GEO-Meß-Systeme GmbH

MESY GmbH · Meesmannstraße 49 · D-44807 Bochum · FRG

BOREHOLE TESTING
HYDROFRACTURING
STRESS MEASUREMENTS
System Design · Planning
Lab + Field Measurements

CBM - PROJECT SIGILLARIA LICENSE AREA

CASED - HOLE PERMEABILITY AND STRESS MEASUREMENTS IN BOREHOLE RIETH - 1

FINAL REPORT

Client	:	CONOCO Mineralöl GmbH, Essen
Contract No.	:	GCBM-04-95, Variation Order No. 001 dated 09.05.1995
MeSy Quotation	:	113.05.95 dated 04.05.1995
MeSy Reporter	:	Dipl.-Geophys. G. Klee Prof. Dr. F. Rummel
Report Date	:	04.08.1995
Report No.	:	29.95

Amtsgericht Bochum 14 HRB 2572
Geschäftsführer: Prof. Dr. F. Rummel

Telefon 02 34 / 5 45 31
Telefax 02 34 / 5 45 33

Sparkasse Bochum
(BLZ 430 500 01) 43 308 618

CONTENT

APPENDIX :

SUMMARY

In borehole Rieth-1 an extensive hydraulic test program was conducted in the cased-hole section at test intervals between 1082 and 1582 m. This report summarizes the results obtained for the cased hole tests.

The test program was carried out with the MeSy wireline technique which consist of a double straddle packer tripped on a borehole logging cable.

The test program closely followed the recommendations prepared by Wilson and Hinchcliff, and can be divided into initial short injection tests, subsequent long-time injection tests (in both cases followed by pressure fall-off monitoring), and hydrofrac tests for stress evaluation. In addition MeSy conducted short-time pressure pulse tests for permeability evaluation.

The tests were carried out at 10 test locations, 7 tests on coal seams, 3 tests on the coal bearings.

The 5 pressure pulse tests conducted yield permeability values of app. 68 ± 21 µD for the coal seam sections, and app. 9 ± 8 µD for the coal bearing sections.

The hydrofrac tests carried out in the cased-hole together with the 2 successful tests in the open-hole yield a rather convincing stress profile for the depth range between 1080 and 1705 m, with the following stress / depth relations for the principal stresses:

$$S_v,\ \text{MPa} = 0.0245 \cdot \text{TVD, m}$$
$$S_h,\ \text{MPa} = 15.9 + 0.0159 \cdot (\text{TVD, m} - 1080)$$
$$S_H,\ \text{MPa} = 32.9 + 0.0343 \cdot (\text{TVD, m} - 1080)$$

The main injection tests yield for 7 test sections permeability values ranging between app. 0.02 and 0.5 mD.

1. INTRODUCTION

As part of the site investigation program for the CBM - project in the Sigillaria License area of the Ruhr - Carboniferous, hydrofrac stress and slow rate injection permeability tests were carried out in borehole Rieth-1, both, in the open-hole section between 1694 m and 1705 m depth and in the cased-hole section between app. 1082 m and 1582 m. The results of the open-hole tests are given in the MeSy report "OPEN-HOLE PERMEABILITY AND HYDROFRAC STRESS MEASUREMENTS IN BOREHOLE RIETH-1", MeSy Report No. 27.95.

The present report describes the results of the tests carried out in the cased hole section, after a casing of 4.8 inches diameter (ID) was cemented to a depth of 1621 m. After perforation, 10 hydraulic injection tests were conducted to determine the in-situ stress profile in the borehole and to measure the permeability of coal seam sections as well as of the coal bearing carboniferous rock. The tests may be divided into injection tests for stress determination and injection / pressure fall-off test for permeability determination.

The tests were carried out during two test phases:

phase I : 25.5 - 4.6.95 (Operation Report dated 7.6.95, App. A)
perforation intervals : 1568.7 - 1571.3 m
1436.9 - 1439.9 m
1579.5 - 1582.0 m
1480.0 - 1483.0 m
1400.0 - 1401.0 m

phase II : 12.6. - 16.6.95 (Operation Report dated 19.6.95 App. A)
perforation intervals : 1591.0 - 1592.0 m
1559.5 - 1560.5 m
1274.5 - 1275.5 m
1247.0 - 1249.8 m
1082.5 - 1085.0 m

In the following, the report describes the test equipment used, the test procedures with reference to the "CASED-HOLE INJECTION PROCEDURE" prepared by P.

Wilson and R. Hinchcliff (19.5.95), and the test results obtained. The final discussion compares the results with previous data.

2. BOREHOLE DATA

Borehole Rieth-1 is located about 22 km south of Münster, app. 4 km south-west of the town of Drensteinfurt. The geographical coordinates are :

N 51.772°, E 7.707°.

The borehole was rotary drilled with an open-hole diameter of 8.5" (216 mm) to a depth of 1737 m. During the open-hole testing the bottom part of the borehole was lost. Subsequently, the borehole was cased with 5.5." OD / 4.8" ID casing and cemented to a depth of 1621 m.

During several stages the cemented casing was perforated by Western Atlas at the following intervals (e.g. see Operation Reports) :

- 1082.4 - 1084.9 m, coal seam
- 1247.0 - 1249.8 m, coal seam
- 1274.5 - 1275.5 m, coal bearings (sandstone)
- 1400.0 - 1401.0 m, coal seam
- 1436.9 - 1439.9 m, coal seam
- 1480.0 - 1483.0 m, coal seam
- 1559.5 - 1560.5 m, coal bearings (shale)
- 1568.7 - 1571.3 m, coal seam
- 1579.5 - 1582.0 m, coal seam
- 1591.0 - 1592.0 m, coal bearings (sandstone).

3. TEST EQUIPMENT

The cased-hole tests were carried out by the MeSy wireline technique where the double straddle packer system is moved in the borehole on a 7-conductor logging cable by a winch system. During the test period the following winch systems were used:

- the MeSy wireline system MKW 5000 during phase I (25.5. - 4.6.95)
- the Western Atlas winch during phase II a (12.6. - 15.6.95)
- the MeSy winch system MKW 1500 during phase II b (15.6. - 16.6.95).

The double straddle packer tool used was the Mesy PERFRAC II system equipped with nylon re-inforced inflatable rubber packer elements type SK-TK 88-V with a diameter of 115 mm and an effective sealing length of app. 1 m. The length of the testing interval between the two packers was app. 8.7 m.

Packers and the injection interval were pressurized via two separate hydraulic stainless steel coil tubing pressure lines (10 mm OD, 8 mm ID for interval pressurization; 6.35 mm OD, 4.5 mm ID for packer pressurization). Both tubings were fixed to the logging cable by the MeSy aluminum clamps in 50 m intervals.

For pressurization the following pumps were used:

- Air-pressure-driven MAXIMATOR type GW 100 for packer pressurization.
- Electric-driven servo three-plunger pump SPECK type HP 400/2-12 for interval pressurization with a capacity of 40 MPa / 0.17 - 12 lpm. The injection fluid was KCL-brine with a density of app. 1.05 g/cm^3.

The transducer unit on top of the packer assembly contained the following transducers:

- a temperature transducer (0-211 °C)
- strain-gauge type pressure transducer for interval pressure monitoring (KELLER, type PA-21, 0 - 40 MPa).

On surface the following transducers were used:

- strain-gauge type pressure transducer (KELLER, type PA-23, 0 -100 MPa) for packer pressure
- flow-rate monitoring transducer in the injection line (UNIMESS, type QPT 04, 1.2 - 10 lpm)
- flow-rates smaller than 1.2 lpm was measured by a special plastic tube device.

Uphole and downhole data were recorded both, analogue on a paper strip-chart recorder (PHILIPS, type PM 8262, 2 channels) and digitally with the MeSy -SILVI system (8 channels, 16 bit, sampling rate 1 and 5 Hz).

4. TEST PROGRAM AND TEST PROCEDURE

The test program is summarized in Table 4.1. Further details can be taken from the operation reports (APPENDIX A) or from the overview plots (APPENDIX B and C). According to the test procedure used the test program may be divided into the following phases:

phase	test no.	perforated test interval	lithology
		m	
I a	1	1568.7 - 1571.3	coal
	2	1436.9 - 1439.9	coal
I b	3	1579.5 - 1582.0	coal
	4	1480.0 - 1483.0	coal
	5	1400.0 - 1401.0	coal
II a	6	1591.0 - 1592.0	coal bearings
	9	1559.5 - 1560.5	coal bearings
	7	1274.5 - 1275.5	coal bearings
	8	1247.0 - 1249.8	coal
II b	10	1082.4 - 1084.9	coal

Test procedures during phase I a closely followed the recommendations "CASED-HOLE INJECTION PROCEDURE FOR RIETH-1" prepared by Wilson and Hinchcliff (19.5.95), i.e.:

- initial injection / pressure fall-off test (injection rate app. 0.17 lpm)
- main injection / pressure fall-off test (injection rate app. 0.17 lpm)
- frac test / pressure step-rate test (injection rate of some lpm).

Phase I b tests were conducted similar as in phase I a but without the initial injection / pressure fall-off test. Due to packer leakage during the start of the frac tests, test no. 3 at the interval 1579.5 - 1580.0 m could not be completed. It was planned to repeat the test during phase II a (but was never carried out).

During phase II a only frac tests for stress measurements were conducted, which consisted of the initial breakdown (frac) test cycle and several subsequent refrac test cycles as well as step-rate pressure tests. Prior to each frac cycle a pressure pulse test was carried out to determine the in-situ rock permeability of test section. At the test interval at 1247 m (test no. 8), the frac test cycles were followed by a main injection / pressure fall-off test.

Phase II b only consisted of testing one test interval, test no. 10 at 1083.7 m. The stress test cycles also were followed by a main injection / pressure fall-off test similar as in the test no. 8 at 1247 m depth.

Table 4.1 : Test Procedure

test no.	start date	test interval	test sequence	test duration	injected volume
		m		min	liters
1	25.05.	1568.7 - 1571.3	ii	10	1.7
			pfo	60	
			mi	2330	416.7
			pfo	2813	
			f	134	
2	29.05	1436.9 - 1439.9	ii	15	2.5
			pfo	60	
			mi	1112	190.1
			pfo	1125	
			f	167	
3	01.06.	1579.5 - 1582.0	pfo	476	
			mi	215	35.7
			f	95	
4	02.06.	1480.0 - 1483.6	mi	450	74.3
			pfo	607	
			f	89	
5	03.06.	1400.0 - 1401.0	mi	638	110.1
			pfo	712	
			f	128	
6	13.06.	1591.0 - 1592.0	f	90	
7	14.06.	1274.5 - 1275.6	f	66	
8	14.06.	1247.0 - 1249.8	f	89	
			mi	123	21.5
			pfo	177	
9	15.06.	1559.5 - 1560.5	f	73	
10	16.06.	1082.4 - 1084.9	f	291	
			mi	167	28.4
			pfo	223	

ii : initial injection

f : frac and refrac tests

pfo : pressure fall-off test

mi : main injection test

5. TEST ANALYSIS AND RESULTS

Overview plots of all injection / pressure fall-off tests are given in APPENDIX B, overview plots of the injection (frac) tests for stress analysis are given in APPENDIX C. The data analysis was conducted on the basis of detailed plots given in APPENDIX D for permeability analysis and in APPENDIX E for stress analysis.

5.1 ANALYSIS OF PRESSURE PULSE TESTS FOR PERMEABILITY EVALUATION

The in-situ rock permeability can be derived from slug tests by the classical method suggested by COOPER et al. (1967). The pressure decline following a sudden pressure increase (pressure pulse) can be treated by the same method. For the specific testing with the MeSy wireline system, MeSy has developed the software code PERM where the measured pressure decline curves are matched with theoretical curves (master curve method) by an inversion procedure for a variety of input parameters such as system stiffness, storage coefficient and rock permeability. The result of calculations is shown as the mean of successful models which satisfy the L^1-standard.

The permeability / transmissivity data derived from the pressure pulse tests (APPENDIX D) are summarized in Table 5.1. The tests on the coal seam sections at 1248.4 m (test no. 8) and at 1083.7 m (test no. 10) yield a permeability of 89 and 47 µD, in comparison to 120 µD and 29 µD derived from the injection / fall-off tests.

The mean permeability of the coal bearing sections ranges between 3 µD and 18 µD.

Tab. 5.1 : Results of pressure pulse tests for permeability / transmissivity estimation

test no.	mean interval depth	depth below surface TVD	permeability	transmissivity	lithology
	m	m	µD	cm^2/s	
10	1083.7	1080.5	47	0.07	coal seam
8	1248.4	1245.2	89	0.15	coal seam
7	1275.0	1271.8	3	0.04	coal bearings
9	1560.0	1556.8	18	0.21	coal bearings
6	1591.5	1588.3	6	0.07	coal bearings

5.2 MAIN INJECTION / PRESSURE FALL - OFF - TESTS

The main injection / pressure fall-off test were evaluated by Conoco. Therefore, MeSy here only supplies the corresponding overview plots (APPENDIX C). Conoco's first analysis yields permeability values for the coal seam test sections ranging between 0.02 and 0.5 mD. The data are presented in Table 5.2.

Table 5.2 : Permeability data for coal seam sections

test no.	mean interval depth	permeability	lithology
	m	mD	
10	1083.7	0.029	coal seam
8	1248.4	0.12	"
5	1400.5	0.07	"
2	1438.4	0.02	"
4	1481.5	0.09	"
1	1570.0	0.5	"
3	1580.7	0.4	"

5.3 HYDROFRAC STRESS TEST ANALYSIS AND RESULTS

Since fracture orientations could not be determined in the cased-hole, the analysis of the hydrofrac tests had to be conducted on the basis of the classical HUBBERT & WILLIS (1957) method with the following assumptions:

- the overburden stress $S_v = \rho g z$ is a principal stress; borehole deviations from vertical can be neglected;
- the rock is homogeneous and isotropic;
- the fracturing fluid does not penetrate into the rock prior to the fracture initiation;
- the induced fracture is vertical and propagates normal to the minimum horizontal stress S_h.

The HUBBERT & WILLIS method then suggests the following simple relations :

$$P_c = 3 S_h - S_H + P_{co} - P_o \quad (5.1)$$

$$P_{si} = S_h \quad (5.2)$$

$$P_{co} = P_c - P_r \quad (5.3)$$

with

P_c breakdown pressure at frac initiation
P_r fracture re-opening pressure
P_{si} shut-in pressure to merely keep the fracture open against S_h
P_o formation pore pressure
P_{co} in-situ hydrofrac tensile strength
S_h minor principal horizontal stress
S_H major principal horizontal stress

Since most of the assumptions are not valid (isotropy, homogeneity, rock impermeability) the stress analysis requires most accurate pressure data for interpretation. Therefore, an extensive pressure analysis program was carried out for the identification of characteristic hydrofrac pressure values (see APPENDIX E):

- The determination of the break-down pressure Pc was not relevant since breakdown events were not observed during the cased-hole tests.

- The determination of the refrac-pressures P_r considers the system stiffness (during the initial pumping cycle). Assuming a constant system stiffness, initially the pressure P linearly increases with the injection fluid volume V. Therefore, a deviation from the linear P vs V plot indicates the opening of a fracture.

- The shut-in pressure P_{si} is determined by a three step analysis of the pressure plots:

  - from a pressure P vs flow-rate Q plot where the moment at which hydraulic flow stops (Q = 0) an upper bound of P_{si} can be derived;
  - from a Muskat-plot a lower bound of P_{si} can be derived, assuming that the linear part of the plot characterizes radial flow, i.e. the stimulated fracture is nearly closed;
  - within the two limits, the P_{si}-value marks the transition from a rapid linear pressure drop to a diffusion dominated pressure decrease; the transition can be determinated by the tangent method (inflection point method).

In some of the tests (particularly tests on coal seams) the determination of P_{si} only could be derived from P vs Q diagrams. The change of slope in such diagrams characterizes the P_{si}-value. It is interesting to mention that test no. 8 (at 1248.4 m) and test no. 4 (at 1481.5 m) yielded clear P_{si}-values independent on the evaluation method.

The characteristic pressure values P_r and P_{si} are given in Table 5.3 and are graphically shown in Figure 5.1 and 5.2, together with the open-hole results at 1694 and 1705 m.

Neglecting the formation pore - pressure P_o the principal horizontal stresses S_h and S_H according to equations 5.1 to 5.3 are listed in Table 5.3. The stress gradients (with respect to depth) and the stress ratios (with respect to S_v) are given in Table 5.4. The principal stress profiles derived are shown in Figure 5.3. Averaging the stress data valid for the depth range 1084 to 1705 the following stress profiles can be suggested:

$$S_v,\ \text{MPa} = 0.0245 \cdot \text{TVD, m}$$
$$S_h,\ \text{MPa} = 15.9 + 0.0159 \cdot (\text{TVD, m} - 1080)$$
$$S_H,\ \text{MPa} = 32.9 + 0.0343 \cdot (\text{TVD, m} - 1080)$$

Table 5.3 : Refrac-pressure P_r and Shut-in pressure P_{si} derived from cased-hole tests in borehole Rieth-1

test no.	depth	depth below surface TVD	P_r	P_{si}	P_{si} -estimation method
	m	m	MPa	MPa	
10	1083.7	1080.5	---	15.9	P - Q analysis
8	1248.4	1245.2	---	17.7	P - Q analysis
				17.74	inflection point
7	1275.0	1271.8	18.75	19.50	inflection point
5	1400.5	1397.3	---	20.95	P - Q analysis
2	1438.4	1435.2	---	23.5	P - Q analysis
4	1481.5	1478.3	---	21.4	P - Q analysis
				21.45	inflection point
9	1560.0	1556.8	20.25 - 21.75	23.13	inflection point
1	1570.0	1566.8	---	21.7	P - Q analysis
3	1580.7	1577.5	---	23.7	P - Q analysis
6	1591.5	1588.3	21.0 - 22.0	23.89	inflection point

Table 5.4 : Result of stress evaluation using the HUBBERT and WIILIS approach

test no.	depth	depth below surface TVD	S_v $\rho = 2.5$ g/cm^3	S_h	S_H
	m	m	MPa	MPa	MPa
10	1083.7	1080.5	26.50	15.9	---
8	1248.4	1245.2	30.54	17.74	---
7	1275.0	1271.8	31.19	19.50	39.75
5	1400.5	1397.3	34.27	20.95	---
2	1438.4	1435.2	35.20	23.5	---
4	1481.5	1478.3	36.26	21.45	---
9	1560.0	1556.8	38.18	23.13	47.64 - 49.14
1	1570.0	1566.8	38.43	21.7	---
3	1580.7	1577.5	38.69	23.7	---
6	1591.5	1588.3	38.95	23.89	49.67 - 50.67
openhole	1694.0	1690.8	41.47	26.75	53.99
tests	1705.0	1701.8	41.74	25.71	54.71

Table 5.5 : Stress gradients and stress ratios

depth	depth below surface TVD	S_h / TVD	S_H / TVD	S_h / S_v	S_H / S_v
m	m	MPa / m	MPa / m		
1083.7	1080.7	0.0147	---	0.60	---
1248.4	1245.2	0.0142	---	0.58	---
1275.0	1271.8	0.0153	0.0313	0.63	1.27
1400.5	1397.3	0.0150	---	0.61	---
1438.7	1435.2	0.0164	---	0.67	---
1481.5	1478.3	0.0145	---	0.59	---
1560.0	1556.8	0.0149	0.0311	0.61	1.27
1570.0	1566.8	0.0138	---	0.56	--
1580.7	1577.5	0.0150	---	0.61	---
1591.5	1588.3	0.0150	0.0316	0.61	1.29
1694.0	1690.8	0.0158	0.0319	0.65	1.30
1705.0	1701.8	0.0151	0.0321	0.62	1.31
mean		0.0150	0.0316	0.61	1.29

Fig. 5.1 : Refrac-Pressure P_r as a function of depth in borehole Rieth-1

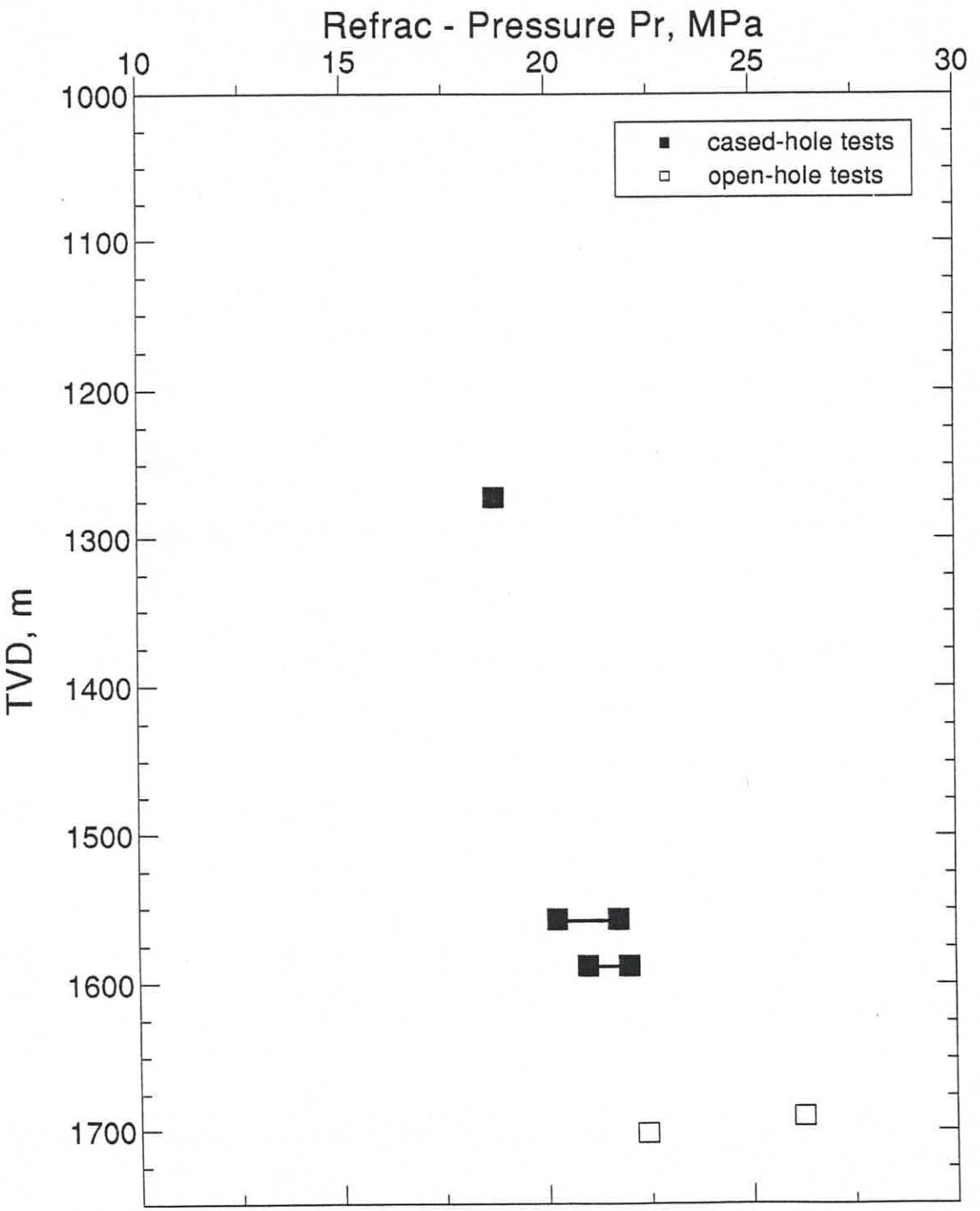


Fig. 5.2 : Shut-in pressure P_{si} as a function of depth in borehole Rieth-1

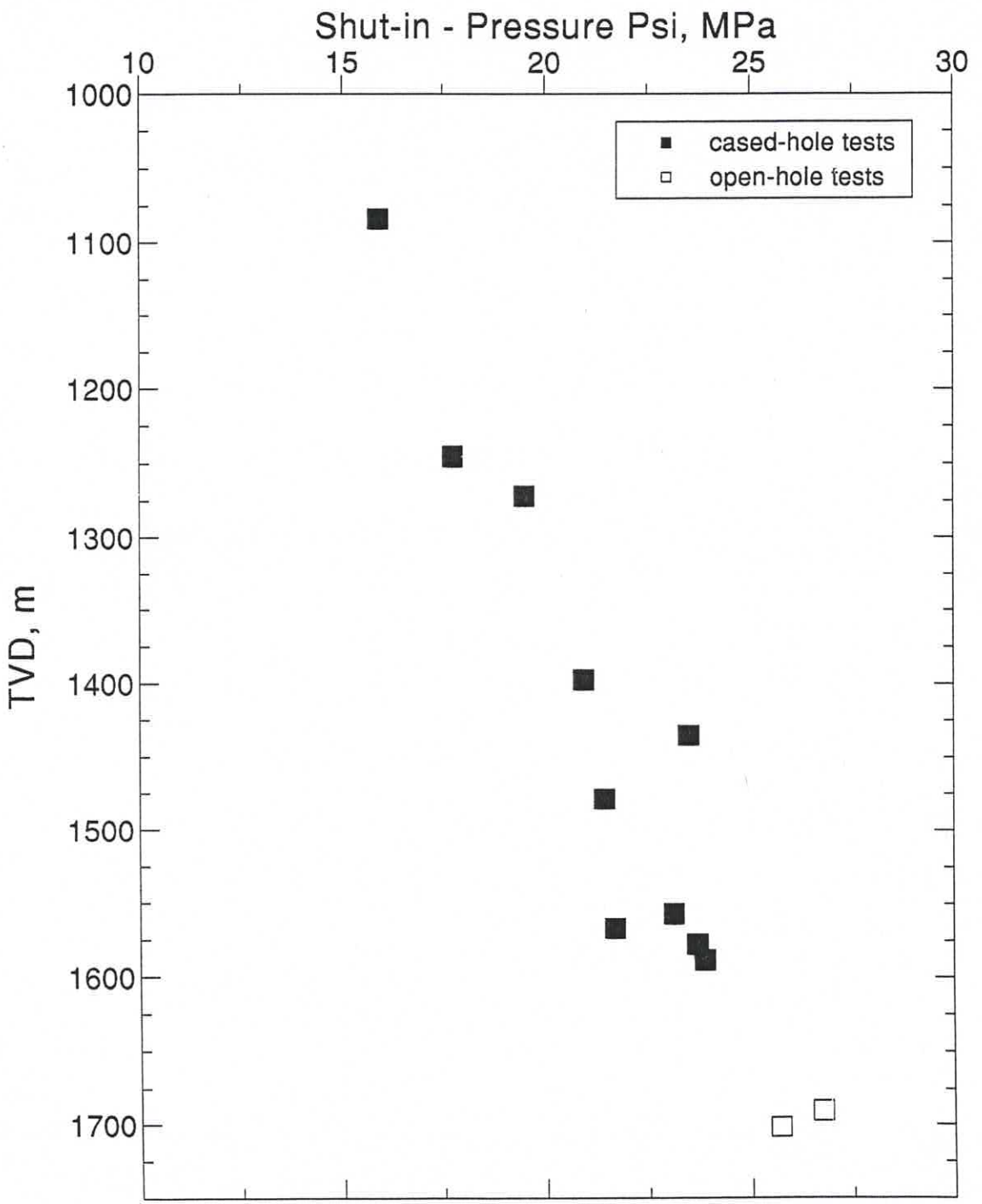
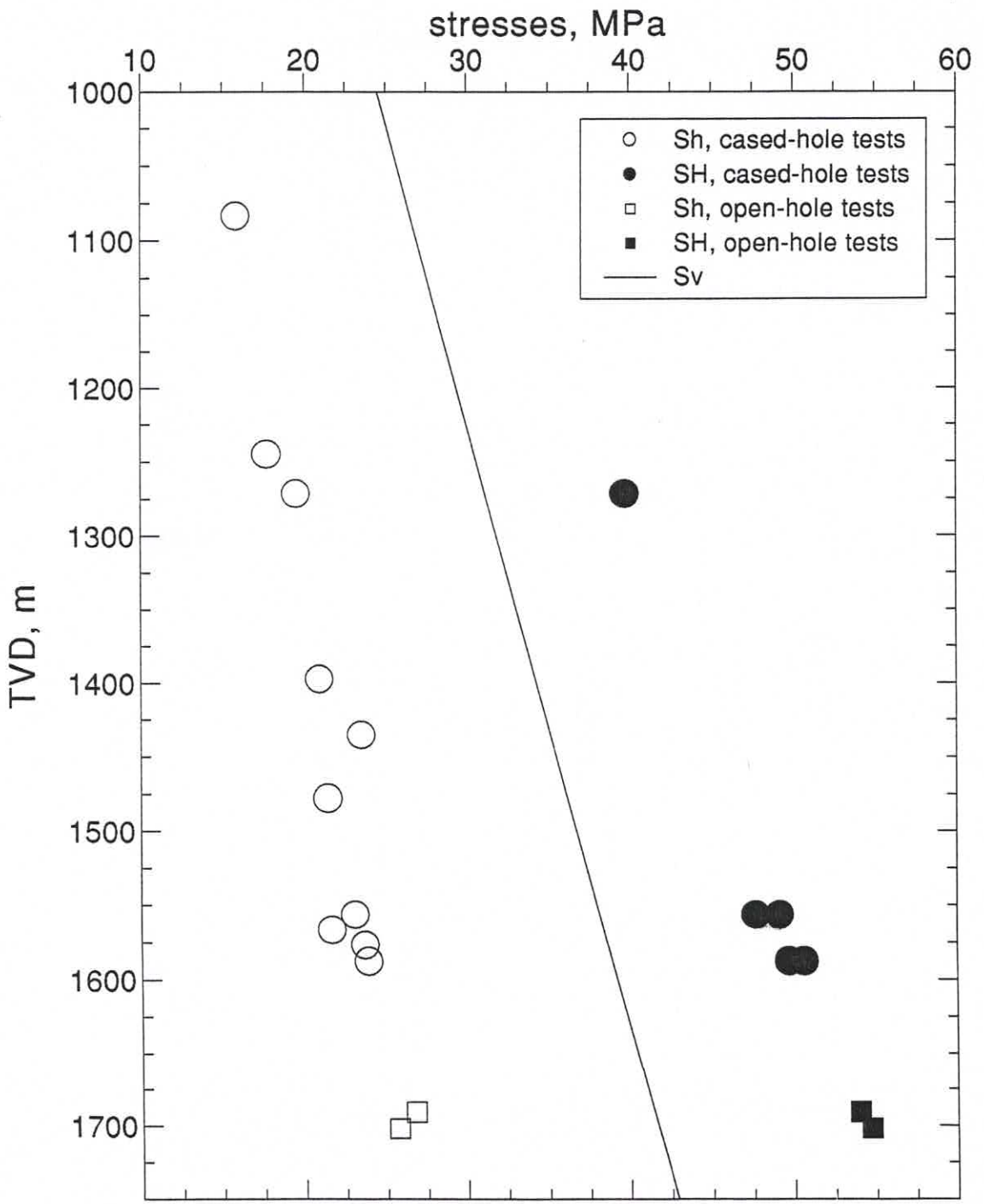


Fig. 5.3 : Principle stresses derived from open-hole and cased-hole hydrofrac stress measurements



6. DISCUSSION OF RESULTS

6.1 PERMEABILITY / TRANSMISSIVITY

The permeability data given in Table 5.1 for the rock bearings correspond to data derived earlier from underground measurements in the Ruhr Carboniferous. Permeability data for the coal seams tested yield new valuable values to be considered for CBM potential evaluation.

6.2 STRESS DATA

Cased-hole hydrofrac tests have to rely on the HUBBERT and WILLIS concept (see section 5.3). The pressure data were derived by detailed procedures. The shut-in pressure data yield a clear linear depth relationship with some deviations (e.g. at 1438.5 m)

This linear pressure vs depth relations suggest horizontal principal stress vs depth profiles (see Fig. 5.3). The results are in good agreement with stress profiles measured in boreholes drilled to a depth of app. 2 km for numerous European locations as shown in Figures 6.1 and 6.2. A similar relationship was already given in the MeSy Report No. 28.94, December 1994, based on extensive stress testing in the Ruhr coal mines during 1980 to 1994.

Fig. 6.1 : Minimum horizontal stress S_h normalized with respect to $S_v = \rho g z$ for Central Europe including stress data for numerous shallow tests from geotechnical projects and deeper tests in Ruhr coal mines

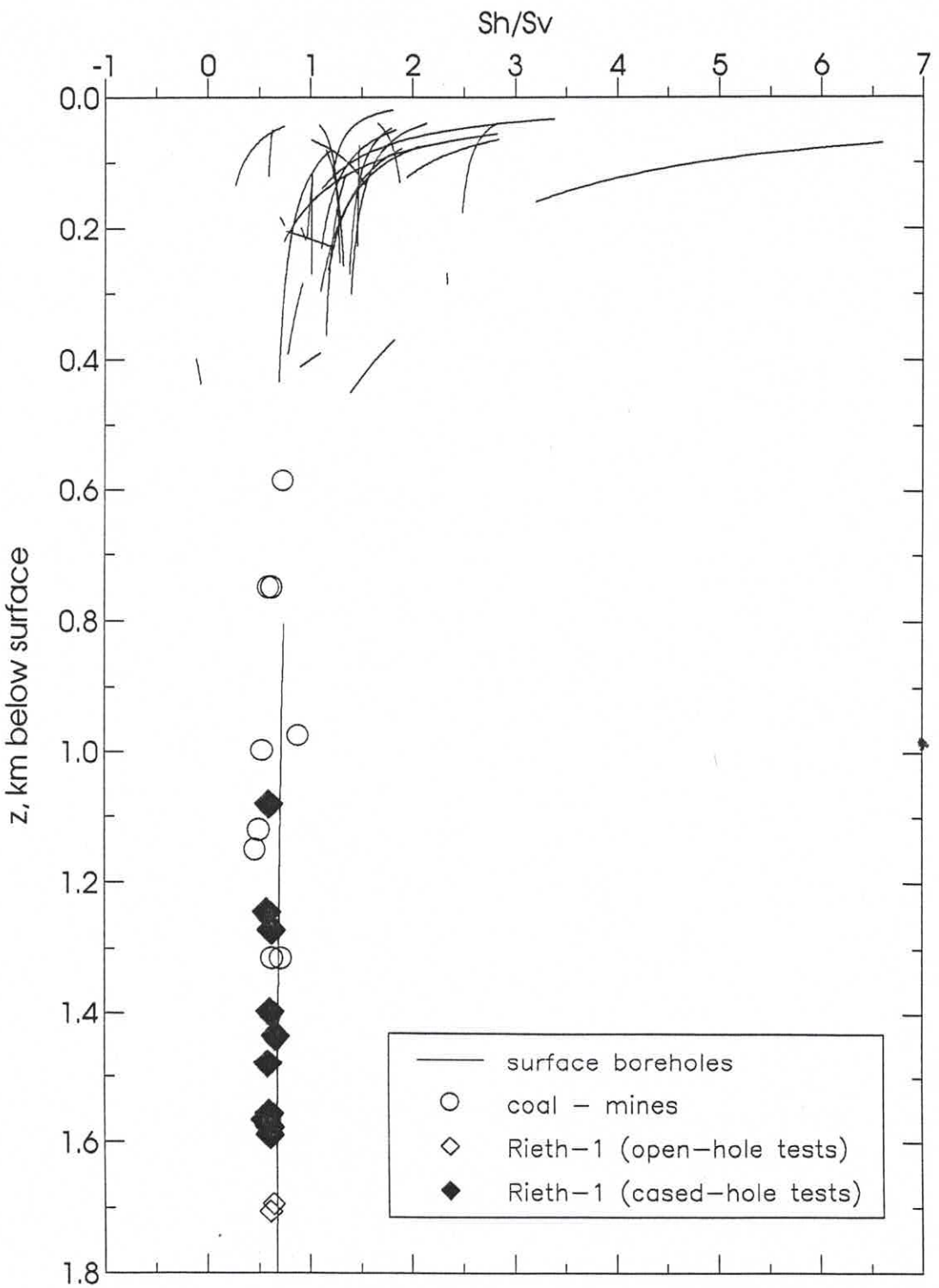
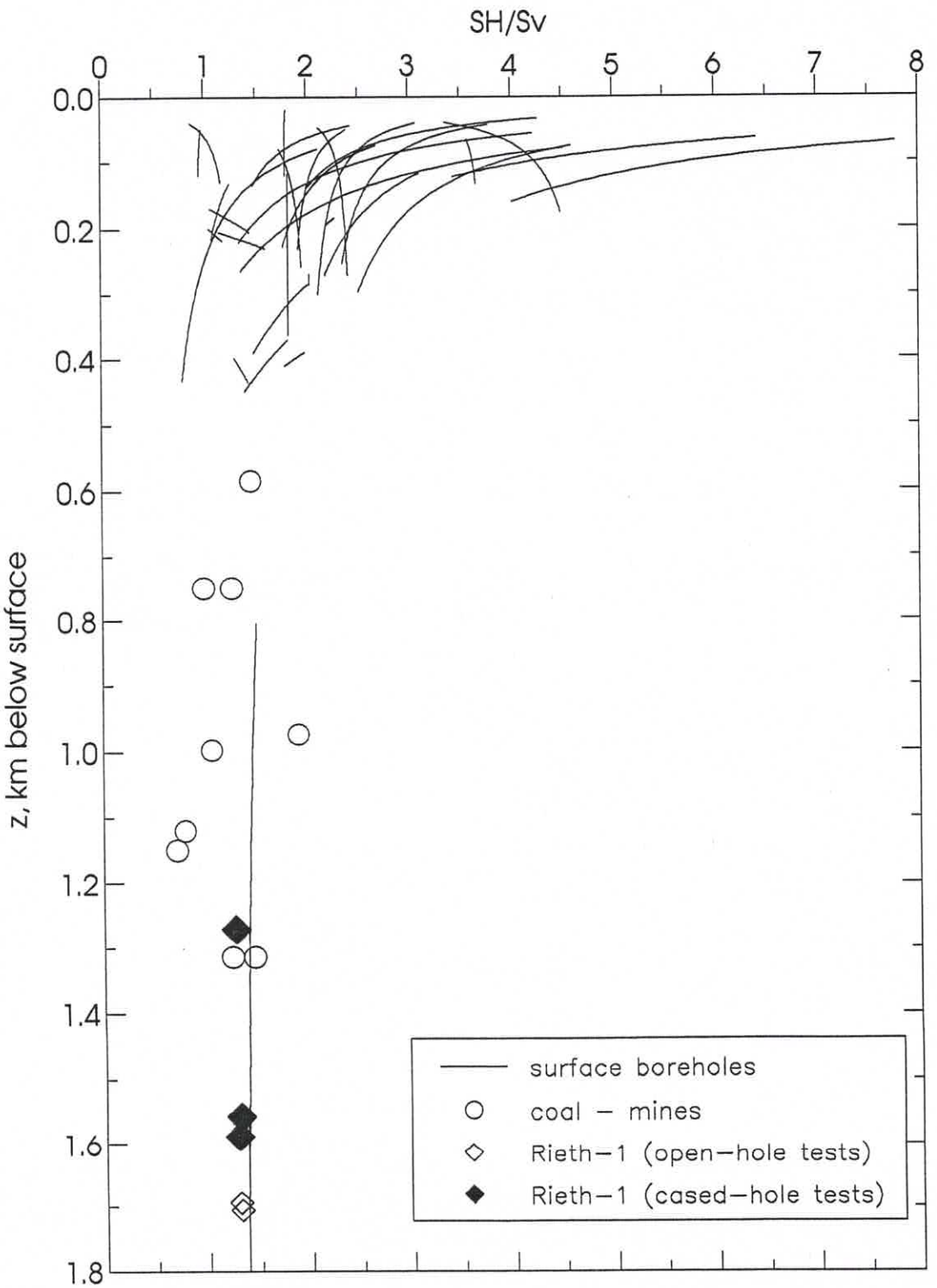


Fig. 6.2 : Maximum horizontal stress SH normalized to Sv as a function of depth (see test in Fig. 6.1)



7. REFERENCES

COOPER, H.H., J.D. BREDEHOEFT and I.S. PAPADOPULUS (1967) : Response of a Finite Diameter Well to an Instantaneous Charge of Water. Water Resource Research, Vol. 3, pp. 263 - 269.

HUBBERT, M.K. and D.K. WILLIS (1957) : Mechanics of Hydraulic Fracturing. Trans AIME, Vol. 210, pp. 153 - 163.

HYDROFRAC STRESS DATA BASE (1994). Institute of Geophysics, Ruhr-University Bochum.

MESY - REPORT (1994) : Compilation of existing hydrofrac in-situ stress data for the Ruhr - Carboniferous. Report - No. 28.94, 09.12.94.

MESY - REPORT (1995) : Open-hole permeability and hydrofrac stress measurements in borehole Rieth-1. Report No. 27.95, 11.7.95

WILSON, P. and R. HINCHCLIFF (1995) : Cased-hole injection procedure, borehole Rieth-1, 19.5.95 (internal Conoco Report)

8. ACKNOWLEDGEMENT

MeSy is grateful for the Conoco contract to carry out the cased-hole tests in borehole Rieth - 1. MeSy is especially grateful to Conoco for the permanent trust in MeSy's technology. We are grateful to Mr. K. Thomas, Mr. St. Strauss, Mr. P. Wilson as well as to Mr. V. Hartong and Mr. L. van Zanten, both for information and infra-structure as well as for help during in-situ testing.

We are grateful to Western Atlas to provide winch service when the MeSy winch was not available.

The MeSy in-situ tests were conducted by P. Hegemann, Th. Hettkamp, G. Klee, J. Kramer, Th. Przybilla, H. Vogt and U. Weber during 24 hours working days. The data analysis was conducted by G. Klee.

APPENDIX A

Operation Reports
dated 07.06.95 and 19.06.95

GEO-Meß-Systeme GmbH

MESY GmbH · Meesmannstraße 49 · D-44807 Bochum · FRG

BOREHOLE TESTING
HYDROFRACTURING
STRESS MEASUREMENTS
System Design · Planning
Lab + Field Measurements

CBM - Project Sigillaria License Area

CASED - HOLE PERMEABILITY AND STRESS MEASUREMENTS IN BOREHOLE RIETH-1

Operation Report

Client:	CONOCO Mineralöl GmbH, Essen
Contract:	GCBM-04-95, Variation Order No. 001 dated 09.05.1995
MeSy-Quotation:	113.05.95 dated 04.05.1995
MeSy-Reporter:	Dipl.-Geophys. G.Klee
Date:	07.06.1995

Amtsgericht Bochum 14 HRB 2572
Geschäftsführer: Prof. Dr. E. Rummel
Telefon 02 34 / 5 45 31
Telefax 02 34 / 5 46 32
Sparkasse Bochum
(BLZ 430 500 01) 12 208 618

Project:	CBM project Sigillaria License Area
Location:	about 4 km SW of Drensteinfurt, NRW, Germany
Borehole:	Rieth-1
Purpose:	cased-hole permeability and stress measurements
Test-Period:	25.05. - 04.06.1995
Participants:	Mr. K. Thomas (Conoco Essen) Mr. S. Strauss (Conoco Houston) Dipl. Ing. P.Hegemann (MeSy) cand. geophys. T.Hettkamp (MeSy) Dipl. Geophys. G. Klee (MeSy) Dipl. Geophys. T. Przybilla (MeSy) Dipl. Ing. H.Vogt (MeSy) Dipl. Geophys. U.Weber (MeSy)

TIME TABLE OF TESTING

date	time	event
24.05.95	14.00-17.00	discussion at well-site (L. van Zanten, T.Schwarz, P.Hegemann)
25.05.95	08.00/09.30	arrival of P.Hegemann, T.Przybilla, H.Vogt
	09.30-10.30	movement of winch-container
	10.30-15.00	set-up of surface and downhole equipment
	15.00-16.25	tool at wellhead, set zero-mark at middle of injection interval, venting of the hydraulic system
	16.25	start tripping into hole
	16.30-16.50	test of tool at 20 m [1] *file: 0020CH01.DAT*
	20.45	tool at 1570.0 m
	20.53	**START OF CASED - HOLE TEST 1 AT 1570.0 m**
	20.53	start data recording *file: 1570CH01.DAT*
	20.54-21.00	set packers to 10 MPa surface pressure
	21.15-21.25	injection-rate calibration
	21.25	**start initial injection-test**

[1] all depth marks were measured from rig-floor and corresponds to the middle of the 8.7 m long test-interval

date	time	event
25.05.95	**21.35**	**end of initial injection**
		total injected volume: 1.7 l
		injection duration: 10 min
		mean injection-rate: 0.17 l/min
	21.35	**start initial fall-off test**
	22.35	**end of initial fall-off test**, end of data recording
		fall-off duration: 60 min
	22.40-23.05	problems to start data-acquisition with a sample-frequency of 30 sec *(loss of file 1570CH02.DAT)*
	23.08	start data recording *file: 1570CH03.DAT*
	23.10	**start main injection-test**
26.05.95	01.00	departure of P.Hegemann and H.Vogt
	03.31	fill of stand-pipe (47.1 l)
	08.57	fill of stand-pipe (46.6 l)
	11.45	end of data recording
	12.08	start data recording *file: 1570CH04.DAT*
	12.15	arrival of P.Hegemann
	12.40	fill of stand-pipe (50.4 l)
	12.45	departure of T.Przybilla
	17.21	fill of stand-pipe (50.1 l)
	18.12	reset packers from 6.5 to 7.5 MPa surface pressure
	22.05	fill of stand-pipe (50.2 l)
	23.44	end of data recording
	23.45	arrival of H.Vogt
	23.50	start data recording *file: 1570CH05.DAT*
27.05.95	00.45	departure of P.Hegemann
	02.41	fill of stand-pipe (50.1 l)
	06.07	reset packers from 5.5 to 6.0 MPa surface pressure
	07.24	fill of stand-pipe (50.3 l)
	10.34	reset packers from 5.5 to 6.1 MPa surface pressure
	11.10	end of data recording
	11.18	start data recording *file: 1570CH06.DAT*
	11.39	fill of stand-pipe (45.3 l)
	12.10	arrival of T.Przybilla
	12.25	departure of H.Vogt
	14.00	reset packers from 5.5 to 6.6 MPa surface pressure

date	time	event
27.05.95	**14.10**	**end of main injection**
		total injected volume: 416.7 l
		injection duration: 2330 min
		mean injection-rate: 0.179 l/min
	14.10	**start main fall-off test**
	18.04	reset packers from 5.5 to 6.2 MPa surface pressure
	19.14	end of data recording
	19.17	start data recording *file: 1570CH07.DAT*
	20.56	reset packers from 5.3 to 6.2 MPa surface pressure
28.05.95	00.07	reset packers from 5.2 to 6.0 MPa surface pressure
	02.37	reset packers from 5.1 to 6.1 MPa surface pressure
	05.12	reset packers from 5.2 to 6.2 MPa surface pressure
	06.40	end of data recording
	06.44	start data recording *file: 1570CH08.DAT*
	06.55	arrival of H.Vogt
	07.20	departure of T.Przybilla
	07.55	reset packers from 5.4 to 6.3 MPa surface pressure
	11.30	reset packers from 5.4 to 6.2 MPa surface pressure
	14.28	reset packers from 5.2 to 6.1 MPa surface pressure
	15.59	reset packers from 5.4 to 6.3 MPa surface pressure
	18.30	reset packers from 5.4 to 6.3 MPa surface pressure
	18.33	end data recording
	18.40	start data recording *file: 1570CH09.DAT*
	20.45	reset packers from 5.4 to 6.2 MPa surface pressure
	23.00	reset packers from 5.3 to 6.2 MPa surface pressure
29.05.95	01.40	reset packers from 5.3 to 6.2 MPa surface pressure
	03.55	reset packers from 5.4 to 6.2 MPa surface pressure
	06.30	reset packers from 5.4 to 6.1 MPa surface pressure
	06.38	end of data recording
	06.41	start data recording *file: 1570CH10.DAT*
	09.33	reset packers from 5.3 to 6.1 MPa surface pressure
	11.00	arrival of T.Przybilla and U.Weber
	11.15	departure of H.Vogt
	12.30	arrival of G.Klee
	13.05	**end of main fall-off test**, end of data recording
		fall-off duration: 2813 min

date	time	event
29.05.95	13.05-13.35	preparation of frac / step-rate test
	13.42-15.56	**frac / step-rate test** *file: 1570.DAT*
		reset packers to 10 MPa surface pressure, conduction of frac-cycle with 1.5 l/min and step-rate test with 3, 4, 5, 6, 7 and 7.3 l/min., maximum injection pressure: 23.09 MPa, shut-in pressure: 22.5 MPa
	15.56	**END OF CASED - HOLE TEST 1**
	15.56-16.30	deflation of packer elements
	16.47	tool at 1438.4 m
	17.07	**START CASED - HOLE TEST 2 AT 1438.4 m**
	17.07	start data recording *file: 1438CH01.DAT*
	17.07-17.14	set packers to 10 MPa surface pressure
	17.15-17.43	injection-rate calibration
	17.43	**start initial injection-test**
	17.58	**end of initial injection**
		total injected volume: 2.5 l
		injection duration: 15 min
		mean injection-rate: 0.167 l/min
	17.58	**start initial fall-off test**
	18.54	end of data recording
	18.56	start data recording *file: 1438CH02.DAT*
	18.58	**end of initial fall-off test**
		fall-off duration: 60 min
	18.58	**start main injection-test**
	20.00	departure of T.Przybilla and U.Weber
	23.13	fill of stand-pipe (45.8 l)
30.05.95	00.00	end of data recording
	00.01	start data recording *file: 1438CH03.DAT*
	00.26	reset packers from 7.5 to 9.0 MPa surface pressure
	04.12	fill of stand-pipe (51.6 l)
	04.20	reset packers from 7.3 to 9.0 MPa surface pressure
	08.33	fill of stand-pipe (44.5 l)
	08.40	end of data recording
	08.42	start data recording *file: 1438CH04.DAT*
	09.13	reset packers from 7.4 to 8.6 MPa surface pressure

date	time	event
30.05.95	09.55	arrival of T.Przybilla
	10.30	departure of G.Klee
	12.00	end of data recording
	12.02	start data recording *file: 1438CH05.DAT*
	12.26	reset packers from 7.5 to 8.7 MPa surface pressure
	12.34	fill of stand-pipe (40.7 l)
	13.28	reset packers from 8.0 to 9.2 MPa surface pressure
	13.30	**end of main injection**
		total injected volume: 190.1 l
		injection duration: 1112 min
		mean injection-rate: 0.171 l/min
	13.30	**start main fall-off test**
	16.58	end of data recording
	17.01	start data recording *file: 1438CH06.DAT*
	20.41	reset packers from 6.0 to 7.4 MPa surface pressure
	20.59	end of data recording
	21.01	start data recording *file: 1438CH07.DAT*
31.05.95	00.54	reset packers from 5.8 to 7.1 MPa surface pressure
	02.56	reset packers from 6.4 to 7.2 MPa surface pressure
	07.15	reset packers from 5.8 to 7.2 MPa surface pressure
	07.50	arrival of H.Vogt and U.Weber
	08.08	end of data recording
	08.10	start data recording *file: 1438CH08.DAT*
	08.20-08.30	preparation of frac / step-rate test
	09.55	arrival of G.Klee
	09.55	**end of main fall-off test**, end of data recording
		fall-off duration: 1225 min
	09.58-12.45	**frac / step-rate test** *file: 1438.DAT*
		reset packers to 10 MPa surface pressure, conduction of frac-cycle with 1.5 l/min and step-rate test with 3, 4, 5, 6, 7 and 7.9 l/min., maximum injection pressure: 26.10 MPa, shut-in pressure: 25.7 MPa
	10.10	departure of T.Przybilla
	12.45	**END OF CASED - HOLE TEST 2**
	12.49-13.00	deflation of packer elements

date	time	event
31.05.95	13.00-15.05	tripping out of hole
	15.05-15.45	tool out of hole, rig-down of downhole equipment for further perforations
	16.30	departure from site
01.06.95	00.00	arrival of G.Klee, H.Vogt and U.Weber
	00.00-01.53	set-up of downhole equipment, venting of the hydraulic system
	01.55	start tripping into hole
	02.00-02.20	test of tool at 20 m *file: 0020CH02.DAT*
	05.15	tool at 1580.7 m
	05.24	**START CASED - HOLE TEST 3 AT 1580.7 m**
	05.24	start data recording *file: 1580CH01.DAT*
	05.24-05.32	set packers to 10 MPa surface pressure
	05.32-05.52	injection-rate calibration
	05.55	**start main injection-test**
	07.00	departure of H.Vogt
	09.27	end of data recording
	09.29	start data recording *file: 1580CH02.DAT*
	09.30	**end of main injection**
		total injected volume: 35.7 l
		injection duration: 215 min
		mean injection-rate: 0.166 l/min
	09.30	**start main fall-off test**
	15.00	arrival of T.Przybilla
	17.26	**end of main fall-off test**, end of data recording
		fall-off duration: 476 min
	17.33-19.08	**frac / step-rate test** *file: 1580.DAT*
		reset packers to 10 MPa surface pressure, conduction of frac-cycle with 1.5 l/min and step-rate test with 3, 4, 5, 6 and 7 l/min., maximum injection pressure: 25.14 MPa, sudden packer-pressure drop at 28.18 MPa downhole
	19.08	**END OF CASED - HOLE TEST 3**
	19.10-19.16	unsuccessful attempt to inflate the packer elements *file: 1580PAC.DAT*
	19.17-19.45	deflation of packer elements

date	time	event
01.06.95	19.45-23.00	tripping out of hole
	23.00	tool out of hole
	23.00-23.10	repair of tubing connector-lines
	23.16-23.30	unsuccessful test of tool at 20 m *file: 0020CH03.DAT*
02.06.95	23.30-01.30	replacement of both packer elements
	01.47-01.59	test of tool at 20 m *file: 0020CH04.DAT*
	02.10	tool out of hole
	02.30	departure of G.Klee, T.Przybilla and U.Weber from site
	11.00	arrival of G.Klee, T.Przybilla and U.Weber at site
	11.00-12.00	set-up of downhole equipment, venting of the hydraulic system
	12.00	start tripping into hole
	14.21	tool at 1481.5 m
	14.26-14.36	determination of the flow-resistance of the system *file: 1481FLOW.DAT*
	14.42	**START CASED - HOLE TEST 4 AT 1481.5 m**
	14.42	start data recording *file: 1481CH01.DAT*
	14.42-14.52	set packers to 10 MPa surface pressure
	14.52-15.03	injection-rate calibration
	15.05	**start main injection-test**
	17.45	departure of G.Klee and U.Weber
	19.48	fill of stand-pipe (46.1 l)
	22.17	reset packers from 8.4 to 10.1 MPa surface pressure
	22.25	end of data recording
	22.27	start data recording *file: 1481CH02.DAT*
	22.35	**end of main injection**
		total injected volume: 74.3 l
		injection duration: 450 min
		mean injection-rate: 0.165 l/min
	22.35	**start main fall-off test**
03.06.95	06.26	end of data recording due to a power-cut (93 min. without data-recording)
	07.59	start data recording *file: 1481CH03.DAT*

date	time	event
03.06.95	08.00	arrival of T.Hettkamp and G.Klee
	08.42	**end of main fall-off test**, end of data recording fall-off duration: 607 min
	08.55-10.24	**frac / step-rate test** *file: 1481.DAT* reset packers to 10 MPa surface pressure, conduction of frac-cycle with 1.5 l/min, injection-cycle with 3 l/min and step-rate test with 4 and 5 l/min., maximum injection pressure: 22.1 MPa, shut-in pressure: 21.5 MPa
	10.24	**END OF CASED - HOLE TEST 4**
	10.26-10.46	deflation of packer elements
	10.58	tool at 1400.5 m
	11.00-11.05	fill of injection line
	11.08	**START CASED - HOLE TEST 5 AT 1400.5 m**
	11.08	start data recording *file: 1400CH01.DAT*
	11.09-11.16	set packers to 9.7 MPa surface pressure
	11.16-11.24	injection-rate calibration
	11.25	**start main injection-test**
	12.45	departure of T.Hettkamp and T.Przybilla
	15.35	fill of stand-pipe (43.7 l)
	19.49	fill of stand-pipe (43.7 l)
	21.27	end of data recording
	21.28	start data recording *file: 1400CH02.DAT*
	22.00	end of data recording
	22.01	start data recording *file: 1400CH03.DAT*
	22.03	**end of main injection** total injected volume: 110.1 l injection duration: 638 min mean injection-rate: 0.172 l/min
	22.03	**start main fall-off test**
04.06.95	08.50	arrival of T.Hettkamp and T.Przybilla
	09.55	**end of main fall-off test**, end of data recording fall-off duration: 712 min

date	time	event
04.06.95	**10.06-12.14**	**frac / step-rate test** *file: 1400.DAT* reset packers to 10 MPa surface pressure, conduction of frac-cycle with 1.5 l/min, step-rate test with 3, 4, 5, 6 and 7 l/min., maximum injection pressure: 24.7 MPa, shut-in pressure: 24.0 MPa
	12.14	**END OF CASED - HOLE TEST 5**
	12.15-12.30	deflation of packer elements
	12.30-15.50	tripping out of hole
	12.30	arrival of U.Weber
	13.00	departure of G.Klee
	15.50-19.15	tool out of hole, rig-down of downhole and surface equipment, dismantling of the equipment
	19.22	departure from site
06.06.95		maintenance of the equipment, demobilization of MKW-5000 winch-system

GEO-Meß-Systeme GmbH

MESY GmbH · Meesmannstraße 49 · D-44807 Bochum · FRG

BOREHOLE TESTING
HYDROFRACTURING
STRESS MEASUREMENTS
System Design · Planning
Lab + Field Measurements

CBM - Project Sigillaria License Area

CASED - HOLE PERMEABILITY AND STRESS MEASUREMENTS IN BOREHOLE RIETH-1

Phase II

Operation Report

Client:	CONOCO Mineralöl GmbH, Essen
Contract:	GCBM-04-95, Variation Order No. 001 dated 09.05.1995
MeSy-Quotation:	113.05.95 dated 04.05.1995
MeSy-Reporter:	Dipl.-Geophys. T. Przybilla
Date:	19.06.1995

Amtsgericht Bochum 14 HRB 2572
Geschäftsführer: Prof. Dr. F. Rummel

Telefon 02 34 / 5 45 31
Telefax 02 34 / 5 45 33

Sparkasse Bochum
(BLZ 430 500 01) 43 308 618

Project:	CBM project Sigillaria License Area
Location:	about 4 km SW of Drensteinfurt, NRW, Germany
Borehole:	Rieth-1
Purpose:	cased-hole permeability and stress measurements
Test-Period:	12.06. - 16.06.1995
Participants:	Mr. K. Thomas (Conoco Essen) Mr. S. Strauss (Conoco Houston) Dipl. Ing. P. Hegemann (MeSy) cand. geophys. T. Hettkamp (MeSy) Dipl. Geophys. G. Klee (MeSy) Dipl. Geophys. J. Kramer (MeSy) Dipl. Geophys. T. Przybilla (MeSy) Dipl. Ing. H. Vogt (MeSy) Dipl. Geophys. U. Weber (MeSy)

TIME TABLE OF TESTING

date	time	event
12.06.95	17.00	arrival of G. Klee, T. Przybilla, H. Vogt and U. Weber at RIETH-1 wellsite
	17.30	S. Strauss decided to start testing at June 13th 1995
	18.00	departure of MeSy engineers from wellsite
13.06.95	05.50	arrival of G. Klee, T. Przybilla, H. Vogt and U. Weber at RIETH-1 wellsite
	06.00-12.55	set-up of surface and downhole equipment, MeSy-GO-cablehead with Western-Atlas-cable (Rochester-cable $^{15}/_{32}$") connected.
	12.55	tool at wellhead, set zero-mark at middle of injection interval
	13.00-13.30	venting of the hydraulic system
	13.30	start tripping into hole
	13.35-13.55	test at 20 m[1], *file: 0020CH01.UMD*

[1] all depth marks were measured from rig-floor and corresponds to the middle of the 8.7 m long test-intervall

date	time	event
13.06.95	17.10	tool at 1591.5 m
		P_{hydr}=16.40 MPa (ρ=1.05 g/cm^3)
	17.17	**START OF CASED - HOLE TEST 6 AT 1591.5 m**
	17.17	**start frac-test**
		start data recording, *file: 1591.UMD*
	17.23	restart of data recording, *file: 1591.UMD*
		set packers to 9 MPa surface pressure, fast decrease of packer pressure
	17.44	deflation of packer elements
	17.47	set packers to 9 MPa surface pressure, still fast decrease of packer pressure, pressure pulse test with leaking packer elements, conduction of frac-cycles with 1.7, 3, 5 and 6 l/min. shut-in pressure: 23.7 MPa
	18.47	**end of frac-test**
	18.47	**END OF CASED - HOLE TEST 6**
	18.48-19.00	deflation of packer elements
	19.15	tool stucks (400 LBS overload)
	22.00	reset of packers and slow deflation of packer elements without any result
	22.45	depth: 1590.5 m, tool moves upward
	22.50-23.13	moving tool up and down at 1587.7 m
	23.13	tool stucks at 1588.3m
	23.45	injection of 50 l into interval
14.06.95	00.00	tool free
	00.00-04.00	tripping out of hole
	04.00	tool out of hole, cable and both tubings up to 2 m above the cablehead damaged
	04.00-08.15	rig-down of downhole equipment, MeSy-GO-cablehead with Western-Atlas cable reconnected, repair of tubings
	08.15-08.30	rig-up of downhole equipment
	08.30	tool at wellhead, set zero-mark at middle of injection interval, venting of the hydraulic system
	09.00	start tripping into hole

date	time	event
14.06.95	09.05-09.25	test at 20 m, *file: 0020CH02.UMD*
		tool leaking
	09.40	tool out of hole
	09.45-09.52	test of tubing and packers, pressurization of tubing, *file: TUBING.UMD*
	10.00-11.45	replacement of both packers, change of o-ring seal at packer expansion piston
	11.45-12.03	venting of the hydraulic system
	12.08	tool at wellhead, set zero-mark at middle of injection interval, start tripping into hole
	12.18-12.30	test at 20 m, *file: 0020CH03.UMD*
	15.30	arrival of T. Hettkamp and J. Kramer at wellsite
	16.42	tool at 1275.0 m, P_{hydr}=13.07 MPa (ρ=1.044 g/cm^3)
	16.48	**START OF CASED - HOLE TEST 7 AT 1275.0 m**
	16.48	**start of frac-test**
		start data recording, *file 1275.UMD*
		set packers to 9 MPa surface pressure, packer elements slightly leaking, conduction of pressure-pulse test and frac-cycles with 1.5, 3 and 5 l/min, shut-in pressure: 19.0 MPa -19.5 MPa.
	17.15	departure of T. Przybilla and H. Vogt from wellsite
	17.54	**end of frac-test**
	17.54	**END OF CASED - HOLE TEST 7**
	17.55-18.10	deflation of packer elements
	18.25	tool at 1248.4 m, P_{hydr}=12.79 MPa (ρ=1.044 g/cm^3)
	18.33	**START OF CASED - HOLE TEST 8 AT 1248.4 m**
	18.33	**start frac-test**
		start data recording, *file: 1248.UMD*
		set packers to 9 MPa surface pressure, conduction of pressure-pulse-test, frac-cycles with 1.5, 3, 4.4, 5 and 6 l/min, shut-in pressure: 17.8 MPa
	20.02	**end of frac-test**
		interval bleed off, end of data recording
	20.02-20.07	preparation for injection-/fall-off-test
	20.07	reset packers to 9.5 MPa surface pressure

date	time	event
14.06.95	**20.28**	**start main injection-test**
		start of data recording, *file: 1248CH01.UMD,* reset packers to 10 MPa surface pressure
	20.30	start injection
	20.35	departure of U. Weber from wellsite
	20.47	reset packers from 3.8 MPa to 9.0 MPa surface pressure
	20.58	reset packers from 4.5 MPa to 9.0 MPa surface pressure
	21.10	reset packers from 5.0 MPa to 10 MPa surface pressure
	21.22	reset packers from 4.7 MPa to 9.0 MPa surface pressure
	21.33	reset packers from 5.0 MPa to 9.0 MPa surface pressure
	21.46	reset packers from 5.0 MPa to 8.6 MPa surface pressure
	21.57	reset packers from 5.1 MPa to 9.2 MPa surface pressure
	22.10	reset packers from 5.1 MPa to 9.1 MPa surface pressure
	22.21	reset packers from 5.2 MPa to 9.3 MPa surface pressure
	22.30	end of data recording
	22.31	start of data recording, *file 1248CH02.UMD*
	22.32	reset packers from 6.1 MPa to 10.0 MPa surface pressure
	22.33	**end of main injection**
		total injected volume: 21.5 l
		injection duration: 123 min
		mean injection-rate: 0.175 l/min
	22.33	**start main fall-off-test**
	23.00	reset of packers from 3.0 MPa to 9.0 MPa surface pressure
	23.21	reset of packers from 3.0 MPa to 9.8 MPa surface pressure

date	time	event
14.06.95	23.44	reset of packers from 2.9 MPa to 8.5 MPa surface pressure
15.06.95	00.06	reset of packers from 3.1 MPa to 8.7 MPa surface pressure
	00.27	reset of packers from 3.0 MPa to 9.1 MPa surface pressure
	00.50	reset of packers from 3.0 MPa to 8.8 MPa surface pressure
	01.15	reset of packers from 3.0 MPa to 8.7 MPa
	01.30	**end of main fall-off-test**
		end of data recording
	01.30	**END OF CASED - HOLE TEST 8**
	01.33-02.00	deflation of packer elements
	05.25	tool at 1560.0 m, P_{hydr}=16.05 MPa (ρ=1.049 g/cm^3)
	05.39	**START OF CASED - HOLE TEST 9 AT 1560.0 m**
	05.39	**start frac-test**
		start data recording, *file: 1560.UMD*, set packers to 9.5 MPa surface pressure, conduction of frac-cycles with 1.5, 3.0, 4.0 and 6.0 l/min, shut-in pressure: 23.0 MPa - 23.5 MPa
	06.52	**end of frac-test**
		end of data recording
	06.52	**END OF CASED - HOLE TEST 9**
	06.54-07.23	deflation of packer elements
	07.23	start tripping out of hole
	08.15	arrival of T. Przybilla, H. Vogt and U. Weber at wellsite
	10.00	departure of T. Hettkamp, G. Klee, J. Kramer
	11.45	tool out of hole
	11.45-15.30	rig-down of downhole equipment, testing of packer elements
	12.00-15.30	perforation work at 1083.7 m by Western Atlas
	12.45	arrival of P. Hegemann at wellsite
	15.30-16.00	rig-up of downhole equipment and MeSy winch system MKW-1500

date	time	event
15.06.95	16.00	tool at wellhead, set zero-mark at middle of injection interval, venting of the hydraulic system
	16.10	start tripping into hole
	16.38-17.06	test of tool at 20 m
		start of data recording, *file: 0020CH04.UMD,* packer pressure decreases
	17.20	stop and restart of data recording: *file 0020CH05.UMD,* pumping into interval, deflation of packer elements, reinflation of packer elements, fluid-losses from packer elements into interval
	18.13	tool out of hole
		leakage at the bottom of the top-packer repaired, change of o-ring seal at bottom-packer
	20.00	tool at wellhead, set zero-mark at middle of injection interval, venting of the hydraulic system
		start tripping into the hole
	20.25	test of tool at 20 m
	22.03	departure of P. Hegemann from wellsite
16.06.95	00.07	tool at 1083.7 m, P_{hydr}=11.10 MPa (ρ=1.044 g/cm^3)
	00.18	**START OF CASED - HOLE TEST 10 AT 1083.7 m**
	00.18	**start of frac-test**
		start of data recording, *file: 1083.UMD,* set packers to 10.1 MPa surface pressure, conduction of pressure-pulse-test and frac-cycles with 1.5, 3.4 and 5 l/min, shut-in pressure: 16.8 MPa
	04.45	preparation for injection test
	04.51	**end of frac-test**
		end of data recording
	05.38	**start main injection-test**
		start data recording, *file: 1083CH01.UMD*
	08.25	**end of main injection**
		total injected volume: 28.37 l
		injection duration: 167 min
		mean injection rate: 0.170 l/min
	08.25	**start main fall-off test**
	12.00	interval bleed off

date	time	event
16.06.95	**12.08**	**end of main fall-off test**
		end of data recording
	12.08	**END OF CASED - HOLE TEST 10**
	12.20-12.40	deflation of packer elements
	12.40	start tripping out of the hole
	16.00	tool out of hole, rig-down of downhole and surface equipment, dismantling of the equipment
	17.39	departure of T. Przybilla, H. Vogt and U. Weber from wellsite
19.06.95		maintenance of the equipment

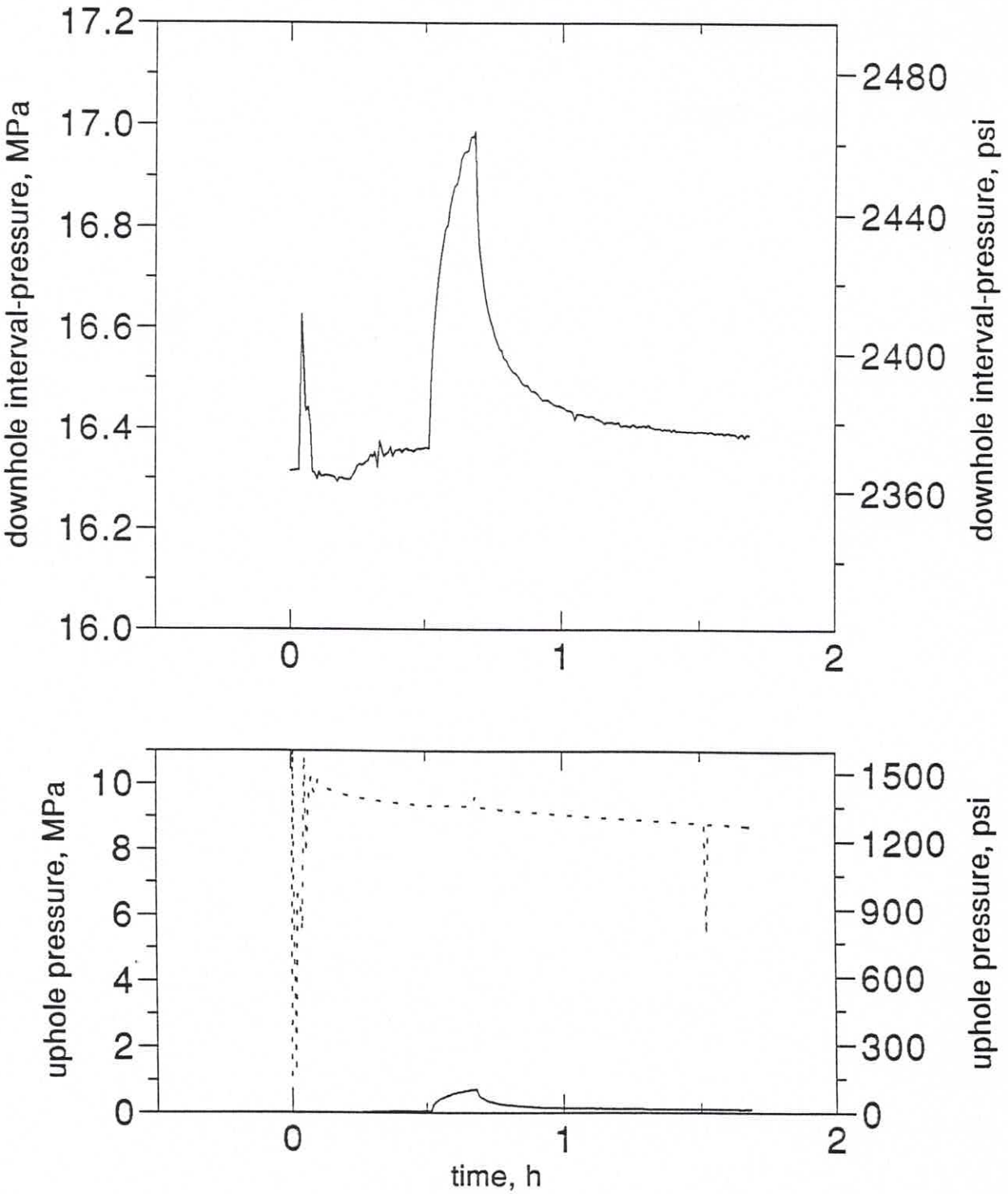
APPENDIX B

Overview - Plots of Injection - Fall - Off - Tests

remark : data were not corrected with respect to power supply induced noise

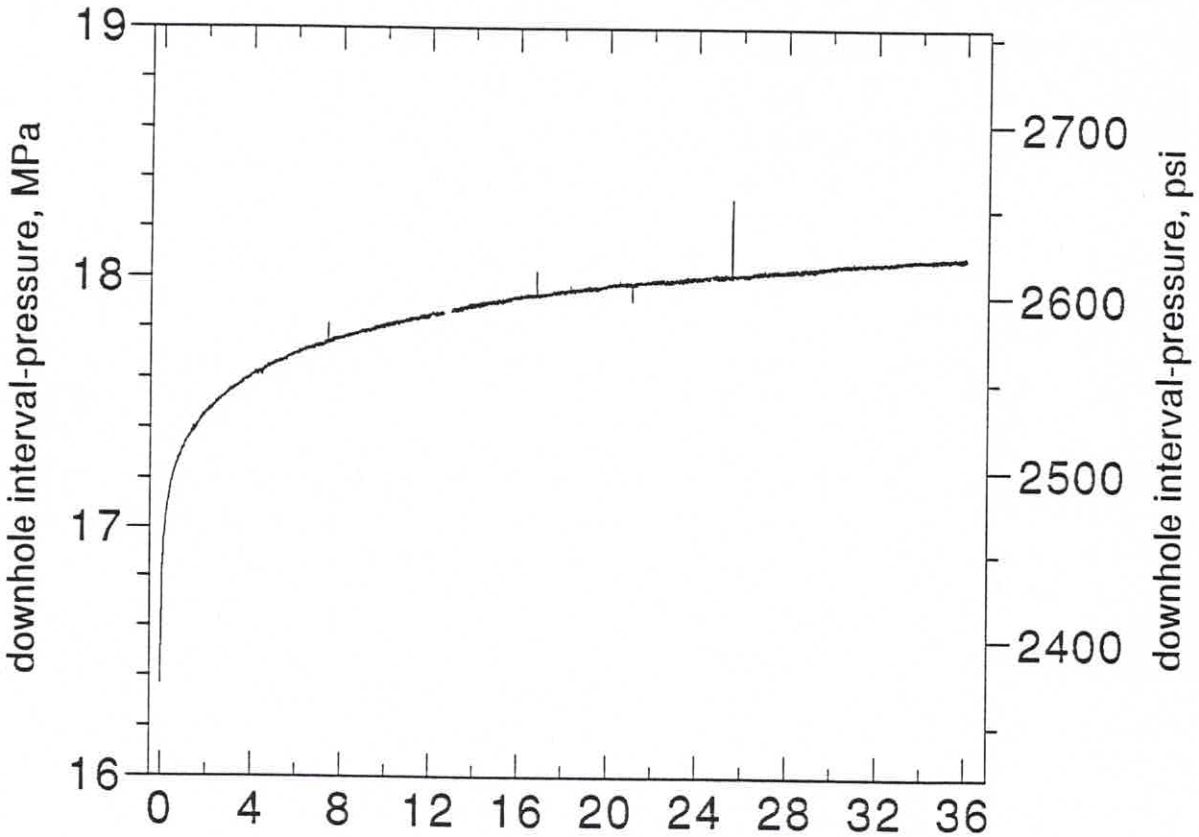
GEO-Meß-Systeme GmbH

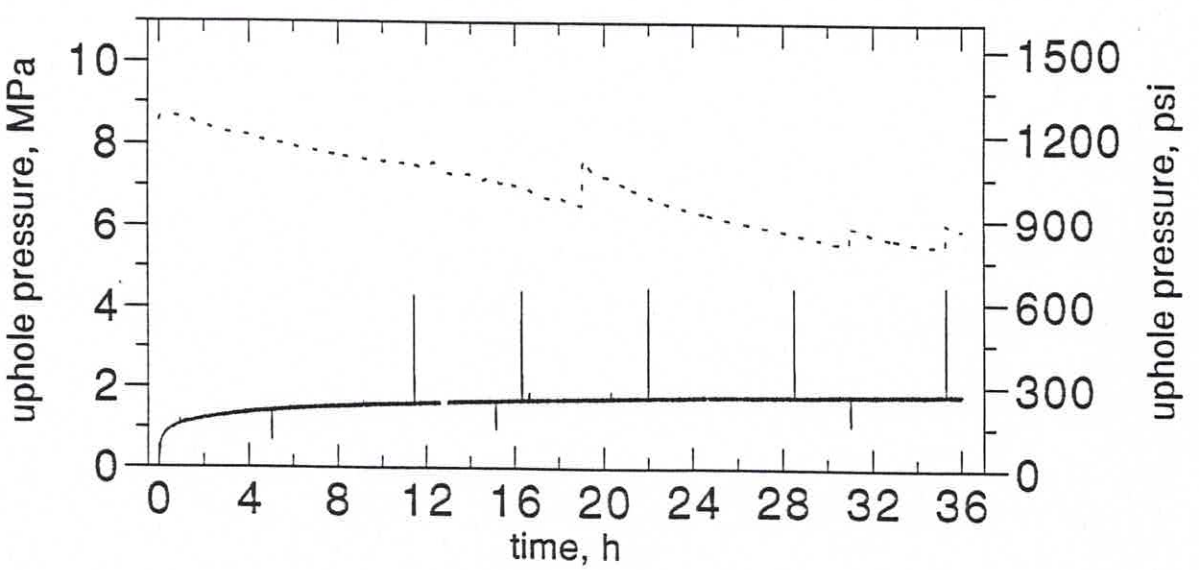
CASED - HOLE TEST 1 AT 1570.0 m
initial injection / fall-off test
file: 1570CH01.DAT
start: 25.05.1995, 20.53 end: 25.05.1995, 22.35



GEO-Meß-Systeme GmbH

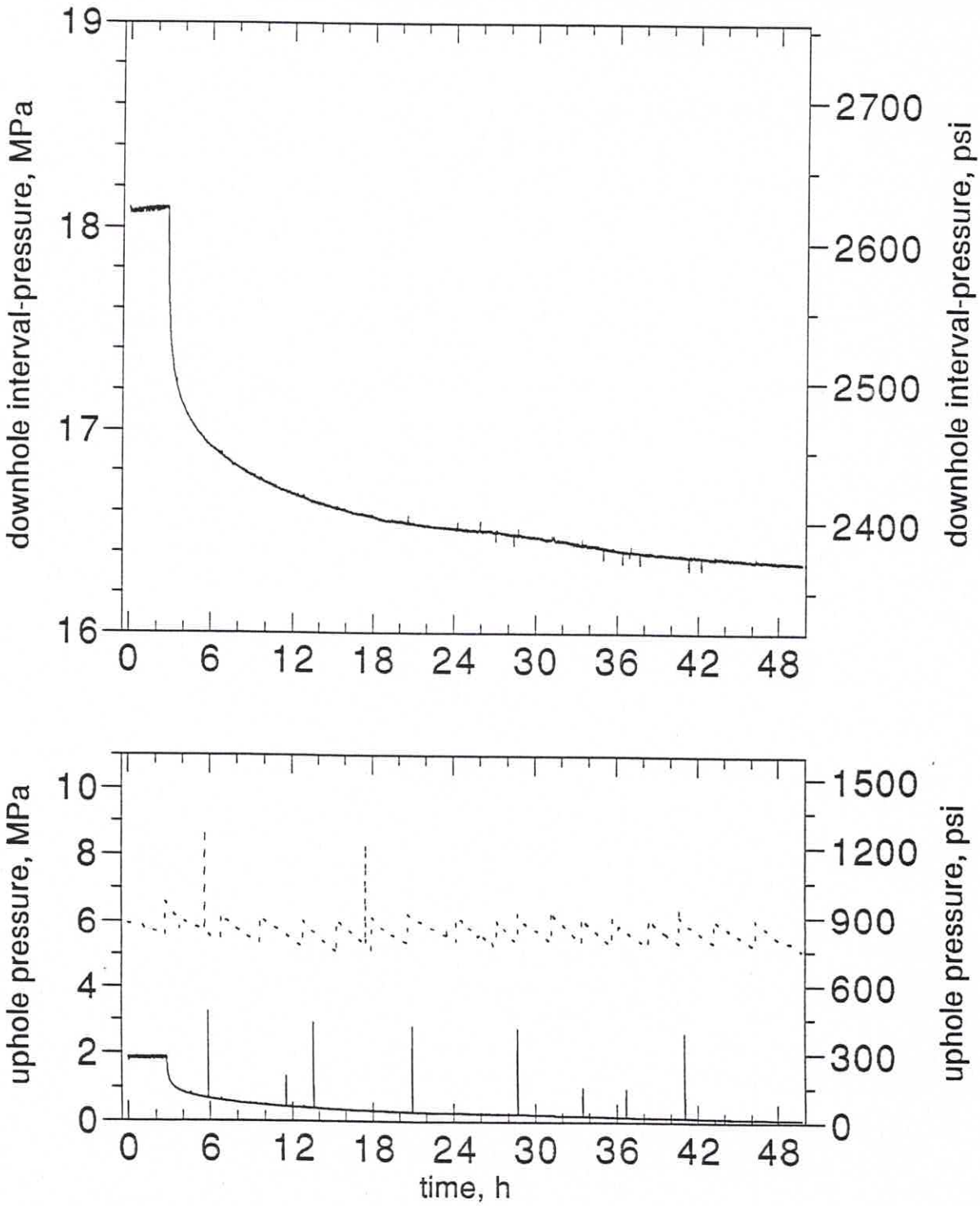
CASED - HOLE TEST 1 AT 1570.0 m
main injection test
files: 1570CH03.DAT, 1570CH04.DAT
1570CH05.DAT
start: 25.05.1995, 23.08 end: 27.05.1995, 11.10





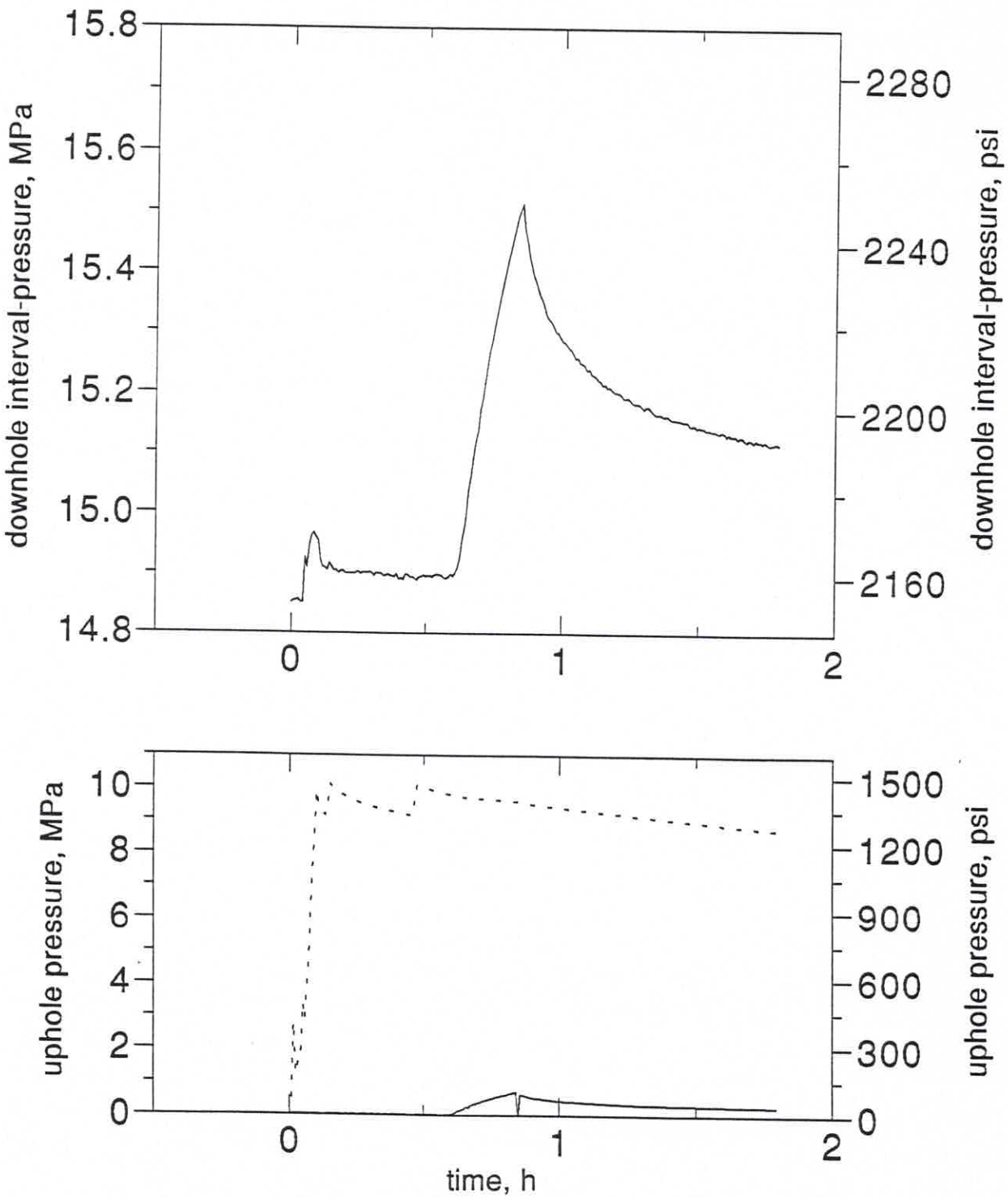
GEO-Meß-Systeme GmbH

CASED - HOLE TEST 1 AT 1570.0 m
main fall-off test
files: 1570CH06.DAT, 1570CH07.DAT
1570CH08.DAT, 1570CH09.DAT
1570CH10.DAT
start: 27.05.1995, 11.18 end: 29.05.1995, 13.05



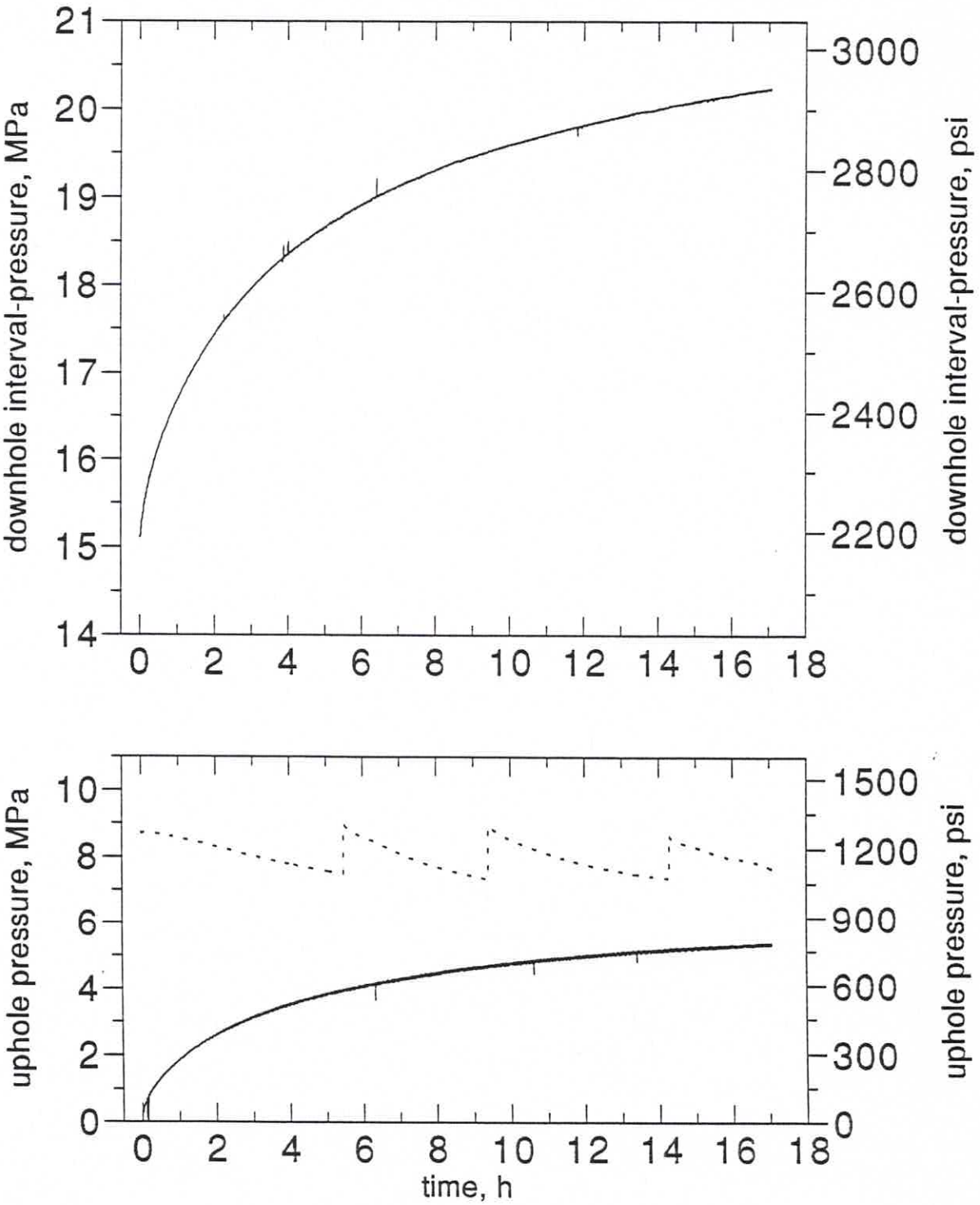
GEO-Meß-Systeme GmbH

CASED - HOLE TEST 2 AT 1438.4 m
initial injection / fall-off test
file: 1438CH01.DAT
start: 29.05.1995, 17.07 end: 29.05.1995, 18.54

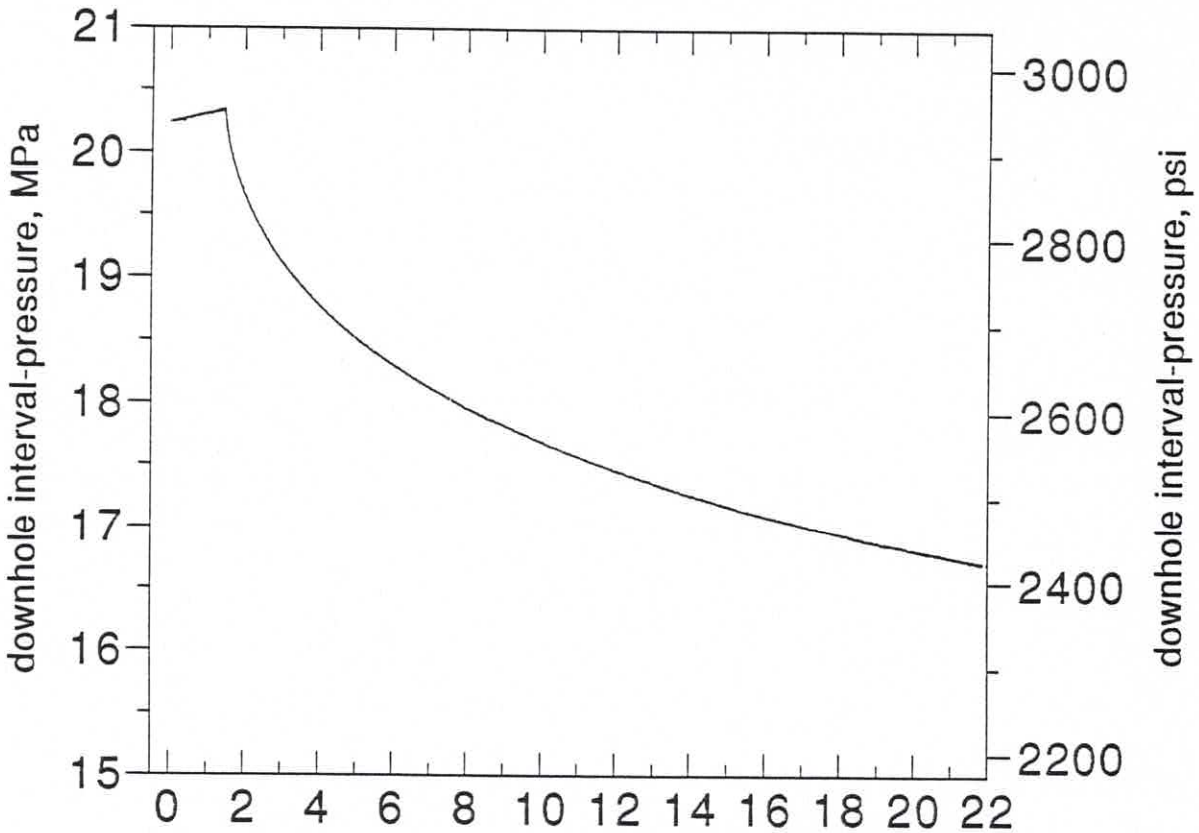


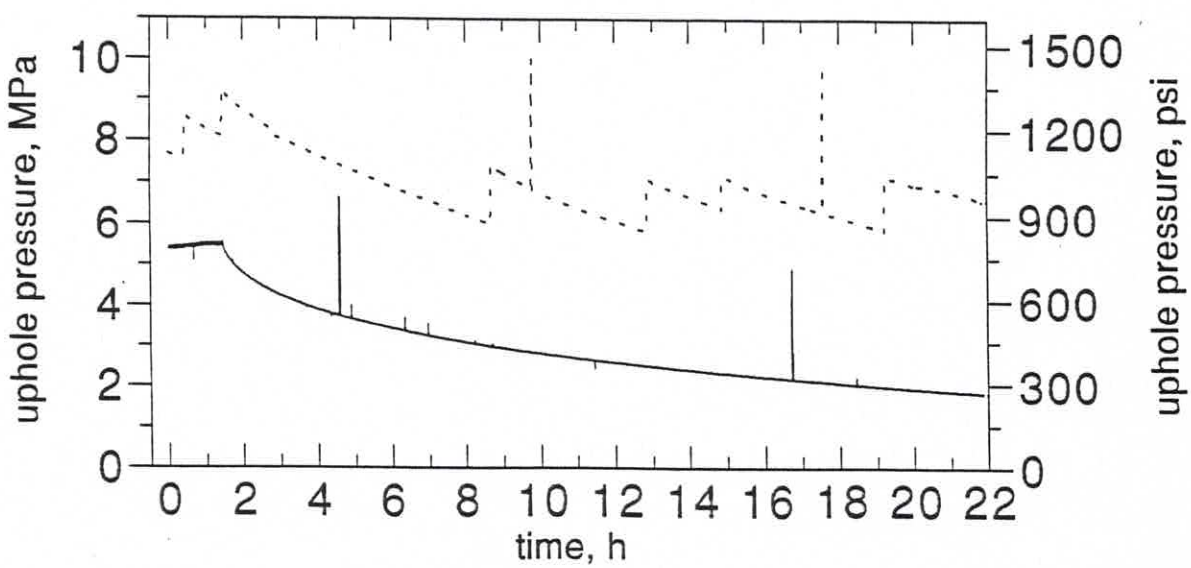
GEO-Meß-Systeme GmbH

CASED - HOLE TEST 2 AT 1438.4 m
main injection test
files: 1438CH02.DAT, 1438CH03.DAT
1438CH04.DAT
start: 29.05.1995, 18.56 end: 30.05.1995, 12.00



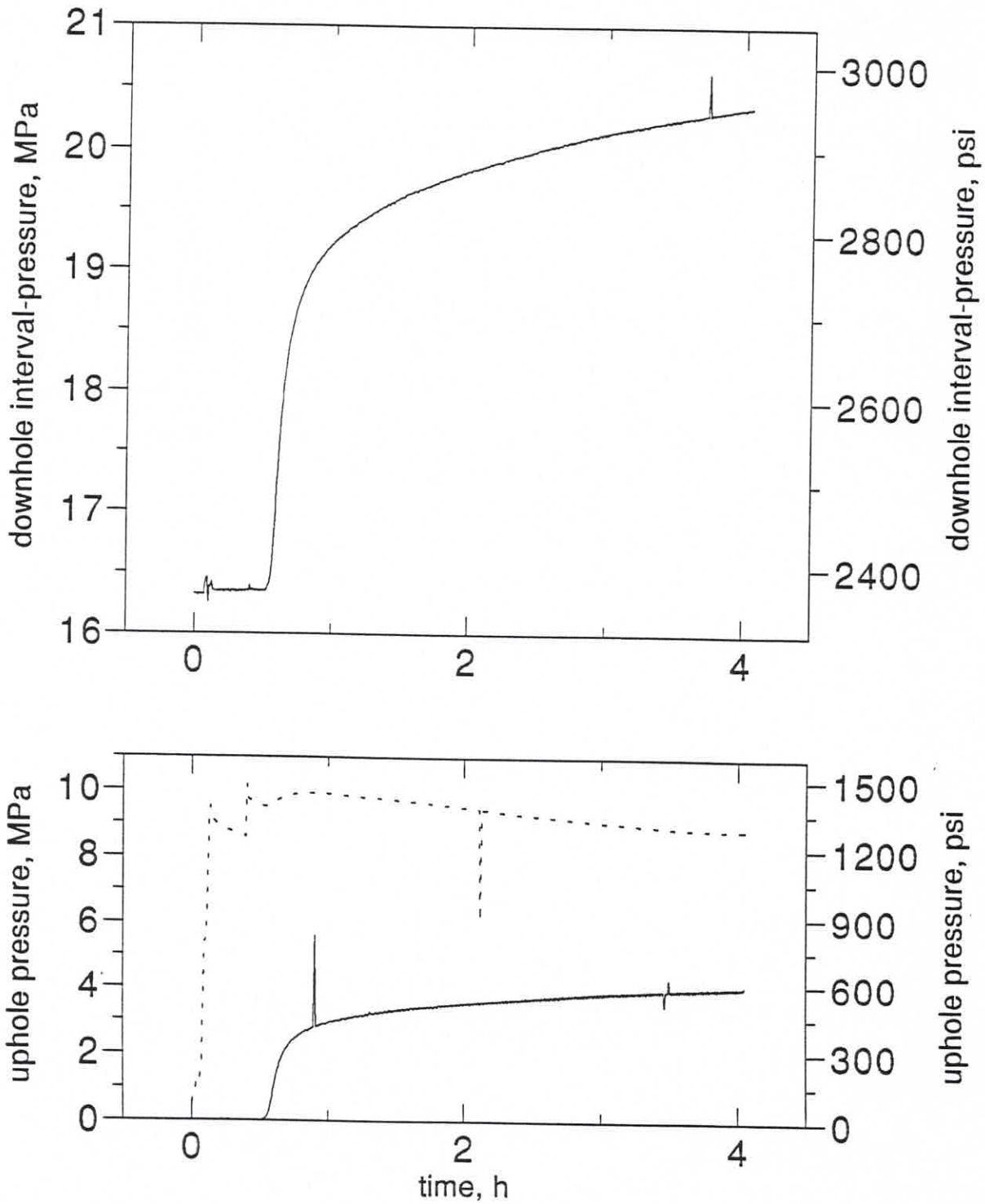
CASED - HOLE TEST 2 AT 1438.4 m
main fall-off test
files: 1438CH05.DAT, 1438CH06.DAT
1438CH07.DAT, 1438CH08.DAT
start: 30.05.1995, 12.02 end: 31.05.1995, 09.55



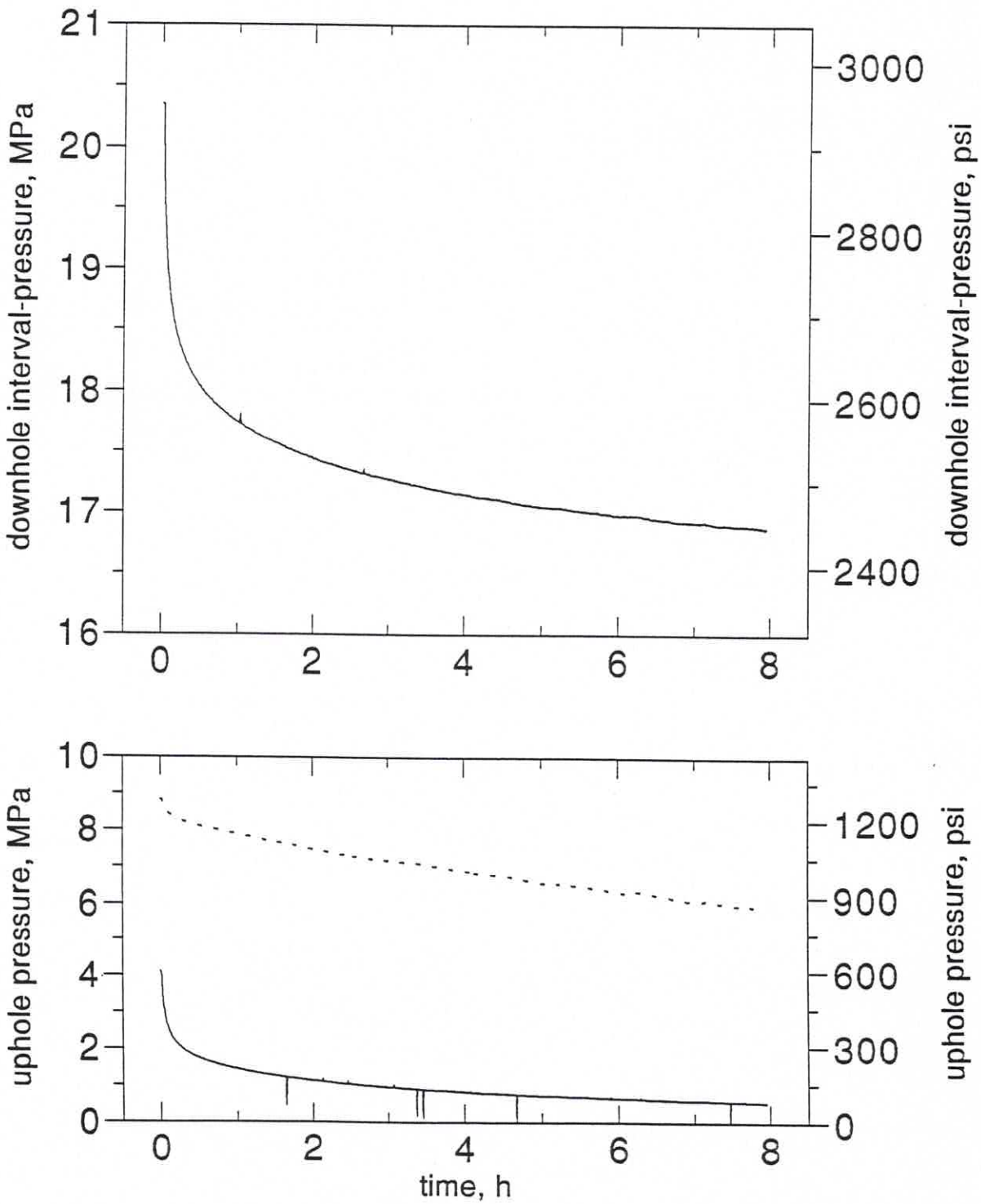


GEO-Meß-Systeme GmbH

CASED - HOLE TEST 3 AT 1580.7 m
main injection test
file: 1580CH01.DAT
start: 01.06.1995, 05.24 end: 01.06.1995, 09.27

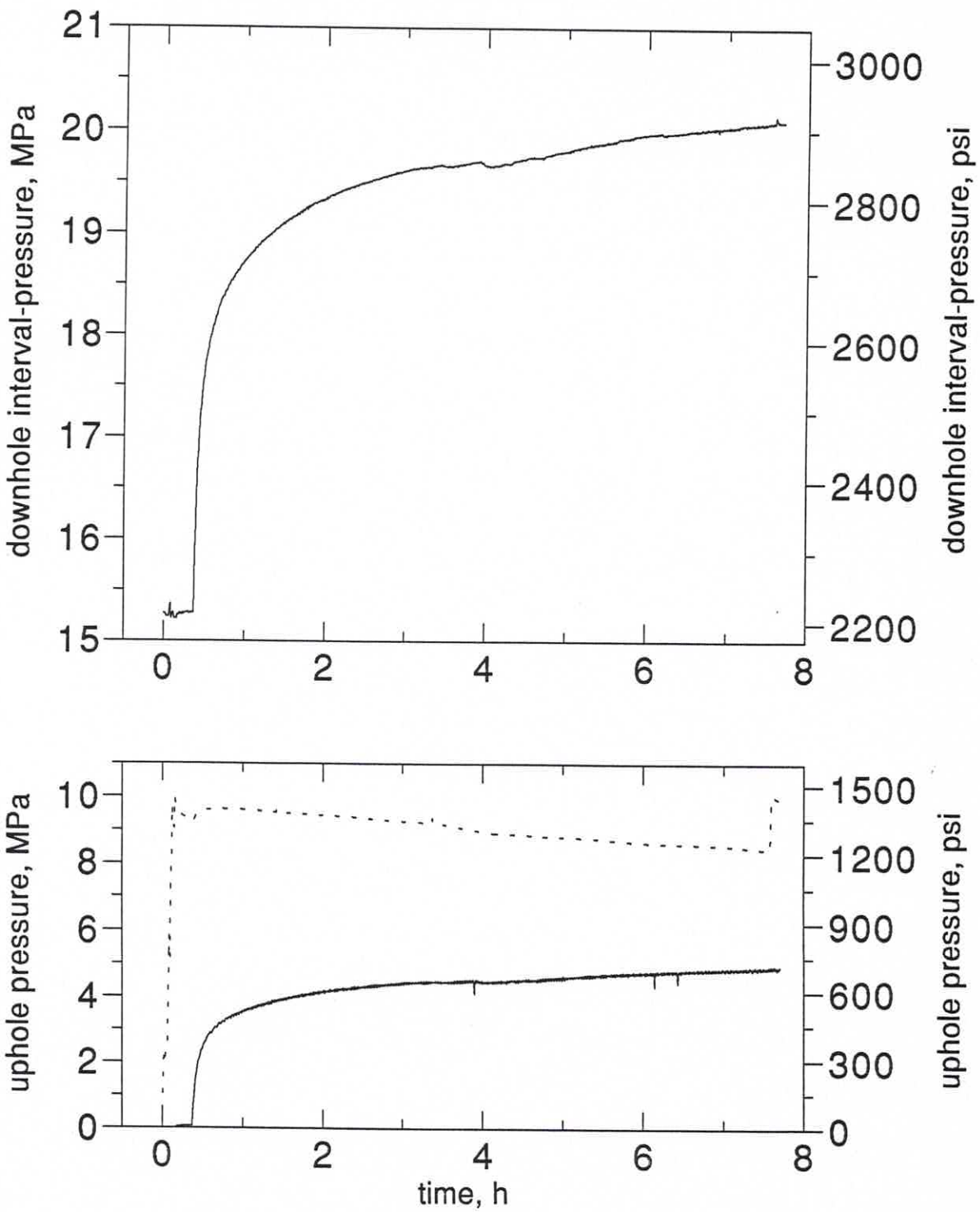


CASED - HOLE TEST 3 AT 1580.7 m
main fall-off test
file: 1580CH02.DAT
start: 01.06.1995, 09.29 end: 01.06.1995, 17.26



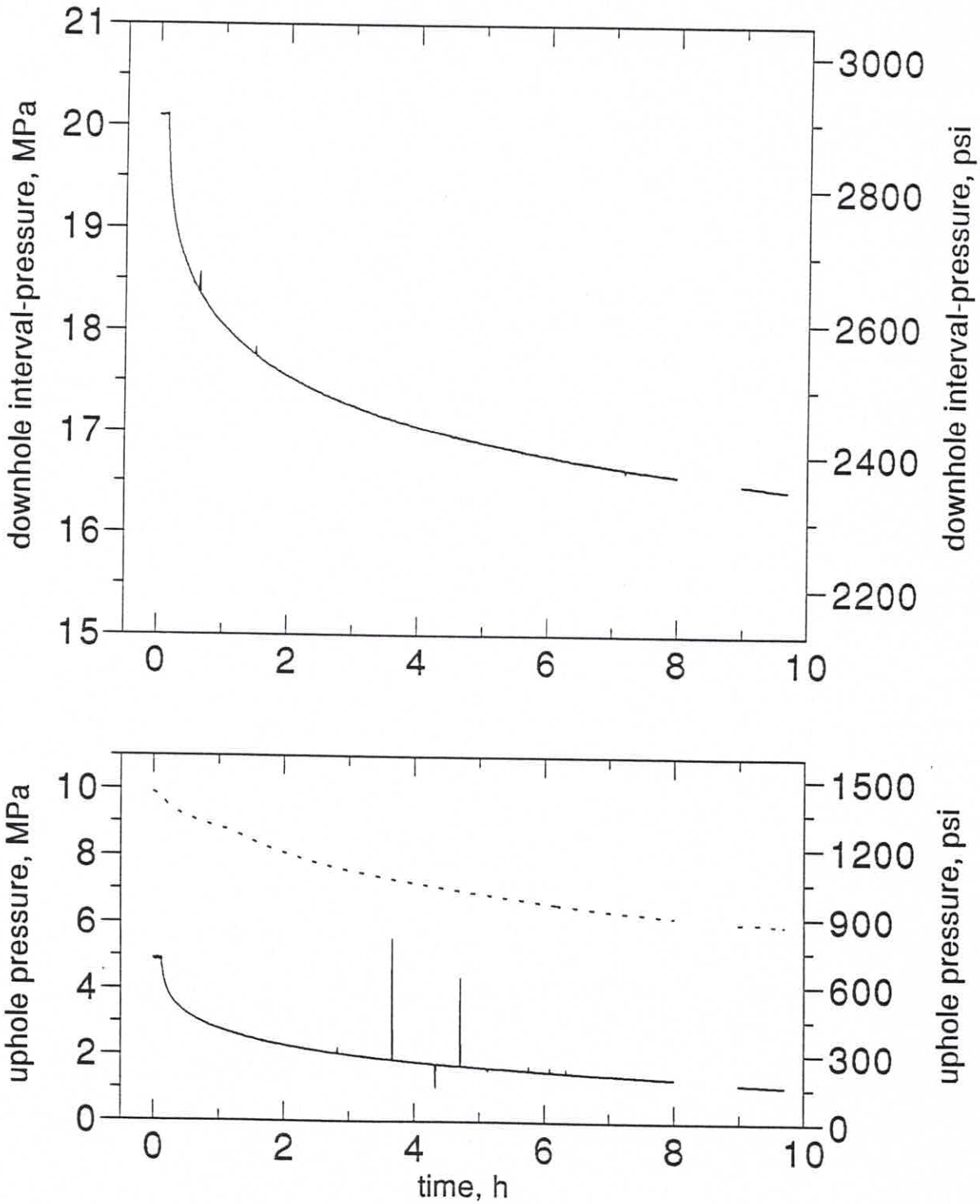
GEO-Meß-Systeme GmbH

CASED - HOLE TEST 4 AT 1481.5 m
main injection test
file: 1481CH01.DAT
start: 02.06.1995, 14.42 end: 02.06.1995, 22.25



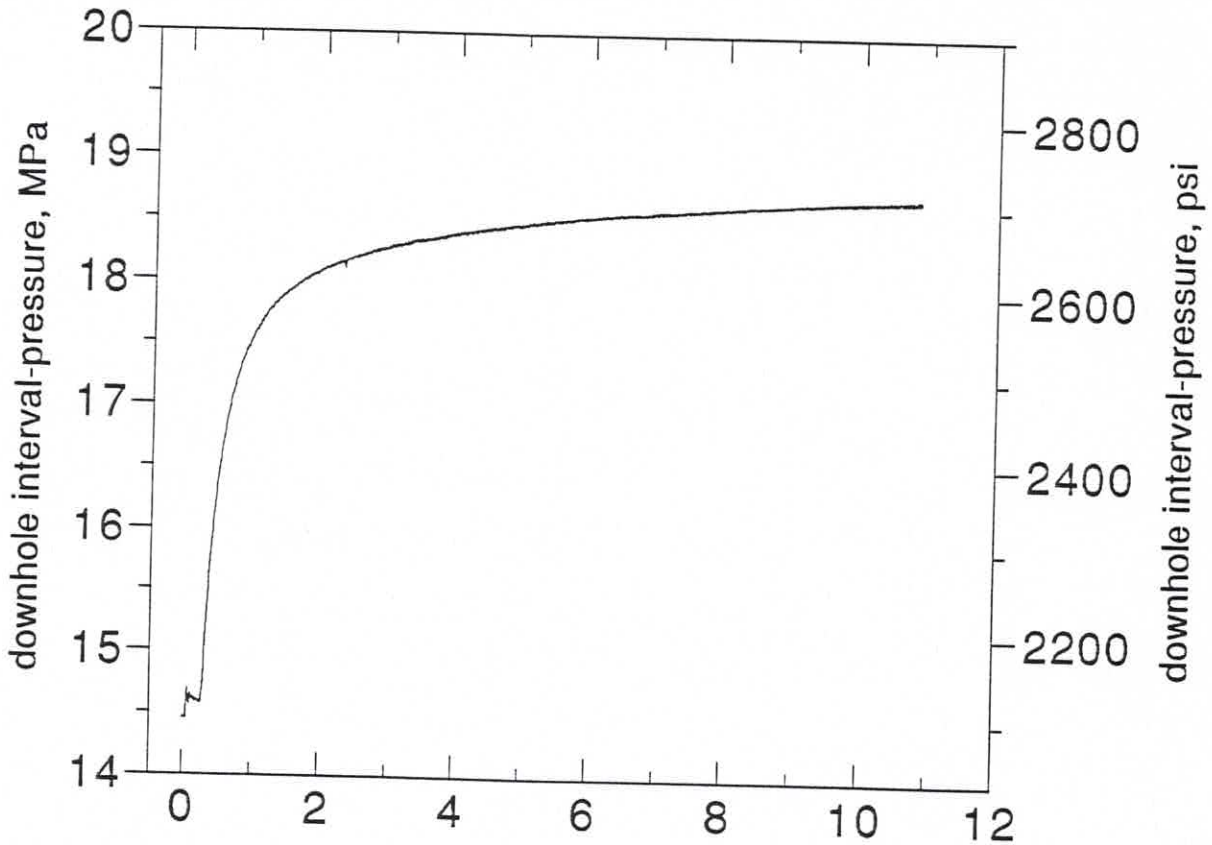
MeSy GEO-Meß-Systeme GmbH

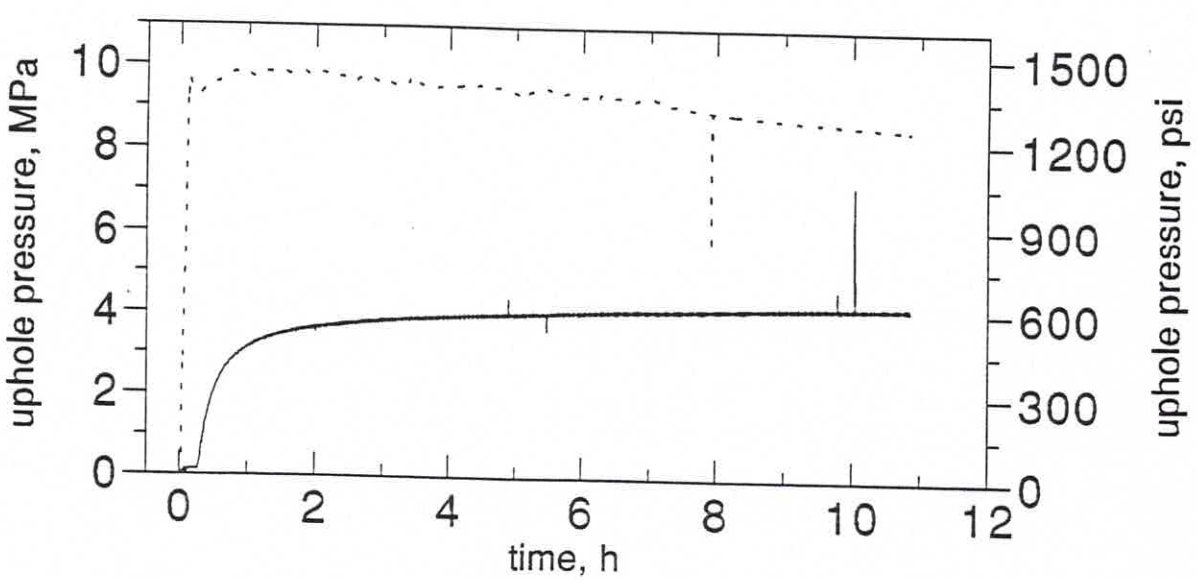
CASED - HOLE TEST 4 AT 1481.5 m
main fall-off test
files: 1481CH02.DAT, 1481CH03.DAT
start: 02.06.1995, 22.27 end: 03.06.1995, 08.42



GEO-Meß-Systeme GmbH

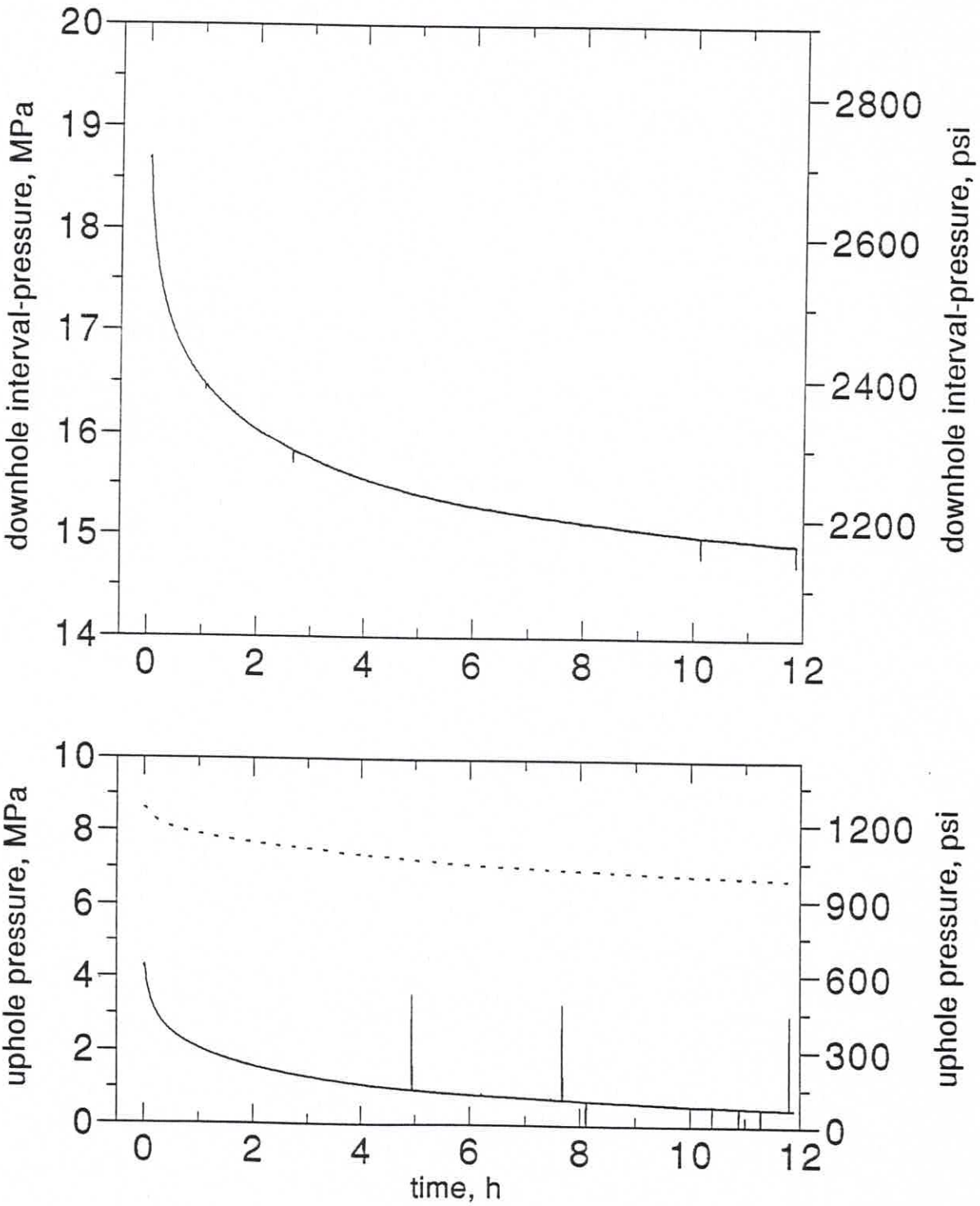
CASED - HOLE TEST 5 AT 1400.5 m
main injection test
files: 1400CH01.DAT, 1400CH02.DAT
start: 03.06.1995, 11.08 end: 03.06.1995, 22.03





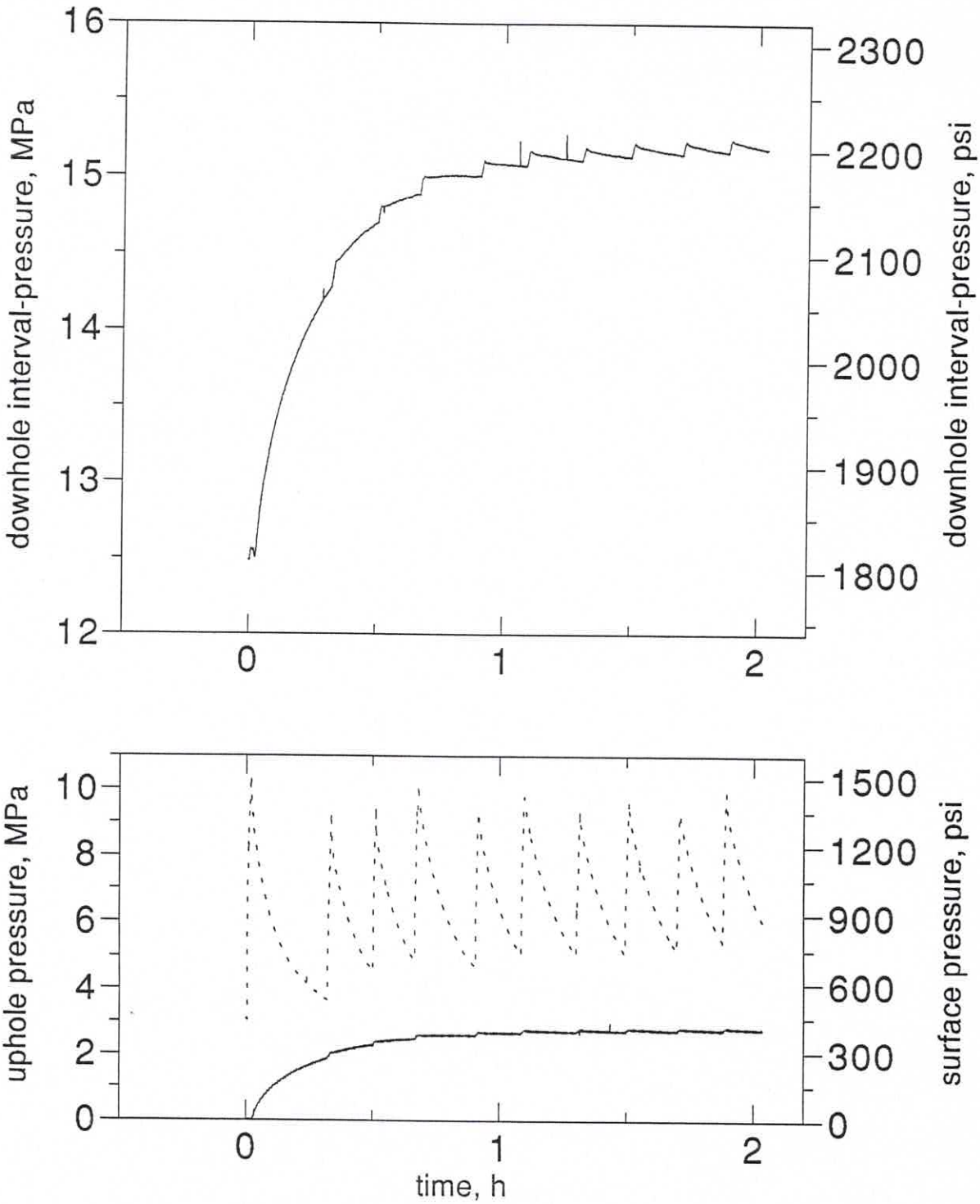
GEO-Meß-Systeme GmbH

CASED - HOLE TEST 5 AT 1400.5 m
main fall-off test
file: 1400CH03.DAT
start: 03.06.1995, 22.03 end: 04.06.1995, 09.55



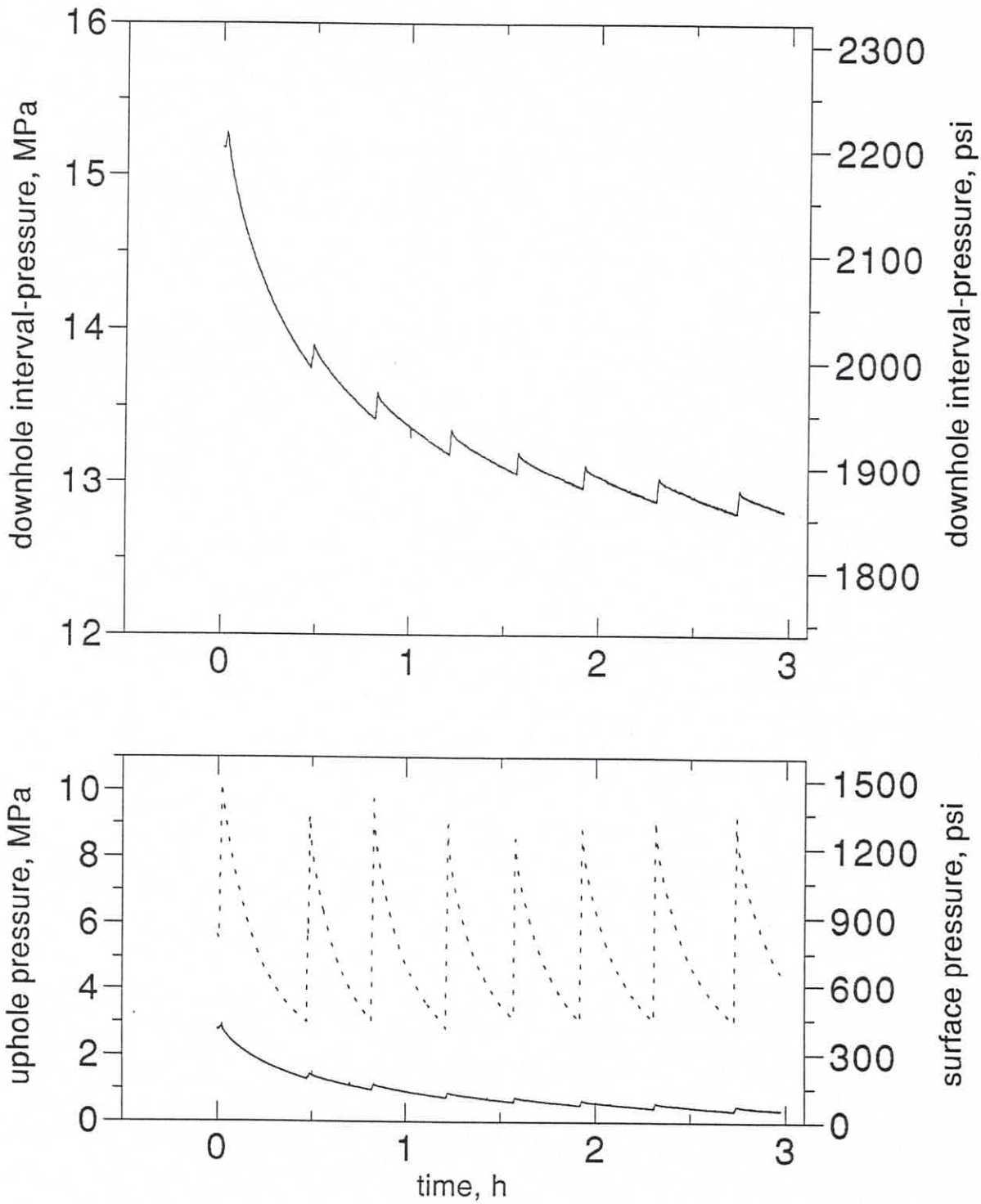
GEO-Meß-Systeme GmbH

CASED - HOLE TEST 8 AT 1248.4 m
main injection test
file: 1248CH01.DAT
start: 14.06.1995, 20.28 end: 14.06.1995, 22.33



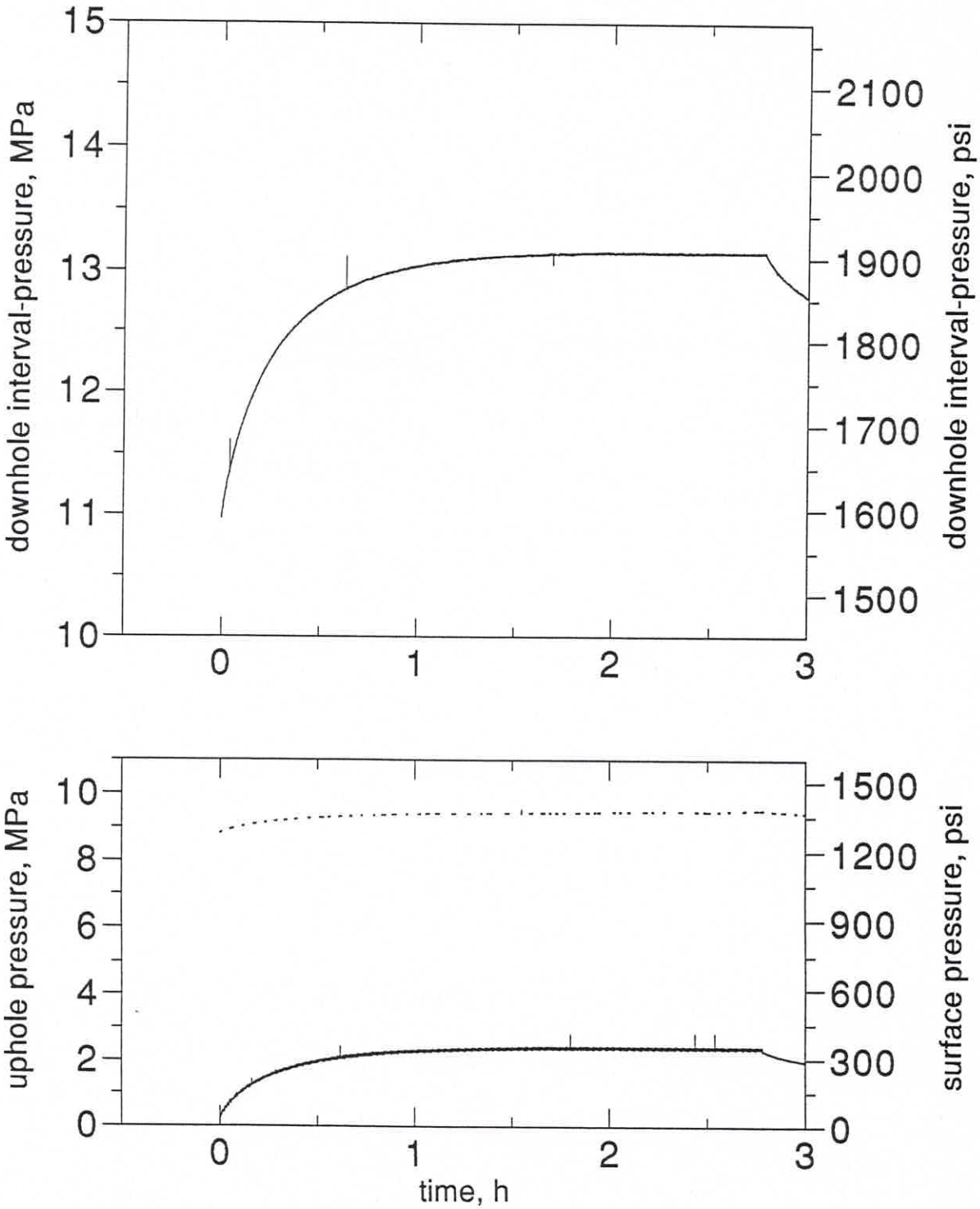
GEO-Meß-Systeme GmbH

CASED - HOLE TEST 8 AT 1248.4 m
main fall-off test
file: 1248CH02.DAT
start: 14.06.1995, 22.33 end: 15.06.1995, 01.30



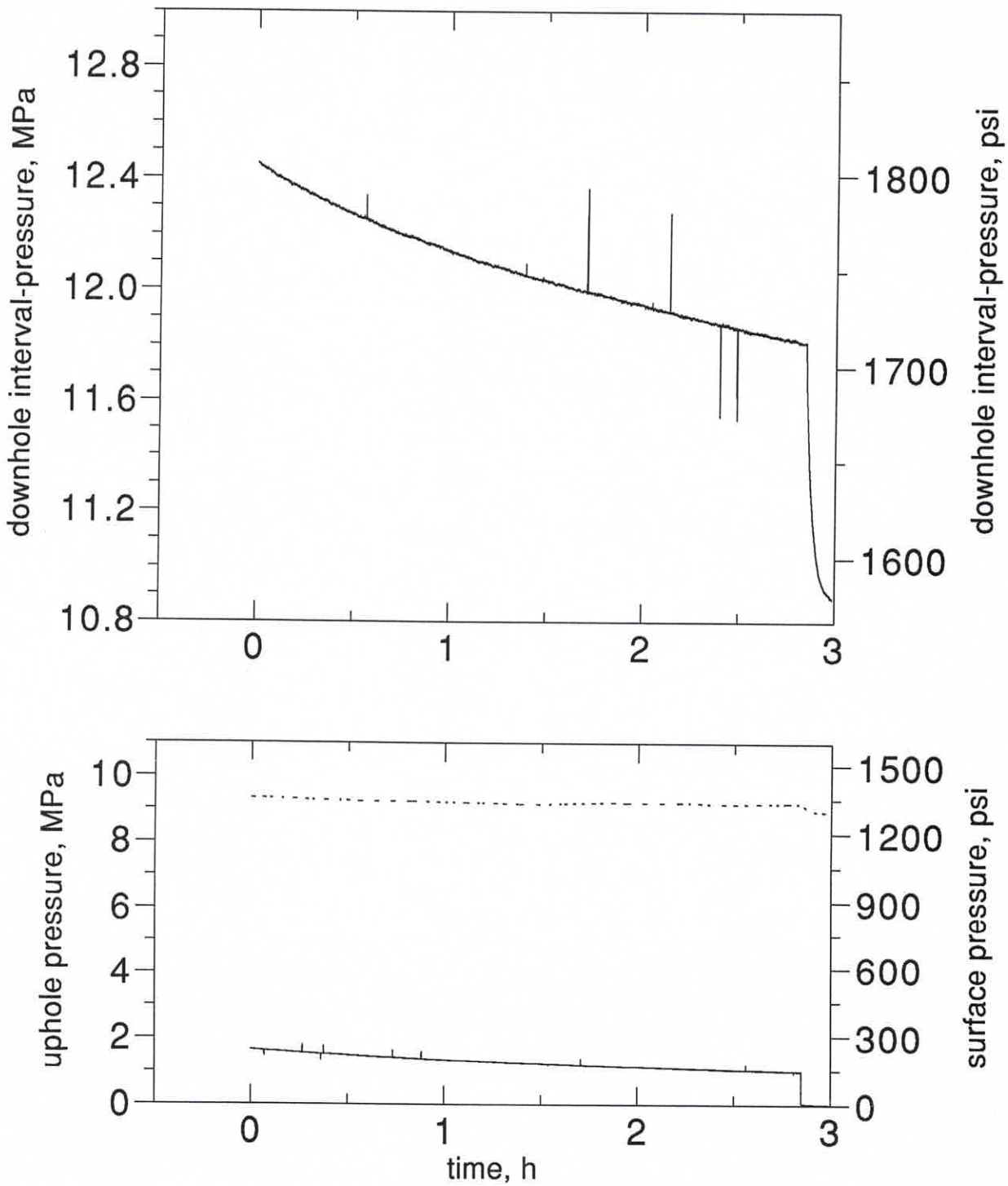
GEO-Meß-Systeme GmbH

CASED - HOLE TEST 10 AT 1083.7 m
main injection test
file: 1083CH01.DAT
start: 16.06.1995, 05.38 end: 16.06.1995, 08.25



GEO-Meß-Systeme GmbH

CASED - HOLE TEST 10 AT 1083.7 m
main fall-off test
file: 1083CH01.DAT
start: 16.06.1995, 08.25 end: 16.06.1995, 12.08



APPENDIX C

Overview - Plots of Downhole Injection - and Packer - Pressure and Surface Flow - Rate Records of Conducted Frac - Tests

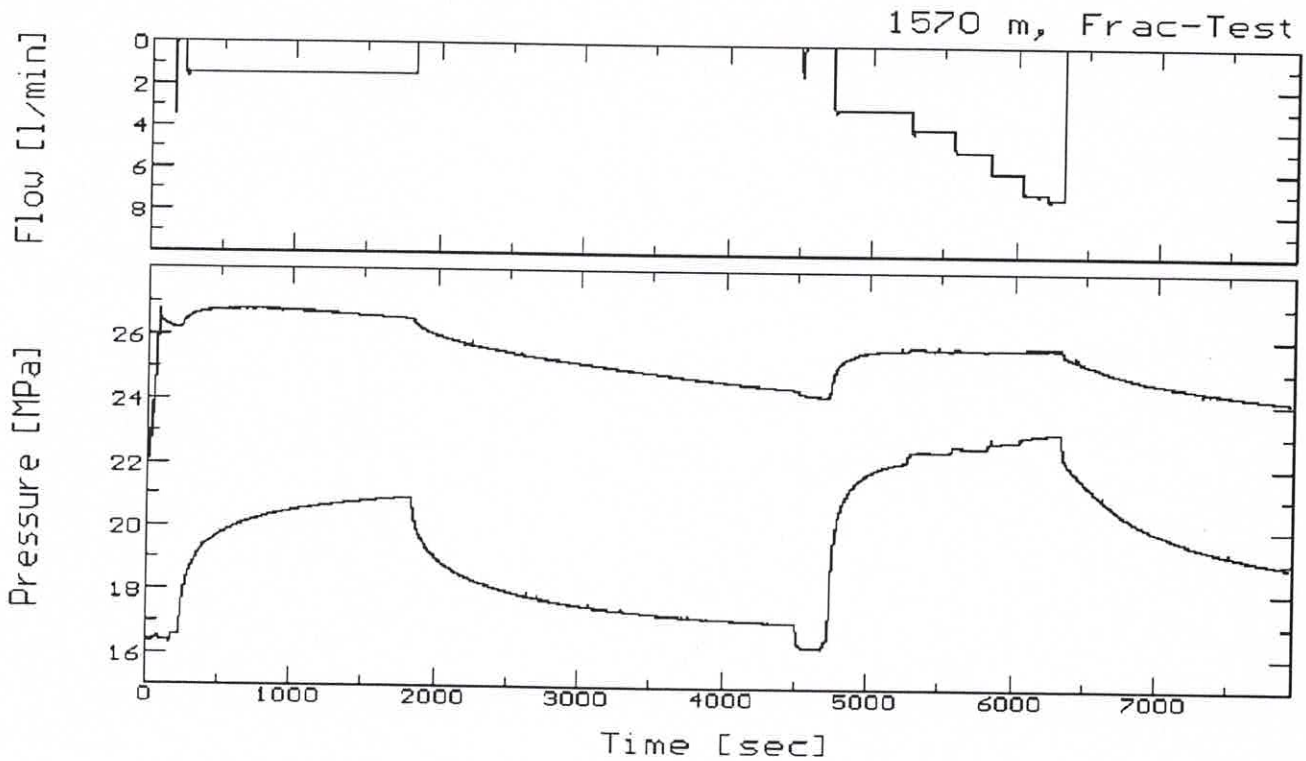
remark : data were corrected with respect to power supply induced noise

GEO-Meß-Systeme GmbH

CASED - HOLE TEST 1 AT 1570.0 m

Frac / Step - Rate Test

file: 1570.DAT

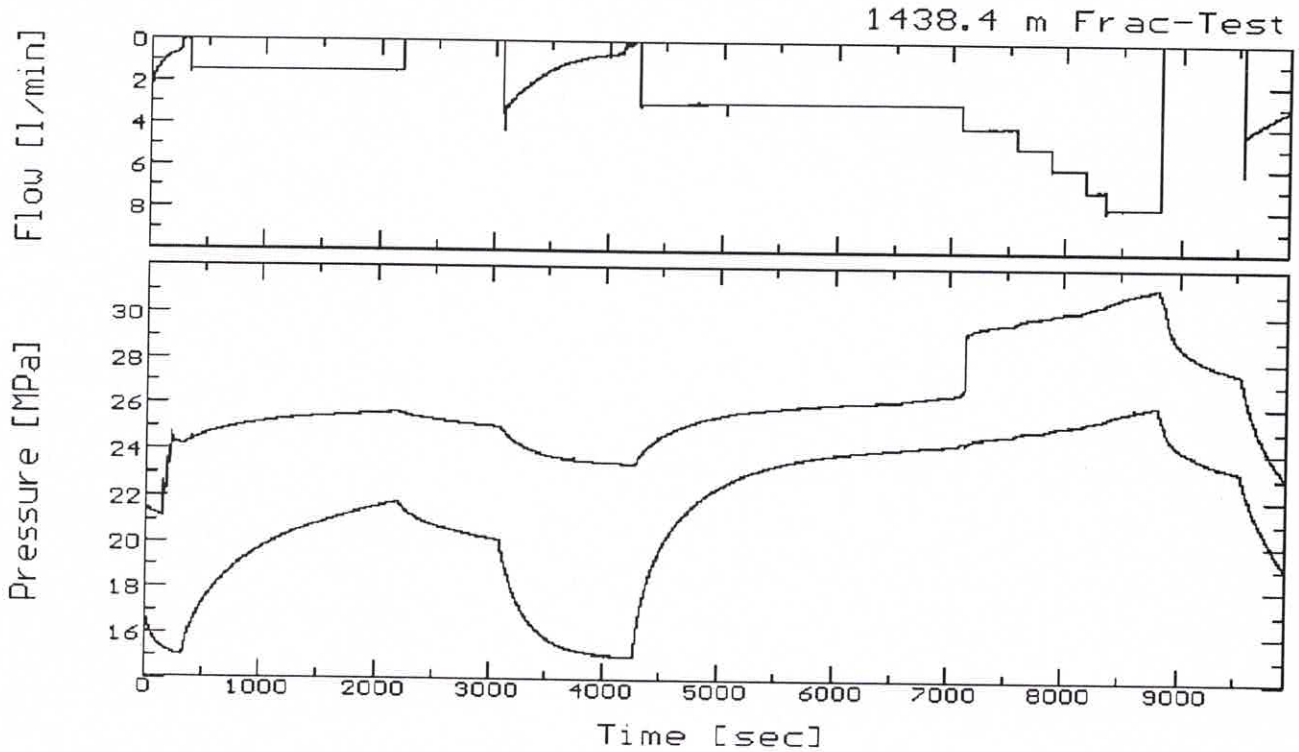


GEO-Meß-Systeme GmbH

CASED - HOLE TEST 2 AT 1438.4 m

Frac / Step - Rate Test

file: 1438.DAT

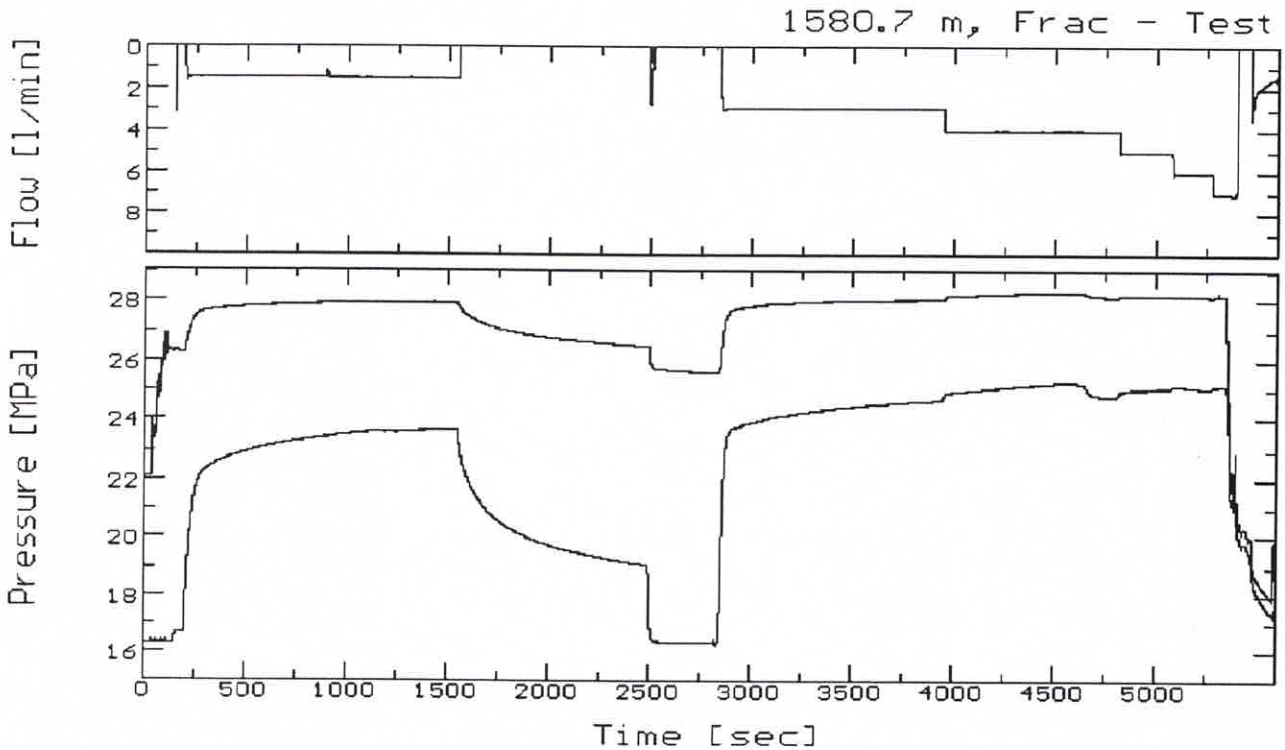


GEO-Meß-Systeme GmbH

CASED - HOLE TEST 3 AT 1580.7 m

Frac / Step - Rate Test

file: 1580.DAT

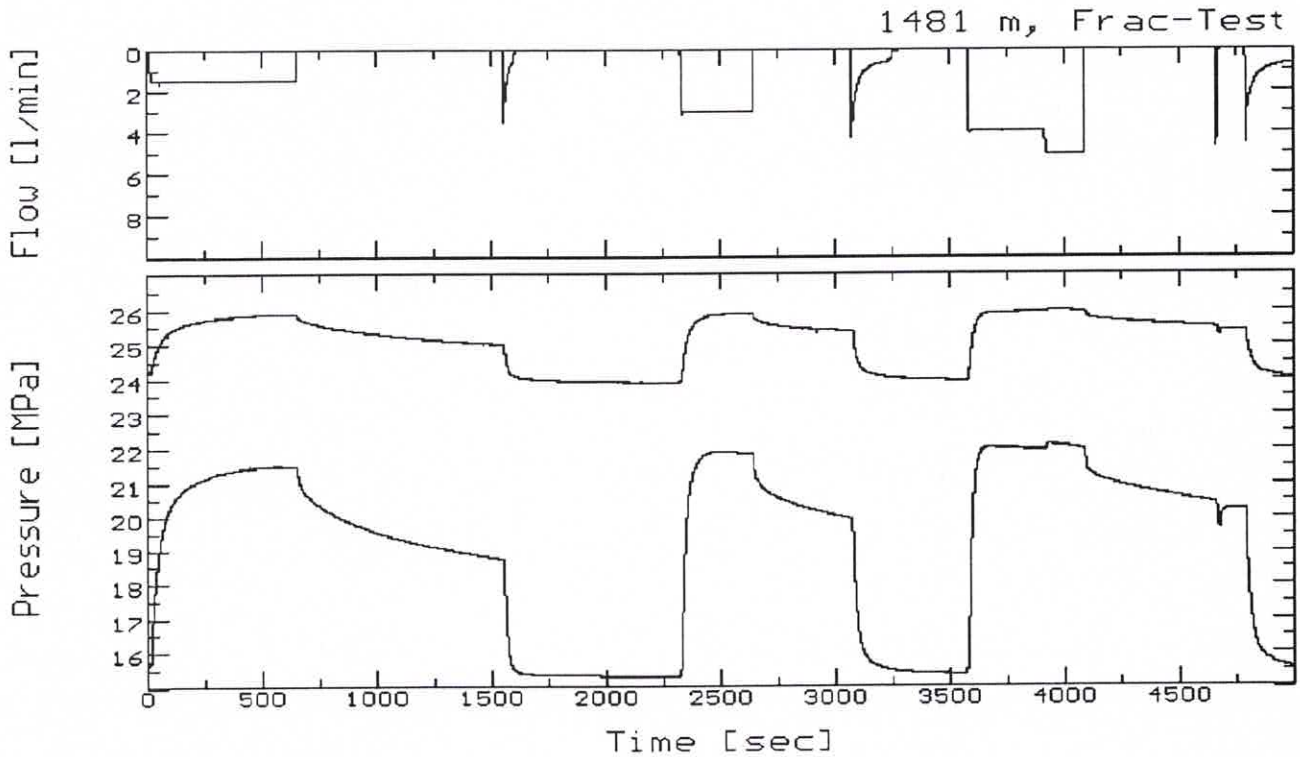


GEO-Meß-Systeme GmbH

CASED - HOLE TEST 4 AT 1481.5 m

Frac / Step - Rate Test

file: 1481.DAT

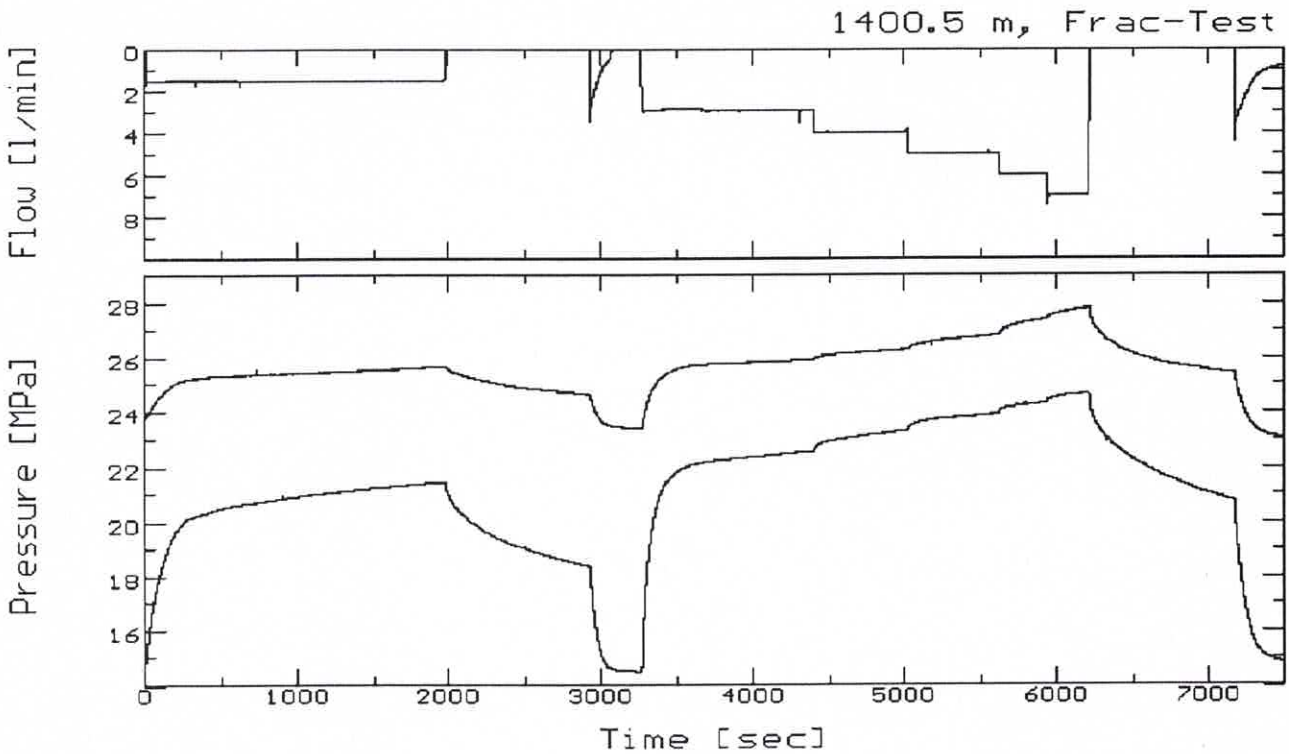


GEO-Meß-Systeme GmbH

CASED - HOLE TEST 5 AT 1400.5 m

Frac / Step - Rate Test

file: 1400.DAT

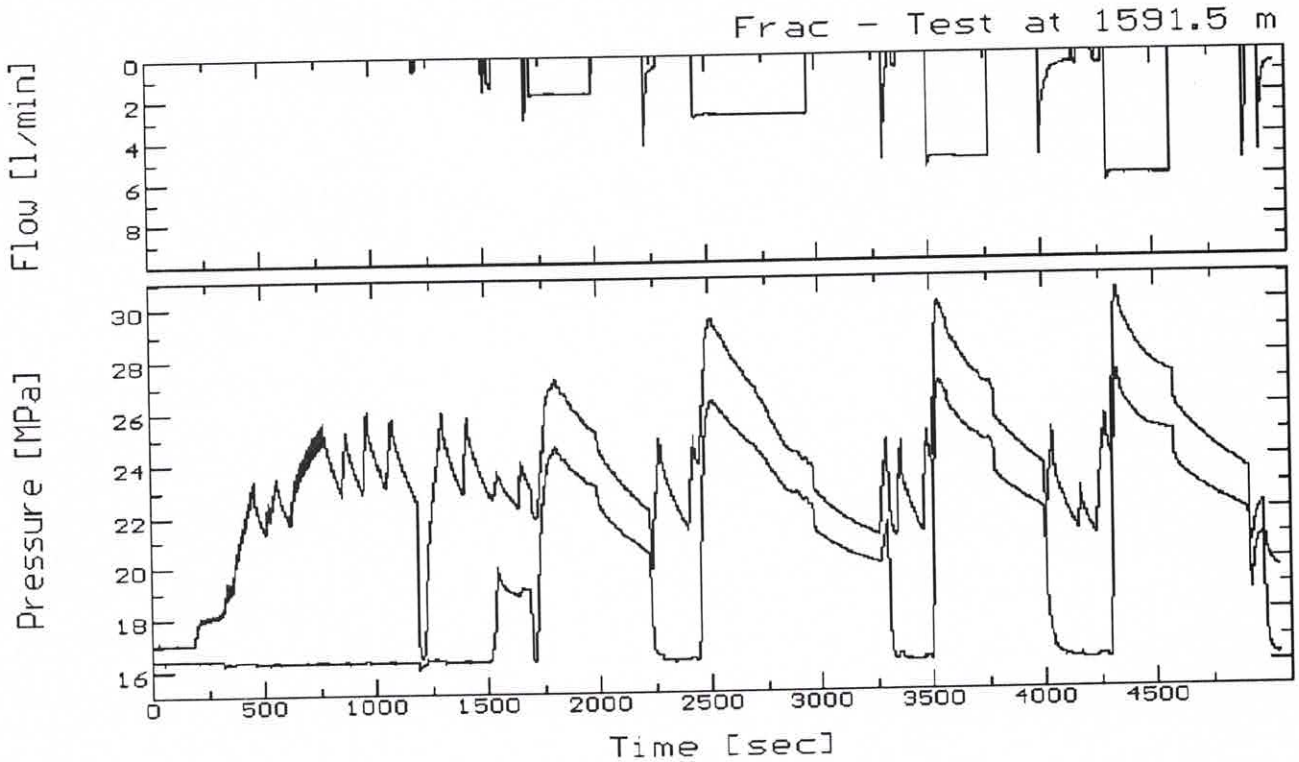


GEO-Meß-Systeme GmbH

CASED - HOLE TEST 6 AT 1591.5 m

Frac / Step - Rate Test

file: 1591.DAT

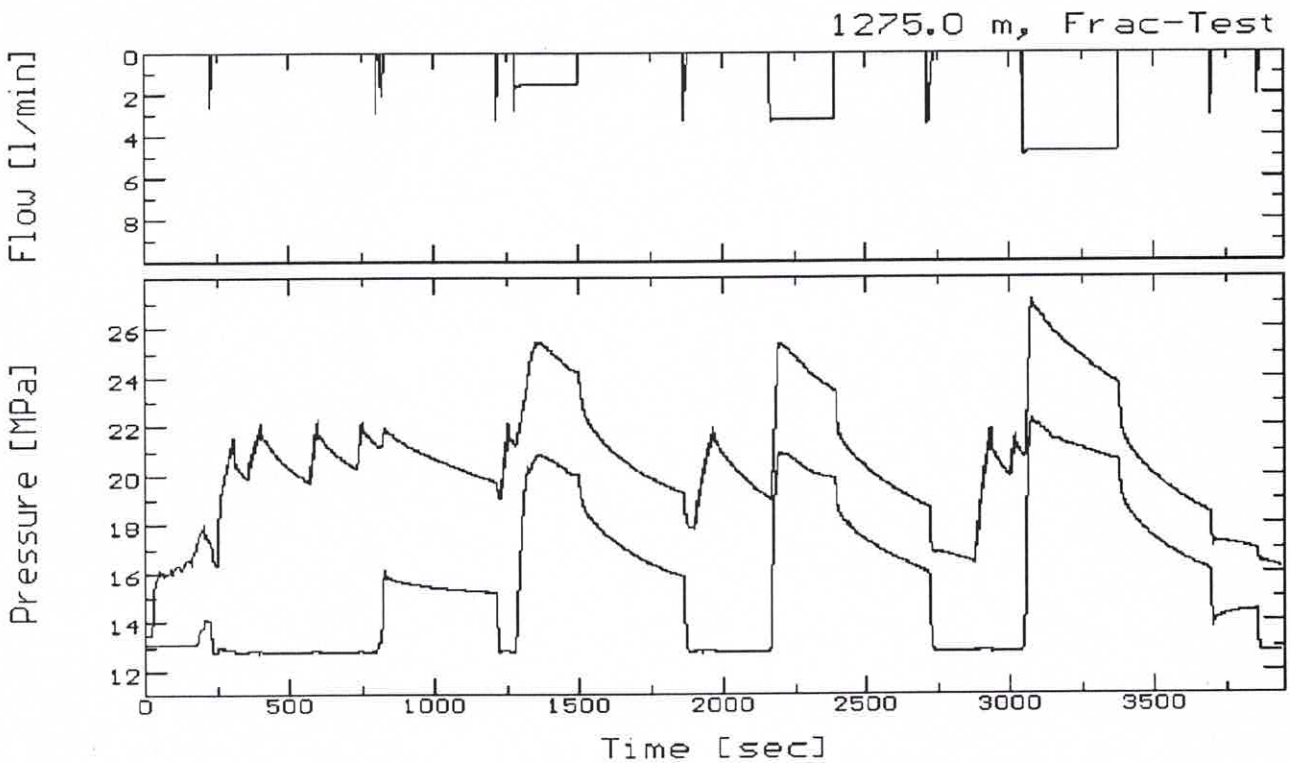


GEO-Meß-Systeme GmbH

CASED - HOLE TEST 7 AT 1275.0 m

Frac / Step - Rate Test

file: 1275.DAT

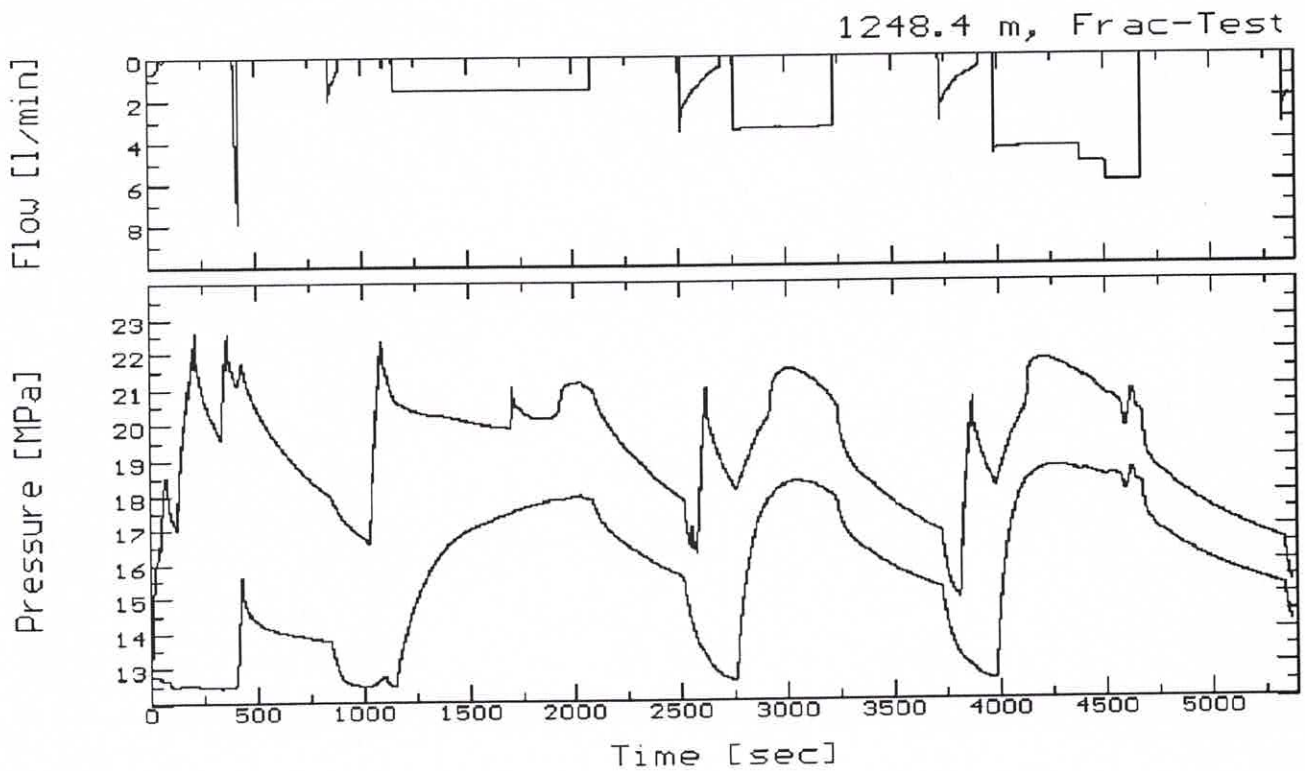


GEO-Meß-Systeme GmbH

CASED - HOLE TEST 8 AT 1248.4 m

Frac / Step - Rate Test

file: 1248.DAT

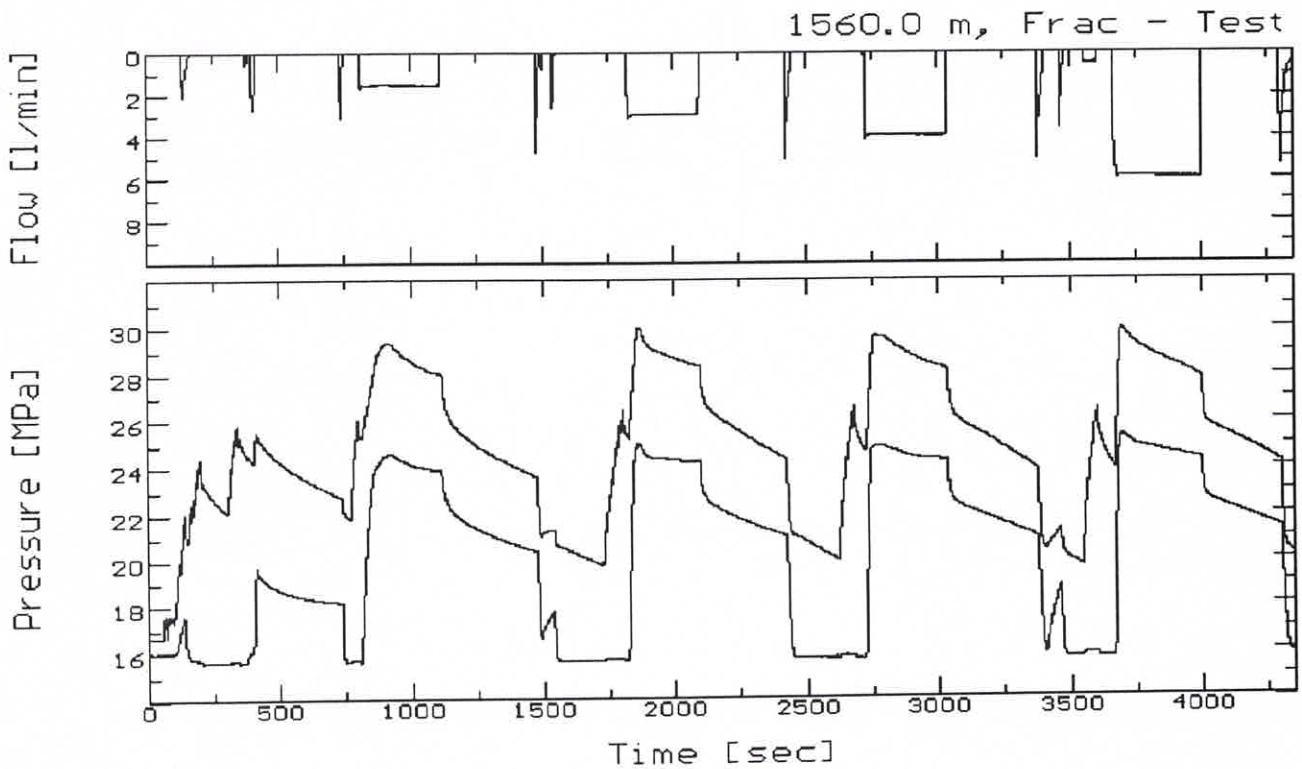


GEO-Meß-Systeme GmbH

CASED - HOLE TEST 9 AT 1560.0 m

Frac / Step - Rate Test

file: 1560.DAT

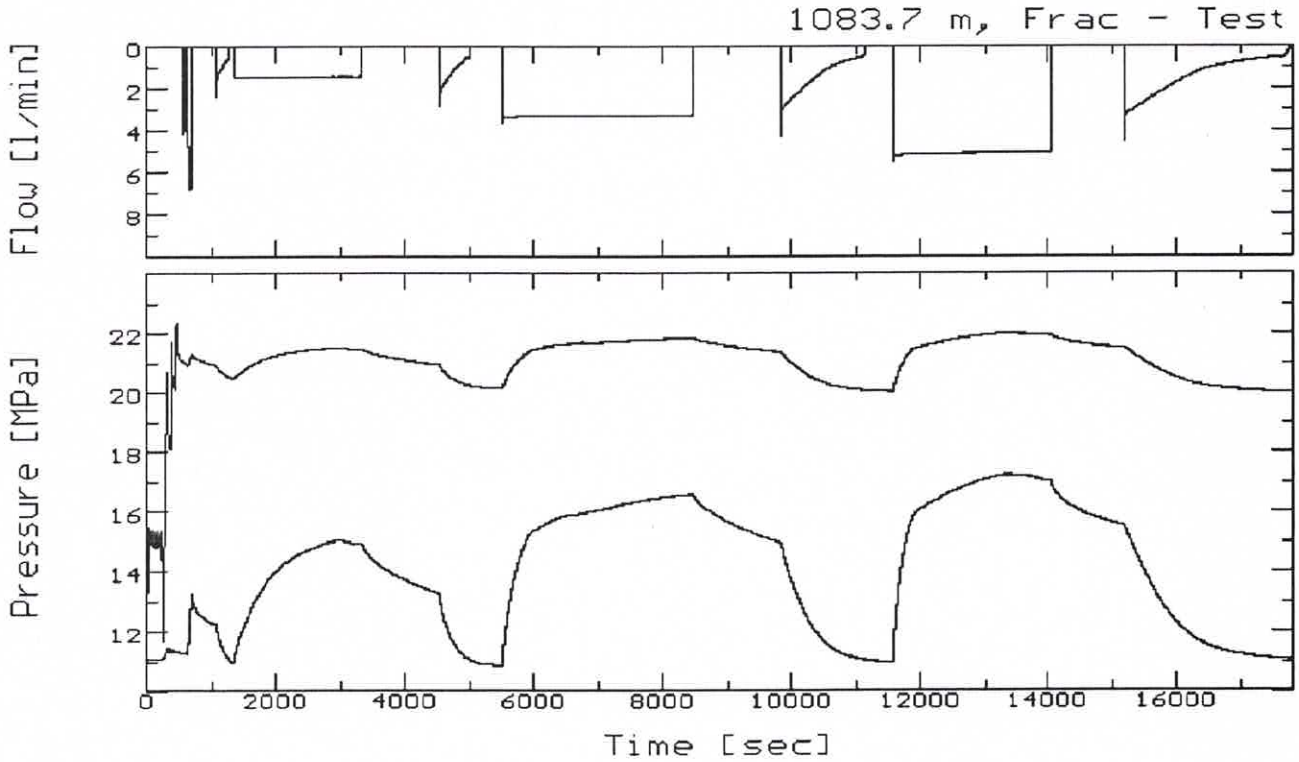


GEO-Meß-Systeme GmbH

CASED - HOLE TEST 10 AT 1083.7 m

Frac / Step - Rate Test

file: 1083.DAT



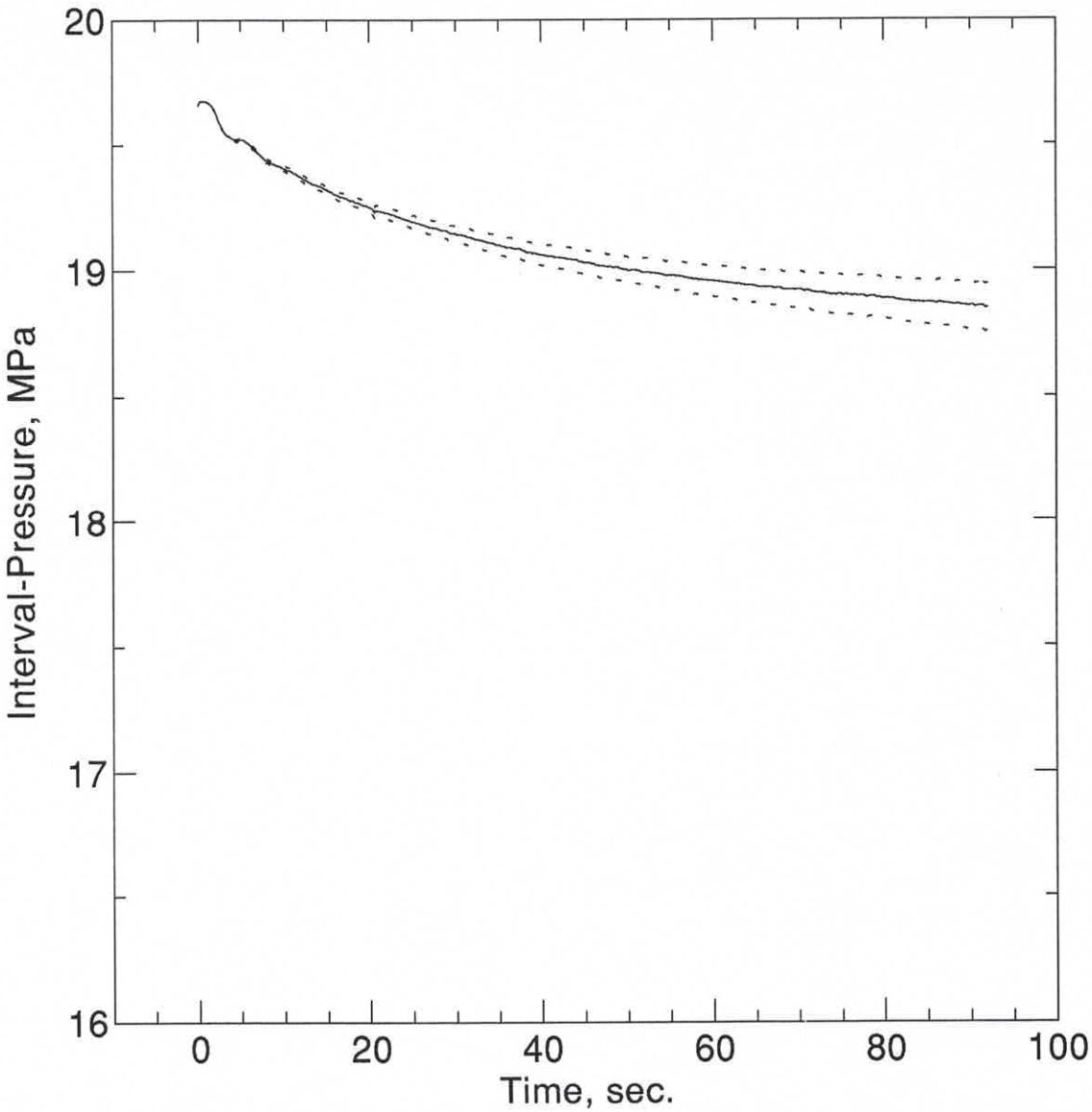
APPENDIX D

Analysis of Pressure Pulse Tests for
Permeability / Transmissivity Evaluation

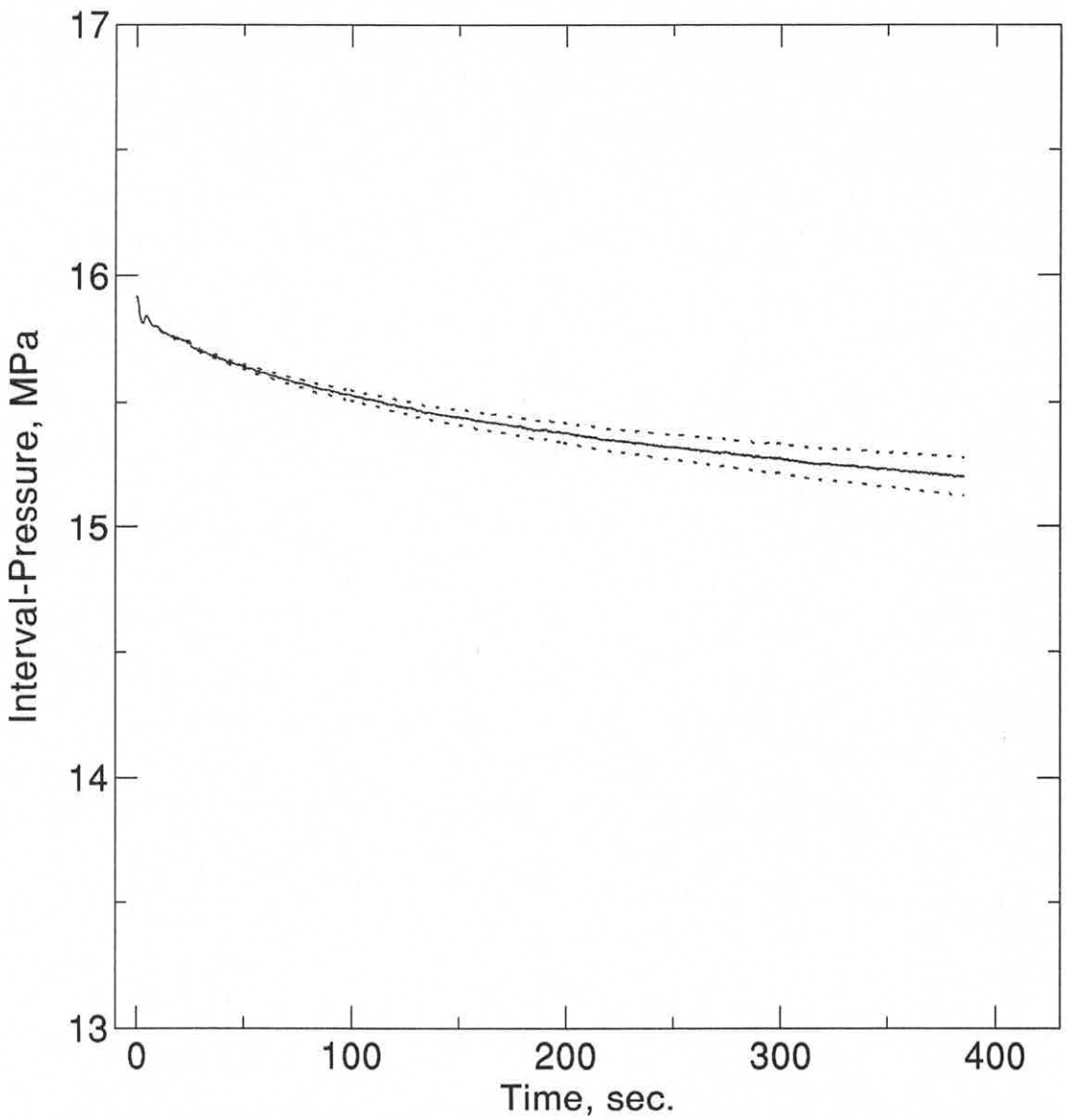
remarks :

- the solid line represents the measured data
- the broken lines represents the max. difference between measured and theoretically calculated pressure decline curves

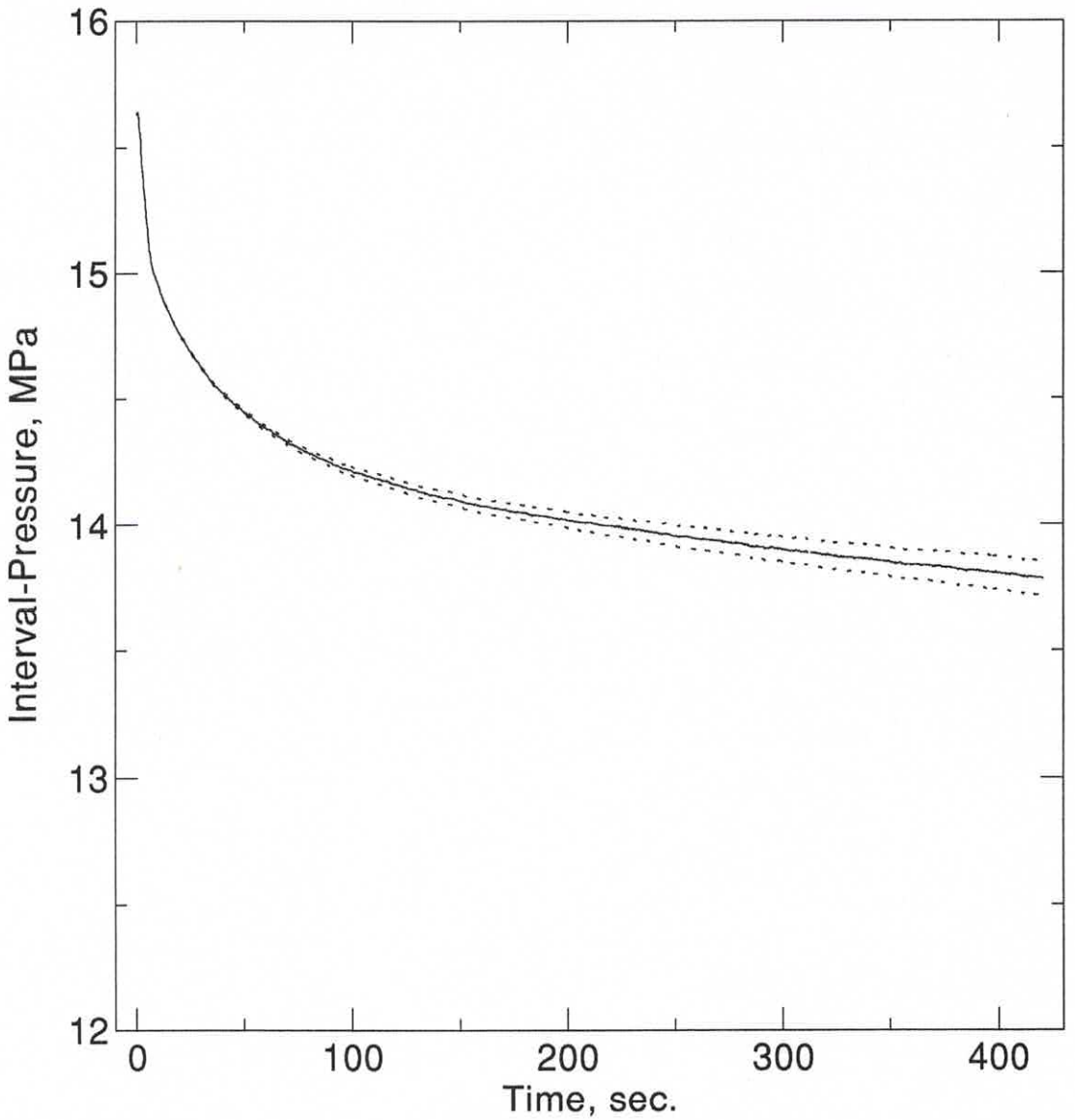
Test 6: 1591.5 m



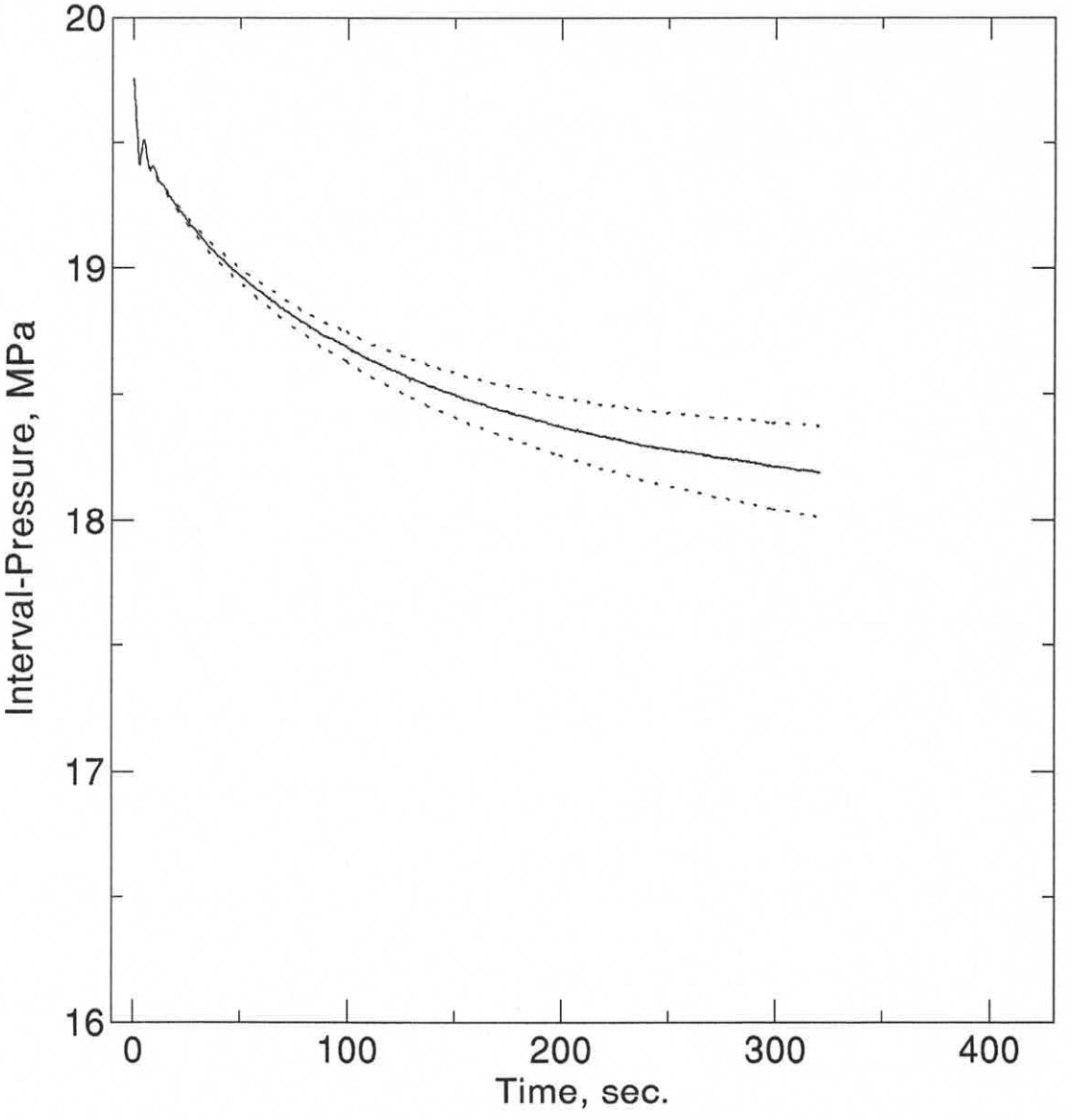
Test 7: 1275.0 m



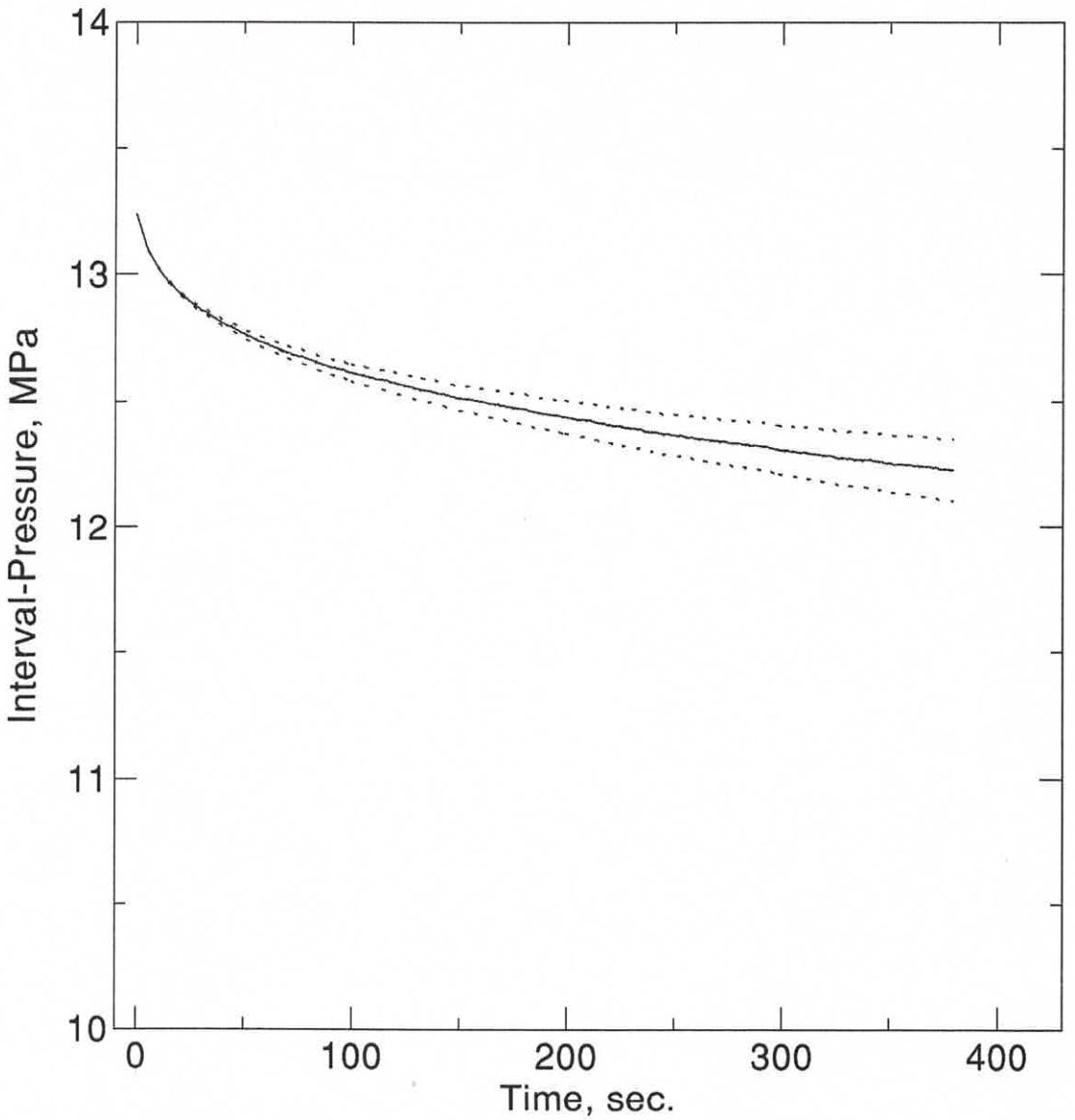
Test 8: 1248.4 m



Test 9: 1560.0 m



Test 10: 1083.7 m



APPENDIX E

Pressure Record Analysis for Stress Estimation

remarks :

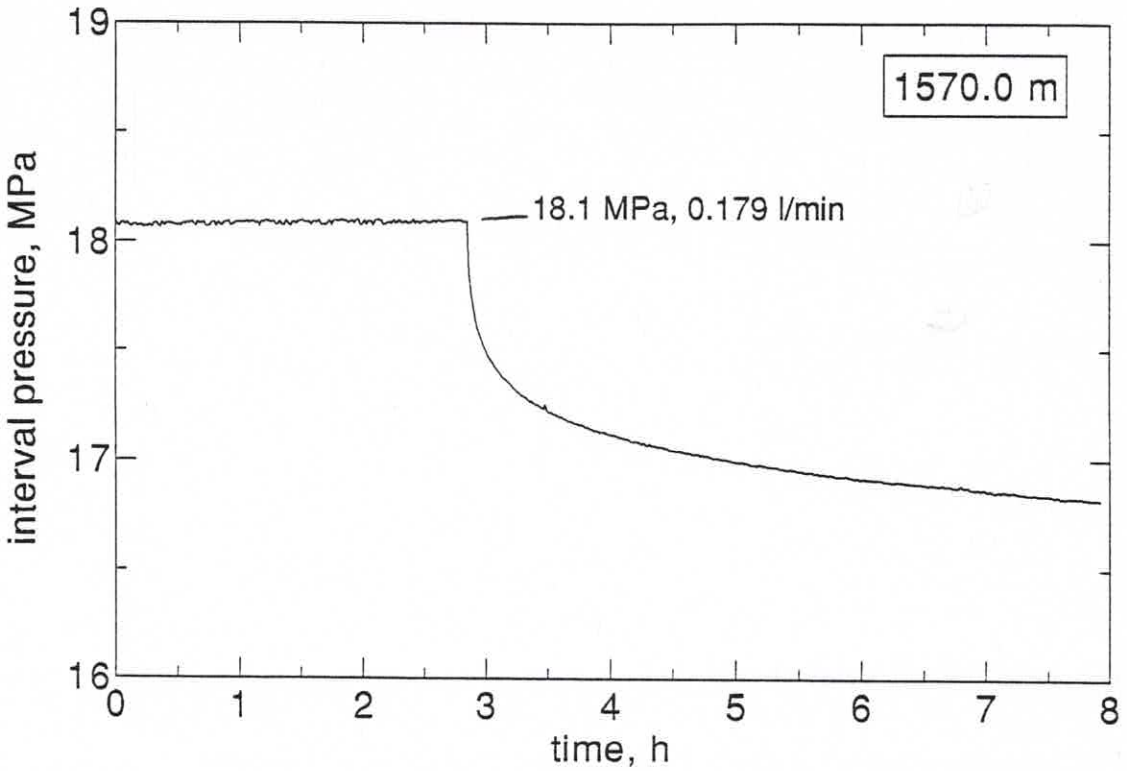
the analysis contains :

- several plots for the determination of pumping pressure P_p
- a pressure vs volume plot for the determination of P_r
- several plots for the determination of P_{si}

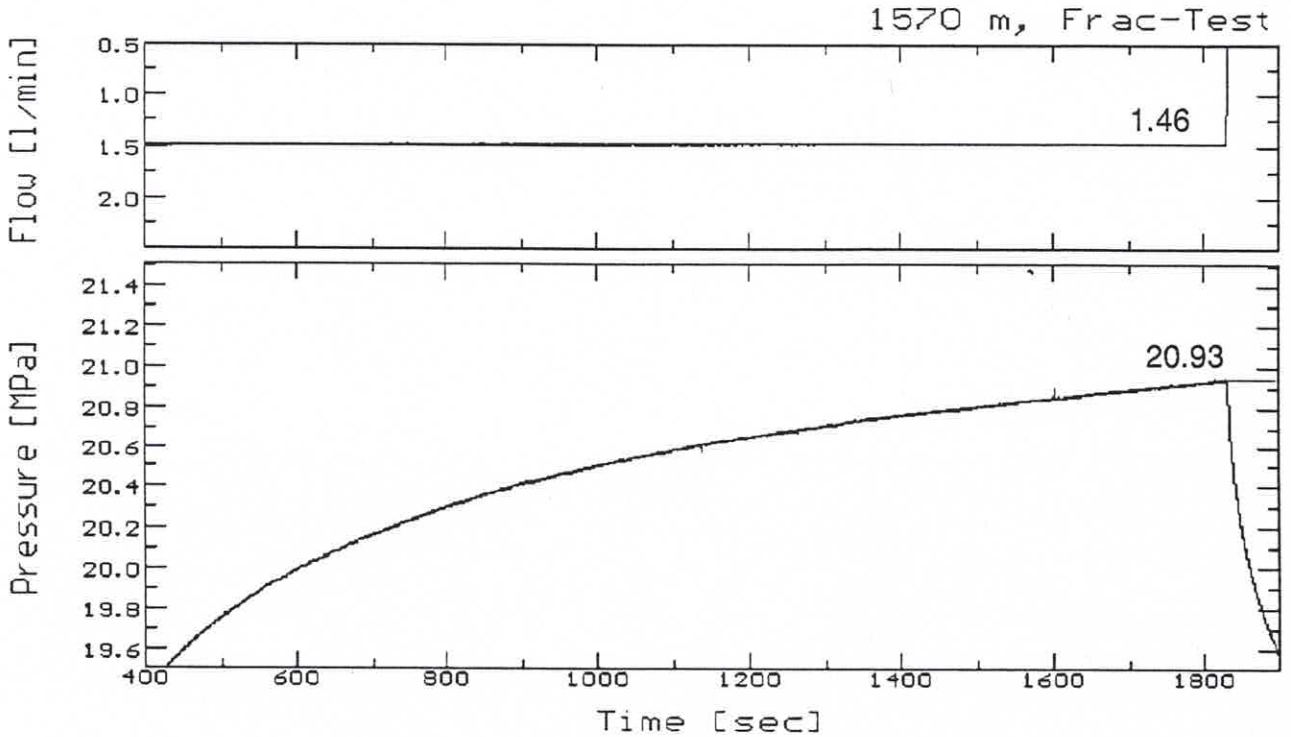
GEO-Meß-Systeme GmbH

Cased - Hole Test 1 AT 1570.0 m

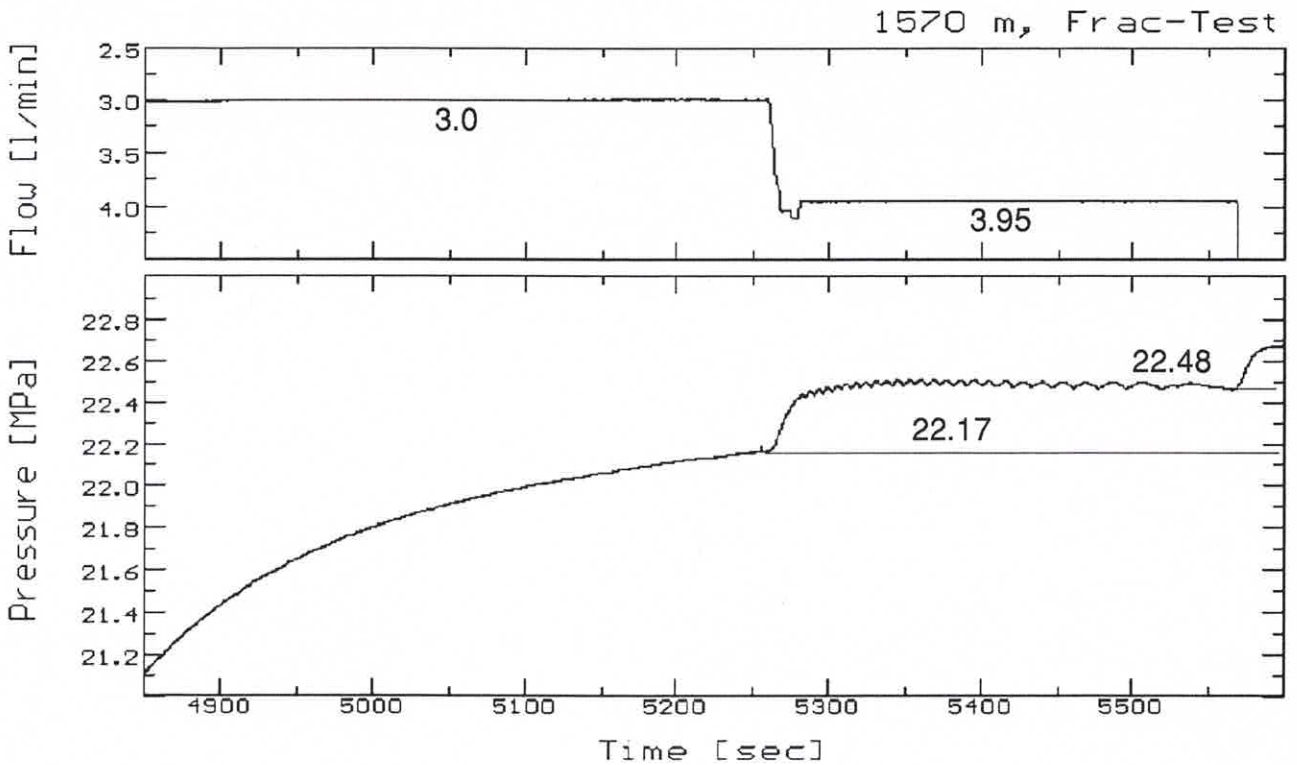
Estimation of P_p (main injection - test)



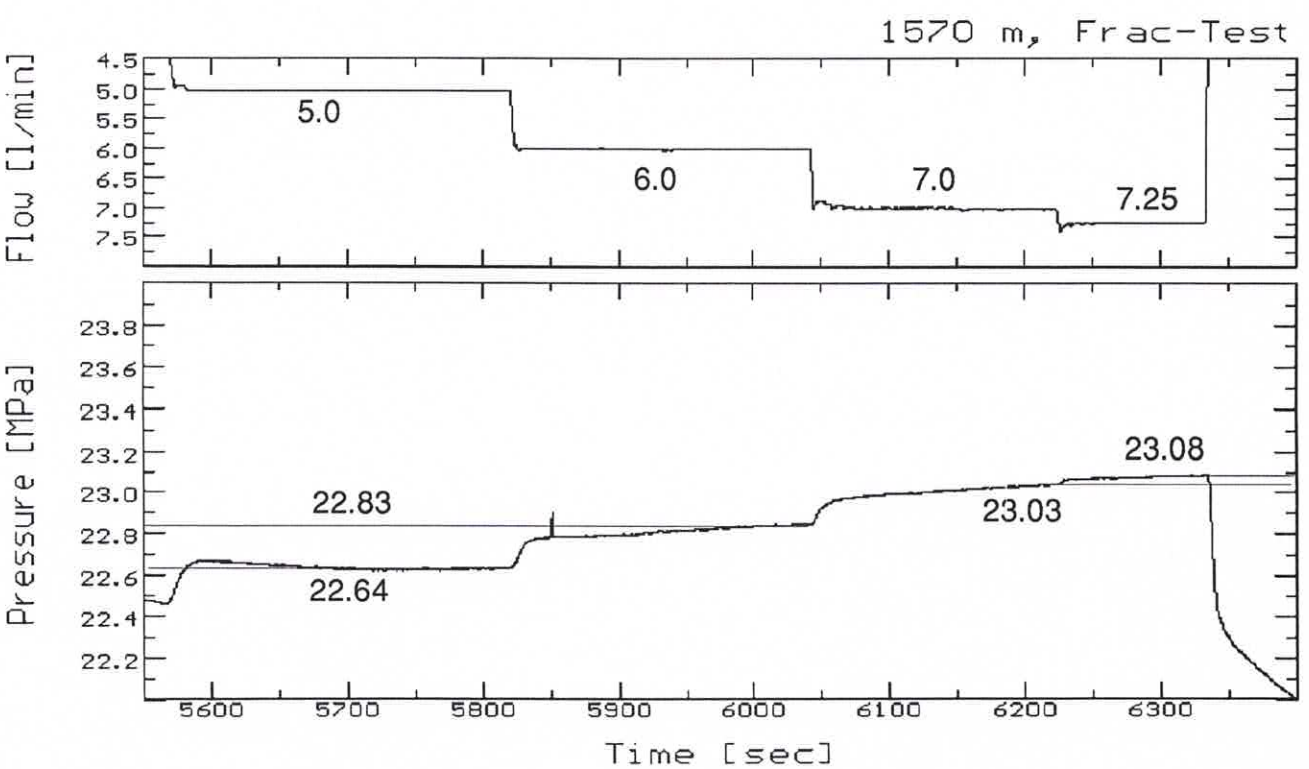
Estimation of P_p (frac - test, 1. injection - cycle)



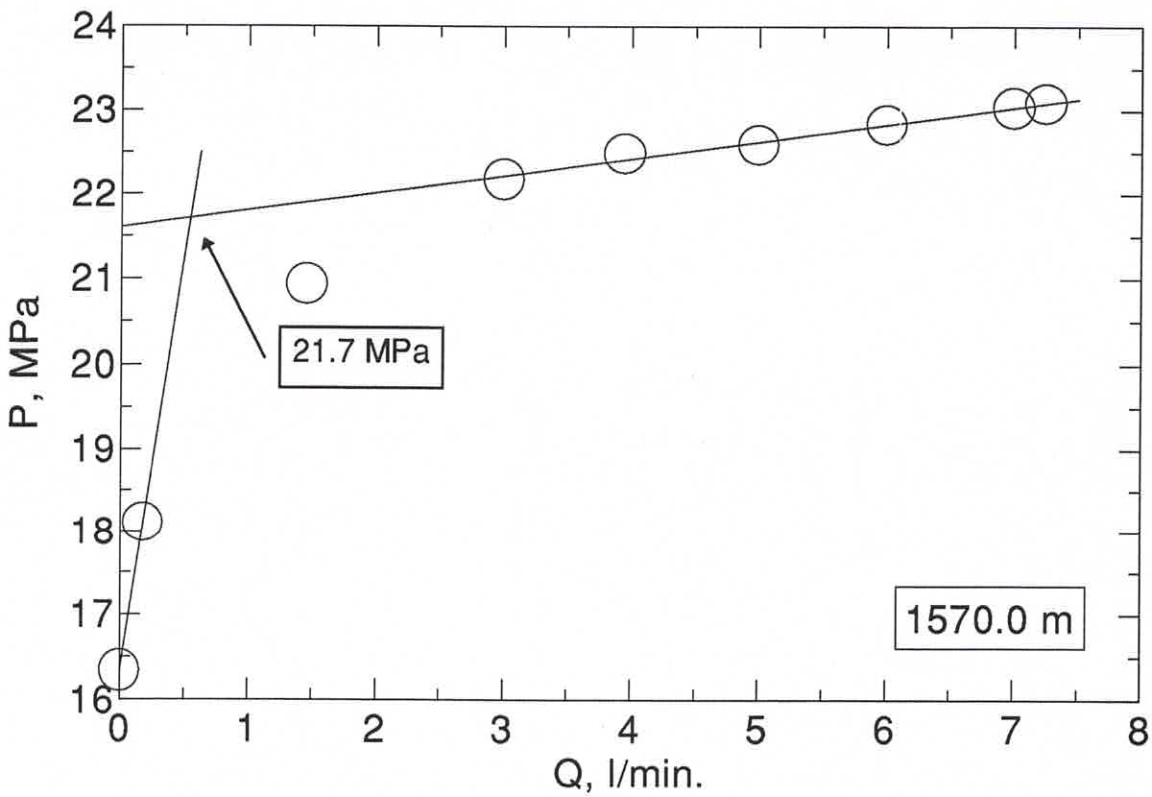
Estimation of P_p (frac - test, 2. injection - cycle, phase I)



Estimation of P_p (frac - test, 2. injection - cycle, phase II)



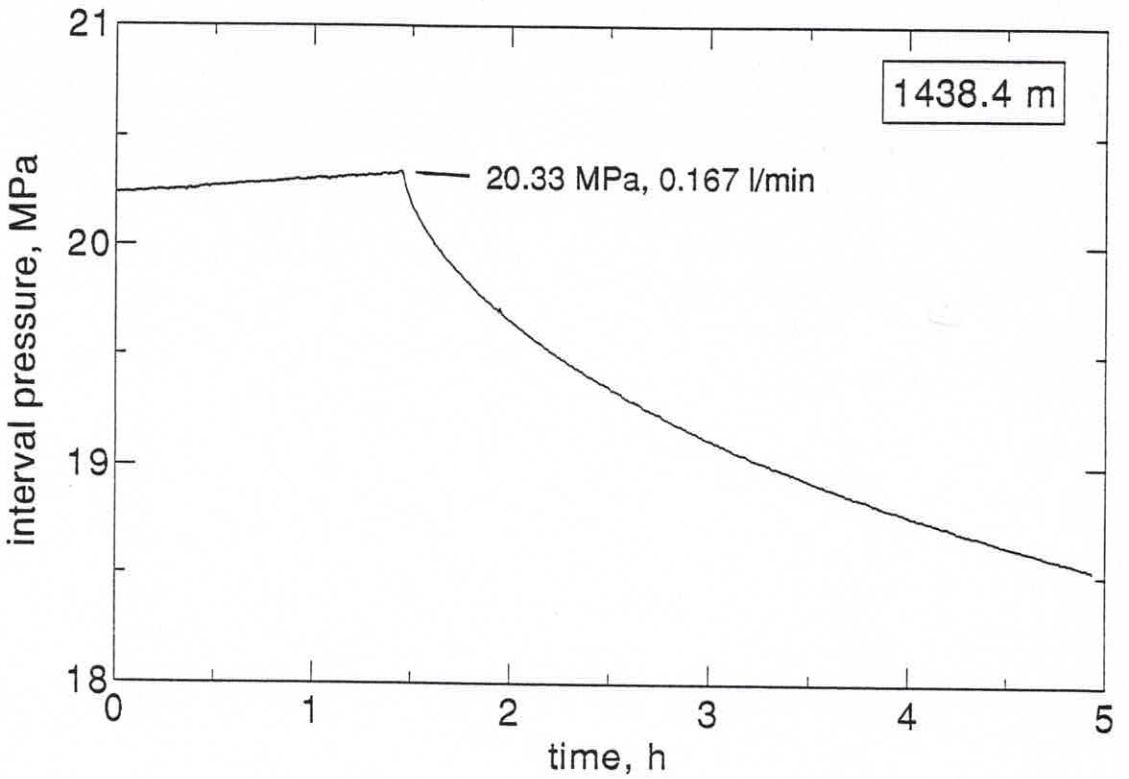
analysis of pumping pressure data



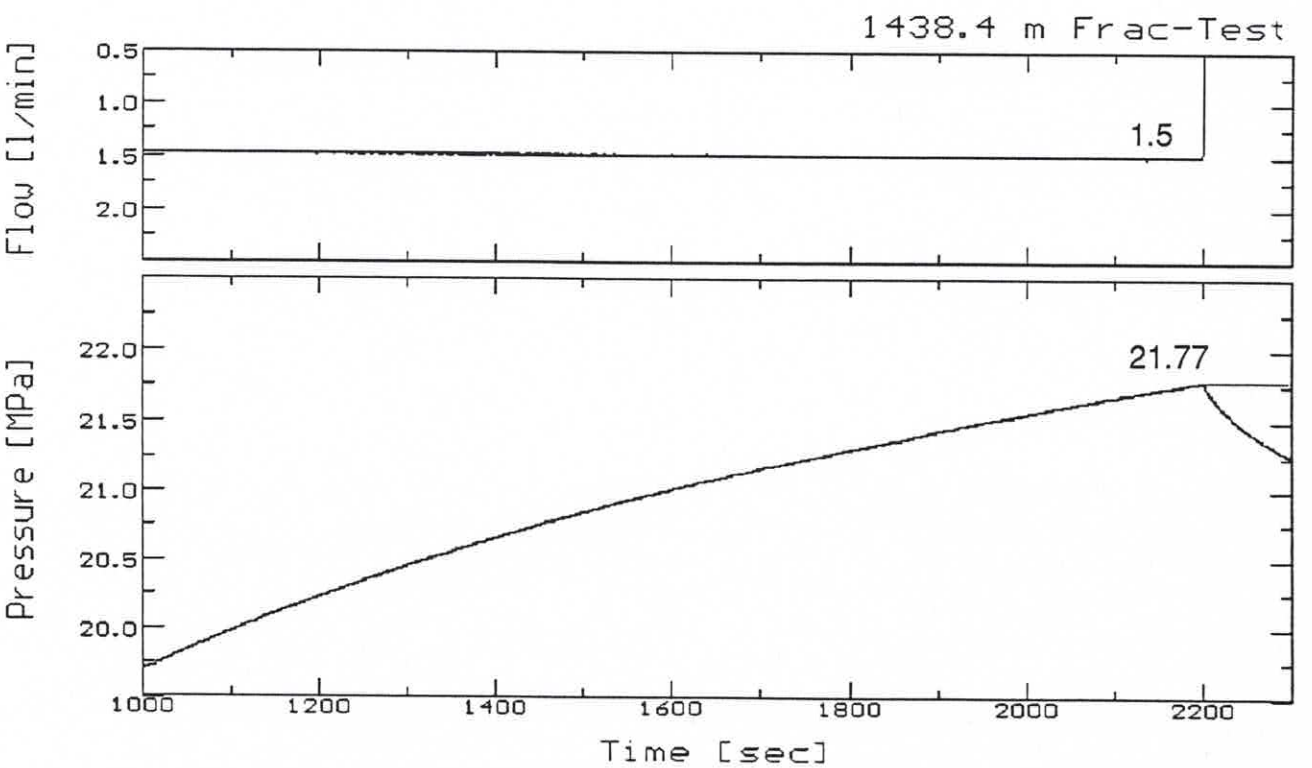
GEO-Meß-Systeme GmbH

Cased - Hole Test 2 AT 1438.4 m

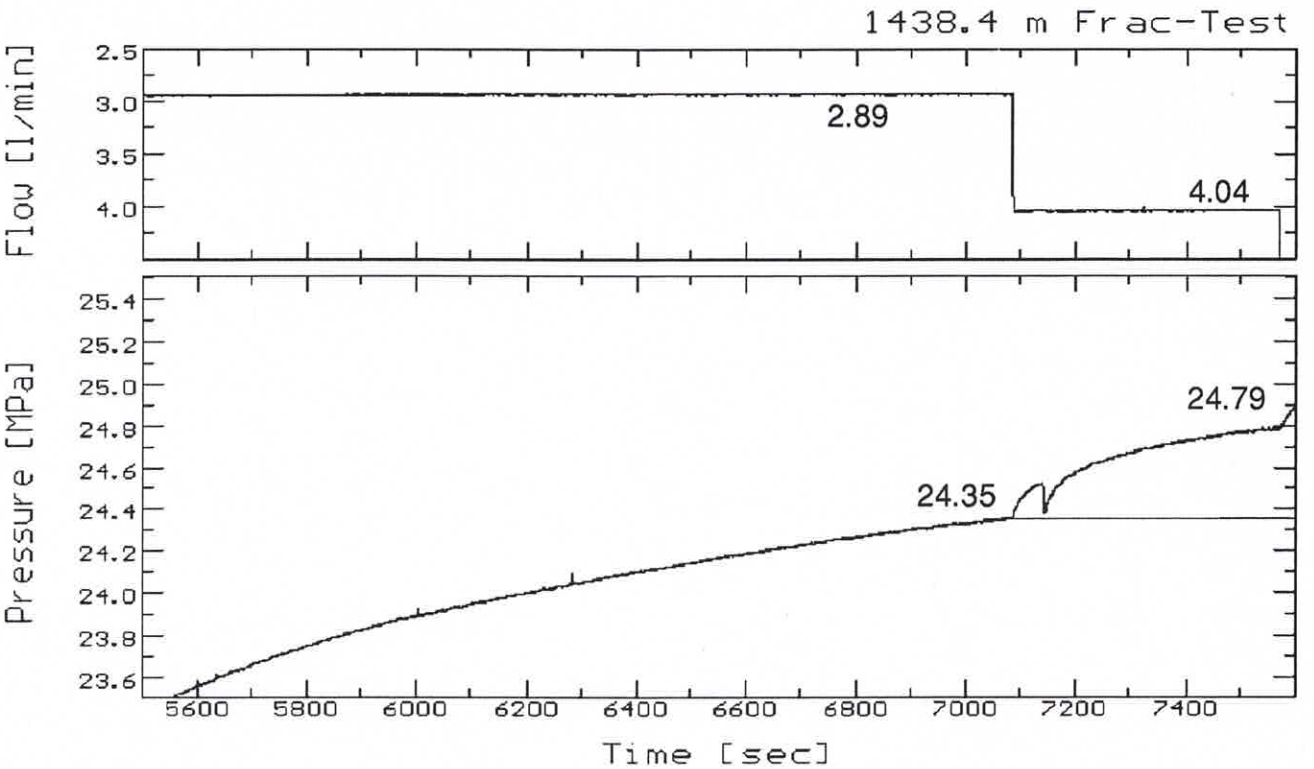
Estimation of P_p (main injection - test)



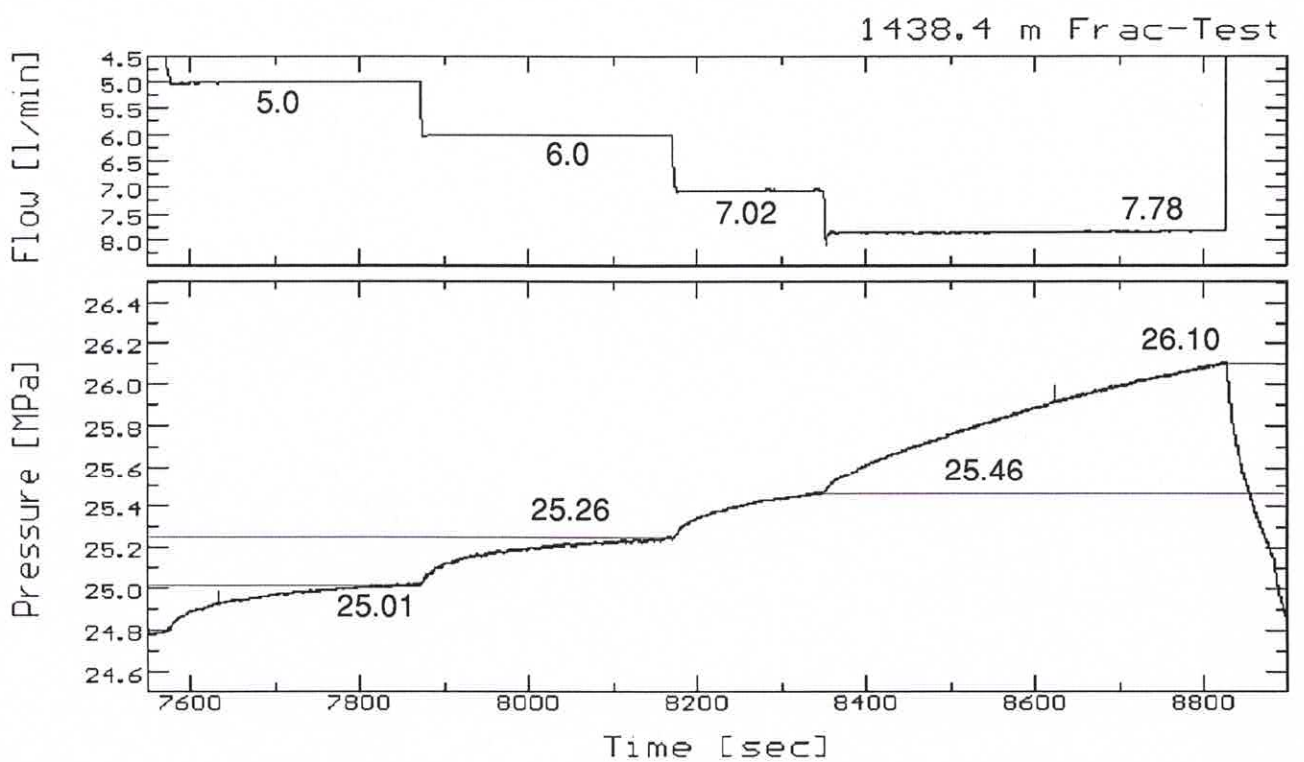
Estimation of P_p (1. injection - cycle)



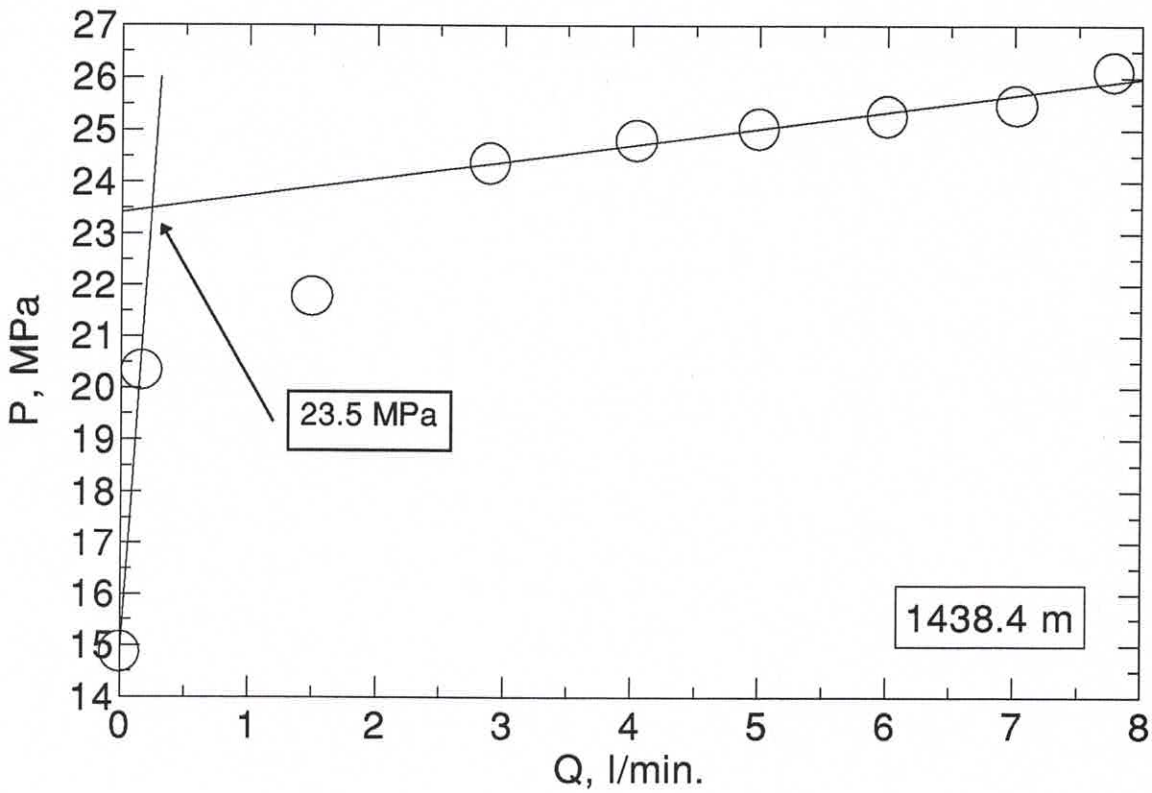
Estimation of P_p (frac - test, 2. injection - cycle, phase I)



Estimation of P_p (frac - test, 2. injection - cycle, phase II)



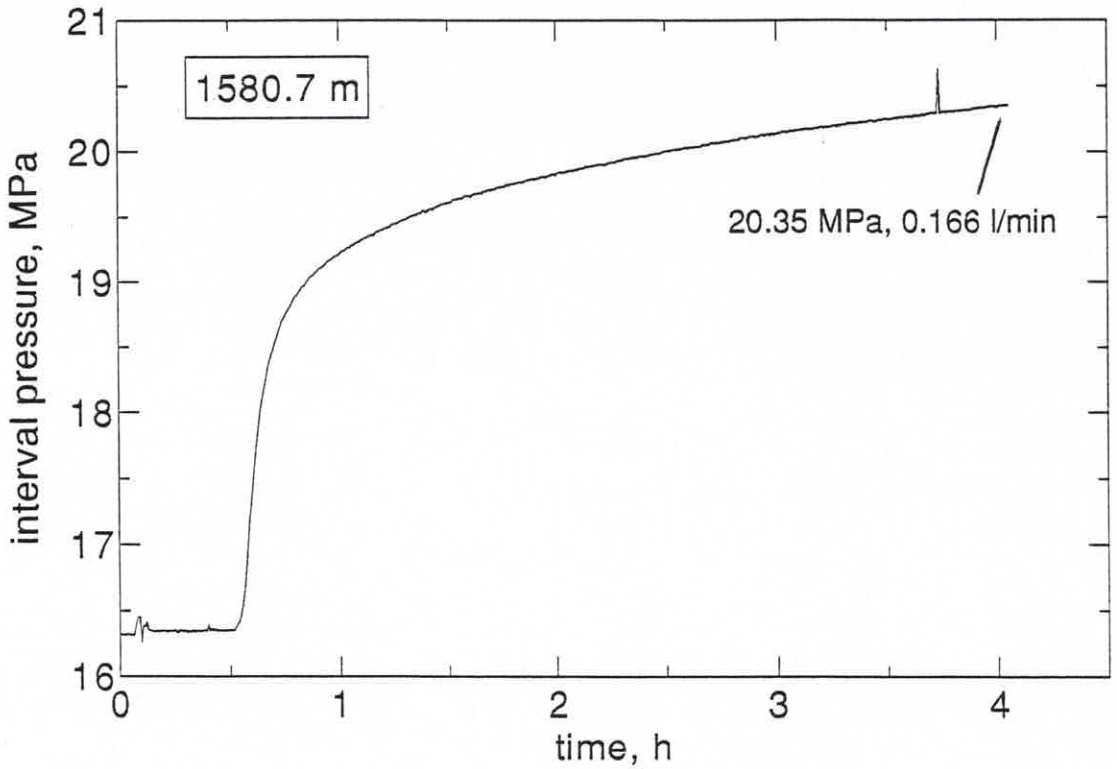
analysis of pumping pressure data



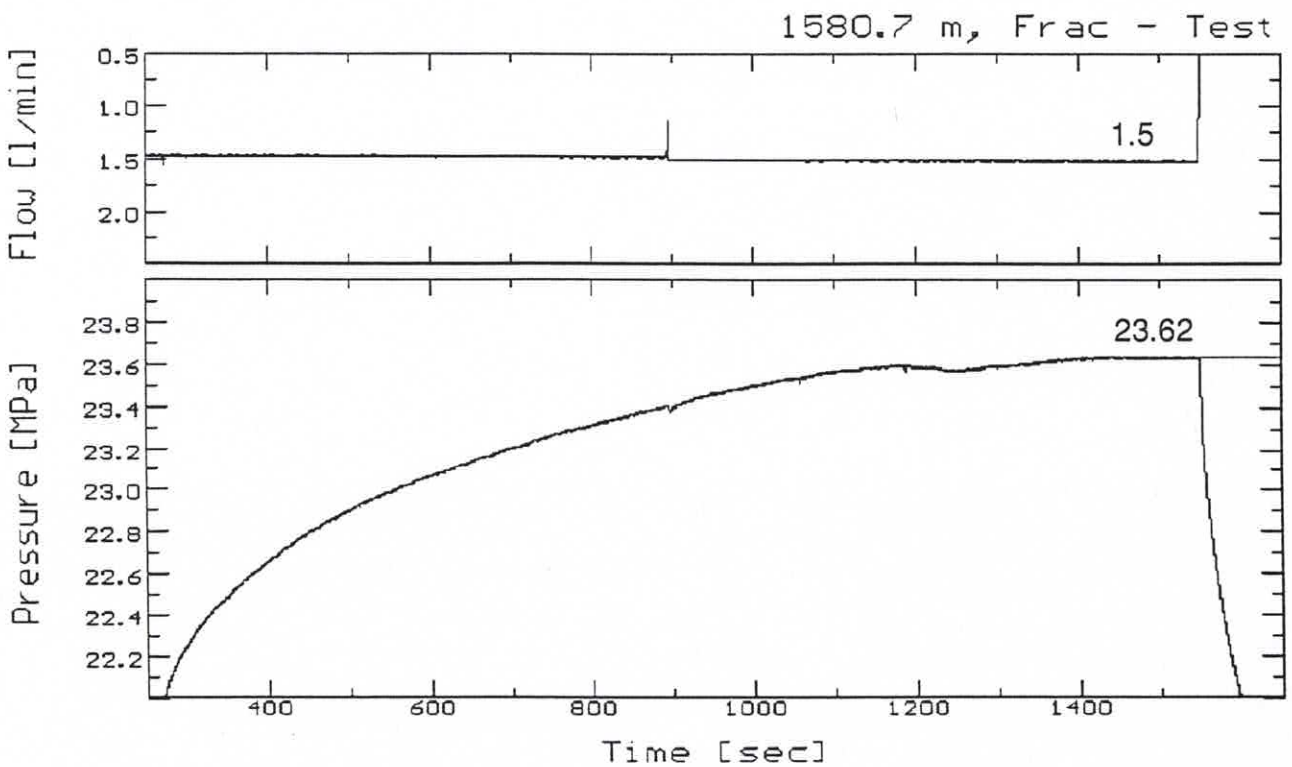
GEO-Meß-Systeme GmbH

Cased - Hole Test 3 AT 1580.7 m

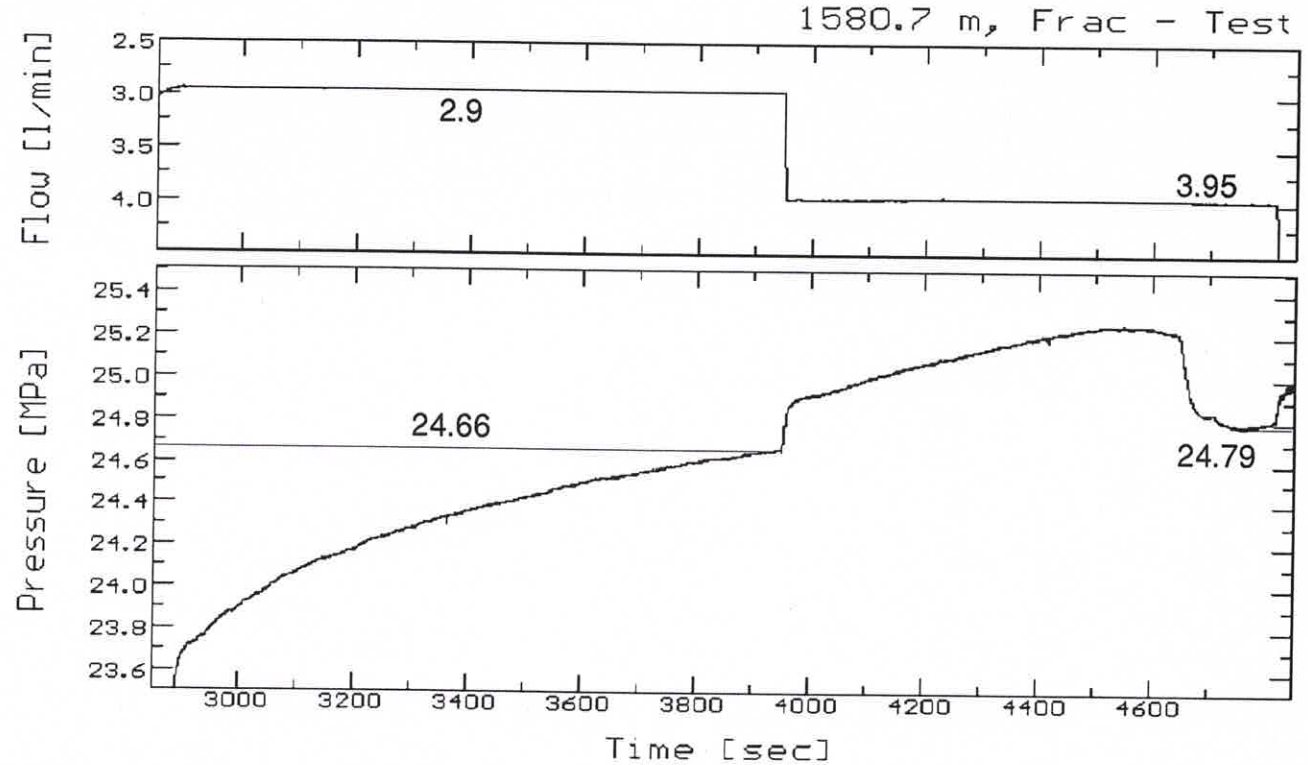
Estimation of P_p (main injection - test)



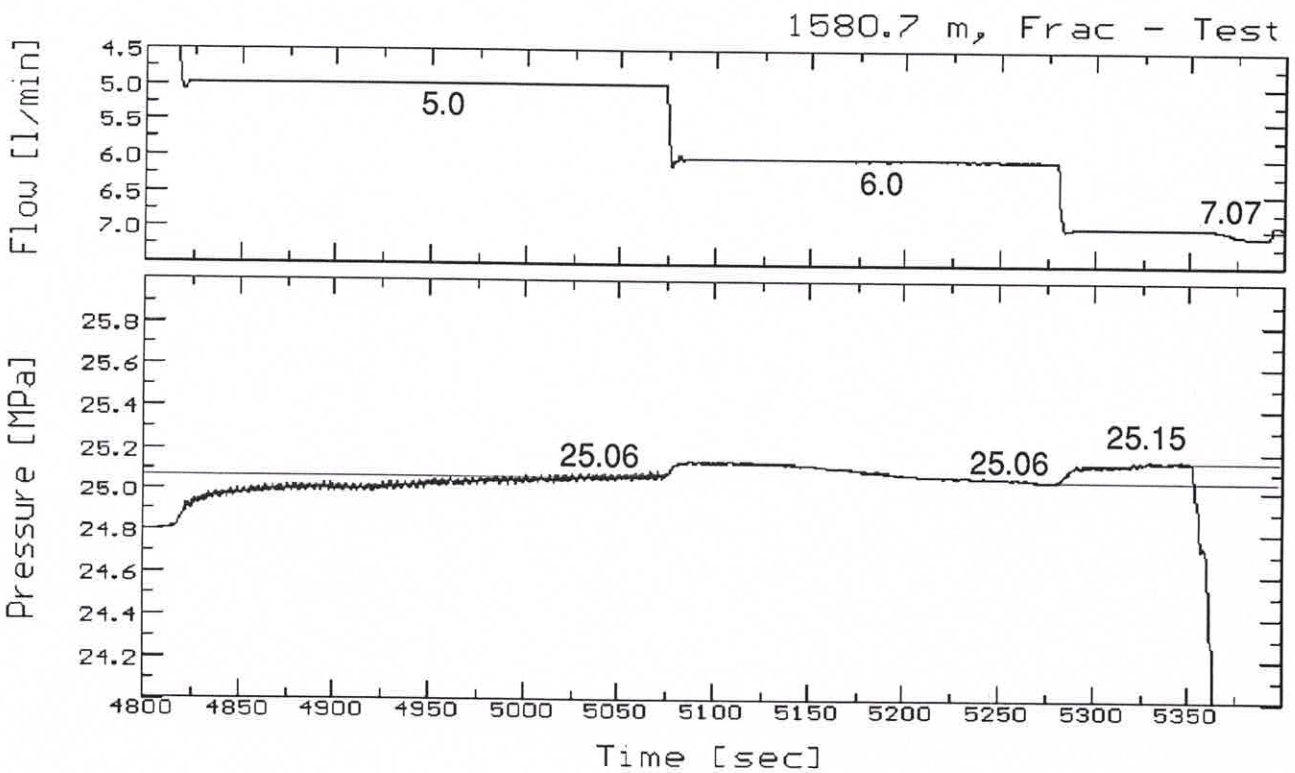
Estimation of P_p (frac - test, 1. injection - cycle)



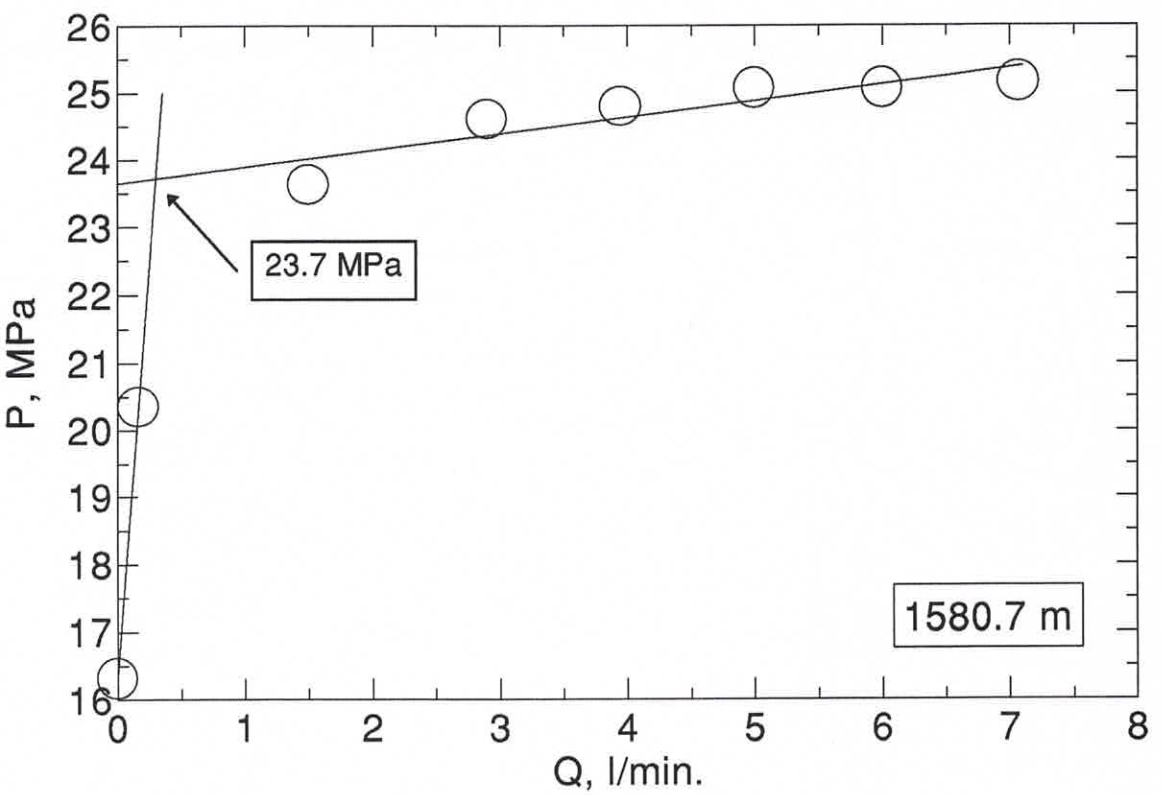
Estimation of P_p (frac - test, 2. injection - cycle, phase I)



Estimation of P_p (frac - test, 2. injection - cycle, phase II)

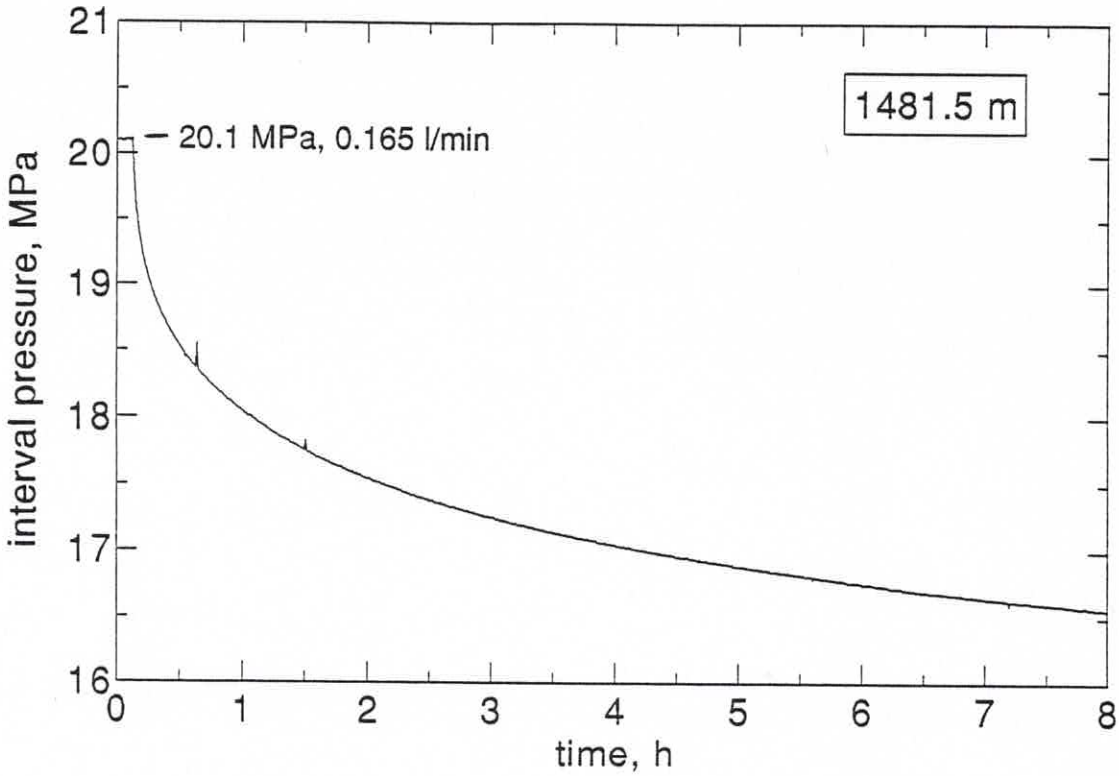


analysis of pumping pressure data

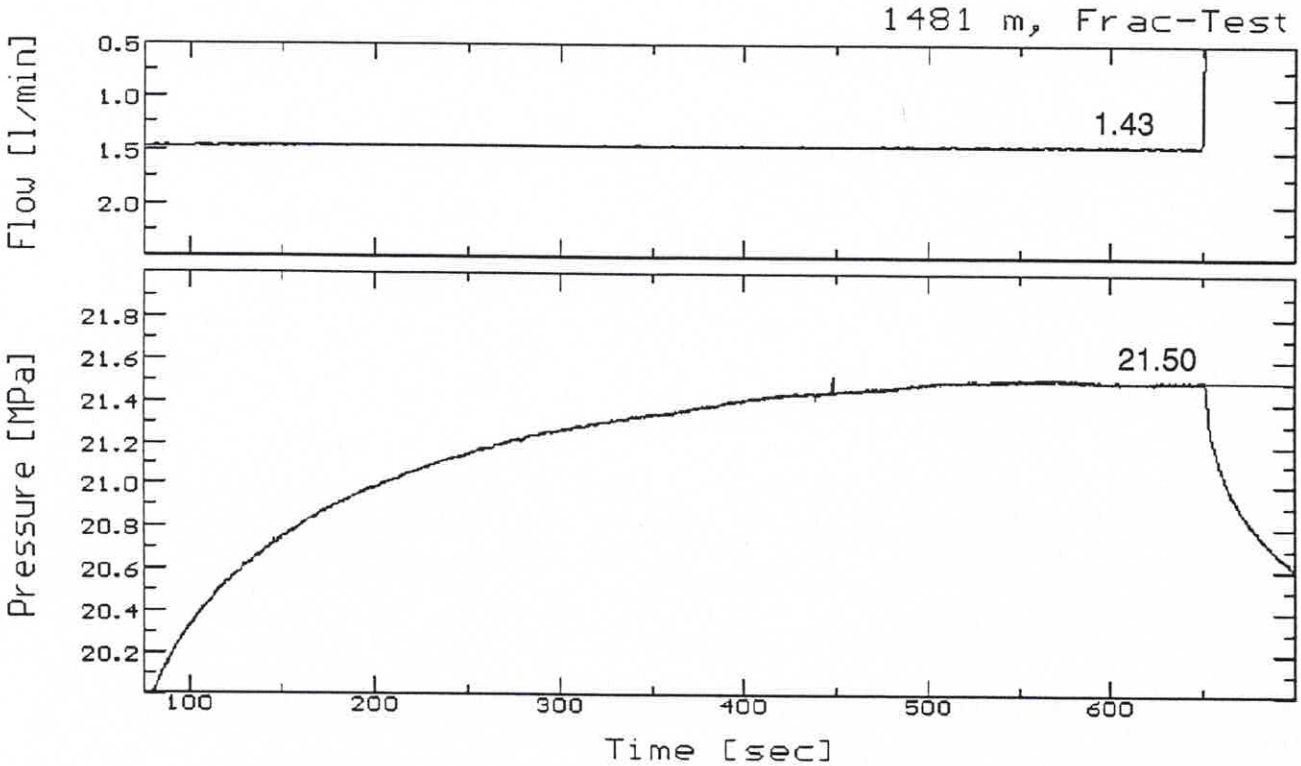


Cased - Hole Test 4 AT 1481.5 m

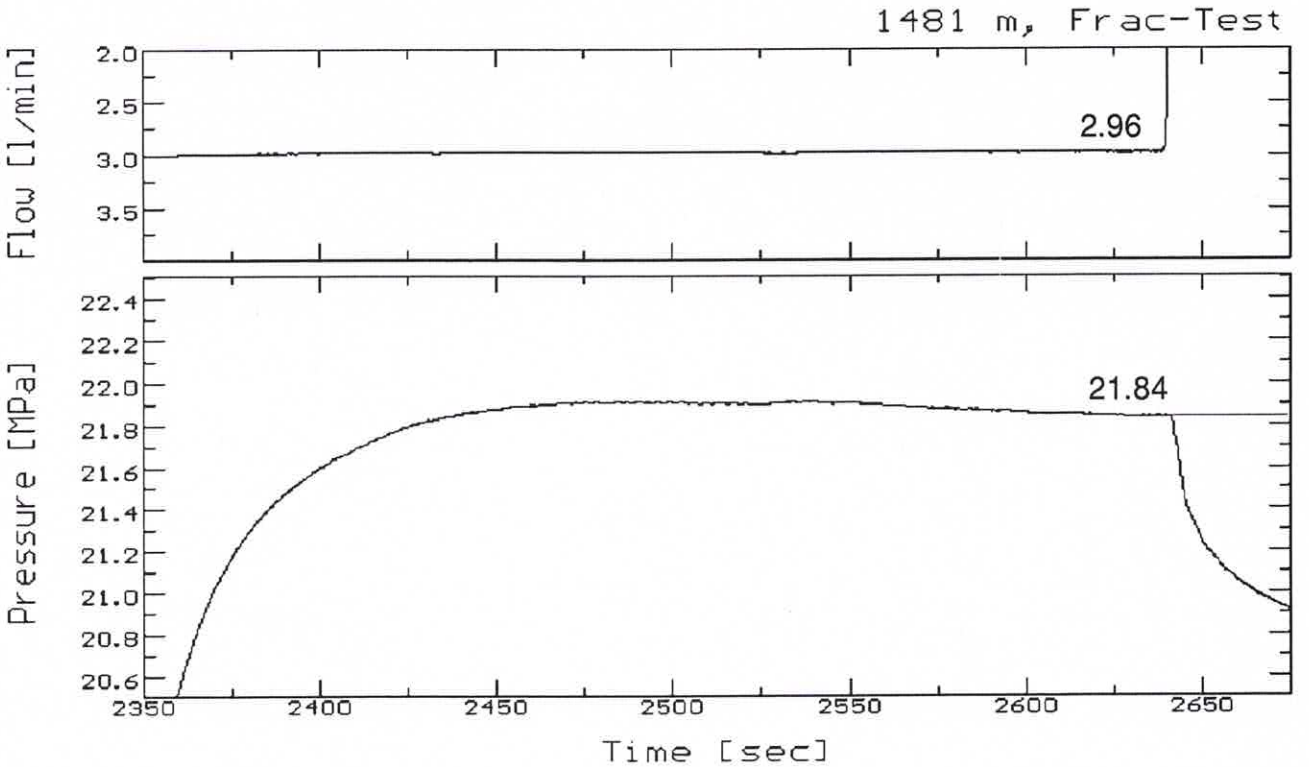
Estimation of P_p (main injection - test)



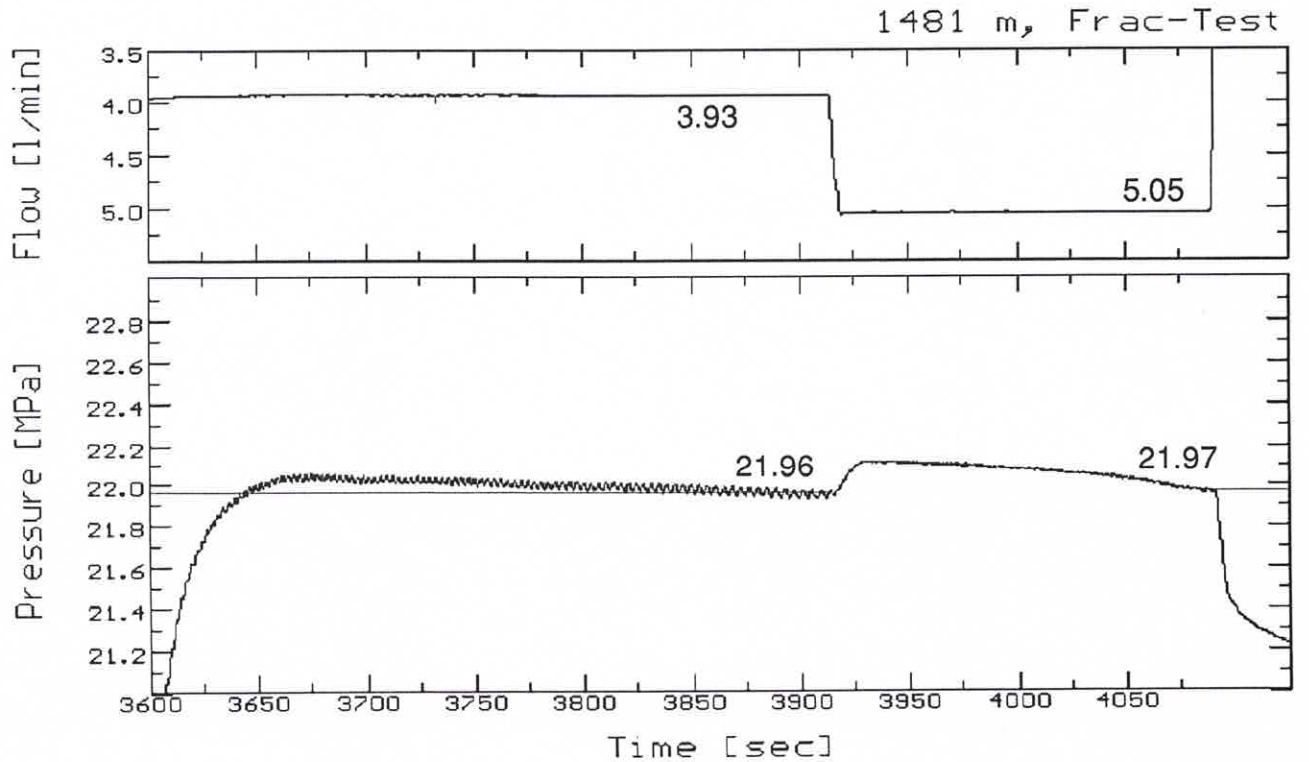
Estimation of P_p (frac - test, 1. injection - cycle)



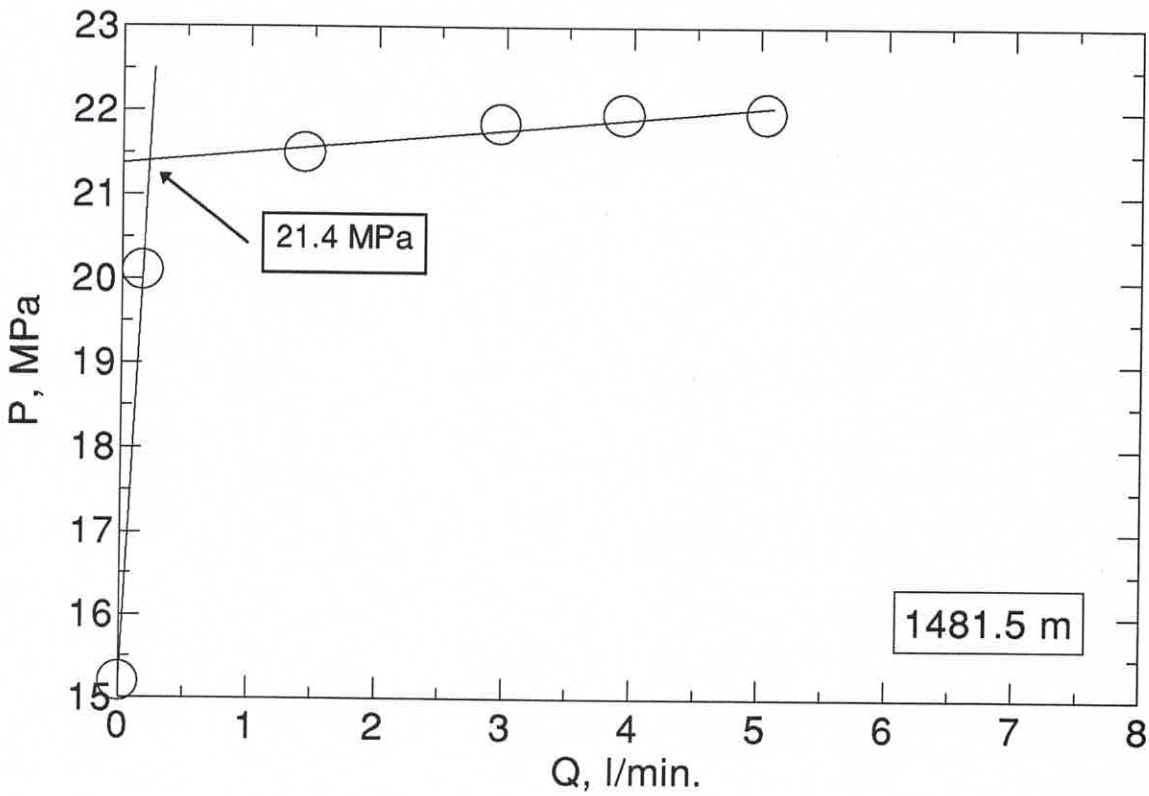
Estimation of P_p (frac - test, 2. injection - cycle)



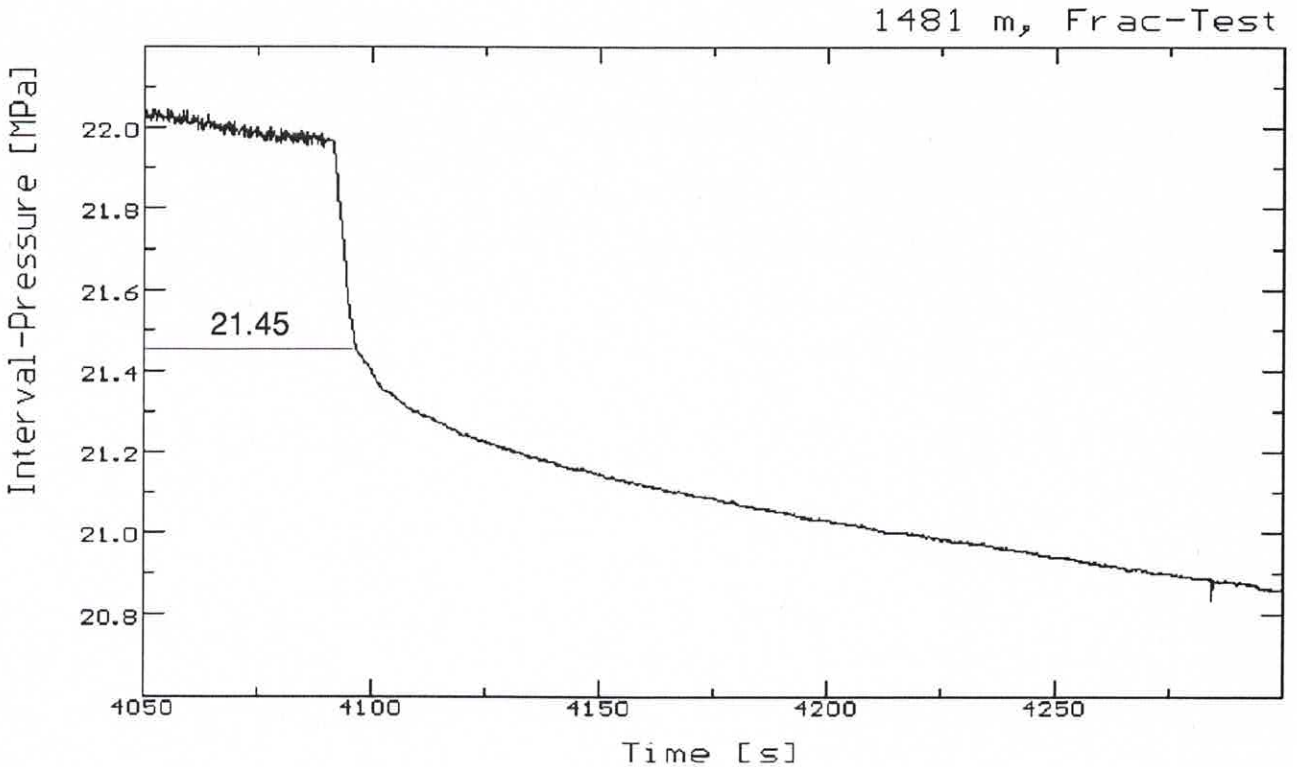
Estimation of P_p (frac - test, 3. injection - cycle)



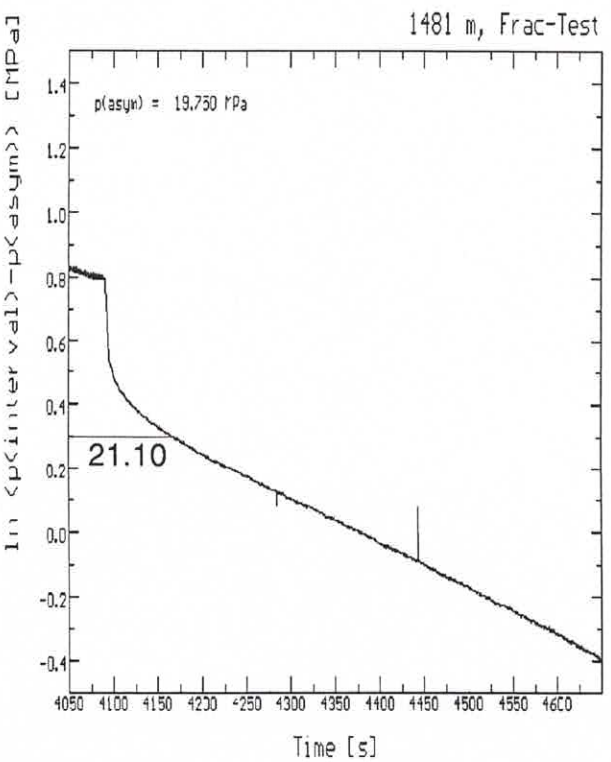
analysis of pumping pressure data



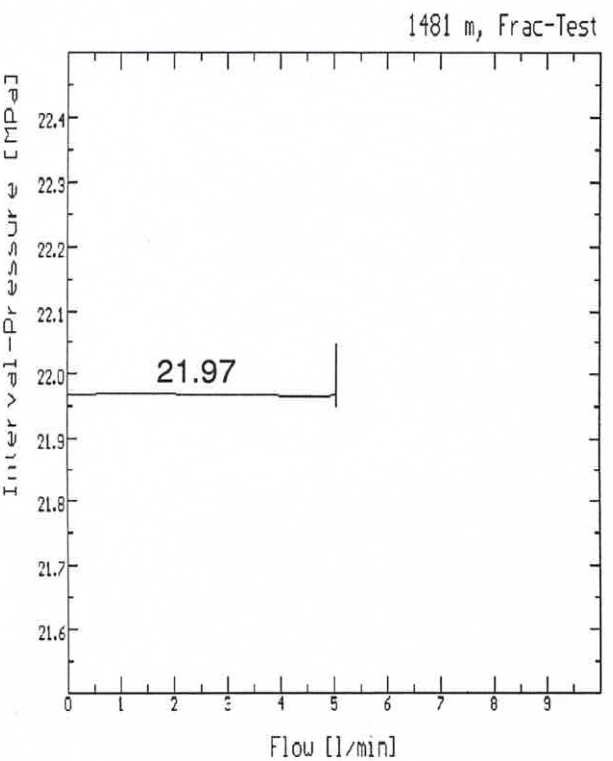
Estimation of P_{si}



Estimation of $P_{si,min}$



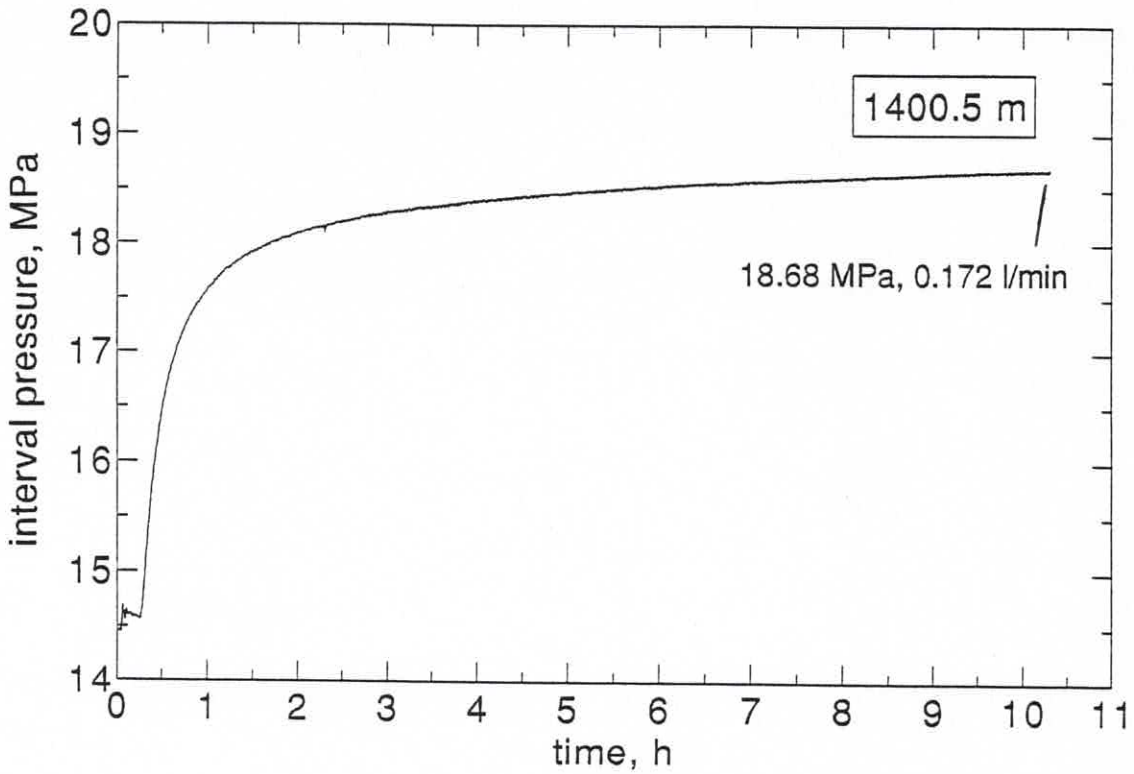
Estimation of $P_{si,max}$



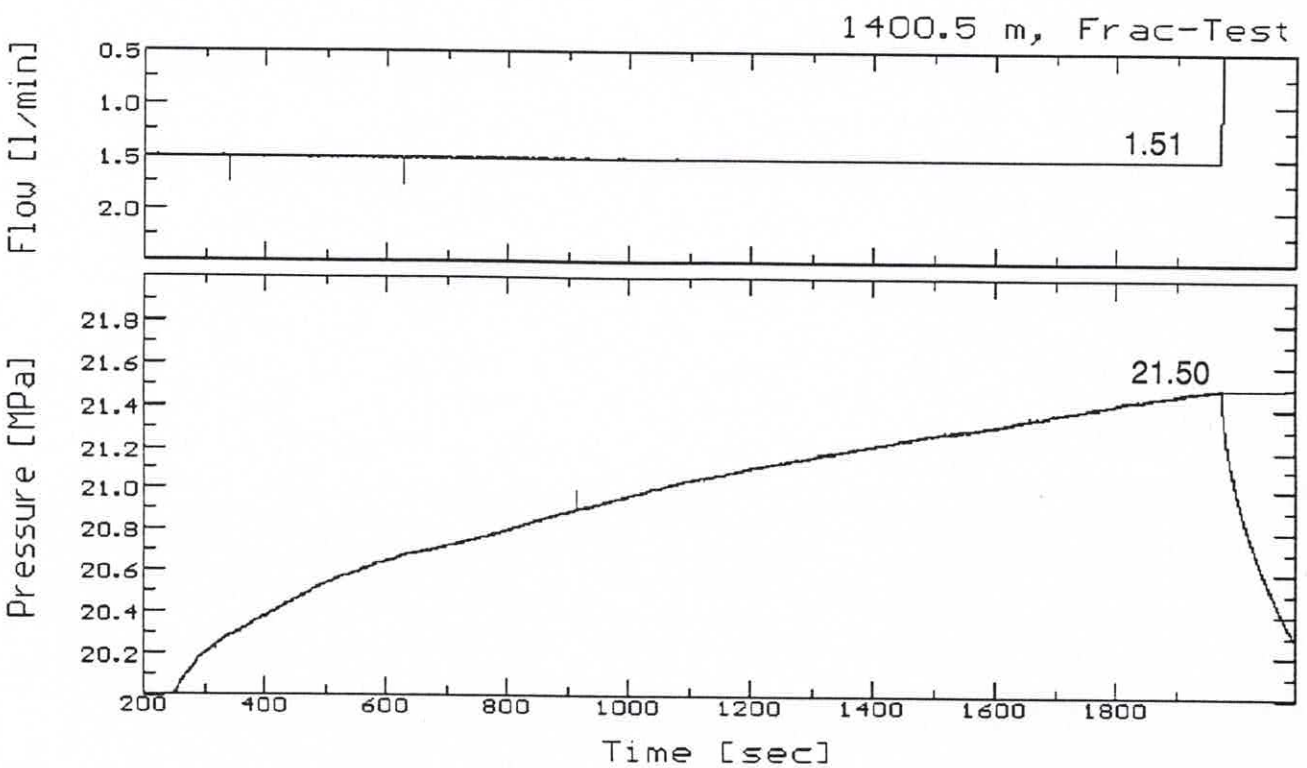
GEO-Meß-Systeme GmbH

Cased - Hole Test 5 AT 1400.5 m

Estimation of P_p (main injection - test)

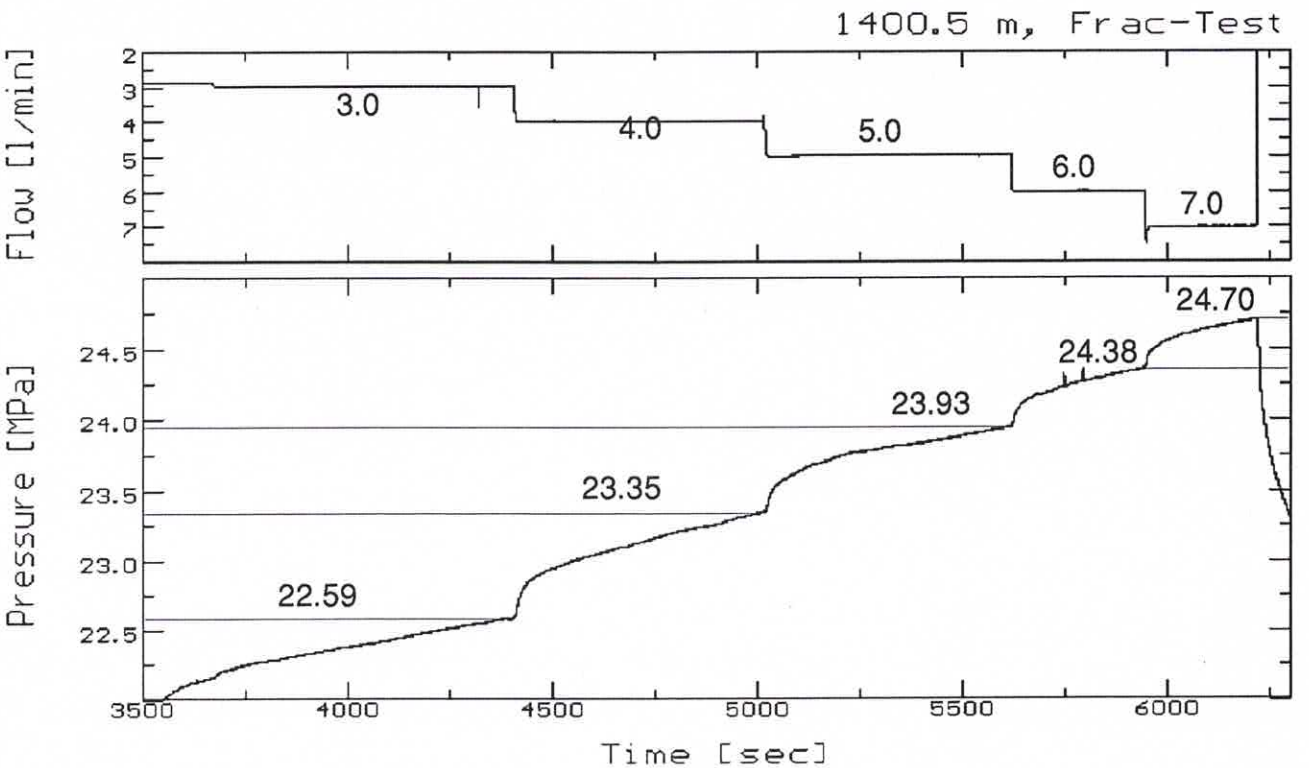


Estimation of P_p (frac - test, 1. injection - cycle)

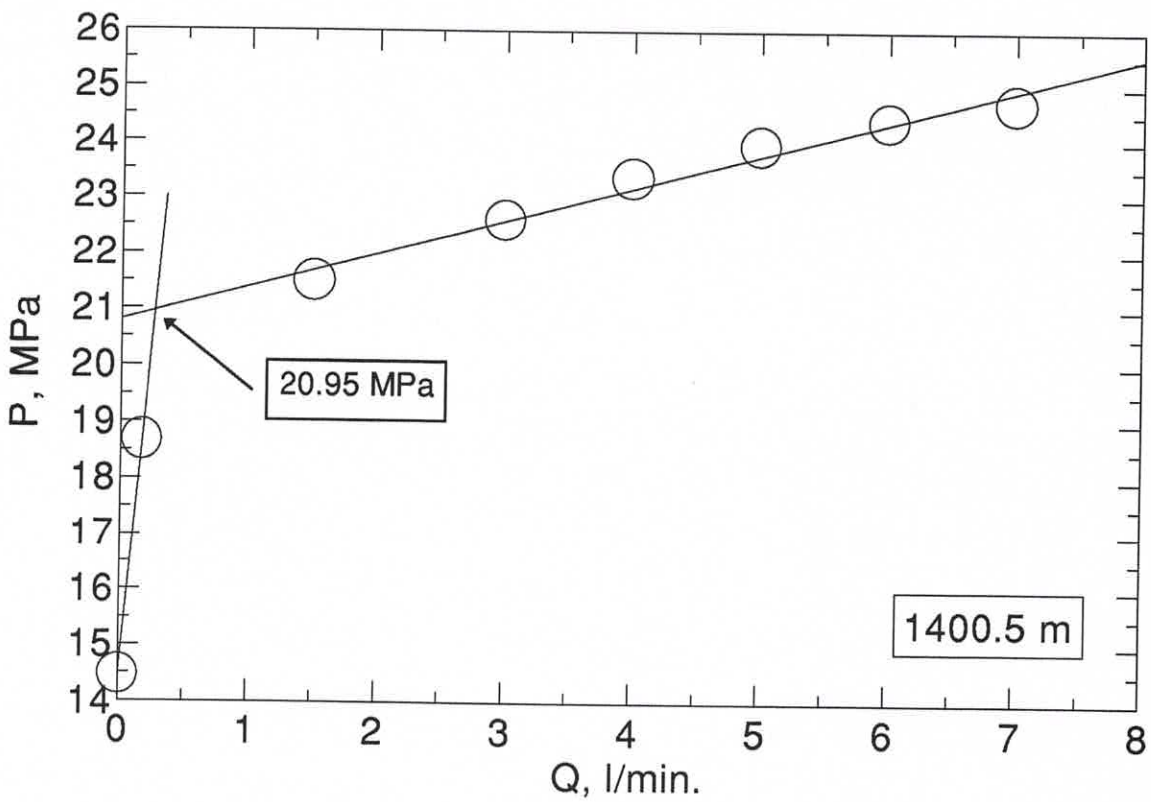


GEO-Meß-Systeme GmbH

Estimation of P_p (frac - test, 2. injection - cycle)



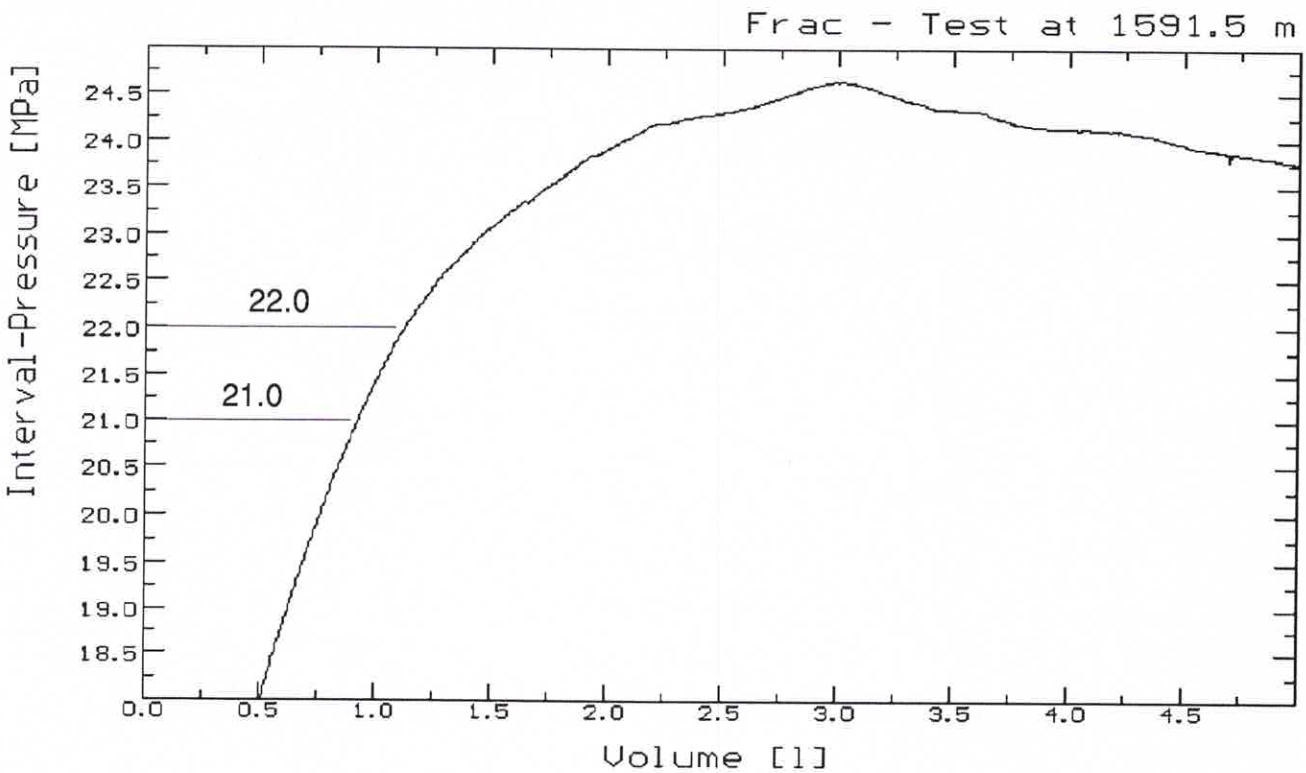
analysis of pumping pressure data



GEO-Meß-Systeme GmbH

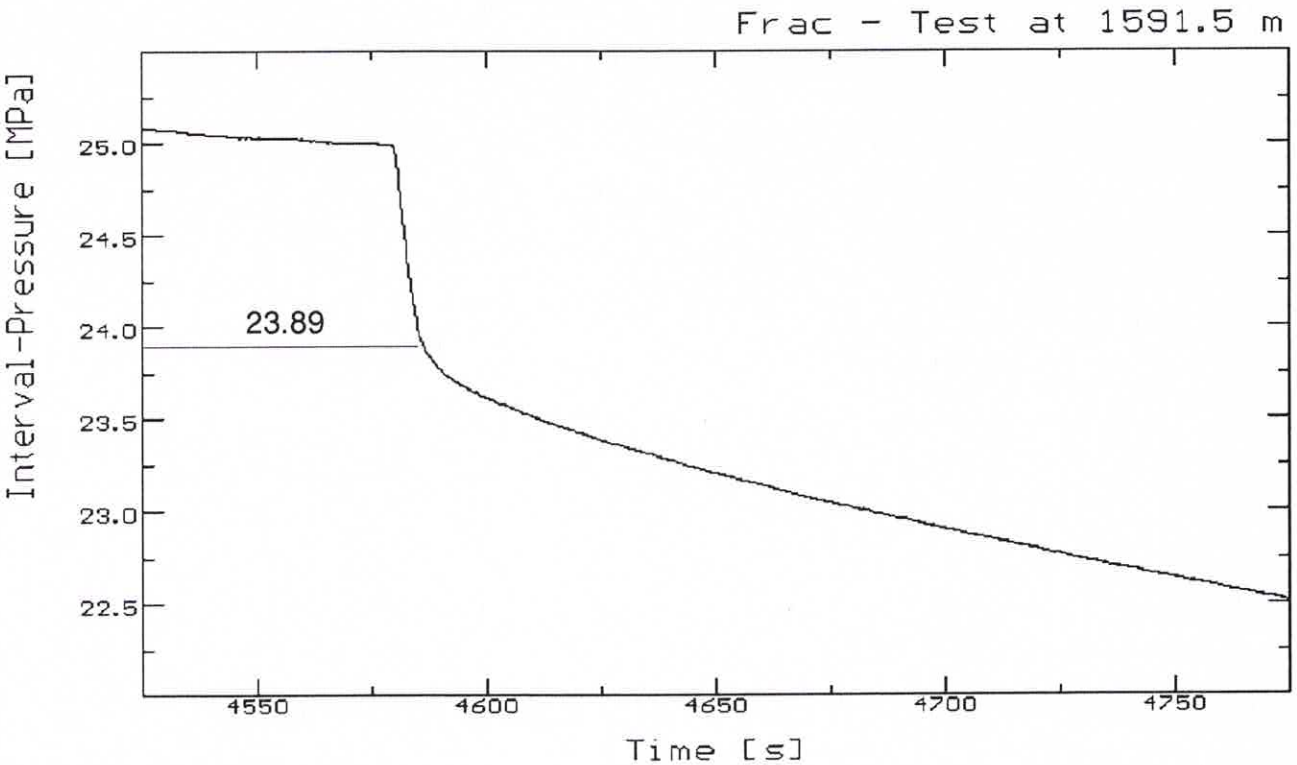
Cased - Hole Test 6 AT 1591.5 m

Estimation of P_r

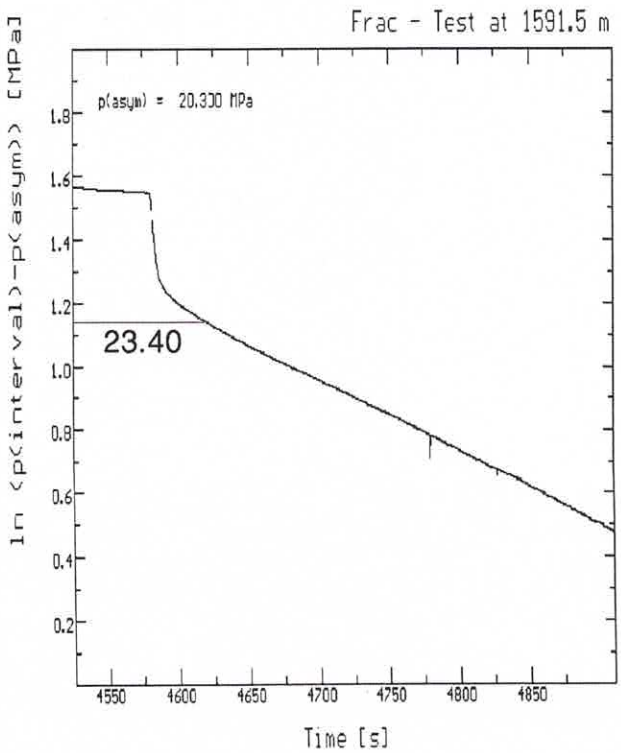


GEO-Meß-Systeme GmbH

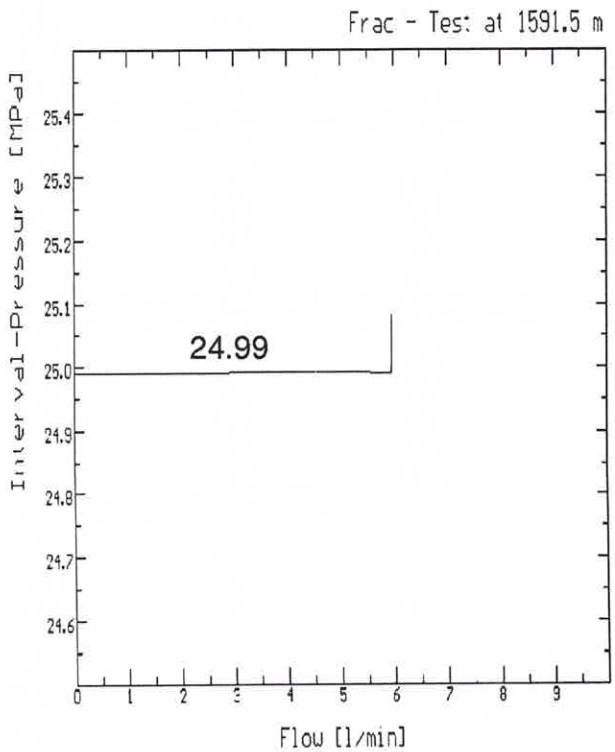
Estimation of P_{si}



Estimation of $P_{si,min}$



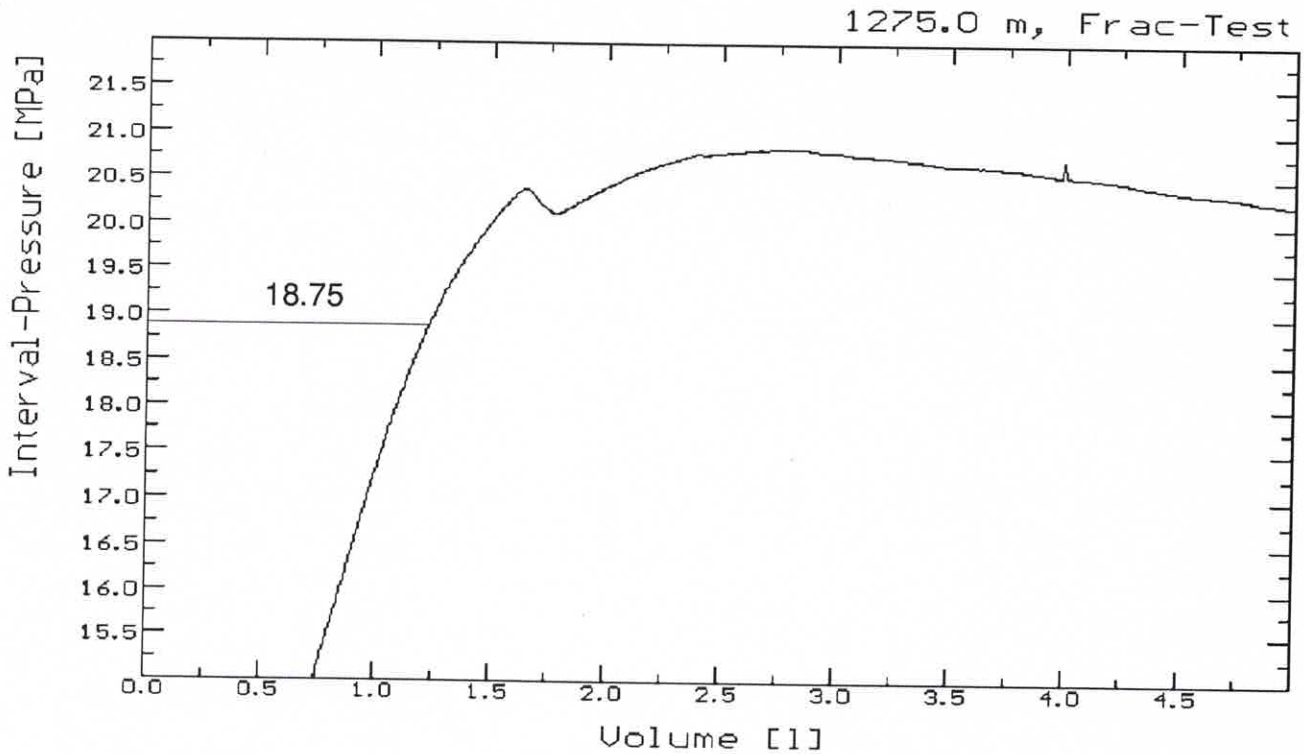
Estimation of $P_{si,max}$



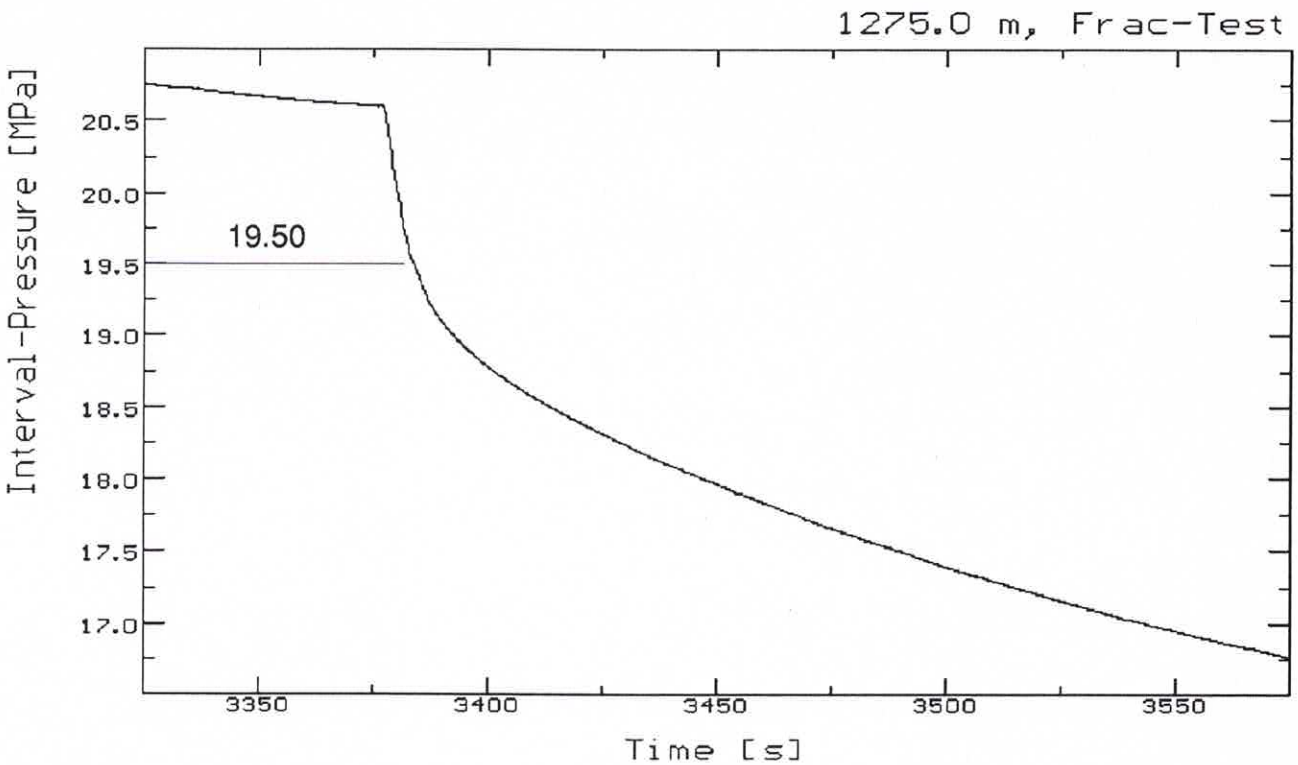
GEO-Meß-Systeme GmbH

Cased - Hole Test 7 AT 1275.0 m

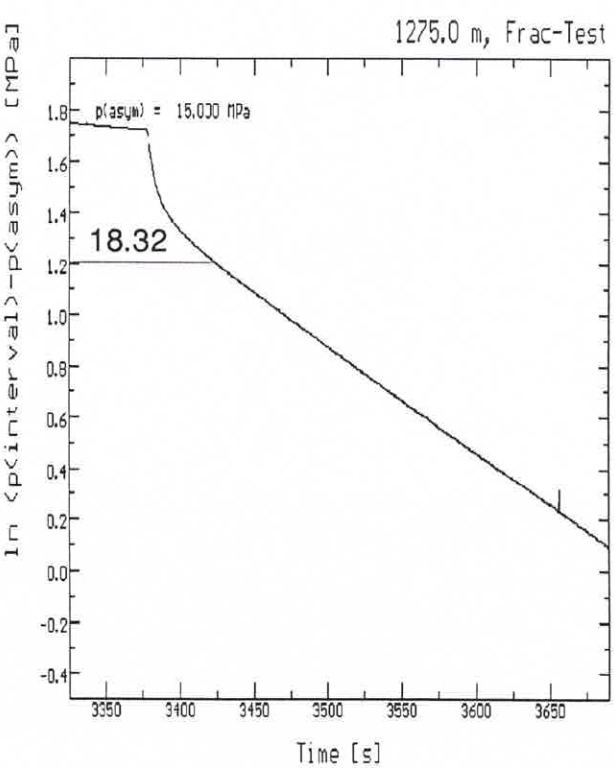
Estimation of P_r



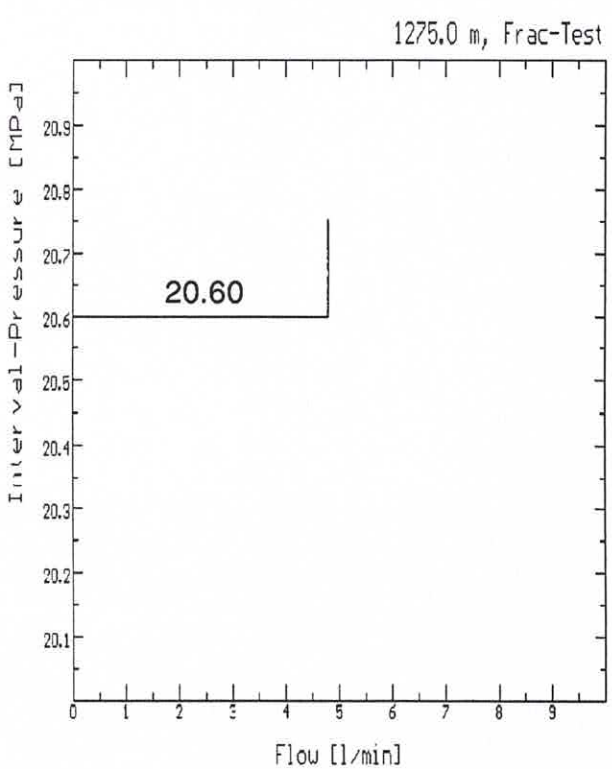
Estimation of P_{si}



Estimation of $P_{si,min}$



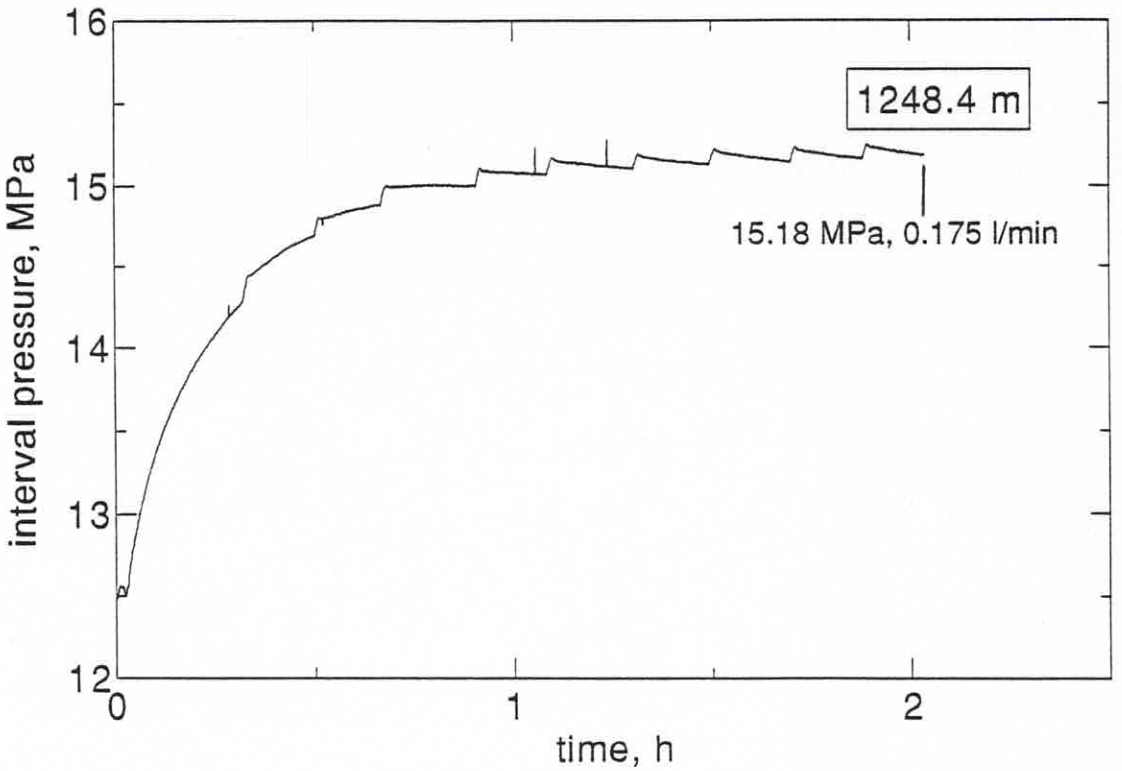
Estimation of $P_{si,max}$



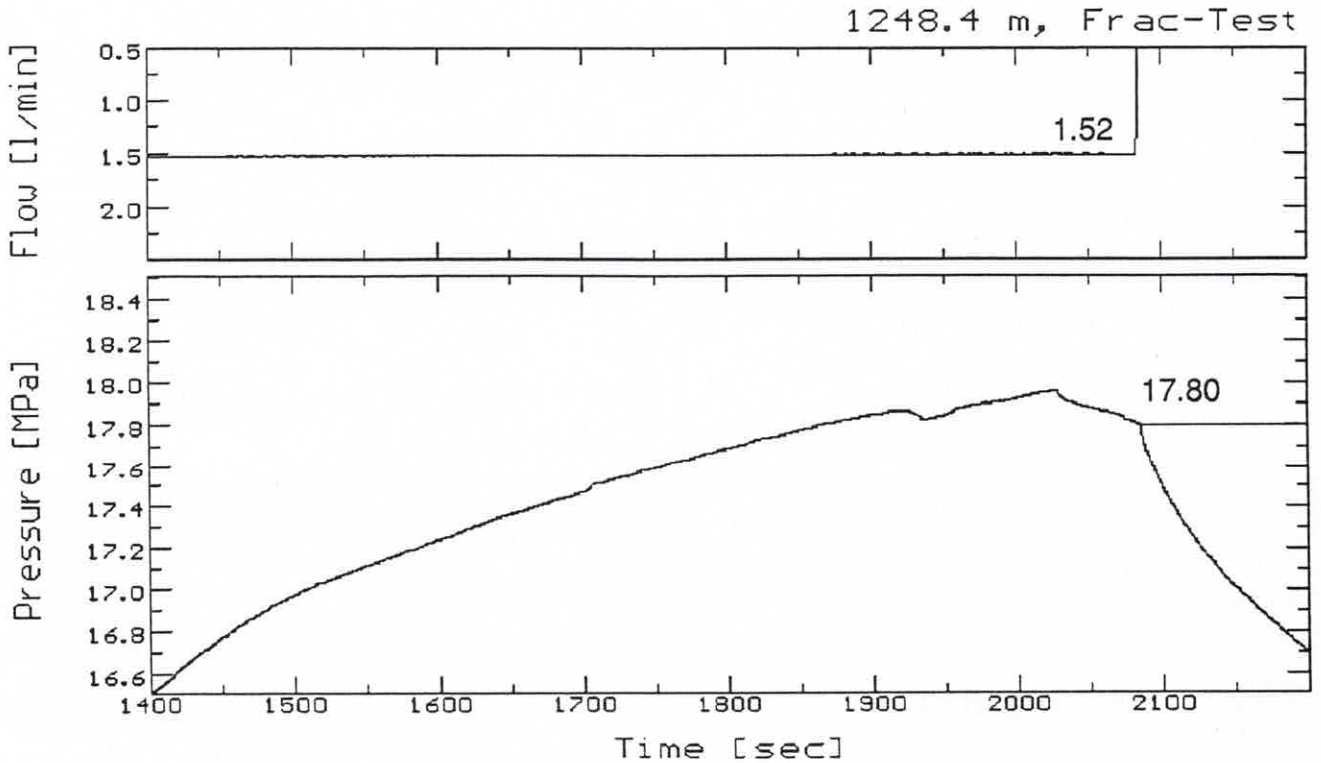
GEO-Meß-Systeme GmbH

Cased - Hole Test 8 AT 1248.4 m

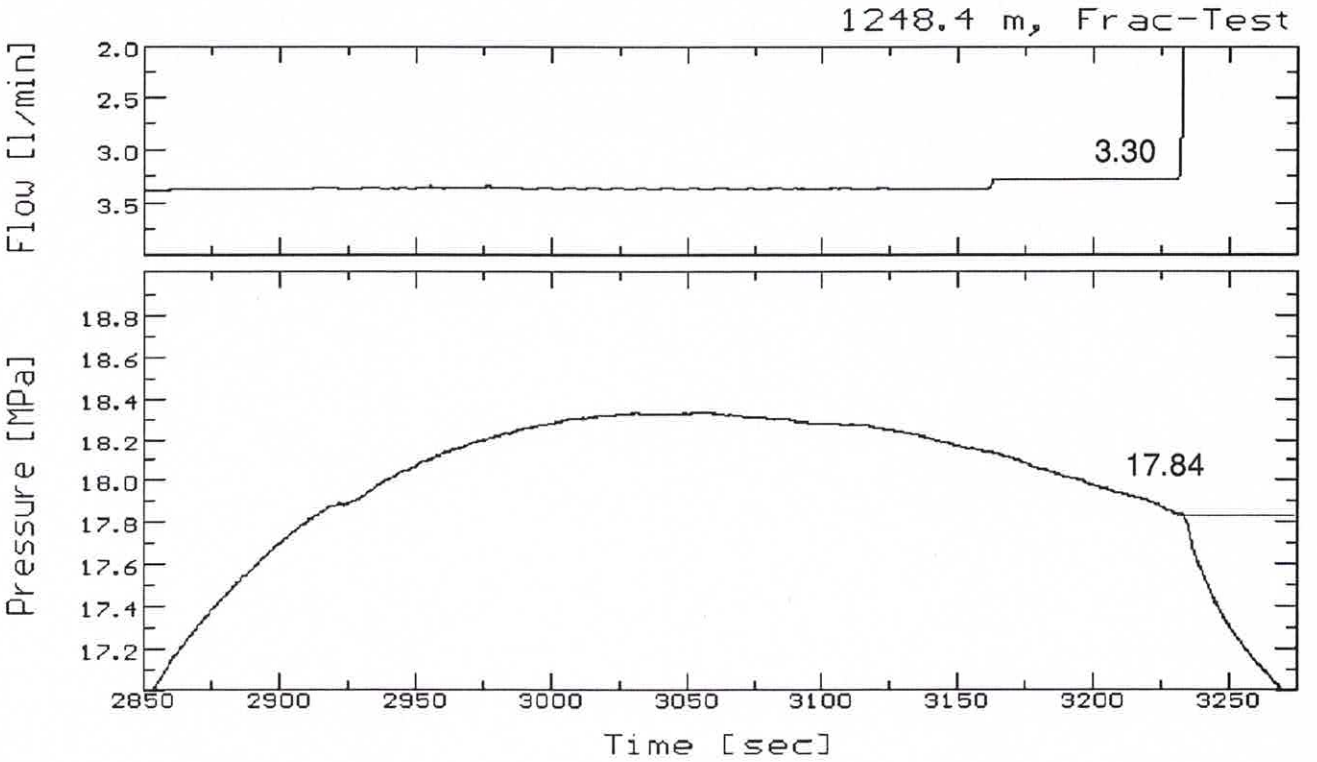
Estimation of P_p (main injection - test)



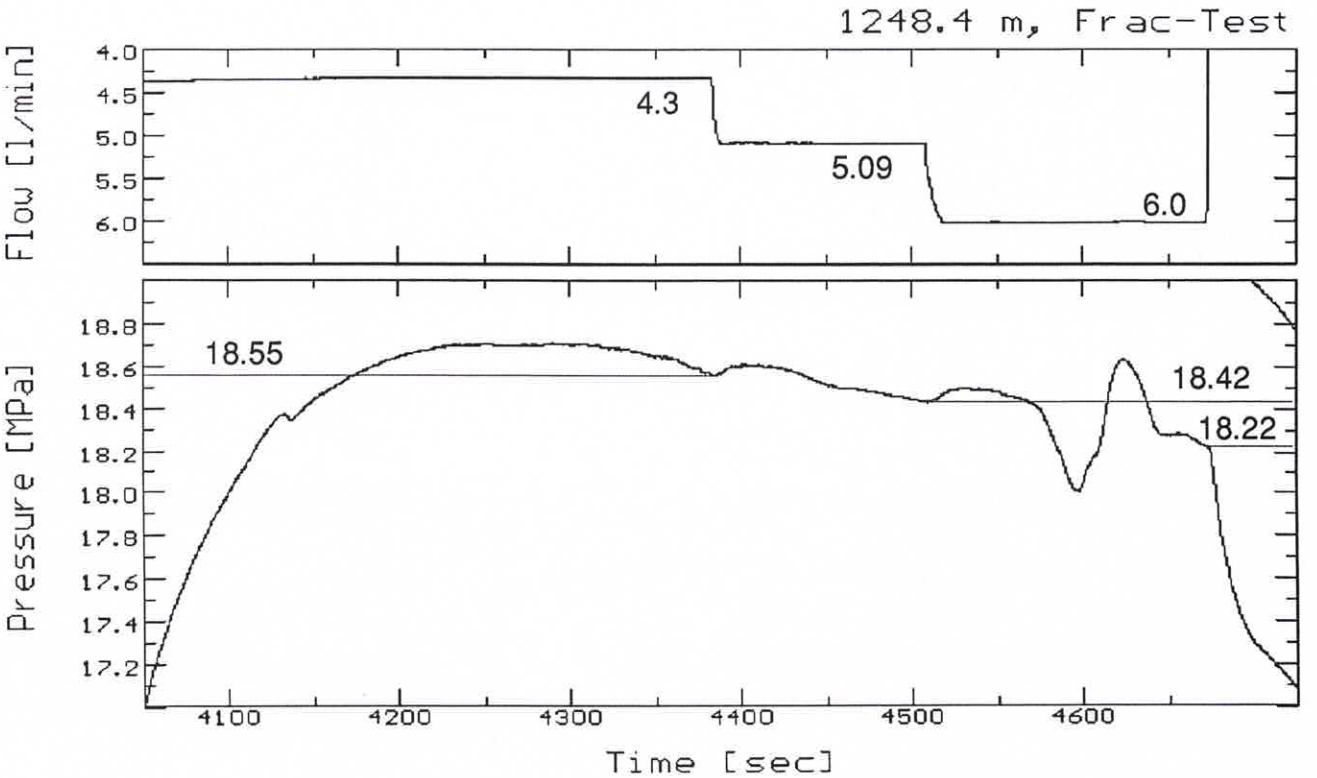
Estimation of P_p (frac - test, 1. injection - cycle)



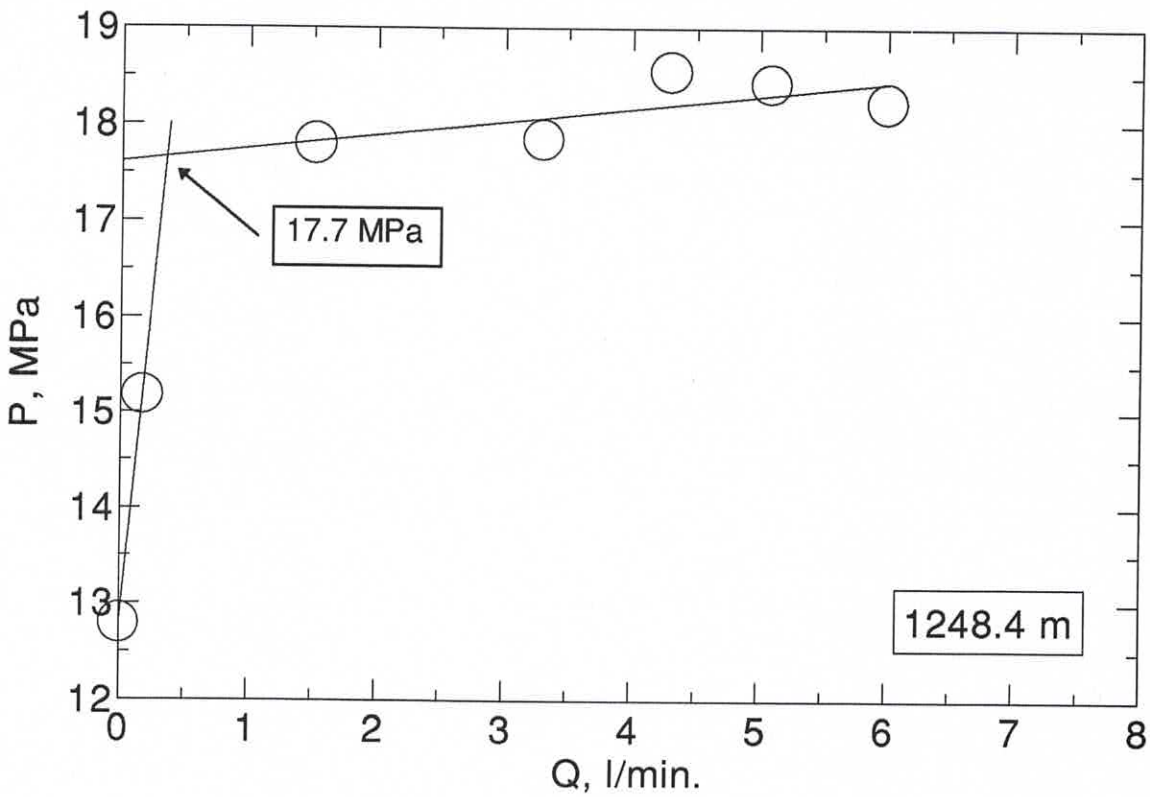
Estimation of P_p (frac - test, 2. injection - cycle)



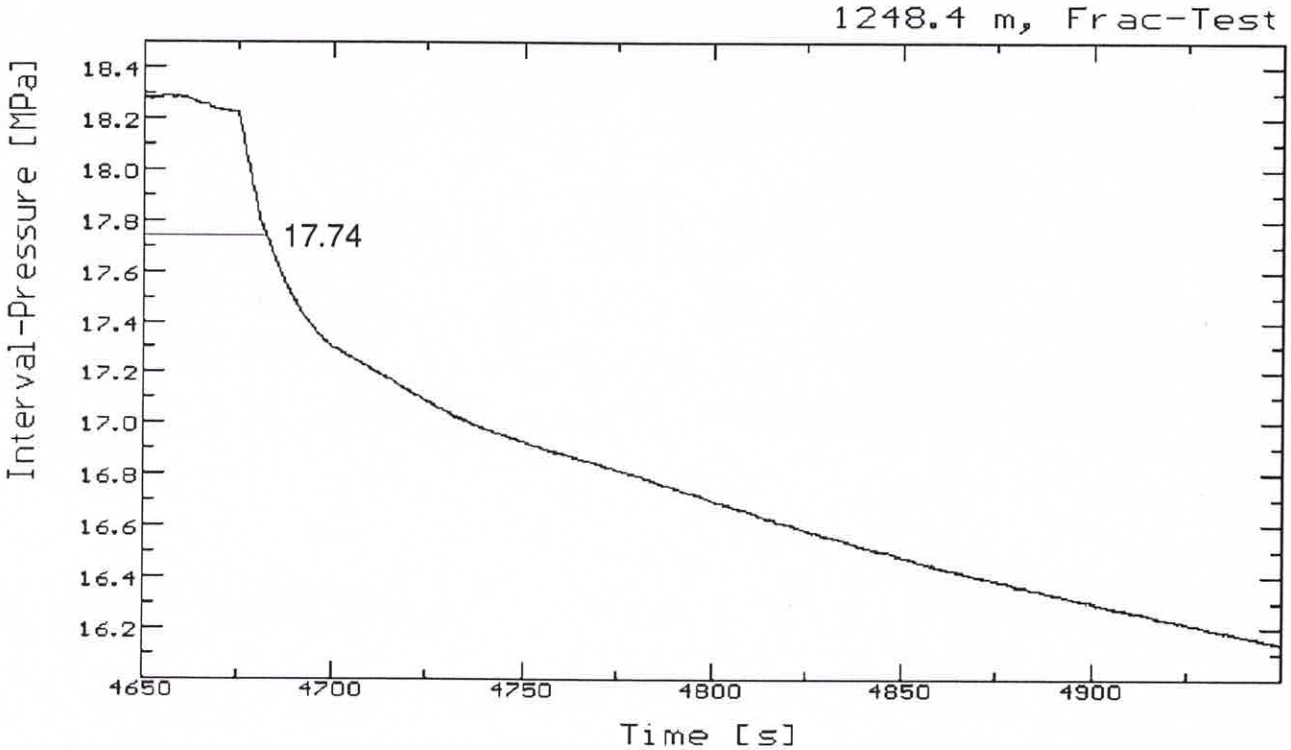
Estimation of P_p (frac - test, 3. injection - cycle)



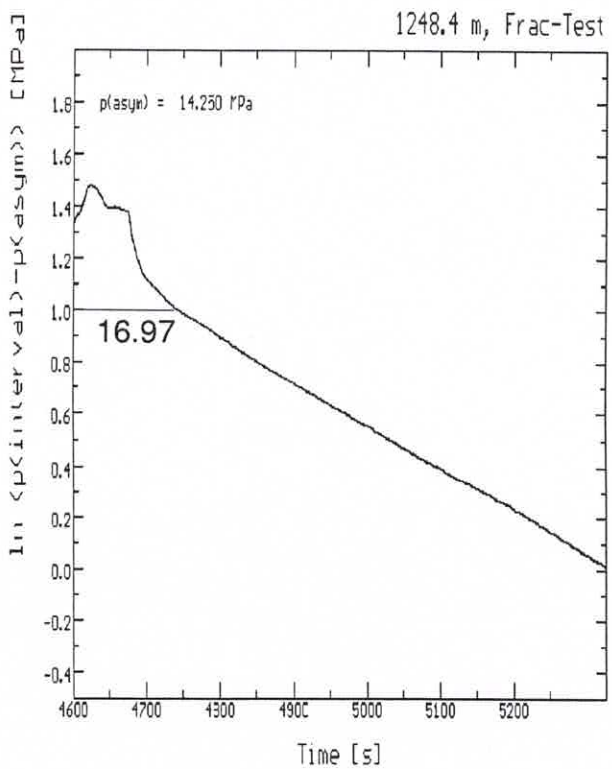
analysis of pumping pressure data



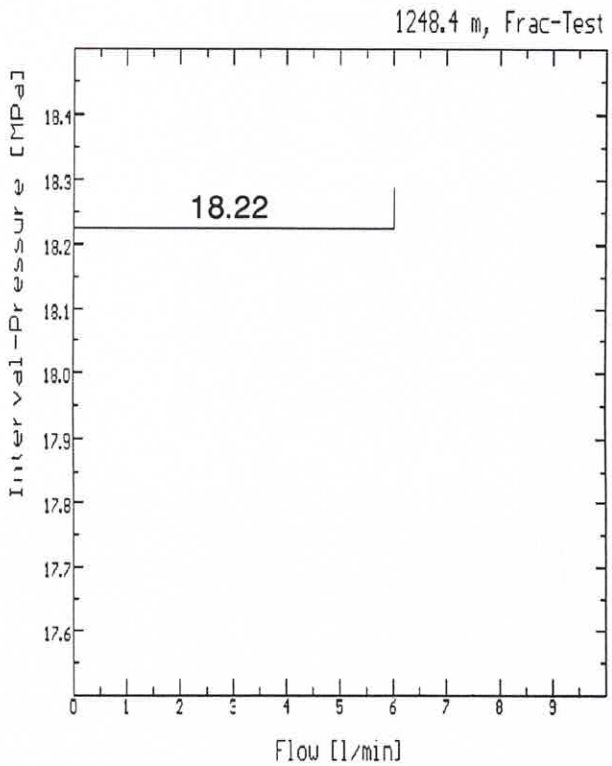
Estimation of P_{si}



Estimation of $P_{si,min}$



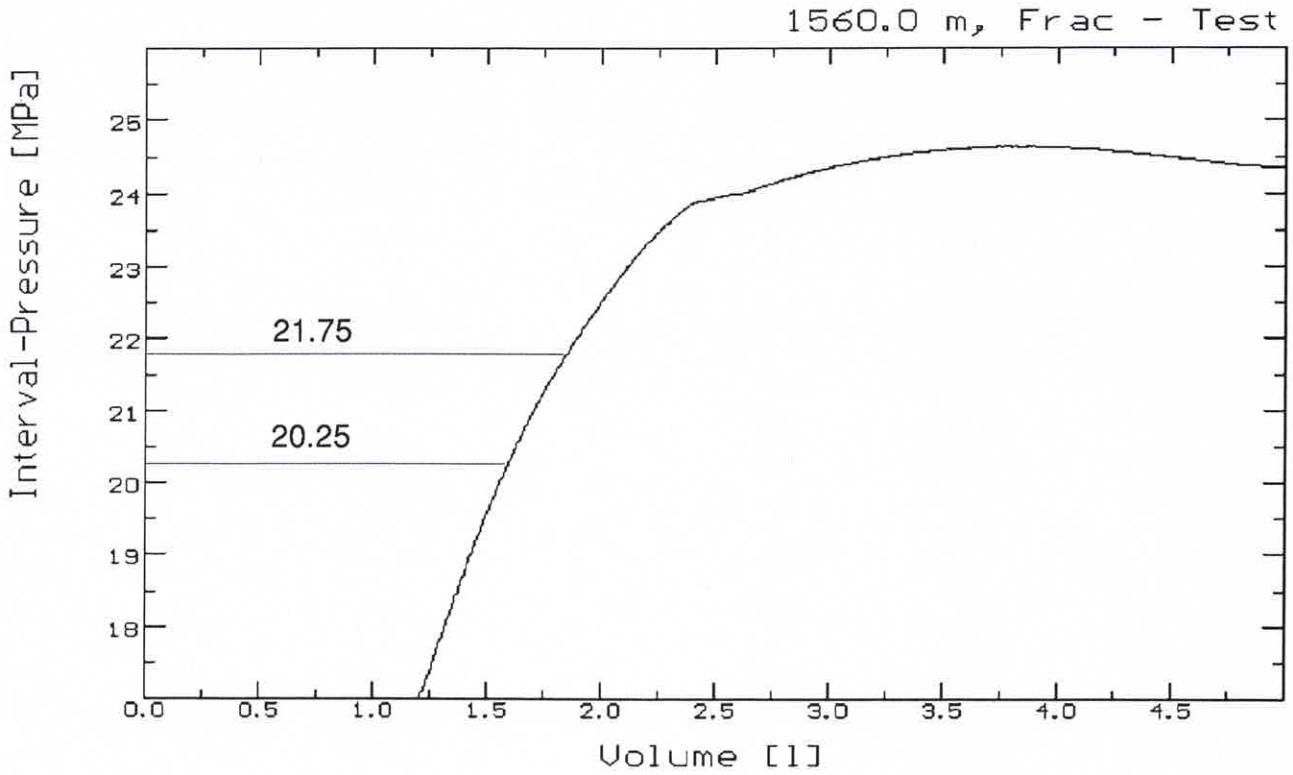
Estimation of $P_{si,max}$



GEO-Meß-Systeme GmbH

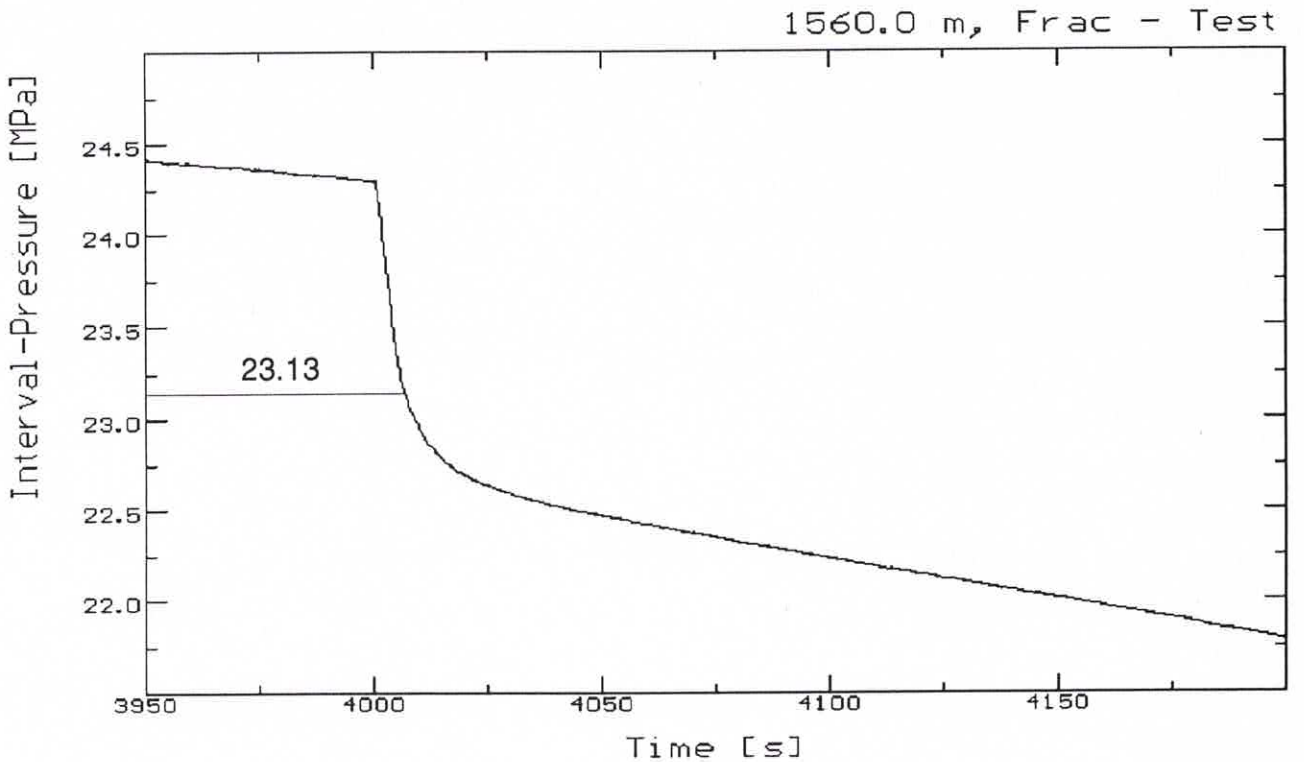
Cased - Hole Test 9 AT 1560.0 m

Estimation of P_r (1. injection - cycle)

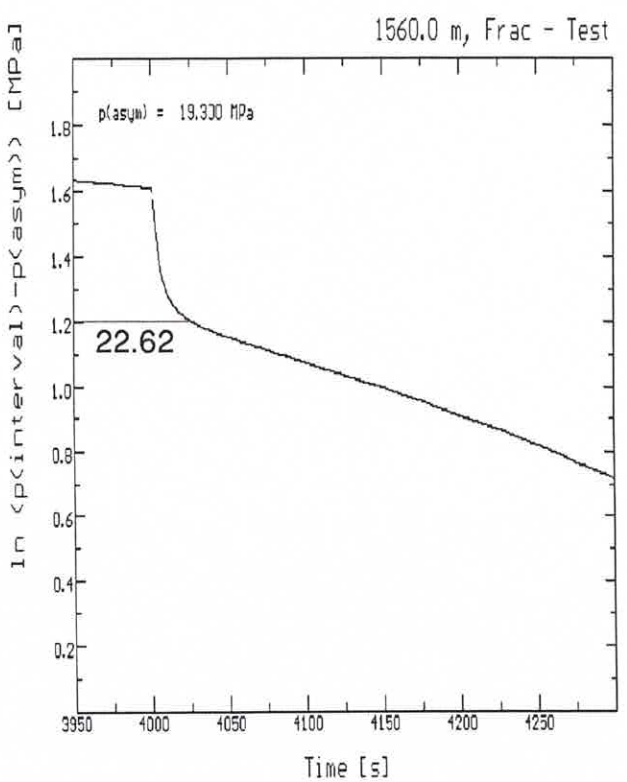


GEO-Meß-Systeme GmbH

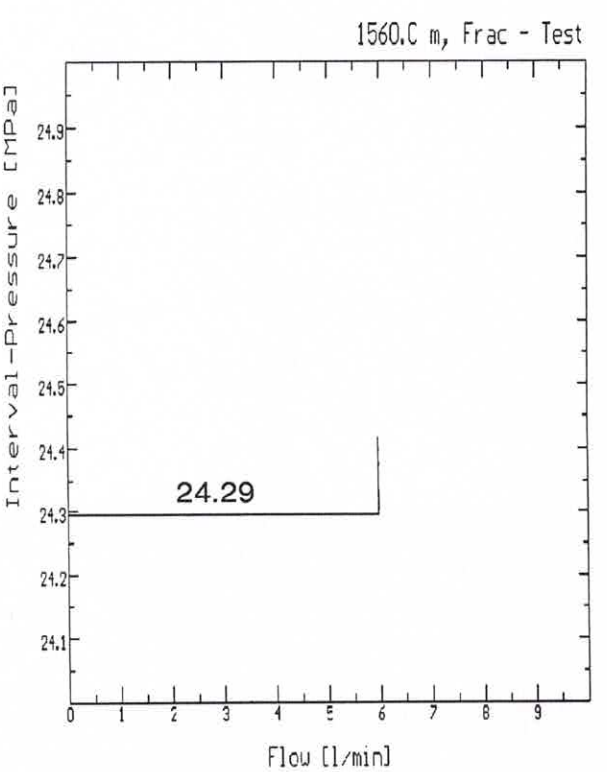
Estimation of P_{si}



Estimation of $P_{si,min}$

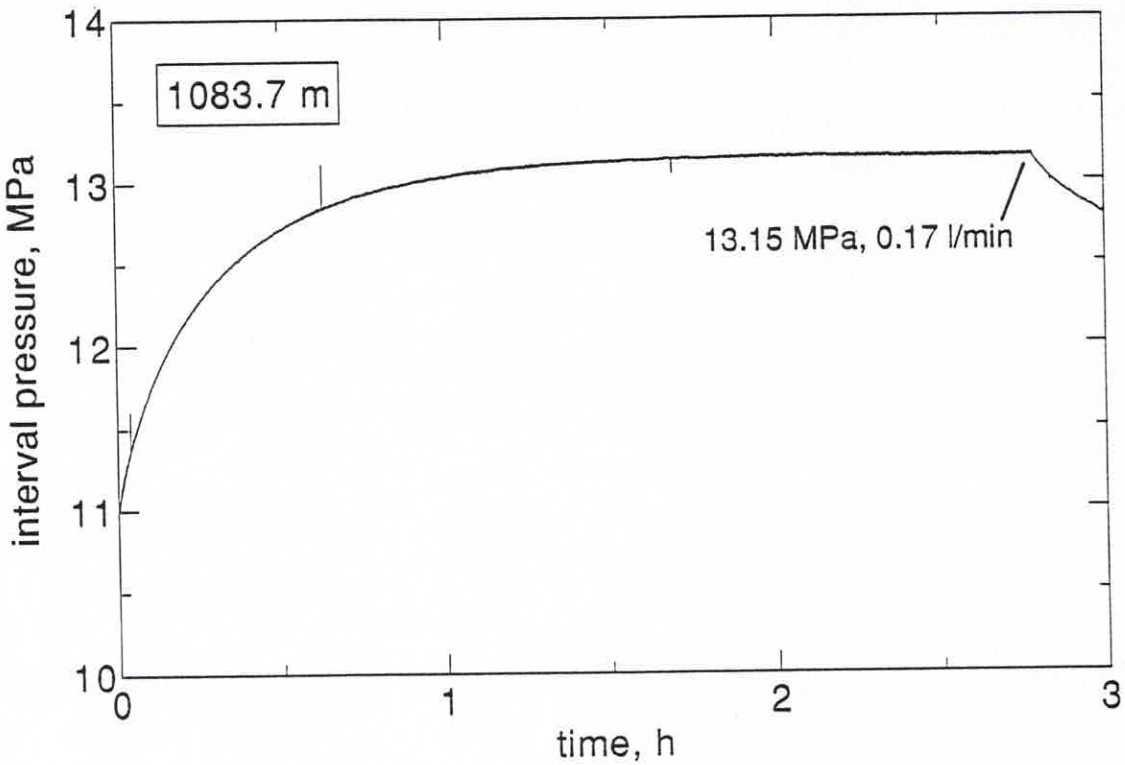


Estimation of $P_{si,max}$

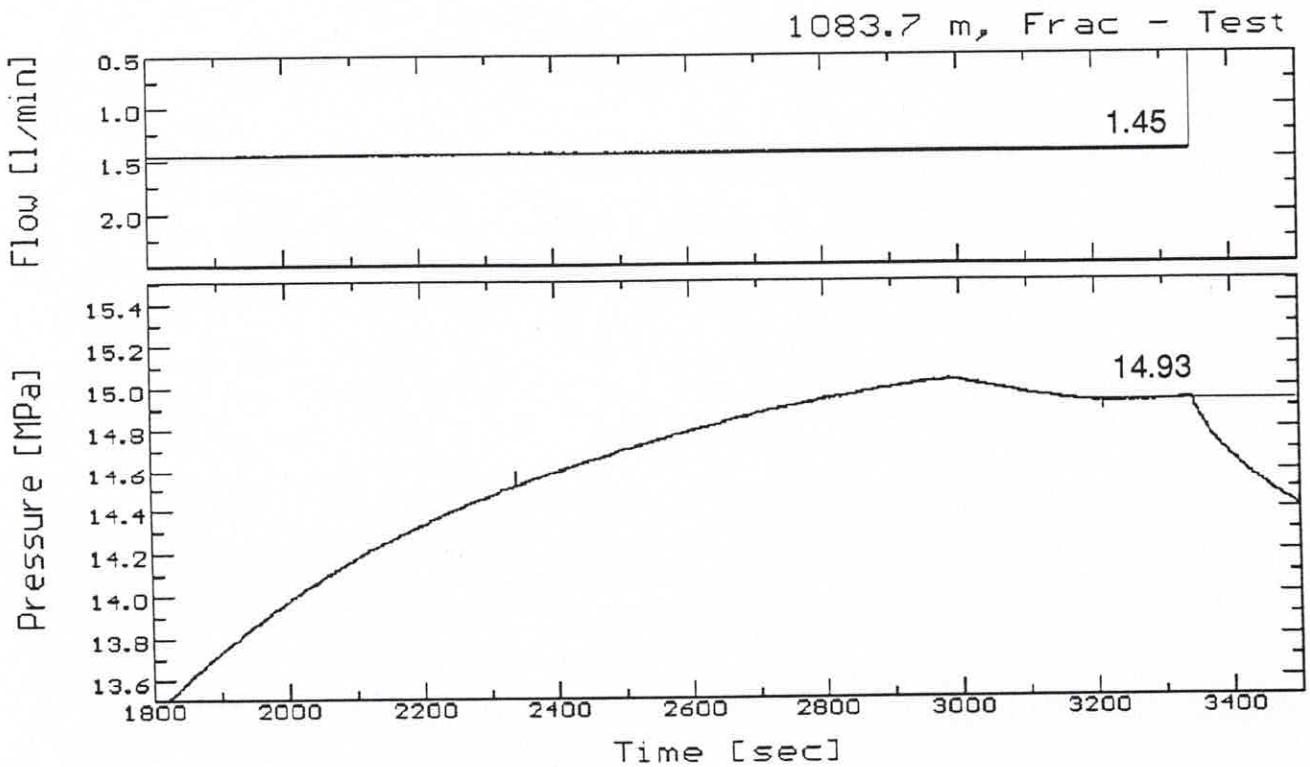


Cased - Hole Test 10 AT 1083.7 m

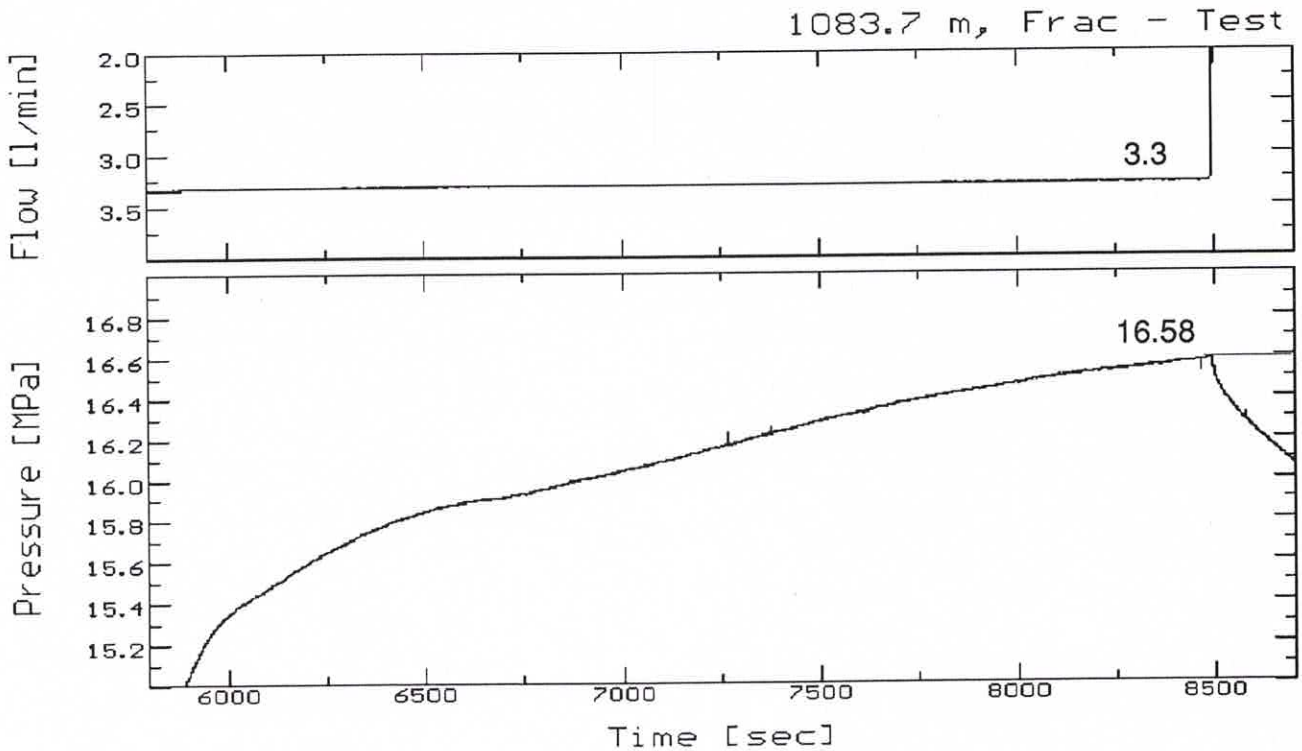
Estimation of P_p (main injection - test)



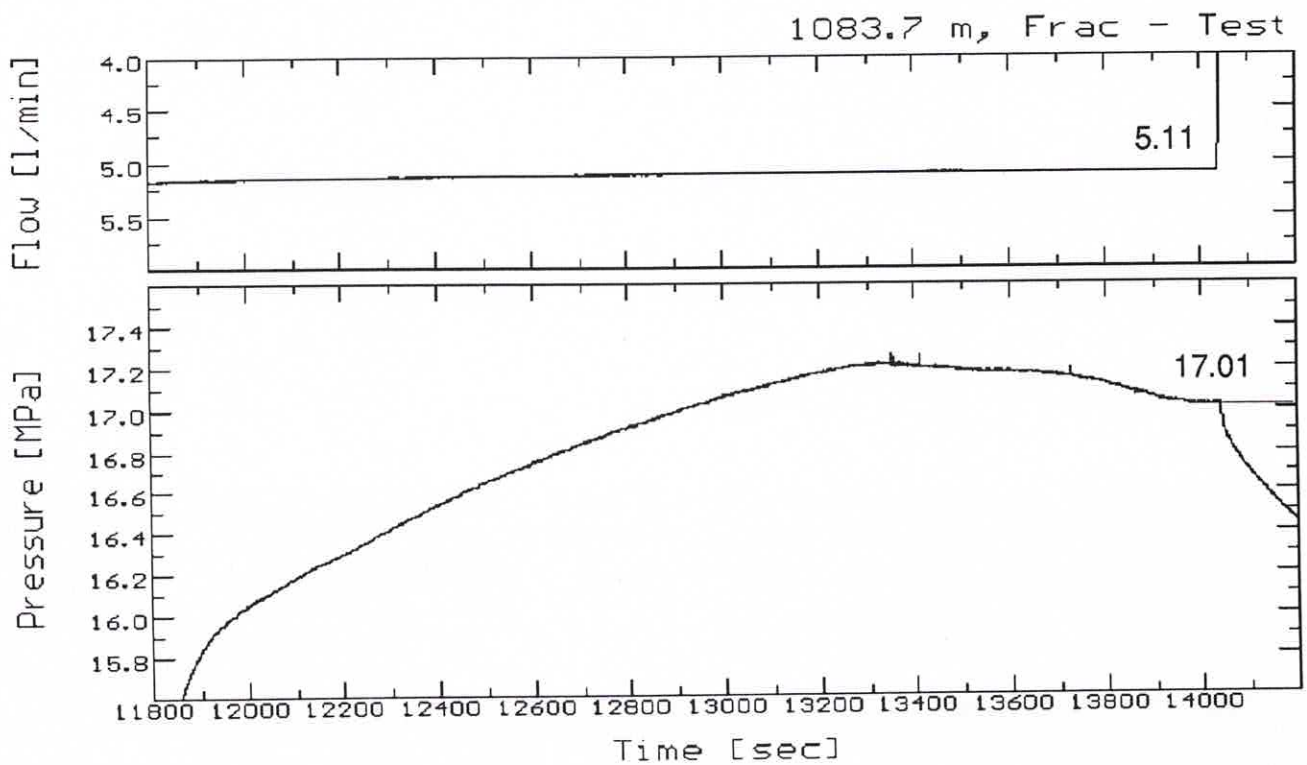
Estimation of P_p (1. injection - cycle)



Estimation of P_p (2. injection - cycle)



Estimation of P_p (frac - test, 3. injection - cycle)



analysis of pumping pressure data