Position Description

1. General Information

Name of the position	**The fluid and granular mechanics of magmatic sulphide ore formation**
Foreseen enrolment date	January 2025
Position is funded by	• COFUND, Marie Skłodowska-Curie Actions (MSCA), Horizon Europe, European Union • Aix Marseille Université (AMU) • Monash University (Monash)
Research Host	Aix Marseille Université
PhD awarding institutions	Aix Marseille Université & Monash University
Locations	Primary: Marseille, France Secondary: Melbourne, Australia
Supervisors	Prof Pascale Aussillous (AMU) A/Prof Anja Slim (Monash)
Group of discipline	Mathematics, Physics, Earth Sciences

2. Research topics (only one of these projects will be funded)

Project 1: *The fluid and granular mechanics of magmatic sulphide ore formation (experiments and mathematical modelling)*
New discoveries of critical metals ore deposits are urgently needed for the transition to renewable energy. Finding them efficiently requires an understanding of the fundamental processes involved in their formation. One significant source of nickel, cobalt and platinum-group elements is in magmatic sulphide deposits. Sulphide-rich liquid forms a small $\lesssim$1% fraction of some molten magmas. Various metals are preferentially absorbed by droplets of this liquid during active transport, and they form valuable ores when deposited in sufficiently high concentration. Crucial questions are: • how do the small droplets of this liquid in an active magmatic system collect into nearly pure mineable deposits and • where do such deposits form?

This project has received funding from the European Union's Horizon Europe research and innovation programme under the Marie Skłodowska-Curie grant agreement № 101081465

The sulphide liquid is significantly heavier and less viscous than the dominant silicate melt. It is also one of the last components of the magma to solidify and hence is thought to interact with granular mushes of silicate crystals.

This project would consider flows of two liquids (representing the silicate and sulphide liquids) through a granular material (representing the silicate crystals) using a combination of analogue experiments and mathematical predictions using well-established continuum models for the deformation of granular materials combined with appropriate limits of the Navier-Stokes equations for fluid flow.

The experimental components of this project would be completed at the Laboratoire IUSTI at Aix-Marseille Université under the supervision of Prof Pascale Aussillous. The mathematical modelling components would be completed at Monash University under the supervision of A/Prof Anja Slim. Application of the outcomes to magmatic sulphide deposits would be under the guidance of Dr Margaux Le Vaillant at CSIRO Mineral Resources.

Supervisors: Prof Pascale Aussillous (AMU); A/Prof Anja Slim (Monash); Dr Margaux Le Vaillant (CSIRO)

Research Fields: Mathematics, Physics

Project 2: *The fluid and granular mechanics of magmatic sulphide ore formation (experiments and data-driven insights)*

New discoveries of critical metals ore deposits are urgently needed for the transition to renewable energy. Finding them efficiently requires an understanding of the fundamental processes involved in their formation. One significant source of nickel, cobalt and platinum-group elements is in magmatic sulphide deposits. Sulphide-rich liquid forms a small $\lesssim$1% fraction of some molten magmas. Various metals are preferentially absorbed by droplets of this liquid during active transport, and they form valuable ores when deposited in sufficiently high concentration. Crucial questions are:

- how do the small droplets of this liquid in an active magmatic system collect into nearly pure mineable deposits and
- where do such deposits form?

The sulphide liquid is significantly heavier and less viscous than the dominant silicate melt. It is also one of the last components of the magma to solidify and hence is thought to interact with granular mushes of silicate crystals.

This project would consider flows of two liquids (representing the silicate and sulphide liquids) through a granular material (representing the silicate crystals) using a combination of analogue experiments and machine learning / AI tools to extract trends from the data and create data-derived models.

The experimental components of this project would be completed at the Laboratoire IUSTI at Aix-Marseille Université under the supervision of Prof Pascale Aussillous. The data analysis components would be completed at Monash University under the supervision of A/Prof Anja Slim. Application of the outcomes to magmatic sulphide deposits would be under the guidance of Dr Margaux Le Vaillant at CSIRO Mineral Resources.

Supervisors: Prof Pascale Aussillous (AMU); A/Prof Anja Slim (Monash); Dr Margaux Le Vaillant (CSIRO)

Research Fields: Mathematics, Physics, Earth Sciences

Project 3: *Flows of two liquids interacting with a granular medium*

This is a version of the above projects with a shift of emphasis from the geological application to a broader exploration of the range of physical behaviours.

In the last two decades, there has been significant progress in understanding slow deformation of granular media and predictive continuum models are well-established. However, an area awaiting further exploration is the interaction of two liquids with a granular medium. Adding a second liquid introduces the additional physical effects of interfacial tension and wetting behaviours that significantly alter both the fluid and granular dynamics.

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This project would experimentally investigate two-liquid flows interacting with a granular medium with broadly varying physical properties. The data would be explored using machine learning / artificial intelligence tools and/or classical modelling approaches from continuum mechanics. The experimental components of this project would be completed at the Laboratoire IUSTI at Aix-Marseille Université under the supervision of Prof Pascale Aussillous. The modelling and data analysis components would be completed at Monash University under the supervision of A/Prof Anja Slim. Some application of the outcomes to magmatic sulphide deposits would be explored under the guidance of Dr Margaux Le Vaillant at CSIRO Mineral Resources.
Supervisors: Prof Pascale Aussillous (AMU); A/Prof Anja Slim (Monash); Dr Margaux Le Vaillant (CSIRO)
Research Fields: Mathematics, Physics

3. Employment Benefits and Conditions

Aix-Marseille Université offers a 36-months full-time work contract (with the option to extend up to a maximum of 42 months).

The remuneration, in line with the European Commission rules for Marie Skłodowska-Curie grant holders, will consist of a gross annual salary of 28,764 EUR. Of this amount, the estimated net salary to be perceived by the Researcher is 1,926 EUR per month (before the deduction of tax at source). However, the definite amount to be received by the Researcher is subject to national tax legislation.

Benefits include

- Becoming a Marie Skłodowska-Curie fellow and be invited to join the Marie Curie Alumni Association.
- Tuition fee waiver at both PhD awarding institutions.
- Yearly travel allowance to cover flights and accommodation for participating in AUFRANDE events.
- 10,000 EUR allowance to cover flights and living expenses for 12 months in Australia.
- 25 days paid holiday leave.
- Contractual doctoral students are subject to the same sick leave rights as other contractual employees of the State Civil Service, namely: the contractual agent in activity benefits, on presentation of a medical certificate, during twelve consecutive months if its use is continuous or during a period including three hundred days of effective services if its use is discontinuous, of sick leave within the following limits
  - After 4 months of service: 1 month on full pay and 1 month on half pay;
  - After 2 years of service: 2 months on full pay and 2 months on half pay;
  - After 3 years of service: 3 months on full pay and 3 months on half pay.
- Parental leave: if the employee has at least 1 year's seniority at the date of the child's birth, he/she is entitled to parental leave at his/her request (after maternity leave for the mother or paternity leave for the father). This leave ends at the latest when the child is 3 years old. The leave is granted for renewable periods of 2 to 6 months. He/She must apply for it at least 2 months before the start of the parental leave.

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4. PhD enrolment

Successful candidates for this position will be enrolled by the following institutions and must comply with their specific entry requirements, in addition to AUFRANDE's conditions.

All applicants must be able to demonstrate a capacity to carry out independent research and have adequate training and ability to pursue the proposed course of study. In particular, applicants must hold a Master's or equivalent degree including a significant research component (at least 25% of one full time equivalent year of work) and including a thesis. It is normally expected that a grade of honours 2A has been obtained for the research thesis or project. Where ungraded, examiners' reports will be taken into account.

Applicants must demonstrate a sound English proficiency.

More information on Aix Marseille Université's requirements

Applicants holding a Master's degree outside the Bologna process or a degree equivalent to a Master's degree must submit an application for a Master's Degree for validation to the doctoral school secretariat prior to their enrolment.

As IUSTI (Aix-Marseille Université) is subjected to ZRR (Zone à Régime Restrictif) regulation, hiring choices must be approved by the Haut Fonctionnaire Securité Défense (HFSD).

Visit the website: https://college-doctoral.univ-amu.fr/en

More information on Monash University's requirements

The qualifications must be from Monash University or an equivalent institution in the opinion of the Graduate Research Committee (GRC).

Full documentary evidence in support of English Language Proficiency (ELP) must be submitted with applications for admission and scholarship. Monash University reserves the right to seek further documentary evidence of ELP.

Visit the websites:
https://www.monash.edu/graduate-research/study/apply
https://www.monash.edu/graduate-research/support-and-resources/handbooks/content/chapter-two/2-1
https://www.monash.edu/graduate-research/support-and-resources/handbooks/content/chapter-two/2-2

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