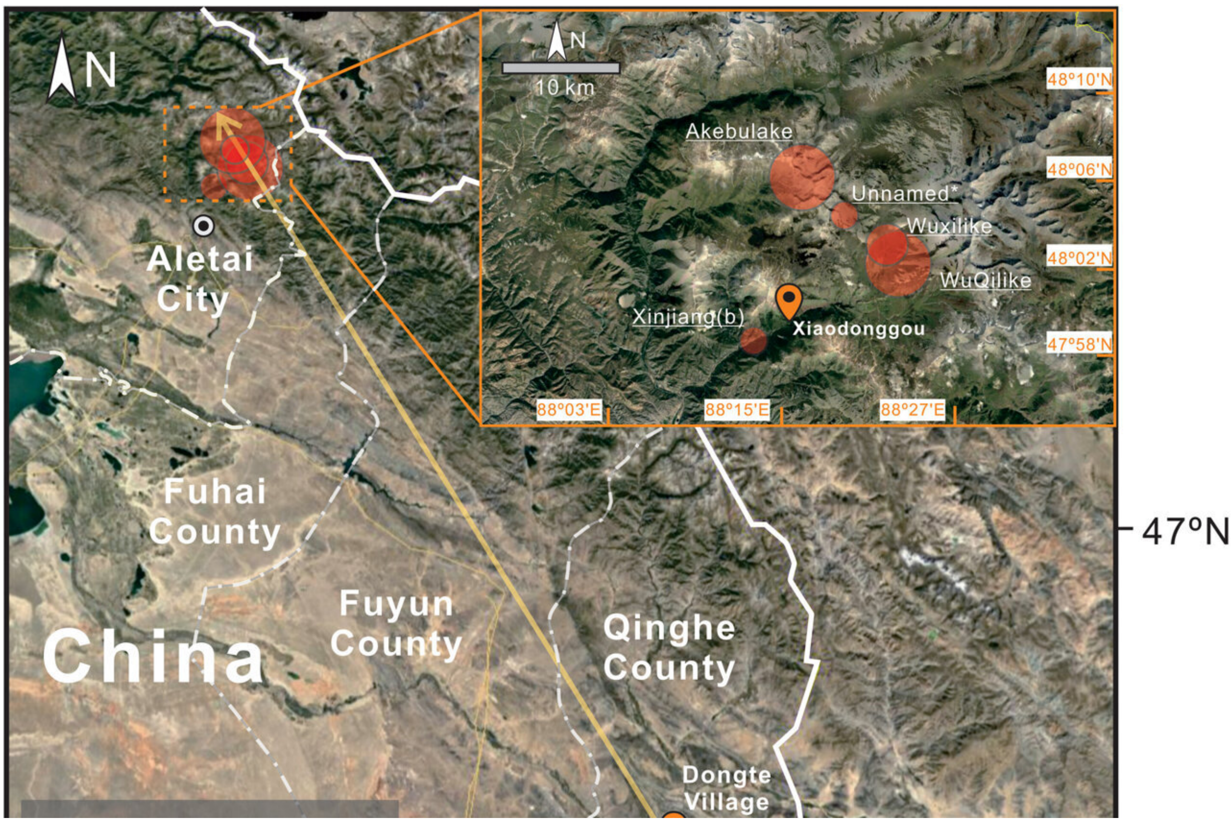
A unique stone-skipping-like trajectory of asteroid Aletai

July 20 2022, by Thamarasee Jeewandara



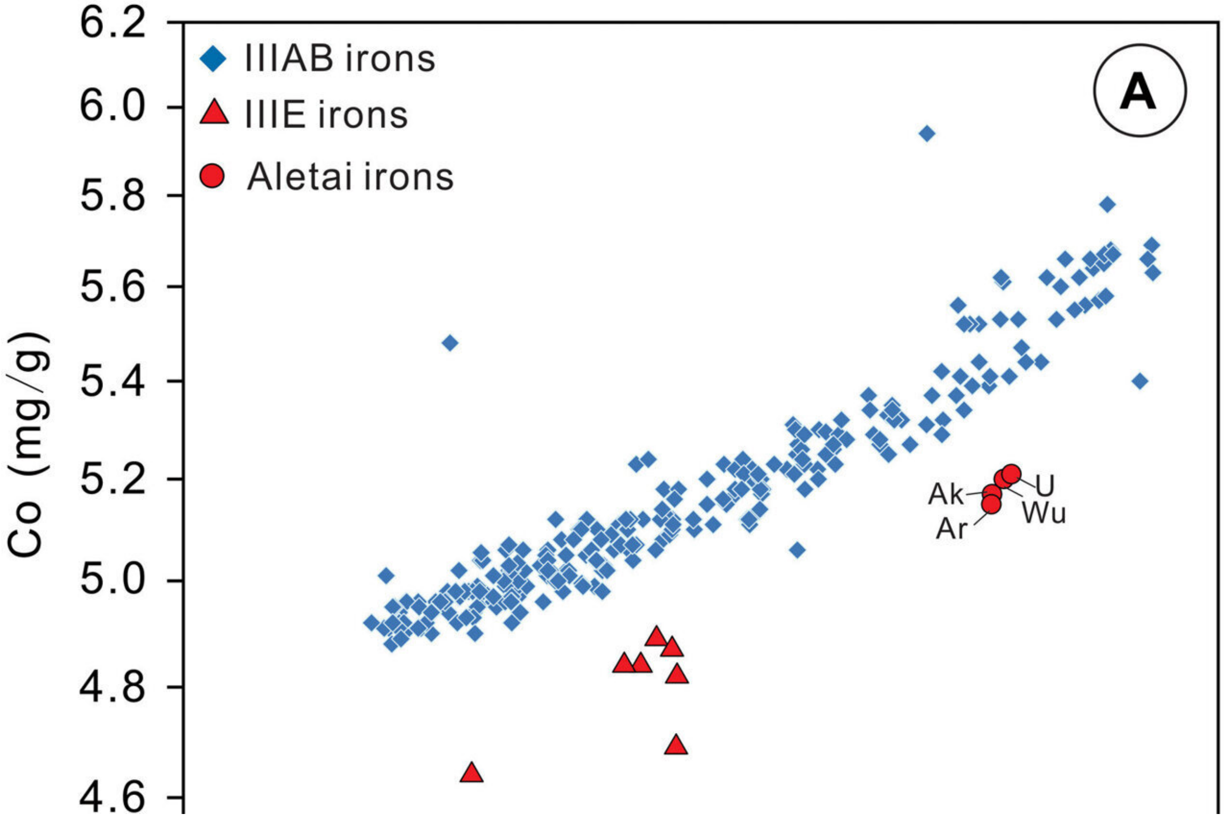
Map of the recovery sites of Aletai masses. The close-up of recovery sites in Xiaodonggou area shown in the top right corner. Only the masses listed in the Meteoritical Bulletin (www.lpi.usra.edu/meteor/metbull.php) are plotted. The base map is from Google Earth. Asterisk denotes the unnamed 15 kg of mass that was found in the Xiaodonggou area close to Wuxilike and Akebulake without precise latitude and longitude. We plot it in the middle between Wuxilike and Akebulake. Credit: *Science Advances* (2022). DOI: 10.1126/sciadv.abm8890

During their entry to Earth, meteoroids and asteroids can deposit energy, causing great concerns to astrophysicists. Recent discoveries of the massive Aletai irons in Northwest China constitute the longest-known strewn field, approximating 430 kilometers, that indicate this unique process. Using petrographic and trace elemental studies, scientists suggest that Aletai masses exhibit unique compositions, and therefore may be from the same event.

In a new report now published in *Science Advances*, Ye Li and a team of scientists at the Chinese Academy of Sciences, the University of Arizona, U.S., and the Institute for Nuclear Research in Hungary, used numerical models to suggest the stone skipping–like trajectory is associated with a shallow-entry angle to facilitate the exceptionally long-strewn field for a single-body entry scenario. While the trajectory of stone-skipping would not contribute to a large impact energy on the ground, the team believes it could lead to energy dissipation during its extremely long-distance flight.

Meteoroids entering Earth's atmosphere

Meteoroids and asteroids can invade the Earth's atmosphere at different entry angles and velocities to break into fragments in the atmosphere and fall as meteor showers to create funnels and craters. During the process, meteoroids and asteroids can deposit large amounts of kinetic energy causing explosions and affecting the ecosystem. It is therefore crucial to understand how meteoroids fall through the atmosphere. The massive Aletai irons were first recovered in the Aletai region in Northwest Xinjiang, China, close to the China-Mongolia Border. The extraordinary long-strewn field implies the trajectory or dynamics of the asteroid Aletai to be unique. In this work, Li and the team conducted a comprehensive study of petrology and whole-rock trace element geochemistry with radionuclide analysis and numerical modeling for Aletai irons. The outcomes showed a 430-km-long strewn field.



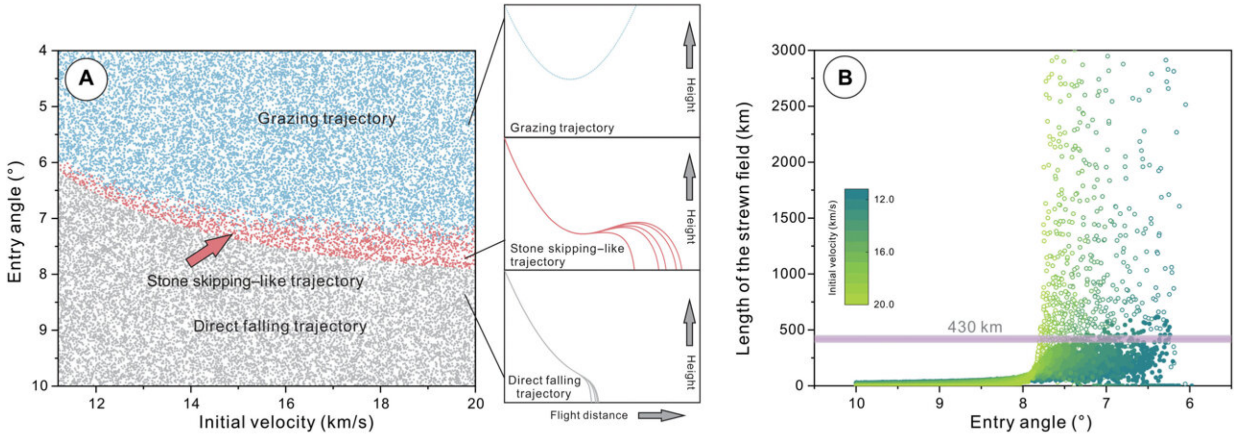
Trace elements versus Au for Aletai irons. Aletai data from this study, and IIIE and IIIAB data for comparison. IIIAB data from Chabot and Zhang. IIIE data from Malvin et al. and online Meteoritical Bulletin Database (www.lpi.usra.edu/meteor/metbull.php). U, Ulasitai; Wu, Wuxilike; Ak, Akebulake; Ar, Armanty. Credit: *Science Advances* (2022). DOI: 10.1126/sciadv.abm8890

The experiments

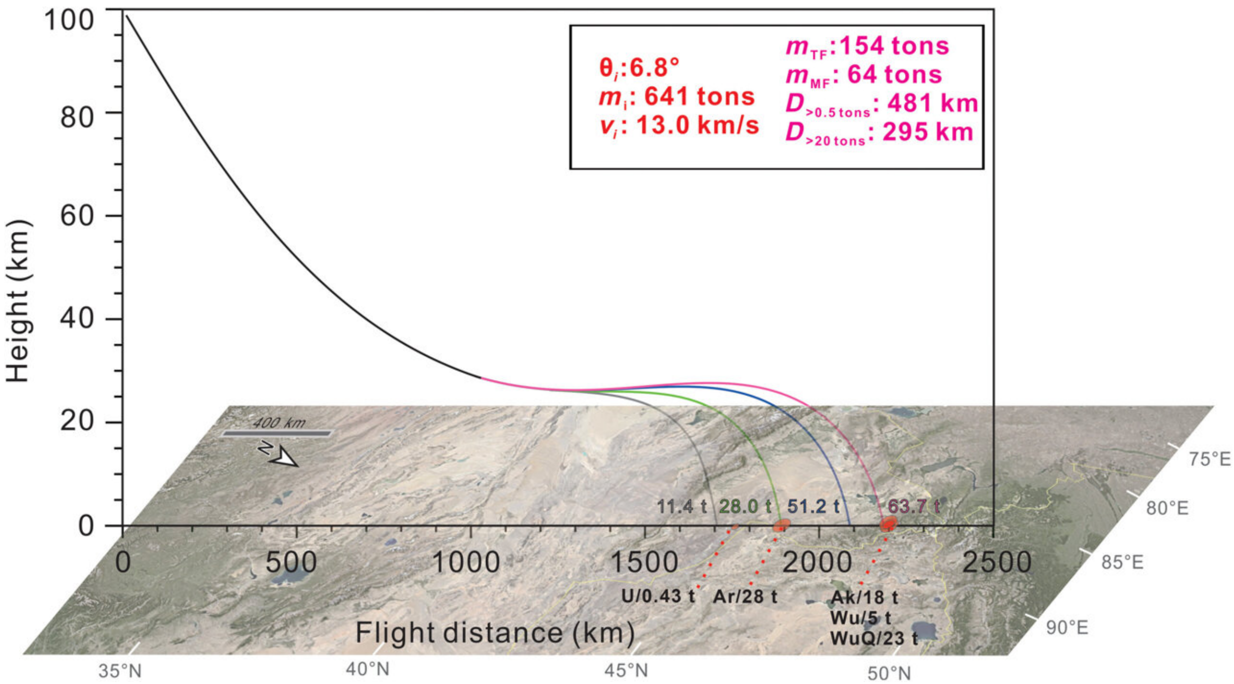
Researchers had previously conducted petrographic studies for some large masses and in this work, the team performed detailed mineralization studies for previously retrieved masses of Akebulake and WuQilike asteroids. They then used neutron activation analysis data of Aletai irons and noted select elements, including copper and gold content. The researchers studied the radionuclide contents and the initial mass of Aletai and credited a larger initial mass to the asteroid; which is more realistic. Using numerical simulations, the team next indicated the flying direction of Aletai to be from Southwest to Northwest, with disintegration occurring near the Northwest region. The team tested the dynamics of the asteroid by assuming a single body entry in the atmosphere. During numerical simulations, they used the Monte Carlo method and input three basic parameters including the initial velocity, initial mass and entry angle. Among the variables, the stone skipping–like trajectory described the flight path of the samples.

The unique strewn field of a stone skipping–like trajectory

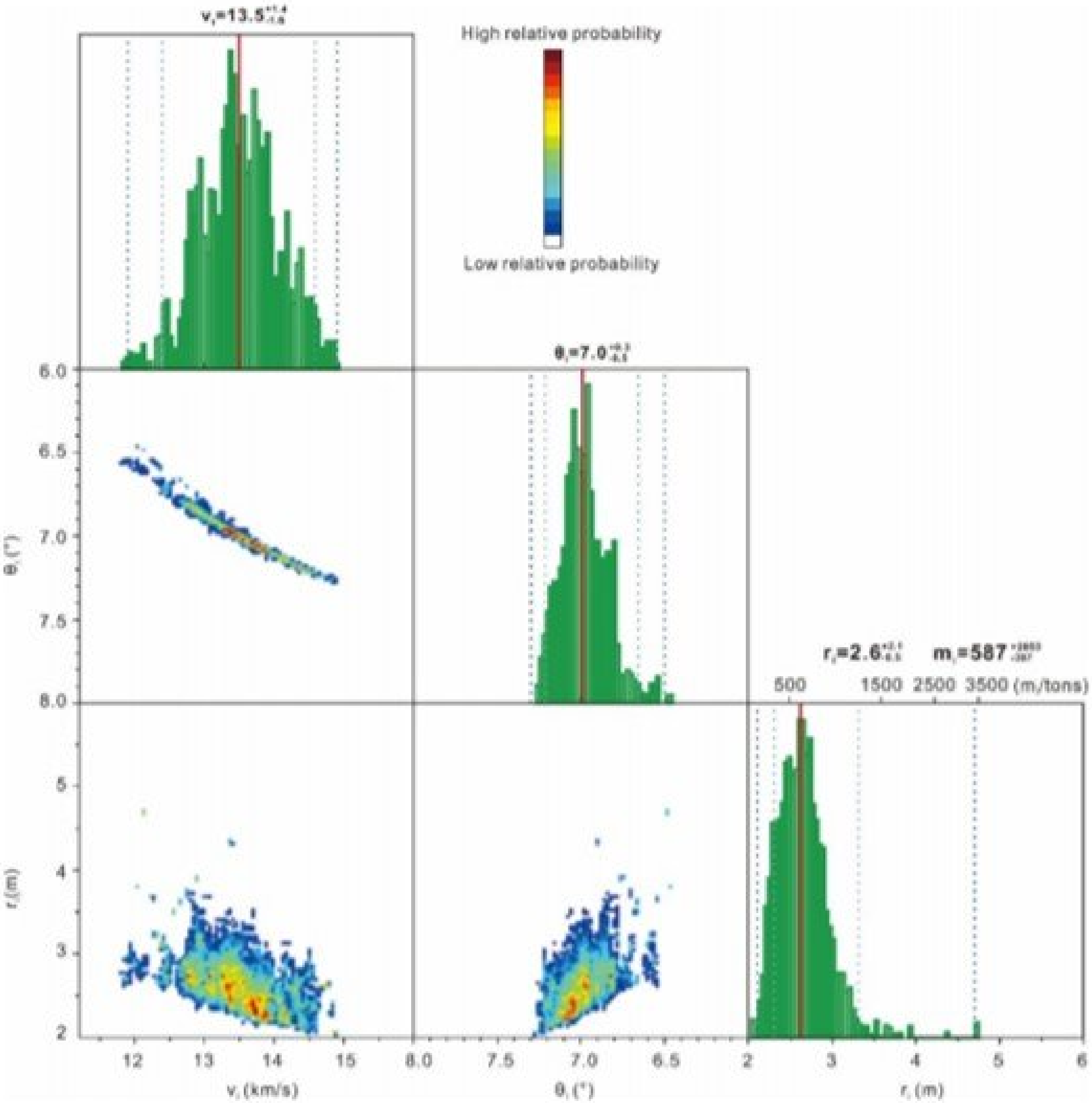
For all samples with a strewn field length of more than 430 km, the stone skipping–like trajectory appeared to be necessary. The scientists explored the trajectory of Aletai via the Markov Chain Monte Carlo method, and the outcomes revealed the Aletai asteroid to have an initial velocity approximating 11.9 to 14.9 km/s. The researchers also calculated an entry angle of 6.5 to 7.5 degrees with an initial mass approximating 280 to 3440 tons with a radius ranging from 2.1 to 4.7 m. The final impact velocity and impact energy were relatively low with an impact angle of 19 to 26 degrees.



MC modeling results for asteroid Aletai. The entry angle versus initial velocity plotting (A) and length of the strewn field versus entry angle plotting (B) based on the Monte Carlo method. In (A), the gray spots refer to the samples with direct falling trajectory, the red spots refer to the samples with stone skipping–like trajectory, and the blue spots refer to the samples as earth's grazers. The schematic trajectory diagrams from Monte Carlo modeling are shown to the right. In (B), the open circles refer to the samples with a stone skipping–like trajectory, and the solid circles refer to the direct falling objects. The length of strewn field is assumed to be equivalent to the longest distance between fragments weighing over 0.5 tons individually. Panel (B) only shows the samples with length of strewn field less than 3000 km; there are also a few samples with length over 3000 km. Credit: *Science Advances* (2022). DOI: 10.1126/sciadv.abm8890



A representative trajectory motion of asteroid Aletai. The numbers above the x axis refer to the computed weight of final masses, and only the fragments with weight over 0.5 tons are shown here. The currently known Aletai masses are marked by red ellipses along the x axis. θi = entry angle, mi = initial mass, vi = initial velocity, mTF = the weight of total final fragments, mMF = the weight of the largest final fragment, D>0.5 tons = the longest distance between fragments with individual weight over 0.5 tons (assumed to be equal to the length of the strewn field), D>20 tons = the longest distance between fragments with individual weight over 20 tons, and WuQ = WuQilike. The base map is from Google Earth. Credit: *Science Advances* (2022). DOI: 10.1126/sciadv.abm8890



Posterior distributions of entry angle, initial velocity and initial mass or radius from MCMC modelling. In the histograms, the red line marks the median value, the dotted light blue lines constrain 95% credible bounds, and the dotted dark blue lines constrain 99% credible bounds. The results shown on the top of histograms are from 99% credible bounds. Credit: *Science Advances* (2022). DOI: 10.1126/sciadv.abm8890

Outlook: Understanding asteroid Aletai

In this way, Ye Li and colleagues showed how the asteroids Akebulake, WuQilike and Aletai masses shared strong similarities in mineral chemistry. The scientists analyzed these masses that maintained identical bulk compositions to suggest pairing in the Aletai masses. They characterized the Aletai irons by higher gold and copper content, and unexpected contents of iridium. The team then combined additional geochemical data with petrologic compositions of Aletai iron to describe its unique and incomparable nature to other samples in the world meteorite collection. The outcomes suggest all Aletai masses to be from the same fall event. The modeling results further highlighted the fragmentation of Aletai into smaller pieces in the atmosphere while emphasizing the entry angle to Earth. The team underscored the significance of the stone skipping–like trajectory, which had not been previously identified, and potentially overlooked in the historical record, and credited its uniqueness to its geochemistry and extremely long-distance flight.

More information: Ye Li et al, A unique stone skipping–like trajectory of asteroid Aletai, *Science Advances* (2022). DOI: 10.1126/sciadv.abm8890

P. Brown et al, The orbit and atmospheric trajectory of the Peekskill meteorite from video records, *Nature* (2003). DOI: 10.1038/367624a0