MINERALOGY AND GEOCHEMISTRY OF BANDED SEDIMENT

DULUTH, MINNESOTA

AMOS A. AND JESSICA E.-B.

NDSU GEOL 422 - PETROLOGY

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outline

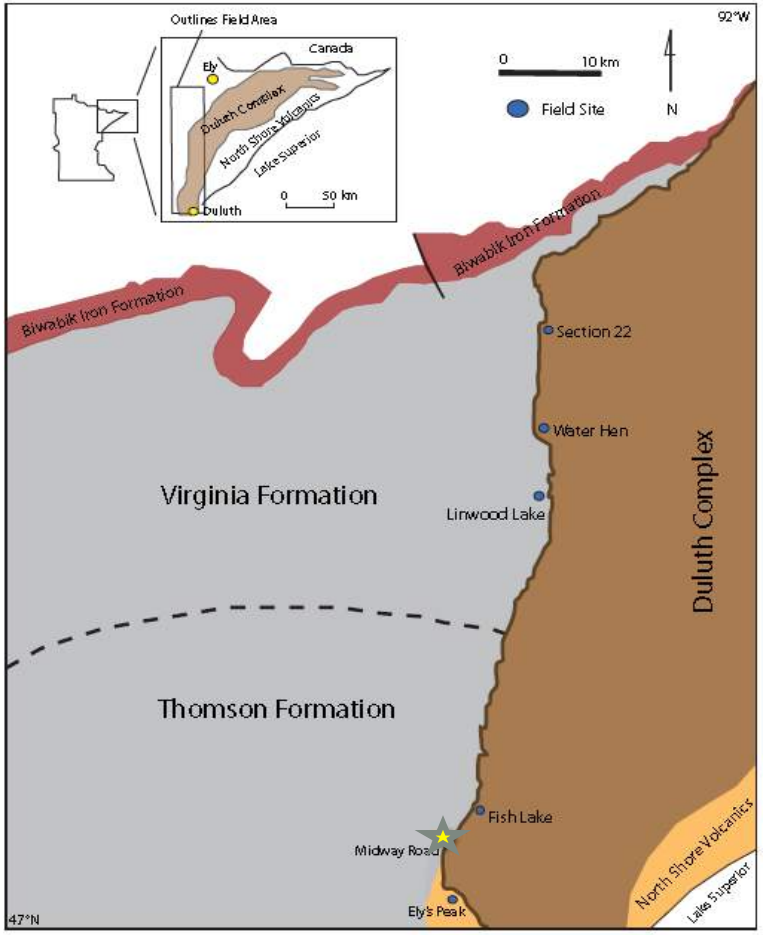
- Background
  - Location of outcrop
- Sample Analysis & Methods

  Methods
  - Hand Specimen observation
  - Petrographic Microscopy (Thin section analysis)
  - X-Ray Diffraction (XRD) chemical analysis
  - Scanning Electron Microscopy (SEM) micro chemical analysis
- Analysis & Results
- Conclusion

Background

Location

- The outcrop from which our sample was recovered represents an unconformity at the Grandview Area, Duluth, Minnesota. Located about 0.95 mi North of Midway Road.
- The site is composed of a series of outcrops that border the contact between the Thomson Formation and the Ely's Peak basalts. (Frost, 2010).
- These outcrops include the lower Proterozoic Thomson Formation, the Middle Proterozoic Nopeming Sandstone, the magnetically reversed Ely's Peak Basalts of the North Shore Volcanic Group (Kilburg, 1972).



A generalized Geologic map of the outcrop location modified from Severson (1995), showing the contact between Thomson and Virginia Formations.

Background

The Thomson Formation

- The Thomson Formation is the uppermost member of the Cuyuna Range, one of the units of the Animikie Group of Sediments.
- It is a thick accumulation of slates and graywackes deposited about 2 Ga in a basin on Archean basement.
- These rocks were deformed and metamorphosed during the Penokean orogeny about 1.85 Ga (Sims and Pet-erman, 1983).
- By the start of rifting, mature quartz sands and gravels, were being deposited on this surface to form the Nopeming Sand-stone which overlies it.

Photo: Jessica E-B, NDSU 2013

Background

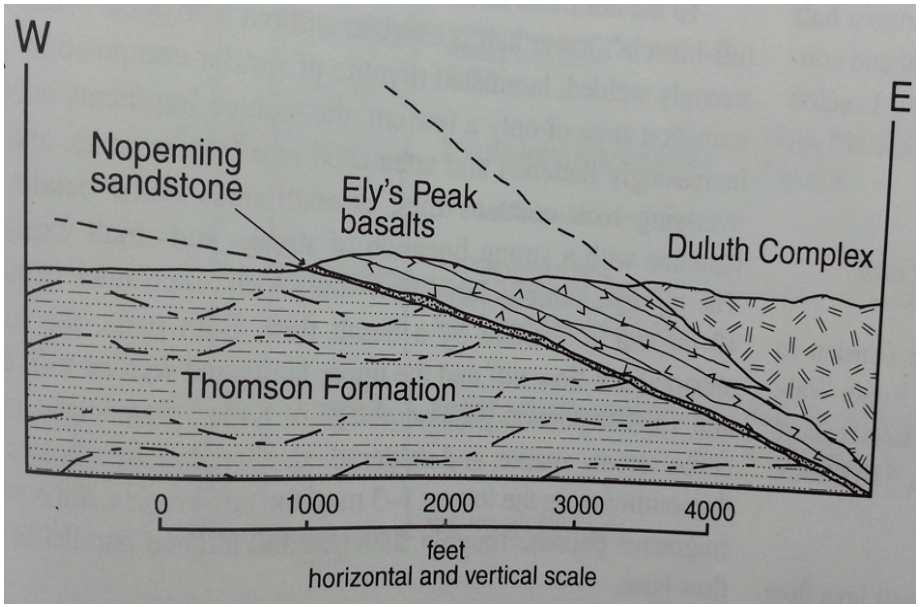
The Ely's Peak Basalts

They are a north-south trending, wedge-shaped section of basalt flows that make up the base of the North Shore Volcanic Group (Goldich et. al., 1961).

- The basalts are made up of a thick package of tholeiitic lavas
- It is composed of at least 20 separate flows (Kilburg 1972).
- Each flow has a unique structure and petrology, the flows are dominantly porphyritic, diabasic, and ophitic.
- The Ely's Peak Basalts overlie the Nopeming Sandstone.

Photo: Geology Field Trip Photo Bucket, NDSU 2013

Background



(Left) Diagrammatic geologic east-west section across the Grandview-Nopeming unconformity site. (Right) a photograph of a rock sediment of the Nopeming Sandstone sandwiched between the Ely's Peak Basalt above and the Thomson Formation below. (photo by Amos, NDSU)

The Nopeming Sandstone

- The Nopeming is about 7.5 m thick
- Contains some pebbly beds and is finer (to silt-size) near its top (Mattis, 1972)
- Composed primarily of quartzose sand
- It was deposited in both distal braided alluvial plains and partially in lakes (Ojakangas, 1997)

Our Questions

- Did our sample come from the Nopeming sandstone or a different rock unit?
- What might have caused the banding?
- Does the banding (dark & light areas) represent different mineralogical compositions?

Photo: Jessica E-B, NDSU 2014

We will carry out analysis to answer these questions.

Methods

Hand Specimen

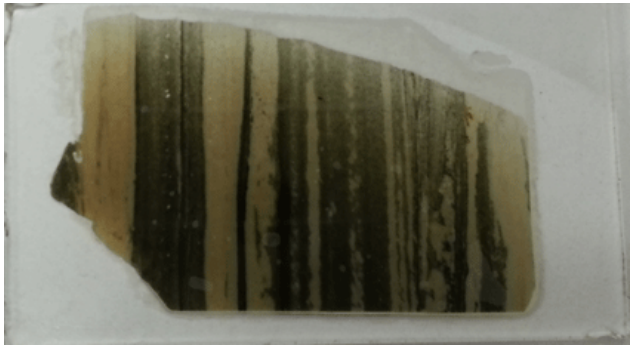
- Texture: fine grained rock
- Appearance: consists of bands of light & dark colored grains
- Average width of bands:
  Light: 2.8mm
  Dark: 2.25mm
- Hardness: 8-9
  easily scratches glass
- Specific Gravity: 2.94

a close up photo of the banded sediment. Card for scale. (Photo by Amos, NDSU)

Methods

Petrographic Microscopy (thin section)

- using a saw, we cut sample into a small piece
- glued the piece on to a thin glass plate using epoxy
- cut the piece to a very thin slide using a special machine at the EM lab
- used 400 micron grit to sand the sample to a thickness of 30 microns



Photos: Jessica E-B, NDSU 2014

Methods

XRD Diffraction (XRD) Preparation

- crushed sample

crushing rock into fine grains (above)
separating dark colored grains from light colored grains (below)

- separated light colored grains from dark colored ones

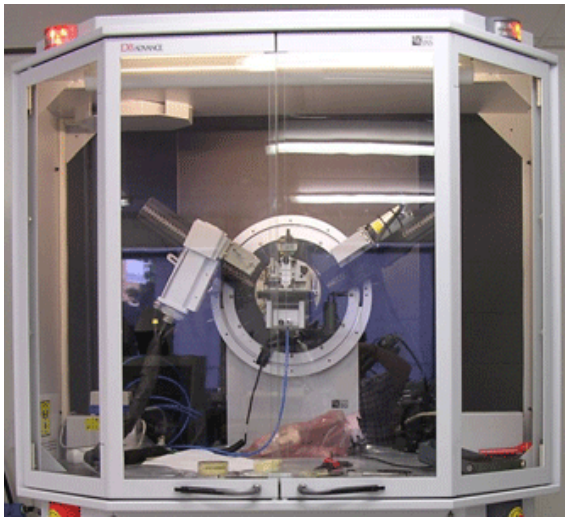
(Photo: by Jessica E-B, NDSU)

Methods

XRD Diffraction (XRD)

Preparation

- grains grounded into very fine powder
- Mixed ethanol with the powder to create a thin layer on a slide
- Run sample in XRD



(photo: by Jessica, NDSU)

Methods

Scanning Electron Microscopy (SEM)

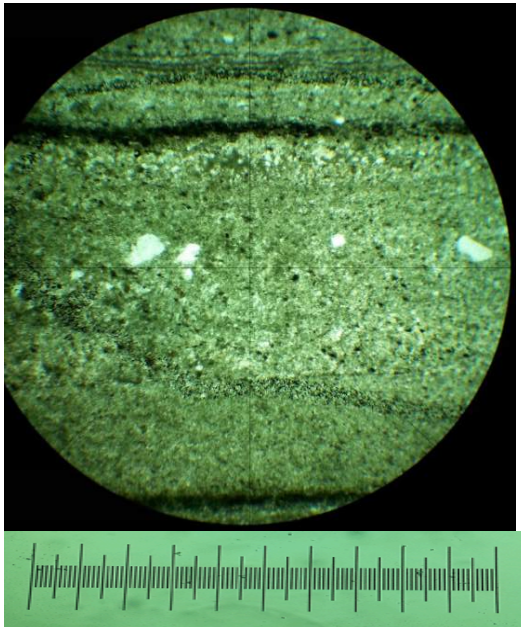
Photo: Center, Amos A., NDSU 2014. Left and right, Jessica E-B, NDSU 2014.

- SEM uses an electron beam that produces a signal when it come in contact with the surface of the sample
- Our slide was coated with carbon to increase the electrical conductivity
- We chose to do an SEM test to identify larger grains found with in our sample

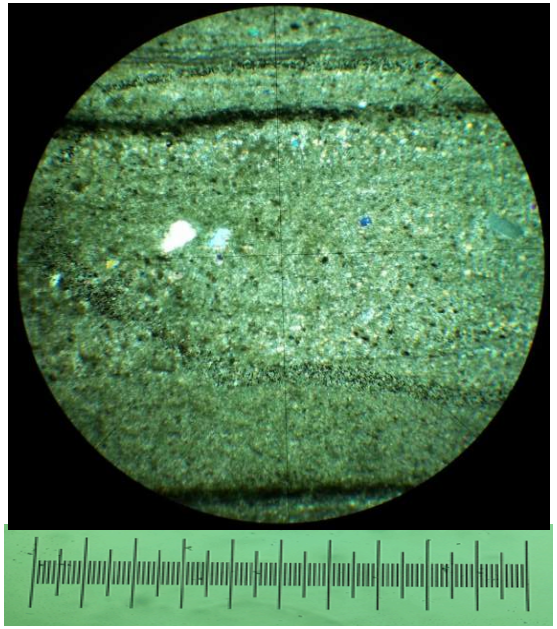
Analysis/Results

Thin Section Microscopy

PL



XPL



Field of view 2mm

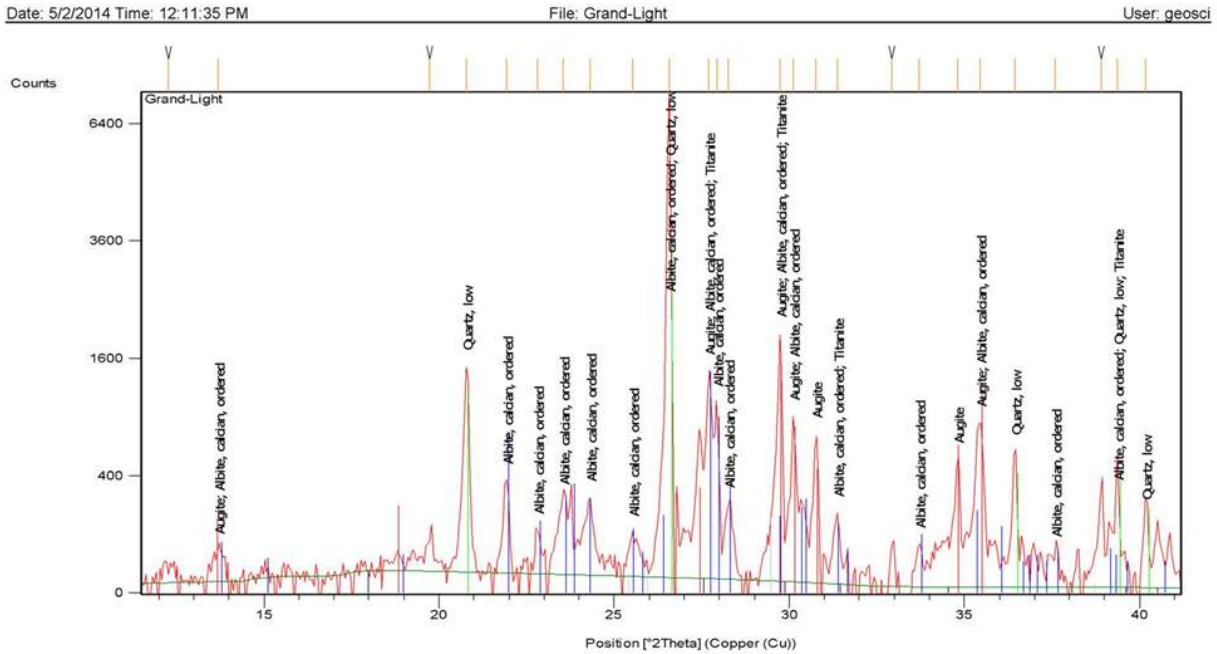
- Grains appear to fine upward
- Larger grains were analyzed using SEM
- Turbidity currents in the depositional environment may explain the fining upward banding

Matrix of very fine and coarse grains as viewed under plain polarized light (ppl) left, and cross polarized light (XPL) right. (Photo by Amos, NDSU)

Analysis/Results

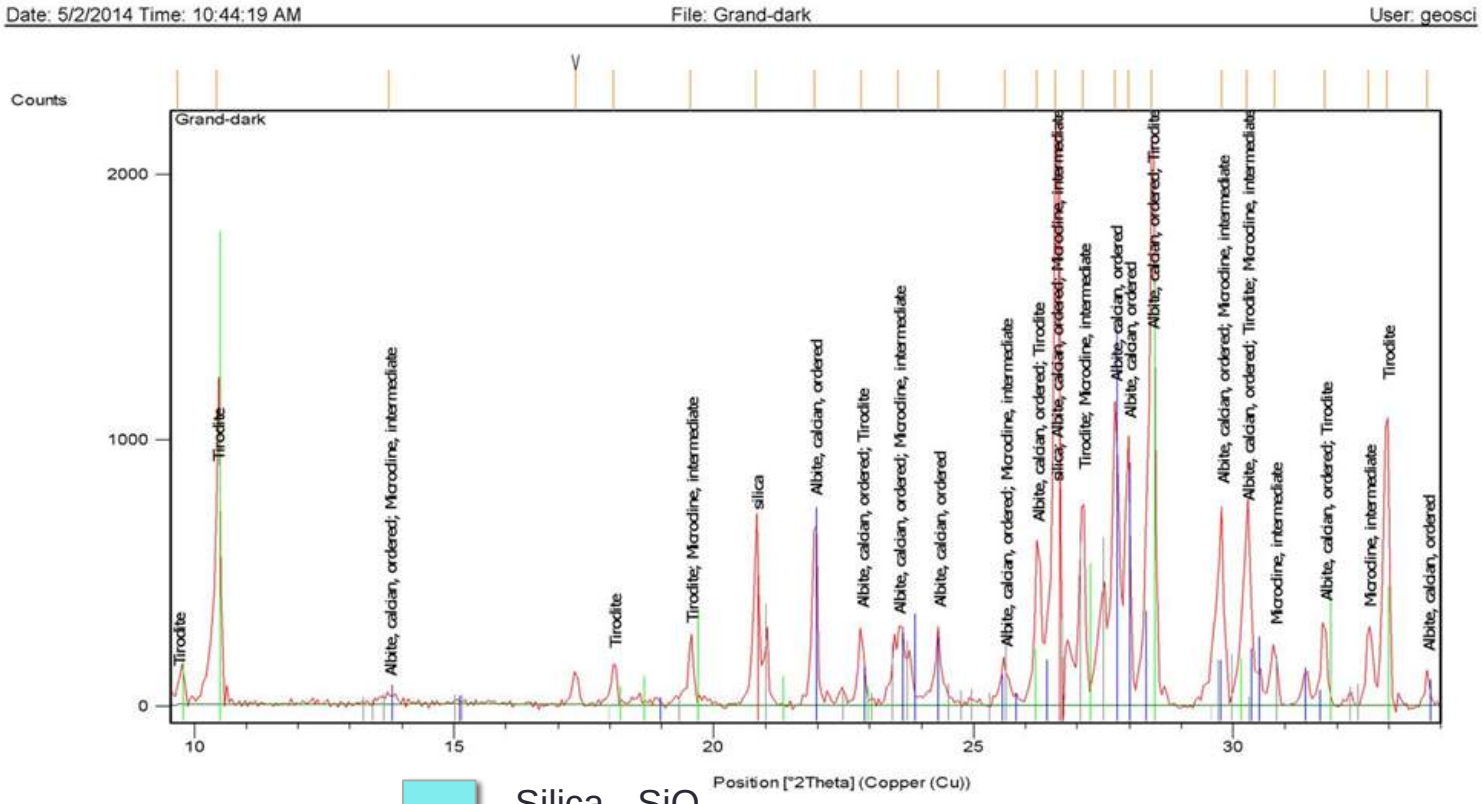
X-Ray Diffraction (XRD)

Light Bands



- Titanite – $CaTiSiO_5$
- Albite – $NaAlSi_3O_5$
- Silica - SiO_2
- Augite- $Ca(Fe, Mg)Si_2O_6$

Analysis/Results
X-Ray Diffraction (XRD)
Dark Bands



Silica - SiO_2

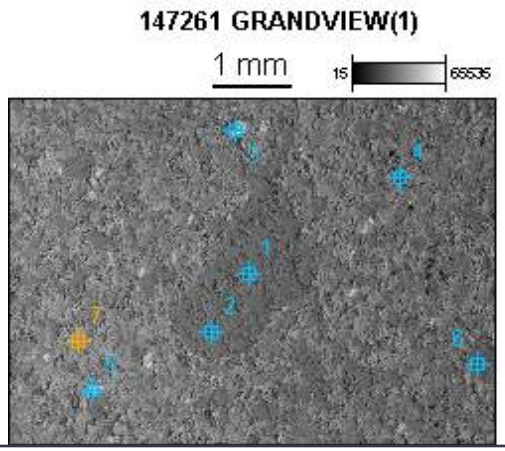
Albite – $NaAlSi_3O_5$

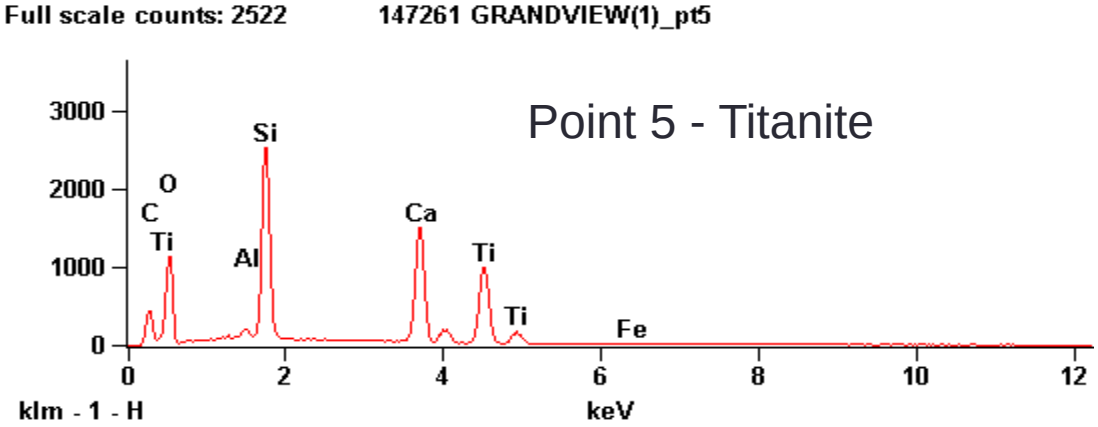
Microcline –$KAlSi_3O_8$

Tirodite - $Mn_2(Mg,Fe)_5Si_8O_{22}(OH)_2$

Analysis/Results

Scanning Electron Microscopy (SEM)

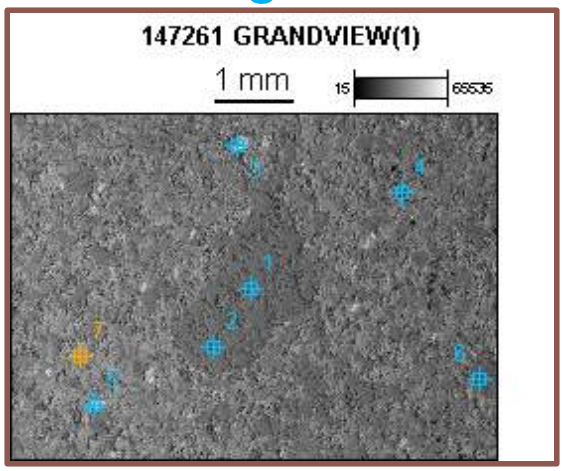




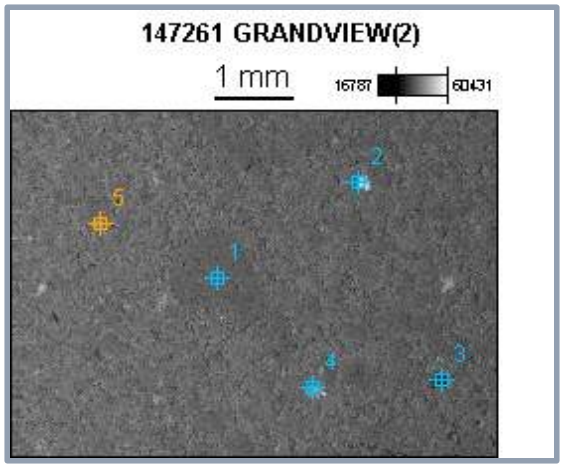
Oxide	Wt%	Molecular Wt.	Molecular Proportions	Cations	Oxygen	On basis of 6 O	Atomic Ratio
TiO_2	40.74	79.87	0.51	0.51	1.02	1.007	1
SiO_2	28.95	60.00	0.48	0.48	0.96	0.94	1
CaO	28.49	56	0.51	0.51	0.51	1.006	1
Fe_2O_3	0.81	160	0.005	0.01	0.015	0.01	0
Al_2O_3	1.07	101.96	0.009	0.018	0.027	0.035	0
Total	100.06				2.532		

Analysis/Results

Scanning Electron Microscopy (SEM)



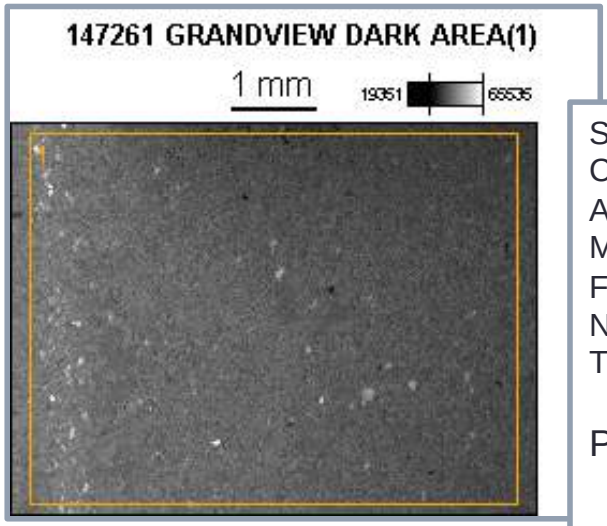
1. Quartz – SiO_2
2. Quartz – SiO_2
3. Ilmenite – $FeTiO_3$
4. Quartz – SiO_2
5. Titanite - $CaTiSiO_5$
6. Quartz – SiO_2
7. Augite – $(Ca, Na)(Mg, Fe, Al)(Si, Al)_2O_6$



1. Quartz – SiO_2
2. Zircon – $ZrSiO_4$
3. Clinopyroxene – $(Ca, Mg, Fe, Al)_2(Si, Al)_2O_6$
4. Titanite - $CaTiSiO_5$
5. Titanite - $CaTiSiO_5$

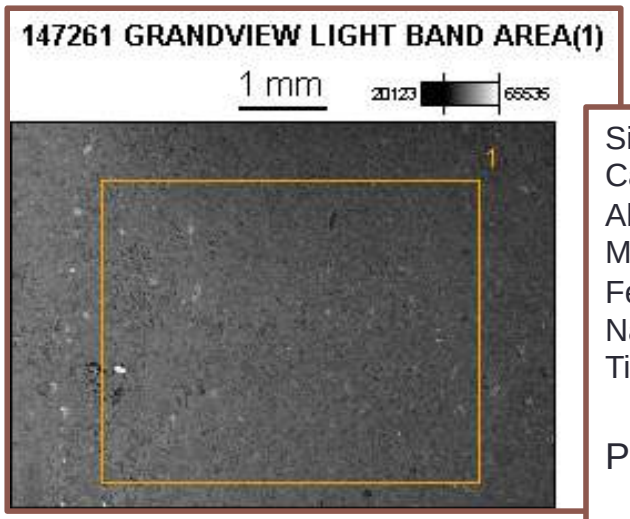
Analysis/Results

Whole rock chemistry (SEM)



SiO_2 65%
CaO 10%
Al_2O_3 10%
MgO 5%
Fe_2O_3 5%
Na_2O 3%
TiO_2 2%

Plagioclase
+
Quartz



SiO_2 65%
CaO 10%
Al_2O_3 10%
MgO 5%
Fe_2O_3 5%
Na_2O 3%
TiO_2 2%

Plagioclase
+
Quartz

Possible Answers to Our Questions

- Did our sample come from the Nopeming sandstone or a different rock unit?

  Most likely
  - It lies below the Ely's Peak Basalt and above the Thomson FM
  - Its composition is consistent with typical sandstones

- What could have caused the banding?
  - The banding may have been caused by turbidity currents resulting in graded bedding (Ashworth, 2014)
  - Deposited in a lake environment
  - Bedded cherts are most often associated with slopes and mass transport. They are frequently found with clinoforms, grain flow and slump deposits (Chatellier, 2004).

- Does the banding (dark & light areas) represent different mineralogical compositions?

  Yes, the light bands contain the minerals titanite, augite, ablite and silica whereas the dark bands contain the minerals tirodite and microcline, in addition to albite and silica

Interpretation

- Manganocummingtonite (tirodite) $Mn_2(Mg,Fe)_5Si_8O_{22}(OH)_2$, the mineral found in the dark bands is an alkali-and Mn-rich amphibole that forms a series with manganogrunerite
- It is commonly found in metamorphosed manganese- rich rocks
- It is likely that this mineral resulted from contact metamorphism of the rock unit by the lava that crystallized the basalts above it

Based on our research analysis, we believe our rock is a banded chert.

- The hardness of our rock (8-9) is higher then a typical chert (6.5-7.5). It is possible that the heat from the Ely basalts caused our rock to become harder then a typical chert.
- Our sample was most likely deposited in a fluvial/lake environment which would provide the fine grains necessary to create chert.
- The conglomerates that underlie our rock layer is evidence of an area with mass transport. This is an ideal environment for the formation of chert.
- The data from our analysis also supports our interpretation
- Specific Gravity: Sample 2.93 Quartz 2.65

Conclusion

Other examples of banded chert

Banded chert from a Gravel Quarry north of Botwood, Newfoundland

Photo: Elfshotgallery.com, 2010.

Banded Chert from the United Verde mine in Jerome, AZ

Photo: vultureaz.blogspot.com, 2012 .

Reference

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