



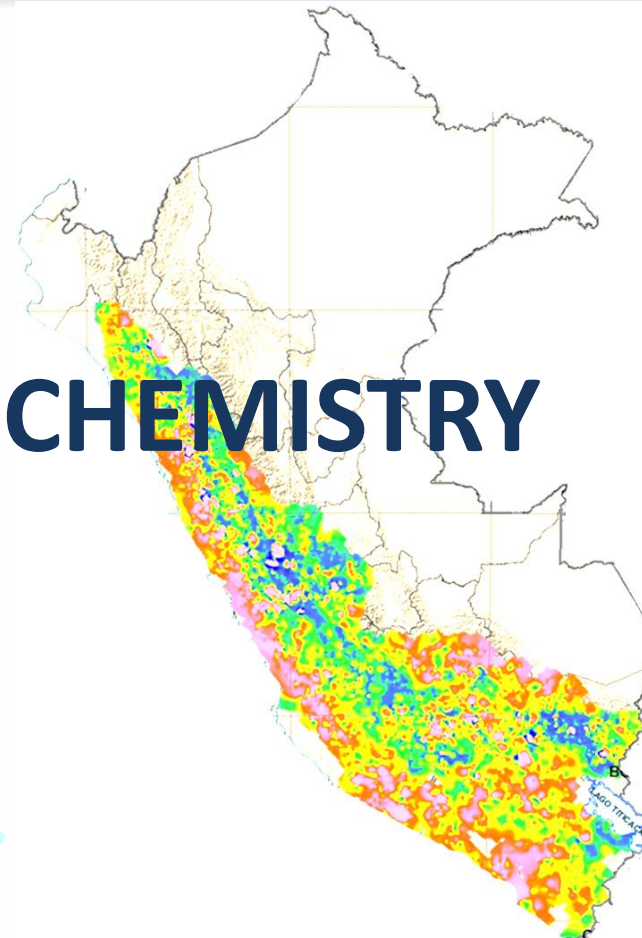
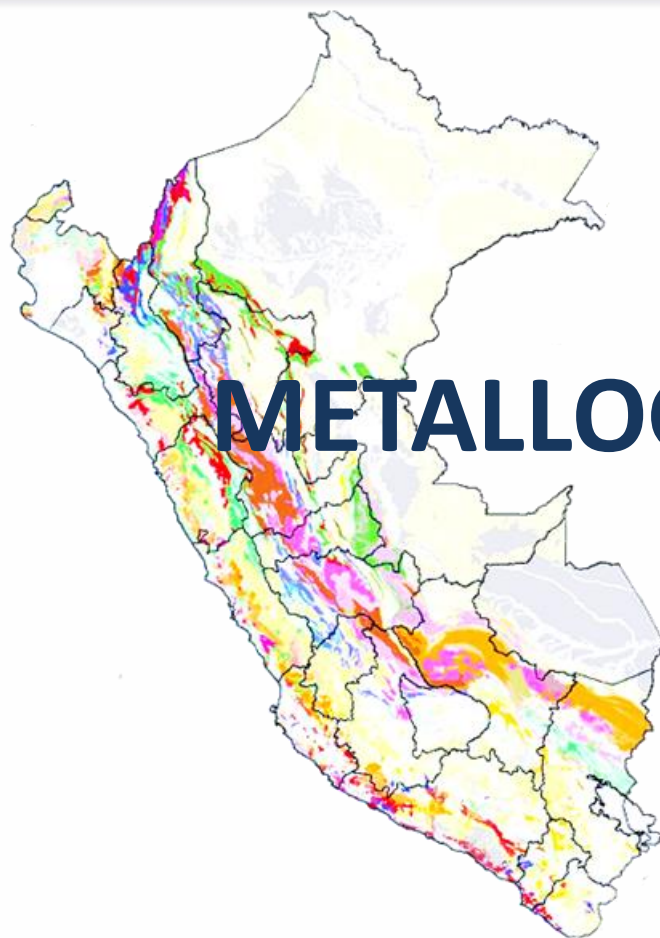
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 **INGEMMET**
INSTITUTO GEOLÓGICO MINERO Y METALÚRGICO

METALLOGENY AND GEOCHEMISTRY OF PERÚ



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Dina HUANACUNI, Italo RODRIGUEZ & Eder VILLARREAL**

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Dirección de Recursos Minerales y Energéticos
Programa de Metalogenia



Content

- Introduction
- Geochemistry
- Geochemical Atlas of Peru
- Metalland zinc metallogenic belts
- Global and local statistical data
- Local production by metallogenic belt and ore mineral deposit type
- National historical production
- Future Pb-Zn producers and supply trend





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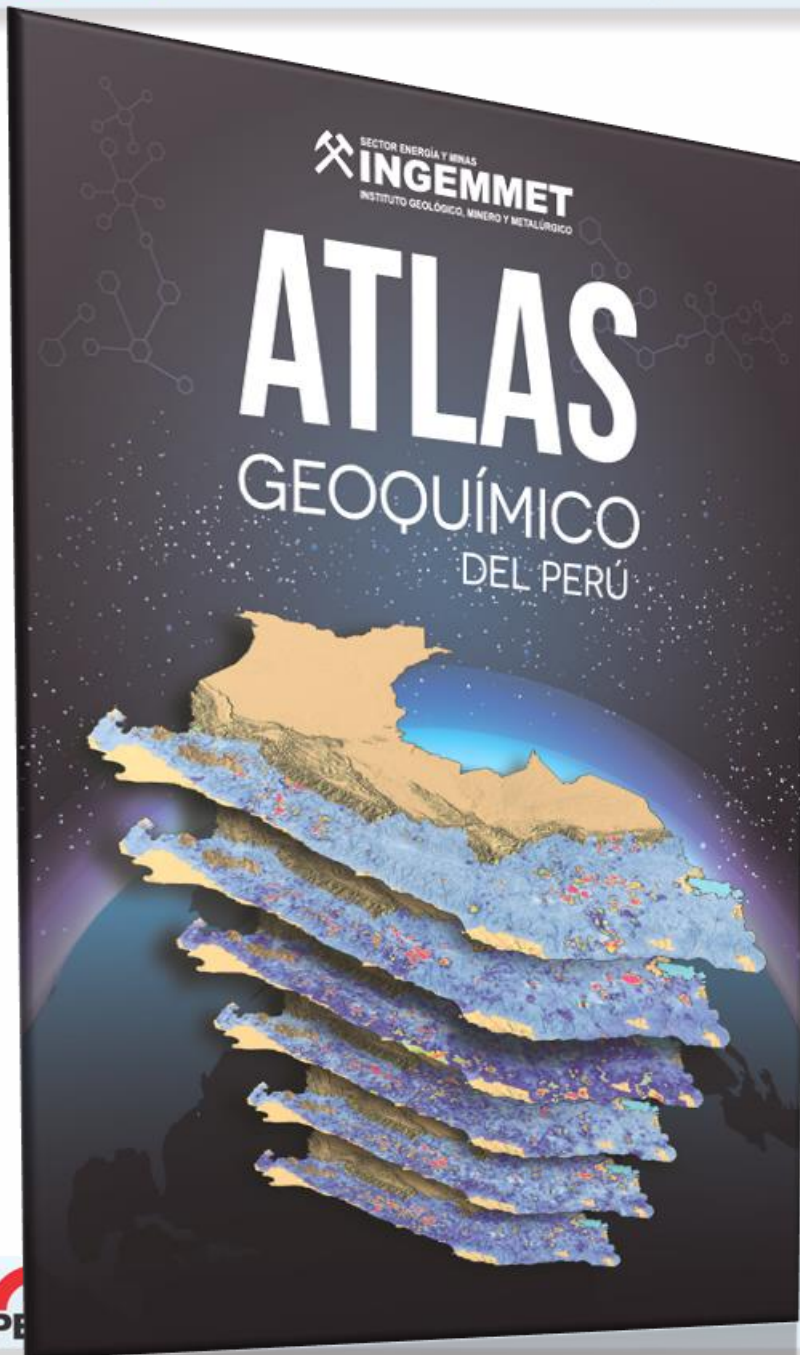
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GEOCHEMISTRY



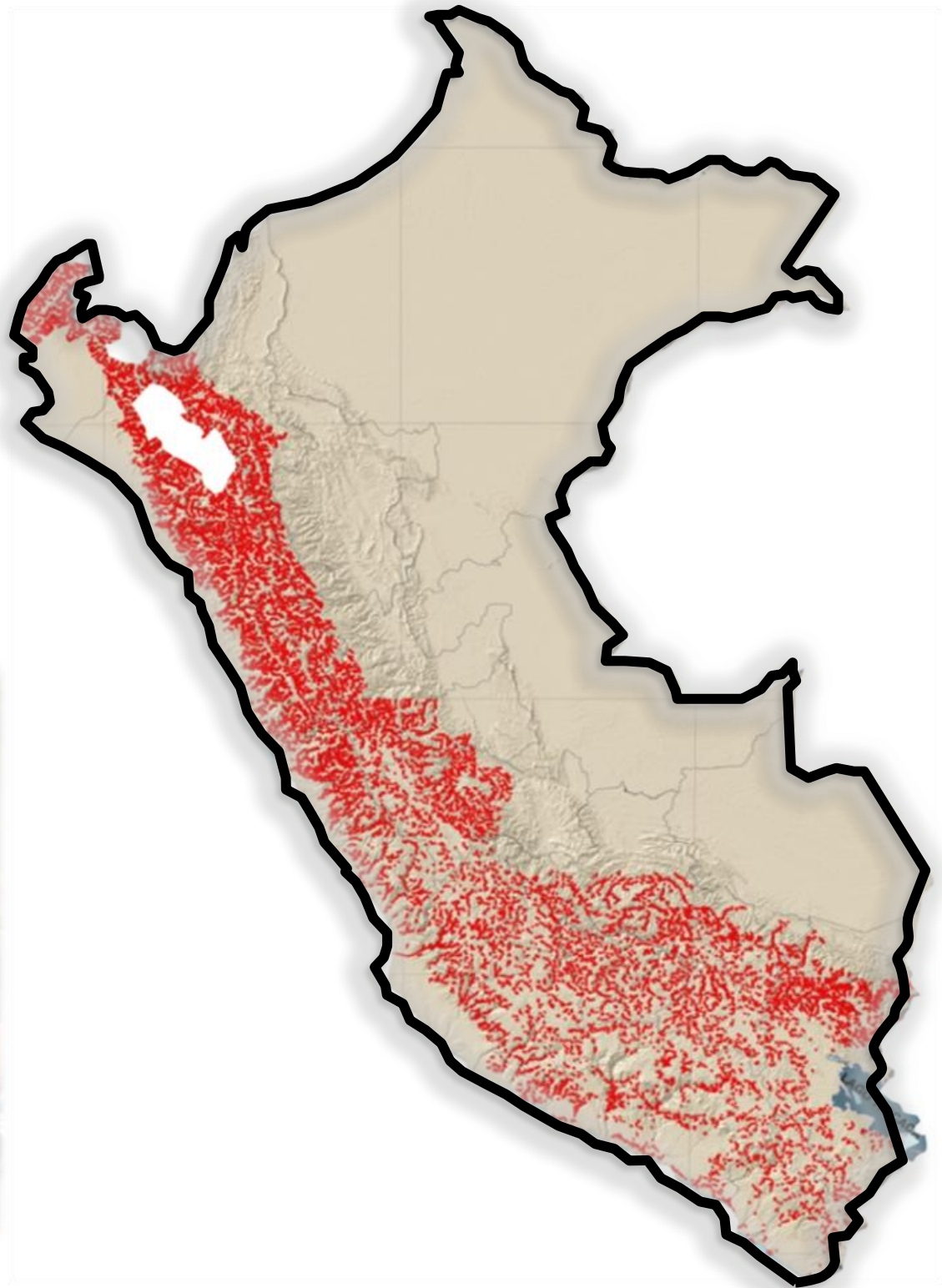
Geochemical Atlas of Peru

- > 22,500 stream sediment samples
- Samples collection from 2000 to 2014
- Number of chemical elements from 18 to 53 (traces and REE)
- 15 domains defined from 1:1'000,000 scale Geologic Map of Peru.



Distribution of stream sediment samples

60% of the territory is covered with stream sediment samples, useful for mineral exploration, geoenvironment base lines, etc.



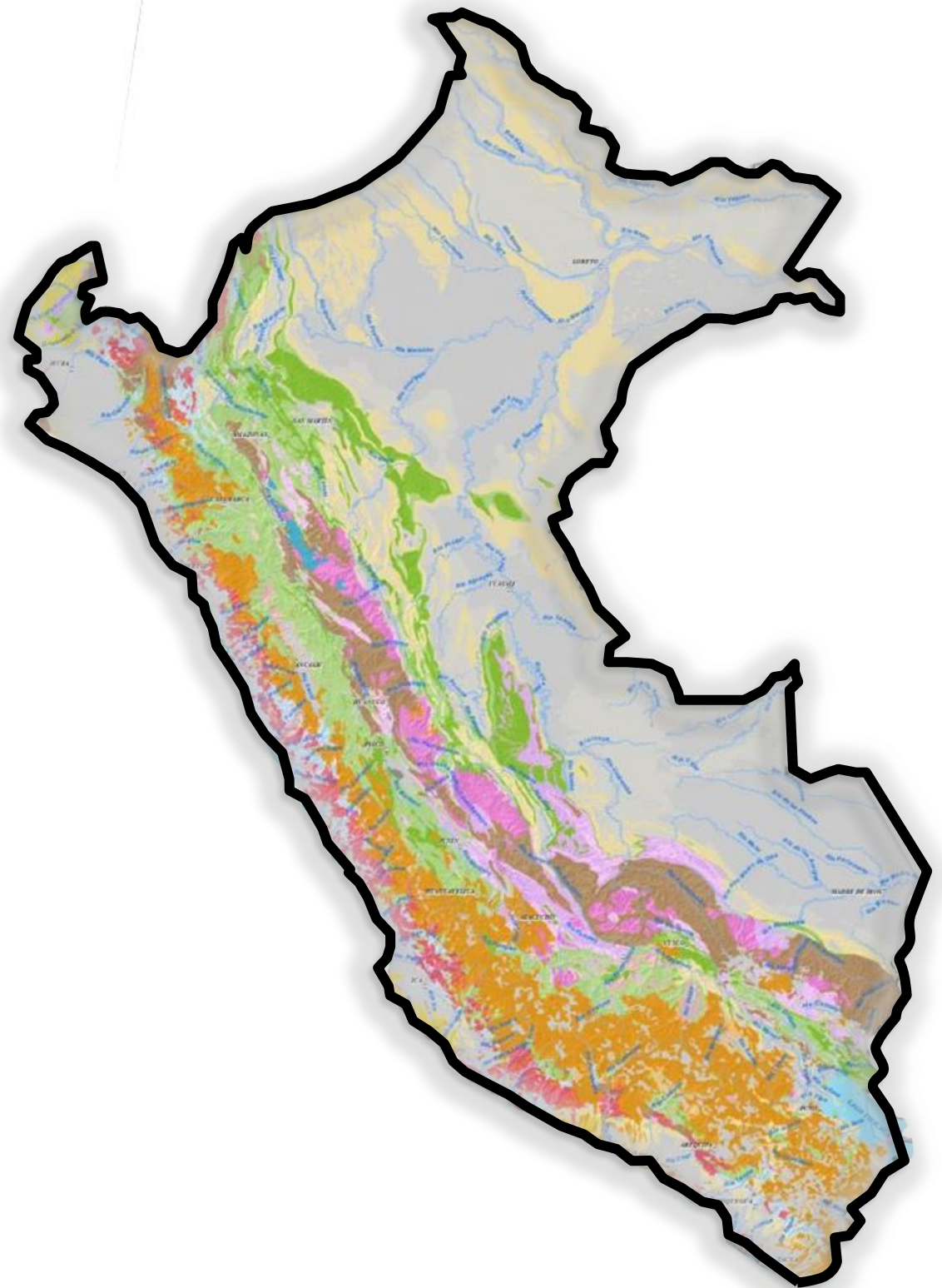
Geochemical Analysis

Chemical elements	Unit	Period
Au	ppb (parts per billion)	1° (2000 - 2003)
Cr, Cu, Mn, P, Sr, V, Zn, Zr, Ag, As, Be, Bi, Cd, Co, Hg, La, Mo, Ni, Pb, Sb, Sc, Sn, W, Y	ppm (parts per million)	
Al, Ca, Fe, K, Mg, Na, Ti	% (porcentage)	
Au	ppb (parts per billion)	2° (2004 - 2014)
Al, Ca, Cr, Cu, Fe, K, Mg, Na, Mn, P, Sr, Ti, V, Zn, Zr, Ag, As, Be, Bi, Cd, Co, Hg, La, Mo, Ni, Pb, Sb, Sc, Sn, W, Y, B, Ba, Li, S, Ce, Cs, Ga, Ge, Hf, In, Lu, Nb, Rb, Se, Ta, Tb, Te, Th, Tl, U, Yb	ppm (parts per million)	

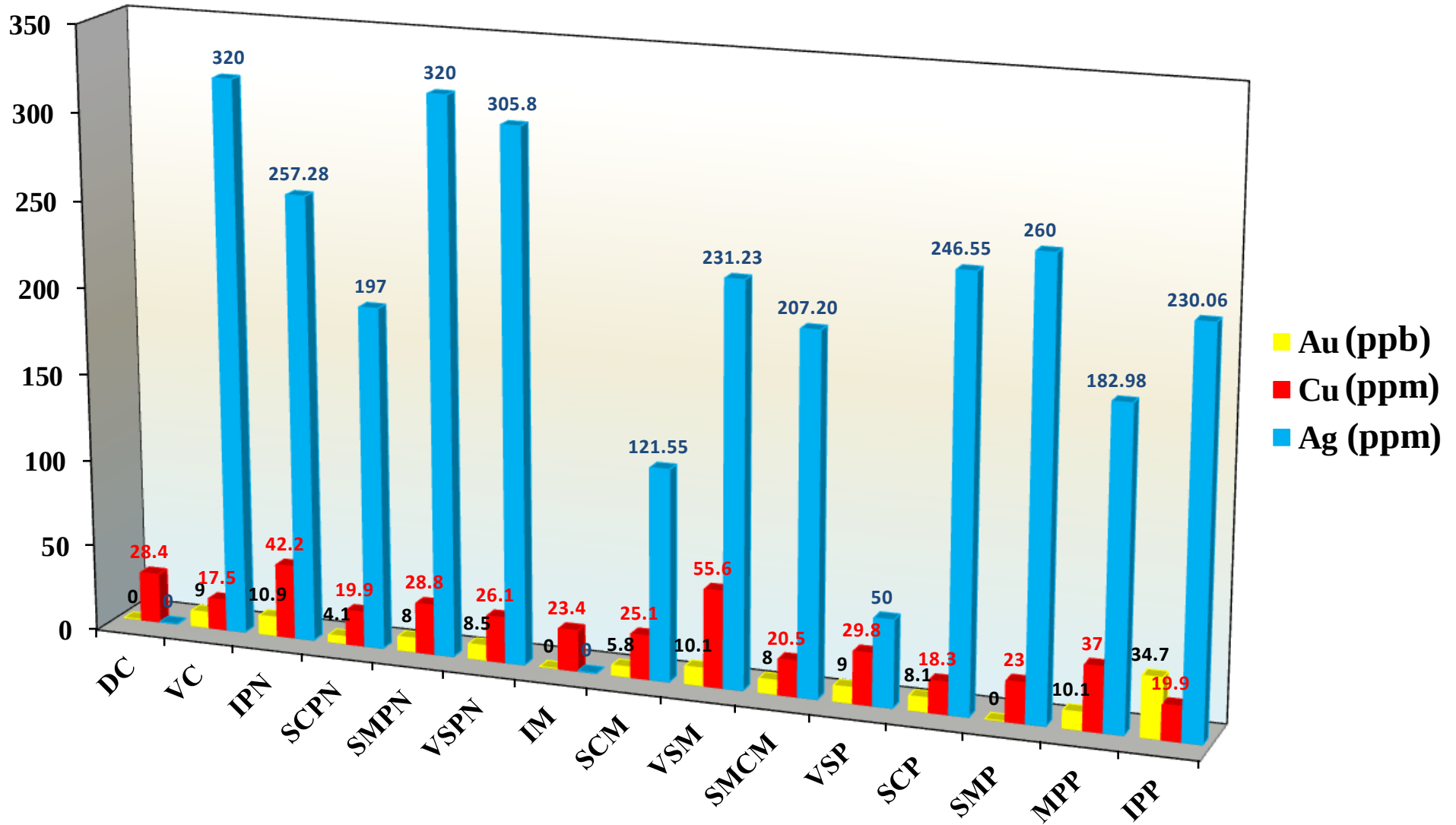
Geologic domain and lithology

Legend

- | |
|---|
| Depósitos del Cuaternario |
| Volcánicos del Cuaternario |
| Volcánicos sedimentarios del Paleógeno-Neógeno |
| Sedimentarios continentales del Paleógeno-Neógeno |
| Sedimentarios marinos del Paleógeno-Neógeno |
| Volcánicos sedimentarios del Mesozoico |
| Sedimentarios continentales del Mesozoico |
| Sedimentarios marinos y continentales del Mesozoico |
| Volcánicos sedimentarios del Paleozoico |
| Sedimentarios continentales del Paleozoico |
| Sedimentarios marinos del Paleozoico |
| Metamórficos del Precámbrico-Paleozoico |
| Intrusivos del Paleógeno-Neógeno |
| Intrusivos del Mesozoico |
| Intrusivos del Precámbrico-Paleozoico |

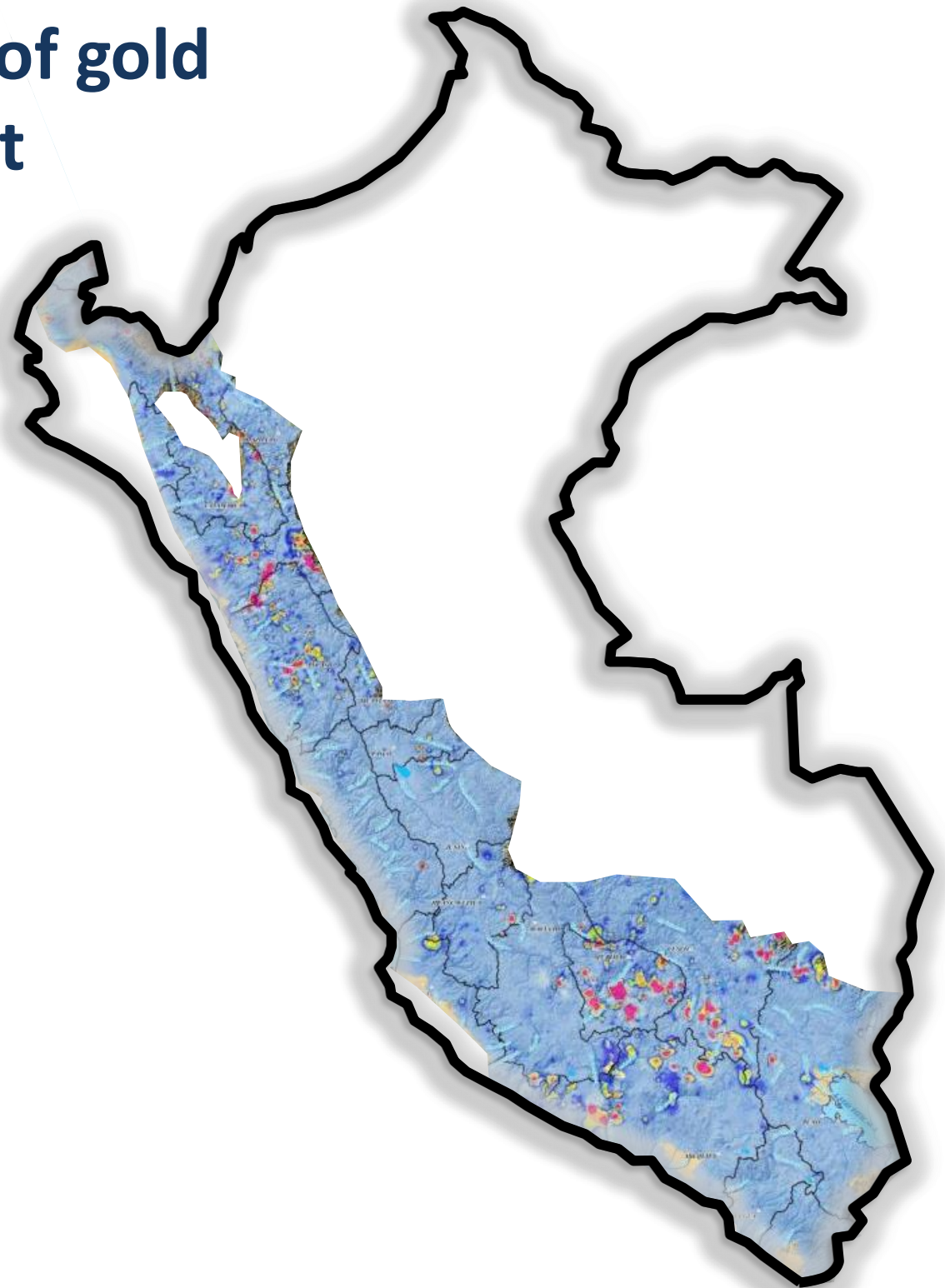
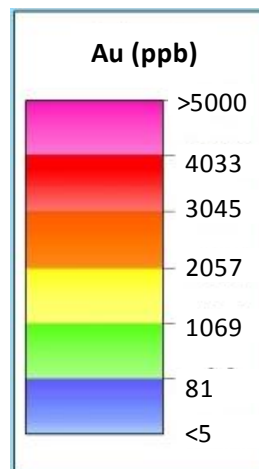


BACKGROUND (Au-Cu-Ag)



Geochemical dispersion of gold in stream sediment

Background: 35-4 ppb
Threshold: 169-19 ppb



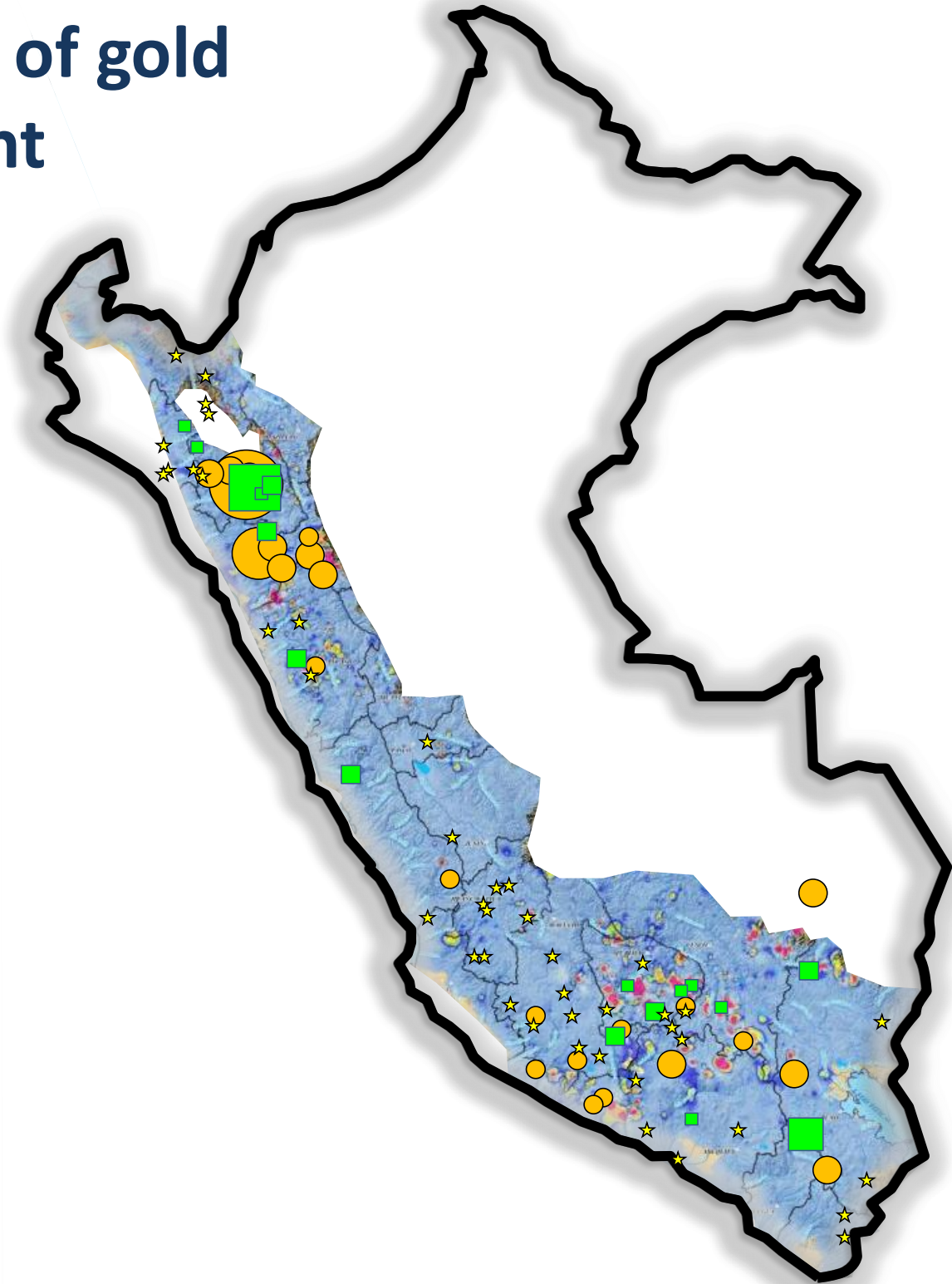
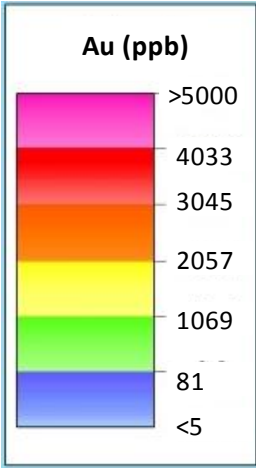
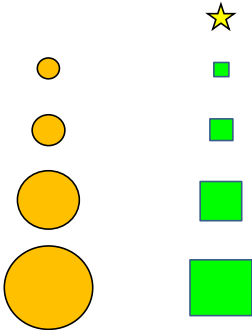
Geochemical dispersion of gold in stream sediment

Actual or planned annual production ounces of fine gold X 1000

- 0
- < 100
- 100-400
- 400-600
- > 600

Mines

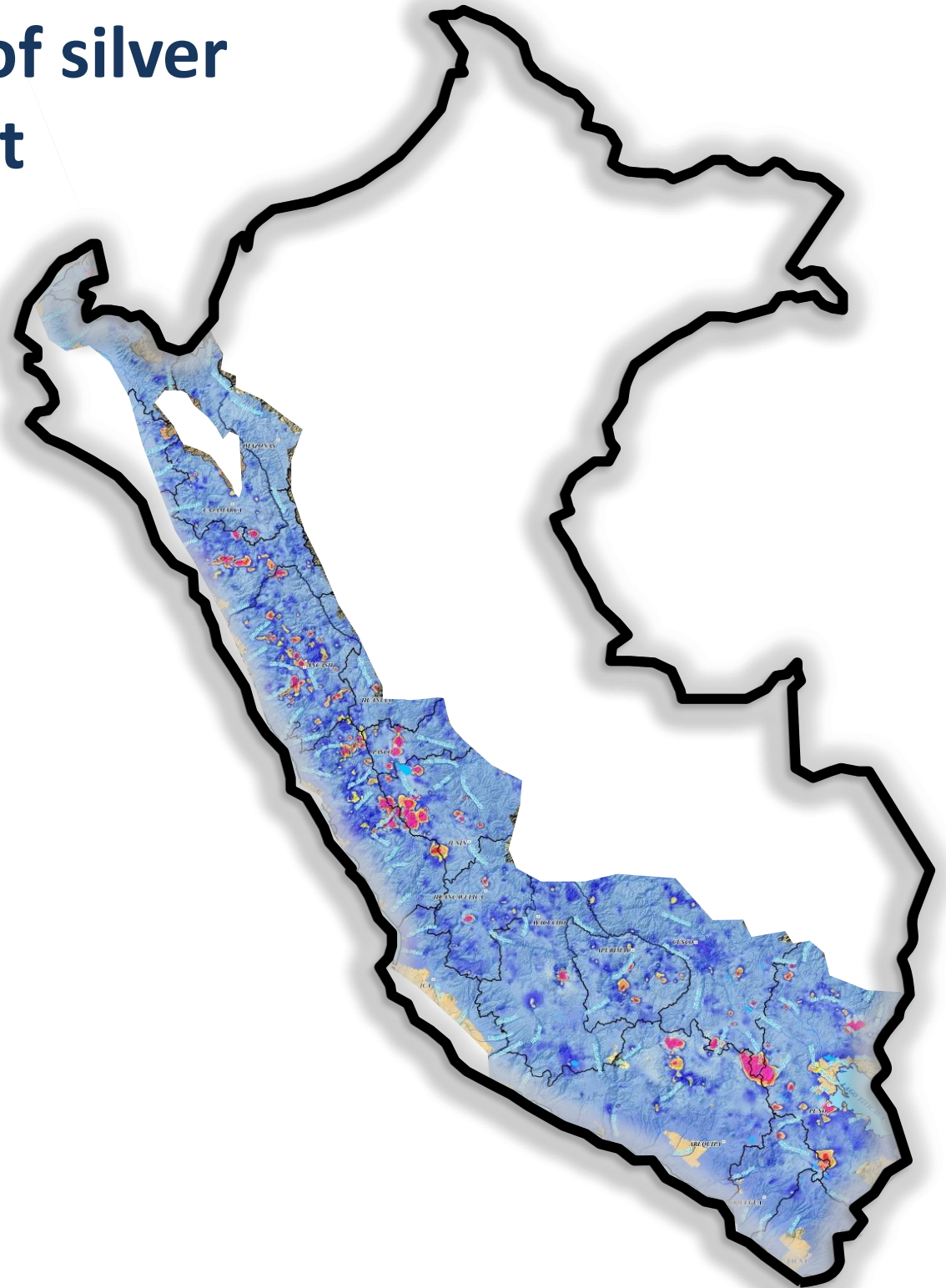
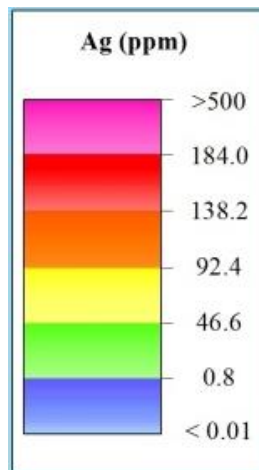
Projects



Geochemical dispersion of silver in stream sediment

Background: 0.32-0.50 ppm

Threshold: 0.93-0.28 ppm

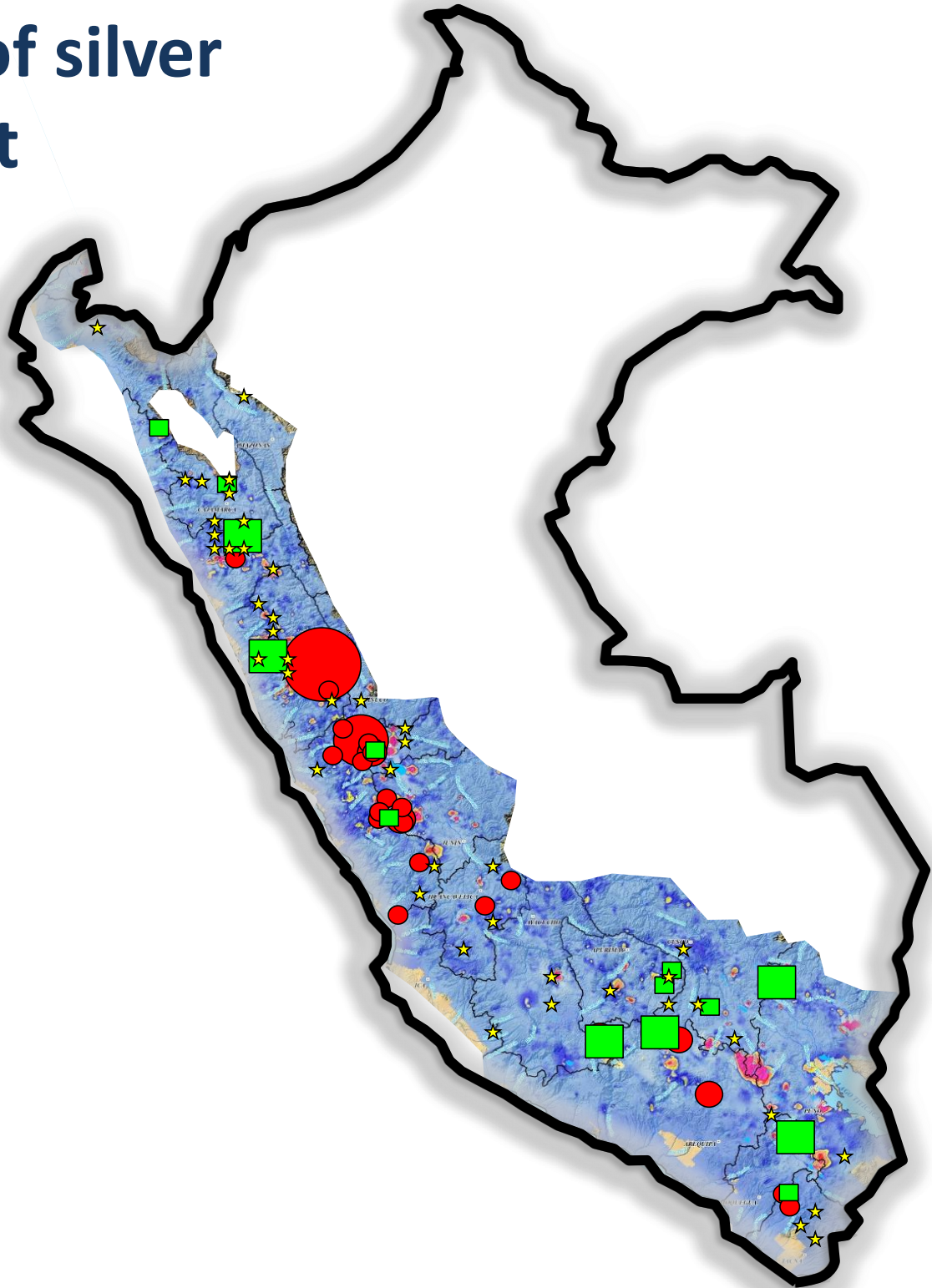
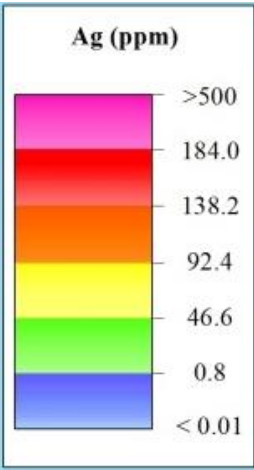
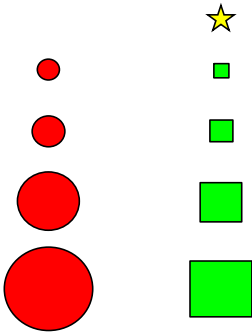


Geochemical dispersion of silver in stream sediment

Actual or planned annual production ounces of fine silver

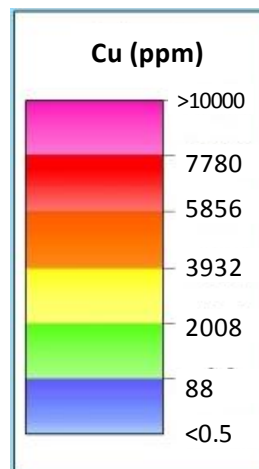
- 0
- < 100
- 100-400
- 400-600
- > 600

Mines Projects



Geochemical dispersion of copper in stream sediment

Background: 56-18 ppm
Threshold: 158-52 ppm



Geochemical dispersion of copper in stream sediment

Actual or planned annual
production metric tons of
fine copper
X 1000

0

1-10

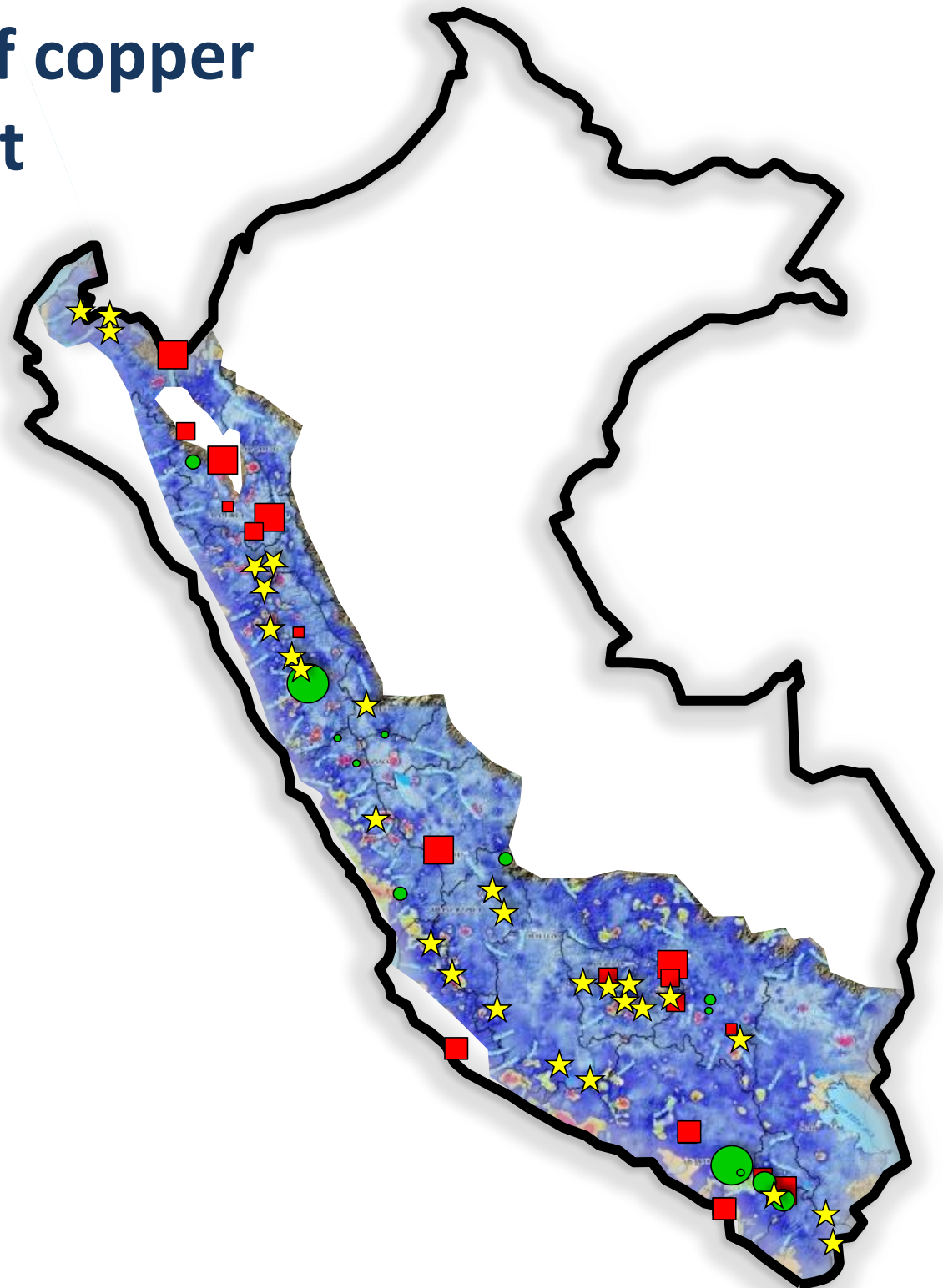
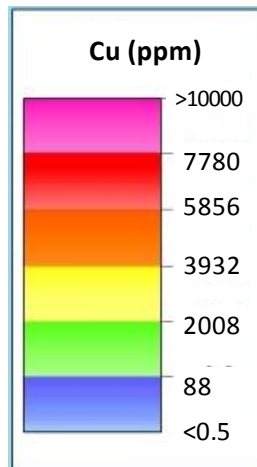
10-50

50-200

200-500

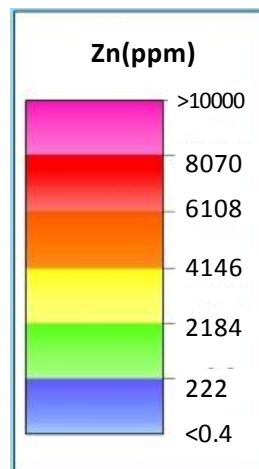
Mines

Projects



Geochemical dispersion of zinc in stream sediment

Background: 94-57 ppm
Threshold: 262-135 ppm



Geochemical dispersion of zinc in stream sediment

Actual or planned annual
metric tons of fine zinc

X 1000

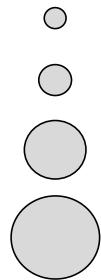
< 50

50-100

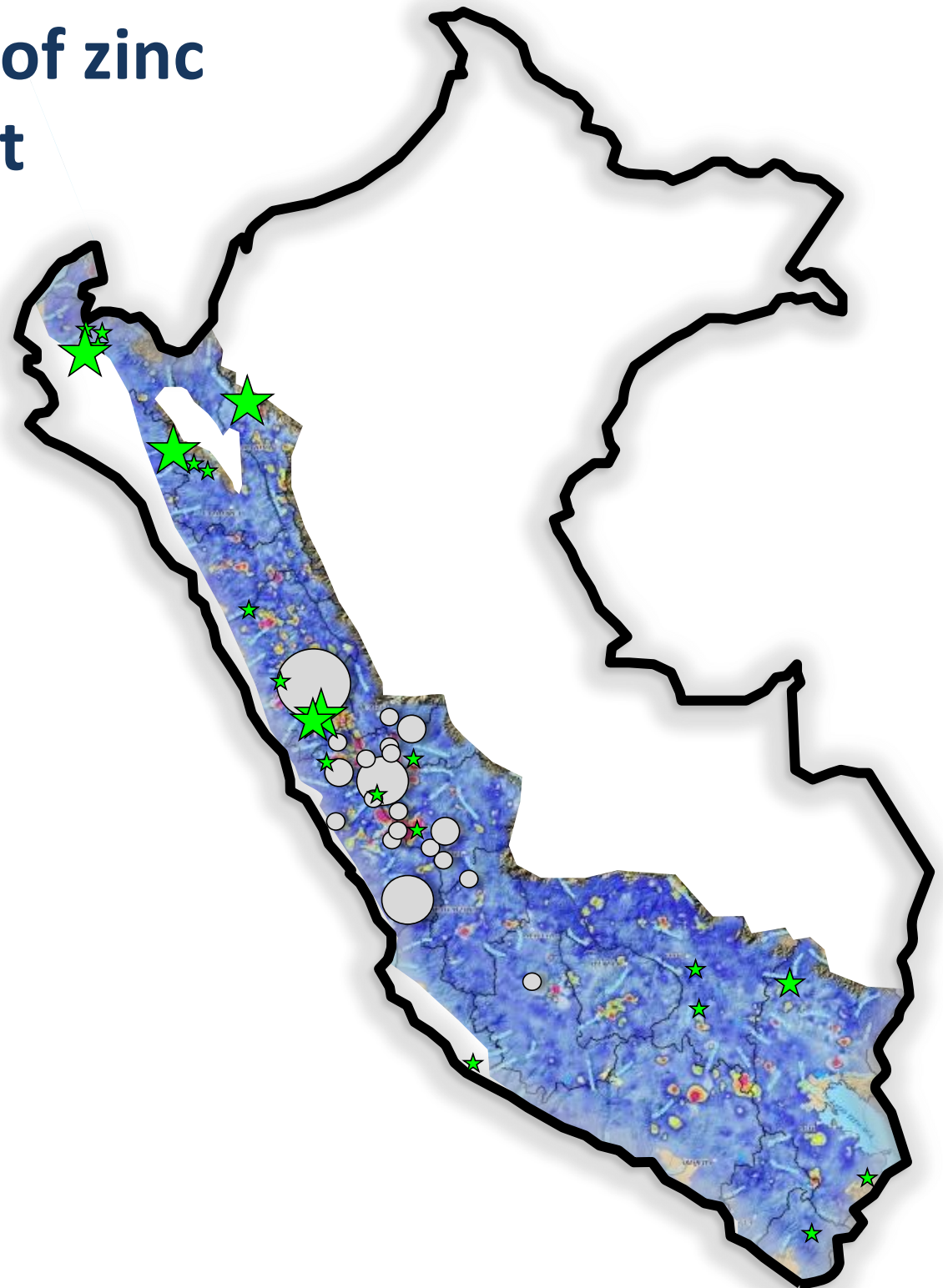
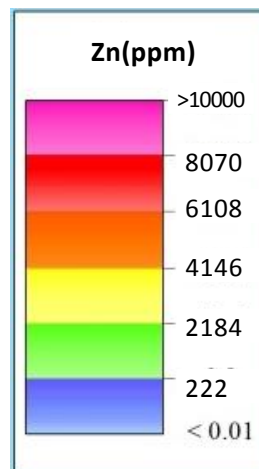
100-200

> 200

Mines



Projects





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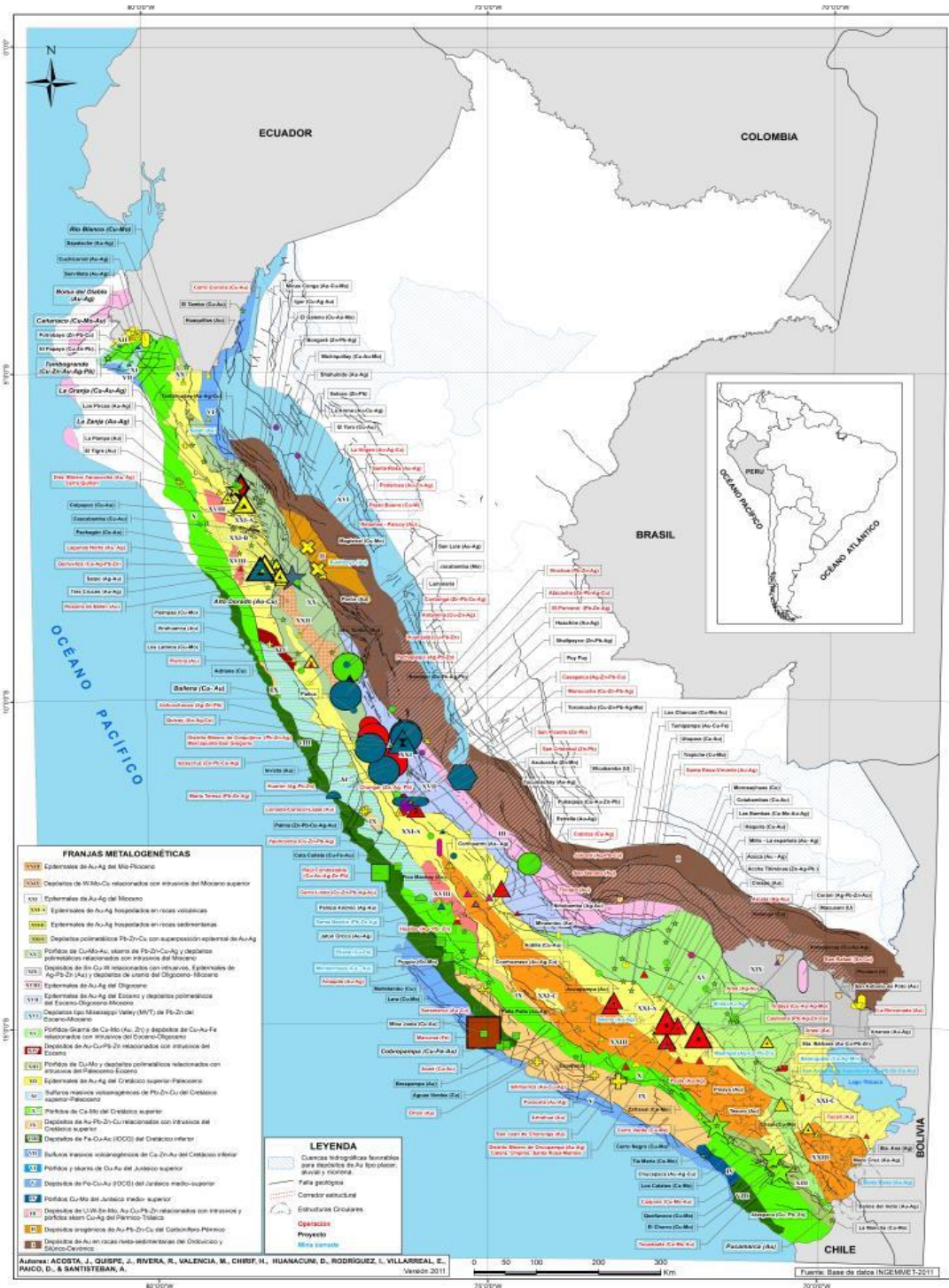
METALLOGENY



Metallogenic map of Peru

23 Metallogenic belt classified by:

- Type of ore mineral deposit
- Size of mineral deposit
- Type of metallic commodity
- Metallic belt production by Au, Ag, Cu, Pb, Zn
- Metallic belt resources by Au, Ag, Cu, Pb, Zn



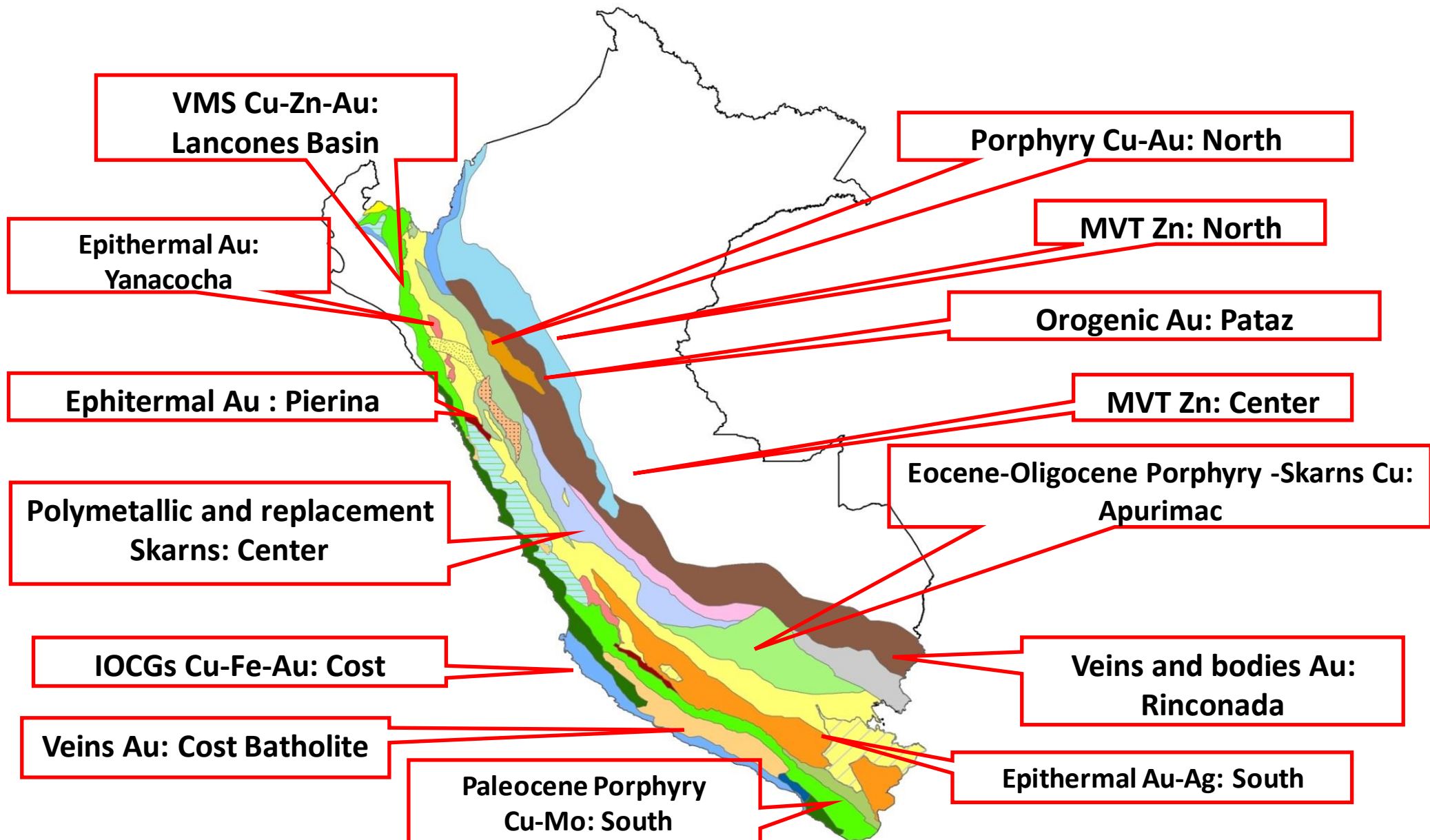
TAMANO DEL VOLUMEN METALICO (TONELADAS)

Elemento	Proyecto	Proyecto	Mediana	Grande	Muy Grande
Au	< 100	100 - 200	200 - 500	> 500	> 1000
Ag	< 100	100 - 200	200 - 500	> 500	> 1000
Cu	< 100	100 - 200	200 - 500	> 500	> 1000
Pb	< 100	100 - 200	200 - 500	> 500	> 1000
Zn	< 100	100 - 200	200 - 500	> 500	> 1000



Sector Energía y Minas
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Metallogenic belts





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Peruvian Gold Belts



Gold Mines in Peru - 2013

Annual Production
Onces of Fine Gold

X 1000

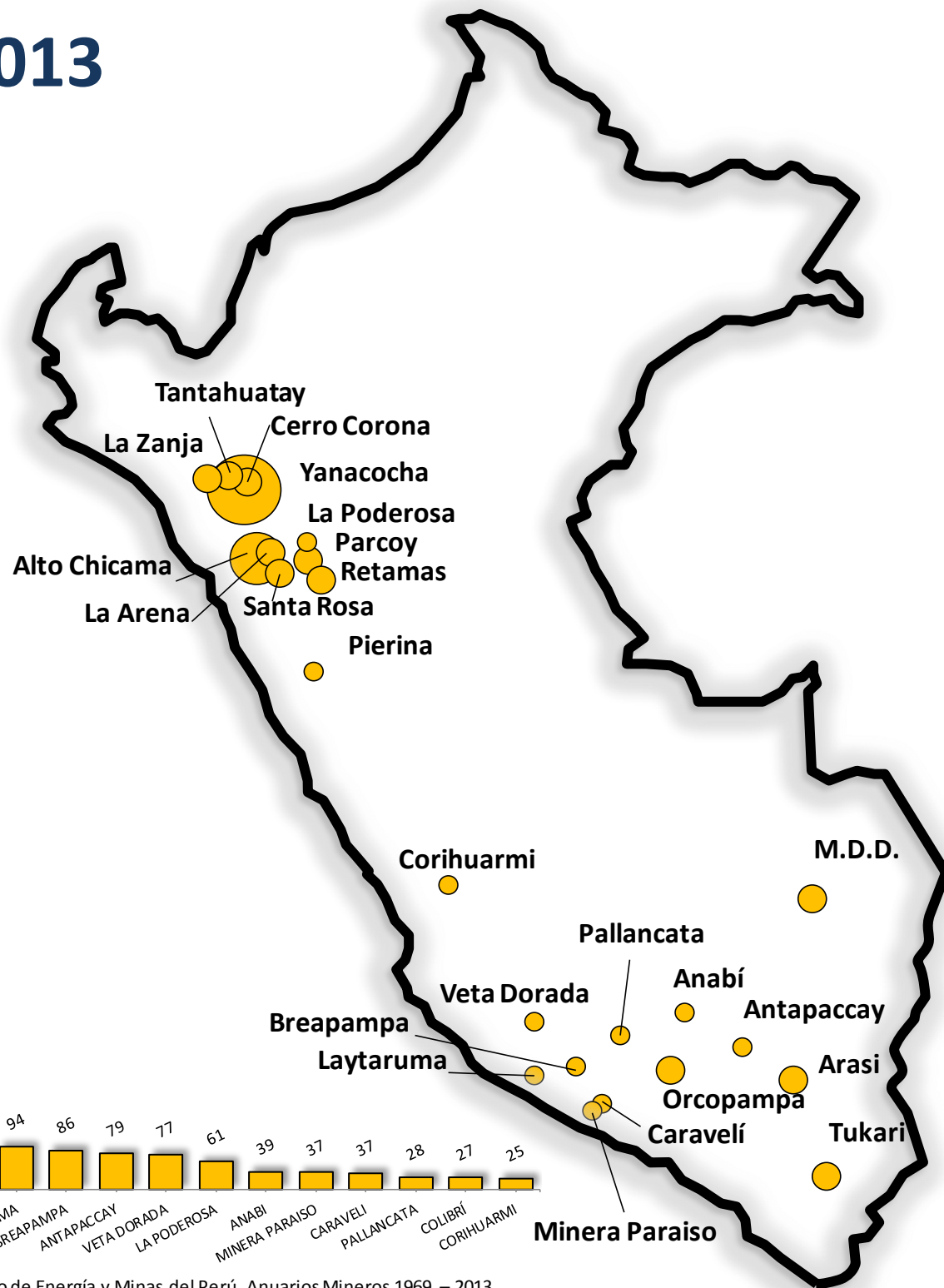
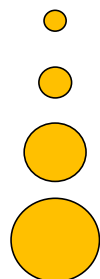
< 100

100-500

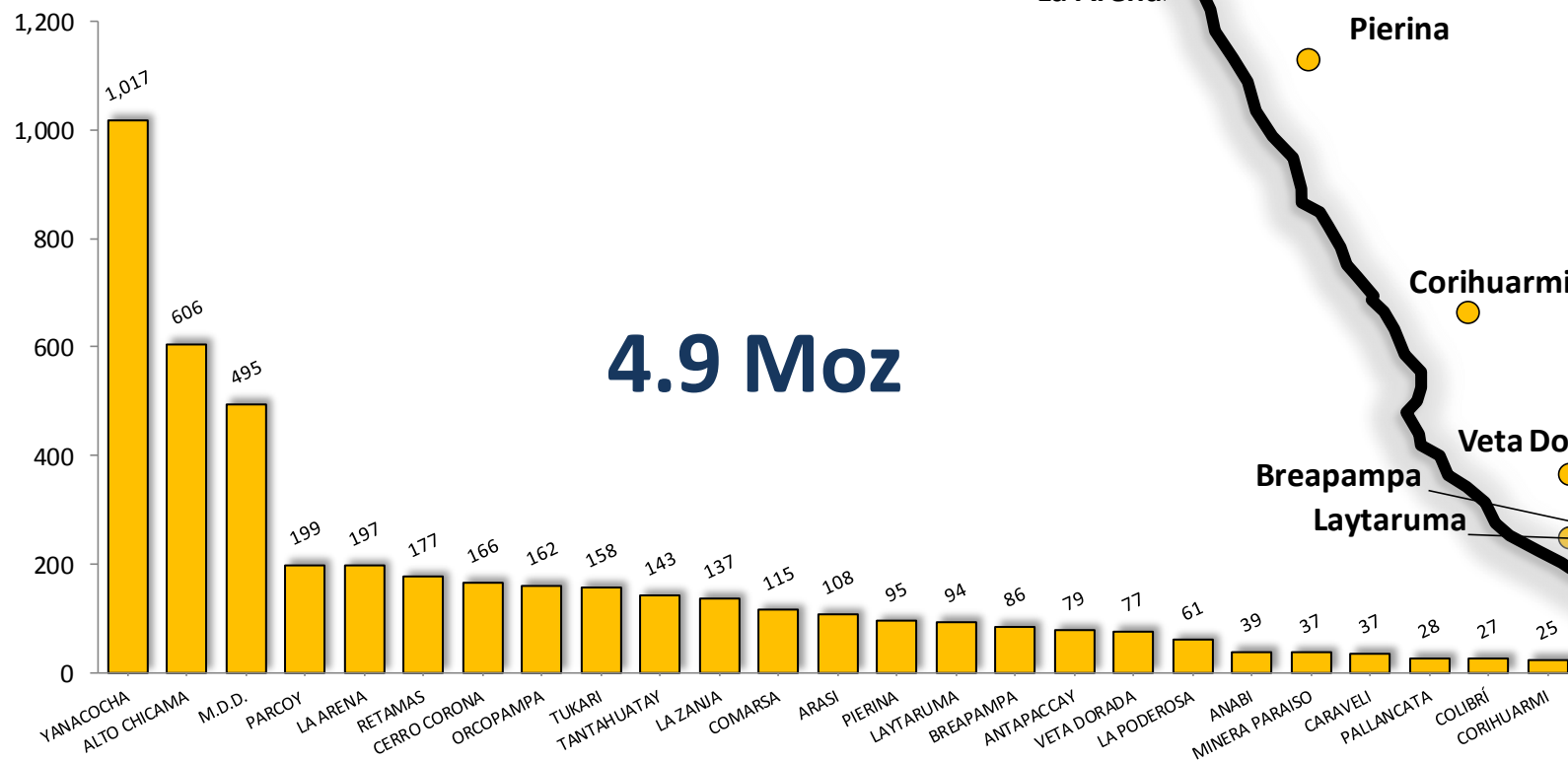
500-1000

> 1000

Mines



4.9 Moz



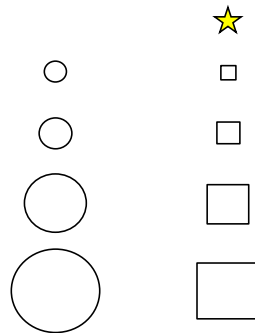
Main Gold Belts, Mines and Projects in Peru

Actual or Planned Annual
Production Onces of Fine
Gold X 1000

0
< 100
100-400
400-600
> 600

Mines

Projects

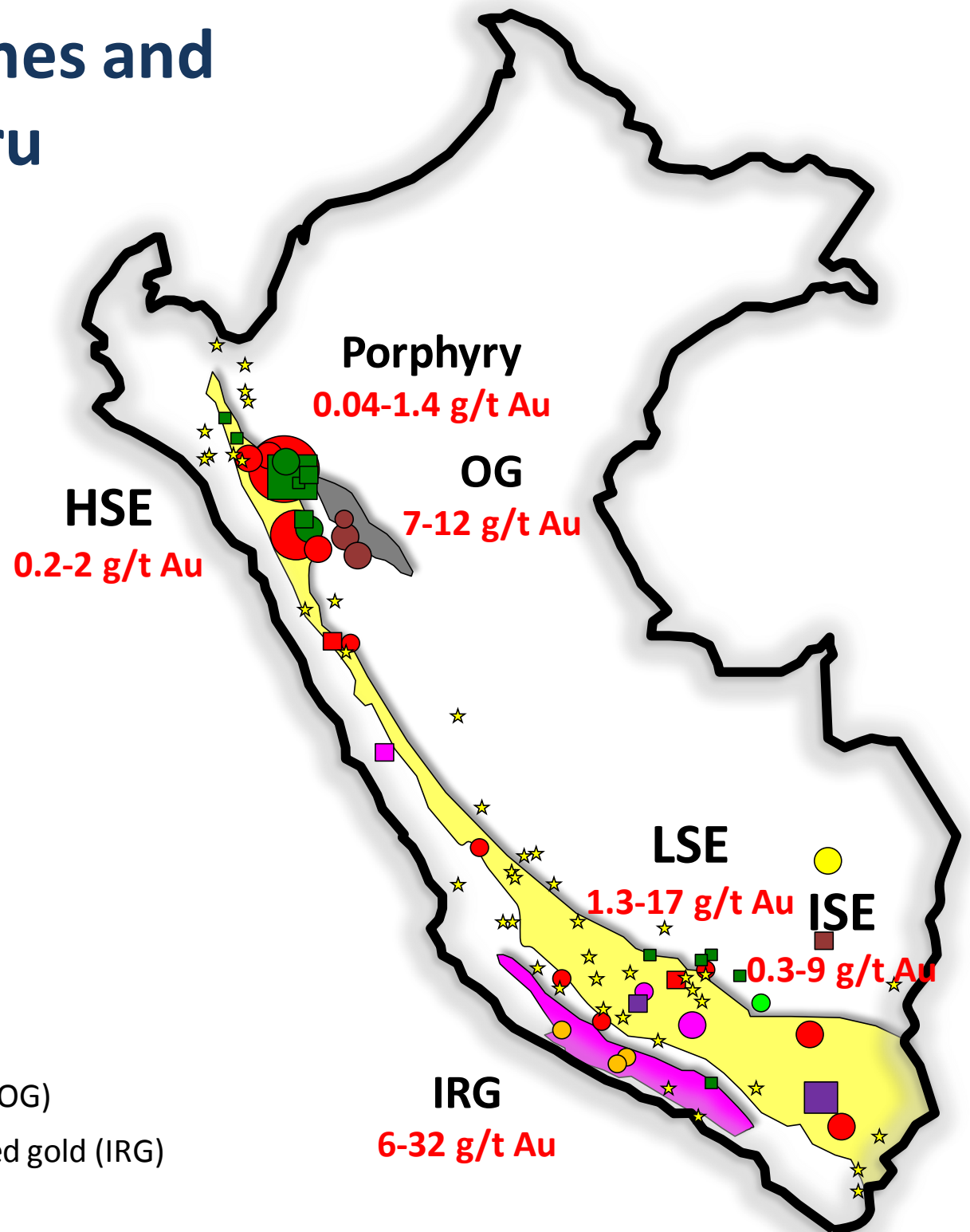


Metallogenic belts

- Miocene epithermal belt
- Upper Cretaceous intrusion-related gold belt
- Carboniferous-Permian orogenic gold belt

Deposit Types

- HS Epithermal (HSE)
- IS Epithermal (ISE)
- LS Epithermal (LSE)
- Porphyry
- Skarn
- Orogenic gold (OG)
- Intrusion-related gold (IRG)
- Placer



Historic Cumulative Gold Production in Peru

Total Production in Peru

118 Moz (100%)

Production from main gold belts

99 Moz (84%)

Other Au belts: 4 Moz (3%)

Other non-Au belts: 15 Moz (13%)

Million Ounces
of Fine Gold

< 1

5-1

30-5

> 30

Mines



Metallogenic belts



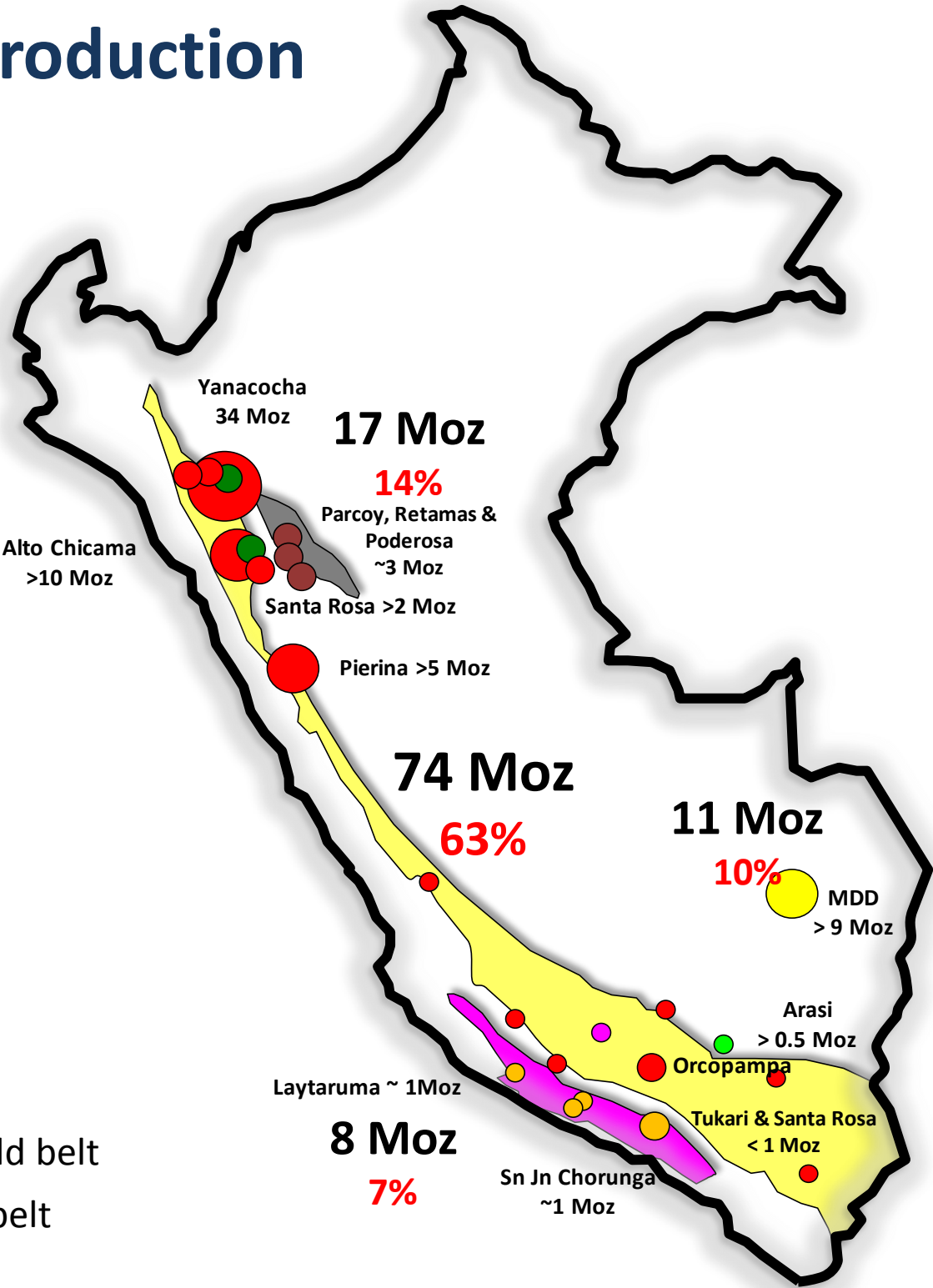
Miocene epithermal belt



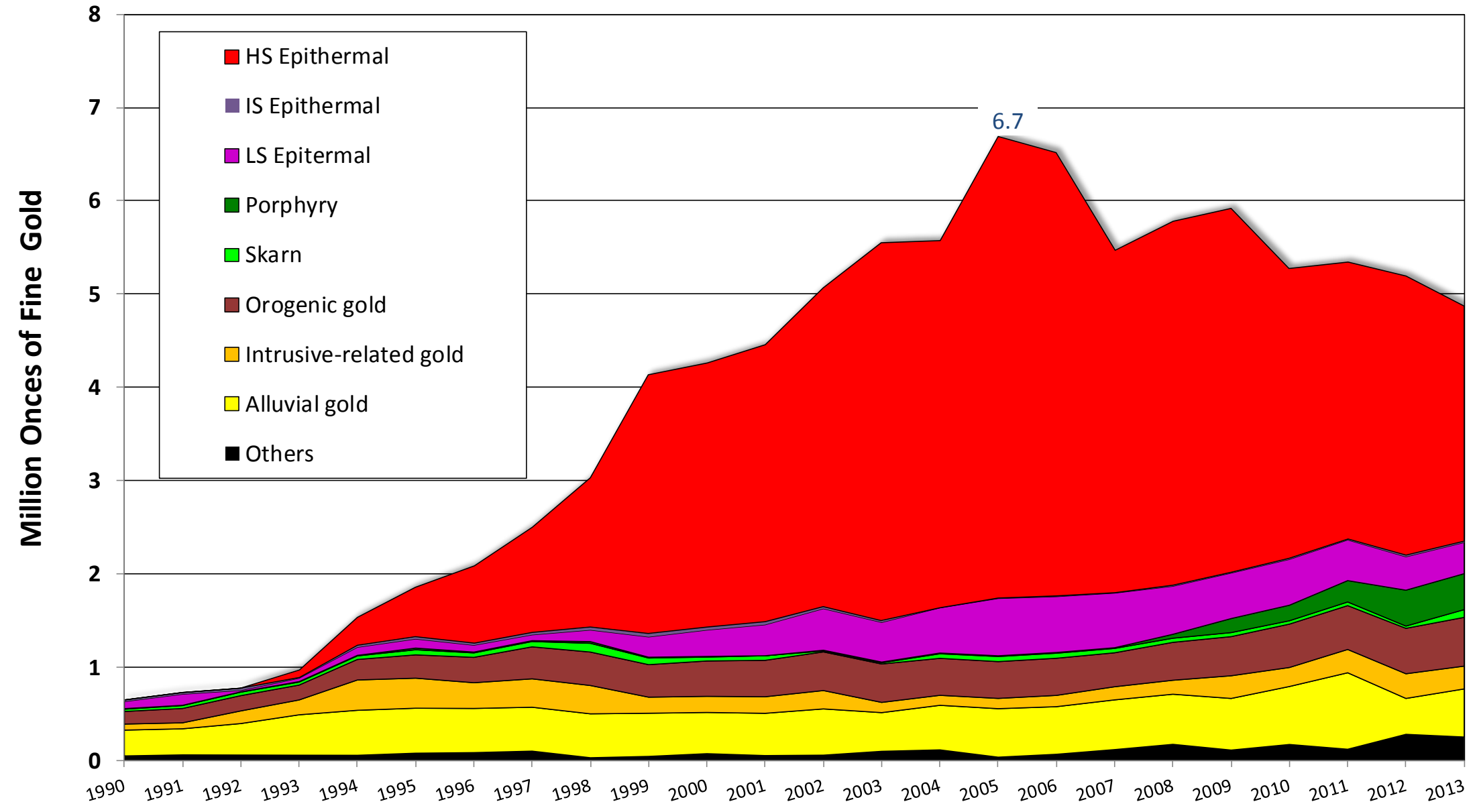
Upper Cretaceous intrusion-related gold belt



Carboniferous-Permian orogenic gold belt



Peruvian Gold Production by Deposit Types



Gold Resources and Reserves in the Main Belts in Peru

Total reported resources in Peru

192 Moz (100%)

Resources from gold belts

130 Moz (67%)

Other Au belts 53 MMT (28%)

Other non-Cu belts 9 MMT (5%)

Millions Ounces of
Fine Gold X 1000

< 2

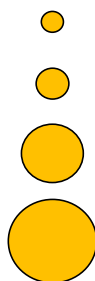
2-4

4-10

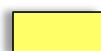
> 10

Mines

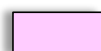
Projects



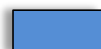
Metallogenic belts



Miocene epithermal belt



Miocene skarn, porphyry, replacement & vein deposits belt



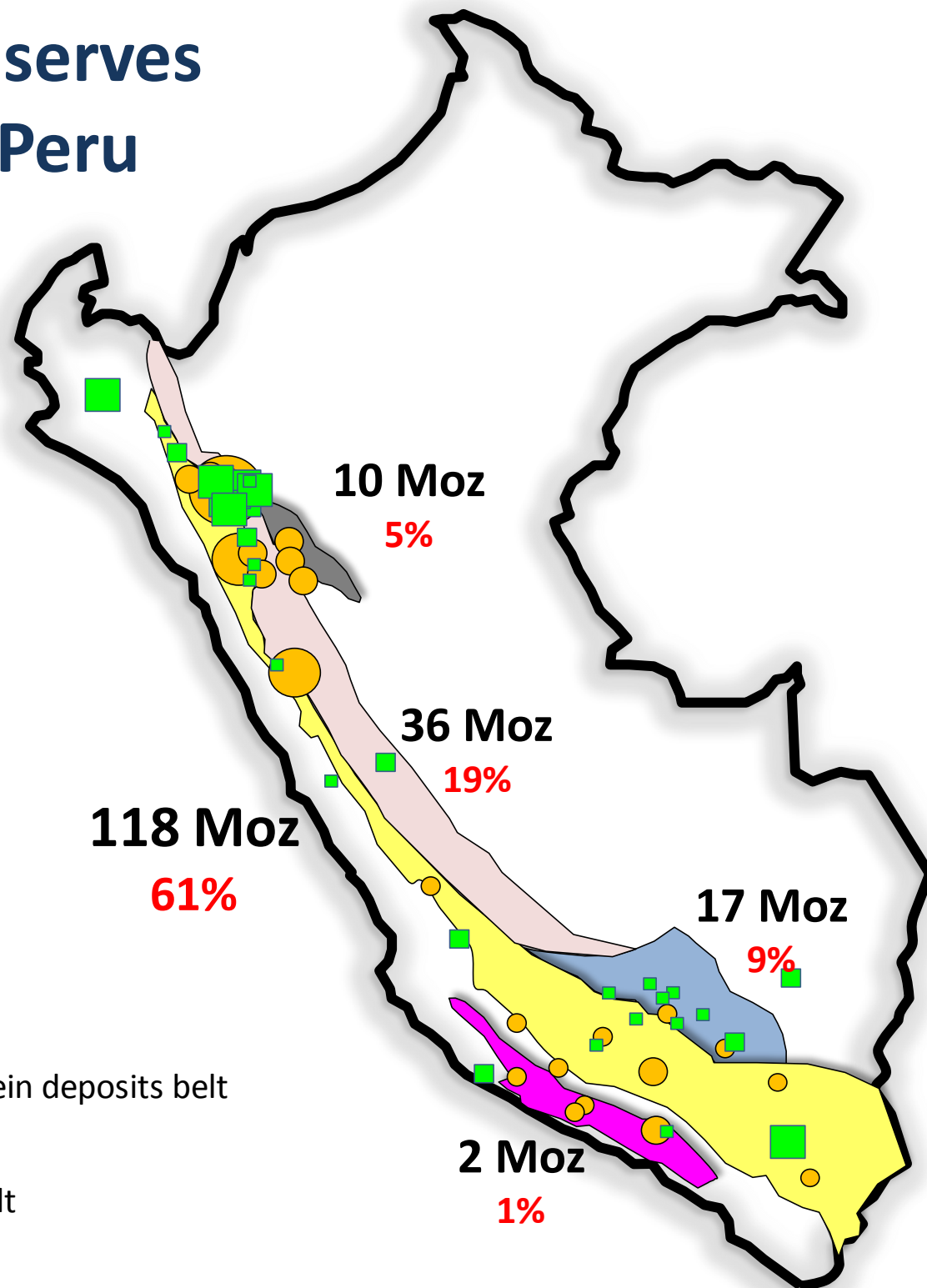
Eocene-Oligocene porphyry belt



Upper Cretaceous intrusion-related gold belt



Carboniferous-Permian orogenic gold belt





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Peruvian Silver Belts

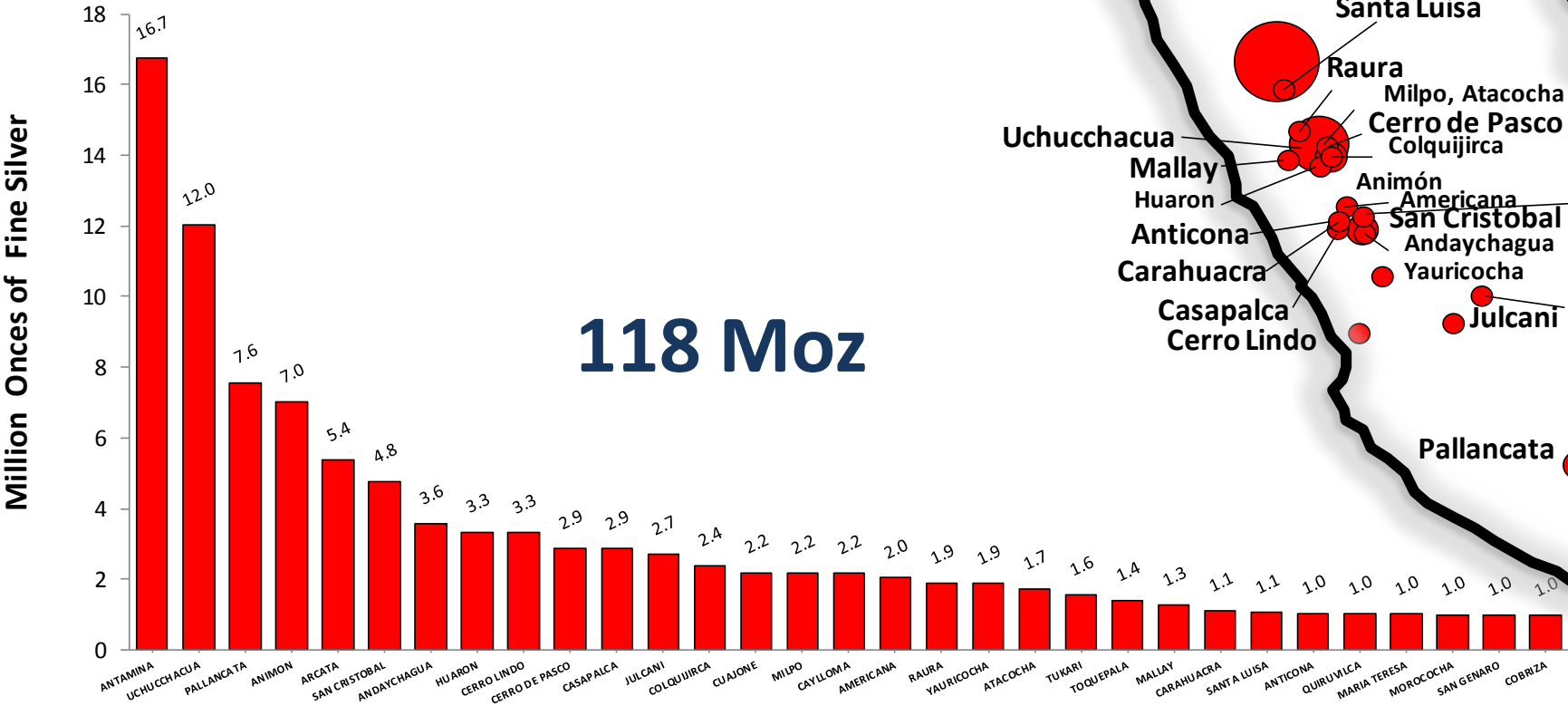
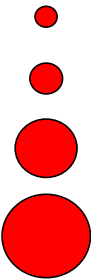


Silver Mines in Peru - 2013

Annual Production
Million Onces of Fine Silver

< 5
5-10
10-15
> 15

Mines



118 Moz



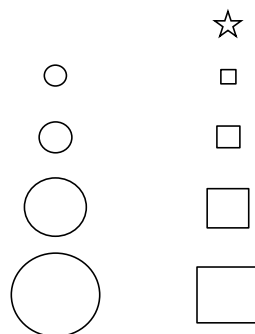
Main Silver Belts, Mines and Projects in Peru

Actual or Planned Annual
Production Ounces of
Fine silver

0
< 100
100-400
400-600
> 600

Mines

Projects



Metallogenic belts

- Miocene epithermal deposits belt
- Miocene skarn, porphyry, replacement & vein deposits belt

Deposit types

- HS Epithermal (HSE)
- IS Epithermal (ISE)
- LS Epithermal (LSE)
- Porphyry
- Skarn, replacement & vein deposits (SRVD)
- IOCG
- VMS
- Others

Porphyry
0.1-6.2 g/t Ag

HSE
1.6-159 g/t Ag

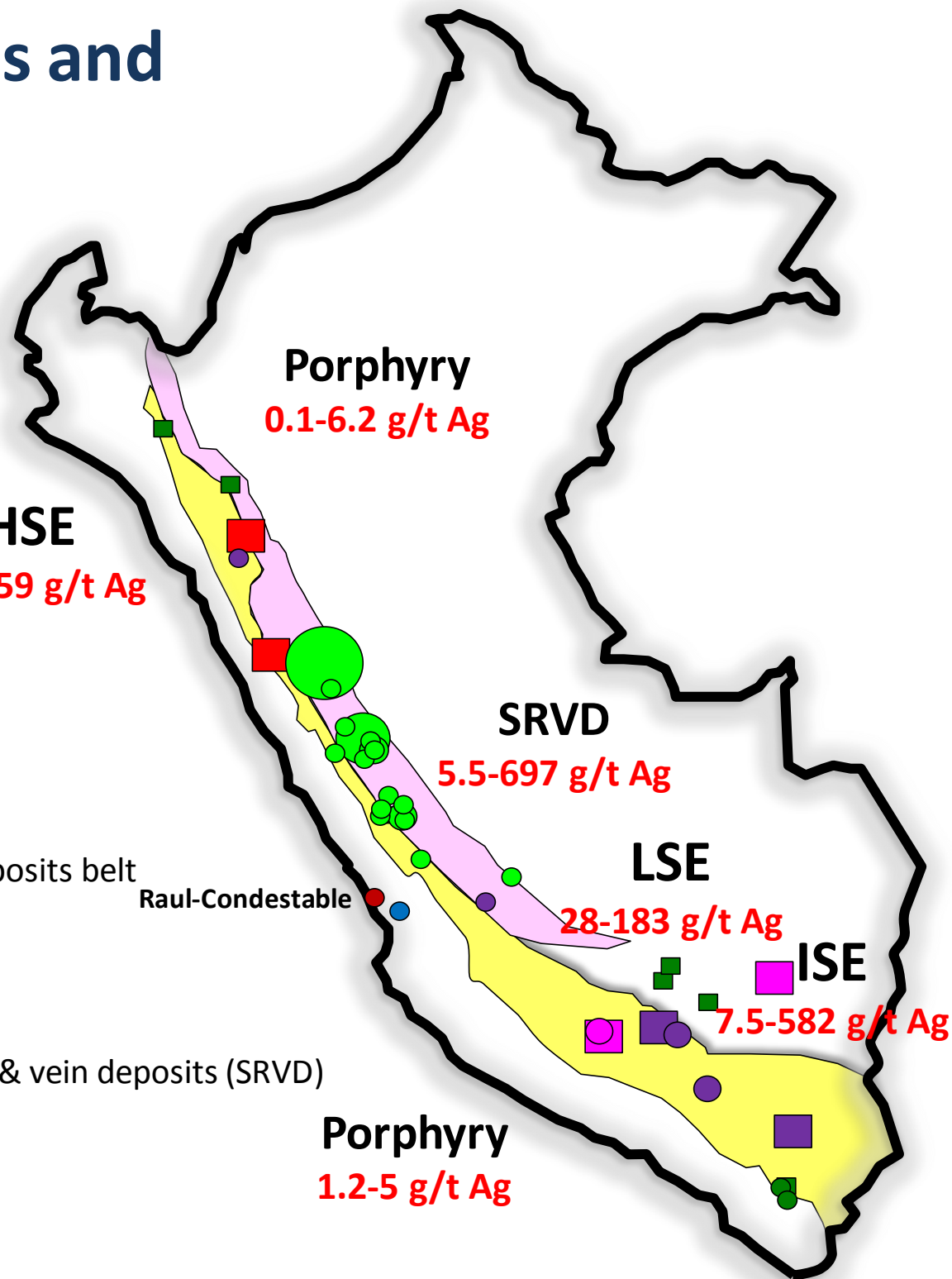
SRVD
5.5-697 g/t Ag

LSE
28-183 g/t Ag

ISE
7.5-582 g/t Ag

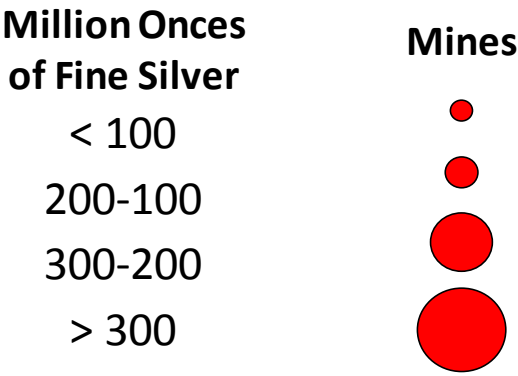
Porphyry
1.2-5 g/t Ag

Raul-Condestable



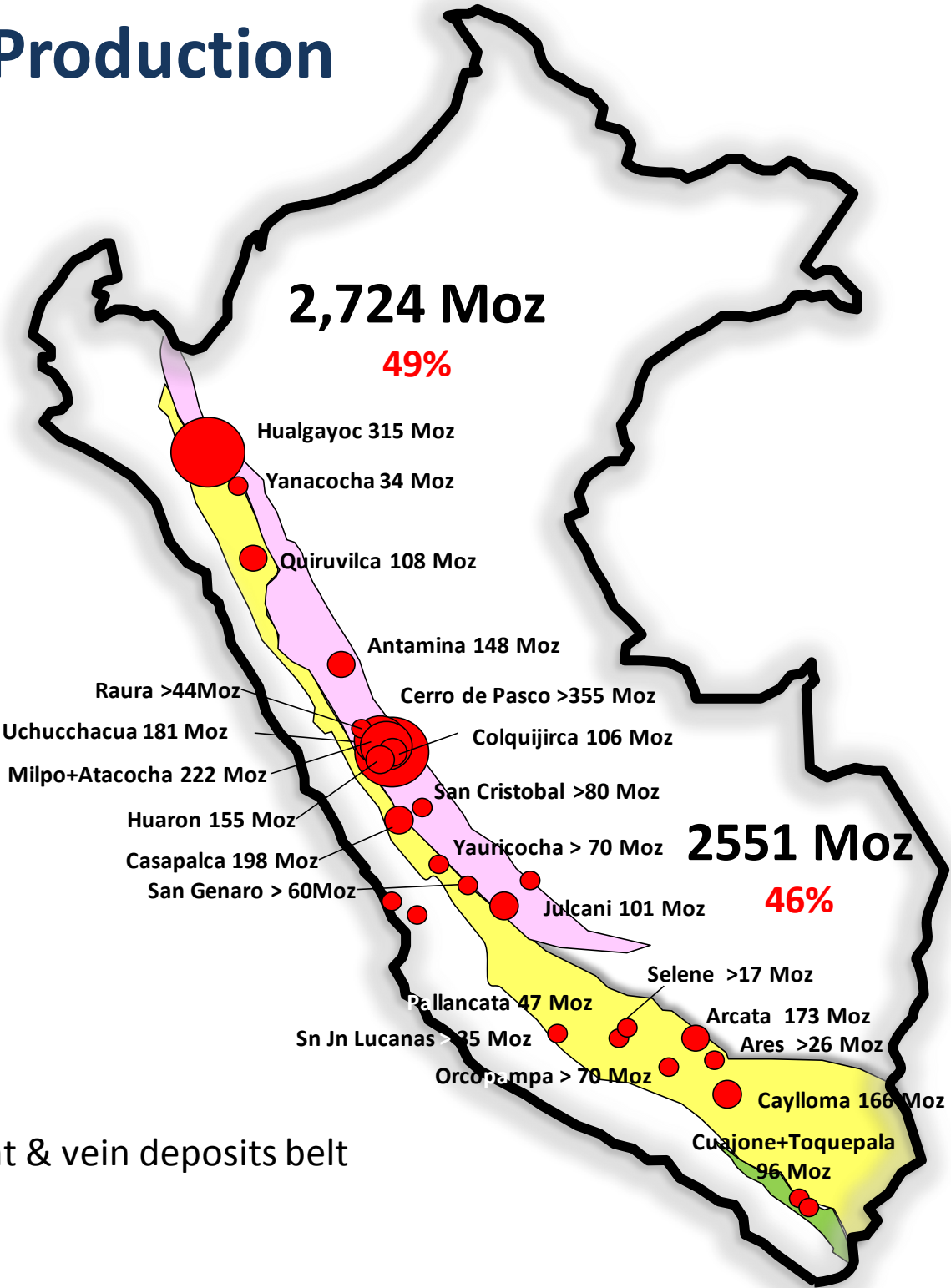
Historic Cumulative Silver Production in Peru

Total Production in Peru
5,565 Moz (100%)
Production from main silver belts
5,275 Moz (95%)
Other non-Ag belts: 290 Moz (5%)

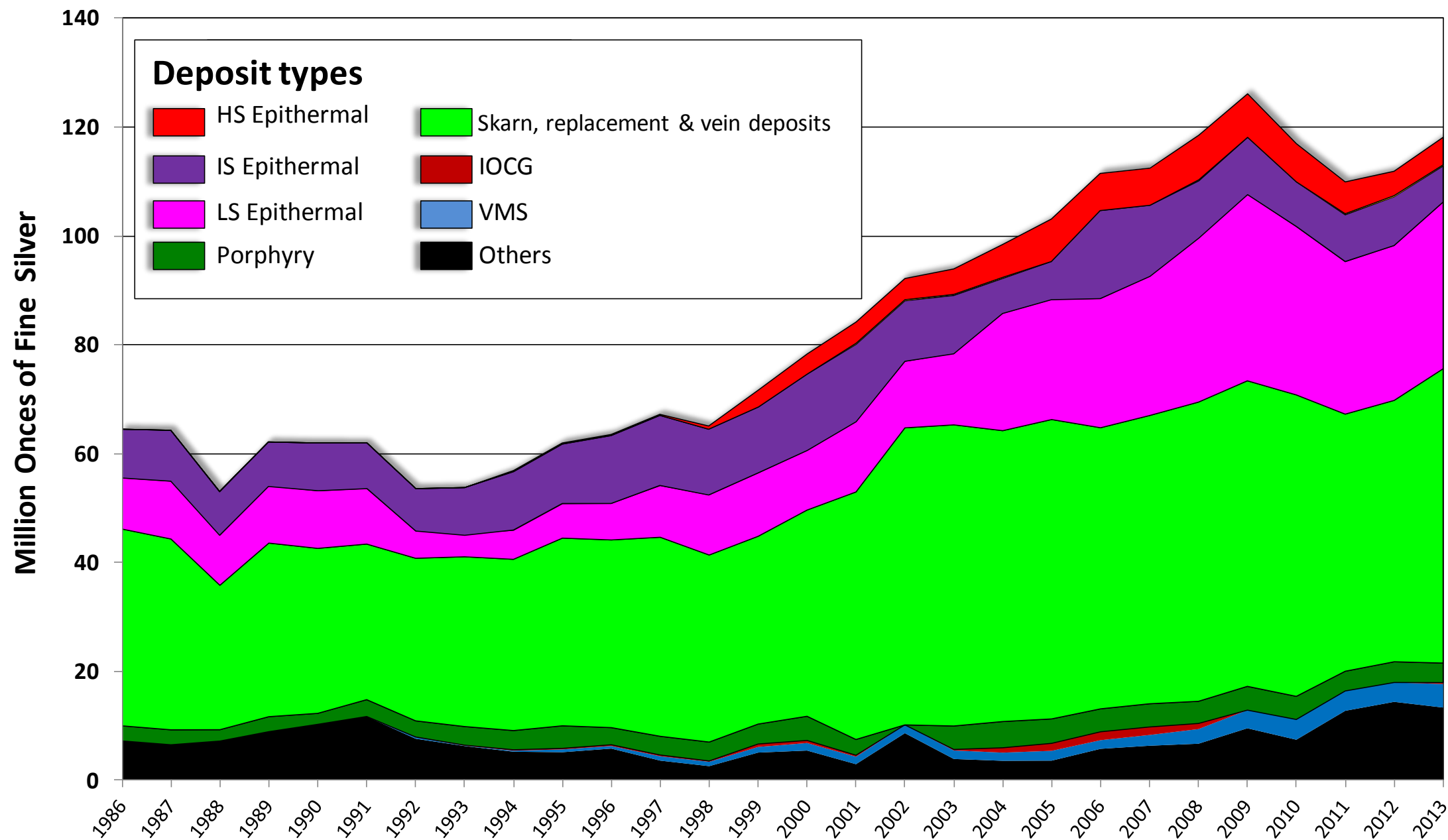


Metallogenic belts

-  Miocene epithermal belt
-  Miocene skarn, porphyry, replacement & vein deposits belt
-  Paleocene-Eocene porphyry belt



Peruvian Silver Production by Deposit Types



Silver Resources and Reserves in the Main Porphyry Belts in Peru

Total reported resources in Peru

7,012 Moz (100%)

Resources from main silver belts

4,818 Moz (69%)

Other Ag belts 1,526 Moz (22%)

Other non-Ag belts 668 Moz (9%)

Millions Ounces of
Fine silver

0

< 100

300-100

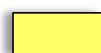
> 300

Mines

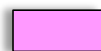
Projects



Metallogenic belts



Miocene epithermal deposits belt



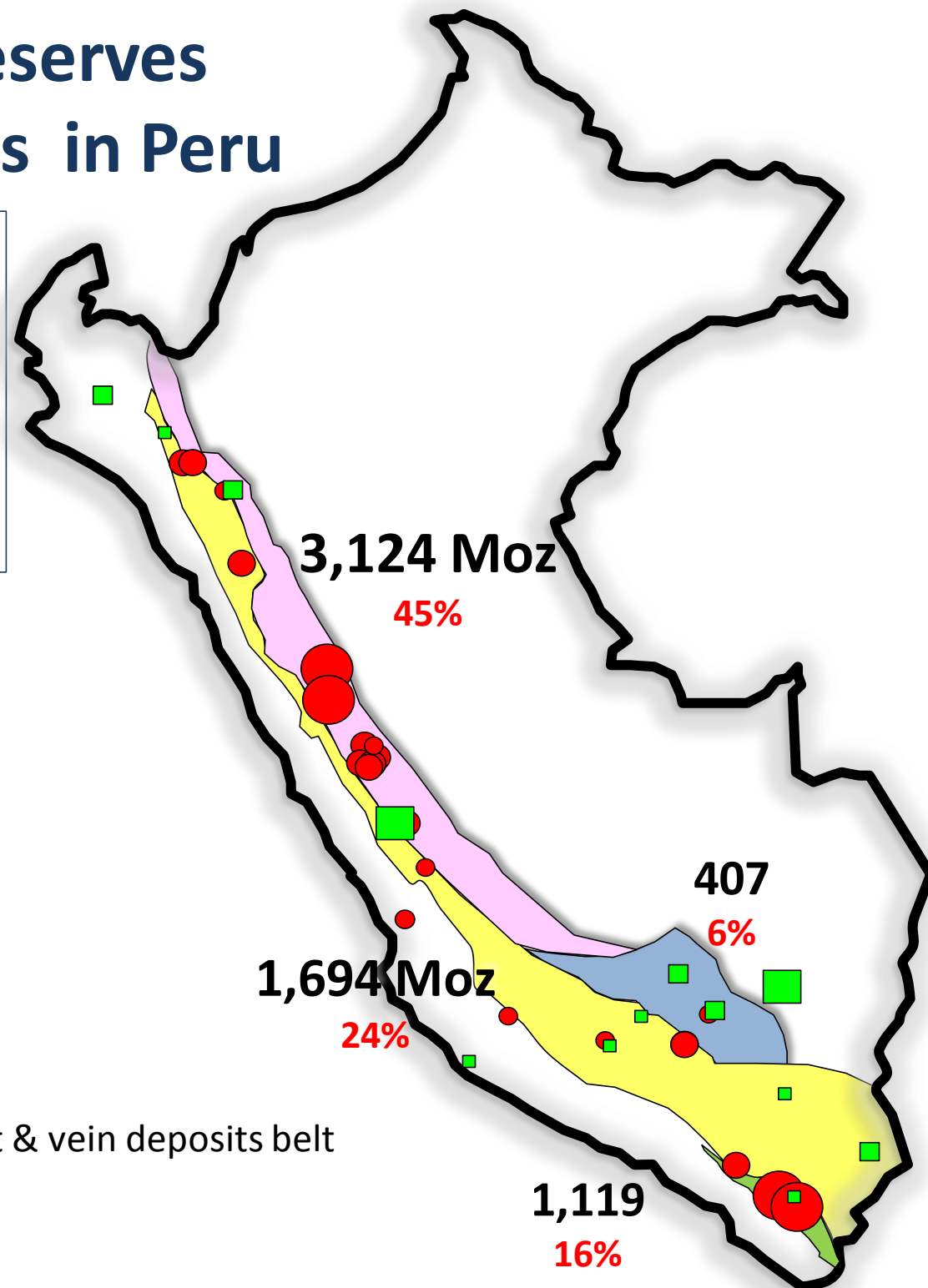
Miocene skarn, porphyry, replacement & vein deposits belt



Eocene-Oligocene porphyry belt



Paleocene-Eocene porphyry belt





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Peruvian Copper Belts

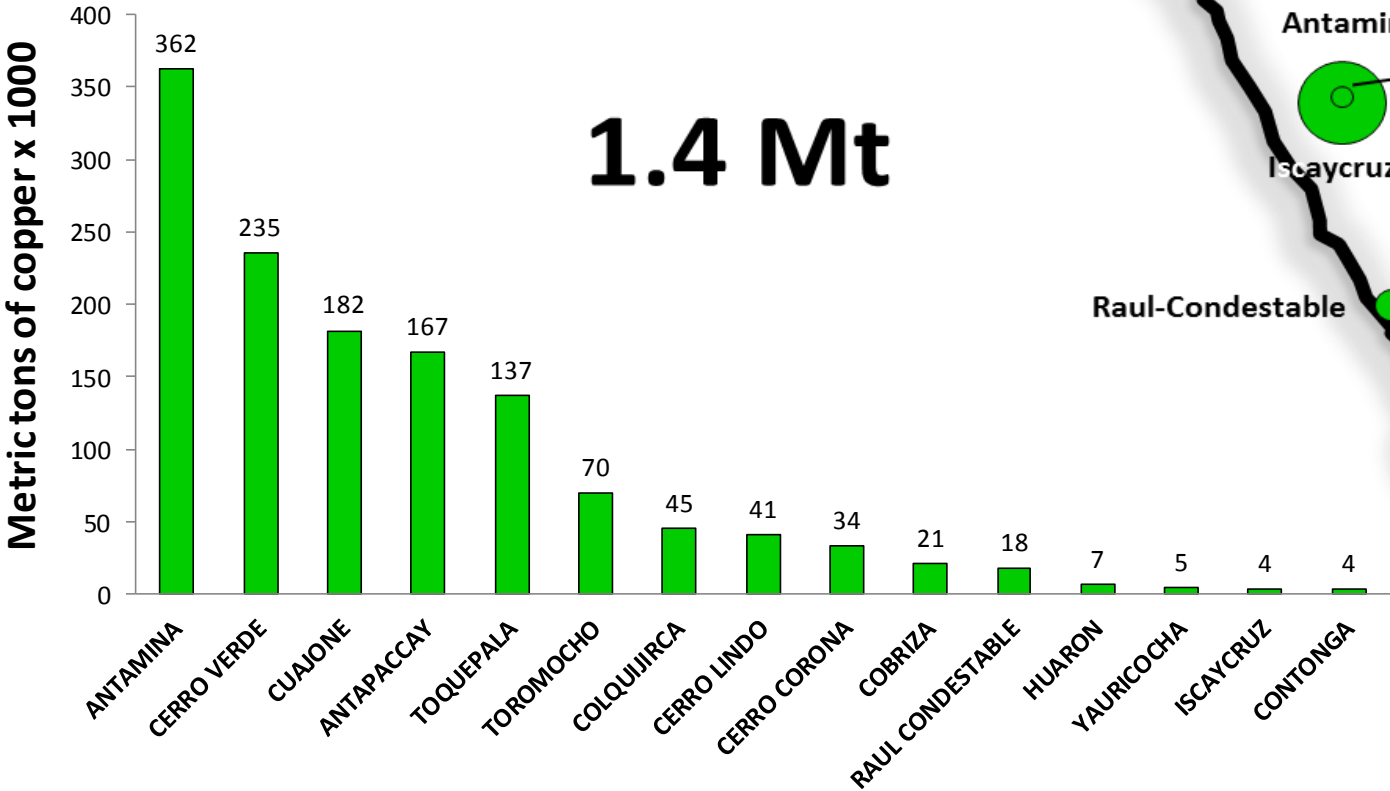
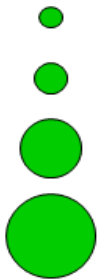


Copper Mines in Peru - 2014

Annual Production
Metric Tons of Copper
X 1000

1-10
10-50
50-200
200-500

Mines



Main Porphyry Belts, Mines and Projects in Peru

Actual or Planned Annual
Production Metric Tons of
Fine Copper
X 1000

0

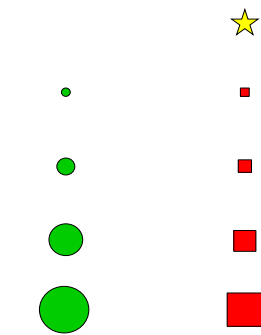
1-10

10-50

50-200

200-500

Mines Projects



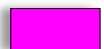
Metallogenic belts



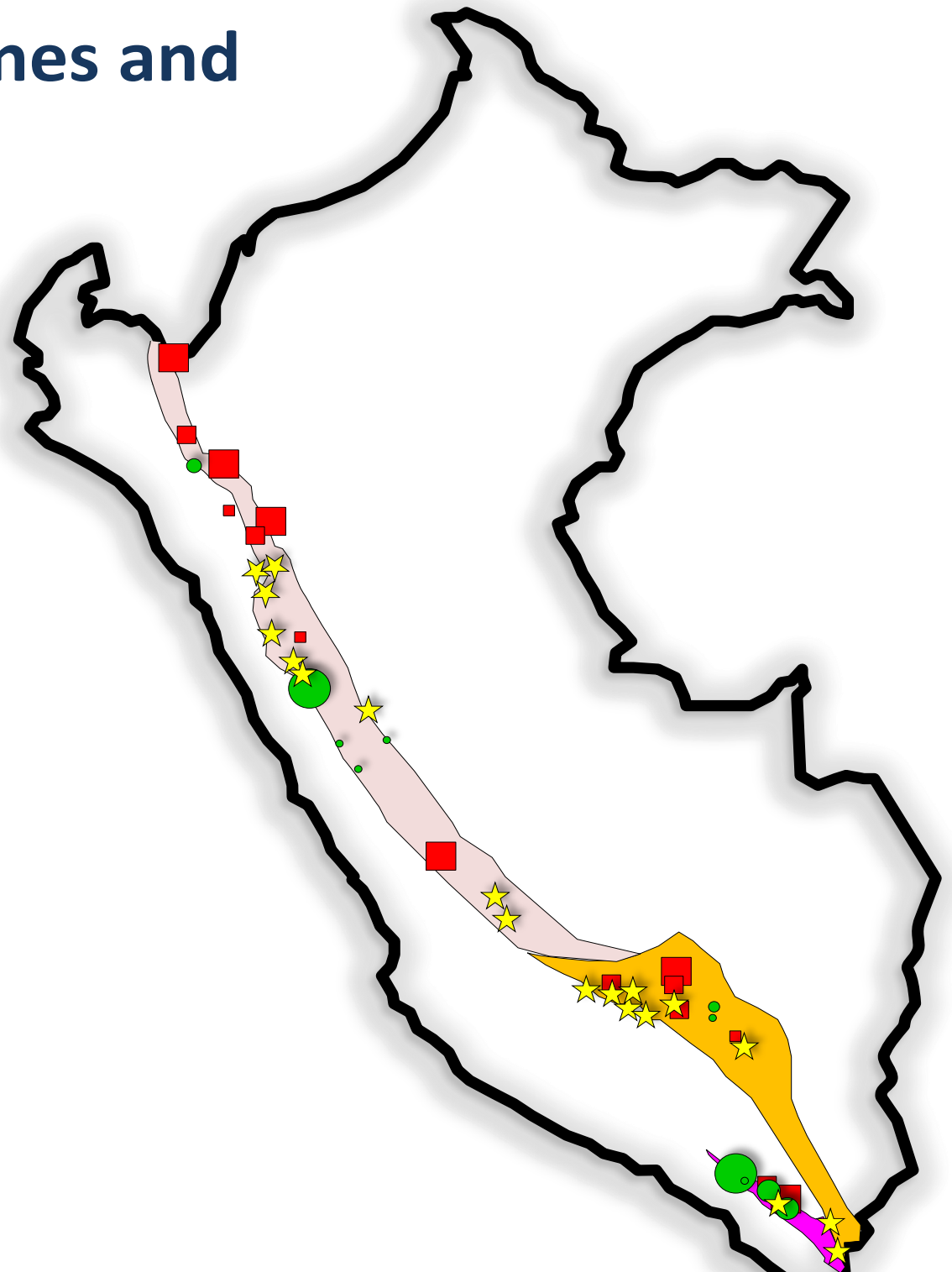
Miocene porphyry belt



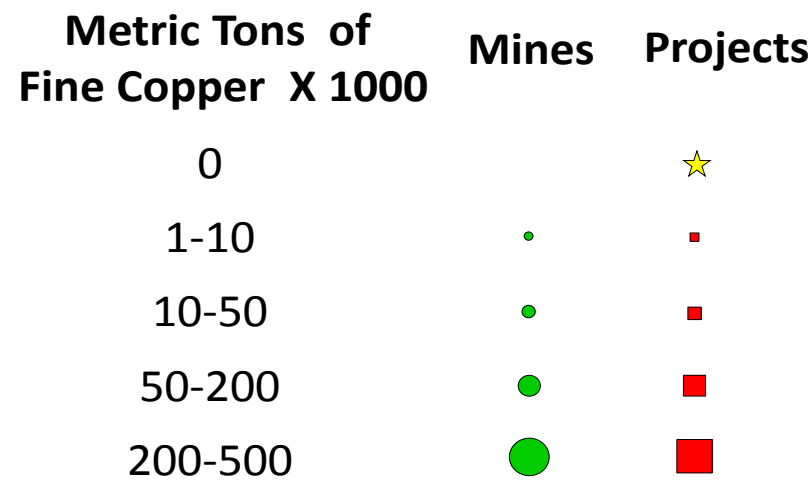
Eocene-Oligocene porphyry belt



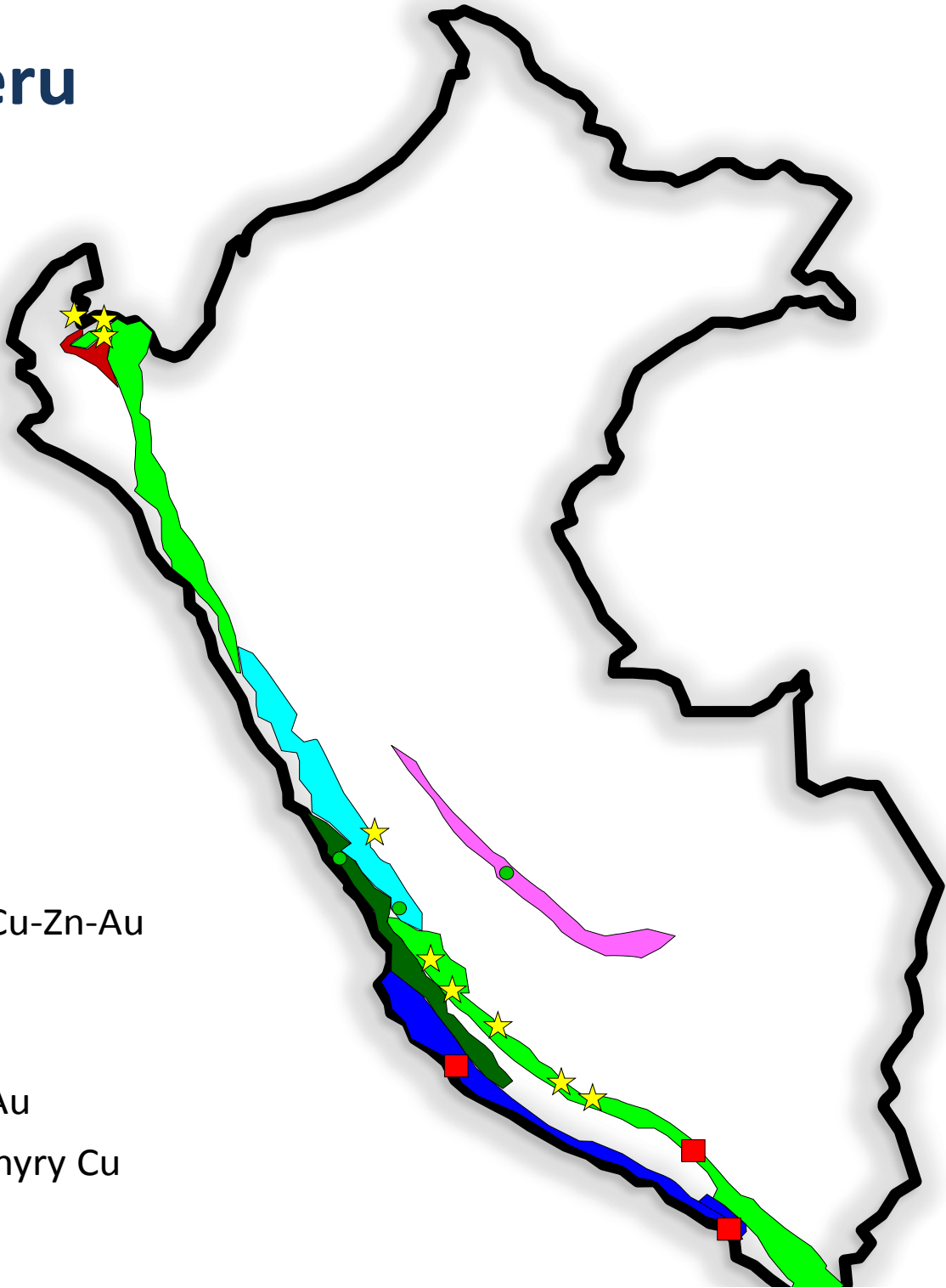
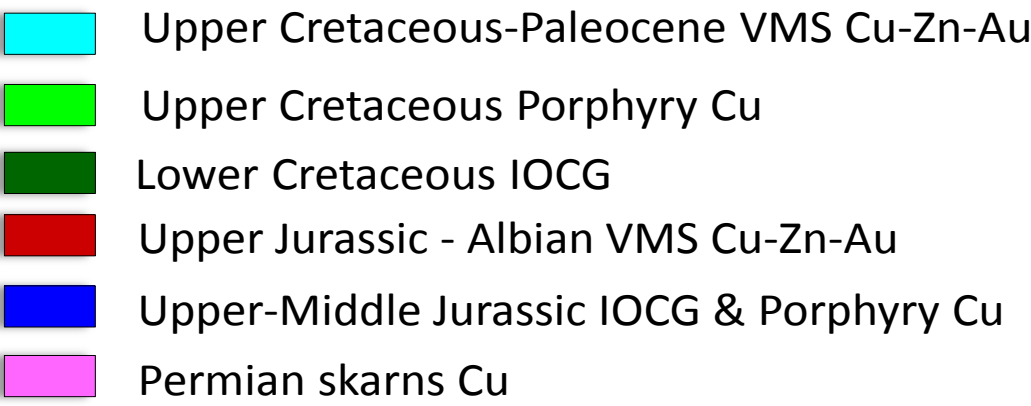
Paleocene-Eocene porphyry belt



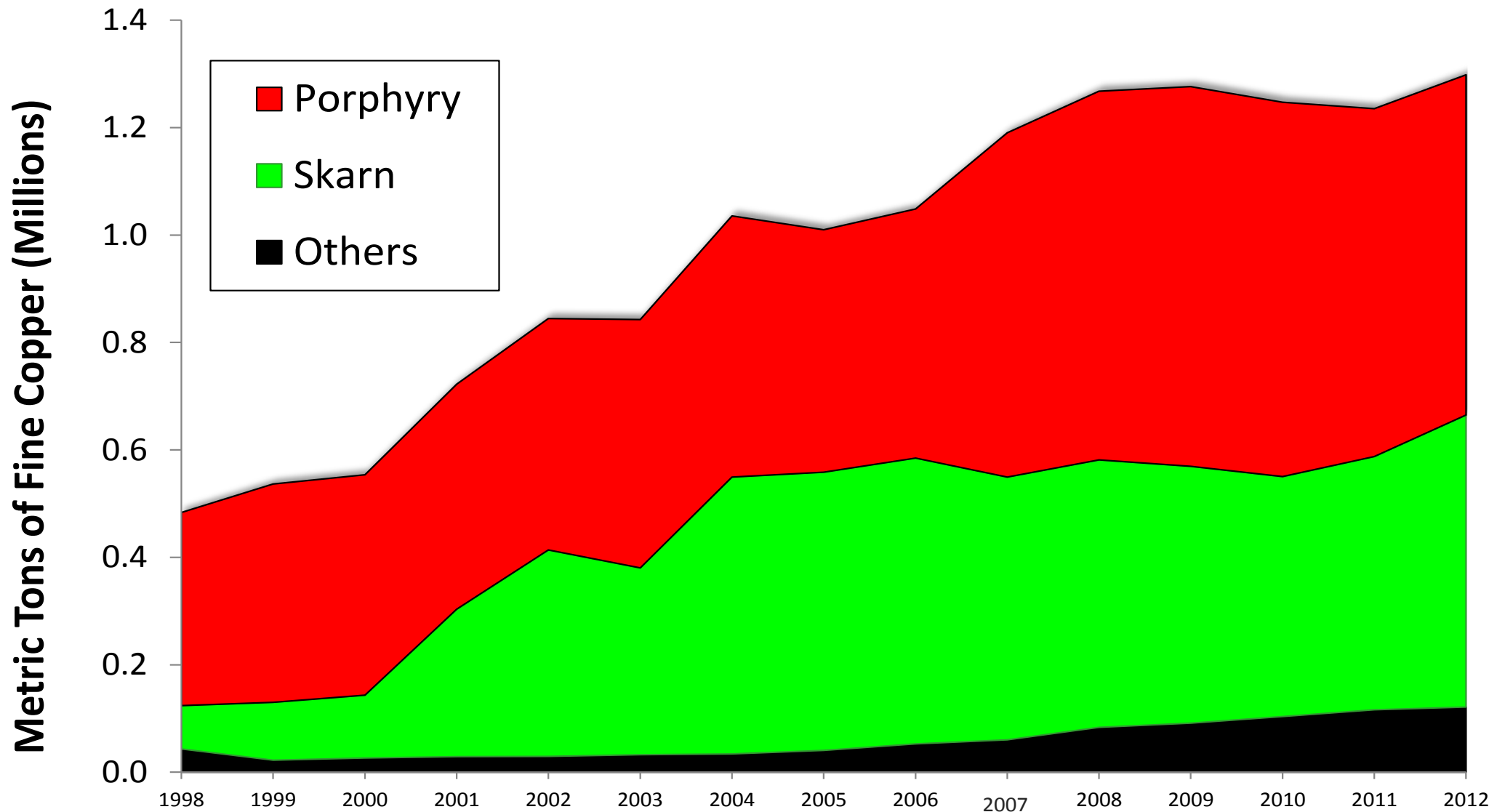
Other Copper Belts in Peru



Metallogenic belts



Peruvian Copper Production by Deposit Types



Historic Cumulative Copper Production in Peru

Total Production in Peru

28 MMT (100%)

Production from main porphyry belts

23 MMT (82%)

Other Cu belts: 2 MMT (7%)

Other non-Cu belts: 3 MMT (11%)

Million Metric Tons
of Fine copper

Mines

< 1



1-3



3-5



5-7



Metallogenic belts



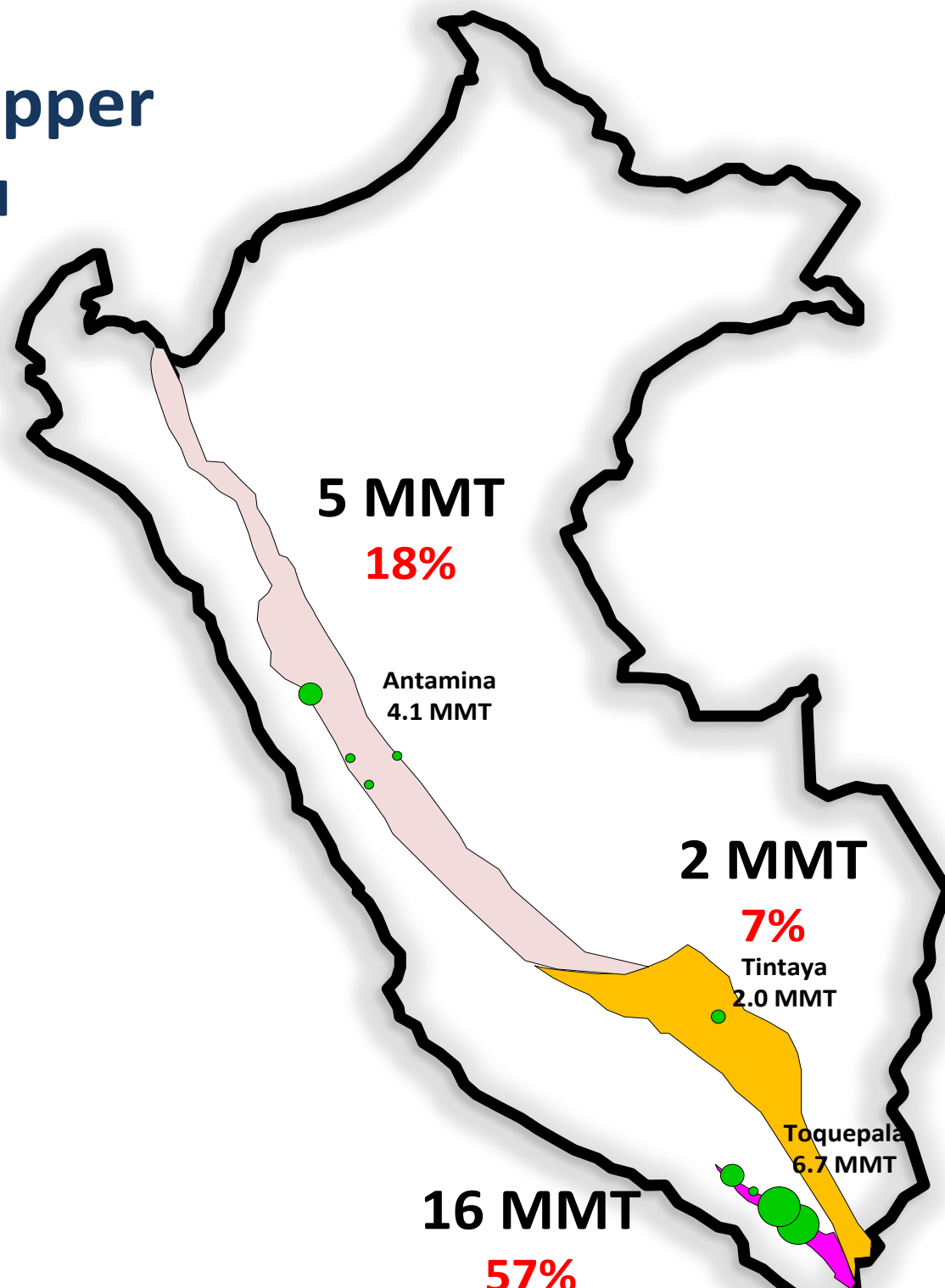
Miocene porphyry belt



Eocene-oligocene porphyry belt



Paleocene porphyry belt



Copper Resources and Reserves in the Main Porphyry Belts in Peru

Total reported resources in Peru

218 MMT (100%)

Resources from porphyry belts

192 MMT (88%)

Other Cu belts 11 MMT (5%)

Other non-Cu belts 15 MMT (7%)

Millions Metric Tons
of Fine Copper

Mines

Future
Producers

Exploration
Projects

< 1



1-5



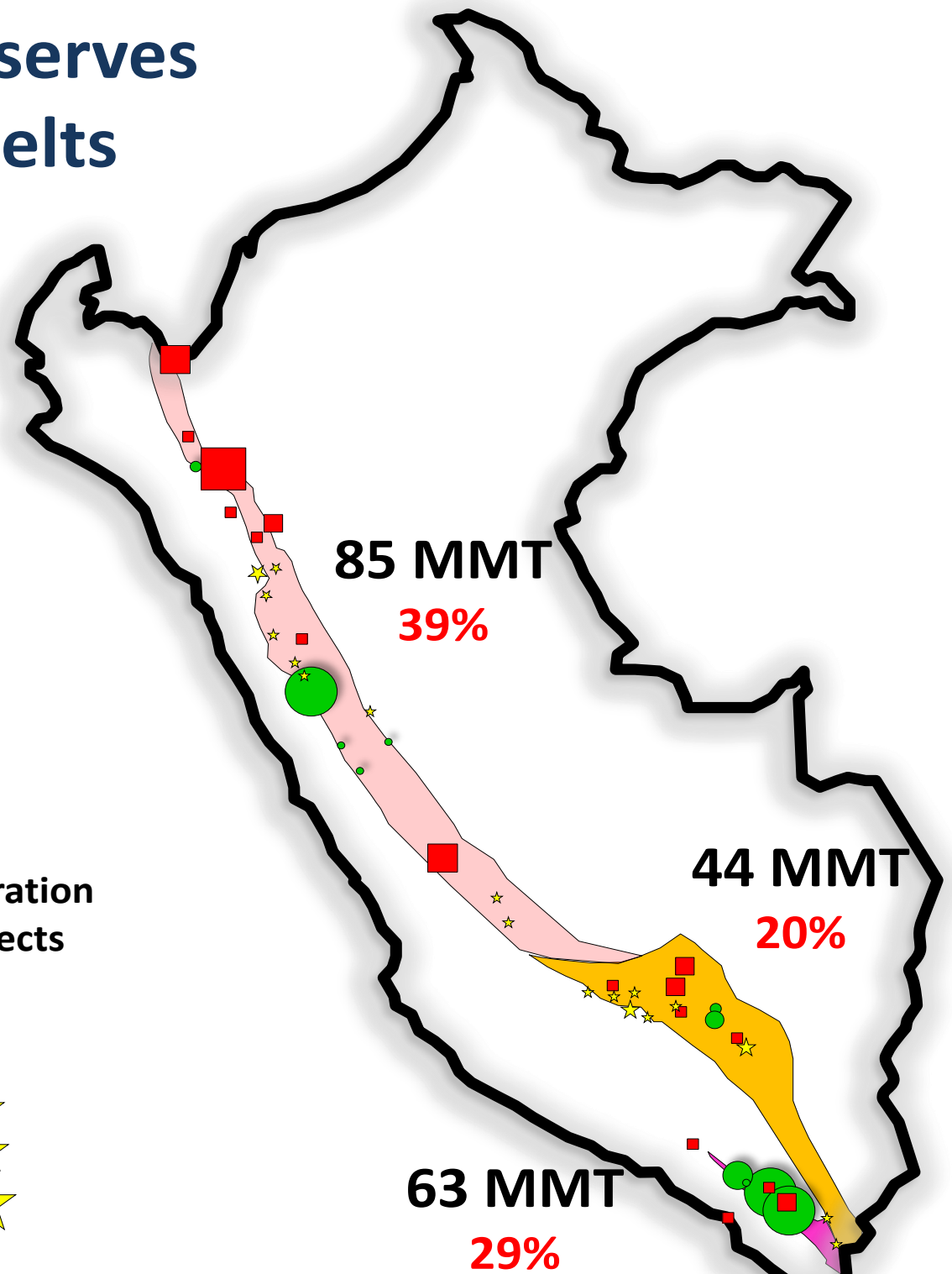
5-10



10-15



> 15





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Lead and Zinc Belts



Main Lead & Zinc Belts in Peru

**Tons of Fine Lead
X 1000**

< 7

7-10

10-15

> 15

Mines

Projects

**Tons of Fine Zinc
X 1000**

< 50

50-100

100-200

> 200

Mines

Projects

Metallogenic belts



Miocene epithermal, skarn, replacement & polymetallic vein deposits



Lower Cretaceous–Paleocene VMS Cu-Zn-Au

Tambogrande

Bongara

La Granja

Antamina

Milpo

Santa Luisa

Cerro de Pasco
Colquijirca

Animón

María teresa

San Cristobal-Volcan

C° Lindo

Catalina Huanca

Corani

San Cristobal-Bateas

Other non Lead & Zinc Belts in Peru

Tons of Fine Lead
X 1000

Mines

Projects

< 7



7-10



10-15



> 15



Tons of Fine Zinc
X 1000

Mines

Projects

< 50



50-100



100-200



> 200



Metallogenic belts



Miocene epithermal Au-Ag deposits



Eocene-Miocene MVT deposits



Eocene-Oligocene porphyry –skarn Cu-Mo-Au

Tambogrande

La Granja

Bongará

Antamina

San Vicente

San Cristobal-Volcan

C° Lindo

Catalina Huanca

Accha

Corani

Constancia

San Cristobal-Bateas

Santa Ana

Source: Modified from Mapa Metalogenético del Perú. INGEMMET, Acosta et al, 2014 - Ministerio de Energía y Minas. Dirección de Energía de Minas.

Source: Jorge ACOSTA et al. 2015. MAIN METALLOGENIC BELTS AND SUPPLY TREND OF LEAD AND ZINC IN PERU. Pro Explo 2015.

Lead & Zinc Belts in Peru: Grades & Tons

Total reserves & resources reported
in Peru

22 MMT Pb

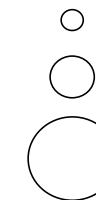
52 MMT Zn

Millions tons of
Fine Lead

< 1

1-10

> 10



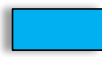
94 MMT @ **0.22-3.0 %Pb**
267 MMT @ **0.8-10 %Zn**

5 MMT @ **0.5-0.6 %Pb**
18 MMT @ **8-14%Zn**

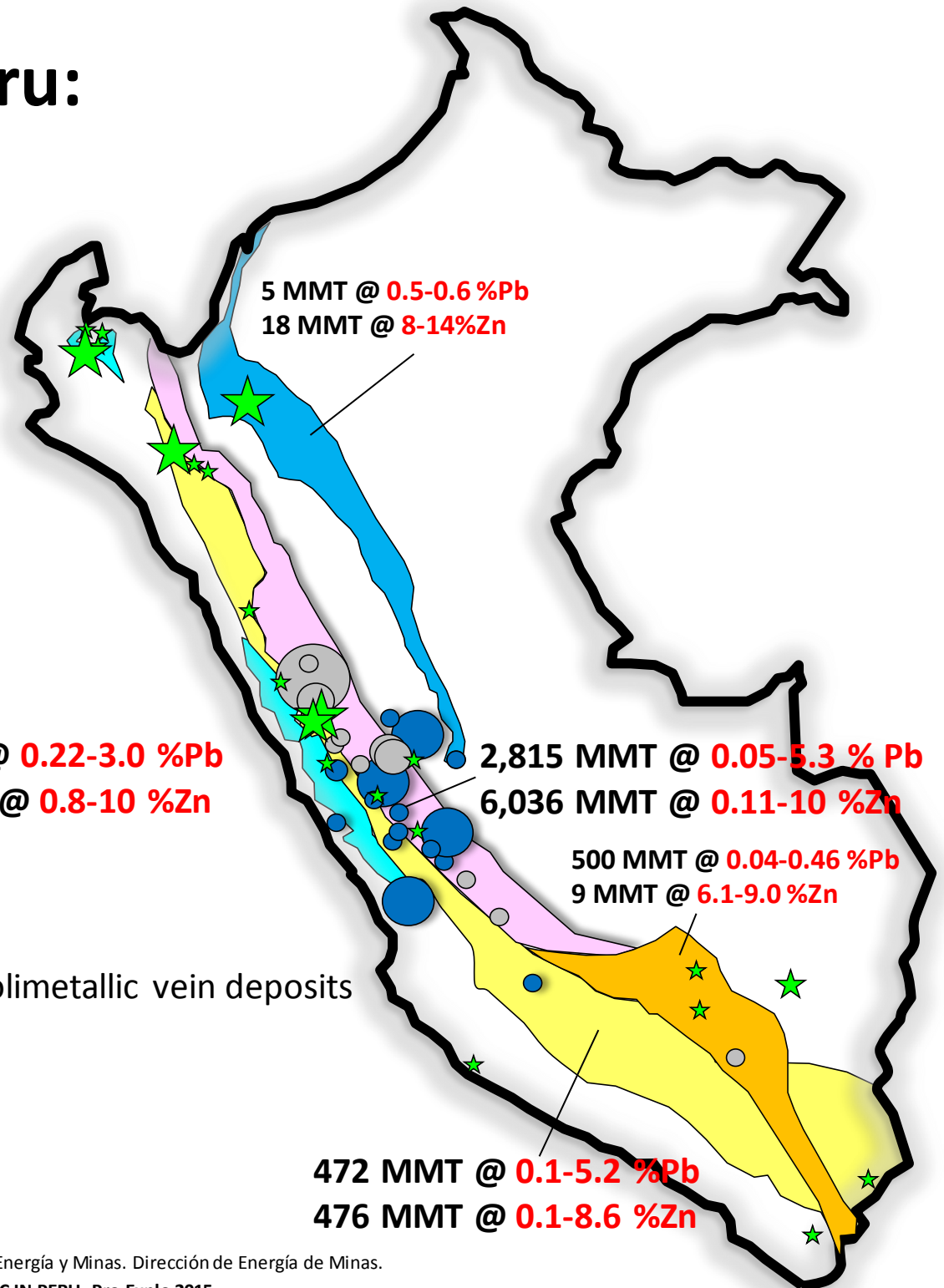
2,815 MMT @ **0.05-5.3 % Pb**
6,036 MMT @ **0.11-10 %Zn**

500 MMT @ **0.04-0.46 %Pb**
9 MMT @ **6.1-9.0 %Zn**

Metallogenic belts

-  Miocene epithermal, skarn, replacement & polymetallic vein deposits
-  Miocene epithermal Au-Ag deposits
-  Eocene-Miocene MVT deposits
-  Eocene-Oligocene porphyry –skarn Cu-Mo-Au
-  Lower Cretaceous– Paleocene VMS Cu-Zn-Au

472 MMT @ **0.1-5.2 %Pb**
476 MMT @ **0.1-8.6 %Zn**



Source: Modified from Mapa Metalogenético del Perú. INGEMMET, Acosta et al, 2014 - Ministerio de Energía y Minas. Dirección de Energía de Minas.

Source: Jorge ACOSTA et al. 2015. MAIN METALLOGENIC BELTS AND SUPPLY TREND OF LEAD AND ZINC IN PERU. Pro Explo 2015.



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Lead



Lead Mines in Peru - 2014

Annual Production
Tons of Fine Lead
X 1000

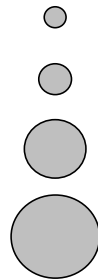
< 7

7-10

10-15

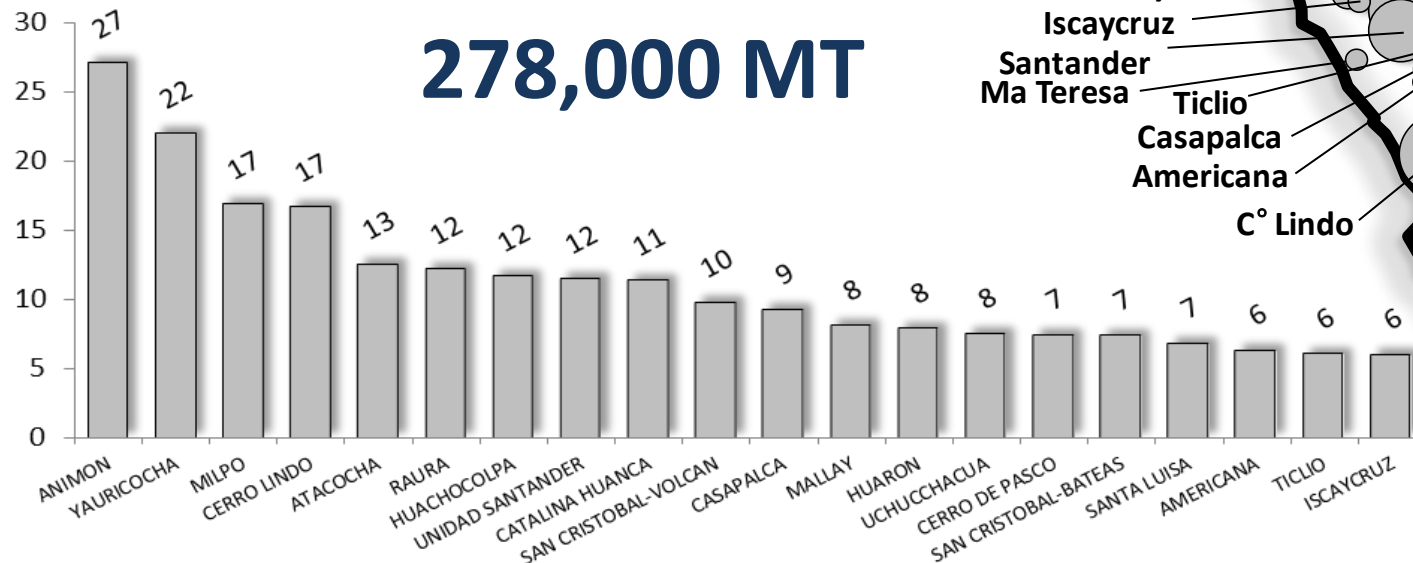
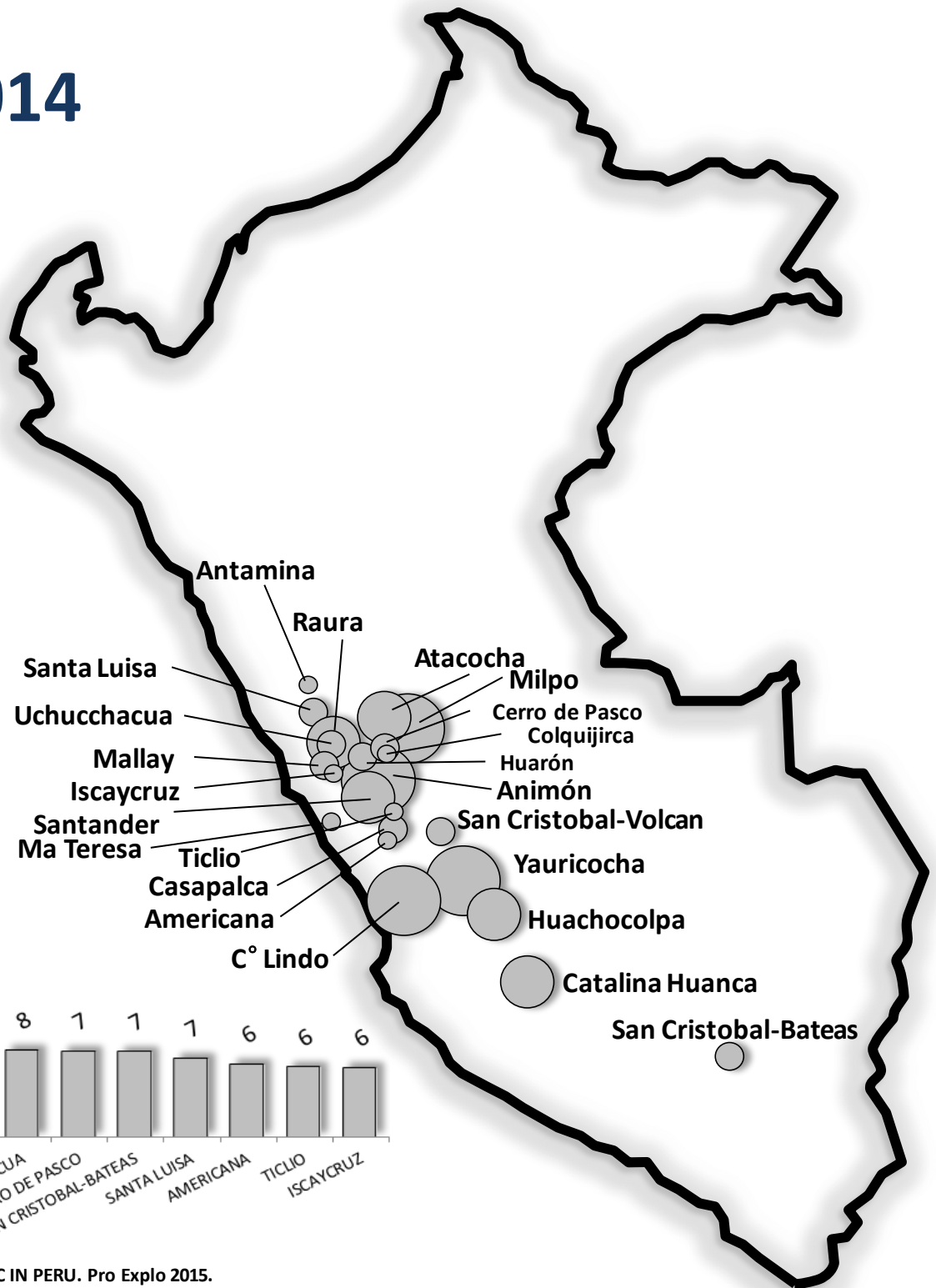
> 15

Mines



Tons of Fine Lead x 1000

278,000 MT



Source: Ministerio de Energía y Minas. Dirección de Energía de Minas. Anuario Minero 2014.

Source: Jorge ACOSTA et al. 2015. MAIN METALLOGENIC BELTS AND SUPPLY TREND OF LEAD AND ZINC IN PERU. Pro Explo 2015.

Historic Cumulative Lead Production in Peru

**Total Production in Peru
~14 MMT (100%)**

From Miocene belt
13.5 MMT (97%)

From Lower Cretacic-Paleocene belt
0.3 MMT (2%)

Other no Pb-Zn belts
0.1 MMT (1%)

**Production 2014
Tons of Fine Lead
X 1000**

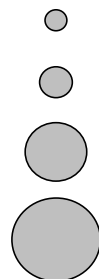
< 7

7-10

10-15

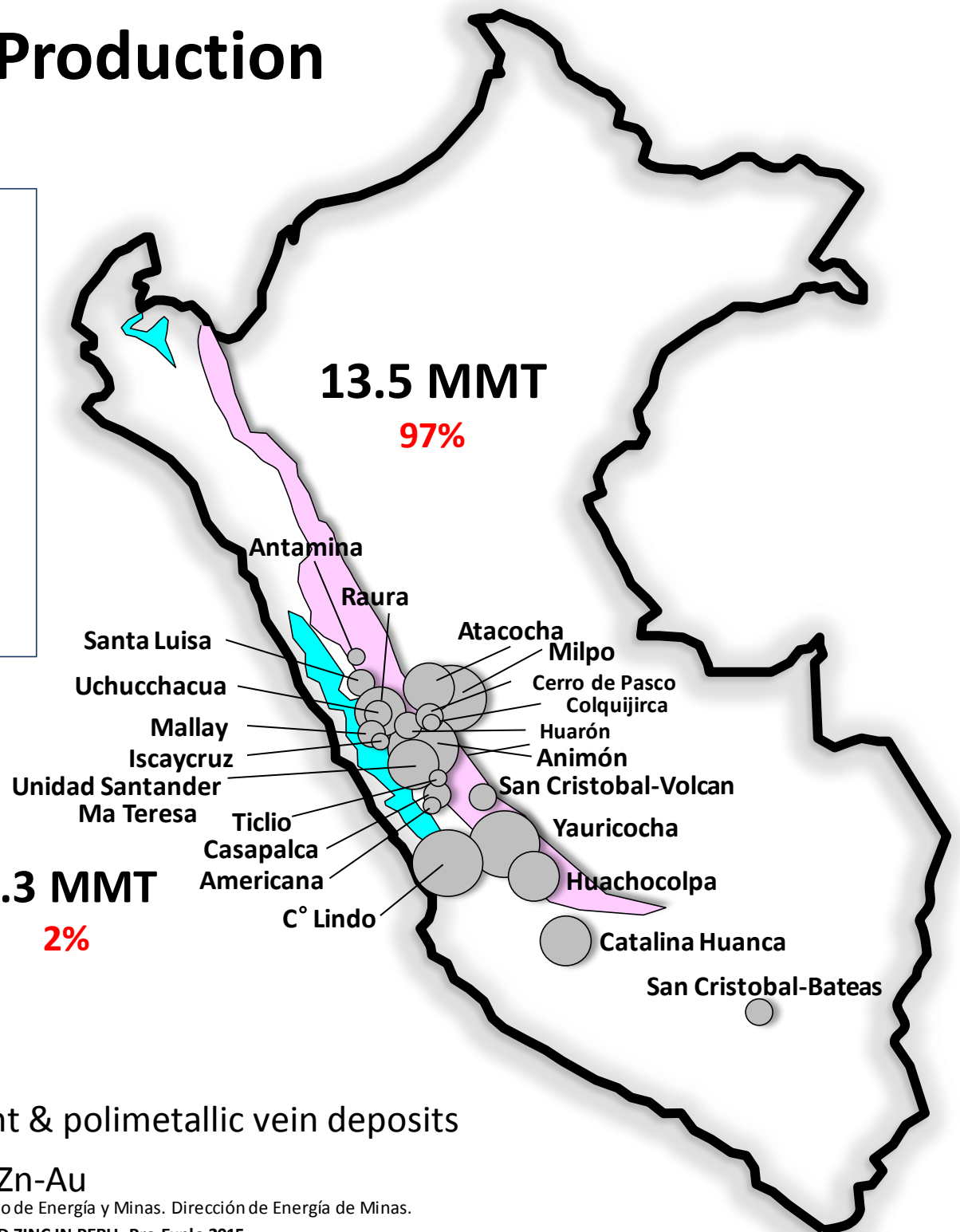
> 15

Mines



**0.3 MMT
2%**

**13.5 MMT
97%**



Metallogenic belts



Miocene epithermal, skarn, replacement & polymetallic vein deposits

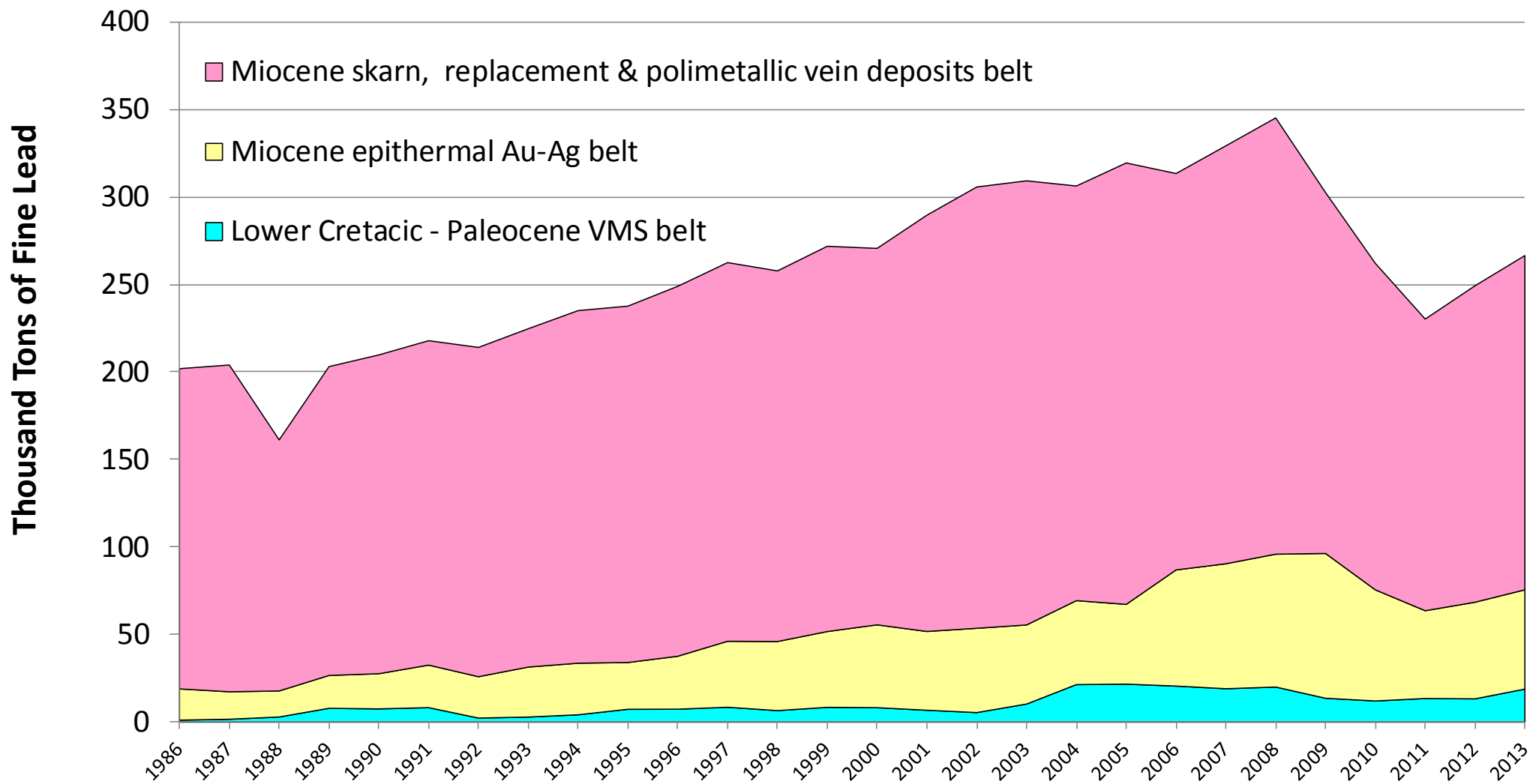


Lower Cretaceous– Paleocene VMS Cu-Zn-Au

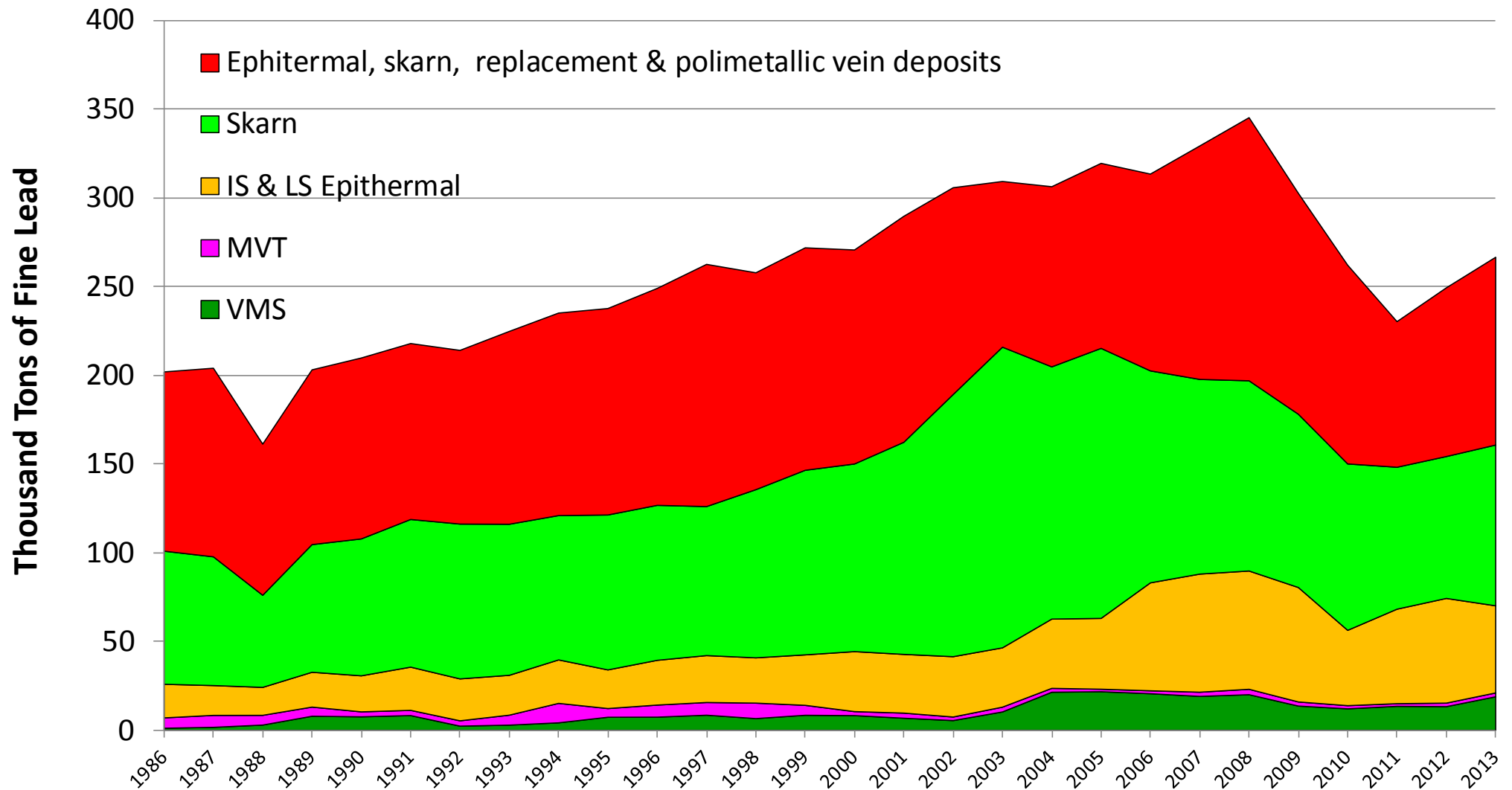
Source: Modified from Mapa Metalogenético del Perú. INGEMMET, Acosta et al, 2014 - Ministerio de Energía y Minas. Dirección de Energía de Minas.

Source: Jorge ACOSTA et al. 2015. MAIN METALLOGENIC BELTS AND SUPPLY TREND OF LEAD AND ZINC IN PERU. Pro Explo 2015.

Peruvian Lead Production by Metallogenic belt



Peruvian Lead Production by Deposit Type



Lead Resources and Reserves in the Main Pb-Zn Belts in Peru

Total reported resources in Peru

~22 MMT (100%)

From Miocene skarn, replacement and veins belt

15 MMT (70%)

From Lower Cretacic-Paleocene belt

0.4 MMT (2%)

From Miocene Epithermal Au-Ag belt

5 MMT (21%)

Other non & Pb belts

1.5 MMT (7%)

Millions tons of
Fine Lead

Mines Projects

< 1

1-10

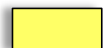
> 10



Metallogenic belts



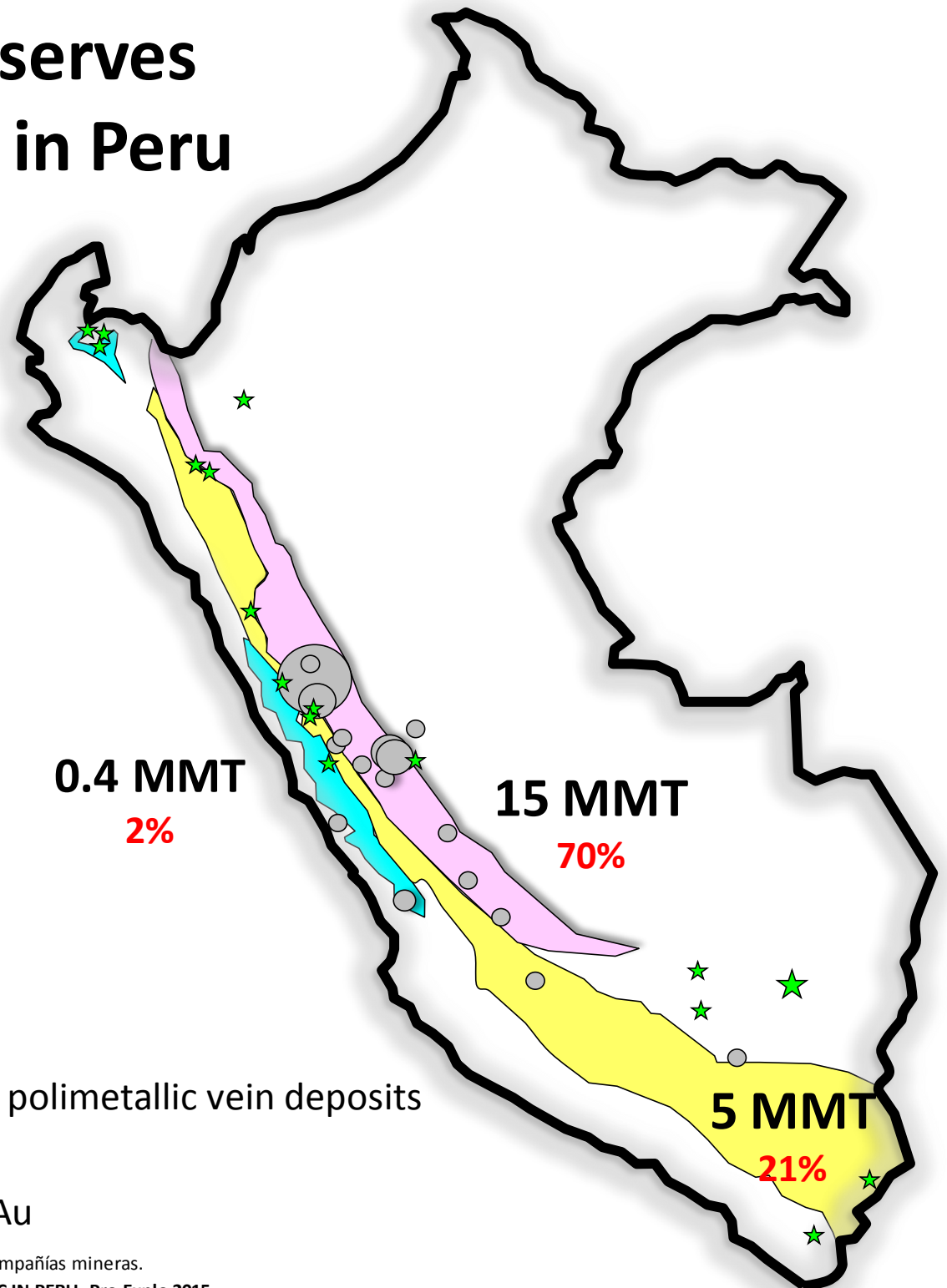
Miocene epithermal, skarn, replacement & polymetallic vein deposits



Miocene epithermal Au-Ag deposits



Lower Cretaceous–Paleocene VMS Cu-Zn-Au



Source: Modified from Mapa Metalogenético del Perú. INGEMMET. Acosta et al, 2014 - Memorias de compañías mineras.

Source: Jorge ACOSTA et al. 2015. MAIN METALLOGENIC BELTS AND SUPPLY TREND OF LEAD AND ZINC IN PERU. Pro Explo 2015.



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Zinc



Zinc Mines in Peru - 2014

Annual Production
Tons of Fine Zinc
X 1000

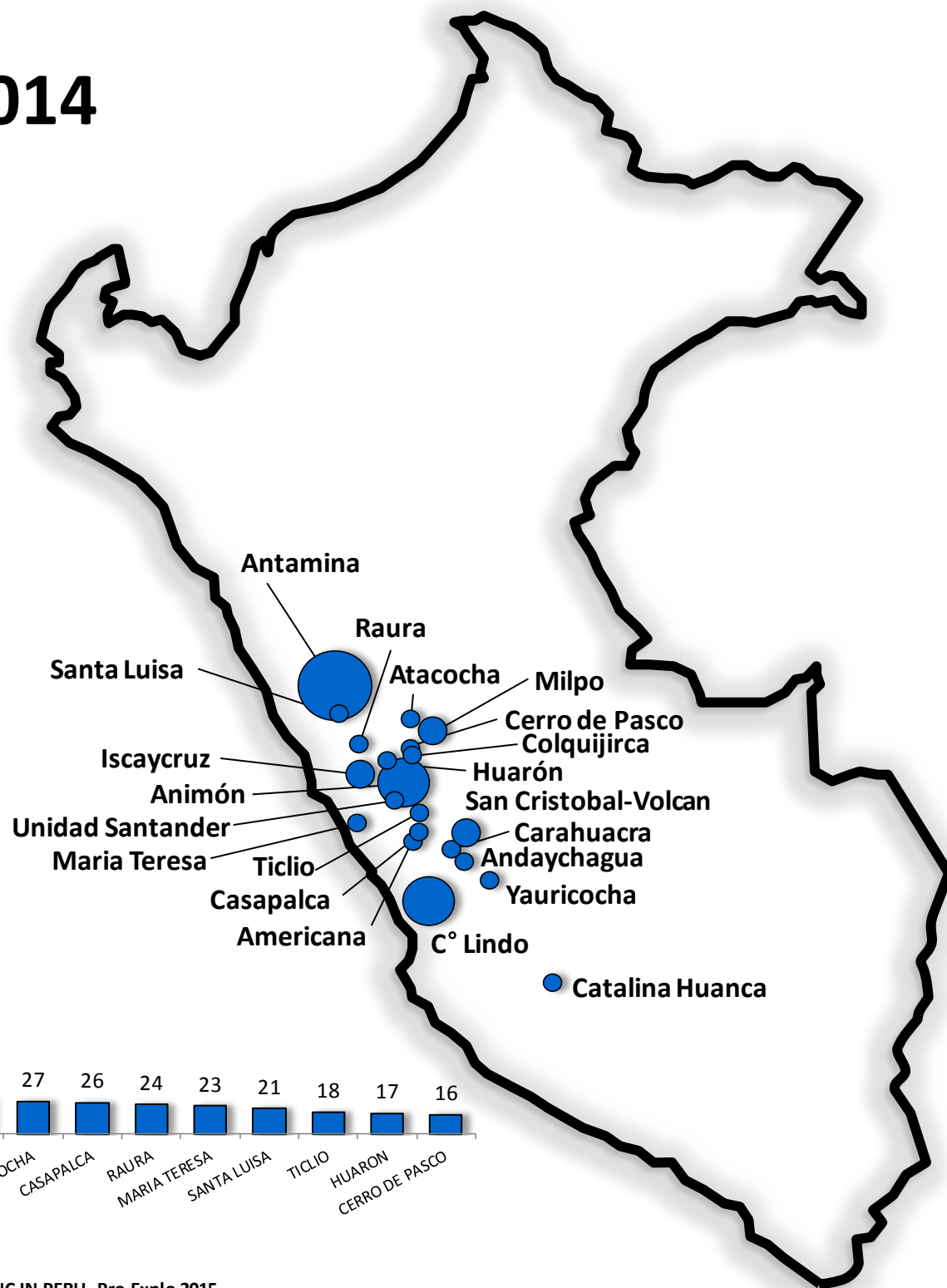
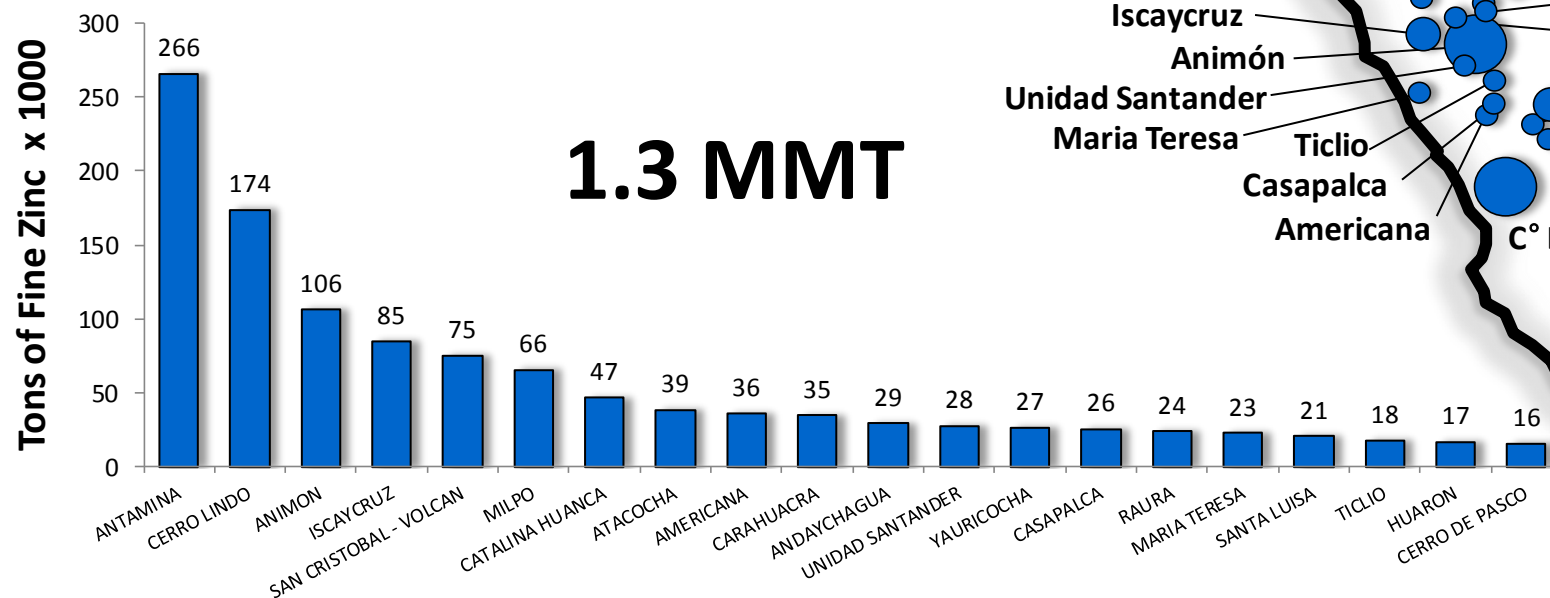
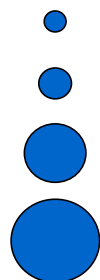
< 50

50-100

100-200

> 200

Mines



Source: Ministerio de Energía y Minas. Dirección de Energía de Minas. Anuario Minero 2014.

Source: Jorge ACOSTA et al. 2015. **MAIN METALLOGENIC BELTS AND SUPPLY TREND OF LEAD AND ZINC IN PERU. Pro Exploración 2015.**

Historic Cumulative Zinc Production in Peru

Total Production in Peru
~41 MMT (100%)

From Miocene belt
 38.4 MMT (94%)

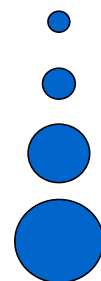
From Lower Cretacic-Paleocene belt
 2 MMT (5%)

Other no Pb-Zn belts
 0.4 MMT (1%)

Production 2014
Tons of Fine Zinc
X 1000

< 50
 50-100
 100-200
 > 200

Mines



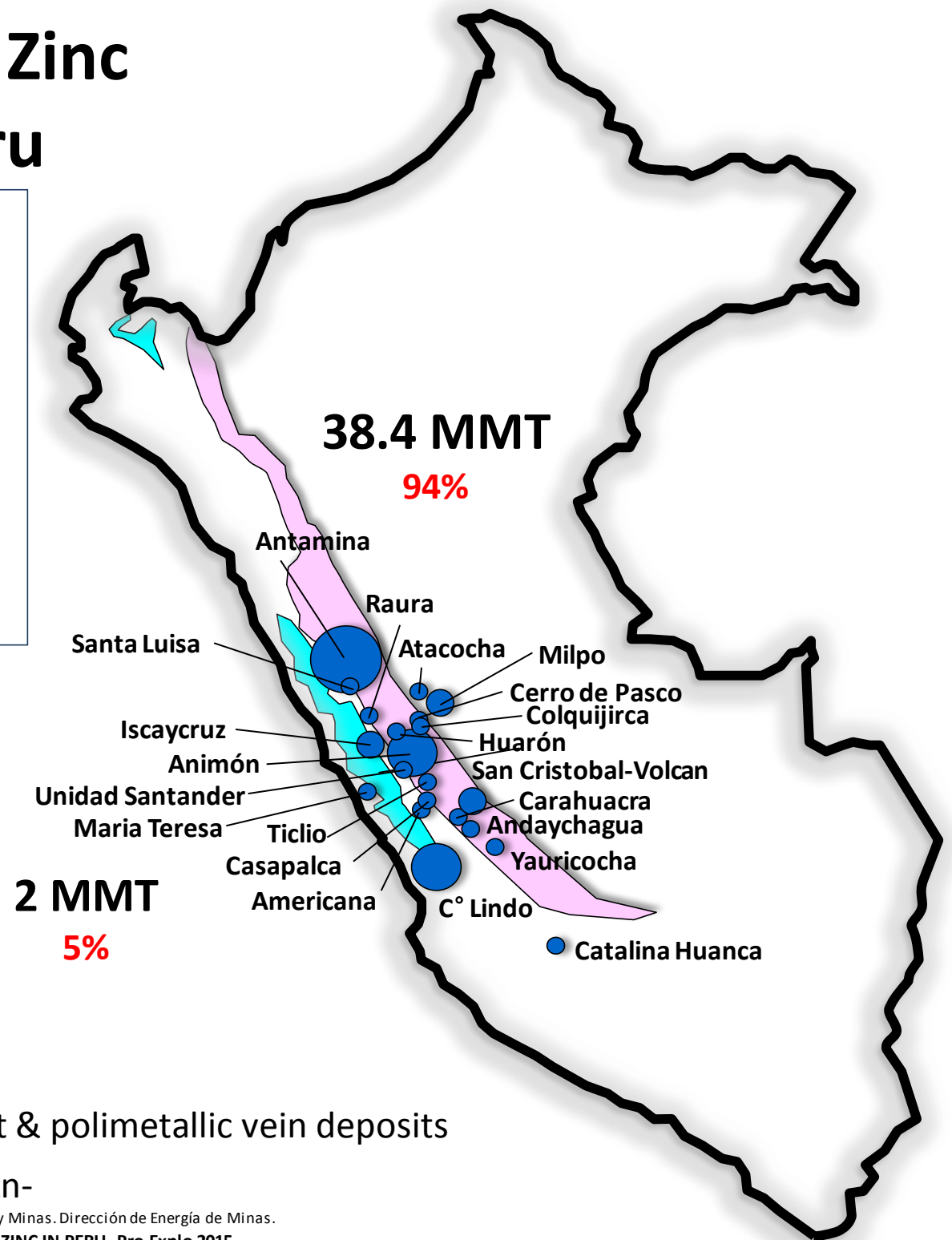
Metallogenic belts



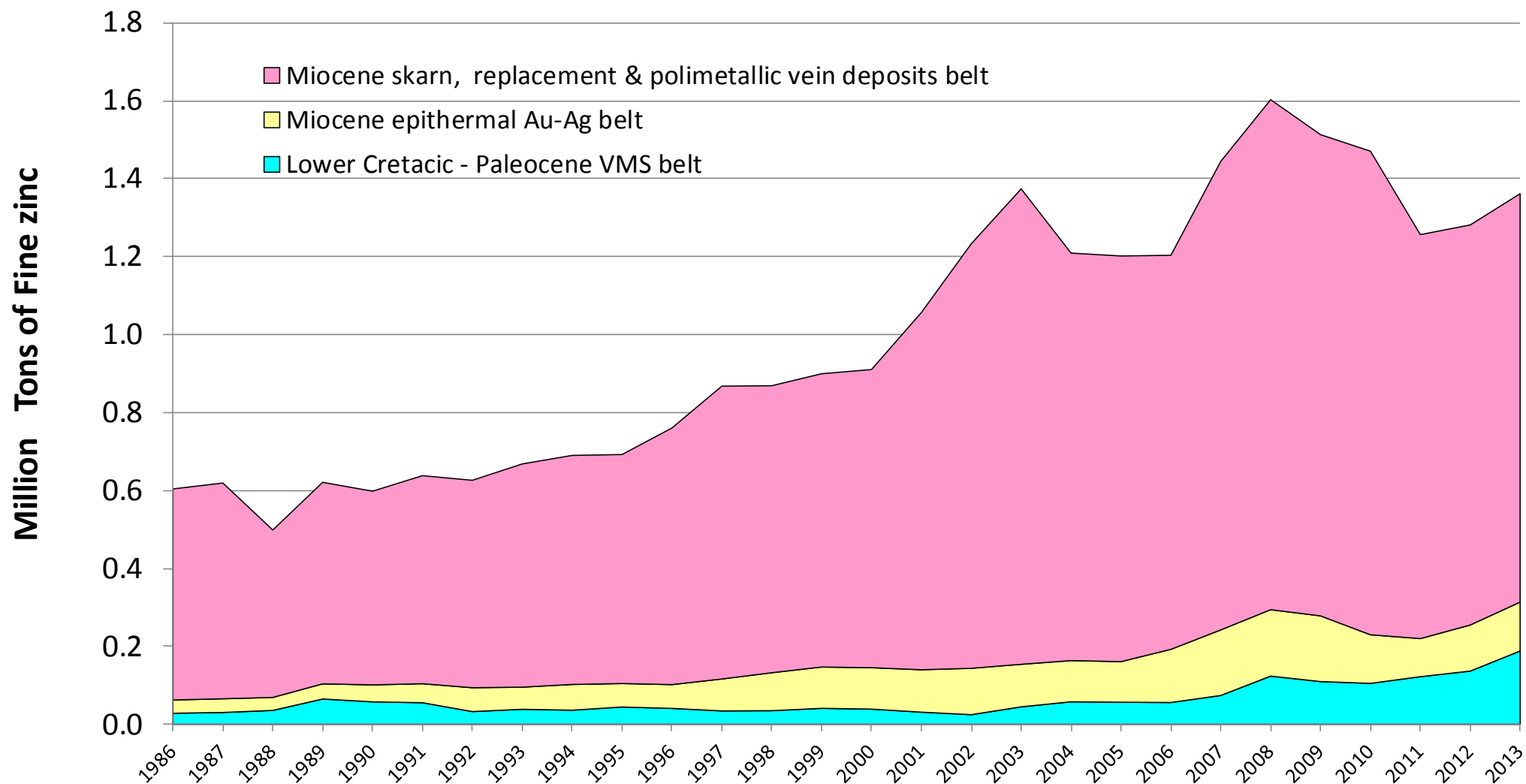
Miocene epithermal, skarn, replacement & polymetallic vein deposits



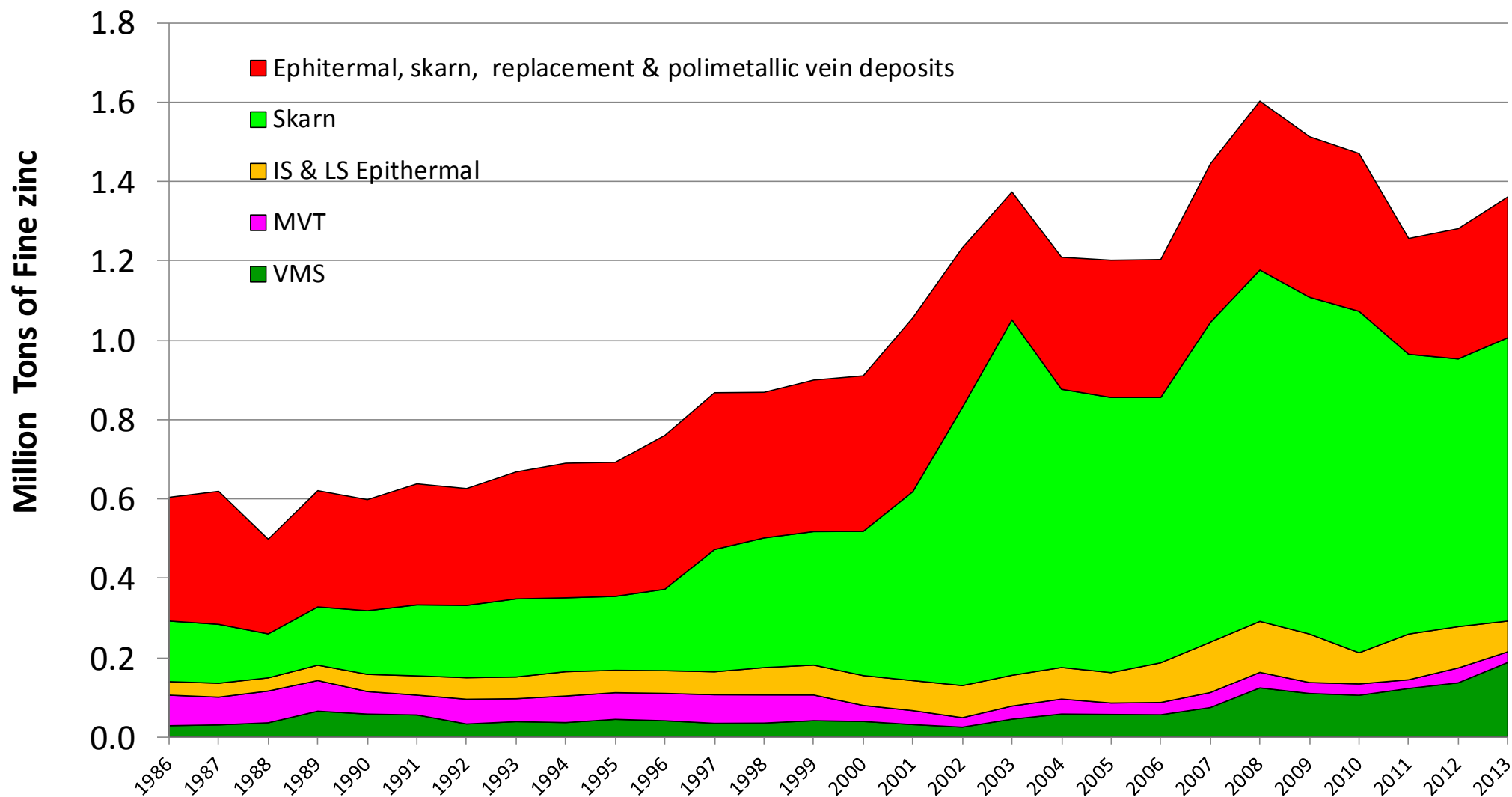
Lower Cretaceous– Paleocene VMS Cu-Zn-



Peruvian Zinc Production by Metallogenic belt



Peruvian Zinc Production by Deposit Type



Zinc Resources and Reserves in the Main Pb-Zn Belts in Peru

Total reported resources in Peru

52 MMT (100%)

From Miocene skarn, replacement and veins belt

30 MMT (58%)

From Lower Cretacic-Paleocene belt

4.6 MMT (9%)

From Miocene Epithermal Au-Ag belt

13.6 MMT (26%)

Other non & Zn belts

3.8 MMT (7%)

Millions tons of
Fine Lead

Mines Projects

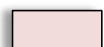
< 1

1-10

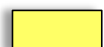
> 10



Metallogenic belts



Miocene epithermal, skarn, replacement & polymetallic vein deposits



Miocene epithermal Au-Ag deposits

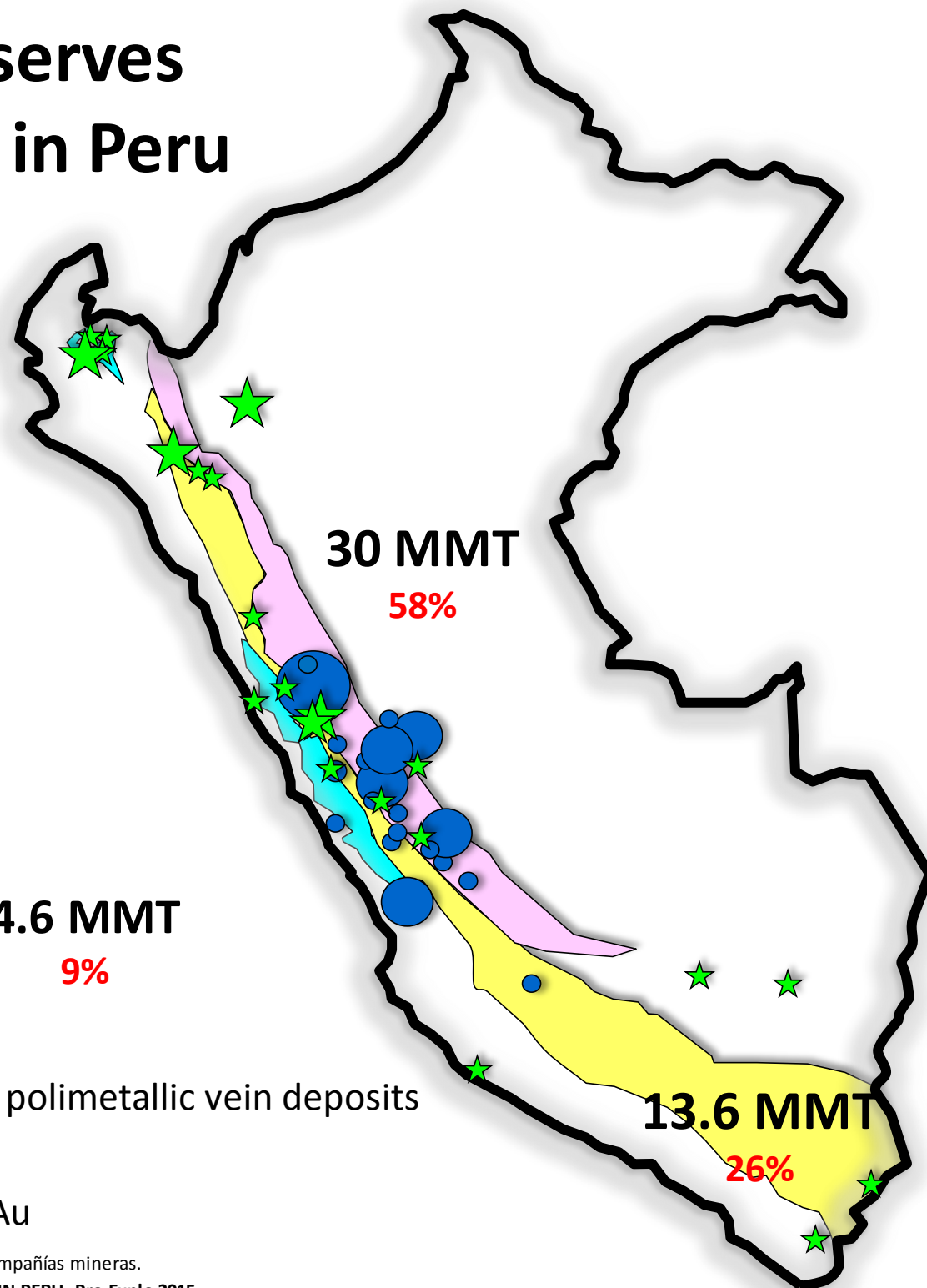


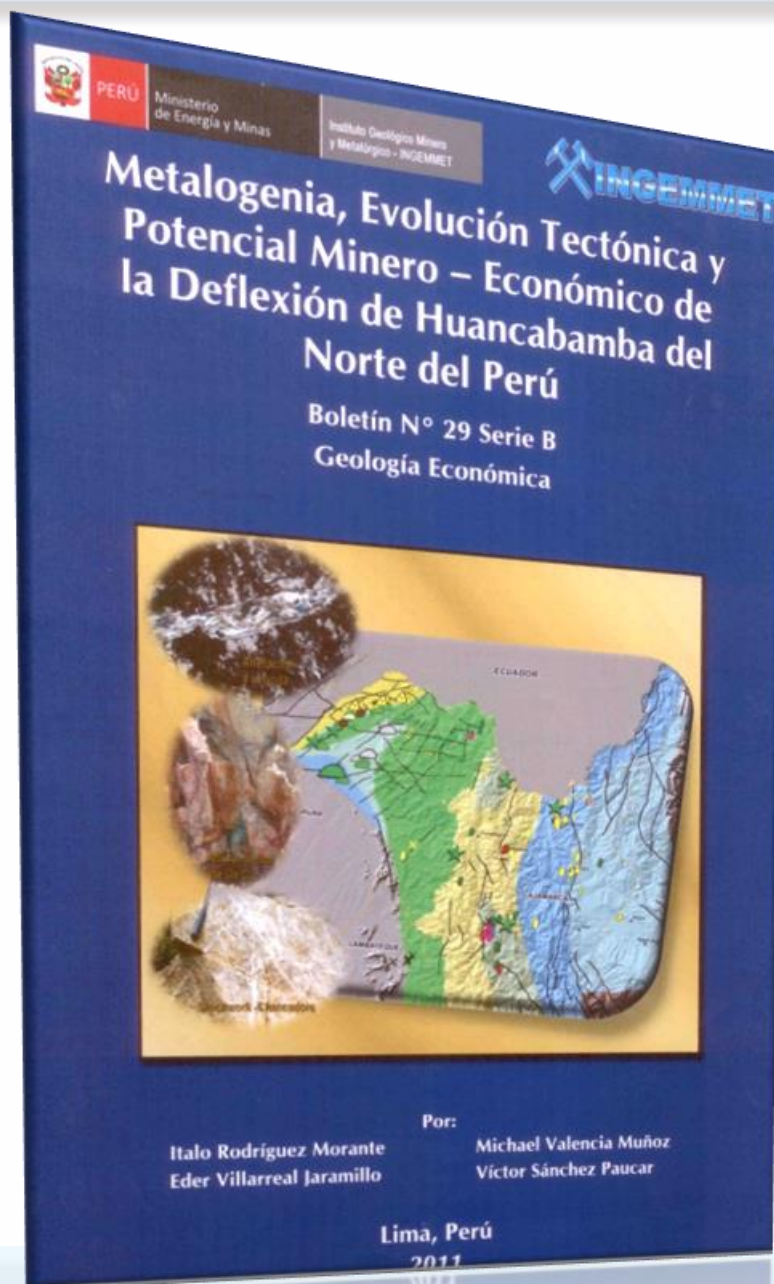
Lower Cretaceous–Paleocene VMS Cu-Zn-Au

4.6 MMT
9%

30 MMT
58%

13.6 MMT
26%

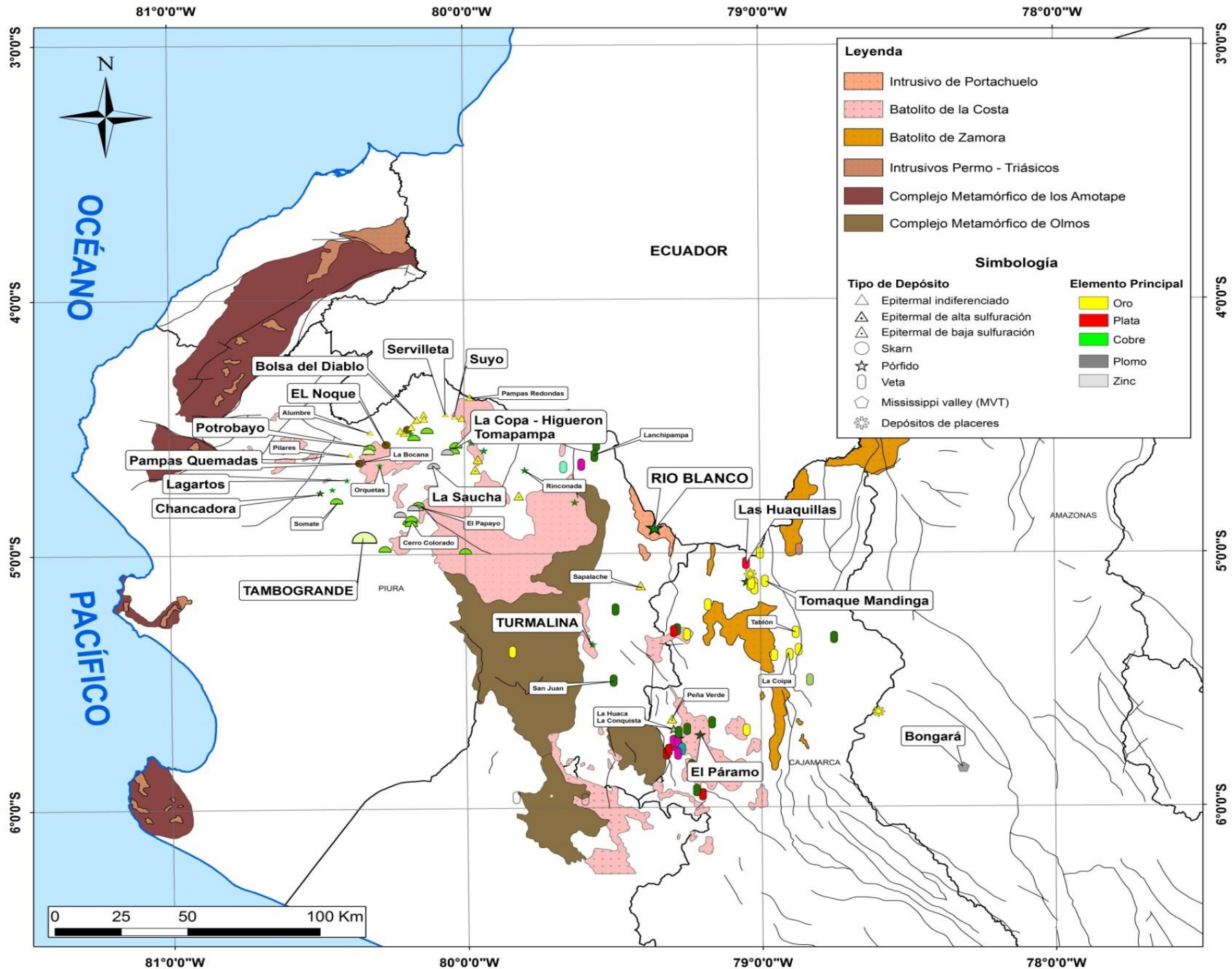




Metallogenic studies in the Equator-Peru border



Ore mineral deposits distribution



Temporal-spatial relationship

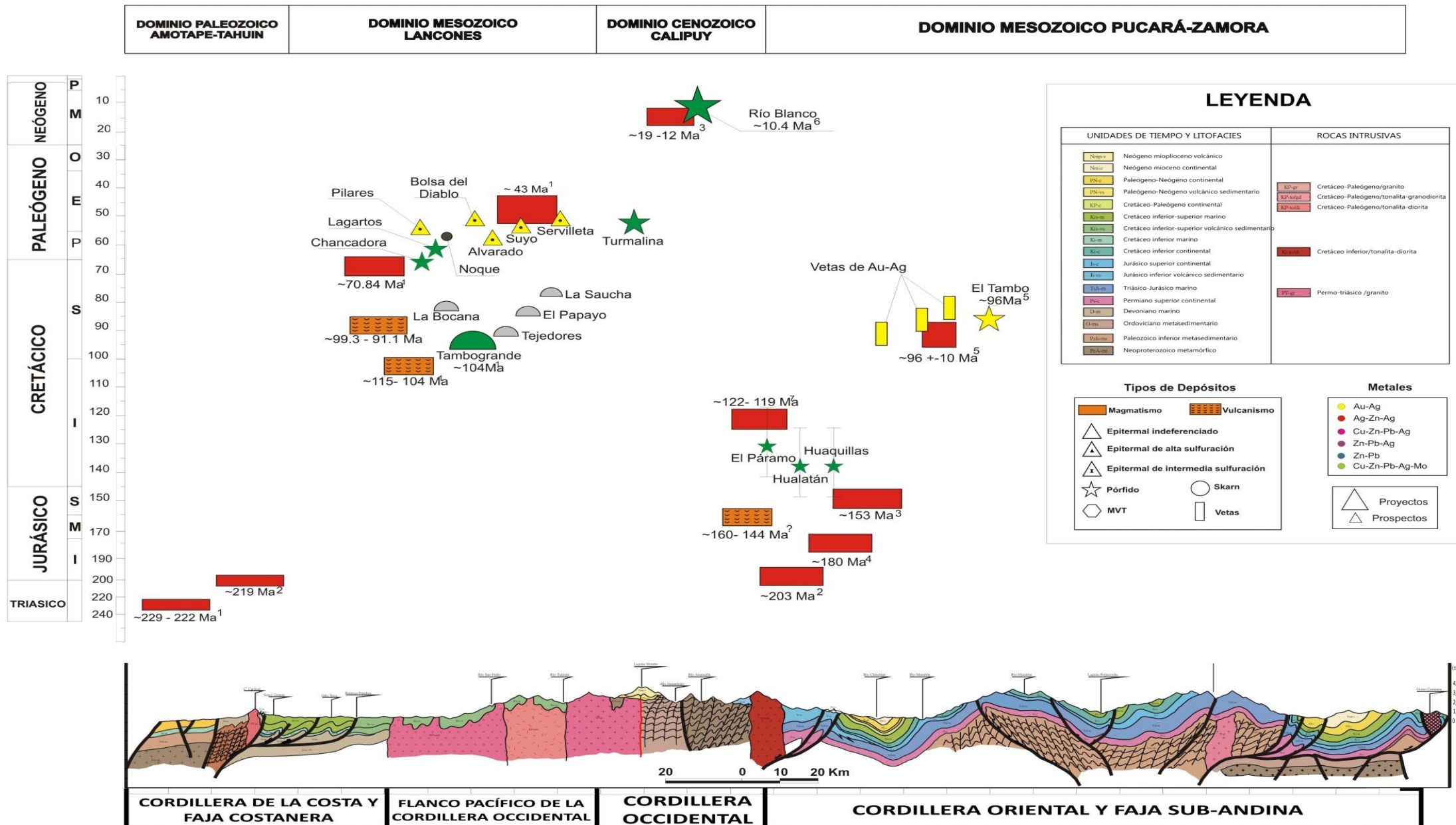
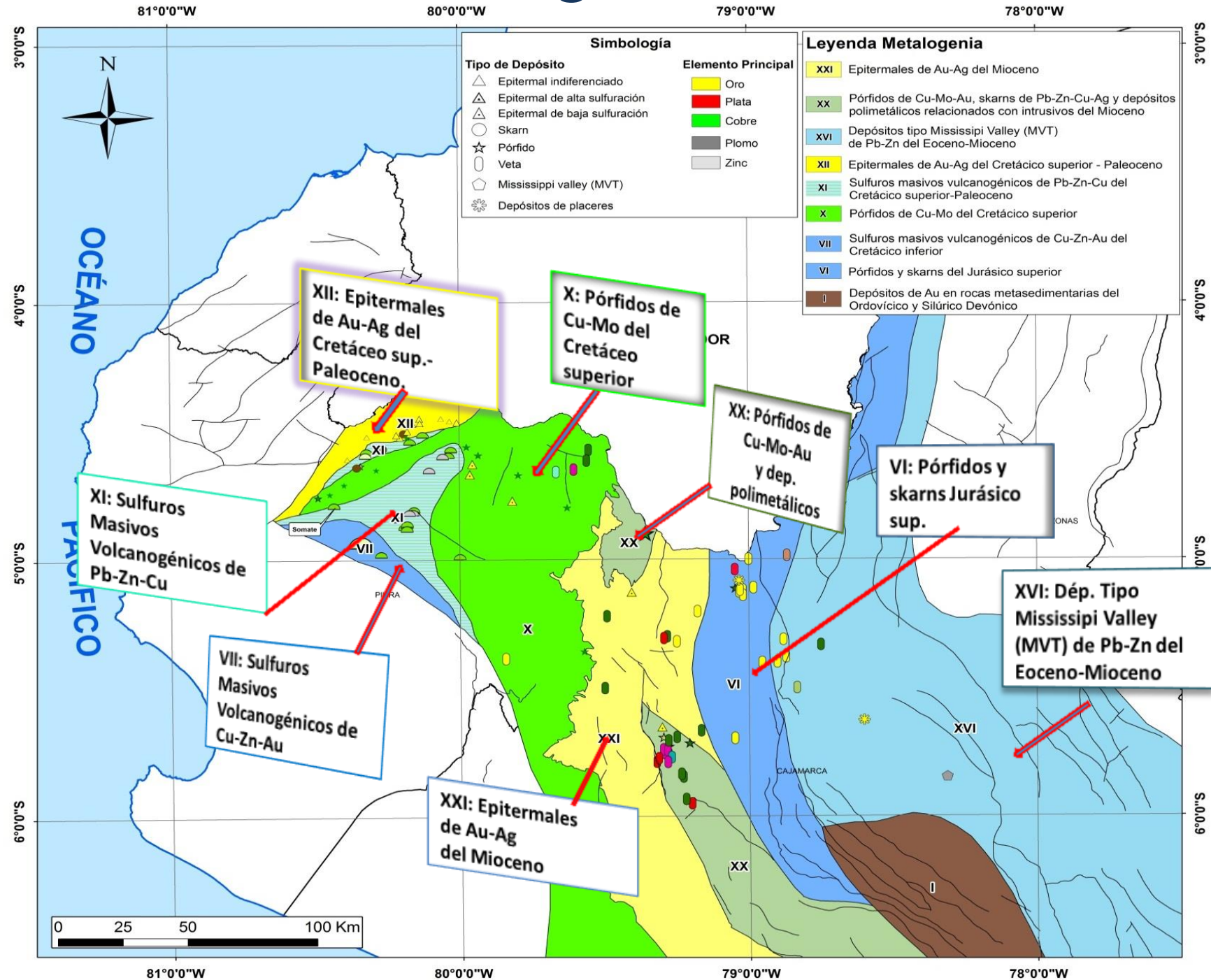


Figura 1. Relación espacio-tiempo entre los tipos de yacimientos y magmatismo asociado. entre las latitudes 05 – 00' S. Datos geocronológicos para la mineralización hipógena: 1= Winter,2008; 2 = Ulrich, 2005; 3 = Litherland,1994; 4 = Baldock, 1977; 5=Datos Tomados de informe Tecnico Dorato Resources Inc., 2008; 6= Tomado de Cia Monterrico Metals, Warren Bristow, Proexpro 2005; 7=Hama, 1990.

Metallogenetic belts



Gracias





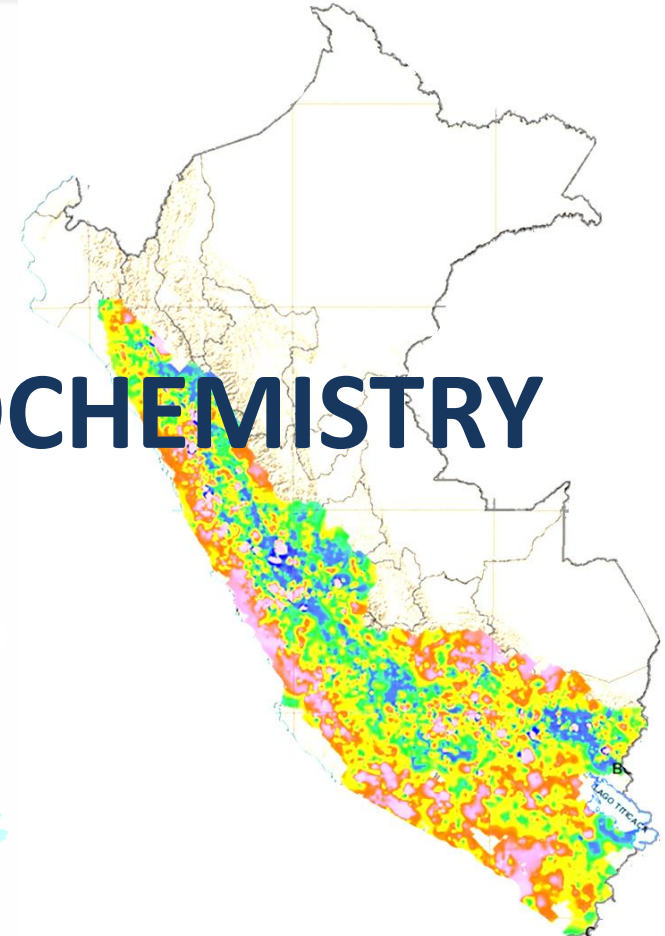
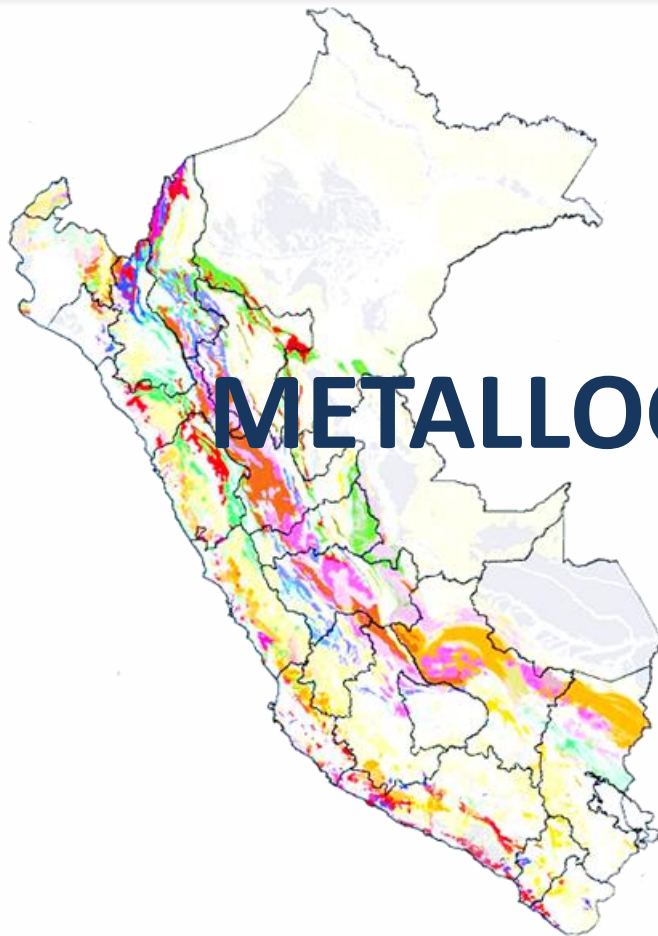
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METALLOGENY AND GEOCHEMISTRY OF PERÚ



Jorge ACOSTA ALE,

**Jorge CHIRA, Michael Valencia, Luis VARGAS, Alexander SANTISTEBAN,
Dina HUANACUNI, Italo RODRIGUEZ & Eder VILLARREAL**

INSTITUTO GEOLÓGICO MINERO Y METALÚRGICO
Dirección de Recursos Minerales y Energéticos
Programa de Metalogenia

