2018

Society of Economic Geologists' Student Chapter

UNIVERSITY OF PORTSMOUTH

FIELD REPORT 2018

SOCIETY OF ECONOMIC GEOLOGISTS FOUNDED 1920

UOP SEG

STUDENT CHAPTER

2016

Preface.

Fieldwork is an essential component of the mineral exploration and mining industries. Through fieldwork students are offered the opportunity to put their learning from the classroom into action, commonly learning and understanding more about geological processes. At Portsmouth we aim to offer an annual SEG fieldtrip each year, which is open to all of our members, offering a greater understanding of mineral deposits, mining heritage and economic geology around the world.

SEG Portugal Collaborative Fieldtrip- Economic Geology and Mining Heritage of Portugal - 1st-6th February, 2018.

The UOP SEG Student Chapter hosted a collaborative international trip with The Universities of Bristol and Oxford to Portugal in early February. A variety of different locations & sites were visited to learn more about the regional geology, economic geology and mining heritage of Portugal, collaborating with a range of academics, and industry professionals operating from grass-root to larger scale projects. The field programme began in the north at Porto, working clockwise to Lisbon, and aiming to undertake economically-orientated exercises & field-based tasks.

The UOP Chapter gratefully acknowledges the SEG for providing a generous grant from the Stewart Wallace Fund Round II, and Minsouth for their generous contribution to the Bristol Chapter, both of which enabled the trip to take place.

We would also like to thank the attendees from other Chapters that helped in the planning of the trip and ensuring it ran successfully; additionally we thank all participants for their interest and attendance of the trip. The group constituted a diverse group of students ranging from first year undergraduates, to post-graduate PhD level students across the various Chapters involved.

Trip Objectives:

- To visit a range of exploration & mining projects, ranging from grass-root to large-scale, to learn about different exploration projects that are occurring and deposit types commonly observed in Portugal.
- To learn about the mining heritage of Portugal, through visiting older workings/projects and collaborating with local people.
- To learn about the regional geology of Portugal, which will enable a better understanding of ore-forming processes and the mineral deposits observed.
- To visit the São Domingos rejuvenation & rehabilitation project to learn about what happens once a mine has reached the end of its production/life cycle. This will also factor in environmental consequences and contamination that is associated with old mine workings and what is being done to combat this.
- Collaborate with local Universities to share knowledge and aid in establishing the first Portuguese SEG Student Chapter.

Day 1- Collaboration with University of Porto, Castromil & Fojo das Pombas.

The Iberian Peninsula, located in Southwest Europe, is comprised of rocks ranging in age from Ediacaran to Holocene and hosts multiple world-class mineral deposits. A complex structural history associated with multiple orogenic events, and a range of magmatic processes controlled both regionally & locally played key roles in the promotion of ore-forming processes and thus, the deposits observed today.

The cohort arrived at the University of Porto direct from the flight, to meet with Professor Alexander Lima and some postgraduate researchers, who provided an introductory presentation to the regional geology of Portugal, additionally giving insight to the rich mining heritage of Portugal and examples of previous workings extending back to the Roman era (*Figure 1*). We also had a brief tour of the University building, including a look into analytical equipment for fluid inclusion studies and ore/mineral collections held at Porto.

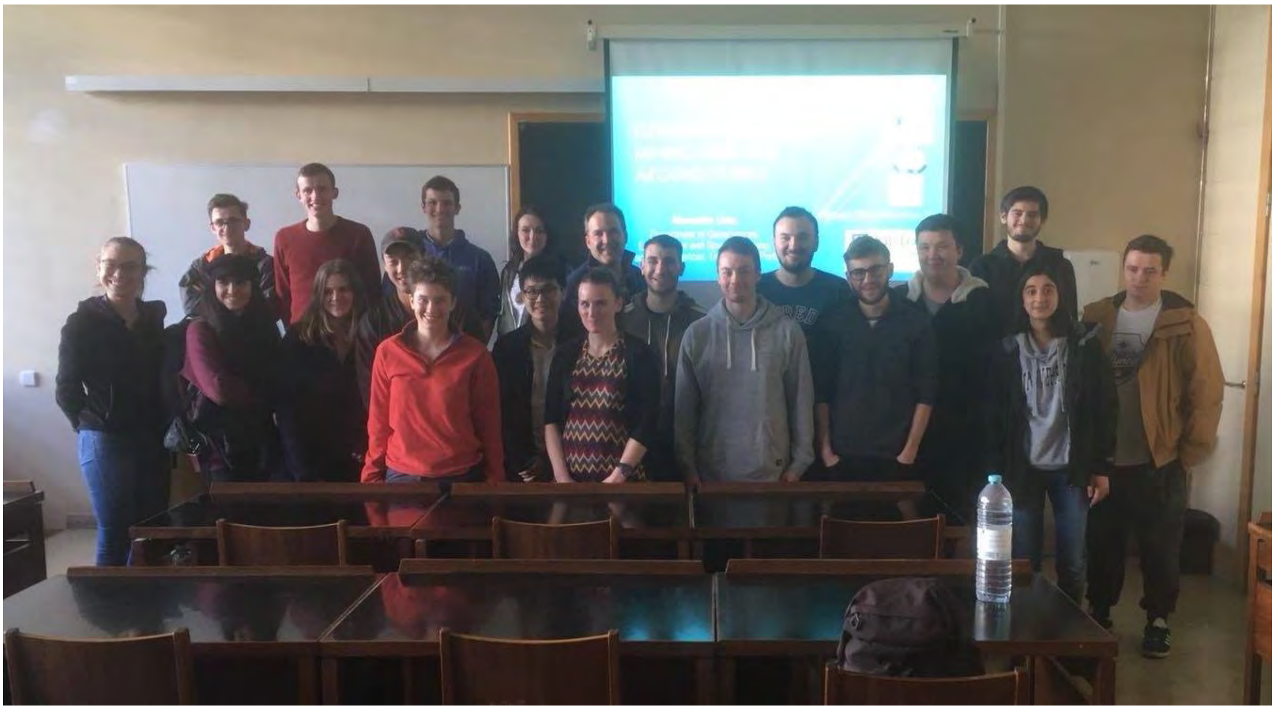


Figure 1- *Collaboration with acadmics at the University of Porto, folling a presentation on the geological history and mining heritage of Portugal.*

Following this, we made our way to Castromil, stopping off en route to visit some road-cutting exposures, outcrops and an adit, to observe auriferous-type mineralisation associated with quartz veins and host kilas. Upon arriving at Castromil, we learned about Roman Gold exploration in the NW peninsular, which is considered to be one of the most productive areas of Roman Gold mining. A majority of the gold is now considered 'invisible gold' due to the finely disseminated nature of the deposit. There are current research programmes running at the University of Porto, focussing on fluid inclusion studies, to determine the source and chemistry (*P*-*T*-*t*) of the mineralising fluids that produced these deposits. Students also got to pan for gold (*Figure 2*) and watch a brief video summarising previous works in the Castromil region; more widely encompassing new LIDAR data that is being used to map old Roman workings and adits.

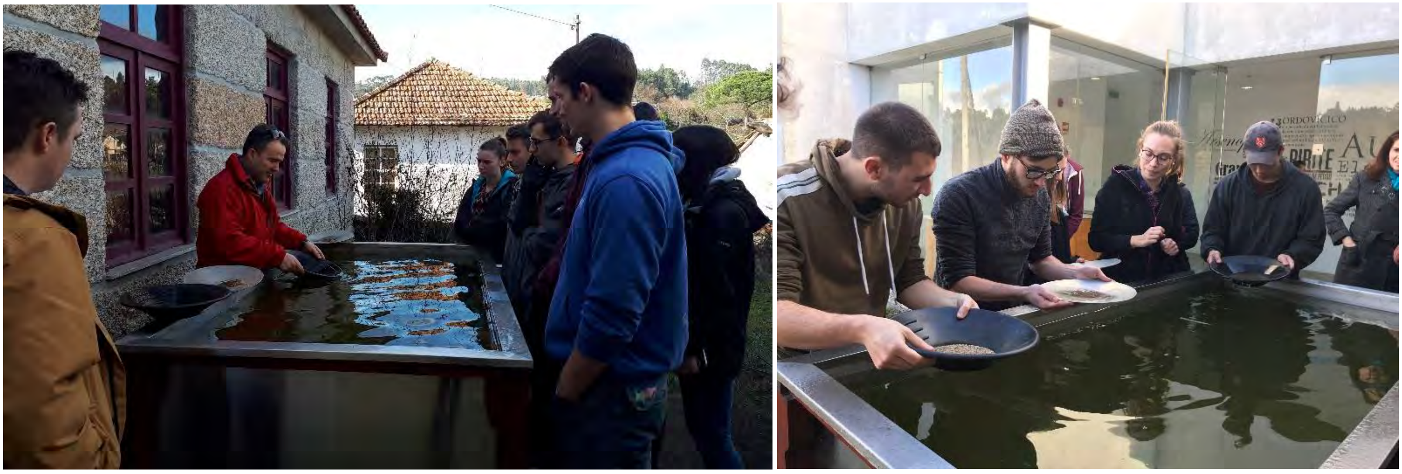


Figure 2- *Students panning for gold with professor Alexandre Lima and University of Porto postgraduate researchers at Castromil.*

Ensuing the visit to Castromil, the cohort travelled to Fojo das Pombas an underground Roman Gold mine. Here, students had the opportunity to go into sub-surface level adits and observe first-hand, the quartz-hosted auriferous-type mineralisation and the relationship it has with the host rock and local structural features i.e. faults. (*Figure 3*). We also walked over the top of the workings, putting into perspective the extent of previous exploration projects and local geology.

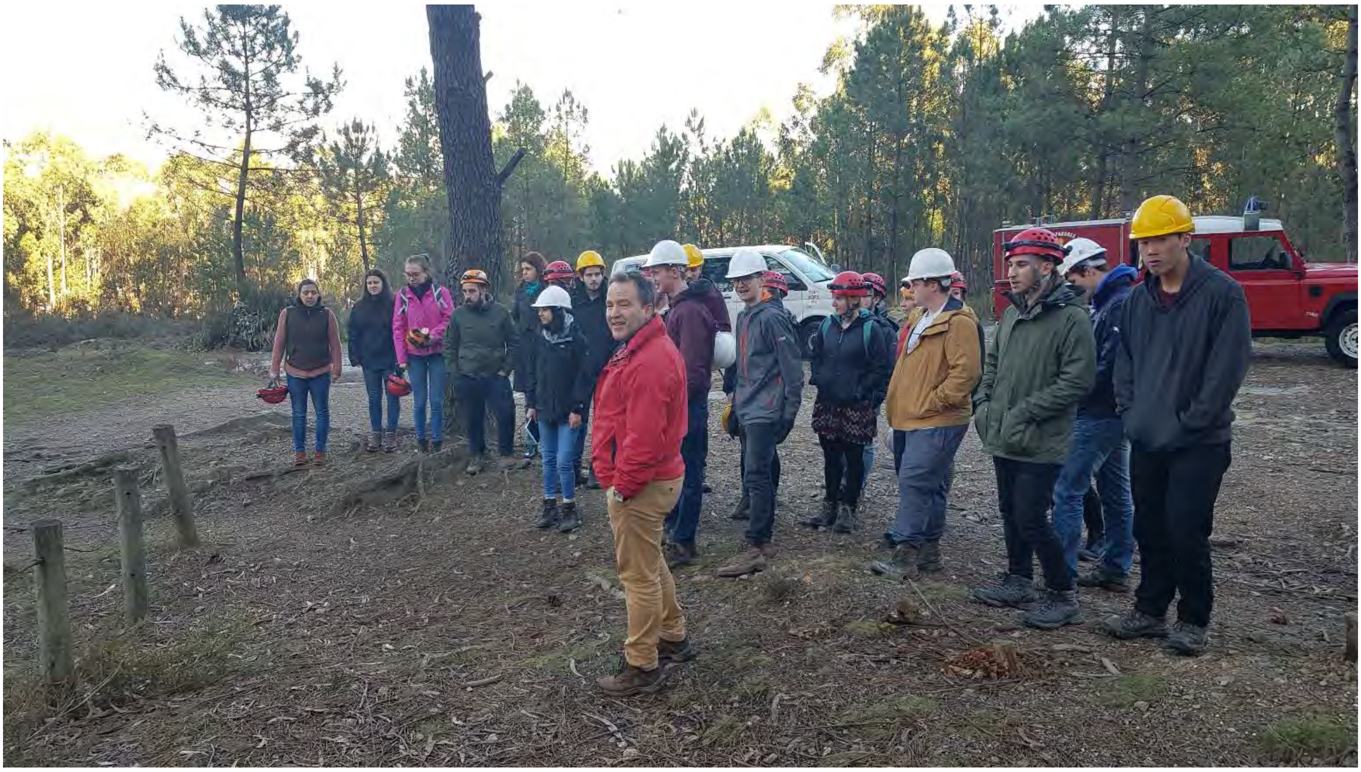


Figure 3- *Students kitted out to go into underground Roman Gold workings at Fojo das Pombas.*

To complete the day, the Universities had a brief networking session, during which establishment of the first Portuguese SEG Student Chapter was discussed, and general research knowledge was exchanged.

Day 2- Góis Escádia Grande Exploration Project.

On the second day, the group headed south to the Escádia Grande exploration project located in the southwestern sector of the central Iberian Zone, to learn about current auriferous and tungstiferous exploration projects at a brownfield site by a junior exploration company. EDM currently holds exploration rights for gold (Au), copper (Cu), silver (Ag), lead (Pb), zinc (Zn), tin (Sn), antimony (Sb) & tungsten (W) in the region, covering an area of 252.75km².

We met Daniele Lobarinhas at the core shed and started off learning about the current exploration project and geological background of the area. She introduced us to quartz vein related auriferous mineralsiation and sulphides associated with NW-SE shear zones; students were then able to observe samples of rotatory drill core and spend some time identifying the different types of mineralisation and structural features in these (*Figure 4*). This was followed by being taught the importance of core and how this is used during the exploration stages of a project. As a number of undergraduate students in Universities have little exposure to core during their studies, this was very beneficial to understand what they may encounter undertaking a graduate level position within a mining or exploration company.

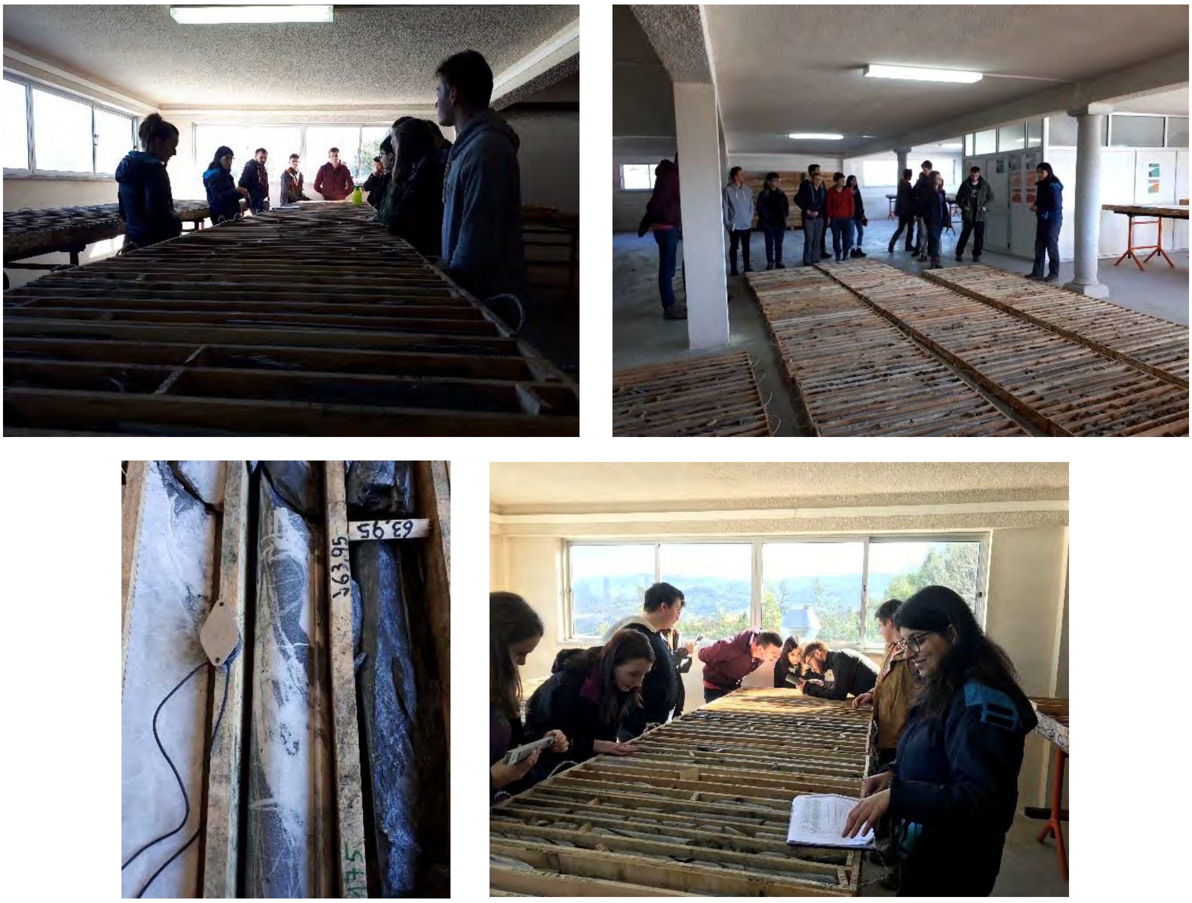


Figure 4- *Students observing and identifying mineralisation and structural features within rotary drill core at the* Escádia Grande project core shed.

The cohort then travelled to the sites of drilling, consisting of four separate localities spaced ~100-200m apart (*Figure 5*). We learned more in depth about the current drilling projects and previous workings in the Góis region, ranging from Roman Era to the 1970s. Daniele also taught us about the Escádia Grande Mine which operated until the late 1950's and was the most important gold mine in the region.

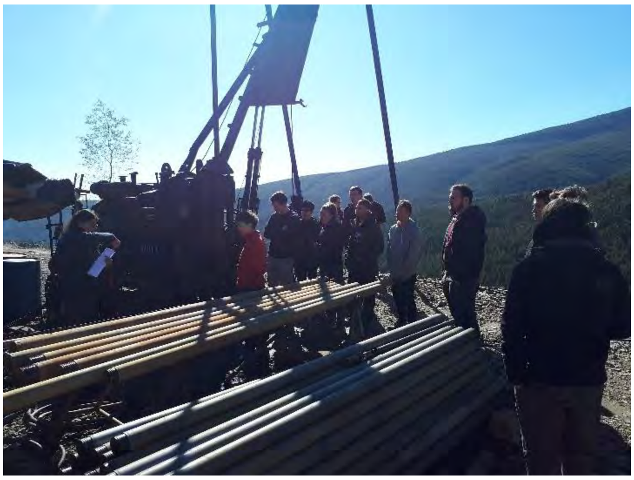
 

Figure 5- *Visit to numerous sites of exploratory drilling, including the chance to see a drill rig and learn more about the way in which this operates.*

Day 3- Cu-Zn Mineralisation in the OMZ & Massive Sulphides in the IPB, and Lousal Mine.

On the third day, the cohort travelled southwards again, to learn about Cu-Zn mineralisation in the Ossa Morena Zone (OMZ) and VMS related massive sulphides in the Iberian Pyrite Belt (IPB).

We met with João Matos at the LNEG Aljustrel Office in the morning, where the cohort were introduced to a geological background and previous mining of the Aljustrel region. *Development of the Center for Geological and Mining Studies of Aljustrel (CEGMA) is an initiative that aims to support the extractive industry in the south of Portugal through the preservation of brownfield sites, and exploitation of ornamental stone revaluating prospecting aspects. Ultimately the project will facilitate access of universities and academics to a database of samples and mining surveys.*

João showed us a previously mined area from a vantage point and discussed previous workings and deposit styles in the area (Figure 6). He went on to add the importance of protection & rejuvenation of brownfield sites, enabling redevelopment of previously mined areas based on resource & material potential. We then set off to observe some gossan deposits in the vicinity of the LNEG office (Figure 7) and learn about massive sulphide deposits; this allowed students to observe different relationships these rocks share and get up close and personal with the geology.

Figure 6- *Overlooking previous open-pit workings in the Aljustrel region & new extraction of stone and decorative stone. This outlined importance of re-evaluation of brownfield sites for mineral potential.*

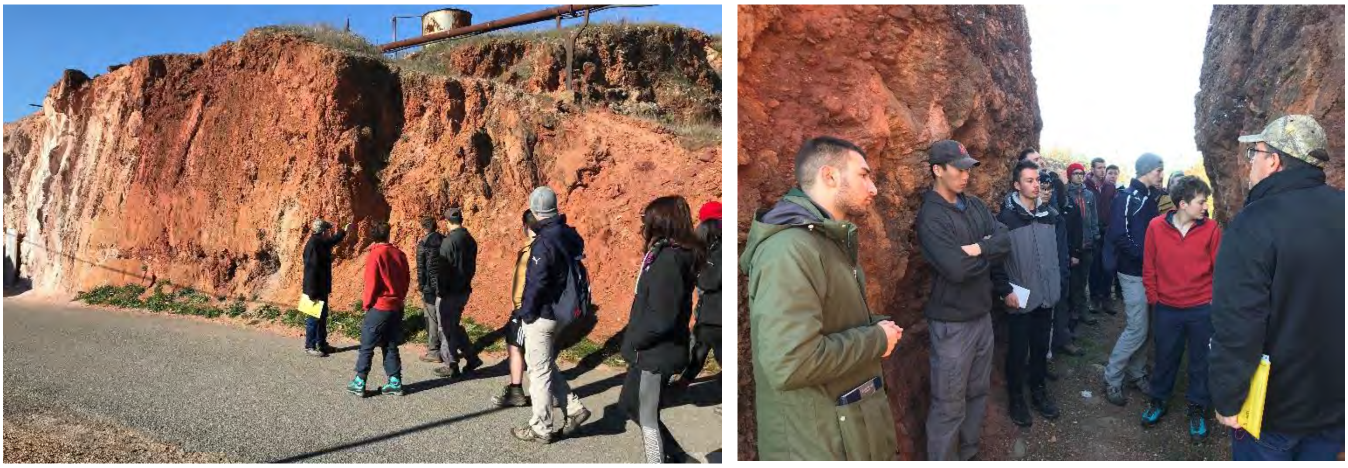


Figure 7- *Students leaning about VMS & gossan deposits in the field.*

Following this, we made our way back to the LNEG office to learn more about sample preparation and curation of ore deposits associated with development of the litho library, involving observation of various ore samples. We also got to look at some core samples of drilling in the area (Figure 8). Numerous localities in the area were then visited to observe gossan and VMS deposits, followed by an operating drill rig.

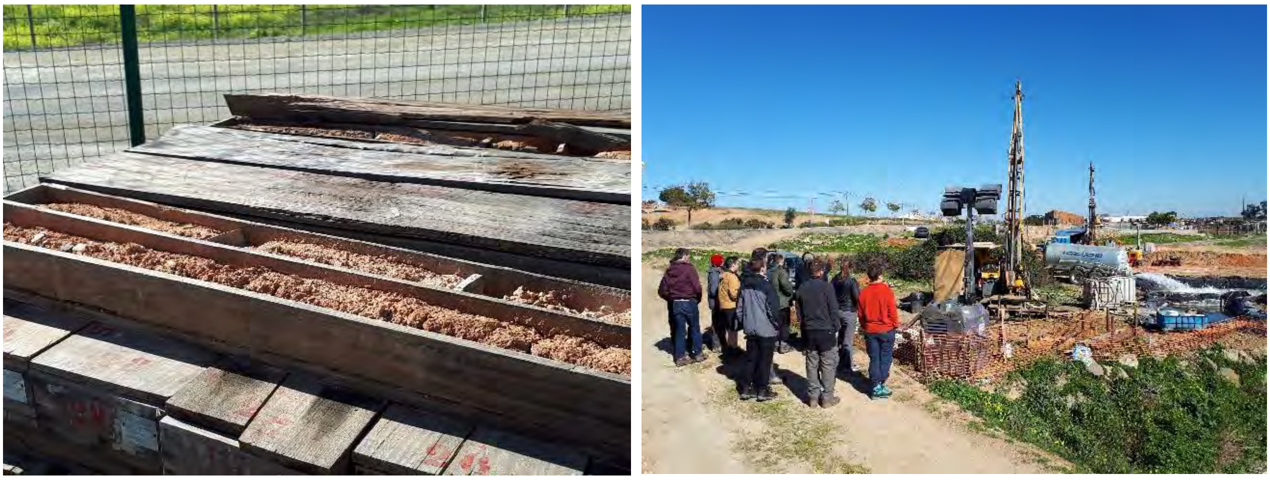


Figure 8- *Drill core samples of current projects at the LNEG and ongoing exploration at an active drilling rig. This allowed students to observe mineralisation within drill core, which they typically have little exposure to in the classroom, additionally learning more about drilling processes.*

In the afternoon, the cohort travelled SE to Mina de Ciêcia, a mining museum which aims to promote scientific & technological culture among local people, and ultimately retain the mining heritage of the region. The Lousal Mine opened in 1900 and operated until 1988, primarily extracting pyrite ore through open pit mining and underground works reaching up to 500m depth; due to the nature of polymetallic mineralisation, Zn-Pb-Cu were also exploited here in association with the pyrite. We got to learn more about mineralisation styles in the IPB and background geology of the region, including ore-forming processes. A number of interactive activities were available in the Science Center (Figure 9).

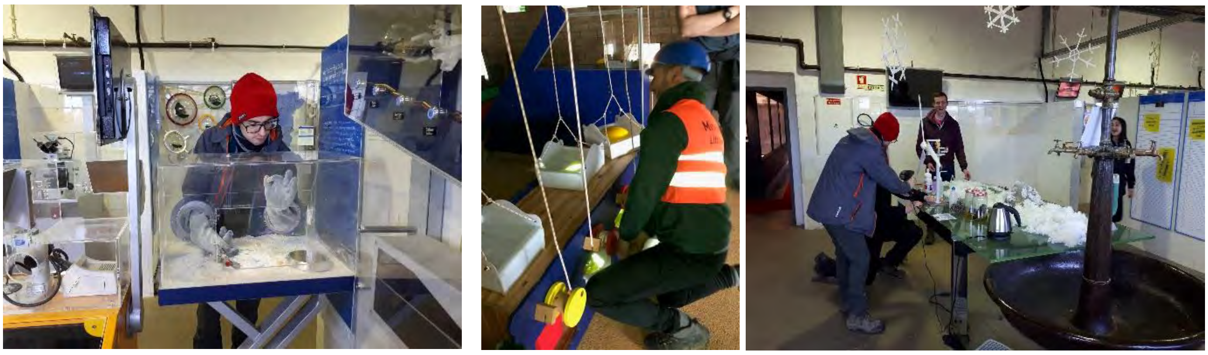


Figure 9- *Students getting involved in interactive activities at Lousal Science Centre, Mina de Ciêcia.*

The outside area consisted of the remains of open pit extraction, tailing ponds and old mining buildings (Figure 10). This outlined the rich mining heritage of the IBP and scale of previous workings at Lousal Mine, stressing the importance of protecting & maintaining these areas.

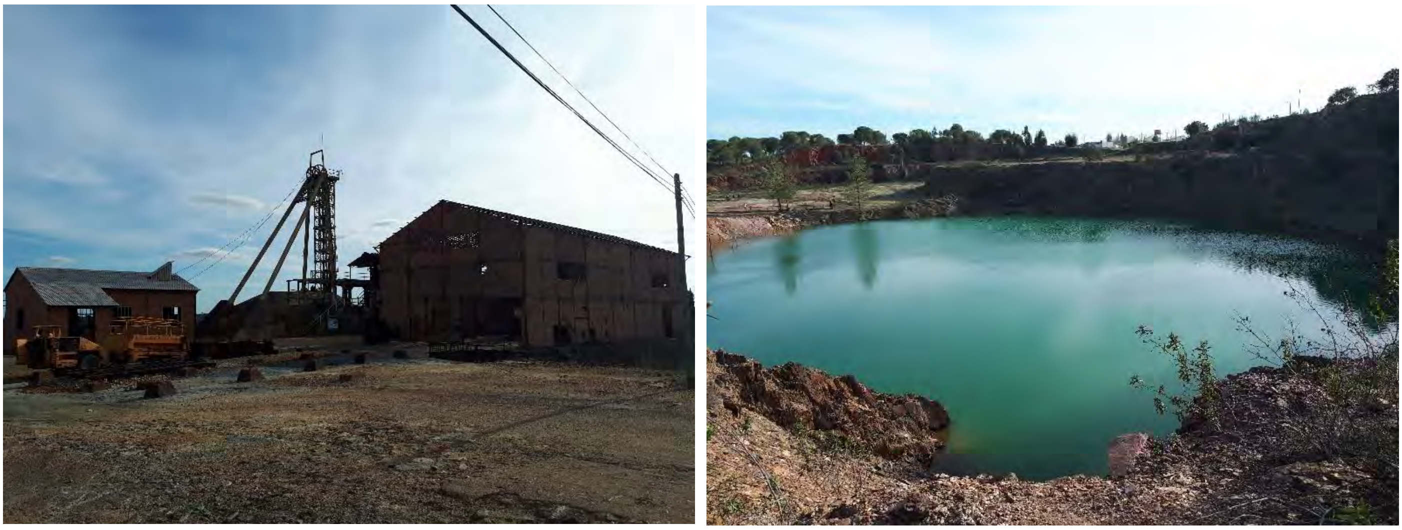


Figure 10- *Historical mining buildings and tailing pond at Lousal Mine. This area demonstrates the importance of maintaining previously worked areas and promote education, to retain the rich mining heritage of Portugal.*

Day 4- São Domingos VMS Mine Rejuvenation & Rehabilitation Project.

On the fourth day, the cohort travelled south to the São Domingos mine to learn more about the renovation and rejuvenation of the area following the end-cycle of a mining project. The São Domingos mine was an open-pit quarry in Portugal that operated until closure in 1966, producing low grade sulphide material- mainly copper (Cu) ore and associated pyrite (FeS_2). During main-stages of production ~25megatones of ore was extracted. The area is currently undergoing environmental rehabilitation run by EDM, due to extremely acidic PH levels in tailing ponds from processes of acid mine draining (AMD) and leaching of waste material in spoil tips causing contamination. Additionally, the project aims to preserve and maintain the previous site and buildings retaining the rich mining heritage of Portugal. We met with Pedro Irvine, a highly-experienced local geologist who is directly involved in the São Domingos rehabilitation project as well as previously working in Neves-Corvo. He started the day by showing students some rock samples in the local mining village to familiarise us with the different lithologies, deposit types and geological history of the area (Figure 11).

Figure 11- *Students getting their eye in on local lithologies and mineral deposit types.*

This was followed by a visit to the Mina and Ruinas de São Domingos where we learned about the current rehabilitation and maintenance of old mining buildings (Figure 12). The cohort then headed towards the main open-pit quarry to learn more about the previous workings, volcanogenic massive sulphide (VMS) deposits and environmental aspects concerning end-cycle of the mine. This enabled students to directly observe outcrops of VMS deposits and associated mineralisation styles. Mining began during the Roman period, through sub-surface tunnels for commodities such as silver (Ag). During the 1800's, open-pit mining was adopted to exploit low-grade sulphide ore deposits (Cu, FeS_2).

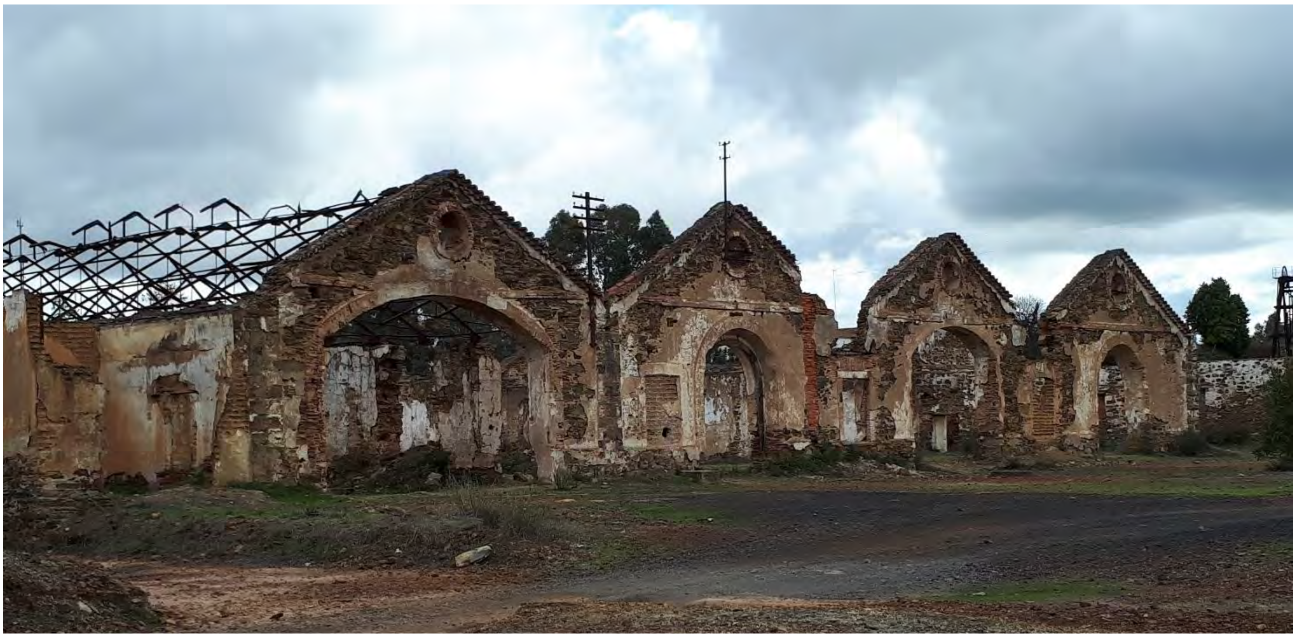
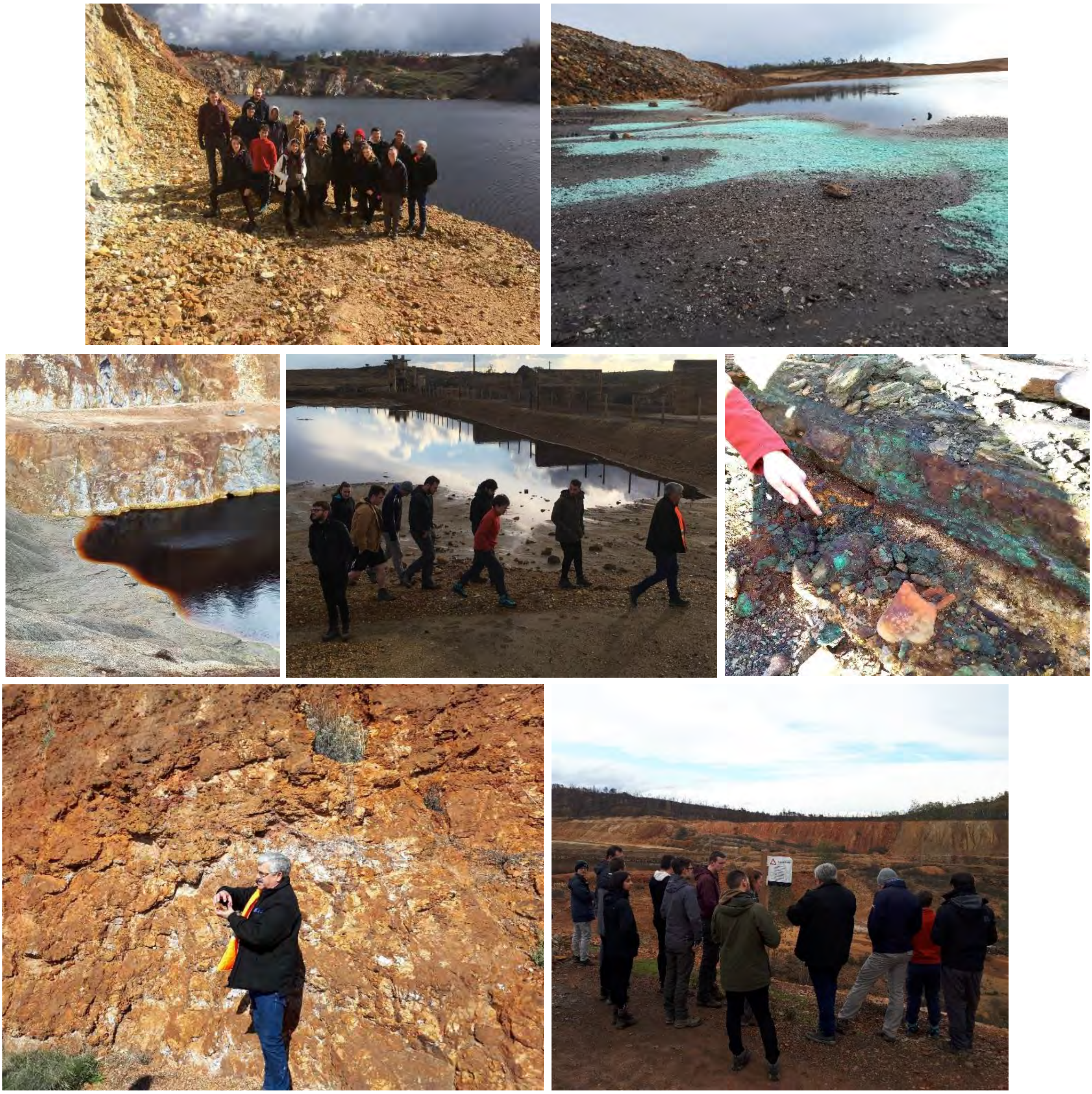


Figure 12- *Old mining buidlings at Mina and Ruinas de São Domingos. Site of Heritage and protection.*

We also learned about the issues concerning processes of leaching and ADM at São Domingos, which has caused the intense acidification of tailing ponds, up to PH 1.0, environmental consequences following this and measures that are being undertaken to mitigate this process. Succeeding an in-depth discussion and observation of stockworks & mineralisation within outcrops, the cohort embarked on a tour of the open-pit to observe different mineralisation styles and geology (Figure 13).



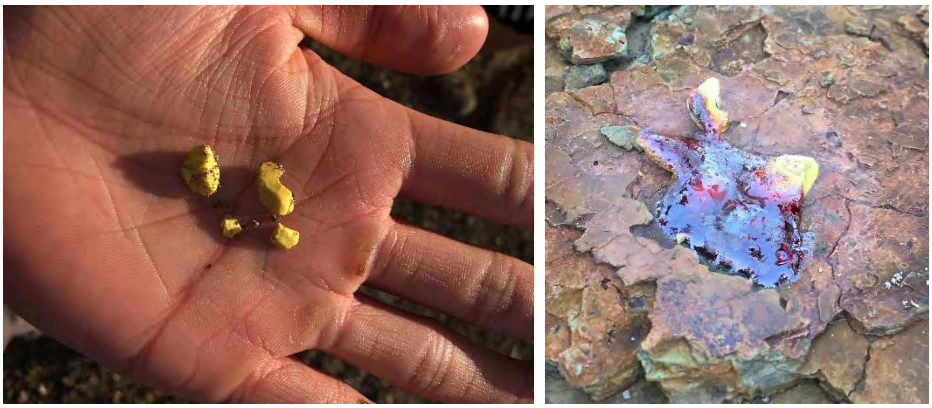


Figure 13- *Assorted images taken at the São Domingos mine. Dark red to orange colours are characteristic of highly acidic tailing 0ponds up to PH 1.0. Numerous styles of mineral deposit and alteration, sulphur and local geology are represented.*

Day 5- The Geology of Almograve.

On the fifth field day, we travelled west towards Almograve, to observe and learn more about the geological history of Almograve. The beaches at Almograve boast stunning coastal outcrops of intensely deformed metasediments, demonstrating polyphase deformation associated with the Variscan Orogeny that lasted ~100myr. This area is analogous to areas such as Bude in the southwest of England, recording a variety of brittle-ductile relationships and features; the field exercises of the day ultimately aim to summarise the geological history and structural evolution of Portugal, putting this into perspective with other known zones of the Variscan Orogen. The structural evolution of a region is intimately linked to magmatic processes, key to ore-formation; it is important not only to understand ore-formation but also the factors that ultimately control and contribute towards this.

We met with Rui Dias, a professor from the University of Evora specialising in the structural geology. The day started by walking down to coastal exposures of intensely folded sediments, metamorphosed up to greenschist facies during the Variscan Orogen. Polyphase deformation is represented by multiple generations of folds, faults, post-depositional quartz-veins (not hosting mineralisation) and microstructures. Rui explained these structures to us and students were able to get involved with some fieldwork, classifying the lithologies, making detailed sketches and getting up close and personal with the geology (Figure 14).

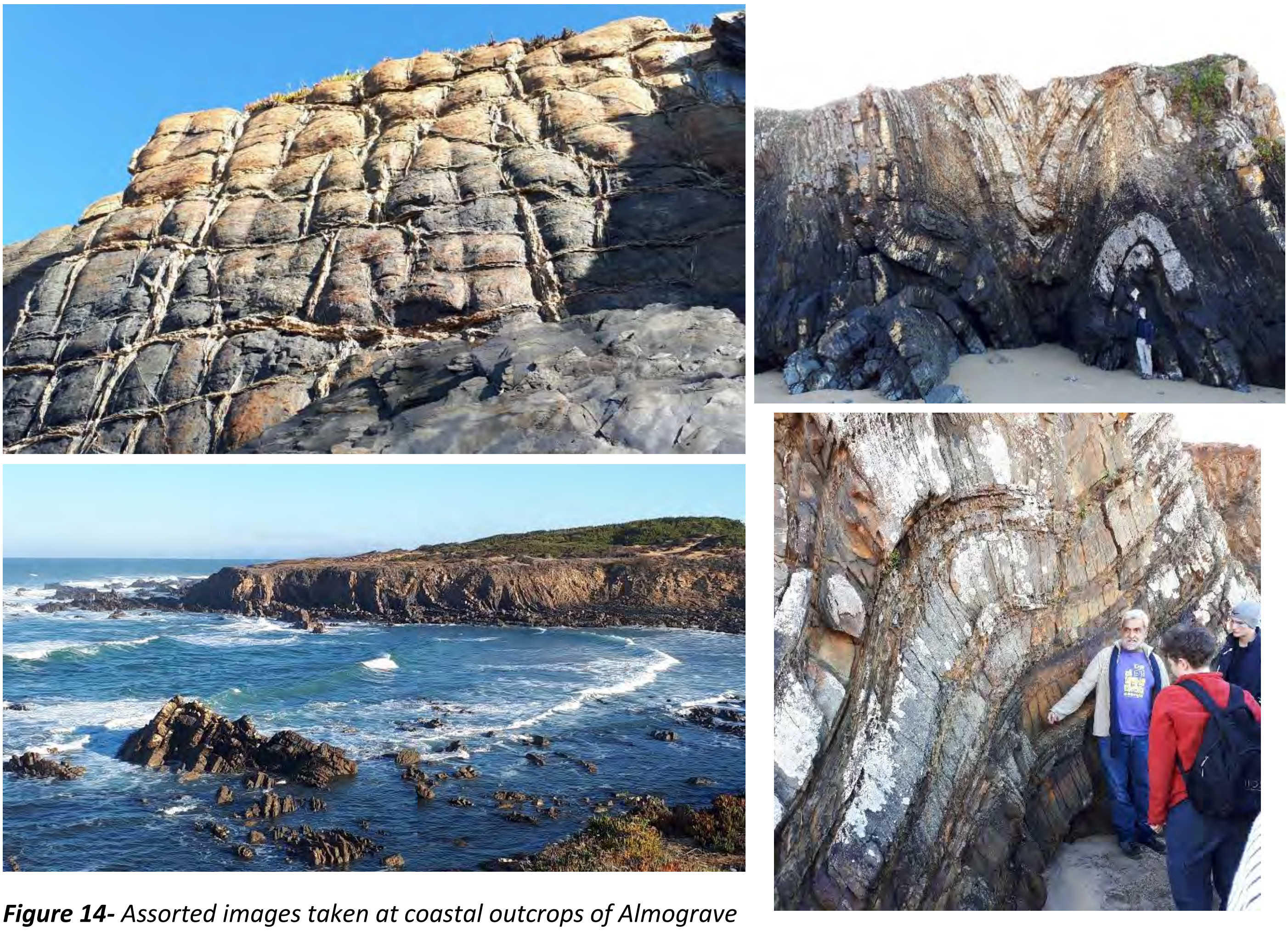


Figure 14- *Assorted images taken at coastal outcrops of Almograve Beach. Note the chocolate-bar quartz veins, representing brittle deformation of sediments following deposition.*

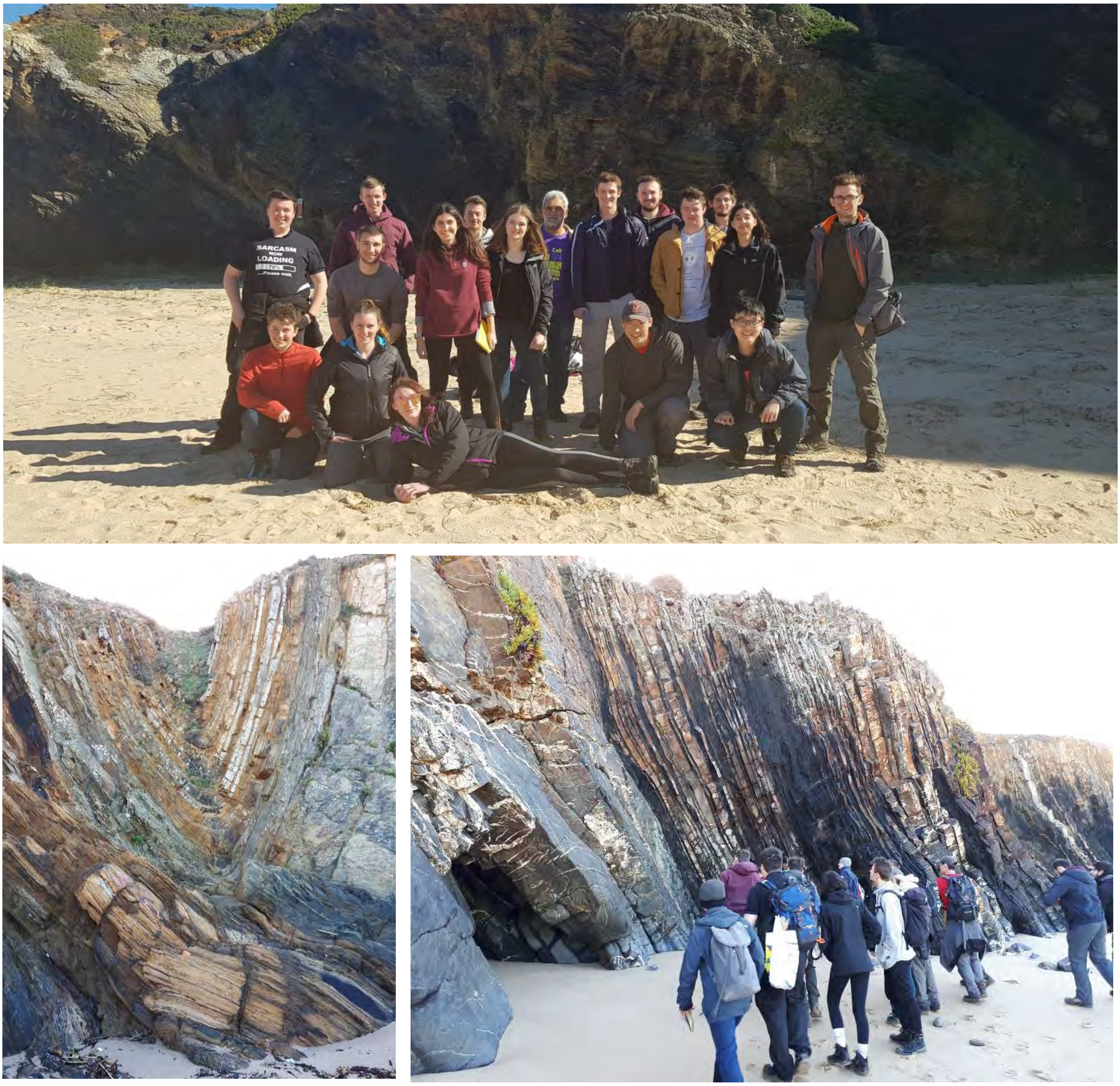


Figure 14 (Continued)- *Assorted images taken at the beach of Almograve, demonstrating inetnse and imrsessive Variscan-related folding with multiple generations of quartz veins.*

Following this, we learned some more about current research work that is being undertaken in the area, such as the identification of multiple generations of quartz veins based on fluid inclusion studies and geochemical techniques. Comparisons were drawn to other analogous terrains with similar structures that represent other zones of the Variscan orogen, enabling a better overall regional understanding. Additionally, Rui informed all the students of opportunities in the summer to undertake structural mapping fieldwork which will enable experience in and development of field skills.

Acknowledgements.

Again, many thanks go to the SEG and Minsouth for their generous contributions which subsidised the tip, ultimately enabling it to run. The chapter would also like to thank all of the people with whom we collaborated with and met during the trip, especially for running such informative and innovative days. It was great to meet such a diverse group of specialists in a range of subjects. Special thanks go to the University of Porto for accommodating us and giving fantastic insight to the regional geological history of Portugal.

Additionally, we would like to especially thank Will Smith and Inês Pereira for coming up with the idea for the trip and securing contacts; this base stage provided invaluable during planning of the trip. Finally we would like to thank all of the other chapters for their participation in the trip, especially committee members of the Bristol and Oxford chapters whom were directly involved in planning of the trip.

SEG Southwest England Fieldtrip- *Critical Metals of the Cornubian Batholith, 30th March- 2nd April 2018.*

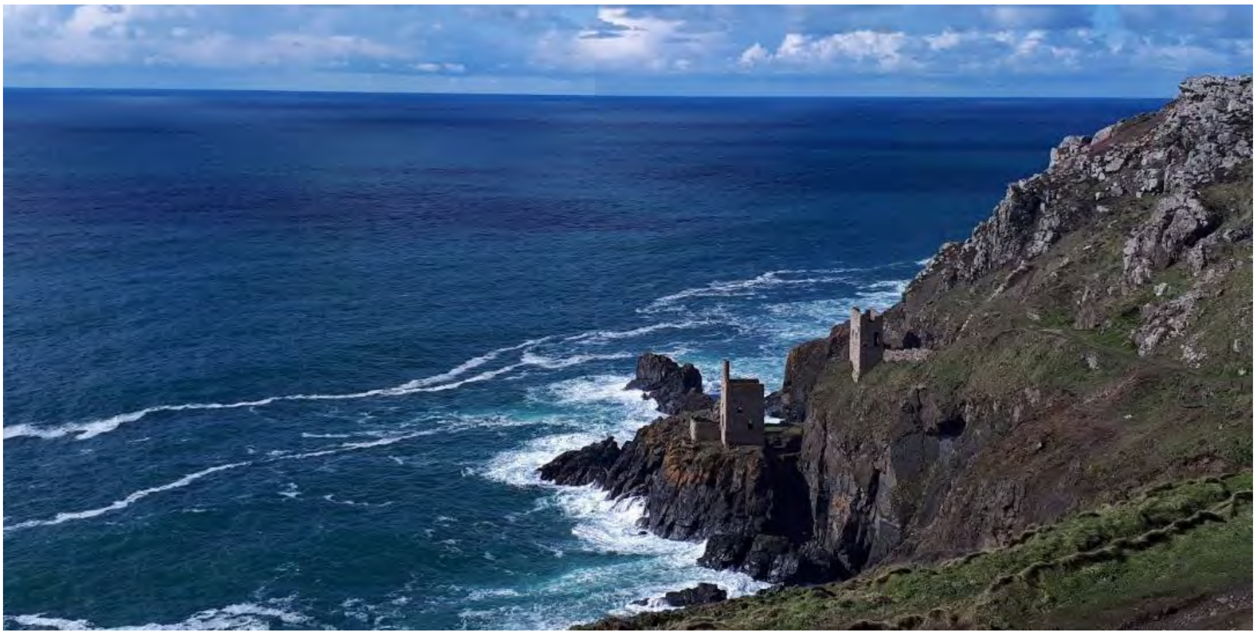
The UOP chapter attended a trip to the Southwest in collaboration with Trinity College Dublin over the Easter weekend, running from the 30th March - 2nd of April. The trip started off in the St Just Mining District, moving northeast and ending in Dartmoor. The localities consisted of a mixture of coastal outcrops, mineral deposits and mine sites, from which mineralisation styles and tectomagmatic evolution of the Cornubian batholith was displayed. The Chapters also attended the 40th International Mining Games, hosted by Camborne School of Mines (CSM), University of Exeter.

The trip aimed to give insight to the ore-forming processes of mineral deposits in the Southwest and to evaluate the potential of these resources. Since the opening of the Drakeland's W-Sn mine in 2015 and with current demand for metals, renewed exploration in the Southwest for precious and critical metals is arguably more important now than ever. The group of students in attendance ranged from 1st year undergraduate to PhD postgraduate students.

The UOP Chapter gratefully acknowledges the invitation from Trinity College Dublin to attend the trip and collaborate allowing us to share our knowledge of the Southwest. Further to this, we thank all the committee members involved for planning and organising the trip.

Trip Objectives:

- To learn about ore-forming processes that formed the various precious and critical metal deposits & mineralisation in the Cornubian Batholith.
- To adopt field work to put tectomagmatic processes that contributed towards and ultimately controlled base-metal enrichment and concentration in the Southwest.
- To learn about the rich mining heritage of the Southwest, through numerous site visits to active mineral exploration/mining projects, previous mines and the rejuvenation/rehabilitation of mines following the end-cycle of mining projects.
- Observe examples of mineralisation in the Southwest, using field skills to understand the processes forming and controlling these on both a local and regional scale.



Day 1- St Just District.

Meeting time was 07:30 at Bristol Airport; the cohort travelled SW to the St Just Mining district, arriving approximately mid-morning at the first locality. This day centred on the St Just mining district and the rich mining heritage of this area; concepts of ore-forming processes and examples of mineralisation were observed in field at locality 1.1 & 1.2. Locality 1.3 introduced students to the scale and styles of previous mining and exploration in the area.

1.1 Priest's Cove

Priest's cove is located in Cape Cornwall, on the extreme western edge of the region. Students learned about the geological background of the area and ore-forming processes constituting mineral deposits observed. This gave students the chance to observe deformed metasediments, tin-bearing tourmaline & quartz-veins, alteration from an exposed granitic contact, and some great examples of cross cutting relationships (Figure 15). The locality also boasts great examples of greisenisation and tourmalinisation alteration processes.

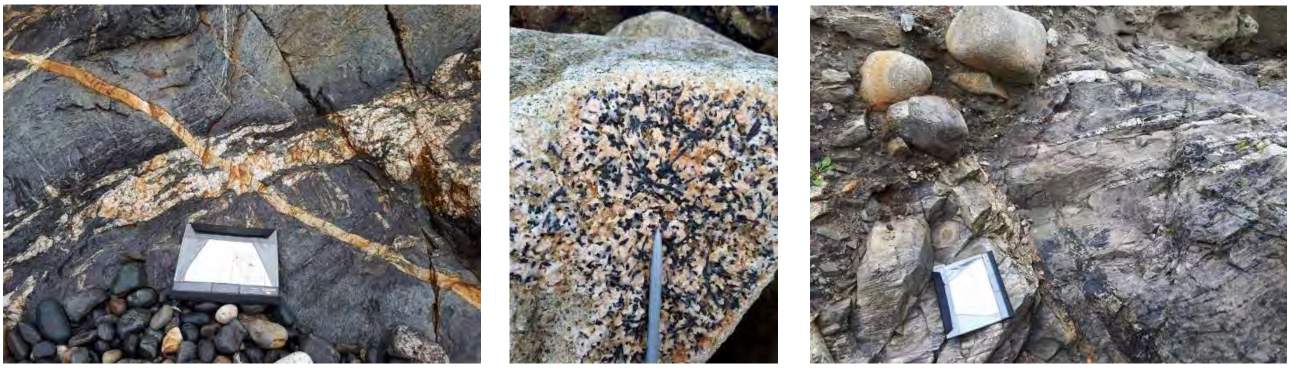


Figure 15- *Assorted images taken at Priests cove. (i) Cross-cutting relationships displayed by quartz veins in Devonian age metasediments of the Mylor Slate Fm, (ii) Well-developed tourmaline laths within granite, exhibiting a degree of radial nucleation, (iii) Mylor Slate Fm metasediments with quartz-veins cross cute by late-stage highly evolved aplitic dykes.*

1.2 Botallack

Now protected by the National Trust, Botallack is a brilliant reminder of the rich mining heritage of the St Just tin mining district (Figure 16). Cu-Sn hosted in sub-vertical lodes was mined from the 1700's, until closure of the mine in 1914. This locality demonstrates great examples of skarns, metasomatic alteration and Cu-Sn deposits, allowing students to learn more about boron metasomatism associated with the exsolution of fluids coeval subsequent of granite emplacement. Old mining buildings are protected at the site and serve as a reminder to the rich mining heritage of Cornwall.

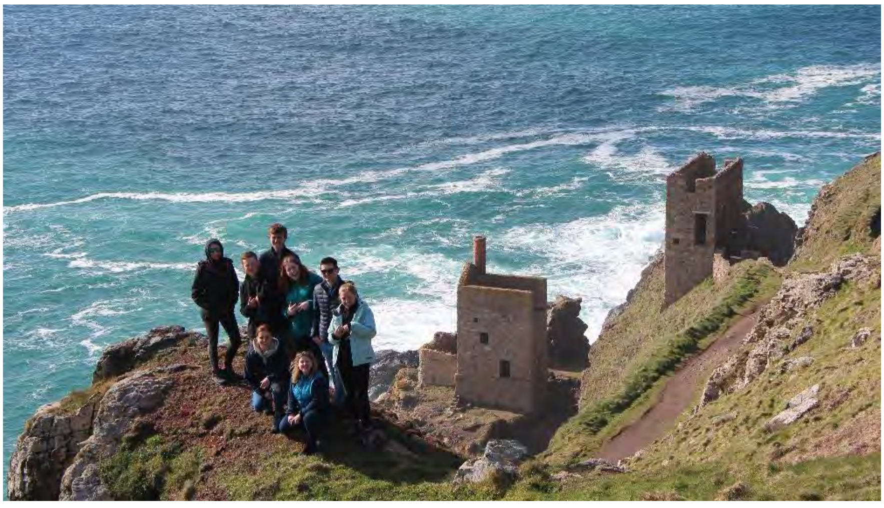
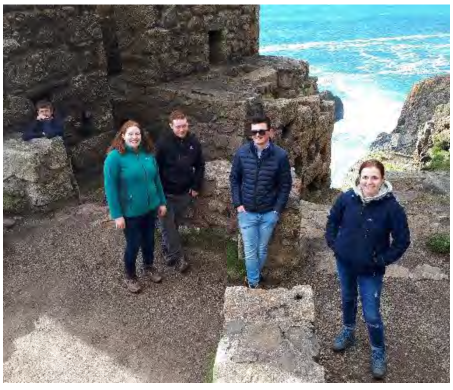
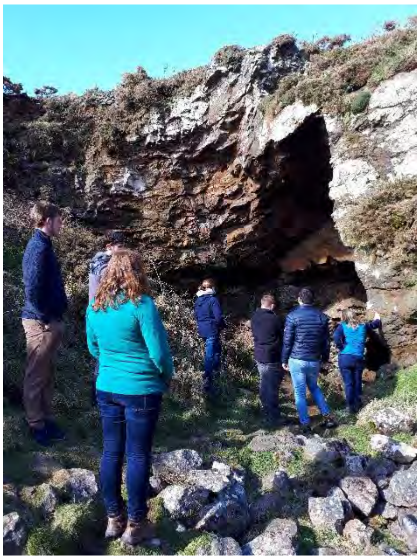


Figure 16- *Old engine houses preserved at the National Trust heritage site of Botallack.*



1.3 Wheal Owles



From Botallack the cohort walked ~500m to Wheal Owles pump house. Mineralisation here is of a different style to that of Botallack, constituting later Triassic mineralisation. Deposits here are constituted of uraniferous & cobaltic lodes and Arsenopyrite (As). Students learned about later Triassic mineralising events and got to observe massive tourmaline replacement textures (Figure 17).

Figure 17- *Students getting up close with Triassic U-Co-As mineralisation and learning more about formational processes. They also got to observe massive tourmaline replacement; tourmalinisation is one of three alteration processes commonly observed in association with Cornubian granites.*

1.4 Geevor Tin Mine

The final stop for the day was Geevor Tin Mine, arriving at ~14:00. Geevor tin mine began operations in 1911 and closed in 1991, during which time some 50,000 tonnes of black tin were produced; Sn-Cu were mined from the late 18th century in the local area. Geevor is now the largest preserved mine site in the country and gives great insight into former operations and heritage of the St Just district.

We started off with a tour of the museum, which displays old workrooms, processing plant machinery and numerous artefacts (Figure 18). This allowed students to learn more about the men and women that were involved in the mining process and numerous techniques used for mining and processing. From here, we got kitted up and went underground into the Wheal Mexico mine (Figure 19), an underground working dating from the late 18th century; these adits were rediscovered in 1995 and constitute one of the small workings that combined to form Geevor Mine.

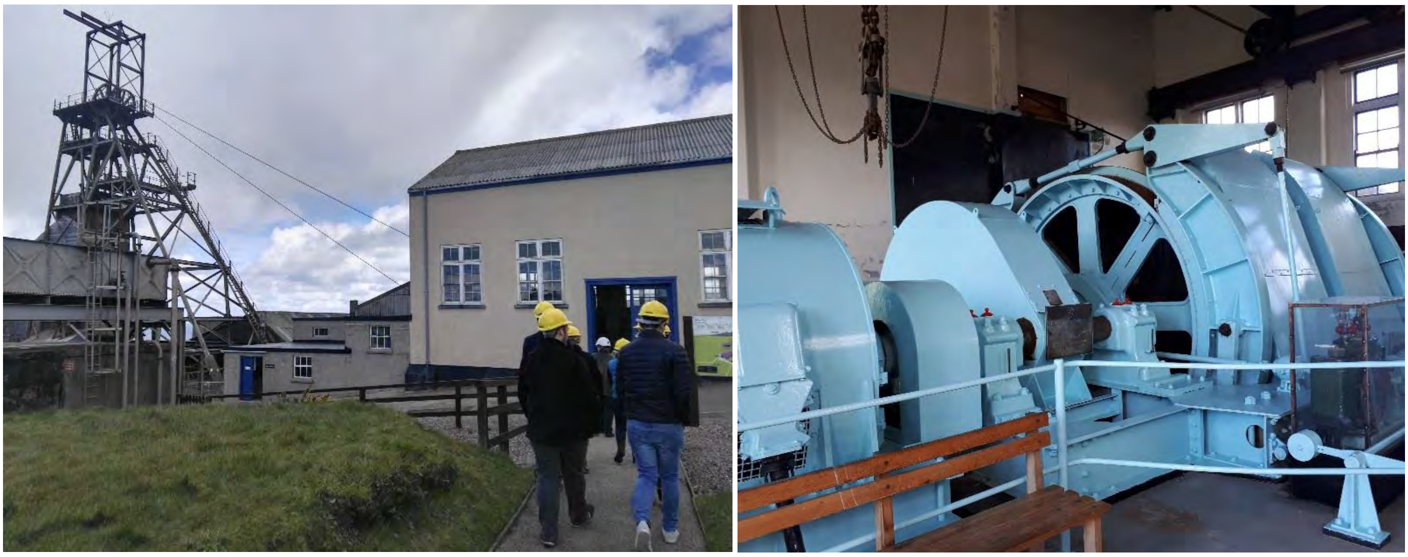


Figure 18- *Preserved 18th-19th machinery and rig at Geevor Tin Mine.*

Figure 19- *Guided tour underground in sub-surface level adits of Wheal Mexico Mine.*

Day 2- 40th International Mining Games (IMG).

On the second day, we travelled towards Camborne to attend the 40th IMG hosted at Kind Edwards Mine by CSM. 40 teams from various universities around the world attend this event, competing in 7 events of traditional mining methods; *the event preserves traditional methods and celebrates the heritage of Cornish mining, additionally commemorating those that have lost their lives in the industry over the years.* This was followed by visits to locality 2.2 & 2.3, where students undertook fieldwork and learned more about mineral deposits.

2.1 40th International Mining Games

The 40TH IMG were hosted by Camborne School of Mines and consists of seven traditional mining methods: *Mucking, Handsteel, Swede Saw, Trackstand, Jack Leg, Survey and Gold Pan* (Figure 20). Teams of six from around the world compete in each of the events. Attending this event gave insight to traditional mining methods used in Cornwall and the importance of preservation of mining heritage. It additionally enabled students to network with a diverse range of students from global Universities.

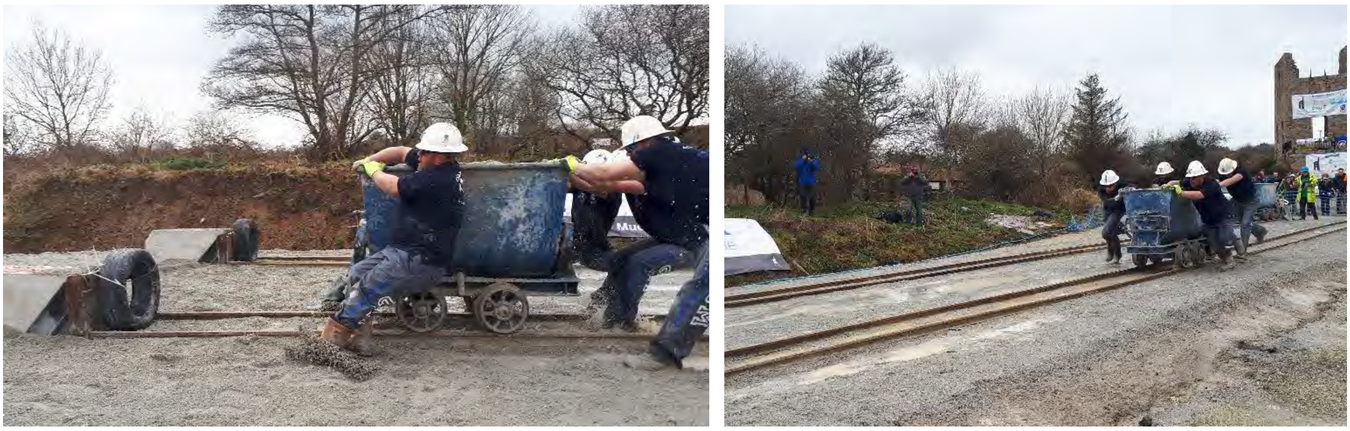


Figure 20- *Univerisites participating in the Mucking event at the 40th IMG.*

This was followed by a visit to the King Edward Mining Museum, where we learned more about processing methods of ore deposits and how this has changed over history. The focus of the Kind Edward Mining Museum is to provide an insight into Cornwall's long mining heritage and preserve some of last remaining historical equipment associated with mining in the Southwest (Figure 21).

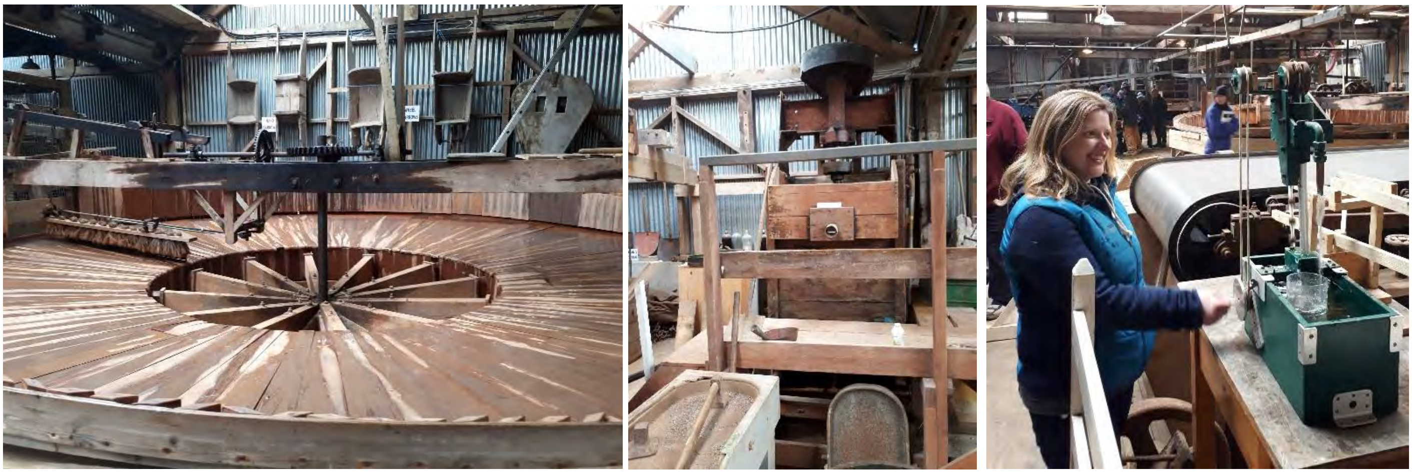


Figure 21- *Preserved processing equipment from the late 18th & 19th centruies atKind Edward Mining Museum. (i) Cornish Round Frame used for recovery of fine tin slimes, (ii) Froth flotation cell, used for removal of contamiating copper (Cu), iron (Fe) & arsenic (As) from tin concentrates*.

2.2 Chapel Porth

The cohort then travelled north, towards the St Agnes heritage coast, stopping at Chapel Porth beach, now protected by the National Trust. In addition to the retention of old engine houses, the exposure of coastal outcrops is a great way to observe mineralisation and faulting history of West Penwith.

Chapel Porth demonstrates multiple phases of granite intrusion and mineralisation. This emphasises the prolonged magmatic history of the batholith and fractionation processes leading to more evolved suites of granite highlighting heterogeneous nature of such bodies. Both early sheeted vein mineralisation and later copper (Cu) mineralsiation from the Permian are observed. Wall-rock alteration and tourmalinisation were also observed, as well as secondary weathering & enrichment of copper (Figure 22). Students got to learn more about structural controls on mineralisation and the relationships between different generations of granite intrusion and mineralsiation, highlighting how this fits into the broader regional picture. The appliance of field observation gave rise to identification of numerous enclaves, xenoliths, tourmaline veins and concentrations of mineralisation.

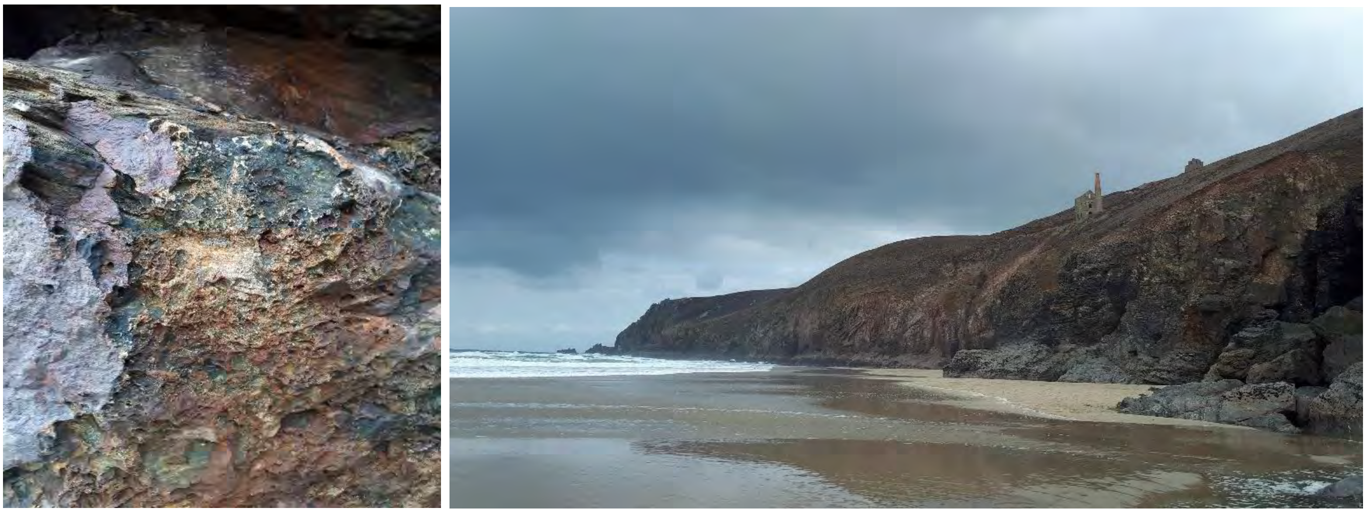


Figure 22- *Assorted images taken at Chapel Porth. (i) Copper mineralisation (green) in Devonain-Carboniferous metasediments, with assocaited tourmalinisation and evident haematisation (Fe enrichment), (ii) Old engine house.*

2.3 Cligga Head

The cohort then travelled further north along St Agnes heritage coast towards locality 2.3. Cligga head is a minor intrusion of typically G2 suite (Muscovite) porphyritic granite, with associated Wolframite (W)- Tin (Sn) mineralisation. Greisen alteration is a common feature here and the W-Sn bearing quartz-veins commonly exhibit well-developed greisen borders; greisenisation is one of three alteration processes commonly observed throughout the Cornubian Batholith. Cligga operated in the early part of the 20th Century, producing some 300 tonnes of wolfram & 200 tonnes of black tin during 1940-1944, until closure of the mine in the late 1940's.

We started off by observing the quartz-veins and their relationship to the granite host, including: greisnening of veins, feldspar orientation & kaolinisation, orientation of veins, and textures of mineralsiation (Figure 23). An area of polymetallic mineralisation, in addition to Sn-W, Arsenopyrite, Chalcopyrite ($CuFeS_2$) & Bornite (Cu_5FeS_4) can also be seen here. Furthermore, the locality has a great example of elvans: highly evolved late-stage quartz-porphyry intrusions, which cross-cut granitic bodies regionally in an ENE-WSW orientation; the role of elvans in base-metal concentration and remobilisation processes is still not well understood. This put local tectomagmatic controls of base metal concentration into perspective for the students and allowed them to observe some classic Cornish geology.

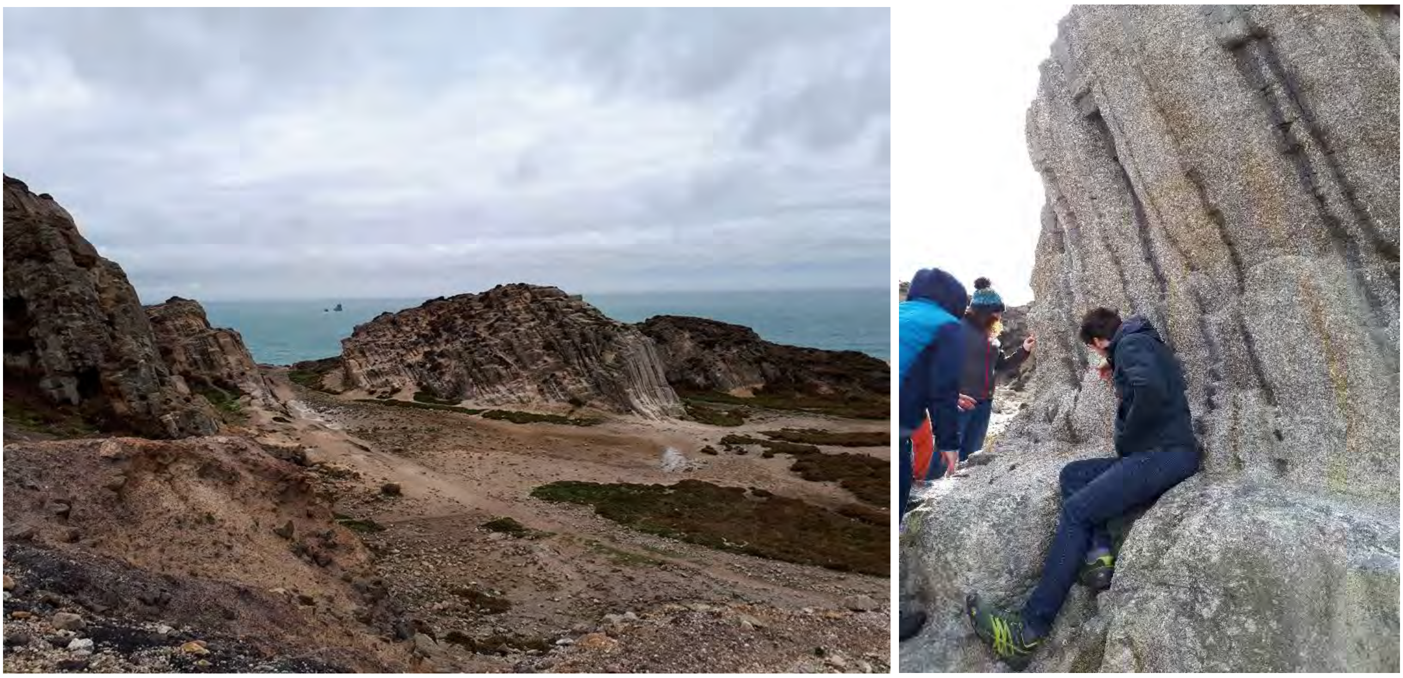


Figure 23- *Assorted images taken at Cligga Head. (i) Outcrop of G2 suite porphyritic granite with well orientated quartz-veins, (ii) Greisen Bordered quartz-veins hosting Cu-As-W-Sn mineralisation, note the orientation of veins related to the development of joints & fractures in the granite associated with post-Variscan regional extension.*

Day 3- St Agnes District.

On the third day, the cohort travelled towards the St Agnes District, towards St Austell. The day started by visiting South Crofty Mine (locality 3.1), which is currently undergoing renewed exploration by Strongbow Exploration Inc. *The original plan to visit Heartlands and Roche Rock had to be altered due to access issues and poor weather conditions, so locality 3.2 was substituted in. The Eden project was chosen on the basis of being a terrific example of regeneration/rehabilitation following the end-cycle of a previous Kaolin Mine.*

3.1 South Crofty Mine

The group travelled to Redruth where we met with Keith Russ, a surveyor at South Crofty. From here we were given a briefing into previous operations, current exploration & operations of Crofty and background geology of the area. South-Crofty began large-scale production of tin in the mid-1600's, working intermittently until final closure in 1998; in association with Sn, W-Cu-Zn-Pb were also worked. Recent renewed exploration fronted by Strongbow Exploration Ltd. in 2016 has inferred economic Sn mineralisation within EWE-WSW lodes.

The cohort then got kitted up to go underground into the workings. We were then taught about the variety of mining and exploration methods used both previously & currently. This outlined the mining heritage and history of the site, giving insight to the conditions miners have previously worked in. Students also had the chance to observe mineralisation, host-kilas, granite and various structures (Figure 24); as undergraduate students do not typically get much exposure to underground workings during their studies, this gave valuable & beneficial insight to the way in which a mine works. This was followed by a collaborative lunch hosted by Strongbow Exploration Ltd. with a range of universities from the mining games and industry professionals.

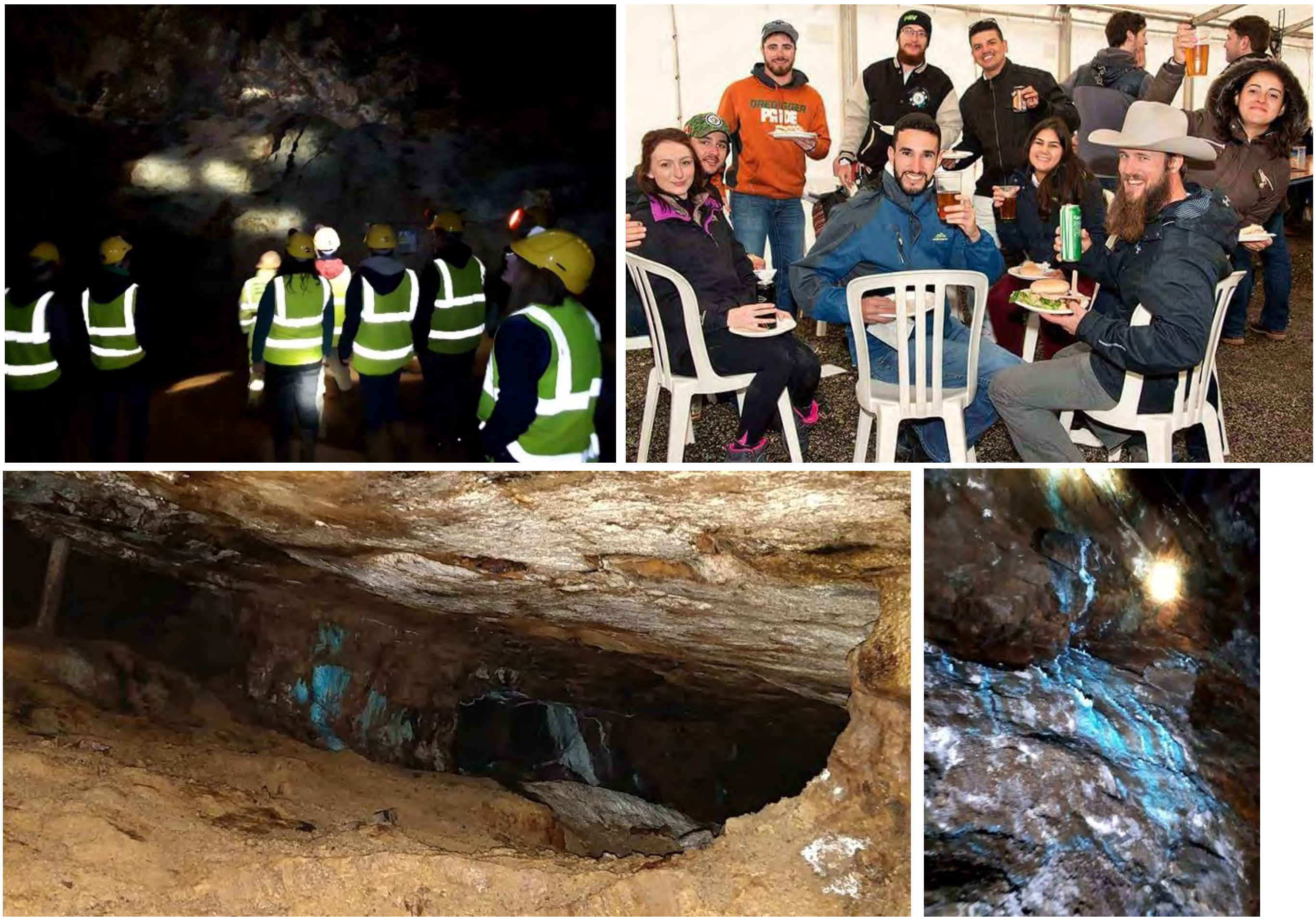


Figure 24- *Assorted images taken at South Crofty showing: tunnels, mineralisation and networking with other Universities from around the world.*

3.2 Eden Project – change to initial plan of Heartlands & Roche Rock

Due to adverse weather conditions, a change was made to the initial plan (outlined at start of Day 3). The Eden project is located ~5km from St Austell, and opened in 2001 following 2 ½ year period of construction. The project is located within a reclaimed China Clay pit that operated for >160 years, and is a great example of the rehabilitation of an old mine following the end-cycle of production and closure (Figure 25).

Kaolinisation is one of the three alteration processes associated with Cornubian granites which forms deposits of china clay and is well observed in the areas around the St Austell Pluton; large scale extraction of this resource over the past is characterised by the 'Cornish Alps' (large steep-sided spoil tips) and numerous pits clearly visible in satellite images. China clay (Kaolinite) is used in the production of china & porcelain, and is also used widely as an ingredient in the production of paper, rubber & paint. Issues with old mines may include degradation of local ecosystems, acid mine drainage (AMD) and contamination from gangue materials; therefore, mines today are required to have rejuvenation/rehabilitation measures in place following end of production and closure of the mine.

The Eden project consists of two main biomes, containing a range of plant species for different environments around the world with the main aims of conservation, research and education. Furthermore, the project has a botanical garden with many native/indigenous plant species to Cornwall.

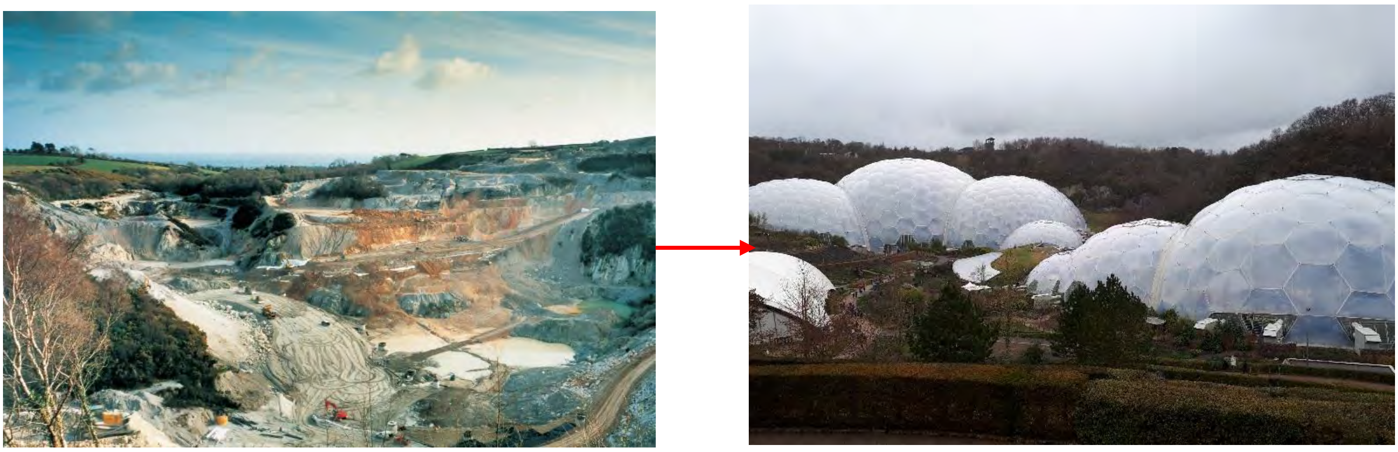


Figure 25- *A before and after image of the Eden project, showing transformation and rehabilitation of a China Clay Pit into a new ecosystem.*

Day 4- Structural evolution of the Southwest & Dartmoor.

On the fourth day, the cohort travelled NE from the Eden Project towards the coastline of NE Cornwall. *Due to the bank holiday weekend, the group was sadly unable to visit Hemerdon Mine, localities 4.1 & 4.2 were added for a better structural understanding of the Batholith.*

We stopped at localities 4.1 & 4.2 to learn more about the structural evolution of the Southwest. The Variscan Orogen lasted ~100myr, during which time progressive convergence caused impressive polyphase deformation of Devonian and Carboniferous sediments within the Rhenohercynian Zone, reaching regional metamorhism grades of greenschist facies (300-350°C). Granites in the Southwest constitute five chemical suites and were emplaced from 295-270ma, following extensional collapse of the short-lived orogen; polymetallic mineralisation associated with granatoid emplacement constitutes the main-stage of ore-formation, and is hosted in typically ENE-SWS trending regional lodes. These are cut by later N-S lodes, associated with Permian wrench-faulting and basinal brines.

It is therefore important that students understand the structural evolution of the province, as tectomagmatic processes have fundamental controls on ore-forming processes, and base-metal concentration & distribution within the batholith.

4.1 Boscastle

The cohort travelled to the north coast of Cornwall, stopping in the village of Boscastle, from there we took the path up to some exposures of the Crackington Fm. The Crackington formation is Late Carboniferous in age and consist of siltstones, mudstones and sandstones representative of a flysch sequence, with incorporated beds of chert. The exposures boast some impressive and intense polyphase folding, with structural and textural features recording five different stages of deformation from: large-scale chevron folding, to parasitic folds (microfolds) and development crenulation cleavage. Numerous ductile and brittle features mark lithological differences and competences allowing a better understanding of structural processes.

The students learned more about the Variscan Orogeny and the role that structural evolution of the region played in the formation of magma that was ultimately emplaced as the Cornubian Batholith, including sequential mineralisation events, base-metal concentration and the structural controls on emplacement of mineralisation (Figure 26). This highlighted not only how Boscastle fits into the broader regional picture, but it also gave a sense of how localised events can be too.

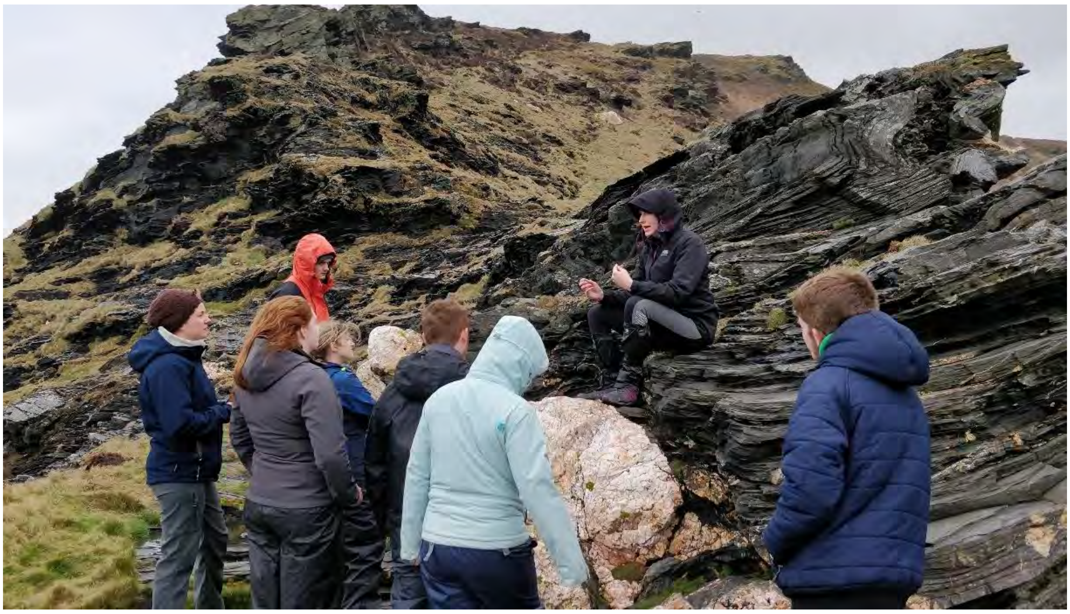


Figure 26- *Portsmouth Chapter President teaching TCD students about the Variscan Orogeny and putting structural controls on mineralisation into perspective.*

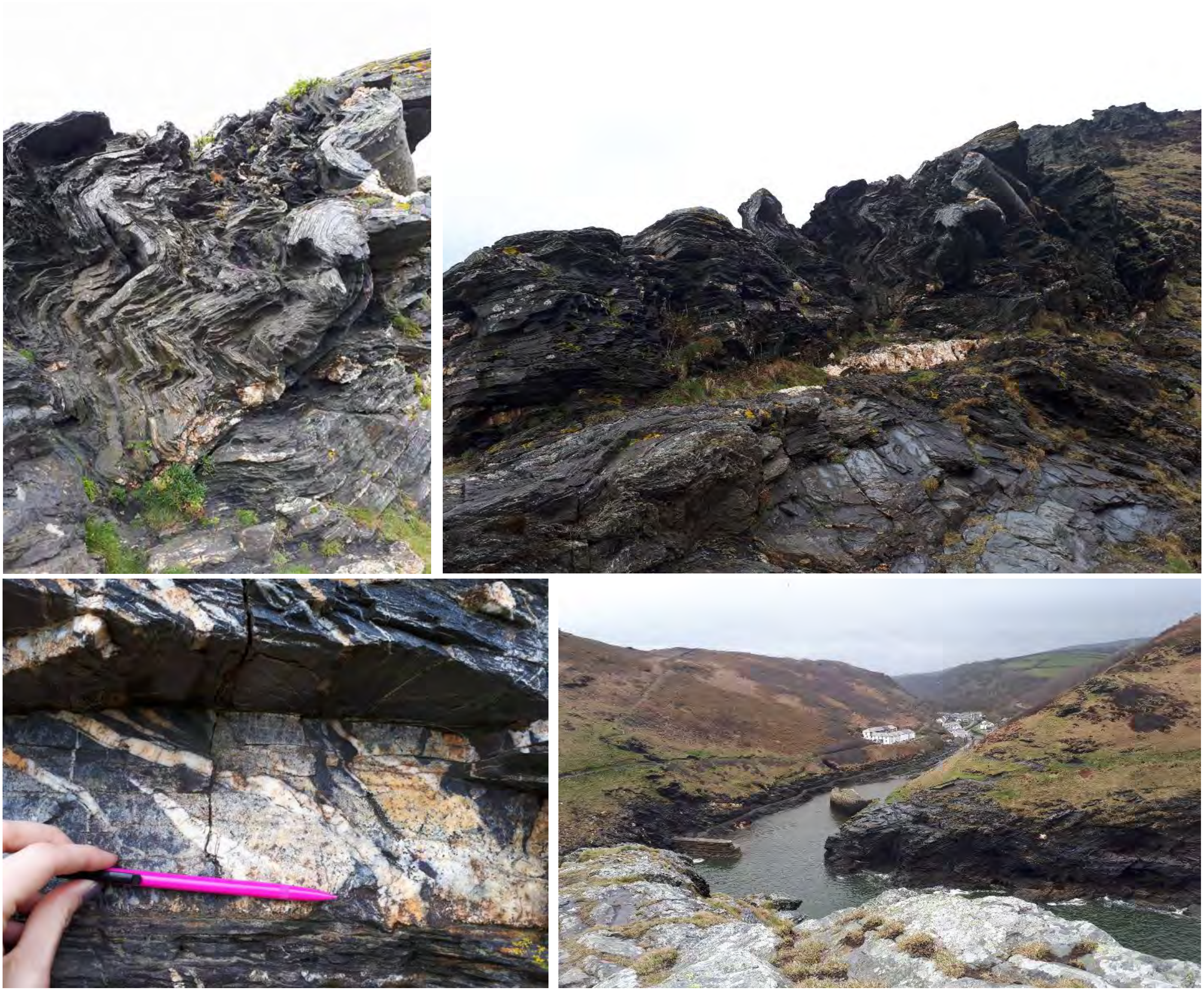


Figure 26 (Continued) - *Intensely folded metasediments of the Crackington Fm exposed at Boscastle. These are regionally metamorphosed up to Greenschist facies metamorphic grade (300-350°C) and exhibit a range of structural features recording multiple deformation events.*

4.2 Millook Haven

Following the stop at locality 4.1, the group travelled north up the coast to locality 4.2. Millook Haven is a textbook example of chevron folding and complemented the regional structural aspect considered at Boscastle very well.

Here the group learned more about structural features and development of the striking recumbent chevron folds; way-up structures were identified and used to identify the direction of younging. Numerous sedimentary features such as: graded bedding, symmetrical ripple marks, low-angle cross-bedding, shearing indicators, faulting and multiple forms of folding, were used to summarise the environment of deposition and geological history of the area (Figure 27). This was then incorporated into the broader regional picture to improve understanding of the Variscan Orogeny.

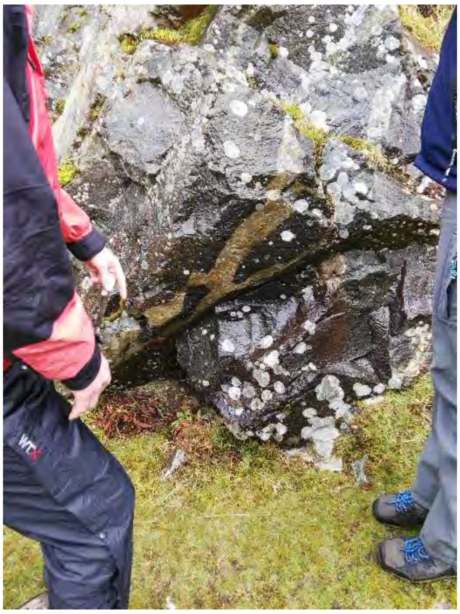
Figure 27- *Assorted images at Millook Haven, Cornwall. (i) & (ii) Recumbent Chevron folds, (iii) Symmetrical ripple marks within Carboniferous strata showing upturned beds, (iv) Post-depositional quartz-veins showing brittle deformation and offset from micro-faulting, (v) Deformed quartz veins indicating shearing.*

4.3 Meldon Quarry

The group set off east towards Dartmoor for the afternoon, arriving at Meldon quarry at ~14:00. Meldon Quarry is a limestone quarry characterised by greenstone, aplitic intrusions and alteration associated with emplacement of the Dartmoor granite; this caused epidote and chloritic alteration to the local limestones and development of local skarns. In close proximity to the granite, hornfelsed kilas can also be observed; heat from the granite has also caused a metamorphic aureole within adjacent country rocks, which can be determined through appliance of indicator minerals such as andalusite (Al_2SiO_5) & cordierite.

Operations at Meldon Quarry began in 1897, extracting ballast and stone products for London and South Western Railway; production around 1897 peaked at ~100,000 tonnes/anum, with extension occurring over the years. By 1953 Meldon Quarry annually produced 340,000 tonnes of ballast. In addition to local skarns and greenstone, sulphide mineralisation and aplitic intrusions can also be observed.

The Meldon Aplite Quarry located just south of the main quarry is now a disused site which records effects of contact metamorphism associated with the intrusion of a major granitic body. Examples of disseminated sulphides such as Arsenopyrite can be observed, in addition to multiple accessories: apatite, purple fluorite and tourmaline (watermelon tourmaline). The group learned about magmatic processes which formed these minerals and the intrusion of highly evolved aplitic veins, both from a regional and local perspective (Figure 28).



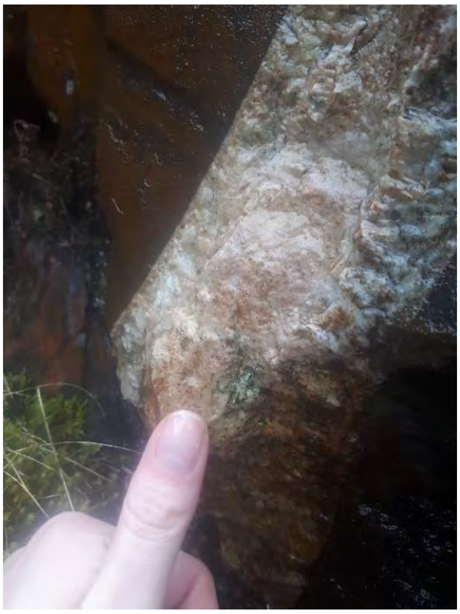


Figure 28- *Images taken at Meldon Aplite Quarry. (i) Aplitic intrusion exploiting extensional joints, (ii) Quartz vein with green tourmaline needles (elabite variety- characterised by high Li & Al content).*

4.4 Dartmoor (Birch Tor)

The final locality for the trip was Birch Tor located SE of Meldon Quarry in central Dartmoor. This area is thought to have been mined since medieval times, intermittently until operations ceased ~80 years ago and large scars can be observed across the landscape (Figure 29).

Here we learned about multiple stages of well-defined mineralisation, representative of pulsed hydrothermal activity. At this locality sulphides are absent and the only economic mineral is cassiterite (Sn), which occurs in a gangue of quartz, tourmaline, chlorite & haematite. This allowed students to observe different mineral textures and fabrics formed by processes associated with hydrothermal and minor tectonic activity (local scale): i.e. brecciation, offset.

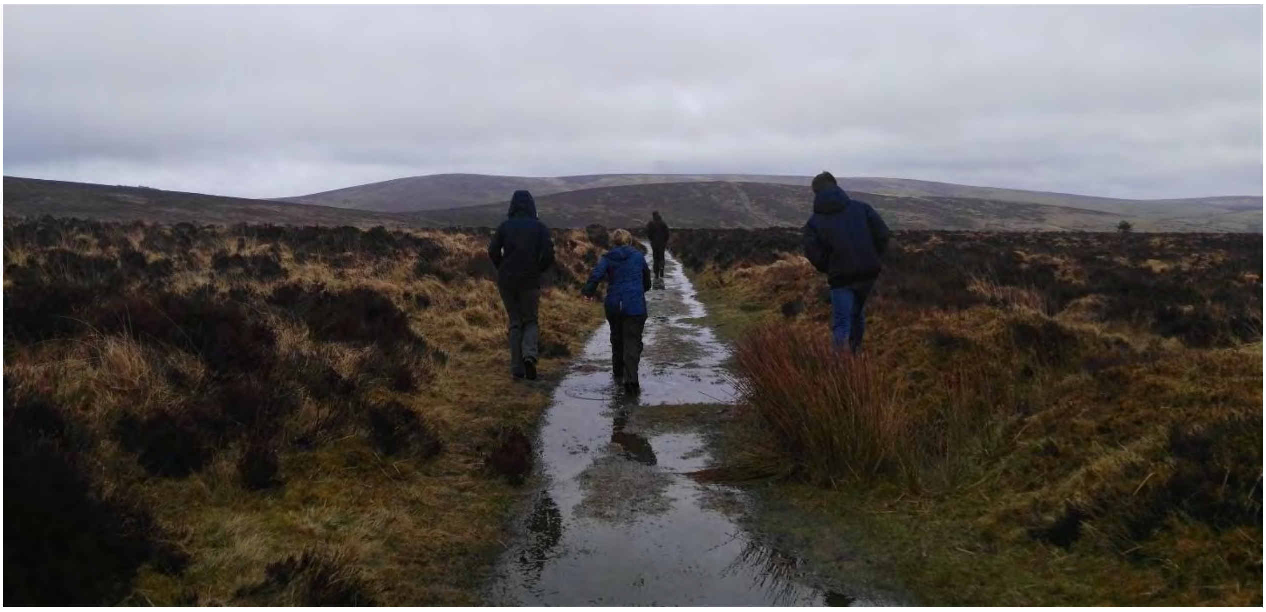


Figure 29- *Some of the group heading up the trail towards Brich Tor, Central Dartmoor.*

Acknowledgements.

First and foremostly, we would like to thank TCD for their invitation to attend the trip, enabling us to share our knowledge of Cornish Geology. We would also like to thank all of those from the TCD SEG committee who were involved in the planning and deliverance of the trip.

We also extend our thanks to CSM for hosting us at the IMG and following awards dinner. We are grateful for all the industry professionals that hosted us at various site visits and extend special thanks to them. Additionally, we would like to thank the SEG for subsiding the trip for TCD students with a generous grant following Round II of the Stewart Wallace Fund.