SYNTHESIS OF METEORITIC ORGANIC COMPOUNDS

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A variety of organic molecules have been identified in carbonaceous chondrites, including polycyclic aromatic hydrocarbons (PAHs), N-heterocyclic compounds, amino acids and carboxylic acids. This mixture of different compound classes probably represents distinct formation sources. These extraterrestrial molecules were delivered to the early Earth through impacts and may have played a key role for the origin of life on Earth.
Interstellar PAHs were probably formed in the outflows of C-rich asymptotic giant branch (AGB) stars (Cherchneff *et al.*, 1992). Benzene, the smallest aromatic molecule, was detected in C-rich proto-planetary nebula CRL 618 (Cernicharo *et al.*, 2001), and its formation in this environment is also plausible from current chemical models (Woods *et al.*, 2002). Chemical and isotopic evidence indicate that PAHs detected in carbonaceous meteorites predate the formation of the parent body (Messenger *et al.*, 1998; Plows *et al.*, 2003), consistent with the proposal that these compounds are interstellar in origin.

The simplest amino acid glycine was detected recently in space by radio astronomical observations (Kuan *et al.*, 2003), and formation pathways for amino acids in the interstellar medium have been proposed (Charnley *et al.*, 2001; Woon, 2002). On the other hand, laboratory experiments have demonstrated that amino acids are highly sensitive to degradation in the interstellar UV-field (Ehrenfreund *et al.*, 2001), leaving it questionable if amino acids survive in space to be incorporated intact into meteorite parent bodies. However, more than 70 different amino acids have been detected in the CM2 carbonaceous chondrite Murchison and others, displaying a wide range of complexity and variability. For example, amino acid analyses of CM1-type carbonaceous chondrites indicate that their organic composition is not simply the product of aqueous alteration of the CM2 composition (Botta *et al.*, 2004a). Mineralogical and isotopic evidence indicate that liquid water was present inside the CM parent body for a few million years after its formation. Simple interstellar precursor molecules such as HCN, NH_3 and carbonyl compounds can react under these conditions to form α-amino acids.

Aromatic N-heterocyclic molecules have also been identified in carbonaceous chondrites (Stoks & Schwartz, 1981, 1982), although there is still a lack of conclusive evidence for the extraterrestrial origin of these compounds (Martins *et al.*, 2004). Astronomical searches for aromatic N-heterocyclic molecules have so far lead to upper limits for the column densities for pyrimidine and quinoline/isoquinoline (Kuan *et al.*, 2004; Botta *et al.*, 2004b). Laboratory experiments have shown that N-heterocyclic compounds are destroyed in the interstellar UV-field (Peeters *et al.*, 2003). Therefore, the extraterrestrial synthesis of this class of molecules probably also has to be placed inside the meteorite parent body. The conditions may have been similar to environments on prebiotic Earth. Synthetic studies for abiotic syntheses of nucleobases (Ferris & Hagan, 1984) indicate that HCN polymerizations can lead to appropriate intermediates, which can react further, for example with formaldehyde and urea, to form purines and pyrimidines.

References: Botta O. *et al.*, *GCA*, 2004a, submitted; Botta O. *et al.*, *Astrobiology* **4**, 271 (2004b); Cernicharo J. *et al.*, *ApJL* **546**, 123-126 (2001); Charnley S. B. *et al.*, *Spectr. Acta A* **57**, 685-704 (2001); Cherchneff I. *et al.*, *ApJ* **401**, 269-287 (1992); Ehrenfreund P. *et al.*, *ApJL* **550**, 95-98 (2001); Ferris J. P. & Hagan W. J., *Tetrahedron* **40**, 1093-1120 (1984); Kuan Y.-J. *et al.*, *ApJ* **593**, 848-867 (2003); Kuan Y-J. *et al.*, *Adv. Space Res.* **33**, 31-39 (2004); Martins Z. *et al.*, *MAPS* **39**, Suppl. 64

(2004); Messenger S. *et al.*, *ApJ* **502**, 284-295 (1998); Peeters Z. *et al.*, *ApJL* **593**, 129-132 (2003); Plows F. L. *et al.*, *GCA* **67**, 1429-1436 (2003); Stoks P. G. & Schwartz A. W., *GCA* **45**, 563-569 (1981); Stoks P. G. & Schwartz A. W., *GCA* **46**, 309-315 (1982); Woods P. M. *et al.*, *ApJL* **574**, 167-170 (2002); Woon D. E., *ApJL* **571**, 177-180 (2002).