Micrometeorites and the Mysteries of Our Origins
Advances in Astrobiology and Biogeophysics

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Preface

From cosmic dust to the birth of life. This book is purposely not a conventional monograph about either interplanetary debris captured by the Earth (i.e., meteorites and micrometeorites), the very thin \( \sim 100 \) km-thick shell dubbed as atmosphere that tops our blue planet, and where life is thriving, or the astonishing role of the Moon and Jupiter in our origin. It is rather an extended cross-disciplinary research report about a chaotic cosmic “detective” investigation conducted by our team with the help of a few colleagues, who could foresee the interest of micrometeorites to tackle the opaque mystery of the first \( \sim 500 \) Myr of the solar system history.

One major objective is to show how we strengthened a qualitative suspicion about the role of the accretion of volatile-rich micrometeorites similar to those recovered from recent Antarctica ices and snows in the formation of the air and oceans of our blue planet. This is an important problem because without water there would be no life, as we know it. For this purpose, a scenario coined “EMMA” (Early Micrometeorite Accretion) was slowly extirpated from a set of confusing data buried in the flow of details usually given in most papers (including ours). Other objectives were to assess the role of juvenile micrometeorites in the prebiotic chemistry that led to the birth of life, and their potential as “probes” of early solar system processes, including the formation of the solar system, the early history of comets, the post-lunar greenhouse effect on the Earth that was the only one to be effective in the origin of life, etc.

We had to navigate out of sight on chaotic, cold and beautiful adventures where we met successively:

- the harsh conditions of the superb Antarctic and Greenland ice sheets, where we collected (in spite of the noisy disapproval of Adélie penguins during our first attempt in Antarctica in 1987) large unmelted micrometeorites with sizes of about 100 \( \mu m \);
- the difficult handling of these micrometeorites, which required their fragmentation into several pieces without losing them (i.e., a typical mission “impossible”), with the view of conducting several distinct destructive analyses of the same micrometeorite;
- their difficult analyses frequently conducted at the limit of sensitivity of the most powerful techniques of microanalyses (i.e., when you claim with the
greatest arrogance that this damned weak signal can be reliably extirpated from its terrible host background);

– the comparison of these micrometeorites with the ~135 groups of meteorites known at this date, which forced us to be kinds of first year students (at least until to morrow) in “Meteoritics” under the guidance of Gero Kurat;

– a stunning “chaos” in the mineralogical, chemical and isotopic compositions of meteorites which is not fully understood;

– several distinct bold intrusions in the friendly world of exobiology where we did not even know about the meanings of the basic letters of the alphabet of this discipline, such as AIB, glycine and peptides, and which were (hopefully) partially successful through the patient and enthusiastic guidance of André Brack;

– authoritative and impressive predictions of models that all rely on hidden adjustable free parameters, which have to be painstakingly identified as to reject courageously, in the greatest loneliness, some models still quoted in the literature as “elegant”, and which are understood by half a dozen experts around the world.

Fortunately, in addition to the Antarctica and Greenland ice sheets, we also met other fascinating beauties such as:

– shooting stars;

– the superbly craterized Moon (that unexpectedly became a “star” in our model);

– the giant Mars-sized body that formed the Moon during its cataclysmic impact with the proto-Earth, and which was on the verge of destroying our baby planet still to become blue;

– the late spike of impactors that formed the 12 large lunar impact basins with diameter ranging from 300 to 1300 km, on the near-side of the Moon, about 3.9 Gyr ago;

– the other inhospitable terrestrial planets (Mars, Venus, Mercury);

– Jupiter, the largest of the giant gaseous planets, which behaves as a gigantic sling firing cosmic projectiles to the Earth;

– asteroids, and comets qualified of small bodies and which have a terrifying killing power;

– the dusty faint enigmatic zodiacal cloud;

– the early dusty solar nebula and its mysterious “x-wind”;

– the dusty stellar “nurseries” where stars are simultaneously born;

– the reviewers, who rejected our papers with the concise and useful statement that they are “not convinced by the authors”;

– beautiful books and challenging papers edited and/or written by a few colleagues who have still a passion for science.

Overview of a cosmic detective investigation. In our investigation “hydrous-carbonaceous” micrometeorites and meteorites turned out to be
major witnesses of the mysteries of our distant past. For the first time, they will be on a par in a book written in English, and their close association will be maintained up to the last final section. They helped to discover a variety of unexpected effects produced by a long lasting giant “storm” of interplanetary dust particles, captured as “juvenile” micrometeorites by the young Earth. It produced a fantastic long-duration storm of shooting stars, with an hourly rate of about 10 million (and not about 10 like today), and which lasted for about 100 Myr after the formation of the Moon.

As about 75% of the incoming flux of micrometeorites is destroyed upon atmospheric entry, either by volatilization or melting, this silent cosmic dust storm effective in the thermosphere (i.e., between about 120 km and 80 km today) induced a new kind of diffuse and soft volcanism “falling from the sky”. It thus injected in particular strong greenhouse gases (H\textsubscript{2}O, SO\textsubscript{2} and CO\textsubscript{2}) and very small “smoke” particles in a kind of giant \(\sim\)50 km thick “cocoon”, located in the thermosphere, and which did homogeneously cap the whole early Earth’s surface for a duration of about 100 Myr!

This accretion was mostly effective just after the formation of the Moon by the impact of a giant Mars-sized body with the Earth. This cataclysmic impact simultaneously blew off most of the complex pre-lunar terrestrial atmosphere, thus leaving a vacant “niche” for the subsequent accumulation of a post-lunar mixture of volatile species generated by this long duration micrometeoritic volcanism. It ended up forming the air and oceans of the early Earth. Furthermore, altogether with micrometeorites that do survive unmelted upon atmospheric entry, it likely opened many new reaction channels that contributed dominantly to the prebiotic chemistry that gave birth to life on the Earth, and possibly on Mars and a few planets orbiting around other Sun-like stars.

One of the key findings supporting this scenario is the astonishing chemical “purity” of the \(\sim\)2.10\textsuperscript{24} g of volatiles that compose the Earth’s atmosphere formed \(\sim\)4.4 Gyr ago, and which includes the air and oceans, but also sedimentary rocks such as the \(\sim\)270 millions of km\textsuperscript{3} of carbonates where early CO\textsubscript{2} is now trapped. Indeed, this mixture of volatiles is similar to that expected for a tiny “puff” of gases, which would be released upon the frictional heating of \(\sim\)5 mg aliquot of \(\sim\)500 micrometeorites with sizes of \(\sim\)100–200 \(\mu\)m, and similar to those recovered from recent Antarctic ices –this is the number of Antarcctica micrometeorites, which were painstakingly analyzed over the last decade to determine their average Ne, N\textsubscript{2}, H\textsubscript{2}O and C contents. We further strengthened this deduction while showing that previous scenarios used to tackle the same problem, as well as interesting criticisms addressed to our model, all roughly stumble against this micrometeoric purity that they can hardly bypass.

Next, we decided to further check the validity of this scenario switching to the concentration of a very refractory and highly siderophile element (iridium) in the very different environment of the Earth’s mantle. The good fit between
predictions and observations for rocks from the upper mantle did build up our confidence to explore the unexpected potential of micrometeorites to decrypt other mysteries of our distant past.

The readers of this book will be in touch with very recent ideas about our origins, which are either still hotly debated or even not published yet – if they want to have a conventional view of the topics discussed in this book they have just to turn to the beautiful Encyclopedia available today. Therefore, the first chapter is a kind of teaching help where they will find the basics required to understand these ideas and the importance of the data that support them. Moreover, these basics will be further developed in each of the following chapters. For example, the complex classification of meteorites, which has already been presented in detail in excellent monographs, will be summarized in just four pages, trying to keep only the most salient features of this classification (Sect. 6.1). Modern ideas about the origin of life, which have also been presented in good monographs, are sketched in the two and a half pages of Sect. 12.1. We also selected a set of 52 figures, which might be consulted first to get a feeling about the topics discussed in this book.

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The most difficult thing when you are right is to prove that you are not wrong

Pierre Dac
French humorist
1893–1975
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