Clay Mineral Distribution in a Modern Sedimentary System, Surface Sediments from Ravenglass Estuary and Beyond*

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Abstract

Ravenglass estuary in North West England is a trap for the transported and in situ clay minerals. A clay mineral study from hinterland geology (granite and Triassic Sandstones) toward estuarine surface sediments has been undertaken using X-ray diffraction (XRD), fourier transform infra red (FTIR) and scanning electron microscopy (SEM/BSE/EDAX) techniques. Samples from (1) fluvial sediments beyond the high tide line, (2) surface sediments at the upper part of the estuary, and (3) lower part of the estuary in respect of the clay minerals, have been analysed. Discrimination of the clay minerals using XRD in association with glycolataion salvage and heating treatment to identify the behaviour of 7Å and 14Å peaks have been discussed and concluded that chlorite from hinterland toward the estuary is being changed in quantity and quality from dioctahedral abundant in fluvial sediments to tetrahedral Fe-rich chlorite in surface estuarine sediments. Chlorite, illite, and kaolinite and possibly berthierine are all present in surface sediment in the estuary. Chlorite, a minor expandable phase such as hydroxyl-interlayer vermiculite (HIV), dioctahedral chlorite and also illite are present in the fluvial sediments, beyond the tidal reach. Given the abundance of kaolinite and illite within the estuarine sediments in comparison to the fluvial sediment, it seems likely that these minerals were formed within the estuarine environment. Sand grains in the estuarine surface sediments are coated with a fine layer of clay minerals including chlorite, illite, mix of illite-chlorite, Fe-rich chlorite, berthierine, and kaolinite.

References

Aagaard, P., J.S. Jahren, A.O. Harstad, O. Nilsen, and M. Ramm, 2000, Formation of grain-coating chlorite in sandstones. Laboratory synthesised vs. natural occurrences: Clay Minerals, v. 35/1, p. 261-269

Anjos, S.M.C., L.F. De Ros, and C.M.A. Silva, 2003, Chlorite authigenesis and porosity preservation in the Upper cretaceous marine sandstones of the Santos Basin, offshore eastern Brazil: International association of Sedimentology Special Publications 34, p. 291-316.

Worden, R.H., and S.D. Burley, 2003, Sandstone diagenesis: The evolution of sand to stone, *in* S.D. Burley and R.H. Worden (eds.), Sandstone Diagenesis; Recent and Ancient: Blackwell Publishing, Malden, MA, International Association of Sedimentologists Reprint Series v. 4, p. 3-44.

Clay Mineral distribution in a modern sedimentary system, surface sediments from Ravenglass estuary and beyond

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now at: Fugro Robertson Ltd, UK

AAPG, Long Beach, USA
April 2012

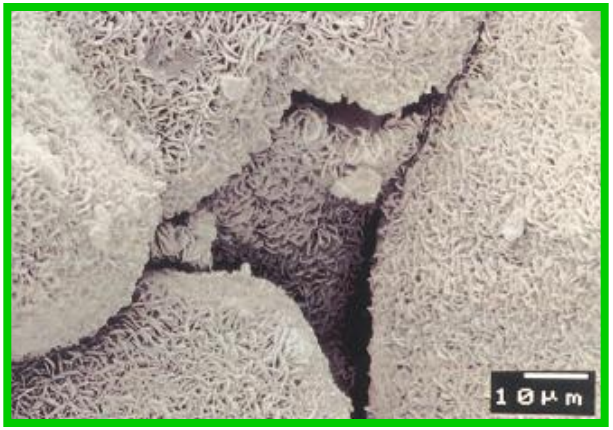
UNIVERSITY OF LIVERPOOL

Shell Eni Chevron Statoil bp ConocoPhillips PETROBRAS ExxonMobil

Why care about Clay minerals?

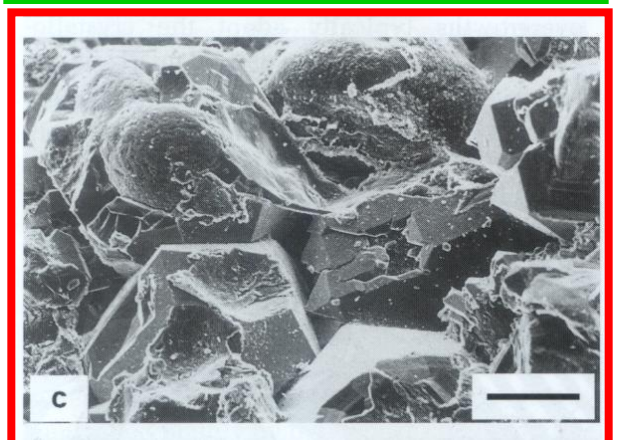
- Fe-chlorite cement can lead to positive reservoir quality anomalies
- Illite can lead to negative reservoir quality

→ Fe-chlorite seems to be able to prevent quartz cementation and so improve reservoir quality



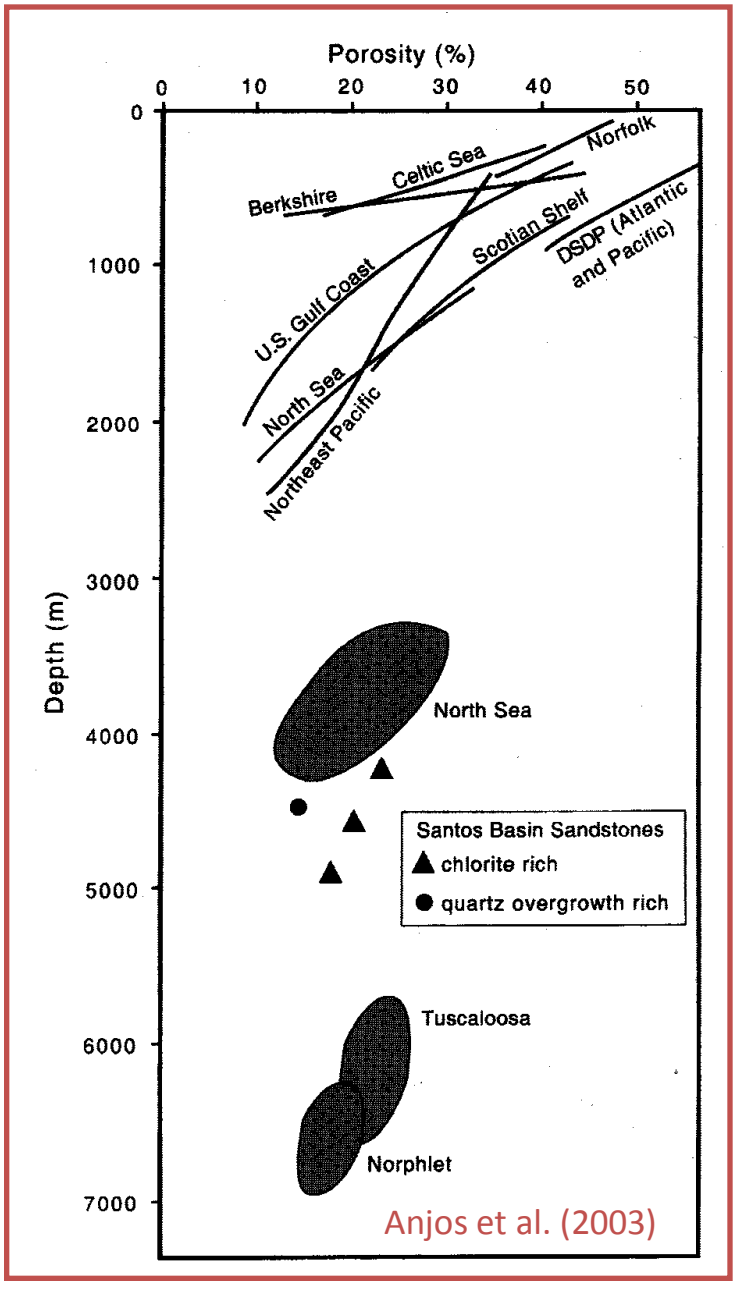
Chlorite cemented sandstone at 6000m

Good porosity



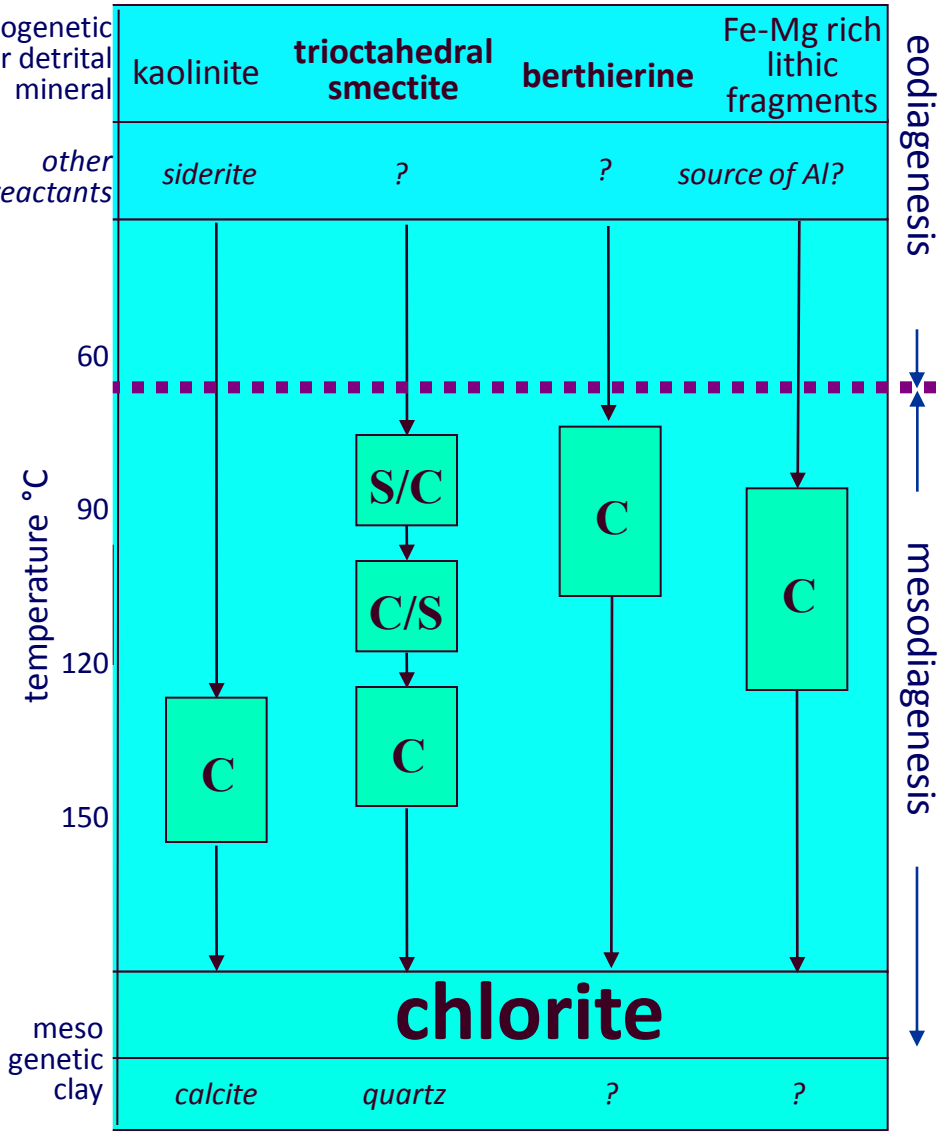
Quartz cemented sandstone at 6000m

Negligible porosity



Why modern sediment systems are important?

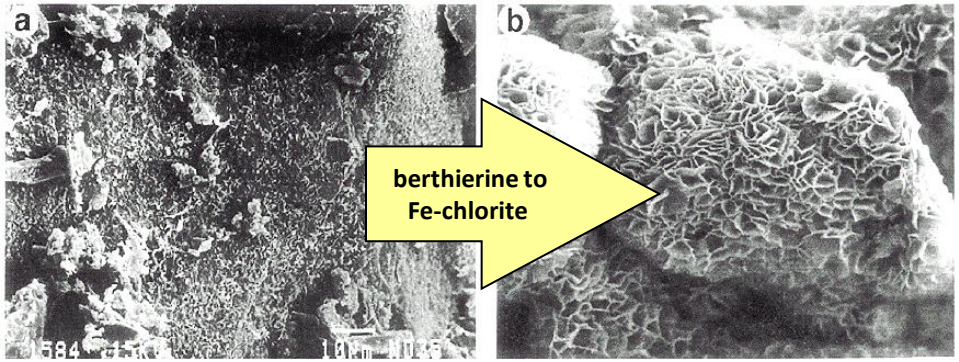
Fe-chlorite is the result of burial diagenesis of Fe-rich precursor minerals: predict Fe-clay minerals to enable prediction of Fe-chlorite



Worden and Burley (2003)

Natural shallow marine sandstone with 7Å Fe-rich clay **berthierine**

Same sandstone following lab **hydrothermal experiment**: *now* with porosity-preserving chlorite coating

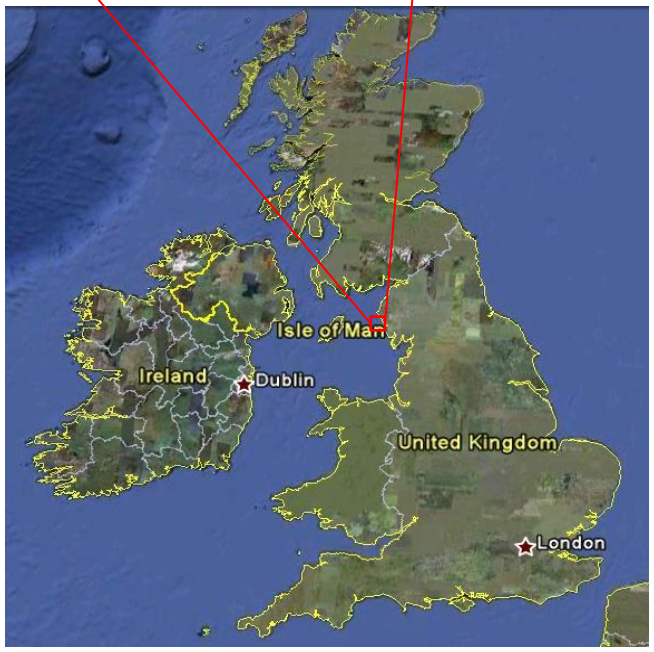


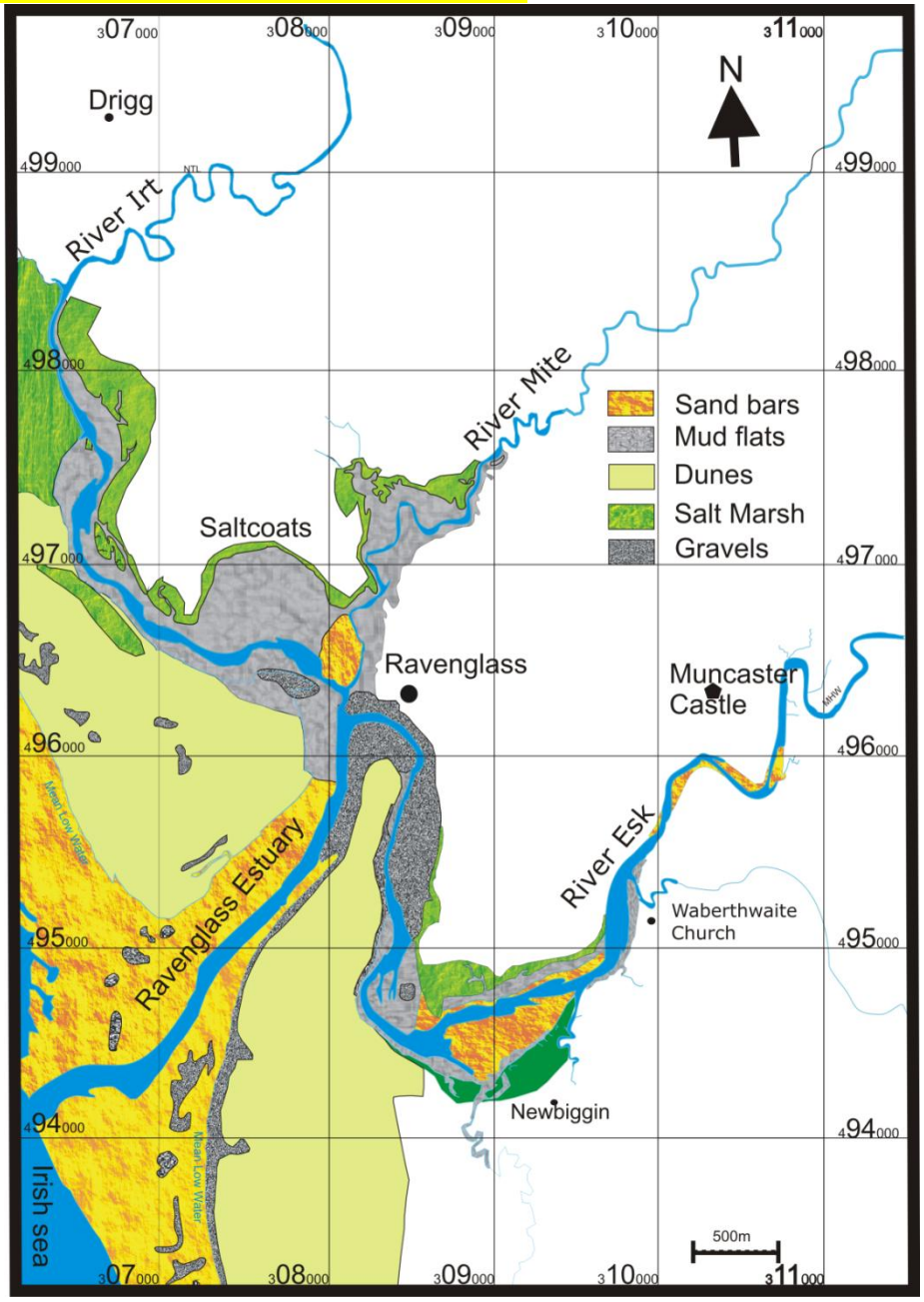
Experimental study by Aagaard et al. (2000)

Modern fluvio-deltaic environments like Estuaries are proficient sediment traps

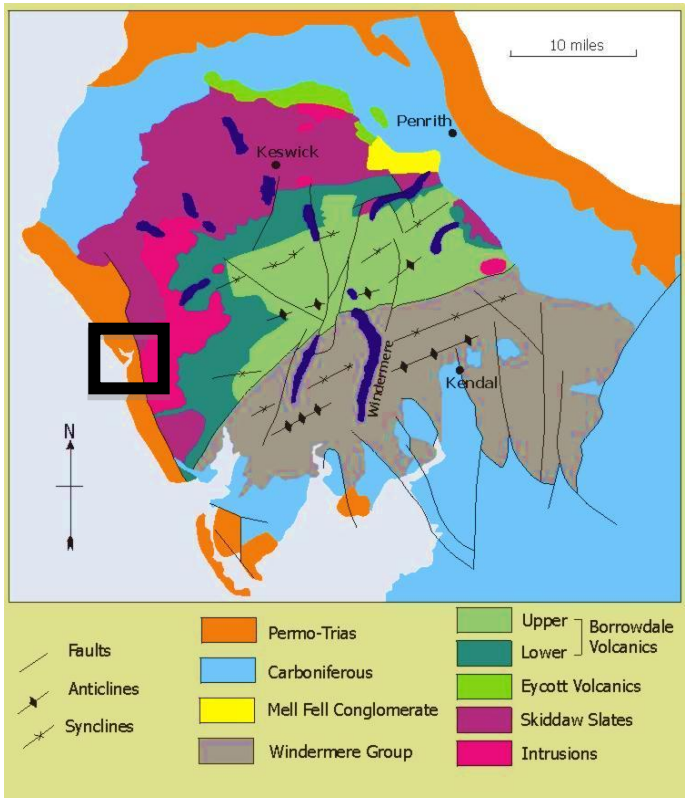
What is the role of hinterland in clay mineral distribution in estuaries?

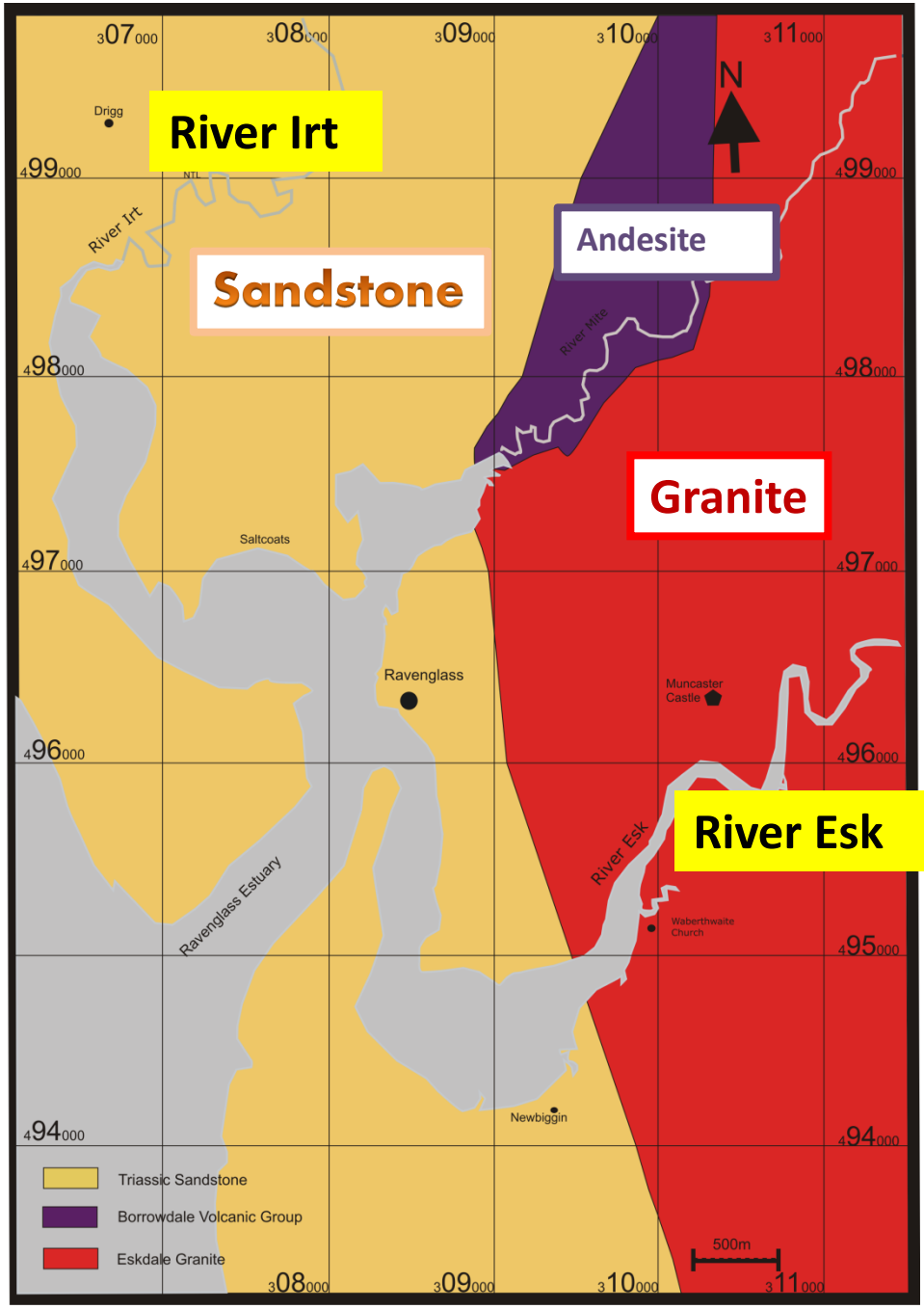
Ravenglass, Cumbria, UK





Geology map





Triassic sandstones

Borrowdale volcanic group

Eskdale granite

Questions

- What clay minerals exist in the estuaries?

X-Ray diffraction (XRD), (SEM/BSE/EDAX) and Fourier Transmitted Infra Red (FTIR)

- What is the role of provenance in clay mineral distribution in the estuaries?

Water and soil samples beyond the high tide, different hinterland geology

- Is there any spatial pattern of clay mineral distribution in the estuaries?

Comparing the results of the different estuaries

- Where do the clay minerals originate?

Sampling strategy

Estuarine sediment samples:

upper and lower part of the each estuary

Fluvial sediment samples:

soils and fluvial sediments from hinterland of each river catchment (beyond the high tide limit)

Estuarine water samples:

tide cycle (12hr) marine dominated and fresh water dominated within each estuary

End member water samples:

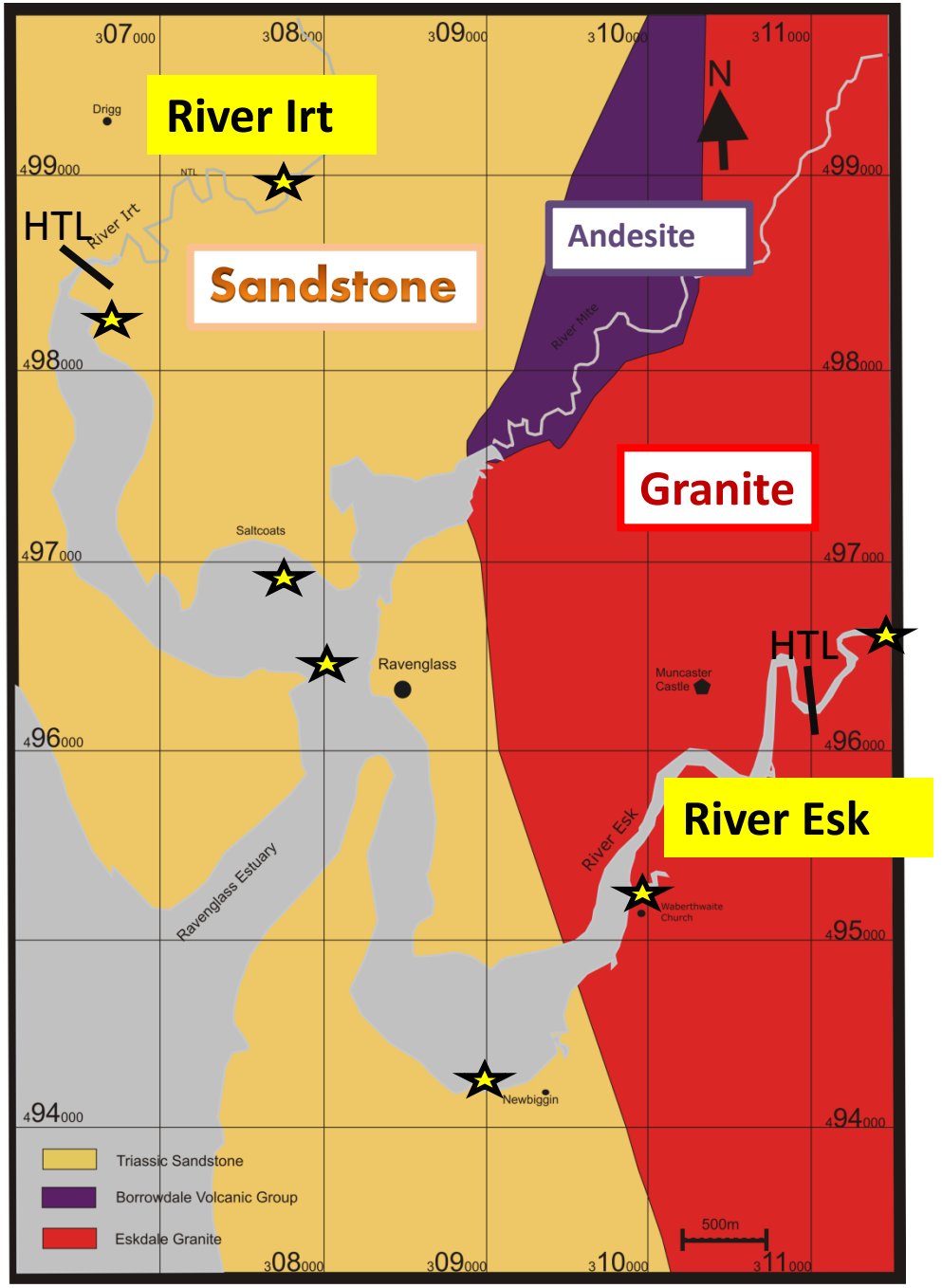
marine water and fresh water (beyond the high tide limit)

Core points and water sampling locations ★

Triassic sandstones

Borrowdale volcanic group

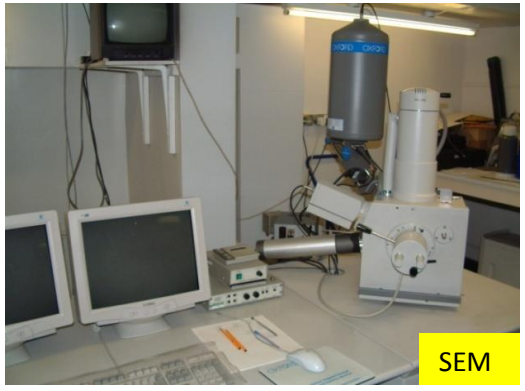
Eskdale granite



Sampling and analytical techniques

Sediment cores and filter papers analysed in the lab using XRD (various prep techniques), SEM, FTIR

Water samples analysed in the lab using ion chromatography, ICP-AES

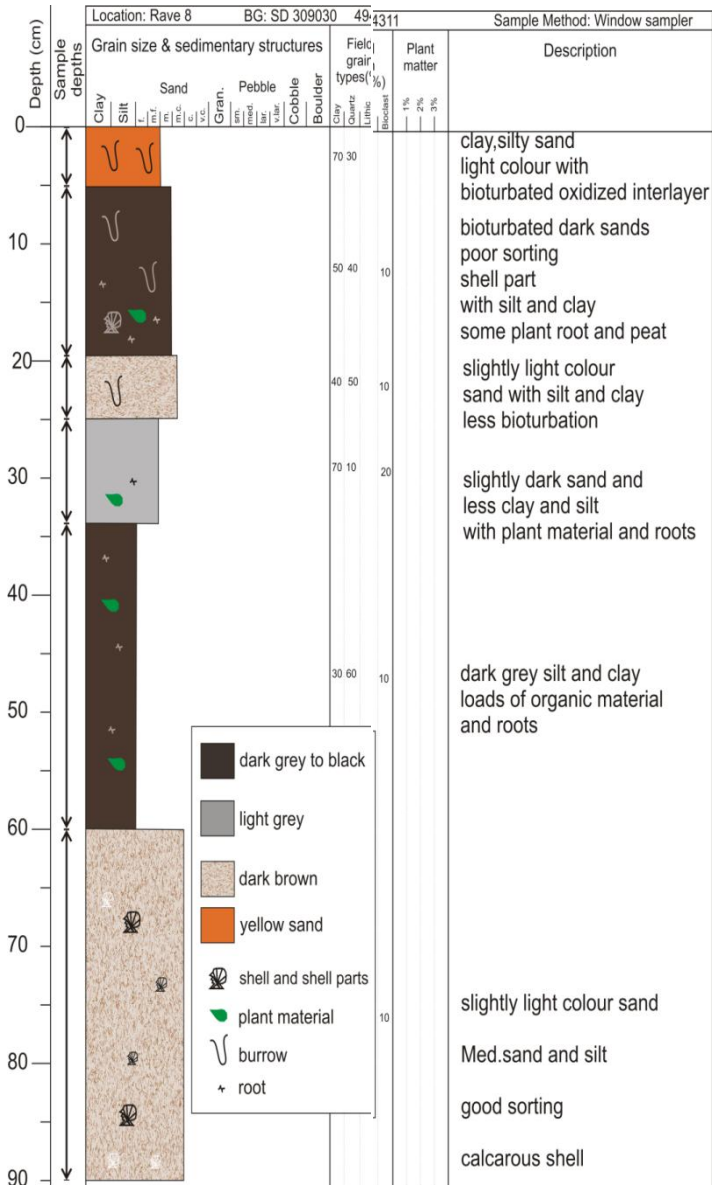

SEM


infrared

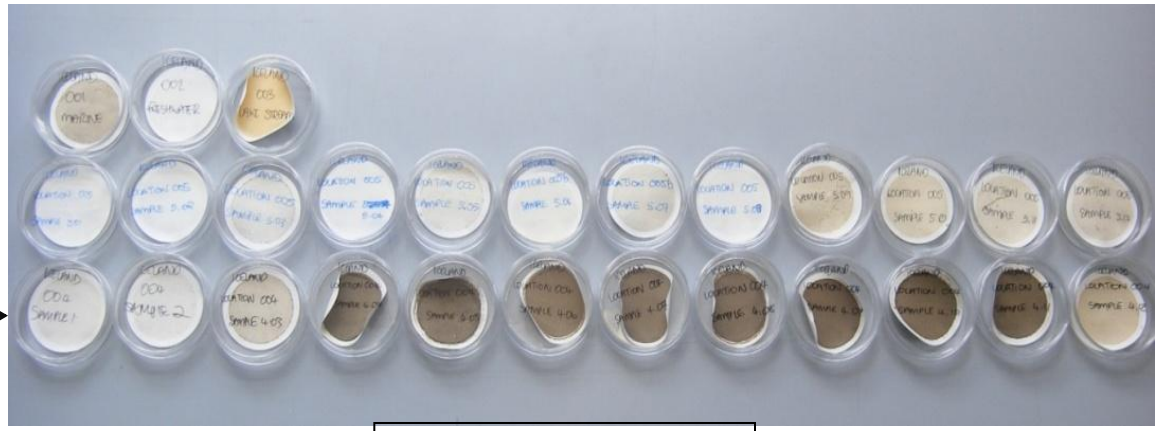

sampling


Ion chromatography

Sediment cores



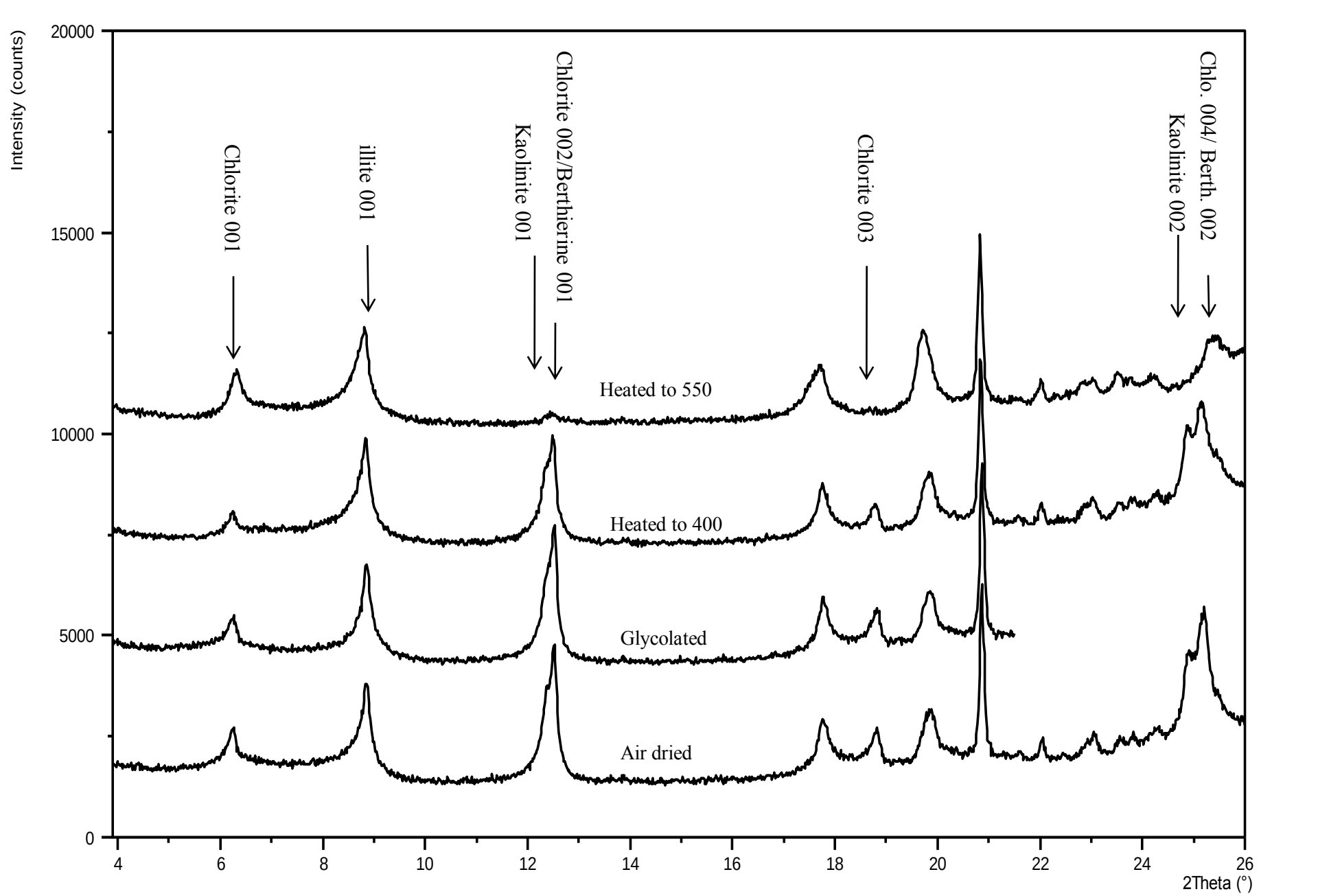
Sediment suspension



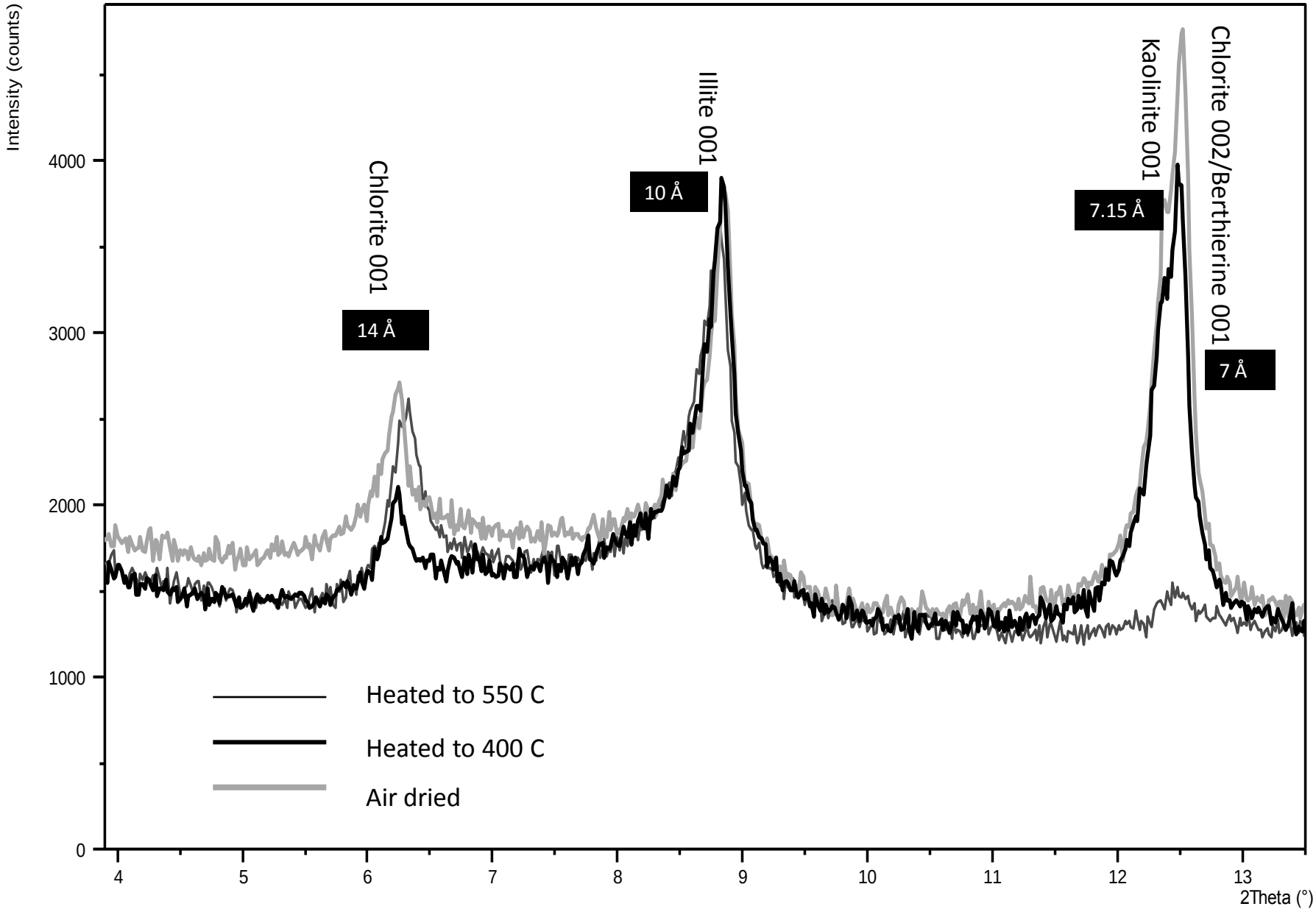
Filtrate samples

- Alkalinity
- pH
- Filtration
- Acidification

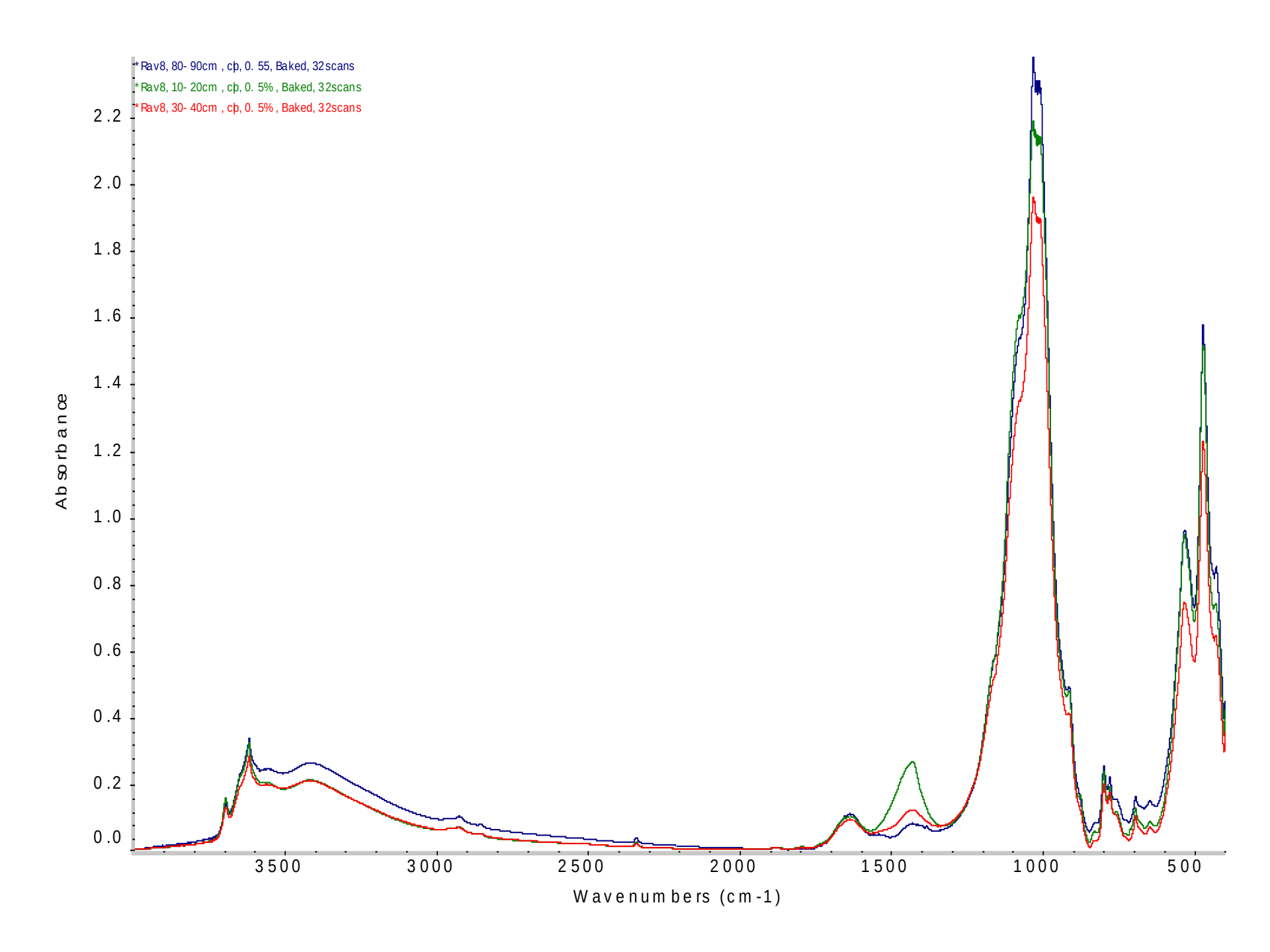
- To identify minerals in suspension in the water column, filter papers were also analysed using XRD
- As seen in filters, the particulate matter varied from marine to freshwater

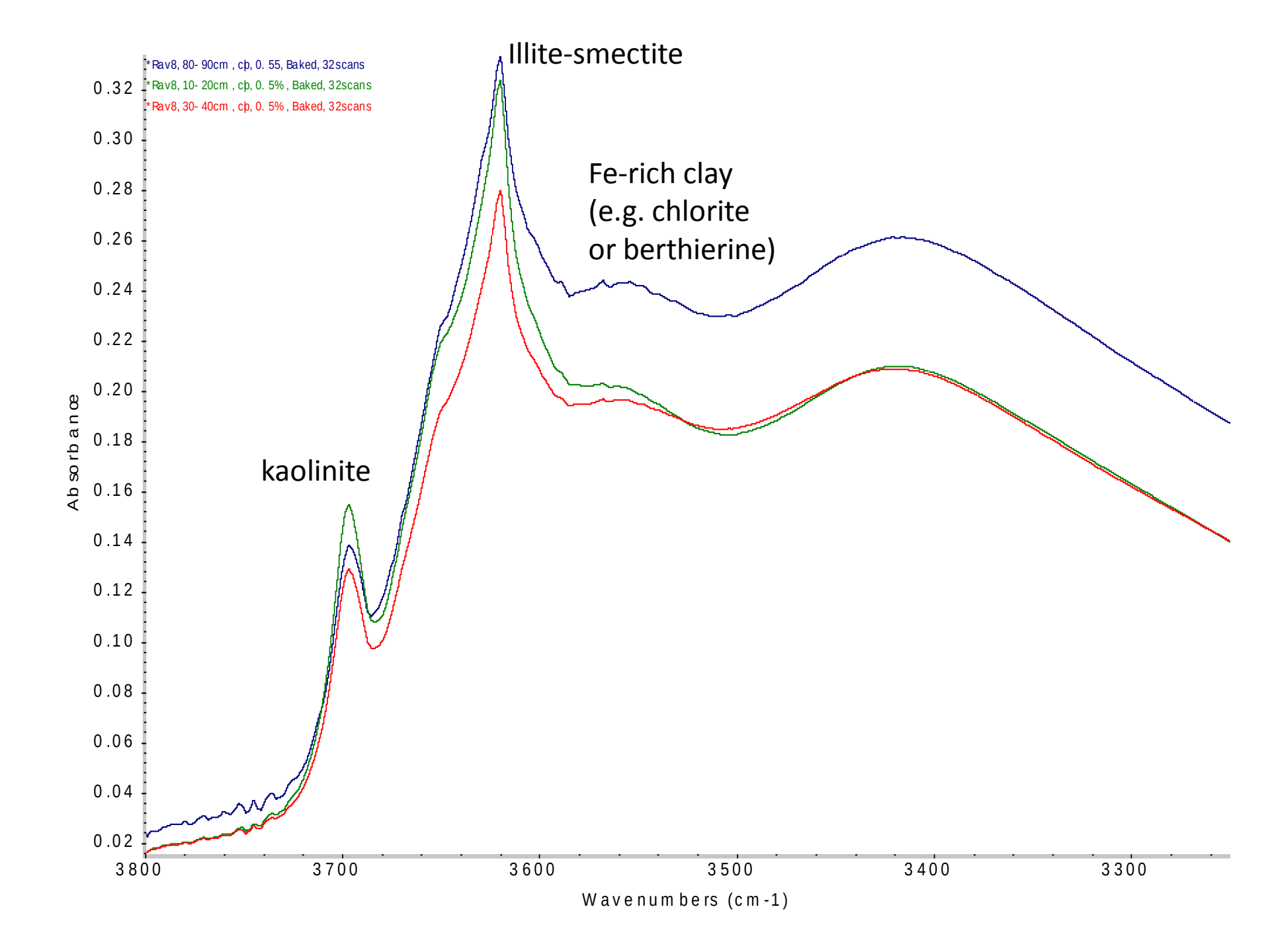


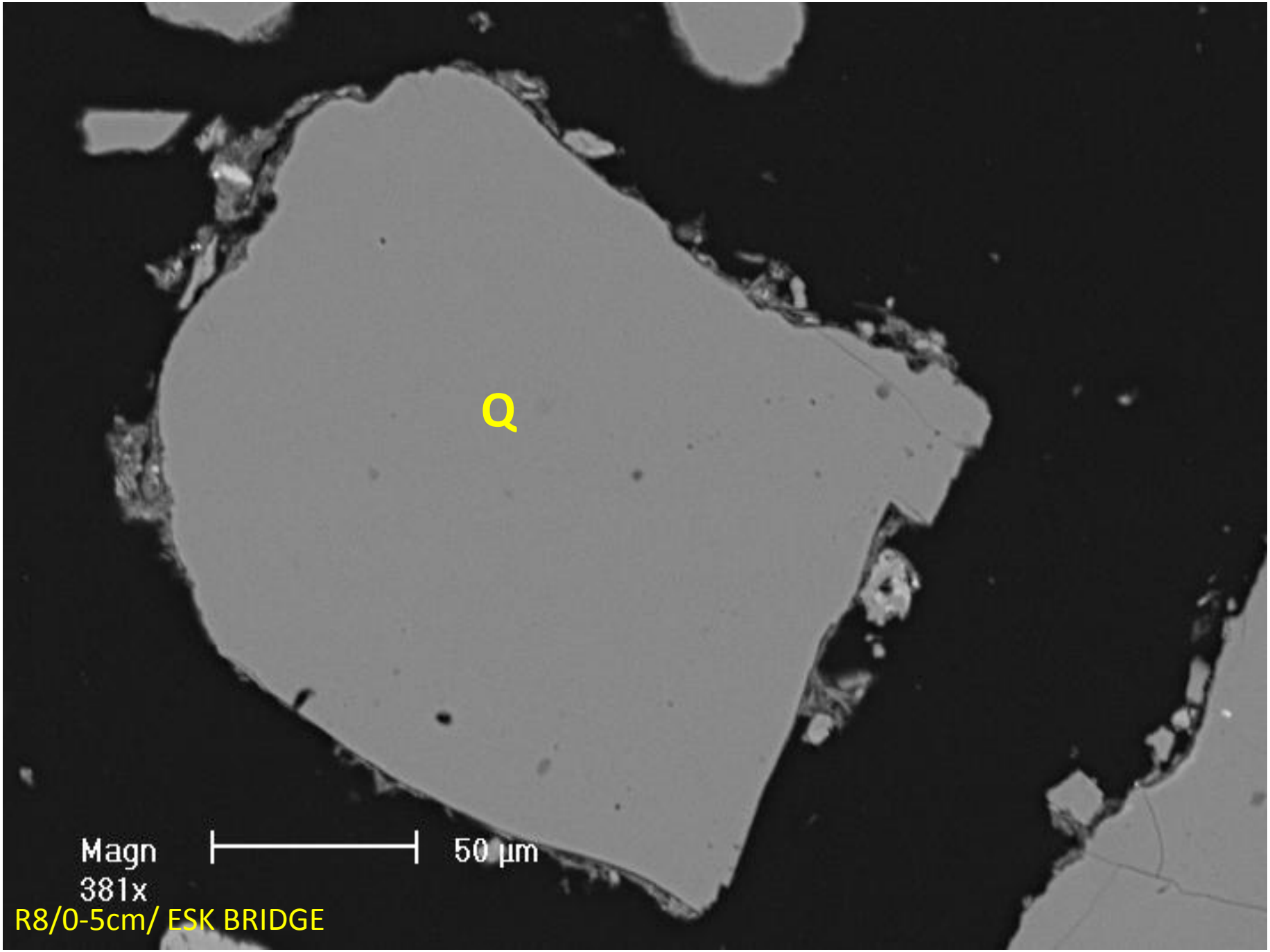
Random powder clay separated , Cu Kα

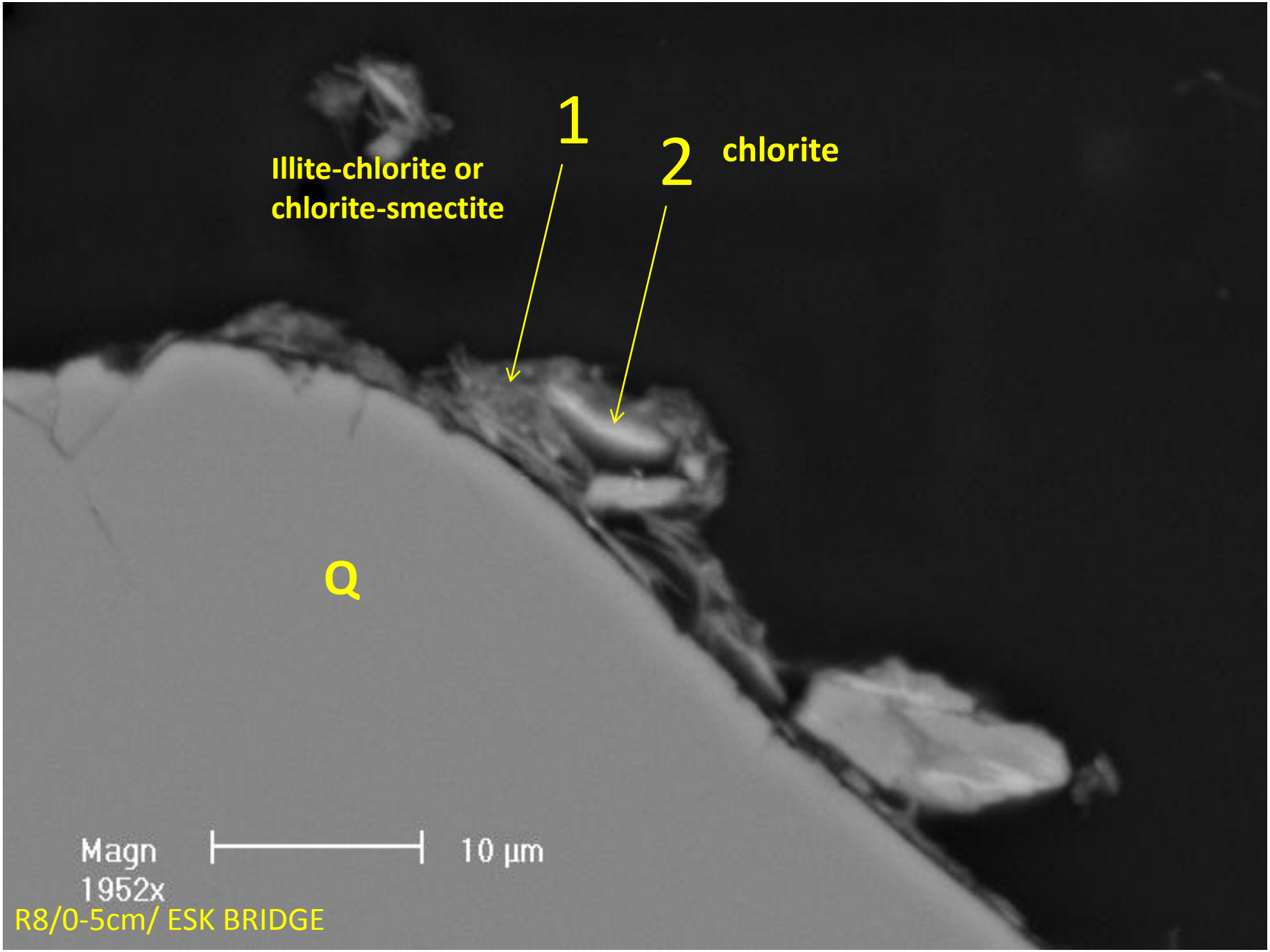


Random powder clay separated , Cu Kα

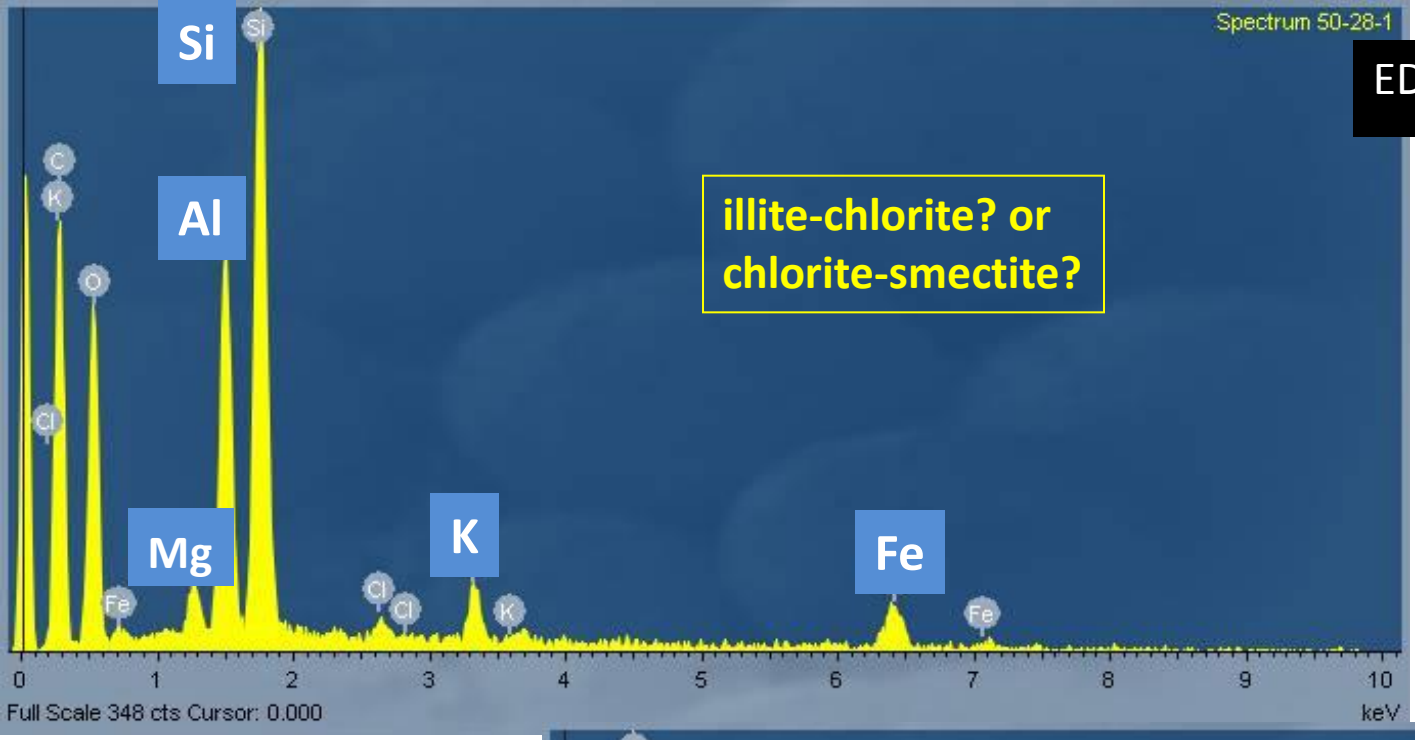

*Rav8, 80- 90cm , cþ, 0. 55, Baked, 32scans
*Rav8, 10- 20cm , cþ, 0. 5% , Baked, 32scans
*Rav8, 30- 40cm , cþ, 0. 5% , Baked, 32scans
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Absorbance
3500
3000
2500
2000
1500
1000
500
Wavenumbers (cm-1)

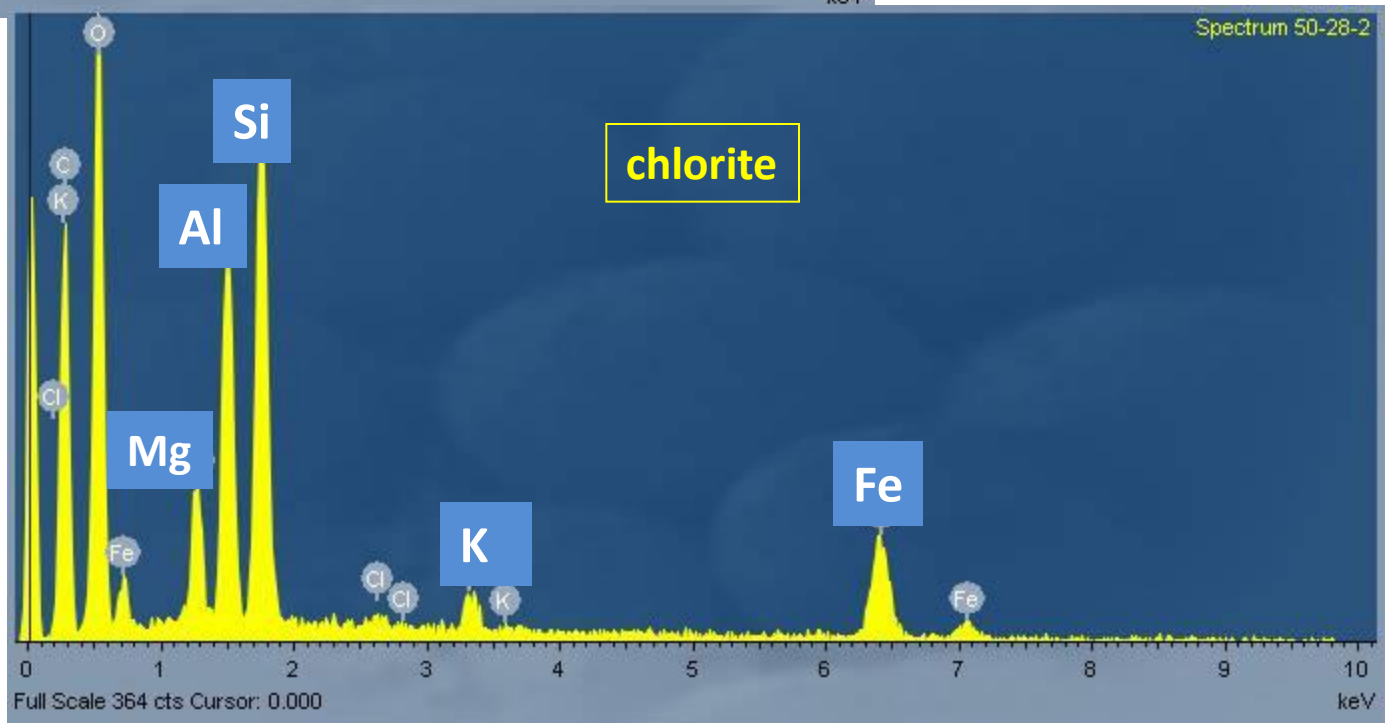

*Rav8, 80- 90cm , cþ, 0. 55, Baked, 32scans
*Rav8, 10- 20cm , cþ, 0. 5% , Baked, 32scans
*Rav8, 30- 40cm , cþ, 0. 5% , Baked, 32scans
Illite-smectite
Fe-rich clay
(e.g. chlorite
or berthierine)
kaolinite
Absorbance
0.32
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
3800
3700
3600
3500
3400
3300
Wavenumbers (cm-1)


Q
Magn
381x
50 µm
R8/0-5cm/ ESK BRIDGE

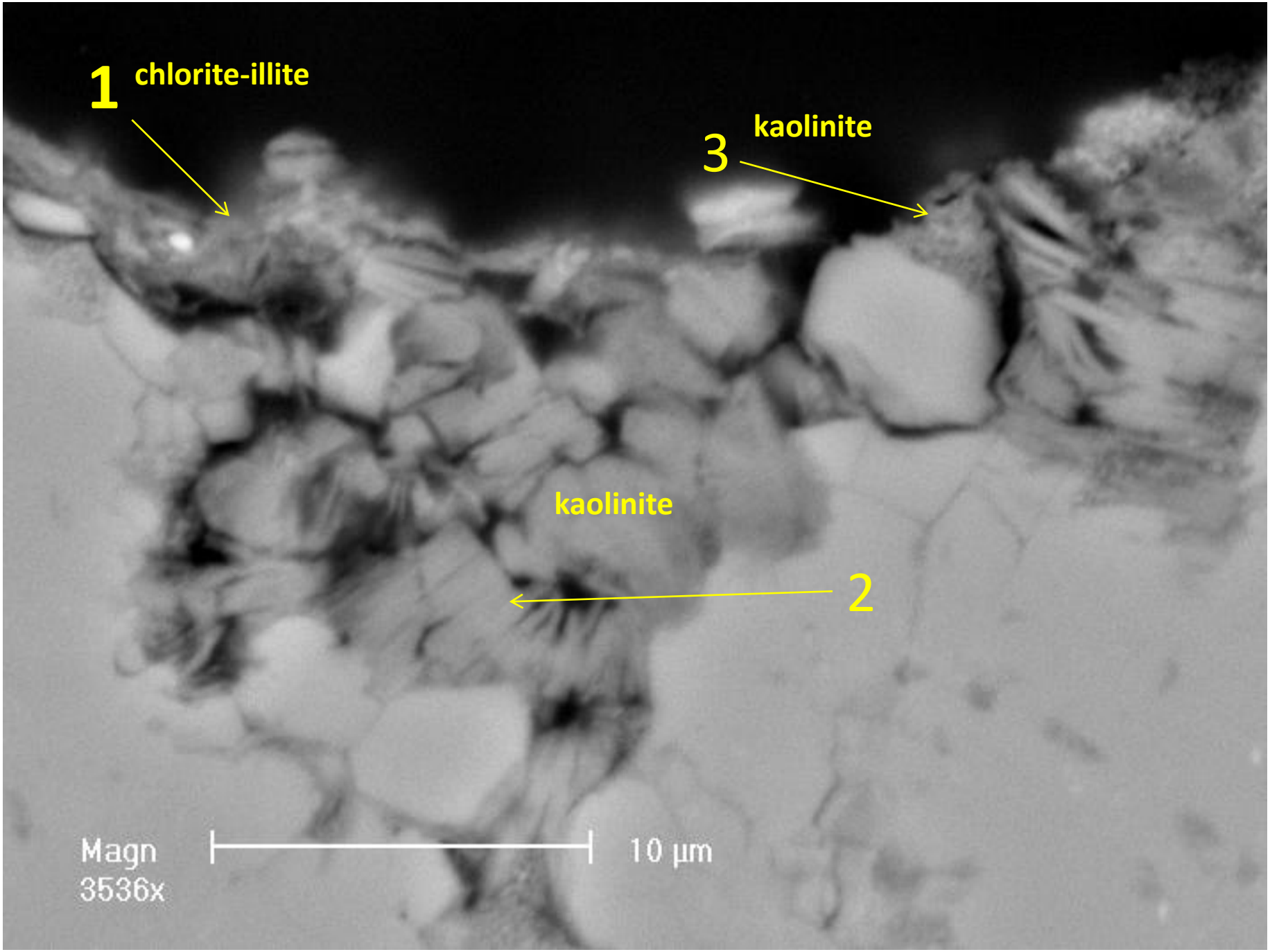

1
2
chlorite
Illite-chlorite or
chlorite-smectite
Q
Magn
1952x
10 µm
R8/0-5cm/ ESK BRIDGE

EDAX Spectrum analysis

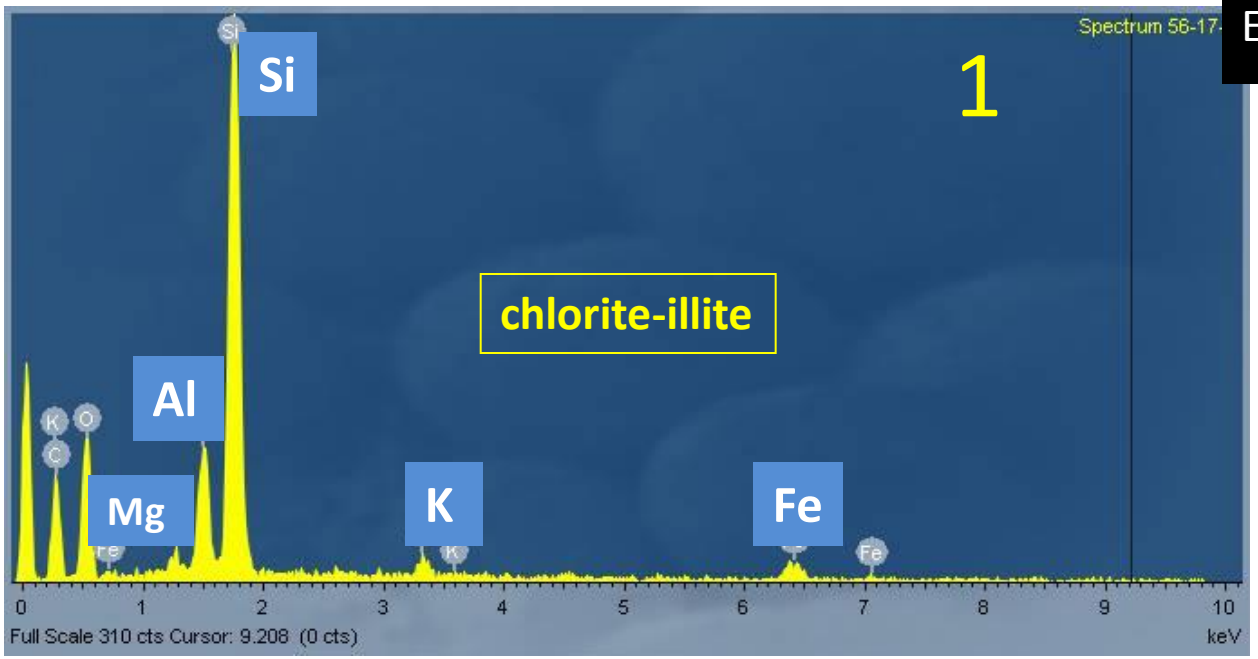


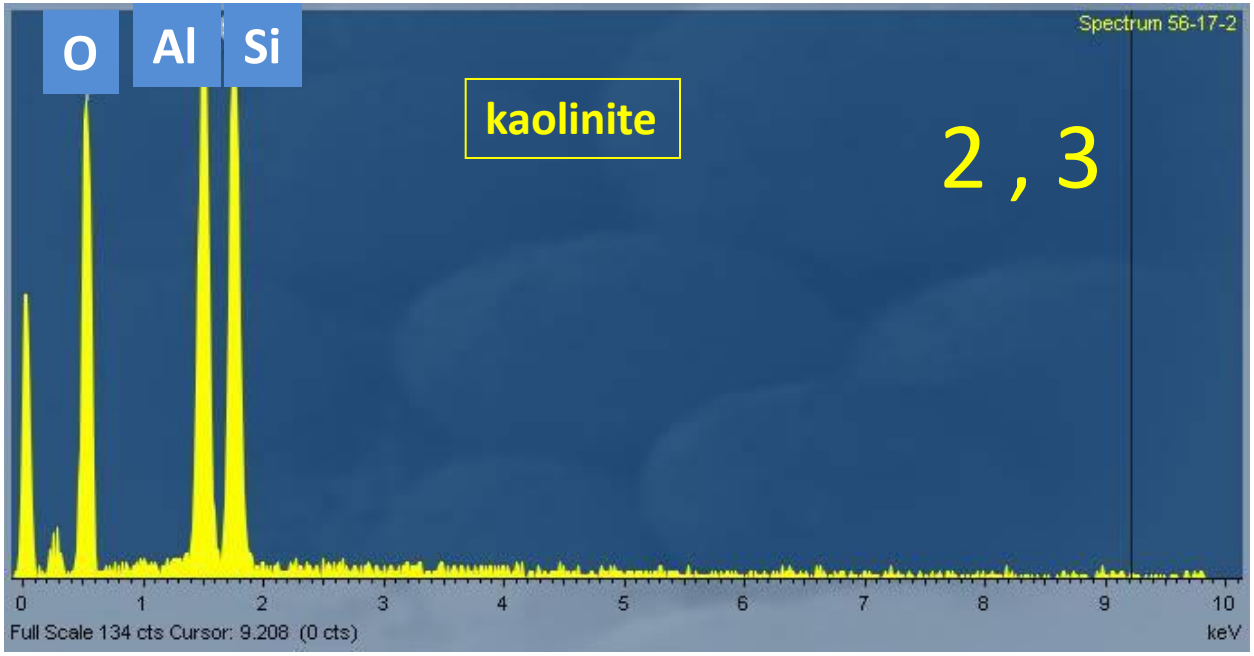


R8/0-5cm/ ESK CHURCH


1
chlorite-illite
3
kaolinite
kaolinite
2
Magn
3536x
10 µm

EDAX Spectrum analysis





Multidisciplinary approach to detail clay mineralogy in the estuary

	TECHNIQUES		
CLAYS	**XRD**	**SEM/BSE**	**FT-IR**
✓chlorite	YES	YES	YES
✓illite	YES	YES	YES
expandable clay minerals	Yes	possible	possible
✓kaolinite	YES	YES	YES
?berthierine	YES	possible	possible
Estuary sediments			

questions & answers

❖What clay minerals exist in the estuaries?

chlorite, kaolinite, illite, apparently berthierine and expandables

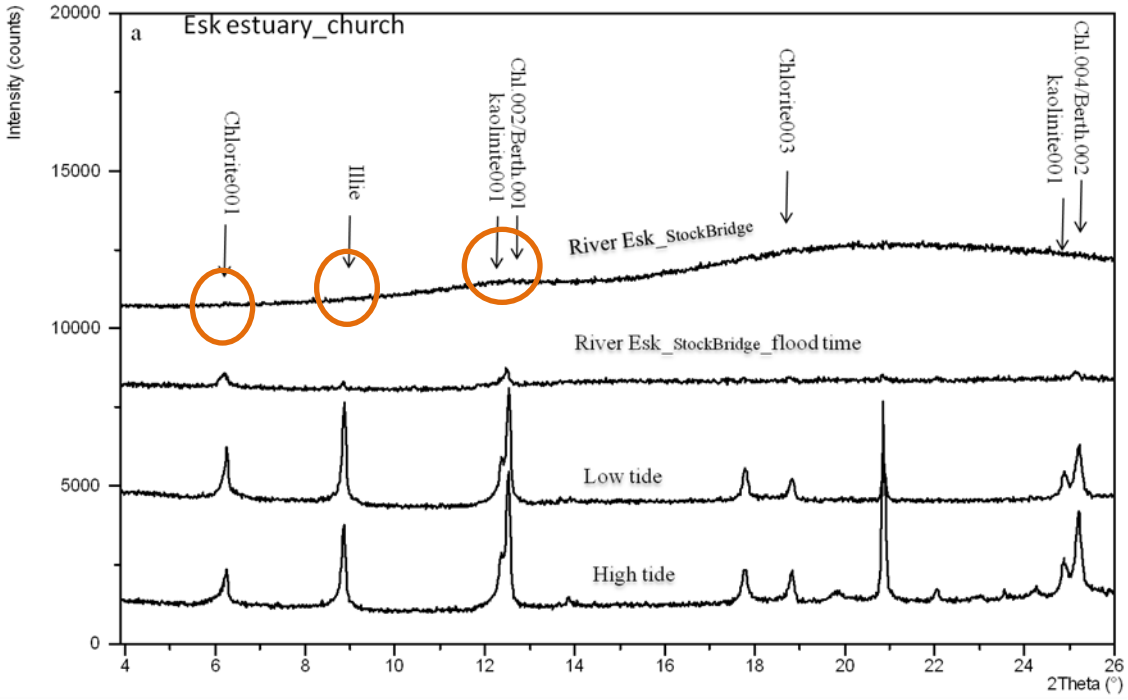
❖What is the role of provenance in clay mineral distribution in the estuaries?

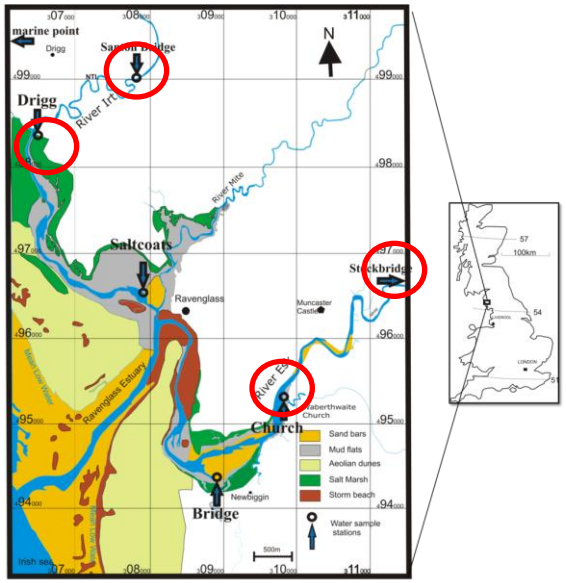
Supply of the different types of the clays, also different product of the alteration and weathering of the parents rocks and flood plain soils

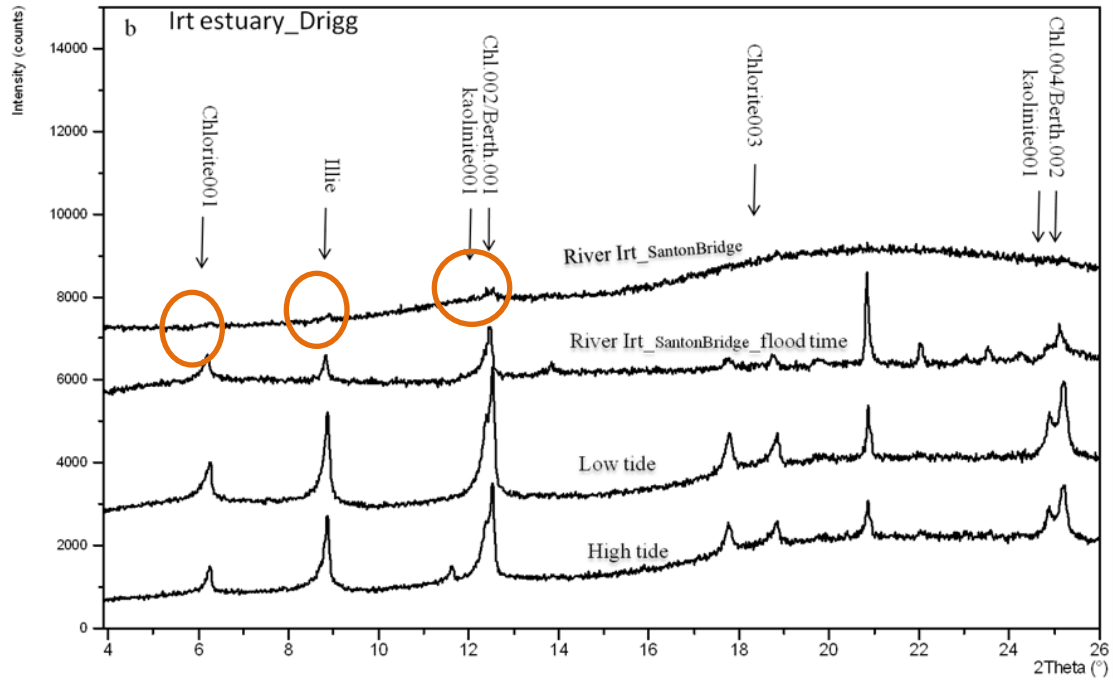
❖Is there any spatial pattern of clay mineral distribution in the estuaries?

Yes, there is. North estuary has relatively more illite, while south estuary has more chlorite

❖Where do the clay minerals originate?

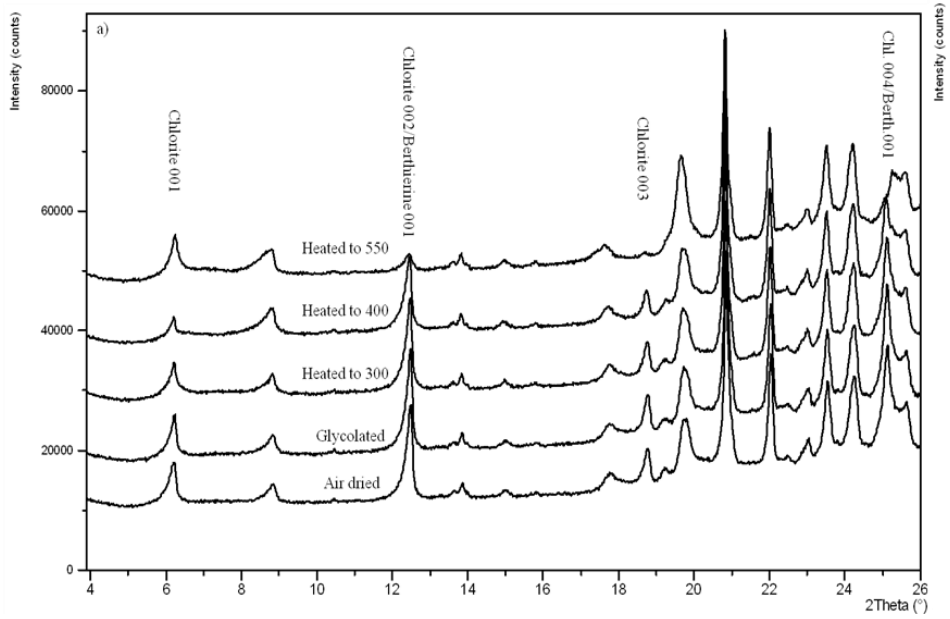


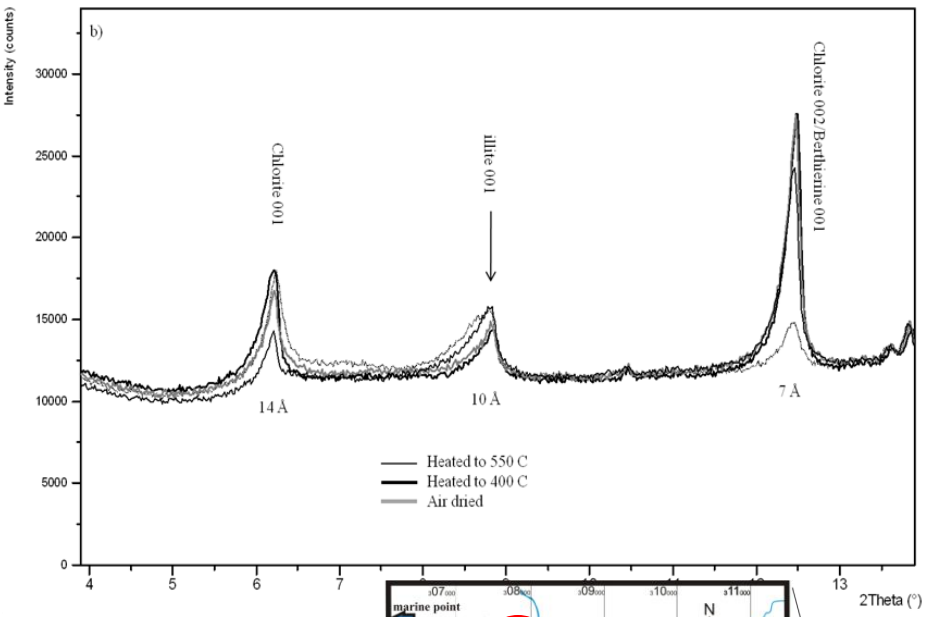




Sediments in suspension beyond the high tide limit

Soils and fluvial sediment beyond the high tide limit



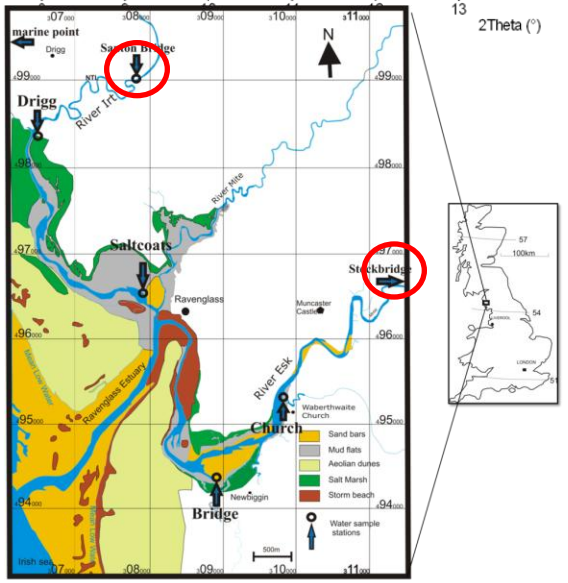


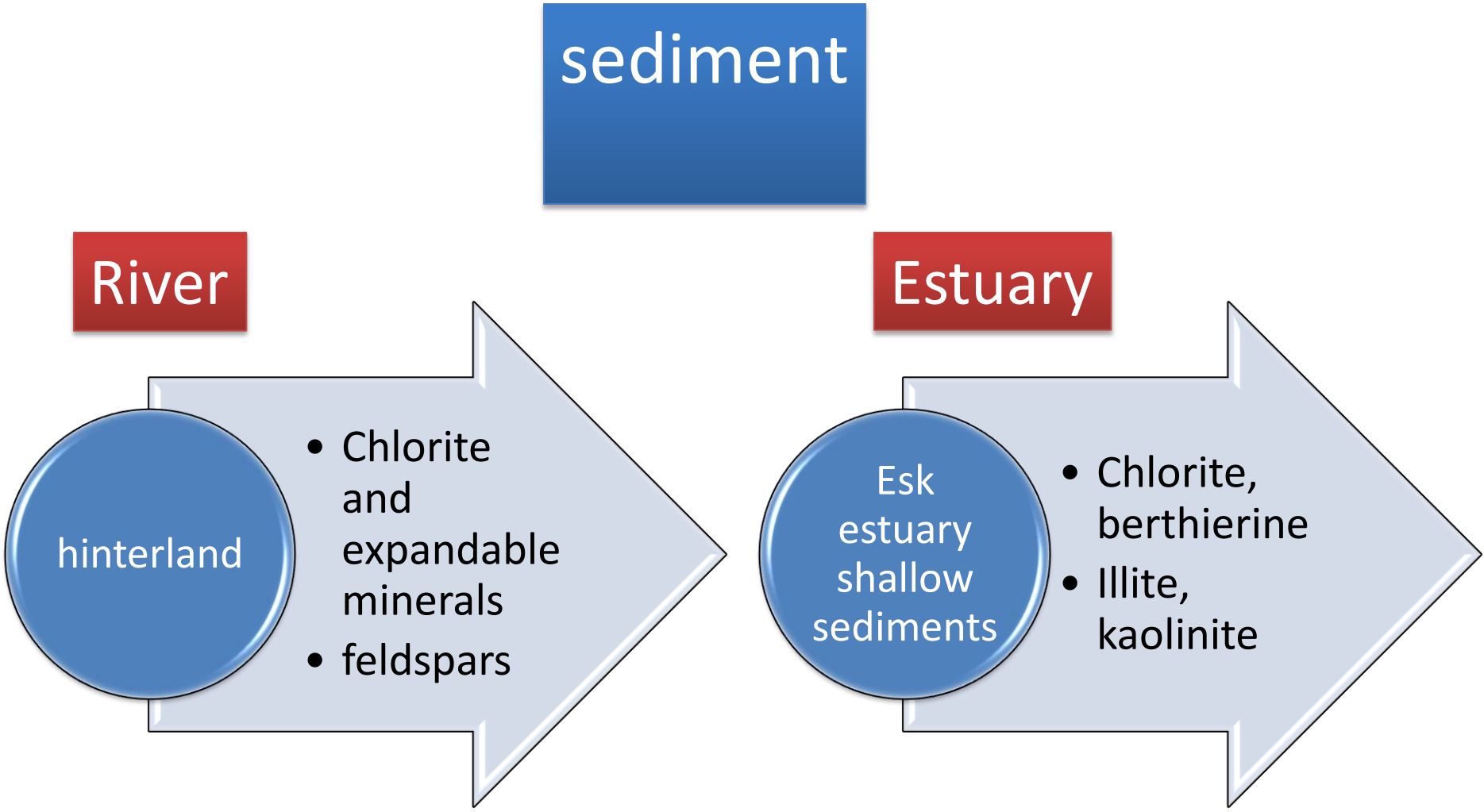
Observed:

chlorite
illite/muscovite
expandables (vermiculite)

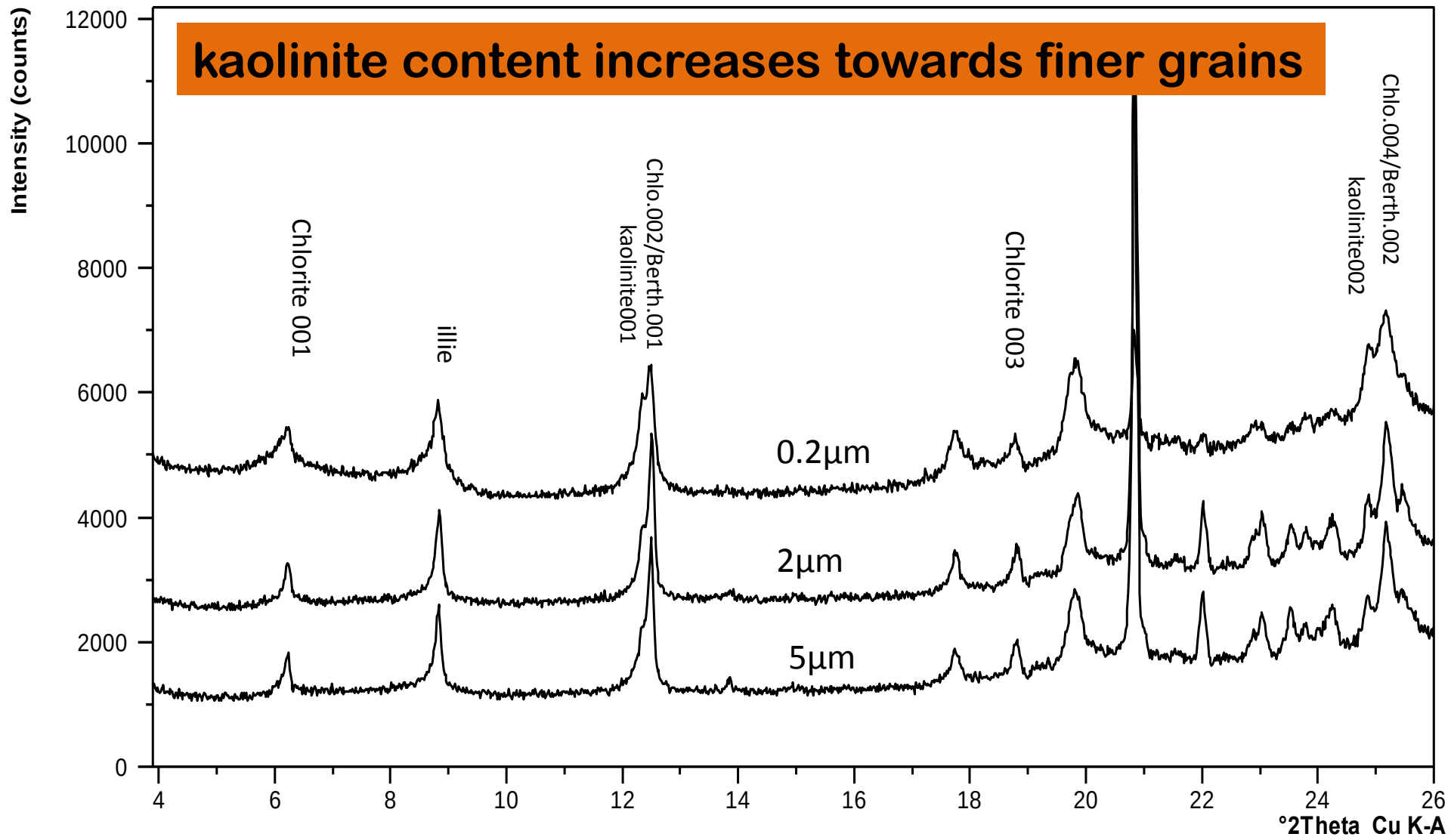
Not observed:

kaolinite




sediment
River
hinterland
Chlorite and expandable minerals
feldspars
Estuary
Esk estuary shallow sediments
Chlorite, berthierine
Illite, kaolinite

XRD pattern for grain size separation



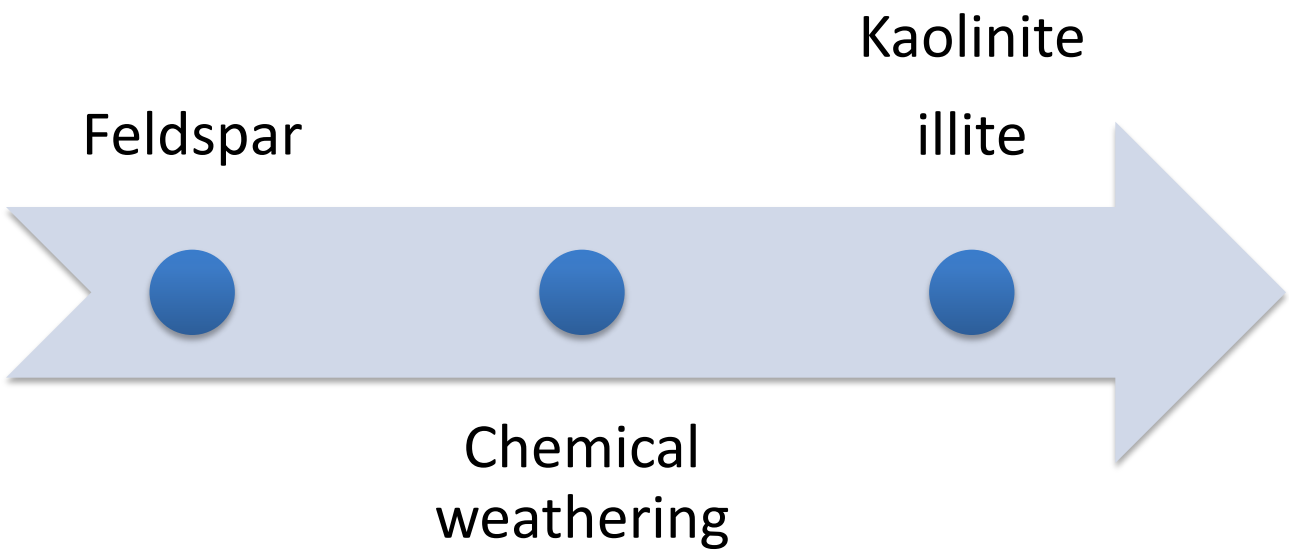
Random powder clay separated , Cu Kα

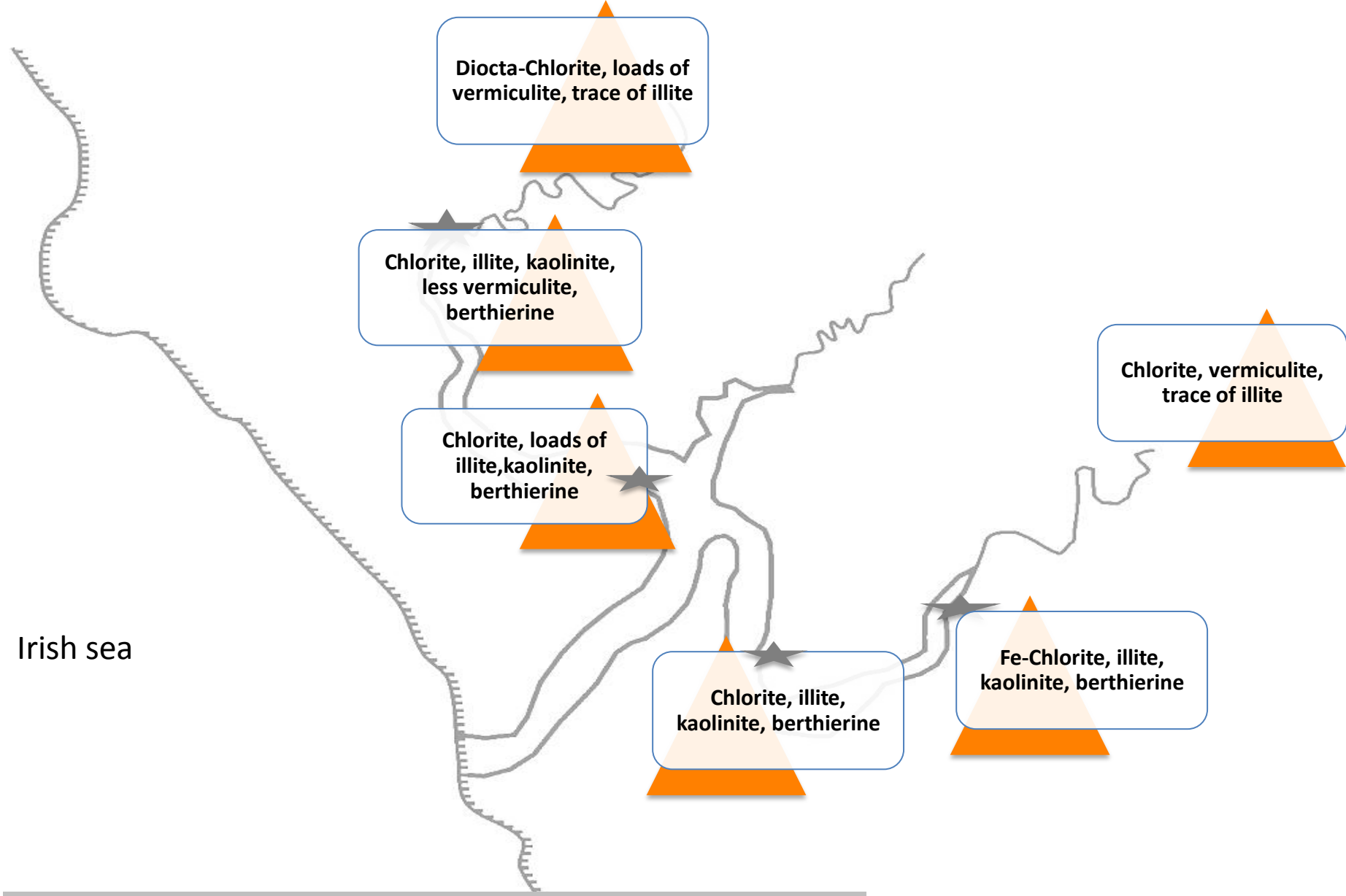
hinterland

Feldspar has high abundance
Illite has low abundance
Kaolinite is below detection

Estuarine surface sediments

Feldspar is not abundant
Illite is abundant
Kaolinite is present





clay mineral distribution in the estuaries and beyond (water and sediments)

conclusion

❖Which clay minerals exist in the estuaries?

Chlorite, kaolinite, illite, apparently berthierine and expandables

❖What is the role of provenance in clay mineral distribution in the estuaries?

Supply of the different types of the clays, also different product of the alteration and weathering of parent rocks and flood plain soils

❖Is there any spatial pattern of clay mineral distribution in the estuaries?

North estuary has relatively more illite and south estuary has more chlorite, especially Fe-rich chlorite and berthierine

❖**Where do the clay minerals originate?**

chlorite has two sources in the estuary suspended clays; dioctahedral chlorite and vermiculite is transported from the hinterland via the rivers into the estuary while trioctahedral chlorite seems to be generated *in situ*, presumably in the sediment column mobilised during flood tides.

kaolinite seems to be generated *in situ*, presumably within the sediment column by alteration or diagenetic processes and subsequently mobilised by flood tide currents.

illite has two sources in the estuary suspended clays; a trace is transported from the hinterland via the rivers (especially the Irt) into the estuary while elevated illite quantities in the suspended fraction seem to be generated *in situ*, presumably in the sediment column by alteration processes, then mobilised by flood tides.

berthierine was formed within the estuarine environment. Berthierine probably forms in the estuarine environment by interaction between fluvial colloidal or suspended Fe phases and aluminosilicate minerals.

Thank you

Questions to

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or

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please!