Main Belt Asteroids: A Melting Pot of Early Solar System Relicts

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The Main Belt between Mars' and Jupiter's orbit hosts a myriad of asteroids, whose most massive members are the 500-km Vesta and 970-km Ceres. A classical view held that the current asteroid belt represents a tiny fraction (~0.1%) of a once-much-more massive population of planetesimals formed in-situ. Due to their being separated "at birth", asteroids were thought to have escaped major evolutionary processes typical of larger planets. As a consequence, asteroids have been largely regarded as primordial relicts of the early Solar System, thus spawning interest in their space exploration. Reconnaissance of first Main Belt asteroids by the Galileo and NEAR missions seemed to support this view.
Meanwhile, with the advent of advanced numerical modeling, it has become increasingly clear that not all asteroids are primordial, and those smaller than about ~100 km in diameter are thought to be collisionally generated fragments of larger siblings.
In recent years, other new ideas have emerged. The overall orbital architecture of the Solar System implies large-scale mobility of the giant planets. In some of the extreme scenarios, the primordial Main Belt is dismantled and reassembled by a migrating Jupiter within the first million of years of formation. Later dynamical instabilities would also add radial mobility resulting in vigorous mixing in the Main Belt region. In these modern views, the Main Belt acts as a melting pot, collecting objects scattered from the four corners of the Solar System: from the terrestrial planet region to the outer trans-neptunian disk.
The exploration of these relatively accessible small worlds, thus, provides us with an unparalleled means to study the broader issues of Solar System formation, such as the formation location and internal evolution of planetesimals. The Dawn mission at Vesta and Ceres has paved the way for these in-depth investigations, but also showed that the study of these fundamental issues is complicated by billions of years of collisional evolution.
The great challenge for future missions, such as Lucy and Psyche, lies in being able to tease out primordial and evolutionary processes in order to reach a deeper understanding of our Solar System formation.

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