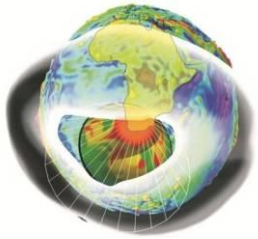


10th Inkaba yeAfrica/!Khure Africa (AEON) Conference/Workshop
Lord Milner Hotel, Matjiesfontein - Karoo
29 September – 3 October 2014

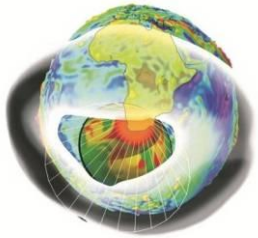
Characteristics of Permian gas-shales in the Lower Karoo Supergroup near Jansenville in the Eastern Cape, South Africa

Claire Geel [1,2] , Peter Booth[1], Maarten de Wit[1], Hans-Martin Schulz[2]

1. *Department of Geoscience, Nelson Mandela Metropolitan University, African Earth Observatory.*
2. *GFZ-German Research for Geoscience*

AEON
AFRICA EARTH OBSERVATORY NETWORK
EARTH STEWARDSHIP THROUGH SCIENCE

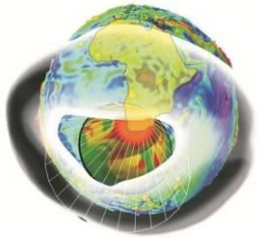
Nelson Mandela Metropolitan University



Project Aim:

- This study aims to create a better understanding the palaeo-depositional environment, thermal maturity and gas bearing potential of the lower Ecca Group in the Karoo Basin.

- Focus is placed on the fine grained mudrocks and shales of the Prince Albert, Whitehill and Collingham Formations, with particular interest in the Whitehill Formation black shale.



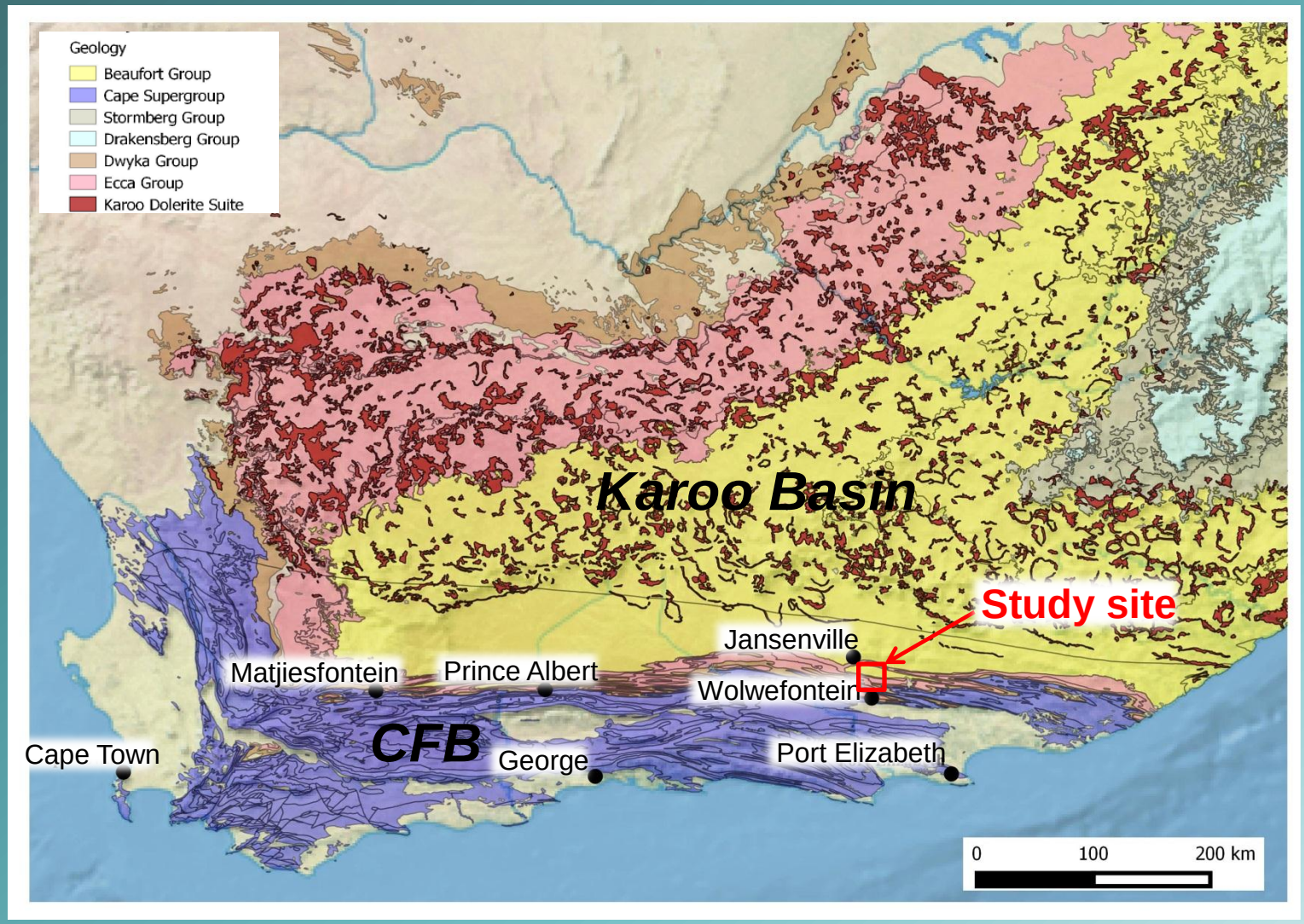
Outline:

1. Mapping of the Ecca Group in the Greystone area, near Jansenville

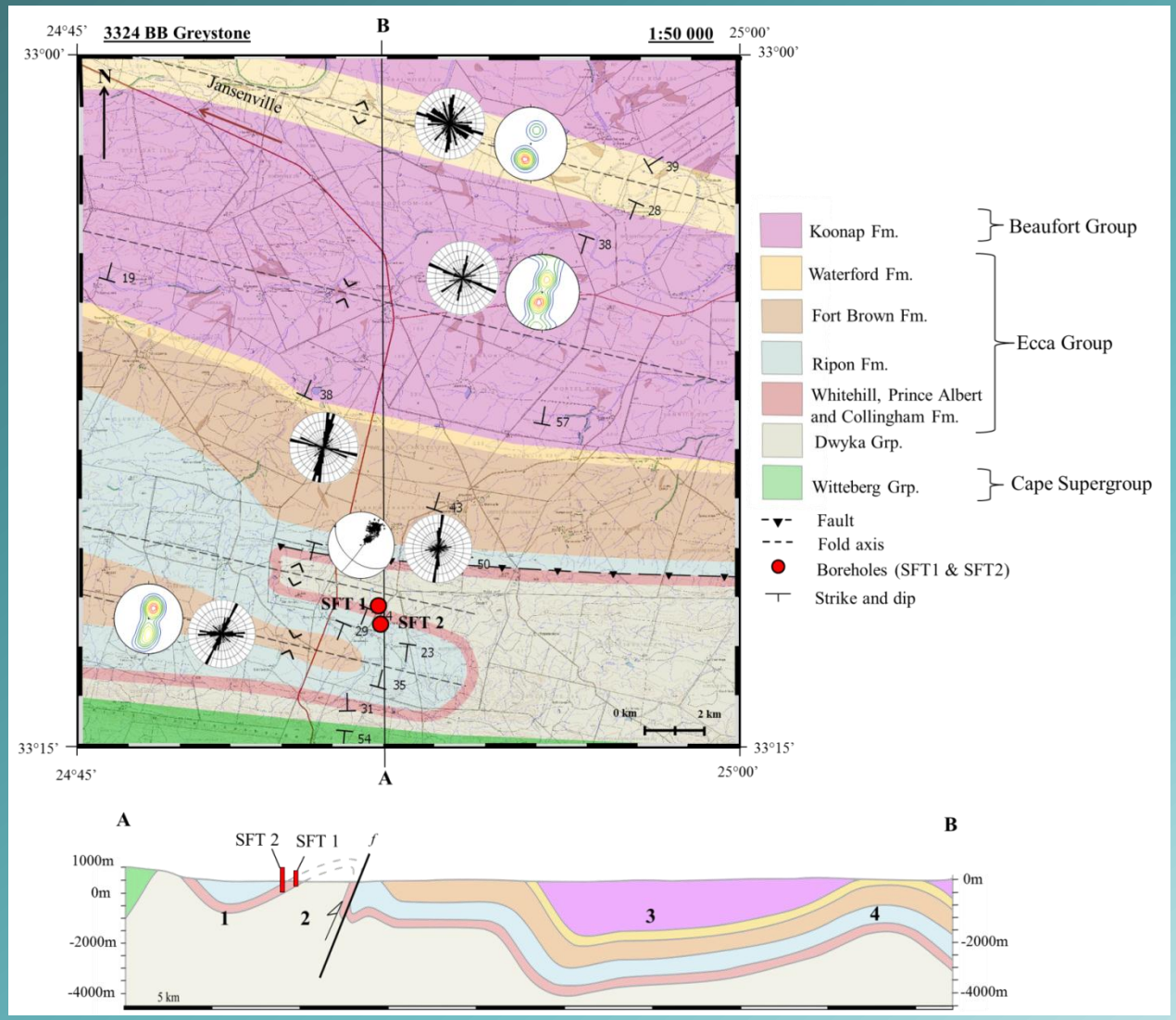
2. Use of structural information to site and drill 2 boreholes from which fresh core of the lower Ecca Group was obtained.

3. Selection of core samples for geochemical and petrophysical analysis conducted at the GFZ Helmholtz-Zentrum, Potsdam, Germany. Analyses include: Scanning Electron Microscope (SEM) and thin section analysis, X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF), TOC/Rock Eval, vitrinite reflectance, $\delta^{12}C$ and $\delta^{15}N$ stable isotope analysis, pyrolysis-gas chromatography, thermovapourization-gas chromatography and mercury intrusion porosimetry

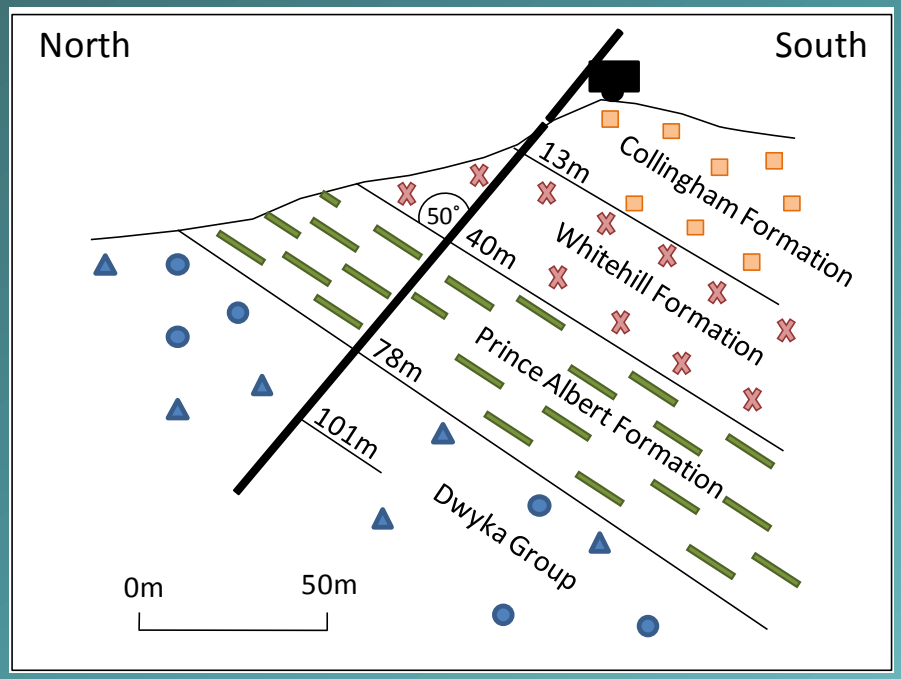
Study Site:

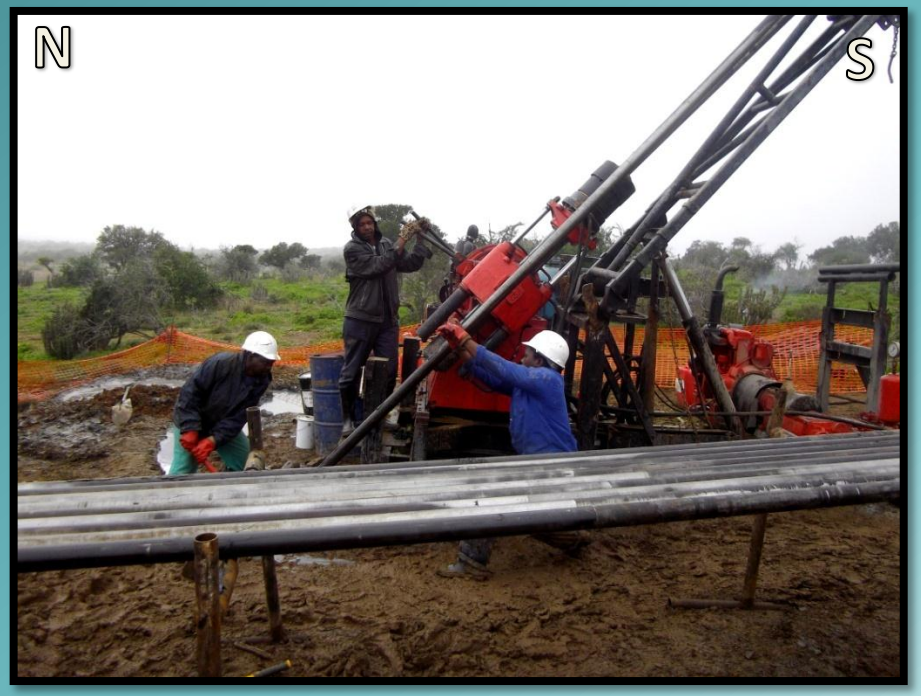

Geology
Beaufort Group
Cape Supergroup
Stormberg Group
Drakensberg Group
Dwyka Group
Ecca Group
Karoo Dolerite Suite
Karoo Basin
Study site
Jansenville
Matjiesfontein
Prince Albert
Wolwefontein
CFB
Cape Town
George
Port Elizabeth
0
100
200 km

Geological map and cross section

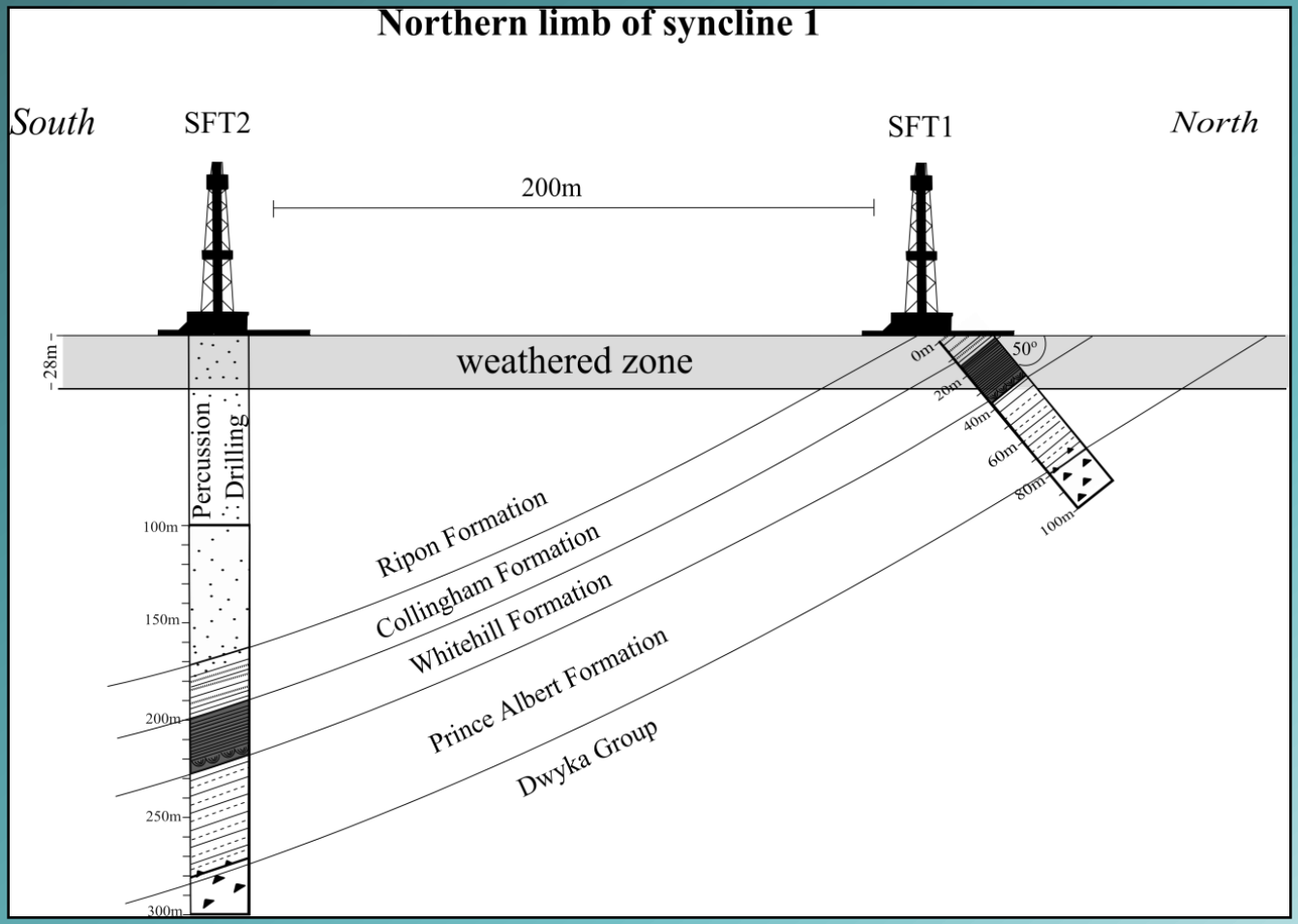


Borehole SFT 1:





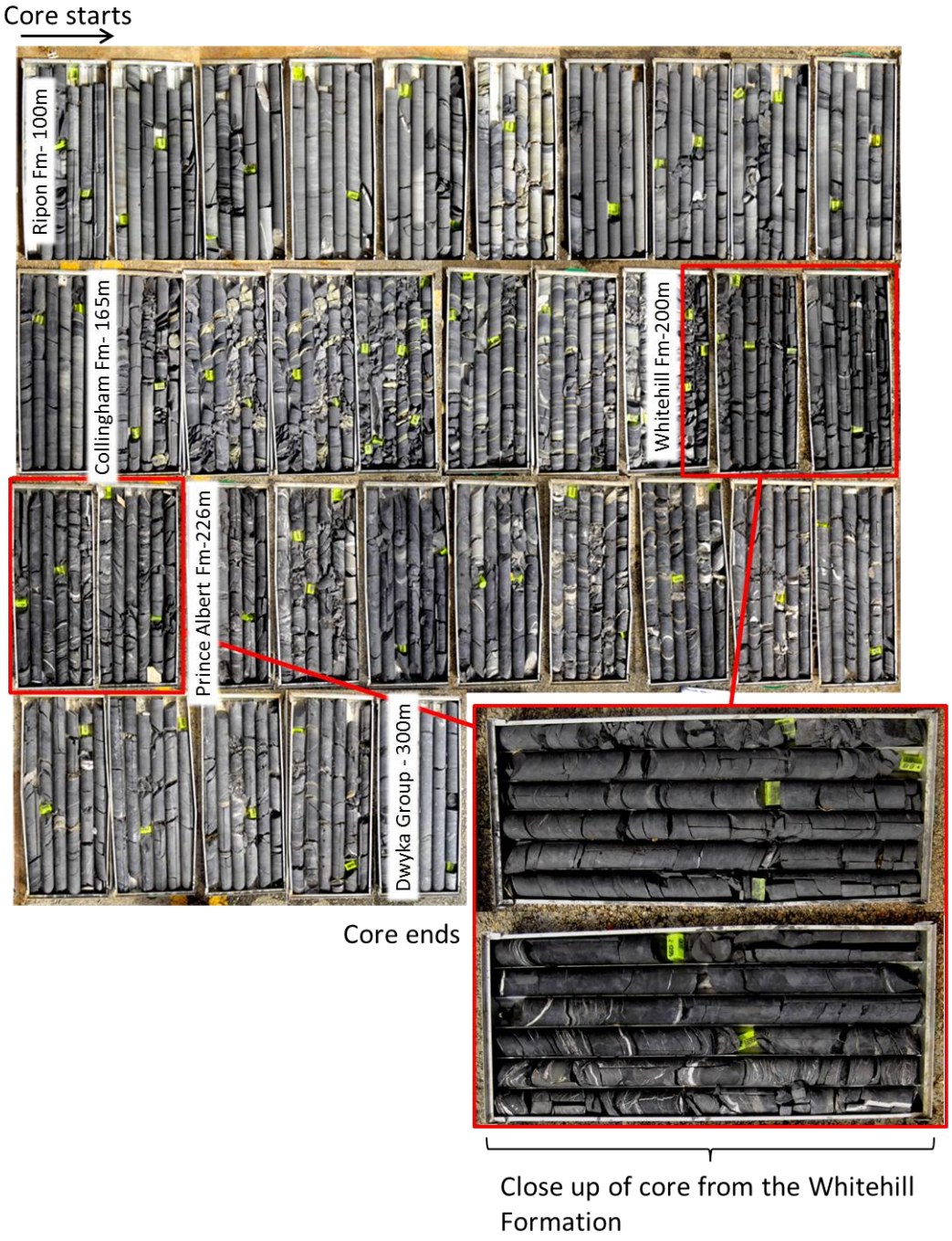
Weathering


Northern limb of syncline 1
South
SFT2
SFT1
North
200m
28m
weathered zone
Percussion Drilling
100m
150m
200m
250m
300m
0m
20m
40m
60m
80m
100m
50°
Ripon Formation
Collingham Formation
Whitehill Formation
Prince Albert Formation
Dwyka Group

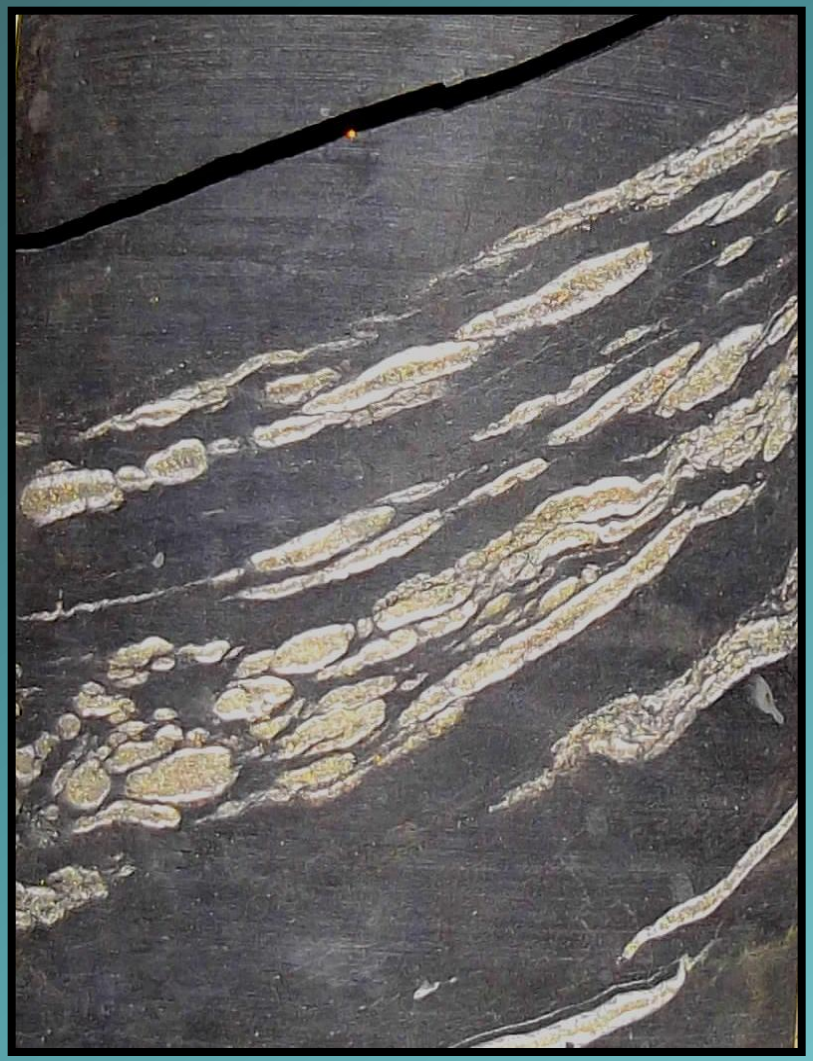
Borehole SFT 2

Vertical hole drilled. 100m percussion followed by 192m core.

Cutting and collecting samples in the field


Core starts
Ripon Fm- 100m
Collingham Fm- 165m
Whitehill Fm-200m
Prince Albert Fm-226m
Dwyka Group - 300m
Core ends
Close up of core from the Whitehill Formation

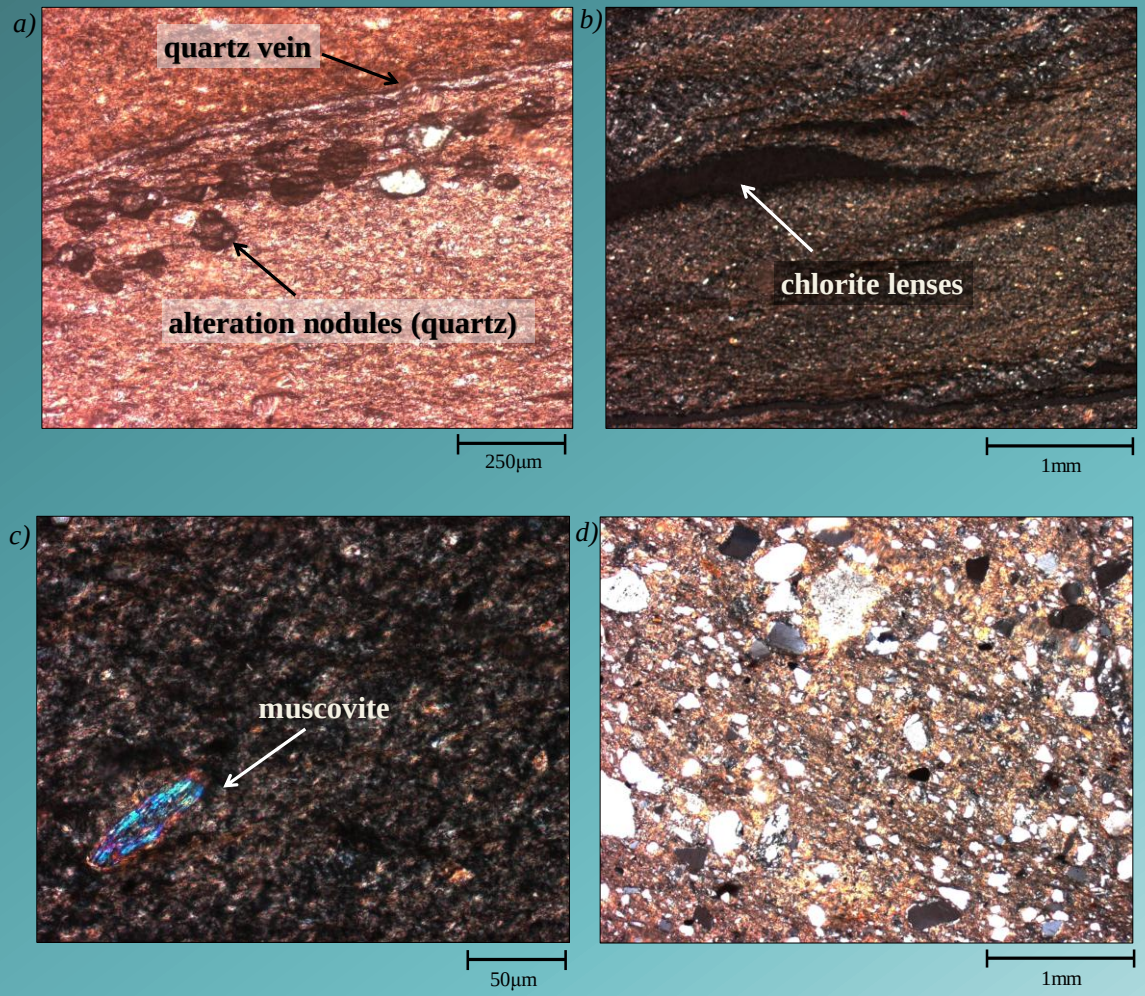
Fresh black shale from the Whitehill Formation



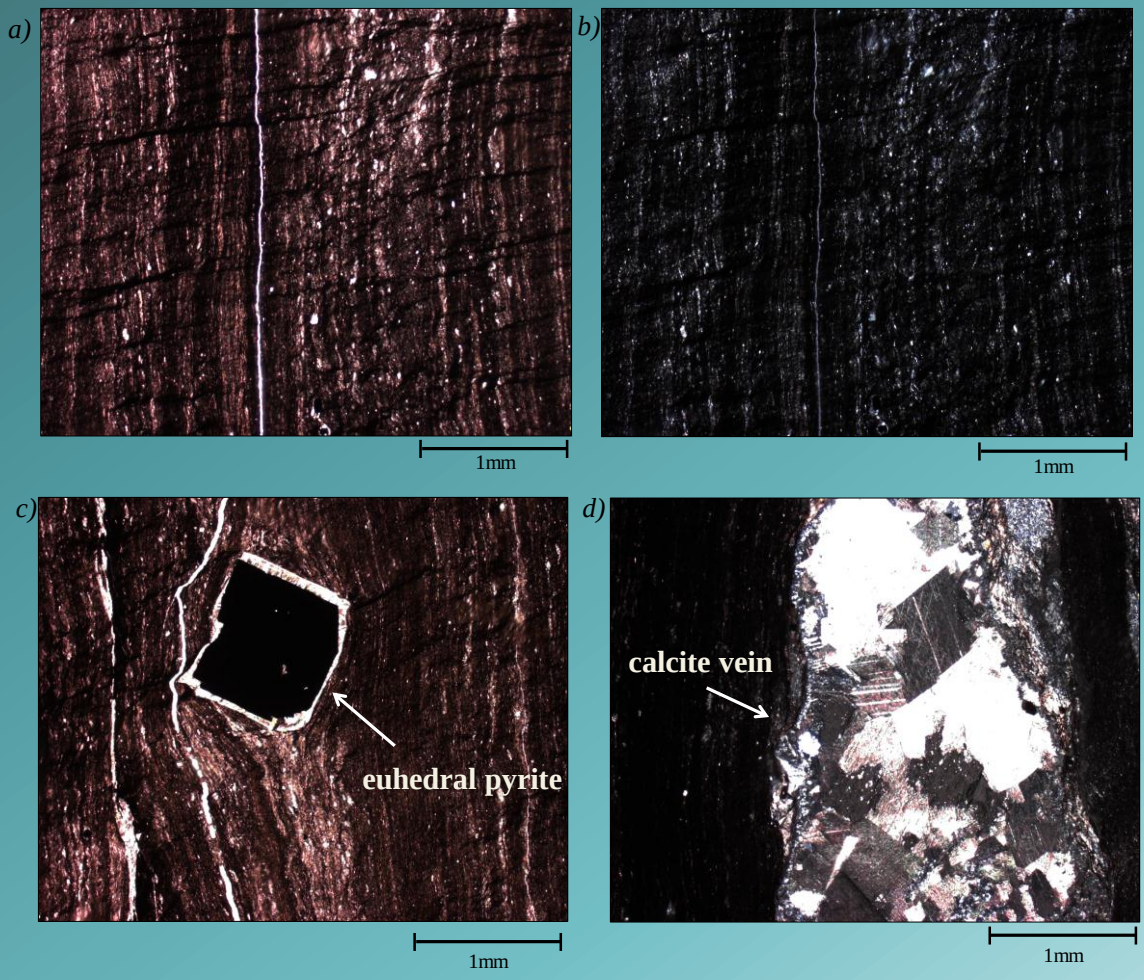
Geochemical and petrophysical analyses:

- Mineralogy (Thin Section,
- SEM, XRD)
- Vitrinite reflectance
- Hg-intrusion porosimetry
- Geochemistry (TOC/Rock Eval, XRF, Stable isotopes, pyrolysis and thermovapourization)

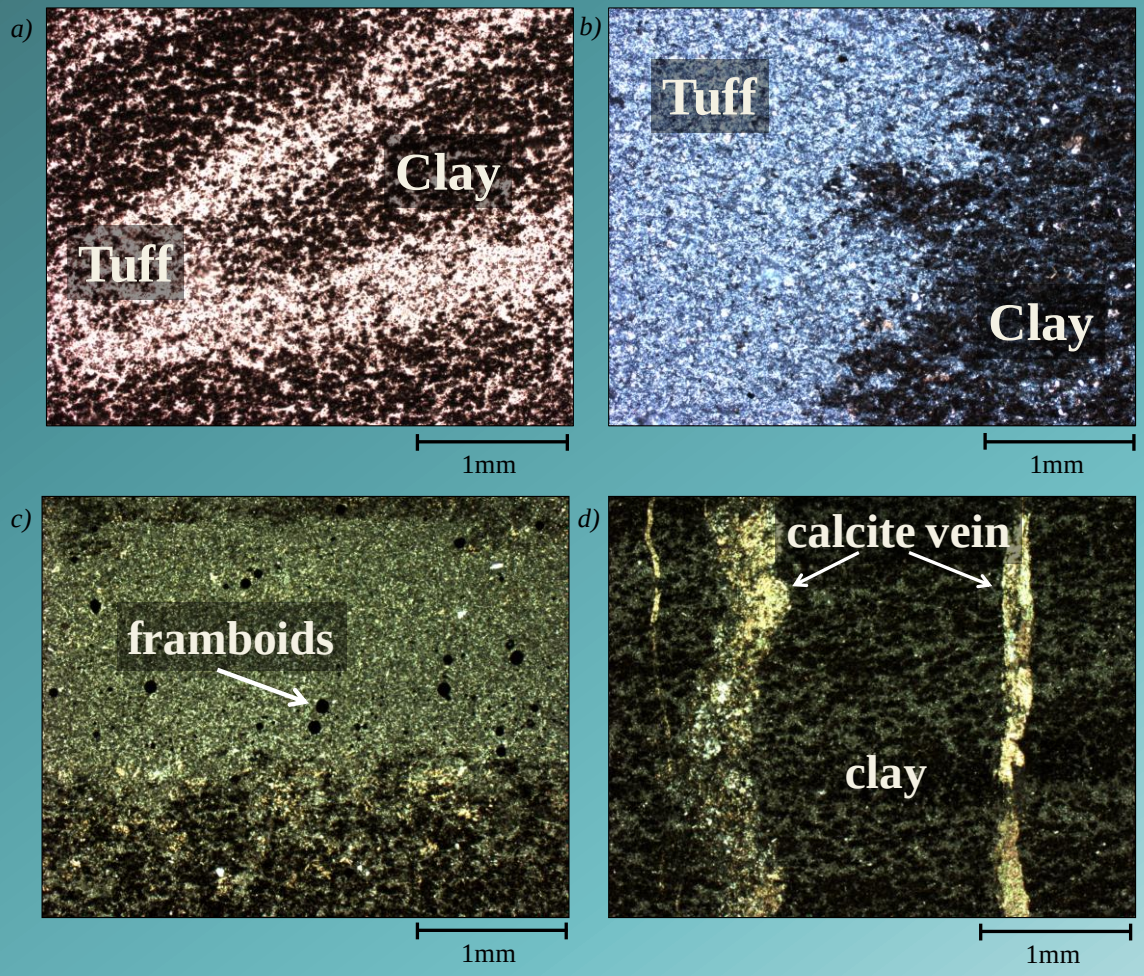
Thin section: Prince Albert Fm



Thin section: Whitehill Fm

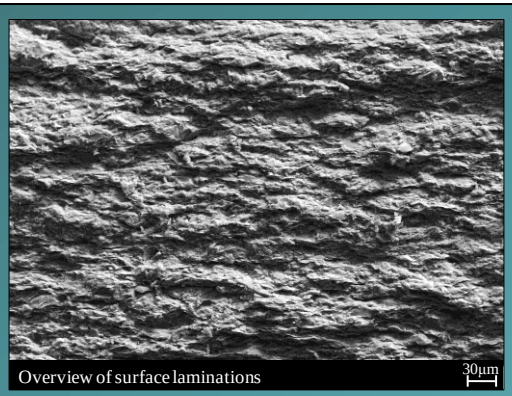


Thin section: Collingham Fm

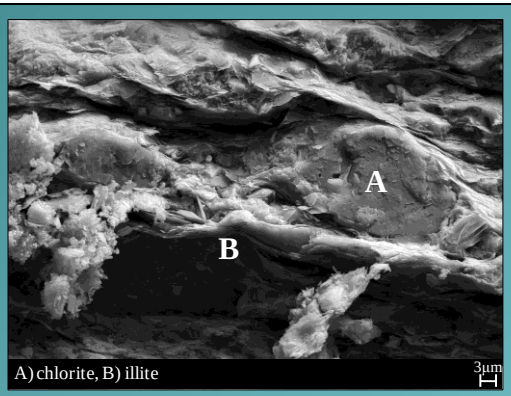


SEM: Prince Albert Fm

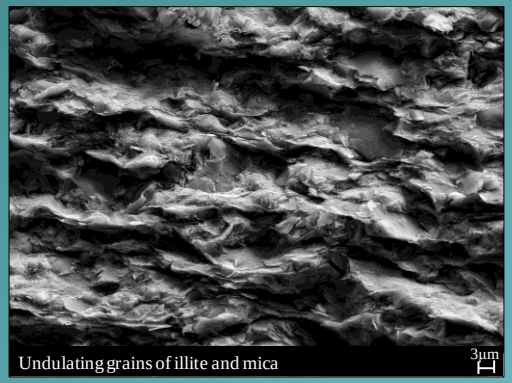
a)



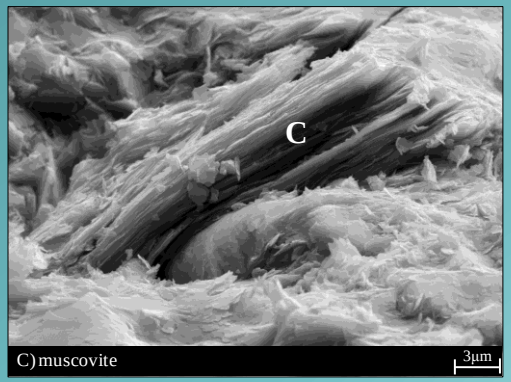
b)



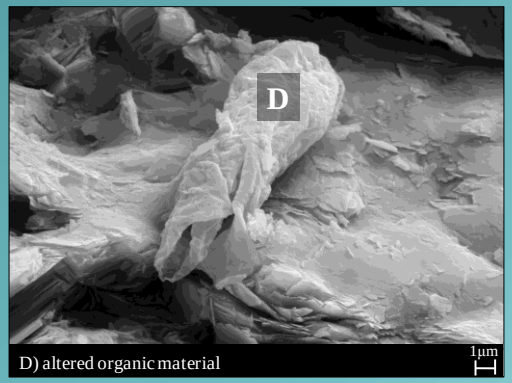
c)



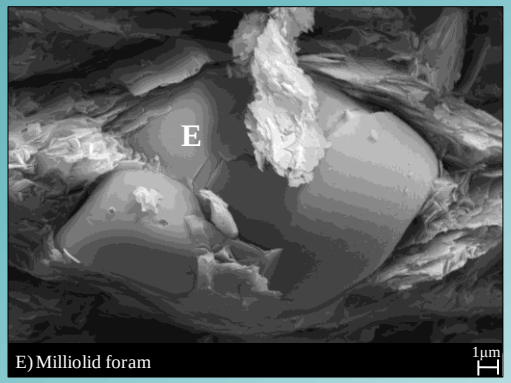
d)



e)

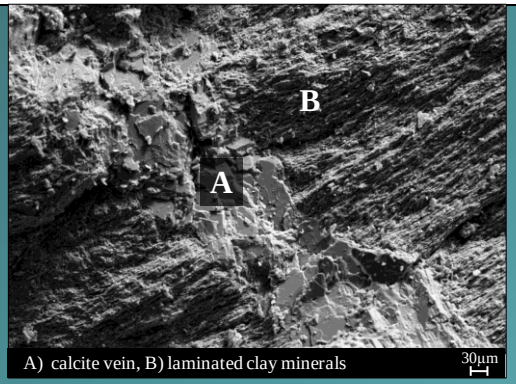


f)

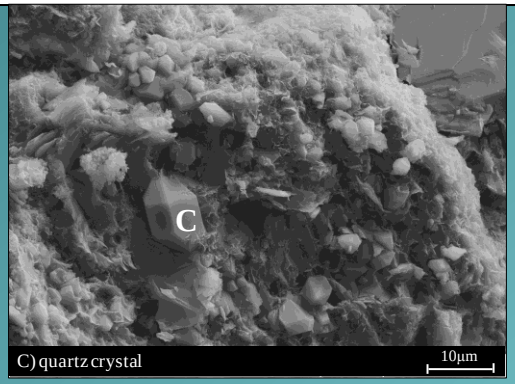


SEM: Whitehill Fm

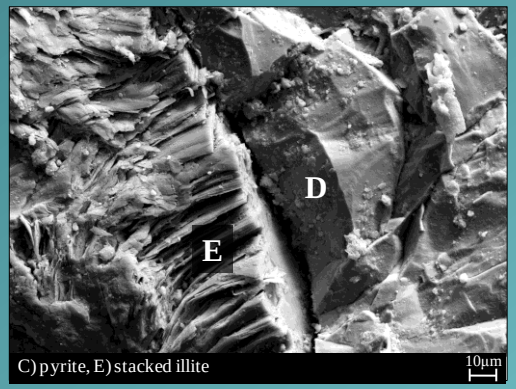
a)



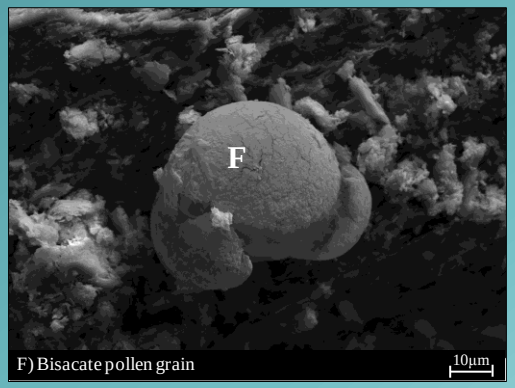
b)



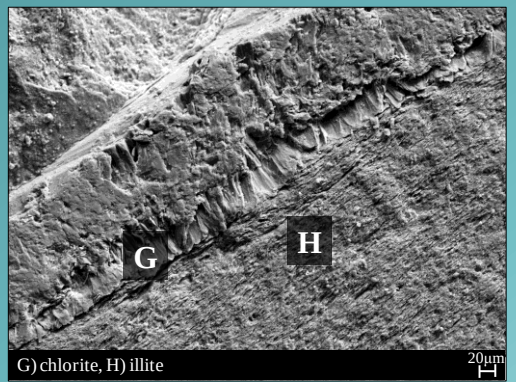
c)



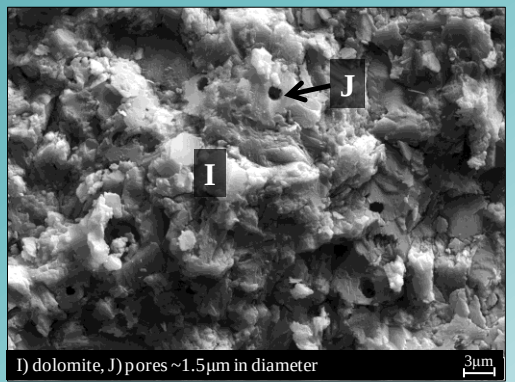
d)



e)

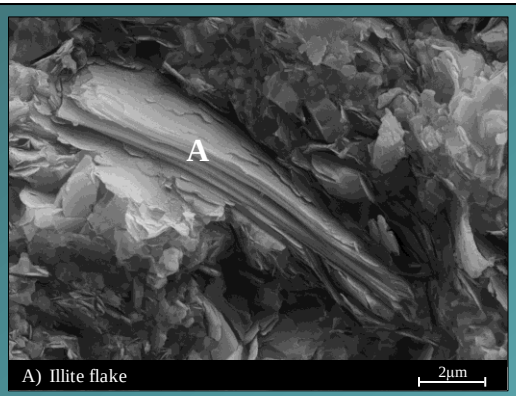


f)



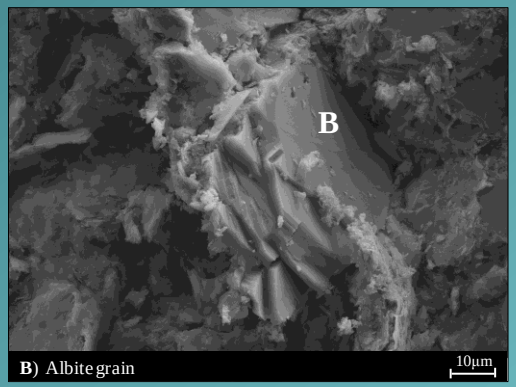
SEM: Collingham Fm

a)

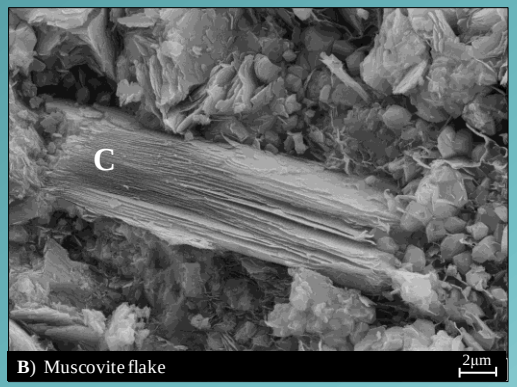


b)

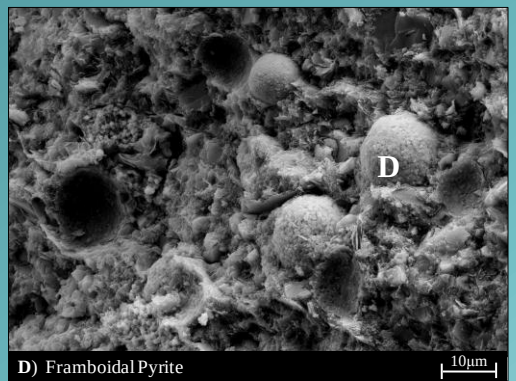
c)



d)

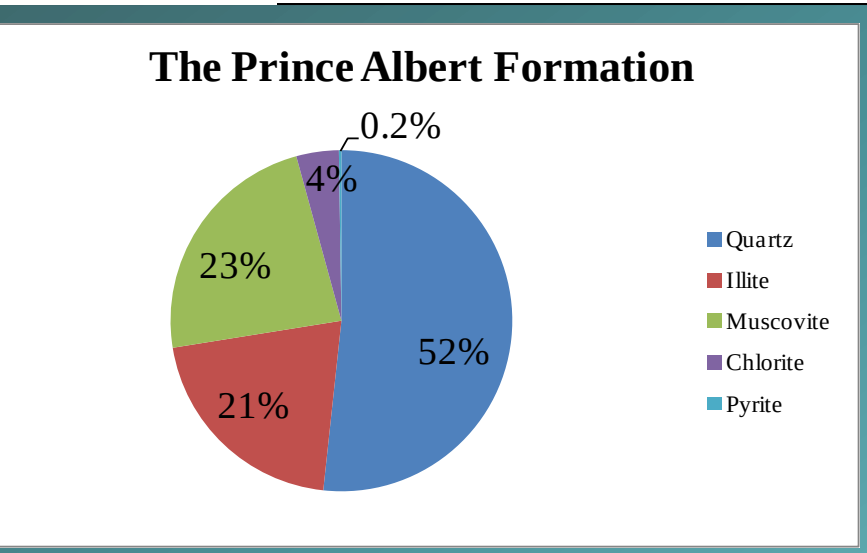


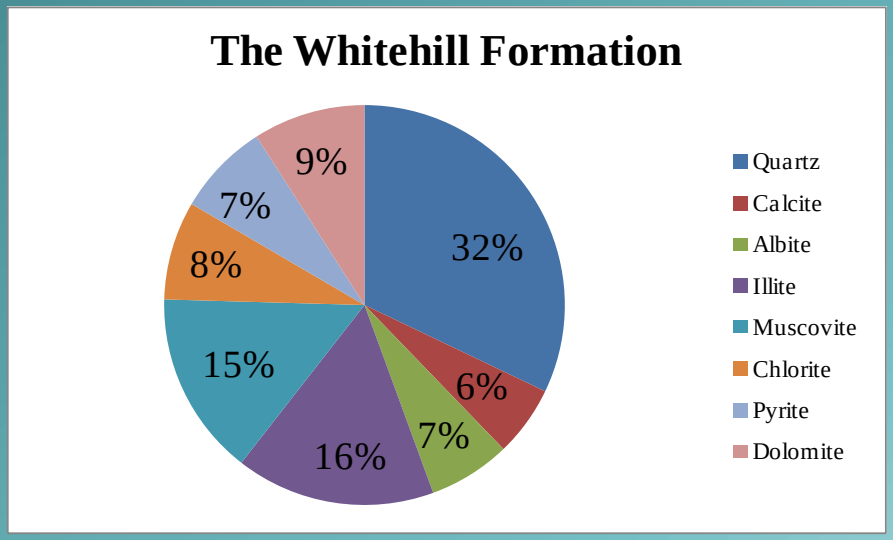
e)



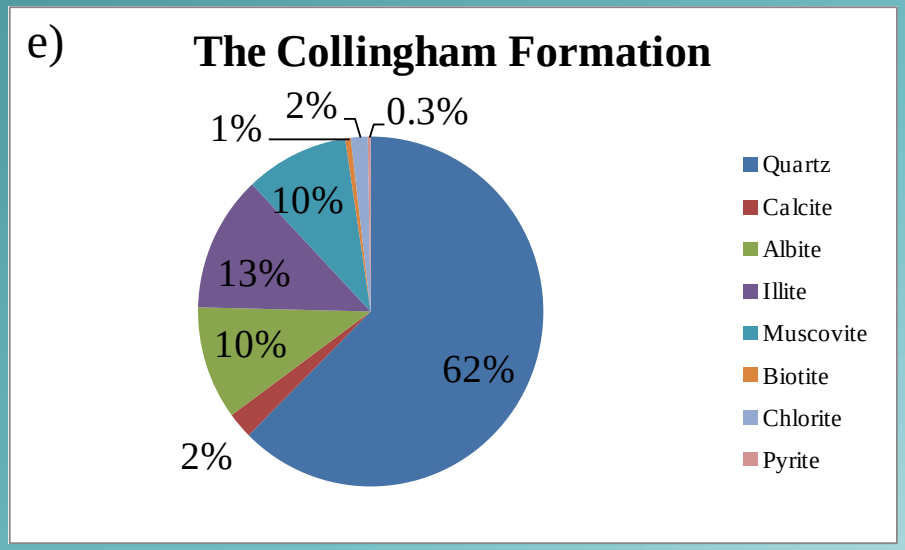
f)

XRD (X-Ray Diffraction)

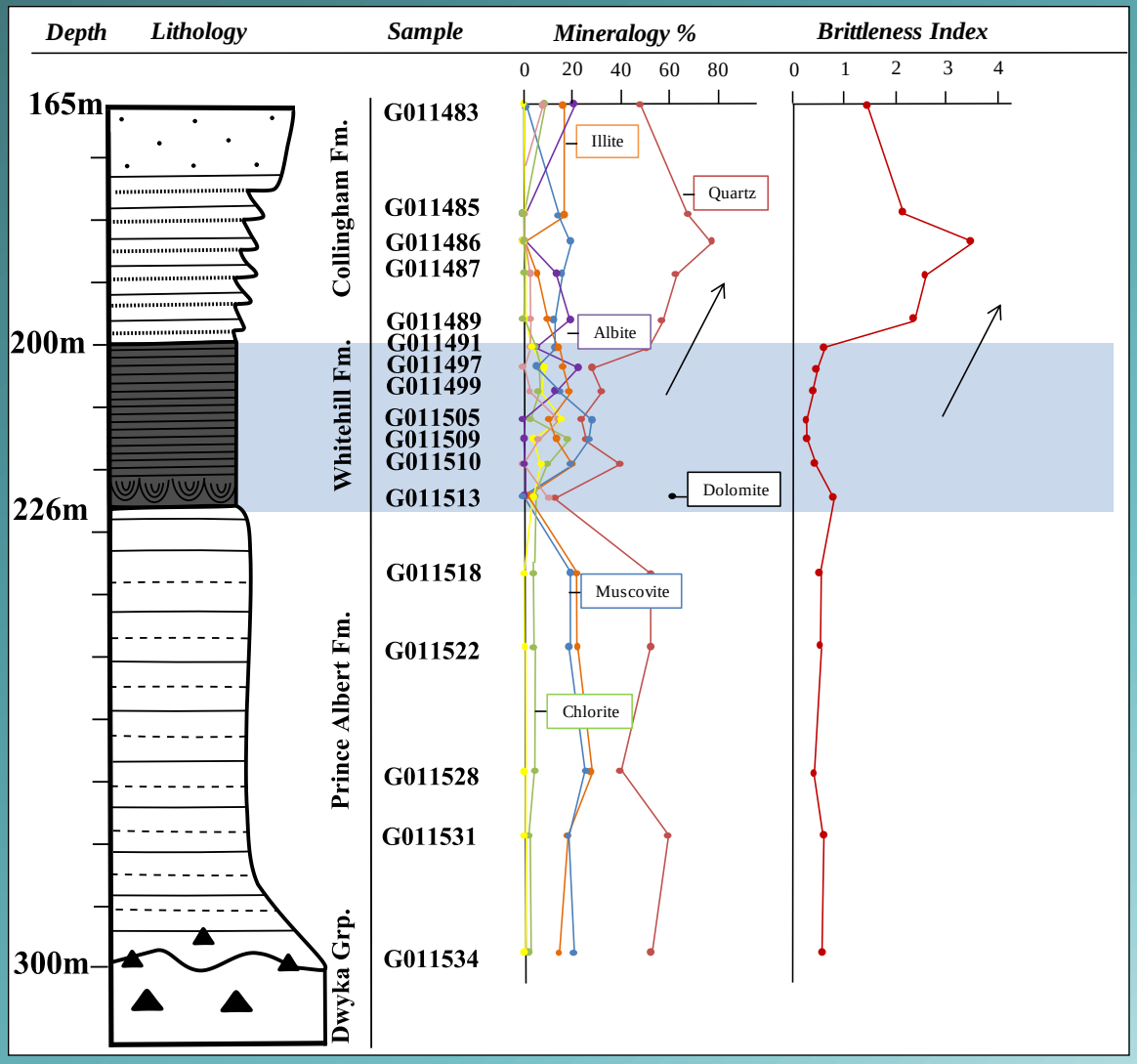




e)



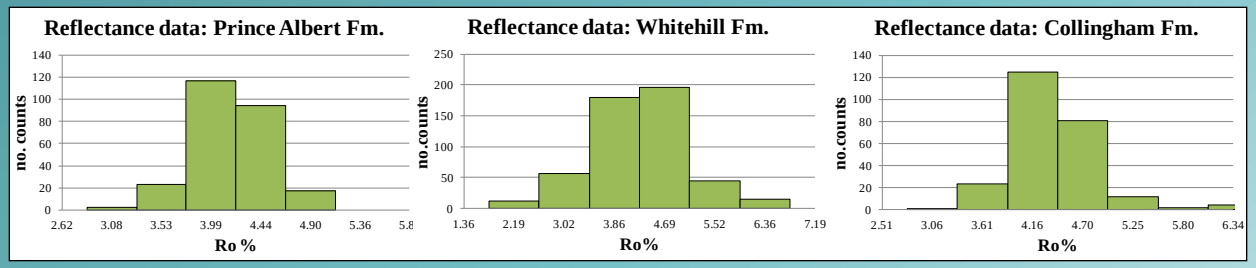
Mineralogy and frackibility



Vitrinite Reflectance

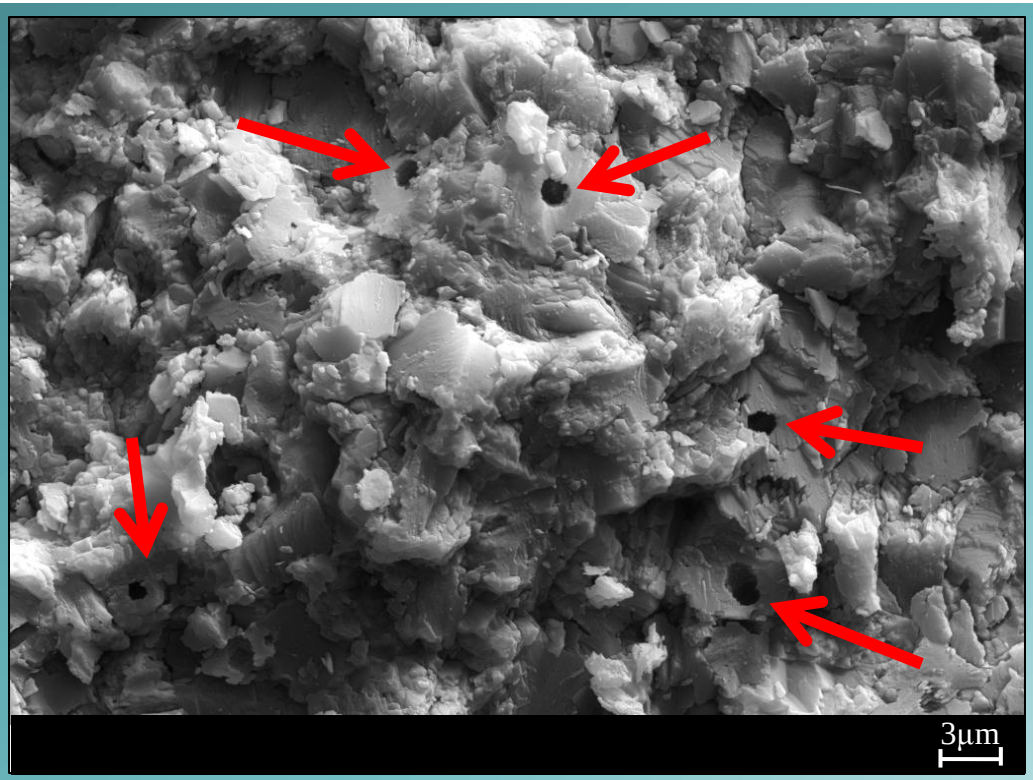
BRo=4%

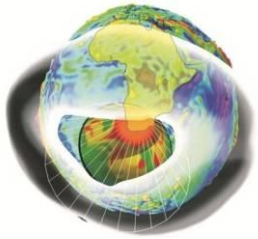
=over mature



Porosity

Formation	% porosity		% porosity (excluding macropores)	
Prince Albert	0.53		0.29	
Whitehill	**Shales**	**Dolomite**	**Shales**	**Dolomite**
	1.35	2.91	0.83	2.90
Collingham	0.40		0.34	

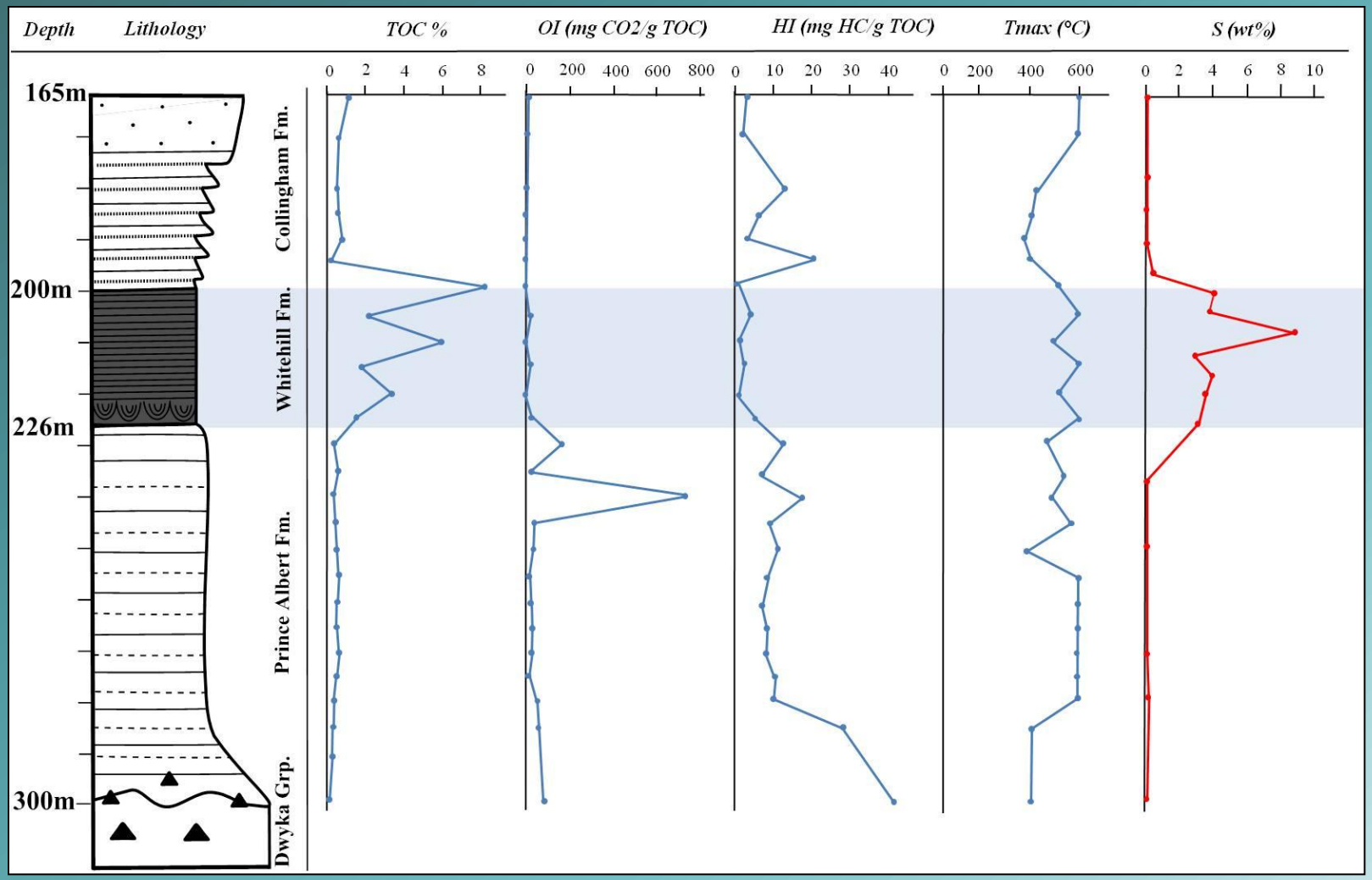




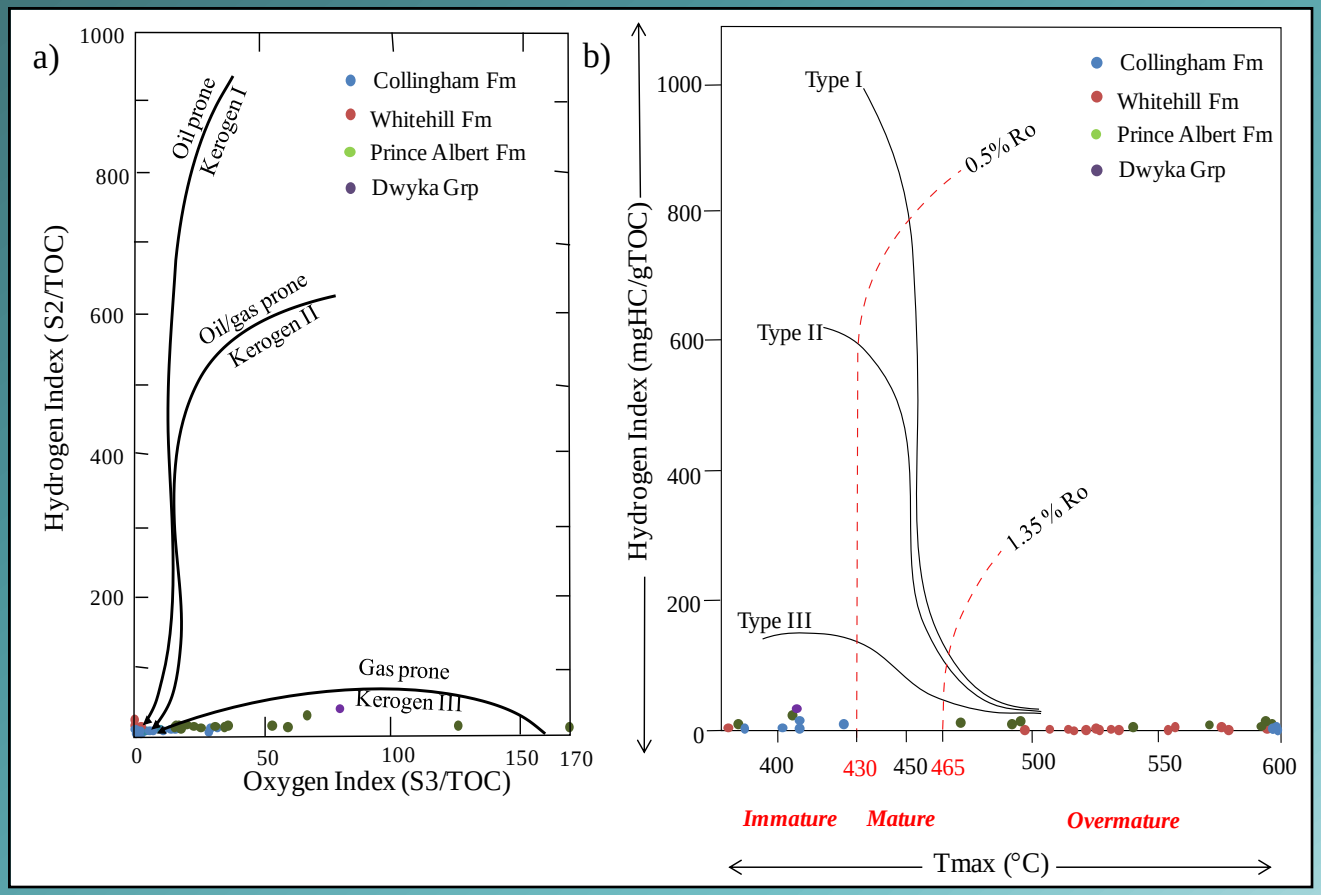
TOC/ Rock Eval

- TOC= Total Organic Carbon
- Rock Eval pyrolysis measures hydrocarbon release of sedimentary rocks which helps characterise maturity and type of organic matter.
- Produces Tmax (maximum hydrocarbon generation), HI (Hydrogen Index) and OI (Oxygen index) values.

TOC/ Rock Eval

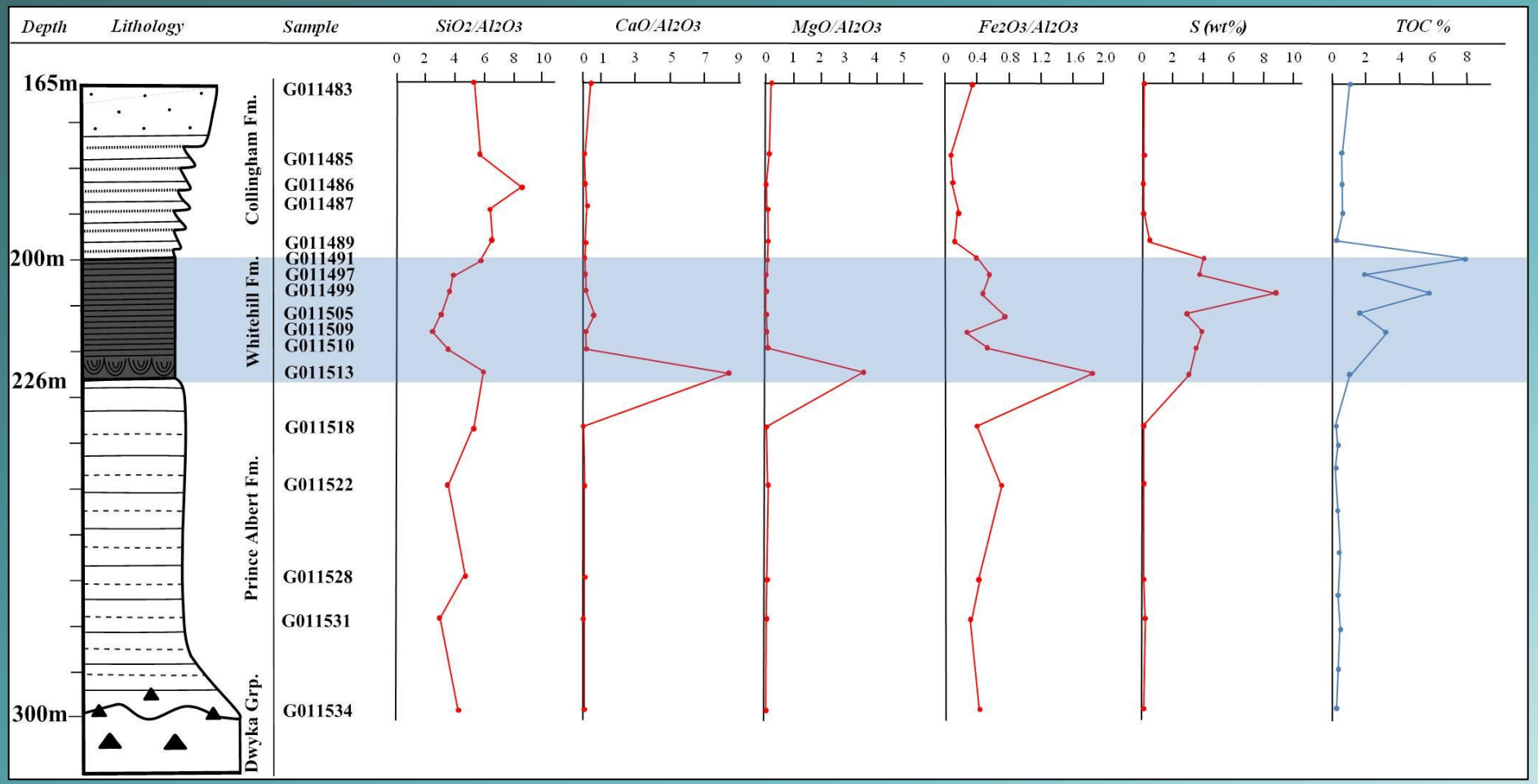


TOC/ Rock Eval

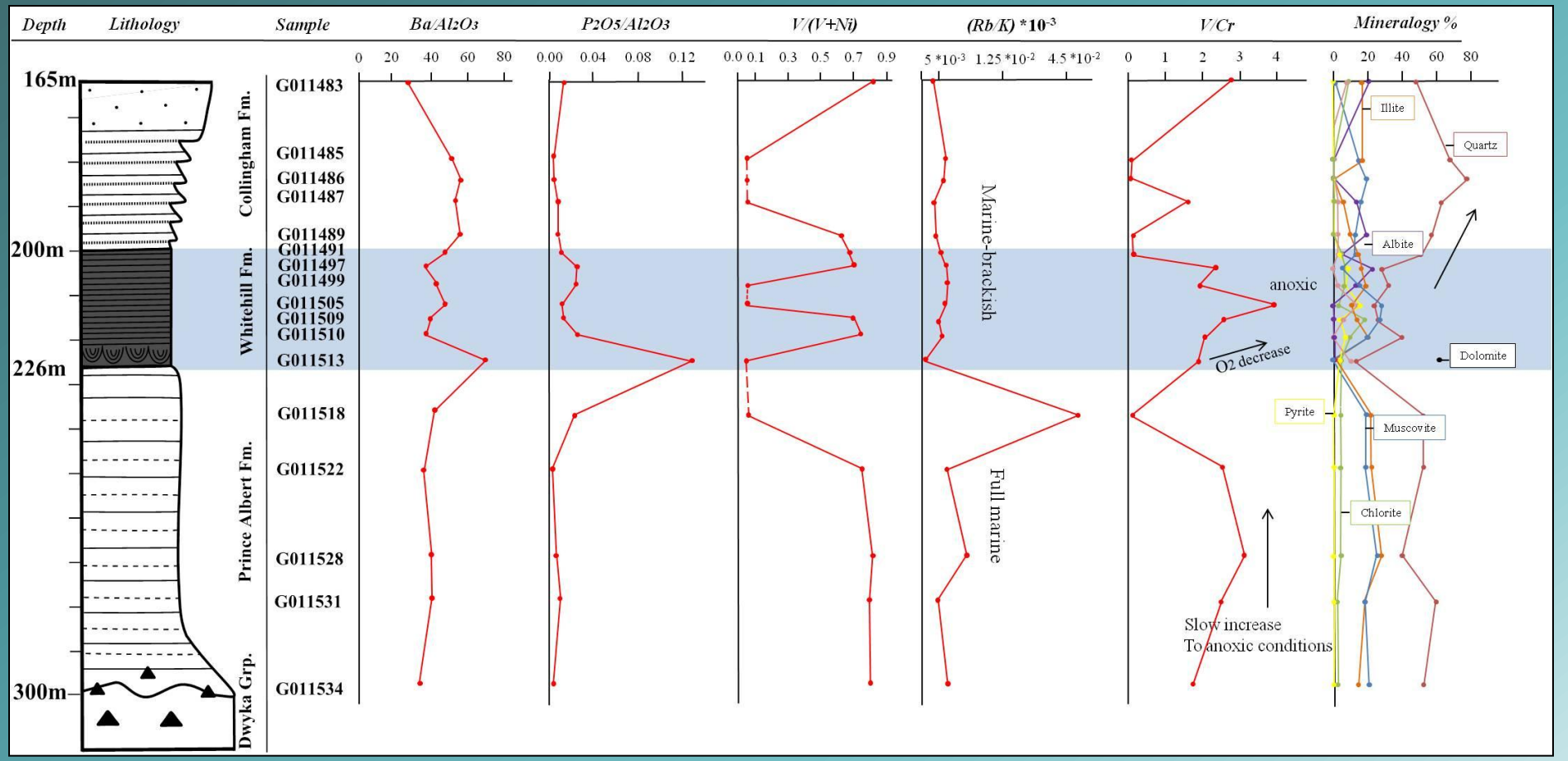


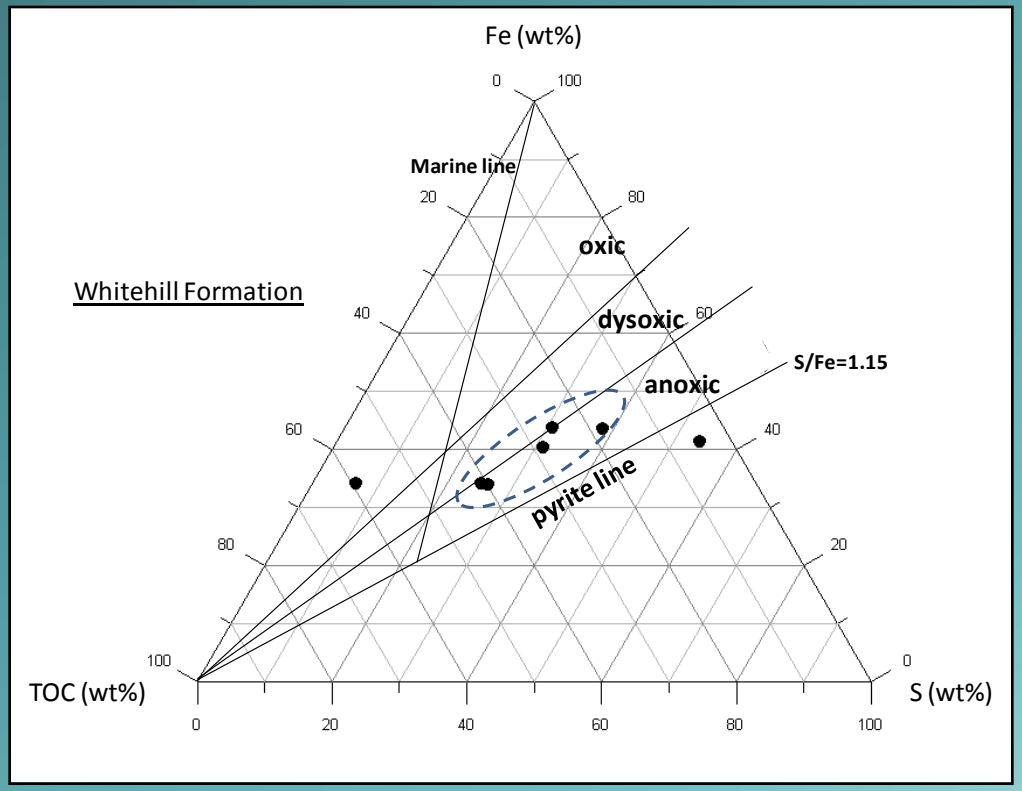
- Tmax values = overmature
- HI and OI values are low due to overmaturity (i.e. low hydrocarbon release)
- Whitehill and Collingham = type II kerogen, Prince Albert =type III kerogen

XRF (X-Ray Fluorescence)



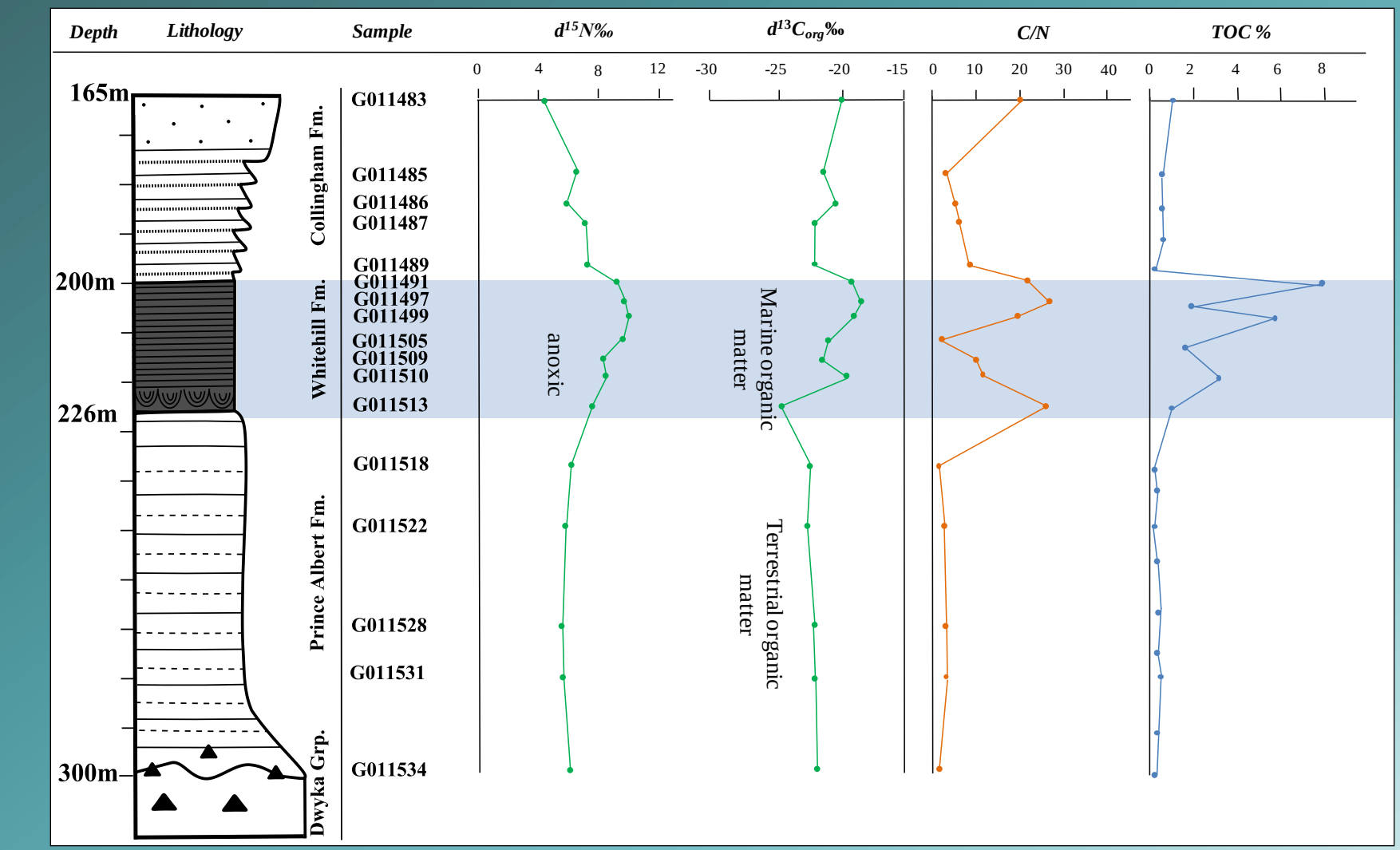
XRF (X-Ray Fluorescence)



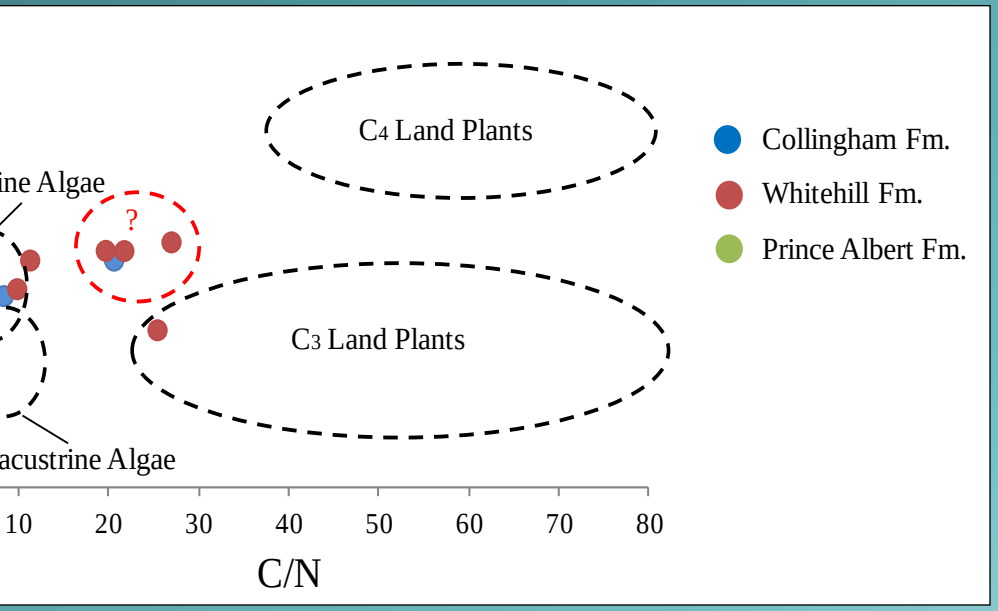


Based on the original by Dean and Arthur (1989)

Stable Isotope Analysis



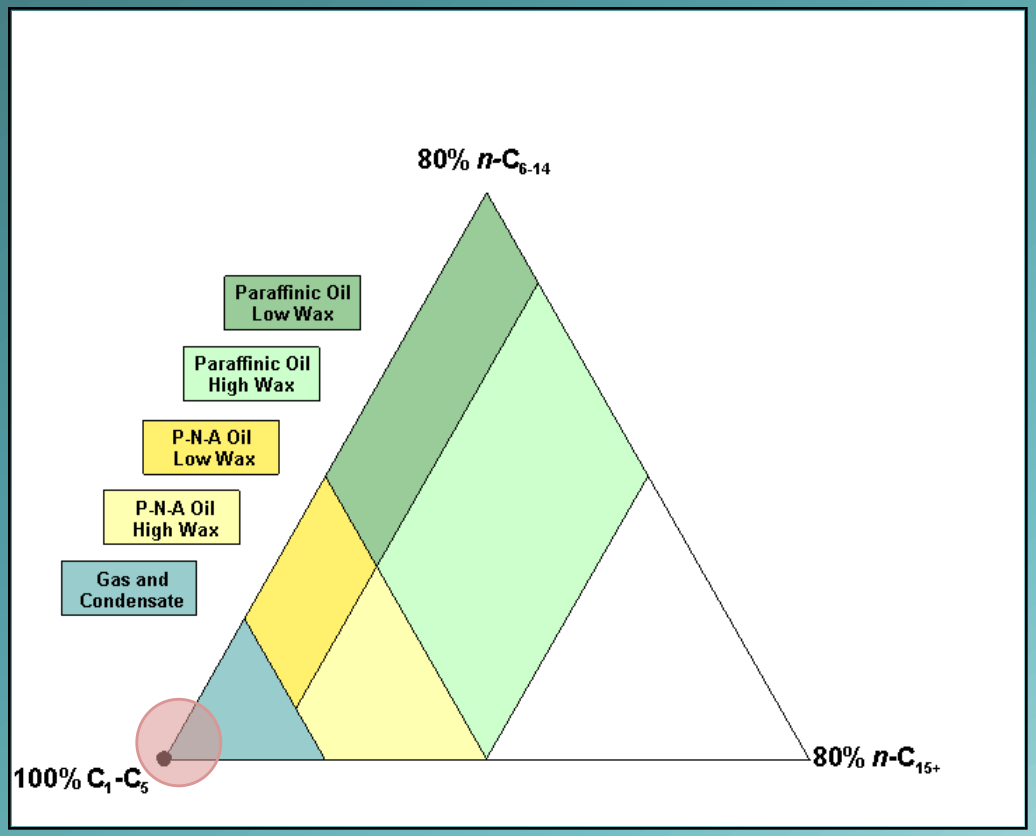
C/N ratios vs $\delta^{13}C$ ‰



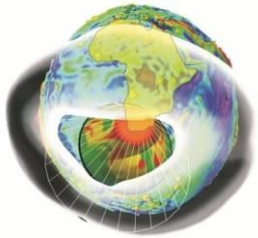
Evidence for mixed organic matter source

Open pyrolysis and thermovapourization

To evaluate source rock potential and the pre-existing hydrocarbons as well as the hydrocarbons that it still may generate



Few short chained hydrocarbons released as a result of over-maturity and the impact of the CFB orogeny



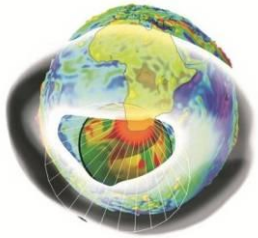
Conclusions-Prince Albert Fm:

Fine-grained mudrock and shales with TOC content of 0.37%.

Deposited via suspension settling in anoxic marine setting.

Evidence of this palaeo-environment includes:

- Milliolid fossil foram suggest marine setting.
- Geochemical proxies such as Rb/K, V/Cr, V(V+Ni) ratios and a high percentage of atomic S, indicates increased salinity and an anoxic-euxinic environment.
- $\delta^{13}C$ and $\delta^{15}N$ stable isotope data, C/N ratios and rock eval data suggest a marine setting with the influx of both terrestrial and marine organic matter.



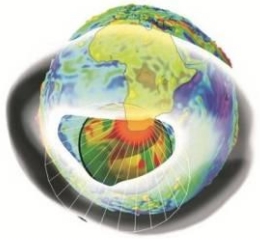
Conclusions-Whitehill Formation

Consists mostly of black, calcareous, carbonaceous shales with sporadic lenses of porous dolomite.

The Whitehill Formation has a high TOC content averaging at 4.5% accompanied with by high sulfur content.

Deposited in an anoxic, quiescent, marine inland sea evidence for this includes:

- Pyrite rich, fine-grained, dark carbonaceous shales is indicative of suspension settling of fine grained sediments under anoxic conditions.
- Geochemical proxies such as elevated Ba/Al_2O_3 and P_2O_5/ Al_2O_3 ratios in the sample of dolomite, indicates increased palaeoproductivity. Ratios of Rb/K, V/Cr, V/V+Ni suggest an anoxic, marine environment. TOC-S-Fe relationships also suggest prevailing anoxic conditions.
- $\delta^{13}C$ and $\delta^{15}N$ stable isotope data, C/N ratios and Rock Eval data suggest a mixed source of organic matter. This is further verified by the discovery of a bisaccated pollen grain (terrestrial) via SEM analysis and a Millolid fossil (marine) in thin section.



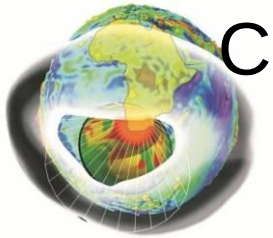
Conclusions-Collingham Formation

Consists mostly of tubiditic mudrocks and shales intercalated with volcanic tuffs. Near the top of the Collingham Formation the mudrock grades into fine-grained sandstone which contains fossil imprints of plant matter.

The TOC content of the Collingham Formation is 0.62%

Represents the basin filling stage and changing from anoxic to oxic, and marine to brackish conditons.Evidence for this palaeo-depositional environment includes:

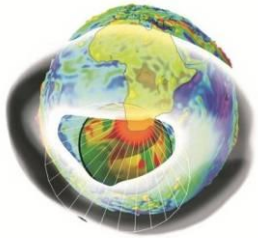
- Turbidites, a multitude of trace fossils (*Planolites* and *Scolicia*) and imprints of plant fossils (*Glossopteris?*) and upwards grading of sediments indicate basin filling and deposition from an unstable slope.
- Geochemical proxies such as Rb/K indicate the transition from marine to more brackish conditions. V/Cr ratios suggest that the water was becoming more oxygenated and pyrite only dominates the lower Collingham Formation where the water was still anoxic.
- $\delta^{13}C$ and $\delta^{15}N$ stable isotope data, C/N ratios and Rock Eval data suggest a mixed source of organic matter. This is particularly evident with fossil plant imprints and animal traces.



Conclusion- The Whitehill Formation as a potential shale gas reservior

- High organic richness (TOC=4.5%)
- Deposited under conditions which allow preservation of organic material.
- Presence of bitumen means thermal cracking took place=gas was formed
- Mineralogy suggests suitable brittleness (good for fracking)
- Mixture of type II and type III kerogen
- Tightness of shales

- Whitehill may be a good source rock for gas, but not in such close proximity to the CFB



Areas for further study

The porosity of the micro-and nano-scale pores and the porosity of the organic material need to be determined. Permeability of the pores should also be determined.

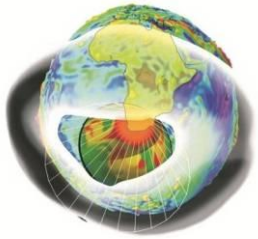
Determine the gas saturation and if the gas is stored in interstitial pores and microfractures. It must be calculated how much gas is adsorbed onto organic matter and how much of it is free gas.

Isotope data for $\delta^{34}S$ and $\delta^{18}O$ is required to help determine the palae-depositional environment of the early Ecca Group.

To better determine the metamorphic conditions, fluid inclusion in metamorphic minerals and quartz veins can be tested

Further data from joint directions, joint densities and joint spacing must be acquired. Joint systems may facilitate in gas escape from the Whitehill Formation.

Data must be attained from further north from the Cape Fold Belt, but in a region that is unaffected by intruded dykes and sills.



Thank you