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Revised June 2006

Oskarshamn site investigation

Geological interpretation of borehole radar reflectors in KSH01, HSH01–03, KAV01 and KSH02

Seje Carlsten, Geosigma AB

April 2004

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

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Reading instructions

For revision no. 1 of this report a recalculation of the directional radar data has been done. The strike angel between the line of plane's cross-section with the surface and the Magnetic North direction was earlier counted counter-clockwise but it is now recalculated as such it counts clockwise. New values for strike and dip are therefore updated in Table 3-5.

Sammanfattning

Denna rapport behandlar geologisk tolkning av borrhålsradarmätningar vilka genomförts i kärnborrhålen KSH01, KAV01 och KSH02 samt i hammarborrhålen HSH01–03. Borrhålsradarmätningarna genomfördes som en del i platsundersökningarna för Oskarshamn. Arbetet har genomförts enligt aktivitetsplanen AP PS 400-03-097 (SKB interna kontrollerande dokument).

Borrhålsradarmätningarna och den preliminära tolkningen av radar reflektorer utfördes av Malå GeoScience/Raycon AB och finns presenterade i rapporterna /SKB P-03-15, SKB P-03-73, SKB P-03-120/ samt /SKB P-03-109/.

De tolkade reflektorerna har korrelerats med geologiska strukturer vilka karterats i Boremap och som i sin tur är belägna inom möjliga deformationszoner, enligt den geologiska enhålstolkningen. Resultatet presenteras i en tabell för varje enskilt borrhål. Tabellen visar reflektorernas skärningsdjup, eventuella orientering, den geologiska karaktären enligt Boremap och reflektorernas utsträckning utanför borrhålet.

Contents

1 Introduction

This document reports geological interpretation of borehole radar measurements performed in KSH01, KAV01, KSH02 and percussion boreholes HSH01–03, performed as part of the site investigation at Oskarshamn. The work was carried out in accordance with the activity plan AP PS 400-03-097 (SKB internal controlling documents).

The borehole radar measurements and the primarily interpretation of radar reflectors was performed by Malå GeoScience/Raycon AB and presented in the reports /SKB P-03-15, SKB P-03-73, SKB P-03-120/ and /SKB P-03-109/.

The interpreted radar reflectors from the borehole radar measurements have been correlated with geological structures mapped in Boremap and situated within *Possible Deformation Zones* from the single hole interpretation.

2 Objective and scope

Borehole radar is used for detecting and orient structures such as deformation zones and rock contacts penetrating the borehole or in the surroundings of the borehole. The objective of this activity is to geologically describe the primarily interpreted radar reflectors situated within *Possible Deformation Zones* with the use of BIPS- and Boremapdata. The result from the classification is intended to be used as input for the singlehole interpretation procedure concerning orientation of *Possible Deformation Zones*.

3 Execution and results

3.1 Analysis and interpretation

The Tables 3-1 to 3-6 include all primarily interpreted reflectors from the different measurements performed by Malå Geoscience/Raycon AB. Radar reflectors used for geological interpretation at *Possible Deformation Zones* in the geological single hole interpretation process have been indicated separately in the tables. In some cases geologically interpreted radar reflectors have been excluded during the single hole interpretation process, due to uncertainty of the interpretation or to changed boundaries of *Possible Deformation Zones*. The selected reflectors are situated within or close to the *Possible Deformation Zones*. The extension outside the borehole of these reflectors has been interpreted from the radar maps in the radar reports. The extension values are shown in the tables, and it should be noted that they have been interpreted solely for the present report.

In the different original radar reports only the strongest radar reflectors (Intensity 1) have been interpreted and presented in tables. In some cases this means that radar reflectors weaker than *Intensity 1* occur within some of the *Possible Deformation Zones*, but they have not been interpreted or presented in the original radar reports. Due to this, a couple of radar reflectors have been interpreted and added to the tables in the present report. The added reflectors have generally been denominated with the prefix SH.

The geological interpretation of radar reflectors as presented in sections 3.1.1–3.1.6 have been used in the geological single hole interpretations of /SKB P-04-32 and SKB P-04-133/.

3.1.1 Borehole KSH01

The result from the dipole antennas with 20, 100 and 250 MHz frequencies presented in /SKB P-03-15/, was used as basis for the geological interpretation of radar reflectors, Table 3-1. The borehole radar measurement and the BIPS measurement in KSH01 were conducted by Malå Geoscience /Raycon AB during February and March 2003. The interpretation was made by Malå Geoscience/Raycon AB and presented in /SKB P-03-15/ (upper part of KSH01) and in /SKB P-03-73/. Data from Boremap mapping was used for geological classification of the radar reflectors.

One radar reflector, denominated SH, has been added during the single hole interpretation process of KSH01. This reflector is not included in the original radar report /SKB P-03-73/.

Table 3-1. Radar reflectors in borehole KSH01.

Name	Intersection depth (m)	Intersection angle (degrees)	Comments	Used for the *Possible Deformation Zones* in the singlehole interpretation	Extension outside borehole (m)
A	141.5	23	Strong reflector, open fracture at 141.8 m, BIPS orientation 115/44. Same as for B.	Yes	14

Name	Intersection depth (m)	Intersection angle (degrees)	Comments	Used for the *Possible Deformation Zones* in the singlehole interpretation	Extension outside borehole (m)
B	145.0	25	Strong reflector, open fracture at 141.8 m, BIPS orientation 115/44. Same as for A.	Yes	7
CC	171.3	73			
C	171.4	31			
D	191.3	21			
EE	199.4	70			
FF	205.4	30			
E	212.5	16	Pegmatite at 210.8 m.		
F	215.2	55			
SH1	249.6	53	Open fractures and cavities between 250.4–251.9 m, BIPS orientation 097/40, 039/47 and 024/21.	Yes	6
G	364.8	36	Rock contact, BIPS orientation 270/70.		
Z	381.5	47	Rock contact/Fractures, BIPS orientation 086/46 and 074/51.		
H	383.3	30			
HH	395.6	71	Fracture, BIPS orientation 103/21.		
I	409.2	31			
J	447.9	11	Strong reflector, open fracture at 441.1 m, BIPS orientation 022/66.	Yes	8
JJ	450.9	21	Strong reflector, rock contact at pegmatite at 448.6 m, BIPS orientation 095/67.	Yes	8
K	510.4	13			
L	542.4	20	Aplite at 541.3 m and 541.9 m, BIPS orientation 278/88 and 283/69.		
M	561.1	52	Strong reflector, open fractures at 560.1 m, BIPS orientation 298/44 and 300/57.	Yes	10
N	579.3	51	Fractures at 579.1 m, BIPS orientations 163/29, 156/34 and 157/34. Open fracture at 579.9 m, BIPS orientation 330/36 and 328/34.		
O	590.6	46	Strong reflector, open fractures at 590.3–590.5 m, BIPS orientation 311/26 and 344/33.	Yes	10
P	628.2	34	Very strong reflector, open fracture at 628.8 m, BIPS orientation 188/59.	Yes	12–14
Q	667.4	47	Strong reflector, tectonized at 670.9–671.1 m, BIPS orientation 200/37.	Yes	6
R	703.5	16	Fractures between 686–689 m and 689.5–690.5 m, BIPS orientations ~200/~70–80.		
S	720.0	58			
T	834.7	66			
Y	838.4	21			

Name	Intersection depth (m)	Intersection angle (degrees)	Comments	Used for the *Possible Deformation Zones* in the singlehole interpretation	Extension outside borehole (m)
X	922.1	47			
W	944.6	23			
U	985.7	40			

3.1.2 Borehole HSH01

The result from dipole antennas with 20, 100 and 250 MHz frequencies presented in /SKB P-03-15/, was used as basis for the geological interpretation of radar reflectors, Table 3-2. The borehole radar measurement and the BIPS measurement in HSH01 were conducted by Malå Geoscience /Raycon AB during September 2002. The interpretation was made by Malå Geoscience /Raycon AB and presented in /SKB P-03-15/. Data from Boremap mapping was used for geological classification of the radar reflectors.

Radar reflectors used together with *Possible Deformation Zones* in the single hole interpretation have been indicated in the table. The extensions outside the borehole only of reflectors used for the geological single hole interpretation are presented in the table. The values for extension outside the borehole have been produced solely for this report.

Table 3-2. Radar reflectors in borehole HSH01.

Name	Intersection depth (m)	Intersection angle (degrees)	Comments	Used for the *Possible Deformation Zones* in the singlehole interpretation	Extension outside borehole (m)
C	8.29	37.60			
D	16.40	33.70	Sealed fracture at 16.6 m.		
B	36.55	49.26	Vein at 37.8 m. Orientation from BIPS is 69/079. Strong and persistent reflector.	Yes	15
A	38.89	18.73	Several sealed fractures as network. Strong and persistent reflector.	Yes	8
E	70.39	32.15	Fine-grained granite at 70.8 m.		
I	86.96	26.72			
F	87.58	24.96	Fracture at 86.9 m.		
G	112.59	22.70			
J	152.10	40.59			
K	167.68	38.70	Open fractures at 167.7 m. Orientation from BIPS is 55/040. Strong but short reflector. Agreement between alpha-angles and BIPS is not good.	Yes	6
M	179.17	27.33	Open fracture at 179.6 m.		

3.1.3 Borehole HSH02

The result from dipole antennas with 20, 100 and 250 MHz frequencies presented in /SKB P-03-15/, was used as basis for the geological interpretation of radar reflectors, Table 3-3. The borehole radar measurement and the BIPS measurement in HSH02 were conducted by Malå Geoscience /Raycon AB during September 2002. The interpretation was made by Malå Geoscience/Raycon AB and presented in /SKB P-03-15/. Data from Boremap mapping was used for geological classification of the radar reflectors.

Radar reflectors used together with *Possible Deformation Zones* in the single hole interpretation have been indicated in the table. The extensions outside the borehole only of reflectors used for the geological single hole interpretation are presented in the table. The values for extension outside the borehole have been produced solely for this report.

Table 3-3. Radar reflectors in borehole HSH02.

Name	Intersection depth (m)	Intersection angle (degrees)	Comments	Used for the *Possible Deformation Zones* in the singlehole interpretation	Extension outside borehole (m)
A	28.27	51.57	Rock contact at 29.0 m. Orientation from BIPS at 68.9 m is 18/171. Strong and persistent reflector.	Yes	20
B	33.24	33.95	Sealed fracture, network at 33–34 m. Strong and persistent reflector.	Yes	18
C	55.65	38.42	Sealed fractures (vein) at 55.7 m.		
E	106.52	30.73	Sealed fracture (vein) at 107.1 m. Orientation from BIPS is 82/234. Short reflector outside the borehole.	Yes	9
D	111.78	28.12	Sealed fracture (vein) at 111.6 m with orientation 44/107. Fine-grained at 112 m with orientation 75/222. Strong and persistent reflector.	Yes	8
F	143.22	23.51	Sealed fracture at 144.4 m. Strong and persistent but not visible close to the borehole.	Yes	11
G	171.90	29.48			

3.1.4 Borehole HSH03

The result from dipole antennas with 20, 100 and 250 MHz frequencies presented in /SKB P-03-15/, was used as basis for the geological interpretation of radar reflectors, Table 3-4. The borehole radar measurement and the BIPS measurement in HSH03 were conducted by Malå Geoscience /Raycon AB during September 2002. The interpretation was made by Malå Geoscience /Raycon AB and presented in /SKB P-03-15/. Data from Boremap mapping was used for geological classification of the radar reflectors.

Radar reflectors used together with *Possible Deformation Zones* in the single hole interpretation have been indicated in the table. The extensions outside the borehole only of reflectors used for the geological single hole interpretation are presented in the table. The values for extension outside the borehole have been produced solely for this report.

Table 3-4. Radar reflectors in borehole HSH03.

Name	Intersection depth (m)	Intersection angle (degrees)	Comments	Used for the *Possible Deformation Zones* in the singlehole interpretation	Extension outside borehole (m)
A	54.42	22.02	Dark vein (sealed) at 54.7 m		
B	68.78	52.02	Crush zone at 68–70 m. Orientation from BIPS is 25/117. Very short reflector.	Yes	5
C	106.97	41.69	Vein (quartz, epidote) at 106.8 m. Orientation from BIPS is 51/208. Short reflector.	Yes	7
E	109.77	14.04	Vein(s) at 109.4 m.		
D	128.44	52.48	Open fracture at 128.6 m.		
H	138.14	30.65			
G	144.96	36.47	Fracture, sealed/open at 144.5 m.		
F	150.55	21.72	Fracture at 151.1 m.		
I	187.53	20.20	Fracture at 187.2 m, several parallel above this length.		

3.1.5 Borehole KAV01

The result from the directional antenna measurement in KAV01 is presented in Table 3-5. The borehole radar measurement in KAV01 was conducted by Malå Geoscience /Raycon AB during October 2003. The interpretation was made by Malå Geoscience /Raycon AB and presented in /SKB P-03-120/. BIPS images were not available for the interpretation. Data from Boremap mapping was used for geological classification of the radar reflectors.

Reflectors in the table marked with ± indicate uncertainty in the interpretation of direction. The orientation can be the given strike or, in a vertical borehole, +180°.

Table 3-5. Radar reflectors in borehole KAV01.

Name	Intersection depth (m)	Intersection angle (degrees)	Dip/Strike	Comments	Used for the *Possible Deformation Zones* in the singlehole interpretation	Extension outside borehole (m)
1	4.0	5	85/204			
2	128.5	54	36/075 ±			
3	136.0	41	49/063	Strong reflector, located outside the borehole.	Yes	4
4	141.4	24	66/033			
5	187.4	39	51/027	Strong reflector, located outside the borehole.	Yes	23
6	209.4	12	78/213	Strong reflector.	Yes	8
7	213.9	45	45/003 ±	Parallel to reflector 8, Strong reflector.	Yes	23
8	220.1	45	45/009	Parallel to reflector 7, Strong reflector.	Yes	17

Name	Intersection depth (m)	Intersection angle (degrees)	Dip/Strike	Comments	Used for the *Possible Deformation Zones* in the singlehole interpretation	Extension outside borehole (m)
9	248.8	42	48/036 ±			
10	250.5	6	84/306 ±			
11	282.9	59	31/021 ±	Located outside the borehole.	Yes	17
12	305.3	29	61/048			
13	309.2	43	47/018			
14	327.4	10	80/105			
15	348.1	10	80/075			
16	376.4	72	–			
17	396.5	78	12/261 ±			
18	438.6	54	36/294	Strong reflector, rock contact, crushed.	Yes	10
19	444.5	55	35/273 ±	Strong reflector.	Yes	17
20	447.3	2	88/114	Rock contact, very uncertain.	Yes	10
21	453.5	53	37/087	Relatively strong reflector, rock contact.	Yes	12
22	479.7	28	62/243	Strong reflector, fine-grained granite.	Yes	13
23	489.4	46	44/078	Relatively strong reflector, fine-grained granite.	Yes	7
24	532.2	70	20/054 ±	Relatively strong reflector.	Yes	8
25	554.0	66	24/312	Relatively strong reflector.		10
26	591.5	3	87/084	Very uncertain, only a short part of the reflector is visible along the borehole.		30
27	592.1	59	–	Weak.		10
28	609.9	37	53/060	Rock contact.		13
29	617.8	47	43/057	Rock contact.		12
30	628.7	16	–			
31	630.7	39	51/276			
32	635.9	35	55/093			
33	653.5	30	–	Outside the borehole.	Yes	15
34	676.2	85	–	Uncertain.	Yes	11
35	677.3	68	22/054 ±	Relatively strong reflector, fine-grained granite.		10
36	689.8	46	44/084			
37	722.1	43	47/348			

3.1.6 Borehole KSH02

The result from the dipole antenna measurement in KSH01 is presented in Table 3-6. The borehole radar measurement and the BIPS measurement in KSH02 were conducted by Malå Geoscience/Raycon AB during June and July 2003. The interpretation was made by Malå Geoscience/Raycon AB and presented in /SKB P-03-109/. Geological mapping data from Boremap and data from BIPS were used for geological classification of the radar reflectors.

A couple of radar reflector, denominated SH, has been added during the single hole interpretation process. These reflectors are not included in the original radar report /SKB P-03-109/.

Table 3-6. Radar reflectors in borehole KSH02.

Name	Intersection depth (m)	Intersection angle (degrees)	Comments	Used for the *Possible Deformation Zones* in the singlehole interpretation	Extension outside borehole (m)
EEE	16.5	10			
A	92.6	37			
B	94.4	22			
C	108.1	19			
D	125.7	53			
EEEE	135.3	15			
E	170.6	24			
F	174.7	17			
GG	188.1	10			
EE	218.1	25			
FF	276.7	72	Crushed rock.	Yes	8
G	302.2	59	Strong reflector. Open fracture at 302.5 m. Orientation from BIPS is 33/034.	Yes	10
H	344.2	44	Relatively strong reflector, Pegmatite at 344.8 m. Orientation from BIPS is 42/066.	Yes	6
I	345.6	29	Reflector outside the borehole, probably part of reflector H.	Yes	9
J	364.3	56	Relatively strong reflector, probably indicating veined fracture at 364.3 m. Orientation from BIPS is 49/036. Uncertain interpretation.	Yes	6
L	395.5	55			
K	401.9	15			
M	423.7	33			
N	467.5	51			
O	476.7	60			
P	498.8	69			
SH4	517.5	13	Open fractures. One dominating fracture at 514.8 m. Orientation from BIPS is 83/023.	Yes	5

Name	Intersection depth (m)	Intersection angle (degrees)	Comments	Used for the *Possible Deformation Zones* in the singlehole interpretation	Extension outside borehole (m)
SH3	526.5	69	Open fractures, fine-grained granite, parallel to reflectors SH1, SH2. Orientation from BIPS at 526.9 m is 45-57/014-033.	Yes	4
SH1	527.7	70	Parallel to reflectors SH2, SH3	Yes	4
SH2	531.5	71	Fine-grained granite, parallel to reflectors SH1, SH2. Orientation from BIPS is 34/347.	Yes	4
Q	556.0	69	Relatively strong reflector. Open fractures at 556.8 m. Orientation from BIPS is 33/358.	Yes	7
R	578.5	90			
S	590.8	50			
T	603.6	58	Strong reflector. Open fractures at 603.5 m. Orientation from BIPS is 43-54/258-327.	Yes	8
TT	620.2	73			
U	635.0	74			
V	656.3	70			
W	678.3	49			
X	695.6	70	Possibly aplite at 695.4 m. Orientation from BIPS is 60/171. Not good agreement between BIPS and radar.	Yes	10
Y	702.9	62	Strong reflector. Open fracture at 702.9 m. Orientation from BIPS is 24/294.	Yes	8
Z	707.4	62	Strong reflector. Open fracture at 707.8 m. Fracture almost perpendicular to borehole axis.	Yes	10
1	727.5	66			
2	739.6	75			
3	759.7	53			
4	780.5	75	Strong reflector. Open fracture at 780.2 m. Orientation from BIPS is 21/046.	Yes	14
5	807.7	60			
5a	809.5	24			
6a	828.4	23			
6	828.8	61			
7	837.6	60			
8	853.5	77	Strong reflector. There are several parallel reflectors close to this reflector. Open fractures at 853.4 m. Orientation from BIPS is 16/084.	Yes	30
10	860.4	19	Strong reflector. Aplite along the borehole axis at 857.6 m. Orientation from BIPS is 78/274.	Yes	18
9	895.8	23			
19	906.8	35			
11	911.2	54			

Name	Intersection depth (m)	Intersection angle (degrees)	Comments	Used for the *Possible Deformation Zones* in the singlehole interpretation	Extension outside borehole (m)
18	920.9	41			
13	923.7	44			
14	941.7	77			
17	963.4	63			
15	976.9	87			
16	995.5	41			
12	999.3	12			

3.2 Nonconformities

For revision no. 1 of this report a recalculation of the directional radar data has been done. The strike angel between the line of plane's cross-section with the surface and the Magnetic North direction was earlier counted counter-clockwise but it is now recalculated as such it counts clockwise. New values for strick and dip are therefore updated in Table 3-5.

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