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THE FRASNIAN-FAMENNIAN MASS KILLING EVENT(S), METHODS OF IDENTIFICATION AND EVALUATION; H.H.J. Geldsetzer, Geological Survey of Canada, 3303-33 Street N.W., Calgary, Alberta, Canada.

The absence of an abnormally high number of earlier Devonian taxa from Famennian sediments has been repeatedly documented and can hardly be questioned. Was this disappearance caused by one or several mass killing events and, if so, was the ultimate cause of terrestrial or extraterrestrial origin?

Primary recognition of the event(s) was based on paleontological data, especially common macrofossils. Most paleontologists place the disappearance of these common forms at the *gigas/triangularis* contact and this boundary has recently been proposed as the Frasnian-Famennian (F-F) boundary. Not unexpectedly, alternate F-F positions have been suggested caused by temporary Frasnian survivors or sudden post-event radiations of new forms.

Secondary supporting evidence for mass killing event(s) is supplied by trace element and stable isotope geochemistry[1] but not with the same success as for the K/T boundary, probably due to additional 300 ma of tectonic and diagenetic overprinting. Another tool is microfacies analysis which is surprisingly rarely used even though it can explain geochemical anomalies or paleontological overlap not detectable by conventional macrofacies analysis.

The combination of microfacies analysis and geochemistry was applied at two F-F sections in western Canada and showed how interdependent the two methods are. The boundary was examined in two different settings – on a carbonate shelf (Northwest Territories) and in a basin adjacent to reef-rimmed carbonate platforms (Alberta). Regional and local stratigraphic relationships had suggested subaerial exposure of the shelf and continuous deposition in the basin at a water depth of about 150 m at the time of the F-F event.

On the shelf the F-F contact zone is marked by an abrupt facies change from stromatoporoid-dominated carbonate below into quartzose sandstone above. The carbonate surface is (a) cut by up to 60 cm deep fissures filled with a wackestone containing abundant sponge spicules and algal fragments and (b) topped by a 4 to 5 cm thick micro-karst infilled with sandstone and argillaceous material. The overlying sandstone contains fragments of the spicule-bearing wackestone and Famennian as well as reworked Frasnian conodonts. Famennian conodonts also occur in the fissure fill indicating that the mass killing event post-dates the stromatoporoid-bearing carbonate and predates the fissure fill. Anomalously high trace element values from the micro-karst fill certainly postdate the F-F event and probably represent a condensed lag deposit. Without microfacies analysis co-occurrence of Frasnian and Famennian conodonts could have been postulated and the trace element anomaly interpreted as a sudden depositional event.

In the basin the F-F contact coincides with an abrupt facies change from bioturbated oxygenated siltstone below into laminated euxinic shaly lime-mudstone above. Along the contact occurs a 0 to 5 cm thick siltstone with 25 per cent framboidal pyrite distributed along gently inclined foresets suggesting syndeposition of silt and pyrite. No trace element anomaly or shocked quartz was detected. However, the framboidal pyrite yielded a strong sulphur isotope peak of $\delta S^{34} = +20.8°/_{oo}$ indicating a sudden influx of anoxic water which may be related to an oceanic turnover event.

Additional F-F sections from western Canada, western United States, France, Germany and Australia have been sampled or re-sampled and await geochemical/microfacies evaluation.

The only parameter common to all sections is a distinct faunal change, an obvious mass killing event in shallow marine environments, but very subtle in basinal settings. Several F-F boundary localities with a paleo-slope setting are characterized by one or a series of cyanobacterial beds. The preservation of these beds in open-marine environments suggests temporary elimination of grazing organisms due to brief anoxic conditions. Such a hostile environment did not prevent the growth of cyanobacteria which may have been chemosynthetic forms. Trace element anomalies are normally absent in basinal or slope settings unless concentrated by such cyanobacteria. Shocked quartz has not been detected so far. Spectacular soft-sediment deformation and breccias are associated with the F-F boundary in Nevada and Utah and could have been caused by tidal waves or earthquakes.

What was the ultimate cause of the mass killing event(s) ? Glaciations and volcanism are often quoted as triggering mechanisms. The Late Devonian was not a time of global cooling and glacial activity which could have caused an oceanic turnover event[2] nor is there a record of any large scale volcanic event. There is, however, evidence of at least two fairly large impact craters (Siljan, Sweden: 52 km crater, 368 ± 1 ma; Charlevoix, Canada: 46 km crater, 360 ± 25 ma) both of which are in continental crustal material[3]. It is likely that one or more oceanic impacts occurred at about the same time the evidence of which has unfortunately, long been subducted.

Even though only limited, these data suggest multiple impacts by a meteorite shower. Could these impacts cause oceanic overturns on a global scale? As a result of prolonged warm climatic conditions during the Late Devonian, oceanic basins had probably become stratified and anoxic levels may have reached relatively shallow depths such as the outer margins of continental shelves. Strong tectonic movements along rising orogenic belts probably caused gradual flooding of shelf areas with this 'shallow' anoxic water mass on a regional or even cratonic scale. Numerous black shales of late Givetian, Frasnian and Famennian age probably document such flooding events. These anoxic sediments are not associated with mass killing events; the process was gradual and allowed ample time for the shelf biota to retreat to unaffected areas. However, conditions during the Late Devonian were such that catastrophic events such as a meteorite shower could provide the necessary energy to trigger oceanic overturns and flooding of shelves and epicontinental seas on a global scale.

[1] Goodfellow, W.D., Geldsetzer, H.H.J., McLaren, D.J., Orchard, M.J., and Klapper, G. (in press) Canadian Society of Petroleum Geology, Memoir 14.
[2] Geldsetzer, H.H.J., Goodfellow, W.D., McLaren, D.J., and Orchard, M.J. (1988) Geology, v. 16, p. 87-88.
[3] Grieve, R.A.F. and Robertson, P.B. (1987) Geological Survey of Canada, Map 1658 A.

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