CARBONATE PLATFORMS AND MASS EXTINCTION EVENTS – A TRIBUTE TO MICHAEL T. WHALEN

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KEY FINDINGS

- Geochemical proxy data support the notion that the Frasnian-Famennian extinction is linked to widespread appearance of terrestrial forests and their alteration of chemical–mechanical weathering patterns and redox state in many epeiric seas.
- Microbial carbonates are an important building block throughout the evolution of the Upper Devonian buildups but survive the extinction event, making them a "survivor fauna" rather than "disaster fauna".
- On the Yucatan platform, the impact crater is filled by prograding carbonate successions, burying the crater – the reason why this impact crater was not found for a long time, allowing the controversy about the cause for the end-Cretaceous extinction to fester.

BACKGROUND

Michael T. Whalen was a post-doc at the CSL from 1993 – 1995, as part of research initiatives on Paleozoic mixed carbonate-siliciclastic systems. His research focused on Upper Devonian buildups - Miette and Ancient Wall - in the Canadian Rocky Mountains. In 2001 he received the *Medal of Merit* from the Canadian Society of Petroleum Geologists for one of his papers stemming from this research (Whalen et al., 2000). After leaving Miami, Mike Whalen pursued the question of how carbonate platform systems change because of mass extinctions. He studied the late Devonian extinction event at the Frasnian-Famennian boundary on the Miette and Ancient Wall platforms in the Western Canada Shale basin (Figure 1). Here, he showed that the microbial carbonates above the Frasnian-Famennian boundary were survivors of microbial carbonates that existed throughout the development of the Frasnian buildup. Later, he investigated the sedimentation in the impact crater on the Yucatán carbonate platform,

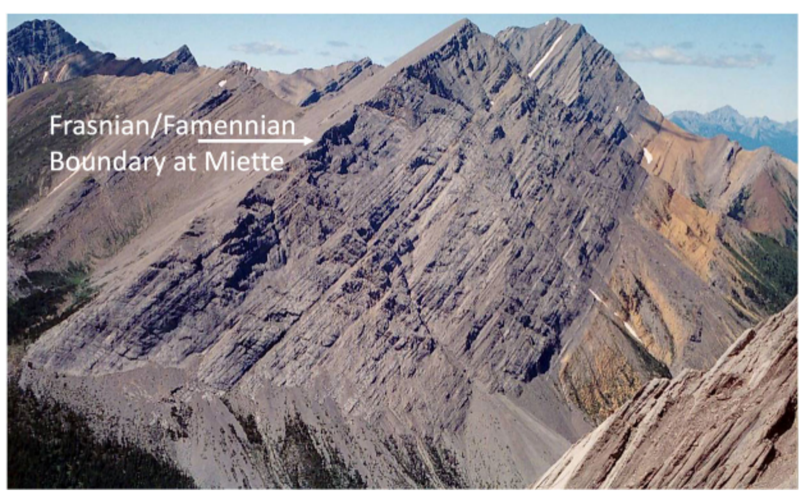

Figure 1: Photograph of the Frasnian Miette carbonate platform in the Canadian Rockies whose decline coincides with the Frasnian-Famennian extinction.

demonstrating "the healing power of carbonates" that fills the impact crater by prograding sequences and buries it within the large Yucatán platform.

THE FRASNIAN-FAMENNIAN EXTINCTION

The cause of the faunal extinction at the Frasnian-Famennian boundary (FF boundary) falls into a time of repeated environmental upheaval, featuring numerous carbon-cycle perturbations and periods of marine anoxia. During one of these anoxic events (Lower Kell Wasser Event) began the decline of marine fauna (such as reef systems) and culminated in a more severe extinction pulse affecting numerous taxanomic groups during the Upper Kellwasser Event that also marks the FF boundary. Precise dating of the FF boundary at 372 myrs now provides evidence that neither the Siljan impact crater nor basalts produced by large-scale volcanism can be correlated to the mass extinction (Percival et al. 2018).

Whalen et al. (2015) using major and trace element geochemistry, stable carbon and nitrogen isotopic analyses and magnetic susceptibility measurements, identified both Kellwasser events in their stratigraphic positons in the upper most portion of the Miette and just above the carbonates in the Ancient Wall area. They interpret trends in the multiproxy geochemical data as a systemic palaeoecological shift associated with the development of widespread terrestrial forests and their alteration of chemical–mechanical weathering patterns. This finding is in line with the proposed cause for the extinction that links the crisis to the development of terrestrial forests and associated changes in root and soil development that ultimately influenced the redox state of many epeiric sea around the world.

Another major finding was the recognition that stromatolites, thrombolites and oncoids above the extinction event were not a new fauna that established after the extinction but were merely the survivors and had existed with other biota such as stromatoporids, corals, brachiopods thoughout the evolution of the buildup (Figure 2).

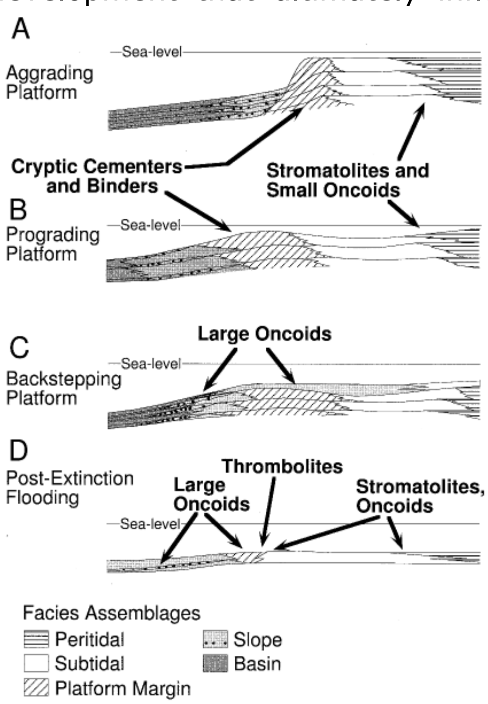

Figure 2: Microbial carbonates are part of the Miette buildup in all stages of the growth (Whalen et al., 2002)

THE CHICXULUB IMPACT CRATER AND THE K/PG BOUNDARY

Iridium anomalies in several stratigraphic sections at several sites on globe have provided strong evidence of a meteor or asteroid impact to be the cause for the end-Cretaceous mass extinction. The lack of an impact crater, however, left room for alternative explanations. This changed with the discovery of the Chicxulub crater on the Yucatán platform. The reason for the late discovery was the fact that the asteroid did not hit the top of a platform but a trough that is now buried by prograding carbonate sequences. The trough was discovered with seismic data in conjunction with the free-air gravity anomaly map, which revealed that, before the impact, the carbonate platform was divided into two blocks by a ~ 95–205 km wide and ~ 470-km long trough (Guzmán-Hildago et al., 2021). The asteroid hit this northward deepening and widening trough, resulting in an asymmetric crater with a missing rim to the north. Because the asteroid diameter was larger than the Yucatán Trough, the platform margins on both sides were destroyed by the impact, widening the trough (Figure3).

Inside and outside of the impact crater the post impact strata is composed of re-worked local material and impact ejecta, containing material from the basement and its sedimentary cover. The IODP/International Continental Scientific Drilling Program Expedition 364 recovered ~130 m of impact deposits in the peak ring of the Chicxulub crater. Above the impact deposits a 75-cm thick, fine-grained, carbonate-rich "Transitional Unit" records the resumption the marine sedimentation. Within the crater the subsequent facies include slope sediments with redeposited gravity flow deposits and soft sediment deformed facies within background pelagic facies. Outside the crater rim neritic outer carbonate platform environments re-established and thick prograding sequences expanded the Yucatán platform (Whalen et al., 2013).

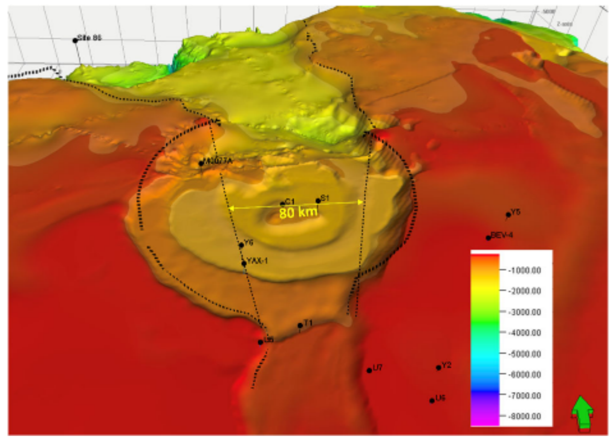

Figure 3: Reconstruction of the impact crater on the Yucatán Platform. The asteroid hit a northward plunging seaway. The width of the previous margins is unknown but extrapolating the margins we estimate the trough to be ~80 km before the impact.

The prograding pulses in these sequences are assumed to be sea-level controlled during the Paleocene and Eocene, while in the Neogene contourite drifts, in particular plastered drifts are contributing to the platform expansion (Whalen et al., 2013). Both, the sea level controlled progradation and the admixture of current deposits produce the large coalesced modern Yucatán platform. The process is a testament to the healing power of carbonates that can fill and cover large impact structures.

Conclusions

Mike Whalen made three significant contributions to the understanding of how carbonate platforms react to mass extinctions. First, he corroborated the notion that the Frasnian-Famennian extinction is an ecological crisis that is related to the appearance of terrestrial forests that changed the redox state in many epeiric seas around the world. Second, he showed that microbial carbonates are an important building block throughout the evolution platforms coexisting with other biota such as stromatoporids, corals, brachiopods. They are simply the sole survivors of the extinction event making them a “survivor fauna” rather than “disaster fauna”. Third, he documented the filling and burial of the impact crater on the Yucatán platform that took it out of sight and is the reason for its late discovery and the ongoing controversy about the cause of the en Cretaceous extinction.

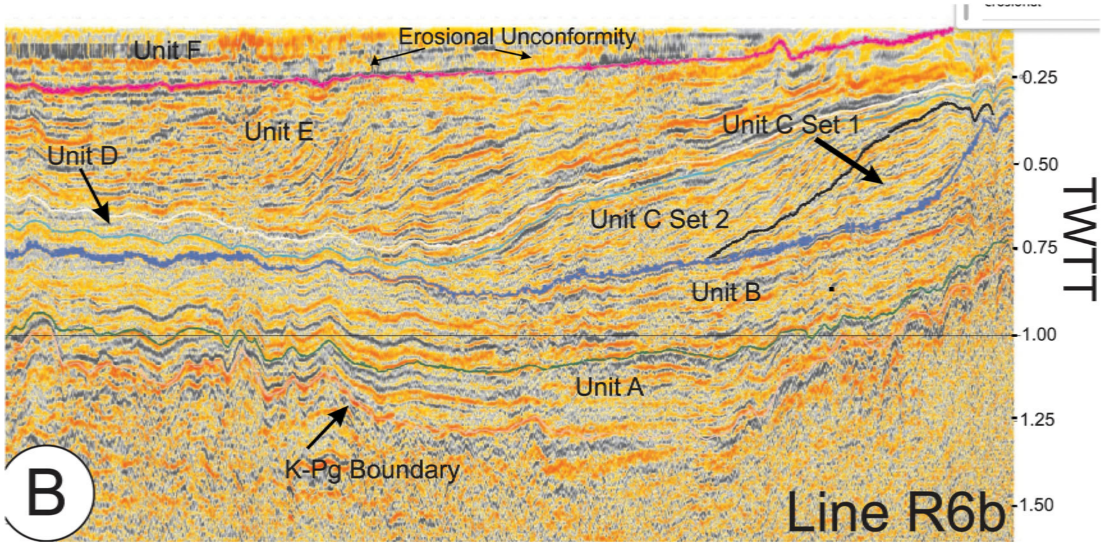

Figure 4: Seismic line across the widest part of the impact crater on the Yucatán peninsula, documenting the filling of the crater by prograidn clinoforms. From Whalen et al. (2013

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