Website Newsletter of the Cape Town Gem & Mineral Club

JANUARY/FEBRUARY 2022

DIARY

February	***5***	***10:00–14:00***	***Open to the Public Day – Rocks, gems, jewellery, mineral specimens to look at, chat about, or buy. NO MASK, NO ENTRY. All Covid-19 protocols still in force. STAY SAFE – GET VACCINATED.***
March	***5***	***10:00–14:00***	***Open to the Public Day – Rocks, gems, jewellery, mineral specimens to look at, chat about, or buy. NO MASK, NO ENTRY. All Covid-19 protocols still in force. STAY SAFE – GET VACCINATED.***
	12		***ANNUAL GENERAL MEETING***

From 0 to 5 762 and Counting: Where Did All These Minerals Come From?

by

Peter Rosewarne

Introduction

There were 3 350 mineral species recognised by the International Mineralogical Association in 1992, >4 200 in 2006 and 5 762 as of November 2021. Have you ever wondered what the first mineral was, how long minerals take to form, where all the elements came from to make them or where the elements came from that make up you/us for that matter (pun intended)? If you believe in a flat Earth and /or that the Earth was created in seven days, then this article isn't for you. However, if you believe in the *Big Bang* theory for the origin of the Universe and in evolution then read on.

Background

Re-reading some books recently on astronomy such as Stardust (Gribbin, 2000) and a past issue of the Mineralogical Record (Vol 46, No 6, 2015) I came across some very interesting background information to the questions posed above. This also took me back to two questions in my Geology finals exams in 1973 which I remember answering, namely, "Write an essay on the origin and development of the earliest crust of the Earth", and, "Give an account of the geology of the Moon". These topics sparked an early interest in the history of the Earth and the Universe which has been expanded over the years by reading numerous 'science-for-the-masses' types of books, in particular, those written by John Gribbin and Stephen Hawking. What have these got to do with minerals and gems you may ask?

Well, as it turns out, everything, although mineral evolution *per se* apparently only came to be seriously researched from 2008 (Hazen, 2015). Note: complex astronomical and physical processes are simplified herein and are not necessarily 'exact' in terms of strict scientific definitions.

Nucleosynthesis and Stardust

Evidence from the so-called *red shift*[1] of light from stars and galaxies indicates that they are all moving away from each other, and it therefore follows logically that all matter or energy (remember $E=mc^2$?) started out concentrated into a single super-dense point or *singularity*. It is generally accepted by cosmologists that the Universe was 'born' about 13 to 15 billion years ago in what has been termed the *Big Bang* when this singularity expanded and, simplistically put, energy was converted into mass. Next time you are tuning your TV into a station and you get 'static' interference on the screen, stare at it in wonder because a small part of that interference is background microwave radiation from the Big Bang that fills all of space in the Universe.

Initially, and for perhaps a few hundred thousand years thereafter, all matter was in the form of a super-hot and dense *plasma*[2] too hot for any atoms or molecules to form. Once the plasma had cooled down enough for atoms to form, hydrogen (H) and helium (He) were produced and gas started to form clouds and clump into protostars and galaxies under the influence of gravity. These early gas and dust clouds may have looked something like in **Figure 1** (after Weiler, 2010), the Cone Nebula, which is 7 light-years[3] long and resides 2 500 light-years away from Earth in the constellation Monoceros.

Figure 1: The Cone Nebula

In the very hot core of these stars a fusion process was set in motion; two H atoms combined to form a He atom; three He atoms then combined to form carbon (C) and so on. This *nucleosynthesis* process could proceed up to the formation of iron (Fe) with an atomic weight[4] of 26 as all these fusion processes generate energy which kept the stars shining, hot and stable. However, when Fe fuses with H to form nickel, it requires an energy <u>input</u> and signals the death-knell for the star.

These first order stars then followed a lifecycle trend that depended on their size, with stars the mass of our Sun expanding into red giants after about 10 billion years of pumping out vast amounts of energy and then collapsing into neutron stars. Stars with a mass of eight times the Sun or more became unstable as their H fuel was used up and they exploded violently in a *supernova.* In the process of these supernovae all 72 elements up to uranium (U) were formed and blasted out into interstellar space as "stardust." An example of a supernova is the Crab Nebula, which was first seen by Chinese astronomers over 1 000 years ago (**Figure 2**, after Weiler, *op cit*). OK, I hear you say, this is all very well, but what about minerals?

Figure 2: The Crab Nebula

[1] Similar to the doppler effect for noise whereby light from objects moving away from an observer is shifted towards the longer wavelengths at the red end of the visible spectrum.

[2] A hot, dense mass of protons and electrons interacting with radiation

[3] The distance travelled in a year by light at a velocity of 300 000 km/s (c)

[4] Number of protons in the nucleus

The First Minerals

Scientists have deduced that the first mineral to form in the Universe, to crystalise, was diamond (see **Figure 3**). This occurred from gases and carbon atoms in the outer atmosphere of the stars where temperatures were of the order of 4 000°C. Diamond was closely followed by graphite and then a further 10 so-called Ur[5] minerals, some of which are familiar and some not. The more familiar ones to us mineral enthusiasts are:

Name	**Formula**	**Class**
Diamond	C	Native element
Graphite	C	Native element
Rutile	TiO_2	Oxide
Corundum	Al_2O_3	Oxide
Spinel	$MgAl_2O_4$	Oxide
Forsterite (Mg-rich olivine[6])	Mg_2SiO_3	Silicate
Enstatite (Mg-rich pyroxene)	$Mg_2Si_2O_8$	Silicate

Figure 3: Octahedral Yellow Diamond Crystal, Duitoitspan Mine, Kimberley Area

The diamond shown at left has been dated at 3.3 billion years old and is one of the oldest known (after De Beers UK, carats not stated).

All of these formed from 10 elements up to the atomic weight of Fe. Enstatite and olivine will be familiar to petrologists as minerals typical of early crystallisation from basaltic magmas at high temperatures. A crystal of forsterite, variety peridot, from the island of Zabargat in the Red Sea (formerly known as St. John's Island) is shown in **Figure 4** (Natural History Museum, London). I presume that it is no coincidence that two of the earliest-formed minerals, diamond and corundum, are the two hardest on Moh's scale of hardness and are prized gems and others are 7-8, although graphite is also one of the softest. However, it is the stable form of carbon and diamond reverts to graphite if the temperature is too high and so this presumably explains its presence in the early Universe and also in some meteorites.

Figure 4: Forsterite Variety Peridot, 686 carats

With the passage of *lots* of time gas (mainly H and some He), the 12 ur-minerals and dust containing traces of all the remaining 62 elements formed by nucleosynthesis coalesced into clouds under gravitational attraction and then further into clumps of matter. Our solar nebula evolved into the central Sun, a second-generation star, four inner rocky planets, including the Earth and four outer gas giants. About 98% of this matter went into forming the Sun which consists of about (estimates vary) 75% H and 24% He and the balance, the heavier elements. As an aside, scientists believe that the majority of the Universe is made up of so-called dark matter, not the stars that shine, but the nature of it has not yet been determined.

5 After Ur the first centralised city-state in the ancient civilisation of Mesopotamia.

6 Forsterite and enstatite always contain some Fe as they are in solid solution with fayalite and ferrosillite, respectively.

Meteorites

Meteorites are remnants of the bits of matter left over from the formation of the solar system about 4.6 billion years ago and, rarely, from our moon, Mars and very rarely, outside of the solar system. Most come from the *asteroid belt*, a region of irregularly shaped objects of mostly <<1 000 km in diameter between the orbits of Mars (a rocky planet) and Jupiter (a gas giant). Some of these asteroids are of dwarf planet size (Pluto has been demoted to a dwarf planet) which have cores and mantles not dissimilar to the Earth's.

Meteorites are grouped into three main categories, irons, stones (chondrites) and stoney irons. The irons consist of a mixture of iron and nickel thought to represent the remains of the core of a planetoid (mass the same as or smaller than Pluto), while the stones represent more differentiated material and the stoney irons are thought to be from the mantles of a planetoid(s). *Pallasites*, a type of stoney iron, form some of the most aesthetic meteorites, especially when cut into slices, with yellow-green olivine crystals set in a matrix of iron-nickel (see **Figure 5**), often showing the characteristic Widmanstatten lines[7]. Chondrites are considered to most closely resemble the chemical composition of the early Earth. A meteorite is the oldest object you can hold in your hands.

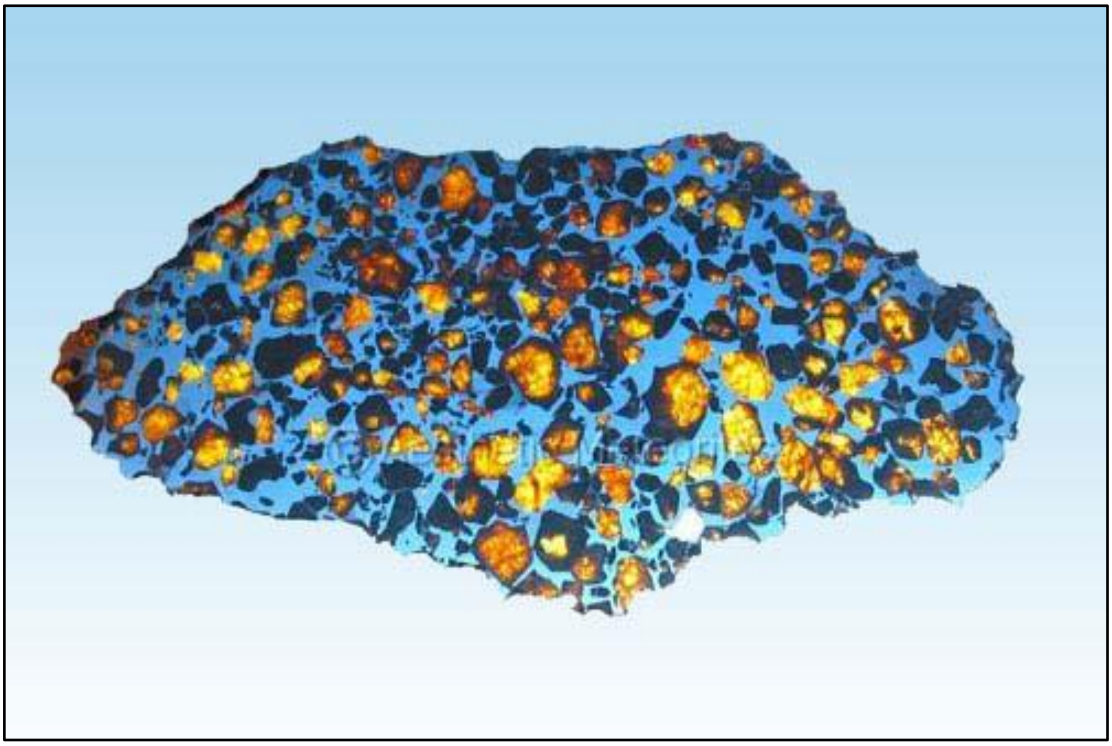

Figure 5: Pallasite Meteorite

The number of minerals occurring in chondrite meteorites is 60 and in all known meteorites is 250. It has been shown that physical processes and the presence of water, as operated on Earth in its early days of evolution, can explain the development of about 1 500 mineral species. These processes included plate tectonics, volcanism and development of an atmosphere and hydrosphere. However, there are some 5 762 and counting mineral species known on Earth so where did the balance come from? The answer is from life. By contrast, it has been calculated that only 420 minerals are possible on an inactive planet with no life, such as Mars.

The Great Oxidation Event

Up until about 2 billion years ago any excess oxygen (O_2) produced by cyanobacteria through photosynthesis was rapidly absorbed by abundant ferrous iron (Fe 2+) to form ferric iron (Fe 3+). This explains the origin of the world's large, banded iron ore formations, e.g. Sishen (see **Figure 6** below)**.**

[7] Crystal structure of iron and nickel on a polished meteorite surface revealed by acid etching

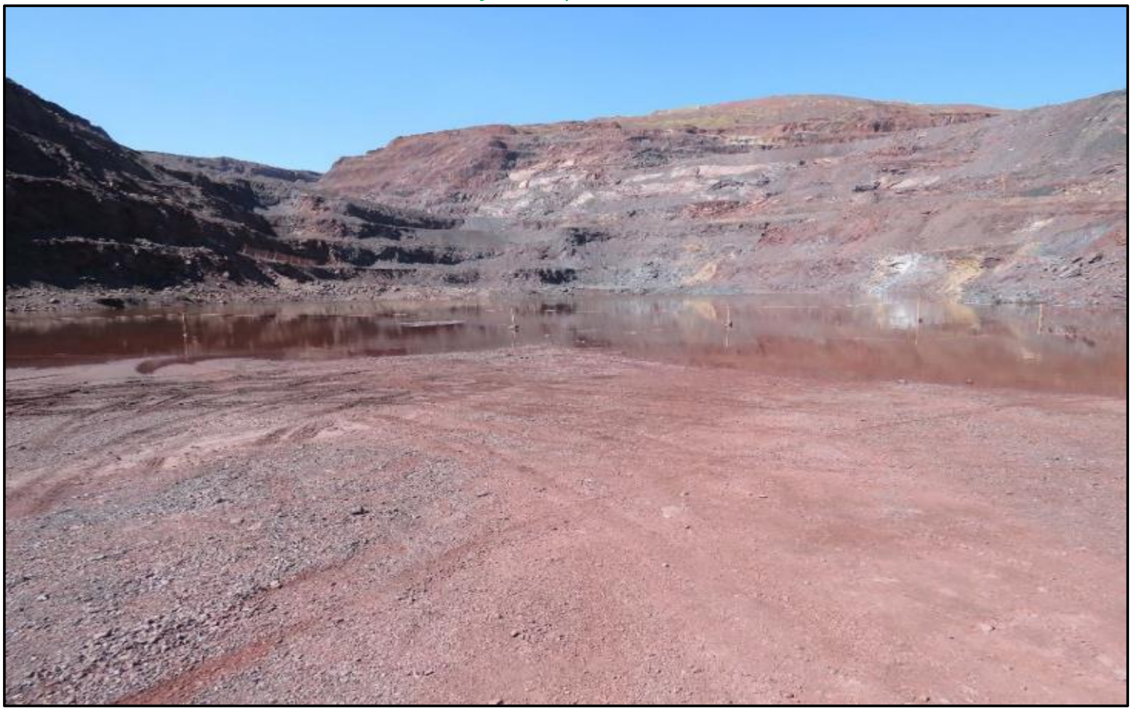

Figure 6: Part of Sishen Iron Ore Mine

It was not until cyanobacteria (see **Figure 7**) were sufficiently widespread and numerous for excess O_2 to be produced that O_2 was available to be incorporated into minerals. Remember, there were no higher organisms around to feed on them. This is known as the *Great Oxidation Event* and allowed the formation of hitherto unknown colourful oxides of e.g. copper, cobalt, nickel and uranium. Minerals in various shades of *inter alia* red (cuprite), green (malachite), yellow (autunite) and blue (azurite) were formed, so beloved by mineral collectors around the world. Manganese also began to be deposited as Fe was depleted and this phase gave rise to the Kalahari Manganese Field. The cyanobacteria formed dome-like clumps called stromatolites (see **Figure 8**) which eventually became thick deposits of dolomite, such as occur on the West Rand (Malmani Dolomites) and Ghaap Plateau.

An interesting finding of scientists researching mineral evolution is how long it took for mineralising fluids to attain concentrations of e.g. beryllium sufficient to start depositing beryl such as aquamarine in pegmatites. These minerals only appeared after about 2 billion years (see **Figure 9**).

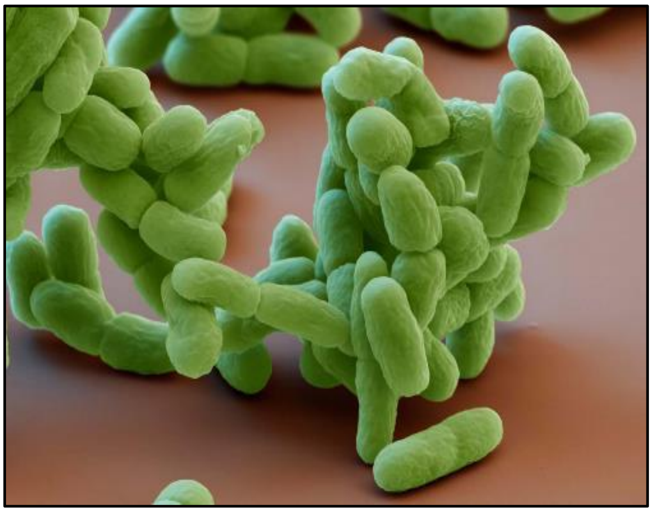

Figure 7: Cyanobacteria

Figure 8: Modern-Day Stromatolites

Figure 9: Varieties of Beryl – Goshenite, Emerald and Aquamarine

Life and a Dynamic Earth

A second boost to mineral formation came about 540 million years ago when primitive life forms started forming crystalline shells, followed shortly, in geological terms, by teeth and bones. These were formed of carbonates, phosphates and silica. There are also regular boosts to mineral formation seen in the geological record and these phases coincided with continent formation/orogeny and subduction and volcanism associated with plate tectonics. A classic example is the Arizona-Sonora Copper Porphyry Belt in northern Mexico/southern Arizona (65–50 Ma), which hosts several well-known ore bodies/mines such as Milpillas, which has produced world-class azurite (to rival Tsumeb), malachite, brochantite and olivenite specimens (see Mineralogical Record September-October 2021 issue). Exotic new minerals were brought to the surface during these orogenic pulses, such as kyanite, staurolite and sillimanite, all alumino-silicates usually associated with medium to high grade regional metamorphism (see **Figures 10a, b** and **c**).

Figure 10: a) Kyanite. b) Staurolite (unusual twin) c) Sillimanite

Figure 11 below shows an annotated sequence of mineral formation on Earth over its history.

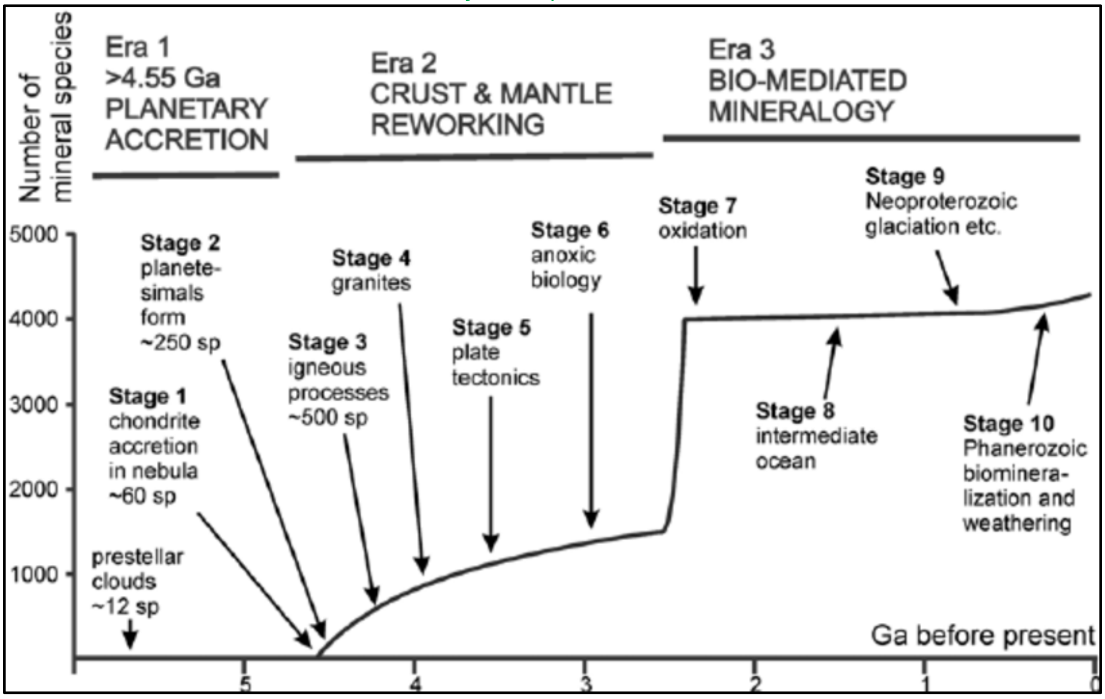

Figure 11: Mineral Evolution on Earth[8] (from Zalasiewicz, 2014)

Some interesting statistics on minerals that you might not be aware of include (Hazen, *op cit*):

- Some 1 100 species have only been identified from one locality.
- More than half of all known minerals are only known from 5 or fewer localities.
- Scientists believe that there are still about 1 500 species to be discovered.
- It has been shown statistically that if the whole process of mineral evolution started from scratch again, you would end up with as many as 25% different species from what we know today.
- Earth's mineralogy is probably unique in the Universe.

Mineral Formation in Southern Africa

A broad, vastly simplified sequence for mineral formation in South Africa (excluding early differentiation of the core and mantle of the Earth) could look something like this, from Archean to Recent times:

- Zircon. Quartz, feldspar and mica (earliest granitic crust of the Kaapvaal Craton). Chlorite, serpentinite, actinolite and other green amphiboles, chrysotile asbestos, talc, magnesite – *after* original mafic/ultramafic volcanics (Barberton Greenstone Belt)
- Gold, antimony, emerald (Barberton, Witwatersrand)
- Dolomite (Transvaal Sequence)
- Hematite, magnetite (Sishen)

→(Great Oxygen Event)

- Manganite, hausmannite, braunite (Kalahari Manganese Field)
- Chromite/Platinum group metals/andalusite (Bushveld Igneous Complex and marginal rocks)
- Apatite, vermiculite, phlogopite, diopside (Palabora intrusions)
- Copper sulfides and later oxides, beryl, tantalite, scheelite (Koperberg Suite, N. Cape pegmatites)
- Coal, uranium oxides (coffinite, uraninite), molybdenite (Karoo)
- Phosphates, amber (Tertiary)
- Anthropogenic minerals (Recent/Anthropocene) Not usually counted as they are synthetic.

Concluding Remarks

So there you have it; a Big Bang, plasma, H and He gases, protostars, fusion, formation of the 12 ur-minerals, collapse and supernovae, seeding of interstellar space with gas and dust containing ur-minerals and traces of 62 other elements up to U, accretion, formation of second- generation stars and planets such as the Sun and Earth with some asteroids left over, the miracle of life, evolution, plate tectonics, c.5 762 mineral species and you, who are made of

[8] Ga – billions of years; sp – mineral species

these supernovae atoms, and your minerals, which also owe their origin to supernovae about 4–5 billion years ago. Where will it all end? Will the Universe keep on expanding for ever or will it reach a point where gravity causes it to start contracting, eventually back to a black hole or singularity? By that time, we will all be stardust again after the Sun has expanded as a Red Giant in about 5 billion years' time and cooked the Earth in a sort of grand cremation (check what you've requested in your Will!) and we will all eventually form part of some new cosmic cycle. Or perhaps by then humans will be saying," Beam me up Scotty!" 😊

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From the Cabinet of Curiosities

This 20cm wide curiosity was found a while ago in a Durbanville junk shop. It is seemingly an item of memorabilia from the construction of the Du Toits Kloof Tunnel between 1984-1988. Possibly it was given to the General Manager of the project, as it has the initials GM hand-written on its base.

The Du Toits Kloof tunnel was bored through Cape Granite and they had to use freezing techniques to stop a large mud/water inrush at one stage. But what sort of granite is this? It seems to have 'normal' grey quartz, pink feldspar and black biotite/amphibole but what is the greenish mineral? Partially altered feldspar? Is this granite on its way to becoming unakite? And we wonder who was the general manager for the project?

Curious!

Describe your own original curiosity and send it to us with a photo.

BITTEN BY THE GEM CUTTING BUG? NEED HELP?

Duncan Miller

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.

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://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=oD6ZlNmtwmM). 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/).

More 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).

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