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 NATARP-1

Operation Report and Overview - Plots

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:	12.09.1995

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

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Project:	CBM project Sigillaria License Area
Location:	about 1.5 km N of Hoetmar, NRW, Germany
Borehole:	Natarp-1
Purpose:	cased-hole permeability and stress measurements
Test-Period:	22.08. - 03.09.1995
Participants:	Mr. K. Thomas (Conoco Essen) Mr. S. Strauss (Conoco Houston) Dipl. Ing. P.Hegemann (MeSy) Dipl. Geophys. G. Klee (MeSy) Dipl. Geophys. T. Przybilla (MeSy) Dipl. Ing. H.Vogt (MeSy) Dipl. Geophys. U.Weber (MeSy)

Operation Report

date	time	event
22.08.95	08.00	arrival of MeSy engineers P.Hegemann, G.Klee, H.Vogt, U.Weber at site
	08.00-13.30	set-up of surface and downhole equipment
	13.45-14.25	tool at wellhead, set zero-mark at middle of injection interval, venting of the hydraulic system
	14.27-14.37	test of tool performance *file: TEST_01.DAT*
	14.37	start tripping into hole
	17.27	tool stands at 1948.3 m (tool bottom: 1954.2 m)
	17.30	tool at 1947.5 m
	17.38	**START OF CASED - HOLE TEST 1[1] AT 1948.95 m (middle of perforation)**
	17.38	start data recording *file: 1948CH01.DAT*
	17.39-17.50	set packers to 8 MPa surface pressure
	17.50-18.01	**pressure pulse test**
	18.01	end of data recording
	18.01-18.06	injection-rate calibration
	18.09	start data recording *file: 1948CH02.DAT*

[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
22.08.95	**18.10**	**start injection test**
	18.10	departure of P.Hegemann
	19.40	**end of injection test**
		total injected volume: 17.7 l
		injection duration: 90 min
		mean injection-rate: 0.197 l/min
	19.40	**start fall-off test**
	23.40	**end of fall-off test**, end of data recording
		fall-off duration: 240 min
	23.40-23.51	preparation of frac / step-rate test
	23.52-00.45	**frac / step-rate test** *file: 1948FRAC.DAT*
23.08.95	**00.45**	**END OF CASED - HOLE TEST 1**
	00.46-01.15	deflation of packer elements
	01.35	tool at 1897.95 m
	01.41	**START CASED - HOLE TEST 2 AT 1897.95 m**
	01.41	start data recording *file: 1897CH01.DAT*
	01.41-01.49	set packers to 8 MPa surface pressure
	01.50-02.00	**pressure pulse test**
	02.01	end of data recording
	02.01-02.04	injection-rate calibration
	02.04	start data recording *file: 1897CH02.DAT*
	02.05	**start injection test**
	02.30	departure of G.Klee and H.Vogt
	05.05	fill of stand-pipe (37.1 l)
	08.05	fill of stand-pipe (39.1 l)
	08.35	**end of injection test**
		total injected volume: 82.8 l
		injection duration: 390 min
		mean injection-rate: 0.212 l/min
	08.35	**start fall-off test**
	17.44	**end of fall-off test**, end of data recording
		fall-off duration: 549 min
	17.50/18.10	arrival of T.Przybilla and P.Hegemann
	17.46-17.55	preparation of frac / step-rate test
	17.56-21.09	**frac / step-rate test** *file: 1897FRAC.DAT*
	21.09	**END OF CASED - HOLE TEST 2**

date	time	event
23.08.95	21.10-21.20	deflation of packer elements
	21.34	tool at 1852.3 m
	21.38	**START CASED - HOLE TEST 3 AT 1852.3 m**
	21.38	start data recording *file: 1852CH01.DAT*
	21.39-21.46	set packers to 8 MPa surface pressure
	21.48-21.59	**pressure pulse test**
	22.00	end of data recording
	22.00-22.04	injection-rate calibration
	22.04	start data recording *file: 1852CH02.DAT*
	22.05	**start injection test**
	23.45	departure of T.Przybilla and U.Weber
24.08.95	**00.27**	**end of injection test**
		total injected volume: 27.2 l
		injection duration: 142 min
		mean injection-rate: 0.192 l/min
	00.27	**start fall-off test**
	06.41	**end of fall-off test**
		fall-off duration: 374 min
	06.46	end of data recording
	06.47-06.55	preparation of frac / step-rate test
	07.00-10.20	**frac / step-rate test** *file: 1852FRAC.DAT*
	09.58	failure of downhole electronics
	10.15	arrival of G.Klee and H.Vogt
	10.20	**END OF CASED - HOLE TEST 3**
	10.45-11.15	deflation of packer elements
	11.15-15.00	tripping out of hole
	15.00	tool out of hole, 7-conductor wireline at cable head damaged
	15.00-20.30	repair of cable head
	17.10	arrival of T.Przybilla
	20.35	tool at wellhead, set zero-mark at middle of injection interval, venting of the hydraulic system
	20.50	start tripping into hole
	21.00	departure of G.Klee
	22.41	tool at 1760.25 m

date	time	event
24.08.95	**22.49**	**START CASED - HOLE TEST 4 AT 1760.25 m**
	23.03	start data recording *file: 1760CH01.DAT*
	23.03-23.12	set packers to 8 MPa surface pressure
	23.13-23.33	**pressure pulse test**
	23.33	end of data recording
	23.33-23.39	injection-rate calibration
	23.39	start data recording *file: 1760CH02.DAT*
	23.40	**start injection test (1. attempt)**
	23.50	departure of P.Hegemann
25.08.95	0.22	sudden increase of packer pressure and decrease of interval pressure
	00.48	reset packer to 11 MPa surface pressure
	01.20	**end of injection test**
		total injected volume: 18.5 l
		injection duration: 100 min
		mean injection-rate: 0.185 l/min
	01.20	end of data recording
	01.21-01.35	deflation of packer elements
	01.43	tool at 1770.0 m
	01.47-02.20	test of tool performance *file: 1770TEST.DAT*
	02.58	tool at 1760.25 m
	03.03	start data recording *file: 1760CH03.DAT*
	03.03-03.09	set packers to 10 MPa surface pressure
	03.11	**start injection test (2. attempt)**
	03.21	power cut, end of data recording
	04.00	bleed-off interval, end of injection test
	04.23	start data recording *file: 1760CH04.DAT*
	04.26	**start injection test (3. attempt)**
	04.27	power cut, end of data recording (data loss)
	04.35	bleed-off interval, end of injection test
	13.50	start of power supply
	14.07	start data recording *file: 1760CH05.DAT*
	14.07-14.09	reset packers to 10 MPa surface pressure
	14.09	**start injection test**

date	time	event
25.08.95	**15.10**	**end of injection test**
		total injected volume: 13.5 l
		injection duration: 61 min
		mean injection-rate: 0.221 l/min
	15.10	**start fall-off test**
	19.00	**end of fall-off test**
		fall-off duration: 230 min
	19.00	end of data recording
	19.00-19.10	preparation of frac / step-rate test
	19.13-20.02	**frac / step-rate test** *file: 1760FRAC.DAT*
	20.02	**END OF CASED - HOLE TEST 4**
	20.02-20.08	deflation of packer elements
	20.52	tool at 1596.15 m
	20.55	**START CASED - HOLE TEST 5 AT 1596.15 m**
	20.55	start data recording *file: 1596CH01.DAT*
	20.55-21.05	set packers to 8 MPa surface pressure
	21.05-21.10	**attempt of pressure pulse test**, low pressure build-up at 6.5 l/min injection rate
	21.10	end of data recording
	21.10-21.15	deflation of packer elements
	21.23	tool at 1615.0 m
	21.23-21.41	test of tool performance *file: 1615TEST.DAT*
	21.41-21.45	deflation of packer elements
	21.51	tool at 1596.15 m
	21.52	start data recording *file: 1596CH02.DAT*
	21.53-21.56	set packers to 9 MPa surface pressure
	21.56-22.06	**attempt of pressure pulse test**, low pressure build-up at 5 l/min injection rate
	22.06	interval bleed-off, 0.9 l/min backflow
	22.06	end of data recording
	22.10-22.16	injection-rate calibration
	22.16	start data recording *file: 1596CH03.DAT*
	22.17	**start injection test**
	23.07	departure of T.Przybilla and H.Vogt

date	time	event
25.08.95	23.15	total injected volume: 11.1 l
		injection duration: 58 min
		mean injection-rate: 0.191 l/min
		increase of injection rate to 0.6 l/min
	23.45	increase of injection rate to 1.2 l/min
26.08.95	00.05	stop injection, shut-in
	00.05-00.25	preparation of pump for higher injection rates
	00.25	re-start injection with 2 l/min
	03.50	increase of injection rate to 2.7 l/min
	07.10	increase of injection rate to 5 l/min
	10.00	**end of injection test**
	10.00	**start fall-off test**
	19.20	arrival of T.Przybilla and H.Vogt
	20.00	**end of fall-off test**
		fall-off duration: 600 min
	20.00	end of data recording
	20.00	**END OF CASED - HOLE TEST 5**
	20.01-20.07	deflation of packer elements
	20.26	tool at 1530.6 m
	20.53	**START CASED - HOLE TEST 6 AT 1530.6 m**
	20.53	start data recording *file: 1530CH01.DAT*
	20.53-21.00	set packers to 9.5 MPa surface pressure
	21.01-21.11	**pressure pulse test**
	21.11	end of data recording
	21.11-21.18	injection-rate calibration
	21.19	start data recording *file: 1530CH02.DAT*
	21.20	**start injection test**
	23.00	departure of H.Vogt and U.Weber
27.08.95	00.26	fill of stand-pipe (36.1 l)
	02.20	**end of injection test**
		total injected volume: 58.8 l
		injection duration: 300 min
		mean injection-rate: 0.196 l/min
	02.20	**start fall-off test**
	09.20	**end of fall-off test**
		fall-off duration: 420 min

date	time	event
27.08.95	09.21	end of data recording
	09.21-09.27	preparation of frac / step-rate test
	09.29-12.01	**frac / step-rate test** *file: 1530FRAC.DAT*
	10.15	power cut
	10.50	start data recording *file: 1530FR_2.DAT*
	11.30	arrival of G.Klee
	12.01	**END OF CASED - HOLE TEST 6**
	12.05-12.25	deflation of packer elements
	13.25	tool at 1627.5 m
	13.30	**START CASED - HOLE TEST 7A AT 1627.5 m**
	13.30	start data recording *file: 1627CH01.DAT*
	13.30-13.34	set packers to 9.5 MPa surface pressure
	13.35-13.45	**pressure pulse test**
	13.46	end of data recording
	13.46-13.54	injection-rate calibration
	13.54	start data recording *file: 1627CH02.DAT*
	13.55	**start injection test**
	14.25	departure of T.Przybilla
	16.51	fill of stand-pipe (35.0 l)
	18.25	**end of injection test**
		total injected volume: 55.5 l
		injection duration: 270 min
		mean injection-rate: 0.206 l/min
	18.25	**start fall-off test**
28.08.95	01.45	arrival of U.Weber
	03.28-03.53	power cut, end of data recording
	03.55	start data recording *file: 1627CH03.DAT*
	04.00	departure of G.Klee
	05.04	**end of fall-off test**
		fall-off duration: 519 min
	05.04	end of data recording
	05.04-05.20	preparation of frac / step-rate test
	05.21-07.36	**frac / step-rate test** *file: 1627FRAC.DAT*
	07.30	arrival of T.Przybilla
	07.36	**END OF CASED - HOLE TEST 7A**
	07.36-07.43	deflation of packer elements

date	time	event
28.08.95	08.13	tool at 1748.4 m
	08.17	**START CASED - HOLE TEST 8 AT 1748.4 m**
	08.17	start data recording *file: 1748CH01.DAT*
	08.18-08.25	set packers to 9 MPa surface pressure
	08.26-08.38	**pressure pulse test**
	08.38	end of data recording
	08.38-08.56	injection-rate calibration
	08.58	start data recording *file: 1748CH02.DAT*
	08.59	**start injection test**
	10.00	departure of T.Przybilla
	12.15	fill of stand-pipe (45.5 l)
	15.16	**end of injection test**
		total injected volume: 83.5 l
		injection duration: 377 min
		mean injection-rate: 0.221 l/min
	15.16	**start fall-off test**
29.08.95	**00.15**	**end of fall-off test**
		fall-off duration: 539 min
	00.15	end of data recording
	00.20	arrival of T.Przybilla and H.Vogt
	00.25-00.52	preparation of frac / step-rate test
	00.52-02.09	**frac / step-rate test** *file: 1748FRAC.DAT*
	02.09	**END OF CASED - HOLE TEST 8**
	02.09-02.12	deflation of packer elements
	03.00	tool at 1428.4 m
	03.02	**START CASED - HOLE TEST 9 AT 1428.4 m**
	03.02	start data recording *file: 1428CH01.DAT*
	03.02-03.07	set packers to 10 MPa surface pressure
	03.08-03.18	**pressure pulse test**
	03.21	end of data recording
	03.20-03.34	injection-rate calibration
	03.35	start data recording *file: 1428CH02.DAT*
	03.36	**start injection test**
	04.20	departure of H.Vogt and U.Weber
	06.16	fill of stand-pipe (36.0 l)

date	time	event
29.08.95	**08.30**	**end of injection test**
		total injected volume: 65.6 l
		injection duration: 294 min
		mean injection-rate: 0.223 l/min
	08.30	**start fall-off test**
	17.00	**end of fall-off test**
		fall-off duration: 510 min
	17.00	end of data recording
	17.00-17.08	preparation of frac / step-rate test
	17.09-18.05	**frac / step-rate test** *file: 1428FRAC.DAT*
	17.55	arrival of G.Klee and H.Vogt
	18.05	**END OF CASED - HOLE TEST 9**
	18.06-18.11	deflation of packer elements
	18.25	tool at 1403.6 m
	18.28	**START CASED - HOLE TEST 10 AT 1403.6 m**
	18.28	start data recording *file: 1403CH01.DAT*
	18.28-18.31	set packers to 9 MPa surface pressure
	18.32-18.43	**pressure pulse test**
	18.44	end of data recording
	18.44-18.49	injection-rate calibration
	18.49	start data recording *file: 1403CH02.DAT*
	18.50	**start injection test**
	21.00	departure of G.Klee and T.Przybilla
	21.19	fill of stand-pipe (31.0 l)
	23.50	**end of injection test**
		total injected volume: 64.7 l
		injection duration: 300 min
		mean injection-rate: 0.216 l/min
	23.50	**start fall-off test**
30.08.95	08.20	arrival of T.Przybilla
	10.45	**end of fall-off test**
		fall-off duration: 655 min
	10.45	end of data recording
	10.45-10.55	preparation of frac / step-rate test
	10.56-12.52	**frac / step-rate test** *file: 1403FRAC.DAT*
	12.52	**END OF CASED - HOLE TEST 10**

date	time	event
30.08.95	12.52-13.00	deflation of packer elements
	13.13	tool at 1379.85 m
	13.22	**START CASED - HOLE TEST 11 AT 1379.85 m**
	13.22	start data recording *file: 1379CH01.DAT*
	13.22-13.28	set packers to 10 MPa surface pressure
	13.29-13.44	**pressure pulse test**
	13.45	end of data recording
	13.45-13.49	injection-rate calibration
	13.49	start data recording *file: 1379CH02.DAT*
	13.50	**start injection test**
	13.55	departure of H.Vogt
	16.59	fill of stand-pipe (42.7 l)
	17.20	**end of injection test**
		total injected volume: 46.7 l
		injection duration: 210 min
		mean injection-rate: 0.222 l/min
	17.20	**start fall-off test**
31.08.95	00.30/01.00	arrival of G.Klee and U.Weber
	01.26	**end of fall-off test**
		fall-off duration: 486 min
	01.26	end of data recording
	01.26-01.33	preparation of frac / step-rate test
	01.34-02.39	**frac / step-rate test** *file: 1379FRAC.DAT*
	02.39	**END OF CASED - HOLE TEST 11**
	02.40-02.55	deflation of packer elements
	03.47	tool at 1627.5 m
	03.51-03.57	set packers to 10 MPa surface pressure
	03.59	**START CASED - HOLE TEST 7B AT 1627.5 m**
	03.59	start data recording *file: 1627CH04.DAT*
	04.00	**start long-term injection test**
	05.10	departure of G.Klee and T.Przybilla
	07.05	fill of stand-pipe (39.5 l)
	09.45	fill of stand-pipe (34.5 l)
	12.35	fill of stand-pipe (38.0 l)
	15.33	fill of stand-pipe (39.5 l)
	18.32	fill of stand-pipe (40.0 l)

date	time	event
31.08.95	21.33	fill of stand-pipe (40.6 l)
01.09.95	00.13	fill of stand-pipe (36.4 l)
	03.03	fill of stand-pipe (38.3 l)
	03.59	end of data recording
	04.00	start data recording *file: 1627CH05.DAT*
	05.03	fill of stand-pipe (39.5 l)
	07.50	arrival of H.Vogt
	08.30	departure of U.Weber
	09.02	fill of stand-pipe (44.2 l)
	12.02	fill of stand-pipe (40.1 l)
	15.01	fill of stand-pipe (40.3 l)
	17.01	reset packers to 10 MPa surface pressure
	18.00	fill of stand-pipe (40.7 l)
	22.00	fill of stand-pipe (54.6 l)
02.09.95	00.00	fill of stand-pipe (26.9 l)
	03.50	reset packers to 10 MPa surface pressure
	04.00	end of data recording
	04.02	start data recording *file: 1627CH06.DAT*
	04.02	fill of stand-pipe (54.5 l)
	06.45	reset packers to 10 MPa surface pressure
	07.00	fill of stand-pipe (40.4 l)
	07.30	reset packers to 10 MPa surface pressure
	08.15	reset packers to 10 MPa surface pressure
	08.45	reset packers to 10 MPa surface pressure
	09.00	**end of long-term injection test**
		total injected volume: 710.2 l
		injection duration: 3180 min
		mean injection-rate: 0.223 l/min
	09.00	**start long-term fall-off test**
	11.50	reset packers to 5 MPa surface pressure
	13.01	reset packers to 5 MPa surface pressure
	14.00	arrival of G.Klee
	14.01	reset packers to 5 MPa surface pressure
	15.08	reset packers to 5 MPa surface pressure
	15.34	reset packers to 5 MPa surface pressure with gas
	16.12	reset packers to 5 MPa surface pressure with gas

date	time	event
02.09.95	16.12	reset packers to 7 MPa surface pressure with gas
	17.10	departure of G.Klee
	19.01	reset packers to 8.5 MPa surface pressure with gas
	22.09-00.10	power cut, end of data recording
03.09.95	00.10	start data recording *file: 1627CH07.DAT*
	02.05	reset packers to 5 MPa surface pressure with gas
	07.30	reset packers to 5 MPa surface pressure with gas
	08.00	arrival of P.Hegemann
	09.00	departure of H.Vogt
	16.00	reset packers to 4.5 MPa surface pressure with gas
	21.45	reset packers to 5 MPa surface pressure with gas
	23.36	reset packers to 5 MPa surface pressure with gas
04.09.95	00.00	end of data recording
	00.10	start data recording *file: 1627CH08.DAT*
	03.50-04.29	power cut, end of data recording (data loss)
	04.29	start data recording *file: 1627CH09.DAT*
	09.00	arrival of U.Weber
	09.20	end of data recording
	09.20	**end of long-term fall-off test**
	09.20	**END OF CASED-HOLE TEST 7B AT 1627.5 m**
	09.22-09.30	deflation of packer elements
	09.58	tool at 1597.0 m
	10.11	start data recording *file: 1597CHFL.DAT*
	10.13	set packers to 3 MPa surface pressure to monitor the pressure build-up within the test interval
	10.15	departure of P.Hegemann
	11.07	deflation of packer elements
	11.11-11.25	injection of N_2 into the interval-line
	11.32	set packers to 3 MPa surface pressure to recover a fluid sample
	11.38-14.32	bleed-off injection interval
	14.15	arrival of G.Klee and H.Vogt
	14.32	end of data recording
	14.35-14.45	deflation of packer elements
	14.45	start tripping out of hole

date	time	event
04.09.95	18.05	tool out of hole
	18.05-21.00	rig-down of downhole and surface equipment, dismantling of the equipment
	21.00	departure from site
05.09.95		maintenance of the equipment
06.09.95		demobilization of MKW-5000 winch-system

APPENDIX B

OVERVIEW - PLOTS OF INJECTION / PRESSURE FALL - OFF TESTS

remarks:

solid line:	downhole interval pressure
broken line:	downhole packer pressure

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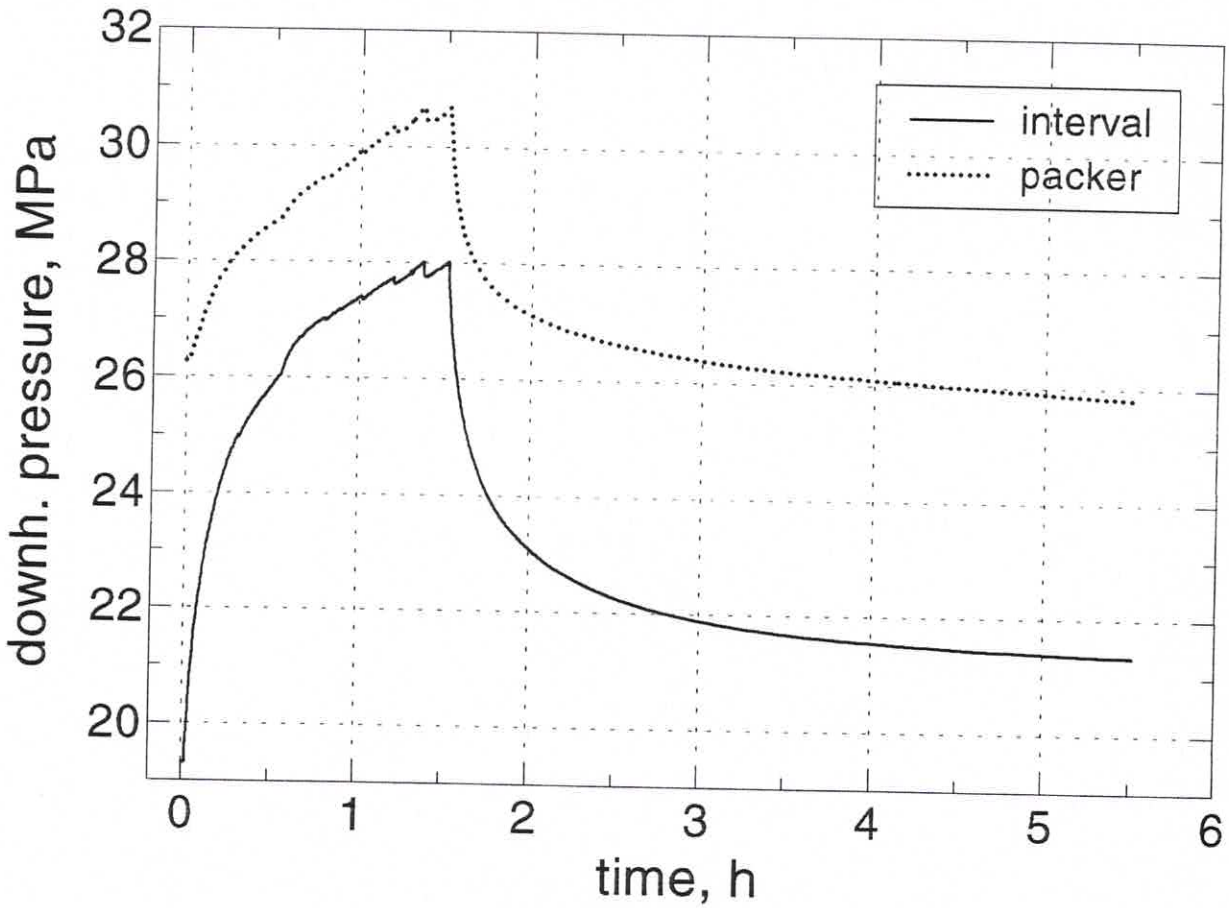
CASED - HOLE TEST 1 AT 1948.95 m
file: 1948CH02.DAT
Start: 22.08.95, 18:09 End: 22.08.95, 23:40



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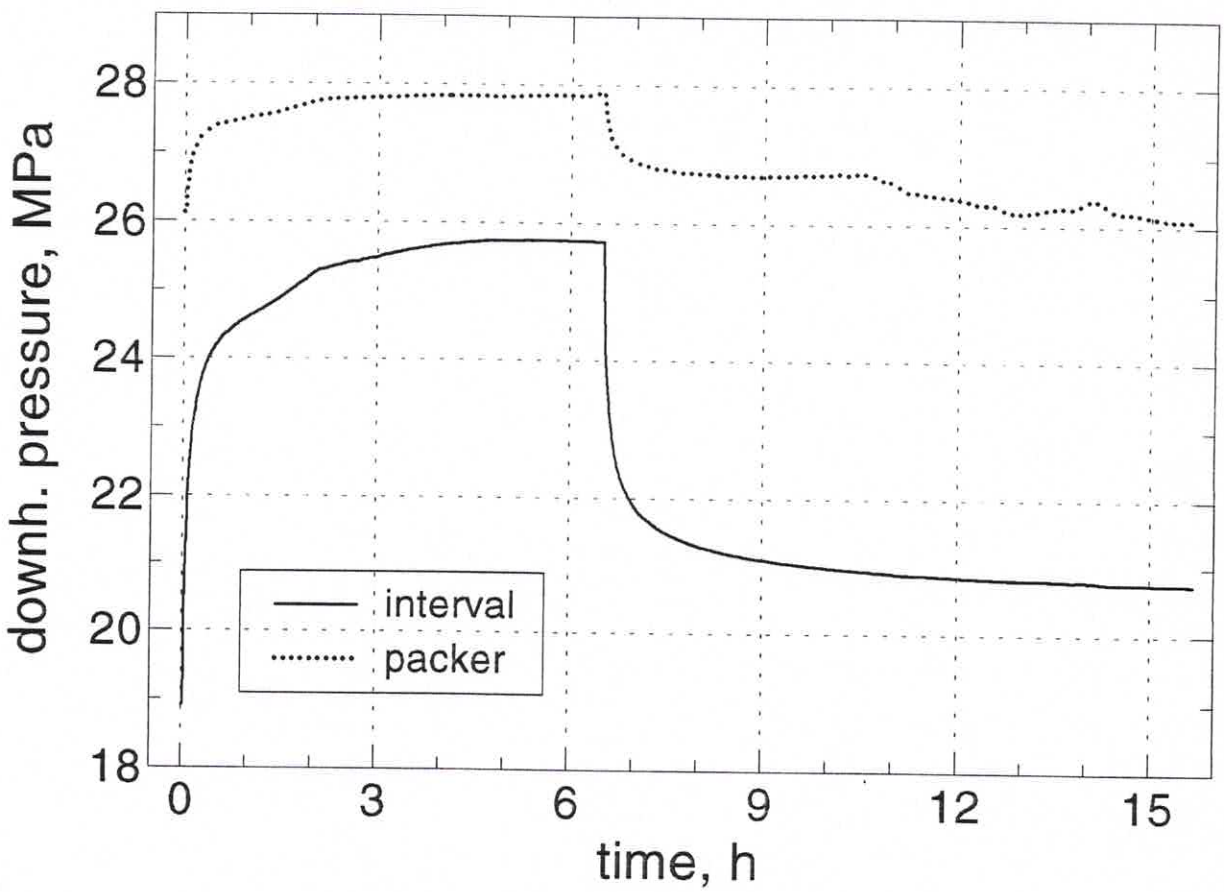
CASED - HOLE TEST 2 AT 1897.95 m
file: 1897CH02.DAT
Start: 23.08.95, 02:04 End: 23.08.95, 17:44



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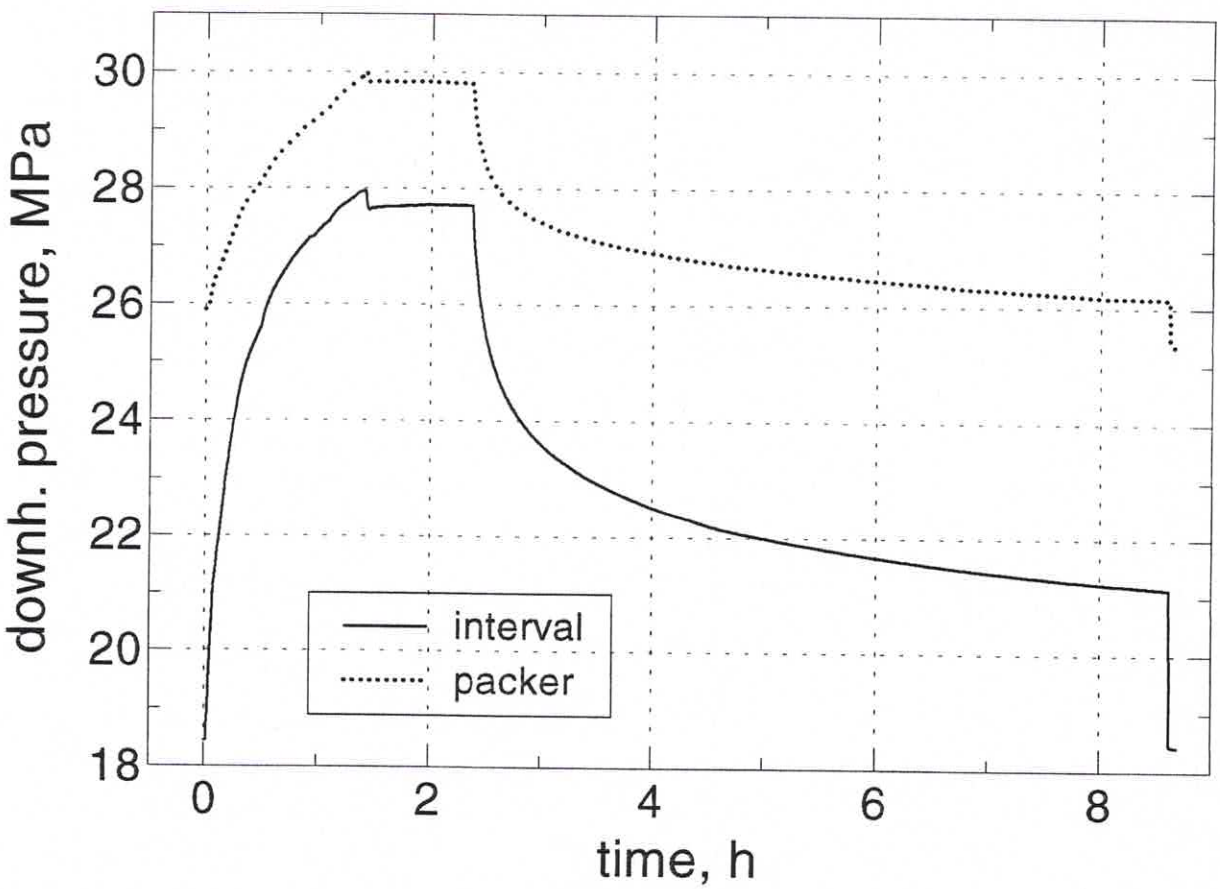
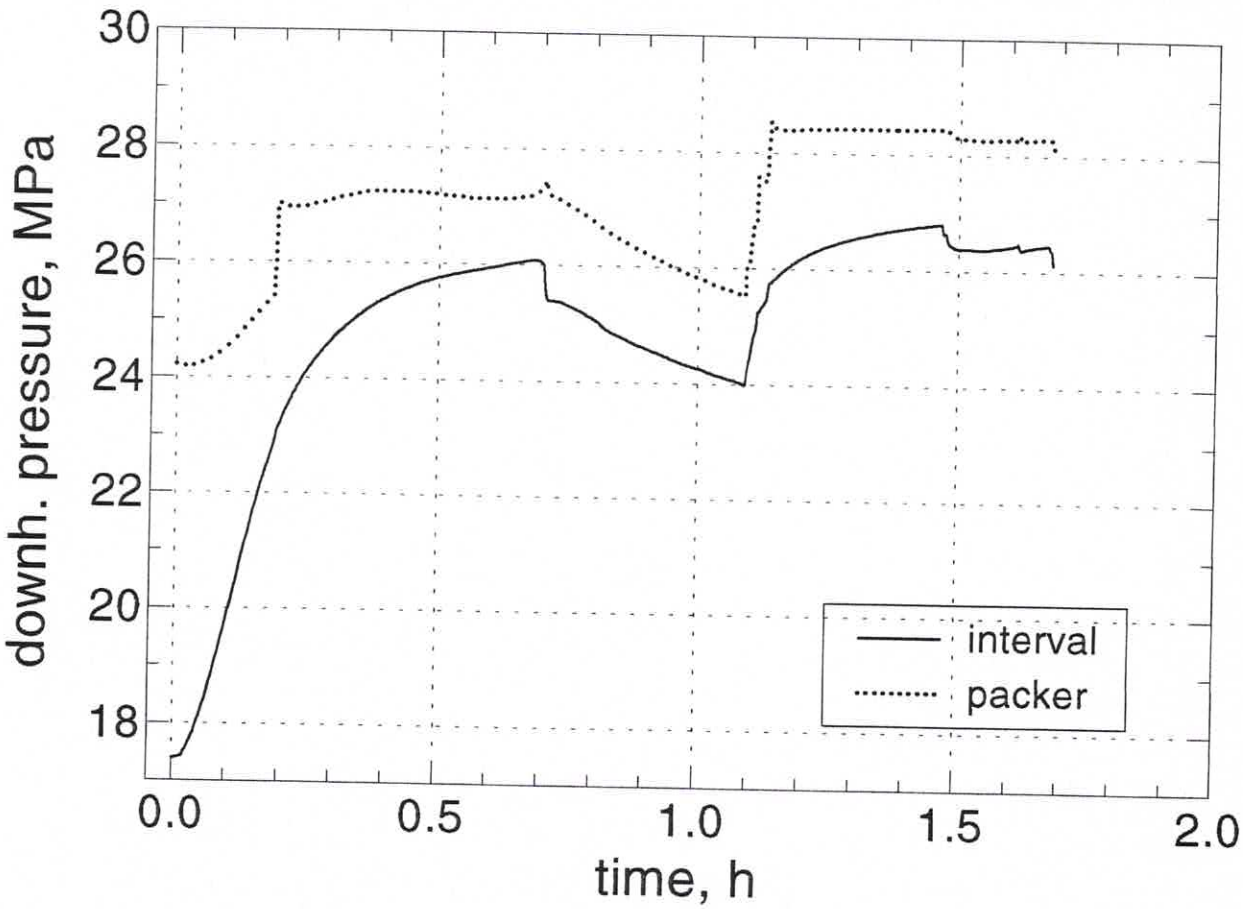
CASED - HOLE TEST 3 AT 1852.3 m
file: 1852CH02.DAT
Start: 23.08.95, 22:04 End: 24.08.95, 06:46

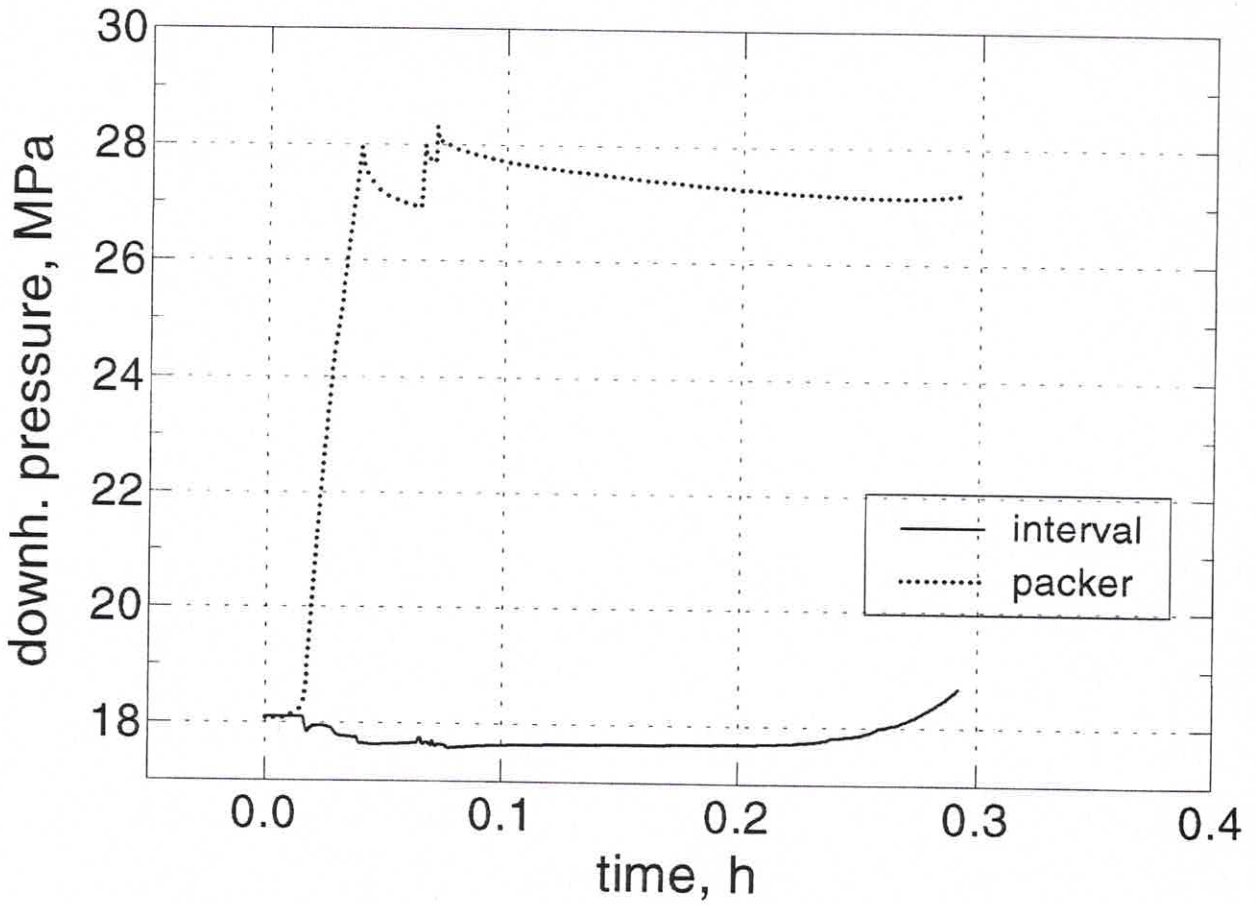


CASED - HOLE TEST 4 AT 1760.25 m
(1. attempt)
file: 1760CH02.DAT
Start: 24.08.95, 23:39 End: 25.08.95, 01:20

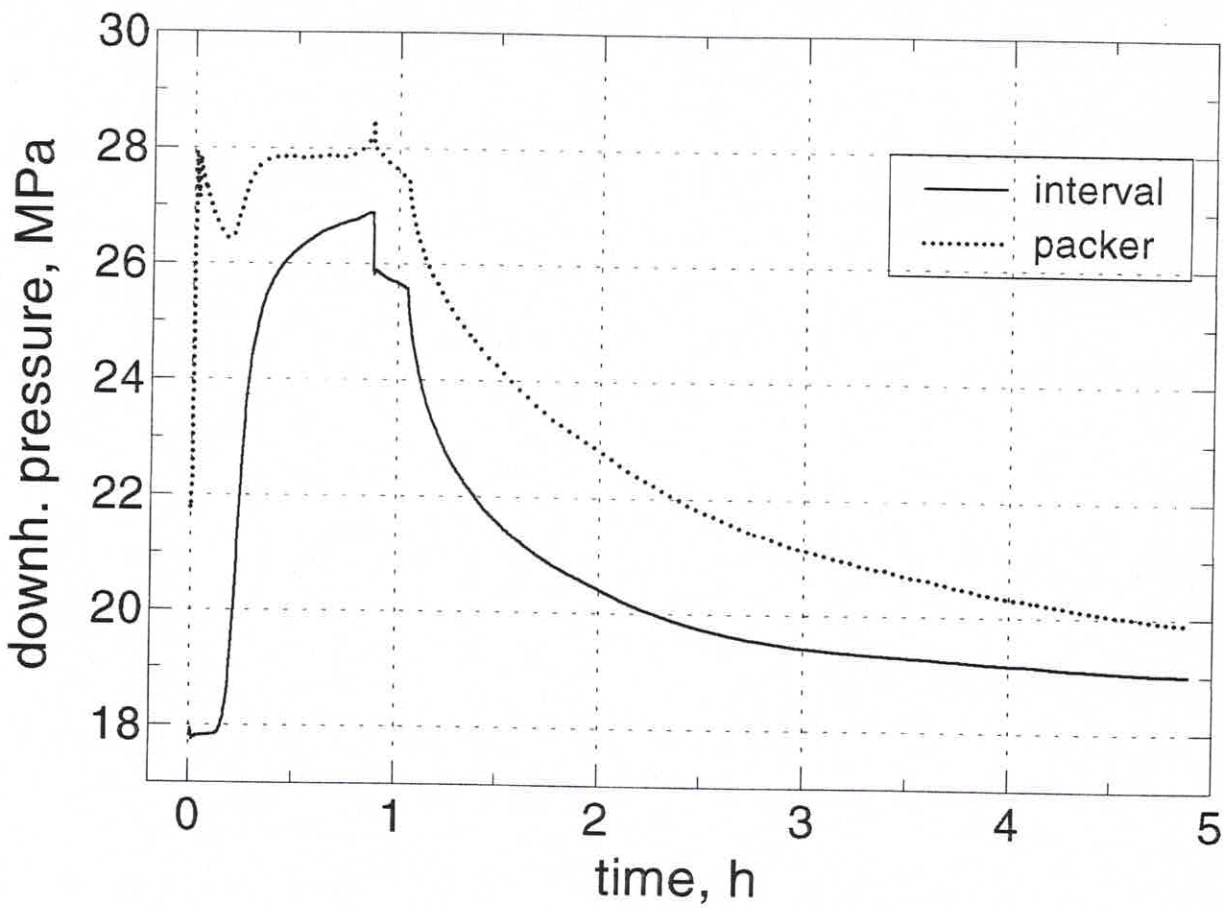


GEO-Meß-Systeme GmbH

CASED - HOLE TEST 4 AT 1760.25 m
(2. attempt)
file: 1760CH03.DAT
Start: 25.08.95, 03:03 End: 25.08.95, 03:21

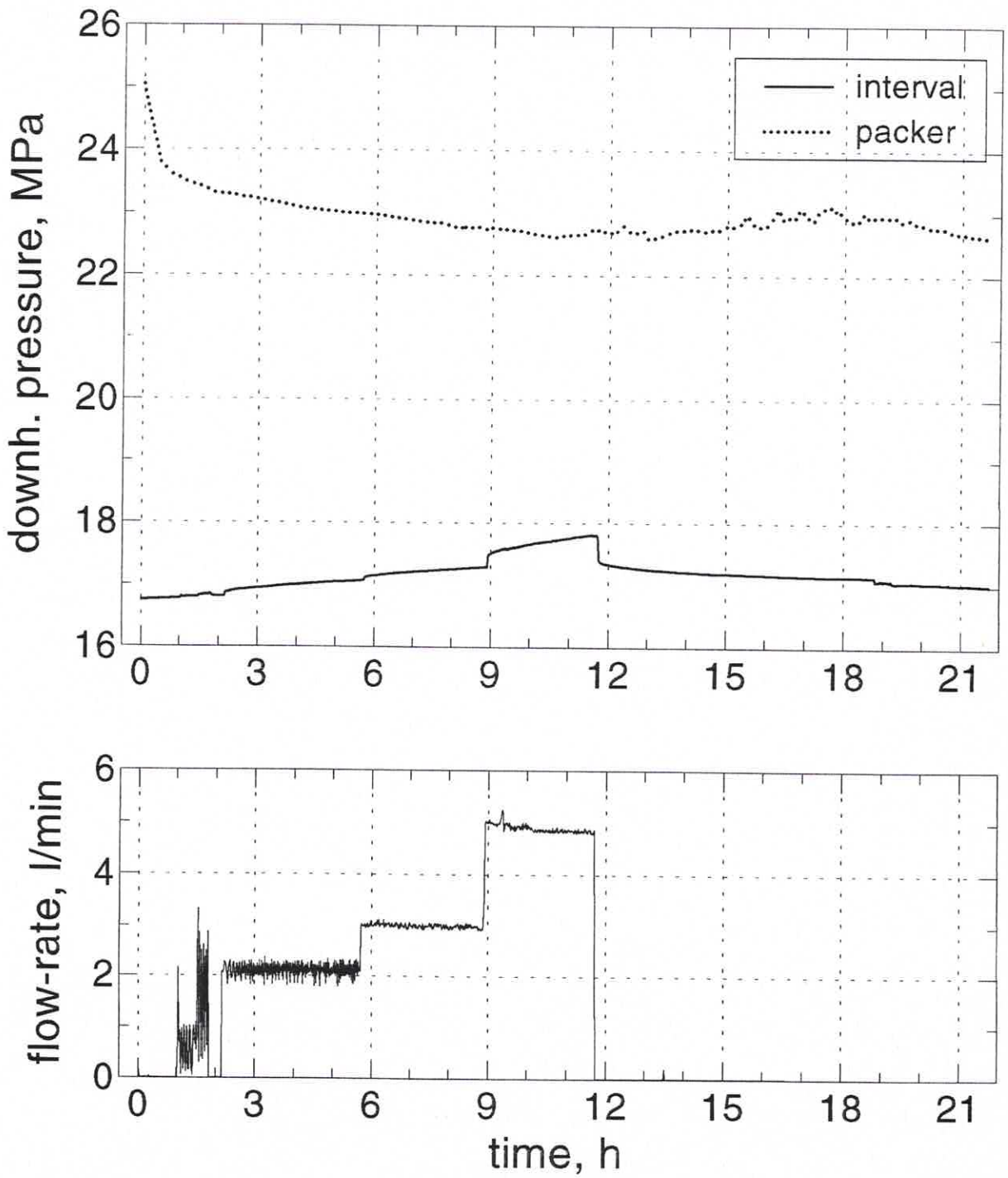


CASED - HOLE TEST 4 AT 1760.25 m
(3. attempt)
file: 1760CH05.DAT
Start: 25.08.95, 14:07 End: 25.08.95, 19:00

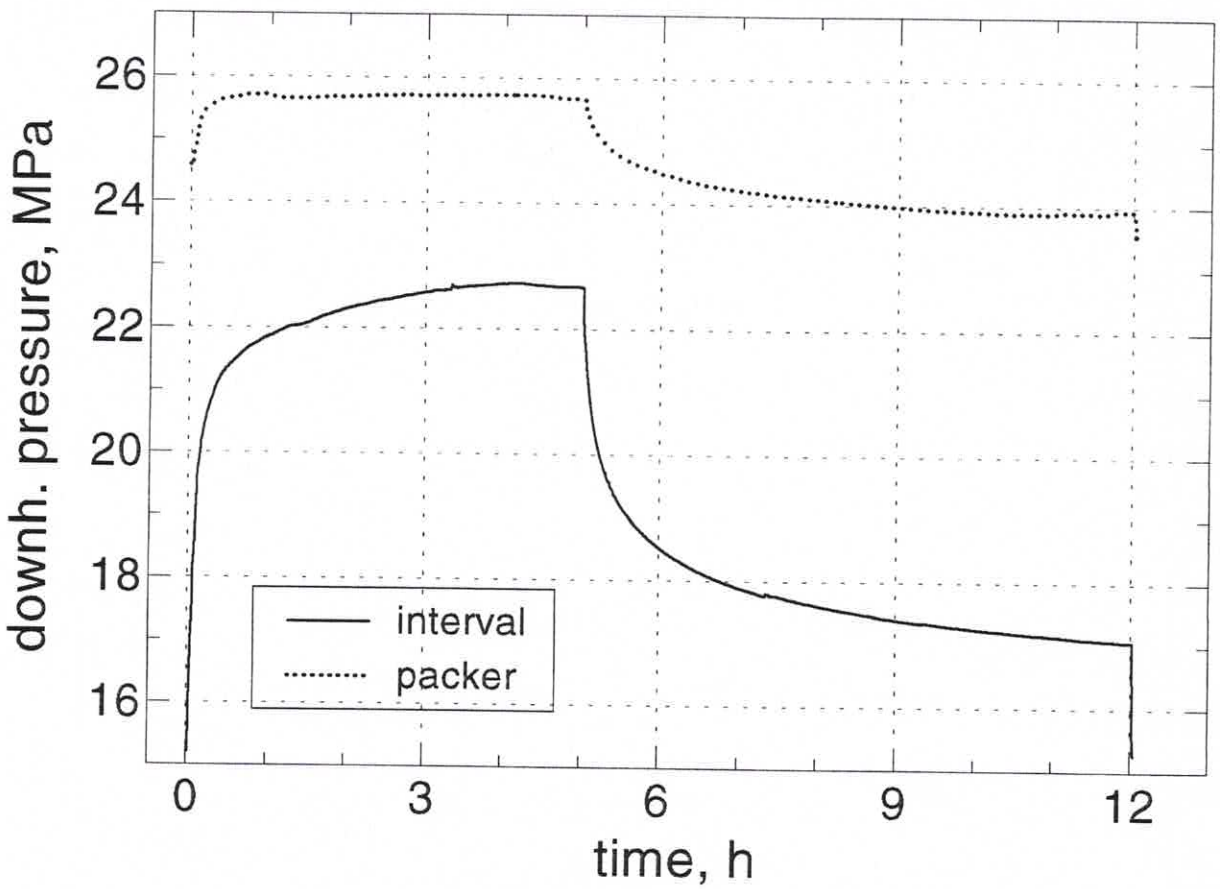


GEO-Meß-Systeme GmbH

CASED - HOLE TEST 5 AT 1596.15 m
file: 1596CH03.DAT
Start: 25.08.95, 22:16 End: 26.08.95, 20:00

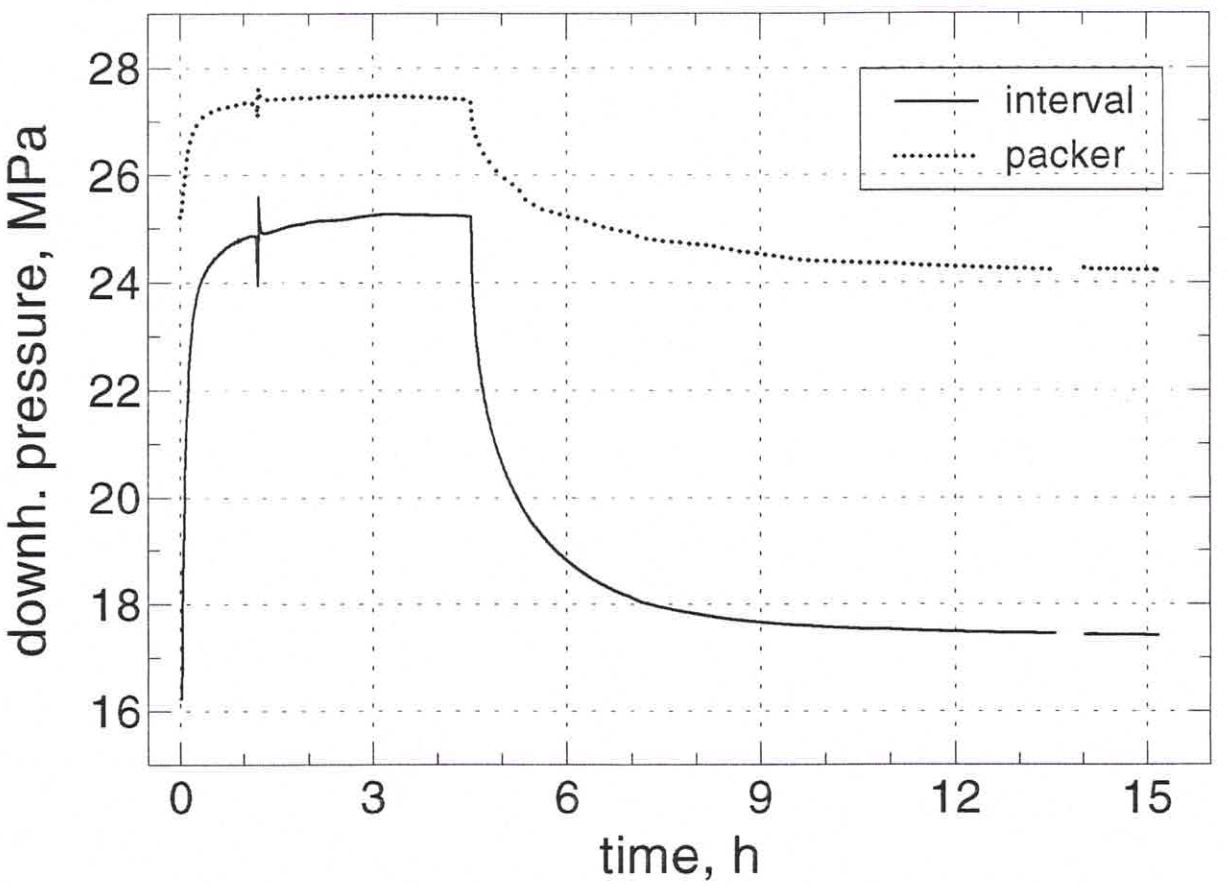


CASED - HOLE TEST 6 AT 1530.6 m
file: 1530CH02.DAT
Start: 26.08.95, 21:19 End: 27.08.95, 09:21

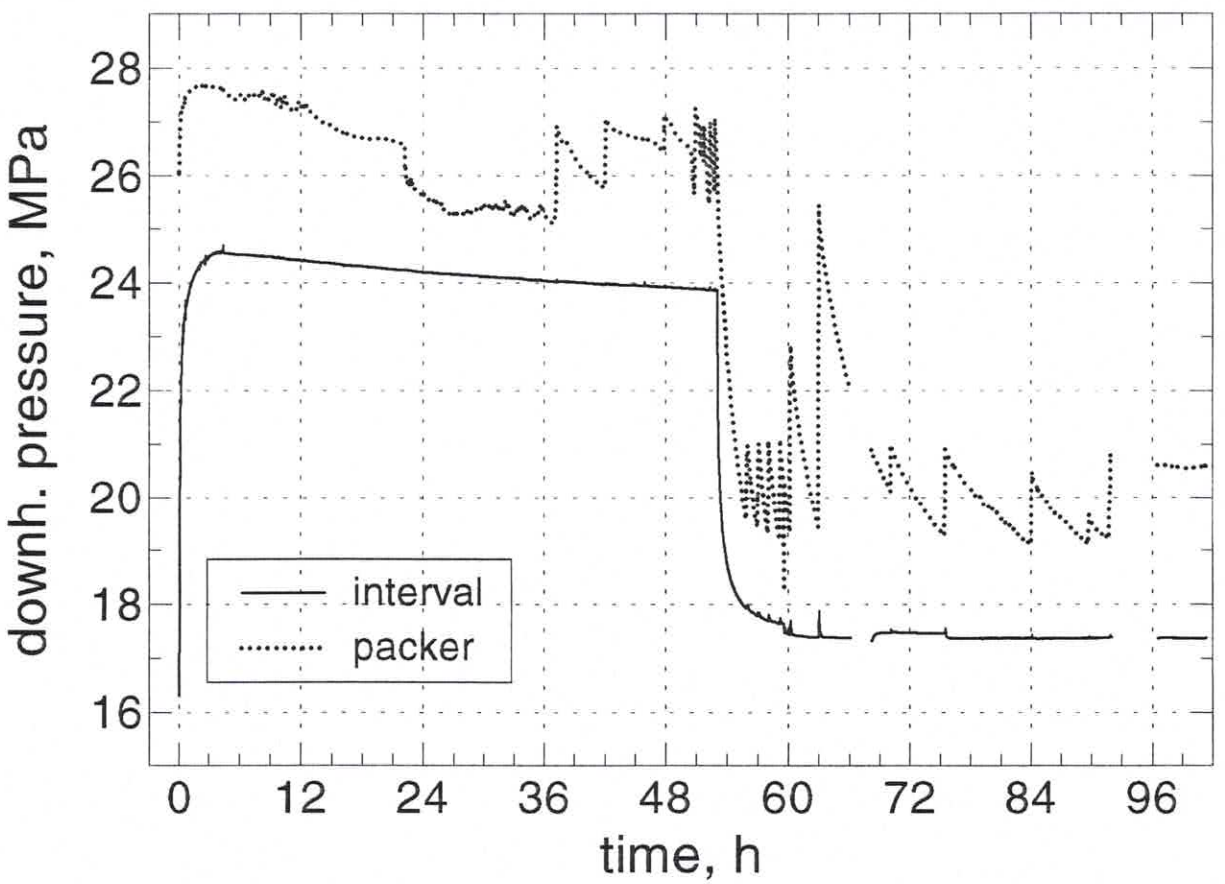


GEO-Meß-Systeme GmbH

CASED - HOLE TEST 7A AT 1627.5 m
files: 1627CH02.DAT, 1627CH03.DAT
Start: 27.08.95, 13:54 End: 28.08.95, 05:04

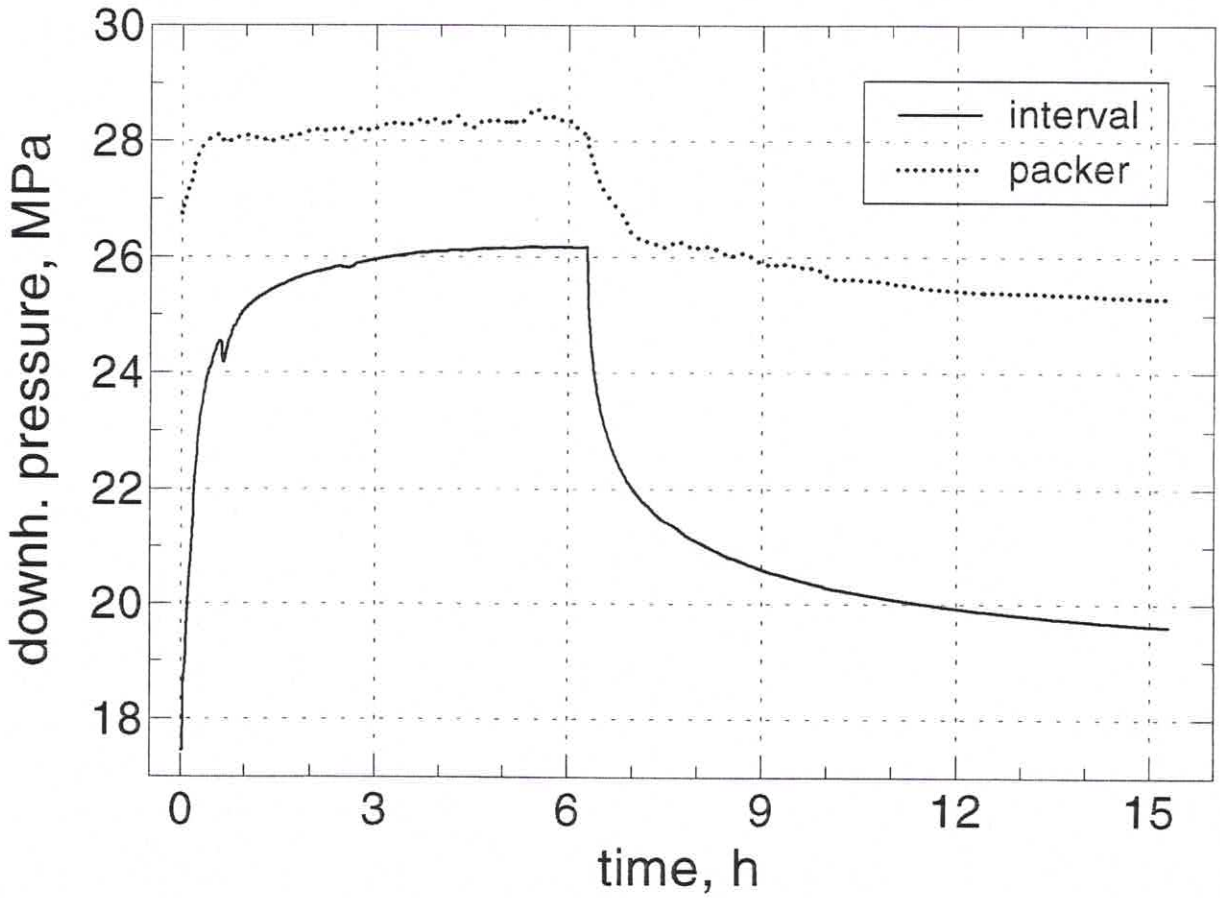


CASED - HOLE TEST 7B AT 1627.5 m
files: 1627CH04.DAT, 1627CH05.DAT,
1627CH06.DAT, 1627CH07.DAT, 1627CH08.DAT
Start: 31.08.95, 03:59 End: 04.09.95, 09:20

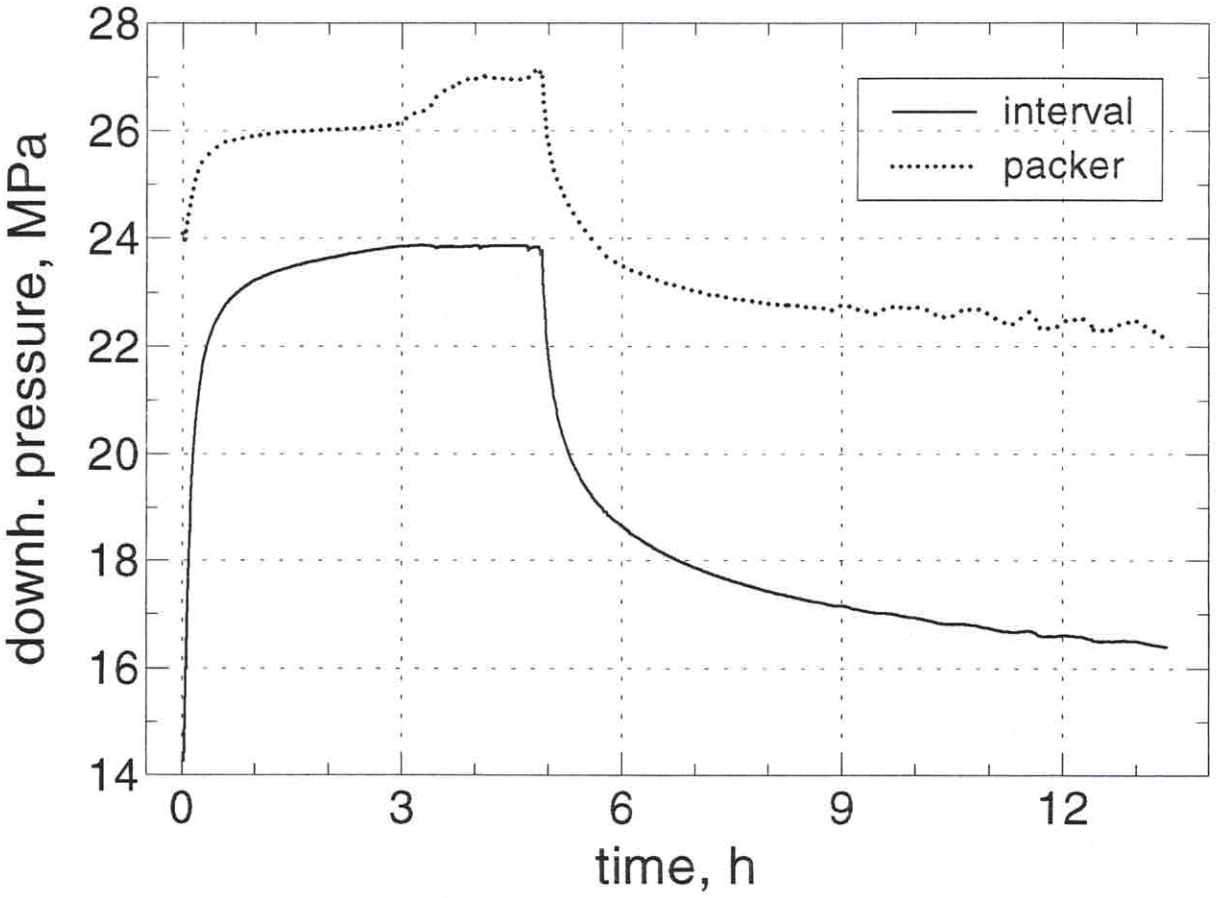


GEO-Meß-Systeme GmbH

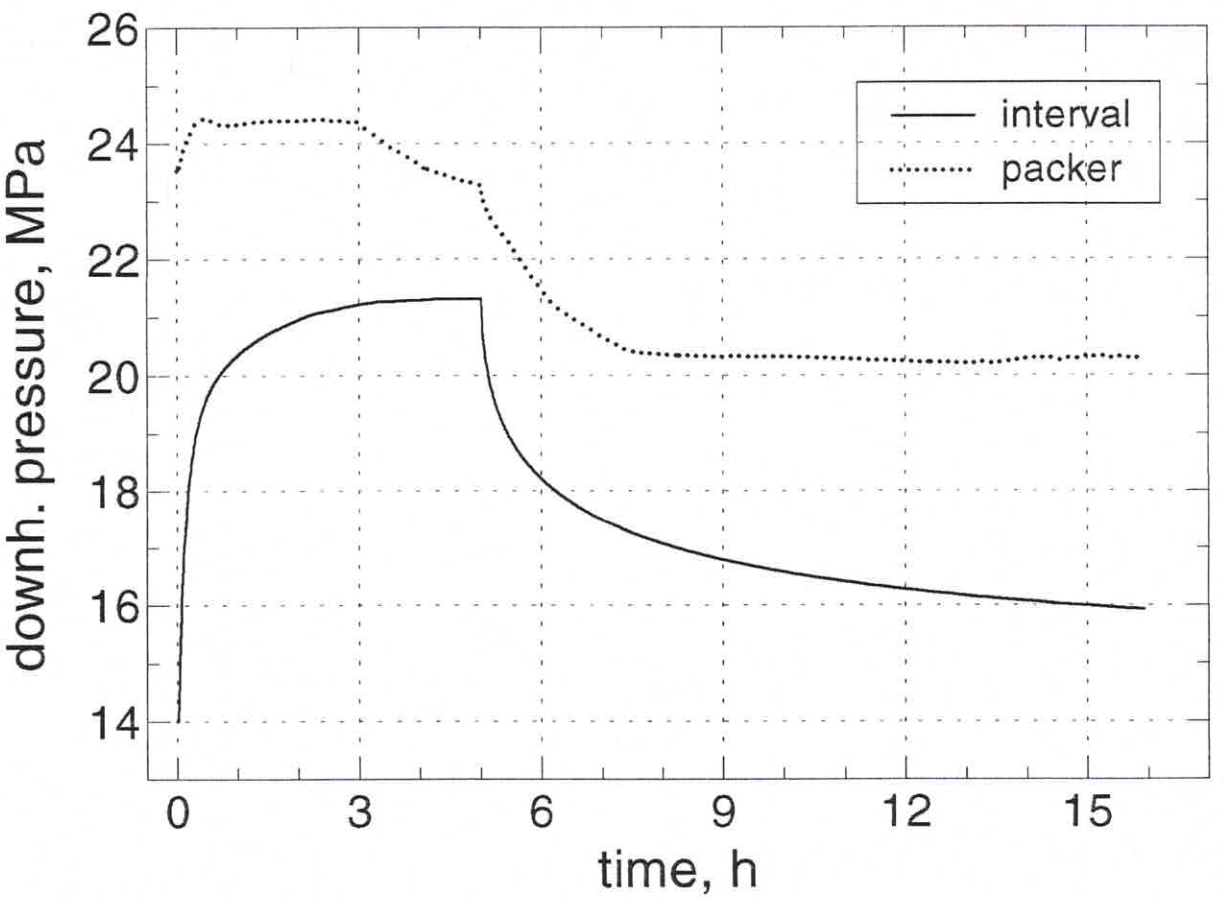
CASED - HOLE TEST 8 AT 1748.4 m
file: 1748CH02.DAT
Start: 28.08.95, 08:58 End: 29.08.95, 00:15



CASED - HOLE TEST 9 AT 1428.4 m
file: 1428CH02.DAT
Start: 29.08.95, 03:35 End: 29.08.95, 17:00

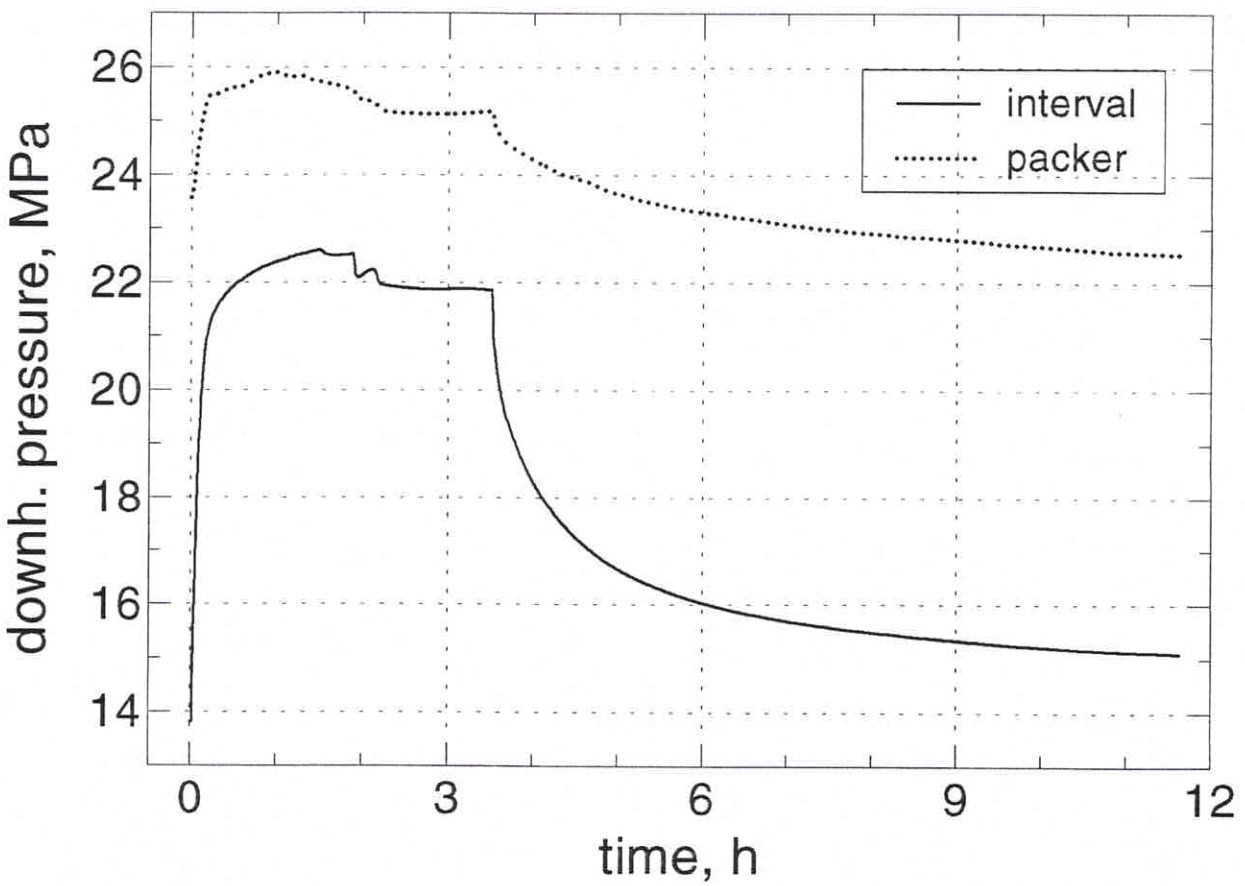


CASED - HOLE TEST 10 AT 1403.6 m
file: 1403CH02.DAT
Start: 29.08.95, 18:49 End: 30.08.95, 10:45



GEO-Meß-Systeme GmbH

CASED - HOLE TEST 11 AT 1379.85 m
file: 1379CH02.DAT
Start: 30.08.95, 13:22 End: 31.08.95, 01:26



APPENDIX C

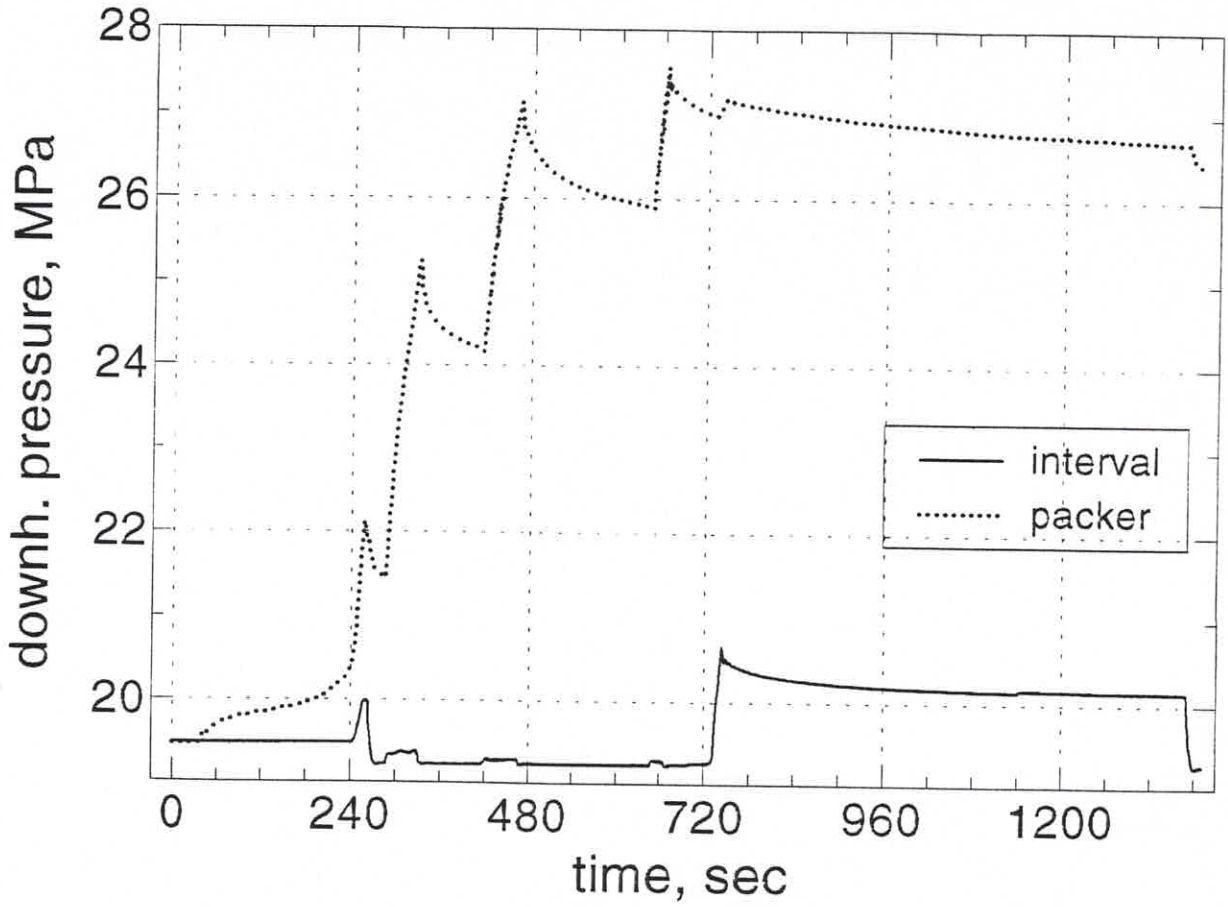
ANALYSIS OF PRESSURE PULSE TESTS FOR PERMEABILITY / TRANSMISSIVITY EVALUATION

remarks :

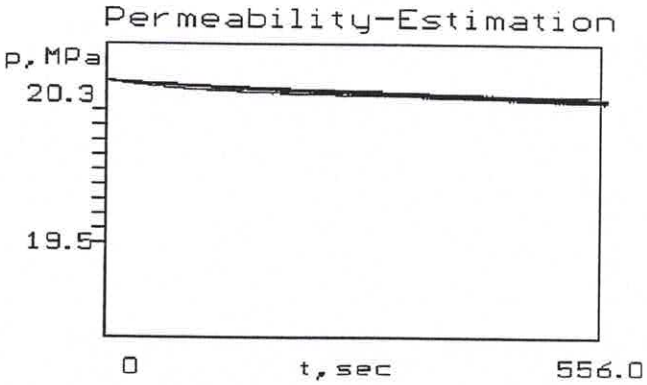
- upper figure: test record
- lower figure: result of type curve analysis

GEO-Meß-Systeme GmbH

CASED - HOLE TEST 1 AT 1948.95 m



overview



INPUTPARAMETERS

filename:	1948.p
samplingrate, sec:	0.40
inv. Stiffness m².m/Pa:	2.6E-0010
interval length, m:	1.00
hole diameter, mm:	127.00
Phyd, MPa:	19.50
Tm (min, max), sec:	100 2000
number of models:	10000
	100
error:	1.5E-0003

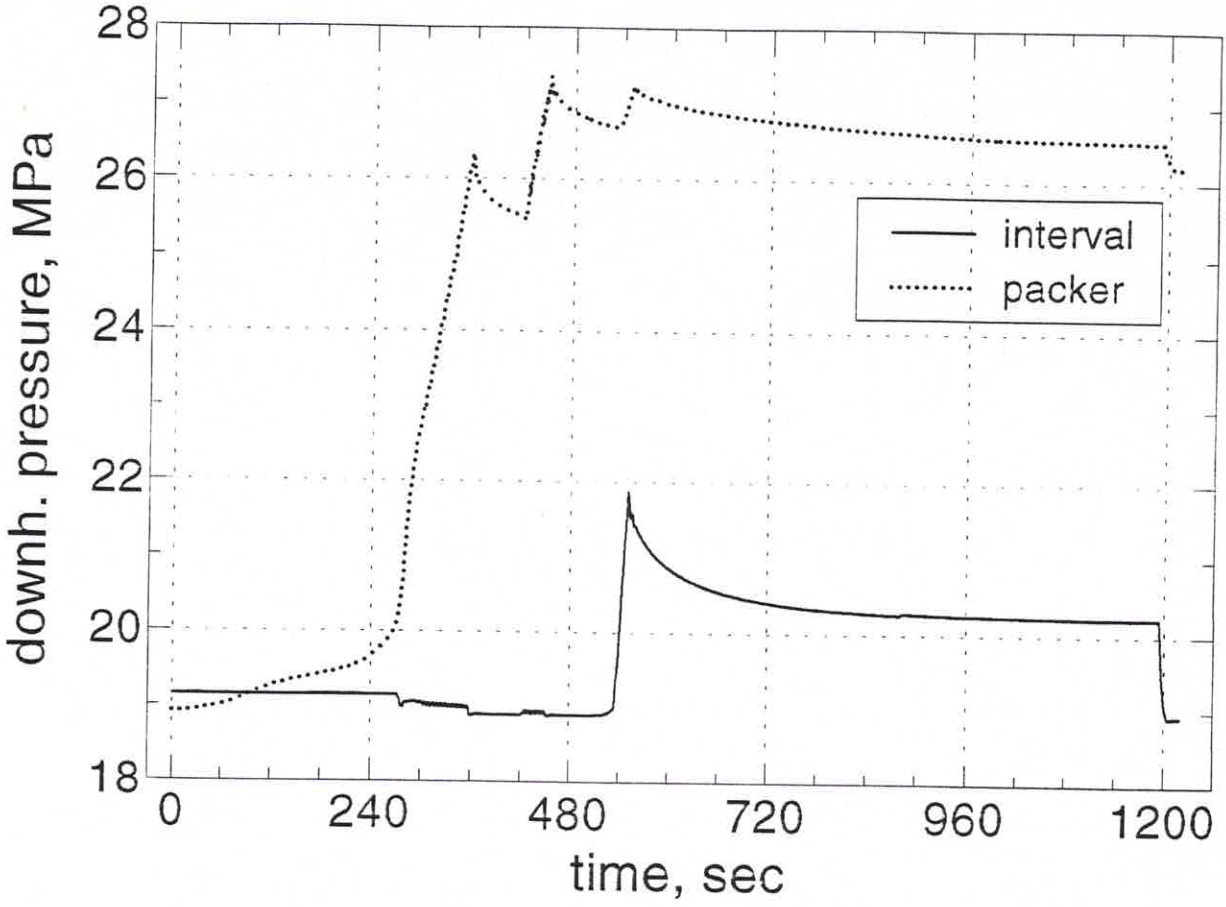
result (mean value of all fitting models):

Permeability	: (	87.5 ±	9.2)	µdarcy
Transmissivity	: (	0.04 ±	0.005)	cm²/s

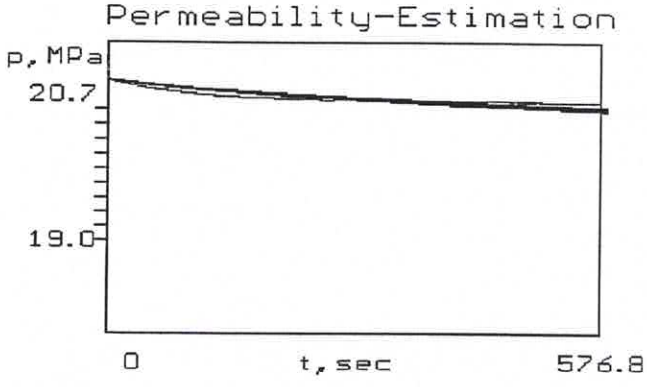
Number of fitting models: 363

MeSy GEO-Meß-Systeme GmbH

CASED - HOLE TEST 2 AT 1897.95 m



overview



INPUTPARAMETERS

filename:	1897.p	
samplingrate, sec:	0.40	
inv. Stiffness m².m/Pa:	2.6E-0010	
interval length, m:	1.85	
hole diameter, mm:	127.00	
Phyd, MPa:	19.00	
Tm (min, max), sec:	100	2000
number of models:	10000	
	100	
error:	4.2E-0003	

result (mean value of all fitting models):

Permeability	: (	42.4 ±	2.4)	µdarcy
Transmissivity	: (	0.04 ±	0.002)	cm²/s

Number of fitting models: 238

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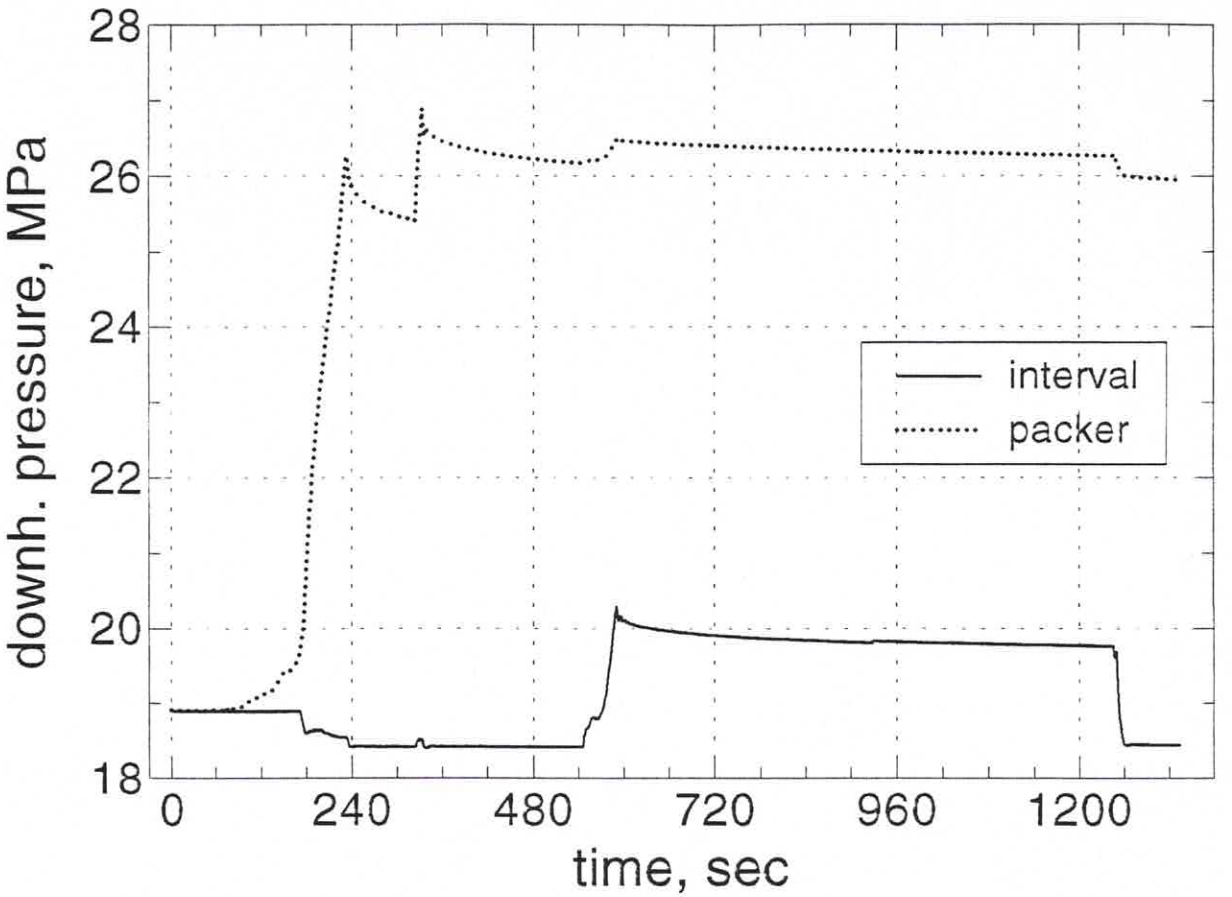
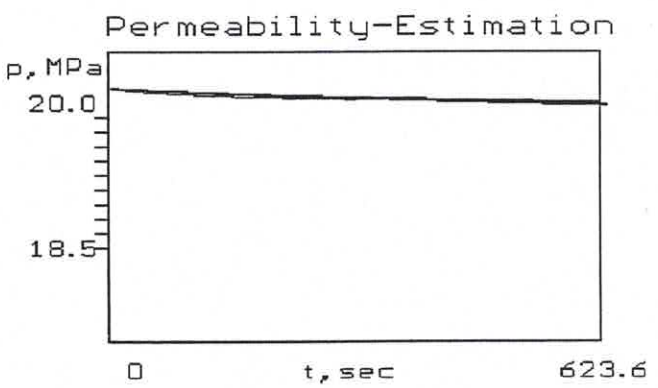
CASED - HOLE TEST 3 AT 1852.30 m



overview



INPUTPARAMETERS

filename:	1852.p
samplingrate, sec:	0.40
inv. Stiffness m².m/Pa:	2.6E-0010
interval length, m:	0.70
hole diameter, mm:	127.00
Phyd, MPa:	18.50
Tm (min, max), sec:	100 2000
number of models:	10000
	100
error:	1.9E-0003

result (mean value of all fitting models):

Permeability : (100.7 ± 3.5) µdarcy

Transmissivity : (0.03 ± 0.001) cm²/s

Number of fitting models: 149

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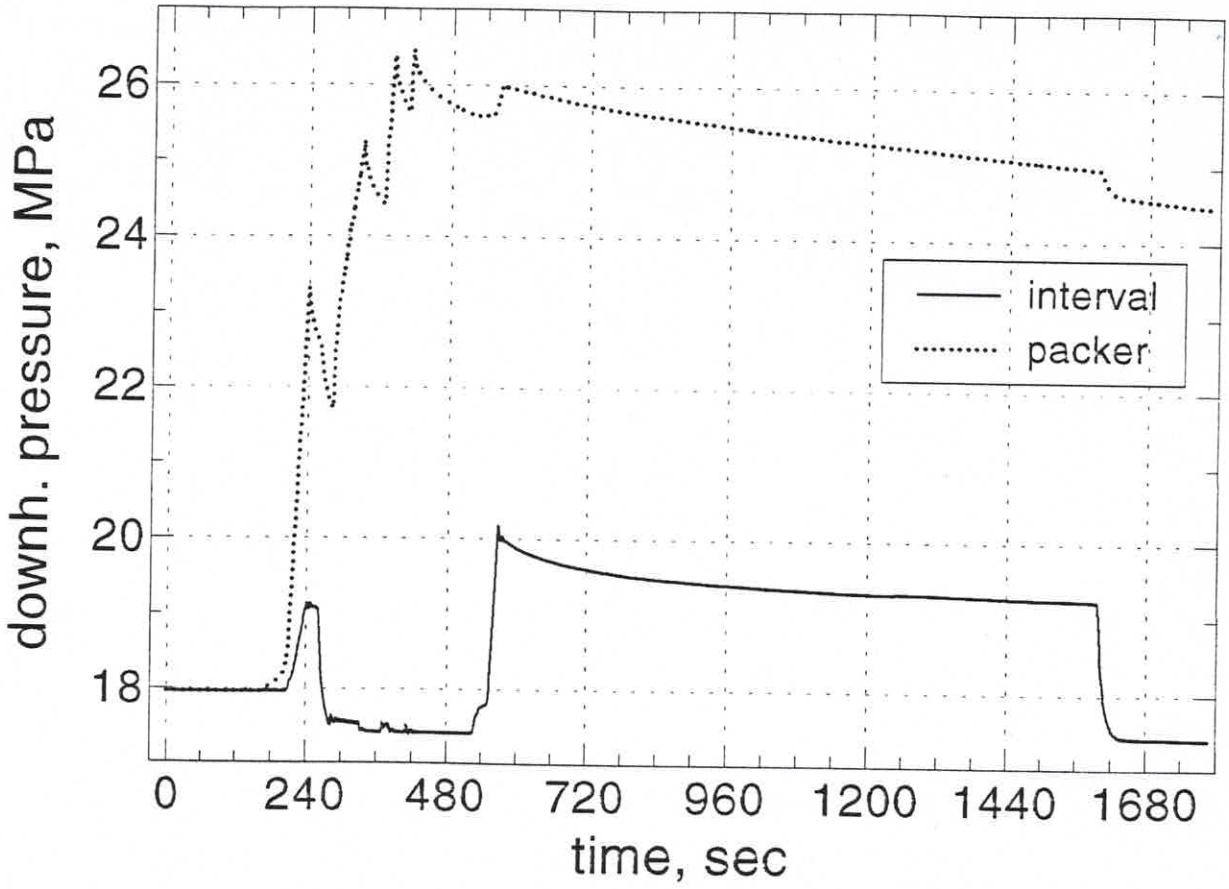
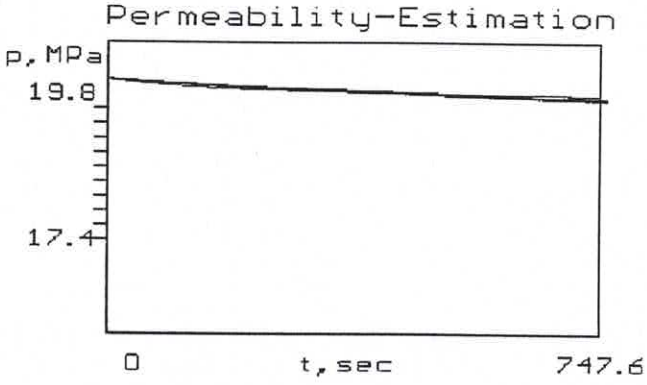
CASED - HOLE TEST 4 AT 1760.25 m



overview



INPUTPARAMETERS

filename:	1760.p
samplingrate, sec:	0.40
inv. Stiffness m².m/Pa:	2.6E-0010
interval length, m:	0.67
hole diameter, mm:	127.00
Phyd, MPa:	17.40
Tm (min, max), sec:	100 2000
number of models:	10000
	100
error:	2.7E-0003

result (mean value of all fitting models):

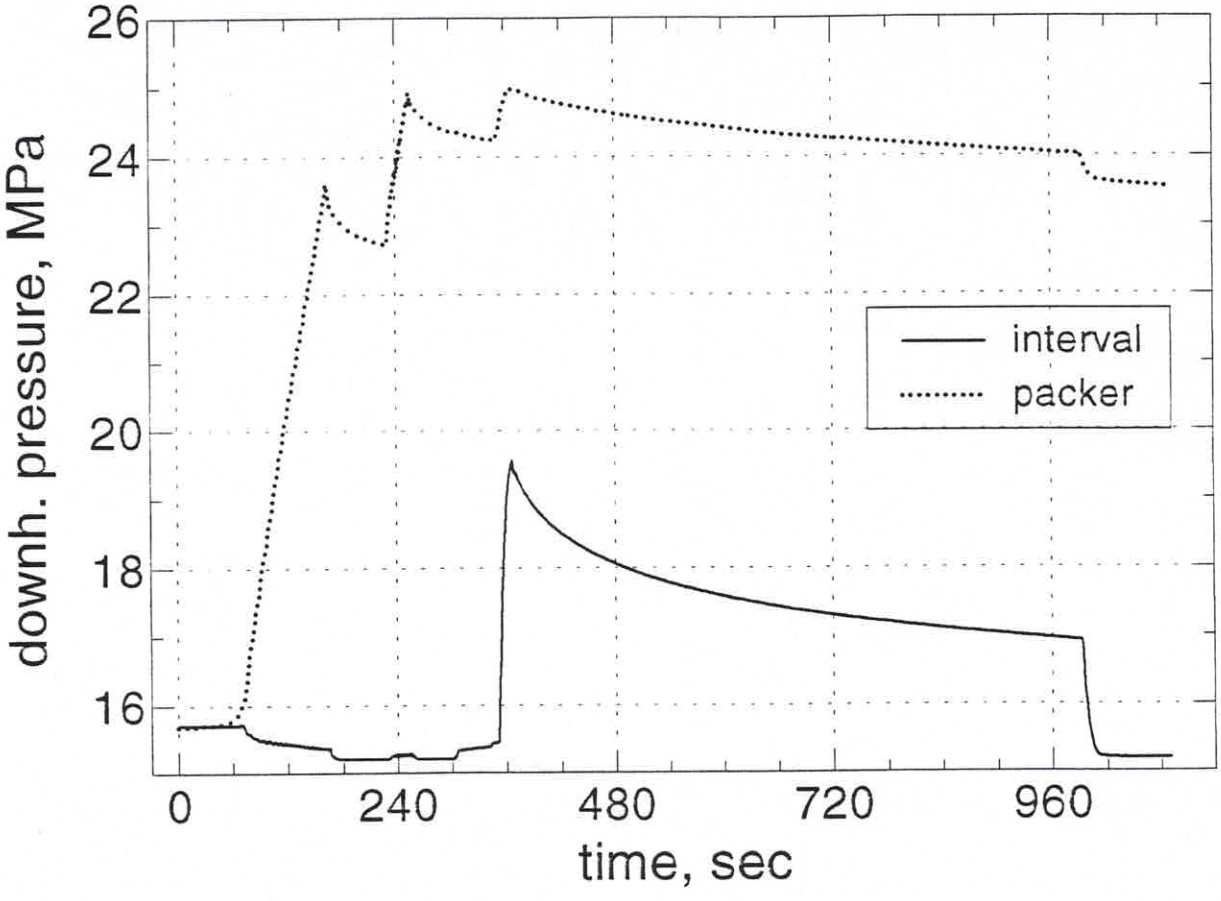
Permeability : (86.1 ± 2.8) µdarcy

Transmissivity : (0.03 ± 0.001) cm²/s

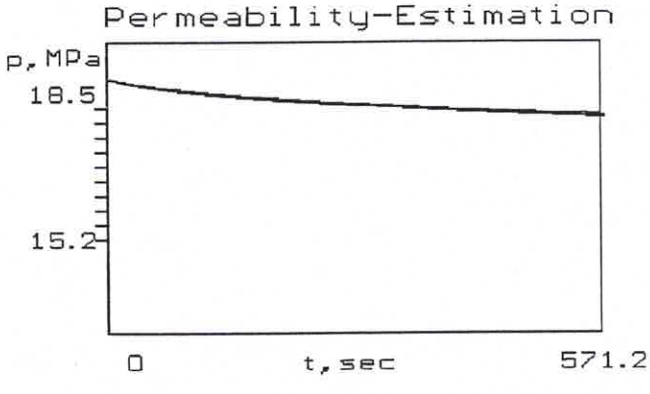
Number of fitting models: 174

GEO-Meß-Systeme GmbH

CASED - HOLE TEST 6 AT 1530.60 m



overview



INPUTPARAMETERS

filename:	1530.p	
samplingrate, sec:	0.40	
inv. Stiffness m².m/Pa:	2.6E-0010	
interval length, m:	1.25	
hole diameter, mm:	127.00	
Phyd, MPa:	15.20	
Tm (min, max), sec:	100	2000
number of models:	10000	
	100	
error:	3.0E-0003	

result (mean value of all fitting models):

Permeability : (105.0 ± 2.2) µdarcy

Transmissivity : (0.06 ± 0.001) cm²/s

Number of fitting models: 53

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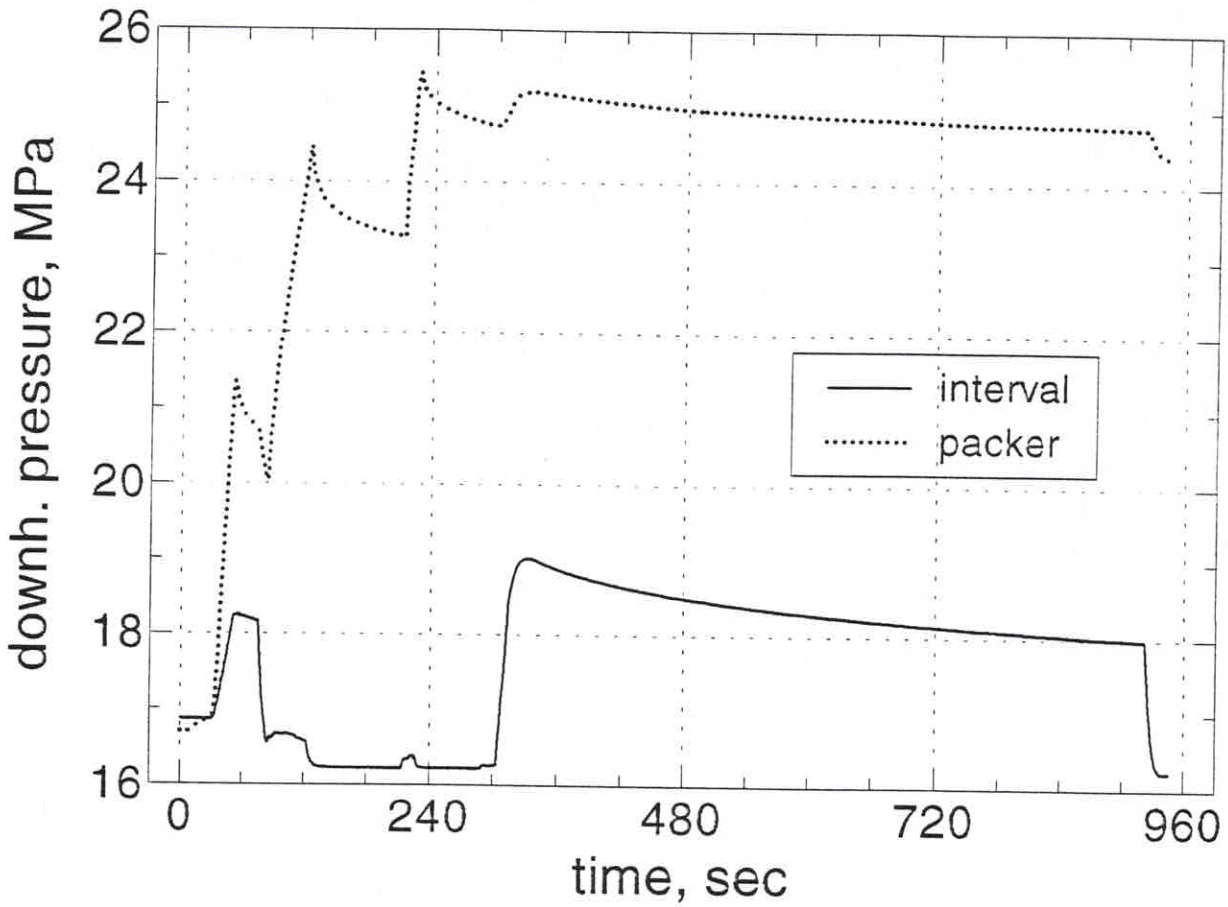
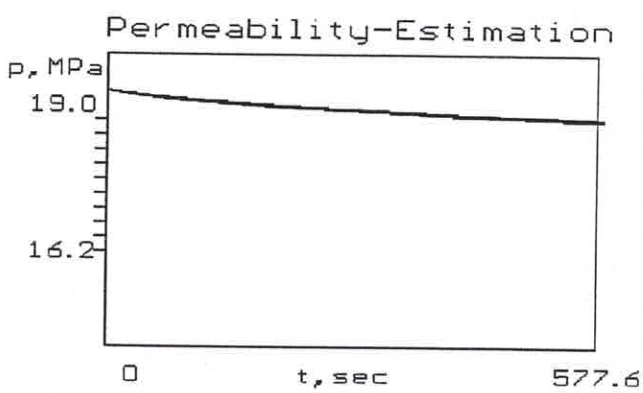
CASED - HOLE TEST 7 AT 1627.50 m



overview



INPUTPARAMETERS

filename:	1627.p
samplingrate, sec:	0.40
inv. Stiffness m².m/Pa:	2.6E-0010
interval length, m:	0.90
hole diameter, mm:	127.00
Phyd, MPa:	16.20
Tm (min, max), sec:	100 2000
number of models:	10000
	100
error:	2.5E-0003

result (mean value of all fitting models):

Permeability : (90.2 ± 3.2) µdarcy

Transmissivity : (0.04 ± 0.001) cm²/s

Number of fitting models: 136

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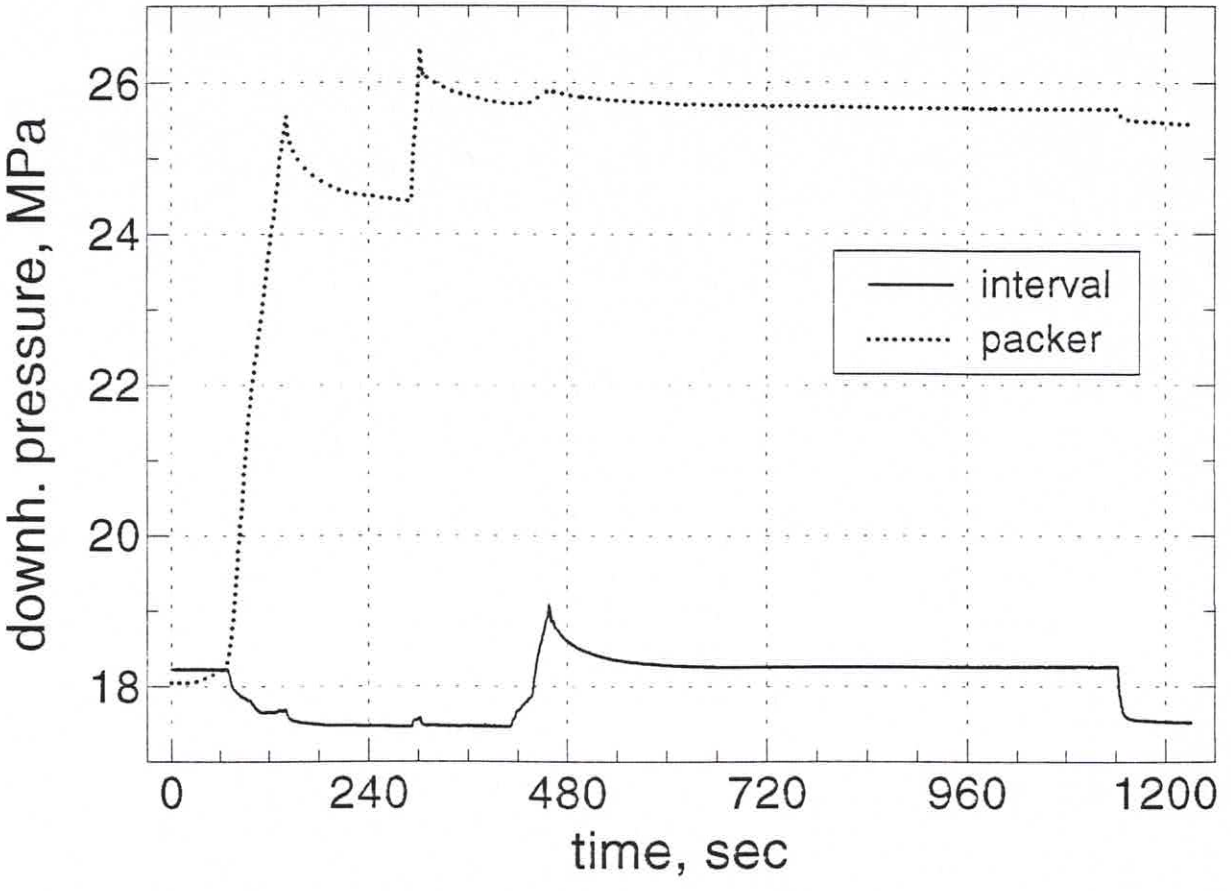
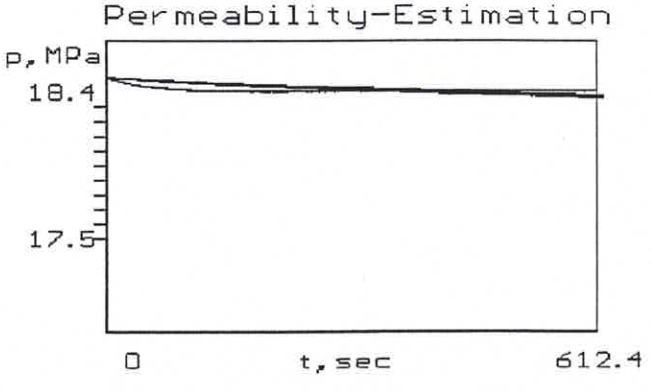
CASED - HOLE TEST 8 AT 1748.40 m



overview



INPUTPARAMETERS

filename:	1748.p
samplingrate, sec:	0.40
inv. Stiffness m².m/Pa:	2.6E-0010
interval length, m:	0.84
hole diameter, mm:	127.00
Phyd, MPa:	17.50
Tm (min, max), sec:	100 2000
number of models:	10000
	100
error:	2.8E-0003

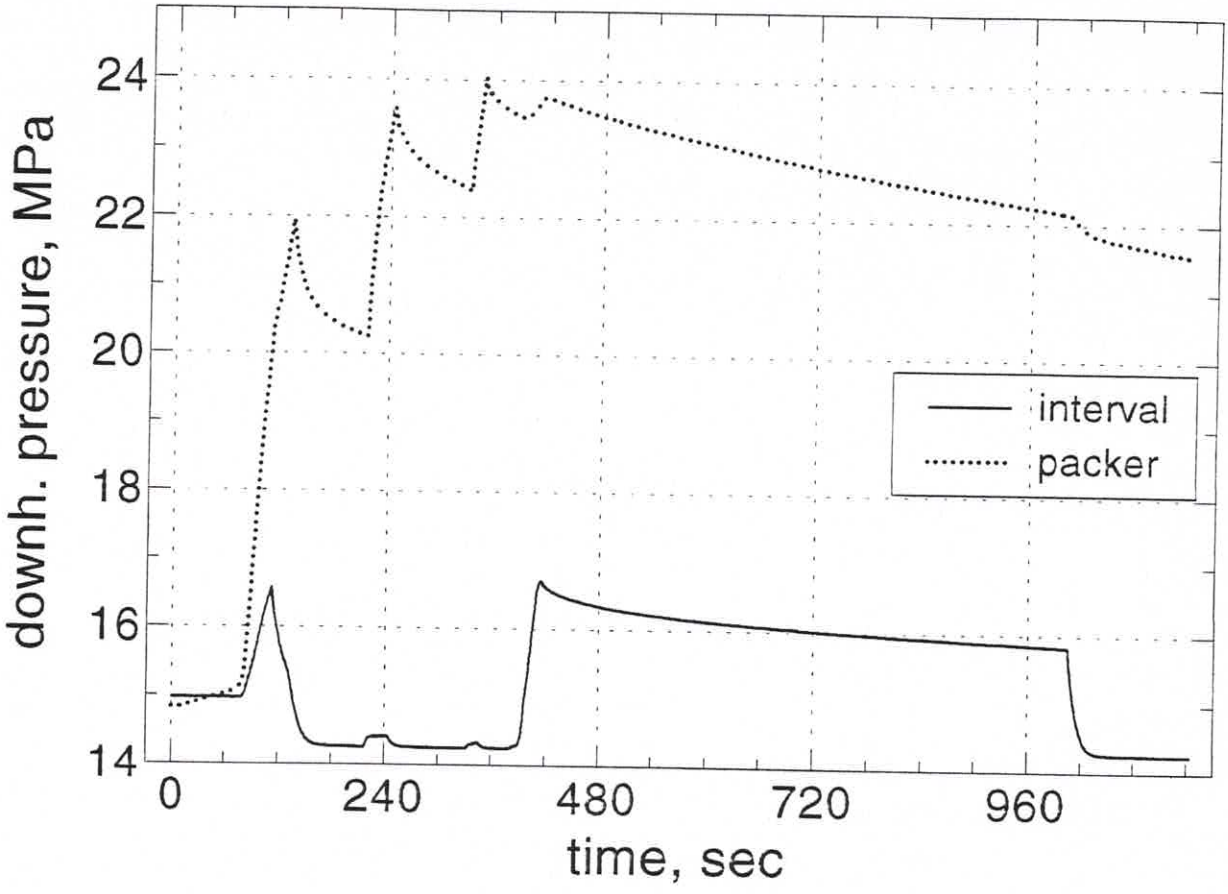
result (mean value of all fitting models):

Permeability	: (	92.9 ±	9.4)	µdarcy
Transmissivity	: (	0.04 ±	0.004)	cm²/s

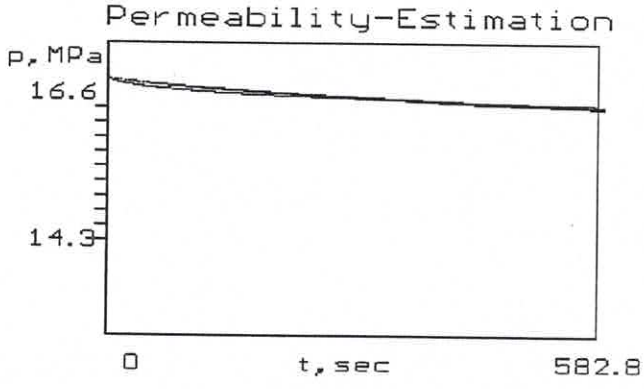
Number of fitting models: 286

GEO-Meß-Systeme GmbH

CASED - HOLE TEST 9 AT 1428.45 m



overview



INPUTPARAMETERS

filename:	1428.p
samplingrate, sec:	0.40
inv. Stiffness m².m/Pa:	2.6E-0010
interval length, m:	0.75
hole diameter, mm:	127.00
Phyd, MPa:	14.30
Tm (min, max), sec:	100 2000
number of models:	10000
	100
error:	4.0E-0003

result (mean value of all fitting models):

Permeability : (105.3 ± 1.6) µdarcy

Transmissivity : (0.04 ± 0.001) cm²/s

Number of fitting models: 65

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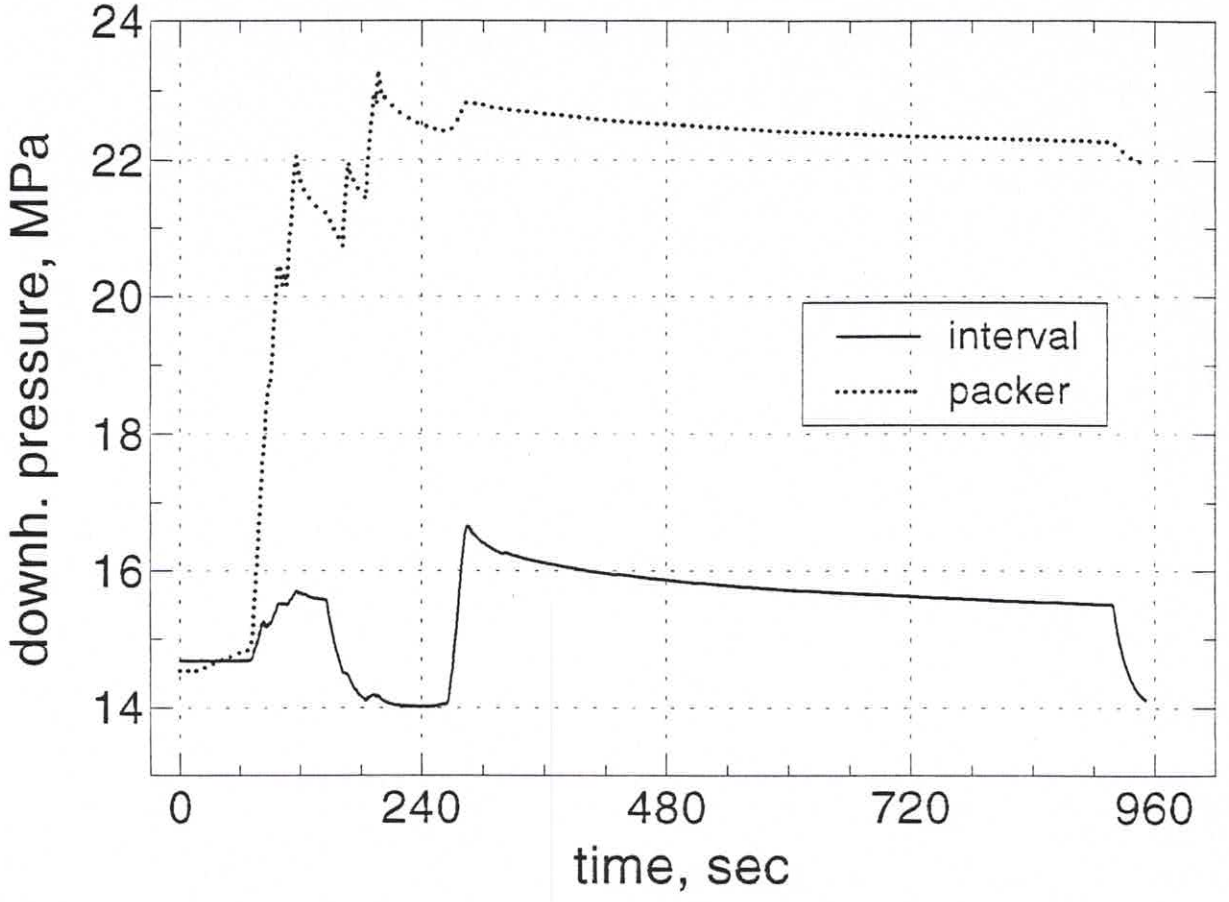
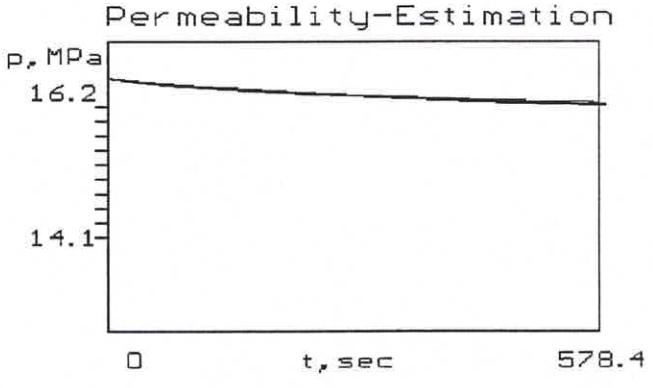
CASED - HOLE TEST 10 AT 1403.60 m



overview



INPUTPARAMETERS

filename:	1403.p
samplingrate, sec:	0.40
inv. Stiffness m².m/Pa:	2.6E-0010
interval length, m:	1.68
hole diameter, mm:	127.00
Phyd, MPa:	14.10
Tm (min, max), sec:	100 2000
number of models:	10000
	100
error:	2.2E-0003

result (mean value of all fitting models):

Permeability	: (	43.9 ±	1.0)	µdarcy
Transmissivity	: (	0.04 ±	0.001)	cm²/s

Number of fitting models: 105

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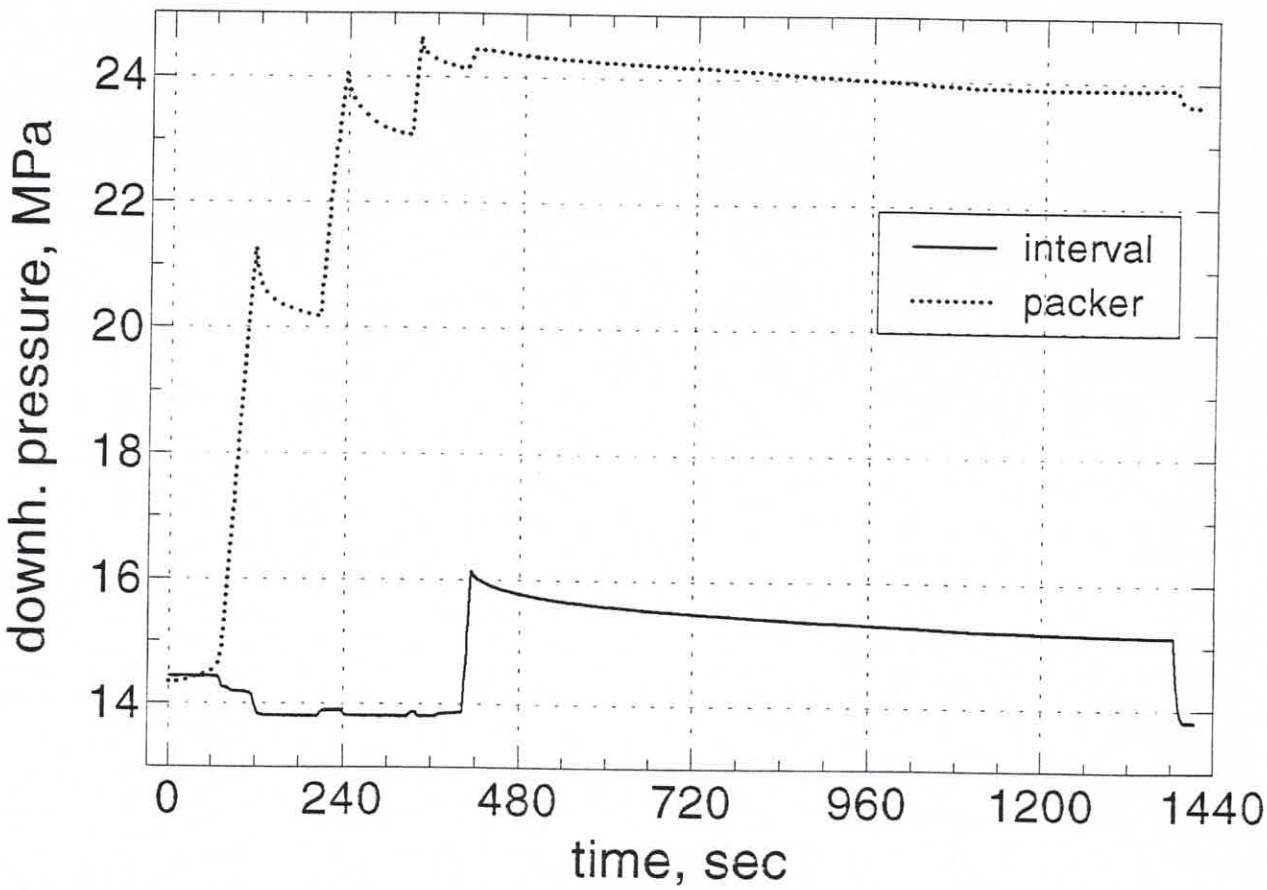
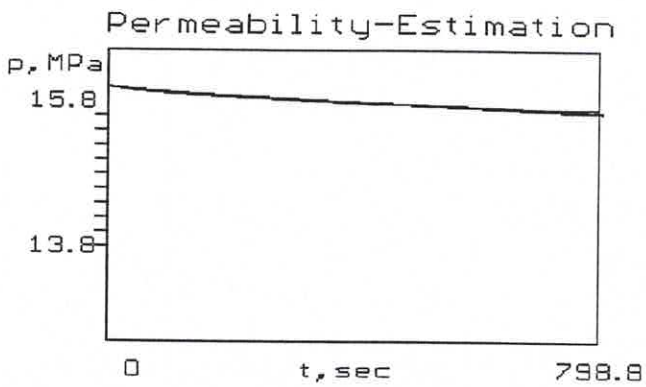
CASED - HOLE TEST 11 AT 1379.85 m



overview



INPUTPARAMETERS

filename:	1379.p
samplingrate, sec:	0.40
inv. Stiffness m².m/Pa:	2.6E-0010
interval length, m:	2.10
hole diameter, mm:	127.00
Phyd, MPa:	13.80
Tm (min, max), sec:	100 2000
number of models:	10000
	100
error:	1.8E-0003

result (mean value of all fitting models):

Permeability :	(	37.5 ±	0.7)	µdarcy
Transmissivity :	(	0.04 ±	0.001)	cm²/s

Number of fitting models: 70

APPENDIX D

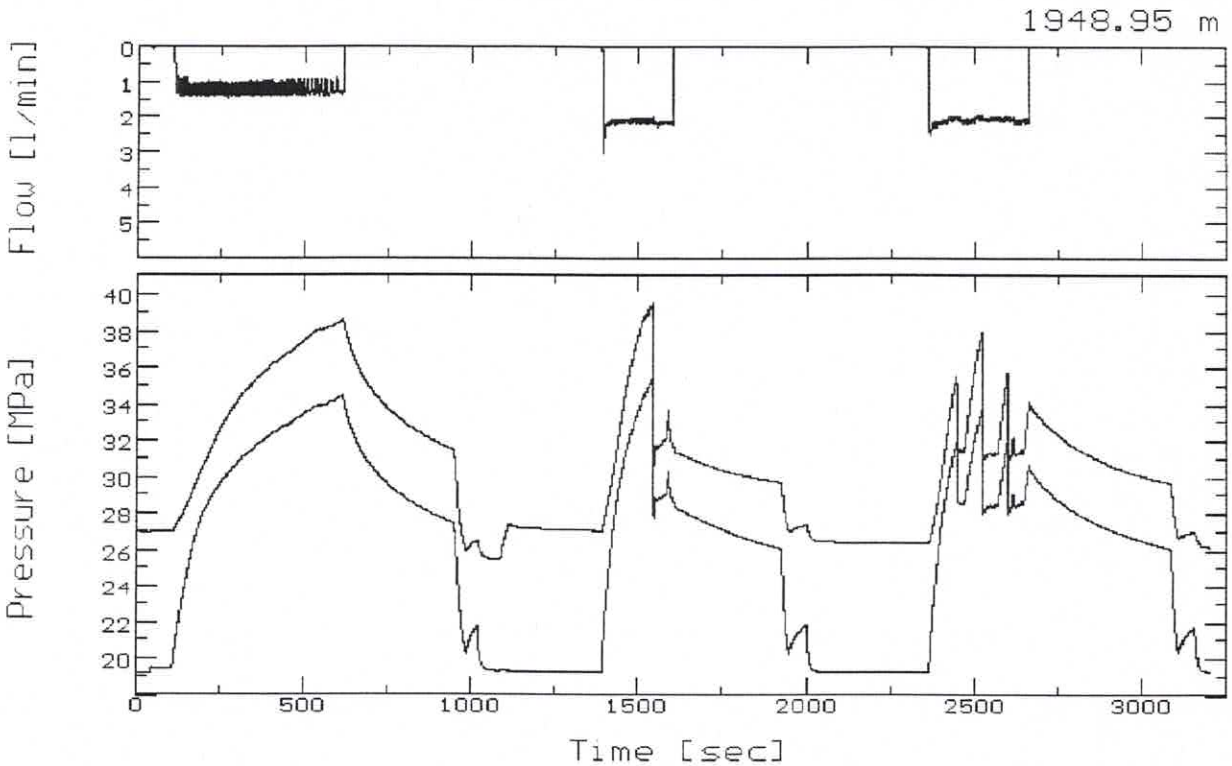
OVERVIEW PLOTS OF HYDROFRAC STRESS TESTS AND PRESSURE RECORD ANALYSIS FOR STRESS ESTIMATION

For each test section, the analysis contains:

- overview - plots of downhole injection- and packer pressure and surface flow - rate records of conducted frac - tests
- a pressure vs. volume or / and pressure vs. system stiffness plot for the determination of the refrac - pressure P_r
- several plots for the determination of the shut - in pressure P_{si}

GEO-Meß-Systeme GmbH

CASED - HOLE TEST 1 AT 1948.95 m



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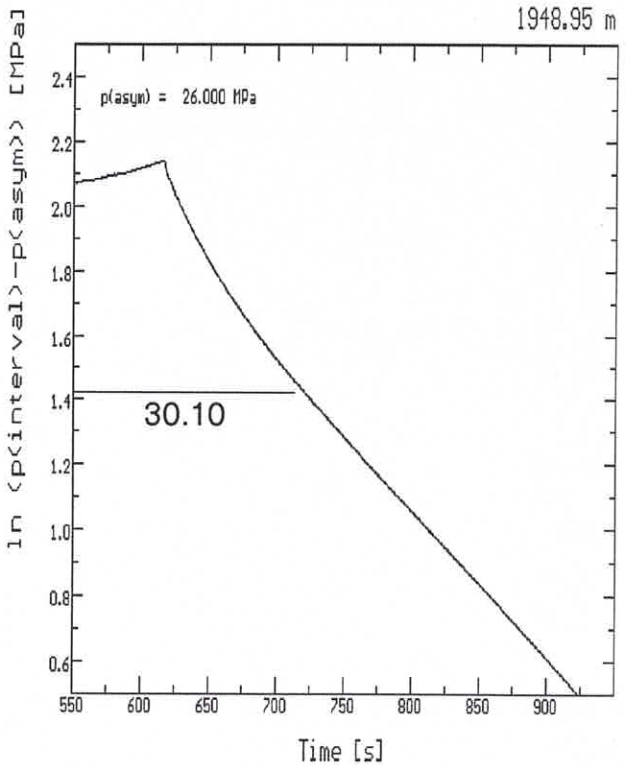
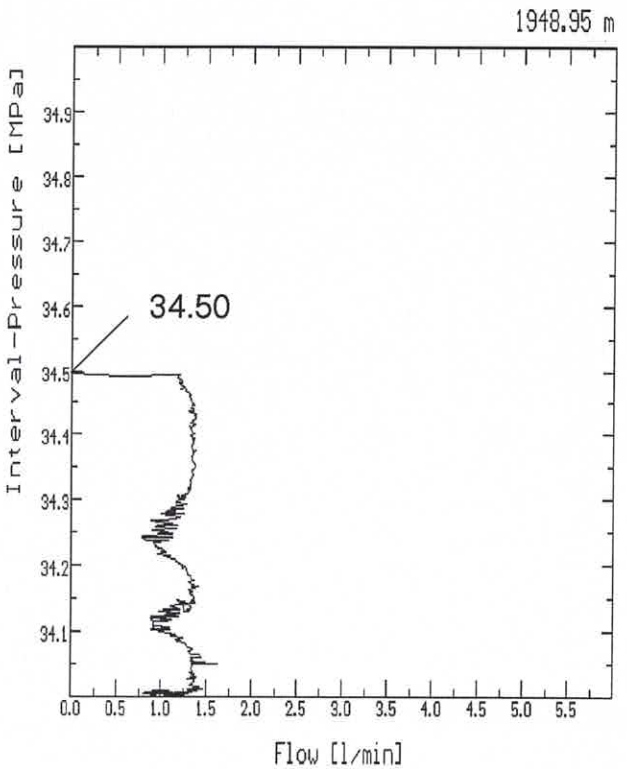
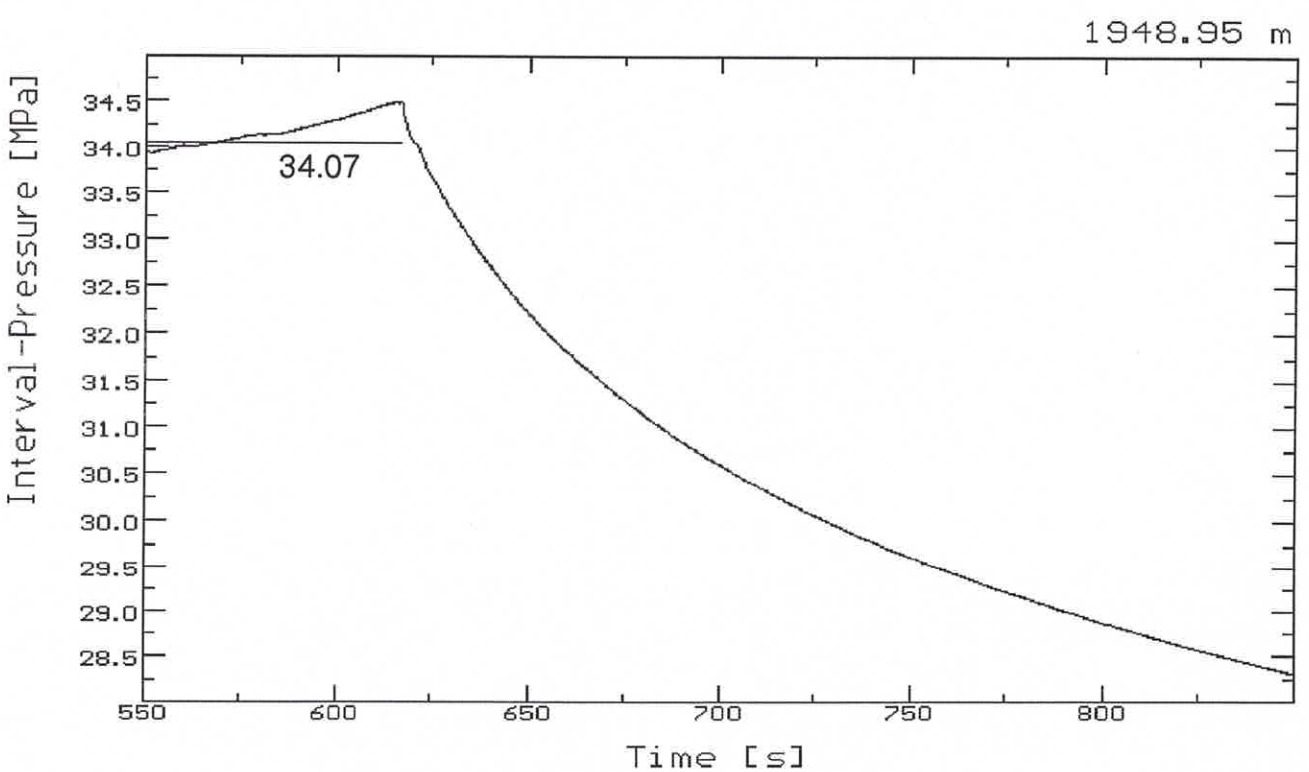
Estimation of $P_{si, min}$



Estimation of $P_{si, max}$

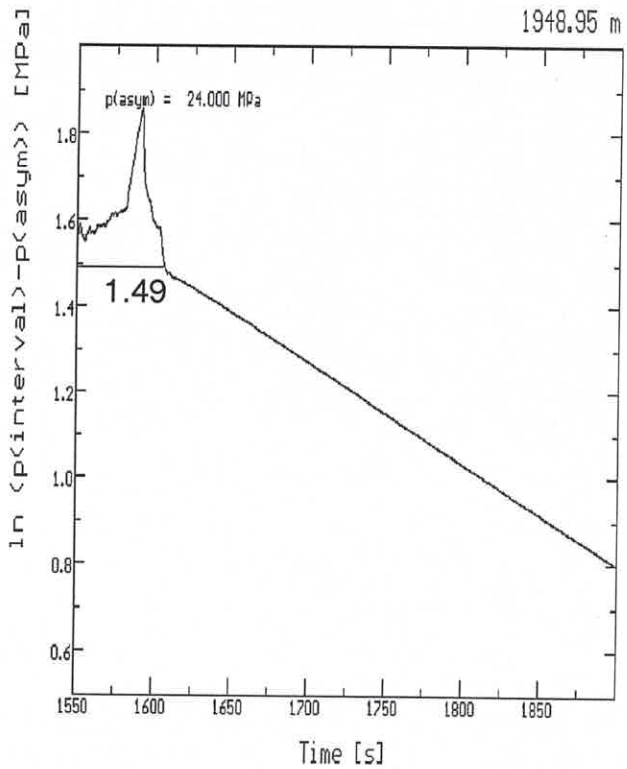


Estimation of P_{si}

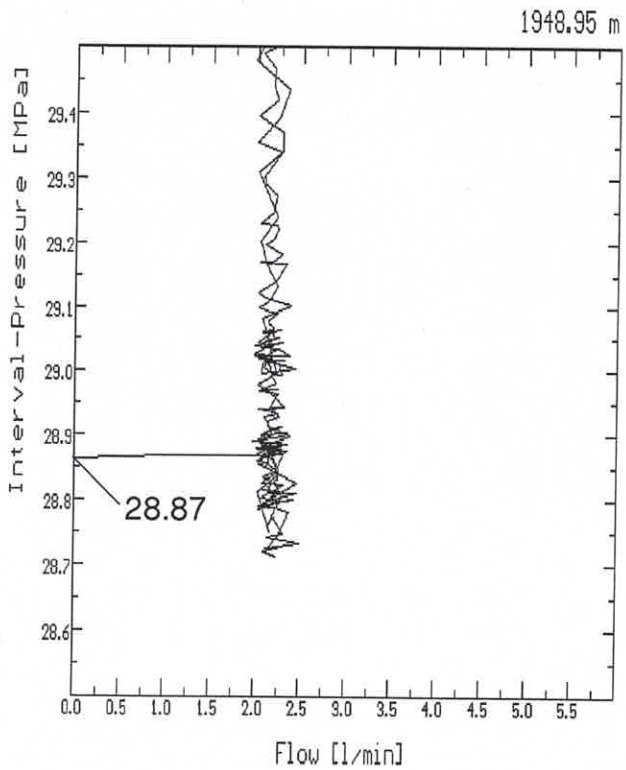


GEO-Meß-Systeme GmbH

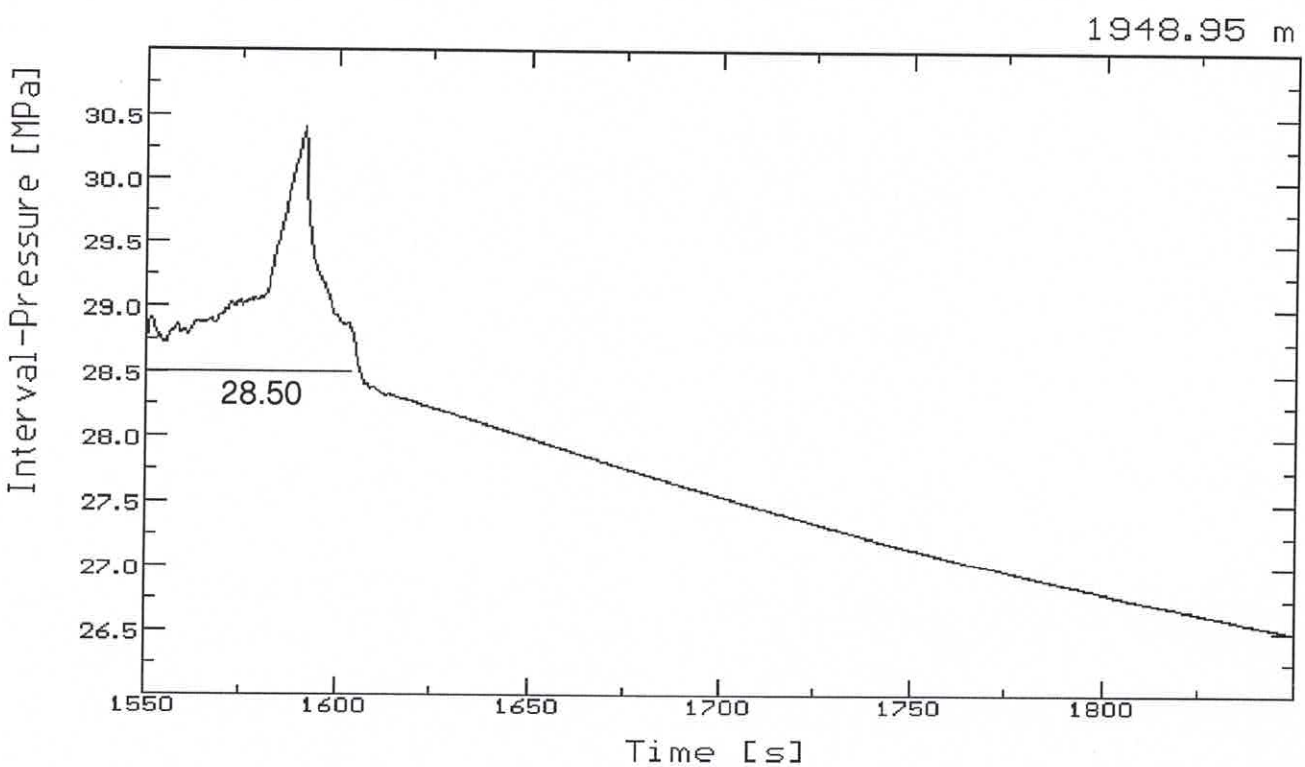
Estimation of $P_{si, min}$



Estimation of $P_{si, max}$

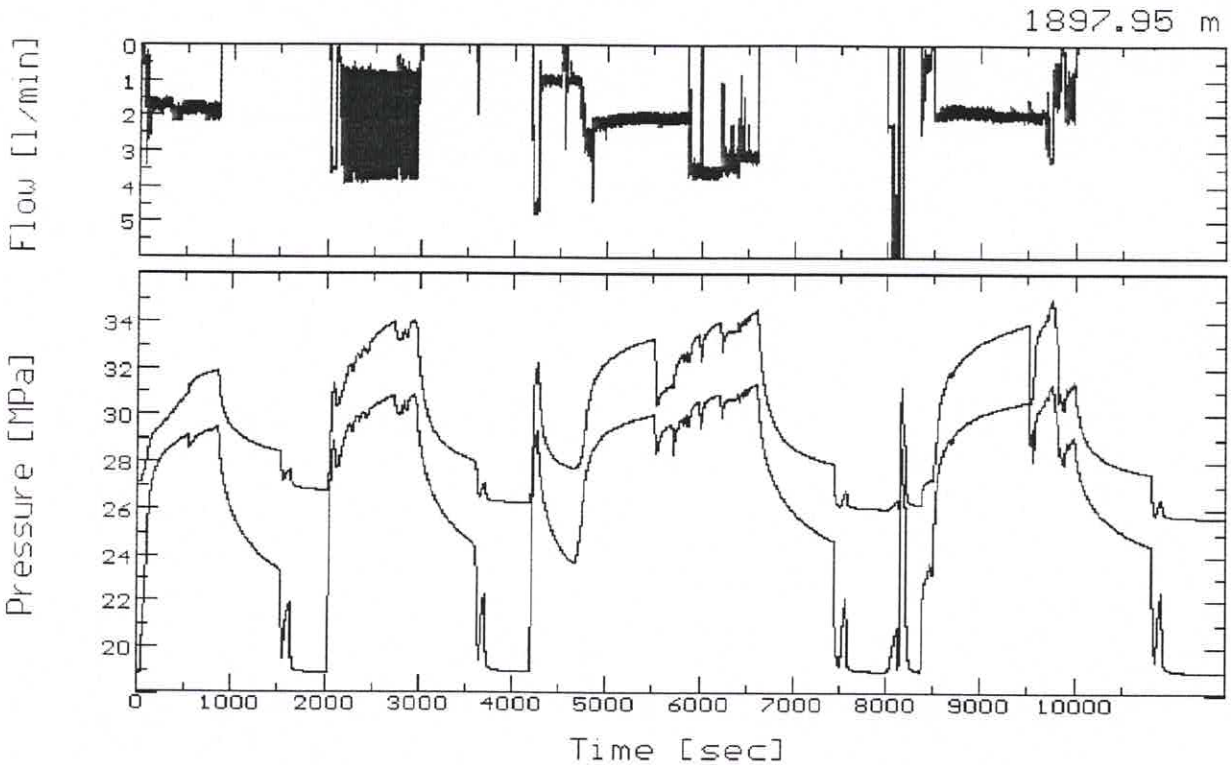


Estimation of P_{si}

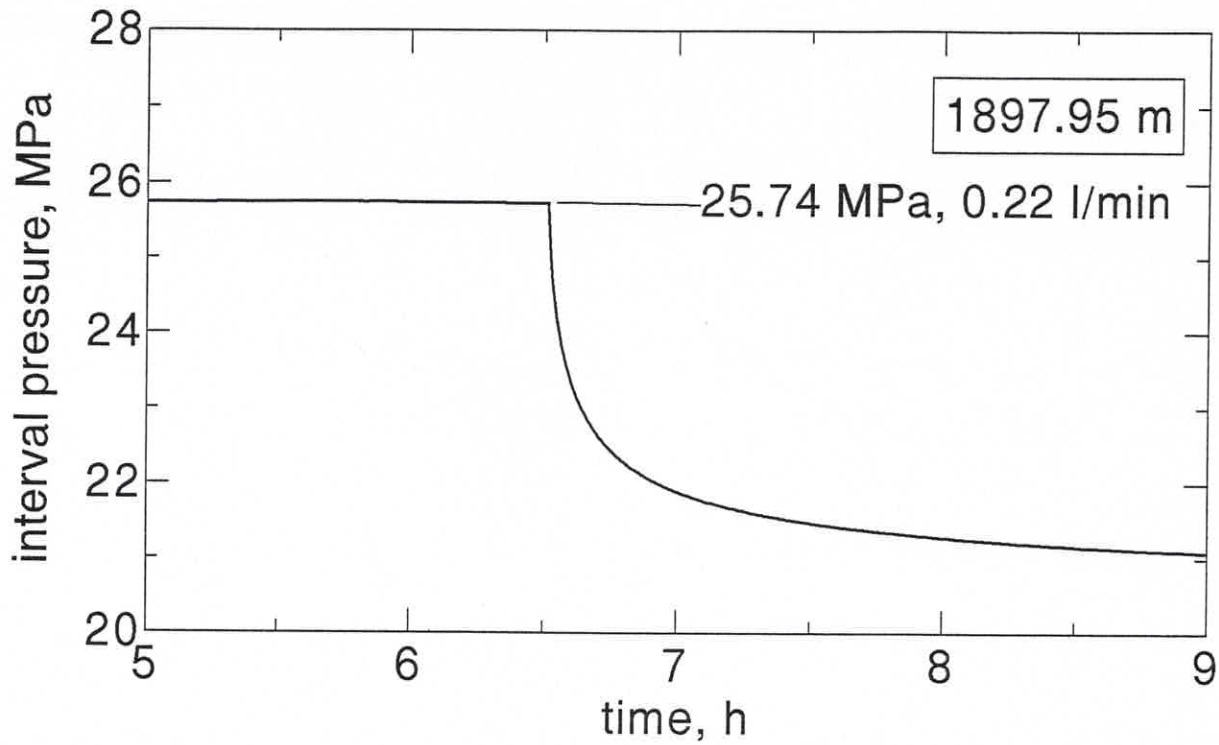


GEO-Meß-Systeme GmbH

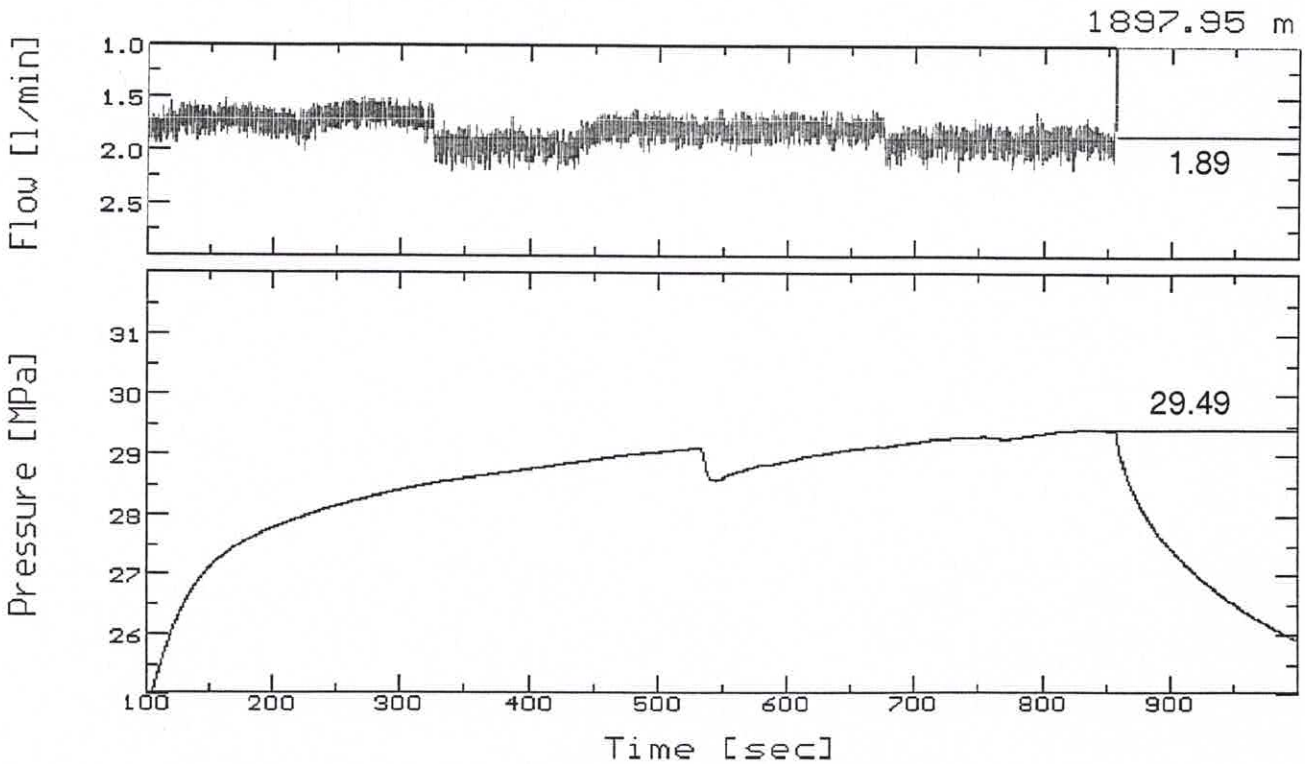
CASED - HOLE TEST 2 AT 1897.95 m



Estimation of P_p (injection - test)



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



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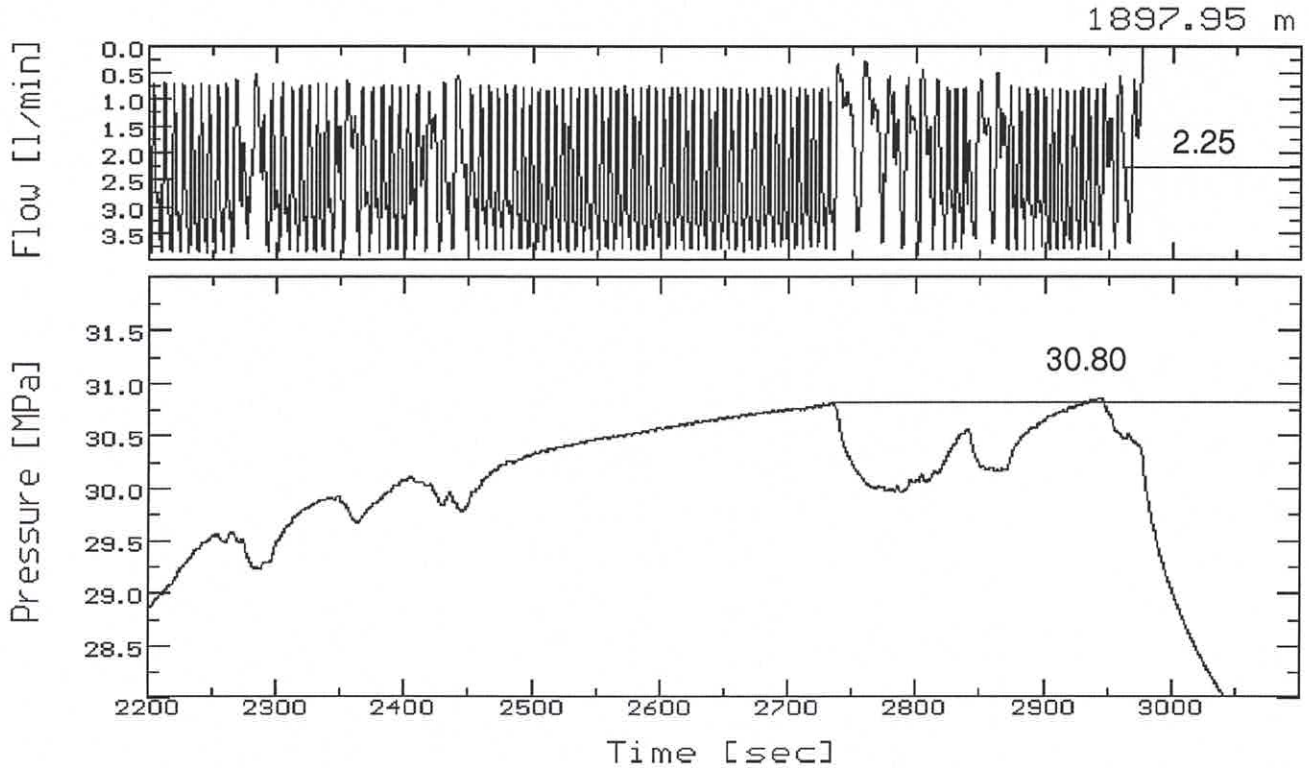
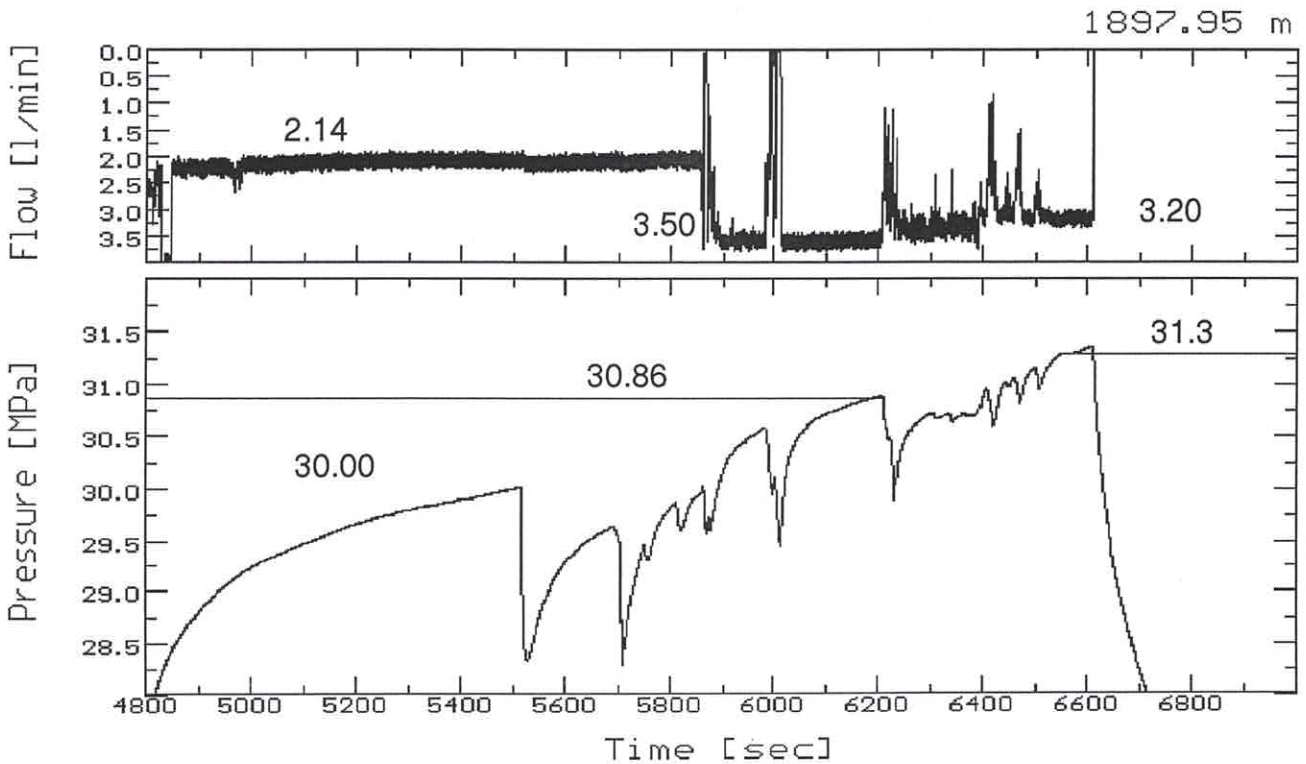
Estimation of P_p (frac - test, 2. injection - cycle)



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



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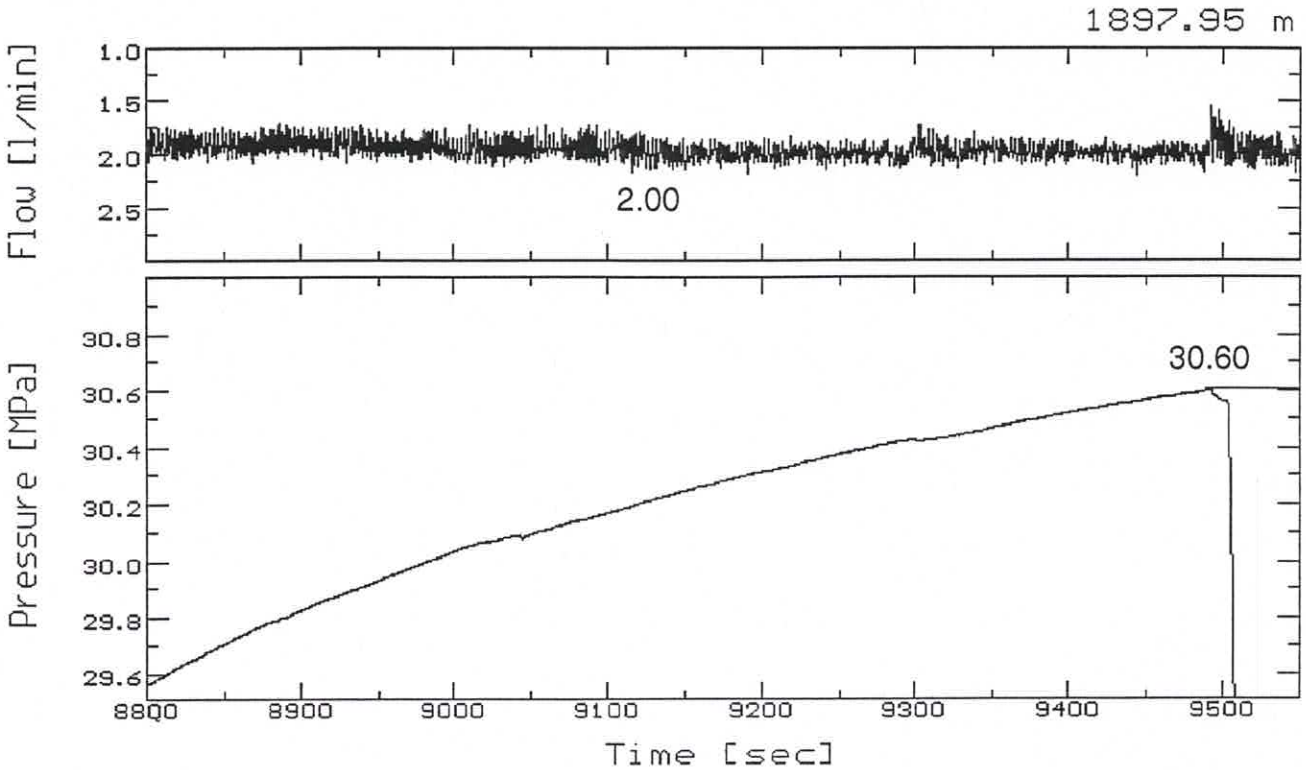
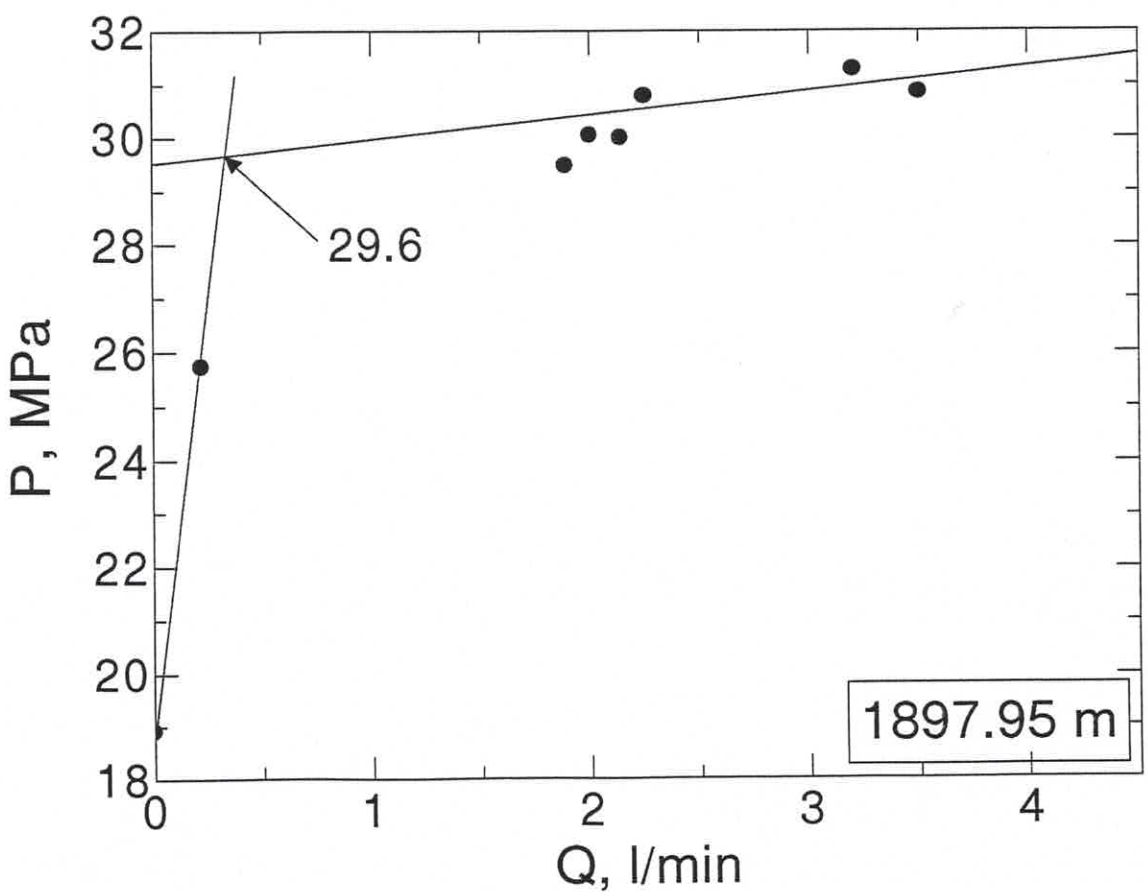
Estimation of P_p (frac - test, 4. injection - cycle)



Analysis of pumping pressure data



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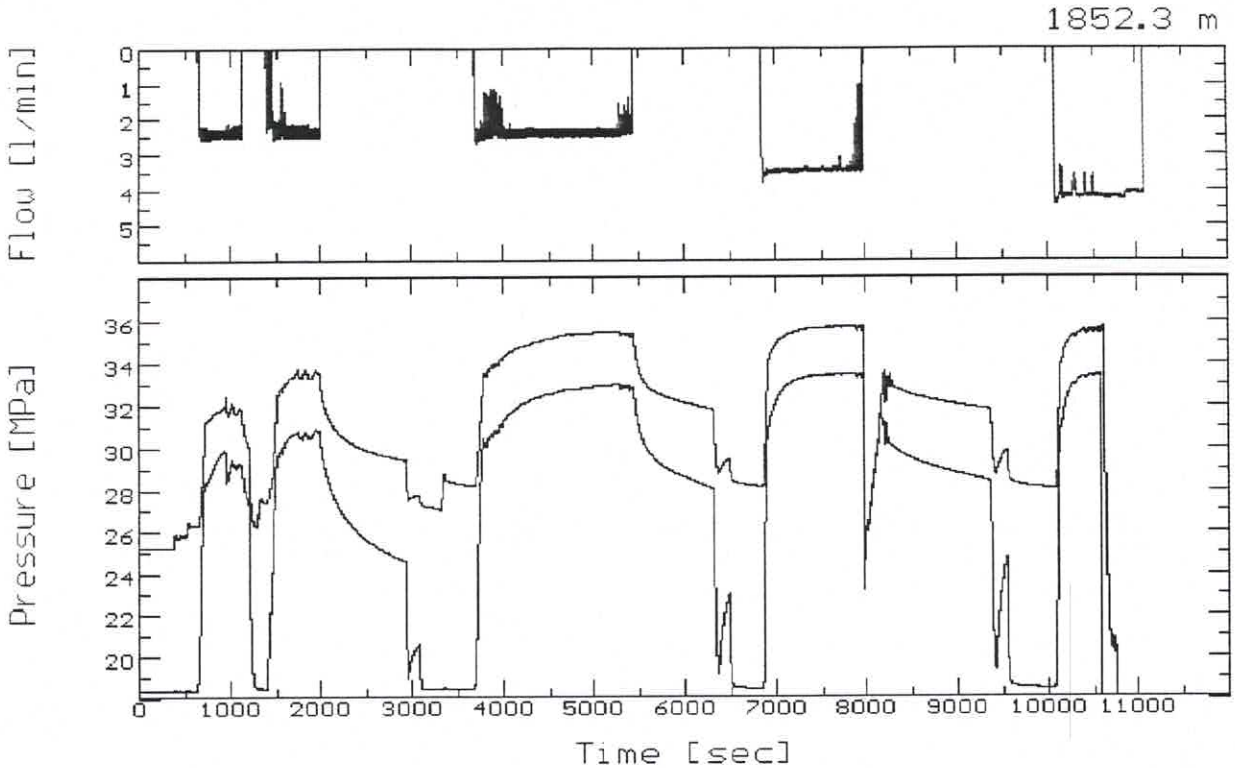
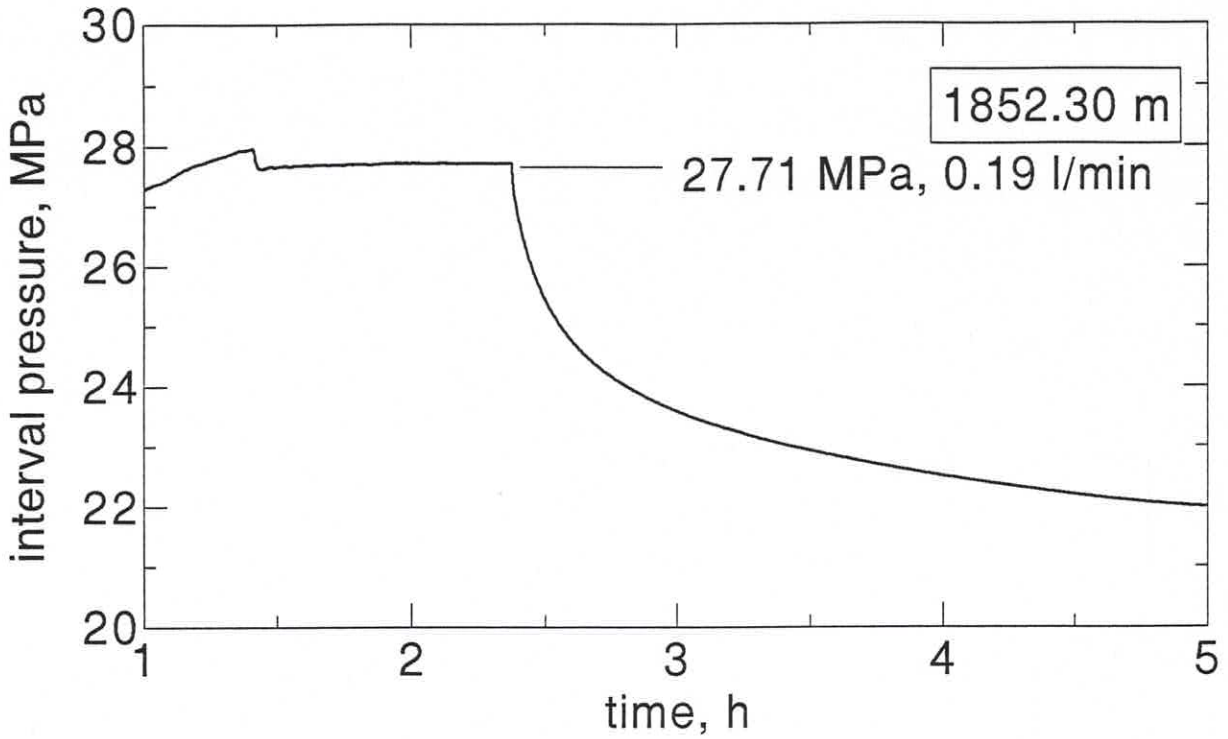
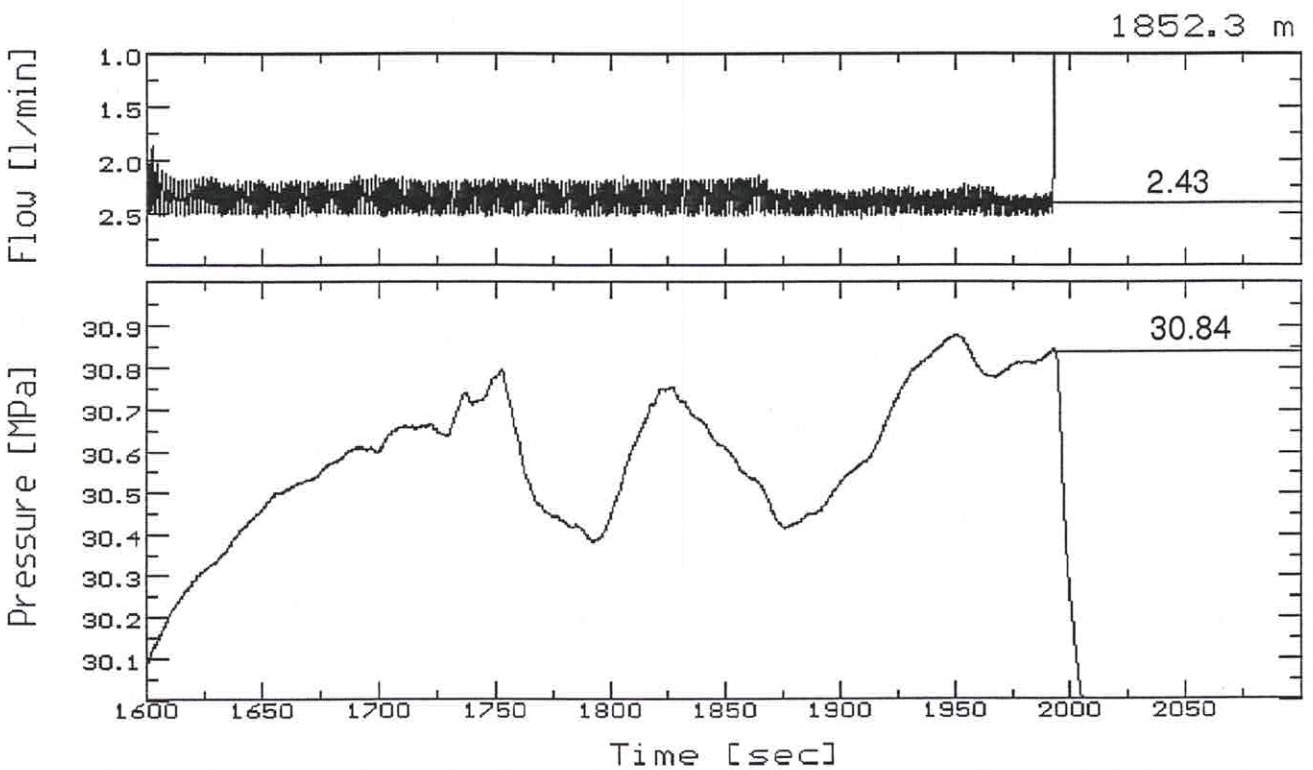
CASED - HOLE TEST 3 AT 1852.3 m



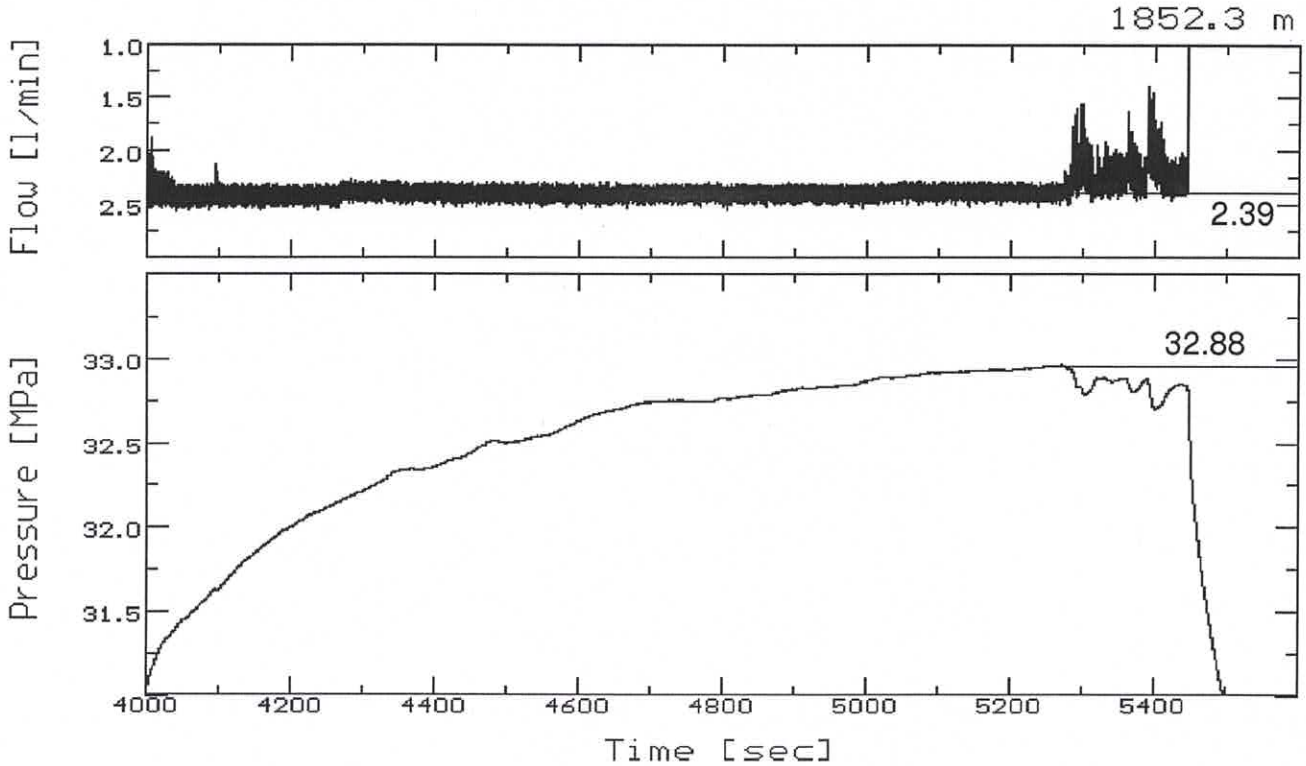
Estimation of P_p (injection - test)



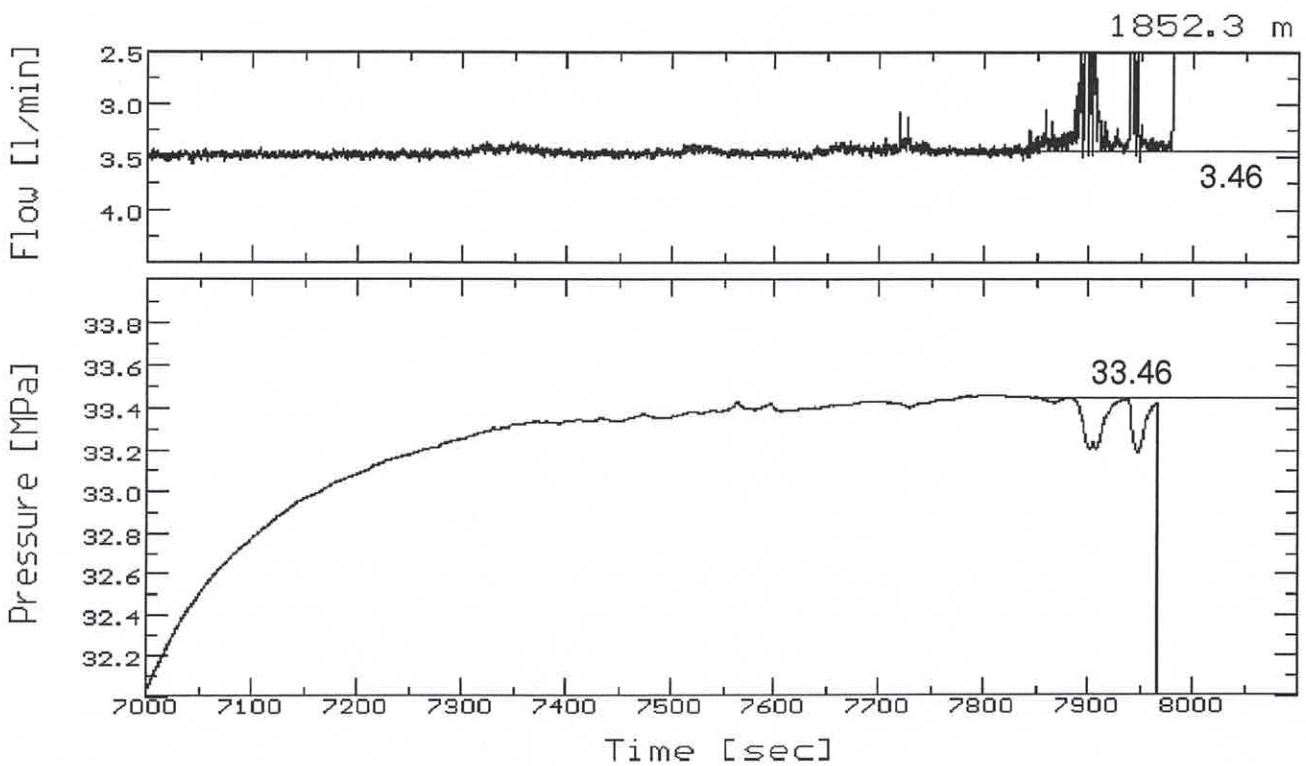
Estimation of P_p (frac - test, 2. injection - cycle)



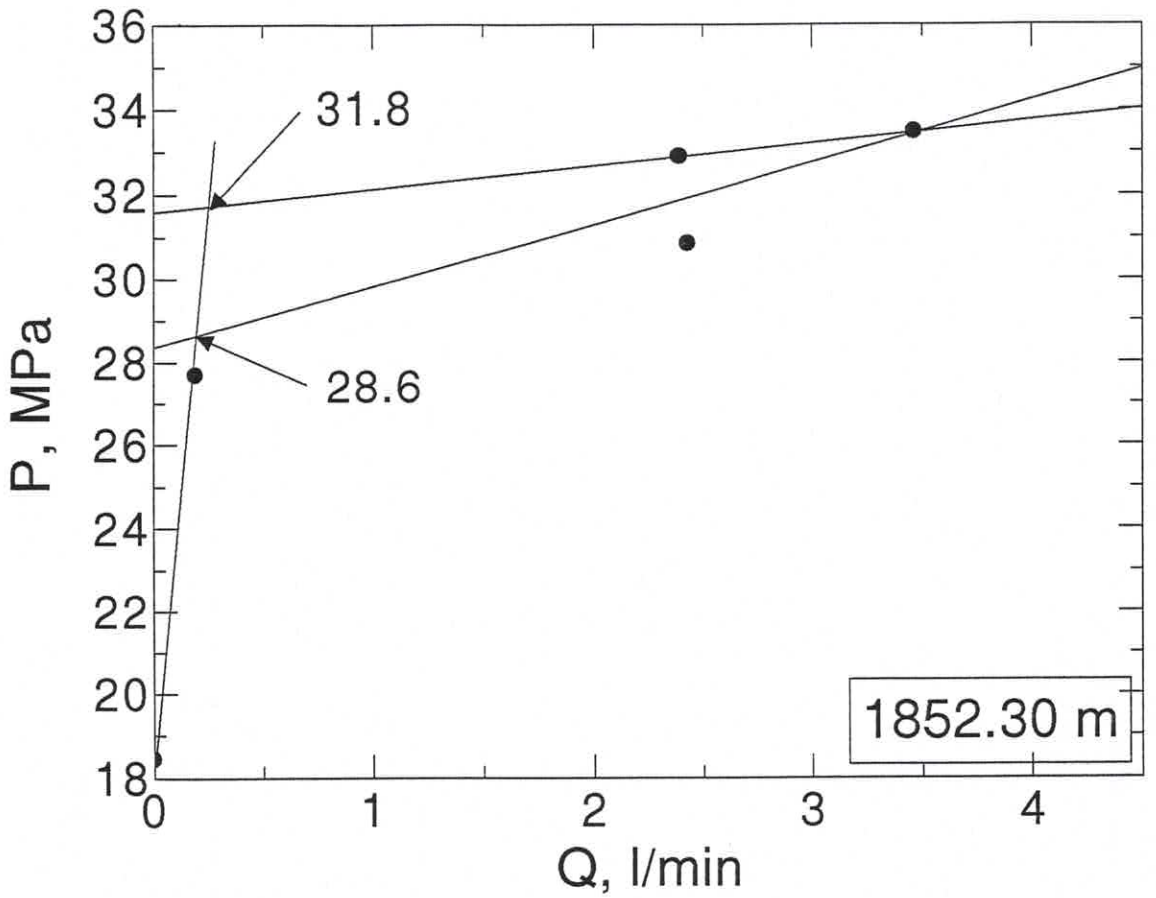
Estimation of P_p (frac - test, 3. injection - cycle)



Estimation of P_p (frac - test, 4. injection - cycle)



Analysis of pumping pressure data



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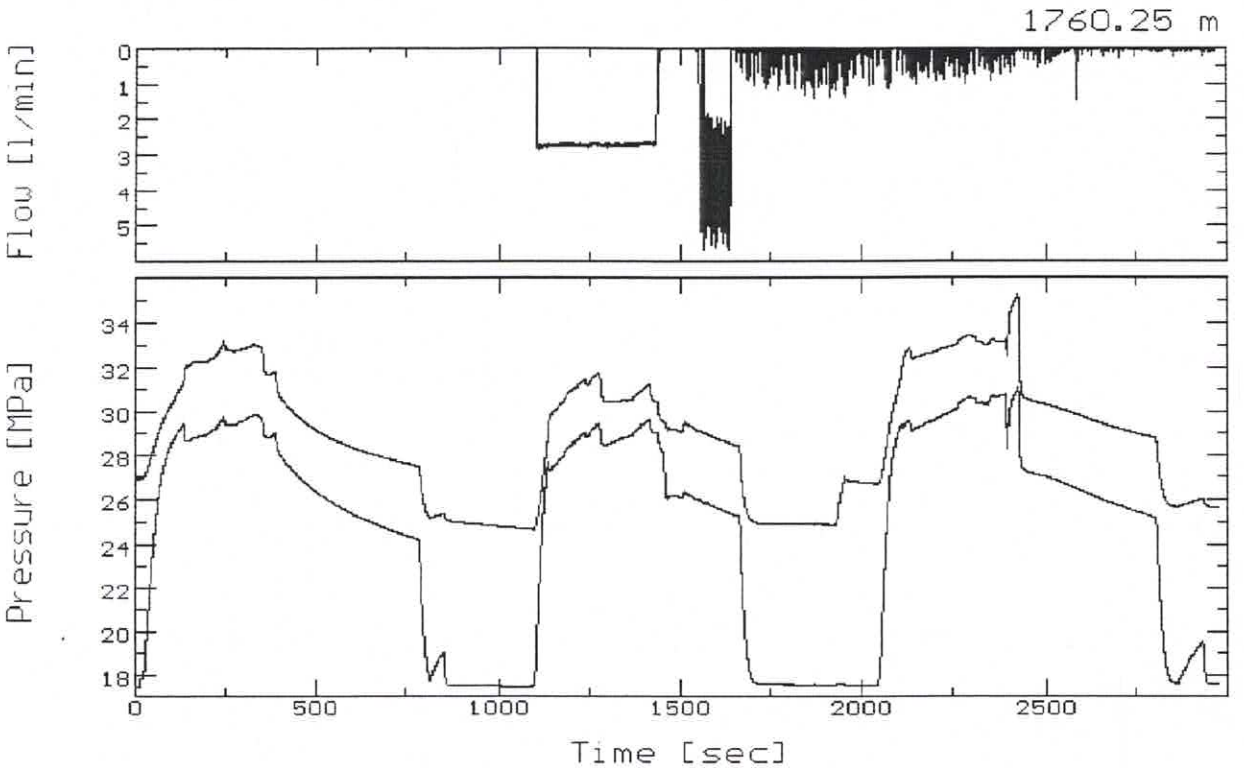
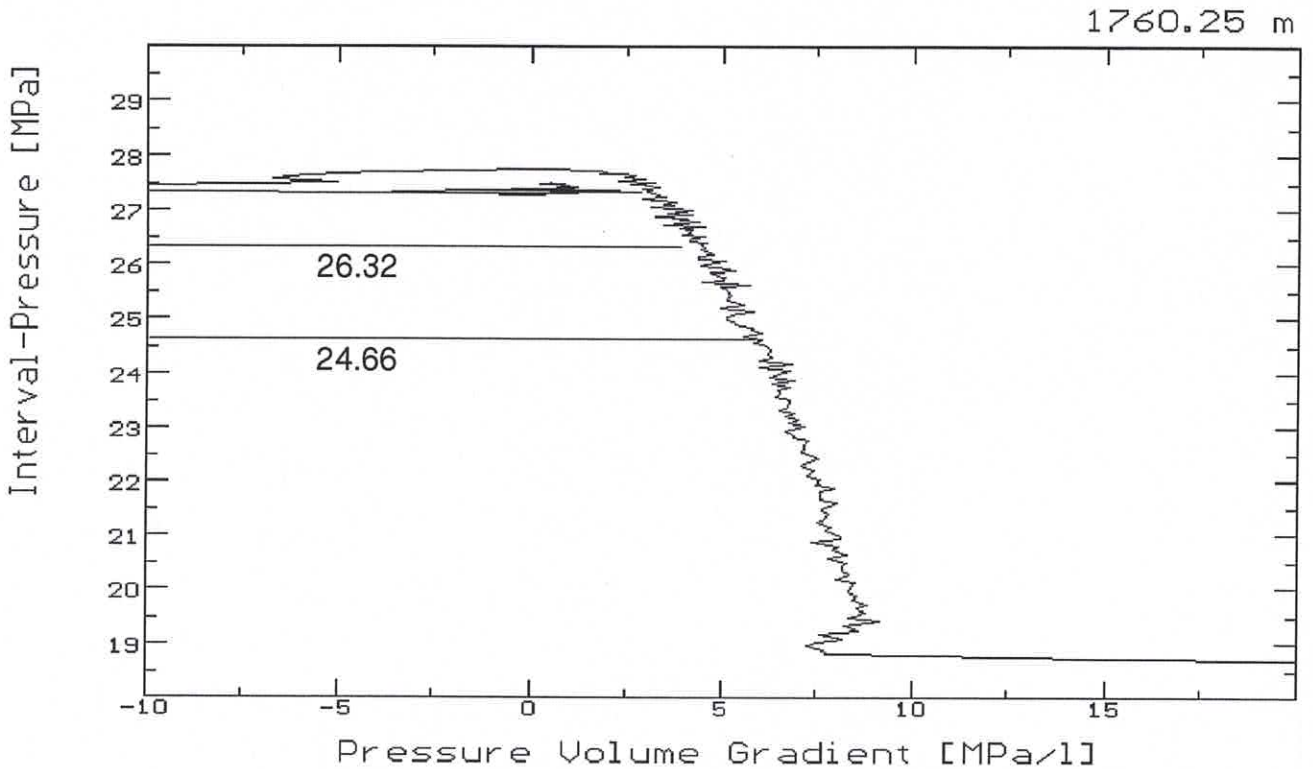
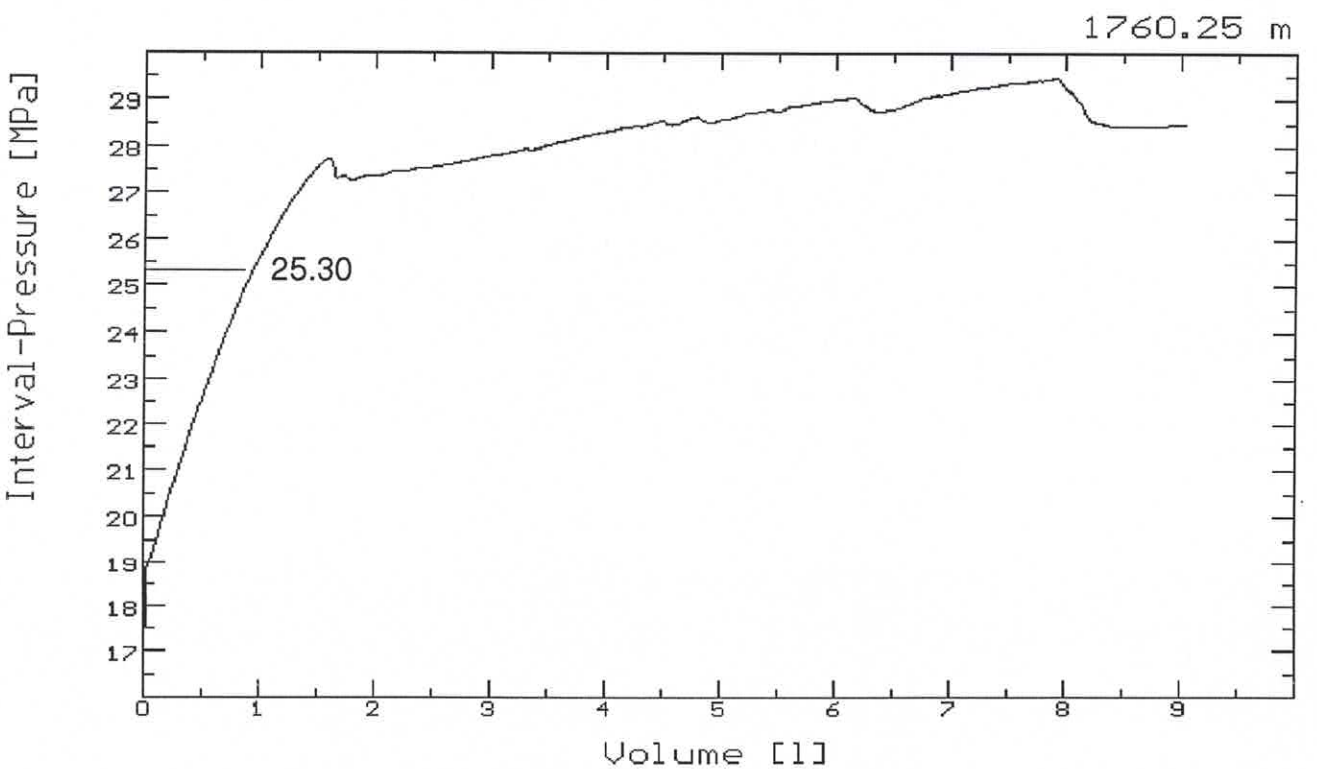
CASED - HOLE TEST 4 AT 1760.25 m

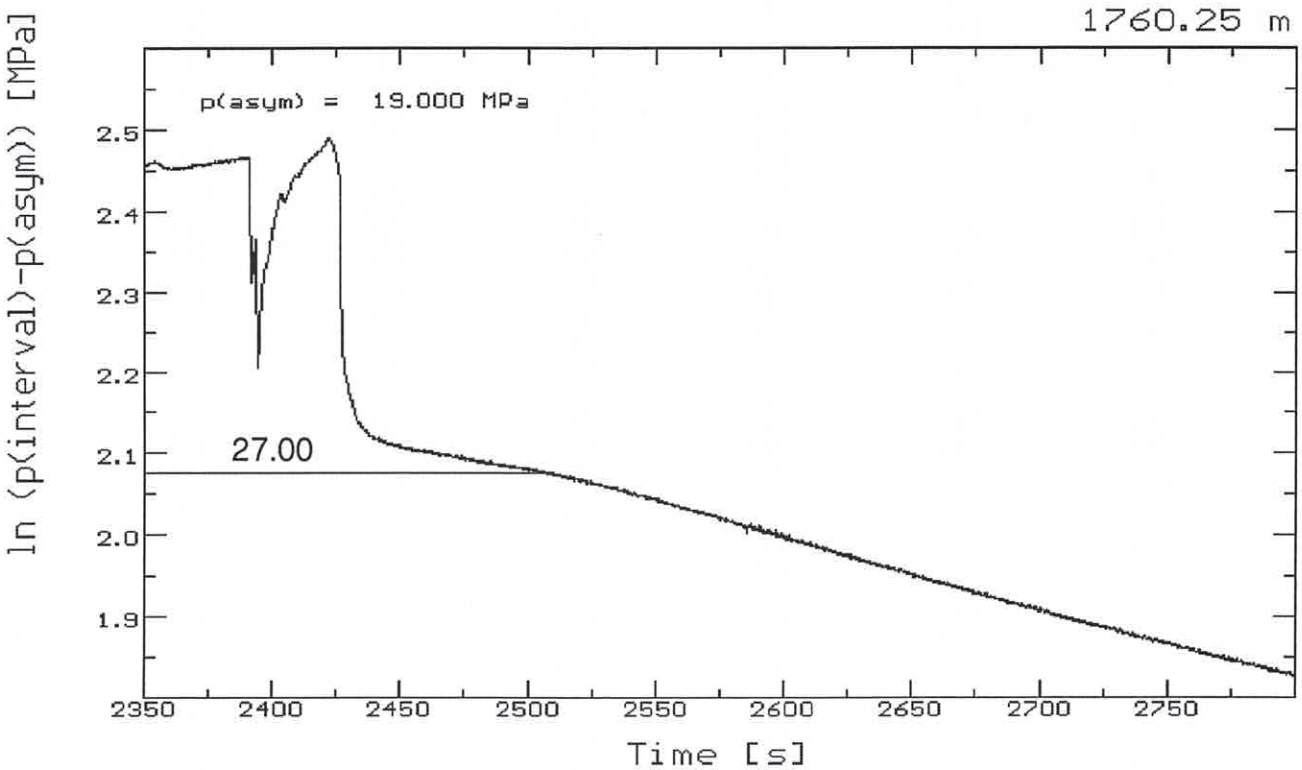




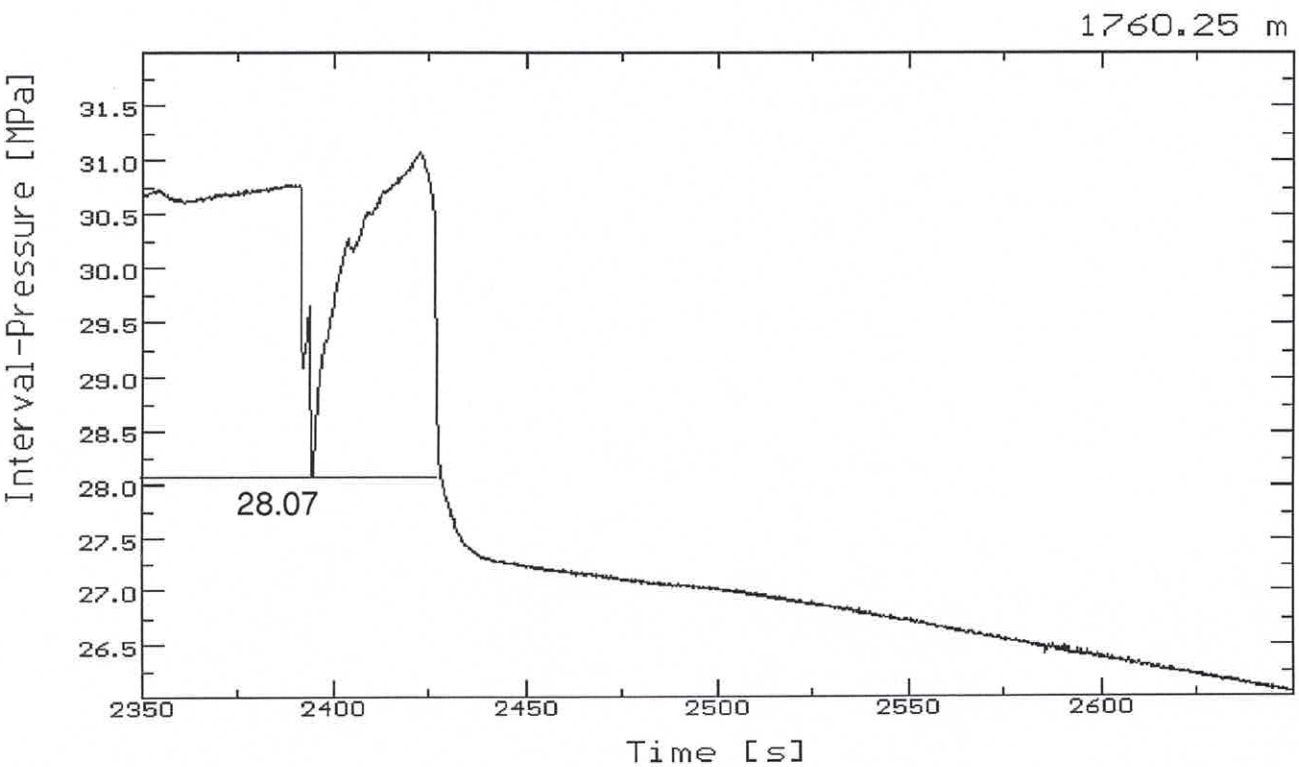
Estimation of P_r



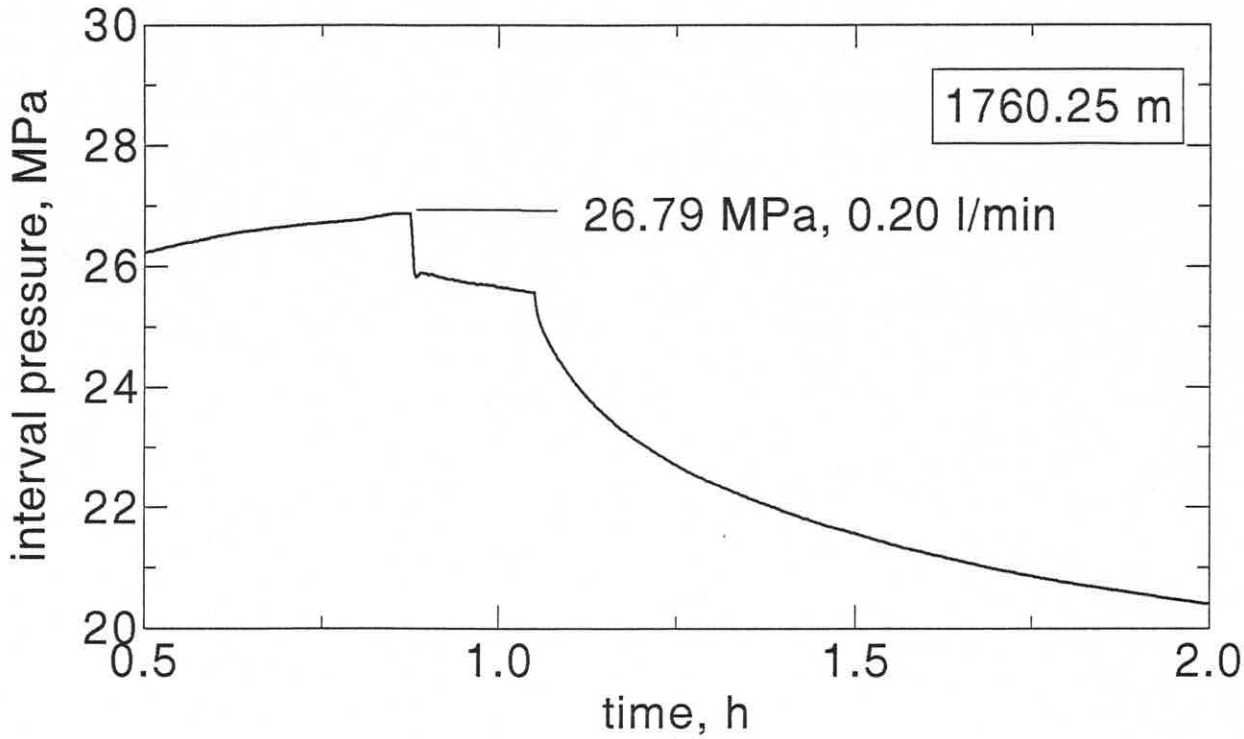
Estimation of $P_{si, min}$ (no flow registration)



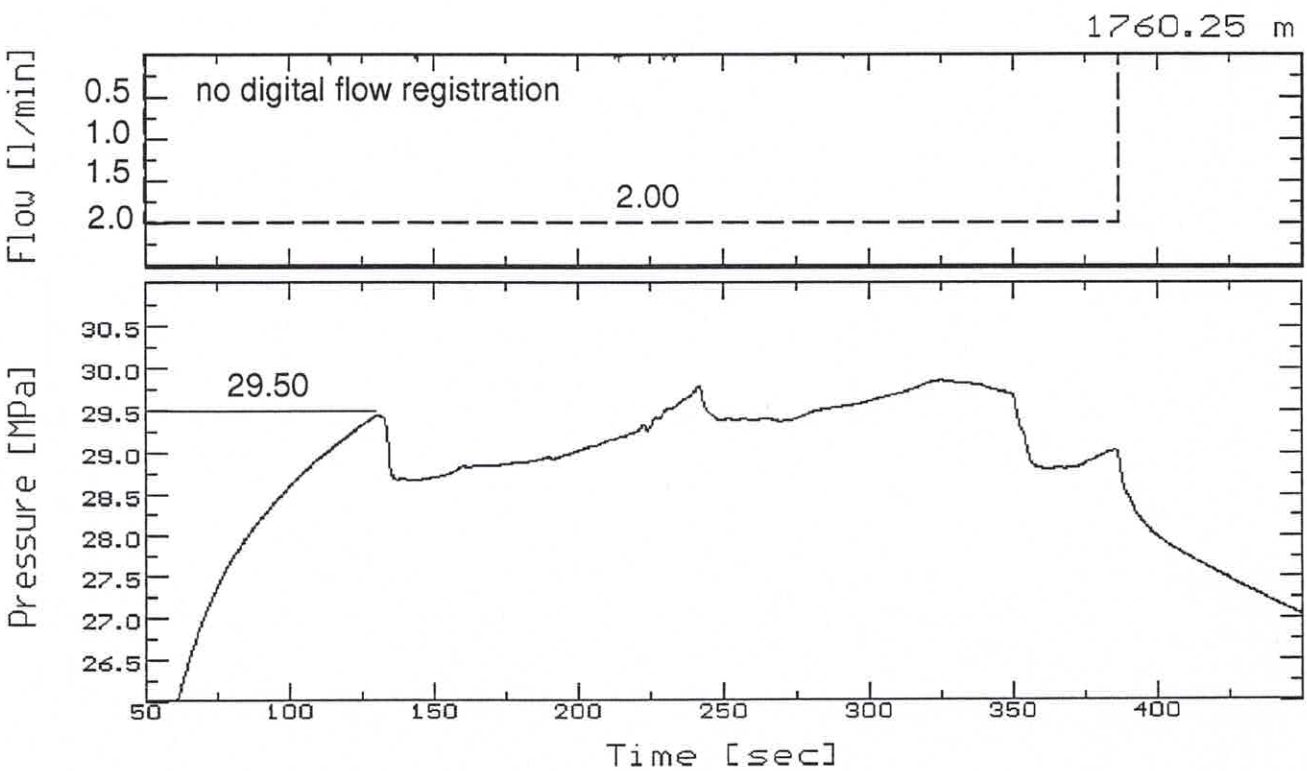
Estimation of P_{si}



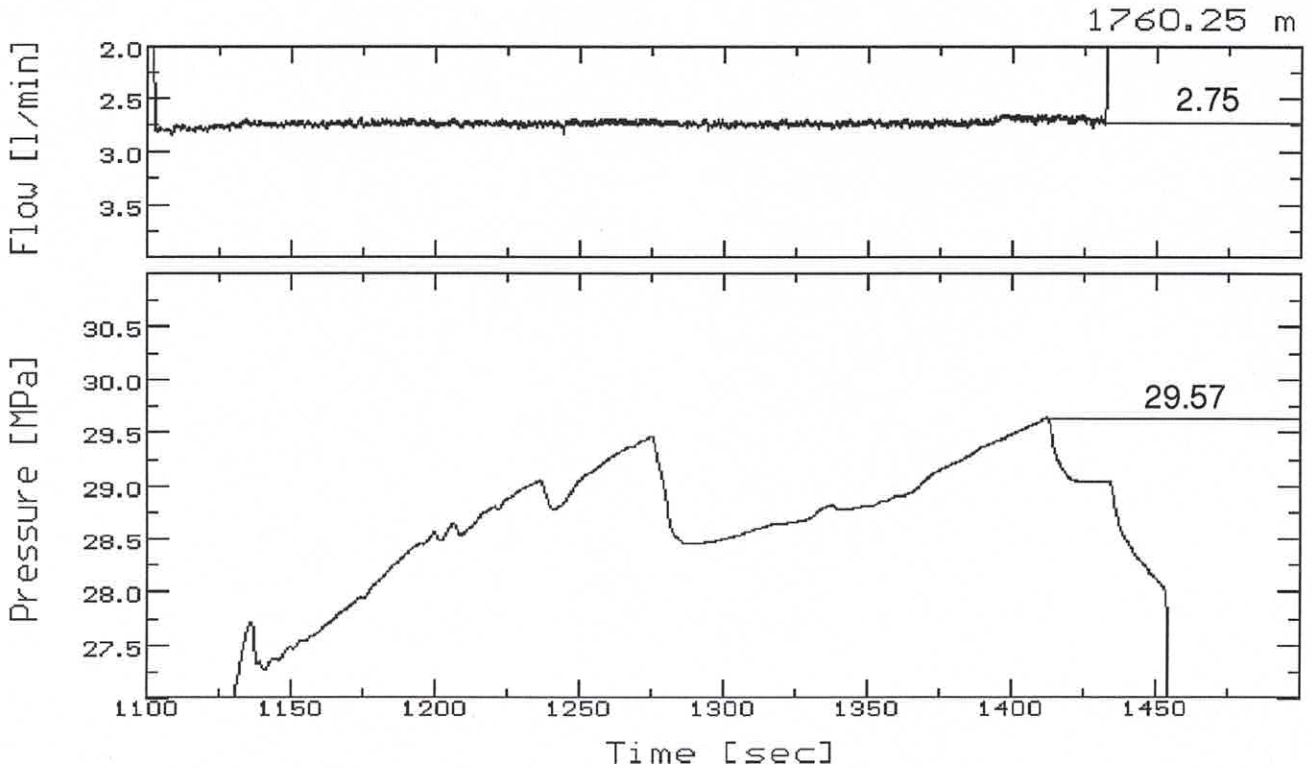
Estimation of P_p (injection - test)



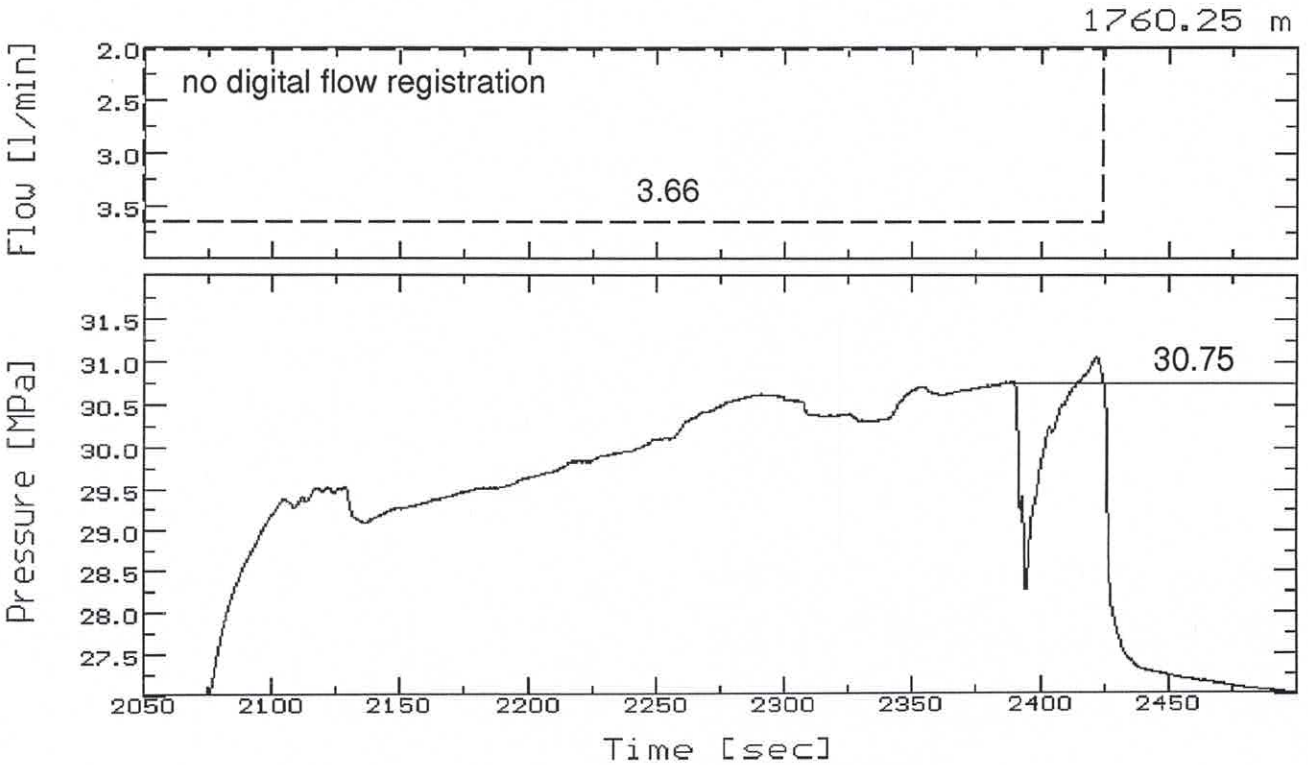
Estimation of P_p (frac - test, 1. injection - cycle)



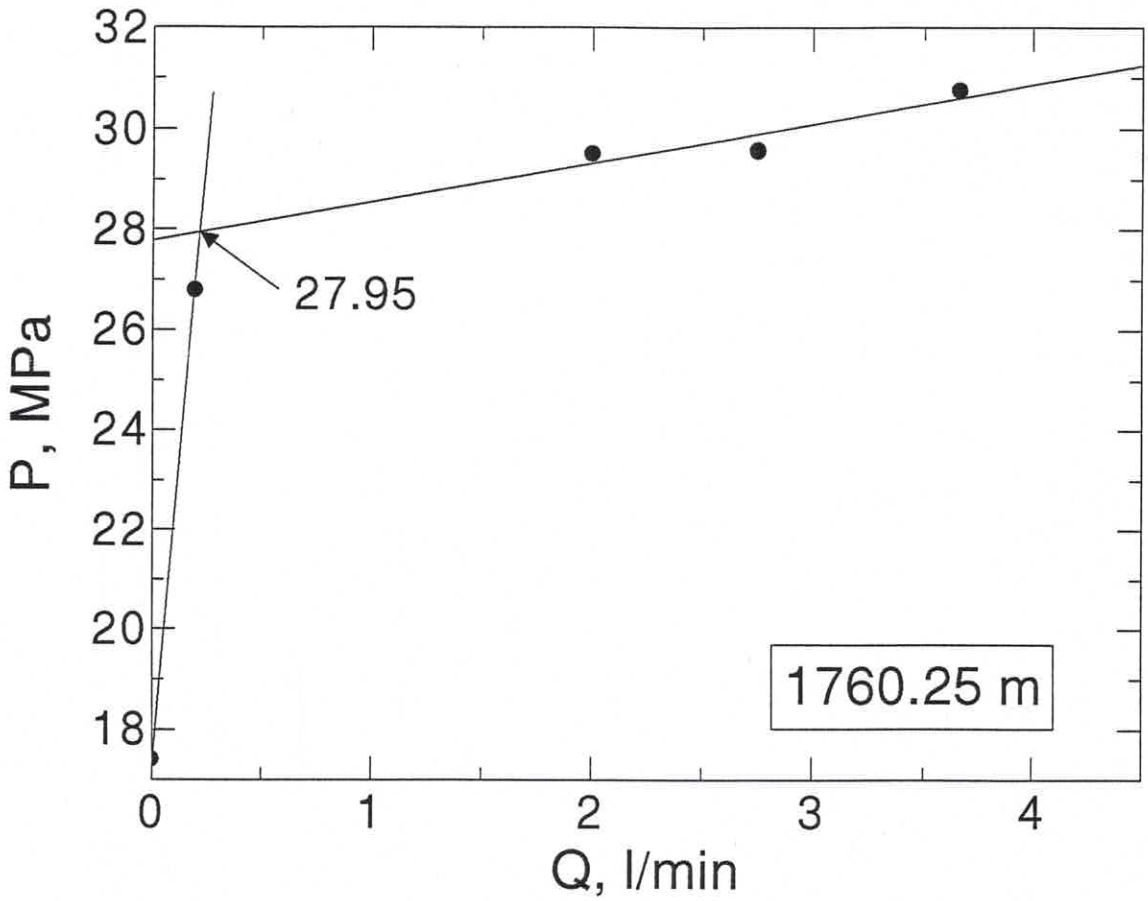
Estimation of P_p (frac - test, 2. injection - cycle)



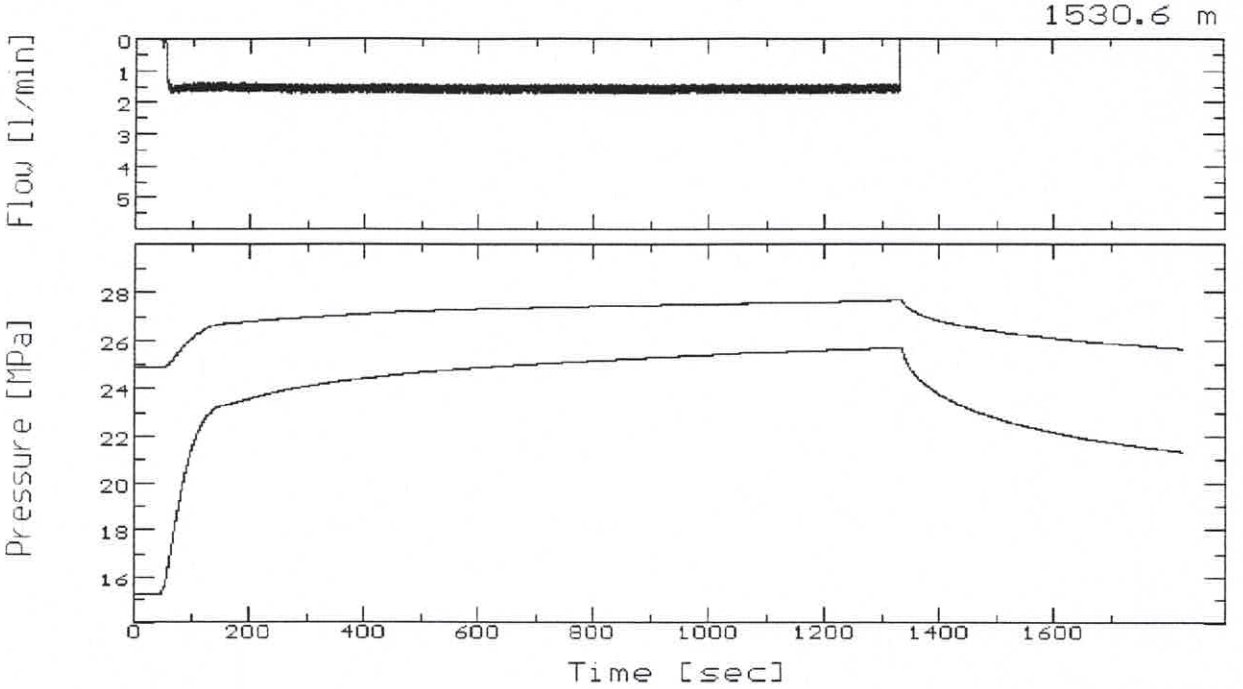
Estimation of P_p (frac - test, 3. injection - cycle)

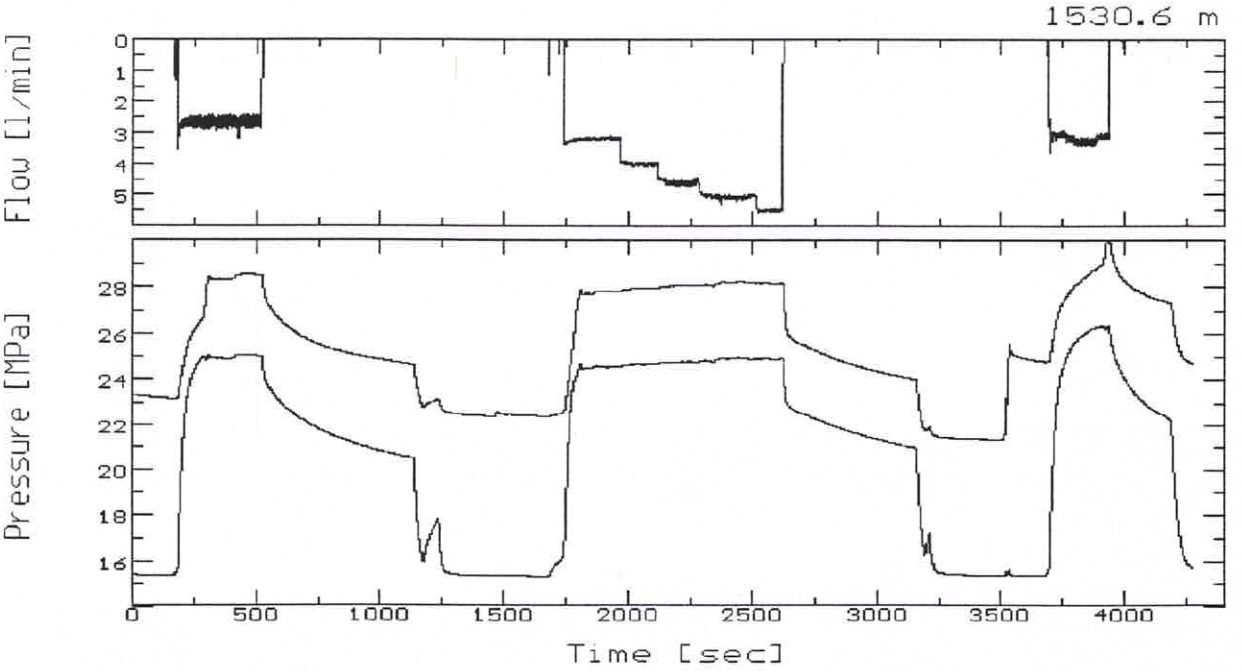


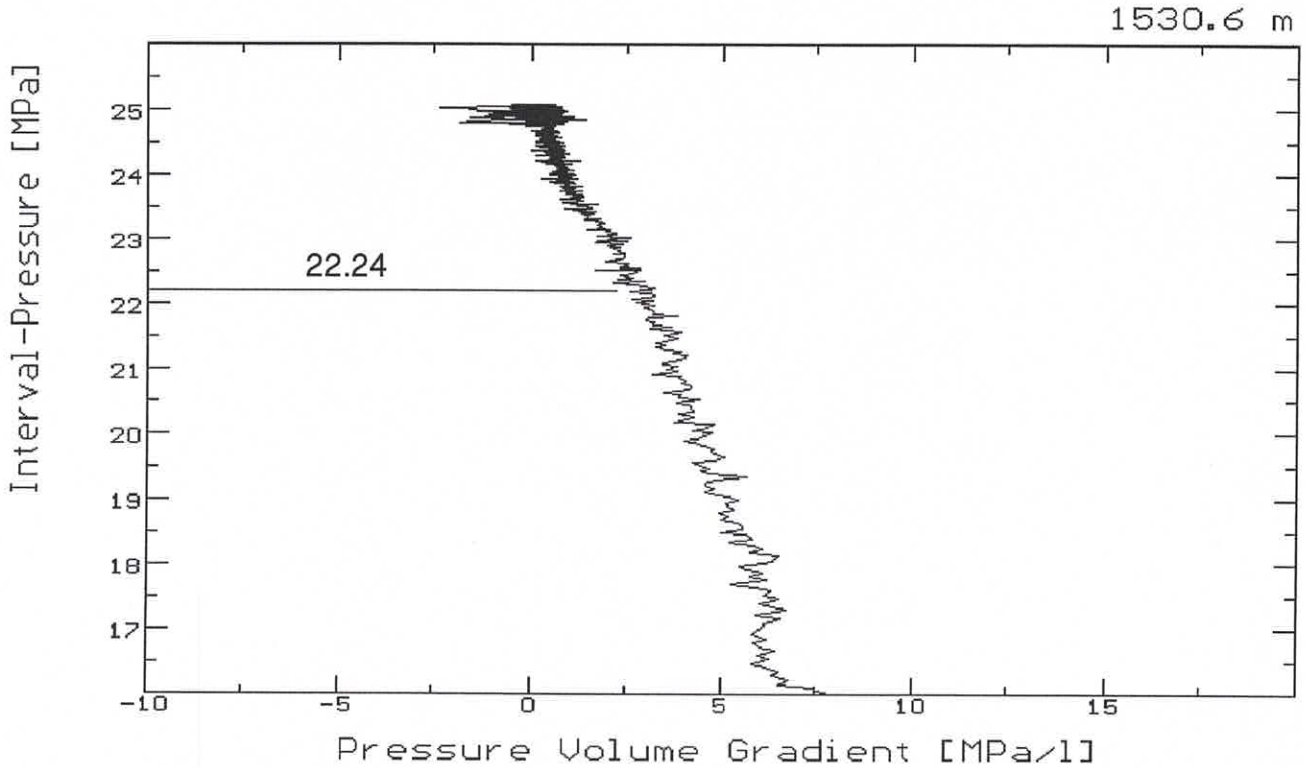
Analysis of pumping pressure data



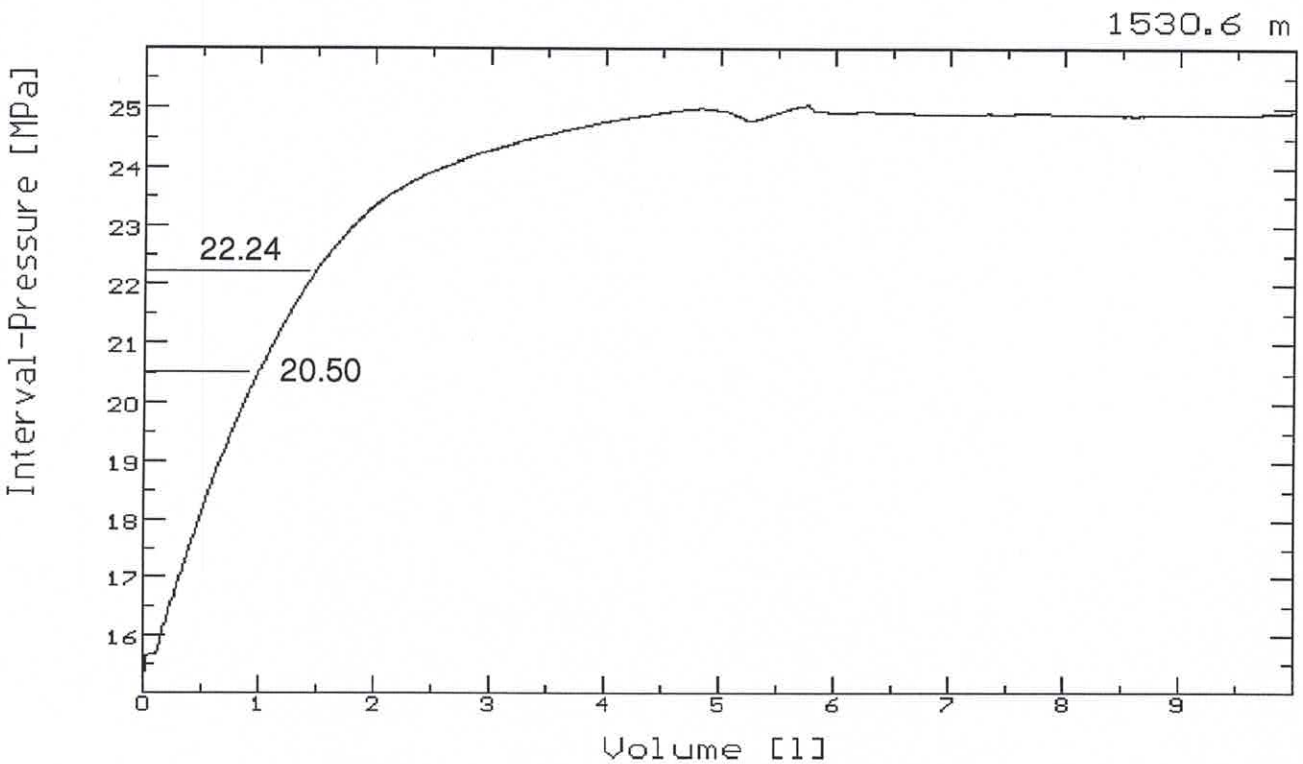
CASED - HOLE TEST 6 AT 1530.6 m







Estimation of P_r



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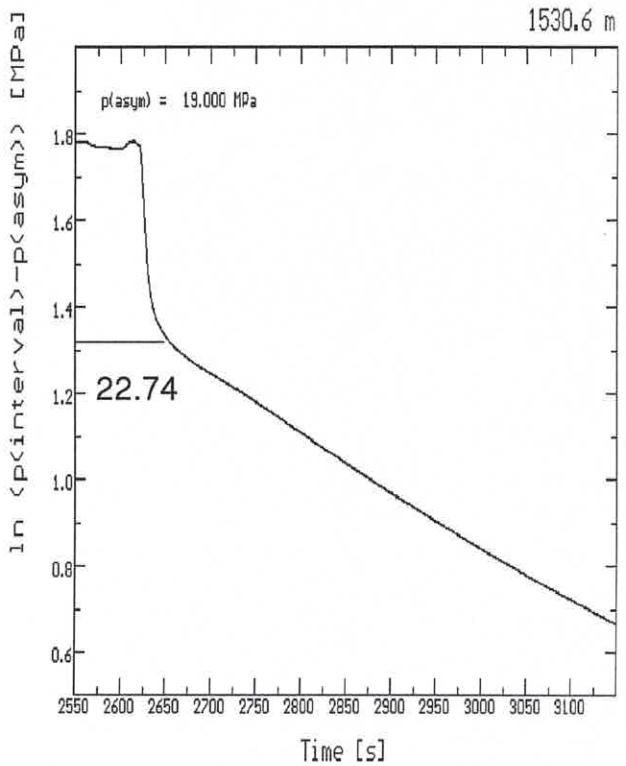
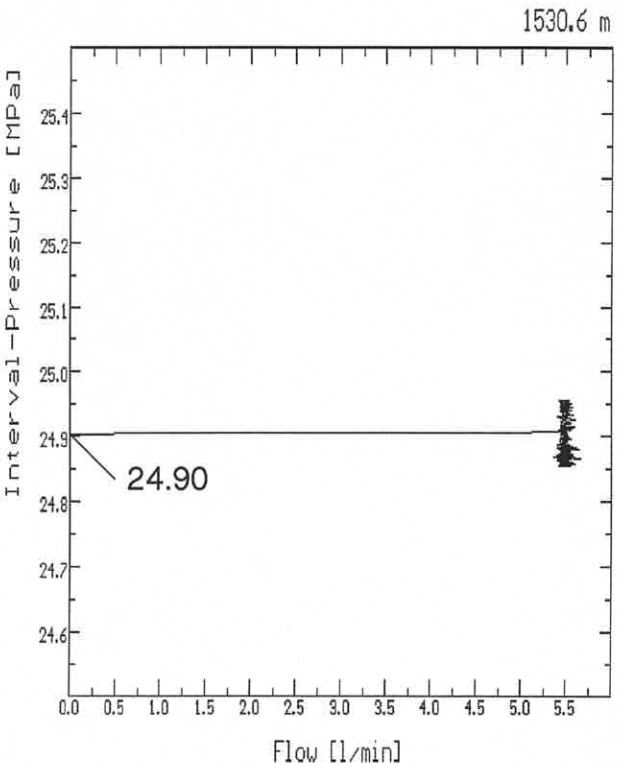
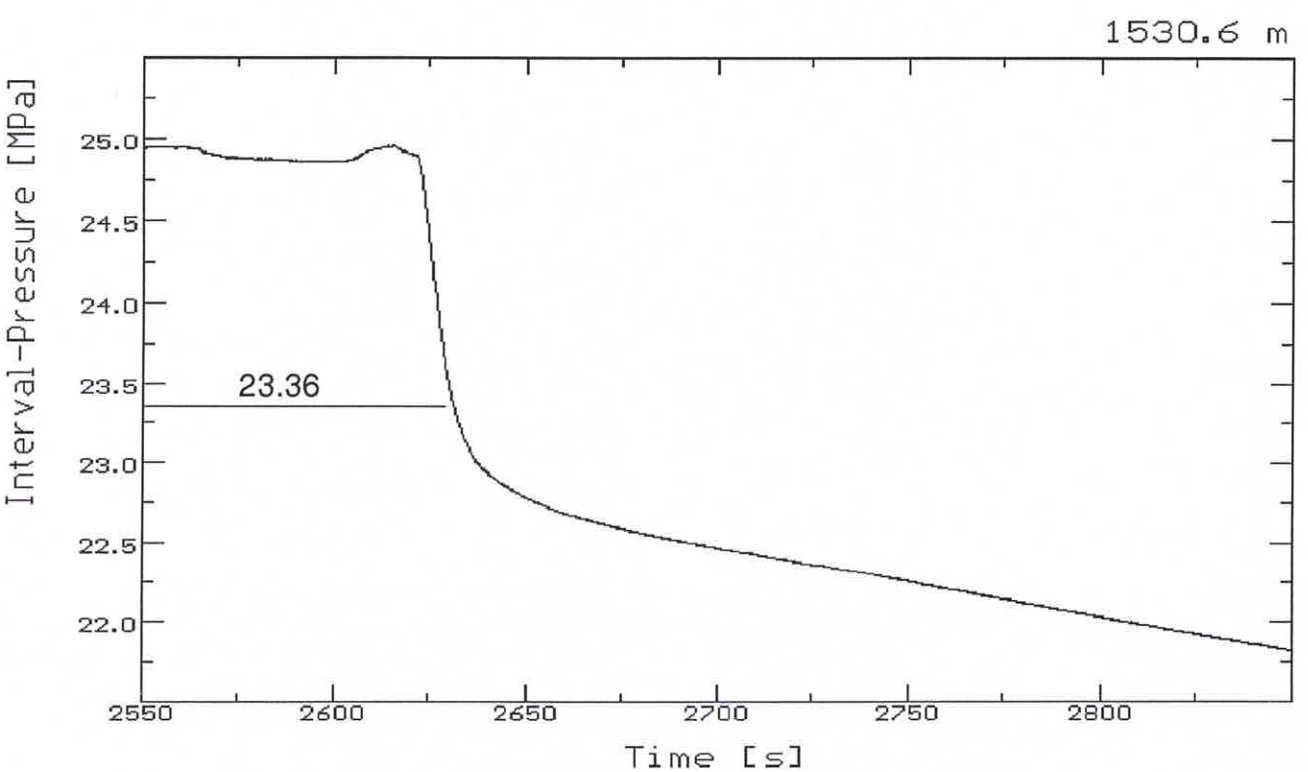
Estimation of $P_{si, min}$



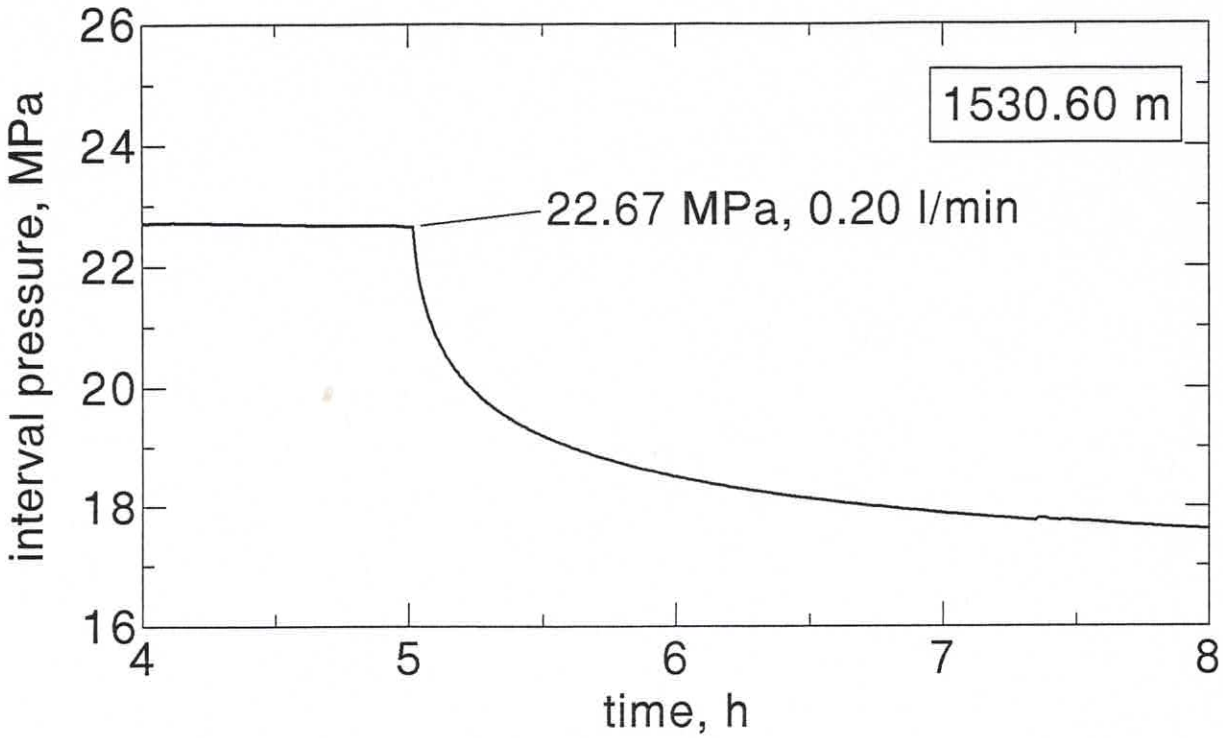
Estimation of $P_{si, max}$



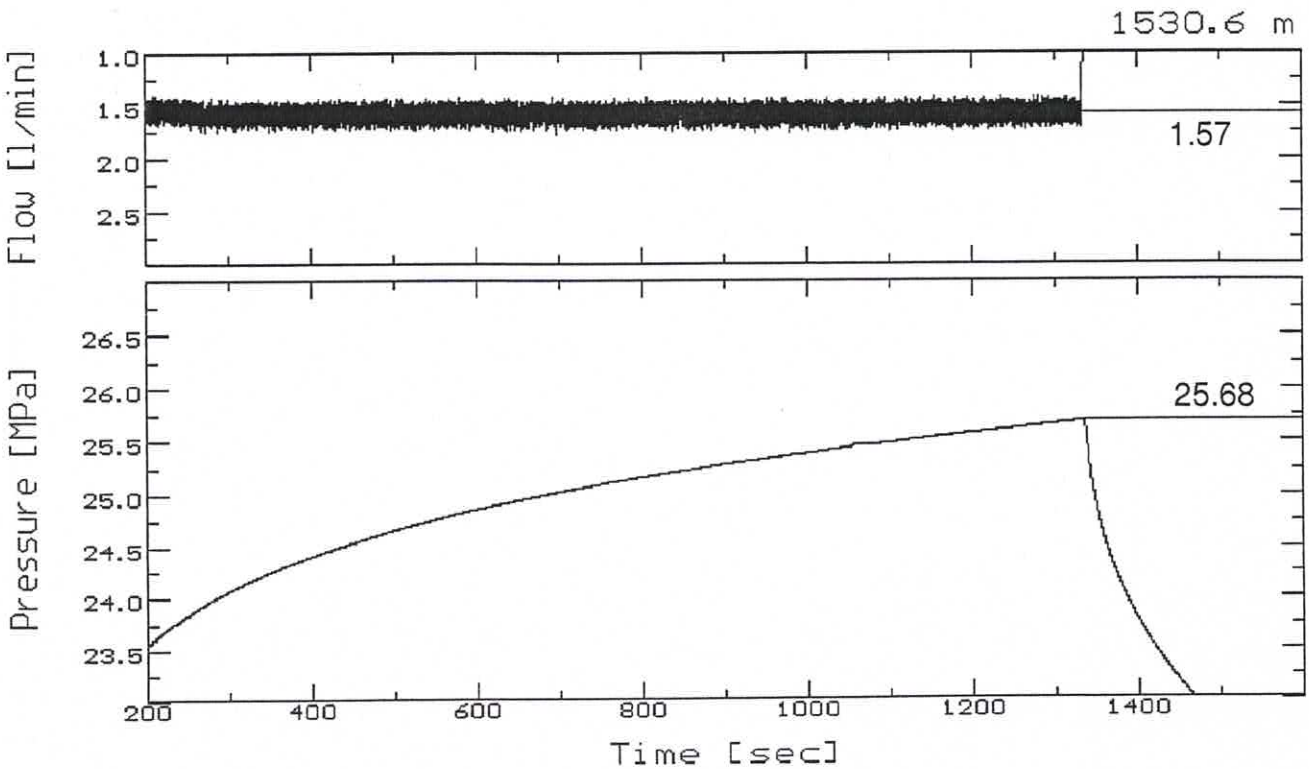
Estimation of P_{si}



Estimation of P_p (injection - test)



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



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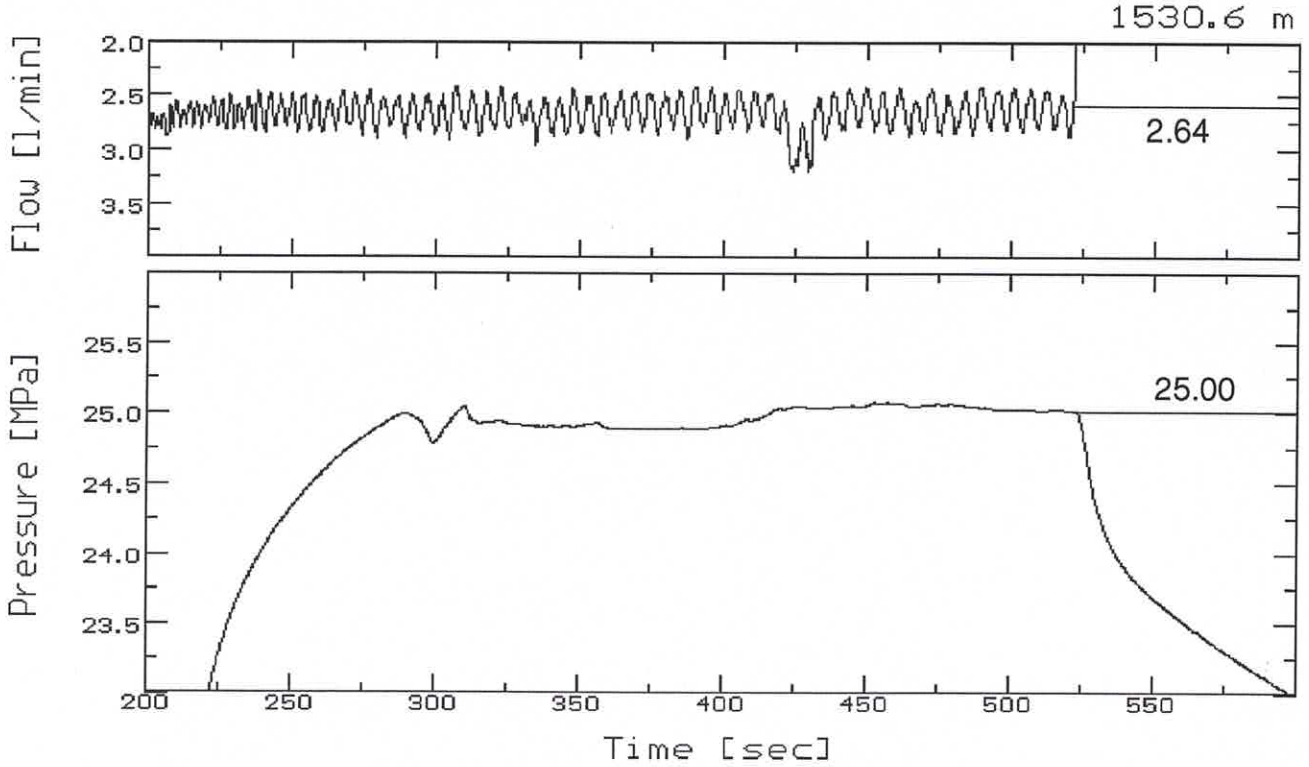
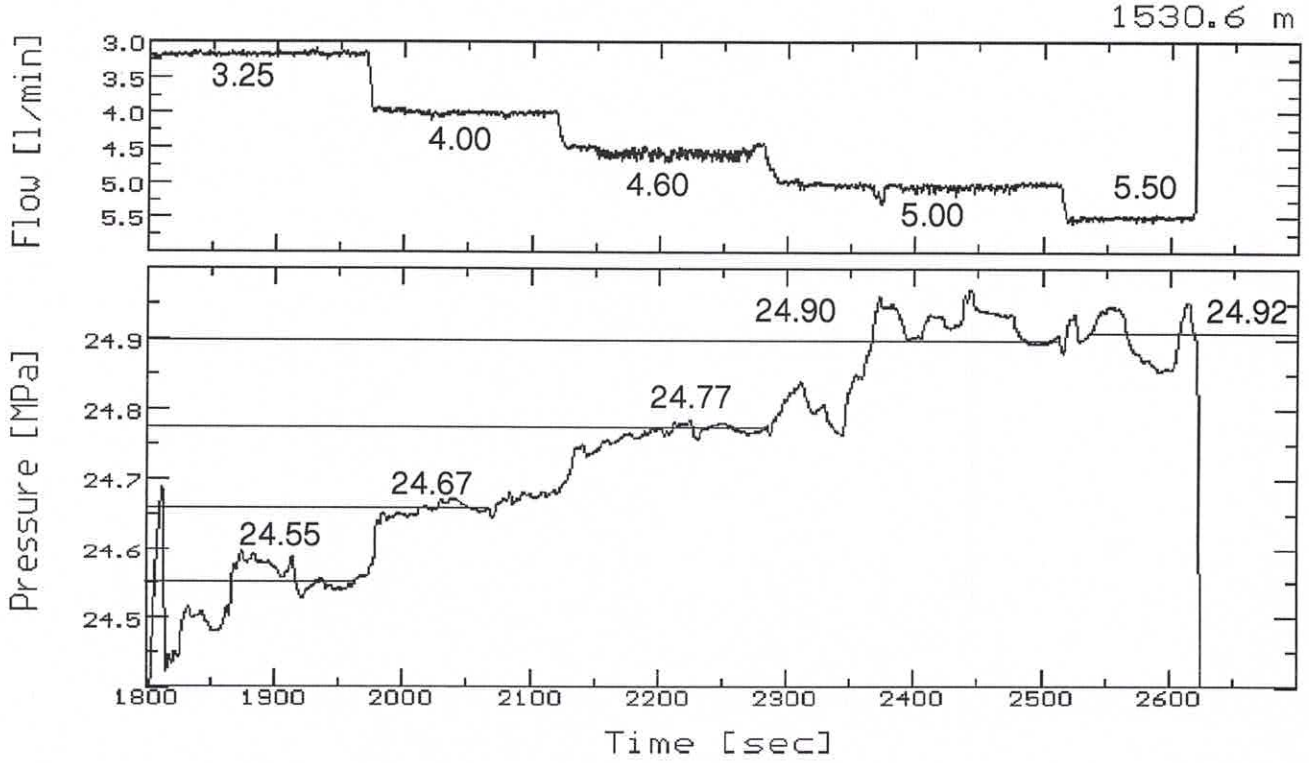
Estimation of P_p (frac - test, 2 .injection - cycle)



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



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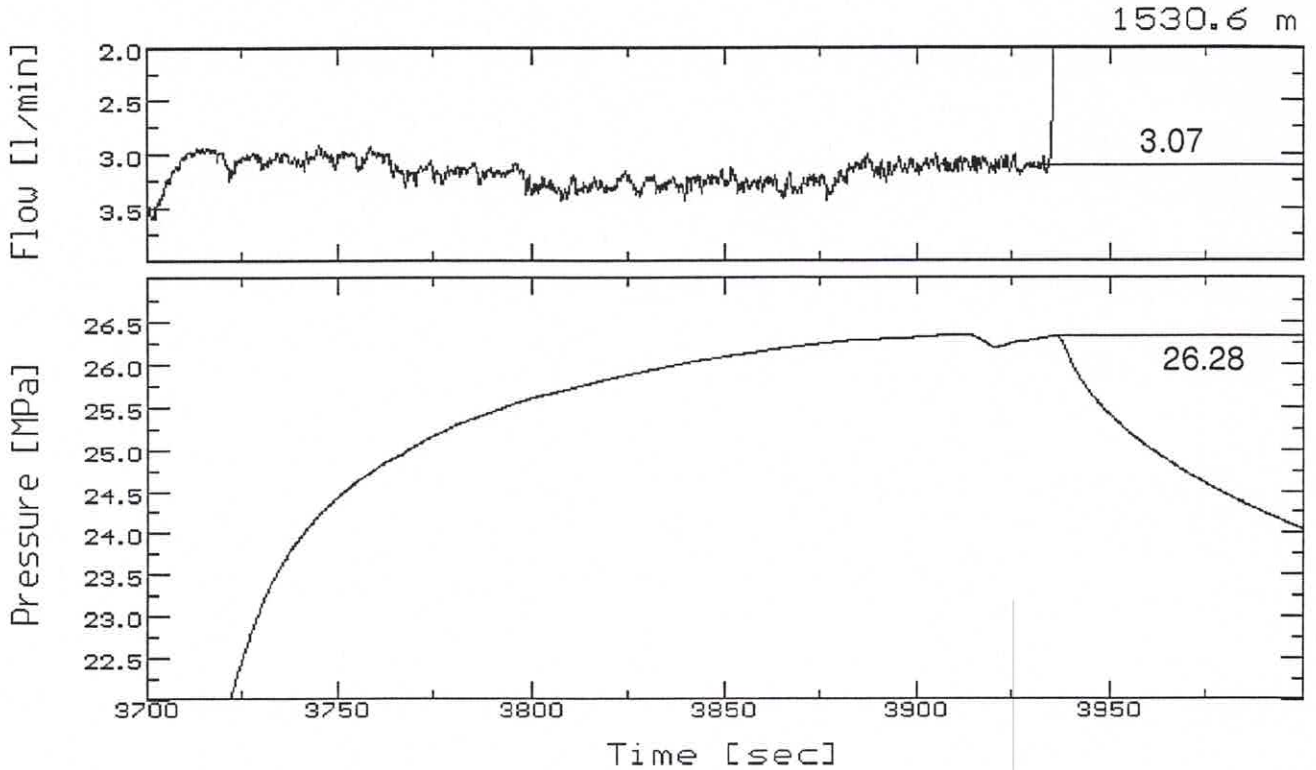
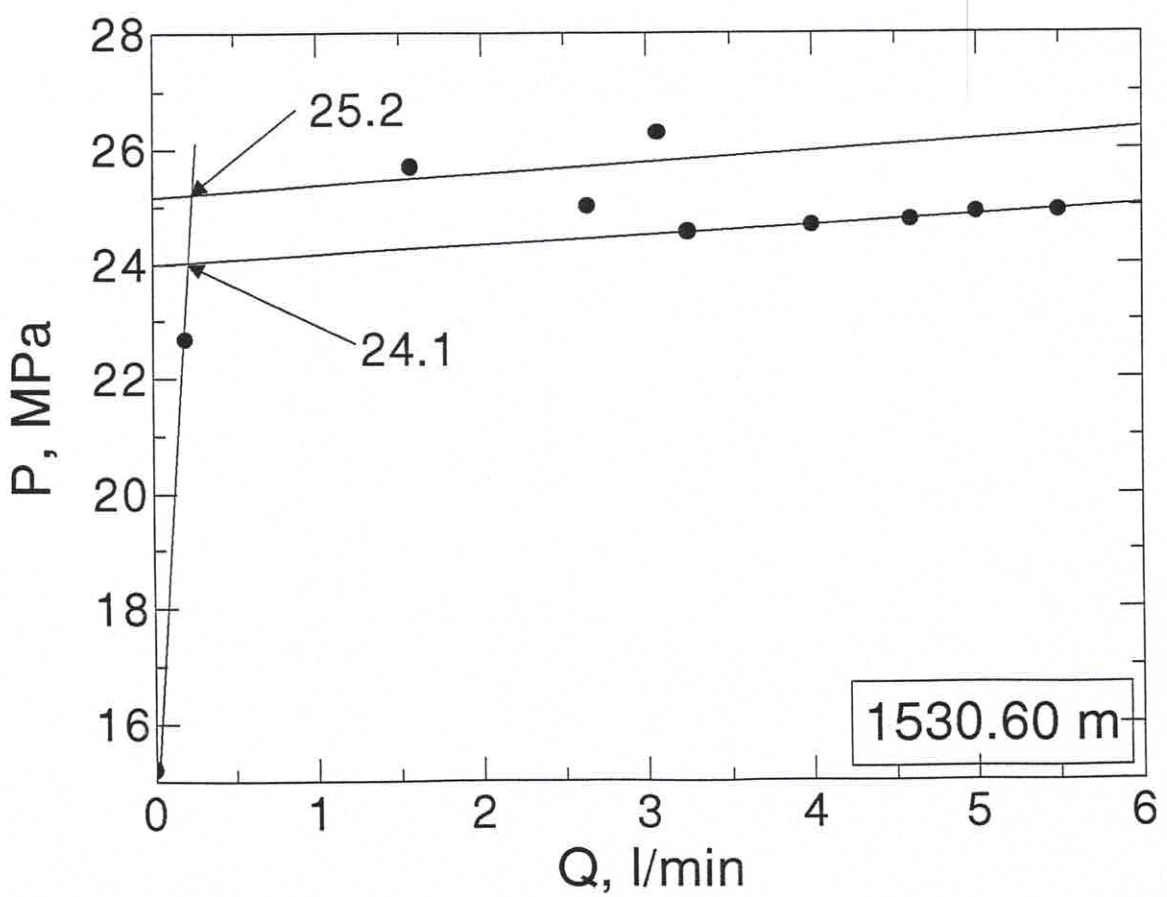
Estimation of P_p (frac - test, 4. injection - cycle)



Analysis of pumping pressure data



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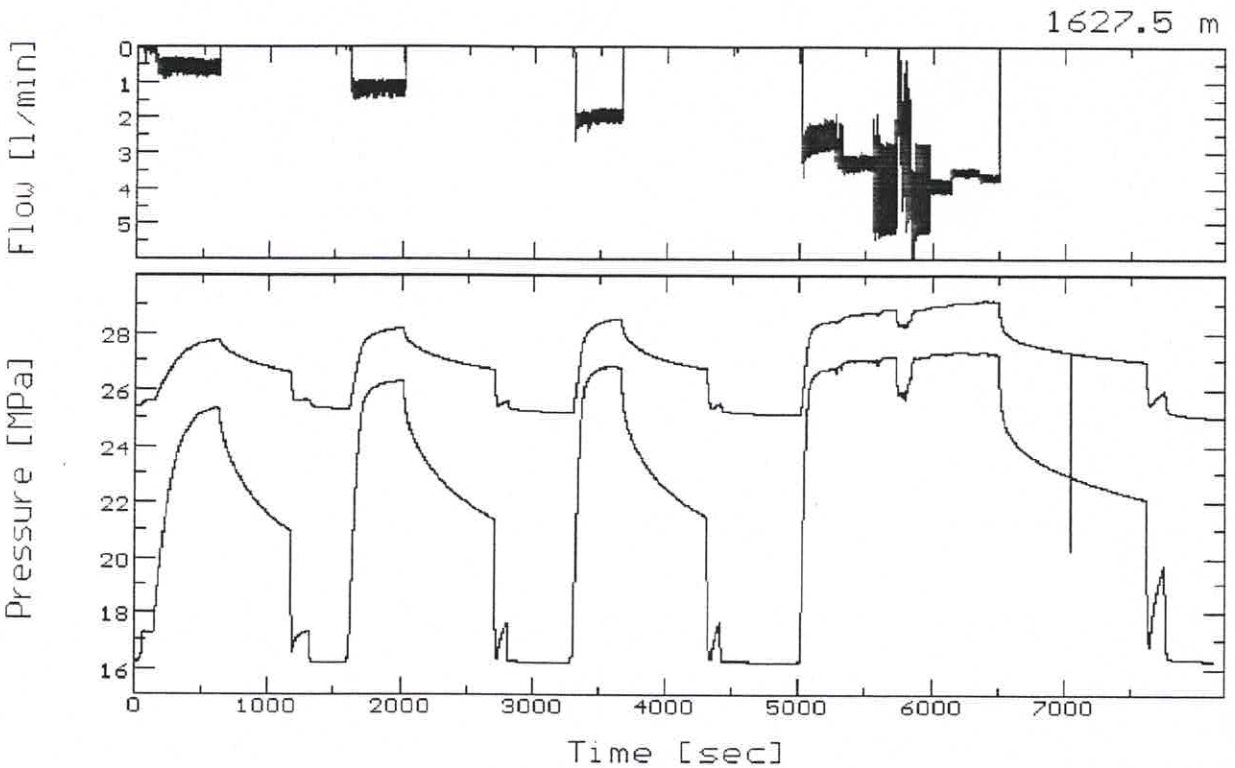
CASED - HOLE TEST 7 AT 1627.5 m



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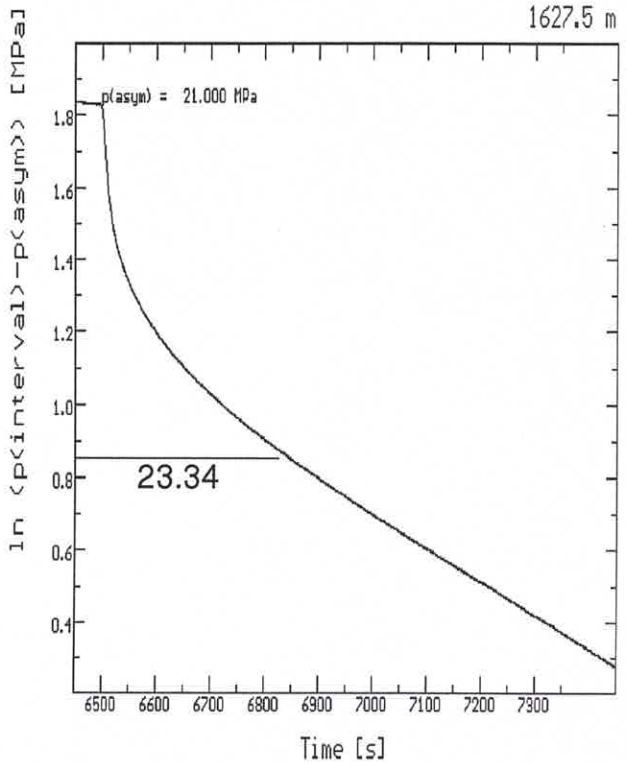
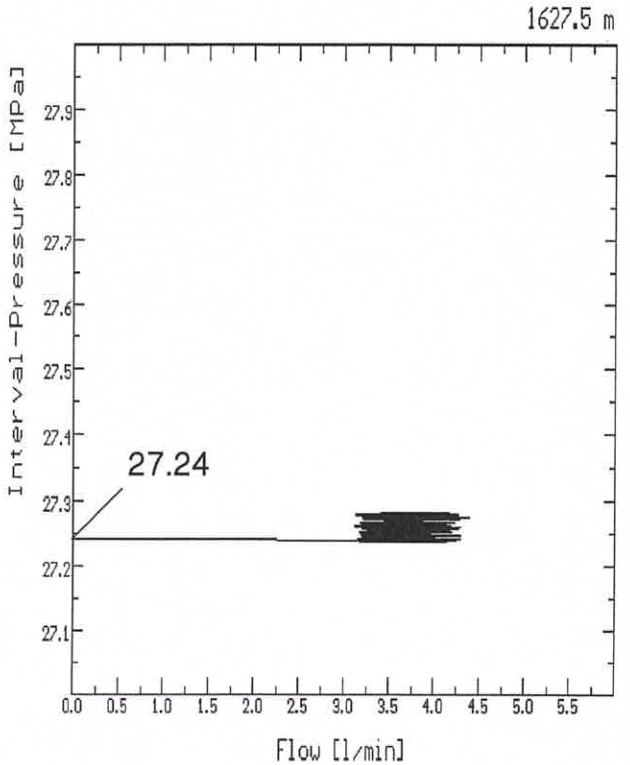
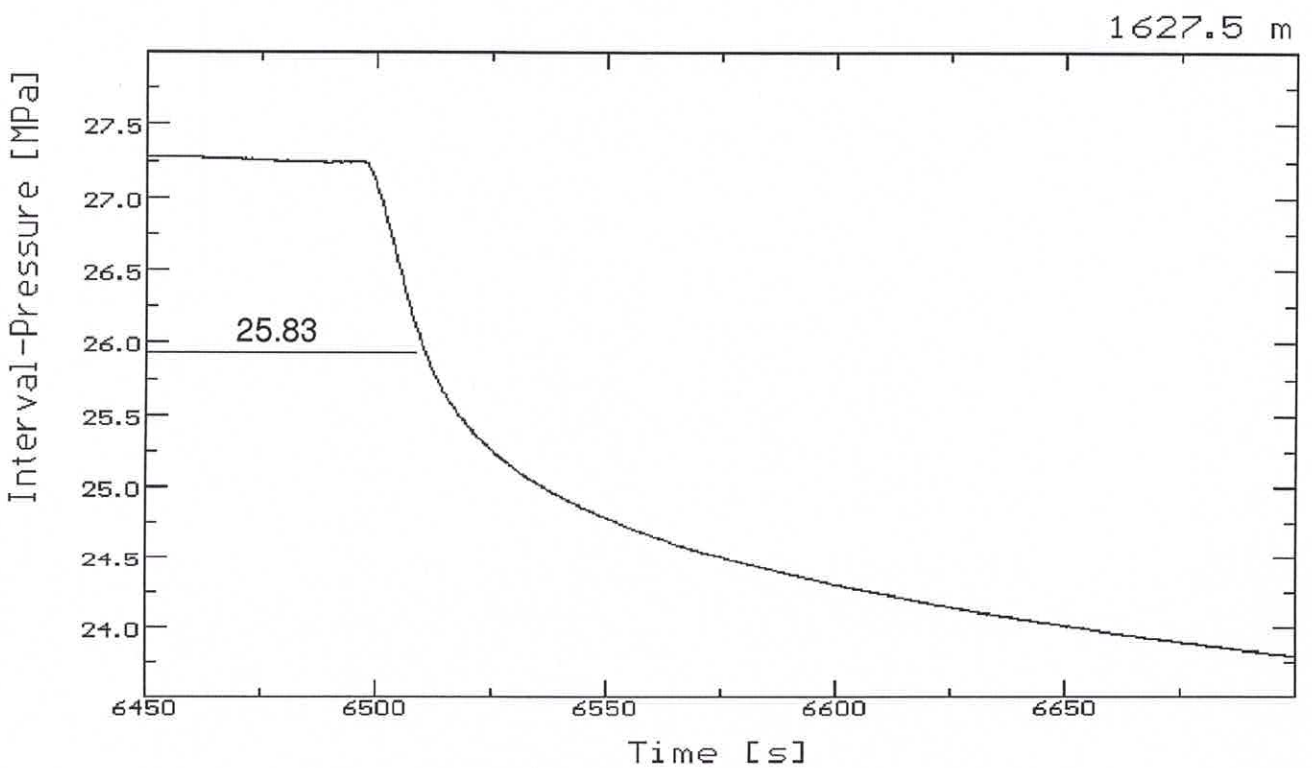
Estimation of $P_{si, min}$



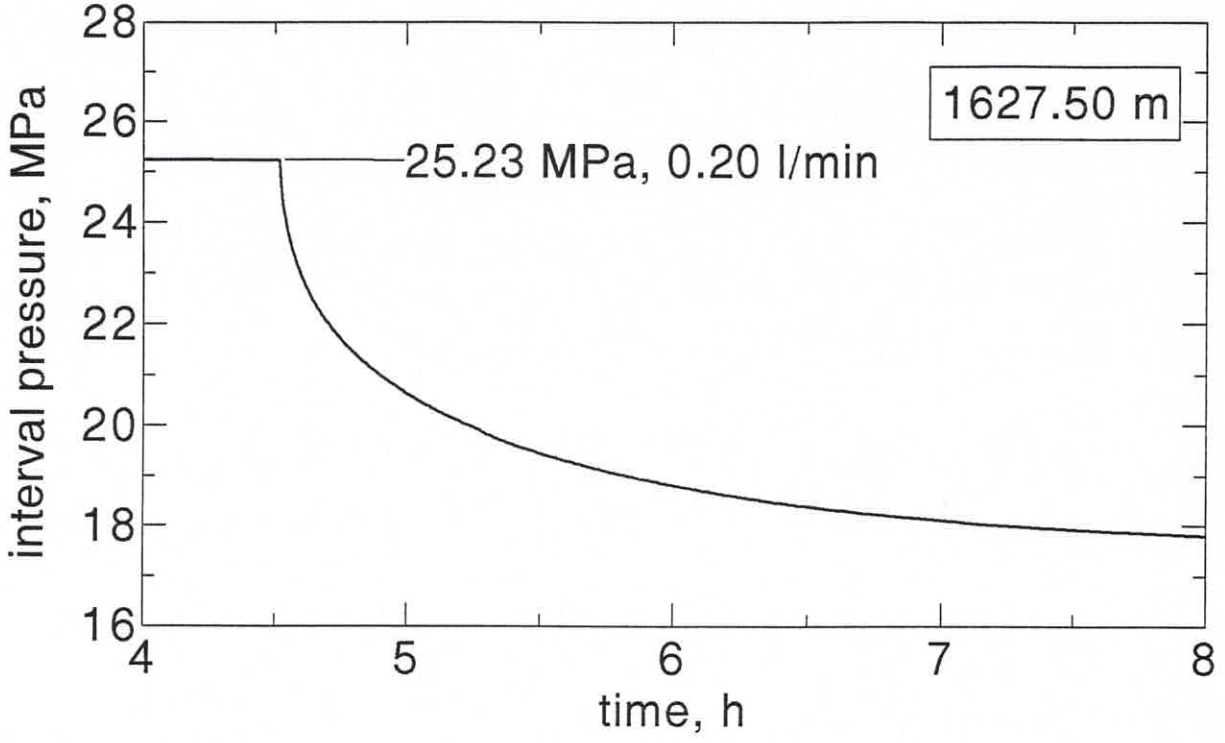
Estimation of $P_{si, max}$



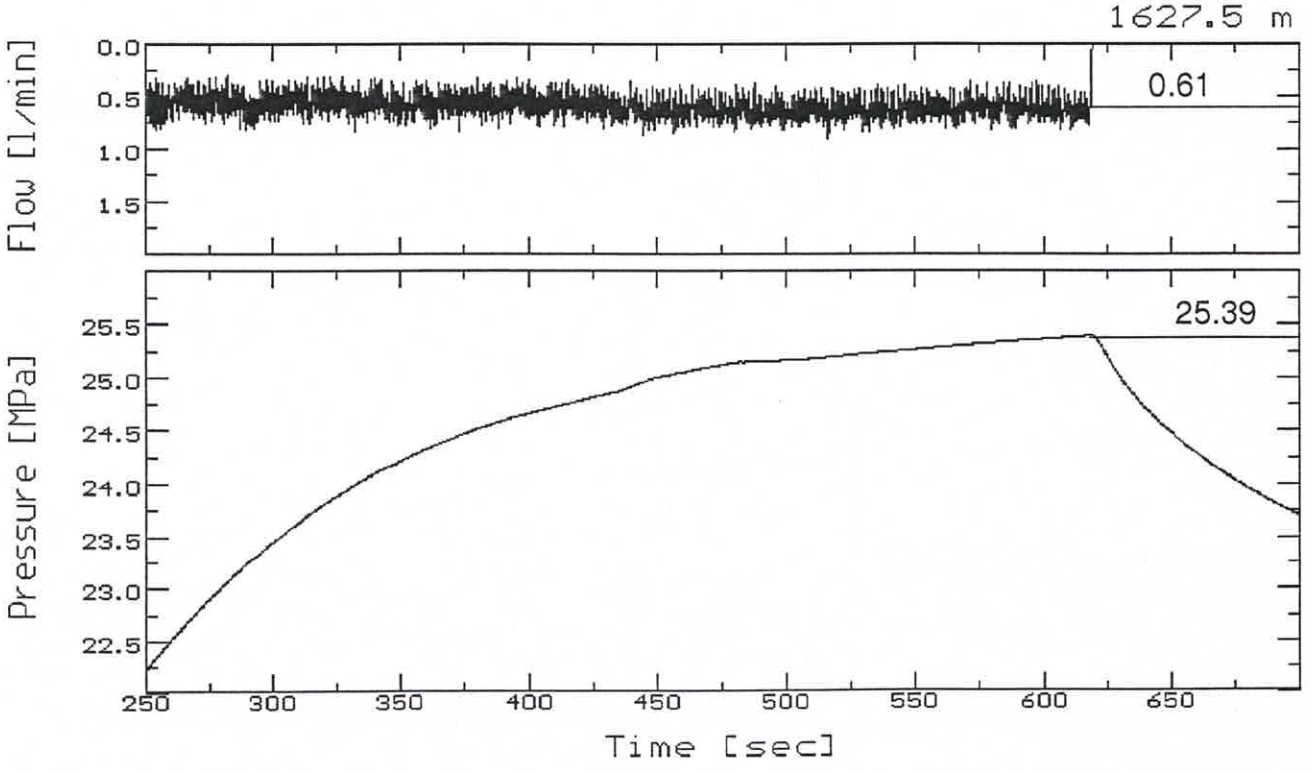
Estimation of P_{si}



Estimation of P_p (injection - test)



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



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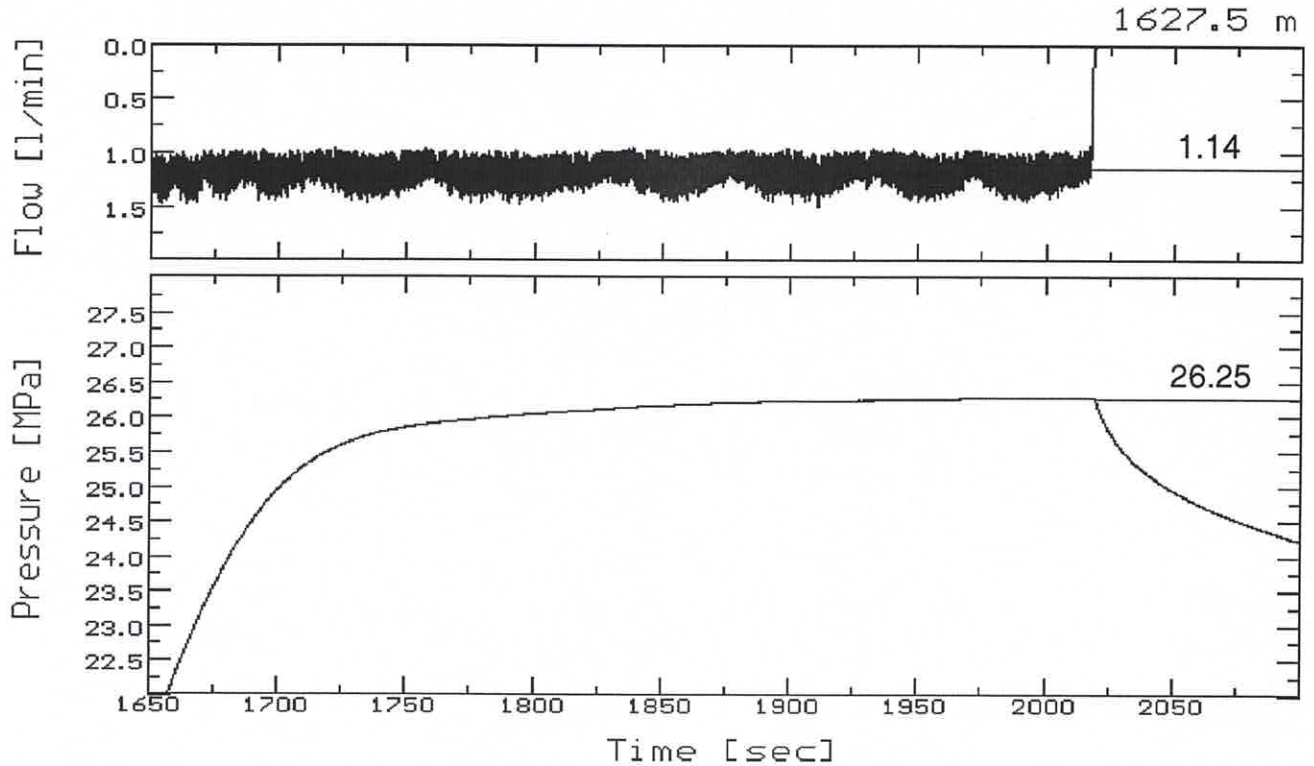
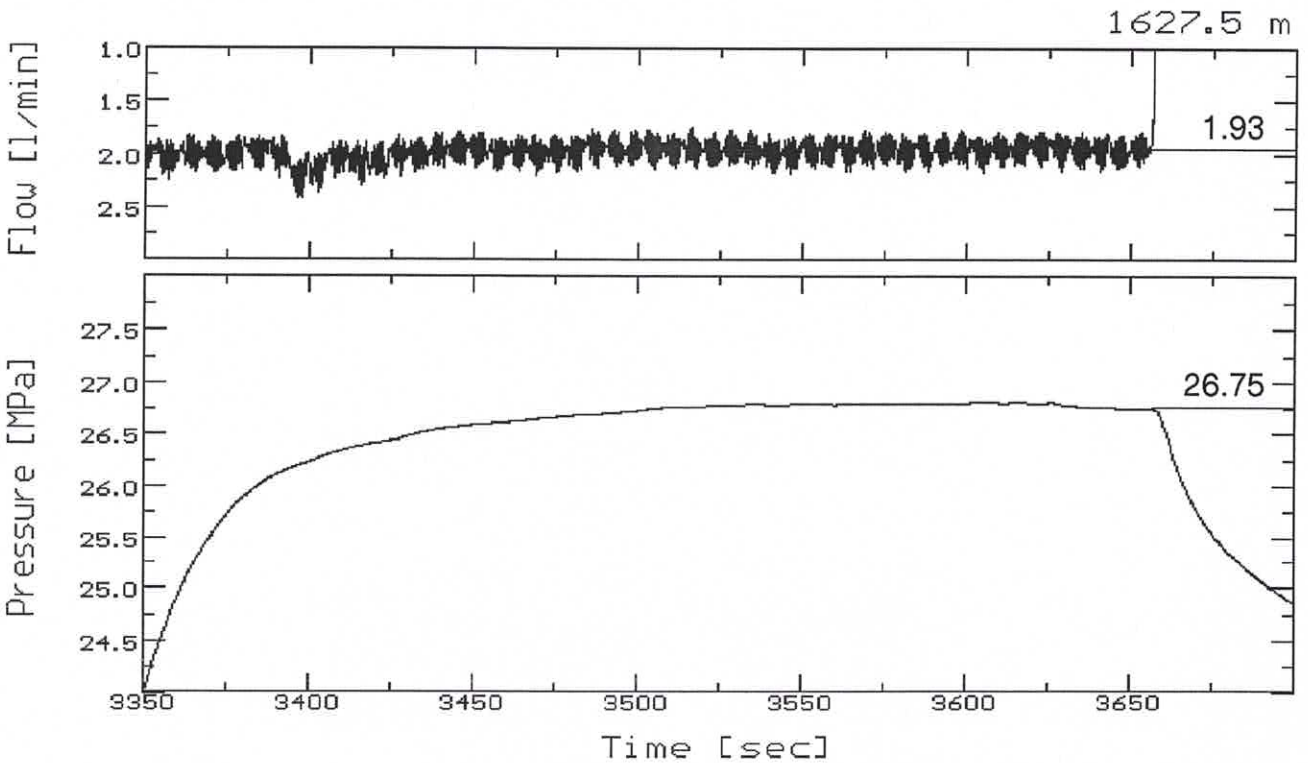
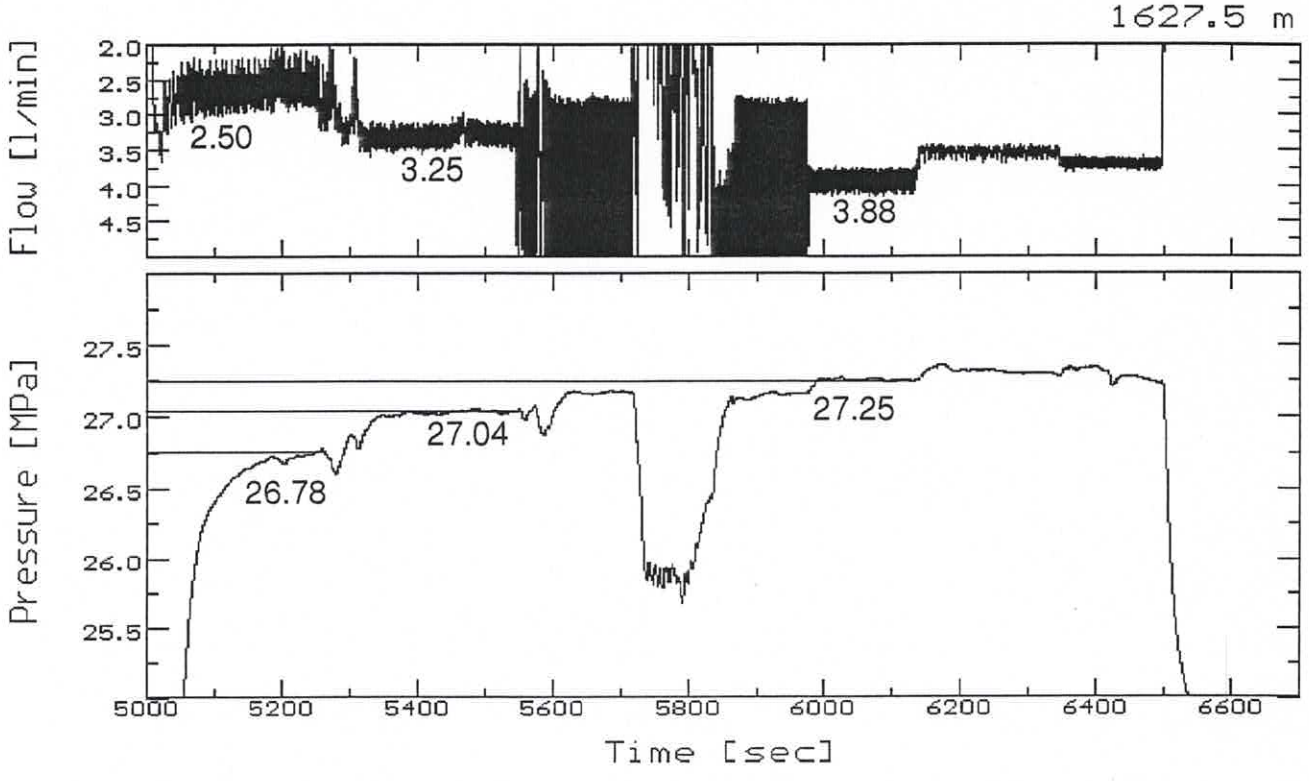
Estimation of P_p (frac - test, 2. injection - cycle)



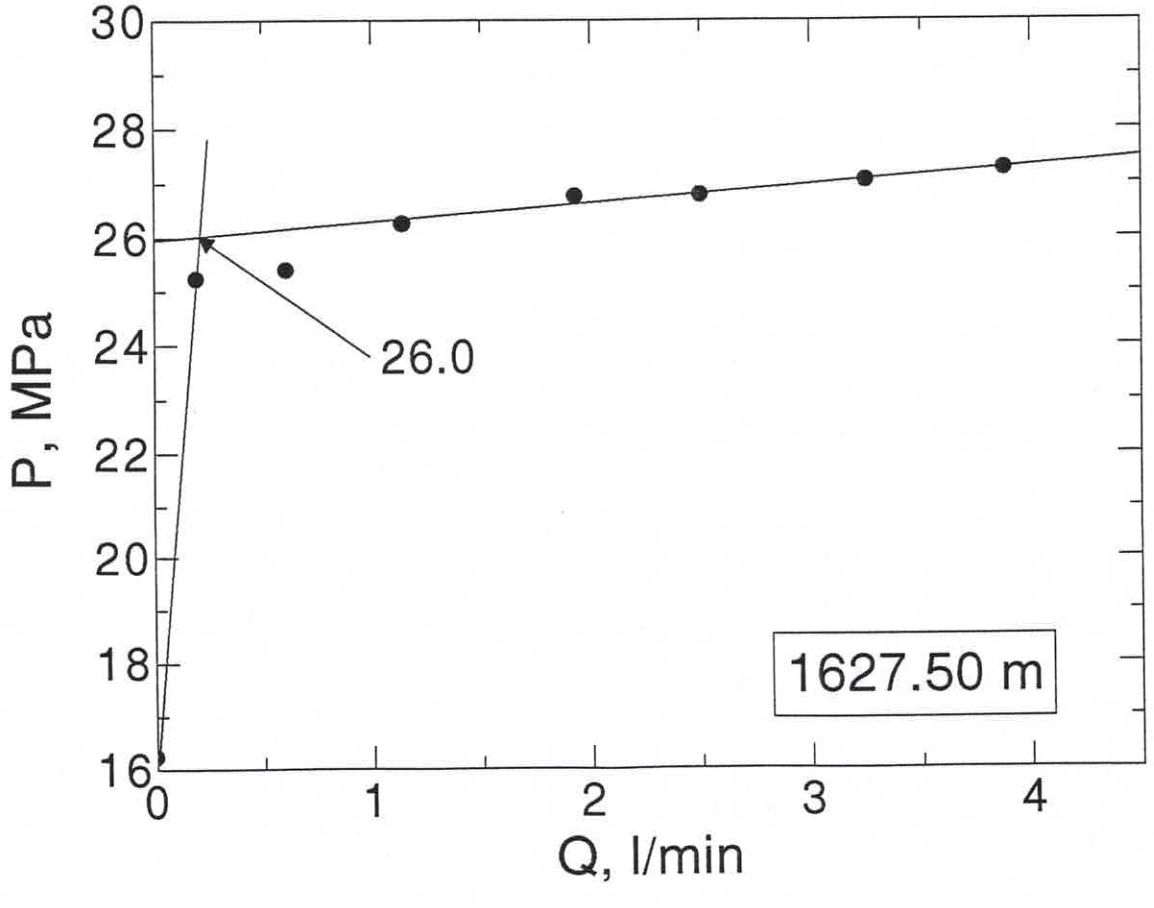
Estimation of P_p (frac - test, 3. injection - cycle)



Estimation of P_p (frac - test, 4. injection - cycle)



Analysis of pumping pressure data



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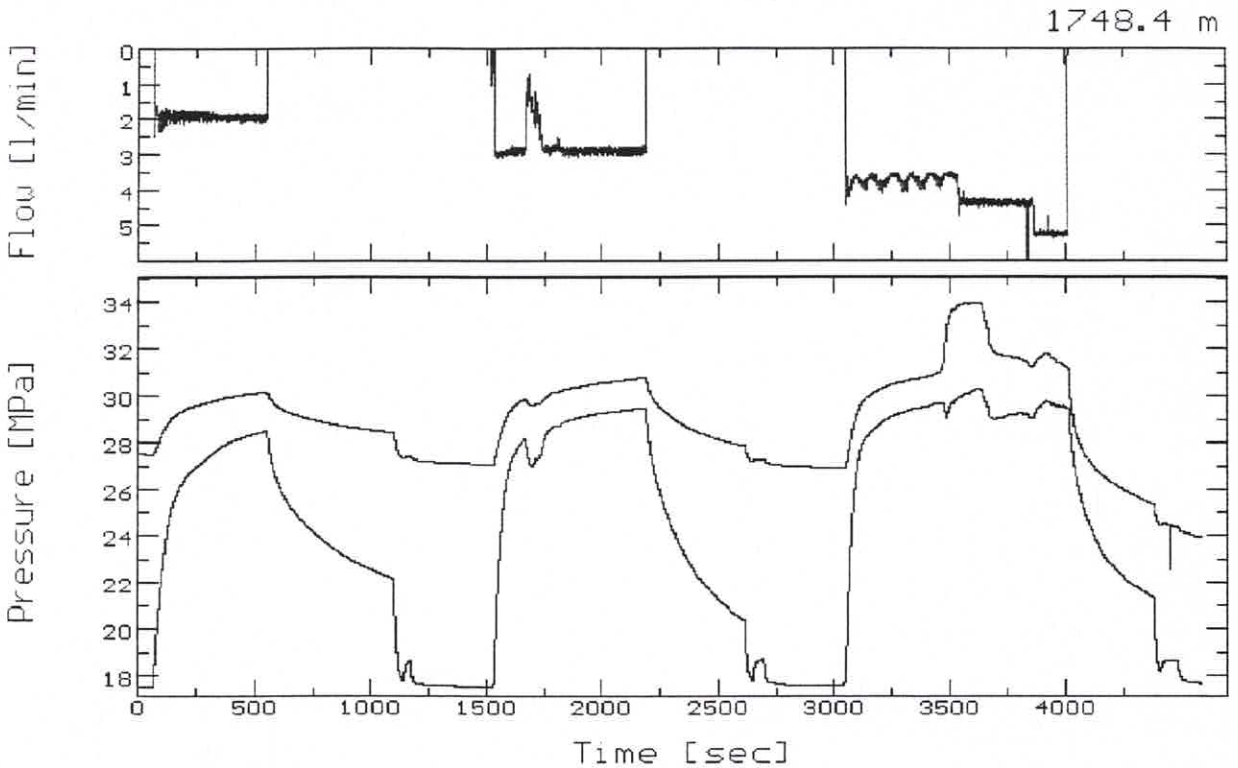
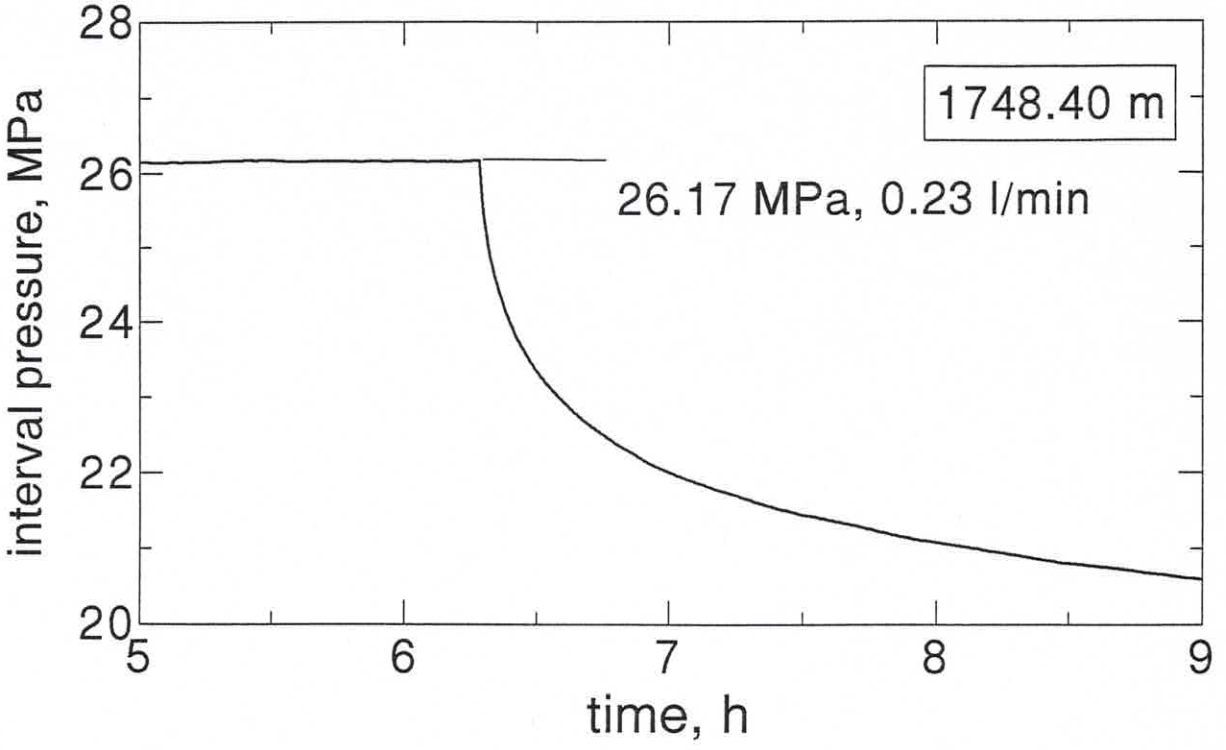
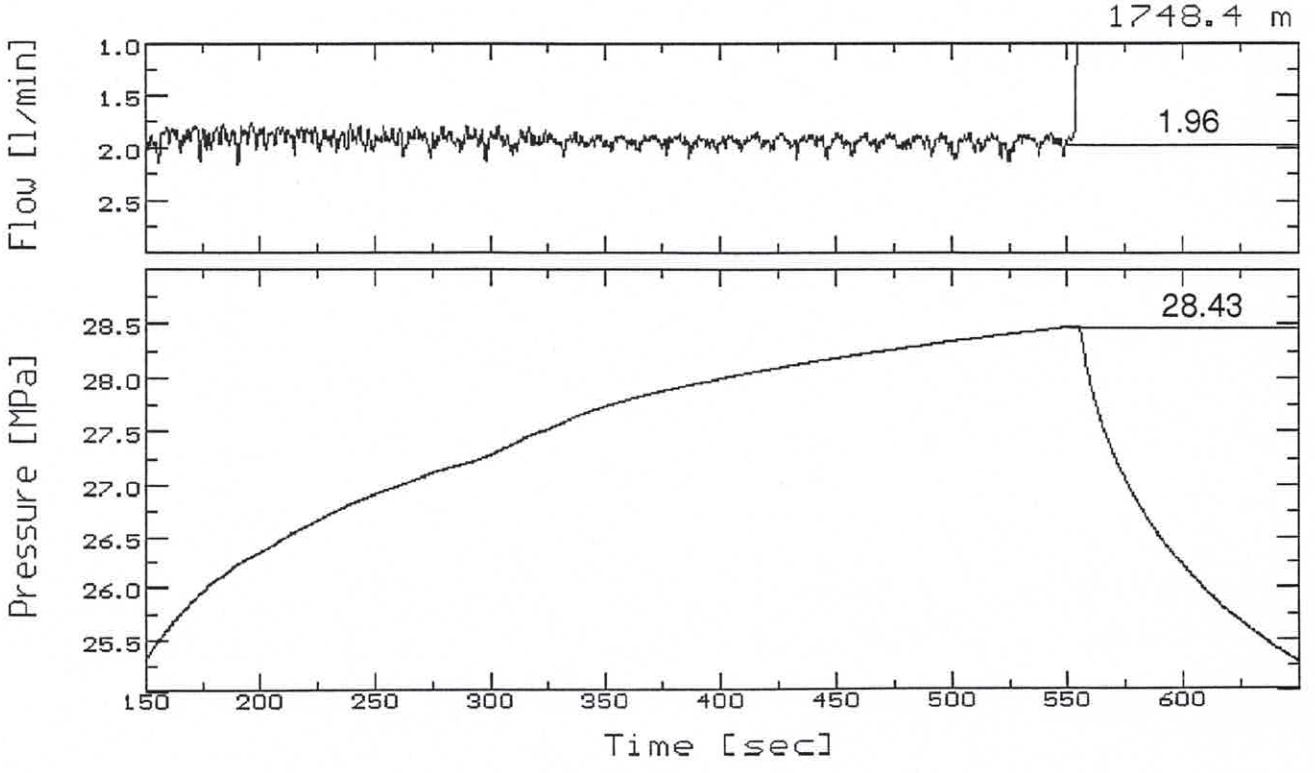
CASED - HOLE TEST 8 AT 1748.4 m



Estimation of P_p (injection - test)



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



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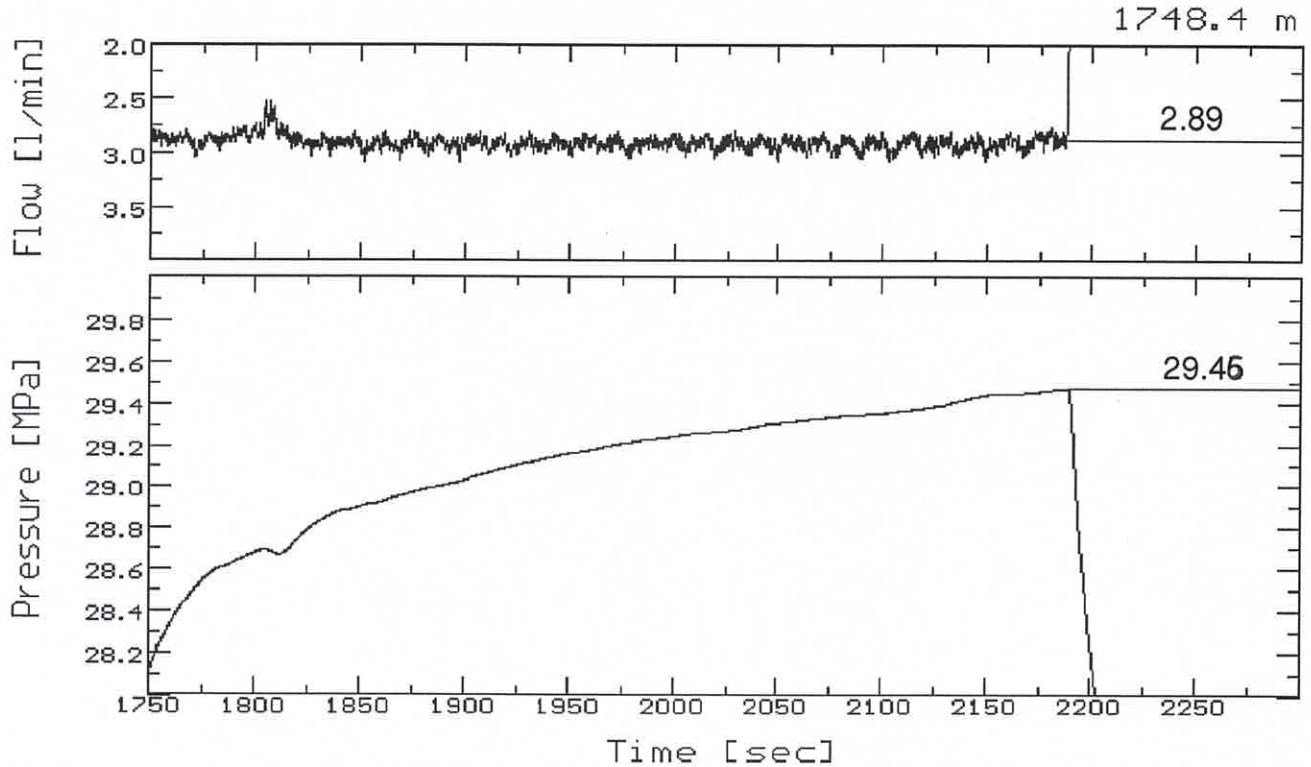
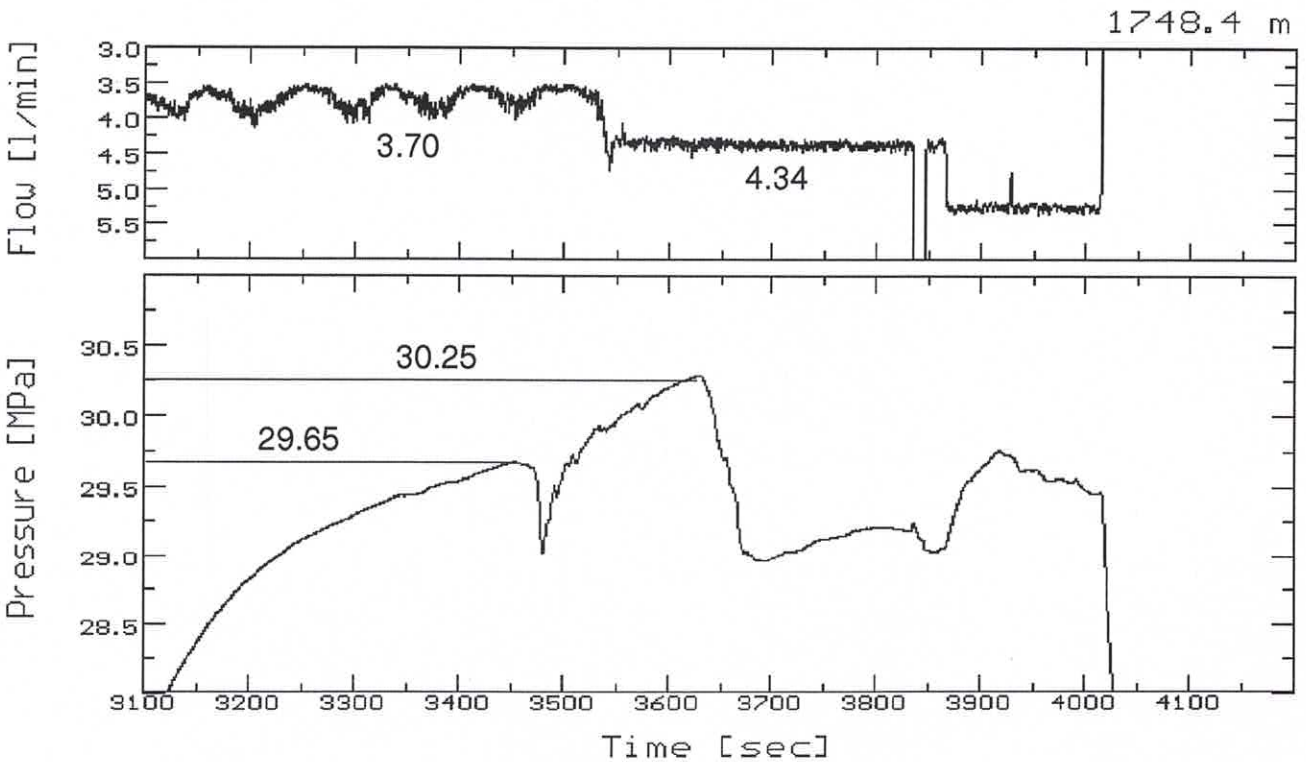
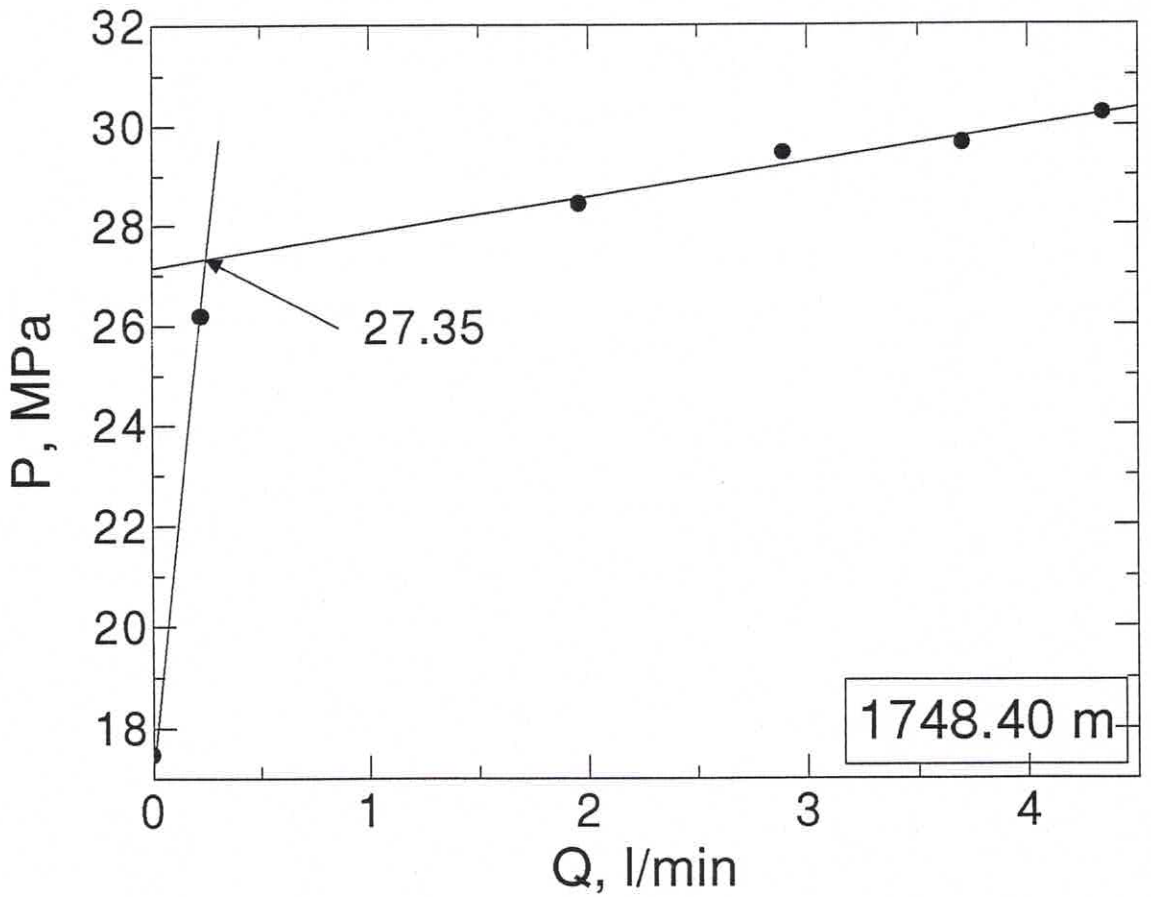
Estimation of P_p (frac - test, 2. injection - cycle)



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



Analysis of pumping pressure data



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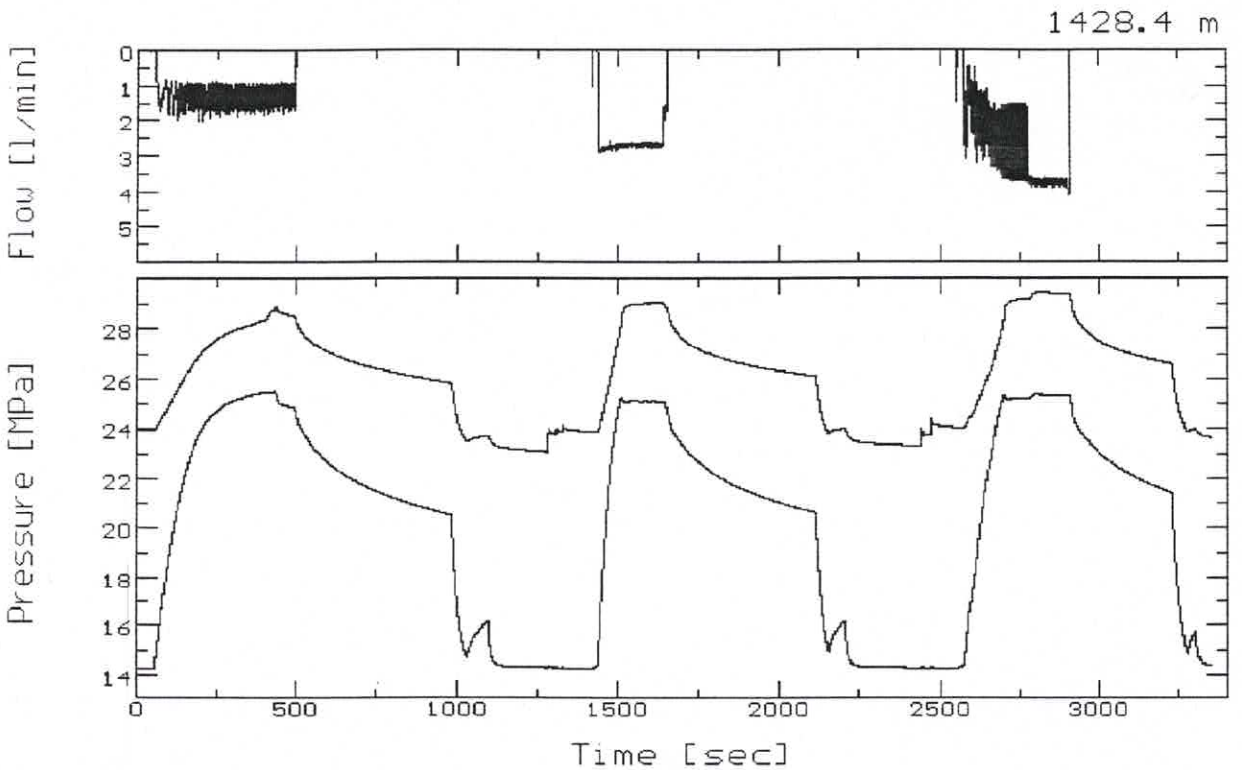
CASED - HOLE TEST 9 AT 1428.4 m



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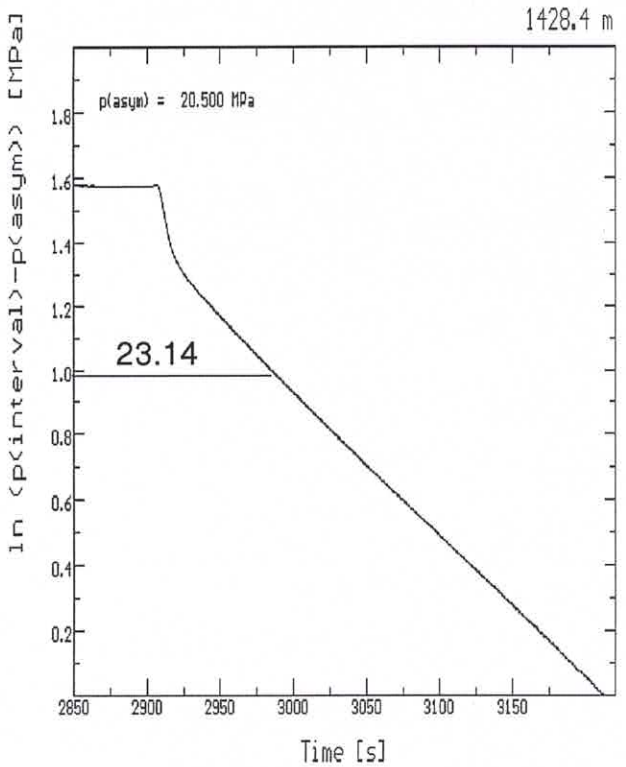
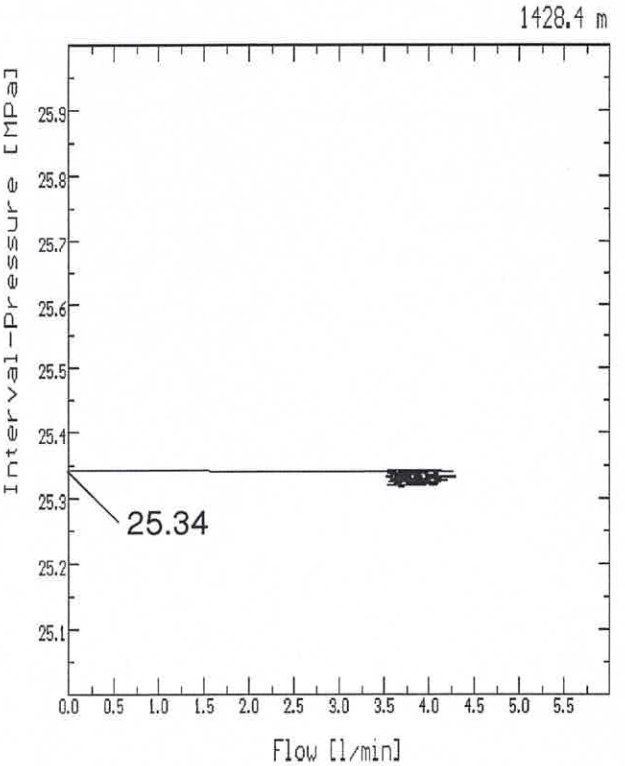
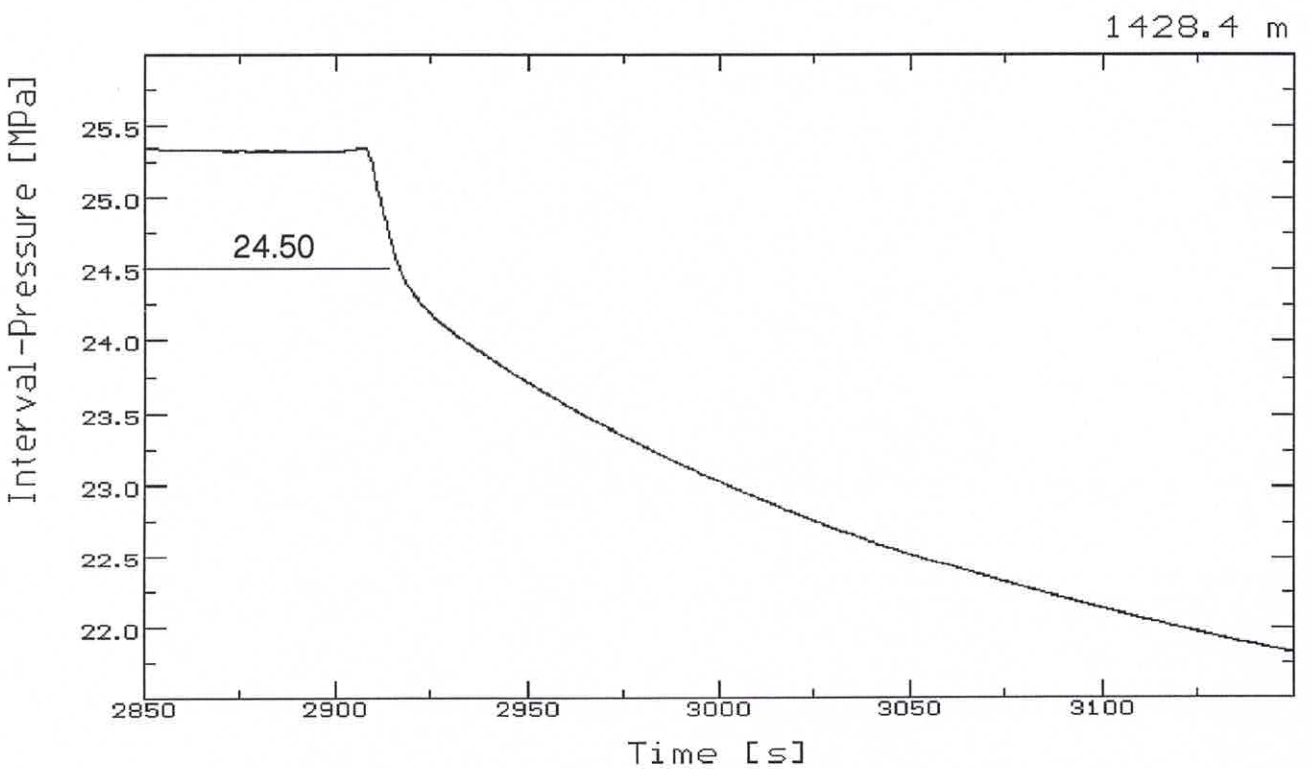
Estimation of $P_{si, min}$



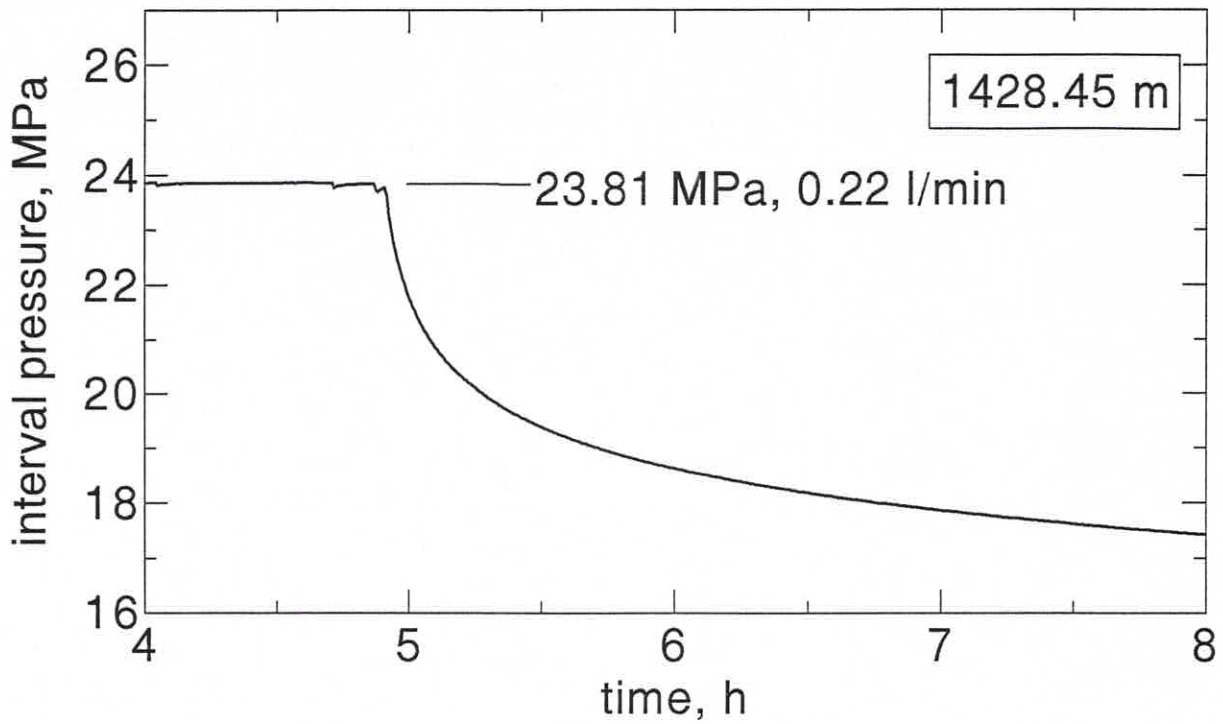
Estimation of $P_{si, max}$



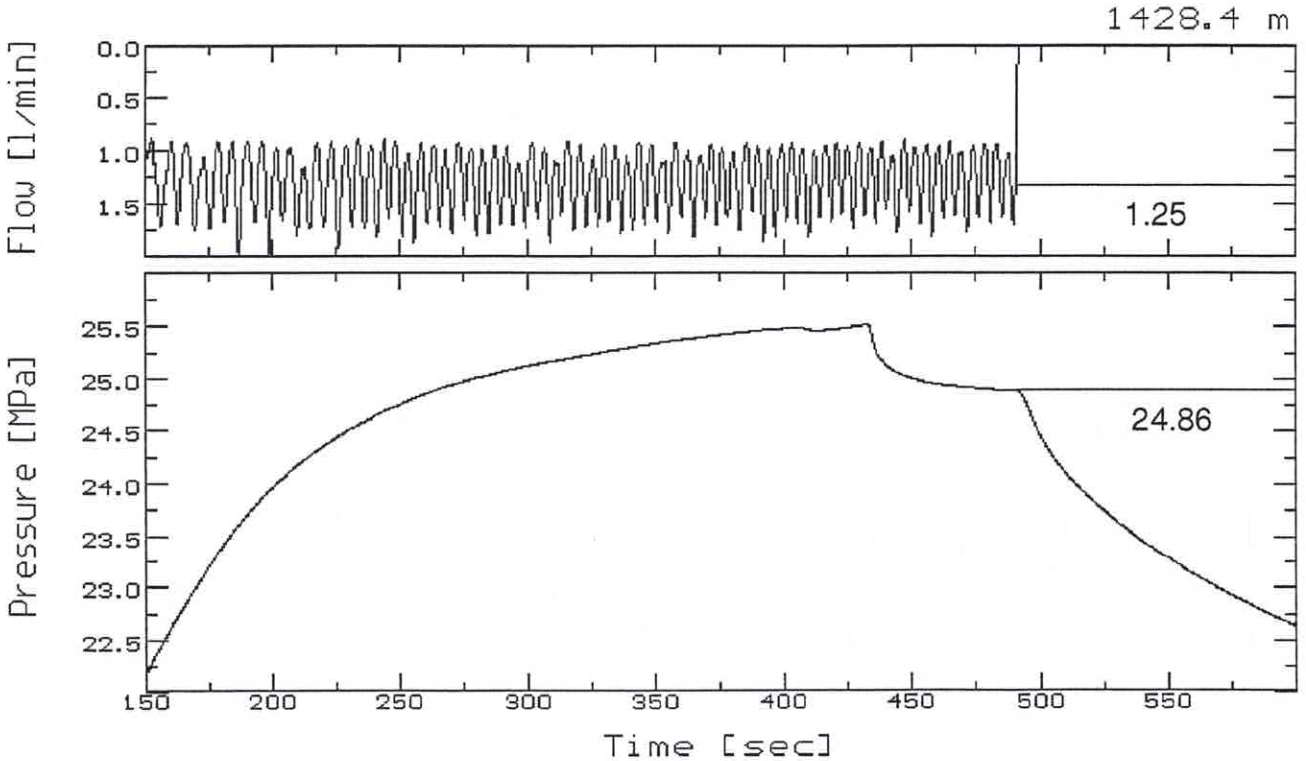
Estimation of P_{si}



Estimation of P_p (injection - test)



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



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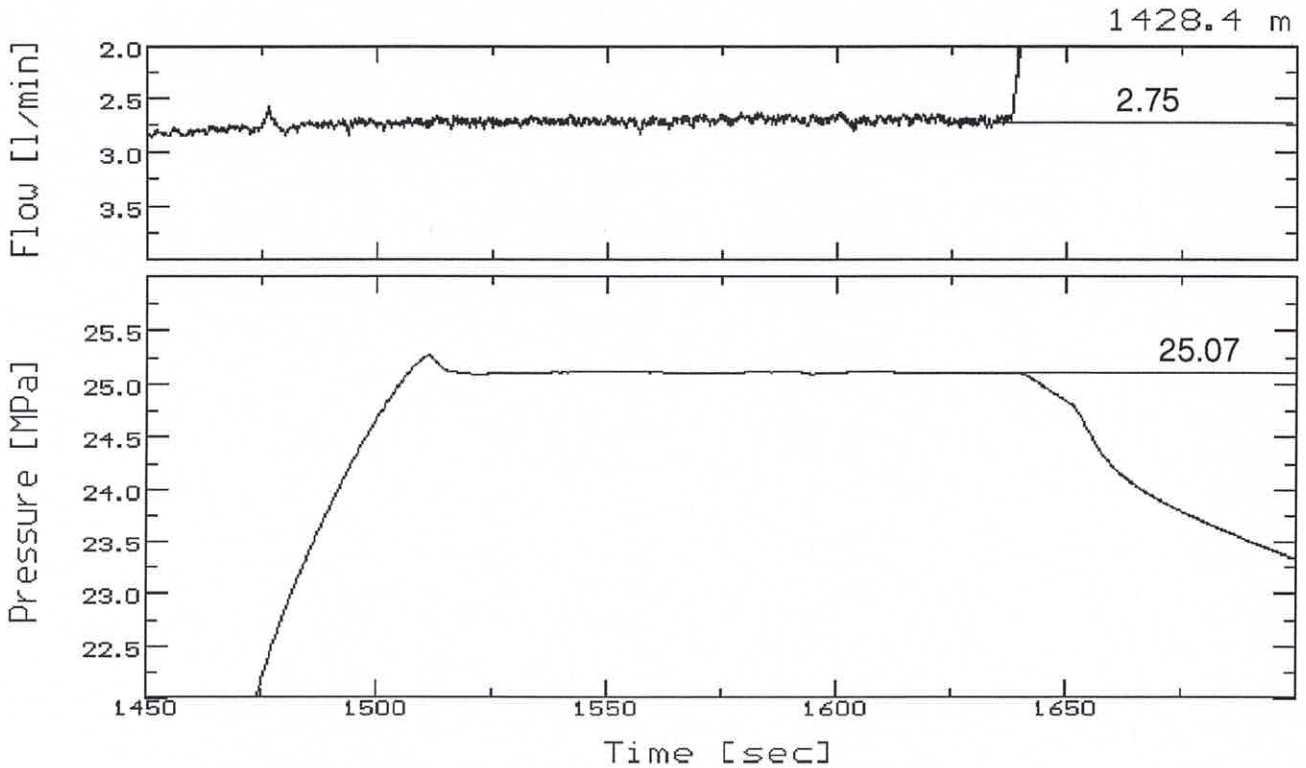
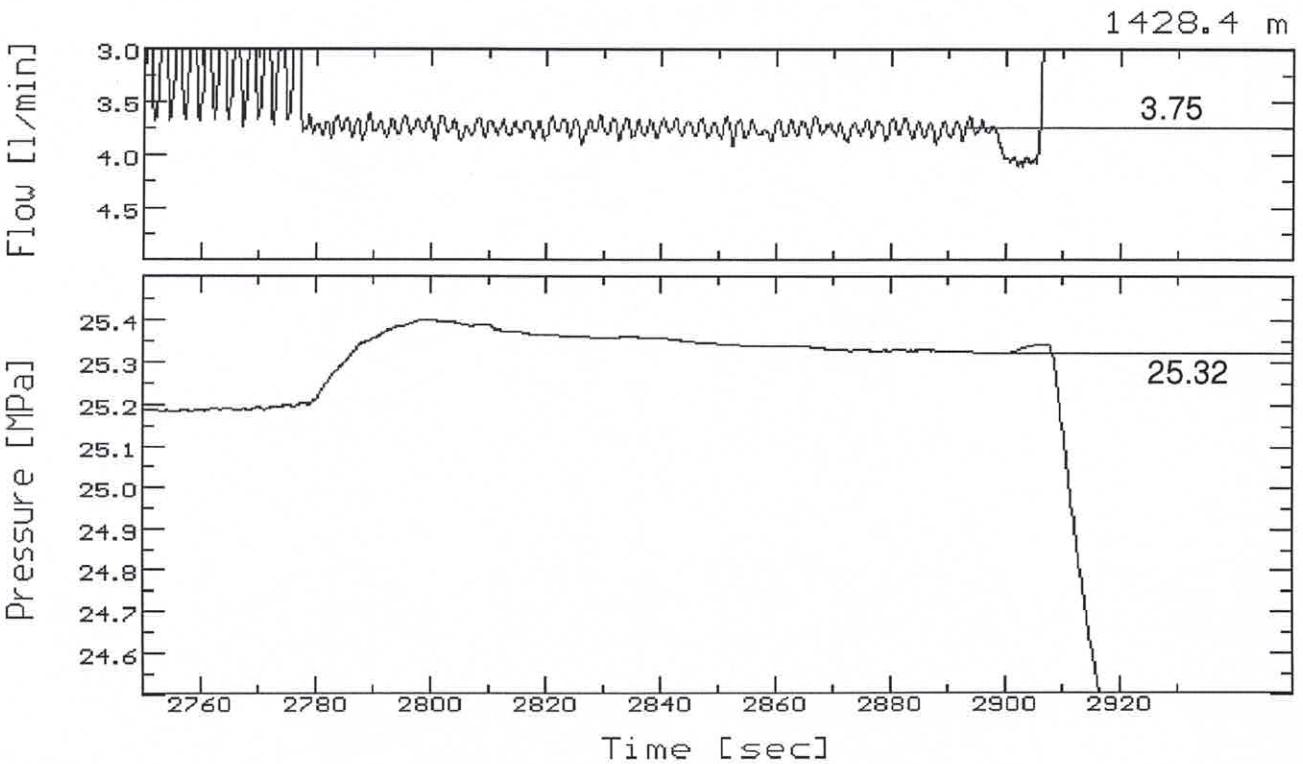
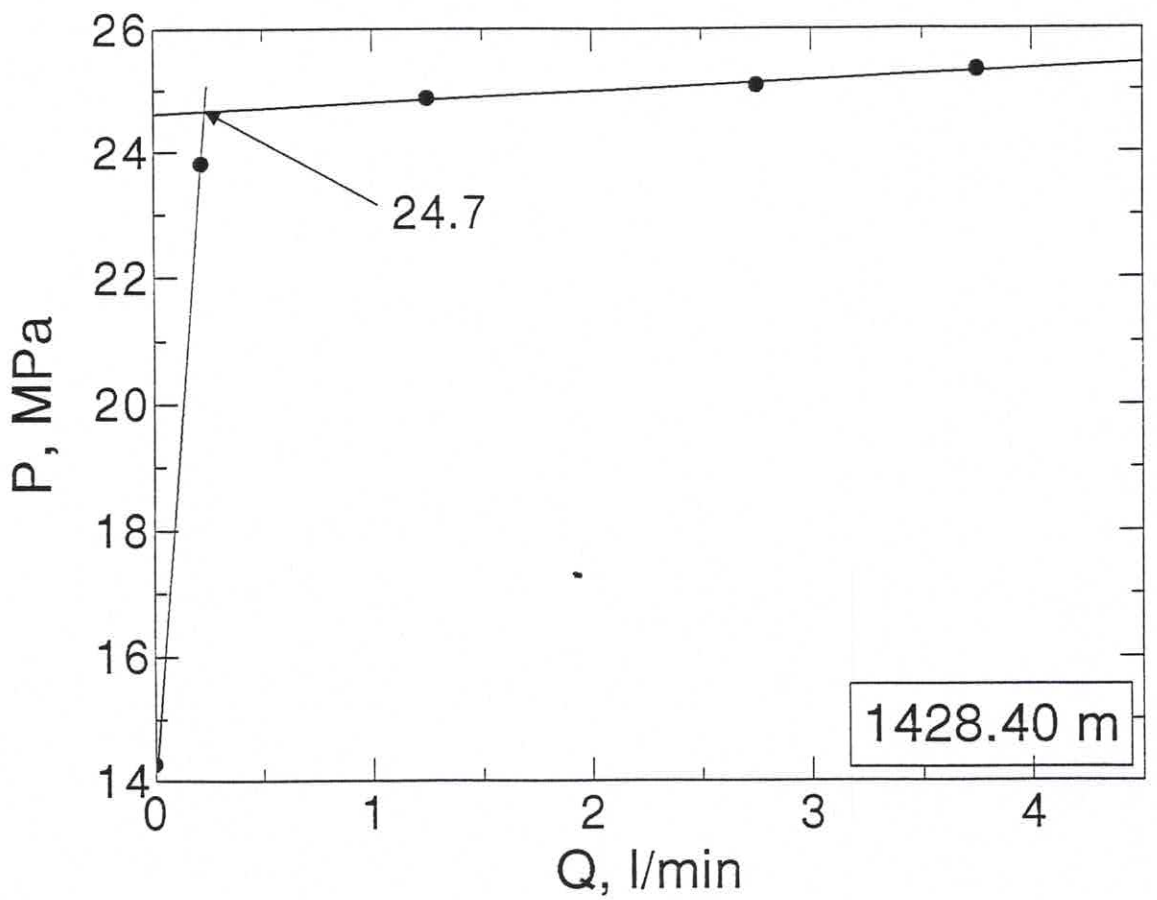
Estimation of P_p (frac - test, 2. injection - cycle)



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



Analysis of pumping pressure data



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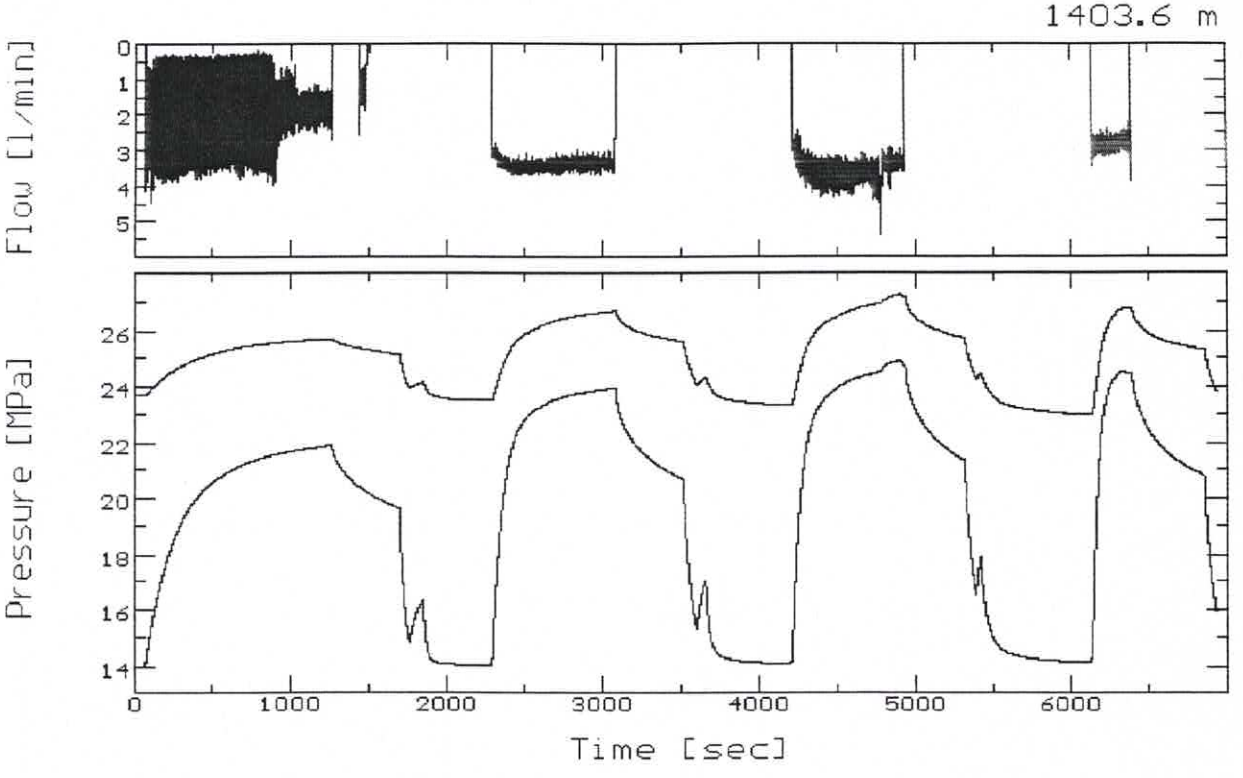
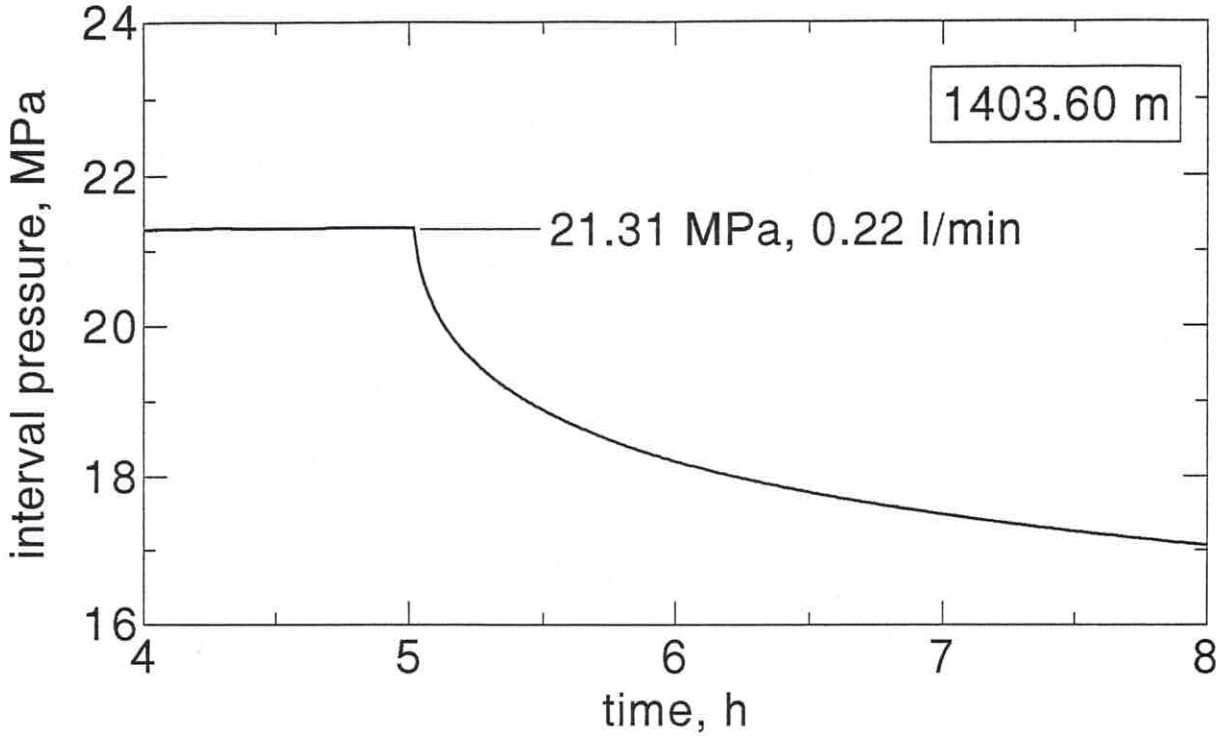
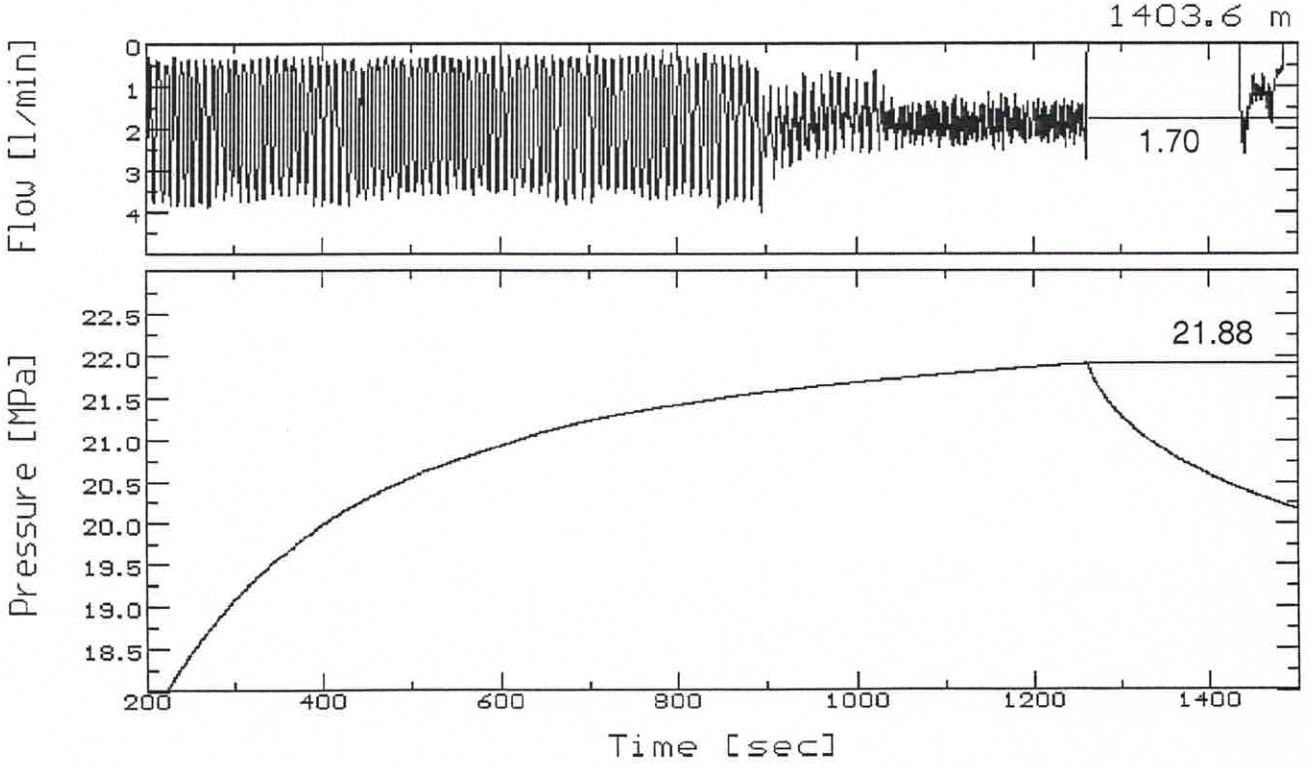
CASED - HOLE TEST 10 AT 1403.6 m



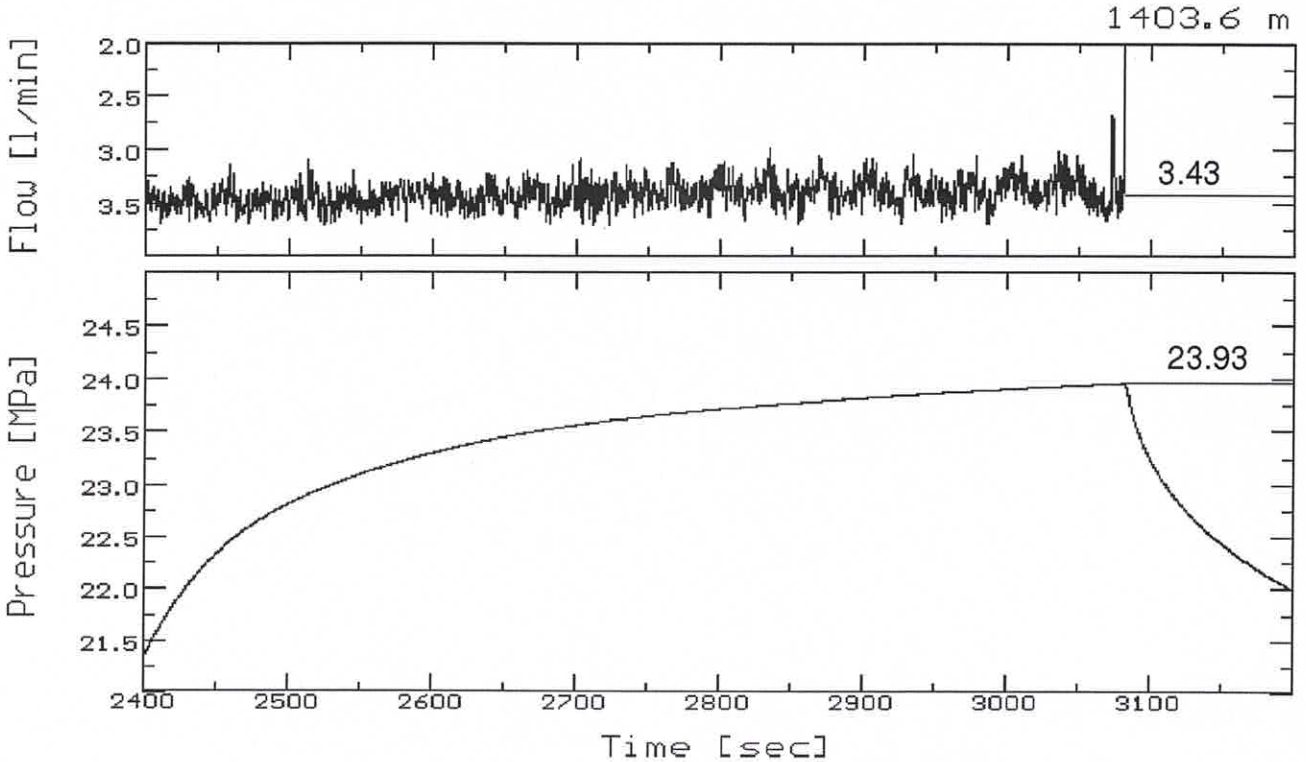
Estimation of P_p (injection - test)



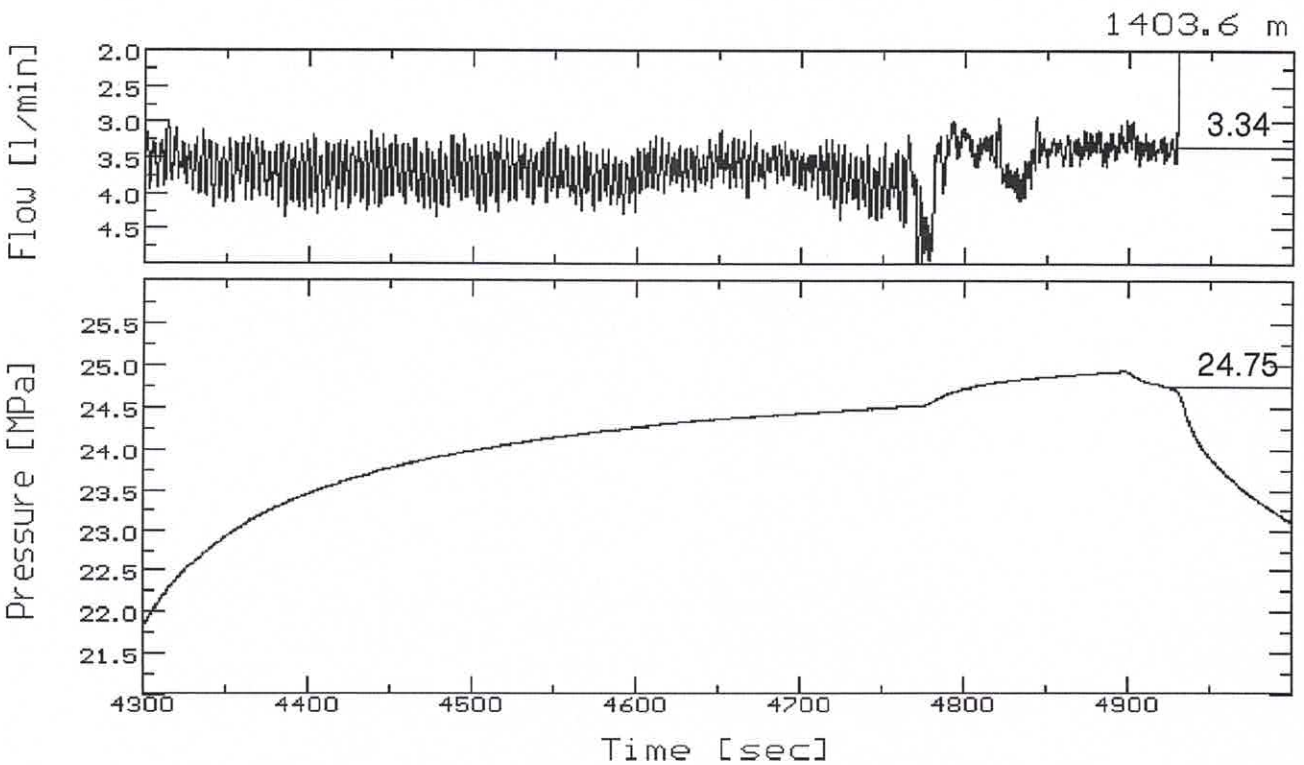
Estimation of P_p (frac - test, 1. injection - cycle)



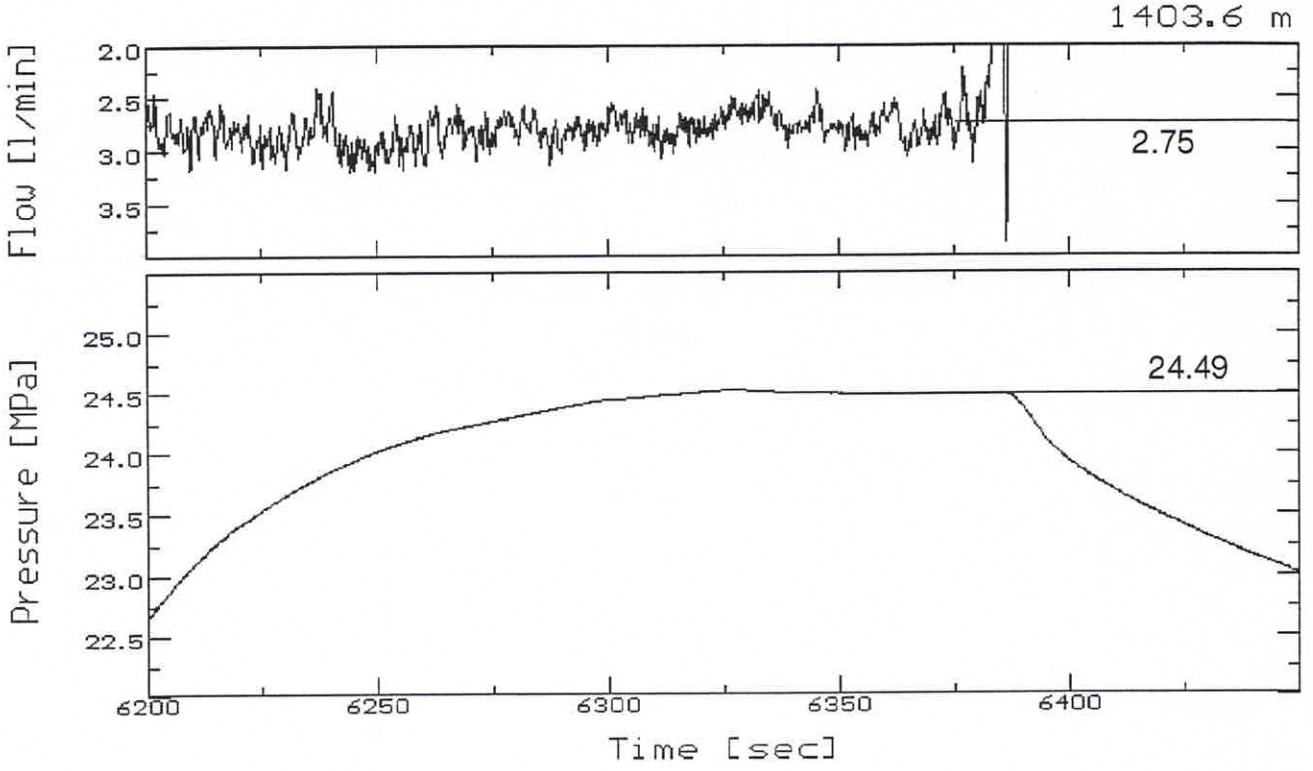
Estimation of P_p (frac - test, 2. injection - cycle)



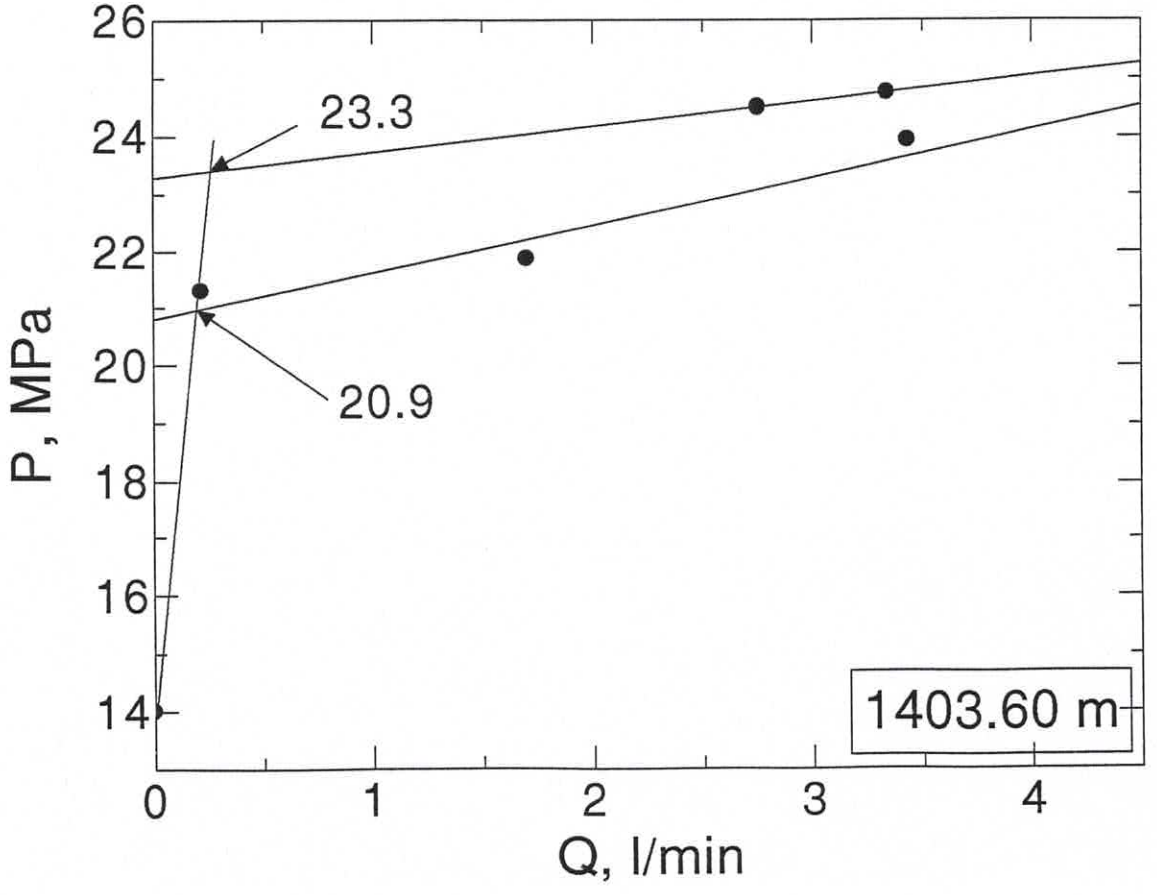
Estimation of P_p (frac - test, 3 .injection - cycle)



Estimation of P_p (frac - test, 4. injection - cycle)



Analysis of pumping pressure data



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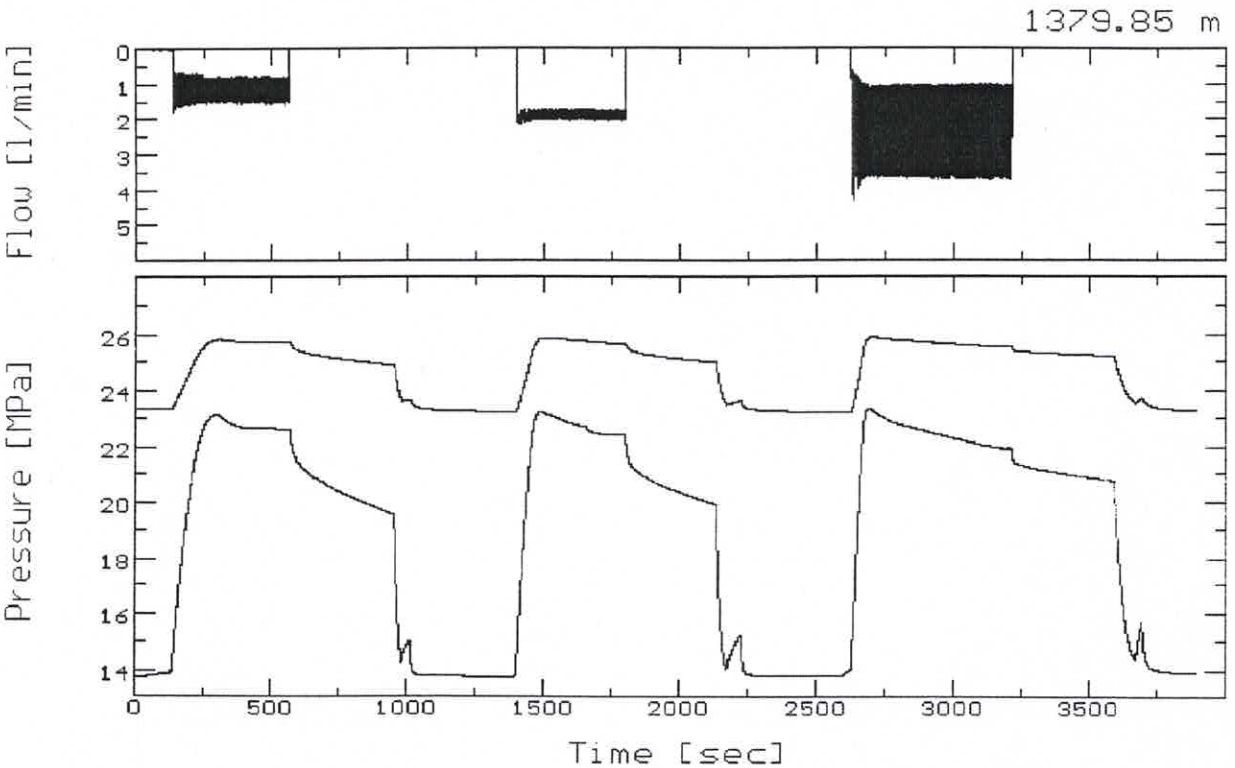
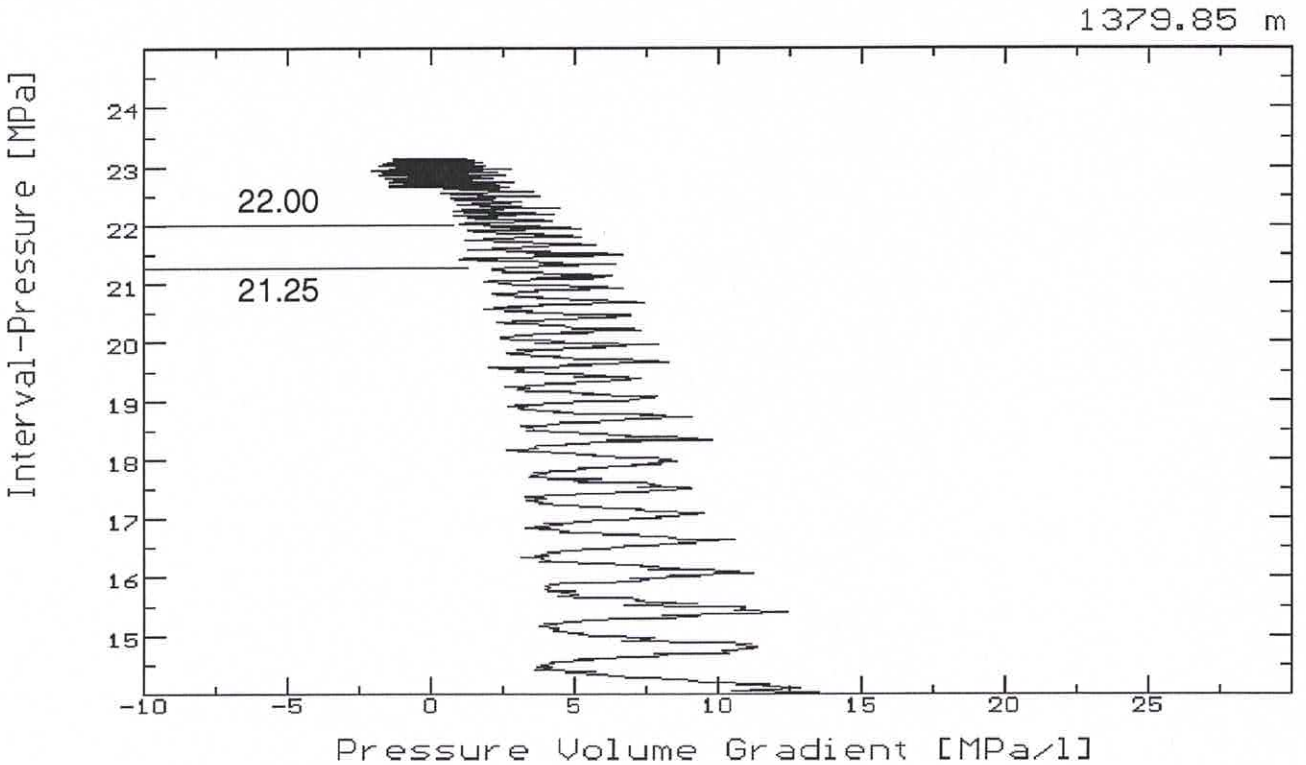
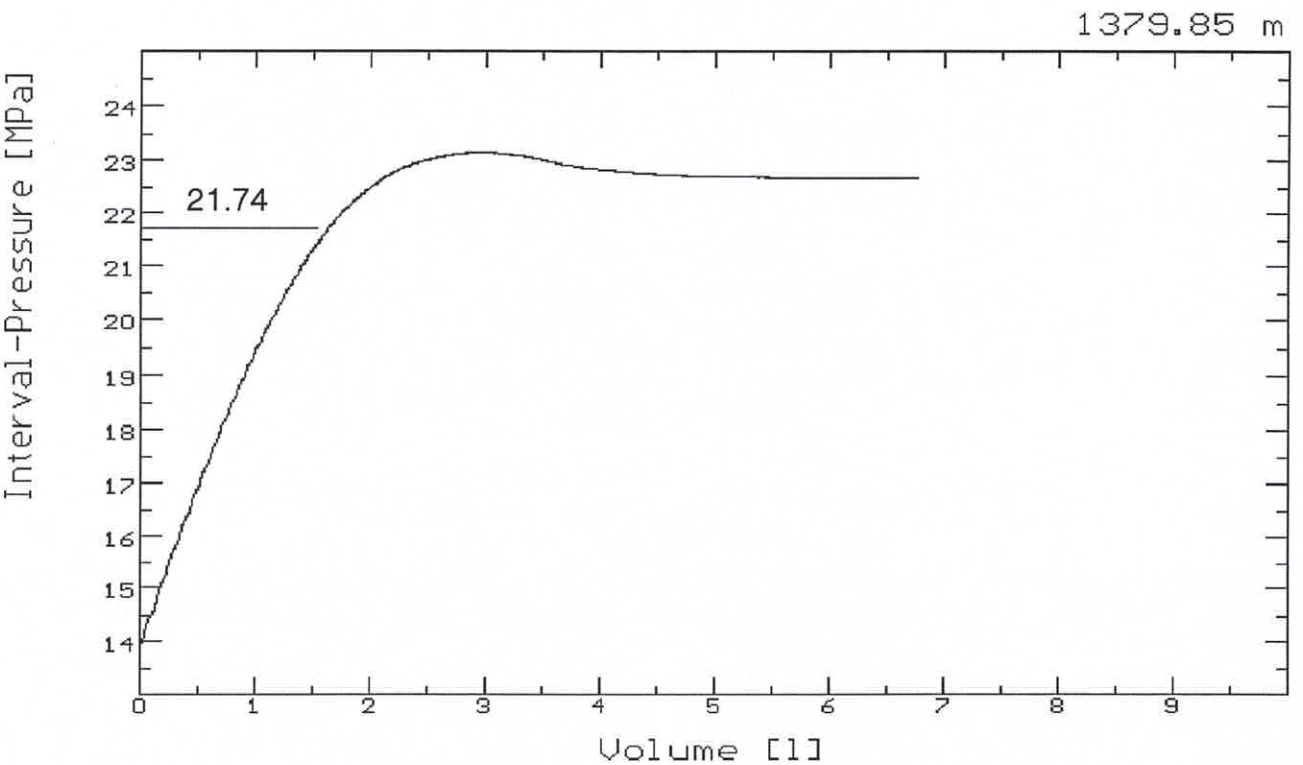
CASED - HOLE TEST 11 AT 1379.85 m





Estimation of P_r



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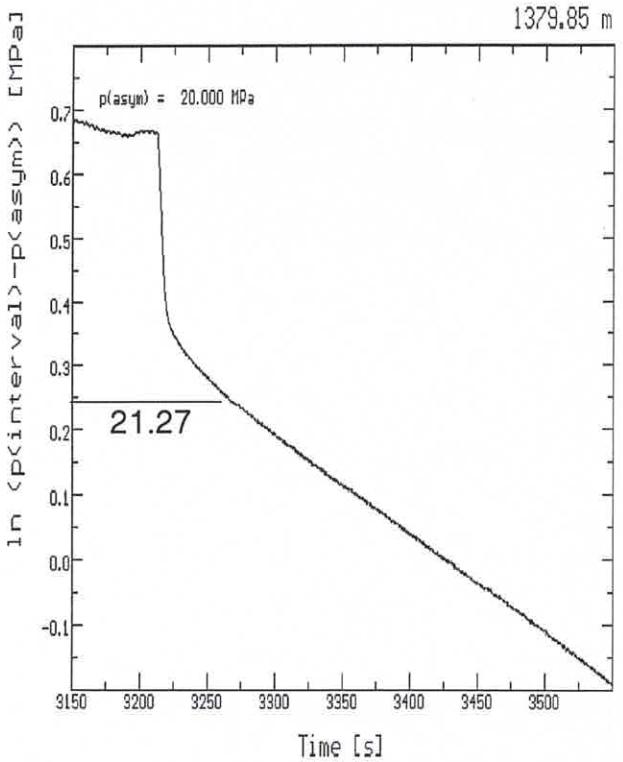
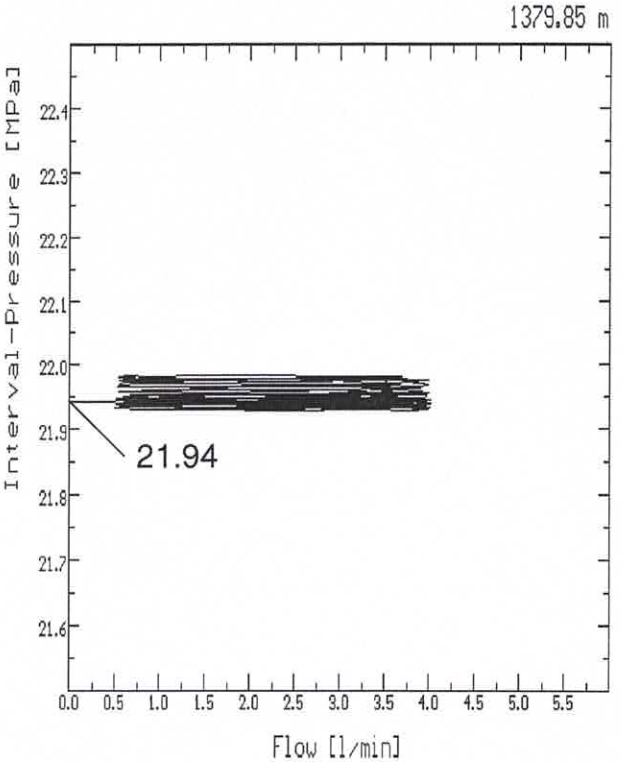
Estimation of $P_{si, min}$



Estimation of $P_{si, max}$



Estimation of P_{si}