NEWS & VIEWS

PLANETARY SCIENCE

Rapid formation of Mars

An analysis of meteoritic material from Mars provides an accurate timeline of the planet's early history. The results have major implications for our understanding of the processes involved in rocky-planet formation. SEE LETTER P.586

LINDA T. ELKINS-TANTON

During their formation, many rocky planets go through a phase known as a magma ocean, during which they are mostly or completely molten. Many researchers thought that the solidification of Mars's magma ocean was protracted, perhaps lasting for up to 100 million years (Myr) after the ocean's formation[1–3]. But on page 586, Bouvier *et al.*[4] show that this process was completed in less than 10 Myr. The finding suggests that habitable conditions existed on Mars up to 100 Myr before they did on Earth.

In the contest between scientific models, empirical evidence is the arbiter. More than 100 meteorites that originated on Mars have been identified on Earth, providing samples of the Martian crust. And advances in the sensitivity of instruments that measure the concentrations of individual isotopes allow the ages of these materials to be determined with high precision.

Bouvier and colleagues looked for minerals known as zircons in Martian meteoritic material. When a zircon crystallizes from its parent magma, its crystal structure allows stray uranium atoms to be trapped in the growing crystal, but rejects lead atoms. Consequently, when researchers study these minerals billions of years later, they can be confident that any lead in the crystals was produced by uranium decay and that no other sources of lead need to be considered. Furthermore, two uranium–lead decay processes (^{235}U to ^{207}Pb and ^{238}U to ^{206}Pb) can be used simultaneously to improve the precision of the results. Uranium–lead geochronology using zircons therefore yields the most precise ages of ancient geological materials that are currently possible.

The authors analysed seven hard-earned zircons and obtained ages ranging from 4,476 to 4,430 Myr. For comparison, the first solids in the gas disk around the growing young Sun, known as calcium–aluminium-rich inclusions (CAIs), formed 4,567.3 Myr ago[5]. Therefore, in the astonishingly short interval of 90 Myr, Mars grew from dust to a planet, solidified from its initial magma-ocean state and formed a crust containing zircons.

This result already shows that models predicting a protracted magma-ocean stage on Mars[1–3] cannot be correct, but Bouvier and co-workers' study yielded even finer constraints. The lutetium–hafnium decay process, ^{176}Lu to ^{176}Hf, can be used to constrain the melting history of the zircons' parent magmas, because the two isotopes behave differently during melting. The authors found that the zircons have unusually low concentrations of ^{176}Hf. This indicates that the parent magmas had lower amounts of ^{176}Lu than would be expected if they originated from the solidified products of Mars's magma ocean. To form these parent magmas, the planet must have partially melted after it had solidified.

Bouvier and colleagues' findings provide a revised timeline for the early stages of Mars's history (Fig. 1). The planet grew to approximately its current size within less than 10 Myr (and probably less than 5 Myr) of the formation of CAIs[6,7]. It then took less than 10 Myr to solidify from its initial magma-ocean phase. To put these timescales into perspective, if the Solar System were one day old, Mars would have fully formed in the first 6 minutes. About 20 Myr after the formation of CAIs, the planet partially melted to produce magmas that rose to the planet's surface; 70 Myr later, these magmas had solidified to form a zircon-containing crust.

The rapid solidification of Mars's magma ocean has important implications for our understanding of both Mars and the planet's formation of rocky planets in general. The speediness suggests that heat was easily lost from Mars, which implies that the planet's atmosphere was relatively thin. Two processes could have produced such an atmosphere: a low release of volatile gases from the magma ocean; and a stripping of the atmosphere by the young Sun[8,9]. Researchers can now constrain the extent to which such processes occur much more closely, and can apply the results to the young Earth.

The early growth and magma-ocean phase of Mars, and, by extension, of other planetary embryos, means that at least some of the planet's formation probably happened while the gas disk was still present around the young

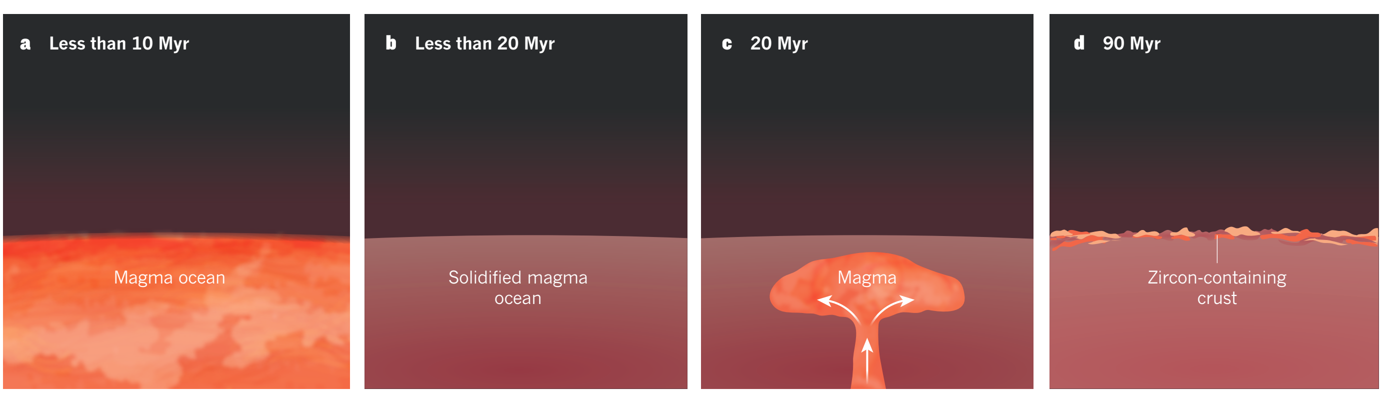

Figure 1 | The evolution of Mars. Bouvier *et al.*[4] analysed minerals known as zircons in meteoritic material from Mars, and determined a timeline for the planet's early history. The numbers represent the approximate time, in millions of years (Myr), since the formation of the first solids in the gas disk around the young Sun. **a**, After Mars had grown to approximately its current size, it existed in a magma-ocean phase, in which it was mostly or completely molten. **b**, The magma ocean solidified. **c**, The planet partially melted to produce magmas that rose (white arrows) to the planet's surface. **d**, These magmas solidified to form a zircon-containing crust.

Sun — on average, such disks exist for only a few million years[10]. Therefore, there is strong reason to think that gas in the disk would have diffused into the magma oceans on these embryos.

This diffusion process could help to answer some long-standing questions about, for example, the noble-gas content of Earth. Today, Earth releases noble gases that must have been implanted in the mantle at the time of the planet's formation. The origin of these gases has been unclear because the rocky material that built Earth contained only a small quantity of noble gases. The diffusion of noble gases from the gas disk directly into the magma ocean might solve the mystery.

Finally, Bouvier and co-workers' timeline allows the early histories of Earth and Mars to be compared directly. About 100 Myr after the formation of CAIs, Earth went through a magma-ocean phase that is thought to have been initiated by the collision of the planet with a Mars-sized body — a collision that led to the formation of the Moon[11]. Consequently, the authors' results suggest that Mars had clement conditions, and was possibly even hospitable to the formation of life, for as long as 100 Myr before such conditions existed on Earth. Mars had a head start on Earth in the planetary-evolution game. ■

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MEDICAL RESEARCH

Cancer drug tackles overgrowth syndrome

Abnormal activity of the enzyme PI3K can drive cancer growth, and mutations in a PI3K subunit can sometimes lead to non-cancerous overgrowth. A cancer drug that inhibits PI3K dramatically reduces such overgrowth. **See Article p.540**

ROBERT K. SEMPLE & BART VANHAESEBROECK

Researchers who investigate rare genetic conditions live in hope that the discovery of disease-causing mutations will lead swiftly to tailored treatments. Sadly, this is not often the case, because genetic defects usually cause impairments that are difficult or impossible to tackle using available medicines. In this issue, Venot *et al.*[1] (page 540) now provide a rare exception to this rule. In severe non-cancerous overgrowth syndromes caused by mutations in an enzyme called PI3K, they show the beneficial effects of a PI3K-inhibitor drug that was initially developed to treat cancer. Their results bring the possibility of a transformative therapy for people with overgrowth conditions one step closer.

The development of humans, from a single fertilized egg to an adult body that contains around 37 trillion cells[2] while maintaining symmetrical, paired body parts, is an astonishing feat that requires the lifelong coordination of cell division, survival and death. Growth-factor proteins can aid cellular coordination by acting on cell-surface receptors to stimulate intracellular signalling networks. These networks often include PI3K, which is essential for the regulation of growth and development by insulin and insulin-like growth-factor hormones.

Cancer arises from a flagrant breach of the rules of good cellular citizenship that are essential in multicellular organisms, and cancer cells acquire genetic abnormalities that subvert the checks and balances that constrain cell growth and migration. Mutations that activate PI3K signalling — mainly those in the gene *PIK3CA*, which encodes p110α, a catalytic subunit of PI3K — are among the most common mutations to drive solid cancers[3]. Such signalling can also be activated by mutations that inactivate the enzyme PTEN, which normally keeps PI3K activity in check. The link between overactive PI3K signalling and cancer motivated researchers to develop compounds known as PI3K inhibitors. However, the clinical impact of these drugs on cancer has been less impressive than hoped because of toxicity associated with high doses. And even when such drugs succeed in inhibiting activated PI3K, other proteins can compensate to provide alternative pathways that promote cancer[4].

In 2012, certain *PIK3CA* mutations, which had previously been linked to cancer, were reported to cause rare, non-cancerous forms of overgrowth in people[5–7]. A hallmark of these overgrowth syndromes is abnormal, excessive tissue growth that affects the body in a patchy and asymmetrical manner. This overgrowth is caused by *PIK3CA* mutations that occur after the start of embryonic development and

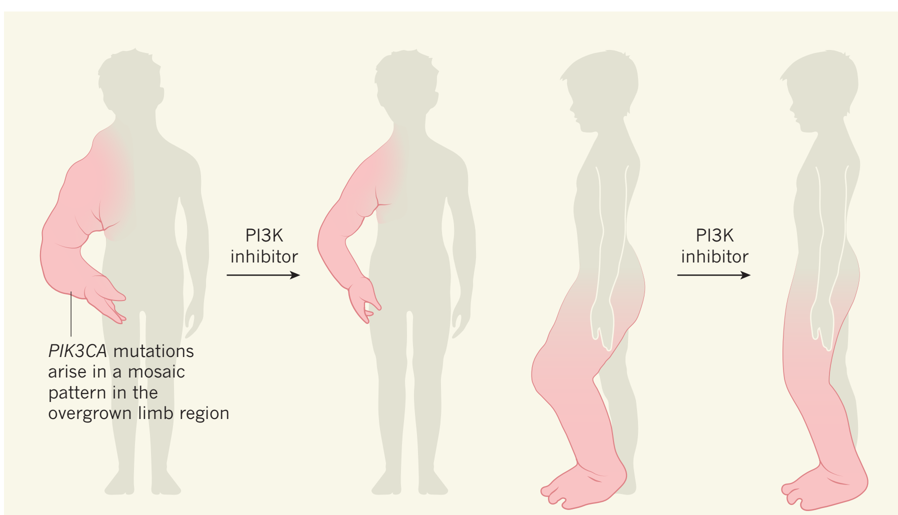

Figure 1 | People who have an overgrowth syndrome respond to treatment with a cancer drug. Venot *et al.*[1] investigated a syndrome linked to abnormal activation of the enzyme PI3K, which can result in the non-cancerous overgrowth of a variety of tissues. The authors tested whether a low dose of a PI3K inhibitor called alpelisib, developed previously as a cancer therapy, could treat people who have mutations in the gene *PIK3CA*, which encodes the catalytic subunit of PI3K. In overgrowth syndromes, these *PIK3CA* mutations arise in a mosaic patchwork pattern[5,6,8] in the region of the affected tissue (pink). Alpelisib treatment caused substantial improvements in the 19 recipients. Two examples of the decrease in overgrown tissue in patients after six months of drug treatment are shown.