P-07-03

Oskarshamn site investigation

Modal analyses on rock mechanical specimens

Specimens from borehole KLX03, KLX04, KQ0064G, KQ0065G, KF0066A and KF0069A

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March 2007

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Keywords: Modal analyses, Classification of rock types, Rock mechanics, Uniaxial compression test, Elasticity parameters, Density, AP PS 400-06-040.

Abstract

This report comprise results of modal analyses performed during 2006 of 26 rock core samples from drill holes at SKB's site ivestigation area in Oskarshamn. The rock cores are taken from drill holes KLX03 and KLX04 at Laxemar area and KF0066, KF0069, KQ0064 and KQ0065 at Äspö HRL (Hard Rock Laboratory). The samples has previously been used for strenght tests, i.e. mainly for uniaxial and triaxial compression tests. The purpose of this work is primarely to investigate if there are any connections between the mineral composition and the results from the rock strenght.

A weak connection is found between the content of quartz and the rock strenght, i.e. a low strenght value responds to a low content of quartz, but not always. Also there seem to be a connection between drill hole and strenght, i.e. in the same drill hole/site (regardless rock type) the expected magnitude responds to the value of the rock strenght.

Sammanfattning

I denna rapport redovisas resultat av modalanalyser utförda på 26 kärnprover från borrhål i både Laxemar och Äspö HRL vid Oskarshamn. Borrhålen från Laxemar är KLX03 och KLX04 och från Äspö HRL KF0066, KF0069, KQ0064 och KQ0065. De analyserade proverna har valts ut från tidigare hållfasthetsprovningar, dvs i huvudsak enaxliga tryckförsök och enstaka treaxliga tryckförsök. Syftet med modalanalyserna på tidigare prov från hållfasthetsprovning är att klargöra om mineralinnehållet har någon koppling till resultaten från hållfasthetsprovningen.

En svag koppling finns mellan kvartsinnehållet och provets hållfasthetsvärde, dvs ett lågt hållfasthetsvärde har oftast ett lågt kvartsinnehåll men inte alltid. Likaså finns en svag koppling mellan borrhål och hållfasthet, dvs inom samma område/borrhål (oberoende bergart) finns en viss koppling till förväntad storleksnivå på hållfasthetsvärdet.

Contents

1 Introduction

This document reports performance and results gained by modal analyses on specimens which had been tested for uniaxial or triaxial compression tests. These three investigations are activities performed within the site investigation at Oskarshamn. The work was carried out in accordance with activity plan AP PS 400-06-040.

In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

Earlier investigations show a high variation in compressive strength, from 150 to 260 MPa. The variation of the results are in the same magnitude in samples from both Laxemar and Äspö HRL. These results leads to an uncertainty in the site description model along with questions regarding the stability of the excavations for the nuclear power waste disposial facility, since the rock stresses increases with depth and the rock strenght become unexpectedly low.

An explanation of the large variety in the compressive strenght could be connected to the content of mineral of the rock cores, and particulary the content of quartz.

Samples were taken in order to characterise the rock types at specimens which has been previously tested for uniaxial or triaxial compression tests.

The uniaxial samples were both from the Laxemar subarea (KLX03 and KLX04) and Äspö HRL (KQ0064G, KQ0065G, KF0066A and KF0069A) and the triaxial samples were from Äspö HRL (KQ0064G and KQ0065G), see Figure 1-1.

The uniaxial or triaxial compression tests were carried out in earlier activities and reported in different reports, see Table 1-2.

Table 1-1. Controlling documents for the performance of the activity.

Activity plan	Number	Version
Modalanalysbestämning för bergmekanisk provning	AP PS 400-06-040	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för bergartsanalyser	SKB MD 160.001	1.0
Uniaxial compression test for intact rock	SKB MD 190.001	2.0
Triaxial compression test for intact rock	SKB MD 190.003	2.0

Table 1-2. The uniaxial or triaxial compression test and where they are reported.

Borehole and number of analyses in this activity	Uniaxial or triaxial compression test	Reported	Reference
KLX03 (6)	Uniaxial	P-05-90 (Laxemar)	/SKB 2005b/
KLX04 (6)	Uniaxial	P-04-261 (Laxemar)	/SKB 2004b/
KQ0064, KQ0065 (5, 4)	Uniaxial and triaxial	R-04-01 (Äspö HRL)	/SKB 2004a/
KF0066, KF0069 (3, 2)	Uniaxial	IPR-05-33 (Äspö HRL)	/SKB 2005a/

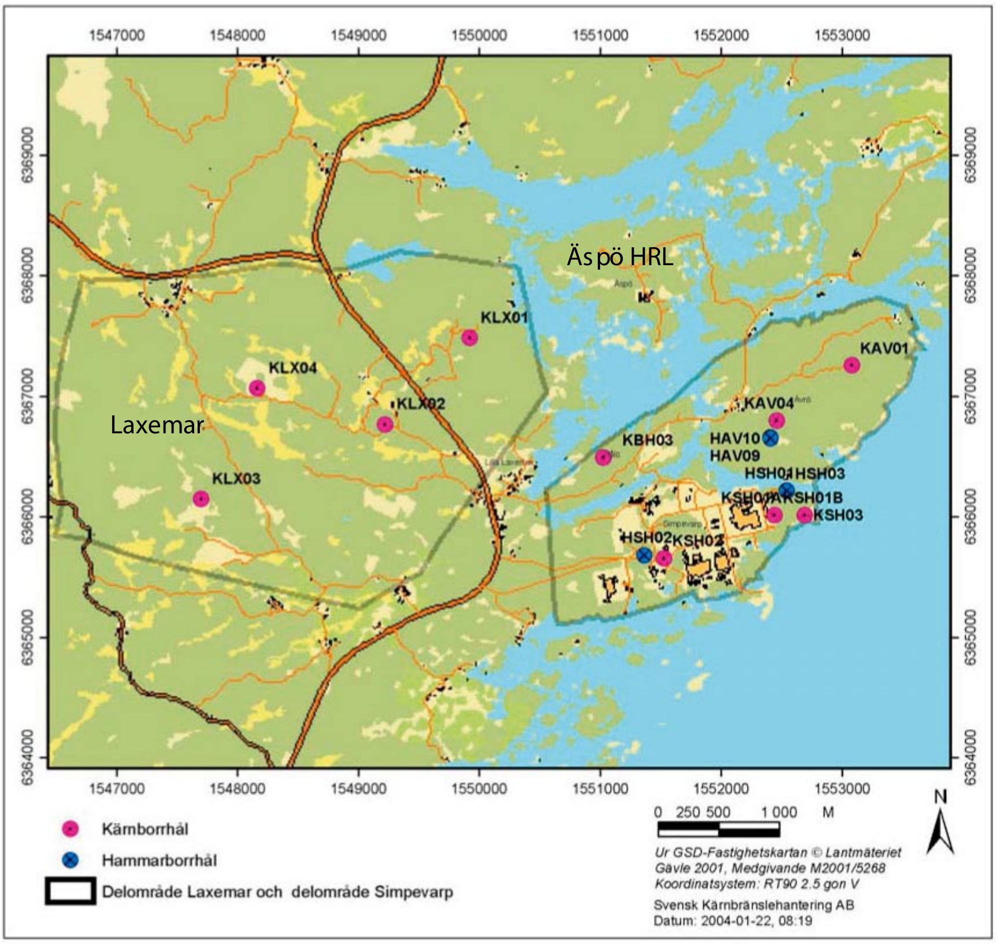

Figure 1-1. *General overview over Oskarshamn site investigation area, with KLX03 and KLX04 and Äspö HRL between Laxemar and Simpevarp subarea.*

2 Objective and scope

The purpose of this activity is to determine the mineralogical characterisation, by modal analyses, on earlier tested specimens from uniaxial or triaxial compression tests. The earlier specimens were taken from both Laxemar subarea and Äspö HRL.

The mineralogy analyses should help to understand the results and its variation from the uniaxial or triaxial compression tests. The results from the compression tests are to be used in the site description rock mechanical model, which will be established for the candidate area selected for the site investigations at Oskarshamn.

3 Equipment

3.1 Description of equipment/interpretation tools

The results of the modal analyses have been recalculated and plotted in the QAP classification diagram of /Streckeisen 1976/.

According to the International Union of Geological Sciences /LeMaitre 2002/, the classification of igneous rocks should be based on the modal composition.

4 Execution

4.1 General

Half of a 5 cm long section of the drill core was selected for analyses. A reference sample of the drill core was kept from the making of the thin-sections. The analyses were carried out in accordance with the method description "Metodbeskrivning för bergartsanalyser" (SKB MD 160.001, SKB internal document).

The identication marks, upper and lower sampling depth (Secup and Seclow) and type of test are shown in Table 4-1.

4.2 Execution of analyses

The modal analyses have been carried out by Ekström Mineral AB by mineral identification and point counting of 500 points in each thin-section.

Table 4-1. Selected samples showing drill hole length and type of test.

Identification	Secup (m)	Seclow (m)	Comment
KLX03-200-1	292.36	292.46	Uniaxial test
KLX03-200-2	292.68	292.78	Uniaxial test
KLX03-200-3	513.27	513.37	Uniaxial test
KLX03-200-4	513.41	513.51	Uniaxial test
KLX03-200-5	690.81	690.91	Uniaxial test
KLX03-200-6	691.38	691.48	Uniaxial test
KLX04-200-1	306.72	306.82	Uniaxial test
KLX04-200-2	306.86	306.96	Uniaxial test
KLX04-200-3	564.77	564.87	Uniaxial test
KLX04-200-4	564.91	565.01	Uniaxial test
KLX04-200-5	747.81	747.91	Uniaxial test
KLX04-200-6	747.95	748.05	Uniaxial test
KF0066A01-1	26.06	26.16	Uniaxial test
KF0066A01-2	29.62	29.72	Uniaxial test
KF0066A01-3	29.75	29.85	Uniaxial test
KF0069A01-1	40.99	41.09	Uniaxial test
KF0069A01-2	46.26	46.36	Uniaxial test
KQ0064G01-1	6.16	6.26	Uniaxial test
KQ0064G01-2	5.34	5.44	Triaxial test
KQ0064G07-1	4.89	4.99	Uniaxial test
KQ0064G07-2	5.28	5.38	Uniaxial test
KQ0064G07-3	5.03	5.13	Triaxial test
KQ0065G01-1	5.19	5.29	Uniaxial test
KQ0065G01-2	5.33	5.43	Uniaxial test
KQ0065G01-3	7.27	7.37	Uniaxial test
KQ0065G01-4	7.43	7.53	Triaxial test

4.3 Analyses and interpretations

The modal analyses have been performed in order to classify and characterize the different rock types. The modal analyses have been recalculated and plotted in the QAPF classification diagram of /Streckeisen 1976/, see Figure 4-1.

4.4 Nonconformaties

The activity plan was followed with no departures.

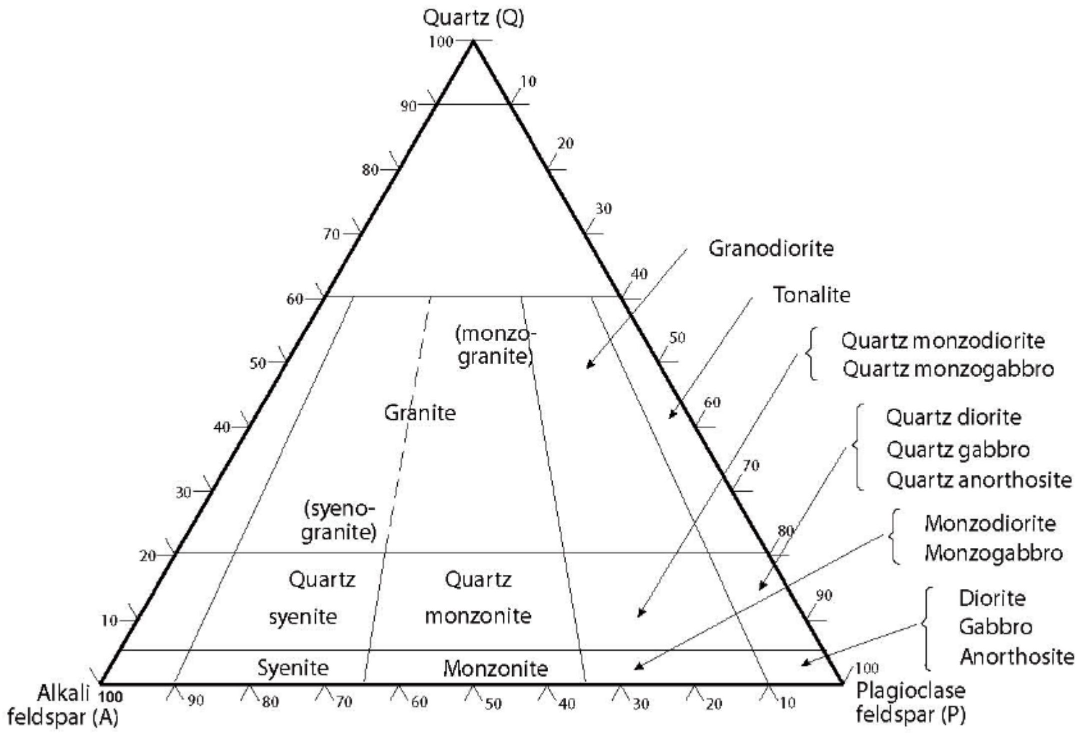

Figure 4-1. QAPF classification by Streckeisen diagram.

5 Results

The results from the modal analyses are presented in Section 5.1 and previous uniaxial and triaxial compression tests in Section 5.2. Some connection between mineralogy characterisation and results from uniaxial or triaxial compression test are presented in Section 5.3.

5.1 Modal analyses

The results of the modal analyses are reported to the SICADA database, where they are traceable by the activity plan number.

A summary of the modal analyses are shown in Table 5-1 to 5-3.

In Appendix A the QAP values, recalculated from the modal analyses, are plotted in the classification diagram of /Streckeisen 1976/ separately for each borehole.

Appendix B shows a complete mineralogy characterisation, based on point counting.

Table 5-1. The results from point counting for the most common minerarals.

Identification	Quartz	K-feldspar	Plagioclase	Biotite
KLX03-200-1	4.2	1.2	67.6	15.6
KLX03-200-2	5.4	0.6	68	12.2
KLX03-200-3	10	7.8	65.6	7.4
KLX03-200-4	12.2	8.2	51.6	13.6
KLX03-200-5	8.2	13	56.2	13
KLX03-200-6	13.8	7.2	51.6	16.2
KLX04-200-1	31	24	37.2	6.4
KLX04-200-2	22.4	21.8	46.4	7
KLX04-200-3	10	20.4	52	10.2
KLX04-200-4	11.6	17.6	50.6	10.8
KLX04-200-5	24.4	23	40.4	9
KLX04-200-6	26	22.2	41.6	7.4
KF0066A01-1	28.4	23.2	38.2	8.0
KF0066A01-2	24.6	16	49.2	7.0
KF0066A01-3	20.4	17.6	54.8	4.2
KF0069A01-1	28	28.4	36.4	4.2
KF0069A01-2	22.6	17.8	49.2	6.6
KQ0064G01-1	17.8	13.6	50	14.4
KQ0064G01-2	20.2	7.6	58.2	6.4
KQ0064G07-1	15.6	6.8	55.2	13.4
KQ0064G07-2	7	8.4	55	17.4
KQ0064G07-3	13.4	6.2	61.4	10.2
KQ0065G01-1	16	2.6	54	20.0
KQ0065G01-2	19	5	58.6	12.4
KQ0065G01-3	10.2	3.2	56.4	21.6
KQ0065G01-4	15.2	3.8	54.4	21

Table 5-2. Results from the QAP classification with rock types and codes, based on Streckeisen classification.

Identification	Quartz (%)	Alkali feldspar(%)	Plagioclase feldspar(%)	Rock type, Streck-eisen classification	Classified code
KLX03-200-1	5.8	1.6	92.6	Quartz diorite	1038
KLX03-200-2	7.3	0.8	91.9	Quartz diorite	1038
KLX03-200-3	12.0	9.4	78.7	Quartz monzodiorite	1037
KLX03-200-4	16.9	11.4	71.7	Quartz monzodiorite	1037
KLX03-200-5	10.6	16.8	72.6	Quartz monzodiorite	1037
KLX03-200-6	19.0	9.9	71.1	Quartz monzodiorite	1037
KLX04-200-1	33.6	26.0	40.3	Granite	1058
KLX04-200-2	24.7	24.1	51.2	Granodiorite	1056
KLX04-200-3	12.1	24.8	63.1	Quartz monzodiorite	1037
KLX04-200-4	14.5	22.1	63.4	Quartz monzodiorite	1037
KLX04-200-5	27.8	26.2	46.0	Granite	1058
KLX04-200-6	29.0	24.7	46.3	Granodiorite	1056
KF0066A01-1	31.6	25.8	42.5	Granite	1058
KF0066A01-2	27.4	17.8	54.8	Granodiorite	1056
KF0066A01-3	22.0	19.0	59.1	Granodiorite	1056
KF0069A01-1	30.2	30.6	39.2	Granite	1058
KF0069A01-2	25.2	19.9	54.9	Granodiorite	1056
KQ0064G01-1	21.9	16.7	61.4	Granodiorite	1056
KQ0064G01-2	23.5	8.8	67.7	Granodiorite	1056
KQ0064G07-1	20.1	8.8	71.1	Granodiorite	1056
KQ0064G07-2	9.9	11.9	78.1	Quartz monzodiorite	1037
KQ0064G07-3	16.5	7.7	75.8	Quartz diorite	1038
KQ0065G01-1	22.0	3.6	74.4	Tonalite	1053
KQ0065G01-2	23.0	6.1	70.9	Tonalite	1053
KQ0065G01-3	14.6	4.6	80.8	Quartz diorite	1038
KQ0065G01-4	20.7	5.2	74.1	Tonalite	1053

Table 5-3. SKB rock types and codes, based on SKB's Boremap.

Identification	SKB rock type	SKB rock code	Comment
KLX03-200-1	Ävrö granite	501044	With low quartz
KLX03-200-2	Ävrö granite	501044	With low quartz
KLX03-200-3	Ävrö granite	501044	With low quartz
KLX03-200-4	Ävrö granite	501044	With low quartz
KLX03-200-5	Quartz monzodiorite	501036	–
KLX03-200-6	Quartz monzodiorite	501036	–
KLX04-200-1	Ävrö granite	501044	With high quartz
KLX04-200-2	Ävrö granite	501044	With high quartz
KLX04-200-3	Ävrö granite	501044	With low quartz
KLX04-200-4	Ävrö granite	501044	With low quartz
KLX04-200-5	Ävrö granite	501044	With high quartz
KLX04-200-6	Ävrö granite	501044	With high quartz
KF0066A01-1	Ävrö granite	501044	With high quartz
KF0066A01-2	Ävrö granite	501044	With high quartz
KF0066A01-3	Ävrö granite	501044	With high quartz
KF0069A01-1	Ävrö granite	501044	With high quartz
KF0069A01-2	Ävrö granite	501044	With high quartz
KQ0064G01-1	Äspö diorite	501037	Likely Ävrö granite with high quartz
KQ0064G01-2	Äspö diorite	501037	Likely Ävrö granite with high quartz
KQ0064G07-1	Äspö diorite	501037	Likely Ävrö granite with low quartz
KQ0064G07-2	Äspö diorite	501037	Likely Ävrö granite with low quartz
KQ0064G07-3	Äspö diorite	501037	Likely Ävrö granite with low quartz
KQ0065G01-1	Äspö diorite	501037	Likely Ävrö granite with high quartz
KQ0065G01-2	Äspö diorite	501037	Likely Ävrö granite with high quartz
KQ0065G01-3	Äspö diorite	501037	Likely Ävrö granite with low quartz
KQ0065G01-4	Äspö diorite	501037	Likely Ävrö granite with high quartz

5.2 Uniaxial and triaxial compression test

A summary of the previously tested results are shown in Table 5-4.

5.3 Connection between mineralogy characterisation and results from compression test

To see possible connections different parameters have been tested versus the rock strength, see Table 5-5.

A weak connection is found between the content of quartz and the rock strength, i.e. a low strength value responds to a low content of quartz, but not always. Also there seem to be a connection between drill hole and strength, i.e. in the same drill hole/site (regardless rock type) the expected magnitude responds to the value of the rock strength.

Table 5-4. Selected samples showing density, compressive strength and confining stress.

Identification	Density (kg/m^3)	Compressive strength (MPa)	Confining stress (MPa)
KLX03-200-1	2,770	178.6	–
KLX03-200-2	2,780	179.1	–
KLX03-200-3	2,750	170.6	–
KLX03-200-4	2,750	166.6	–
KLX03-200-5	2,820	193.8	–
KLX03-200-6	2,810	182.2	–
KLX04-200-1	2,670	204.8	–
KLX04-200-2	2,670	195.5	–
KLX04-200-3	2,720	156.8	–
KLX04-200-4	2,740	150.5	–
KLX04-200-5	2,690	180.8	–
KLX04-200-6	2,690	186.0	–
KF0066A01-1	2,660	274.7	–
KF0066A01-2	2,670	249.4	–
KF0066A01-3	2,680	232.8	–
KF0069A01-1	2,680	305.1	–
KF0069A01-2	2,690	297.7	–
KQ0064G01-1	2,741	221.1	–
KQ0064G01-2	2,716	243.5	1.0
KQ0064G07-1	2,715	189.5	–
KQ0064G07-2	2,717	131.7	–
KQ0064G07-3	2,725	180.8	1.0
KQ0065G01-1	2,751	244.3	–
KQ0065G01-2	2,740	236.7	–
KQ0065G01-3	2,747	186.5	–
KQ0065G01-4	2,732	255.9	1.0

Table 5-5. Different parameters versus connection of rock strenght.

Parameter	Connection with rock strenght
Content of quartz	Weak, see Figure 5-1 and 5-2
K-feldspar	None
Plagioclase	None
Biotite	None
Alkali feldspar, from QAP	None
Plagioclase, from QAP	None
Rock type	Clear, see Figure 5-3
Density	None, see Figure 5-4
Drill hole	Weak, see Figure 5-5

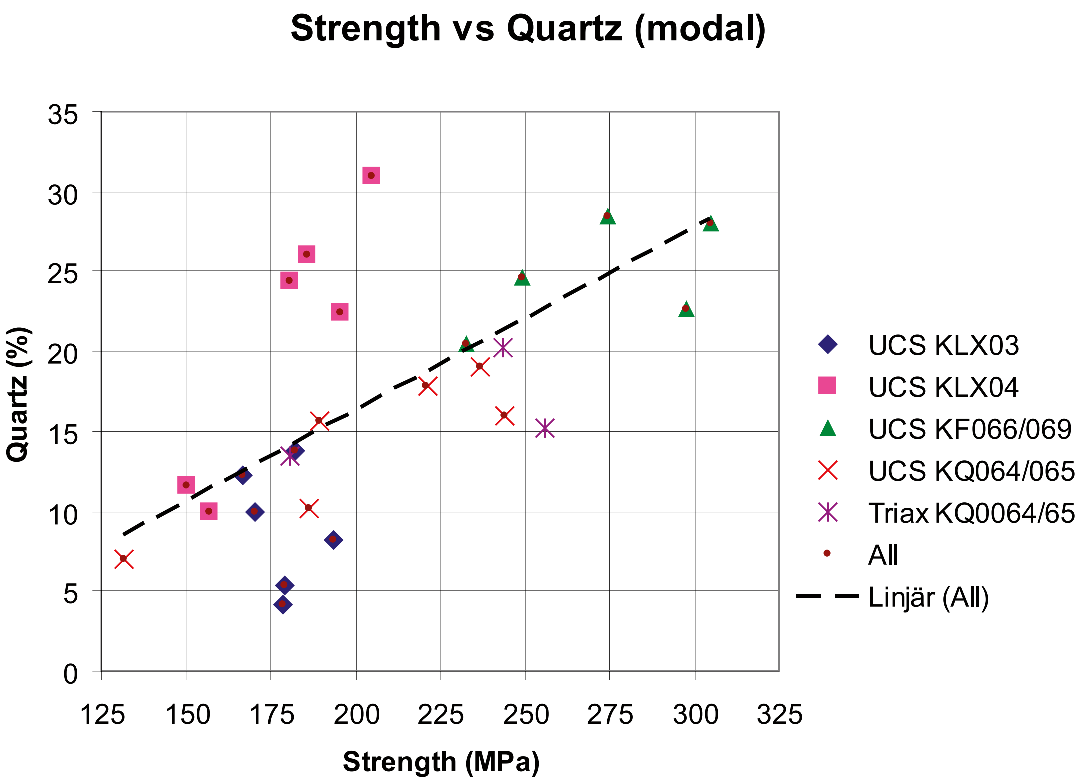

Figure 5-1. *Strength versus content of quartz, based on modal analyses.*

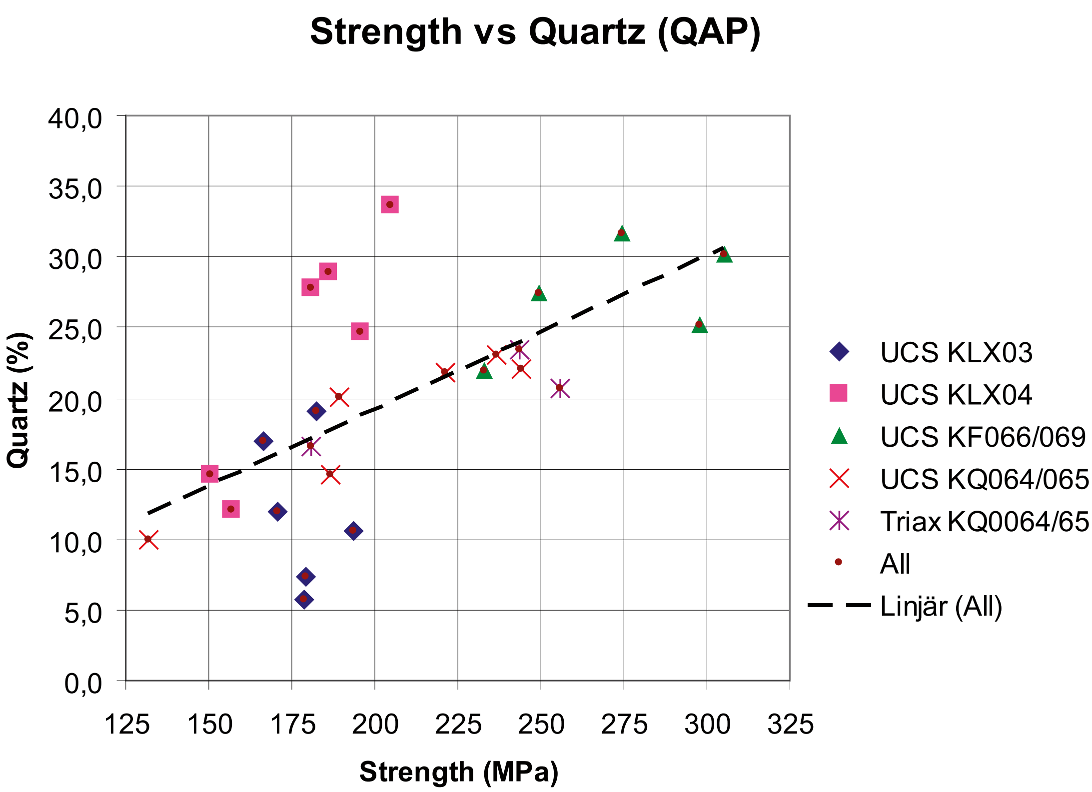

Figure 5-2. *Strength versus content of quartz, based on Streckeisen classification.*

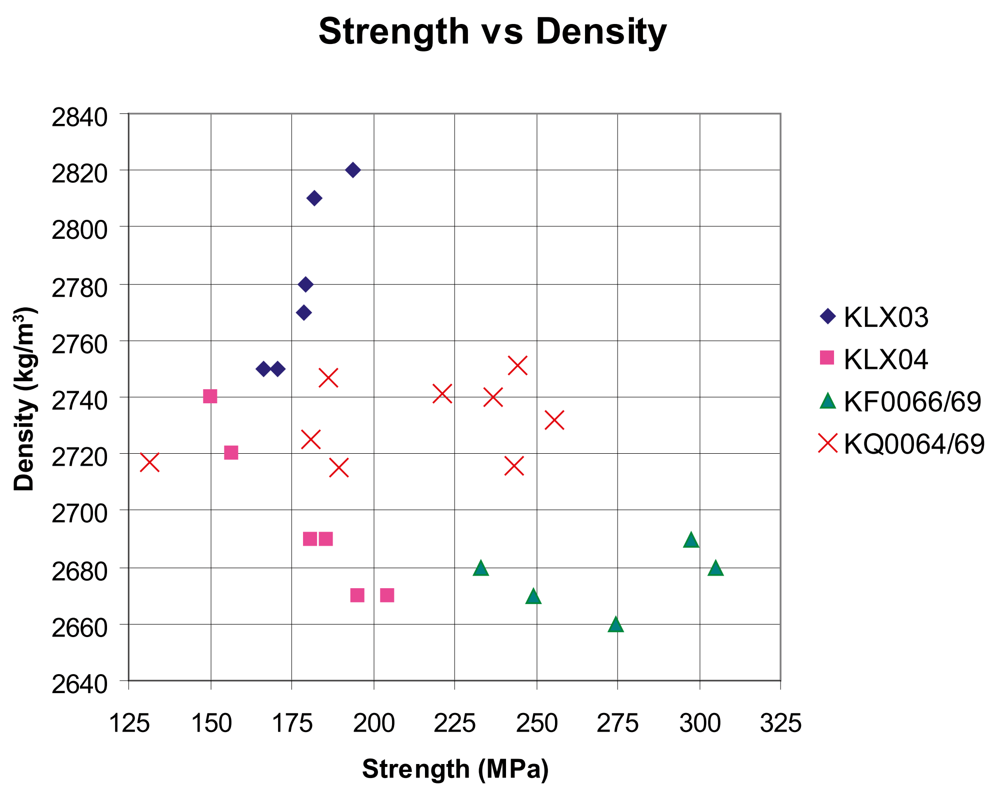

Figure 5-3. *Strength versus density of rock.*

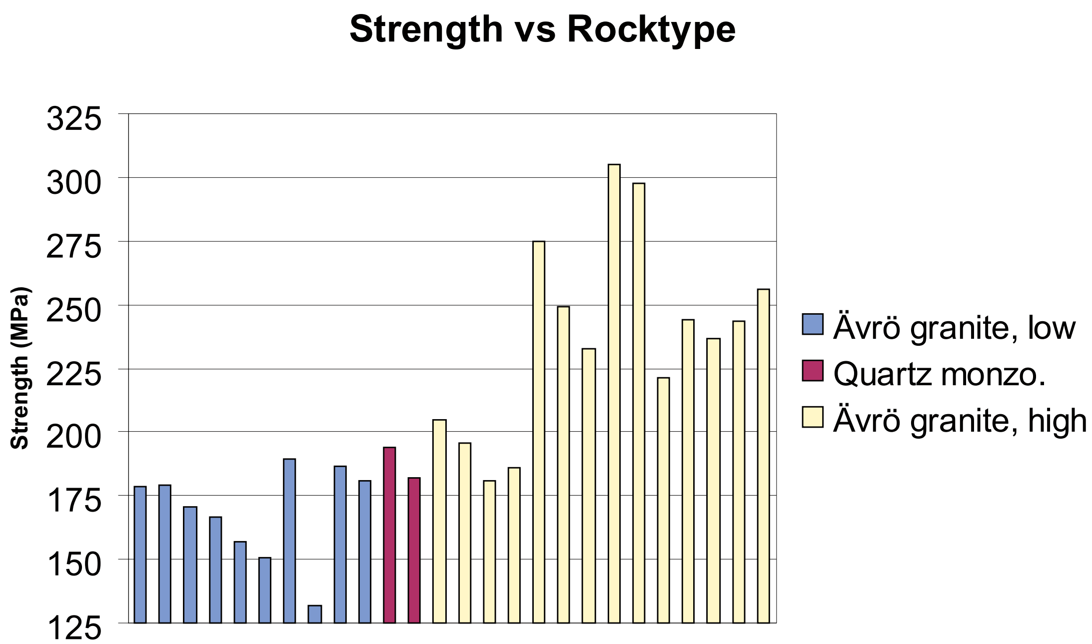

Figure 5-4. *Strength versus type of rock, include both uniaxial and triaxial compression tests.*

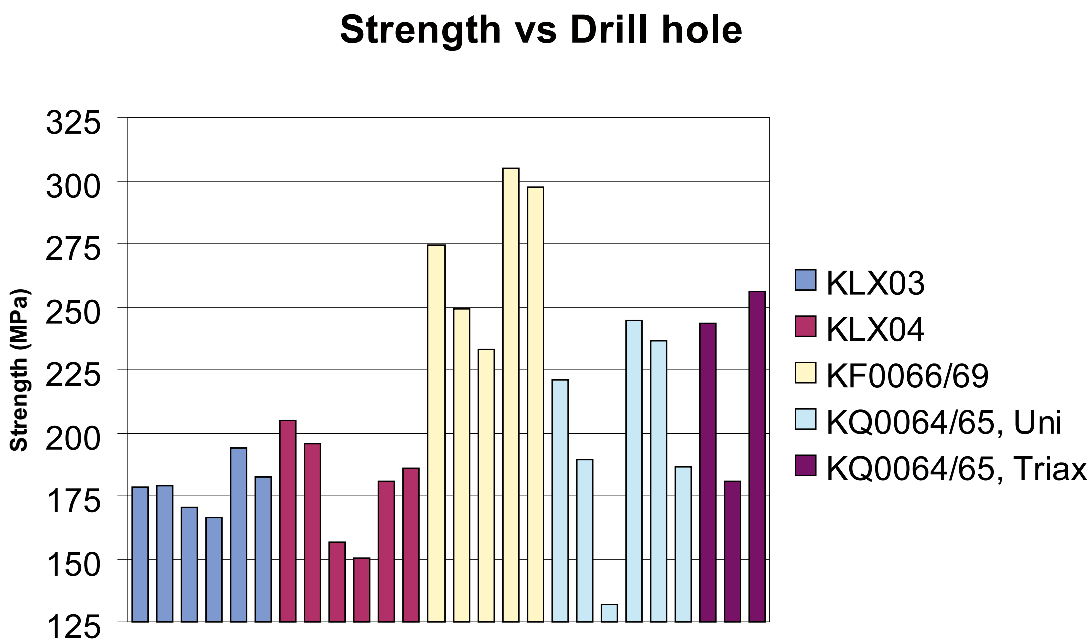

Figure 5-5. *Strenght versus drill hole.*

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SKB, 2005a. Uniaxial compression tests of intact rock specimens at dry condition and at saturation by three different liquids: distilled, saline and formation water. Äspö HRL, Decovalex. SKB IPR-05-33, Svensk Kärnbränslehantering AB.

SKB, 2005b. Borehole KLX03A. Uniaxial compression test of intac rock, Oskarshamn site investigation. SKB P-05-90, Svensk Kärnbränslehantering AB.

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The modal analyses plotted in the classification diagram of /Streckeisen 1976/

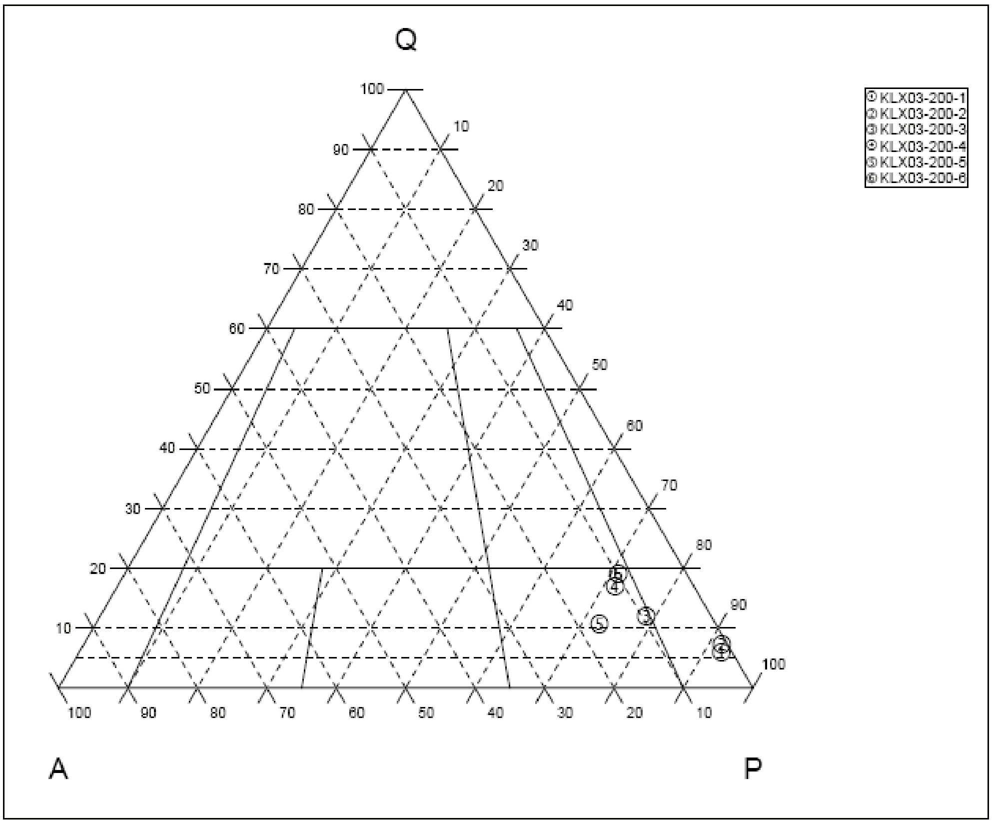

Figure A-1. *QAP classification from KLX03 samples, according to /Streckeisen 1976/.*

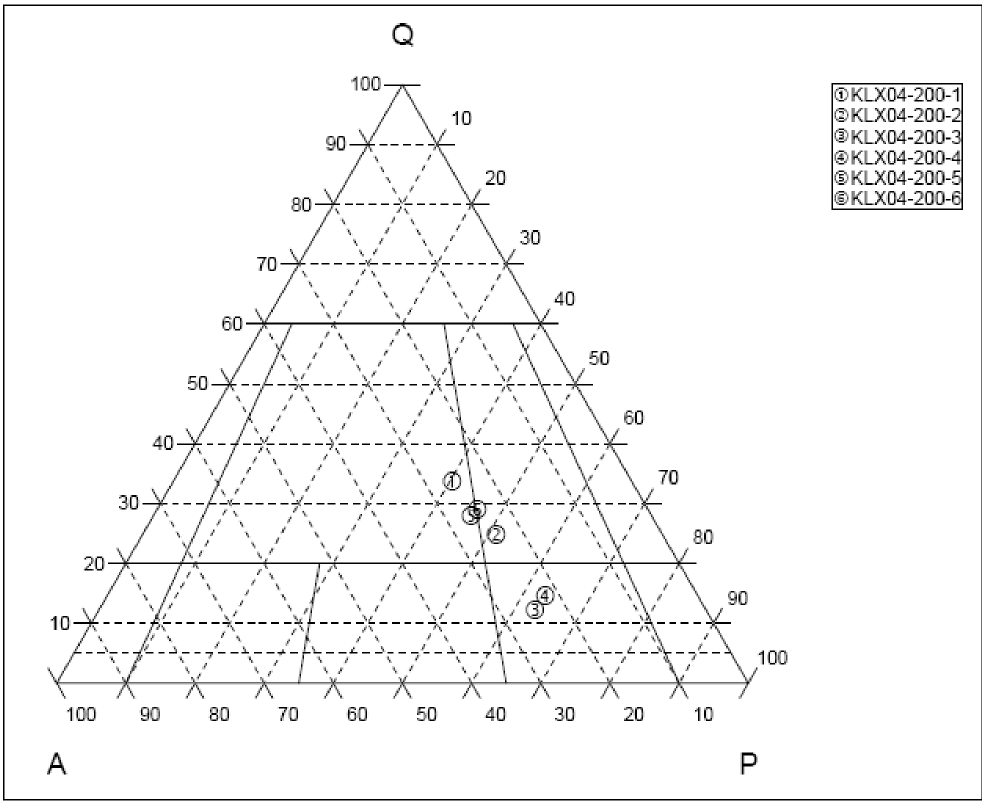

Figure A-2. *QAP classification from KLX04 samples, according to /Streckeisen 1976/.*

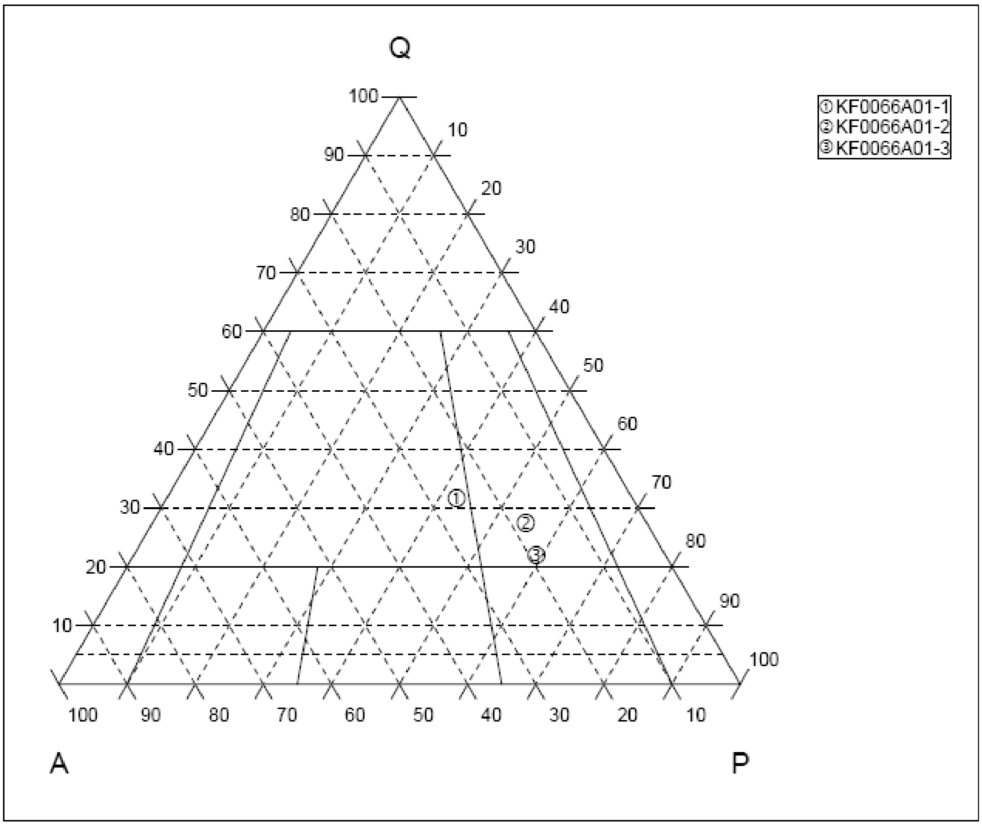

Figure A-3. *QAP classification from KF0066A01 samples, according to /Streckeisen 1976/.*

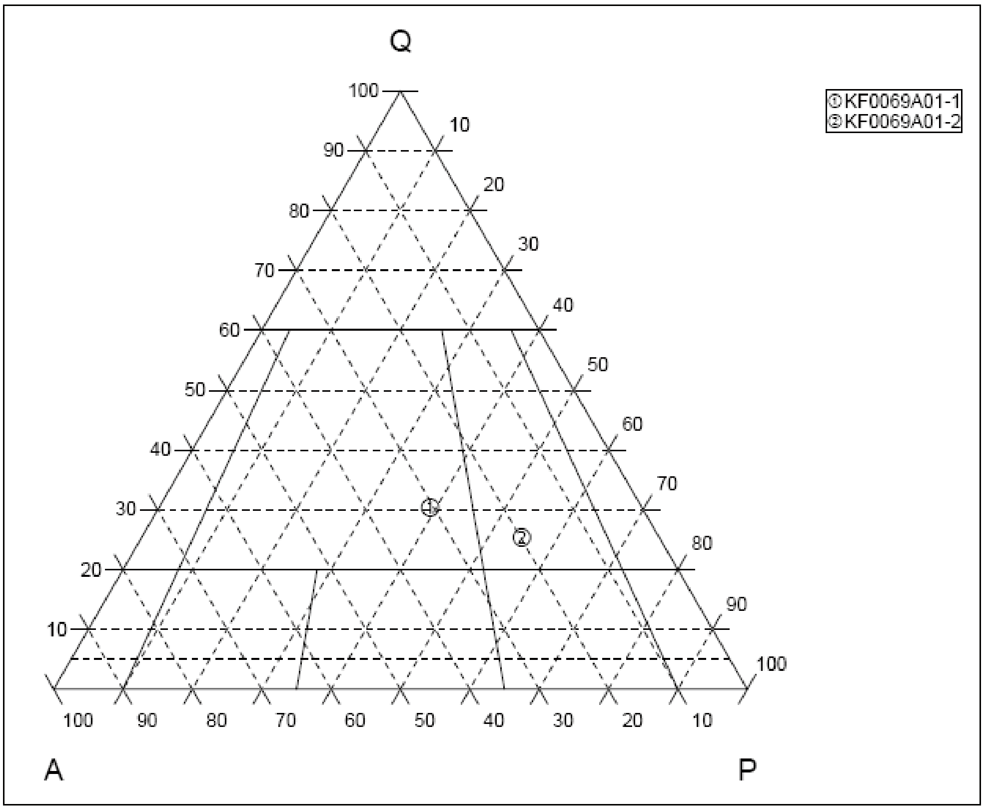

Figure A-4. *QAP classification from KF0069A01 samples, according to /Streckeisen 1976/.*

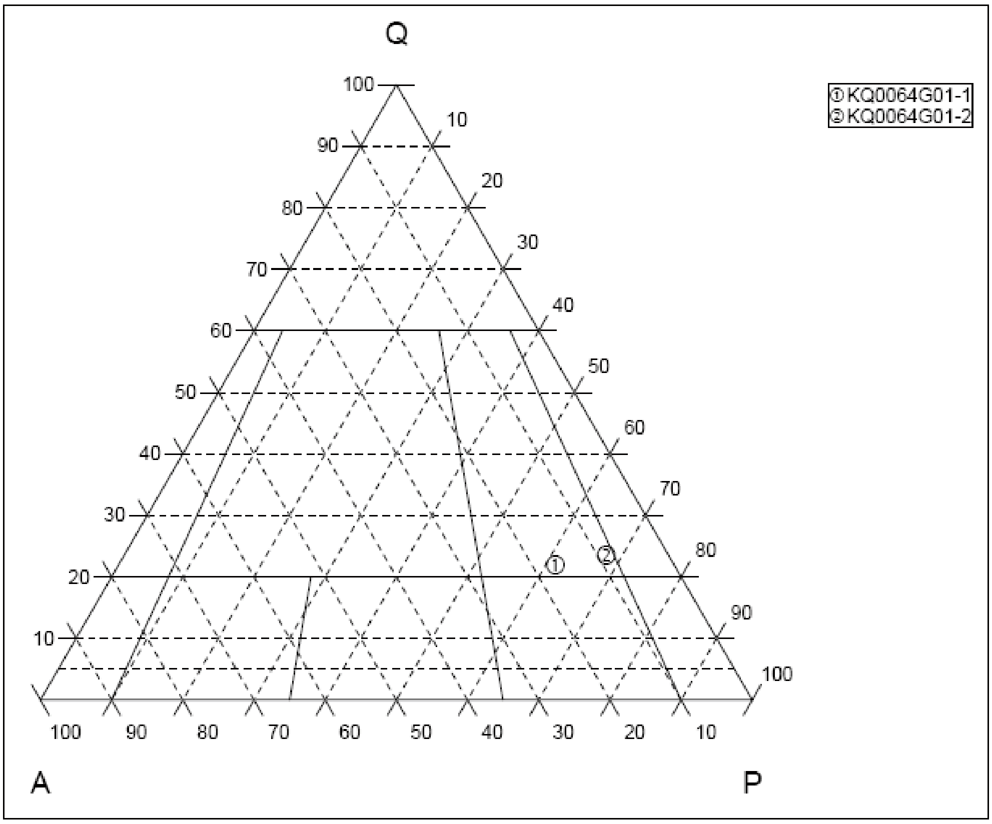

Figure A-5. *QAP classification from KQ0064G01 samples, according to /Streckeisen 1976/.*

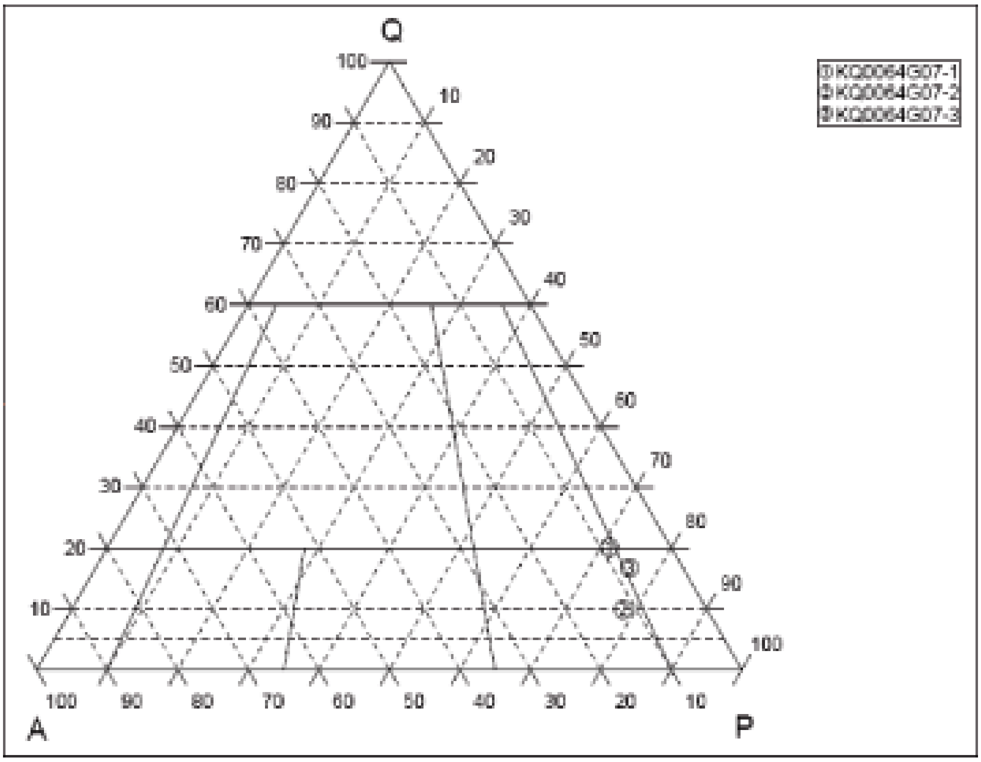

Figure A-6. *QAP classification from KQ0064G07 samples, according to /Streckeisen 1976/.*

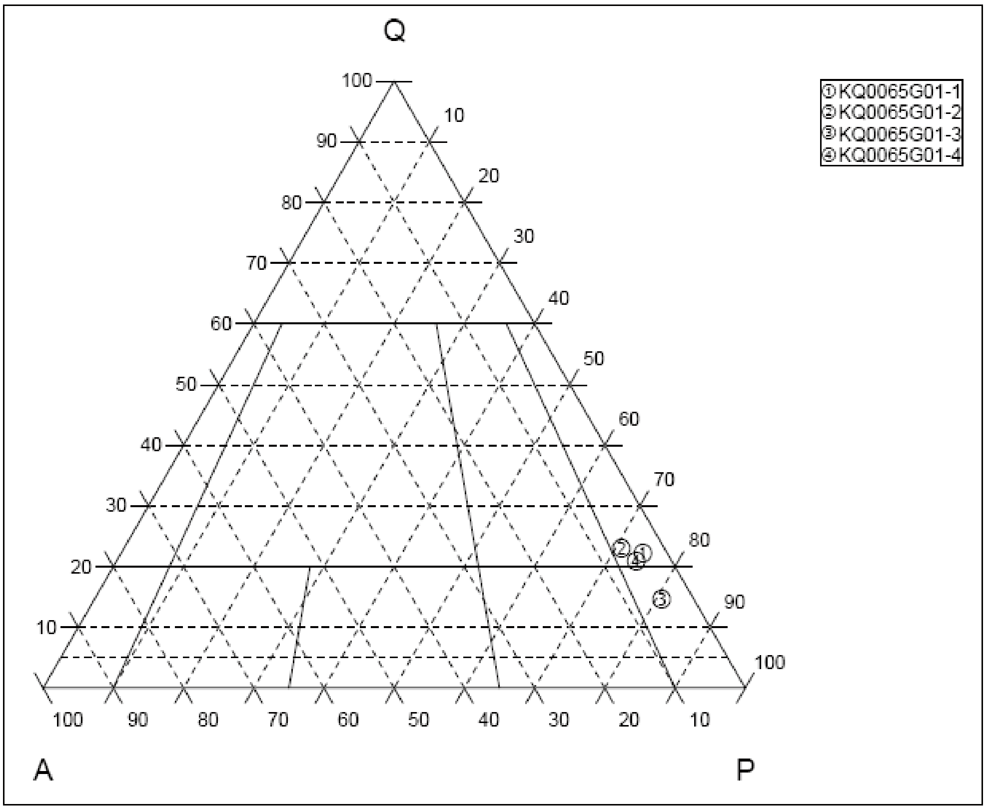

Figure A-7. *QAP classification from KQ0065G01 samples, according to /Streckeisen 1976/.*

Appendix B

Mineralogy characterisation, based on point counting

idcode	secup	seclow	quartz	k_feldspar	plagioclase	biotite	muscovite	epidote	titanite	calcite	hornblende	opaque	apatite	zircon	clinopyroxene	correncite	fluorite
KLX03-200-1	292.36	292.46	4.2	1.2	67.6	15.6		0.8	0.4		6.4	2.6	0.4		0.8		
KLX03-200-2	292.68	292.78	5.4	0.6	68	12.2		0.8	0.2	0.2	4.2	3.6	1	0.2	4		
KLX03-200-3	513.27	513.37	10	7.8	65.6	7.4		0.6	1		7	0.6					
KLX03-200-4	513.41	513.51	12.2	8.2	51.6	13.6					3.6	3	0.2		7.2	0.4	
KLX03-200-5	690.81	690.91	8.2	13	56.2	13	0.8	1	0.6		6.6	0.4	0.2				
KLX03-200-6	691.38	691.48	13.8	7.2	51.6	16.2				0.4	0.8	2.4	1		6.6		
KLX04-200-1	306.72	306.82	31	24	37.2	6.4		0.4	0.2	0.2		0.6					
KLX04-200-2	306.86	306.96	22.4	21.8	46.4	7		0.2	0.8	0.2		1	0.2				
KLX04-200-3	564.77	564.87	10	20.4	52	10.2		1.6	0.8		4	0.8	0.2				
KLX04-200-4	564.91	565.01	11.6	17.6	50.6	10.8		2.8	1.2		4	1	0.4				
KLX04-200-5	747.81	747.91	24.4	23	40.4	9		1.6	0.4	0.2	0.4	0.2	0.2				
KLX04-200-6	747.95	748.05	26	22.2	41.6	7.4	0.2	1.2	1.0			0.4					
KF0066A01-1	26.06	26.16	28.4	23.2	38.2	8.0		0.2	1			0.4	0.2	0.2			
KF0066A01-2	29.62	29.72	24.6	16.0	49.2	7.0		0.6	1			1		0.4			
KF0066A01-3	29.75	29.85	20.4	17.6	54.8	4.2	0.4	0.6	1.2	0.2		0.2		0.4			
KF0069A01-1	40.99	41.09	28.0	28.4	36.4	4.2		1.6	0.2	0.2		0.2	0.6	0.2			
KF0069A01-2	46.26	46.36	22.6	17.8	49.2	6.6	0.2	2	0.6			1					
KQ0064G01-1	6.16	6.26	17.8	13.6	50.0	14.4		2.6	0.8	0.2		0.2	0.4				
KQ0064G01-2	5.34	5.44	20.2	7.6	58.2	6.4	0.2	4	2	1.2		0.2					
KQ0064G07-1	4.89	4.99	15.6	6.8	55.2	13.4		7.2	1.2	0.2			0.2				
KQ0064G07-2	5.28	5.38	7.0	8.4	55.0	17.4		9	1.8	0.2		0.2	0.4				0.6
KQ0064G07-3	5.03	5.13	13.4	6.2	61.4	10.2	0.2	5.6	1.8	0.8		0.4					
KQ0065G01-1	5.19	5.29	16.0	2.6	54.0	20.0	0.2	5.2	1.6	0.2		0.2					
KQ0065G01-2	5.33	5.43	19.0	5.0	58.6	12.4		3.8	1			0.2					
KQ0065G01-3	7.27	7.37	10.2	3.2	56.4	21.6		6.4	1.4	0.2		0.6					
KQ0065G01-4	7.43	7.53	15.2	3.8	54.4	21		2.6	2.4	0.2		0.4					