PETM data comparison and interpretation: **Questions for students**

1. What happened to the total amount of calcite in the sediments during the PETM? Describe the pattern over time.

2. Why would calcite have become less common in the sediment?

3. Consult Document 2. What is the pattern to the color in the sediment core? Explain this pattern.

4. If you were to correlate Documents 1 and 2, what point in each data set would you match up?

5. Compare the two graphs in Document 1. Note how the $\delta^{13}C$ measurements right at the Paleocene/Eocene Boundary (PEB) are sparse or absent. Why would this be the case?

6. Focus on the colors to the data sets, designating core depth. What is the pattern to the "recovery" (return to a $\delta^{13}C$ of 2‰) after the PETM event, in terms of the of various core depths? Think about the position of the CCD in the water column. (Put another way: did the deep cores return to normal more quickly, or did the shallow cores?) Why is this?

7. Overall, how long did it take the ocean to recover to "normal" after the PETM event began?

8. Many species of benthic foraminiferids (seafloor-dwelling single-celled creatures) go extinct at the bottom of the clay-rich layer (start of the PETM). Why might this have happened?

9. At the same time, the ranges of tropical organisms in both the ocean and on the land shift toward the poles and away from the equator. Why might this have happened?

10. The PETM was a natural event, with no human influence. It is estimated that the sudden release of about 2000 gigatonnes (gT) of carbon into the atmosphere was responsible. Where could all the carbon have come from? Make hypotheses: Suggest several possible sources.

11. How would you test the hypotheses you suggested above, to figure out if they were or were not the source of the extra PETM carbon?

12. In the modern day, we are also transferring a large amount of carbon from the fossil fuel reservoir in Earth's crust to the atmosphere, life, and oceans. The current rate of human release of carbon is around 9 gTC/yr. For simplicity, let us assume that rate of carbon release is constant for 200 years; 200 x 9 gT = 1800 gT. How does the modern atmosphere's extra pulse of carbon compare to that inferred for the PETM?

13. If we assume the rate of recovery to be similar today to the rate observed in the PETM (see question 5), how long will it take the biosphere, oceans, and atmosphere to recover from the current pulse of extra carbon?

14. How long has human civilization existed? Compare your answers to this question and the previous question.

Document 1: Figure 3 from Zachos, *et al.,* 2005 (an article in the journal *Science*)

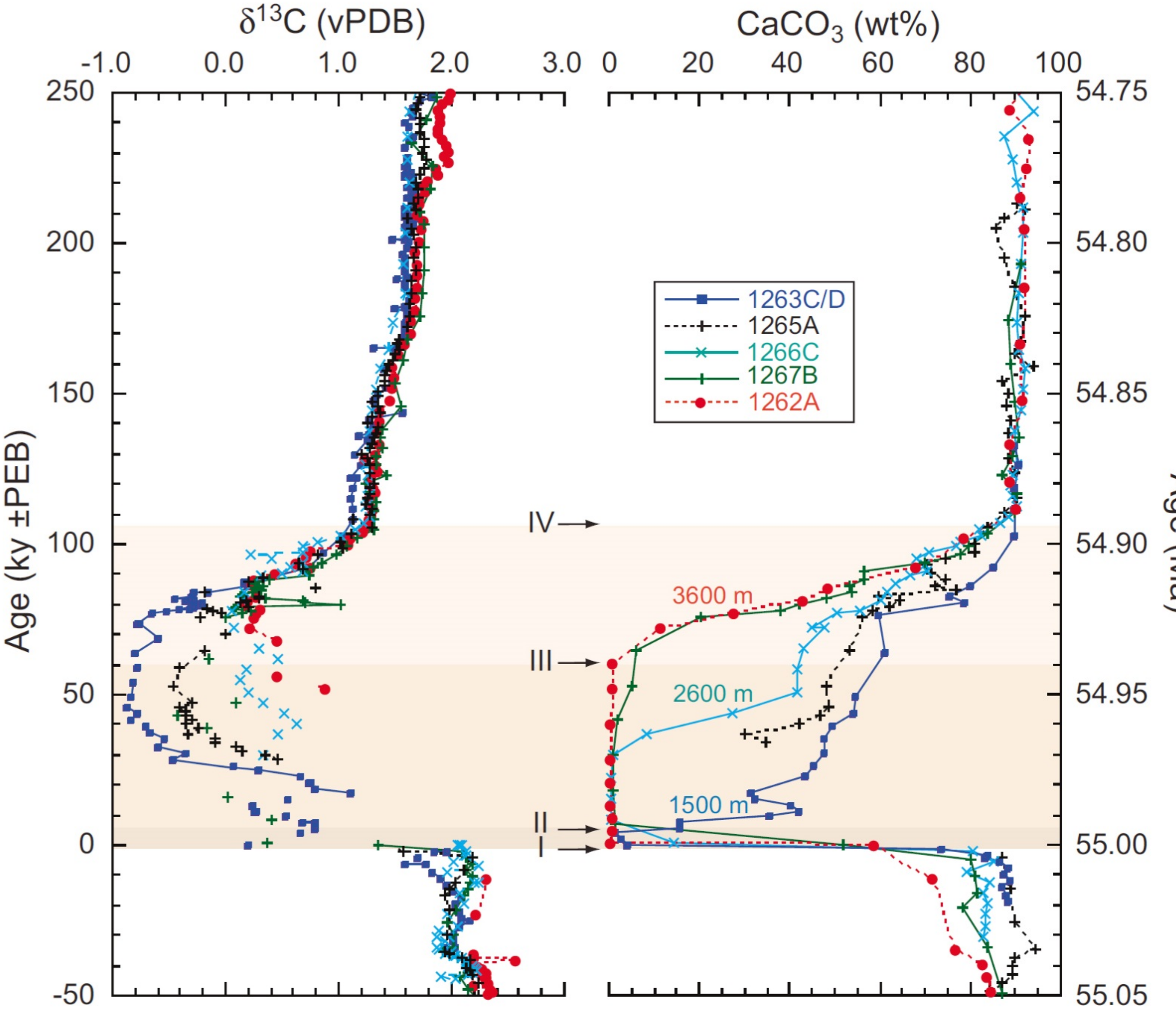

Fig. 3. Bulk sediment $\delta^{13}C$ and weight % carbonate content ($g_{CaCO3}/g_{Total} \times 100$) plotted versus age for ODP sites 1262, 1263, 1265, 1266, and 1267. Age (ky) relative to the P-E boundary is plotted on the left axis and absolute age (Ma) along the right. Age models (table S4) are based on correlation to site 690 (*8*) using the carbon isotope stratigraphy as verified with the nannofossil events in Fig. 2 and with the Fe and MS cycles in fig. S2. Transferring the 1263 age model to deeper sites with carbon isotopes could only be achieved where sufficient carbonate was present. Ages within the clay layers for sites 1266, 1267, and 1262 were derived through linear interpolation from tie points E and A. Paleodepths (~55 Ma) are provided for sites 1263 (1500 m), 1266 (2600 m), and 1262 (3600 m). Key events in the evolution of south Atlantic carbonate chemistry were (i) the rapid drop in content to <1% for all sites with the exception of site 1265, where the lowermost Eocene is absent (marked I); (ii) the return of the CCD to site 1263 roughly 5 ky after the excursion (marked II); (iii) the return of the CCD to site 1262 at 60 ky (marked III); and (iv) the lysocline descending to a point below the deepest site at 110 ky after the excursion (marked IV). PEB, Paleocene-Eocene boundary.

Document 2: Photograph by Ira Block for National Geographic

Photo caption: **When the Ocean Went Dark**
Paleoceanographer James Zachos holds a replica of a sediment core that shows an abrupt change in the Atlantic Ocean 56 million years ago, at the onset of the Paleocene-Eocene Thermal Maximum (PETM).

Document 3: Figure 1 from Zachos, *et al.,* 2005 (an article in the journal *Science*)

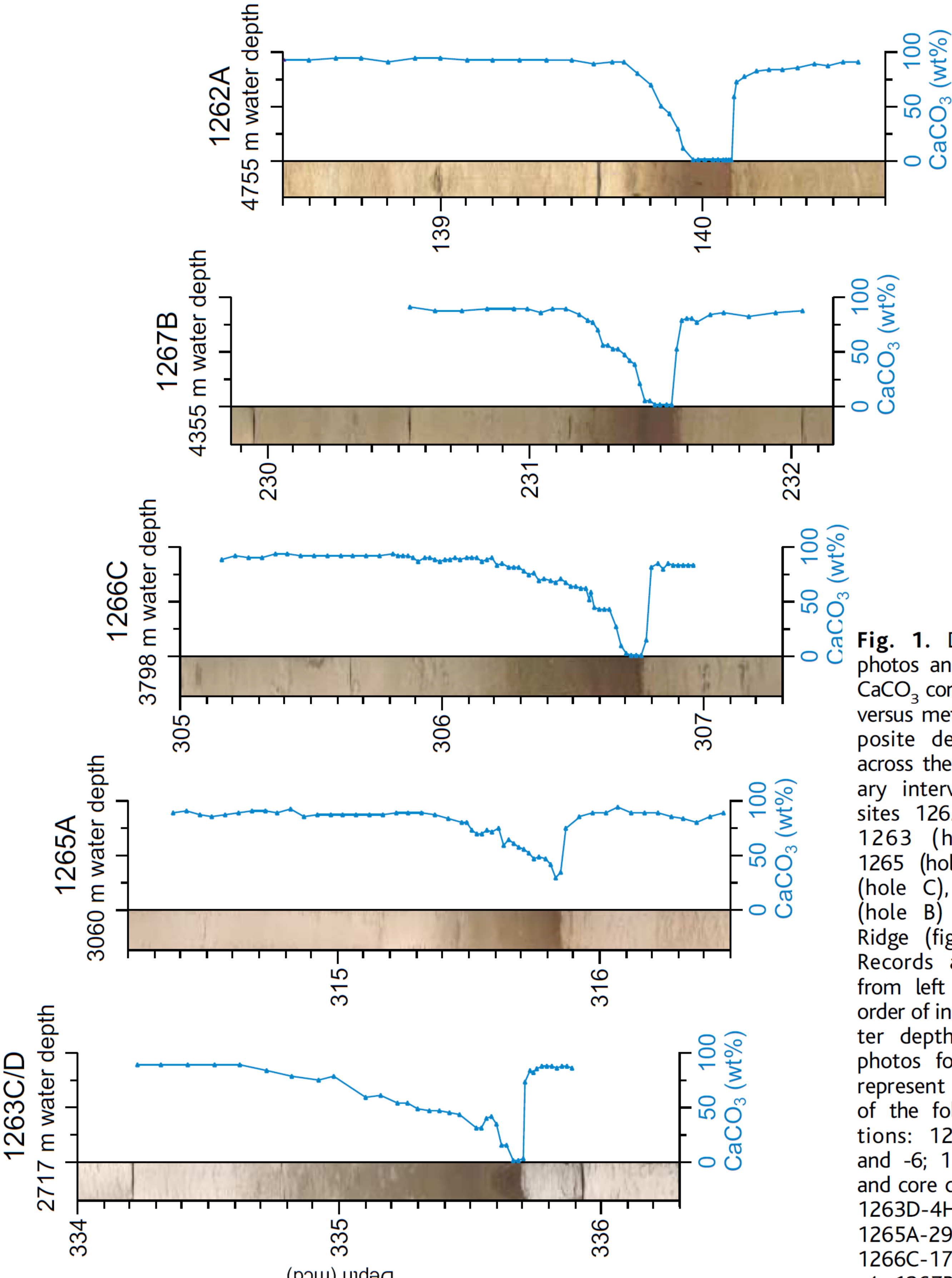

Fig. 1. Digital core photos and weight % $CaCO_3$ content plotted versus meters of composite depth (MCD) across the P-E boundary interval at ODP sites 1262 (hole A), 1263 (hole C/D), 1265 (hole A), 1266 (hole C), and 1267 (hole B) on Walvis Ridge (fig. S1) (*18*). Records are plotted from left to right in order of increasing water depth. The core photos for each site represent composites of the following sections: 1262A-13H-5 and -6; 1263C-14H-1 and core catcher (CC); 1263D-4H-1 and -2; 1265A-29H-6 and -7; 1266C-17H-2, -3, and -4; 1267B-23H-1, -2, and -3