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Exploring the Ecological Impact of Mass Extinction: measuring the effects of stress on communities during the Ordovician-Silurian Mass Extinction on Anticosti Island, Quebec Canada

Project Report

The distribution of life on Earth is controlled by the effects of stress at multiple levels of the biological hierarchy, from cellular tolerances to individual organisms to entire ecosystems. Mass extinctions represent some of the most extreme intervals of stress in the history of life on Earth and provide an ideal setting for the study of the effects of stress on biological systems[1]. The purpose of this study is to quantify the effects of a mass extinction on an ancient ecosystem by adapting an ecological method (rank-abundance curves[1,3]) for use in conjunction with traditional paleoecological methods. The end-Ordovician is the second largest mass extinction and occurred as two pulses coinciding with the onset and cessation of a ~ 1myr glaciation[2]. The differing causal mechanisms of the two extinction pulses provide a valuable framework for comparing the effect of different stresses on similar ancient communities. The hypothesis is community structure will change in response to the stresses leading to extinction. The predictions are: 1) overall community structure will change with increasing stress before each pulse, 2) different taxonomic groups will display different changes in community structure, and 3) the rate and nature of the changes in community structure will be different for each pulse. Preliminary results for a single taxonomic group (brachiopods – the most abundant and diverse group in Ordovician-Silurian communities) support these predictions. The rate and severity of change in community structure will indicate the sensitivity of both the entire community and the various elements of the community to the lethal combination of stresses that lead to mass extinctions.

To quantify changing community structure, marine invertebrate macrofossil assemblages were surveyed on Anticosti Island, Quebec, which has the most complete record of a shallow-water (<100m) shelly fauna from the Ordovician-Silurian boundary[4,5]. There are seven stratigraphic intervals on Anticosti Island from the Upper Ordovician through the Llandovery[4,5] that include the interval preceding both extinction pulses through the taxonomic recovery. Sampling was focused on the three stratigraphic formations corresponding to the Katian and Hirnantian Ages of the latest Ordovician, and the Rhuddanian Age of the earliest Silurian. The extinction pulses occur at the start and end of the Hirnantian Age represented by the lower and upper boundary of the Ellis Bay Formation on Anticosti Island. The fossil assemblages are well-preserved and diverse within a well-constrained environmental and stratigraphic framework that has been extensively sampled and studied[4,5]. Field-work was completed over four weeks during June and July of 2012. Although field-work had originally been planned for the summer of 2011, there was not sufficient time to obtain the necessary permits until the following summer. During the 2012 field season, 62 localities (supplemental figure 1) were surveyed yielding over 200 samples. Each sample represents a single limestone surface with at least 25 identifiable fossils (usually between 50-100) and with no evidence of transport or other taphonomic signals that indicate disruption of the community signal. As the Ordovician and Silurian strata crop out along >150 km perpendicular to the paleo-shoreline, it was possible to collect samples to represent the ecosystem along a paleo-depth gradient in the Anticosti Basin. The paleo-environment is interpreted as a normal marine foreland basin with several shallowing upwards sequences in response to glaciation[4,5]. Limiting the samples to the surface of limestone beds avoids measuring community signals from extreme environmental changes. Each surveyed surface was measured, and all taxa were identified and counted to yield abundance data, noting fragments. A lithologic description was completed for each sample, also noting the presence of any trace fossils and the number of adjacent fossiliferous beds. Additional processing of the surveyed surfaces will include point counts from a 1cm by 1cm grid, providing biovolume data by recording any taxa at the intersection of grid lines.

Preliminary analysis of the community surveys reveal distinct faunal shifts associated with both extinction pulses and relatively rapid faunal turnover between the two pulses. Within-community richness declines immediately before each extinction pulse and recovers quickly compared to global diversity. The second, and final, extinction pulse had a larger impact on community composition and diversity. These patterns may indicate that multiple extinction pulses and prolonged stress on an ecosystem compound the overall ecological impact. However, the fossil assemblages on Anticosti Island also reveal relatively rapid recovery at the community level (10^5 years), in contrast to the much slower recovery of global diversity (10^7 years).

Further analysis of the community surveys are planned as follows. Community structure will be quantified for each surface sample using richness, evenness, abundance and biovolume comparison, and rank-abundance curves (species-abundance distributions, measured by kurtosis[1,3]) both for the entire community and for individual taxonomic groups (i.e., brachiopods, bryozoans, corals, crinoids, and molluscs). Community metrics will be analyzed and compared from before, during, and after the pulses of the extinction, allowing for detection of changes in community structure related to the extinction pulses and subsequent recovery. The metrics will be compared within samples to ascertain variation between abundance and biovolume signals, then compared within localities and finally between stratigraphic intervals. The final analysis will investigate any trends through the study interval, revealing any changes in community structure before and during the extinction event and during the recovery period. The results of this study will be of broad interest to paleobiologists, ecologists, and astrobiologists as the results will provide important information on ecological processes during extreme stresses, specifically during the two pulses of a major mass extinction and the subsequent recovery. The methods used in this study also have the potential to aid in modern conservation efforts by identifying communities that are especially vulnerable, and to increase understanding of patterns and dynamics for other extinction events in the fossil record. All publications resulting from this project will be submitted to the American Philosophical Society.

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