MODULE 7- ZINC MINING IN PERU

I have never been to Peru, Chile is the closest I have gotten, so I am not going to pretend to be an expert on mining in Peru, particularly zinc mining. What I will pass along therefore is basically a compilation of the work I have done looking at what information is available in order to add to the body of knowledge with respect to zinc mining in Peru. I have added commentary where I have felt comfortable doing so.

Table 1 summarizes 2015 Peru zinc mine production. Highlighted in blue are what I would call the Big 4. Antamina, Milpo, Glencore and Volcan.

If you think I took a long time to put this table together, think again. Peru has their act together like no other country I have come across. Production figures are reported by every mine every month and tabulated by the Ministerio de Energia y Minas for 2015 here . For the latest monthly and year to date figures you can find them here. Table 1 is my attempt to simplify the 2015 figures. There is one problem however with the data the government reports. It appears to also contain zinc in concentrates that are not recovered (payable) at a smelter such as zinc in a lead or copper concentrate. They have labelled this "subproducto zinc", or byproduct zinc in monthly data but do not break it out in annual data. So this table slightly overstates (1-4%) figures provided by numerous companies. In the case of Antamina and Milpo this was a substantial discrepancy. In these cases I report company figures. Where company data is available I have used it but have fallen back to government data at times.

Some of my key findings are:

- Most mines have a significant reserve and resource base so I expect little in the way of closures to 2022 but expansions are also unlikely for various reasons;
- The cash costs per tonne of ore mined and milled are quite low and this means that lower grade deposits uneconomic elsewhere are quite economic in Peru;
- Access to capital has appeared constrained in the past but numerous miners have aligned themselves with more deep pocketed foreign parent companies by desire or necessity;
- There are a handful of undeveloped deposits in Peru that appear to have the requisite grades by Peruvian standards necessary for future development but the list is short;
- The ability to find new deposits appears good as witnessed by Tinka's (accidental) discovery of substantial zinc resources on their Ayawilca property in 2012;
- A multitude of mines consider themselves to be silver mines with zinc as a byproduct. They will likely not close at low zinc prices. Indeed some have the flexibility to switch to high copper/silver grade ore;
- The underground mines to a large extent use labour intensive mining methods.

TABLE 1- PRODUCCIÓN MINERA METÁLICA DE ZINC (TMF) - 2015

COMPANY	MINE	REGION	ZINC IN CONCENTRATE
CATALINA HUANCA SOCIEDAD MINERA S.A.C.	CATALINA HUANCA	Ayacucho	**48,383**
COMPAÑIA MINERA ANTAMINA S.A.	ANTAMINA	Ancash	**235,000***
COMPAÑIA MINERA CASAPALCA S.A.	AMERICANA	Junin	**35,188**
COMPAÑÍA MINERA MILPO S.A.A.	CERRO LINDO	Ica	**176,992***
MILPO ANDINA PERU S.A.C.	MILPO Nº1(EL PORVENIR)	Pasco	**61,664***
COMPAÑIA MINERA ATACOCHA S.A.A.	ATACOCHA	Pasco	**30,301***
COMPAÑIA MINERA RAURA S.A.	ACUMULACION RAURA	Huanuco	**33,823**
COMPAÑIA MINERA SAN IGNACIO DE MOROCOCHA S.A.A.	SAN VICENTE	Junin	**24,380**
COMPAÑIA MINERA SANTA LUISA S.A.	SANTA LUISA	Ancash	**20,658**
EMPRESA MINERA LOS QUENUALES S.A.	ACUMULACION ISCAYCRUZ	Lima	**77,628**
EMPRESA MINERA LOS QUENUALES S.A.	CASAPALCA-6 (YAULIYACU)	Lima	**23,815**
TREVALI PERU S.A.C.	UNIDAD SANTANDER	Lima	**29,943**
MINERA BATEAS S.A.C.	SAN CRISTOBAL	Arequipa	**17,210**
MINERA CHINALCO PERÚ S.A.	TOROMOCHO	Junin	**17,980**
MINERA COLQUISIRI S.A.	MARIA TERESA	Lima	**25,180**
NYRSTAR ANCASH S.A.	CONTONGA	Ancash	**12,906**
PAN AMERICAN SILVER HUARON S.A.	HUARON	Pasco	**16,184**
SOCIEDAD MINERA CORONA S.A.	ACUMULACION YAURICOCHA	Lima	**20,527**
SOCIEDAD MINERA EL BROCAL S.A.A.	COLQUIJIRCA Nº 2	Pasco	**56,316**
EMPRESA ADMINISTRADORA CHUNGAR S.A.C.	ANIMON	Pasco	**46,443**
EMPRESA ADMINISTRADORA CHUNGAR S.A.C.	ACUMULACION ANIMON	Pasco	**44,503**
EMPRESA ADMINISTRADORA CERRO S.A.C.	ACUMULACION CERRO	Pasco	**10,203**
VOLCAN COMPAÑÍA MINERA S.A.A.	SAN CRISTOBAL	Junin	**75,009**
VOLCAN COMPAÑÍA MINERA S.A.A.	CARAHUACRA	Junin	**48,682**
VOLCAN COMPAÑÍA MINERA S.A.A.	ACUMULACION ANDAYCHAGUA	Junin	**27,700**
VOLCAN COMPAÑÍA MINERA S.A.A.	ACUMULACION TICLIO	Junin	**12,726**
VOLCAN COMPAÑÍA MINERA S.A.A.	ANDAYCHAGUA	Junin	**11,374**
SMALL MINERS			**107,816**
			1,348,534

*company reported figures. Remainder are government reported and may include unpayable quantities. These will not reconcile with figures you see later as discussed on page 1.

Only mines listed with +10,000 T zinc in concentrate production are listed in Table 1. Remaining output is listed under Small Miners. Do not be deceived by the company names listed above. Most of these mines are owned by substantial foreign entities.

Summary of Actual and Expected Peru Zinc Mine Production

Table 2 summarizes my findings with respect to zinc mined in Peru from 2012 to 2015. Table 3 is my forecast for 2016-2022 for existing producers.

Table 2 Calculated Zinc Mine Production, Tonnes Zinc in Concentrate

	2012	2013	2014	2015
Antamina	219,000	260,400	211,000	235,000
Cerro Lindo	108,000	155,000	167,000	177,000
El Porvenir	70,700	61,700	64,900	61,700
Atacocha	44,000	44,300	37,900	30,300
Iscaycruz	87,617	81,539	85,037	77,628
Yauliyacu	24,924	25,946	25,759	24,917
Santander	0	0	27,100	29,100
Yauli	157,600	163,100	162,700	179,900
Chungar	99,100	104,600	106,400	90,900
C. Pasco	49,600	20,300	14,000	13,000
Alpamarca	0	0	5,900	8,700
Colquijirca	30,180	24,219	10,126	53,319
Uchucchacua	9,820	8,146	6,349	5,692
Mallay	6,088	8,973	9,893	9,173
Morococha	12,900	16,400	17,100	12,300
Huaron	11,824	14,017	14,200	13,550
Yauricocha	22,600	23,050	24,800	20,000
Catalina Huanca	38,670	42,732	46,708	48,383
Contonga	15,496	13,409	14,287	12,906
San Cristobal	10,150	11,400	12,400	16,252
SIMSA	37,570	26,498	13,820	24,479
S. Luisa	33,804	34,834	26,423	27,321
Raura	20,741	23,870	24,006	33,823
Casapalca	32,831	31,960	36,043	35,118
Colquisiri	22,639	18,890	22,941	25,180
A. Duvaz	5,382	5,498	7,287	8,053
Subtotal	1,171,236	1,220,781	1,194,079	1,273,694
Small Miners	33,020	41,767	55,988	68,355
TOTAL	1,204,256	1,262,548	1,250,067	1,342,049
Net change		4.6%	-1.0%	6.9%

Company reported data is used where possible. Otherwise government data is used. Some small miners not listed in Table 1 are broken out here.

Table 3 Expected Zinc Mine Production, Tonnes Zinc in Concentrate

	2016	2017	2018	2019	2020	2021	2022
Antamina	220,000	350,000	350,000	350,000	376,000	376,000	376,000
Cerro Lindo	185,000	180,000	175,000	175,000	175,000	175,000	175,000
El Porvenir	65,000	65,000	65,000	65,000	65,000	65,000	65,000
Atacocha	35,000	40,000	45,000	45,000	45,000	45,000	45,000
Iscaycruz	0	0	0	0	0	0	0
Yauliyacu	25,000	25,000	25,000	25,000	25,000	25,000	25,000
Santander	28,000	28,000	27,000	27,000	26,000	26,000	25,000
Yauli	180,000	180,000	180,000	180,000	180,000	180,000	180,000
Chungar	95,000	95,000	95,000	95,000	95,000	95,000	95,000
C. Pasco	0	0	0	0	0	0	0
Alpamarca	10,000	9,000	9,000	8,000	6,000	0	0
Colquijirca	47,200	55,000	60,000	60,000	60,000	60,000	60,000
Uchucchacua	10,800	8,000	8,000	8,000	8,000	8,000	8,000
Mallay	7,200	9,000	9,000	9,000	9,000	9,000	9,000
Morococha	17,000	16,000	16,000	16,000	16,000	16,000	16,000
Huaron	19,400	18,000	18,000	18,000	18,000	18,000	18,000
Yauricocha	23,000	21,900	19,700	20,600	18,300	13,500	15,000
Catalina Huanca	49,800	50,000	50,000	50,000	50,000	25,000	25,000
Contonga	12,000	14,000	14,000	14,000	14,000	14,000	14,000
San Cristobal	19,802	14,703	14,750	19,435	16,357	15,576	16,000
SIMSA	23,000	25,000	25,000	25,000	25,000	25,000	25,000
S. Luisa	21,000	25,000	25,000	25,000	25,000	25,000	25,000
Raura	37,000	35,000	35,000	35,000	35,000	35,000	35,000
Casapalca	40,000	35,000	35,000	35,000	35,000	35,000	35,000
Colquisiri	21,000	23,000	23,000	23,000	23,000	23,000	23,000
A. Duvaz	7,000	7,000	7,000	7,000	7,000	7,000	7,000
Subtotal	1,198,202	1,328,603	1,330,450	1,335,035	1,352,657	1,316,076	1,317,000
Small Miners	75,000	80,000	85,000	90,000	95,000	100,000	105,000
TOTAL	1,273,202	1,408,603	1,415,450	1,425,035	1,447,657	1,416,076	1,422,000
Net change	-5.4%	9.6%	0.5%	0.7%	1.6%	-2.2%	0.4%

The decrease in 2016 is essentially due to the closure of the Iscaycruz mine. Production then increases due to increased zinc output at Antamina.

Existing Producers

Antamina

Antamina is Peru's largest zinc producer and zinc production is set to increase markedly. This mine is a joint venture between BHP, Glencore, Teck and Mitsubishi. This open pit mine processes roughly 150,000 T a day of ore, well above nameplate capacity. There are two key types of ore at the mine, copper ore and copper-zinc ore. The mill is configured depending upon which ore type is milled. The reason why zinc production will increase is that the percentage of copper-zinc ore processed will increase compared to previous years. This is largely a function of the pit mining sequencing. Copper ore is in the core of the pit and copper-zinc ore is on the periphery.

Teck describes Antamina as follows:

> *The Antamina polymetallic deposit is skarn-hosted. It is unusual in its persistent mineralization and predictable zonation, and has a SW-NE strike length of more than 2,500 metres and a width of up to 1,000 metres. The skarn is well-zoned symmetrically on either side of the central intrusion with the zoning used as the basis for four major subdivisions being a brown garnet skarn, green garnet skarn, wollastonite/diopside/green garnet skarn and a marbleized limestone with veins or mantos of wollastonite. Other types of skarn, including the massive sulphides, massive magnetite, and chlorite skarn, represent the remainder of the skarn and are randomly distributed throughout the deposit. The variability of ore types can result in significant changes in the relative proportions of copper and zinc produced in any given year.*

Table 4 illustrates recent production performance and estimated production to 2022. Treatment capacity was expanded in 2012. Teck indicates that 2016 production will be in the range of 220,000 T Zn and this is going to increase substantially to the 350,000 T Zn range for 2017-2019.

Table 4 Previous and Expected Antamina Zinc in Concentrate Production

2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
219,000	260,400	211,000	235,000	220,000	350,000	350,000	350,000	376,000	376,000	376,000

Reserves as of December 31, 2015 are listed in Table 5.

Table 5 2015 Production and Antamina Reserves as of December 31, 2015

	T	Zn%	Cu%	Ag g/t	Mo%
P+P reserves copper only ore	335,700,000		1.00	8.1	0.034
P+P reserves copper-zinc ore	263,000,000	2.0	0.89	14.0	
2015 Production copper only	37,163,000		0.83*	nr	nr
2015 Production copper-zinc ore	19,033,000	1.52	0.83*	nr	

*A total of 56,196,000 T were processed in 2015. The copper grade listed is for all tonnage. The zinc grade listed only applies to the copper-zinc ore. Zinc recovery for this stream was 81.4%, nr= not reported by Teck.

For the years 2020-2022 I have assumed that the average ratio of reserves remaining (56% copper only, 44% copper-zinc) is used at average reserve zinc grade and recent recoveries:

150,000 tpd x 350 d/y x 44% x 2% Zn x 81.4% recovery = 376,000 T Zn a year.

Since the pit is very large and broad, the potential for short term mining/milling flexibility is present. In other words, a rise in zinc price can result in the temporary increase in processing copper-zinc ore at the expense of copper only ore to surpass the annual quantities listed above.

Although current reserves will be exhausted in roughly 12 years, there are another billion tonnes or so of inferred resources present. An expansion is therefore not out of the cards but this may only be to maintain current production levels as grade decreases.

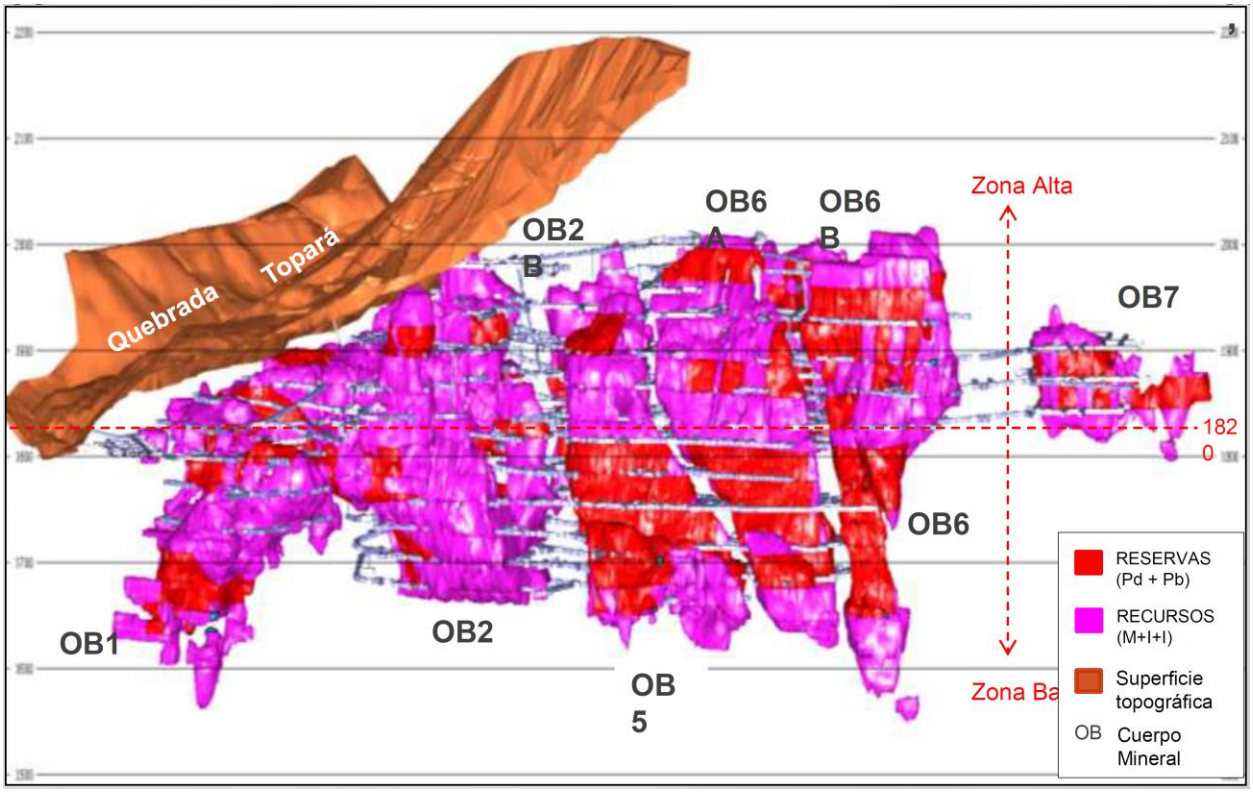
Reference: Technical Report, Mineral Reserves and Resources, Antamina Deposit, Peru 2010. January 31, 2011 NI 43-101 Teck Resources www.sedar.com . Although the document is dated there is a good description of the geology and milling.

Milpo

Votorantim of Brazil has recently increased their ownership stake in Milpo to 80%. They know a good thing when they see it. They also have a controlling stake in the Cajamarquilla zinc refinery.

Cerro Lindo

This is Milpo's flagship mine which has been progressively expanded to 18,000 T per day since opening in 2007. The deposit is located 70 km from the coast in Ica region. For an underground mine this tonnage rate is a very substantial undertaking. A further expansion to 20,000 T per day is under review. For those Spanish speakers, a good PowerPoint presentation for the expansion from 10,000 to 15,000 T per day can be found here. Blasthole stoping of seven orebodies is conducted. These are typical volcanic massive sulphide (VMS) deposits. The ease with which the underground expansions have occurred is illustrated in the figure below. The ore is near surface so it can be readily trucked out of the mine.



The reserves and resources as of December 31, 2015 are illustrated in Table 6.

Table 6 Cerro Lindo Reserves and Resources as of December 31, 2015

	Tonnes	Zn%	Pb%	Cu%	Ag g/t
P+P Reserves	46,119,265	2.45	0.26	0.76	24
M+I Resources	41,048,986	2.66	0.31	0.81	27
Inferred Resources	15,039,543	2.71	0.30	0.84	25

Milpo does not publish tonnage mined a year nor the grade or recovery. However, historic zinc recoveries have been 91% and assuming the milling of 18,000 tpd (6.57 MT a year), this results in a mined grade of ~2.9% Zn in order to achieve the 2015 zinc output of 176,992 T zinc in concentrate reported in the 2015 Annual Report.

Therefore any expansion to 20,000 tpd would be to merely maintain zinc output as mining grade gradually decreases to reserve grade. Reserves include dilution whereas resources do not so when resources are converted to reserves they will likely also be in the 2.45% Zn range.

A mine in Canada would not survive on those grades listed in Table 6 but in Peru they do quite nicely since the site costs are a mere $US28.20/ T. This is one third of the cost a similar mine in Canada or Australia would experience. Cheap productive labour and most likely cheap power are the key. The Peruvian advantage. The trick is to have a good uncontested water supply. Cerro Lindo uses desalinated seawater since they are reasonably close to the coast.

Actual and forecast zinc production is listed in Table 7.

Table 7 Previous and Expected Cerro Lindo Zinc in Concentrate Production

2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
108,000	155,000	167,000	177,000	185,000	180,000	175,000	175,000	175,000	175,000	175,000

Figures for 2012-2015 are company figures. 2016 figures are three times Jan.-Apr. production reported to the government.

El Porvenir/Atacocha

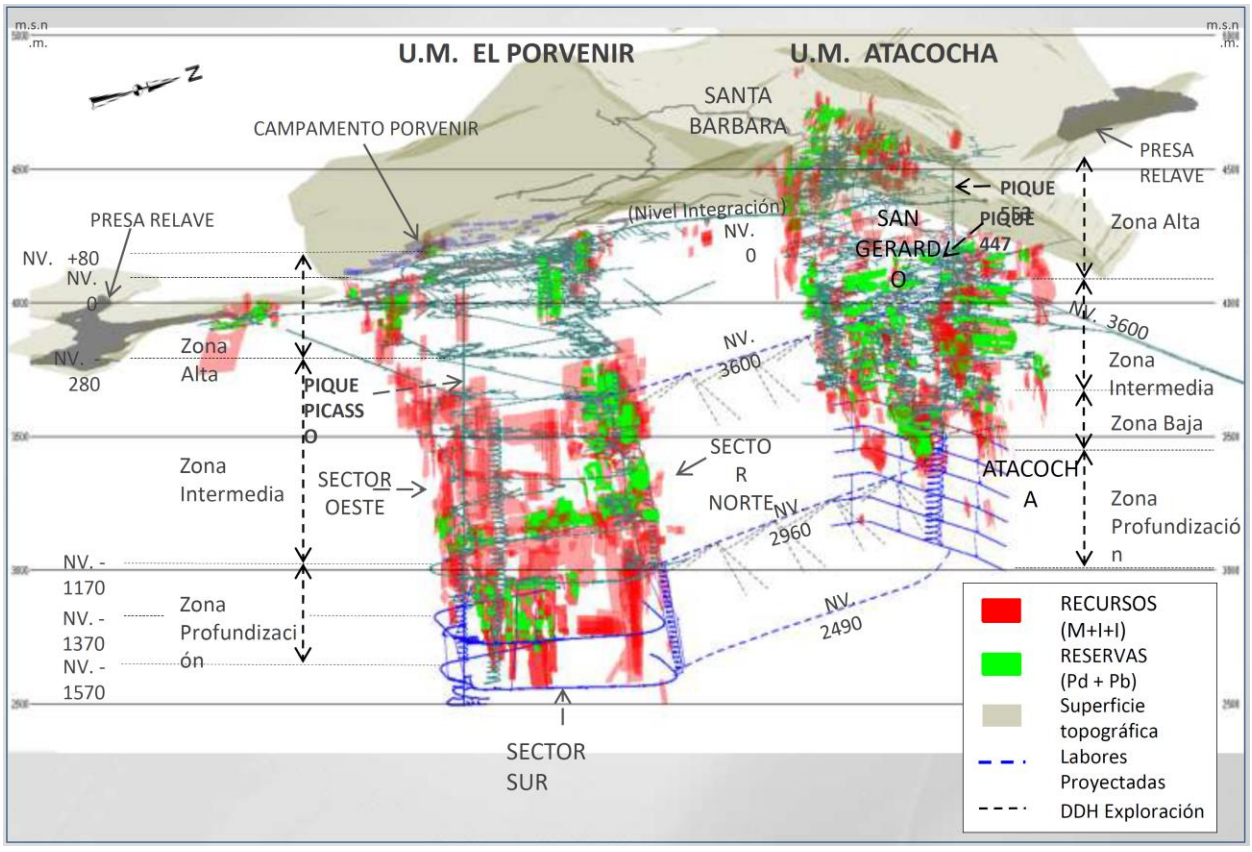
El Porvenir has been in operation since 1949. Milpo acquired the neighboring Atacocha mine in 2008. The deposits are located north of Cerro de Pasco which has been a prolific base metal mining region of Peru. Reserves and resources for both operations are presented in Tables 8 and 9.

Table 8 El Porvenir Reserves and Resources as of December 31, 2015

	Tonnes	Zn%	Pb%	Cu%	Ag g/t
P+P Reserves	23,411,331	3.64	0.68	0.25	46
M+I Resources	10,197,859	4.41	1.03	0.30	68
Inferred Resources	19,599,781	3.96	1.00	0.31	65

Table 9 Atacocha Reserves and Resources as of December 31, 2015

	Tonnes	Zn%	Pb%	Cu%	Ag g/t
P+P Reserves	10,258,869	2.18	1.19	0.18	55
M+I Resources	8,122,822	2.96	1.27	0.24	59
Inferred Resources	15,939,792	3.74	1.79	0.31	76



Milpo is currently integrating the two mines by developing connections between the two mines on three levels. The mill at El Porvenir can treat 2.0 MT of ore a year and the concentrator at Atacocha can treat 1.5 MT of ore a year. These are mature assets with El Porvenir being the deepest mine in Peru at roughly 1,500 m. Ore is hoisted to surface at both operations. Based on the underground layouts and unit costs I assume blasthole stoping is used at both operations but I have found no information that confirms this.

My guess is that as the mining rate at Atacocha decreases due to reserve depletion, higher grade ore from El Porvenir will be transported underground to Atacocha to take advantage of spare hoisting and milling capacity there. Atacocha is essentially a marginal operation at current commodity prices. Site costs at El Porvenir were $US40/T in 2015 and at Atacocha they were $US47.70/T. By displacing the ore at Atacocha it should be possible to marginally increase total zinc production.

Table 10 illustrates previous production results and my forecast of zinc output going forward.

Table 10 Previous and Expected El Porvenir/Atacocha Zinc in Concentrate Production

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
El Porvenir	70,700	61,700	64,900	61,700	65,000	65,000	65,000	65,000	65,000	65,000	65,000
Atacocha	44,000	44,300	37,900	30,300	35,000	40,000	45,000	45,000	45,000	45,000	45,000
Total	114,700	106,000	102,800	92,000	100,000	105,000	110,000	110,000	110,000	110,000	110,000

Glencore (Empresa Minera Los Quenuales S.A.)

Iscaycruz

I have researched this operation in the past and have generally come up pretty dry. Glencore describes the geology as:

> *Zinc, lead and copper mineralisation are exposed as subvertical massive sulphide ore bodies; described as skarn, breccias and carbonate replacement type along 12km corridor hosted in clay-rich limestone and dolomite rocks. Hydrothermal mineralisation assemblages are mainly composed of sphalerite, galena, pyrite, chalcopyrite distributed in five production zones named Limpe Centro, Chupa, Tinyag II, Tinyag I and Santa Este from North to South.*

From what I can gather, the ground conditions underground are poor and the term "clay-rich" sends a shiver up a mining engineer's spine. The undercut and fill mining method has been used in the past and this is a last resort, very high cost approach which implies very bad ground conditions. I had a look at a technical paper that confirms the weak ground at one of the deposits at least. The need for steel sets in the drawpoints for sublevel caving at the Tinyag deposit (as seen in the paper you can download here, page 3 photo e) is an indication of very bad ground hence high to very high mining costs. If this is indicative of all of the deposits at Iscaycruz, this is likely a high cost per tonne mined operation. Glencore however is not in the business of disclosure so I will assume the worst in lieu.

This was one of the zinc assets that Glencore placed on care and maintenance in October 2015. About the best I can do is look at the deteriorating reserve and resource base here and draw some inferences. From this I conclude that the economics have deteriorated dramatically following the extraction of higher grade ore and this mine would have been a candidate for cutback or closure irrespective of the big bang announcement. I recall mining grades being well above 10% Zn for a number of years but proven reserve tonnes and grade has deteriorated to less than two months of mill feed at 4.9% Zn, 0.49% Pb. 0.30% Cu and 28.3 g/t Ag by the end of 2015 as illustrated in Table 11. This is likely one dead parrot like the one here. So if production does resume, output will likely be constrained by considerably lower grades. Although the remaining zinc grade may appear attractive in comparison to some other Peruvian zinc mines, it looks like high underground mining costs related to weak rock are a key, if not the key, issue so I do not show this mine reopening during the period assessed. Without NI 43-101 or Annual Information Form level of disclosure, this is the conclusion I draw. Poor disclosure cuts both ways.

Table 11 Recent Reserves and Production Performance for Iscaycruz

	2011		2012		2013		2014		2015	
	MT	Zn%	MT	Zn%	MT	Zn%	MT	Zn%	Mt	Zn%
Proven Reserves*	1.2	9.75	1.45	9.2	0.97	10.5	0.7	8.77	0.18	4.9
Probable Reserves*	1.2	7	4.2	5.8	3.1	6.1	3.0	7.0	2.7	6.1
Production	nr	nr	nr	nr	1.2	7.3	1.3	7.2	1.2	7.1
Zinc in Concentrate	121,103		87,617		81,539		85,037		77,628	

*Proven and probable reserves are at the end of the calendar year. nr= not reported

Measured and indicated resources at the end of 2015 total 4.6 MT @ 6.5% Zn, 0.6% Pb, 0.4% Cu and 36 g/t Ag. Resources are undiluted. Therefore, a substantial fall in mining grade would occur if the mine reopened (without concerted exploration efforts).

As illustrated above open pit mining also occurred and these were probably the glory days for this operation in terms of zinc output and unit costs. It must have been a little intimidating working at the bottom of that pit knowing the tailings pond was above you.

Yauliyacu (Casapalca-6, Casapalca-8)

Since Silver Wheaton has a silver royalty for this mine there actually is some decent, though dated, information on the mine. This mine is typical of many in Peru. It is classic narrow vein mining that has largely disappeared in North America and Australia apart from perhaps the Lucky Friday mine in Idaho. These mines typically have 2-5 years of reserves on the books but perhaps 10-20 years of resources that can easily be converted into reserves since it is just a matter of exploring on strike or usually down dip to do so. Continuity of these veins is generally excellent.

Probable reserves as of December 31, 2015 are 3.8 MT @2.0% Zn, 0.3% Pb, 0.2% Cu and 130 g/t Ag. Measured and indicated resources total 15 MT at similar grades. This is essentially a silver mine yet much of the silver value is attributed to Silver Wheaton and not Glencore (which is why I concur with Rob McEwen that royalty streaming companies are evil since they threaten the commercial viability of operations by taking away a potentially critical component of annual site revenues).

Silver Wheaton describes the mine as follows:

> *The Yauliyacu mine is an underground zinc-lead-silver mine owned and operated by Glencore. The mine has been in continuous production for over 100 years. The Yauliyacu mill has a capacity of 3,600 tonnes per day. Processing consists of conventional crushing, grinding and flotation, and is capable of producing separate copper (copper, silver), lead (lead, silver) and zinc (zinc, silver) concentrates that are shipped for smelting.*
>
> *Mineralization occurs in hydrothermal polymetallic veins ("Vetas") and disseminated orebodies ("Cuerpos"). The Vetas are up to 5.0 kilometres along strike on surface of which 4 kilometres have been exposed underground and have a known vertical range over 2 kilometres, and average 0.3 to 1.2 metres in width. At points where the veins converge, mineralization widths can exceed 5 metres, contributing significant tonnage capacity to the mining operations. Cuerpos were discovered in the late 1980s and have proven to be an important part of the Yauliyacu reserve. Mineralization at Yauliyacu is zoned vertically and laterally. Vertical zoning occurs with high grade silver near surface and high grade zinc in the lowest levels of the mine. Despite this long mining history, the mine has successfully replaced production and expanded reserves*

I have assumed it is steady as she goes here during the period assessed. Therefore Table 12 illustrates actual and expected zinc production.

Table 12 Previous and Expected Yauliyacu Zinc in Concentrate Production

2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
24,924	25,946	25,759	24,917	25,000	25,000	25,000	25,000	25,000	25,000	25,000

2012-15 figures are government reported figures.

Reference: Silver Wheaton Corp. Yauliyacu Lead/Zinc Mine NI 43-101 Report, April 10, 2006
www.sedar.com

Santander

Glencore constructed and operates this mine on behalf of Trevali and they are also the largest debt holder and a small shareholder. So I look upon Trevali as essentially a Glencore investment vehicle or leveraged tracking stock for the price of zinc. Trevali does not appear to have much management depth.

The Santander mine is a past producer but current production is derived from a series of new zones discovered a few kilometers from previous workings. They are easily accessible from surface through a portal. Blasthole stoping is used and site costs are in the range of $US35/T. A previously used 2,000 tpd mill was relocated to site by Glencore.

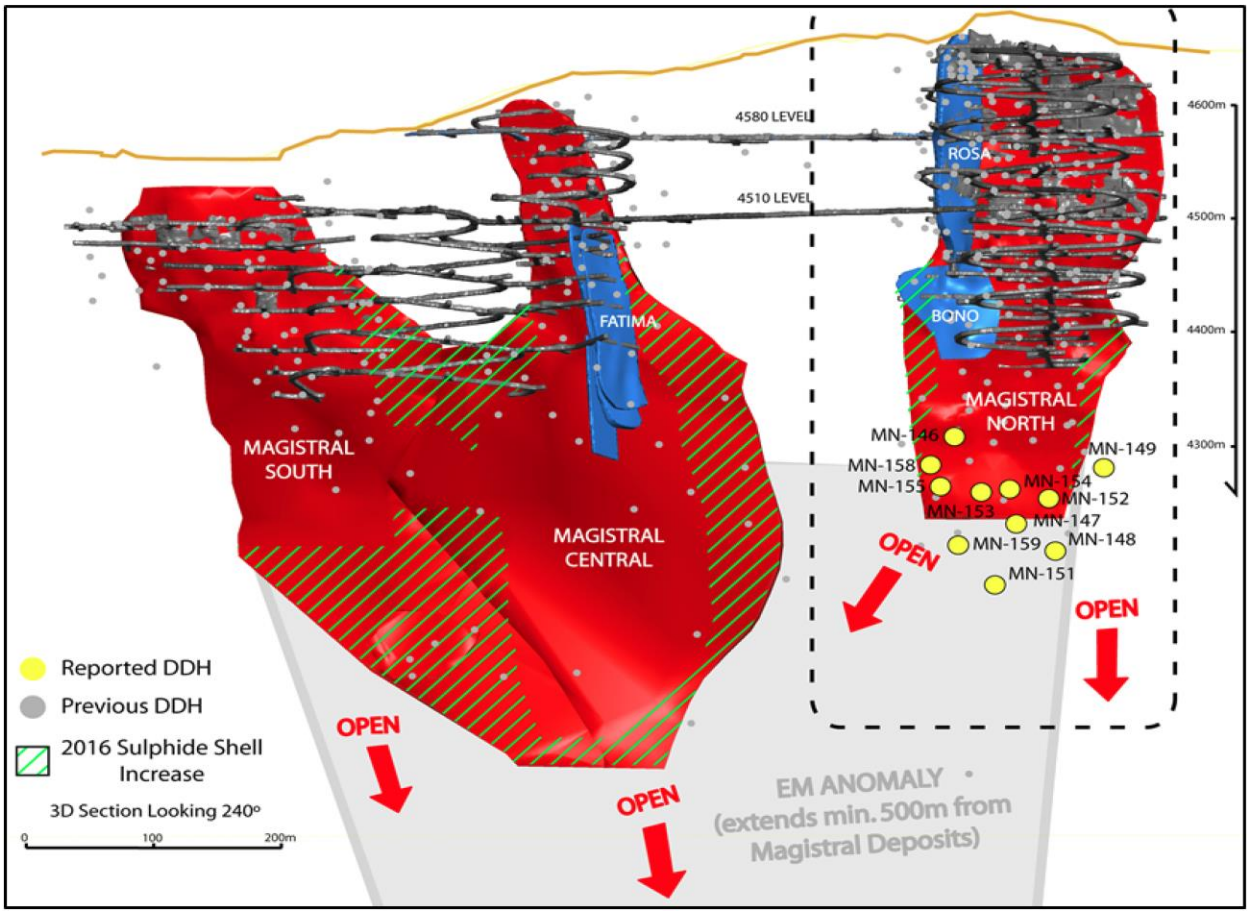


Table 13 illustrates recent production results and the resources present which can be readily increased at depth. For some mysterious reason Trevali refuses to report reserves and resources would be undiluted. At current commodity prices the mine is modestly profitable but I am not sure whether operating cash flows cover sustaining capital let alone pending debt repayment obligations to Glencore.

Table 13 Indicated Resources as of December 31, 2015 and 2015 Production for Santander

	Tonnes	Zn%	Pb%	Cu%	Ag g/t
Indicated Resources	6,264,000	3.62	1.3	0.07	43
2015 Tonnes Milled	778,151	4.14	2.09	0.31	53

Note: payable copper is not recovered.

Table 14 illustrates actual zinc in concentrate production and my expectations going forward. Milling grade has been above undiluted resource grade to date so the piper will have to be paid sometime through lower grades and output.

Table 14 Previous and Expected Santander Zinc in Concentrate Production

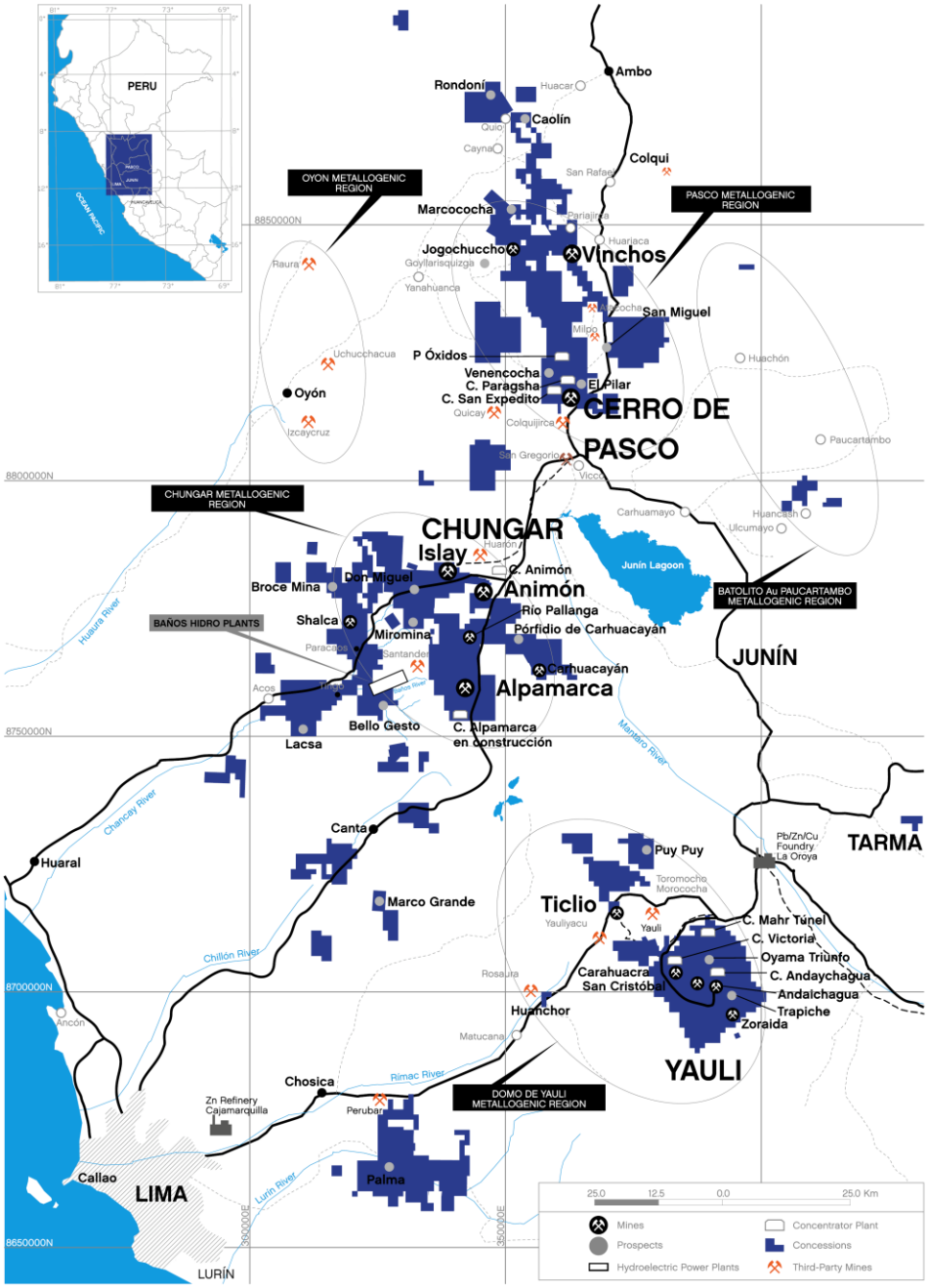
2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
0	0	27,100	29,100	28,000	28,000	27,000	27,000	26,000	26,000	25,000

2014-15 figures are company reported figures derived by multiplying the tonnes of zinc concentrate by zinc concentrate grade.

Reference: Trevali Mining Corporation, Santander Property, NI 43-101 Report, November 26, 2013
www.sedar.com

Volcan

Volcan operates numerous base metal mines in Peru. Many of these mines were acquired through acquisitions over the past 20 years. Previously they mined the Cerro de Pasco open pit and underground mines with zinc production in the 150,000 T per year range but these mine ceased large scale production recently due to economic ore exhaustion. No zinc production has been reported for 2016 for Cerro de Pasco.



Volcan has three production units:

Yauli

Listed in Table 15 is the mine production performance for 2014 and 2015 for the Yauli production unit.

Table 15 2014 and 2015 Mine Production for the Yauli Production Unit

YAULI PRODUCTION BY MINE

	Treated tonnage (000 MT)		Zn grade (%)		Pb grade (%)		Cu grade (%)		Ag grade (oz / MT)	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
San Cristóbal	1,532	1,555	4.9	5.0	0.6	0.8	0.2	0.2	3.1	3.3
Andaychagua	979	1,127	3.8	3.9	0.6	0.7	0.1	0.1	5.3	5.9
Ticlio	368	289	5.1	5.6	1.7	1.8	0.2	0.3	2.2	2.4
Carahuacra	433	653	7.0	6.9	0.3	0.3	0.1	0.1	2.0	2.1
Tajo Carahuacra Norte	414	369	1.8	2.0	0.3	0.3	0.0	0.0	3.4	2.9
Toldorrumi	52		4.1		0.2		0.0		1.7	
Third-party mineral	59		2.9		2.3		0.3		1.7	
Total Yauli	**3,837**	**3,994**	**4.5**	**4.8**	**0.7**	**0.7**	**0.1**	**0.2**	**3.5**	**3.7**

The first four mines listed are underground blasthole stoping operations. Tajo Carahuacra Norte is a small open pit mine that ceased production at the end of 2015. Production at Ticlio was reduced to focus on higher grade ore.

The mines feed three separate mills listed in Table 16. Like many mines in Peru, the tonnes of zinc concentrate is reported, not the zinc in concentrate. Therefore actual zinc production is roughly half of the figures listed.

Table 16 Mill Performance for the Yauli Production Unit, 2014-15

TREATED TONNAGE AT YAULI, BY CONCENTRATOR PLANT

	Treated tonnage (000 MT)		Zn concentrate (000 MT)		Pb concentrate (000 MT)		Cu concentrate (000 MT)	
	2014	2015	2014	2015	2014	2015	2014	2015
Victoria	1,610	1,752	148	175	16	20	4	4
Andaychagua	1,210	1,211	73	78	15	18	0	0
Mahr Túnel	1,017	1,031	82	86	16	16	5	6
Total Yauli	**3,837**	**3,994**	**303**	**339**	**48**	**54**	**9**	**10**

The Victoria mill was expanded to 5,200 tpd in 2015 from 4,500 tpd previously. The reserves for the various mines are listed in Table 17.

Table 17 Ore Reserves for All Volcan Mines as of December 31, 2015

ORE RESERVES BY MINING METHOD

Ore Reserves by Mining Method		Thousands MT	Grades Zn %	Pb %	Cu %	Ag oz/MT
Underground mines		**43,116**	**5.17**	**1.06**	**0.15**	**3.53**
Yauli	San Cristóbal	15,521	5.78	1.02	0.19	4.12
	Carahuacra	3,976	5.93	0.49	0.07	2.29
	Andaychagua	9,054	4.03	0.64	0.11	4.47
	Ticlio	3,113	5.82	1.69	0.22	1.79
Chungar	Animón	9,648	5.43	1.63	0.16	2.04
	Islay	1,633	1.49	0.70	0.04	7.72
Alpamarca	Río Pallanga	170	1.30	0.79	0.18	5.58
Open pits		**26,997**	**2.19**	**0.79**	**0.08**	**2.31**
Yauli	Carahuacra N & others	846	2.61	0.68	0.02	1.29
	Oyama	2,120	-	-	0.94	0.73
Cerro	Raúl Rojas	15,290	3.51	1.21	0.00	1.56
	In situ oxides	5,854	-	-	-	4.94
Alpamarca	Alpamarca	2,887	1.11	0.73	0.07	2.40
Stockpiles		**6,779**	**0.30**	**0.46**	**0.24**	**7.70**
Cerro	Oxides SP	2,081	-	-	0.15	9.56
	Pyrite Sulfide SP	4,698	0.43	0.67	0.28	6.88
Total Reserves		**76,891**	**3.69**	**0.91**	**0.14**	**3.47**

Resources are also substantial. 2015 was a difficult year for Volcan with numerous layoffs and belt tightening due to low lead/zinc prices. 2014 unit costs for the various mines are relatively high by Peruvian standards and are listed in Table 18. Unit costs for H1 2016 at Yauli are now down to $58.20/T and $49.60/T for Chungar.

Table 18 Site Unit Costs by Production Unit for 2013/14

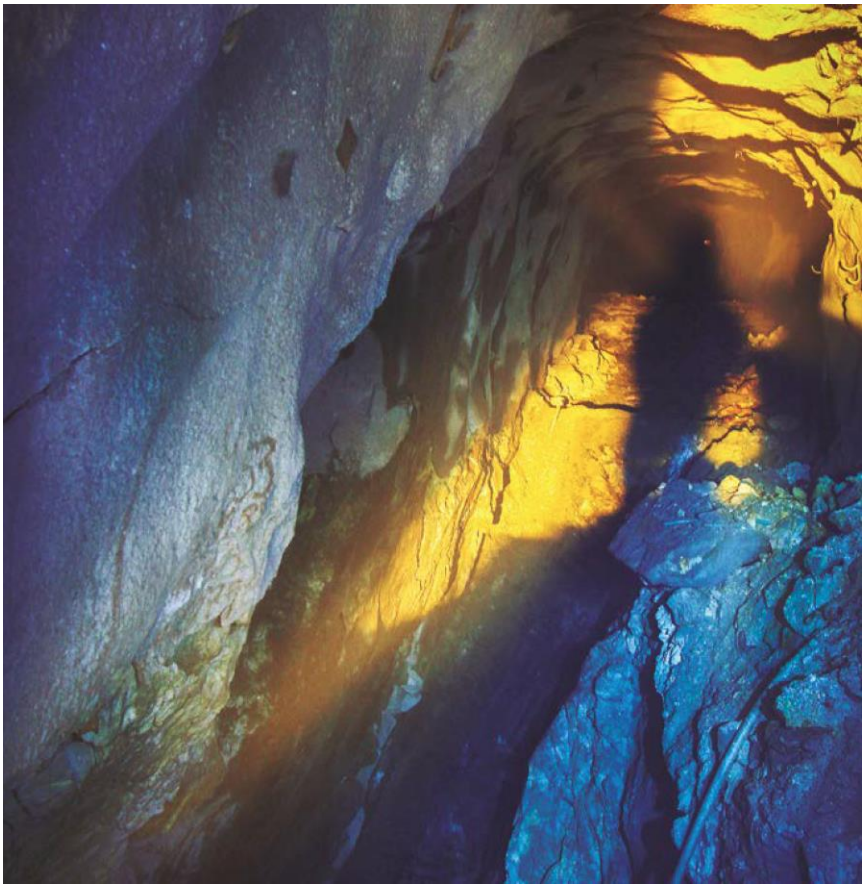
UNIT COST (USD/MT)

Unit	2013	2014	var %
Yauli	66.2	66.1	-0.2
Chungar	56.9	53.6	-5.8
Cerro**	96.3	99.6	3.3
Vinchos	50.1	49.0	-2.1
Alpamarca		47.6	
Consolidated**	67.6	63.9	-5.4

** The reported cost of production is the cost of production itself, which does not includes the cost of buying ore concentrates and third parties, nor those extra costs from the liquidation of staff.

Chungar

The 4,000 tpd Animon Mine utilizes blasthole stoping of narrow veins whereas the 1,800 tpd Islay Mine utilizes both blasthole stoping and cut and fill mining. The mines feed the concentrator at Animon. Islay is essentially a silver mine. Recent production performance for both mines is listed in Table 19. Mill performance is listed in Table 20. Note that zinc in concentrate is approximately 50% of the Zn concentrate tonnage listed.



Narrow Vein Blasthole Stoping at Animon

Table 19 Chungar Production Unit Mine Performance for 2014-15

CHUNGAR PRODUCTION, BY MINE

	Treated tonnage (000 MT)		Zn grade (%)		Pb grade (%)		Cu grade (%)		Ag grade (oz / MT)	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Animón	1,495	1,365	6.9	6.5	1.7	1.7	0.2	0.2	2.5	1.9
Islay	459	532	1.8	1.3	0.9	0.7	0.1	0.0	7.1	5.6
Total Chungar	**1,954**	**1,896**	**5.7**	**5.0**	**1.5**	**1.4**	**0.2**	**0.1**	**3.6**	**3.0**

Table 20 Animon Plant Mill Performance for 2014-15

CONCENTRATOR PLANT

Treatment Animón Plant (000 MT)	2014	2015
Treated tonnage	1,954	1,896
Zn concentrate	179	158
Pb concentrate	38	31
Cu concentrate	5	3

Reserves and unit costs were previously provided in Tables 17 and 18.

Cerro de Pasco Unit

The demise of this unit is amply illustrates in the graph below. Mine production for 2014-15 is listed in Table 21.

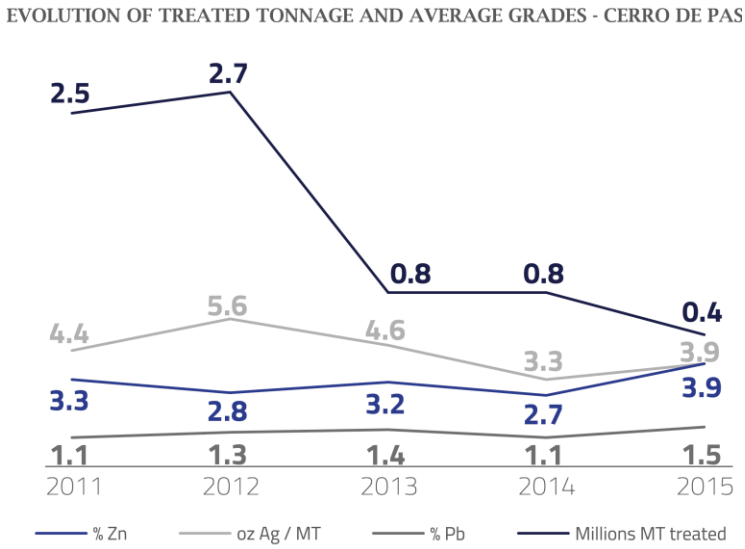


Table 21 Cerro de Pasco Production Unit Mining Performance, 2014-15

CERRO DE PASCO PRODUCTION, BY MINE

	Treated tonnage (000 MT)		Zn grade (%)		Pb grade (%)		Ag grade (oz / MT)	
	2014	2015	2014	2015	2014	2015	2014	2015
Paragsha Underground Mine	224	252	4.9	5.3	1.7	2.0	4.5	4.0
Tajo Raúl Rojas Marginals	274	35	2.0	2.1	0.6	0.6	1.1	1.3
Islay (Chungar)	184	111	1.4	1.5	0.6	0.6	4.8	4.5
Vinchos	90	0	2.4	1.3	1.7	1.2	4.4	3.9
Total Cerro de Pasco	**771**	**399**	**2.7**	**3.9**	**1.1**	**1.5**	**3.3**	**3.9**

The small Paragsha mine utilized very expensive mining methods employing timber shoring due to highly stressed ground conditions. Production has been suspended. Some ore from Islay was also milled at Cerro de Pasco in 2015.

The future of Cerro de Pasco lies in the treatment of oxide high in silver content at a new processing plant. No zinc will be recovered. Table 22 lists 2014-15 mill performance.

Table 22 Cerro de Pasco Mill Performance for 2014-15

CONCENTRATOR PLANT

Treatment San Expedito Plant (000 MT)	2014	2015
Treated tonnage	771	399
Zn Concentrate	29	27
Pb Concentrate	14	13

No reserves are reported for Cerro de Pasco apart from surface stockpiles. Zinc production has ceased.

Alpamarca Unit

The development of this tiny mine essentially tells you that Volcan does not have a good pipeline of projects. The mill treats 2,500 tpd of both open pit and underground ore. Reserves are listed in Table 17. Production in 2015 was 8,700 T of zinc.

Production Summary

Table 23 lists actual production and my forecast of production for Volcan going forward for the various production units. Emphasis still seems to be on reducing costs so I don't foresee any mine expansions on the horizon. The Yauli and Chungar mines all have ample reserves for the forecast period so steady state production is illustrated. Alpamarca on the other hand only appears to have sufficient reserves and resources to 2020.

Table 23 Volcan Actual and Expected Zinc Production, 2012-2022

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Yauli	157,600	163,100	162,700	179,900	180,000	180,000	180,000	180,000	180,000	180,000	180,000
Chungar	99,100	104,600	106,400	90,900	95,000	95,000	95,000	95,000	95,000	95,000	95,000
C. Pasco	49,600	20,300	14,000	13,000	0	0	0	0	0	0	0
Alpamarca	0	0	5,900	8,700	10,000	9,000	9,000	8,000	6,000	0	0
Total	306,300	288,000	289,000	272,500	285,000	284,000	284,000	283,000	281,000	275,000	275,000

Quick Notes on Other Mines

Buenaventura

Colquijirca (Sociedad Minera El Brocal S.A.A. 59.26% owned by Buenaventura)

The mine is also known as Tajo Norte. This mine is 10 km south of Cerro de Pasco. Open pit mining is utilized. Total milling capacity is now 18,000 tpd (up from 11,000 tpd in 2013) but this mill is shared with their adjacent Marcapunta Norte underground copper mine. Proven and probable reserves as of December 31, 2015 were 56.2 Mt @ 2.3% Zn, 0.85% Pb and 35.15 g/t Ag. A total of 3.1 MT of this ore was milled in 2015 at 2.77% Zn head grade to recover 53,319T of zinc in concentrate. Zinc recovery was a poor 61.96% apparently due to a high clay and salt content in the ore. You can practice your Spanish here. I assume they get on top of their milling challenges in Table 24 and mill at roughly the same annual rate for the zinc stream. Output was constrained in 2014 due to milling capacity existing at that time being largely dedicated to the copper mine.

Table 24 Actual and Expected Production for Colquijirca, 2012-2022

2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
30,180	24,219	10,126	53,319	47,200	55,000	60,000	60,000	60,000	60,000	60,000

2012-2015 data is from Form 20-F www.sec.gov 2016 data is H1 2016 actual prorated to 12 months.

The adjacent San Gregorio deposit has a resource of approximately 83 MT @~6% Zn, 1.4% Pb and 8 g/t Ag so has obvious substantial production potential particularly with a large mill nearby. However, a failure to reach an agreement on land use with the community of Vicco has stalled development for over 20 years. This is a very key, if not the key issue with mine development today in Peru. Some of the issues surrounding new mine development in Peru are discussed here. I have assumed that San Gregorio will be a bolt on operation with production commencing when Tajo Norte is mined out. In other words, after the period assessed here.

Uchucchacua

This is a gem of a silver mine with 2015 tonnes and grade mined of 1,121,474 T @ 1.05% Zn, 0.82% Pb and 460 g/t Ag. Reserves are sufficient for four years but the ability to replace reserves with resources is unknown. I show production continuing to 2022 in Table 25 but this is an assumption on my part.

Mallay

This is a tiny silver mine with 2015 tonnes and grade mined of 158,124 T @ 6.6% Zn, 5.05% Pb and 269 g/t Ag. Zinc production is therefore minor. Actual and expected zinc production is also included in Table 25. This mine typically only keeps 6-9 months of proven and probable reserves on the books ahead of mining so I assume they manage to keep on mining through 2022 (but I could be wrong).

Table 25 Actual and Expected Zinc Production for the Uchucchacua and Mallay Mines

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Uchucc.	9,820	8,146	6,349	5,692	10,800	8,000	8,000	8,000	8,000	8,000	8,000
Mallay	6,088	8,973	9,893	9,173	7,200	9,000	9,000	9,000	9,000	9,000	9,000
Total	15,908	17,119	16,242	15,865	18,000	17,000	17,000	17,000	17,000	17,000	17,000

2012-2015 data is from Form 20-F www.sec.gov 2016 data is H12016 actual prorated to 12 months.

Reference: Form 20-F for years 2012-2015 Buenaventura Mining Co. www.sec.gov

Pan American Silver

Morococha Property (Compania Minera Argentum SA, 92.3% Pan American Silver)

This mine is in an unusual situation. It is adjacent to Chinalco's Toromocho copper mine and much of its infrastructure has or will be demolished and replaced as the pit encroaches upon the mine. This includes demolition and construction of a new mill for which no commitment has been made to date. The clock is ticking here since a new mill will be required by around 2020. The property is subdivided into three administration units: Morococha, Anticona and Manuelita.

This mine is essentially a silver mine. Narrow epi-mesothermal silver-zinc-lead-copper veins and stratiform silver and base metal mantos are mined. Labour intensive jackleg and stoper cut and fill mining is used for the narrowest veins (as narrow as 1.0 m) with mechanized cut and fill or blasthole stoping used in wider areas.

Reserves as of December 31, 2015 along with 2015 production results are listed in Table 26. Reserves are readily replaced through exploration. Production for 2015 was 690,500 tonnes of ore recovering 12,300 tonnes of zinc, 2,800 tonnes of lead, 8,800 tonnes of copper and 2.3 million ounces of silver.

Table 26 Morococha Reserves as of December 31, 2015 and 2015 Production Results

	Tonnes	Zn%	Pb%	Cu%	Ag g/t
P+P Reserves	4,200,000	3.63	1.26	0.66	188
2015 Production	690,500	2.83	0.71	1.52	124

Table 27 lists past and expected production levels assuming a new mill is constructed for 2020 commissioning or pit stripping does not require a new mill by that time. 2015 zinc production suffered since copper rich zones were targeted.

Table 27 Actual and Expected Production at Morococha, 100% Basis

2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
12,900	16,400	17,100	12,300	17,000	16,000	16,000	16,000	16,000	16,000	16,000

2012-15 data is from company reports. 2016 figure is H12016 prorated to 12 months.

Reference: Pan American Silver Corp. Morococha Property NI 43-101, June 30, 2014 www.sedar.com

Huaron Property

Mining commenced in 1912 at this property which was acquired by Pan American Silver in 2000. The mine is located near Volcan's Animon and Islay mines. A swarm of veins are mined using conventional cut and fill mining, mechanized cut and fill and blast hole stoping. The operation therefore resembles Morococha. Reserves as of December 31, 2015 are listed in Table 28. 2015 production is also illustrated. Reserves are readily replaced annually and a long mine life is likely going forward. Site costs are approximately $85/T which is reflective of the labour intensive mining methods used.

Table 28 Huaron Reserves as of December 31, 2015 and 2015 Production Results

	Tonnes	Zn%	Pb%	Cu%	Ag g/t
P+P Reserves	9,800,000	3.06	1.47	0.36	170
2015 Production	894,500	2.41	1.08	0.97	157

Table 29 illustrates past and expected zinc production. This assumes steady state production rates. Zinc output should rise as higher grade zinc ore is mined instead of higher grade copper ore recently.

Table 29 Actual and Expected Production at Huaron

2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
11,824	14,017	14,200	13,550	19,400	18,000	18,000	18,000	18,000	18,000	18,000

2012-15 data is from company reports. 2016 figure is H12016 prorated to 12 months.

Reference: Pan American Silver Corp. Huaron Property NI 43-101, June 30, 2014 www.sedar.com

Sierra Metals (Sociedad Minera Corona S.A.)

Yauricocha

Sierra Metals recently filed an updated NI 43-101 report for this mine which has been in operation since 1948. Multiple zones are mined primarily by underground sublevel caving and cut and fill methods to produce over 800,000 T a year of ore. Two key types of ore are mined: Polymetallic ore containing Zn/Pb/Cu/Ag/Au and oxide ore containing Pb/Ag.

Reserves as of December 31, 2015 and 2015 production are listed in Table 30 based on a cut-off of $55-$75/T of ore depending on zone. Mine deepening is underway and this should result in the conversion of sufficient resources to maintain production through the period assessed here. The new Esperanza zone has also extended the known mine life. Table 31 therefore illustrates past zinc production, future zinc production as presented in the NI 43-101 to 2021 (using the SRK production schedule and 90% Zn recovery) and assumed production in 2022 assuming resources are converted to reserves as expected. Site costs are expected to be in the $US57/T range.

Table 30 Yauricocha Reserves as of December 31, 2015 and 2015 Production Results

	Tonnes	Zn%	Pb%	Cu%	Ag g/t	Au g/t
P+P Reserves	3,787,000	2.92	1.15	0.84	61.1	0.62
2015 Production	832,225	2.57	2.93	0.49	102.6	0.70

Esperanza zone P+P (1,520,000 T) is as of June 30, 2016

Table 31 Previous and Expected Yauricocha Zinc in Concentrate Production

2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
22,600	23,050	24,800	20,000	23,000	21,900	19,700	20,600	18,300	13,500	15,000

2012-15 data is from company reports. 2016 figure is H12016 prorated to 12 months. 2017-2021 data from NI 43-101

Reference: Sierra Metals, Yauricocha Mine NI 43-101, September 9, 2016 www.sedar.com

Trafigura

Catalina Huanca

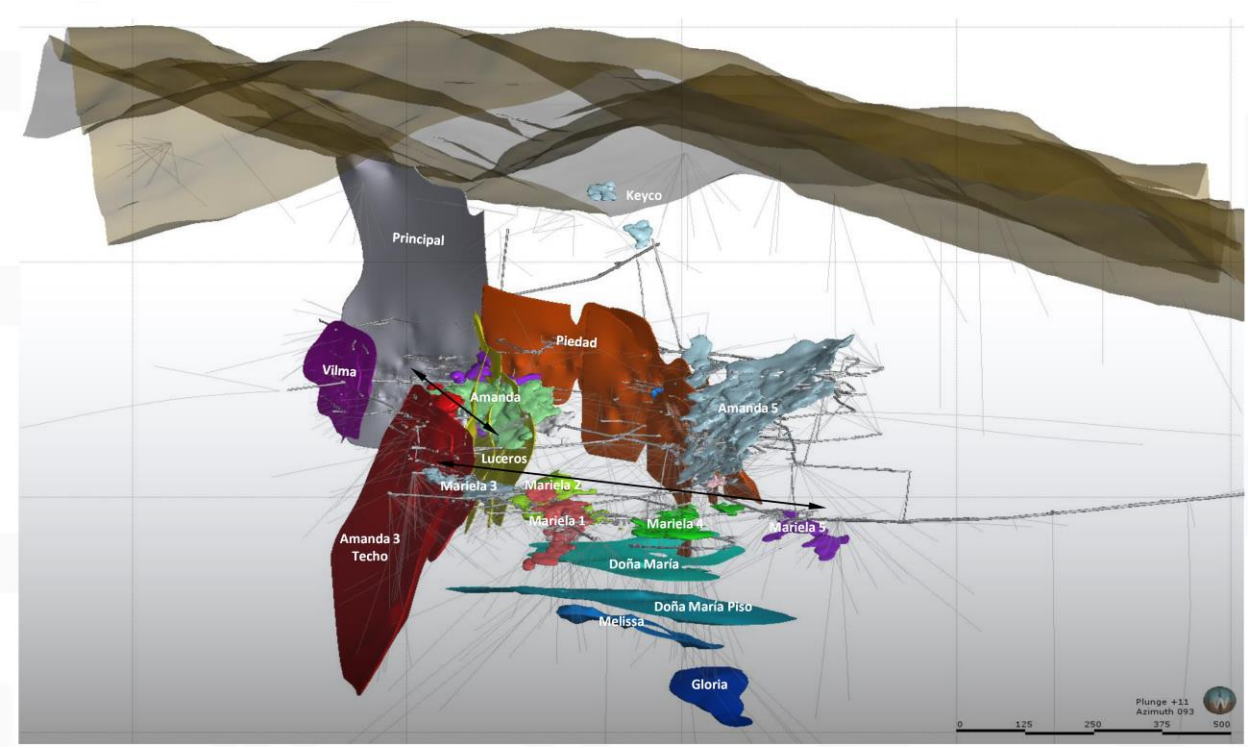
Trading house Trafigura owns this mine. The only document of significance I have located is here. This is pretty shaky information to go on. This 2015 document reports a four year mine life remaining (as of the start of the year I assume) but with potential to convert resources to reserves. Reserves are reported as 2,887,000 T grading 9.03% Zn, 1.79% Pb, 0.25% Cu, 1.52 oz/T Ag and 0.18 g/t Au.

Mill capacity is 1,900 tpd. For lack of any decent information, I assume in Table 32 that current production rates are maintained to 2020 and then at 50% of this rate for 2021 and 2022 but this is a crapshoot. When you see very long exploration drifts emanating from the main workings you know they are getting desperate with respect to finding things to mine.

Table 32 Actual and Expected Zinc Production for Catalina Huanca

2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
38,670	42,732	46,708	48,383	49,800	50,000	50,000	50,000	50,000	25,000	25,000

2012-2015 data is from government statistics. 2016 data is Jan-Apr. data prorated to 12 months.



Nyrstar

Contonga

Nyrstar describes the geology of the mine as follows:

> *The Contonga mine is an underground polymetallic operation with more than 27 years of mining history. The mine site is located in the Central Peruvian Andes, 470 kilometres north-east of Lima, Peru. At the Contonga mine, vertically zoned mineralization of skarn replacement is controlled by bedding orientation. Faulting occurs predominantly in strongly folded limestone, which surrounds the well-defined Contonga stock. There is strong geological continuity of the mineralization as demonstrated in the extensive diamond drilling and underground development.*

2015 proven and probable reserves and production obtained for the first half of 2016 is illustrated in Table 33. Nyrstar has their zinc mining assets currently for sale but there has been no announcement related to this mine. Reserves are not sufficient to maintain current production levels through the period assessed in this report. So I assume resource conversion.

Table 33 Contonga Reserves as of December 31, 2015 and H1 2016 Production Results

	Tonnes	Zn%	Pb%	Cu%	Ag g/t
P+P Reserves	1,570,000	4.24	1.48	1.03	87.12
H1 2016 Production	225,000	3.09	0.32	1.52	43.07

Like other mines, it appears that mining is currently being skewed towards copper rich zones due to low lead/zinc prices.

A net smelter return cut off of $US80/T of ore was utilized to determine reserves. This value also includes provision for exploration, capitalized development and sustaining capital. Site cash costs are reported as $73/T for 2015. No information was located describing the mining methods utilized. I assume that 2015 performance is maintained to 2022 but this requires the successful conversion of resources to reserves. Table 34 presents actual and expected production.

Table 34 Actual and Expected Zinc Production for Contonga

2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
15,496	13,409	14,287	12,906	12,000	14,000	14,000	14,000	14,000	14,000	14,000

2012-2015 data is from government statistics. 2016 data is H1 data prorated to 12 months.

Nyrstar's nearby Pucarrajo mine has been on care and maintenance since 2008 due to weak commodity prices. Likewise, their Coricancha mine 90 km east of Lima has been on care and maintenance since 2013 and has been optioned to Great Panther Silver Ltd.

Reference: www.nyrstar.com

Fortuna Silver Mines Inc. (Minera Bateas S.A.C.)

Caylloma Property (San Cristobal)

An NI 43-101 report was recently filed for this property and the reserve statement along with 2015 production results is listed in Table 35. Reserves are readily replenished by resources (see Figure 15.4 in the report to be convinced of this).

Table 35 Caylloma Property Reserves as of December 31, 2015 and 2015 Production Results

	Tonnes	Zn%	Pb%	Ag g/t	Au g/t
P+P Reserves	1,979,000	3.55	2.83	121	0.30
2015 Production	466,286	3.84	2.47	136	0.26

Narrow vein cut and fill mining is used for multiple veins. Refer to the technical report for ample details. Actual and expected zinc production is illustrated in Table 36. I will have a closer look here when I have some time. I like what I see.

Table 36 Actual and Expected Zinc Production for Caylloma (San Cristobal)

2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
10,150	11,400	12,400	16,252	19,802	14,703	14,750	19,435	16,357	15,576	16,000

2012-2015 figures are as reported by the company. 2016-2021 figures are from the NI 43-101. 2022 figure is authors estimate assuming resources are converted to reserves.

Reference: Fortuna Silver Mines Inc., Caylloma Property, NI 43-101 Technical Report August 31, 2016 www.sedar.com

Even Quicker Notes on Other Mines

In a number of cases I came up stone cold with respect to decent information on a number of mines. Many of these mines are privately owned hence have no need to describe to the world who they are. In all cases I have assumed production going forward is the average of production achieved in the recent past. Companies that frustratingly keep a very low profile in Peru:

SIMSA (**Compania Minera San Ignacio de Morococha S.A.A**.) **San Vicente Mine**

- In recent years the mine has maintained reserves in the range of 3.2 MT grading 7.6% Zn, 0.5% Pb;
- 2015 production of 24,000 T Zn according to government statistics;
- Strategic alliances with Trafigura and Korea Zinc;
- Mining of numerous deposits as illustrated though a little blurry here;
- Mining of Palmpata suspended in 2013.

Compania Minera Santa Luisa (Mitsui Mining and Smelting) **Huanzala and Pallca Mines**

- Mitsui refers to the mines as Huanzala and Pallca;
- No reserves reported publically by Mitsui;
- According to government statistics 2015 production of 27,300 T Zn from Santa Luisa and El Recuerdo which I assume to be local names for Huanzala and Pallca.

Compania Minera Raura S.A. **Raura Mine**

- Ah, finally a good mining video here. I just need the smell of a fresh blast to feel right at home. I am sure there is some good information there but google has not created Translate for YouTube yet;
- Locally controlled by the Breca Group (now called the Pandora Group from what I understand);
- 2015 production of 33,800 T Zn according to government statistics;
- In production since 1960 so I assume it will keep on chugging along;
- Production has expanded annually recently.

Compania Minera Casapalca S.A. **Americana Mine**

- Locally owned by the Gubbins Group;
- Reportedly mining at a depth of 1,000 m below surface;
- A very old paper describing area geology is here;
- 2015 production of 35,000 T Zn according to government statistics;
- Numerous labour relations issues over the years.

Minera Colquisiri S.A. **Maria Teresa Mine**

- 2015 production of 25,000 T Zn according to government statistics.
- In operation since 1984.
- 2016 award winner for the mine with the least information publically available. Second place goes to Glencore.

Sociedad Minera Austria Duvaz S.A. **Austria Duvaz Mine**

- This mine is adjacent to Chinalco's Toromocho copper mine.
- 110 year old mine using narrow vein shrinkage and cut and fill methods.
- Copper, zinc, silver and lead mined. Some colour here and here.
- 2015 production of 8,000 T Zn according to government statistics.
- I assume this mine continues operation and is not closed due to the Toromocho pit.

Table 37 summarizes actual and guesstimated production for these mines.

Table 37 Actual and Estimated Zinc Production for Mines with Little Public Information Available

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
SIMSA	37,570	26,498	13,820	24,479	23,000	25,000	25,000	25,000	25,000	25,000	25,000
S. Luisa	33,804	34,834	26,423	27,321	21,000	25,000	25,000	25,000	25,000	25,000	25,000
Raura	20,741	23,870	24,006	33,823	37,000	35,000	35,000	35,000	35,000	35,000	35,000
Casapalca	32,831	31,960	36,043	35,118	40,000	35,000	35,000	35,000	35,000	35,000	35,000
Colquisiri	22,639	18,890	22,941	25,180	21,000	23,000	23,000	23,000	23,000	23,000	23,000
A. Duvaz	5,382	5,498	7,287	8,053	7,000	7,000	7,000	7,000	7,000	7,000	7,000
Total	152,967	141,550	130,520	153,974	149,000	150,000	150,000	150,000	150,000	150,000	150,000

2012-2015 figures are from government statistics. 2016 figures are Jan.-Apr, figures prorated to 12 months. 2017-2022 are the authors' wild crapshoot guesses.

Casapalca Americana Mine

Zinc Projects in Peru

I don't claim to have any deep knowledge of potential zinc producers in Peru but I did stumble across a few during my research. It is important to understand that mining companies in Peru tend to identify themselves as either precious metal (silver) miners or base metal miners. Pan American Silver for instance will not be interested in a largely lead/zinc play unlike Milpo or Volcan. Indeed, Pan American has recently completed the sale of 75% of the shares in Compania Minera Shalipayco S.A.C. to Votorantim Metals – Cajamarquilla S.A.

Milpo

Shalipayco Project

Milpo bought 50% of this project from parent Votorantim for $US35M. They have since exercised an option for an additional 25% under undisclosed terms. An external pre-feasibility study has been completed. A mining rate of 3,000 tpd was used in this study. Conceivably this could lead to roughly 50,000 T of zinc in concentrate production annually.

This project is in Pasco and is 62 km from Milpo's existing El Porvenir and Atacocha mines. Milpo envisages synergies here including the ability to ship ore to existing mills. Unfortunately, Pan American Silver never filed an NI 43-101 for this project prior to vending it away so apart from a resource statement I have found little information of substance. Resources are listed in Table 38. The deposit is reportedly open to the north/south and at depth.

Table 38 Shalipayco Project Resources

	Tonnes	Zn%	Pb%	Ag g/t
M+I Resources	6,160,441	5.83	0.45	40
Inferred Resources	14,000,043	5.55	0.51	39

Bongara

The Bongara project is located on the north-eastern side of the Andes Mountains in very rugged country with dense vegetation and tropical climate. Milpo states:

> *Geologically, the project is characterized by carbonate rocks outcrops of the Pucará Group (Chambara, Aramachay and Condorsinga formations), being the fossiliferous lime stones and Dolomites of Chambara formation of greater incidence in the project and which host PB - Ag mineralization in cloaks and bodies, associated with structural and lithological control. Between 1997 and 2013, there were 487 drills with 117,380 meters of exploratory diamond drilling. In addition, 2,423 meters of exploratory drilling was carried out for the purpose of geotechnical and hydrogeological studies.*

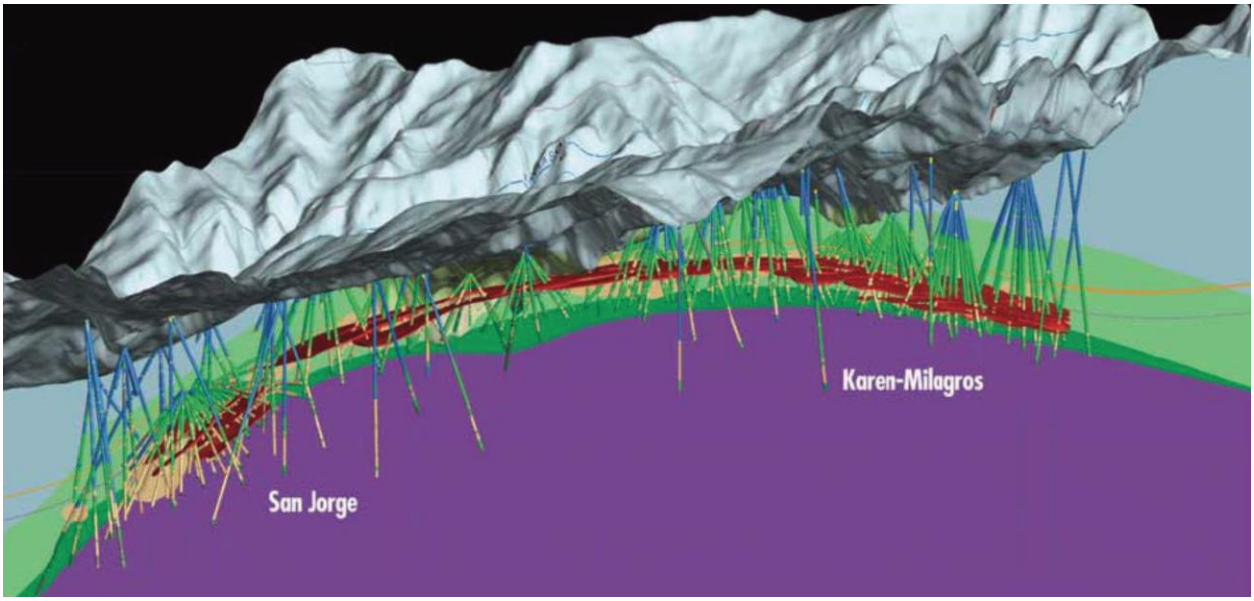
Solitario has a 30% interest in this project and is carried by Milpo until production. An NI-43-101 report was filed in 2014. Table 39 lists the current resources.

Table 39 Bongara Project Resources

	Tonnes	Zn%	Pb%	Ag g/t
M+I Resources	3,442,480	11.80	1.47	18
Inferred Resources	9,913,268	9.24	0.91	11

Milpo has recently completed a road into the site and I understand they are now conducting road construction on site to allow additional drilling. The mineralization would likely be mined by room and pillar mining methods not materially different to the Missouri Lead Belt or the previous Nanisivik mine on Baffin Island, Canada. Based upon the known M + I resources, I could envision a mine of 2,000 tpd

capacity. Zinc recovery for this type of mineralization (MVT) is usually very high so annual production could be in the range of 70,000-80,000 T of zinc in concentrate for perhaps 10-12 years if all the stars aligned and the inferred resources translated into reserves. Room and pillar mining leaves plenty of ore behind in pillars.



Infrastructure in the area is lacking. The NI 43-101 mentions plans for power generation in the area but at this stage it must be assumed that the company will have to look after their own power needs. Based upon the costs of other underground base metal mines of similar size in Peru, site costs could perhaps be in the $45-$55/T range. It is more the lack of infrastructure in the area that concerns me than the mining and milling assuming the ground is competent and not excessively wet. Getting the concentrate to market for instance.

I have not sorted out what this all means for Solitario but I will find the time to do so. I have to confess, I was a shareholder in this company back in the 1990's when Cominco was drilling this property. There were some exciting intersections back then and I made a little money on this one. Things then seemed to fizzle out on the project though, and Cominco seemed to fizzle out also, so I was surprised to see Solitario still part owner of this project.

So I will keep an eye on what Milpo plans here in order to complete a desk top assessment well before they do. The market capitalization for Solitario is low and they are cashed up. I suspect Milpo's game plan is to convert inferred resources to indicated resources in order to conduct a prefeasibility study. So mining could be 4-5 years away at the earliest. So there may not be much sexy news here for a while. The stock is likely a leveraged proxy for the price of zinc in the meantime.

Reference: Solitario Exploration and Royalty Corp. Bongara Zinc Project NI 43-101 Report June 18, 2014 www.sedar.com

Hilarion Project

This project is located 50 km south of Antamina in Ancash Department. Milpo has spent a number of years drilling this project and report the resources listed in Table 40. Unfortunately there are no details concerning geology or potential mining methods that can be publically located. Milpo appears to have conducted some preliminary in-house studies but I was mystified by this statement in the 2015 Annual Report:

> *It is worth mentioning that, in the case of Hilarion project, possible scenarios are being defined for a potential implementation of operations, through the partnership with a third party to optimize existing infrastructure use.*

Table 40 Hilarion Project Resources

	Tonnes	Zn%	Pb%	Cu%	Ag g/t
M+I Resources	38,151,375	4.58	0.63	0.06	1
Inferred Resources	13,967,973	4.37	0.84	0.05	1

Volcan

Volcan lists a number of prospects in their latest Annual Report but most are copper prospects. Concept studies and extensive diamond drilling have been completed for the Palma project which is a VMS style zinc deposit. No resources have been reported.

Grassroots type work is underway at the Carhuacayan zinc/lead/silver and Zoraida silver/lead/zinc projects.

A pit wall push back at the Raul Rojas open pit at Cerro de Pasco has been under assessment for a number of years.

Volcan states:

Inorganic growth, through prioritizing activities in the central highlands, continues to be a potential path for growth. In 2015, the Company continued to evaluate opportunities for acquiring projects and mining operations that are aligned with its strategy. Acquisitions are evaluated with the goal of maintaining Volcan's leadership in zinc, lead and silver production. The priorities for the Company are opportunities in the area of influence and the existence of competitive advantages that will support the development of synergies through the addition of these assets.

So this brings me to…..

Tinka

I very seldom speculate on exploration companies but I am a small shareholder here based on the work I have done here. My rationale is that I believe:

- the price of zinc needs to increase substantially;
- the company has a good shot at expanding the current resource base;
- the company has a good shot at attracting a joint venture partner such as Milpo or Volcan in order to put a local face on this project. Alternatively, an outright sale with Net Smelter Royalty kicker is possible.

Similar to Bongara, Tinka is a leveraged play on the price of zinc and there should be a good news flow coming shortly from the drilling of new prospective targets adjacent to current resources hopefully leading to an increase in resources.

A NI 43-101 report for the Ayawilca Property was filed on June 29, 2016. Resources are listed in Table 41 for the three zinc zones discovered to date. The grades listed would not fly as a mine in Canada for instance. But as you have seen throughout this report most underground operations in Peru are in the 5% Pb+Zn range with byproduct credits since the site costs are 33-50% of those in Canada or Australia. So at current zinc prices (~$1/lb.) this is probably a marginal situation where it would be tough to justify the capital. Hence the high leverage should the zinc price rise to ~1.50/lb. as I believe.

Table 41 Ayawilca Property Inferred Zinc Resources

	Tonnes	Zn%	Pb%	Ag g/t
West Zone	4,500,000	7.6	0.2	17
Central Zone	9,500,000	5.2	0.2	13
East Zone	4,800,000	5.6	0.3	16
Total	18,800,000	5.9	0.2	15

Tinka also lists indium grades but I am not convinced smelters will actually pay for this.
A tin/copper resource and silver resource is not listed.

What the project has going for it however is bulk mining potential and it is shallow hence ramp mining such as at Cerro Lindo or Santander may be used. The two lowest cost mines reviewed here. Additionally, the deposit is in the Cerro de Pasco area meaning there is good infrastructure nearby. Volcan for instance has a large mill sitting idle in the area. When I looked at the topography of the project it would probably be better to build a mill on site instead of shipping ore to the Cerro de Pasco area mills. Glencore relocated a mill to Santander to minimize project capital cost and the same philosophy could be applied here.

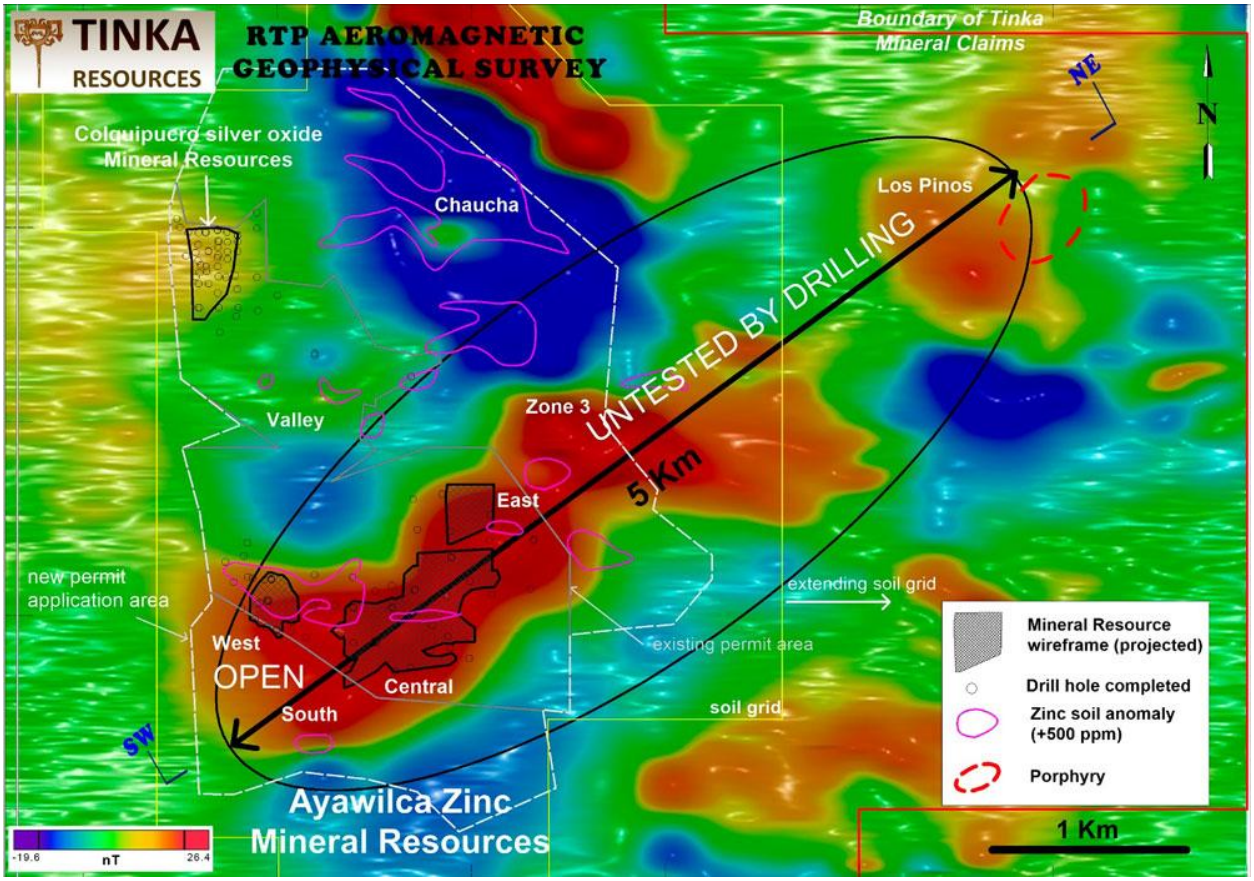
The existing inferred resource base, if upgraded to measured and indicated resources could likely support a 3,000 tpd mine utilizing blasthole stoping for the West Zone and East Tennessee zinc mine style bulk room and pillar mining for the Central and East Zones for perhaps 10-12 years. This assumes good ground conditions underground. So a mine producing in the 40,000 T a year of zinc with some minor byproduct credits could be envisioned assuming good mill recoveries. Unit costs could be similar to Santander's at a low $US35-40/T due to the shallow depth and bulk mining methods used.

The two key concerns I have are water supply and receiving a social license from local communities. The path to new mine approval in Peru has been tortuous lately. Indeed, getting permission to even drill exploration holes can be difficult. Santander likely benefited from an existing site mining license.

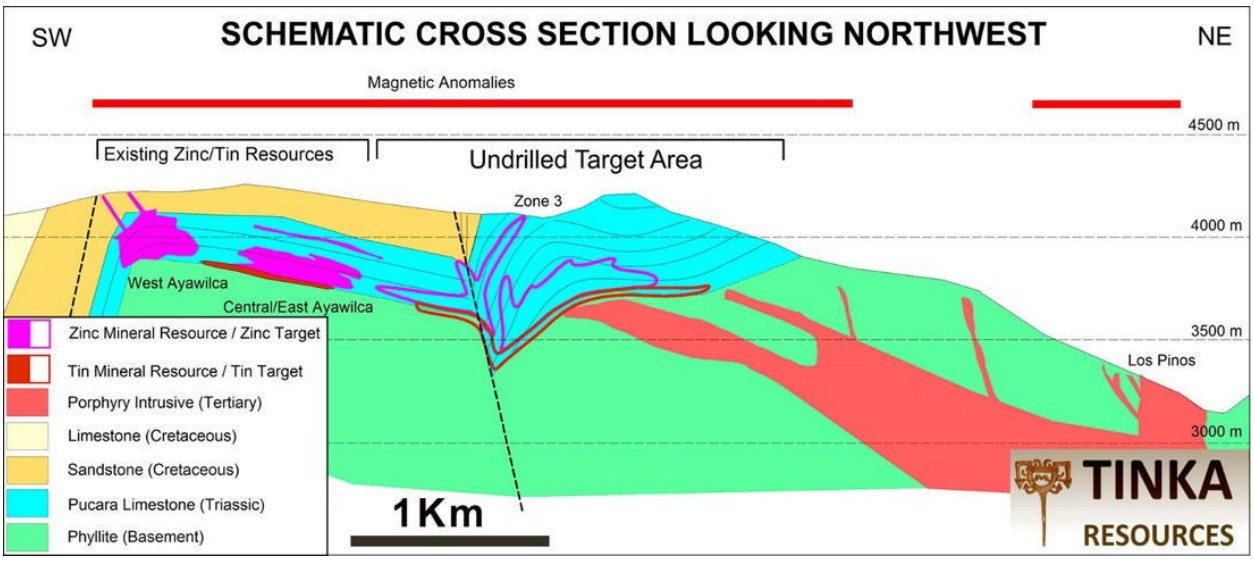
The pipeline of projects that Volcan has is slim to non-existent so they could be a willing JV partner here. Likewise, Milpo may see the wisdom of a JV or acquisition along the lines of Shalipayco. If Glencore pulls the plug on Iscaycruz like I think they will, they suddenly have a mill that can be relocated along the lines of what they did for Santander. Finally if the reserves at Catalina Huanca are being rapidly depleted, Trafigura may also be a willing partner or acquirer.

All of this mental ~~mastur~~ brainstorming on my part of course hinges on proving out the resource but I buy the geological model that they are presenting and we shall know soon if this is correct or not. So I am willing to lose 50% of my speculation for the possibility of gaining 100% for this low market capitalization situation. The money to be made is in the public recognition that this has the potential to be an economically mineable deposit, not in the waiting around for the mining to actually happen.

Reference: Tinka Resources Ltd. Ayawilca NI 43-101 Report, June 29, 2016 www.sedar.com



Drilling in the new permit application area has now been approved. The theoretical Zone 3 can now be proved out or dispelled. The West Zone may have some potential to the southwest.



The shallow nature of the mineralization is illustrated here. The significance of the porphyry intrusive is illustrated in Figure 8-1 of the NI 43-101 report. The theoretical Zone 3 has to date been outside the permitted drilling area. It could be geo-fantasy but I hope not.

Zincore Metals Inc.

AZOD Zinc Oxide Project

As I have mentioned in the past, I am only looking at zinc sulphide projects (sphalerite) since I do not understand the economics of zinc oxide refining at all. However, I will bring to your attention this project and the 393 page technical report here. I will put reading this report on my to do list.

Condor Resources claims to be a project generator in Peru so it may be worthwhile watching what they are up to. Vena Resources, the once zinc project developer, then uranium project developer has now switched back to zinc but I saw nothing of interest in their portfolio. I did note however that they had a lawsuit dust up with Glencore on their previous zinc endeavor a few years ago. Go figure.

So there you have it. Module 7 put to bed. Without a doubt it was the most complex one to date but I don't like leaving too many stones unturned. Being a mining engineer and all.

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