Boliden Summary Report

Resources and Reserves | 2019

Garpenberg

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1 SUMMARY

In 2019 the total mineral reserves in Garpenberg decreased by 1.3 Mt (million metric tonnes) to 74.8 Mt. Measured and indicated resource in Garpenberg increased by 4.5 Mt to 44.3 Mt. Inferred resource increased by 5.0 Mt to 24.1 Mt.

Table 1-1 Mineral Resources and Mineral Reserves in Garpenberg 2019-12-31

	2019						2018					
	kton	**Au**	**Ag**	**Cu**	**Zn**	**Pb**	kton	Au	Ag	Cu	Zn	Pb
Classification		**(g/t)**	**(g/t)**	**(%)**	**(%)**	**(%)**		(g/t)	(g/t)	(%)	(%)	(%)
Mineral Reserves												
Proved	**21 000**	**0.24**	**99**	**0.04**	**3.5**	**1.4**	22 800	0.24	101	0.03	3.6	1.4
Probable	**53 800**	**0.34**	**95**	**0.05**	**2.9**	**1.4**	53 400	0.32	94	0.05	2.9	1.4
Total	***74 800***	**0.31**	**96**	**0.05**	**3.1**	**1.4**	*76 100*	0.30	96	0.05	3.1	1.4
Mineral Resourcess												
Measured	**4 300**	**0.31**	**100**	**0.06**	**3.3**	**1.6**	4 400	0.31	100	0.06	3.3	1.6
Indicated	**40 000**	**0.35**	**89**	**0.05**	**2.7**	**1.3**	35 400	0.35	88	0.05	2.8	1.3
Total M&I	***44 300***	**0.35**	**90**	**0.05**	**2.8**	**1.3**	*39 800*	0.34	90	0.05	2.8	1.4
Inferred	**24 100**	**0.43**	**59**	**0.07**	**2.6**	**1.5**	19 100	0.48	56	0.08	2.8	1.7

1.1 Competence

Multiple participants have been involved and contributed to this summary report. Roles and responsibilities are listed in Table 1-2.

Table 1-2. Contributors and responsible competent persons for this report

Description	**Contributors**	**Responsible CP**
Compilation of this report	Johan Högnäs	Thomas Hedberg
Geology	Johan Högnäs	
Resource estimation	Johan Högnäs	
Metallurgy	Anders Sand	
Mining	Johan Högnäs	
Environmental and legal permits	Lotta Tanse, Johan Högnäs	

Thomas Hedberg has a background in numerous Managerial positions in Boliden from Mining Engineering to Mine Manager in Sweden and Canada. Currently as Senior Project Manager for Boliden Mines. This experience gives the general view and understanding of the whole mining process from exploration to concentrate.
Member in FAMMP[1] since 2018.

[1] Fennoscandian Association for Metals and Minerals Professionals

2 GENERAL INTRODUCTION

This report is issued annually to inform the public (shareholders and potential investors) of the mineral assets in Garpenberg held by Boliden. The report is a summary of internal / Competent Persons' Reports for Garpenberg. Boliden method of reporting Mineral Resources and Mineral Reserves intends to comply with the Pan-European Reserves and Resources Reporting Committee (PERC) "PERC Reporting Standard 2017".

The PERC Reporting Standard is an international reporting standard that has been adopted by the mining associations in Sweden (SveMin), Finland (FinnMin) and Norway (Norsk Bergindustri), to be used for exploration and mining companies within the Nordic counties

2.1 Pan-European Standard for Reporting of Exploration Results, Mineral Resources and Mineral Reserves – The PERC Reporting Standard

PERC is the organisation responsible for setting standards for public reporting of Exploration Results, Mineral Resources and Mineral Reserves by companies listed on markets in Europe. PERC is a member of CRIRSCO, the Committee for Mineral Reserves International Reporting Standards, and the PERC Reporting Standard is fully aligned with the CRIRSCO Reporting Template.

The PERC standard sets out minimum standards, recommendations and guidelines for Public Reporting of Exploration Results, Mineral Resources and Mineral Reserves in Europe.

2.2 Definitions

Public Reports on Exploration Results, Mineral Resources and/or Mineral Reserves must only use terms set out in the PERC standard.

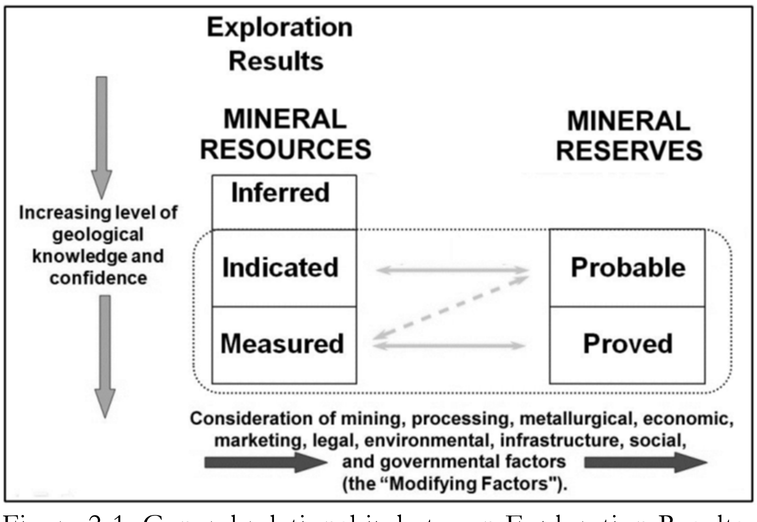

Figure 2-1. General relationship between Exploration Results, Mineral Resources and Mineral Reserves (PERC 2017).

2.2.1 Mineral Resource

A Mineral Resource is a concentration or occurrence of solid material of economic interest in or on the Earth's crust in such form, grade or quality and quantity that there are reasonable prospects for eventual economic extraction.

2.2.2 Mineral Reserve

A Mineral Reserve is the economically mineable part of a Measured and/or Indicated Mineral Resource.

It includes diluting materials and allowances for losses, which may occur when the material is mined or extracted and is defined by studies at Pre-Feasibility or Feasibility level as appropriate that include application of Modifying Factors. Such studies demonstrate that, at the time of reporting, extraction could reasonably be justified.

3 GARPENBERG

3.1 Project Outline

Garpenberg is a Zn-Pb-Ag-(Cu-Au) underground mine where the ore is mined from between 500 meters to more than 1,400 meters below surface. The mine encompasses several polymetallic ore lenses. See Figure 3-3, Figure 3-4 and Figure 3-5.

The mined out ore tonnage in 2019 totaled 2 865 Kton which is an increase of 240 Kton from previous year. Almost 80 % of the mined tonnage derives from the largest ore lens, Lappberget.

Zinc is the most valuable commodity in Garpenberg, accounting for about 40 % of the revenue. The second most valuable commodity is silver at 30 %, followed by lead at 20 % and copper-gold at 10 %.

3.2 Major changes 2019

In 2019 mineral reserves in Garpenberg decreased by 1.3 Mt (million metric tonnes) to 74.8 Mt. Measured and indicated resource in Garpenberg increased by 4.5 Mt to 44.3 Mt. Inferred resource increased by 5.0 Mt to 24.1 Mt.

3.2.1 Technical studies

No technical studies have been carried out in 2019.

3.3 Location

Garpenberg is located in the Hedemora municipality in central Sweden 180 km NW of Stockholm at coordinates (WGS84) latitude 60° 19' 27"N, longitude 16° 13' 38". Figure 3-1 and Figure 3-2 show the geographic location and the mining concessions of Garpenberg.

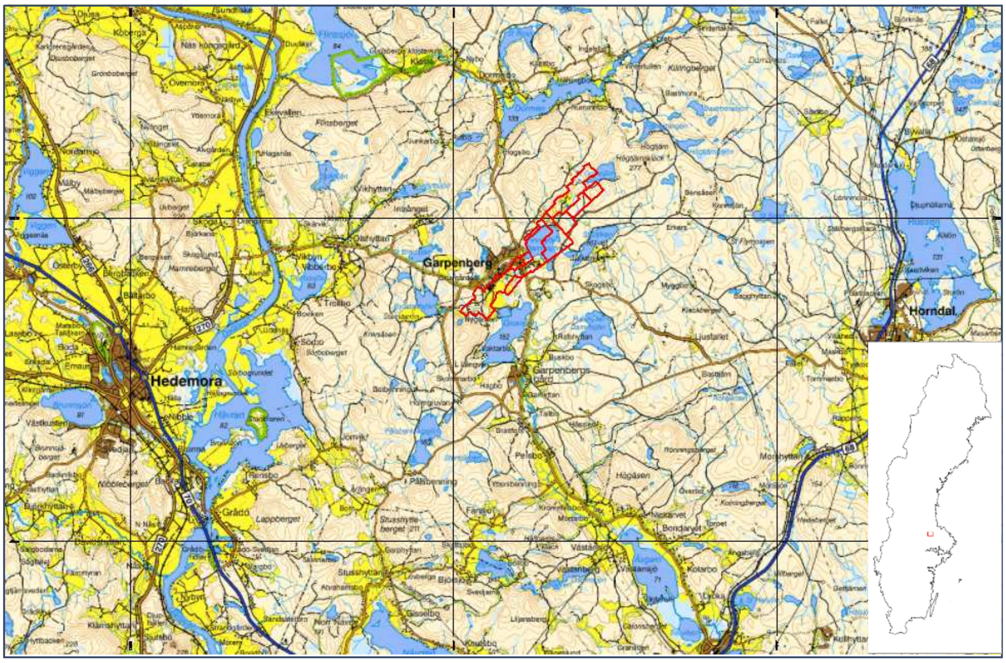

Figure 3-1. Regional map showing Garpenberg mining concession licenses in red colour. Coordinate system in the map is RT90 2.5 gon W.

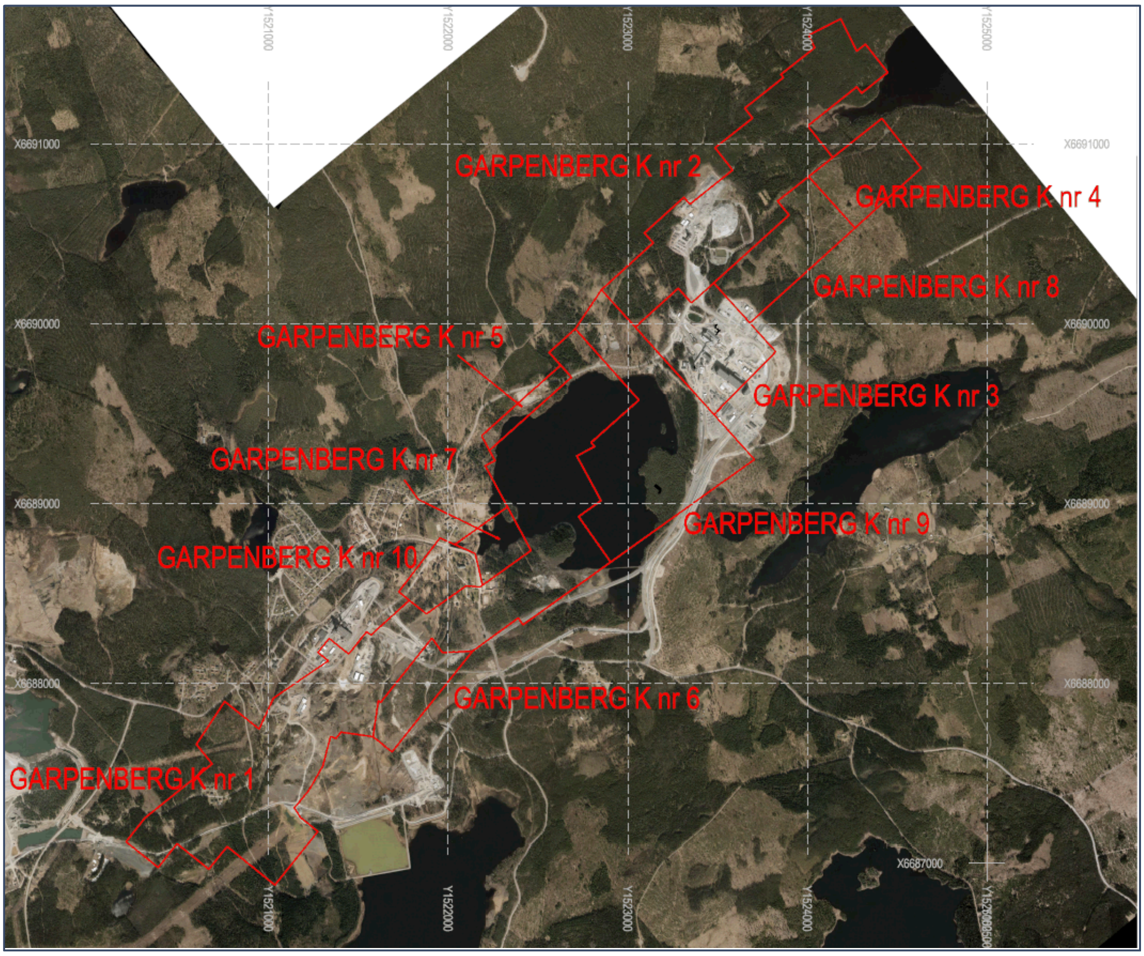

Figure 3-2. Detailed map of Garpenberg mining concessions.

3.4 History

Historical documents show that systematic mining has been conducted in Garpenberg since the 13th century. Recent studies from lake sediments 2017 however push back the evidence for early ore mining in Garpenberg even further, from the Middle Ages to the pre-Roman Iron Age around 400 BC.

In 1957 Boliden acquired the Garpenberg mine from Zinkgruvor AB. A total of 54.4 Mt of ore has been processed since Boliden took over the operations (Table 3-1).

A chronological list of historically significant events is presented in appendix 1.

Table 3-1. Annual production numbers 1957-2019. Between 1957 and 1995 the processed ore tonnes and grades are presented with 5-year intervals, while figures for mined ore are missing. From 2005 to 2014 ore from the Lovisagruvan mine was also processed in Garpenberg. A total of 54.4 Mt of ore has been processed since Boliden acquired the mine from Zinkgruvor AB in 1957.

Year	**Mined Ore**	**Processed Ore**	**Grades**				**Lovisa**
	Kton	**Kton**	**Au g/t**	**Ag g/t**	**Zn g/t**	**Pb g/t**	**Kton**
1957		260	1.2	69	2.84	2.34	
1960		306	0.7	81	4.3	3.0	
1965		297	0.9	116	4.9	3.3	
1970		307	0.9	110	4.2	2.7	
1975		349	0.6	114	3.2	1.9	
1980		427	0.5	112	3.0	1.8	
1985		534	0.4	138	3.0	1.9	
1990		747	0.5	135	3.6	2.0	
1995		750	0.4	133	4.3	2.2	
2000	1003	976	0.5	141	3.9	1.9	
2001	1018	984	0.4	136	3.9	1.8	
2002	997	1058	0.4	153	4.0	1.8	
2003	1067	1062	0.4	151	4.6	1.9	
2004	1087	1074	0.3	124	5.6	2.2	
2005	1115	1102	0.3	117	5.8	2.3	13.3
2006	1167	1182	0.4	123	5.7	2.2	17.1
2007	1218	1255	0.3	126	6.3	2.5	17.1
2008	1341	1365	0.3	130	6.9	2.6	27.7
2009	1425	1394	0.3	139	7.3	2.8	31.7
2010	1369	1443	0.3	133	6.6	2.5	28.9
2011	1441	1456	0.3	134	6.1	2.4	37.5
2012	1602	1484	0.27	130	5.6	2.1	39.0
2013	1600	1495	0.3	153	5.2	2.1	39.8
2014	1891	2224	0.31	136	5.1	2.1	38.7

2015	2304	2367	0.32	156	5.0	2.1
2016	2610	2622	0.31	150	4.4	1.8
2017	2630	2634	0.30	134	4.3	1.8
2018	2625	2622	0.29	135	4.1	1.6
2019	2865	2861	0.26	118	4.1	1.5

Resource estimates for new ore bodies are produced by the exploration department by drilling the mineralized rock body in a 50 x 50 m grid, producing an inferred of indicated resource. This is typically followed up by denser drilling carried out by the mine department resulting in a measured resource and eventually a mineral reserve. More on mineral resources and mineral reserves in chapters 3.12 and 3.13, respectively.

The mineral reserve estimates are constantly being revised against the metal grades of the actual mined tonnage through the reconciliation process, see chapter 3.15.

3.5 Ownership

Boliden Mineral AB owns 100 % of the Garpenberg mine.

3.6 Permits

Boliden is the owner of all land where the mining operations are currently developed. Boliden has 10 mining concessions covering the mine area. The concessions are presented in Table 3-2, Figure 3-1 and Figure 3-2**Error! Reference source not found.**.

Table 3-2. Mining concessions in Garpenberg

Name	Active from	Expires	Minerals
Garpenberg K nr 1	2000-01-01	2025-01-01	Zinc, lead, silver, copper, gold
Garpenberg K nr 2	2000-01-01	2025-01-01	Zinc, lead, silver, copper, gold
Garpenberg K nr 3	2001-06-18	2026-06-18	Zinc, lead, silver, copper, gold
Garpenberg K nr 4	2001-06-18	2026-06-18	Zinc, lead, silver, copper, gold
Garpenberg K nr 5	2002-12-13	2027-12-13	Zinc, lead, silver, copper, gold
Garpenberg K nr 6	2002-12-13	2027-12-13	Zinc, lead, silver, copper, gold
Garpenberg K nr 7	2002-12-13	2027-12-13	Zinc, lead, silver, copper, gold
Garpenberg K nr 8	2003-01-07	2028-01-07	Zinc, lead, silver, copper, gold
Garpenberg K nr 9	2003-04-17	2028-04-17	Zinc, lead, silver, copper, gold
Garpenberg K nr 10	2004-03-19	2029-03-19	Zinc, lead, silver, copper, gold

Boliden has the necessary environmental permits in place to operate the mine. The main permit, in accordance to the Swedish Environmental Act, was issued by the Swedish Environmental Court in 2012 (M461-11 2012-01-31) and the final discharge limits to water were set in 2016 (M461-11 2016-04-15). In 2018 applied for some changes in the permit which were approved in December 2018 (M467-18, 2018-12-20). These changes in the permit will allow Boliden to deposit waste-rock according to life-of-mine plan and tailings for 10 years (the longest building period allowed for activities under chapter 11 in the Swedish Environmental Act). The permit allows Boliden to operate the mine as described in the application and in particular to (chapter 9 Environmental Act):

- extract and process up to 3 Mtpa of ore in Garpenberg,
- deposit tailings in the Ryllshyttan tailings management facility (TMF), and backfill the mine.

In addition, the permit allows Boliden to (chapter 11 Environmental Act):

- raise the dams at Ryllshyttan TMF to the level of +256m with the maximum water level of +254 m and to construct a new outlet, and
- extend the waste-rock dumps.
- set the financial guarantee for closure to 490 MSek.
- raise the water level in the clarifcation pond to the level of +227,9 m,
- extract mine water, and
- extract up to 1,9 Mm3/yr fresh water from the lakes Gruvsjön och Finnhytte-Dammsjön, of which a maximum of 0,95 Mm3 from Finnhytte-Dammsjön.

The permit is associated with a series of conditions and limit values regarding e.g., discharge water quality and noise levels in neighbouring houses.

The long history of mining in Garpenberg has resulted in a complex environmental situation with numerous historical objects on and around Bolidens land holdings in Garpenberg. Due to the age of these objects, Boliden is assessed to have very limited liability for any future remedial works to limit the environmental impact of these objects; however, as landowner Boliden has the responsibility to conduct investigations in order to determine the impact of these historical objects. These investigations are ongoing, as well as a dialogue with the competent authority regarding the extent of the liability for any future remedial actions on these objects. A processes has been initiated by the Water Authority to assess if it necessary to modify the environmental quality standards (EQS) for Gruvsjön and downstream lying water bodies as it has been shown that it is not a realistic admission to meet current EQS, even in a long-term perspective

3.7 Geology

The Garpenberg mine is situated in the heavily mineralized Palaeoproterozoic igneous province of Bergslagen, south central Sweden, which is host to a variety of ore deposits, and especially Fe-oxide and polymetallic sulphide deposits. Garpenberg is the largest sulphide deposit in the region, and comprises several individual ore bodies distributed over a distance of 4 km along a limestone horizon, see Figure 3-3. The main host rock is calcitic marble (limestone) altered to dolomite and Mg +/- Mn-rich skarns. The footwall comprises strongly phlogopite-biotite-cordierite-sericite-quartz altered felsic volcaniclastic rocks, whereas the hanging-wall comprises relatively unaltered volcaniclastic and sedimentary rocks and dacitic intrusions. The stratigraphic succession is attributed to the volcanic cycle of a felsic caldera complex, and includes rhyolitic to dacitic, juvenile pumiceous, graded mass-flow breccia deposits and rhyolitic to dacitic ash-siltstone and sandstone in the footwall, and polymict conglomerates and juvenile, rhyolitic, pumiceous breccias in the hanging-wall. These pumiceous breccias in the hanging-wall record a climactic eruption that formed a caldera over 500 m deep and over 9 km in diameter in the Garpenberg area. The limestone hosting the ore is interpreted as a stromatolitic carbonate platform, formed in a shallow, marine environment during a hiatus in volcanism.

The ore-host limestone shows a complex geometry due to large scale folding, shearing and faulting. Folding and late faults have locally remobilized the ore into fault- and fracture-hosted sulphide veins, some of which have been thick enough and rich enough to mine. These structural features have resulted in complex synforms and antiforms, and have a major influence on the position, geometry and metal grades of the ore bodies. The Lappberget ore body is interpreted as an over 1.5 km long, subvertical anticlinal tube fold with the top of the antiform just below 200z. The initial main stage of mineralization and alteration at all the known Garpenberg ore bodies is interpreted to be essentially syn-volcanic in timing and to pre-date regional metamorphism and deformation.

The Garpenberg mine encompasses several ore lenses which follow a limestone-marble horizon occurring in a synform structure. The structure is compressed at the southern end and opens to the north. The horizon is strongly isoclinally folded and the structure tectonic and divided into blocks. The ore lenses occur in the contact zone between the limestone and underlying siltstones. The contact zone is heavily altered to skarn and the limestone to dolomite. The structures are consistently steeply dipping

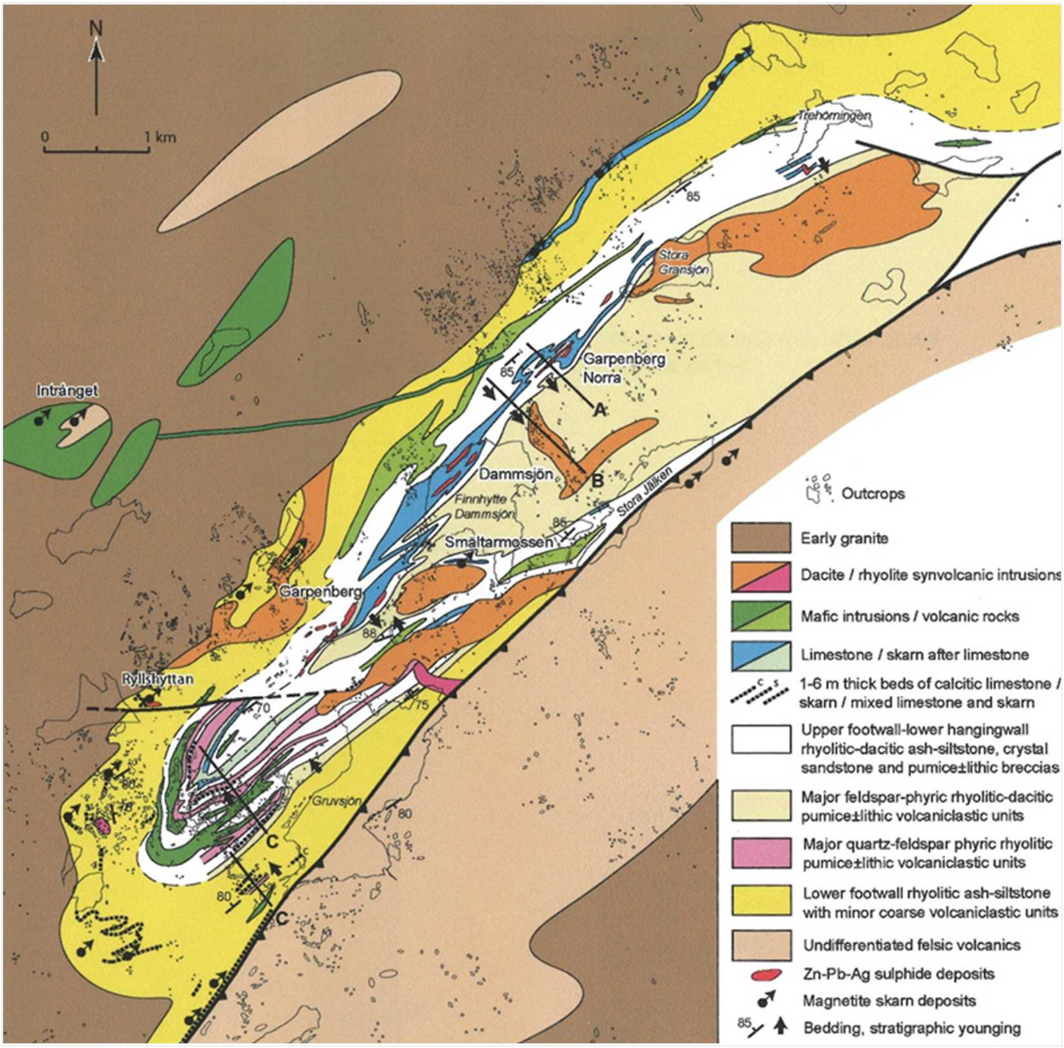

Figure 3-3. Geological map of Garpenberg. From Allen et al., 2003

Mineralisation is mainly of replacement style and is likely to have taken place where metal-bearing fluids penetrated up along synvolcanic, extensional faults and came in contact with reactive limestone to form large, massive sulphide bodies. The exact timing and the depth below the sea floor that this mineralizing process took place is still unknown.

The different ores are strongly structurally related and the largest ore bodies linked to antiforms as Lappberget and Kaspersbo. The mineralization comprises pyrite, sphalerite, galena and silver mineral in some places forming semi-compact blisters in the quartzite and skarn-altered contact zones. Also between the lenses occur mineralizations controlled by tectonic mica-rich shear zones. In the entire field occurs mineralization also as remobilization along the axial planes. Remobilizations intersect the more or less semi-compact lenses and both expand and extending the lenses especially at depth.

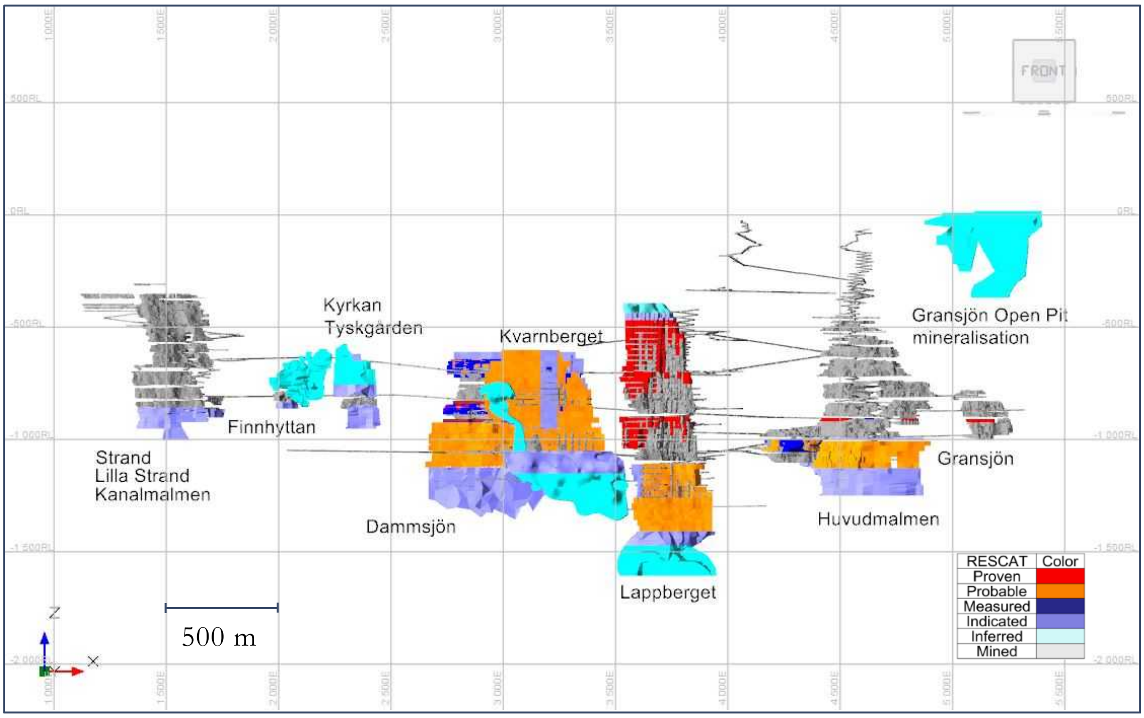

Figure 3-4. Front view of the Garpenberg ore lenses looking north in the local coordinate system. Colors according to resource category

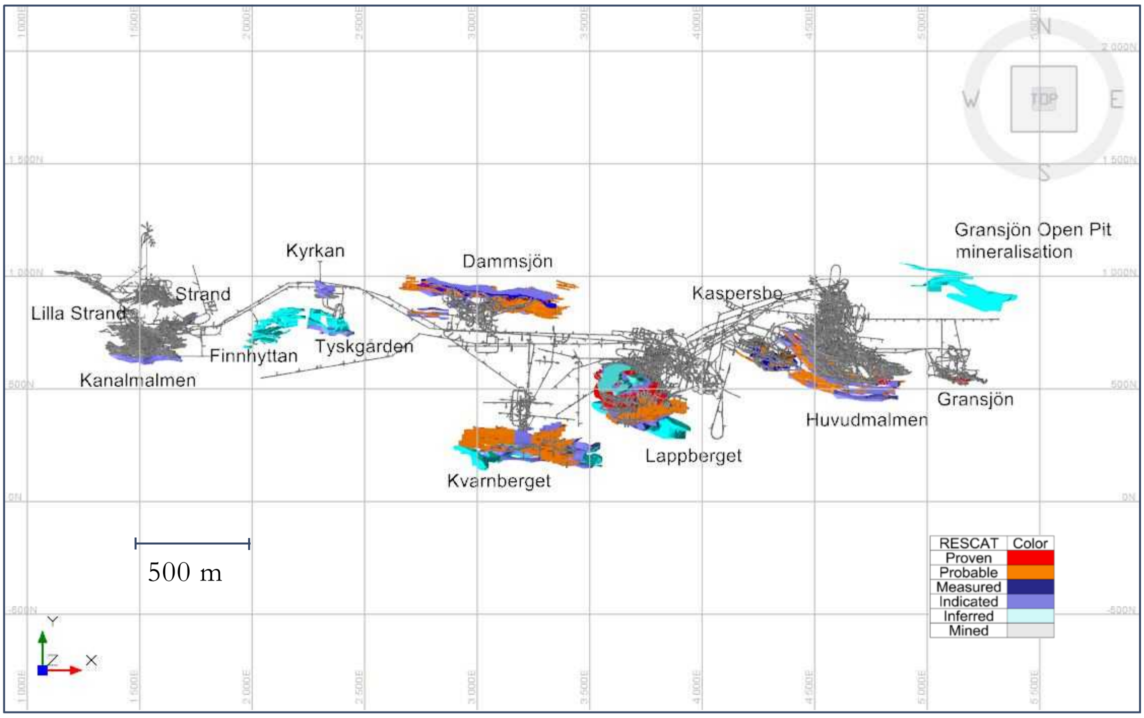

Figure 3-5. Top view of the Garpenberg ore lenses. Colors according to resource category.

3.8 Exploration procedures and data

3.8.1 Drilling techniques and downhole survey

Diamond drilling assay data is used for mineral resource estimation. Diamond drilling is performed by drilling contractor Drillcon and supervised by Boliden personnel. By default drilling dimension in Garpenberg is B-size with a core diameter of 3.9 mm. The current practice is to measure all drillholes longer than 100 m for deviation with Reflex Maxibor2. Drill holes longer than 400 m are measured with IS Gyro.

3.8.2 Logging and sampling

The drill core is logged by Boliden geologists and sampled by Boliden technical personnel. Different level of logging detail is being applied depending on whether drill holes are exploration- or infill drill holes. However, features which are always logged are: lithological units, fractures, level of schistosity and content of talc. For infill drill holes the whole core is usually sampled, leaving no core left in the core boxes. Exploration drill holes are sawed in half along the drill core axis and one half is sent for analysis while the other half is stored in Boliden's core archive.

3.8.3 Density

Density data has been collected from bulk samples from each ore lens. This data has been used to produce individual density formulas for each ore lens based on metal content. As an example, the density formula for Lappberget is 2.8 +0.004Cu + 0.004Zn + 0.02Pb + 0.0365S. Average bulk densities for the ore lenses vary between 2.71 (Garpenberg south) and 3.15 (Gransjön).

3.8.4 Analysis and QAQC

Drill core analyses are carried out by ALS laboratories. Sample preparation is done in Piteå, Sweden and assays are carried out in ALS's hub-lab in Loughrea, Ireland. ALS laboratories are accredited according to ISO/IEC 17025. Umpire lab check assays are done by MS Analytical. An overview of the different analytical methods is presented in table Table 3-3

Table 3-3 Overview of ALS's designation of analytical methods. Over-range method applies to samples where assay result reached upper detection limit of primary method

	Method	**Over-range method**
Preparation	PREP-31B	
Assay Au	Au-ICP21	Au-AA25/Au-GRA21
Assay Ag, Cu, Pb, Zn	ME-OG46	Ag - GRA21 Pb - AAORE Zn - ME-ICPORE
Assay S	IR08	
Assay other (48 elements)	ME-MS61	
Specific gravity (core)	OA-GRA08	
Specific gravity (pulp)	OA-GRA08b	

Preparation of the samples, coded PREP-31B, comprises crushing the rock to 70% less 2mm, riffle splitting off 1 kg and pulverizing the split to better than 85% passing 75 microns.

Au-ICP21 is a package of fire assay with an ICP-AES analysis. In ME-OG46 Aqua Regia is used to dissolve base metals and silver while assay is done with ICP-AES. IR08 is used for total sulphur analysis using a Leco Sulphur analyzer. ME-MS61 is a package of a 4-acid digestion process with an ICP-MS analysis. Specific gravity is measured either directly on drill core (OA-GRA08), or on pulps using a pycnometer (OA-GRA08b).

All samples are prepared and analyzed with Au-ICP21, ME-OG46 and IR08 while selected drillholes are analyzed with ME-MS61 and Specific Gravity as well. For the latter, analysis on pulp is the preferred method. Table 3-4 shows which elements are analyzed with lab codes ME-OG46 and ME-MS61.

Table 3-4 Elements analyzed with ME-OG46 and ME-MS61.

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	**Cu**	**Zn**	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	**Ag**	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	**Pb**	Bi	Po	At	Rn
Fr	Ra	Ac¨	Ku	Ha													

*	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
¨	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

ME-OG46 ME-MS61

Quality assessment and quality control is continuously monitored using QAQC samples such as in-house standards, blanks and umpire lab checks (pulp duplicates). It is required that each sample batch is submitted with at least one blank sample and one standard sample. Batches with more than 16 samples also require a pulp duplicate sample. As the number of samples in a batch increases so does the required QAQC samples, for example a batch with 100 samples requires two blanks samples, three standard samples and one pulp duplicate sample.

A review of all yearly QAQC samples utilized shows that the results fall within the predetermined acceptable limits. The results have been summarized in Boliden's internal QAQC report, DMS # 1576258, see references.

3.9 Exploration activities and infill drilling

In 2019 near mine exploration activities were focused on delineating the upper extent of the Kvarnberget and Lappberget deposits respectively, see Figure 3-6. The upper limit of the Kvarnberget deposit remained open due to the steep upward drill angle required to intersect the upper extent of the mineralization when collared from the 700 level. In recent years the development of Lappberget and the resultant 554 level facilitated drill testing of Kvarnberget above the 600 z. This programme was carried out during 2019 with 5853 metres of drilling indicating that the Kvarnberget mineralization extends to at least 500 z although the two main lenses at these levels become thinner. Further work will be required to follow up this programme above 500z where mineralization is still partially open. Interestingly, Kvarnberget drilling in 2019 has shown that the altered limestone package is considerably thicker than expected to the west where the strike orientation is oblique to the known Kvarnberget strike. This increases potential for exploration to the west towards the historical Smältarmossan mine and Finnhyttan area at the 400 – 600 level.

A resource estimate was also completed in 2019 for levels below 1050 z and associated processing tests (grindability and floatation) were carried out. Due to focus on depth extent of Kvarnberget resource estimate on levels above 600 z based on 2019 drilling will be performed in 2020.

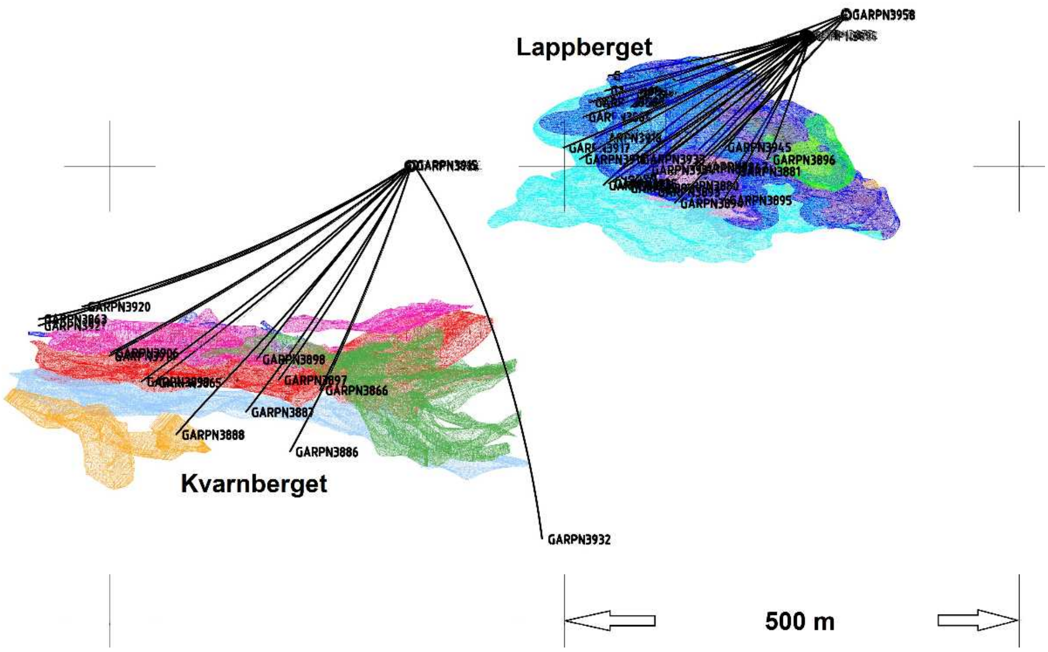

Figure 3-6. Distribution of near mine exploration resource drilling in 2019 above existing resource models for respective deposits.

Exploration to delineate the upper levels of Lappberget began with 3646 meters of resource drilling targeting the 400 – 435 level from the Lappberget ramp. Given the availability of a ventilation drift at the 330 level for drilling, exploration continued to test the Lappberget mineralization up to 300 z during the second half of 2019. This showed that the Lappberget mineralization continues up to 300 z where it remains open upwards (over a limited strike extent of ca 75m) and to the west where further follow up drilling is a priority.

Resource drilling carried out by near mine exploration was included in the Lappberget resource calculation carried out by the mine planning department however drilling continued into late 2019 and not all results were finalized in 2019. Therefore near mine exploration will carry out resource estimation work on Lappberget above 390 z in 2020. Processing tests have also been ordered in 2019 on drill core representative of the mineralization at 300 z and 400 z.

3.10 Mining methods, processing and infrastructure

Almost 90% of the mined ore in Garpenberg is extracted by sublevel stoping (also called longhole stoping), where the ore is mined in layers between two drifts vertically 25 m apart. The ore body is split into primary and secondary stopes, which are mined in a predefined order and pyramid shape sequence. In Lappberget there are six levels of stopes, each being 25 meters high with stope numbers ranging from 5 to 23. Primary stopes are 10 meters wide, and secondaries 15 meter wide.

Other mining methods include cut and fill, avoca (rill), and in some cases residual mining of sill pillars (Table 3-5). With the cut and fill method mining is carried out in slices along the steeply dipping, narrow ore body. The bottom slice is mined first. The excavated area is then backfilled, so mining can continue with the slice above.

Mine reconciliation is the comparison of the planned stopes against the actual outcome. Table 3-6 shows the reconciliation for the large scale mining methods in 2019.

Table 3-5. Mining method and cut-off for Garpenberg ore lenses

Mining method	Ore lens	Cut-off (SEK/t)	Min width (m)	Percentage of total mined tonnes
Sublevel stoping	Lapp, Kvarn, Kasp	270	10 alt 15	94%
Cut and fill	Damm	345	6 alt 7	4%
Avoca (rill)	Damm	320	10	2%

Table 3-6. Reconciliation for sublevel stoping and rill in 2019.

Stopes	Average Recovery (t)	Average OverBreak (%)	Edges Dilution (m)
Primary	87,71%	17,14	0,40
RILL	88,36%	14,10	0,48
Secondary	82,39%	17,41	0,55
Total Geral	**86,35%**	**17,17**	**0,48**

The expansion project to 2.5 Mt which was completed in 2014 increased the capacity of the mine with the construction of a new crusher, shafts, ore hoists etc. Today there are two underground crushing plants at 700 z and 1087 z. Transport to the crushers is done by trucks from the active mining areas. The crushed ore is hoisted to surface in a shaft, unloaded into a bin in the headframe and then transported by a conveyor belt to an intermediate ore storage, which can hold approximately two days' of production.

In the concentrator, the ore is ground in two stages with autogenous grinding in the primary stage and pebble mill grinding in the second. After grinding, the ore is screened, with the coarse fraction being returned to the primary mill and the fine fraction undergoing gravimetric separation (Knelson) in order to separate coarse gold out at an early stage of the process. Knelson concentrate is collected in big bags. After gravity separation, material is classified using hydrocyclones. The overflow constitutes the main flotation feed, while the underflow undergoes flash flotation in the grinding circuit, from which the concentrate is sent directly to CuPb separation in the flotation plant and the tailings back to the mills.

Flotation is carried out in a three-stage process: CuPb flotation, CuPb separation and Zn flotation. Regrind mills are installed both in the CuPb and Zn circuits. The mineral concentrates are dewatered using thickeners and pressure filters. Three mineral concentrates are produced in flotation: zinc, lead and copper concentrates. The precious metals report primarily to the copper and lead products. Of the flotation tailings, approximately 1/3 is utilized in the paste plant for producing backfill material for the mine and 2/3 is deposited at the tailings management facility.
The zinc and lead concentrates are transported by truck to Gävle port and from there by ship to Boliden's smelters in Finland, Sweden and Norway. The copper and Knelson concentrates are trucked and reloaded to rail for onward transport to the Boliden Rönnskär smelter in Skelleftehamn.

3.11 Prices, terms and costs

Mineral Resources and Mineral Reserves are the basis for the company's long-term planning and will be mined for many years to come. Planning prices, which are an expression of the anticipated future average prices for metals and currencies, are, therefore, primarily utilized in the estimations. Boliden currently uses the prices shown in Table 3-7 below.

Table 3-7.Long term planning prices currently used in Boliden

Commodity / Currency	Planning prices 2019
Copper	USD 6,600/tonne
Zinc	USD 2,400/tonne
Lead	USD 2,100/tonne
Gold	USD 1,200/tr.oz
Silver	USD 17/tr.oz
USD/SEK	8.00
EUR/SEK	9.35
EUR/USD	1.17

The mining cost is 341 SEK/tonne of ore and the processing cost is 167 SEK/tonne of ore. Total mining cost including post-mining treatment plan is 566 SEK/tonne of ore of which 170 SEK/ton is the depreciation. This will give a direct operating cost of 396 SEK/tonne of ore.

An average break-even NSR cut-off value (NSR is based on Boliden's long term estimation on metal prices for zinc, silver, lead, copper and gold and is expressed as SEK/t) for the whole mine is calculated by deducting depreciation and other costs, such as diamond drilling, from the total cost of the mine and processing plant. Different cut-off values are used for different mining methods and ore lenses, see Table 3-5.

3.12 Mineral resources

Classification of mineral resources are reported according to the PERC standard. See Figure 2-1. The classification is based on geological complexity, quality and quantity of informing data and confidence in the block estimates. Typically a drilling grid of 100 x 100 m is required for inferred resource, 50 x 50 m for indicated and 25 x 25 m for measured resource. Tyskgården-Finnhyttan is an exception, where complex geological conditions demand a more dense drilling pattern. The wireframe by which the mineral resource is calculated is based on geological interpretation and NSR (Net Smelter Return). The wireframe can also be obtained by the Deswik Stope Optimizer employing existing geological interpretation and block model (more information on the Deswik Stope Optimizer in chapter 3.13). The latter case will represent a more realistic mineable tonnage, which signifies less adjustments when eventually converting mineral resources into mineral reserves.

All reserve and resource tonnes are calculated from block models. There are seven active block models in Garpenberg, see table Table 3-8. In 2019 the block model for Kvarnberget was updated with new drilling results and the limit of the block model was extended downwards to -1325 z.

Table 3-8. Block models in Garpenberg

Block model	Ore lens(es)
BLGAR	Garpenberg South*
BLTYS	Finnhyttan and Kyrkan-Tyskgården
BLDAM	Dammsjön
BLKVB	Kvarnberget
BLLPB	Lappberget
BLNOR	Kaspersbo, Huvudmalmen and Gransjön UG
BLGRN	Gransjön Open Pit

* Including Kanal, Strand, Finnhyttan and Kyrkan-Tyskgården

Ordinary kriging and inverse distance weighing methods are used for estimating mineral resources. Currently there are two alternative software packages which are being used for the estimations. Propack, which is an add-on to CAD program Microstation has historically been used by Boliden, but in recent years Datamine is being used increasingly. Geological modelling prior to Datamine estimation is done in Leapfrog or Microstation. Table 3-9 shows estimation method and software used for each of the ore lenses in Garpenberg and Table 3-10 shows block sizes for each model. The block sizes are selected from spacing in supporting data in combination with complexity in ore geometry and scale of mining.

Table 3-9.Estimation methods for the Garpenberg ore lenses

Block model	Ore lens code	Name	Method	Software
BLGAR		Garpenberg south	Inv Dist	Datamine
BLTYS	FI1-6, TY1-3, KY1-2	Finnhyttan, Kyrkan-Tyskgården	Inv Dist	Datamine

BLDAM	DAM	Dammsjön	Inv Dist	Propack
BLKVB	KVA, KVB, KVC, KVD	Kvarnberget	Kriging	Datamine
BLLBP	LA, LB, LC	Lappberget	Kriging	Propack
BLNOR	D, E, F, G	Huvudmalmen 881-918 Z	Inv Dist	Propack
BLNOR	HU1-HU6	Huvudmalmen 990-1250 Z	Kriging	Datamine
BLNOR	KA	Kaspersbo	Kriging	Propack
BLGRN	AAA, BBB, CCC, DDD	Gransjön Open Pit	Inv Dist	Propack

Table 3-10. Block sizes and subdivision for Garpenberg block models.

Model	Xsize	Ysize	Zsize	Subdivision
BLDAM	4	6	6	2
BLGAR	3	10	5	2
BLGRN	5	10	10	2
BLKVB	4	6	12.5	1
BLLPB	6	10	6	1
BLNOR	10	20	6	2

Bench scale processing tests are systematically done on ore from new mineral resources in order to confirm that the ore is technically extractable and economically viable. In 2019 tests were carried out on ore from Kvarnberget 1050-1324 z and Finnhyttan.

3.13 Mineral reserves

When converting mineral resources to mineral reserves one has to consider a number of parameters, the most important ones being economic feasibility and rock mechanics. The rock mechanic conditions will determine the amount and size of pillars and sill pillars as well as the length and width of mined stopes. Weak or unstable rock volumes might be discarded completely from the mineral reserves. The volume and geometry of the mineralization will likely determine which mining method to apply. The choice of mining method should also optimize the NPV (net present value) of the ore volume.

With the sublevel stoping method the mineral reserves will be defined by designed stopes whereas the corresponding mineral resources will be defined either by designed stopes or by the mineralized envelope above cut off. Since designed rooms mostly are formed as cubes with 90 degree corners and the mineralized envelope is irregular some of the ore at the edge of the mineralization might get left out when converting resources to reserves. Likewise some waste rock might be included at the edges of the mineralization. See Figure 3-7 from Lappberget 1407 Z for explanation.

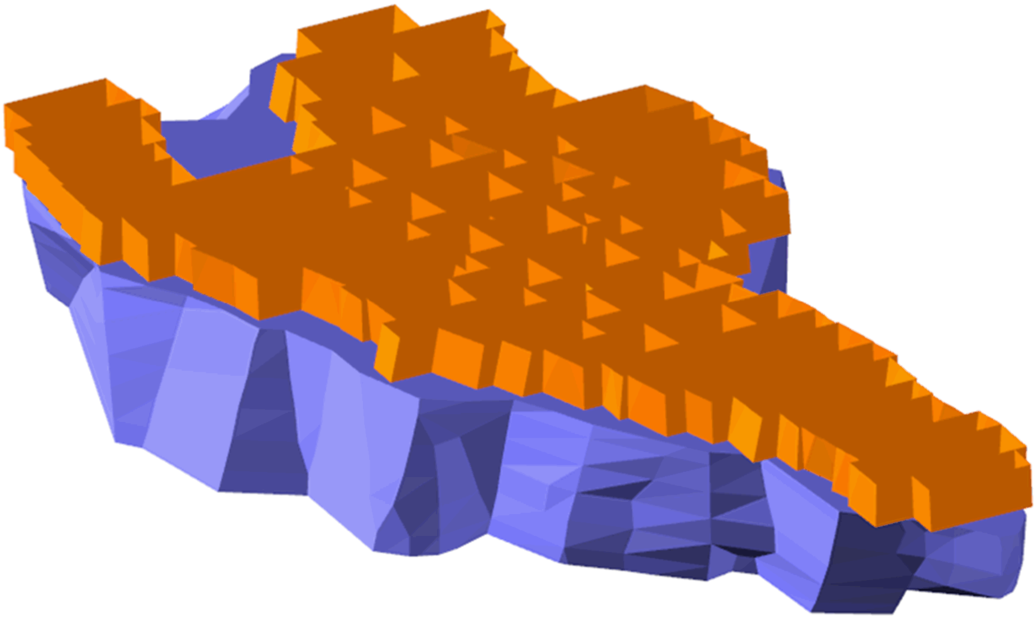

Figure 3-7. Lappberget at the 1407 Z level, which marks the transition from probable reserve in orange colour to indicated resource in blue colour. Note that the stopes in the probable reserve in general don't extend as far as the interpreted limit of the mineralization of the resource

Boliden Garpenberg utilizes mine planning tool Deswik Stope Optimizer (SO) for designing of stopes. SO automates the design process and allows for a number of stope properties including general shape and orientation, cut-off grade, dilution and pillar size. For the latest design the cut-off grade for the stopes is 270 SEK/t and maximum allowed dilution is 25% waste. Stope length is 10-80m for Lappberget and 10-40 m for Kvarnberget and Dammsjön Stope height is 24-25m.

With the cut and fill method the tonnage in a mineral reserve is also generally lower than that of the corresponding mineral resource. This is illustrated quite clearly in Figure 3-8, which shows a top view of Dammsjön at 854 Z. The blue shape outlines the mineral resource and the red shape outlines the mineral reserve. The mining method simply does not allow for the entire mineralized envelope to be included in the mineable mineral reserves, due to geotechnical reasons or other limitations.

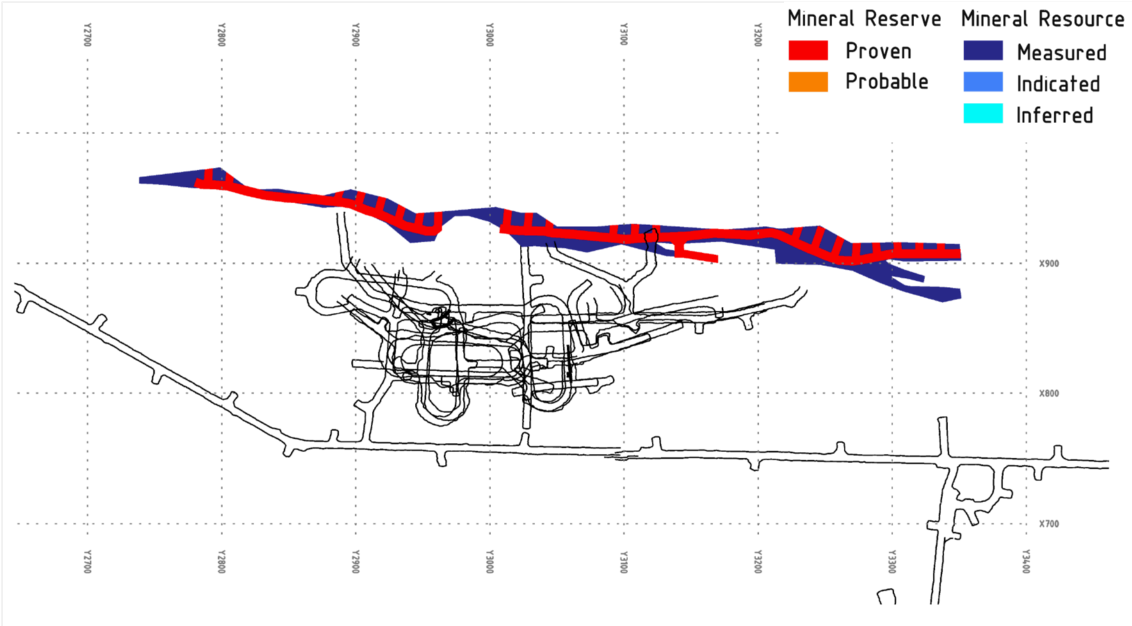

Figure 3-8.Top view of Dammsjön at level 854 Z showing the outline of the mineral resource in blue colour and the mineral reserve in red colour

Table 3-11 shows the Mineral Resources and Mineral Reserves Garpenberg Area as per 2019-12-31.

Table 3-11. Mineral Resources and Mineral Reserves in Garpenberg 2019-12-31

	2019						**2018**					
	kton	**Au**	**Ag**	**Cu**	**Zn**	**Pb**	kton	Au	Ag	Cu	Zn	Pb
Classification		**(g/t)**	**(g/t)**	**(%)**	**(%)**	**(%)**		(g/t)	(g/t)	(%)	(%)	(%)
Mineral Reserves												
Proved	**21 000**	**0.24**	**99**	**0.04**	**3.5**	**1.4**	22 800	0.24	101	0.03	3.6	1.4
Probable	**53 800**	**0.34**	**95**	**0.05**	**2.9**	**1.4**	53 400	0.32	94	0.05	2.9	1.4
Total	*74 800*	0.31	96	0.05	3.1	1.4	*76 100*	0.30	96	0.05	3.1	1.4
Mineral Resourcess												
Measured	**4 300**	**0.31**	**100**	**0.06**	**3.3**	**1.6**	4 400	0.31	100	0.06	3.3	1.6
Indicated	**40 000**	**0.35**	**89**	**0.05**	**2.7**	**1.3**	35 400	0.35	88	0.05	2.8	1.3
Total M&I	*44 300*	0.35	90	0.05	2.8	1.3	*39 800*	0.34	90	0.05	2.8	1.4
Inferred	**24 100**	**0.43**	**59**	**0.07**	**2.6**	**1.5**	19 100	0.48	56	0.08	2.8	1.7

3.14 Comparison with previous year

In 2019 mineral reserves in Garpenberg decreased by 1.3 Mt to 74.8 Mt. Measured and indicated resource in Garpenberg increased by 4.5 Mt to 44.3 Mt. Inferred resource increased by 5.0 Mt to 24.1 Mt. Table 3-12 shows the changes in detail, including changes in metal grades.

The major change derives from Kvarnberget where new exploration- and infill drilling and subsequent block model- and design updates have added more than a total of 9 Mt. Most of the new tonnage is attributed to the extensive exploration drilling program carried out between -1050 z and -1324 z. Deswik’s Stope Optimizer was used for designing of the stopes upon which the tonnage for the mineral reserve between -600 z and 1050 z was calculated. Due to the irregular nature and thin shape of the mineralization stopes sometimes extend beyond the mineralized envelope and into rock which has been the categorized as waste. The new stope design therefore includes 16.5 % waste. The waste rock contains 0.45 % Zn, 0.21% Pb and 21 g/t Ag. More consistent and regularly shaped ore bodies such as Lappberget will have less inclusion of waste. Figure 3-9 shows the new stope design compared to the old one.

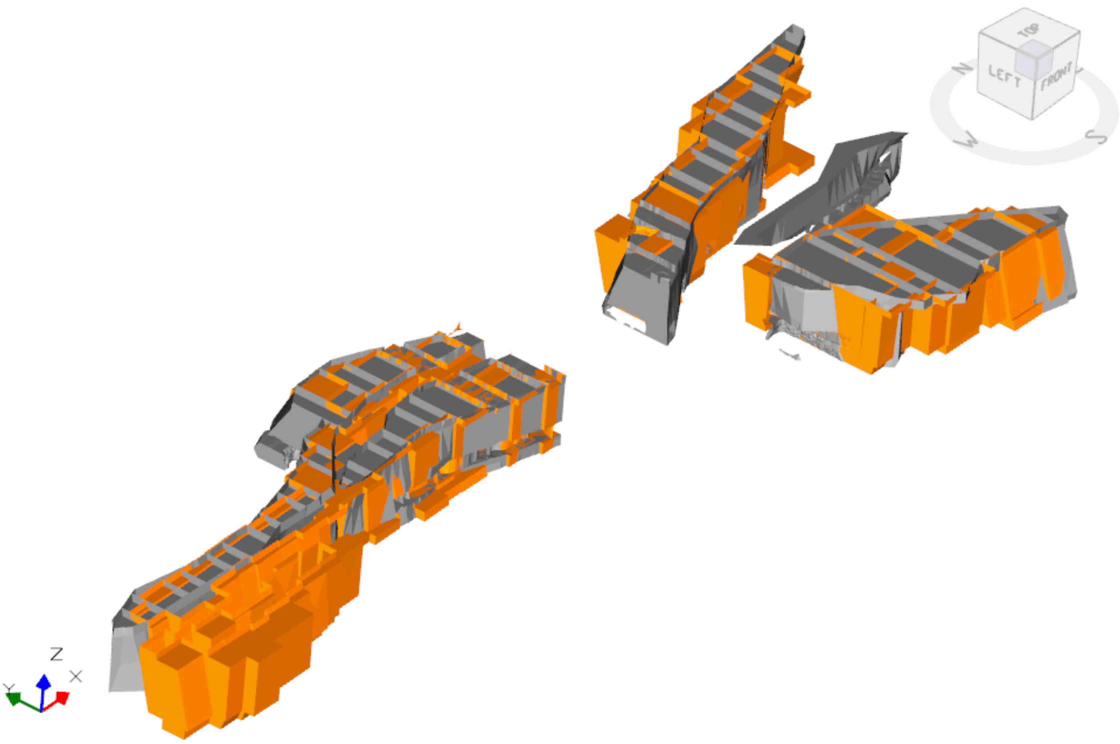

Figure 3-9. Oblique view of Kvarnberget 810 z showing new stope design in orange compared to old stope design in grey. Infill drilling and a new geological interpretation has resulted in a new ore lens on the SW side of Kvarnberget. Stope height is 25 m.

Exploration drilling was also carried out in Lappberget, which resulted in the addition of 1.8 Mt of inferred resources at level 390-435 z.

Mined out tonnage in 2019 totals 2 685 kton, which is an increase of 240 kton from previous year. Metal grades of the mined out tonnage is as follows: 4.1% Zn, 1.5% Pb and 118 ppm Ag. Almost 80% of all mined out ore derives from Lappberget.

Table 3-12. Mineral Resources and Mineral Reserves in Garpenberg as per December 31, 2019. Numbers in brackets show changes from last year.

Classification	kton 2019-12-31		Au (g/t)		Ag (g/t)		Cu (%)		Zn (%)		Pb (%)	
Proved Mineral Reserve	21 036	(-1 730)	0.24	(-)	99	(-2)	0.04	(-)	3.5	(-0.1)	1.4	(-)
Probable Mineral Reserve	53 799	(+434)	0.34	(+0.02)	95	(+1)	0.05	(-)	2.9	(-)	1.4	(-)
Total Mineral Reserve	*74 836*	*(-1 296)*	*0.31*	*(+0.01)*	96	*(-)*	*0.05*	*(-)*	*3.1*	*(-)*	*1.4*	*(-)*
Measured Mineral Resource	4 323	(-53)	0.31	(+0.01)	100	(-)	0.06	(-)	3.3	(-)	1.6	(-)
Indicated Mineral Resource	39 962	(+4 570)	0.35	(-)	89	(-)	0.05	(-)	2.7	(-)	1.3	(-)
Sum Measured and Indicated	*44 285*	*(+4 517)*	*0.35*	*(-)*	*90*	*(-)*	*0.05*	*(-)*	*2.8*	*(-)*	*1.3*	*(-)*
Inferred Mineral Resource	24 092	(+4 990)	0.43	(-0.05)	59	(+3)	0.07	(-0.01)	2.6	(-0.2)	1.5	(-0.2)
Total Mineral Resource	*68 377*	*(+9 507)*	*0.38*	*(-0.01)*	*79*	*(-)*	*0.06*	*(-)*	*2.7*	*(-0.1)*	*1.4*	*(-0.1)*

3.15 Reconciliation

In order to confirm the precision of the geological interpretation, modelling, grade interpolation etc. actual mining volumes times block model grades are checked against the measured results from the processing plant. This procedure is called reconciliation and is carried out every month and presented quarterly. Monthly estimates vary dramatically depending on the mine's logistics of stocks in mine and on surface. The turnover of the stocks also varies a lot.

The grades of the mined out ore are calculated from the block model using the tonnage reported as loaded from the stopes and surveyed tonnage from cut and fill and development ore. The ore can either be transported directly to the plant or put in stockpiles underground. Above ground there is an ore storage facility which at the beginning of 2019 contained 30 Kton of ore. During the year the tonnage fluctuated between 23 Kton and 101 Kton. At the end of the year the storage contained 53 Kton of ore.

For the annual report of reserves and resources the reconciliation is compiled from a weighted aggregation of the four quarters (rolling 4 quarters). Table 3-13 shows monthly and quarterly results for 2019 from the mine and the processing plant. The year total on the bottom row. The official grades for Garpenberg are those of the processing plant. The total tonnage reported derives from production reports and differs slightly from the processed tonnage and from tonnage calculated from the block model in Table 3-13

Table 3-13. Comparing measured results from the processing plant with calculated results from the block model. Note that the numbers from the processing plant for December are preliminary.

	Metal grades of processed ore						Metal grades of mined ore (from block model)					
Quarter	kton	Au g/t	Ag g/t	Cu %	Zn %	Pb %	PP kton	Au g/t	Ag g/t	Cu %	Zn %	Pb %
Jan	211.7	0.25	107	0.06	4.08	1.45	216.2	0.20	99	0.03	3.55	1.28
Feb	232.6	0.23	118	0.05	4.15	1.63	227.3	0.24	105	0.03	4.13	1.58
Mar	270.2	0.21	110	0.05	4.08	1.45	274.3	0.26	97	0.03	4.04	1.35
2019 Q 1	**714.4**	**0.23**	**112**	**0.05**	**4.10**	**1.51**	**717.8**	**0.23**	**100**	**0.03**	**3.93**	**1.40**
Apr	246.4	0.22	126	0.06	4.24	1.53	235.2	0.22	121	0.03	3.87	1.36
May	172.9	0.28	116	0.05	3.58	1.34	230.0	0.31	91	0.05	3.32	1.32
Jun	281.0	0.27	114	0.06	3.60	1.37	216.1	0.29	119	0.04	3.55	1.40
2019 Q 2	**700.3**	**0.26**	**119**	**0.06**	**3.82**	**1.42**	**681.3**	**0.27**	**110**	**0.04**	**3.58**	**1.36**
2019 Q 1+2	**1414.7**	**0.24**	**115**	**0.05**	**3.96**	**1.47**	**1399.0**	**0.25**	**105**	**0.04**	**3.76**	**1.38**
Jul	247.6	0.29	118	0.05	3.54	1.36	208.7	0.22	104	0.03	4.59	1.52
Aug	225.4	0.27	120	0.06	6.01	1.93	228.6	0.25	111	0.03	4.79	1.65
Sep	252.5	0.24	110	0.05	4.37	1.65	242.3	0.27	122	0.05	5.05	1.98
2019 Q 3	**725.5**	**0.27**	**116**	**0.06**	**4.60**	**1.64**	**679.6**	**0.25**	**113**	**0.04**	**4.81**	**1.72**
2019 Q 1-3	**2140.2**	**0.25**	**115**	**0.05**	**4.18**	**1.52**	**2078.6**	**0.25**	**108**	**0.04**	**4.11**	**1.49**
Oct	286.8	0.32	103	0.06	3.66	1.57	279.0	0.28	91	0.06	4.50	1.74
Nov	171.1	0.25	177	0.05	3.38	1.34	206.0	0.25	169	0.04	2.79	1.25
Dec	262.7	0.26	119	0.04	3.95	1.42	245.5	0.21	121	0.03	4.67	1.67
2019 Q 4	**720.6**	**0.28**	**126**	**0.05**	**3.70**	**1.46**	**730.5**	**0.25**	**123**	**0.04**	**4.08**	**1.58**
2019 Q 1-4	**2860.8**	**0.26**	**118**	**0.05**	**4.06**	**1.51**	**2809.1**	**0.25**	**112**	**0.04**	**4.10**	**1.51**

The rolling 4-quarter graph for zinc, lead and silver is shown below in Figure 3-10. The graph shows the difference in % in weighted metal grades between processed ore and mined ore and is calculated with the following equation: (Metal Grade Processing Plant/Metal Grade Block Model)-1. Thus a positive number means that the grade is higher in the processing plant than in the block model. The values for Q 1-4 2019 seen at the rightmost side of the graph are: -0.9% Zn, -0.5% Pb and +5.8 % Ag.

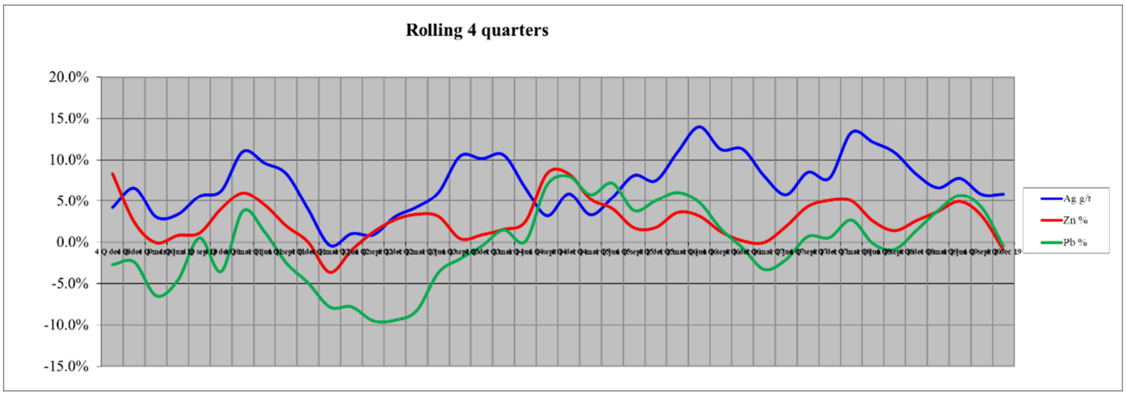

Figure 3-10. Metal grades in processed ore vs metal grades of the mined ore based on the block model, over a ten-year period. The figure shows that particularly silver grades have been higher in the processing plant than the block model during 2019.

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