Analysis of Low and High Latitude Planktonic Foraminiferal Distributions Across the Late Maastrichtian Deccan Volcanism Event

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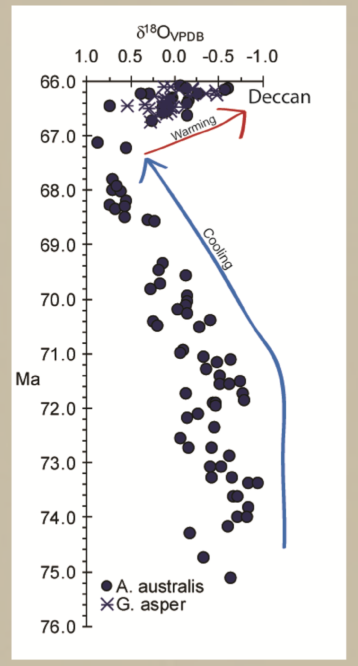
Introduction

The biotic turnover at the Cretaceous-Paleogene (K-Pg) boundary has long been recognized as one of the most devastating events in the history of life. Despite overwhelming evidence that the asteroid impact caused the terminal Cretaceous extinctions, some researchers still argue that volcanism during an eruption of the Deccan flood basalts (west central India) ~250 kyr before the K-Pg boundary also caused biotic extinctions and major environmental change[3]. If true, there should be evidence of volcanic-induced biotic stress in the ocean, including a globally consistent record of corresponding extinctions and a test size reduction (also known as a “Lilliput Effect”) among environmentally sensitive species[2].

This study examines changes in stratigraphic distributions, species diversity, and test size changes of multiple species that lived in mixed layer and thermocline habitats among planktonic foraminiferal assemblages during the last 500 kyr of the Cretaceous[1]. Deep-sea boreholes ODP Holes 1049C (low latitude; Blake Plateau, North Atlantic) and 690C (high latitude; Maud Rise, southern South Atlantic) were selected to identify evidence of such biotic stress. Both sites are stratigraphically complete across the K-Pg interval and have excellent age control and warming evidenced by stable isotope data across the late Maastrichtian Deccan Event.



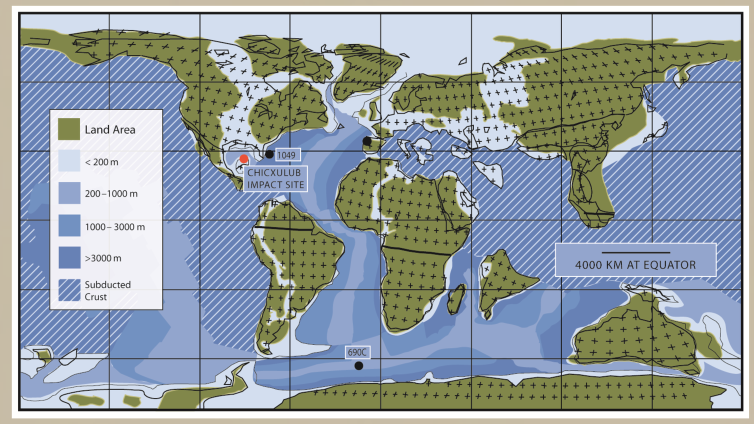


Figure 1. Map of ODP Holes 1049C (low latitude), 690C (high latitude), and Chicxulub impact.

Figure 2. 76.0Ma- 66.0Ma $\delta^{18}O$ excursion from site 690 samples. Plot defines a cooling interval to the warming that has been stated to be in result of the Deccan Event.

Methods

Wash sample through >150 μm sieve (690C only)

Microsplit for 200-400 planktonic specimens (690C only)

Pick all specimens from tray, organize on slide by species, and count specimens per species (690C only)

Random number generator to select 20 specimens per species to measure

Image and measure using biometric software

Figure 3. >150 micron sieve and microsplitter.

Figure 4. Picking tray, paintbrush and slide.

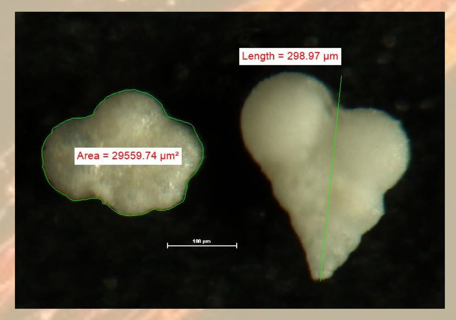


Figure 5. Measuring spiral and serial species.

Site 1049C

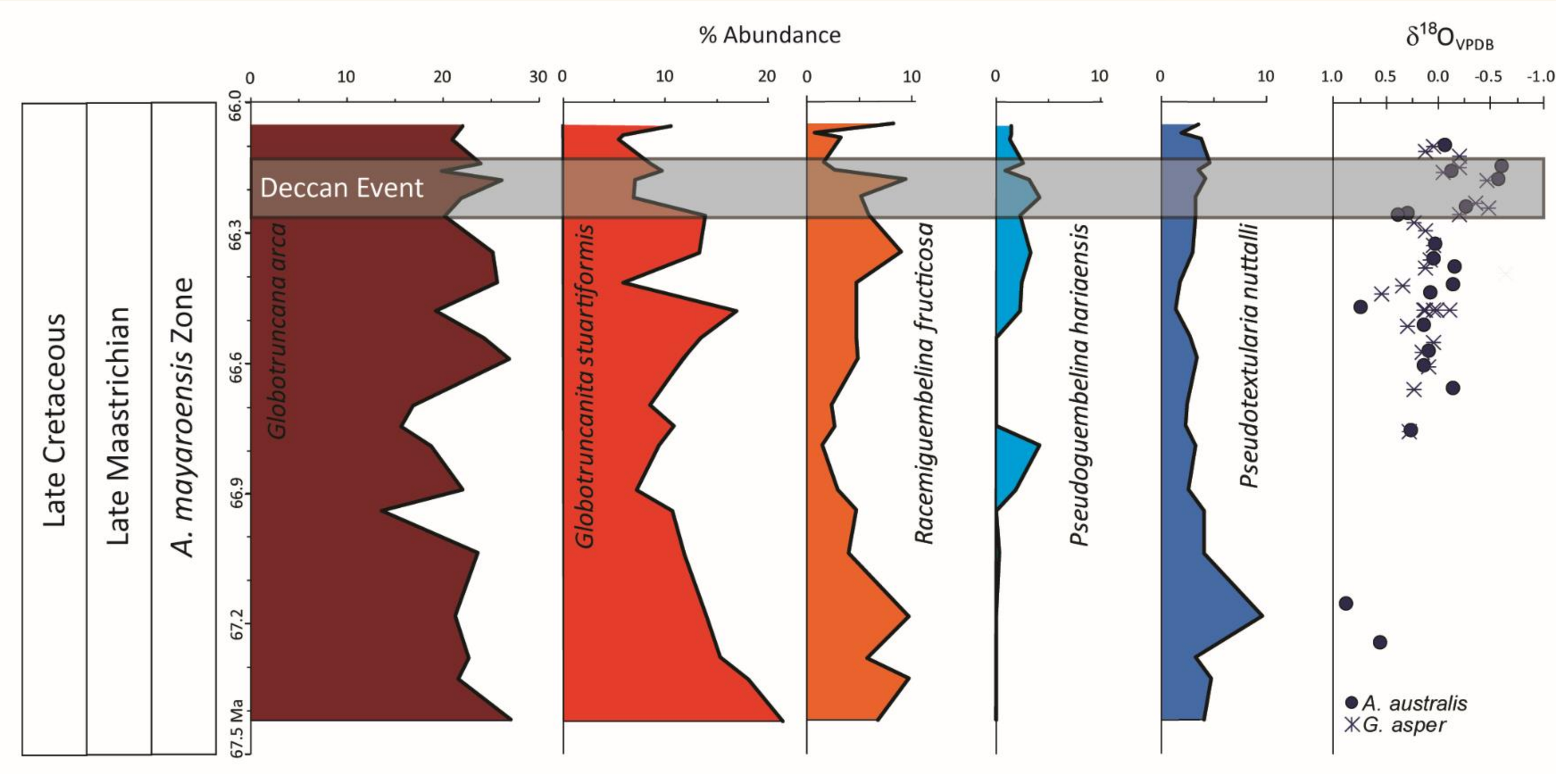


Figure 6. Area abundance graphs of 1049C species from 66.0-67.5 Ma with $\delta^{18}O$ graph from site 690 samples. There is a defined negative $\delta^{18}O$ excursion that is recognized as the warming interval of Deccan volcanism (66.15-66.26Ma).

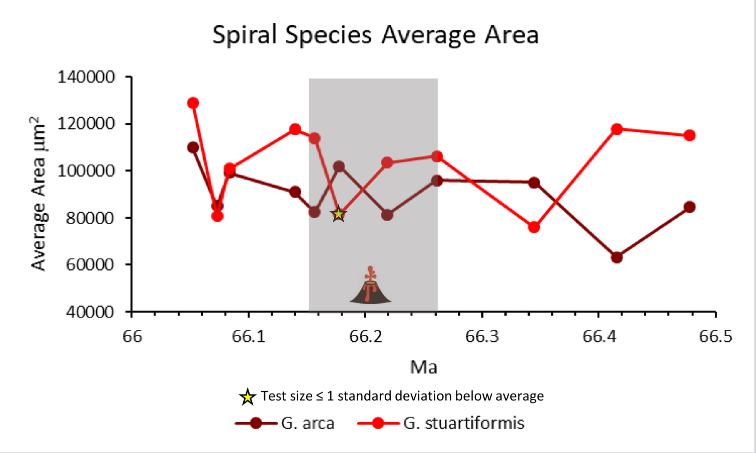


Figure 7. Average test areas of spiral species *Globotruncana arca* and *Globotruncanita stuartiformis* from pre to post Deccan volcanism. The star marks when *G. stuartiformis* achieved a test area less than or equal to one standard deviation below average.

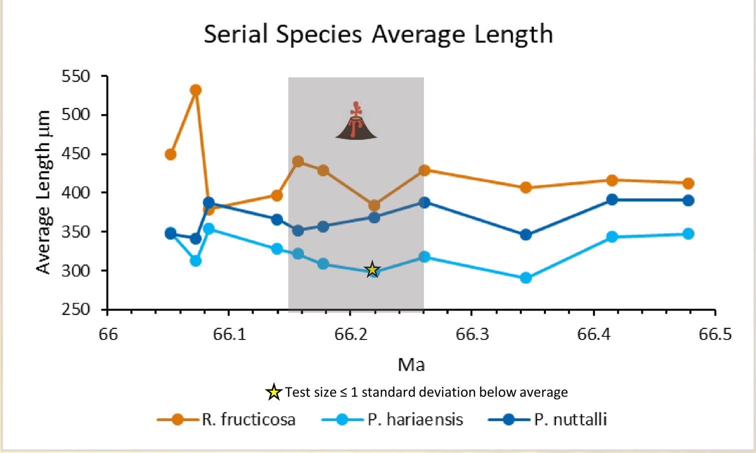


Figure 8. Average test lengths of serial species *Racemiguembelina fructicosa, Pseudoguembelina hariaensis, Pseudotextularai nuttalli* from pre to post Deccan volcanism. The star marks *when P. hariaensis* achieved a test length less than or equal to one standard deviation below average.

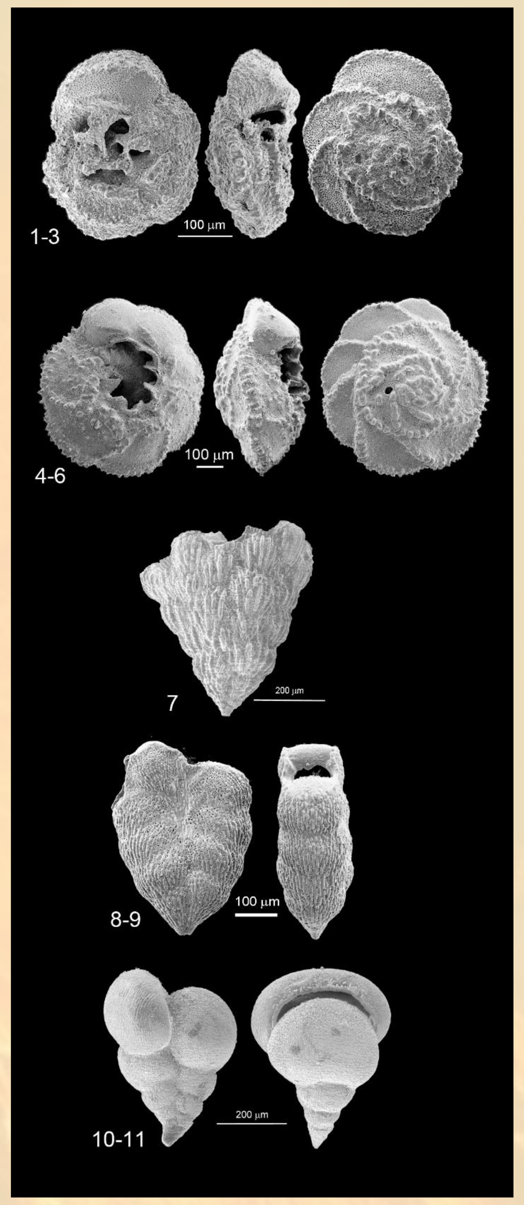


Figure 9.
1-3. *Globotruncana arca*
4-6. *Globotruncanita stuartiformis*
7. *Racemiguembelina fructicosa*
8-9. *Pseudoguembelina hariaensis*
10-11. *Pseudotextularai nuttalli*

Site 690C

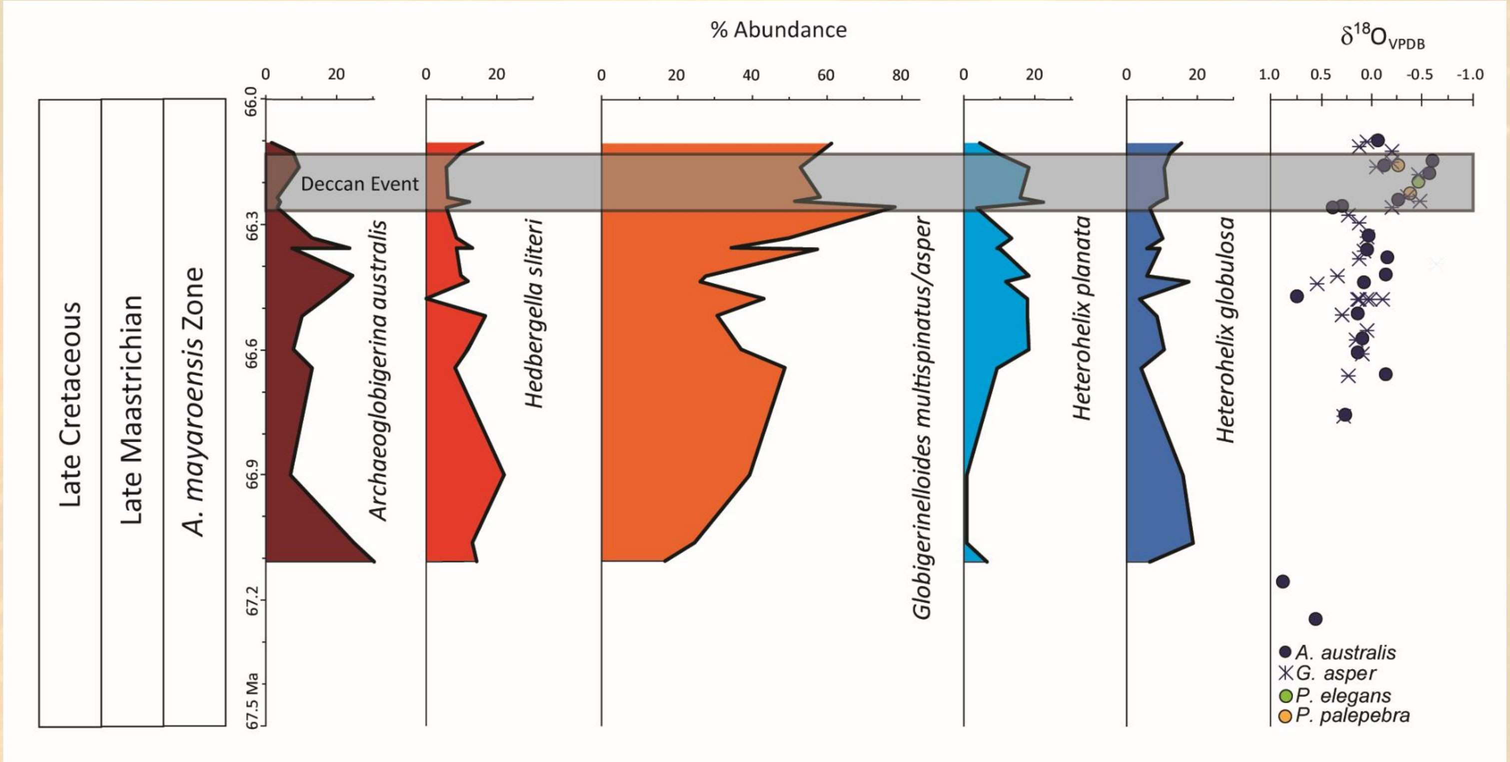


Figure 10. Area abundance graphs of 1049C species from 66.0-67.5 Ma with $\delta^{18}O$ graph from site 690 samples. There is a defined negative $\delta^{18}O$ excursion that signifies the warming interval from Deccan volcanism. The presence of the warm water species *P. elegans* and *P.palepebra* are noted on the $\delta^{18}O$ plot within the span of Deccan volcanism (66.15-66.26Ma).

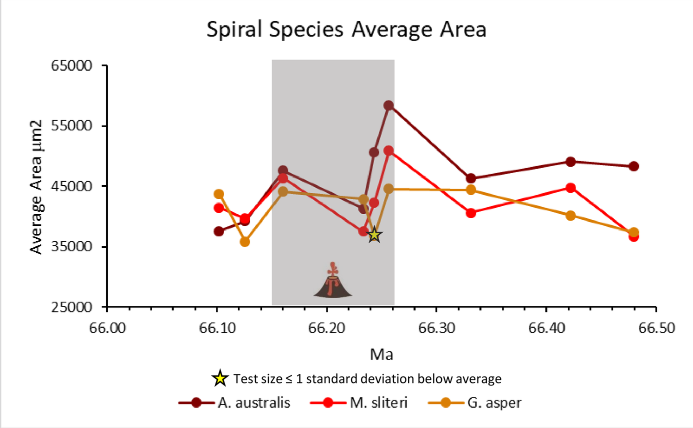


Figure 11. Average test areas of spiral species *Archaeoglobigerina australis*, *Muricohedbergella sliteri*, and *Globigerinelloides asper* from pre to post Deccan volcanism. The star marks when *G. asper* achieved a test area less than or equal to one standard deviation below average.

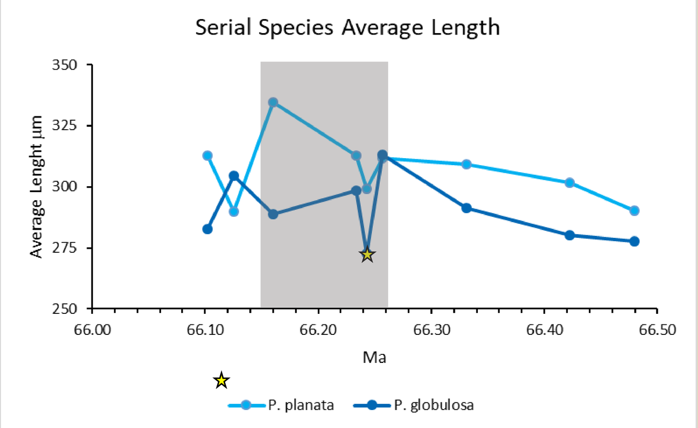


Figure 12. Average test lengths of serial species *Planoheterohelix planata* and *Planoheterohelix globulosa* from pre to post Deccan volcanism. The star marks *when P. globulosa* achieved a test length less than or equal to one standard deviation below average.

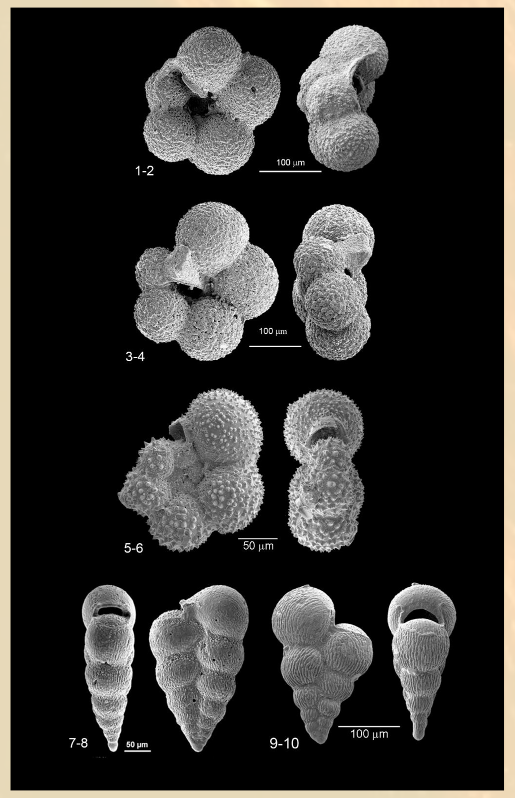


Figure 13. 1-2. *Archaeoglobigerina australis* **3-4.** *Muricohedbergella sliteri*
5-6. *Globigerinelloides asper*
7-8. *Planoheterohelix planata*
9-10. *Planoheterohelix globulosa*

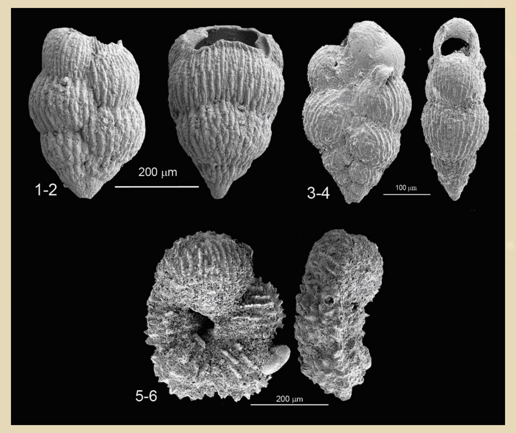


Figure 14. 1-2. *Pseudotextularia elegans*
3-4. *Pseudoguembelina palepebra*
5-6. *Abathomphalus mayaroensis*

Results

		Site 1049C	Site 690C
Abundance		• Remained relatively constant across the Deccan Event • Drops in abundance during volcanism are smaller than those that occurred earlier • Double keeled species, *G. arca* and *G. stuartiformis*, survived the event	• Abundance remained relatively constant from pre- to post-Deccan • Drops in abundance during volcanism are less significant than those that occurred earlier • Double keeled species *A. mayaroensis* survived the event • Presence of low latitude warm water species *P. elegans* and *P. palpebra* within the Deccan interval
Size		• Decreased test size in *G. stuartiformis* and *P. hariaensis* during Deccan • *G. arca*, *G. stuartiformis*, and *P. hariaensis* all reached their smallest test size pre-Deccan • All species except *P. nuttalli* reached an above average test size after the Deccan event	• Decrease in test size for *G. asper* and *P. globulosa* during Deccan • *A. australis* and *M. sliteri* reached their smallest test sizes before the Deccan event • All species except *G. asper* reached their largest test size after the Deccan event

Discussion and Conclusions

Abundance: All species, even specialists were found across the interval of Deccan. Thus, no extinctions.

Size: Although 4 of 10 species show a test size reduction within the Deccan, the lack of a consistent size pattern within the warming and sporadic size changes below it lead us to conclude that the Lilliput dwarfing proposal[2] is unsupported.

Migration: The presence of *P. elegans and P. palepebra* in subantartic waters suggests a poleward migration of warm water species was induced by the Deccan warming.

Based on this study, there remains the possibility that volcanic induced biotic stress influenced foraminiferal test size for some species, but there is no evidence for species extinctions caused by Deccan volcanism. Overall, late Maastrichtian planktonic foraminifera show negligible changes until the mass extinction at the terminal Cretaceous asteroid impact bed.

Figure 15. Chicxulub impact

Future Work

- Analyze the <150 μm size fraction of both sites across the Deccan Event to look for any test size changes
- Obtain stable isotope analyses of *P. nuttalli* to better define its depth paleoecology
- Obtain new $\delta^{18}O$ data from planktonic species at Site 1049 to identify the Deccan warming interval at low latitudes

References and Acknowledgements

1. Huber, B. T., and Watkins, D. K., 1992, Biogeography of Campanian-Maastrichtian calcareous plankton in the region of the Southern Ocean: paleogeographic and paleoclimatic implications, *in* Kennett, J. P., and Warnke, D. A., eds., The Antarctic Paleoenvironment: A Perspective on Global Change, Antarctic Research Series, Volume 56: Washington, D.C., American Geophysical Union, p. 31-60.
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3. Schoene, B., Eddy, M. P., Samperton, K. M., Keller, C. B., Keller, G., Adatte, T., and Khadri, S. F. R., 2019, U-Pb constraints on pulsed eruption of the Deccan Traps across the end-Cretaceous mass extinction: Science, v. 363, p. 862-866.

I would like to thank the NHRE program and the National Science Foundation for making programs like NHRE possible.

REU Site, OCE-1560088