

FACETIPS – A GEM CUTTER’S NOTEBOOK

Duncan Miller

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INTRODUCTION

In the spirit of *Faceter's Companion* produced by the Old Pueblo Lapidary Club in the USA (<http://www.rockhounds.com/oplc>), here is a compilation of the FACETIPS articles published over the past few years for *Mineral Chatter*, the monthly newsletter of the Cape Town Gem & Mineral Club (<http://ctminsoc.org.za/>). Most of these articles are by Duncan Miller, except for a few by Jo Wicht as indicated.

These articles have been rearranged roughly into logical categories and subjected to minimal editing, so there may be some duplication in content. With time, some of the hyperlinks may expire.

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BITTEN BY THE GEM BUG? NEED HELP?

How to teach yourself faceting, in three easy steps:

1. Acquire a faceting machine. <https://facetorsguild.com.au/About-Faceting-Machines>
2. Learn to facet. <https://www.gemsociety.org/article/lapidary-fundamentals-gemstone-faceting/>
3. Become an expert.
<https://www.youtube.com/watch?v=oD6ZINmtwmM&list=PLFIMjYf BtnvaVZNQkHJ4ieF-v1fqPgqu&index=2>

These are good introductory lessons for those starting out faceting, and perhaps don't have access to a mentor or teacher. Things get a lot more difficult when you want to facet non-standard, soft, or easily cleavable stones. For the past few months I have tackled various soft gem materials. This required learning some new skills. I had to practise and perfect hybrid dopping using wax and cyanoacrylate glue with a necessary accelerator to ensure the glue set. Faceting soft, and easily cleaved materials requires using sharp, fine diamond grit laps. Some very soft materials, like cerussite, tend to bind to the finest laps, so a compromise is necessary. The steepest learning curve was in polishing. Directional cutting and polishing were mandatory because of their differential susceptibility to cleave, chip and scratch. Polishing direction and pressure had to change for just about every facet. For such stones, patience and a responsive polishing technique are as important as choice of lap and polishing medium.



Cerussite 75,42 ct; 18 mm

Recently I have received several enquiries about learning to facet. As I no longer offer hands-on lessons or demonstrations, I thought it may be helpful to compile an annotated list of sources and resources relating to faceting, some international but some more locally South African.

The primary source of information about faceting is the Lapidary Corner: Colored Stones thread on GemologyOnline (<https://www.gemologyonline.com/Forum/phpBB2/viewforum.php?f=8>). It has a good search function and links to a wealth of information, books, designs, gemmological information, etc.

The most recently published book on faceting for amateurs is the two-volume set by Tom Herbst 'Amateur Gemstone Faceting. It is available through the GemologyOnline bookshop, Amazon.com and numerous other outlets on the internet (<https://duckduckgo.com/?t=ffab&q=herbst+amateur+gemstone+faceting&atb=v160-1&ia=web>).

You will need to learn something about mineralogy and crystallography. There are lots of online sources for this too, but I like the lessons compiled by Barbara Smigel (<https://www.bwsmigel.info/> or <https://web.archive.org/web/20180307004225/http://www.bwsmigel.info/>).

Justin K Prim offers a convenient online list of machines (<https://medium.com/justin-k-prim/a-list-of-current-faceting-machine-manufacturers-4c46775949cc>) and a lot more besides about faceting, current and historical (<https://medium.com/justin-k-prim>). Tom Herbst's Volume 1 also contains a list of the manufacturers of all the common and less common faceting machines.

There are numerous other online sources of relevant information, for which you only need do an online search. A useful example is the webpage of the Columbia-Willamette Faceters' Guild with a plethora of useful links (<https://facetersguild.com/faceting-gemstone-links/>).

If you want to view online demonstrations of faceting there are many on YouTube, and once you have viewed one it prompts you to others. A good place to start is Arya Akhavan's Faceting 101 for beginners (<https://www.youtube.com/watch?v=oD6ZINmtwmM>). Steve Moriarty of MoreGems.com has many more step-by step demonstrations (for example, <https://www.youtube.com/watch?v=xf-VitnGQVA>).

In South Africa the premier supplier of lapidary machines, including faceting machines, and gem rough is African Gems & Minerals (<http://www.africangems.com/>).

Brian Norton in KwaZulu-Natal sells selected faceting rough, by the individual piece and sometimes in small parcels (<https://briannortongemstones.com/>).

Several South African gem and mineral clubs have members who facet, and some clubs offer lessons. Links to all the local clubs are on the FOSAGAMS website (<https://fosagams.co.za/clubs/>).

FACETIPS articles published in the Mineralogical Chatter, the monthly newsletter of the Cape Town Gem & Mineral Club, can be found on the club's website. (<http://ctminsoc.org.za/articles/category/Faceting>).

WHAT DO YOU NEED TO POLISH STONES? (SOMEWHAT TONGUE-IN-CHEEK)

I wrote this to accompany the demonstration of a home-made grinding and polishing machine to school children in Beaufort West in the Karoo, during a teacher training session attended by the Cape Town Gem & Mineral Club.

EQUIPMENT

Old bicycle & stand & old stockings	Grease for bearing/arbor
or	Waterproof sandpaper
Transformer, motor & pulley & drive belt	Genchem glue for sand paper
Bearing or arbor with a rotating shaft	Polishing powder or compound
Plank to support motor & bearing/arbor	Wooden rods (or old pencils)
Big nut for the top of the rotating shaft	Methylated spirits (blue spirits)
Base plate for the top of the shaft	Toilet paper or roller towel
Hard rubber discs for sand paper	Red sealing wax
Hard felt disc for polishing	Candle, candle holder & matches
Splash pan (old cake tin or bent metal sheet)	Small pocket knife
Water supply (Coke bottle on wire stand)	Stones to grind and polish

All you need to shape and polish stones is a simple machine, which you can make out of scrap. You will need the following things.

1. A motor of some kind. This machine uses an old sewing machine motor, which runs off a 12 volt transformer from a portable radio. It could also run off a 12 volt car battery. A big machine motor, like a washing machine motor, is too powerful and too fast. The motor must run slowly and be fairly weak, so it isn't dangerous. If you can't find a suitable electric motor you can use an old sewing machine with a foot treadle, or a bicycle. You can use a bicycle for powering a stone polishing machine, or any other kind of small machine like a lathe or a pottery wheel for instance. You need to lift the back wheel on a metal stand (which you can make out of scrap metal), replace the back tyre with a belt (which you can make out of old stockings), and drive a pulley with it. A friend sits on the bicycle and pedals steadily, and the power from the back wheel drives the belt and pulley, which in turn can drive your machine.
2. A pulley on a rotating shaft. My machine uses a discarded bearing from another stone working machine, but you could use a similar bearing from any other machine, or use old motor car bearings. The pulley must be attached firmly to the shaft, which must rotate without too much wobble. Lubricate the bearing with grease, to keep water out and to keep it rotating smoothly.

3. The shaft must go through some kind of barrier like a thick plank, to give it stability and to keep water off the motor and the bearing. The top of the shaft must have some kind to screw thread and a nut, so that you can attach various grinding and polishing wheels.
4. You need some kind of splash pan around the top of the shaft. The splash pan must have a waterproof seal around the base of the shaft. My splash pan is an old plastic cake box, with a hole cut in the bottom, and glued down with waterproof glue. I have glued a small tube through a hole at the bottom of the splash pan to let water drain out of it.
5. A water supply is important to keep your stone cool and to wash the waste way on the grinding wheels. My machine uses an empty cold drink bottle with a tiny hole punched through the cap, and held up with a bent wire coat hanger. The bottle can be filled easily and water drips out of the hole onto the grinding wheel.
6. The top of the shaft has a flat base plate made out of a stiff plastic sheet or thin metal plate. You must use something light like perspex or aluminium for the base plate, so that the weight doesn't strain the motor. This base plate must be about 15 cm (about 6 inches) in diameter. It is a support for the grinding wheels.
7. The grinding wheels I use are made of off-cuts of thick rubber, like the rubber used for shoe soles. This is cut into a disc about 15 cm in diameter, with a hole in the middle to fit over the shaft. The grinding disc is held down on the base plate with a nut on the top of the shaft.
8. The surface of each grinding disc is covered with waterproof sandpaper, called emery paper. It comes in black sheets, and you will have to buy this from a hardware shop. You need different grades of emery paper, that is, different coarseness of the sanding grit on the paper. I use three grades: 120 grit, 380 grit, 600 grit. These are coarse, medium, and fine (in that order). You can also use extra fine 1200 grit, if you have four wheels. It makes the final polishing easier. The emery papers are glued to the upper surface of each rubber wheel with a contact glue, like GenKem. When the paper has worn out and is smooth or torn, then you peel it off, remove the old glue, and glue on a fresh sheet. This you have to do quite often.
9. For the final polish you need a felt wheel, which you will also have to buy new from a hardware shop, because it needs to be clean. And you must keep it clean. You will also need to buy a very fine and hard polishing powder from a hardware shop, to use with the felt polishing wheel. The polishing wheel is attached to the shaft just like the grinding wheel, by screwing it down onto the base plate with the nut on the shaft.
10. Finally, you will need something to hold your stones. This can be any suitable round wooden rod, like old pencils or pieces of wooden dowel rod. You will also need some methylated spirits, toilet paper, red sealing wax, a candle, matches, and stones to grind and polish. You should choose hard stones, which will polish nicely.

HOW DO YOU GRIND AND POLISH STONES?

Grinding and polishing stones means making finer and finer scratches until they are so fine you can't see them. Then the stone looks shiny. This is how you do it.

1. You choose a rough stone a few centimetres in size, and more or less the shape you finally want. Usually gem stones are cut into oval shapes with rounded tops and flat bottoms, so they can be set in jewellery easily. But you can make any shape you like. You need to clean all fat or grease off the stone first, with a bit of methylated spirits (blue spirits) and a clean cloth or piece of toilet paper. This is so that you can glue it to a stick, like a pencil, to use as a handle. The glue you use is sealing wax, which you heat and soften using the candle. You also heat the end of the stick, without letting it burn, then twist some of the soft wax onto the end of the stick. Then you heat the wax on the end of the stick until it is very soft and nearly runny, and stick the bottom of the rough stone onto it. Make sure the stone also gets good and hot so that it sticks properly. You can smooth the hot wax around the stone with your fingers, just wet them with spit first.
2. Put the coarse grinding disc on the machine, turn it on, and make sure the water drips onto the disc to keep it cool and flush away the grindings. Then hold the stick handle firmly, and grind the top of the stone into a smoothly rounded shape on the coarse grinding wheel. Remember to keep it wet all the time. Don't press hard on the wheel. Let the sand paper do the work. You must keep turning the stone around and around with the stick, so that you get a nice evenly domed surface.
3. When you have a good shape, wash the stone to remove any coarse grit, and swap the grinding wheels so you can use the medium grit wheel. Then you repeat step 2, grinding away all the coarse grooves.
4. When this is done, put the fine grinding wheel on the machine, and repeat step 3. If you have a 1200 grit wheel, repeat the whole grinding process with that too. You should have a smooth, almost shiny, evenly curved, surface with very fine, even scratches. Take your time with the finer grinding, to make sure all the coarse scratches have been removed. If there are coarse scratches left, go back one or more steps, and start again.
5. The final step is to wash the stone, the stick, and your hands, and put the felt polishing wheel on the machine. Make sure the felt is damp but not sopping wet. In a clean glass or plastic bottle mix some polishing powder with water to make a thin slurry like milk. You don't need very much powder. Don't make a thick paste, it is a waste. Dribble a bit of the polishing mixture on the felt wheel, turn on the machine, and rub the stone back and forth on the felt wheel, keeping it moving so that it doesn't get too hot and melt the wax. Twist the stone around so that you polish from all directions. After a few minutes your stone should be polished and shiny. Check in a strong light to see if all the fine scratches have been removed.
6. When you are satisfied with the polish, heat the wax gently over the candle flame again and remove the stone. You can cut the extra wax off the stone carefully with a pocket knife. Then you need to grind the back of the stone flat or into a shallow dome shape. Start with the coarse grinding wheel, and move up to the fine wheel, just like you did with the top of the stone. If the stone will be set in jewellery, try to get the outside edge (where the top meets the bottom) straight. If this edge is wavy, it will make it difficult for the jeweller to set the stone in a metal frame. You can polish the back if you like, especially if it is going to show.
7. Keep the different grinding and polishing wheels clean. Store them in separate plastic bags. It is important that you don't get any grit on the polishing wheel, or it will make scratches.

FACETING IN THE 21ST CENTURY – AN EQUIPMENT GUIDE FOR BEGINNERS

[Revised and updated from the original publication: Miller, D. 2012. Faceting in the 21st century – an equipment guide for beginners. *South African Lapidary Magazine* **44**(1):15–18.]

The beginner faceter is confronted by a bewildering array of equipment options. This article is an introduction to modern faceting equipment, to help those just starting out to make sensible equipment choices.

Machines

You need a machine. If you buy a second hand one, expect to pay anywhere between a couple of hundred Rands up to R30 000, depending on make, condition, and accessories. Unless you like rebuilding old equipment, make sure that any second hand machine you consider buying is in good condition, that the bearings are not badly worn, and that the quill and mast are not bent. Running through Paul Head's calibration and alignment exercise before you buy may save you money and frustration (<https://usfacetersguild.org/faceting-machine-alignment/>).

The second-hand machines most readily available in South Africa are those of Graves and Ultra Tec, the difference being between a Polo and a Porsche, both of which will get you to your destination. Both Graves and Ultra Tec come in analogue and digital models. You will be able to cut perfectly acceptable stones on any of them, so what you buy is a matter of your budget and perfectionism. The digital models primarily give you greater control over accuracy, particularly when going from a grinding to a polishing lap (more about laps later). There are other advantages to the digital models, like increased speed, fewer setting mistakes, and the ability to follow modern faceting diagrams that give angles to hundredths of a degree. This is not crucial – depending on how obsessive you are. A digital machine is not something you absolutely NEED, it is something you WANT. (Suppliers of these machines are listed at the end of this article.)

New faceting machines come supplied with basic accessories, like a transfer fixture, a table adaptor to enable you to work the table of the stone at 45°, and a basic set of dops – the rods onto which you glue your stone. You probably would want to buy an extra set of dops. You need two of each anyway if you want to cut pairs of stones in tandem. Most manufacturers offer a range of optional accessories. You don't need those to start with, and can order later those you may find you want.

Saws

You will need something to remove bulk material from rough stones. You could buy a small trim saw, but a cheaper and often more convenient option is to use your faceting machine as a saw, using a firm supporting metal or Lucite base plate (old CDs are not stiff enough), a fine 6" continuous rim saw blade, and a large washer to hold these three down on the faceting machine platen. Attach your rough to a dop, insert it in the machine, run plenty of water on the saw, and saw away. Use high speed, and make sure the stone is trailing, so that it cannot jam against the saw. You can preform the main pavilion facets of your stone this way, which can save a lot of time in coarse grinding.

Grinding laps

If you prefer to grind your preform to shape you need a coarse grinding lap, around 260 mesh. For this you can use a so-called 'topper', a thin metal lap with an electro-bonded diamond coating used on top of a metal master lap or base plate. A coarse one wears out quickly, particularly on large stones, but if you plan on cutting only a few stones a year it will last years. If you intend cutting large stones or numerous stones, in the long run the cheaper option is to buy a copper lap and charge it yourself, using diamond grit or paste, and a roller. Neither the coarse topper nor the copper lap need to be particularly flat. At this stage you are just removing bulk quickly.

The next step is medium grinding, for which you need a 600 mesh lap. If you can afford it, the best lap for this is a diamond sintered bronze lap, available from various USA manufacturers. They are expensive, but last a lifetime with only the occasional need for dressing with a fine silicon carbide dressing stick. The alternatives are a 600 mesh topper or a solid steel lap like those manufactured by Crystalite, or another copper lap charged with 600 mesh diamond grit and a separate, dedicated roller. The 600 mesh lap is used to place all the larger facets, and on a large stone all the smaller facets as well. Again, this lap does not have to be absolutely flat, nor the facet meets perfect, because you still have one more grinding step to do.

Pre-polishing laps

Many people use a 1200 or 3000 mesh lap for the final grinding step. The 1200 mesh is losing popularity because it does not produce a very fine pre-polish and when grinding corundum gems it can produce a coarse orange-peel effect on some facets, which is difficult to remove by polishing. The 3000 mesh electro-bonded laps have only a very thin diamond layer, get damaged easily, and wear out quickly. The alternatives are yet another copper lap charged with 3000 mesh diamond with its own dedicated roller, or charging a tin-based alloy lap with diamond paste. Gearloose Lapidary

makes several pre-polish laps suitable for charging with 3000 or 8000 mesh grit, and they are gaining in popularity worldwide. The Batt™ laps are the least expensive (<http://www.gearloose.co>).

Polishing laps

Established faceters have numerous polishing laps, for use with various different polishing compounds for different stones. Most of these now are redundant. Traditionally for quartz, one used a Lucite lap with a slurry of cerium oxide, but it tends to round the facet junctions slightly. Most other stones, except corundum, could be polished on tin/lead alloy laps with fine synthetic alumina powder, marketed as Linde A. Corundum gems were polished on a cast iron lap with ¼µ diamond paste. You may be able to buy any or all of these laps second-hand. If so, they must be skimmed in a lathe to remove all traces of previous polishing agent, to avoid inheriting unknown grit sizes and any contamination. The modern solutions to polishing problems are from Gearloose Lapidary. The Darkside™ lap can be used interchangeably with polishing oxides as well as diamond, so is as close to a universal polishing lap as you can get. Gearloose also produces various combination laps, with a pre-polish outer ring and a polishing inner ring. If you are careful to avoid contamination this is an economical option, which also avoids having to reset the mast height when going from pre-polish to polishing.

What equipment you buy will depend on your budget, how many stones you intend to cut, and how precise you wish them to be. The total cost can range anywhere from a few thousand to many tens of thousands of rands. Of course, you will also need to buy rough. Some you may be able to get from local gem and mineral clubs; other rough you can source from various dealers. Several well-known South African dealers are listed below. Good rough is never cheap, but why waste your time on poor quality rough. Because faceting is a relatively expensive hobby to start, you should take some lessons first, before embarking on buying your own equipment and then possibly discovering that you don't have the interest, dedication or patience to continue. Several South African gem and mineral clubs offer faceting courses.

Sources

Machines: African Gems & Minerals (gems@africangems.com); Ultra Tec (<http://www.ultratec-facet.com>)

Saw blades: African Gems & Minerals (gems@africangems.com)

Diamond laps: African Gems & Minerals (gems@africangems.com); Kingsley North (<https://kingsleynorth.com/lapidary-equipment-supplies/faceting-machines-supplies.html>); Ultra Tec (<http://www.ultratec-facet.com>)

Polishing laps: African Gems & Minerals (gems@africangems.com); Gearloose Products (www.gearloose.co)

Polishing oxides: African Gems & Minerals (gems@africangems.com); Gearloose Products (www.gearloose.co)

Diamond grits, sprays and pastes: Gearloose Products (www.gearloose.co); Bolt & Engineering 021 555 1290 (diamond pastes from 3 μ –45 μ in 10 ml syringes); African Gems & Minerals (gems@africangems.com) (diamond pastes from ¼ μ –45 μ in 5 ml syringes)

Gem rough: African Gems & Minerals (gems@africangems.com); Brian Norton (<https://briannortongemstones.com/>)



Figure 1 The Graves digital faceting machine



Figure 2 The Ultra Tec V5 digital faceting machine



Figure 3 Using the faceting machine as a trim saw



Figure 4 Copper lap charged with coarse diamond paste from a syringe using a roller

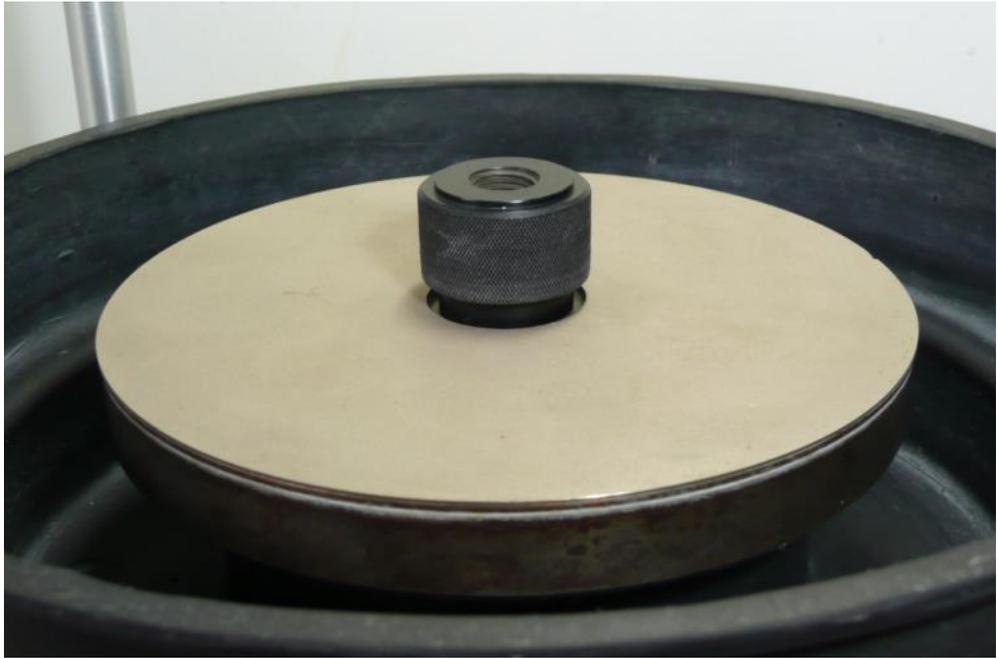


Figure 5 Sintered 600 mesh diamond lap, showing the diamond/bronze layer on the steel backing



Figure 6 Worn 3000 mesh electro-bonded diamond lap



Figure 7 New Batt™ tin alloy lap, for charging with diamond paste as a pre-polish or polishing lap



Figure 8 The Darkside™ polishing lap for use interchangeably with oxides or diamond as a universal polishing lap

FACET CUTTING LAPS

Introduction

'Cutting' facets is really a grinding operation where diamonds embedded in flat discs or 'laps' do the work of removing material from the gem rough. There are three types of facet cutting laps available. These are electroplated or bonded laps, solid metal laps, and sintered bronze laps – all available in six inch and eight inch diameter versions. This article describes the properties of the various laps in these three categories.

Diamond grit

All three types of laps are designed to hold diamond grit to provide an abrasive surface. Laps are available with various different diamond size abrasives. Two different measurements are used to describe diamond abrasives, whether as loose powder, or in a paste, or already embedded in a lap. 'Mesh' is related to standard sieve sizes while 'micron' describes the mean diamond size. The relationship between mesh and micron is tabulated and illustrated graphically in Figure 1.

Grit size (mesh)	Size range (micron)	Grade number (micron)
230	54–80	60
600	22–36	30
1200	12–22	15
1800	8–12	9
3000	4–8	6
8000	2–4	3
14 000	0–2	1
50 000	0–1	1/2
100 000	0–1/4	less than 1/4

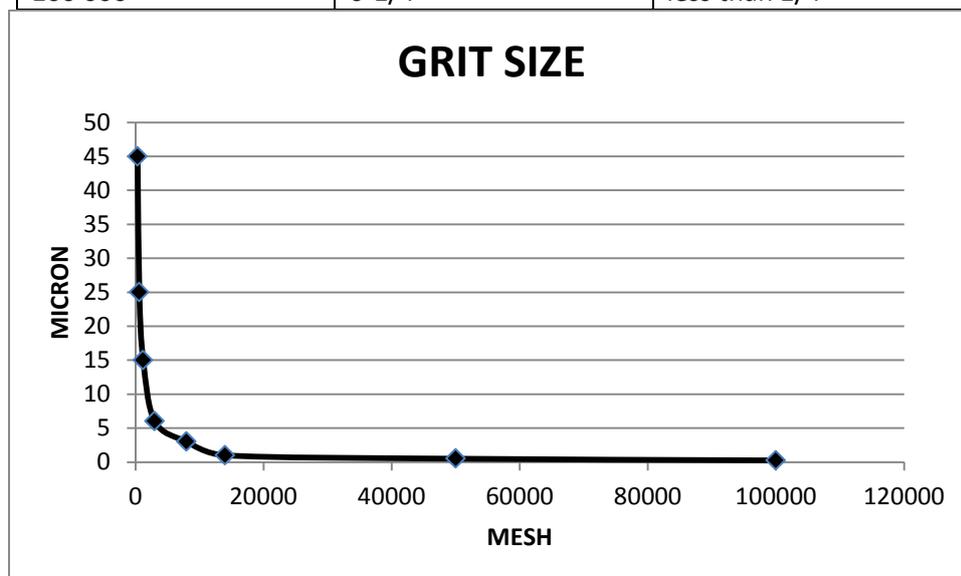


Figure 1. The relationship between mesh and micron grit sizes

As you can see from the graph the relationship between mesh and micron grit sizes is not linear. For faceting it doesn't matter which scale is used, as long as you understand the relationship between

them. With the mesh scale, higher numbers mean finer grit. With the micron scale lower numbers mean finer grit.

Diamond grits also come in different varieties. There are natural grits, produced by crushing mined diamond crystals. These are sharp and splintery. There are blocky synthetics, usually with a cubo-octahedral shape (Figure 2). These are the most commonly used grits in grinding laps because of their more regular shape. There are also 'friable' diamond synthetics, which consist of aggregates of much smaller particles. These break down quite quickly to finer sizes with use and can be useful in polishing.

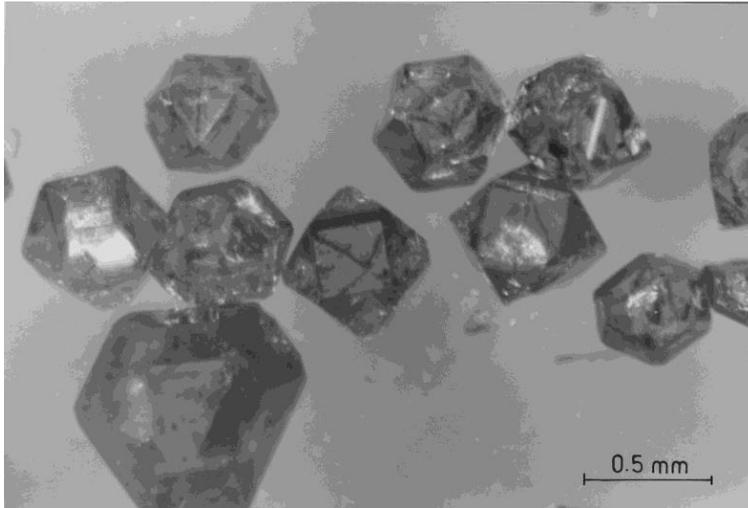


Figure 2. Cubo-octahedral synthetic diamond crystals

Electroplated or bonded laps

There is a wide variety of bonded laps available. They all rely on an electroplated layer of metal, usually nickel, to hold the diamond grit on the surface. The thickness of this electroplated layer varies with the size of the diamond grit, so the finer grits are held in a very thin layer. There is a wide range of prices too. Solid steel laps are sturdy and flat. So-called 'toppers' or top plates are thin. Some have adhesive backs to glue them down to a solid lap. Others simply have a protective copper backing to inhibit corrosion. The loose toppers tend not to be very flat and particularly the larger eight inch diameter ones suffer from flutter or run-out near the outer edge. This can produce uneven or domed facets. There are discs with the diamonds bonded in rippled or dotted patterns that are intended to remove bulk material quickly.

Electroplated laps are convenient to use and they are relatively inexpensive. This accounts for their popularity with hobby cutters. They are fine if you are just starting out, or don't intend cutting very numerous or very large stones. They have some drawbacks. The finer grits, like 3000# have such thin electroplated layers, that they are prone to damage by sharp facet edges or corners. Some of them simply peel and shed fragments of diamond-coated metal, causing deep scratches. The coarser grit laps start out cutting very rapidly because the exposed diamond points are sharp. As the points develop wear flats the cutting action slows down and you have to use increasing force to remove material. All of them are susceptible to clogging, especially if you are cutting quartz. They can be cleaned with a mild abrasive, but abrasion risks damaging or even removing the electroplated

bonded surface. Sometimes blunt electroplated laps can be rejuvenated a bit by carefully grinding a soft abrasive silicon carbide stick, but this usually destroys the surface of the lap. When they are worn out or damaged you simply have to discard and replace them. For these reasons many faceters do not use bonded laps.

Solid metal laps

Traditional faceting laps were solid copper laps and they seem to be coming back into more regular use again. These are simply solid copper discs, about 5 mm thick for stability, machined flat and parallel on both sides. Some manufacturers partially anneal the copper discs to produce a softer matrix for the diamond particles. A different lap is used for each different grit size. Diamond powder can be mixed with a light oil carrier or even Vaseline and spread on the lap surface. Nowadays diamond grits are available in formulated pastes, in an oil-based or water-based carrier in syringes or cylindrical 'lipsticks'. Some of these need suitable dilution, others don't. The only practical differences between the two carriers is that the water-based ones tend to dry out but using them makes it is easier to wash any excess grit off the lap after charging.

The copper laps need initial charging and repeated recharging when they start cutting slowly or when copper is rubbed off on the stone. The diamond paste is spread evenly over the lap surface with a clean finger. Then a dedicated roller (a 1 cm roller bearing on a dowel works fine) or piece of synthetic corundum is used to work the grit particles into the metal. With coarse grit laps this is best done away from the faceting machine. With finer grits it can be done on the slowly rotating machine. With the finest grits there is no need to embed the diamonds before cutting. The pressure on the facets does the job. When charging a suite of laps it makes sense to start with the finest grit size first. That way you don't risk contaminating the finer laps with coarse grit. When the charging operation is finished the laps must be washed to remove any loose diamond that may lead to contamination.

Metals other than copper can be used. A hard tin alloy (Batt), brass, bronze and zinc laps are available for use as rechargeable cutting laps. With harder laps like zinc, the diamonds do not embed as easily or deeply as in copper and this produces a very aggressive surface more suitable for pre-polishing with the finer diamond grits. Loose coarse diamond grit on a lap is not desirable. Not only does this lead to a risk of contamination of finer laps, but diamonds rolling between the stone and the metal can abrade the softer metal rather than the stone, leading to rapid wear of the lap. All grinding laps need to be used with an even sweeping motion across the full width of the lap, to maintain even wear and a flat surface. Bumpy or uneven metal grinding laps need to be resurfaced by lathe machining. Machinists generally do not like doing this because the diamond particles destroy their cutting tools.

Solid metal laps require sensible care. They need to be scrubbed clean of swarf after use and stored separately, not stacked upon each other. Sturdy plastic bags or lap boxes can help prevent contamination. They should not be dropped because they may bend. Laps and their containers need to be labelled clearly so that grit sizes are not muddled. A fine grit lap can be downgraded to a coarser one, but not the other way around. The fear of contamination by loose diamond puts many people off using rechargeable laps, but with sensible care contamination isn't a problem; and a contaminated lap can be remachined. The advantages of using solid metal laps are that they can be

recharged to produce even, rapid cutting and that when the diamonds wear the laps don't have to be replaced.

Sintered bronze laps

Sintered bronze laps are the professional's choice of grinding laps, despite their expense. Typically they consist of a 3,5 mm thick layer of bronze containing a specific mesh size of diamond, sintered onto a steel base. These laps have a very long lifetime and can be rejuvenated easily by 'dressing' with an abrasive stick when the grinding action slows down or if they get clogged with swarf. They are dressed by grinding the abrasive stick with the lap rotating in the direction of intended use. They are sold dressed in a particular direction. In practice this makes no difference because the dressing direction can be changed easily. The dressing wears away some of the bronze, exposing fresh diamond points, supported by a comet tail of metal behind them (Figure 3).

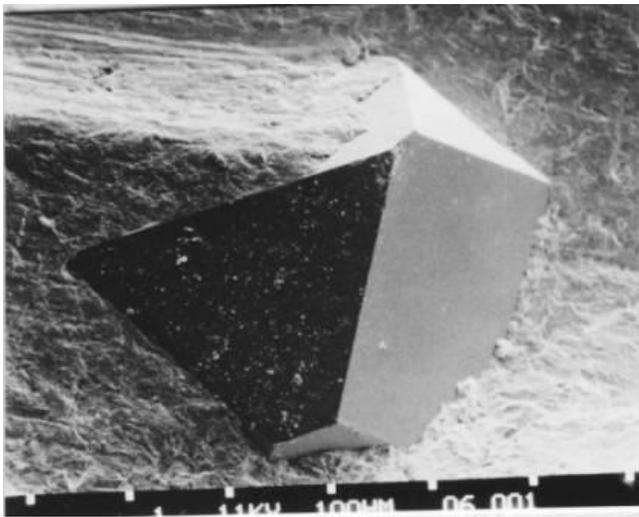


Figure 3. A newly exposed diamond point in a sintered bronze matrix

Sintered laps need very little maintenance apart from a scrub to remove swarf after use and occasional dressing. They cut evenly and quickly, there is negligible risk of contamination, and they last 'forever'.

What grinding laps do you need?

What you need depends on what machine you have, what you want to cut and how frequently. Six inch laps cost less than eight inch ones, but the larger laps have twice the surface area so can accommodate larger stones. Some faceting machines can only use six inch laps. If you are starting out, intend to cut only a few stones a month and do not want to cut doorknobs out of quartz, then a set of electroplated laps with do. You will need coarse, medium and fine grinding laps; say 325 mesh, 600 mesh and 1200 mesh. Avoid the temptation to buy a 3000 mesh bonded lap. It simply won't last. The 325 and 600 mesh laps can be toppers. If possible, buy a solid steel 1200 mesh lap for fine cutting because it will be flat.

When this set of laps wears out, you may want to replace it with a set of copper laps (and rollers or synthetic corundum burnishers). Here 325 mesh, 600 mesh and 3000 mesh are recommended. For some unknown reason the 1200 mesh diamond has a nasty habit of producing an irregular 'orange

peel' surface on harder stones like sapphire, and with a solid copper 3000 mesh lap you can avoid this problem.

If you have deep pockets, are self-indulgent, or intend cutting professionally then you should invest in one or more sintered bronze laps. They come in a range of mesh sizes, from around 220 mesh to 3000 mesh. If you can only afford one, the 600 mesh is the most useful. A full set will cost you almost as much as a new faceting machine!

Pre-polishing laps

There is no fixed boundary between grinding and pre-polishing laps. The grinding behaviour of any particular lap cuts depends not only on the diamond mesh size, but also the actual size distribution, the density of particles exposed on the lap surface, their condition (sharp or worn), and the metal matrix itself. For example, a zinc lap charged with 3000 mesh will cut as vigorously as a new 1200 mesh topper. Whether you need a pre-polishing step or not depends on the finish produced by your fine cutting lap. Depending on the material and size of the stone, sometimes you can go straight from 600 mesh to polishing. Often 1200 mesh will be a sufficient pre-polish, especially with stones of moderate hardness. With harder materials like corundum, 3000 mesh or 8000 mesh on solid metal laps may be necessary for pre-polishing, unless you want to spend ages trying to polish out scratches and sub-surface damage produced by a coarser laps.

Various dual finishing laps are available now, with a pre-polish band on the outside and a polishing band on the inside. Some of these require only water as a lubricant with no added abrasive, while others depend on using diamond paste of two different grades (and carefully avoiding contamination of the inner band). There has been a rapid development of these laps and other speciality polishing laps, which can be ordered from Gearloose (<https://gearloose.co/>).

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Miller, D. 2014. Facet cutting laps: Part 2. *Southern African Gems and Minerals* **46**(1):3-5.]

Postscript: For a detailed and well-illustrated history of faceting and faceting laps, see Justin Prim's article at <https://medium.com/justin-k-prim/lapidary-technology-through-the-ages-laps-and-polish-59c29f05a11a>.

IMAHASHI – MY NEW TOY

A few months ago I bought an Imahashi faceting machine, Faceting Unit Model FAC-8C, the earlier of two models. This one dates from 1970, co-incident with when I started faceting. Sometime during the 1970s my father owned one briefly, but I took no notice of it then. Now it intrigued me, because it is a platform machine, unlike the more familiar mast machines. Platform machines have several attractive features. You can lift the entire handpiece free of the machine to inspect the stone, and the smaller quill assembly is more stable when cutting low angle crown facets. This model Imahashi also has an ingenious system of replaceable cams that allow you to preform ovals, marquise and pear-shaped stones to specific length/width ratios. Not only that, but the mechanical cam system enables you to set the angle for any one tier of facets, say the crown mains, only once; then as you work your way around the index settings the angles are adjusted automatically for the rest of the facets of that tier. This facilitates and speeds up the production of standardised brilliant cuts in these low-symmetry shapes. So far I haven't used the cam system, but cut a standard round brilliant in smoky quartz, just to get a feel for the machine. This model Imahashi doesn't have a cheater and the dops are not keyed, so alignment after transfer and polishing can be tricky.

A later model, FAC-8P, doesn't have the cam assembly, but it does have a cheater. This was developed in response to requirements of professional cutters who wanted greater flexibility in the indexing, especially for recutting gemstones. Justin Prim has documented the history of these developments and how they revolutionised gem cutting in Sri Lanka (<https://medium.com/justin-k-prim/the-mo...94a5a504c3>). Justin is a faceting historian and has described the operation of various other faceting machines in his World of Faceting Machines YouTube videos (<https://www.gemologyonline.com/Forum/phpBB2/viewtopic.php?f=8&t=24388&sid=d26b305d3cd54942497e079f0cf95fcf>).



SAWING ON YOUR FACETING MACHINE

So, you don't have a trim saw for cutting valuable rough? But, you have a faceting machine. Well, you **do** have a trim saw!

You need a thin diamond charged blade – the thinner the better, preferably with a continuous sintered bronze rim. If your faceting machine has a large platen, like an Ultra Tec, then you can put the blade directly on that. If your machine has a small platen you will need some support for the saw blade. This could be a suitably sized Perspex disc, or possibly even a stack of old CDs. What you can use will depend on the diameter of the blade, and that depends on the diameter of your splash pan. On a machine designed to take only six inch diameter laps, like the Raytech-Shaw, you need a four inch blade to give yourself some clearance between the blade and the splash pan. Then a large washer should do to support the blade. On a machine designed to take eight inch laps, you can use a six inch blade and CDs for support. This will give you one inch clearance between the blade and the splash pan, and about $\frac{3}{4}$ inch working clearance between the edge of the blade and the CD stack. If you need greater working clearance for larger pieces of rough, you will need a smaller support disc for the blade. You also need something to hold the blade down. If you use only the machine's nut, it probably will dish the saw. So you need something more or less the same size as the lower support to place on top of the saw blade before you screw down the nut. Ultra Tec sells a purpose made saw blade adapter suitable for six inch saw blades, but you can improvise your own.

You **have** to dop the stone you wish to saw. If you try holding it by hand you probably will ruin the blade, the rough, and your fingers. With the machine switched off, set the protractor at the angle you wish to cut. Then lower the mast with the stone between the edge of the saw and the splash pan until the saw is at the level at which you wish to make the cut. Make sure that the stone will be trailing so that if it jams on the saw it will be knocked away from the blade. Then swing the stone away from the saw, run a **copious** water stream onto the blade, switch on the machine to run at full speed, and again make sure that the stone will be trailing. If you can, run the saw blade counter-clockwise so that if the stone flies off the dop it flies away from you. **Very** gently feed the stone into the saw blade, taking care not to flex the thin blade. Allow the diamonds in the blade to do the work. Do not force the stone onto the blade. Use just enough finger pressure to keep the blade cutting the stone. Swing the stone gently off the blade intermittently to allow water to flush the cut and reach the underside of the saw blade. Feed it back in carefully, allowing the blade to find the groove. Throughout, this is a delicate, unhurried operation.

Why would you want to do this? Setting the protractor at your pavilion mains angle means you can preform the bottom of a big stone very quickly, saving your coarse lap from wear, and possibly saving workable pieces of rough to cut smaller stones. Using the 45 degree adaptor enables you to section long crystals very accurately or to cut thin slices.

SELECTING ROUGH

If you are going to facet, you need to learn something about mineralogy because you need to know what stones you should obtain, how their characteristics affect their behaviour while you are cutting and polishing them, and how they affect the optical properties of your finished gemstone. The easiest **material** for beginners to cut and polish is common red garnet. It presents no problem with cleavage or orientation for colour, and generally behaves itself well during 'cutting' and polishing. The only drawback is that most common red garnet is very dark, and so unless you make it small your final stone also will be dark. A good alternative is aquamarine. Even lightly included stones will give you a pretty gem, and it has no problem with cleavage. High quality, expensive aquamarine with a deep blue colour needs to be orientated properly for colour, but that is not the sort of material you should be cutting at first. Many people start faceting with quartz. It is cheap and readily available, so it is not a bad choice. Some people find quartz difficult to polish, but with an appropriate combination of lap and oxide polish it should not be problematic.

Colourless topaz is also fairly readily available and cheap, but with topaz you need to orientate your stone to avoid having any major facet, and in particular, the table facet, parallel to the **cleavage** plane. In well-shaped crystals the cleavage plane direction usually is easy to determine, and your stone must be orientated with the table facet at least five degrees off the cleavage plane. With water-worn pebbles of topaz it can be difficult to identify the cleavage plane and you will have to ask someone with experience to help you. You also have to be able to distinguish water-worn topaz from water-worn quartz, either by relative hardness or density measurement. Topaz is harder in most directions than quartz, and it is more dense. But you need some experience in determining these differences.

Soft stones like fluorite and calcite are not recommended for beginners. They are heat sensitive, are far more difficult to polish, and have several different directions of easy cleavage, so are more tricky to orientate.

In selecting rough you have several things to look for, apart from mineral species. Rough needs to be a suitable **shape**. Long needle-like crystals are difficult to facet without fracturing them. Thin, flat pieces of rough do not have enough depth to produce a good stone. Chunky pieces of rough will give you better recovery than pieces with irregular protrusions.

You need to look for **inclusions and flaws**. Immersing the rough in water or a mineral oil like 'liquid paraffin' sold as a laxative, will allow you to see the interior to inspect it for flaws and inclusions. Do not hold the rough up to a strong light and peer directly at it to try to see inside it. Rather hold the stone under the edge of a shaded lamp, or shine a penlight torch through it from the side or beneath, but ensuring that the lighting is perpendicular to your line of sight. The extent of inclusions that make an acceptable stone is entirely up to you. Some inclusions, like rutile needles, can enhance a gem. Large numbers of fractures can destabilise a stone and interfere with the passage of light. Small inclusions can be 'hidden' underneath facets near the girdle, where they will not be so obvious.

To assess the **colour** of coloured rough, again do not hold it up to a strong light to look through the stone. This will give you a completely false idea of the colour of any gem you cut from it. Place the

rough on a piece of white paper or a pocket mirror and inspect it in strong, but indirect white light. Don't direct the light through the 'back' of the stone, but look at the colour reflected back through the stone. If you can't see a desirable colour with this 'white paper test', the stone is not worth cutting.

Uneven colouring needs to be orientated when you plan your stone. A strong band of colour in an otherwise colourless stone can be orientated parallel to the table to enhance the colour of the finished stone. A spot of deeper colour can be positioned in the middle of the stone or deeper towards the bottom point or keel, to reflect throughout the stone.

Many minerals show **pleochroism**, that is, they have different colours when viewed in different directions. Tourmaline is a good example, usually having a stronger or different colour when viewed down the length of the crystal as opposed to across its width. Where possible given the shape of the rough, strongly pleochroic stones need to be orientated to produce the most desirable colour when viewed through the table facet.

This all may sound a bit much, but fortunately you don't usually have to take all these issues into account for any one stone. Shape and clarity probably are your main concerns to start with, then orientating for colour and cleavage. Sometimes you have to compromise. All the time, you have to keep learning.



Ametrine rough – quartz with different sectors coloured yellow and purple, a real puzzle when it comes to orientating the rough, in this case to try to capture both colours when viewing the stone through the table.

SCHLENTERS

“Schlenter” is a delightfully South African term in origin, initially for a fake rough diamond. The meaning has expanded to encompass anything not genuine, counterfeit, dishonest or underhand (<https://www.lexico.com/definition/schlenter>). In his book *Gemstones*, Arthur Thomas extends the gemmological usage of schlenter to any fraudulent gem materials, specifically rough that has been treated in some way to represent something more valuable.

A few years ago an elderly but adventurous friend of mine in Cape Town was offered some rough diamonds from Namibian transport riders. To try to discourage him from buying them I lent him a copy of Basil Watermeyer’s *Diamond Cutting* so that he could see that cutting any rough stones he might buy to make them legal was not a viable option. Against the strenuous opposition of his wife and my warning that it was dangerous he bought them anyway. In South Africa it is illegal to deal in uncut diamonds without a specific license and the police are keen to trap people who do. This is an arguably unfair colonial law, originally designed to protect the profits of private diamond mining companies and now to protect government revenue by using tax-payers’ money to police the industry. Nevertheless, it is a very risky business to get involved in illicit diamond buying (IDB). A few months later I bumped into him at a social function and he said, “You know, about those diamonds you warned me against, I have good news and bad news, and the news is the same. They were not diamonds.” It transpired he had smuggled them out of the country on a holiday trip to England and hawked them around Hatton Gardens to try to sell them. There he learned that they were schlenters, cleverly-made fakes resembling uncut diamonds, and of no commercial value. So he had lost his money, risked arrest, and had an exciting adventure. It could have gone much more horribly wrong. More recently there was a press report of an arrest of people in Namaqualand for IDB, and prosecution for fraud for being “in illegal possession of fake diamonds”! (Of course, it is not illegal to be in possession of fake diamonds, but it is illegal to try to sell them as genuine.) The moral of this story is that local gem cutters, and visiting gem collectors, should be aware that IDB is illegal, that you may be taken for a ride buying schlenters, or even entrapped by plain-clothes police.

Schlenters can be made in various ways. The oldest, and easiest, and a great exercise for children to do at home, is to make a saturated solution of alum and let it crystallise. Alum forms neat octahedral crystals that look like perfect diamond octahedra. They dissolve again in warm water, which is a rather simple test. Carved octahedra, with curved faces typical of naturally etched diamond rough are more convincing, especially if they are slightly irregular. These can be carved out of any transparent material – glass, topaz, cubic zirconia, YAG – and require routine gemmological testing to distinguish them from diamond. There must be factories somewhere churning out these fakes, because they are quite common.

Other schlenters commonly encountered are intended to look like rough emerald crystals. These can be made from quench-crackled quartz with green dye in the cracks, or molten green glass poured into moulds. Some of them are very convincing, with naturally-shaped crystal outlines and adhering biotite mica. The give-away here is that some of them are five-sided, whereas beryl crystals are hexagonal, and they contain numerous, round gas bubbles in swirls characteristic of glass. Similar glass fakes offered as garnet or even ruby rough do the rounds intermittently. More examples of

these and other fake gem rough are illustrated and described at <https://www.mindat.org/msg-350039.html>.



Schlenters carved out of cubic zirconia to look like naturally etched rough diamond crystals



A batch of fake emerald rough made from green glass coated with mica to look like natural crystals

UNTANGLING SOME TERMINOLOGY – BIREFRINGENCE, DISPERSION, BRILLIANCE

Birefringence, dispersion, and brilliance describe different things. Birefringence is the property of optically anisotropic crystals that results in visible double refraction in some crystallographic directions, commonly seen in zircon. Dispersion (fire) is the production of prismatic colours by different degrees of refraction of different wavelengths of light, commonly seen in diamond. Brilliance refers to the light return from a gem and is defined as "the surface and total internal reflection of light" (Read, P. 2006. Gemmology). This is distinct from scintillation (sparkliness with movement), which can affect one's perception of brilliance. The surface brilliance is called lustre and is related to the RI and degree of polish (and viewing angle). The internal reflection depends on the RI, cut, polish, and limpidity (freedom from inclusions). When comparing the brilliance of real gems, not computer models of them, one has to consider at least illumination, RI, cut, polish, colour intensity, and clarity (limpidity). Macroscopic, microscopic, and even sub-microscopic inclusions can affect clarity dramatically, especially in gems like emerald, hessonite garnet, peridot, and rose quartz - the last three often being described as "sleepy". This is distinct from the fuzzy double refraction seen in highly birefringent stones like zircon when viewed across the optic axis. Some gems, like peridot, can display a combination of double refraction fuzziness and inclusion-induced sleepiness.

HOMEMADE DICHROSCOPES

So you want to check the pleochroic colours of a piece of faceting rough or a cut gem but you don't have a dichroscope. It is not difficult to improvise.

1. You need a flat screen computer, which produces plane polarized light, usually at some inclined angle. Rotate the stone through various orientations in front of the screen and observe the colour changes. Simple eh! (Some older cell phone screens may work too.)
2. If you want to view the pleochroic colours side by side, cut a sheet of Polaroid in half, rotate one half through 90° and mount them in a frame, like an old 35 mm photographic slide frame. View the stone illuminated with ordinary white light in various orientations through the split filter to see the different pleochroic colours in each half.
3. You can make a dichroscope with nothing more than a cleavage rhomb of clean calcite about 3 cm on an edge and some black insulating tape. Draw a small rectangle on paper and view it through the calcite rhomb, rotating it until the double images are parallel. Note the orientation of the rectangle relative to the rhomb. Then using four pieces of tape make a small rectangular window on one side of the rhomb, in the same orientation as the drawn one. You may have to experiment to get the window the right size to produce double images parallel and just touching each other. Then tape up the sides of the rhomb to avoid internal reflections. Detailed instructions with illustrations can be found in Tom Herbst's *Amateur Gemstone Faceting Volume 2* (pages 379–382).
4. If you are more ambitious, you can make a more sophisticated dichroscope, with magnification. You will need a small cleavage rhomb of clear calcite, thin card or brass shim, an old low-power microscope ocular, and some stuffing (pipe cleaner or rolled up paper towelling). Grind the calcite gently into a straight-sided prism to fit into the microscope ocular (one end of which should unscrew). It helps to paint the sides black to avoid internal reflections. Make a small rectangular window out of two overlapping pieces of brass shim or thin card, and glue them inside the smaller lens of the ocular. Secure the calcite prism in the body of the ocular, using the pipe cleaner or rolled up paper wrapped around it. Reassemble the ocular. Now view the rectangular window through the larger lens of the ocular. You should see two images of the window. If they overlap, you need to open the ocular again and rotate the calcite prism a little. Do this repeatedly if necessary until the two rectangular images are next to each other. Now you have a magnifying polariscope, useful for viewing the pleochroic colours of smaller stones illuminated by strong, white light. The two photographs below show the necessary components.



A 1 cm long square calcite prism, painted black on the sides to reduce internal reflections, next to a 6x microscope ocular.



The microscope ocular with one end screwed off, to show the rectangular window made out of brass shim, and some of the internal packing to hold the calcite prism in place.

THE POLARISCOPE, THE FACETER'S FRIEND

A polariscope consists essentially of two polaroid filters, or a source of plane polarised light and one polaroid filter. The source of polarised light can be a white computer screen or even the sky, viewed at 90 degrees to the Sun. For the filter, or analyser, you can use a sheet of polaroid, or a lens from a cheap pair of 3D movie spectacles.

Let's start with a white computer flat screen, even an older cell phone screen without a plastic cover produces plane polarised light. Rotate an elongated transparent tourmaline crystal in front of your white computer screen and see what happens. It goes from light to dark four times in a full rotation and the colour changes. You are seeing the pleochroic colours of the dichroic tourmaline crystal. Now take up the analysing polaroid filter or 3D movie glasses and rotate these in front of the white computer screen. What do you see? Four times in a full rotation the polarising filter goes black. (You have may to look through the 'front' of the 3D movie glasses to see this.) Now hold the analysing filter in the black position (called 'crossed polars') and rotate your elongated tourmaline crystal, or an elongated quartz or beryl crystal, between the filter and the computer screen. What do you see? The crystal goes dark four times in a full rotation. Try this with other minerals – a sheet of mica, a rhomb of calcite, etc. – and then with a piece of glass. The glass will stay dark for the full rotation, when most of the other minerals will blink from dark to light. If you experiment long enough you may find that some minerals that blink on and off in some directions stay dark in others. So we have some explaining to do.

Glass, plastic, and minerals in the cubic system – including diamond, spinel, garnet – are optically isotropic and should stay dark for rotation in any orientation between crossed polars. In reality they may not stay completely dark, but waver between dark and light as you rotate them, and if they are internally strained they may show waves of bright colours. But with some practice you will distinguish this behaviour between that of the crystals that are not isotropic – like tourmaline, quartz, beryl, etc. – thank in most orientations blink on and off, light/dark four times in a full rotation between crossed polars. So there you have one means of possibly distinguishing between glass and some common gem minerals with your polariscope set-up.

Optically uniaxial minerals, like quartz, beryl and tourmaline, have one direction in which they do not blink light and dark between crossed polars. This is the direction of the *c*-axis, and often these crystals are elongated parallel to this direction. It can be useful to be able to determine this direction in rough, especially if it is an irregular lump of nicely coloured rough. In aquamarine and pink tourmaline, for example, this is the direction of best colour and ideally the table of the gem should be perpendicular to it.

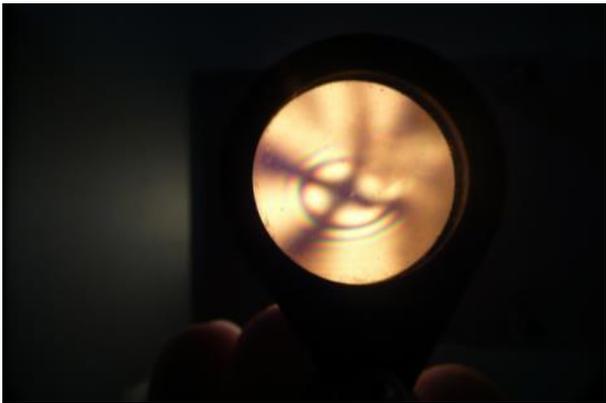
Twinning can cause opposite bands of dark and light under crossed polars. This is how people looking for twinned calcite can determine quickly in advance if the rough is twinned, and the orientation of the twin planes. These need to be orientated at an oblique angle to the table facet in order to produce the rainbow interference colours displayed by some faceted calcite.

A more sophisticated polariscope consists of a stand, with a light in the base and two polaroid filters. The upper one can be rotated into the dark position. This allows you to manipulate the crystal or cut gemstone more easily, to gain more information. Faceted synthetic quartz often is cut with the table perpendicular to the **c**-axis. Under crossed polars with the **c**-axis orientated vertically, a faceted synthetic quartz often displays bright interference colours. If you insert a 10× lens between the stone and the analyser, with luck you may see a typical quartz 'bull's-eye' interference figure, of a dark cross with concentric coloured rings around a coloured or colourless centre. Other uniaxial minerals in similar orientation will produce a similar interference figure of the dark cross with concentric coloured rings, but without the bull's eye centre. So this can help you distinguish quartz from other uniaxial minerals or glass. If you have a quartz sphere, or even a quartz bead, rotate it between crossed polars and see what happens. In one orientation it will produce an interference figure magically. Then you are looking straight down the **c**-axis.

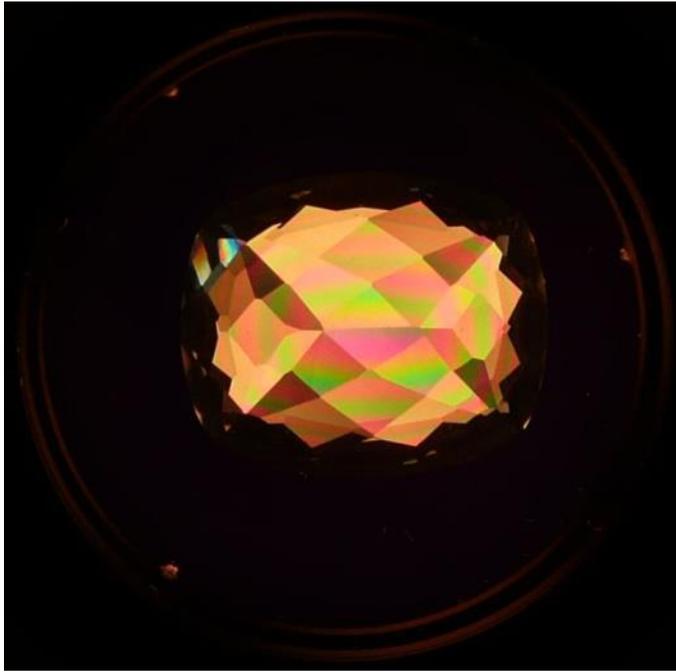
There are other more sophisticated things you can do with a polariscope, but for the faceter it is a quick and easy way to distinguish glass from common minerals like quartz and beryl, and is very useful for finding the **c**-axis in irregular uniaxial rough. It is easy to experiment with polarised light, without having to invest in expensive equipment, and you can learn a great deal about the practical applications of crystal optics in faceting and gemmology without having to get to grips with the complicated physics (see 'How to play with polarized light' and more detailed information at <http://homepage.ruhr-uni-bochum.de/Olaf.Medenbach/eng.html>)



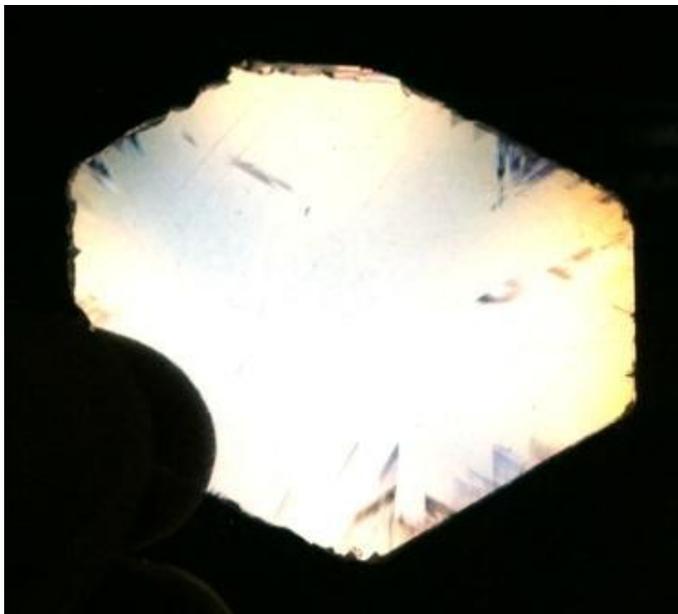
A polariscope used with a magnifying lens to photograph the interference figure produced by a scapolite crystal



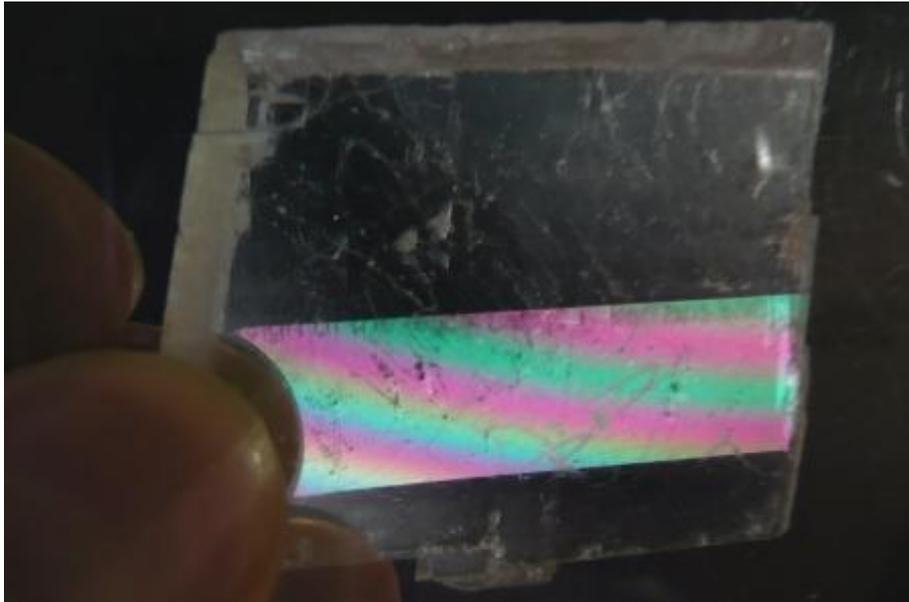
The slightly distorted uniaxial interference figure of scapolite viewed down the **c**-axis in the polariscope with a 10× magnifying lens



Synthetic quartz cut with the table perpendicular to the **c**-axis, showing bright interference colours viewed in the polariscope with crossed polars. Inserting a magnifying lens between the stone and the upper polarising filter would produce a typical bull's eye interference figure for quartz.



Slice through a quartz crystal perpendicular to the **c**-axis, under crossed polars, showing dark wedges due to Brazil law twinning



Twinning in calcite revealed by interference colours under crossed polars in the polariscope

THE C-AXIS, WHAT IT IS AND WHY IT IS USEFUL TO GEM CUTTERS

All crystals fall into one of seven crystal systems, based on their symmetry. In crystal drawings, by convention, the c-axis usually is orientated vertically, in the plane of the paper. All crystals except those in the cubic (or isometric) crystal system have a c-axis. Cubic system crystals, like diamond, garnet and spinel, have no c-axis because all three crystallographic axes are necessarily the same length. In the other crystal systems the c-axis can be longer or shorter than the other crystallographic axes. In many minerals, particularly those in the tetragonal, hexagonal and trigonal crystal systems, the c-axis is associated with unique optical properties. These are useful to know if you are a gem cutter. Here are some examples.

Star ruby and sapphire gemstones are corundum, crystallising in the trigonal crystal system. The c-axis here has three-fold rotational symmetry. Fine, needle-like rutile inclusions in three sets form perpendicular to the c-axis and intersect at 120°. If the c-axis is orientated vertically in a cabochon stone, light reflected from these rutile fibres results in a 6-rayed bright star in the stone.

Zircon crystallises in the tetragonal crystal system, often forming elongated crystals with a square cross-section at right angles the c-axis. The strong facet-edge doubling due to the high birefringence of zircon is not visible if the stone is viewed parallel or perpendicular the c-axis. So if the table facet of the stone is orientated perpendicular or parallel to the c-axis, the fuzzy doubling effect will be minimised in a zircon gem.

Topaz crystallises in the orthorhombic system, with the same symmetry as a matchbox. The c-axis runs down the length of the crystal, and is perpendicular to the easy cleavage planes. When faceting a topaz, it is important to avoid having the c-axis either perpendicular or parallel to the table facet. If the table is perpendicular to the c-axis, it will be very difficult to polish it, as it will tend to cleave. If the table is parallel to the c-axis, two opposite girdle facets will be difficult to polish and will be prone to vertical cracking because of the cleavage.

Tourmaline crystallises in the trigonal system, often in elongated crystals with striations along the length. The c-axis is then the long axis of the crystal. Gem cutters describe tourmaline as having an 'open' or 'closed' c-axis. The absorption of colour may be very strong in the direction of the c-axis, in which case the crystal has a 'closed' c-axis. If the colour is light when viewed along the length of the crystal, or parallel to the c-axis, it is 'open'. Open c-axis tourmalines tend to produce better gems, without the darkening effect of the intense light absorption of the 'closed' c-axis stones.

Scapolite and spodumene often have more intense, better colour when viewed parallel to the c-axis. They also have two directions of easy cleavage parallel to the c-axis. This means stones need to be orientated carefully with respect to the c-axis, in order to optimise the colour and at the same time to avoid having cleavage planes parallel to any major facets.

So, how does one recognise the c-axis in rough gemstones? Sometimes it is easy. In elongated tourmaline crystals, for instance, the c-axis is parallel to the length and any striations there may be. It is perpendicular to the bulging triangular cross-section. In 'closed' c-axis specimens the colour will be very dark or even black when viewed in the c-axis direction. In ruby and sapphire the c-axis runs down the length of the elongated barrel-shaped crystals, or perpendicular to the flat ends of squat

six-sided crystals. Quartz is trigonal, but often forms six-sided crystals terminated by a point made up of two sets of three triangular faces. The c-axis runs along the length of the crystal from the point. Beryl also forms six-sided crystals, but belongs to the hexagonal crystal system. Here the c-axis also is parallel to the length. In tetragonal scapolite and zircon crystals, the c-axis runs from the pyramidal point, parallel to the rectangular side faces. Topaz crystals usually show their cleavage as a flat 'base' or as parallel fractures in the crystal. This plane is perpendicular to the c-axis.

But what if you are looking at irregular gem rough, with no convenient crystal faces to guide you? In some cases, careful inspection of the rough stone will reveal traces of cleavage. This can be seen as regularly flat-stepped fractures on broken surfaces, or as reflective internal cleavage planes. These are best seen in oblique or dark-field lighting. A convenient way to achieve this is by holding the stone just below the rim of a desk lamp, with the lamp shading your eyes. Knowing the crystallographic orientation of any particular mineral's cleavage should enable you to identify the c-axis direction and orientate the stone crystallographically.

But what if there is no visible cleavage? In the case of star ruby or sapphire, reflection from the crystallographically orientated rutile inclusions may help. The c-axis is perpendicular to the intersection of the six arms of the star. In strongly birefringent stones like zircon, the direction in which you see least doubling of the image of fractures on the far side of the rough will be either the c-axis direction, or perpendicular to it. So, how does one tell the difference?

Here, and with weakly birefringent stones with no easy cleavage, like quartz and beryl, a polariscope is very useful. A polariscope consists of a light source and two polarising filters. This can be a commercially available piece of optical equipment, or something homemade. You can use two pieces of Polaroid sheet or even the lenses from a pair of 3D movie spectacles. A flat computer screen can act as a source of plane polarised light. In this case you only need one polarising filter. The technique for finding the c-axis in gems with only one optic axis (which includes quartz, beryl, scapolite and zircon) is to cross the polars or rotate a single polarising filter to the dark position, effectively cutting out all the light. Then holding them steady, rotate the stone between them in a variety of orientations, until the stone stays uniformly dark (or in some cases, uniformly light). In this position, when the transmitted light through the stone does not fluctuate from light to dark as you rotate it, you are looking in the c-axis direction. A spot of marker pen ink on the surfaces nearest and furthest from you will define the c-axis orientation. Having found the c-axis direction, all you now have to do is orientate the gem design appropriately for the mineral species in question, and cut your stone.

For those wanting a bit more adventure, once you have found the c-axis of an optically uniaxial crystal using a polariscope, try inserting a lens (a 10× loupe will do) between the stone and the upper polarising filter. With a bit of jiggling, you will see an interference figure consisting of coloured rings and a dark central cross. There are all sorts of useful gemmological things you can do with polarised light. A good place to learn is from 'How to play with polarised light', downloadable from Olaf Medenbach's superb website <<http://homepage.ruhr-uni-bochum.de/Olaf.Medenbach/eng.html>>.

EMERALD CUT SEQUENCE

The Emerald Cut is not a meetpoint design so cutting stones with repeatable proportions and facet widths involves guesswork. The following sequence for cutting pavilion and crown avoids most of the guesswork and enables you to cut pairs or sets of matched stones. This sequence is modified from FACET DESIGN Vol. 4 by Robert Long & Norman Steel, in turn based partly on FACETING FOR AMATEURS by Glenn & Martha Vargas. This example uses 5° steps for the three pavilion tiers, but you can use any equal steps up to 10° (say 41°, 51°, 61°) to match the RI and depth of the stone.

1 & 2: Establish desired length and width at 90° by direct measurement.

3 & 4: Cut four keel facets at culet angle (say 40°) to create level temporary girdle.

5 & 6: Cut four break facets at highest angle (say 50°) to equal width in plan-view (guesswork or finicky measurement here).

7 & 8: Cut four intermediate main facets at angle midway between the two previous tiers (say 45°) to create steps of equal width.

9: Cut four corner main facets at intermediate angle (say 45°) to meetpoint of 3,4,7,8.

10: Cut four corner break facets at break angle (say 50°) to meetpoint of 5,7,9.

11. Cut four facets at 90° to level girdle.

The pavilion has been cut first and the stone transferred to cut the crown. This example uses 40° main facets but you can use any combination of mains +15° and mains -15° for the tiers of crown facets.

1 & 2: Cut four break facets at highest angle (mains +15°, say 55°) to equal girdle thickness.

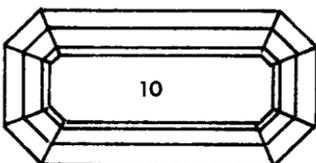
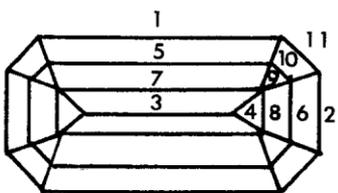
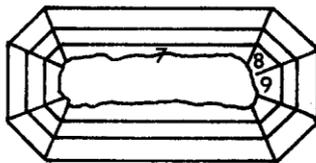
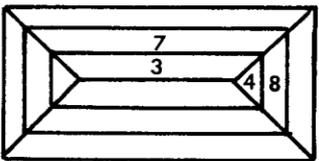
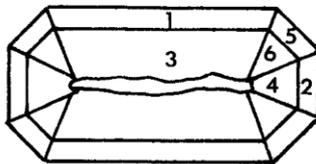
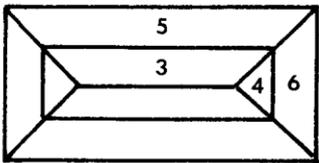
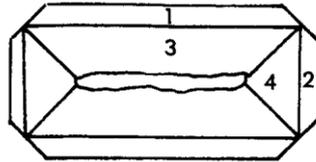
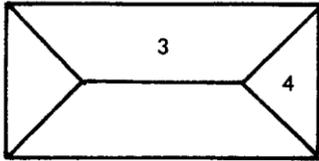
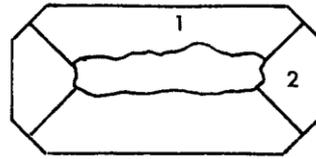
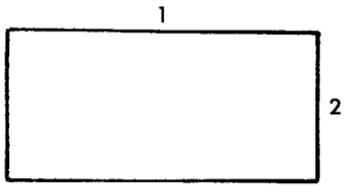
3 & 4: Cut four main facets (say 40°) to corner meetpoint. This establishes the width of 1 & 2 without guesswork.

5: Cut four corner break facets (55°) to level girdle.

6: Cut four corner main facets (40°) to meetpoint 1,3,5,6.

7, 8 & 9: Cut eight facets at mains -15° (say 25°) until mains and breaks are equal width in plan-view (guesswork or very finicky measurement here).

10: Cut table facet at 0° to preferred size, or until 7, 8 & 9 look nice and narrow.

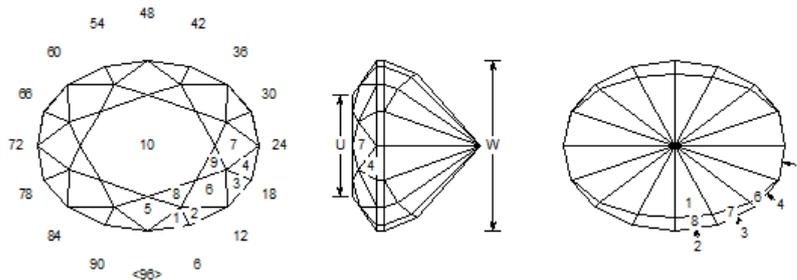


Emerald cut pavilion

Emerald cut crown

OVAL WITH A FULLY CONICAL PAVILION

Here is a quick and easy oval with a standard 1:1.30 proportion. It has a fully conical pavilion, so you can spin a conical preform, stopping just short of producing a point. This means you don't have to change angles and mast height when cutting the sixteen pavilion facets, which saves time and avoids mistakes. This is a fully meetpoint design that doesn't require a preform, so it would be good for a beginner's first oval. This design is for quartz or beryl, but would work better in material with a higher refractive index, like corundum, garnet or zircon.



Omni oval with fully conical pavilion

Duncan Miller
 5 October 2016
 Angles for R.I. = 1.540
 61 + 16 girdles = 77 facets
 2-fold, mirror-image symmetry
 96 index
 $L/W = 1.297$ $T/W = 0.792$ $U/W = 0.595$
 $P/W = 0.573$ $C/W = 0.147$
 $Vol./W^3 = 0.366$

PAVILION

1	42.00°	04-11-17-21- 27-31-37-44- 52-59-65-69- 75-79-85-92
2	90.00°	02-46-50-94
3	90.00°	07-41-55-89
4	90.00°	13-35-61-83
5	90.00°	21-27-69-75
6	66.62°	13-35-61-83
7	68.76°	07-41-55-89
8	69.99°	02-46-50-94

CROWN

1	41.88°	02-46-50-94
2	40.24°	07-41-55-89
3	36.16°	13-35-61-83
4	34.97°	21-27-69-75
5	36.00°	96-48
6	31.58°	10-38-58-86
7	30.26°	24-72
8	20.33°	05-43-53-91
9	16.65°	16-32-64-80
10	0.00°	Table

The fully conical pavilion allows you to spin a conical preform. Stop just short of producing a point, to cut clean pavilion main facets to the final point. Tangent ratio the pavilion mains to change the depth. Performs best in corundum or higher RI material.

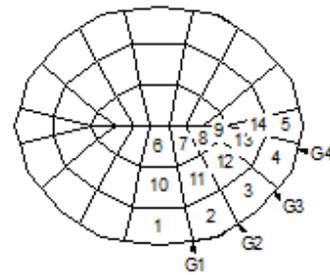
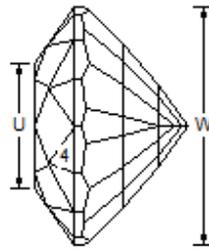
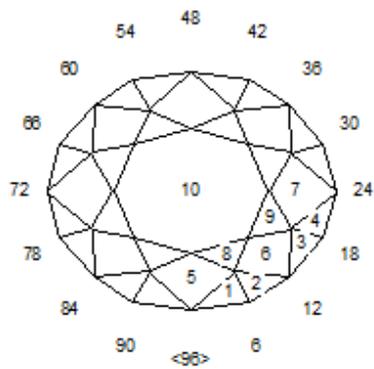
C:\Users\Duncan\Documents\GemCad designs\Ovals\Oval omni 1_3.gem

OVALS – MAKING A CUSTOM DIAGRAM

This stemmed from a jeweller's request. The setter had broken one of a matching pair of blue-green stones, destined for earrings, bought by the client in India as emeralds. They were apatite; but nevertheless the broken stone had to be replaced to fit the already-made setting. Fortunately I had just one piece of blue-green apatite that matched the colour. In order to produce a stone of the same size and proportion I had to replicate the oval precisely. I could have slapped facets on it and hoped for the best, but being a precision cutter I made a diagram to guide me. To produce the correct girdle outline it required a preform, for which the rough was too shallow to cut to a point, so I built it up with low temperature green wax. Once the girdle was established, following the cutting pattern was relatively easy, although not the sort of thing a meetpoint faceter would relish doing.

I am going to use this example to demonstrate how to use Robert Strickland's GemCad program to make a preform from any faceting diagram that may need one. First, you need a copy of GemCad, which you can download for the very modest fee of US\$95 from www.gemcad.com. Next, you need a GemCad copy of the design for which you wish to make a preform. This presumes it doesn't have a girdle preform already and isn't a meetpoint design that generates the girdle outline as you cut the design (like an Omni oval). Then, in GemCad you delete all the facet tiers except for the girdle facets. This leaves you with a tall prism shape. Simply cut a series of facets at the girdle indexes to meet at a common point on top. There, you have your preform. What angles to use? I usually start with 40° for the steepest facets, the ones where the girdle is nearest the centre point, but once you have the preform you can tangent ratio the facets in GemCad to accommodate your rough and the design.

The next section describes how to produce preforms for ovals of any standard proportion from scratch.



Oval for apatite

Duncan Miller

12 June 2014

Angles for R.I. = 1.540

79 + 16 girdles = 95 facets

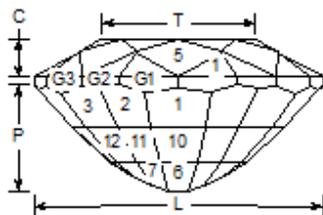
2-fold, mirror-image symmetry

96 index

L/W = 1.199 T/W = 0.634 U/W = 0.524

P/W = 0.442 C/W = 0.160

Vol./W³ = 0.295



PAVILION

G1	90.00°	02-46-50-94
G2	90.00°	09-39-57-87
G3	90.00°	13-35-61-83
G4	90.00°	20-28-68-76
1	45.36°	96-48
2	45.61°	07-41-55-89
3	45.97°	10-38-58-86
4	47.03°	18-30-66-78
5	47.24°	24-72
6	35.33°	96-48
7	35.67°	07-41-55-89
8	35.97°	10-38-58-86
9	36.18°	18-30-66-78
10	40.56°	96-48
11	40.94°	07-41-55-89
12	41.28°	10-38-58-86
13	42.07°	18-30-66-78
14	42.95°	24-72

CROWN

1	38.39°	02-46-50-94
2	36.64°	09-39-57-87
3	40.14°	13-35-61-83
4	37.53°	20-28-68-76
5	33.80°	96-48
6	34.64°	10-38-58-86
7	29.86°	24-72
8	23.00°	04-44-52-92
9	19.87°	18-30-66-78
10	0.00°	Table

Cut preform to obtain girdle for placement of crown facets

C:\Users\Duncan\Documents\GemCad designs\Ovals\ovalapatite.gem

OVALS – CREATING A PREFORM

I started faceting in pre-GemCad days and found cutting ovals very laborious. I would cut the girdles by eye, using various oval templates, and placed the brilliant-style facets by eye too. Producing matching pairs was very trying. The advent of meetpoint faceting and GemCad overcame all these difficulties. Now there are lots of designs for ovals that are meetpoint, requiring no preform, with the girdle outline evolving out of the cutting sequence. You can access some of these at <http://www.facetdiagrams.org/>. Click on Search; select Oval on the dropdown menu Shape?; check the box Only show Open designs (with GemCad ASC files and cutting instructions); and click on I agree. Search! There you are – a huge selection of oval cutting recipes in every conceivable proportion. Many of the Long & Steele ones have interchangeable pavilions and crowns to give you overwhelming choice. (Of course, there are other internet sites with oval diagrams. One of my favourites is at https://www.gemologyproject.com/wiki/index.php?title=Faceting_Designs.)

Some of the designs on facetdiagrams.org do require preforms and some of those are not supplied. What to do? If you have GemCad you can open the file, download it (the blue download option, lower left), and open it with GemCad. Then you can apply the preform generating sequence described above to produce the appropriate preform.

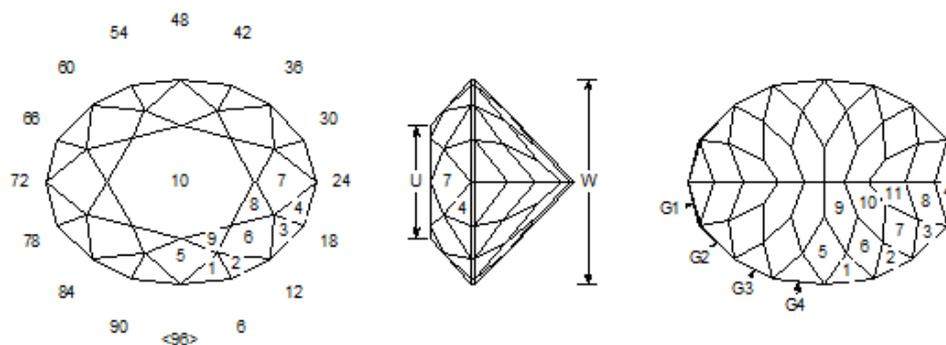
Many of the Long & Steele designs are for ovals with common length/width proportions. For these ovals Long & Steele provided a very convenient table to generate the required preforms, published in their book 'Facet Design Volume 1 Ovals', part of which I will reproduce here. This enables you to cut a suitable preform for a Long & Steele oval of specified L/W ratio without having to construct the preform yourself in GemCad.

Extract of Table D-5 SIXTEEN FACET GIRDLE OUTLINES FOR SELECTED OVALS (from Long & Steele, Facet Design Volume 1 Ovals, second edition)

L/W ratio	Indices (96 wheel)	Angle (degrees)	Typical size (mm)
1.20	02, 08, 13, 21, etc.	45.0; 43.5; 42.1; 40.1	5×6, 10×12, 15×18
1.22	02, 08, 13, 21, etc.	45.0; 43.4; 41.8; 39.6	9×11, 18×22, 27×33
1.25	02, 08, 13, 21, etc.	45.0; 43.1; 41.4; 39.0	4×5, 8×10, 12×15, 16×20
1.29	02, 07, 12, 20, etc.	45.0; 43.3; 41.3; 38.6	7×9, 14×18, 21×27
1.33	02, 07, 12, 20, etc.	45.0; 43.0; 40.6; 37.6	3×4, 6×8, 9×12, 12×16
1.40	02, 07, 12, 20, etc.	45.0; 42.6; 39.7; 36.2	5×7, 10×14, 15×21
1.50	02, 06, 11, 19, etc.	45.0; 42.7; 39.2; 34.9	2×3, 4×6, 6×9, 8×12

OVALS – ‘CLASSICAL’ MIXED-CUT DIAGRAMS

Recently I have been learning how to cut ‘classical’ mixed-cut ovals without a diagram, receiving lots of help from Steven Dente ‘1bwana1’ on GemologyOnline. After several attempts I managed to cut a symmetrical oval pavilion with three tiers of lozenge-shaped facets, and satisfied my curiosity about how it is done. I think it needs a lot of patient practicing, and I found guessing which angles and indices to use unsatisfying. So I set about creating a GemCad design to produce something similar. Here it is, in a 1:1.30 L/W ratio, with a crown derived from Long & Steele.



Mixed oval 1:1.30

Duncan Miller
 6 June 2018
 Angles for R.I. = 1.540
 75 + 16 girdles = 91 facets
 2-fold, mirror-image symmetry
 96 index
 $L/W = 1.306$ $T/W = 0.713$ $U/W = 0.547$
 $P/W = 0.479$ $C/W = 0.190$
 $Vol./W^3 = 0.330$

PREFORM

PF1	45.00°	02-46-50-94
PF2	43.22°	07-41-55-89
PF3	41.01°	12-36-60-84
PF4	38.16°	20-28-68-76
G1	90.00°	20-28-68-76
G2	90.00°	12-36-60-84
G3	90.00°	07-41-55-89
G4	90.00°	02-46-50-94

PAVILION

1	47.47°	02-46-50-94
2	48.64°	07-41-55-89
3	50.00°	12-36-60-84
4	54.73°	20-28-68-76
5	44.52°	96-48
6	44.58°	04-44-52-92
7	45.59°	10-38-58-86
8	45.78°	16-32-64-80
9	42.60°	02-46-50-94
10	42.00°	07-41-55-89
11	43.00°	14-34-62-82

CROWN

1	44.83°	02-46-50-94
2	42.68°	07-41-55-89
3	43.26°	12-36-60-84
4	40.26°	20-28-68-76
5	40.00°	96-48
6	37.75°	09-39-57-87
7	32.81°	24-72
8	20.33°	16-32-64-80
9	28.01°	04-44-52-92
10	0.00°	Table

NOTE: PREFORM DOESN'T SCALE IF YOU CHANGE THE L/W RATIO.

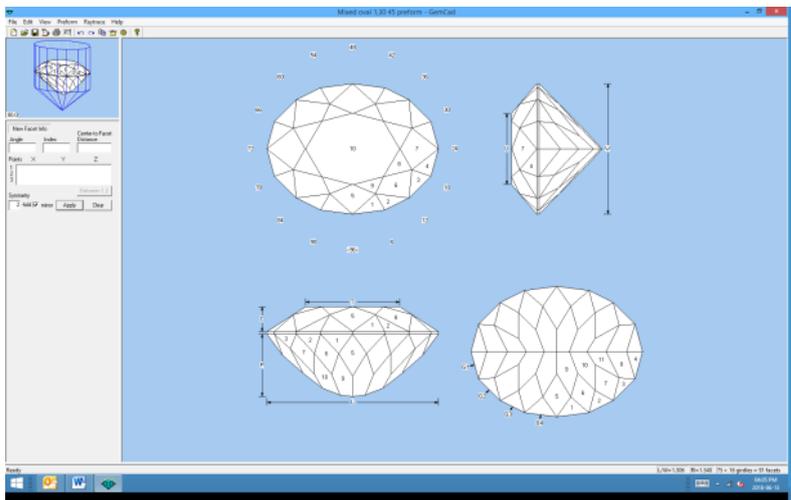
C:\Users\Duncan\Documents\GemCad designs\Ovals\Mixed oval 1,30 45 preform.gem

You can see it uses the Long & Steele index formula 02, 07, 12, 20 for an oval of this L/W ratio. If you compare the angles of PF1-PF4 in the diagram with the recommended preform angles in the extract of Table D-5 above for L/W = 1.29, they vary slightly. This is because of the slight difference in L/W ratios; 1.306 in my diagram, 1.29 in Table D-5.

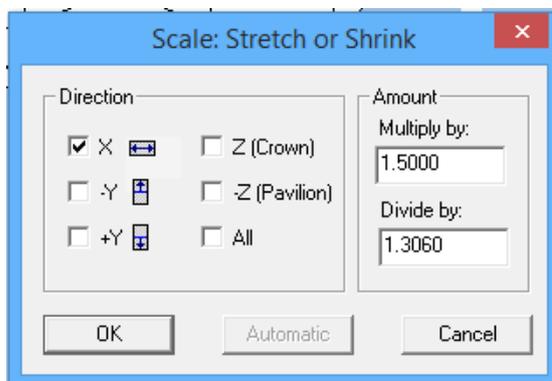
Next I will explain how to scale this diagram, or any other diagram, to any desired L/W ratio.

This is very easy if the diagram is a fully meetpoint diagram, without a preform. You note the initial L/W ratio from the Print Preview and then click on Scale in the Edit menu. Here you check the X box because you want to change the proportions in the X direction, then enter the appropriate numbers to divide by the initial L/W ratio and to multiply by the one you want, and press OK. The next menu offers to round the indexes to the nearest notches. As we are working with a 96 index wheel it will use that. Press YES – horrors, see all those fractional indexes! – then press OK, and they will vanish.

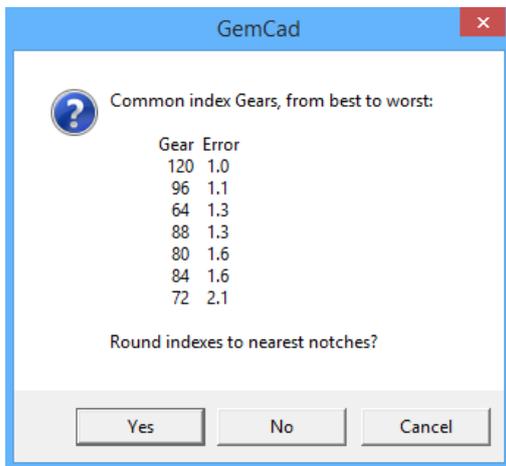
OK, now let's do it with an example. I am going to use the same mixed oval 1:1.30 design as last month. Here is a screen shot of the design.



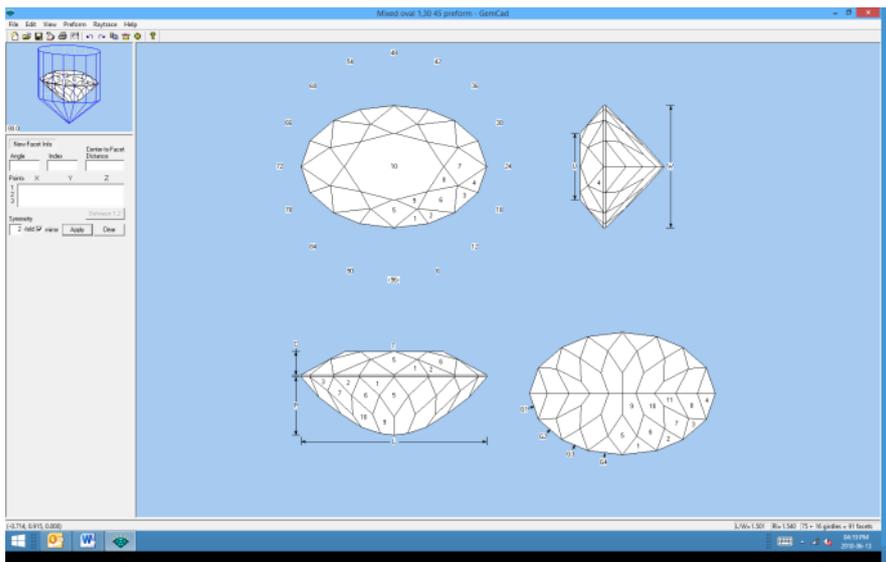
Here is the Edit Scale menu box with the appropriate entries.



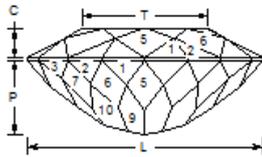
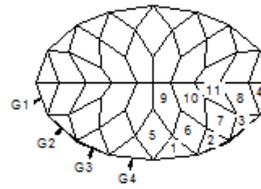
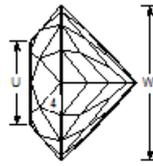
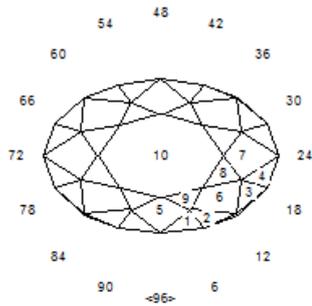
And here is the index rounding option.



Pressing YES produces a terrible list of fractional indexes, but OK in the next menu will round them. The end result looks like this.



If there are grey cut-offs because the diagram now is too long, you can Scale All to shrink it a bit for the diagram to fit. (I did that here.) The preform doesn't rescale, so it is meaningless. You can remove it with Preform Delete. If you are going to save the rescaled diagram you should change the heading using Edit Heading/Footnote. The final diagram is on the next page.



Mixed oval rescaled to 1:1.50

Duncan Miller
 13 June 2018
 Angles for R.I. = 1.540
 75 + 16 girdles = 91 facets
 2-fold, mirror-image symmetry
 96 index
 L/W = 1.501 T/W = 0.805 U/W = 0.539
 P/W = 0.474 C/W = 0.188
 Vol./W³ = 0.370

PAVILION		
G1	90.00°	19-29-67-77
G2	90.00°	11-37-59-85
G3	90.00°	06-42-54-90
G4	90.00°	02-46-50-94
1	47.58°	02-46-50-94
2	47.20°	06-42-54-90
3	48.97°	11-37-59-85
4	50.22°	19-29-67-77
5	44.29°	96-48
6	44.16°	04-44-52-92
7	43.94°	09-39-57-87
8	42.77°	15-33-63-81
9	42.11°	02-46-50-94
10	41.37°	06-42-54-90
11	41.07°	13-35-61-83

CROWN		
1	44.47°	02-46-50-94
2	41.33°	06-42-54-90
3	40.60°	11-37-59-85
4	36.55°	19-29-67-77
5	39.26°	96-48
6	35.70°	08-40-56-88
7	28.55°	24-72
8	18.78°	15-33-63-81
9	27.63°	04-44-52-92
10	0.00°	Table

C:\Users\OPTIPLEX 9020\Documents\GemCad designs\Ovals\Mixed oval rescaled1-50.gem

There are several things to notice about this rescaling. Crown star facets 9 will need tweaking to meet. The girdle indexes have changed from the 02, 08, 13, 21 set to 02, 06, 11, 19. This is the same as given for a L/W ratio of 1.50 in Table D-5 of Long & Steele, in the table below. This means we can use the Long & Steele recommended preform angles for L/W 1.50 to cut a preform for this design. And remember that in GemCad you can change the pavilion culet angles easily to deepen the stone if necessary, using the New angle option in the Facet dialog box that appears if you click on a facet.

Extract of Table D-5 SIXTEEN FACET GIRDLE OUTLINES FOR SELECTED OVALS (from Long & Steele, Facet Design Volume 1 Ovals, second edition)

L/W ratio	Indices (96 wheel)	Angle (degrees)	Typical size (mm)
1.20	02, 08, 13, 21, etc.	45.0; 43.5; 42.1; 40.1	5×6, 10×12, 15×18
1.22	02, 08, 13, 21, etc.	45.0; 43.4; 41.8; 39.6	9×11, 18×22, 27×33
1.25	02, 08, 13, 21, etc.	45.0; 43.1; 41.4; 39.0	4×5, 8×10, 12×15, 16×20
1.29	02, 07, 12, 20, etc.	45.0; 43.3; 41.3; 38.6	7×9, 14×18, 21×27
1.33	02, 07, 12, 20, etc.	45.0; 43.0; 40.6; 37.6	3×4, 6×8, 9×12, 12×16
1.40	02, 07, 12, 20, etc.	45.0; 42.6; 39.7; 36.2	5×7, 10×14, 15×21
1.50	02, 06, 11, 19, etc.	45.0; 42.7; 39.2; 34.9	2×3, 4×6, 6×9, 8×12

Scaling other designs that have preforms means you will have to construct a new preform from the rescaled design, using the technique described above.

HYBRID DOPPING WITH WAX AND CYANOACRYLATE GLUE

Initial dopping requires a flat surface on your rough. Prepare a flat dop with a blob of hot wax on it and in the transfer fixture push this against another flat dop face to form a layer of wax a few millimetres thick. You can build this up with several layers if the stone you are going to cut is very heat sensitive. Clean the flat on your rough with alcohol. When the wax is cold, apply a small drop of cyanoacrylate glue (CA), position the rough on the dop quickly, and let the glue set. Paint the join with clear nail varnish to protect the CA bond from softening in water. Then cut the pavilion.

There are two ways to do the transfer. If the stone is not very heat sensitive, fill the pavilion dop with wax and let it cool until it is still just plastic and takes a dent from a fingernail. Then push the pavilion into it, in a transfer fixture of course, and pull it out again quickly to make an impression of the pavilion. Use a small amount of CA in the impression to glue the pavilion to the wax. Using a CA accelerator, like Zip Kicker by ZAP, helps set the glue if it is reluctant. When the CA has set, paint the join with clear nail varnish. To remove the initial dop, hold the stone itself between your fingers, heat the stem of the initial dop, and with a twisting motion detach it as soon as the wax layer is soft enough to release it. You can scrape the surplus cold wax off the stone with a blade.

For very heat sensitive stones, the alternative is to make yourself a set of 'anti-dops' by grinding three large cylindrical dops into a 45° cone, a wedge, and a trigonal pyramid on a coarse lap. (I owe this idea to Tom Herbst's *Amateur Gemstone Faceting*.) Use an appropriate one of these in the transfer fixture to make an impression in soft, low temperature wax, like jeweller's green wax. When it has cooled you can glue a heat sensitive stone into that impression, preferably using a gap-filling CA and accelerator, followed by the clear nail varnish treatment. Remove the initial dop as described above, without allowing the stone to heat up at all. After cutting the crown, soaking the stone and dop in acetone overnight will result in a clean stone. (Gap-filling CA and Zip Kicker are available from hobby shops selling model kits.)

THE SECRET OF A GOOD POLISH – IS A GOOD PREPOLISH

In the bad old days, one cut facets on a 600 mesh lap, followed by a 1200 mesh lap and then went on to polish. The 1200 mesh leaves quite deep scratches, and on some material produces ‘orange peel’, a mottled surface with alternating rough and smooth patches. This makes polishing tedious. A pre-polishing step, with 3000 mesh or 8000 mesh diamond gets rid of the scratches and any orange peel. You might think the additional step adds time to the process, but in practice it speeds it up because it makes polishing so much quicker and easier. So, 3000 mesh or 8000 mesh, and on what kind of lap?

If you can afford it, you can buy a 3000 mesh sintered bronze diamond lap and prepolish on that. I use diamond paste on a metal lap because it is a less expensive outlay and enables you to ‘tune’ the surface – more about that later. The metal lap can be old-fashioned tin/lead alloy, or a more recent lead-free tin alloy like Gearloose Batt laps, or traditional copper or high quality cast zinc. The softer laps allow the diamond particles to embed further, so they work better with 3000 mesh diamond. The harder laps, like copper and zinc, work well with the finer 8000 mesh diamond. Whether you use oil-based or water-based diamond paste is a matter of your choice. Either way, apply the diamond paste very sparingly. There is no need to use a steel roller or piece of synthetic corundum to embed the diamond. The facets you are prepolishing will do that anyway. If scratches appear on a facet there is either too much diamond on the lap or a build up of swarf – black gunk that must be removed. This you can do with a piece of paper towel dampened with the appropriate lubricant for the type of diamond paste, wiping the spinning lap from the centre to the periphery. If necessary you then can apply another small amount of diamond paste to produce a quick prepolish.

What about the ‘tuning’? Once you have removed all the scratches and any ‘orange peel’ you should have a nicely even, frosted surface. If now you clean off the lap with a piece of dampened paper towel only the embedded diamond particles remain. A few sweeps of the facet on the cleaned surface will produce an even finer prepolish finish than before. For larger facets you can tune the lap by adding a bit more diamond paste to make it more aggressive. On smaller facets you can tune the lap by cleaning it to slow down the abrasive process. You can vary the behaviour to accommodate harder or softer facets on stones with marked differential hardness.

Working with diamond paste can be a bit messy, with black gunk getting on your fingers. You don’t want to spread that around, so keep some fingers clean to enable you to apply diamond paste to the lap with a clean finger tip. And wash your hands thoroughly with warm water, soap and a scrubbing brush before moving to the polishing lap.

RE-CUTTING OR RE-POLISHING A GEMSTONE

Re-cutting or re-polishing a gemstone is not for the faint-hearted. It requires a careful assessment of what can be done to improve the stone and whether the work is likely to increase the value. This is not a trivial exercise and depends on the type and extent of the damage, as well as the intrinsic value of the material. Sometimes a full recut is warranted, either by following a design derived from measurement of the existing dimensions of the stone, or by cutting without a diagram but placing facets by eye to follow the original design of the stone. Following a diagram allows for an accurate estimate of the final weight of the stone, while cutting by eye requires extensive experience of facet placement. This can be very time-consuming, especially if what is needed is to re-polish existing facets, with their placement through guesswork and judicious trial-and-error.

A comprehensive guide to the necessary skills could fill a small textbook, but Martine van der Westhuyzen has found a very helpful 37 page article by Nancy and Steven Attaway of High Country Gems, USA, that describes the process in considerable detail (https://www.dropbox.com/s/2ooemqlutipnng3/Attaway_NancySteve.pdf?dl=0). There are extensive discussions and numerous illustrations under ten main headings.

1. What Is a Damaged Gemstone Worth?
2. Factors that Affect Gemstone Value
3. What Constitutes Damage?
4. Economics of Re-Cutting for an Improved Appraisal Grade
5. Re-Cutting Examples
6. Repair and Re-Cut Options
7. When is Re-Cutting Not Economical or Ill-Advised?
8. Safety
9. Summary
10. References

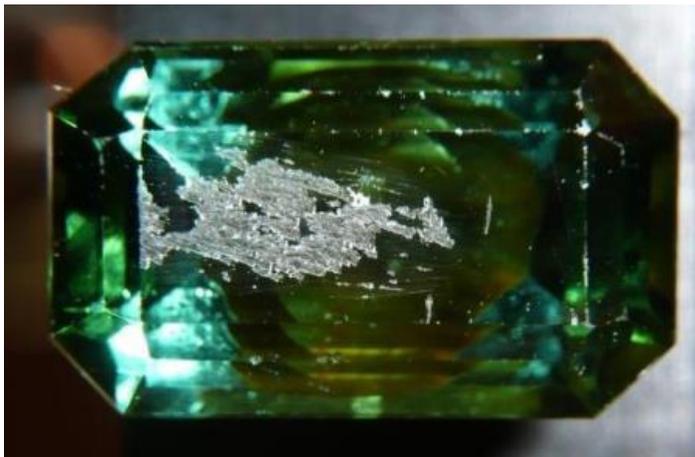
This 2018 publication is as comprehensive a guide as is available at present, and recommended reading for all gem cutters, jewellers, and appraisers.



Tanzanite 8.67 ct, with a very asymmetrical pavilion and wide table facet, before recutting



Tanzanite 5.39 ct, after recutting to the original depth, deliberately thick girdle to preserve weight



A green tourmaline with table damaged by an inexperienced attempt at removing scratches with a 1200 mesh sintered diamond lap. The hardened 'skin' produced by the original polishing peeled off, leaving coarse sub-surface damage that required more material removal than should have been necessary. The remedy for this is to use loose 3000 mesh diamond grit on a copper lap to remove the original scratches. For some unknown reason this avoids the 'orange peel' and deep damage caused by the sintered diamond lap's interaction with the original polished surface.

TRIALS AND TRIBULATIONS WITH GEMSTONE HEATING

Inspired by the dramatic change in colour of the large tourmaline illustrated in last month's Mineralogical Chatter, that went from autumn brown to a purplish-pink on heating by the client for whom I had cut it, I decided to experiment myself. A friend lent me a small 'enamelling' kiln; I bought a suitable crucible from jewellers' supplier Lipman & Son in Cape Town (<https://lipmanson.co.za/>); and Ian Lipman generously gave me jewellery casting investment powder to protect the stones. My first experiment was to find out how the kiln's temperature controller worked and how long it took to reach the required temperatures. I also had to research what those temperatures were for different gemstones. An enquiry to GemologyOnline led to a longish online conversation, with detailed advice from some very experienced lapidaries and gemstone dealers (<https://www.gemologyonline.com/Forum/phpBB2/viewtopic.php?f=8&t=26065>).

My first experiment was on a small, dark red tourmaline that looked like a garnet. It was buried in two tablespoons of investment powder in the crucible and heated in one step to 500°C. It took only 15 minutes to reach this temperature, overshoot to 535°C, and then settled down for a one-hour soak at 500°C. Obviously the kiln control would have to be nursed when approaching a set temperature. The kiln was left to cool overnight before removing the stone. The tourmaline had changed colour to a bright pink, but the internal flaws became more visible and the facets all developed scattered pitted areas. I thought that may be due to some reaction with the investment powder.

Then I tried more controlled heating of three khaki-brown tourmalines, taking the kiln up in steps of 200°C per hour, with a one-hour soak at 500°C. Two of the stones were wrapped in aluminium foil to isolate them from the investment powder. The third was 'naked' to see if it developed surface damage. It didn't, and all three stones changed to a not very appealing yellowish-green with serious internal crazing. It was clear from these very limited tests with tourmaline that heating has a low potential of success unless the stones are free of inclusions and flaws to start with.

The owner of the kiln had given me two pairs of light greenish-blue aquamarines to heat to try to remove the green cast. I only heated one pair, to keep the other for comparison. The pair of stones heated slowly to 450°C and cooled overnight lost the green and became a more pure blue, but they were pale to start with so the change was not dramatic. They didn't suffer any damage, which was a pleasant relief after the lack of success with the tourmalines.

My experiment with heat-treating dark amethyst was a bit more successful. Many years ago I had lightened dark Namaqualand amethyst in a kiln at UCT, but had forgotten the temperature used. A quick search on the internet produced a link to a recent, detailed, open-source article on the effects of heating amethyst (<https://www.nature.com/articles/s41598-020-71786-1>). So I buried four stones in the dry investment powder and set the kiln controller to 300°C, knowing that it would overshoot that mark. It reached 360°C, which was the initial temperature I was aiming for, and then I switched it off to cool overnight. The result was that all four stones lightened slightly. Three stones suffered no damage, while the larger oval developed visible internal cracks that were not present originally. But they were still rather dark, so they were heated again to 385°C. The additional 25°C made a bigger difference. Interestingly, all the stones did not lighten to the same degree. Even different portions within some individual stones responded differently.

My conclusion from reading about heat treatment of gemstones online and this brief experiment is that it is a somewhat hit-and-miss business with a substantial failure rate. The advice of experienced heat treaters is that even gem stones from the same source may respond differently to heating, with rather unpredictable outcomes. I have satisfied my curiosity, and don't plan on doing any more gemstone heat treatment for now.



Amethyst before heating



Amethyst after heating to 360°C



Amethyst after heating to 385°C

FACETING THE SOFTIES



These are rhodochrosite, presumably from Hotazel. The 'pink' stones (above) are 0,65 ct; 0,68 ct; 1,46 ct; and 0,96 ct. The 'red' stones (below) are 1,39 ct; 1,66 ct; and 1,71 ct. The rough was acquired more than twenty years ago as a small batch of broken and half-finished stones. A recent article about faceted rhodochrosite in *The Journal of Gemmology* inspired me to try to resurrect them. Dopping was not problematic, using low-temperature green jeweller's wax. Cutting the facets I did on a copper lap with 3000 mesh diamond. Polishing was on a speciality lap from Gearloose.co with 100 000 diamond, and lots of trial and error to find an effective combination of diamond paste, lubricant, rotational speed and direction. Rhodochrosite has three directions of perfect cleavage, so each facet became its own adventure to avoid pitting, chipping and scratching. Some residual scratches remain because trying to polish them out simply made them worse.

Having faceted several of the gemstones 5 and below in hardness –apatite, barite, cerussite, cuprite, fluorite, rhodochrosite – I can offer some general advice about how to deal with these often troublesome materials. The essential thing is to avoid any thermal shock. This requires a modified dopping technique, and often extra care when polishing.

First study the rough carefully to identify the cleavage planes and plan the cutting to avoid all of these if possible. Then, using a 1200 mesh lap, by hand grind a flat where you want to place the table facet. Clean the stone thoroughly and stick the pavilion-to-be to a dop with Prestik (or ‘blutack’ or dental wax). Select a suitable flat dop, heat it, and apply a layer of wax to the face. Build this up to an even layer at least 3 mm thick, and while it is soft flatten it against another flat face dop in a transfer fixture. Remove it from the transfer fixture and set it aside to cool thoroughly, replacing it with the dop holding the stone. Orientate the stone appropriately and press the table-to-be against the initial flat dop to position the stone for dopping. Replace this flat dop with the one with the wax layer. Coat the wax surface with your glue of choice, either superglue or epoxy, and slide the dops towards each other so that the table-to-be seats firmly against the flat wax surface. Let the glue set and then facet and polish the pavilion.

Transfer dopping can be done in one of two ways. The more risky way is to prepare a suitable pavilion dop with plenty of dopping wax and allowing it to cool until it just takes an indentation using a fingernail. In the transfer fixture slide the stone into the just pliable wax and quickly out again, to create an impression of the pavilion. When the wax has cooled completely you can glue the pavilion into the impression with the glue of your choice. After the glue has set, wrap the stone and the new dop in a strip of water-dampened paper towel. Hold the stone with your fingers – it must not get hot – and heat the first dop until you can just twist it off the initial wax layer, leaving the wax on the stone. Your transfer is done.

The less risky way is to have a set of anti-dops at hand (Figure 1), as described by Tom Herbst in his *Amateur Gemstone Faceting*. Select one with a shape that approximates the pavilion and using it in a transfer fixture make an impression in hot wax in a suitable pavilion dop. After the dop has cooled, replace the anti-dop with the one holding the stone, and glue the stone in place. For this, epoxy is preferable to using superglue, because there will be some mismatch between stone and wax with gaps that need to be filled. (I suppose you could use a gap-filling epoxy, but I don't have any.) After the glue has set, wrap the stone and the new dop in a strip of water-dampened paper towel. Hold the stone with your fingers – it must not get hot – and heat the first dop until you can just twist it off the initial wax layer, leaving the wax on the stone. Your transfer is done.

With either transfer technique, after transfer DO NOT use a hot blade to remove the excess wax adhering to the crown-to-be of the stone. The hot blade will destroy your stone (Figure 2). Grind off the wax carefully on a 600 mesh lap, leaving just a thin film to avoid damaging the stone. When dopping or transfer dopping with superglue, it helps to coat the join with clear nail varnish, to protect the superglue join from softening in water, especially with smaller stones.

Initial facet cutting of soft stones I usually do on a 1200 mesh sintered bronze lap, with fine cutting with 8000 mesh diamond paste on a copper lap or a tin alloy lap, like BATT™. Some stones behave better on the softer tin alloy lap. You need to experiment. Polishing also calls for experimentation with different lap and polishing medium combinations. I have settled only two laps – a wax lap and a LIGHTSIDE™ lap from Gearloose (<https://gearloose.co/>). On the wax lap one uses water and oxide

pastes, either tin oxide or aluminium oxide, whichever works. It does round the facet edges somewhat, which is more noticeable on smaller stones than larger ones. I have found it essential if a facet needs to be polished close to a cleavage plane. Most soft stones will polish easily on a Gearloose LIGHTSIDE™ lap, using 100 000 mesh diamond paste and an oily lubricant. I use WD40. The lap is just damp, with very little diamond paste, and wiped almost dry. Polishing is at slow speed, with just enough pressure to create some drag. Too much lubricant and the stone will just slide on the surface. Too much diamond paste and the stone will scratch. If a facet scratches persistently, reverse the lap direction. Inspect the stone after each 5 or 6 sweeps of the lap, and beware of any heat build-up, which may open up cleavages.

There is no single solution to the difficulties encountered in polishing soft stones. It takes patience, and trial and error to discover just the right touch to produce a good polish. When the crown has been completed, heat the dop just sufficiently to release the wax. Do not try to remove the wax adhering to the stone, but soak it in alcohol overnight to dissolve the wax, and then in acetone to dissolve any remaining glue.



Figure 1. Anti-dops for cones, keels and trilliant pavilions



Figure 2. A 20 × 10 mm barite from Brukkaros in Namibia, with cleavage fractures caused by using a hot blade to remove excess wax after transfer – a not-to-be repeated mistake.

WHO CUT THAT STONE, OR WHAT IS A GEM CUTTER WORTH?

The photograph below is of a magnificent 164,11 ct spodumene (variety kunzite) in the collection of the Smithsonian Institution, USA (<https://geogallery.si.edu/10002906/spodumene-var-kunzite>).



The accompanying text credits the mine at which it was found (in 2010 at the Oceanview Mine in Pala, California), the funds with which it was acquired (Tiffany & Co. Foundation endowment in 2012), and the photographer (Greg Polley). So who cut this stone? This is like acknowledging the art gallery, the picture framer, and the photographer of an artwork, but not mentioning the artist. It is a very odd situation. Why is this?

Traditionally, gem cutting was a backroom job done by semi-skilled or even skilled workmen and given no more credit than the jobbing artisan goldsmith working for a jewellery emporium. With the advent of precision faceting this really needs to change. The precision faceter no longer churns out coloured jub-jubs with a semi-random patchwork of facets, but works of art that maximise the optical properties of a particular piece of gem rough. This is a highly skilled enterprise, requiring a detailed knowledge of crystallography and familiarity with the other physical properties of gem crystals, laboriously acquired manual dexterity, and often an investment in expensive machinery and consumables. The precision gem cutter is an artist, and the cutter's name should form part of the pedigree of the stone.

But for this to happen, there would need to be significant changes in the gem industry. Laser engraving a signature on the finished girdle can 'sign' a stone to be recorded on grading reports, hopefully enhancing the value. New blockchain technology recently proposed for tracking gemstones from source to consumer (Cartier, L., Ali, S.H. & Krzemnicki, M.S. 2018. Blockchain, chain of custody and trace elements: an overview of tracking and traceability opportunities in the gem industry. *The Journal of Gemmology* **36**: 212–27.) could include a record of the cutter. But self-promotion through publishing photographs of one's gems, participating in online discussion groups, winning competitions, and maintaining a good website probably remain the most effective ways for gem cutters to achieve recognition for their skills.

This prompts the question 'What is a gem cutter's skill worth'. Obviously this will vary with location but it is fun to make some comparisons. In Cape Town a plumber or electrician may charge around R500 per hour for labour. An experienced copy editor may charge a similar fee. A piano tuner charges R1000 (and the piano doesn't stay in tune for ever). Very few cutters can produce a precision-cut stone in an hour. A standard round brilliant in something easy would take me at least two hours. I set aside at least a day to cut a medium-sized, high value gemstone, say a 2,5 ct emerald. Some stones have taken me several days, including the planning, cutting, and communication with the customer.

An informal survey done in 2015 showed that some precision cutters in the USA charged \$100/hour. A well-known Canadian repair cutter charged the equivalent of R1 800 to R3 500 for a full recut. A Durban cutter was charging R900 to R1 800 to facet a medium-sized stone from rough. An established commercial cutter in Cape Town charged around R500 per 1–2 ct stone. My faceting rates have ranged from R800 to R3 000 per stone, depending on size, final value, and difficulty. Compared to US\$100/hour these prices are low!

DISTINGUISHING RUBY FROM GARNET AND RED GLASS USING FLUORESCENCE

Cut rubies, red garnets and red glass can look very similar. There are several techniques that can be used to determine if a red stone is a ruby. These include a semi-destructive relative hardness test (ruby will scratch garnet and glass, but not the other way around); using a polariscope to test for birefringence (ruby is birefringent whereas glass and most garnet is not); and using a dichroscope to see the two pleochroic shades of red in ruby (which are absent in garnet and glass). Microscopic examination may show round bubbles and swirl marks in glass, or inclusions characteristic of ruby and garnet, although often these look very similar.

A simple optical test that depends on the fluorescence of ruby is the so-called 'crossed filters test'. This was described as a gemmological technique in 1953 by Anderson, but it was first demonstrated a hundred years earlier by Stokes (Webster, R. 1994. *Gems*: 82, 850-1. Oxford: Elsevier.). It involves passing white light through a blue filter that passes only blue light, and illuminating a ruby only with that blue light. The ruby will reflect some of the blue light, but also will absorb some and emit red light by fluorescence. If the ruby is viewed through a red filter that removes all the reflected blue light it will appear to glow red. Indeed, this happens in daylight anyway, which is why good rubies exhibit a true glow due to their absorbing blue wavelengths of light and emitting visible red light by fluorescence.

Distinguishing red fluorescent ruby from other non-fluorescent red stones simply involves viewing the stones together under 'crossed filters' and seeing which appear to glow red. A dramatic demonstration of this involves shining the light from a slide projector through a round-bottomed flask of concentrated copper sulphate solution. The flask acts as a lens to focus a beam of blue light onto the stones. If this is done in the dark, garnet appears black, while ruby glows red. A simpler set-up consists of a small cardboard box – I used an old card file box – with a blue camera lens filter set in the hinged top and a red lens filter mounted in one side as a viewing port. The stones to be tested are placed inside the box on a black background and a strong light shone through the blue filter on top. Viewed through the red filter in the side, rubies glow red while the other stones appear black. It can be illuminated easily with a small torch, and is more portable than lugging around an old slide projector and a flask of copper sulphate solution!



Figure 1: The small filing box is fitted with a blue filter in the opened lid and a red filter in the side.



Figure 2: The three red unknown stones are placed on black paper inside the opened box.



Figure 3: The closed box, with the three red stones inside, is illuminated by a torch from above, through the blue filter.

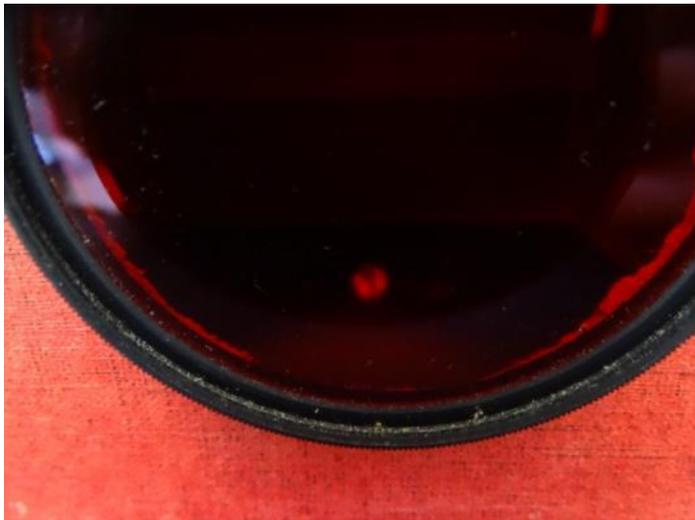


Figure 4: The three stones, illuminated with blue light through the blue filter in the lid, are viewed through the red filter mounted in the side of the box. Only the central stone is visible, fluorescing bright red. This is a synthetic ruby. The two stones flanking it are red glass and a garnet. They don't fluoresce, so in blue light they appear black through the red filter.

A GEM CUTTER'S JUNK BOX

After several years, or after many years, a gem cutter lands up with a junk box. Mine contains disappointing stones abandoned in disgust and partly-worked stones that came over the years with various faceting machines and batches of rough. As a lock-down project I decided to see what I could make from the contents of the faceting junk box. (There are another two – one with cabochons and another with broken synthetics. You never know, you know...)

To make it something of a challenge and not just house-keeping, I decided to try to cut as many as possible into 6,5 mm diameter brilliants. That worked for seven stones. Another five turned out a little smaller, 6 to 5,5 mm. One partly-worked purple-pink tourmaline obviously would not make a round, so it became a 13 mm long simple step cut stone. Now the faceting junk box contains only some really hopeless amethyst cast-offs and almost colourless quartz stones that must have been cut by someone learning to facet in the dark.

All of the finished stones have their problems. After all, that is why they landed up in the junk box in the first place. Some of the garnets are too dark to be pretty. Most of them contain some visible inclusions if you look carefully. One stone that I thought could be a demantoid garnet turned out to be a tourmaline. And the pale blue topaz (that looks white in the photograph) had been orientated originally with the table parallel to the cleavage. So I had to polish that. It took a while. A long while; on a slowly turning wax lap with Linde A. After a few hours the table, all of 3,5 mm wide, was acceptable, with just a few remaining pits from the cutting lap visible with a loupe in oblique lighting. I would not do this again, but it proves it is possible.

What will I do with them? The same as my other stones – put them in a box and wait for the future.



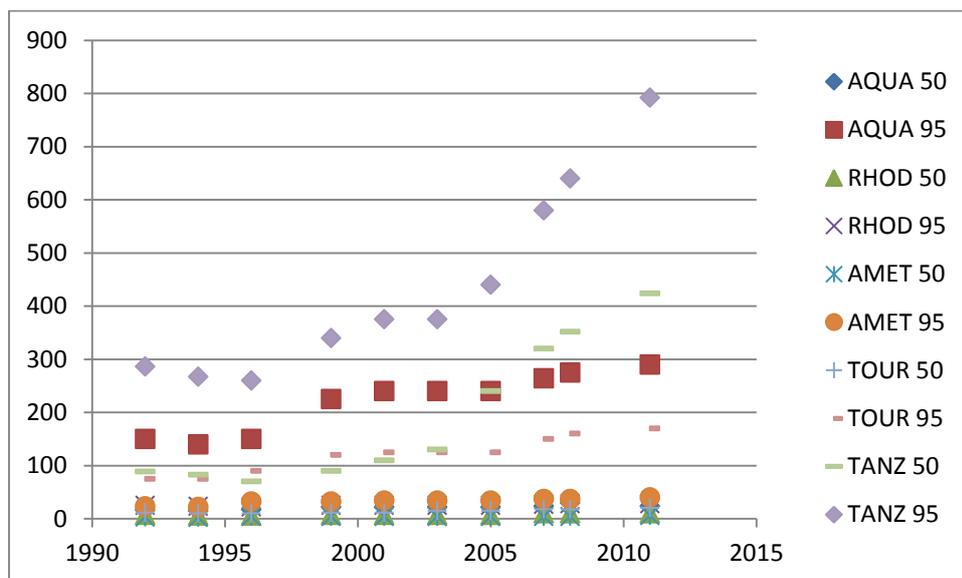
Top row, left to right: amethyst, garnet, tourmaline, peridot, citrine, topaz, amethyst

Bottom row, left to right: amethyst, garnet, aquamarine, garnet, tourmaline, tourmaline

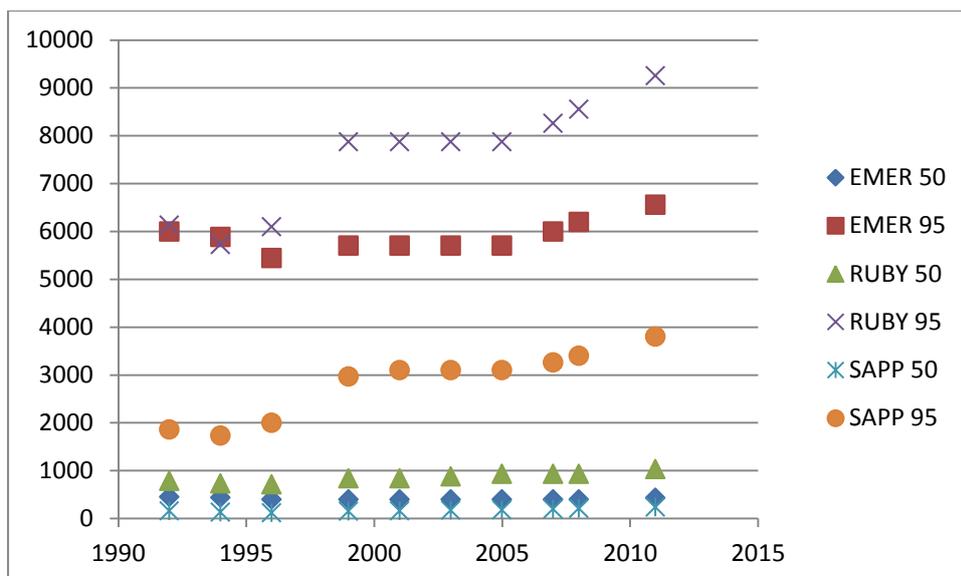
ARE COLOURED GEMSTONES A GOOD INVESTMENT?

The recent turmoil in global financial markets has many people wondering what asset classes make for good long-term investments. This set me wondering how coloured gemstones perform. For the past nineteen years I have acquired intermittently the South African Independent Coloured Stones Price Guide, published by Ian Campbell. This gives the recommended trade prices for various gemstones, on a grade scale from 5 to 95 on the basis of an explicit set of quality characteristics. The prices are in US dollars, although for the South African market. These are the recommended prices for a dealer selling to a retailer, not the prices a retail customer would pay. (Retail mark up can be anything from 1,3 to 2,6 times or more, with the more expensive stones being marked up less.)

I selected two sets of gemstones for comparison. The one set is the lower value stones; aquamarine, rhodolite garnet, amethyst, green tourmaline and tanzanite. The other set is the traditionally higher value stones; emerald, ruby and blue sapphire. For each set I compared the recommended trade prices for 1 ct stones, with grades of 50 and 95, although grade 95 stones are very rare. The results are in the following two graphs.



Graph 1 South African trade prices in US dollars from 1992-2011 for 1 ct stones of 50 and 95 grades in aquamarine, rhodolite garnet, amethyst, green tourmaline and tanzanite



Graph 2 South African trade prices in US dollars from 1992-2011 for 1 ct stones of 50 and 95 grades in emerald, ruby, and sapphire

From Graph 1 it is clear that the lower grade gemstones, with low prices to start with, did not appreciate much in dollar terms over nearly 20 years. (They are all huddled on the bottom of the graph.) The best quality green tourmaline appreciated by around 220%, just beating the more expensive top quality aquamarine, which doubled in value. Top quality tanzanite increased by 280%.

Graph 2 shows that the medium quality emerald, ruby, sapphire and tanzanite also did nothing dramatic, with emeralds not appreciating at all until recent years. Top quality ruby increased in value by 150%; top quality blue sapphire appreciated by 200%. It is surprising that even larger stones did not appreciate significantly more. For instance, a top quality 4 carat blue sapphire may have been valued at \$4 600/ct in 1992, and at \$9 500/ct in 2011, just over double. Ruby, sapphire and emerald have always commanded the highest prices, but comparing the two graphs shows that good quality aquamarine, green tourmaline and tanzanite actually appreciated somewhat more in percentage terms over the past two decades. Tanzanite is a special case, because of customer response since 2004 to the tremendous marketing drive led by Tanzanite One. In US dollar terms none of these are dramatic increases in value, but one must remember that in 1992 the exchange rate was R2,8/\$ and in late 2011 it was R8/\$. So in rand terms all these stones have become much more expensive.

So, are coloured gemstones a good investment? In dollar terms, the value of top quality one carat stones seems more or less to have doubled over the past twenty years. Good quality tanzanite has more than trebled, but most of the increase has been fairly recent and in response to vigorous marketing, which makes it a special case. I am not an investment adviser, but a doubling in dollar value over twenty years does not sound very attractive to me. Most of the apparent growth in rand

terms would have been due to devaluation of the rand against the dollar. If you bought the stone from a retailer, there may have been a substantial mark up in the first place, increasing the initial cost over the trade value, and then when you want to sell the stone, the real snag is finding a buyer!

While good quality stones, and particularly the more durable, expensive ones like rubies and sapphires do not lose value, they don't seem to perform well as financial 'investments'. Rather they should be seen as emotional investments – investment in their romance, their rarity, their beauty, and the pleasure they give their owners.

THE MANY COLOURS OF QUARTZ

The Journal of Gemmology (2012, Vol. 33, Nos 1/4) has an excellent article by Ulrich Henn and Rainer Schultz-Güttler called 'Review of some current coloured quartz varieties'. For those who don't have access to this journal, published by the Gemmological Association of Great Britain, this is a short summary to help you distinguish the different varieties.

We all know that quartz occurs naturally in various colours with varietal names – colourless rock crystal, yellow citrine, purple amethyst, pink rose quartz, brown smoky quartz, black morion, and the rare natural green prasiolite. Some of these colours can be produced artificially by radiation, sometimes coupled with heating. Artificial heating can also lighten some dark coloured quartz. Given the variations in natural quartz and their different reactions to irradiation and heating, a correspondingly wide range of artificial colours can be produced.

Most colourless natural quartz contains chemical impurities, even if these do not produce visible colour. They are mainly iron, in Fe-bearing quartz, and aluminium, in Al-bearing quartz. Natural or artificial irradiation with subsequent heating causes different colours in these two different quartz varieties.

First let's consider Fe-bearing quartz. Naturally occurring clear Fe-bearing quartz crystals can experience low-level gamma irradiation from radioactive minerals in the surrounding rock. Over long periods of geological time this produces a change in the bonding of the iron impurity atoms, which results in the violet or purple colour of amethyst. Heating most amethyst to about 450°C causes it to bleach to colourless or pale yellow. Continued heating causes precipitation of iron oxide particles, which causes a deeper yellow. Most citrine on the gemstone market is such heat-treated amethyst. Because the colour is caused by uniformly dispersed iron oxide particles, this citrine is not pleochroic, that is, it does not show different intensities of colour when viewed in different crystallographic directions. Heat treated amethyst usually shows evidence of Brazil law twinning, often with colour zoning.

Some amethyst, when heated, turns green. Natural prasiolite is very rare and probably results from natural heating of amethyst. Most prasiolite on the gemstone market is artificially heated amethyst. This colour is produced by another change in the bonding of the impurity iron atoms, rather than by the precipitation of iron oxides. This material comes from only a few sources, mainly the Montezuma mine in Minas Gerais, Brazil.

Prasiolite itself can be subjected to artificial gamma irradiation and subsequent heat treatment to produce so-called 'blueberry quartz'. This is a deep violet blue and resembles tanzanite.

Heating amethyst above 500°C not only bleaches it but can produce a milkiness, resulting in so-called 'neon quartz'. This looks like lilac-coloured rose quartz. Stronger heating bleaches out the lilac colour completely and tiny water droplets form in the quartz. This material resembles adularescent gem materials and may be used as imitation moonstone.

Natural ametrine is bicolour quartz, purple and yellow, mainly from the Anahí mine in Bolivia. The colouring process is complicated. It involves differing concentrations of water in different growth sectors of the crystal and natural irradiation acting on the water to inhibit the formation of the purple colour in those sectors. Artificial heat treatment of ametrine to bleach the amethyst sectors can produce bicoloured citrine/colourless stones, sometimes marketed as 'Lunasol'.

So much for Fe-bearing quartz. What about Al-bearing quartz? Usually the concentrations of aluminium in quartz are much higher than iron. Low levels of natural irradiation of Al-bearing quartz produces natural coloured citrine – yellow, yellow-green to yellow-orange. The details of the production of colour with irradiation in Al-bearing quartz is not well understood, but with increased levels of gamma irradiation the colour darkens, producing smoky quartz, and eventually black morion. Obviously, these colours also can be produced artificially with gamma irradiation, as is the case with the black Arkansas quartz.

Al-bearing quartz can also contain lithium in significant quantities. If it is lithium-poor, morion can be bleached by heat treatment to produce smoky quartz (and presumably some yellowish smoky quartz could be bleached to citrine). If Al-bearing morion, either naturally or artificially produced, is also lithium-rich, then gentle heat treatment at below 280°C can produce yellowish-green 'lemon quartz'.

The distinctive characteristics of untreated and treated Al-bearing quartz are that if it is coloured it is pleochroic, and that it does not show evidence of Brazil law twinning. So naturally coloured citrine will show pleochroism from pale to intense yellow and no Brazil law twinning, while citrine produced by heat treatment of Fe-bearing amethyst will show no pleochroism but Brazil law twinning may be present. Lemon quartz produced by heat treatment of Al-bearing smoky quartz will show yellow to yellow-green pleochroism but no Brazil law twinning.

Other quartz varieties exist too. 'Greened amethyst' is produced by artificial gamma irradiation of pale amethyst containing a very high content of water, from southern Brazil. The resulting crystals can be a deep green, with a 'greasy' lustre. This green quartz shows red under the Chelsea Colour Filter, while Fe-bearing prasiolite shows green. Heating above 500°C produces a cloudy opalescence due to exsolved water in very fine droplets.

Common pink rose quartz, generally described as 'massive' although it is crystalline, is thought to owe its pink colour to tiny included crystals of pink dumortierite. The cloudy appearance is due to scattering of light from these tiny inclusions. (In some material these inclusions must be crystallographically orientated, because they can produce asterism.) The much less common rosettes of pink quartz, usually on a white quartz crystal matrix, are essentially different from massive rose quartz. These clusters of pink single crystals have colour attributed to aluminium and phosphorus. Gamma irradiation can intensify the colour of these rosettes of single crystals to a stronger purplish pink.

The tendency of coloured quartz varieties to change colour on heating means that jewellers need to take care to avoid heating stones when repairing jewellery set with any coloured variety of quartz.



An assortment of quartz gems cut by Jo Wicht

FACETING AND POLISHING QUARTZ

This is the first of an intended series of articles on faceting and polishing a variety of gemstones. I am beginning with quartz because that is what most people start faceting when they first take up the hobby. Quartz rough is inexpensive and readily available in a wide range of colours. It is not necessarily the easiest material to polish, but if a particular stone behaves badly it is no great loss to set it aside to be tackled at a later date. You should try to select rough that is free from cracks and veils. Smoky quartz rough should not be so dark that placed on white paper it looks black. Clean but slightly milky rose quartz can be faceted, usually with a pleasingly sleepy look. Colour in amethyst and citrine often is patchy or banded. In this case, orientate the stone so that any strong banding lies parallel to the table facet. A strongly coloured patch in an otherwise light stone should be positioned in the centre of the stone, although many references recommend you put it near the culet. A multitude of different minerals can be found as inclusions in quartz, and some of these can make very interesting gemstones.

If you are going to cut large quartz gems it makes sense to remove unwanted bulk on a capping grindstone or a coarse lap, around 100 mesh grit size. This will leave considerable damage that needs to be removed with subsequent grinding steps. Depending on the size of the stone you need to work your way up the scale, coarse faceting with 325 or 600 mesh, and fine faceting with 1200 or 3000 mesh. I used to go straight to polish from 1200 mesh, but now I pre-polish with 3000 or 8000 mesh diamond paste on copper. This makes polishing quicker and easier. Quartz polishes best with cerium oxide or zirconium oxide. I haven't found much difference between them. There are numerous lap alternatives for polishing quartz: UltraLaps; Corian; Lucite (Perspex); Darkside or Creamway from Gearloose Lapidaries; phenolic; old CDs, etc. I used to use a scored Lucite lap with cerium oxide mixed to a thin slurry but now I use Gearloose's Creamway lap with the zirconium oxide Battstik crayon.

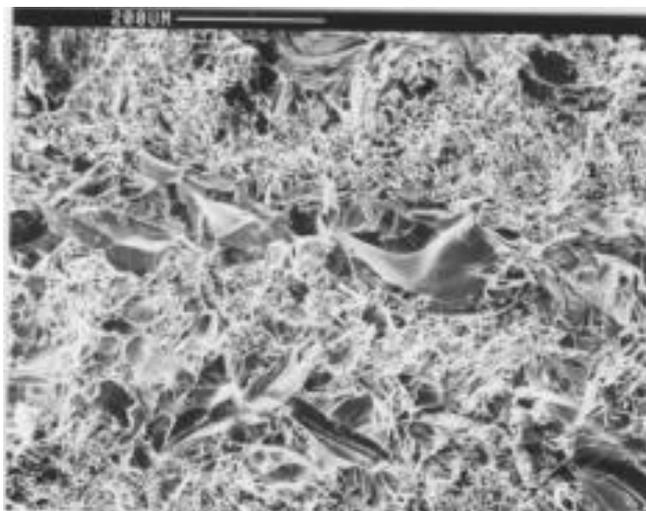
Deeply coloured quartz – amethyst, citrine, smoky – is pleochroic, so you may want to try to orientate your stone not only for colour banding and spots but also for the most desirable shade. Some intensely coloured amethyst, if orientated to take advantage of the blue-purple, can look almost like tanzanite. Bicoloured quartz, like ametrine, needs to be orientated in a suitably designed cut to allow separation of the colours, unless you deliberately want to mix the colours. Quartz has no strong cleavage, so apart from colour orientation you usually don't need to worry about the crystallography. Prolonged polishing sometimes produces geometric relief on facet surfaces, particularly with amethyst. It is most noticeable in oblique lighting. This is due to Brazil law twinning, with different twin elements having slightly different polishing hardness. The way to minimise this is to have a very good prepolish, preferably with 8000 mesh, so that polishing happens quickly.

Quartz is not particularly heat sensitive, so dopping with wax is my preference. Any hot stone can crack if the temperature changes suddenly, so avoid heating or cooling the stone too quickly. Polishing on some laps, like Lucite and phenolic, can heat the stone to the point of softening the wax and allowing the stone to shift on the dop. Be aware of this and keep the stone cool with damp paper towelling if necessary. Quartz is quite brittle, and pavilion keel facets need to be polished with the lap running parallel to the keel edge to avoid chipping. Apart from the problem of polishing out chips, you don't want a quartz chip to embed in your polishing lap. The residue from grinding can

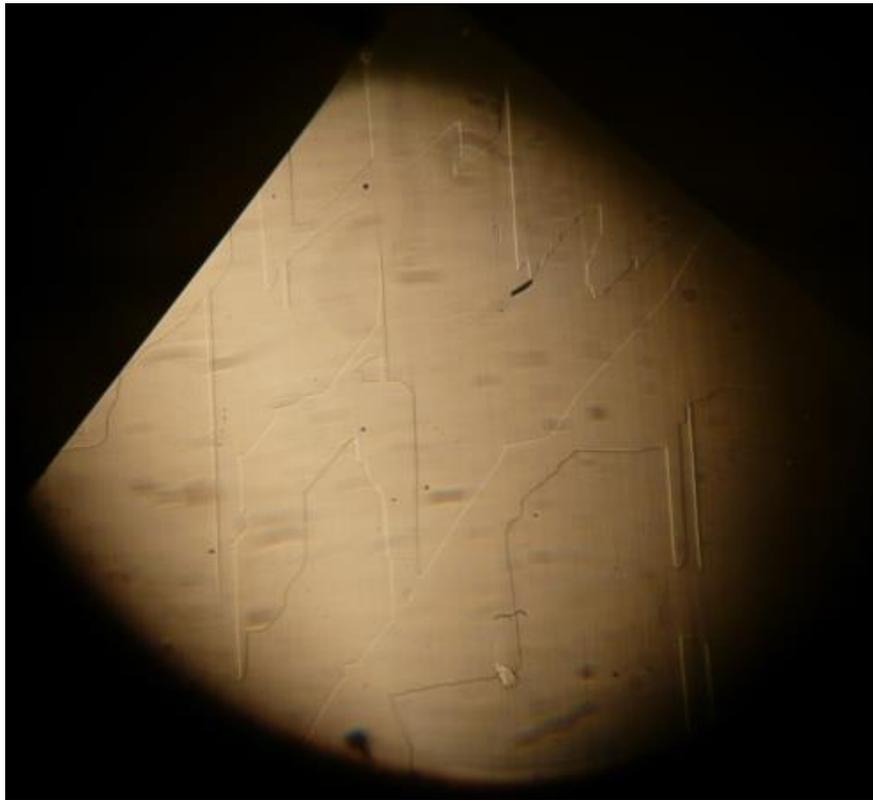
also foul faceting laps, so don't let your laps dry out with quartz powder on them. It will set hard and be difficult to remove. Wash each lap thoroughly immediately after use. If you following these guidelines you should have no difficulty faceting and polishing quartz.



110 ct natural citrine, Tripolar Brilliant



Typical damage in quartz caused by coarse diamond grinding, imaged in a scanning electron microscope (width of field of view about 1 mm)



Geometric polishing relief due to Brazil law twinning in quartz, viewed in oblique light

(This is a follow-up to the previous article on faceting quartz)

Every faceter knows quartz, those great big glassy-looking chunks that seem to cry out to be turned into doorknobs. Or pretty, golden 'citrine' that can cut brilliant yellow stones. Or glowing, dark purple amethyst with seductive blue flashes, dreamy rose quartz, or rutilated quartz with geometric golden blades. The range of possibilities is vast. The material is relatively inexpensive. What's not to like?

Quartz is not the easiest material to facet and often it is disheartening for the beginner, battling to get a good polish. But let's start at the beginning. If you are going to cut a lot of quartz you need a coarse lap to remove surplus material, or you need to grind preforms on a vertical wheel. A 320 mesh electrobonded topper works well and when it wears out you just throw it away and buy another. Or you can charge a copper lap with coarse diamond yourself, and replenish the charge as necessary. Quartz swarf tends to clog diamond laps, so clean them thoroughly after use. I collect chunks of pumice off the local beach and grind that with lots of running water. It cleans electrobonded and sintered bronze laps quickly and efficiently. Alternatively, scrub the lap under running water before the swarf has had time to dry out and set hard.

Selecting material usually is easy. Unless it has attractive inclusions, and they cover a wide spectrum of the mineralogical world, avoid material with cracks and veils. Although, if you are lucky, internal flaws can produce rainbow interference colours that enhance an otherwise plain stone. Different colours of rough present their own selection issues. Amethyst can be too dark, resulting in an almost black stone. But many of these respond to cautious heat treatment in a closed kiln, lightening significantly at about 450°C. Quartz from various different localities responds differently to treatment, either by heat and/or radiation, to produce a wide variety of colours not encountered naturally (see long discussion here: <https://www.mindat.org/forum.php?read,55,350011,350166#msg-350166>).

The problems in cutting facets are few. The only difficulty I have experienced has been with some rutilated quartz, in which a few of the straight needles actually slide back and forth from one side of the stone to the other, protruding further and further as you cut opposing facets. The solution was a drop of cyanoacrylate (super glue) at either end to hold the needles in place during fine grinding.

Polishing can be a different matter though, and many people struggle to get a good polish on quartz. As with all stones, a fine prepolish – 3000 mesh or 8000 mesh – is a pre-requisite. Cerium oxide and zirconium oxide are the oxides of choice for polishing quartz, using a very thin, water-based slurry. Polishing laps impregnated with these oxides are available. I have graduated from using a Lucite lap with cerium oxide to a Gearloose Creamway lap with zirconium oxide; and completely failed to be able to polish quartz with a Gearloose Darkside lap. Other people have no trouble with the Darkside. Some polish quartz with 60 000 mesh or 100 000 mesh diamond on soft metal laps like tin/lead or Batt, or on specially formulated polymer composite laps like Gearloose's Diamatrix. You use whatever works for you.

One of the vexing issues in polishing quartz is caused by Brazil twinning and is particularly evident in amethyst polished with oxides. This takes the form of geometric patterns of relief that appear on some facets, due to differential hardness in the twin lamellae. It is best avoided by ensuring that you have a very fine prepolish and don't need to polish for long, or to resort to diamond polishing.

CITRINE - THE QUEEN OF QUARTZ (AMETHYST IS THE KING)

Citrine is yellow quartz, not canary yellow “lemon” quartz, but a more brownish cognac yellow. Citrine grades into yellowish-brown smoky quartz and there is no sharp distinction between the two. Most natural citrine is a light yellow, producing very pale small gems, but gloriously coloured ones if they are large. The pale colour of most natural citrine has led to experiments to produce a darker material, and there is a lot of it around these days. Most dark citrine is produced by heating amethyst. If the amethyst originally contained Fe^{3+} it will produce a yellow colour on heating. (Fe^{2+} makes it green, called prasiolite.) The lighter citrine shown here, of 110,5 ct is natural material, with a bit of darker colour banding. The dark stone, of 21,7 ct is so-called “Congo citrine”, which I am assured is unheated but it looks suspiciously dark orange. Nevertheless, Webster (Gems, 5th edition, 2003) quotes Wild maintaining that heat treated citrine is virtually non-dichroic, while in unheated citrine the dichroism is quite strong. My “Congo citrine” is strongly dichroic, showing very distinctly different shades of golden yellow through the dichroscope, so perhaps it is unheated after all.

Cutting big quartz gems poses some problems, as quartz is not the easiest material to facet. (Clean aquamarine is.) First, you have a giant preform to deal with, which usually means access to a fairly coarse diamond grinding wheel or a long time spent wearing out a 260 grit lap. I have found that with care unwanted material can be shaved off the stone quickly by grinding on the very edge of a coarse lap, where the diamonds have not yet worn. This produces deep scratches though, which will have to be removed later. It also runs the risk of your stone catching on the edge of the lap, with various possible negative consequences; the worst being serious damage to your stone, your lap, your machine, or yourself. Any coarse grinding produces deep damage and this has to be removed anyway, so preforming and rough faceting takes a long time.

Dopping big stones needs big dops. If the dop head is not at least 50% of the width of your stone, the stone is very likely to come off during grinding or polishing because of the relatively high forces generated on large facets. I use wax for dopping so I heat a large stone slowly to avoid cracking it because of its size. I also make sure not to allow it to heat up on the lap, or the wax may soften and the stone shift on the dop - serious unhappiness ensues. You simply have to take your time at each stage of the process. It is a character-building exercise in patience. I grind in my main facets with a 260 grit Crystallite lap, redo all the facets with a 600 grit diamond impregnated bronze lap, and prepolish on a 1200 grit Crystallite lap. Only at this final stage do I fuss about getting meets to meet precisely, and even then some need to be nudged into meet when polishing. For large quartz stones I polish on Perspex (Lucite) with cerium oxide so that I can do this nudging into place. With big facets it might take some pressure, which tends to crumple a paper-thin Ultralap.

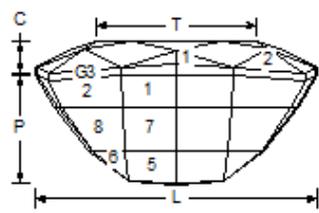
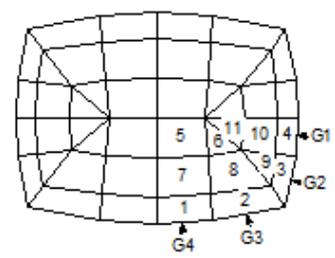
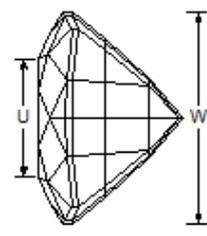
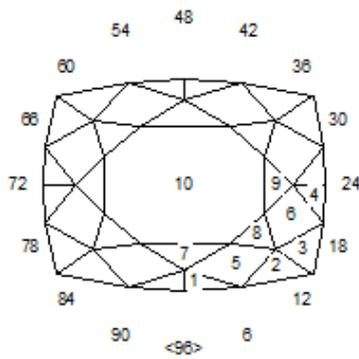
Don't be alarmed if you see sparks inside your stone when trim sawing. This is due to triboluminescence, as individual diamonds remove microscopic chips of quartz. While quartz is fairly tough you need to watch out for unwanted large chips when preforming. You also need to remove

all cracks and flaws early on or your work will be prolonged annoyingly later. If a large facet starts “glazing” when you are fine grinding, try changing direction so that the diamonds attack the quartz crystal lattice at a different angle. Polishing sometimes reveals the differential hardness of twinning in twinned quartz, which most is even if not visible in a piece of rough. This shows up as geometric islands on some facet surfaces, usually only readily visible in very oblique light, but irritating nevertheless. I haven’t found any way to avoid this, although it can be minimised by a good quality prepolish that reduces the necessary polishing time. Del Delpont encouraged me to try a Ceran lap to avoid this and the annoying hairline scratches that sometimes appear just as the polish approaches perfection, but I haven’t got around to experimenting with it yet.

With careful orientation of the rough the colour banding common to amethyst and citrine can be made to vanish, and with a properly designed cut and a good polish, you can make a large quartz gem look really spectacular. It is worth the time and effort, and quartz is the one material inexpensive enough to enable one to play around with producing really large stones.

Jewellers sometimes ask for the impossible, and it’s a challenge to try and oblige. This design was developed to cut the citrine for a dome-shaped ring. It had to be a ‘classical’ mixed cut with curved girdle lines to match the curve of the top of the ring. This design requires a preform to get the girdle facets the right size. The relative depth of the pavilion tiers affects the angles of the triangular corner facets, but these can be tweaked to reach the meets.





Mixed cut cushion

with curved girdle
 Duncan Miller
 18 May 2008, modified 12 June 2018
 Angles for R.I. = 1.540
 77 + 16 girdles = 93 facets
 2-fold, mirror-image symmetry
 96 index
 $L/W = 1.318$ $T/W = 0.752$ $U/W = 0.558$
 $P/W = 0.516$ $C/W = 0.155$
 $Vol./W^3 = 0.409$

PREFORM

PF1	45.00°	01-47-49-95
PF2	43.55°	03-45-51-93
PF3	36.71°	21-27-69-75
PF4	37.19°	23-25-71-73
G1	90.00°	23-25-71-73
G2	90.00°	21-27-69-75
G3	90.00°	03-45-51-93
G4	90.00°	01-47-49-95

CROWN

1	33.46°	02-46-50-94	Leave enough girdle
2	35.53°	05-43-53-91	
3	30.07°	18-30-66-78	
4	26.23°	22-26-70-74	
5	30.00°	03-45-51-93	
6	24.93°	21-27-69-75	
7	20.67°	96-48	
8	13.64°	11-37-59-85	
9	19.94°	24-72	
10	0.00°	Table	

PAVILION

1	51.40°	01-47-49-95	
2	51.43°	02-46-50-94	
3	59.52°	22-26-70-74	
4	59.53°	23-25-71-73	
5	39.19°	01-47-49-95	Cut to half depth of 1
6	39.19°	02-46-50-94	
7	48.03°	01-47-49-95	Cut to half depth of 5
8	48.06°	02-46-50-94	
9	52.05°	22-26-70-74	Adjust angle to meet
10	52.00°	23-25-71-73	
11	37.63°	23-25-71-73	Adjust angle to meet

Designed with curved girdle lines to match domed crown of a ring. Originally cut in citrine, but performs better in corundum, with about 70% face-up light return.

C:\Users\Duncan\Documents\GemCad designs\Favourites\Mixed cut cushion.gem

WORKING WITH DIAMOND

No, this is not about polishing diamonds, which in South Africa is illegal without a license, but about working with diamond grit or paste. For the coloured stone gem cutter, diamond paste is easier to source and to use. Loose grit and pastes are available in a range of mesh sizes, with crushed natural diamond or synthetic diamond. Synthetic diamond is made as single crystals and polycrystalline aggregates. The polycrystalline diamond breaks down with use to produce finer particles. Single crystal diamond is used for grinding, pre-polishing and polishing. Polycrystalline diamond is more suitable for pre-polishing and polishing. Pastes are available in both water-soluble and oil-soluble formulations, and recently in dual formulations that are compatible with either water or oil. For a bewildering array of available alternatives visit the Gearloose Lapidary website (www.gearloose.co).

Diamond grit sizes are measured in mesh or in microns. Mesh is supposed to indicate the number of holes per inch in a sieve, and common sizes run from 100 mesh to 100 000 mesh. The higher the mesh number, the finer the diamond. There are corresponding micron sizes, which are supposed to indicate the mean (average) particle size measured in thousandths of a millimetre. The lower the micron number, the finer the diamond. Both scales actually involve a range of sizes around a mean. Some products have a narrower range than others, although it is difficult or impossible to get details of this from the producers.

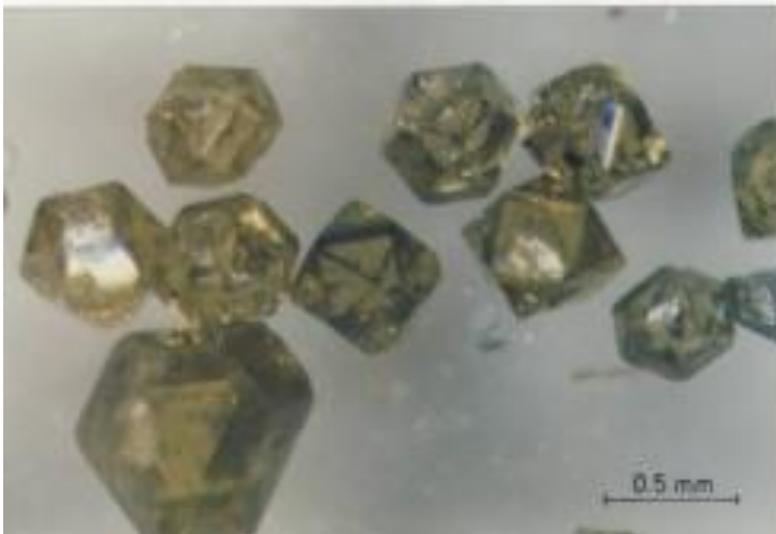
Diamond grinding grit or paste needs to be added to metal laps. Of course, with electrobonded laps and sintered bronze laps, the diamonds are permanently bonded to them or impregnated in them. Loose grit or paste can be applied to tin/lead, Batt, zinc or copper laps for facet grinding and pre-polishing. Typical grit sizes are 325 mesh for coarse grinding, 600 mesh for large facet cutting, 1200 mesh for fine faceting, 3000 mesh or 8000 mesh for pre-polishing. For pre-polishing 3000 mesh is preferable on the softer metal laps, because the diamonds embed further, and 8000 mesh on the harder zinc or copper laps. The coarse grinding grits or pastes need to be spread evenly on the lap using an appropriate extender – oil-based or water – and forced into the metal with a roller, a ball bearing on a stick or screwdriver handle, or a flat face on a hard mineral like synthetic corundum. After the diamond has been forced into the lap, wash the lap thoroughly to remove loose particles. Then cut the facets using water as a lubricant. When charging a series of laps, work from the finest to the coarsest, so you don't risk contamination, and you don't have to wash your hands between each lap. When laps become dull, simply recharge them again to keep the grinding action constant. You do need to develop your own charging technique to avoid contamination and a mess. There are several good videos on YouTube demonstrating the process.

The finer mesh size used for pre-polishing doesn't need to be forced into the lap, and applying it to the lap with a clean fingertip is sufficient, before you simply start pre-polishing; or you can work it into the lap first with a dedicated stone if you wish. Loose grit will need some lubricant, while pastes usually lubricate themselves. When black swarf builds up on the pre-polish lap, clean it off with a piece of paper towel dampened with methylated spirits, or water or WD-40, depending on what type of paste you are using. Use the grit or paste sparingly. A little goes a long way.

Diamond polishing is necessary when faceting hard stones like sapphire and chrysoberyl. Some people use it for softer stones as well, although for those I prefer an oxide polish. Suitable polishing

laps to use with diamond include cast iron, tin/lead, Batt, BA5T and Diamatrix (the last three available from Gearloose Lapidary). First you dampen the lap with the appropriate lubricant, then add a tiny amount of 50 000 mesh or 100 000 mesh diamond paste, and polish. I use a clean fingertip to apply the paste to the slowly spinning lap, and polish at low speed. Scratching usually means you have applied too much diamond or not cleaned off accumulated swarf. Water-based paste make it easier to clean the facet for inspection, but oil-based paste seems to work better with troublesome facets. I use Gearloose's BA5T to polish sapphire but members of the GemologyOnline lapidary forum (<http://www.gemologyonline.com/Forum/phpBB2/viewforum.php?f=8>) sing the praises of the Diamatrix ceramic composite lap.

Grit size	Size range(micron)	Grade number (micron)
230	54–80	60
600	22–36	30
1200	12–22	15
1800	8–12	9
3000	4–8	6
8000	2–4	3
14 000	0–2	1
50 000	0–1	½
100 000	0–¼	less than ¼



Very coarse, blocky, single crystal synthetic diamond grit



Diamond paste, copper lap and dedicated roller to charge the lap with coarse mesh diamond

THE MECHANISM OF DIAMOND GRINDING

[This article was first published in The United States Faceters Guild Newsletter, Volume 23 Number 1, March 2013, and was reproduced with permission in Mineral Chatter, October 2022.]

Many years ago Dr Stephen Attaway published an important article in *the New Mexico Faceter*. In it he described Dr Scott Wilson's research into sub-surface grinding damage in manufacturing mirrors. Dr Wilson and his colleagues found that cracks could extend below the surface by between four to ten times the diameter of the abrasive grit used. Presumably this research was conducted on glass, although the article does not say so. Dr Attaway published a table, reproduced often since, showing the relationship between grit size and the range of subsurface damage that can be expected. He emphasised that to obtain a well polished final surface, the damage produced by each previous grinding step has to be removed by each successive step. If this is not done, subsurface damage will become evident later on in the polishing process. I like to think of this as 'Attaway's Rule'. Recent discussion on GemologyOnline has included criticism of Attaway's Rule, on the grounds that what occurs in glass, which is largely amorphous, may not occur in crystalline materials. The purpose of this article is to present photographic evidence of the extent of diamond grinding damage in a variety of single crystal materials, analogous to the gemstones we facet, and to describe the mechanism of material removal, in defence of Attaway's Rule.

It is nearly impossible to view the interaction between diamonds on the surface of a grinding tool like a lap and the workpiece, in our case a single crystal material. I have tried, using a high-speed camera to take a movie of a diamond impregnated bronze drill bit drilling into a block of synthetic single crystal quartz polished on one side, in an attempt to capture an image of the crack front propagating into the quartz. For various reasons this was not successful and I had to resort to photographing the damage from above, after the fact.

Before considering what a sliding diamond does, let's look at what a stationary diamond under load does to a crystalline material. To make actual measurements of the pressure, I used fairly large single crystals of synthetic diamond with a cubo-octahedral shape (Figure 1). Under a microscope I measured the area of selected cube faces on three different crystals and then placed them between the polished faces of synthetic single crystal corundum anvils in a compression testing machine. (My faceting machine came in handy for polishing the anvils.) The real intention was to determine the pressure at which the diamond crystals fractured. It was around 4.44 GPa. But an interesting consequence was the damage caused in the synthetic corundum (Figure 2). You can see some straight cracks, caused by crystalline slip or cleavage, and some ring cracks. These penetrate into the material in widening cones, or Hertzian fractures. Such expanding cone fractures are also produced under dynamic impact in brittle materials, as when a bullet hits a thick sheet of glass. (In the mountain rivers near Cape Town where I live, the hard quartzite boulders are covered with circular

scars where such ring cracks caused by tumbling impact have been exposed to various depths by abrasive erosion of the rock surface.)

Now think about a single diamond, under load but not sufficient to cause failure of the diamond, being dragged across a crystalline surface. A 'bow wave' of compression exists in front of and underneath the diamond, and a 'wake' of tension follows the passage of the diamond. If the stress in the surface is sufficient, then cracks form to release the tension in the crystal lattice, causing a succession of cleavage cracks and ring cracks, intersecting each other. Multiple diamonds under load will cause overlapping tracks of damage, consisting of successions of cracks and excavation of previously loosened material. In brittle solids this fracturing and excavation is the main mechanism of material removal by abrasion, rather than grooving caused by plastic deformation (like metal being scraped with a sharp object).

For abrasion tests I used 40/50 mesh synthetic cubo-octahedral diamond crystals in a sintered bronze matrix in specially made 20 mm diameter drill bits. These I drilled into a variety of materials to study the interaction of the diamonds with various rock types. But I also drilled into blocks of three single crystal materials – synthetic quartz, natural calcite, and amazonite feldspar. The scanning electron micrographs in Figures 3 to 5 show the typical tracks made in these three materials, all at approximately the same magnification. The fracture in quartz consists mostly of conchoidal fracture from interacting cone cracks. The fracture in feldspar shows large-scale spalling due to cleavage between individual diamond tracks, which show finer fracture. The track in calcite shows clear cleavage fracture, as well as some plastic grooving by the diamond tips.

So, what does this have to do with faceting? Although we cannot see into the material, it is clear in all three cases that in diamond grinding extensive brittle fracturing takes place. The extent of fracturing varies with the material. Where cleavage is insignificant, as in quartz, Hertzian fracture predominates. The fracture mechanism observed in studies on glass appears to be similar to those in gem materials with weak or no cleavage. In materials with easy cleavage, cleavage fracture produces even more extensive damage than in quartz, under similar abrasive conditions, i.e. diamond size, load, speed, etc. Although the extent of subsurface damage was not quantified in these tests, the photographic results show that it can be expected to be of the same order of magnitude as in tests on glass, and in some cases even worse.

Figure 6 shows details of a single diamond track in quartz, at two different magnifications. This shows how angular particles of quartz can be released by intersecting fractures, or loosened sufficiently to be excavated by successive passes of diamond. We can expect that a more uniformly fractured surface would be obtained when faceting, because of sweeping the lap so that individual diamonds don't repeatedly travel in the same 'groove'. Nevertheless, the general extent of damage would be similar, and all of it needs to be removed at each successive grinding stage. If this is not achieved, then intersecting deep fractures can release angular particles later on, producing pits and

scratches to frustrate the polishing process. I think if you keep Figure 6 in mind while facet grinding, you will be constantly reminded of the necessity of following Attaway's Rule.

So far we have been concerned only with 'coarse' diamond grinding. How coarse is coarse? This is a difficult question to answer, but as one moves to finer diamond grits different mechanisms seem to take place. Many faceters will be familiar with the effect of 'glazing' or partial facet polishing when grinding with 1200 mesh diamond. This seems to be the point at which material removal by brittle fracture starts to be overtaken by the poorly understood mechanisms of polishing. Traditionally diamond polishing has been seen simply as successively finer grinding until the scratches are sufficiently fine not to interact with visible light. The phenomenon of glazing shows this cannot be the case with many gemstones. I have experienced it with not only corundum, where it is encountered frequently, but also in tourmaline and even beryl.

Figure 7 shows a scanning electron micrograph of the junction between a glazed area and unglazed area on a facet cut in synthetic single crystal corundum with a 1200 mesh diamond sintered bronze faceting lap. The crystallographic orientation of the surface is the same on both sides of the junction but on the left the diamonds have caused fracture and on the right they have produced a smoother surface. This glazing phenomenon has several characteristics that beg explanation. 1) It occurs mainly with 'finer' diamond laps. 2) It seems to be more prevalent on faces of some particular crystallographic direction than on others. 3) It doesn't necessarily extend over a whole facet (as shown by Figure 7). 4) It slows down or even stops the grinding process. 5) Sometimes it can be removed by increasing the load, i.e. pressure per diamond. 6) When a previously polished area is removed by grinding the exposed surface beneath seems to be more coarsely fractured than one would expect with that mesh size grit.

Any description of the polishing mechanism with diamond needs to address the glazing phenomenon and explain it, because it seems to represent a 'tipping point' between abrasive grinding and polishing. I suspect that when a gemstone surface reaches some critical degree of smoothness, the diamonds can no longer overcome the compressive strength of the surface, so they cannot indent sufficiently to excavate fractured material or induce new fractures, and instead slide over the surface removing asperities but no longer creating new fractures. The diamonds on the lap present a combined bearing surface below the critical load threshold required for indentation of the individual particles. This is merely an hypothesis, and I have no experimental evidence other than the phenomena observed during faceting to support it. The proposed sliding or 'planing' mechanism of diamond polishing is not novel and was suggested a long time ago by Fred Van Sant. No-one seems to have tackled it with directed experimentation since.

An internet search for 'diamond polishing mechanism' located numerous articles about diamond polishing diamond but I could find none about other gem materials except the undated ones by Stephen Attaway (www.attawaygems.com/NMFG/cabinet_makers_and_chain_saws.html) and Fred

Van Sant (www.usfacetersguild.org/articles/fred_van_sant/polishing_with_diamond/). For anyone interested in the rock drilling experiments, conducted as part of a Ph.D. in materials engineering, they too were published a long time ago.

Miller, D.E. & Ball, A. 1990. Rock drilling with impregnated diamond microbits – an experimental study. *International Journal of Rock Mechanics and Mining Sciences* 27:363–371.

Miller, D.E. & Ball, A. 1991. The wear of diamonds in impregnated diamond bit drilling. *Wear* 141:311–319.

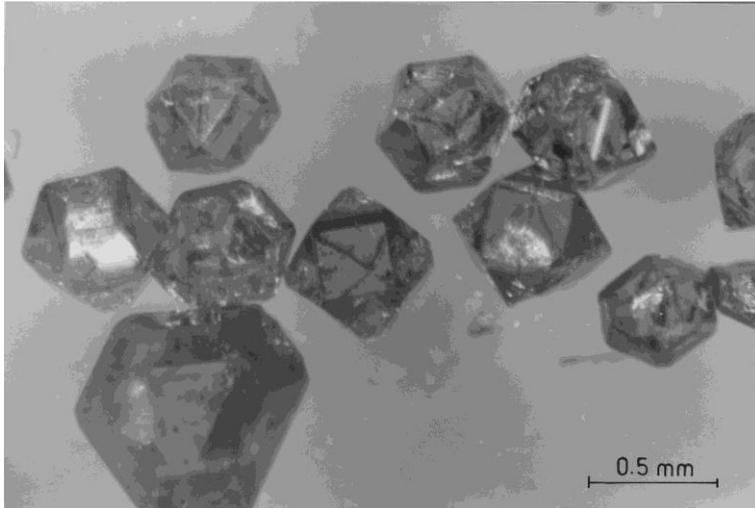


Figure 1 Cubo-octahedral synthetic diamond crystals used in indentation experiments

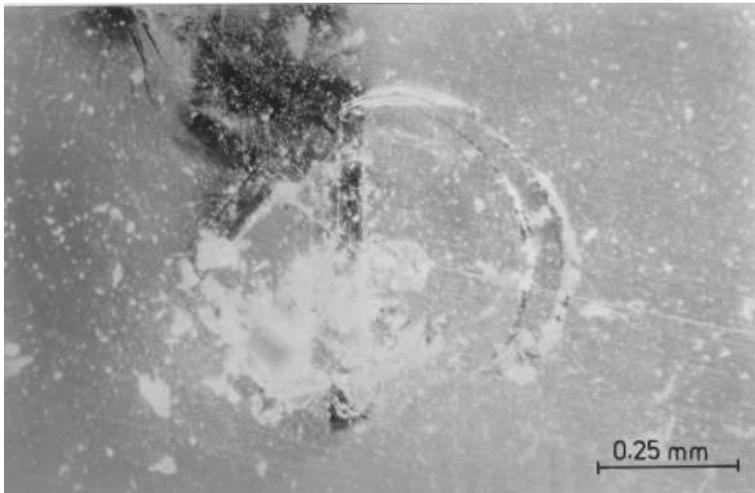


Figure 2 Cracks in synthetic single crystal corundum caused by a diamond loaded to failure. There are straight slip bands or cleavage cracks and circular ring cracks, which extend conically into the corundum. The white powder is crushed diamond.

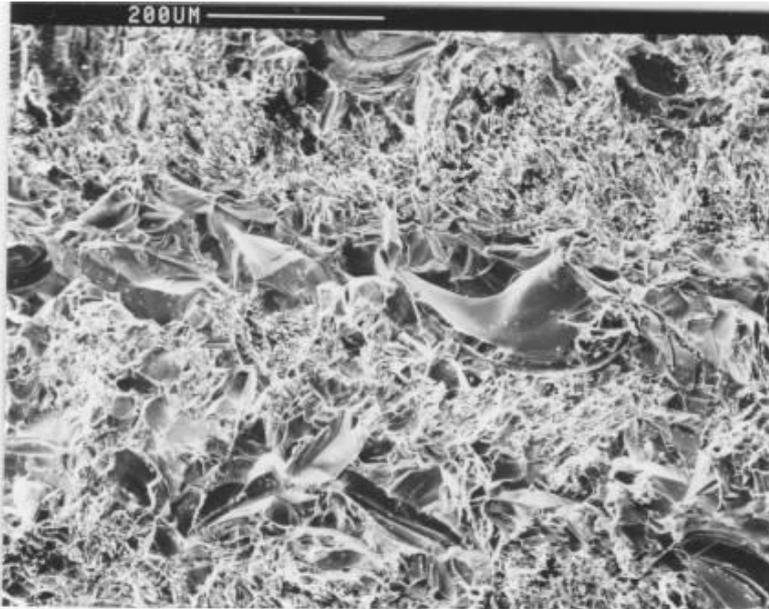


Figure 3 Diamond abrasion track in synthetic single crystal quartz

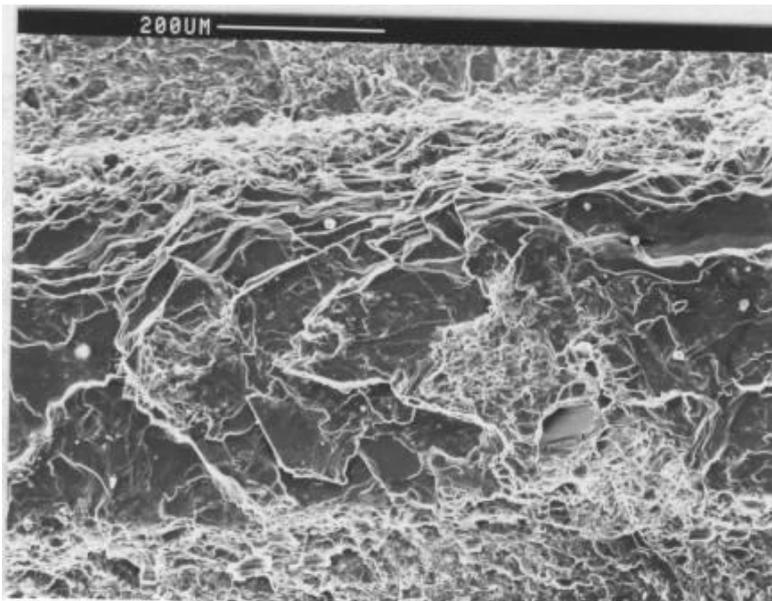


Figure 4 Diamond abrasion track in natural single crystal amazonite feldspar

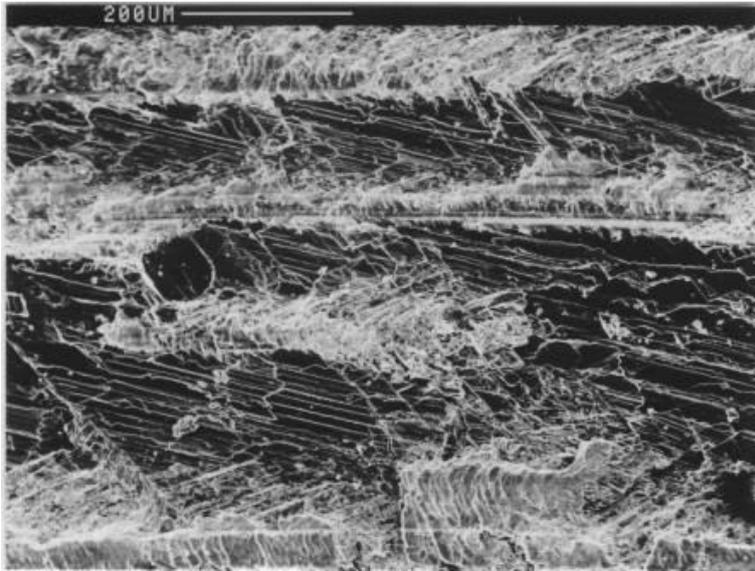


Figure 5 Diamond abrasion track in natural single crystal calcite

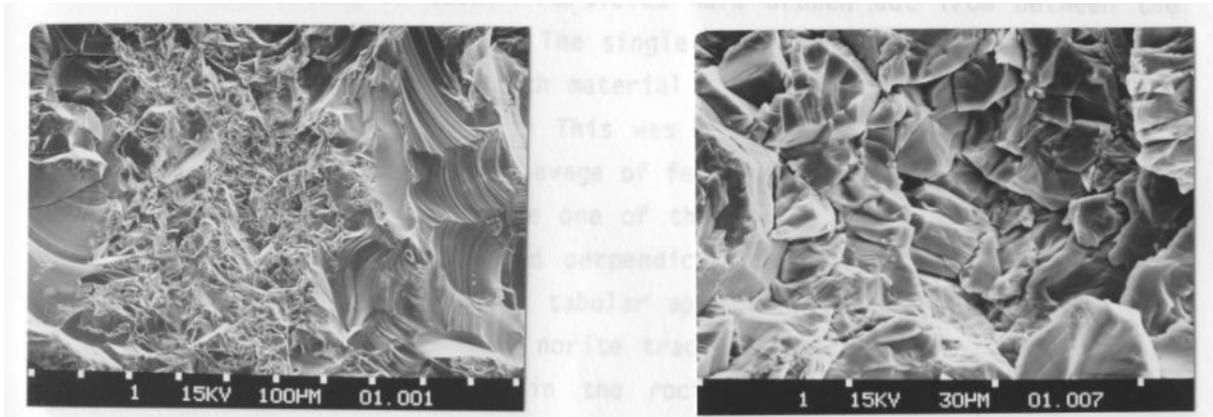


Figure 6 Detail of diamond abrasion tracks in single crystal quartz at different magnifications

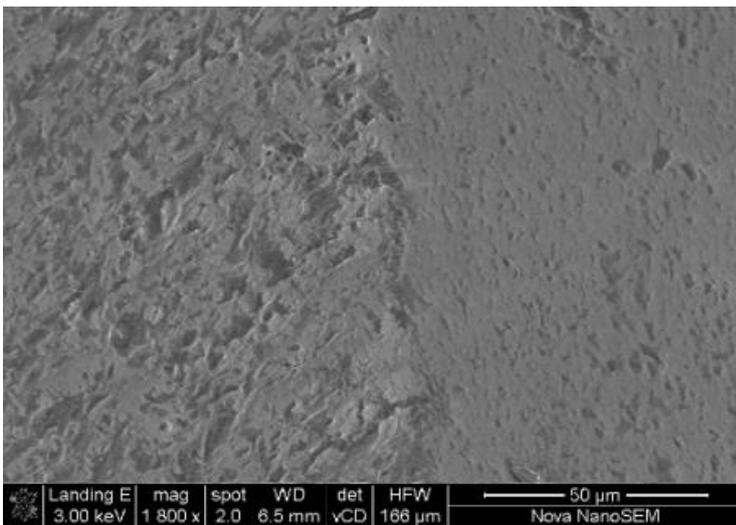


Figure 7 Interface between glazed surface (right) and ground surface (left) on a single facet on synthetic single crystal corundum after grinding with a 1200 mesh diamond impregnated bronze lap

SYNTHETICS

Synthetics are a wonderful source of relatively inexpensive faceting rough, in a wide array of colours, some of them not available at all in natural stones. On the whole, synthetic gem rough is predictable in its behaviour and also enables the cutter to explore quirky cuts in larger sizes than would be affordable in natural rough. And increasingly jewellers are setting well-cut synthetics in precious metal jewellery. So dive in, and enjoy yourself.

The most commonly available synthetics are cubic zirconia, corundum and spinel. Cubic zirconia is produced in angular chunks, often elongated, that look somewhat like natural crystals, but they are produced in huge quantities in industrial-scale furnaces. Early production of cubic zirconia was very expensive and coloured rough quite rare, but now it is readily available in a huge range of colours, some even displaying colour-change effects in different lighting. It is also obtainable in very large pieces now, allowing you to cut huge gemstones if you like punishment. Synthetic corundum also is produced in a vast range of colours, although the most commonly encountered colours mimic natural ruby and blue sapphire. The rough most commonly available is in split boules – finger-like single crystals split down the middle to relieve the built-in strain due to their manufacture. Most synthetic spinel is not an exact mineralogical copy of any natural spinel, but is structurally stabilised (as is cubic zirconia) by various additives. The boules of synthetic spinel are not split like corundum, but often have a characteristic network of surface cracks. There are numerous other synthetics available from specialist outlets (for example <http://morioncompany.com/> or <http://www.gemshub.com/rough-stones.php>). These include quartz, beryl, YAG, and various diamond simulants.

The ‘common’ synthetics – cubic zirconia, corundum and spinel – are best treated like natural sapphire when cutting and polishing. This means facet cutting on standard mesh size diamond laps, either electrobonded, sintered, or rechargeable copper with loose diamond or paste. Corundum tends to produce an ‘orange peel’ surface on 1200 electrobonded or sintered diamond laps, so many people go straight from facet cutting with 600 mesh to fine cutting and pre-polishing with 3000 mesh loose diamond or paste on copper or zinc laps. After a good pre-polish, polishing the hard synthetics usually is not a problem with 50 000 mesh or 100 000 mesh diamond on tin/lead, Batt™, BA5T™ or Diamatrix™ laps (the last three available from Gearloose Lapidary). Some cubic zirconia, especially early production rough, can spall and cause scratching problems when polishing. It is cheap enough these days to discard troublesome rough.

Cubic zirconia and synthetic spinel are cubic, or pseudo-cubic, in structure and have no cleavage, so they do not have to be orientated crystallographically. The cracked ‘skin’ on synthetic spinel needs to be removed by preforming before facet cutting. The synthetic corundum is trigonal, with the c-axis lying nearly parallel to the split boule face. This means that in the ruby version the best colour is obtained with the table of the stone perpendicular to this face. Placing the table parallel to the split boule surface, which is tempting, produces a more unnatural looking colour. The deep blue boules that mimic natural blue sapphire often have a dark rind and a nearly colourless interior. It is important to exploit this dark rind to obtain a richly coloured stone. It is best to orientate the rind in the table if possible. Because of the curvature of the outside of the boule, on larger stones this often is not possible. The alternative placement of the blue rind in the culet can produce a stone with a

darker centre and lighter periphery. More expensive blue corundum rough is available with the colour uniformly present throughout the stone.

One of the most worthwhile synthetics to cut is synthetic emerald. It is available in various grades with different densities of inclusions, to mimic natural material more closely. Large, perfectly clean synthetic emeralds tend to look a bit glassy and 'artificial', so a scattering of inclusions can make for a more realistic-looking stone. I am not advocating fraud here, and any synthetic must be declared as such for a legal sale.



A selection of cubic zirconia rough, showing some of the wide range of available colours (www.tradeindia.com)



A small selection of synthetic corundum, showing the typical size of the readily available split boules, about 12 mm in diameter



A selection of synthetic spinel boules, showing the range of colours from colourless to a deep 'sapphire' blue



Synthetic spinel boules, showing the typical network of surface cracks in the yellow boule

FIRE AND ICE (or The Junk Box Revisited)

Apart from the left-over quartz in the junk box, some of which I cut anyway, there were two chunks of rather garish cubic zirconia. These were partly preformed with their girdles already cut and some irregular pavilion facets. I had no intention of cutting them, until I did. I last cut cubic zirconia what seems like decades ago and polishing it did not go well. After facetting on a 1200 mesh plated lap polishing even small stones on a copper lap with ¼ micron diamond was very slow. This was before I learnt the necessity of a good prepolish. This time things were completely different. The material cut easily on a 1200 mesh diamond sintered bronze lap, with a 3 micron diamond prepolish on copper and quick polishing with ¼ micron diamond on BA5T™ – actually the outer and inner bands of an Gearloose Redwing dual prepolish/polish lap, which doesn't appear to be made any more (see www.gearloose.co for the rather bewildering selection of current products). The results were quite fun, although my camera doesn't capture the dispersion typical of cubic zirconia. The 10,7 mm octagonal yellow stone is 8,62 ct in the Parapet design by Tom Herbst. The 11,2 mm square blue stone is 12,80 ct in the Squartuguese design by Marco Voltolini.



POLISHING REALLY TROUBLESOME FACETS

Polishing soft gem materials, Mohs's hardness 5 and less, and facets near the cleavage of some harder materials can be very difficult with commonly used polishing laps. Some years ago, Gearloose Lapidary (www.gearloose.co) introduced the Lightside™ lap, intended specifically for polishing soft materials. It is a 'reduced-friction' composite lap, used with diamond or oxide slurry to produce flat facets without significant edge rounding. It is described as a 'durable, predictable replacement for wax laps'. I have found that it works well for some materials, and not well for others. I have used it successfully to polish fluorite, cuprite and rhodochrosite, but not cerussite. For that I used a commercially obtained, relatively hard wax lap, supplied by Rob Smith of African Gems & Minerals. Originally, this wax lap was a bit warped, but it flattened nicely under a heap of books. It has an intentionally rippled surface, but the tin oxide slurry I use on it has embedded and with light pressure it polishes facets with minimal rounding of the facet edges.

I have another wax lap, a homemade one, that I used previously for polishing cuprite and some troublesome facets on apatite. It is an old Crystalite electrobonded lap with the reinforcing aluminium ribs on the back turned down in a lathe, leaving just the central hub and a raised outer rim. This is placed on a sheet of aluminium foil on a kitchen stove plate and chips of ordinary candle wax melted in the hollow, until it is filled. When the wax has solidified, the lap surface is trued in the faceting machine, using an old lathe cutter tool held in the quill at an appropriate angle to skim off any irregularities due to uneven contraction of the wax as it cooled. Both laps are illustrated below, the homemade one on the left and the commercial one on the right.



The wax polishing lap on the left is homemade, using the hollowed out back of a Crystalite faceting lap, filled with molten candle wax. The wax lap on the right is a commercially obtained one, with tin oxide slurry impregnated in the surface through use.

Wax laps are not only useful for polishing really soft gemstones, but also a useful remedy for really troublesome facets. Facets near a cleavage plane sometimes refuse to respond to anything you do on a conventional lap. They continue to pit and score no matter how you reduce pressure and rotational speed, change angle of attack, change polishing oxide or slurry consistency. Then it is time to resort to a wax lap. A good example that I cut recently is an 'orthoclase' feldspar—actually sanidine—from Itrongay in Madagascar (<https://www.mindat.org/loc-2273.html>). The facets on one side of the crown were very close to the plane of perfect cleavage. While the other facets on the crown polished easily with a little chromium oxide on a Gearloose Greenway™ lap, some facets remained matt and pitted, even at slow rotational speed on a Lightside™ lap. I resorted to polishing all the facets on one side of the crown on the wax lap with tin oxide. See if you can notice any facet rounding in the photograph below.



Sanidine ('orthoclase') feldspar from Itrongay, Madagascar. The 26,19 ct stone is 19 mm wide. The yellow colour in the reflection is closer to the true body colour of the stone.

CUTTING CERUSSITE

Cerussite is lead carbonate (PbCO_3) and probably the best crystals come from Tsumeb. These can be large and glassy, usually clear, but sometimes grey, brown or red. It has a hardness of $3\frac{1}{2}$, a specific gravity of 6,5, distinct cleavage in two directions, is very brittle and extremely heat sensitive. The refractive index is high, at 1,90 to 2,07, and the birefringence very strong. The dispersion is high. The high refractive index and dispersion should make it a spectacular gemstone and it occurs in fairly large crystals. So why don't we see more faceted cerussite? The rest of the list of properties makes it quite daunting – lack of hardness, two directions of cleavage and extreme heat sensitivity.

Recently Rockey Ollewagen gave me a rough crystal, a bit brownish and battered, and said "See what you can do with it". I like a faceting challenge, so I did. First I looked for cleavage cracks and ground a flat angled well away from them to act as a temporary table facet, using a 600 mesh sintered bronze diamond lap. Then I prepared a flat dop with a layer of wax, flattened against a cold face-plate dop in a transfer jig. When the wax had cooled I glued the stone to the wax surface with a small drop of cyanoacrylate 'superglue'. Then it was a matter of grinding away surplus material with the 600 mesh lap until I had a roughly square preform for the chosen design, "Squartuguese" by Marco Voltolini (available for download on GemologyOnline). It is one of my favourite designs – a corner-cut square with a brilliant pavilion. The pavilion facets were cut with a 1200 mesh sintered bronze lap and polished with no problem on a wax lap (generously donated by Rob Smith of African Gems and Minerals) using Linde A aluminium oxide in quite a thick paste. So far so good. Now for transfer.

This presented a problem because obviously I could not use hot wax in a cone dop. So I tried gluing the pavilion into the dop with superglue. It didn't set overnight because the fit was not tight. So I filled a cone dop with a two part epoxy putty, pushed the pavilion of the stone into it to make a negative impression, pulled it out again, and waited for the putty to set, overnight again. It did. So then I glued the pavilion into its impression in the putty with superglue. When that had set, which was quickly, I heated the initial dop to soften the wax layer. Ting! went the stone!! Aargh!!! A very obvious crack appeared across one corner, threatening to spall off the entire corner; but it didn't. So I scraped and dissolved off the residual wax and positioned the new dop in the faceting machine's quill. As I started cutting I was puzzled. Where had the corner crack gone? All that was left of it was a tiny trace near one edge and no amount of neck twisting and illumination fiddling could get it to reflect. I had to accept the improbable, that it self-healed. Never happened before. Unlikely to happen again. Anyway, I cut the crown on the 1200 mesh lap, modifying it slightly to give it a bit more height, to preserve material and enhance the dispersion. Polishing went without a hitch, including the table. Then, to remove the stone.

A soak overnight in a jar of acetone turned the superglue/putty combination into a jelly. The stone literally fell out, but left a chunk of pavilion behind. Not the corner, but a chunk in the middle of the cone. I suspect that the epoxy mould had distorted slightly as it cured and that when I pushed the pavilion too firmly into the mould it caused a chip. After a few days I decided to recut the pavilion. The extremely high refractive index meant that the pavilion facets could be lowered by a few degrees to remove the shallow hole left by the chip. So I redopped the crown, using a thicker layer of wax with superglue, and a clean cone dop to reposition the stone on axis in the transfer jig.

With nice big girdle facets on the stone, re-orientating the dop in the quill was easy, and recutting the pavilion went smoothly. Removing the stone from the dop also went without mishap, despite the existence of a cleavage crack that opened up in the middle of a side facet at some stage. Anyway, the stone held and the final result was worth the effort. The photograph (courtesy of Jo Wicht) picks up the inclusions more strongly than the naked eye does, but also shows the coloured dispersion spectra very well.

Grinding cerussite made a horrible, goey, toxic, white slurry. I am not sure I want to do it again. But if I do, I will grind two opposing flats on the rough and cut the crown first. This will enable me to transfer dop to another flat face, using a drop of superglue on a flat wax surface and avoiding the use of a cone dop altogether. I have no experience with cold dopping using epoxy glue, but that could be an alternative.



17 mm square, 55 carat cerussite from rough provided by Rockey Ollewagen (photograph by Jo Wicht)

FACETING THE NAMIBIAN RARITIES

During the 1974/75 university holidays I was fortunate to work for Sid Pieters in Windhoek for several months. It was a wonderful experience, including seeing some of the most famous mineral specimens then coming out of Tsumeb, but also to encounter some very special gem materials. Through Sid Pieters's generosity I returned home to Cape Town with a few small fragments of jeremejevite from the original Namibian occurrence at Cape Cross and some pieces of cuprite from Onganja to experiment with polishing. From the jeremejevite I managed to cut two tiny gemstones. The cuprite baffled me for years, and I stashed it.

The jeremejevite, apart from its small size, was very easy to cut and polish. I dopped it with ordinary faceters' brown wax on my smallest dops, and cut the facets very gently on a 1200 mesh sintered lap. Polishing on tin/lead with Linde A slurry was quick. It behaves, and looks like, aquamarine. Many years later jeremejevite was discovered on Ameib ranch in the Erongo mountains and became more plentiful, although facetable pieces remained rare. A friend of mine approached me with a 'large' crystal with an equally large inclusion and asked if it could be cut into an acceptable gemstone. There was only one way to find out and that was to cut it. The result was very pleasing, with the curved central crack actually enhancing the interest of the stone. And it is a gigantic 2,34 carats! (Subsequently I read in *The Journal of Gemmology* of a unique 100 ct colourless jeremejevite gem from Sri Lanka, but I have my doubts.¹)

About a year ago Rockey Ollewagen gave me a lump of cerussite from Tsumeb to try to facet. Previously I had had some success in polishing a few cuprite gems for the late Sigri Barella, including a 100 ct oval, about which I don't have any doubts. For this I used a home-made wax lap and Linde A, but it rounded the facet junctions quite noticeably and I didn't dive into my own cuprite stash. But I took on the challenge of cutting the cerussite and polished it quite easily without too much facet rounding with Linde A on a wax lap given me by Rob Smith. This story I have told earlier in the *Min Chat*, but what I withheld is something I thought would make me look crazy if published. When I transferred the stone it cracked – audibly and visibly – and an entire corner threatened to break off. In mild despair I put it one side to let it and myself cool off. When I returned to the stone the crack had disappeared. I don't believe in healing gemstones, but this one had healed itself! Recently I read in a description of faceting cerussite that this is a unique characteristic of this material,² so I am relieved not to be so crazy after all.

The recent visits to the club by Stuart Moir, who worked the Onjanga copper mine, stimulated my trying to polish cuprite again. I didn't want to return to the wax lap, so imported a Lightside™ lap from Gearloose Lapidaries in the USA. After facet cutting on a 1200 sintered bronze lap and pre-polishing with 3000 mesh diamond paste on copper, I struggled to get a good polish with the Lightside using a Gearloose AIOx Battstik™ in a water slurry. Using WD-40 with the AIOx (crazy combination) worked a bit better. Better still was 100 000 mesh Diastik™ with WD-40 on the Lightside™. This produced an OK polish, but under 10× magnification under oblique lighting there was a haze of fine scratches. Not to be deterred in the quest for the perfect polish on cuprite, I

¹ Smith, C.P. 2014. A rare 100+ carat jeremejevite. *The Journal of Gemmology* 34(2):138-142.

² (Faceting the Good the Bad and the Ugly in *Rare Gems* by John Rhoads
http://www.attawaygems.com/NMFG/Program_Speaker_John_Rhoads_on_Rare_Gems.html)

imported another Lightside™ lap and Jon Rolfe (aka Gearloose) made up a special 200 000 mesh Diastik™ for me. This produced an even better polish, but very slowly as one might expect. The problem with this was that cleaning the WD-40 off the stone with an alcohol-dampened paper towel to inspect the facet sometimes scratched it and adjacent facets. The published hardness of cuprite is 3½–4, so even a grain of house dust (mainly quartz) could scratch it. I am still trying to get the reliable perfect polish on cuprite. Perhaps I am crazy after all.



Jeremejevite, rough and cut, from Mile 72, Namibia. The larger faceted stone is 3 mm, the smaller 2 mm in diameter and is the smallest stone I have ever cut.



Jeremejevite from the Erongo, 2,34 ct, cut in an opposed bar cut.



Cerussite, 16 mm square, from Tsumeb (photograph by Jo Wicht)



Cuprite, 4,78 ct, 8 mm triangular stone in Tom Herbst's 'Tris de Garnet', polished with 200 000 mesh Diastik™ on a Gearloose Lapidary Lightside™ lap

TOPAZ

Topaz is a rather under-rated gemstone. This perhaps it due to the fact that pure, colourless topaz is relatively plentiful. Much of it is irradiated and then heat-treated to produce various intensities of bright blue. Natural blue topaz tends to be much paler, although dark blue stones do occur naturally. These are rare and hence more valuable. Natural topaz occurs in a wide variety of colours, including light green, yellow, orange and pink. The famous orangey-pink topaz from near Ouro Preto in Brazil, known in the gem trade as 'Imperial topaz' usually is heavily included and clean stones command a high price. Unhappily, some strongly coloured topaz fades in sunlight.

Large, clear crystals of so-called 'Silver topaz' occur in the pegmatites of the Klein Spitzkopje and the miarolitic cavities in the Erongo granite. This inexpensive material is readily available from artisanal miners and local dealers. Clean rough can produce very brilliant stones because of the high lustre.

Faceting topaz requires attention to the crystallography. Topaz crystals often are elongated in the direction of the **c**-axis, and the prism faces (the 'side' faces) often have striations parallel to the **c**-axis. This is one of the characteristics that distinguish topaz crystals from quartz, in which the prism faces are striated perpendicular to the **c**-axis. Other distinguishing features are the rectangular or rhombic horizontal cross-sections of well-formed topaz crystals, as opposed to the hexagonal cross-section of quartz. Topaz is both denser and harder than quartz, so a specific gravity test or a Mohs hardness test can distinguish more irregular rough. Topaz has one direction of easy cleavage perpendicular to the **c**-axis of the crystal. Careful inspection of water-worn chunks often reveals cleavage traces either inside the crystal or as tiny, regular step fractures in chipped areas.

Locating the cleavage direction is important for orientating the stone to be cut. You want to avoid any facet on or near the cleavage. The rule of thumb is to orientate the table of the stone at least 5° off the cleavage, and 7° to 10° is better. An alternative with elongated rough is to orientate the cleavage 10° off the vertical in your stone, to avoid having the cleavage near any girdle facet.

Preforming can be done on a sharp coarse lap with light pressure, to avoid creating cleavage cracks. Because topaz is relatively hard (8 on the Mohs scale) a really good pre-polish is necessary, at least a 3000 mesh finish. I prefer 8000 mesh diamond on copper. Polishing with aluminium oxide (Linde A) is possible, but slow. Polishing with 60 000 mesh or 100 000 mesh diamond on a metal lap like Batt or tin/lead, or a Diamatrix composite lap, is preferable. If the cleavage gives trouble when polishing any facet, changing the direction of polishing often solves the problem.

BERYL FAMILY

Many faceters recommend that beginners start with aquamarine. It usually presents no problems in faceting or polishing, is relatively easy to obtain, and in lighter colour it is not overwhelmingly expensive. Aquamarine is the blue or blue-green gem variety of the mineral beryl, an aluminium beryllium silicate. It occurs in elongated hexagonal barrel-shaped crystals. It is dichroic, with the most intense colour when viewed along the length, the so-called **c**-axis. This is a pity, because the best recovery usually means placing the table facet parallel to the **c**-axis.

Selecting rough involves checking for inclusions. The crystals often have fine tubes running parallel to the **c**-axis. These can produce a sleepy but nevertheless pretty stone, perfectly suitable for a beginner's practice. Avoid rough with irregular internal cracks. These will interfere with the light reflections and may cause the stone to break while you are faceting it. Light blue-green glass and blue synthetic quartz are common aquamarine simulants. The glass usually contains swirls of round bubbles; and is isotropic, staying dark on all rotations between crossed polarising filters. The blue synthetic quartz is more difficult to distinguish so it is best for beginners to stick to aquamarine rough in the characteristic hexagonal crystals, or bought from a reputable dealer.

Aquamarine is not particularly heat sensitive. After trimming off unwanted material I dip with wax, cut larger facets with 600 mesh followed by recutting them and cutting finer facets with 1200 mesh, and then polish with aluminium oxide (Linde A) on a Batt lap. I used to use a tin/lead lap, which works just as well. Aquamarine traditionally is cut in elongated step cuts, like emerald cuts, because that is what fits well-shaped crystal rough. But trillions, round brilliants and fancy cuts with the table perpendicular to the **c**-axis can produce beautiful stones with stronger colour. Many greenish-blue aquamarines are heat-treated to remove the green component and produce more fashionably blue stones.

Other gem varieties of beryl include pink morganite, yellow heliodor, colourless goshenite, and green emerald. Morganite can be available in large pieces. Small stones can be nearly colourless and approach goshenite. Neither varieties present much trouble in faceting and polishing, although some morganite contains numerous microscopic inclusions that can make polishing without fine scratches difficult. Emerald is a different story. Apart from being very expensive, clear emerald rough usually is small. Larger pieces often are heavily included and don't produce very attractive stones. There is a lot of fake emerald rough doing the rounds in South Africa. You need to be able to recognise these fakes to avoid being taken for a ride. A convincing fake consists of green glass that has been melted and poured into moulds lined with biotite mica. This mimics a common occurrence of emerald in biotite schists. Some of these have only five side faces – a dead give-away because emeralds form hexagonal crystals. Another common fake consists of dyed, quench-cracked quartz, but this is less attractive because of the crazing.

I preform emeralds on 600 mesh and facet them with 1200 mesh laps. They polish easily so a prepolish isn't necessary. I used to polish them on tin/lead with Linde A, but both the polishing medium and bits of metal stuck in cracks and voids. This has to be cleaned out with dilute nitric acid. Now I polish on one of Gearloose Lapidary's water-only polishing laps, either Greenway or Skyway. I find the Greenway, already impregnated with chromium oxide, works more rapidly, but it can round small facets a bit.

There is ongoing argument among gemmologists if all green beryl gems should be called emerald. Typical emeralds are coloured by small amounts of chromium, often with some vanadium. Vanadium coloured beryls tend to be called emeralds these days, while those coloured mainly by iron tend to be called green beryl. There is no strict dividing line, and most of us are not experienced spectroscopists! So if in doubt, just call your greenish beryl gem 'green beryl' and you won't be wrong.



Various rough beryl crystals (clockwise from top left) – goshenite, morganite, green beryl, two emerald crystals, aquamarine, heliodor (probably irradiated)



Fake aquamarine rough – glass with swarms of round bubbles and irregularly ground ‘faces’



Fake emerald rough – glass with adhering mica, and some pieces five-sided



Fake emerald rough – glass 'crystal' with one side polished to reveal the swirl of bubbles in the interior

AN 'EPIDOTE' ANECDOTE

A few years ago, faceting friends of mine in Durban bought some green gem quality material sold as epidote or possibly peridot. It was nice clear green, and some pieces of rough still adhered to a matrix, "dug out of the ground right in front" of the vendor from Moçambique. The cutting and polishing was easy, apparently working like tanzanite. But the surface of the polished stone degraded quite rapidly, developing hazy spots, so samples were sent to me for identification.

The specific gravity measured by hydrostatic weighing was 3,55. It was quite soft, with a Mohs's hardness of about 5, and had perfect cleavage, forming faces at 90° to each other. This indicated that it probably was cubic, so it could not be epidote, or peridot. Between crossed polars it was isotropic, which figured with its being cubic, but the cleavage meant it wasn't glass. Under magnification, it contained swarms of fine, round bubbles. This was a puzzle. So I polished a face to measure the refractive index, which was 1,73.

This combination of properties indicated synthetic periclase (MgO). Webster's Gems notes that it has been marketed under the trade name of Lavernite. So what about the matrix specimen? A closer look at that showed some nice little brown cubic crystals lining vugs in cleaved green masses.

Another piece had an opaque, vesicular brown matrix, probably also periclase but with higher iron content. The vendor had lied.



A piece of synthetic periclase (MgO) sold as natural faceting rough. The front and side faces are cleavage faces at 90° to each other. The top face is a saw cut. The samples is 15 mm long.



A 'matrix' specimen of synthetic periclase, with small brown cubic crystals lining vugs in the green periclase 'matrix'. The field of view is 25 mm wide.

GARNET

Garnets are among the easiest gem materials to facet. They have no distinct cleavage, although some crystals have a parting that causes them to fracture into flat slabs. The rough often is in globular shapes, which is good for weight recovery. When choosing rough, avoid being fooled by fake material. Red glass is sometimes covered in adhering deceptive 'grit' to mimic natural nodules. Illuminated from behind or the side with a torch, the characteristic internal swirls and round gas bubbles of glass give away the game. The only real issue lies in selecting red or brownish red rough that is not too dark to bother faceting. With dark garnet rough doing the 'white paper' test is necessary. You should be able to see good colour through the stone laid on white paper in strong, but indirect, light if you want to cut stones with a full pavilion. Larger, fewer pavilion facets are preferable on dark stones. But dark red garnets can be faceted into rose cuts, with no pavilion but a polished, flat base that reflects light coming from the sides.

Garnets occur in literally all the colours of the rainbow, including purplish blue garnets discovered recently in Madagascar. Bright red pyrope garnets, usually in small sizes, occur in the southern African kimberlite pipes, and have been marketed as so-called 'African rubies', a trade name that should be discouraged. Green demantoid and yellow andradite garnet come from deposits near the Erongo mountain in Namibia. Garnets in a wide variety of red, orange and yellow colours are found in the gem deposits of East Africa and Nigeria. These varied colours of garnets are due to the fact the garnets are a family of chemically distinct minerals, with varied compositions and diverse colouring, that also can form mixtures with each other. This causes some variation in the density and refractive indices of the different gem varieties, and some minor differences in optical and physical behaviour.

The brown and golden varieties of grossular garnet, known as hessonite or cinnamon stone, often have a swirled interior appearance, that can look similar to glass. The Namibian demantoids sometimes have bands of slightly differing refractive index, looking a bit like cleavage planes, but they are not. They also are somewhat softer than other gem garnets and the variation in hardness in different directions can take you unawares, resulting in over-cut facets. The softer facets have a rougher surface before polishing, and these can need more polishing, throwing out the meets. You need to be aware of this and avoid it by cutting these facets slightly short. I polish Namibian demantoid garnets on a Gearloose Lapidary Greenway lap. This has chromium oxide embedded in the polymer surface, and avoids getting polishing agent stuck in the voids and cracks that these stones often have. Other than this, garnets present no problems in faceting and polishing. The other garnet gem varieties I cut on 600 mesh or 1200 mesh, prepolish larger stones on 3000 mesh on copper, and polish on a Batt lap, similar to tin/lead, with aluminium oxide (Linde A).

Some garnets, including some Namibian demantoids, show a subtle but distinct change of colour between fluorescent and incandescent light, making them difficult to photograph accurately.



Fake garnet rough in fake 'matrix'



Run-of-the-mill brownish red garnets, almost too dark and included to facet



Namibian demantoid garnet rough, 43 ct total, showing the variety of colour



Namibian demantoid garnet, 4,07 ct, showing subtle change of colour in fluorescent (left) and incandescent (right) light



Namibian demantoid garnet, 4,91 ct, showing the high dispersion typical of andradite garnet

TOURMALINE

Tourmaline can be temperamental. Rough tourmaline occurs in two distinct shapes – globular nodules and elongated pencil-like crystals elongated in the direction of the **c**-axis. The globular nodules sometimes spall concentrically, like onions, and the pencils sometime fracture transversely. This behaviour is difficult, if not impossible to predict, although fine cracks in the ‘skin’ of tourmaline pencils is not a good sign. The cracked skin must be removed by preforming or the cracks will run. But usually tourmaline presents no problem. As always, watch out for fake gem rough.

Tourmaline is pleochroic, sometimes strongly, so the rough must be orientated for colour. Blue and green crystals usually show the best colour transverse to the **c**-axis. Some are so dark in the direction of the **c**-axis that they are ‘closed’, and need to be cut with steep pavilion facets at the short ends, to minimise darkening of the finished gem. ‘Open **c**-axis’ green and blue tourmalines command a premium. Pink tourmalines, by contrast, often show the best colour viewed parallel to the **c**-axis and the table is best placed perpendicular to it, if the rough allows. Despite these constraints, well-shaped tourmaline rough can give you very good weight return after cutting. When choosing tourmaline rough, remember to do the white paper test and reject any rough that is too dark to allow you to see good colour through the crystal placed on white paper in strong indirect light. Avoid long, narrow crystals. They tend to break and long, narrow stones are difficult to sell or set.

Faceting tourmaline, once you have removed any peripheral cracks, is quite easy. I cut large facets on 600 mesh, then recut them and cut finer facets on 1200 mesh, followed by a 8000 mesh prepolish and polish on a Gearloose Lapidary’s Matrix lap with aluminium oxide Battstik. Formerly I used to use tin/lean or a Batt lap with Linde A made up into a thin slurry, the consistency of milk. Less rather than more polishing agent is better, to avoid streaking or scratching. Unless your laps are new and very flat, long facets need to be cut and polished with the length parallel to the running direction, or the end up curved. Curved facets can cause problems when repolishing a commercially cut stone, and often complete recutting is preferable.

Another problem when trying to repolish a tourmaline, especially the table facet, is that you need to remove the original polished layer with a relatively coarse lap, at least 1200 mesh and often 600 mesh. Initially this produces a very rough surface, so usually this necessitates recutting and polishing the adjacent crown facets too. I think this ‘hard’ surface layer is due to plastic work-hardening during polishing, but I have no way of proving this assertion. This phenomenon occurs on other stones as well, including sapphire, but doesn’t seem as pronounced as on tourmaline. Tourmaline also has quite marked differential hardness and end facets on long stones, transverse to the **c**-axis polish differently from those parallel to it. A light touch here and sweeping the lap avoids streaking and grooving of these facets.

Tourmalines come in every colour imaginable, and some mixes of colours are very captivating. But avoid stones that have green and pink pleochroism (although they make wonderful mineral specimens) because the blended colour is a muddy khaki, unless you plan an elongated stone to take advantage of the dichroism.



Top quality 65,91 ct green tourmaline rough from Namibia...



and the 21,90 ct gem I cut from it.



A pair of 9 mm square pink tourmalines, unfortunately not of the same intensity of colour or clarity, cut from the same batch of rough. The stone on the right is at least twice the value of the stone on the left.



Fake tourmaline 'crystal', bought at the Kleine Spitzkopje, shaped out of green bottle glass. Note the randomly ground rather than striated facets and the tell-tale round air bubble (mid lower left).

MOLDAVITE

Continuing the theme of International Year of Glass in 2022, I decided to facet a moldavite.

Moldavites are a kind of tektite, lumps of natural glass found in eastern Europe, that may be the result of melting due meteorite impact. They are irregular to drop-shaped, usually dark green, and have a naturally etched, rough surface. The irregular pieces and faceted stones sometimes are set in jewellery, where they look like dark green bottle glass. There are many fakes around because it is easy to etch dark green bottle glass in acid to produce the characteristically grooved surface. As moldavites are glass, all the usual tests to distinguish glass from other gems are useless. They have similar hardness, often a similar refractive index, and contain lots of bubbles and swirl marks due to internal variation in composition.

Figure 1 is a photograph of three supposed moldavite specimens. The small one on the right I suspect is an etched fragment of bottle glass, purely based on its thickness and curved shape. The central drop-shaped one looks more plausible. Immersion in 'liquid paraffin' – a highly refined mineral oil with a refractive index of around 1,48 – and illuminated from behind to peer into the specimen wasn't very successful. The rough exterior trapped numerous air bubbles and even after most of those had been dislodged by vigorous shaking the interior scene was uninformative – just swirl marks and lots of bubbles as one would expect from any poor-quality glass. The specimen on the left was a sawn fragment and the piece I planned to facet. But I didn't want to waste my time faceting bottle glass, so needed to confirm its identity.

Turning to the internet for advice about identifying genuine moldavite turned up plenty of sites purporting to sell genuine moldavites and suggesting that real ones can be distinguished from fakes based on appearance. That wasn't working for me. Some also claim that moldavites have specific vibrations that can be felt as a tingling. As molecular vibrations are of the order of 10^{13} – 10^{14} Hz they are way beyond my sensory capabilities, so I had to resort to more prosaic tests. An article by Jaroslav Hyršl, published by the GIA (<https://www.gia.edu/gems-gemology/spring-2015-gemnews-moldavites-natural-fake>) had more useful advice. The refractive index of moldavite is a bit lower than that of most of the imitations. So I polished one sawn face and measured an RI of 1.485, which is in the quoted range of 1.480–1.510 and lower than most glass fakes. According to Hyršl, UV-VIS spectroscopy also can distinguish between real and fake, but as I don't have a UV-VIS spectrometer that wasn't much help.

What Hyršl and several of the web sites illustrate are characteristic internal features that look like tadpoles with elongated and convoluted tails. These are schlieren of a nearly pure silica (SiO_2) glass called lechatelierite, formed by melting pure quartz grains. This is visible under the microscope because it has an even lower refractive index of 1.462, which creates visible contrast with the moldavite matrix glass that contains more impurity elements like iron. Fortunately, the polished face enabled me to view the interior of the specimen under the microscope. Figure 2 shows a photograph of lechatelierite schlieren in this specimen. It looks unmistakably similar to lechatelierite photographs by Hyršl and on this commercial site <https://www.innervisioncrystals.net/pages/fake-moldavite>, and unlike the swirl marks so common in other glass. So at least this piece is genuine.

Facetting it was like facetting any other piece of glass, except that the very low refractive index meant either making the pavilion very deep or living with a 'window'. I decided on the window, to avoid a very dark, deep, narrow stone. Figure 3 shows you the result, with strong lighting. It's a curiosity, and not a particularly exciting gemstone, unless you can feel tingling vibrations.



Figure 1. Three specimens of supposed moldavite. The central one is 35 mm tall.

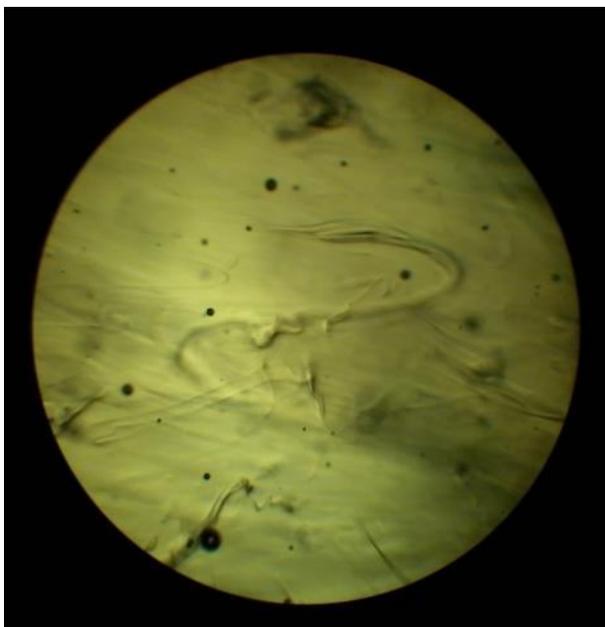


Figure 2. A photograph under the microscope of characteristic lechatelierite in moldavite. The round spots are empty bubbles. The diameter of the field of view is 4 mm.

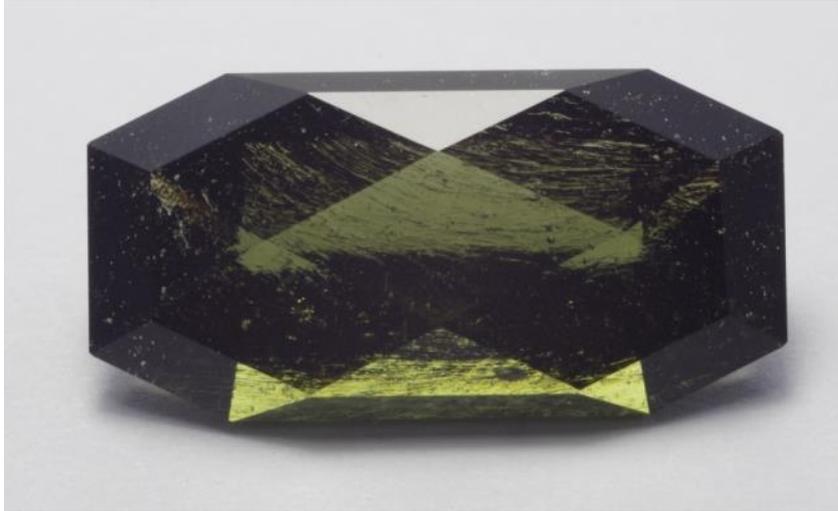


Figure 3. Moldavite, cut in Jeff Graham's *Bag of Diamonds*; 22,5 × 11,3 mm; 12,03 ct. You can see clearly the internal swirl marks and bubbles typical of glass. The characteristic lechatelierite schlieren are only clearly visible under magnification. The white spots are not dust, but surface-reaching open bubbles.

PREFORMING 'DOORSTOPS'

by Jo Wicht

I have an unfortunate tendency to cut 'doorstops', which in the faceting world means cutting a mighty big gem, such as the 50 carat amethyst shown here.



When a piece of rough asks to be cut into a gemstone, I always feel that I would like get the maximum-sized stone from the rough, regardless of a few inclusions, as they always add a bit of interest or a few additional flashes to the finished result.

BUT..... cutting big pieces of quartz and not having any kind of pre-forming grinding wheel, makes for difficulty. Often a fair bit of the rough must be removed on only certain sides of the stone once it has been centrally dopped in order to get it into a basic working shape. This is both time-consuming for me and hard-wearing on my 260 Cristalite laps. Coming from more of a lapidary, stone-carving, background, I am used to using 4" Velcro backed diamond encrusted pads (which come in grits from 50 to 3000) to do the work of removing excess stone on my large carving work. The ease with which the diapads wear down stone of all hardnesses, made me think that perhaps they could speed up the removal of rough from my gems too. I work with a Raytech faceting machine, and first tried the 200 grit 4" discs that I already had but they didn't cover enough of the lap when it came to cutting girdles. Recently I went back to my supplier and found that there is also a 200 grit 6" (approx. 15 cm) diamond encrusted pad available, and this fits exactly onto the lap area of my faceting machine. Despite the apparent gap between the pads (see photo), and the high pitched humming noise that occurs when a chunk of dopped rough is first put on the surface, it is remarkably fast in removing excess rough. Once the basic shape and the beginning of the break facets are in place I can return to a 260 grit Crystalite lap and then cut down sufficiently to remove any scratches made by the 200 diapad and then go straight on to the 1200 Crystalite for fine cutting.

It is comparatively inexpensive and well worth a try for the occasional 'doorstop'.



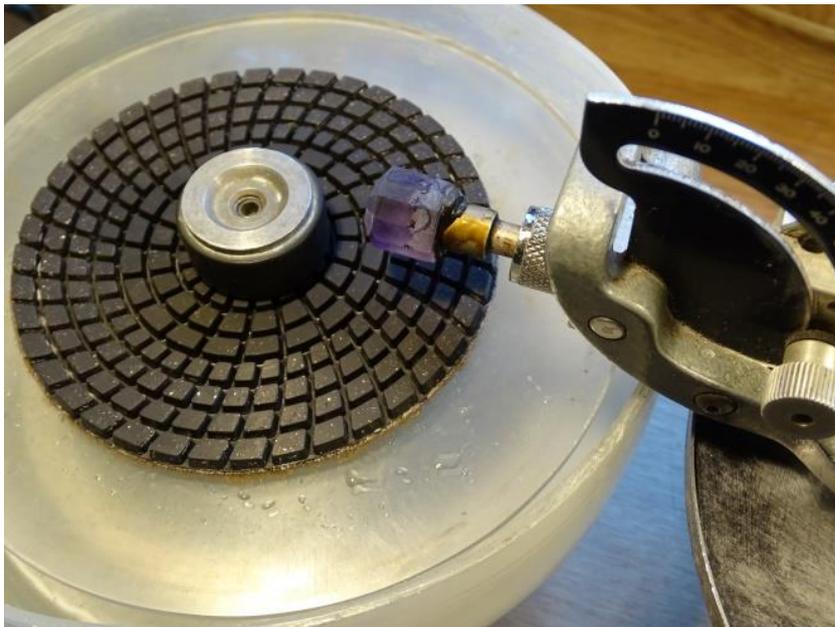
PLAYING WITH STARS

by Jo Wicht

I cut off the end of a damaged Goboboseb quartz crystal because it had a deep purple central inclusion at the one end, which I thought would make an interesting stone to facet.

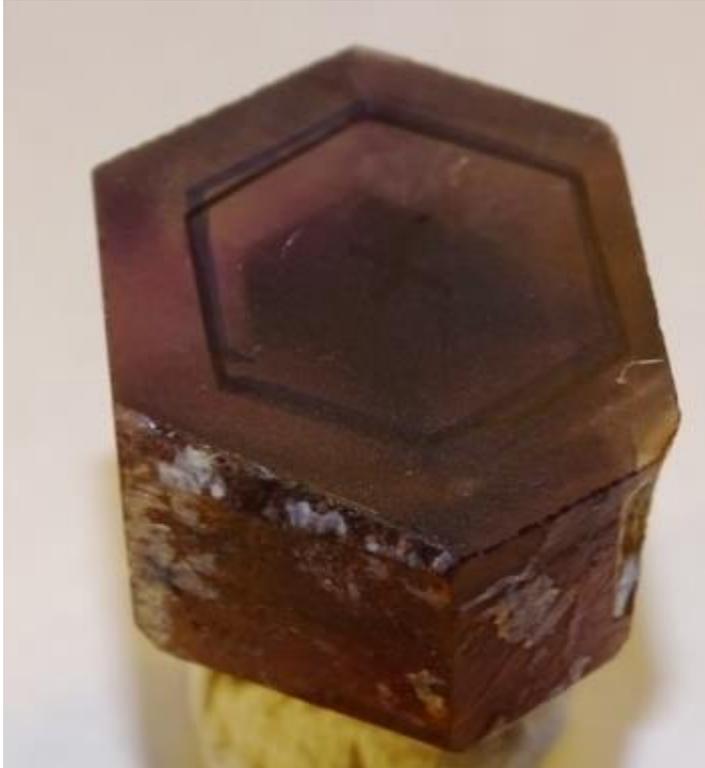


But then I noticed that the end of the remaining piece had regular purple stripes radiating from the centre to the points of the hexagonal crystal. So I cut off another section of the crystal to the depth I hoped I would need for cutting a gem. I first tried to find the middle of the purple star shape, and marked stencil lines to make sure the radiating stripes went out to the points of the hexagon.



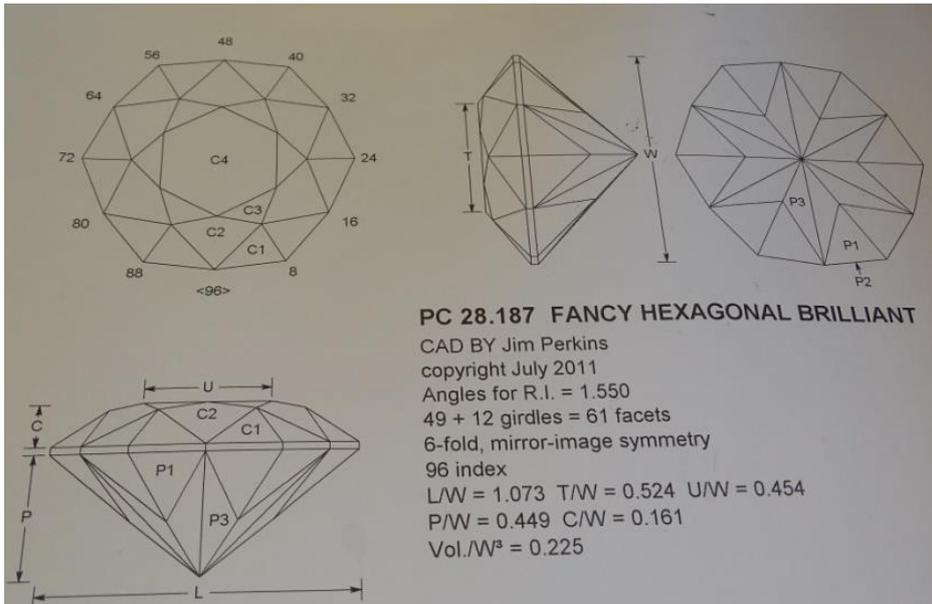
From here I dipped the stone with wax and after adjusting the indices to match the sides of the hexagon, I started to work the girdle down to the marked lines with a 50# diapad on my faceting machine for speedy removal of excess stone. Even before starting work, the crystal had a nicely regular hexagonal shape.

When I had worked down equally all round to about 2 mm from the nearest marked line, I then had some idea as to how accurately the stone was dopped from my centre mark. To finally adjust this I gently reheated the dop and when the wax was just soft, I eased the stone about 2 mm to one side to get it more central. Luckily my girdle facets stayed in the same index position and I didn't need to re-adjust them when I started to cut again. Now I changed to a 260# sintered lap and cut the girdle to an accurate depth all round.



As the radiating lines were mainly at one end of the crystal section, I decided to cut the crown first to keep as much of them as possible. Finding the depth of the crown breaks was a matter of trial cuts to make sure the minimum depth of stone was removed, but was enough to cut the mains and a table.

I had chosen the following design which is called a hexagonal brilliant, but in fact it has 12 girdle facets. It was therefore necessary to adjust the facets to match the correct index setting once working the design, so that the purple lines radiated out to the six sharpest points of the design, in this case 8, 24, 40, 56, 72 and 88).



Once everything had been worked out and I was on track, it was a matter of completing the cutting and polishing of the girdle and crown before transferring the stone. Then I worked the pavilion second. It was the first time that I have done things that way round. It took some thinking out I must admit, but I got there. The final stone is 13 ct.



View looking down onto the crown

FACETING FOR INCLUSIONS

Inclusions in gemstones often are seen as just a nuisance by faceters, who find themselves urged to buy only 'clean' rough. I suppose it is a matter of taste, but inclusions that do not detract from the visual appearance of a gemstone can aid in proving its authenticity. And some inclusions definitely enhance the value and appearance of certain gems. A visible 'horse tail' inclusion of asbestos fibres in Russian demantoid is perhaps the most famous example of desirable inclusions, not that many people will get to see a real life example. But rutiled quartz would just be plain quartz without the rutile needles, and a multitude of different minerals can make attractive inclusion scenery in quartz. Some inclusions are so characteristic of their host material, that examples without them are rare. Lily pad inclusions, small disc-like cracks around minute black inclusions in peridot, are a good example.

Undesirable inclusions that cannot be removed by preforming, often can be hidden partially beneath crown main and break facets. Avoid having these placed in the centre of a stone, where they will be multiplied by reflection in the pavilion facets. The very worst place to allow an undesirable inclusion to lurk is in the culet, so remove any damaged or cracked 'skin' from your rough before blocking out the pavilion main facets. Fine tubular inclusions, often seen in aquamarine, can be orientated vertically in the stone to minimise their visual intrusion. Stones containing a multitude of finely dispersed inclusions may appear 'sleepy' or milky, like much rose quartz. Such stones can be cut into very beautiful gems with some crown facets left frosted to increase the contrast between them and polished surfaces.

Orientating to display desirable inclusions involves the inverse of hiding them. For example, many cutters search for years for that piece of quartz or topaz with a single needle of rutile or tourmaline to orientate vertically through the centre of the stone. This will produce multiple reflections if centred properly, but how do you get it dead centre? I am sure there are other possibly more elegant solutions to the problem but I roughly preformed the stone, used a drill with a ball burr to grind two small hollows in the opposite ends of the rutile needle, and clamped the stone between two pointed dops in the transfer block before fixing the stone to one dop firmly with lots of wax. Then I removed the other dop, replaced it with a face-plate dop, and proceeded as if doing a transfer. The result was a needle perfectly centred in line with the dop axis to cut a round brilliant. (Unfortunately in this instance the rutile needle was very fine, which compromise the result. Perhaps one should just drill a hole through a stone and fill it with dye...)

Orientating other desirable inclusions depends on their nature and the shape of the rough. Deliberate central placement will cause multiple reflections. Perhaps you want two dissimilar inclusions side by side. It often is a good idea to avoid having inclusions breaking the surface of the crown. The difference in hardness relative to the host could leave polishing hollows or raised bumps. Once, when cutting large facets on some rutiled quartz, I was frustrated by some of the straight needles actually pushing through the quartz and emerging slightly on the other side. This would have caused a polishing disaster. So, what to do? A drop of cyano-acrylate glue on either end tethered the needles so that the little projections could be removed in pre-polishing to avoid scoring the polishing lap.

So next time you are selecting rough, don't automatically discard included stones. Think creatively what you might be able to do with them to enhance their appearance and increase their value by cleverly including the inclusions. All the gems in the illustrations were cut by Duncan Miller.



Centreing a rutile needle in the transfer fixture between two dops ground to points



A 17,77 ct scapolite from Merelani tanzanite mines, with unidentified inclusions like ink spots



Very rare helical inclusions in a 64,66 ct Brazilian aquamarine



Hollandite inclusions in a 15,86 ct Madagascar quartz, cut to follow the original shape of the crystal

INCLUSIONS – MINERAL SIGNATURES

Many gem cutters seek flawless stones, devoid of inclusions. This is especially true for faceted gems. But inclusions can add a special interest to a gem. With the escalating price of flawless rough, included material may be all one can afford. In either case, orientating the inclusions cleverly can enhance the appearance and often the value of a gemstone.

Sometimes the goal is to hide or minimise the visibility of one or more inclusions. Coloured stone cutters can learn from the diamond industry, where inclusions and flaws often are 'hidden' below the crown facets between the table and the girdle. The closer they are to the girdle, the less likely they are to be reflected in the pavilion facets and hence visible through the table of the stone. This is an old trick to improve the apparent clarity.

In coloured stones, flat cracks like internal cleavage cracks in iolite or tanzanite, stress cracks in tourmaline, or so-called 'lily-pad' inclusions in peridot can be orientated perpendicular to the table to make them less readily visible. The scattered, sugary inclusions in grossular garnets (hessonite) and in many other stones can be masked to some extent by faceting a chequer-top design. The lack of a large table facet and the numerous facets on the crown allow for sparkle without a clear view of the interior of the stone. The numerous, fine, parallel growth tubes running along the length of many aquamarine crystals can be obscured if a cut stone is cut with the table facet perpendicular to the tubes. These are all techniques for hiding inclusions rather than revealing them.

There are numerous instances where a cutter might want to reveal inclusions rather than hide them. For example, the classical demantoid garnets from the Urals often contain bundles of asbestos fibres. A faceted demantoid with a well orientated 'horse tail' inclusion visible through the table facet is worth more than a clean stone of otherwise similar quality. This is partly because the inclusion is visually interesting, and partly because it proves the identity of the stone. In some cases crystallographic orientation of the inclusions can produce special optical effects in a gem. Examples are cats-eye stones and star stones. In cats-eye stones, like cats-eye chrysoberyl, light reflecting from fibrous inclusions all running in one direction produces a bright line perpendicular to the orientation of the fibres if the stones are properly orientated and cut as cabochons. This is analogous to reflection from a reel of cotton or silk thread. In star stones, intersecting sets of crystallographically orientated fibres (usually two or three sets) give rise to four-rayed or six-rayed stars if cabochon stones are orientated properly. In the case of star corundum (ruby and sapphire) there are three intersecting sets of fine rutile inclusions producing six-rayed stars, if cabochons are cut with their vertical axes parallel to the vertical (or c-axes) of the original rough crystals.

In less valuable material the gem cutter can play with the inclusions to produce unique stones from quite inexpensive rough. The hunt for suitably included rough is part of the fun. One of the most desirable, and something many faceters spend years searching for, is a single needle of tourmaline running through clear quartz, or better still, topaz. If this is orientated vertically and centrally in the cut stone, it is reflected in every pavilion facet to produce a multi-spoked wheel effect.

In some material orientating the inclusions in the gem is not important. An example would be randomly orientated rutile needles in quartz. But sometimes the rutile is not randomly orientated and forms radiating bundles that need the gem to be planned carefully so that they are clearly visible. Whenever elongated inclusions are required to be visible, they need to be orientated as parallel to the table facet as possible, or they will be at least partly obscured. In many cases both the orientation and the shape of the finished stone will be determined by the orientation of the inclusions. Several examples are illustrated here. The enigmatic helical cracks in the faceted beryl run parallel to the c-axis and this stone was cut specifically to show them clearly (Figure 1). Similar inclusions have been found in topaz and spodumene, and their cause or growth mechanism is unknown. Proper orientation of these inclusions to display them well produces a very rare gemstone. By contrast, the goethite-included Brazilian quartz is quite plentiful, and often cut to display the tufts of inclusions, adding value to otherwise rather pale amethyst (Figure 2). (The inclusion mineral in this material is often erroneously described as 'cacoenite' – which probably sells better than plain old 'goethite'.) The ilmenite and rutile-included quartz was cut from a broken crystal chunk, and took hours of planning in order to retain as much of the rutile as possible while orientating the ilmenite blade so that it was visible (Figure 3). Faceting this stone was not really an option because the geometrically placed facets would have interfered with the image of the geometrically shaped ilmenite crystal and the orientated rutile growing from its edges. The faceted scapolite trilliant did not suffer these restrictions and it was only necessary to orientate the lines of inclusions, like slightly smeary lines of ink, parallel to the table facet (Figure 4).

The hollandite-included quartz and the haematite quartz phantom are special cases. Here again the phantoms, caused by inclusions lying on specific planes within the crystals, dictated not only the orientation but also the shapes of the finished stones. The faceted hollandite-included stone had to be designed with the pavilion facets following the original six rhombohedral faces of the quartz crystal, because the hollandite 'spiders' were perched on buried rhombohedral planes parallel to these faces. This dictated both the shape and orientation of the finished stone (Figure 5). The cabochon had to be cut high and with its vertical axis parallel to the c-axis of the quartz crystal to centre the phantom and its six radiating planes through the stone (Figure 6).

The inclusions in these stones give them distinct signatures, either declaring their nature or producing unique gems. The hunt for suitable rough and the intellectual exercise of planning such gemstones is very rewarding. The end products are intriguing and often more valuable than their clear and flawless counterparts might be. Gem cutters should be encouraged not only to seek flawless rough, but to use their resourcefulness in crafting unique works of art from included material. Of course, most cabochon cutters don't need to be told this, but to some faceters it might be an entertaining novelty.

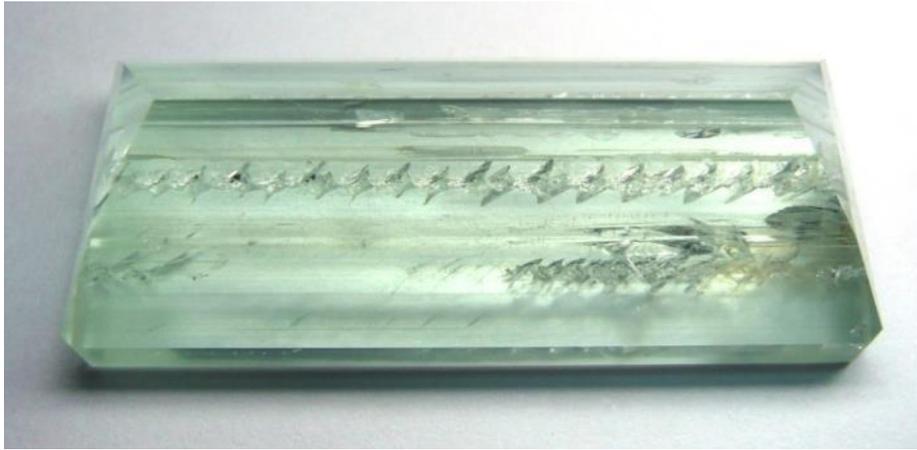


Figure 1. Helical growth features in Brazilian aquamarine beryl. Similar helical cracks have been found in topaz and spodumene, but their mode of growth is unknown. (stone 40 mm long)



Figure 2. Brazilian amethyst with goethite inclusions (stone 12 mm wide)



Figure 3. Brazilian quartz cabochon with ilmenite and rutile inclusions. The rutile grew epitaxially from the edges of the hexagonal ilmenite platelet, orientated at about 30° to the base of the cabochon. (Stone 22 mm wide)



Figure 4. Scapolite from Merelani, Tanzania with unidentified inclusions (probably graphite). (Stone 18 mm wide)



Figure 5. Quartz with hollandite inclusions, from Madagascar. The hollandite sprays lie on phantom faces parallel to the original six rhombohedral faces of the quartz crystal. (Stone 20 mm wide)



Figure 6. Quartz cabochon with included haematite phantom, from Namaqualand. (Stone 28 mm wide, by Lorna Quinton)

ON GIVING UP FACETING

Giving up faceting is perfectly natural. The late Fr Tony Garman said he gave it up regularly - about once a month. It was good for his technique. I give it up more frequently, sometimes more than once a day, but usually in the early evening when I have been faceting successfully all day long and then find myself making mistakes, like setting the wrong index, or the stone starts scratching all by itself for no perceivable reason. Others give it up only once, permanently.

There are various reasons for giving up faceting, some remediable, others not. Those who give up permanently usually do so after cutting their first stone. They realise they lack the patience to grind and polish little flat faces on broken fragments of crystal, and sensibly avoid becoming permanently infected. Those of us who are permanently infected need help, and particularly when despair threatens. Giving up faceting for the night when you are tired works wonders. The next day your indexing problems and scratches often just vanish. Giving up because you just can't get it right needs more energetic remedies. Here you actually have to do something active to seek help, not just sleep on it.

Fortunately, these days there is plenty of help at hand. When I first learned faceting all there was as a source of advice was Vargas's "Faceting for Amateurs", and I had read it through often enough to know much of it by heart. The one professional faceter I consulted about a tourmaline polishing problem simply said "If it takes more than three seconds to polish a tourmaline facet you are doing it wrong". Fat help. But nowadays we have the internet, and it has transformed faceting. Anyone interested in faceting should join the United States Faceters Guild Faceters List on Yahoo <<http://groups.yahoo.com/group/usfgfaceterslist/>>. This is your entry to a world of online information and advice. Then you should download a copy of Faceters Companion <<http://www.rockhounds.com/oplc/>> and read everything in it.

Faceting despair usually is caused by a relatively short list of problems, which have a long list of possible solutions. Here are some shortcuts to solutions which have worked for me (they may not work for you though – that is the perverse beauty of this individualistic art).

Dopping involves gluing a piece of stone onto a metal rod. This is done using either wax or glue, or a combination of both. The combination method is gaining popularity and is described in detail by Tom Herbst <http://www.boghome.com/TomsPages/How_I_Dop/How_I_Dop.html>. He uses five minute epoxy, but I use cyano-acrylate (super glue) to attach the stone to a wax self-mould. Sounds complicated, but it's easy.

An erroneous faceting diagram can drive one to terminal despair. Remedy: pre-cut unfamiliar designs in GemCad by Robert Strickland. A free DOS based version is downloadable from <http://www.gemcad.com/>. Download all the free stuff from this site and then go back to Tom Herbst's site to download BOG. Armed with these programs you can 'cut' a stone on your computer to test the design, and then optimise its angles for best appearance. Learning these programs will keep you busy for weeks. You may even give up real hard rock faceting for a while because playing with these programs is so captivating.

Polishing problems probably cause the most desertions from faceting. They certainly prompt the most discussion on the USFG Faceters List. The solutions are numerous and depend on the nature of the polishing problem. There is no readily available scientific background to the polishing of gem materials, and all the advice is anecdotal, i.e. what works for the particular writer. There is no alternative but to experiment for yourself, which in itself can be bewildering. The options are numerous, but all involve either oxide or diamond polishing media, on plastic or metal laps. The USFG Faceters List site is searchable, and you can read numerous individual polishing recommendations there. There seems to be a general consensus (with exceptions of course) that cerium oxide on one of numerous plastic laps is good for quartz; aluminium oxide on metal laps, usually of some tin alloy, is good for most other things; and diamond on metal laps is resorted to for particularly hard or difficult materials. The most fashionable polishing medium/lap combinations, and lots of polishing tips, are available from Gearloose Lapidary <http://www.gearloose.co/>.

All machines need cleaning, servicing and sometimes repair. Faceting machines often need their alignment to be checked and adjusted, particularly as they age. If your machine is out of alignment it can make it impossible to produce symmetrical stones, and it will be very much more difficult to get your meets to meet. And apart from a good polish, symmetry and meeting meets is the meat of faceting. You really need to get to know your faceting machine, its quirks and inaccuracies, so that you can either fix them or compensate for them. In order to do this, you need to understand faceting machine alignment, no matter how daunting you might find this. Paul Head has written a short but comprehensive guide to checking the alignment of your faceting machine http://www.rockhounds.com/oplc/cd_online/faceting_articles/paul_head/alignment.html. Without working your way patiently through this procedure, you simply won't understand the functioning of your machine.

There you have it – remedies for all your faceting ills are literally at your fingertips, so there is no excuse for giving up faceting through despair; unless of course you realise at the outset that you really lack the patience to complete more than one stone.