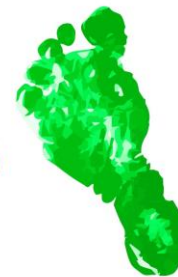


# Effect of deposit types, mine development & industry structure on primary lead & zinc economics in Australia, North America & Europe

Laurie Reemeyer  
Principal Consultant

Resourceful Paths



# Introduction

- **Industry overview – Europe, Australia and North America**
  - Major mines and deposits – geology and geography
  - Smelting and refining
- **Consolidation and changes in industry structure**
  - By region and level of vertical integration
- **Metallurgical developments**
- **Economic drivers and what this means for past, present and future**



# Deposit Types – North America, Australia, Europe

Deposit type	Example	Country
SEDEX	McArthur River, Mt Isa, Century Red Dog Selwyn, MacMillan's Pass	Australia USA Canada
Broken Hill Type (high grade metamorphic)	Broken Hill Cannington	Australia
Carbonate Replacement Deposit	Taylor (Hermosa)	USA
Mississippi Valley Type/Irish Type	Missouri Lead Belt, Tennessee Pine Point Tara	USA Canada Ireland
VMS	Manitoba Operations, Izok, Kidd Greens Creek Garpenberg, Neves Corvo Rosebery	Canada USA Sweden, Portugal Australia
Epithermal	Penasquito Elura (Endeavour)	Mexico Australia



# Deposit Types – Head Grades

Deposit			Resource or Reserve Grades					
Name	Country	Type	Zn	Pb	Cu	Ag (g/t)	Au (g/t)	Pb:Zn
Cannington	Australia	Broken Hill	3.7%	7.0%		266		1.89
Mount Isa	Australia	SEDEX	5.5%	2.5%		35		0.45
Rosebery	Australia	VMS	10.6%	3.5%	0.3%	110	1.6	0.33
Century	Australia	SEDEX	9.3%	1.5%		30		0.16
East Tennessee	USA	MVT	3.6%					0.00
Red Dog	USA	SEDEX	17.0%	4.0%		70		0.24
Greens Creek	USA	VMS	7.6%	2.8%		394	3.1	0.37
Taylor	USA	CRD	3.4%	3.7%		69		1.08
Selwyn	Canada	SEDEX	5.5%	2.1%				0.38
Penasquito	Mexico	Epithermal	0.6%	0.2%		23.5	0.66	0.36
Izok	Canada	VMS	13.3%	1.4%	2.4%	73		0.11
Garpenberg	Sweden	VMS	4.0%	1.7%	0.1%	113		
Tara	Ireland	Irish Style	6.0%	1.6%				

Significant grade differences even for same ore types



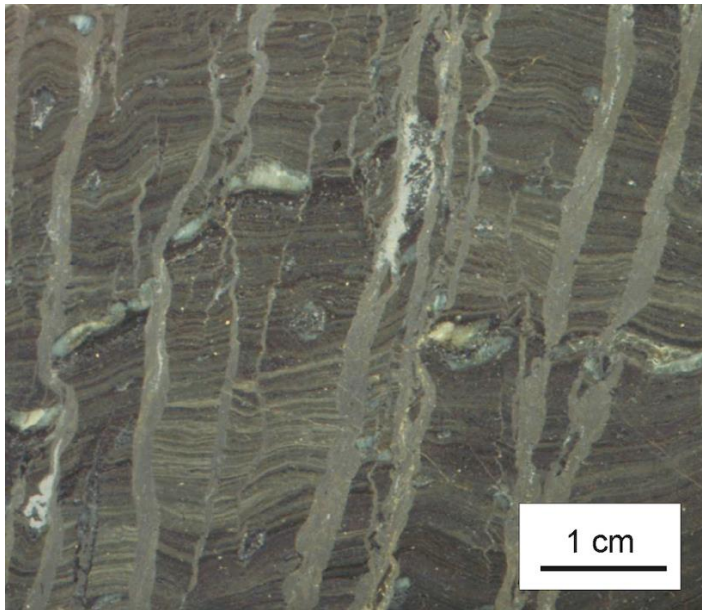
# Geology Influencing Mining, Mineral Processing

- **Influence on mining method (shape, orientation, depth)**
  - MVT and Irish deposits suitable for cheap room and pillar underground
  - VMS typically deep underground stoping
- **Mineralogy affecting mineral processing and waste management**
  - Fine grained SEDEX deposits need fine grind mineral separation vs. coarse MVT
  - VMS high pyrite tailings high ARD potential vs. MVT/Irish inert carbonate rich tails
  - VMS concentrates may be elevated in precious (Ag, Au) and deleterious (Sb, Se, Hg) elements vs. MVT/Irish concentrates that are devoid of these
  - MVT concentrates high Zn grades with low Fe, SiO<sub>2</sub> vs. SEDEX concentrates often high in Fe, Mn and SiO<sub>2</sub>, which increase residue formation in smelters
  - VMS setting and zonation affect metal distribution, e.g. Canadian high Cu, low Pb

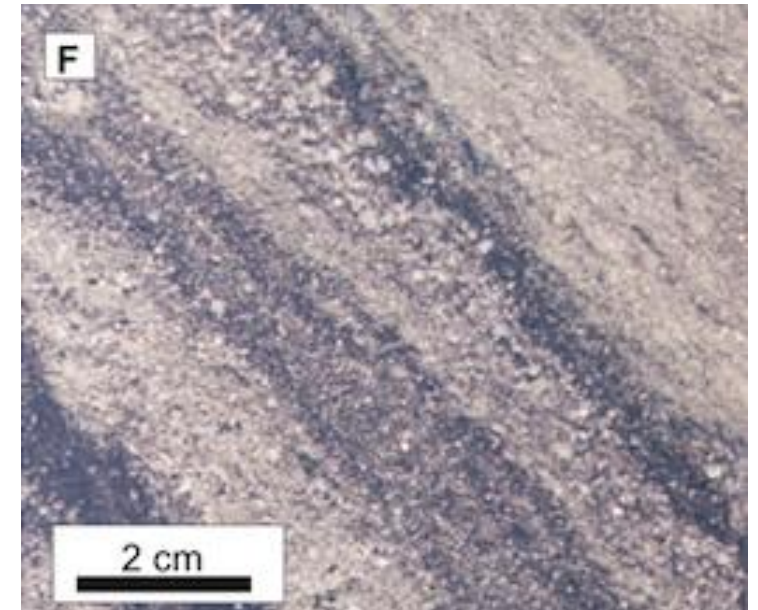
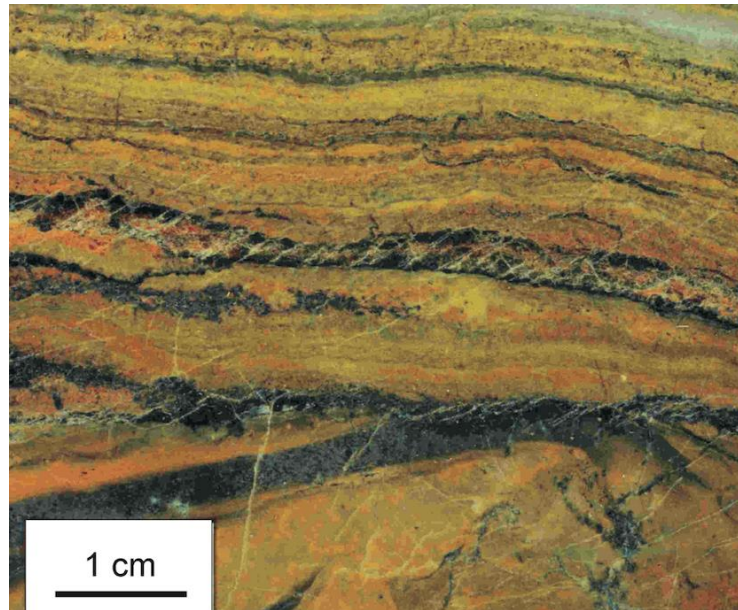




# However, every deposit is unique

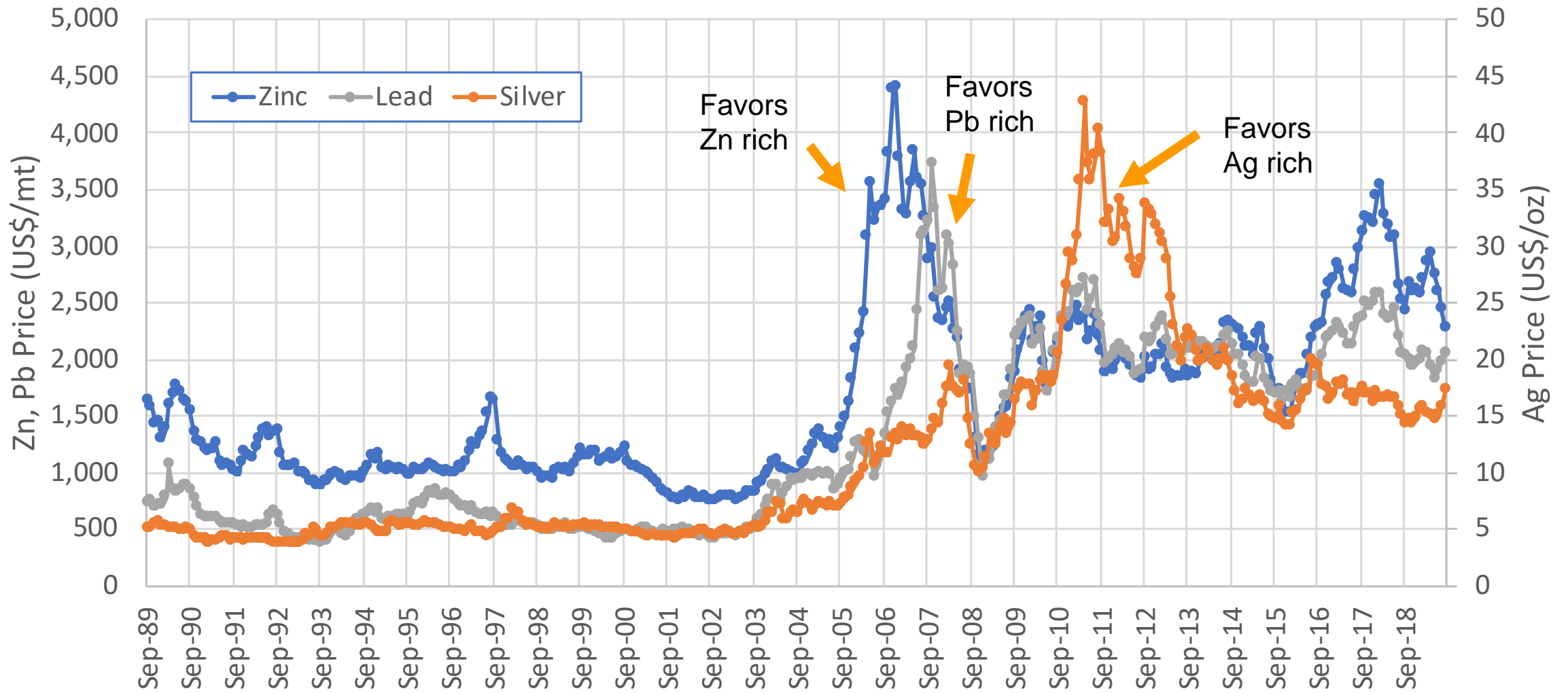


Source: Goodfellow, Base Metal Metallogeny of the Selwyn Basin, Canada, 2007

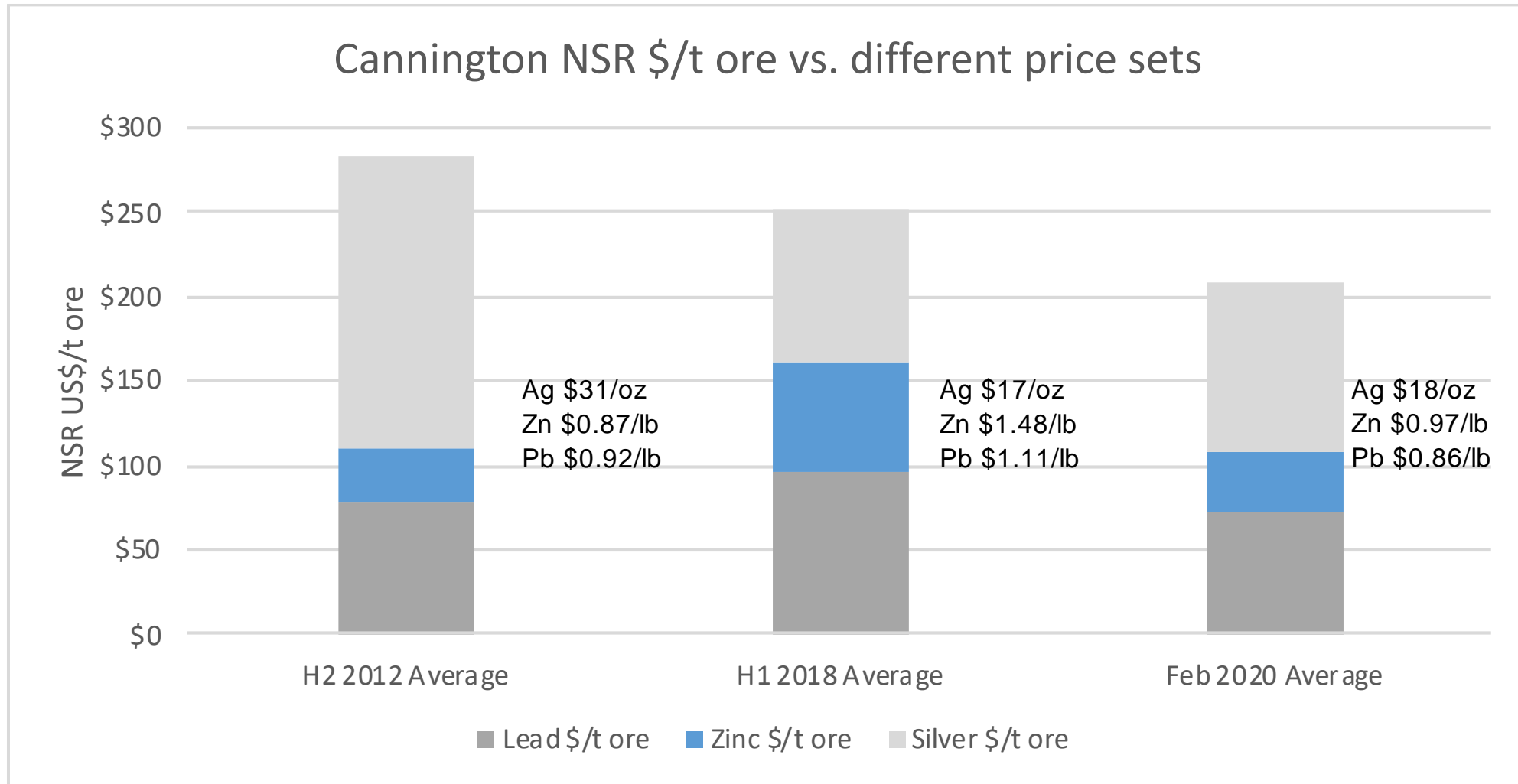


Source: Goodfellow, Metallogeny of the Bathurst Mining Camp, Northern New Brunswick, 2007

# Zn, Pb and Ag Prices - 1989 to 2019

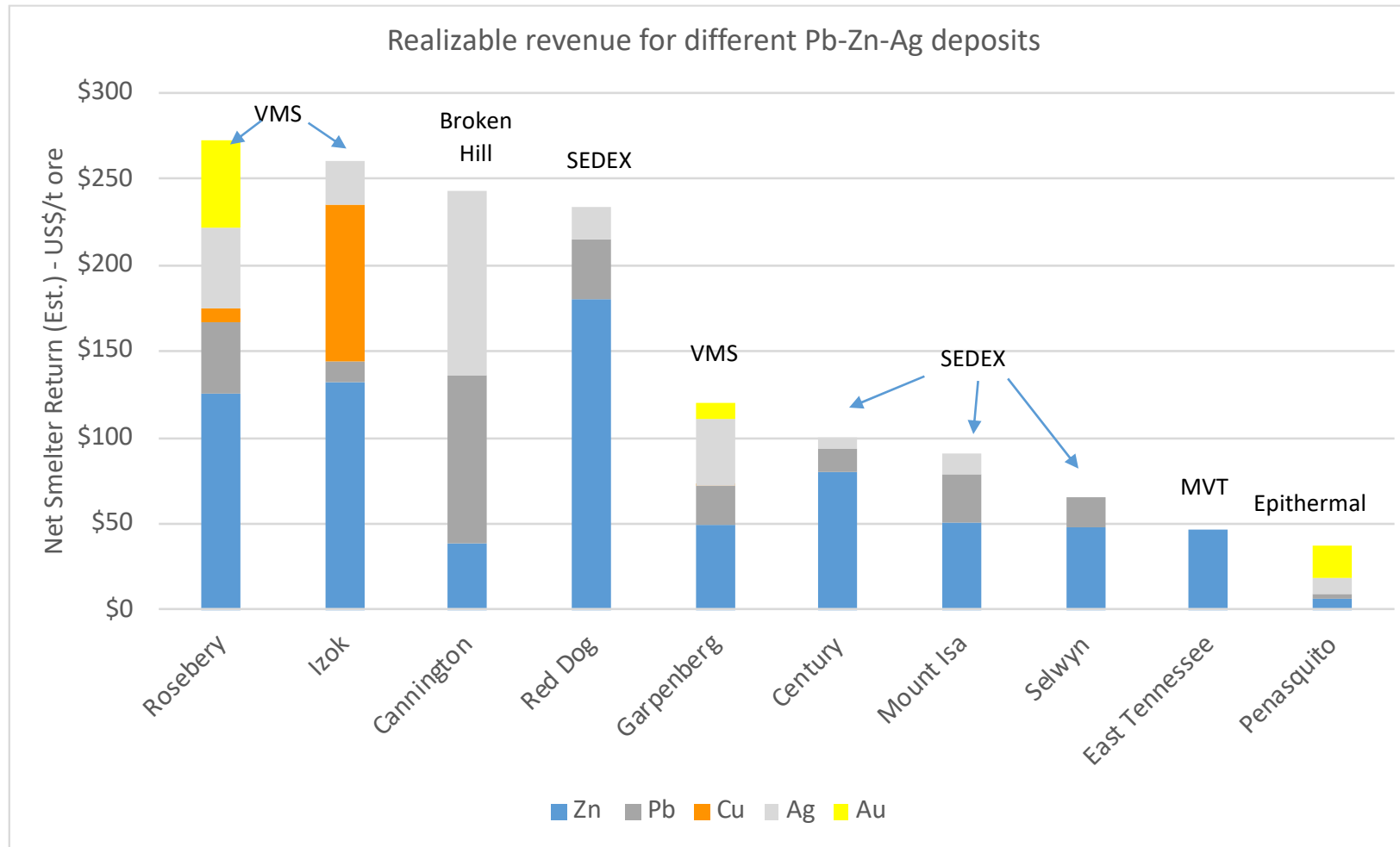


# Net Realizable Revenue Sensitivity to Prices

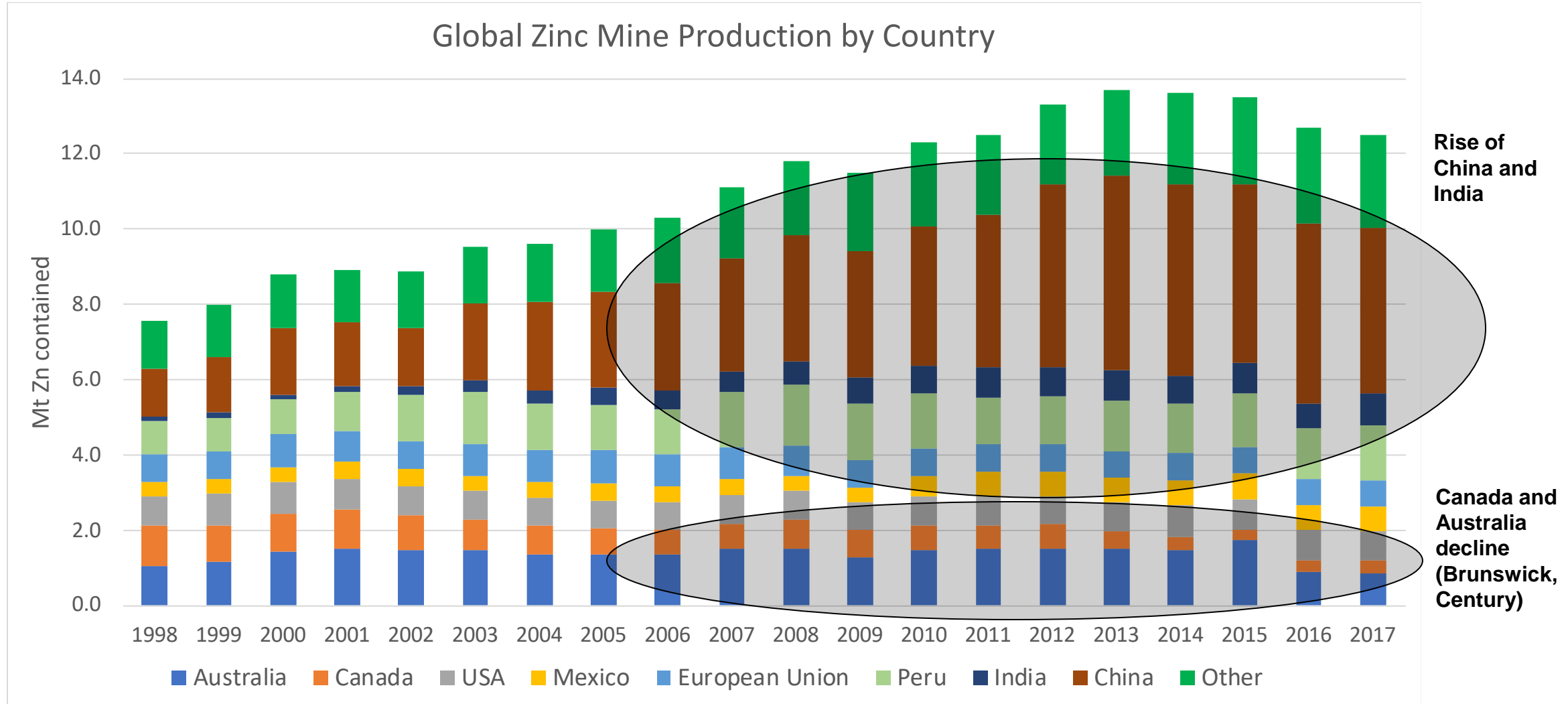




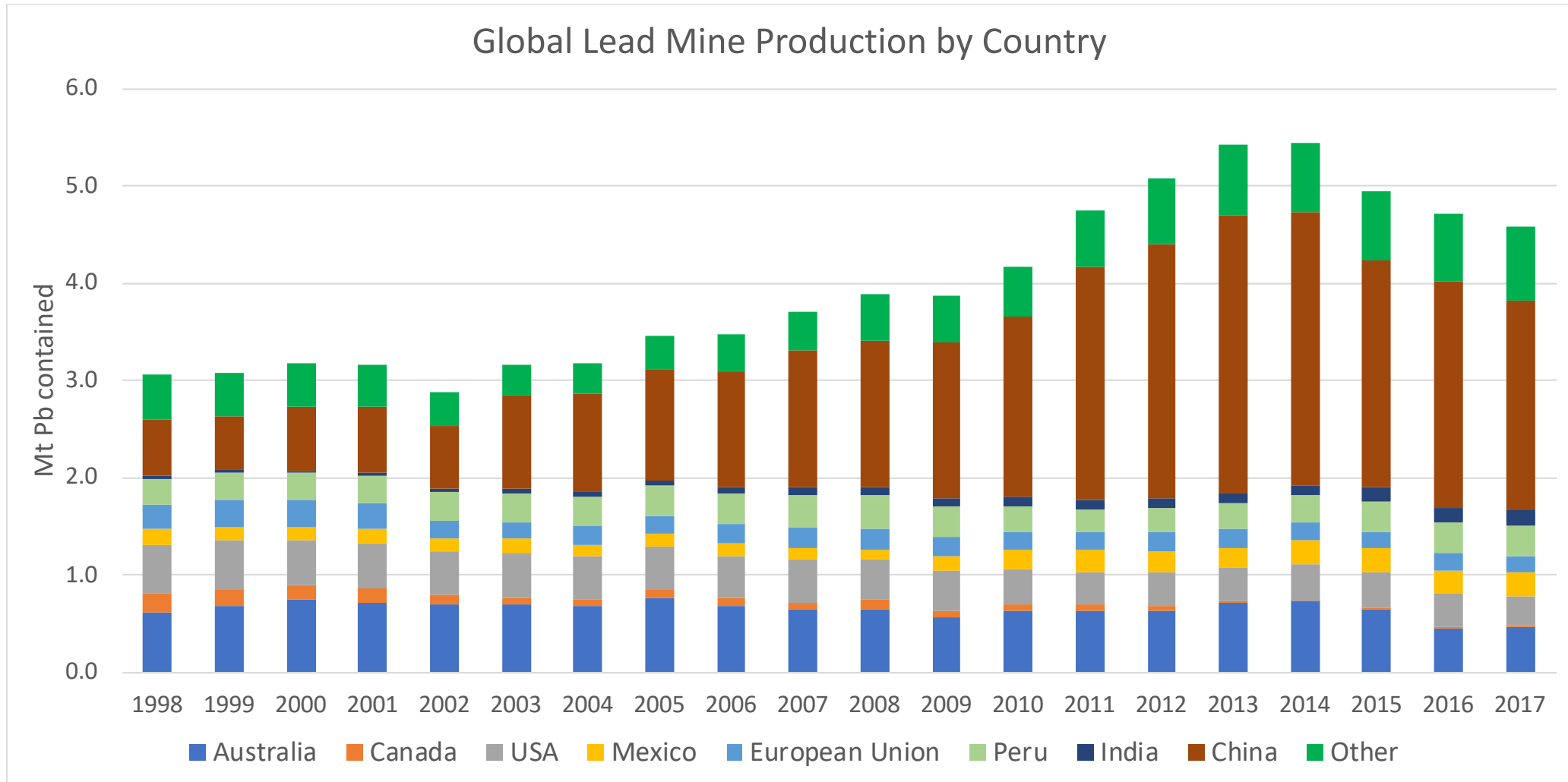
# Economics of Example Pb-Zn Deposits



# Industry Overview: Regional Production - Zn



# Industry Overview: Regional Production - Pb



# Industry Structure: Europe, Australia, Nth America

- **Major changes in ownership structures since 2000**
  - The collapse of Western Metals (Australia)
  - Anglo American Manitoba Operations sale to Hudbay
  - Asset swaps between Outokumpu and Boliden
  - Consolidation of former MIM and Falconbridge by Xstrata then Glencore
  - The breakup of Pasminco/Zinifex and the formation of Nyrstar
  - Acquisition of Breakwater Resources by Nyrstar and Zinifex Zn mines by MMG
  - Consolidation of Zn mines in Europe by Lundin and Vedanta
  - The effective takeover of Nyrstar by Trafigura
- **Several major mine and smelter closures**
- **Teck Red Dog and Trail integration has continued**





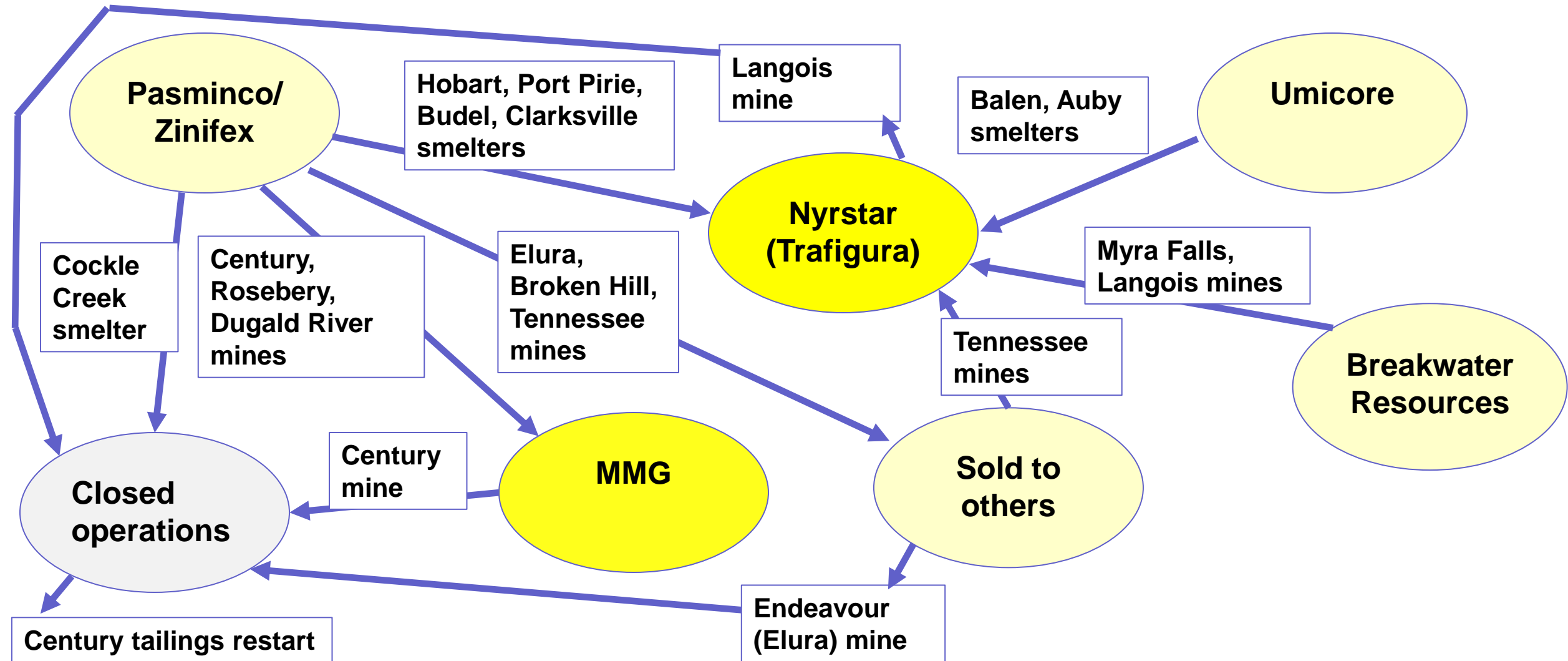
# Smelter Closures

- **Closures, esp. Imperial Smelter Plants and Pb sinter plant-blast furnace**
  - **Challenges: emissions controls, high energy costs, reduced access to feed stocks**

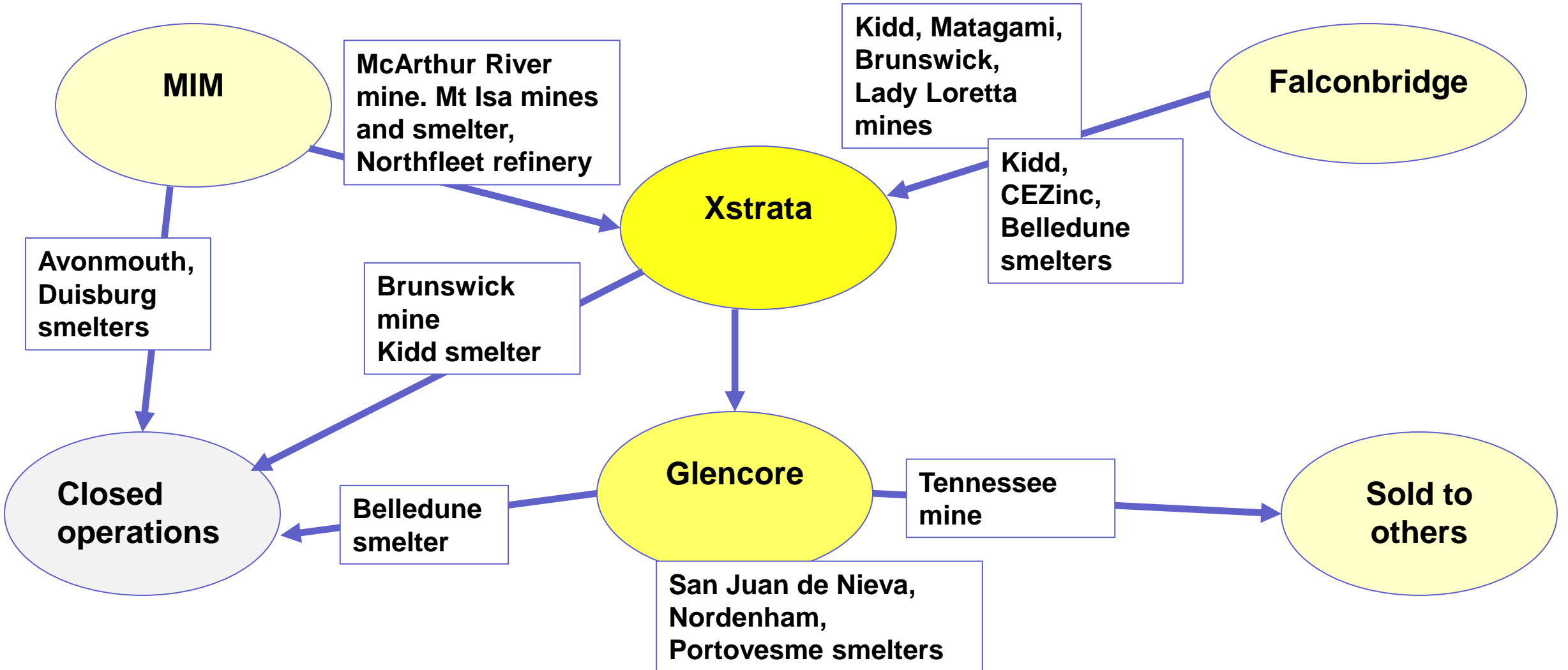
Name	Country	Metal	Process	Capacity	Year closed
Cockle Creek (Pasminco)	Australia	Pb-Zn-Ag	ISP	90,000 tpa Zn, 35,000 tpa Pb	2003
Avonmouth (MIM)	UK	Pb-Zn-Ag	ISP	90,000 tpa Zn, 35,000 tpa Pb	2003
Noyelles-Godault (Metaleurop)	France	Pb-Zn-Ag	ISP	100,000 tpa Zn, 140,000 tpa Pb	2003
Duisburg (MIM)	Germany	Pb-Zn-Ag	ISP	100,000 tpa Zn, 35,000 tpa Pb	2005
Big River Zinc (Korea Zinc)	USA	Zn	Electrolytic	90,000 tpa Zn	2006
Ruhr Zink (GEA)	Germany	Zn	Electrolytic	140,000 tpa Zn	2008
Kidd (Xstrata)	Canada	Zn	Electrolytic	145,000 tpa Zn	2010
Herculaneum (Doe Run)	USA	Pb	Sinter plant blast furnace	115,000 tpa Pb	2013
Belledune (Glencore)	Canada	Pb-Ag	Sinter plant blast furnace	120,000 tpa Pb	2019



# De-integration: Pasminco/Zinifex – 2001 - 2019



# MIM/Falconbridge/Xstrata/Glencore – 2001 - 2019



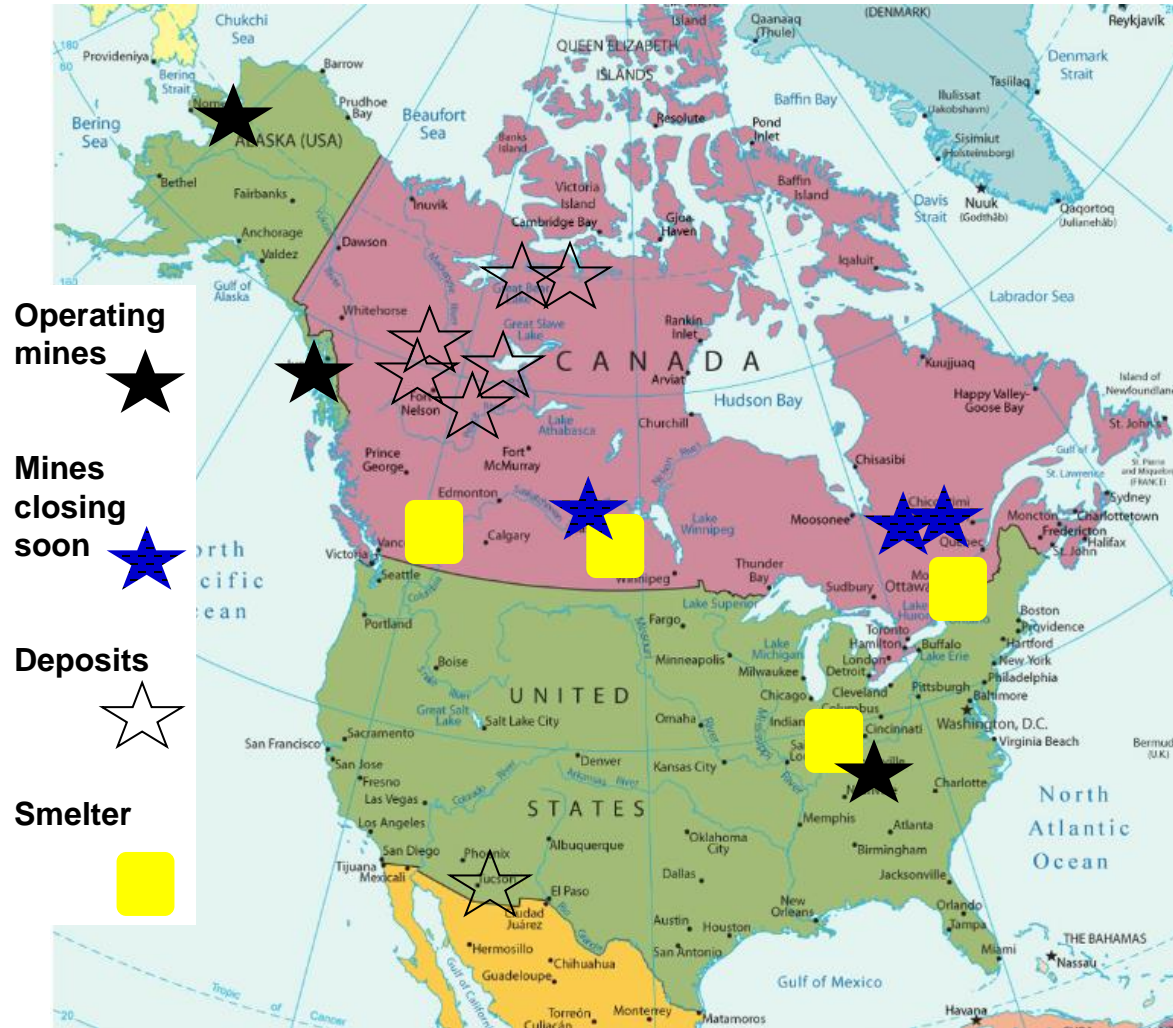
# Process Developments

- **Pasminco/Zinifex smelter process (Budel, Hobart) to handle higher SiO<sub>2</sub>, low Fe Century concentrates**
- **Decline in ISF smelting has created a need for alternative processing options for Zn concentrates with high Pb levels:**
  - **Ultrafine grinding and improved selective flotation**
  - **McArthur River oxidative leach to make Pb concentrate to Mt Isa smelter and higher grade Zn concentrate, installed Albion leaching circuits at San Juan de Nieva, Nordenham to produce PbSO<sub>4</sub> + S<sub>(0)</sub> residue for secondary treatment**
  - **Investigations into TSL smelting technologies integrated with Zn smelters to process Pb bearing residues (Port Pirie model)**





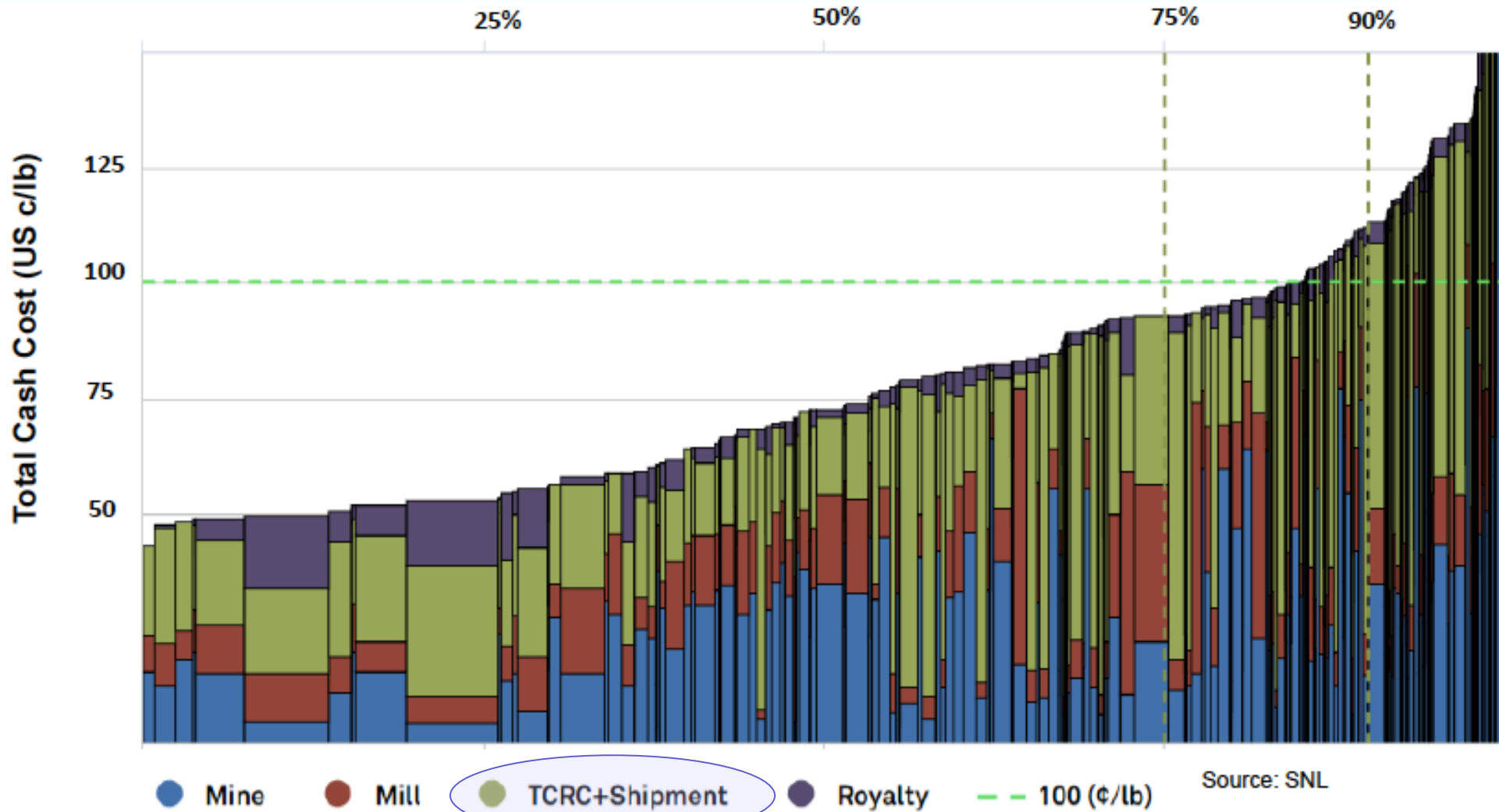
# Canada and US Major Zn Bearing Deposits



- **Long-life mines in US:**
  - Red Dog and Greens Ck, AK
  - Tennessee + Clarksville Smelter
- **Cu-Zn mines to close soon**
  - 777, SK
  - Kidd, Matagami ON
- **Major Zn deposits**
  - YK, NWT, NU - formidable transport challenges
  - AZ cheaper transport via Mexico



# Cash Costs - Zn



- TC and transport is major component of costs for most mines

Source: SNL

Source: Osisko Metals Corporate Presentation Q1 2020



# Treatment Charges



- TCs reflect relative scarcity/abundance of concentrates
- Huge volatility in spot TCs
- Major increase in benchmark TCs in 2019 after previous lows
- Formerly integrated miners and smelting companies were less susceptible to TC variation

Source:

[https://vp217.alertir.com/sites/default/files/report/q4\\_2019\\_boliden\\_presentation\\_0.pdf](https://vp217.alertir.com/sites/default/files/report/q4_2019_boliden_presentation_0.pdf)



# TC and Transport for Remote Canadian Projects

- Remote Zn projects in Yukon, NWT or Nunavut have ~US\$0.30 to \$0.45/lb payable Zn costs for transport and treatment charges
- Minimal advantage for sale to remaining Canadian Zn smelters due to locations and logistics
- High Zn metal prices needed to stimulate development of these projects (typically >US\$1.25/lb Zn)

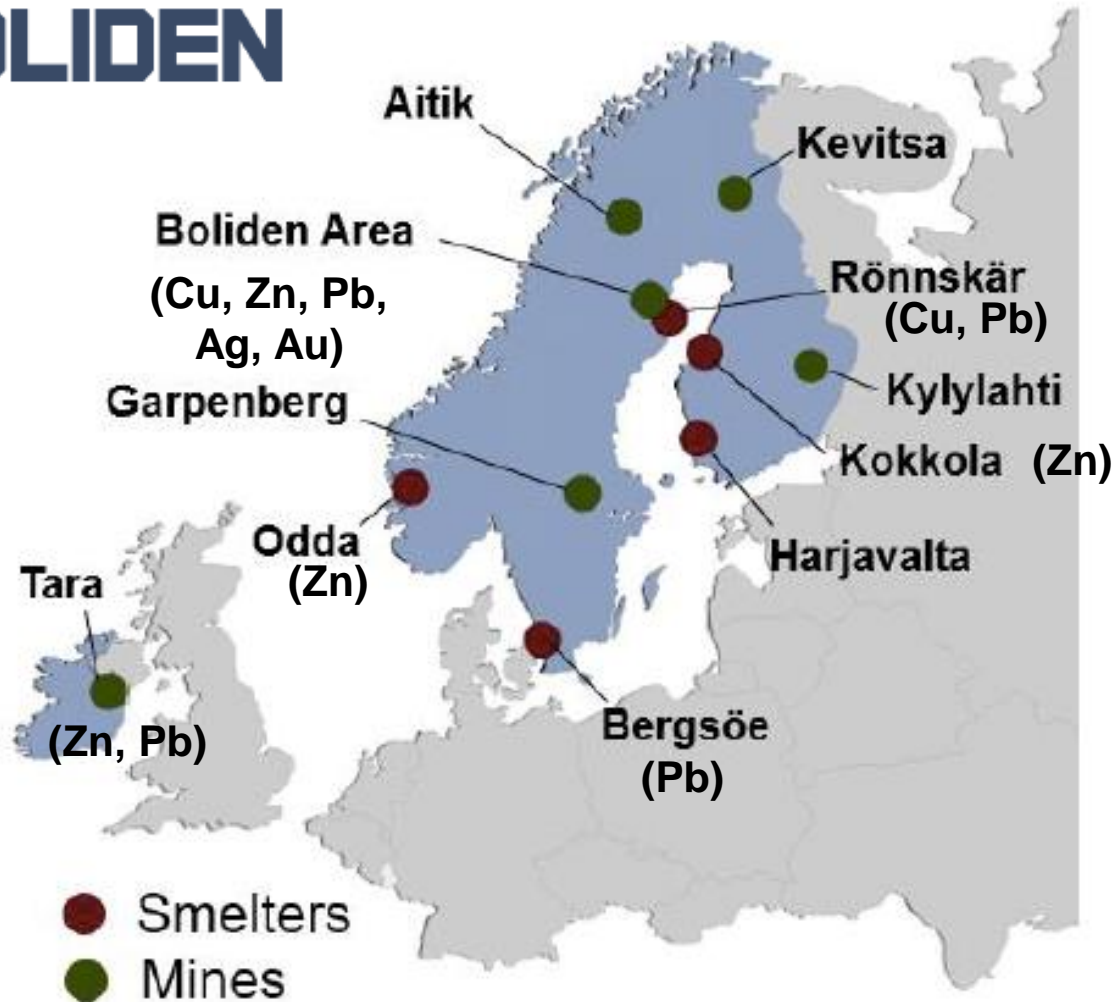
Zn con grade	54%
Actual payable	85%
lb Zn payable Zn/t con	1012
TC (US\$/dmt)	US\$/lb Zn payable
20	0.02
80	0.08
150	0.15
200	0.20
285	0.28
Transport (US\$/dmt)	US\$/lb Zn payable
175	0.17





# Case Study - Boliden

**BOLIDEN**



- **Integrated European mining, smelting and refining company**
  - Zn, Pb, Cu, Ni, precious metals, Polymetallic mines and smelters
  - Regional focus => low transport costs, access to other European Zn mines
  - Net importer ~200k Zn in concentrates
  - Smelters have flexibility for treating recycled materials (Pb, Cu, Ag, Au)
  - Synergies in Cu, Zn and Pb extraction
  - Vertical integration makes business less susceptible to shifts in TCs



# Conclusions

- **Geology affects mining methods, processing flowsheets, concentrate quality, by-product recovery and residue management => economics**
- **Role of primary Pb-Zn production in Australia, North America and Europe diminished, but still have an important role**
- **Major industry consolidation occurred in last 20 years, some painful**
- **Sustained higher metal prices needed stimulate development of major Canadian Zn-Pb-Ag resource projects to cover TCs, transport costs**
- **Some core mining and smelting assets will remain viable, esp. in companies with strategic vertical integration (Boliden, Teck, Glencore)**



# Questions?

**Resourceful Paths**



**Laurie Reemeyer**

**Principal Consultant**

**[laurie@resourcefulpaths.com](mailto:laurie@resourcefulpaths.com)**

**[www.resourcefulpaths.com](http://www.resourcefulpaths.com)**

