

Beginning of Life on Planets

Abdul L. Bhuiyan¹

¹ Head Post Office, Comilla, Bangladesh

Correspondence: Abdul L. Bhuiyan, Box 13, Head Post Office, Comilla 3500, Bangladesh. E-mail: ananda.computers@yahoo.com

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Abstract

Beginning of life on a planet including earth would occur with the formation of nucleotides from such precursors as linear polyphosphate anion, D-ribose, and heterocyclic bases in presence of metasilicate anion of composition $(\text{SiO}_3^{2-})_n$, metaborate anion of composition $(\text{BO}_2)_n^{n-}$, and enstatite (MgSiO_3). These complex silicates and borates might have acted as catalysts as well as moulds for the production of the nucleotides of DNA/RNA.

Keywords: Beginning of Life on Planets, Silicates, Borates as Moulds, Catalysts for Nucleotides

1. Introduction

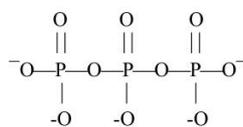
Previously, this author (Bhuiyan, 2016) predicted that, starting with photons in reversible equilibrium with electron-positron pairs at the beginning of the universe, all chemical elements and their compounds including the complex (or mixed) oxides had formed in space in the early universe. Since the temperature at that time was very high, all these substances including water existed in the gaseous state. As cooling proceeded for a considerable period of time, the gaseous water together with the interspersed substances formed cloud. On further cooling, the cloud transformed into liquid drops which fell down upon the surface of a planet including earth in the form of rain water. In this way, the rain water carried most of all substances formed in space upon the surface of a planet. Some of these substances which would later act as precursors of RNA/DNA, in one way or the other, after their arrival on the planet, might be of the following kinds: sugars, ammonia, alcohols, polyoxides of phosphorus, purines, pyrimidines, heterocyclic bases, complex (or mixed) oxides of metals and elements, etc. Production of some sugars including ribose in the laboratory, under outer space conditions, by some investigators (Meinert et al., 2016; CNRS, 2016) from a mixture of water, methanol and ammonia and production of some precursors of RNA in the laboratory, also under outer space conditions, using pyrimidine as starting material by NASA scientists in March, 2015 (Marlaire, 2015) lend support to our predictions. However, the following observations made by NASA scientists on the findings through the exploration with the help of the Curiosity Mars rover (NASA, 2016) appear to be noteworthy.

- (i) The Curiosity rover has found evidence of the presence of borates and clay on the surface of Mars.
- (ii) Borates and clay form a possible “Bridge” from simple organic molecules to RNA.
- (iii) As the Curiosity rover climbed progressively uphill a layered mountain, compositions of the layers trend toward more clay and more borates.

The word “Bridge” seems to be of special significance here. If the process of conversion of simple molecules into RNA/DNA is comparable to a chemical change, then the word bridge may be comparable to a catalyst, suggesting that the conversion of the simple molecules, or precursors, into RNA/DNA might have possibly been catalyzed by borates and clays at the beginning of life on a planet including the earth under favorable conditions of temperature, pressure, etc. However, we shall return to the observation (iii) later in this paper.

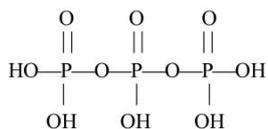
Complete degradations of a DNA/RNA molecule yield: (a) either D-ribose or 2-deoxy-D-ribose, (b) a heterocyclic base, and (c) a phosphate ion (Solomons, 1978). The compounds (a) through (c) may, therefore, be regarded as the precursors of nucleotides of DNA/RNA. In other words, the nucleotides are phosphate esters of base-substituted ribose. It is stated earlier above that all elements and compounds including the oxides were produced in space in early universe. As the universe continued to cool, the oxides of phosphorus started to agglomerate into various polymeric anions, such as linear cyclic, etc. The linear polymeric form is represented

by the general formula $(P_nO_{3n+1})^{(n+2)-}$ (Cotton & Wilkinson, 1972) which produces the following tripoly phosphate anion (I) for $n=3$.



(I)

The structure (I) of tripolyphosphate represents its state completely in the anionic form. However, its unionized state may be represented by the following structure (II) in the neutral or physiological p^H s.



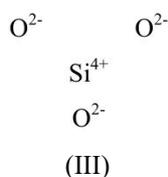
(II)

So, after the linear phosphate polymers had been carried by the rain water upon the surface of a planet, they might have acted for phosphorylating (or transferring the phosphate ions to) the base-substituted ribose molecule. As a result, the nucleotides of RNA/DNA were formed. This paper is, therefore, intended to elucidate the formation of nucleotides of RNA/DNA from: (a) D-ribose, (b) heterocyclic bases, and (c) linear phosphate polymers in presence of clays/borates which had arrived earlier from space and collected in layers upon the surface of a planet including earth. But before going into details of formation of nucleotides of RNA/DNA, we need to ascertain the role that was likely to be played by clay/borates in facilitating the first formation of these nucleotides on planets.

2. Role Played by Clays/Borates

The Curiosity Mars rover has found clay materials, silicates, borates, compounds of Fe(II) and Fe(III) magnesium, etc. on Mars.

The clay materials comprise a series of simple as well as complex silicates. Our understanding of silicate comes from a wide variety of naturally occurring silicates. As borates and silicates are solid substances, they may possess catalytic activities of solid catalysts. In a chemical reaction a solid catalyst usually adsorbs through certain mechanism the reacting molecules on its surface where the chemical reaction is initiated or takes place. With the reactants adsorbed on its surface, the catalyst lowers the energy barrier between the reactants and the products, so that the reaction can proceed rapidly at lower temperatures. Therefore, larger the surface of a catalyst larger the amount of reactants adsorbed and consequently, greater the amount of products obtained in a shorter period of time. Besides, if a certain size/shape of a product molecule is desired, then the structure of a catalyst should possess a space such as a cavity on its surface so that the cavity orients the reacting molecule in such a form that the product molecule acquires automatically the desired form after the reaction. In this respect the cavity may be regarded as a mould. So, neither all silicates nor all borates will be suitable candidates for catalyzing and moulding the precursors into nucleotides of DNA/RNA; that is, the catalyzing and moulding properties of a silicate or of a borate would depend upon its structure. As infinitely long single-strand chains of metasilicate anions of composition $(SiO_3^{2-})_n$, in which the chains run parallel to each other and contain cavities in them, may satisfy this requirement. The structure of a segment of such an anion is given in Figure 1. The structure shows that the area bounded by EFGJKML forms a cavity on the chain. The boundary of this cavity contains four oxyanions- E, G, K and L. All these oxyanions are doubly negatively charged oxygen anions as shown in structure (III) below (Evans, 1966).



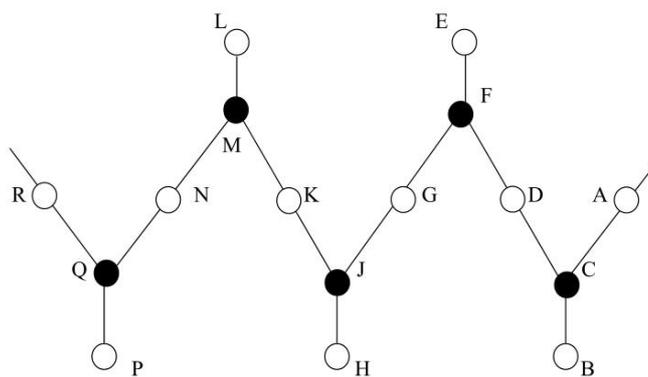


Figure 1. Structure of a segment of a linear chain of metasilicate anion of composition $(\text{SiO}_3^{2-})_n$

●: Si; ○: O

As metaborate anions of composition $(\text{BO}_2)_n^{n-}$ possess structure similar to that of metasilicate anions, the structure of the former may be obtained by replacing the silicon atoms in Figure 1 with boron atoms. This shows that the metaborate anions would possess cavities similar to those in metasilicate anions and that both anions would possess similar catalytic and moulding activities. We describe the mechanism of catalytic and moulding activities of polysilicate anions in producing nucleotides of RNA in the following section 3 of this paper. Once we have understood the mechanism involved with polymetasilicate anion, we have understood the one involved with the polymetaborate anion.

3. Production of the Nucleotides of RNA

Let us reproduce the cavity bounded by the oxyanions E, G, K and L on the chain of a metasilicate anion from Figure 1 into Figure 2.

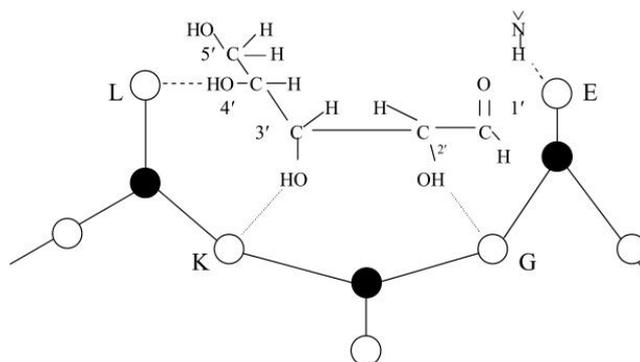
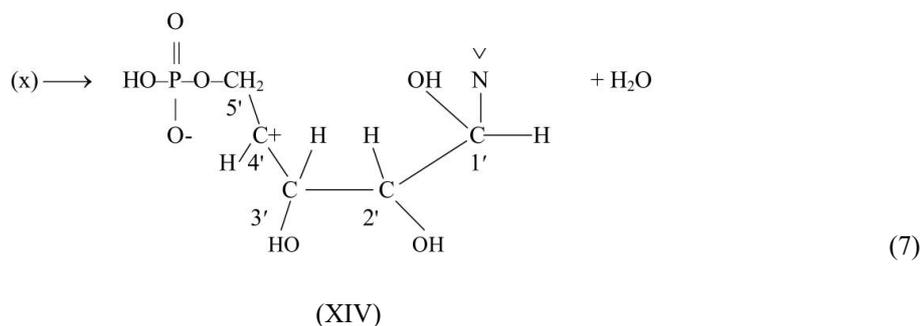


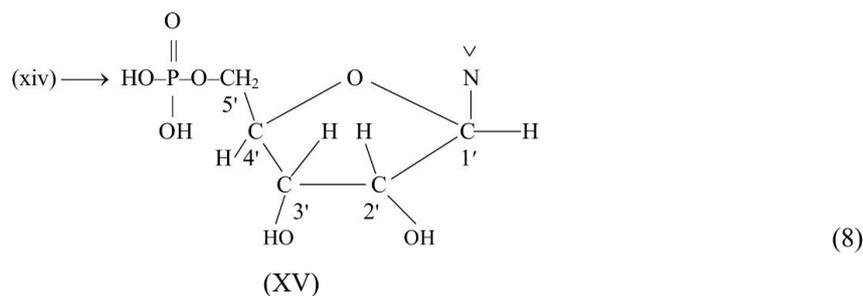
Figure 2. (a) Adsorption through hydrogen bonding of a ribose molecule in the cavity of a linear chain of metasilicate anions; (b) Adsorption through hydrogen bonding of a base between its secondary amino hydrogen (-NH) and the oxyanion in the vicinity of 1'- carbon atom of the ribose molecule

●: Si; ○: O

First of all let a ribose molecule seep through the lattice and arrive at the cavity. It may position itself in such a manner that its 2'-, 3'-, and 4'- hydroxyl hydrogens can effectively interact with the oxyanions at positions G, K and L, respectively and form hydrogen bonding that will keep it in a rigid position and environment required to allow the necessary reactions on it to happen. With this orientation, the terminal aldehyde group (-CHO) of ribose may lie in close proximity to the oxyanion E. Next, let a molecule of a heterocyclic base enter the cavity and position itself so that the NH group associated with the heterocyclic base is so oriented that its hydrogen is hydrogen bonded to the carbonyl oxygen of the aldehyde group of the ribose molecule. Under this condition, the N-H bond is subjected to the action of two forces. One, the strong electrostatic attraction force exerted by the electron-rich oxygen of the carbonyl group on hydrogen. Two, the electron-withdrawing effect of the aromatic heterocyclic ring. Both the forces, acting in opposite directions, may cause the homolytic scission of the N-H bond as follows.



As the negative charge in the phosphate radical is delocalized, it is unlikely for it to interact with the carbonium ion at 4'- position. For this, the carbonium ion will interact with the oxygen of the hydroxyl group at 1'-carbon atom producing the heterocyclic ring consisting of one oxygen atom and 1'-, 2'-, 3'- and 4'- carbon atoms of the ribose molecule. The proton displaced from the hydroxyl group neutralizes the negative charge on the phosphate radical. The resulting compound (XV) may represent a nucleotide of RNA produced naturally before life appeared first on planets.



The reactions (5) through (8) might occur simultaneously.

Therefore, the nucleotide (XV) of RNA consists of: (a) a phosphate group (b) a heterocyclic base (a purine or pyrimidine) and the central portion of five-membered ring consisting of one oxygen atom and 1'-, 2'-, 3'- and 4'- carbon atoms of D-ribose. The phosphate group is present as a phosphate ester.

The nucleotides are monomeric units of a nucleic acid chain in the primary structure in which the phosphate esters link the 3'-hydroxyl of one ribose with the 5'-hydroxyl of another. This may be supported by examining the secondary structure of RNA. In this structure two nucleic acid chains are held together by hydrogen bonds between base pairs on opposite strands. The internal distance between the two chains of the double helix is such that it allows only a purine-pyrimidine type of hydrogen bonding between base pairs on opposite strands; that is, if cytosine appears in one chain, then guanine must appear in the other. This is shown in Figure 3.

Where Cy: Gua represents cytosine-guanine base pairs.

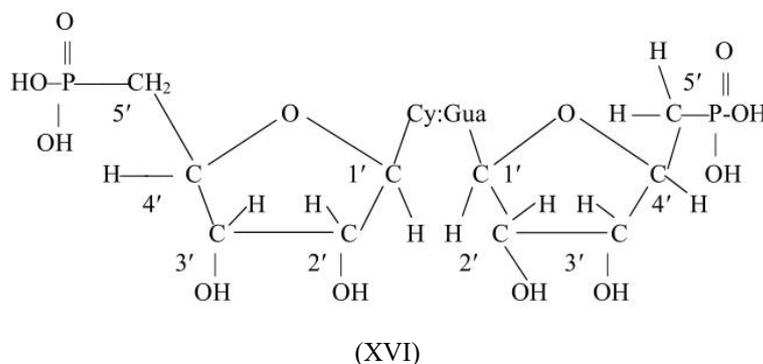


Figure 3. Base pairing through hydrogen bonding between cytosine and guanine on two phosphate-ribose chains of the double helix of RNA. The two chains are wound into a helix with both chains sharing the same axis

The Figure 3 shows that the base pairs lie on the inside of the helix and the sugar-phosphate backbone on the outside. As each nucleotide is a monomeric unit of a nucleic acid chain, the combination (XVI) is a monomeric unit of the double helix. This monomeric unit is, therefore, called a rung of the double helix. It is evident that, like the base pairs, the two hydroxyl groups on the 2'-carbon atoms of both the nucleotides lie on the inside of the helix while, like the sugar-phosphate backbones, the hydroxyl groups on the 3'-carbon atoms of both the nucleotides lie outside on the same sides of the phosphate groups. For this, the phosphate esters will link the 3'-hydroxyl of one ribose with the 5'-hydroxyl of another forming the double helix of RNA.

4. Formation of Nucleotides of DNA

A nucleotide of DNA contains a phosphate radical, a 2'-deoxy-D-ribose unit and one of four heterocyclic bases, either adenine, cytosine, guanine, or thymine while a nucleotide of RNA contains a phosphate radical, a 2'-D-ribose unit, one of four heterocyclic bases, either adenine, cytosine, guanine, or uracil. It is obvious that a nucleotide of DNA differs from that of RNA in two respects. Firstly, the -OH group at 2'-carbon atom of the ribose unit in RNA is replaced by -H at the same position in DNA. Secondly, the heterocyclic base uracil in RNA is replaced by thymine in DNA. The replacement of uracil by thymine may occur if thymine instead of uracil is allowed by the lattice of a silicate polymer (as in Figure 1.) to reach the vicinity of the aldehyde group at 1'-position. But the replacement of -OH by -H may be obtained by using a metal cation, M^{2+} , in the silicate lattice, of large ionic potential which may, with the help of high polarizing power, distort the outer electron clouds of the oxygen atom to such an extent that homolytic scission of the C-O and O-H bonds occurs simultaneously. The isolated H. atom instantly combines with the 2'-C. atom producing the C-H covalent bond while the isolated oxygen atom may simultaneously form covalent oxide with the metal ion. If all these theoretical considerations hold, then it may be concluded that the presence, or absence, of appropriate metal cations in the lattice of a suitable silicate polymer determined the formation of DNA/RNA on the surface of a planet. Based on these arguments, we now proceed to discuss in details the formation of DNA on the surface of a planet.

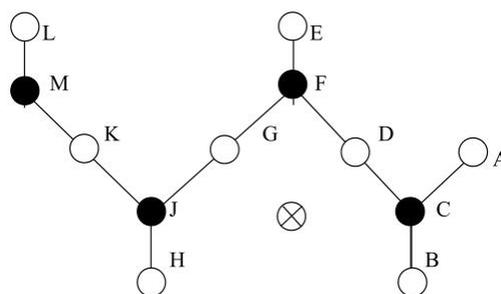
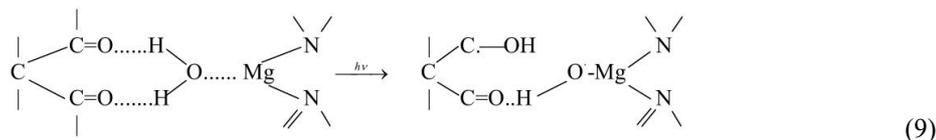


Figure 4. A segment of the metasilicate anion (SiO_3^{2-}) containing two adjoining cavities represented by LMKJGFE and BCDFGJH, respectively

●: Si; ○: O; ⊗: Mg(II) or Fe(II)

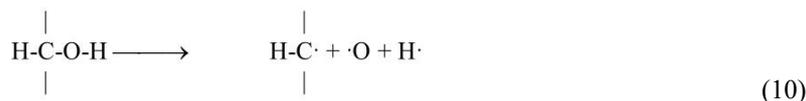
Let us reproduce the segment LMKHJGEFDBCA of the chain of a metasilicate anion polymer from Figure 1 into Figure 4. This segment contains two cavities - one represented by LMKJGFE and the other by BCDFGJH, named cavity-1 and cavity-2, respectively. The oxyanions: L, K, G, and E lie on the border of cavity-1 and the ones B, D, G and H lie on the border of cavity-2. The cavity-1 was used in Figure 2 for producing the nucleotide of RNA. Now we use both the cavities together for producing the nucleotide of DNA. Let us choose Mg^{2+} for the metal cation M^{2+} and station it at the center of cavity-2. The choice of Mg^{2+} ion is based on the following criteria.

- It possesses higher polarizing power due to its large ionic potential.
- It can form covalent oxide, MgO, with an isolated oxygen atom.
- It can maintain a formal 4-coordinate status with the oxyanions B, D, G, and H as in chlorophyll but can extend this coordination number to 5 as in magnesium tetraphenylporphyrin hydrate (Timkovitch & Tulinsky, 1969). In the 5-coordinate state the magnesium atom can interact with, and abstract through coordination, oxygen atom from oxygen-containing compounds such as water, hydroxyls, ketones, etc. For example, electron spin resonance studies of light-irradiated chlorophyll indicate the probable formation of the following radicals (Garcia-Morin et al., 1969).

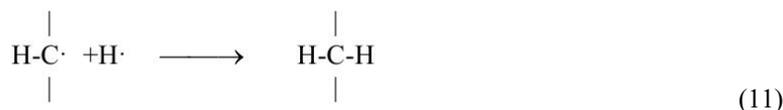


(d) It forms adducts with oxygen compounds, such as ethers (Guggenberger & Rundle, 1968).

Equation (9) indicates that the magnesium atom may interact with oxygen of water molecule whose hydroxyl hydrogens are hydrogen-bonded to carbonyl oxygen. In Figure 4 we get a molecule of D-ribose adsorbed on the surface of cavity-1 as was done previously in Figure 2 in the formation of the nucleotide of RNA. The hydroxyl group of the 2' -carbon atom of the ribose molecule is hydrogen-bonded to the oxyanion G. The Mg²⁺ ion sitting at the center of cavity-2 interacts with the oxygen of the hydroxyl group and draws the outermost electron cloud surrounding the oxygen atom toward it. As a result, both the C-O and O-H bonds become so weakened as to undergo homolytic scission as follows.



The isolated oxygen atom may remain associated with the 5-coordinate magnesium ion. Alternatively, the isolated oxygen atom may occupy the remaining corner of the tetrahedron of a nearby SiO₃ group and form a covalent bond with the silicon atom through the lone electron sitting there. The liberated hydrogen atom may simultaneously combine with the 2'-carbon atom radical to form C-H covalent bond; thus

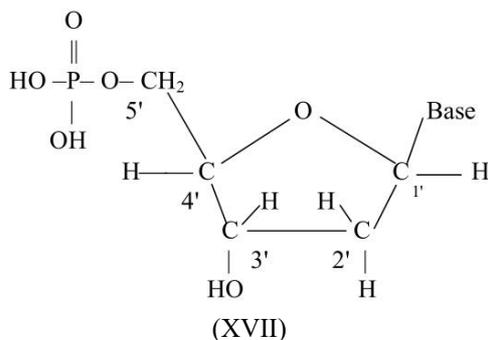


Equation (11) indicates that the -OH group linked to the 2'-carbon atom is replaced by a hydrogen atom; that is, the COH group is reduced to CH group and consequently, D-ribose is converted into 2'-deoxy-D-ribose.

Initially, the silicate/borate layers covering the surface of Mars might contain plenty of Fe(II) compounds which were gradually oxidized by Mars' atmospheric oxygen to ultimately hematite. So, the presence of today's hematite on Mars might be traced to the presence of Fe(II) compounds in the initial stage, for which the probability of participation of Fe(II) ion in the production of nucleotide of DNA could not be excluded. As Mg(II) is four-coordinate in chlorophyll and can extend its coordination number to 5, so is Fe(II) in heme and can extend its coordination number to 5 as in oxygenated hemoglobin. For this, one could substitute Mg(II) with Fe(II) in Figure 4 and obtain, through similar sequence of reactions, the nucleotide of DNA.

Now, let a molecule of a base (either adenine, or cytosine, or guanine, or thymine) seep through the lattice up to the vicinity of the oxyanion E (near 1'-carbon atom) where it undergoes condensation reactions with the aldehyde group of the ribose molecule according to equations (1) through (4) to produce the base- substituted 2'-deoxy-D-Ribose.

Finally, the linear polymer (P_nO_{3n+1})⁽ⁿ⁺²⁾⁻ may seep through the lattice with its end segment (VIII) pointing to the 5'-carbon atom situated at the end opposite to the end of the cavity-1 at which the heterocyclic base is bonded to the ribose molecule and undergo condensation reactions of types (5) through (8) to produce the phosphate ester of the base- substituted 2'-deoxy-D-ribose i.e. a nucleotide of DNA (XVII).



It may be noted that the Mg^{2+} ion, situated at the center of cavity-2, is surrounded by three SiO_3^{2-} ions, for which there is probability for it to attach itself to any of them at an instant so that the combination of the two ions may be expressed as $MgSiO_3$ which is called enstatite. Therefore, the use of metasilicate anion polymer may yield the nucleotides of RNA while the use of enstatite may yield the nucleotides of DNA. This suggests that the locations of the surface of a planet where metasilicate anions were collected from space saw the appearance of RNA while the ones where enstatite was collected saw the appearance of DNA. However, the locations where both metasilicate anions and enstatite were collected together saw the simultaneous appearance of DNA and RNA.

The mechanism of formation of primary and secondary structures of DNA would be similar to that of RNA. Further, as metasilicate anions and metaborate anions possess similar structures, the use of metaborate anions as catalysts and moulds would yield results similar to those of metasilicate anions. Therefore, once we have understood the role played by metasilicate anions in producing the nucleotides of RNA/DNA, we have understood the role that would be played by metaborate anions in the production of the nucleotides of RNA/DNA.

Therefore, the positioning of Mg(II) or Fe(II) in Figure 4 is supported by the report (Wikipedia, 2018) that the linked SiO_3^{2-} groups which lie side by side are held together by the magnesium atoms and that the nonbonding oxygens are shared with magnesium (Douglas & McDaniel, 1965).

5. Compositions of Borates and Silicates in the Mountain Layers

The NASA scientists observed that, as the Curiosity rover climbed progressively uphill a layered mountain, compositions of the layers trend toward more clay and more borates. This may be explained as follows. It may be deduced from this observation that the layers were formed one after another and stacked one upon another in such a manner that the succeeding layer contained larger amount of silicates and borates than the neighboring preceding one. This means that the nth layer contains larger amount of silicates and borates than the (n-1)th layer. As the temperature was very high in the early universe, the oxides of boron and silicon supposedly existed in the monomeric form. Almost all structures of borates were derived from the basic planar BO_3 group which might have occurred as BO_3^{3-} unit or BO_2^{-1} unit. As the cooling of the early universe continued, the monomer unit BO_2^{-1} continued to form polymers of composition $(BO_2)_n^{n-}$. If the rain had occurred intermittently, then the boron oxide in each layer might have polymerized to metaborate anions of compositions given in Table 1. These metaborate anions possess linear chainlike structures like the metasilicate anions described below.

Table 1. Content of metaborate anion in each layer

Layer	Composition of Metaborate
First (bottom)	BO_2^{-1}
Second (from bottom)	$(BO_2)_2^{2-}$
Third (from bottom)	$(BO_2)_3^{3-}$
-----	-----
nth (from bottom)	$(BO_2)_n^{n-}$

However, other polymer borate anions based on the monomer unit BO_3^{3-} anion might also exist in each layer.

The silicon oxide monomer units SiO_2 , SiO_3^{2-} , and SiO_4^{4-} might have been produced initially in the early universe. As the universe continued to cool, these monomers polymerized ultimately into $(SiO_2)_n$, $(SiO_3^{2-})_n$, and $(SiO_4^{4-})_n$, respectively. It is also assumed here that rains occurred intermittently as the universe continued to cool and consequently, the silicates deposited layerwise as is shown in Table 2.

Table 2. Content of silicate anion in each layer

Layer	Composition of Silicate
First (bottom)	$SiO_2, SiO_3^{2-}, SiO_4^{4-}$
Second (from bottom)	$(SiO_2)_2, (SiO_3^{2-})_2, (SiO_4^{4-})_2$
Third (from bottom)	$(SiO_2)_3, (SiO_3^{2-})_3, (SiO_4^{4-})_3$
-----	-----
nth (from bottom)	$(SiO_2)_n, (SiO_3^{2-})_n, (SiO_4^{4-})_n$

Both Table 1 and Table 2 show the stacking of borates and silicates in order of increasingly larger contents of borates and silicates per layer which is in agreement with the finding of the Curiosity rover. It is assumed that the number n corresponds to the size of the n -mer which in turn corresponds to the number of the layer of silicates/borates in the mountain. Therefore, as the temperature of the universe continued to fall, the monomers continued to polymerize in greater numbers and consequently, the size of the silicate/borate polymers continued to increase. Each time a rainfall occurred, it carried polymers of increasingly larger size down to the surface of a planet. According to NASA scientists, each layer of the mountain was deposited at a different time, indicating that if t_n be the period of time in which the n th layer was deposited, then the period of time, $t_{(n-1)}$, during which the $(n-1)$ th layer was deposited was different from t_n . As the amount of materials forming the n th layer is greater than that of the $(n-1)$ th layer, the deposition of the former had probably taken place for a longer period of rainfall, provided that the rainfall was approximately uniform during the periods t_n and $t_{(n-1)}$ as the temperature of the universe continued to fall. Simultaneously, as the temperature of the universe continued to fall, more and more oxide monomers continued to polymerize into larger and larger molecules. As a result, the n th layer started to consist of more and more complex oxides. In this way, layers of increasingly greater amount of silicate/borate polymers continued to be deposited in forming the layered mountain.

6. Conclusions

Production of some precursors of RNA/DNA in the laboratory under outer space conditions by NASA scientists and other investigators lend support to our predictions that, starting with photons and electron-positron pairs through quarks, all substances including these precursors were formed in space in early universe. All these substances were later carried down upon the surface of a planet including earth by rain water. After the arrival on the surface of a planet, some of these substances, such as polyphosphate anions, D-ribose and heterocyclic bases combined together in presence of polymetasilicate anions, or polymetaborate anions, to produce the nucleotides of RNA while the same precursors in presence of enstatite (magnesium metasilicate) produced the nucleotides of DNA. The magnesium ion in the magnesium metasilicate has been shown to reduce the -COH group bonded to the 2'-carbon atom of the D-ribose molecule to -CH group thus leading to the formation of deoxy-D-ribose molecule from D-ribose.

The structures of polymetaborate anions and polymetasilicate anions indicate that there are cavities in them. These cavities are bordered with oxyanions of the borate/silicate structures. These oxyanions play the role of adsorbing the ribose molecule through hydrogen bonding between them and the hydroxyl groups of the sugar molecule so that the sugar molecule is so oriented that it is kept in a rigid position and environment required to facilitate the esterification of the -CH₂OH group bonded to the 5'-carbon atom of the sugar molecule by the polyphosphate anion as well as the base-substitution reaction between the -NH group of a heterocyclic base and the -CHO group containing the 1'-carbon atom of the ribose molecule and would also facilitate the cyclization involving the 4'-carbon atom and 1'-carbon atom of the sugar molecule. All these show that the cavities in the polyborate anions and polysilicate anions acted as catalysts-cum-moulds for the formation of first nucleotides of DNA/RNA on a planet.

If a system contains infinitely long single-strand chains of metasilicate/metaborate anions, in which the chains run parallel to each other, then it is likely to contain infinitely large number of cavities in it. As a nucleotide formed in one cavity contains one base, the system is likely to contain an infinitely large number of base pairs distributed in all DNA/RNA double helices (or genes). According to genetic calculations, there are approximately 1500 base pairs in a single gene, suggesting that the four different bases should give 4^{1500} different gene isomers which should be equal to all the different genes that might have simultaneously appeared first on a planet including Earth, Mars, etc.

Conflict of interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

- Bhuiyan, A. L. (2016). Formation of Elements and Compounds in Space in Early Universe. *Applied Physics Research*, 8(6), 86-95.
- Cotton, F. A., & Wilkinson, G. (1972). *Advanced Inorganic Chemistry: A comprehensive Text* (pp. 396-398). Third (Completely revised) edition, Interscience publishers, A Division of John Wiley & sons, Inc.
- Douglas, B. E., & McDaniel, D. H. (1965). *Concepts and Models of Inorganic Chemistry* (pp. 131-132). Blaisdell Publishing Company, A Division of Ginn and Company, London.
- Evans, R. C. (1966). *An Introduction to Crystal Chemistry* (p. 238). Cambridge University press.

- Garcia-Morin, M., Uphaus, R. A., Norris, J. R., & Katz, J. J. (1969). *J. Phys. Chem.*, 73,1066.
- Guggenberger, L. J., & Rundle, R. E. (1968). *J. Amer. Chem. Soc.*, 90, 5375.
- Marlaire, R. (2015, March 3). *NASA Ames Reproduces the Building Blocks of Life in Laboratory*. NASA. Retrieved from <https://en.wikipedia.org/wiki/Meteorite>
- Meinert, C., Myrgorodska, I., De Marcellus, P., Buhse, T., ..., & Meierhenrich, U. J. (2016). Ribose and related sugars from ultraviolet irradiation of interstellar ice analogs. *Science*, 352(6282), 208-212.
- NASA. (2016). *Curiosity Mars rover drilling*. Retrieved from <https://mars.nasa.gov/msl/news/newsroom/>
- Science Daily. (2016). *CNRS*. Origin of Life: An artificial comet holds the missing piece.
- Solomons, T. W. G. (1978). *Organic Chemistry: Revised printing* (p. 985). John Wiley & Sons, Inc., New York.
- Timkovitch, R., & Tulinsky, A. (1969). *J. Amer. Chem. Soc.*, 91, 4430.
- Wikipedia. (2018). Retrieved from http://rruff.info/uploads/ZK75_1.pdf

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