LATE ORDOVICIAN MASS EXTINCTIONS: CAUSES AND CONSEQUENCES - A VIEW FROM LAURENTIA. William B.N. Berry, Department of Earth and Planetary Science, 301 McCone Hall, University of California, Berkeley, California 94720 USA. bberry@uclink4.berkeley.edu

Introduction: Sepkoski [1] closely studied the generic-level Ordovician taxonomichistories of most marine invertebrates and concluded that the early part of the "Ordovician Period encompasses one of the most profound evolutionary radiations and marine faunal transitions of the Phanerozoic." That dramatic radiation was truncated abruptly in the Late Ordovician by one of the two or three most severe mass extinctions among marine organisms to occur within the Phaneroic. In that extinction Sepkoski [1] noted, generic diversity dropped to about the level of the pre-early-Ordovician proliferation. The Late Ordovician extinctions took place during a 1 to 2 million year interval of continental glaciation which developed in north-central Africa. Marine environmental and faunal consequences of that glacial interval have been examined closely in a number of Laurentian Plate stratigraphic successions. The Laurentian Plate lay within the tropics of the time. The studies reveal patterns inherent in the mass extinction and suggest a possible cause.

The Great Basin: One such study [2] has involved refined sedimentologic and biostratigraphic analyses of Late Ordovician environments representative of an inner shelf, an outer shelf and slope on the shelf margin. The area investigated lay on the western (in terms of modern orientation) side of Laurentia and is within the Great Basin. Graptolites and conodonts abound in the slope and ourter shelf successions. Conodonts and organic-walled microfossils are found in shelf strata. Inner shelf strata bear brchiopods, corals, crinozoans and bryozoans. The following patterns have been documented in study of the Great basin successions: 1) Late Ordovician graptolites inluded taxa that lived close to or on the periphery of oceanic oxygen minimum zones and taxa that lived in relatively more oxic waters, relatively removed from oxygen minimum zones. An oxygen miniumum zone existed along the Laurentian Plate margin during the latter part of the Ordovician. Sedimentologic evidence indicates that as sea level dropped, presumably as a result of glacio-eustacy, a shelf-marginal oxygen minimum zone became diminished and, ultimately, disappeared during glacioeustatic lowstand. Graptolites living near the oxygen minimum zone became extinct as their habitat disappeared. Disappearances were not synchronous, for those living closer to the oxygen minimum zone became extinct prior to those living near the periphery of the zone. Those graptolites living in oxic waters survived all oceanic changes during the glacial episode and even proliferated modestly during it. 2) Conodont taxa in the same stratal successions as the graptolites continued to survive as sea level fell. When depositional environments shallowed significantly , conodonts living in slope/basinal waters disappeared first. Their disappearance was followed by loss of the shelf-dwelling taxa. 3) Significant faunal turnovers occurred among the brachiopods [3] and most other shelly taxa as sea level fell. Among brachiopods, this turnover led to establishment of a new faunal association which persisted through the glacial episode. When deglaciation commenced and sea level rose, a second faunal turnover took place during which elements of the faunas that typify the Silurian appeared [3].

Carbon Isotopes: .Carbon isotope studies of whole rock carbonates bearing conodonts and graptolites in Nevada [2] reveal a sudden marked shift toward enhanced carbon-12 values at onset of glacio-eustatic sea level fall, followed by a marked enrichment in carbon-13 that persisted throughout marine lowstand. Potential sinks for carbon-12 during the glacial interval include wetland organisms inhabiting former marine depositional sites and within cold ocean water sinking in high latitudes.

Potential Cause. The Late Ordovician depositional record of the eastern (in modern directions) side of the Laurentian Plate suggests a potential factor that resulted in glaciation. Siliclastic sediments accumulated in a complex of fluviatile and deltaic environments (the Queenston delta) that spread widely on the eastern side of the Laurentian Plate, with the thickest deposits found in Pennsylvania, New York, and adjacent states [4]. Dennison [4] described this deltaic-fluviatile complex, suggesting that it developed during glacio-eustatic sea level fall. As sea level dropped, base level was lowered and siliclastics, including red silts and muds, spread westward from an eastern highland source. This source resulted from plate collisions with Laurentia in the Late Ordovician [5]. Potentially, weathering of siliclastics that composed the source highlands of the Queenston deltaic complex could lowered atmospheric carbon dioxide concentrations and been a causal element leading to glaciation.

Tectonic Overprint. Interestingly, a latest Ordovician-early Silurian tectonic overprint is seen on Laurentian Plate margins. Dennison [4] described an unconformity separating Queenston deltaic sediments from superjacent Silurian strata. Great Basin slope sediments bearing latest Ordovician graptolites are overlain by early-late Silurian graptolite-bearing strata [2]. Similarly mid-early Silurian strata overlie latest Ordovician slope strata on the southern (in modern directions) Laurentian margin. Latest Ordovician-early Silurian tectonism on most Laurentian plate margins led to a depositional hiatus between glacial episode strata and those of mid to Late Llandovery age.

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