

CHEMICAL EVOLUTION AND THE EVOLUTION OF THE EARTH'S CRUST

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Abstract. It is hypothesized that there is a close relationship between the geologic evolution of the global plates of the Earth's crust and the chemical evolution of life on the Earth. Characteristics of the axes of plate spreading are discussed in relation to postulated environments conducive to the synthesis of chemical compounds thought to be important biological precursors. Likely locations for *in situ* measurements to test the hypothesis are identified.

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The Oparin-Haldane hypothesis has been supported by many laboratory experiments beginning with those conducted by Miller (1953). Three basic assumptions underlie these laboratory experiments: (1) the doctrine of uniformitarianism, (2) the doctrine of probable events vs rare events, and (3) the principle of biochemical similarity (Kenyon and Steinman, 1969). While these assumptions are reasonable, they do not substitute for verification in the natural environment. Such verification to date has been elusive.

Thiocyanates have been detected in thermal springs in volcanic areas and hydrocyanic acid has been measured in volcanic gases (Mukhin, 1974). The discovery of organic compounds such as α amino acids formed by abiotic processes has never been confirmed primarily because all sites heretofore thought likely for chemical evolution have been contaminated by bacteria and other life forms. As a result, there has been a search for organic compounds from extra-terrestrial sources. The occurrence of abiotically formed α amino acids on both meteorites (Kvenholden *et al.*, 1970) and the Moon has been reported (Harada *et al.*, 1971). Such a discovery has not yet been reported on Earth.

The search for a likely terrestrial site for further confirmation of the Oparin-Haldane Hypothesis should be based on the assumptions mentioned and the known laboratory experiments. It has been widely suggested that there is a close relationship between volcanism and prebiological evolution. Many involved in laboratory experimentation, however, favor the tidal environment as the most likely location for chemical evolution on the primitive Earth.

We believe the most fruitful, natural sites for testing the chemical evolution model are the brine pools associated with the axes of plate spreading. One such brine area is the Atlantis II Deep in the Red Sea (Figure 1). This site was chosen because it has the following characteristics thought to be important for the process of chemical evolution: (1) it is reported sterile (Watson and Waterbury, 1969); (2) the environment is reducing (Ryan *et al.*, 1969); (3) there is no free oxygen (Brewer *et al.*, 1969); (4) the methane and

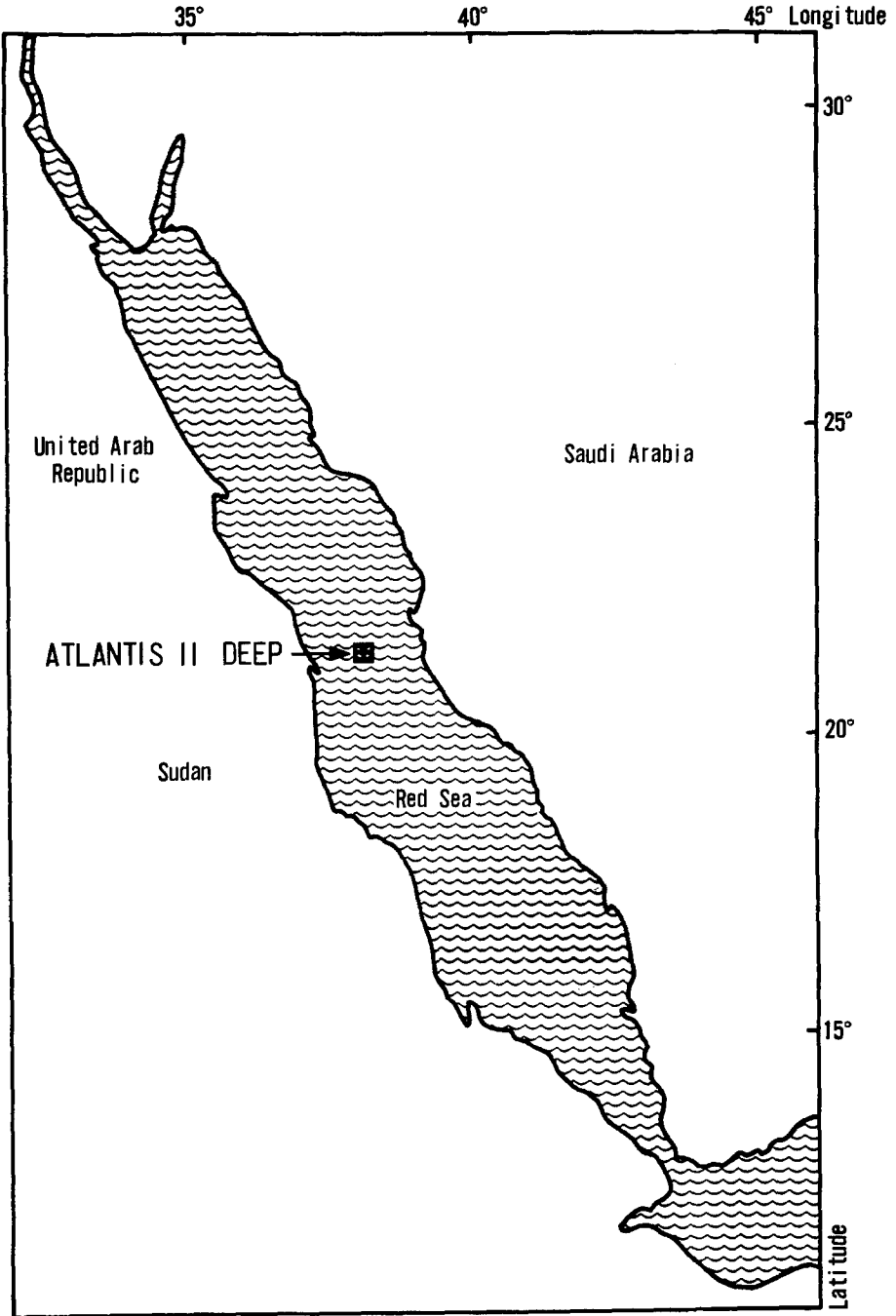


Fig. 1. Red Sea and the Atlantis II Deep.

ethane content is high (10^3 times normal sea water) (Swinnerton and Linnenbom, 1969); (5) montmorillonite is present (Bischoff, 1969); (6) residual gases from the Earth's paleoatmosphere are indicated present (Craig and Lupton, 1975); and (7) the temperature is over 56°C (Ross, 1972).

A theoretical argument involving crustal spreading zones also supports the choice of the Atlantis II Deep. The axes of global plate spreading occupy a large geographic region comprising a ridge system of more than $1.5 \times 10^5 \text{ km}^2$. The majority of this system is submarine. The process of plate spreading is thought to have been begun sometime during the Precambrian Era and to have been continuous (Hargraves, 1976). Evidence for sea water percolating downward into the crust along fractures is abundant. There would be an irregular thermal gradient between the seawater and upwelling magma (1100°C) from the sea floor to perhaps 2 km or more in the Earth. Along the gradient would be high temperature anhydrous environments and low temperature hydrous environments. This environment would be ideally suited for the generation and evolution of small molecular weight compounds thought to be important for chemical evolution.

An important relationship, thus, may exist between the evolution of the Earth's crust and chemical evolution. Volcanoes *per se* are not believed sufficient for generation of prebiotic compounds, because the temperature is too high, the thermal gradient too steep, the geographic extent too limited, and the energy too episodic. At the same time, the characteristics of both volcanic and tidal environments which make them attractive choices by experimentalists are also characteristics of the axes of plate spreading.

Recent theory about Precambrian geologic history suggests that during the first 10^9 years of the Earth's existence, there was a globe-encircling sea underlain by a shell of sial with a thermal gradient of about 65°C per km (Hargraves, 1976). Venting of this shell would have been widespread, and the deep sea water would have been reducing. If this theory is true, there could have been no tide pools during the period of the Earth's history when chemical evolution is thought to have first occurred. Conditions at much of the sea floor, however, would have been similar to conditions at present plate spreading axes. This theory, while not crucial to our hypothesis, complements and strengthens it.

In summary, there may be an important link between the process of the origin and evolution of the Earth's crust and the process of chemical evolution. It is possible to test this hypothesis by investigating the Atlantis II Deep brine and the sediments beneath it in the Red Sea or other hydrogeothermal zones associated with axes of plate spreading.

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