MODULE 12 ZINC MINING IN CENTRAL AND SOUTH AMERICA

Note the following exclusions:

Mexico see Module 9

Peru see Module 7

Bolivia see Module 10 (tagged onto the back end of the Africa Module)

Summary

All existing mines assessed, except Escobal, are mature assets. The only greenfield development project that I stumbled upon is Aripuana. A Canadian junior has a 30% interest here but I did not complete due diligence for this company. Risk takers may want to take a peek. Table 1 summarizes the reports findings.

This essentially wraps up my look at the miners (seriously this time). It is highly unlikely that there is much information in the public forum on Chinese, Russian and Iranian zinc mines or their intentions going forward so I am not going to go there.

Mongolia has two zinc mines (~50,000 tpa) that I am aware of and strangely enough I have driven by both while hunting for uranium with the Cameco geologists (they hunted, I suntanned). Both were operated by the Chinese, the first at Baruun-Urt on the edge of the Gobi Desert, the most godforsaken place I have ever spent a night, and the second, on the steppe, north of Choibalsan near the Russian border. (An incredible battle was fought near there between the Russians and Japanese, which the Japanese lost, months prior to WWII. Zhukov earned his stripes there. Some claim it then set in motion the attack on Pearl Harbour two years later. OK, back to zinc.)

The Mae Sod mine in Thailand closed last year removing about 30,000 tpa from the market. Saudi Arabia and Tajikistan are also modest producers that I have no intention of looking at. Table 2 summarizes all the mines I researched in detail.

Table 1 Actual and Forecast Zinc Production for the Mines Assessed

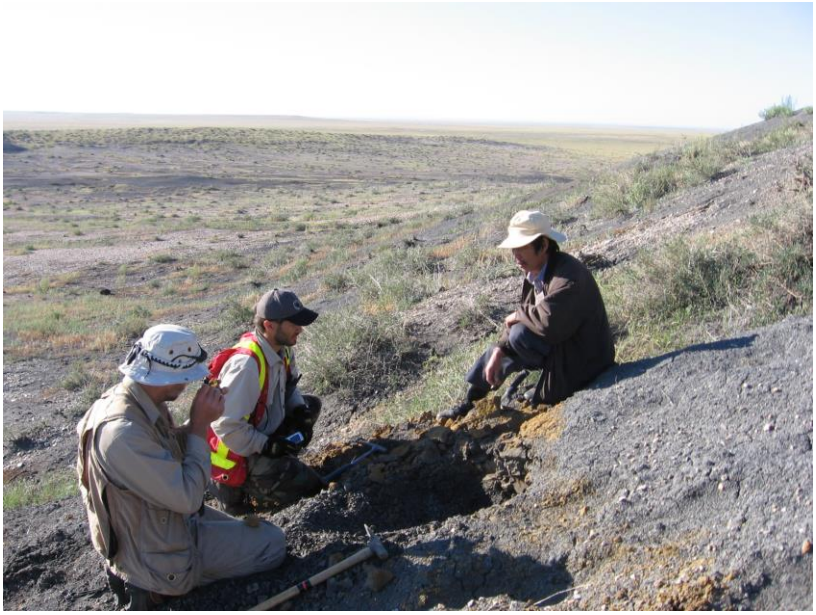
Country	Mine	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Argentina	Aguilar	33.5	32	27.5	29.5	24	30.5	30.5	30.5	30.5	23.5	23.5
	Pirquitas	5	12.3	13.6	4.3	0	0	0	0	0	0	0
Chile	El Toqui	20	23	36.7	37.9	28.4	32	32	32	32	32	32
Honduras	El Mochito	26	25	29.5	23	23	17	23	30	30	30	30
Guatemala	Escobal	0	1.2	13.4	14.8	10.5	15.3	15.3	15	18.7	10.5	13.5
Brazil	Vazante/ Morro Agudo	164.3	152.1	159	160	165	160	155	150	150	150	150
	Aripuana	0	0	0	0	0	0	0	0	0	30	60
	Total	**248.8**	**245.6**	**279.7**	**269.5**	**250.9**	**254.8**	**255.8**	**257.5**	**261.2**	**276**	**309**

Doug Beattie, Mining Engineer (Retired)

Table 2 A Summary of All the Modules Assessed

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
10a	Africa	310.0	304.2	312.8	322.8	368.2	441.5	455.8	620.5	789.4	766.0	761.0
10b	Bolivia* (partial)	230.0	237.0	239.0	259.0	285.0	295.0	295.0	295.0	295.0	295.0	295.0
11	Kazakhstan	425.0	427.0	378.0	369.0	366.0	354.0	369.0	398.0	399.0	371.0	338.0
12	C. and S. America**	248.8	245.6	279.7	269.5	250.9	254.8	255.8	257.5	261.2	276.0	309.0
		7,719.5	**7,583.1**	**7,574.0**	**7,560.9**	**6,577.5**	**7,179.0**	**7,237.2**	**7,509.8**	**7,715.8**	**7,486.9**	**7,360.5**
			-1.8%	-0.1%	-0.2%	-15.0%	8.4%	0.8%	3.6%	2.7%	-3.1%	-1.7%

***San Cristobal and Illapa/Sinchi Wayra only.**
**** minus Peru, Mexico and Bolivia**



Following up on old Russian U anomalies near the Baruun-Urt zinc mine. I sure did pack a lot into that 35 years. We drilled here the next year but the U intersected was marginal. Garth, Sergei and Bagii.

Argentina

Argentina possesses two mines that produce zinc: Glencore's Aguilar Zn/Pb/Ag mine and Silver Standards Pirquitas Ag/Zn mine. Both mines are in Jujuy province which was recently ranked dead last in the world for attractive mining investment out of 104 possibilities by the Fraser Institute. Even Afghanistan is ranked higher .

Aguilar- Glencore

To say the Aguilar mine is a mature asset is an understatement. Mining commenced in the 1930's and has been continuous to date. The mine was originally developed by St. Joe Lead and eventually ended up in Glencore's hands in 2005. Traditional mining methods transitioned to mechanized cut and fill and sublevel stoping methods. Underground ore is supplemented by an open pit. Rated mill capacity is approximately 700,000 tpa. No information could be found with respect to how the underground ore is transported to surface but I presume it to be by truck via adit since I saw no evidence of a headframe in satellite photos. The mine sits above 4,000 m in elevation in Jujuy province near the borders of Chile and Bolivia.

To paraphrase an historic geological description of the mine:

The El Aguilar Mine originally consisted of ten major stratiform Pb-Zn orebodies, which were hosted in a 200 m thick section of interbedded metaquartzite and hornfels of the Cretaceous Aguilar quartzite. The orebodies averaged 150 to 1000 metres in length, 50 to 300 metres in width, and 5 to 80 metres in thickness. The ore units extended a minimum 2000 m north-south along strike in the southwestern contact aureole of the Aguilar granite. The quartzite unit dips approximately 70 degrees to the west.

Glencore states in the latest reserve report that there is three years of reserves remaining, or five years if it is assumed that resources will convert into reserves (which they have a very good track record of doing). At a number of Glencore operations, the mine life statements don't mean much since ongoing exploration replaces depletion by mining. But in this case, anecdotal evidence points to ore exhaustion around the end of this study period.

Table 3 illustrates the recent reserve and resource figures. A gradual decline in both resources and reserves is illustrated. Although only underground ore is considered to be in the reserve column currently, open pit mining of lower grade mineralization is also conducted. This betrays that the underground production rate is insufficient to fill the mill so "incremental" material from the pit is used to top it up even if this material is not an economic reserve due to prevailing commodity prices. The underground bottleneck may be related to lack of flexibility with respect to workplaces as the reserves dwindle.

Table 3 Resources and Reserves for the Aguilar Mine

Year		M +I Resources	Zn%	P + P Reserves	Zn%
2016	OP	1,000,000	2.8	0	
2016	UG	2,400,000	8.9	1,500,000	7.6
2015	OP	1,400,000	2.5	0	
2015	UG	3,300,000	8.8	1,500,000	8.5
2014	UG/OC	5,100,000	4.8	3,400,000	4.9
2013	UG/OC	7,100,000	4.2	4,600,000	4.7
2012	UG/OC	5,400,000	6.1	3,700,000	6.7
2010*	UG/OC	5,300,000	5.4	3,100,000	7.2

*from IPO document, no 2011 data available.

Recent mine performance is illustrated in Table 4.

Table 4 Recent Mine Performance for the Aguilar Mine

Year	Tonnes	Zn%	Pb%	Ag g/t	Assumed Zn recovery	Assumed Zn output
2016	580,000	4.6	5.1	111	90%	24,000
2015	670,000	4.9	4.4	101	90%	29,500
2014	690,000	4.4	4.6	93	90%	27,500
2013	680,000	5.2	5.4	122	90%	32,000
2012*	680,000	5.5	5.0	100	90%	33,500

*placeholder only, no data provided.

Two fatalities underground in 2014 may have translated into the milling of more lower grade open pit ore due to the disruption such events cause.

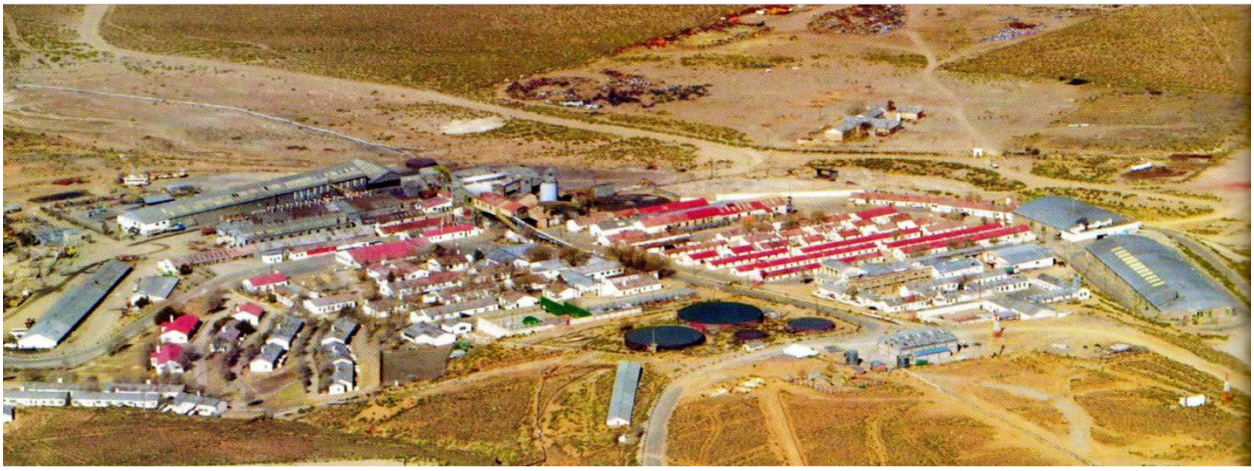
Based upon head grade to the mill is appears that approximately 350,000 T of underground ore mining occurs annually and this is supplemented with approximately 300,000 T of open pit mineralization.

In 2016, the remaining underground resource was reduced by 900,000 T which I assume to include depletion by mining of 350,000 T and the loss of 550,000 T due to the "result of the sterilisation campaign on portions of Pique Inferior and Capa (*orebodies*) that are impossible to access." When mines conduct these sorts of campaigns it usually is a sign that the end of operations is close and there is little exploration potential. There is good potential therefore that this mine will close in the 2021/22 timeframe and this decision will likely be based upon commodity prices at that time.

In order to forecast production to 2022, Table 5 illustrates the mining of 350,000 T of underground ore supplemented with 300,000 T of open pit mineralization for 2017 to 2020 and then only underground ore for 2021 and 2022. It is assumed that all underground resources are converted to reserves.

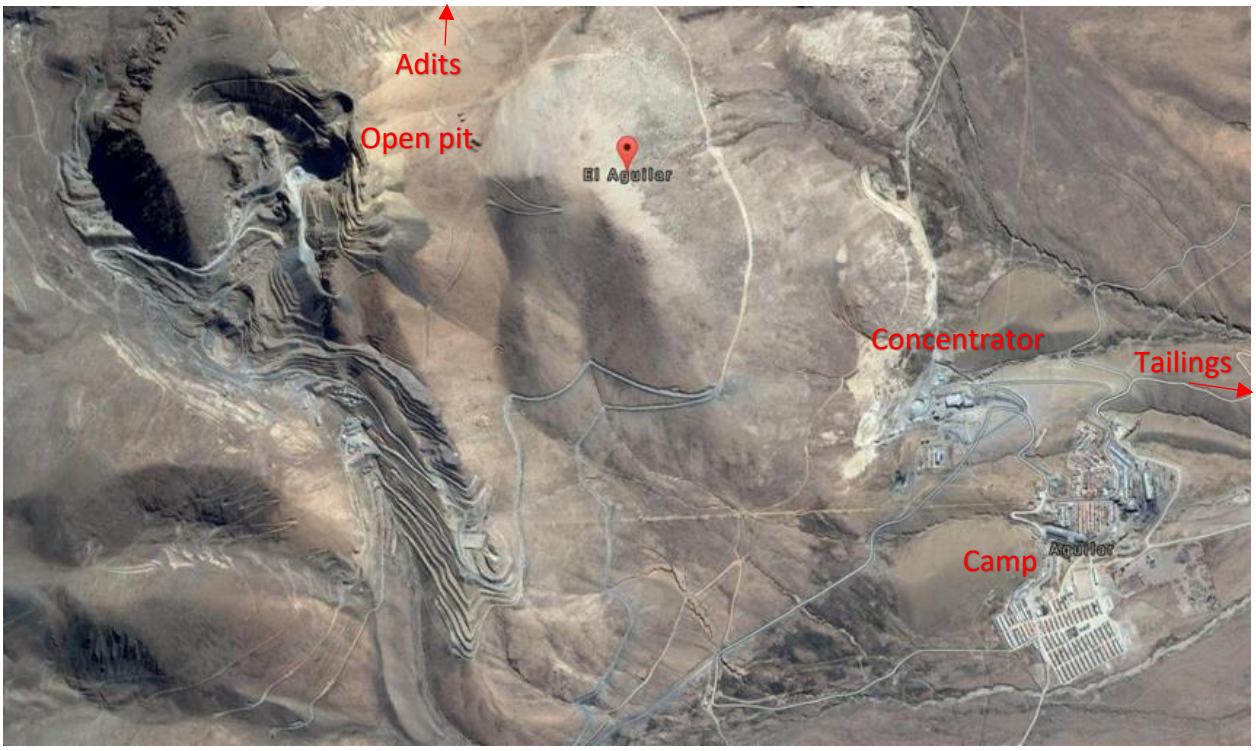
Table 5 Forecast Production for the Aguilar Mine

Year	Tonnes	Zn%	Assumed Zn recovery	Assumed Zn output
2017	650,000	5.2	90%	30,500
2018	650,000	5.2	90%	30,500
2019	650,000	5.2	90%	30,500
2020	650,000	5.2	90%	30,500
2021	400,000	6.5	90%	23,500
2022	400,000	6.5	90%	23,500



Some of the local infrastructure. I am not quite sure what those industrial buildings are (dis)used for. The concentrator appears to be nearby. The active open pit is easily seen and a least two adits are identified (after much searching) here .

The open pit and adits are in the mountain behind the valley where the concentrator and camp are located.



Reference: Various reports here .

Pirquitas- Silver Standard

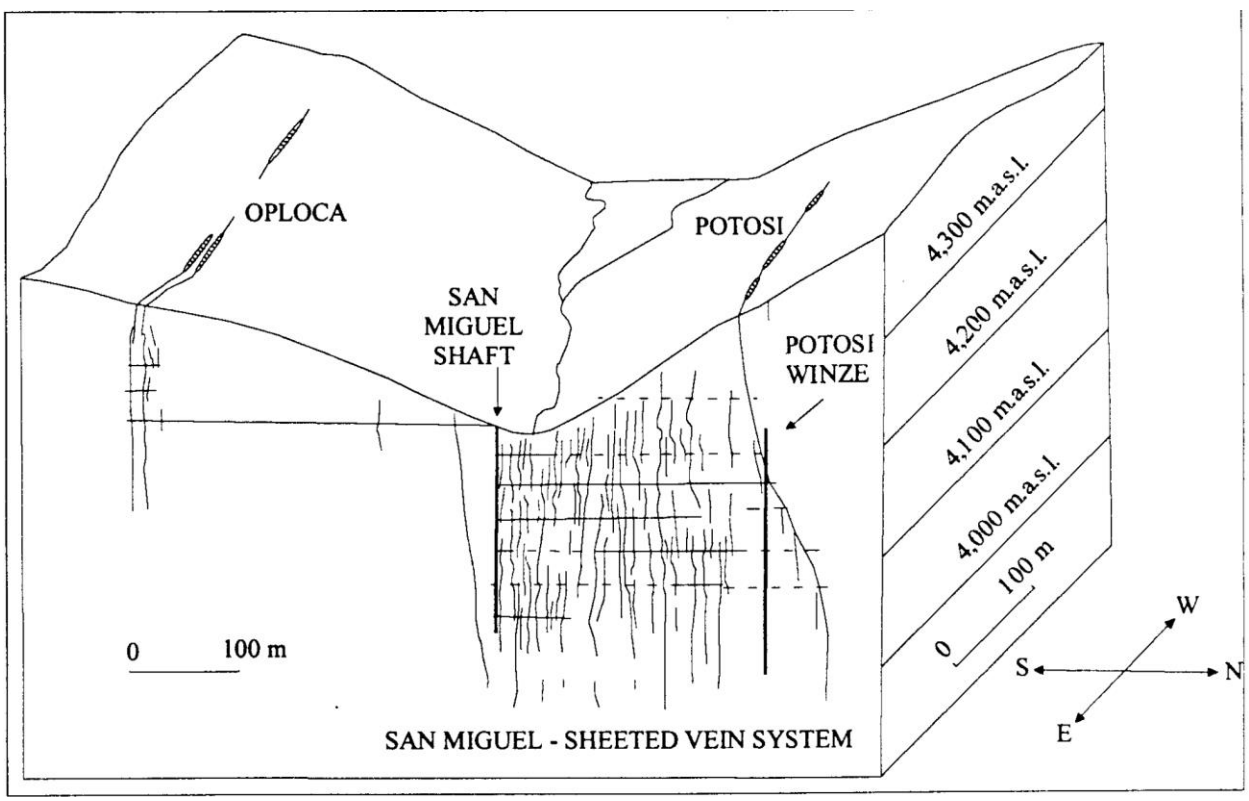
This predominantly silver mine was a minor zinc producer for a handful of years. The Pirquitas open pit mined a swarm of veinlets rich in silver. Mining ceased recently and milling from stockpiles should be complete in late 2017 or early 2018. No zinc has been recovered since 2015. Despite this, I am going to discuss this mine in detail and you will see why.

Excerpting from one of the three NI 43-101 reports completed:

Pirquitas is a polymetallic (silver, tin, and zinc) deposit situated in the Puna de Atacama of northwestern Argentina, in the Province of Jujuy. It is classed as one of the silver-tin deposits that lie within the Bolivian tin belt that begins in southern Peru and extends through Bolivia into northwestern Argentina, with the deposits becoming more silver-rich in the southern part of the belt. The project is located in mountainous terrain, with elevations ranging from 4,100 to 4,400 m above sea level.

The Pirquitas deposit includes the San Miguel zone, a broad area of sheeted veinlets and microveinlets, and the Potosí and Oploca veins. The two principal veins, Potosí and Oploca, occur to the north and south, respectively, of the main San Miguel area (Figure 9-1). The majority of structures that control mineralization strike east-southeast and dip steeply to vertically. The Oploca vein and San Miguel structures generally dip to the south, and the Potosí vein generally dips to the north.

Figure 9-1: Schematic Drawing of San Miguel, Potosí, and Oploco



Silver, tin and, to some extent, zinc mineralization at Pirquitas occurs within veins and fracture systems characterized by three dominant structural orientations: east-southeast (100° to 110° azimuth), northwest

(300° to 310° azimuth), and northeast (70° to 80° azimuth). Over 60% of the identified veins in the district occur along the east-southeast orientation.

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Mineralization is controlled by the dominant structural fabric and, to a lesser extent, by the permeability and porosity characteristics of the host rocks. Silver, tin, and zinc are spatially associated in a broad sense, but locally, the relationship is non-existent; there are veinlets with only one, all three, or any combination of the three metals. There are also veinlets of pyrite devoid of any silver, tin, and zinc. There appear to be three principal styles of mineralization: low-grade disseminated/weak, discontinuous stockwork, sheeted zones of microveinlets, and veins/veinlets. The broad, low-grade halo of silver mineralization is centered on San Miguel, but in general, also encompasses the Potosí vein. Isolated, discontinuous zones of higher-grade micro-stockwork sporadically occur within this broad halo of low grade mineralization.

Zinc mineralization has an inverted bowl-shaped geometry with a weakly to unmineralized core. Higher grade zones also seem to trend east-southeast, but these merge into broad zones toward the west end of San Miguel. These broad zones of higher-grade mineralization are open-ended and appear to be made up of dense stockwork and/or narrow, steeply-dipping veinlets of sphalerite, often light-pale brown in color. Underground, veinlet mineralization occurs in a similar fashion to the silver and tin, but high-grade zinc is not confined to the narrow veinlets.

A total of four reserve calculations were conducted for various technical and feasibility studies and they are presented in Table 6. Each study had slightly different assumptions used for cut off grades and exploration was conducted between studies. The fourth reserve estimate was completed after roughly two years of mining had occurred. This excludes already mined ore containing 18.6 M oz silver.

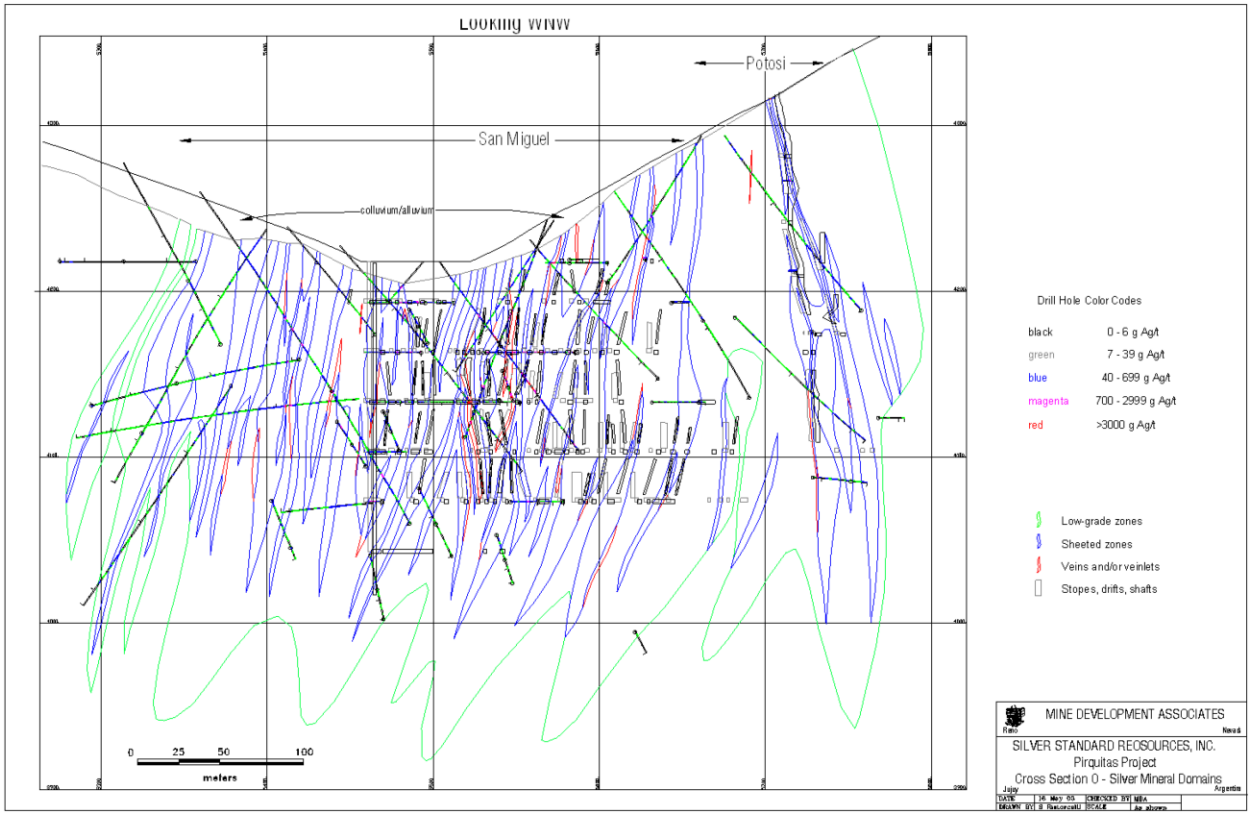
Table 6 Various Reserve Calculations for the Pirquitas Mine

	Author	Year	MT	Ag g/t	Zn %	M oz Ag
1	Winters	1999	21.6	167	0.57	116,000,000
2	MDA	2003	18.9	177	0.61	107,600,000
3	In-house	2008	30.4	199.6	0.82	195,100,000
4*	In-house	2011	16.7	173.7	0.71	93,300,000

*after recovery of 18.6 M oz from mining in 2009- Nov 2011. 93.3 + 18.6= 111.9 M oz Ag. Tin grades not illustrated.

Of note is the similarity of reserve estimates 1,2 and 4. Estimate 3 however varies markedly compared to the others and this was the estimate taken to the bank used to justify construction.

Estimates 1 and 2 were conducted by independent third parties placing hard boundaries around the numerous silver domains and using ordinary kriging and inverse distance squared methods to calculate the resource inside each domain.



Estimates 3 and 4 were conducted in-house using multiple indicator kriging unconstrained by the domains illustrated above. Estimate 4 had the benefit of two years of completed mining. Estimate 4 back calibrated well with pit experience but confirmed that Estimate 3 was inaccurate which contributed to a shortening of the mine life. Grade control drilling is possible to delineate ore/waste contacts in an open pit and good vertical continuity of veinlets would also provide a degree of bench grade predictability.

Multiple indicator kriging is often used for mineralization with a high nugget effect and has been more accurate than ordinary kriging is certain situations. But the model inputs are critical and it appears they were too aggressive here.

I could ramble on here for pages and get myself in Muddy Waters style trouble but suffice to say, I have my issues with non-linear multiple indicator kriging particularly when it is being applied to an underground situation such as Pretium's Brucejack where Silver Standard's CEO migrated to prior to estimate 4 being published. Is another train wreck on the horizon? I tend to think so and will go on the record to state that I think this mine will have a troubled existence similar to Pirquitas if not much worse.

Table 7 lists Pirquitas' production performance. It is apparent the operators high graded the mine hence shortened its life by six years compared to estimate 3 expectations. Only a third of the silver from the reserve estimate conducted to justify financing and construction (estimate 3) was ever recovered and shareholders consequently suffered. I'll leave it there.

Table 7 Production Performance for the Pirquitas Mine

Year	T Milled	Ag g/t	Contained Oz	Ag Recovery %	Recovered Oz	Zn%	Zn Recovery %	T Zn Recovered
2009	410,454	185	2,441,607	45.0	1,114,300			
2010	1,255,000	233	9,402,412	65.2	5,936,657		0	0
2011	1,089,000	253	8,859,068	79.5	7,055,589		0	0
2012	1,623,000	217	11,324,469	76.3	8,624,000	0.74	38	5,067
2013	1,575,000	217	10,989,550	74.9	8,216,000	1.63	48	12,264
2014	1,587,000	221	11,277,395	77.3	8,733,000	1.79	47.9	13,613
2015	1,557,000	250	12,516,077	82.6	10,339,000	0.62	45	4,288
2016	1,774,000	235	13,404,823	77.8	10,422,000		0	0
Stockpiles*	2,420,000	118.1	9,189,775	78.0	7,168,024		0	0
	13,290,454	**209.2**	**89,405,177**	**75.6**	**67,608,570**			**35,232**

*totals assume all stockpiles are milled in 2017/18. Recovery % is assumed.

Reference: Silver Standard NI 43-101 reports May 9, 2006, September 29, 2008, December 23, 2011

www.sedar.com

Chile

El Toqui

This underground zinc/gold mine is located 1,350 kilometres south of Santiago. Lac Minerals acquired this property in 1987. Barrick acquired Lac in 1994 and spun this asset out to Breakwater Resources in 1997. Breakwater was then acquired by Nyrstar in 2011. Nyrstar has recently divested of this mine to Laguna Gold Ltd. of Australia. The mine appears to be well run based on steady production rates over many years.

From the 2008 NI 43-101:

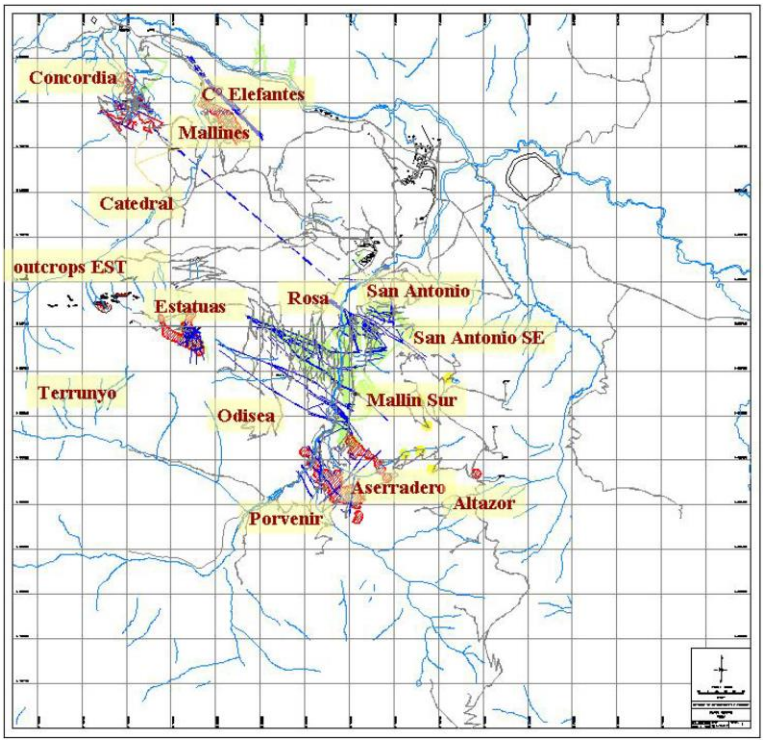
Geology

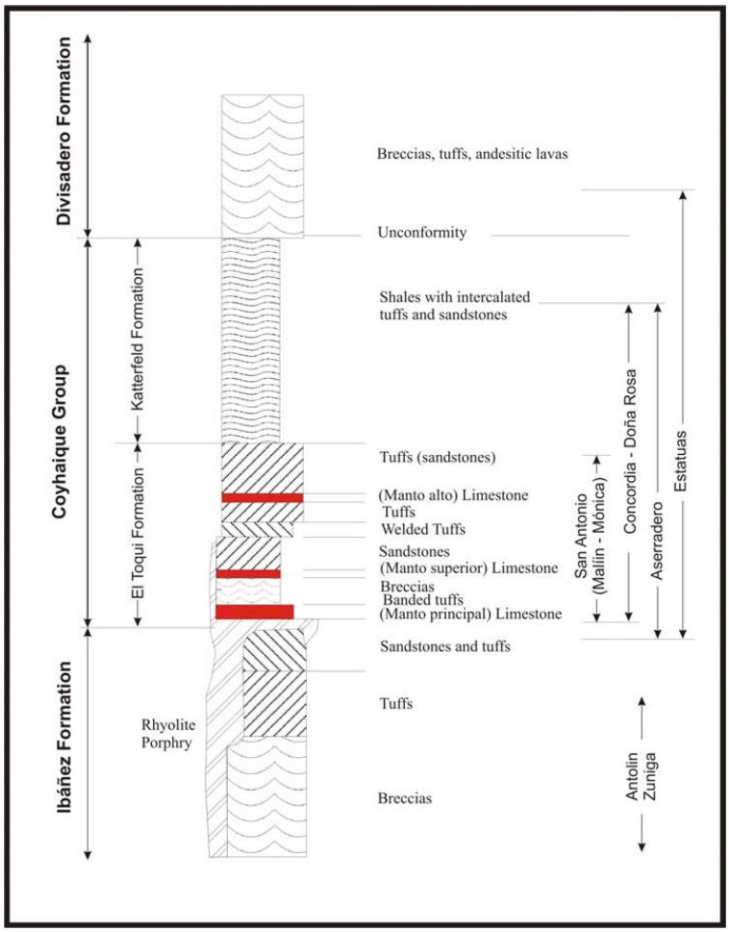
The Toqui property encompasses an area of approximately 1,800 square kilometres. This area includes the Doña Rosa zinc-gold mine, Rosa West zinc-lead mine, the San Antonio East and Mallín-Mónica and Mallín South zinc mines, the Aserradero gold-zinc mine, the Estatuas zinc mine, the Concordia Norte and Concordia Sur zinc-lead mine and the Porvenir and Concordia-Mallínes advanced stage zinc projects, Altazor (previously known as the Rampa and Macizo exploration projects) and the Aserradero East exploration zinc and zinc-gold projects and a 1,475 tonne per day concentrating plant.

The zinc-gold (lead-silver) mineralization being exploited at the Toqui deposits is primarily in the Principal Manto of the calcareous Toqui (Cotidiana) formation in the Coyhaique group. The manto was subject to structurally controlled and selective replacement by hydrothermal solutions that variably deposited sphalerite, galena, pyrrhotite, arsenopyrite, pyrite and chalcopyrite as the principal mineral assemblages. Zinc, gold, lead, and silver are the elements of economic interest. The stratabound mineralization, which occurs as fossil-shell replacement, consists principally of sphalerite, pyrrhotite, pyrite, arsenopyrite with minor chalcopyrite, magnetite and galena. The sulphide assemblages can contain iron-rich marmatite intergrown with pyrrhotite (principally at the Doña Rosa deposit).

Mineral replacement within calcareous horizons was channeled and controlled by a set of northwest trending faults. Where these faults intersect a similar, north trend that is roughly coincident with the porphyritic rhyolite dike, large iron envelope areas rich in pyrrhotite occur.

The mineralization appears strongly associated with principal NW-SE trending faults, some of which are associated with massive sulphide polymetallic mineralization (Aurum and Cuprum faults). The majority of the faults are carbonate filled and exhibit up to several tens of metres of displacement between co-relatable mineralized horizons. The mineralized manto varies in thickness between three metres and 11 metres, averaging 7.5 metres, with the minimum economic manto having a mineable height of approximately four metres.


Concordia
C° Elefantes
Mallines
Catedral
outcrops EST
Estatuas
Rosa
San Antonio
San Antonio SE
Terrunyo
Odisea
Mallin Sur
Aserradero
Altazor
Porvenir


Divisadero Formation
Coyhaique Group
Ibáñez Formation
Katterfeld Formation
El Toqui Formation
Rhyolite Porphry
Breccias, tuffs, andesitic lavas
Unconformity
Shales with intercalated tuffs and sandstones
Tuffs (sandstones)
(Manto alto) Limestone
Tuffs
Welded Tuffs
Sandstones
(Manto superior) Limestone
Breccias
Banded tuffs
(Manto principal) Limestone
Sandstones and tuffs
Tuffs
Breccias
San Antonio (Mallin - Mónica)
Concordia - Doña Rosa
Aserradero
Estatuas
Antolin Zuniga

Reserves as of December 31,2015, are illustrated in Table 8. Reserves have been readily replaced through exploration so there is no threat of this mine closing anytime soon for lack of ore.

Table 8 Reserves for El Toqui as of December 31,2015

Tonnes	Zn%	Pb%	Ag g/t	Au g/t
7,060,000	5.59	0.35	16.77	1.04

Mining

The Toqui deposits are amenable to room and pillar mining. The Doña Rosa, Estatuas, and Concordia mining areas are accessed via adits. Aserradero and Porvenir are or will be accessed through the Doña Rosa mine and access ramp. Mining is normally carried out in a single horizon from flat lying mineralization varying in thickness from four metres to 12 metres, except where localized faulting may offset the manto into smaller stopes accessed via mine ramps. In Estatuas, there is a lower secondary manto which has economic zinc grades and is being mined.

A room and pillar extraction method is used with 11 metre rooms around eight metre pillars. Generally, ground conditions are good and roof support consists of friction split set bolts installed in a 1.5 metre by 1.5 metre pattern. The mine is currently in the process of converting the roof support to grouted rebars. In more highly faulted zones such as in Estatuas, mesh and shotcreting are used, especially at drift intersections and where intersecting and low lying faults exist. Part of the mine plan is partial pillar recovery, normally 50 percent of the design size. During 2007, studies were carried out on the feasibility of building a paste backfill plant on site that would allow 100 percent recovery of the economical pillars. The study anticipates that in the future, the mining method will be converted to drift and fill to take advantage of the paste fill.

The mine operations are well staffed. Daily production is achieved with six metre by six metre drift development mining, slashing and some pillar mining. There are four jumbos and four eightyard load haul dump scooptrams, two rock bolters, four 50 tonne trucks, two 40 tonne trucks, and three utility vehicles used for loading of explosives and services installation. The mining areas, which are situated well above the valley bottom, are relatively dry. Rainfall in the area is high and some localized water inflow occurs that is collected and pumped out. Mine water inflow volumes are small and submersible pumps feed small fixed base pumps which pump water to surface from each mining area.

Table 9 illustrates production results for 2012-2016.

Table 9 Recent Production at the El Toqui Mine

Year	Tonnes	Zn%	Pb%	Ag g/t	Au g/t	Zn recovery	Zn output
2016	520,000	6.0	0.2	15.3	0.78	90.7%	28,400
2015	583,000	6.9	0.6	18.1	0.8	93.9%	37,900
2014	575,000	6.9	0.6	20.2	1.4	92.4%	36,700
2013	553,000	5.0	0.4	39.7	3.0	83.2%	23,000
2012	533,000	4.3	0.3	9.1	3.8	84.9%	20,000

Table 10 illustrates forecast production going forward. Since Laguna is a private company, no guidance has been provided and it is assumed operations will remain at current production levels. Generally, when higher grade gold zones are identified, mining focuses on these areas. The table below illustrates constant grade and output but this will likely vary by up to +- 20% zinc content. I could certainly have fun hiking in this attractive area. It looks like it rivals Banff or the South Island of New Zealand.

Table 10 Forecast Production for the El Toqui Mine

Year	Tonnes	Zn%	Pb%	Ag g/t	Au g/t	Zn recovery	Zn output
2017	580,000	6.0	0.3	16	0.8	92%	32,000
2018	580,000	6.0	0.3	16	0.8	92%	32,000
2019	580,000	6.0	0.3	16	0.8	92%	32,000
2020	580,000	6.0	0.3	16	0.8	92%	32,000
2021	580,000	6.0	0.3	16	0.8	92%	32,000
2022	580,000	6.0	0.3	16	0.8	92%	32,000

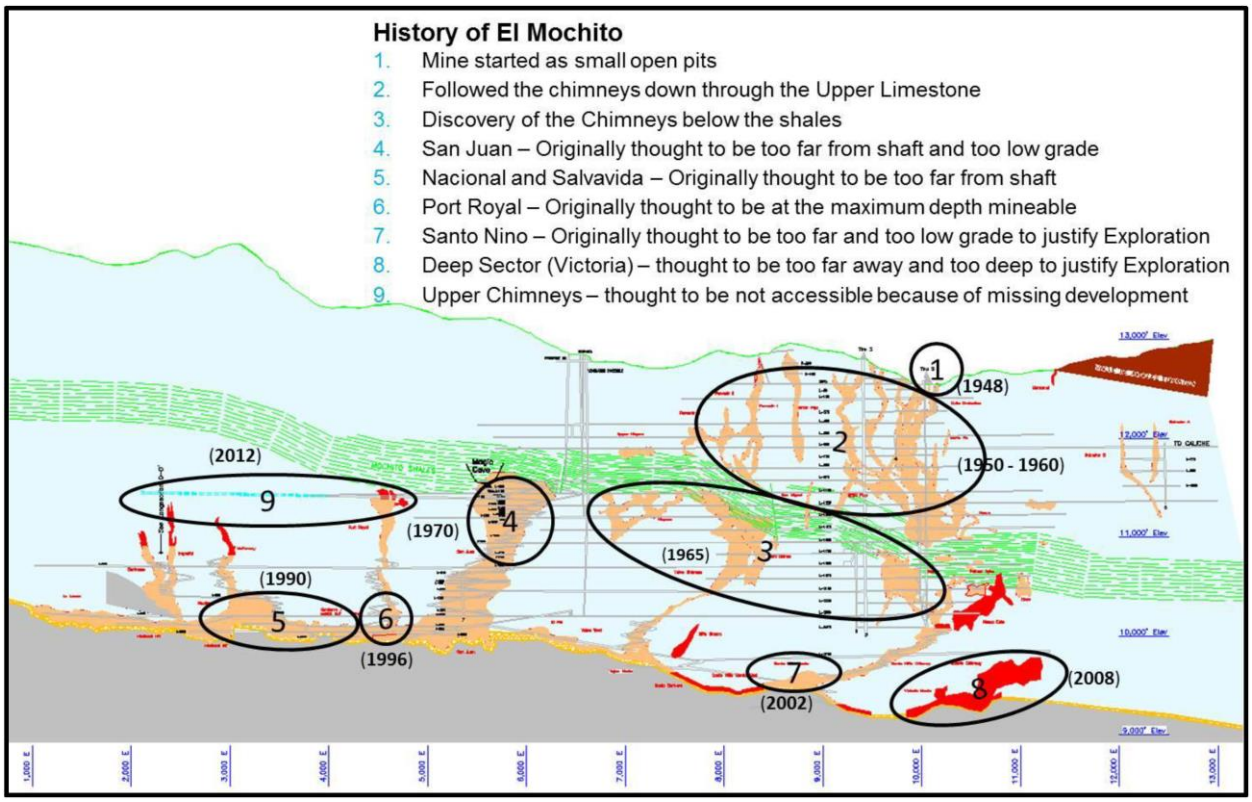
Reference: Breakwater Resources NI 43-101 report www.sedar.com

Honduras

El Mochito

Nyrstar essentially abandoned the mine recently by giving it to unknown Morumbi Resources for a token $0.5M (and two third round draft picks?). Morumbi has since changed their name to Ascendant Resources. Ascendant does not appear to have fully appreciated what they got themselves into based upon a February 3,2017 press release that had buyers remorse undertones. Mining commenced here in the 1940's.

A graphical presentation of the expansion of the mine since the 1940's is illustrated below.



Light orange represents mined out areas or areas of no economic interest. Red areas are reserves/resources. The distance between grid lines is 1000' so you can see that this is not only a deep mine but an extensive mine also. Much of the current mining appears to be well below shaft bottom at around 1000 m depth.

Geology

From the 2010 NI 43-101:

Mochito belongs to the economically important class of high-temperature replacement lead-zinc deposits in carbonates of which a number are, or were, important producers along the Cordillera of the Americas — Midway and Sä Dana Hes in the northern Cordillera of Canada, Gilman and Leadville in Colorado, Tintic and Park City in Utah, Eureka and Pioche in Nevada, the important deposits of Santa Eulalia, Naica, and Zimapan in Mexico, and in Peru, Santander and Cerro de Pasco, the latter in a subvolcanic setting.

Carbonates are particularly susceptible to replacement by acid hydrothermal solutions which, in the case of Mochito, have deposited skarn minerals such as garnet, epidote and pyroxene together with sulphides of iron, zinc and lead.

The replacement deposits can take two shapes: some follow the essentially flat bedding of their host rock ("mantos") while others cut across the rocks ("chimneys" or "pipes"). At Mochito, both of the replacement deposits are prominently developed, with mantos forming at the lower contact of the Cretaceous Atima limestone, where upwelling solutions emerged from the underlying Todos Santos siltstone package. Mantos also formed at the lower contact of the Mochito shale, a 150 metre thick limy siltstone unit some 550 metres above the base of Atima limestone. In many cases, a chimney-type connection between the lower and upper mantos is present, the largest of which is the San Juan pipe, now largely mined out. Others are the Nacional, Salva Vida, Yojoa, Niña Blanca and Nueva pipes. Overall, some 70% of the total known tonnage at Mochito occurs in the chimney/pipe setting.

There is also a tendency for the formation of manto-like bodies immediately above the Mochito shale from which a number of individual pipes rise into the 450 metres of overlying upper Atima limestone where a number of high-grade pipes or chimneys sustained the mine in its earlier years. The known mineralization at Mochito occurs within a rock volume measuring some 2.5 kilometres east-west and 600 metres north-south, with a vertical (stratigraphic) extent of more than one kilometre. Within these dimensions, the known mineralized bodies occupy 0.3% of the overall volume.

As illustrated below, reserves as of the end of 2015 were sufficient for less than three years of mining at 2,000-2,200 tpd. Successful conversion of resources to reserves is assumed later in forecasting.

Mineral Reserve Statement

Metal	Unit	Proven Mineral Reserves		Probable Mineral Reserves		Total Mineral Reserves	
		2015	2014	2015	2014	2015	2014
	Mt	0.57	0.72	1.34	2.31	1.91	3.03
Zinc	%	4.59	4.93	4.94	4.96	4.84	4.95
Lead	%	2.63	2.61	2.27	1.93	2.38	2.10
Silver	g/t	77.40	89.40	47.60	45.30	56.50	55.80

Nyrstar, 2016b, 2015 Mineral Resource and Mineral Reserve Statement 27 April, 2016.

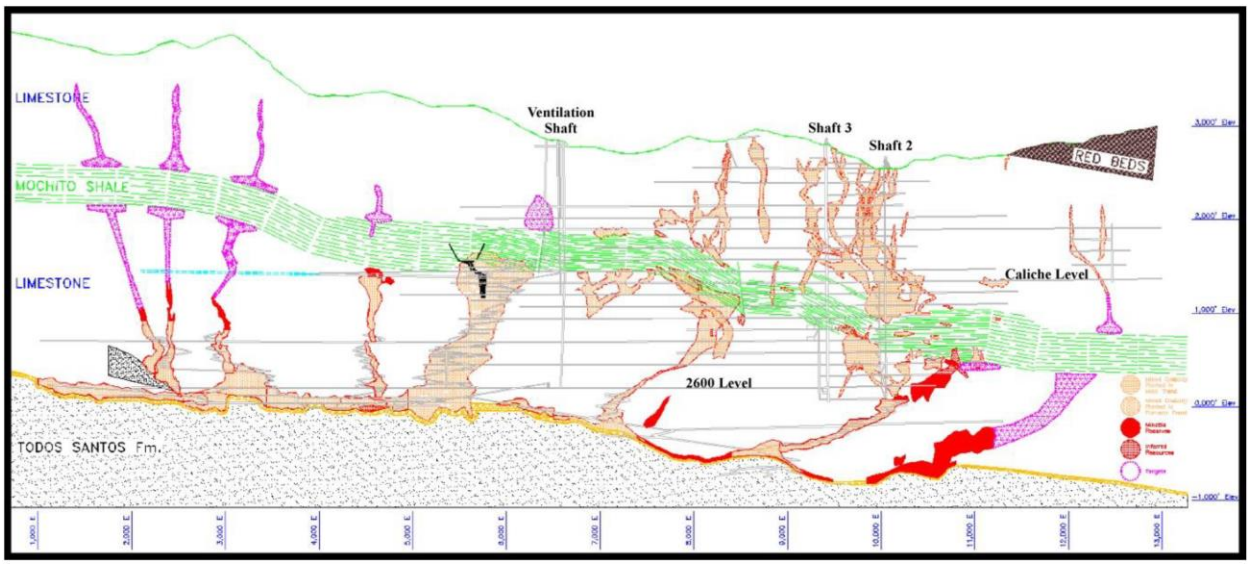
Mineral Resource Statement

Metal	Unit	Measured Mineral Resources		Indicated Mineral Resources		Measured plus Indicated Mineral Resources		Inferred Mineral Resources	
		2015	2014	2015	2014	2015	2014	2015	2014
	Mt	1.38	1.53	4.03	5.90	5.40	7.44	3.86	4.15
Zinc	%	5.22	4.91	4.72	4.43	4.85	4.53	5.11	5.13
Lead	%	1.93	1.97	1.65	1.48	1.72	1.58	1.38	1.37
Silver	g/t	62.10	66.40	38.80	37.40	44.70	43.40	35.00	34.30

Nyrstar, 2016b, 2015 Mineral Resource and Mineral Reserve Statement 27 April, 2016.

Illustrated in purple below are areas Nyrstar thought had exploration potential. One thing that struck me about this cross section is that it likely bears some similarity to Arizona Mining's Taylor deposit from the perspective that they are intersecting higher grade chimney and vein ore (the steep stuff, source of those sexy numbers in the press releases) but plenty of mundane grade mantos ore (the flat lying stuff) also. As El Mochito has found over the years, the success of the mine largely depends upon finding higher grade chimneys but they are not easy exploration targets and could be of quite limited aerial extent. The grade of the mantos is typically only 70-75% of the chimneys at El Mochito and a similar trend at Taylor appears likely.

Unfortunately, when Nrystar decided to leave the mining business, exploration, mine development, and backfilling all appear to have taken a hit at the mine according to the recent press release. That is the best means of saving money when under the gun but threatens the viability of the mine going forward due to the lack of mining flexibility it imposes in the short term. The lack of recent exploration effort is revealed in the resource and reserve statements. Neither resources or reserves were replenished in 2015 compared to 2014.



Mining

From the 2010 NI 43-101:

The present mineralized bodies are mined employing a "post and pillar" cut and fill method, using pneumatic jumbos with hydraulic backfill yielding approximately 84% recovery of the reserves. This method is ideally suited for the mine's variable geometry, grade distribution and rock conditions. Historically, good control over grade and dilution has been achieved. The mine functions well within the constraints of small shafts and has consistently improved over the years.

Mineralized material in the Nacional, Santo Niño, Lower San Juan, Salva Vida, Yojoa, La Leona and Imperial is loaded by 2.7 cubic metre capacity load haul dump vehicles into 15 and 20 tonne trucks for transport to an ore-pass which feeds an underground crusher and then a 0.9 metre wide conveyor. The material is then conveyed upgrade to chutes on the shaft-access rail system where it is transported to the shaft ore-pass system. Material is hoisted via ten tonne skips to surface, where it is conveyed to the surface crushing circuit and subsequently to storage in a surface bin.

The figure below illustrates how spread out mining is. The 2016 NI 43-101 mentions that mine ventilation rates are also well below normal industry standards so this would impose a further constraint on mining.

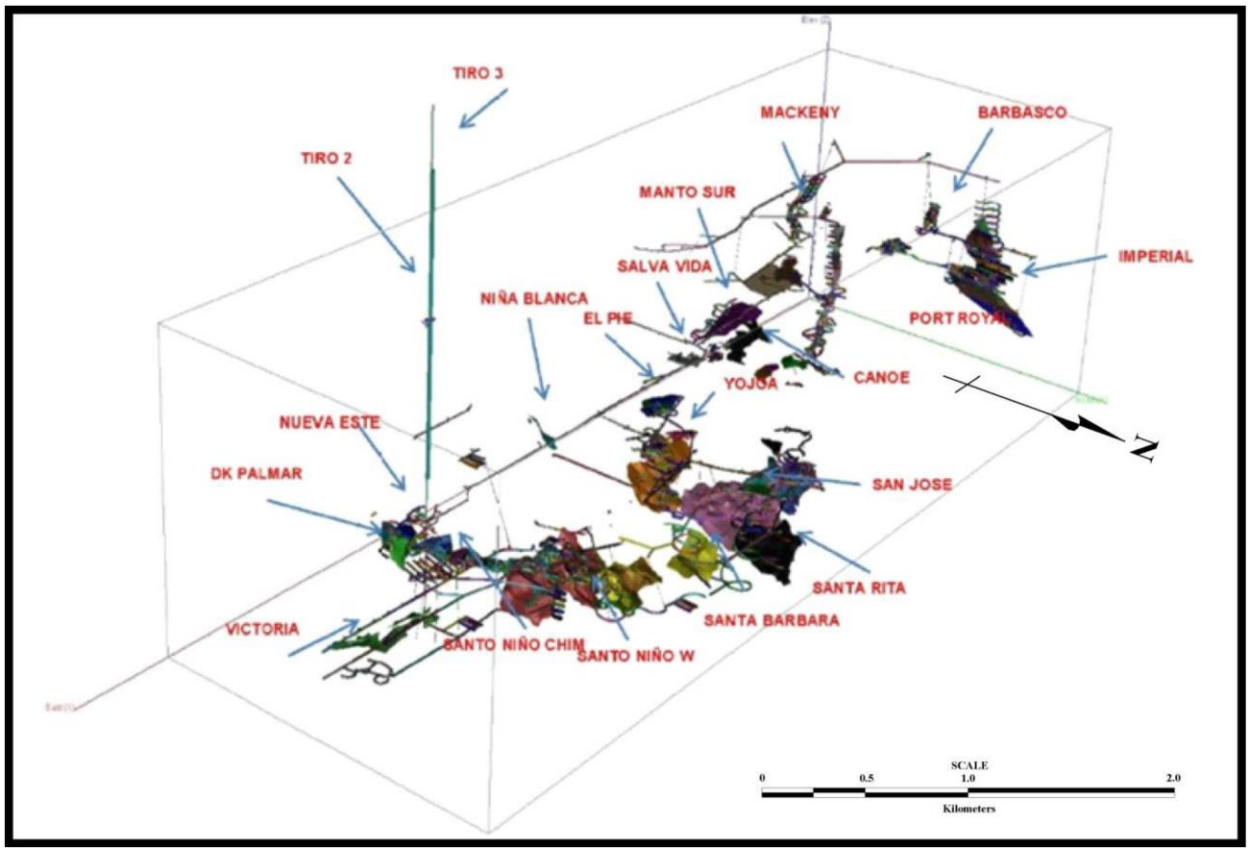


Table 11 illustrates output and financial results for 2009 and 2010 which is the last time this degree of transparency was provided. The mine had a good year in 2010 but the ore grade now is only 60% of what it was then. However, site cash costs in the $US60-70/t milled range have not materially changed over recent years. Nyrstar unfortunately did not provide financial results by mine and appear to have sustained substantial periods of negative free cash flow. Ascendant will need to rely on high zinc prices to overcome lower grades. Recent production figures are illustrated in Table 12.

Table 11 Mine Operating and Financial Performance for 2009 and 2010

($000's)	2010	2009
Gross sales revenue	147,609	89,273
Treatment and marketing costs	29,043	25,417
Net revenue	118,566	63,856
Direct operating costs	48,917	36,691
Depreciation and depletion	15,172	14,150
Reclamation and closure costs	1,168	1,307
Contribution from mining activities	53,309	11,708
Exploration	4,221	1,219
	49,088	10,489
Income and mining tax provision	9,338	2,689
Net earnings	39,750	7,800
Capital expenditures	19,857	12,977

Revenue:

The following tables and discussion provide details of Mochito's gross sales revenue for the periods indicated:

	2010				2009			
	Concentrate sold *(tonnes)*	Payable metal [1]	Realized price [1] *(US$)*	Gross sales revenue *($000's)*	Concentrate sold *(tonnes)*	Payable metal [1]	Realized price [1] *(US$)*	Gross sales revenue *($000's)*
Zinc	74,414	33,056	2,069	68,403	59,295	26,615	1,564	41,625
Lead	30,063	18,591	2,191	40,734	18,439	11,390	1,638	18,657
Silver	n.a.	1,718,353	19.99	34,343	n.a.	1,323,888	14.24	18,858
Other [2]	n.a.			(291)	n.a.			33
	104,477				77,734			
Gross sales revenue in US$				143,189				79,173
Exchange rate				1.0309				1.1276
Gross sales revenue in C$				147,609				89,273

(1) Payable metal and realized price(s) for zinc and lead are per tonne and for silver is per ounce.

(2) Other gross sales revenue represents revaluations of prior period concentrate receivables.

Table 12 Recent Production Performance

Year	Tonnes	Zn%	Pb%	Ag g/t	Zn recovery	Zn output
2016*	(520,000)	3.4	1.2	46.3	90.7%	(14,500)
2016	750,000	3.4	1.2	46.3	90.7%	23,000
2015	756,000	3.5	1.7	51.8	86.4%	23,000
2014	756,000	4.6	2.6	85.9	85.6%	29,500
2013	775,000	3.8	1.9	76.2	85.2%	25,000
2012	748,000	4.1	2.1	77.7	84.1%	26,000

*I am going to assume that these are the figures up to when Nrystar declared El Mochito to be a discontinued operation in September so I have prorated them to 12 months.

Zinc grade from 2006 to 2010 ranged between 5 and 6 % so there has been a steady deterioration since then.

The intrinsic assumption in Table 13 are zinc prices staying above $1.25 /lb. during the assessment period. Also illustrated is a return to full production in 2019 due to the predicted damaging effect of lack of sustaining capital by Nyrstar in the past year or two. Development, exploration and backfilling will likely all need to be accelerated. Since the new owner does not have deep pockets to fall back on, it will be easy prey should zinc prices fall under $0.90 /lb for a sustained period (which I doubt). But, there are better investment opportunities out there in my mind. This mine will be a sustaining capital pig likely meaning ample shareholder dilution no different than Breakwaters previous frequent secondary market antics that destroyed considerable shareholder wealth. This mine is well past its prime. I had to restrain myself from using harsher language.

Table 13 Forecast Production Assuming High Zinc Price

Year	Tonnes	Zn%	Pb%	Ag g/t	Zn recovery	Zn output
2017	550,000	3.5	1.5	45	88%	17,000
2018	650,000	4.0	1.8	50	88%	23,000
2019	750,000	4.5	2.0	60	88%	30,000
2020	750,000	4.5	2.0	60	88%	30,000
2021	750,000	4.5	2.0	60	88%	30,000
2022	750,000	4.5	2.0	60	88%	30,000

Reference: NI 43-101 reports Ascendant Resources September 9, 2016,

Breakwater Resources March 31, 2010

Guatemala

Escobal Mine

Tahoe Resources issued an excellent NI 43-101 report for the Escobal Mine in November, 2014. This was based upon feasibility level information. Production commenced in Q4 2013. This is a 4,500 tpd underground mine with a large and high grade silver resource with minor zinc. It would be very difficult to lose money at this mine due to the rich silver grade and low cost mining methods. Zinc grades have no bearing on production decisions.

Geology

From the NI 43-101 report:

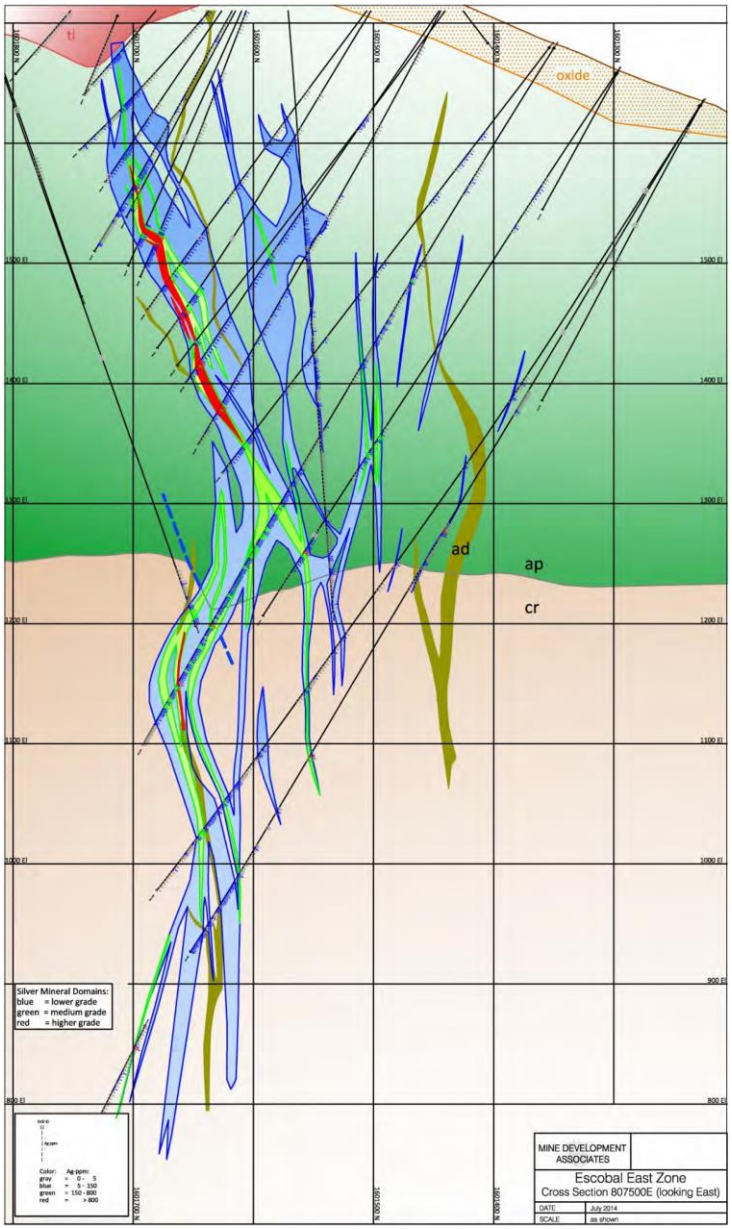
The Escobal deposit is an intermediate-sulfidation fault-related vein system formed within Tertiary sedimentary and volcanic rocks within the Caribbean tectonic plate. The Escobal vein system hosts silver, gold, lead and zinc, with an associated epithermal suite of elements, within quartz and quartz-carbonate veins. Quartz veins and stockwork up to 50 m wide, with up to 10% sulfides, form at the core of the Escobal deposit and grade outward through silicification,quartz-sericite, argillic and propylitic alteration zones.

Drilling to date has identified continuous precious and base metal mineralization at Escobal over 2,400 m laterally and 1,200 m vertically in four zones; the East, Central, West/Margarito and East Extension zones. The vein system is oriented generally east-west, with variable dips. The East and East Extension zones dip to the south from 60° to 75° with recent drilling showing a change to a more vertical dip at depth. The majority of the mineralized structure(s) in the Central and Margarito zones dip from 60° to 75° to the north, steepening to near-vertical at depth. The upper eastern portion of the Central Zone dips 60° to 70° to the south as in the East Zone.

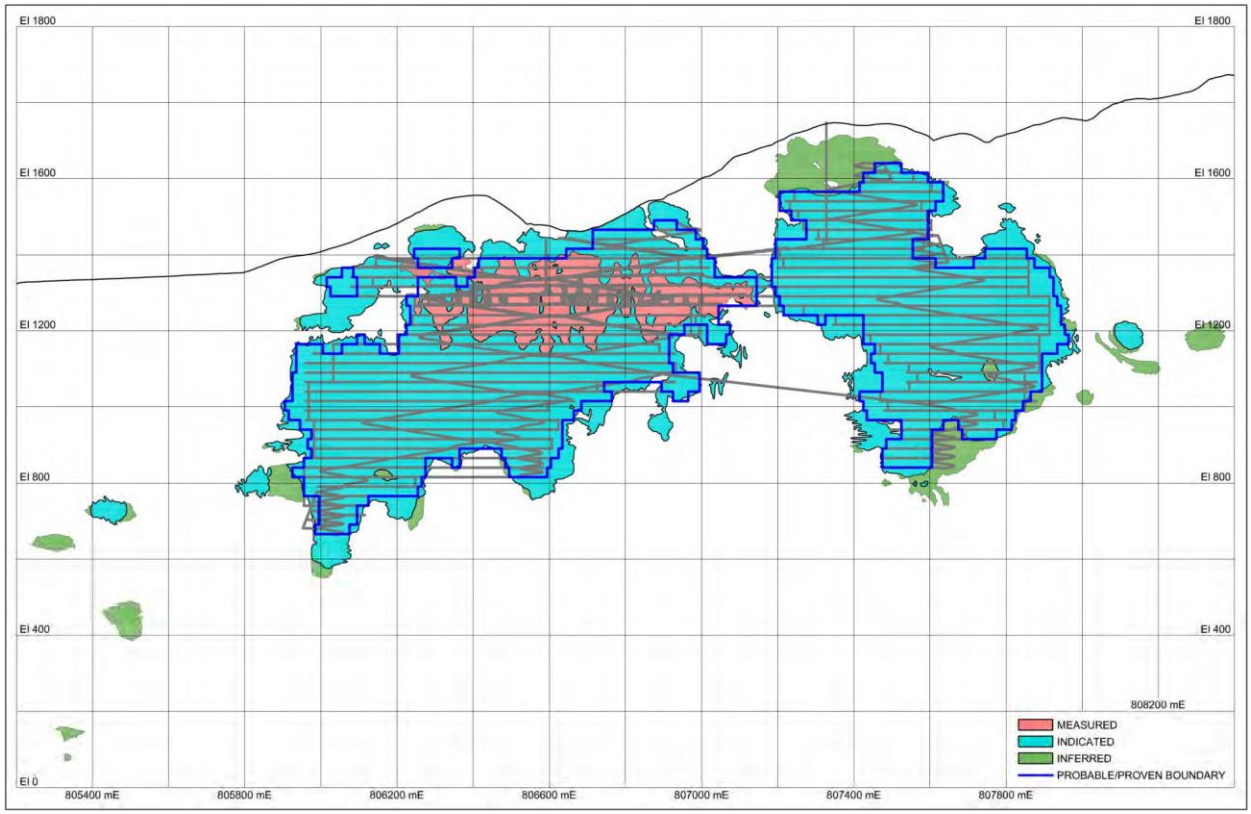
The figure below illustrates the ore zone with red being high grade, green medium grade and blue low grade. Grid spacing is 100 m. Resources and reserves are illustrated below.

January 2016: SUMMARY OF MINERAL RESOURCES									
Classification	**Tonnes (M)**	**Silver (g/t)**	**Gold (g/t)**	**Lead (%)**	**Zinc (%)**	**Silver (Moz)**	**Gold (koz)**	**Lead (kt)**	**Zinc (kt)**
Measured Mineral Resources	4.9	470	0.39	0.87	1.53	74,080	61.6	42.9	75
Indicated Mineral Resources	31.6	310	0.32	0.69	1.12	315,357	323.4	217.4	355.5
Measured & Indicated Mineral Resources	36.5	332	0.33	0.71	1.18	389,437	385.0	260.2	430.5
Inferred Mineral Resources	1.4	205	1.11	0.24	0.45	9,320	50.4	3.4	6.3

NOVEMBER 2014 ESCOBAL FEASIBILITY STUDY: SUMMARY OF MINERAL RESERVES									
Classification	**Tonnes (M)**	**Silver (g/t)**	**Gold (g/t)**	**Lead (%)**	**Zinc (%)**	**Silver (Moz)**	**Gold (koz)**	**Lead (kt)**	**Zinc (kt)**
Proven Mineral Reserves	4.5	416	0.34	0.81	1.41	60,075	49.3	36.2	63.5
Probable Mineral Reserves	24.6	317	0.32	0.71	1.15	250,343	255.3	175.7	283.4
Proven & Probable Mineral Reserves	29.1	332	0.33	0.73	1.19	310,418	304.6	211.9	3,486.9



The mine layout is quite standard as illustrated below.



Mining

Being lazy, another cut and paste job from the NI 43-101:

The Escobal mine is accessed via two primary declines (East Central and West Central ramps) which provide access to the Central Zone of the deposit. A third internal primary ramp is being driven into the East Zone from the East Central ramp. Access ramps are driven from the main ramp system to establish sublevel footwall laterals driven parallel to the vein on 25 m vertical intervals. Primary and secondary development headings are mined 5 m wide by 6 m high with arched backs. The primary ramps are typically driven at a maximum inclination of -15%. Mining is currently being done by transverse longhole stoping with future mining by a combination of transverse and longitudinal longhole stoping. The stopes are accessed from the footwall laterals.

Ore is hauled to the surface by truck to the ore stockpile, located proximal to the primary crusher. Development waste rock is hauled by truck to the surface and used as construction material for the dry stack tailings buttress.

Filtered tails from the process plant are combined with cement and water to make a structural fill for use as backfill underground. A paste backfill plant located on the surface produces backfill for delivery via piping into the mine for placement in the mined out stopes.

Underground development of the Escobal mine commenced in May 2011, with construction of the East Central and West Central decline portals; after which ramp development began. Through June 2014, approximately 17,000 m of mine development and 230 m of vertical development (ventilation raises) had been completed. As of June 30, 2014,the mine produced 786,551 tonnes of ore grading 566 g/t silver, 0.46 g/t gold, 1.01% lead and 1.39% zinc.

The life of mine plan as of July 1, 2014 forecasts the Escobal mine to produce a total of 31.4 million tonnes of ore at average grades of 347 g/t silver, 0.33 g/t gold, 0.74% lead and 1.21% zinc.

It does not come any easier than this underground. The orebody geometry and dimensions are excellent. Ground conditions are reasonable. For a sense of how we look at core to determine its competency, Section 16.3 of the NI 43-101 report summarizes the geotechnical work conducted that any new mine needs to complete.

Table 14 illustrates actual and forecast production. I could ramble on here but you are much better off reading the NI 43-101 to get an understanding of how the sausage is made. Section 16 is basically what I did for a living. Section 17 is without a doubt the best description of base metal milling I have come across in my research for the modules. Kudos to M3 (who I believe are a 1,000 person outgrowth of a company started as M2 by some former classmates in the 1980's, the Marsden brothers. Us Queen's guys got around).

Table 14 Actual and Forecast Production for Escobal

Year	Tonnes	Ag g/t	Au g/t	Pb%	Zn%	Contained Zinc	Zn % Recovery	Recovered Zinc- T
2012	0							0
2013	159,000							1,221
2014	1,245,730	585	0.42	0.93	1.43	17,814	75.2	13,394
2015	1,510,000	487	0.39	0.77	1.27	19,177	77.4	14,810
2016	1,624,000	441	0.31	0.65	1.13	18,351		10,483*
2017	1,658,000	442	0.32	0.67	1.12	18,570	82.6	15,338
2018	1,642,000	442	0.32	0.67	1.13	18,555	82.6	15,326
2019	1,633,000	442	0.4	0.66	1.11	18,126	82.6	14,972
2020	1,633,000	442	0.61	0.82	1.39	22,699	82.6	18,749
2021	1,631,000	442	0.27	0.46	0.78	12,722	82.6	10,508
2022	1,619,000	398	0.34	0.61	1.01	16,352	82.6	13,507

2016-2022 data is from the NI 43-101. *2016 zinc output is actual results but recovery does not reconcile with the NI 43-101.
No grade data provided by Tahoe for 2013. 2014-15 is actual results.

Reference: Tahoe Resources NI 43-101 November 5, 2014.

Brazil

Unfortunately, folks detailed information on recent zinc mine performance in Brazil is sketchy. I am sure it is out there somewhere, I just have not found it.

There are two zinc mines in Brazil and they are owned and operated by Votorantim: Vazante and Morro Agudo. Technical information from the company is patchy so I have had to rely on third party technical papers and articles written over the years. Both mines are developing satellite deposits in order to maintain production.

The annual reports issued by Votorantim are more of a public relations sustainability document and lack basic information on production, plant capacities and financial results. Likewise, production reporting in other documents and presentations on their website are very sketchy and are not broken out by mine site. Production in 2016 was fairly steady at 40,000-42,000 tonnes zinc per quarter but there is no breakout by mine. In other years, production has been lumped with Milpo in Peru and I have not performed a breakout. However, there are some tidbits provided from time to time. From the 2015 Sustainability report:

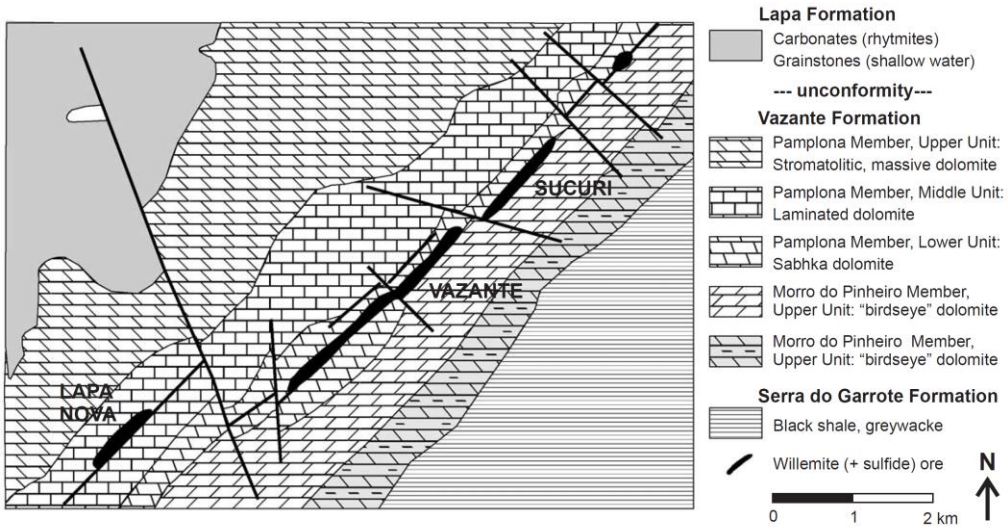
Another important investment during the year was the implementation of the project to extend the useful life of the Vazante mine, in the state of Minas Gerais. This was a highly challenging project from a technical perspective and it is expected to produce significant results for Votorantim Metais over the long term. Approximately R$ 600 million will be invested in this unit in the coming years, to enable it to access the ore reserves existing at greater depths within the current exploration area. The useful life of the mine is forecast to have been extended by more than ten years, ensuring the ongoing competitiveness of Votorantim Metais's access to zinc mineral deposits.

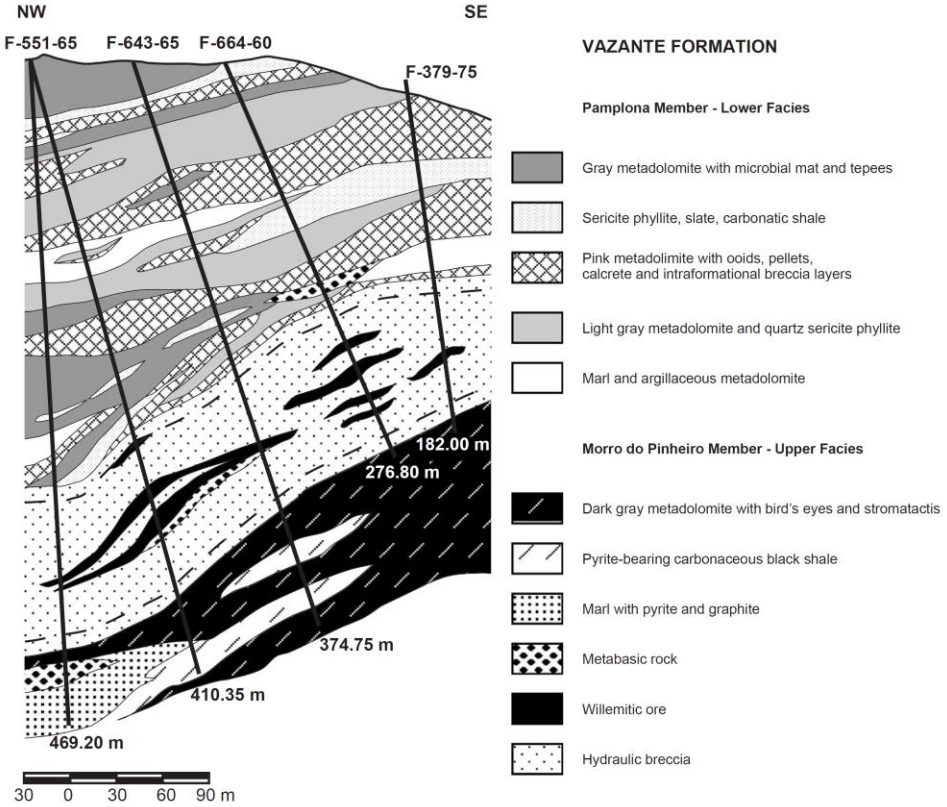
With a similar aim, Votorantim Metais is investing R$ 215 million in the Extremo Norte project, also located in Vazante. The project is designed to produce an additional 470 thousand metric tons/year of raw ore, which is equivalent to about one third of the unit's current production. The project was granted a provisional environmental and installation license in 2012. Today, the activities at the Extremo Norte project are being executed under a Provisional Operating Authorization (known as APO).

The Ambrosia project is a zinc ore deposit in an area adjacent to the existing Morro Agudo mine. It will ensure the continued use of the unit's processing facilities up until 2029.

Vazante

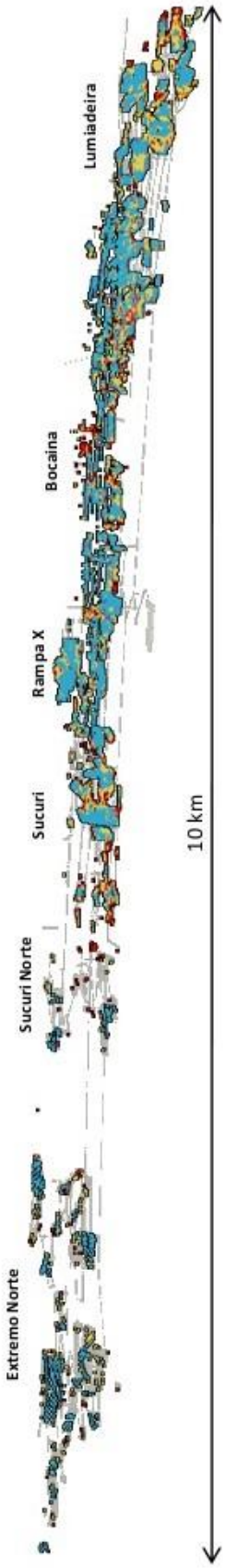
Following 14 years of open pit mining, underground mining commenced in 1983. This is a very unique mine in that zinc oxide ore is mined by underground methods. Although there appears to be an ample library of papers describing the geology, here is one in English. Morro Agudo is also discussed. A good description of the mine along with others is also contained in the document here . A plan and cross sectional view of the deposit is illustrated below.





From what I can gather, the "expansion" at Vazante refers to an expansion of the mine workings, not an expansion of zinc in concentrate output. Production is falling in the core mining areas so both depth and expansion along strike is necessary to maintain production. When the expansion is complete, mine workings will extend 10 km along strike as illustrated below. Gut feel is they will be hard pressed to maintain current zinc production rates.

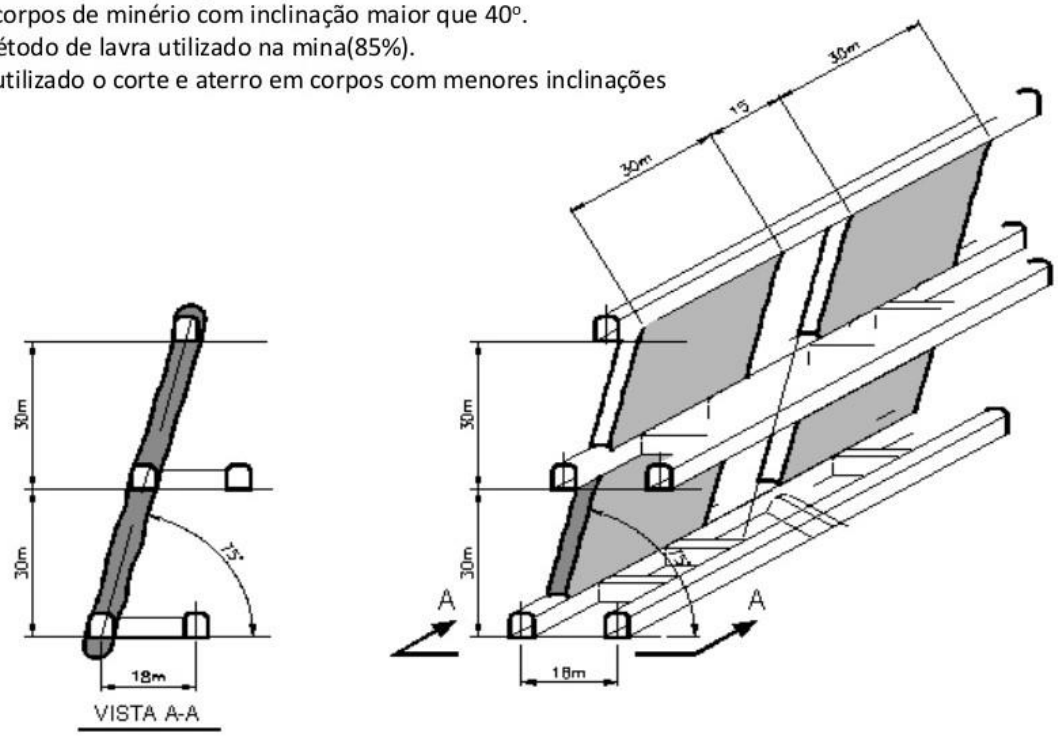
Vazante is a very wet mine with installed dewatering capacity of 13,500 m^3 per hour being quoted in historic documents. Groundwater is probably the reason why the term "highly challenging" was used by the company. One of three pump stations are illustrated below which sends a bit of a shiver up my spine since that is one major installation typically only seen in southern Africa. Fortunately, the mine is shallow so it is possible to pump large volumes at low head.


Extremo Norte
Sucuri Norte
Sucuri
Rampa X
Bocaina
Lumiadeira
10 km

A variation of blasthole stoping is utilized for mining steeply dipping though narrow ore. This is a little confusing to me since the cross section above shows plenty of flat dipping mineralization where this method would not be applicable. If my Spanish is correct blasthole stoping (VRM) accounts for 85% of mining and is used for ore dipping greater than 40 degrees. My understanding is that cut and fill mining constitutes the other 15%. As illustrated, the ore zones are often quite narrow. In the mine longitudinal above, blue represents ore > 3m , yellow 1.5-3.0 m and red <1.5 m in thickness.

VRM (Vertical Retreat Mine)

Aplicado a corpos de minério com inclinação maior que 40º.
Principal método de lavra utilizado na mina(85%).
Também é utilizado o corte e aterro em corpos com menores inclinações



The ore is trucked from the mine via adits. A better description of the operation, although over ten years old can be found here .

Plus or minus 20%, my best guess is that Vazante currently mines roughly 1.3 Mt of ore annually at a grade of 13% Zn and produces in the order of 130,000 tpa of zinc in concentrate. That is the best I can do.

Votorantim has two zinc plants in Brazil with a nameplate capacity totalling 270,000 tpa of zinc metal. The concentrate from Vazante is therefore processed internally.

Morro Agudo

A description of the geology may be found in both documents linked previously. The mine is located about 90 km north of Vazante. This is a conventional sulphide deposit that has been classified as MVT/SEDEX or Irish style by various geologists. It is flat dipping therefore room and pillar mining is conducted in very competent ground. Previous rated capacity was in the range of 30,000- 35,000 tpa of zinc in concentrate. Reserve grade has been stated previously as 6.3% Zn and 2.9% Pb. Reading between the lines this implies an annual production rate in the 600,000- 700,000 t ore range. Two sources imply that this deposit should have been mined out by now and the nearby Ambrosia deposit, currently being placed into production, was described as "uneconomic" in the Slezak thesis referenced. So, I am not sure what to make of all this. I have downgraded the zinc production rate to 25,000 tpa in Table 15 which summarizes both mines as best as I can. No Brazilian government statistics were located so I have relied on the British Geological Survey and the USGS for national production rates to 2014.

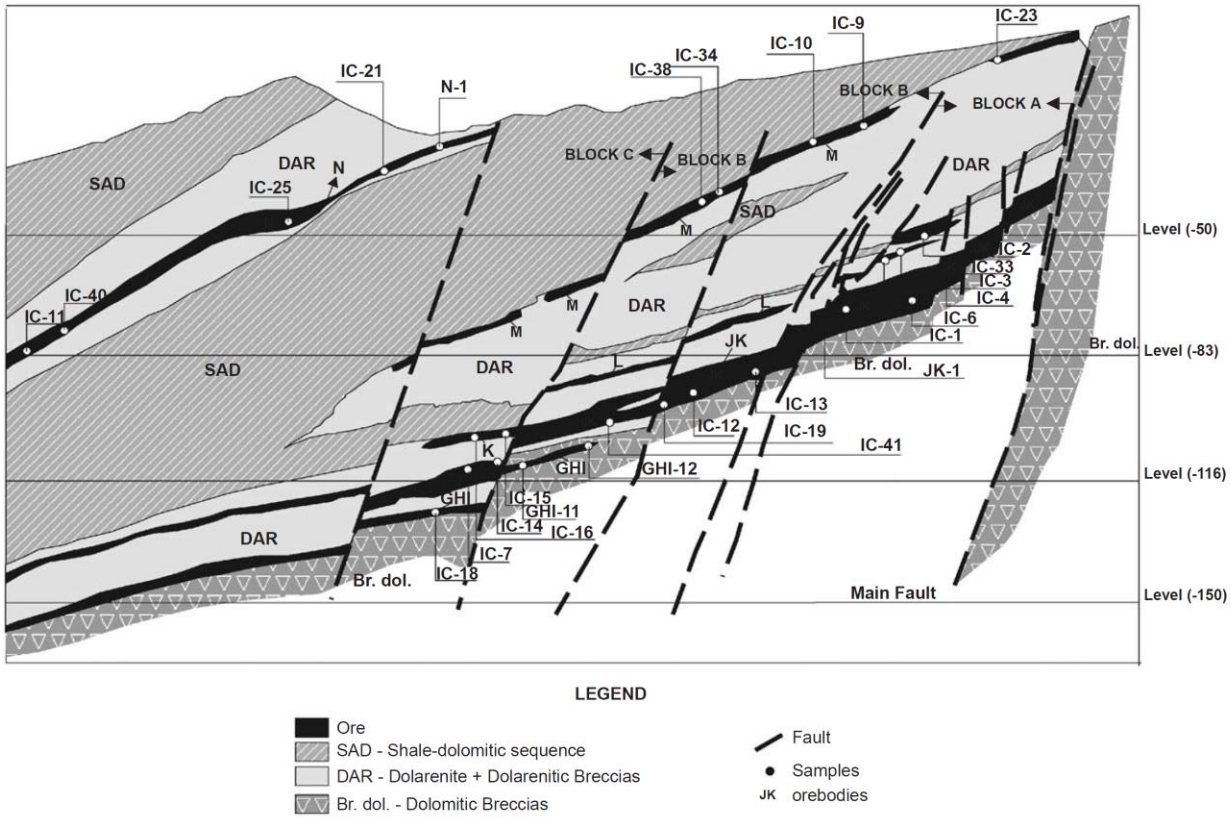


Table 15 My Best Shot at Vazante Plus Morro Agudo Actual and Forecast Output

2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
164,258	152,147	159,000	160,000	165,000	160,000	155,000	150,000	150,000	150,000	150,000

Reference: http://www.votorantim.com.br/en-us/grupoVotorantim/perfil/Pages/perfil.aspx

Aripuana Zinc Project

Well, here is one that has been keeping well below the radar. Votorantim states cryptically in their 2015 sustainability report that they expect to place this into production in 2020. They control 70%. They have spent roughly $C50M exploring the project since 2004. Canadian listed Karmin Resources has the remaining 30%.

It looks like I should have had a look here a month ago based on Karmin's share performance recently. My bad, once again. This is a low daily share volume, low share count (~75M), even worse free float, situation so tread very carefully here. There were days (and weeks) in 2016 where the stock never traded. Karmin is carried here through to a bankable feasibility study. A Votorantim pre-feasibility study is underway looking at a 1,200,000 tpa milling rate to produce 60,000 tpa of zinc, 20,000 tpa lead and 6,000 tpa copper. Honest to god, I said Karmin who? an hour ago, then looked at their share performance in the past week, then said "damn" under my breath. But one hour does not constitute due diligence so I am not sure what the warts are yet nor am I interested in speculating is situations such as this that have terrible liquidity.

http://www.karmin.com/projects/aripuana-zinc-project/

AMEC completed a study on this project during the last run up in zinc price in 2007 and RPA completed an NI 43-101 report in 2013. They can be found here .

Much of the ore can be mined by low cost open pit. Resources are illustrated below and there is good exploration potential for what could be a VMS camp. The grades listed are not much different than the grades mined previously by open pit at Aznalcollar in Spain. At first blush, it looks good.

		Grade					Contained Metal				
	Tonnage Mt	Zn %	Pb %	Cu %	Au g/t	Ag g/t	Zn M lb	Pb M lb	Cu M lb	Au Oz	Ag K Oz
AREX											
Measured	2.4	7.15	2.50	0.51	0.24	73	378	132	27	19,000	5,633
Indicated	2.5	3.50	1.18	1.36	0.64	37	195	65	76	52,000	2,996
Inferred	3.2	3.9	1.4	0.8	0.7	39	278	101	57	73,000	4,001
AMBREX											
Indicated	14.2	3.39	1.23	0.07	0.18	29	1,062	386	23	82,000	13,389
Inferred	11.5	5.0	1.7	0.1	0.30	40	1,269	436	36	108,000	14,657
AREX+AMBREX											
Measured + Indicated	**19.1**	**3.87**	**1.38**	**0.30**	**0.25**	**36**	**1,635**	**584**	**125**	**153,000**	**22,018**
Inferred	**14.7**	**4.8**	**1.7**	**0.3**	**0.4**	**39**	**1,547**	**536**	**93**	**181,000**	**8,560**

Notes:

1. CIM definitions were followed for Mineral Resources.
2. Mineral Resources are reported as within mineralized wireframes modelled at 3% Zn in the stratabound zone and 0.5% Cu in the stringer zone and include internal dilution.
3. The Ambrex resource database does not include results of drilling in 2012.
4. Numbers may not add due to rounding.

Aripuanã's measured and indicated mineral resources total 19.1 million tonnes containing:

Figure 9-1: Isometric View of Arex Deposit (Looking NE)

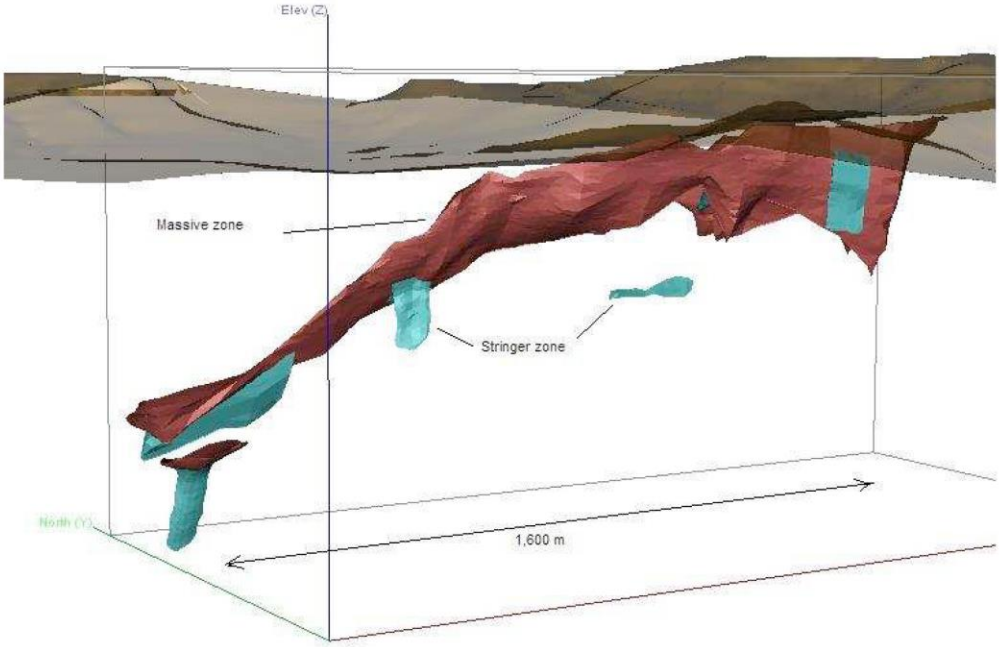
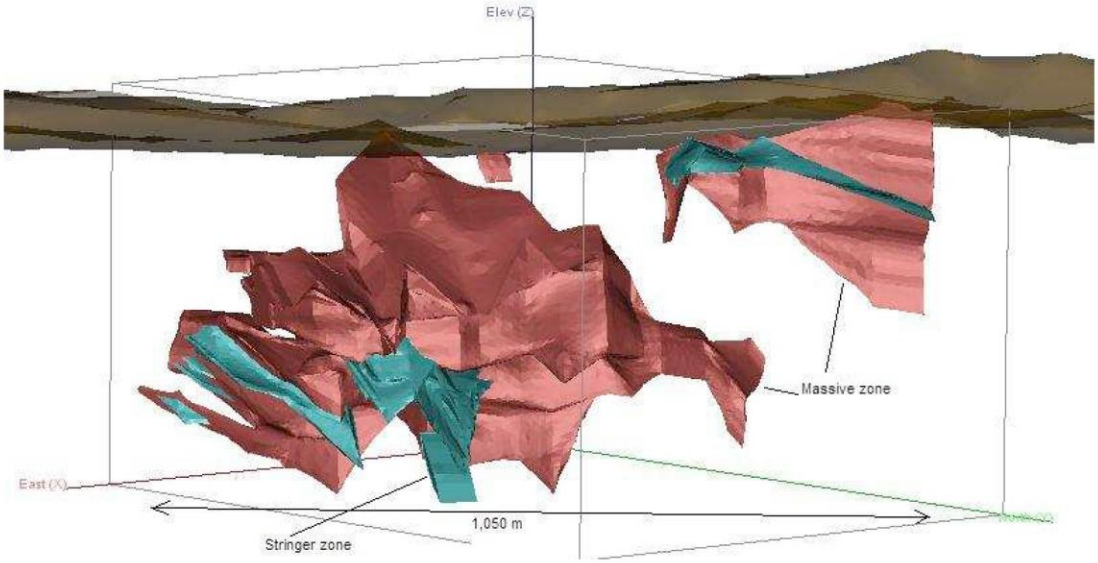


Figure 9-2: Isometric View of Ambrex Deposit (Looking SW)



Well, I hate to leave you in suspense like this but I am heading out of country later today so I am going to assume that Votorantim does pull the trigger here and hits full production in 2022 with a 2021 start up. They will need new sources of feed to counter the expected gradual wind down of their current mines in the next decade. I will leave it to you to perform due diligence on Karmin to see if it represents good value or not. They are not in the drivers' seat and must come up with 30% of the mine financing so it is not all clear sailing. This could be an ideal situation to convert to a royalty structure.

I did not come across any other projects of merit during my research for this report but this may just be a shortcoming on my part.

What I want to do next is put all the countries assessed into an editable spreadsheet so I can start tracking my various forecasts. When I have something presentable I will share it.

DISCLOSURE

The author has received no compensation for the generation of this report. The author may, from time to time have a long or short position in securities mentioned and may make purchases and/or sales of those securities in the open market. At the time of writing the author has a short position in Pretium Resources mentioned constituting less than 1% of his investment portfolio.

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