N85-32713

ORIGINAL PAGE IS
OF POOR QUALITY

Sherwood
S. Chang: ORIGIN OF LIFE

The pathways of organic chemical synthesis, that is of chemical evolution on the early Earth leading to life must have been constrained by the development of the planet by accretion and core formation. No doubt the accretion and differentiation into the core-mantle-crust-atmosphere system strongly influenced the temperature and composition of the atmosphere, surface, and interior; but large gaps persist in our understanding of these processes. We do not know the time-span over which Earth aquired its volatiles, the composition of these volatiles, and the conditions under which outgassing of volatiles occurred to form the atmosphere. Uncertainties in existing models for Earth accretion and early planetary development allow a wide range of possible prebiotic atmospheric compositions at the time and temperature when liquid water appeared and thermally-labile organic compounds could survive. These compositions range from strongly reducing atmospheres (dominated by high abundances of H_2, CO, and CH_4) to mildiy reducing ones (containing mostly N_2 with minor to trace amounts of CO_2 and H_2).

Synthesis of organic matter occurs readily in strongly reducing atmospheres as laboratory experiments indicate. Organic chemical syntheses in mildly or non-reducing atmospheres merit much more study. The conversion of N_2 to nitrogen-containing organic compounds in any prebiotic atmosphere by atmospheric photochemical processes must have been limited; production of nitrate by electrical discharges may have been more effective. Prebiotic organic syntheses need not have occurred only in the atmosphere; they could have occurred on land, in the seas, and at a variety of atmosphere, sea, and land interfaces. The involvement of inorganic matter in the origin of life was probably a natural consequence of the geological context within which atmospheric and chemical evolution occurred. Metal ions and minerals, particularly clays, may have served as reactants, catalysts, and even templates for prebiotic organic synthesis.

Considerable success has been achieved in producing the monomeric and oligomeric building blocks of proteins and nucleic acids under putative prebiotic conditions. But the connections between the model environmental conditions and the geologic and meteorologic realities of the prebiotic Earth remain to be established. Until constraints can be imposed on the range of possible prebiotic atmospheric compositions and surface environments, and in the absence of direct evidence of organic chemical evolution on the Archean earth, it is important to explore and assess pathways for organic synthesis in all model environments that are consistent with evidence unveiled in the cosmochemical, geological, and biological records.

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CARBON, HYDROGEN AND NITROGEN ISOTOPE FRACTIONATION VALUES IN ORGANIC MATTER FROM METEORITES AND EARTH SAMPLES

Summary of the range of values [a]

Organic Fraction	^{13}C per mil	D per mil	^{15}N per mil
Soluble compounds in some carbonaceous chondrites	+5 to +40	+100 to +500	+50 to +100
Insoluble compounds in some carbonaceous chondrites	-13 to -21	+600 to +2500	+10 to +150
All natural organic matter on Earth	-90 to -10	-250 to +80	-10 to +25

[a] Delta values are defined in per mil units as follows, as for example in the case of carbon:

$$\delta^{13}C = \left[\frac{\left(^{13}C/^{12}C\right)_{sample}}{\left(^{13}C/^{12}C\right)_{standard}} - 1\right] \times 1000$$

The standards for C, H and N, respectively, are Peedee Belemnite limestone, mean ocean water and air.

Table I-2. Carbon, hydrogen and nitrogen isotopic fractionation values in organic matter from meteorites and Earth samples. The fractionation values for carbon 13, deuterium (D) and nitrogen 15 are calculated analogously to the example given for carbon below **Table I-3.**

CARBON COMPOUNDS
in the
MURCHISON METEORITE

	relative quantity by weight
Carbonate/CO_2	0.2 to 0.4%
Acid Insoluble "Polymer"	1.2 to 1.6%
Dicarboxylic Acids	200 - 400 ppm
Monocarboxylic Acids	~100 ppm
Hydrocarbons	40 - 70 ppm
Amino Acids	~20 ppm
Ketones & Aldehydes	~5 ppm
Alcohols	~5 ppm
Amines	~5 ppm
All Others	≤ 1 ppm

SUMMARY: 1.44 - 2.07 per cent
BULK CARBON: 2.1 - 2.4 per cent

Table I-3. **Carbon compounds in the Murchison Meteorite.** The Murchison meteorite, a carbonaceous chondrite that landed in Murchison, Australia in 1969, was found to contain an abundance and variety of extraterrestrial organic matter.