The reliability of the first generation infrared refractometers

Fernando Acevedo Suez

Dissertations in Geology at Lund University,
Bachelor's thesis, no. 351
(15 hp/ECTS credits)

Department of Geology
Lund University
2013

The Reliability of the First Generation Infrared Refractometers

Bachelor's thesis

Fernando Acevedo Suez

Department of Geology
Lund University
2013

Contents

Cover Picture: The first generation infrared refractometer. Photograph: Ivan Suez.

The reliability of the first generation infrared refractometers

FERNANDO ACEVEDO SUEZ

Acevedo Suez, F., 2013: The reliability of the first generation infrared refractometers. *Dissertations in Geology at Lund University*, No. 351, 49 pp. 15 hp (15 ECTS credits) .

Abstract: One of the most valuable instruments for gem identification is the refractometer. The standard refractometer is based on visible light, but a first generation infrared refractometer is out on the market. This new refractometer has not showed accurate values, and therefore the purpose of this project has been to test different parameters and see their influence on the results. The temperature seem to have certain influence on the result, whereas the cut of the stone does not. Most likely, when calibrating the instrument, the manufacturer took into account that there is a difference in wavelength between visible light and infrared light, and thus the algorithm which is used should be correct. Since the manufacturer now has replaced one of the calibration stones, the one with RI = 1.470, with a calibration stone with RI = 1.4875, the fact that my instrument was calibrated with a stone with lower RI could be the reason for obtaining inaccurate values.

Keywords: infrared, refractometer, evaluation, temperature, cut.

Supervisors: Loren E. Babcock and Leif Johansson

Fernando Acevedo Suez, Department of Geology, Lund University, Sölvegatan 12, SE-223 62 Lund, Sweden.
E-mail: Fernandinho_46@hotmail.com

Pålitligheten av första generationens infraröda refraktometrar

FERNANDO ACEVEDO SUEZ

Acevedo Suez, F., 2013: Pålitligheten av första generationens infraröda refraktometer.
Examensarbeten i geologi vid Lunds universitet, Nr. 351, 49 sid. 15 hp.

Sammanfattning: En av de mest användbara instrumenten för identifiering av ädelstenar är refraktometern. Standardrefraktometern är baserad på synligt ljus, men en första generationens infraröd refraktometer är ute på marknaden. Den här nya refraktometern har inte visat rätt värden och därför är syftet med detta projekt att testa olika parametrar och se deras påverkan på resultaten. Temperaturen verkar ha en viss påverkan på resultatet, medan hur stenen är slipad inte tycks ha någon påverkan på resultatet. Troligtvis tog tillverkaren vid kalibrering av instrumentet hänsyn till att där är en skillnad i våglängd mellan synligt ljus och infrarött ljus, och därför borde algoritmen som används vara korrekt. Eftersom tillverkaren nu har ersatt en av kalibreringsstenarna, den med RI = 1.470, med en kalibreringssten med RI = 1.4875, kan det faktum att min mätare kalibrerades med en sten med lägre RU vara anledningen till att fel värden fås.

Nyckelord: infraröd, refraktometer, utvärdering, temperatur, slipning.

Handledare: Loren E. Babcock och Leif Johansson

Ämne: Berggrundsgeologi

Fernando Acevedo Suez, Geologiska institutionen, Lunds universitet, Sölvegatan 12, 223 62 Lund, Sverige.
E-post: Fernandinho_46@hotmail.com

1 Introduction

One of the most valuable instruments for gem identification is the refractometer. The basis of this instrument is to identify the RI (Refractive Index) of a gemstone, which is characteristic for a specific gemstone. A standard refractometer has an approximate range of RI = 1.30-1.80 and uses a refractive fluid to create contact between the gemstone and the instrument (Babcock 2012).

A first generation infrared refractometer is out on the market. It has a wider range (RI = 1.30-2.99) and does not need the use of refractive fluid (Opticsfactory 2013). All in all, the new instrument appears to be of great use and an improvement on the old refractometer. The problem is that you do not obtain accurate values.

Therefore the purpose of this thesis is to, through testing gemstones with both the standard refractometer (Link RHG - 181, see Fig. 1.), and with the first generation infrared refractometer (Digital Gem Refractometer, see Fig. 2.), see how temperature and cut can affect the results with the first generation infrared refractomeeter.

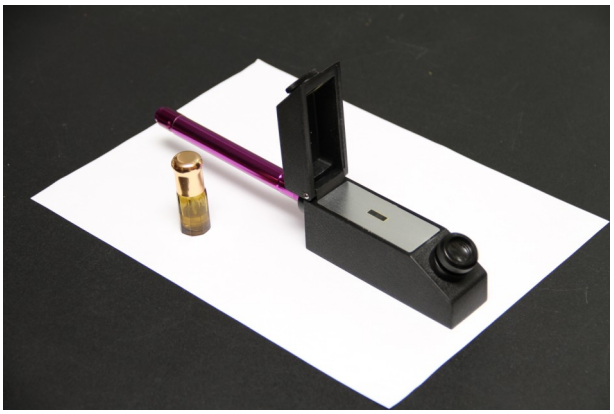


Fig. 1. The standard refractometer. Photograph: Ivan Suez

2 Background

Fig. 2. The first generation infrared refractometer. Photograph: Ivan Suez.

2.1 The standard refractometer

In the rear of the device, there is an opening to which a light source is applied. The light hits a mirror which sends the light to the center of a hemicylinder made of high refractive glass (usually N-LaSF made by Schott, with RI ≈ 1.88 and a hardness of about 6.5 on Moh's scale). At the boundary between the hemicylinder and the gemstone, some of the light will reflect directly back into the hemicylinder, and some of the light will refract inside the gemstone. The reflected light will pass through a reading scale and then through one or more lenses, depending on the refractometer. Further on, a mirror will bounce the light, through the ocular, through a detachable polarizing filter and to one's eye (The Gemology Project 2013a), see Fig. 1.

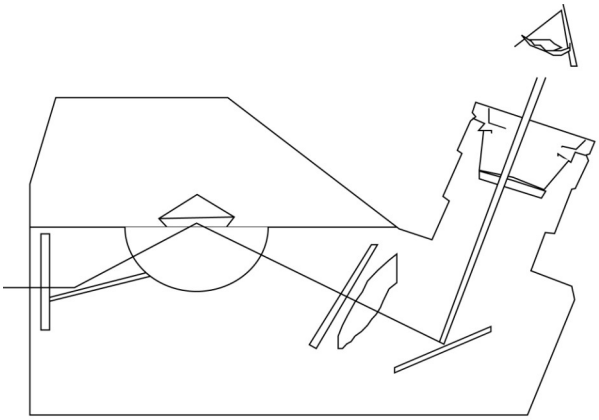


Fig. 1. The standard refractometer, modified after (The Gemology Project 2013a)

The hemicylinder has higher refractive index (RI) than the gemstone. Therefore, the light will either reflect back into the hemicylinder or refract inside the gemstone. The limit between when light is refracted or reflected is called the critical angle (ca). The light that comes in on the inside of the critical angle respective to the normal will be refracted inside the gemstone. The light that comes in on the outside of the critical angle respective to the normal will be reflected back into the hemicylinder and hit the reading scale (The Gemology Project 2013b). The critical angle can be calculated with Snell's law, $n_1\sin(\theta_1) = n_2\sin(\theta_2)$, where θ_1 is the angle of incidence and θ_2 is the angle of refraction (Wikipedia 2013). This means that since the RI of the hemicylinder is constant, and the angle of the incoming light is constant, the angle of the refracted light depends on the gemstone that is being tested. This also means that the critical angle (ca) is specific for each gemstone, and since the angle of the incoming light is the same, every material will refract and reflect different amount of light, and thus we can se a difference in the reading scale, which shows $RI = \sin(\theta_1) / \sin(\theta_2)$ (Babcock 2012).

Before the gemstone is placed on the hemicylinder, a drop of refractive fluid should be applied on the glass, with the purpose to increase the contact between the gemstone and the hemicylinder. This fluid contains

methylene iodide saturated with sulfur, so surgical gloves are recommended. This fluid should also be used in a well-ventilated area, and pregnant women should avoid using it (Babcock 2012).

2.2 The first generation infrared refractometer

Basically, the first generation infrared refractometer is used without the need of applying the hazardous refractive fluid, the light source (infrared light) is built in it, and the result is presented digitally. This refractometer can also test a wider range (RI = 1.30 - 2.99).

There is not much information to be found about the infrared refractometer specifically that I have used for this project, but there is information about another refractometer which does not measure the refractivity, but the percentage of reflectivity, and then converts it to a refractive index value through an algorithm (Gem-n-Eye 2013).

3 Method

After trying the first generation infrared refractometer in normal room temperature, the test results did not appear to be accurate. Therefore, the objective of this project is to find out which parameters affect the results.

3.1 Testing in different temperatures

Since the instructions for the first generation infrared refractometer say that the working temperature is 25-28°C, the first part of the testing has been to test gemstones in different temperatures to see how this affect the results.

34 different gemstones were tested in 20-25°C. Among the tested gemstones, 14 gemstones were tested again in 25-28°C and again in 30-35°C. Also the the calibration stones were tested, with different combinations of the temperature in which the instruments were calibrated in, and the temperature in which the gemstones were tested.

At every temperature, the testings for every gemstone began with the standard refractometer. A drop of refractive fluid was placed on the hemicylinder, and then the gemstone was placed, the value from the reading scale was written down and then the polarizing filter was turned 90° to test for double refractivity and this value was written down as well. This was repeated three times for each gemstone at each temperature. Between every test, both the hemicylinder and the gemstone were wiped off with a piece of paper with alcohol.

Then the tests proceeded with the first generation infrared refractometer. The refractometer was calibrated following the procedure written in the manual; First the ”test” button was pressed for 7 seconds, the calibration stone with RI = 1.470 was placed on the platforf and the ”test” button was pressed again. Then the ”test” button was pressed for 4 seconds, the calibration stone with RI = 1.755 was placed on the platform, the ”test” button was pressed again and then the ”test” button was pressed for 4 seconds.

The testing procedure was easier: I placed the gemstone on the centre of the testing plate, pressed the ”test” button and wrote down the value that appeared on the screen. Then I turned the stone 90° for testing for double refractivity, pressed the ”test” button and wrote down the value. I repeated this three times for each gemstone at each temperature, wiping off the gemstone with a gem cleaning cloth with alcohol between each test.

3.2 Testing different cut

After acquiring information about another instrument, (Gem-n-Eye 2013), chances are that our first generation infrared refractometer works the same way, measuring the percentage of reflectivity and then converts it to a refractive index value through an algorithm. In that case, a possibility is that the infrared light is not only reflected hitting the table of the gemstone, but also when hitting the pavilion, and thus, gemstones with different angles on the pavilions could give different values.

I decided to test eight amethysts faceted in five different ways and four sapphires faceted in three different ways to see how the results differed.

The testing procedure was the same as when testing for temperature, except the fact that I did all the tests in room temperature.

4 Results

4.1 Testing in different temperatures

The results are here presented the following way:

First, the results from the tests on the calibration stones are presented, and then the results from the tests on the real gemstones. Remember that the real gemstones were tested at the same temperature as the instruments were calibrated at.

T = Temperature and H = Humidity.

For the mean value, two values are given: The first value, the lower value, is the mean value for the three lower test results. The second value, the higher value, is the mean value for the three higher test results. This way, double refractivity can be displayed.

The deviation value is the difference between the mean value and the value given in a table over refractive index (Babcock 2012). Also here, I have given two values; The first value is the difference between the lower mean value and the lower value given in the table over refractive index. The second value is the difference between the higher mean value and the higher value given in the table over refractive index.

For each gemstone, a diagram illustrates the result, together with a picture of the stone, see Figs. 4-16.

Since this project is about why the first generation infrared refractometer does not give accurate values, and we already know that the standard refractometer works, I only present values from the tests with the

first generation infrared refractometer here. The values from the tests with the standard refractometer can be found in the full results sheet for the calibration stones in Appendix A, and for the gemstones in Appendix B.

4.1.1 Calibration stone with RI = 1.470

Calibrated at: T: 26.8 H: 24.9
Tested at: T: 23.3 H: 28.5
Mean value: 1.465 - 1.467
Deviation: 0.005 - 0.003

Calibrated at: T: 22.9 H: 29.0
Tested at: T: 26.2 H: 24.9
Mean value: 1.465 - 1.468
Deviation: 0.005 - 0.002

Calibrated at: T: 26.2 H: 24.4
Tested at: T: 26.2 H: 24.5
Mean value: 1.477 - 1.478
Deviation: 0.007 - 0.008

Calibrated at: T: 34.6 H: 18.2
Tested at: T: 26.8 H: 24.2
Mean value: 1.467 - 1.468
Deviation: 0.003 - 0.002

Calibrated at: T: 26.6 H: 25.5
Tested at: T: 30.5 H: 20.9
Mean value: 1.467 - 1.468
Deviation: 0.003 - 0.002

Calibrated at: T: 32.0 H: 18.6
Tested at: T: 31.9 H: 19.4
Mean value: 1.472 - 1.472
Deviation: 0.002 - 0.002

4.1.2 Calibration stone with RI = 1.755

Calibrated at: T: 24.9 H: 26.8
Tested at: T: 23.0 H: 28.7
Mean value: 1.747 - 1.756
Deviation: 0.008 - 0.001

Calibrated at: T: 22.9 H: 29.0
Tested at: T: 26.6 H: 24.3
Mean value: 1.742 - 1.751
Deviation: 0.013 - 0.004

Calibrated at: T: 26.2 H: 24.4
Tested at: T: 26.1 H: 25.1
Mean value: 1.746 - 1.747
Deviation: 0.009 - 0.008

Calibrated at: T: 34.6 H: 18.2
Tested at: T: 26.5 H: 24.4
Mean value: 1.752 - 1. 755
Deviation: 0.003 - 0

Calibrated at: T: 26.6 H: 25.5
Tested at: T: 31.3 H: 19.9
Mean value: 1.754 - 1.758
Deviation: 0.001 - 0.003

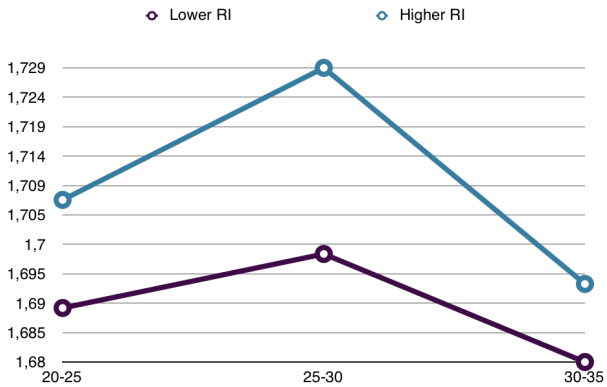
Calibrated at: T: 32.0 H: 18.6
Tested at: T: 33.0 H: 18.1
Mean value: 1.753 - 1.756
Deviation: 0.002 - 0.001

4.1.3 Alexandrite ($Al_2(BO_4)$) (RI = 1.746 - 1.755) - Cut

Tested at: T: 23.0 H: 22.0
Mean value: 1.689 - 1.707
Deviation: 0.057 - 0.048

Tested at: T: 26.8 H: 29.9
Mean value: 1.698 - 1.729
Deviation: 0.048 - 0.026

Tested at: T: 33.0 H: 25.5
Mean value: 1.680 - 1.693
Deviation: 0.066 - 0.062



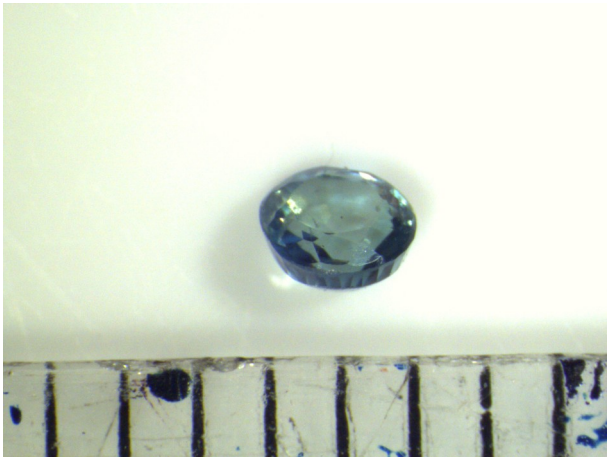


Fig. 4a. Mean value for alexandrite at different temperatures. Fig. 4b. The tested alexandrite.

4.1.4 Amethyst (Quartz) (SiO_2) (RI = 1.544 - 1.553) - Faceted

Tested at: T: 22.9 H: 20.0
Mean value: 1.563 - 1.564
Deviation: 0.019 - 0.011

Tested at: T: 26.8 H: 28.4
Mean value: 1.560 - 1.574
Deviation: 0.016 - 0.021

Tested at: T: 32.0 H: 21.5
Mean value: 1.555 - 1.560
Deviation: 0.011 - 0.007

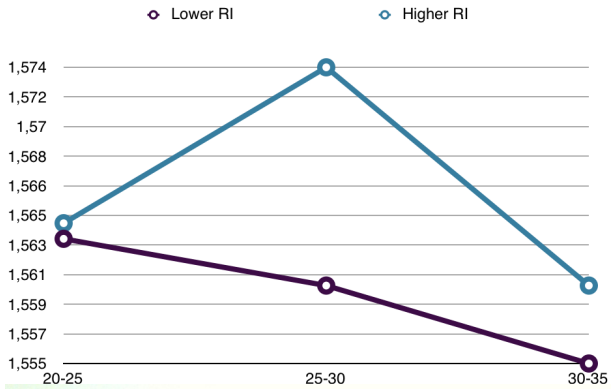


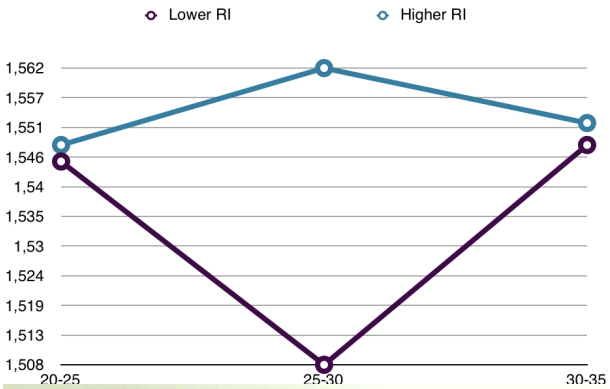
Fig. 5a. Mean value for amethyst at different temperatures.
Fig. 5b. The tested amethyst.

4.1.5 Ametrine (Quartz) (SiO_2) (RI = 1.544 - 1.553) - Faceted

Tested at: T: 23.2 H: 18.7
Mean value: 1.545 - 1.548
Deviation: 0.001 - 0.005

Tested at: T: 26.3 H: 28.7
Mean value: 1.508 - 1.562
Deviation: 0.036 - 0.009

Tested at: T: 33.4 H: 19.3
Mean value: 1.548 - 1.552
Deviation: 0.004 - 0.001



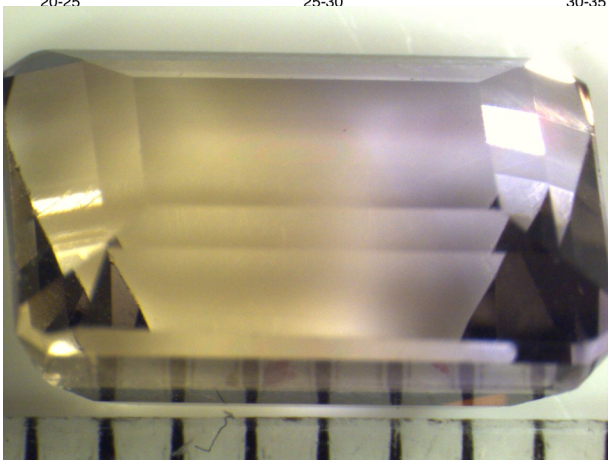


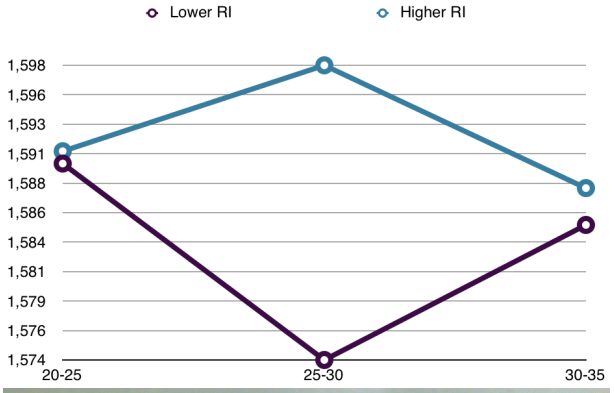
Fig. 6a. Mean value for ametrine at different temperatures.
Fig. 6b. The tested ametrine.

4.1.6 Aquamarine (Beryl) ($Be_3Al_2(SiO_3)_6$) (RI = 1.577 - 1.583) - Faceted

Tested at: T: 23.2 H: 19.8
Mean value: 1.590 - 1.591
Deviation: 0.013 - 0.008

Tested at: T: 26.5 H: 29.1
Mean value: 1.574 - 1.598
Deviation: 0.003 - 0.015

Tested at: T: 31.7 H: 26.6
Mean value: 1.585 - 1.588
Deviation: 0.008 - 0.005



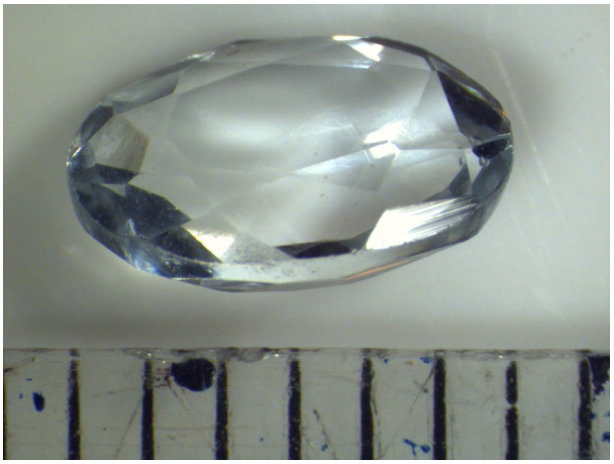


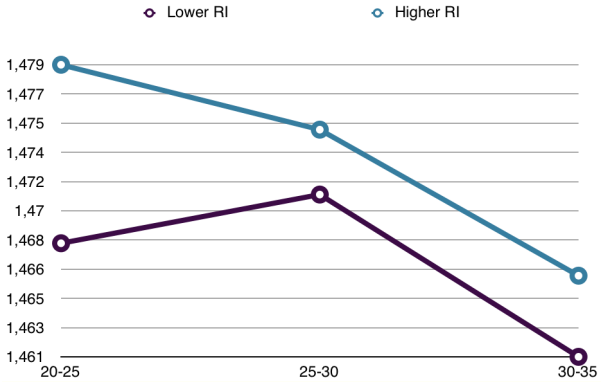
Fig. 7a. Mean value for aquamarine at different temperatures. Fig. 7b. The tested aquamarine.

4.1.7 Black Onyx (Quartz) (SiO_2) (RI = 1.544 - 1.553) - Faceted

Tested at: T: 22.8 H: 25.2
Mean value: 1.468 - 1.479
Deviation: 0.076 - 0.074

Tested at: T: 26.3 H: 27.7
Mean value: 1.471 - 1.475
Deviation: 0.073 - 0.078

Tested at: T: 34.1 H: 16.9
Mean value: 1.461 - 1.466
Deviation: 0.083 - 0.087



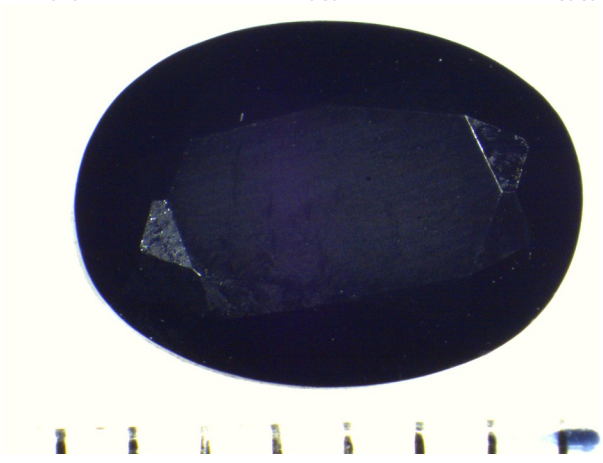


Fig. 8a. Mean value for black onyx at different temperatures. Fig. 8b. The tested .

4.1.8 Bloodstone (Chalcedony) (SiO_2) (RI = 1.535 - 1.539) - Cabochon

Tested at: T: 23.4 H: 20.1
Mean value: 1.554 - 1.564
Deviation: 0.019 - 0.025

Tested at: T: 26.6 H: 28.8
Mean value: 1.553 - 1.561
Deviation: 0.018 - 0.022

Tested at: T: 31.7 H: 19.2
Mean value: 1.547 - 1.554
Deviation: 0.012 - 0.015

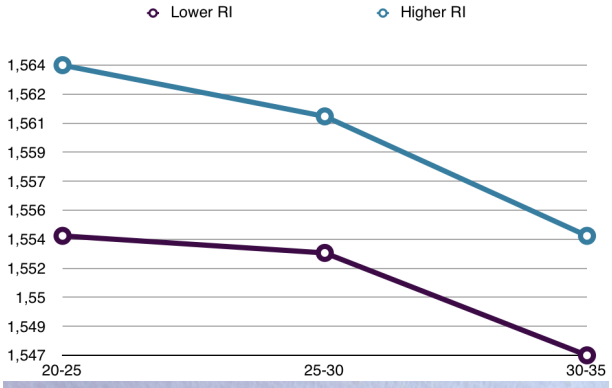


Fig. 9a. Mean value for bloodstone at different temperatures. Fig. 9b. The tested bloodstone.

4.1.9 Iolite ($(Mg,Fe)_2Al_4Si_5O_{18}$) (RI = 1.542 - 1.551) - Faceted

Tested at: T: 23.2 H: 25.1
Mean value: 1.530 - 1.533
Deviation: 0.012 - 0.018

Tested at: T: 26.6 H: 30.7
Mean value: 1.538 - 1.540
Deviation: 0.004 - 0.011

Tested at: T: 30.9 H: 23.2
Mean value: 1.521 - 1.528
Deviation: 0.021 - 0.023

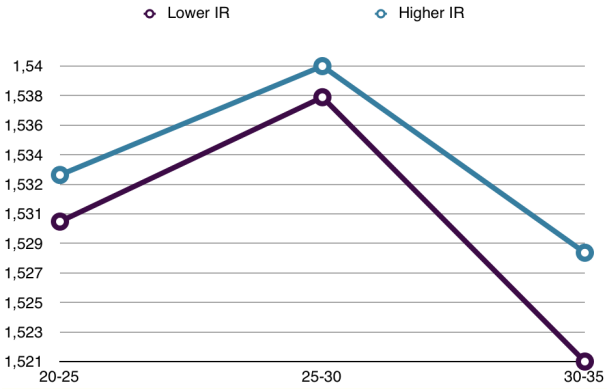


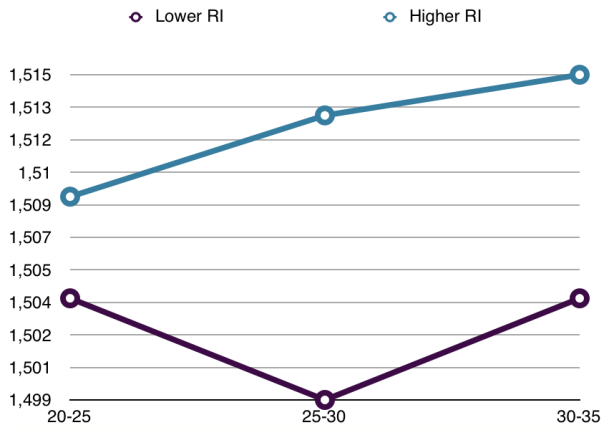
Fig. 10a. Mean value for iolite at different temperatures. Fig. 10b. The tested iolite.

4.1.10 Lab Sapphire (SiO_2) (RI = 1.584) - Faceted

Tested at: T: 22.9 H: 25.2
Mean value: 1.504 - 1.509
Deviation: 0.080 - 0.075

Tested at: T: 26.6 H: 28.8
Mean value: 1.499 - 1.513
Deviation: 0.085 - 0.071

Tested at: T: 31.8 H: 19.2
Mean value: 1.504 - 1.515
Deviation: 0.080 - 0.069



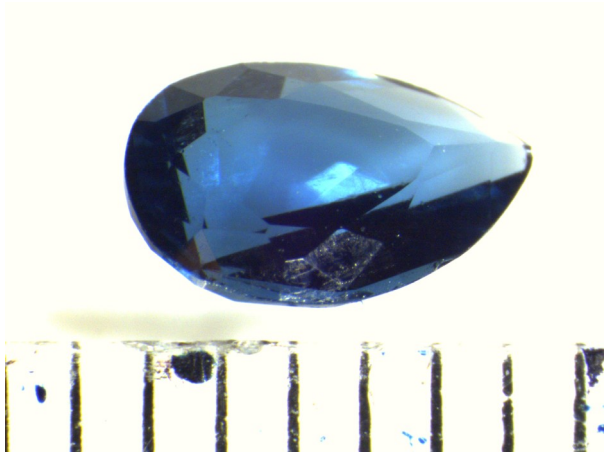


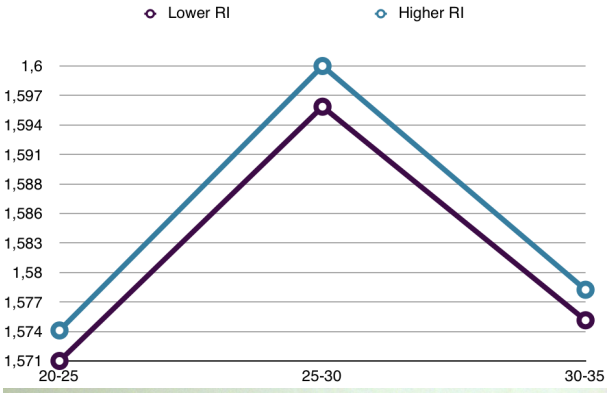
Fig. 11a. Mean value for lab sapphire at different temperatures. Fig. 11b. The tested lab sapphire.

4.1.11 Morganite (Beryl) ($(Be_3Al_2(SiO_3)_6)$) (RI = 1.577-1.583) - Faceted

Tested at: T: 23.0 H: 22.0
Mean value: 1.571 - 1.574
Deviation: 0.006 - 0.009

Tested at: T: 26.7 H: 28.8
Mean value: 1.596 - 1.600
Deviation: 0.019 - 0.017

Tested at: T: 33.2 H: 18.1
Mean value: 1.575 - 1.578
Deviation: 0.002 - 0.005



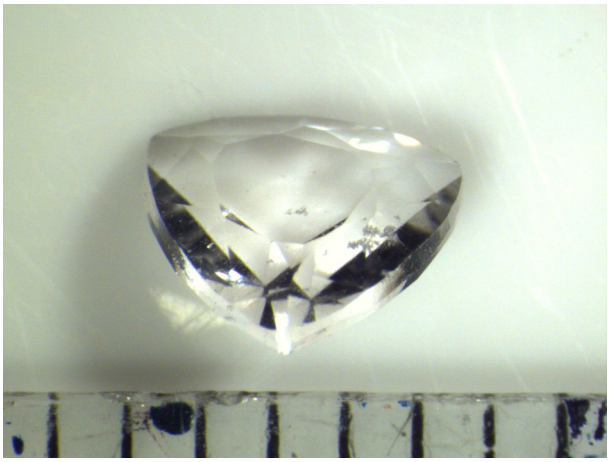


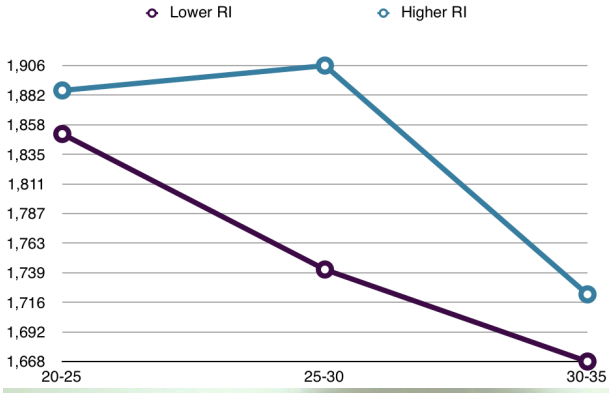
Fig. 12a. Mean value for morganite at different temperatures. Fig. 12b. The tested morganite.

4.1.12 Pearl ($CaCO_3$)
(RI = 1.530 - 1.685) - Cabochon

Tested at: T: 23.0 H: 23.0
Mean value: 1.851 - 1.886
Deviation: 0.321 - 0.201

Tested at: T: 26.7 H: 27.7
Mean value: 1.742 - 1.906
Deviation: 0.212 - 0.221

Tested at: T: 33.8 H: 17.9
Mean value: 1.668 - 1.722
Deviation: 0.138 - 0.037



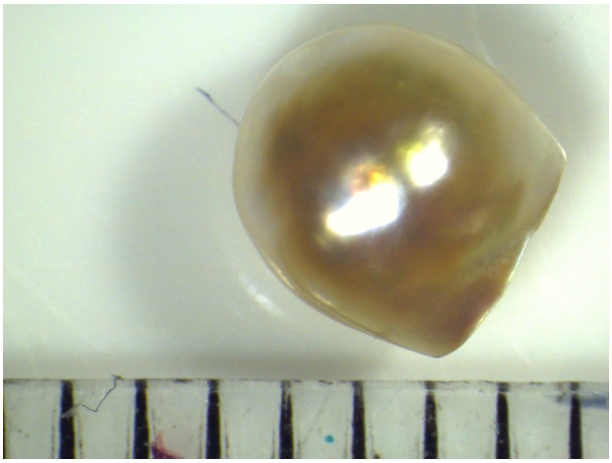


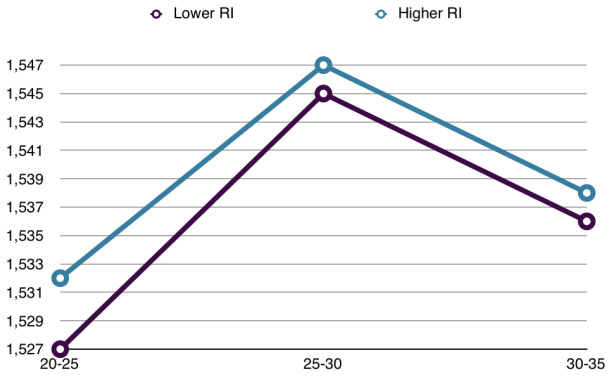
Fig. 13a. Mean value for pearl at different temperatures.
Fig. 13b. The tested pearl.

4.1.13 Prasiolite (Quartz) (SiO_2)
(RI = 1.544 - 1.553) - Faceted

Tested at: T: 23.2 H: 25.2
Mean value: 1.527 - 1.532
Deviation: 0.017 - 0.021

Tested at: T: 26.8 H: 26.6
Mean value: 1.545 - 1.547
Deviation: 0.001 - 0.006

Tested at: T: 32.7 H: 19.2
Mean value: 1.536 - 1.538
Deviation: 0.008 - 0.015



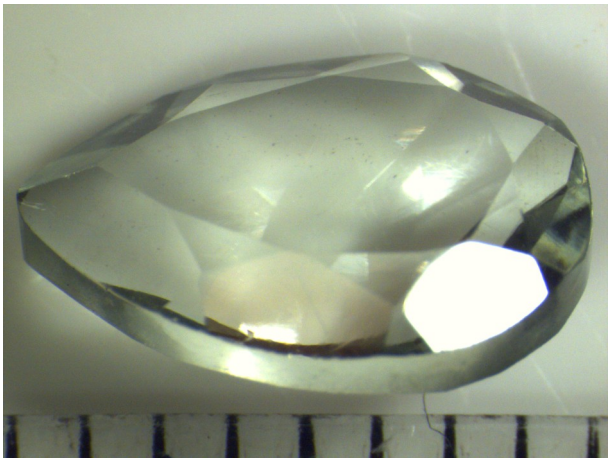


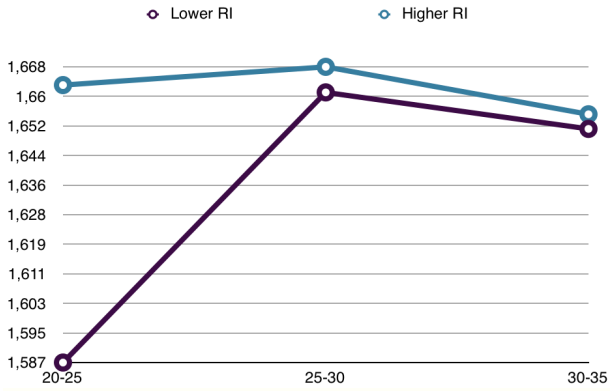
Fig. 14a. Mean value for prasiolite at different temperatures.
Fig. 14b. The tested prasiolite.

4.1.14 Tourmaline ((Ca,K,Na[])(Al,Fe,Li,Mg,Mn)$_3$ (Al,Cr,Fe,V)$_6$(BO$_3$)$_3$(Si,Al,B)$_6$O$_{18}$(OH,F)$_4$) (RI = 1.624 - 1.644) - Faceted

Tested at: T: 23.4 H: 19.8
Mean value: 1.587 - 1.663
Deviation: 0.037 - 0.019

Tested at: T: 26.5 H: 30.9
Mean value: 1.661 - 1.668
Deviation: 0.037 - 0.024

Tested at: T: 33.8 H: 24.9
Mean value: 1.651 - 1.655
Deviation: 0.027 - 0.011



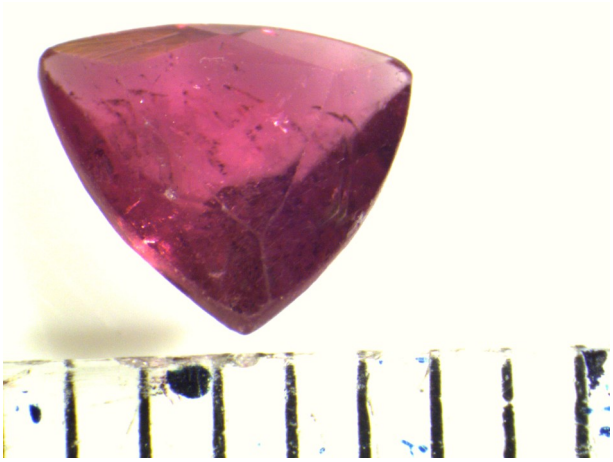


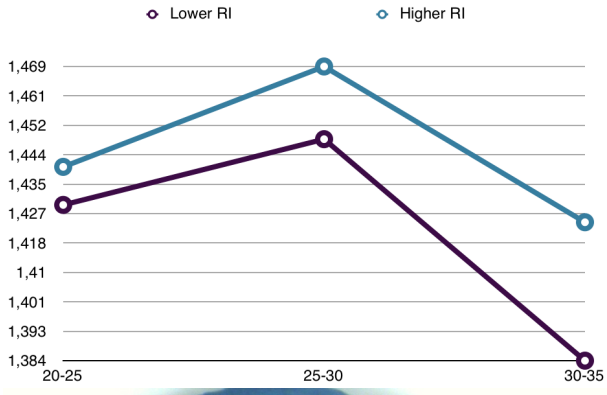
Fig. 15a. Mean value for tourmaline at different temperatures. Fig. 15b. The tested tourmaline.

4.1.15 Turquoise ($CuAl_6(PO_4)_4(OH)_8 5H_2O$) (RI = 1.61) - Cabochon

Tested at: T: 22.9 H: 21.9
Mean value: 1.429 - 1.440
Deviation: 0.181 - 0.170

Tested at: T: 26.3 H: 27.5
Mean value: 1.448 - 1.469
Deviation: 0.162 - 0.141

Tested at: T: 32.4 H: 19.1
Mean value: 1.384 - 1.424
Deviation: 0.226 - 0.186



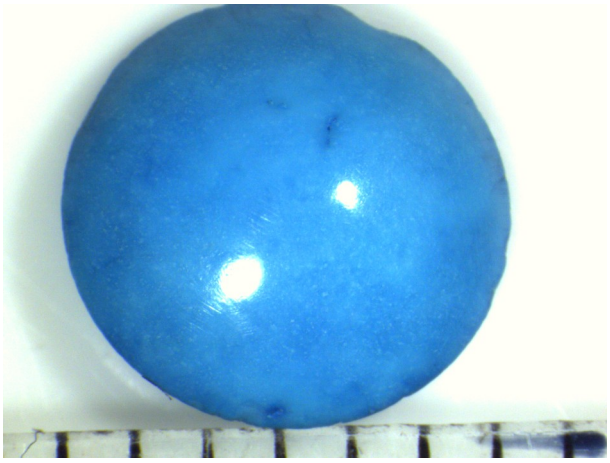


Fig. 16a. Mean value for turquoise at different temperatures. Fig. 16b. The tested turquoise.

4.2 Testing different cut

The results from testing the same gemstone faceted in different ways are presented the same way as the results from testing in different temperatures.

For every gemstone, a picture of the tested gemstone is presented, see Figs. 17-28.

In this series of tests, all the test were made in room temperature.

The full result sheet can be found in Appendix C.

4.2.1 Amethyst (Quartz) (RI = 1.544 - 1.553)

4.2.1.1 Octagon cut 1

Tested at: T: 22.8 H: 53.4
Mean value: 1.566 - 1.572
Deviation: 0.022 - 0.019

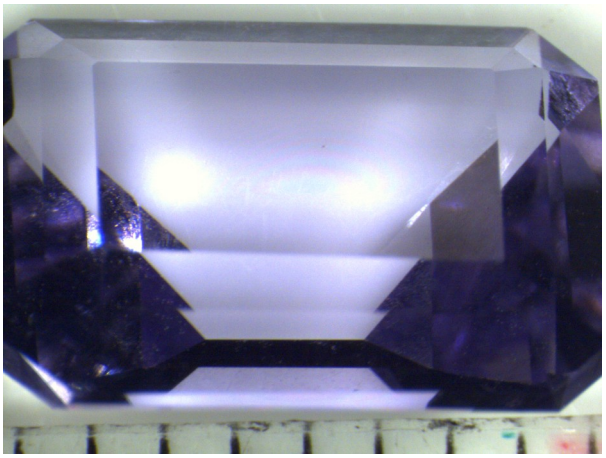


Fig. 17. Amethyst with octagon cut 1.

4.2.1.2 Octagon cut 2

Tested at: T: 23.0 H: 53.3
Mean value: 1.561 - 1.566
Deviation: 0.017 - 0.013

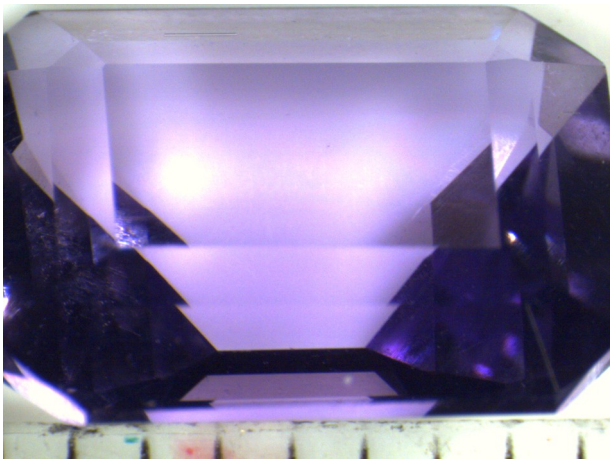


Fig. 18. Amethyst with octagon cut 2.

4.2.1.3 Oval cut 1

Tested at: T: 22.6 H: 38.0
Mean value: 1.543 - 1.551
Deviation: 0.001 - 0.002

Fig. 19. Amethyst with oval cut 1.

4.2.1.4 Oval cut 2

Tested at: T: 22.6 H: 39.0
Mean value: 1.555 - 1.562
Deviation: 0.011 - 0.009

Fig. 20. Amethyst with oval cut 2.

4.2.1.5 Pear cut 1

Tested at: T: 22.7 H: 39.2
Mean value: 1.531 - 1.533
Deviation: 0.013 - 0.020

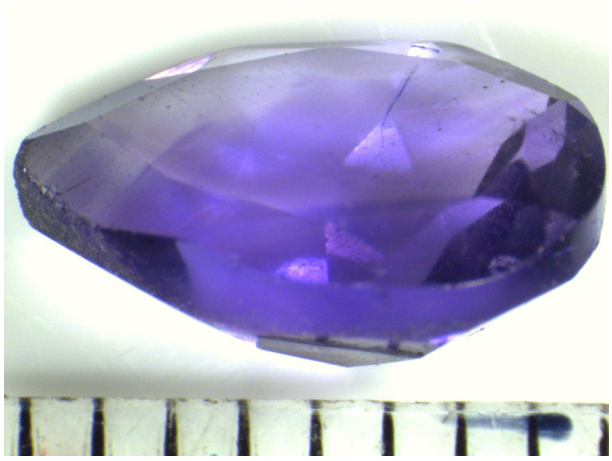


Fig. 21. Amethyst with pear cut 1.

4.2.1.6 Pear cut 2

Tested at: T: 22.9 H: 40.1
Mean value: 1.543 - 1.545
Deviation: 0.001 - 0.008

Fig. 22. Amethyst with pear cut 2.

4.2.1.7 Princess cut

Tested at: T: 23.1 H: 54.2
Mean value: 1.530 - 1.537
Deviation: 0.014 - 0.016

Fig. 23. Amethyst with princess cut.

4.2.1.8 Square cut

Tested at: T: 23.0 H: 40.6
Mean value: 1.538 - 1.539
Deviation: 0.006 - 0.014

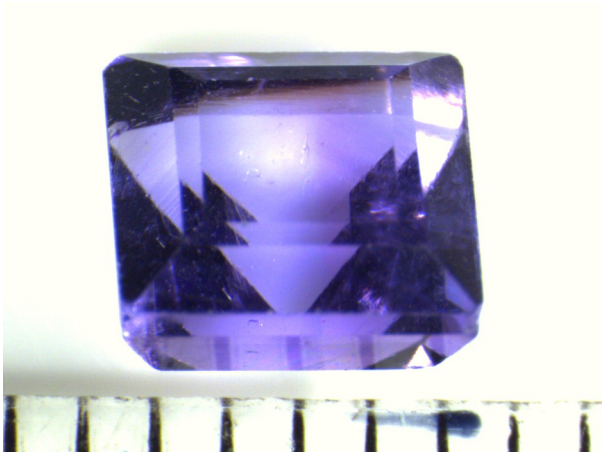


Fig. 24. Amethyst with square cut.

4.2.2 Sapphire (Corundum) (RI = 1.762 - 1.770)

4.2.2.1 Oval cut

Tested at: T: 23.4 H: 54.6
Mean value: 1.686 - 1.732
Deviation: 0.076 - 0.038

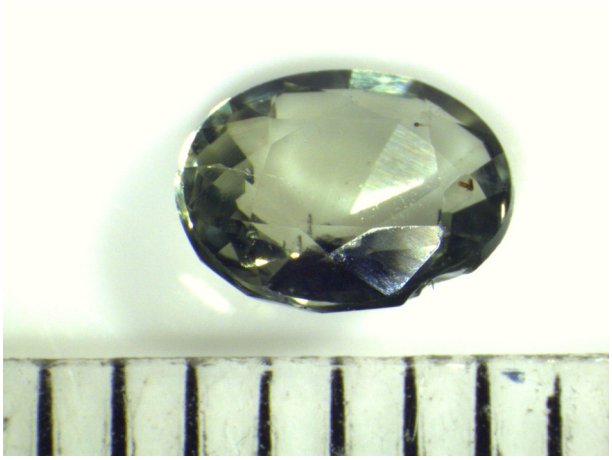


Fig. 25. Sapphire with oval cut.

4.2.2.2 Pear cut 1

Tested at: T: 22.4 H: 54.3
Mean value: 1.751 - 1.755
Deviation: 0.011 - 0.015

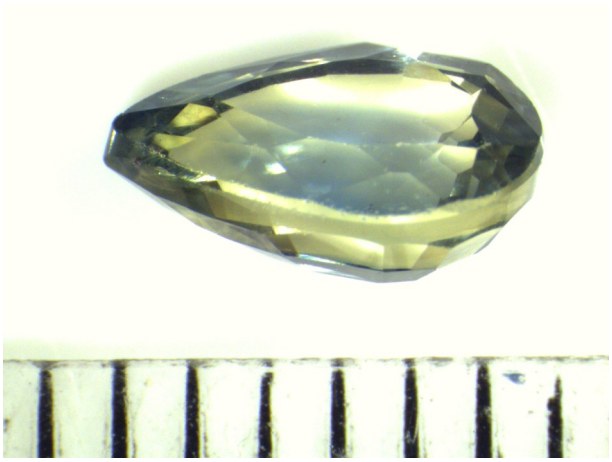


Fig. 26. Sapphire with pear cut 1.

4.2.2.3 Pear cut 2

Tested at: T: 23.2 H: 55.5
Mean value: 1.740 - 1.756
Deviation: 0.022 - 0.014

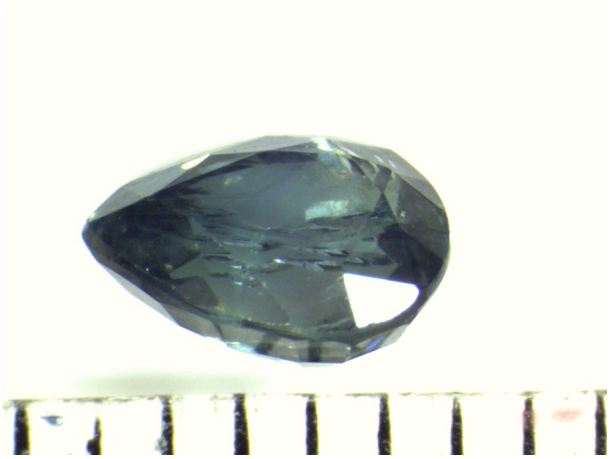


Fig. 27. Sapphire with pear cut 2.

4.2.2.4 Round cut

Tested at: T: 23.2 H: 55.1
Mean value: 1.760 - 1.763
Deviation: 0.002 - 0.007

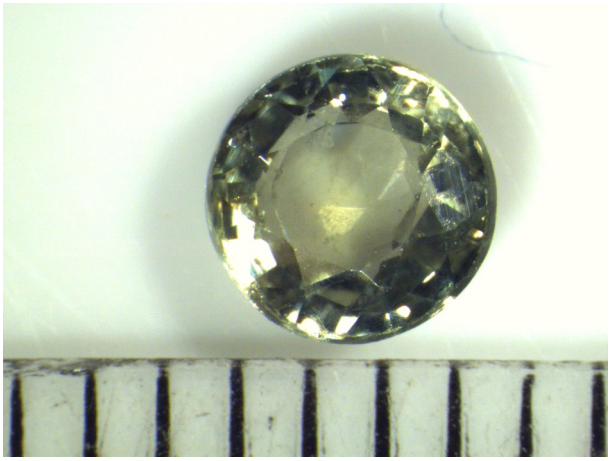


Fig. 28. Sapphire with oval cut.

5 Discussion

5.1 Testing in different temperatures

In the tests on the calibration stones, the most accurate values were obtained when calibrated or tested in over 30°C, whereas calibrated and tested in the normal room temperature (20-25°C) did not give good values.

Only one stone obtained the best values at 20-25°C: Black Onyx (quartz). Most stones (eight stones: lab sapphire, morganite (beryl), aquamarine (beryl), tourmaline, iolite, amethyst (quartz), ametrine (quartz), bloodstone (chalcedony) and pearl) obtained the best values at 30-35°C. Four stones (alexandrite, iolite, prasiolite (quartz) and turqoise) obtained the best values at 25-28°C.

Most stones (five stones: lab sapphire, morganite (beryl), tourmaline, amethyst (quartz) and ametrine (quartz)) obtained the worst values at 25-28°C. Four stones obtained the worst values at 20-25°C (aquamarine (beryl), prasiolite (quartz), bloodstone (chalcedony) and pearl) and four stones obtained the worst value at 30-35°C (alexandrite, iolite, turquoise and black onyx (quartz).

None of the three cabochons (turquoise, bloodstone (chalcedony) and pearl) obtained good values. They all had a deviation of more than 0.01.

Four faceted gemstones (morganite (beryl), aquamarine (beryl), prasiolite (quartz) and ametrine (quartz)) obtained pretty good values (a deviation of less than 0.01), while the remaining six faceted gemstones (lab sapphire, alexandrite, tourmaline, iolite, amethyst (quartz) and black onyx (quartz)) did not obtain good values (deviation of more than 0.01).

5.2 Testing different cut

I tested two amethysts with oval cut and two amethysts with pear cut. One of each obtained a very good value (deviation of less than 0.01) while one of each obtained a very inaccurate value (deviation of 0.009 to 0.020). Both octagon cut amethysts obtained pretty inaccurate values (deviation of 0.013-0.022). All in all, there is not much difference in results between the amethysts cut in different ways.

I also tested four sapphires faceted in three different ways. The best results were obtained with the round cut (deviation of 0.002-0.007), while the worst results were obtained with the oval cut (deviation of 0.076-0.038). The values with pear cut were better than with the oval cut, but worse than with the round cut.

Some differentiation between the different cuts can be seen when testing the sapphires, but as seen when testing the amethyst, there could also be a difference between gemstones faceted the same way. Therefore, we can only see an indication, but more tests should be carried through to see if any difference between the different cuts can be stated.

5.3 Why the malfunction of the first generation infrared refractometer?

Since only one gemstone (black onyx (quartz)) obtained the best values at 20-25°C, and most stones obtained the best values at 25-28, which is the working temperature according to the manufacturer (Opticsfactory), temperature appear to have certain influence on the result.

I tried to find any information from the manufacturer's webpage about how the instrument is built, how it works, or any other clue that can help to solve the problem. The only thing I found out is that they have now changed one of the calibration stones. The calibration stone with RI = 1.470 is now replaced with a calibration stone with RI = 1.4875. That is quite a difference, and chances are I have got wrong values because the instrument was calibrated the wrong way because of the calibration stones that came with it.

Another possibility is that the instrument gives wrong values because the manufacturer did not take into account that since the instrument uses infrared light instead of visible light, the refractive index should be different due to the different wavelength. In that case, the algorithm used to convert the reflection to refractive index should be replaced. I find this hard to believe due to the difference in refractive index between two amethyst faceted the same way and tested in the same temperature.

6 Conclusions

The temperature proved to have certain influence on the result, while the cut did not show any notable relevance to the results. The fact that the results are inaccurate do not seem to be because wrong algorithm is used in the first generation infrared refractometer, since a wide differentiation can be seen also within samples of the same gemstone faceted the same way and tested in the same temperature. Since the manufacturer has replaced the calibration stone with the lower RI = 1.470 with a calibration stone with RI = 1.4875, chances are that this is the reason why I do not get the correct values.

7 Acknowledgements

First of all, I want to thank my supervisors in this project; Loren Babcock and Leif Johansson. I also want to thank my course mates for these three fantastic years. Thanks to my family, which has always supported me.

8 References

Babcock, L. E., 2012: A Concise Guide to Gemstones and Precious Metals. Lund University. 190 pp.

Gem-N-Eye. 2013. Retrieved 130521 17:00, from http://www.mineralab.com/Gem-n-Eye.htm.

Opticsfactory. 2013. Retrieved 130521 14:28, from http://www.opticsfactory.com/digital-gem-refractometer-gemstone-tool-foctory-selling/.

The Gemology Project. 2013a. Retrieved 130521 15:01, from http://gemologyproject.com/ wiki/index.php?title=Refractometer.

The Gemology Project. 2013b. Retrieved 130521 16:19, from http://gemologyproject.com/ wiki/index.php?Title=Course:Total_internal_ reflection.

Wikipedia. 2013. Retrieved 130521 16:30, from http://en.wikipedia.org/wiki/Snell's_law.

Appendix A

Results sheet for the tests on the calibration stones in different temperatures. Tests 1, 2 and 3 are with the stones in one direction, and test 4, 5 and 6 are after turning the stone 90°. T = Temperature, H = Humidity, IR = The value obtained with the first generation infrared refractometer.

RI = 1.470

Calibrated at: T = 26.2°C, H = 24.4 %

Test	Tested at (T)	Tested at (H)	IR
1	23.4	28.5	1.466
2	23.3	28.5	1.468
3	23.2	28.5	1.466
4	23.4	28.5	1.468
5	23.3	28.5	1.465
6	23.2	28.5	1.464

Calibrated at: T = 22.9°C, H = 29.0 %

Test	Tested at (T)	Tested at (H)	IR
1	26.0	25.5	1.468
2	26.2	24.9	1.472
3	26.4	24.4	1.465
4	26.1	25.5	1.461
5	26.3	24.4	1.472
6	26.4	24.4	1.463

Calibrated at: T = 26.2°C, H = 24.4 %

Test	Tested at (T)	Tested at (H)	IR
1	26.2	24.4	1.473
2	26.2	24.4	1.480
3	26.2	24.9	1.479
4	26.2	24.4	1.476
5	26.2	24.4	1.480
6	26.2	24.4	1.479

Calibrated at: T = 34.6°C, H = 18.2 %

Test	Tested at (T)	Tested at (H)	IR
1	27.0	23.9	1.467
2	26.8	23.9	1.470
3	26.7	24.4	1.468
4	26.9	23.9	1.467
5	26.8	24.4	1.468
6	26.7	24.4	1.467

Calibrated at: T = 26.6°C, H = 25.5 %

Test	Tested at (T)	Tested at (H)	IR
1	30.4	21.4	1.463
2	30.5	20.2	1.472
3	30.6	20.2	1.466
4	30.4	21.4	1.464
5	30.6	21.4	1.471
6	30.7	20.8	1.467

Calibrated at: T = 32.0°C, H = 18.6 %

Test	Tested at (T)	Tested at (H)	IR
1	31.9	19.2	1.471
2	31.6	19.2	1.472
3	32.2	19.2	1.474
4	31.8	19.2	1.471
5	31.6	19.7	1.472
6	32.4	19.7	1.472

RI = 1.755

Calibrated at: T = 24.9°C, H = 26.8 %

Test	Tested at (T)	Tested at (H)	IR
1	23.1	28.5	1.756
2	23.0	28.5	1.751
3	23.0	29.0	1.756
4	23.1	28.5	1.747
5	23.0	28.5	1.755
6	22.9	29.0	1.743

Calibrated at: T = 22.9°C, H = 29.0 %

Test	Tested at (T)	Tested at (H)	IR
1	26.5	24.4	1.733
2	26.6	24.4	1.756
3	26.7	24.4	1.750
4	26.6	24.4	1.745
5	26.6	24.4	1.744
6	26.6	23.9	1.753

Calibrated at: T = 26.2°C, H = 24.4 %

Test	Tested at (T)	Tested at (H)	IR
1	26.1	24.4	1.755
2	26.0	25.5	1.740
3	26.2	24.9	1.747
4	26.1	24.9	1.752
5	26.0	25.5	1.739
6	26.2	25.5	1.746

Calibrated at: T = 34.6°C, H = 18.2 %

Test	Tested at (T)	Tested at (H)	IR
1	26.6	24.4	1.753
2	26.2	24.4	1.754
3	26.4	24.4	1.752
4	26.6	24.4	1.751
5	26.5	24.4	1.756
6	26.4	24.4	1.756

Calibrated at: T = 26.6°C, H = 25.5 %

Test	Tested at (T)	Tested at (H)	IR
1	31.1	20.3	1.747
2	31.7	19.2	1.763
3	31.3	19.7	1.755
4	31.1	20.3	1.755
5	31.5	19.7	1.760
6	31.2	20.3	1.754

Calibrated at: T = 32.0°C, H = 18.6

Test	Tested at (T)	Tested at (H)	IR
1	32.8	18.1	1.754
2	32.8	18.1	1.755
3	33.2	18.2	1.755
4	32.8	18.1	1.749
5	32.9	18.1	1.756
6	33.3	18.2	1.758

Appendix B

Results sheet for the tests on gemstones in different temperatures. Tests 1, 2 and 3 are with the stones in one direction, and test 4, 5 and 6 are after turning the stone 90°. T = Temperature, H = Humidity, VL = The values obtained with the standard refractometer, IR = The values obtained with the first generation infrared refractometer.

Tests in 20-25°C

Alexandrite

Test	VL	T	H	IR	T	H
1	1.78	23.0	22.0	1.674	23.0	22.0
2	1.77	23.0	22.0	1.693	23.0	22.0
3	1.75	23.0	22.0	1.701	23.0	22.0
4	1.78	23.0	22.0	1.709	23.0	22.0
5	1.74	23.0	22.0	1.706	23.0	22.0
6	1.74	23.0	22.0	1.705	23.0	22.0

Amethyst

Test	VL	T	H	IR	T	H
1	1.54	22.8	20.8	1.563	23.0	19.8
2	1.54	22.8	20.8	1.563	23.0	19.8
3	1.54	22.8	20.8	1.562	22.8	20.3
4	1.55	22.8	20.8	1.564	23.0	19.8
5	1.55	22.8	20.8	1.567	23.0	19.8
6	1.55	22.8	20.8	1.562	22.8	20.3

Ametrine

Test	VL	T	H	IR	T	H
1	1.54	23.2	18.7	1.522	23.2	18.7
2	1.54	23.3	18.7	1.559	23.2	18.7
3	1.54	23.2	18.7	1.561	23.2	18.7
4	1.55	23.2	18.7	1.516	23.2	18.7
5	1.55	23.3	18.7	1.561	23.3	18.7
6	1.55	23.2	18.7	1.560	23.2	18.7

Aquamarine

Test	VL	T	H	IR	T	H
1	1.57	23.1	19.8	1.594	23.2	19.8
2	1.57	23.2	19.8	1.590	23.2	19.8
3	1.57	23.2	19.8	1.588	23.2	19.8
4	1.58	23.1	19.8	1.594	23.2	19.8
5	1.58	23.2	19.8	1.590	23.2	19.8
6	1.58	23.2	19.8	1.585	23.2	19.8

Black Onyx

Test	VL	T	H	IR	T	H
1	1.54	22.6	25.2	1.473	22.8	25.2
2	1.54	22.7	24.2	1.459	22.8	25.2
3	1.54	22.7	25.2	1.473	22.8	25.2
4	1.53	22.6	25.2	1.492	22.8	25.2
5	1.53	22.7	24.2	1.471	22.8	25.2
6	1.53	22.7	25.2	1.471	22.8	25.2

Bloodstone

Test	VL	T	H	IR	T	H
1	1.53	23.2	19.8	1.564	23.3	19.8
2	1.53	23.2	19.8	1.560	23.4	19.8
3	1.53	23.3	19.8	1.568	23.3	20.3
4	1.53	23.2	19.8	1.564	23.4	20.3
5	1.53	23.2	19.8	1.559	23.3	20.3
6	1.53	23.3	19.8	1.540	23.4	20.3

Cubic Zirconia (Cz)

Test	VL	T	H	IR	T	H
1	No value	-	-	2.069	22.7	21.9
2	No value	-	-	2.138	22.7	21.9
3	No value	-	-	2.115	22.8	21.9
4	No value	-	-	2.067	22.7	21.9
5	No value	-	-	2.135	22.8	21.9
6	No value	-	-	2.114	22.8	21.9

Diamond

Test	VL	T	H	IR	T	H
1	No value	-	-	1.265	23.2	24.2
2	No value	-	-	1.278	23.2	24.2
3	No value	-	-	1.333	23.2	24.2
4	No value	-	-	1.590	23.2	24.2
5	No value	-	-	1.418	23.2	24.2
6	No value	-	-	1.360	23.2	24.2

Glass (”lab sapphire”)

Test	VL	T	H	IR	T	H
1	1.58	22.8	25.2	1.513	22.9	25.2
2	1.58	22.9	25.2	1.507	22.9	25.2
3	1.58	22.9	25.2	1.507	22.9	25.2
4	1.59	22.8	25.2	1.504	22.9	25.2
5	1.58	22.9	25.2	1.507	23.0	25.2
6	1.59	22.9	25.2	1.502	22.9	25.2

Goldstone glass

Test	VL	T	H	IR	T	H
1	1.52	23.2	18.7	1.459	23.2	18.7
2	1.52	23.2	18.7	1.494	23.2	18.7
3	1.52	23.2	18.7	1.522	23.2	18.7
4	1.52	23.2	18.7	1.523	23.2	18.7
5	1.52	23.2	18.7	1.494	23.2	18.7
6	1.52	23.2	18.7	1.508	23.2	18.7

Haematite

Test	VL	T	H	IR	T	H
1	No value	-	-	2.150	22.6	23.0
2	No value	-	-	2.186	22.6	21.9
3	No value	-	-	2.140	22.6	21.9
4	No value	-	-	1.983	22.6	21.9
5	No value	-	-	2.110	22.6	21.9
6	No value	-	-	1.970	22.6	21.9

Iolite

Test	VL	T	H	IR	T	H
1	1.54	23.2	25.2	1.529	23.2	25.2
2	1.54	23.2	25.2	1.530	23.2	24.7
3	1.54	23.2	25.2	1.532	23.2	25.2
4	1.55	23.2	25.2	1.531	23.2	25.2
5	1.55	23.2	25.2	1.534	23.2	25.2
6	1.55	23.2	25.2	1.535	23.2	25.2

Morganite

Test	VL	T	H	IR	T	H
1	1.59	23.0	22.0	1.567	23.0	22.5
2	1.59	22.9	21.9	1.577	23.0	22.0
3	1.59	22.9	21.9	1.572	23.0	21.9
4	1.58	23.0	22.0	1.573	23.0	21.9
5	1.58	22.9	21.9	1.573	22.9	21.9
6	1.58	22.9	21.9	1.573	23.0	21.9

Opal

Test	VL	T	H	IR	T	H
1	1.41	23.3	19.8	1.432	23.3	19.20
2	1.41	23.3	19.8	1.384	23.3	19.20
3	1.41	23.3	19.8	1.455	23.3	19.20
4	1.41	23.3	19.8	1.432	23.2	19.20
5	1.41	23.3	19.8	1.384	23.3	19.20
6	1.41	23.3	19.8	1.472	23.3	19.20

Orthoclase feldspar (chatoyant)

Test	VL	T	H	IR	T	H
1	No value	23.0	20.9	1.370	23.0	23.0
2	No value	23.2	19.8	1.370	23.1	23.1
3	No value	23.2	19.8	1.384	23.1	23.1
4	No value	23.2	19.8	1.370	23.0	23.0
5	No value	23.2	19.8	1.385	23.1	23.1
6	No value	23.2	19.8	1.348	23.1	23.1

Pearl

Test	VL	T	H	IR	T	H
1	1.57	22.8	21.9	1.695	23.0	23.0
2	1.58	22.8	21.9	2.066	23.0	23.0
3	1.61	22.8	21.9	1.807	22.9	23.0
4	1.57	22.8	21.9	1.785	23.0	23.0
5	1.58	22.8	21.9	2.066	23.0	23.0
6	1.61	22.8	21.9	1.793	22.9	23.0

Peridot

Test	VL	T	H	IR	T	H
1	1.68	23.6	24.2	1.670	23.6	24.2
2	1.68	23.6	24.2	1.673	23.6	24.2
3	1.68	23.6	24.2	1.674	23.6	23.6
4	1.66	23.6	24.2	1.673	23.6	24.2
5	1.66	23.6	24.2	1.673	23.6	24.2
6	1.66	23.6	24.2	1.675	23.6	23.6

Plastic

Test	VL	T	H	IR	T	H
1	1.77	23.2	24.2	1.734	23.4	24.2
2	1.77	23.3	24.2	1.855	23.4	24.2
3	1.77	23.3	24.2	1.232	23.5	23.2
4	1.77	23.2	24.2	1.744	23.4	24.2
5	1.77	23.3	24.2	1.820	23.4	24.2
6	1.77	23.3	24.2	1.579	23.5	24.2

Prasiolite

Test	VL	T	H	IR	T	H
1	1.54	23.2	25.2	1.529	23.2	25.2
2	1.54	23.2	25.2	1.538	23.2	25.2
3	1.54	23.2	25.2	1.523	23.2	25.2
4	1.55	23.2	25.2	1.535	23.2	25.2
5	1.55	23.2	25.2	1.532	23.2	25.2
6	1.55	23.2	25.2	1.519	23.2	25.2

Ruby

Test	VL	T	H	IR	T	H
1	1.76	23.2	27.9	1.721	23.2	28.5
2	1.76	23.2	28.5	1.722	23.2	28.5
3	1.76	23.2	28.5	1.767	23.2	28.5
4	1.77	23.2	27.9	1.722	23.2	28.5
5	1.77	23.2	28.5	1.768	23.2	28.5
6	1.77	23.2	28.5	1.772	23.2	28.5

Russian lab white diamond (CZ)

Test	VL	T	H	IR	T	H
1	1.77	23.2	25.2	2.133	23.1	27.9
2	1.77	23.0	27.9	2.035	23.1	27.9
3	1.77	23.1	28.5	2.120	23.2	27.9
4	1.77	23.2	25.2	2.130	23.1	27.9
5	1.77	23.0	27.9	2.131	23.2	27.9
6	1.77	23.1	28.5	2.135	23.2	28.5

Rutilated quartz

Test	VL	T	H	IR	T	H
1	No value	22.9	21.9	1.435	22.9	21.9
2	No value	22.9	21.9	1.478	22.9	21.9
3	No value	22.9	21.9	1.497	22.9	22.5
4	No value	22.9	21.9	1.496	23.0	22.0
5	No value	22.9	21.9	1.497	23.0	22.0
6	No value	22.9	21.9	1.581	22.9	22.5

Sapphire

Test	VL	T	H	IR	T	H
1	1.76	23.9	23.7	1.762	23.7	23.6
2	1.77	23.8	24.2	1.761	23.6	23.6
3	1.77	23.9	23.7	1.760	23.5	23.6
4	1.75	23.9	23.7	1.761	23.6	23.6
5	1.76	23.8	24.2	1.761	23.6	23.6
6	1.76	23.9	23.7	1.765	23.5	23.6

Spessartite garnet

Test	VL	T	H	IR	T	H
1	1.77	22.8	22.5	1.779	22.9	23.0
2	1.77	22.8	22.5	1.782	22.9	22.5
3	1.77	22.8	22.5	1.783	22.9	22.5
4	1.77	22.8	22.5	1.779	22.9	23.0
5	1.77	22.8	22.5	1.780	22.9	22.5
6	1.77	22.8	22.5	1.780	22.9	22.5

Spinel

Test	VL	T	H	IR	T	H
1	1.71	22.2	34.8	1.698	22.6	34.8
2	1.71	22.5	34.8	1.689	22.7	34.8
3	1.71	22.5	34.8	1.685	22.8	34.8
4	1.71	22.5	34.8	1.693	22.6	34.8
5	1.71	22.5	34.8	1.697	22.8	34.8
6	1.71	22.5	34.8	1.676	22.7	34.8

Sunstone

Test	VL	T	H	IR	T	H
1	1.77	23.6	24.2	1.248	23.6	24.2
2	1.77	23.6	23.6	1.212	23.7	24.2
3	1.77	23.7	24.2	1.231	23.6	24.2
4	1.77	23.6	24.2	1.247	23.6	24.2
5	1.77	23.6	23.6	1.247	23.6	24.2
6	1.77	23.7	24.2	1.249	23.7	24.2

Tanzanite

Test	VL	T	H	IR	T	H
1	1.69	23.2	28.5	1.690	22.6	29.5
2	1.69	23.0	28.5	1.692	22.6	29.5
3	1.69	22.6	29.5	1.696	22.5	29.5
4	1.70	23.2	28.5	1.692	22.6	29.5
5	1.70	23.0	28.5	1.695	22.6	29.5
6	1.70	22.6	29.5	1.698	22.5	29.5

Topaz

Test	VL	T	H	IR	T	H
1	1.61	23.0	25.2	1.591	23.0	25.2
2	1.61	23.0	25.2	1.603	23.0	25.2
3	1.61	23.0	25.2	1.614	23.1	25.2
4	1.62	23.0	25.2	1.607	23.0	25.2
5	1.62	23.0	25.2	1.597	23.0	25.2
6	1.62	23.0	25.2	1.614	23.1	25.2

Tourmaline

Test	VL	T	H	IR	T	H
1	1.62	23.3	19.8	1.656	23.4	19.8
2	1.62	23.3	19.8	1.630	23.4	19.8
3	1.62	23.4	19.8	1.474	23.4	19.8
4	1.64	23.3	19.8	1.658	23.4	19.8
5	1.64	23.3	19.8	1.666	23.4	19.8
6	1.64	23.4	19.8	1.666	23.4	19.8

Tourmaline

Test	VL	T	H	IR	T	H
1	1.41	23.2	18.7	1.577	23.2	18.7
2	1.43	23.2	18.7	1.578	23.2	18.7
3	1.48	23.2	18.7	1.577	23.2	18.7
4	1.45	23.2	18.7	1.577	23.2	18.7
5	1.44	23.2	18.7	1.511	23.2	18.7
6	1.49	23.2	18.7	1.584	23.2	18.7

Turquoise

Test	VL	T	H	IR	T	H
1	1.60	22.8	21.9	1.413	22.9	21.9
2	1.61	22.8	21.9	1.474	22.9	21.9
3	1.60	22.9	21.9	1.401	22.9	21.9
4	1.59	22.8	21.9	1.416	22.9	21.9
5	1.60	22.8	21.9	1.464	22.9	21.9
6	1.60	22.9	21.9	1.441	23.0	22.0

Unknown

Test	VL	T	H	IR	T	H
1	1.55	23.2	18.7	1.425	23.2	18.7
2	1.58	23.2	18.7	1.492	23.2	18.7
3	1.58	23.2	18.7	1.489	23.2	18.7
4	1.55	23.2	18.7	1.425	23.2	18.7
5	1.55	23.2	18.7	1.488	23.2	18.7
6	1.57	23.2	18.7	1.485	23.2	18.7

Unknown

Test	VL	T	H	IR	T	H
1	No value	22.6	21.9	1.258	22.6	21.9
2	1.77	22.6	21.9	1.258	22.6	21.9
3	1.77	22.6	21.9	1.254	22.7	21.9
4	No value	22.6	21.9	1.257	22.7	21.9
5	1.77	22.6	21.9	1.258	22.6	21.9
6	1.77	22.6	21.9	1.258	22.6	21.9

Whitby jet

Test	VL	T	H	IR	T	H
1	1.61	22.6	21.9	1.592	22.7	21.9
2	1.62	22.7	21.9	1.596	22.7	21.9
3	1.61	22.7	21.9	1.587	22.7	21.9
4	1.61	22.6	21.9	1.592	22.7	21.9
5	1.62	22.7	21.9	1.591	22.7	21.9
6	1.61	22.7	21.9	1.553	22.7	21.9

Tests in 25-28°C

Alexandrite

Test	VL	T	H	IR	T	H
1	1.74	26.4	30.9	1.678	26.8	29.9
2	1.74	26.6	30.9	1.684	26.8	29.9
3	1.74	26.7	30.4	1.734	26.9	29.9
4	1.74	26.4	30.9	1.729	26.8	29.9
5	1.77	26.6	30.9	1.725	26.8	29.9
6	1.77	26.7	30.9	1.733	26.8	29.9

Amethyst

Test	VL	T	H	IR	T	H
1	1.54	26.7	28.8	1.557	26.7	28.8
2	1.54	26.8	28.8	1.554	26.8	28.8
3	1.54	26.8	28.8	1.571	26.8	28.2
4	1.55	26.7	28.8	1.579	26.8	28.2
5	1.55	26.8	28.8	1.572	26.8	28.2
6	1.55	26.8	28.8	1.570	26.8	28.2

Ametrine

Test	VL	T	H	IR	T	H
1	1.54	26.8	28.2	1.415	26.3	28.3
2	1.54	26.5	27.7	1.550	26.3	28.7
3	1.54	26.4	28.2	1.558	26.3	28.7
4	1.55	26.8	28.2	1.562	26.3	28.7
5	1.55	26.5	27.7	1.562	26.3	28.7
6	1.55	26.4	28.2	1.561	26.2	28.7

Aquamarine

Test	VL	T	H	IR	T	H
1	1.57	26.8	28.8	1.593	27.0	28.8
2	1.57	26.8	28.8	1.594	26.7	28.8
3	1.57	26.9	28.8	1.604	26.0	29.8
4	1.58	26.8	28.8	1.594	26.9	28.8
5	1.58	26.8	28.8	1.524	26.2	29.3
6	1.58	26.9	28.8	1.607	26.0	28.8

Black Onyx

Test	VL	T	H	IR	T	H
1	1.53	26.1	27.6	1.471	26.2	27.6
2	1.53	26.2	27.6	1.470	26.3	27.7
3	1.53	26.2	27.6	1.471	26.3	27.7
4	1.54	26.1	27.6	1.473	26.2	27.6
5	1.54	26.2	27.6	1.480	26.3	27.7
6	1.54	26.2	27.6	1.471	26.3	27.7

Bloodstone

Test	VL	T	H	IR	T	H
1	1.53	26.4	29.3	1.557	26.6	28.8
2	1.53	26.5	28.8	1.559	26.6	28.8
3	1.53	26.5	28.8	1.542	26.7	28.8
4	1.53	26.4	29.3	1.564	26.6	28.8
5	1.53	26.5	29.3	1.559	26.6	28.8
6	1.53	26.5	28.8	1.560	26.7	28.8

Glass (”lab sapphire”)

Test	VL	T	H	IR	T	H
1	1.58	26.5	28.8	1.515	26.6	28.8
2	1.58	26.6	28.8	1.489	26.6	28.8
3	1.58	26.6	28.8	1.503	26.6	28.8
4	1.58	26.5	28.8	1.505	26.6	28.8
5	1.58	26.6	28.8	1.511	26.6	28.8
6	1.58	26.6	28.8	1.512	26.7	28.8

Iolite

Test	VL	T	H	IR	T	H
1	1.54	26.4	32.5	1.539	26.5	30.9
2	1.54	26.4	32.0	1.537	26.5	30.9
3	1.54	26.5	32.0	1.541	26.6	30.4
4	1.55	26.4	32.5	1.538	26.5	30.9
5	1.55	26.4	32.0	1.540	26.6	30.9
6	1.55	26.5	32.0	1.540	26.6	30.4

Morganite

Test	VL	T	H	IR	T	H
1	1.58	26.7	28.2	1.596	26.7	26.8
2	1.58	26.7	28.2	1.604	26.7	26.8
3	1.58	26.6	28.8	1.601	26.7	26.8
4	1.59	26.7	28.2	1.596	26.7	26.8
5	1.59	26.7	28.2	1.601	26.7	26.8
6	1.59	26.6	28.8	1.590	26.7	26.8

Pearl

Test	VL	T	H	IR	T	H
1	1.77	26.2	28.7	1.830	26.5	27.7
2	1.77	26.3	28.7	1.850	26.6	27.7
3	1.77	26.4	28.2	1.865	26.7	27.7
4	1.77	26.2	28.7	2.003	26.6	27.7
5	1.77	26.3	28.7	1.675	26.7	27.7
6	1.77	26.4	28.2	1.721	26.8	27.7

Prasiolite

Test	VL	T	H	IR	T	H
1	1.54	26.6	27.7	1.547	26.9	26.6
2	1.54	26.8	26.6	1.550	26.8	26.6
3	1.54	27.0	26.6	1.541	26.6	26.6
4	1.55	26.6	27.7	1.544	26.8	26.6
5	1.55	26.8	26.6	1.550	26.8	26.6
6	1.55	27.0	26.6	1.545	26.8	26.6

Tourmaline

Test	VL	T	H	IR	T	H
1	1.62	27.0	29.9	1.660	26.3	30.9
2	1.62	27.0	29.9	1.670	26.4	30.9
3	1.62	27.0	29.9	1.670	26.6	30.9
4	1.64	27.0	29.9	1.663	26.3	30.9
5	1.64	27.0	29.9	1.671	26.5	30.9
6	1.64	27.0	29.9	1.654	26.6	30.9

Turquoise

Test	VL	T	H	IR	T	H
1	No value	26.2	27.1	1.458	26.4	27.7
2	No value	26.2	27.1	1.477	26.3	27.1
3	No value	26.4	27.7	1.464	26.3	27.1
4	No value	26.2	27.1	1.413	26.4	27.7
5	No value	26.2	27.1	1.468	26.3	27.7
6	No value	26.4	27.7	1.472	26.3	27.7

Unknown

Test	VL	T	H	IR	T	H
1	1.58	26.4	30.4	1.479	26.4	29.8
2	1.55	26.6	29.8	1.499	26.4	29.8
3	1.57	26.5	29.8	1.502	26.4	29.8
4	1.58	26.4	30.4	1.490	26.4	29.8
5	1.58	26.6	29.8	1.495	26.4	29.8
6	1.57	26.6	29.8	1.494	26.4	29.8

Tested at 30-35°C

Alexandrite

Test	VL	T	H	IR	T	H
1	1.75	31.4	28.1	1.679	32.1	27.0
2	1.74	32.2	25.5	1.692	33.2	24.9
3	1.74	32.4	25.9	1.669	33.3	24.9
4	1.75	31.4	28.1	1.697	32.5	26.5
5	1.75	32.2	25.5	1.691	33.4	24.9
6	1.75	32.4	25.9	1.701	33.3	24.9

Amethyst

Test	VL	T	H	IR	T	H
1	1.54	32.0	21.5	1.547	31.1	22.5
2	1.54	31.2	22.5	1.558	31.8	21.4
3	1.54	30.9	22.5	1.561	32.3	21.5
4	1.55	32.0	21.5	1.558	31.4	22.0
5	1.55	31.2	22.5	1.558	32.0	21.5
6	1.55	30.9	22.5	1.565	33.6	19.9

Ametrine

Test	VL	T	H	IR	T	H
1	1.54	32.9	19.8	1.553	32.6	20.4
2	1.54	32.3	20.4	1.552	33.7	19.3
3	1.54	32.2	20.3	1.549	33.8	19.3
4	1.55	32.9	19.8	1.550	33.2	19.3
5	1.55	32.3	20.4	1.546	33.8	18.2
6	1.55	32.2	20.3	1.552	33.5	19.3

Aquamarine

Test	VL	T	H	IR	T	H
1	1.57	32.1	26.5	1.585	32.2	25.9
2	1.57	31.9	26.4	1.587	31.8	27.0
3	1.58	33.4	24.9	1.588	31.4	27.0
4	1.58	32.1	26.5	1.585	32.0	25.9
5	1.58	31.8	26.4	1.591	31.6	27.0
6	1.58	33.4	24.9	1.584	31.4	27.0

Black onyx

Test	VL	T	H	IR	T	H
1	1.53	34.0	17.1	1.463	34.6	17.1
2	1.53	33.7	17.6	1.459	34.3	17.1
3	1.53	34.6	17.1	1.463	33.6	17.0
4	1.54	34.0	17.1	1.475	34.5	15.9
5	1.54	33.7	17.6	1.457	34.2	17.1
6	1.54	34.6	17.1	1.463	33.6	17.0

Bloodstone

Test	VL	T	H	IR	T	H
1	1.53	35.0	16.0	1.552	31.3	19.2
2	1.53	31.6	19.2	1.559	31.4	19.2
3	1.55	31.3	20.3	1.552	32.3	19.2
4	1.53	35.0	16.0	1.546	31.3	19.2
5	1.53	31.6	19.2	1.543	31.4	19.2
6	1.55	31.3	20.3	1.552	32.4	19.2

Glass (”lab sapphire”)

Test	VL	T	H	IR	T	H
1	1.58	31.7	19.2	1.492	31.8	19.2
2	1.58	31.8	19.2	1.515	31.8	19.2
3	1.58	31.9	19.2	1.517	31.7	19.2
4	1.58	31.7	19.2	1.512	31.9	19.2
5	1.58	31.8	19.2	1.512	31.8	19.2
6	1.58	31.9	19.2	1.507	31.8	19.2

Iolite

Test	VL	T	H	IR	T	H
1	1.54	32.1	23.6	1.511	30.7	23.6
2	1.53	30.8	23.6	1.530	30.8	23.6
3	1.54	30.7	23.6	1.523	31.1	22.5
4	1.55	32.1	23.6	1.533	30.7	23.6
5	1.54	30.8	23.6	1.528	30.8	23.6
6	1.55	30.7	23.6	1.523	31.4	22.5

Morganite

Test	VL	T	H	IR	T	H
1	1.58	32.8	18.1	1.570	33.0	18.1
2	1.58	33.0	18.1	1.584	33.3	18.2
3	1.58	33.0	18.1	1.575	33.4	18.0
4	1.59	32.8	18.1	1.572	33.0	18.1
5	1.59	33.0	18.1	1.579	33.3	18.2
6	1.59	33.0	18.1	1.577	33.4	18.2

Pearl

Test	VL	T	H	IR	T	H
1	1.66	31.7	19.2	1.796	31.9	19.2
2	1.66	31.3	19.7	1.605	34.0	18.2
3	1.66	32.0	19.2	1.665	34.9	17.1
4	1.66	31.7	19.2	1.818	32.4	19.2
5	1.66	31.3	19.7	1.544	34.7	17.1
6	1.66	32.0	19.2	1.742	34.6	16.5

Prasiolite

Test	VL	T	H	IR	T	H
1	1.54	31.4	20.3	1.532	32.7	19.3
2	1.54	31.8	20.3	1.536	32.8	18.7
3	1.54	32.1	19.2	1.541	32.4	19.2
4	1.55	31.4	20.3	1.536	32.8	19.3
5	1.55	31.8	20.3	1.537	32.7	19.3
6	1.55	32.1	19.2	1.539	32.5	19.2

Tourmaline

Test	VL	T	H	IR	T	H
1	1.62	34.2	25.0	1.638	33.9	24.9
2	1.62	34.0	25.0	1.657	33.7	24.8
3	1.62	33.5	25.0	1.657	33.7	24.9
4	1.64	34.2	25.0	1.647	33.9	24.9
5	1.64	34.0	25.0	1.660	34.0	25.0
6	1.64	33.5	25.0	1.658	33.7	24.9

Turquoise

Test	VL	T	H	IR	T	H
1	1.56	32.2	19.2	1.413	32.2	19.2
2	1.62	31.8	19.8	1.332	32.1	19.2
3	1.61	31.8	19.2	1.407	32.6	19.2
4	1.56	32.2	19.2	1.443	32.2	19.2
5	1.62	31.8	19.8	1.418	32.2	19.2
6	1.61	31.8	19.2	1.411	32.8	18.7

Unknown

Test	VL	T	H	IR	T	H
1	1.57	34.6	18.2	1.455	33.2	18.2
2	1.56	32.6	19.2	1.488	32.2	18.7
3	1.55	32.8	18.1	1.489	32.0	18.6
4	1.57	34.6	18.2	1.475	32.4	19.2
5	1.56	32.6	19.2	1.486	32.2	19.2
6	1.55	32.8	18.1	1.489	31.9	19.2

Appendix C

Results sheet for the tests on gemstones faceted in different ways. Tests 1, 2 and 3 are with the stones in one direction, and test 4, 5 and 6 are after turning the stone 90°. T = Temperature, H = Humidity, VL = The values obtained with the standard refractometer, IR = The values obtained with the first generation infrared refractometer.

Amethyst

Octagon 1

Tests	VL	T	H	IR	T	H
1	1.54	22.4	54.7	1.557	22.7	54.2
2	1.54	22.5	54.2	1.569	22.8	53.8
3	1.54	22.6	54.2	1.573	22.8	53.3
4	1.55	22.4	54.7	1.569	22.7	54.2
5	1.55	22.5	54.2	1.573	22.8	53.8
6	1.55	22.6	54.2	1.571	22.8	53.3

Octagon 2

Tests	VL	T	H	IR	T	H
1	1.54	22.9	53.3	1.559	22.9	53.3
2	1.54	23.0	53.3	1.562	23.0	53.3
3	1.54	22.9	53.3	1.567	23.0	53.3
4	1.55	22.9	53.3	1.569	23.0	53.3
5	1.55	23.0	53.3	1.563	23.0	53.3
6	1.55	22.9	53.3	1.563	23.0	53.3

Oval 1

Tests	VL	T	H	IR	T	H
1	1.54	22.5	37.9	1.550	22.6	38.0
2	1.54	22.5	37.9	1.647	22.6	38.0
3	1.54	22.5	37.9	1.533	22.6	38.0
4	1.54	22.5	37.9	1.553	22.6	38.0
5	1.54	22.5	37.9	1.552	22.6	38.0
6	1.54	22.5	37.9	1.548	22.6	38.0

Oval 2

Tests	VL	T	H	IR	T	H
1	1.54	22.6	39.0	1.557	22.6	39.0
2	1.54	22.6	39.0	1.562	22.6	39.0
3	1.54	22.6	39.0	1.567	22.7	39.0
4	1.55	22.6	39.0	1.550	22.6	39.0
5	1.55	22.6	39.0	1.557	22.6	39.0
6	1.55	22.6	39.0	1.559	22.6	39.0

Pear 1

Tests	VL	T	H	IR	T	H
1	1.54	22.7	39.0	1.532	22.8	39.0
2	1.54	22.7	39.0	1.528	22.7	39.0
3	1.54	22.7	39.0	1.533	22.7	39.5
4	1.54	22.7	39.0	1.532	22.8	39.0
5	1.54	22.7	39.0	1.534	22.7	39.0
6	1.54	22.7	39.0	1.533	22.7	39.5

Pear 2

Tests	VL	T	H	IR	T	H
1	1.54	22.8	39.5	1.543	22.9	40.1
2	1.54	22.8	39.5	1.545	22.9	40.1
3	1.54	22.8	39.5	1.545	22.9	40.1
4	1.55	22.8	39.5	1.543	22.9	40.1
5	1.54	22.8	39.5	1.548	22.9	40.1
6	1.55	22.8	39.5	1.542	22.9	40.1

Princess

Tests	VL	T	H	IR	T	H
1	1.54	23.0	53.8	1.530	23.0	53.8
2	1.54	23.0	54.3	1.523	23.1	54.3
3	1.54	23.0	54.8	1.541	23.1	54.3
4	1.55	23.0	53.8	1.543	23.0	54.3
5	1.54	23.0	54.3	1.527	23.1	54.3
6	1.54	23.0	54.8	1.537	23.1	54.3

Square

Tests	VL	T	H	IR	T	H
1	1.54	22.9	40.6	1.543	23.0	40.6
2	1.54	22.9	40.6	1.539	23.0	40.6
3	1.54	23.0	40.6	1.534	23.0	40.6
4	1.54	22.9	40.6	1.542	23.0	40.6
5	1.55	22.9	40.6	1.538	23.0	40.6
6	1.55	23.0	40.6	1.536	23.0	40.6

Sapphire

Oval

Tests	VL	T	H	IR	T	H
1	1.76	23.3	54.8	1.722	23.4	54.8
2	1.76	23.3	54.8	1.720	23.4	54.3
3	1.76	23.3	54.8	1.617	23.3	54.8
4	1.76	23.3	54.8	1.740	23.4	54.8
5	1.76	23.3	54.8	1.736	23.4	54.8
6	1.77	23.3	54.8	1.720	23.4	54.3

Pear 1

Tests	VL	T	H	IR	T	H
1	1.76	23.4	54.8	1.737	23.4	54.3
2	1.76	23.4	54.3	1.756	23.4	54.3
3	1.76	23.4	54.8	1.762	23.4	54.3
4	1.76	23.4	54.8	1.742	23.4	54.3
5	1.77	23.4	54.3	1.762	23.4	54.3
6	1.77	23.4	54.8	1.760	23.4	54.3

Pear 2

Tests	VL	T	H	IR	T	H
1	1.75	22.9	56.3	1.766	23.2	55.8
2	1.76	23.0	55.8	1.760	23.2	55.3
3	1.76	23.2	55.8	1.706	23.2	55.3
4	1.76	22.9	56.3	1.764	23.2	55.8
5	1.77	23.0	55.8	1.751	23.2	55.3
6	1.77	23.2	55.8	1.742	23.3	55.3

Round

Tests	VL	T	H	IR	T	H
1	1.76	23.0	56.3	1.760	23.2	55.3
2	1.76	23.2	55.3	1.761	23.2	55.3
3	1.76	23.2	55.3	1.761	23.2	54.8
4	1.77	23.0	56.3	1.759	23.2	55.3
5	1.77	23.2	55.3	1.764	23.2	55.3
6	1.77	23.2	55.3	1.766	23.2	54.8

Tidigare skrifter i serien ”Examensarbeten i Geologi vid Lunds universitet”:

300. Lindenbaum, Johan, 2012: Identification of sources of ammonium in groundwater using stable nitrogen and boron isotopes in Nam Du, Hanoi. (45 hp)
301. Andersson, Josefin, 2012: Karaktärisering av arsenikförorening i matjordsprofiler kring Klippans Läderfabrik. (45 hp)
302. Lumetzberger, Mikael, 2012: Hydrogeologisk kartläggning av infiltrationsvattentransport genom resistivitetsmätningar. (15 hp)
303. Martin, Ellinor, 2012: Fossil pigments and pigment organelles – colouration in deep time. (15 hp)
304. Rådman, Johan, 2012: Sällsynta jordarts-metaller i tungsand vid Haväng på Österlen. (15 hp)
305. Karlstedt, Filippa, 2012: Jämförande geokemisk studie med portabel XRF av obehandlade och sågade ytor, samt pulver av Karlshamnsdiabas. (15 hp)
306. Lundberg, Frans, 2012: Den senkambriska alunskiffern i Västergötland – utbredning, mäktigheter och faciestyper. (15 hp)
307. Thulin Olander, Henric, 2012: Hydrogeologisk kartering av grund-vattenmagasinet Ekenäs-Kvarndammen, Jönköpings län. (15 hp)
308. Demirer, Kursad, 2012: U-Pb baddeleyite ages from mafic dyke swarms in Dharwar craton, India – links to an ancient supercontinent. (45 hp)
309. Leskelä, Jari, 2012: Loggning och återfyllning av borrhål – Praktiska försök och utveckling av täthetskontroll i fält. (15 hp)
310. Eriksson, Magnus, 2012: Stratigraphy, facies and depositional history of the Colonus Shale Trough, Skåne, southern Sweden. (45 hp)
311. Larsson, Amie, 2012: Kartläggning, beskrivning och analys av Kalmar läns regionalt viktiga vattenresurser. (15 hp)
312. Olsson, Håkan, 2012: Prediction of the degree of thermal breakdown of limestone: A case study of the Upper Ordovician Boda Limestone, Siljan district, central Sweden. (45 hp)
313. Kampmann, Tobias Christoph, 2012: U-Pb geochronology and paleomagnetism of the Westerberg sill, Kaapvaal Craton – support for a coherent Kaapvaal-Pilbara block (Vaalbara). (45 hp)
314. Eliasson, Isabelle Timms, 2012: Arsenik: förekomst, miljö och hälsoeffekter. (15 hp)
315. Badawy, Ahmed Salah, 2012: Sequence stratigraphy, palynology and biostratigraphy across the Ordovician-Silurian boundary in the Röstånga-1 core, southern Sweden. (45 hp)
316. Knut, Anna, 2012: Resistivitets- och IP-mätningar på Flishultsdeponin för lokalisering av grundvattenytor. (15 hp)
317. Nylén, Fredrik, 2012: Förädling av ballast-material med hydrocyklon, ett fungerande alternativ? (15 hp)
318. Younes, Hani, 2012: Carbon isotope chemostratigraphy of the Late Silurian Lau Event, Gotland, Sweden. (45 hp)
319. Weibull, David, 2012: Subsurface geological setting in the Skagerrak area – suitability for storage of carbon dioxide. (15 hp)
320. Petersson, Albin, 2012: Förutsättningar för geoenergi till idrottsanläggningar i Kallerstad, Linköpings kommun: En förstudie. (15 hp)
321. Axbom, Jonna, 2012: Klimatets och människans inverkan på tallens etablering på sydsvenska mossar under de senaste århundradena – en dendrokronologisk och torvstratigrafisk analys av tre småländska mossar. (15 hp)
322. Kumar, Pardeep, 2012: Palynological investigation of coal-bearing deposits of the Thar Coal Field Sindh, Pakistan. (45 hp)
323. Gabrielsson, Johan, 2012: Havsisen i arktiska bassängen – nutid och framtid i ett globalt uppvärmningsperspektiv. (15 hp)
324. Lundgren, Linda, 2012: Variation in rock quality between metamorphic domains in the lower levels of the Eastern Segment, Sveconorwegian Province. (45 hp)
325. Härling, Jesper, 2012: The fossil wonders of the Silurian Eramosa Lagerstätte of Canada: the jawed polychaete faunas. (15 hp)
326. Qvarnström, Martin, 2012: An interpretation of oncoid mass-occurrence during the Late Silurian Lau Event, Gotland, Sweden. (15 hp)
327. Ulmius, Jan, 2013: P-T evolution of paragneisses and amphibolites from Romeleåsen, Scania, southernmost Sweden. (45 hp)

328. Hultin Eriksson, Elin, 2013: Resistivitetsmätningar för avgränsning av lakvattenplym från Kejsarkullens deponis infiltrationsområde. (15 hp)
329. Mozafari Amiri, Nasim, 2013: Field relations, petrography and 40Ar/39Ar cooling ages of hornblende in a part of the eclogite-bearing domain, Sveconorwegian Orogen. (45 hp)
330. Saeed, Muhammad, 2013: Sedimentology and palynofacies analysis of Jurassic rocks Eriksdal, Skåne, Sweden. (45 hp)
331. Khan, Mansoor, 2013: Relation between sediment flux variation and land use patterns along the Swedish Baltic Sea coast. (45 hp)
332. Bernhardson, Martin, 2013: Ice advance-retreat sediment successions along the Logata River, Taymyr Peninsula, Arctic Siberia. (45 hp)
333. Shrestha, Rajendra, 2013: Optically Stimulated Luminescence (OSL) dating of aeolian sediments of Skåne, south Sweden. (45 hp)
334. Fullerton, Wayne, 2013: The Kalgoorlie Gold: A review of factors of formation for a giant gold deposit. (15 hp)
335. Hansson, Anton, 2013: A dendroclimatic study at Store Mosse, South Sweden – climatic and hydrologic impacts on recent Scots Pine (*Pinus sylvestris*) growth dynamics. (45 hp)
336. Nilsson, Lawrence, 2013: The alteration mineralogy of Svartliden, Sweden. (30 hp)
337. Bou-Rabee, Donna, 2013: Investigations of a stalactite from Al Hota cave in Oman and its implications for palaeoclimatic reconstructions. (45 hp)
338. Florén, Sara, 2013: Geologisk guide till Söderåsen – 17 geologiskt intressanta platser att besöka. (15 hp)
339. Kullberg, Sara, 2013: Asbestkontamination av dricksvatten och associerade risker. (15 hp)
340. Kihlén, Robin, 2013: Geofysiska resistivitetsmätingar i Sjöcrona Park, Helsingborg, undersökning av områdets geologiska egenskaper samt 3D modellering i GeoScene3D. (15 hp)
341. Linders, Wictor, 2013: Geofysiska IP-undersökningar och 3D-modellering av geofysiska samt geotekniska resultat i GeoScene3D, Sjöcrona Park, Helsingborg, Sverige. (15 hp)
342. Sidenmark, Jessica, 2013: A reconnaissance study of Rävliden VHMS-deposit, northern Sweden. (15 hp)
343. Adamsson, Linda, 2013: Peat stratigraphical study of hydrological conditions at Stass Mosse, southern Sweden, and the relation to Holocene bog-pine growth. (45 hp)
344. Gunterberg, Linnéa, 2013: Oil occurrences in crystalline basement rocks, southern Norway – comparison with deeply weathered basement rocks in southern Sweden. (15 hp)
345. Peterffy, Olof, 2013: Evidence of epibenthic microbial mats in Early Jurassic (Sinemurian) tidal deposits, Kulla Gunnarstorp, southern Sweden. (15 hp)
346. Sigeman, Hanna, 2013: Early life and its implications for astrobiology – a case study from Bitter Springs Chert, Australia. (15 hp)
347. Glommé, Alexandra, 2013: Texturella studier och analyser av baddeleyitomvandlingar i zirkon, exempel från sydöstra Ghana. (15 hp)
348. Brådenmark, Niklas, 2013: Alunskiffer på Öland – stratigrafi, utbredning, mäktigheter samt kemiska och fysikaliska egenskaper. (15 hp)
349. Jalnefur Andersson, Evelina, 2013: En MIFO fas 1-inventering av fyra potentiellt förorenade områden i Jönköpings län. (15 hp)
350. Eklöv Pettersson, Anna, 2013: Monazit i Obbhult-komplexet: en pilotstudie. (15 hp)
351. Acevedo Suez, Fernando, 2013: The reliability of the first generation infrared refractometers. (15 hp)

LUNDS UNIVERSITET

Geologiska institutionen
Lunds universitet
Sölvegatan 12, 223 62 Lund