Abiotic Catalysis of RNA Polymerization in Aqueous Metal Chloride Solutions. V. S. Riggiv1, E. B. Watson12, L. B. McCown23, K. L. Rogers12, 1Department of Earth and Environmental Sciences, (riggiv@rpi.edu), 2New York Center for Astrobiology, 3Department of Chemistry and Chemical Biology, Rensselaer Polytechnic Institute, Troy, NY 12180.

Introduction: The transition from an abiotic to biotic early Earth necessarily involved the synthesis of essential biomolecules. Ribonucleic acids have been hypothesized to meet the dual requirement of catalysis and information storage during this transition, prior to replacement by DNA and proteins [1]. Several different methods of producing RNA oligomers from imidazole-activated nucleotides have been demonstrated, including implementation of a mineral catalyst to concentrate and drive condensation [2]. Montmorillonite clay is commonly implemented in the lab, however, recent experiments demonstrate that other common minerals, including calcite, can have a similar effect under certain conditions [3]. Furthermore, data collected from experiments designed to mimic hydrothermal chimney-forming environments suggest that these conditions may be particularly conducive to abiotic nucleic acid formation [4]. In addition to polymerization catalyzed by mineral phases, catalysis via various aqueous metal cations has also been demonstrated in the absence of solid phases, including low concentrations of Pb2+ and UO22+ [5-7].

In modern natural geologic systems, exposed mineral surfaces are key sources of dissolved ionic species. Here, the capacity of a variety of aqueous metal cations to drive polymerization of imidazole-activated adenosine monophosphate (ImpA) was evaluated based upon the length of the oligomer products detected. Particular attention was directed towards those metal cations that are abundant in natural systems. The effects of cation concentration on polymerization were assessed, and a wide array of elements was used in order to identify the key variables responsible for the observed phenomenon.

Results: A clear dependence of RNA product length on the concentration of aqueous metal cations was observed. Metals fell within one of two groups. The first group produced longer RNA oligomers at high metal concentration, approaching a maximum length as the solution approached saturation. This group included common ions such as sodium, magnesium, and calcium, and yielded maximum-length oligomer products ranging from trimers to octamers. These elements appeared to reach a local maximum of RNA oligomer length at low concentrations far from saturation. A visible difference in the amount of precipitate was observed between experiments and was also affected by the concentration of metal ions in the solution. Higher concentrations produced a greater amount of visible precipitate than experiments of lower concentrations.

In addition to the observed dependence on concentration, these experiments show that, at high enough concentrations, common aqueous metal cations such as calcium and magnesium can provide a significant driving force for abiotic polymerization of RNA, which exceeds that previously observed and described. Furthermore, the maximum length of oligomeric RNA observed for each metal seems to depend upon the ratio of the cation’s charge to the ionic radius, with elements possessing higher charge densities generally yielding longer oligomers.

Discussion: The RNA oligomers produced in experiments containing high concentrations of Na+, Ca2+, and Mg2+, are of particular interest despite falling short of the product lengths observed for other species. This is due to their relative abundance and geologic significance, as these metals are common in most modern aqueous environments. While seawater concentrations fall short of the concentrations in which the maximum effects are observed, hypersaline environments and evaporite-producing brines exhibit similar chemical compositions which may be relevant to the prebiotic rising of functional ribonucleic acids. These common metal cations are also more widely available than the clay minerals often employed as catalysts, and can surpass them in effectiveness when compared to untreated natural samples. From the wide availability of these metal cations, it follows that the rising of prebiotic RNA from simple precursors may be less remarkable than previously thought and more of a commonplace occurrence, both on Earth and elsewhere.