noted the outcrop of sandstone, now attributed to the coal measures and the area of boggy ground where a small stream flows over the coal measure shales. Finally reaching the higher ground of the Carboniferous limestone. A pleasant picnic lunch was eaten on the benches near the car park.

After lunch we drove a little way down the road to the NT Ebbor gorge car park and made our way into the woods, then following the stream, to the location of an abandoned mineshaft. Doug explained how in 1871 the shaft was sunk to 36m in depth in the search for coal. It may be presumed that the reddish sandstone we had seen earlier, had been mis-identified as Triassic in age or the presence of carbonaceous shales had misled the investors. A contemporary account by the geologists' Bristow and Woodward describes the folly of the event *''The sinking of this shaft under such manifestly hopeless conditions shows a want of knowledge of the elements of geology and coal-mining that could scarcely be supposed to exist at the present day on the part of persons likely to embark in a search for coal within five miles of a Cathedral City"* (Geological Magazine, V8 November 1871, pp. 500-505)

We then drove into Wookey Hole and made our way to the garden of David Scarth. His house is set in an old quarry and the Triassic Sandstone quarry walls form the boundary of his garden. This was the perfect place for a group photo (Fig. 5).

Fig. 5: Group Photo, Bath Geological Society participants.

The sandstones have a slight westerly dip, they are very thick bedded and laterally persistent. They probably represent stream flood deposits during the Triassic. Some thinner bedded units were recognised as more nodular and probably represent a palaeo-soils. Of special interest is a small normal fault in the east side of the quarry, this has a strike of 030/210 degrees and a throw of about 1m down to the west. It is called 'Doug's Fault' as it goes under Doug's house! Fortunately, there has been no recent movement on it.

During the final part of trip, we walked east across the fields following the Triassic, past its onlap point, until we came again onto the Carboniferous limestone where there is a large disused quarry and lime kiln. The Carboniferous limestone here is the Burrington Oolite Formation. The massive nature of the limestone means that bedding planes are quite difficult to identify, and the group spent some time identifying candidate bedding surfaces. There are also a number of mineral bands, about 30cm wide, with symmetric banding, the veins have grown in thickness by opening and closing along the vein fracture and progressive depositing minerals on the growth surface (Fig. 7).

Fig 6: Doug demonstrates the throw on 'Doug's Fault'

Fig, 7: Symmetric banding within a mineral vein

The group returned to Wookey Hole, having enjoyed wonderful weather and a great day learning about the rocks of the Mendips. We thanked Doug and David for a very informative and enjoyable field trip.

-.-

Making thin sections at home

by Jonathan Slack

Last year I wrote an article for this journal entitled "Fun with thin sections". As all readers of this journal will know, thin sections of rocks enable identification of the constituent minerals and are often also very beautiful. At that time they were made for me by Robert Gill of Geosec. I did not believe that it would be possible for an amateur to make them at home because of the complex equipment I thought would be required. However, as a result of the Covid pandemic, Robert Gill was unable to continue processing customers' own specimens. This meant that if I wanted any more sections, I should have to grasp the nettle and have a go myself.

Setting up to do this kept me busy for much of Autumn 2020 and involved a lot of trial and error. In the end I can make fairly good thin sections although I suspect not quite of professional quality. I shall only describe the process I have ended up with, and not all the failures on the way. Some of the details are covered in the Appendix.

The procedure in 9 steps:

1.	Collect the samples.
2.	Cut suitable size blocks.
3.	Grind and polish one face to complete smoothness.
4.	Dry thoroughly, then glue this face to a glass slide.
5.	Slice off the rest of the block leaving about 1mm thickness stuck to the slide.
6.	Grind this down to 50-100µm thickness.
7.	Grind further by hand keeping a careful eye, and finish when the section is 30µm thick.
8.	Wash, dry, and apply some Canada Balsam and a coverslip.
9.	Allow the balsam to set and label the slide.

The great thing about making your own sections is that you can make as many as you like since they are no longer rationed by cost. Also, for each sample, you can make more than one block and keep for future reference any that are not immediately used. The specimens can be anything, depending on your interests. The prettiest results come from plutonic rocks because of the crystals they contain, but most kinds of rock can yield something of interest. I prefer samples actually taken from the bedrock, as you can then be sure of what you have got. As hammering bedrock is not allowed in some places, it may be necessary to take pieces that are lying around which look as though they have been eroded off the neighbouring bedrock. The ideal size for a sample is about the size of a fist. Pieces that are not too thick are easier to cut up with a tile cutter, but many samples do not come in the ideal shape and so it is necessary to break them up further. This is better done by cutting a deep groove and then breaking as gently as possible with a chisel, rather than hammering, so as not to introduce unwanted cracks which can cause the blocks to fall apart.

When I collect each sample, I put it in a plastic bag with a note of when and where it was found. As soon as possible I photograph it and give it a name (e.g., NQ7 is the seventh rock collected on a trip to the Newquay area). I also record a tentative identification based on hand lens inspection.

I cut out the blocks using an ordinary tile cutter (Fig.1a). I keep separate diamond edge wheels for cutting the blocks and for trimming them after they have been glued to the slide. Ideally a block should be about 2x2.5 cm in area and thick enough to handle easily (Fig. 1b), although I have used many smaller than this and many with somewhat irregular shapes. The blocks are labelled in felt tip with the name of the sample.

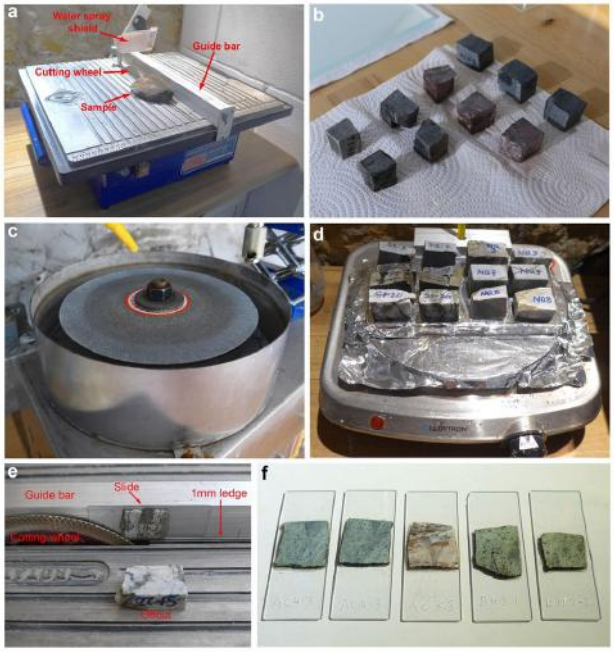

Fig. 1: (a) Tile cutter used for making small rectangular blocks. (b) Some blocks prepared. (c) Flat lap wheel for creating a smooth surface on the block. (d) Drying the blocks preparatory to mounting on slides. (e) Trimming the blocks to about 1mm thickness. (f) Slides bearing trimmed samples, ready for grinding.

Then one face of the block needs to be made absolutely flat. This is done by grinding on a flat lap machine, which has a horizontally mounted diamond-coated wheel (Fig. 1c). I hold the block by hand and use a 120 grit (coarse) wheel to get a flat surface, followed by manually grinding with 600 (medium) grit silicon carbide powder, with some water on a glass plate, to make it even flatter and to remove the grooves made by the wheel. Final polishing is done by rubbing for a minute or two with aluminium oxide powder (1200 grit) and water. The opposite face just needs to be ground fairly flat, and approximately parallel, so that it can rest on this surface when the slide is applied to the polished surface. I then put the blocks on a hotplate at about 100°C and dry them for several hours (Fig. 1d). This is to remove any water from deep cracks and crevices that might erupt and generate bubbles at a later stage.

I use 7.5x2.5cm glass slides. Petrographic sections are often made on smaller format slides, but I am wedded to the 7.5x2.5cm size which is used in biology. I use a thickness of about 1.4mm, which is quite thick and chosen to reduce the risk of the slides cracking as the epoxy resin sets. The epoxy resin I use is heat-activated and can be mixed in advance and stored indefinitely at -20° C. I allow the container to warm up before opening to avoid condensation. The blocks are placed polished side up on the hotplate at a surface temperature about 150°C. One drop of epoxy is spread over the surface of a block then a slide applied carefully so as to avoid bubble formation. A pre-heated weight is placed on top and the epoxy is allowed to gel for a few minutes. Then the weight is removed and the slide is turned over and

placed on the hotplate to achieve a hard set over about 30 minutes.

Once the blocks have been attached to their slides, the slides themselves are labelled with a diamond pen. The blocks are cut down to a thickness of about 1mm using the same tile cutter with a thinner blade. The guide bar I made for this step has attached to the base a thin steel plate to act as a ledge allowing the slide to be slid smoothly past the cutting wheel (Fig. 1e, f).

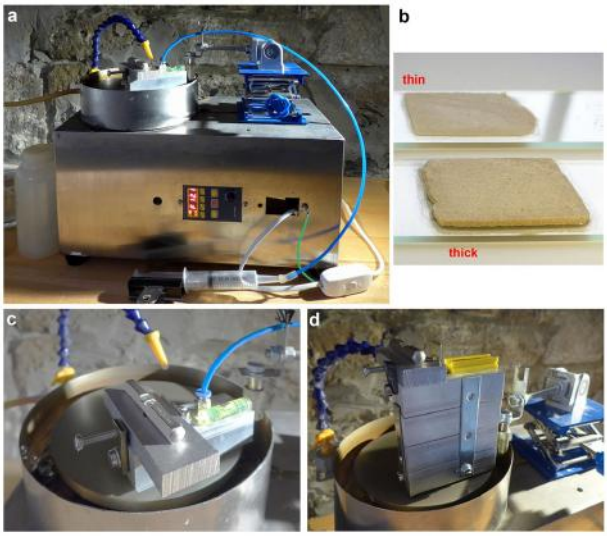

Fig. 2: (a) Slide grinding apparatus. (b) Reduction of sample thickness. (c) Close up of slide holder. (d) Heavy slide holder.

Now each sample is on its own labelled slide and is about 1µm (=1000mm) thick. This needs to be reduced to 30µm which is the standard thickness for petrographic sections. The reduction of thickness is mostly carried out using the flat lap machine (Fig. 2a, b). The slide holder used for this stage (Fig. 2c) is my own design and consists of a rectangular block of aluminium carrying two small spirit levels for levelling. It has a hole through the centre bearing a vacuum line attached to a syringe, the modest vacuum from this being enough to retain the slide in place. Between the aluminium body and the slide is a sheet of silicone rubber, with some silicone grease on the metal side, or sometimes both sides, to achieve a vacuum-tight seal. The slide holder is held by a ball and socket joint which can be raised and lowered with a lab jack to level it, as shown in Fig. 2a. The grinding regime depends on the hardness of the rock. I usually start with a coarse, 120 grit, wheel and steady the slide holder by hand until a flat level surface has been produced. Grinding is continued using a finer wheel, usually about 240 grit. A soft rock requires only minutes to reduce while a hard one may need hours, especially if the wheel is getting old. For hard rocks I may use an alternative slide holder which weighs 900 gm rather than 300 gm and therefore exerts more pressure on the sample (Fig. 2d). Careful timing and regular inspection is required to avoid grinding the sample away completely or allowing it to become less than perfectly level in both axes. Fig. 2b shows "before" and "after" views of the thickness reduction process.

When reduction has proceeded to something under 100µm the slide is removed and finished by hand. Now I hold it with a simple sucker and syringe device and grind it on a glass plate using water and silicon carbide powder, usually 400 grit (Fig. 3a, b). Hand grinding allows careful monitoring of the uniformity of the thickness, and regular examination under the microscope usually enables a final thickness of 30µm to be obtained.

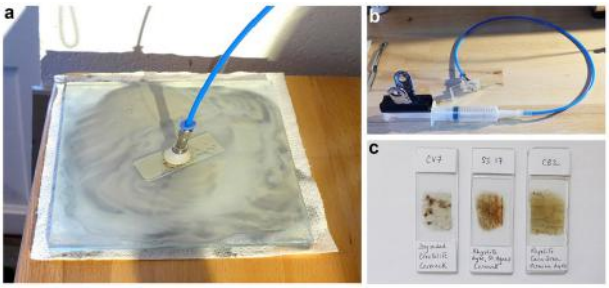

Fig. 3: Manual finishing. (a) Grinding on a glass plate with silicon carbide grit. (b) the slide holder. (c) the finished product.

How do you know when you have got to 30µm? The easiest way is to have some quartz or plagioclase feldspar in the section. Quartz has a very uniform composition and at 30µm should give a maximum white birefringence (see below for explanation of birefringence). If the quartz shows a maximum orange-yellow colour, then the section is about 50µm thick, if shows a maximum of light blue then it is about 75µm thick. Plagioclase is easy to recognise as it often has a stripy appearance (lamellar twinning) and at 30µm these stripes should be alternating black and white rather than the colours shown by thicker sections. If the specimens contains neither of these minerals, then it is more difficult to assess the thickness. Sometimes I make a small hole in the middle with a diamond pen and can then focus up and down through the section and note the thickness from the number of fine adjustment gradations traversed.

When I am satisfied with the thickness, the slide is washed in reverse osmosis water and dried on a 70°C hotplate. The coverslip is cleaned with xylene and meths, a streak of Canada Balsam is applied to the section and the coverslip carefully laid on top, avoiding bubble formation. It is then left overnight on the hotplate to set the balsam, and finally labelled (Fig. 3c). Although Canada Balsam is a very old-fashioned mounting medium, I use it instead of epoxy because, if there is a problem, it is easy to dissolve it off with xylene and to apply the coverslip again. Since I don't have a fume cupboard at home, I handle xylene and other noxious solvents outdoors.

Once the slide is ready, I look at it with my old Zeiss microscope, which has a rotating stage and a polarising attachment. I now use an AmScope MU300 camera in preference to the Canon used a year ago. These are remarkably cheap, have good resolution (3MPx), a flat field, and the software enables live streaming and image capture with colour temperature correction. You can even make videos of the image as you rotate the stage. I keep images of typical or attractive views and allow myself to adjust the sharpness, brightness, contrast, colour balance and intensity using Photoshop. However, my scientific background inhibits me from making any non-linear adjustments to the images, as this would be unethical and is forbidden in publications!

As I indicated in last year's article, it is fairly easy to become familiar with the main minerals found in sedimentary and igneous rocks, but the minerals of metamorphic rocks can be very tricky. Here I will just illustrate what can be done by showing a few specimens sectioned during the last year which present some point or other of interest.

Some results

First, a brief recap on optical terminology. The slides are usually viewed in plane polarised light (PPL) or in crossed polarised light (XPL). PPL gives a similar view to unpolarised transmitted light except that some minerals show *pleochroism*, meaning that they change colour when the stage is rotated. XPL shows the *birefringence* of mineral crystals. This is a colour caused by the interference of light rays taking different routes through a crystal. For the standard section thickness of 30µm, each mineral will show a characteristic maximum degree of birefringence when it is oriented in the correct way. Since crystals in any specimen are normally oriented at random, only some of them will show the maximum birefringence. Birefringence manifests itself as one of a sequence of colours, starting with grey, then white, then yellow, orange, pink, blue and green, then approximate repeats of the same sequence. The whole repeating series of colours is known as Newton's scale, and it is shown in all books on optical petrology. Some minerals, such as metallic oxides and sulphides, are opaque even at 30µm and these are best viewed in reflected light (RFL), for which I use a fibre optic light guide shining obliquely onto the slide.

The average refractive index of a mineral crystal determines its *relief*, or how it appears in transmitted light or PPL when immersed in Canada Balsam. The balsam has a refractive index of 1.516 and minerals close to this, such as quartz, appear almost invisible, and said to have a low relief. Minerals whose index deviates below, or, more usually, above this value show up more clearly and are said to have a medium or high relief depending on how great the deviation is.

The *cleavage* of a mineral crystal denotes cracks parallel to one or two of the main crystal planes. Their appearance, and the angle between them if there is more than one cleavage, is characteristic of the mineral. When viewing birefringence in XPL, as the stage is rotated, the colour will come to maximum intensity and fade to zero four times in each complete rotation. The point of zero transmission, or *extinction*, may be parallel to a principal cleavage plane, or may be at a characteristic maximum angle. This again is characteristic of the mineral.

Hopefully most minerals crystals can be identified by looking at the morphology, the relief, the pleochroism, if any, the maximum birefringence, and the maximum extinction angle. The nature of the rock will, of course, be defined by its mineral composition.

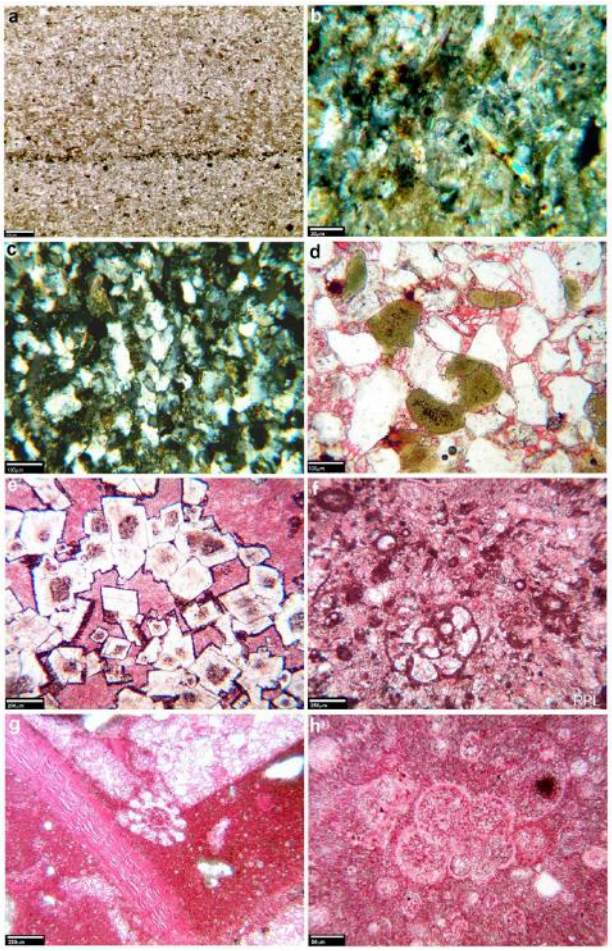

Fig. 4: (a) A Silurian shale from Shropshire, viewed in transmitted light. (b) High power view of the same shale. (c) May Hill sandstone (XPL). (d) Upper Greensand, viewed in PPL with alizarin stain of the calcite cement. (e-h) Limestones. (e) A Devonian limestone with many crystals of dolomite. Alizarin stain. (f) A Carboniferous limestone. Alizarin stain. (g) Great oolite from my garden in Bradford on Avon, . Alizarin stain. (f) A chalk from Bratton, Wiltshire. Alizarin stain.

Sections of a few sedimentary rocks

I must confess to have spent much more time on igneous than on sedimentary rocks. But I have collected a few sedimentary samples. Fig. 4a, b shows a randomly selected example of a shale from the Silurian of Shropshire (Edenhope Hill). It is composed of fine particles of clay minerals with a little quartz. The horizontal lamination, whose presence makes it a shale rather than a mudstone, is apparent. The high-power view shows the birefringence of the clay minerals.

Fig. 4c and d are sandstones. By definition, sandstones consist largely of quartz particles, and Fig. 4c is May Hill sandstone of the Silurian period, collected from the Malvern Hills. The majority mineral is quartz, visible as white and grey crystals, but there is also 5-10% of feldspar and some clay mineral particles. A less typical type of sandstone is the Greensand, found in the Lower Cretaceous. This gives attractive thin sections because it contains the bright green mineral glauconite, in between the quartz particles. The example shown in Fig. 4d is Upper Greensand from near Potterne, Wiltshire. It contains a calcite cement, presumably derived from the huge amount of overlying chalk, which binds the particles of quartz and glauconite together. The cement is

here stained with alizarin which makes it pink and gives a pleasing three-colour effect, with white quartz crystals, green glauconite and pink calcite.

Carbonate rocks are quite varied in thin section appearance. They have various different microstructures and often contain abundant microfossils. The principal mineral, calcite, has an exceptionally strong birefringence. In fact, it is so strong that in a 30µm section it is often not visible at all, although it can show a characteristic cross-hatched appearance (apparent in Fig. 9f below). Because calcite often shows up poorly in XPL, I usually stain limestone sections with alizarin which colours calcite pink. Fig. 4e-h shows some specimens stained in this way. The first is a Devonian limestone from Black Head, Torquay. This contains crystals of dolomite, which does not take up alizarin, against a pink matrix of calcite, which does. The second is a Carboniferous limestone from Goblin Combe, near Bristol Airport. This is very rich in microfossils which I confess I have not attempted to identify. The third is a sample of limestone from my garden in Bradford on Avon, which is perched on a steep slope of the Jurassic Great Oolite above the River Avon. The fourth is a Cretaceous chalk from Bratton, Wiltshire. Both of these are also rich in microfossils.

Sections of a few igneous rocks

For much of the last year travel has been restricted so I was unable to go out to collect any new samples. This meant that I had to rake through my collection to see if there was anything that might be worth sectioning and was also large enough to be able to preserve a portion. One sample came from a long-ago expedition to Mount Kilimanjaro (Fig. 5a). Kilimanjaro lies near the equator in the north of Tanzania and is a dormant volcano with just a few fumaroles indicating its former activity. Because of its altitude of 5895m, it is cold enough at the summit to have an ice cap. Fig. 5b shows me standing on the summit of Kilimanjaro in 1969 along with a very tall Dutchman and our guide. Although bemused by oxygen starvation I did pick up a piece of what I thought at the time was obsidian (Fig. 5c), but on later examination proved to be too brittle to really be obsidian. In 2021 a thin section and a little research on the geology of the mountain revealed that it was a phonolite lava. Fig. 5d-f show some crystals of anorthoclase feldspar and another of crystals of (probably) olivine and apatite, all surrounded by a dark brown matrix.

In 2003 my family went to Tenerife, where there is another dormant volcano, Mount Teide (Fig. 6a). At my insistence we took the cable car up to near the summit and I collected a black and a red sample of the local lava (Fig. 6b). These lay in a drawer until 2021 when I processed the black lava sample and made a thin section. Although there is phonolite on Mt Teide, this particular lava sample is very different from that from Kilimanjaro. The section revealed that it is an andesite containing nice crystals of plagioclase feldspar, hornblende and clinopyroxene in a matrix of feldspar laths (Fig. 6c-e).

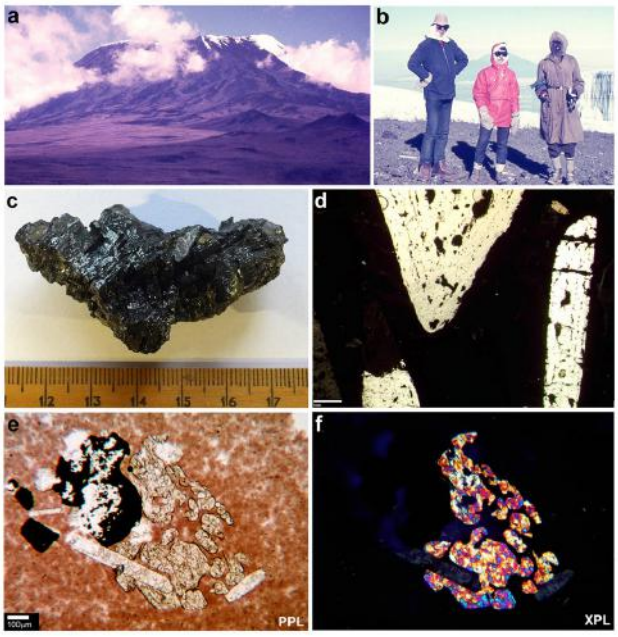

Fig.5. Kilimanjaro. (a) Kibo summit. (b) Summit party at Uhuru Point. I am in the middle flanked by a tall Dutchman and our guide. (c) A sample of the black lava from the crater rim. (d) Phenocrysts of anorthoclase feldspar. (e,f) PPL and XPL views of olivine and apatite in a brown matrix.

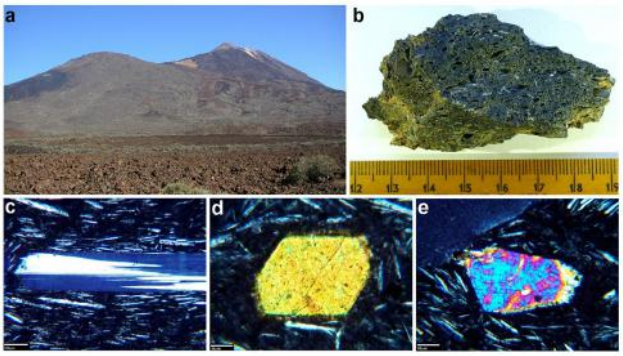

Fig. 6: Mt. Teide, Tenerife. (a) The mountain. (b) Sample of black lava. (c) Plagioclase feldspar. (d) Hornblende. (e) Clinopyroxene. (c,d,e are all XPL views).

An unlikely source of igneous, indeed somewhat metamorphosed, material is Portishead, just south of Bristol on the Somerset coast. I was able to go there on a day trip in between lockdowns in the summer of 2020. The bedrock is mostly limestone and Pennant sandstone, both of Carboniferous age, along with some conglomerate from the Triassic. It is not at all an igneous location as on the beach by the Royal Hotel there are some pieces of gneiss (Fig. 7a, b). These are mentioned by Williams and Hancock in Chapter 3 of *Geological Excursions in the Bristol District*, University of Bristol 1977. They may be fragments from a glacial erratic or are perhaps just part of a ship's ballast that was dumped in the area. Anyway, they are still there and they make nice sections showing a largely granitic composition. There is abundant microcline, the triclinic form of potassium feldspar, which is characterised by a tartan-like black and white birefringence (Fig. 7c). There is plenty of quartz and biotite, the latter being brown with strong pleochroism (Fig. 7d, e). There are also some garnets (Fig. 7f, g), which are indicative of some metamorphism. Because garnet belongs to the cubic crystal system it is optically

the same in all directions and shows no birefringence. This means it appears black in XPL at all angles of rotation

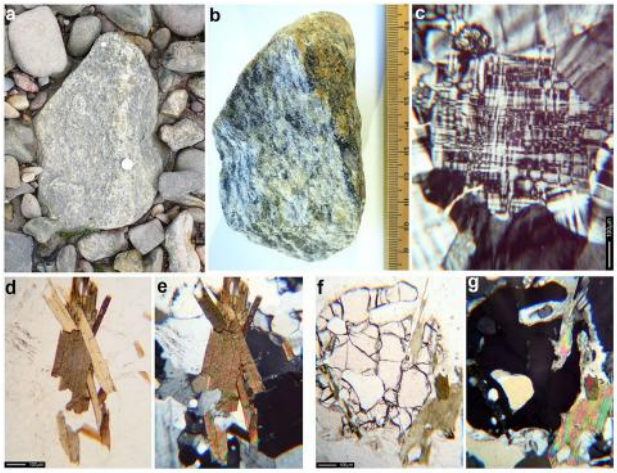

Fig. 7: Definitely in the wrong place. (a) A piece of granitic gneiss on the beach at Portishead. The coin is 10p. (b) A different sample under better illumination shows clear foliation. (c) It contains abundant microcline. (d, e) Biotite and quartz. PPL and XPL views. (f, g) A garnet with some more biotite. PPL and XPL views.

When regulations loosened enough to go for overnight trips to the South West coast path, I was able to collect some new material as an adjunct to the main business of walking. Fig. 8 shows a few of the products, with a focus on mineralised granite. Although Cornwall is legendary for its minerals, I find it difficult to find examples of the principal ores of tin and copper, respectively cassiterite (SnO_2) and chalcopyrite ($CuFeS_2$). I suspect that collectors have already removed all the surface specimens, and that the spoil tips of the old mines have all been well searched. Carn Brea is a classic mining area adjacent to Redruth, but the granite from the summit is quite ordinary without noticeable mineralisation (Fig. 8a, b). Fig. 8c shows a famous quarry at Cligga Point, which displays a "sheeted vein complex" with parallel bands of granite and of greisen, which is granite mineralised by hydrothermal fluids. The greisen bands here appear dark. They contain a few probable crystals of cassiterite (Fig. 8d) and a lot of pyrite (FeS), which is opaque in thin section but appears a silvery-yellow colour in reflected light (Fig. 8e). Iron oxides and hydroxides usually appear as opaque clumps but can sometimes be more picturesque and the delicate tendrils in Fig. 8e are fine enough to appear a translucent brown in transmitted light. Tourmaline is a ring silicate containing boron and fluorine, and is very abundant in mineralised granites. Fig. 8 (f) shows a crystal with zones showing blue-green and brown pleochroism as the plane of polarisation is rotated.

Another of our walking haunts is Offa's Dyke which runs the length of Wales approximately along the England-Wales border. Once you get north of Hay on Wye, some igneous sites come into range. Just off the dyke, west of Kington, is Stanner Hill. This is the northerly of three hills which are Neoproterozoic igneous intrusions. Stanner Hill provides both mafic (Mg and Fe rich) and felsic (SiO_2 and Al rich) rocks for the collector. The mafic region is displayed in a gabbro quarry at the south end of the hill and a felsic dyke cuts across the summit (Fig. 9a, b). This gabbro contains plenty of clinopyroxene, with cleavages exaggerated by the presence of iron ore (known as a "diallage" structure) (Fig. 9c, d).

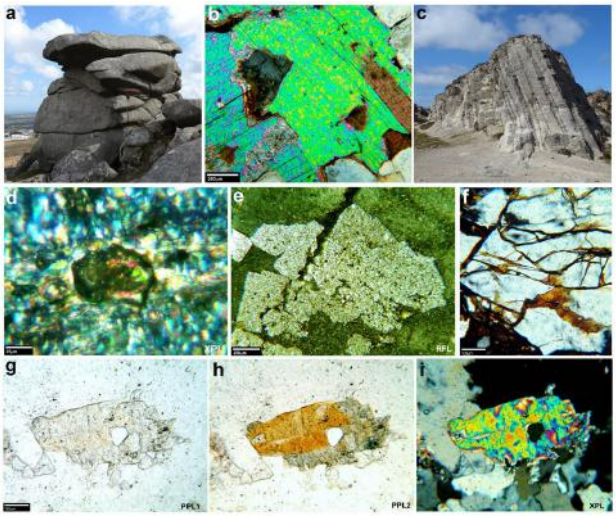

Fig. 8: (a) Granite tor on Carn Brea, Redruth. (b) Muscovite in granite from Carn Brea. (c) Quarry at Cligga Point, Cornwall, showing dark greisen veins. (d) Probable crystal of cassiterite in a mica-rich vein within the greisen. (e) Pyrite crystals viewed in reflected light. (e) Iron mineralisation in a sample from Botallack mine, XPL. (g-i) Tourmaline in greisen. Note the high pleochroism in PPL2 and the birefringence in XPL.

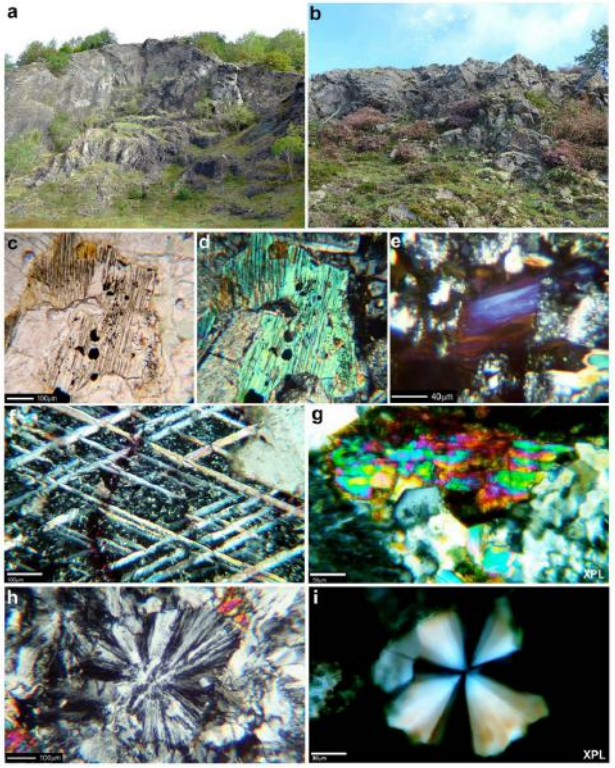

Fig. 9: (a) Stanner Rocks, gabbro quarry. (b) Stanner rocks. Felsic dyke. (c,d) Gabbro: diallage, PPL and XPL views. (e) Chlorite, XPL. (f) Calcite in vein, XPL. (g) Epidote (upper centre), XPL. (h) Spherulite in the felsic rock, XPL. (i) Spherulite from microgabbro of Corndon Hill, XPL.

It has taken me some time to get used to the fact that the appearance of igneous rocks, particularly the older ones,

can diverge a lot from the textbook norm because of "alteration"; a slow change of the constituent minerals due to chemical reactions, especially with water. This is particularly true for mafic rocks, and the Stanner Hill gabbro is no exception. There is plenty of alteration visible, with the presence of abundant chlorite. Chlorite is a variable group of minerals with a sheet type of molecular structure comparable to the micas. Despite its name it does not contain chlorine. It is a common alteration product of mafic rocks and is notable for showing birefringence colours outside the normal Newton's series. These are a Prussian Blue and a deep brown, both evident in Fig. 9e. This gabbro also contains some calcite veins showing a typical "cross hatched" appearance in XPL (Fig. 9f).

The felsic dyke at the summit of the hill is very different. It consists of quartz and feldspar with some crystals of epidote (Fig. 9g). Epidote is a chain silicate with a characteristic high relief and an attractive "stained glass" appearance in XPL. It is an alteration product that arises in felsic rocks from metamorphism or hydrothermal processes. The feldspar in the dyke displays abundant spherulitic structures, which are radial masses of thin birefringent fibres (Fig. 9h). They apparently develop when volcanic glasses devitrify and crystallise in a radial manner. I later found some even more spectacular spherulites further up Offa's Dyke at Corndon Hill, near Church Stoke. In this case they are present in a microgabbro (Fig. 9i). As the slide is rotated the "Maltese Cross" moves round the spherulite, because the birefringence is coming from a full 360° of radial fibres.

Conclusions

The aim of my activities has been to find out if making thin sections at home was feasible and to generate some elegant and attractive specimens. I have not attempted to analyse any particular rock type or locality in detail. I have found that it is indeed possible to make thin sections of reasonable quality and at moderate expense. It does not require a lot of engineering skill or geological knowledge, although some general lab experience and the ability to take care is undoubtably helpful.

As an amateur, I still have a lot of trouble identifying minerals down the microscope! Any society member who would be willing to assist me looking at some slides for an hour or two will be very welcome. I can be contacted at: j.m.w.slack@bath.ac.uk.

Appendix on equipment and supplies

A set of equipment and starter set of consumables can be acquired for about £800. This Appendix gives some more detail about the equipment, the procedures, the problems and the sources of materials.

Tile cutter

I use a Vitrex 750 tile cutter. This is a simple one-speed device with quite a large working area. It has a water reservoir to cool the wheel. This reduces the risk of breathing in rock dust but does create a substantial muddy spray, meaning that the device is best used outdoors. The device comes with an adjustable guide bar, called a rip fence, to steady the tile. Because this is not entirely satisfactory for cutting up rocks, I have made two new rip fences from aluminium bar. One is used for cutting rocks up into the small blocks and is rather heavier and higher than the original (shown in Fig. 1a). The other, which is lighter, is used to trim the blocks to 1mm after they are glued to the slide (shown in Fig. 1e). To enable the slide to be slid smoothly along this guide bar, I attached a metal strip to its base with superglue. This projects about 1mm clear of the guide bar which is about enough to support the slide without fouling the cutting wheel (red arrow, Fig. 1e). For the cutting, I use an ordinary diamond-edge wheel to cut rock specimens down to blocks, and a thinner porcelain cutting wheel for trimming down the blocks once they are glued to the slides. The cutting wheels get dulled by a lot of cutting through rock and so they do need changing every so often.

Hotplate

My hotplate is just an electric cooking plate (Fig. 1d). As this is quite crude, I am currently considering replacement with a proper stirrer/hotplate which would have more reliable temperature control. I place a number of 1cm thick aluminium blocks on top to spread the heat. One of these contains a boring for a thermometer which I take as measuring the surface temperature.

Lapping device

My lapping wheel is described as a gem-faceting machine ("Vevor" brand from Amazon). It was made in China and the original electrics were of very poor quality. I have replaced the control box, all the wiring, the switch, removed the other peripherals and earthed the casing. After all this it seems to work fairly reliably. The advantage of this model is that it has a steel case which allows for mounting of a lab jack from which to suspend the slide holder. The actual slide holder took some time to perfect. My final version is an aluminium block held horizontal with a ball joint. Between the block and the slide is a thin silicone sheet, anchored with silicone grease, to act as a vacuum seal. The block has a vertical hole into which a vacuum line is attached. The actual vacuum does not need to be very strong and is generated simply with a syringe held open with a bulldog clip, as shown in Fig. 2a. On the surface of the aluminium block are two spirit levels at right angles (Fig. 2c). One, glued along the long axis, enables levelling by adjustment of the lab jack. The other is held on a 1cm aluminium block mounted crossways. If there is a deviation from level this block can be slid to one side or the other to provide a slight extra weight to that side. The ball and socket joint is quick-release enabling the whole slide holder to be removed easily to inspect the state of the slide underneath. The whole weighs 300 grams, enough to impart a modest pressure to the slide.

Hard rocks containing a lot of quartz can take a long time to grind down, so I have also made a heavier slide holder, shown in Fig. 2d. This weighs 900 grams and the extra weight does increase the grinding speed somewhat. The arrangement is similar to that of the small slide holder except that no vacuum is necessary. Because of the extra weight the slide seems to stay put if a little silicone grease is applied both to it and to the silicone sheet.

The diamond lap wheels do not last long, and to get the most value out of them I have found it best to use the coarsest grade that is compatible with a smooth action, that is avoiding hunting movements. This is 180 or 240 grit. I try to use as much of the surface as possible by occasionally moving sideways the arm holding the attachment socket. When the diamond coating is worn out, some additional life can be obtained by reversing the direction of the wheel.

Manual finishing

This requires only a smooth glass plate, I use one 20cm x 20cm x 6mm thick (Fig. 3a). I use a suction pad connected to a syringe to hold the slide, although if it needs preferential grinding on one side this is best done just holding by finger or thumb. Mostly I use 400 grit silicon carbide plus some water for manual grinding. On the rare occasions when more than about 50µm needs removing I may use 120 grit to speed things up, although the finer grade is needed later to remove score marks.

Alizarin stain

Alizarin is useful for staining calcium carbonate (calcite and aragonite, but not dolomite). It is used as 0.2% Alizarin Red S in 1.5% v/v hydrochloric acid, which is more or less a saturated solution. The acid etches the section slightly and so the timing of treatment with the stain is important. I normally use one minute and then wash off the stain in tap water, which is slightly alkaline and stops the reaction.

Reverse osmosis water

To generate RO water for making up solutions (and for our steam iron) I use an aquarium system from Water Filterman. This produces about 4 litres per hour when connected to a mains pressure tap.

Sources of materials

For construction:
Aluminium bars: Metals 4U.
Ball and socket joints: Springfix linkages.
Feeler strip (Starretts), silicone sheet: Amazon
Suction caps, vacuum fittings, pivot joint, threaded rods: RS Components

Consumables:
Alizarin Red S: APC Pure.
Canada Balsam: discdi_9558, Bulgaria (Ebay)
Methylated spirit, hydrochloric acid: Local hardware store.
Petrographic Epoxy Resin: Electron Microscopy Sciences, Hatfield, PA, USA.
Silicon carbide grit: Craft and Design UK.
Silicone grease: RS Components.
Slides and coverslips: Galvoptics
Tile cutter blades, diamond lapping wheels, xylene, acetone: Amazon

Trouble Shooter

Problem	Solution
Cutting wheel dulling	Replace wheel
Bubbles under epoxy	If the rock contains cracks or holes, coat with epoxy first, allowing to gel on a piece of aluminium foil. Then peel off the foil and mount as usual.
Slide cracking	Don't use too much epoxy. Be careful not to stress the slide when trimming the block. Avoid vibration when trimming.
Lapping wheel dulling	Clean after each use with a nylon brush. Reverse sense of rotation. Replace wheel.
Keeping specimen absolutely level	Pay careful attention to the spirit levels while reducing thickness and adjust as necessary. Manual grinding can be done preferentially on part of the section if necessary.
Edge thinning relative to centre	Make sure the epoxy layer is as thin as possible so the section is not raised up from the slide. Grind as thin as possible on the lap before commencing manual grinding.
Controlling thickness	While finishing, check under the polarising microscope regularly. Continue until the quartz maximum birefringence is white, or the plagioclase is black and white. If these minerals are absent, make a small hole in the centre and focus up and down through the section thickness, noting the position of the fine adjustment knob.

Safety

Hazard	Risk	Remedy
Breathing in rock dust	Silicosis and other respiratory diseases	Always use water to lubricate cutting and grinding wheels, and to remove dust. Wear mask if necessary.
Inhaling solvents	Poisoning	Handle hazardous solvents outdoors.
Corrosive materials	Damage to hands	Wear gloves when handling epoxy, Canada Balsam, acids and solvents.
Hot items	Burns	Show warning notice when hotplate is on. Handle hot items with forceps.
Cutting and grinding wheels	Grazes	Use guard on tile cutter. Keep fingers clear!
	Spatter	Wear face shield to protect face and eyes.

-.-