Orbital forcing as a mechanism for Devonian metre-scale cycles. To be or not to be?..... that is the question.

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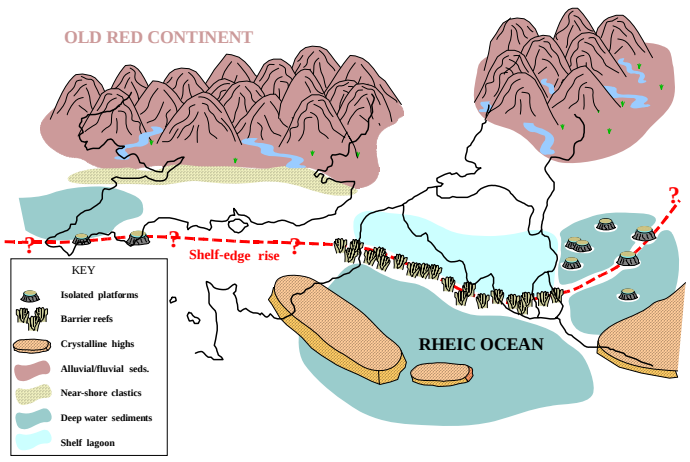
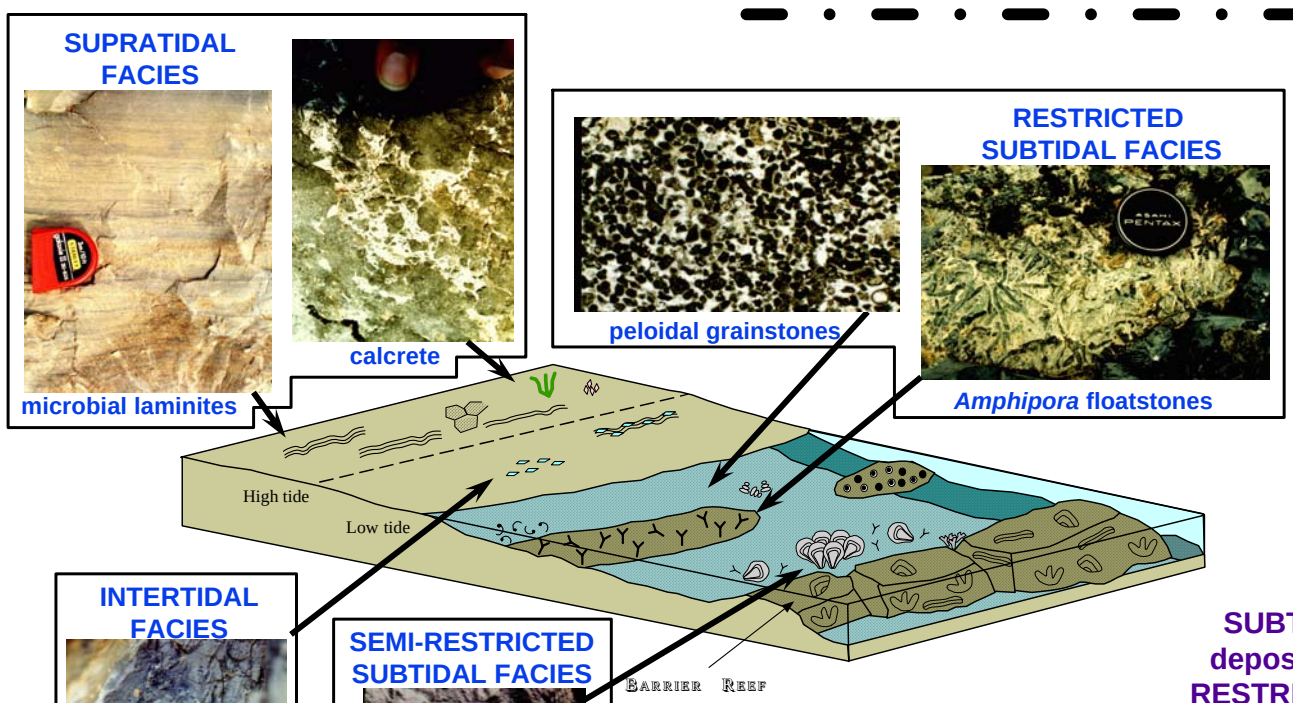
Introduction

The Middle and Upper Devonian (Givetian - Frasnian) shallow-water carbonate facies of western Europe were deposited as a large-scale transgressive succession over continental facies of the Old Red Continent. The carbonate platform had a complex internal structure, where two major palaeosettings could be identified. A rimmed-shelf existed over much of the Ardennes area where stromatoporoid reefs along the shelf-edge provided protection for an extensive shelf lagoon. The rimmed -shelf extended from Boulogne in the west to Aachen in the east. Isolated carbonate platforms, between 20km^2 and 200km^2 in area, developed in the Rheinisches Schiefergebirge area of Germany and in southwest England.





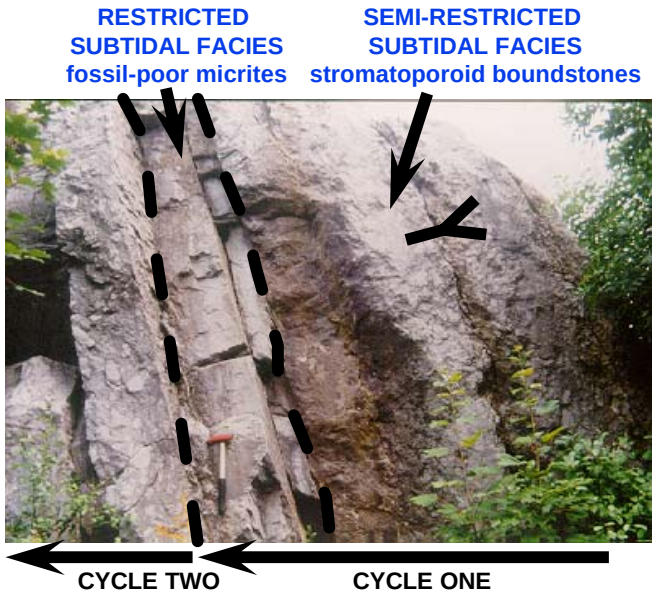
Facies

Lagoonal facies in both the rimmed-shelf and isolated platforms have been extensively studied in terms of facies and cyclostratigraphy. Facies can be organised into four major groups. SEMI-RESTRICTED SUBTIDAL facies are richly fossiliferous and were deposited in the immediate back-reef environment. RESTRICTED SUBTIDAL facies are characterised by poorly-fossiliferous facies or facies which have a monospecific fossil-assemblage (commonly *Amphipora* or molluscs). INTERTIDAL facies are typified by laminoid or irregular fenestral limestones. HIGH INTERTIDAL-SUPRATIDAL facies are represented by microbial laminites, dolomudstones or calcretes.

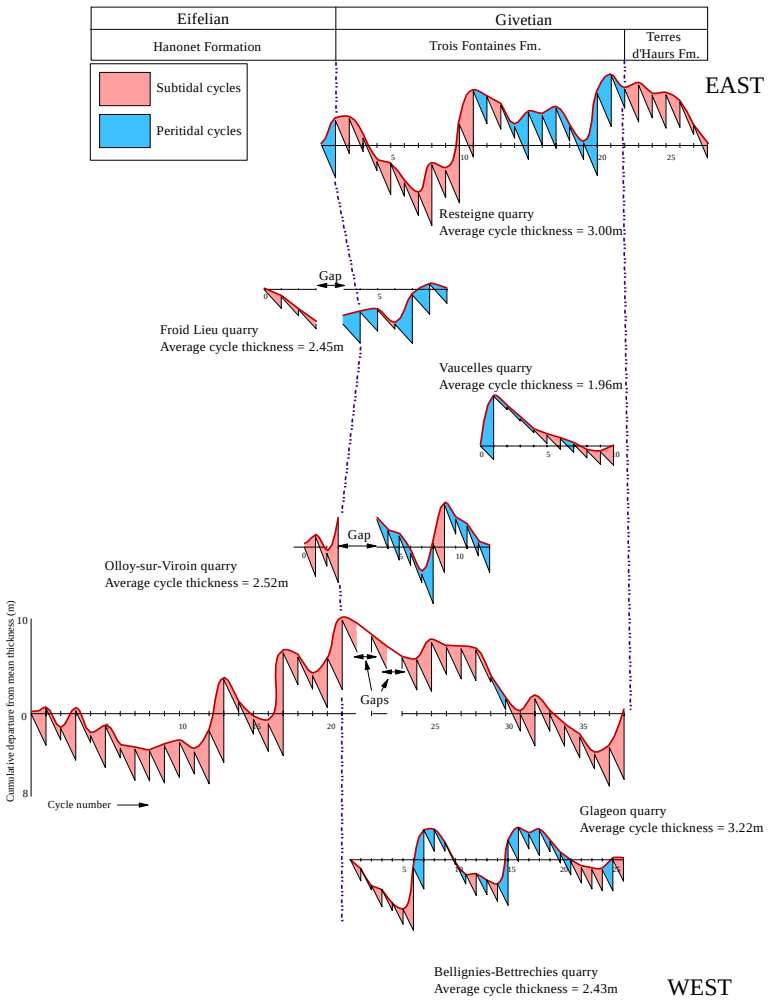
Cyclicity

A metre-scale cyclicity is prevalent throughout the studied successions, and two major cycle-types have been identified. SUBTIDAL cycles are typified by a stromatoporoid-rich base and are capped by unfossiliferous lime muds. Facies are entirely subtidal in nature and cycles show a decrease in circulation, decrease in diversity of organisms and increase in fluctuation of salinity upwards through the cycle. Subtidal cycles are commonly 2-4m thick. PERITIDAL cycles shallow-upwards from a subtidal, fossil-rich base through to a fenestral or microbially laminated cap, indicating deposition along intertidal-supratidal flats. Peritidal cycles are generally thinner than subtidal cycles, averaging 1-2m. Cycles are mostly regressive; however, transgressive-regressive cycles are not uncommon. Subtidal cycles seem particularly common within isolated carbonate complexes, but both peritidal and subtidal cycles are identified in the shelf lagoon.

Subtidal cycle



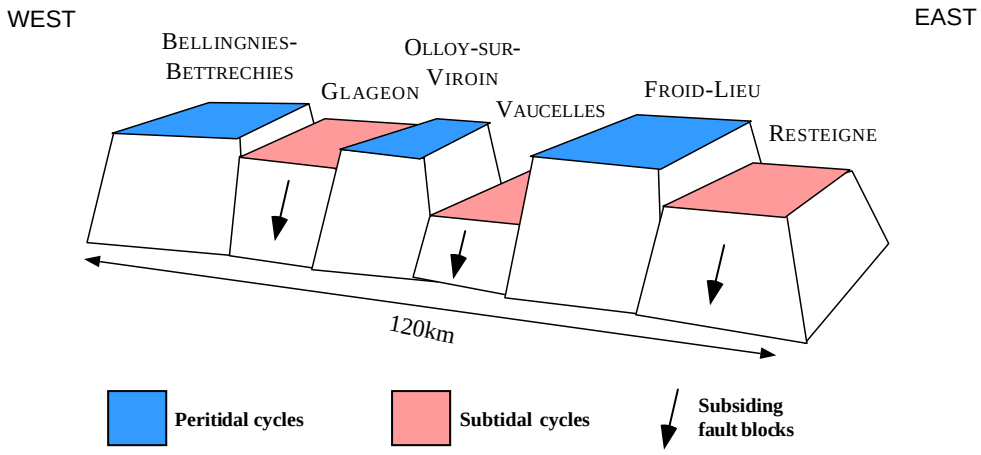
Peritidal cycle



Correlation

The Devonian carbonate platform was dissected by numerous faults, and differential subsidence and synsedimentary volcanism played a very important role in cycle and platform development.

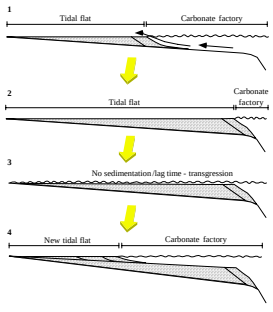
Fischer plots have proved to be a very powerful tool for identifying the relative elevation of fault blocks. For example, during the lower Givetian stage (upper Middle Devonian) the Resteigne and Glageon areas were undergoing rapid subsidence since only subtidal cycles are recorded. On the other hand, Froid Lieu, Olloy-sur-Viroin and Glageon fault blocks were relatively elevated recording peritidal deposition. Although individual cycles are not correlatable over the platform trends in cycle-thickness (larger-scale curves on the Fischer plot), can be correlated.



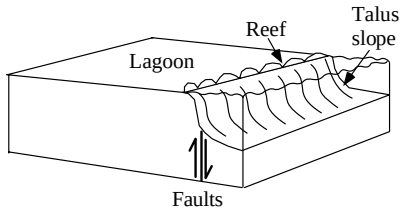
Mechanism producing metre-scale cyclicity

Using the palaeoenvironmental information provided by faunas, floras and sedimentology, relative sea-level fluctuations producing the metre-scale cyclicity were in the order of 1-3m. Duration of the cycles is a little more difficult to determine as absolute dating is not on a sufficiently high resolution, and 'missed beats' where there has been non-deposition through exposure are undoubtedly present. However, by using the refined conodont zone durations of House (1995) and by calculating the number of cycles within a specific zone, an estimate of 42Ky duration for upper Givetian cycles can be obtained.

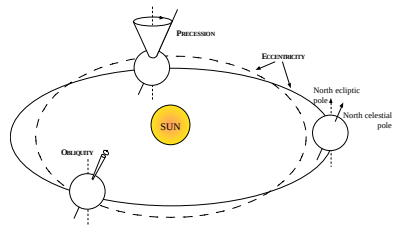
Three major mechanisms can be used to explain repetitive shallow-water metre-scale cycles: sedimentary, tectonic and eustatic.



The sedimentary mechanism suggests that under conditions of steady subsidence/sea-level rise, shallowing-upwards cycles can develop by the autocyclic process of tidal flat progradation.



The tectonic mechanism suggests that a short-term episodic creation of accommodation space can be provided by synsedimentary faulting.



The eustatic/orbital forcing mechanism suggests that variations in the Earth-Moon-Sun system strongly influences the amount of solar insolation reaching the Earth, and thus affects climate, erosion/weathering patterns, temperature, and global sea-level.

Mechanism	Evidence for 4	Evidence against ✗
Sedimentary	✓ Inability trace single cycles laterally ✓ Mechanism would produce idealised shallowing-upwards cycle	✗ Presence of subtidal cycles ✗ Cyclicity also in deep water & reef-core facies ✗ Some cycles have transgressive facies at base ✗ Development of calcretes
Tectonic	✓ Fault blocks present in shelf and isolated platforms are fault bounded ✓ Evidence of synsedimentary volcanics	✗ Mechanism cannot account for repetitiveness of cycles ✗ Some cycles have transgressive facies at base
Eustatic	✓ Cycles are regular ✓ Duration of cycles ~42,000yr, within Milankovitch band (obliquity) ✓ Can laterally correlate packages of cycles ✓ Cyclicity not restricted to lagoon - also seen in reef-core and deep-water ✓ Mechanism can explain transgressive facies at bases of cycles, and subaerial exposure through missed beats ✓ Devonian metre-scale cycles are seen world-wide	✗ Do not often see a well-developed pattern in superimposition of cycles ✗ Cycle-types are not restricted to specific parts of the sea-level curve

Conclusions

The most attractive mechanism, which can explain majority of the features seen in the Devonian cycles of western Europe, is orbital-forcing. The tectonic mechanism cannot explain the repetitiveness of cycles as faulting is not periodic. The sedimentary mechanism cannot explain the presence of entirely subtidal cycles and also cannot explain the cyclicity seen in reef-core and deep-water facies. The obliquity cycle is the most likely cause of cyclicity, as cycles have been calculated at 42,000yr duration. Although orbital forcing is the most likely explanation for cycle development, it clearly does not work on its own. Tectonic influences such as variable subsidence rates invariably modify cycle-type distribution and it is highly likely that autocyclic processes did affect cycle development..

References

House, M.R. 1995. Devonian precessional and other signatures for establishing a Givetian timescale. In: *Orbital forcing timescales and cyclostratigraphy* (M.R. House & A.S. Gale, eds.). *Geol. Soc. Spec. Pub.*, 85, 37-49