Clay minerals as a formation catalyst and a stabilizer of ribose on the prebiotic EarthClay minerals as a formation catalyst and a stabilizer of ribose on the prebiotic Earth

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Ribose is the most abundant organic component in RNA which has ability both as biocatalysts and the medium of gene information. The typically discussed chemical reaction that forms ribose on the prebiotic Earth is the formose reaction, which is the condensation of formaldehyde under alkaline conditions. Ribose and other sugars form in this reaction, but the product ribose is subsequently consumed in the following sequential processes under alkaline conditions. Therefore, the sequestration of ribose is a key process for the accumulation of ribose under alkaline conditions and spontaneous formation of RNA on the prebiotic Earth. Borate ion strongly improves the stability of sugars particularly ribose. Silicate ion and silica also have some effects on the improvement in the stability of sugars. Effects by other ions and minerals remain unclear. Clay minerals such as kaolinite and montmorillonite are proposed to catalyze the formose-like reaction even under acidic and neutral conditions. However, the product sugars were not identified in these reactions. Further, the effects of clay minerals on the stability of ribose remained unclear. We investigated effects of kaolinite on the stability of ribose and other sugars. We also investigate the effects of clay minerals on the products of the formose reaction under neutral conditions. Residual amounts of sugars are analyzed with liquid chromatography mass spectrometry whereas the product sugars are analyzed with gas chromatography mass spectrometry after derivatization. In our stability investigation, kaolinite was added to alkaline ribose solution and the residual amount of ribose was measured. In this solution, less than half of ribose was adsorbed on kaolinite crystal edge while more than half of the added ribose was dissolved in alkaline solution. The degradation rate of ribose was significantly decelerated with the presence of kaolinite. The structure of ribose on the kaolinite edge was fixed in pyranose form which is the six-member ring form of pentose. The formose reaction happened under neutral conditions with kaolinite and montmorillonite. Conversely, the formose reaction was not happened with silica. The formose reaction with kaolinite/montmorillonite formed many sugars including ribose, although the reaction rate was lower than typical formose reaction under alkaline conditions. The products of the incipient formose reaction with kaolinite contained both aldopentoses and branched pentoses. Further investigations on clay-catalyzed formose reaction and stabilization may expand the availability of RNA sugar on the prebiotic Earth and even extraterrestrial environments.

Keywords: Ribose, Kaolinite, formose reaction

