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Äspö Hard Rock Laboratory

TRUE Block Scale project

Analysis of needs for re-instrumentation of boreholes KA2511A, KA2563A and KI0025F

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July 1999

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Abstract

This report summarises the history of instrumentation for three boreholes in the TRUE Block Scale array, KA2511A, KA2563A and KI0025F. Pressure responses resulting from activities like drilling and cross-hole interference tests are discussed in relation to the different instrumentation set-ups. Based on this analysis, suggestions for re-instrumentation of the boreholes are given focusing on future tracer experiments in a network of structures. Further, some results based on the decisions and measures taken based on the suggestions are reported.

Sammanfattning

Denna rapport sammanfattar instrumenteringsförloppet för tre borrhål i TRUE Block Scale-uppställningen, KA2511A, KA2563A och KI0025F. Tryckresponser från olika aktiviteter som borrning och interferenstester diskuteras i relation till de olika instrumentuppställningarna. Baserat på dessa analyser presenteras förslag för ominstrumentering av borrhålen med fokus på framtida spårämnesförsök i ett nätverk av strukturer. Vidare presenteras några resultat baserade på beslut och utförda åtgärder.

Executive Summary

Three boreholes, KI0025F, KI0025F02 and KI0023B, have been drilled from the I-tunnel at tunnel length L=3/510 m as a part of the TRUE Block Scale Preliminary and Detailed Characterisation Stage (PCS & DCS). These boreholes complement the existing boreholes, KA2511A, KA3510A and KA2563A, the latter drilled as a pilot borehole as part of the TRUE Block Scale Scoping Stage. The boreholes have been characterised using different geological, geophysical and hydrogeological methods and are instrumented with multi-packer systems.

The multi-packer systems have been optimised to enable pressure monitoring and tracer injection/sampling in geological structures in the selected portion of the TRUE Block Scale target rock block. The older boreholes KA2511A and KA2563A have so far been re-instrumented three and two times, respectively, during the project. The investigations in the three 76-mm boreholes have contributed a substantial data set of the connectivity and orientation of structures in the target block.

The main objective of this study was to analyse the need for re-instrumentation of boreholes KA2511A, KA2563A and KI0025F based on the new information obtained and the future focus on tracer experiments.

KA2511A

Based on the response pattern observed in KA2511A during seven different occasions the following conclusion can be drawn:

- The pressure responses along the entire length of KA2511A have been observed at several different occasions and during all three packer arrays.
- The pressure responses along KA2511A occur only when structures #4, #5, and #7 are pumped.
- The tests performed within KA2511A shows that the packer system effectively seals the different sections from each other.

The proposal for re-instrumentation of KA2511A includes the same number of packers as the previous one (8) but no circulating sections or extra flow lines. Thus, the borehole may be considered purely as a pressure measurement borehole providing boundary conditions. It is also suggested that the tubing dimension generally is set to 4 mm inside diameter to at least enable water sampling over reasonable time frames.

Based on the recommendations the following activities were initiated in KA2511A:

- Detailed flow logging using the POSIVA tool
- Re-installation of the packer system according to the proposal presented in this report.

The POSIVA flow logging (Rouhiainen & Heikkinen, in prep.) performed in January 1999 did not show any new, undetected, structures in the borehole. The packer system was then re-installed according to the proposal.

KA2563A

The major concern about borehole KA2563A was the observations that the innermost section (R1) in KA2563A responds extremely well to pressure disturbances in structures #9, 13 and 20 in other boreholes. These responses are the far best in the entire borehole array. These extreme responses have raised questions regarding the status of the instrumentation in KA2563A.

Based on the results from the interference tests performed in spring 1998 (Andersson et al., 1998) it is clear that the current instrumentation of KA2563A is not optimised and focused on the target structures for the tracer tests (#9, #13, and #20). Furthermore, sections R2 and R3 are both very low transmissive and only respond to a few of the tests while the currently blind section between 229 and 261 m includes several conductive structures according to the detailed flow logging performed (Gentzschein, 1997a). Thus a re-instrumentation of KA2563A would give:

- Continued isolation of Structure #20 with continued possibility for tracer injection
- A better isolation of Structures #9 and #13, which makes it possible to use them for tracer injection if flow lines and dummies are installed.
- Possibility to monitor pressure in flowing structures in between #13 and #9 (229-261 m), at least three structures with a total flow of 11 l/min (presently contained in a blind section).

The fact that KA2563A is located much closer to the target area for the Block Scale Project makes it more important to optimise this borehole. It was also discovered that a large economical investment was needed for a reaming of the borehole as suggested in this report. In the end the following decision was taken:

- Perform a detailed flow logging with a double-packer system (5-m intervals) between 230-300 m borehole length.
- Perform a POSIVA flow logging in the interval 0-300 m borehole length. The test also included a second run performed during opening of borehole section KI0023B:P6. The latter to help identify Structure #9 in KA2563A.

The results of the detailed flow log in KA2563A showed a dual intercept associated with Structure #19 and no response that could be associated with the high-connectivity Structure #9. The results of the POSIVA flow logging (Rouhiainen & Heikkinen, in prep.) were also consistent with the results of the detailed flow logging. In addition, the tests during opening of KI0023B:P6 resulted in clear indications of flow connectivity to sections 188.3-190.3 m (Structure #20) and 206-208 m (Structure #13).

The POSIVA flow log in combination with the results from the detailed packer-logging indicated that a more focused instrumentation of the borehole was possible. This fact in combination with an improved design of the packer, made it possible to install a 9-packer system with three sections equipped for tracer injection/sampling. Given the fact that structure #9 potentially was an artefact, a more focused instrumentation was possible without reaming.

A complementary interference test was performed in KA2563A using a different methodology. In this test a 2.5-m long packer assembly was placed over the flowing structures (flow inhibition) while the rest of the borehole remained open. The results indicated:

- that structure #13 could be identified at 207 m,
- that the structures at 252m and 266 m are associated with structure #19,
- that the remaining candidate for structure #9 at 229 m still was uncertain

A final short-term interference test confirmed that the high-connectivity path was an artefact.

For borehole KI0025F no re-instrumentation was recommended. However, the updating of the structural model of the TRUE Block Scale rock volume in March 1999 (Hermanson, in prep.) included a new structure (#22) that was interpreted to intersect KI0025F beneath a packer at 88.8 m borehole length. Therefore a simple test was suggested by moving the entire packer string in three steps of 0.5 m inwards from the current position (Andersson in prep.).

This procedure should determine whether the intercept at 88.8 m (#22) is conductive or not, and possibly also the interaction with structure #20 at 87.7 m in the same borehole.

Contents

Appendix A: Andersson P, 1999: Flow logging KA2563A, January 21-22, 1999 - preliminary results. GEOSIGMA PM 99-01-22.

Appendix B: Andersson P, 1999: Comments and suggestions regarding instrumentation of KA2563A. GEOSIGMA PM 99-02-11.

Appendix C: Andersson P, 1999: Complementary flow logging in KA2563A – Preliminary results. GEOSIGMA PM 99-02-19.

Appendix D: Andersson P, 1999: Confirming pressure interference test in KA2563A. GEOSIGMA PM 99-03-05.

Appendix E: Andersson P, 1999: Optimisation of borehole installations in KI0025F and KI0025F02. GEOSIGMA PM 99-03-30.

1 Background

The Preliminary Characterisation Stage (PCS) of the TRUE Block Scale Project has been finalised. Three boreholes, KI0025F, KI0025F02 and KI0023B, have been drilled from the I-tunnel at tunnel length L=3/510 m. These boreholes, 76 mm in diameter, are gently inclined (I=20-25 degrees) and complement the existing boreholes, KA2511A, KA3510A and KA2563A, the latter drilled as a pilot borehole as part of the TRUE Block Scale Scoping Stage. The boreholes have been characterised using different geological, geophysical and hydrogeological methods and instrumented with multi-packer systems.

The multi-packer systems have been optimised to enable pressure monitoring and tracer injection/sampling in geological structures in the selected portion of the TRUE Block Scale rock block. The older 56 mm boreholes KA2511A and KA2563A have so far been re-instrumented three and two times, respectively, during the project. The investigations in the three 76-mm boreholes have contributed to a substantial data set of the hydraulic connectivity and orientation of the major structures in the target block. The new information has also implied that there is a need to analyse and further optimise the instrumentation of the boreholes in order to focus on the target features for the forthcoming tracer tests.

2 Objectives

The main objective of the study is to analyse the need for re-instrumentation of boreholes KA2511A, KA2563A and KI0025F based on the new information and future focus on tracer experiments, or more specifically:

- To check that the observed pressure response pattern in KA2511A is not an effect of the instrumentation.
- To suggest new packer positions in borehole KA2511A, if necessary.
- To investigate the need for reaming borehole KA2563A to 76 mm.
- To suggest new packer positions in KA2563A, if necessary.
- To suggest new packer positions in KI0025F, if necessary.

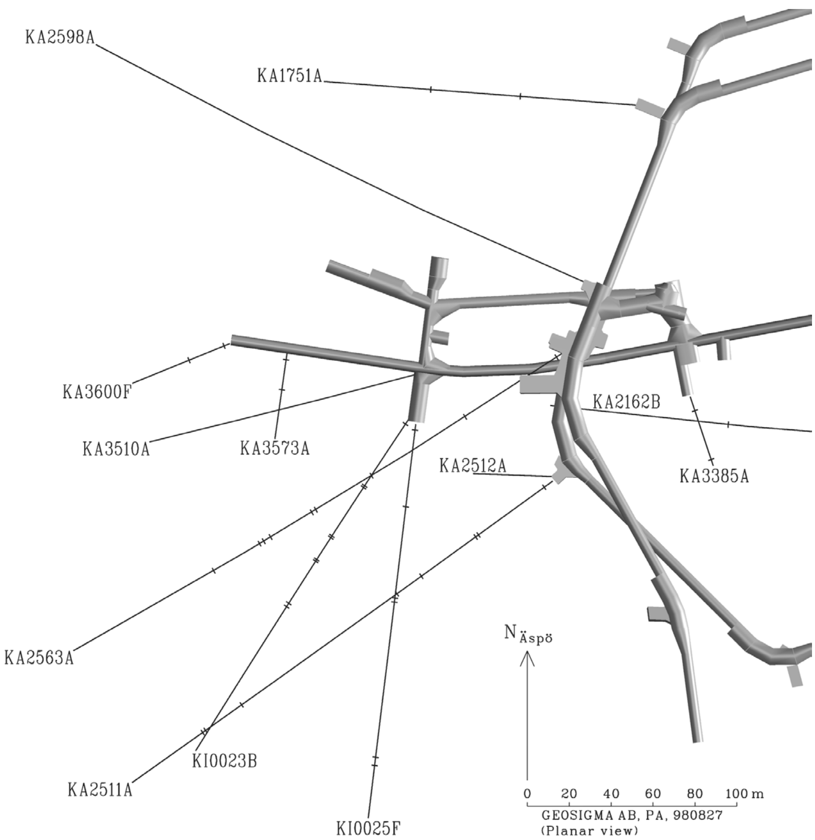

Figure 2-1. *Planar view of the TRUE Block Scale area including all boreholes used for pressure monitoring. The tics on the borehole projections represent packer positions.*

3 Borehole KA2511A

3.1 History of instrumentation

KA2511A is a 293-m long 56-mm borehole with a downward dip of 34 degrees. The borehole was drilled in 1993 within the drilling programme for localisation of experimental sites in the Äspö HRL. The borehole was instrumented with a 4-packer system in May 1994 and later re-instrumented with a 6-packer system in July 1997 and finally, with an 8-packer system in March 1998. The section limits for the three systems are given in Table 3-1.

Table 3-1. Section limits for the three multi-packer systems in borehole KA2511A. (P, R, S = pressure monitoring sections, B= blind sections, C=Circulation sections). Structures defined by Sep'98 Structural Model (Hermanson, 1998)

First instrumentation			Second instrumentation			Third instrumentation		
940504-970429			970716-980209			980219-		
Sec	Bh length (m)	Structure	Sec	Bh length (m)	Structure	Sec	Bh length (m)	Structure
P1	171-293	#19,10,11,18	R1	231-293	#10, 18, 11	B1	245-293	#11
P2	81-170	#6,16,20,17	R2	171-230	#19	S1	242-244	#18
P3	31-80	#7	R3	139-170	?	S2	217-241	#10
P4	6-30	#4	R4	92-138	#6,16,20,17	S3	110-216	#20,17,19
			R5	64-91	?	S4	92-109 (C)	#6, 16
			R6	6-63	#4, 7	B2	55-91	?
						S5	52-54	#7
						B3	6-51	#4

All three packer-systems were manufactured by GEOSIGMA. The system allows a maximum of 10 flow lines through each packer one of which is used for packer inflation/deflation. Therefore, in the third instrumentation, a number of blind sections had to be installed to allow one section (S4) to be equipped for tracer injection/sampling. An extra flow line was also installed in section S5 to allow simultaneous flow and pressure monitoring. Thus, all 10 lines were used in the third instrumentation.

3.2 Pressure responses in KA2511A at different occasions

During the evaluation process in the Preliminary Characterisation Stage it has been noted that the pressure responses in borehole KA2511A are different from other boreholes in the TRUE Block array. This pattern has been identified at several occasions:

3.2.1 Drilling of KA2563A (960811-960924)

During this period a 4-packer system was installed (Table 3-1). Figure 3-1 shows that all four sections respond very fast when major structures are intersected by KA2563A. This pressure response pattern shows up when penetrating structure #4, #5 and #7 according to the September 1998 structural model (Hermanson, 1998). However, close-ups of the response to structures #4, #5, and #7 (Figures 3-2 to 3-4), shows that the sections respond somewhat differently. Thus, it is clear that there exists a good connectivity between structures contained in all four sections of the borehole. Given the fact that the magnitudes of the responses are different, a direct communication through the equipment is unlikely.

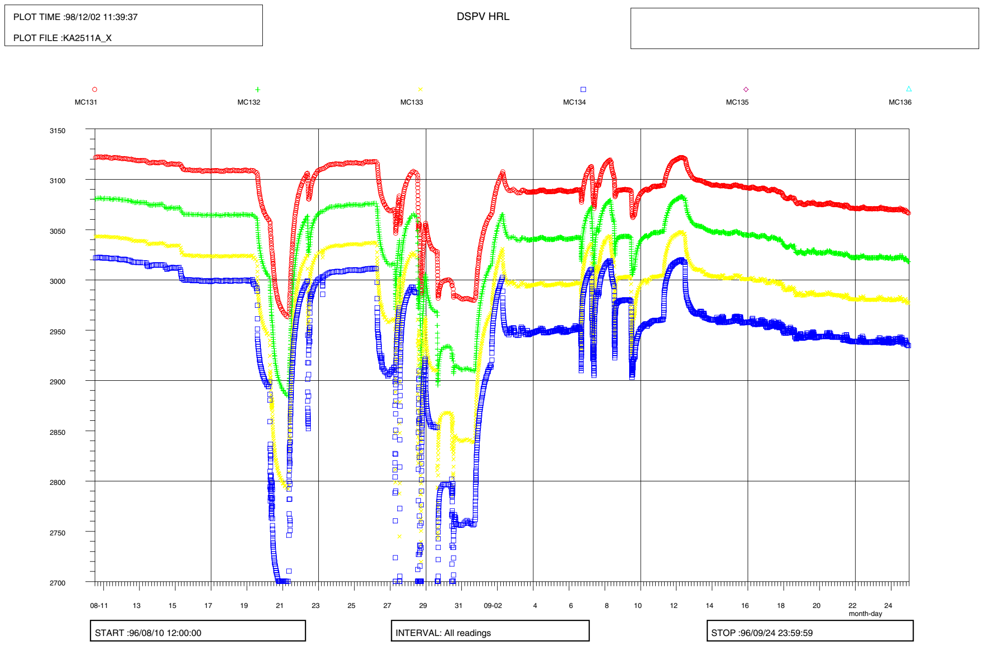

Figure 3-1. *Pressure responses in KA2511A resulting from drilling of KA2563A, August 10th to September 24th, 1996.*

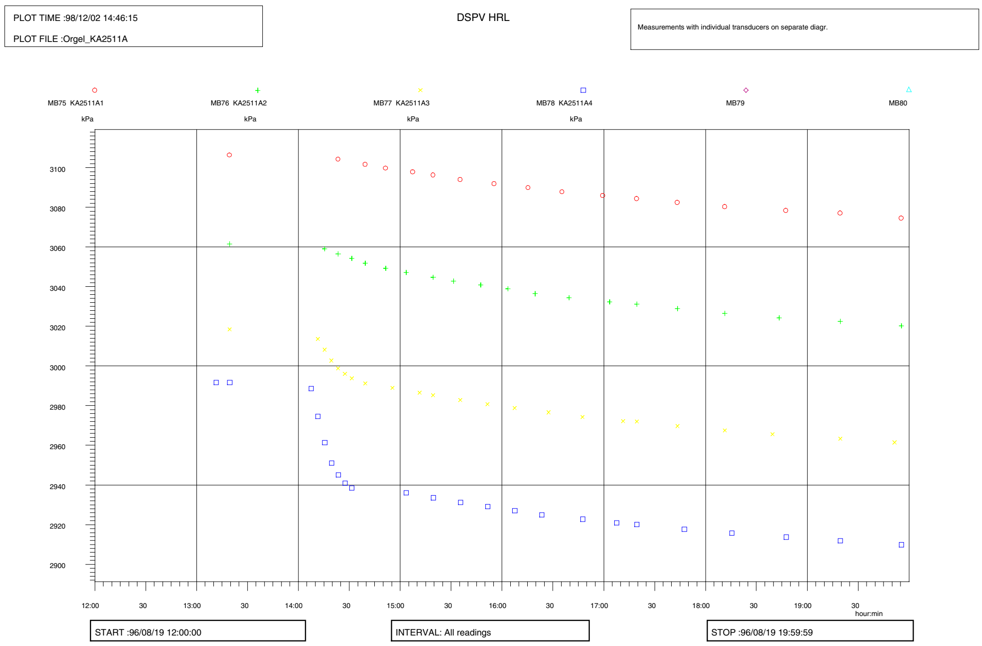

Figure 3-2. *Pressure responses in KA2511A resulting from penetration of Structure #4 during drilling of KA2563A on August 19th, 1996.*

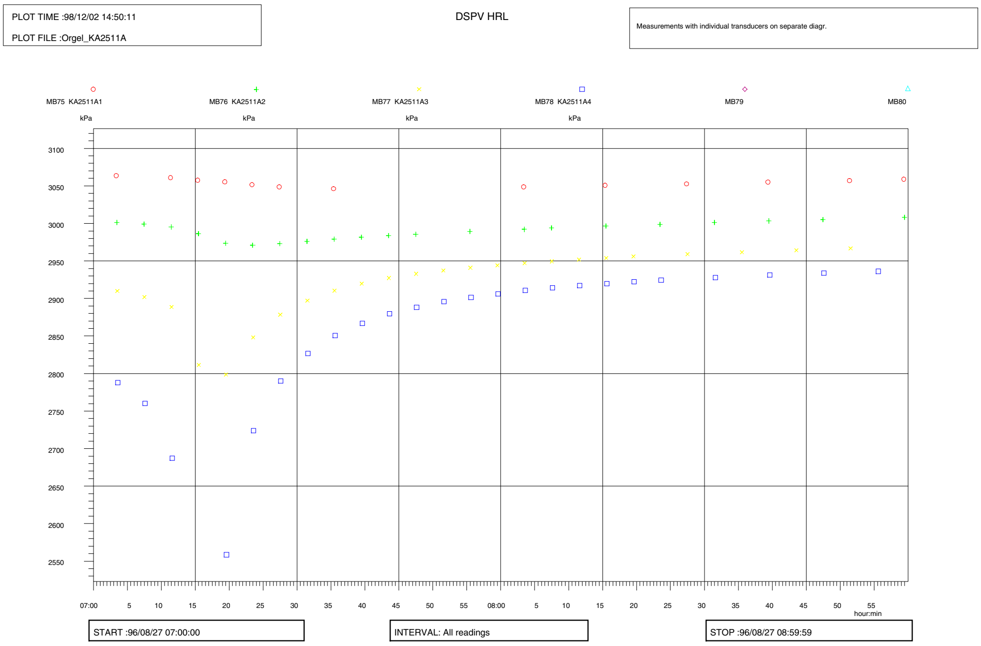

Figure 3-3. *Pressure responses in KA2511A resulting from penetration of Structure #5 during drilling of KA2563A on August 27th, 1996.*

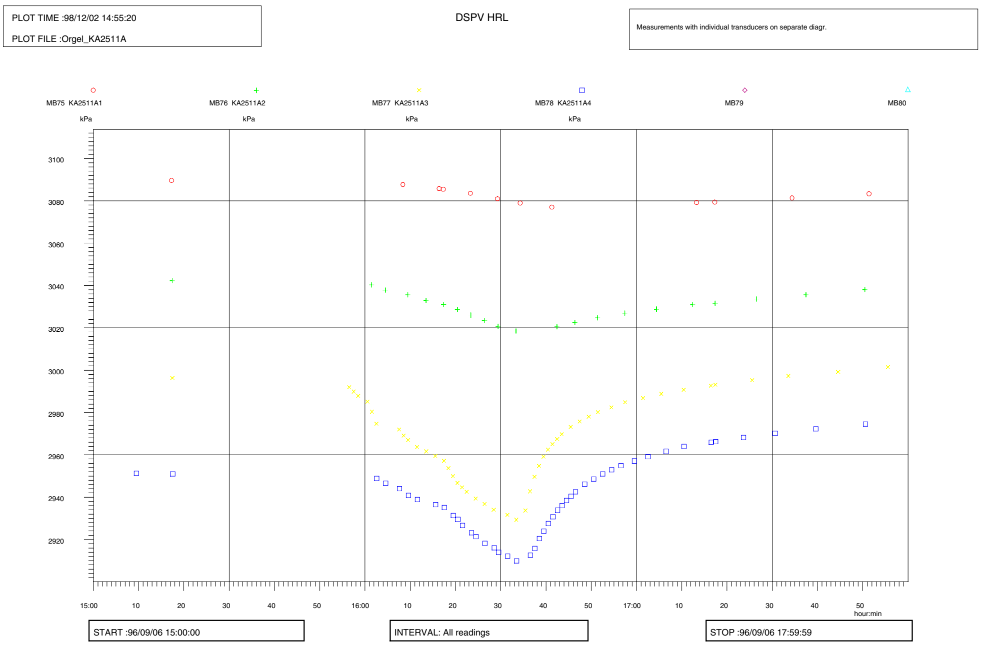

Figure 3-4. *Pressure responses in KA2511A resulting from penetration of Structure #7 during drilling of KA2563A on September 6th, 1996.*

3.2.2 Drilling of KI0025F (970408-970426)

The observed response pattern in KA2511A is very similar to the one described above when intersecting Structure #5. However, no responses were found when penetrating Structures #6 and #7. Also in this case the 4-packer system was installed. This is thoroughly described in Winberg (1997).

3.2.3 Drilling of KA3573A and KA3600F (970905-970924)

At this time a 6-packer system was installed in KA2511A, cf. Table 3-1. Boreholes KA3573A and KA3600F are interpreted to intersect Structure #5 and possibly also Structure #15 (Hermanson, 1998). The response pattern when penetrating these structures is very uniform. All six sections respond almost simultaneously but with different magnitude. Again, this is the same response pattern as with the previous packer system.

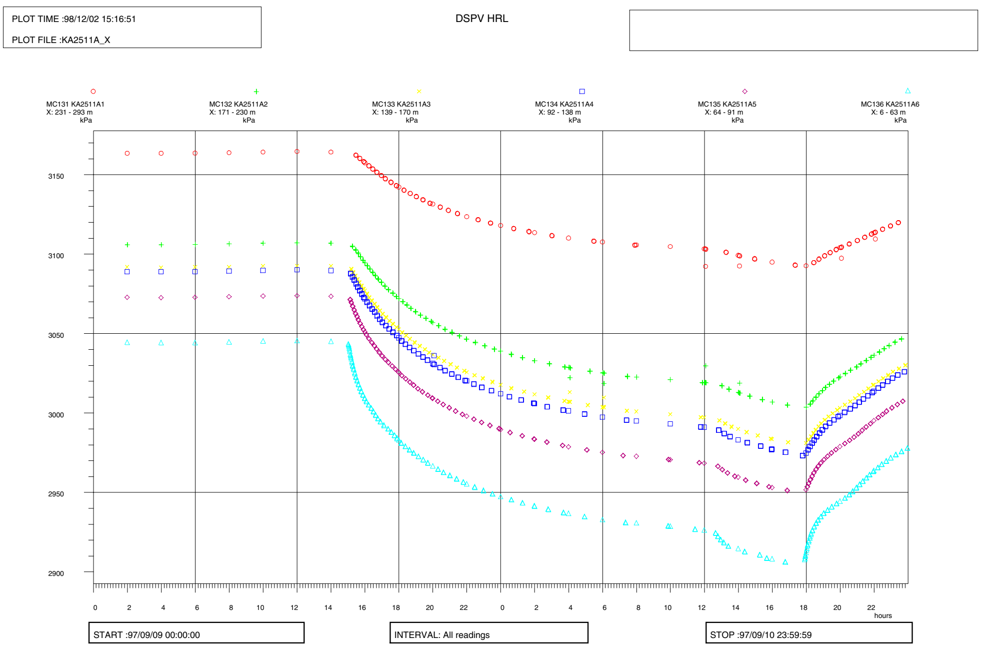

Figure 3-5. *Pressure responses in KA2511A resulting from penetration of Structures #5 (September 9th 15.00) and #15 (September 10th 12.00) during drilling of KA3573A, September 9th to 10th, 1997.*

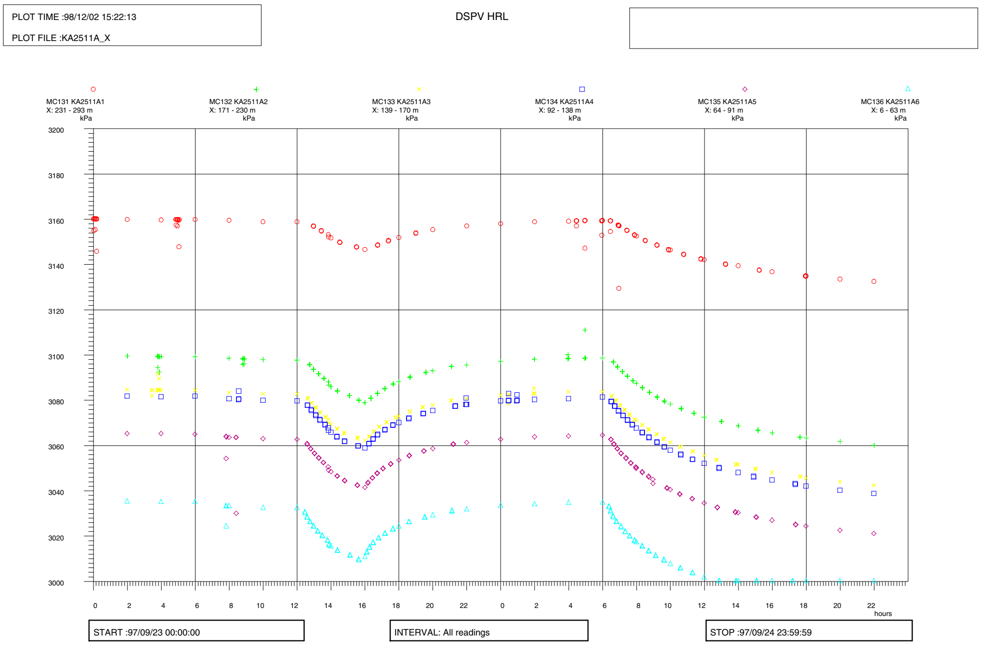

Figure 3-6. *Pressure responses in KA2511A resulting from penetration of Structure #5 during drilling of KA3600F, September 23rd to 24th, 1997.*

3.2.4 Drilling of KI0023B (971019-971120)

The intersection of Structure #5 on October 24th gives exactly the same response pattern (Figure 3-7) as described above. A closer look at the data shows that the time when different sections start to respond is quite spread out in time. In this case, section R6 responds immediately while the others are delayed some 8-40 minutes. The magnitude of the drawdown is also varying from about 60-160 kPa.

The response pattern is somewhat different when deeper zones of KI0023B are penetrated. Figure 3-8 shows the response in KA2511A when Structure #10 at 171 m in KI0023B is penetrated. In this case the response in the deepest sections are strongest.

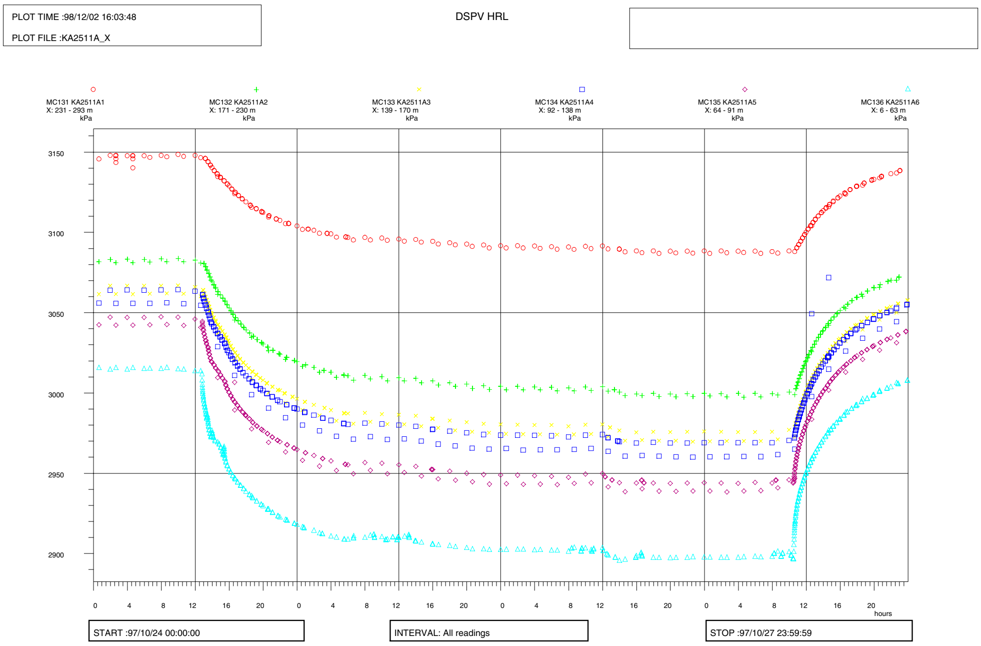

Figure 3-7. *Pressure responses in KA2511A resulting from penetration of Structure #5 during drilling of KI0023B, October 24th to 27th, 1997.*

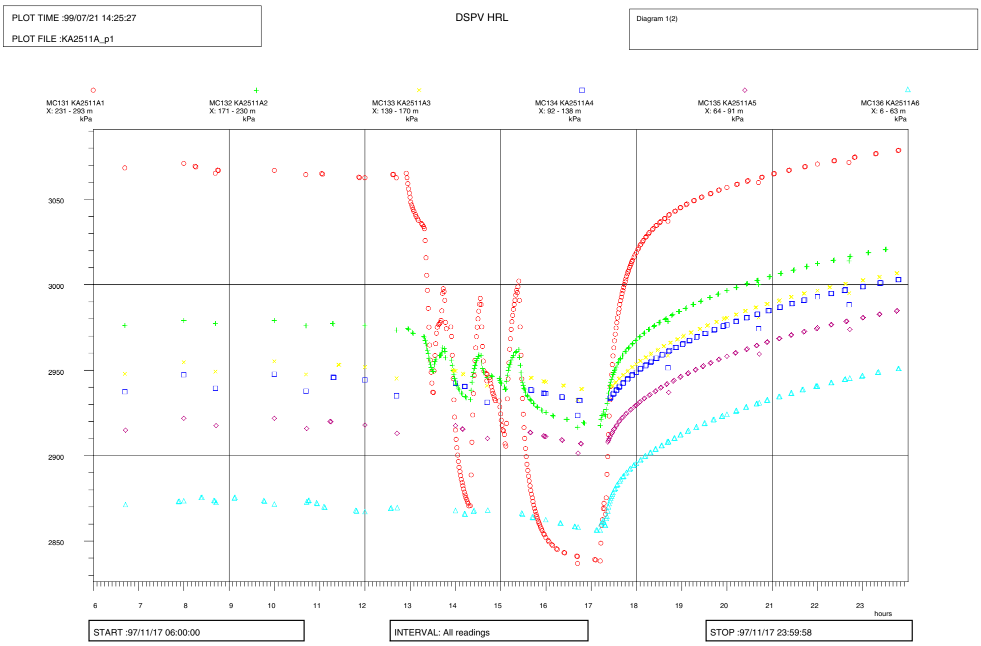

Figure 3-8. *Pressure responses in KA2511A resulting from penetration of Structure #10 during drilling of KI0023B, November 17th, 1997.*

3.2.5 Interference test ENW-2 (980311)

This test was performed immediately after installing the 8-packer system in the borehole, cf. Table 3-1. The test was performed by using section KA2511A:S5 as a sink. This section is interpreted to be intersected by Structure #7. Figure 3-8 shows the resulting drawdown in all five pressure monitored sections of the borehole. Sections S2-S4 do not respond much while section S1 does not respond at all, as it is almost non-flowing (cannot be seen in Figure 3-8). These results indicate that no direct contact between the sections occur as a result of some equipment failure or malfunction. Another indication of this is that the sections have significantly separated pressures although they have the same reference level.

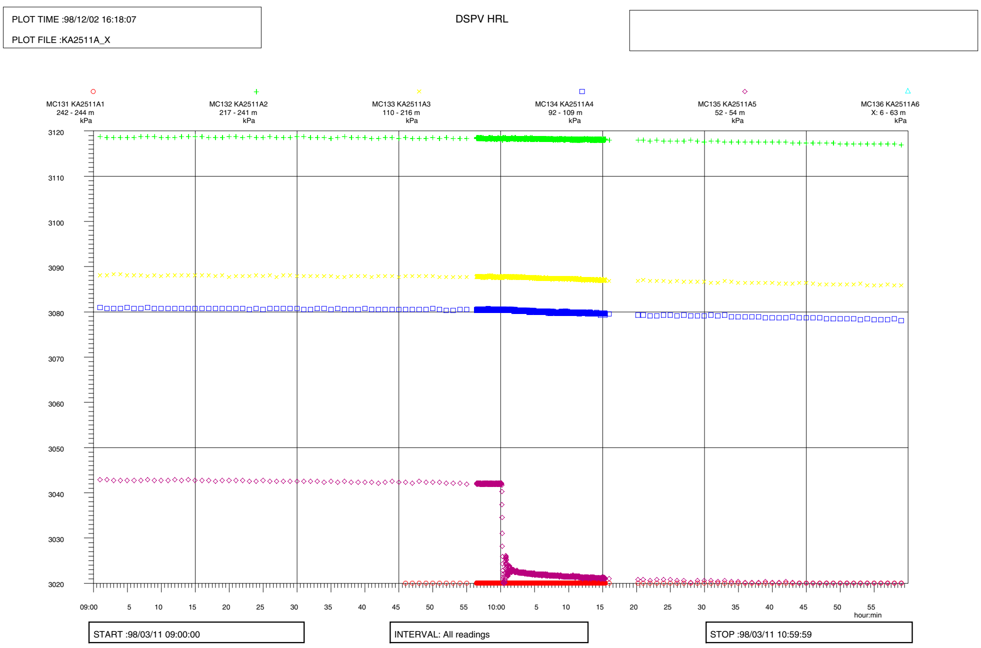

Figure 3-8. *Pressure responses in KA2511A resulting from interference test in Structure #7 (section S5), March 11th, 1998.*

3.2.6 Interference test #6 in KA2511A:S4 (980518)

In this case section S4, interpreted to be intersected by Structures #6 and #16, is used as sink with a significant drawdown of about 350 kPa (Figure 3-9). However, only very small responses are noted in sections S3 and S5 while section S2 does not respond at all. This also strengthens the conclusion that the sections are well isolated from each other within the borehole.

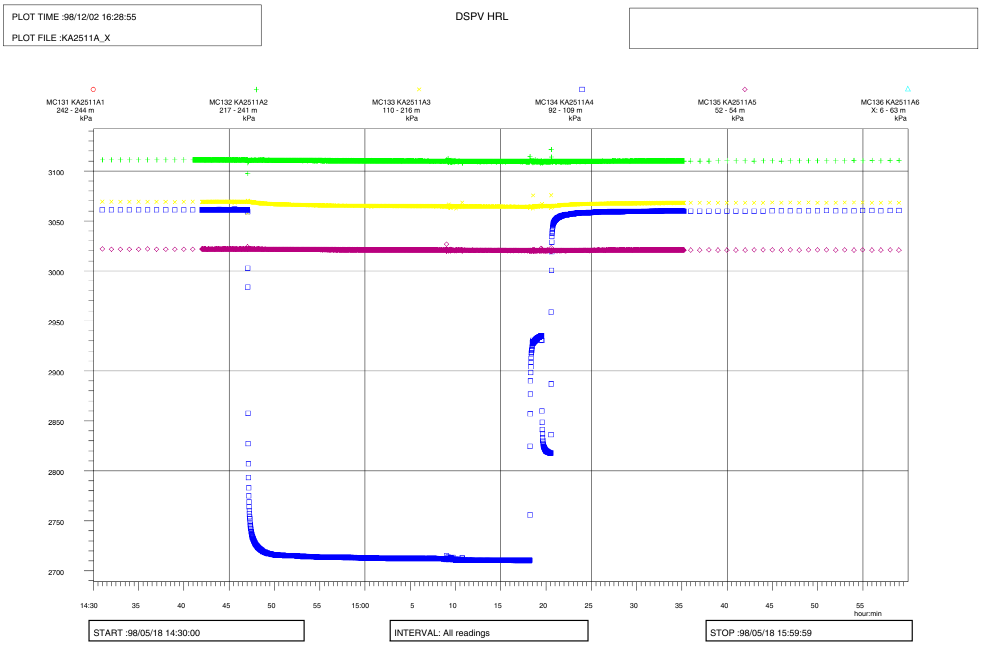

Figure 3-9. *Pressure responses in KA2511A resulting from interference test using section S4 as sink, May 18th, 1998.*

3.2.7 Packer installation in KA2511A (980217-980218)

At this occasion KA2511A was completely open to the atmosphere during 31.5 hours. Borehole KI0023B was instrumented as it is today while boreholes KA2563A and KI0025F had slightly different instrumentation compared to present. The responses from this activity (Table 3-2) are visible in all 22 sections in the three observation boreholes. Table 3-2 shows that the most significant responses, in terms of drawdown, are found in sections associated with structures #4, 5, 6, 7 and 10. These structures are also interpreted to intersect KA2511A. However, also structures #9, #13 and #20 respond, although significantly less.

3.3 Summary of observations and conclusions regarding the status of the instrumentation

Based on the response pattern observed during these seven occasions described above the following conclusion may be drawn:

- The pressure responses along the entire length of KA2511A have been observed at several different occasions and with all three-packer systems.

- The pressure responses along KA2511A occur only when structures #4, #5, and #7 are pumped.

- The tests performed within KA2511A shows that the packer system effectively seal and separate the different sections from each other.

The opening of KA2511A for re-instrumentation shows a similar “global” response pattern in the TRUE Block Scale array. In fact, all 22 sections in KA2563A, KI0025F, and KI0023B respond, including the target structures (#6, #9, #13, and #20) for the planned tracer tests.

One possible explanation for the observed response pattern in KA2511A may be that structures in the upper and lower parts of the borehole intersect not far from KA2511A. This explanation is also supported by the radar measurements in the borehole (Carlsten, 1993) where a pattern of intersecting structures was found east of the borehole (Figure 3-10). Some of these radar reflectors are interpreted as lithological contacts with fine-grained granite that may act as local connectors between structures.

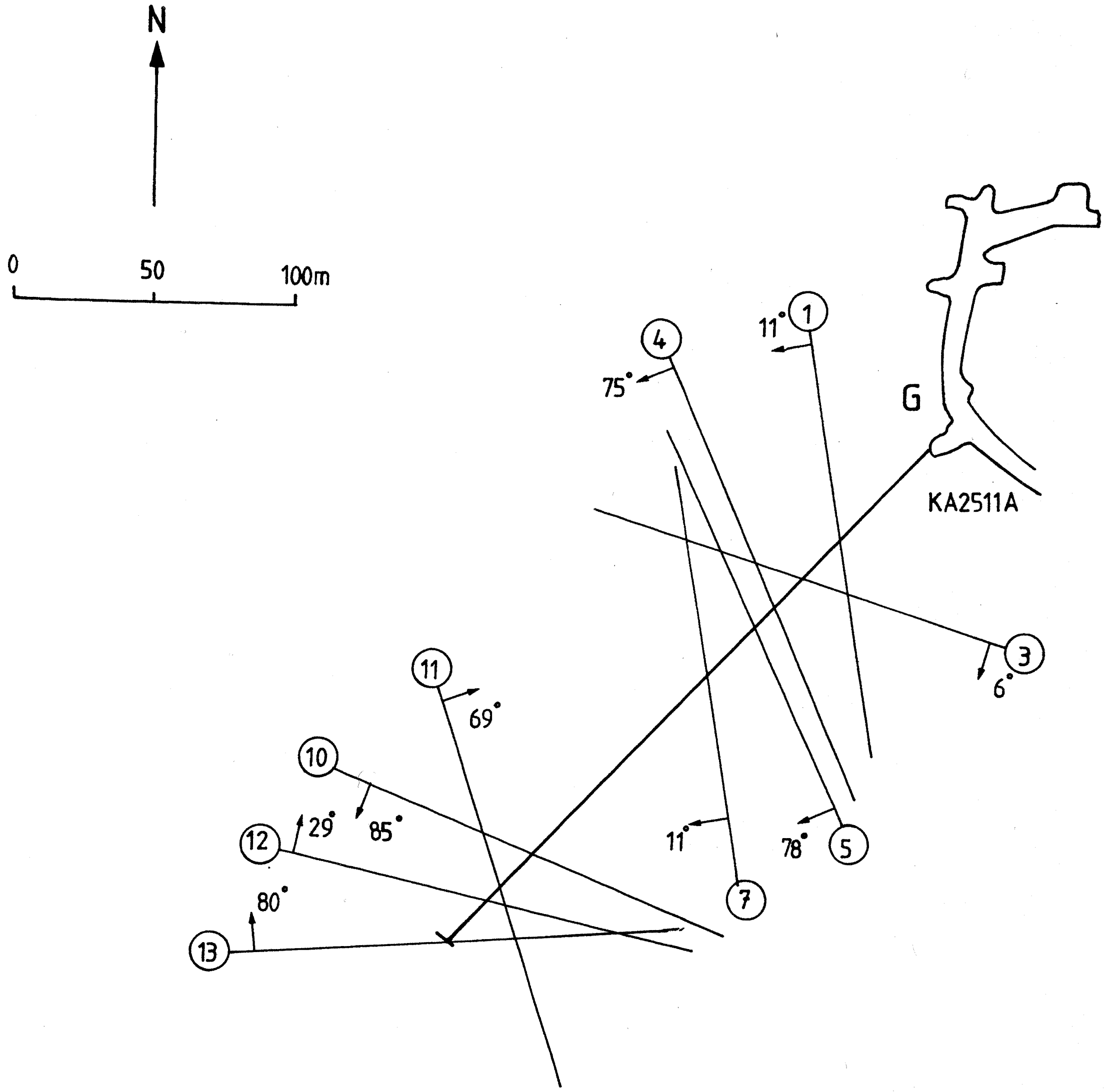

Figure 3-10. Plan map at –335 m level showing borehole KA2511A and intersection points of radar interpreted reflectors with magnitude 1. From Carlsten, (1993).

3.4 Proposal for re-instrumentation of KA2511A

The current instrumentation of KA2511A is not optimised in terms of separating structures hydraulically and covering the entire length of the borehole. The focus with the current instrumentation was to cover the sub-horizontal structures, (#16, #17, #18) which have turned out to be of minor importance for the connectivity within the TRUE Block Scale rock volume. One of the sections (S1) also turned out to be very low transmissive and could not be used for water sampling or reliable pressure measurements. Furthermore, section S5 (Structure #7) was instrumented for tracer dilution tests but no significant changes of the flow rate has been found during any of the performed interference tests (Andersson et al., 1998). Based on these arguments, and also the fact that KA2511A is located in the periphery of the target area for the planned tracer tests, a re-instrumentation of the borehole is suggested with a focus on separating as many structures as possible and neglecting possibilities for flow measurements. This strategy would make it possible to isolate and measure (pressure) up to nine sections.

The proposal for re-instrumentation (Table 3-2) includes the same number of packers as the previous installation (N=8) but no circulating sections or extra flow lines. Thus, the borehole may be considered as a pure pressure measurement borehole providing boundary conditions. It is also suggested that the tubing dimension should generally be set to 4 mm inside diameter to at least enable water sampling over reasonable time frames. It should be noted that this is a preliminary proposal, the final decision should be taken after performing a detailed flow log (POSIVA) of the entire borehole.

Table 3-2. Proposal for re-instrumentation of borehole KA2511A

Current instrumentation			New instrumentation		
Section	Bh length (m)	Structure	Section	Bh length (m)	Structure
B1	245-293	#11	T1	239-293	#10, 11, 18
S1	242-244	#18	T2	171-238	#19, ?*
S2	217-241	#10	T3	139-170	**?
S3	110-216	#17,20,19	T4	111-138	#17, 20
S4	92-109 (C)	#6, #16	T5	103-110	#16
B2	55-91	?	T6	96-102	#6
S5	52-54	#7	T7	65-95	***?
B3	6-51	#4	T8	6-64	#4, 7

* Several parallel fractures at 220-238 m, flow ≈ 25 l/min
** Flowing NE-structure at 143 m, flow ≈ 4 l/min
*** Flowing structure at 80-85 m, flow ≈ 2 l/min

3.5 Decisions and measures taken for optimisation of borehole KA2511A

A final decision was taken regarding optimisation of KA2511A based on the recommendations in Chapter 3.4 and comments from other members of the TRUE Block Scale Technical Committee. The following activities were initiated:

- Detailed flow logging using the POSIVA tool
- Re-installation of the packer system according to the proposal in Table 3.2.

The POSIVA logging (Rouhiainen & Heikkinen, in prep.) performed in January 1999 did not show any new, undetected, structures in the borehole.

The packer system was re-installed according to the proposal in Table 3-2 on February 18th, 1999.

4 Borehole KA2563A

4.1 History of instrumentation

KA2563A is a 362-m long 56-mm diameter borehole with a downward dip of 42 degrees. The borehole was drilled in 1996 as a part of the drilling programme for Scoping Stage characterisation of the TRUE Block Scale site. The borehole was instrumented with a 7-packer system in November 1996 and later re-instrumented with a 9-packer system in February 1998. The section limits for the three configurations are given in Table 4-1.

Table 4-1. Section limits for the two multi-packer systems in borehole KA2563A. (P, R = pressure monitoring sections, B= blind sections, C=Circulation sections). Structures defined by Sep'98 Structural Model (Hermanson, 1998)

First instrumentation			Second instrumentation		
961120-980220			980225-		
Section	Bh length (m)	Structure	Section	Bh length (m)	Structure
P1	266-362	#10	R1	262-362	#9, 10
P2	197-265	#13, 19, 8	B1	229-261	#8
P3	187-196	#20, 18	R2	225-228	#19
P4	146-186	#6, 7	R3	220-224	?
P5	113-145	?	R4	191-219	#13
P6	76-112	#4, 5, 17	R5	187-190 C	#20
P7	6-75	#1, 16	R6	146-186	#6, 7
			R7	76-145	#4, 5, 17
			B2	6-75	#1, 16

Both packer systems were manufactured by GEOSIGMA. The system allows a maximum of 10 tubes through each packer one of which is used for packer inflation/deflation. Therefore, in the second instrumentation, two blind sections had to be installed to allow one section (R5) to be equipped for tracer injection/sampling. Thus, all 10 lead-throughs were used in the second instrumentation.

4.2 Observations and conclusions regarding the status of the instrumentation

In the evaluation process of pressure responses during drilling and interference tests it has been observed that the innermost section (R1) in KA2563A responds extremely well to pressure disturbances in Structures #9, 13 and 20 in other boreholes. These responses are the far best in the entire borehole array. The same response pattern can also be seen when Structure #20 is used as a sink in the same borehole (section R5), while the sections in between (R2 and R3) do not respond at all. These extreme responses have raised concerns regarding the status of the instrumentation in KA2563A. However, there are also two facts indicating that the instrumentation is functioning and correctly installed:

1. The structural model in fact includes an almost EW structure (#9) that is interpreted to intersect KA2563A at 265 m borehole length. However, it should be noted that this structure still is hypotetical.

2. The pressure is highest in section R1 (farthest away from the tunnel) (Figure 4-1). A wrongly connected pressure line would possibly show up as an anomaly in the pressure distribution along the borehole.

These two facts do not rule out the possibility that there is something wrong with the instrumentation. The proposed re-instrumentation (cf. Chapter 4.3) will probably verify if this suggested high-connectivity path exists or not.

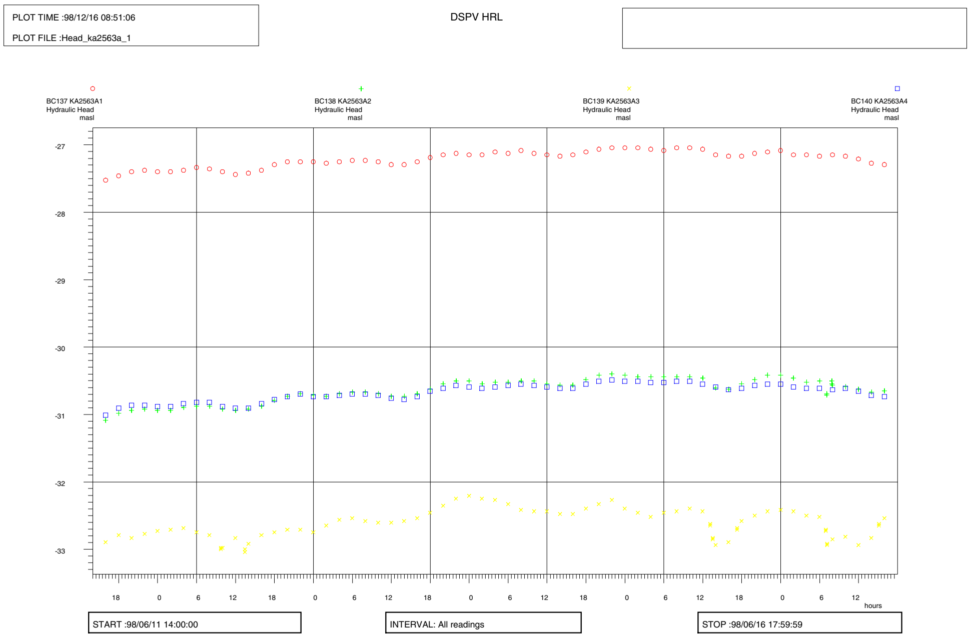

Figure 4-1. *Hydraulic head distribution in KA2563A, sections R1-R4, under undisturbed conditions, June 11th to 16th, 1998.*

4.3 Proposal for re-instrumentation of KA2563A

Based on the results from the interference tests performed in Spring 1998 (Andersson et al., 1998) it is clear that the current instrumentation of KA2563A is not optimised and focused on the target structures for the planned tracer tests (#9, #13, and #20). Furthermore, sections R2 and R3 are both very low transmissive and only respond to a few of the tests while the currently blind section between 229 and 261 m is known to include several conductive structures according to the detailed flow logging performed (Gentzschein, 1997a). Thus a re-instrumentation of KA2563A would provide:

- Continued isolation of Structure #20 with continued possibility for tracer injection

- A better isolation of Structures #9 and #13, which makes it possible to use them for tracer injection if flow lines and dummies are installed.

- Possibility to monitor pressure in flowing structures in between Structures #13 and #9 (229-261 m), at least three structures with a total flow of 11 l/min (presently contained in a blind section).

The maximum number of available flow and pressure monitoring lines is 9 in the currently installed configuration. Each structure that is equipped for tracer injection requires three lines. Thus, with the current system, no other sections than the three target structures may be monitored for pressure. A re-instrumentation focusing on the target structures for tracer tests requires that the borehole is reamed from 56 mm to 76 mm. Then a maximum of 16 lines, including the packer inflation line, (with the GEOSIGMA packer system) will be available for flow and pressure measurements. A proposal including 11 packers, 9 pressure monitoring sections and 3 sections for tracer injection/sampling is presented in Table 4-2. Sections marked with C are equipped with two flow lines for tracer injection/sampling and dummies to reduce the volume.

Given the focusing of the project towards tracer tests, it is recommended that the borehole is reamed to 76 mm down to about 275 m borehole length. If reaming is rejected based on e.g. economical reasons, it is recommended that the current instrumentation is kept as it is. The possibility to inject/sample tracers with the current set of packers will then be limited to section R5 which is equipped with extra flow lines and dummies.

Table 4-2. Proposal for re-instrumentation of KA2563A. The proposal requires that the borehole is reamed to 76 mm down to L=275 m.

Old instrumentation 980225-			New instrumentation		
Section	Bh length (m)	Structure	Section	Bh length (m)	Structure
R1	262-362	#9, 10	B1	268-362	#10?
B1	229-261	#8	S1	263-267 C	#9
R2	225-228	#19	S2	242-262	#8, ?*
R3	220-224	?	S3	229-241	?**
R4	191-219	#13	S4	210-228	#19
R5	187-190 C***	#20	S5	205-209 C	#13
R6	146-186	#6, 7	B2	191-204	#18?
R7	76-145	#4, 5, 17	S6	187-190 C	#20
B2	6-75	#1,2,3,16	S7	146-186	#6, 7
			S8	76-145	#4, 5, 17
			S9	6-75	#1,2,3,16

* Flowing structures at 245-255 m, flow ≈ 8 l/min
** Flowing structures at 230-240 m, flow ≈ 3 l/min
*** Presently dummy material exists in section R5

4.4 Decisions and measures taken for optimisation of borehole KA2563A

The fact that KA2563A is located much closer to the target area for the Block Scale Project makes it more important to optimise this borehole. It was also discovered that a large economical investment was needed for a reaming of the borehole, as suggested in Chapter 4.3. The recommendations in Chapter 4.3 were therefore thoroughly debated and discussed within the TRUE Block Scale Technical Committee. In the end the following decision was taken:

- Perform a detailed flow logging with a double-packer system (5-m intervals) between 230-300 m borehole length (cf. Appendix A).

- Perform a POSIVA flow logging in the interval 0-300 m borehole length. The test also included a second run performed during opening of borehole section KI0023B:P6.

The detailed flow logging performed January 21-22nd , 1999, also included analyses of pressure responses from each of the measured intervals. The results (Appendix A) showed a dual intercept associated with Structure #19 and no response that could be associated with the high-connectivity Structure #9.

The results of the POSIVA flow logging (Rouhiainen & Heikkinen, in prep.) were also consistent with the results of the detailed flow logging. In addition, the tests during opening of KI0023B:P6 resulted in clear indications of flow connectivity to sections 188.3-190.3 m (Structure #20) and 206-208 m (Structure #13).

The POSIVA flow log in combination with the results from the detailed packer-logging indicated that a more focused instrumentation of the borehole was possible. This fact in combination with a further development of the packer design which enabled two extra flow lines through the 56-mm packers (totally 12), made it possible to install a 9-packer system with three sections equipped for tracer injection/sampling. Given the fact that Structure #9 potentially was found to be an artefact, a more focused instrumentation was possible without reaming.

A proposal for instrumentation without reaming was put forward (Appendix B) but before taking the final decision the uncertainty of Structure #9 and #13 was still to be revealed. A complementary interference test was performed in KA2563A using a different methodology. In this test a 2.5-m long packer assembly was placed over the flowing structures (flow inhibition) while the rest of the borehole remained open (cf. Appendix C) and the flow measured and pressure responses noted. This test was done on totally 6 structures in the interval 188-267.5 m. The results presented in Appendix C indicated:

- that Structure #13 could be identified at 207 m,

- that the Structures at 252m and 266 m are associated with structure #19,

- that the remaining candidate for Structure #9 at 229 m still was uncertain

In order to get a final answer to the existence and location of the high-connectivity path between the lower part of the borehole and structure #20 at 189 m a short-term interference test was performed (Appendix D). The results of the test confirmed earlier indications that the structures at 265 and 230 m not are connected to Structure #20 and thus, that the high-connectivity path is an artefact. The test also resulted in a final proposal for re-instrumentation (Table 4-3).

The borehole was instrumented according to this proposal on February 25th, 1999.

Table 4-3. Proposal for re-instrumentation of KA2563A (C=Circulation section, B=Blind section, S=Pressure monitoring section). Structures defined by Sep'98 Structural Model (Hermanson, 1998). No reaming to 76 mm required.

Old proposal (990211)			**New proposal**		
Section	Bh length (m)	Structure	Section	Bh length (m)	Structure
B1	255-362	#10?	B1	247-362	#10?
S1	233-254	#19	S1	242-246 **C**	#19
S2	228-232 **C**	#9	S2	236-245	#19?
B2	209-227	?	B2	209-235	#?
S3	206-208 **C**	#13	S3	206-208 **C**	#13
B3	191-205	?	B3	191-205	?
S4	187-190 **C**	#20	S4	187-190 **C**	#20
S5	146-186	#6, 7	S5	146-186	#6, 7
B4	6-145	#1,2,3,4,5 ,16, 17	B4	6-145	#1,2,3,4, 5, 16,17

5 Borehole KI0025F

5.1 History of instrumentation

KI0025F is a 194-m long 76-mm borehole with a downward dip of 20 degrees. The borehole was drilled in April 1997 as a part of the drilling programme for the Preliminary Characterisation Stage. The borehole was instrumented with a 7-packer system in July 1997 and later re-instrumented with a 7-packer system in February 1998. **The section limits for the two systems are given in Table 5-1.**

Table 5-1. Section limits for the two multi-packer systems in borehole KI0025F. (P, R = pressure monitoring sections, B= blind sections, C=Circulation sections). Structures defined by Sep'98 Structural Model (Hermanson, 1998)

First instrumentation			Second instrumentation		
970710-980226			980304-		
Section	Bh length (m)	Structure	Section	Bh length (m)	Structure
P1	169-194	#Z	R1	169-194	#Z
P2	158-168	#19	R2	164-168 C	#19
P3	152-157	?	R3	89-163	?
B1	89-151	?	R4	86-88 C	#20
P4	86-88	#20	R5	41-85	#6, 7
P5	41-85	#6, 7	R6	3.5-40	#5
P6	3.5-40	#5			

Both packer systems were manufactured by GEOSIGMA. The system allows a maximum of 16 tubes through each packer one of which is used for packer inflation/deflation. Two sections (R2 and R4) were equipped with extra tubes for tracer injection/sampling. Thus, a total of 10 lead-throughs were used in the second instrumentation.

5.2 Observations and conclusions regarding the status of the instrumentation

The current instrumentation of KI0025F seems to work well. There are only a few water- conducting structures identified in the borehole and all of them are isolated from each other with the exception of structures #6 and #7. However, according to the detailed flow log (Gentzschein, 1997b) there is almost no flow into the borehole at the interpreted intersection with structure #7. The lack of interpreted intercepts with Structures #9 and #13 has raised the question whether these structures have disappeared before reaching KI0025F or if they are represented in yet undefined water conducting structures in the borehole.

The detailed flow log in KI0025F (Gentzschein, 1997b), covering the borehole length 42-167 m, only show one 5-m section having higher flow rate than 3 ml/min, namely section 152-157 m (125 ml/min). This section was isolated in the first instrumentation (see Table 5-1) and an analysis of the pressure responses from drilling of KI0023B shows that this section (P3) responds exactly as section P2 (Figure 5-1). Therefore, it is likely that the structure at 152-157 m is associated with Structure #19.

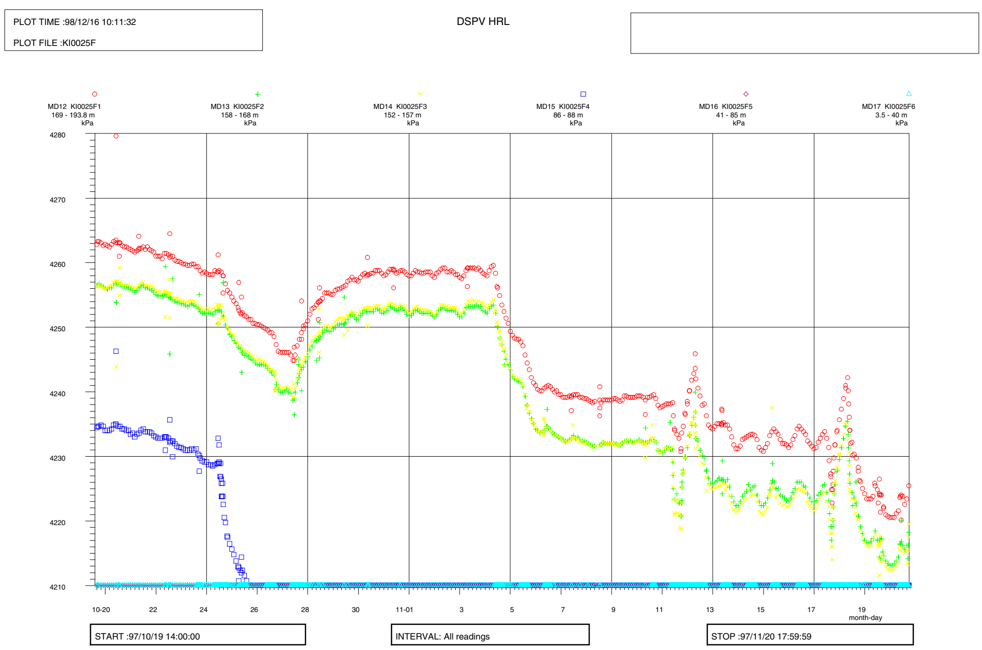

Figure 5-1. *Pressure responses in KI0025F (sections R1-R4) during drilling of KI0023B October 19th to November 20th, 1997.*

The focus of the TRUE Block Scale Project towards tracer tests in a network of structures requires that several sections for tracer injection and/or sampling exists. The current instrumentation of the borehole seem to cover all structures well but there is only one injection/sampling point for tracers associated with the target structures (#6, 9, 13 and 20). However, the performed interference tests (Andersson et al., 1998) do not show any measurable responses in Structure #6 when Structures #9, 13 or 20 are used as sinks. Therefore, no re-instrumentation is proposed for this borehole.

5.3 Decisions and measures taken for optimisation of borehole KI0025F

The updating of the structural model of the TRUE Block Scale rock volume in March 1999 (Hermanson, in prep.) included a new structure (#22) that was interpreted to intersect KI0025F at 88.8 m borehole length. A new check of existing data of flowing structures was therefore made (cf. Appendix E). It was concluded that this structure potentially may be water conducting but it could not be separated from structure #20, located only about 1 metre away, in the available data set. Decisions were taken to:

- Keep the current instrumentation during the pre-tests for the tracer tests
- Do a simple test by moving the entire packer string in three steps of 0.5 m inwards from the current position.

This procedure should determine whether the intercept at 88.8 m (#22) is water conducting or not, and possibly also the interaction with structure #20 at 87.7 m in the borehole.

6 Boreholes KI0023B and KI0025F02

Both these boreholes are instrumented with multi-packer systems manufactured by SOLEXPERTS. This report will not go into any detail about the instrumentation of these two boreholes but a technical description of the system is given by Adams (1998a). Both boreholes have only been instrumented once.

6.1 Borehole KI0023B

Due to an equipment failure in KI0023B it is not possible to move the equipment without substantial risk of loosing the equipment or destroying the borehole. Andersson et al (in prep.) discuss possible short-circuit effects within the borehole due to an unfavourable packer positioning.

6.2 Borehole KI0025F02

The current positioning of the multi-packer system in KI0025F02 is given by Adams (1998b). The instrumentation has earlier been reviewed (cf. Appendix E) and found to be satisfactory. The only possible improvement would be the separation of structures #13 and #21 that currently are located in the same section at 93.9 and 97.9 m, respectively. However, the intercept at 93.9 m (#13) has a low transmissivity (about $4 \cdot 10^{-9}$ m^2/s), probably would be too low to allow transport over the distances involved (20-50 m). The intercept at 97.9 m (#21) has a transmissivity that is about one order of magnitude higher. Based on these arguments it was recommended to keep the instrumentation as it is.

7 REFERENCES

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APPENDICES

Appendix A: Andersson P, 1999: Flow logging KA2563A, January 21-22, 1999 - preliminary results. GEOSIGMA PM 99-01-22.

Appendix B: Andersson P, 1999: Comments and suggestions regarding instrumentation of KA2563A. GEOSIGMA PM 99-02-11.

Appendix C: Andersson P, 1999: Complementary flow logging in KA2563A – Preliminary results. GEOSIGMA PM 99-02-19.

Appendix D: Andersson P, 1999: Confirming pressure interference test in KA2563A. GEOSIGMA PM 99-03-05.

Appendix E: Andersson P, 1999: Optimisation of borehole installations in KI0025F and KI0025F02. GEOSIGMA PM 99-03-30.

Peter Andersson
PM 99-01-22

FLOW LOGGING KA2563A, JANUARY 21-22, 1999 - PRELIMINARY RESULTS

Introduction

This PM presents preliminary results from flow logging in 11 borehole sections, each of 5 m length, within the interval 230-300 m with double packer technique in borehole KA2563A.

The objectives of the flow logging was to:

- Get an update of the flow conditions within the interval 230-300 m (flow logging has been performed also earlier in this borehole down to 280 m depth)

- Obtain extended knowledge of the hydraulic connections between borehole KA2563A and a number of other boreholes within the True Block Scale rock volume.

Performance

The flow logging was performed as an interference test, where pressure responses were observed in four sectioned boreholes (KI0023B, KI0025F, KI0025F02, KA3510A). Borehole KA2511A was not monitored due to an unintentional shut-down of the monitoring system.

The flow logging was performed using a rubber sealing cone at borehole collar to maintain ambient pressure in the borehole outside the test section. The flow logging test cycle was:

- initiation of one minute logging at the HMS-system
- start of data logger (one minute measurement interval is selected)
- packer inflation 15 min
- the "SEQ"-option of the logger is initiated (stepwise increasing intervals)
- opening of test section valve
- flow measurements 30 min; flow is measured during one minute at five occasions: at minutes 1, 5, 10, 20 and 30
- closing of test section valve
- the "SEQ"-option of the logger is ended and the one minute interval is selected
- packer deflation 5 min
- transfer to next section 10 min with the test section valve closed and rubber cone slightly open

The time needed to accomplish a complete test cycle will be approximately one hour.

Results

The sections measured, flow rates and preliminary evaluated pressure responses are listed in Table 1.

Table 1. Summary of flow and pressure data from flow logging in KA2563A

Measured section	Flow rate* (l/min)	Pressure responses	Structure
230-235 m	0.60	No response	
235-240 m	2.50	KI0023B:P2, 30 kPa	#19
		KI0025F02:P2, 25 kPa	#19
		KI0025F:R2, 1 kPa	#19
240-245 m	0.24	No response	
245-250 m	6.20	KI0023B:P2, 95 kPa	#19
		KI0025F02:P2, 80 kPa	#19
		KI0025F:R2, 5 kPa	#19
250-255 m	0.97	No response	
265-270 m	1.50	No response	
270-275 m	1.46	No response	
280-285 m	0.009	No response	
285-290 m	0.020	No response	
290-295 m	0.018	No response	
295-300 m	0.048	No response	

* after 30 minutes

The two flowing structures at 235-240 m and 245-250 m both seem to be associated with structure #19. The structure between 265-270 m has been interpreted as structure #9 but no responses were observed. The reason for this may either be that the interpretation is wrong or that the pressure response is too weak to be monitored. The latter explanation is possible in view of the short time for pressure recovery between the tests. The moving of the equipment creates a pressure drop that is not fully recovered at the start of the next test.

Peter Andersson
PM 99-02-11

COMMENTS AND SUGGESTIONS REGARDING INSTRUMENTATION OF KA2563A

This PM deals with the question to ream KA2563A or not in view of the flow logging tests performed by GEOSIGMA with a double-packer system and by POSIVA´s flow logging.

<u>Comments on status of previous instrumentation</u>

One of the big questions regarding the status of the previous instrumentation was the extremely good responses in section R1 which was interpreted to be associated with structure #9. In a report written by myself I stated some arguments where the strongest was that "the pressure is highest in section R1 (farthest away from the tunnel). A wrongly connected pressure line would show up as an anomaly in the pressure distribution along the borehole". This is true, but the situation that the blind section between 228-262 m in the borehole would also have a higher pressure than the other sections. Thus, it is possible that the responses are related to this section, direct (leakage though fittings) or indirect (short-circuiting fractures or expansion/deflation of the tubing to section R1) where the new interpretation of structure #9 is located (at 230 m) and some strong conductors related to structure #19 (at 238 and 245 m).

There are three new facts that led to this conclusion:

- That the conductors at 265 and 272 m do not give any responses in the #9, 20, 13-system during GEOSIGMA flow logging
- That the strong conductors at 238 and 245 m are clearly related to #19
- That the intercept at 230 m fits much better with the orientation of structure #9 in other intercepts

<u>Comments to Peter Meier´s and Tom Doe´s ideas about the observed flow and pressure responses in KA2563A during flushing/shut-in of KI0023B:P6</u>

I agree with Anders Winberg and Peter Meier that the transient behaviour of some of the responses may indicate connectivity between the sections. There are also other arguments for the interpretation of #9 and #13 in KA2563A namely, that the intersecting structures fit well with the orientation of #9 and #13 in other boreholes. I also think that Tom Doe is right about the general pressure behaviour of KA2563A but I personally cannot find a good explanation for the transient flow responses. One argument might be that we see equipment responses, but why don´t we see them in all tests?

Tom had a suggestion to flush KA2563A for one day and then shut in the sections of interest and observe the pressure responses in the borehole array. I think it is a good idea but this is very similar to what already has been done by GEOSIGMA although we did it the other way around. First a shut in of the entire KA2563A and the opening of the target sections one by one for 30 minutes. The problem with our target sections (question-marks) in KA2563A is that they are relatively low transmissive, so I do not believe that we can observe responses over >20 m distance as #20 has at least 20 times higher transmissivity in KA2563A. The only way to do it, in my opinion, would be to instrument the borehole and do pumping with tracer dilution tests.

Peter Andersson
PM 99-02-11

Alternatives for instrumentation of KA2563A

Reaming KA2563 will, in my opinion, be a very risky operation. If we need the possibility to circulate and inject tracers in structures #9, 13, 19, and #20, then reaming is necessary. If one of them can be left out I think it might be possible to instrument KA2563 without reaming. We then need to ”sacrifice” monitoring on the south side of #19 and in the outer parts of the bore-hole (Table 1). The use of #19 as an injection point for tracers has earlier been discussed. Previous interference tests have shown that #19 is relatively isolated from our target features which is my motivation for skipping circulation in #19. I think that the other three candidates (#9, 13, 20) are more essential to cover. Distances are relatively short (20-40 m to KI0023B) and the chance that these sections are possible tracer injection candidates is much higher, given their orientation.

Another alternative may be to skip the guard packer at 6 m and construct a manifold with lead-throughs like in KI0023B. This will enable pressure measurement in the outer part of the bore-hole as well. An additional lead-through in the guard packer is also possible according to our constructors. An additional packer then has to be built (takes about one week). The old proposal is shown in Table 2 for comparison.

Table 1. New Proposal for re-instrumentation of KA2563A. 56 mm and 76 mm alternatives. C=Circulation section

56 mm instrumentation			**76 mm instrumentation**		
Section	Bh length (m)	Structure	Section	Bh length (m)	Structure
B1	255-362	#10?	B1	274-362	#10?
S1	233-254	#19	S1	250-273	#?
S2	228-232 **C**	#9	S2	233-249 **C**	#19
B2	209-227	?	S3	228-232 **C**	#9
S3	206-208 **C**	#13	B2	209-227	#?
B3	191-205	?	S4	206-208 **C**	#13
S4	187-190 **C**	#20	B3	191-205	#18?
S5	146-186	#6, 7	S5	187-190 **C**	#20
B4	6-145	#1,2,3,4,5 ,16, 17	S6	146-186	#6, 7
			S7	6-145	#1,2,3,4, 5, 16,17

Table 2. Old Proposal for re-instrumentation of KA2563A. The proposal requires that the borehole is reamed to 76 mm.

Old instrumentation			New instrumentation		
980225-					
Section	Bh length (m)	Structure	Section	Bh length (m)	Structure
R1	262-362	#9, 10	B1	268-362	#10?
B1	229-261	#8	S1	263-267 C	#9
R2	225-228	#19	S2	242-262	#8, ?*
R3	220-224	?	S3	229-241	?**
R4	191-219	#13	S4	210-228	#19
R5	187-190 C***	#20	S5	205-209 C	#13
R6	146-186	#6, 7	B2	191-204	#18?
R7	76-145	#4, 5, 17	S6	187-190 C	#20
B2	6-75	#1,2,3,16	S7	146-186	#6, 7
			S8	76-145	#4, 5, 17
			S9	6-75	#1,2,3,16

* Flowing structures at 245-255 m, flow ≈ 8 l/min

** Flowing structures at 230-240 m, flow ≈ 3 l/min

*** Presently dummy material exists in section R5

Peter Andersson
PM 99-02-19

COMPLEMENTARY FLOW LOGGING IN KA2563A – PRELIMINARY RESULTS

A complementary flow logging was performed in KA2563A on February 18th, 1999. The methodology was:

1. The borehole (KA2563A) was opened completely for 42 hours (Q=45 l/min).
2. A 2.5-m long double-packer was placed over a flowing section and inflated for 18-76 minutes. The flow from the inner portion of the borehole passes through the double-packer system without frictional losses.
3. Flow is measured before and after inflation of the packers, pressure changes due to the packing-off are recorded by the HMS system in KI0023B, KI0025F, KI0025F02.

The sections measured, times for inflation and deflation and the flow rates before and after inflation is given in Table 1. The accuracy of the flow measurement is about ± 1l/min.

Table 1.

Test	Section	Structure	Inflation	Deflation	Flow inflated (l/min)	Flow deflated (l/min)
1	188.0-190.5	#20	08.30*	08.52	37.6	45.7
2	205.7-208.2	#13	09.10	09.47	45.2	45.7
3	229.3-231.8	#9?	10.23	11.01	45.2	45.7
4	244.2-246.7	#19	11.30	12.46	40.0	45.7
5	251.7-254.2	#?	13.00	13.34	41.3	45.2
6	265.0-267.5	#?	13.55	14.30	45.2	45.2

*test stopped, deflation 08.32 re-inflation 08.34

The resulting pressure responses are shown in Figures 1-6. In summary, responses were monitored in all tests except test 3 although the responses in tests 5 and 6 are very weak. A rough and preliminary evaluation of the pressure responses (magnitude) is summarised in Table 2. The pressure response in some sections at 12.50 is probably caused by interfering activities in the prototype repository.

The results indicate that the structure at 206 m is structure #13, that the structure at 229 m still is unknown and that the structures at 252 and 266 m are connected to structure #19.

Table 2.

Test	Monitoring section	Response (kPa)	Structure
1	KI0023B:P6	513	#9
	KI0023B:P7	489	#6,20
	KI0025F02:P5	445	#20
	KI0023B:P5	330	#?
	KI0025F:R4	285	#20
	KI0023B:P3	222	#?
	KI0025F02:P6	202	#6
	KI0025F02:P8	151	#9
	KI0023B:P4	140	#13
	KI0025F02:P7	60	#?
	KI0025F02:P3	12	#13
	KI0025F:R3	10	#?
	KI0025F:R5	2	#6,7
	KI0025F:R6	2	#5
	KI0025F02:P9	1	#7
2	KI0023B:P4	245	#13
	KI0023B:P3	>0	#?
	KI0023B:P5	>0	#?
	KI0023B:P6	>0	#9
4	KI0023B:P2	124	#19
	KI0025F02:P2	106	#19
	KI0025F:R2	7	#19
	KI0025F:R3	6	#?
	KI0025F:R1	3	Z
	KI0023B:P3	2	#?
	KI0025F02:P3	2	#13
5	KI0025F02:P2	>0	#19
	KI0023B:P2	>0	#19
6	KI0023B:P2	2	#19

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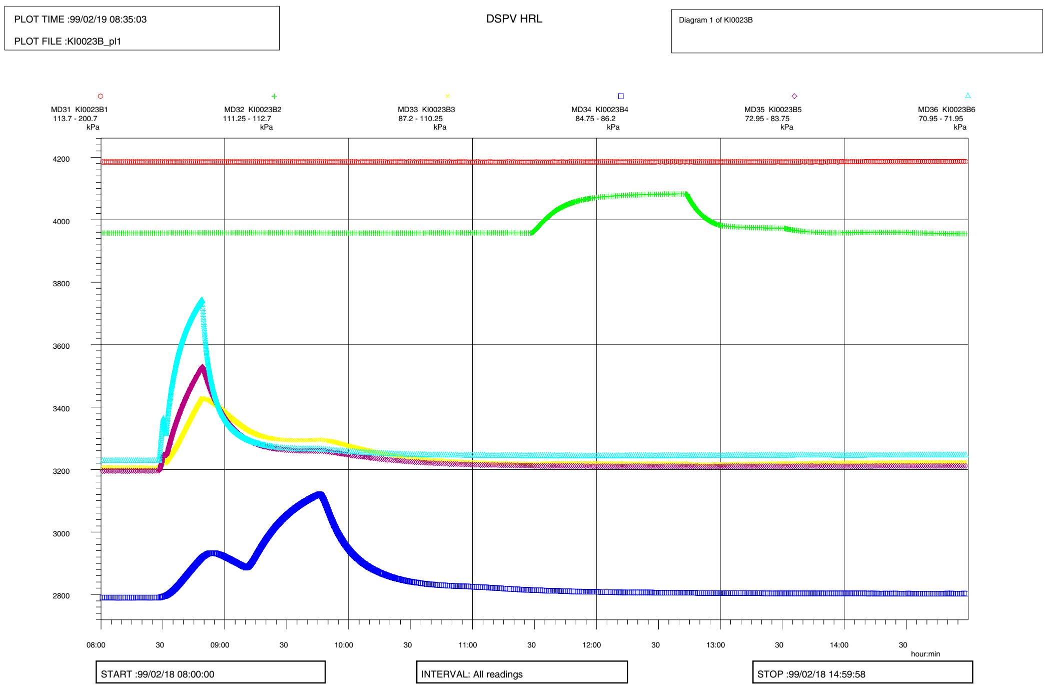
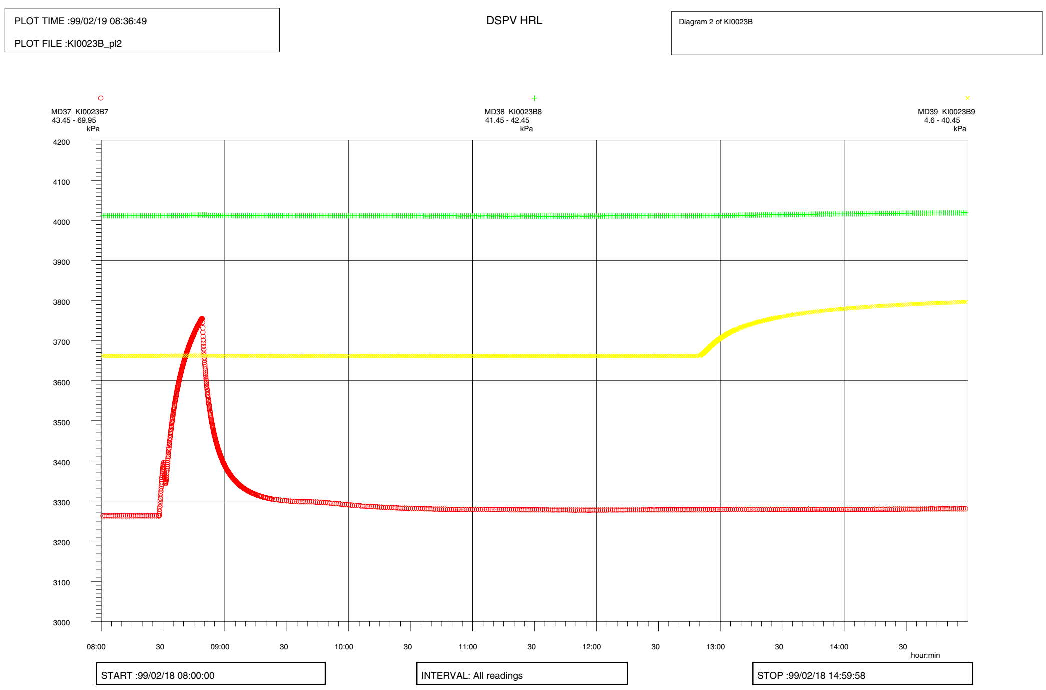
PM 99-02-19





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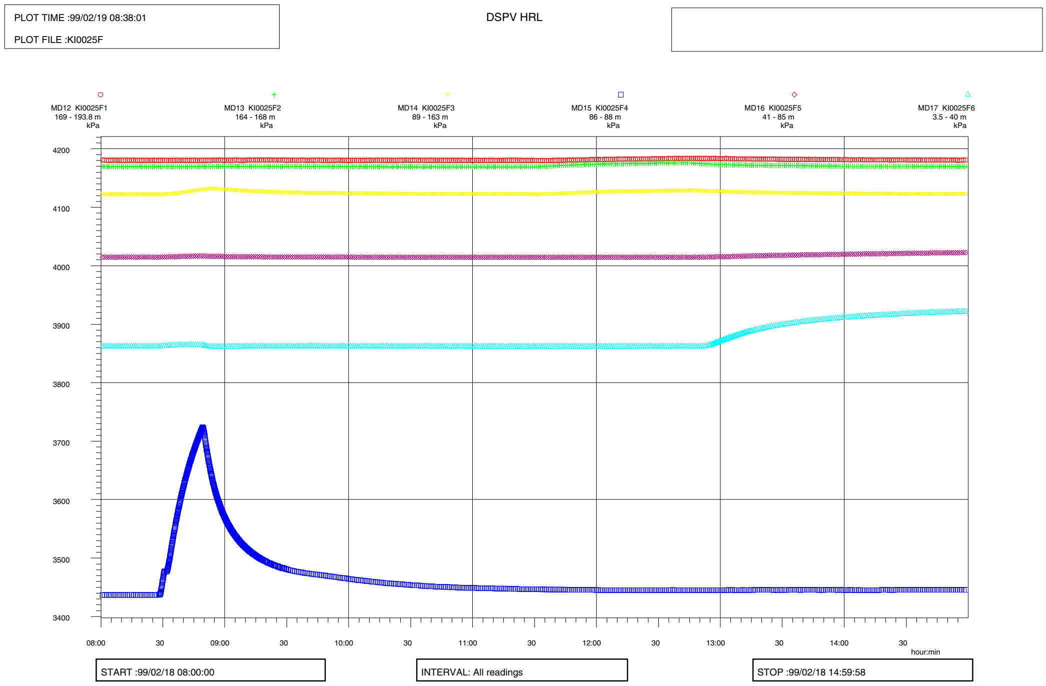

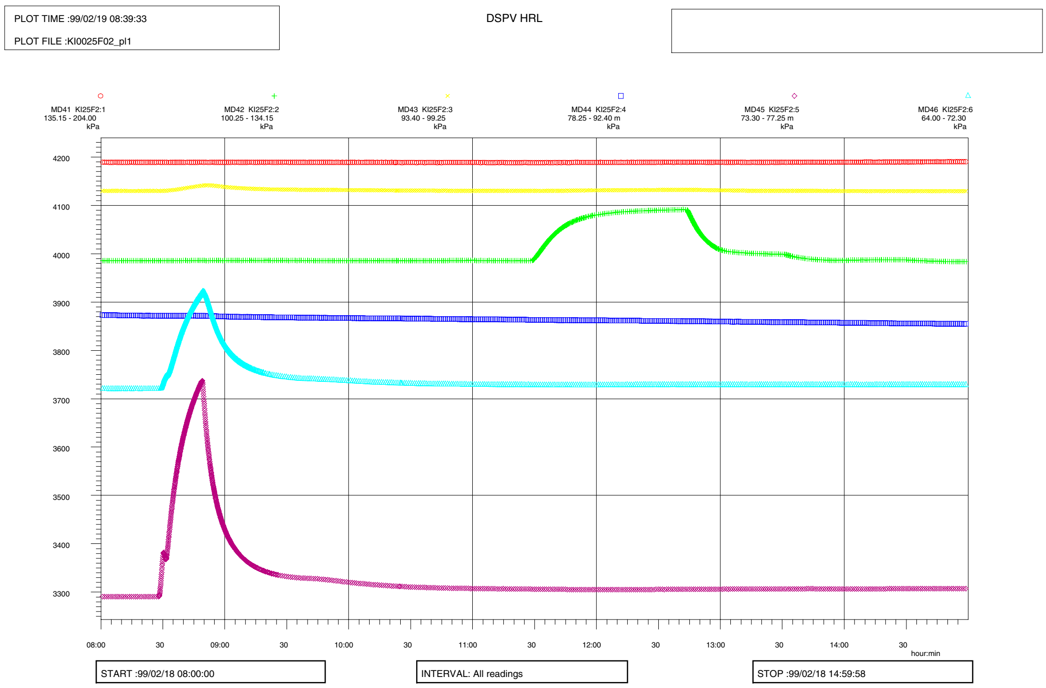

GEOSIGMA

C:5

1999-02-19

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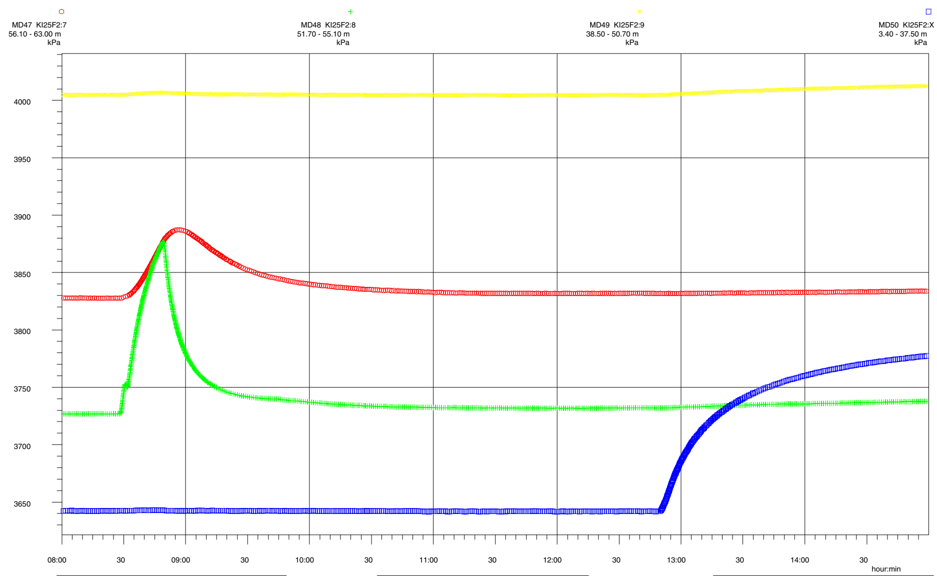
PLOT TIME :99/02/19 08:41:08
PLOT FILE :KI0025F02_pl2

DSPV HRL



START :99/02/18 08:00:00

INTERVAL: All readings

STOP :99/02/18 14:59:58

Peter Andersson
PM 99-03-05

CONFIRMING PRESSURE INTERFERENCE TEST IN KA2563A

Background

A short-term interference test was performed in borehole KA2563A with the purpose to test if earlier monitored pressure responses in the innermost section of the borehole (beyond 262 m) were artefacts or not. A second test was also performed with the purpose to test if the structure at 230 m is associated with structure #9.

Performance and results

The borehole was instrumented with 4 packers located at 3-4, 186-187, 190-191 and 261-262 m depth isolating 4 sections of the borehole. All 4 sections were connected to pressure transducers (HMS system) and the two outermost sections, 4-186 m and 187-190 m were equipped with two extra lines for flow.

In the first test section 187-190 m (structure #20) was flushed for 20 minutes. Pressure responses were observed in all borehole sections earlier interpreted to include structure #20 but no response was found in section 262-363 m in KA2563A were extremely good responses had been noted in earlier tests, e.g. interference test ESV-1a (Andersson et al., 1998).

In the second test the packer system was lowered 41 m so that the interval which initially was used to flow Structure #20 at 187-190 m, now covered the prime candidate for Structure #9 between 228-231 m. The section now including structure #20 (45-227 m) was flushed for 20 minutes. An instantaneous response of 3 kPa was observed in section 228-231 m. However, the shape of the pressure response indicate that this is a storage effect caused by de-pressurisation of the nylon tubes passing through the flushed section in combination with the relatively low transmissivity of section 228-231 m (Figure 1).

Conclusions and recommendations

- The structure at 265 m in KA2563A is <u>not</u> associated with structure #20 and the pressure responses earlier monitored were artefacts.
- The structure (candidate for structure #9) at 230 m in KA2563A is <u>not</u> in good hydraulic contact with structure #20 and is therefore not considered to be of interest for future tracer experiments.
- It is recommended to change the focus from the earlier preferentiated Structure #9 to Structure #19, cf. Table 1.

Peter Andersson
PM 99-03-05

Table 1. Proposal for re-instrumentation of KA2563A. C=Circulation section, B=Blind section, S=Pressure monitoring section

Old proposal (990211)			New proposal		
Section	Bh length (m)	Structure	Section	Bh length (m)	Structure
B1	255-362	#10?	B1	247-362	#10?
S1	233-254	#19	S1	242-246 **C**	#19
S2	228-232 **C**	#9	S2	236-245	#19?
B2	209-227	?	B2	209-235	#?
S3	206-208 **C**	#13	S3	206-208 **C**	#13
B3	191-205	?	B3	191-205	?
S4	187-190 **C**	#20	S4	187-190 **C**	#20
S5	146-186	#6, 7	S5	146-186	#6, 7
B4	6-145	#1,2,3,4,5,16, 17	B4	6-145	#1,2,3,4, 5, 16,17

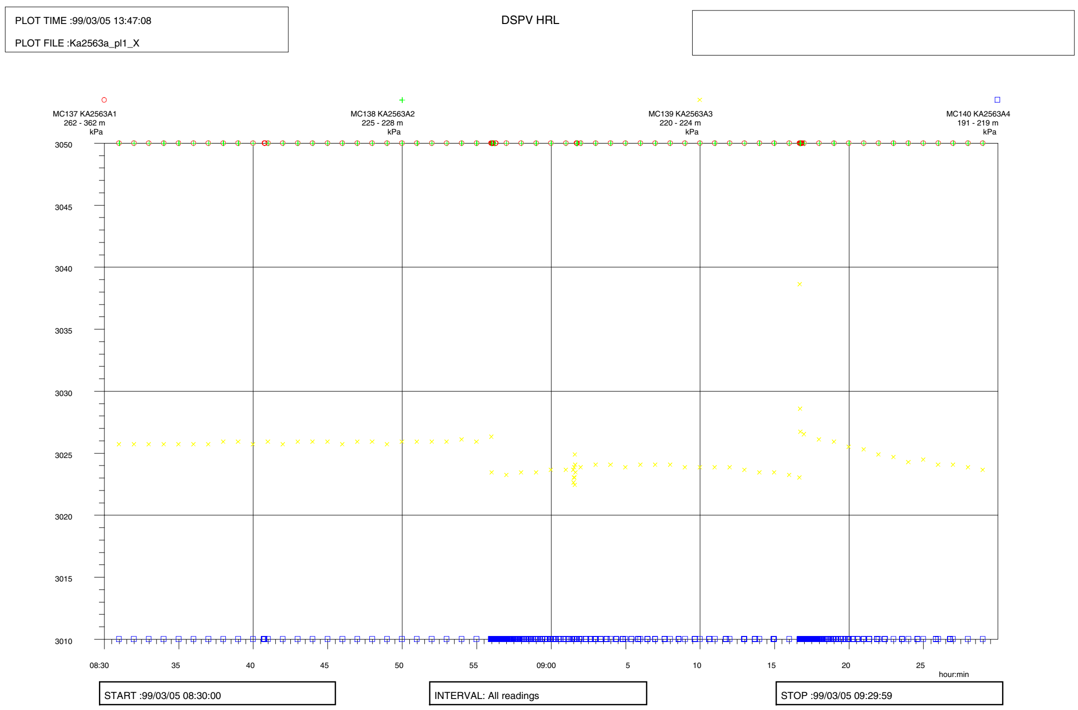


Figure 1. Pressure response in section 228-231 m during flushing of structure #20 in KA2563A.

Peter Andersson
PM 99-03-30

OPTIMISATION OF BOREHOLE INSTALLATIONS IN KI0025F AND KI0025F02

Introduction

The results of the current updating of the TRUE Block Scale structural model (March 99) includes some minor structures that earlier not has been included. These structures (#21 and #22) together with some modifications of the locations of a few other already existing structures, has raised the question whether to reconfigure the borehole instrumentation in some of the boreholes already at this point or to wait for the results of the planned pre-tests (PT-1 to PT-5). This PM deals with arguments for and against a reconfiguration and gives a recommendation.

March 99 structural model

Table 1 shows the updated intercepts with the five boreholes in the TRUE Block Scale array according to Hermanson (in prep).

Table 1. March´99 structural model. ***Updates and new structures in Italics.***

Bh	**KA2563A**		**KA2511A**		**KI0025F**		**KI0023B**		**KI0025F02**	
Structure	Intercept (m)	Sec	Intercept (m)	Sec	Intercept (m)	Sec	Intercept (m)	Sec	Intercept (m)	Sec
6	*157,2*	S5	89,2	T7	*61,8*	R5	44,2	P7	*52,3*	P8
7	153,4	S5	*38*	T8	(37.1)	R6	42,2	P8	*39,9*	P9
9	*230*	B	-	-	-	-	-	-	-	-
13	207	S3	-	-	-	-	85,6	P4	*93,9*	P3
19	*237,9*	S1	(156.4)	T3	166,4	R2	111,6	P2	*138,5*	P1
20	188,7	S4	122	T4	87,7	R4	69,8	P7	*74,7*	P5
21	-	-	-	-	(166,4)	R2	*71,1*	P6	*97,9*	P3
22	-	-	-	-	*88,8*	B	-	-	*66,8*	P6

\- = no recorded intercept

Possible optimisations

The table shows that, based on this interpretation, a few changes in the borehole instrumentation can be done to optimise the isolation of the different structures. It should be noted that borehole KA2511A and KA2563A already have been optimised and that borehole KI0023B cannot be further optimised. The possible optimisations are:

1. Isolation and enabling of tracer injection/sampling in structure #22 in KI0025F
2. Enabling tracer injection/sampling in structure #6 in KI0025F
3. Separation of #13 and #21 in KI0025F02

Structure #22 is not very easily detected as an open structure on the BIPS log. However, there are indications that this may be a water conducting structure. During the detailed flow logging (5-m sections) in KI0025F (Gentzschein, 1997), a flow of 1.08 l/min was measured in the interval 86-92 m with a head drop of 41.5 bar. Later this structure was tested during the pressure build-up tests where a flow of only 0.39 l/min was measured with a similar head drop (Gentzschein & Morosini, 1998). A more detailed localisation of the structure was also attempted by moving the 1-m test section in small steps. Unfortunately, this localisation procedure ended at 88.75 m, i.e. only about 0.05 m from the currently interpreted structure #22. Thus, the flow not accounted for (about 0.7 l/min) may come from structure #22.

Isolation of structure #22 in KI0025F requires that a packer is placed very accurately since the distance between #22 and #20 is 1.1 m and the packer lengths are 1.0 m. Currently, a packer is placed over the intercept at 88.8 m (88.0-89.0 m).

The intercept with structure #6 in KI0025F was found to be rather low transmissive during the detailed flow logging (5-m sections). A flow of only 1 ml/min was measured in this interval.

The separation of #13 and #21 in KI0025F02 is possible to perform as the distance between the intercepts is 4.0 m. However, the intercept at 93.9 m (#13) has a low transmissivity (about 4E-9 m^2/s) which probably would be too low to allow transport over the distances involved (20-50 m). The intercept at 97.9 m has a transmissivity that is about one order of magnitude higher. It should also be noted that the flow path between the intercepts of structure #21 in KI0023B:P6 and KI0025F02:P3 already has been tested with a tracer dilution test during pumping. The test showed an increased flow with a factor 7 in KI0025F02:P3 during pumping in KI0023B:P6 although the distance is rather long (36 m).

Recommendations

Arguments for a re-instrumentation of KI0025F and KI0025F02 prior to performing the pre-tests are:

- Two more potential tracer injection points may be included (KI0025F at 88.8 m (#22) and KI0025F02 at 97.9 m (#21)
- It is possible that a POSIVA flow log is needed in KI0025F to confirm structure #22 and it may be good to do this and the potential re-instrumentation before performing the pre-tests.

Arguments against are:

- There are only two possible “improvements” of which one is uncertain (KI0025F at 88.8 m) and one possibly not will be useful (KI0025F02 at 97.9 m)
- There are many other uncertainties and question-marks already whether it is feasible to perform tests at all in this array

- The pre-tests may give results that give other options for re-instrumentation, which have a higher priority, which could be included in a later stage.
- The two new structures #21 and #22 are only detected in two borehole sections each and the former with deviating orientations

In summary, the arguments for doing a optimisation of the packer installations in KI0025F and KI0025F02 prior to the pre-tests do not seem to be strong enough at this point in time.

The recommendation is to first do the planned pre-tests, secondly to do a simple test in KI0025F by pushing the packer assembly in steps of 0.5 m inwards and measure the flow from the tubing. This procedure will determine whether the intercept at 88.8 m (#22) is water conducting and possibly also the interaction with structure #20 at 87.7 m.