The ruby mines of Mogok

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The world's finest rubies all come from the metamorphic rocks of Mogok, in Myanmar. Traditional methods of mining, with little mechanization, are still used; they work best in digging the gemstones out of narrow calcite veins and thin beds of buried placer gravel.

There is an elite group of names on the world map – Klondike, Kimberley, Coober Pedy and a handful of others – that are synonymous with mineral wealth and all that is exciting about geology and treasures from the ground. Right there among them is Mogok, the town and the valley that produces nearly all the world's gem-quality rubies. That Mogok may be less widely known is due to its location; it lies tucked away in the Shan mountains east of the Ayeyarwady River, in the heart of Myanmar, the nation that used to be known as Burma (Fig. 1).

It is unfortunate that Mogok's rubies have been mired almost permanently in political turmoil. It is not known when they were first found, but Marco Polo recounted stories of fabulous ruby wealth before 1300. In 1597 the King of Burma (the lowlands of the Ayeyarwady basin) took Mogok from the Shan rulers (who controlled the highlands) and worked the mines with slave labour on a steadily declining scale. The British created Burma by combining the Burmese and Shan states, and ran the mines from 1886 until 1925, when its company collapsed in a failed attempt at mechanizing the mines. Small private mines resumed working in 1931. Burma became independent in 1948, but the illegal Ne Win regime took control in 1962, and nationalized the mines the year after. Since then the mining has thrived, because it was a major earner for the regime, and renewed partial privatization ensures continuing activity today.

Fig. 2. The valley floor at Kyatpyin.

Fig. 1. Outline map of Myanmar and just the most important mineral sites. Mogok lies in the highlands east of the Ayeyarwady plains.

Myanmar is the new (and more historically correct) name for what was Burma, and it was an almost totally closed country from 1962 to 1992. Its borders are opening only slowly, but visiting most parts of the country is now possible. Sadly, the military junta retains an immoral control, and the elected leader Aung San Suu Kyi remains under virtual house arrest. So the politically aware visitor travels independently in Myanmar, using local transport and private facilities where possible, thereby minimizing cash flow to the junta's nationalized tourist structure that handles all the group tours. Myanmar is a beautiful country inhabited by lovely people; a visit is a delight.

Mogok has recently ceased to be a closed site, so now belongs on the itinerary of any visitor with a geological interest. It is reached in about five hours by road from Mandalay. Mogok's rubies are still largely extracted by traditional methods of mining that are labour-intensive but remain appropriate (Fig. 2); they provide an insight to mining in the largely closed parts of Myanmar that are rich in precious minerals, with jade (the real jadeite), placer diamonds (of poor quality, and kimberlite pipes have not yet been found) and vein and placer gold, beside ruby and

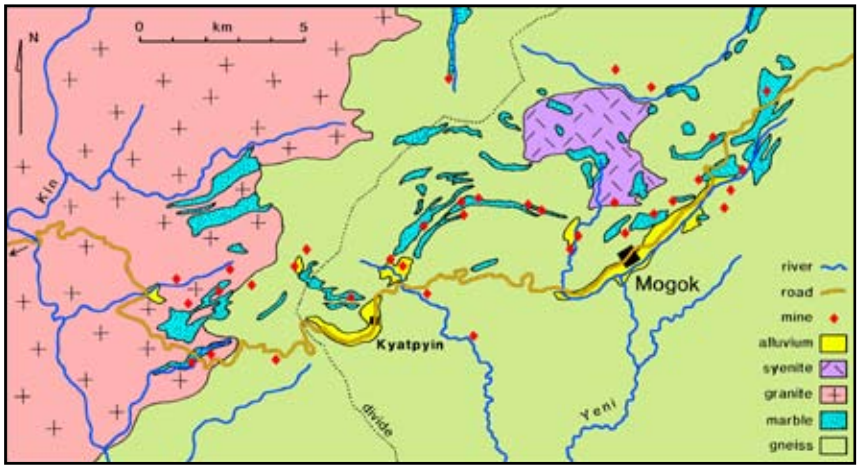

Fig. 3. The main geological features of the Mogok Stone Tract. The alluvial *byon* of the Mogok and Kyatpyin valleys has shaft mines and open pits throughout the outcrops, and individual mines are not marked. Only the mines referred to in the text are named. (For meaning of *byon* see later text.)

sapphire at sites other than Mogok, and a host of lesser gemstones.

The area known as the Mogok Stone Tract straddles the divide between the basins of the Kin and Yeni Rivers (Fig. 3) close to the western edge of the great ranges of north–south mountains that form the Shan State of eastern Myanmar and extend into China and Thailand. Mogok is the main town, in the largest valley of the Yeni catchment, but villages have grown in every valley with an alluviated floor that can be cutivated for rice or dug for rubies. The valleys lie at elevations of about 1200 m, between forested mountains that rise to over 2000 m. A blacktop road heads west to a ferry port on the Ayeyarwady River, but the main route down the valley is now on the relatively new road south to Mandalay.

Ruby and sapphire

These two intensely coloured minerals are both varieties of Al_2O_3, corundum (Fig. 4). They are formed mainly in high-grade metamorphic environments where hydrothermal fluids meet limestone. The red in ruby is due to isomorphous replacement of some aluminium by chromium, and the typical crystal form is a hexagonal prism with flat terminations. Star rubies contain fibres of rutile that follow the hexagonal structure; when cut into domed cabochons and viewed under a strong lamp, these fibres create a star of light rays. Gem-quality rubies larger than 10 carats are very rare, at Mogok or anywhere else, and the largest gems are therefore more prized than diamonds.

Fig. 4. Minerals of Mogok: on the left, a cleavage rhomb of calcite contains a chip of ruby; on top of it stands a hexagonal prism of ruby, waterworn because it came out of the *byon* placer; on the right, a crystal of poor-quality sapphire protrudes from its syenite host: the ruby prism is 9 mm high and weighs 7 carats.

Sapphire's blue colouring is due to titanium, and its crystals typically occur as barrel-shaped bipyramids. Stones of poor quality commonly exceed 25 mm in diameter, but the Mogok sapphires do not have the rarity value of the rubies. A sapphire crystal of 63 000 carats, over 150 mm in diameter, is the largest found at Mogok this century, but sadly it is not of gem quality.

It is perhaps disheartening for the industrious miners that the most abundant red minerals at Mogok are not ruby but spinel. These are the $MgAl_2O_4$ member of the spinel isomorphous series (including magnetite) that form such excellent octahedral crystals. Their colour is a pure red, as distinct from the slightly purplish hue of the ruby, whose best colour is described as that of pigeon's blood. Spinels do have their own value, much less than that of rubies, and many have been set into jewellery under the mistaken impression that they were rubies.

The geology of Mogok

Mogok lies in a belt of high-grade metamorphic rocks that form much of the Shan state mountains and are thought to have originated largely as Precambrian sediments. The dominant rock around the Mogok valley is banded gneiss with biotite, garnet, sillimanite and oligoclase. Within it, bands and lenses of marble are distinguished by grain sizes that reach up to 80 mm in spectacular mosaics of calcite rhombs; there are minor dolomitic marbles and also various calc-gneisses. The marbles north-east of Mogok are karstified; the Pinpyit sinkholes, some large dolines and the Onbinyedwet risings are all close to the cave passage found in the Dattaw mine (Fig. 3).

Intruding the metamorphic series is the biotite granite of the Kabaing pluton, with its outcrop just west of Mogok. There are also large outcrops of alkaline syenite and a lesser extent of urtite (a nepheline aegerine intrusive). Both marble and urtite appear as large floats within the granite, and it is likely that the two alkaline rocks were produced by assimilation of carbonate into the granitic magma.

No clear metamorphic aureole has been recognized in the gneisses that are in contact with the granite, but there are many features of metasomatism and hydrothermal reaction. Some large pegmatite dykes have crystals of lepidolite, topaz and clear quartz all up to 150 mm across, and have lapis lazuli at sites of pneumatolytic reaction with bands of marble. Nearly all the primary rubies and spinels occur in calcite veins and marbles that are within the gneiss away from the granite; marbles in the Kin valley lie wholly

within the granite but contain no gemstones. Both the rubies and the spinels appear to be features of distal hydrothermal reactions with marble. The sapphires are different, in that their primary source is the syenite, with some in the urtite and very few occurring in calcite.

Most of the gemstones are mined from a secondary deposit known as *byon*. This is essentially an alluvial and lacustrine soil; most of it is therefore sorted and stratified, but it does include units of unsorted colluvium. It is up to 50 m thick under the valley floors, and extends along the Mogok valley for 5 km long and up to 1 km wide (Fig. 3); there is more of it in small patches and terraces higher on the hillsides. *Byon* is all derived from weathering of the gneisses and the granite, and also contains the insoluble residues from the marble. It is therefore a natural trap for the heavy gemstones; at most sites, fluvial sorting during deposition of the alluvial material created the fossil placer deposits that are the paystreaks now searched out by the miners.

Barren red earth and colluvium, 2–10 m thick, now blankets the outcrops of bedrock and alluvial *byon* alike. Combined with the dense vegetation cover, this makes detailed geological mapping and systematic mineral exploration next to impossible. The Linyaungui mine was founded in 1970 when prospectors dug deeper into strips of ruby-rich soil that lay along the weathered veins. The last new site was found purely by chance, when a landslide exposed sapphires that were spotted by passing hunters; two mines are now working into the hillside.

There are now over 1000 mines in the Mogok Stone Tract, about half in the *byon* and nearly as many in bedrock. Most are small operations, very traditional and very well suited to the local geology, but some are larger and more mechanized.

The shaft mines

For hundreds of years the Mogok miners have recognized that the best rubies are found in the thick soils, the *byon*, of the valley floors. Modern placers have never yielded great numbers of stones at Mogok, but they pointed the way to the deep valley soils as the source of further riches. The oldest type of mine is the *twinlon*, a round, unlined shaft that was sunk through cohesive soils to depths of about 15 m. Digging down, the miner looked for traces of garnet and mica, which are the most conspicuous markers of a mineral-rich horizon in the layered *byon*. Once a horizon was found, levels were dug outwards to extract as much of the rich earth as possible.

Unlined *twinlons* have their limitations, and the main type of shaft mine used today is the *lebin* (Fig. 5). This is a square shaft, 1200 mm on its edge, lined with a framework of bamboo and timber that holds back a matte of leaves. This is stable in less cohesive sandy soils, and can be taken to depths of 30 m in search of deeper pay horizons within the *byon*. At each successive horizon, galleries reach as far as is reasonably safe in the loose ground, generally no more than 10 or 12 m. And once good ground is found, more and more shafts are sunk, rarely more than about 10 m apart; the end effect is comparable to an old English bell-pit field.

Each *lebin* is worked by three men. One digs the earth with a shovel, one hauls it back to the shaft foot, and one works the winch, powered or by hand, on the surface. A sheet of metal foil over the winch reflects sunlight down the shaft, to another reflector below. Ventilation is a domestic fan linked to flimsy polythene tubes, with junctions made out of supermarket plastic bags. Safety clothing is shorts and T-shirt, and there is no ladder in the shaft – just climb down the bamboo lining, carefully. The method has worked for centuries; why change it? But the hand winch has replaced the old *maundaings* that were used on the shallower *twinlons*; these were huge bamboo cantilevers mounted on high frames, rather like man-powered nodding giraffes (since copied in the oilfields).

At a cluster of dozens of *lebins* near Kyatpyin, porters carry the mined earth from the shafts' winches across to a collective washing site (Fig. 6). The earth is tipped into open boxes 3 m square, where it is soaked and trampled to break it up. All but the large rocks are shovelled into large hand sieves with a very fine mesh. Bent double, the miners shake and twist the sieveful of soil half in water, so that all the heavy gemstones sink to the centre middle. With an adept flip, they upturn the sieve's contents onto the spoil pile – and all the gemstones are sitting on top, waiting to be picked out by nimble fingers. Colour is the big guide, and they can always tell a ruby from a spinel, but they take out all the

Fig. 5. Two of the *lebin* shafts at Kyatpyin. Each is 30 m deep, and ventilation is provided by air pumped through the plastic piping that emerges from the carrier-bag 'junction box'.

stones of value. The rest is dumped, and young boys re-sieve it to find yet more stones, mainly the smaller spinels. Then the bottom scrapings from each box are carefully collected and sieved for the heavy gemstones that sank through the freshly trampled soil; and then a new load of soil arrives.

The open-pit mines

The few large and relatively modern open-pit mines have the benefit of clearly exposing the geology. One of the largest currently working is the Shwepyiaye mine just outside Mogok town. Started in 1987, its pit is now about 300 m across and over 30 m deep (Fig. 7). Nearly 10 m of barren red soil overburden has been stripped away to expose the *byon*. This has many mineral-rich horizons within it, so the whole lot is scraped up with a backhoe and trucked out. Half goes to the washing plant and half goes onto a stockpile, ready to be washed in the monsoon season when the pit is all too often flooded.

Machinery cannot cope with the rockhead at Mogok, which is fretted by karstic dissolution of the marble into a pinnacled profile (Fig. 8). Fissures isolate blades, ribs, arches and spires that stand up to 5 m high. This chaotic surface is exhumed from a sticky clay, the lowest bed of the *byon*. It can also be the richest, because the soil has been disturbed, ravelled and leached down into the marble, and many of the heavy gemstones are found right at the rockhead. Dozens of miners swarm over the fretted marble, and every bit of the soil between the pinnacles is carefully dug out by hand, so that bags of rich soil are heaved onto the backs of more porters, destined for the washing plant or stockpile.

Fig. 7. The Shwepyiaye open pit. Ruby-bearing alluvial *byon* is excavated on the right by machines, until rockhead is reached. *Byon* between the rockhead pinnacles is hand worked on the left. The upper bench exposes the cover of barren red earth.

Fig. 6. Sorting the mined earth from a group of shaft mines at Kyatpyin. Rubies are concentrated at the bottoms of the seives that are hand-shaken in water.

The washing plant at Shwepyiaye is a partly mechanized version of those at the shaft mines. Truckloads of the gem-bearing earth are tipped into concrete basins where powerful jets of water break them up and wash all but the large boulders through 60-mm screens into a water sluice. A screen in the sluice separates fractions larger and smaller than 20 mm, both of which drop through into large vibrating sieves. Just as in the hand sieving, water and clay drop through the fine screen, and the gems are concentrated at the bottom of the clean gravel of each size. Overturned onto tables, the precious stones are picked out by operators with eagle eyes and pairs of tweezers (Fig. 9). Each day the plant processes about 100 tonnes of *byon*, to yield about 25 carats of ruby, the same of sapphire, and more of spinel and other stones. The yield of rubies is therefore around 0.05 ppm, which is about half the yield rate at a good diamond mine and accounts for the rarity value of ruby. But every so often a jackpot stone comes out of that upturned sieve.

Spoil from the big pit goes out with the sluice water and is reworked by the *kanase*. These are the poor people – originally just women – who have hereditary rights to work these tailings; they sieve and wash the soils all along the streams downstream of the mines (Fig. 10). It's the nearest there is to traditional placer mining, except that they never use the gold miners' pan; rubies are not heavy enough to settle in the swirl of a pan, and ruby dust is worthless, so the throughflow in a sieve is far more efficient.

Another type of open mine at Mogok is the *hmyawdwin*. Similar to an old Pennine hush, a stream is turned down a hillside to scour out the *byon* and create a natural sluice into which more earth is shovelled, before the whole lot is sieved by hand at the foot of the slope. These *hmyawdwins* are now found only in the hills, where they are commonly sited in old terrace deposits.

The hard-rock mines

The oldest mines into the rock are the *loodwins* – tunnels that were driven to follow the bands of crystalline calcite richest in ruby. The productive calcite is clearer than the milky rhombs of the main marble and appears to be the result of hydrothermal redeposition at the time when the rubies were formed.

Gatotat is a deep mine into bedrock. Its richly mineralized calcite vein appears to be a hydrothermal feature within a narrow band of marble that lies within the gneiss (Fig. 11). It is just 2–3 m wide, dips at 80° and has been followed to a depth of 300 m. There are 15 stagings within this huge open stope, amid a minimum of timber braces, with no sign of any ladders. It takes over an hour for the miners to climb down to the working faces, and all the calcite that they break out of the vein is shuttled up each of the 15 stages by hand-powered winches. For hundreds of metres along the vein, winchmen pull up buckets of crystalline calcite, which is then hammered open by groups of men and women in their endless search for the hidden rubies, with spinels coming out as a consolation prize.

At the Linyaungchi mines, a hill of marble is riddled with tunnels at multiple levels that follow a complex of calcite veins on one major fault and a suite of minor faults. The tunnels are now partly exposed on one side by an open pit that has stripped the *byon* right back to the hillside rockhead (Fig. 12). The active tunnel, 2 m high and wide, is timber-propped through stacked deads, and was advanced by blasting, with shotholes placed by a hand-held percussion drill on a single pneumatic leg. It heads into a complex area of collapse where an older tunnel has been breached, and the whole zone of fallen soil and rock may well have been a filled karstic sinkhole (nearby, the Dattaw mine broke into a natural cave more than 10 m high). The miners just know that this zone yields good rubies, so they keep digging away in not very safe conditions. A notice in the mine office lists the 127 rubies and 10 sapphires of gem quality larger than 3 carats that have been found in the last three years; the largest ruby was 87 ct, and sold for £100 000.

The problem with the deep mines is water. Only since 1970 have they extended below valley floor level, where they require continuous pumping. Through the monsoon the mines are allowed to flood, but they are normally pumped out in November and worked from December to May. This has to be a co-operative effort between all the mines, and in 1998 there was no deep mining because prices were down and pumping was economic; but 1999 was better and the mining resumed.

Fig. 8. A deeply fissured rockhead is exposed in the Shwepyiaye pit where the *byon* soil has been dug by hand from between the marble pinnacles. Sacks of *byon* are carried by porters from the pit to the washing plant.

Fig. 9. (below) The sorting tables at the Shwepyiaye mine. Each sorter picks over a pile of stones upturned from a sieve, with the heavier dark stones concentrated in the centre.

Fig. 10. (above) *Kanase* people working the stream sediments for small escaped stones, downstream of the Linyaungchi mine.

Fig. 11. The Gatotat mine, a deep vein stope open to daylight.

The gem markets

Mogok and Kyatpyin are the main towns of the area, and both have extensive open-air markets that include large sections for dealing in rubies. Most of the stones from the smaller private mines are traded through these markets, and dealers periodically come up from Mandalay and Yangon. Nearly all the trading is by women; they gather in groups around low tables and produce paper packets from their pockets and handbags (Fig. 13). Unfolded, they reveal collections of stones; most are uncut, flawed, under 10 carats and less than 10 mm across. Stones are passed around for inspection amid complete trust; discussions of value are quiet, discreet and confident, but thick wads of banknotes regularly change hands. Not just ruby – they also trade the sapphire, spinel, topaz, peridot (which is snapped up by the Chinese with their love of green stones), tourmaline, smokey quartz, lapis lazuli, moonstone and all the lesser gemstones that are dug out of Mogok's provident *byon*.

Fig. 13. (right) A dealer in the Mogok gem market displays a handful of uncut rubies on an open table.

Fig. 12. Old tunnel mines are exposed in the marble at the Linyaungchi mine, where all the *byon* cover has been worked out, and the miners are now blasting into bedrock.

Away from the markets there are gem shops, many of which have cutting rooms behind them. Again, it is mainly the smaller stones that are worked locally, but they expertly facet the clear stones and polish the star stones into rounded cabochons. An uncut ruby crystal of 50 carats was offered for £700, while a large star-ruby cabochon was there for £300, but bargaining is a way of life, and the offer price is always way above the amount that finally changes hands.

Most of the ouput from the government-owned mines, and all the large stones, go straight to the Myanma Gems Enterprise in Yangon, where serious money can be encountered. The 87-ct ruby from the Linyaungchi mine sold for £100,000, and a 47-ct stone of better quality from the same mine earned £900 000. The Nawata ruby is a flawless, gem-quality 504 carats found in the Dattaw mine in 1990; beyond valuation, it is now a national treasure.

On such wealth a town can thrive, and there are now about 400 000 people living off the rubies (and a little farming) in the Stone Tract. They produce over 100 000 carats (20 kg) of rubies per year, and three times that amount of other gemstones. The town of Mogok stood initially on the valley floor, but was completely moved before 1900 so that the valley could be transformed into a giant open pit. This was at the peak of the British era of mining, when the valley *byon* was found to have 17 ruby-rich horizons. The huge open pit was drained by a tunnel 2000 m long, but when this collapsed in 1925 the pit flooded; it is now the lake that lies in the heart of the town.

Fig. 14. Buddhist *zedis* rise above the mixture of housing along the main road into Mogok.

Mogok still has the transient air of a miners' town (Fig. 14). Its buildings are all new and its main street is untarred, while there is a general buzz of activity; the people seem to have a purpose as they walk about the town – and many of them have a pocketful of rubies. It's the sort of place that makes geology come alive, and it's well worth a visit.

Suggestions for further reading

Iyer, L.A.N. 1953. *The Geology and Gemstones of the Mogok Stone Tract*, Burma, Memoir of the Geological Survey of India, v.82, 100pp.

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