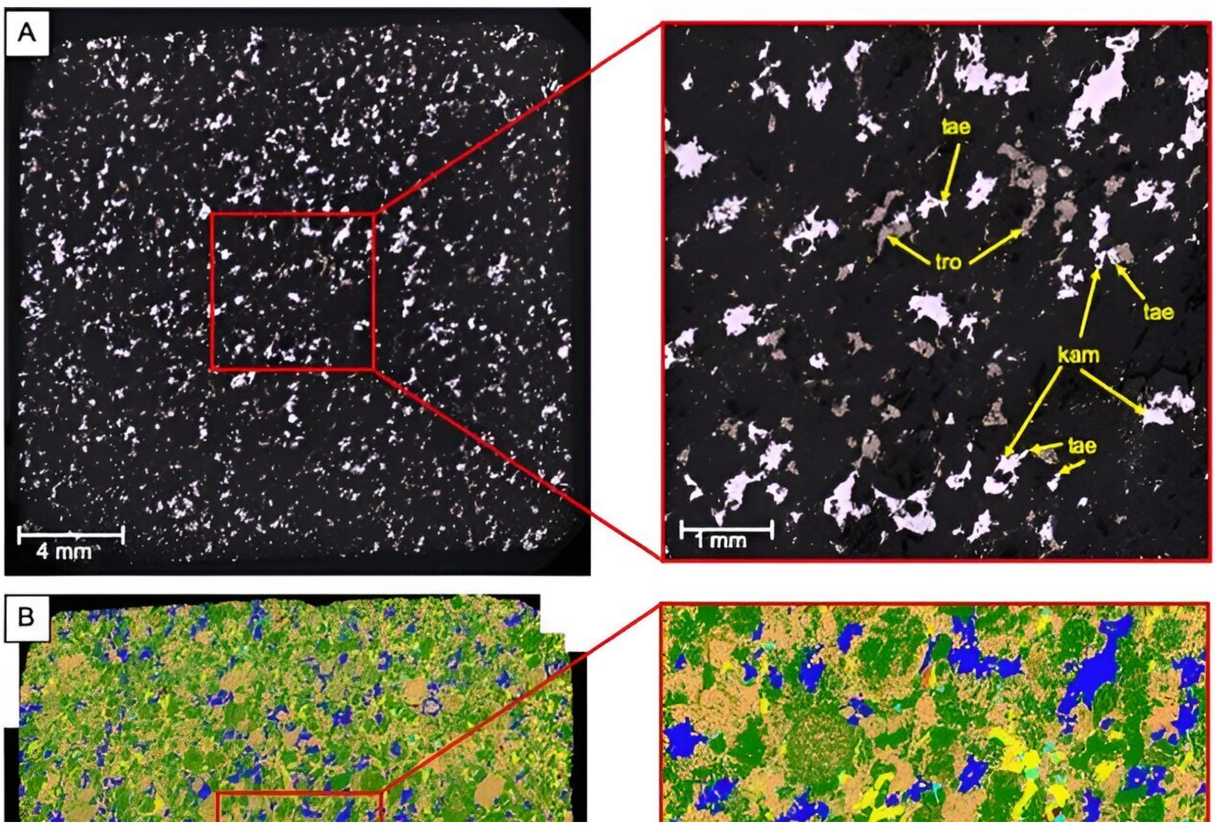
Mining asteroids: A new method to extract metals from asteroids

October 31 2023, by Thamarasee Jeewandara



(A) Reflected light images of meteorite NWA 13876 (tae: taenite, tro: troilite, kam: kamacite) and (B) corresponding false color mineral map generated by SEM–EDX analysis. Credit: *Scientific Reports*, doi: 10.1038/s41598-023-44152-0

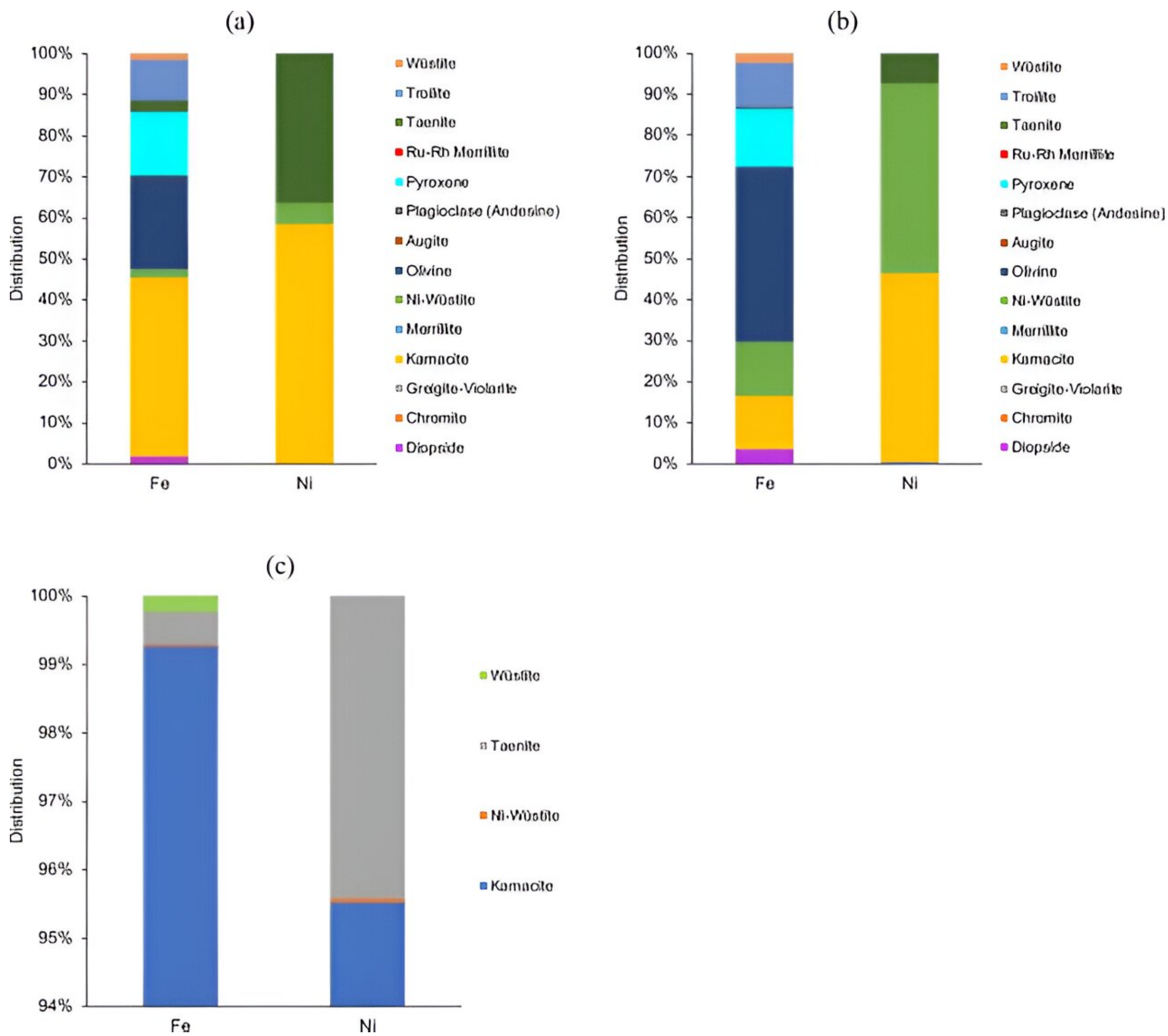
Extraterrestrial mining and metal processing are key strategies for space exploration. In a new study in *Scientific Reports*, Rodolfo Marin Rivera, and a team of scientists in materials science, conducted catalytic dissolution of metals from meteorite proxies of metal-rich asteroids by using a deep eutectic solvent. These solvents are important for extraterrestrial mining since they can be designed to have relatively low vapor pressures and can comprise organic waste products from extraterrestrial settlements.

The team studied three types of meteorites, two chondrites, and one iron meteorite. The chondrite samples contained silicates with metal-rich phases such as native alloys, sulfides, and oxides, of which, the metallic iron-nickel and troilite formed the most abundant metal-bearing phases in all three samples, with specific hues in the iron-rich meteorite.

The scientists subjected the samples to chemical micro-etching experiments with iodine and iron (III) chloride as oxidizing agents in a deep eutectic solvent formed by mixing choline chloride and ethylene glycol.

Extraterrestrial iron meteorites

It is possible to establish viable extraterrestrial metal extractions, and the efficient use of local materials and resource recovery from space can significantly reduce the mass, cost, and environmental constraints of space missions. These large metal-rich asteroids are parental bodies of iron meteorites and metal-rich carbonaceous chondrites. These metals can provide a local source of materials to establish a human settlement in space or other terrestrial bodies. Near Earth asteroids contain valuable platinum group metals and iron, nickel, and cobalt greater than that found on the Earth's surface.



Mineral distribution of iron and nickel as determined by automated SEM–EDX analysis in (a) NWA 13876, (b) NWA 7160 and (c) Campo del Cielo. Credit: *Scientific Reports*, doi: 10.1038/s41598-023-44152-0

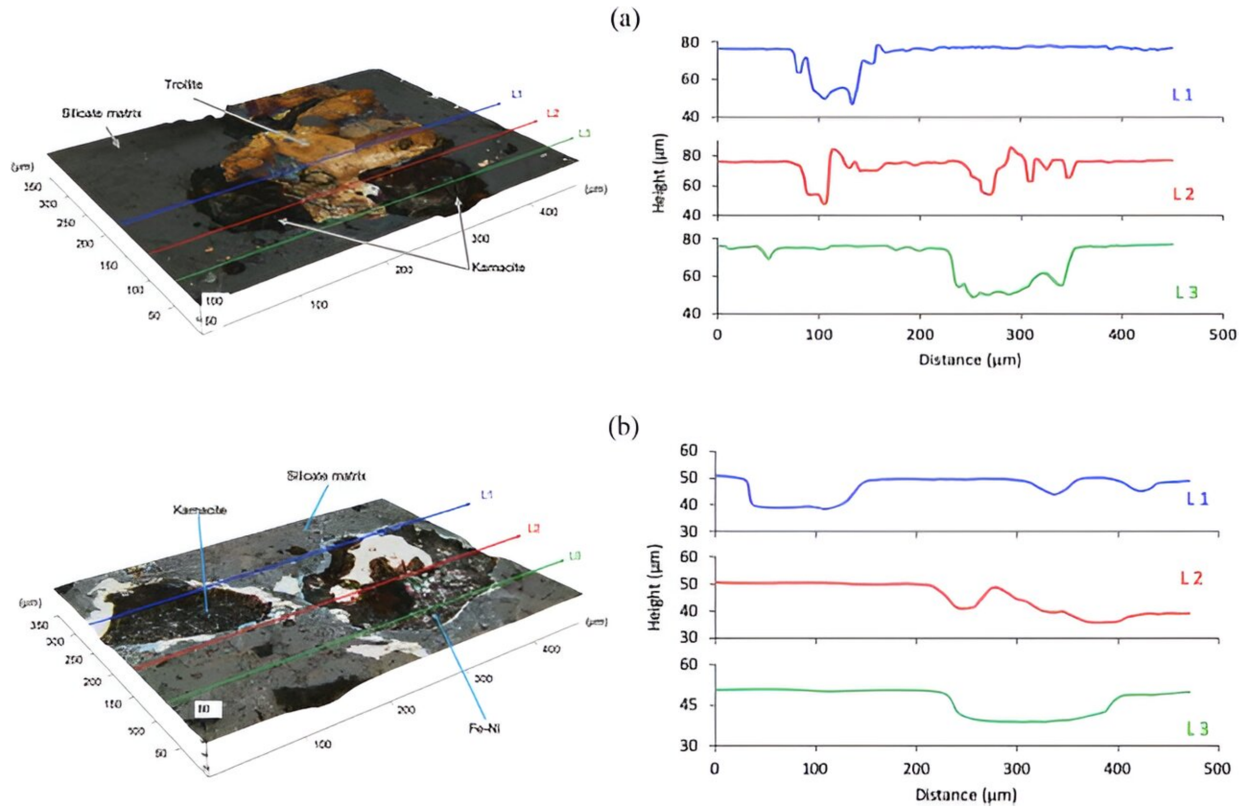
The asteroid signatures were much like the asteroid 16 Psyche, the largest metal-rich body in the solar system. This work investigated a proof-of-concept method to extract metals from meteorite proxies of asteroids by using non-aqueous deep eutectic solvents.

Rivera and team determined the depth and dissolution rates by analyzing the 3D topography of the etched samples, prior to and after etching. Chondrite meteorites can be characterized by diverse minerology where the olivine, pyroxene, plagioclase, and kamacite minerals are the most prominent, and the composition depends on the degree of metamorphosis to which they were subject.

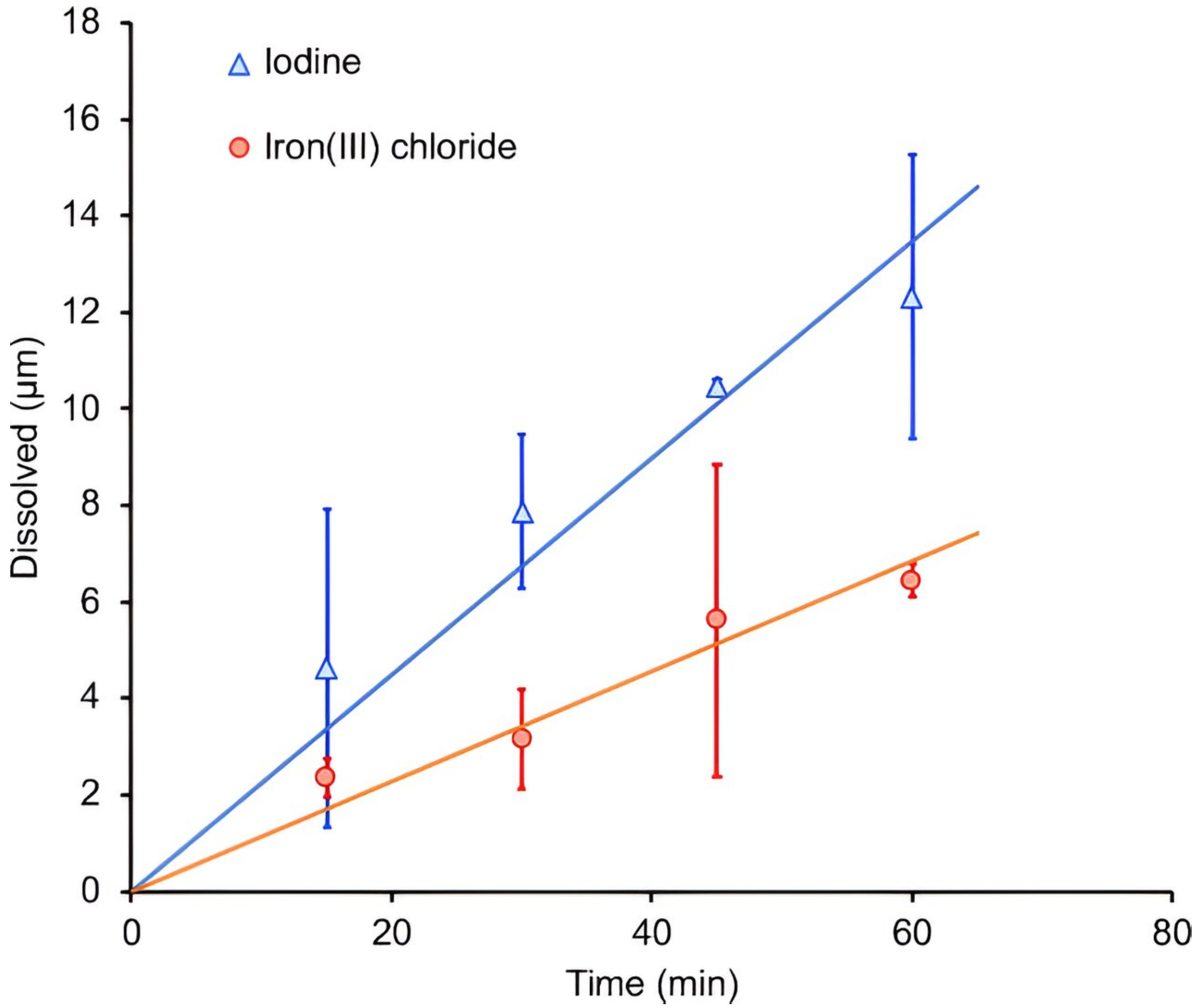
Sample diversity

Diverse samples of chondrites contained iron-nickel alloys, iron sulfide and iron oxide minerals, while less abundant in iron-nickel-rich minerals with a higher proportion of iron sulfide. The silicate matrix is made of chondrule forming olivine and pyroxene, with traces of plagioclase feldspar.

They showed the capacity to classify chondrules of H3 chondrites petrographically into six widely disperse chondrules. The Campo del Cielo sample for example is an iron-nickel meteorite entirely composed of iron-nickel rich mineral phases. Kamacite is documented to contain significant trace element components.



Etch depth in sample references (a) NWA 13876 and (b) NWA 7160, after 60 min of etching with 0.1 mol dm^{-3} iodine as oxidizing agent. In the left-hand side, the 3D reflected light images (with line profiles) are described, whereas the topographic line profiles are shown in the right-hand side of the corresponding 3D image. Credit: *Scientific Reports*, doi: 10.1038/s41598-023-44152-0



Etch depth of iron-rich phases in the Campo del Cielo meteorite with 0.1 mol dm^{-3} of iodine and $FeCl_3$ as oxidizing agents in the ChCl: 2EG eutectic system at 50 °C. Straight lines describe the corresponding trend. Error bars indicates the standard deviation of triplicate experiments. Credit: *Scientific Reports*, doi: 10.1038/s41598-023-44152-0

Rivera and team studied the iron and nickel mineral distributions across meteorite samples, where iron was primarily hosted in silicate phases including olivine, pyroxene, and augite, alongside several different highly notable elements. The team explored the catalytic oxidation of metals including superalloys, and minerals, and the chemical etching of chondrite meteorites. Rivera and the team conducted additional chemical etching of the Camp del Cielo meteorites with iodine and iron chloride as oxidizing agents before and after chemical etching.

Outlook

In this way, Rodolfo Marin Rivera and team used iron (III) chloride and iodine as oxidizing agents to solubilize metals from three meteorite proxies of near-Earth asteroids, using deep eutectic solvent.

Analytical studies confirmed the chemical association of nickel with iron-rich metal phases in the original samples, the researchers further identified additional metals of interest for space technologies including traces of ruthenium and rhodium.

The use of asteroids as mineral and metal resources provide a key step during space exploration with further investigations required for viable economic activity. The proposed technology is at a nascent stage and is very promising for metal recovery.

More information: Rodolfo Marin Rivera et al, A novel method for extracting metals from asteroids using non-aqueous deep eutectic solvents, *Scientific Reports* (2023). DOI: 10.1038/s41598-023-44152-0

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