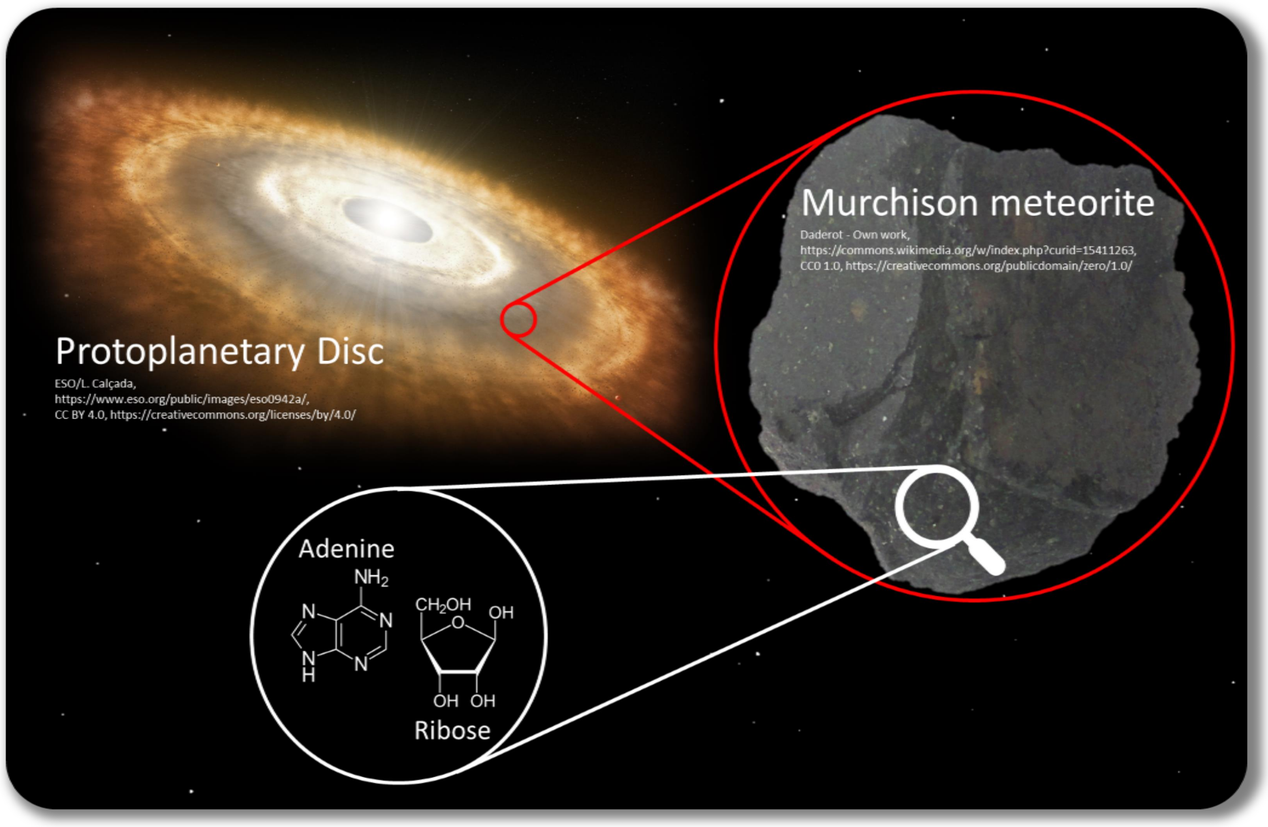
Meteorites and the RNA world: Synthesis of Nucleobases and Ribose in Carbonaceous Planetesimals

Klaus Paschek[1] *on behalf of*

Dmitry Semenov[1,2], Ben Pearce[3,4], Kevin Lange[5], Kai Kohler[2,1], Thomas Henning[1], Ralph Pudritz[3,4], Oliver Trapp[2]

[1] Max Planck Institute for Astronomy, Heidelberg, Germany; [2] Department of Chemistry, Ludwig-Maximilians-University Munich, Munich, Germany;
[3] Origins Institute, McMaster University, Hamilton, Canada; [4] Department of Physics and Astronomy, McMaster University, Hamilton, Canada;
[5] Institute for Theoretical Astrophysics, Center for Astronomy, Heidelberg University, Heidelberg, Germany



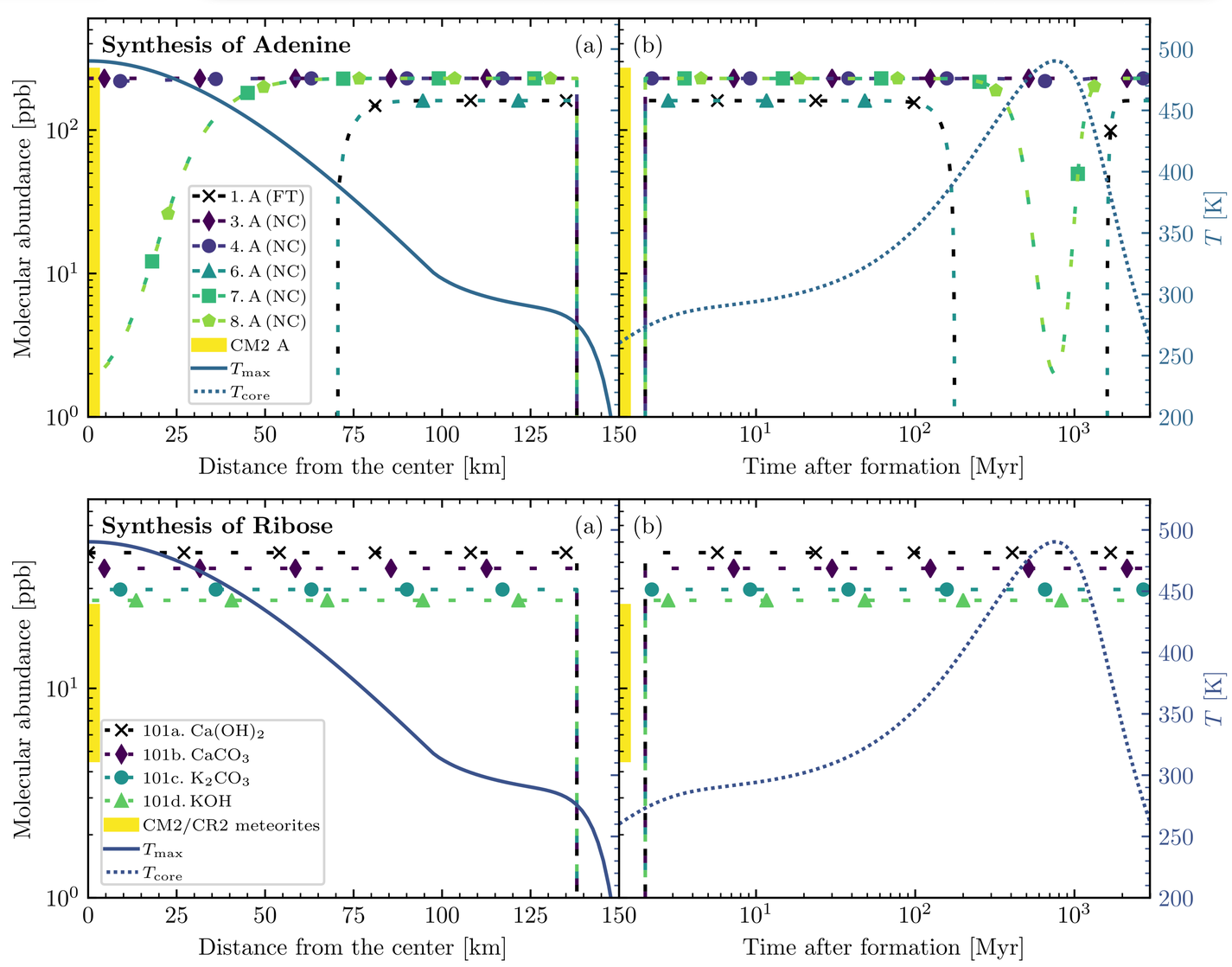


The origin of life might be sparked by the polymerization of the first RNA molecules in Darwinian ponds during wet-dry cycles. The nucleobases and the sugar ribose are key life-building blocks and were found in carbonaceous chondrites. Their exogenous delivery onto the Hadean Earth could be a crucial step toward the emergence of the RNA world. Here, we present the formation of these prebiotic organics through the Strecker synthesis and a simplified version of the formose reaction inside carbonaceous chondrite parent bodies. By using a coupled physico-chemical model, we calculate the abundance of these molecules within planetesimals of different sizes and heating histories. We perform laboratory experiments using catalysts present in carbonaceous chondrites to infer the yield of ribose among all pentoses forming during the formose reaction. These laboratory yields are used to tune our theoretical model that can only predict the total abundance of pentoses. We found that the calculated nucleobase and ribose abundances were similar to the ones measured in carbonaceous chondrites. In conclusion, the Strecker synthesis and aqueous formose reaction might produce most of these organics in carbonaceous chondrites. The life-building blocks of the RNA world could be synthesized inside parent bodies and later delivered onto the early Earth.

Table 1. Candidate reaction pathways within meteorite parent bodies.

No.	Type	Reaction	Source(s)
Adenine			
1	FT	$CO + H_2 + NH_3 \xrightarrow{NiFe+\|\|Al_2O_3+\|\|SiO_2} \mathbf{A} + H_2O$	Yang & Oró (1971); Hayatsu et al. (1968)
3	NC	$5\,HCN_{(aq)} \longrightarrow \mathbf{A}_{(aq)}$	Larowe & Regnier (2008)
4	NC	$HCN + NH_3 \longrightarrow \mathbf{A}$	Yamada et al. (1969); Wakamatsu et al. (1966)
6	NC	$5\,CO + 5\,NH_3 \longrightarrow \mathbf{A} + 5\,H_2O$	Hayatsu et al. (1968)
7	NC	$HCN + H_2O \longrightarrow \mathbf{A}$	Ferris et al. (1978)
8	NC	$HCN + NH_3 + H_2O \longrightarrow \mathbf{A}$	Oró & Kimball (1961)
Uracil			
29	NC	$2\,HCN_{(aq)} + 2\,CH_2O_{(aq)} \longrightarrow \mathbf{U}_{(aq)} + H_{2(aq)}$	Larowe & Regnier (2008)
32	NC	$\mathbf{C} + H_2O \longrightarrow \mathbf{U} + NH_3$	Robertson & Miller (1995); Garrett & Tsau (1972); Ferris et al. (1968)
Cytosine			
43	FT	$CO + H_2 + NH_3 \xrightarrow{NiFe+\|\|Al_2O_3+\|\|SiO_2} \mathbf{C} + H_2O$	Yang & Oró (1971); Hayatsu et al. (1968)
44	NC	$3\,HCN_{(aq)} + CH_2O_{(aq)} \longrightarrow \mathbf{C}_{(aq)}$	Larowe & Regnier (2008)
Guanine			
51	FT	$CO + H_2 + NH_3 \xrightarrow{NiFe+\|\|Al_2O_3+\|\|SiO_2} \mathbf{G} + H_2O$	Yang & Oró (1971); Hayatsu et al. (1968)
54	NC	$5\,HCN_{(aq)} + H_2O \longrightarrow \mathbf{G}_{(aq)} + H_{2(aq)}$	Larowe & Regnier (2008)
Thymine			
58	NC	$2\,HCN_{(aq)} + 3\,CH_2O_{(aq)} \longrightarrow \mathbf{T}_{(aq)} + H_2O$	Larowe & Regnier (2008)
62	NC	$\mathbf{U} + CH_2O + CH_2O_2 + H_2O \longrightarrow \mathbf{T}$	Choughuley et al. (1977)
Ribose			
101	CA	$CH_2O_{(aq)} + C_2H_4O_{2(aq)} \longrightarrow \mathbf{R}_{(aq)}$	Butlerow (1861); Socha et al. (1980)

NOTE—FT: Fischer-Tropsch, NC: Non-catalytic, CA: Catalytic.
+||: One, or the other, or all catalysts used in laboratory experiments.



The predicted abundances for the nucleobases (see upper plot for adenine as one example) and the sugar ribose (see lower plot) closely match the measured abundances in actual carbonaceous chondrites (yellow bars in plots) found on Earth today. Considering the depletion of initial volatile reactants in the inner region of the early solar system compared to the today measurable cometary abundances in the outer regions is key to accurately model the synthesis of prebiotic organic molecules in parent body planetesimals of carbonaceous chondrites meteorites, which might have seeded the Hadean Earth with crucial building blocks for the origin of life.

Related Publications:

Paschek, K., Kohler, K., Pearce, B. K. D., Lange, K., Henning, T. K., Trapp, O., Pudritz, R. E., Semenov, D. A. **2022a**. *Possible Ribose Synthesis in Carbonaceous Planetesimals*. Life, 12, 404, https://doi.org/10.3390/life12030404

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