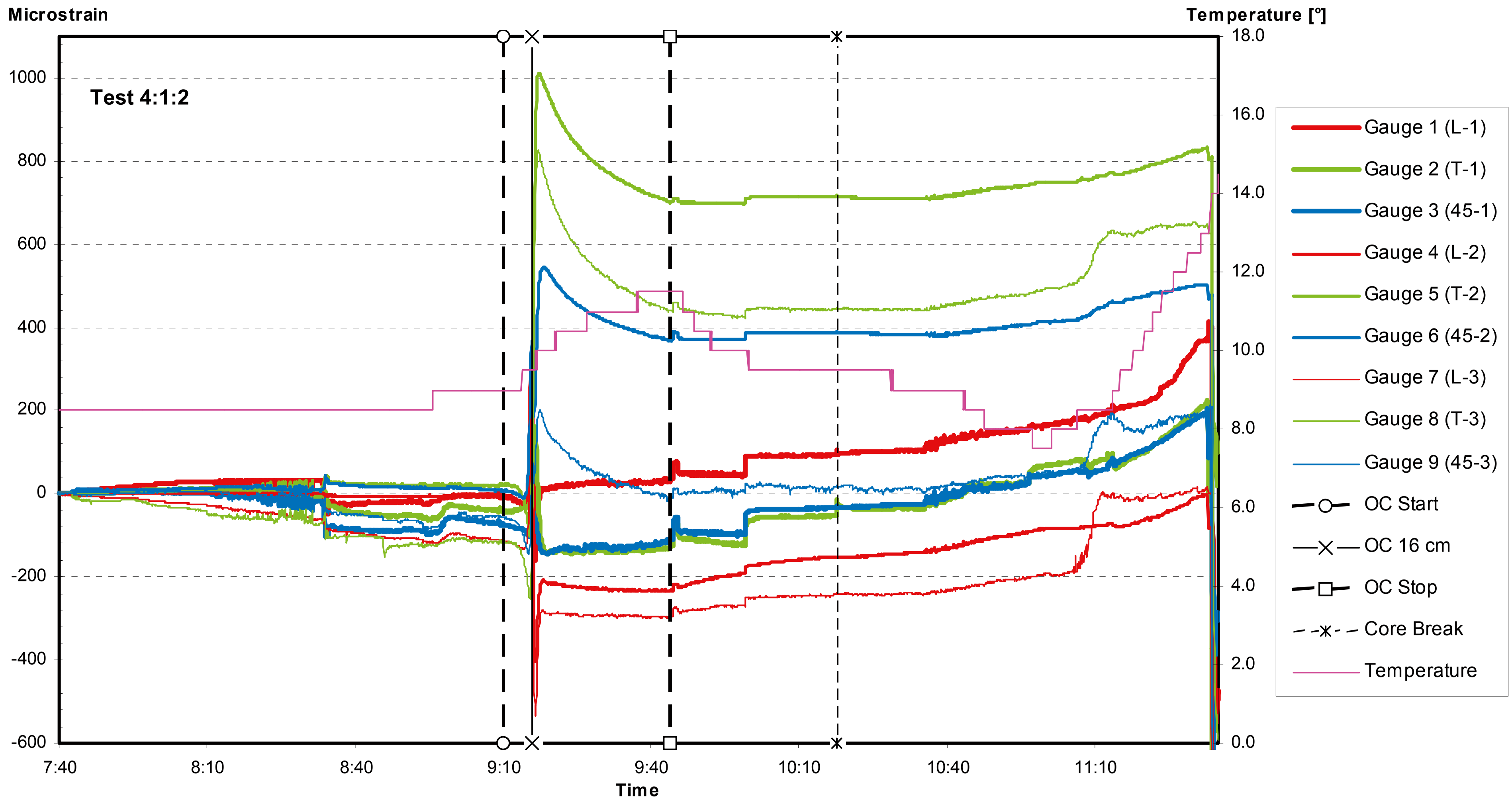


Figure B-28. *Recorded strain data and temperature during overcoring (from start to stop) for test no. 4:1:2, 238.05 borehole length. Strain values reset to zero at 07:40.*

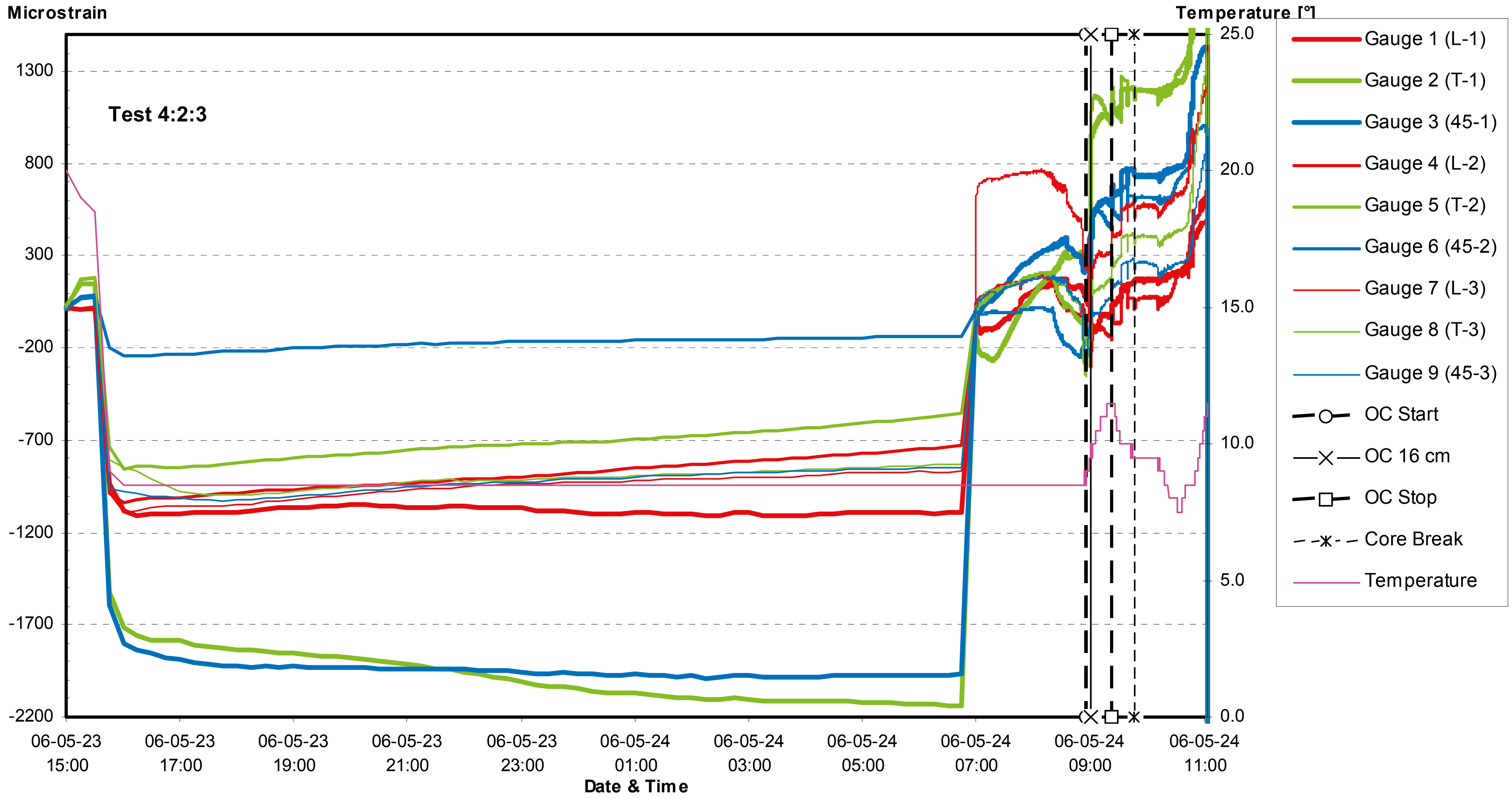


Figure B-29. *All recorded strain data and temperature from activation of probe to recovery from borehole for test no. 4:2:3, 242.70 m borehole length.*

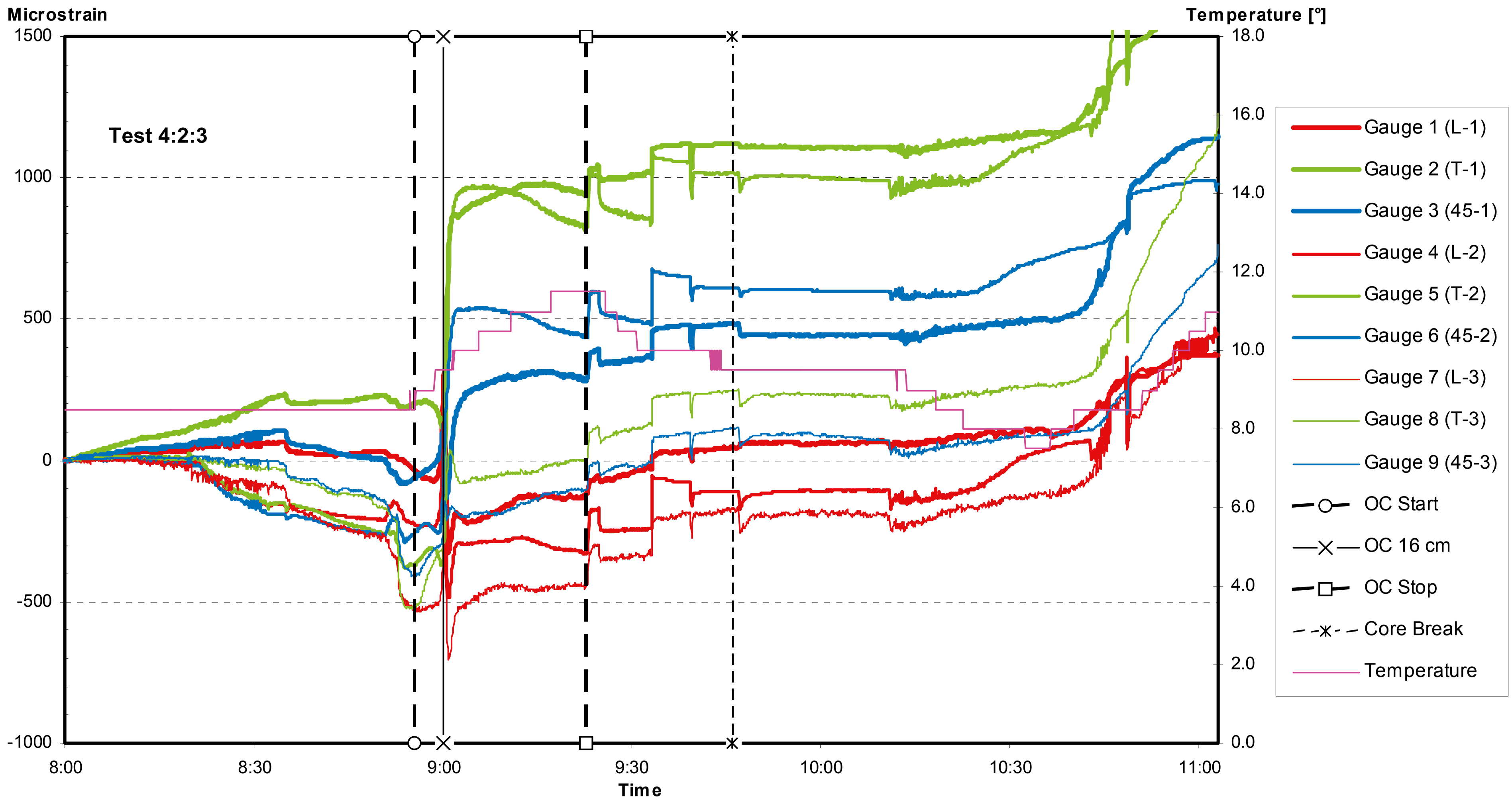


Figure B-30. *Recorded strain data and temperature during overcoring (from start to stop) for test no. 4:2:3, 242.70 borehole length. Strain values reset to zero at 08:00.*

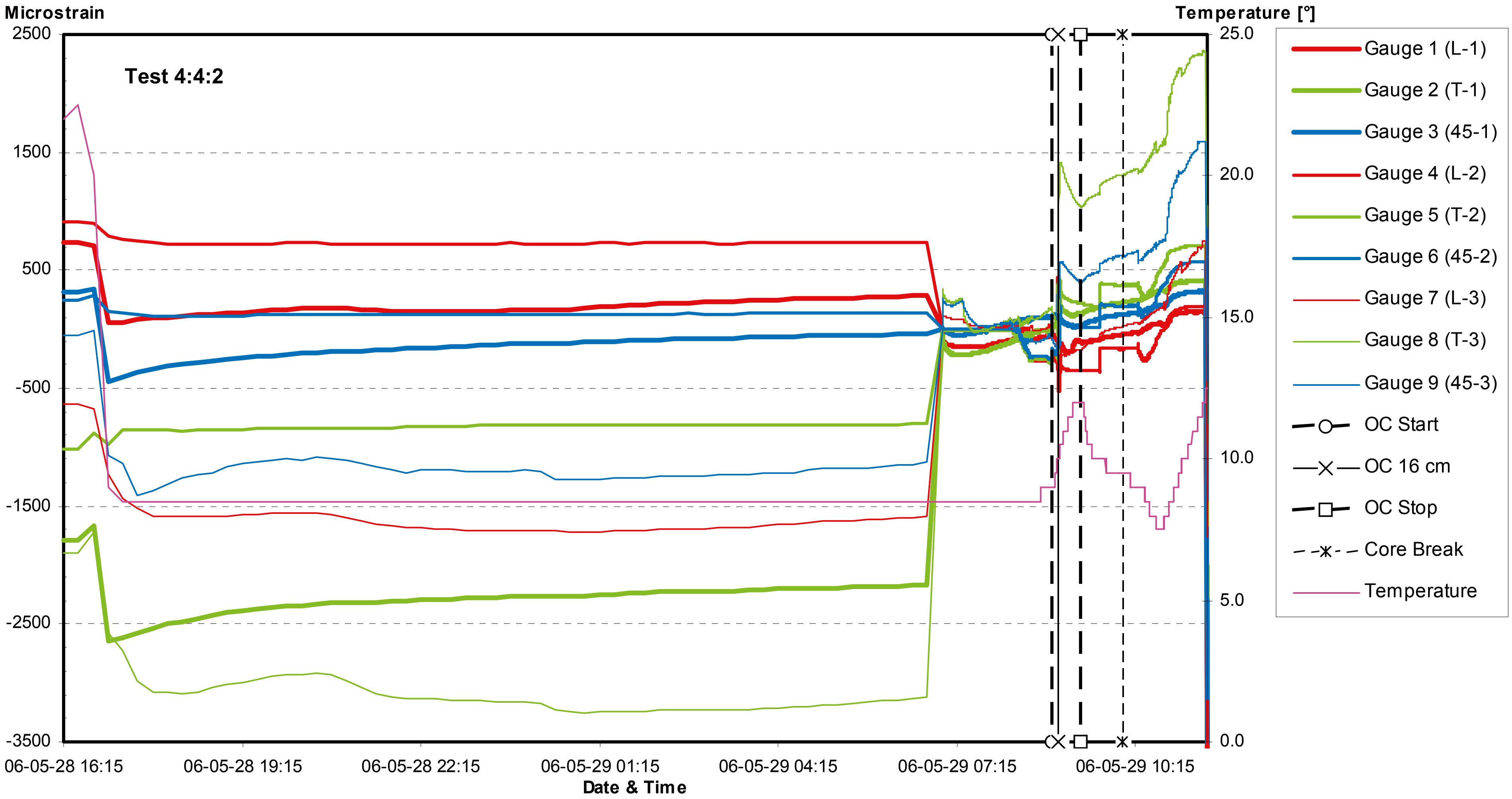


Figure B-31. *All recorded strain data and temperature from activation of probe to recovery from borehole for test no. 4:4:2, 258.73 m borehole length.*

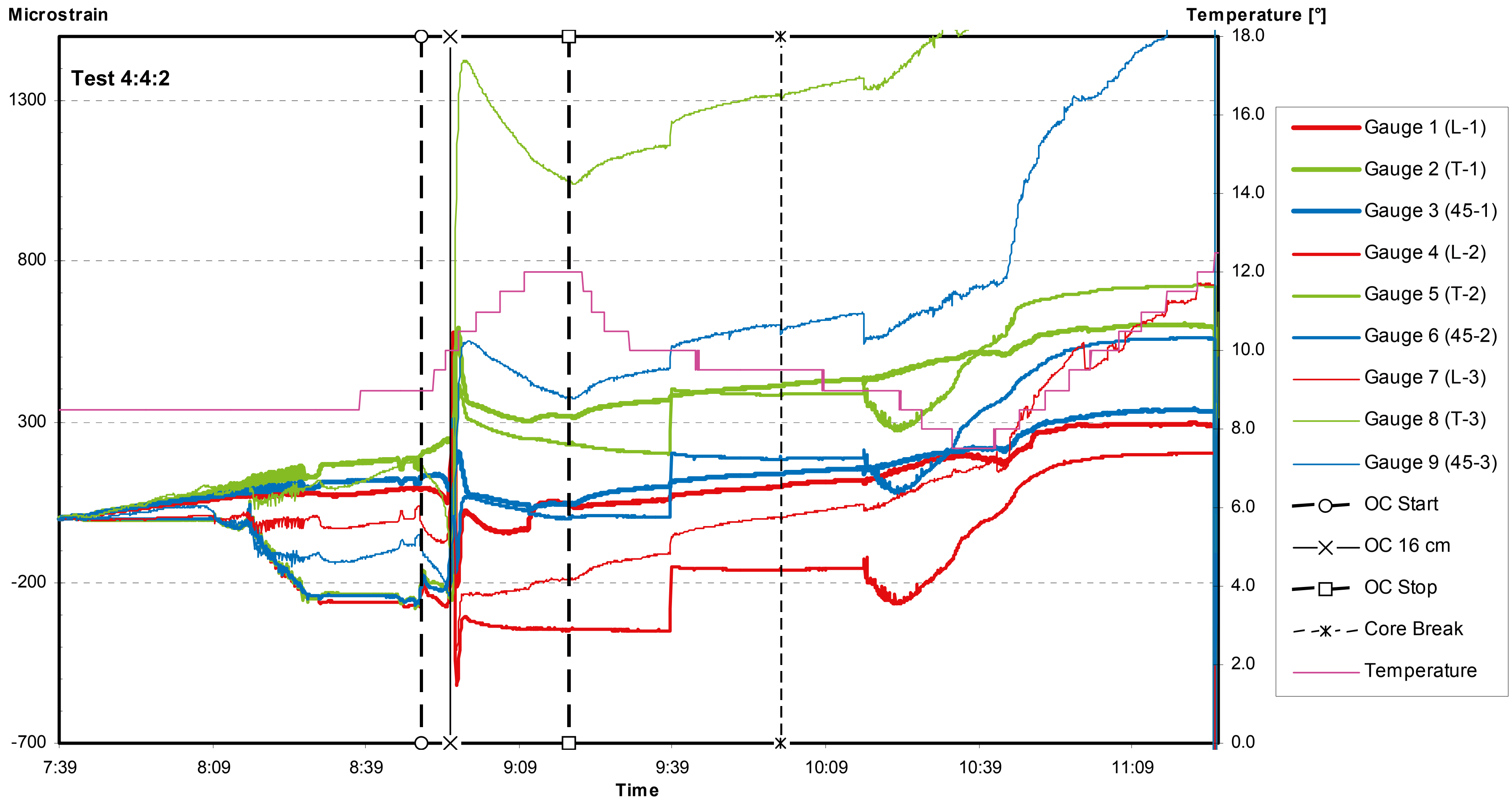


Figure B-32. *Recorded strain data and temperature during overcoring (from start to stop) for test no. 4:4:2, 258.73 borehole length. Strain values reset to zero at 07:39.*

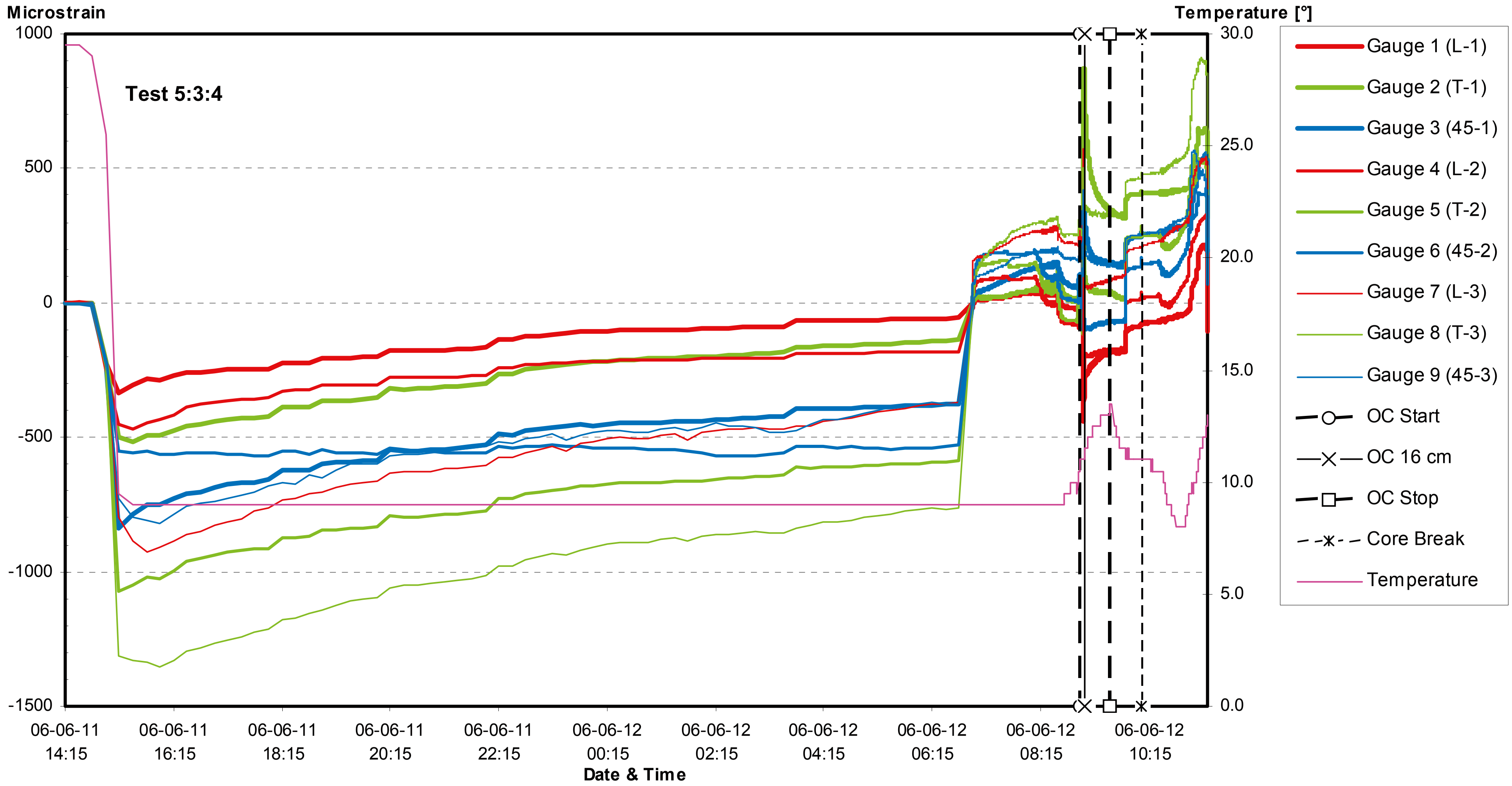


Figure B-33. *All recorded strain data and temperature from activation of probe to recovery from borehole for test no. 5:3:4, 316.25 m borehole length.*

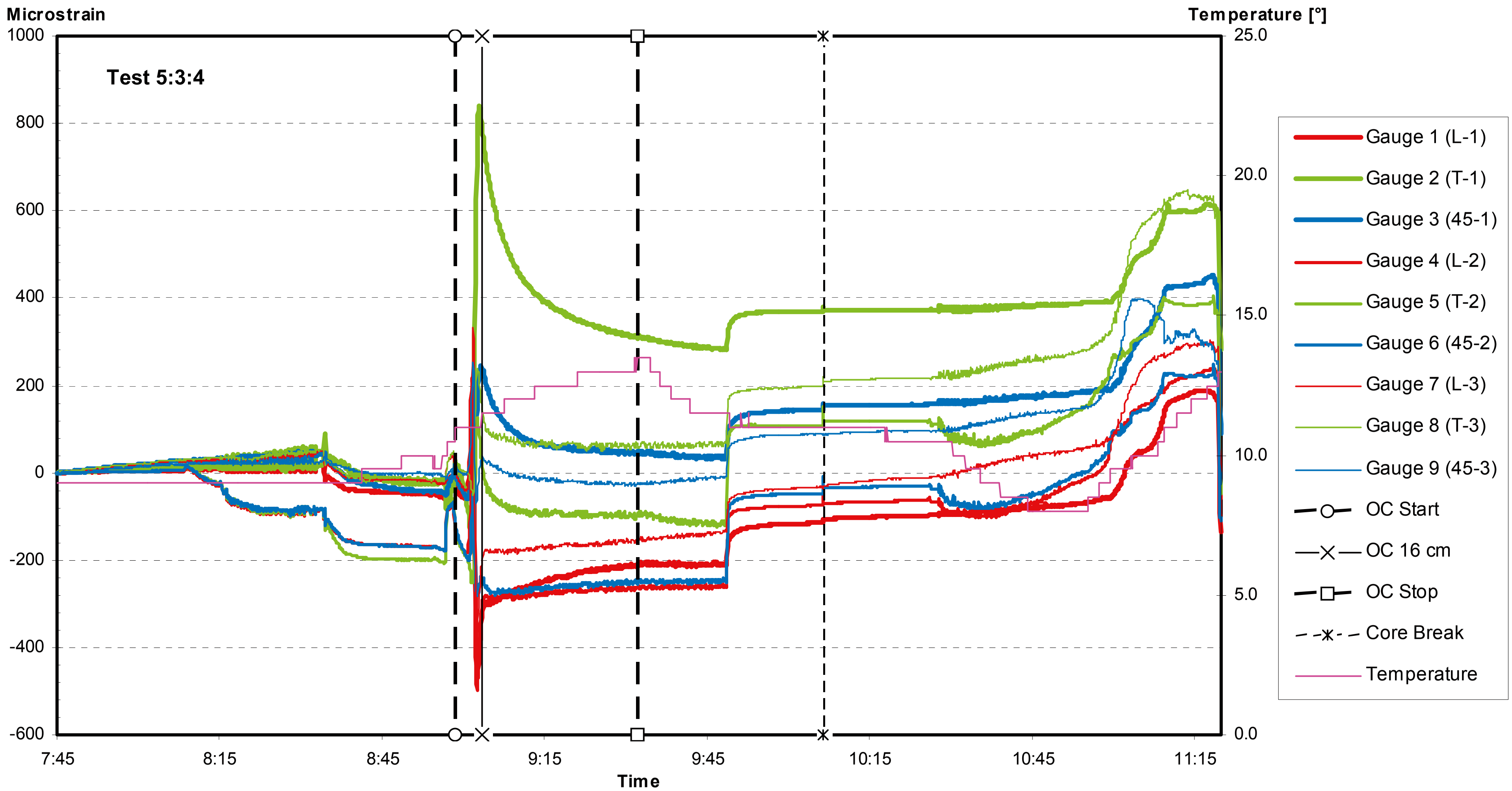


Figure B-34. *Recorded strain data and temperature during overcoring (from start to stop) for test no. 5:3:4, 316.25 borehole length. Strain values reset to zero at 07:45.*

Biaxial test data

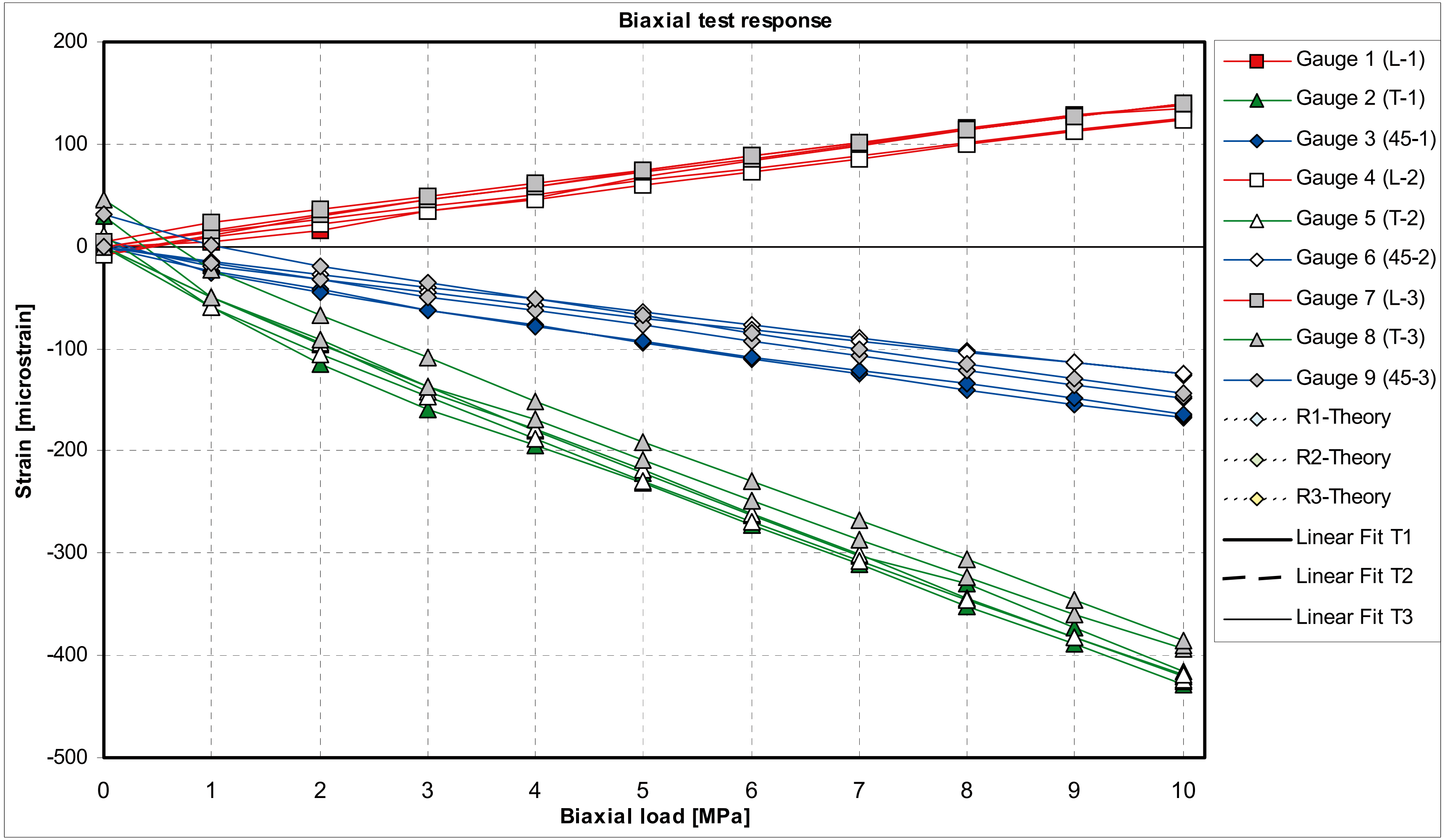


Figure C-1. *Results from biaxial testing of test no. 1:2:4, 104.53 m borehole length.*

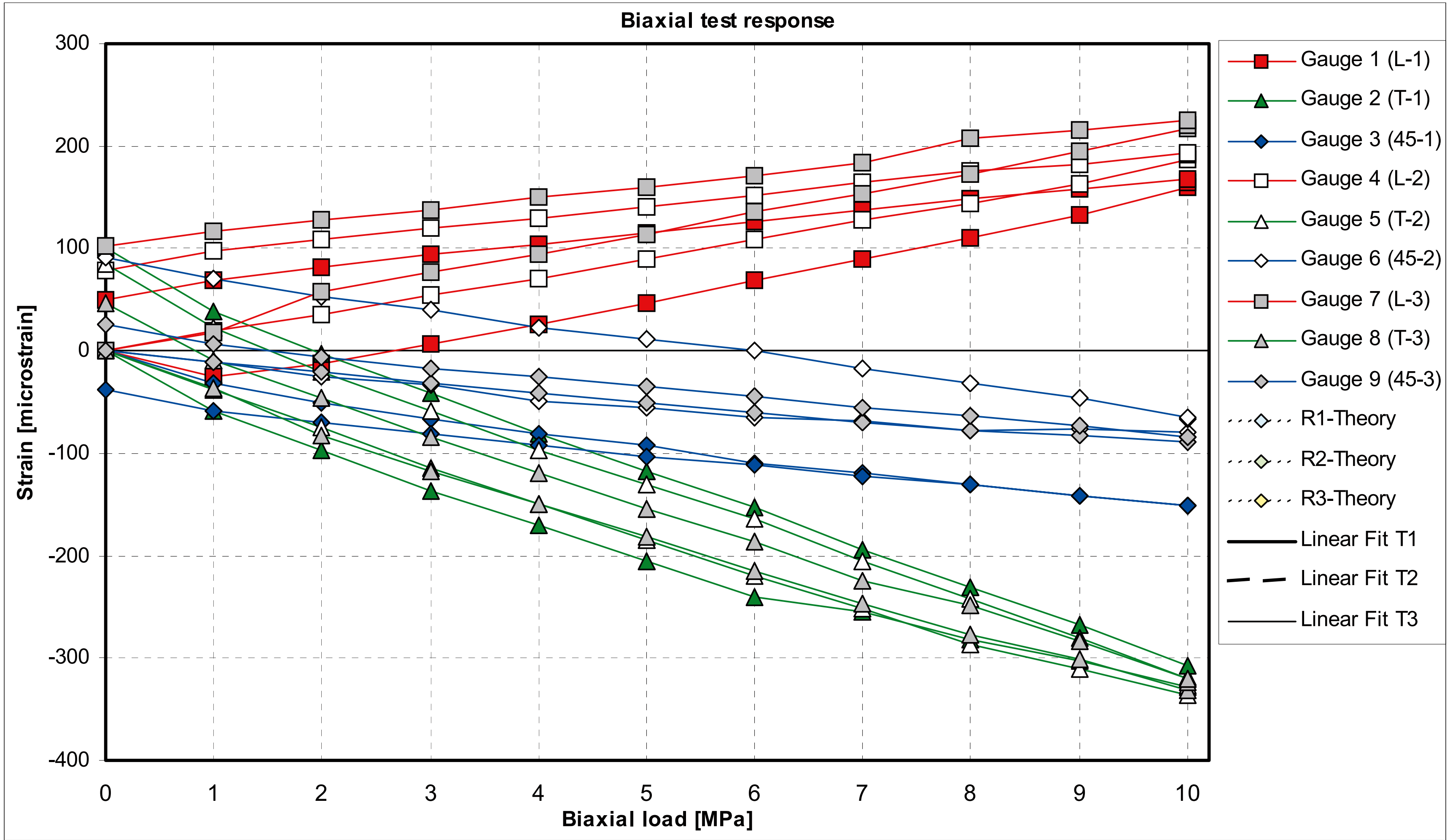


Figure C-2. *Results from biaxial testing of test no. 1:4:1, 108.42 m borehole length.*

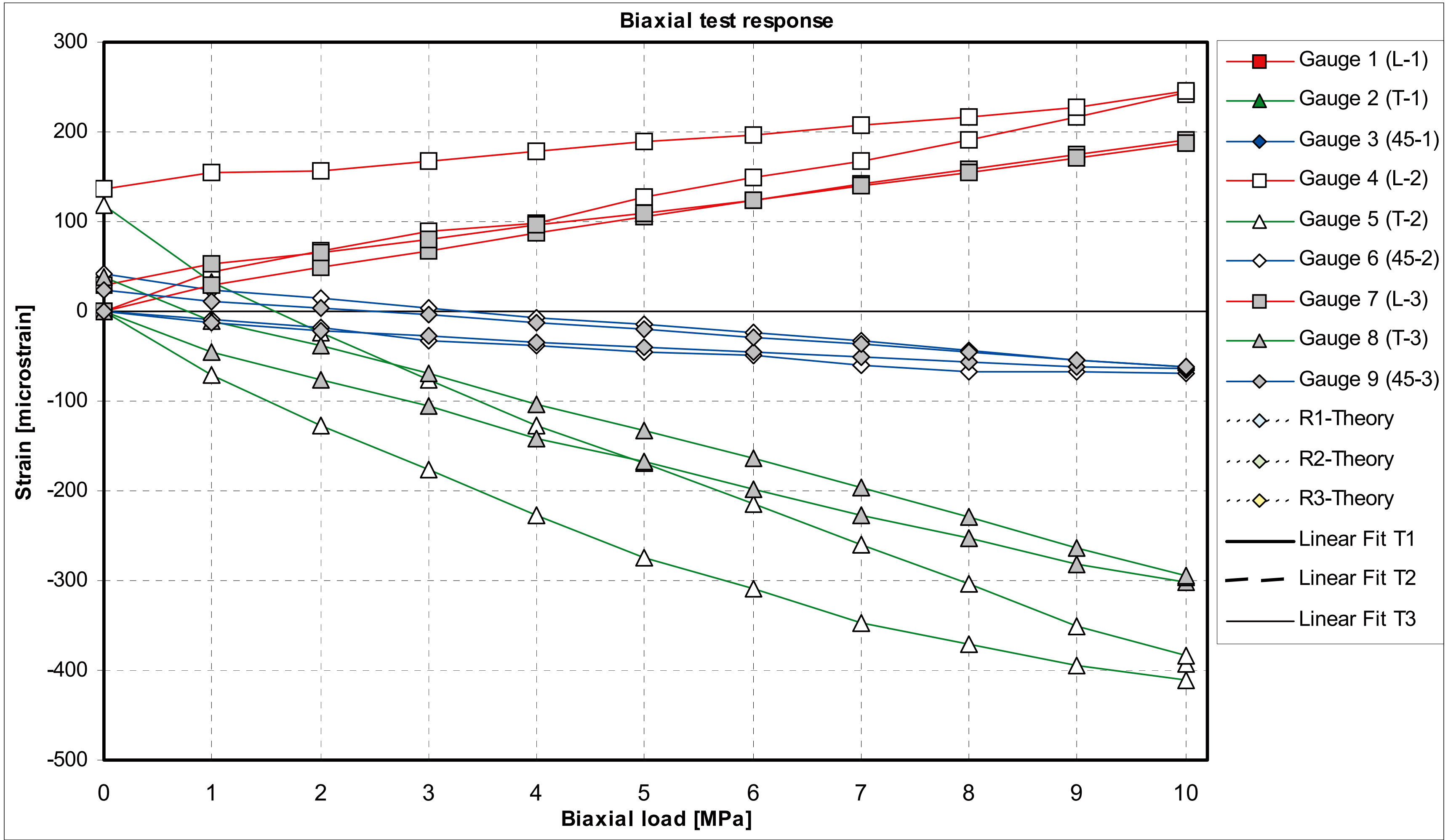


Figure C-3. *Results from biaxial testing of test no. 2:1:3, 158.28 m borehole length, excluding rosette no. 1 due to unstable strain response.*

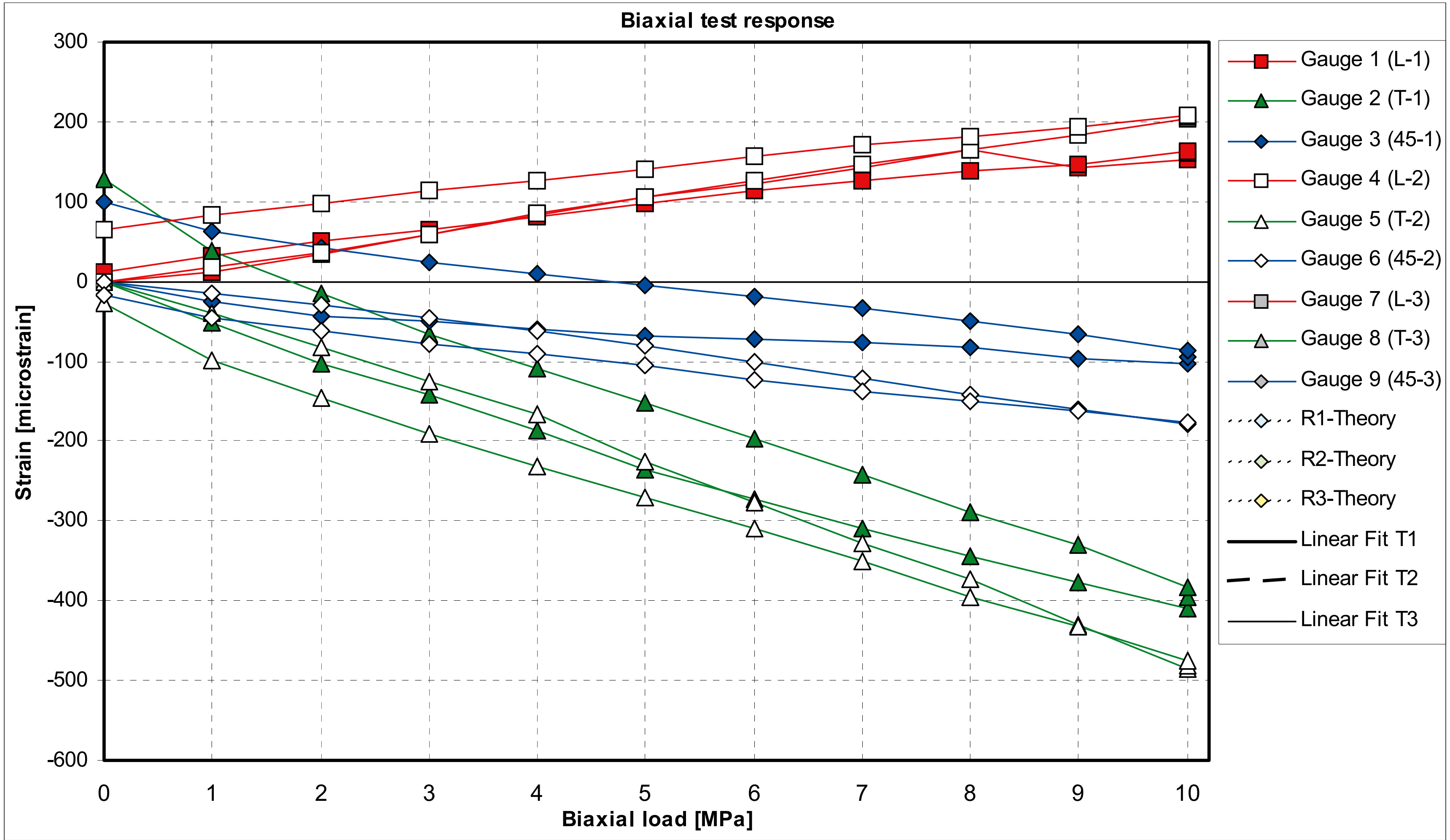


Figure C-4. *Results from biaxial testing of test no. 2:3:1, 160.37 m borehole length, excluding rosette no. 3 due to unstable strain response.*

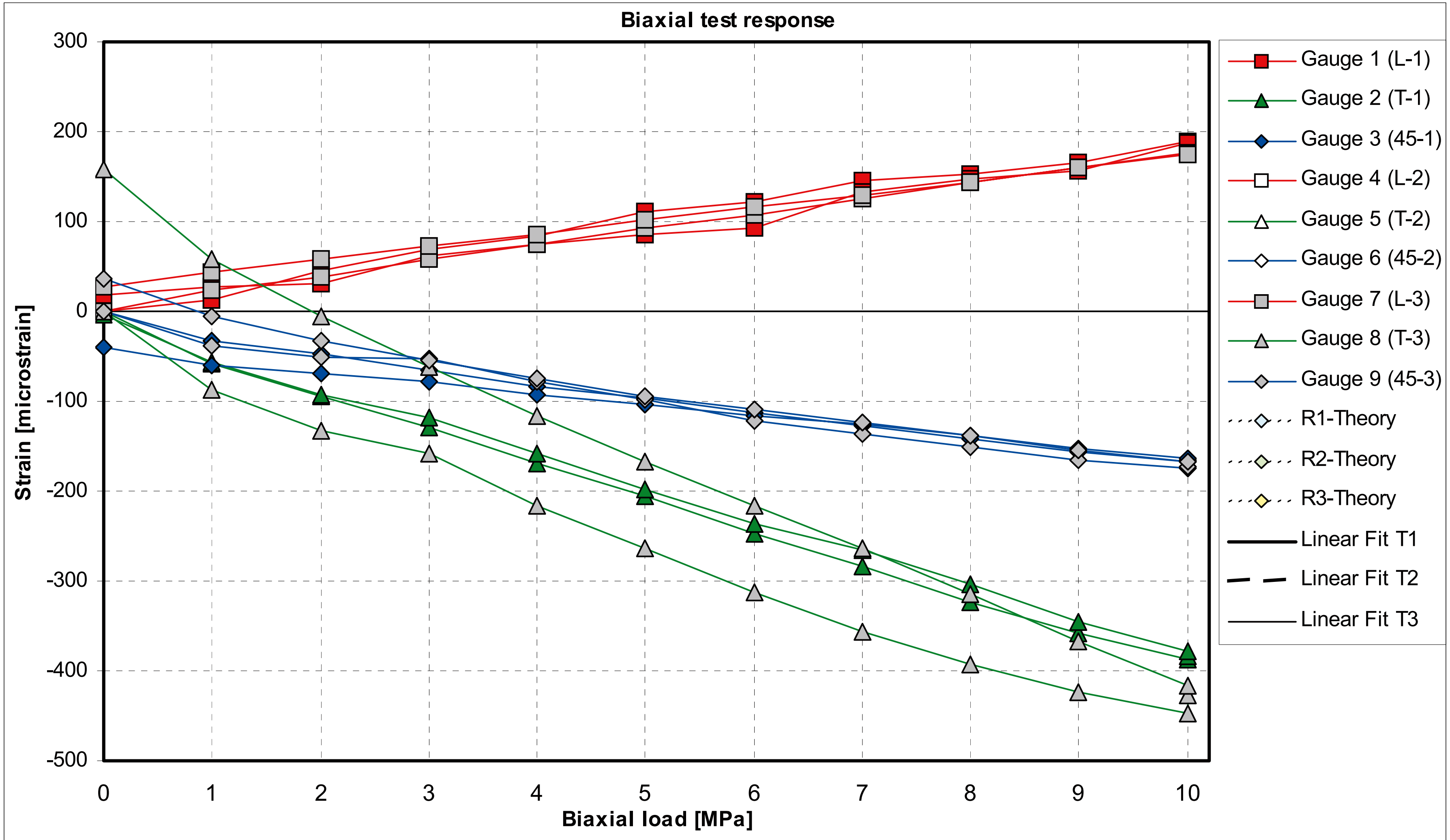


Figure C-5. *Results from biaxial testing of test no. 2:4:1, 162.69 m borehole length, excluding rosette no. 2 due to unstable strain response.*

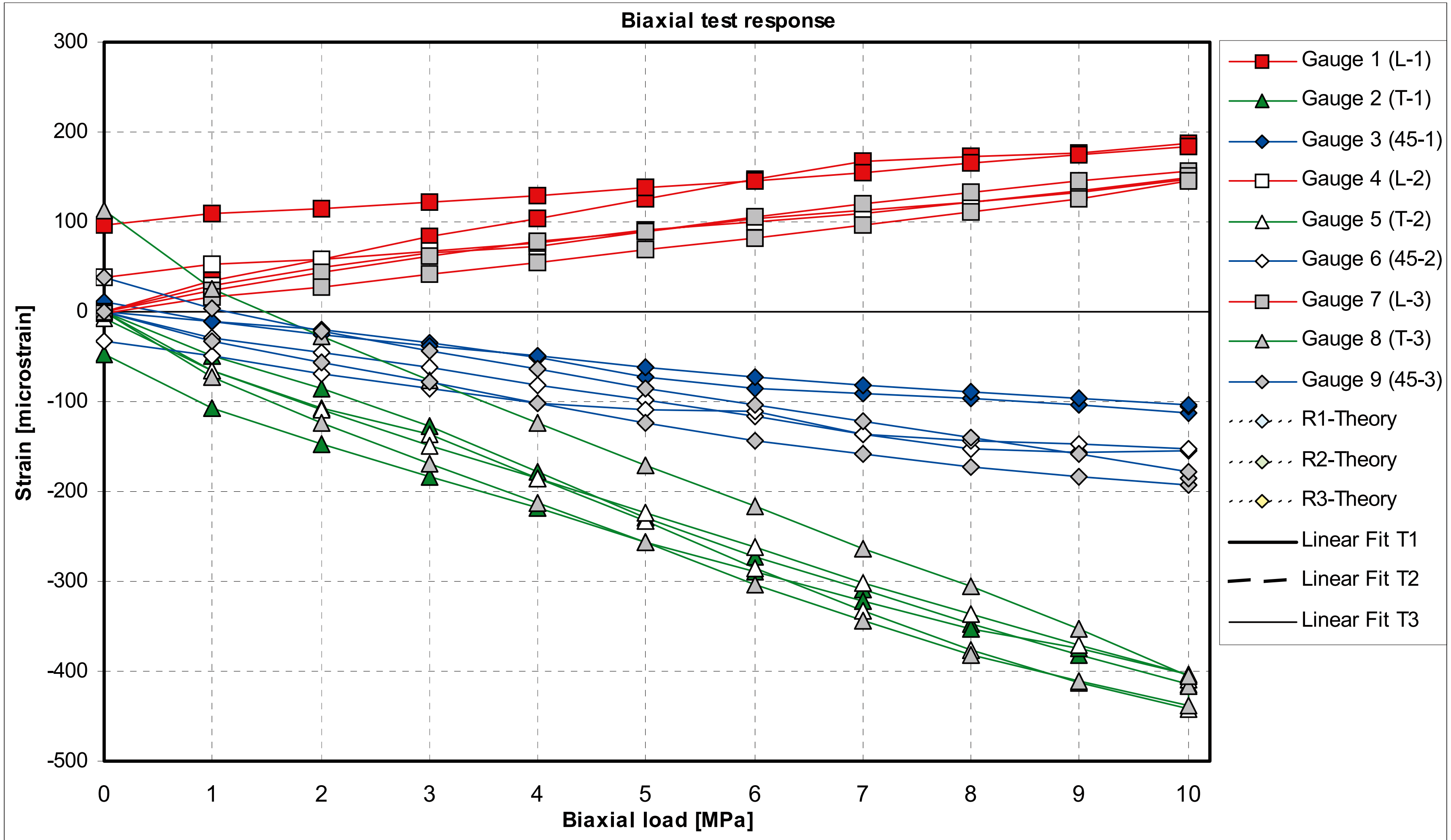


Figure C-6. *Results from biaxial testing of test no. 2:8:1, 174.60 m borehole length.*

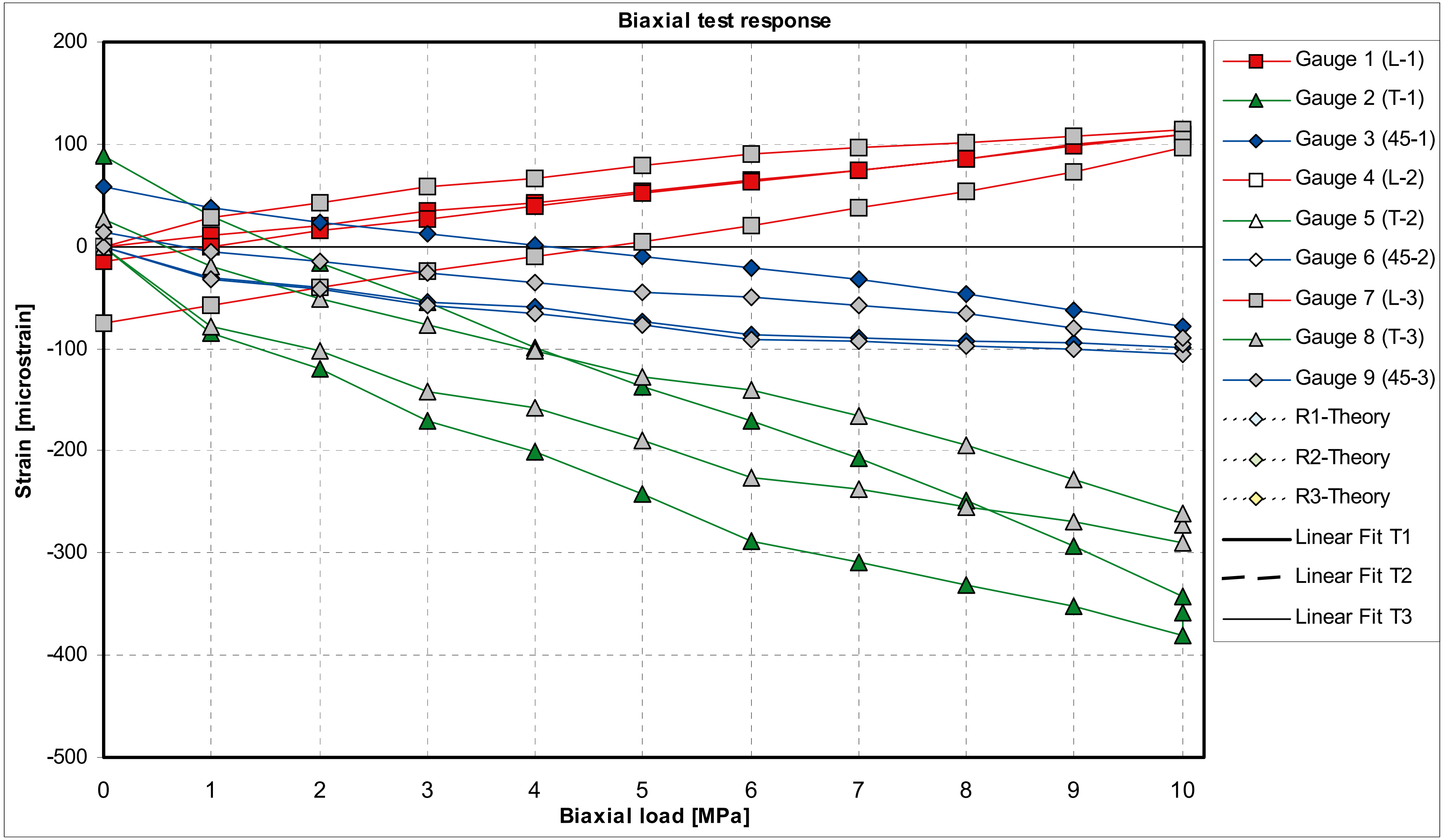


Figure C-7. *Results from biaxial testing of test no. 2:9:1, 175.62 m borehole length, excluding rosette no. 2 due to unstable strain response.*

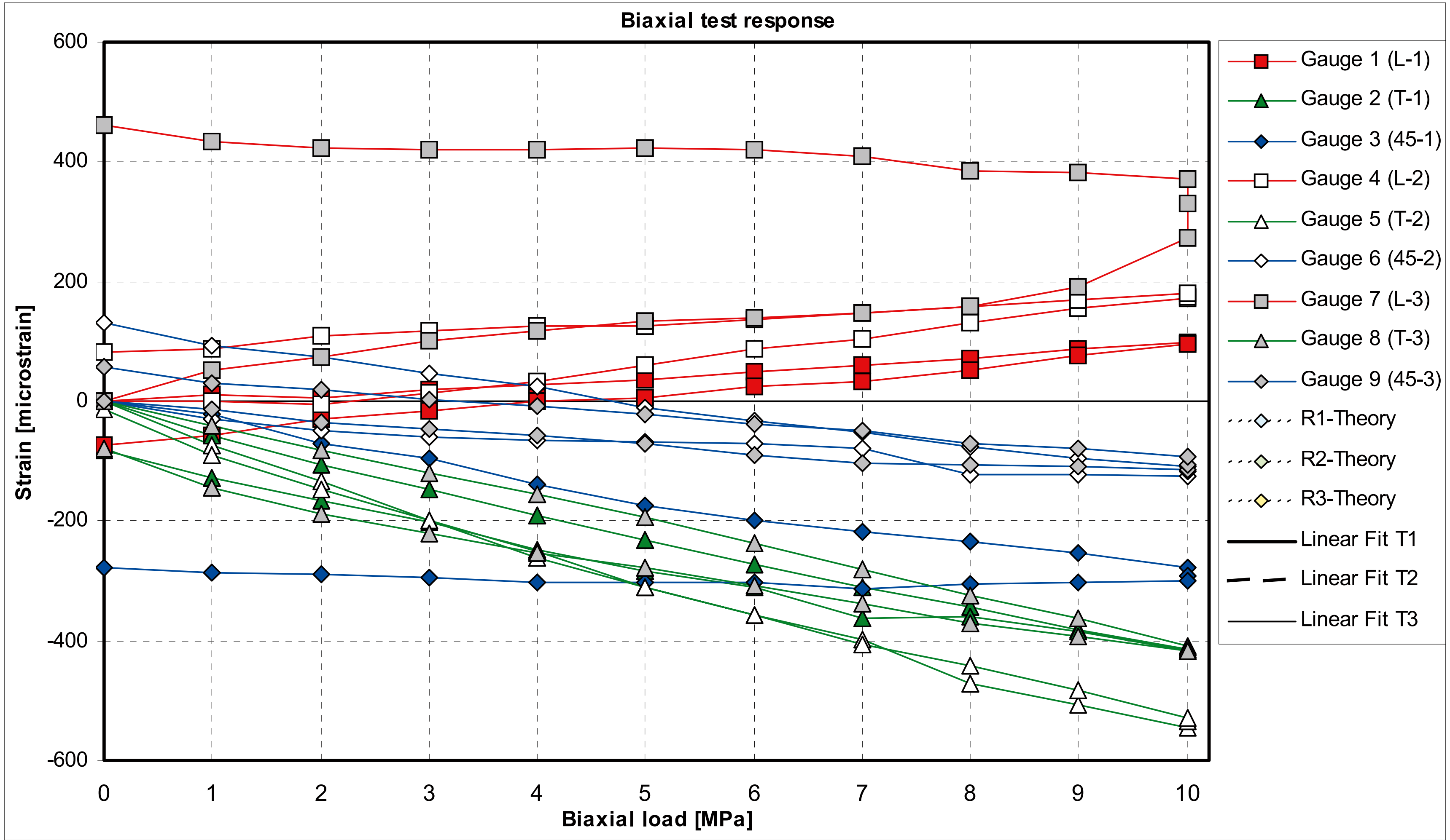


Figure C-8. *Results from biaxial testing of test no. 2:10:1, 176.65 m borehole length.*

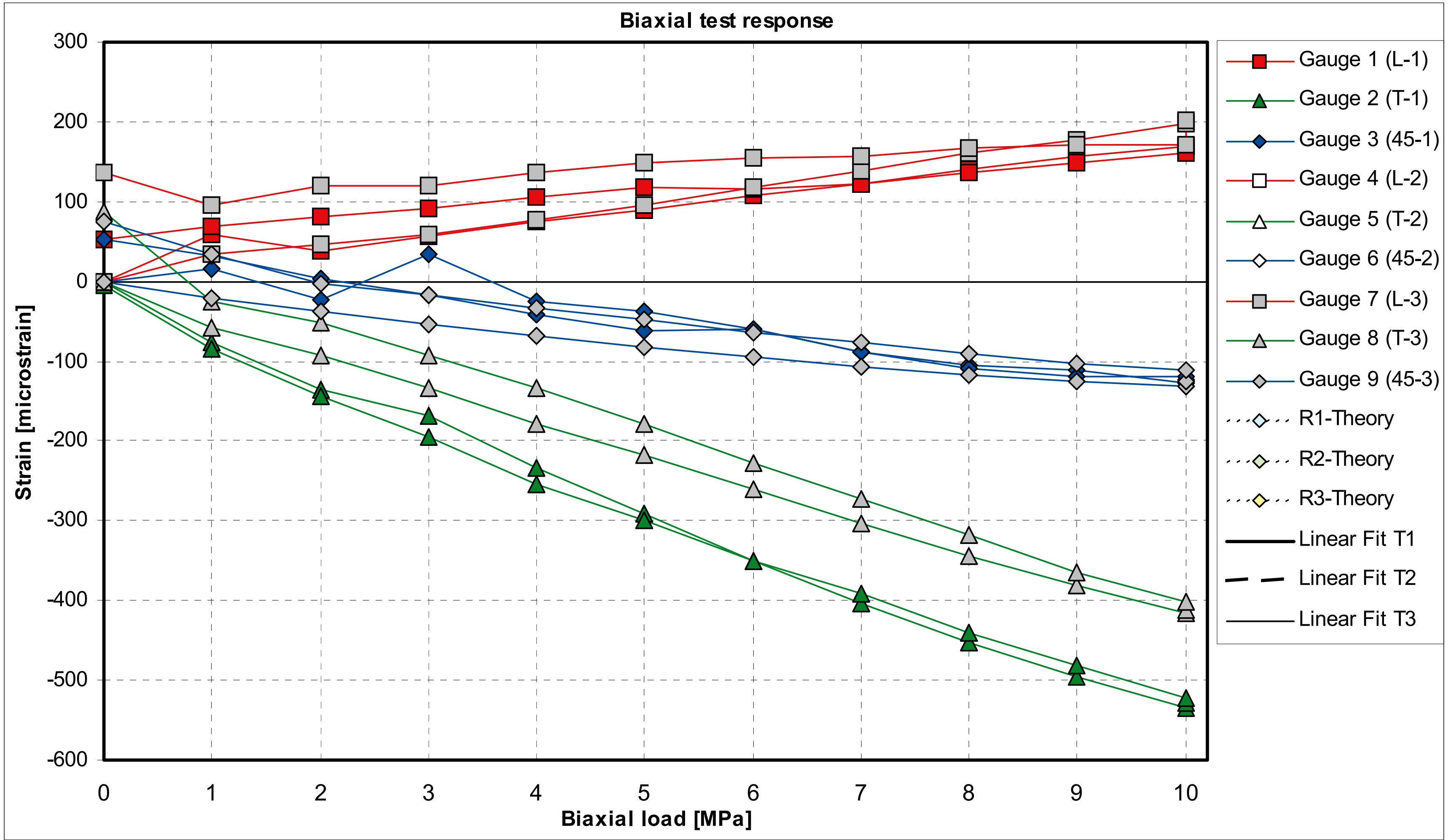


Figure C-9. *Results from biaxial testing of test no. 2:11:1, 177.65 m borehole length, excluding rosette no. 2 due to unstable strain response.*

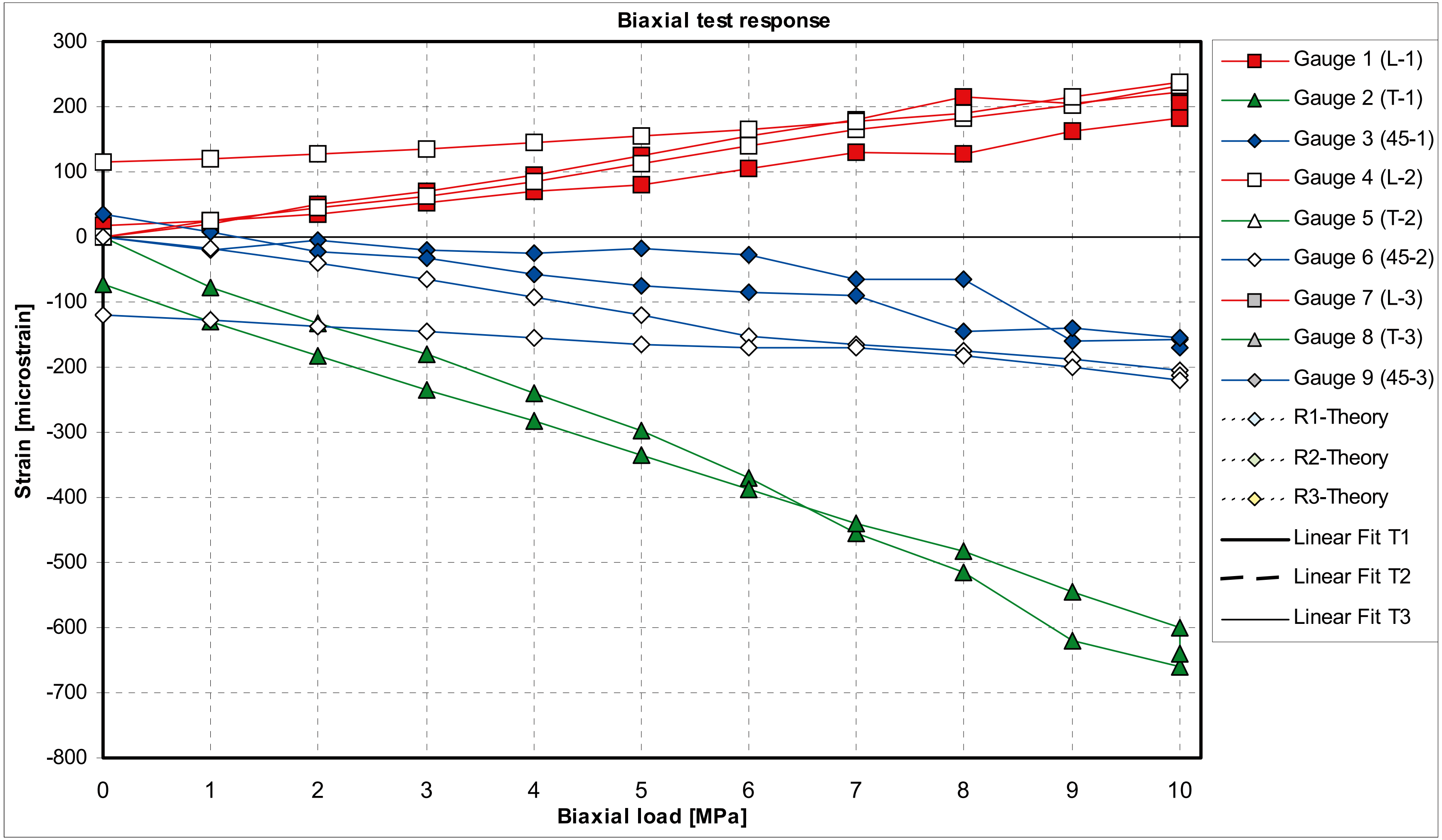


Figure C-10. *Results from biaxial testing of test no. 3:1:1, 192.47 m borehole length, excluding rosette no. 3 and gauge 5 rosette no.2 due to unstable strain response.*

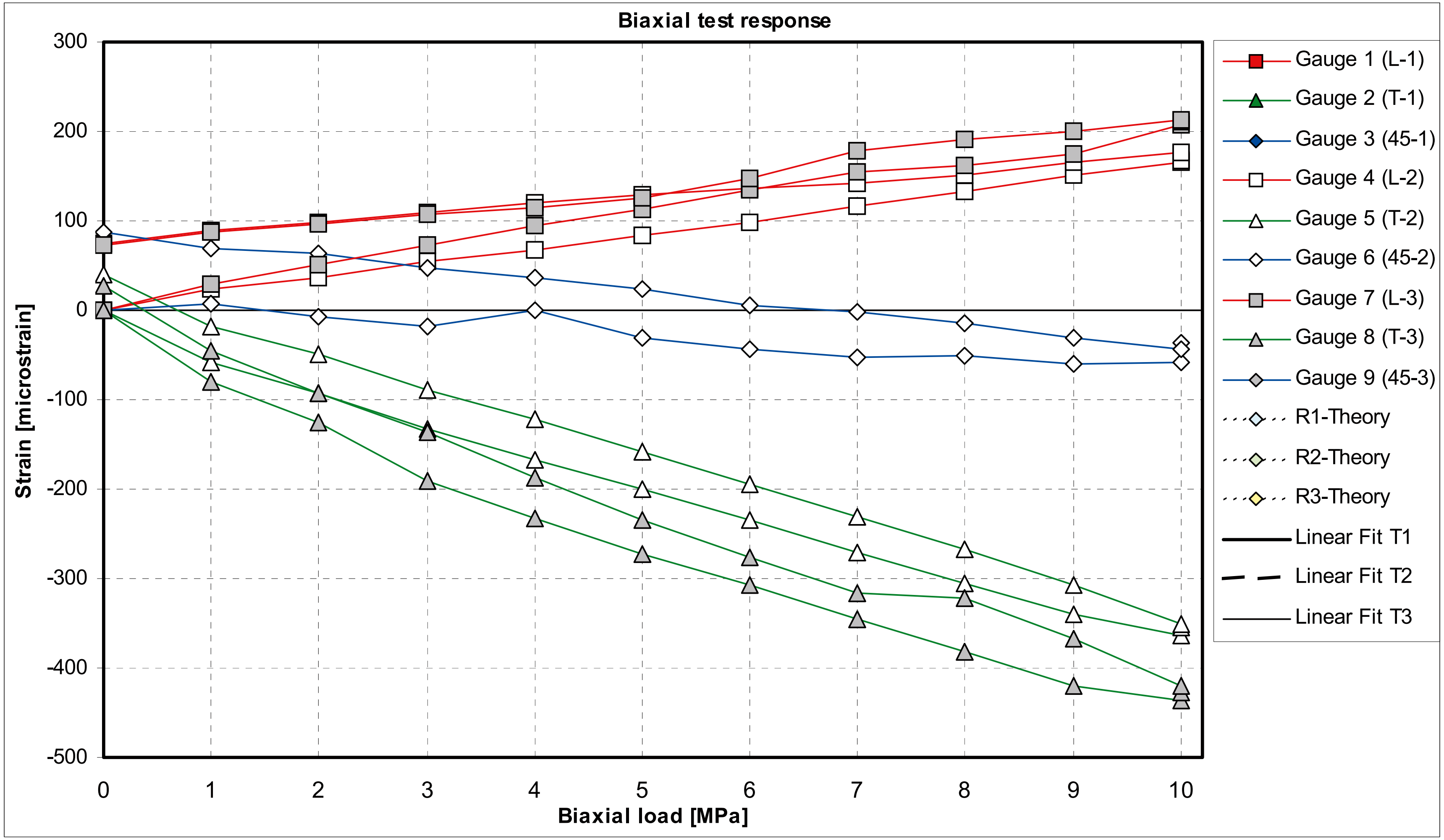


Figure C-11. *Results from biaxial testing of test no. 3:4:1, 195.31 m borehole length, excluding rosette no. 1 and gauge 9 rosette no. 3 due to unstable strain response.*

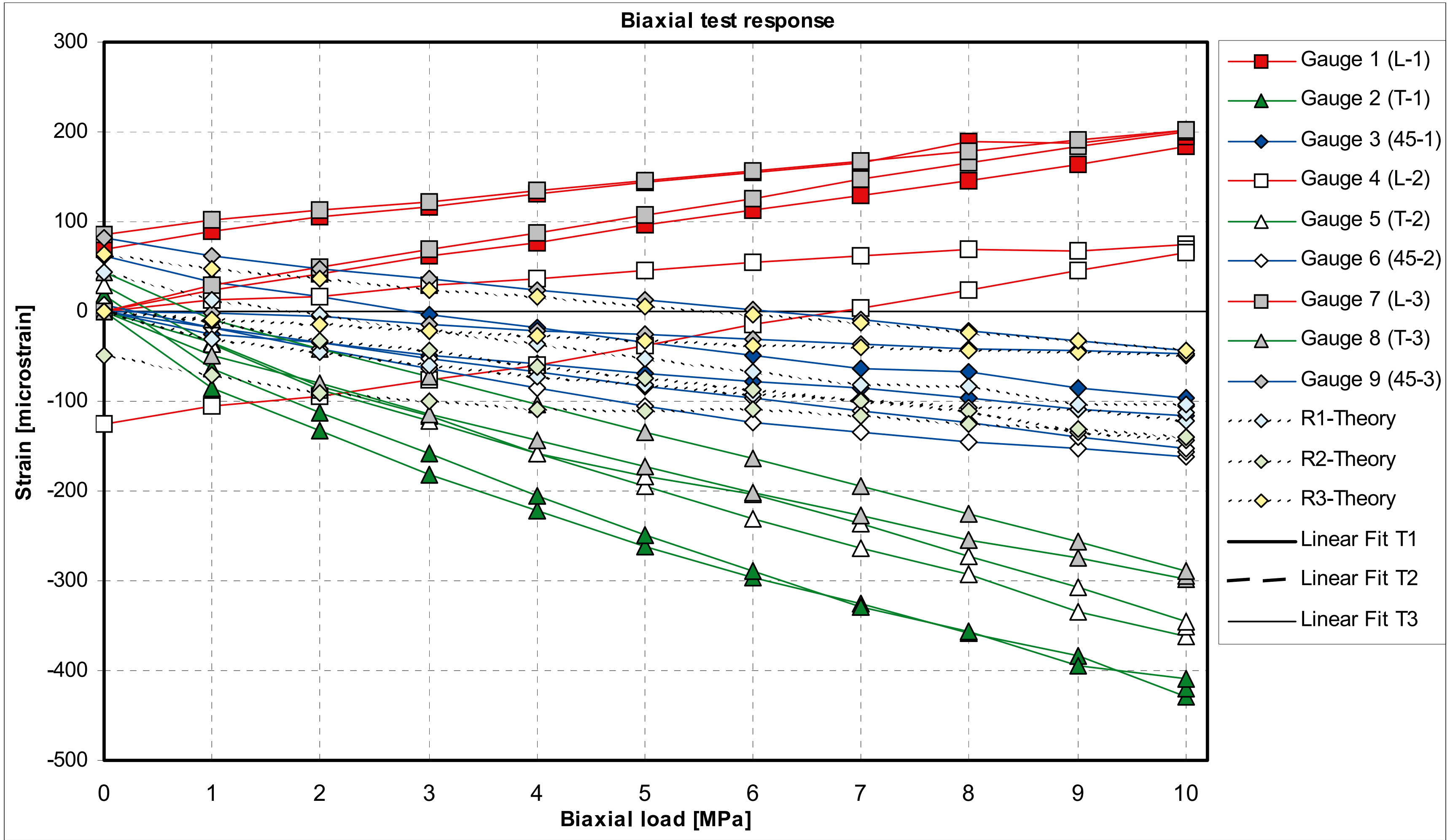


Figure C-12. *Results from biaxial testing of test no. 3:6:1, 197.28 m borehole length.*

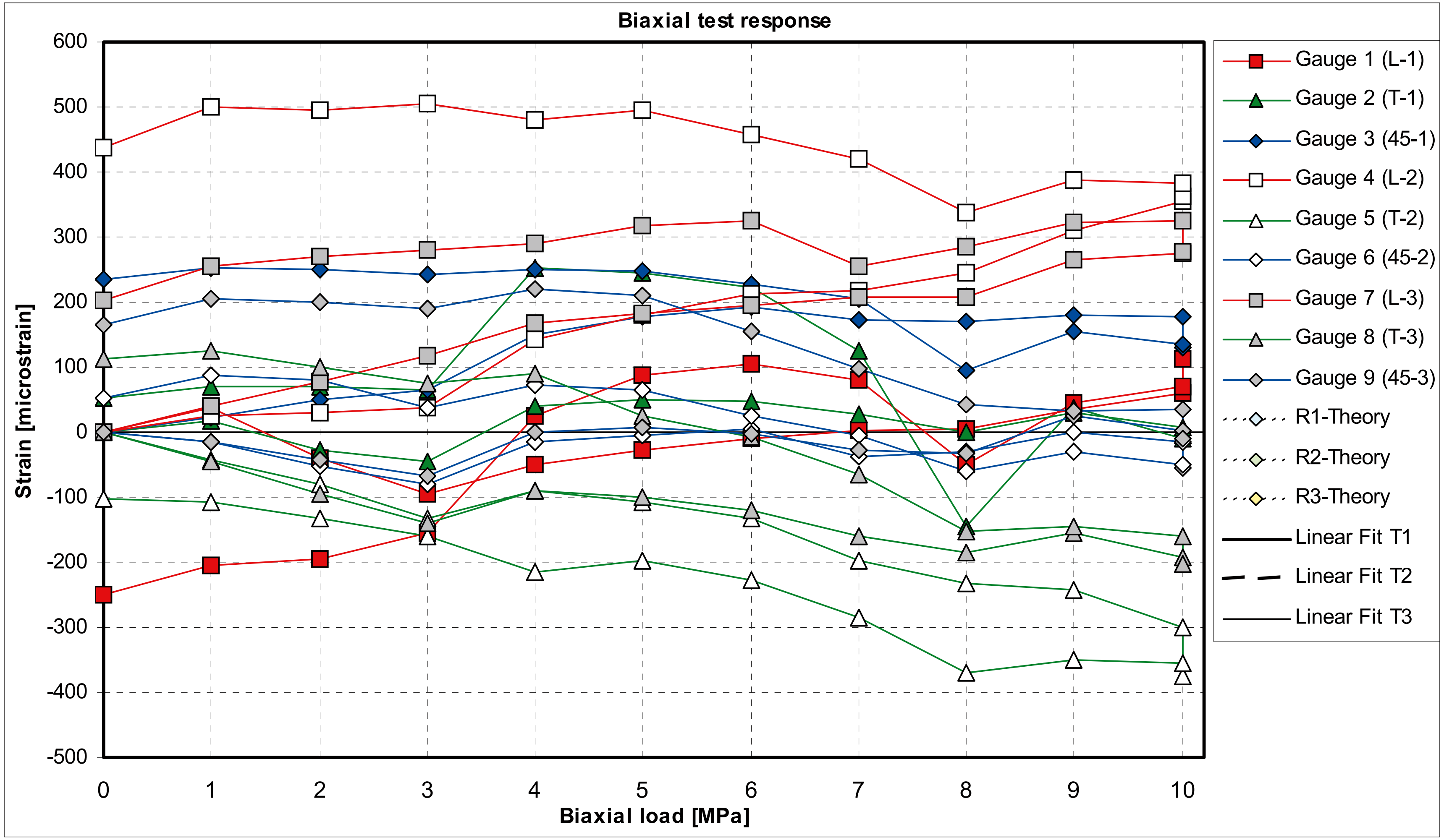


Figure C-13. *Results from biaxial testing of test no. 4:1:2, 238.05 m borehole length.*

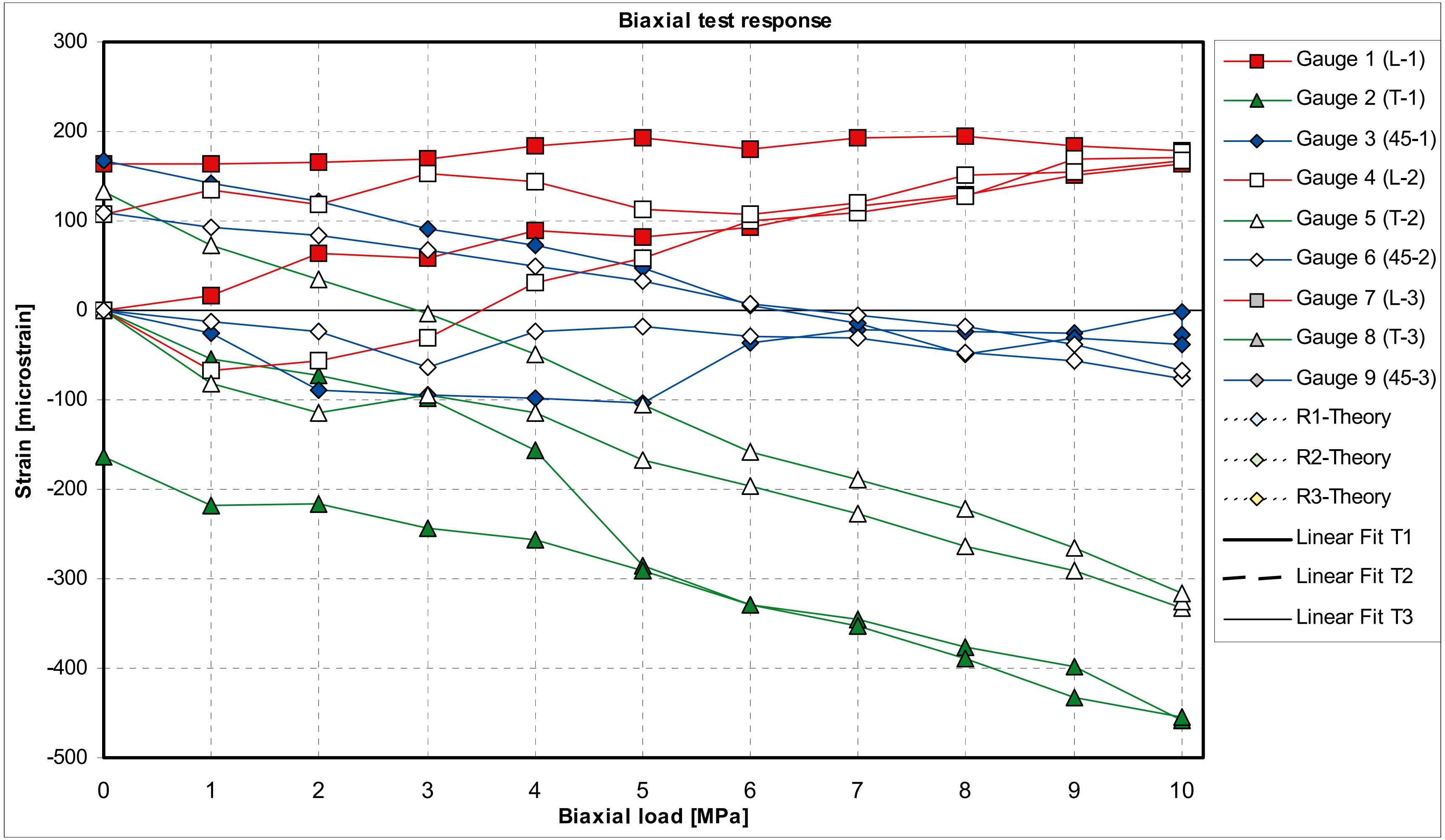


Figure C-14. Results from biaxial testing of test no. 4:2:3, 242.70 m borehole length, excluding rosette no. 3 due to unstable strain response.

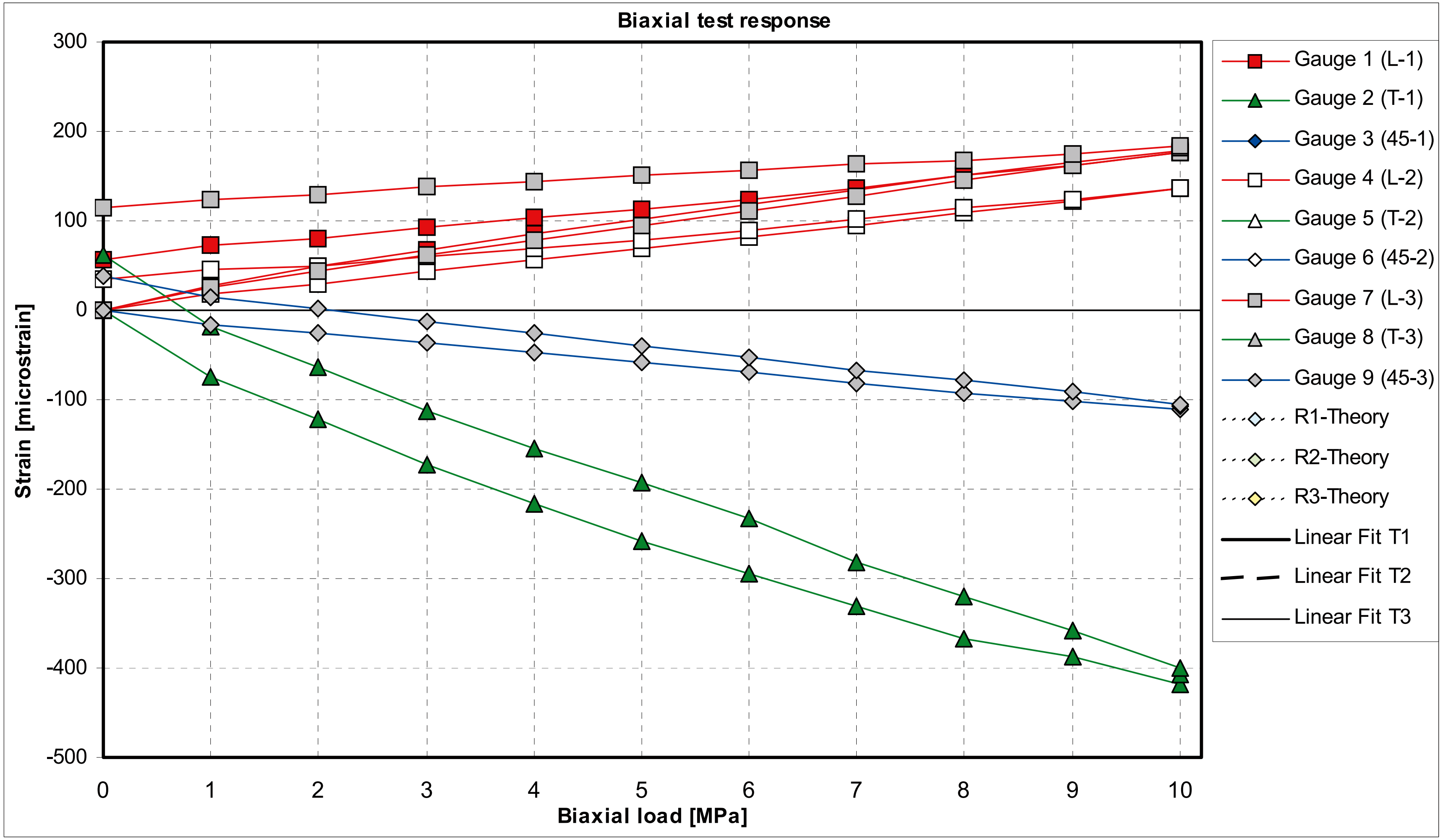


Figure C-15. *Results from biaxial testing of test no. 4:4:2, 258.73 m borehole length, excluding gauge 3 (rosette no. 1), gauges 4 and 6 (rosette no. 2) and gauge 8 (rosette no. 3) due to unstable strain response.*

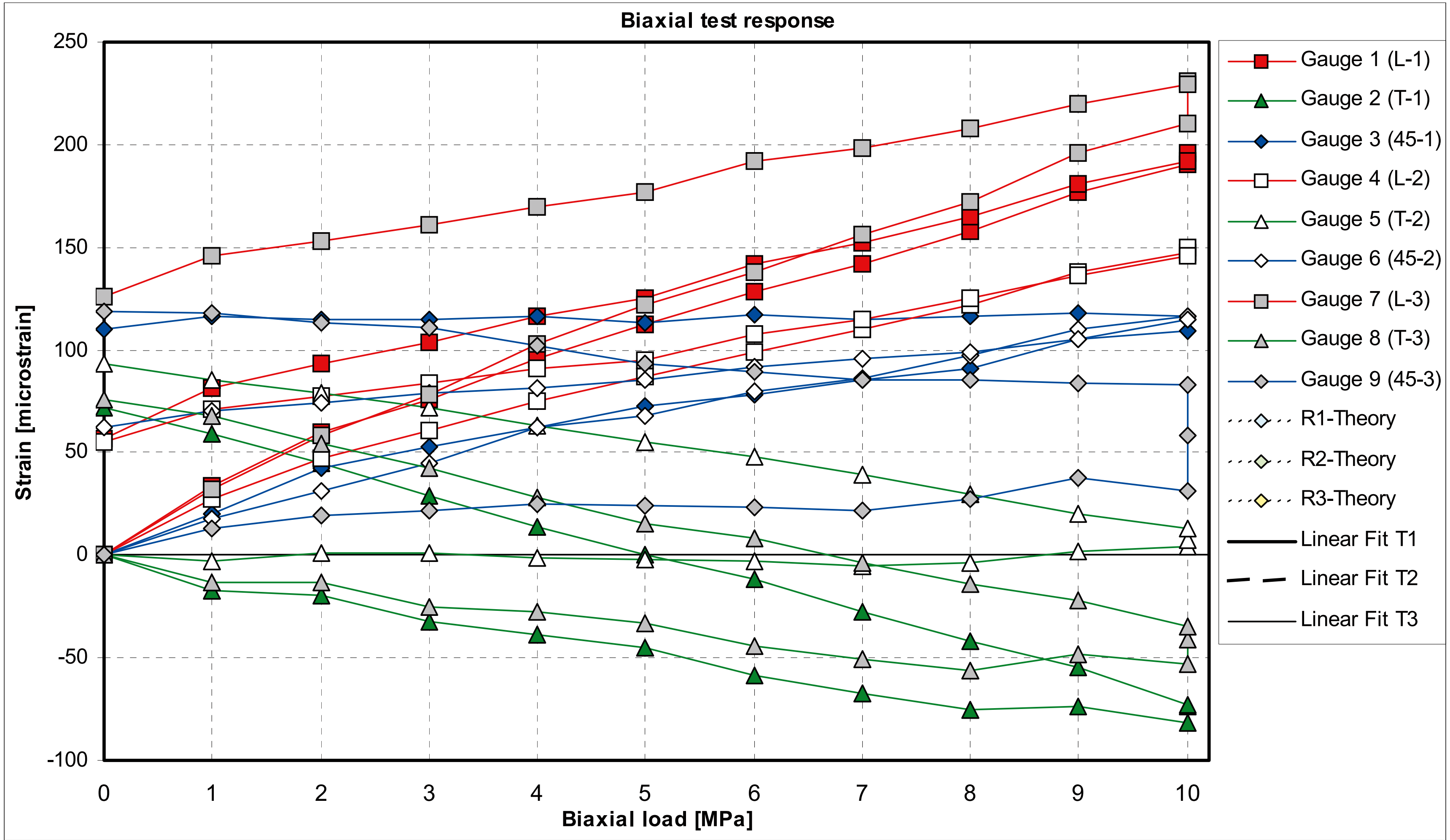


Figure C-16. *Results from biaxial testing of test no. 5:3:4, 316.25 m borehole length.*

Appendix D

Stress calculation input data and results

Table D-1. Measured and mean in situ stresses for borehole KFM07C, Level 1, tests nos. 1:1:5, 1:2:4 and 1:4:1.

VATTENFALL

OVERCORING STRESS MEASUREMENTS

Project Description : Forsmark KFM07C
Measurement Level : 7C_Level1_Final_Stress
Date : 2007-02-20

(values for gauge and resistance factor are always 2 and 1, respectively)

Input Data

Depth [m]	Hole dip [°]	Hole bearing [°]	Bearing (ball) - X [°]	Young's modulus [GPa]	Poisson's ratio	Needle bearing [°]	Overcoring Time [hh:mm:ss]	Overcoring Time [hh:mm:ss]
98.76	83.66	153.83	271	63.4	0.30	65	Start=08:50:55	Stop=09:15:00
104.53	83.68	154.3	128	63.4	0.30	282	Start=08:51:20	Stop=09:22:55
108.42	83.72	154.29	84	72.7	0.30	238	Start=08:48:25	Stop=10:17:30

Strains

Depth [m]	ε_{L1} (gauge no. 1) [μstrain]	ε_{T1} (gauge no. 2) [μstrain]	ε_{45_1} (gauge no. 3) [μstrain]	ε_{L2} (gauge no. 4) [μstrain]	ε_{T2} (gauge no. 5) [μstrain]	ε_{45_2} (gauge no. 6) [μstrain]	ε_{L3} (gauge no. 7) [μstrain]	ε_{T3} (gauge no. 8) [μstrain]	ε_{45_3} (gauge no. 9) [μstrain]
98.76	-100	548	-19	-181	587	566	-133	956	333
104.53	-146	287	51	-91	936	196	-63	391	405
108.42	-73	283	418	-116	245	-33	-78	752	117

Calculated Principal Stresses

Depth [m]	σ_1 [MPa]	σ_1 - Dip [°]	σ_1 - Bearing [°]	σ_2 [MPa]	σ_2 - Dip [°]	σ_2 - Bearing [°]	σ_3 [MPa]	σ_3 - Dip [°]	σ_3 - Bearing [°]
98.76	28.0	3.0	174.8	22.0	21.4	83.6	1.5	68.4	272.3
104.53	26.2	9.0	169.7	12.1	22.2	263.4	1.3	65.9	59.1
108.42	24.5	23.5	9.9	12.8	20.9	109.4	-2.4	57.7	236.5
Mean	*24.8*	*1.9*	*353.9*	*14.5*	*18.4*	*84.5*	*2.6*	*71.5*	*258.2*

Calculated Horizontal and Vertical Stresses

Depth [m]	Major stress σ_A [MPa]	σ_A - Bearing [°]	Minor stress σ_B [MPa]	σ_B - Bearing [°]	Vertical stress σ_z [MPa]	Error (sum of squares)	Strains re-calculated?
98.76	27.9	177.2	19.2	87.2	4.3	3700.7	No
104.53	25.7	167.5	10.5	77.5	3.4	3571.6	No
108.42	21.1	178.3	10.1	88.3	3.8	1110.5	No
Mean	*24.8*	*173.3*	*13.3*	*83.3*	*3.9*		

Table D-2. Measured and mean in situ stresses for borehole KFM07C, Level 2A, tests nos. 2:1:3, 2:3:1 and 2:4:1.

VATTENFALL

OVERCORING STRESS MEASUREMENTS

Project Description : Forsmark KFM07C
Measurement Level : KFM07C_Level2A_Final_Stress
Date : 2007-02-20

(values for gauge and resistance factor are always 2 and 1, respectively)

Input Data

Depth [m]	Hole dip [º]	Hole bearing [º]	Bearing (ball) - X [º]	Young's modulus [GPa]	Poisson's ratio	Needle bearing [º]	Overcoring Time [hh:mm:ss]	Overcoring Time [hh:mm:ss]
158.28	83.85	154.18	1	71.3	0.32	155	Start=08:44:20	Stop=09:44:45
160.37	83.85	154.14	275	58.5	0.31	69	Start=08:45:30	Stop=09:35:50
162.69	83.85	154.02	218	63.5	0.30	12	Start=12:34:50	Stop=13:31:15

Strains

Depth [m]	ε_{L1} (gauge no. 1) [µstrain]	ε_{T1} (gauge no. 2) [µstrain]	ε_{45_1} (gauge no. 3) [µstrain]	ε_{L2} (gauge no. 4) [µstrain]	ε_{T2} (gauge no. 5) [µstrain]	ε_{45_2} (gauge no. 6) [µstrain]	ε_{L3} (gauge no. 7) [µstrain]	ε_{T3} (gauge no. 8) [µstrain]	ε_{45_3} (gauge no. 9) [µstrain]
158.28	-210	273	186	-229	63	-263	-248	860	332
160.37	-92	306	39	-160	1081	606	-24	580	201
162.69	-176	1279	638	-119	1050	341	-148	407	173

Calculated Principal Stresses

Depth [m]	σ_1 [MPa]	σ_1 - Dip [º]	σ_1 - Bearing [º]	σ_2 [MPa]	σ_2 - Dip [º]	σ_2 - Bearing [º]	σ_3 [MPa]	σ_3 - Dip [º]	σ_3 - Bearing [º]
158.28	22.4	4.3	282.3	5.6	26.3	14.4	-10.2	63.3	183.7
160.37	27.9	0.7	139.0	13.0	8.6	48.9	6.8	81.4	233.3
162.69	39.6	1.5	214.7	21.3	11.3	305.0	8.5	78.6	117.2
Mean	*22.9*	*4.3*	*285.9*	*19.5*	*7.7*	*16.5*	*2.6*	*81.1*	*167.0*

Calculated Horizontal and Vertical Stresses

Depth [m]	Major stress σ_A [MPa]	σ_A - Bearing [º]	Minor stress σ_B [MPa]	σ_B - Bearing [º]	Vertical stress σ_z [MPa]	Error (sum of squares)	Strains re-calculated?
158.28	22.2	100.9	2.5	10.9	-6.9	722.1	Yes
160.37	27.9	139.0	12.9	49.0	7.0	9248.1	Yes
162.69	39.6	34.5	20.8	124.5	9.0	1631.4	Yes
Mean	*22.8*	*103.2*	*19.2*	*13.2*	*3.0*		

Table D-3. Measured and mean in situ stresses for borehole KFM07C, Level 2B, tests nos. 2:8:1, 2:9:1, 2:10:1 and 2:11:1.

VATTENFALL

OVERCORING STRESS MEASUREMENTS

Project Description : Forsmark KFM07C
Measurement Level : KFM07C_Level2B_Final_Stress
Date : 2007-02-20

(values for gauge and resistance factor are always 2 and 1, respectively)

Input Data

Depth [m]	Hole dip [°]	Hole bearing [°]	Bearing (ball) - X [°]	Young's modulus [GPa]	Poisson's ratio	Needle bearing [°]	Overcoring Time [hh:mm:ss]	[hh:mm:ss]
174.60	83.86	153.55	168	67.0	0.23	322	Start=08:38:35	Stop=09:23:35
175.62	83.86	153.56	158	80.9	0.36	312	Start=08:38:30	Stop=09:16:25
176.65	83.86	153.57	291	69.2	0.28	85	Start=08:37:50	Stop=09:28:50
177.65	83.86	153.41	52	56.4	0.16	205	Start=08:42:30	Stop=09:29:40

Strains

Depth [m]	ε_{L1} (gauge no. 1) [μstrain]	ε_{T1} (gauge no. 2) [μstrain]	ε_{45_1} (gauge no. 3) [μstrain]	ε_{L2} (gauge no. 4) [μstrain]	ε_{T2} (gauge no. 5) [μstrain]	ε_{45_2} (gauge no. 6) [μstrain]	ε_{L3} (gauge no. 7) [μstrain]	ε_{T3} (gauge no. 8) [μstrain]	ε_{45_3} (gauge no. 9) [μstrain]
174.60	-108	1050	473	-162	1157	589	-97	213	41
175.62	-111	387	203	-99	641	195	-48	103	24
176.65	-14	637	234	-39	135	135	11	759	376
177.65	-29	629	353	200	1026	589	86	712	370

Calculated Principal Stresses

Depth [m]	σ_1 [MPa]	σ_1 - Dip [°]	σ_1 - Bearing [°]	σ_2 [MPa]	σ_2 - Dip [°]	σ_2 - Bearing [°]	σ_3 [MPa]	σ_3 - Dip [°]	σ_3 - Bearing [°]
174.60	38.5	7.5	355.2	17.4	1.3	85.4	5.1	82.4	185.1
175.62	23.5	1.5	175.9	8.8	2.6	266.0	4.1	87.0	56.5
176.65	26.3	5.2	50.7	13.1	24.9	143.1	8.3	64.5	309.8
177.65	26.8	6.1	270.4	19.7	7.4	1.2	12.2	80.4	141.3
Mean	*24.9*	*3.7*	*8.9*	*18.2*	*0.2*	*278.9*	*7.8*	*86.3*	*186.3*

Calculated Horizontal and Vertical Stresses

Depth [m]	Major stress σ_A [MPa]	σ_A - Bearing [°]	Minor stress σ_B [MPa]	σ_B - Bearing [°]	Vertical stress σ_z [MPa]	Error (sum of squares)	Strains re-calculated?
174.60	37.9	175.1	17.4	85.1	5.7	3721.2	No
175.62	23.5	175.9	8.7	85.9	4.1	2284.7	No
176.65	26.1	50.0	12.3	140.0	9.3	1250.1	Yes
177.65	26.6	89.5	19.6	179.5	12.5	26220.7	Yes
Mean	*24.9*	*8.9*	*18.2*	*98.9*	*7.9*		

Table D-4. Measured and mean in situ stresses for borehole KFM07C, Level 3, tests nos. 3:1:1, 3:4:1 and 3:6:1.

VATTENFALL

OVERCORING STRESS MEASUREMENTS

Project Description : Forsmark KFM07C
Measurement Level : KFM07C_Level3_Final_Stress
Date : 2007-02-20

(values for gauge and resistance factor are always 2 and 1, respectively)

Input Data

Depth [m]	Hole dip [º]	Hole bearing [º]	Bearing (ball) - X [º]	Young's modulus [GPa]	Poisson's ratio	Needle bearing [º]	Overcoring Time [hh:mm:ss]	[hh:mm:ss]
192.47	83.89	152.34	118	78.3	0.24	270	Start=08:23:30	Stop=09:29:40
195.31	83.9	152.51	292	68.5	0.26	85	Start=08:48:45	Stop=09:53:40
197.28	83.9	152.64	334	76.1	0.41	127	Start=08:56:00	Stop=09:43:20

Strains

Depth [m]	ε_{L1} (gauge no. 1) [μstrain]	ε_{T1} (gauge no. 2) [μstrain]	ε_{45_1} (gauge no. 3) [μstrain]	ε_{L2} (gauge no. 4) [μstrain]	ε_{T2} (gauge no. 5) [μstrain]	ε_{45_2} (gauge no. 6) [μstrain]	ε_{L3} (gauge no. 7) [μstrain]	ε_{T3} (gauge no. 8) [μstrain]	ε_{45_3} (gauge no. 9) [μstrain]
192.47	-22	640	512	40	538	137	102	85	43
195.31	23	225	139	35	767	249	47	222	220
197.28	-55	234	92	-93	652	351	-131	765	243

Calculated Principal Stresses

Depth [m]	σ_1 [MPa]	σ_1 - Dip [º]	σ_1 - Bearing [º]	σ_2 [MPa]	σ_2 - Dip [º]	σ_2 - Bearing [º]	σ_3 [MPa]	σ_3 - Dip [º]	σ_3 - Bearing [º]
192.47	27.2	16.0	116.1	10.8	7.7	23.9	9.4	72.1	269.1
195.31	22.6	22.1	326.1	9.8	45.6	80.6	7.2	36.1	218.9
197.28	31.2	5.7	222.3	16.1	9.9	313.3	11.8	78.5	102.7
Mean	*20.4*	*0.8*	*303.6*	*17.2*	*6.1*	*33.7*	*11.1*	*83.8*	*206.2*

Calculated Horizontal and Vertical Stresses

Depth [m]	Major stress σ_A [MPa]	σ_A - Bearing [º]	Minor stress σ_B [MPa]	σ_B - Bearing [º]	Vertical stress σ_z [MPa]	Error (sum of squares)	Strains re-calculated?
192.47	25.9	116.3	10.8	26.3	10.8	7688.1	Yes
195.31	20.7	144.0	8.2	54.0	10.7	877.4	Yes
197.28	31.0	42.0	15.9	132.0	12.1	2888.0	Yes
Mean	*20.4*	*123.5*	*17.1*	*33.5*	*11.2*		

Table D-5. Measured and mean in situ stresses for borehole KFM07C, Level 4, tests nos. 4:1:2, 4:2:3 and 4:4:2.

VATTENFALL

OVERCORING STRESS MEASUREMENTS

Project Description : Forsmark KFM07C
Measurement Level : KFM07C_Level4_Final_Stress
Date : 2007-02-20

(values for gauge and resistance factor are always 2 and 1, respectively)

Input Data

Depth [m]	Hole dip [°]	Hole bearing [°]	Bearing (ball) - X [°]	Young's modulus [GPa]	Poisson's ratio	Needle bearing [°]	Overcoring Time [hh:mm:ss]	[hh:mm:ss]
239.05	83.97	153.16	332	81.7	0.40	125	Start=09:10:30	Stop=09:57:25
242.70	83.98	153.27	127	81.7	0.40	280	Start=08:49:30	Stop=09:31:55
258.73	84.02	152.78	277	72.2	0.42	70	Start=08:44:50	Stop=09:37:45

Strains

Depth [m]	ε_{L1} (gauge no. 1) [μstrain]	ε_{T1} (gauge no. 2) [μstrain]	ε_{45_1} (gauge no. 3) [μstrain]	ε_{L2} (gauge no. 4) [μstrain]	ε_{T2} (gauge no. 5) [μstrain]	ε_{45_2} (gauge no. 6) [μstrain]	ε_{L3} (gauge no. 7) [μstrain]	ε_{T3} (gauge no. 8) [μstrain]	ε_{45_3} (gauge no. 9) [μstrain]
239.05	-176	91	-26	-189	680	364	-162	540	54
242.70	-63	781	349	-33	1110	747	-48	266	-90
258.73	-95	182	-142	-90	443	247	-99	1004	567

Calculated Principal Stresses

Depth [m]	σ_1 [MPa]	σ_1 - Dip [°]	σ_1 - Bearing [°]	σ_2 [MPa]	σ_2 - Dip [°]	σ_2 - Bearing [°]	σ_3 [MPa]	σ_3 - Dip [°]	σ_3 - Bearing [°]
239.05	27.1	4.9	208.3	9.3	10.2	299.2	-0.7	78.6	93.0
242.70	47.1	18.3	323.6	26.9	43.2	71.6	17.3	41.2	216.8
258.73	32.9	11.4	2.6	15.6	41.0	102.7	7.3	46.7	260.2
Mean	*31.0*	*11.3*	*354.4*	*18.6*	*5.3*	*85.5*	*11.3*	*77.5*	*200.1*

Calculated Horizontal and Vertical Stresses

Depth [m]	Major stress σ_A [MPa]	σ_A - Bearing [°]	Minor stress σ_B [MPa]	σ_B - Bearing [°]	Vertical stress σ_z [MPa]	Error (sum of squares)	Strains re-calculated?
239.05	26.9	27.8	9.0	117.8	-0.2	364.7	Yes
242.70	44.7	139.8	21.9	49.8	24.8	450.1	Yes
258.73	32.1	0.3	11.8	90.3	11.9	40.7	Yes
Mean	*30.2*	*173.7*	*18.6*	*83.7*	*12.1*		

Appendix E

Transient strain analysis results

Table E-1. Results from transient strain analysis of selected overcoring measurements in borehole KFM07C, Level 1.

Test no.	Hole length [m]		G1 ε_{L1}	G2 ε_{T1}	G3 ε_{45_1}	G4 ε_{L2}	G5 ε_{T2}	G6 ε_{45_2}	G7 ε_{L3}	G8 ε_{T3}	G9 ε_{45_3}	Unexplained strain [%]	Max tensile stress [MPa]	Comments
1:1:5	98.76	Max strain amplitude [µstrain]	461	658	175	515	700	613	663	1,097	353	5	27	The measuremnts has *a*-rating and in general good agreement between calculated and measured strains, especial for tangential strains. Low amount of unexplained strains, though relative high measured tensile stress.
		Max strain difference [%]	67	11	59	28	9	15	36	7	25			
1:2:4	104.53	Max strain amplitude [µstrain]	522	407	177	378	1,043	265	383	481	423	34	28	The measuremnts has *a*-rating but showed large deviations between measured and calculated strains. High amount of unexplained strains and tensile stress.
		Max strain difference [%]	25	70	111	75	19	59	105	23	55			
1:4:1	108.42	Max strain amplitude [µstrain]	310	354	437	444	339	115	268	826	220	13	28	The measuremnts has *b*-rating but showed large deviations between measured and calculated strains. Relatively low amount of unexplained strains and but high tensile stress.
		Max strain difference [%]	48	34	39	58	39	165	109	21	39			

Table E-2. Results from transient strain analysis of selected overcoring measurements in borehole KFM07C, Level 2A.

Test no.	Hole length [m]		G1 ε_{L1}	G2 ε_{T1}	G3 ε_{45_1}	G4 ε_{L2}	G5 ε_{T2}	G6 ε_{45_2}	G7 ε_{L3}	G8 ε_{T3}	G9 ε_{45_3}	Unexplained strain [%]	Max tensile stress [MPa]	Comments
2:1:3	158.28	Max strain amplitude [µstrain]	405	350	204	400	173	269	310	943	398	43	30	The measuremnts has *b*-rating but showed large deviations between measured and calculated strains. High amount of unexplained strains and tensile stress.
		Max strain difference [%]	74	125	117	66	187	94	142	58	71			
2:3:1	160.37	Max strain amplitude [µstrain]	469	449	138	511	1,212	646	542	688	211	37	26	The measuremnts has *b*-rating but showed large deviations between measured and calculated strains. High amount of unexplained strains and tensile stress.
		Max strain difference [%]	57	40	206	61	37	38	62	60	125			
2:4:1	162.69	Max strain amplitude [µstrain]	739	1,436	694	712	1,195	353	658	602	259	18	35	he measuremnts has *a*-rating but showed large deviations between measured and calculated strains. Relatively low amount of unexplained strains and but high tensile stress.
		Max strain difference [%]	20	28	27	27	15	55	45	22	51			
2:8:1	174.60	Max strain amplitude [µstrain]	578	1,176	535	595	1,290	598	606	425	183	23	32	The measuremnts has *b*-rating but showed large deviations between measured and calculated strains. High amount of unexplained strains and tensile stress.
		Max strain difference [%]	22	20	35	26	26	46	23	47	53			

Table E-3. Results from transient strain analysis of selected overcoring measurements in borehole KFM07C, Level 2B.

Test no.	Hole length [m]		G1 ε_{L1}	G2 ε_{T1}	G3 ε_{45_1}	G4 ε_{L2}	G5 ε_{T2}	G6 ε_{45_2}	G7 ε_{L3}	G8 ε_{T3}	G9 ε_{45_3}	Unexplained strain [%]	Max tensile stress [MPa]	Comments
2:9:1	175.62	Max strain amplitude [µstrain]	335	454	248	329	721	208	282	201	94	87	26	The measuremnts has *b*-rating but showed large deviations between measured and calculated strains. High amount of unexplained strains and tensile stress.
		Max strain difference [%]	90	132	97	109	126	205	139	219	275			
2:10:1	176.65	Max strain amplitude [µstrain]	358	717	241	348	281	207	404	857	404	47	21	The measuremnts has *b*-rating but showed large deviations between measured and calculated strains. High amount of unexplained strains and tensile stress.
		Max strain difference [%]	53	68	105	67	63	69	50	43	46			
2:11:1	177.65	Max strain amplitude [µstrain]	474	748	382	495	1,142	617	493	830	376	32	17	The measuremnts has *b*-rating but showed large deviations between measured and calculated strains. High amount of unexplained strains and tensile stress.
		Max strain difference [%]	53	21	65	55	19	41	49	17	36			

Table E-4. Results from transient strain analysis of selected overcoring measurements in borehole KFM07C, Level 3.

Test no.	Hole length [m]		G1 ε_{L1}	G2 ε_{T1}	G3 ε_{45_1}	G4 ε_{L2}	G5 ε_{T2}	G6 ε_{45_2}	G7 ε_{L3}	G8 ε_{T3}	G9 ε_{45_3}	Unexplained strain [%]	Max tensile stress [MPa]	Comments
3:1:1	192.47	Max strain amplitude [µstrain]	309	720	544	318	614	188	215	215	111	78	23	The measuremnts has *b*-rating but showed large deviations between measured and calculated strains. High amount of unexplained strains and tensile stress.
		Max strain difference [%]	109	53	83	126	121	245	180	452	341			
3:4:1	195.31	Max strain amplitude [µstrain]	314	311	210	267	854	270	234	300	241	43	19	The measuremnts has *b*-rating but showed large deviations between measured and calculated strains. High amount of unexplained strains and tensile stress.
		Max strain difference [%]	99	134	98	109	29	78	148	67	68			
3:6:1	197.28	Max strain amplitude [µstrain]	422	370	156	491	754	382	482	878	253	29	31	he measuremnts has *a*-rating but showed large deviations between measured and calculated strains. High amount of unexplained strains and tensile stress.
		Max strain difference [%]	68	52	98	61	48	45	55	36	100			

Table E-5. Results from transient strain analysis of selected overcoring measurements in borehole KFM07C, Level 4.

Test no.	Hole length [m]		G1 ε_{L1}	G2 ε_{T1}	G3 ε_{45_1}	G4 ε_{L2}	G5 ε_{T2}	G6 ε_{45_2}	G7 ε_{L3}	G8 ε_{T3}	G9 ε_{45_3}	Unexplained strain [%]	Max tensile stress [MPa]	Comments
4:1:2	238.05	Max strain amplitude [µstrain]	343	203	104	433	774	408	420	624	179	51	35	The measuremnts has *b*-rating but showed large deviations between measured and calculated strains. High amount of unexplained strains and tensile stress.
		Max strain difference [%]	64	97	51	45	45	55	43	66	135			
4:2:3	242.70	Max strain amplitude [µstrain]	502	901	379	630	1,277	784	612	461	270	31	45	The measuremnts has *b*-rating but showed large deviations between measured and calculated strains. High amount of unexplained strains and tensile stress.
		Max strain difference [%]	33	20	90	32	19	15	40	61	160			
4:4:2	258.73	Max strain amplitude [µstrain]	456	327	284	397	546	308	534	1,153	596	20	36	The measuremnts has *b*-rating but showed large deviations between measured and calculated strains. High amount of unexplained strains and tensile stress.
		Max strain difference [%]	46	30	87	46	21	78	44	26	29			

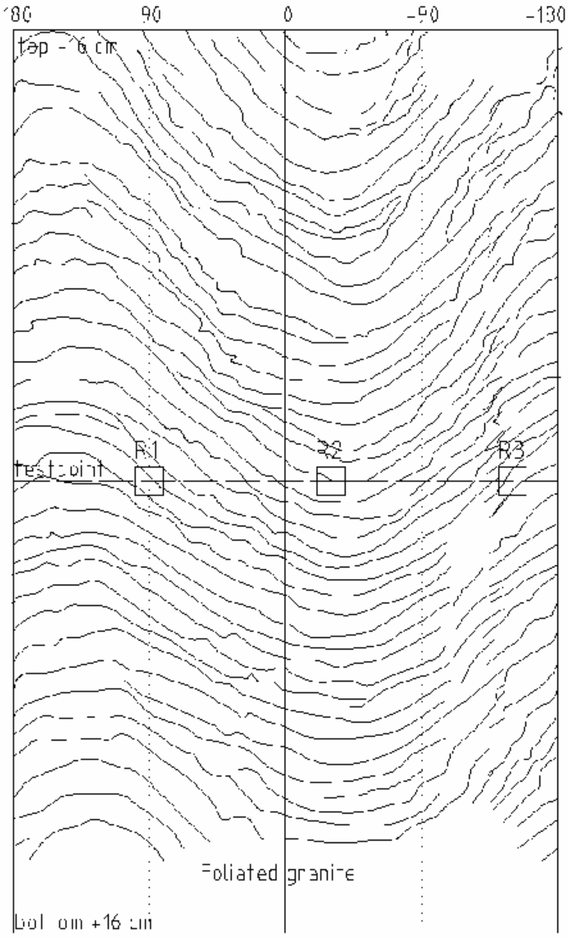
Table E-6. Results from transient strain analysis of selected overcoring measurements in borehole KFM07C, Level 5.

Test no.	Hole length [m]		G1 ε_{L1}	G2 ε_{T1}	G3 ε_{45_1}	G4 ε_{L2}	G5 ε_{T2}	G6 ε_{45_2}	G7 ε_{L3}	G8 ε_{T3}	G9 ε_{45_3}	Unexplained strain [%]	Max tensile stress [MPa]	Comments
5:3:4	316.25	Max strain amplitude [µstrain]	150	333	122	149	100	95	149	98	54	90	10	The measuremnts has *b*-rating but showed large deviations between measured and calculated strains. High amount of unexplained strains and tensile stress.
		Max strain difference [%]	195	208	185	202	153	134	227	159	484			

Overcore logging sheets

OVERCORE SAMPLE LOG

Borehole no., test no., depth : **KFM07C, Test no. 1:1:5, 98.76 m depth**



Angle clockwise in borehole direction
rosette 1 =+90 degrees
rosette 2 =-30 degrees
rosette 3 =-150 degrees

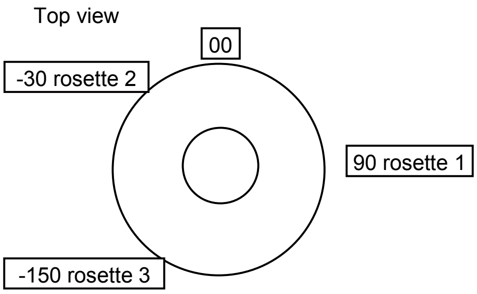
GEOLOGY

Foliated granite

STRUCTURES (JOINTS)

No fractures before or after biaxial testing.

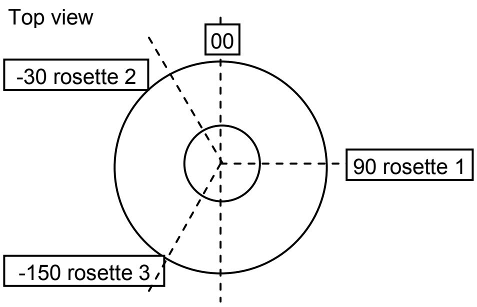
Mark any observed fractures



COMMENTS

Strain gauge orientation OK.

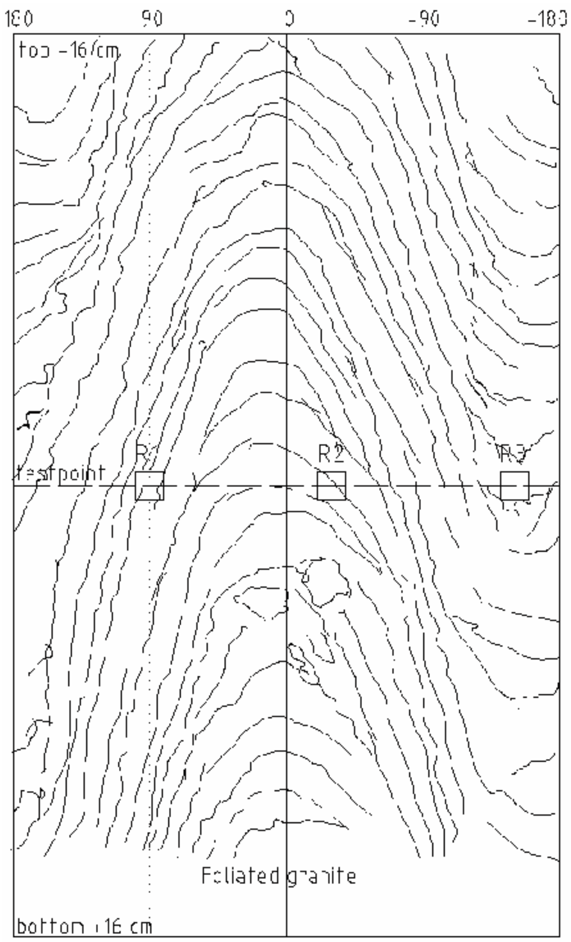
Control of strain gauge orientation



Use special tool to check that strain gauges are 120 degrees apart. Mark any deviations in the figure.

OVERCORE SAMPLE LOG

Borehole no., test no., depth : KFM07C, Test no. 1:2:4, 104.53 m depth



Angle clockwise in borehole direction
rosette 1 =+90 degrees
rosette 2 =-30 degrees
rosette 3 =-150 degrees

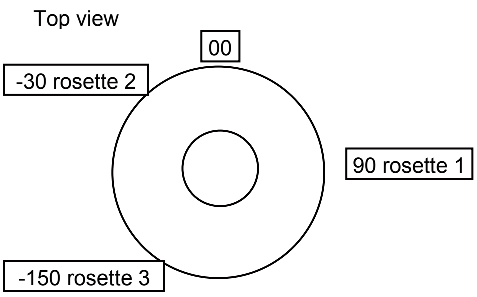
GEOLOGY

Foliated granite

STRUCTURES (JOINTS)

No fractures before or after biaxial testing.

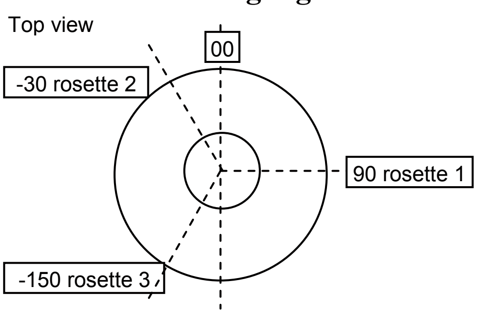
Mark any observed fractures



COMMENTS

Strain gauge orientation OK.

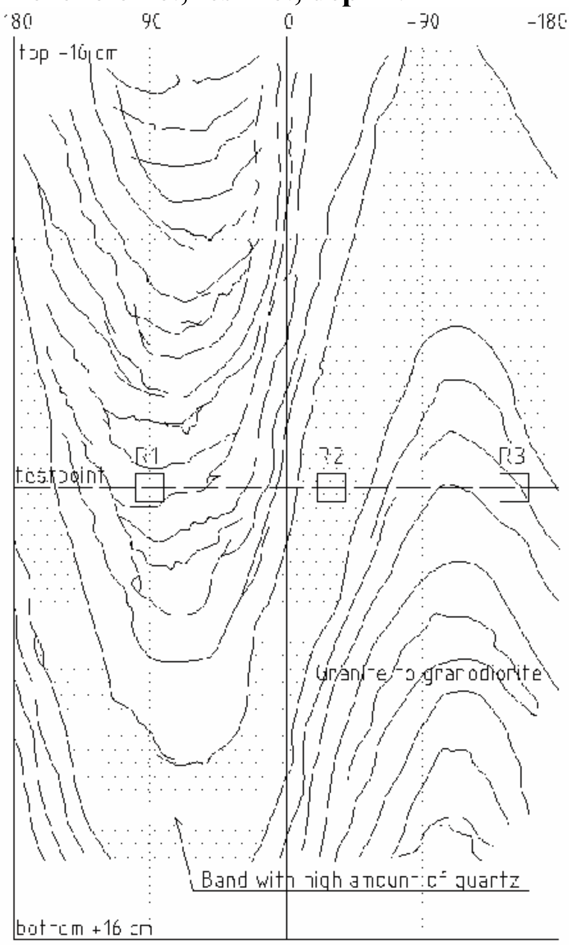
Control of strain gauge orientation



Use special tool to check that strain gauges are 120 degrees apart. Mark any deviations in the figure.

OVERCORE SAMPLE LOG

Borehole no., test no., depth : **KFM07C, Test no. 1:4:1, 108.42 m depth**



Angle clockwise in borehole direction
rosette 1 =+90 degrees
rosette 2 =-30 degrees
rosette 3 =-150 degrees

GEOLOGY

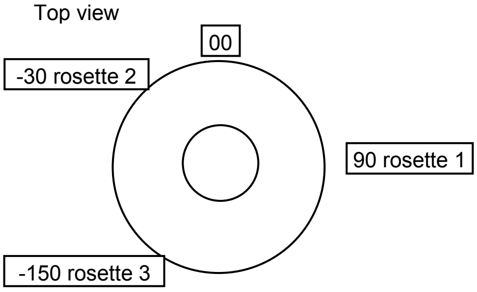
Granite- Grandiorite band with high amount of quartz

STRUCTURES (JOINTS)

No fractures before or after biaxial testing.

Mark any observed fractures

Top view

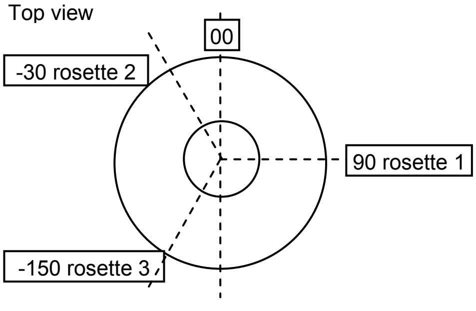


COMMENTS

Strain gauge orientation OK.

Control of strain gauge orientation

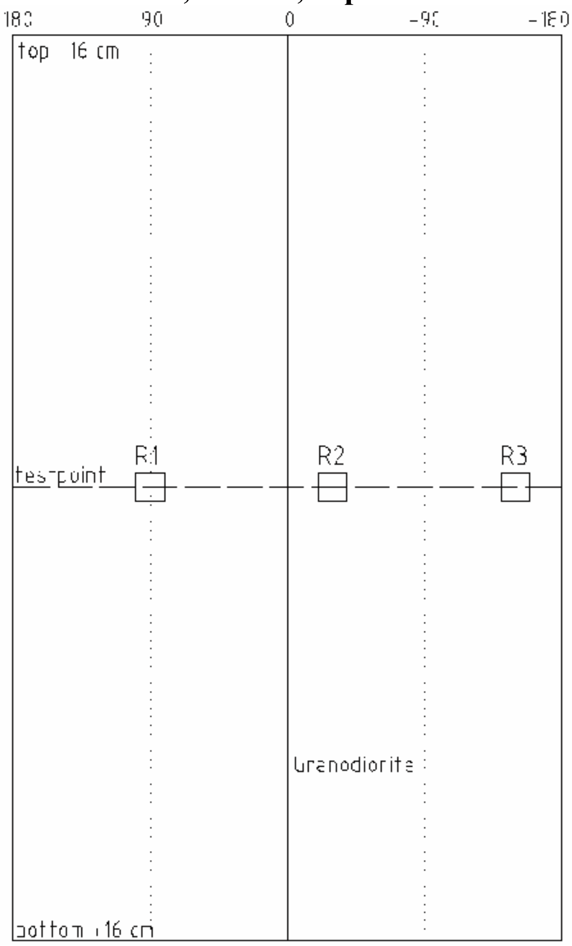
Top view



Use special tool to check that strain gauges are 120 degrees apart. Mark any deviations in the figure.

OVERCORE SAMPLE LOG

Borehole no., test no., depth : **KFM07C, Test no. 2:1:3, 158.28 m depth**



Angle clockwise in borehole direction
rosette 1 =+90 degrees
rosette 2 =-30 degrees
rosette 3 =-150 degrees

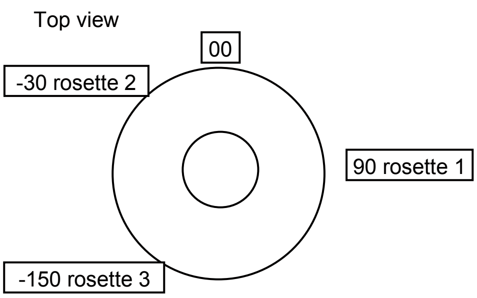
GEOLOGY

Granodiorite

STRUCTURES (JOINTS)

No fractures before or after biaxial testing.

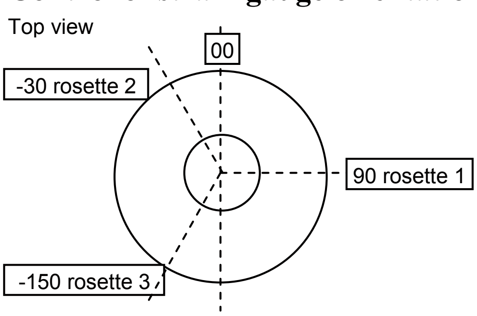
Mark any observed fractures



COMMENTS

Strain gauge orientation OK.

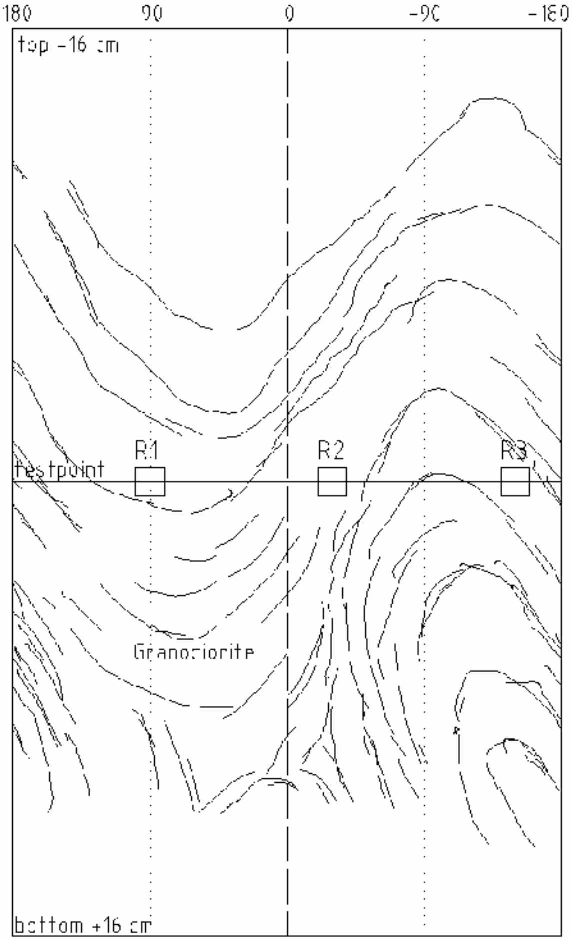
Control of strain gauge orientation



Use special tool to check that strain gauges are 120 degrees apart. Mark any deviations in the figure.

OVERCORE SAMPLE LOG

Borehole no., test no., depth : **KFM07C, Test no. 2:3:1, 160.37 m depth**



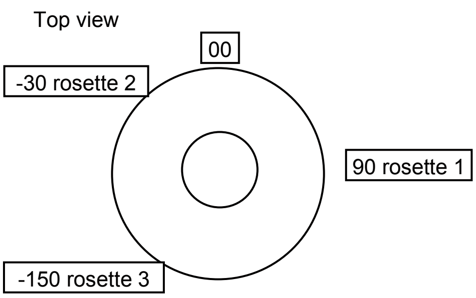
Angle clockwise in borehole direction
rosette 1 =+90 degrees
rosette 2 =-30 degrees
rosette 3 =-150 degrees

GEOLOGY

Granodiorite

STRUCTURES (JOINTS)

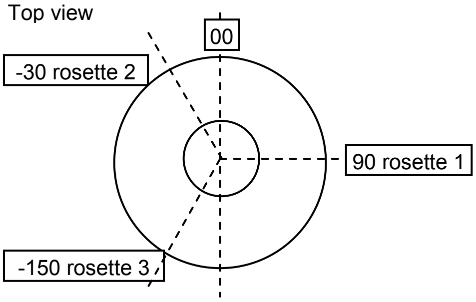
Mark any observed fractures



COMMENTS

The core split after 58 cm of overcoring.

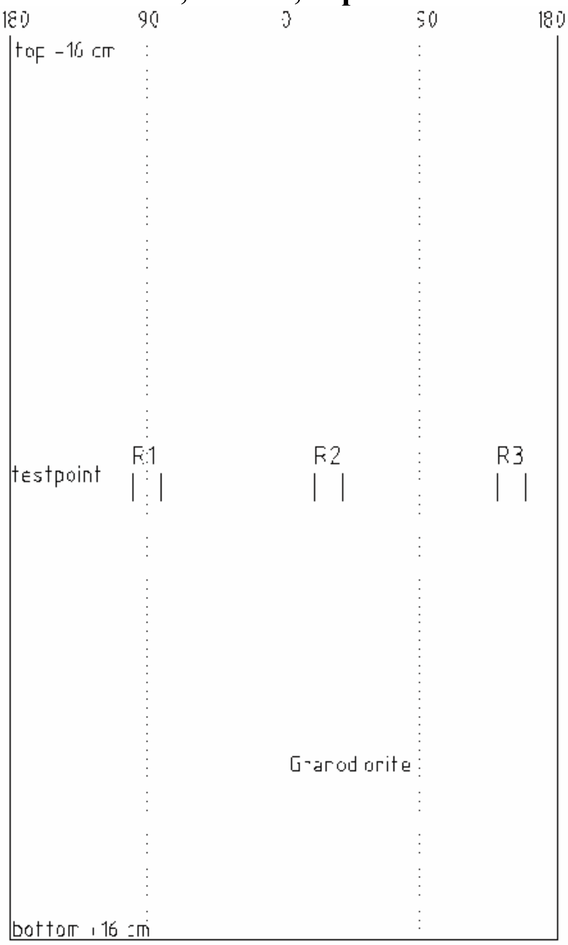
Control of strain gauge orientation



Use special tool to check that strain gauges are 120 degrees apart. Mark any deviations in the figure.

OVERCORE SAMPLE LOG

Borehole no., test no., depth : KFM07C, Test no. 2:4:1, 162.69 m depth



Angle clockwise in borehole direction
rosette 1 =+90 degrees
rosette 2 =-30 degrees
rosette 3 =-150 degrees

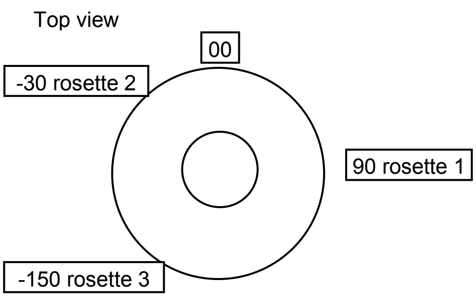
GEOLOGY

Granidiorite

STRUCTURES (JOINTS)

No fractures before or after biaxial testing.

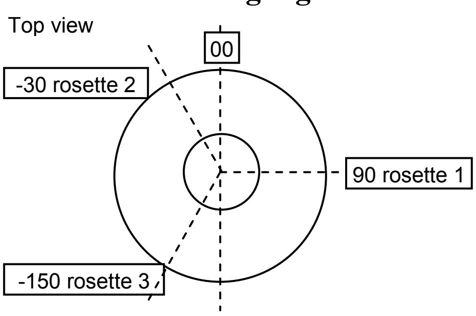
Mark any observed fractures



COMMENTS

Strain gauge orientation OK.

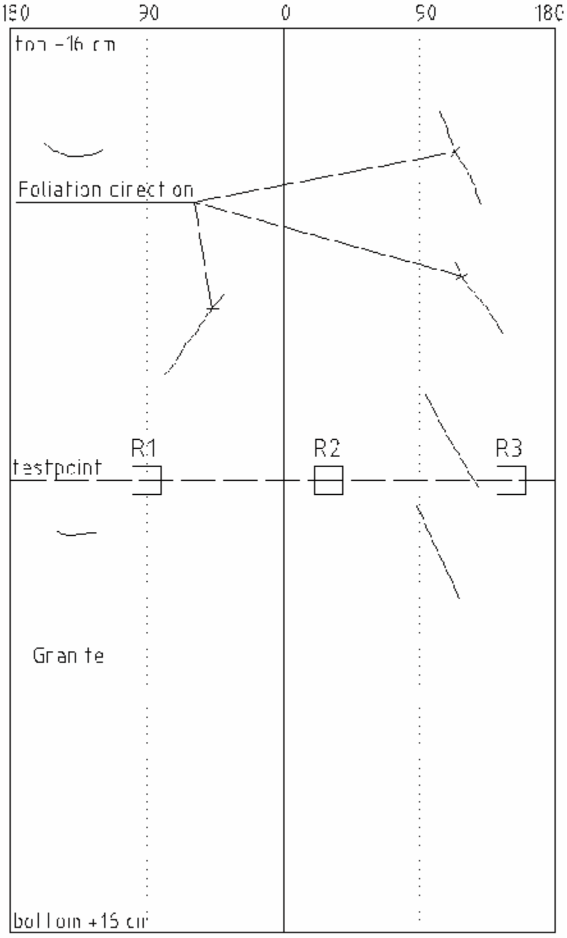
Control of strain gauge orientation



Use special tool to check that strain gauges are 120 degrees apart. Mark any deviations in the figure.

OVERCORE SAMPLE LOG

Borehole no., test no., depth : **KFM07C, Test no. 2:8:1, 174.60 m depth**



Angle clockwise in borehole direction
rosette 1 =+90 degrees
rosette 2 =-30 degrees
rosette 3 =-150 degrees

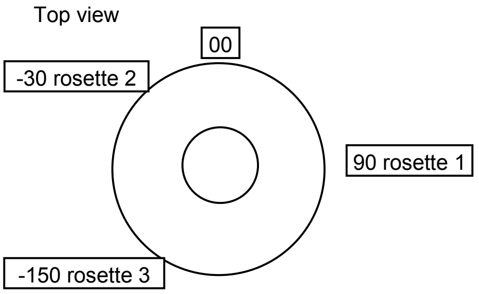
GEOLOGY

Granite, foliated

STRUCTURES (JOINTS)

No fractures before or after biaxial testing.

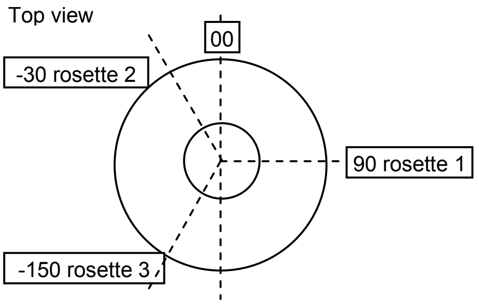
Mark any observed fractures



COMMENTS

Strain gauge orientation OK.

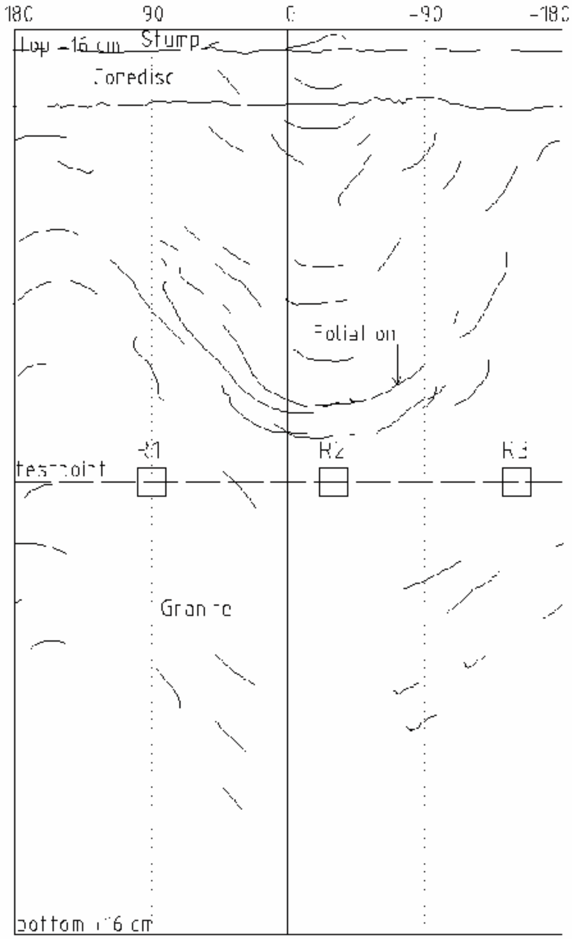
Control of strain gauge orientation



Use special tool to check that strain gauges are 120 degrees apart. Mark any deviations in the figure.

OVERCORE SAMPLE LOG

Borehole no., test no., depth : **KFM07C, Test no. 2:9:1, 175.62 m depth**



Angle clockwise in borehole direction
rosette 1 =+90 degrees
rosette 2 =-30 degrees
rosette 3 =-150 degrees

GEOLOGY

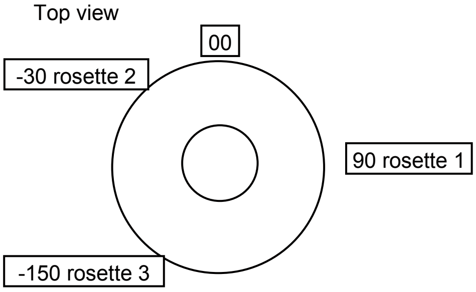
Granite, foliated

STRUCTURES (JOINTS)

Ring disking 2 cm from the top

Mark any observed fractures

Top view

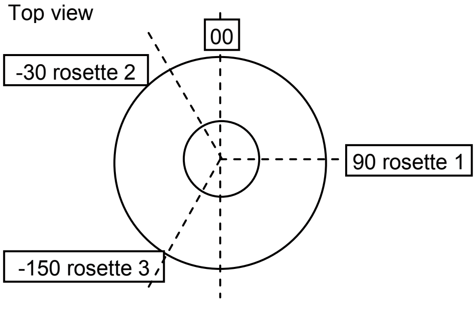


COMMENTS

Strain gauge orientation OK.

Control of strain gauge orientation

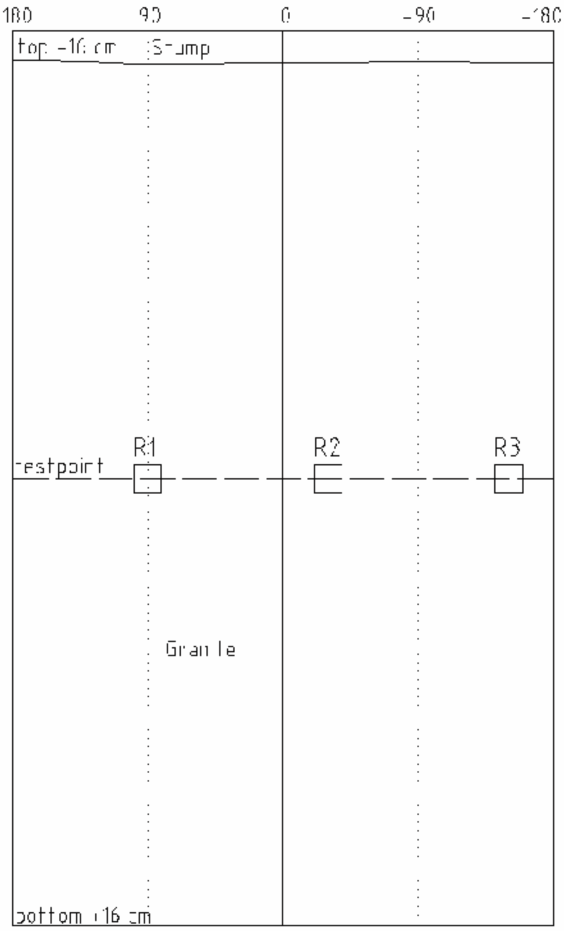
Top view



Use special tool to check that strain gauges are 120 degrees apart. Mark any deviations in the figure.

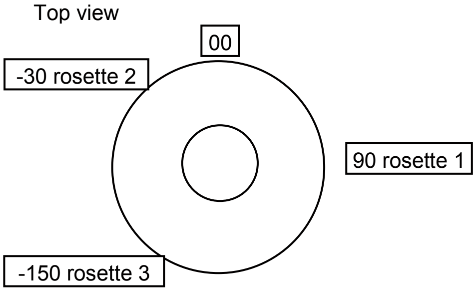
OVERCORE SAMPLE LOG

Borehole no., test no., depth : **KFM07C, Test no. 2:10:1, 176.65 m depth**



Mark any observed fractures

Top view



Angle clockwise in borehole direction
rosette 1 =+90 degrees
rosette 2 =-30 degrees
rosette 3 =-150 degrees

GEOLOGY

Granite

STRUCTURES (JOINTS)

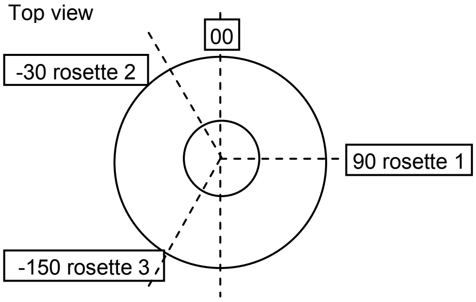
No fractures before or after biaxial testing.

COMMENTS

Strain gauge orientation OK.

Control of strain gauge orientation

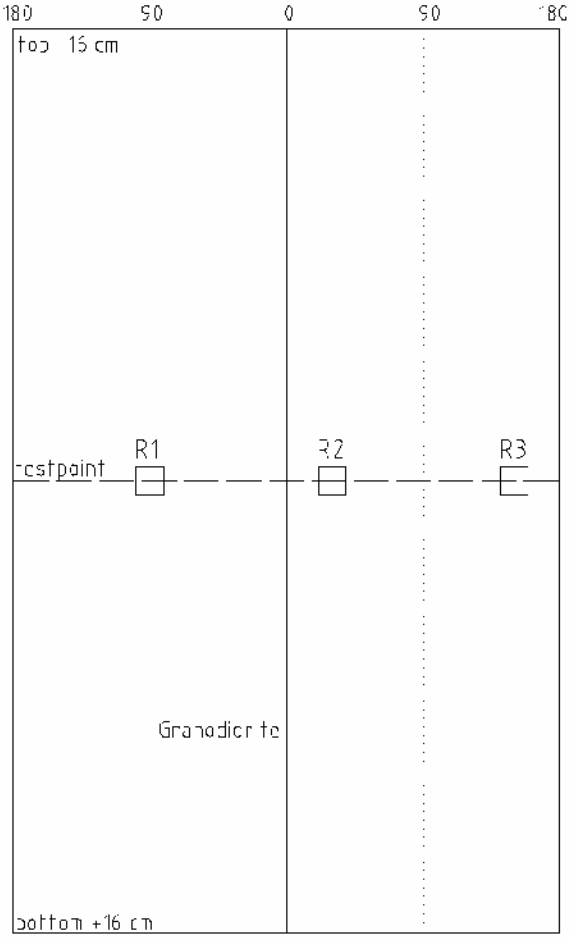
Top view



Use special tool to check that strain gauges are 120 degrees apart. Mark any deviations in the figure.

OVERCORE SAMPLE LOG

Borehole no., test no., depth : **KFM07C, Test no. 2:11:1, 177.65 m depth**



Angle clockwise in borehole direction
rosette 1 =+90 degrees
rosette 2 =-30 degrees
rosette 3 =-150 degrees

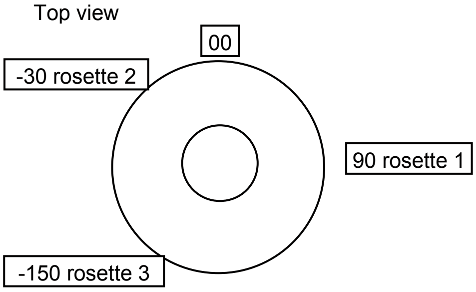
GEOLOGY

Granodiorite

STRUCTURES (JOINTS)

No fractures before or after biaxial testing.

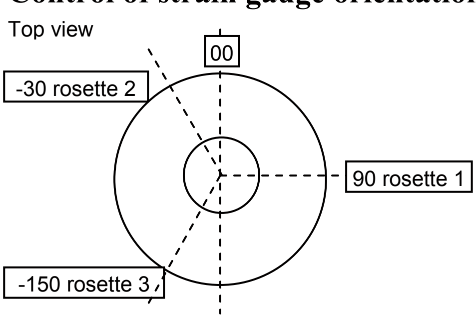
Mark any observed fractures



COMMENTS

Strain gauge orientation OK.

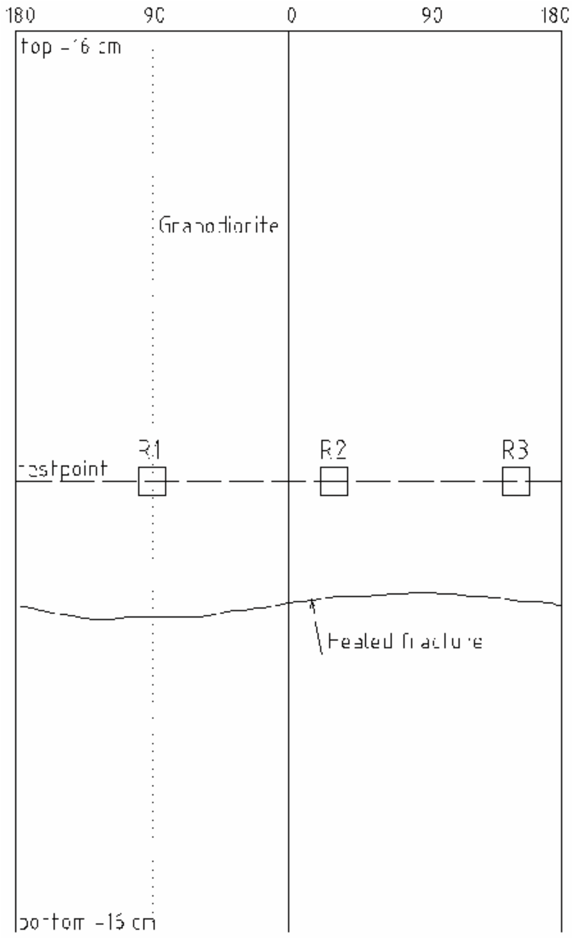
Control of strain gauge orientation



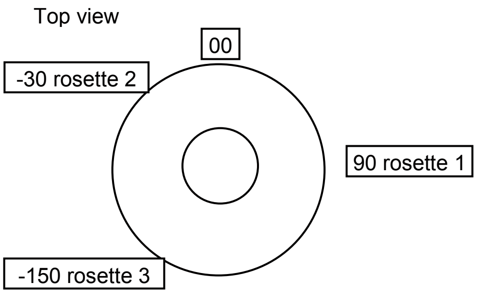
Use special tool to check that strain gauges are 120 degrees apart. Mark any deviations in the figure.

OVERCORE SAMPLE LOG

Borehole no., test no., depth : **KFM07C, Test no. 3:1:1, 192.47 m depth**



Mark any observed fractures



Angle clockwise in borehole direction
rosette 1 =+90 degrees
rosette 2 =-30 degrees
rosette 3 =-150 degrees

GEOLOGY

Granodiorite

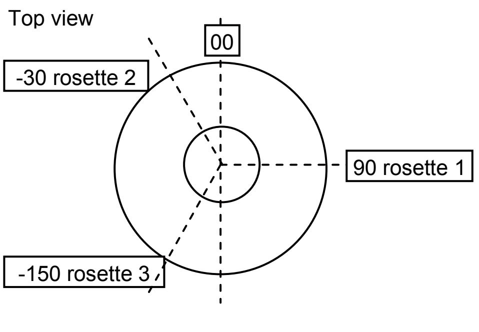
STRUCTURES (JOINTS)

Healed fracture

COMMENTS

Strain gauge orientation OK.

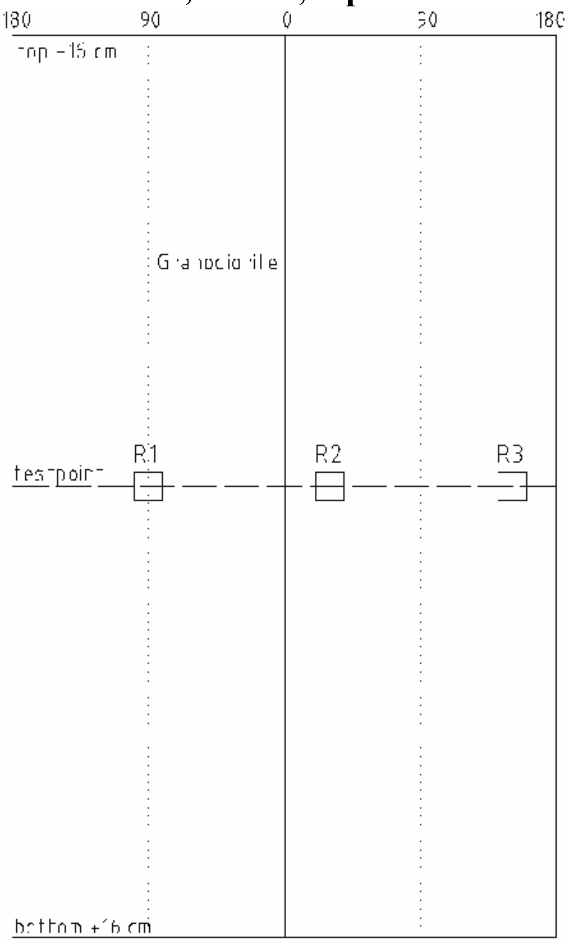
Control of strain gauge orientation



Use special tool to check that strain gauges are 120 degrees apart. Mark any deviations in the figure.

OVERCORE SAMPLE LOG

Borehole no., test no., depth : **KFM07C, Test no. 3:4:1, 195.31 m depth**



Angle clockwise in borehole direction
rosette 1 =+90 degrees
rosette 2 =-30 degrees
rosette 3 =-150 degrees

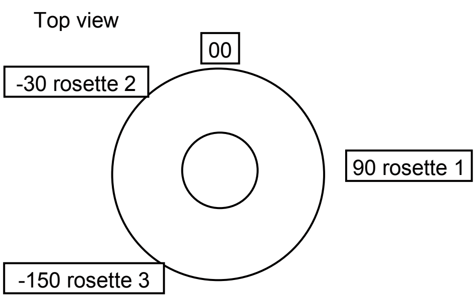
GEOLOGY

Granodiorite

STRUCTURES (JOINTS)

No fractures before or after biaxial testing.

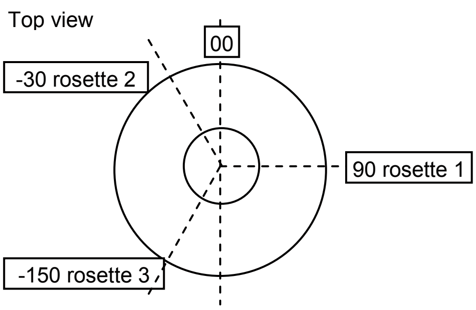
Mark any observed fractures



COMMENTS

Strain gauge orientation OK.

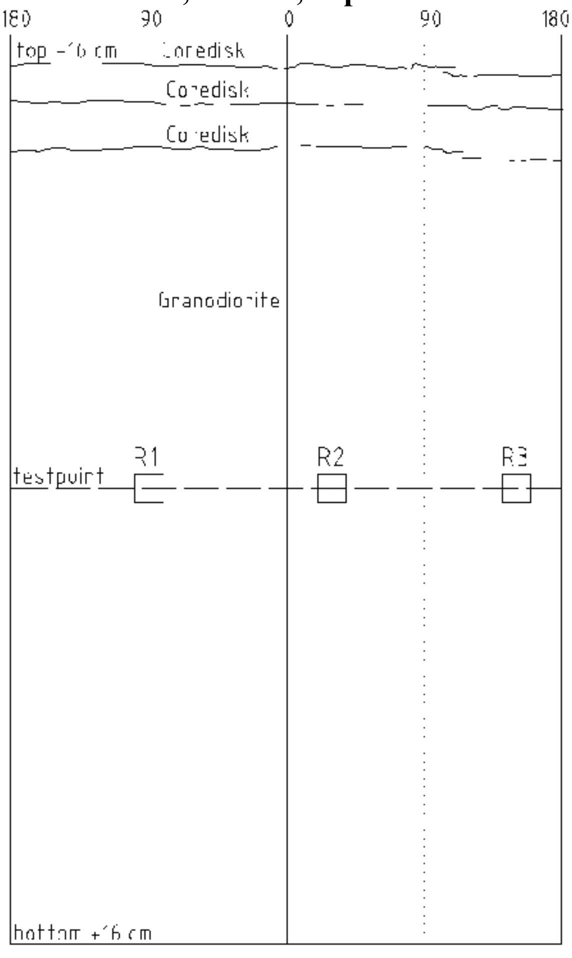
Control of strain gauge orientation



Use special tool to check that strain gauges are 120 degrees apart. Mark any deviations in the figure.

OVERCORE SAMPLE LOG

Borehole no., test no., depth : **KFM07C, Test no. 3:6:1, 197.28 m depth**



Angle clockwise in borehole direction
rosette 1 =+90 degrees
rosette 2 =-30 degrees
rosette 3 =-150 degrees

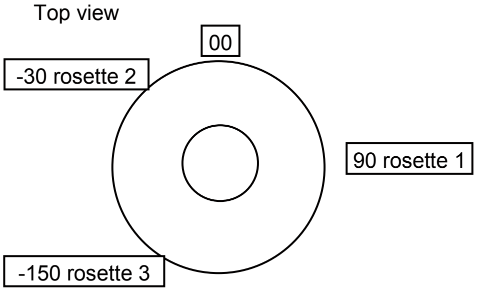
GEOLOGY

Granodiorite

STRUCTURES (JOINTS)

No fractures before or after biaxial testing.

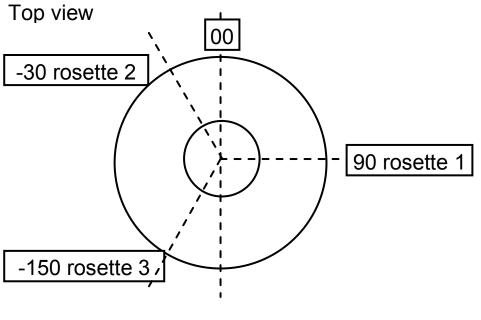
Mark any observed fractures



COMMENTS

Strain gauge orientation OK.

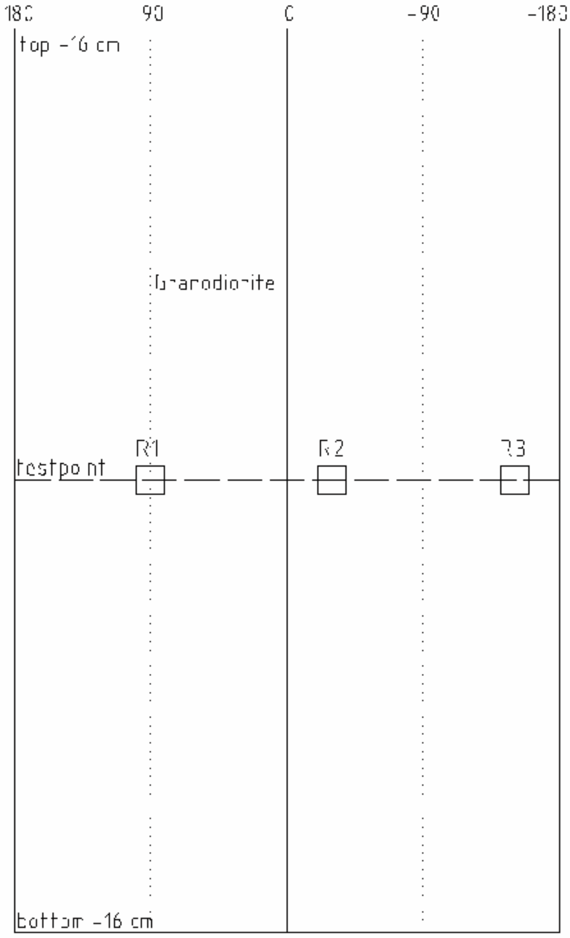
Control of strain gauge orientation



Use special tool to check that strain gauges are 120 degrees apart. Mark any deviations in the figure.

OVERCORE SAMPLE LOG

Borehole no., test no., depth : **KFM07C, Test no. 4:1:2, 238.05 m depth**



Angle clockwise in borehole direction
rosette 1 =+90 degrees
rosette 2 =-30 degrees
rosette 3 =-150 degrees

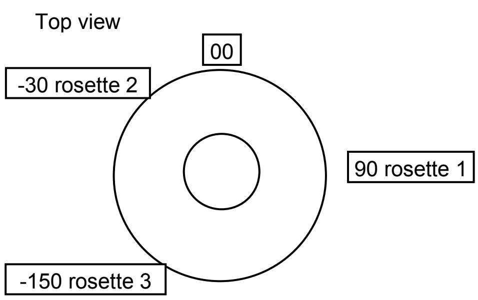
GEOLOGY

Granodiorite

STRUCTURES (JOINTS)

No fractures before or after biaxial testing.

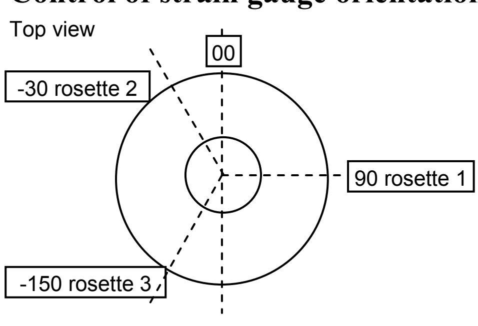
Mark any observed fractures



COMMENTS

Strain gauge orientation OK.

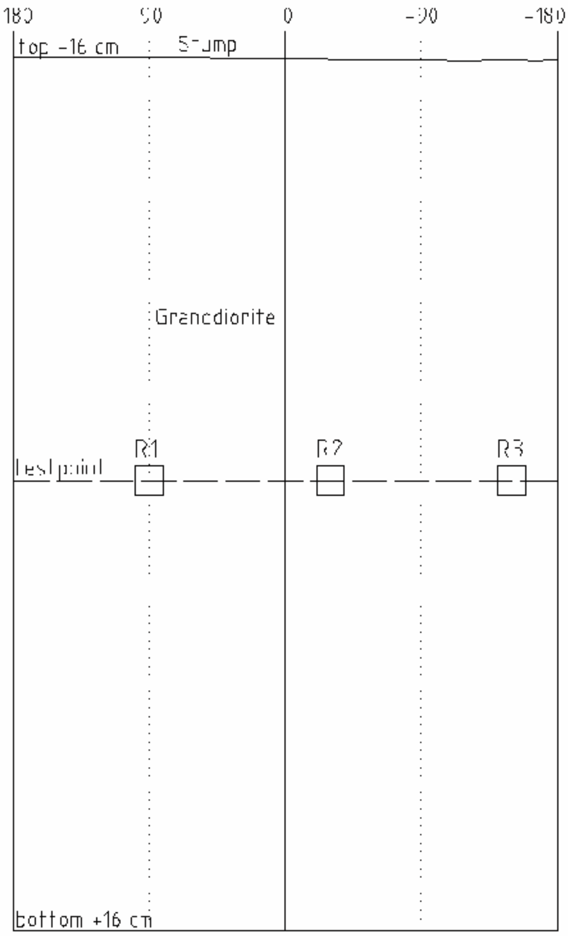
Control of strain gauge orientation



Use special tool to check that strain gauges are 120 degrees apart. Mark any deviations in the figure.

OVERCORE SAMPLE LOG

Borehole no., test no., depth : **KFM07C, Test no. 4:2:3, 242.70 m depth**



Angle clockwise in borehole direction
rosette 1 =+90 degrees
rosette 2 =-30 degrees
rosette 3 =-150 degrees

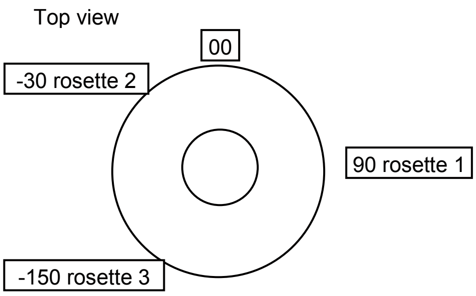
GEOLOGY

Grandiorite

STRUCTURES (JOINTS)

No fractures before or after biaxial testing.

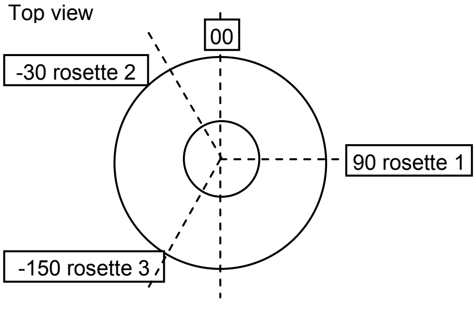
Mark any observed fractures



COMMENTS

Strain gauge orientation OK.

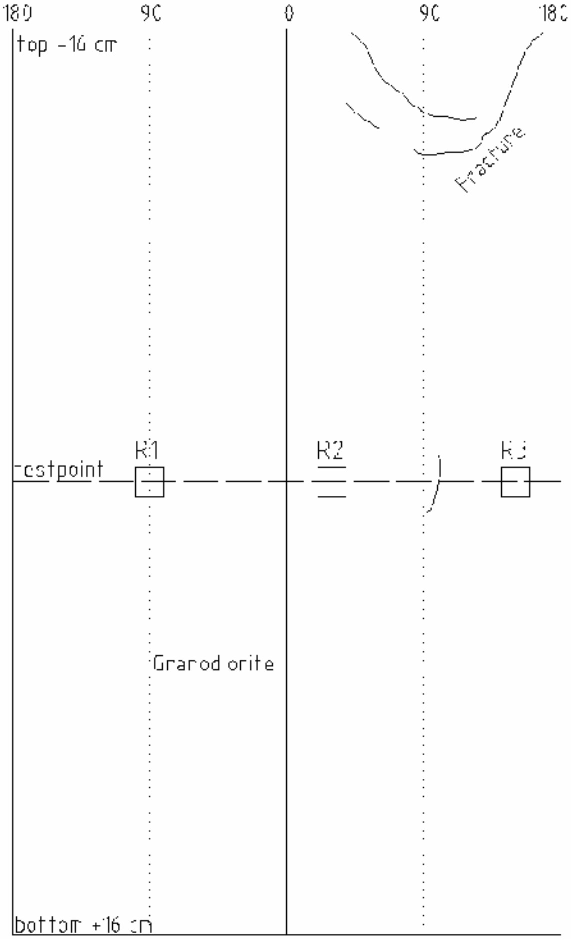
Control of strain gauge orientation



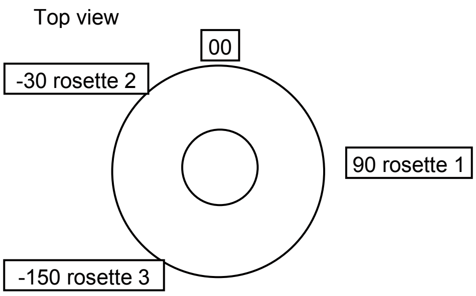
Use special tool to check that strain gauges are 120 degrees apart. Mark any deviations in the figure.

OVERCORE SAMPLE LOG

Borehole no., test no., depth : **KFM07C, Test no. 4:4:2, 258.73 m depth**



Mark any observed fractures



Angle clockwise in borehole direction
rosette 1 =+90 degrees
rosette 2 =-30 degrees
rosette 3 =-150 degrees

GEOLOGY

Grandiorite

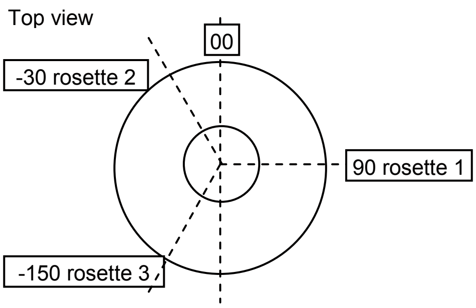
STRUCTURES (JOINTS)

No fractures before or after biaxial testing.

COMMENTS

Strain gauge orientation OK.

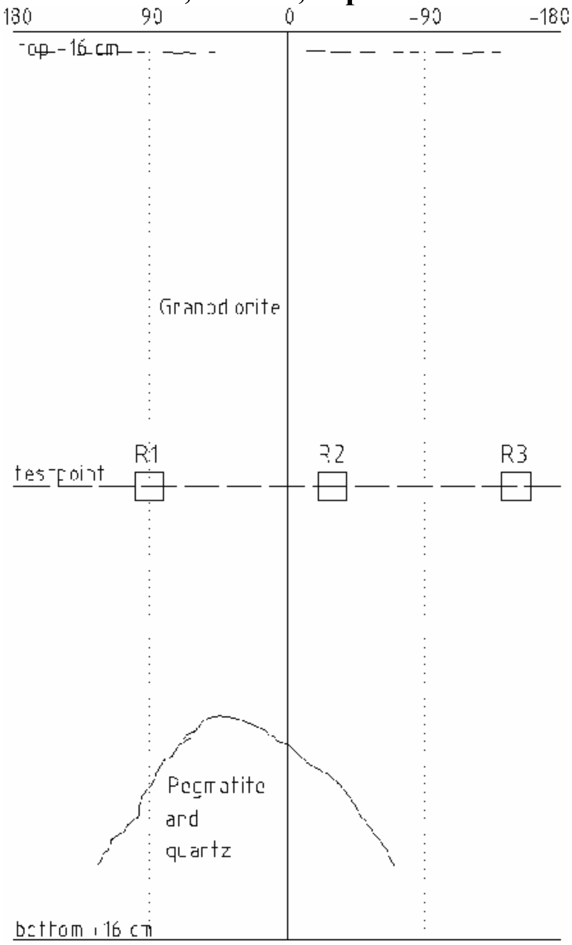
Control of strain gauge orientation



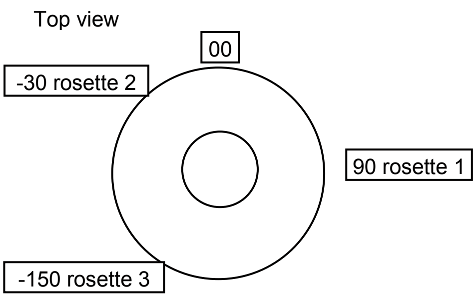
Use special tool to check that strain gauges are 120 degrees apart. Mark any deviations in the figure.

OVERCORE SAMPLE LOG

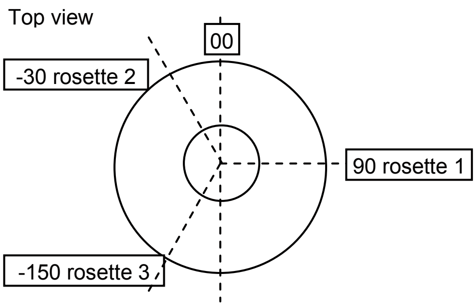
Borehole no., test no., depth : **KFM07C, Test no. 5:3:4, 316.25 m depth**



Mark any observed fractures



Control of strain gauge orientation



Angle clockwise in borehole direction
rosette 1 =+90 degrees
rosette 2 =-30 degrees
rosette 3 =-150 degrees

GEOLOGY

Granodiorite, pegmatite och quartz

STRUCTURES (JOINTS)

No fractures before or after biaxial testing.

COMMENTS

Strain gauge orientation OK.

Use special tool to check that strain gauges are 120 degrees apart. Mark any deviations in the figure.

Photos of core samples

1:1:5, 98.76 m – pilot core

1:1:5, 98.76 m – overcore sample

1:2:4, 104.53 m – pilot core

1:2:4, 104.53 m – overcore sample

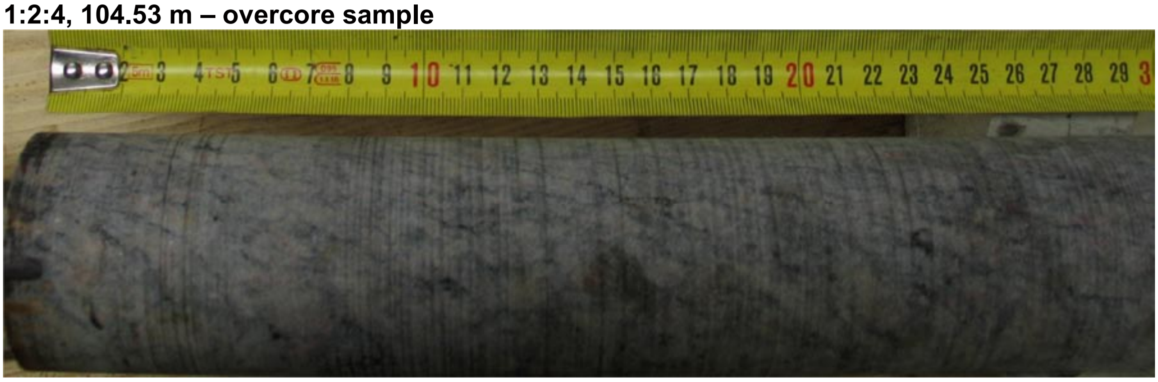


Figure G1. *Photos of pilot core and overcore sample for borehole KFM07C, Level 1.*

1:4:1, 108.42 m – pilot core

1:4:1, 108.42 m – overcore sample

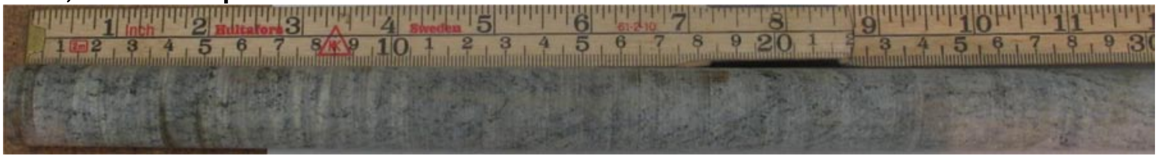
Figure G1. *(Concluded.)*

2:1:3, 158.28 m – pilot core

2:1:3, 158.28 m – overcore sample

Figure G2. *Photos of pilot core and overcore sample for borehole KFM07C, Level 2.*

2:3:1, 160.37 m – pilot core



2:3:1, 160.37 m – overcore sample

2:4:1, 162.69 m – pilot core

2:4:1, 162.69 m – overcore sample

2:8:1, 174.60 m – pilot core

2:8:1, 174.60 m – overcore sample

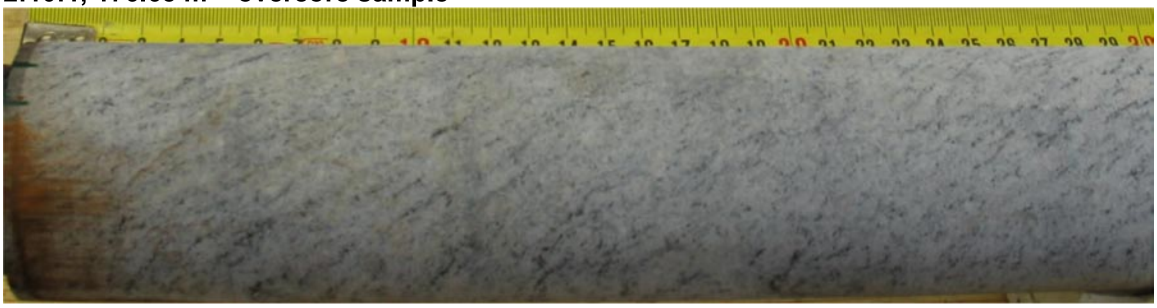
Figure G2. *(Continued.)*

2:9:1, 175.62 m – pilot core

2:9:1, 175.62 m – overcore sample

2:10:1, 176.65 m – pilot core

2:10:1, 176.65 m – overcore sample



2:11:1, 177.65 m – pilot core

2:11:1, 177.65 m – overcore sample

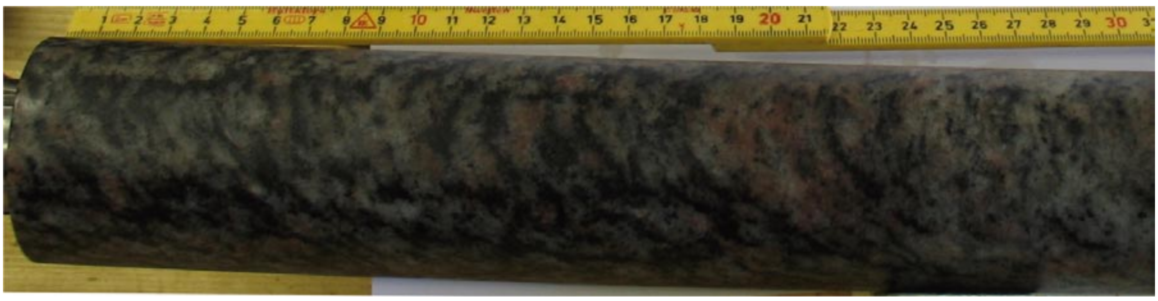
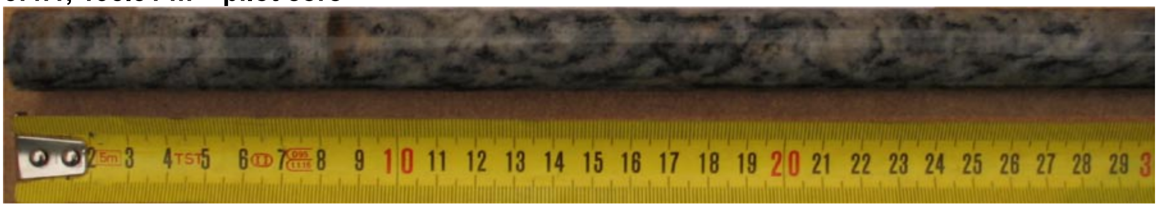


Figure G2. *(Concluded.)*

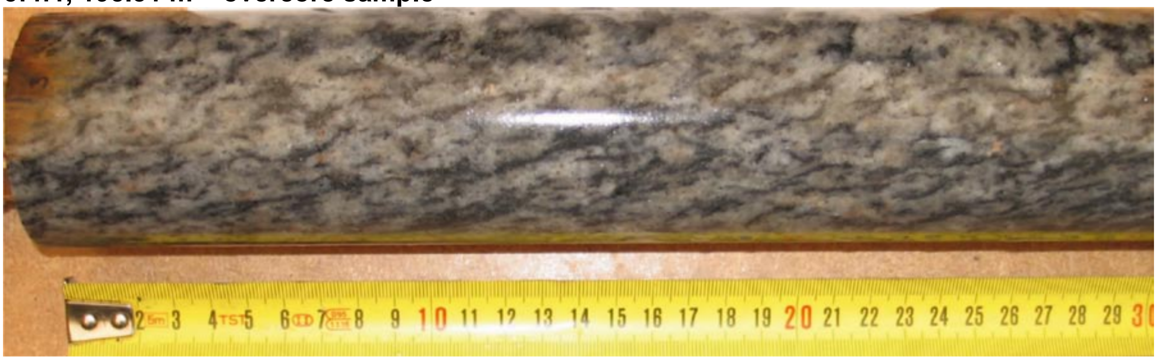
3:1:1, 192.47 m – pilot core

3:1:1, 192.47 m – overcore sample

3:4:1, 195.31 m – pilot core



3:4:1, 195.31 m – overcore sample



3:6:1, 197.28 m – pilot core

3:6:1, 197.28 m – overcore sample

Figure G3. *Photos of pilot core and overcore sample for borehole KFM07C, Level 3.*

4:1:2, 238.05 m – pilot core

4:1:2, 238.05 m – overcore sample

4:2:3, 242.7 m – pilot core

4:2:3, 242.7 m – overcore sample

4:4:2, 258.73 m – pilot core

4:4:2, 258.73 m – overcore sample

Figure G4. *Photos of pilot core and overcore sample for borehole KFM07C, Level 4.*

5:3:4, 316.25 m – pilot core

5:3:4, 316.25 m – overcore sample

Figure G5. *Photos of pilot core and overcore sample for borehole KFM07C, Level 5.*

Appendix H

Confidence intervals for measured stresses

Table H-1. 90%-confidence intervals for the principal stresses as determined from overcoring measurements in borehole KFM07C.

Level		Magnitude and Trend/Plunge of principal stresses					
		σ_1		σ_2		σ_3	
		[MPa]	[°]	[MPa]	[°]	[MPa]	[°]
Level 1	Average	24.8	354/02	14.6	085/18	2.6	258/71
	90% lower	20.6	*)	3.9	*)	–7.8	*)
	90% upper	34.4		25.2		7.1	
Level 2A	Average	22.9	286/04	19.5	017/08	2.6	167/81
	90% lower	22.7	*)	–2.0	*)	–19.9	*)
	90% upper	54.1		24.0		15.8	
Level 2B	Average	24.9	009/04	18.2	279/0	7.8	187/86
	90% lower	16.0	*)	6.1	*)	–0.8	*)
	90% upper	43.2		26.4		13.5	
Level 3	Average	20.4	303/01	17.2	034/06	11.1	206/84
	90% lower	16.3	*)	8.1	*)	–6.2	*)
	90% upper	40.6		25.8		12.2	
Level 4	Average	31.0	354/11	18.6	085/5	11.3	200/77
	90% lower	22.1	*)	4.7	*)	–11.5	*)
	90% upper	55.6		32.9		19.1	

* All orientation data presented in Figure H-1, Figure H-2, Figure H-3, Figure H-4 and Figure H-5.

Table H-2. 90%-confidence intervals for the horizontal and vertical stress components as determined from overcoring measurements in borehole KFM07C.

Level		σ_H [MPa]	σ_h [MPa]	σ_v [MPa]	Trend σ_H [°]
Level 1	Average	24.8	13.4	3.9	173
	90% lower	19.6	–0.6	–4.2	*)
	90% upper	32.7	23.3	12.0	
Level 2A	Average	22.7	19.2	3.0	103
	90% lower	22.2	–14.1	–15.7	*)
	90% upper	52.8	23.1	21.9	
Level 2B	Average	24.8	18.2	7.9	009
	90% lower	15.6	1.8	–15.7	*)
	90% upper	43.0	26.3	21.9	
Level 3	Average	20.4	17.1	11.2	123
	90% lower	14.4	–5.2	8.1	*)
	90% upper	39.8	24.5	14.3	
Level 4	Average	30.2	18.6	12.1	174
	90% lower	18.5	–4.1	–6.9	*)
	90% upper	53.7	30.0	31.2	

* All orientation data presented in Figure H-7, Figure H-8, Figure H-9, Figure H-10 and Figure H-11.

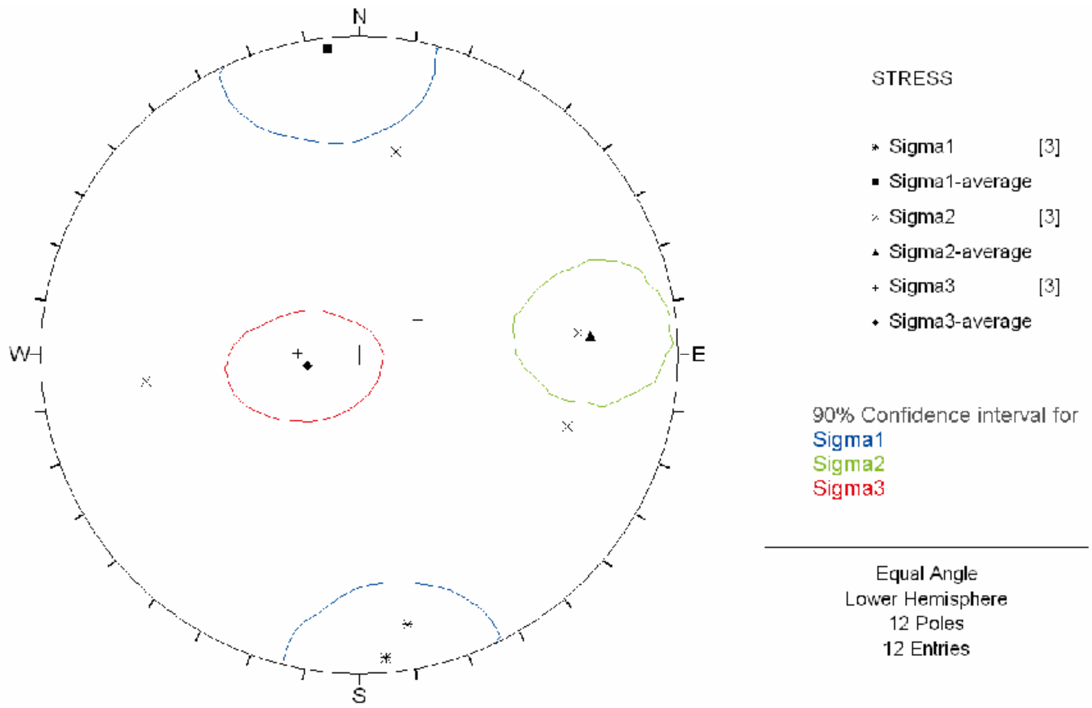


Figure H-1. *90%-confidence interval for the orientation of the principal stresses in borehole KFM07C Level 1, shown in a lower hemisphere projection.*

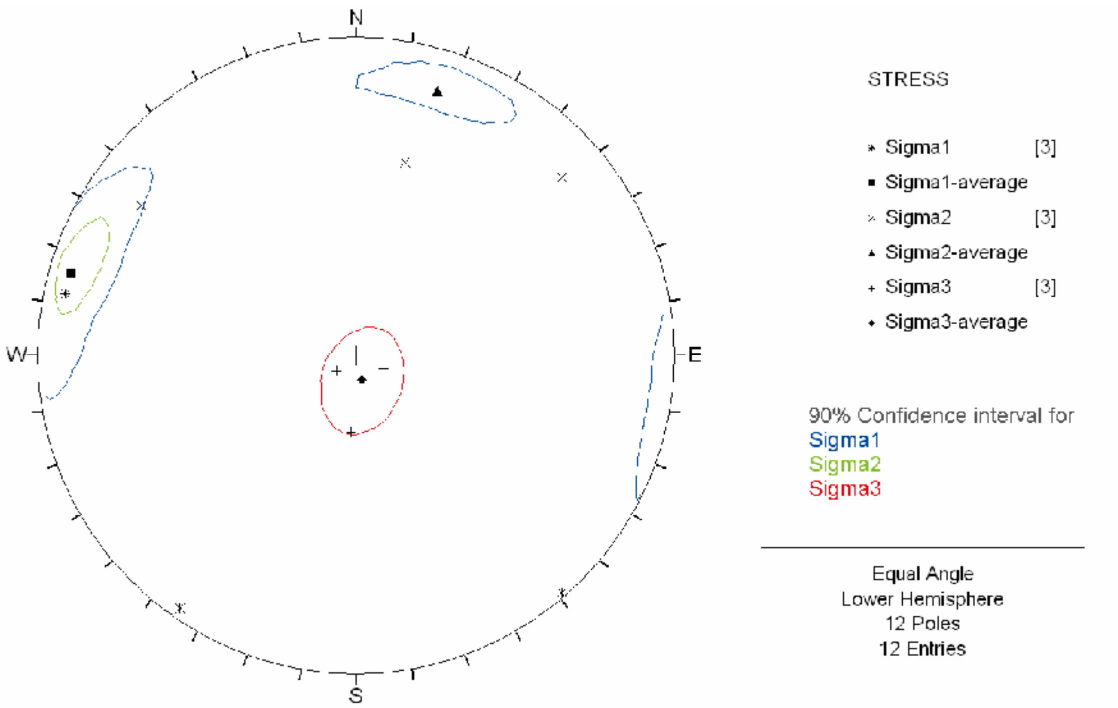


Figure H-2. *90%-confidence interval for the orientation of the principal stresses in borehole KFM07C Level 2A, shown in a lower hemisphere projection.*

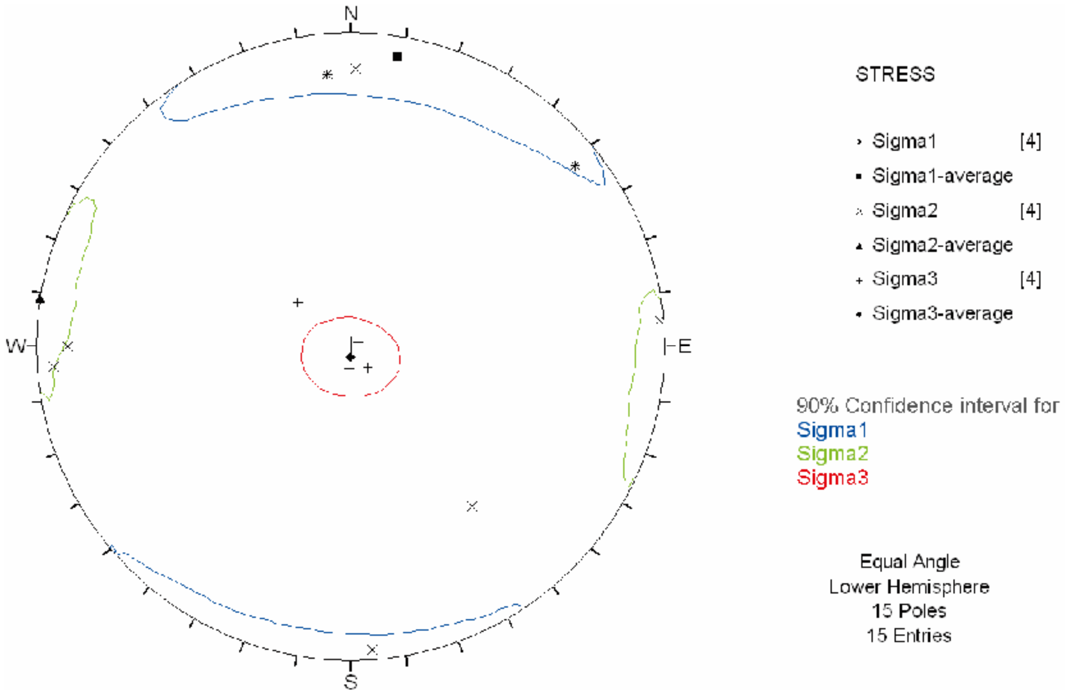


Figure H-3. *90%-confidence interval for the orientation of the principal stresses in borehole KFM07C Level 2B, shown in a lower hemisphere projection.*

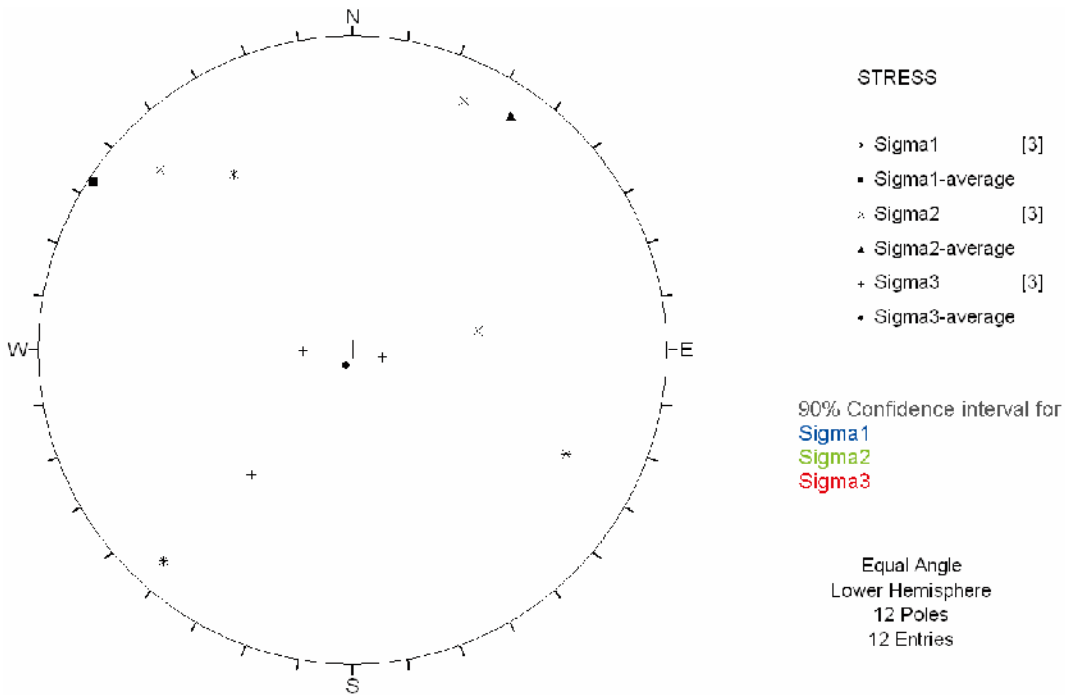


Figure H-4. *90%-confidence interval for the orientation of the principal stresses in borehole KFM07C Level 3, shown in a lower hemisphere projection.*

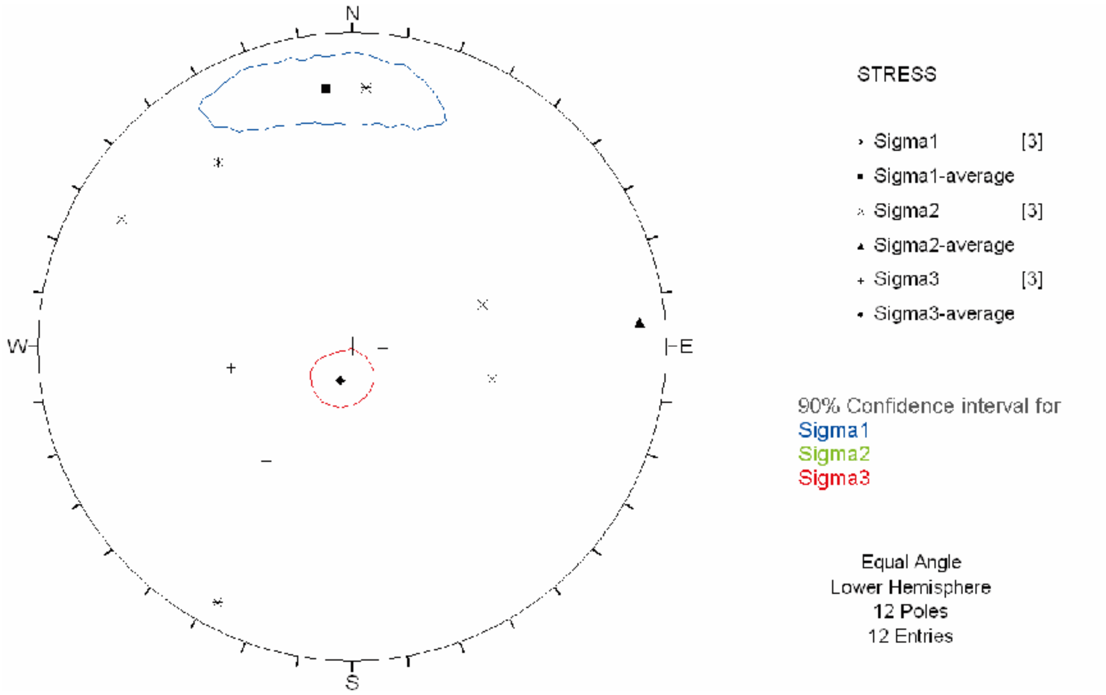


Figure H-5. *90%-confidence interval for the orientation of the principal stresses in borehole KFM07C Level 4, shown in a lower hemisphere projection.*

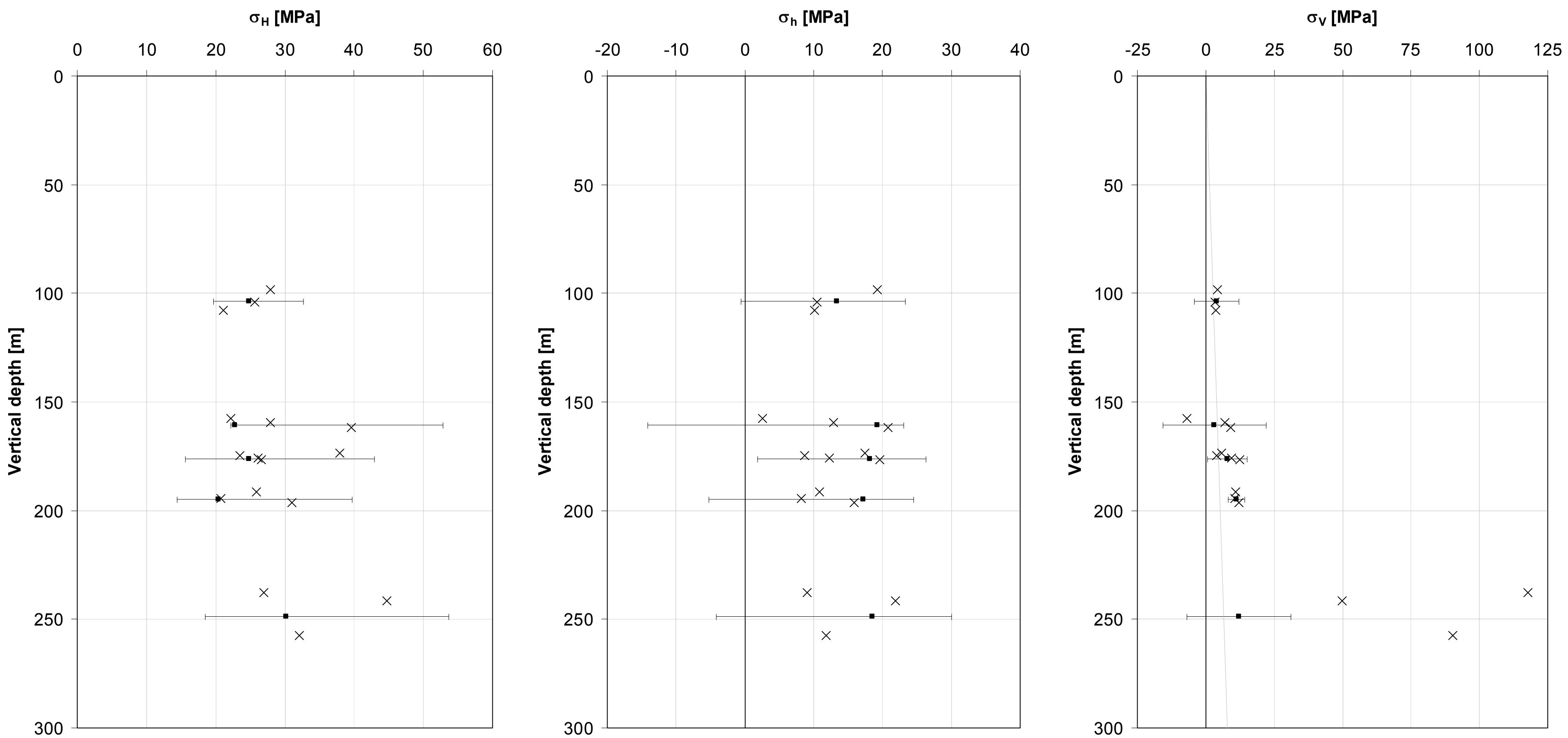


Figure H-6. *Average values (■-markers) and 90%-confidence intervals ( ) for the horizontal and vertical stress components, shown together with measured values for each measurement level (x-markers) in borehole KFM07C.*

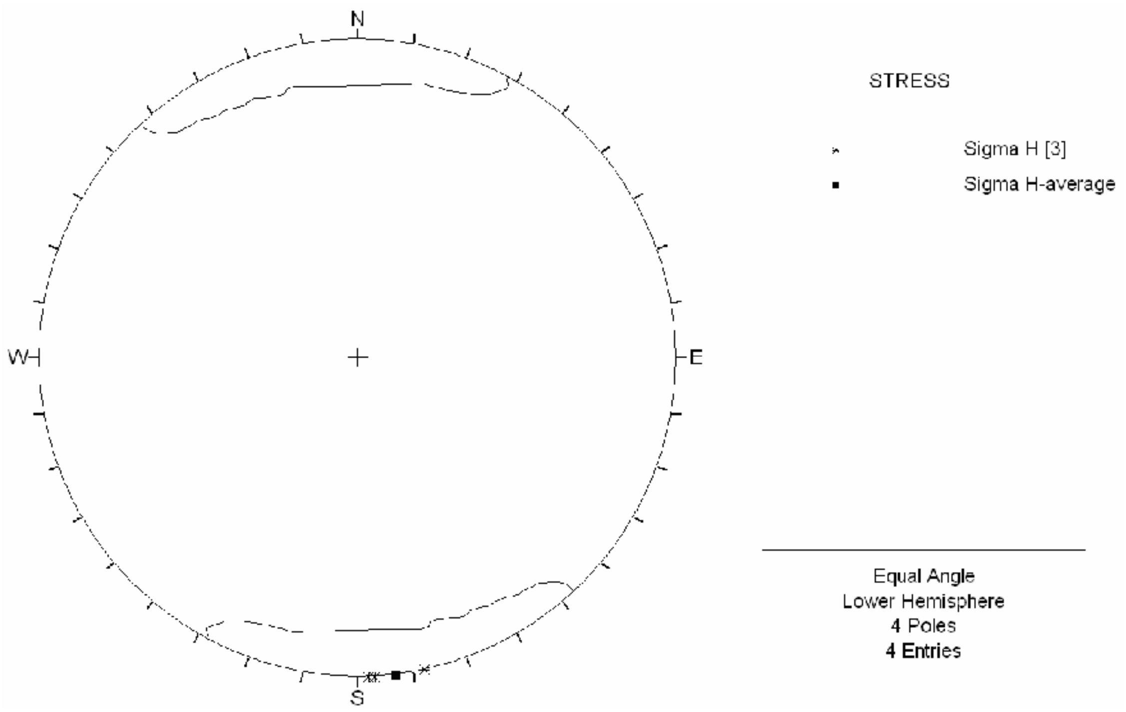


Figure H-7. *90%-confidence interval for the orientation of the maximum horizontal stress for Level 1 in borehole KFM07C, shown in a lower hemisphere projection.*

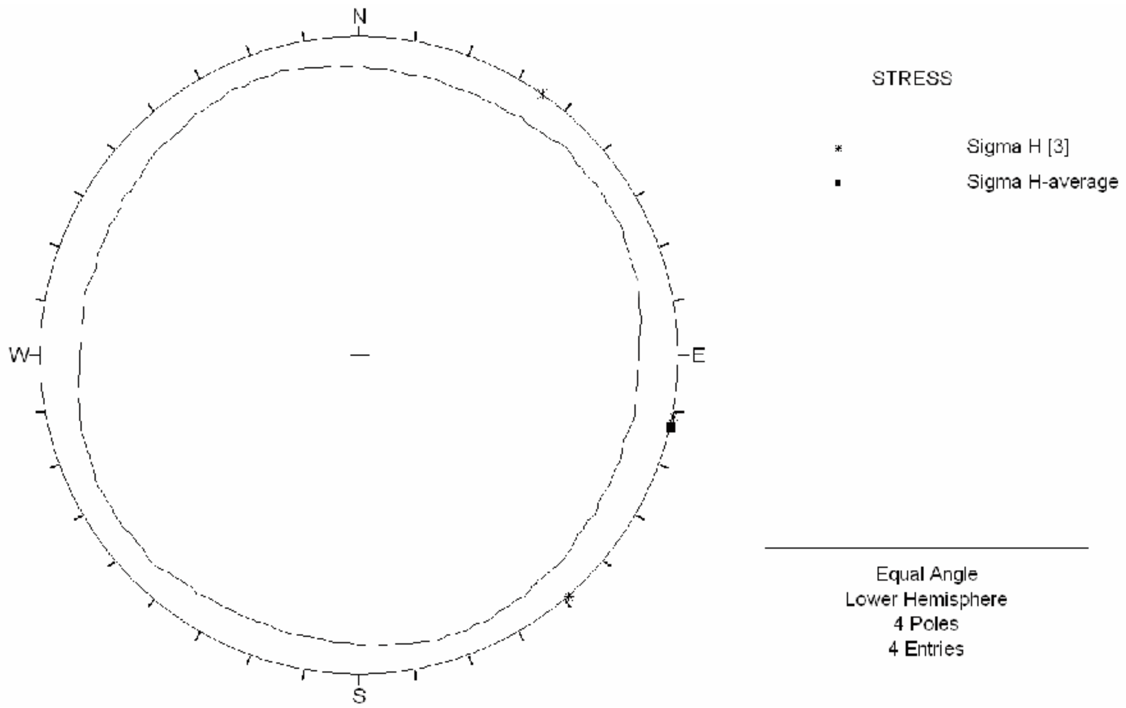


Figure H-8. *90%-confidence interval for the orientation of the maximum horizontal stress for Level 2a in borehole KFM07C, shown in a lower hemisphere projection.*

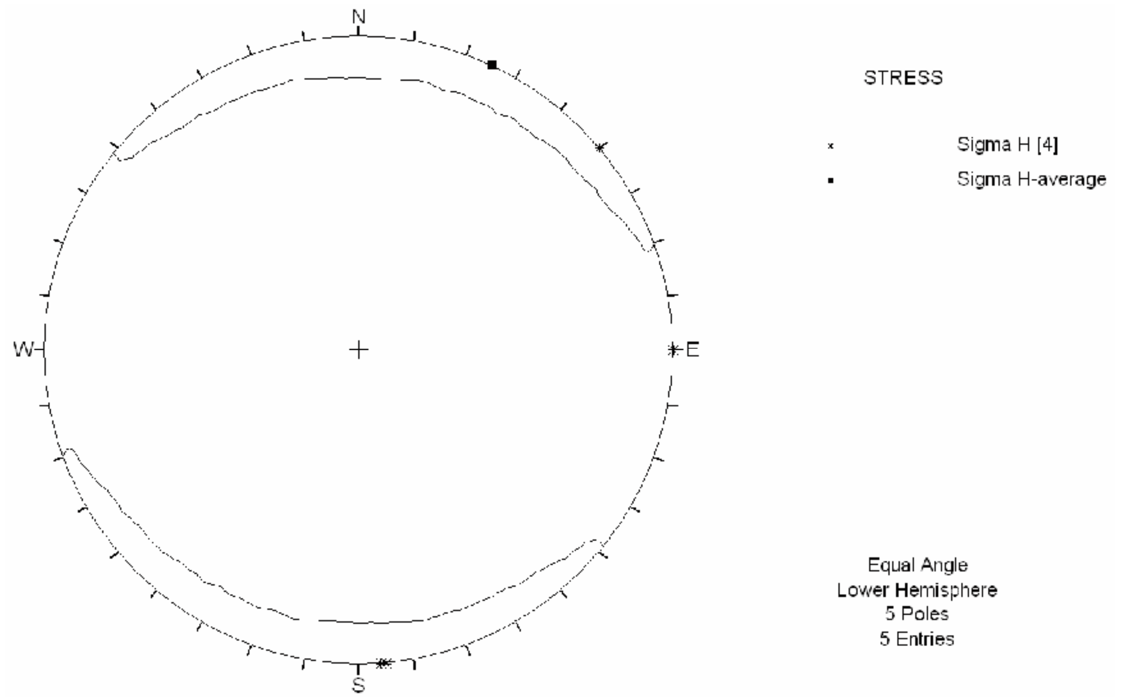


Figure H-9. *90%-confidence interval for the orientation of the maximum horizontal stress for Level 2b in borehole KFM07C, shown in a lower hemisphere projection.*

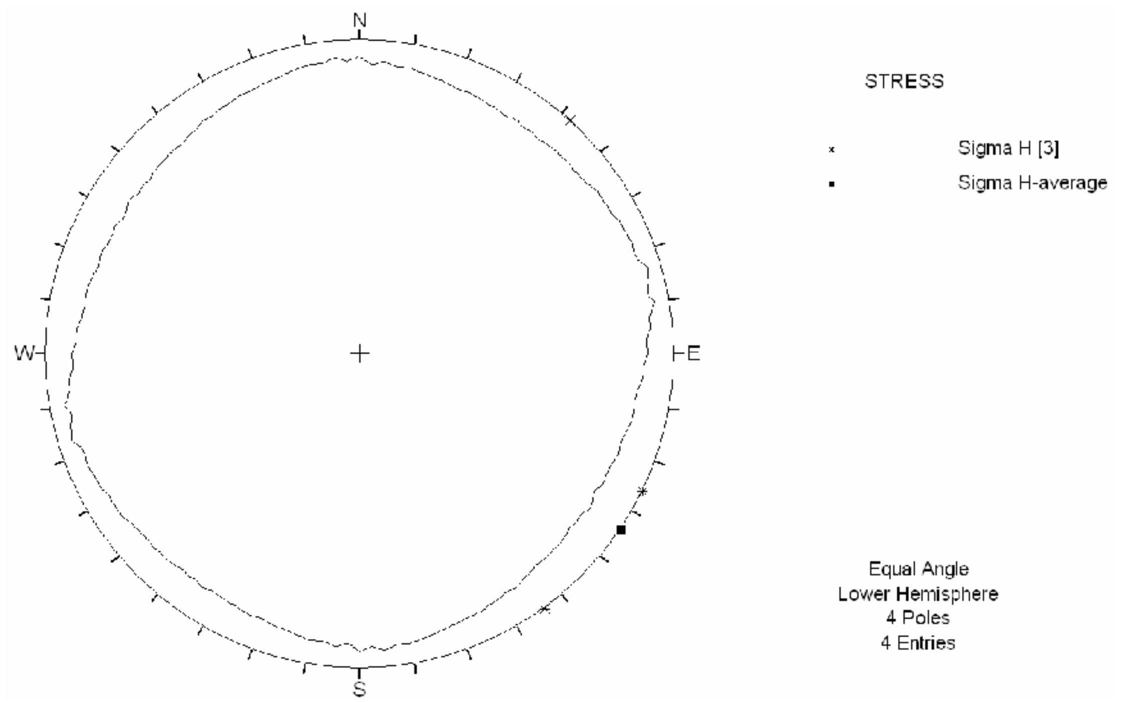


Figure H-10. *90%-confidence interval for the orientation of the maximum horizontal stress for Level 3 in borehole KFM07C, shown in a lower hemisphere projection.*

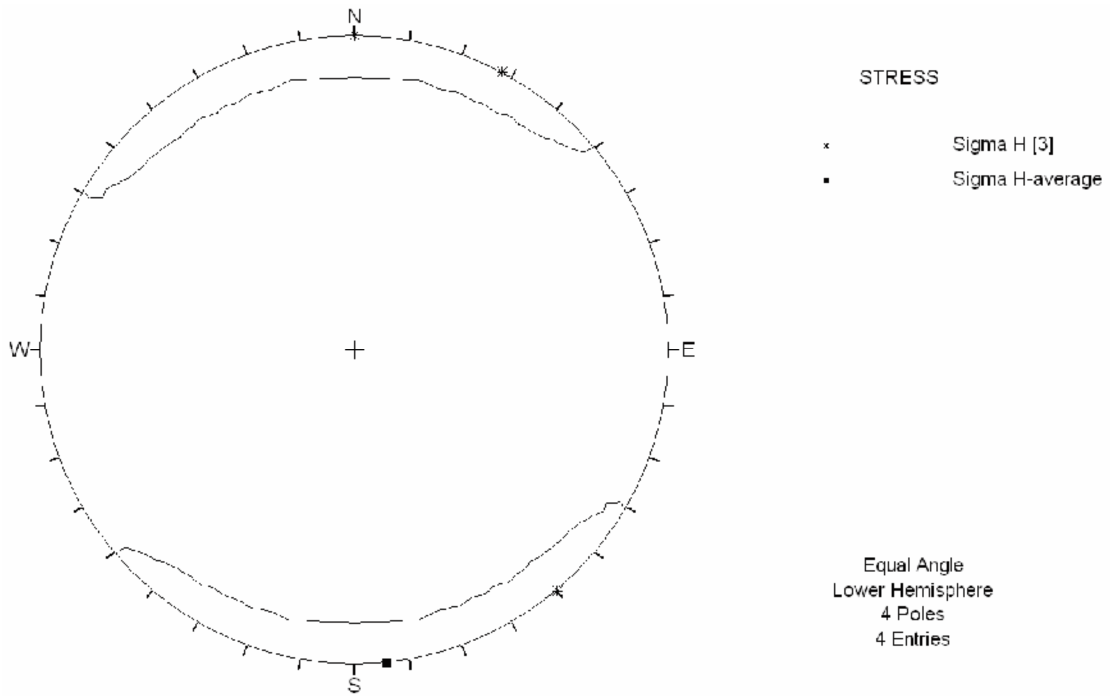


Figure H-11. *90%-confidence interval for the orientation of the maximum horizontal stress for Level 4 in borehole KFM07C, shown in a lower hemisphere projection.*

Appendix I

Quality operating procedures for overcoring measurements

The following quality operating procedures are adhered to when conducting overcoring rock stress measurements using the Borre probe. A complete description of each procedure with adjoining checklists, can be obtained (on request) from the measurement contractor.

Pre-mobilization equipment assembly and checking

- Strain gauges assembly
  - Visual check of geometry
  - Check of glued parts
  - Visual check of wires and resistance measurement
- Glue test on new batches
- Computer and software
- Packing and transport
  - Equipment
  - Consumable supplies

Mobilization

- Mobilization on site
- Drilling contractor contacts, instructions for operation, etc
- Function test of the Borre probe
- Function test of biaxial load cell and pump
- Function test of installation tool (adapter)
- Function test of computer and computer programs
- Glue test (if required by the client)
- Function test and control of drilling equipment

Overcoring stress measurement procedure

- Pilot hole drilling and examination
  - Planing and drilling of pilot hole
  - Examination of pilot core and decision on installation (or not)
  - Flushing and checking the pilot hole with dummy probe
- Preparation of the Borre-cell
  - Attaching strain gauges, including resistance check and geometry check
  - Function test of Borre probe with attached gauges
- Installation of Borre probe
  - Function test of installation tool (adapter)
  - Glue application including thickness and application check
- Overcoring
  - Check glue hardening time
  - Check that no activity is on-going in the borehole
  - Retrieval of adapter
  - Drill string in place and marked every 4 cm (0–32 cm)
  - Flushing and overcoring activities according to specification list
  - Retrieval of drill string and Borre probe

- Recovery of the Borre probe
  - Orientation of probe installation recorded
  - Data collection (transfer to computer from logger)
- Logging and photography of overcore sample
- Biaxial testing of the overcore sample
  - Test setup and programming of logger (Borre probe)
  - Biaxial testing
  - Data collection (transfer to computer from logger)
  - Logging of overcore sample after biaxial testing

Evaluation and analysis

- Plotting of overcoring and biaxial test data on computer
- Data assessment (reliability, sources of error, rating)
- Stress calculation for successful measurements; average stresses calculated for each measurement level
- Continuous reporting to client

Demobilization

- Packing and transport

Final reporting

- Complementary data assessment and rating of tests
- Final stress calculation
- Transient strain analysis on selected tests
- Calculation of final stress averages
- Final reporting to client

Appendix J

Results from uniaxial testing of pilot core samples

Table J-1. Results from unaxial compressive tests, Level 1.

Test no.	Hole length [m]	Density [kg/m³]	E-secant [GPa]	Linearly fitted data			ν-secant	Comments		
				E-ini-tang [GPa]	E-UL tang [GPa]	E-ini-50% [GPa]		E-ini-tang [GPa]	E-UL tang [GPa]	E-ini-50% [GPa]
1:1:5 A	98.85	2,639	72.2	67.3	75.0	73.1	0.23	0.19	0.23	0.27
1:1:5 B	98.90	2,643	72.9	74.8	76.2	74.1	0.21	0.18	0.22	0.28
1:1:5 C	98.96	2,638	68.5	65.6	72.2	71.4	0.20	0.17	0.22	0.28
1:1:5 average	**98.90**	**2,640**	**71.2**	**69.2**	**74.5**	**72.9**	**0.21**	**0.18**	**0.22**	**0.28**
1:1:5 stand. dev	**0.06**	**3**	**2.3**	**4.9**	**2.1**	**1.4**	**0.01**	**0.01**	**0.01**	**0.01**
1:2:4 A	104.45	2,656	70.9	67.9	74.6	74.9	0.23	0.21	0.24	0.29
1:2:4 B	104.50	2,650	74.8	76.0	77.1	77.2	0.23	0.19	0.23	0.25
1:2:4 C1	104.56	2,663	71.3	68.2	75.8	–	0.23	0.21	0.24	–
1:2:4 C2	–	–	–	–	–	77.5	–	–	–	0.27
1:2:4 average	**104.50**	**2,656**	**72.3**	**70.7**	**75.8**	**76.1**	**0.23**	**0.20**	**0.24**	**0.27**
1:2:4 stand. dev	**0.06**	**7**	**2.2**	**4.6**	**1.3**	**1.6**	**0.00**	**0.02**	**0.01**	**0.03**

Table J-2. Results from unaxial compressive tests, Level 2.

Test no.	Hole length [m]	Density [kg/m³]	E-secant [GPa]	Linearly fitted data			ν -secant	Comments		
				E-ini-tang [GPa]	E-UL tang [GPa]	E-ini-50% [GPa]		E-ini-tang [GPa]	E-UL tang [GPa]	E-ini-50% [GPa]
2:2:1 A	159.24	2,648	63.6	56.2	68.6	69.1	0.24	0.18	0.25	0.28
2:2:1 B	159.29	2,656	67.0	61.2	71.5	74.4	0.22	0.18	0.23	0.31
2:2:1 C	159.35	2,659	68.2	58.3	71.1	72.4	0.22	0.16	0.24	0.25
2:2:1 D	159.41	2,654	65.7	57.7	68.6	71.1	0.22	0.17	0.24	0.29
2:2:1 average	**159.32**	**2,654**	**66.1**	**58.4**	**70.0**	**72.0**	**0.23**	**0.17**	**0.24**	**0.28**
2:2:1 stand. dev	**0.07**	**5**	**2.0**	**2.1**	**1.6**	**2.7**	**0.01**	**0.01**	**0.01**	**0.03**
2:8:1 A	174.52	2,643	70.0	61.9	73.5	74.0	0.22	0.18	0.23	0.27
2:8:1 B	174.57	2,655	69.8	59.6	73.6	74.0	0.23	0.18	0.21	0.32
2:8:1 C	174.63	2,656	66.3	54.8	71.4	71.9	0.22	0.15	0.24	0.32
2:8:1 average	**174.57**	**2,651**	**68.7**	**58.8**	**72.8**	**73.3**	**0.22**	**0.17**	**0.23**	**0.30**
2:8:1 stand. dev	**0.06**	**7**	**2.1**	**3.6**	**1.2**	**1.2**	**0.01**	**0.02**	**0.01**	**0.03**

Table J-3. Results from unaxial compressive tests, Level 3.

Test no.	Hole length [m]	Density [kg/m³]	E-secant [GPa]	Linearly fitted data			ν -secant	Comments		
				E-ini-tang [GPa]	E-UL tang [GPa]	E-ini-50% [GPa]		E-ini-tang [GPa]	E-UL tang [GPa]	E-ini-50% [GPa]
3:4:1 A	195.23	2,646	62.9	46.8	70.8	75.3	0.19	0.12	0.22	0.33
3:4:1 B	195.28	2,659	63.2	47.8	69.3	71.8	0.19	0.12	0.22	0.28
3:4:1 D	195.34	2,663	60.3	40.7	68.3	70.4	0.19	0.09	0.23	0.27
3:4:1 average	**195.28**	**2,656**	**62.1**	**45.1**	**69.5**	**72.5**	**0.19**	**0.11**	**0.22**	**0.29**
3:4:1 stand. dev	**0.06**	**9**	**1.6**	**3.8**	**1.3**	**2.5**	**0.00**	**0.02**	**0.01**	**0.03**

Table J-4. Results from unaxial compressive tests, Level 4.

Test no.	Hole length [m]	Density [kg/m³]	E-secant [GPa]	Linearly fitted data			ν -secant	Comments		
				E-ini-tang [GPa]	E-UL tang [GPa]	E-ini-50% [GPa]		E-ini-tang [GPa]	E-UL tang [GPa]	E-ini-50% [GPa]
4:1:2 A	237.97	2,657	67.3	56.8	71.4	72.7	0.23	0.17	0.24	0.27
4:1:2 B	238.02	2,653	70.6	57.1	72.9	75.1	0.21	0.18	0.22	0.29
4:1:2 C	238.08	2,663	70.5	55.5	73.0	70.5	0.22	0.16	0.23	0.31
4:1:2 average	**238.02**	**2,658**	**69.5**	**56.5**	**72.4**	**72.8**	**0.22**	**0.17**	**0.23**	**0.29**
4:1:2 stand. dev	**0.06**	**5**	**1.9**	**0.9**	**0.9**	**2.3**	**0.01**	**0.01**	**0.01**	**0.02**
4:2:3 A	242.63	2,657	72.1	61.0	76.2	76.5	0.23	0.18	0.24	0.27
4:2:3 B	242.68	2,654	73.1	65.4	77.1	76.9	0.23	0.20	0.24	0.30
4:2:3 C	242.74	2,654	70.6	63.8	74.5	74.9	0.25	0.21	0.26	0.32
4:2:3 average	**237.97**	**2,657**	**67.3**	**56.8**	**71.4**	**72.7**	**0.23**	**0.17**	**0.24**	**0.27**
4:2:3 stand. dev	**238.02**	**2,653**	**70.6**	**57.1**	**72.9**	**75.1**	**0.21**	**0.18**	**0.22**	**0.29**

Table J-5. Results from unaxial compressive tests, Level 5.

Test no.	Hole length [m]	Density [kg/m³]	E-secant [GPa]	Linearly fitted data			ν -secant	Comments		
				E-ini-tang [GPa]	E-UL tang [GPa]	E-ini-50% [GPa]		E-ini-tang [GPa]	E-UL tang [GPa]	E-ini-50% [GPa]
5:3:4 A	316.17	2,639	71.9	60.7	74.4	74.9	0.21	0.16	0.22	0.25
5:3:4 B	316.22	2,645	68.7	59.9	74.0	75.0	0.21	0.14	0.22	0.29
5:3:4 C	316.28	2,645	70.4	62.3	74.6	74.8	0.23	0.18	0.24	0.31
5:3:4 average	**316.22**	**2,643**	**70.3**	**61.0**	**74.3**	**74.9**	**0.22**	**0.16**	**0.23**	**0.28**
5:3:4 stand. dev	**0.06**	**3**	**1.6**	**1.2**	**0.3**	**0.1**	**0.01**	**0.02**	**0.01**	**0.03**

Table J-6. Results from unaxial compressive tests, Level 6.

Test no.	Hole length [m]	Density [kg/m^3]	E-secant [GPa]	Linearly fitted data			ν -secant	Comments		
				E-ini-tang [GPa]	E-UL tang [GPa]	E-ini-50% [GPa]		E-ini-tang [GPa]	E-UL tang [GPa]	E-ini-50% [GPa]
6:2:1 A	420.30	2,640	70.5	63.5	74.6	75.8	0.24	0.21	0.24	0.27
6:2:1 B	420.35	2,650	73.5	73.1	76.2	75.4	0.24	0.23	0.25	0.32
6:2:1 C	420.41	2,650	70.0	62.1	74.0	74.4	0.22	0.18	0.24	0.31
6:2:1 average	**420.35**	**2,647**	**71.3**	**66.2**	**74.9**	**75.2**	**0.23**	**0.21**	**0.24**	**0.30**
6:2:1 stand. dev	**0.06**	**6**	**1.9**	**6.0**	**1.1**	**0.7**	**0.01**	**0.03**	**0.00**	**0.02**

Appendix K

Summary of angular variation of P-wave velocity

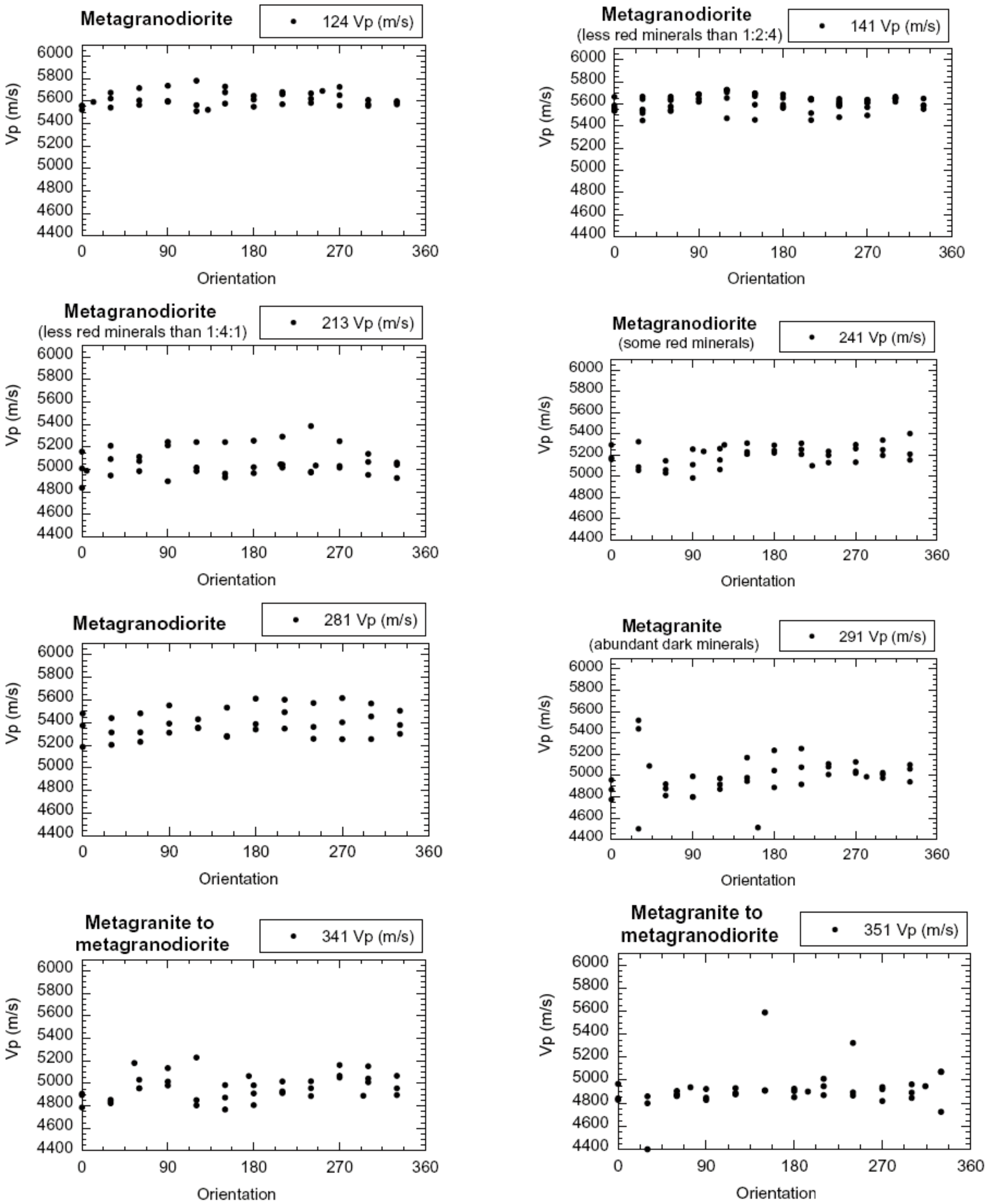


__Figure K-1.__ Plots of angular variation of P-wave velocity of each individual tests for test samples 1:2:4 to 3:5:1. The numbering in the legend in the plots are slightly different compared to the rest of the report, for example 124 is equal to test no. 1:2:4 etc. Orientation 0 = North.

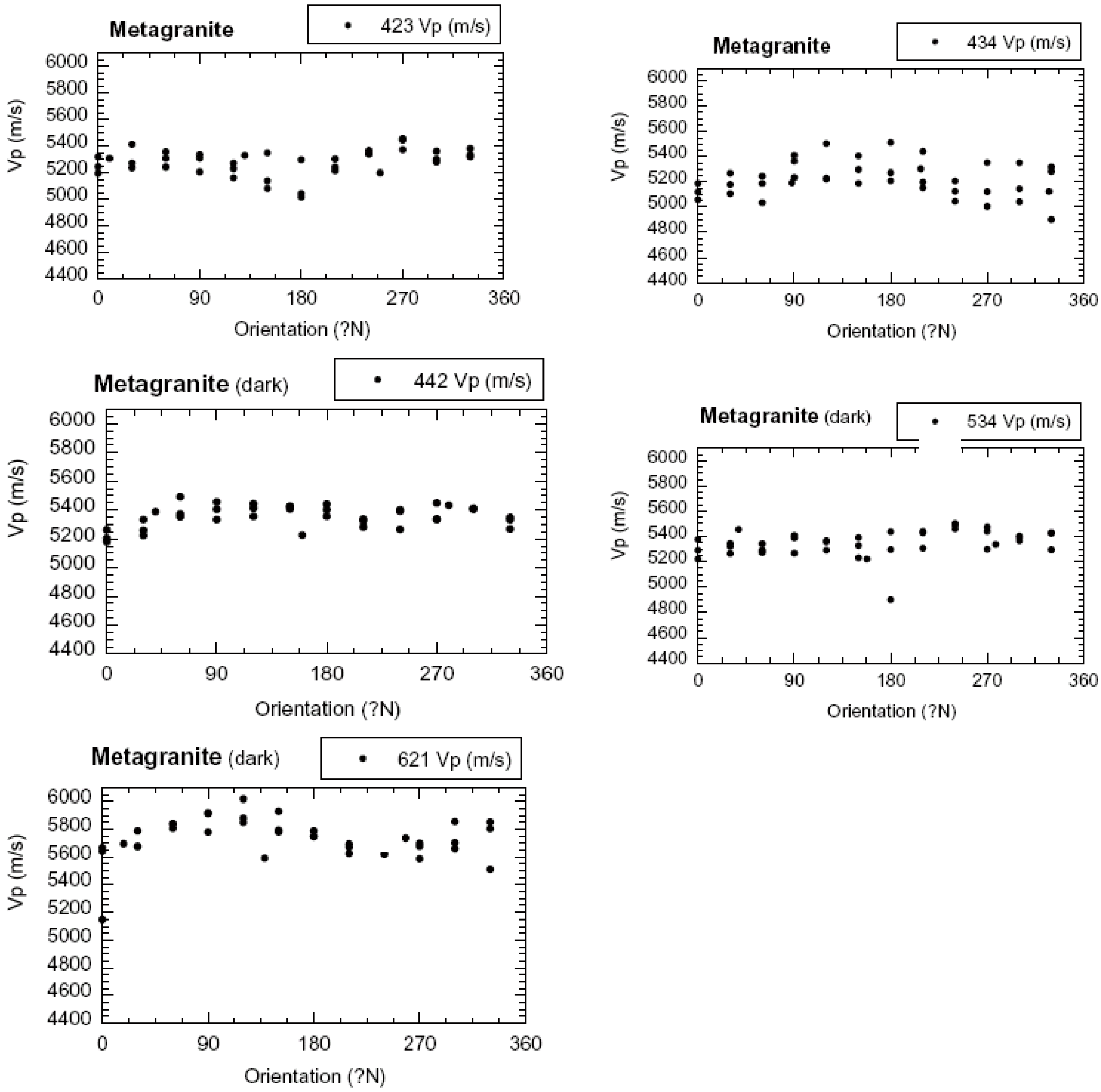


Figure K-2. *Plots of angular variation of P-wave velocity of each individual tests for test samples 4:2:3 to 6:2:1. The numbering in the legend in the plots are slightly different compared to the rest of the report, for example 423 is equal to test no. 4:2:3 etc. Orientation 0 = North.*