GEOLOGY 3520 Homework #3
Due: Thursday 5 March 2009

The Late Paleocene Thermal Maximum (LPTM)

In a recent lecture we studied the LPTM, a freak event that occurred about 56 MY ago, during which massive amounts of C were suddenly released from the shallow ocean bottom. Carbon isotope changes in marine carbonates suggest the amount of C released was on the order of 5000 GtC (this assumes the released C was a mix of methane C from submarine methane hydrates and C from terrestrial and marine organic matter). According to oxygen isotope changes, also in marine carbonates, the event led to an ~5 °C warming of the deep ocean. There is also evidence for associated acidification of the oceans, dissolution of marine carbonates, and partial extinction of ocean bottom dwelling organisms. In this exercise we will use a version of Robert Berner's GEOCARB model provided by your textbook author to evaluate this event in more detail.

Begin by pointing your browser to http://forecast.uchicago.edu/Projects/geocarb.doc.html. The model calculates and displays a variety of C-cycle and climate parameters for different geologic conditions. To convince your self that the model is reasonable, let's first see if we can use it to reproduce recent conditions. Hit "Run me" to open the model to its default specifications. Begin by changing the "transition CO_2 spike" to 0 GTC. (The "transition CO_2 spike" is a function that enables you to perturb the model's carbon cycle with an instantaneous injection of CO_2). Recall from an earlier lecture (and Fig. 4.7 of your text) that "Delta T_{2x}" refers to the climate sensitivity to CO_2 change, which is defined here as the amount of global warming for a doubling of the atmospheric CO_2 concentration. Three °C is roughly the consensus estimate for climate sensitivity from the Intergovernmental Panel on Climate Change (IPPC at http://www.ipcc.ch/). Hit "Run the model" and view your results. Looking at graphs note the estimated atmospheric pCO_2 value. How does this compare to recent pre-industrial pCO_2 measured in ice cores? How do calculated average global air and ocean temperatures compare with observed average values?

In a second experiment, inject a "transition CO_2 spike" equivalent to the amount of C released during the LPTM. You may also wish to set the year for solar luminosity to 56 MY (to account for the fact that solar luminosity has been increasing by about 1%/100 MY since the Earth formed 4.6 BY ago). Hit “Run the model” and view your results. Note the maximum pCO_2 achieved and the associated change in ocean and atmosphere temperature. How does the latter compare with the amount of deep ocean warming inferred from oxygen isotopic evidence? Why is the inferred atmospheric temperature change so much larger than the change in ocean temperature?

Recall that dissolution of CO_2 into seawater produces carbonic acid, which dissociates to produce free H+ ions (i.e. acidity). These protons react in turn with $CO_3^=$ (carbonate ion). So the absorption of CO_2 by the sea acts to consume carbonate ion that would otherwise be used to produce carbonate shells that are eventually buried in sediments. In the experiment just performed, what is the change in ocean $CO_3^=$ concentration? In order to compensate for this change, the burial of $CaCO_3$ was influenced (see the graphical output called “$CaCO_3$ equilibrium”). Describe the change in $CaCO_3$ burial (i.e. it changes from "X to Y" moles per year). Suggest what you think may be meant by “negative burial” and why it might occur. (Note that “E12 mol/yr” is short hand for 10^{12} moles/year).

Lastly, how does the estimated magnitude of anomalous C release during the LPTM compare to the estimated amount of fossil fuel remaining in the rock reservoir? How might the experiments just performed inform our understanding of what might happen if we were to burn all available fossil fuel in the next few hundred years?

Present your answers neatly and clearly in writing.

<u>Model notes</u>:

“CO_2 degassing rate” refers to the volcanic release of CO_2, which we have not changed in these experiments.

The model presents results on timescales (X axes) of both millions and thousands of years. The latter will document the response to perturbations in greater detail.