This text goes with two PowerPoint slides showing the model of Garrels and Lerman and the next slide showing evidence supporting the model

A Model for the Earth as a Biogeochemical System Garrels and Lertnan. (1981) developed a simple model for the biogeochemistry of the Earth's surface which includes interactions between the atmospheric, oceanic, and crustal compartments and the biosphere (Fig). The model assumes that the atmosphere and the oceans have not shown large changes in their composition during geologic time. Of course, we know that this has not always been true, but for the last 60 million years or so, there is good geologic evidence that this assumption is reasonable (Holland et al. 1986). With these constraints, the model couples reactions in the atmosphere and oceans to seven compartments that represent major crustal minerals, such as gypsum (CaS04 • 2H20), pyrite (FeS2), and calcium carbonate (CaC03). For instance, if the weathering of limestone transfers 8 units of Ca2+ to the world's oceans and the Ca content of seawater does not change, then the same amount of Ca must be deposited in a sedimentary mineral on the seafloor.

Organic materials, living and dead, constitute the biosphere, which appears in the model compartment labeled CH20, representing the approximate stoichiometric composition of living tissues. Changes in the mass of the biosphere through geologic time are indicated by net transfers of material into and out of that compartment.

Consider the increase in the total mass of organic matter that must have occurred during the Carboniferous Period, when large areas of land were covered by swamps. Here, dead vegetation accumulated as peat that was later transformed into coal. Storage of carbon in dead materials, detritus, represents an increase in the mass of the biosphere. With no change in the C02 content of the atmosphere or the C02 dissolved in the oceans as HC03, the carbon added to the biosphere must have been derived from the weathering of carbonate minerals. Weathering of carbonate minerals, however, would also transfer Ca and Mg to the oceans, and to maintain constant seawater chemistry the model predicts that Ca must be deposited as CaS04 and that Mg must be deposited in silicate minerals by various reactions that occur in ocean sediments. To deposit CaS04 with no change in the S04 content of the world's oceans, sulfur must be derived from another pool. Oxidative weathering of pyrite (FeS2) would supply S04 to the oceans, also consuming some of the oxygen that would have been added to the atmosphere by photosynthesis. The remaining oxygen would be consumed in the deposition of Fe203. Note that the total 02 consumed by these reactions is in molar stoichiometric balance with the carbon stored in organic matter by photosynthesis, so the atmospheric content of 02 does not change .

This model illustrates how minerals such as magnesium silicates, not traditionally the focus of biological studies, are linked to the activities of the biosphere. Certainly, it is legitimate to ask whether this is a reasonable model for the linkage of chemical reactions on Earth. Support for the model would be found if large geologic deposits of gypsum are associated with periods in which there were large net stores of organic carbon, since the model predicts a coupled balance,

$$\text{pyrite} + \text{carbonates} \rightarrow \text{gypsum} + \text{organic carbon}$$

through geologic time. Indeed, Garrels and Lerman (1981) show that the molar ratio of organic carbon to gypsum has remained fairly constant through geologic time, with large deposits of gypsum associated with the Carboniferous Period, when large amounts of organic carbon were stored in coal (Fig). ·

The model developed by Garrels and Lerman (1981) reminds us that the size of the biosphere axes and wanes as a result of the balance between photosynthesis and respiration. During the history of life on Earth the mass of the biosphere has increased at times when high rates of photosynthesis have resulted In a net storage of organic carbon and the release of free 02 as a by-product:

$$CO_2 + H2O \rightarrow CH2O + O2$$

The. metabolic activities of microbes and higher animals – heterotrophic respiration – convert organic carbon back to CO2 and H2O. fire can also perform this reaction abiotically and very quickly. When we compare the conditions on Earth to those on other planets, we will see that the storage of organic carbon and the release of free Q2 are the essence of life; evidence for a significant production of either material on another planet would be strongly suggestive of life there as well. ·