CSIRO Mineral Resources Discovery Internship Program

We are seeking applicants for CSIRO Mineral Resources Discovery Internship Program, running between July 2021 and June 2022.

Applications are open for outstanding ***university students (3rd-year undergraduate or postgraduate level***) to join ***a 3-month internship*** at CSIRO. The internship projects relate to the Discovery Program's research on Exploration Through Cover, Orebody Knowledge, Geodata Analytics, and Critical Metals.

CSIRO offers a ***total living allowance of $6,000*** to a minimum of ***6 successful interns*** (note that upfront travel costs will need to be met by the successful applicants).

Due to COVID-19 restrictions, CSIRO will offer this year's internships only to applicants already within Australia or New Zealand*. (*This will depend on cross-border restrictions in case of unforeseen local lockdowns). All internships are based in Perth, Western Australia, unless otherwise specified or agreed upon.

Available projects for 2021-2022:

- Natural hydrogen as pathfinder for Fe-minerals?
- Deportment of critical metals during weathering in nickel laterite profile
- Real-time mine site water monitoring system development
- Mineralogical and geochemical trends at the bedrock-cover interface
- REE and HFSE fractionation and mobility under intense weathering
- Building multiscale 3D geology models using geochemical data
- Data Fusion to explore Australia's deepest diamond drill hole
- High Resolution EBSD to understand deformation in vein-hosted gold systems
- Structural inheritance (or not) during alteration
- Image processing, Landscapes and ArcGIS
- New Mineral Systems in Old Terranes, Copper Prospectivity in the Fortescue Group

To apply for an internship please ***send an email*** (subject: ***Discovery Internship application***) to Ignacio González-Álvarez ***(ignacio.gonzalez-alvarez@csiro.au)*** before the **15th June 2021,** with the following:

- ***A one-page cover letter***, including a summary of your areas of research interest. Your preferred two project title(s), and why you are interested in the selected projects.
- ***Full CV***, including current university course, expected completion dates, and contact details of an academic supervisor.

Note that all interns MUST be registered as a student at a university DURING their internship.

Interns will be placed within one of the research groups and supervised by a team member during their internship at CSIRO. Interns will be expected to write a short report during the internship and/or deliver an oral presentation communicating their research after the internship.

Applicants will be advised of the outcome of their applications by the ***15th of July 2021***.

PROJECT DESCRIPTIONS BELOW

Natural hydrogen as pathfinder for Fe-minerals?

Supervisors: ***Chloe Plet, Erick Ramanaidou, Ema Frery***

Sometimes called the "God Molecule", hydrogen can be used as a fuel and also as feedstock for industry. Currently over 95% of hydrogen production is from natural gas or coal. As to reach a net zero emission objective by 2040 in Australia, the part of hydrogen produced by green energies (i.e. green hydrogen) must be challengingly increased in a short timeframe. The exploration and production of natural hydrogen systems could present an opportunity to greatly lower greenhouse emissions while providing a sustainable source of energy.

A well-known process of H_2 formation is the oxidation of ferrous sediments into ferric sediment *via* the release of H_2. This process is the best candidate to explain the high hydrogen concentration (>300 ppm) measured above Brazilian H2 surface emitting-features (Prinzhofer, Moretti et al. 2019). Through this process it is likely that H_2 could play a major role as pathfinder for Fe-minerals.

Western Australia is ideally suited to further the investigation into natural H_2 as it hosts abundant ferrous sediments and as hydrogen surface emitting-features-alike have already been identified from satellite images (Moretti et al., 2021). However, to determine the potential of using natural H_2 for mineral exploration, we need to gain greater understanding of i) the processes of H_2 production during ferrous sediment oxidation and ii) the changes it creates in the water chemistry (e.g. pH, Eh).

This project will clarify the role H_2 in undercover iron deposit exploration. To achieve this the successful candidate will 1) undertake laboratory oxidation of sedimentary ferrous minerals while monitoring H_2 production and water chemistry evolution; 2) plan and participate to field work; and 3) integrate laboratory and field data into a presentation to the CMR discovery program.

Deportment of critical metals during weathering in nickel laterite profile

Supervisors: ***Walid Salama and Louise Schoneveld***

Critical metals are elements with unique chemical and physical properties required for the high-tech applications associated with renewable energy, reduction of greenhouse gases and energy transition technologies. The rapidly growing market in this sector (e.g. production of permanent magnets, solar panels, cell phones, electric cars, wind turbines) has led to an increasing demand of these metals over the last few years. The production of many critical minerals is strongly dependent upon the production of major commodities; therefore, there are opportunities to recover these elements from ores in which the critical minerals may be enriched but are not yet extracted. There is limited information available, however, about the concentration and deportment of critical minerals in most Australian ores and their weathering products.

Many of the critical metals such as PGE, Ni, Co, Cr, V, Mn, Sb, Bi, Se, Te, Sc and Mo are concentrated in nickel laterite deposits. These deposits can develop on barren or Ni sulfide hosting ultramafic rocks. The supergene enrichment processes that form Ni laterites also affect the ultramafic rocks hosting Ni sulfide deposits. The high Ni content of the weathered ultramafic host rocks makes it difficult to recognise the signature of sulfides, using Ni alone, whether at surface or deep in the weathering profile, and there are commonly no significant differences in Ni abundances over barren or mineralized host rocks. Lateritic Ni enrichments may follow steeply dipping structural elements such as shears, emulating the distribution of oxidised sulfide-rich rocks.

In this project, the student will have the opportunity to study the Ni laterite profile developed on serpentinized dunite at the Goongarrie nickel project, 70 km NW of Kalgoorlie in Western Australia. The student will learn and gain experience in: 1) logging Ni laterite profiles from drill holes; 2) carrying mineralogical analyses and element mapping on indicator mineral concentrates separated from the Ni laterite and serpentinized dunite using optical and scanning electron microscopy and laser ablation ICP-MS; and 3) interpreting multielement geochemistry to assess the potential of the Goongarrie project for Ni sulfide prospectivity.

Real-time mine site water monitoring system development

Supervisors: ***Anicia Henne and Nathan Reid***

Potentially toxic drainage of waters from mine sites is a major environmental concern in Australia. Hence, many active mine sites have requirements for zero discharge and strict water quality criteria for offsite discharge. In addition, many abandoned mines leak untreated mine drainage into the surrounding environment. Both the reuse of waters at active mines, and treatment and remediation at abandoned mines require continuous, often costly monitoring.

CSIRO previously developed a Fluid Monitoring System (FMS) prototype consisting of up to 12 sensors (including Eh, pH, EC and up to 8 ion selective electrodes, adjustable to water composition). This project aims to adapt and test this prototype in an environmental monitoring space to measure the impact of mine discharge treatment activities with the aim to reduce costs of remedial activities at abandoned and active mine sites.

The project will include laboratory testing of additional ion selective electrodes to identify possible detection limits and pH ranges for metals of interest and a trial deployment into a field setting. We will encourage the publication of the research results.

Key interests: geochemistry, instrument testing, experimental design, field work

Mineralogical and geochemical trends at the bedrock-cover interface

Supervisor: ***Carsten Laukamp***

Vast parts of the Australian continent are prospective for precious and base metal mineralisation, but exploration is hindered by extensive cover of often deeply reaching regolith. Remote sensing methods can help characterising the cover and potentially provide information about bedrock signatures. However, mineralogical variations across the bedrock-cover interface are still poorly understood. Drill core hyperspectral data provide an unprecedented detail about changes of mineral assemblages and compositional variations of single mineral species along complete drill holes, allowing a comparison of various geological environments and related mineral footprints.

For this project, drill cores intersecting the bedrock-cover interface will be selected from AuScope's National Virtual Core Library (http://portal.auscope.org/portal/gmap.html), in order to investigate mineralogical variations inferred from visible-near, shortwave and thermal infrared spectral signatures. Selected drill cores will be visually logged at GSWA's drill core library in Perth and compared with the hyperspectral results, as well as available and newly collected geochemical data (e.g. pXRF). The acquired data and results will be collated to generate an atlas of mineralogical patterns across different geological environments, which will improve our understanding of bedrock-cover interface and be useful for exploration in regolith dominated areas.

REE and HFSE fractionation and mobility under intense weathering

Supervisor: **Ignacio González-Álvarez and Yuan Mei**

Rare Earth Elements (REE) are abundant in Earth's crust. Nevertheless, known economical deposits of such are fewer than for most other ores. This group of elements has been referred to as the "oil of the XXI century" due to their key use in advanced technology, which spans from production of alternative energy, through the communications industry, to cutting edge technology. The study and understanding of REE mobility and accumulation processes is fundamental in their exploration.

REE have a preferred trivalent oxidation state (with the exclusion of Ce and Eu, which are redox sensitive and can have 2+ and 4+ forms). The original REE budget of rocks can be mobilized, disperse, fractionated or accumulated under specific conditions such as in weathering, hydrothermal or basinal brines activity. Therefore, REE can be used as an efficient proxy to provide insights for geochemical dispersion processes in regolith and sedimentary sequences.

This project will use available geochemical datasets from different Australian geological locations to evaluate how weathering fractionates and accumulates REE under intense weathering, and how this knowledge can be used as a vector in mineral exploration.

Building multiscale 3D geology models using geochemical data

Supervisors: ***Dr June Hill and Dr Alex Otto***

3D geology models are fundamental tools used by geologists to understand subsurface geological architecture. Scales of geology models vary depending on their purpose. For example, a relatively coarse scale may be used to develop a deposit-wide geology model for near-mine exploration purposes. While a finer scale model of the orebody may be used for mine planning. Many mineral exploration and mining companies collect large amounts of geochemical data from drill hole samples. This is very valuable data to supplement traditional subjective geological logging. Multielement geochemistry data can be classified into rock types using expert based classification methods or machine learning. In either case, the classification is applied at the sample scale. This can result in very noisy litho-geochemistry logs with many fine-scale units below the scale of the required 3D model.

We have developed a tool, called Data Mosaic, which, when combined with machine learning techniques, can provide a rapid and consistent multiscale classification of the geochemistry data. We wish to demonstrate the capacity of the geochemical data and Data Mosaic to be used to generate litho-geochemical geology models at more than one scale. The successful applicant will learn how to use Data Mosaic, machine learning and geological modelling to demonstrate how these tools are used to generate multiscale 3D models. The results will be used as a case study for training purposes.

Suitable applicants should have a sound background in geology, preferably with some knowledge of machine learning and basic mathematics.

Data Fusion to explore Australia's deepest diamond drill hole

Supervisors: **Mark Pearce, Renee Birchall, Jessica Stromberg**

Diamond drill core is the main currency of advanced greenfields and brownfields exploration. New sensors and analysis technologies mean analysing these drill-cores is increasingly data-rich. Objective analysis techniques (e.g. Data Mosaic; Hill et al, 2020) are replacing subjective processes, like geological logging, which rely on the opinions of individual geologists and all the inherent bias that introduces. Objective logging replicates, and improves an existing process meaning that geologists have more time to interpret the geology rather than collecting data. However, there is significant potential for new types of analysis, derived from combinations of data e.g. downhole chemistry, mineralogy, and petrophysics, which have never been possible before. This project will focus on combining continuous chemistry (from a Minalyze XRF core scanner; Sjöqvist et al. 2015) and mineralogy (from Hylogger; Schodlok et al. 2016) to analyse core Australia's deepest diamond drill hole beneath the Jundee gold deposit.

The successful applicant will brainstorm new 'products' that could be produced from combining these two different data streams and work with spectral geologists, geochemists and data scientists to revolutionise drill-core analysis. To complete this project you will need to be interested in applying analysis to drill-core for exploration. While a working knowledge of geology is useful, and may be your main research area, your expertise may be in physics, signal processing, or another data science discipline. You will complete your internship by presenting your ideas and new developments to industry representatives.

Hill et al. 2020. https://doi.org/10.1007/s11004-020-09859-0

Schodlok et al. 2016. https://doi.org/10.1080/08120099.2016.1231133

Sjöqvist et al. 2015. https://doi.org/10.5194/sd-19-13-2015

High Resolution EBSD to understand deformation in vein-hosted gold systems

Supervisors: **Mark Pearce, Renee Birchall, Siyu Hu**

Archean gold systems are often hosted in quartz or carbonate veins within greenschist facies metamorphic rocks. Many models exist where gold is deposited co-incident with the vein minerals. However, evidence from both carbonate and quartz vein-hosted deposits suggest that gold is introduced or concentrated during subsequent deformation of the veins (Voisey et al, 2020). This mechanism separates the wall-rock alteration (e.g. sulphidation, potassic alteration) from the gold deposition but also produces easily accessible, free-milling gold that is easily recoverable. Therefore, understanding how the vein-hosted mineralisation form will aid exploration. One way of understanding the successive formation and deformation of veins is combining chemical imaging (e.g. X-ray mapping or cathodoluminescence) with microstructural analysis using electron backscatter diffraction.

This internship will focus on applying High Resolution EBSD (HR-EBSD) to map out subtle lattice orientation changes around fractures that contain gold. HR-EBSD quantifies lattice strain and subtle orientation changes by comparing diffraction patterns (Wallis et al, 2017). This has been shown in garnet (Griffiths et al, 2014) to be an effective way of examining the interaction between host and inclusion minerals. The applicant will collect new EBSD, chemical and CL datasets on gold-bearing samples. They should be familiar with the fundamentals of EBSD and basic coding to ensure that the project can be completed during the internship but will have the opportunity to develop and test new hypotheses about the nature of vein-hosted gold deposits.

Griffiths et al. 2014. http://doi.org/10.1007/s00410-014-1077-4

Voisey et al. 2020. https://doi.org/10.5382/econgeo.4692

Wallis et al. 2017. https://doi.org/10.1016/j.jsg.2017.12.012

Structural inheritance (or not) during alteration

Supervisors: **Mark Pearce, Renee Birchall**

Mineralisation at the Jundee gold deposit occurs in the greenschist facies rocks of the Yandal greenstone belt. Recent deep drilling has revealed high metamorphic grade rocks at depth that have a fabric formed during amphibolite facies deformation. The metamorphism at Jundee is overprinted by the alteration associated with mineralisation. The alteration leads to intense micaceous foliations and quartz-carbonate fabrics in rocks around high economic grade gold mineralisation. Gold is associated with, but not necessarily always hosted in, quartz and carbonate veining. This internship will evaluate to what extent early fabrics developed during the metamorphism, across both greenschist and amphibolite facies, are reactivated during alteration and veining events.

The intern will examine a suite of 450 samples taken from Australia's deepest diamond drill core to study the geometry and mineralogy of the early metamorphic fabrics, altered equivalents and mineralised samples. They will analyse the fabrics using electron backscatter diffraction and energy dispersive X-ray spectrometry and predict the mechanical properties of the rocks using elastic volume averaging schemes. The project will aim to address whether there is any evidence of structural control on fluid flow channels from deep beneath Jundee into the faults and fractures that host mineralisation of if the stress state is the primary control on fracture orientations in the gold deposit.

Image processing, Landscapes and ArcGIS

Supervisors: **Neil Francis and Ignacio González-Álvarez**

Image processing algorithms and the availability of digital elevation model (DEM) datasets have opened the possibility to understand landscape evolution at a scale unthinkable before. Algorithms have been coded for processing Digital Elevation Map (DEM) images that utilise popular open-source Python GIS-libraries, such as geopandas and rasterio. This code is unusable by GIS application end-users who are unfamiliar with the Python programming environments and who need tools that work in the environment they are familiar with. The goal of this project is to transform methods for processing images, such as the Multi-resolution Valley Bottom Flatness (MrVBF) algorithm such that they can be used in GIS application software.

This multi-disciplinary project would suit software engineering or computer science students with knowledge of the Python programming language, with an interest in GIS applications and working with the APIs of popular GIS applications to integrate and improve upon established image processing and unsupervised learning methods. The project may also be suitable for GIS or geology students with familiarity with GIS applications, strong maths skills, and some Python, who would like to develop their software development skills to customise the functionality of GIS applications to perform new tasks. Since these algorithms utilise linear systems theory, an understanding of the maths behind filtering methods in image processing applications will be valuable. This project's outputs will enhance the use of Multi-resolution Valley Bottom Flatness algorithms for landscape evolution in Western Australia and globally using ArcGIS.

The MrVBF algorithm is documented at: https://doi.org/10.1029/2002WR001426

New Mineral Systems in Old Terranes, Copper Prospectivity in the Fortescue Group

Supervisors: **Jessica Stromberg and Sam Spinks**

Sediment hosted copper deposits are a key global Cu source but are not known prior to ~2.0 Ga[1]. However, recent work by CSIRO in the West Pilbara Superterrane indicates potential Keweenawan White Pine style sediment hosted Cu mineralization in the ~2.7 Ga Fortescue Group in the basal mudstones of the Tumbiana Formation above the Kylena Formation metavolcanic contact[2]. These results occur in three drill holes across ~10 km strike length, at 150-750 m depth, but the Tumbiana-Kylena contact outcrops further north with percent level Cu and base metals in grab samples[3]. This project will build on previous work in which data from three diamond drill holes was investigated[2], but only drill hole one was sampled, and not with the aim of targeting or constraining Cu mineralization.

The successful applicant will sample and characterize Cu mineralization across these three drill holes, using high-resolution geochemical datasets such as large scale XRF mapping (MaiaMapper™) informed by existing continuous geochemical (Minalyze CS™) and hyperspectral (HyLogger3™) datasets. They will have a working knowledge of sedimentary basins, geochemistry, and microanalytical techniques and will gain the opportunity to challenge long held paradigms around the temporal distribution of sediment hosted Cu deposits, and improve our understanding of base metal prospectivity in the Fortescue Group.

[1]Groves et al., 2005. Geological Society, London, Special Publication, v. 248, p. 71–101.

[2]Stromberg, Spinks, Pearce. 2019. Geochemical Stratigraphy of the Neoarchean Lower and Middle Fortescue Group, Western Australia. Kensington, WA. CSIRO EP192724.

[3]Artemis Resources. 2018. ASX Announcement, 'Artemis to drill +3,300 metre super-deep hole in Pilbara. 28 February 2018.