SURVIVAL OF BLUE-GREEN ALGAE UNDER PRIMITIVE ATMOSPHERIC CONDITIONS*

R. R. STOECKER

Mauna Olu Campus, United States International University, Makawao, Hawaii, 96768, U.S.A.

(Received 7 December, 1970)

Abstract. Conditions on the primordial Earth are reviewed and information on pertinent microfossils and primitive microorganisms presented. A series of simulated pre-Cambrian environments are set up and 8 strains of blue-green algae are tested under 7 different anaerobic, mildly reducing atmospheres. Of 61 cultures tested, 12 showed growth, 32 survived and 17 died. Growth was measured spectrophotometrically. Microscopic examination failed to show any gross morphological changes in the experimental cultures. It is concluded that certain strains of blue-green algae have retained their ability to survive or grow under a primordial atmosphere.

1. Introduction

It is now well established that the atmosphere of the primitive Earth was reducing in nature and probably composed largely of nitrogen, ammonia, methane and water vapor. This primitive atmosphere may have existed, at least in part, up to 1.5 to $2.0 \times 10^9$ yr ago (Rutten, 1962). During the early pre-Cambrian there was a gradual oxidation of the reducing atmosphere caused by the molecular oxygen derived from both photodissociation of water vapor and photosynthesis.

Schopf and Barghoorn (1967) unearthed alga-like microfossils from the early pre-Cambrian strata of South Africa. These microfossils, which are $3.1 \times 10^9$ yr old, predate the rise of the modern oxidizing atmosphere by at least one and possibly two billion years. In reporting their findings, Schopf and Barghoorn postulated that the microfossils are either directly related to modern coccoid blue-green algae or that they are their evolutionary precursors. Siegel (1967) discovered a microorganism which has an affinity for high (25%) concentrations of ammonia and shortly thereafter found that it was identical to another microfossil found by Barghoorn and Tyler (1965). The fossil form was named *Kakabekia umbellata* and was discovered in the Gunflint chert deposit and is about two billion years old. The contemporary microorganism was named *Kakabekia barghoorniana*. *Kakabekia* cannot be readily classified among known groups of microorganisms but its ammonia affinity as well as its phylogeny suggest that the Earth had a reducing atmosphere long after the advent of the blue-green algae. Since the primitive Earth provided a reducing environment and since blue-green algae apparently evolved when such conditions prevailed, a series of seven experiments were performed to see if the algae could indeed survive and grow under a presumed primordial atmosphere.

* This study supported by The Graduate Department of Marine Science, Long Island University. The author wishes to thank Dr George Claus for his kind assistance.
2. Materials and Methods

The following 8 cultures of blue-green algae were obtained from the collection of Dr George Claus:

A – *Synechococcus elongatus* Nag.
B – *S. elongatus* Nag. forma
C – *S. parvus* Mig.
D – *S. lividus* Copeland
E – *Synechosystis salina* Wislouck
F – *Anabaena variabilis* Kutz. f. *tenuis* Popova
G – *Gloeothece rupestris* (lyngb.) Born. var. *tepidatriorum* (A. Br.) Hansg.
H – *Gleocapsa alpica* (lyngb.) Born.

The algae were cultured in 13 x 100 mm glass culture tubes using Kratz and Myers (1955) ‘C’ medium. The environmental chambers used were 4L ‘Anaero-Jars’; glass jars with aluminium screw type caps, rubber seals, pressure and vacuum gauges and needle valves. The algae were subcultured from the stocks aseptically into the tubes in duplicate, one serving as the experiment and one as the control. The experimental cultures, consisting of 5–8 different species of the algae listed above, were placed in the chambers and the matching controls were kept in normal air. The chambers were evacuated and flushed several times with pure nitrogen until an atmosphere of 99.9 + % nitrogen was obtained. The chambers were then evacuated again and filled with the desired mixture of gases on a volume basis. All cultures were incubated at 24°C, 25 cm from a 75 W continuous light source (fluorescent). Growth, or the lack of it, was ascertained from turbidity change with a Bausch and Lomb Spectrophotometer at 540 nm. The cultures were examined microscopically to determine if any morphological changes occurred.

**Results**

A total of 61 cultures were tested under 7 different reducing atmospheres. At the termination of each experiment the cultures were divided into 3 classes: those that (i) died, (ii) survived, (iii) exhibited significant growth. Significant growth is defined as an increase of 0.5 Absorbance units during the time period under study (up to 21 days). Survival or stagnation is defined as no significant growth and death as visible and marked dissolution of the cultures. The spectrophotometric readings were cross-checked with microscopic examinations for culture density and cell size. Table I shows the per cent compositions of the atmospheres used, the number and types of cultures examined, the duration of each study and the per cent and types of cultures that died, survived or exhibited growth.

**3. Discussion**

The results indicate that at least 8 strains of blue-green algae have some degree of tolerance toward anaerobic, mildly reducing atmospheres. This not surprising in light of the presumed phylogenetic history of the blue-green algae.