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High Abundance of Borate in Hadean Proto-Arc Environments to form Prebiotic Ribose and Nucleotide?: Geological Constraints from Isua Supra-crustal Belt

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High abundance of borate is necessary to form prebiotic ribose under alkaline conditions [1]. On the other hand, it has been questoned if such borate-rich environments were present on the early Earth, because of uncertainties on (1) availability of boron source rocks, i.e., felsic igneous rocks and (2) mechanism to concentrate borate on the prebiotic Earth.

Proto-arc model has been proposed to explain tectonic evolution of 3.8 to 3.7 Ga Isua Supracrustal Belt, Greenland [2]. Felsic igneous rocks are present at ISB. Those felsic igneous rocks, which were source rocks of boron, were produced by metling of proto-arc materials at depth. Boron in felsic rocks could be extracted by deep fluids and transported further in distance. This model is supported by previous report [3]: boron-bearing fluids, generated around felsic igneous rocks, discharged into oceans as hydrothermal fluids, and precipitating tourmalines in isolated basin on proto-arc of ISB.

In addition, abundant tourmaline crystals are found in metamorphosed sedimentary rocks of ISB in the present study. These geological evidence suggest that 3.8 Ga ocean water already contained appreciable amounts of borate, and borate were enriched in specific basin and/or inside of marine sediments at 3.8 Ga Earth. Early Archean evaporite carbonate was reported from ISB [4]. These carbonate rocks were most likely formed in shallow, partially isolated and alkaline basin. Such basin was formed on platform of proto-arc. Therefore, boron-rich, alkaline and eveportae environments were also present at 3.8 Ga.

Here I propose that environments created by proto-arc were ideal not only for formation of felsic igneous rocks but also for prebiotic ribose and nucleotide formations at Hadean age. In isolated and shallow basin on Hadean proto-arc, evaporation may have helped to concentrate borate and phosphate, probably precipitating lüneburgite ($Mg_3B_2(PO_4)_2(OH)_6 \bullet 8H_2O$). Water in this isolated and shallow basin was alkaline. Lüneburgite further promote phosphorization of nucleoside [5]. Boron-rich and alkaline environments also expected locally at mud volcano and inside ofmarine sediments around proto-arc [6]. Formorse reaction could happen not only at shallow evaporite basin but also in deep marine environments around the Hadean proto-arc. As a result, ribose would have been the major aldopentose in Hadean proto-arc environments followed by formations of ribo-nuculeotiside and ribo-nucleotide by help of lüneburgite.

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