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Results of Televiewer Logging in Well K-18 in Krafla High Temperature Area, NE-Iceland

Sigurveig Árnadóttir

Prepared for IMAGE

ÍSOR-2014/066

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Report
Project no.: 13-0388

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ÍSOR-2014/066 December 2014

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Key page

Report no.	Date	Distribution
ÍSOR-2014/066	December 2014	☒ Open ☐ Closed

Report name / Main and subheadings	Number of copies / Number of pages
Results of Televiewer Logging in Well K-18 in Krafla High Temperature Area, NE-Iceland	5 21 + CD (Appendix 2)
Authors	**Project manager**
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Classification of report	**Project no.**
	13-0388

Prepared for
IMAGE
Cooperators

Abstract

Televiewer logging was performed in well K-18 in Krafla high temperature field at 470–2180 m depth in October 2014 as a part of the IMAGE (Integrated Methods for Advanced Geothermal Exploration) European project. Results of structural analysis on grounds of the Televiewer data indicate that joints and fractures within the logged interval predominantly strike from NW-SE to N-S and dip towards NE/E. Fractures and joints observed in the Televiewer images are filled/cemented or tight/discontinuous, and in several cases partially open. No major open fractures were observed within the logged interval. Interfaces observed in the Televiewer images are considered to mark intrusion boundaries, and can be roughly divided into steeply dipping N-S and NE-SW striking interfaces (dykes) and sub-horizontal ~WNW-ESE striking, ~SSW-dipping interfaces (sill intrusions). The latter are in some cases non planar, which may suggest that magma intruded a still unsolidified intrusive material.

Key words	ISBN-number
Televiewer logging, well K-18, Krafla high temperature field, IMAGE, structural analysis, interface, joints, fracture, dips	
	Project manager's signature: Gylfi Páll Hersir
	Reviewed by: HMH, SThor, GPH

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1 Introduction

Well K-18 in Krafla high temperature field, NE-Iceland, is located in the Suðurhlíðar sub-area (Figure 1), approximately 300 m northeast of the bottom of well KJ-39 which was drilled into a supercritical region in 2008 (Árnadóttir et al., 2009). K-18 was vertically drilled in the year 1981 to 2215 m depth and as no workable feed-points were found to exist below the production casing, a liner was not installed (Stefánsson et al., unpubl.). Televiewer logging was performed in the well at 470–2180 m depth on 10th of October 2014 as a part of the IMAGE (Integrated Methods for Advanced Geothermal Exploration) European project. Results of structural analysis on grounds of the Televiewer data are presented in this report. The research leading to these results has received funding from the European Community's Seventh Framework Programme under grant agreement No. 608553 (Project IMAGE).

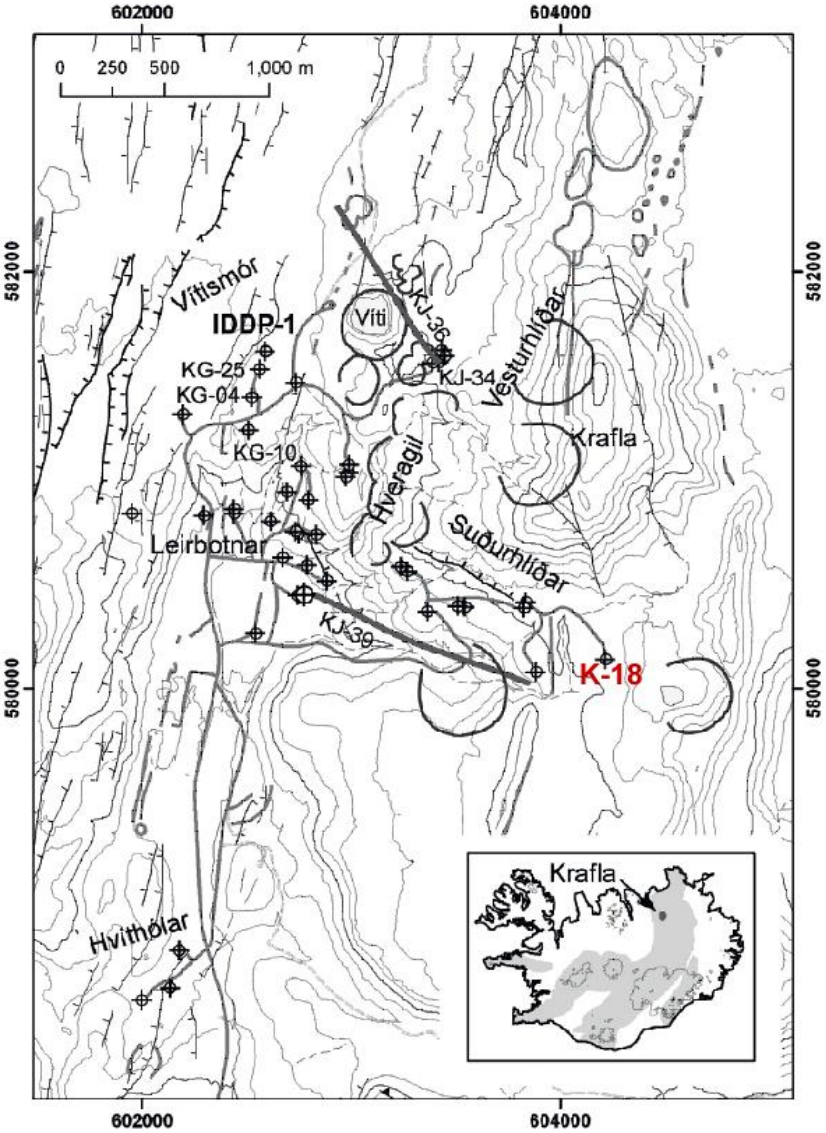

Figure 1. *Location of well K-18, shown on a map of the Krafla well field from Mortensen et al. (2014). Thin grey lines with dashes highlight faults. The two thickest grey lines signify the well paths of KJ-39 and KJ-36.*

2 Televiewer logging

Televiewer logging in well K-18 was carried out with ABI-43 (Acoustic Borehole Imaging tool 43") type logging equipment. A list of logging runs is presented in Table 1. Data processing and interpretation were performed in the petro-physical and borehole data analysis program WellCAD (version 4.4 build 3303). The data were oriented at import time to magnetic north and the amplitude and travel time images were rotated 12.52°W to correct for magnetic declination. The casing end is clearly visible on the Televiewer images at 659.3 m depth. As the exact depth of the end of the production casing is uncertain, it has been decided to use 665 m as estimation. Hence, the Televiewer logs were shifted 5.7 m downwards. Both the 12.52°W rotation and the 5.7 m downwards shifting were performed afterwards, in the WellCad program.

Table 1. *List of logging runs:*

470-2182 m	Downwards measured (poor image quality)
650-901 m	measured upwards
900-961 m	measured upwards
960-971 m	measured upwards
970-1052 m	measured upwards
1051-1332 m	measured upwards
1330-1382 m	measured upwards
1380-2150 m	measured upwards
2148-2180 m	measured upwards

The well is vertically drilled and generally tilts only ~1° (apart from the interval at ~1900–2050 m, where the tilt is ~2°). A slight deviation is thus recorded in the well path, as presented in Figure 2. The blue lines in the figure signify the well path when the azimuth log from the Televiewer, which records tool azimuth from magnetic north, has been corrected with respect to magnetic declination, while the red lines show the path before correction of the azimuth data. The projection of the well path onto a horizontal plane as seen from the top is shown to the left in the figure (bull's eye projection), while the distance from a virtual vertical axis at the well´s origin to the measurement point for each measured depth is displayed in the middle (closure view projection). A 3D view of the well path is shown to the far right.

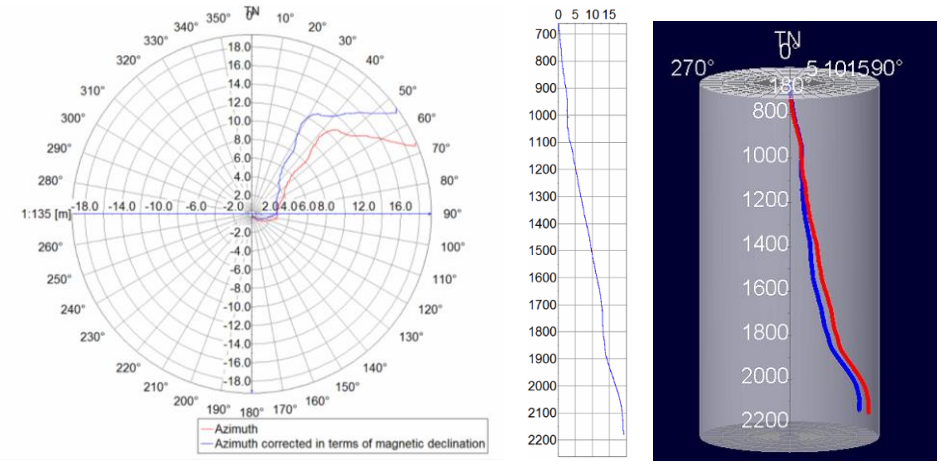

Figure 2. *Well path of K-18. The blue lines signify the well path when the azimuth log has been corrected with respect to magnetic declination. Left: bull's eye projection, middle: closure view projection (see text), right: 3D view of the well path.*

Image quality is good from casing end to 795 m (which is the boundary between intrusions and a hyaloclastite formation) and from ~2127 m to the bottom of the Televiewer log (which is at 2185.5 m after the downward shift of 5.7 m), where strong acoustic signal was acquired. Weak acoustic signal was acquired between these intervals, at 795–2127 m depth. Intervals of good image quality (strong acoustic signal) are identified with pink color in Figure 3, where they are presented in comparison with an overview of density of interpreted features ("truedip"), caliper-, gamma-, neutron- and resistivity logs, lithology, image logs and a 3D image of the well. As shown in the figure, the majority of interpreted features are located within intervals of good image quality. Comparisons of fracture densities should therefore be made with caution and only between intervals of similar image quality ranking.

Drill cutting analysis presented on images in this report are from two sources, on the one hand a simple lithology log from ÍSOR's preliminary Petrel model of Krafla (in progress), which is based on Guðmundsson et al. (1981), and on the other hand a more detailed cutting analysis from Stefánsson et al.'s unpublished report, drafted in 1983. A comparison of data from these two sources is presented in Figure 3.

Legend for lithology, alteration and feed-point symbols presented in this report is shown in Figure 4.

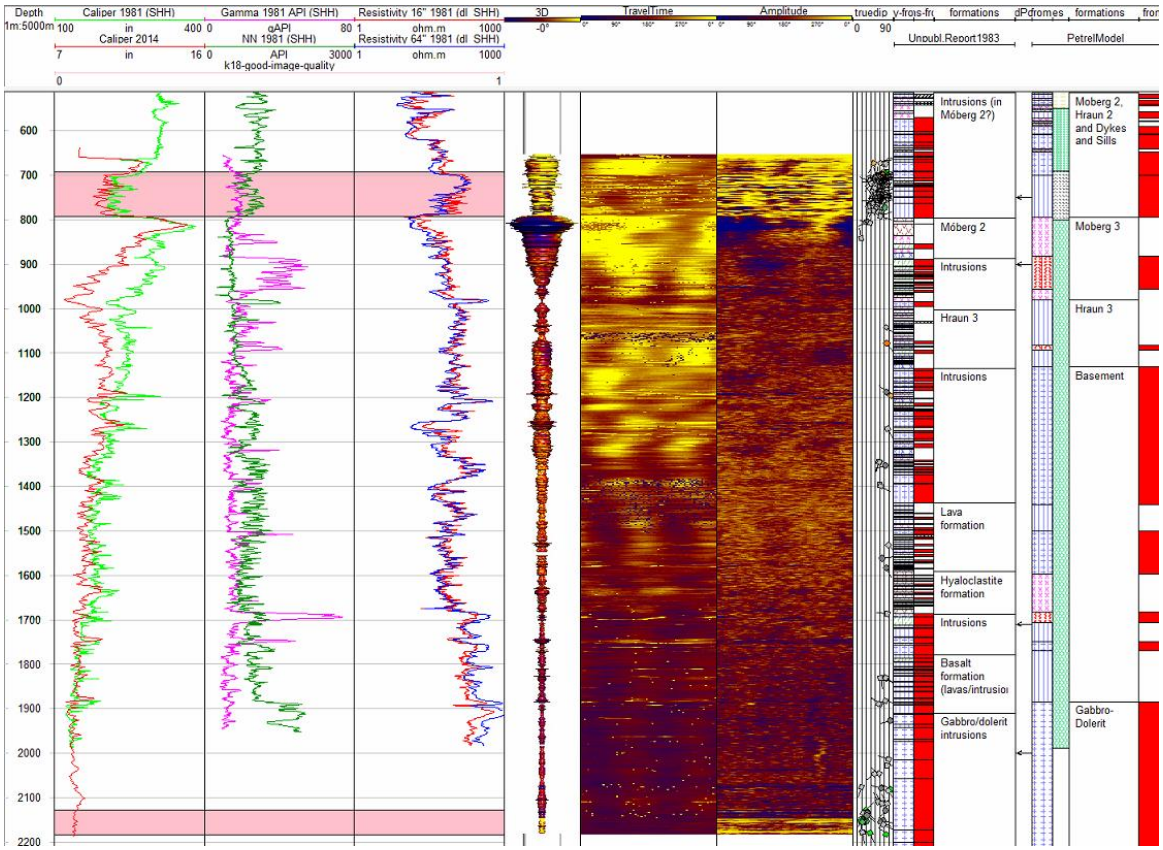

Figure 3. *Overview of the density of interpreted fractures („truedip") in comparison with intervals of good image quality (strong acoustic signal), identified with pink color.*

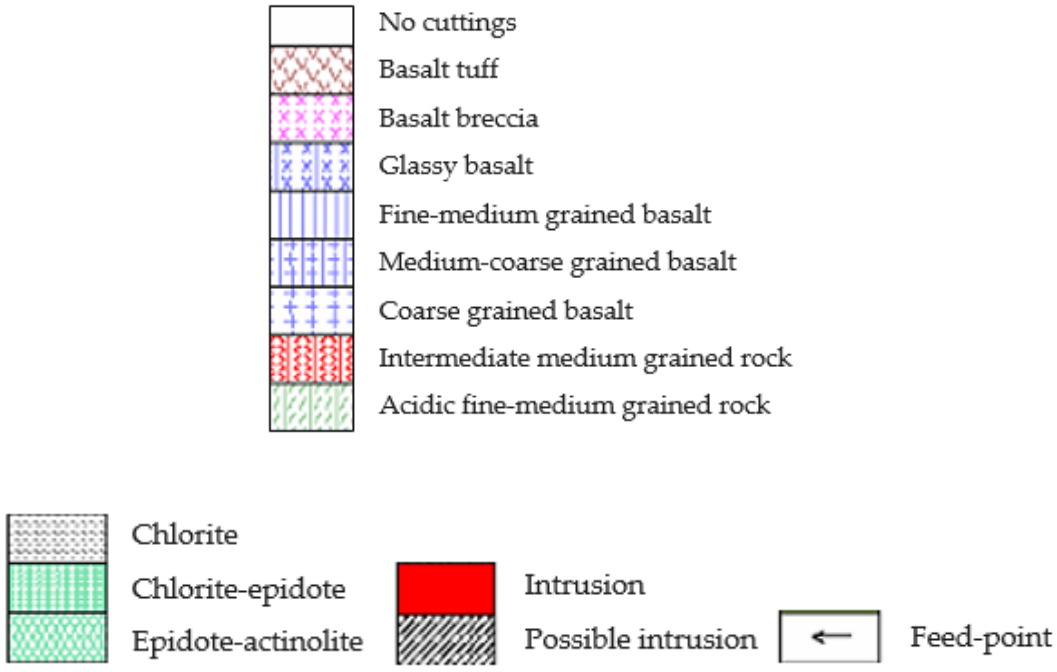

Figure 4. *Legend for lithology, alteration and feed-point symbols presented in this report.*

3 Structural analysis

The ABI-43 logging tool provides an oriented image of the inside of the borehole wall which relies on the time duration and amplitude of a reflected acoustic pulse. Planar features intersecting the borehole appear as sinusoids across the 2D image, and are derived from the image log by fitting sine waves interactively to the observed features. Each feature has its true orientation (dip from horizontal & dip direction), which is calculated automatically, taking into account image orientation, caliper measurements and orientation of the well.

Identified geological features were classified into two basic categories; joints/fractures and interfaces. Joints/fractures were further divided into closed (filled/cemented or tight/discontinuous) and partially open (partially filled/cemented joints/fractures or tight/discontinuous joints/fractures that appear on the Televiewer images to be partially open). Two levels of confidence are assigned to each feature type. High confidence features (CL1) are those that appear as continuous sine waves in the Televiewer images and are picked with the least ambiguity. Low confidence features (CL2) are more difficult to accurately select in an image, and tend to form only partial or discontinuous sinusoids with lengths less than the describing sine wave. Discontinuity may be caused by the event itself being discontinuous or non-planar, or by the hole shape, borehole conditions or poor signal. Orientation (dip & dip direction) of low confidence features are used with caution and only to reinforce interpretations made from high confidence features. The groups, along with color legend, are presented in Table 2.

Table 2. *Color legend for feature classification:*

Color	Feature type	Level of confidence
	Partially open joint/fracture	High confidence level (CL1)
	Partially open joint/fracture	Low confidence level (CL2)
	Filled/cemented or tight/discontinusous joint/fracture	High confidenece level (CL1)
	Filled/cemented or tight/discontinusous joint/fracture	Low confidence level (CL2)
	Interface	High confidenece level (CL1)
	Interface	Low confidence level (CL2)
	Broken zone/uncertain classification	High confidence level (CL1)

The majority of identified features is located at the interval from the casing end to 795 m, where acoustic signal is strong. Few features are interpreted at the interval at 795–2127 m, where acoustic signal is weak, and those interpreted are usually picked with low confidence. The interval from 2127 m to the bottom of the log is not as fractured as the upper interval of good image quality. Orientations of the interpreted geological features are presented on Wulff plots (upper hemisphere) in Figure 5 and on rose diagrams in Figure 6 (joints/fractures) and Figure 7 (interfaces), showing that joints and fractures predominantly dip towards ENE. Interfaces can be roughly divided into steeply dipping, N-S- and NE-SW striking features and sub-horizontal, ~E-W- to ESE-WNW striking features. Orientations of the interpreted features are presented in table format in Appendix 1 and on Wulff plots for each 5 m interval in Appendix 2.

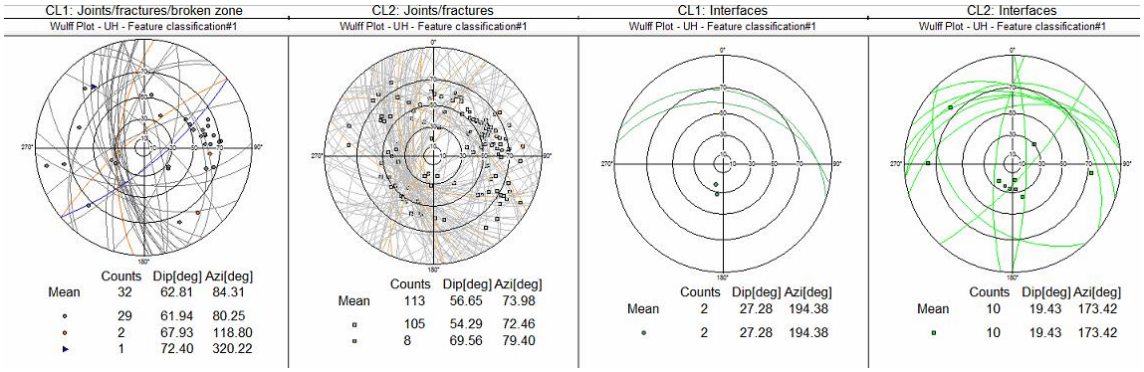

Figure 5. *Planes of features interpreted at 665–2185.5 m depth, projected on Wulff plots (upper hemisphere). Left and second from left: closed and partially open joints/fractures, right and second from right: interfaces. CL1: features picked with high confidence; CL2: features picked with low confidence. Averages of dips from horizontal („Dip") and dip azimuths („Azi") are presented below each Wulff plot.*

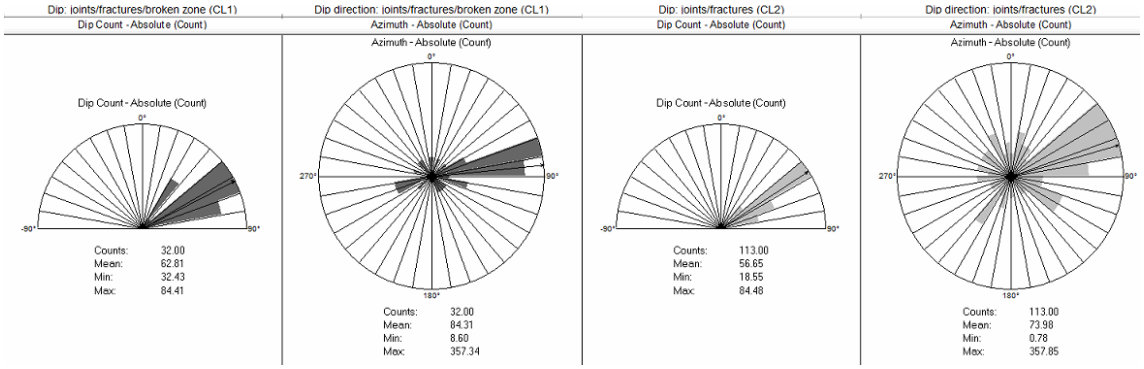

Figure 6. *Rose diagrams showing the dips (from horizontal) and dip directions of joints and fractures interpreted at 665–2185.5 m. Dark grey: features picked with high confidence; light grey: features picked with low confidence.*

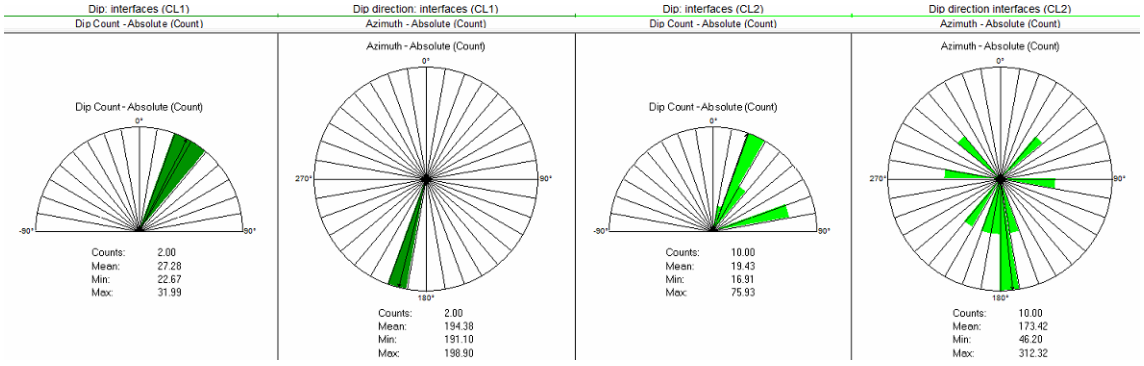

Figure 7. *Rose diagrams showing the dips (from horizontal) and dip directions of interfaces interpreted at 665–2185.5 m. Dark green: features picked with high confidence; light green: features picked with low confidence.*

3.1 Joints and fractures

The majority (134; thereof 29 picked with high confidence and 105 picked with low confidence) of identified features (157 total features) are filled/cemented or tight/discontinuous joints and fractures. Ten fractures in addition appear to be partially open (2 picked with high confidence; 8 picked with low confidence). No large open fractures were observed. Results of the Televiewer data analysis suggest that joints and fractures within the logged interval predominantly strike from NW-SE to N-S and dip 58° on average towards NE/E. Eight of the 10 joints/fractures interpreted as partially open strike from ~NW-SE to NE-SW and dip ~60–80° from horizontal towards ~NE/E/SE, while two strike ESE-WNW, one dipping towards NNE, while the other dips SSW. Closed joints and fractures strike more variously than partially open, but the most prominent orientation of such features is ~NNW-SSE strike and ~50–70° dip from horizontal towards ENE.

Three feed-points are estimated within the logged interval; at 750, 900 and 1710 m (Stefánsson et al., unpubl.). One of these, at 750 m depth, is located in the vicinity of observed partially open fractures at 744 and 746 m (~N-S striking, ~63° dip towards E), indicating that these could possibly be permeable. No correlation is seen between feed-points and fractures observed in the Televiewer images within the interval of weak acoustic signal (795–2127 m).

One feature, at 773–774.5 m depth (Figure 8b), is of uncertain classification, but is considered to represent a broken zone, or even possibly hyaloclastite between two intrusions. The feature, which is picked with high confidence, strikes NE-SW and dips 72° towards NW.

3.2 Interfaces

A feature is classified as an interface if it marks the boundary between two distinct image fabrics, as the fabric is the image response to the bulk lithology making up the formation (e.g. Trice, 1999). Altogether 12 features were classified as interfaces (2 picked with high confidence; 10 picked with low confidence). Two of these, at 692 and 694 m, are considered to represent contacts between basaltic dykes and an adjacent hyaloclastite formation (Figure 8a), as these are observed in the vicinity of such boundaries with regard to drill cutting analysis. These interfaces are steeply dipping and strike N-S and dip towards W and E. A dyke contact is also considered to exist at the bottom of the Televiewer log (2182 m), striking NE-SW and dipping 75° towards NW (Figure 8f). Additionally, dyke contacts are considered to be observed at ~703 and ~792 m depth, although the orientations of these could not be determined. The upper contact (703 m) is considered in terms of cutting analysis to be between a fine-medium grained and a medium-coarse grained basaltic intrusion (Figure 8c), while the lower (792 m) probably represents the change from intrusion to a hyaloclastite formation (Figure 8d).

Changes were detected in the image logs at two locations within the interval of weak acoustic signal, which are believed to be related to changes observed in drill cuttings and in lithology logs. These are very obscure in both cases, thus orientations could not be determined. The upper is observed at ~983–991 m depth (Figure 9, left), and is

considered to represent an intrusion into basalt breccia, detected in drill cuttings (Stefánsson et al., unpubl.) and also indicated by the lithology logs at similar depth. The lower change is observed within dolerite at ~1258–1275 m (Figure 9, right). At similar depth, decrease is seen in resistivity logs, increase in caliper, and some fluctuations in the neutron log (which could be related to changes in caliper). Furthermore, the color of the dolerite is dark-green to grey-black at this interval, but light-green to green above and below (Stefánsson et al., unpubl.).

The remainder of the interpreted interfaces is located in the lowermost part of the well (2127–2185 m), within gabbro intrusions according to drill cutting analysis (Guðmundsson et al., 1981; Stefánsson et al., unpubl.). These are most often sub-horizontal features, some of which are non-planar and do not fit to a sinus wave. In several cases, the interfaces are observed as very abrupt changes in the image fabric (Figure 8e). Where possible, orientations of the observed interfaces were picked, and in cases of non-planar features, picking was assigned to the low confidence level. The results indicate that these interfaces, which are discussed further in the next paragraphs, generally strike in the range from ESE-WNW to ~E-W and dip ~30° towards SSW/S.

3.2.1. Speculations on the nature of the sub-horizontal interfaces

Considering the depth of the sub-horizontal interfaces, located at 2127–2185 m depth within gabbro intrusions, they are believed to mark boundaries between distinct intrusions, presumably sill intrusions as indicated by the small dip of the interface features. The non-planar features observed in the amplitude image (Figure 8e) may suggest that magma intruded a still unsolidified intrusive material.

Very coarse-grained intrusion rock is predominant in cutting samples from the lowermost part of the well (1910–2216 m; Stefánsson et al., unpubl.). As the samples are fairly mixed, details on this depth interval in the well on grounds of cutting analysis were prevented (Stefánsson et al., unpubl.). Gamma ray logs do not reach to the depth in question and are thus not useful in determining the lithology at this location in the well in more detail than has been done on grounds of drill cuttings, and as the properties measured during borehole image log surveys are not direct indicators of lithology, lithology of the sill intrusions is uncertain. Given that alternating granophyre and dolerite intrusions have been recorded at similar depth in other wells in Krafla (e.g. Guðmundsson et al., 1992), it could be of interest to look further into if this is also the case in the lowermost part of well K-18.

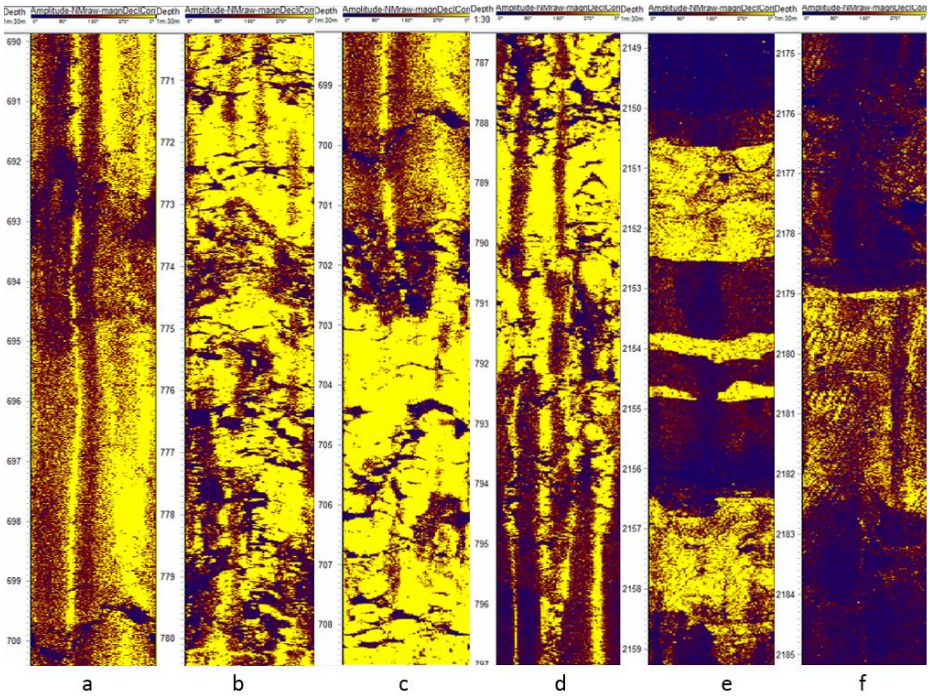

Figure 8. *Interfaces. a: dyke/hyaloclastite contacts at 692 and 694 m (hyaloclastite seen at 692–694 m), b: broken zone (uncertain classification) at 773–774.5 m, c: contact between a medium-coarse grained basaltic intrusion (above 703 m) and a fine-medium grained intrusion (below 703 m) at 703 m, d: contact between intrusion and hyaloclastite at ~792 m, e: sub-horizontal planar and non-planar interfaces in gabbro in the lowermost part of the Televiewer log, f: steeply dipping interface (dyke contact) at 2182 m.*

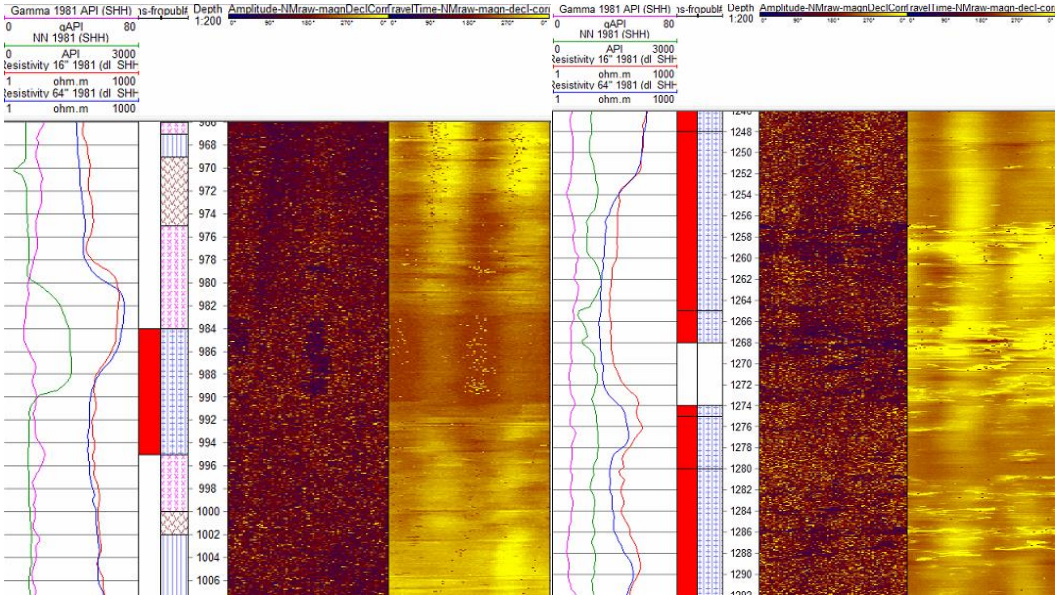

Figure 9. *Left: a change is observed at ~983–991 m depth, probably representing an intrusion analysed in drill cuttings at 984–995 m and also indicated by lithology logs at similar depth. Right: a change at ~1258–1275 m within dolerite. The color of the dolerite is dark-green to grey-black at 1258–1275 m according to drill cutting analysis, while it is light-green to green above and below this interval. Changes are also detected in lithology logs at this interval. Note that the depth scale here is 1:200.*

4 Conclusions

Results of the structural analysis of well K-18 in Krafla on grounds of Televiewer data suggest that no large open fractures exist within the logged interval, only filled/-cemented, closed/discontinuous and partially open joints and fractures. Results of the data analysis indicate that joints and fractures within the logged interval predominantly strike in the range from NW-SE to N-S and dip 58° on average towards NE/E. Interfaces observed in the Televiewer images, which can be roughly divided into steeply dipping and sub-horizontal features, are considered to represent contacts of intrusions, either with adjacent hyaloclastite or other intrusions. The steeply dipping interfaces, representing dykes, strike from ~N-S to ESE-WSW and dip towards W, NW, NNW and E. The sub-horizontal interfaces, which are observed in the lowermost part of the well within gabbro intrusions according to drill cutting analysis, generally dip ~30° towards SSW and are considered to represent boundaries of sill intrusions. Some of these interfaces are non-planar, which may suggest that magma intruded a still unsolidified rock material.

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Appendix 1: Dip and dip direction of interpreted features

Depth (m)	Dip Azimuth (°)	Dip (°)	Feature type
672,72	70,99	51,88	CL2: Filled/cemented or tight/discontinuous joint/fracture
672,88	64,93	53,13	CL2: Filled/cemented or tight/discontinuous joint/fracture
673,07	211,31	52,53	CL2: Partially open joint/fracture
673,32	55,58	68,81	CL2: Filled/cemented or tight/discontinuous joint/fracture
673,38	56,38	72,02	CL2: Partially open joint/fracture
692,26	270,52	75,93	CL2: Interface
694,99	96,31	71,83	CL2: Interface
699,66	84,49	69,95	CL2: Partially open joint/fracture
701,48	112,2	59,47	CL2: Partially open joint/fracture
701,92	77,32	52,16	CL2: Filled/cemented or tight/discontinuous joint/fracture
702,33	99,81	54,32	CL2: Filled/cemented or tight/discontinuous joint/fracture
702,35	128,45	59,65	CL2: Filled/cemented or tight/discontinuous joint/fracture
702,93	43,48	51,41	CL2: Filled/cemented or tight/discontinuous joint/fracture
703,82	8,6	52,29	CL1: Filled/cemented or tight/discontinuous joint/fracture
704,64	67,67	73,66	CL2: Filled/cemented or tight/discontinuous joint/fracture
704,97	84,04	78,85	CL2: Partially open joint/fracture
705,17	345,04	52,38	CL2: Filled/cemented or tight/discontinuous joint/fracture
705,39	7,71	57,95	CL2: Filled/cemented or tight/discontinuous joint/fracture
705,91	58,46	59,01	CL2: Filled/cemented or tight/discontinuous joint/fracture
706,27	248,17	55,27	CL2: Filled/cemented or tight/discontinuous joint/fracture
706,7	56,76	44,15	CL2: Filled/cemented or tight/discontinuous joint/fracture
706,75	75,21	35,08	CL2: Filled/cemented or tight/discontinuous joint/fracture
707,8	262,17	51,29	CL2: Filled/cemented or tight/discontinuous joint/fracture
708,03	357,34	51,6	CL1: Filled/cemented or tight/discontinuous joint/fracture
708,04	85,02	64,69	CL2: Filled/cemented or tight/discontinuous joint/fracture
709,65	85,36	70,73	CL1: Filled/cemented or tight/discontinuous joint/fracture
709,82	76,62	68,41	CL2: Filled/cemented or tight/discontinuous joint/fracture
711,77	67,48	63,28	CL2: Filled/cemented or tight/discontinuous joint/fracture
712,47	85,71	69,79	CL1: Filled/cemented or tight/discontinuous joint/fracture
712,49	288,44	38,41	CL2: Filled/cemented or tight/discontinuous joint/fracture
712,6	244,73	49,13	CL2: Filled/cemented or tight/discontinuous joint/fracture
713,22	78,92	56,78	CL1: Filled/cemented or tight/discontinuous joint/fracture
713,66	55,67	60,41	CL2: Filled/cemented or tight/discontinuous joint/fracture
714,37	73,54	59,17	CL1: Filled/cemented or tight/discontinuous joint/fracture
714,51	66,63	58,15	CL2: Filled/cemented or tight/discontinuous joint/fracture
714,92	215,5	51,96	CL2: Filled/cemented or tight/discontinuous joint/fracture
716,27	68,62	56,19	CL2: Filled/cemented or tight/discontinuous joint/fracture
716,67	274,84	45,48	CL2: Filled/cemented or tight/discontinuous joint/fracture
717,64	218,7	41,63	CL2: Filled/cemented or tight/discontinuous joint/fracture
717,73	63,21	61,02	CL2: Filled/cemented or tight/discontinuous joint/fracture
719,09	84,03	40,56	CL2: Filled/cemented or tight/discontinuous joint/fracture
719,16	50,84	53,84	CL2: Filled/cemented or tight/discontinuous joint/fracture
719,26	218,86	50,57	CL2: Filled/cemented or tight/discontinuous joint/fracture
721,89	115,26	75,51	CL2: Filled/cemented or tight/discontinuous joint/fracture
721,9	260,04	36,48	CL2: Filled/cemented or tight/discontinuous joint/fracture
722	120,3	75,94	CL2: Filled/cemented or tight/discontinuous joint/fracture
723,24	74,44	64,27	CL2: Filled/cemented or tight/discontinuous joint/fracture
723,44	100,43	52,49	CL2: Filled/cemented or tight/discontinuous joint/fracture
725,96	25,55	61,61	CL2: Filled/cemented or tight/discontinuous joint/fracture
726,05	55,15	56,49	CL2: Filled/cemented or tight/discontinuous joint/fracture
726,45	66,62	65,66	CL1: Filled/cemented or tight/discontinuous joint/fracture
727,55	21,23	61,14	CL2: Filled/cemented or tight/discontinuous joint/fracture
727,68	27,04	58,78	CL2: Filled/cemented or tight/discontinuous joint/fracture
728,6	198,35	47,83	CL2: Filled/cemented or tight/discontinuous joint/fracture
735,66	61,59	59,42	CL2: Filled/cemented or tight/discontinuous joint/fracture
735,9	39,42	55,28	CL2: Filled/cemented or tight/discontinuous joint/fracture
737,07	59,57	58,94	CL2: Filled/cemented or tight/discontinuous joint/fracture
737,29	0,78	59,36	CL2: Filled/cemented or tight/discontinuous joint/fracture
741,2	78,57	58,56	CL2: Filled/cemented or tight/discontinuous joint/fracture
742,18	335,78	48,6	CL2: Filled/cemented or tight/discontinuous joint/fracture
742,24	69,25	51,02	CL2: Filled/cemented or tight/discontinuous joint/fracture
742,4	79,48	56,92	CL2: Filled/cemented or tight/discontinuous joint/fracture

Depth (m)	Dip Azimuth (°)	Dip (°)	Feature type
742,88	87,1	63,19	CL1: Filled/cemented or tight/discontinuous joint/fracture
743,28	50,27	54,16	CL2: Filled/cemented or tight/discontinuous joint/fracture
743,79	33,96	50,23	CL2: Filled/cemented or tight/discontinuous joint/fracture
744,27	307,46	62,28	CL2: Filled/cemented or tight/discontinuous joint/fracture
744,38	95,38	62,96	CL1: Partially open joint/fracture
744,97	88,36	61,62	CL2: Filled/cemented or tight/discontinuous joint/fracture
745,21	87,01	59,31	CL1: Filled/cemented or tight/discontinuous joint/fracture
746,12	72,61	62,37	CL2: Partially open joint/fracture
749,22	330,04	43,55	CL2: Filled/cemented or tight/discontinuous joint/fracture
750,85	79,01	59,94	CL1: Filled/cemented or tight/discontinuous joint/fracture
752,62	90,95	63,64	CL2: Filled/cemented or tight/discontinuous joint/fracture
752,96	63,4	50,59	CL1: Filled/cemented or tight/discontinuous joint/fracture
753,38	79,75	63,89	CL2: Filled/cemented or tight/discontinuous joint/fracture
753,69	83,33	61,08	CL2: Filled/cemented or tight/discontinuous joint/fracture
753,95	77,93	59,86	CL1: Filled/cemented or tight/discontinuous joint/fracture
754,37	57,06	41,48	CL2: Filled/cemented or tight/discontinuous joint/fracture
756,4	318,51	74,69	CL2: Filled/cemented or tight/discontinuous joint/fracture
757,18	87,1	68,76	CL2: Filled/cemented or tight/discontinuous joint/fracture
757,94	18,62	56,69	CL2: Partially open joint/fracture
758,03	269,72	42,36	CL2: Filled/cemented or tight/discontinuous joint/fracture
758,1	356,12	55,91	CL2: Filled/cemented or tight/discontinuous joint/fracture
758,4	62,22	57,14	CL2: Filled/cemented or tight/discontinuous joint/fracture
759,09	79,77	48,11	CL2: Filled/cemented or tight/discontinuous joint/fracture
759,56	66,59	52,08	CL2: Filled/cemented or tight/discontinuous joint/fracture
759,95	47,34	52,68	CL2: Filled/cemented or tight/discontinuous joint/fracture
760,27	56,4	49,79	CL1: Filled/cemented or tight/discontinuous joint/fracture
760,73	70,19	51,67	CL1: Filled/cemented or tight/discontinuous joint/fracture
768,35	28,33	36,95	CL1: Filled/cemented or tight/discontinuous joint/fracture
771,12	142,8	34,68	CL2: Filled/cemented or tight/discontinuous joint/fracture
773,82	320,22	72,4	CL1: Broken zone (uncertain classification)
775,03	233,4	52	CL2: Filled/cemented or tight/discontinuous joint/fracture
775,14	35,83	55,94	CL2: Filled/cemented or tight/discontinuous joint/fracture
775,21	216,85	50,3	CL2: Filled/cemented or tight/discontinuous joint/fracture
780,73	13,96	45,31	CL2: Filled/cemented or tight/discontinuous joint/fracture
780,89	344,34	36,21	CL2: Filled/cemented or tight/discontinuous joint/fracture
783,49	357,85	61,1	CL2: Filled/cemented or tight/discontinuous joint/fracture
783,9	131,53	56,96	CL2: Filled/cemented or tight/discontinuous joint/fracture
784,01	19,02	63,07	CL2: Filled/cemented or tight/discontinuous joint/fracture
790,33	71,41	63,93	CL1: Filled/cemented or tight/discontinuous joint/fracture
792,33	108,03	61,79	CL2: Filled/cemented or tight/discontinuous joint/fracture
805,66	10,28	29,95	CL2: Filled/cemented or tight/discontinuous joint/fracture
806,49	248,07	35,03	CL1: Filled/cemented or tight/discontinuous joint/fracture
807,25	280,11	38,48	CL2: Filled/cemented or tight/discontinuous joint/fracture
841,4	352,99	18,55	CL2: Filled/cemented or tight/discontinuous joint/fracture
1042,3	126,2	73,81	CL2: Filled/cemented or tight/discontinuous joint/fracture
1079,35	140,2	75,93	CL1: Partially open joint/fracture
1188,48	312,36	74,41	CL2: Filled/cemented or tight/discontinuous joint/fracture
1189,19	315,09	74,9	CL1: Filled/cemented or tight/discontinuous joint/fracture
1196,08	118,34	84,48	CL2: Partially open joint/fracture
1344,71	192,71	57,61	CL2: Filled/cemented or tight/discontinuous joint/fracture
1344,87	201,32	59,21	CL2: Filled/cemented or tight/discontinuous joint/fracture
1354,26	258,2	73,4	CL1: Filled/cemented or tight/discontinuous joint/fracture
1395,96	178,48	59,78	CL2: Filled/cemented or tight/discontinuous joint/fracture
1399,42	123,35	62,41	CL2: Filled/cemented or tight/discontinuous joint/fracture
1531,95	134,83	79,11	CL2: Filled/cemented or tight/discontinuous joint/fracture
1562,39	80,2	66,45	CL1: Filled/cemented or tight/discontinuous joint/fracture
1584,13	154,35	74,81	CL1: Filled/cemented or tight/discontinuous joint/fracture
1686,29	277,31	76,36	CL2: Filled/cemented or tight/discontinuous joint/fracture
1830,72	120,25	71,01	CL2: Filled/cemented or tight/discontinuous joint/fracture
1830,92	170,65	61,64	CL2: Filled/cemented or tight/discontinuous joint/fracture
1831,01	119,72	72,96	CL2: Filled/cemented or tight/discontinuous joint/fracture
1881,55	109,97	72,34	CL2: Filled/cemented or tight/discontinuous joint/fracture
1888,83	303,78	61,04	CL2: Filled/cemented or tight/discontinuous joint/fracture
1889,04	312,56	56,83	CL2: Filled/cemented or tight/discontinuous joint/fracture
1927,56	259,21	84,41	CL1: Filled/cemented or tight/discontinuous joint/fracture

Depth (m)	Dip Azimuth (°)	Dip (°)	Feature type
2013,02	289,54	79,02	CL2: Filled/cemented or tight/discontinuous joint/fracture
2028,04	93,54	76,98	CL2: Filled/cemented or tight/discontinuous joint/fracture
2046,23	305,06	58,31	CL2: Filled/cemented or tight/discontinuous joint/fracture
2046,53	232,55	47,89	CL2: Filled/cemented or tight/discontinuous joint/fracture
2075,31	196,86	19,5	CL2: Filled/cemented or tight/discontinuous joint/fracture
2079,52	287,25	63,48	CL1: Filled/cemented or tight/discontinuous joint/fracture
2084,28	143,93	78,43	CL2: Filled/cemented or tight/discontinuous joint/fracture
2109,24	334,88	57,1	CL2: Filled/cemented or tight/discontinuous joint/fracture
2112,77	330,12	75,91	CL2: Filled/cemented or tight/discontinuous joint/fracture
2113,01	328,58	64,67	CL2: Filled/cemented or tight/discontinuous joint/fracture
2127,69	46,2	30,14	CL2: Interface
2129,06	223,46	72,61	CL1: Filled/cemented or tight/discontinuous joint/fracture
2132,88	185,24	30,44	CL2: Filled/cemented or tight/discontinuous joint/fracture
2132,94	187,27	25,56	CL2: Interface
2133,62	240,18	33,22	CL1: Filled/cemented or tight/discontinuous joint/fracture
2134,15	204,55	23,29	CL2: Filled/cemented or tight/discontinuous joint/fracture
2136,04	130,51	33,17	CL1: Filled/cemented or tight/discontinuous joint/fracture
2141,35	127	32,43	CL1: Filled/cemented or tight/discontinuous joint/fracture
2150,06	163,44	34,88	CL2: Interface
2150,63	219,75	22,87	CL2: Interface
2151,63	105,8	67,53	CL1: Filled/cemented or tight/discontinuous joint/fracture
2152,53	171,96	16,91	CL2: Interface
2153,79	191,1	31,99	CL1: Interface
2154,1	199,9	24,26	CL2: Interface
2154,86	198,9	22,67	CL1: Interface
2156,39	108,91	62,49	CL1: Filled/cemented or tight/discontinuous joint/fracture
2160,33	119,17	67,55	CL2: Filled/cemented or tight/discontinuous joint/fracture
2178,42	168,88	21,4	CL2: Filled/cemented or tight/discontinuous joint/fracture
2178,95	172,85	26,28	CL2: Interface
2182,26	312,32	75,42	CL2: Interface

Appendix 2:

Image logs, with RBR, Azimuth, Tilt, MagnField and Gravity from the Televiewer tool, Caliper-, gamma-, NN-, and resistivity-logs, drill cutting analysis, and Wulff plots for each 5 m interval