

**PhD Project Proposal at Laboratoire Navier** (in Champs-sur-Marne, near Paris, [navier-lab.fr](http://navier-lab.fr))

This project is proposed at Laboratoire Navier by Jean-Noël Roux ([Jean-Noel.Roux@univ-eiffel.fr](mailto:Jean-Noel.Roux@univ-eiffel.fr)), in collaboration with Alfredo Taboada (Géosciences Montpellier, [Alfredo.Taboada@umontpellier.fr](mailto:Alfredo.Taboada@umontpellier.fr))

## **Granular Inclusions as Tracers of the Stress State of the Surrounding Medium: Geophysical Applications**

Different geophysical methods aim to infer the state of tectonic stress in the Earth's upper crust from field measurements of brittle deformation. Among these, “striated pebbles”—decimetric rock inclusions whose surfaces record contact traces with smaller surrounding particles—provide valuable yet underexploited information. For several decades, the geophysical community has sought to interpret these features through various conceptual frameworks.

A research project currently conducted by A. Taboada at Géosciences Montpellier seeks to systematize both the acquisition and interpretation of such data. This effort is supported by the development of a methodology enabling in situ scanning of these objects at outcrop scale, coupled with a dedicated online application for the analysis of striation patterns.

The proposed PhD project relies on the Discrete Element Method (DEM) for granular numerical simulations, in conjunction with continuum modeling approaches and field observations. Its primary objective is to assess the validity, robustness, and accuracy of existing interpretative frameworks under a range of mechanical loading paths applied to a medium containing inclusions. Both coaxial stress/strain regimes and shear-dominated loading conditions will be investigated in order to characterize their influence on the resulting striation fields.

The study will initially consider a simplified configuration consisting of a single spherical inclusion embedded within a granular medium composed of smaller spherical particles. Increasing levels of complexity and realism will subsequently be introduced, including ellipsoidal inclusions, polydispersity in grain size and shape, and interactions among multiple inclusions.

How do contact trajectories at the surface of an inclusion reflect the stress state and deformation orientation of the surrounding medium? What statistical frameworks are most appropriate for analyzing these surface contact patterns? What are the representative parameter choices for practically relevant configurations (e.g., sample size, size ratios between inclusion and surrounding grains)? To what extent can a continuum description of the medium (e.g., elastoplastic models) capture the observed behavior? How should such continuum models be parameterized, particularly regarding constitutive laws and interface behavior? These are the questions that should be addressed in this PhD.

Preliminary DEM simulations have already been performed and are currently under analysis. These results demonstrate that meaningful insights can be obtained at a computational cost that remains manageable. For example, quasi-static deformation up to 50% strain of a sample containing approximately 20,000 grains—with a diameter ratio of 8 (corresponding to a volume ratio of 512) and realistic stiffness parameters—can be achieved in less than one day on a standard desktop computer. The resulting striation patterns (i.e., contact trajectories on the inclusion surface) exhibit systematic trends consistent with certain interpretative models.

These initial findings will be extended through systematic simulation campaigns and more comprehensive statistical analyses.

The PhD student will be based at Laboratoire Navier, in Champs-sur-Marne, near Paris. Regular meetings with the Montpellier team will be conducted remotely, and research visits to Géosciences Montpellier will be organized.

This project is suited to a Master's-level student with training in physics or granular/disordered media mechanics, and an interest in numerical simulation.

