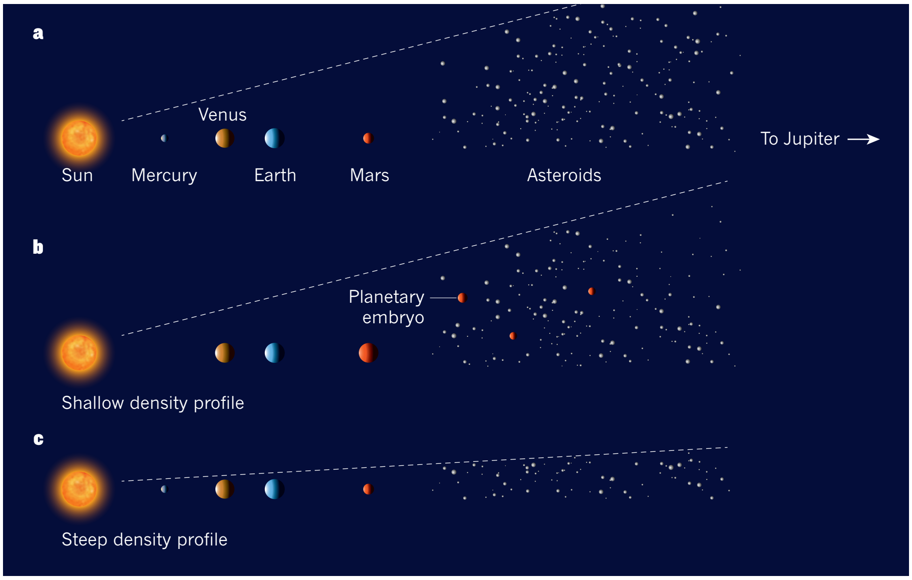

Figure 1 | The inner Solar System and outcomes of simulations of its formation. In these cartoons, distances are roughly to scale, but the sizes of the planets relative to the Sun have been increased. **a**, The inner Solar System contains the terrestrial planets (Mercury, Venus, Earth and Mars) and the asteroid belt. Asteroid orbits can be inclined by up to 30° to the ecliptic (Earth's mean orbital plane). **b**, Simulations of the Solar System's formation in which material in the nascent system has a 'shallow' density profile (that is, planetary embryos can be found within 4 AU of the Sun; 1 AU is the distance from the Sun to Earth) typically result in an Earth-sized 'Mars' and asteroid orbits 'excited' at sizeable inclinations; Mercury is often absent. Embryos may get stuck in the asteroid belt for long times, eventually leading to a different belt from that now observed. **c**, Izidoro and colleagues[2] report simulations of steep initial density profiles (embryos within 2 AU of the Sun). The size and orbital distributions of the terrestrial planets are well reproduced in these simulations, but the asteroid belt remains nearly flat.

the embryos would have had to have decamped quickly, otherwise the asteroid belt would look very different today.

Building a huge 'Mars' and trapping massive embryos in the asteroid belt might not occur if most embryos are initially gathered within the orbit of Mars — that is, if a steep density profile develops in the early Solar System. This could occur if solid material in the gas disk accumulates near the Sun so that embryo formation is favoured in this region[4]. In their work, Izidoro *et al.* modelled the steep-profile scenario and compared it with other density profiles, but did not detail how this accumulation occurred.

Their main result is that, no matter what the density profile, it is impossible both to solve the Mars problem and to build a correctly structured asteroid belt (Fig. 1b, c). Steep density profiles reproduce the terrestrial planets fairly well, unlike shallow profiles. But asteroid excitation follows the opposite trend: steeper density profiles give much lower inclination excitations, because of the lack of embryos in the belt. Once the terrestrial planets have formed, leftover planetesimals cannot excite each other enough to produce the observed structure of the asteroid belt, because their gravity is weak. Perturbations from the giant planets cannot do the job either, even if they change their orbits abruptly later in the Solar System's evolution, as modern models predict (see ref. 5, for example). So the asteroid belt must have been both depleted of mass and excited before the terrestrial planets began to assemble.

Standard formation models don't consider the fact that giant planets can substantially change their orbits while forming in the disk. An intricate migration pattern of the giants has been reported[6] to produce a mass distribution that solves the Mars problem and generates an asteroid belt broadly similar to the observed one. As Izidoro *et al.* point out, this is the only known model that is compatible with their results, although it assumes a match between the growth and migration-time profiles of Jupiter and Saturn that has not been reproduced in simulations.

Planet-formation models have, in fact, been undergoing revision since it was realized that trillions of small pebbles in gas disks can spiral onto planetesimals as the pebbles drift towards the Sun, causing planetesimals to grow swiftly into embryos[7]. Pebble accretion, combined with gravitational self-stirring, has been shown to produce the giant planets within the short lifetime of the disk[8] — the first time that this has been achieved in a model. More-recent work[9] suggests that the same process might explain the structure of the inner Solar System, without the need for giant-planet migration. However, this accretion model also depends sensitively on largely unknown physical properties of both the gas disk and the growing bodies.

Izidoro *et al.* do not offer a final model of terrestrial-planet formation. But their work convincingly demonstrates that standard models cannot satisfy major constraints on the process, the toughest of which is set by asteroids.

NATURE

50 Years Ago

Fortunately, our distant ancestors appear to have had a mania for making lists. Some of these lists are in a sense the beginnings of history, just as others, which perform a preliminary work of classification, are in a sense the beginning of the natural sciences. It was when they put together their lists of successive kings or priests that these ancient peoples acquired their first impressions of the tremendous stretch of time behind them. The ancient Greeks had very defective lists and thought that only a comparatively short period separated them from the age when the gods had walked and sported about on the Earth. But some of them learned about the huge lists of Egyptian priests and came to realize that there had been thousands of years of human history before their day. If the whole of this is taken together, it involves a change in what it means to have an existence in time—a time which stretches behind and before.

From *Nature* 11 December 1965

100 Years Ago

First Aid in the Laboratory and Workshop by A. A. Eldridge and Dr. H. V. A. Briscoe

The authors of this little book, who have been in charge of first aid organisation in chemical and physical laboratories, have found that the ordinary text-books devote too much space to serious fractures and other injuries, but give little information regarding ordinary accidents, such as are apt to occur in laboratories and workshops, for instance, burns produced by chemicals, eye injuries, shocks produced by electric currents, and poisoning. They have therefore written this pamphlet to meet this need.

From *Nature* 9 December 1915