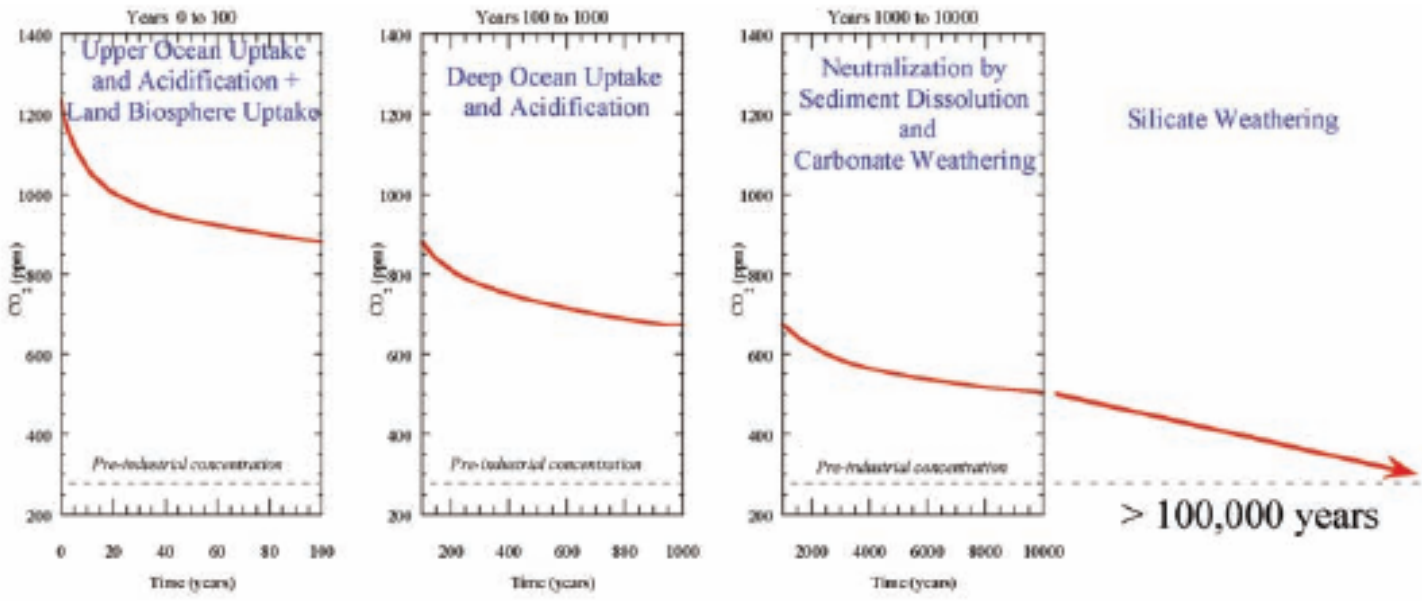
BOX 2.2 TIMES CALES FOR REMOVAL OF CO_2 FROM THE ATMOSPHERE



The figures show the fate of a pulse of 2,600 Gt of carbon released instantaneously into the atmosphere as CO_2. In the first hundred years CO_2 is absorbed into the upper ocean. The resulting acidification limits further uptake by the upper ocean waters. During this time period, there is also typically some uptake by the land biosphere. In the next 900 years, the saturated upper ocean waters mix with the deep ocean, allowing further uptake. Eventually, the deep ocean acidifies as well, limiting further uptake. Over the next 10,000 years the ocean becomes buffered by dissolution of carbonate sediments and by carbonates washed in from land, reducing the acidity and allowing the ocean to take up additional carbon. Over longer time scales spanning *more than* 100,000 years, most of the remaining CO_2 is removed by reacting with silicate minerals to form carbonates (e.g., limestone). We have not attempted to state the precise time required for silicate weathering to cause recovery to pre-industrial values, because of uncertainties in silicate weathering parameterization and uncertainties in the long term response of the glacial-interglacial cycle. The only long-term sink of CO_2 is silicate weathering, which is a very slowly increasing function of temperature. It would require over 20°C of warming to balance a steady state fossil fuel emission of only a half Gt of carbon per year, so that even an emission as low as this would lead to a steady accumulation of CO_2 in the atmosphere. This calculation does not allow for any long-term net release of carbon from land ecosystems or marine sediments, though it is known that the Earth system is capable of such releases. Any such release would increase the long term CO_2 concentrations and delay the recovery to pre-industrial values. (Data up to 10,000 years based on carbon cycle simulations of Eby et al. (2009). Silicate weathering time scale estimated from data given in Berner (2004). See Archer et al. (1997), and Archer (2005) for more details on the mechanisms of CO_2 removal.