The Malmberget iron mine, Sweden – A world class mineral locality

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Abstract

The Malmberget iron mine near Gällivare, Lappland, Sweden has produced a series of well crystallised, interesting mineral species since the end of the 19th century. Since the 1980's the author has documented and participated in some discoveries of exceptional crystals such as hematite, calcite, fluorite, stilbite, stellerite, pyrite, fluorapatite, quartz, feldspars, ferrohornblende, chalcopyrite, titanite etc.

It should be noted that during most of the last two decades, primarily a couple of miners have had the license from the mining company to recover mineral specimens. These miners, together with the miners giving them tips of encountered pockets, and the positive attitude of the LKAB mining company to restricted mineral specimen recovery, are the true heroes of saving world class specimens and thus have been vital in making Malmberget a world renowned locality among connoiseurs.

Geology

Northern Sweden has several of the worlds largest and richest magnetite deposits of magmatic origin of Precambrian origin. Only during the last decades of the 20th century geologists were convinced of the magmatic origin of these large sheetlike orebodies. The largest ones are the ore deposits at Kiruna (Luossavaara-Kirunavaara), Malmberget and Svappavaara.

The ore at Kiruna is a huge fine grained, slightly metamorphosed sheetlike, steeply dipping orebody with minor interesting mineralisations. The Svappavaara ores have a portion with a rich mineralisation of iron phosphates, some of them of exceptional beauty and rarity. What makes the Malmberget deposit exceptional as a deposit of well crystallised mineral specimens, is the strong metamorphoses which took place after the ore forming event.

The ore body was folded, faulted and metamorphosed and invaded by granitic pegmatites which resulted in large skarn formations, as well as hydrothermal solutions giving rise to the rich formation of numerous small to giant cavities, some of them with well crystallised minerals. This spectacular feature has given the Malmberget mine world reputation for exceptional mineral specimens, notably perhaps the finest golden calcite specimens and emerald green fluorites in the world (Lyckberg 1988/1989 unpublished, Lyckberg 1996).

It must be noted that even at Malmberget most of the pockets are almost completely barren of interesting mineral specimens, and even those containing fine specimens may do so only in a small portion of the pocket.

Calcite and stilbite are the most commonly occurring minerals, and only a very small portion are of interest to collectors of esthetic mineral specimens, but nonetheless very interesting from a genetic and more unusual mineral perspective.

The age of the orebodies is approximately 1900 Ma, but the late stage mineralizations at Malmberget of interest to collectors and scientists have been calculated from 1613 to 1737 Ma (Romer 1996).

Thousands of pockets have been exposed by mining, and there are many very old stories from miners telling about old days finds. Several of these old finds have been possible to follow up during the past 20 years and have resulted in the re-discovery of major pockets with giant and fine crystals of calcite in a multitude of forms, fluorite, fluorapatite etc.

Magnetite, the principal ore, is rather rich in phosphorous (fluorapatite) and it was not until the Bessemer methods was invented that these ores could properly be utilised. During much of the industrial revolution, 2000 smaller iron mines in the Bergslagen district in south central Sweden supplied approximately 50% of the worlds iron ore. Thus being of vital importance to the world development. This is very rarely acknowledged in historically oriented litterature.

By 1888, when the railway from Lulea reached Malmberget, the mine started serious production, and until 2006 approximately 500 MT of ore have been produced, making it second only to Kiruna in production of this type of ore deposit.

Because of the higly irregular orebodies, mine tunnels at Malmberget are very extensive and thus even more pockets have been encountered, especially so in the hanging wall of the 14 major ore bodies.

The magnetite ore carries approximately 61 % Fe and less than 0.8 % P (Grip & Frietsch 1973). The ores are hosted by strongly metamorphosed and highly deformed rocks of felsic to mafic composition. These rocks are traditionally, as in Bergslagen, called leptites in Malmberget mining field. Locally, a porphyritic texture is preserved in the felsic rocks. Amygdules are occasionally encountered, supporting the extrusive origin. The ores and wall rocks at Kiruna are well preserved and show more of their original structure, and it is there clearer that the origin of the ore is magmatic extrusive. At Kiruna the porphyries have kept their original texture.

Mafic rocks are mainly found adjacent to the orebodies as comformable to discordant lenses. Occasionally they contain remnants of plagioclase phenocrysts and amygdules. Most of the mafic rocks are suggested to have formed as sills or extrusions (Geijer 1930), but some are probably also dykes.

To the northwest, a large intrusion of Line granite is present, and there is a clear increase of recrystallisation of the host rock in that direction. Also right next to most of the orebodies, and cutting some of them, are granite and pegmatite veins/dykes. Pegmatites may locally be enriched in schorl ("black" tourmaline), hematite, apatite, titanite and in rarer cases molybdenite.

The orebodies form a large, almost S-shaped mass, and make up an almost continous body 5-6 km in length. The main part of the orezone comprises 14 different orebodies but there are several smaller ones, especially to the west of the ore field.

Mining started on the top of Malmberget (Ore Mountain in English, or Erzgebirge in German) and was excavated in open pits during the first decade. Soon mining was started in underground galleries, and currently the mine level is at 800 metres depth.

In the western and northern part of the deposit, the ores of primarily magnetite, but also some major ones of hematite, may be banded with apatite, but less so in the more separate, large rich ore bodies to the east.

The Malmberget deposit has been strongly affected by ductile deformation, and the large-scale structures are controlled by at least two facies of folding. The present shape of individual orebodies is mainly a result of stretching parallel to a fold axis 40 to 50 degrees to the SSW. Many ore bodies are boudinaged in the plunging direction, and some of the granite-pegmatite dykes exhibit a similar style of deformation (Geijer 1930).

The orebodies are plunging under the Malmberget village itself, and part by part homes have been moved. It is foreseen to move the entire original village as new orebodies continue to be found at depth right under and beyond the village center.

History

The rich orebodies originally cropped out on the ridge of Malmberget mountain itself, and is believed to have been known at least since the end of the 17th century. Earlier, this part of Sweden was only sporadically populated, primarily by the reindeer herding lap (Sami) people.

After the completion of the railroad to Lulea in 1888 the deposit underwent quick development. Already at the top workings big pockets with beautiful mineral specimens were encountered and for a long time miners could tell of declining numbers of pockets at depth compared to the "good old days".

Surprisingly few specimens have been preserved from the early mining days, but some were illustrated in Flink (1930). In the early, mid and late 1960's the author's grandparents visited the mine, which has always been opened to tourist visits (nowdays by underground bus). In 1966 the first sample, a solid piece of magnetite ore with small gemmy apatite grains was received as a gift from the author's grandmother. In 1970-1972 she told stories of pockets and crystals in the mine which she and her husband visited every second year. The author must admit that the stories sounded to good to be true as his grandmother pointed out specific minerals in the author's collection (apatite from Durango, Mexico, calcite, pyrite, ferrohornblende with amiant terminations, quartz etc). She also described the size, color, shape and clarity of some. The crystals had been viewed underground *in situ*, in an underground mine museum and some in a mining museum above ground. It was not until a decade later that the author realised how perfectly correct these observations were.

In 1976 the first mineral show took place at Kopparberg in the Bergslagen district of south central Sweden. Having been the old traditional mining center of Sweden, with many at that time still mines in operation, there were plenty of miners and collectors present during the first shows. A few people brought specimens from Lappland. The first fine batch of Malmberget calcites was brought to Kopparberg in 1978. These were light yellow to light "honey colored" (with a brownish tone) scalenohedrons from a several metre wide pocket located in the roof of an access tunnel, and they were finest so far found in Sweden.

In 1982 an exceptional find of emerald green fluorite octahedrons were made in a metre-sized pocket in the middle of the roof in a tunnel in the Baron orebody. A second pocket was found thereafter in the wall. The first pocket yielded the finest large green octahedrons found at Malmberget, in association with quartz, orange stilbite, chalcopyrite (in complex comb-spheroidal aggregates), calcite, fine grained hematite and chlorite.

In 1986 the author received a lump of rock with some small (1 cm) scalenohedral deep golden calcite crystals. The color being outstanding and the beautiful shape made the author raise his eyebrows. Having visited the Elmwood mines in Tennesee in 1987, which at the time was the most outstanding comtemporary calcite specimen producer, the author went to Malmberget in 1988 to search for more of these golden calcites.

A new mining-friend showed a 3 cm gemmy, clear broken off calcite scalenohedron from the same site as the above-mentioned matix. It was of superior quality, but not really appreciated enough by the miner. After long searches in the mine, the author and this miner finally came to the site where it had been collected years before. In a curve of a ramp, a small blasting had been made to the side, probably to store explosives or park vehicles. The wall rock showed no golden calcite at all, only some small fissures with white calcite.

On the left side of the "parking spot" in the regular tunnel wall, there was a 15-20 cm wide fissure in the solid magnetite. It was almost perfectly vertical, filled with large grained magnetite sand and showed absolutely no signs whatsoever of any crystallisation on the wall. It only looked like a rupture of the magnetite with no second mineralization.

After taking turns of digging the magnetite sand from the 1.5 m high pocket, the author and the miner discovered a flower of golden calcite scalenohedrons upon a solid wall of black magnetite. The cluster consisted of approximately 30 crystals 5-12 cm in length. The center having a depression i.e. lacking the perfect crystals, but still this was by far the finest calcites ever discovered in Sweden (Lyckberg 1996). Today these are seen as among the finest golden calcite scalenohedrons ever found, together with crystals from a second pocket described in the following.

The difficult position of the cluster of calcite scalenohedrons urged serious work to recover the group complete on matrix. That first evening, only one group of two crystals and a single loose crystal were brought up to the surface as these came sliding down a sand slope 2.5 meter into the pocket while we were working to widen the fissure to enable future recovery of the magnificent specimen. That evening we backfilled the pocket (protecting the calcite crystal cluster with clean cloth) and left no traces of recent work.

Further work, making a 3 metre tunnel to intersect the pocket right up facing the cluster, was made by the miner while the author was back after having an exam at University. Unfortunately, the miner mentioned these crystals to, at the time, a completely inexperienced miner (who was later to become one of the two best). He went down with his father and simply knocked the crystals off the wall. These crystals were quickly distributed all over Scandinavia despite the promise by the miner to keep all of them for the author's next arrival, in order to reassemble the cluster. Upon arrival, the crystals were gone, but the original discoverers collected several more specimens from a network of the pocket, called "The Gem Pocket" (or locally the gold calcite hole). A third miner blasted the rock face to smitherings, and it was depressing to see thousands of fragments littering the floor, specimens which could have been of world class. At last, after this blast, the largest gem quality calcite ever discovered was found in a small thin crevasse growing from wall to just touching the other wall. The scalenohedrons from "the Gem Pocket" are unique from the Malmberget mine with their characteristic alternatively frosted faces, deep golden color, and gemminess. In total less than a dozen exceptional crystals were saved, while some had mostly broken terminations or were even broken in half.

A neighbour of one of the miners, a woman, was talking loudly about the find, and some other jealous miners quickly spread a rumour that they had found a cave with larger crystals of the same color. This turned out to be completely untrue, but the two miners now understanding the quality of these calcites, searched the mine tunnels and discovered a second pocket with not as gemmy, but very large scalenohedrons in a pocket only 50 m vertically from the first find.

The outer part of the pocket had been sprayed by shot concrete. Luckily the entrance to the big pocket was very narrow and bending, thus hindering the shot concrete to cover the amazing calcites which were yet to be discovered there.

One of the miners immediately called the author and explained the size of the pocket. What made the author almost jump out of his chair was the description of 10 cm large flat calcites looking like butterflies sitting upon the scalenohedrons.

Upon repeatedly asking the miner, he confirmed the size and shape and not the least the color. This was only the second time of the mines history (documented) that the golden calcite had been found (only in conjunction with pure magnetite) and on hematite carrying brecciated wall rock.

The description of large butterfly twins seamed almost too good to be true. Wise and sceptic from unjustified earlier finds of exceptional minerals from the mine, the author explained the unique nature of these crystals and explained how the miners must do everything to remove as large plates as possible intact from the pocket.

Most of the twins were found on a half a metre, ball-like specimen at the bottom of the pocket However, the miner said that the rock was exceedingly hard. Adviced to remove a big part of the wall rock below the pocket before even attempting the removal of specimens, the miners succeeded to remove three large specimens, all of them with several large butterfly twins growing upon calcite scalenohedrons. The specimens were completely clean in the pocket and as fresh as having been formed "yesterday", just like the gemmy, golden calcite from "the Gem Pocket".

The author flew immediately to Lappland to see this marvellous pocket and document it by photographing it and helping to recover specimens. The pocket was even more impressive than the first one. Only sections of the walls had large deep colored calcites, while other parts had smaller, light yellow calcite crystals. Still *in situ* were large butterfly twin calcites and large scalenohedrons. High humidity caused the lens to get foggy all the time but despite this, some perfectly clear images were captured in the pocket. Present were the author, his brother and one miner. The author found a second smaller pocket in the back left end of the Butterfly twin pocket where a couple of large calcite twins were growing from the bottom.

It should be noted here that most of the large butterfly twins grew at the bottom of the pocket. The largest calcite scalenohedrons (up to 30 cm) usually 10-20 cm were clustered in the upper left corner of the pocket, right above the best specimen usually referred to as "the Lyckberg calcite" but named "storblocket" ("the big boulder") at the find by the miners.

All the large matrix specimens had two or more twin calcites broken of the matrix, and it took several years for the author to gather the majority of these from all corners of Scandinavia. Unluckily one of the two miners did not understand the interest of these "loose" crystals and did the same as the first time... dispersed them quickly for nothing.

There are still two butterfly twin type crystals missing which should be placed back onto their matrix. Any reader who knows of such crystals is encouraged to notify the author of the whereabouts of these.

These three major specimens are outstanding in quality and are part of the author's collection. It took several years of work to gather the money needed to buy out one of the miners in his share of these specimens, and then the second one as well.

A group of three major crystals (with a forth attached) was illustrated on the cover of the Mineralogical Record. It is also in the author's collection. Immediately after the recovery at the mine it was exposed, but due to the risk of having visitors ruining and scratching it, the sample was packed carefully in protecting plastic and secured in a box for several years. Some specimens were destroyed within few years being exposed to numerous uncareful visitor's hands in the miners home.

For several years after the find of "the Gem pocket" intense traffic of visitors (collectors and dealers) from Sweden, Norway, Germany, Japan, USA, Canada etc., some bribing other miners by money, salmon and other commodities to "go and get" similar specimens resulted unfortunately not in the recovery of any additional truly exceptional specimens.

Rather half of the "Butterfly Twin pocket" was destroyed by these non-mineral collector miners by pounding on the hundreds of scalenohdrons and butterfly twins still in the pocket shortly after the photographic documentation in January 1989. Upon returning to the pocket the view was really sad. The pocket filled with fragments of calcite, and in principal nothing left of the hundreds of specimens possible to recover from the walls.

During the years since these exceptional finds, some more pockets were discovered yielding many interesting specimens. However, nothing in the quality compared to the above mentioned ones. One pocket at Västra Fältet yielded fine, small, green fluorite octahedrons in combination with large hematite crystals, smoky quartz crystals, calcite, pyrite and feldspars. Another pocket yielded four specimens of some exceptional hedenbergite-diopside specimens (March-July 2000), as good as the world famous ones from the Nordmark district in Värmland.

At the same time a pocket with a few exceptional, honey colored, doubly terminated calcites growing separately on matrix, and with a thin white calcite on the flat pinacoid terminations was found. Four exceptional specimens are in the author's collection. A pocket yielded clear colorless selenite gypsym crystals to 10-20 cm in association with pyrite. One pocket with giant "hedenbegrite-diopside crystals", some of the single crystals to large to lift by one miner, was also encountered.

A compilation of the most remarkable finds from this mine is under going by the author and will be published in the future. There is still a lot of descriptive and analytical work to be done, but this will be left to future mineralogists.

The most important mission this author saw was to document these finds, educate the miners in specimen recovery, the correct recovery and preservation of specimens, and the recovery and documenting the adjoining information. This project took much of the author's resources both in time and finances during studies and later working years being a father of small children.

Below is a very short summary list of some of the minerals encountered. Only a few finds will be described. It shall be noted that numerous other micro minerals have yet to be identified, and of course to be found.

Albite
As small fine crystals.

Allanite
Primarily microscopic sharp elongated crystals in paragenesis with sulphides was studied and analysed by the author (unpublished data).

Amphiboles
The minerals in this group are well represented at Malmberget. The skarn is rich in amphiboles and pyroxenes and it is not rare to find well-developed crystals.

Andalusite
Encountered as less attractive specimens.

Anhydrite
Sometimes as huge multicoloured crystalline masses of white, purple and green color to 2 meter in diameter. Rare in pockets. Crystals rivalling those from the Gotthard tunnel has yet to be found.

APATITE
Apatite is rather common in sharp to rounded hexagonal crystals in pockets. Usually they are localized to a section or a bottom corner of a pocket. They occur usually well hidden in chlotite, often associated with fine specular hematite, or with magnetite crystals. In many cases covered by a late stage stilbite. At the Printz Skjold orebody huge cave-like pockets were explored by the author, his brother and two miners in the summer of 1999.
In one of them, a slightly sloping tunnel-shaped pipe, walls in the magnetite ore body exposed in a corner between two tunnels at some 6 m height were covered by thin apatite crystals 1-4 cm in size and of slender character. The magnetite is usually very poorly developed. Large crystals of apatite to 15 cm lay loose in the rubble on the floor. In the upper section of the pocket where the tunnel split into an Y, large boulders covered with very sharp beautiful hedenbergite-diopside crystals to 10 cm occurred.
Shortly after this tunnel-like pocket (miners first thought it was a mine tunnel from the old days when encountering it due to its perfect rounded inverse U shape) a huge cave system was partly explored by the author in 1999.
A huge zone below this cave produced small, gemmy green apatites. The cave system had typical cave formation on the floor, i.e. secondary growth of clay minerals formed from dripping and running water. 20-30 meter inside the wind from inside the cave was rather strong and the acoustics suggested a major cave system. There was a lack of promising mineralization so only a fraction of the system was explored but this was the largest open system seen by the author in the mine. This part of the mine was shortly after abandoned due to large cave-ins.
On the level 50 m above, a 20x20x1-5 metre high "drive in cave" was explored in the summer of 1999. Here gemmy fluorapatite crystals to 8 cm occurred together with sharp pyrite to 8 cm, feldspar pseudomorphs after scapolite, titanite twins, magnetite octahedrons, massive chalcopyrite, quartz crystals, stilbite-stellerite etc.

The largest apatite crystals from the mine were found in a giant pocket encountered while driving an exploration tunnel. In fact the pocket itself was so large that the exploration tunnel had to be diverted for several hundred metres. Miner stories of huge, hexagonal green crystals the size of half an arm were confirmed first by one miner who visited this pocket and brought out giant apatite crystals to 30 cm in length and 12 cm in diameter. These are very sharp and free formed in pockets, occasionally overgrown with small needles of calcite. In the same pocket 10-20 cm large sharp feldspar crystals were also recovered. Apatites often have small monazite crystals 1-

8 mm as inclusions and some transparent crystals may show a beautiful schiller and red color due to hematite inclusions. Sometimes apatite show minute tubes giving rise to cats eye-effect schiller interpreted as rapid growth conditions.

Apophyllite
Rarely as fine crystals.

Barite
Rare as small yellowish crystals in pockets.

Biotite
As sharp crystals in pockets associated with a serie of minerals.

Bornite
Rather rare. There are probably more Cu species to be studied at malmberget.

CALCITE
Very commonly covering small fissures up to "church size" cavities. One cavity was called the church because of its enormous size. Calcite has been found in a multitude of shapes and associations. Plates up to one meter, huge scalenohedrons to over half a meter, heart, fish tail and butterfly twins, paper spat, and so on. Most commonly of grey to white to pale yellow colors. The most noble ones of a deep golden color as world class specimens in scalenohedral, rhombohedral or as rare butterfly twins. A large cave found yielded "Mutter Kalsitt" in great clusters, which were lacquered and sold at the Kopparberg show. When the sun appeared and the specimens the collectors had bought started smelling the vendor fled the show.

Chabazite
As a multitude of smaller crystals 5-10 mm covering smaller fissures.

Chalcopyrite
In crystals usually in the 5-30 mm range. As large single crystals on matrix, as large numbers of small crystals, especially at "Björnidet" a large amiant filled pocket, together with blue and emerald green fluorites.

Chlorite
Very commonly filling pockets.

Copper
Native copper is rather rare, but has been found as sharp plate-like crystals to small arborescent tree-like aggregates to a few cm.

Cuprite
Reported

Corundum
Only locally common. One part of the orebody is rather rich in black corundum. This is the site where salesmen from drill companies are brought to demonstrate their high quality steel drills and has been to amusement many times according to the miners. So far LKABs own drill seem to have had no competition.

Datolite

Rather rare.

Diaspor
Not uncommon, but probably often missed.

Epidote
Despite being a very common mineral, it is rather uncommon at Malmberget.

Feldspar group
A number of feldspar varieties are found as exceptional crystals at the Malmberget mine typically in the 2-15 cm range. Yet, they need to be studied individually as to species, morphology and paragenesis. It is interesting to note that feldspars with booth moonstone and sunstone effect occur, sometimes the two even in the same pocket.

Ferro Hornblende
Common. Sometimes as beautiful crystals

Fluorite
Rather common in some parts of the mine, primarily together with quartz, chalcopyrite, stilbite and calcite. The most appreciated colors are emerald green, ice blue on quartz crystals and very rare pink (found frozen in calcite in one open pit). The best few emerald green samples being second to none.

Garnet group
Garnets are rather uncommon and crystal size is rather small even for Swedish iron mines. They often occur as rather poorly developed crystals 5+-10 mm in size of dark red to brown colors.

Goethite
Uncommon but maybe overlooked. No exceptional specimens found yet.

Graphite
Rare

Harmotome
Rather common

Hematite
Rather common. In exceptional cases as large well developed crystals to 10-15 cm. Some of them associated with green fluorite etc.

Hornblende group
Very common. Ferrohornblende in large fine crystals, sometimes with hairy structure at terminations.

Ilmenite
Rather uncommon

Kaolinite
Rather common. However, little attention has been paid to clay minerals despite their abundance in pockets in the mine.

Magnetite
Despite having had a production of 6-12 M tons of magnetite ore per year, good magnetite crystals are exceedingly rare at Malmberget. Groups of crystals 5-15 cm in size with individual crystals 5-10 mm are even rare. Striated octahedrons. The largest documented approximately 3 cm growing on an 8 cm floater pyrite crystal from Printz skjold orebody and recovered in 2000.

Malachite
Rather rare.

Mica group
Rather common both in pockets and in wall rock.

Microcline/perthite
Common and occurring as fine crystals (se feldspars)

Molybdenite
Rather uncommon, but occurring in crystals to 5 cm. Often in association with quartz crystals and stilbite free growing in pockets.

Monazite group
Brown 5-10 mm crystals not uncommon in fluorapatite crystals.

Mottramite
As rather unimpressive specimens.

Oligoclase
See feldspar

Plagioclase
See feldspar

Pyrite
Common, but rare as fine crystals. Cubes, modified cubes to octahedrons. Individual crystals usually small and only 5-15 mm in size. Largest exceptionally fine single crystal 8 cm, but huge crystals have been reported by miners. One complete tunnel face was covered by 1 cm sharp octahedrons. Very few preserved. Sometimes in combination with apatite, magnetite.

Pyrophyllite
Uncommon

Pyroxene group
Very common, in part as large fine crystals.

Quartz
White to pale smoky non-transparent crystals common. Rare green and deep red crystals highly coveted by miners (due to inclusions). Occurs in beautiful combinations with fluorite, calcite, stilbite, apatite, hematite etc.

Rutile
Uncommon

Scapolite
Common, often pseudomorphed to feldspar. Sometimes as purple non-gemmy crystals to several cm in length.

Sericite
Rather common

Sillimanite
Rather common in some parts.

Stellerite
Common. Sometimes in very beautiful balls.

Stilbite
Very common. Fine specimens recovered of stilbite in combinations.

Titanite
Common as small sharp crystals to 6 cm. Large crystals to 15 cm found, some even larger only as imprints in other minerals and overgrown partly with calcite.

Tourmaline group
"Black" tourmaline i.e. perhaps schorl present. Analyses to be made.

Vermiculite
Very common as large "light weight rolls" in pockets, sometimes overgrown by stilbite/stellerite, and calcite.

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