WHEN WORLDS COLLIDE

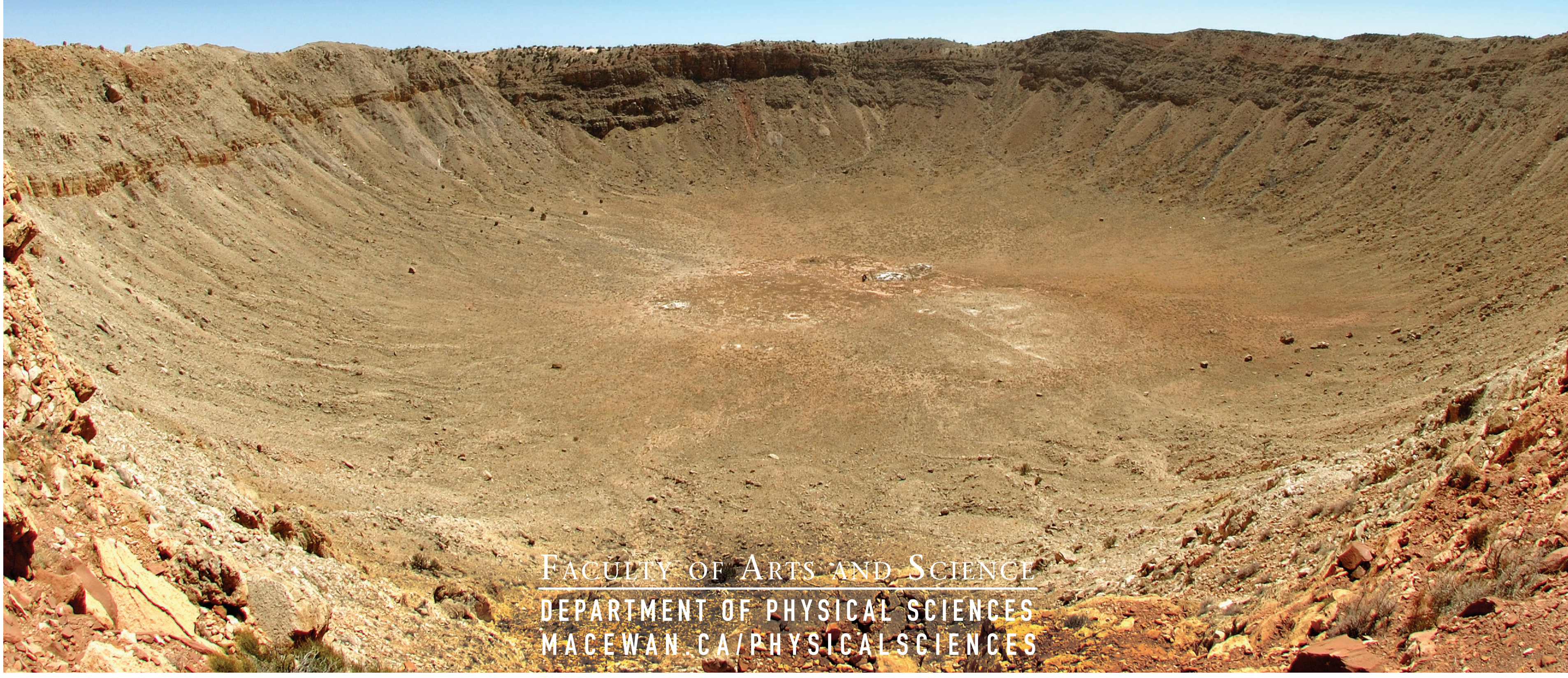
Investigating the Steen River impact structure in NW Alberta

Presented by:

Dr. Erin Walton
MacEwan University

Thursday, March 5, 2015
11 a.m. - 12 p.m.
Room 5-322

Join Dr. Erin Walton as she describes her investigation of the remnant of the largest known impact crater in the Western Canada Sedimentary Basin.



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An Overview of Impact Cratering: The Steen River Impact Structure

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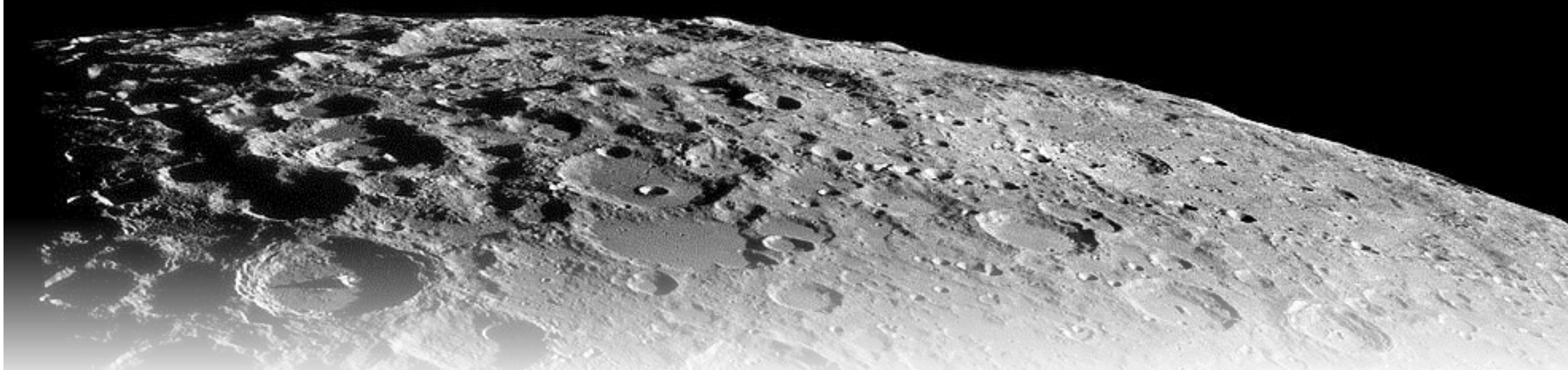

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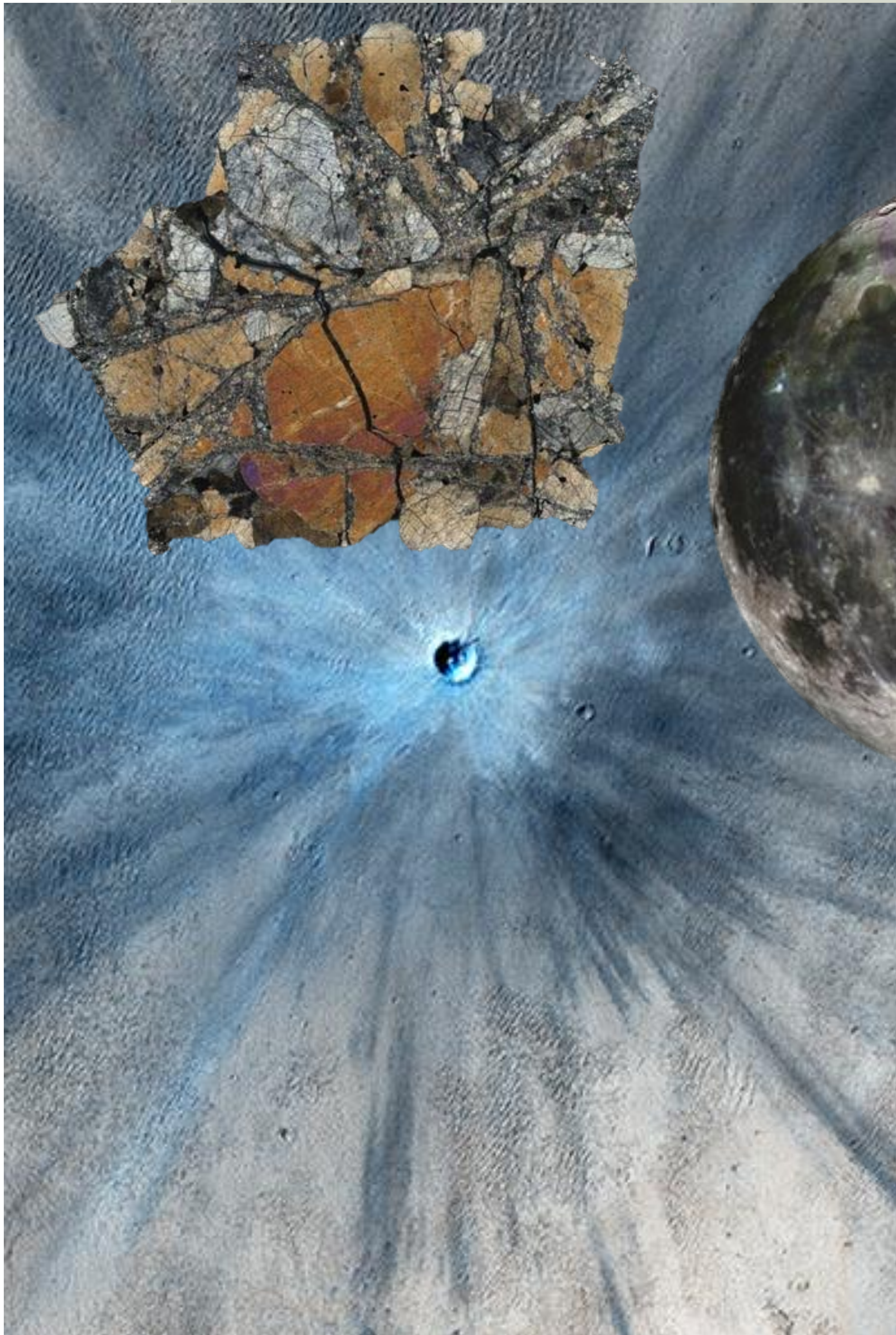
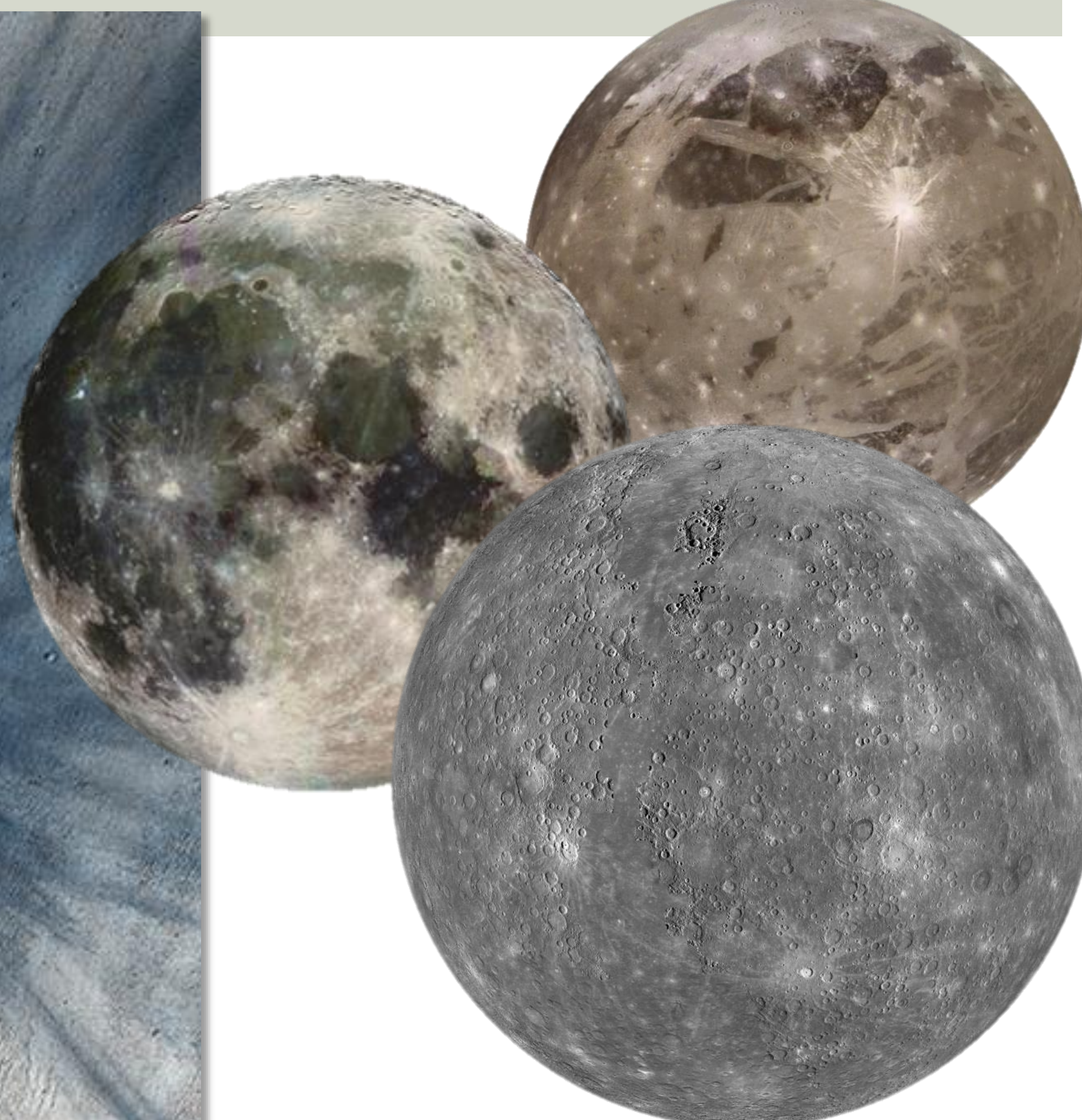
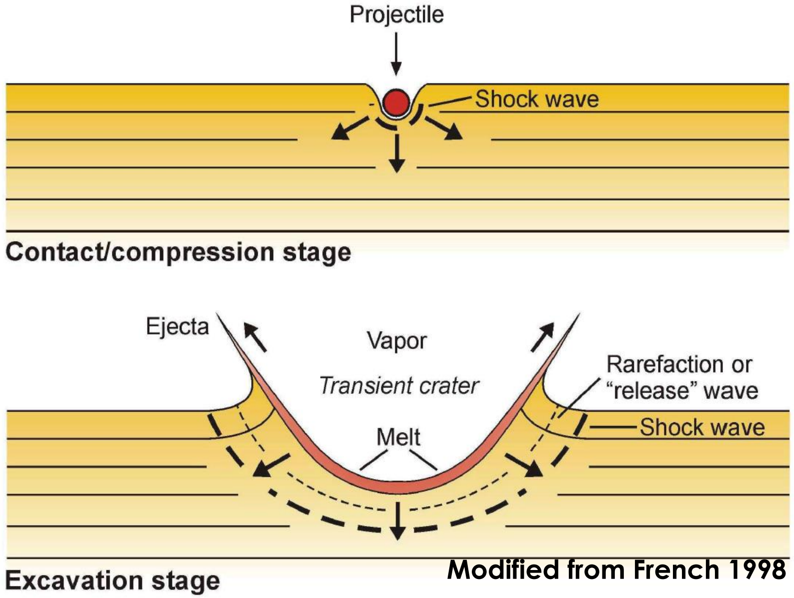




(left) inset, ~4 Ga meteorite ALHA84001 photo © Open University and a fresh impact crater (d = 30 m) on Mars imaged by HiRISE on NASA MRO. (above) Ganymede, (NASA / JPL image), MESSENGER composition image of Mercury and Earth's Moon (NASA / JPL)

How are Impacts Different?

1. Rare
2. Immense Energy
3. Instant Effects
4. Concentrated Energy Release
5. Extreme Physical Conditions
6. Unique Deformation Effects



Modified from French 1998

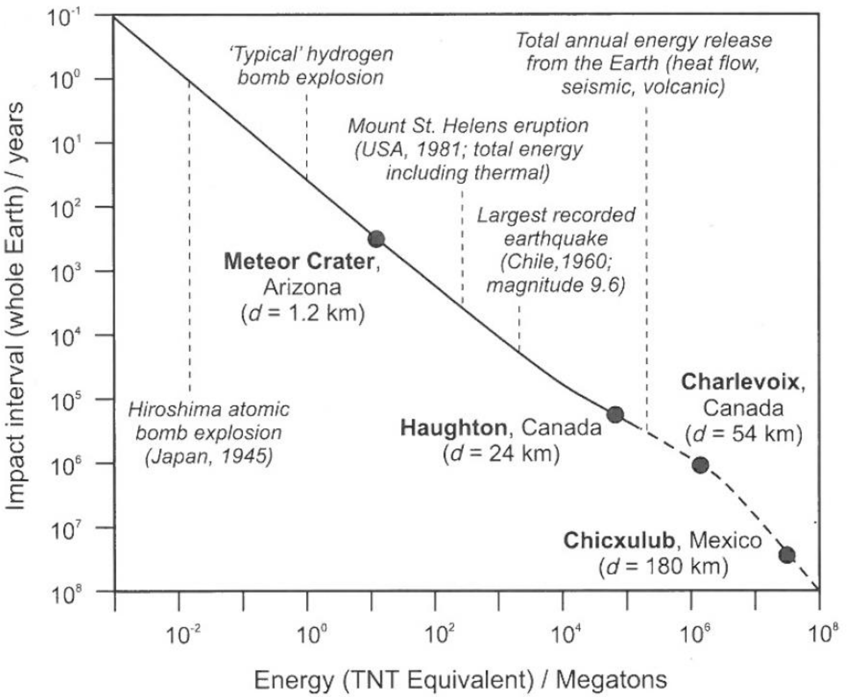
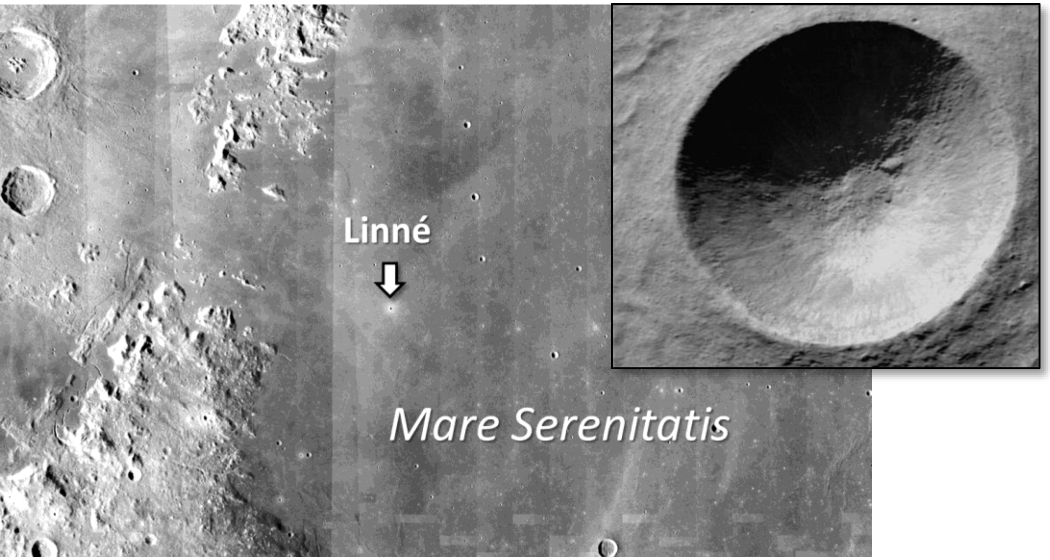
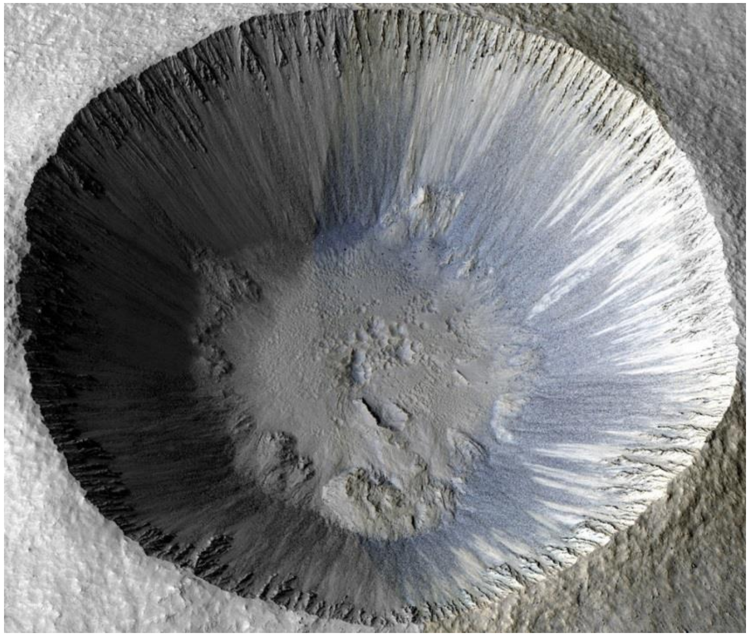


Fig. 1.2 Osinski & Pierazzo 2013 Impact Cratering: processes & products

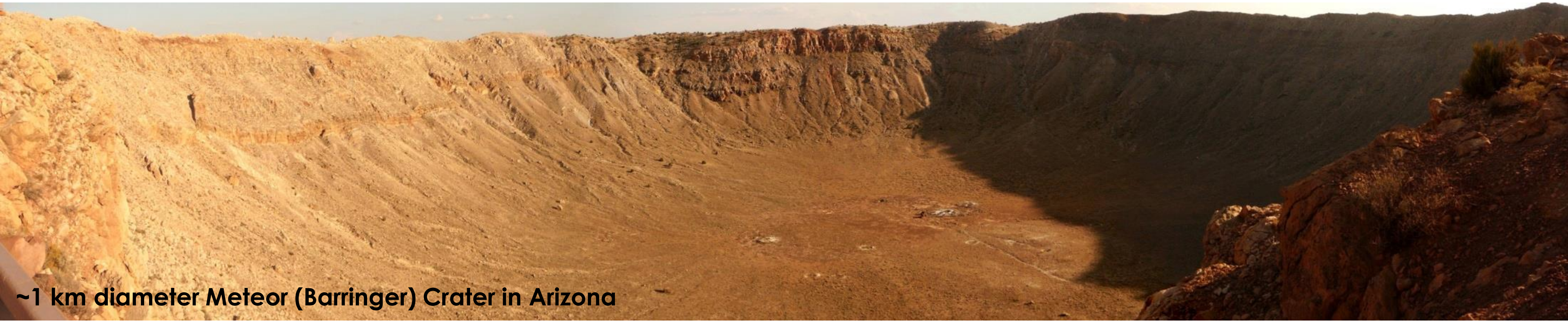


2.4 km diameter LinnCrater on the Moon (LRO)

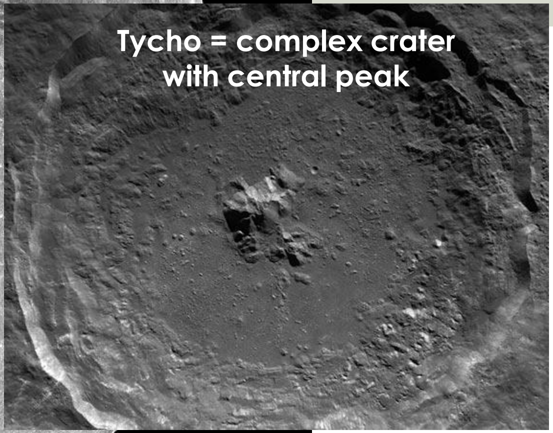


3.3 km diameter Zumba Crater on Mars (HiRISE)

Impact craters come in all shapes and sizes ranging from "simple" to "complex"

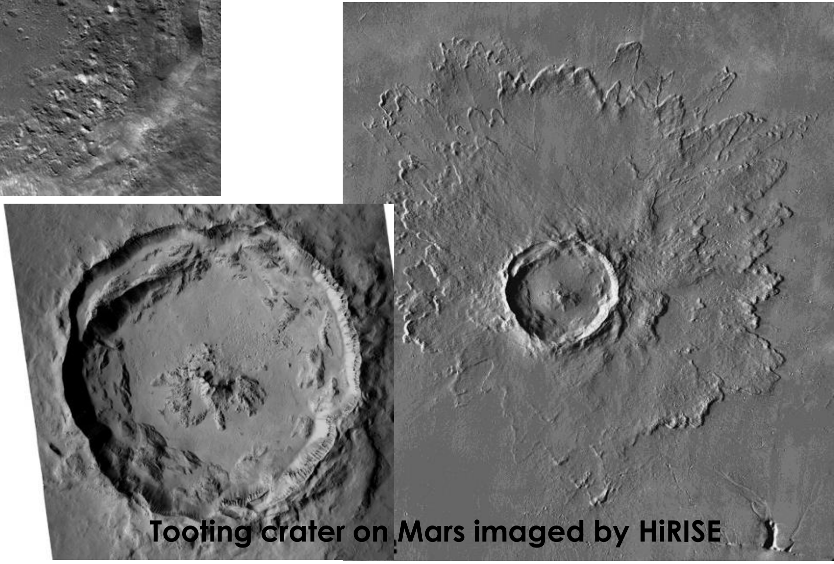


~1 km diameter Meteor (Barringer) Crater in Arizona



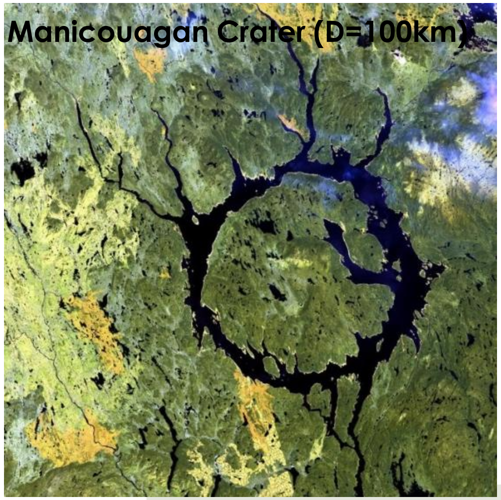
Tycho = complex crater with central peak

Rayed craters on the Moon including Copernicus (D = 93 Km upper left) and Tycho (D = 85 km lower right) from LRO



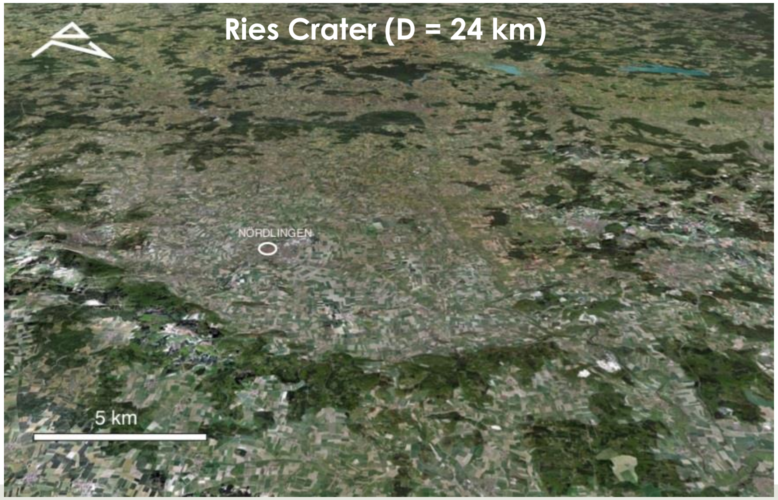
Tooting crater on Mars imaged by HiRISE

Impact craters come in all shapes and sizes ranging from "simple" to "complex"



Manicouagan Crater (D=100km)

Haughton Crater (D = 23 km)

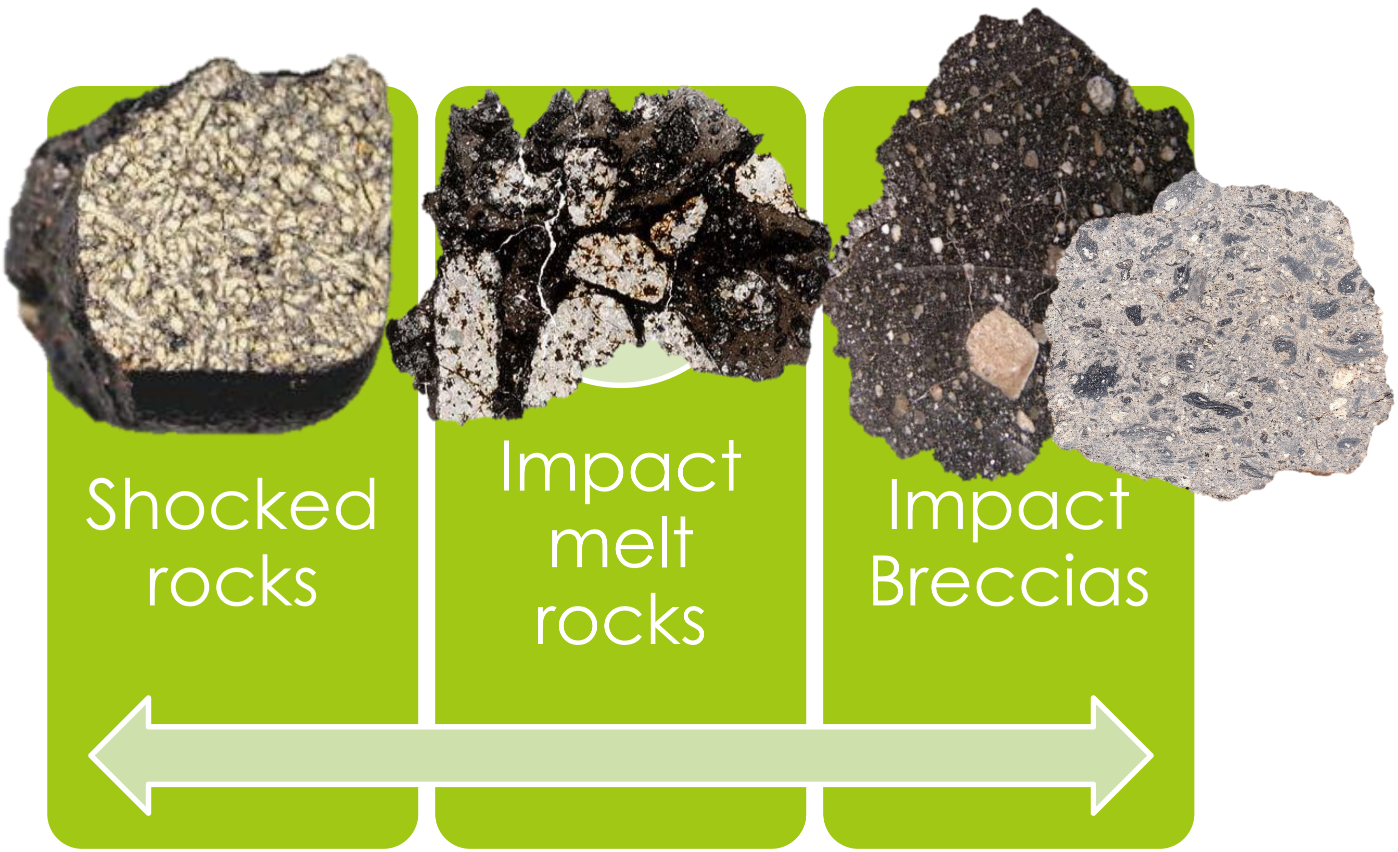


Ries Crater (D = 24 km)

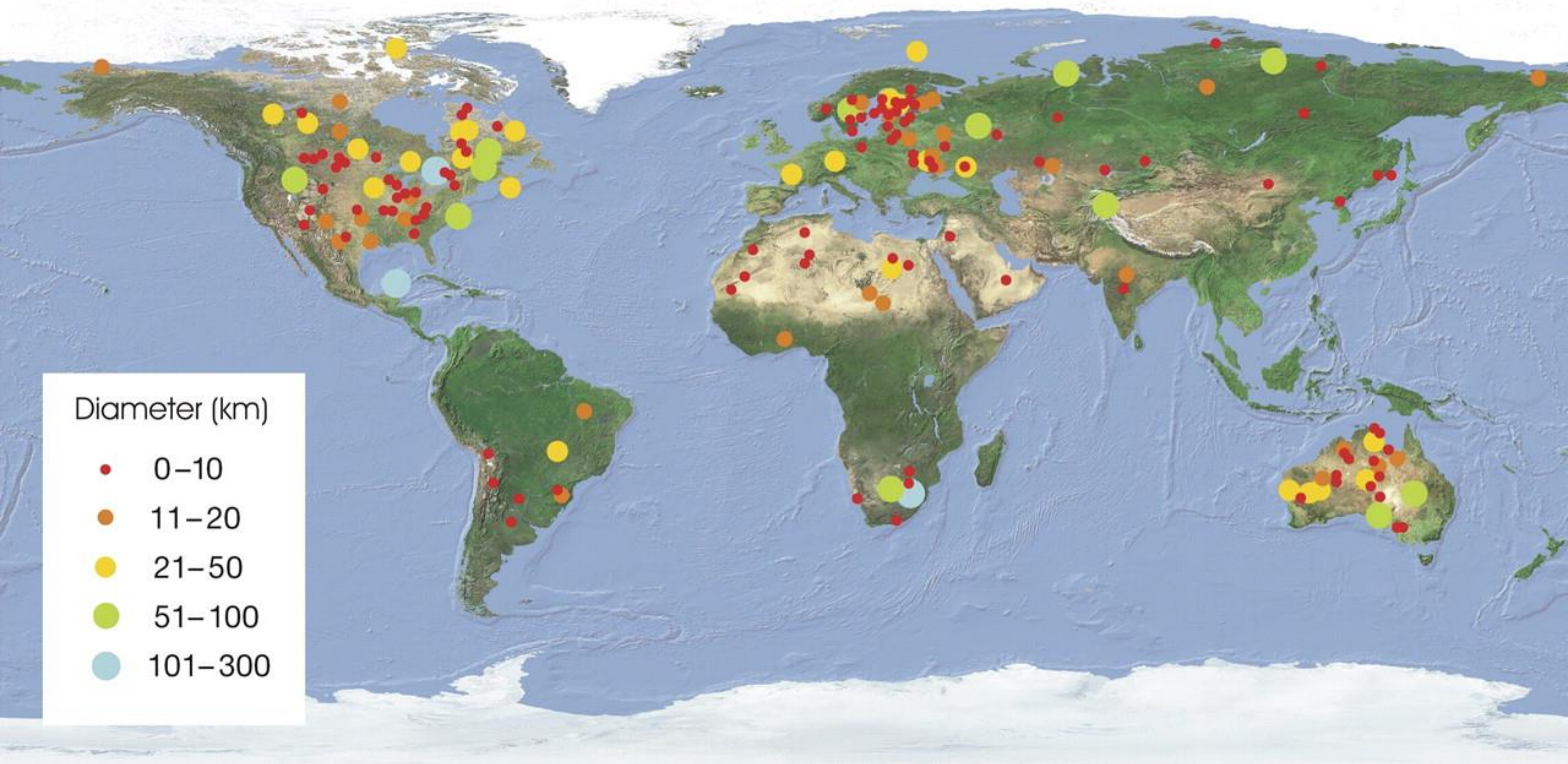
Impactite Classification

- **Impactite** is the general term given to any rock affected by one or more hypervelocity impact events

  →*applies to both terrestrial and extraterrestrial rocks*



Distribution of Impact Craters on Earth

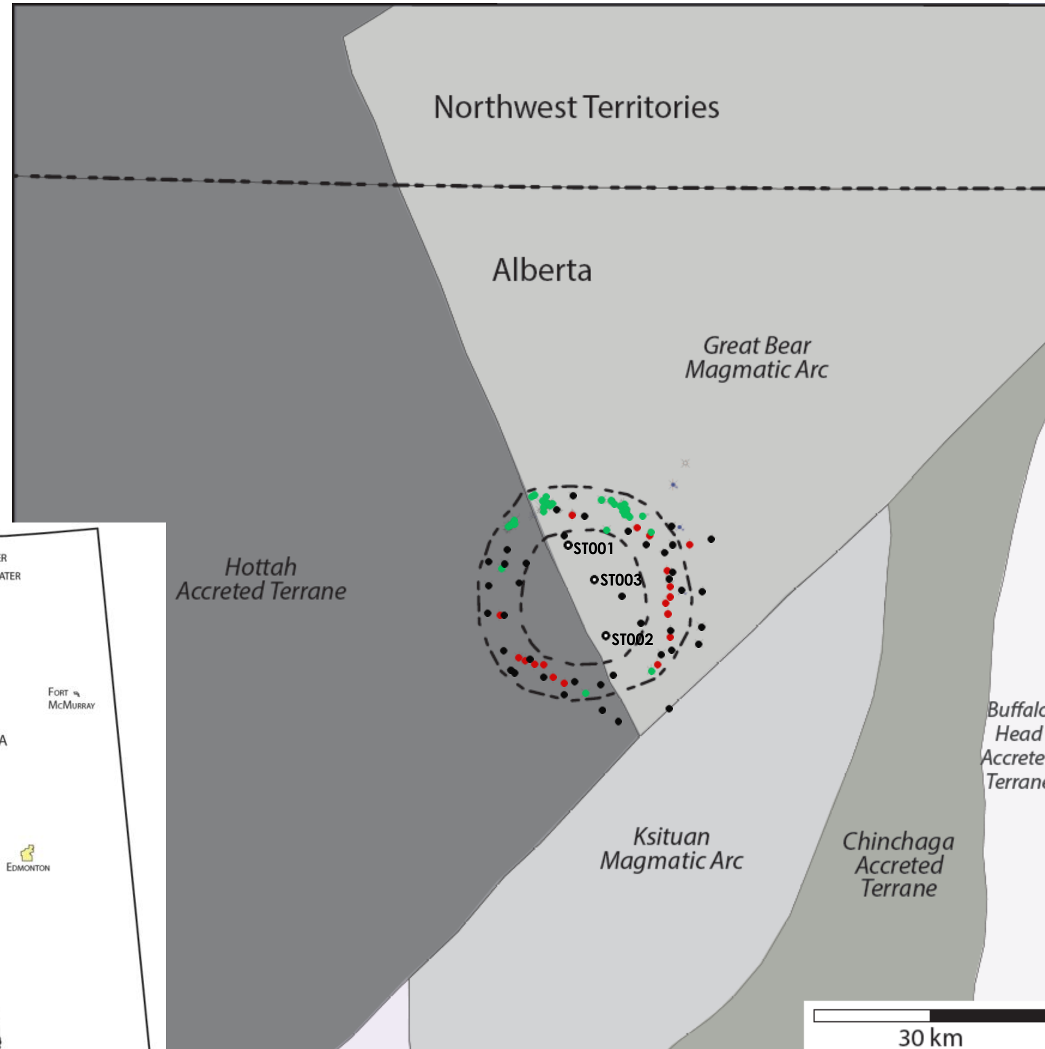


Elements Magazine

Location of the Steen River Impact Structure

- The SRIS is a complex impact structure
  - 59°31'N, 117°39'W
  - ~25 km diameter

- **Target rocks**: 70 m of Mississippian calcareous shale underlain by 1530 m of Devonian (Wabamun Group, Hay river shale, Elk Point group) on top of granites and granitic gneisses of the Precambrian basement



“Fieldwork”

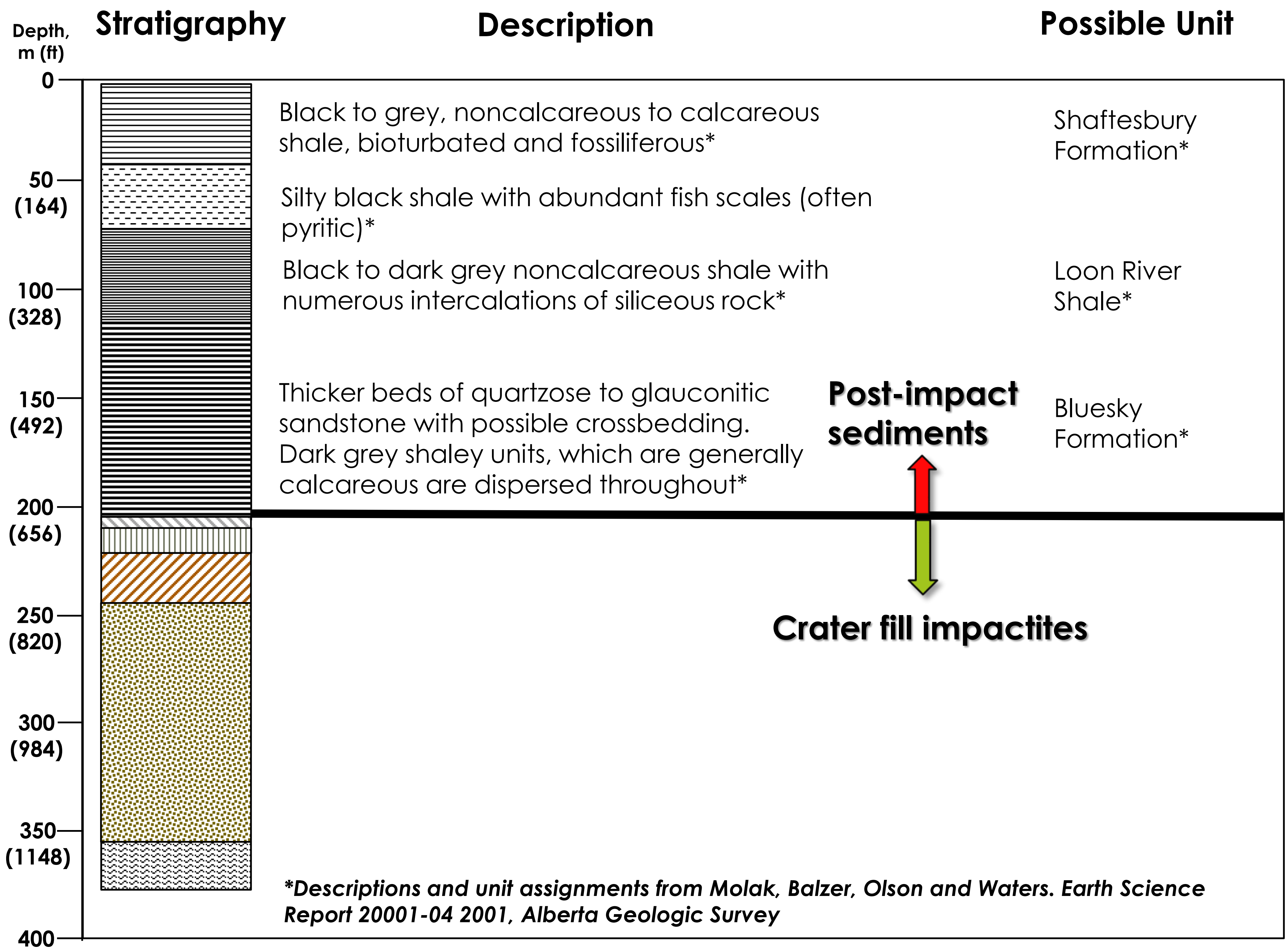
The SRIS is buried beneath ~206 m of marine shale

Drilled in 1960s and early 2000

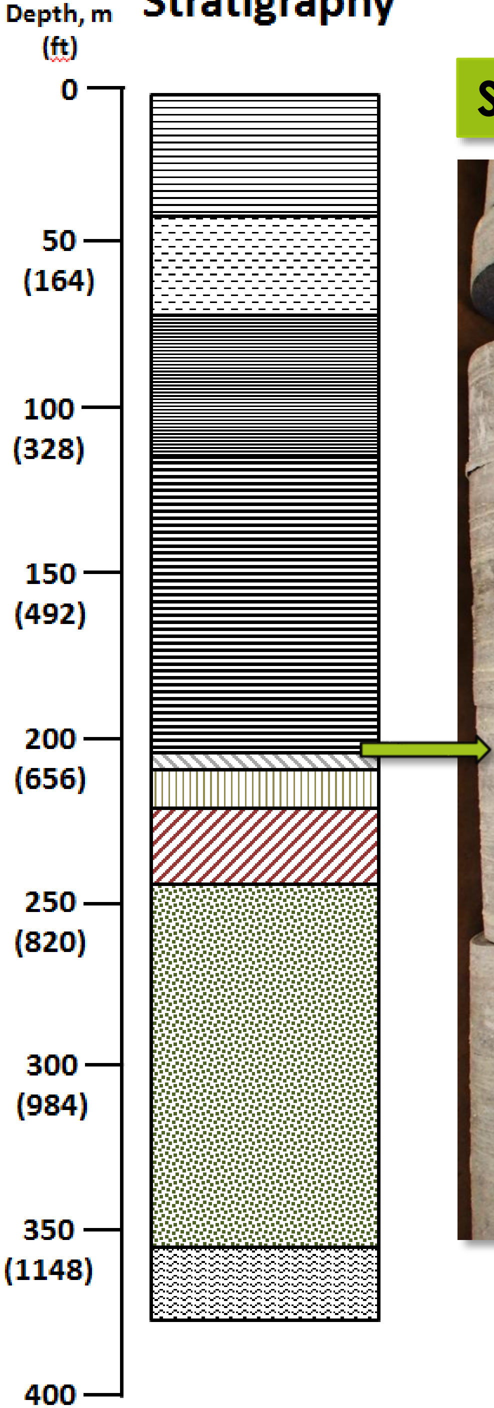
Core at CRC and MCRF

ST003 core at MCRF

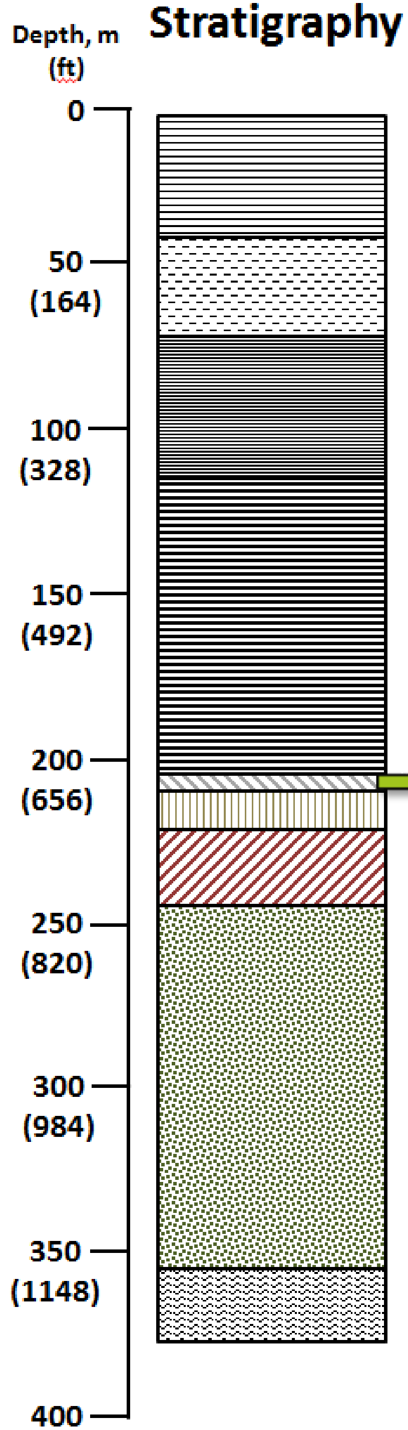
Image Todd Korol for National Post


Depth, m (ft)
Stratigraphy
Description
Possible Unit
0
50 (164)
100 (328)
150 (492)
200 (656)
250 (820)
300 (984)
350 (1148)
400
Black to grey, noncalcareous to calcareous shale, bioturbated and fossiliferous*
Shaftesbury Formation*
Silty black shale with abundant fish scales (often pyritic)*
Black to dark grey noncalcareous shale with numerous intercalations of siliceous rock*
Loon River Shale*
Thicker beds of quartzose to glauconitic sandstone with possible crossbedding. Dark grey shaley units, which are generally calcareous are dispersed throughout*
Post-impact sediments
Bluesky Formation*
Crater fill impactites
*Descriptions and unit assignments from Molak, Balzer, Olson and Waters. Earth Science Report 20001-04 2001, Alberta Geologic Survey

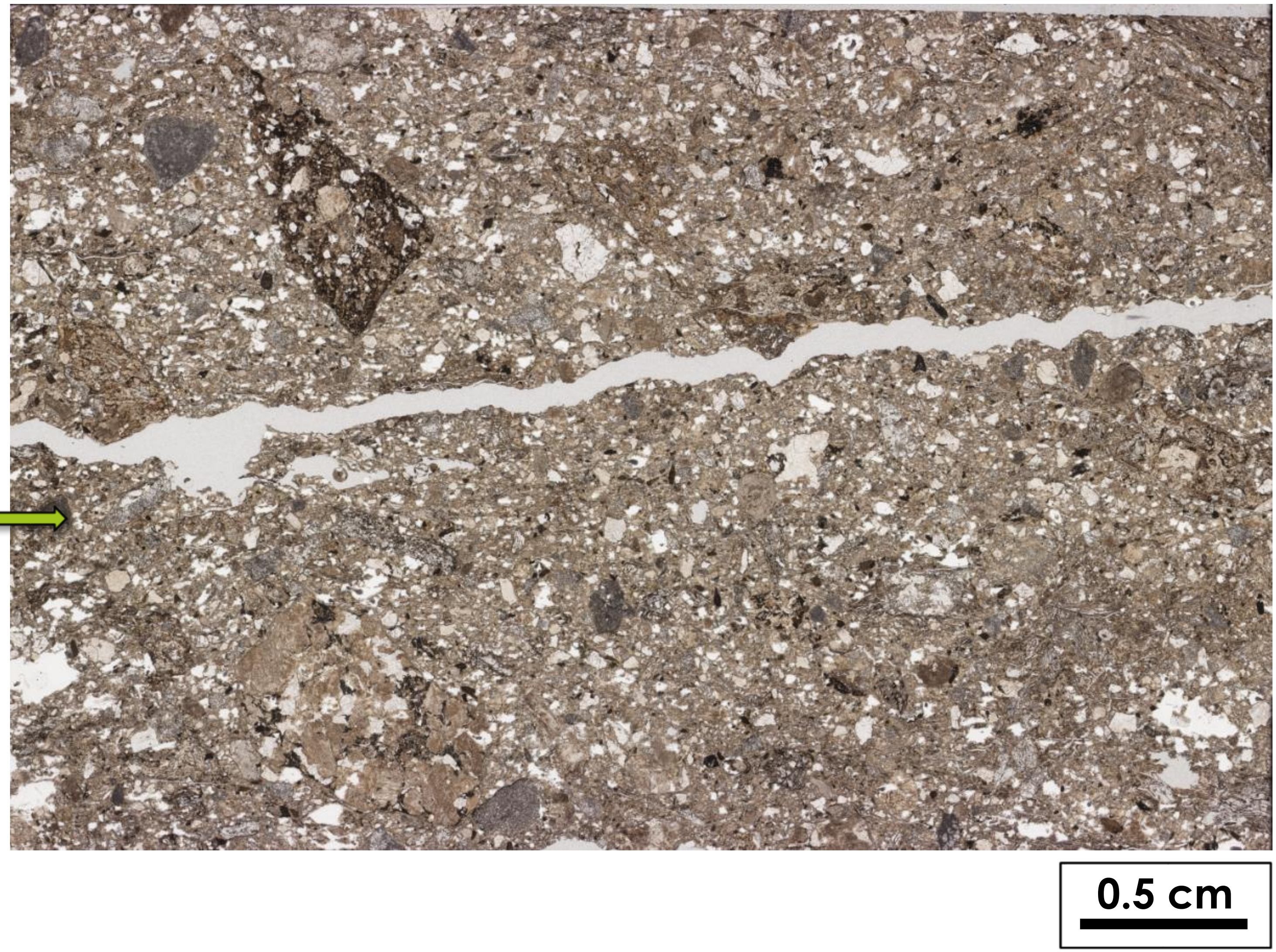
Stratigraphy



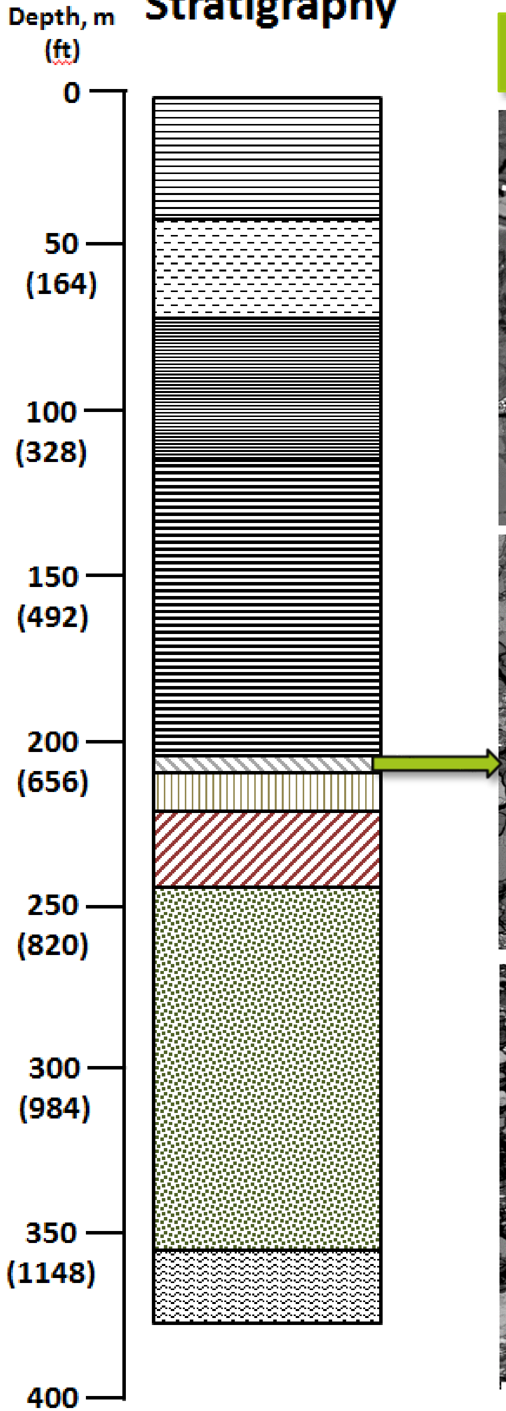
ST003 at upper shale / crater fill contact



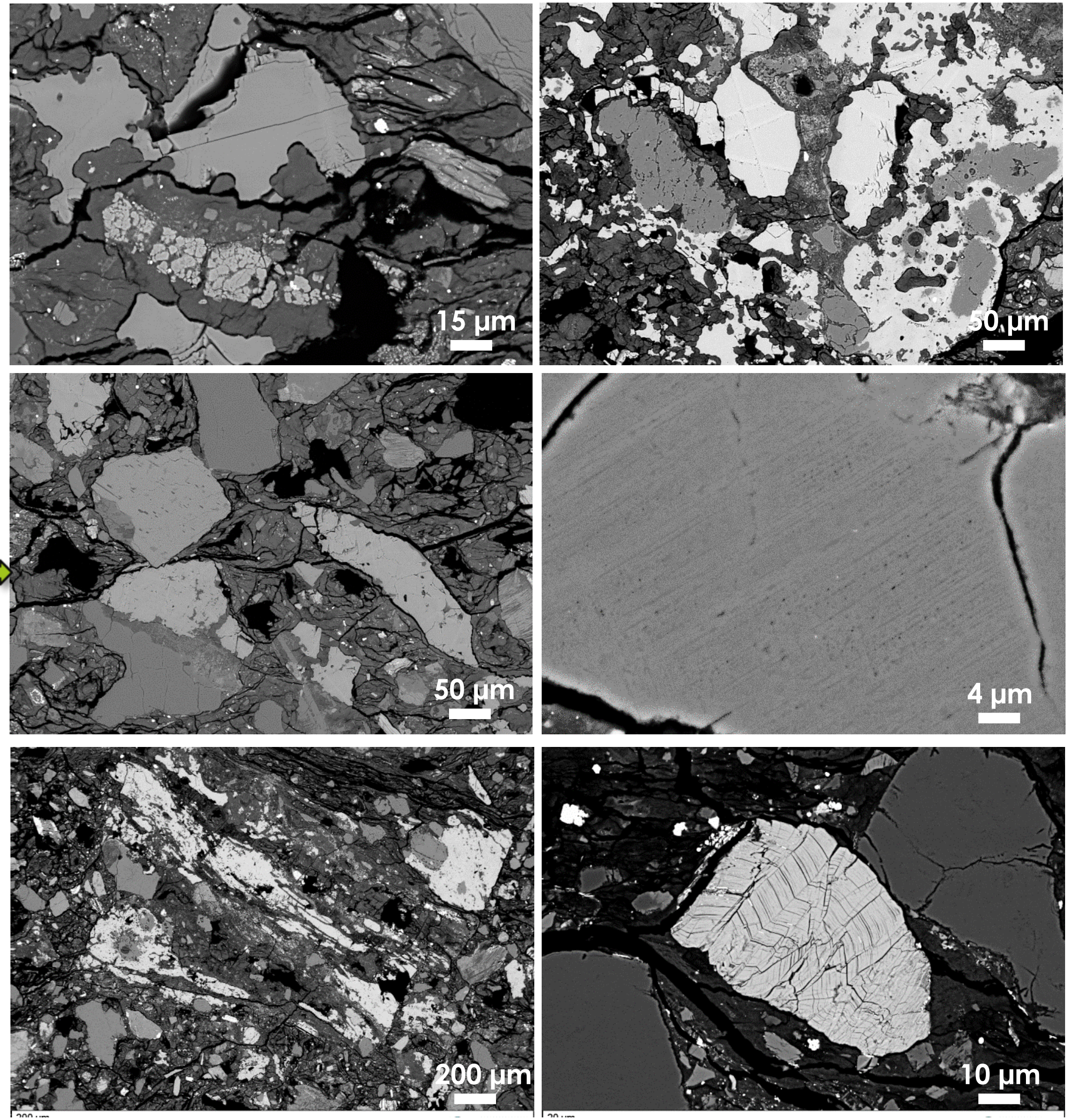
Thin Section 688-5A in transmitted light



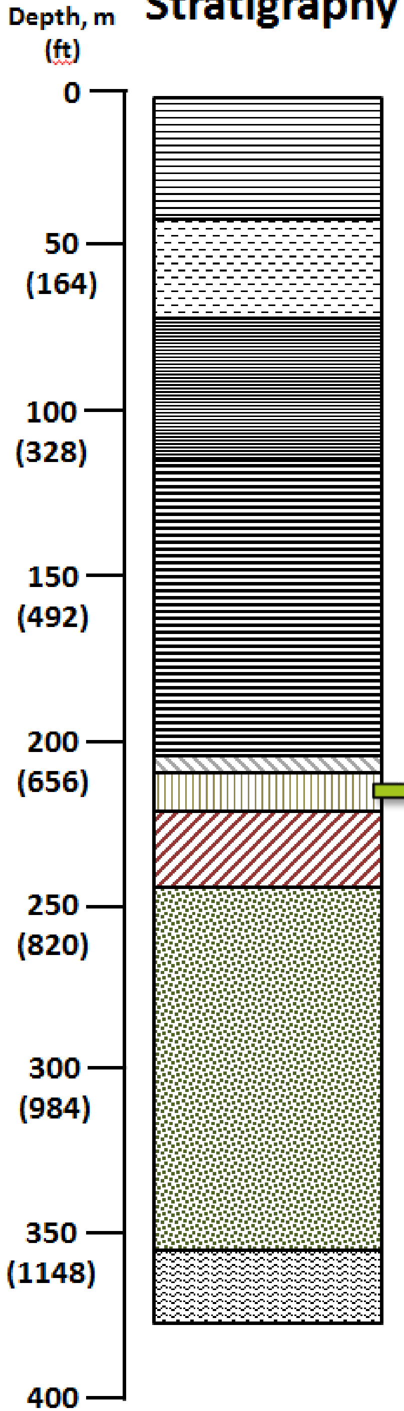
Stratigraphy



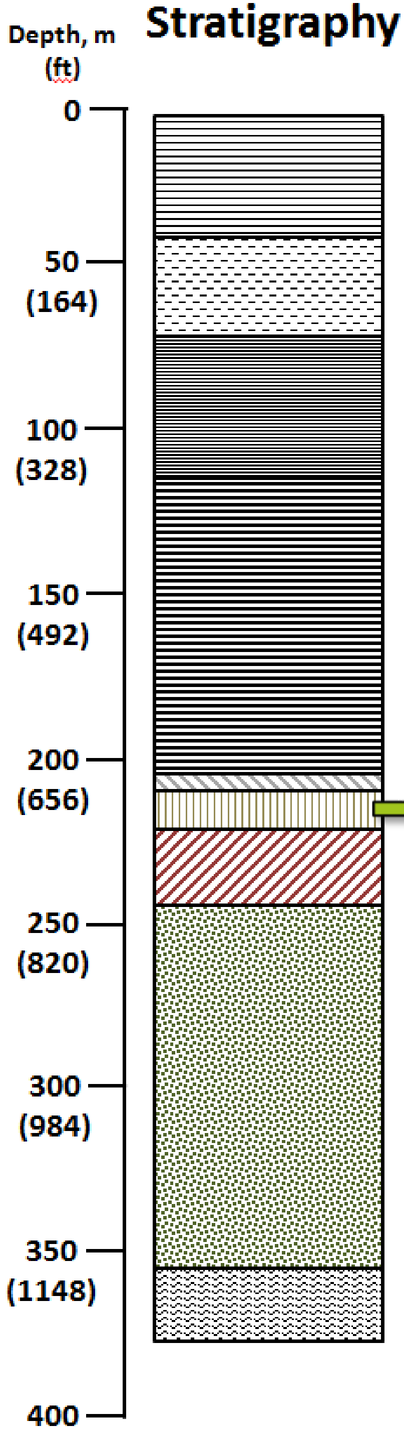
BSE images of Thin Section 688-5A



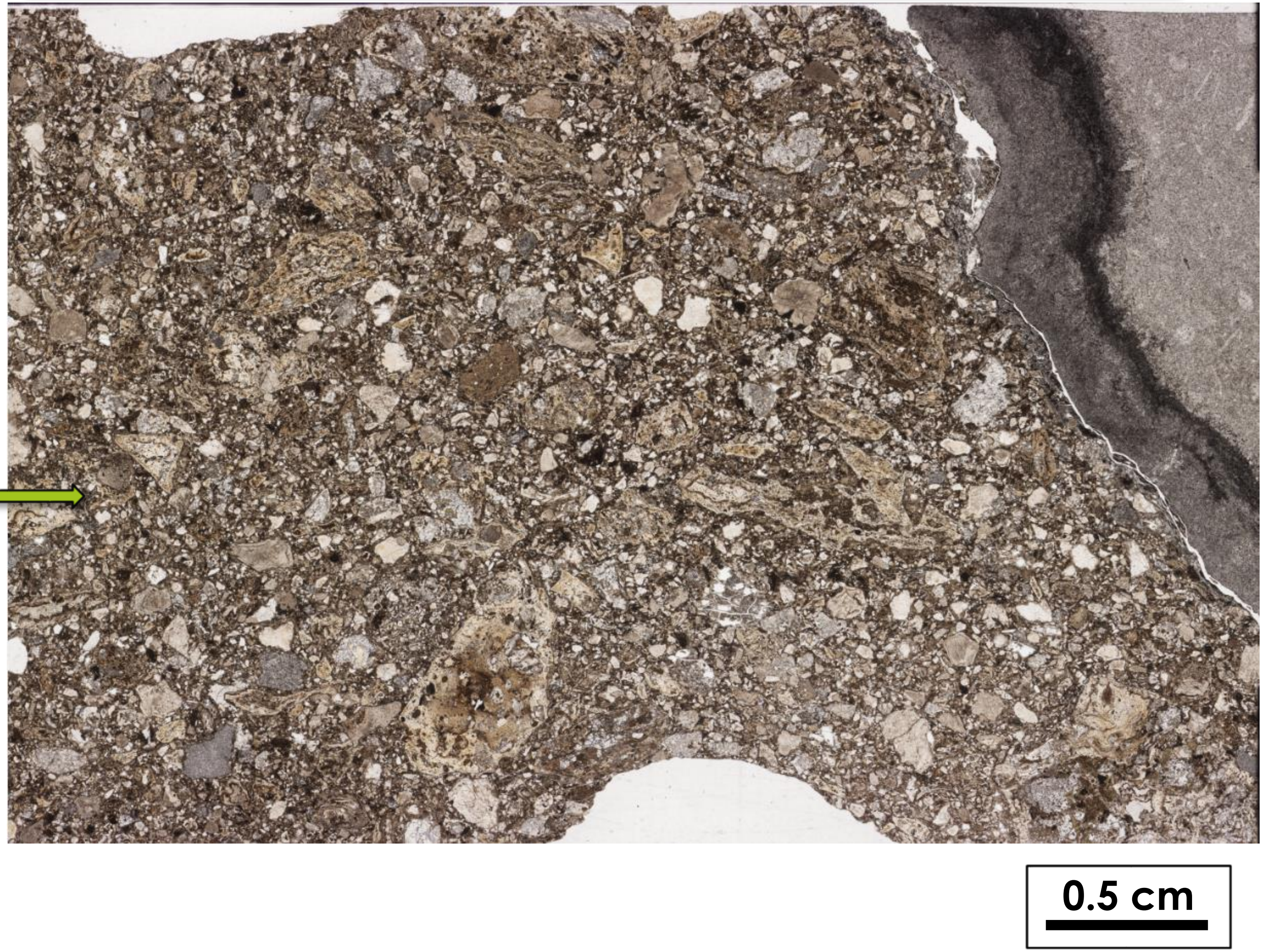
Stratigraphy

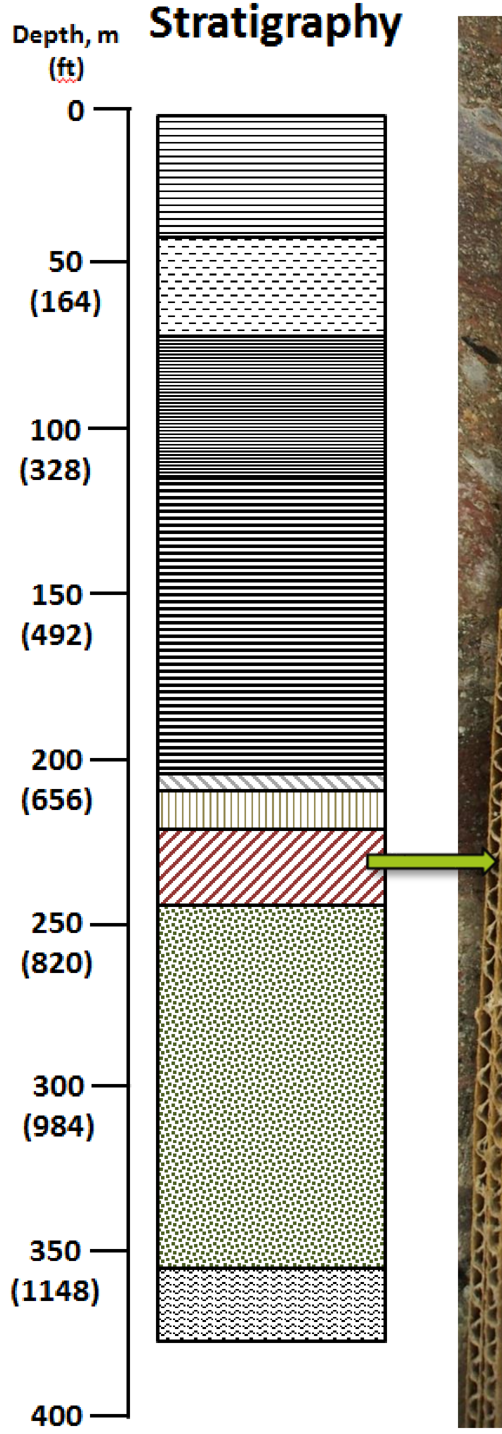


Appearance of core between 697 – 740 ft ; tan, compact, melt-clast-rich

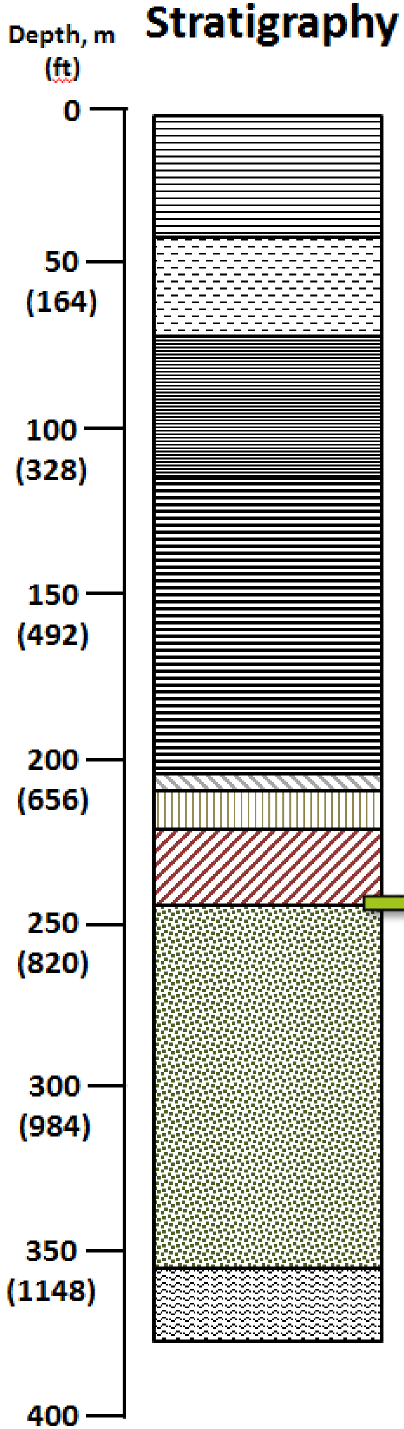


Thin Section 703A in transmitted light

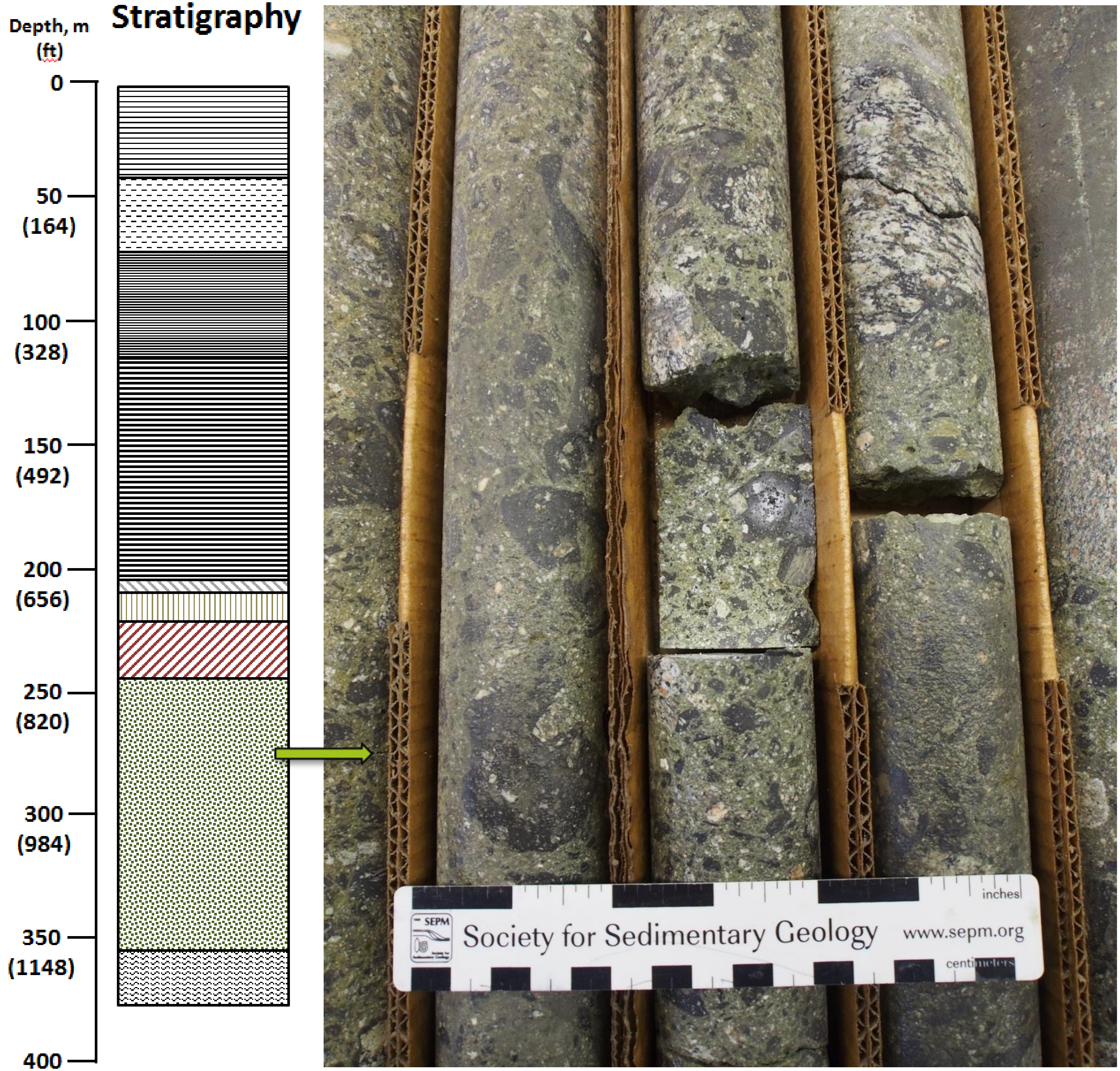




Below a depth of 740 ft the core takes on a reddish appearance (observed to 786 ft)

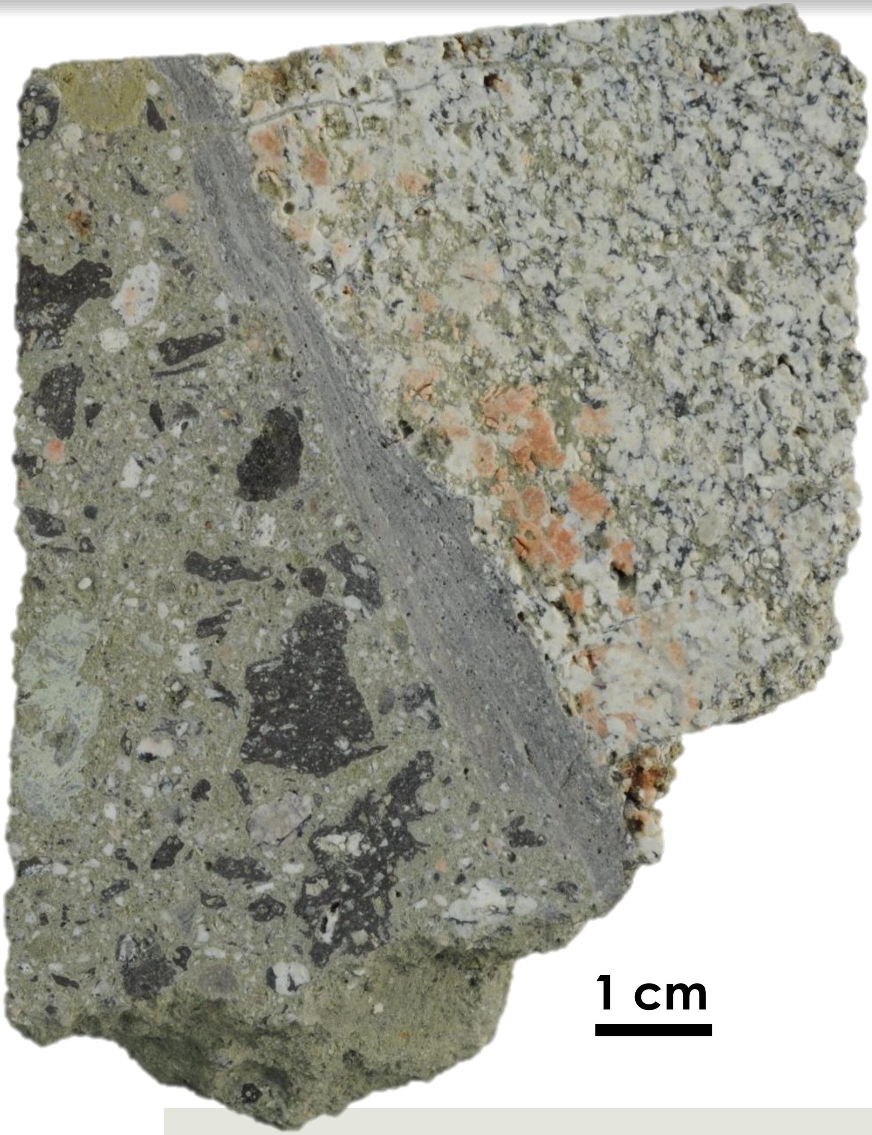


Contact between "red" core on right and and "green" core on the left which occurs at ~786 feet (240 m)



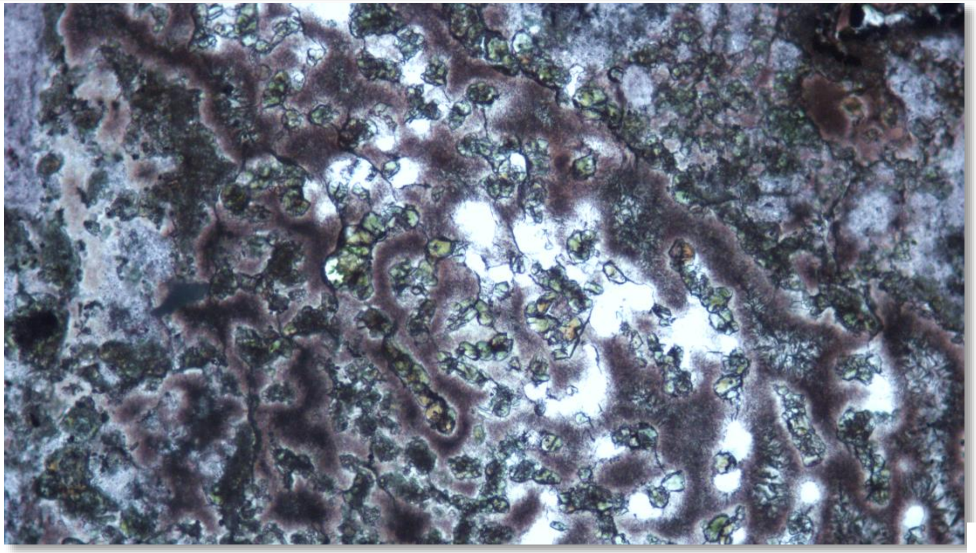
The ST003 core from 240 m – 360 m is dominated by a clast-rich melt bearing breccia with green colour

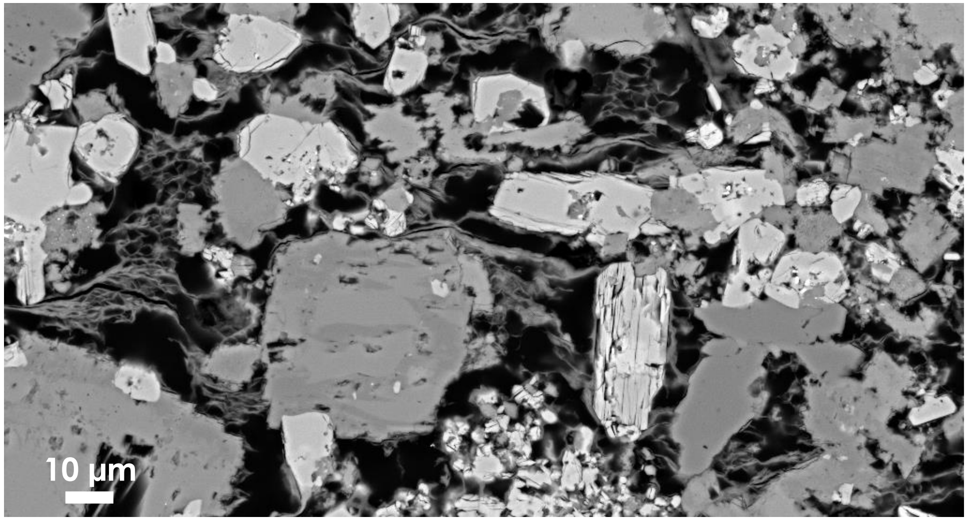
Mineralogy & Microtextures of Green Crater Fill



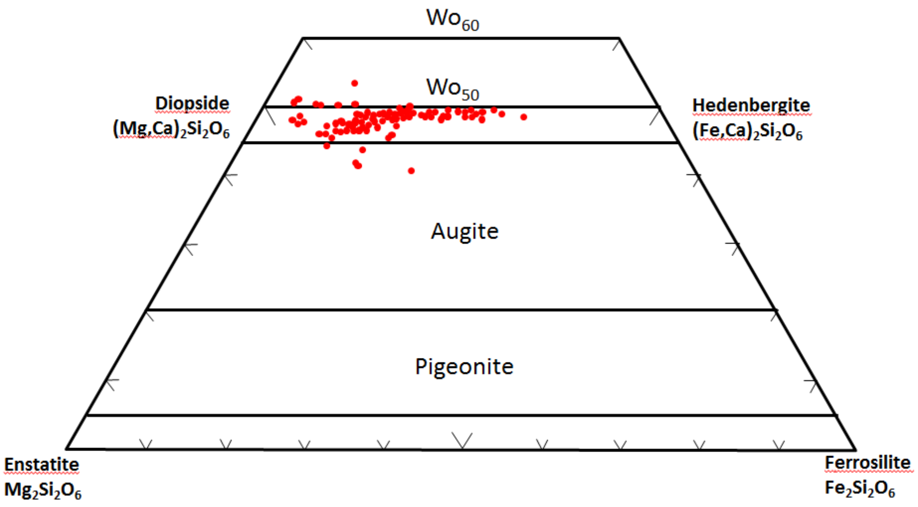
- Groundmass has a distinct green colour
- Impact melt glass is black
- Clast population dominated by crystalline basement rocks
  - General increase in clast size down core
  - Clasts are typically enrobed in melt
- Limestone clasts are rare

Mineralogy & Microtextures of Green Crater Fill

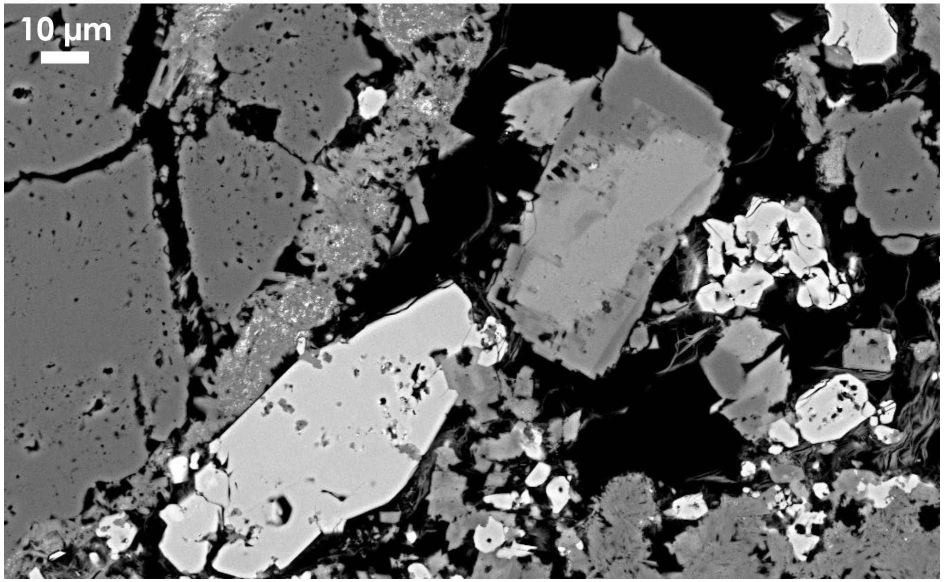


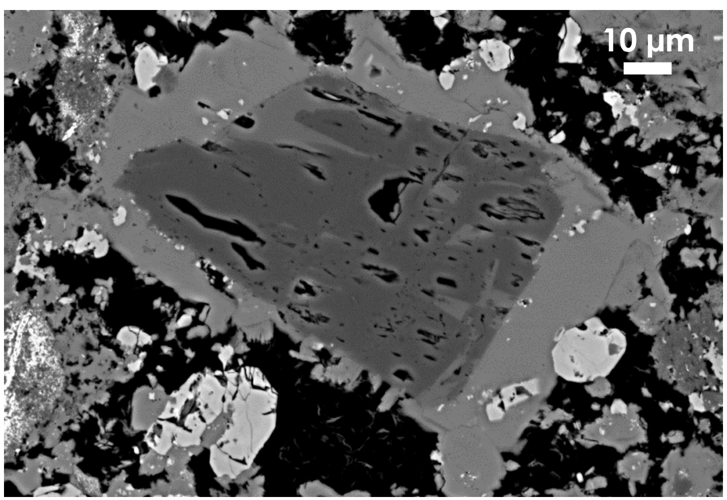


- Mineralogy of the groundmass
  - Major minerals include **Pyroxene** + sanidine + Na-rich feldspar with poikilitic texture
    - ***Pyroxene is very calcic***

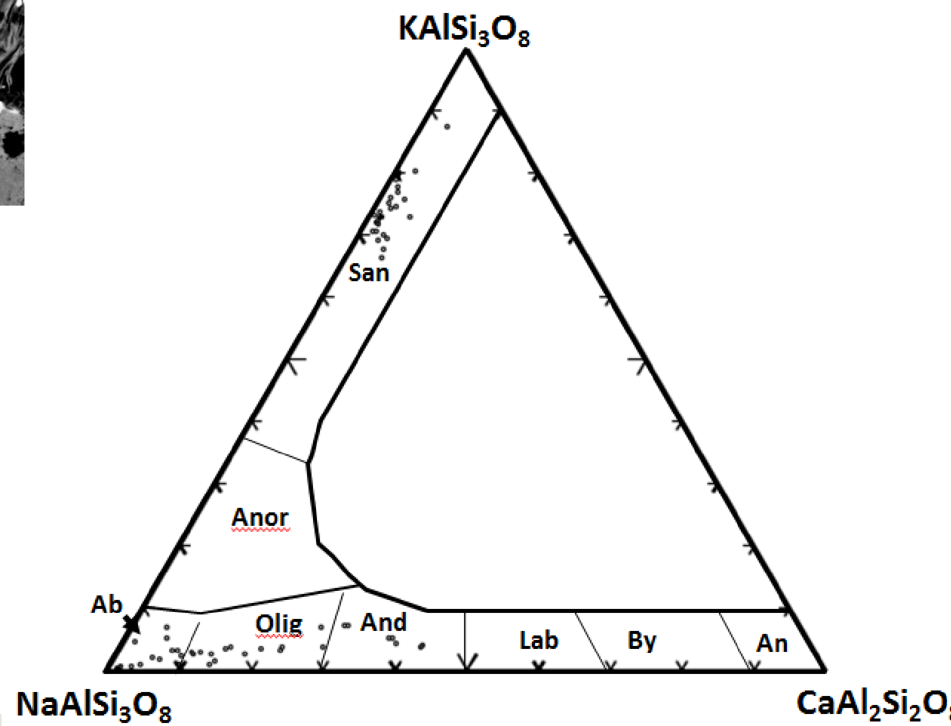


Mineralogy & Microtextures of Green Crater Fill



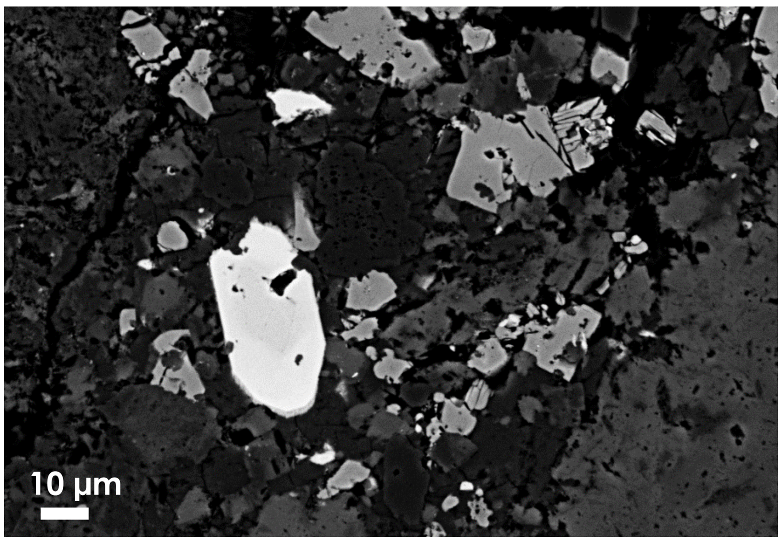


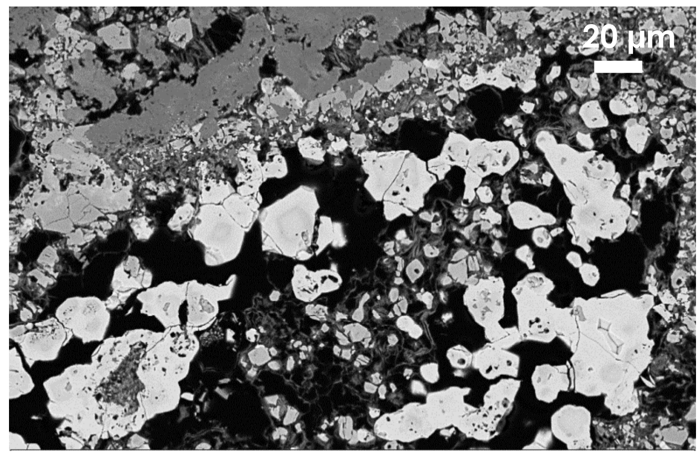
- Mineralogy of the groundmass
  - Major minerals include Pyroxene + **sanidine** + **Na-rich feldspar** with poikilitic texture

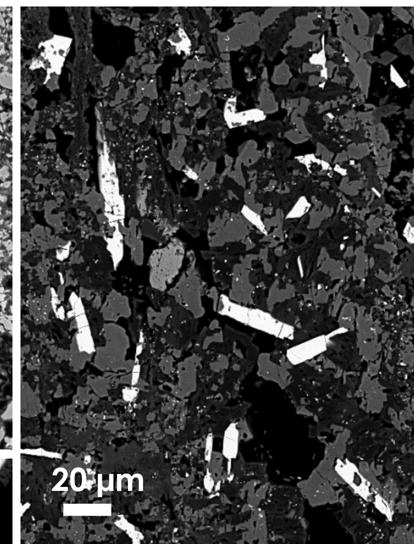


Mineralogy & Microtextures of Green Crater Fill

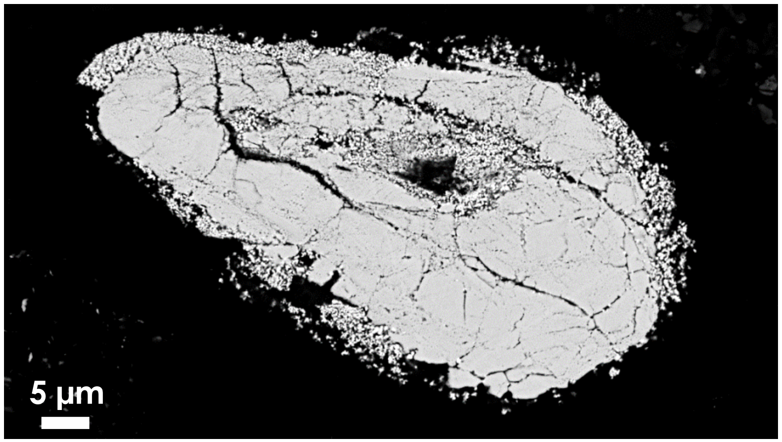
- Mineralogy of the groundmass
  - Volumetrically minor **titanite**, **ilmenite**, **magnetite** and **grossular**



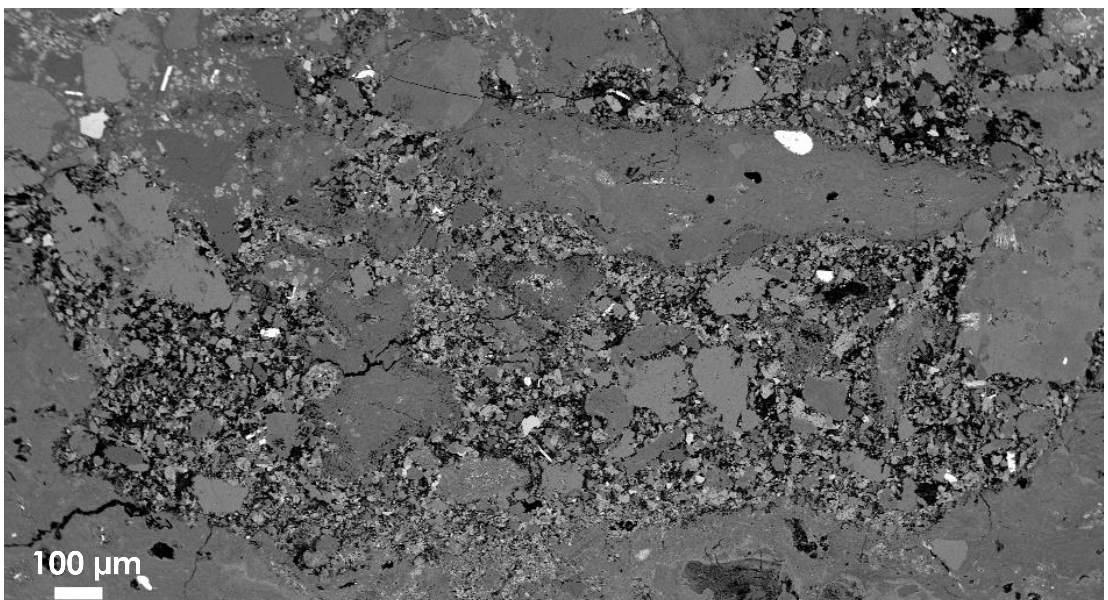


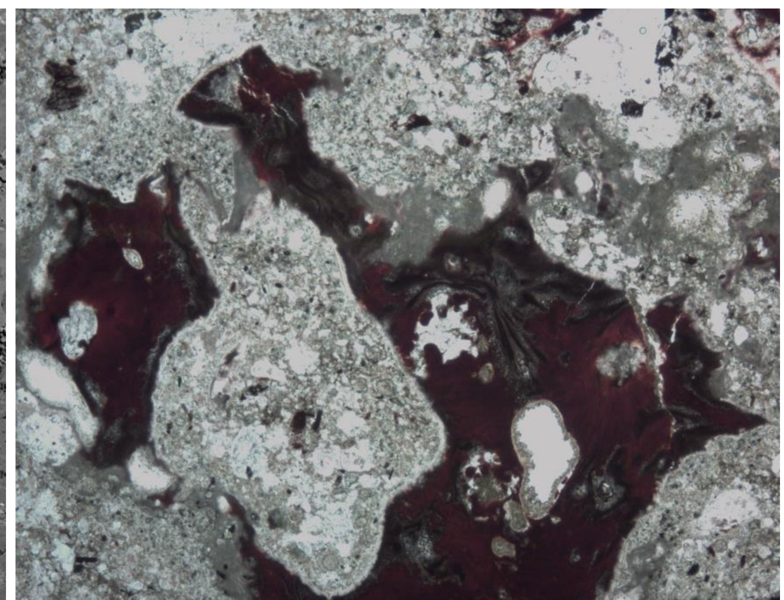


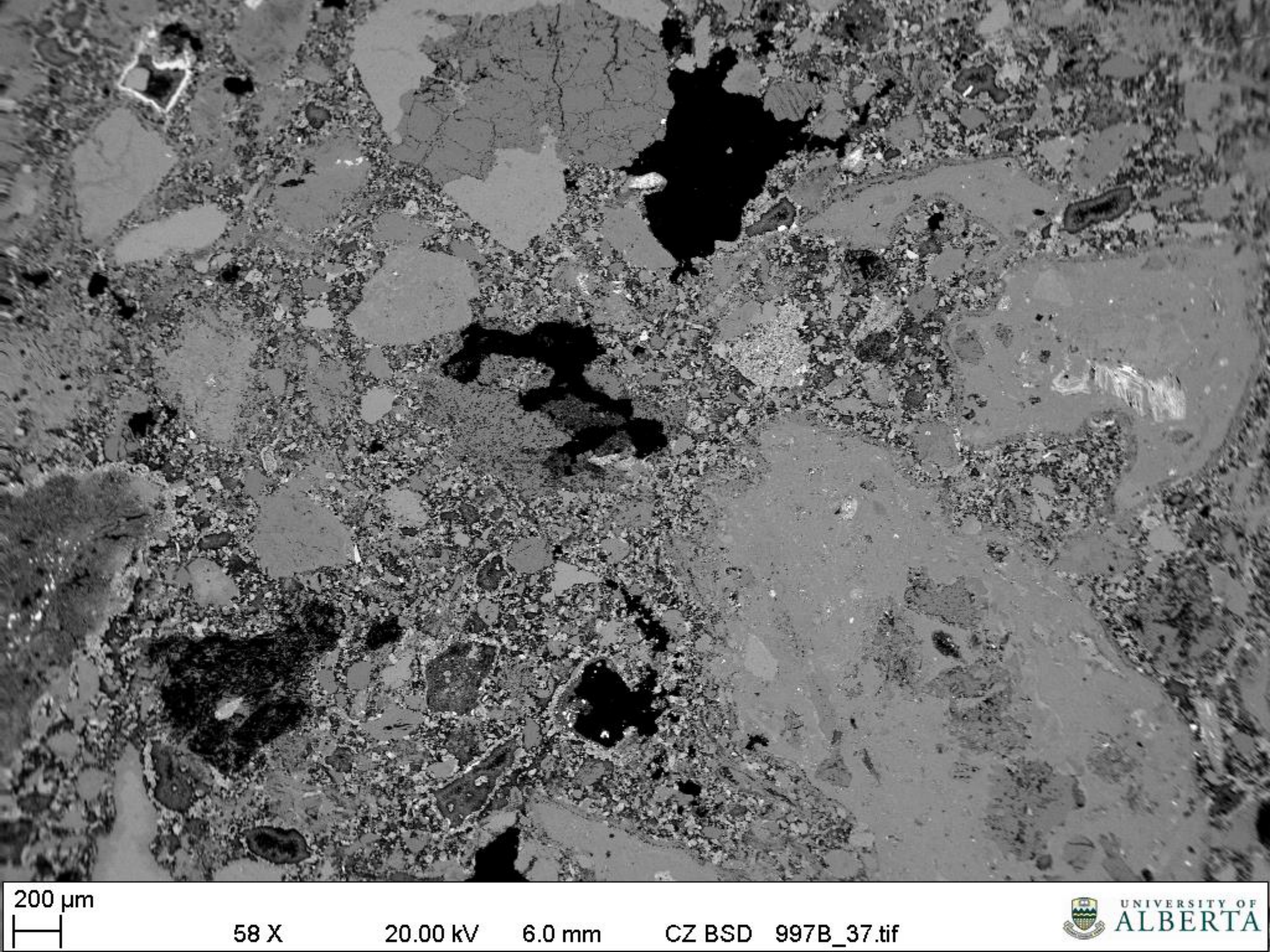
Impact Melt Glass in Green Crater Fill



- Thermal decomposition of zircon to baddelyite + glass
  - T > 1700 °C
- Most glass is devitrified






200 µm
58 X
20.00 kV
6.0 mm
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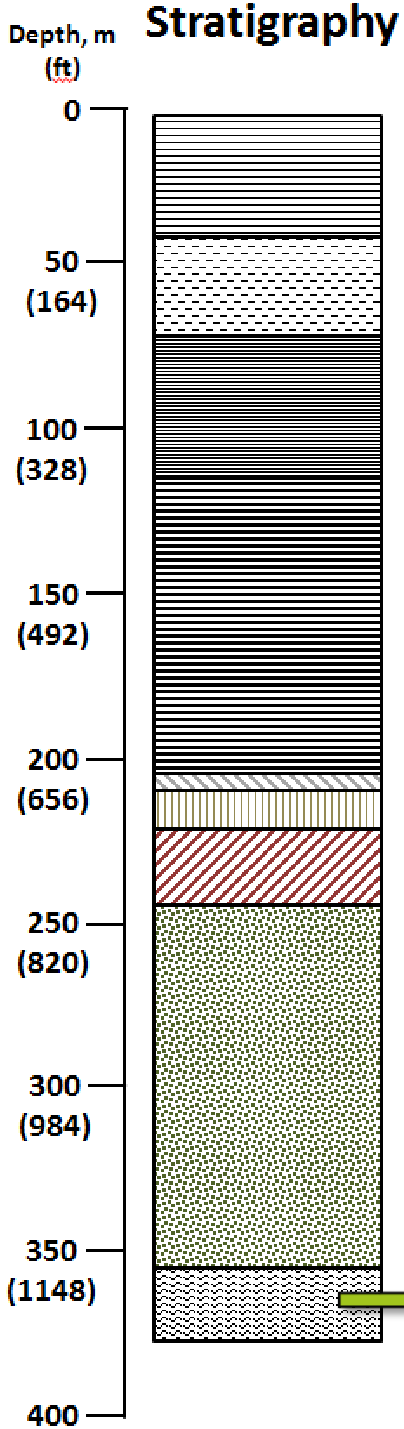
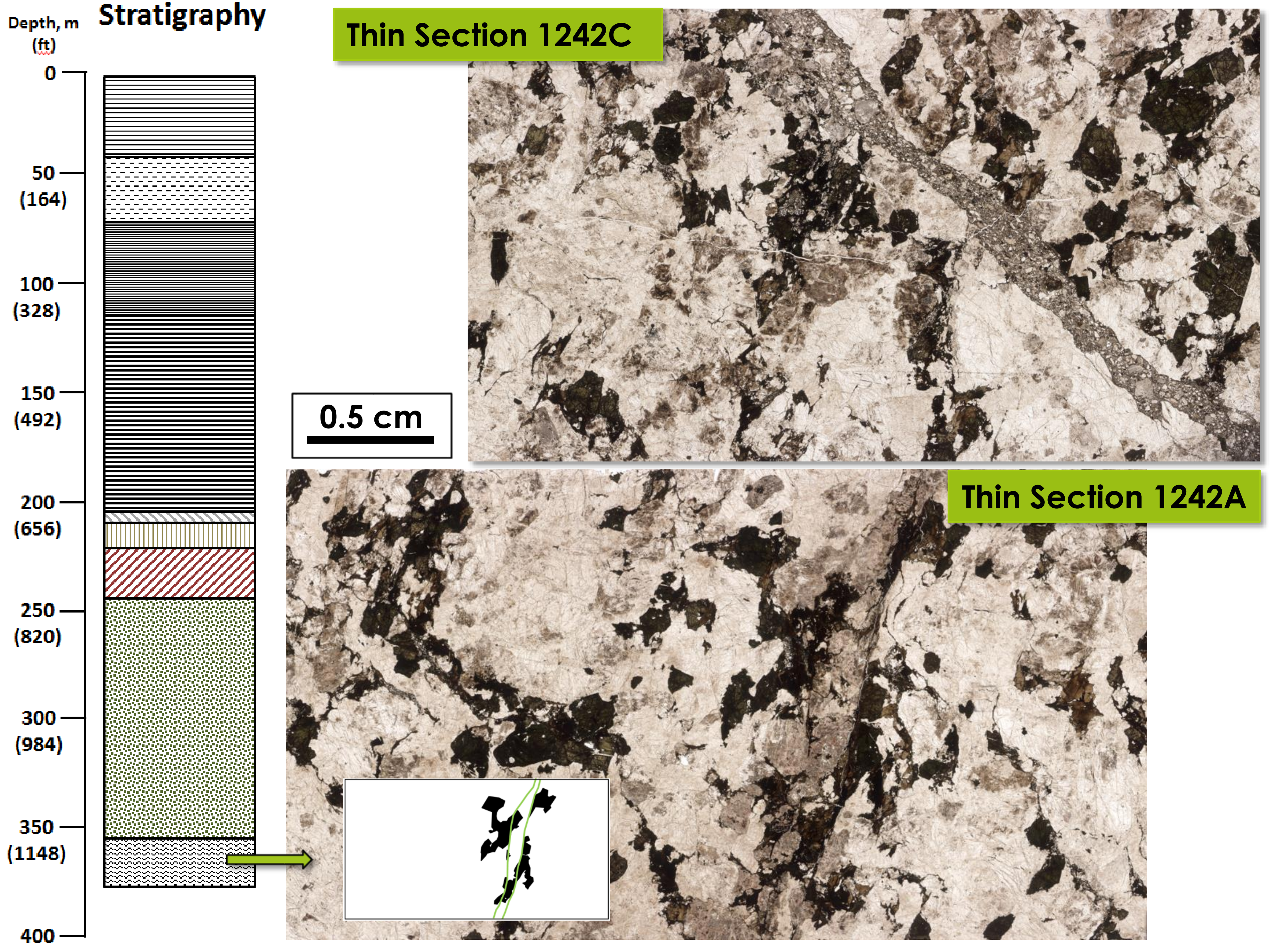
How do we classify SRIS Impactites?

- Interpretation of groundmass: formed from a **high degree of thermal metamorphism** of an extremely fine-grained superheated dust
- Similar texture to "suevite" but unique matrix

Left, melt-bearing crater fill from the SRIS and bottom, the so-called "suevite" classified as a melt-bearing impact breccia from the Ries Crater in Germany

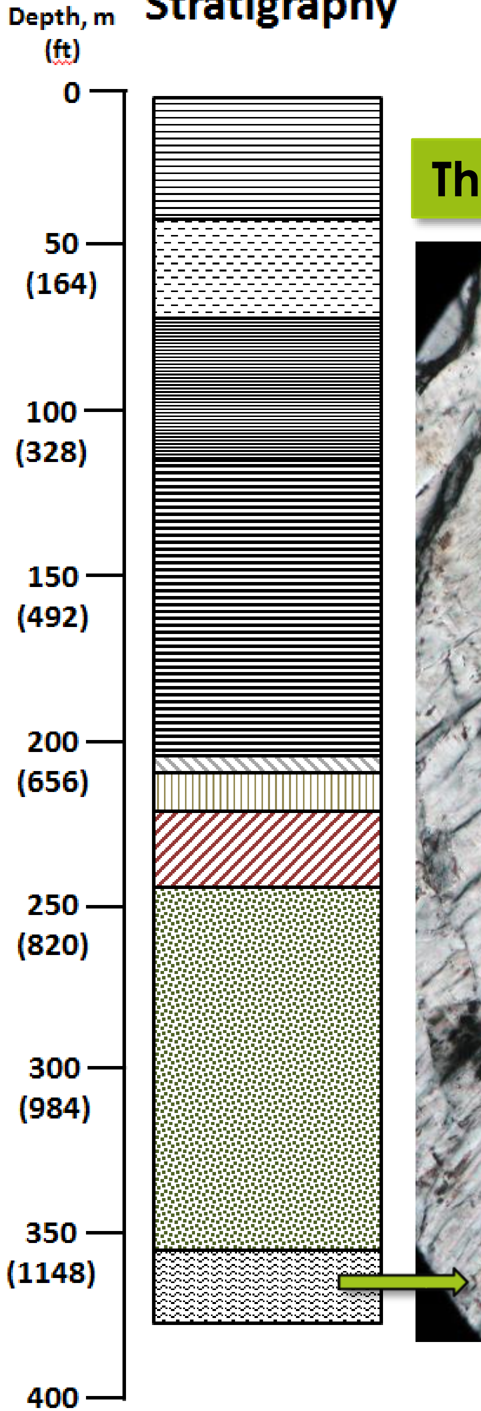
Photograph of the lower few meters of core which penetrate crystalline rocks of the Precambrian Basement



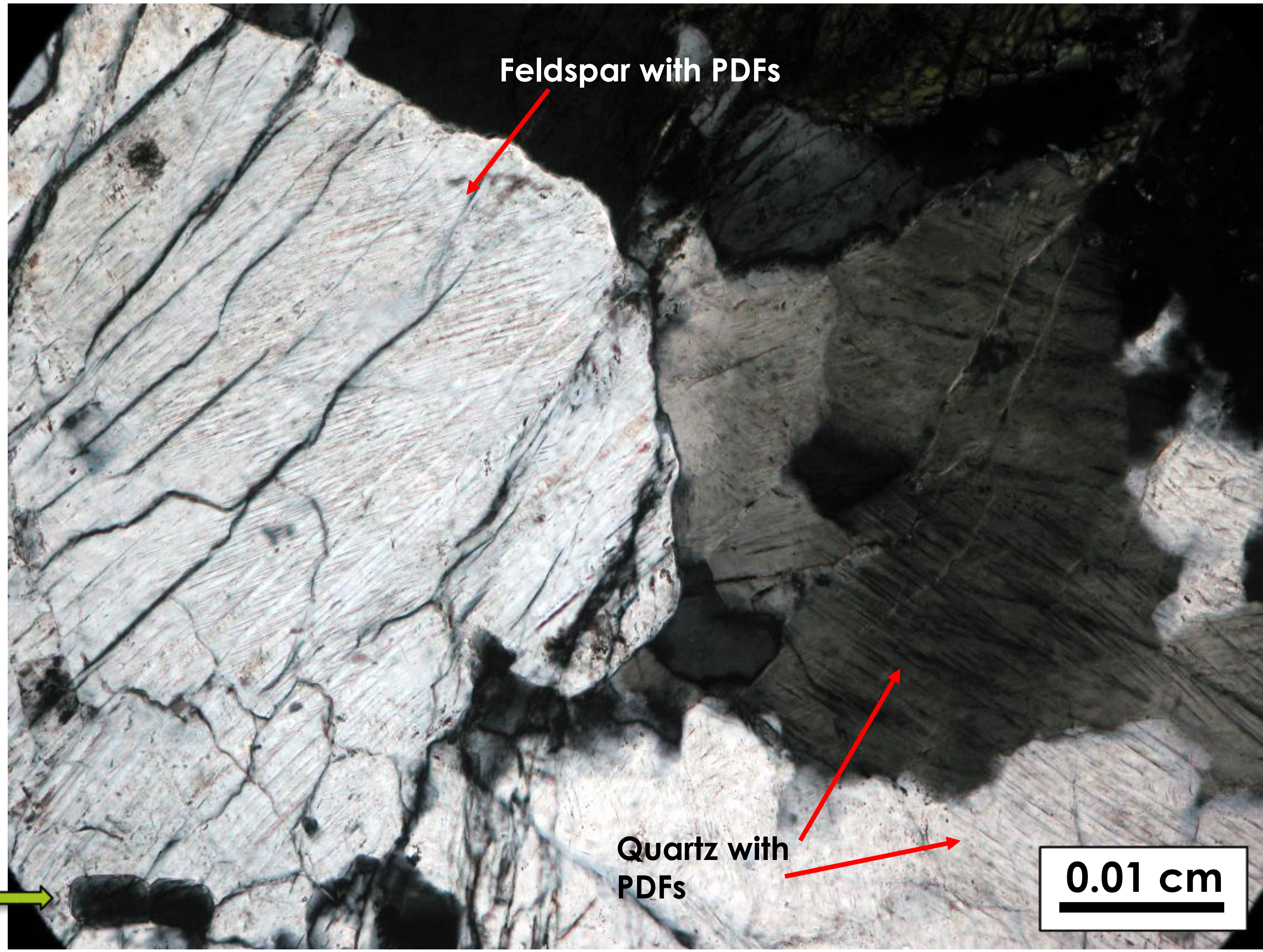


Stratigraphy
Depth, m
(ft)
0
50
(164)
100
(328)
150
(492)
200
(656)
250
(820)
300
(984)
350
(1148)
400
Thin Section 1242C
0.5 cm
Thin Section 1242A

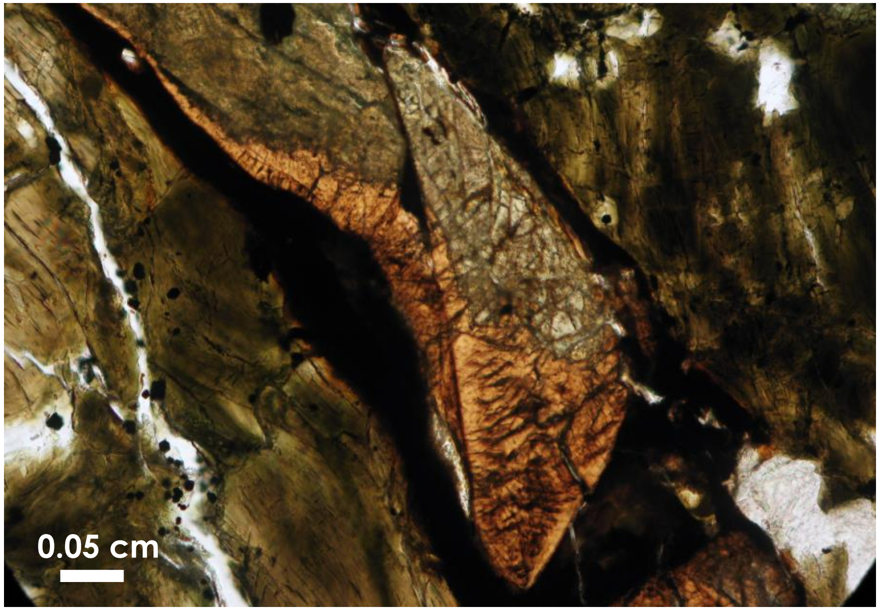
Stratigraphy

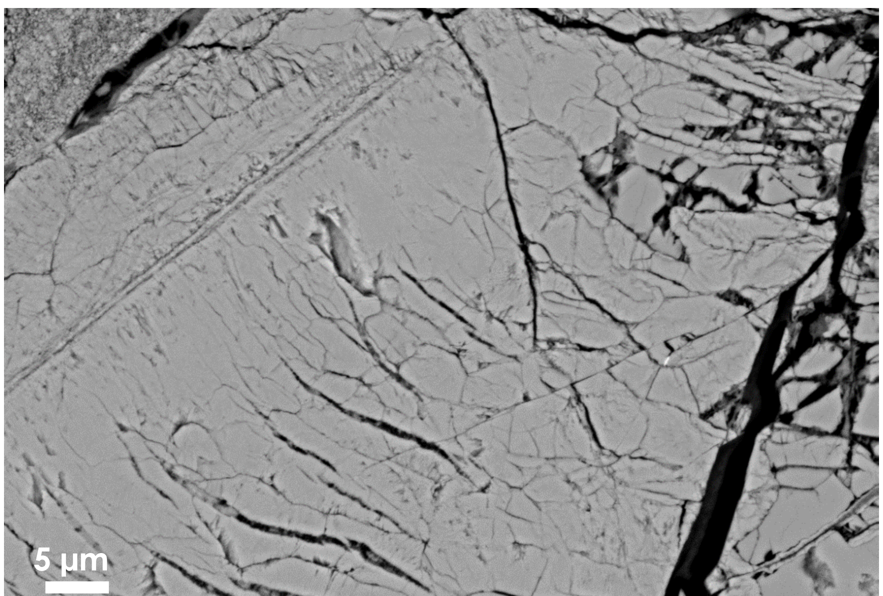


Thin Section 1242A in transmitted light



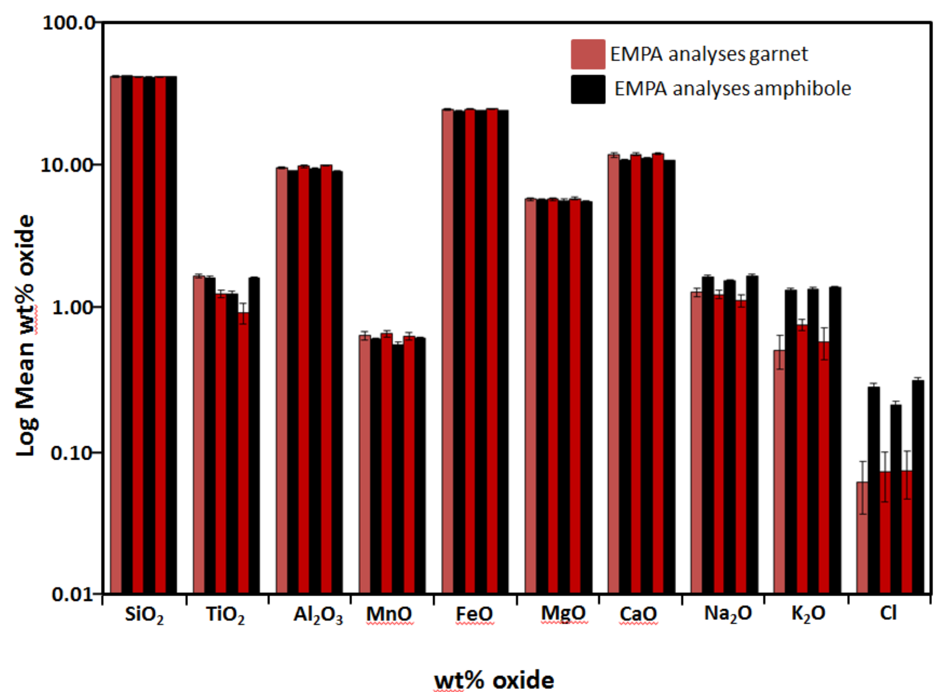
Thin Section 1242A in transmitted light



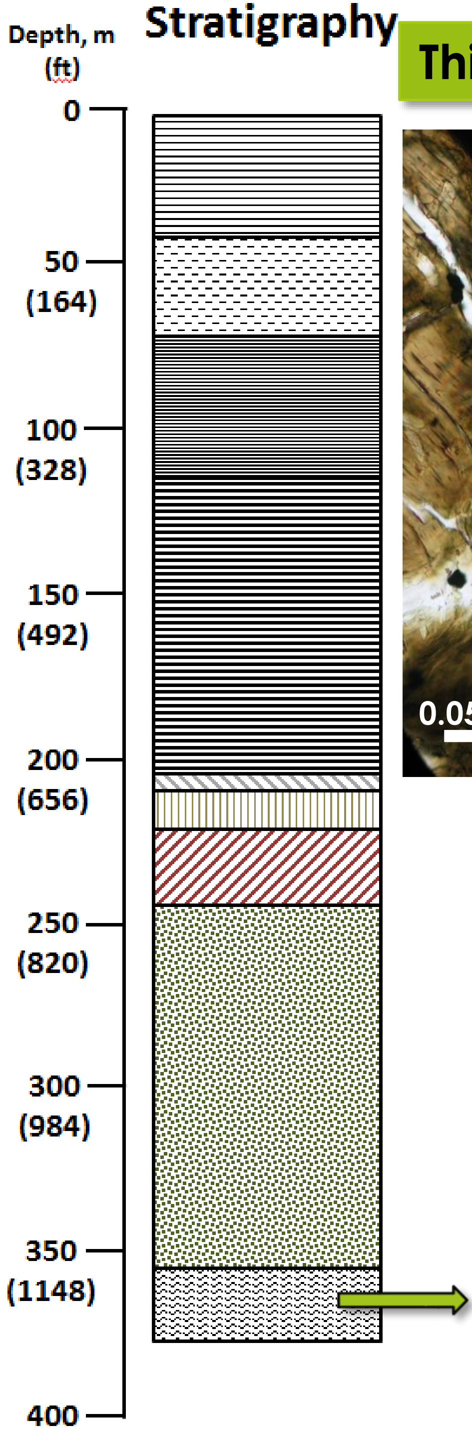


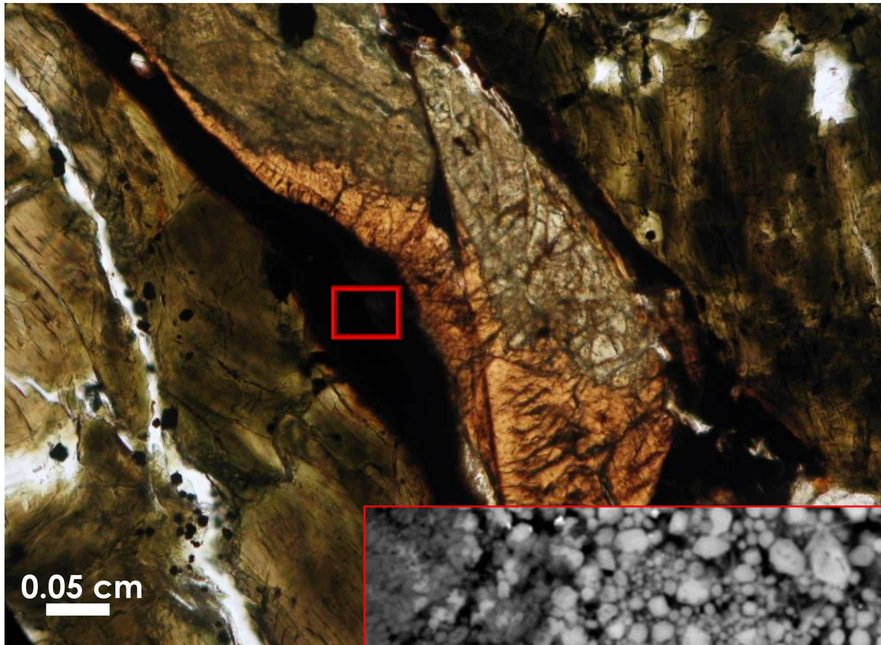
Amphibole in the target rock is ferro-pargasite with general formula,
$(Na_{0.41}K_{0.27})(Ca_{1.82}Na_{0.10}Mn_{0.08})(Fe^{2+}_{3.04}Mg_{1.33}Al_{0.29}Ti_{0.19}Fe^{3+}_{0.14})(Si_{6.60}Al_{0.40})O_{22}(OH)_2$

→In direct contact with shock veins, pargasite has undergone a nearly isochemical transformation to almandine garnet,
$(Fe_{1.37}Ca_{0.97}Mg_{0.42}Na_{0.2}Mn_{0.05})(Al_{0.92}Si_{0.36}Fe_{0.35}Mg_{0.22}Ti_{0.10})Si_3O_{12}$, **with 36% majorite component**

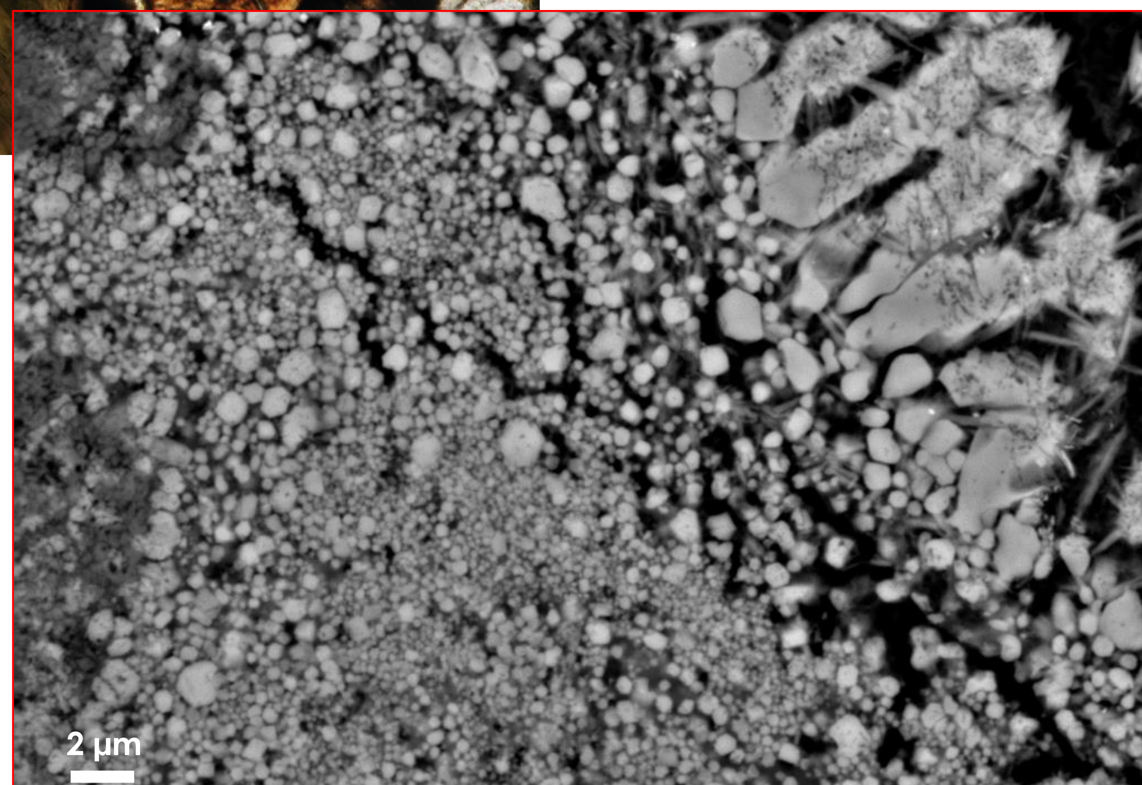


Thin Section 1242A in transmitted light



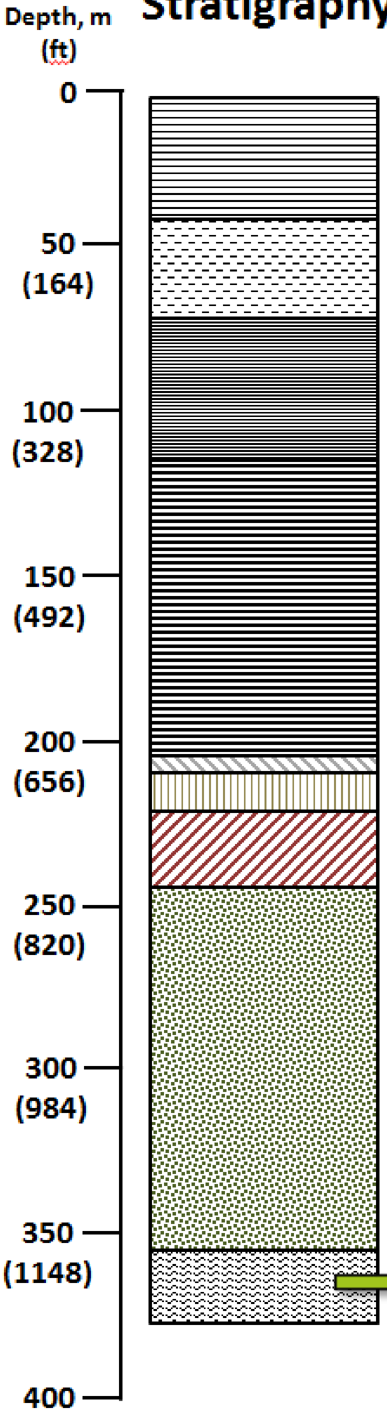


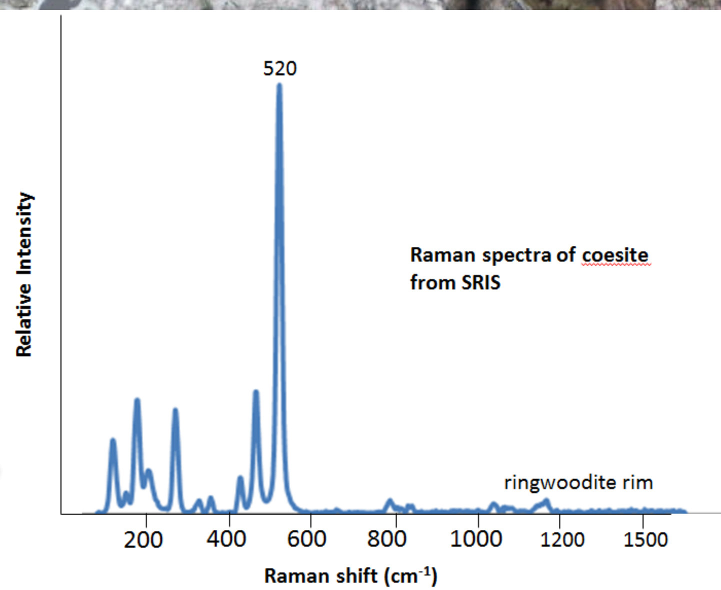
Almandine garnet $(Fe_{1.54}Mg_{1.31}Ca_{0.05}Na_{0.04}Mn_{0.03})(Al_{1.81}Si_{0.11}Mg_{0.04}Ti_{0.03})Si_3O_{12}$ **has crystallized from the shock vein with 11% majorite component**

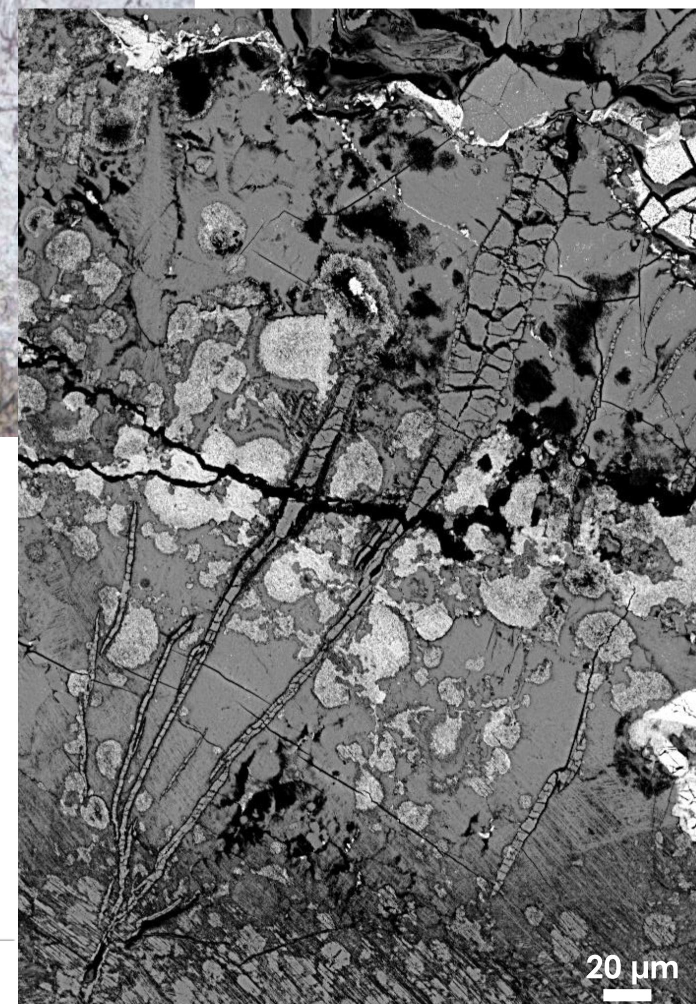


Thin Section 1242A in transmitted light and BSE image

Stratigraphy

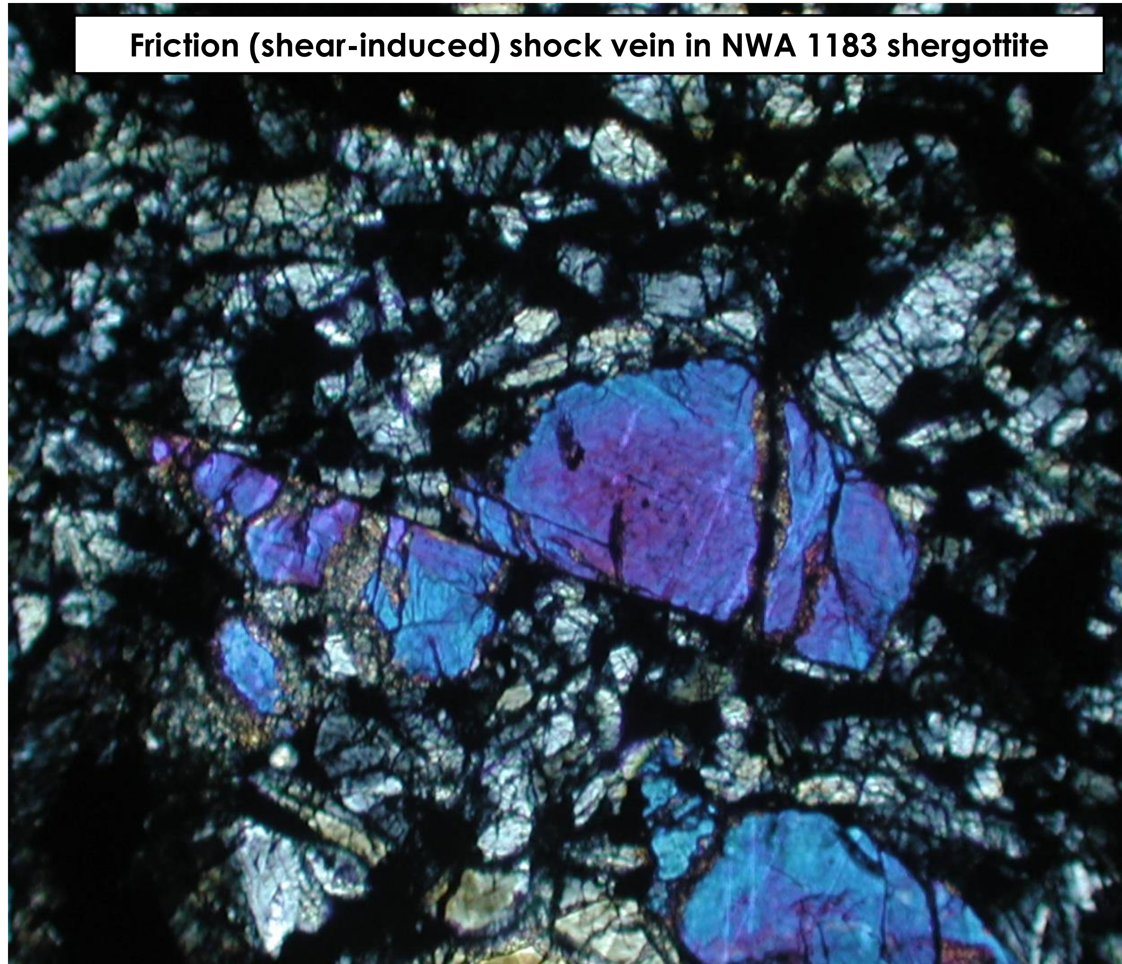






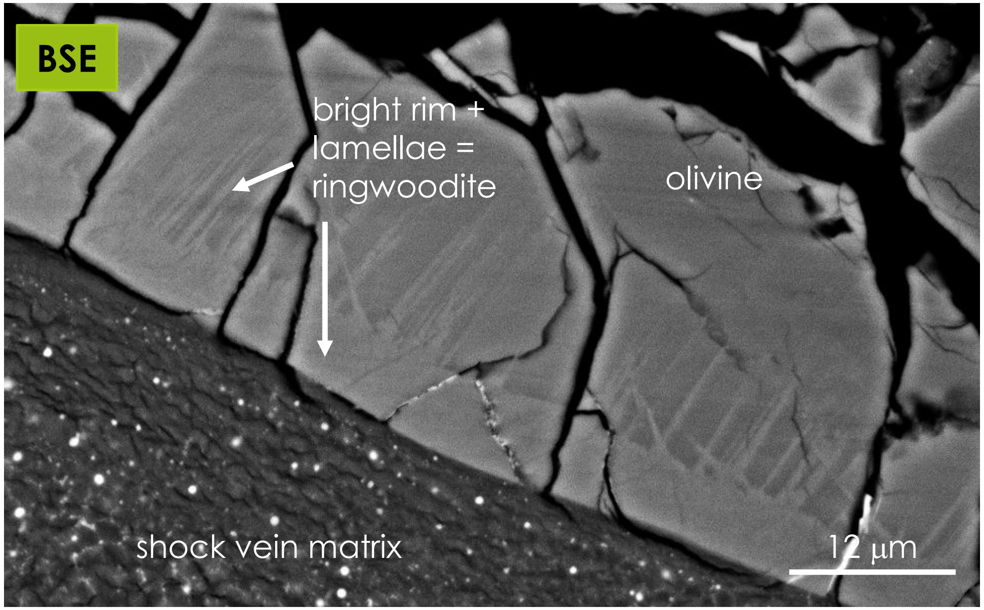
The Distribution of HP-HT Minerals

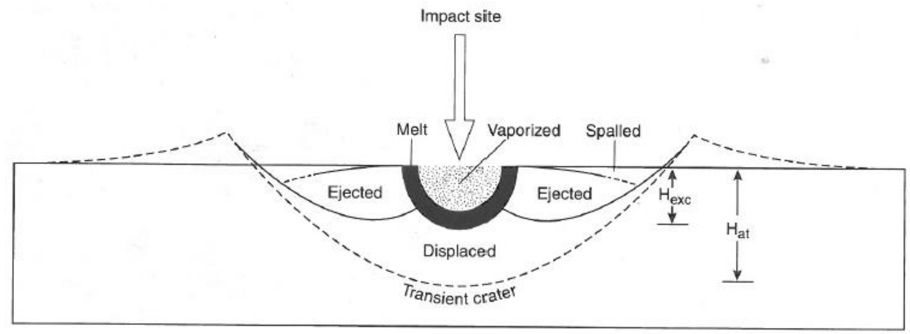
- **Coesite** associated with **shock veins**
- **Reaction kinetics** are greatly **enhanced** in or close to shock melts due to **heat** derived from shock-induced frictional melts
- Previous studies could not isolate coesite at SRIS
- Why?



Shock melts once formed with cool by conduction of heat to the surrounding host rock

Comparison with Meteorites

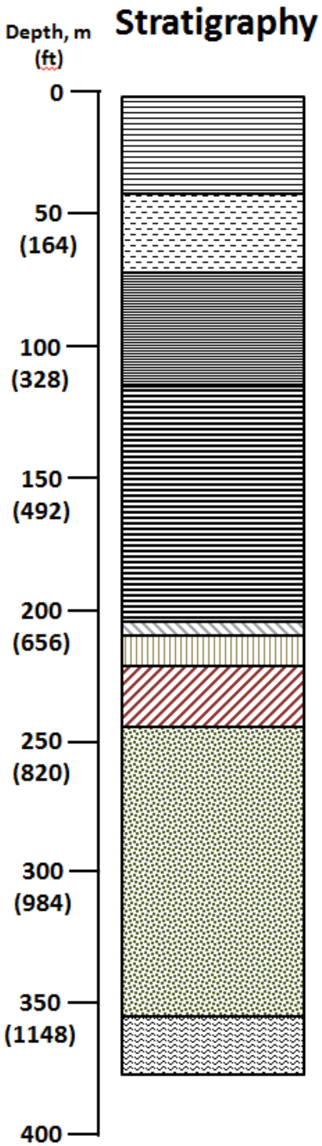




- Shock veins ubiquitous in meteorites
- P-T indicated by minerals are much higher compared to SRIS
- Originate closer to the point of impact

Top, BSE image Tissint and bottom, hand specimen of Zagami (Martian basalts)

Summary of Observations at SRIS

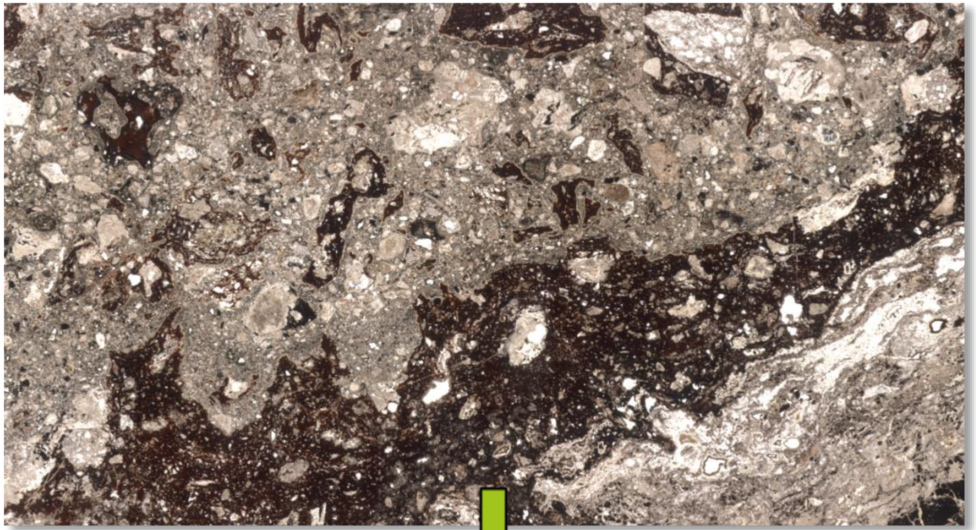


- Over 170 m of crater fill impactites sampled
- Preserves overall pre-impact stratigraphy
- Impact melt glass throughout – different colours likely represent alteration
- Comparison with "suevite" at the 24 km Ries Impact Structure
- Mineralogy of shock veins suggest shock pressures **15-17 GPa**

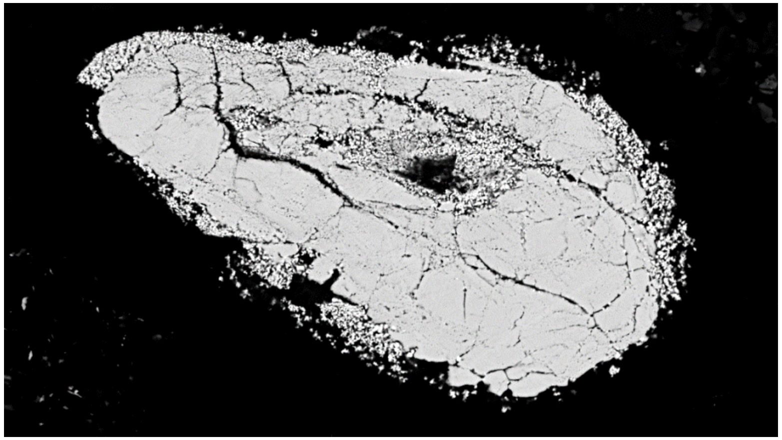
"Suevite" clast rich impact melt-bearing breccia at Ries, Germany

Ongoing Research Projects

- Constrain age of the crater
  - Quoted as 95 ± 7 Ma
  - Single whole rock K-Ar age on breccia
- Use shocked / decomposed zircons and newly crystallized titanite
- Look at amount of erosion which could have taken place prior to infill of the crater



What does an age represent when you "date" a rock like this?



Student Involvement at SRIS

- Astromaterials Research and Training Opportunities (**ASTRO**) Cluster funding provided by the CSA in 2014
  - Summer student Alexandra Hughes
- **NSERC** Undergraduate Student Research Awards (**USRA**) funding for summer 2015 work on SRIS
  - Summer student Ebberly MacLagan
  - Study glasses, identify impactor
- Pursuing funding through **MITACS Accelerate Program** funding for graduate student research on the SRIS with industry partnership
- Opportunities at **MacEwan University** through **EASC 498 Independent Research Project**

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- Martin van Dollen and Andrew Locock at UofA
- Collaborators: Dr. Chris Herd, Dr. Des Moser, Alex Hughes

Here's a cool website: http://impact.ese.ic.ac.uk/ImpactEffects/

"Earth Impact Effects Program" run by the Imperial College of London and Purdue University
Used to calculate the regional and global environmental consequences of impact events on Earth!