Diagenesis and reservoir quality of late Palaeozoic carbonates of the Barents Shelf

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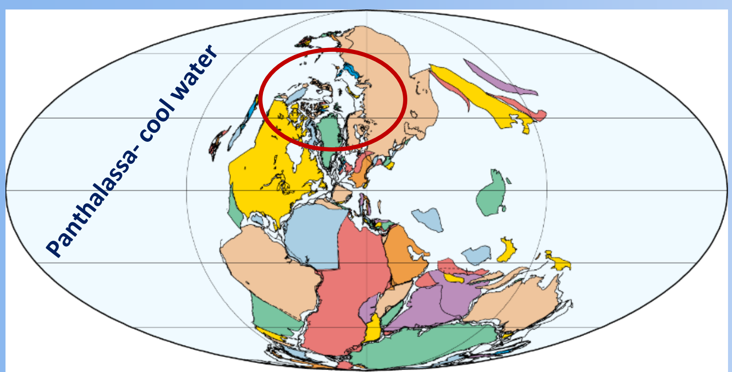
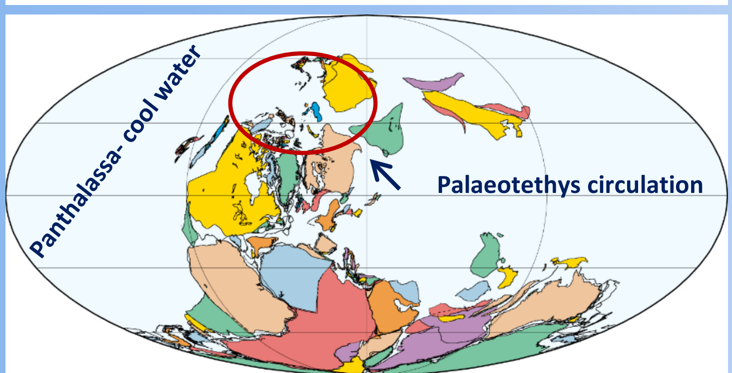
Introduction

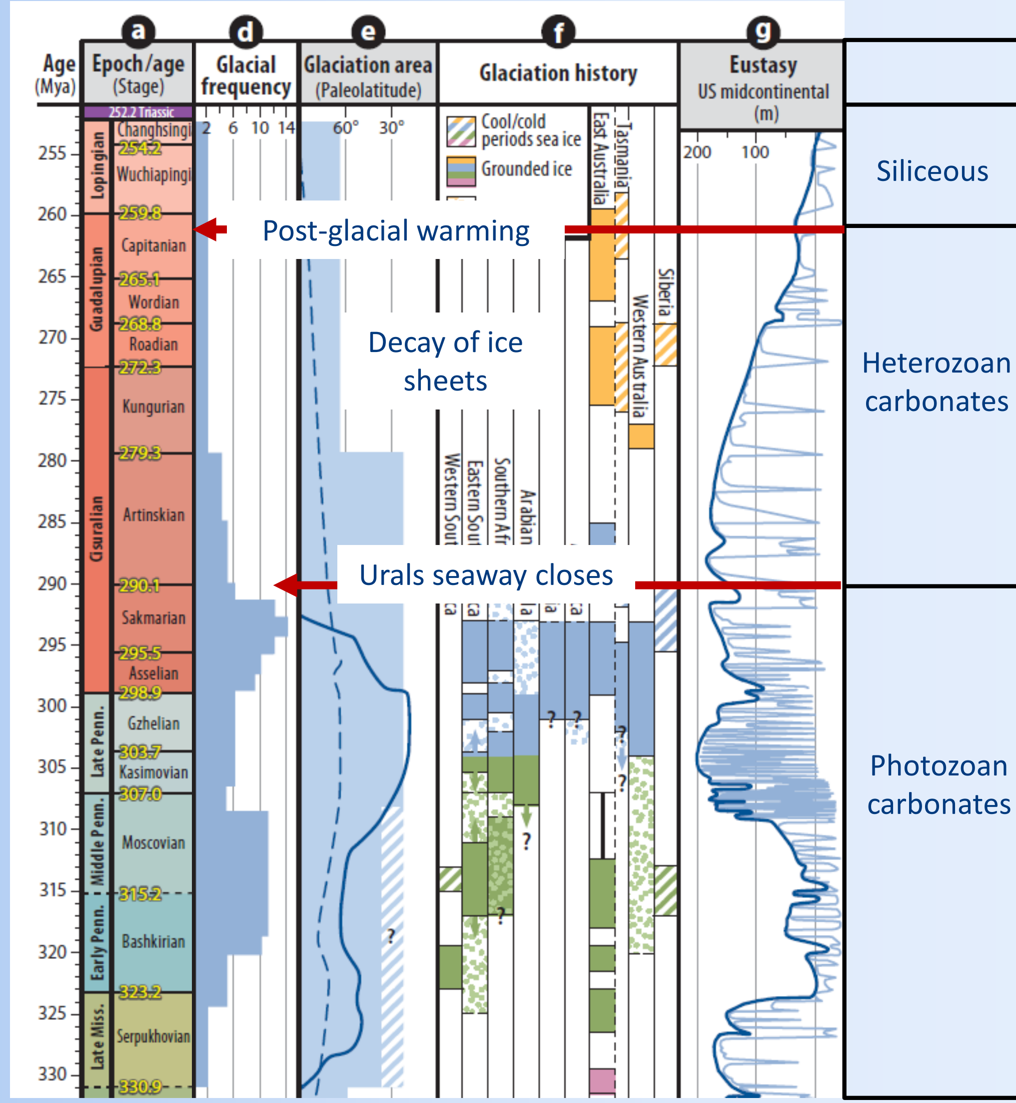
- Estimating carbonate reservoir quality is a challenge in exploration
- Reservoir quality starts with early diagenetic processes
  - Initial mineralogy of grains: potential for dissolution and cementation
  - Palaeoclimatic conditions: Availability of meteoric water and susceptibility to dolomitisation
  - Nature of eustasy (glacio-eustatic vs. greenhouse): Duration and amplitude of exposure during low stands
- The late Palaeozoic is a time of major global change
  - If we understand how these changes influence diagenetic and pore systems
  - We can explain why we expect different reservoir types and quality in different carbonate systems
  - Go some way to risking reservoir properties in carbonates and siliceous facies

Late Palaeozoic global changes

- Palaeotectonic
  - Closure of Urals
  - Northward drift
- Eustatic
- Palaeoclimatic

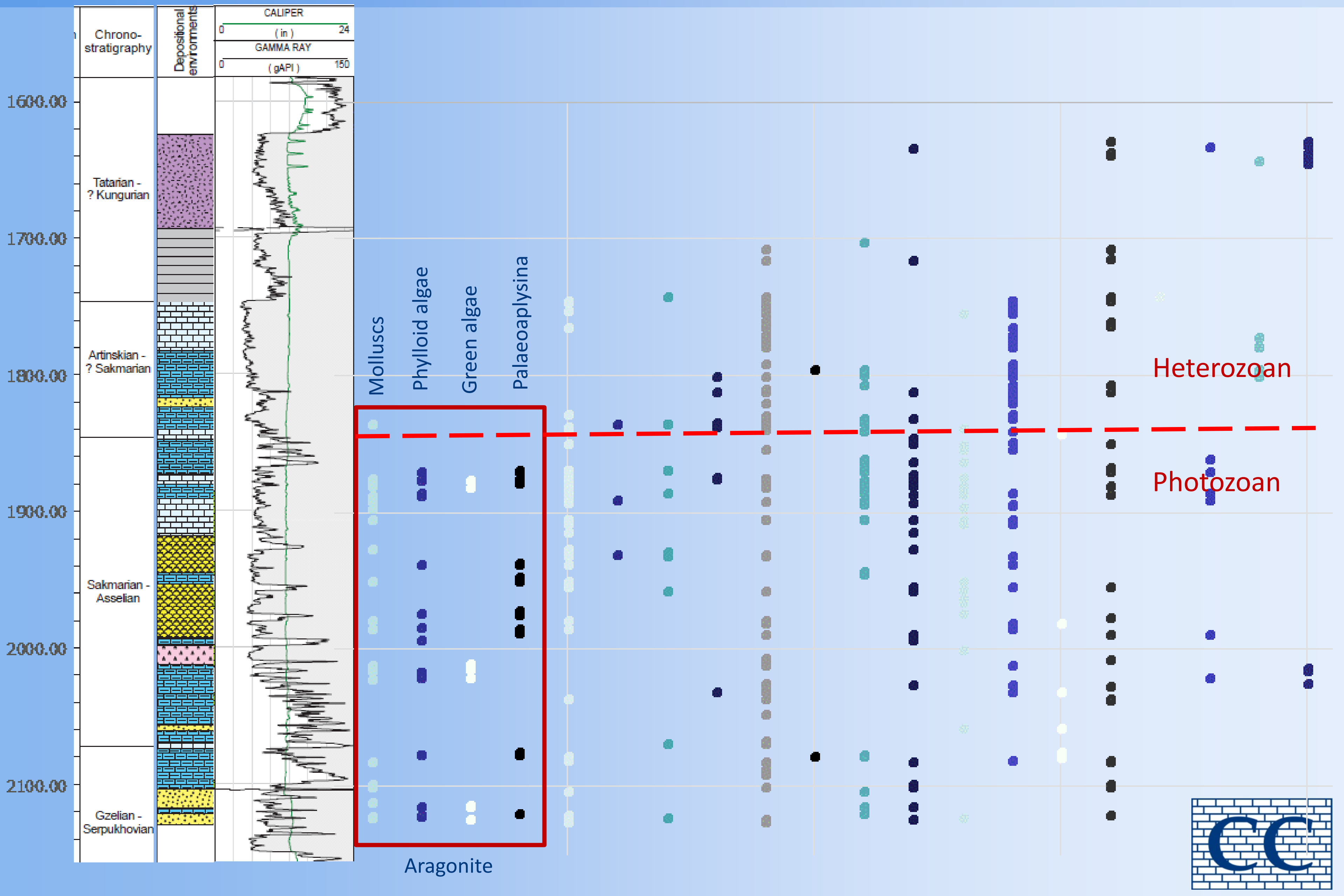




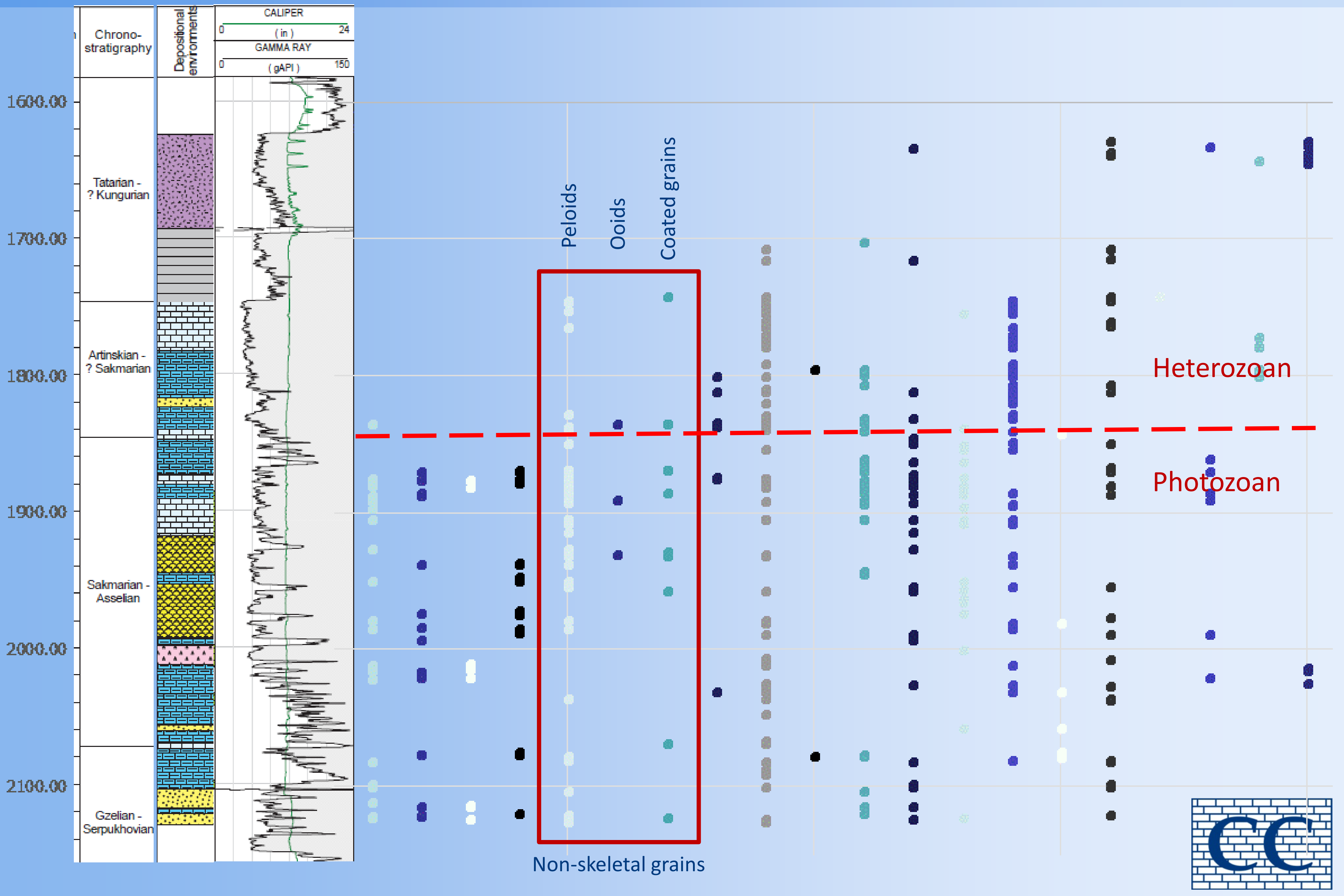


Montañez & Poulsen 2013

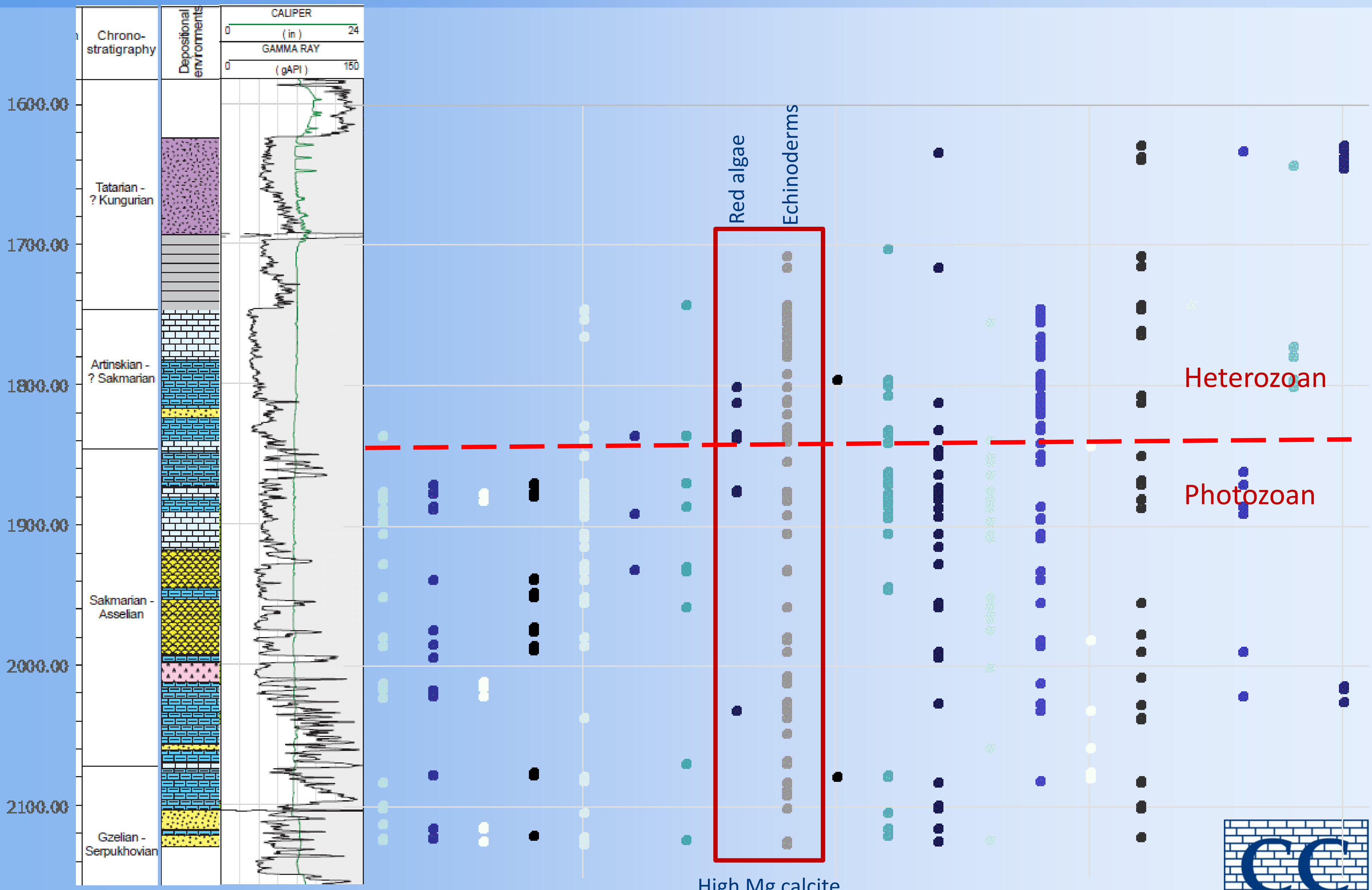
7128/6-1: carbonate microfacies



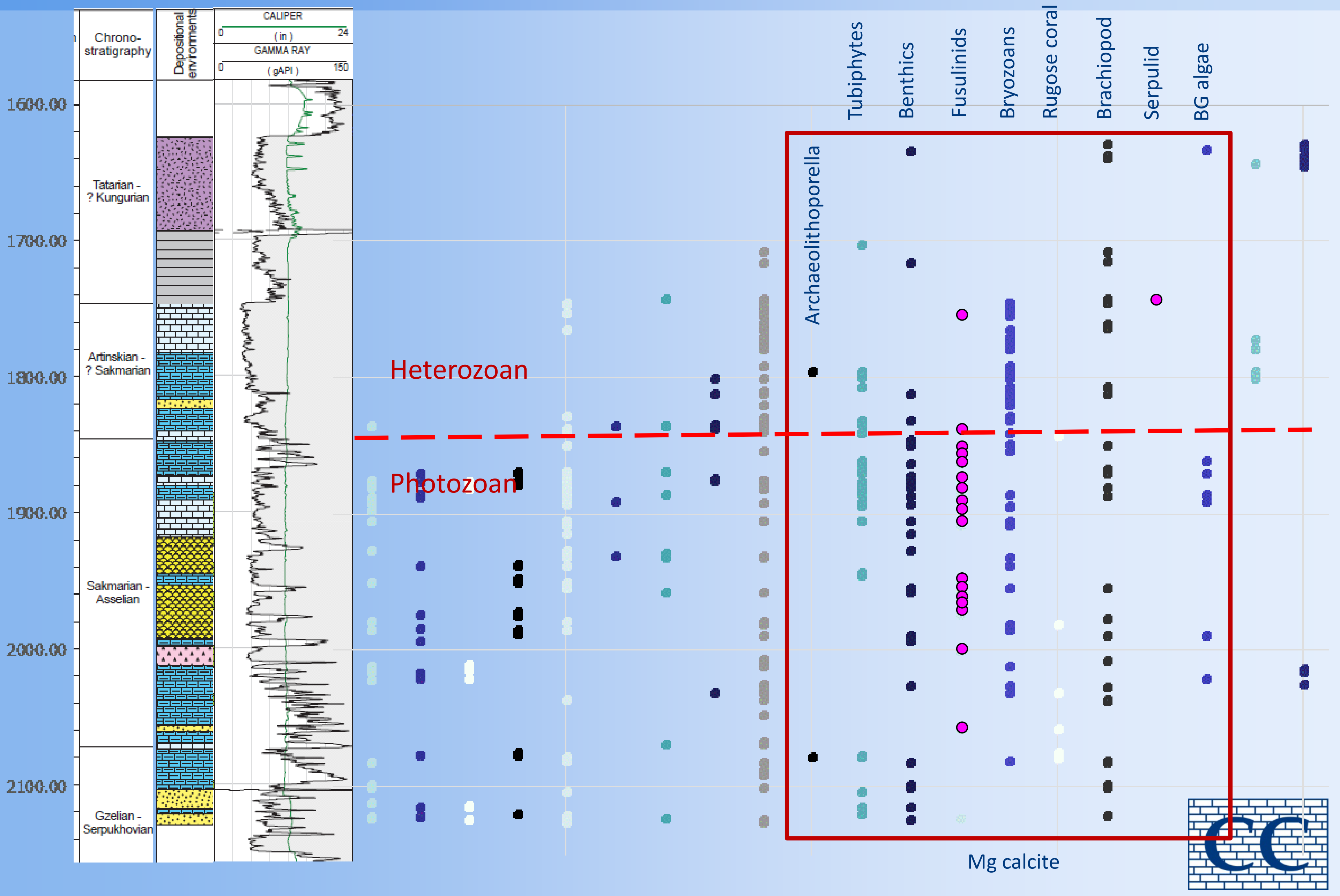
7128/6-1: carbonate microfacies



7128/6-1: carbonate microfacies



7128/6-1: carbonate microfacies



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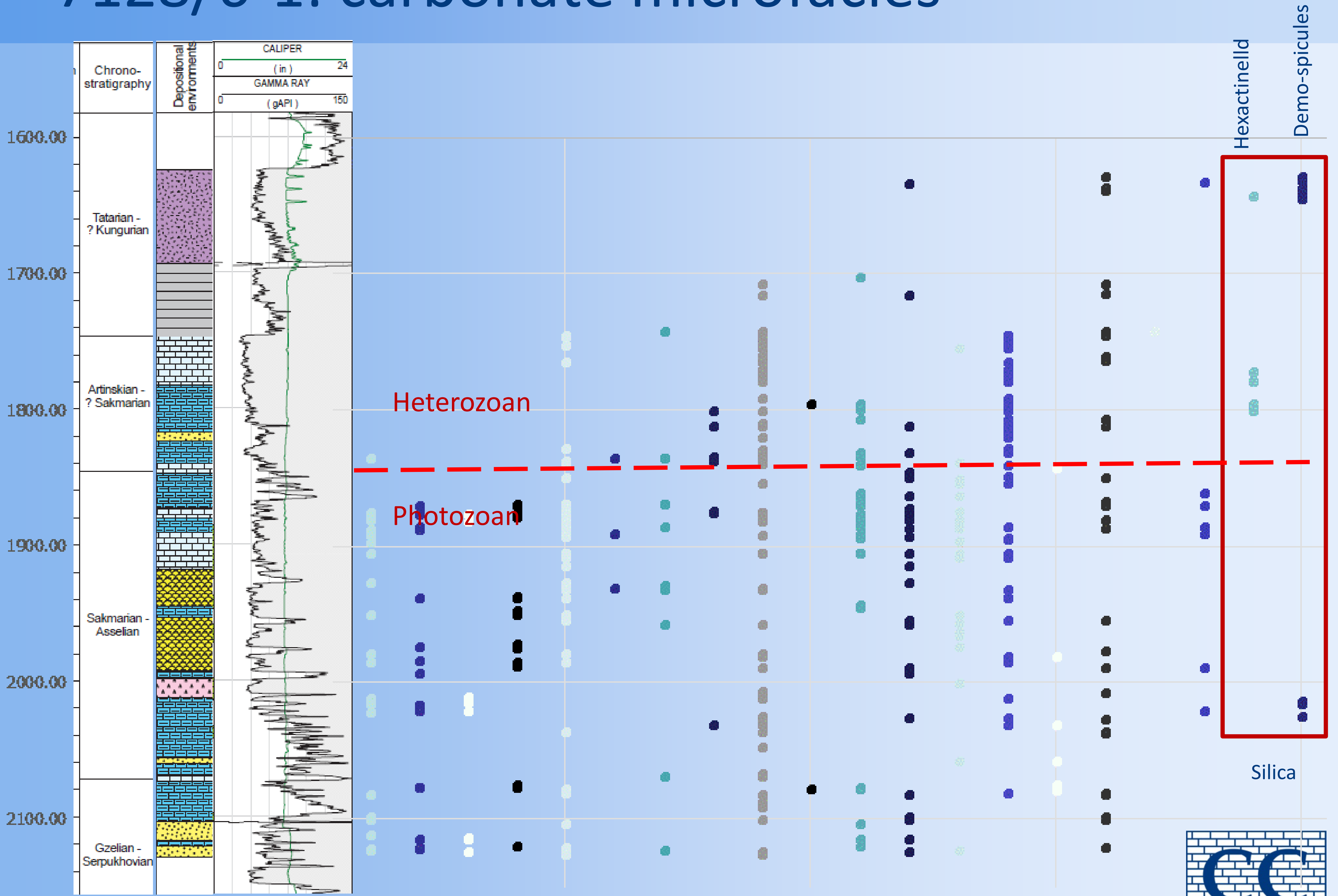
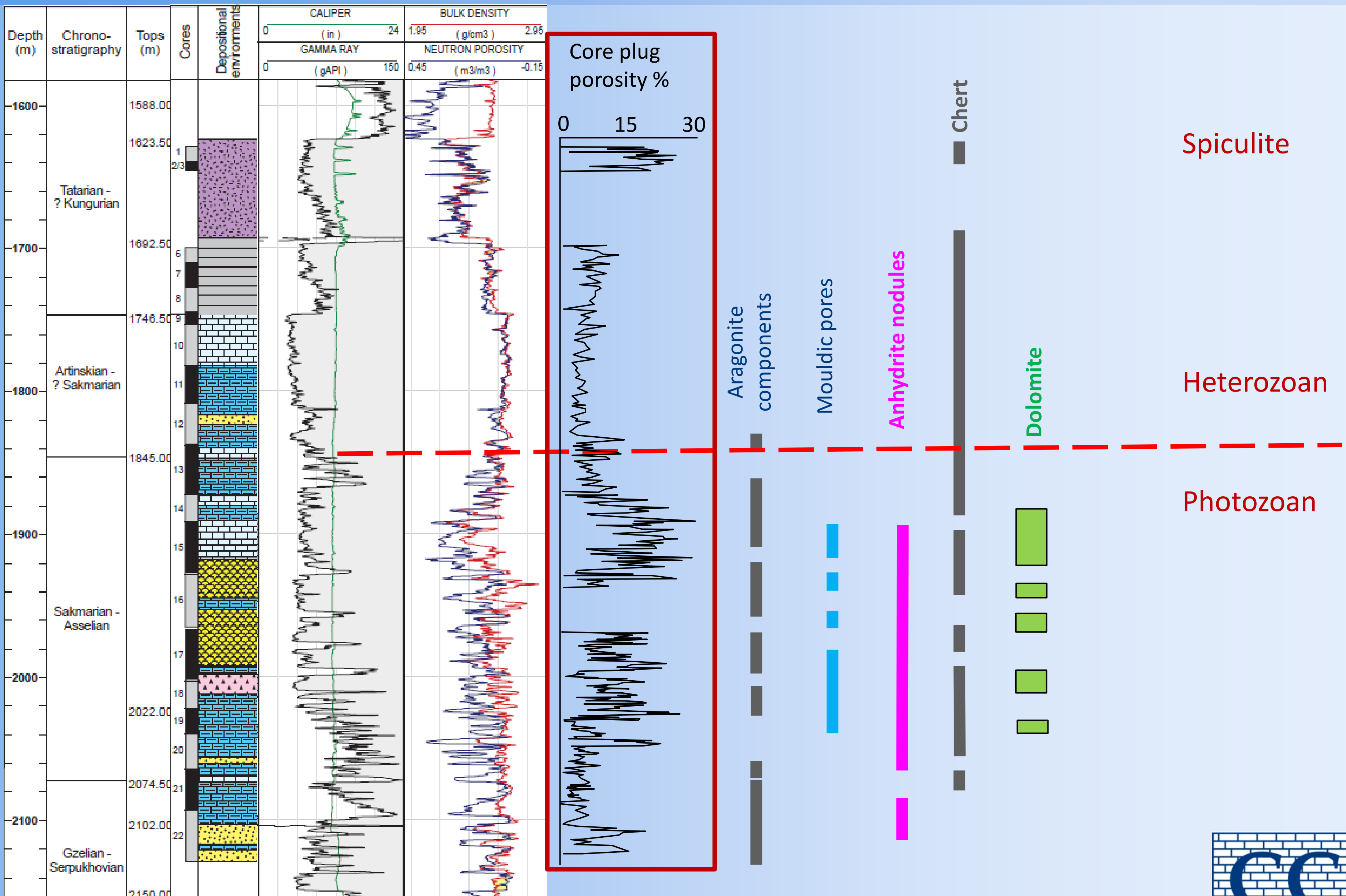
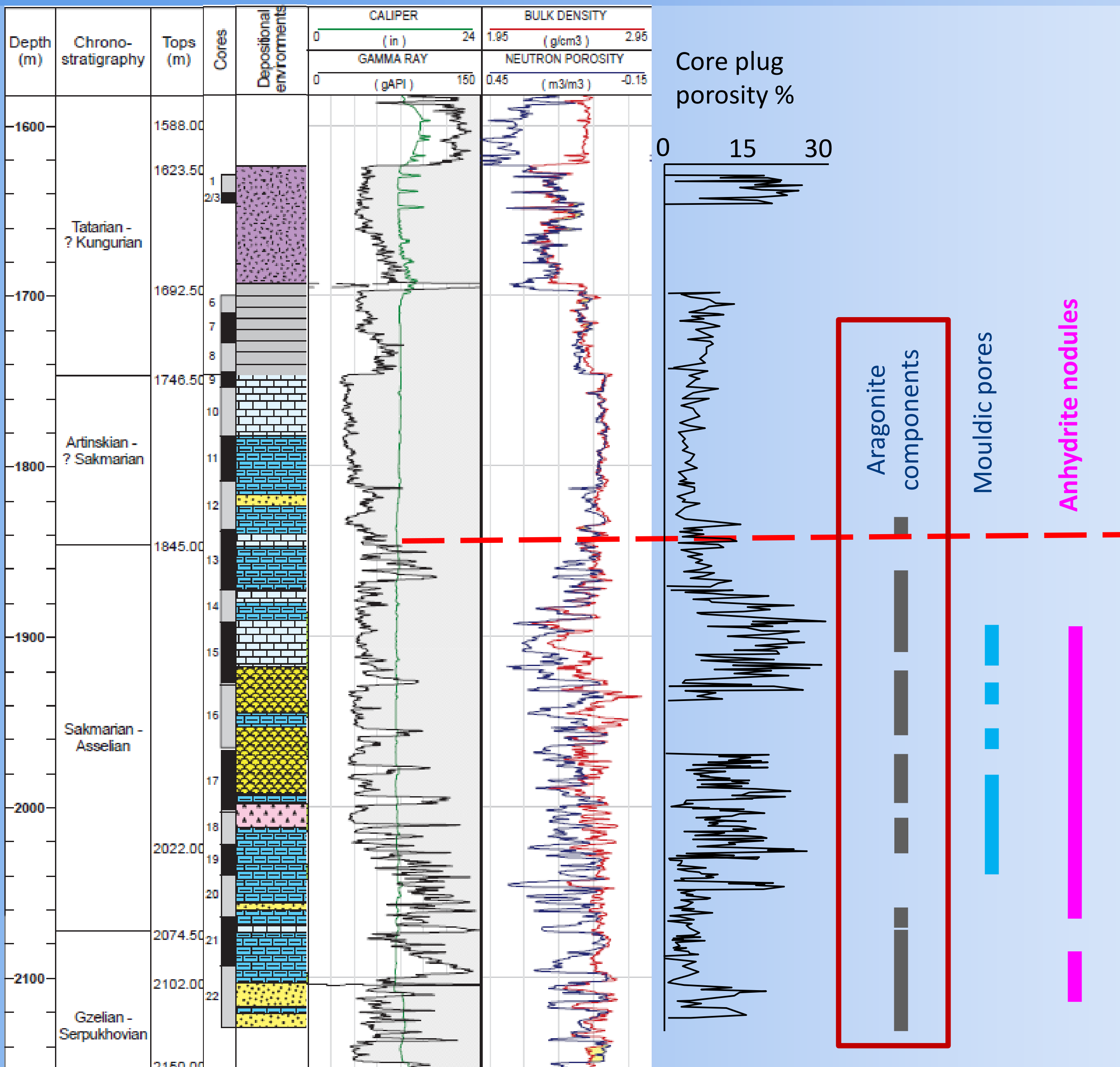
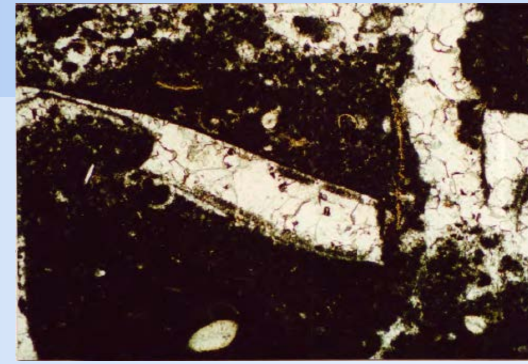


7128/6-1: diagenesis overview



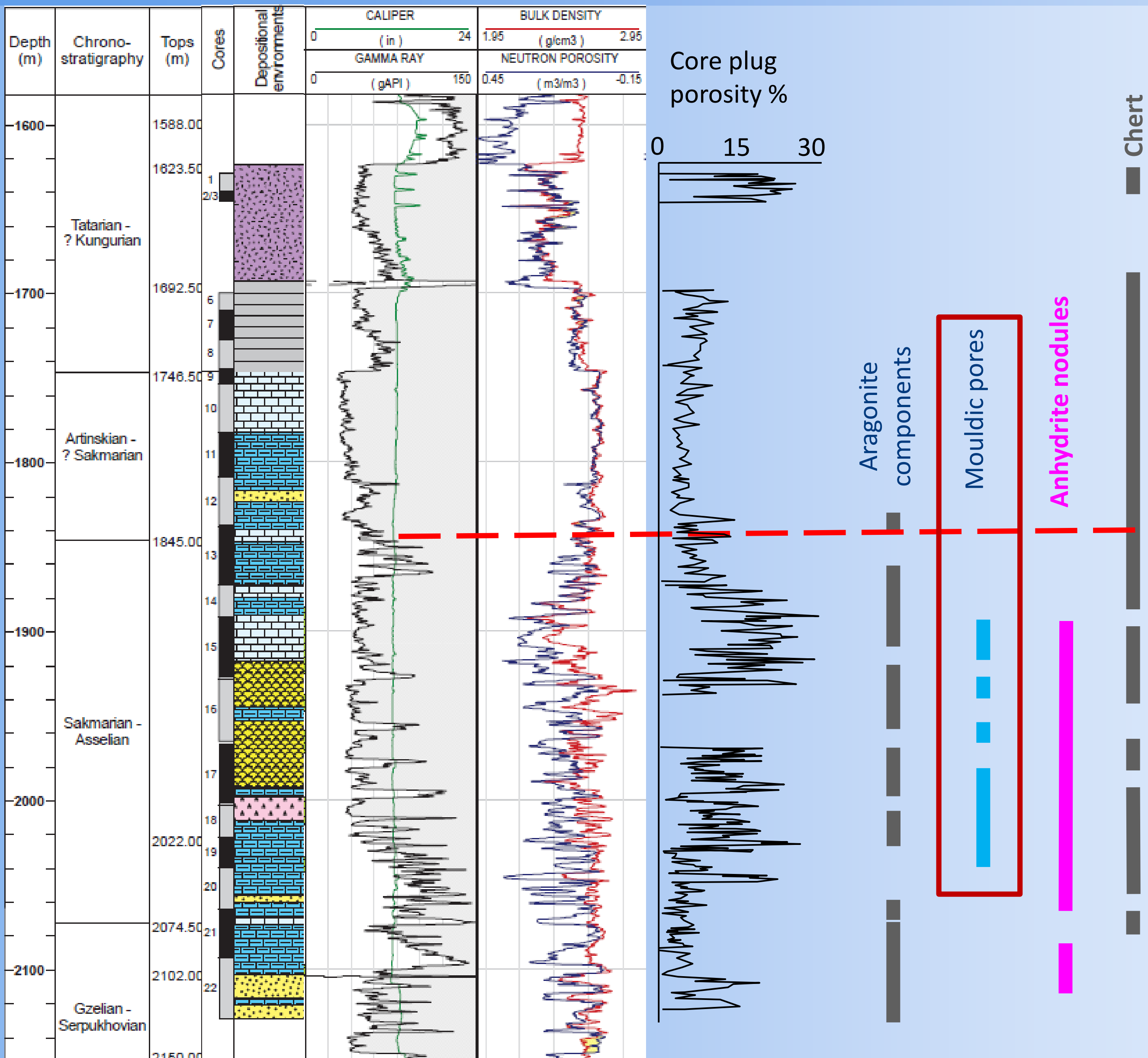
7128/6-1: diagenetic features

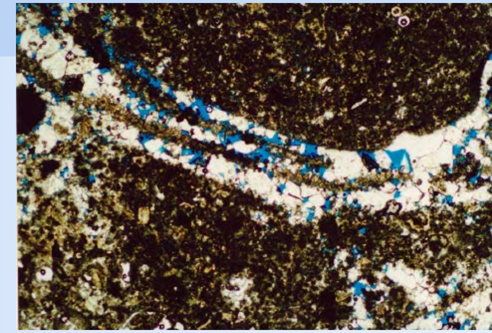




Phylloid algal plate, Gipsdalen Group 2103.6m FoV 5mm

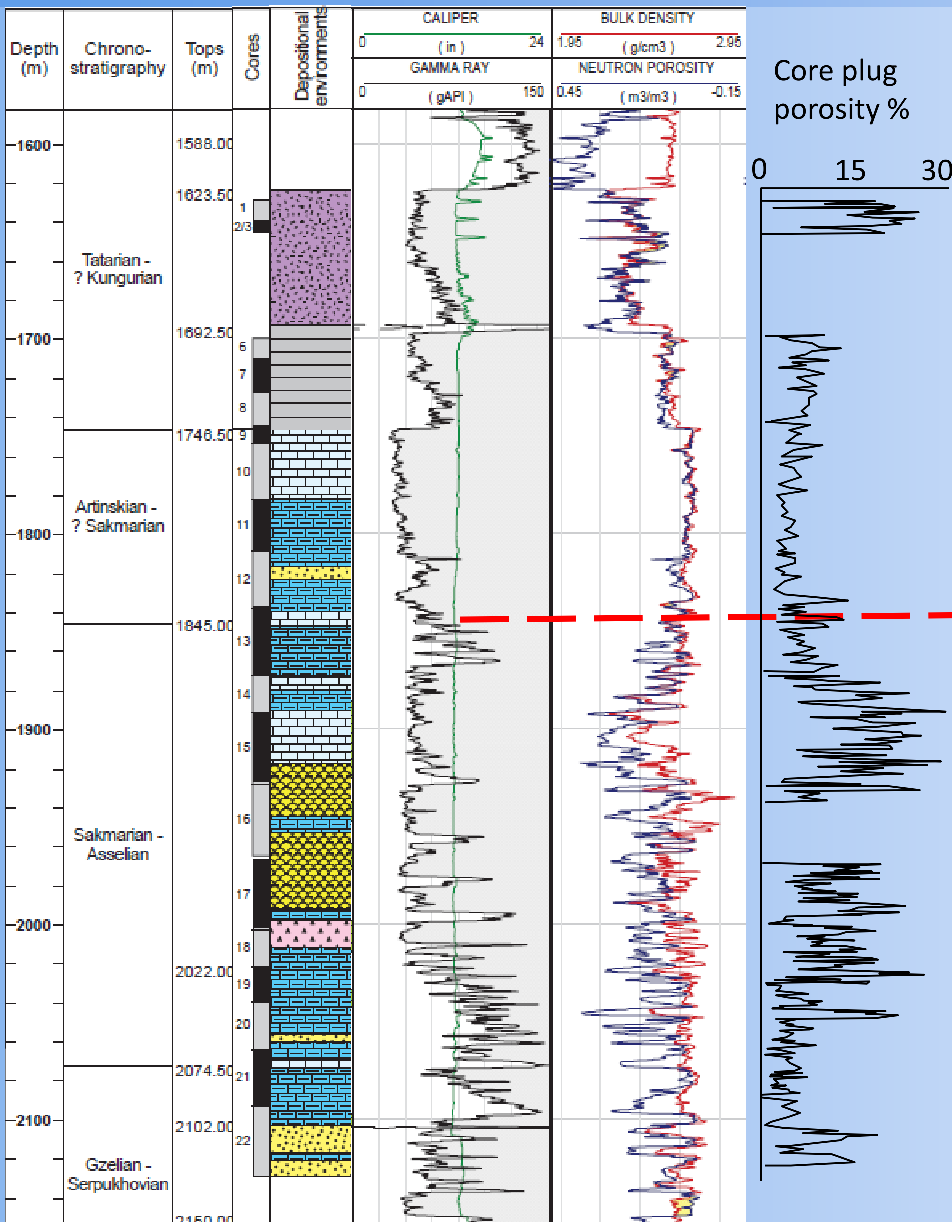
7128/6-1: diagenetic features

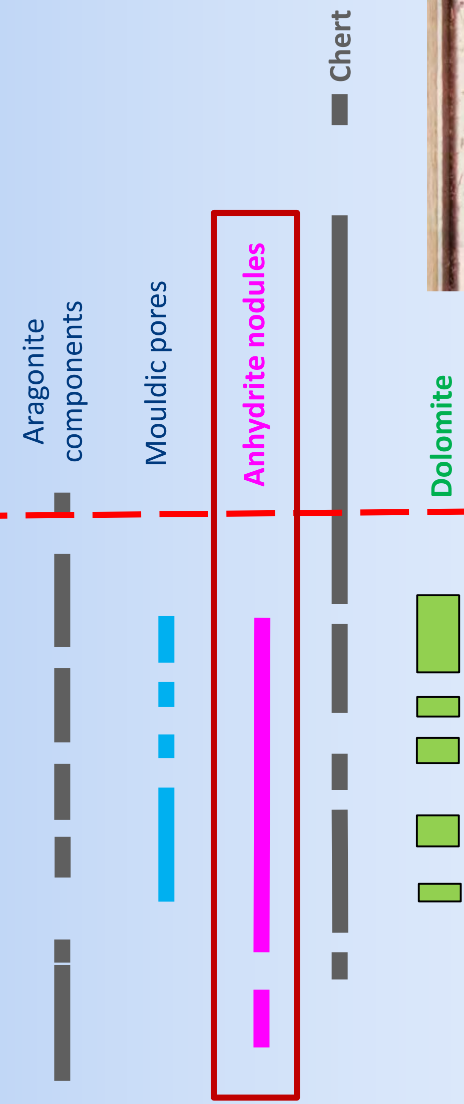




Phylloid biomould, Gipsdalen Group 2075.60m FoV 5mm

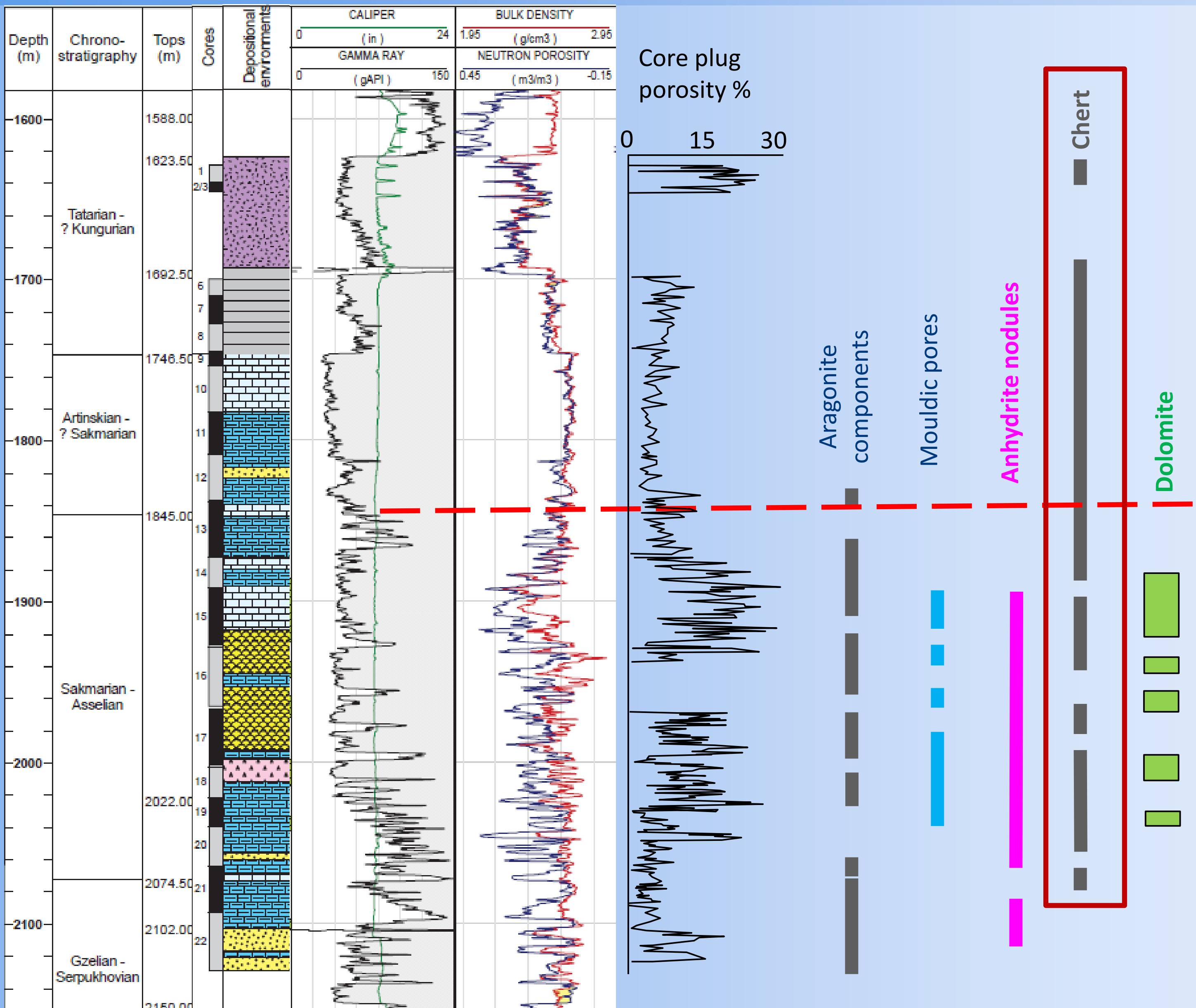
7128/6-1: diagenetic features





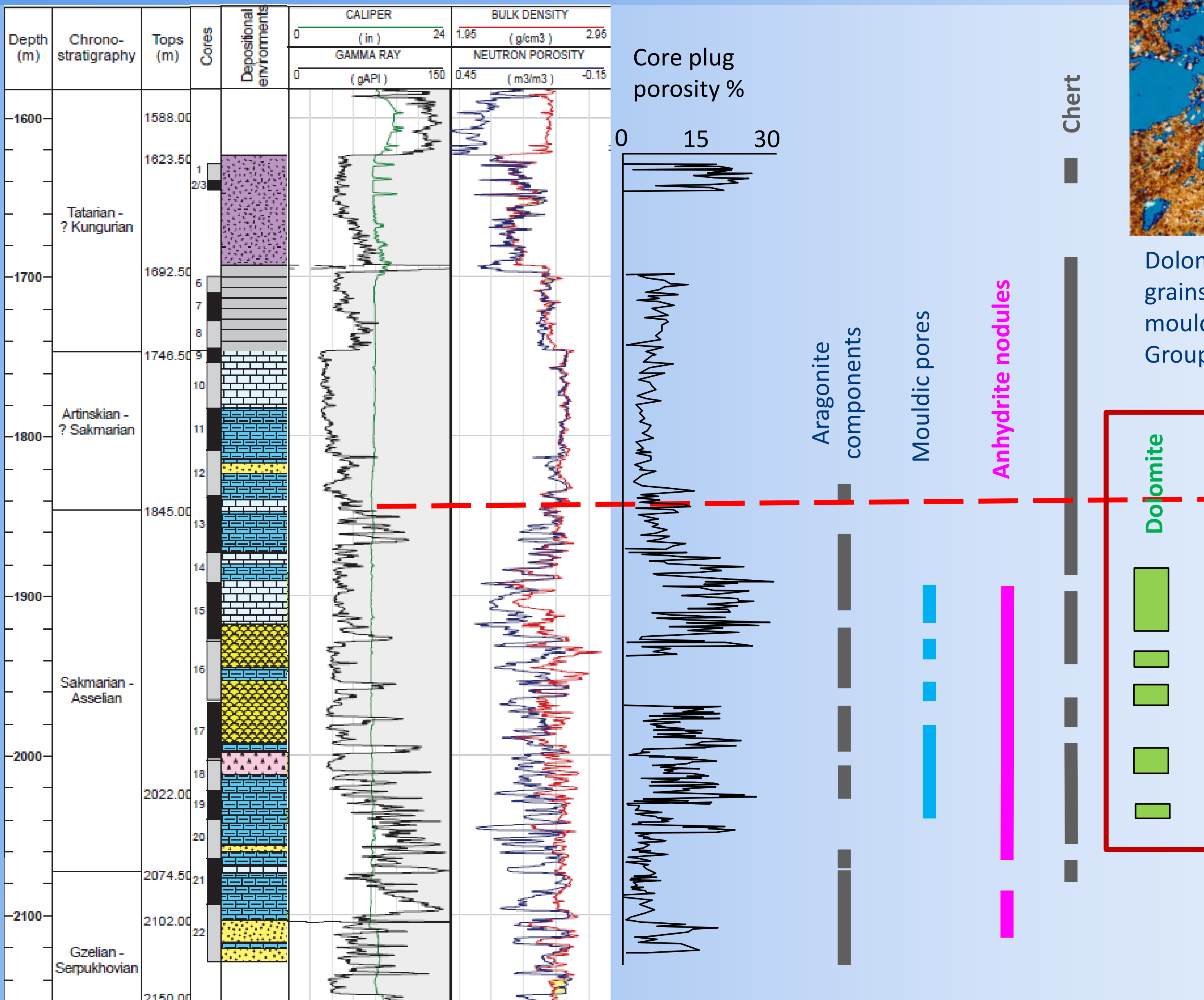
Anhydrite nodules in *Palaeoaplysina* bioherm Gipsdalen Group 1968.5m

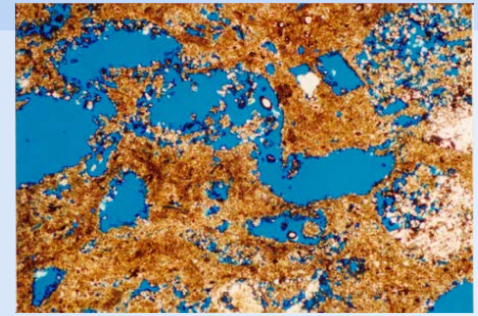
7128/6-1: diagenetic features



Chert nodules
Tempelfjorden Group
1718.5m

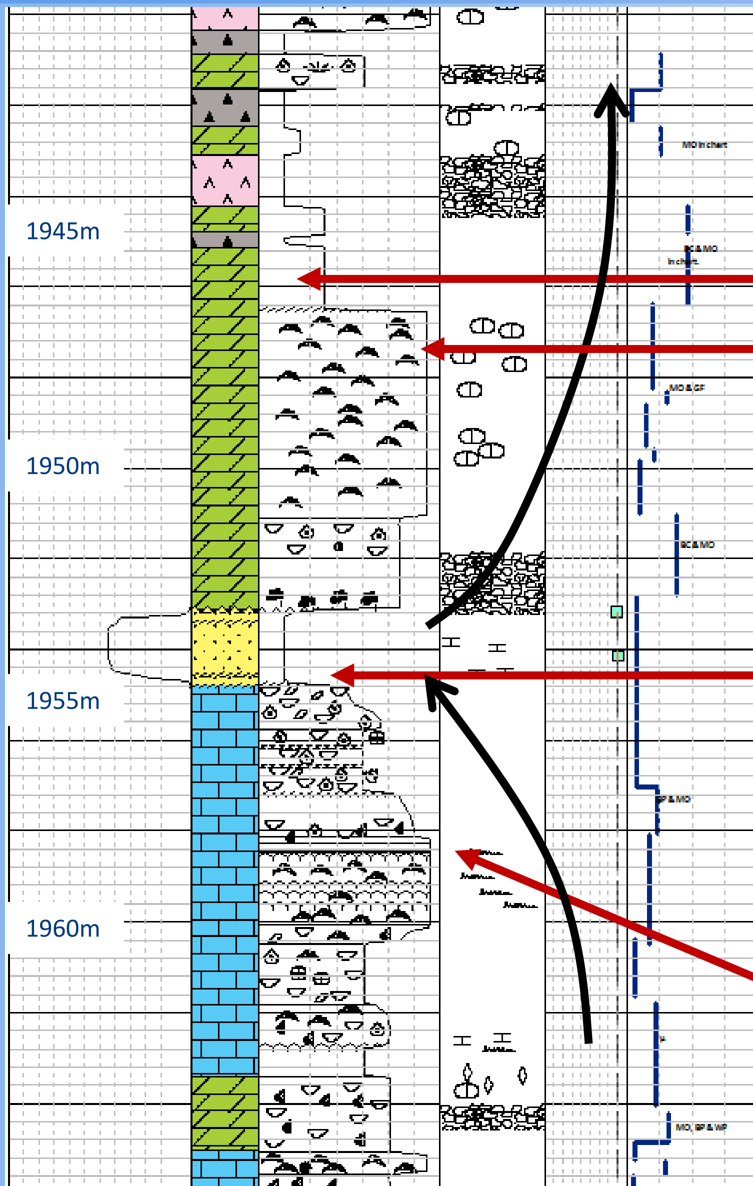
7128/6-1: diagenetic features





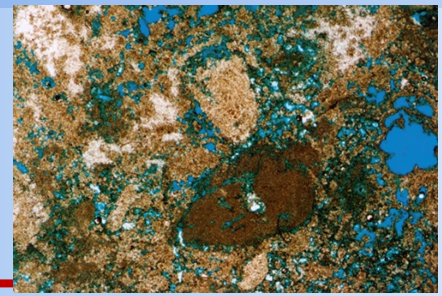
Dolomitised subtidal fusulinid grainstone with intercrystal and mouldic porosity. Gipsdalen Group 1964.75m FoV 5mm

Porosity in photozoan carbonates

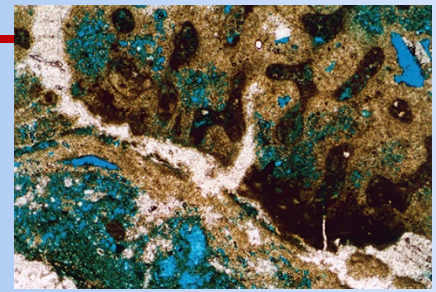


Gipsdalen Group, Ørn Fm

Dolomitised cycle

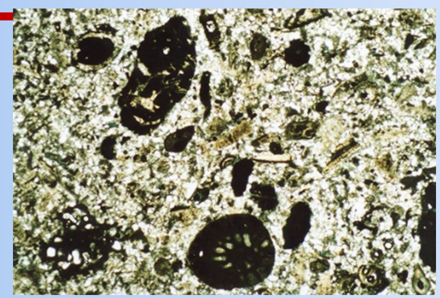


Intergranular and mouldic pores in oncoid packstone enhanced by dolomitisation

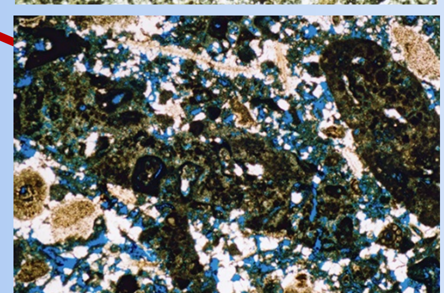


Internal and mouldic pores in Palaeoaplysina boundstone enhanced by dolomitisation

Partly dolomitised cycle

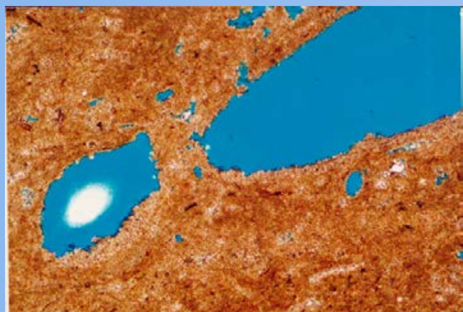


Clastic LST/TST – porosity reduced by compaction and calcite cement



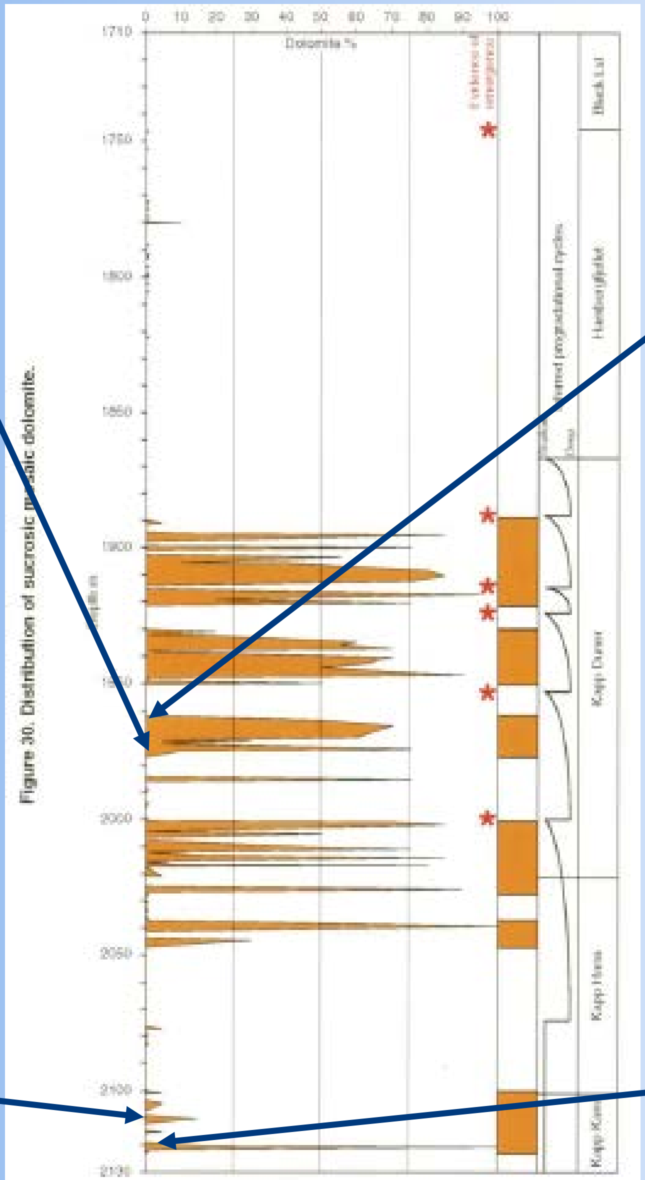
Intergranular and mouldic pores in subtidal packstone; minor calcite cement

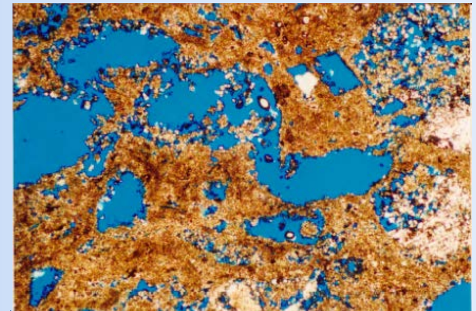
Dolomitisation: 7128/6-1



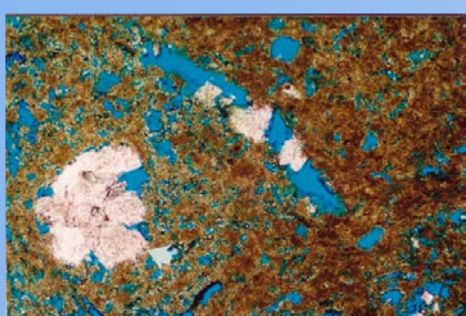
Fusulinid moulds in dolomitised matrix. Subtidal facies Gipsdalen Group 1973.75m

NB relatively early anhydrite nodules common throughout core replacing all depositional facies

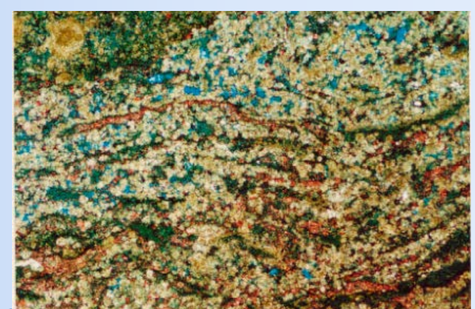




Dolomitised fusulinid grainstone with intercrystal and mouldic porosity. Subtidal facies Gipsdalen Group 1964.75m



Dolomitised bioclast packstone with mouldic pores, some with saddle dolomite Gipsdalen Group 2014.5m

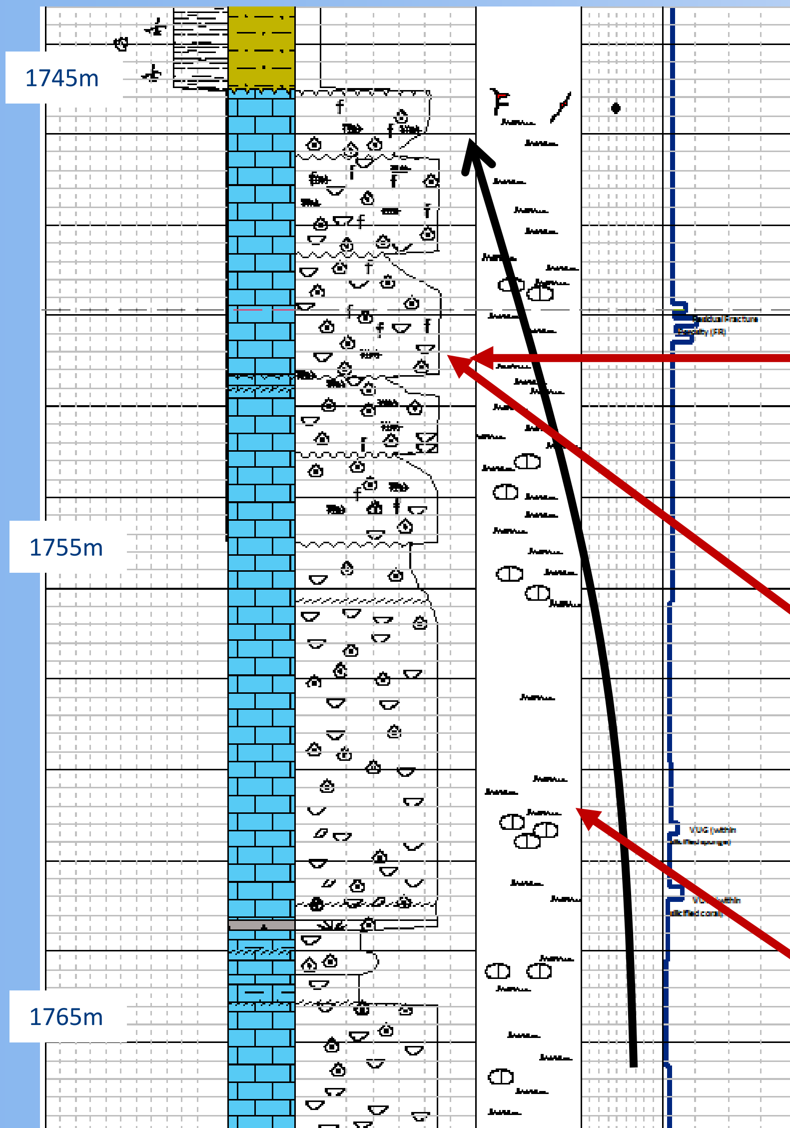


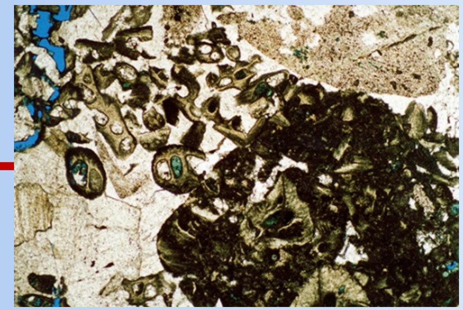
Intercrystal pores in dolomitised bindstone. Cycle top peritidal facies Gipsdalen Group 2017.5m

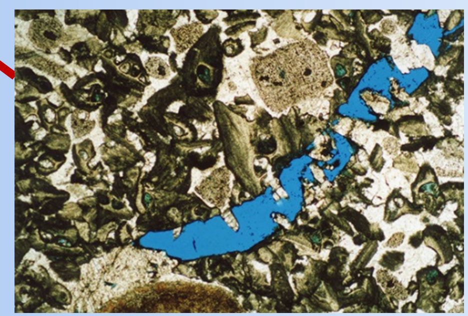
Photozoan carbonates: cyclicity

- Good preservation of depositional porosity
  - Minimal cementation or alteration at emergent surfaces
  - High Mg calcite and aragonite allochems – early mouldic pores
  - Intensive micritisation, inhibits early cementation
  - Subtidal to emergent HST part of cycles
- Emergent surfaces/cycle boundaries
  - Microcodium, fine sandstone, deepening events
  - No karst or superficial deposits
  - Cycles 5-25m thick
- Evaporitic dolomitisation
  - Minor plugging of porosity by evaporites
- Reservoirs
  - Layered – enhanced by dolomitisation
  - Matrix porosity

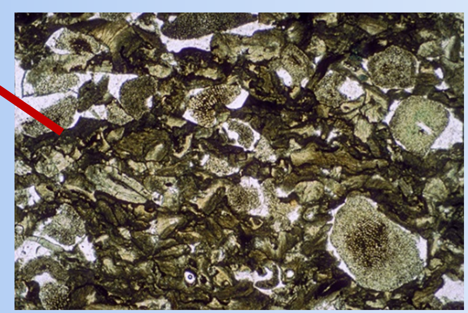
Porosity in heterozoan carbonates







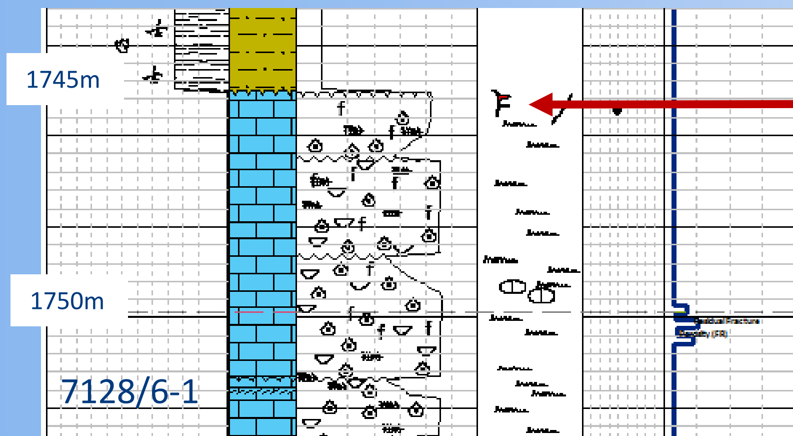
Overgrowth cement on crinoids;
Fracture-bridging cement
preserve fracture porosity

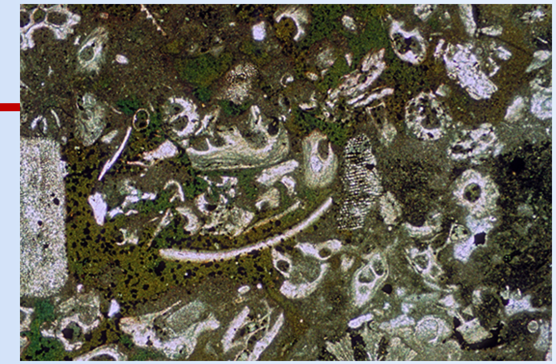


Porosity reduced by
overgrowths and compaction

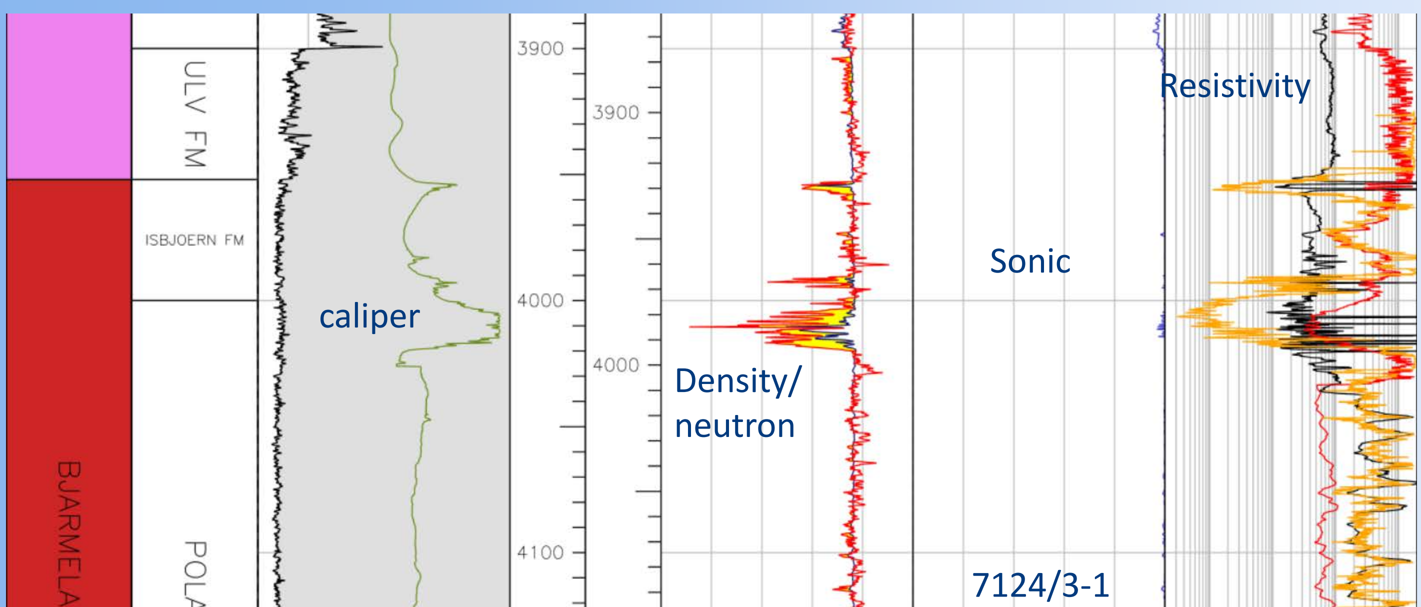
Bjarmeland Group, Isbjørn Fm

Karst development at sequence boundaries





Karst surface and matrix FoV 5mm

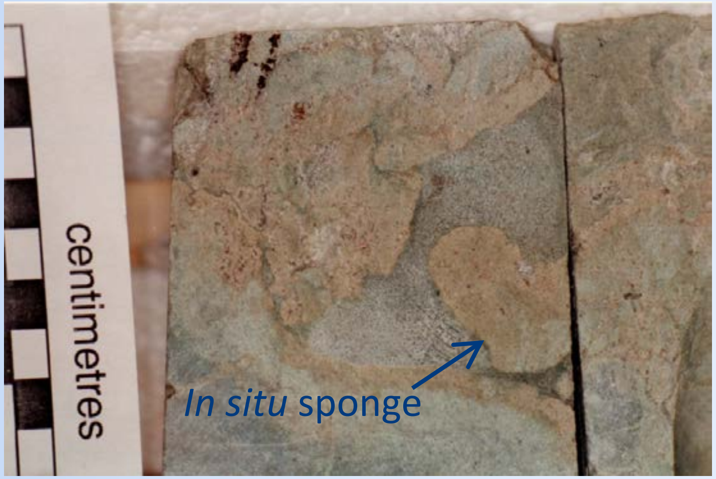


Heterozoan carbonates

- Poor preservation of depositional porosity
  - Echinoderms are dominant allochem with rare micritisation – early overgrowth cementation
  - Rare aragonite allochems - poor potential for early mouldic pores
  - Rare depositional porosity associated with LST/TST sandstone
- Emergent surfaces/cycle boundaries
  - Karst and superficial deposits associated with varying orders of low stand
  - Cycles 50+m thick
- No associated evaporites
  - Or dolomite
- Reservoir types
  - Karst systems penetrating from sequence boundaries
  - Fracturing

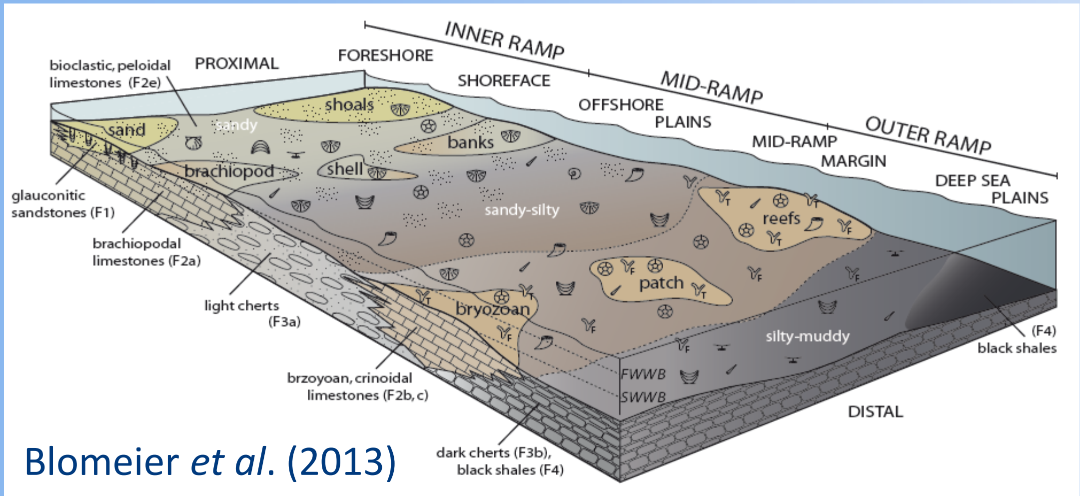
Late Permian biogenic silica production

- Onset of global warming after glaciation
  - Acidification of ocean
  - Carbonate production replaced by biogenic silica
  - Eustasy changes to lower frequency/amplitude green house cycles

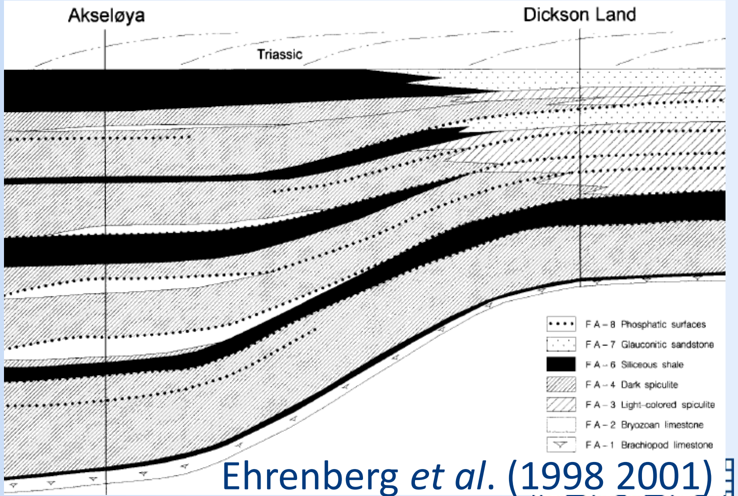


7128/4-1 1574.4m

Ramp model and sequence stratigraphic context based on Svalbard outcrop



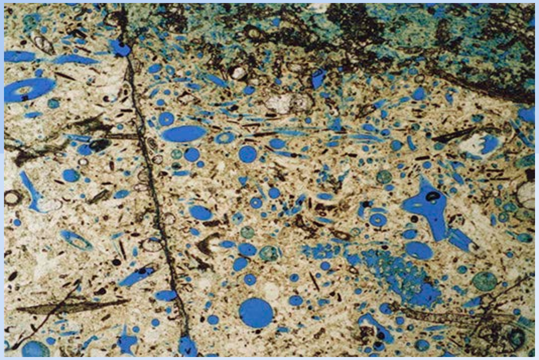
Blomeier *et al*. (2013)



Ehrenberg *et al*. (1998 2001)

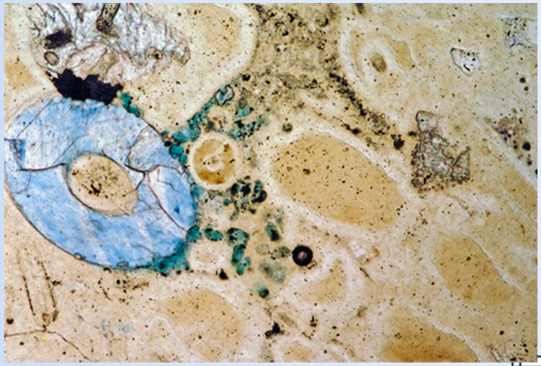
Biogenic silica production

- Initial bioclasts
  - Hollow spicules with walls of opaline silica
  - Highly metastable initial mineralogy
  - Various diagenetic pathways
- Now all quartz



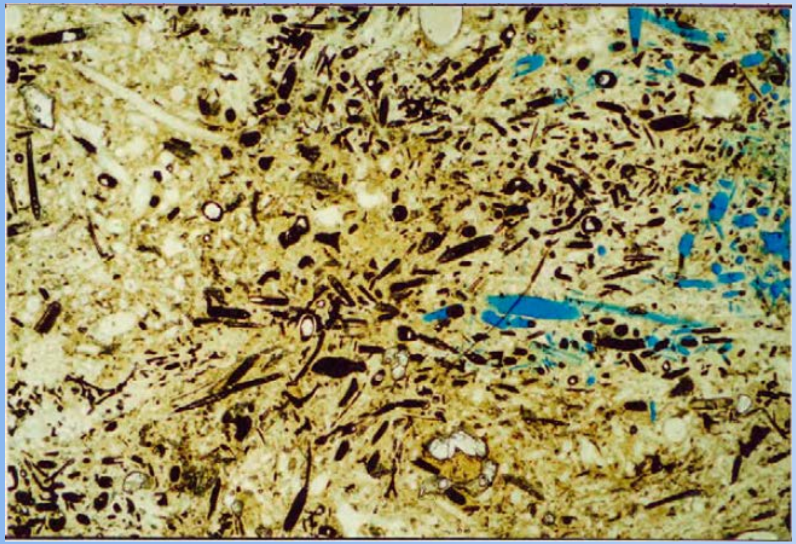
Demosponge spicules 7128/6-1 1629.70m FoV 5mm

Demosponge spicules 7128/4-1 1576.12m FoV 5mm

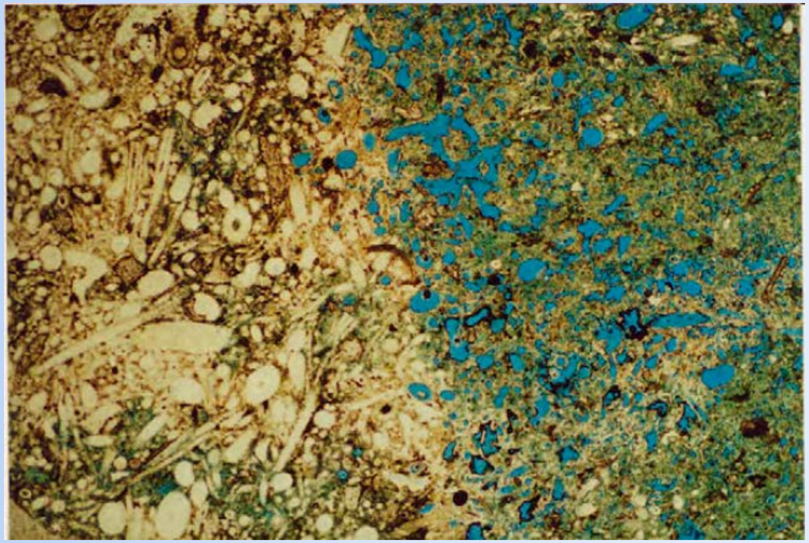


Demosponge spicules 7128/4-1 1576.21m FoV 1.25mm

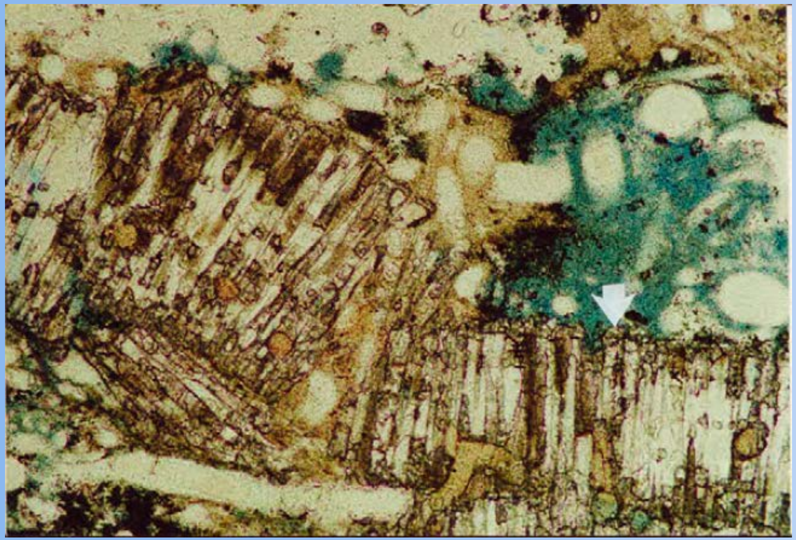
Porosity in the spiculite



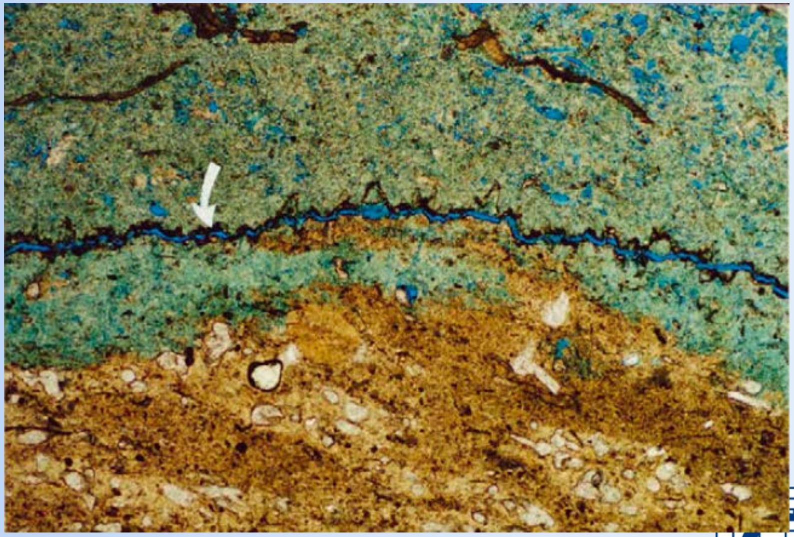
Dissolved sponge spicules partly infilled by hydrocarbons 1930.75m FoV 5mm 7128/6-1



Margin of chert nodule in porous spiculite 1631.75m FoV 5mm 7128/6-1



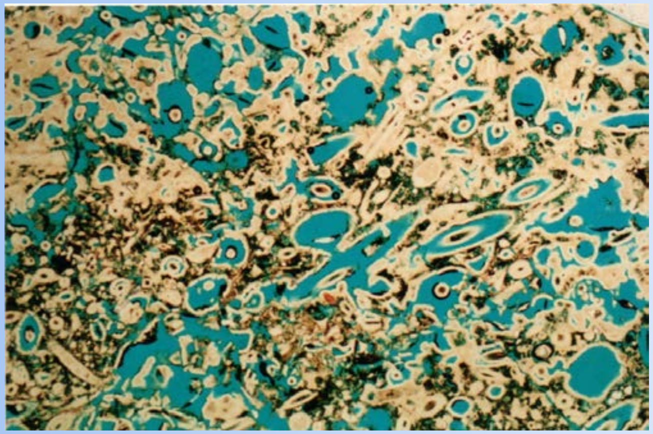
Dissolution of prismatic bivalves in porous spiculite 1929.00m FoV 5mm 7128/6-1

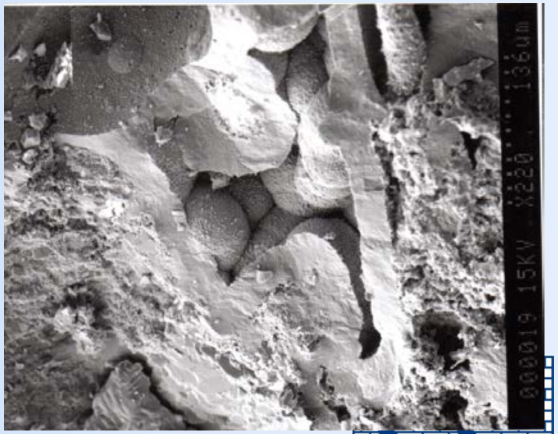


Post-stylolite dissolution of brown carbonate matrix in porous spiculite 1634.50m FoV 5mm 7128/6-1

Porosity preservation in spiculite

- Original opal A and CT changes to chalcedony/quartz
  - Multiple events of silica dissolution and reprecipitation
- Openness of diagenetic system
  - Poorly winnowed argillaceous facies, quartz stays in system (poor permeability or complexed by clays) resulting in local cementation
  - Clean winnowed facies, open diagenetic system quartz lost to pore fluid and no cementation
- Pore system comprises micro- very small mesopores
  - Need fracturing (compactive) or dissolution to improve permeability





Images from 7128/4-1

Conclusions

- Reservoir quality can be better understood in the context of late Palaeozoic global events that influenced carbonate and siliceous sedimentary and diagenetic systems
  - Initial mineralogy of carbonate grains: potential for early dissolution and cementation
  - Palaeoclimatic conditions: availability of meteoric water and susceptibility to dolomitisation
  - Nature of eustasy (glacio-eustatic vs. greenhouse): Duration and amplitude of exposure during low stands
- Different carbonate and siliceous systems will have different reservoir types
- Go some way to risking reservoir properties in carbonates and siliceous facies

Acknowledgments

- Thanks to Lundin Norway and PL 492 partner Aker BP
- Sarah Thompson for the microfacies analysis