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LATE FRASNIAN MASS EXTINCTION: CONODONT EVENT STRATIGRAPHY, GLOBAL CHANGES, AND POSSIBLE CAUSES

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ABSTRACT

Several abrupt changes in conodont biofacies are documented to occur synchronously at six primary control sections across the Frasnian-Famennian boundary in Euramerica. These changes occurred within a timespan of only about 100,000 years near the end of the latest Frasnian *linguiformis* Zone, which is formally named to replace the Uppermost *gigas* Zone. The conodont-biofacies changes are interpreted to reflect a eustatic rise followed by an abrupt eustatic fall immediately preceding the late Frasnian mass extinction. Two new conodont species are named and described. *Ancyrognathus ubiquitus* n.sp. is recorded only just below and above the level of late Frasnian extinction and hence is a global marker for that event. *Palmatolepis praetriangularis* n.sp. is the long-sought Frasnian ancestor of the formerly cryptogenic species, *Pa. triangularis*, indicator of the earliest Famennian Lower *triangularis* Zone. The actual extinction event occurred entirely within the Frasnian and is interpreted to have been of brief duration - from as long as 20,000 years to as short as several days. The eustatic rise-and-fall couplet associated with the late Frasnian mass extinction is similar to eustatic couplets associated with the demise of most Frasnian (F2h) reefs worldwide about 1 m.y. earlier and with a latest Famennian mass extinction about 9.5 m.y. later. All these events may be directly or indirectly attributable to extraterrestrial triggering mechanisms. An impact of a small bolide or a near miss of a larger bolide may have caused the earlier demise of Frasnian reefs. An impact of possibly the same larger bolide in the Southern hemisphere would explain the late Frasnian mass extinction. Global regression during the Famennian probably resulted from Southern-Hemisphere glaciation triggered by the latest Frasnian impact. Glaciation probably was the indirect cause of the latest Famennian mass extinction.

INTRODUCTION

Our preliminary investigation (SANDBERG, ZIEGLER, & DREESEN, 1987a) demonstrated that a mass extinction (TEICHERT, 1988) occurred entirely within the late Frasnian. The extinction event was completed before the start of the Lower *triangularis* Zone, which is sedimentologically, faunally, and historically the beginning of the Famennian Stage in Belgium. Herein, we provide documentation that a rapid eustatic rise followed by an abrupt eustatic fall immediately preceded the late Frasnian mass extinction and that the fall continued unabated into the early Famennian. This documentation is provided by abrupt, synchronous, sequential changes in conodont biofacies and faunas that were observed in thin successions of rocks representing the *linguiformis* Zone (named herein to replace the former Uppermost *gigas* Zone) at most studied sections representing almost every possible paleotectonic setting. The rapid rise-and-fall couplet within the *linguiformis* Zone is a repetition of a less abrupt eustatic couplet that began about a million years earlier within the Lower *gigas* Zone. The earlier couplet coincided with demise of F2h reefs in Belgium and of most global reef building. Reef communities had already been greatly diminished when they were subjected to the later (second) eustatic couplet that preceded, accompanied, and followed the late Frasnian mass extinction. Our early work (SANDBERG & ZIEGLER, 1984) has already shown that a similar but less severe eustatic couplet preceded and accompanied a late Famennian mass extinction. Herein, we ponder whether these rise-and-fall couplets, and specifically the late Frasnian ones, were the causes of mass extinction or merely harbingers that resulted from the same triggering mechanism.

Possible causes and consequences of extinction

Our interpretation of the possible causes and consequences of the late Frasnian mass extinction are summarized in Table 6. This table interprets the event stratigraphy of that extinction through a sequence of 12 events. Events 1-3 produced the first, short, late Frasnian peak in the sea-level curve (Fig. 4). Closely similar but more intense events 5-8, with which this paper is primarily concerned, produced the second, even shorter, latest Frasnian peak on the curve. These two packages of events are separated by event 4, the reestablishment of faunas on

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mudmound buildups replacing drowned reefs. Events 1 - 3 and 5 - 8 are closely similar and probably related to the same or similar extraterrestrial mechanisms. These might have been an impact by a small bolide followed by an impact by a larger bolide, or they might have been a close pass followed by an impact of the same large bolide. We believe these peaks were of too short duration to have been caused by Southern Hemisphere glaciation. The actual extinction mechanism probably was caused by a variety of interelated factors: rapid rise and fall of sea-level causing corresponding changes in the oxygen -minimum level, stratification and de-stratification of the water column, and reversal of current directions producing oceanic turnover. These violent happenings are evidenced by unusual storm layers on the shelf in Belgium, where the extinction layer is relatively thick. After the extinction, continued eustatic fall produced event 9, telescoping of conodont biofacies, followed by event 10, tsunamis, as carbonate-platform margins collapsed. Surviving conodont faunas became better established during event 11, the start of a new transgressive-regressive cycle. A general Famennian regression, interrupted by six transgressions (SANDBERG, POOLE & JOHNSON, 1988) occurred as event 12 in the Northern Hemisphere, while glaciation interrupted by 6 interglacial episodes occurred in the Southern Hemisphere. Glaciation of the Southern Hemisphere has been dated in terms of a spore flora by CAPUTO (1985) and related to a general Paleozoic sea-level curve by VEEVERS & POWELL (1987). We believe that this glaciation began as a consequence of a large bolide impact that caused the late Frasnian mass extinction, greatly disturbed oceanic circulation, and changed the global climate.

TABLE 6.-- EVENT STRATIGRAPHY OF LATE FRASNIAN MASS EXTINCTION

CONODONT ZONE	
	12. FAMENNIAN GLACIATION IN SOUTHERN HEMISPHERE CREATING REGRESSION IN NORTH
Middle *triangularis*	11. REESTABLISHMENT OF FAUNAS DURING NEW TRANSGRESSION
Lower *triangularis*	10. TSUNAMIS (BREAKUP OF CARBONATE PLATFORM MARGINS AS REGRESSION CLIMAXES)
	9. REGRESSION CONTINUES UNABATED (TELESCOPING OF CONODONT BIOFACIES)
linguiformis	8. LARGE BOLIDE IMPACT? (THEORIZED) AND **EXTINCTION** (STORMS ON SHELF IN BELGIUM)
	7. INCREASED SHALLOWING AND REGRESSION
	6. SEVERE EUSTATIC FALL
	5. EUSTATIC RISE (SECOND FRASNIAN HIGHSTAND, STRATIFICATION OF WATER COLUMN CREATING BASINAL ANOXIA)
Upper *gigas*	4. REESTABLISHMENT OF FAUNAS (NO REEFS, ONLY MUDMOUNDS)
Lower *gigas*	3. CLOSE PASS BY LARGE BOLIDE OR IMPACT BY SMALLER BOLIDE? (THEORIZED)
	2. EUSTATIC FALL (*Ancyrognathus triangularis* ACME IN BELGIUM)
	1. EUSTATIC RISE AND DROWNING OF F2h REEFS (FIRST FRASNIAN HIGHSTAND, *Palmatolepis semichatovae* TRANSGRESSION)

CONCLUSIONS

This paper introduces a new, conodont-biostratigraphic approach to interpreting the late Devonian mass extinction that took place entirely within the late Frasnian. Conodont zonation demonstrates that the actual extinction occurred in far less than 20,000 years and more likely within a few years or days. Conodont biofacies demonstrate that abrupt eustatic rise and fall, more severe than a similar rise-and-fall couplet that caused the demise of Fransnian reefs a million years earlier, immediately preceded the mass extinction. A plot of studied Euramerican and North African localities on a 367 Ma global paleogeographic reconstruction suggests that evidence for a large bolide that may have triggered the succession of extinction-related events should be sought in the Southern Hemisphere. Changes in oceanic circulation patterns probably were the direct cause of the extinction. The resulting changes in global climate produced a glacial episode in the Southern Hemisphere during the Famennian, while regression occurred in the Northern Hemisphere. This glaciation probably caused a second late Devonian mass extinction immediately before the close of the Devonian.

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