

The Ø 8 x 7 km elliptical Warwick Impact Crater (East-Australia)

- Raman Spectra of selected Rock Samples - by Harry K. Hahn, 30.6.2021 -

Summary :

The Ø 8 x 7 km elliptical Warwick Crater is located in East-Australia ≈150 km south-west of Brisbane, near the town Warwick. The crater is visible on the Magnetic Intensity Map as a precise elliptical structure

This elliptical ring structure indicates an oblique impact crater. This means the impactor arrived in a very shallow angle of probably < 10°. The orientation of the elliptical ring structure corresponds to the orientation of the assumed ejecta blanket (see lines on the geological map which mark the ejecta blanket) The age of the oblique impact in all probability is ≈ 252 Ma. (→ PT-boundary age). The red- and pink colored rock types on the geological map, which present ejecta of the crater, formed ≈ 230-250 Ma ago !

The impact direction of the elliptical Warwick Crater points towards the Cape York Crater (-chain). Therefore the Ø8x7 km “Warwick Crater” probably was caused by a large ejecta fragment of the Cape York Impact Event. But it is also possible that it was caused by an ejecta fragment of the PT-Impact Crater.

(→ weblink to my Permian Triassic Impact Hypothesis : see [Part 1 \(P1\)](#) & [Part 2 \(P2\)](#) of my hypothesis)

(Please also read my study : → [The 320 km Cape York Crater](#) (or alternative : [weblink 2](#))

I have analysed some rock samples which I have collected inside the Ø8x7km elliptical Warwick Crater.

The Raman spectrum of quartz from sample site 43 provides first evidence for an impact shock event as the probable cause of the elliptical ring structure of the Warwick Crater. The shifts of the main Raman peaks, of the analysed quartz, to the lower frequencies 463 and 204 cm⁻¹, provide indication for an impact shock event that caused a shock pressure of around 22 GPa.

Further indication comes from the Raman spectra of quartz grains from **sample site 53** which show shifts of the main Raman peaks to the lower frequencies **263 and 205 (204) cm⁻¹**, and from Raman spectra of **sample site 51 and 54**, which show shifts of the main Raman peaks of the analysed quartz grains to the lower frequencies **263 and 205 cm⁻¹**, to **260 and 126 cm⁻¹** and to **262 (265) and 204 (207) cm⁻¹**.

Microscopic images of some of the analysed quartz grains may provide further proof for a shock event. (see images on the **pages : 7, 11, 12 and 22**).

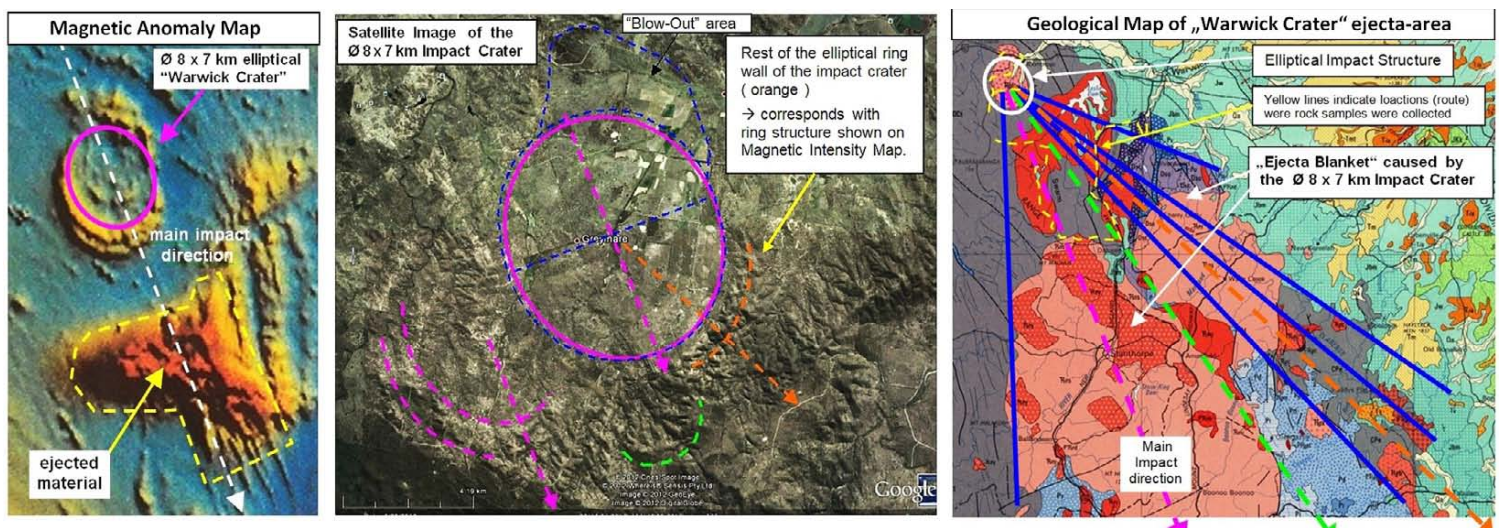
All spectra were made with a **BRUKER Senterra-II Raman Microscope** (wavenumber precision <0.1cm⁻¹)

→ Images of the analysed rock samples and photos of the sample sites are in the Appendix at **page 23**.

→ More images of all sample sites are available on www.permiantriassic.de or www.permiantriassic.at

→ **General Summary** of my Analysis : see [Part 6 \(P6\)](#) of my **PTI-hypothesis (P1)** / References : **page 29**

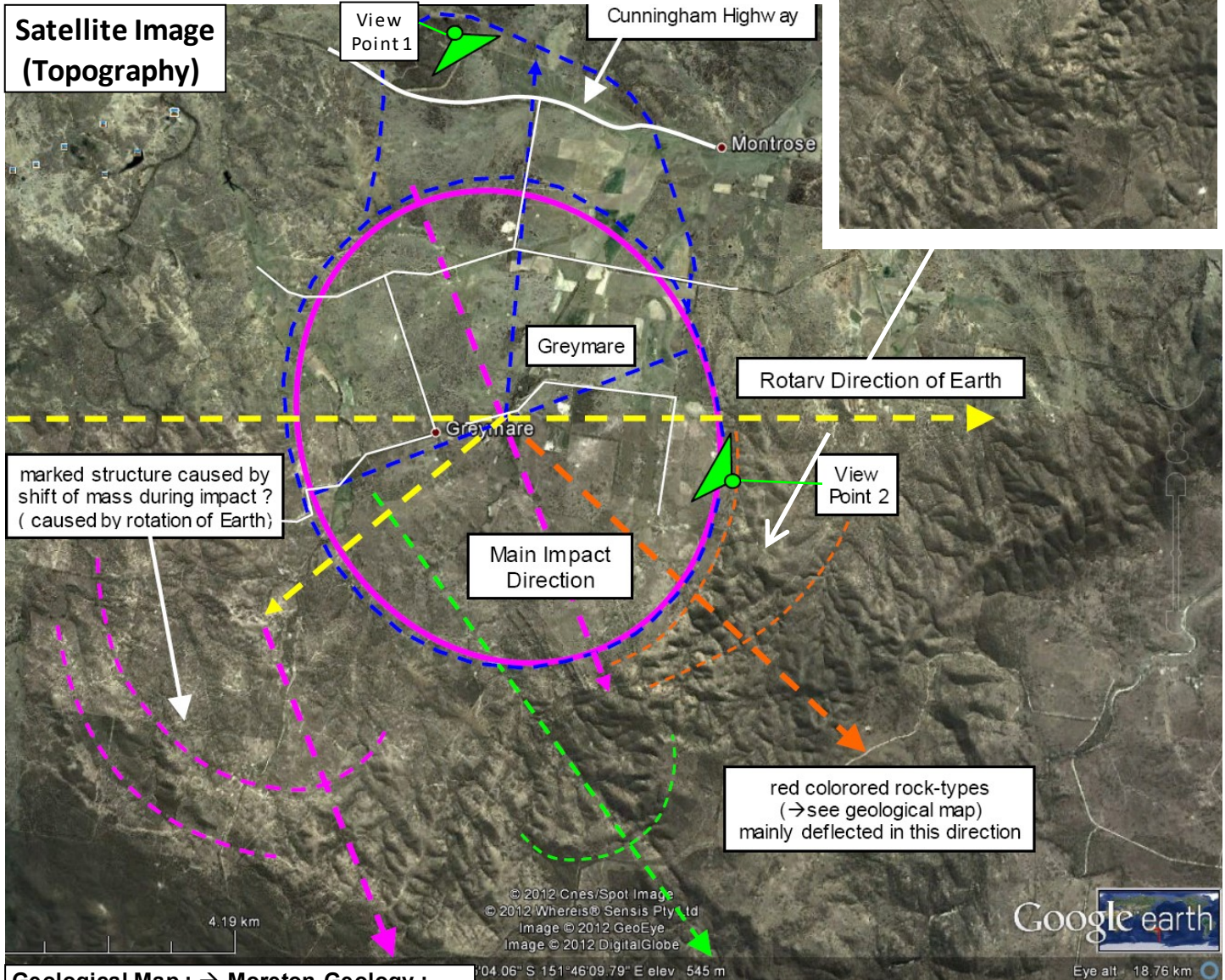
Note: A shock pressure of 20 GPa exceeds every pressure caused by normal terrestrial metamorphism. The indicated shock pressure of ≈20 GPa is lower than the shock pressure that occurred in other large impact craters on Earth. This indicates that the “**Warwick Crater**” was caused by an oblique impact and that the impactor (→ ejecta of the Cape York Crater or PT-Crater) impacted with low velocity <8 km/s.



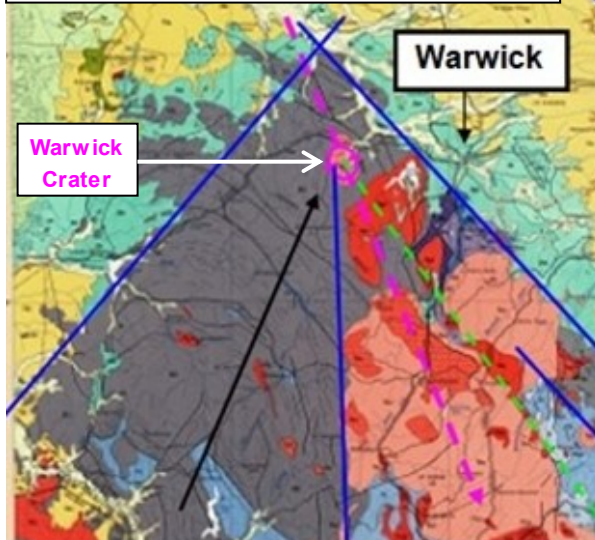
The Ø 8 x 7 km elliptical Warwick Impact Crater

In all probability this crater is a secondary-crater of the Cape York Impact, which was a large-scale secondary impact event in NE-Australia caused by the Permian-Triassic (PT) Impact Event, according to my PTI-hypothesis.

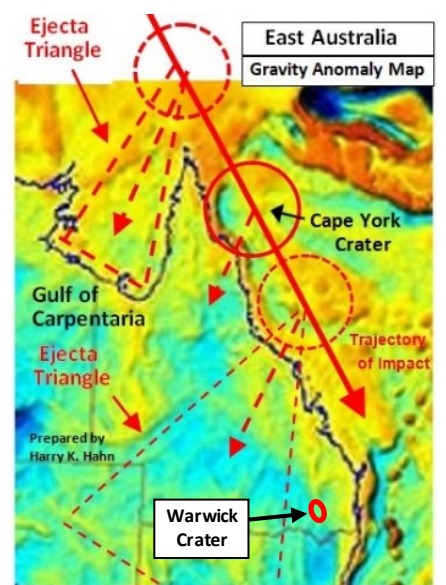
But it will be difficult to prove this impact crater ! Because the shock pressure that has formed this crater, was relatively low !, probably mostly $\ll 22$ GPa. But there is clear geophysical evidence for the crater. The magnetic anomaly map shows a clear signature of the crater and the topography (→ see satellite map) still shows an intact section of the elliptical crater-wall (see right image) (Please also read : → [The 320 km Cape York Crater](#) (alternative : [weblink 2](#))



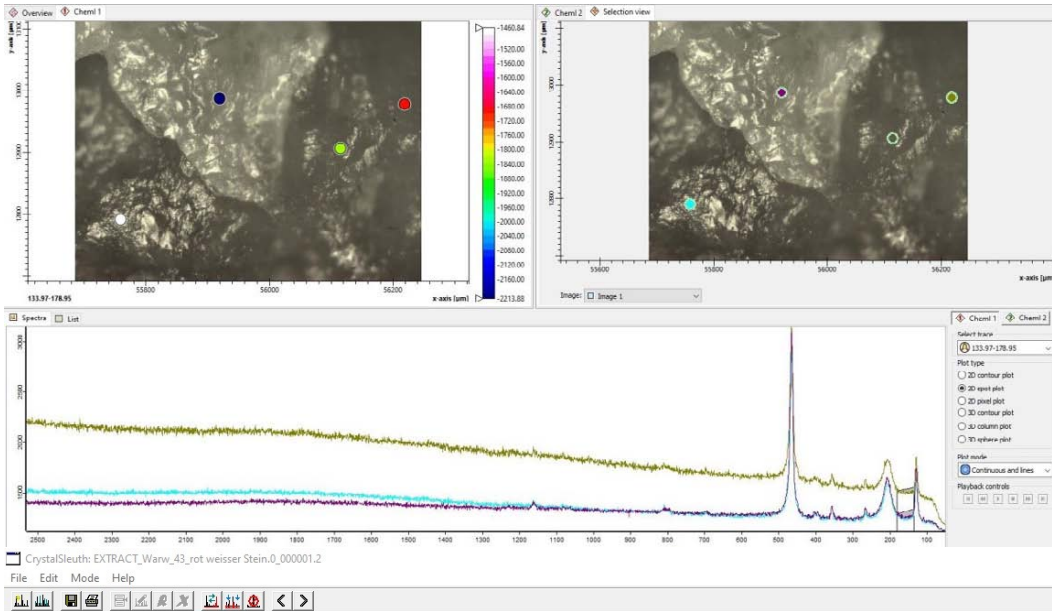
Geological Map : → Moreton Geology : go to : [Geology Maps](#) → type in : **WARWICK**



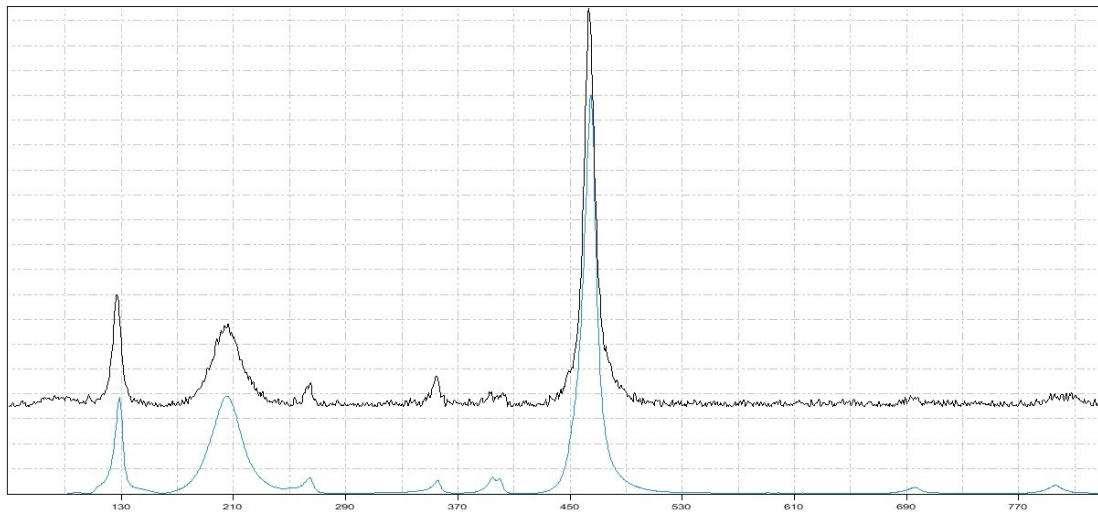
Note : The red and pink marked rock types on the geological map have a measured age of 230-240 Ma (in all probability **PT-boundary age !!**) And the surrounding grey rock-type has an age of 330-370 Ma. The markings on the geological map (left) indicate that the grey- and red-colored rock-types seem to be the result of Ejecta, probably from the assumed Ø 320 km Cape York Crater (right image) that was scattered over the Warwick area ! The red and pink rock-types may come from a large ejecta fragment !



Sample Site **43** : Stone 1_spectra 1 indicates : **Quartz** (→ see RRUFF_CS results)



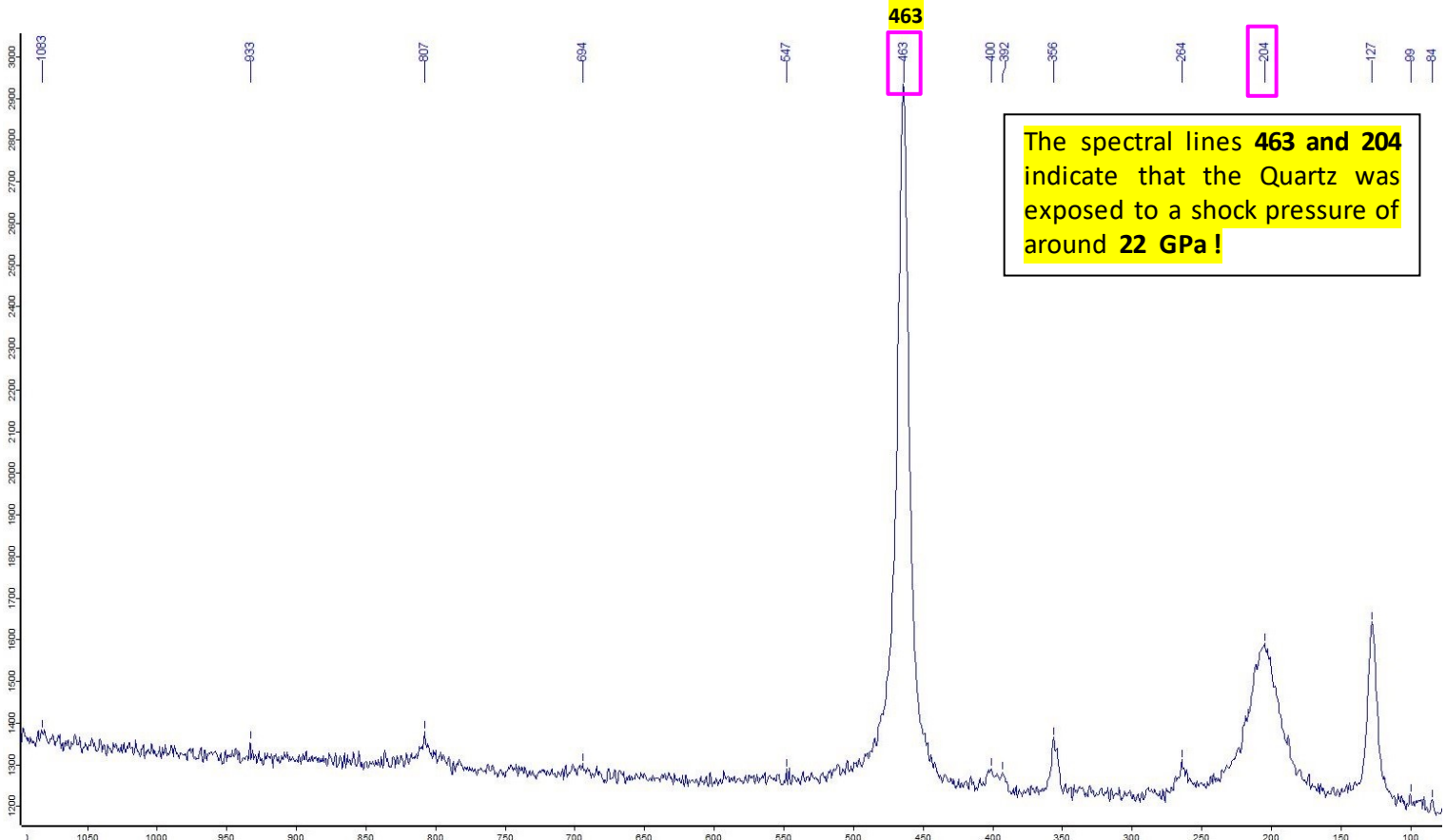
Sample :



% Match	Spectrum Name	RRUFF ID
98	< Quartz (532nm)	X080016
98	Quartz (532nm)	X080015
98	Quartz (532nm)	R060604
97	Quartz (532nm)	R050125
97	Quartz (532nm)	R040031
89	Sodalite (532nm)	R040141
89	Sodalite (532nm)	R060436
88	Sodalite (532nm)	R060405
88	Dachardite-Na (532nm)	R061116
88	Sodalite (532nm)	R060416
88	Sodalite (532nm)	R060354
87	Sodalite (532nm)	R060435
87	Sodalite (532nm)	R060355

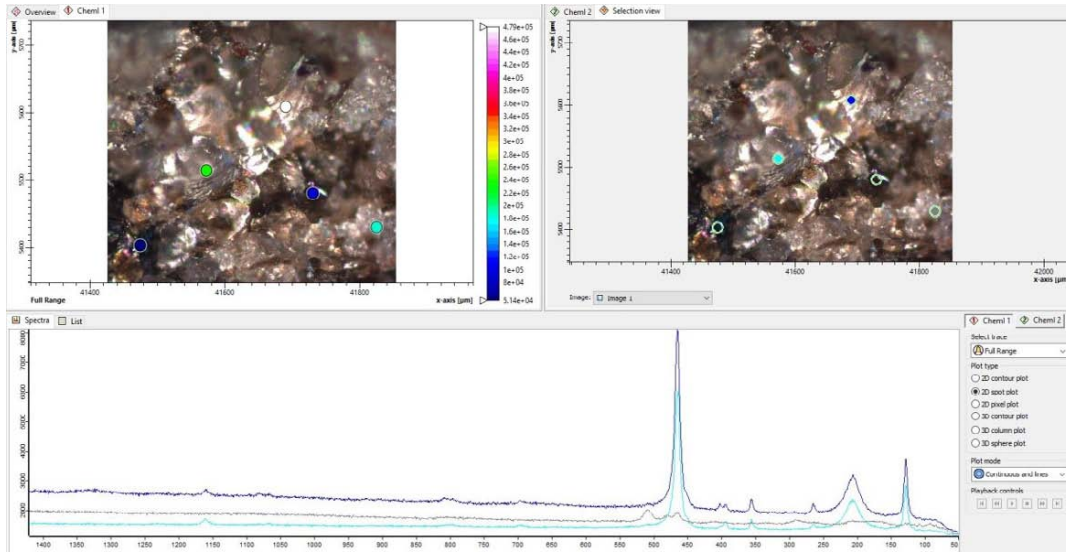
X080016
Quartz
SiO₂
Synthetic

Indication for a shock event are the shifts of the marked Quartz spectral lines towards 463, 204 and 127

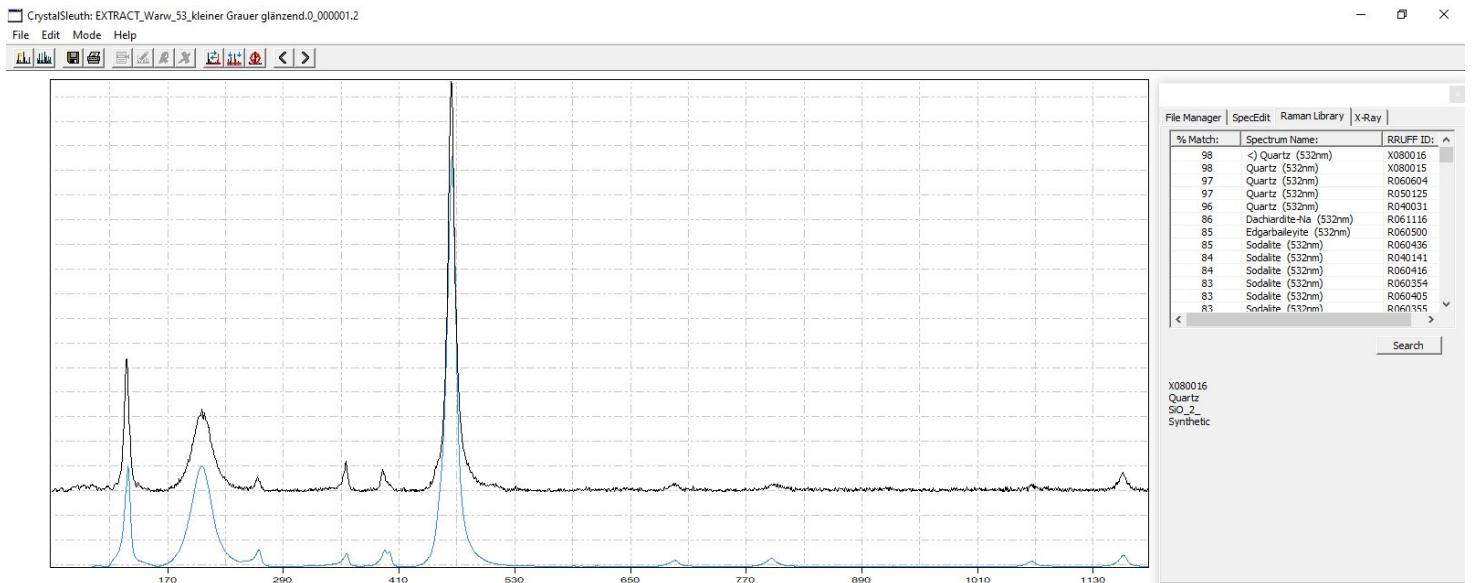


The spectral lines 463 and 204 indicate that the Quartz was exposed to a shock pressure of around 22 GPa !

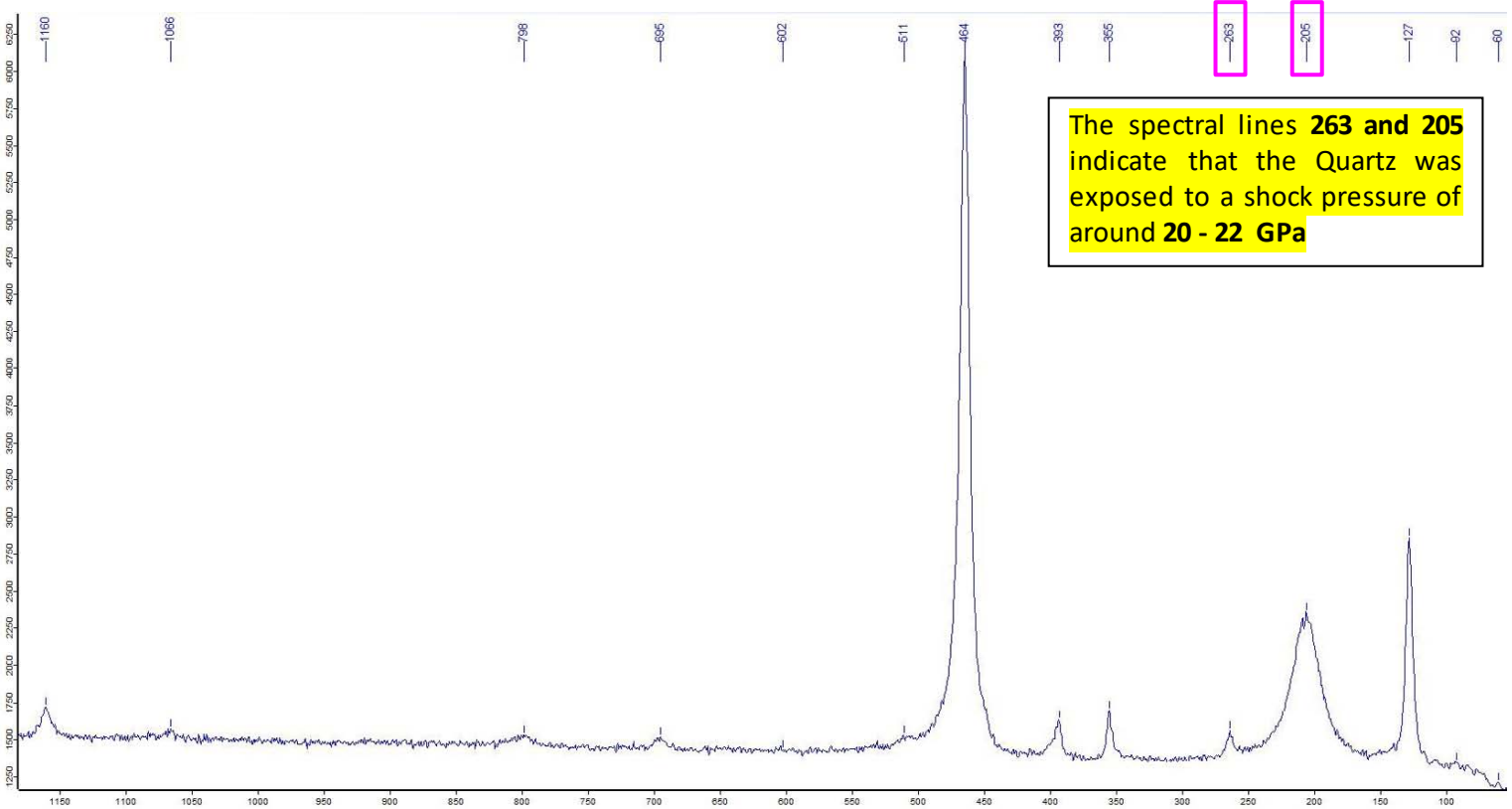
Sample Site **53** : Stone 1_spectra 1 (grey mineral) indicates : **Quartz** (→ see RRUFF_CS results)



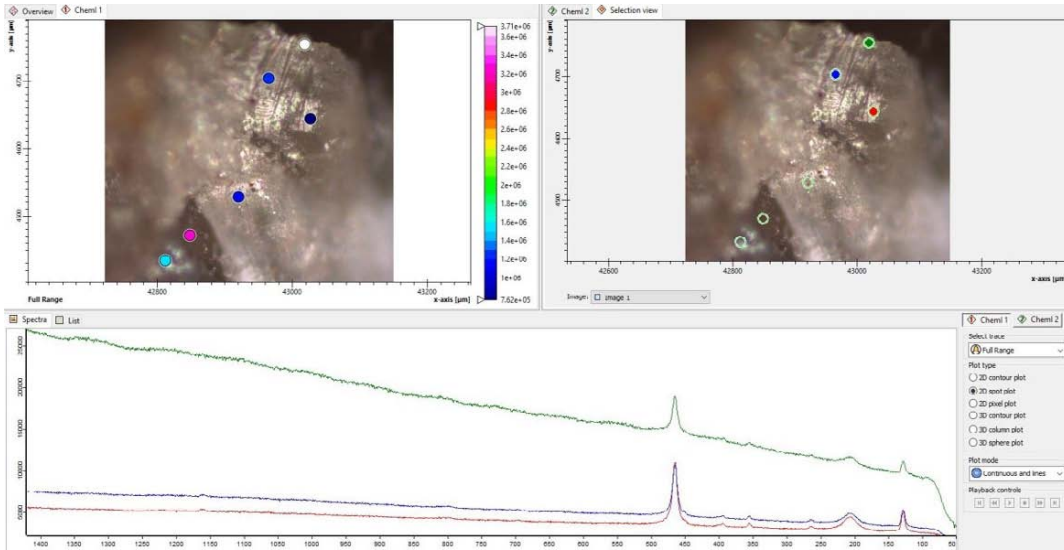
Sample :



Indication for a shock event are the shifts of the marked Quartz spectral lines towards 263 and 205



Sample Site **53** : Stone_2_spectra 1 (white mineral) indicates : **Quartz** (→ see RRUFF_CS results)

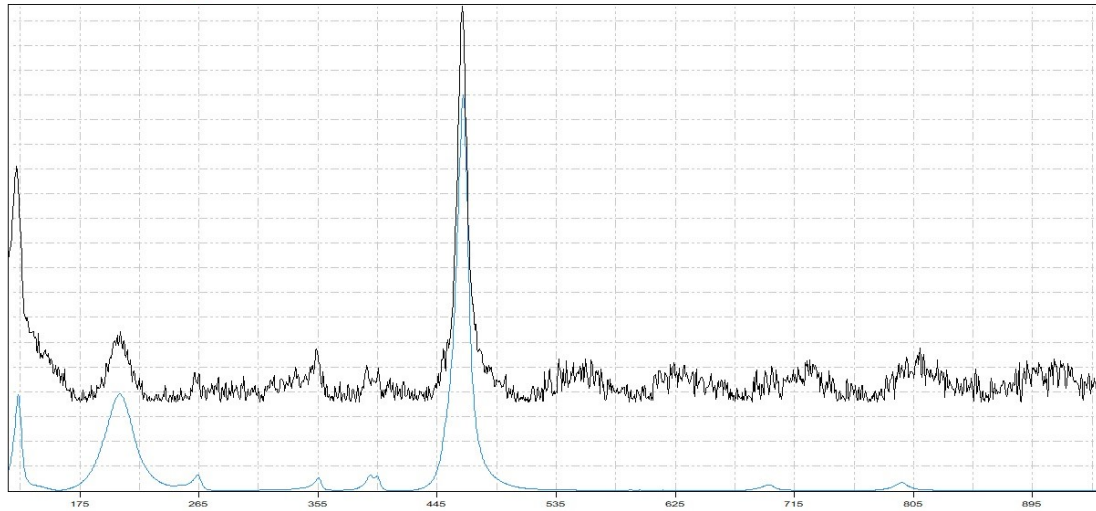


Sample :



CrystalSleuth: EXTRACT_Warw_53_quarzhänelicher Stein_1_000000.0

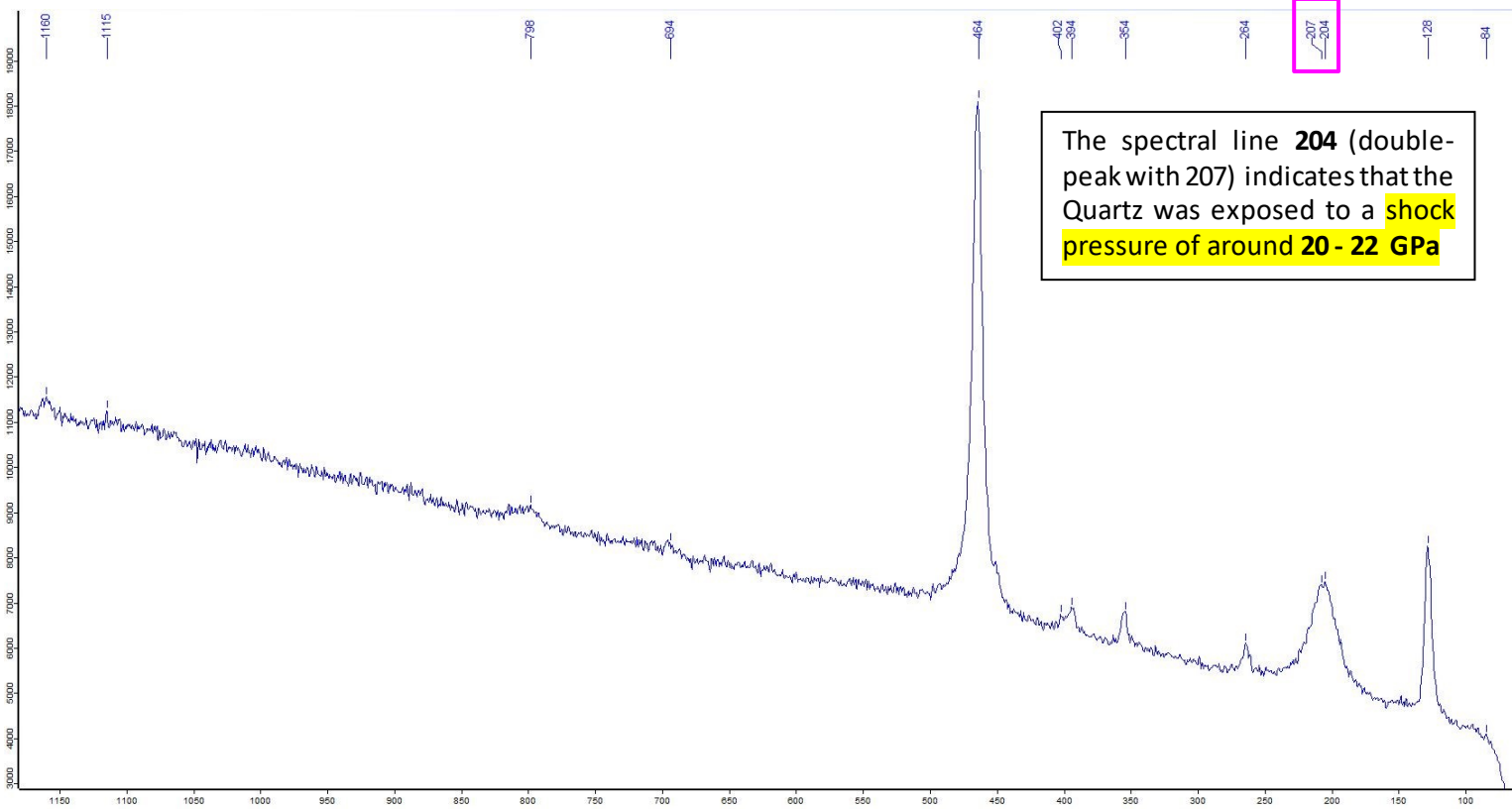
File Edit Mode Help



% Match:	Spectrum Name:	RRUFF ID:
84	< Quartz (532nm)	X080016
83	Quartz (532nm)	X080015
83	Quartz (532nm)	R060604
81	Quartz (532nm)	R040031
80	Quartz (532nm)	R050125
78	Sugilite (532nm)	R070684
77	Dachauerdeite-Ha (532nm)	R061116
76	Edgarbaleite (532nm)	R060500
76	Sodalite (532nm)	R060405
76	Sodalite (532nm)	R040141
75	Sodalite (532nm)	R060436
75	Sodalite (532nm)	R060435
75	Sodalite (532nm)	R060164

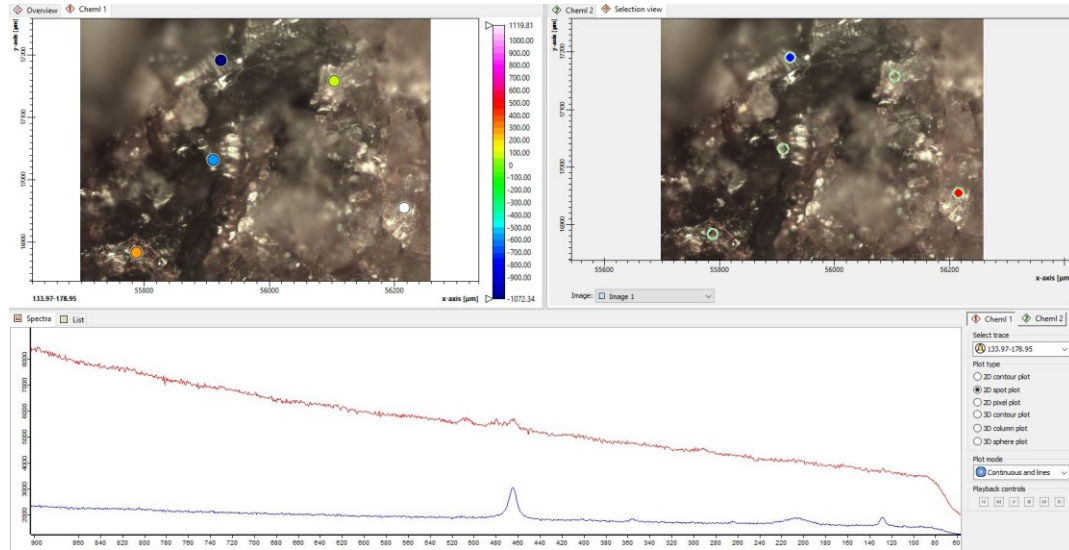
X080016
Quartz
SiO₂
Synthetic

Indication for a shock event is the shift of the marked Quartz spectral line towards **204 (207)**

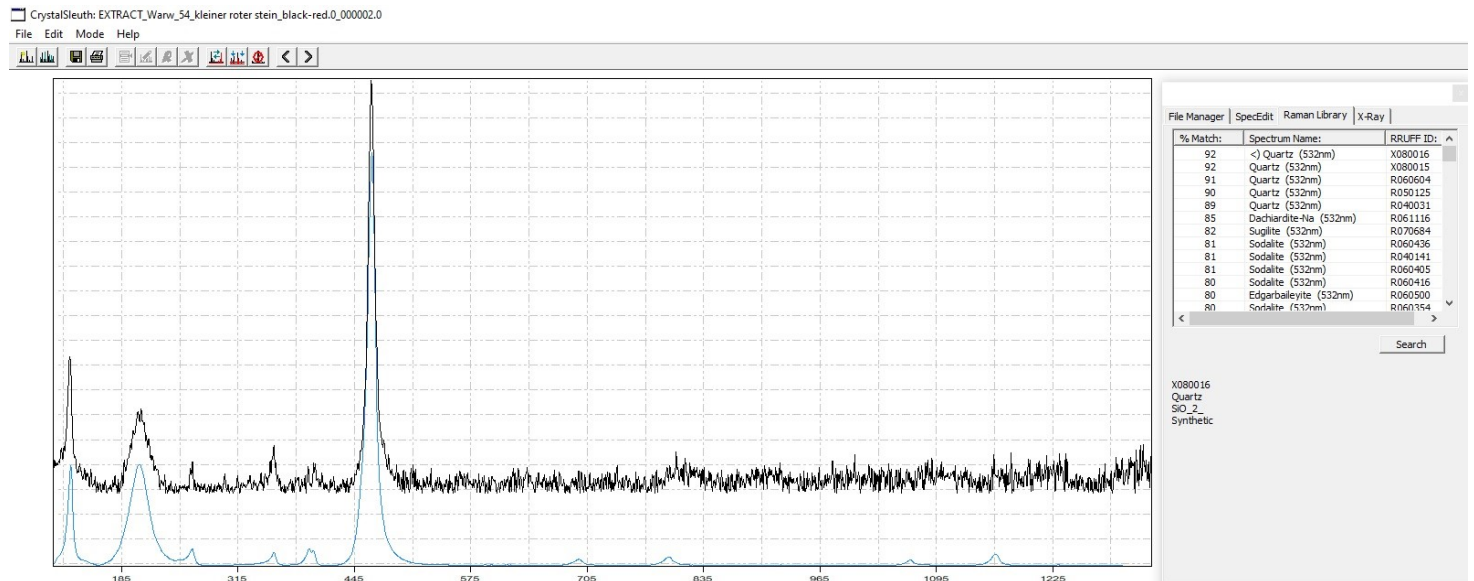


The spectral line **204** (double-peak with 207) indicates that the Quartz was exposed to a **shock pressure of around 20 - 22 GPa**

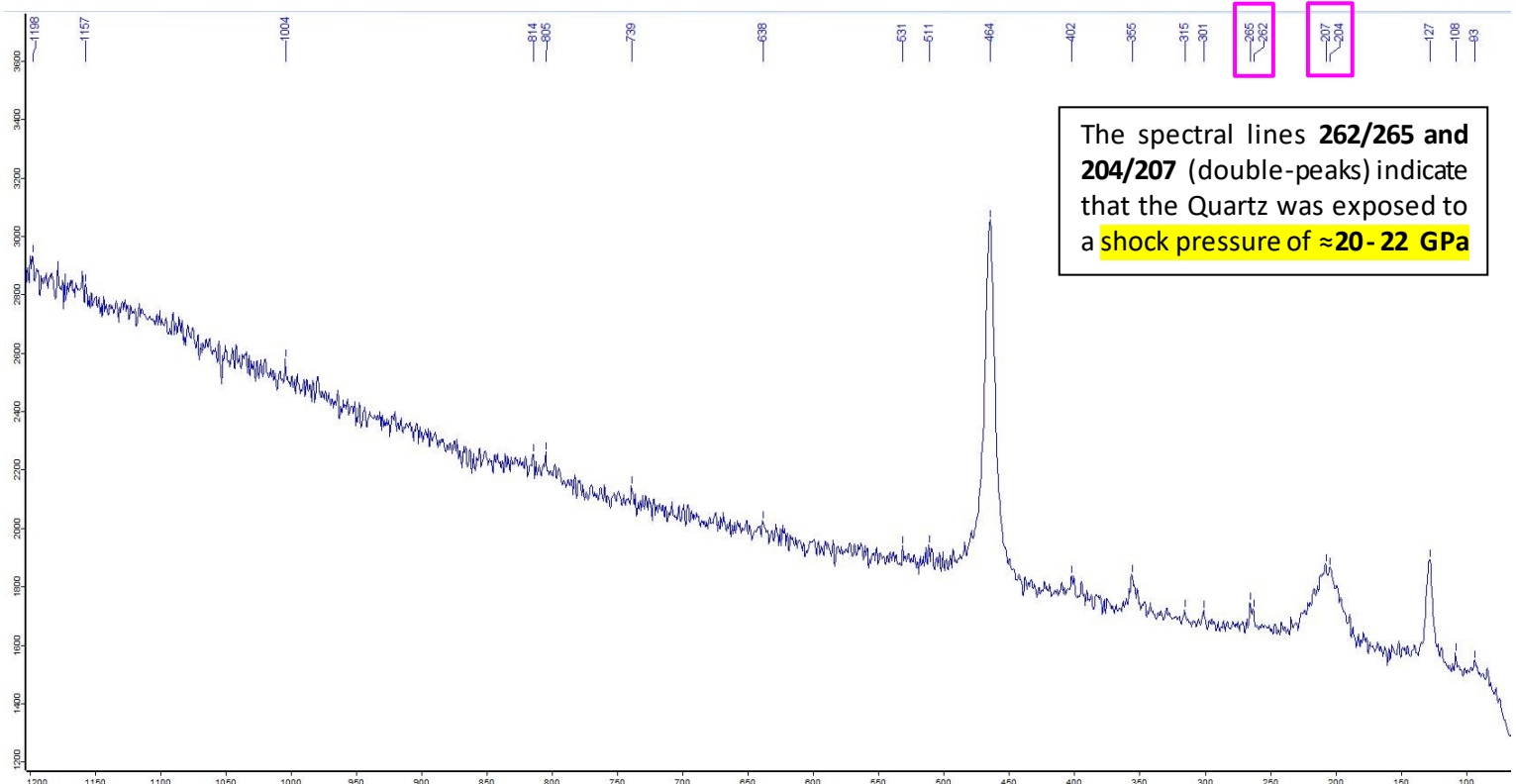
Sample Site **54** : Stone 1_spectra 1 indicates : **Quartz** (→ see RRUFF_CS results)



Sample :



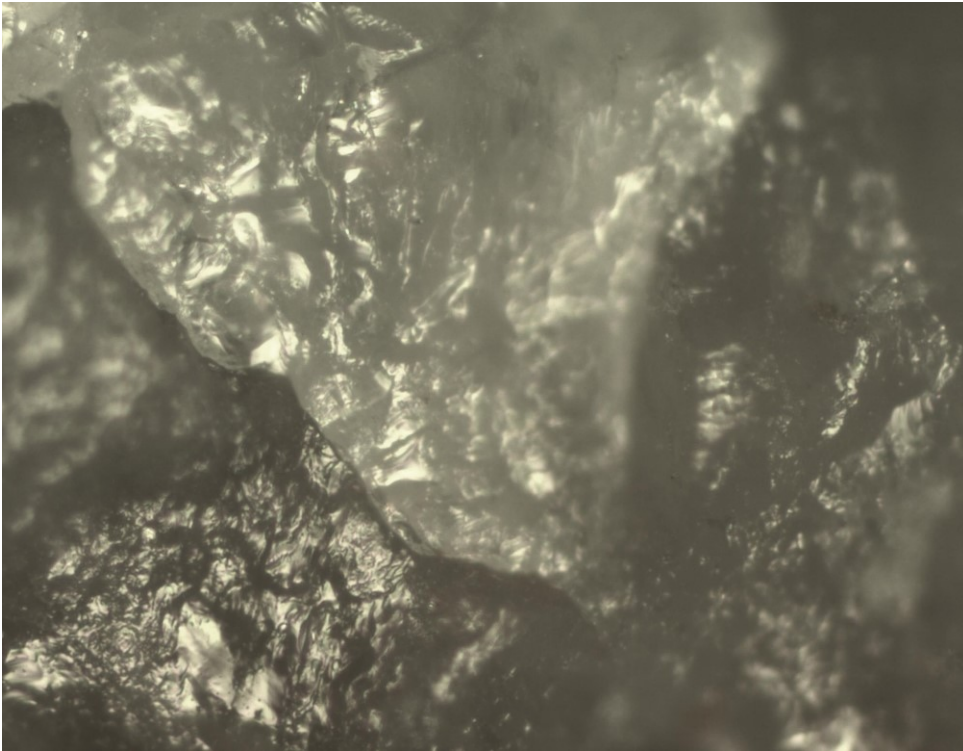
Indication for a shock event are the shifts of the marked Quartz spectral lines towards 262 and 204 (double-peaks)



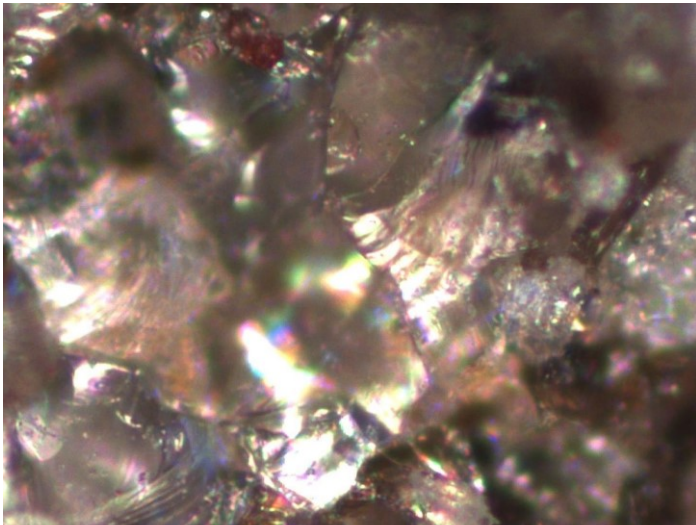
The spectral lines **262/265** and **204/207** (double-peaks) indicate that the Quartz was exposed to a **shock pressure of ≈20- 22 GPa**

Microscopic Images : Sample from Sites 43, 53 & 54 → original state (no preparation for analysis)

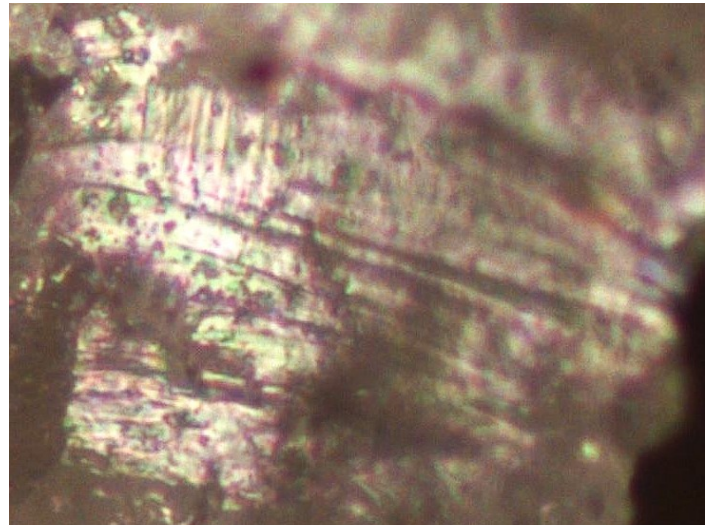
Sample Site **43** : Stone 1_spectra 1 indicates : **Quartz** - Image size : ~ 400 x 300 μm



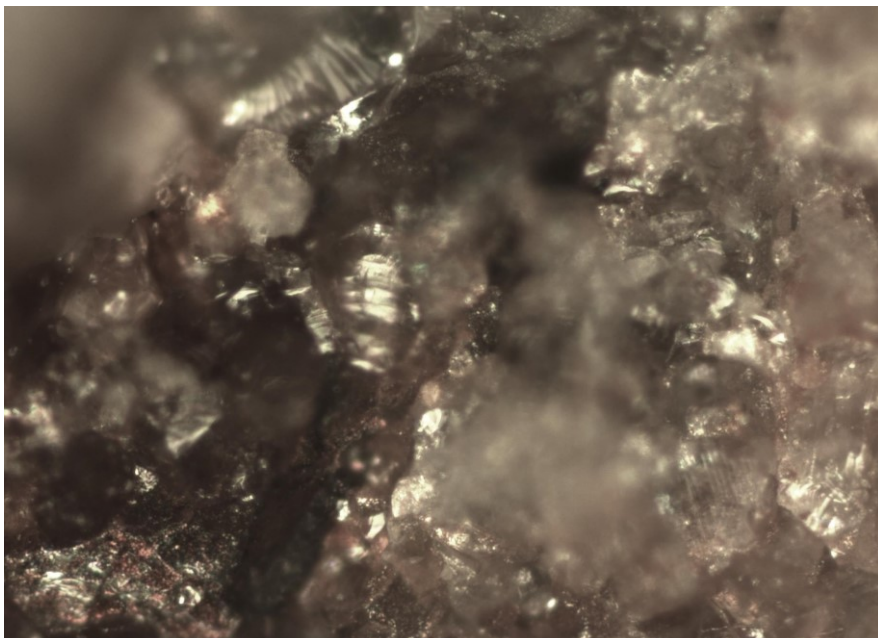
Sample Site **53** : Stone 1_sp. 1 : **Quartz** ~ 200 x 200 μm



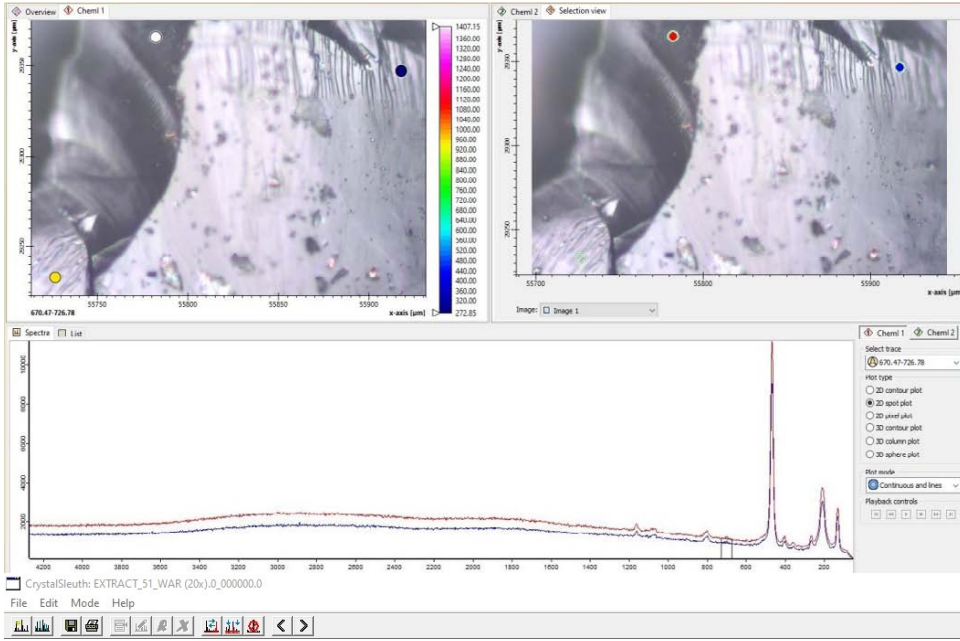
Sample Site **53** : Stone 2_sp. 1 : **Quartz** ~ 150 x 100 μm



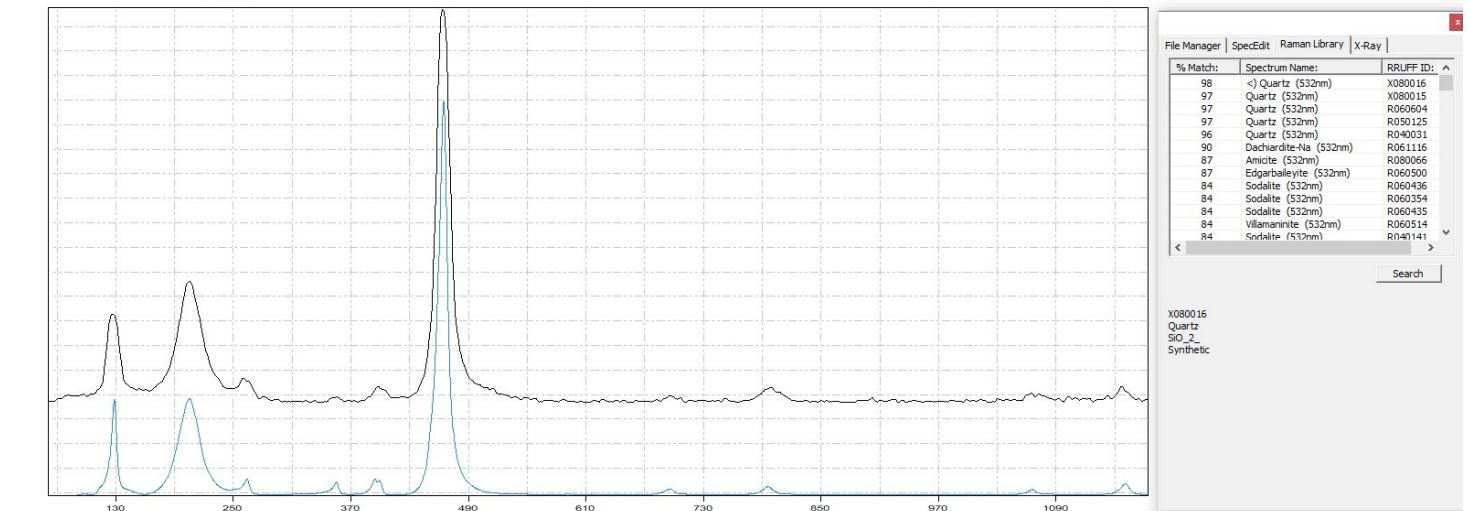
Sample Site **54** : Stone 1_spectra 1 (white mineral) indicates : **Quartz** - Image size : ~ 400 x 300 μm



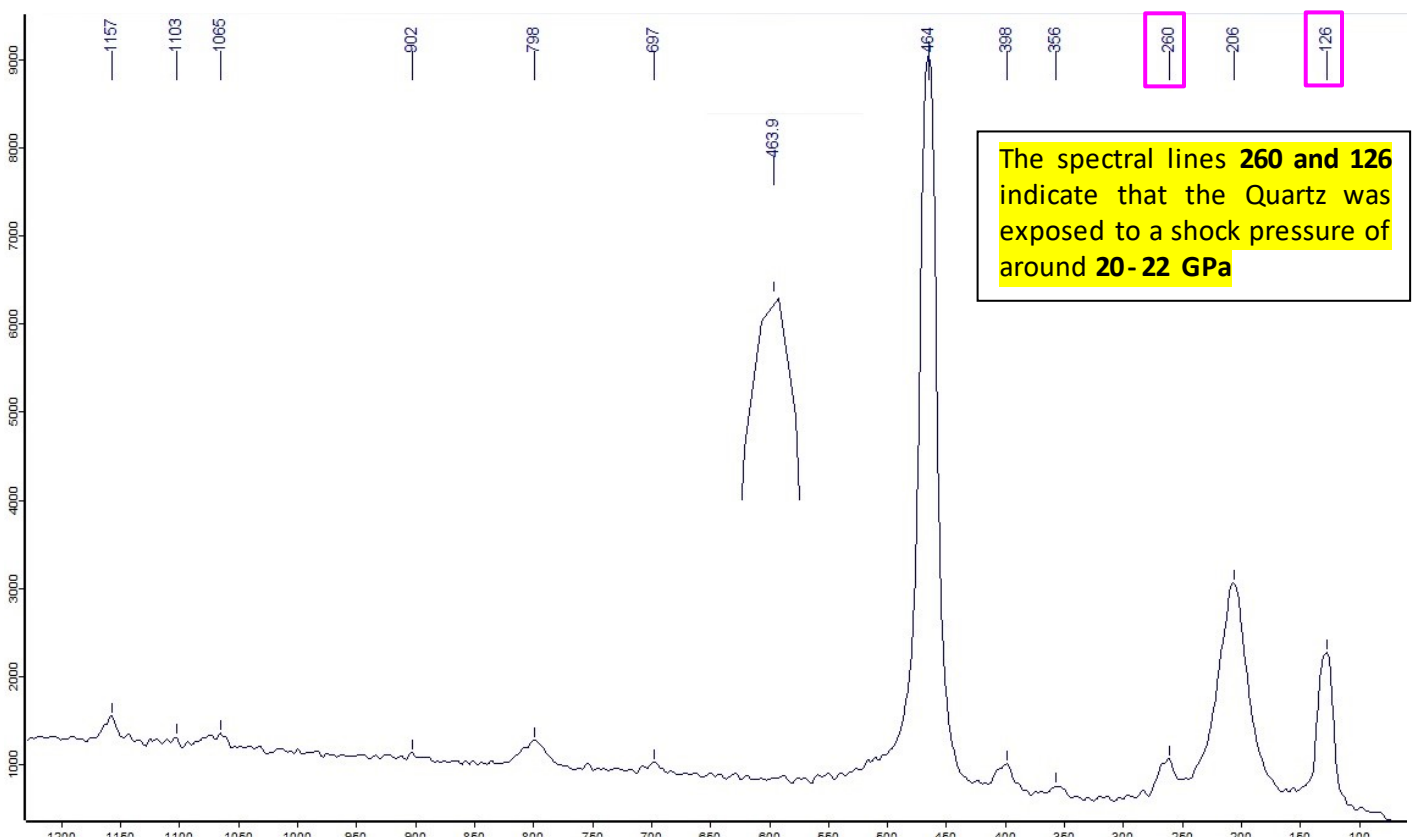
Sample Site **51** : Stone 1_spectra 1 indicates : **Quartz** (→ see RRUFF_CS results)



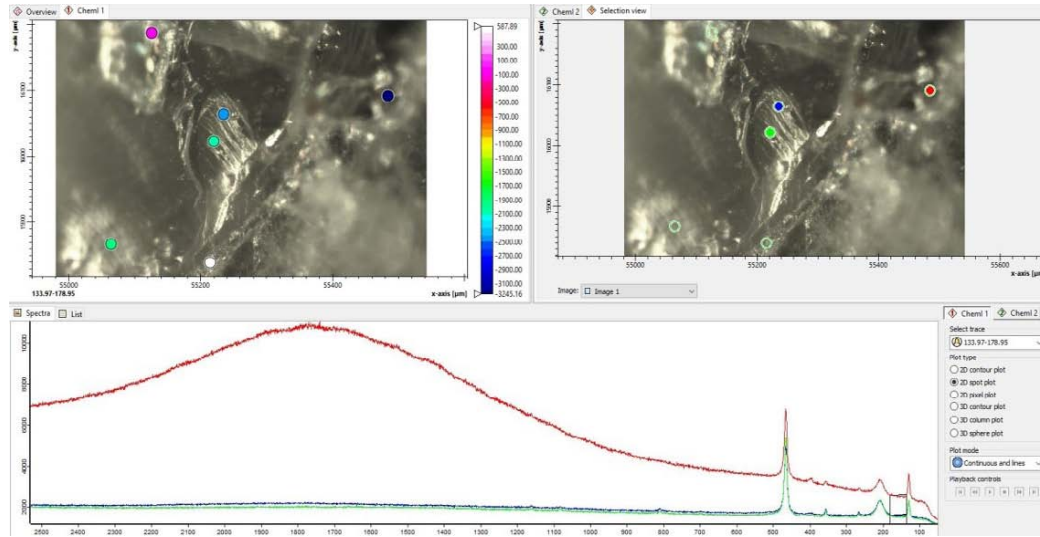
Sample :



Indication for a shock event are the shifts of the marked Quartz spectral lines towards 260 and 126



Sample Site **51** : Stone 2_spectra 1 indicates : **Quartz** (→ see RRUFF_CS results)

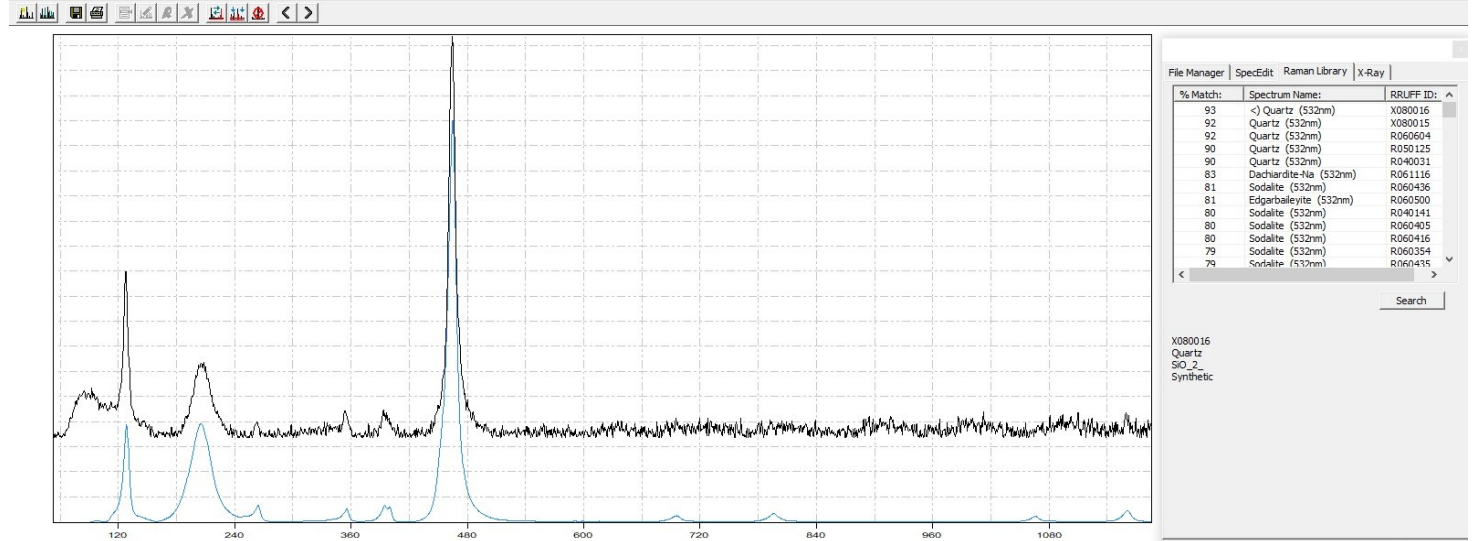


Sample :

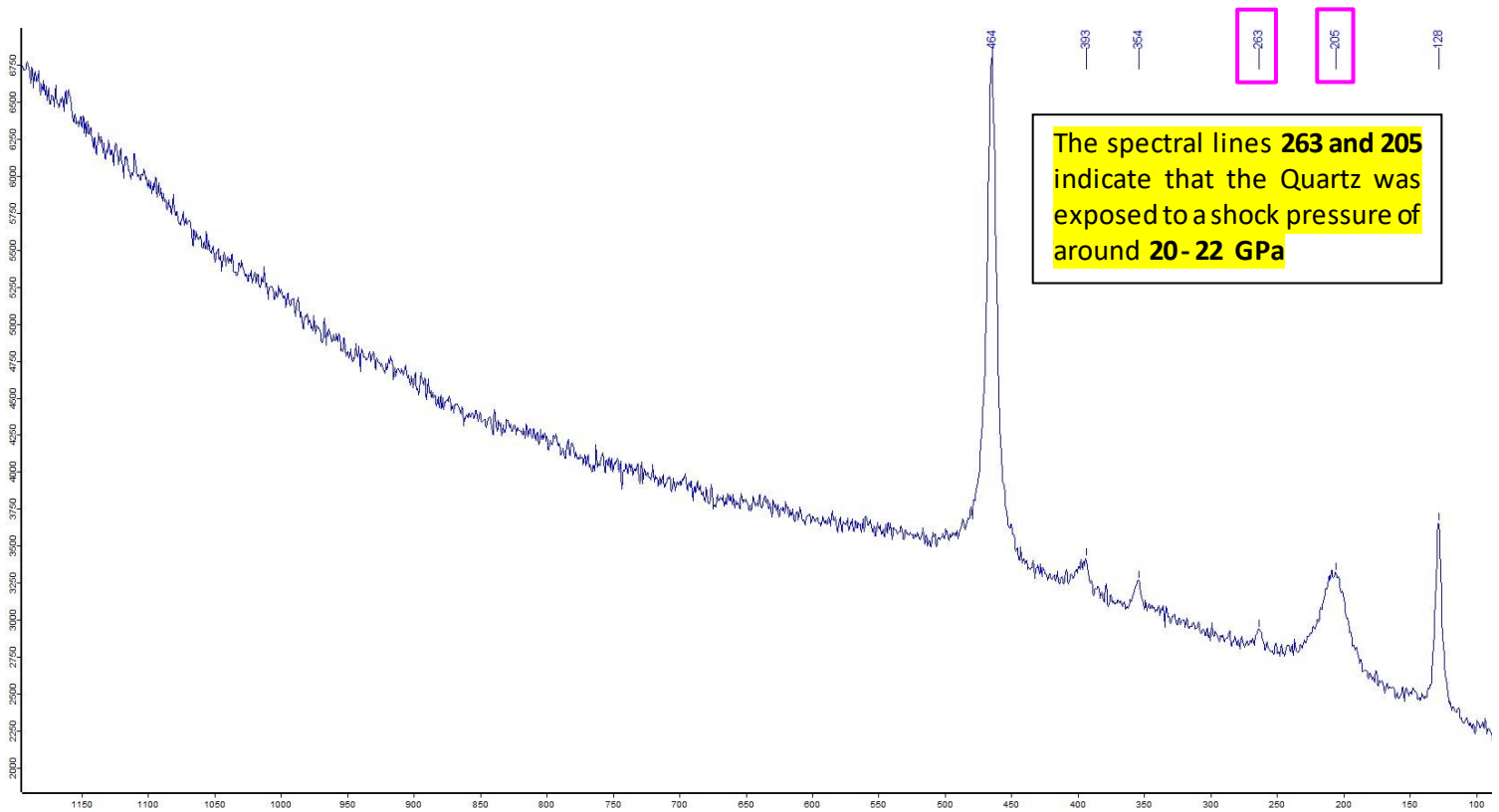


CrystalSleuth: EXTRACT_Warw_51 (new Stone_white mineral_2)_0_000005.0

File Edit Mode Help

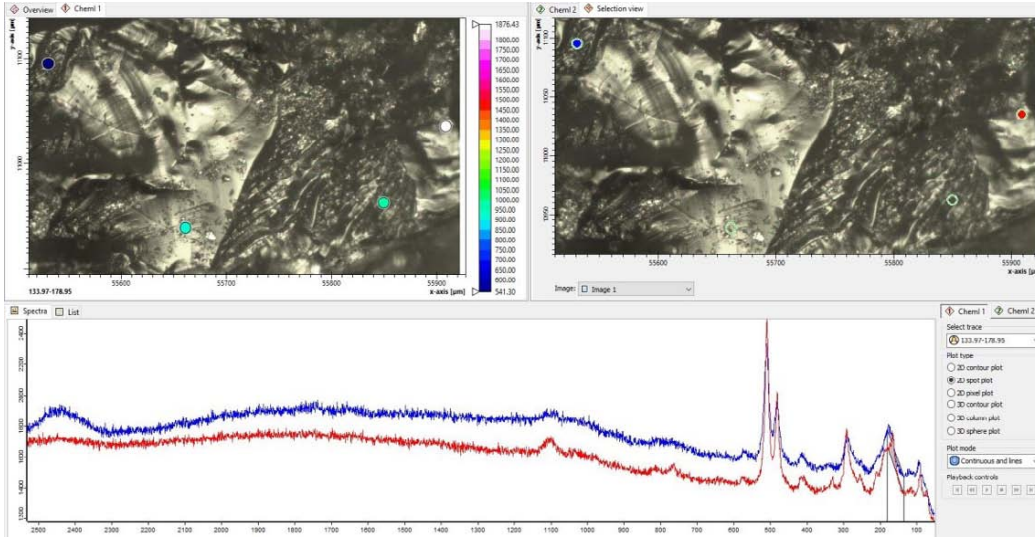


Indication for a shock event are the shifts of the marked Quartz spectral lines towards 263 and 205



The spectral lines 263 and 205 indicate that the Quartz was exposed to a shock pressure of around 20- 22 GPa

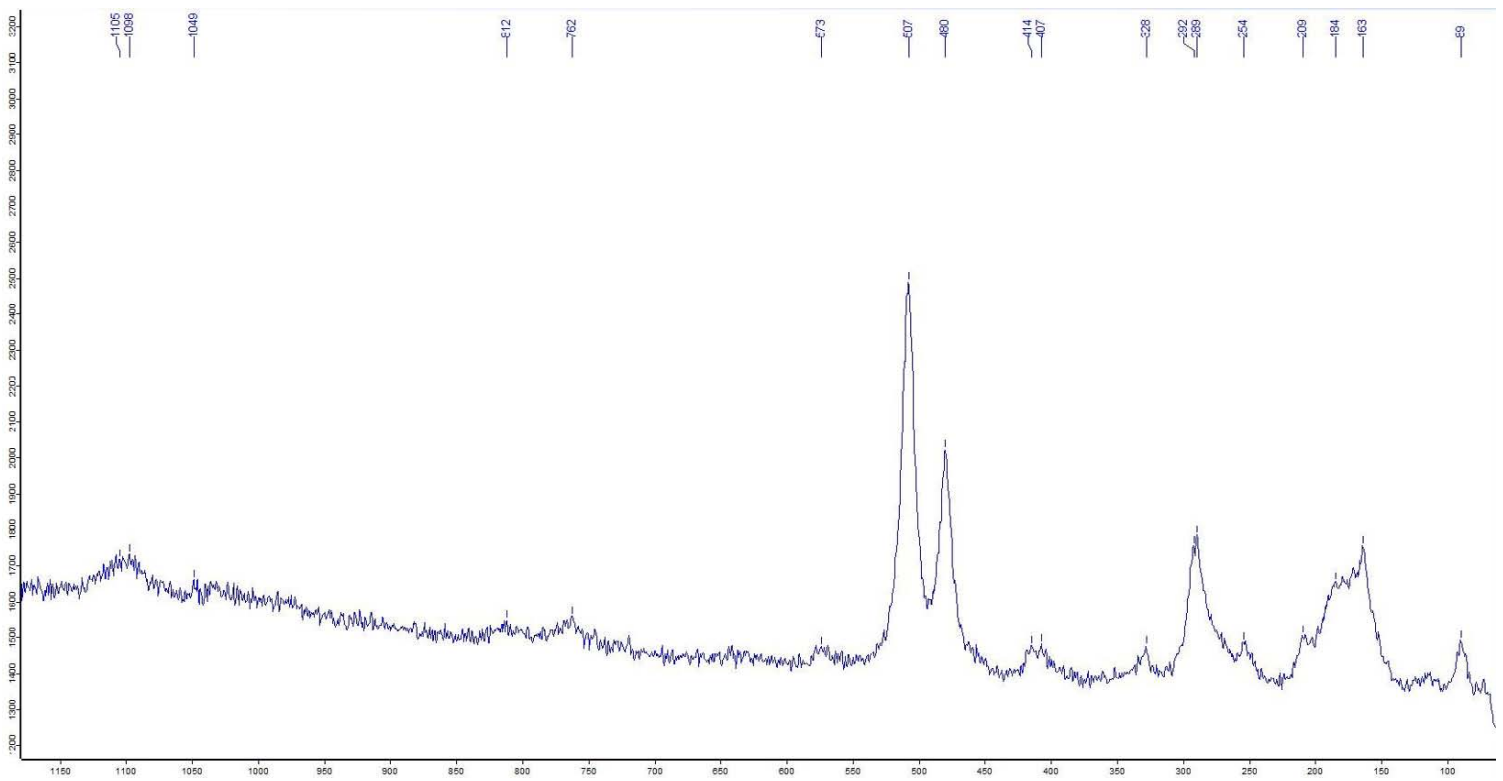
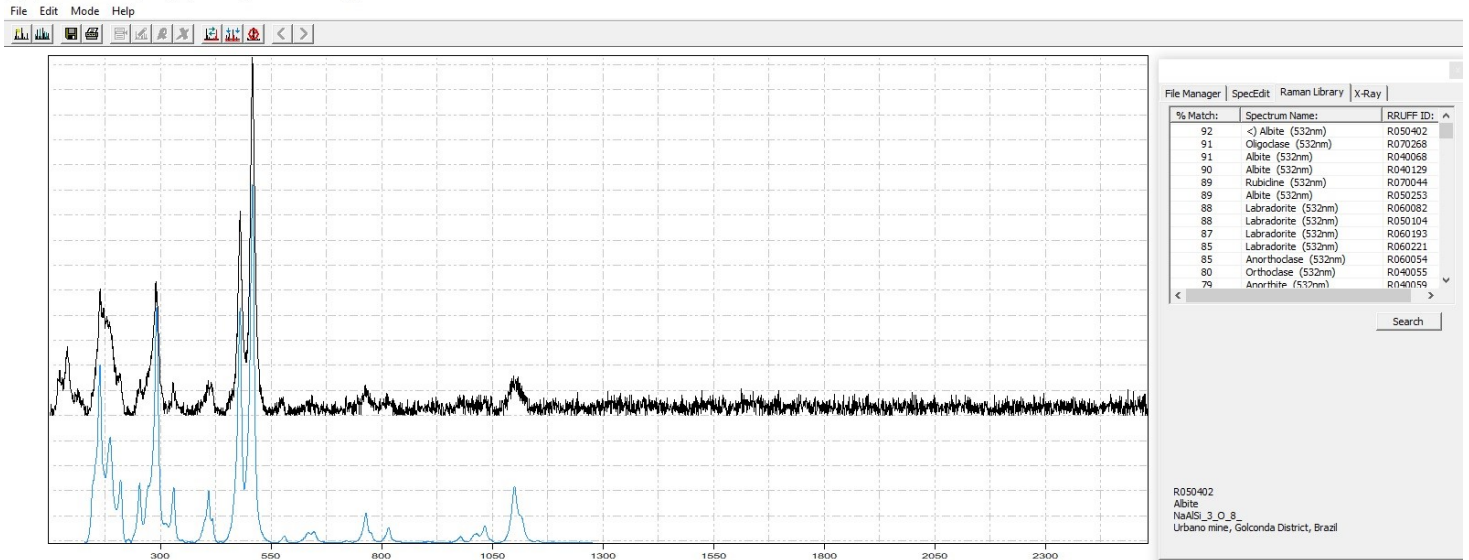
Sample Site **51** : Stone 2_spectra 2 indicates : **Albite** (→ see RRUFF_CS results)



Sample :

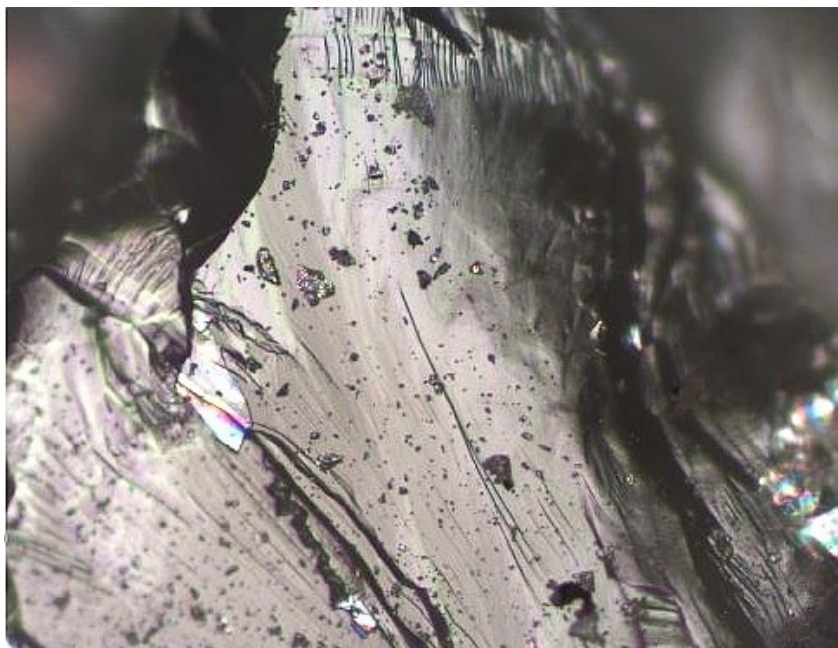


CrystalSleuth: EXTRACT_Warw_51 (new Stone_near black inclusion)_0_000003.2

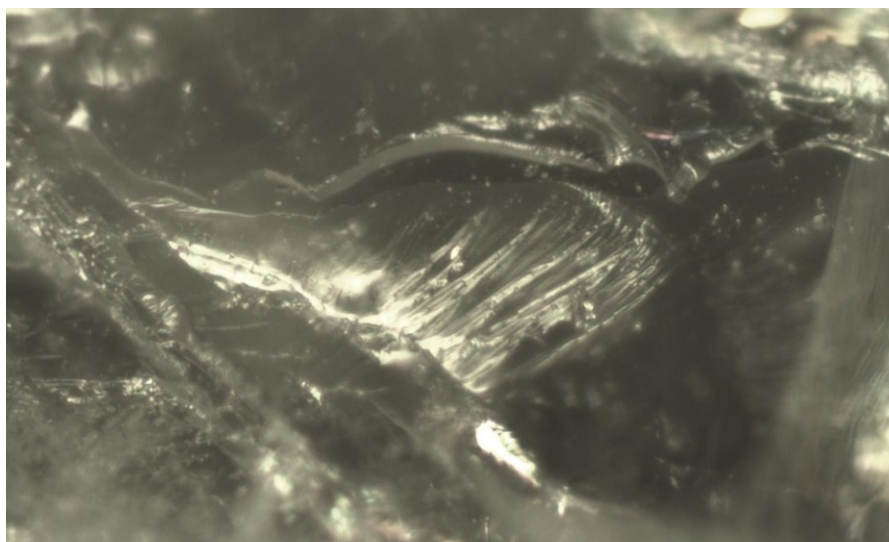


Microscopic Images : Sample from Site 51 → original state (no preparation for analysis)

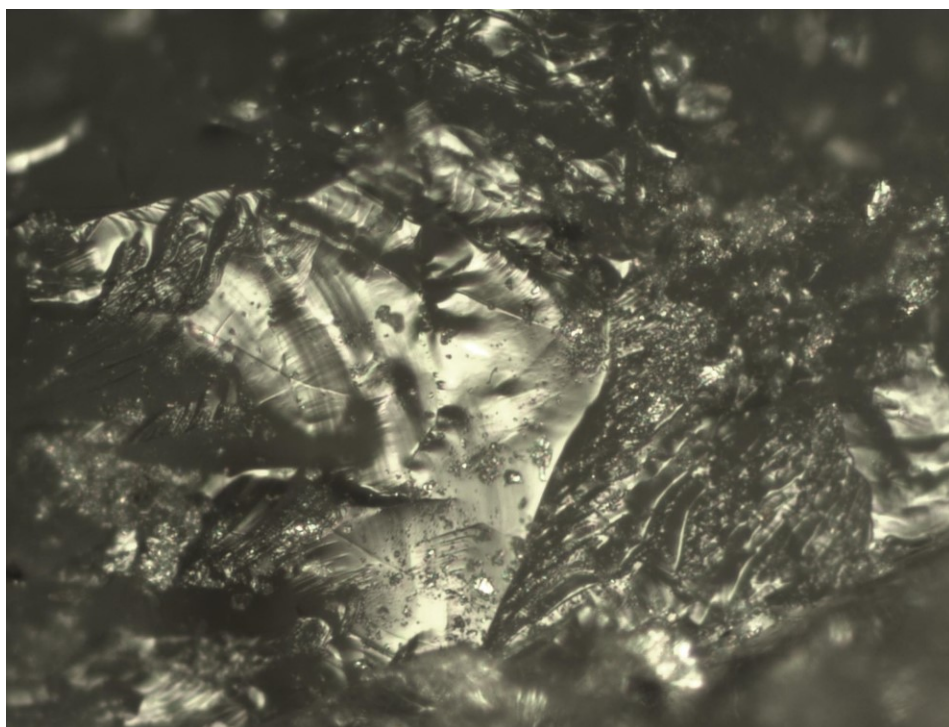
Sample Site **51** : Stone 1_spectra 1 indicates : **Quartz** - Image size : ~ 400 x 350 μm



Sample Site **51** : Stone 2_spectra 1 indicates : **Quartz** - Image size : ~ 300 x 200 μm

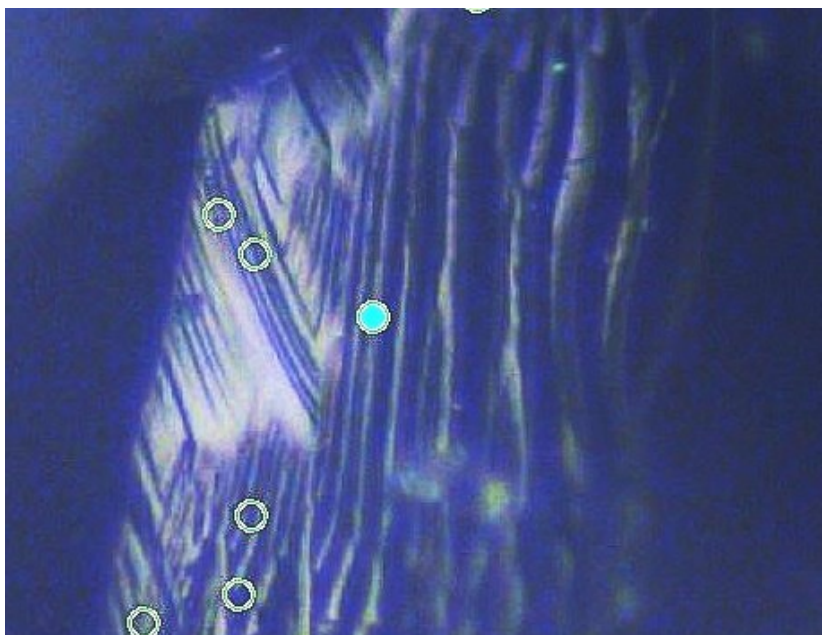


Sample Site **51** : Stone 2_spectra 2 (black mineral) indicates : **Albite** - Image size : ~ 400 x 300 μm

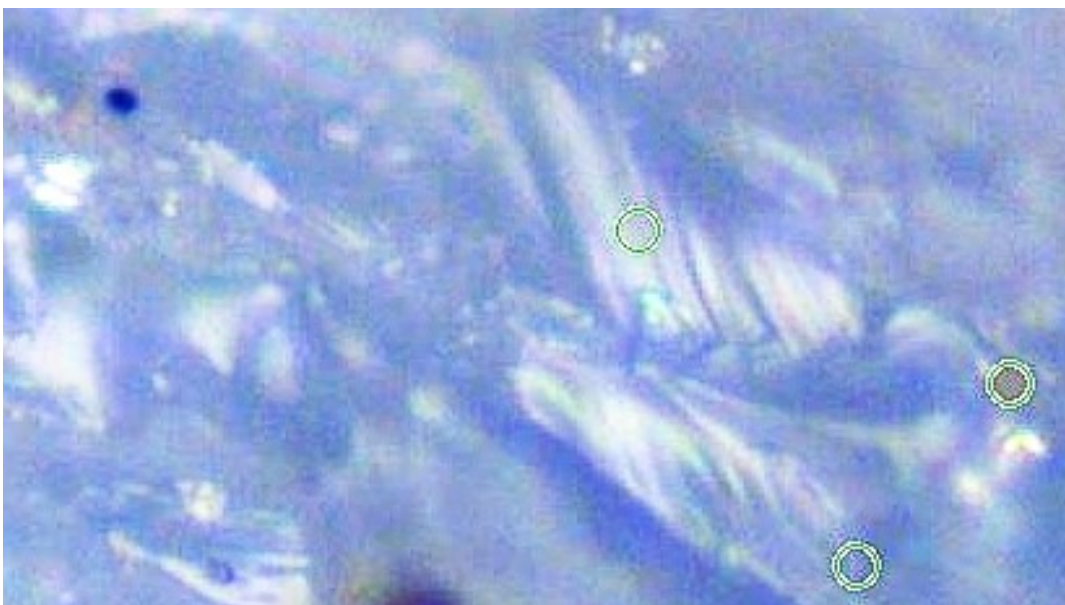


Microscopic Images : Sample from Site 51 → original state (no preparation for analysis)

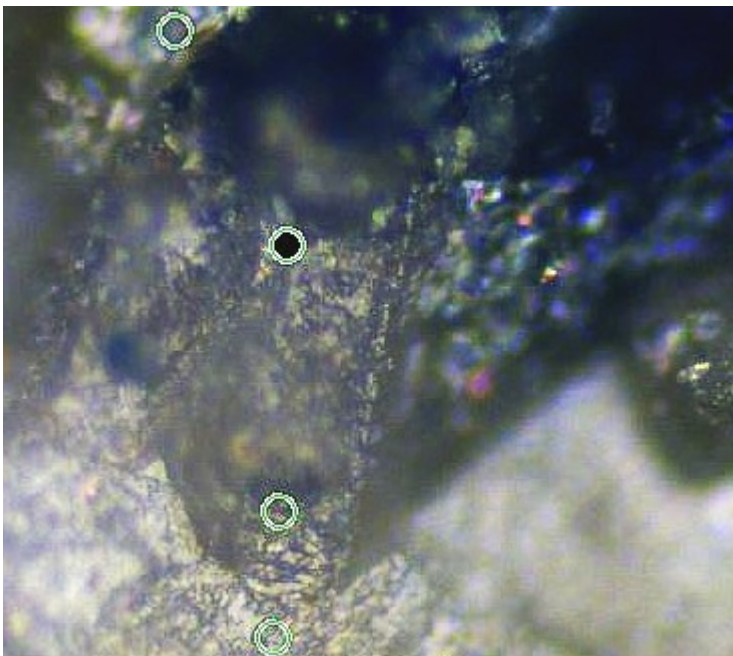
Sample Site **51**: Stone 1_spectra 2 indicates: **Orthoclase** - Image size : ~ 200 x 200 μm



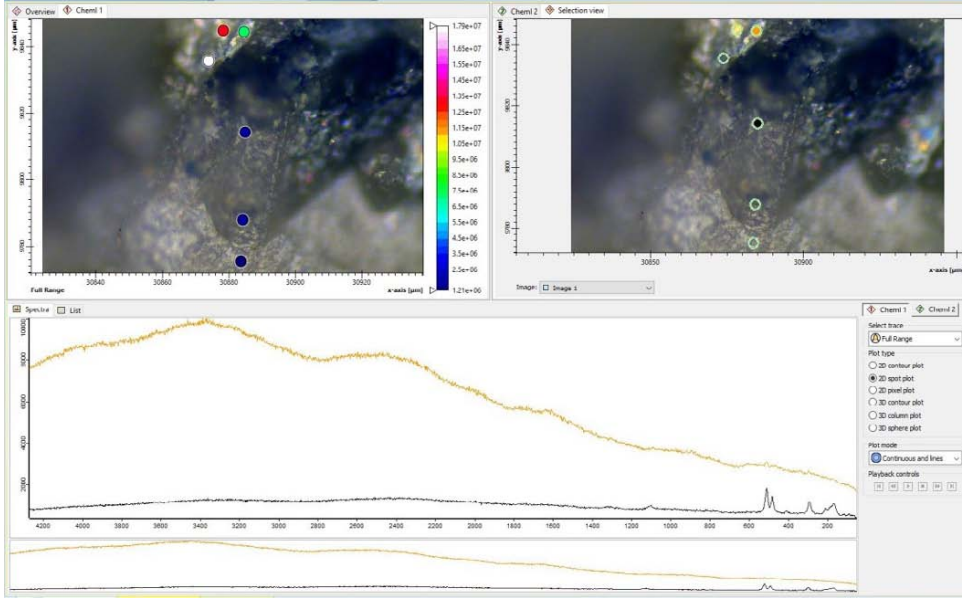
Sample Site **51**: Stone 1_spectra 3 indicates: **Labradorite** - Image size : ~ 150 x 100 μm



Sample Site **48**: Stone 1_spectra 1 indicates: **Albite** - Image size : ~ 200 x 200 μm



Sample Site 48 : Stone 1_spectra 1 indicates : **Albite** (→ see RRUFF_CS results)

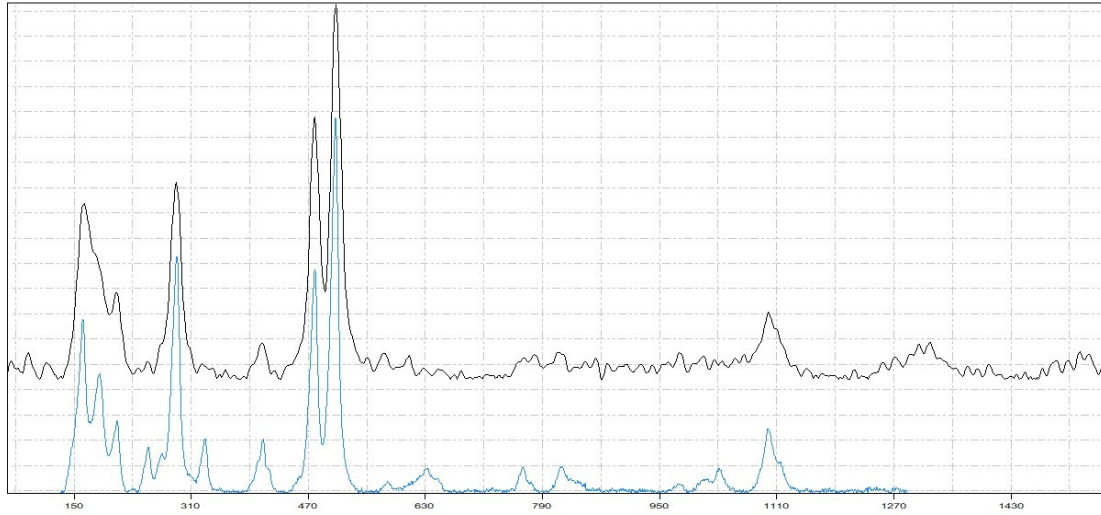


Sample :



CrystalSleuth: EXTRACT_48-WARW_0_000000_0_G2_NK

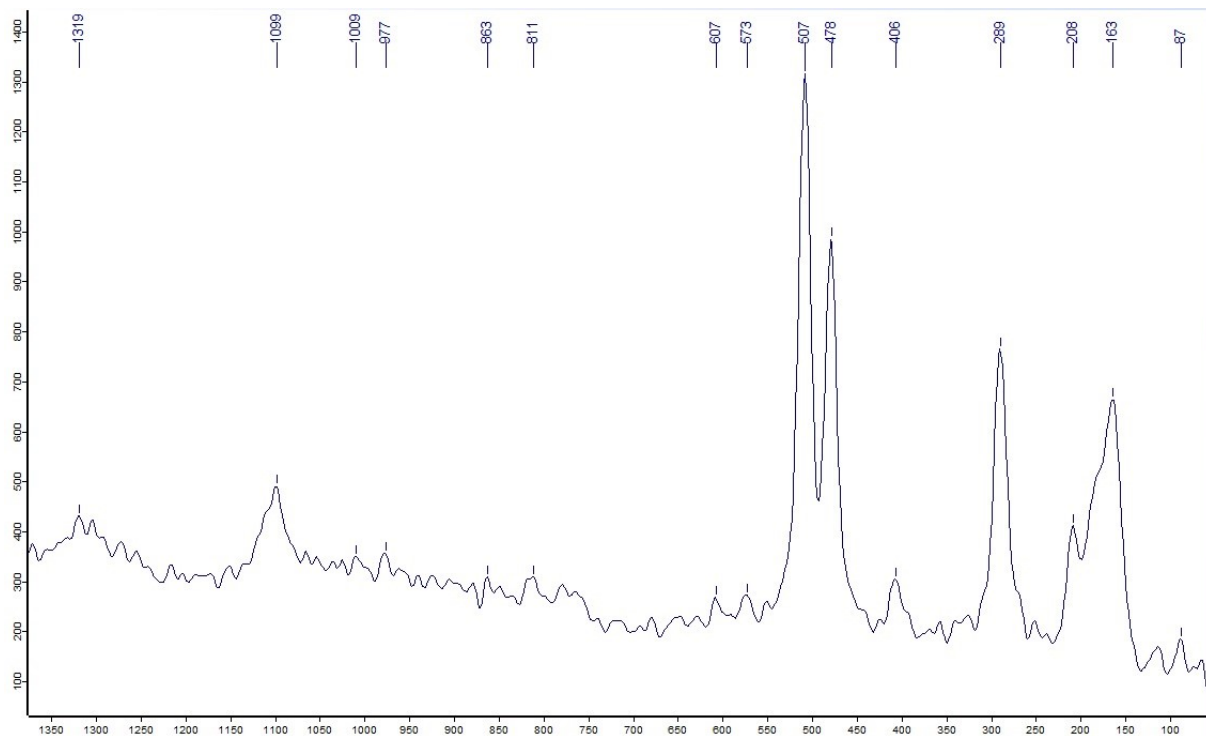
File Edit Mode Help



% Match:	Spectrum Name:	RRUFF ID:
95	< Albite (532nm)	R040068
95	Albite (532nm)	R050402
93	Albite (532nm)	R040129
93	Oligoclase (532nm)	R070268
90	Labradorite (532nm)	R060082
90	Labradorite (532nm)	R050104
89	Albite (532nm)	R050253
89	Anorthoclase (532nm)	R060054
88	Labradorite (532nm)	R060193
88	Rubicline (532nm)	R070044
87	Labradorite (532nm)	R060221
82	Orthoclase (532nm)	R040055
81	Crynoclase (532nm)	R050167

Search

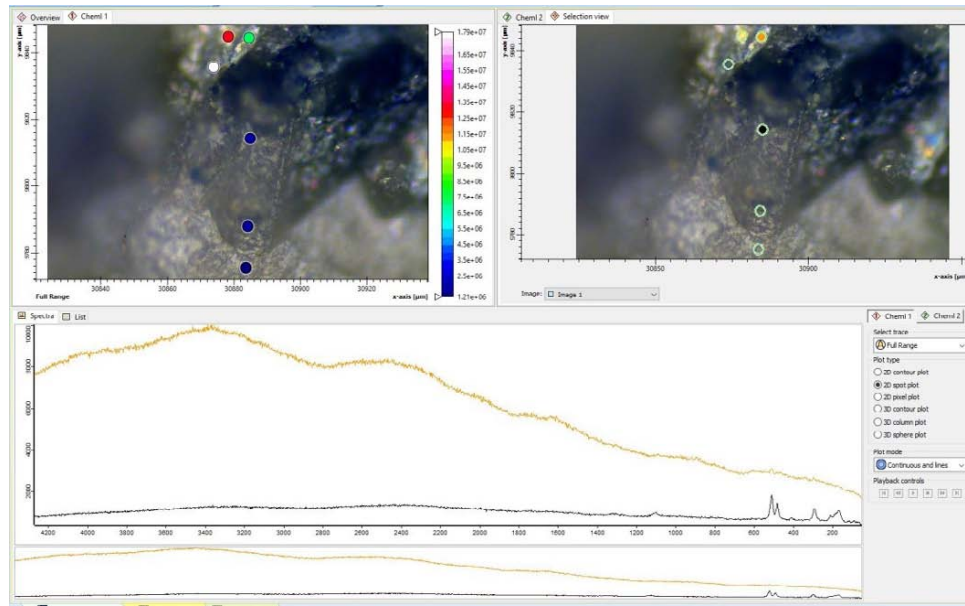
R040068
Albite
NaAlSi₃O₈
Harding Pegmatite, Dixon, New Mexico, USA



Sample Site 48 : Stone 1_spectra 2 indicates : **Anorthoclase (or Albite)**

(→ see RRUFF_CS results)

→ This result is guesswork because the spectra contains less information !

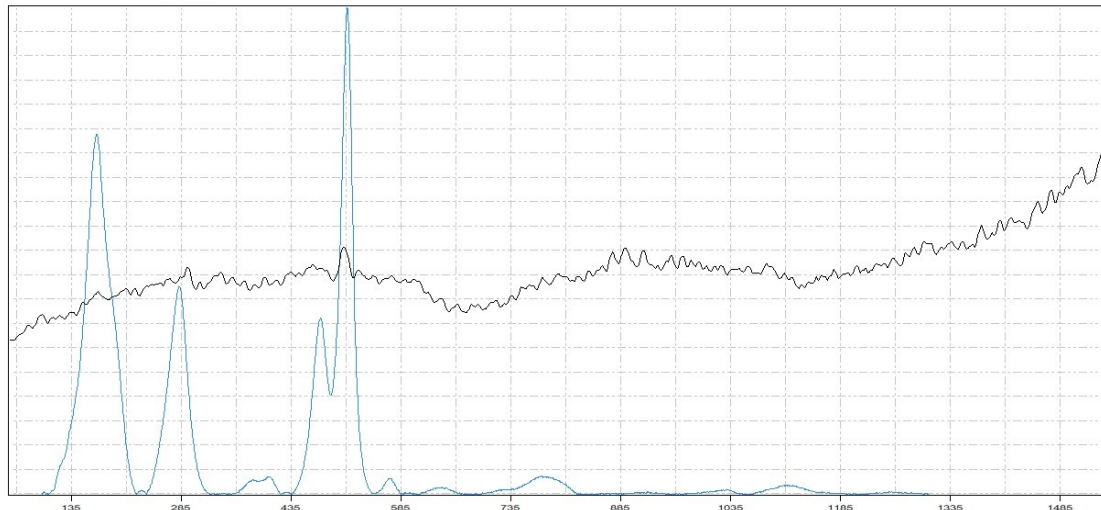


Sample :



CrystalSleuth: EXTRACT_48-WARW_0_000005.0_NK_Y_G1

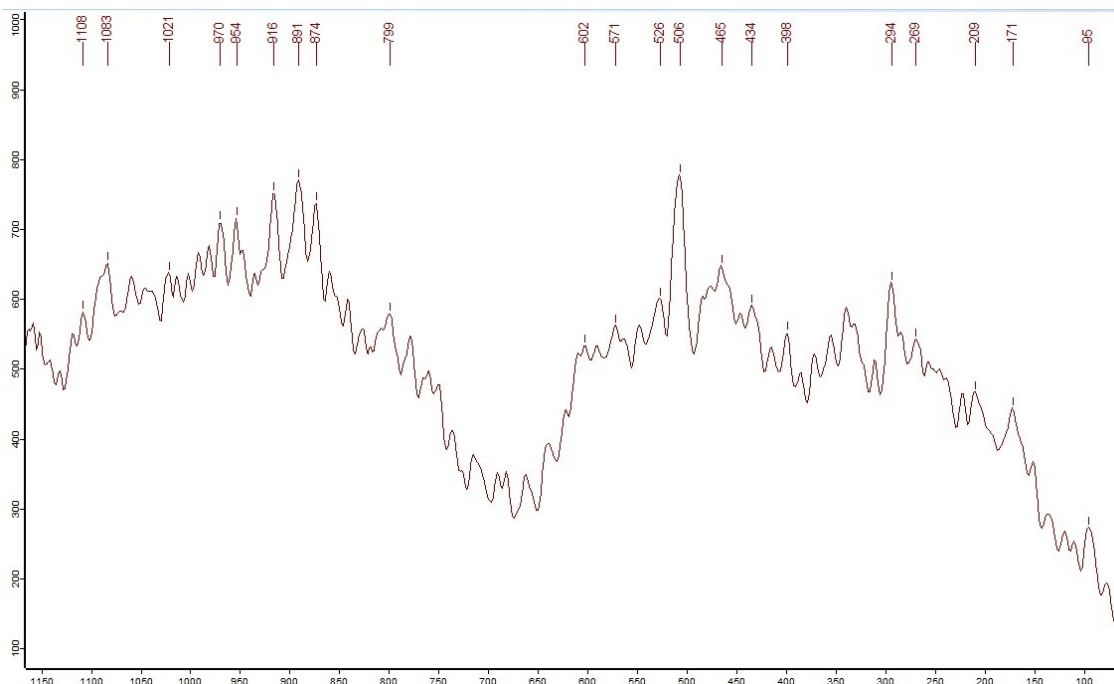
File Edit Mode Help



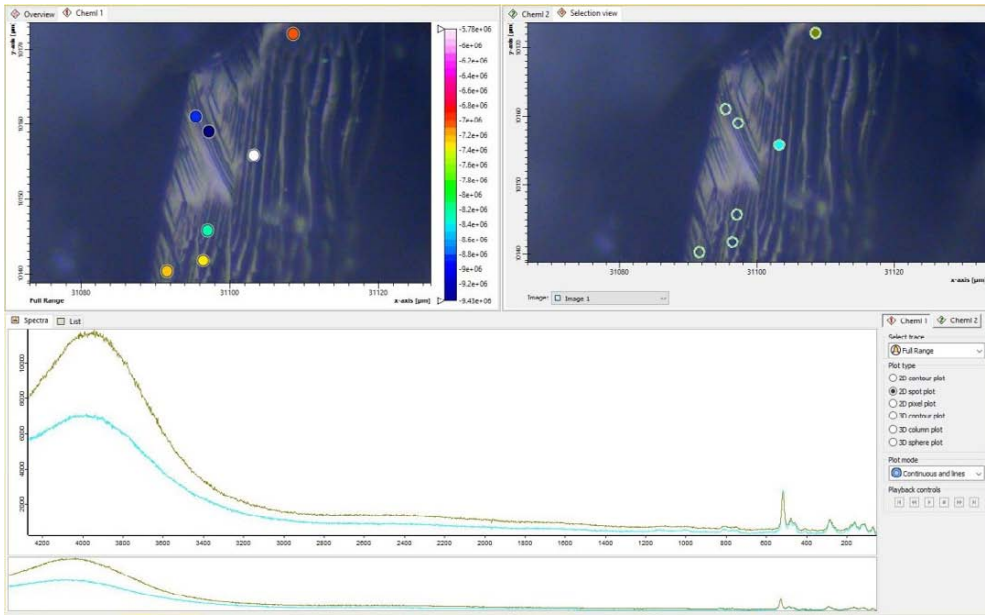
% Match	Spectrum Name	RRUFF ID
78	Pyrope (532nm)	R060445
78	Wulfenite (532nm)	R050149
78	Hedenbergite (532nm)	R060040
78	Brassite (532nm)	R060042
78	Brianyoungite (532nm)	R060431
78	<-> Anorthoclase (532nm)	R060054
78	Brannerite (532nm)	R080091
78	Fluorite (532nm)	R050046
78	Muscovite (532nm)	R040108
78	Plattnerite (532nm)	R080019
78	Reyerite (532nm)	R060749
78	Amesite (532nm)	R070132
78	Paite (532nm)	R060854

Search

R060054
Anorthoclase
(Na,K)AlSi₃O₈
Mt. Erebus, Antarctica



Sample Site 51 : Stone 1_spectra 2 (dark mineral) indicates : **Orthoclase** (→ see RRUFF_CS results)

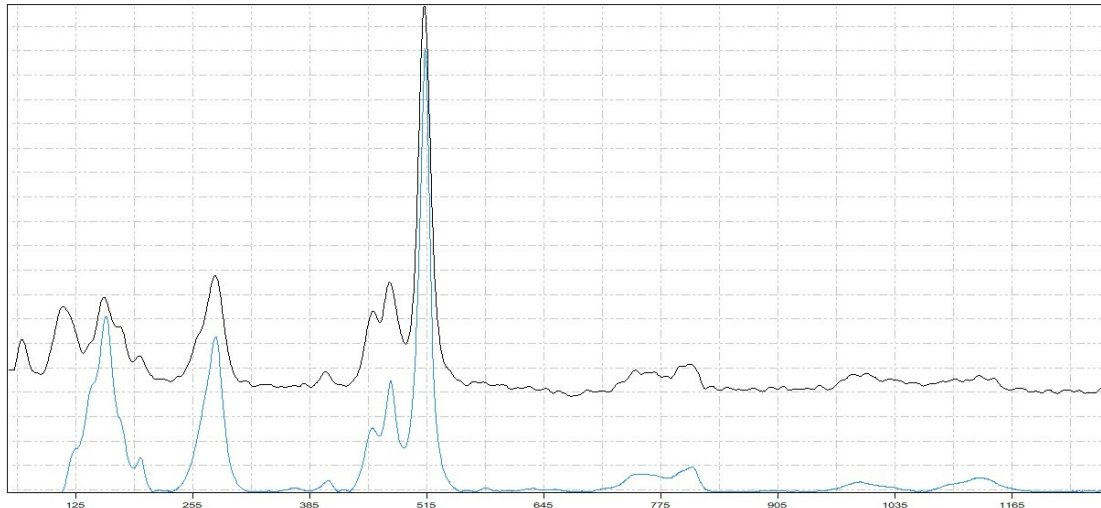


Sample :



CrystalSleuth: EXTRACT_51-WARW_0_000000.0_NK_G2

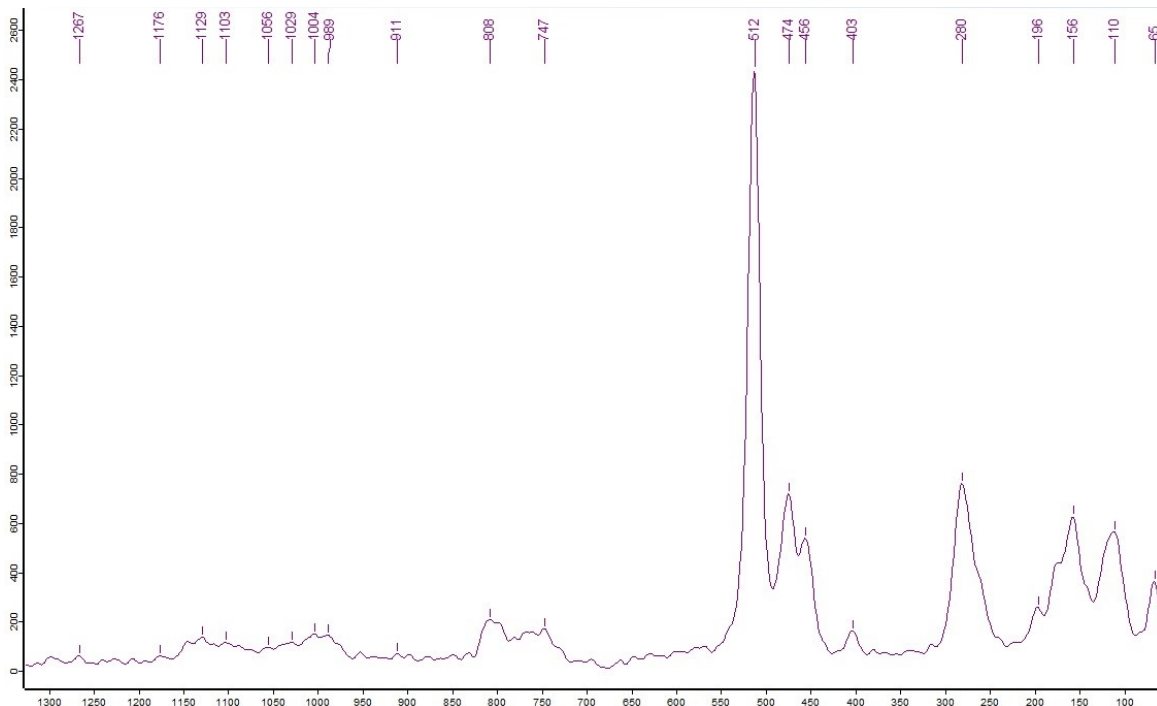
File Edit Mode Help



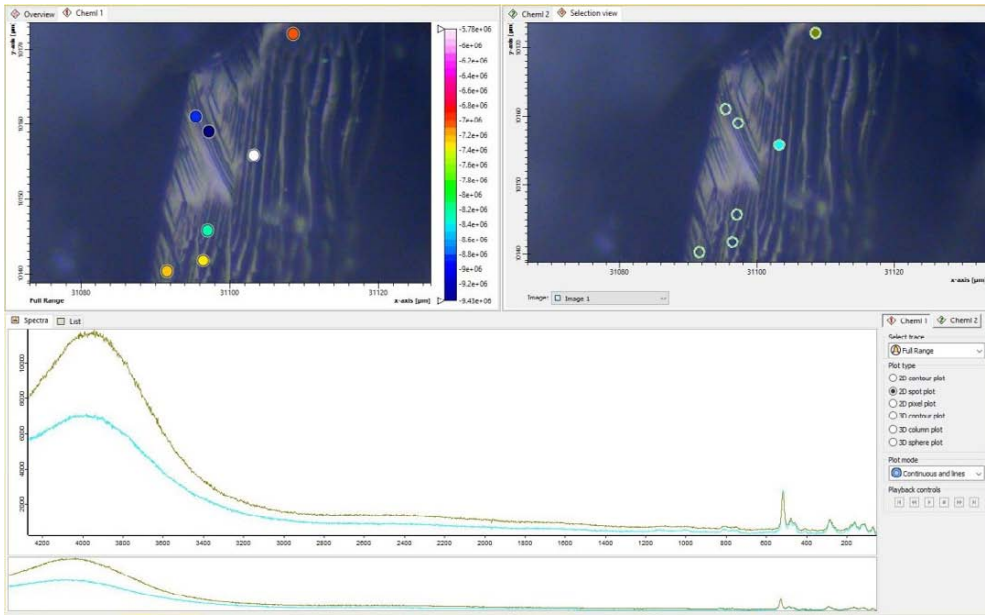
% Match:	Spectrum Name:	RRUFF ID:
93	< Orthoclase (532nm)	R060077
93	Orthoclase (532nm)	R050185
93	Orthoclase (532nm)	R040055
92	Orthoclase (532nm)	R050367
91	Microcline (532nm)	R050193
91	Orthoclase (532nm)	R070001
90	Microcline (532nm)	R050054
89	Microcline (532nm)	R040154
88	Microcline (532nm)	R050150
85	Labradorite (532nm)	R050104
84	Anorthoclase (532nm)	R060054
81	Oligoclase (532nm)	R070268
80	Sanidine (532nm)	R060193

Search

R060077
Orthoclase
KASI_3_0_3
pegmatite near Minh Tien, 15 km south of Luc Yen, Vietnam



Sample Site 51 : Stone 1_spectra 2 (dark mineral) indicates : **Orthoclase** (→ see RRUFF_CS results)

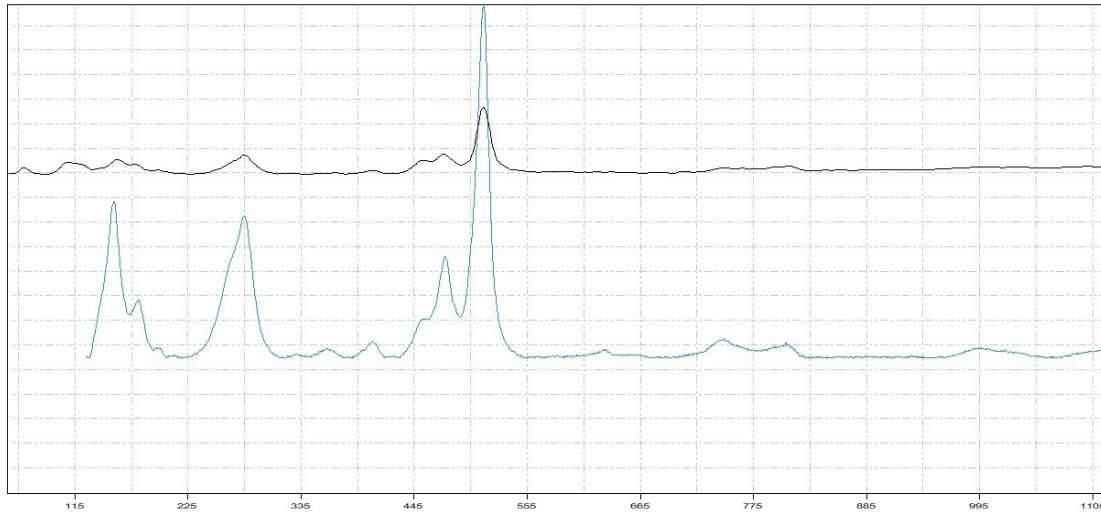


Sample :



CrystalSleuth: EXTRACT_51-WARW_0_000006.0_Y_G2

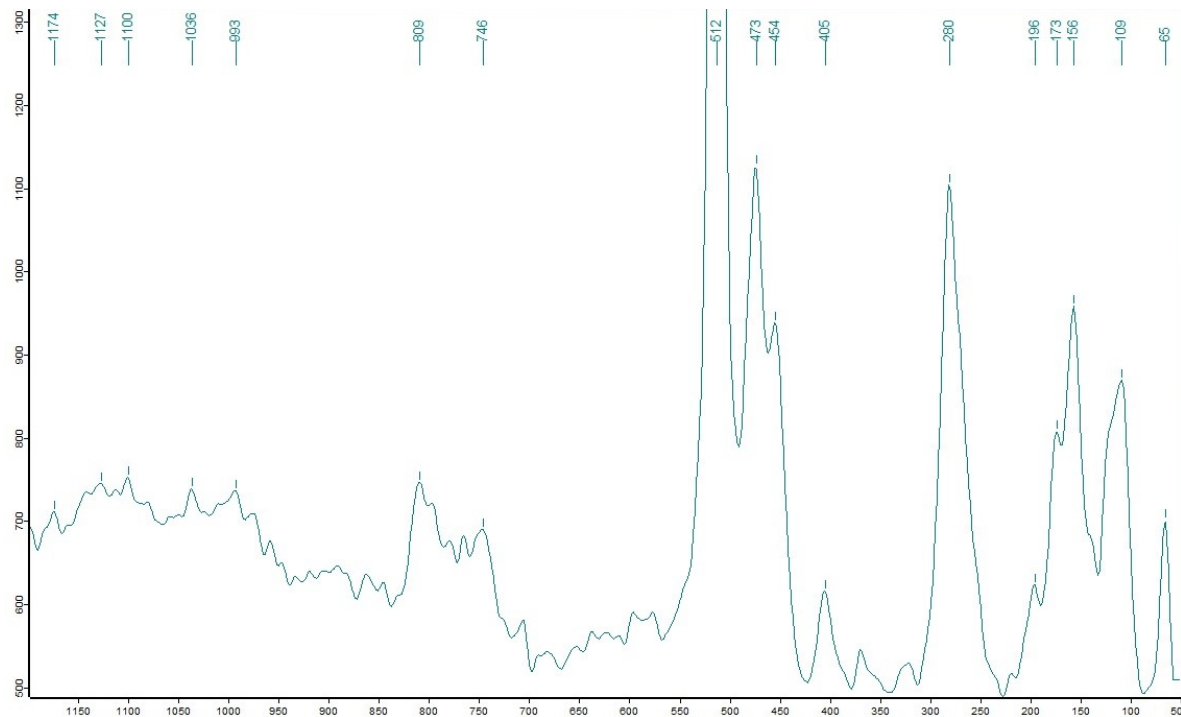
File Edit Mode Help



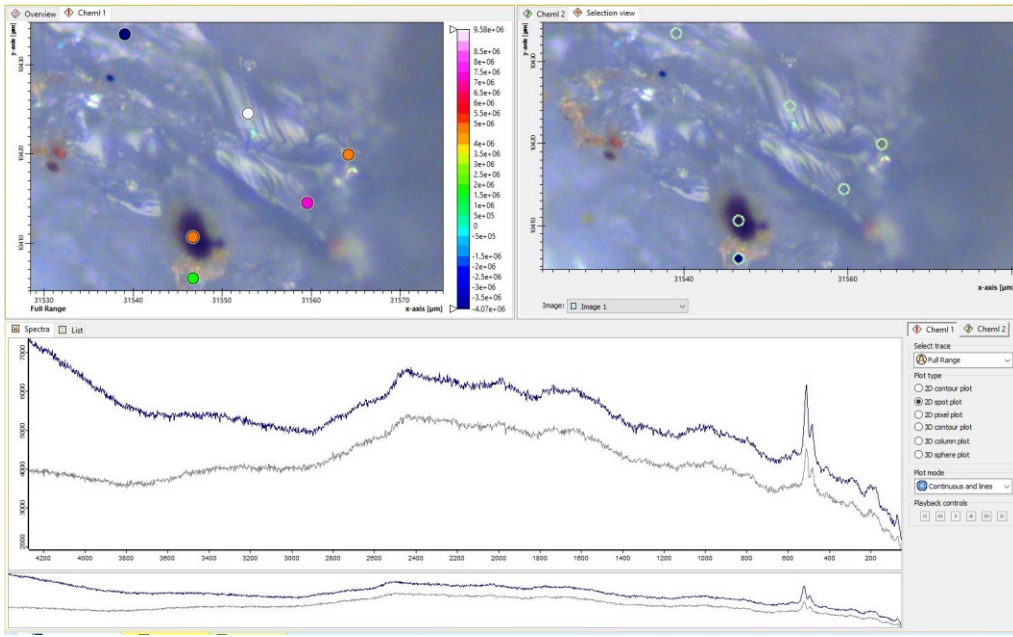
% Match	Spectrum Name	RRUFF ID
84	Jamesonite (532nm)	R050430
83	Bytownite (532nm)	R070598
83	Meta-autunite (532nm)	R050612
83	Anorthoclase (532nm)	R060054
82	Cronstedtite (532nm)	R061026
82	Delindite (532nm)	R060518
82	Wickenburgite (532nm)	R060048
82	Tuscanite (532nm)	R050324
82	<) Orthoclase (532nm)	R050367
82	Onyrolite (532nm)	R060264
82	Orthoclase (532nm)	R050185
82	Attikaite (532nm)	R070217
82	Mexxonite (532nm)	R060955

Search

R050367
Orthoclase
KAS1_3_0_3
Pazunsek, Mandalay Division, Burma



Sample Site 51 : Stone 1_spectra 3 (white mineral) indicates : **Labradorite** (→ see RRUFF_CS results)

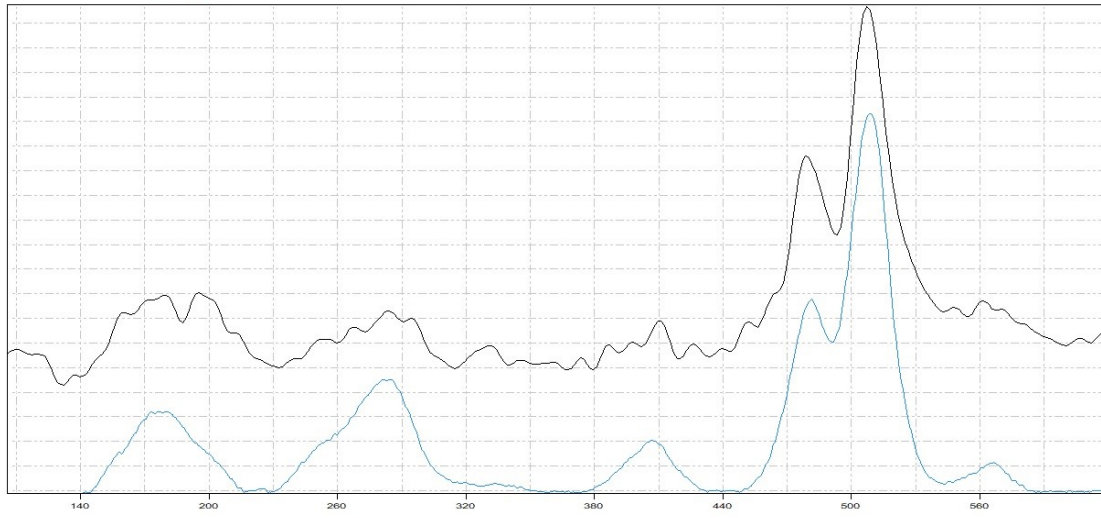


Sample :



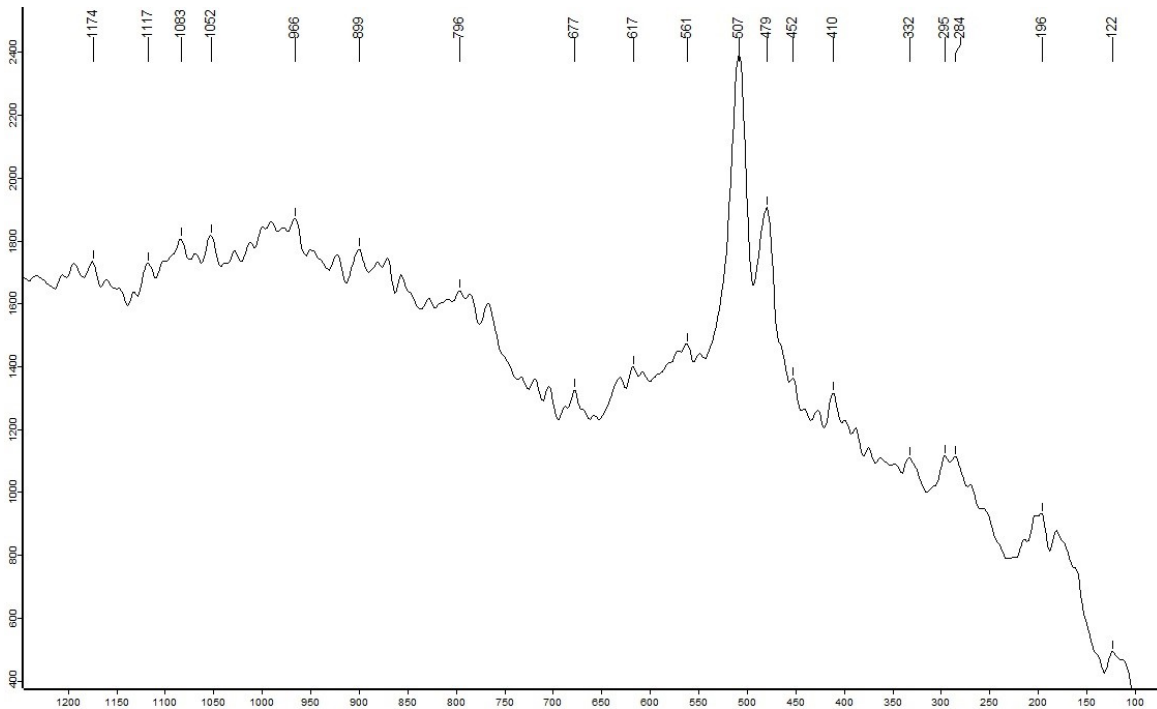
CrystalSleuth: EXTRACT_51-WARW_2(white)_0_000000_0_NK_G2

File Edit Mode Help

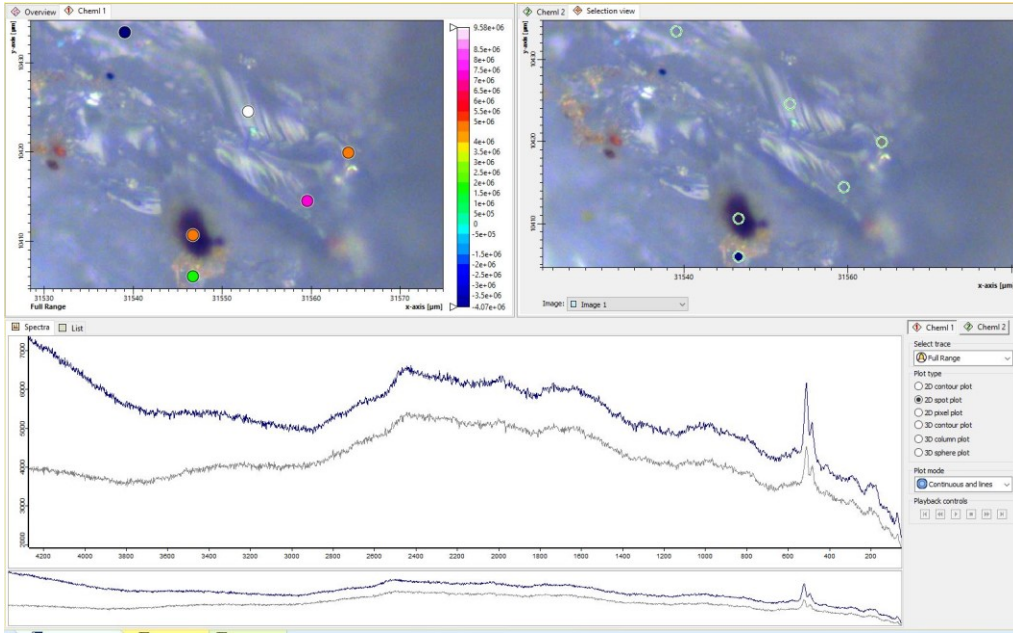


% Match:	Spectrum Name:	RRUFF ID:
94	<J> Labradorite (532nm)	R050104
94	Labradorite (532nm)	R060221
93	Labradorite (532nm)	R060193
91	Oligoclase (532nm)	R070268
90	Labradorite (532nm)	R060082
90	Tengerite (γ) (532nm)	R060480
89	Jameelite (532nm)	R060274
89	Perite (532nm)	R060765
89	Romette (532nm)	R060736
89	Cobalttharmeyerite (532nm)	R070400
88	Bytownite (532nm)	R070510
88	Arakite (532nm)	R060812
88	Faureströmite (532nm)	R070462

R050104
Labradorite
Na_{0.5}-0.3Ca_{0.5}-0.7Al_{1.5}-1.7Si_{2.5}-2.3O₈
unknown



Sample Site 51 : Stone 1_spectra 3 (white mineral) indicates : **Labradorite** (→ see RRUFF_CS results)

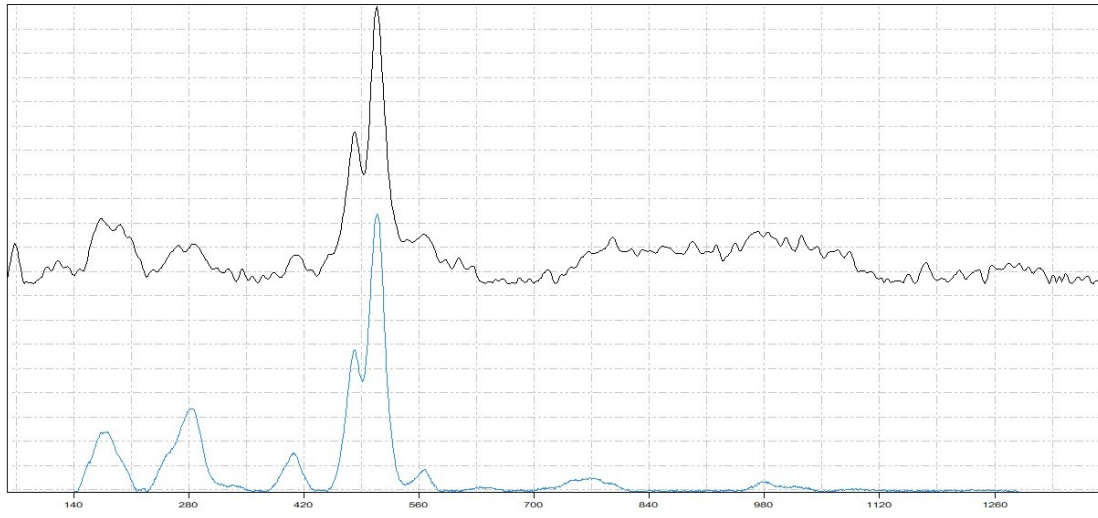


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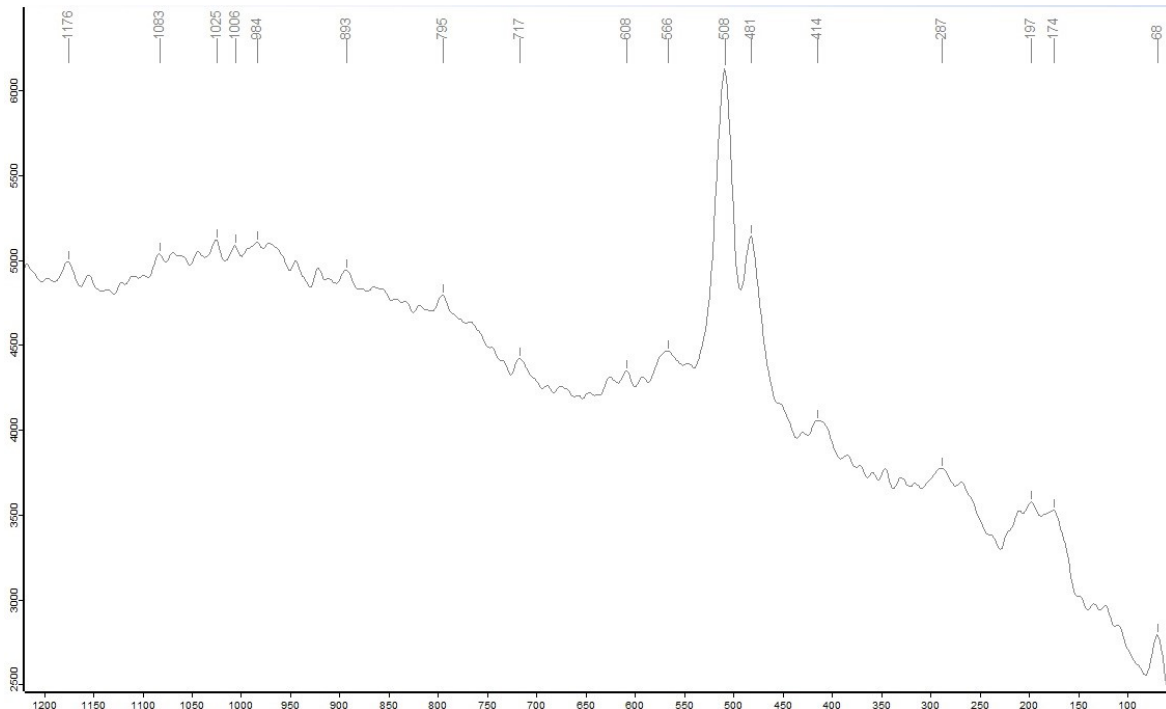
CrystalSleuth: EXTRACT_51-WARW_2(white)_0_000005.0_G2

File Edit Mode Help

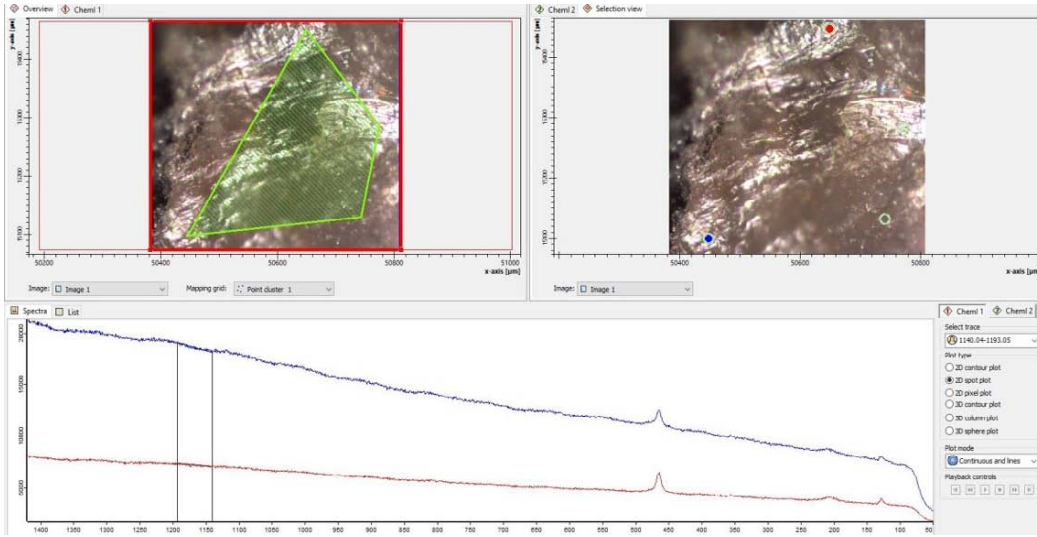


% Match	Spectrum Name	RRUFF ID
97	< > Labradorite (532nm)	R050104
97	Labradorite (532nm)	R060221
97	Labradorite (532nm)	R060082
96	Labradorite (532nm)	R060193
95	Oligoclase (532nm)	R070268
95	Massicot (532nm)	R060454
94	Sindheimerite (532nm)	R050546
94	Anorthoclase (532nm)	R060054
94	Bytownite (532nm)	R070510
93	Siderite (532nm)	R040034
93	Faujasite-Ca (532nm)	R070462
93	Jameelite (532nm)	R060274
93	Cobaltntharmeverite (532nm)	R070400

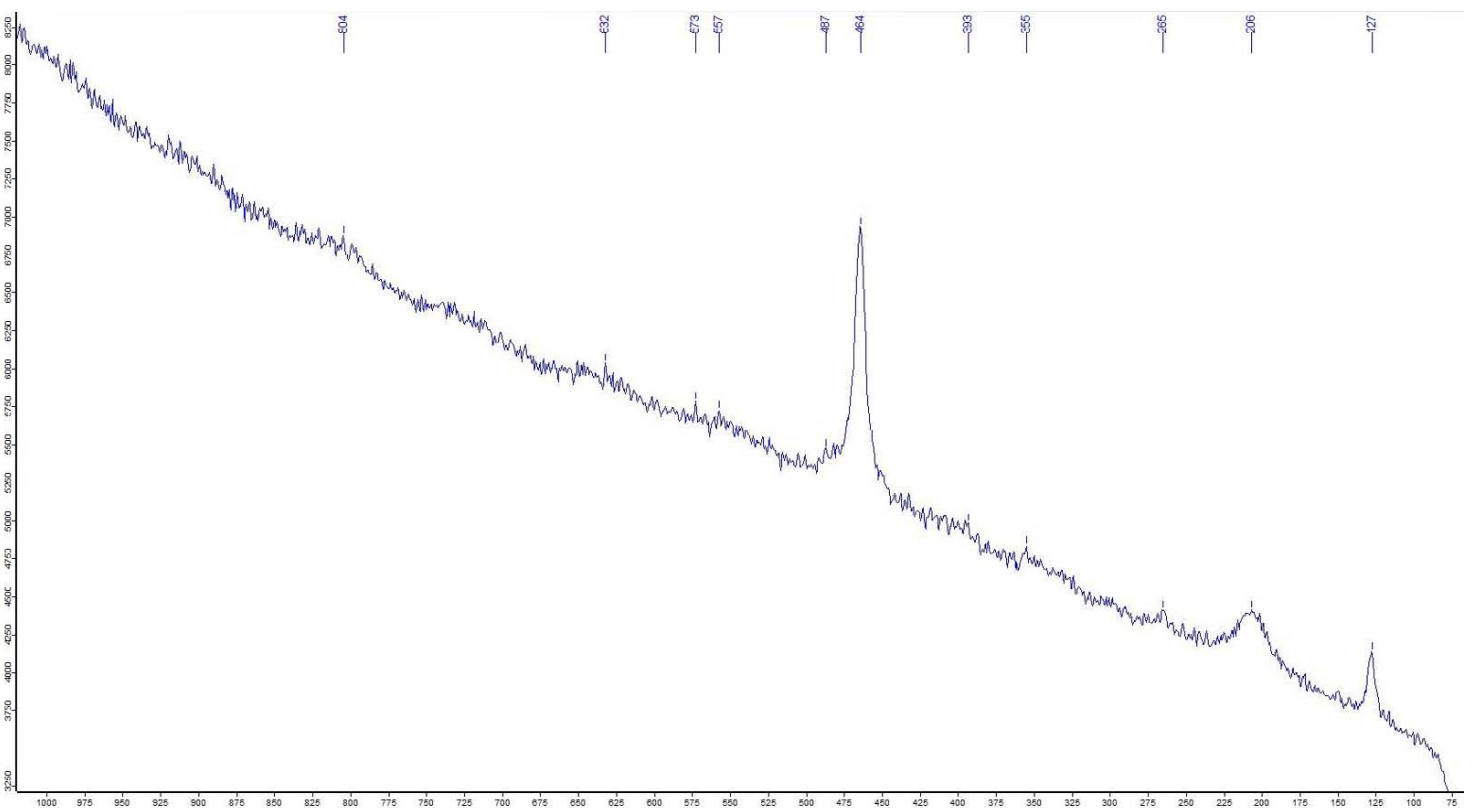
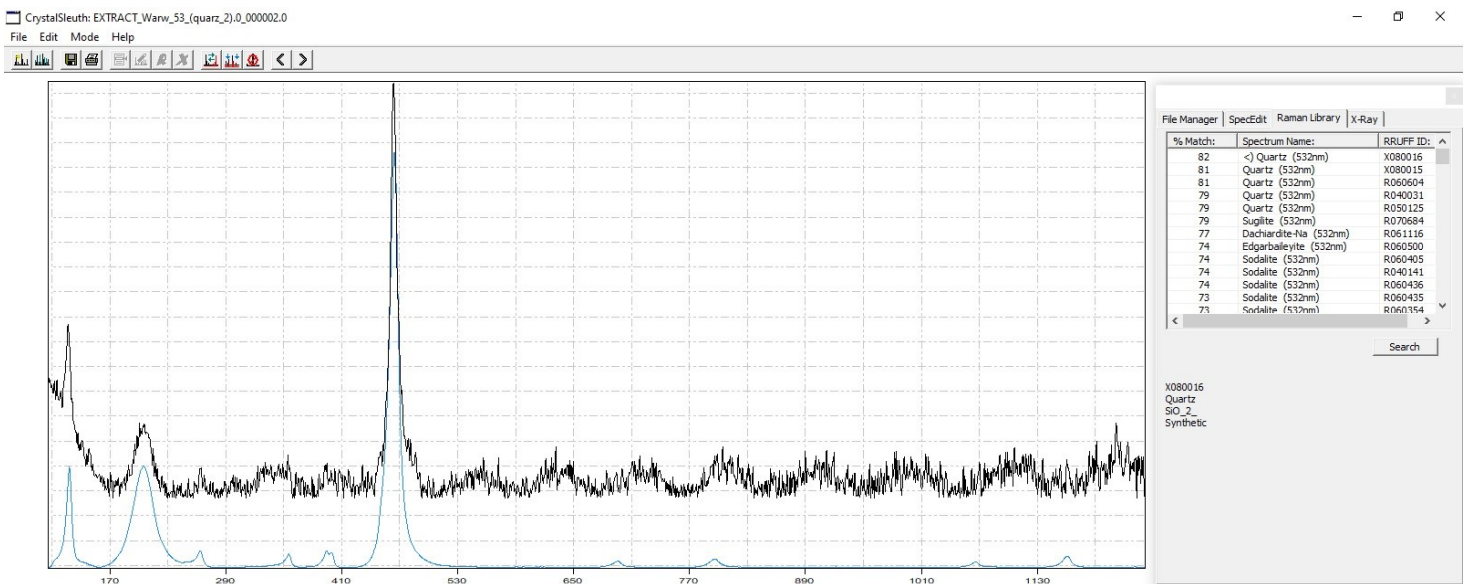
R050104
Labradorite
Na_0.5-0.3_Ca_0.5-0.7_Al_1.5-1.7_Si_2.5-2.3_O_8
unknown



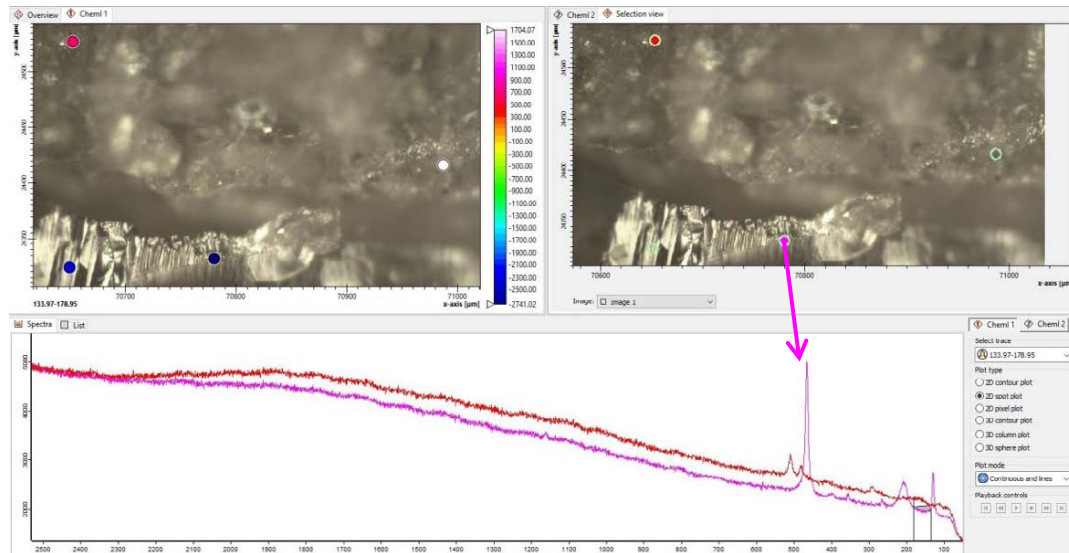
Sample Site **53** : Stone_2_spectra 2 indicates : **Quartz** (→ see RRUFF_CS results)



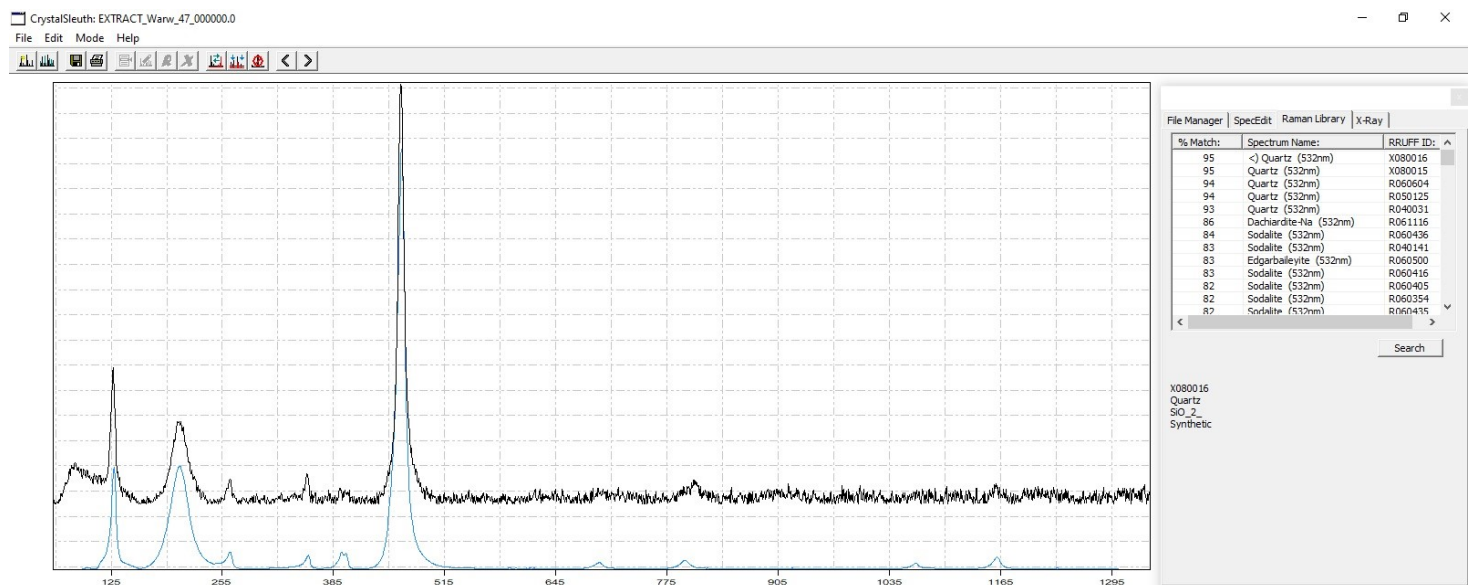
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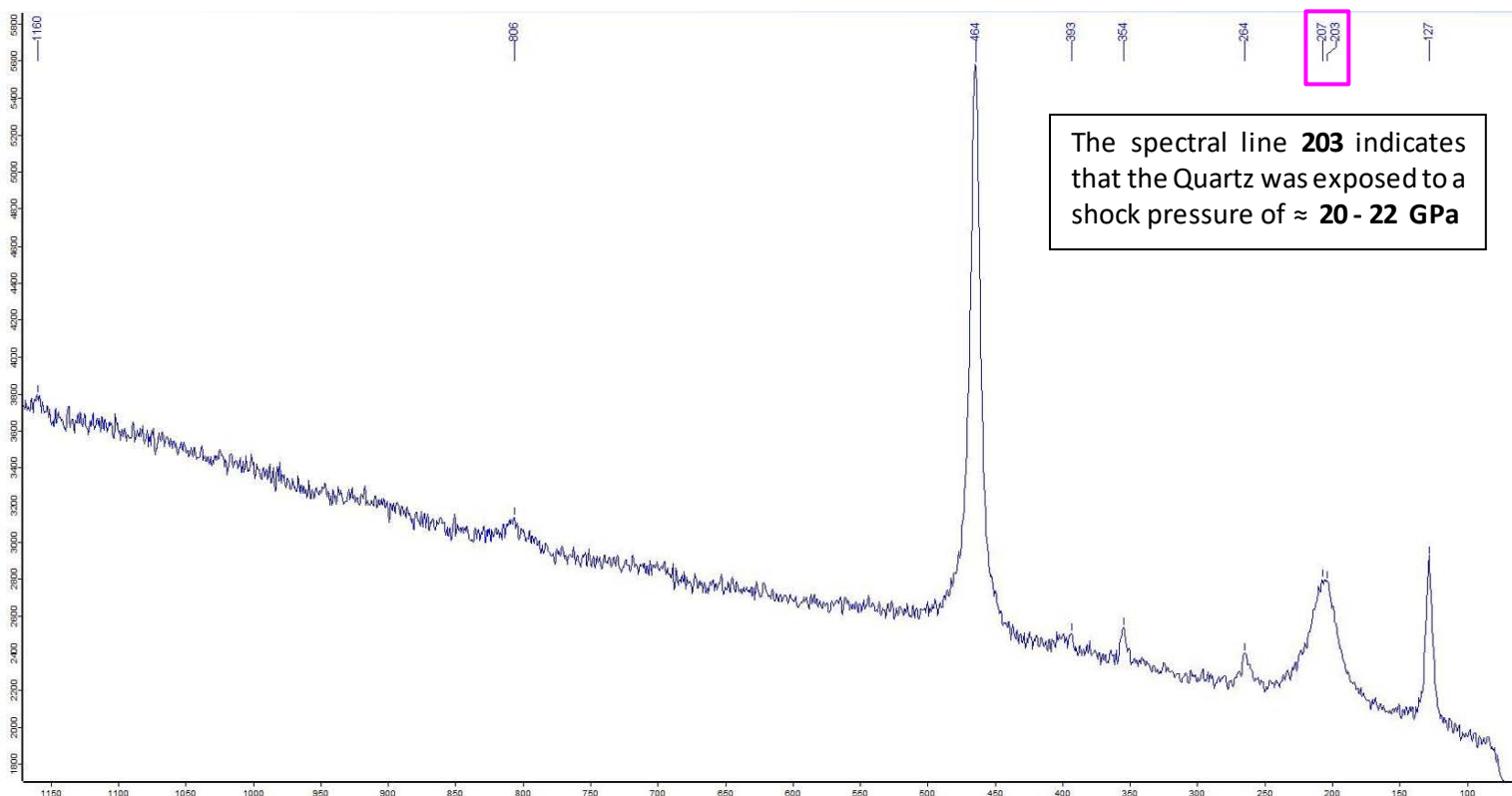
Sample Site **47** : Stone 1_spectra 1 indicates : **Quartz** (→ see RRUFF_CS results)



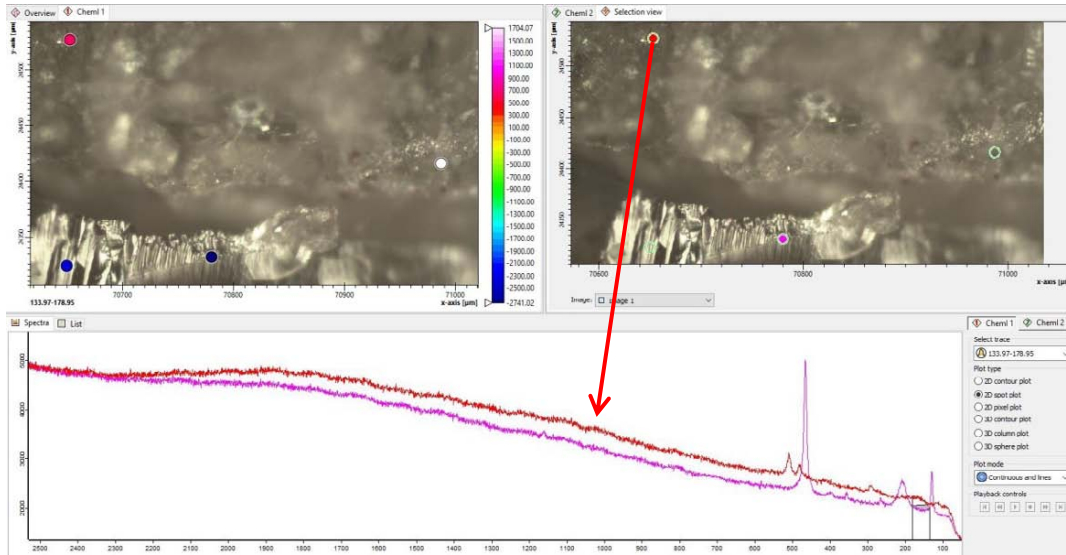
Sample :



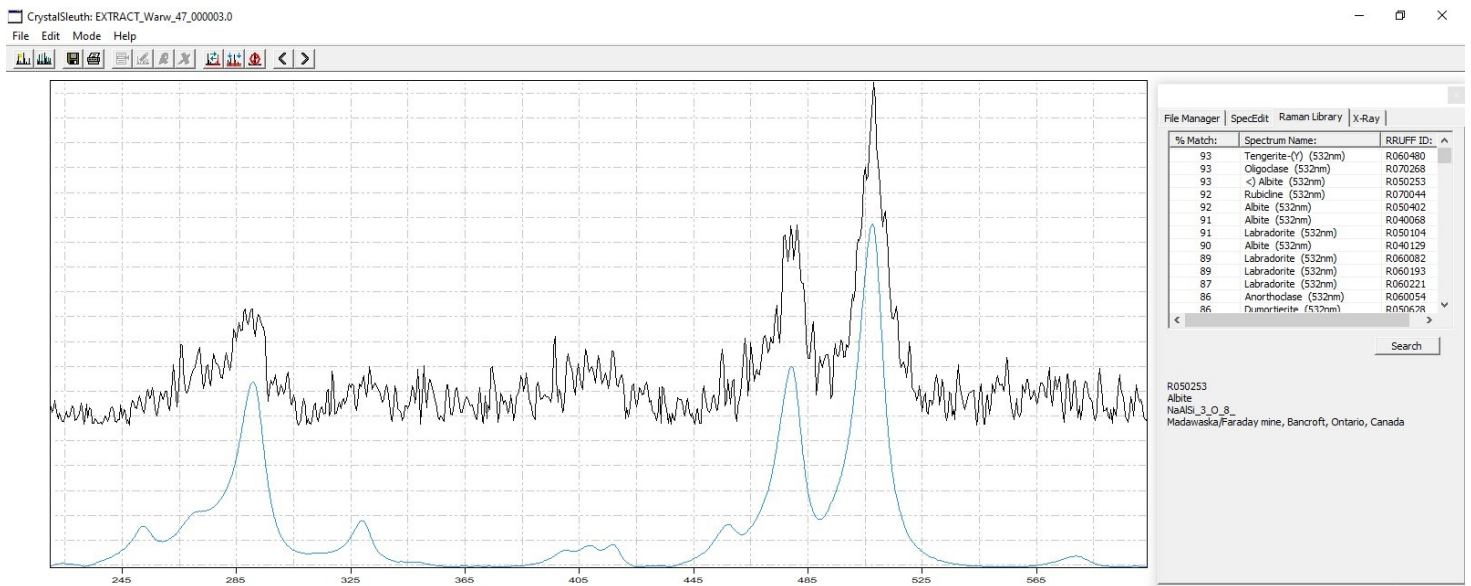
Indication for a shock event is the shift of the marked Quartz spectral lines towards 203 (double-peak)



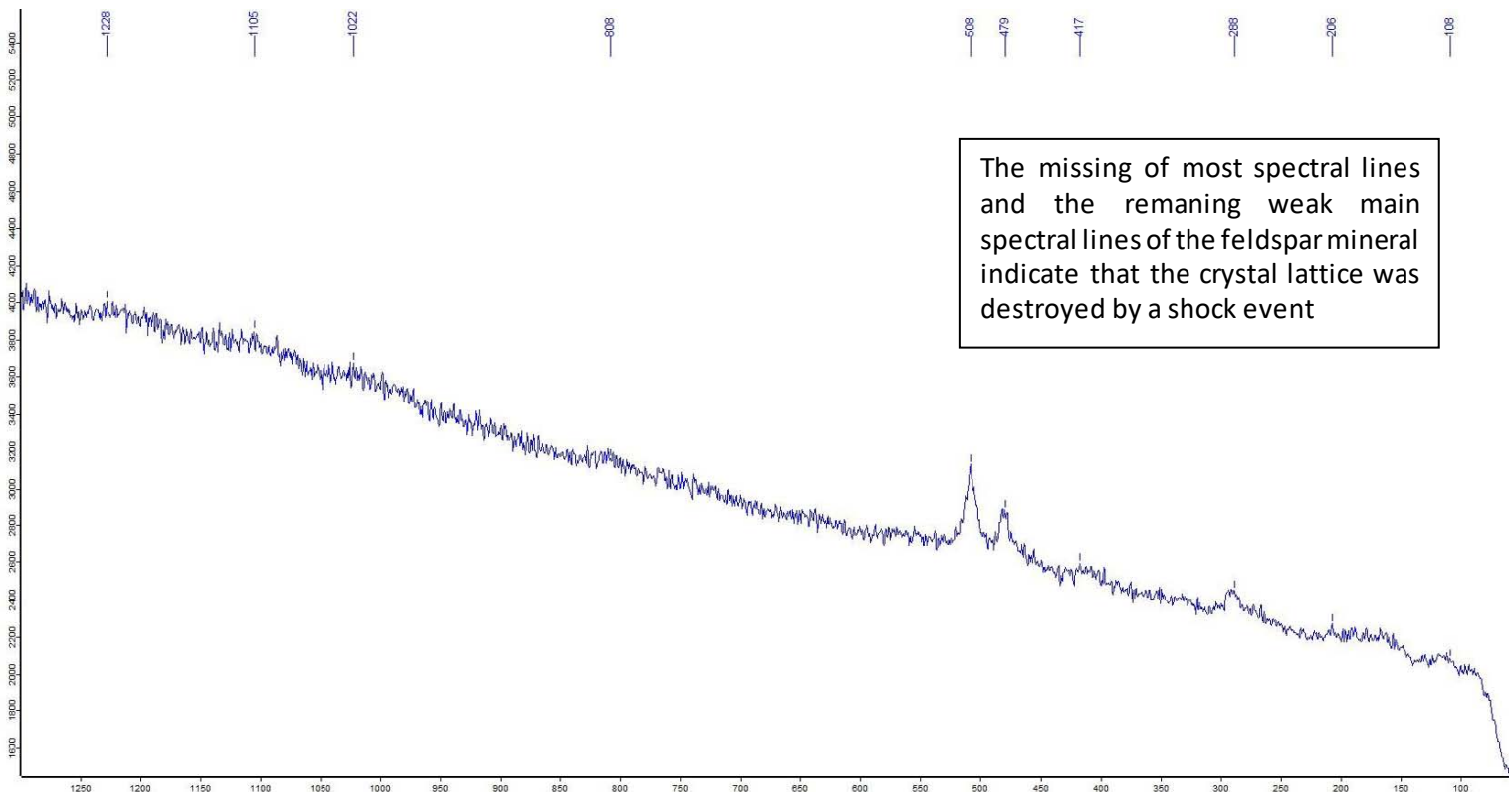
Sample Site 47 : Stone 1_spectra 2 indicates : **Albite** (→ see RRUFF_CS results)



Sample :



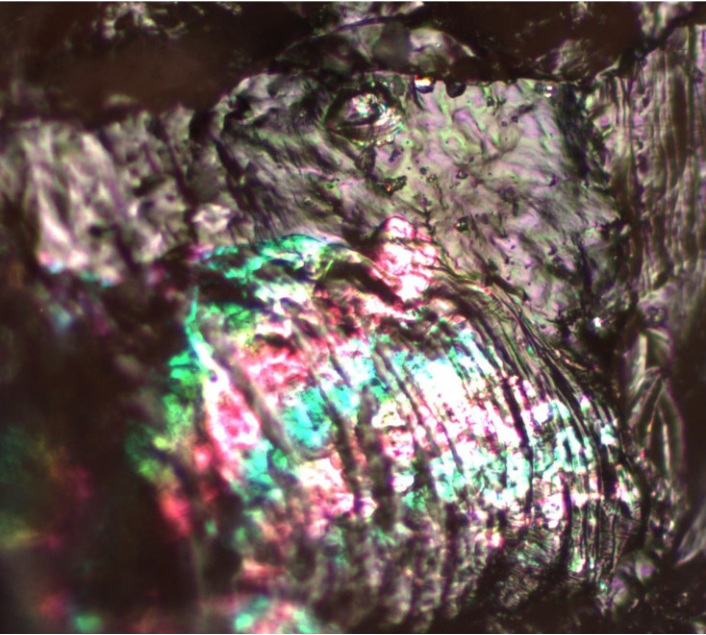
The Raman spectra indicates a weakly-shocked to moderately-shocked Feldspar mineral



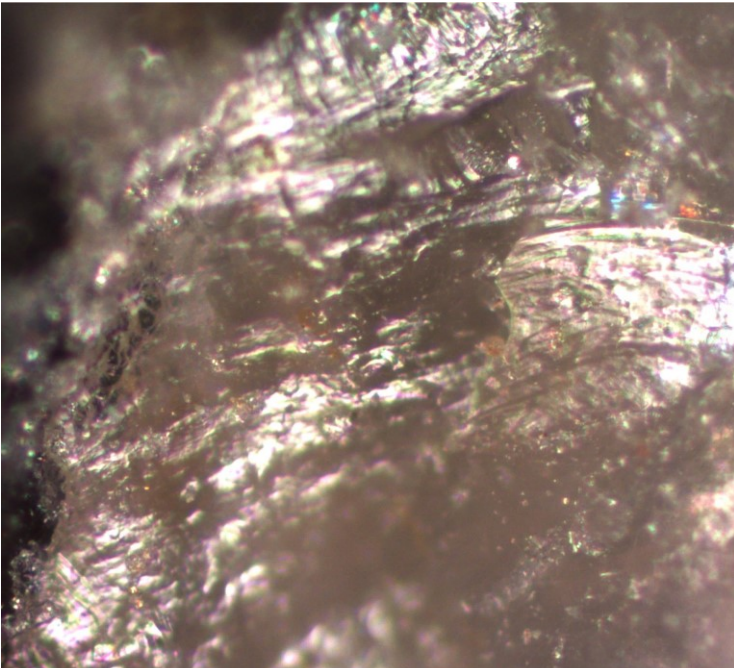
The missing of most spectral lines and the remaining weak main spectral lines of the feldspar mineral indicate that the crystal lattice was destroyed by a shock event

Microscopic Images : Samples from Sites 53 and 47 → original state (no preparation for analysis)

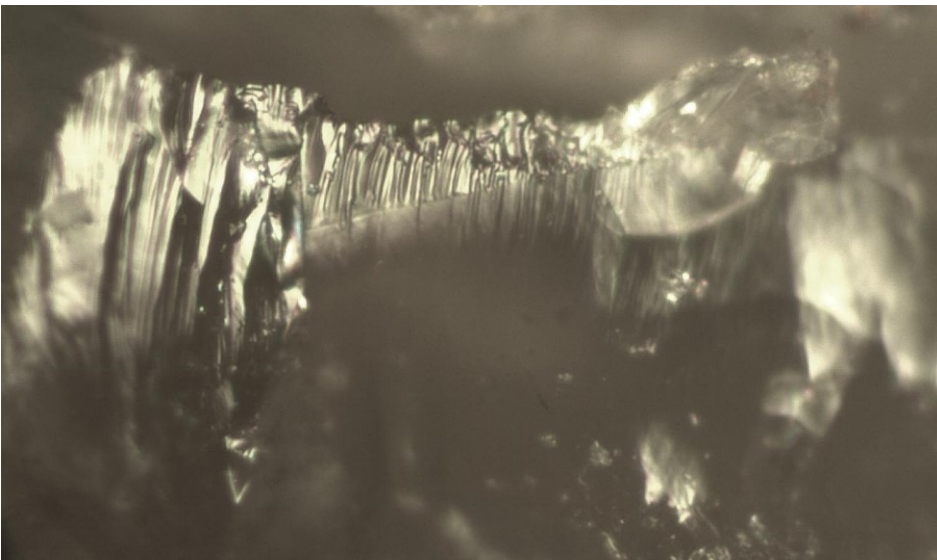
Sample Site **53** : Stone 2_spectra 2 indicates : **Quartz** - Image size : ~ 400 x 400 μm



Sample Site **53** : Stone 2_spectra 2 indicates : **Quartz** - Image size : ~ 400 x 400 μm

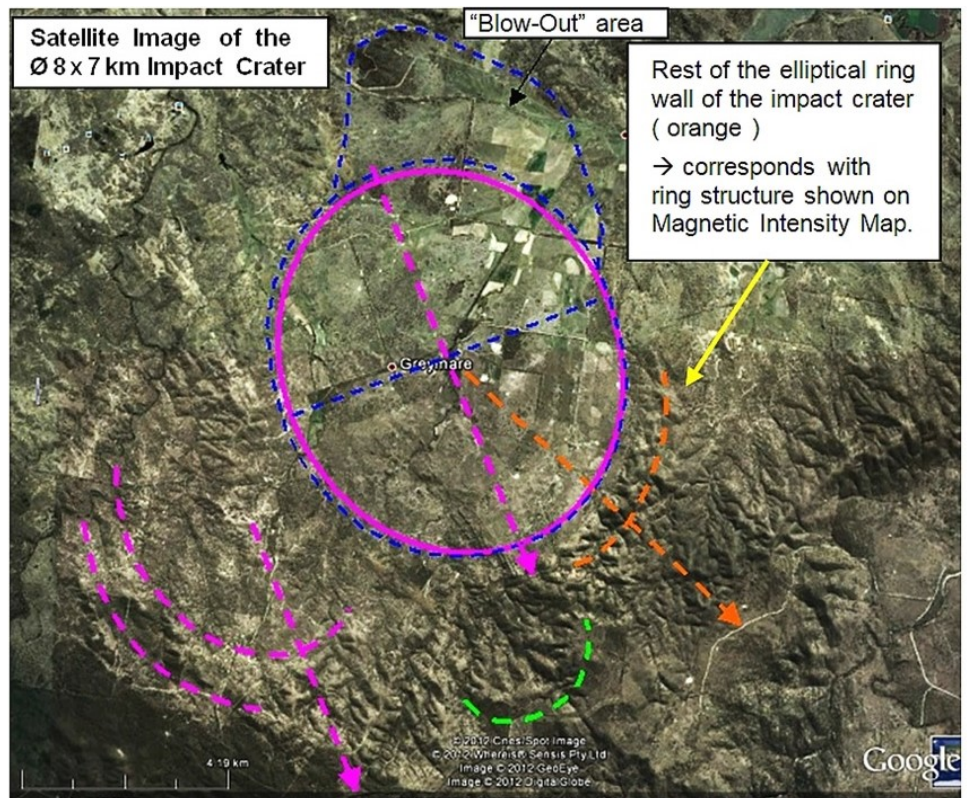
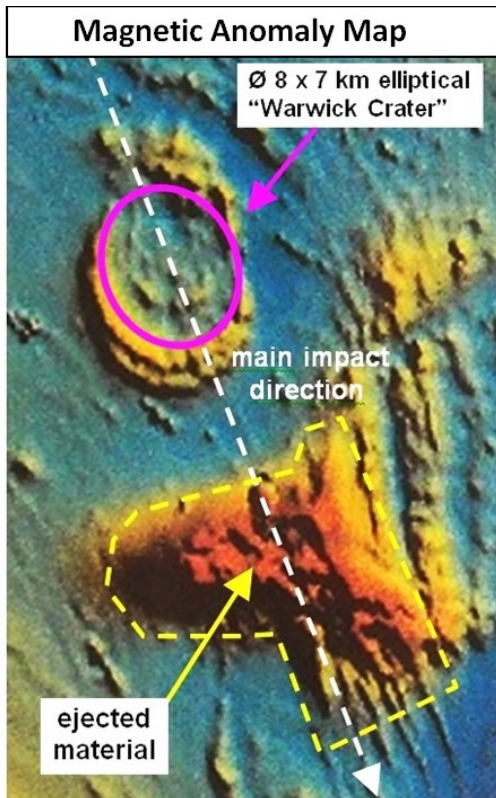


Sample Site **47** : Stone 1_spectra 1 indicates : **Quartz** - Image size : ~ 250 x 150 μm

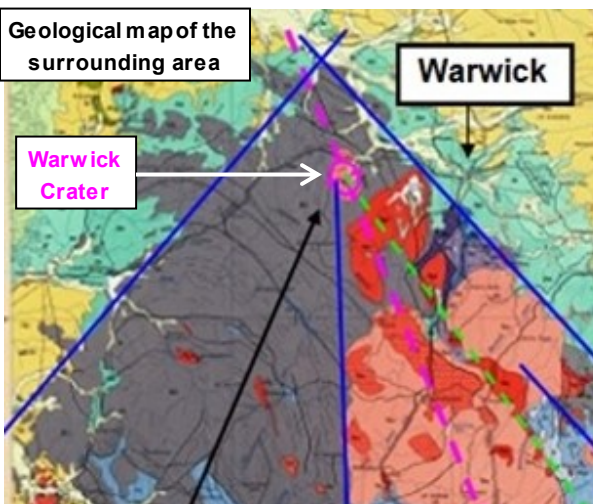
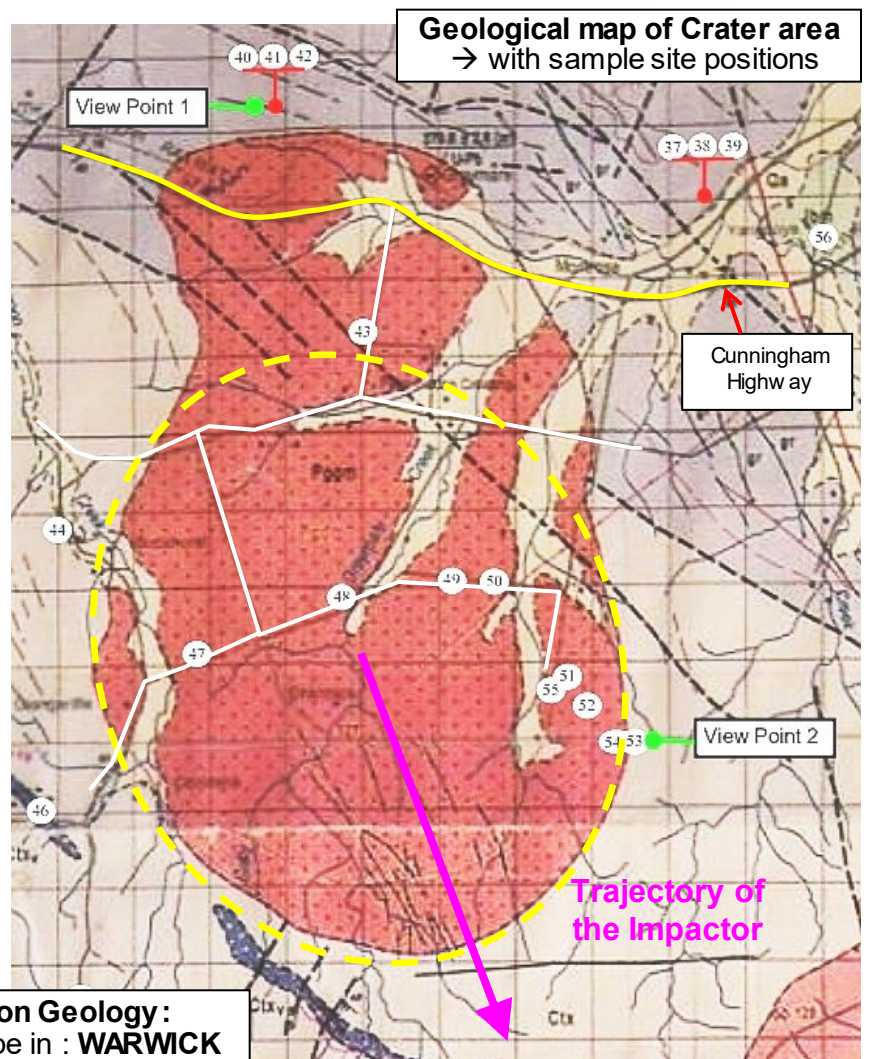


Appendix 1 : Photos of the rock samples from sample sites : 43, 47, 48, 51, 53 and 54
 → **See next page !**

Please note : Photos of Sample Sites and other sample sites are also available here → weblink : **Sample Sites – Ø 8 x 7 km Warwick Crater**



The Warwick Crater area is accessible over an unsealed road, through a gate, from the Cunningham Highway near Montrose (sign : Greymare). It lies on private pasture land. But the marked roads are accessible. The red marked rock type on the geological map has a measured age of 230-240 Ma (probably **PT-boundary age !**) And the surrounding grey rock-type has an age of 330-370Ma. The markings on the geological map below indicate that the grey- and red-colored rock-types seem to be the result of ejecta, probably from the 320 km Cape York Crater, that was scattered over this area !



Geological Map : → Moreton Geology : go to : **Geology Maps** → type in : **WARWICK**



43

43 | 28° 11.288 S | 151° 45.418 E | 12 m | Warwick

The rock samples are from the boulders visible in the image

Photos of the rock samples from the sample sites : 43, 47, 48, 51, 53 and 54 and from other sites are also available here : [Sample Sites- Ø 8 x 7 km Warwick Crater](#)



51



51

51 | 28° 13.790 S | 151° 46.879 E | 8 m | Warwick



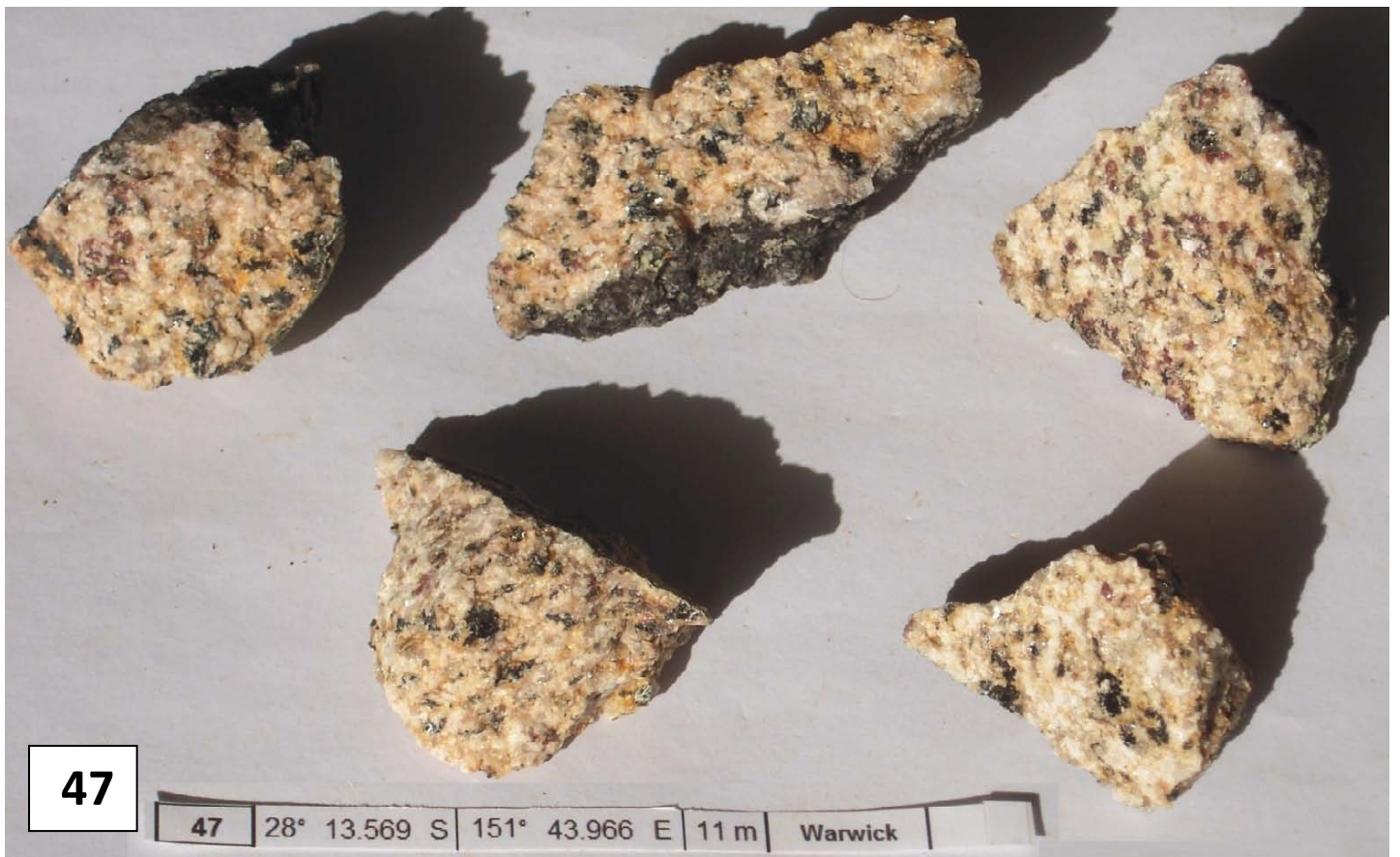
Sample site 53 is located on a section of the original elliptical crater-wall of the \varnothing 8 x 7 km Warwick Crater





The rock samples are from the boulders visible in the image





The rock samples are from the boulders visible in the image



Appendix 2 : A short overview : The Raman bands (peaks) of Quartz shocked with 22-26 GPa

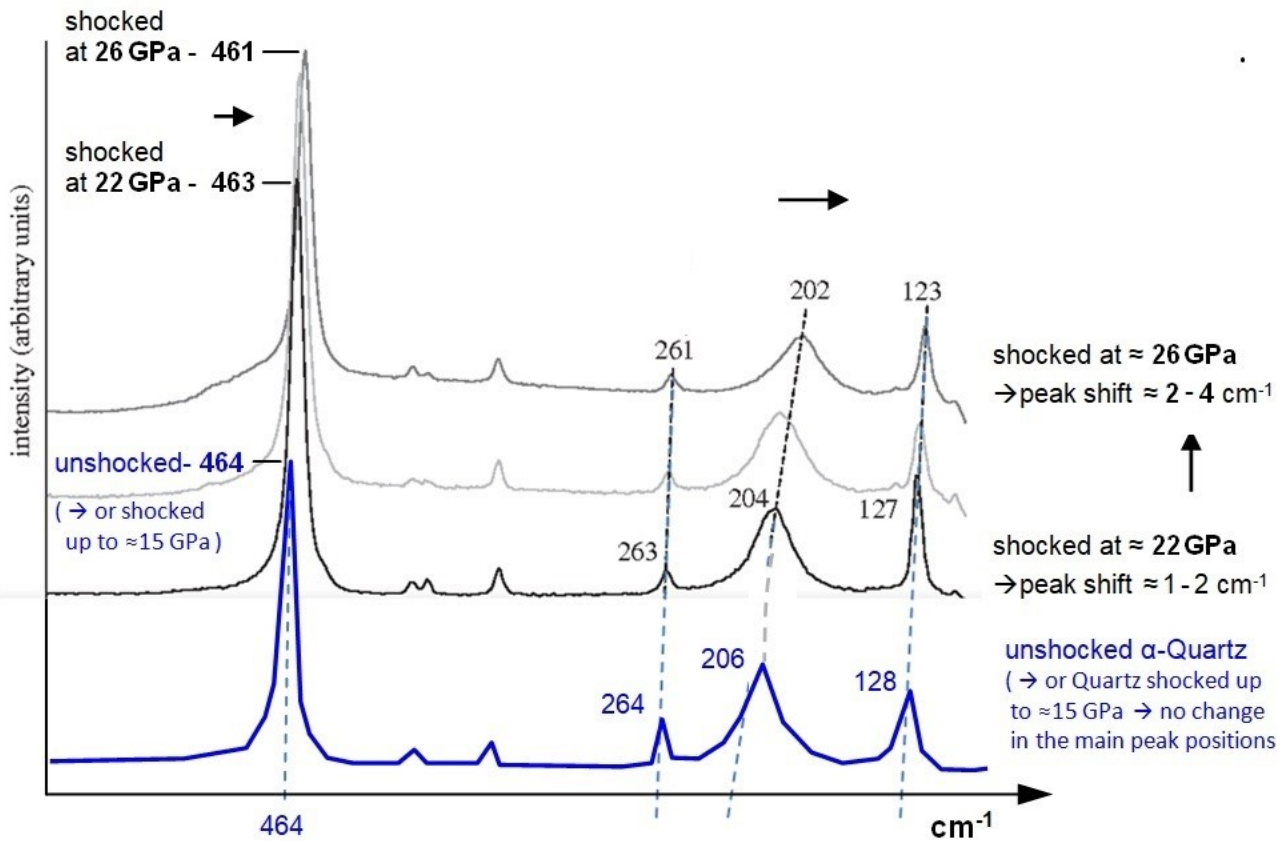
In order to verify a sample site as an impact site or impact structure, [shock-metamorphic effects](#) must be discovered in the rocks of the sample site. This can be done by different methods.

For example with the help of PDFs (planar deformation features) which are visible in the quartz with the help of a microscope. However this requires careful preparation of the samples and expertise.

Another, easier method, is the use of a RAMAN microscope. Micro-RAMAN Spectroscopy on quartz grains in the samples can provide the first evidence for a shock event, that was caused by an impact.

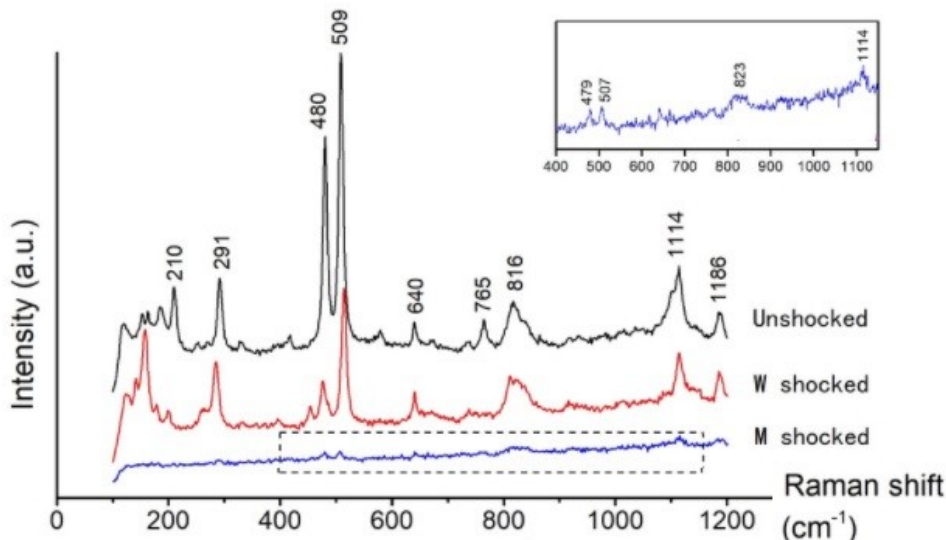
Mc Millan et al. (1992) and others have shown that the main RAMAN-peaks of Quartz shift towards lower frequencies if the Quartz was exposed to a shock-pressure > 15 GPa. → see diagram below

The shift of the main quartz RAMAN-peaks can be used to identify quartz that was shocked by an impact



Quartz shocked with 22 GPa and 26 GPa shows shifts of the main RAMAN-peaks of 1 - 4 cm⁻¹ to lower frequencies

Appendix 3 : Raman spectra of (W) weakly-shocked & (M) moderately-shocked Alkali-Feldspar



Weakly shocked alkali feldspar mainly developed irregular fractures and undulatory extinction. Note that the Raman-lines 210 and 765 are missing in the w-shocked feldspar, and an additional line at ≈ 150 appears.

The shock pressure for the w-shocked feldspar was estimated to be between 5 and 14 GPa

References :

Photos of all Sample Sites & Rock Samples are available on : [Samples Ø 8 x 7 km Warwick Crater](#) (or : [Warwick Crater](#))

The 320 km Cape York Impact Crater and the Cape York Crater Chain in North-East Australia - by Harry K. Hahn
<https://vixra.org/abs/2101.0136> alternative : <https://archive.org/details/the-320-km-cape-york-impact-crater-in-ne-australia>

RAMAN spectra of quartz samples from the Cape York impact area : [Evidence for the Cape York Crater](#) (or here : [link4](#))

The Permian-Triassic(PT) Impact hypothesis - by Harry K. Hahn - 8. July 2017 :

Part 1 : [The 1270 X 950 km Permian-Triassic Impact Crater caused Earth's Plate Tectonics of the Last 250 Ma](#)

Part 2 : [The Permian-Triassic Impact Event caused Secondary-Craters and Impact Structures in Europe, Africa & Australia](#)

Part 3 : [The PT-Impact Event caused Secondary-Craters and Impact Structures in India, South-America & Australia](#)

Part 4 : [The PT-Impact Event and its Importance for the World Economy and for the Exploration- and Mining-Industry](#)

Part 5 : [Global Impact Events are the cause for Plate Tectonics and the formation of Continents and Oceans \(Part 5\)](#)

Part 6 : [Mineralogical- and Geological Evidence for the Permian-Triassic Impact Event](#)

Alternative weblinks for my Study **Parts 1 - 6 with slightly higher resolution** : [Part 1](#), [Part 2](#), [Part 3](#), [Part 4](#), [Part 5](#), [Part 6](#)

Parts 1 – 6 of my PTI-hypothesis are also available on my website : www.permiantriassic.de or www.permiantriassic.at

Shock-metamorphic effects in rocks and minerals - <https://www.lpi.usra.edu/publications/books/CB-954/chapter4.pdf>

Shock metamorphism of planetary silicate rocks and sediments: Proposal for an updated classification system

Stöffler - 2018 - Meteoritics & Planetary Science – Wiley: <https://onlinelibrary.wiley.com/doi/epdf/10.1111/maps.12912>

A Raman spectroscopic study of shocked single crystalline quartz - by P. McMillan, G. Wolf, Phillippe Lambert, 1992

<https://asu.pure.elsevier.com/en/publications/a-raman-spectroscopic-study-of-shocked-single-crystalline-quartz>

alternative : <https://www.semanticscholar.org/paper/A-Raman-spectroscopic-study-of-shocked-single-McMillan-Wolf/cfaaf6eb3e46fbd2912fb91c7acf40e88e721132>

Raman spectroscopy of natural silica in Chicxulub impactite, Mexico - by M. Ostroumov, E. Faulques, E. Lounejeva

https://www.academia.edu/8003100/Raman_spectroscopy_of_natural_silica_in_Chicxulub_impactite_Mexico

alternative : <https://www.sciencedirect.com/science/article/pii/S1631071302017005>

Shock-induced irreversible transition from α -quartz to CaCl₂-like silica - Journal of Applied Physics: Vol 96, No 8

<https://aip.scitation.org/doi/10.1063/1.1783609>

Shock experiments on quartz targets pre-cooled to 77 K - J. Fritz, K. Wünnemann, W. U. Reimold, C. Meyer

https://www.researchgate.net/publication/234026075_Shock_experiments_on_quartz_targets_pre-cooled_to_77_K

A Raman spectroscopic study of a fulgurite – by E. A. Carter, M.D. Hargreaves, ...

https://www.researchgate.net/publication/44655699_Raman_Spectroscopic_Study_of_a_Fulgurite

alternative : <https://royalsocietypublishing.org/doi/abs/10.1098/rsta.2010.0022>

Shock-Related Deformation of Feldspars from the Tenoumer Impact Crater, Mauritania - by Steven J. Jaret

<https://trace.tennessee.edu/cgi/viewcontent.cgi?article=1002&context=pursuit>

A Study of Shock-Metamorphic Features of Feldspars from the Xiuyan Impact Crater - by Feng Yin, Dequi Dai

https://www.researchgate.net/publication/339672303_A_Study_of_Shock-Metamorphic_Features_of_Feldspars_from_the_Xiuyan_Impact_Crater

https://www.researchgate.net/publication/339672303_A_Study_of_Shock-Metamorphic_Features_of_Feldspars_from_the_Xiuyan_Impact_Crater

Shock effects in plagioclase feldspar from the Mistastin Lake impact structure, Canada – A. E. Pickersgill – 2015

<https://onlinelibrary.wiley.com/doi/pdf/10.1111/maps.12495>

Shock Effects in feldspar: an overview - by A. E. Pickersgill

<https://www.hou.usra.edu/meetings/lmi2019/pdf/5086.pdf>

ExoMars Raman Laser Spectrometer RLS, a tool for the potential recognition of wet target craters on Mars

https://www.researchgate.net/publication/348675414_ExoMars_Raman_Laser_Spectrometer_RLS_a_tool_for_the_potential_recognition_of_wet_target_craters_on_Mars