# Internship project proposal for MISIP 2024 [Project1]

1) Project title: Rheological measurement of Martian dust slurries
2) Supervisors (*corresponding): Jun Kameda*
3) Number of students: 1
4) Detailed description of the project (including aim, detailed plan and expected outcome):

**Aim**

Various landforms have developed on the Martian surface that are thought to have been formed by the involvement of liquid water. For example, gullies and lobe-like deposits have been observed at some slope sites, and it has been suggested that these may have been formed by debris flow-like events that occur in watery environments, rather than dry granular flows (e.g., Iverson 1997; Naruse, 2016). Therefore, rheological characterization of Martian dust-water mixtures is important for understanding such landform formation processes. The aim of this project is to conduct rheological experiments on water-dispersed samples of Martian dust simulants to evaluate their flow properties and, based on these findings, to understand the landform development processes described above.

**Detailed plan**

*Slurry samples*

Solid samples will be MGS-1 (CLASS Exolith Lab, 2019), recently proposed as a Mars dust simulant, and its clay mineral or gypsum-added derivatives (MGS-1C and MGS-1S). Slurries are prepared by dispersing these samples in water with different solids/water ratios.

*Rheological experiments*

Rheological measurements will be conducted using a stress-controlled rheometer (HR2; TA Instruments) with a flat plate geometry to study the yield strength, viscosity, and sol-gel transition behavior of slurries and their temperature dependence (around 5 to 40°C). If the sample is a sedimentable sample, vane test will also be performed by using a viscometer (DV2T, Brookfeld).

*Numerical modeling of debris flows*

For run-out modeling of debris flows, simulations of one-dimensional downslope flow will be conducted on the hypothetical slopes of Mars using the BING program developed by Imran et al. (2001).

**Expected outcome**

This project may provide some constraints on the question of whether liquid water existed on the Martian surface. It is expected to contribute to our understanding of the evolutionary processes of the Martian surface environment.

**References:**


CLASS Exolith Lab (2019) Datasheet for MGS-1 Mars global simulant. University of Central Florida, USA.

Imran, J., Harff, P. and Parker, G. (2001) A numerical model of submarine debris flow with graphical user interface. Comp. Geosci. 27, 717−729.

Iverson, R.M. (1997) The physics of debris flows. Rev. Geophys. 35, 245−296.

Naruse, H. (2016) Origins of lobate landforms on Mars: Preliminary examination from an inverse analysis of debris-flow deposits. J Geography, 125, 163−170.

# Internship project proposal for MISIP 2024 [Project 2]

1) Project title: Understanding the origin of organic matter heterogeneity and organic matter-mineral relationships within the matrix of CM2 carbonaceous chondrites.

2) Supervisors (*corresponding): Christian Potiszil*, Katsura Kobayashi, Ryoji Tanaka, Tak Kunihiro, Hiroshi Kitagawa, Tsutomu Ota, Masahiro Yamanaka and Chie Sakaguchi

3) Number of students: 3-4

4) Detailed description of the project (including aim, detailed plan and expected outcome)

During MISIP 2023, the matrix of carbonaceous chondrite meteorites Aguas Zarcas (CM2) and Murchison (CM2) were investigated. It was found that the Raman spectra of darker and brighter areas of the Aguas Zarcas matrix demonstrated distinct differences in terms of their organic matter. The darker areas were found to be richer in phyllosilicate minerals, whereas, the brighter areas were enriched in Tochilinite. However, it was unclear exactly why the organic matter between the two regions was so different. Leading on from MISIP, 2023, a comprehensive examination of the mineralogy and organic matter, including isotopic composition, within the brighter and darker regions of the matrix is necessary. Nebula, accretionary and parent body processes all contribute to the end composition and isotopic characteristics of a given carbonaceous chondrite. Therefore, after completing a comprehensive analysis of the carbonaceous chondrite matrix of Murchison and Aguas Zarcas, it will be possible to evaluate the reason for the differences in organic matter between brighter and darker regions of the matrix.

The internship students will work together to undertake a comprehensive analysis of the Aguas Zarcas and Murchison carbonaceous chondrites. The methodology will include sample preparation procedures (including standard preparation), bulk analysis and in situ analysis of both elements and isotopes, as well as the determination and mapping of inorganic and organic phases. Bulk analytical techniques will include elemental analysis (C, H, O, N) using an isotope ratio mass spectrometer (EA-IRMS) and Noble gas mass spectrometer for noble gas isotopes (Ne). In-situ analysis will include phase and elemental abundance determination and mapping using scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDS), organic and inorganic phase characterization with Raman spectroscopy and acquisition of isotopic and compositional information through the application of secondary ion mass spectrometry (SIMS). The internship students will then discuss and interpret the data, to build up a picture of the processes affecting the organic and mineral phases within the matrix carbonaceous chondrites.

The students will be exposed to an array of different analytical techniques and set-ups, as well as lab environments. Such experience will greatly contribute to the student's scientific experience and aid them in a future career in science, whether that be in academia or industry. A large comprehensive data set will be acquired and the students will gain valuable data analysis and interpretation skills. In terms of the scientific outcomes, the students will help to determine the extent of heterogeneity with the matrix of different carbonaceous chondrites and thus increase our understanding of mineral-organic relationships and both pre-accretionary and asteroidal processes. With this information a better understanding of the formation and evolution of solar system materials will be obtained.

# Internship project proposal for MISIP 2024 [Project 3]

1) Project title: Detection of water in Martian mantle
2) Supervisors (*corresponding): Takashi Yoshino
3) Number of students: 1
4) Detailed description of the project (including aim, detailed plan and expected outcome):

Where did the water that flowed on Mars billions of years ago go? This is a long-standing mystery. We know that some of water is trapped as ice just below the surface. Studies of Mars' atmosphere show that some of the water escaped into space. Earth's magnetosphere prevents the atmosphere from escaping into space, while Mars' magnetosphere is weak, and even moisture can escape from the planet. But given the current proportion of hydrogen in Mars' atmosphere, that's probably not the only place the water goes. In other words, most of the water must have gone somewhere else. One likely candidate is rocks inside Mars.

The InSight mission found that the Martian mantle is shallower than previously thought, and that bridgmanite, which is dominant phase in the Earth's lower mantle, does not appear, and ringwoodite is thought to exist at the bottom of the mantle. Ringwoodite is a high-pressure polymorph of olivine and is known to be able to incorporate a large amount of water into its crystal structure. Electrical conductivity measurement is an effective method for detecting the amount of water.

In this project, we investigate the effect of water on the electrical conductivity of ringwoodite. A selected student will synthesize iron-rich ringwoodite, which is thought to be stable under conditions at the bottom of the Martian mantle, using a Kawai-type multi-anvil, and measure the electrical conductivity of this sample under similar pressure conditions at low temperatures where dehydration does not occur. We investigate the effect of water on the electrical conductivity of ringwoodite. By comparing this result with existing proposed electrical conductivity profiles, we will consider the amount of water present in the Martian mantle.

Plan

1) Preparation of olivine powder using gas-controlled furnace
2) Synthesis of Fe-rich ringwoodite with various amounts of water
3) Phase identification of synthetic materials by XRD, SEM and FTIR
4) In situ electrical conductivity measurements of ringwoodite by impedance analyzer under high pressure and high temperature
5) Post-experimental analysis of recovered samples

# Internship project proposal for MISIP 2024 [Project 4]

1) Project title: Effect of water on viscosity of mantle mineral
2) Supervisors (*corresponding): D. Yamazaki*
3) Number of students: 1 (max)
4) Detailed description of the project (including aim, detailed plan and expected outcome):

Viscosity of Earth's mantle is a key parameter to constraint the convection of the mantle because viscosity indicates the mobility of deforming material, and hence many geophysical observations have been done to estimate viscosity of the mantle. On the other hand, from the material scientific point of view by means of theoretical calculation and/or experimental approach, viscosity-related rheology of the mantle minerals is not well-known.

Many researches may believe the large effect of water on physical and chemical properties, for example, water enhance the chemical diffusion and hence decrease viscosity and increase electrical conductivity, reduce the rigidity and resultant elastic wave velocities, decrease the melting temperature. In the Earth, a capability of water storage in the mantle transition zone is much higher than those of the other mantle regions because the main mantle transition zone constituting minerals, wadsleyite and ringwoodite, can contain a few wt. % of water. Although such high capability of the mantle transition zone, water effects on rheology and viscosity of wadsleyite and ringwoodite are not studied well.

In this internship project, as the first step of the study on effect of water on rheology of the mantle transition zone, the relative deformation strength between "dry" and "wet" ringwoodites are experimentally measured to estimate directly the water effect on viscosity. In the experiments, polycrystalline "dry" and "wet" ringwoodites can be synthesized for the starting materials in the Kawai-type multianvil apparatus and be deformed simultaneously with the series setting in the deformation cell assembly by using D111-type high pressure deformation apparatus. After deformation, recovered samples can be analyzed by XRD for phase identification, SEM for the sample length measurement to estimate the strain, and EBSD for crystallographic orientation measurement to estimate the dominant deformation mechanism.

# Internship project proposal for MISIP 2024 [Project 5]

1) Project title: Water cycle in Mars inferred from water contents of Fe-rich silicates
2) Supervisors (*corresponding): Takayuki Ishii*
3) Number of students: 1
4) Detailed description of the project (including aim, detailed plan and expected outcome):

Unlike Earth, present Mars has no ocean and active plate tectonics. However, early Mars seems to be covered with oceans. An open question is how water is distributed in Mars. Water is considered to have been stored in the Martian mantle since its formation. Although the water content of the Martian mantle is still under debate, weight percent levels of water can be stored in the Martian mantle through the Martian history. Because water can lower melting temperature and viscosity of the Martian mantle rocks, it can affect thermal evolution of the Martian interior and control crustal formation as well as presence of oceans on the Martian surface. To better understand evolution of the Martian surface and interior, quantitative constraints on water in the Martian mantle are essential.

Water distribution and budget in the Martian mantle can be estimated from water contents in Martian mantle minerals because water is likely stored in minerals mainly as structurally-bound hydroxyl groups (OH). A distinctive feature of the Martian mantle composition is enrichment in iron compared with the Earth's mantle composition, resulting in $(Mg,Fe)_2SiO_4$ iron-enriched magnesium silicates as major minerals such as olivine, wadsleyite, and ringwoodite depending on depth. The Fe/(Mg+Fe) (mol) of these minerals in the Martian mantle is in a range of 0.3-0.4, which is much higher than those in the Earth's mantle (~0.1). Previous experimental studies constrained water contents of these minerals mainly at the Earth's mantle composition, estimating water contents up to 1-2 wt.%. The effect of iron on water content of olivine has been investigated up to Martian mantle compositions. On the other hand, water contents of olivine high-pressure polymorphs of wadsleyite and ringwoodite at Martian mantle compositions have not been investigated yet.

In this project, you will investigate effects of iron on water contents of wadsleyite and ringwoodite up to Fe/(Mg+Fe) = 0.4 by means of multi-anvil high-pressure experiments in combination with post-analyses of recovered minerals. Based on the results, you will discuss water cycle in Mars.

Plan

1) Preparation of starting materials of $(Mg_x,Fe_{1-x})_2SiO_4$ (x=0.3-0.5) plus 15 wt% of water from using MgO, FeO, $SiO_2$, and $Mg(OH)_2$
2) Preparation of high-pressure experiments
3) High-pressure syntheses of wadsleyite and ringwoodite single crystals with dimensions more than 100 microns up to 20 GPa and 1600-2000 K
4) Post-experimental analyses of recovered samples using X-ray diffraction, Raman spectroscopy, Fourier Transform Infrared Spectroscopy, and electron microprobe analysis

# Internship project proposal for MISIP 2024 [Project 6]

1) Project title: **Understanding Planetary Surfaces; A Remote Sensing and Laboratory-based Approach for Future Mission Planning**
2) Supervisors (*corresponding): **Trishit Ruj * (trishitruj@okayama-u.ac.jp) / Matthew Izawa (matthew_izawa@okayama-u.ac.jp)**
3) Number of students: **1 or 2.**
4) Detailed description of the project (including aim, detailed plan, and expected outcome):

**Aim:** To familiarize students with geospatial and hyperspectral Planetary data, increasing their understanding of how both types of data sets are used to interpret Planetary surface processes. Using mission data combined with laboratory measurements will develop real-world skills in planetary exploration.

**Detailed Plan:** There are two parts of this project. Firstly, Remote Sensing and data handling (supervised by Ruj), and spectral measurements of relevant meteorite analogs (Izawa) to facilitate the interpretation of surface compositions and geological histories (both).
The internship program will commence with a comprehensive introduction to planetary geospatial data sets and acquisition techniques, along with interpretation through GIS software. To ensure a deep understanding of planetary surface processes, interns will be assigned to specific case studies relevant to their research interests (possibly related to JAXA's future mission). They will learn to employ analytical software (GIS, ENVI) and data visualization tools, with milestones set for demonstrating proficiency. They will then select (with guidance) relevant meteorite and mineral analogs and conduct spectral reflectance measurements. Combining their measurements with available spectral libraries, they will provide their own synthesis of mapping, mineralogy, and meteorite linkages to interpret the geological history of their target body/bodies. Potential targets dark asteroids possibly linked to carbonaceous chondrites (e.g., Ryugu, Bennu, Phobos, Ceres), iron-rich surfaces (e.g., Psyche), or selected regions of Mars.

**Expected outcome:** The culmination of the program will be a capstone presentation where interns present their findings and insights, showcasing their skill development in planetary data handling and interpretation. It is expected that new insights into the geology, mineralogy, and extent of analogy with known meteorites will be produced.