MODULE 10-ZINC MINING IN AFRICA AND AN ADDENDUM TO THE INDIA MODULE

This is my tenth and final module looking at the zinc miners around the world. This time it is Africa.

The key nations or deposits that I have not had a look at are:

- Kazakhstan (400,000 T). Largely Glencore assets see pages 942-1634 here ;
- Brazil (150,000 T). Essentially Votorantim;
- Arizona Mining's Taylor deposit;
- Russia (200,000 T) and the undeveloped Ozernoe deposit.

I have added an addendum for India here since Vedanta stated recently that due to geotechnical issues they will not be taking the Rampura Agucha pit down as far as planned and this will reduce production from this deposit by roughly 400,000 T zinc in the 2019-2020 timeframe. And as a wonderful Black Friday parting gift, at the end I discuss Bolivia's two largest producers.

Summary of Africa Zinc Mine Supply

As illustrated in Table 1, zinc mine supply in Africa is set to double with new production from Bisha and expected mine construction and commissioning at Gamsberg and Kipushi during the study period. The Skorpion and Black Mountain mines are expected to be exhausted.

Table 1 Summary of Actual and Expected African Zinc Mine Production

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Bisha	0	0	0	0	40,200	97,500	116,800	121,500	109,350	81,000	81,000
B.Mountain	38,577	28,999	27,022	29,272	30,000	30,000	30,000	30,000	20,000	0	0
Skorpion	145,342	124,924	102,188	82,029	90,000	109,000	109,000	109,000	100,000	0	0
Gamsberg	0	0	0	0	0	0	0	100,000	180,000	250,000	250,000
Rosh Pinah	52,000	52,000	54,000	55,500	55,000	55,000	55,000	55,000	55,000	55,000	55,000
Perkoa	0	33,300	63,400	86,000	83,000	80,000	75,000	75,000	75,000	70,000	65,000
Morocco	47,600	44,200	45,412	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000
Kipushi	0	0	0	0	0	0	0	60,000	180,000	240,000	240,000
Other	26,500	20,757	20,769	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000
Total	**310,019**	**304,180**	**312,791**	**322,801**	**368,200**	**441,500**	**455,800**	**620,500**	**789,350**	**766,000**	**761,000**

Summary of Regions Reviewed for Mined Zinc Supply

The figures for India have been adjusted based on recent news from Vedanta discussed later and African zinc mine supply has been added to produce the totals illustrated in Table 2 for all countries reviewed to date. With the addition of Africa, zinc mine supply returns to 2015 levels in 2020 but then again begins a gradual decline as further mines close or reduce production.

Table 2 Summary of Mined Zinc Production for the Regions Reviewed Below

Mod.	Region	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
2	Canada	622.6	412.8	332.5	295.6	316.1	332.0	320.0	319.0	264.0	160.0	105.0
3	USA	738.0	774.0	812.0	817.0	769.0	751.0	736.0	721.0	682.0	662.0	659.0
4	India	738.5	764.7	758.7	744.2	546.0	854.0	683.0	652.0	750.0	729.0	688.0
5	Australia	1,541.2	1,524.5	1,561.1	1,547.0	840.3	841.8	1,016.5	1,078.0	1,051.7	1,011.0	972.7
7	Peru	1,204.3	1,262.5	1,250.1	1,342.0	1,273.2	1,408.6	1,415.5	1,425.0	1,447.7	1,416.1	1,422.0
8	Europe	1,000.8	988.3	990.2	907.1	911.7	902.0	906.3	931.5	958.5	980.5	986.5
9	Mexico	660.3	642.5	659.9	687.7	651.1	744.3	784.3	812.3	817.3	820.3	824.3
10	Africa	310.0	304.2	312.8	322.8	368.2	441.5	455.8	620.5	789.4	766.0	761.0
		6,815.7	**6,673.5**	**6,677.3**	**6,663.4**	**5,675.6**	**6,275.2**	**6,317.4**	**6,559.3**	**6,760.6**	**6,544.9**	**6,418.5**
			-2.1%	0.1%	-0.2%	-14.8%	10.6%	0.7%	3.8%	3.1%	-3.2%	-1.9%

I have therefore looked at over 80% of the zinc mines by zinc tonnage outside of China. The only reliable source I have come across for Chinese data is the consulting firm Antaike ($$).
http://www.antaike.com

Existing Zinc Mines in Africa

Nevsun Resources

Bisha Mine- Eritrea

Nevsun has done a good job moving the Bisha deposit along through major transitions from gold mining to copper mining and are now in the final transition stage to primary zinc/copper mining. This final stage however is having a rough start up in the mill.

The metallurgical information provided in the 2012 NI 43-101 was somewhat sketchy and acknowledged that there were outstanding issues related to making good copper and zinc concentrates. But, you have to go back to the 2006 NI 43-101 to get good detail on the studies conducted. Testing was conducted in 2005 only.

What AMEC discovered early on in testing was that the primary ore oxidized rapidly and this had a major impact upon metallurgical performance. In order to stop the oxidation prior to lab testing they had to air dry the samples, put them in double heavy plastic bags in a drum that was then purged with nitrogen. So, contrast this with the 2.3 million tonne stockpile of primary ore sitting on surface at Bisha for varying lengths of time oxidizing away recently. Nevsun simply rediscovered what AMEC discovered in 2006. You can't make a decent copper concentrate with oxidized ore.

Readers can follow the story more fully in the 2006 NI 43-101. My intent is not to air all their dirty laundry here but to make a reasonable forecast of zinc output going forward.

Nevsun is now milling ore fresh from the pit so the degree of oxidation occurring is being minimized. This should hopefully resolve their milling issues. Unfortunately, the future of the 2.3 MT stockpile is uncertain. Table 3 lists the probable reserves as reported in the 2012 NI 43-101.

Table 3 Probable Reserves for the Primary Ore as Reported in the 2012 NI 43-101

	Tonnes	Zn%	Cu%	Au g/t	Ag g/t
Probable Reserves	17,600,000	6.54	1.13	0.73	49

The amount of fresh ore remaining therefore is:

Classification	Tonnes
Probable Reserves	17,600,000
Milled in Q2/Q3 2016	600,000
Oxidized Stockpile	2,300,000
"Fresh" Ore Remaining	14,700,000

Nevsun also has a problem however coming up in their pit that they readily acknowledge. The probable reserves are based on the final pit limit shown in the figure below. They need to conduct over 20 MT of waste stripping a year to get to this pit bottom but have been doing less than half of this for years. According to the NI 43-101, "Phase 9" contains 7.8 MT of ore yet they are not conducting the waste

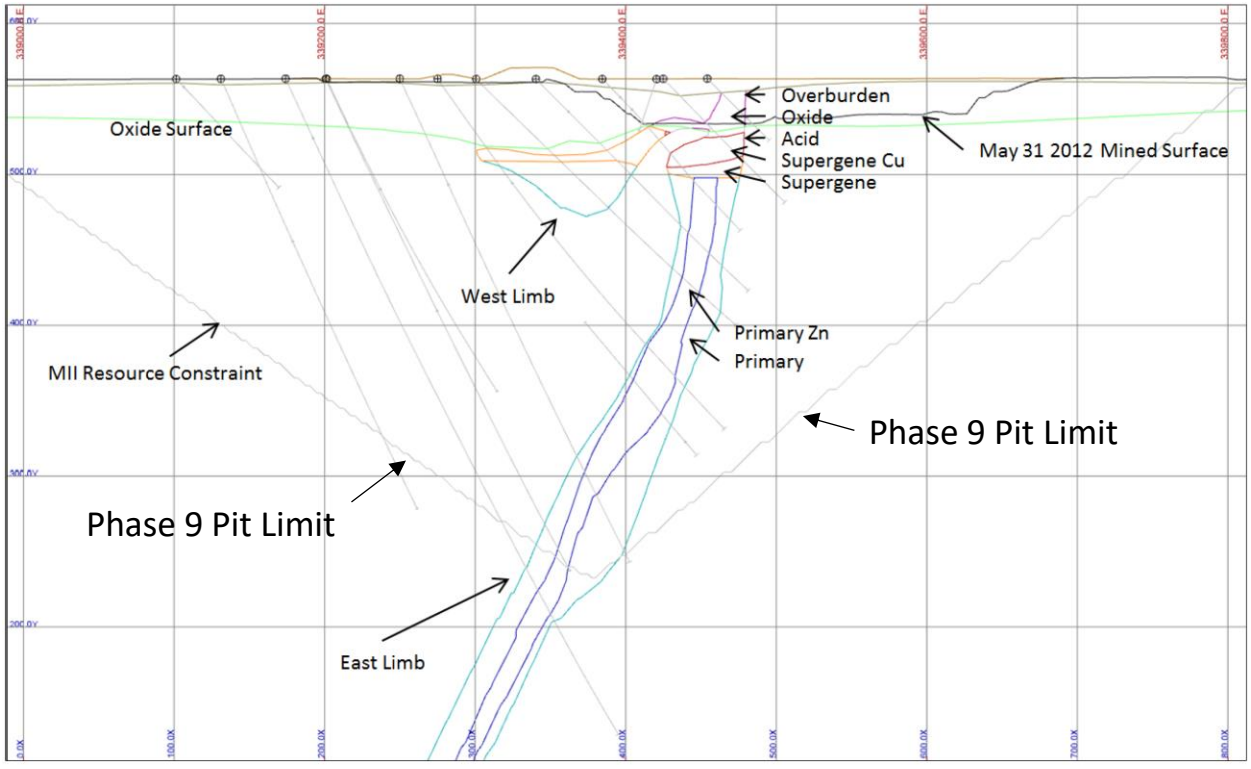
stripping for this phase. What this means is that the planned pit will only access an additional ~7 MT of fresh primary ore so by roughly mid-2020 they will essentially have nothing fresh to mill.

Nevsun therefore has three choices: Increase the amount of waste stripping immediately, conduct underground mining, or reduce the milling rate. They have not decided what they will do here and it does not look like they plan to for another year or so. This is a ticking time bomb and shareholders should press for an early resolution here. In my opinion, underground mining will not provide 2 MT of ore a year, 1-1.2 MT a year perhaps.

Therefore, illustrated in Table 4 is a reduction in the mines production rate starting in 2020. Nevsun needs to provide better guidance here. This table assumes they will attempt to blend some of the surface oxidized stockpile with an underground option post-2020. But I could be generous here.

Table 4 Potential Bisha Production Schedule

Year	Tonnes	Grade	Recovery	T Zn in Concentrates
2016	1,100,000	5.8	63%	40,200
2017	2,000,000	6.5	75%	97,500
2018	2,000,000	7.3	80%	116,800
2019	2,000,000	7.5	81%	121,500
2020	1,800,000	7.5	81%	109,350
2021	1,500,000	7.2	75%	81,000
2022	1,500,000	7.2	75%	81,000



References: NI 43-101 Technical Reports dated August 31,2012

November 15, 2006

October 1, 2004

www.sedar.com

Vedanta

Vedanta acquired the Skorpion and Black Mountain mines and the undeveloped Gamsberg deposit from Anglo American in 2011. Skorpion is in Namibia whereas Black Mountain and Gamsberg are near to each other in South Africa.

Both Skorpion and Black Mountain are mature assets with closure of both expected during the study period. Gamsberg will be ramping up production from what will ultimately be a large open pit.

Until recently, I was scratching my head about Vedanta's ultimate strategy here. The Gamsberg deposit is well known for its high manganese content (just google "Gamsberg manganese pdf" for a sample of available papers). This gums up electrolytic zinc smelters which is the key reason this orebody has not been developed to date.

Until very recently the plan was to ship the manganese contaminated zinc concentrate to the soon exhausted Skorpion mine and refinery where it would be roasted and then made into zinc metal in the 150,000 T a year refinery. The capacity of the mine would therefore be dictated by the capacity of the refinery. A roaster requires construction.

My confusion was based on the fact that they are actively pre-stripping the Gamsberg open pit and finalizing the engineering and procurement for the Gamsberg 4 MT a year mill to produce 250,000 T of zinc in concentrate a year. But no action was being taken to engineer and construct the roaster at Skorpion and it would be too small to take all the concentrate anyways.

Vedanta resolved this confusion recently by stating that they will be selling the zinc concentrate from Gamsberg into the market and committing to a pit deepening at Skorpion to extend its mine life by 2-3 years. (I suspect this is all in response to the recent set back at Rampura Agucha open pit discussed as an Addendum to my India Module later).

This news was quite a revelation that changes the zinc concentrate supply story markedly. Firstly, it betrays the current desperation of zinc smelters to find feed. They are willing to accept what they were reluctant to for the past forty years. (Other possibilities include treatment charges plus penalties are now quite reasonable and/or they intend to use some of this concentrate at their Indian smelters to make up for shortfalls at existing mines.) Secondly, Gamsberg is no longer constrained production wise by the size of the refinery in Namibia. Vedanta has looked at eventual milling rates up to 10 MT a year which would produce in excess of 500,000 T of zinc in concentrate.

Black Mountain- South Africa

Phelps Dodge and Gold Fields developed this underground zinc/lead mine in the late 1970's. It was later acquired by Anglo American who sold it to Vedanta in 2011. This is a deep mine with the main shaft down to 1,750 m. Annual production has varied from 1.35 MT to 1.58 MT over the past five years. Table 5 lists recent reserves.

Table 5 Proven and Probable Reserves as of March 31, 2016

	Tonnes	Zn%	Pb%
P+P Reserves	6,900,000	2.81	3.00

Annual mined grades are not reported but appear to be somewhat worse than reserve grades for the past three years when zinc in concentrate production is compared to the annual tonnage mined. For 2015 for instance:

Tonnes mined: 1,579,633 T

Zinc in concentrate: 29,272 T

Recovered grade: 29,272 T/1,579,633 T = 1.85% or 66% of reserve grade.

Vedanta states that the mine converted last year from cut and fill mining to longhole stoping. This could explain the increase in mined tonnes and decrease in grade due to higher dilution. Predicting mine life here is a bit of a crapshoot. Reserves are ample to 2020 but there are also lower grade resources. Reserves and resources however dropped 4.7 MT last year, or three times the rate of mining, so the mine appears to be at the inevitable stage of realizing much of what they have on the books is crap. Every mine goes through this process near the end and gradually takes the hit hoping no one notices. So, in Table 6 I assume 1.5 MT mined per annum at a recovered grade (after mine dilution and mill losses) of 2% Zn for 30,000 T zinc a year to 2021 then mine closure.

Table 6 Actual and Expected Mined Zinc Production

FY2012	FY2013	FY2014	FY2015	FY2016	2016	2017	2018	2019	2020	2021
31,770	38,577	28,999	27,022	29,272	30,000	30,000	30,000	30,000	20,000	0

FY2016- financial year ending March 31,2016. 2106-2021 are calendar years.

The Headframe at Sunset

Skorpion Mine- Namibia

Skorpion is a non-sulphide zinc deposit in Namibia that required the construction of a dedicated refinery to handle the unique ore type. I looked for a very brief description of the geology and this is about the best I can do. Way too many big words for mining engineers who still struggle to get their E's pointing in the right direction:

The supergene non-sulphide ores have formed by oxidation of the base metal sulphide protore by wall rock replacement and in-situ oxidation. The non-sulphide ore minerals comprise predominantly sauconite (Zn-smectite), substantial amounts of hemimorphite and smithsonite, and subordinate amounts of hydrozincite, tarbuttite and chalcophanite. The supergene ore minerals form mainly euhedral and subhedral crystals and occur as open space fillings in inter- and intragranular voids, fractures and breccias. The supergene non-sulphide ore body is hosted mainly by metasiliciclastic rocks, which are composed of meta-arkoses and –subarkoses, and subordinately by felsic metavolcanic rocks and their volcaniclastic equivalents. The ore body is irregularly shaped, transgressive to sedimentary layering and major tectonic features. It displays a relatively flattop, which is covered by a blanket of unmineralised overburden consisting of alluvial sediments, calcrete and Recent sand dunes. The supergene ore body is laterally zoned displaying a pronounced supergene lateral metal zonation pattern, which has developed as a result of differences in metal solubilities. Iron and copper zones represent the leached part of the supergene ore body that corresponds to the location of the sulphide protore. The more mobile zinc has precipitated away from the iron and copper zones forming a markedly supergene zinc enrichment zone.

Us mining engineers don't really understand geology but we do understand pictures so below is a couple from the open pit including a more recent photo.

The mine started in 2003 with a reserve of 24.6 MT grading 10.6% Zn. When the mine is operating at full capacity, roughly 1.6 MT of ore are processed annually. The refining process comprises sulphuric acid atmospheric leaching, zinc solvent extraction (SX) and electrowinning (EW) to produce London Metal Exchange (LME) Special High Grade (SHG) zinc. Further description of the process can be found here.

The market has been expecting the imminent closure of this mine but Vedanta committed recently to a pit deepening to extend the mine life "by an estimated 2 years – 3 years". Table 7 lists the remaining reserves and resources. FY2016 production results were impacted by labour issues. I assume that the commitment to pit deepening now places the resources into the reserve column and the mine will continue to 2020.

Table 7 Reserves and Resources as of March 31,2016

	Tonnes	Zn%
P+P Reserves	5,200,000	9.00
M+I Resources	2,100,000	9.59

Table 8 is my estimate of production through to mine closure. Vedanta does not report annual mining grades but when I compared reserve grade to zinc annual output, it is apparent that the recovered grade has slipped steadily. My gut feel is that as the pit gets deeper, they are encountering sulphides that won't leach. So, I have assumed 80% recovery of remaining zinc in the reserves and resources to account for this and I have diluted the resources.

Table 8 Actual and Expected Mined Zinc Production

FY2012	FY2013	FY2014	FY2015	FY2016	2016	2017	2018	2019	2020	2021
144,755	145,342	124,924	102,188	82,029	90,000	109,000	109,000	109,000	100,000	0

Gamsberg

When Anglo American first shaped the project they envisioned a mill processing 10 MT a year and submitted the project description for approvals here. Vedanta has since split the project up into two phases, a 4 MT a year phase for 12 years and then a possible expansion after this point. The project description implies that the overall waste striping ratio will be 10:1. The Gamsberg North deposit will be mined.

Vedanta stated recently that:

"At Gamsberg, pre-stripping mining was successfully completed and prestart mining is progressing well with 11 million tonnes of excavation. Techno-commercial discussions with vendors for plant and infrastructure and bulk mining orders have been completed. The first ore production is expected to in mid-2018 and fully ramp up to full 4 mtpa within 12 months."

The reserves and resources for Gamsberg are listed in Table 9.

Table 9 Reserves and Resources as of March 31, 2016

	Tonnes	Zn%	Pb%
P+P Reserves	53,200,000	6.63	0.51
M+I Resources	97,900,000	6.20	0.54

The timeline appears to be too aggressive considering they have only spent $US33 M of the $US400M budget and have yet to pour any concrete. So, Table 10 assumes a Q1 2019 for the start of mill production with an 24 month ramp up. Due to the mine life extension at Skorpion, Vedanta states:

> *"The Gamsberg concentrate will therefore be placed in the market for its first three years and offtake appetite has been tested and found adequate."*

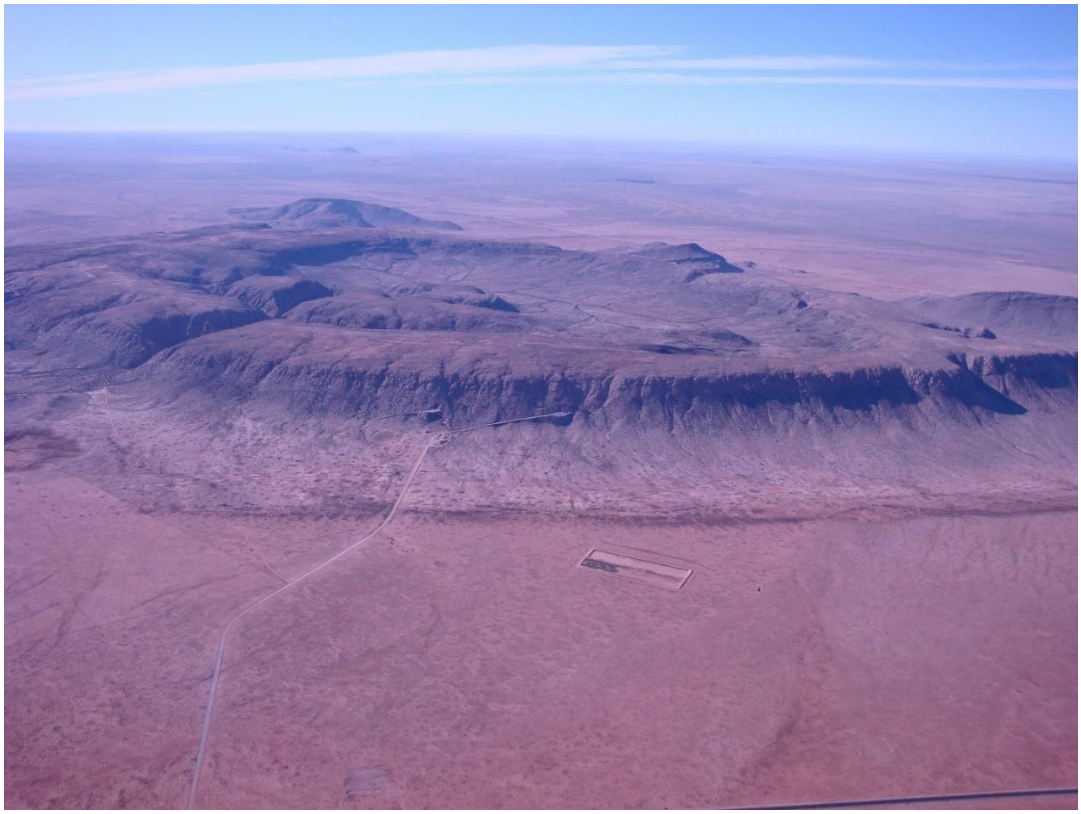
This implies that they expect Skorpion to remain in production to 2020.

Table 10 Assumed Zinc Production Ramp Up at Gamsberg

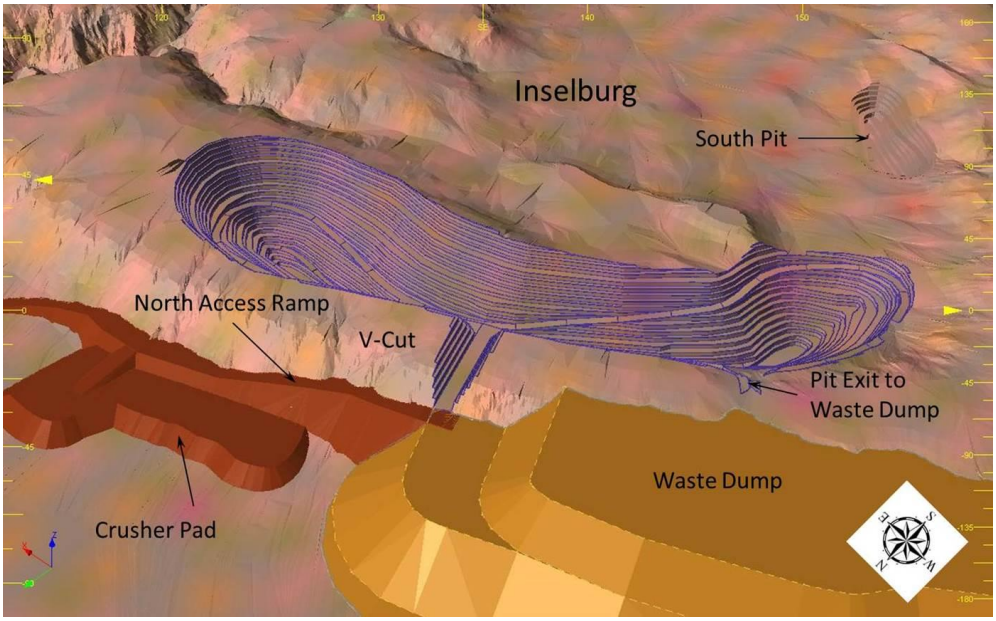
2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
0	0	0	0	0	0	0	100,000	180,000	250,000	250,000

The roaster at Skorpion will be required in the 2019/2020 timeframe to keep the zinc plant in operation as Skorpion runs out of ore. This will mean most Gamsberg concentrate is then sent to Skorpion.

The manganese is reported to be in the sphalerite crystal lattice and present in the host waste rock. So, it does not appear possible to reject the manganese in the mill. Although the technical paper found here discusses largely the Gamsberg East deposit, a good description of the area geology and issues surrounding manganese are presented for readers wanting more in-depth information. High manganese concentrations lead to a build up of a manganese layer on the zinc plant anodes. Further discussion on the impact of impurities on electrolytic zinc smelters may be found here.



Gamsberg North Deposit Location Looking South



Gamsberg North Planned Open Pit Looking South

Vedanta Summary

Table 11 summarizes Vedanta's actual and forecast production in Africa.

Table 11 Actual and Expected Mined Zinc Production in Africa for Vedanta

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Black Mountain	38,577	28,999	27,022	29,272	30,000	30,000	30,000	30,000	20,000		
Skorpion	145,342	124,924	102,188	82,029	90,000	109,000	109,000	109,000	100,000	0	0
Gamsberg	0	0	0	0	0	0	0	100,000	180,000	250,000	250,000
Total	183,919	153,923	129,210	111,301	120,000	139,000	139,000	239,000	300,000	250,000	250,000

I have conveniently ignored the three month difference between financial year and calendar year here to simplify maters.

Glencore

Rosh Pinah- Namibia

This Glencore underground mine is located near Skorpion. Glencore states:

> *Sedimentary exhalative (SEDEX) and remobilised zinc and lead sulphide ores are contained within the so-called Ore Equivalent Horizon, a stratiform horizon that is extensively folded and thrusted, resulting in discreet, subvertical orebodies that vary in size from 0.4 - 8Mt.*

Glencore acquired this mine in 2012. Table 12 lists proven and probable reserves and 2015 production results. I am not certain what the underground mining method is but probably blasthole stoping and/or cut and fill. Reserves are ample to maintain production through the study period and Glencore states that the ability to find additional resources is good. Table 13 lists actual and forecast production.

Table 12 Proven and Probable Reserves as of December 31, 2015 and 2015 Production Results

	Tonnes	Zn%	Pb%	Ag g/t
P+P Reserves	5,700,000	9.0	1.6	25
2015 Production	710,000	8.7	2.1	nr

nr= not reported

Table 13 Estimated and Expected Mine Zinc Production

2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
52,000	52,000	54,000	55,500	55,000	55,000	55,000	55,000	55,000	55,000	55,000

2012- no data available, placeholder used. 2013-2015 data assumes 90% recovery of zinc reported in tonnes and grades mined. Glencore does not split out this mines results separately. 2016-2022 assumes 700,000 T a year @ 8.7% Zn with 90% recovery

Perkoa- Burkina Faso

Some people have wondered why I have not shown much enthusiasm for investing in Canada's Trevali Mining. The key reason has been that shareholders of junior joint venture partners of Glencore have generally not faired well. Perkoa is another example of Glencore taking over an asset when the junior company could not or would not come up with the necessary funds to meet cash calls. In this case, it was Australia's Blackthorn Resources, which was delisted in 2014 despite having a very good zinc asset. Part of their problem appears to be a low-ball feasibility study estimate of $US72.5M by Snowden so they are likely responsible for most of their own downfall. A world financial crisis did not help matters much either.

Anyone considering a joint venture with Glencore should review the case studies of Donner Minerals, Katanga Mining, Aurelia Metals, Indophil Resources, Precious Metals Australia, Anaconda Nickel, Vena Resources, Trevali Mining and Blackthorn Resources to ensure they have a joint venture agreement properly structured to survive pre-production cost over-runs in particular. In some cases, Glencore is no doubt the mines saviour but in other cases there are some rather upset parties.

OK, so having my Glencore rant out of the way for this Module, onto Perkoa. As orebodies go, this one is small potatoes but the zinc grade is exceptional. AIM Resources of Australia, which later became Blackthorn completed a feasibility study for this deposit in 2005. The study was based on the mining of 6.3 MT of ore grading 14.47% Zn at 500,000 T a year with 93.5% mill recovery. Glencore no longer reports the minor lead (0.2%) and silver content (40 g/t) in the orebody so I assume they have shutdown the lead recovery circuit in the mill.

The orebody is a classic volcanic massive sulphide deposit shown in section below. The resource appears open at depth as illustrated in the accompanying cartoon.

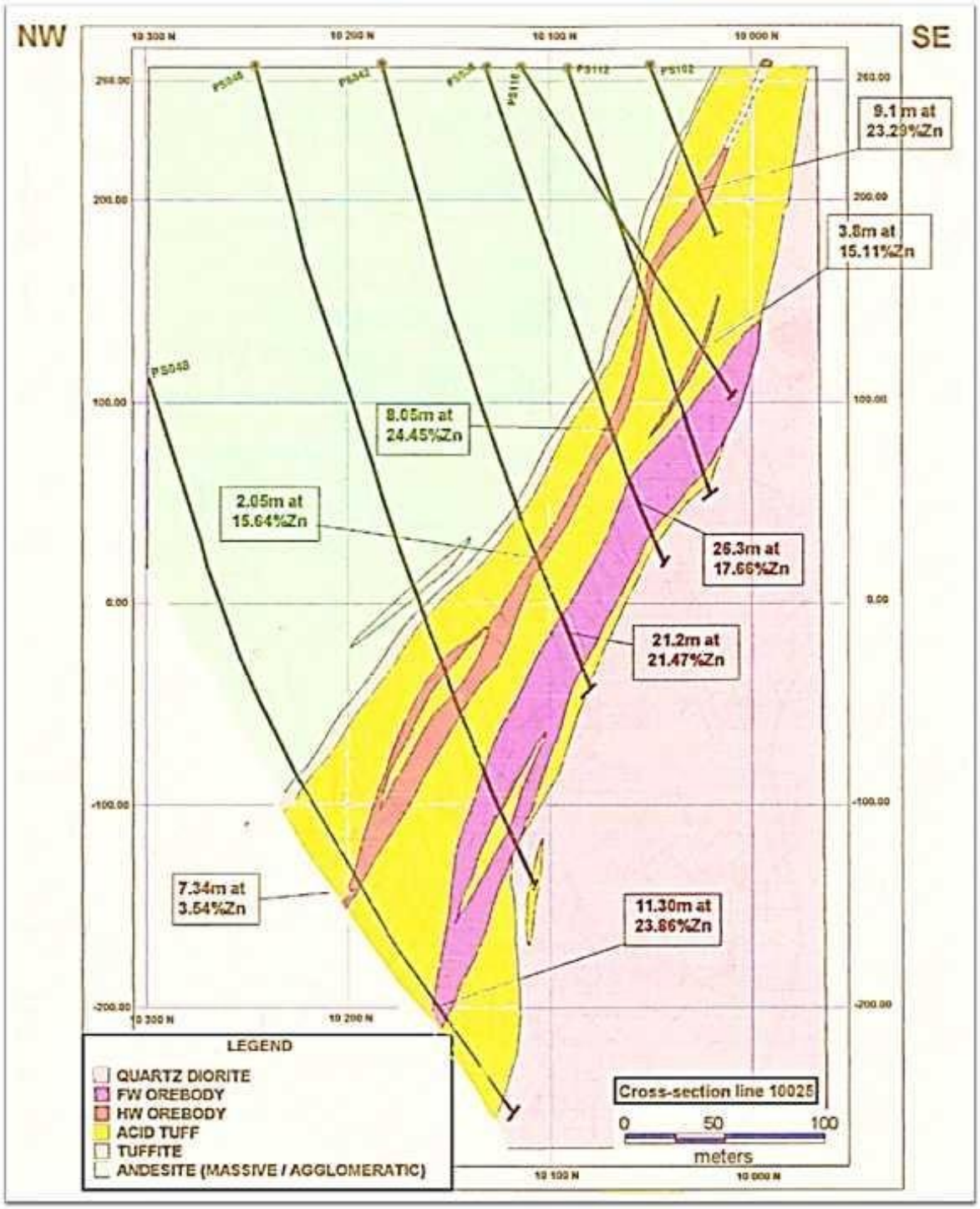
Glencore placed this orebody into production in 2013. Proven and probable reserves for 2015 and 2015 production results are listed in Table 14. Glencore does not break out zinc production separately in production reporting so I have applied the feasibility level 93.5% mill recovery to come up with estimated and expected zinc production in Table 15. I have assumed the milling of 500,000 T a year with zinc grade gradually dropping to reserve grade. There are adequate resources here to ensure production rates through the period assessed.

Table 14 Proved and Probable Reserves as of December 31,2016

	Tonnes	Zn%
P+P Reserves	3,300,000	15.0
2015 Production	500,000	18.4

Table 15 Estimated and Expected Mined Zinc Production

2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
0	33,300	63,400	86,000	83,000	80,000	75,000	75,000	75,000	70,000	65,000


NW
SE
9.1m at 23.29%Zn
3.8m at 15.11%Zn
8.05m at 24.45%Zn
2.05m at 15.64%Zn
26.3m at 17.66%Zn
21.2m at 21.47%Zn
7.34m at 3.54%Zn
11.30m at 23.86%Zn
LEGEND
QUARTZ DIORITE
FW OREBODY
HW OREBODY
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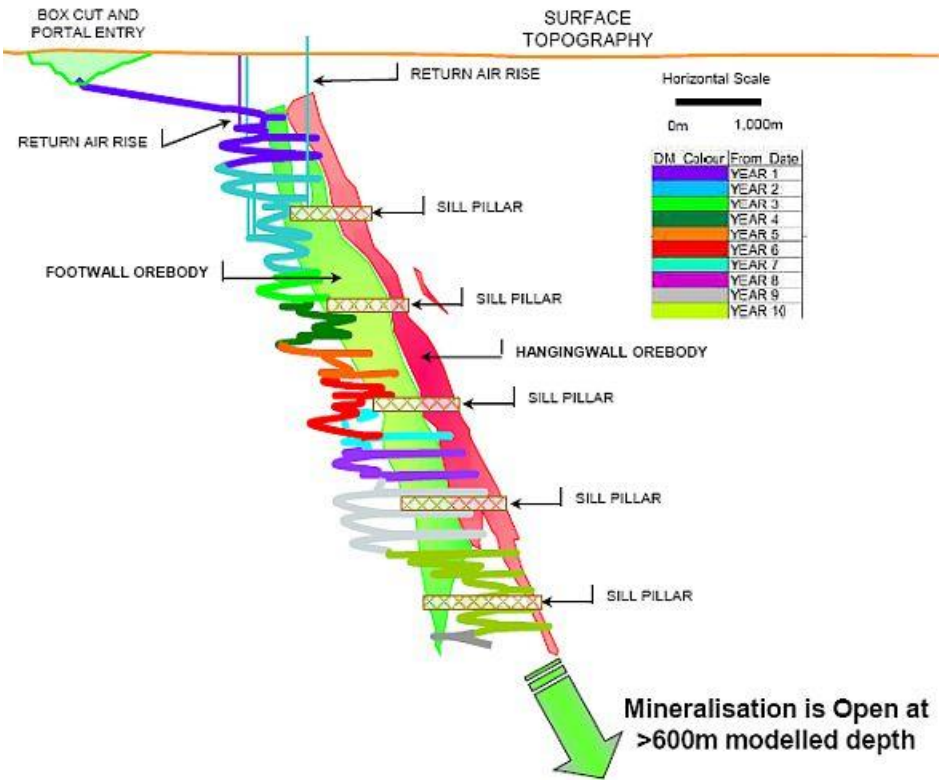
BOX CUT AND
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SILL PILLAR
FOOTWALL OREBODY
SILL PILLAR
HANGINGWALL OREBODY
SILL PILLAR
SILL PILLAR
SILL PILLAR
Mineralisation is Open at
>600m modelled depth

Morocco

I found this summary somewhere in my search:

> *Much of Morocco's metal mining is in the hands of the ONA Group (Omnium Nord Africain), the country's largest private mining operator, through its mining holding company MANAGEM. The principal subsidiaries of the latter are…… CMG or Compagnie Minière des Guemassa (Hajar and Draa Sfar VMS Zn-Pb-Cu mines)…. Another large private mining group is the CRAM or Compagnie Royale Asturienne des Mines, which largely owns the Compagnie Minière de Touissit (CMT) that mines the remaining MVT-style Zn-Pb deposits in the NE of the country.*

MANAGEM's mines are near Marrakesh. A few years ago, I tried to find information on these mines but there was little to be had, so I am not going to beat myself up with a repeat exercise. Table 16 below is my steady state placeholder guesstimate of production going forward.

Table 16 Actual and Assumed Mined Zinc Production for Morocco

2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
47,600	44,200	45,412	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000

2012-2014 data is from the British Geological Survey.

Reference: MANAGEM website here **.** A corporate presentation in English is here . Figures listed in the presentation are for zinc concentrate, not zinc in concentrate.

Congo, Nigeria and Tunisia

This British Geological Survey lists some minor production from all three of these nations but I have not conducted any research into where this is coming from. I merely list their production as "Other" in Table 1.

At one time Breakwater Resources operated the Bougrine mine in Tunisia and some information is available in the reference below.

References: Breakwater Resources, Technical Report, filed January 24,2002, www.sedar.com

Potential Producers

I am only going to look at one potential producer here and that is Kipushi. I am not aware of any other zinc deposits chomping at the bit to get producing though I am sure there may be a few. I seem to recall Tunisia having some potential.

Ivanhoe Mines

Kipushi- Congo

I have reviewed the May 2016 NI 43-101 issued by Ivanhoe and found at www.sedar.com.

The Mining Journal had this to say about Kipushi in the late 1990's:

> *Possibly one of the world's most important zinc deposits, Kipushi was considered the world's largest zinc mine in its heyday. Annual production peaked at 143,000 t of mined zinc and 43,000 t of mined copper in 1988 before the mine was finally shut down by Gecamines in the early 1990s, for lack of operating funds and spare parts. Based on the current haulage capacity at the mine, potential future production could reach 160,000 t/y of zinc and 30,000 t/y of copper in concentrates.*
>
> *Quick to recognise the opportunities that abound in Zaire, notwithstanding the political risk factor associated with such projects, Mr Jean Raymond Boulle, co-founder and co-chairman of Diamond Fields Resources (of Voisey's Bay fame), established America Mineral Field Resources in 1995 which has secured the exclusive right to conduct feasibility studies on the Kipushi mine through a framework agreement with Gecamines. This was ratified by the government in July 1996.*
>
> *The mine is located some 30 km from the town of Lubumbashi and directly employs around 1,800 staff. Two power lines have been completed in the area and pylons for a third are in place. Hydro-generated electricity is available at very low cost and a railhead in Lubumbashi is available to export concentrate production.*
>
> *The operation at Kipushi is centred on a hydrothermal polymetallic vein deposit and is closely associated with a set of intersecting faults estimated to be some 600-650 million years old. This makes the deposit distinct from the stratiform copper/cobalt deposits that predominate on the Zaire/Zambia Copper Belt. The steeply dipping Kipushi orebody has a varied mineralisation style, both along the strike of the ore zone and at depth. Zoned in copper and zinc, with the copper grade decreasing at depth as the zinc grade increases, the main mineralisation is chalcopyrite/borite/spahlerite.*
>
> *Originally exploited during the last century by artisans, Union Miniere of Belgium began open pit operations at Kipushi in 1925 and operated the mine until 1967 when the Zaire Government nationalised Union Miniere's assets. The mine continued to operate under Gecamines control until 1993 when operations were suspended due to a lack of funds necessary to purchase spare*

parts for the underground mining fleet. Production at that time was running at 140,000 t/y of zinc and 30,000 t of copper. Although the mine has been on care and maintenance since 1993, some reprocessing of stockpiles of low grade concentrates at the processing plant did take place between 1994 and 1996.

Most of the mineralisation identified to date extends to the 1,500 m level, although additional drilling is planned to test the potential to a depth of 1,800 m. The orebody has a known strike length of approximately 600 m and varies between 40 m and 120 m in width. The dip varies between 55 deg. and 70 deg.

A single shaft, the No.5 shaft, services the mine and prior to closure, ore production was being sourced from the 1,295 m level with an access ramp completed to a depth of 1,330 m. Two additional ramps were also completed to allow for unrestricted movement of ore from the mine. Some 22.6 Mt of proven and probable reserves have been delineated to a depth of 1,500 m at an average grade of 2.1% copper and 13.8% zinc. Annual mine capacity is approximately 1.5 Mt of ore and 0.3 Mt waste. Mining involved top-slicing initially but problems were encountered with this method at depth. As a result, Gecamines began sub-level caving around 20 years ago.

Ore production was running at around 1.5 Mt/y using this method, with gravity feed to the 1,150 m level and then tram hauling of the ore to the shaft. Levels are driven across the orebody at 12.5 m intervals and the ore is hoisted to surface in 2 X 15 t capacity skips. Based on the current haulage capacity at Kipushi, potential future production could reach as much as 160,000 t/y of zinc and 30,000 t of copper (in concentrates).

Careful planning in the design of the mine is evident from the exceedingly high standard of underground workings. The rock is very competent, with little in the way of support needed, and all the drilling and loading equipment appears to be in generally good order, requiring only minor work to bring it back into production. Indeed, many of the stopes have already been drilled, and several months of ore is available without the need for further drilling in the short term. It is estimated that the revitalisation of the mine will take between two and six months at a cost of some US$ 30 million, crucial to which will be the acquisition of a new haulage fleet.

To resolve the problem of water ingress at the mine, an underground pump station was constructed in 1989 at a cost of some US$ 50 million. Incorporating seven CCM Sulzer units, each with a capacity of 620 m3 /h, the facility normally runs three or four units for a pumping capacity of 1,800 - 2,400 m3 /h.

The concentrator section of the processing plant is comprised of two sections, one constructed in 1935 and the second in the mid-1970s. The older section incorporates two parallel crushing circuits, ball mills and a differential flotation circuit, whilst the newer facility consists of ore handling and a single, fully autogenous milling section. The replacement of high-wear

components of the old concentrator and the upgrading of most other mechanical and electrical equipment will be sufficient to refurbish the concentrator in the short term.

The flotation section of the plant, meanwhile, requires replacement by a modern flotation circuit during the second phase of the project. This modernisation will include the expansion of the newer milling section to the enable the processing of higher production levels from the mine.

Feasibility studies will be conducted over a two year period and will examine: rehabilitating and reopening the Kipushi mine at an estimated cost of US$ 13 million; rehabilitating the concentrator (US$ 12 million); possible construction of a new zinc/copper smelter in the Kipushi area; construction of an acid plant; and processing of the Kipushi tailings where a sulphide resource of some 25 Mt has been outlined averaging 2.3% Zn, 0.4% Cu and 1.6% Pb.

One thing that has been constant is state owned Gecamines involvement. They are currently a 32% owner with Ivanhoe holding the remainder.

I recall this mine being a very wet one but it is curious how such a material fact did not make it into Ivanhoe's recent NI 43-101 based on a PEA. This is another reason why I always view PEA's (or at least the NI 43-101 summaries of them) with caution. The bottom 400 m of the mine flooded in 2011. Numerous mines in the Congo and Zambia have or had very serious water inflow issues, usually from the dolomites. They are some of the wettest mines in the world so dewatering is an important and costly aspect of the operation.

AMF became Adastra Minerals Inc. which later merged with First Quantum in 2006. They essentially spun their wheels here on this project up to the merger with no clear agreement made with Gecamines on how to advance the project. The project ended up in the infamous Dan Gertler's hands which is a whole story in itself (google "Dan Gertler Congo" for an afternoon of entertainment). Ivanhoe bailed out Gertler in 2011.

So, if I was conducting a thorough due diligence here (which I am not), the first place I would start is to get hold of the contract document between Ivanhoe and Gecamines (which could be buried on sedar somewhere) to understand precisely what it covers and what each partner's obligations, financial and otherwise, are. Does Ivanhoe in fact have clear sailing here to put the deposit back into production? I have assumed so but for those who know about Gecamines' less than stellar past, this is never a given. The 2015 Annual Information Form for Ivanhoe only states in the Material Contracts section (page 88) that they are obligated to deliver a Feasibility Study in 2014 (yes, 2014). Only a PEA is complete. There is no discussion about the mechanism for placing this mine back into production. Once they do complete studies to Gecamines satisfaction, do they then need to negotiate an agreement to put the deposit back into production? I get the sense they do. So, Ivanhoe in my mind, needs to clarify the arrangements here.

Ivanhoe is focussing on a zinc rich portion of remaining reserves called the Big Zinc Zone.

Mining

The Big Zinc Zone is incredibly rich as illustrated in Table 17.

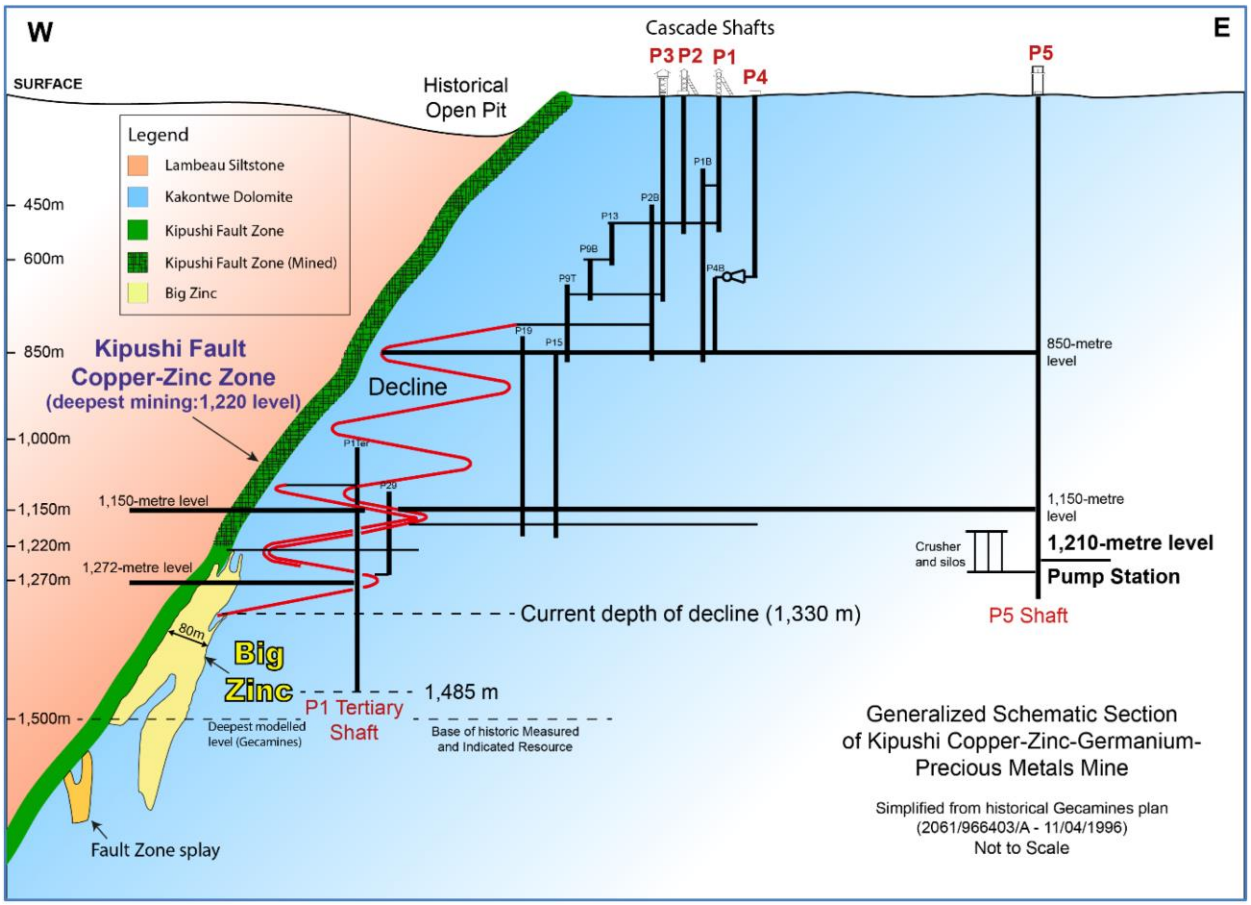
Table 17 Measured and Indicated Resources for Kipushi

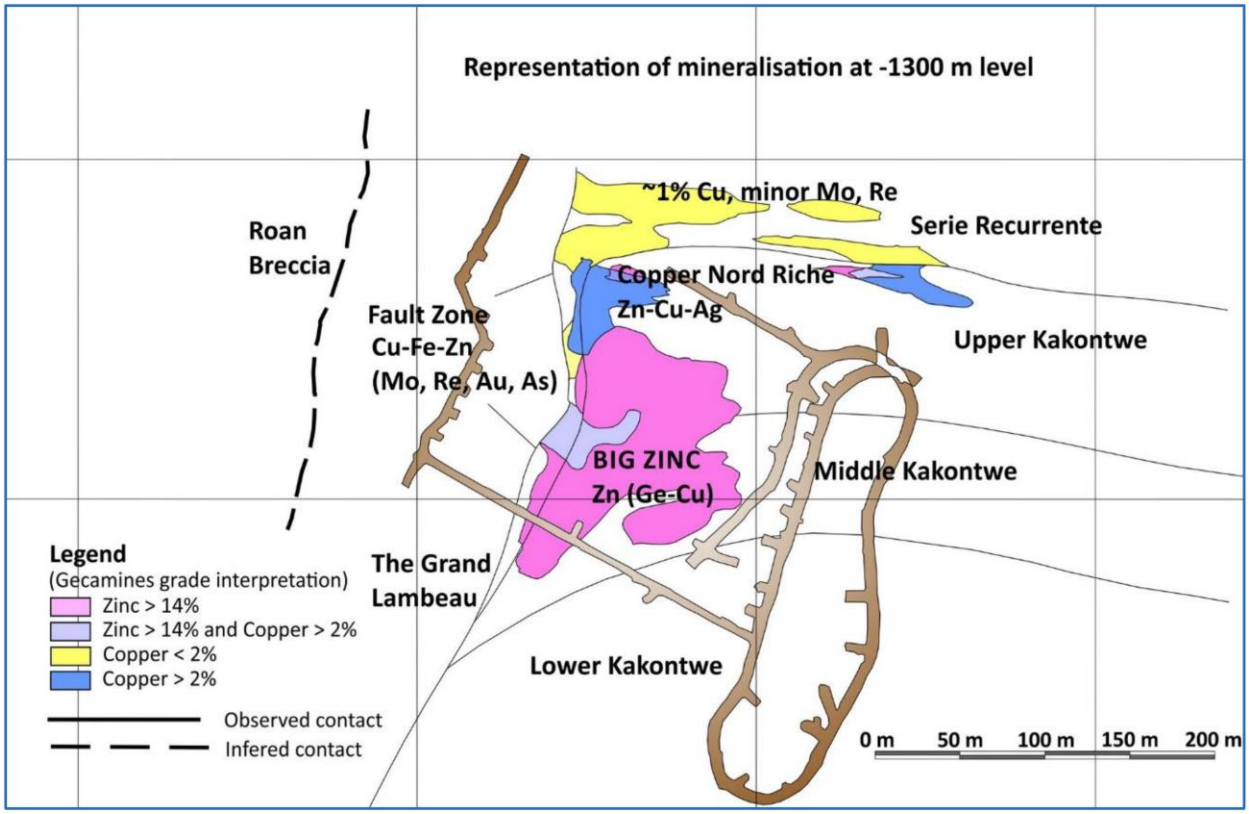
	Tonnes	Zn%	Pb%	Cu%	Ag g/t	Co ppm	Ge g/t
M+I Resources	10,190,000	34.89	0.96	0.65	20	15	51

It is located 1,220 m to +1,800 m below surface. It will be mined predominantly by blasthole stoping. The geometry is suitable for this method. Geotechnically, the zone looks good and operationally, it is not very different than what Vedanta is currently achieving at Black Mountain at similar depths.

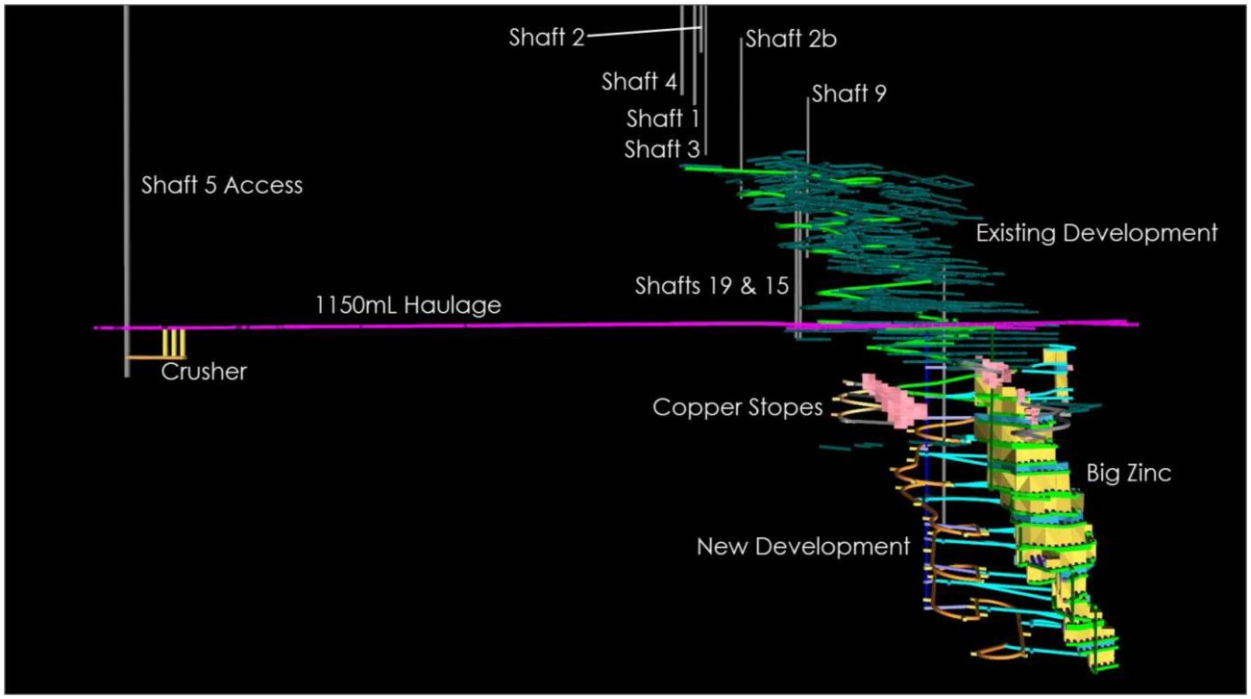
The annual production rate of 1.1 MT is certainly technically achievable with this primary mining method making this potentially one of the largest zinc mines in the world for a decade or so once it hits full production. I assume Ivanhoe is restoring the previous hoisting capacity mentioned above.

Ivanhoe is in the process of rehabilitating the mine which is not an easy task considering the mine was last in operation in 1993 and much of the infrastructure was under water for a number of years. Electrical infrastructure (motors, substations etc.) would essentially require complete changeout. In these types of situations, it may be difficult to do too many things concurrently underground, they must occur consecutively.





Some development is already in place for the upper sublevels as illustrated here.



My gut feel is, it will require another 15-18 months to get the underground back into shape. Mine development however is essentially near complete for the first stoping block.

Milling

The PEA described in the NI 43-101 utilizes a simple dense media separation plant to upgrade the ore to grades typical at electrolytic smelters. This type of plant exploits the differences in specific gravity between the ore and waste. No grinding of the ore is planned, just fine crushing. There was no mention of discussions with smelters to see if the product was acceptable to them. The table below is an excerpt of expected concentrate quality and typical thresholds for penalties or rejection by smelters.

Element	Ideal Content Range	Kipushi Zinc Concentrate
Cadmium	<0.3%	0.22%
Chlorine	<500 ppm	260.3 ppm
Copper	<0.5%	0.3%
Fluorine	<200 ppm	861.3 ppm
Iron	<6%	7.5%
Lead	<1%	2.1%
Mercury	<20 ppm	37.9 ppm
Moisture	7%–9%	8%
Silica	<2%	1.2%
Sulphur	28%–33%	29.3%
Zinc	52%–58%	55.4%

So the questions that should be resolved in the PFS are:

- Are smelters happy with the concentrate metallurgically?
- Are smelters happy to receive what is essentially gravel instead of a fine powder?

If the answer is no, a conventional grinding/floatation plant will be required at considerable extra cost.

BHP's Cannington mine also had an issue with high fluorine in the concentrate and put a leaching circuit on the back end of the mill to reduce levels to typically 200 ppm. Is this going to be an issue here? I don't know, since I am not sure what the rejection point is for smelters for fluorine but the high fluorine levels seem to have been glossed over in the PEA.

I suppose in a nutshell however, if smelters are now willing to accept high manganese feed from Gamsberg, high fluorine may not be a big issue currently either. Beggars can't be choosers I guess. That is, until the zinc miners create an oversupply of concentrate once again.

Infrastructure

Another key issue discussed in the NI 43-101 is getting the concentrate to market. Approximately 30 km of rail line from the mine site onwards requires rehabilitation and some of the remaining +3,000 km of rail to the port of Durban is in poor shape but useable. Since there are numerous other mines in the area I assume some of them are shipping copper concentrate by rail to port so this may not be a huge issue. It is important to note that the transport costs listed in the NI 43-101 are about three times the site costs on a tonnage basis.

Finally, having a reliable power supply is important. The NI 43-101 does not discuss this topic in much depth but there have been numerous issues at other mines in the area particularly across the border in Zambia. On-site back up power generation for say 10-15 MW may be the right thing to do to keep the pumps and shaft running during outages.

Schedule

The issues above are quite solvable and I have no doubt that this mine will get back into production again providing Ivanhoe has a clear contractual mandate to do so. Ivanhoe sound like they are talking to a third partner that would come into this project as an equity investor. The CEO's model in the past has been to dilute their equity down in projects before construction and ramp-up and I assume that is the model planned here also. So this could inject some delays into the project.

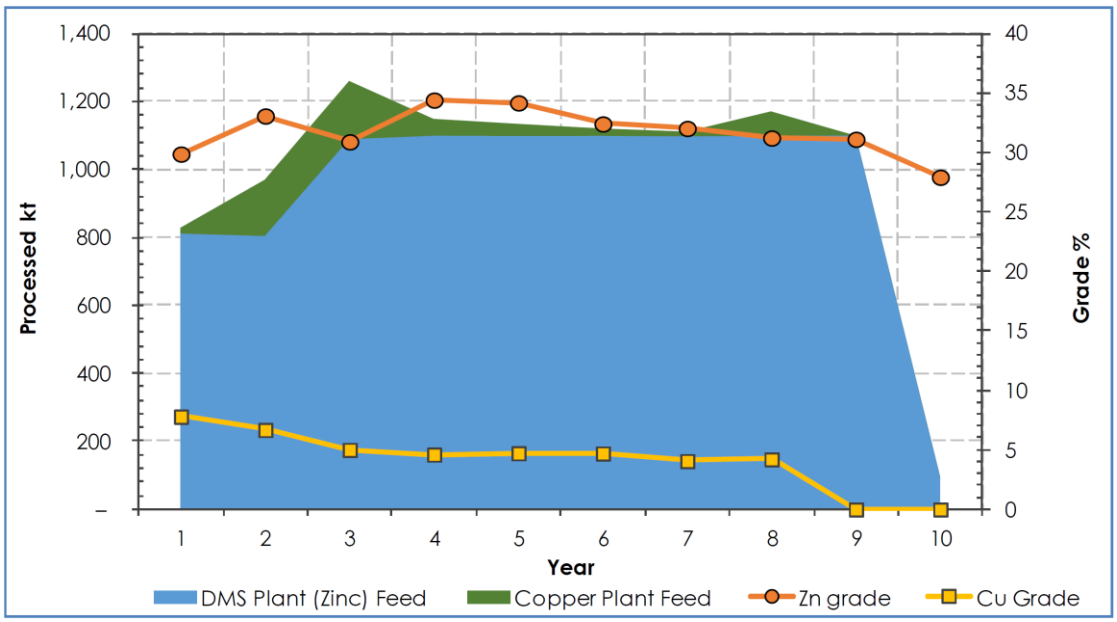
With regards to timing therefore, I suspect they will require another 15-18 months to complete mine rehabilitation. During that timeframe, they will complete the pre-feasibility study (Q2 2017) and may proceed straight to basic and detailed engineering after this. If the mill circuit is as simple as they are betraying and they can get the rail line fixed up, I assume they could get into production by mid- 2019 with a 12 month ramp-up to full production. If they do need a floatation plant or have issues getting rail, and perhaps power or joint venture issues resolved, this would push out this start to production for an indeterminant amount of time. There is no financing currently in place amongst other impediments.

An old friend of mine who grew up and worked in this area (at Mufulira) stated to me one time that the movie "The God's Must be Crazy" was not a comedy, it was a documentary. In other words, crazy shit goes on in this part of the world so it is best to work in a bit of a fudge factor when it comes to schedules and costs. I have therefore applied a 20% The God's Must be Crazy factor to the PEA figures to come up with the production schedule in Table 18. This could be optimistic if there are contractual issues.

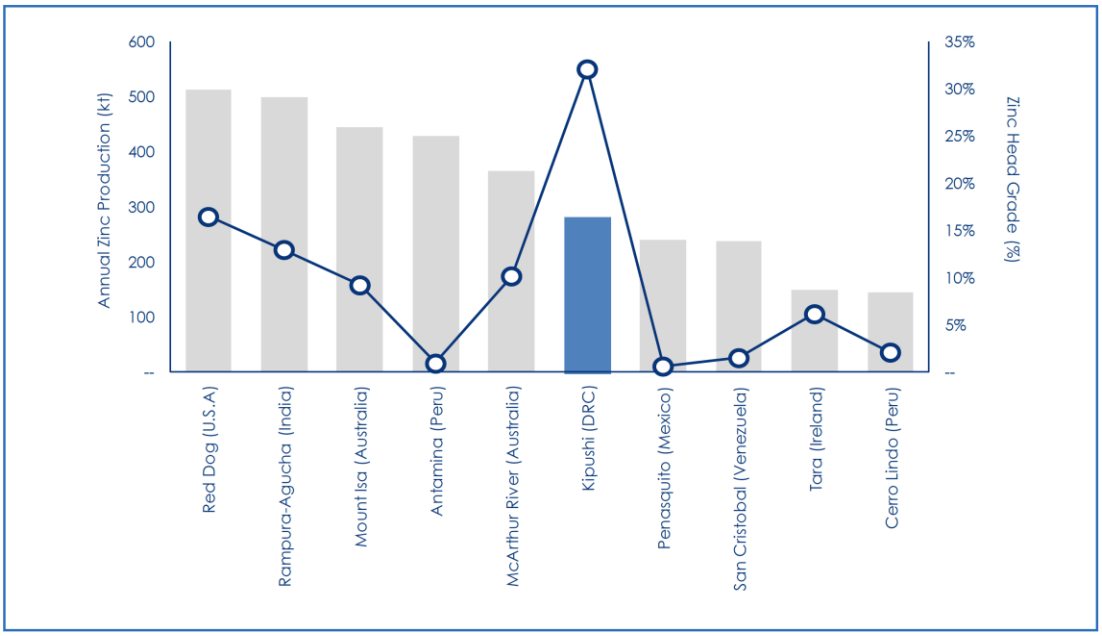
I have not reviewed operating and capital cost assumptions in the NI 43-101.

Table 18 Assumed Kipushi Gods Must be Crazy Production Schedule, Zinc in Concentrate

2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
0	0	0	0	0	0	0	60,000	180,000	240,000	240,000



The PEA Production Ramp-up and Mining Grades



Kipushi could be a Top 10 zinc producer.

San Cristobal is in Bolivia, not Venezuela. I have discussed all the other heavy hitters in other Modules. I discuss San Cristobal at the end of this report.

Addendum to Module 4- Zinc Mining in India

On November 10, 2016 on page 22 of their quarterly release, Vedanta dropped this bombshell on the markets:

"With the objective of mitigating the risk of any delays in the ramp-up of Rampura Agucha underground mine, Stage V was conceptualised in late 2014 to extend the life of the open cast mine to 2019-2020, deepening the pit by an additional 50 metres. However, concurrent mining at Rampura Agucha is leading to geotechnical challenges in both the open pit and underground. After deliberations with internal and global technical experts, Vedanta decided to modify Stage V and limit the incremental pit depth to 30 metres. This will mitigate pit wall challenges and significantly reduce waste-ore ratio, providing a fresh impetus to accelerating mine development at the underground mine in a safe manner."

The reserves in the pit for the 50 m deep extension were 8,800,000 T grading 13% zinc for 1,144,000 T of contained zinc and roughly 1,030,000 T of recovered zinc. This is 20,600 T of recovered zinc per vertical metre.

Therefore, only taking the pit down a further 30 metres means that roughly 400,000 T of zinc will not be recovered by Vedanta during 2019/2020. I am sure the guys underground are doing their best to ramp up production but simply because the pit is running out does not mean they can do any better. You can only shove so many ants into an anthill and expect them to be productive. So, I do not expect anything to change there particularly in light of further talk of underground geotechnical issues also. I suspect the backs of the stopes are caving which is the same problem we had at Noranda's Geco mine in ore hosted in a graphite-

mica-sillimanite schist. It would create havoc on pit bottom to have a stope cave to daylight while they were still mining the pit. The stress concentration between pit bottom and the top of the underground stopes is also likely aggravating matters.

Pictured below is my understanding of the open pit situation. I assume Vedanta has decided to only strip the pit on only one side instead of two.

Table 19 is from Module 4 where I estimated mill production at Rampura Agucha. I have modified this table and reproduced it as Table 20 to illustrate the impact upon mill output. I have then incorporated these changes into Table 2 at the beginning of this report. The impact on world markets will be felt the most in 2019 since the drop in production is essentially identical to all of Canada's current annual production.

Table 19 Expected Rampura Agucha Mill Zinc Production from Module 5

Calendar Year		2016	2017	2018	2019	2020	2021	2022	Total
Rampura Agucha OP	'000 t	1,150	3,150	500	2,800	1,200			8,800
Grade	% Zn	13%	13%	13%	13%	13%			
Contained Zn	'000 t	150	410	65	364	156			
Recovered Zn	'000 t	136	373	59	331	142			
Rampura Agucha UG	'000 t	1,000	1,300	1,800	2,300	3,200	3,500	3,500	16,600
Grade	% Zn	14.10%	14.10%	14.10%	14.10%	14.10%	14.10%	14.10%	
Contained Zn	'000 t	141	183	254	324	451	494	494	
Recovered Zn	'000 t	128	167	231	295	411	449	449	
Kayad UG	'000 t	1,000	1,000	1,000	1,000	1,000	500		5,500
Grade	% Zn	11%	13%	13%	13%	11%	9%		
Contained Zn	'000 t	110	130	130	130	110	45		
Recovered Zn	'000 t	100	118	118	118	100	41		
Milled Tonnage	'000 t	3,150	5,450	3,300	6,100	5,400	4,000	3,500	30,900
Zinc in Concentrate	**'000 t**	**364**	**658**	**408**	**745**	**653**	**490**	**449**	

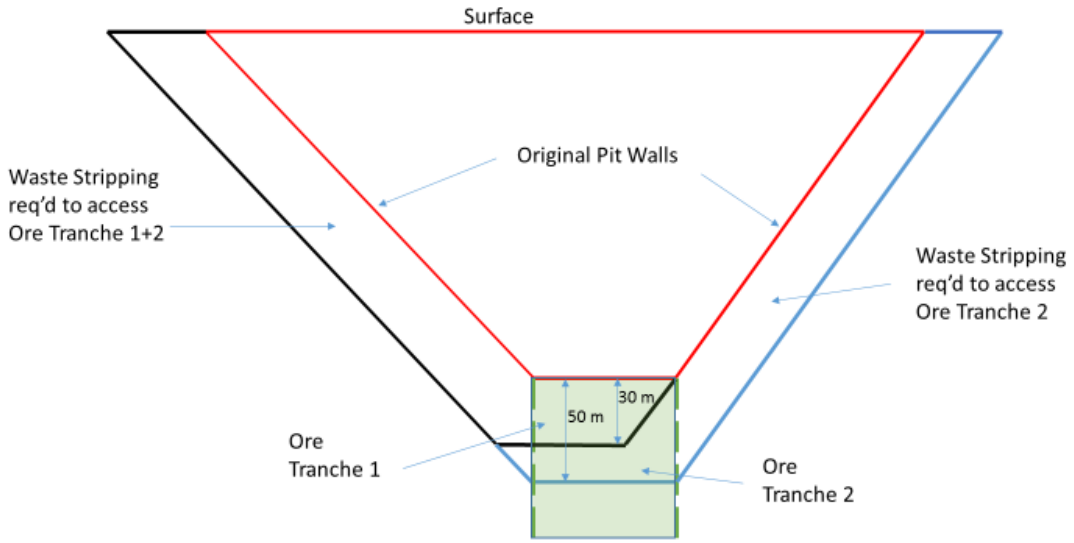


Table 20 Revised Rampura Agucha Mill Zinc Production based on November 10, 2016 Vedanta PR

Calendar Year		2016	2017	2018	2019	2020	2021	2022	Total
Rampura Agucha OP	'000 t	1,150	3,150	1000					5,300
Grade	% Zn	13%	13%	13%					
Contained Zn	'000 t	150	410	130					
Recovered Zn	'000 t	136	373	118					
Rampura Agucha UG	'000 t	1,000	1,300	1,800	2,300	3,200	3,500	3,500	16,600
Grade	% Zn	14.10%	14.10%	14.10%	14.10%	14.10%	14.10%	14.10%	
Contained Zn	'000 t	141	183	254	324	451	494	494	
Recovered Zn	'000 t	128	167	231	295	411	449	449	
Kayad UG	'000 t	1,000	1,000	1,000	1,000	1,000	500		5,500
Grade	% Zn	11%	13%	13%	13%	11%	9%		
Contained Zn	'000 t	110	130	130	130	110	45		
Recovered Zn	'000 t	100	118	118	118	100	41		
Milled Tonnage	'000 t	3,150	5,450	3,800	3,300	4,200	4,000	3,500	30,900
Zinc in Concentrate	**'000 t**	**364**	**658**	**467**	**413**	**511**	**490**	**449**	

Zinc Mining in Bolivia

The US and British Geological Surveys report Bolivia producing more than 400,000 T zinc annually from mines. I look at two of these operations below which total approximately 260,000 T annually. Pan American Silver mines small by-product quantities of zinc also, at their San Vicente Property and I assume the remainder is from state run Comibol and small miners for which there is virtually no information available. I have not added Bolivia to Table 2 since I am not comfortable forecasting national output going forward.

Glencore

Illapa and Sinchi Wayra

From Glencore's IPO in 2012 for Sinchi Wayra:

> *Glencore owns 100 per cent. of Sinchi Wayra, a company which operates five mining units and concentrating facilities in the Oruro and Potosi regions of Bolivia and which employs approximately 2,600 people. One of these five mines, Bolivar, is operated as a 50:50 joint venture with the Bolivian state mining company, Comibol. Two of the mines, Porco and Colquiri, are run under a lease contract with Comibol.*
>
> *The fourth mine, Poopo, is run under a lease agreement with a local co-operative. The fifth mining unit, the Caballo Blanco group, consists of the wholly owned San Lorenzo/Colquechaquita and its operations are expected to end in the near future. In early 2010, Sinchi Wayra acquired into the Caballo Blanco group, two additional mines, Reserva and Tres Amigos. Both mines became operative in May 2010 and it is intended that these mines will replace the declining production levels at San Lorenzo/Colquechaquita.*
>
> *Collectively, the mines have a current capacity of 205k MT of zinc concentrate, 15k MT of lead concentrate and 6k MT of tin concentrate per annum. The expected life of the mines as a group, considering current production capacities, on average is two years based on reserves and seven years based on resources. Further to a capital expenditure estimated at approximately U.S.$65 million, management believes that annual output can potentially be increased to approximately 300k MT of zinc concentrate and 30k MT of lead concentrate by 2013. The plan is currently being considered further by management, but such a plan is expected to include a project to reprocess old tailings containing significant levels of zinc and tin at the Colquiri mine, together with works to remove processing and hoisting bottlenecks.*
>
> *Glencore has a 100 per cent. off-take agreement for the life of the mine which is priced on an arm's length basis. Historically, a proportion of Sinchi Wayra's tin concentrates was sold locally to take advantage of lower costs of transportation but, since the fourth quarter of 2009, for commercial reasons, all sales have been made to Glencore.*

In 2012 the Colquiri mine was nationalized by Bolivia and Glencore recently filed for arbitration.

From the most recent reserves report:

> *The majority of the deposits within the Illapa and Sinchi Wayra portfolio are epigenetic-hydrothermal base metal type vein and fault filled mineralisation hosted within a variety of lithologies from volcanic tuffs to sedimentary packages. The main mineral assemblages are composed of sphalerite, marmatite, galena, silver rich galena and silver sulfosalts. The resources are usually based on multiple structures with Porco containing over 100 different veins. The typical dimensions of these structures is +500m in length and +450m depth profile with mineralisation open at depth; average vein widths from 0.2 - 4.0m.*
>
> *Caballo Blanco operational unit consists of three mines: Colquechaquita, Reserva and Tres Amigos, supplying the central plant "Don Diego" situated close to Potosi.*

Table 21 lists the reserves and resources remaining as of December 31, 2015. The reserve base is usually only ample for 2-3 years' production but the resources are readily converted to reserves and are readily replenished.

Table 21 Reserves and Resources for Glencore's Bolivian Mines

	Proven and Probable Reserves				**Measured and Indicated Resources**			
	Tonnes	**Zn%**	**Pb%**	**Ag g/t**	**Tonnes**	**Zn%**	**Pb%**	**Ag g/t**
Bolivar	930,000	9.2	1.1	234	4,400,000	8.5	1.0	192
Porco	860,000	6.6	0.5	83	1,200,000	10.0	0.7	103
Poopo	110,000	7.3	0.6	165	400,000	7.9	0.6	218
Caballo Blanco	390,000	11.0	1.4	94	4,200,000	9.4	1.3	84

Glencore does not split out production for these mines. I have assumed 90% zinc recovery for recent production. 2015 production for these mines is listed in Table 22. I assume steady state production going forward in Table 23.

Table 22 2015 Mine Production

	Tonnes	**Zn%**	**Pb%**	**Ag g/t**
Bolivar	310,000	7.8	1.0	240
Porco	320,000	5.6	0.5	79
Poopo	100,000	6.9	0.5	248
Caballo Blanco	330,000	7.0	1.0	108
Total	**1,060,000**	**6.8**	**0.8**	**151**

Table 23 Estimated and Forecast Production

2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
65,000	67,000	65,000	65,000	65,000	65,000	65,000	65,000	65,000	65,000	65,000

Sumitomo

San Cristobal Mine

Apex Silver Mines developed this low grade open pit deposit in Bolivia with Sumitomo as a 35% partner. Apex later declared bankruptcy leaving Sumitomo as full owner.

Below is an excerpt from Apex Silver's 10-K in 2010 before bankruptcy:

The San Cristóbal mine is located at an elevation of approximately 13,000 feet in the Bolivian Altiplano in the Andes Mountains, approximately 500 kilometers south of the city of La Paz. The San Cristóbal mine is accessible by an improved gravel road from the town of Uyuni, approximately 100 kilometers to the northeast, and from the Chilean border town of Ollagüe, approximately 135 kilometers to the west. The mine is located approximately 50 kilometers south of a railroad that runs between Bolivia and Chile. A spur has been built to connect the mine to the railroad for the shipment of concentrates. MSC has constructed a private airstrip at the mine, which is used primarily for the transport of personnel. The map below shows the location of the San Cristóbal mine.

Other than sporadic underground mining in the area of the current pit over the previous 350 years, only one portion of the San Cristóbal mine, the Toldos deposit, has been previously mined. The Toldos mine was operated by Empresa Minera Yana Mallcu S.A. as a block-caving underground operation between 1985 and 1988, and as an open-pit mine and silver heap leach between 1989 and 1995. The Toldos mine was shut down in 1995, and no significant mining or processing plant or equipment remains from that operation.

The San Cristóbal mine is comprised of certain mining concessions that are part of a large block of concessions covering approximately 500,000 acres that we own or control. MSC has the right to carry out exploration, mining, processing and marketing of all mineral substances located within the concessions, and to use the water found on

the concessions. In order to maintain its rights to the San Cristóbal concessions, MSC must make annual mining patent payments to the Bolivian government totaling approximately $575,000.

MSC spent approximately $760 million to develop and construct the mine from inception of the project in January 2004. This amount excludes operating expenses incurred during start-up and thereafter and approximately $100 million spent at the site prior to January 1, 2004 on early stage exploration and development activities.

The San Cristóbal mine consists of an open pit mine and concentrator with a designed capacity of 40,000 tonnes per day. A contract miner extracts ore from the open pit by conventional truck and shovel operation and transports mined ore by truck from the pit to the primary crusher. The crushed ore is then transported by a 1.7 kilometer overland conveyor to an ore stockpile. A reclaim system moves crushed ore from the stockpile for grinding in a semi-autogenous (SAG) and ball mill circuit. The ore is then processed by a selective flotation process in which lead is first floated and zinc is suppressed to produce a lead-silver concentrate, and then zinc is floated and lead is suppressed to produce a zinc-silver concentrate. Concentrates are then filtered, loaded into containers and transported by rail to the port in Mejillones, Chile, and then by ocean vessel to smelters and refineries around the world.

SC commenced production at the San Cristóbal mine in August 2007. During 2008, MSC shipped approximately 421,000 tonnes of zinc and lead concentrates containing approximately 14.6 million ounces of payable silver, 158,000 tonnes of payable zinc and 59,000 tonnes of payable lead. As of December 31, 2008 it had stockpiled approximately 29.9 million tonnes of work-in-process ore. Approximately 9.5 million tonnes of the stockpiled ore is sulfide ore and the remainder is oxide ore. The mill currently processes sulfide ore, with the oxide ore scheduled for processing later in the mine life.

Reserves

Reserves at the San Cristóbal mine are based on 549 reverse circulation drill holes and 85 diamond case drill holes totaling approximately 150,000 meters. The drill holes were generally spaced at intervals of approximately 75 meters. This drilling indicates that the mineralization is present over an area of 1,500 meters by 1,500 meters. The ore deposit defined by this drilling is open at depth and laterally…..

The following table shows our proven and probable sulfide and oxide reserves of silver, zinc, and lead. Our reserves were calculated using a fully designed pit model that incorporates design slopes, practical mining shapes and access ramps. Ore blocks within the deposit model are designated as proven if they are within 40 meters (40% of the average variogram range) and at least three drill holes were used to evaluate the block. Ore blocks are designated as probable if they are between 40 meters and the average variogram range of 100 meters and at least two drill holes were used to evaluate the block. Additionally, blocks within 40 meters but evaluated by a single drill hole were also classified as probable. Proven and probable classifications are determined only after economic criteria are applied to define the ore.

	Proven and Probable Reserves						
		Average Grade			Contained Metals(1)		
	Tonnes of ore (000s)	Silver Grade (g/tonne)	Zinc Grade (%)	Lead Grade (%)	Silver Ounces (000s)	Zinc Tonnes (000s)	Lead Tonnes (000s)
Sulfide Ore							
Proven In-pit	154,800	51.9	1.61	0.53	258,000	2,500	813
Proven Stockpile	9,400	45.7	0.87	0.46	14,000	81	43
Probable	35,700	49.6	1.72	0.53	57,000	614	190
Oxide Ore							
Proven In-pit	2,500	122.0	0.06	0.67	10,000	2	17
Proven Stockpile	20,500	98.0	0.13	0.62	64,000	26	127
Probable	1,000	94.7	0.09	0.47	3,000	1	5
Total	223,900	56.5	1.44	0.53	406,000	3,224	1,195

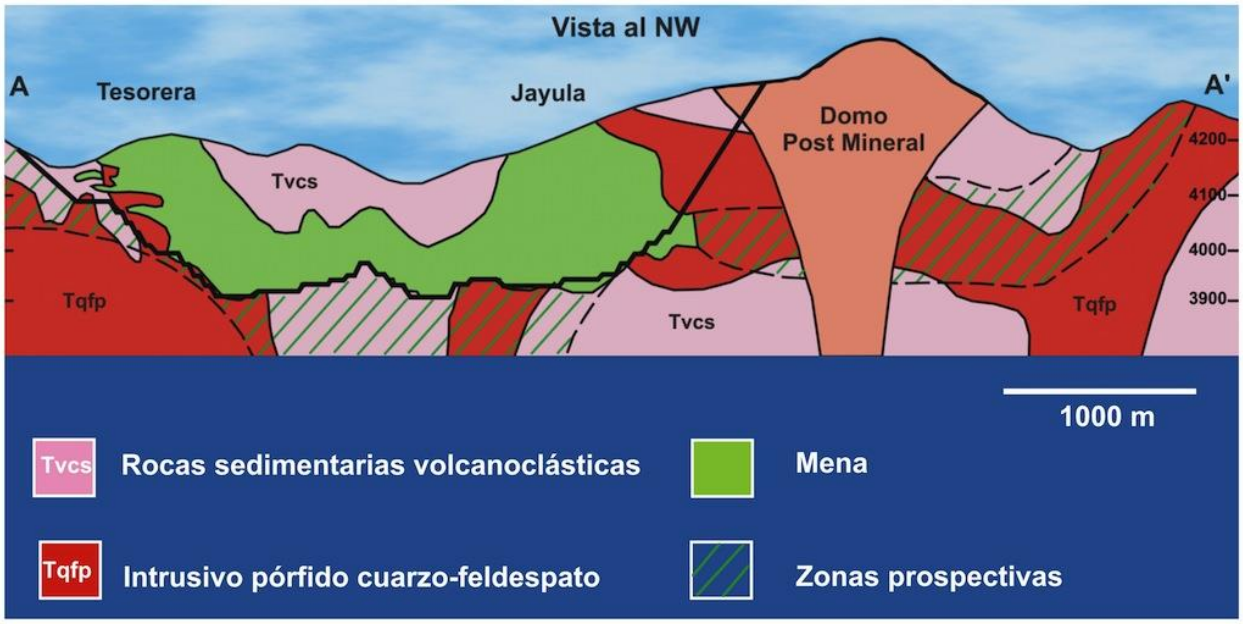
(1)

Amounts are shown as contained metals in ore and therefore do not reflect losses in the recovery process. Sulfide ore reserves are expected to have an approximate weighted average recovery of 67% for silver, 85% for zinc and 73% for lead. Oxide ore reserves are expected to have an average recovery of 60% for silver and 50% for lead. The estimated strip ratio of the mine is 2.08:1.

Geology

The geology of the San Cristóbal deposit dates to the Miocene age and is comprised of volcaniclastic rocks (tuff and tuffites), sedimentary and igneous (intrusive) rocks within a circular volcanic crater approximately four kilometers in diameter. Volcaniclastic and sedimentary units formed during periods of intense volcanism and subsequent erosion, occupying the center portion of the crater, and were intruded by repeated intrusive events.

The San Cristóbal orebody is comprised of two major mineralized zones (Jayula and Tesorera), which outcrop at the surface but join at depth to form a contiguous orebody. The San Cristóbal orebody has formed as a result of syngenetic and epigenetic mineralizing events. Approximately half of the current known mineralization lies within the volcaniclastic units as disseminated stratabound mineralization, which is of a higher grade than mineralization in the intrusives. Mineralization within the intrusives is largely restricted to breccias on the contacts with the surrounding rocks and in veins and disseminations in the interior of the intrusive bodies. The dominant sulfide minerals hosting the zinc, lead and silver are sphalerite, galena and tetrahedrite, respectively. Surface weathering has affected the upper part of the orebody (approximately 45 to 70 meters), creating a small layer of oxide ore which covers the larger sulfide orebody beneath.



Sumitomo completed further drilling in 2011 and declared these reserves:

Estimated reserves through June 30, 2011, obtained as a result of the most recent drilling campaign are: 285,303,000 tonnes, including 1.41% Zn, 0.48% Pb, and 53.0 g/t Ag.

This equates to an approximate 20-year mine life which means they can expand currently to capture rising commodity prices if they choose to do so. More information on the operation is found here.

Actual zinc production has increased annually since 2012 and I assume this is due to the ability to source higher grade ore from an ever-expanding pit. Table 24 therefore illustrates actual and forecast zinc production to 2022 assuming no expansion.

Table 24 Actual and Forecast Zinc Production

FY2012	FY2013	FY2014	FY2015	2016	2017	2018	2019	2020	2021	2022
165,000	170,000	174,000	194,000	220,000	230,000	230,000	230,000	230,000	230,000	230,000

FY2015 ended March 31,2016, calendar year data reported after this time. Sumitomo forecast for FY2016 (ending March 31.2017 is 226,000 T)

Tesorera Pit

Jayula Pit

So, that's it folks. I hope all three of you that have managed to read along enjoyed the ride. As I stated previously, instead of me just banging up a spreadsheet with all my conclusions on the various mines output and keeping it to myself, I thought I would put it in writing and spread the joy instead. In part so I can test my assumptions and logic in a couple years' time, in part to pass on the knowledge I have gained.

The zinc mining business has been a long ignored one but judging by the 50% increase in price from the time I commenced these modules until now, it looks like the world is waking up to the fact that a new suite of mines is required and the zinc price must be high enough to justify the capital expenditure. I still feel this means $1.50-$1.75 a pound for perhaps a two or three year timeframe in order to get plenty of concrete poured and holes dug for new mines. The price should then settle down to what would likely be in the $1.25-$1.50 range. This largely is a function of the demand side, not reviewed here, and how carried away the miners get believing $1.75/lb zinc is here to stay.

Mines are wasting assets and additional mines such as Tara will be closing shortly after the end of the assessment period here.

Since it can be reasonably expected that China will add undisciplined zinc smelter capacity, it will be up to the miners to control the supply of slab zinc to world markets by controlling the amount of zinc concentrate they produce. This is not a role they have played very well in the past so it will be interesting to see if they have learned any lessons. Mahalo.

I will continue to check in at ceo.ca and my personal e-mail for business related matters is

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