

***Mineralogy and Provenance of
Carboniferous Sandstone and Shale Units in
the Deer Lake and Bay St. George Basins,
Western Newfoundland***

Paul Sylvester

Memorial University, St. John's, Newfoundland, Canada

2:40 pm – 3:00 pm, June 18, 2012

The Suncor Energy Fluvarium, St. John's, NL

Project Outline

- Studies on provenance, distribution and prospectivity of shale units in DLB and BSGB as shale gas or conventional oil plays
- Porosity, TOC, form and distribution (image analysis) of organic materials in shales
- Provenance (inferred basin entry routes of paleodrainage) determined by
 - ❖ Mineralogy and geochronology of detrital accessory heavy phases (zircon, tourmaline, rutile, apatite, ilmenite, etc.)
 - ❖ Whole rock geochemistry (REEs, Nd isotopes)

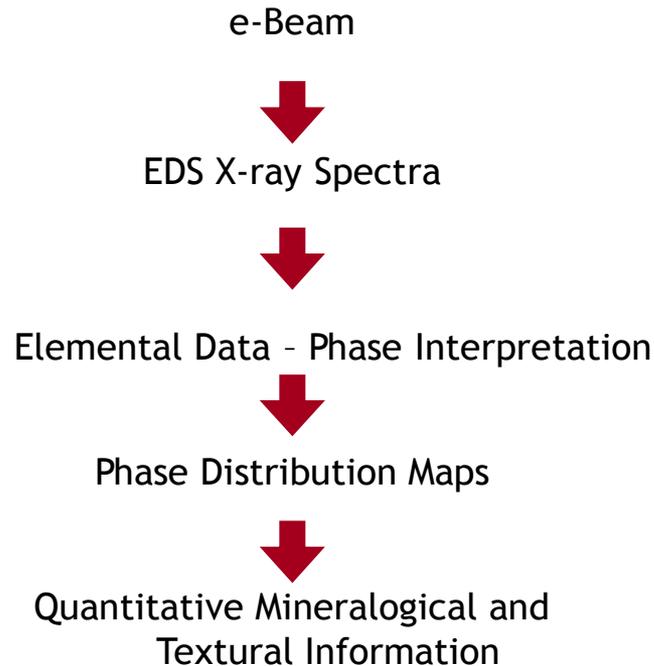
Accessory Detrital Mineralogy

- Relative abundances, compositions and ages of detrital minerals can pinpoint their source terranes
- Well-established method for sandstones
- 130+ years of research, based around optical microscopy and (since 1960s) electron microprobe
- Modern work includes automated scanning electron microscope (SEM-MLA); in situ dating (LA-ICPMS)
- Little work on shales due to very fine-grain sizes of clay (<4 μm) and silt (<63 μm) particles

Automated Mineralogy Fundamentals

Automated electron-beam analysis system:

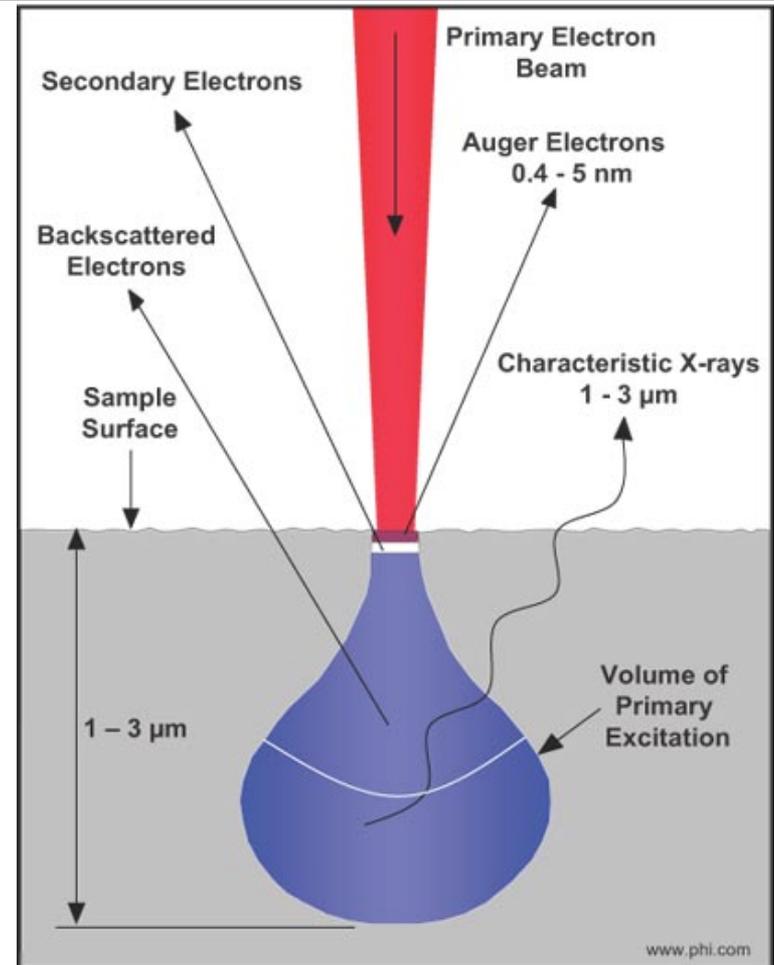
- Based on FEI Quanta SEM (W or FEG source)
- Custom software combines BSE and EDS x-ray detection,
- Multiple EDS detectors for accurate high-speed data acquisition.



MLA

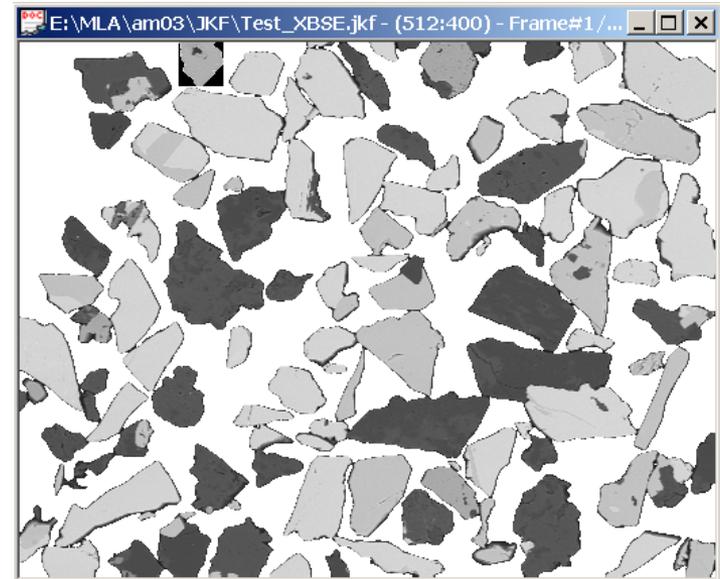
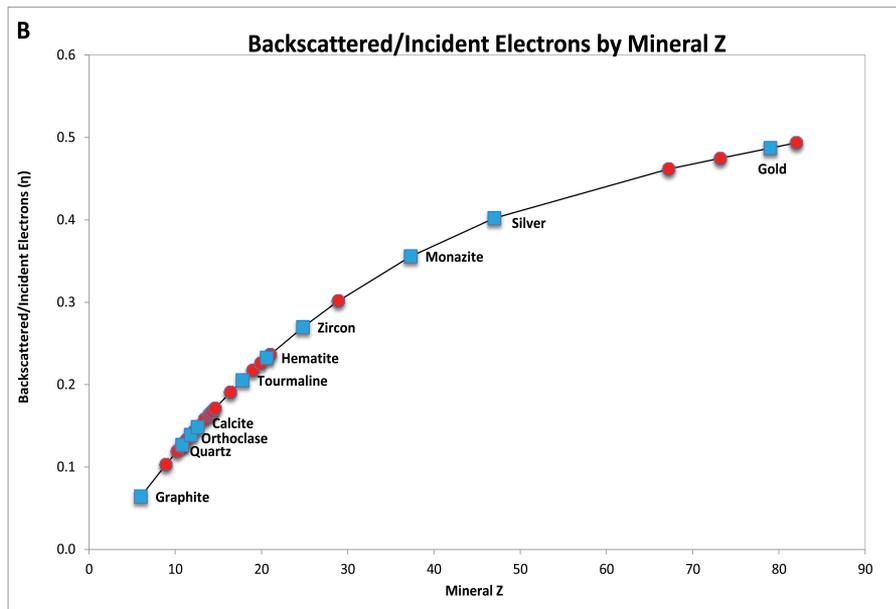
Electron Beam – Sample Interaction

- Electrons react with the specimen to produce three basic types of signals: backscatter electrons (BSE), secondary electrons (SE) and X-rays
- BSE and SE detector units pick up these signals and convert them to an amplified electrical signal which is then synchronised to the Scan Unit and displayed on the screen to produce an image
- Energy-dispersive X-ray (EDX) detectors collect the spectrum of energies of X-ray photons released



Backscattered Electron (BSE) Images

- Intensity of BSE signal proportional to the average atomic number (AAN) of the specimen, e.g., Gold has a relatively high AAN of 79.0 and appears bright, compared to Quartz (SiO_2) which has a low AAN of 10.8 and appears dark



Polished Particle Mounts

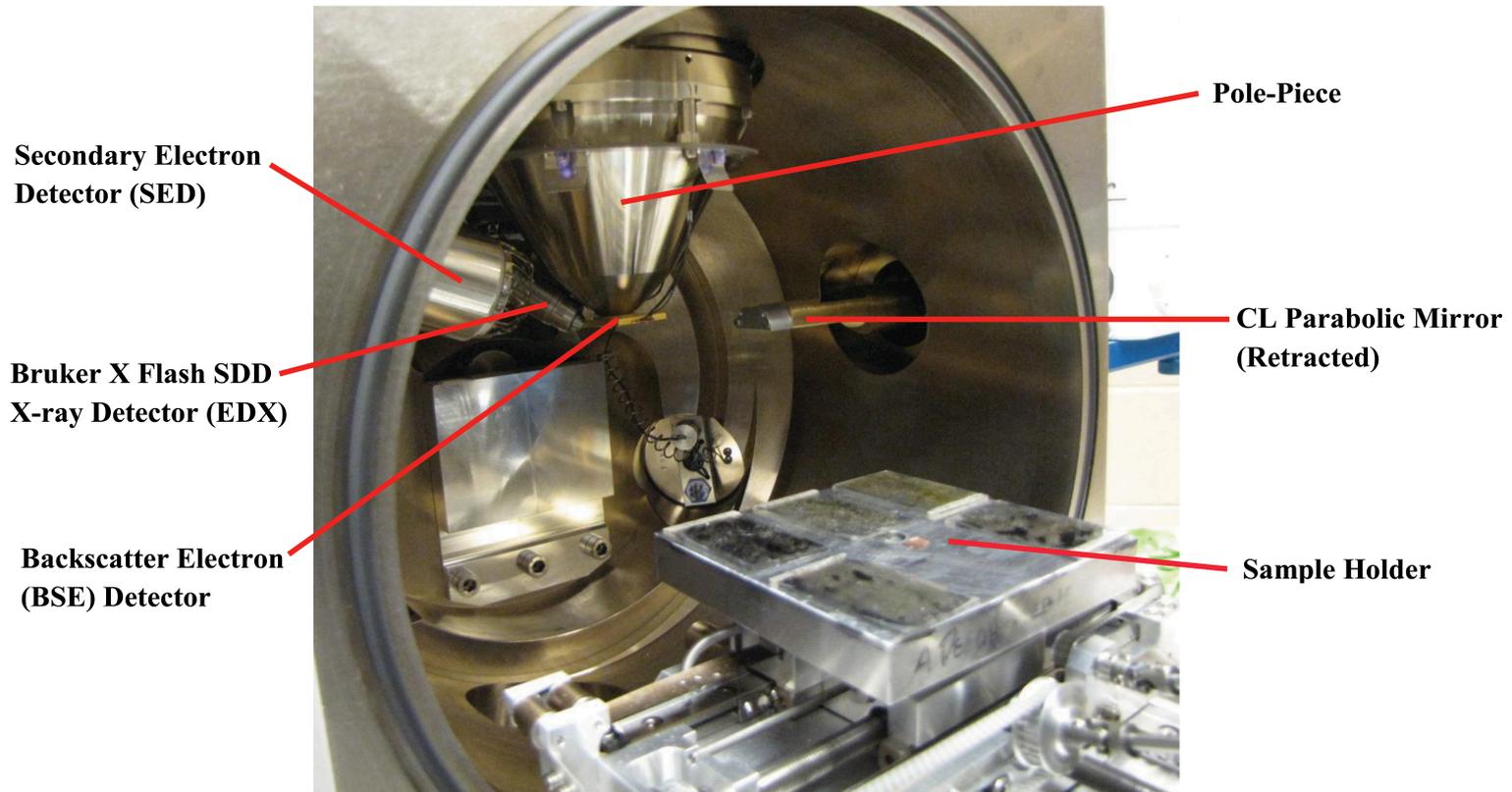
- Epoxy mounts of sediments or crushed sedimentary rocks
- Made after sieving the particles into discrete size fractions, typically
 - ❖ 63 to 125 microns (230 to 120 mesh),
 - ❖ 125 to 177 microns (120 to 80 mesh),
 - ❖ 177 to 354 microns (80 to 45 mesh)

~50,000 100 um particles



Polished Thin Sections

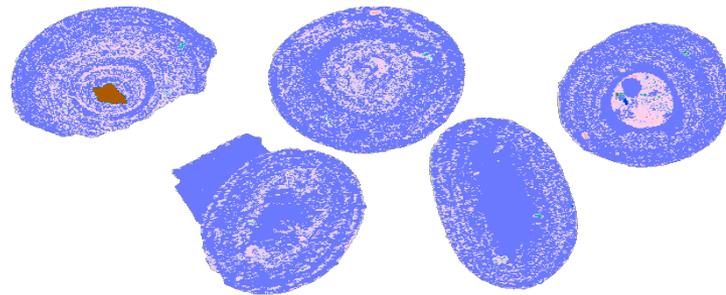
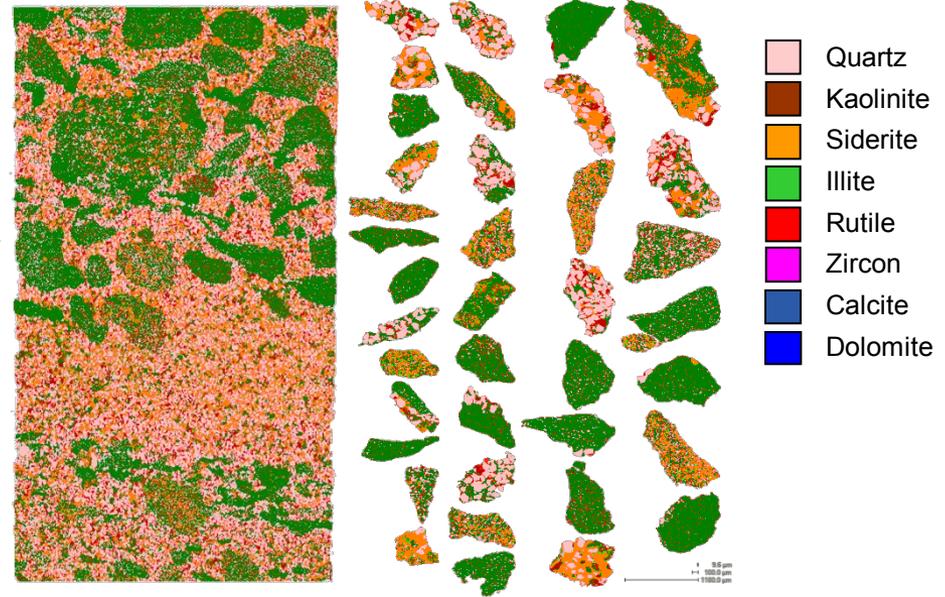
- Appropriate for finer-grained samples (shales) for which crushing and sieving muds is difficult



Signature Output and Data

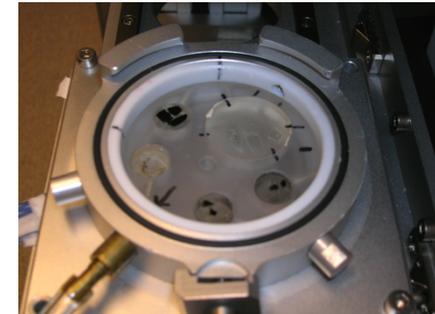
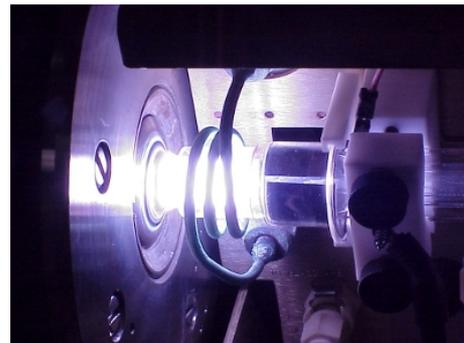
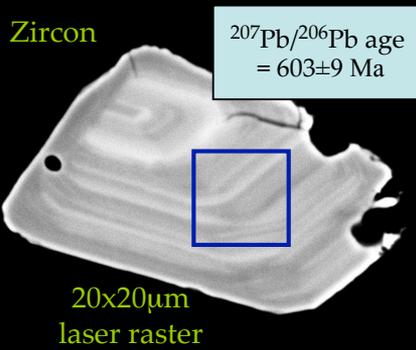
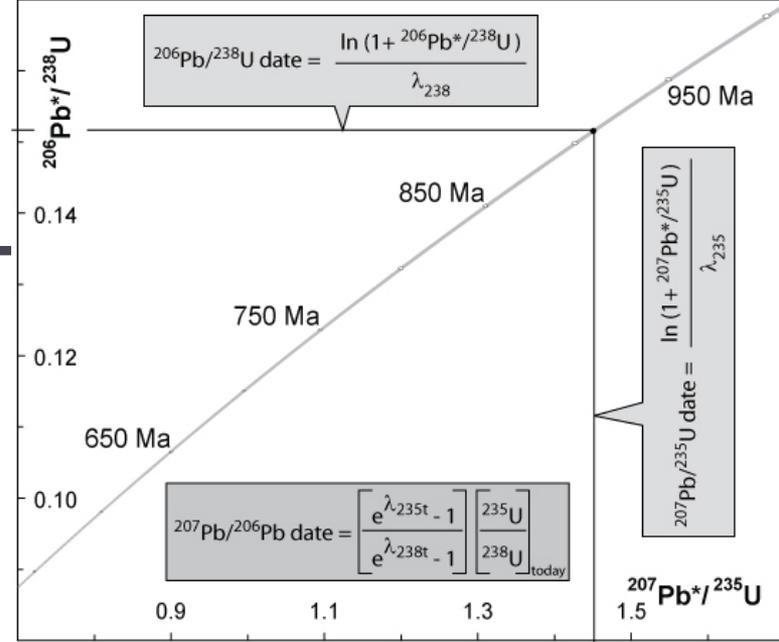
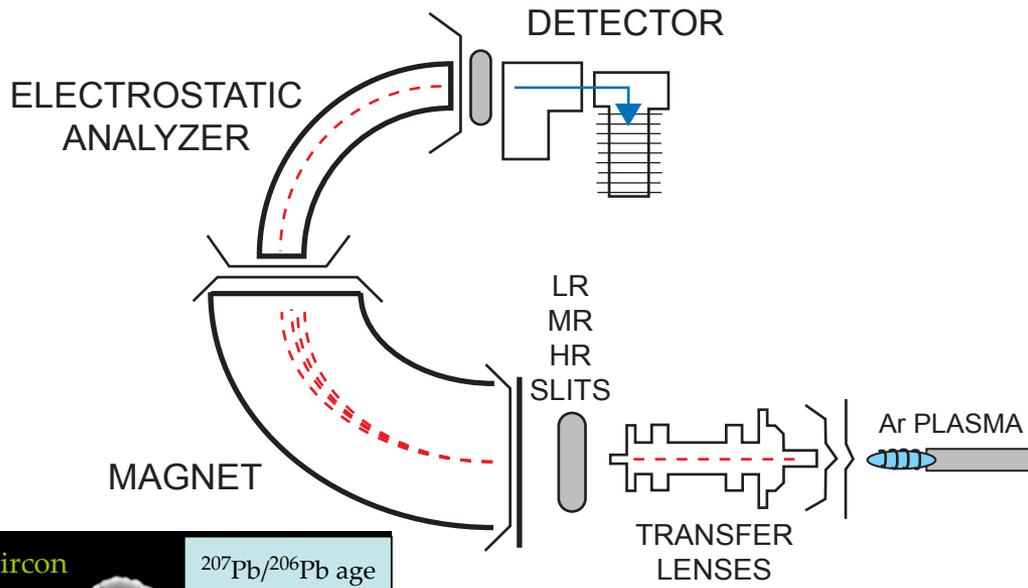
- Digital mineral maps
- Mineral Proportions
- Particle and Grain size
- Particle and Grain shape
- Mineral Processing Data
 - Liberation
 - Mineral Associations
 - Grade vs. Recovery
- Oil and Gas Data
 - Lithotyping
 - Porosity

Cuttings and core from same stratigraphic interval



Ooidal grainstone cuttings

In Situ U-Pb Dating by LA-ICPMS

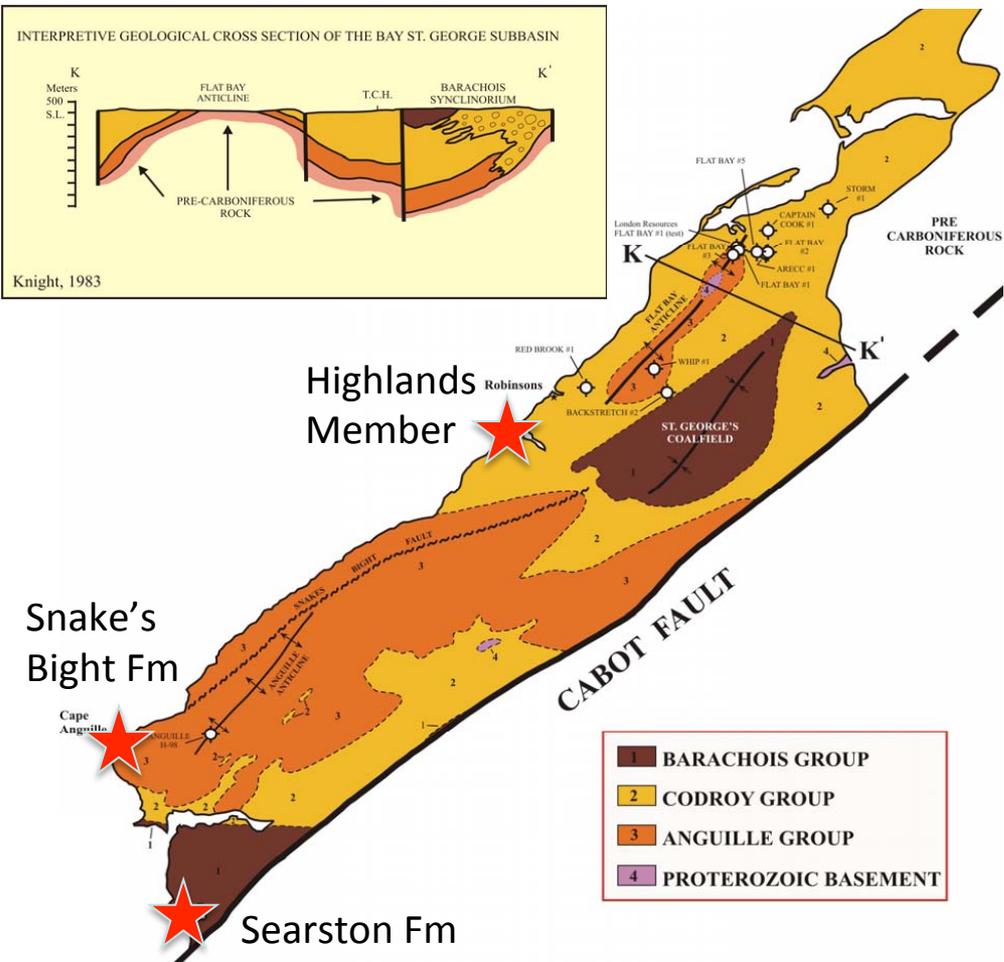


10/31/2007 HV Det WD Mag HPW 20.0um
2:14:30 PM 25.0 kV SSD 13.8 mm 2990x 90.42 um
MUN-IIC SEM/MLA

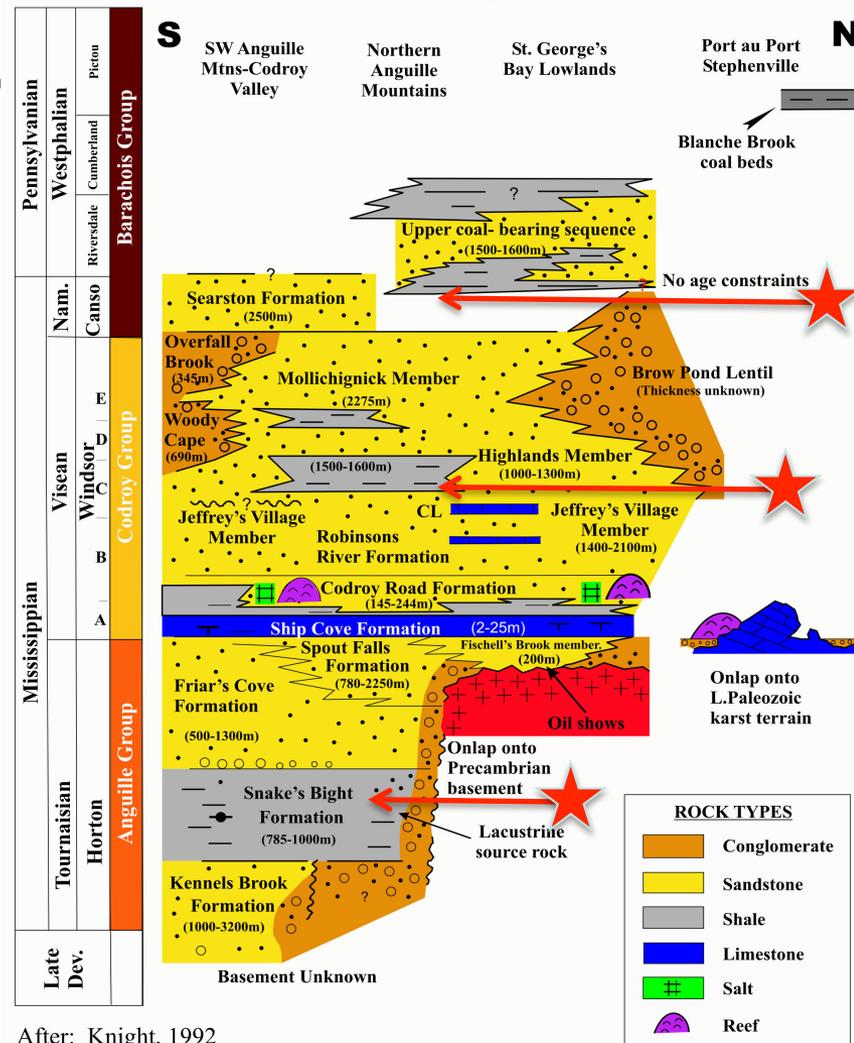
Preliminary Applications to Carboniferous Units in DL and BSG Basins

- Heavy mineral assessments of various shale (mudrock) intervals
- Comparisons of detrital sources in adjacent sandstone and shale units, using heavy minerals
- Distinguishing paleo-transport routes of detritus in sandstone units, using U-Pb ages of detrital zircons

Sample Locations – Bay St. George Basin



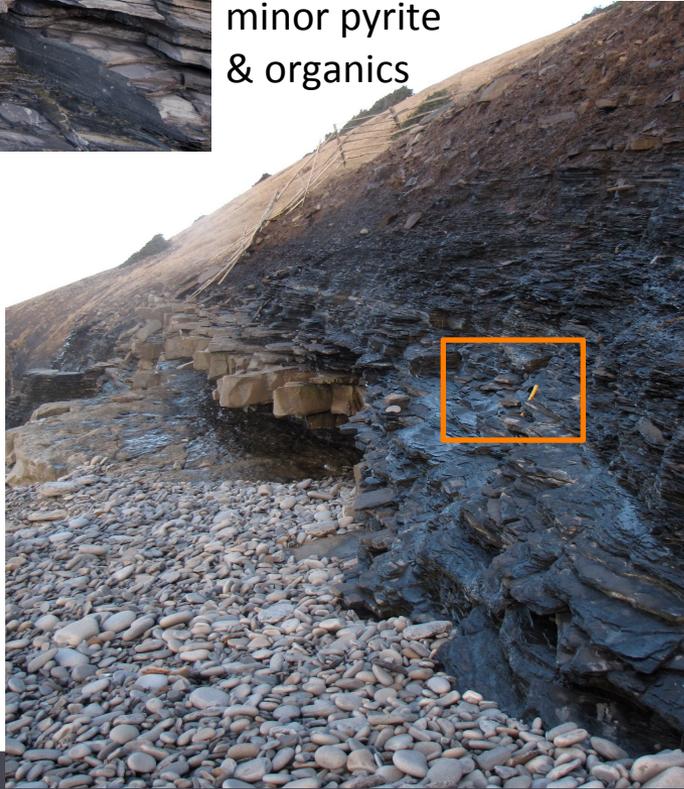
Carboniferous Stratigraphy Bay St. George Area



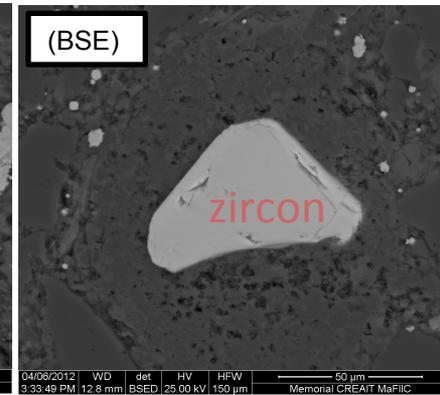
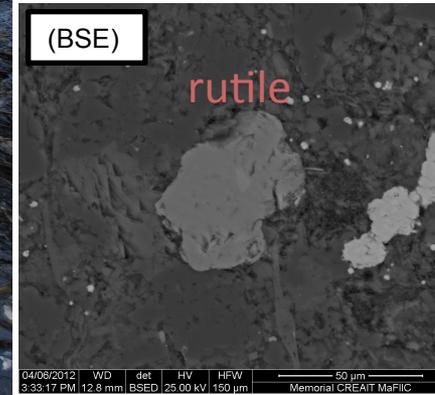
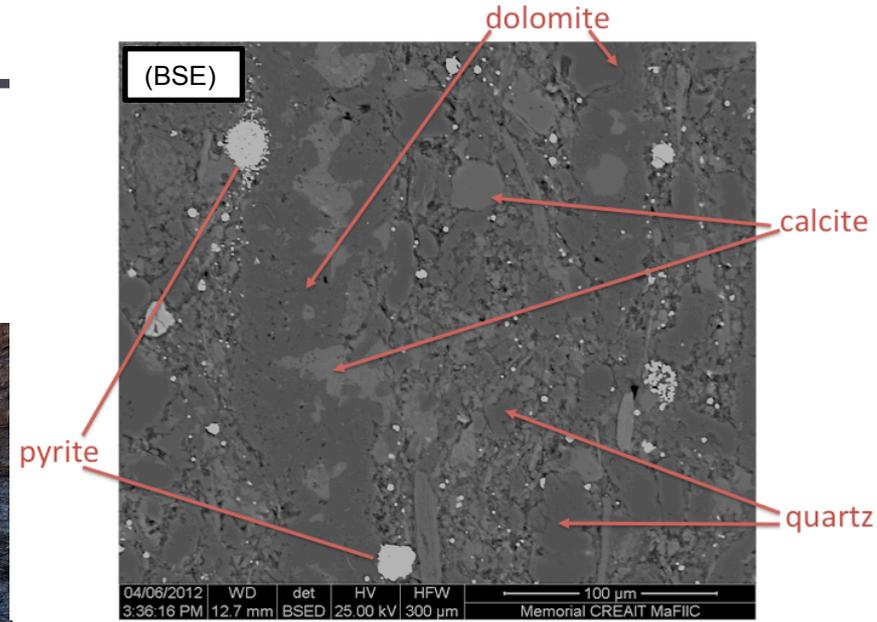
Black Shale, Snake's Bight Formation at Cape Anguille



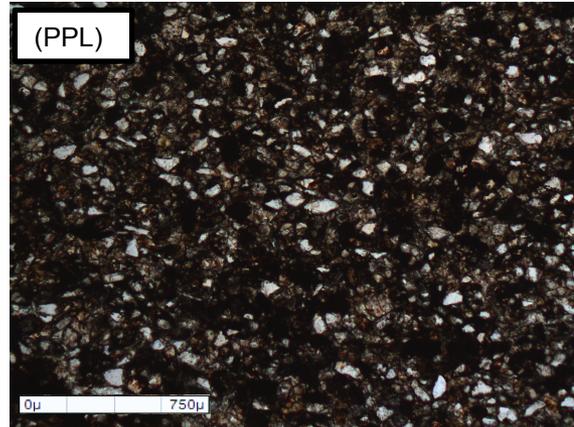
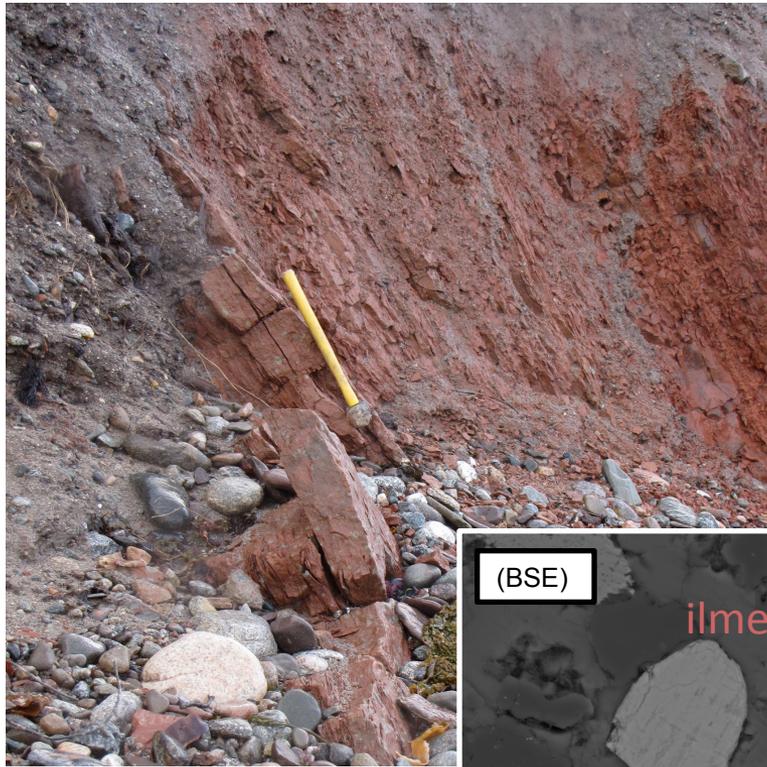
Fine-grained dolomite (30%), quartz (15%), feldspar (20%), clay minerals (10%) with minor pyrite & organics



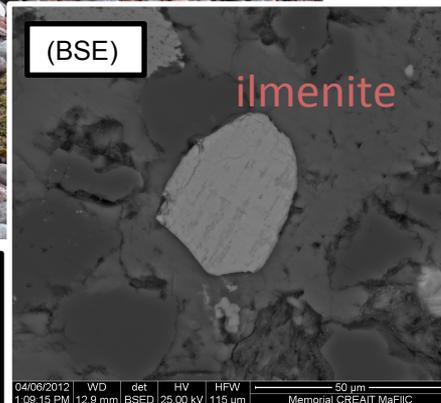
Contains 0.4 wt.% heavy minerals (~4,500 grains in thin section)



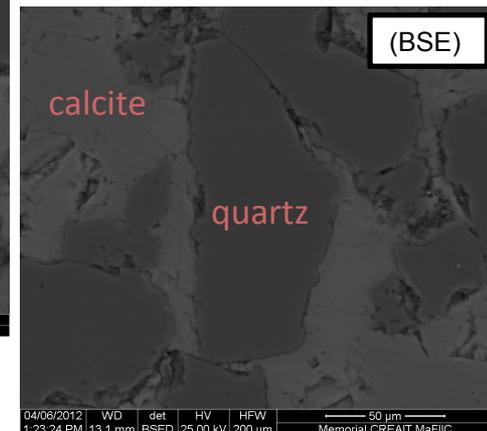
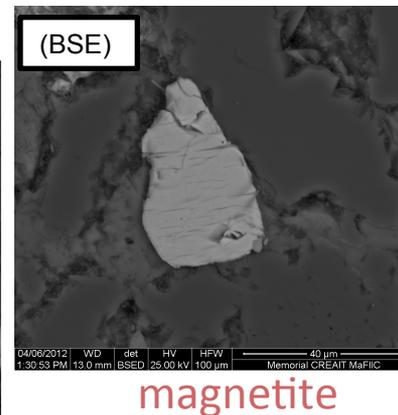
Tan Siltstone, Highlands Member, Robinsons River Formation at Crabbes Head



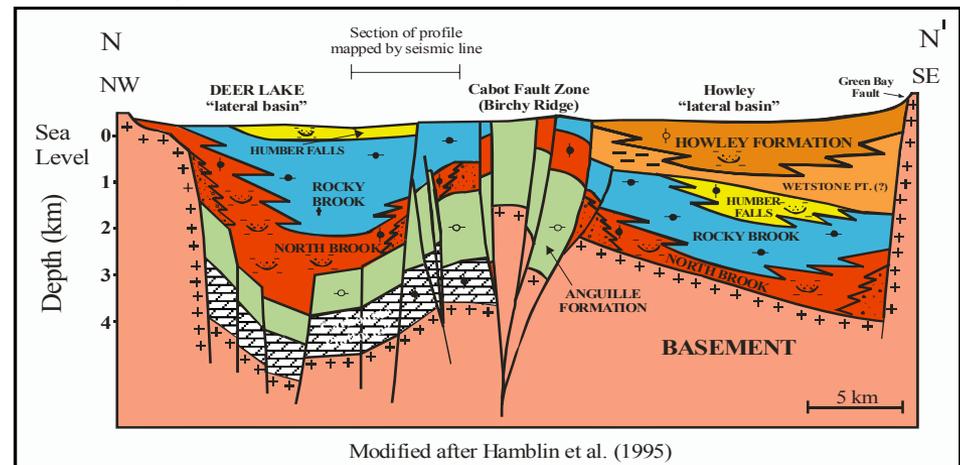
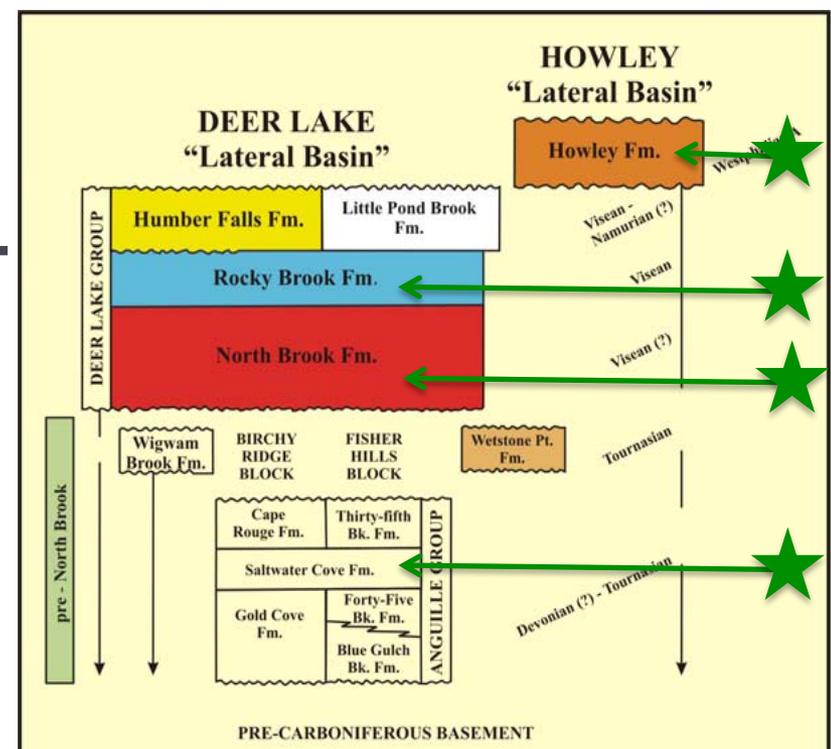
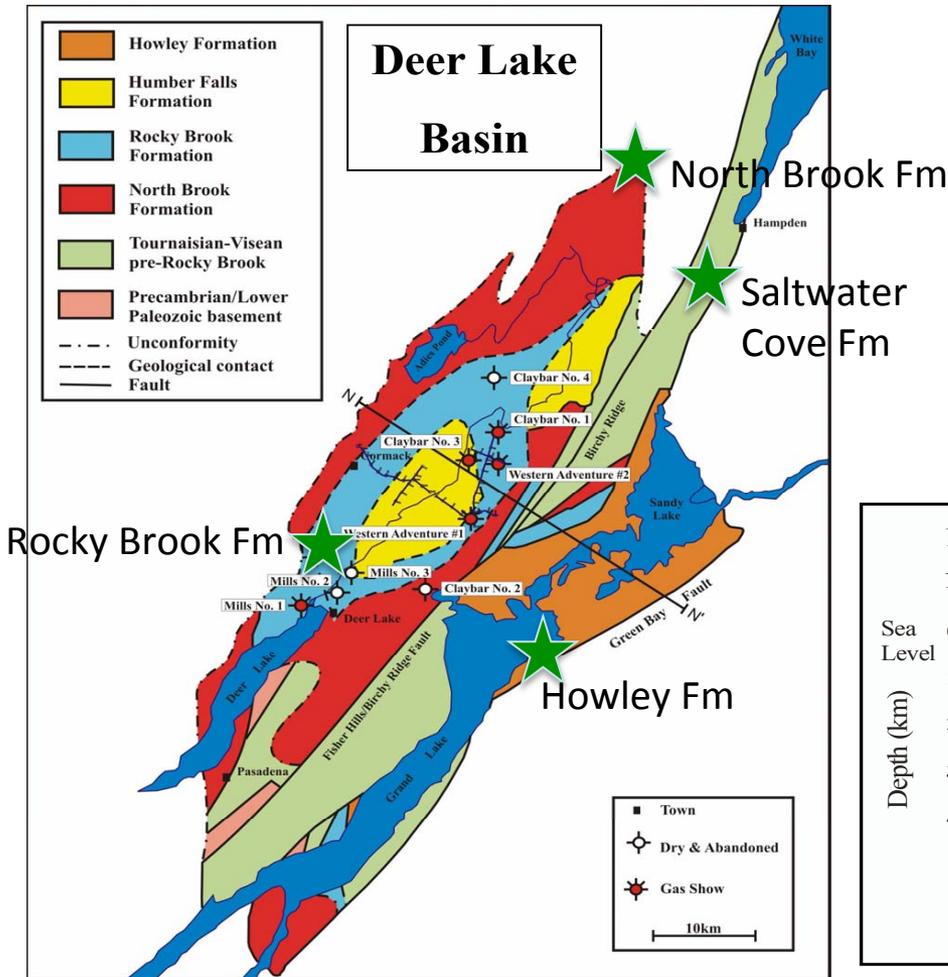
Quartz microclasts (40%), clay minerals & fine-grained feldspar set in pervasive calcite (30%) cement



Contains 1.3 wt.% heavy minerals (~10,000 grains in thin section)



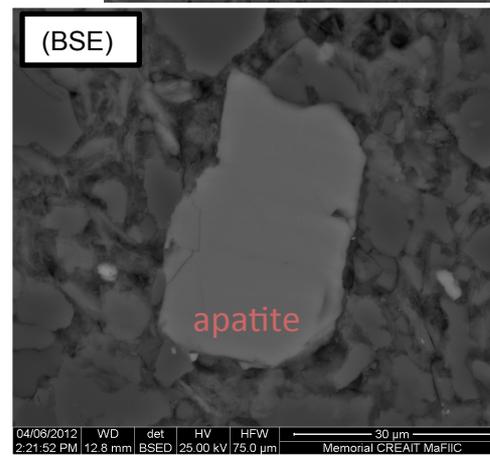
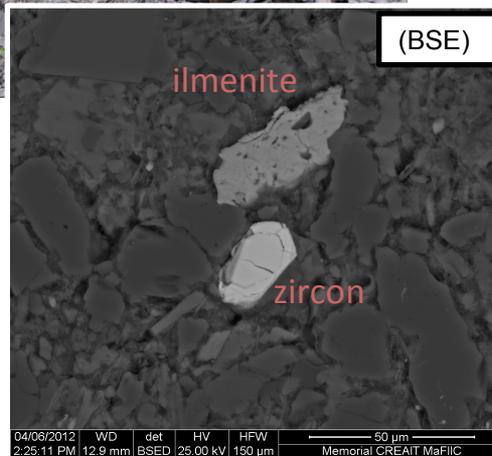
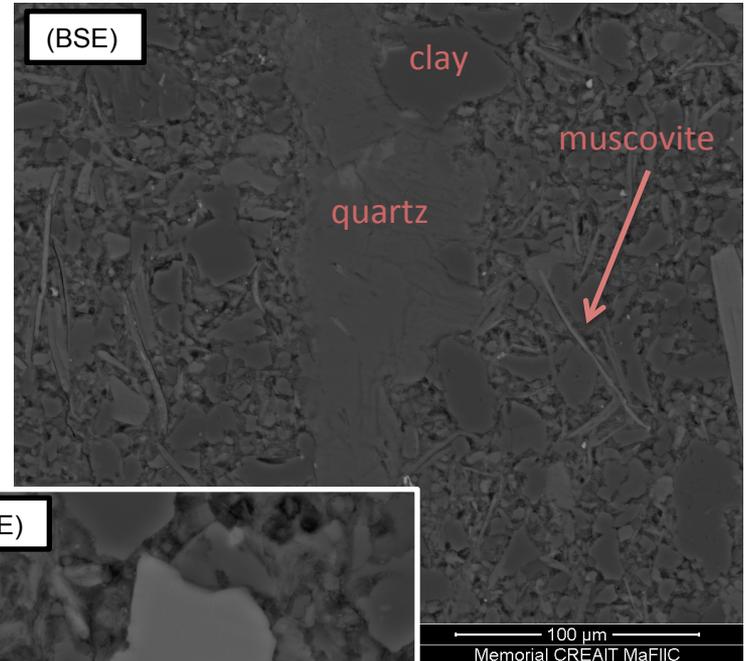
Sample Locations – Deer Lake Basin



Grey to Black Shale, Saltwater Cove Formation, along Sops Arm road



Fine-grained clay minerals (36%), quartz (22%), feldspar (20%), calcite (10%), mica (5%) with minor organics



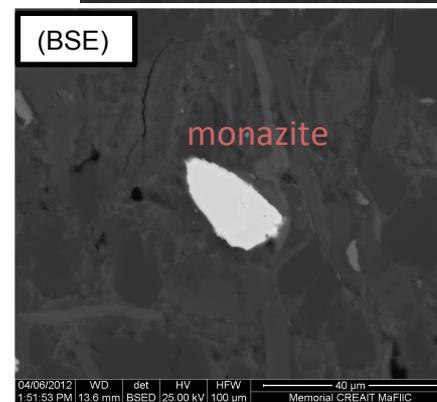
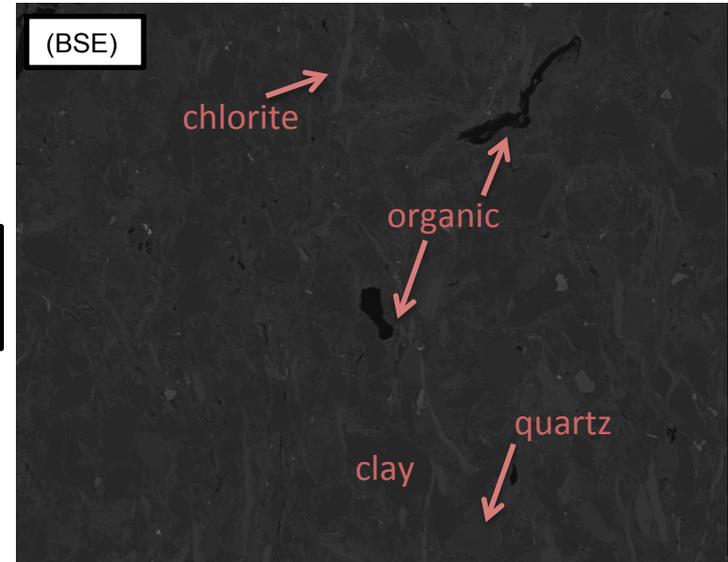
Contains 1.1 wt.% heavy minerals (~11,000 grains in thin section)

Grey to Black Shale, Rocky Brook Formation, Stream Bank, Highway 422

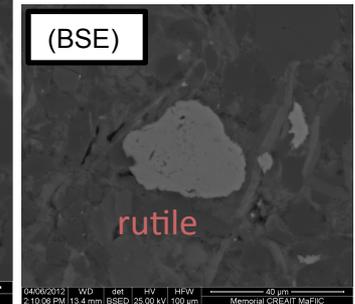


Fine-grained quartz (22%), clay minerals (20%), mica (19%), feldspar (18%), chlorite (16%), with minor calcite and organics

Contains 0.5 wt.% heavy minerals (~9,000 grains in thin section)



mag □ 100 µm
597 x Memorial CREAIT MaFIC



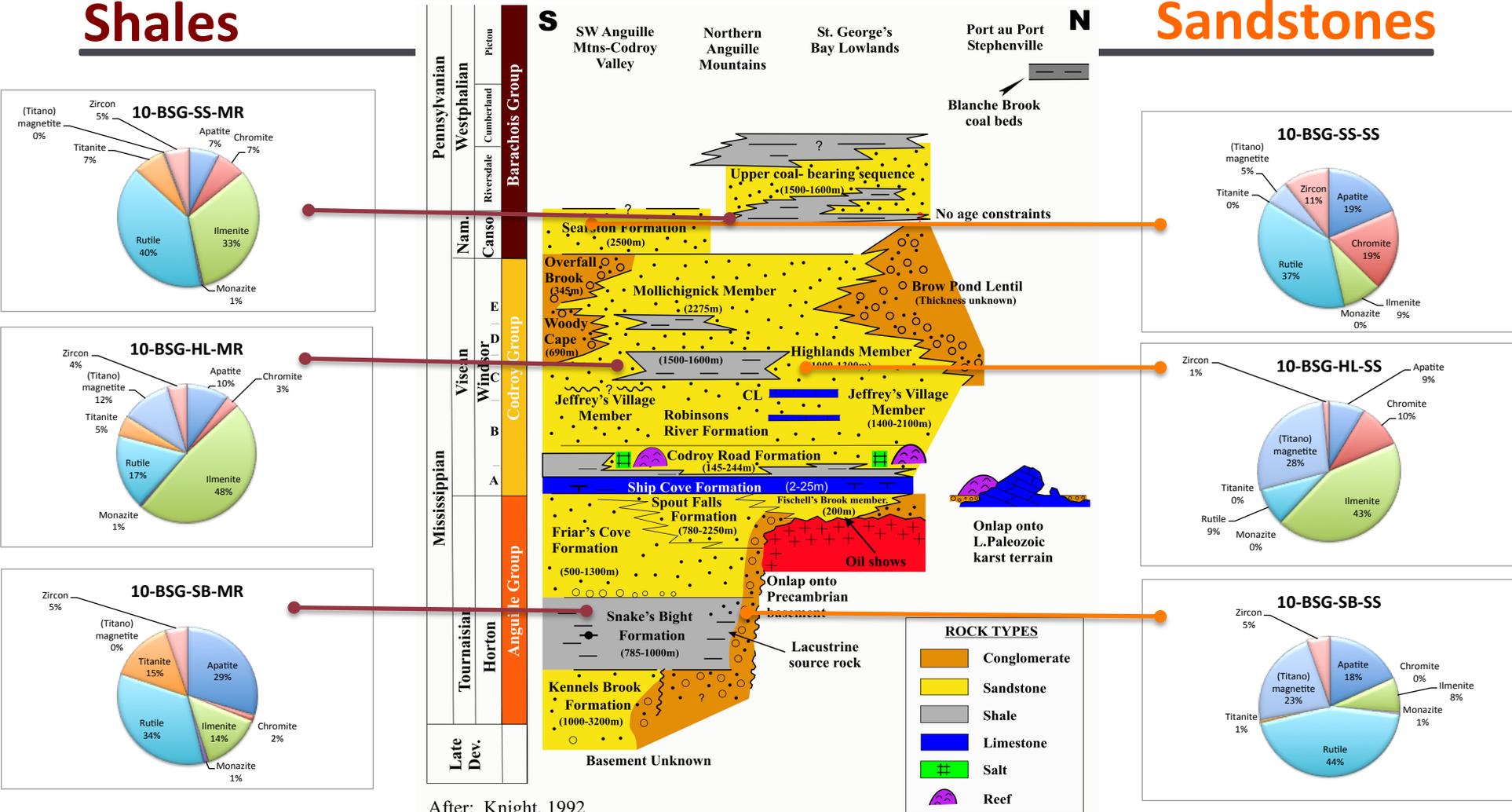
Preliminary Applications to Carboniferous Units in DL and BSG Basins

- Heavy mineral assessments of various shale (mudrock) intervals
- Comparisons of detrital sources in adjacent sandstone and shale units, using heavy minerals
- Distinguishing paleo-transport routes of detritus in sandstone units, using U-Pb ages of detrital zircons

Heavy Mineral Comparison – BSG Basin

Shales

Sandstones

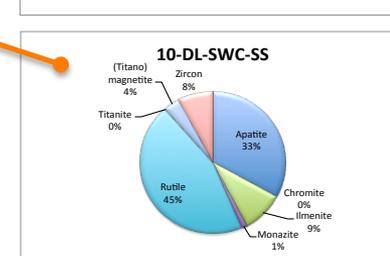
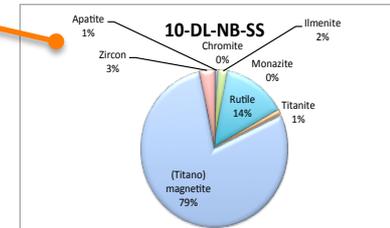
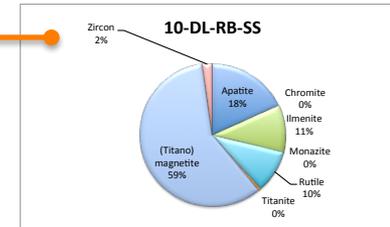
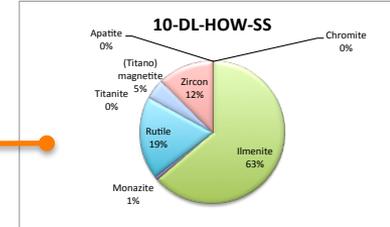
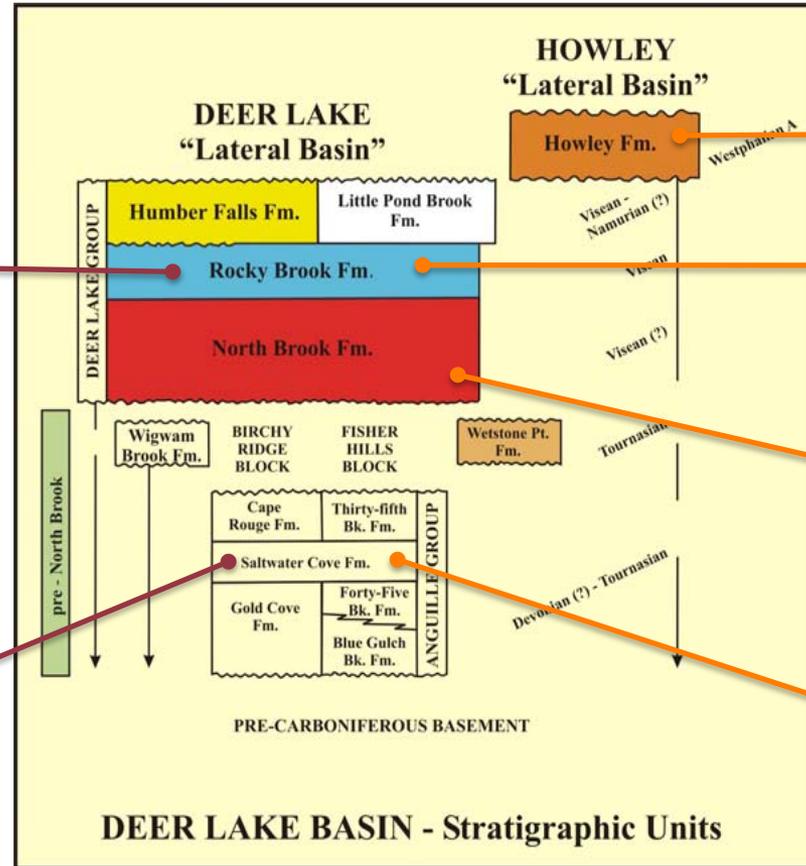
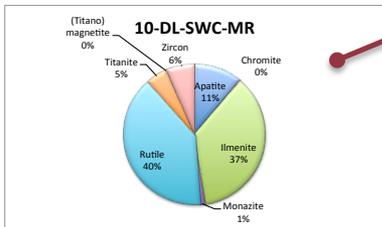
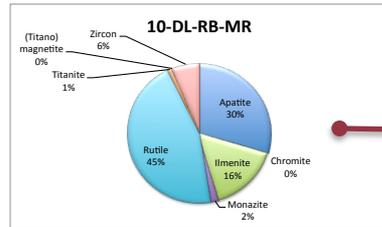


After: Knight, 1992

Heavy Mineral Comparison – DL Basin

Shales

Sandstones



Preliminary Applications to Carboniferous Units in DL and BSG Basins

- Heavy mineral assessments of various shale (mudrock) intervals
- Comparisons of detrital sources in adjacent sandstone and shale units, using heavy minerals
- Distinguishing paleo-transport routes of detritus in sandstone units, using U-Pb ages of detrital zircons

Detrital Zircon U-Pb Ages: BSG Basin

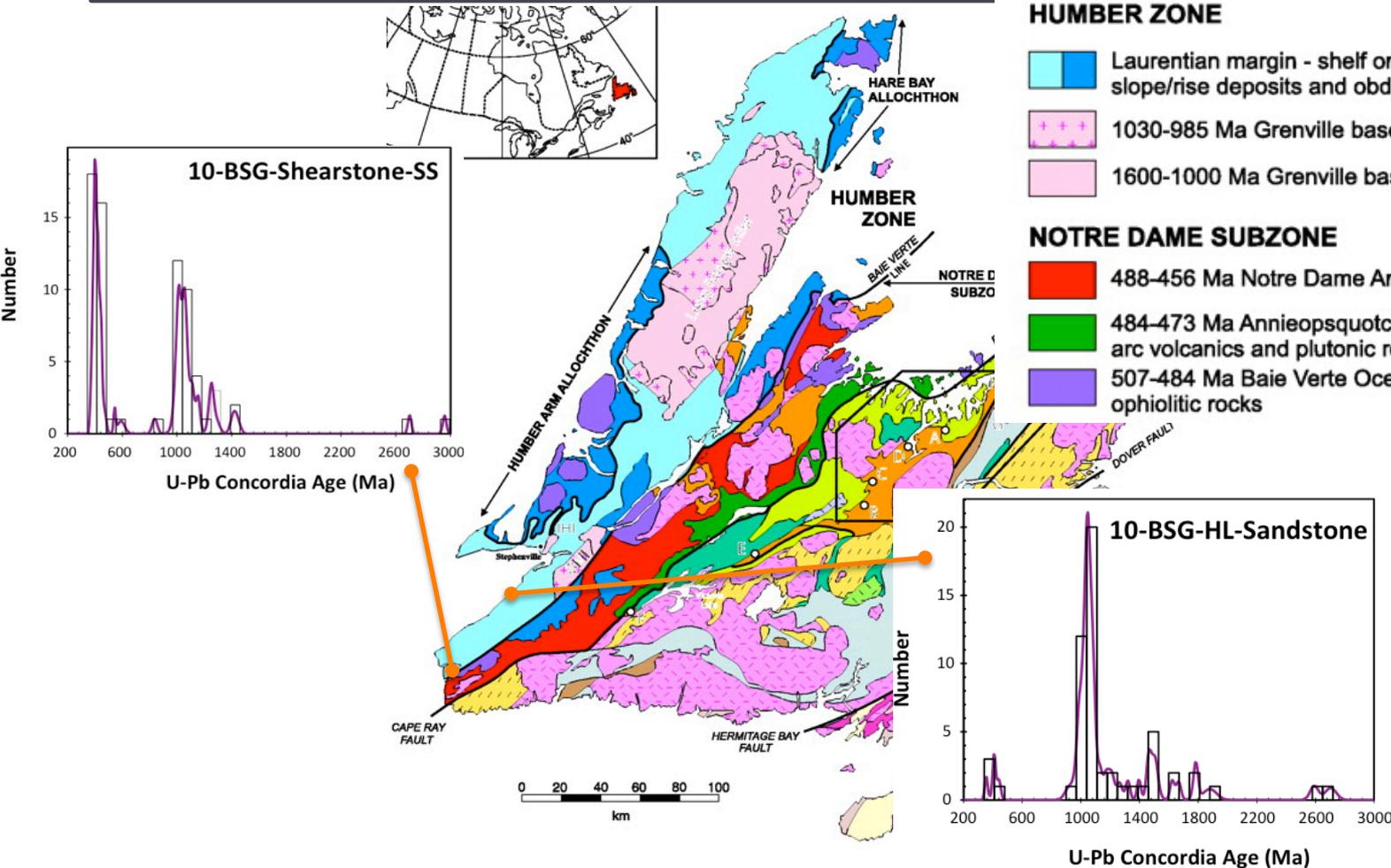
-  443 Ma and younger plutons
-  443 -ca. 410 Ma shallow marine and subaerial clastic sedimentary rocks southeast of Dog Bay Line
-  443 -ca. 410 Ma shallow marine and subaerial clastic sedimentary and volcanic rocks northwest of Dog Bay Line

HUMBER ZONE

-  Laurentian margin - shelf or undivided; rift & slope/rise deposits and obduction melange
-  1030-985 Ma Grenville basement intrusions
-  1600-1000 Ma Grenville basement gneiss

NOTRE DAME SUBZONE

-  488-456 Ma Notre Dame Arc volcanic & plutonic rocks
-  484-473 Ma Annieopsquotch Accretionary tract arc volcanics and plutonic rocks
-  507-484 Ma Baie Verte Oceanic tract volcanic and ophiolitic rocks



Detrital Zircon U-Pb Ages: DL Basin

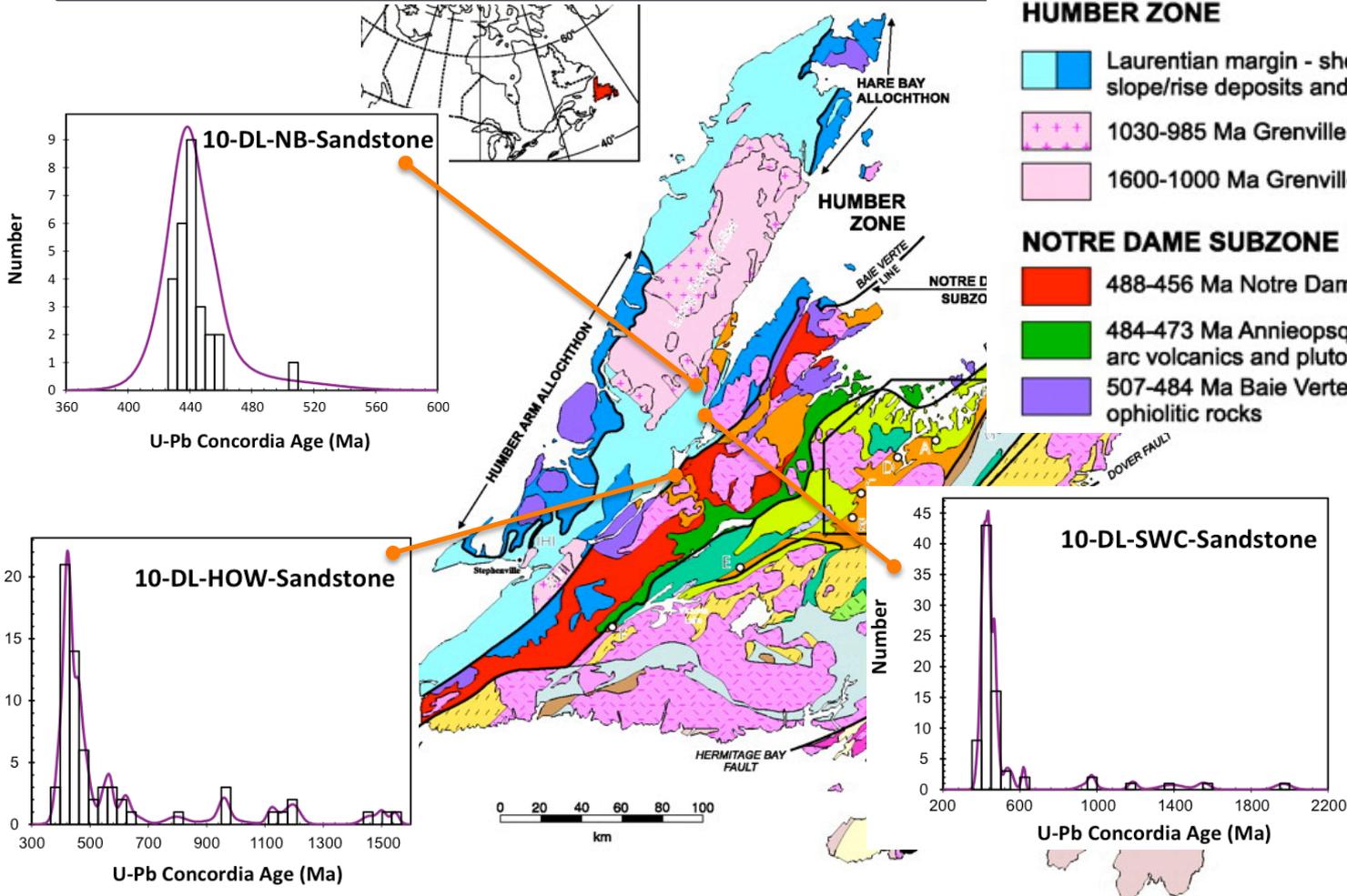
-  443 Ma and younger plutons
-  443 -ca. 410 Ma shallow marine and subaerial clastic sedimentary rocks southeast of Dog Bay Line
-  443 -ca. 410 Ma shallow marine and subaerial clastic sedimentary and volcanic rocks northwest of Dog Bay Line

HUMBER ZONE

-  Laurentian margin - shelf or undivided; rift & slope/rise deposits and obduction melange
-  1030-985 Ma Grenville basement intrusions
-  1600-1000 Ma Grenville basement gneiss

NOTRE DAME SUBZONE

-  488-456 Ma Notre Dame Arc volcanic & plutonic rocks
-  484-473 Ma Annieopsquotch Accretionary tract arc volcanics and plutonic rocks
-  507-484 Ma Baie Verte Oceanic tract volcanic and ophiolitic rocks



Summary

- Presence of significant abundances of heavy minerals in shales holds considerable promise for understanding their provenance and depositional relationships with interbedded sandstones
- Heavy minerals in some interbedded shales & sandstones in the Deer Lake & Bay St George basins suggest similar detrital sources with the exception of an example in the Rocky Brook Fm
- Detrital zircon U-Pb ages indicate that sandstones deposited on the eastern sides of the DL and BSG basins are dominated by Silurian-Ordovician detritus of the Notre Dame subzone (as expected) but also received minor amounts of Grenville-derived detritus, presumably via paleodrainage routes from the west