SECTOR ENERGÍA Y MINAS
INGEMMET
INSTITUTO GEOLÓGICO, MINERO Y METALÚRGICO

Simexmin
X SIMPÓSIO BRASILEIRO DE EXPLORAÇÃO MINERAL
X BRAZILIAN SYMPOSIUM ON MINERAL EXPLORATION

X SIMEXMIN

El Mapa Metalogenético del Peru: aplicaciones y actualización
The Metallogenic Map of Peru: applications and update

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INSTITUTO GEOLÓGICO MINERO Y METALÚRGICO
INGEMMET
METALLOGENY PROGRAM

The Metallogenic Map of Peru: applications and update

1. History of the metallogenic maps of Peru
2. Metallogenic map of Peru - metallogenic belts at a scale of 1: 3,000,000
3. Metallogenic chart at a scale of 1:250,000
   a. Map of Tectonostratigraphic Units at a scale of 1: 250,000
   b. Structural map at scale 1 : 750,000
   c. Geophysical map at scale 1 : 750,000
   d. Stream sediment geochemical maps at a scale of 1:750,000
   e. Map of spectral anomalies at a scale of 1:750,000
   f. Tectono-stratigraphic chart at scale 1 : 750,000
   g. Table of radiometric ages of the main ore deposits at a scale of 1: 750,000

1. HISTORY OF THE METALLOGENIC MAPS OF PERU

Casas & Tumialán **(1967)**
Bellido, Girard & Paredes **(1972)**

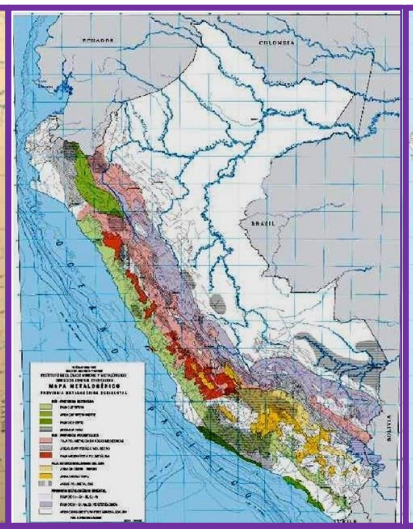
Ponzoni **(1980)**

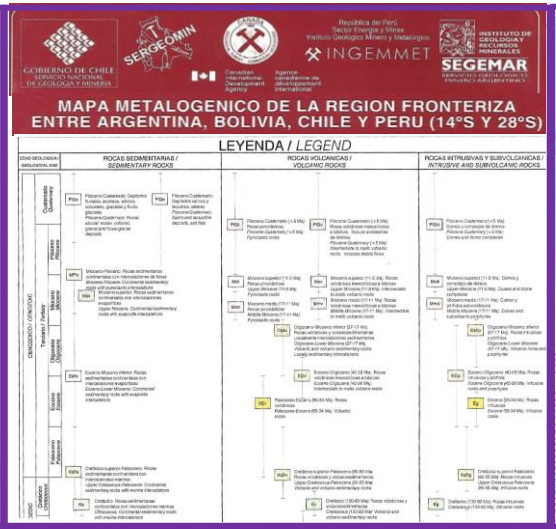
Canchaya, Aranda,
& Guevara **(1995)**

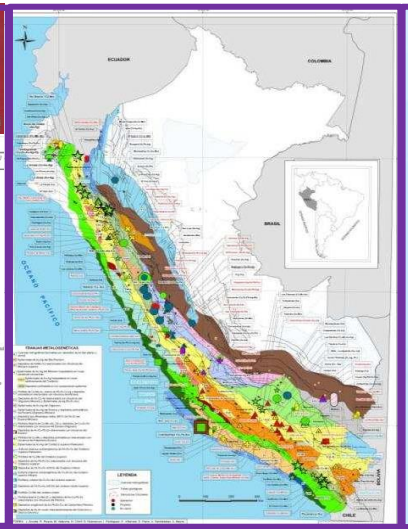
Zappettini et al., **(2001)**
Andean Multinational Project

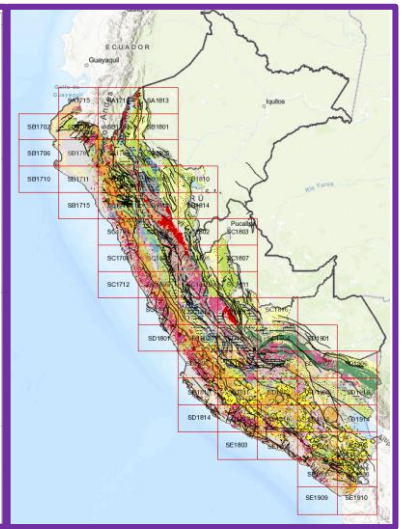
J. Quispe **(2006-2008)**
J. Acosta **(2009-2021)**

L.Quispe et al. **(2021)**









METALLOGENETIC CHART

64 SHEETS TO SCALE 1:250,000

METALLOGENIC PROVINCES

METALOGENIC AREAS AND LITHOTECTONIC UNITS

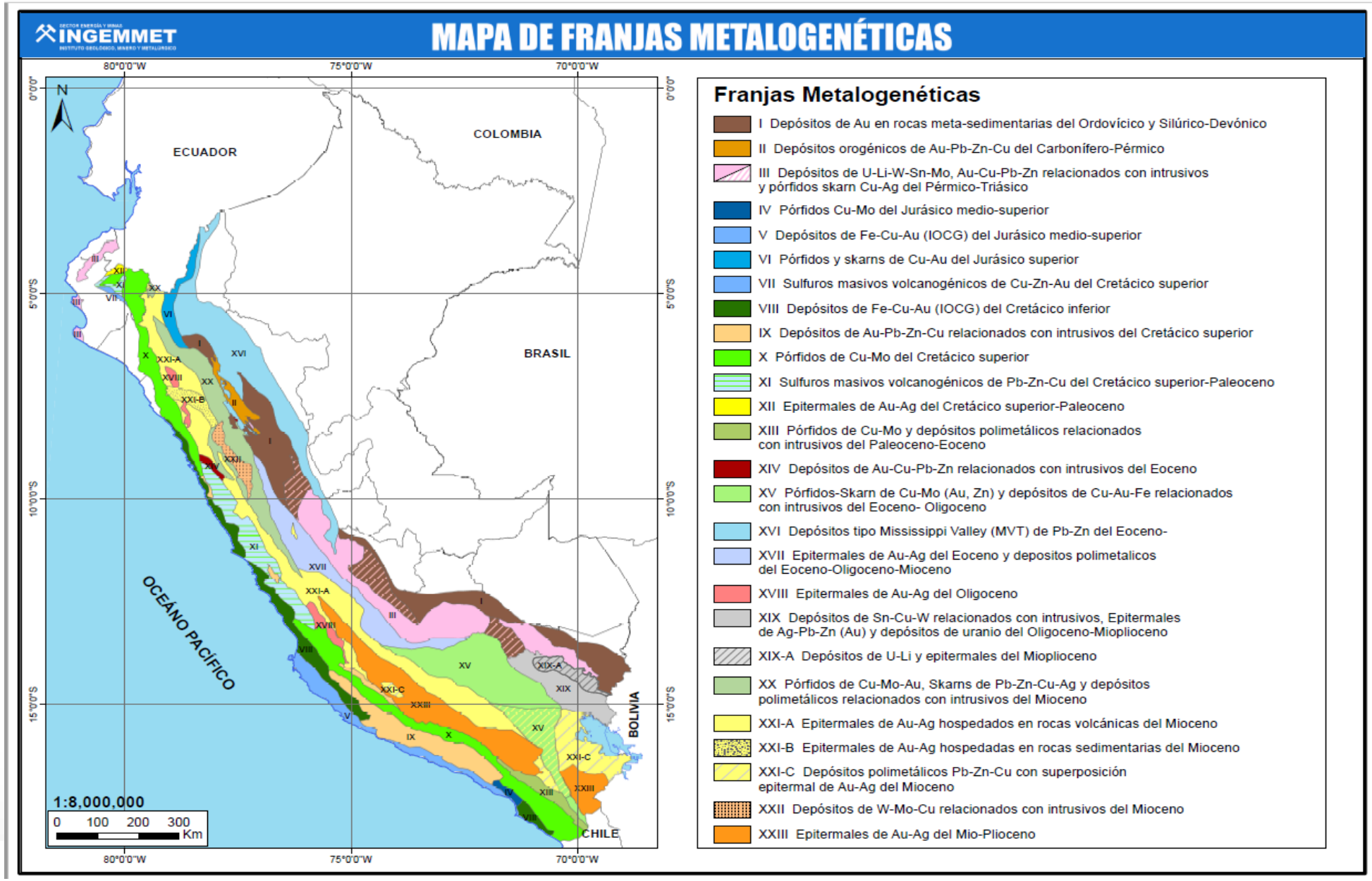
GEOLOGICAL UNITS AND ASSOCIATED RESERVOIRS

23 METALLOGENETIC BELTS

TECTONO-STRATIGRAPHIC UNITS

X SIMEXMIN

2. METALLOGENETIC MAP OF PERU-METALLOGENETIC BELTS AT A SCALE OF 1 : 3,000,000



X SIMEXMIN

2. METALLOGENETIC MAP OF PERU-METALLOGENETIC BELTS AT A SCALE OF 1 : 3,000,000

COPPER

Total Production 2021

2.30 Mtmf

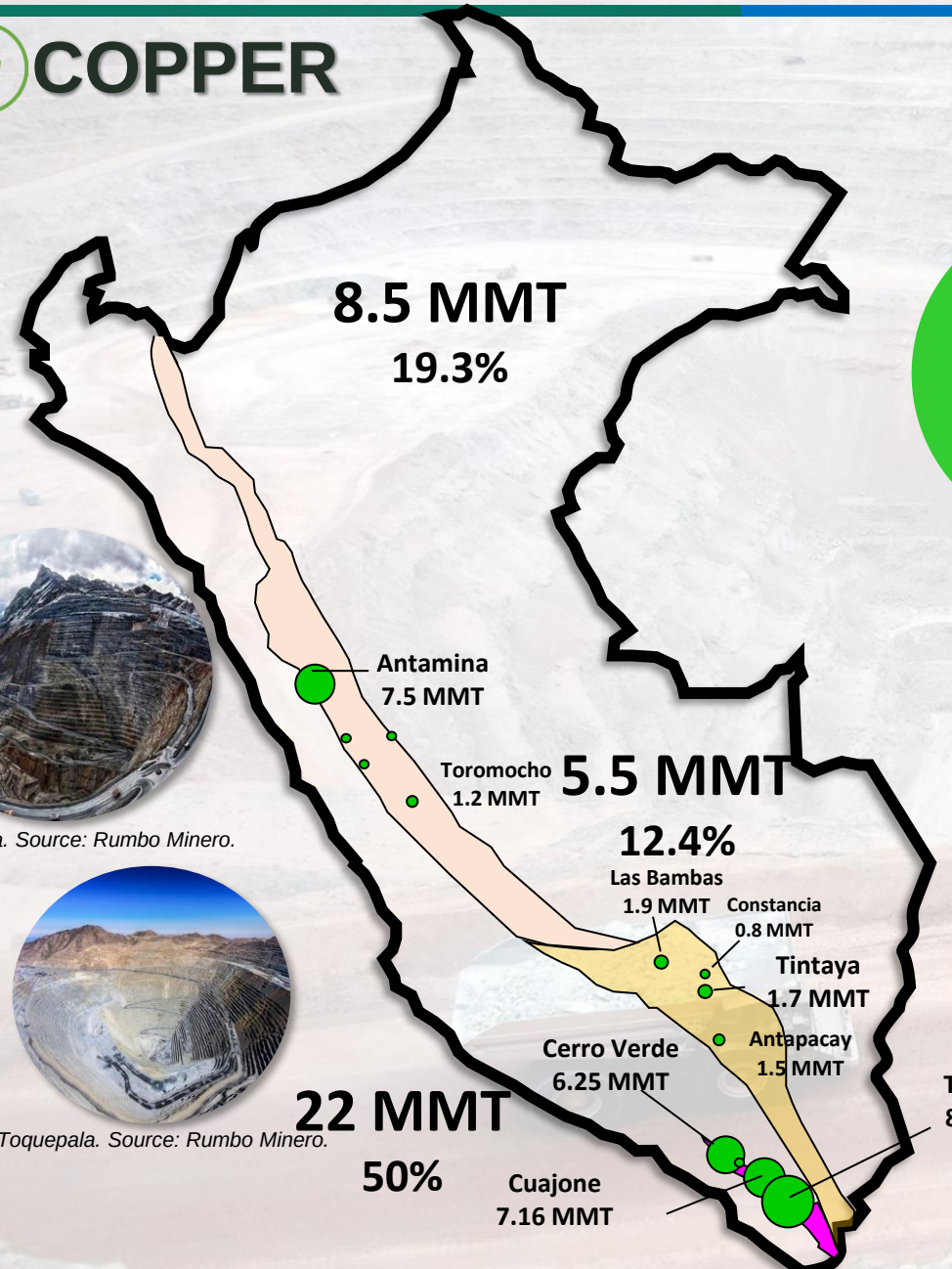
Total production in Peru

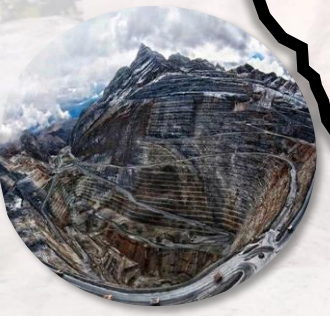
~46.4 MMT (100%)

Production from main porphyry belts

38.05 MMT (82%)

Other Cu belts: 3.25 MMT (7%)
Other non-Cu belts: 5.1 MMT (11%)





Antamina. Source: Rumbo Minero.

Toquepala. Source: Rumbo Minero.

Cuajone. Source: Camiper.

Million Metric Tons of Fine copper	Mines
< 1	
1-3	
3-5	
5-7	

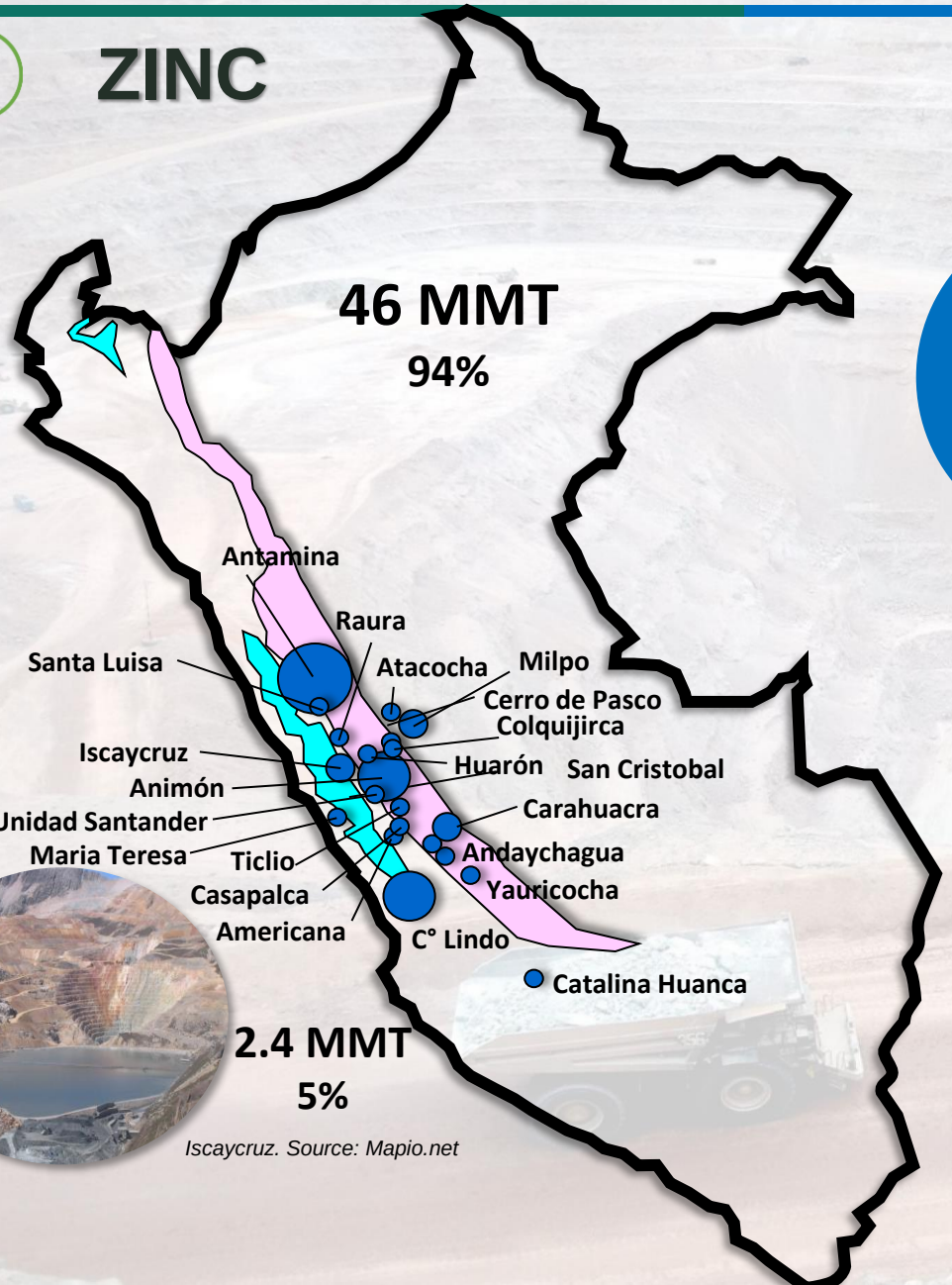
Metallogenic belts

- Miocene porphyry belt
- Eocene-Oligocene porphyry belt
- Paleocene porphyry belt

Source: Modified from Jorge ACOSTA ALE, A. BUSTAMANTE & M. CARDOZO. 2013. **Cooper in Peru: Facts and Challenges. 31° PERUMIN**

2. METALLOGENETIC MAP OF PERU-METALLOGENETIC BELTS AT A SCALE OF 1 : 3,000,000

ZINC



Iscaycruz. Source: Mapio.net

Total Production 2021

1.50 Mtmf

Cerro Lindo.
Source: rumbominero.com

Total production in Peru

~50.2 MMT (100%)

From Miocene belt

47.2 MMT (94%)

From Lower Cretaceous-Paleocene belt
2.5 MMT (5%)
Other no Pb-Zn belts
0.5 MMT (1%)

Production 2014
Tons of Fine Zinc
X 1000

< 50

50-100

100-200

> 200

Mines

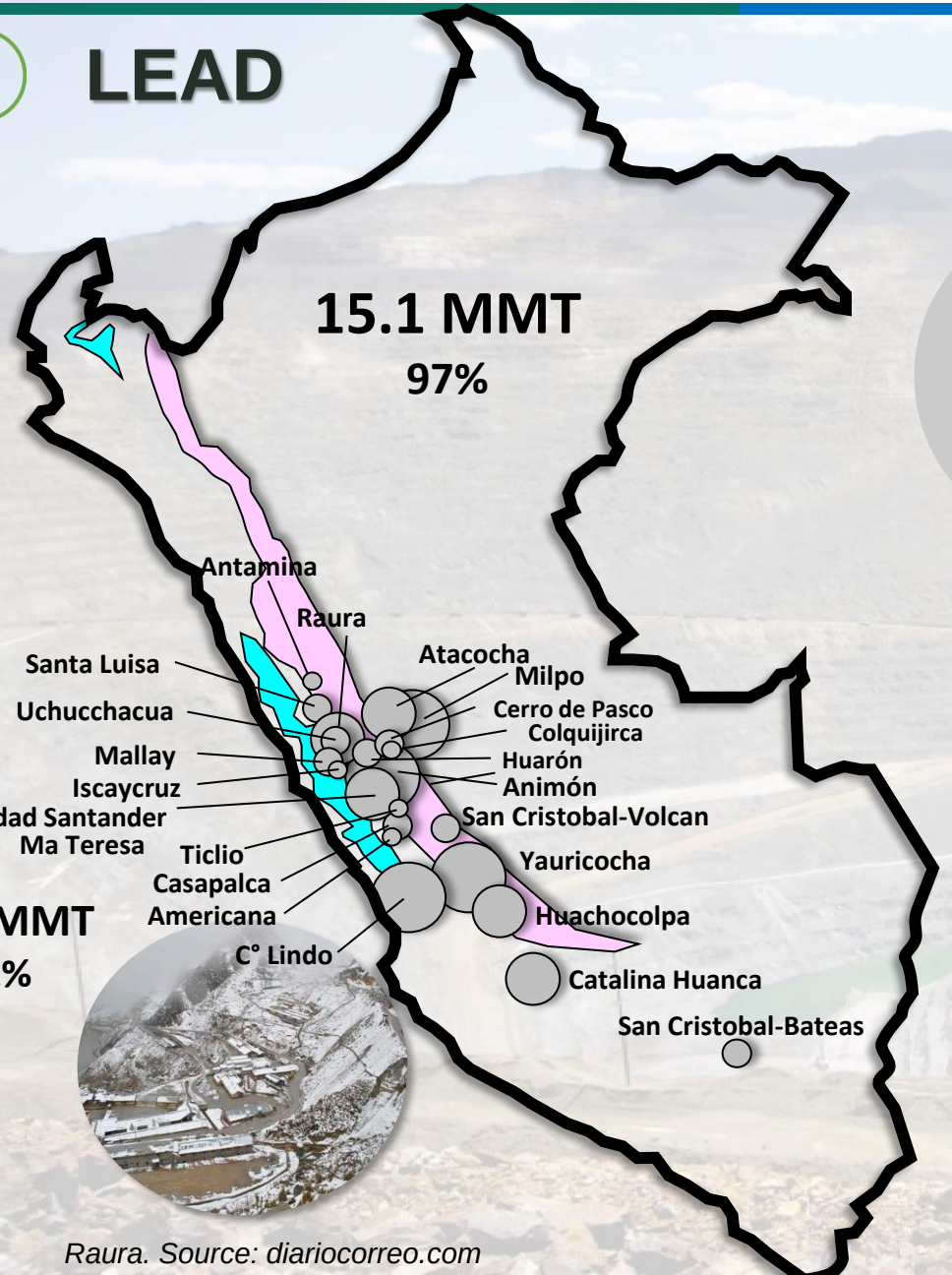
Metallogenic belts

- Miocene epithermal, skarn, replacement & polimetallic vein deposits
- Lower Cretaceous– Paleocene VMS Cu-Zn-Au

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

2. METALLOGENETIC MAP OF PERU-METALLOGENETIC BELTS AT A SCALE OF 1 : 3,000,000

LEAD



Raura. Source: diariocorreo.com

Total Production 2021

264 Ktmf

Total production in Peru

~15.9 MMT (100%)

From Miocene belt
15.42 MMT (97%)

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

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

Yauricocha.
Source: rumbominero.com

Production 2014
Tons of Fine Lead
X 1000

< 7
7-10
10-15
> 15

Mines

Metallogenic belts

Miocene epithermal, skarn, replacement & polimetallic vein deposits

Lower Cretaceous– Paleocene VMS Cu-Zn-Au

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

2. METALLOGENETIC MAP OF PERU-METALLOGENETIC BELTS AT A SCALE OF 1 : 3,000,000

SILVER

Total Production 2021

106.4 Moz

Total production in Peru

~5024 Moz (100%)

Production from main silver belts

4,772 Moz (95%)

Other non-Ag belts: 251 Moz (5%)

Hualgayoc. Source: grufides.org

Cerro de Pasco.
Source: Revista Proactivo.com

Million Onces of Fine Silver	Mines
< 100	
200-100	
300-200	
> 300	

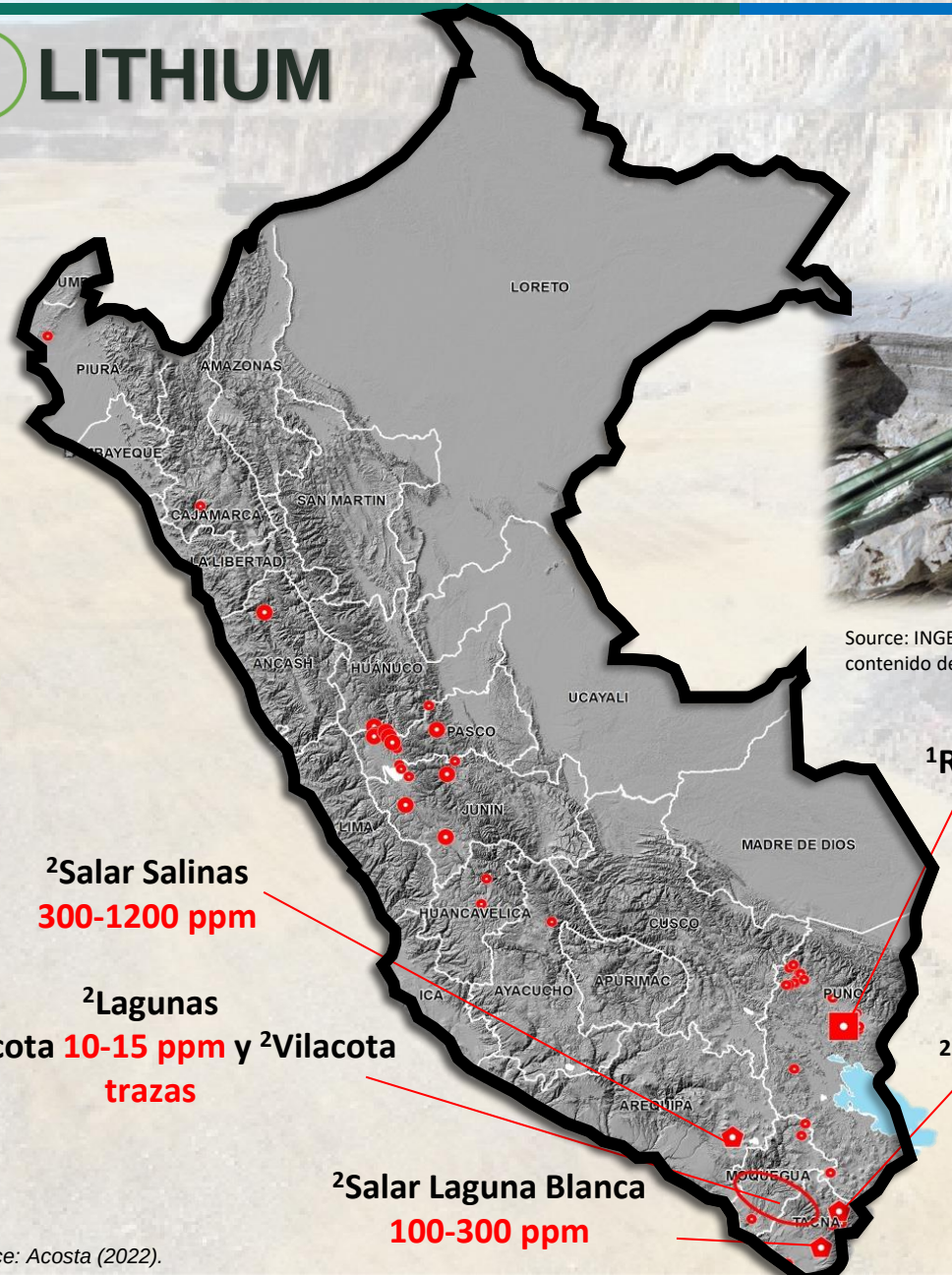
Metallogenic belts

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

Source: Modified from J. ACOSTA Ale *et al*. 2014. Production of Gold and Silver in Peru: Past, Present and Future. 11th International Gold & Silver Symposium, 2014.

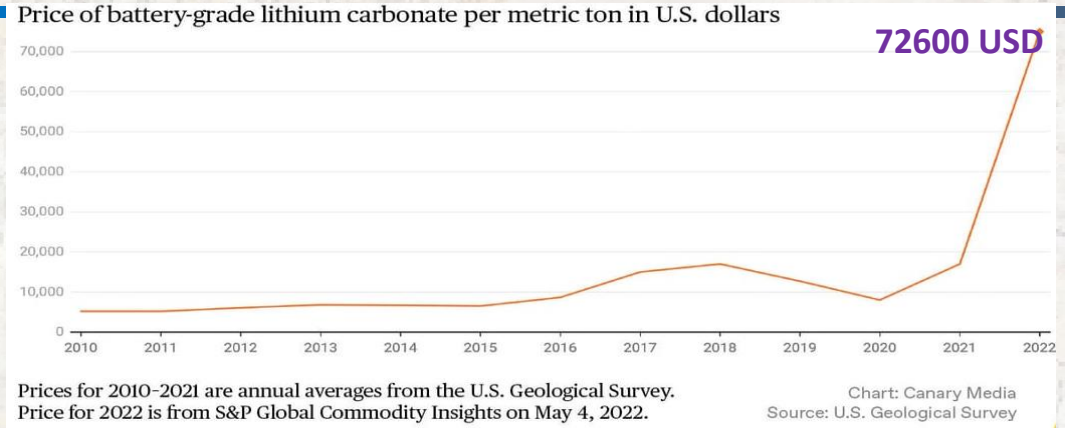
2. METALLOGENETIC MAP OF PERU-METALLOGENETIC BELTS AT A SCALE OF 1 : 3,000,000

LITHIUM



Total Production 2021

Source: INGEMMET. Rocas volcánicas – Macusani con contenido de litio



Mineral Deposit	Indicated	Li_2O (%)	Inferred	Li_2O (%)
Macusani[1]	40.6 Mt	0.67	121.7 Mt	0.59

1: Source: Macusani Yellowcake S.A.C - unofficial data

Lithium content expressed as carbonate:

Indicated Resources= **0.63 Mt LCE**

Inferred Resources = **1.41 Mt LCE**

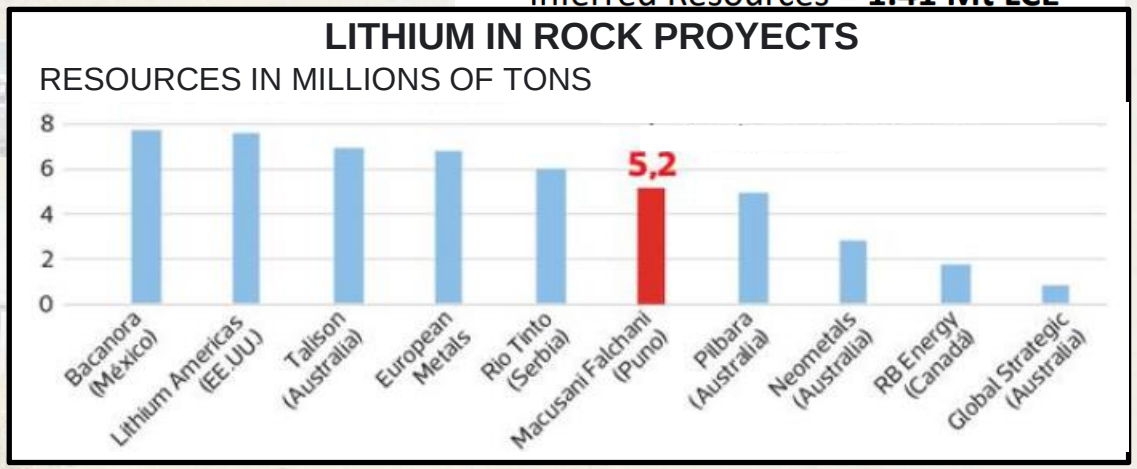
[1]Rocas volcánicas - Macusani
3000-3500 ppm

[2]Salar Salinas
300-1200 ppm

[2]Lagunas
[2]Loriscota 10-15 ppm y [2]Vilacota
trazas

[2]Salar Chilicolpa
10-15 ppm

[2]Salar Laguna Blanca
100-300 ppm



Source: Acosta (2022).

2. METALLOGENETIC MAP OF PERU-METALLOGENETIC BELTS AT A SCALE OF 1 : 3,000,000

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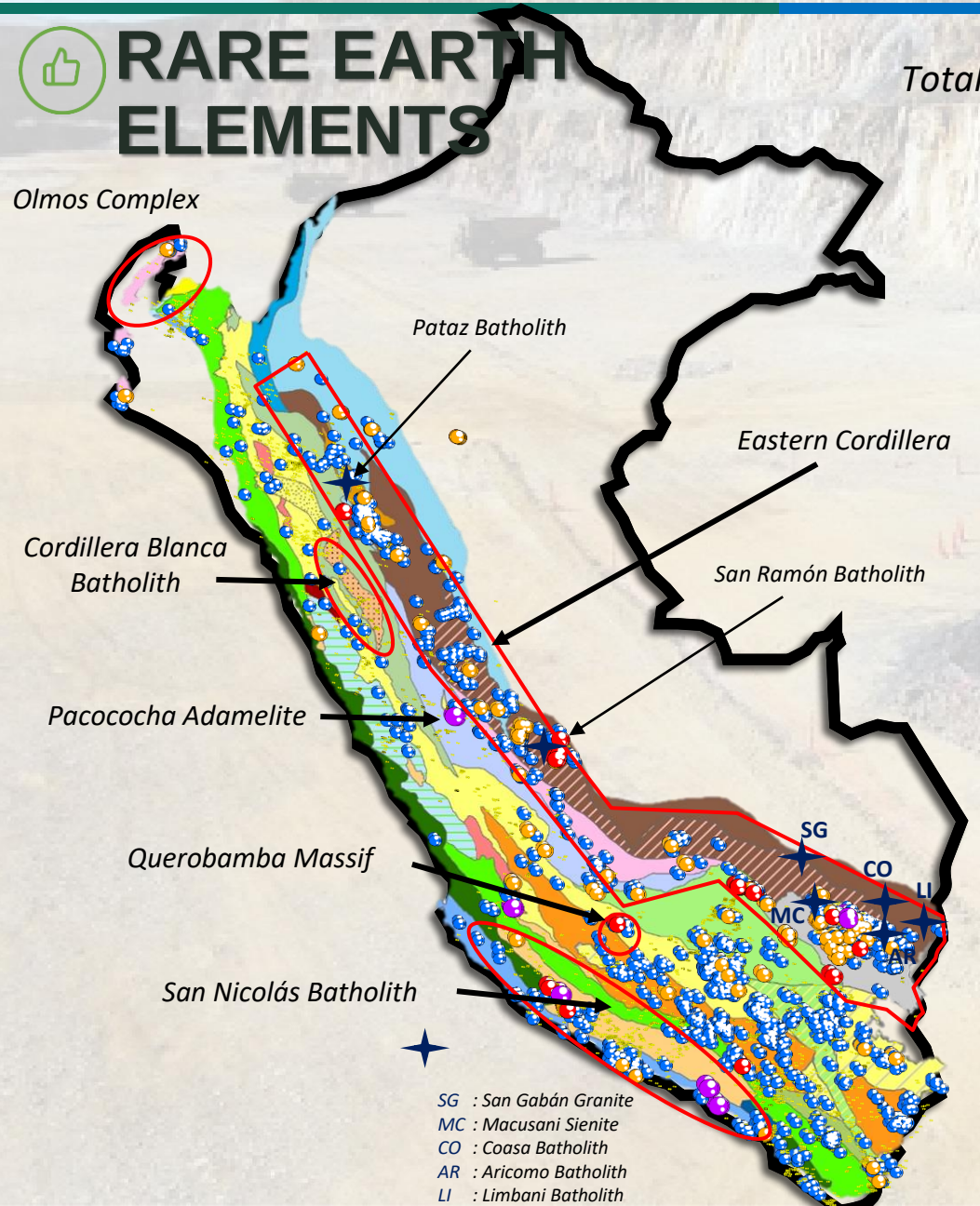
X BRAZILIAN SYMPOSIUM ON MINERAL EXPLORATION

RARE EARTH ELEMENTS

Total rock samples: ***11,358***



Concentración geoquímica	
Elementos	Rock (ppm)
La	0.02 to 2 870
Y	0.05 to 1 555

Óxidos totales (TREO) en Rocas

- 1500 – 10304 ppm (0.15 – 1.30%)
- 1000 – 1500 ppm (0.10 – 0.15%)
- 500 – 1000 ppm
- 250 – 500 ppm
- <250ppm

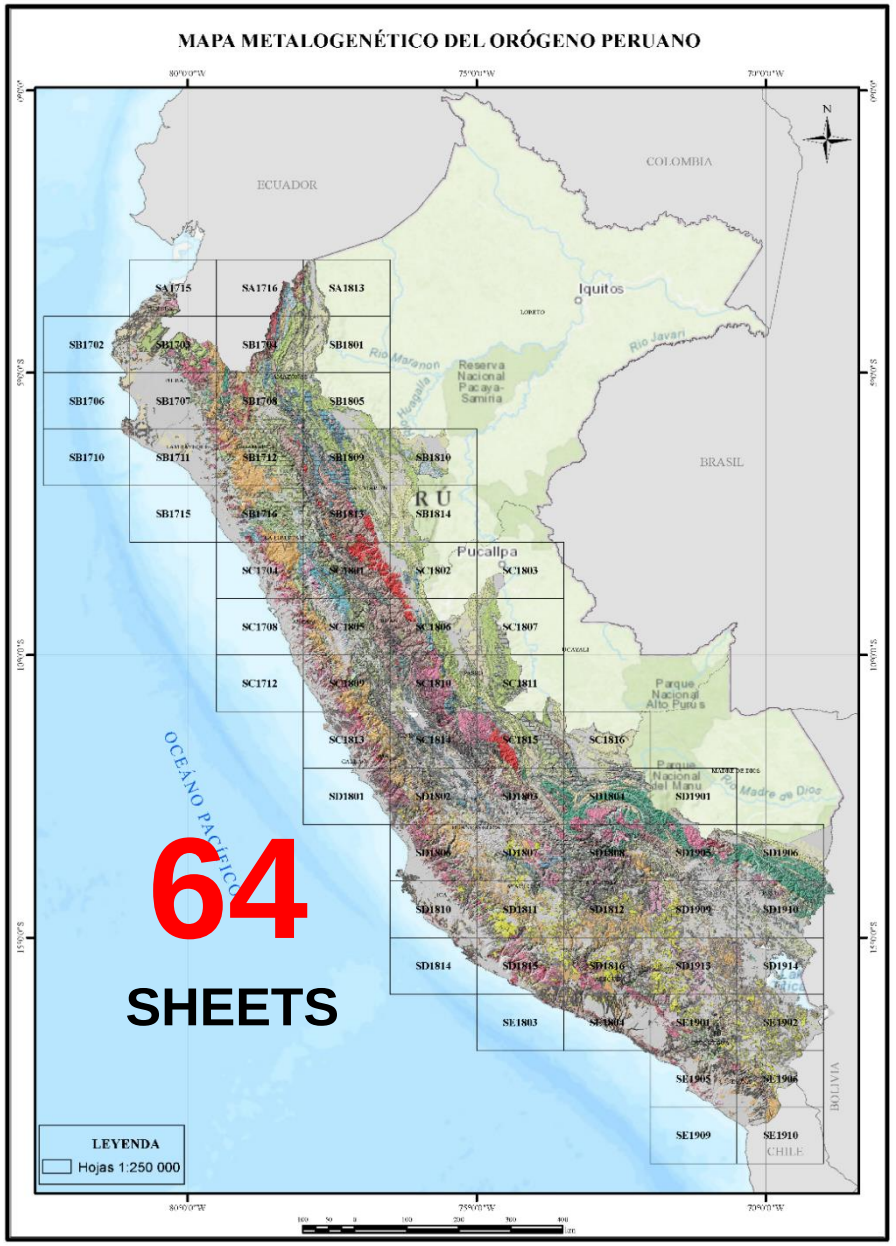
n: 1,223

- 15 elements
- Total number of sampless: 11,358

METALLOGENIC BELTS

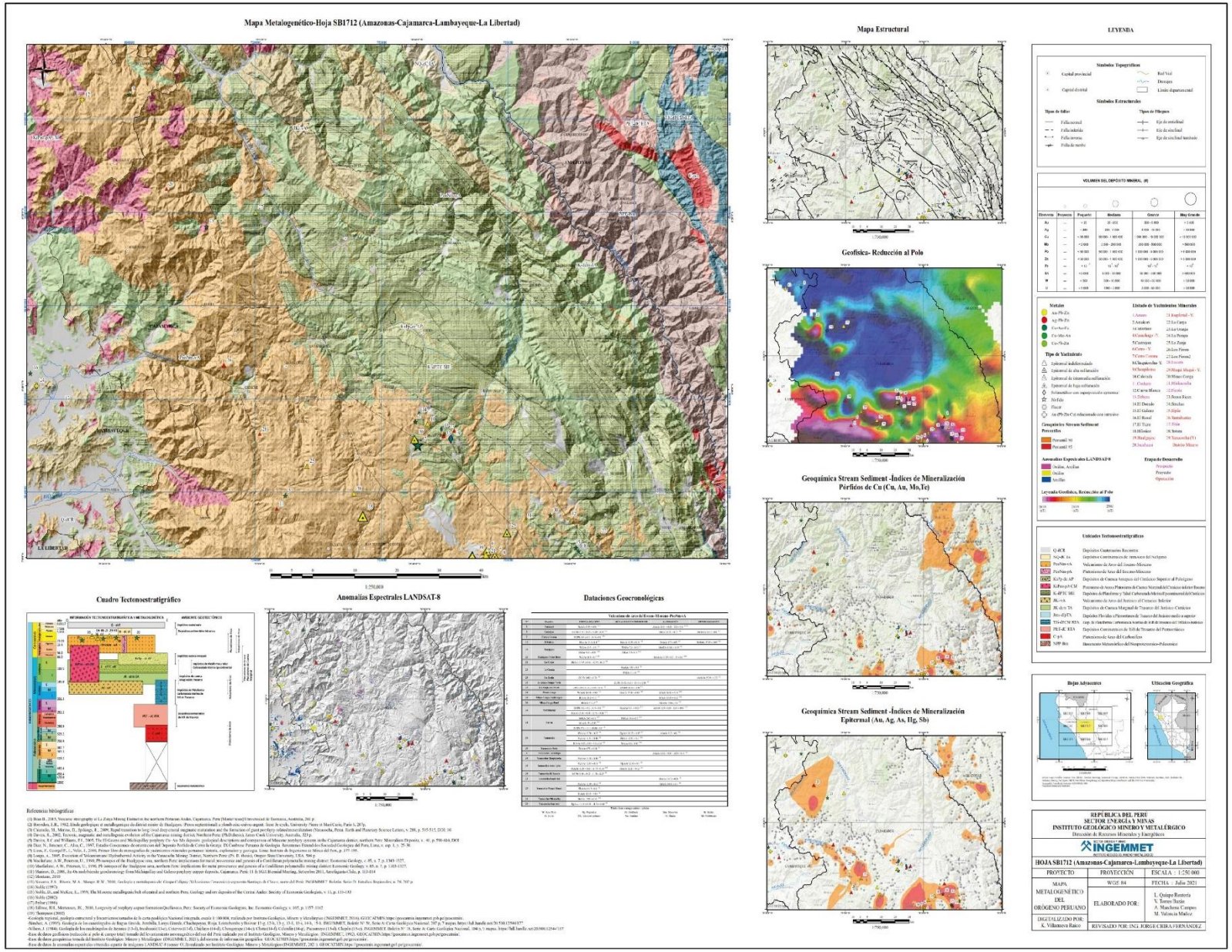
- XXIII Miocene - Pliocene Au-Ag epithermal.
- XXII Upper Miocene intrusive-related W-Mo-Cu deposits.
- XXI Au-Ag epithermal Miocene deposits .
- XXI-A Au-Ag epithermal deposits hosted in volcanic rocks.
- XXI-B Au-Ag epithermal deposits hosted in Cretaceous sedimentary rocks.
- XXI-C Polymetalic deposits with epithermal overprint.
- XX Miocene Cu- Mo- Au porphyry, Pb- Zn- Cu -Ag skarn and intrusives- related polymetallic deposits.
- XIX Oligocene-Miocene intrusive-related Sn-Cu-W deposits and Ag-Pb-Zn (Au) epithermal.
- XVIII Oligocene Au-Ag epithermal.
- XVII Eocene Au-Ag epithermal and Eocene-Oligocene-Miocene polymetallic deposits.
- XVI Eocene-Miocene Mississippi Valley Pb-Zn deposits.
- XV Cu-Mo (Au-Zn) porphyry-skarn and Eocene-Oligocene intrusive-relatived Cu-Au-Fe deposits.
- XIV Eocene intrusives - related Au-Pb-Zn-Cu deposits.
- XIII Cu-Mo porphyry and Paleocene-Eocene intrusives-related polymetallic deposits.
- XII Upper Cretaceous - Paleocene Au - Ag epithermal.
- XI Upper Cretaceous-Paleocene Volcanogenic Massive Sulphide Pb-Zn-Cu deposits.
- X Upper Cretaceous Cu-Mo porphyry.
- IX Upper Cretaceous intrusives - related Au - Pb - Zn - Cu deposits.
- VIII Lower Cretaceous Fe-Cu-Au (IOCG) deposits.
- VII Upper Jurassic - Albian Volcanogenic Massive Sulphide Cu-Zn-Au deposits.
- VI Upper Jurassic porphyry and Cu-Au skarns.
- V Upper-Middle Jurassic Fe-Cu-Au (IOCG) deposits.
- IV Middle Jurassic Cu-Mo porphyry.
- III Permian intrusives - related U-W-Sn-Mo, Au- Cu-Pb-Zn and porphyry and skarns Cu - Ag deposits.
- II Carboniferous - Permian orogenic Au - Pb - Zn-Cu deposits.
- I Gold in Ordovician and Silurian - Devonian meta - sedimentary rocks.

3. METALLOGENETIC CHART AT A SCALE OF 1 : 250,000

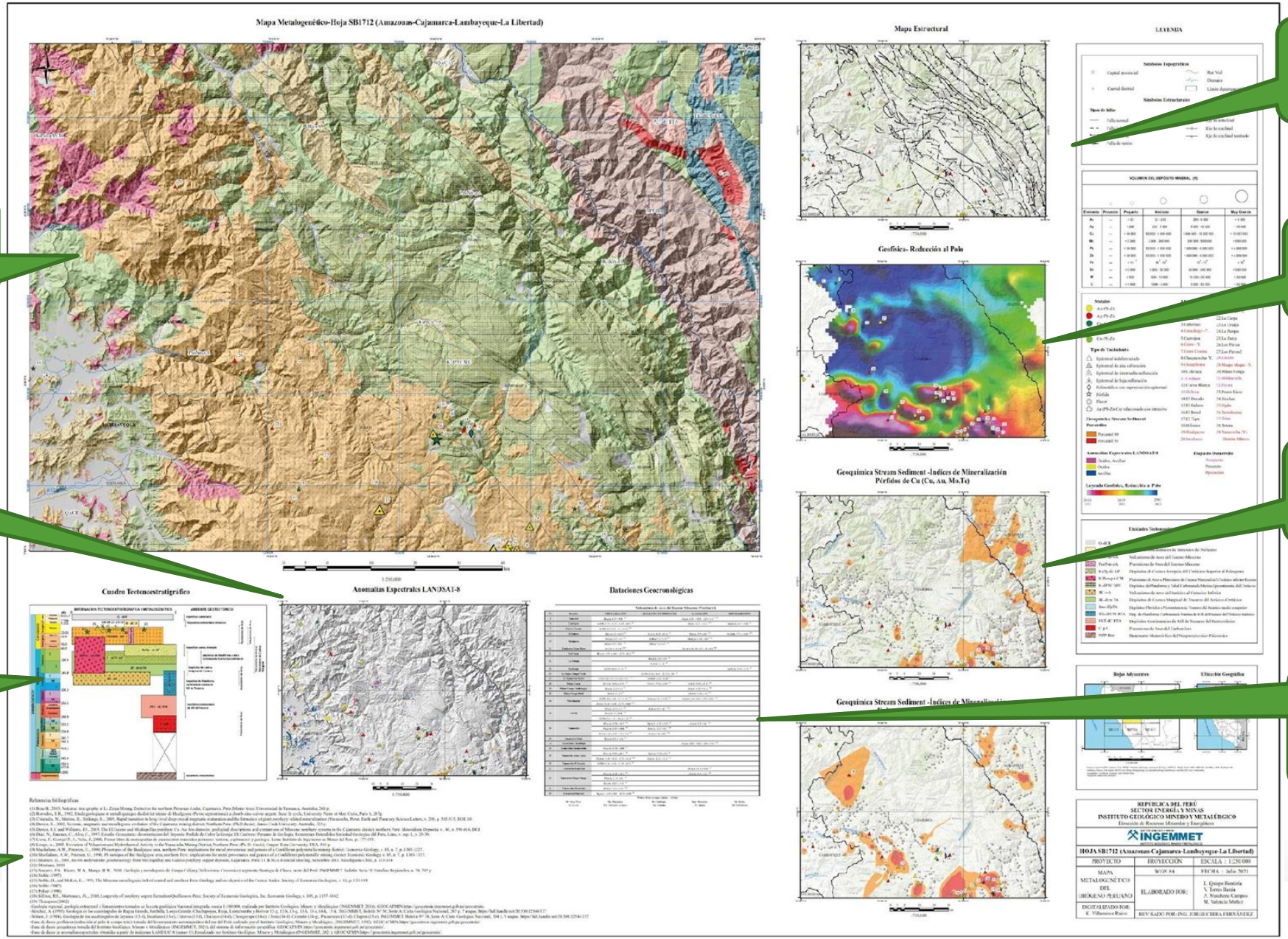


64

SHEETS



3. METALLOGENETIC CHART AT A SCALE OF 1 : 250,000



a. Map of Tectonostratigraphic Units (1: 250 000)

b. Structural map (1 : 750 000)

c. Geophysical map (1:750 000)

d. Stream sediment geochemical maps (1:750 000)

e. Map of spectral anomalies (1:750 000)

f. Tectono-stratigraphic chart (1:750 000)

g. Table of radiometric ages of the main ore deposits

Bibliographic references

MEXMIN

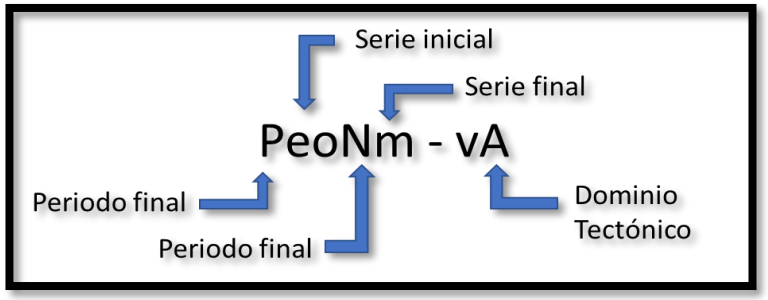
X SIMEXMIN

a. Map of Tectonostratigraphic Units at a scale of 1: 250 000

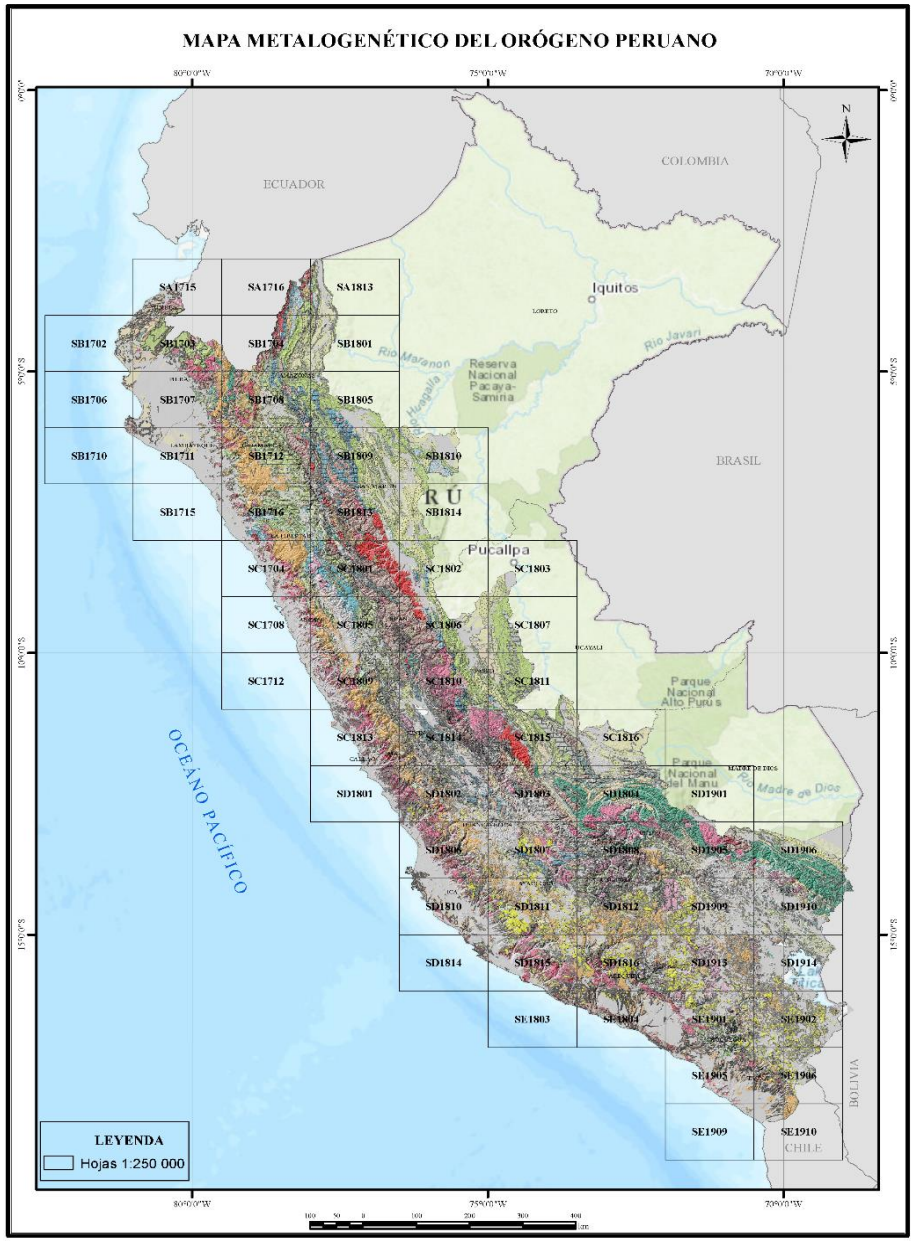
61 Litostratigraphic units

25 Tectonostratigraphic units

Label structure

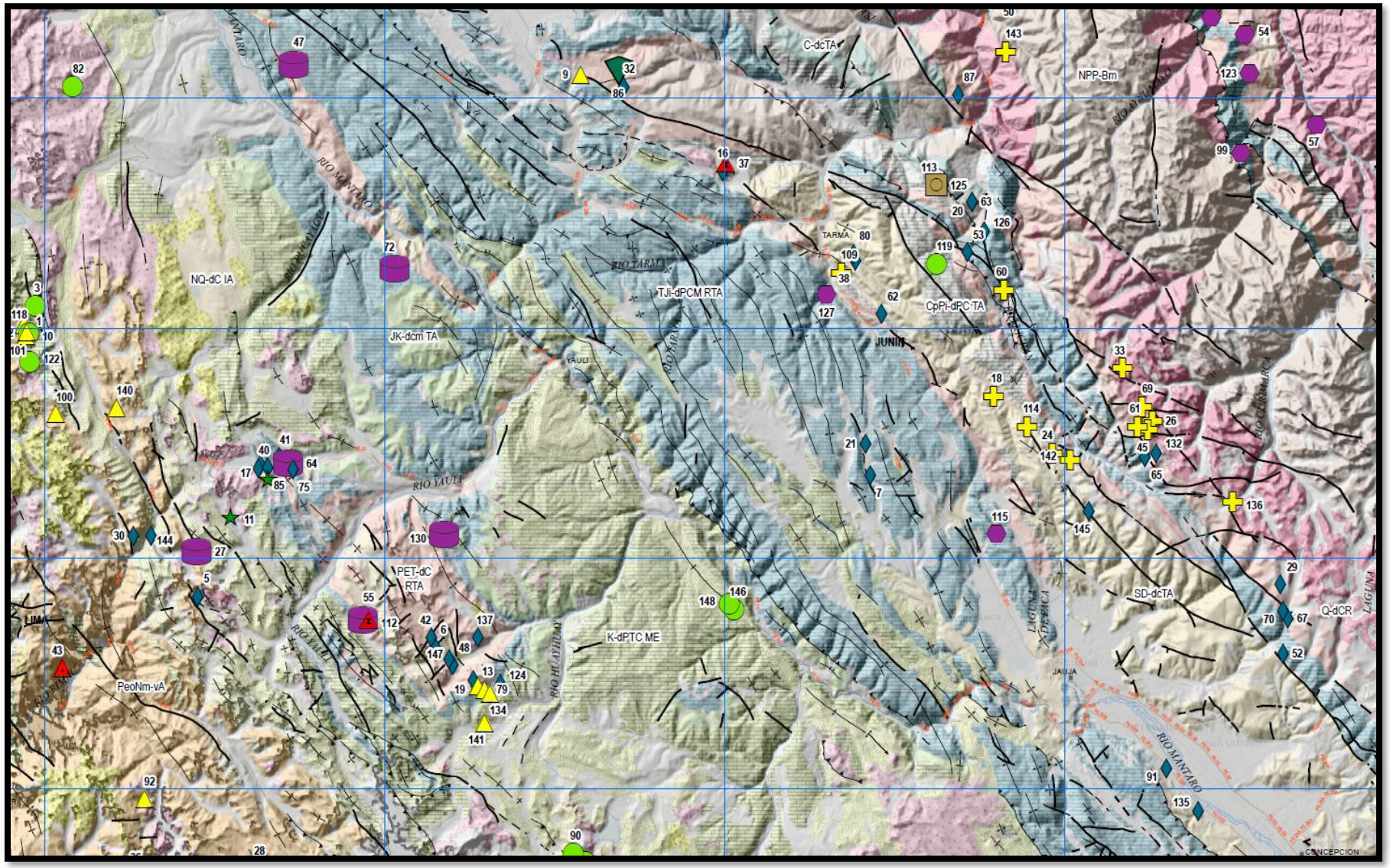


Unidades Litoestratigráficas	Unidades Tectonoestratigráficas		
	Depósitos Cuaternarios Recientes		
Grupo Andahua	Magmatismo de Arco Reciente		
Formación Ocoruro Formación Capillune	Depósitos Continentales de IntraArco del Neógeno		
Formación Picotani Formación Quenamari Formación Cayconi	Vulcanismo de Trasarco del Mioceno - Plioceno		
Grupo Barroso Formación Huaylillas Formación Sencca Grupo Nazca	Vulcanismo de Arco del Miopleistoceno		
Formación Pisco Formación Camaná	Depósitos de Cuenca Marina Somera de AnteArco del Eoceno-Mioceno		
Grupo Tacaza Grupo Sillapaca Formación Astobamba Formación Alpabamba Grupo Palca Formación Orcopampa Formación Aniso Grupo Palca Formación Millo Formación Moquegua Formación Sotillo	Vulcanismo de Arco del Eoceno-Mioceno	Plutonismo de Arco Eoceno-Mioceno	Batolito de Andahuaylas Yauri
	Depósitos Continentales de AnteArco del Eoceno-Plioceno	Plutonismo de Arco a Plutonismo de Cuenca Marginal del Cretácico inferior-Eoceno	Batolito de la Costa
Grupo Moho Formación Pozo Formación Huanca Formación Seraj Grupo Puno Formación Cihuaya Formación Chilcane Formación Ashua Formación Arcurquina Formación Ayabacas Formación Murco Formación Matalaque Formación Huaracané Formación Huancané Formación Viluyo Formación Muni Formación Copara Grupo Yura	Depósitos de Cuenca Antepais del Cretácico Superior al Paleógeno		
	Depósitos de Plataforma y Talud Carbonatada Marina Epicontinental del Cretácico		
	Magmatismo de Arco del Cretácico		
	Depósitos de Cuenca Marginal de Trasarco del Jurásico-Cretácico		
Formación Chocolate Formación Río Grande Formación Guaneros	Vulcanismo de Arco del Jurásico al Cretacico Inferior	Plutonismo de Arco del Jurásico	
Formación Socosani	Depósitos de Cuenca Marina Profunda del Jurásico medio		
Grupo Mitu	Depósitos Continentales de Rift de Trasarco del Permotriásico	Plutonismo Extensional	
Grupo Copacabana Grupo Tarma	Depósitos de Plataforma Carbonatada Marina de Trasarco del Carbonífero Pensilvaniano-Pérmico inferior		
Grupo Ambo	Depósitos de Cuenca Trasarco del Carbonifero		
Formación Ananea Formación Lampa Grupo Cabanillas Formación Chagrapi	Depósitos de Cuenca Trasarco del Silúrico-Devónico	Plutonismo de Arco Post-Colisional del Silúrico	Batolito de San Nicolás
Formación San Gabán Formación Calapuja Formación Iparo Formación Purumpata Formación Sandia Grupo San José Formación Marcona	Depósitos de Cuenca Marina del Cámbrico-Ordovicico	Plutonismo de Arco del Ordovicico	Batolito Atico Camaná
Complejo Basal de la Costa	Basamento metamórfico del Proterozoico		



3. METALLOGENETIC CHART AT A SCALE OF 1 : 250,000

a. Map of Tectonostratigraphic Units at a scale of 1: 250 000



Unidades Tectonoestratigráficas

Q-dCR	Depósitos Cuaternarios Recientes
NQ-dC IA	Depósitos Continentales de IntraArco del Neógeno
Nmp-vA	Vulcanismo de Trasarco del Mioceno - Plioceno
PeoNm-vA	Vulcanismo de Arco del Eoceno-Mioceno
PeoNm-pA	Plutonismo de Arco del Eoceno-Mioceno
KsPp-dc AP	Depósitos de Cuenca Antepais del Cretácico Superior al Paleógeno
KsP-pTA	Plutonismo de Trasarco del Cretácico-Paleógeno
KiPeo-pA CM	Plutonismo de Arco a Plutonismo de Cuenca Marginal del Cretácico inferior-Eoceno
K-dPTC ME	Depósitos de Plataforma y Talud Carbonatada Marina Epicontinental del Cretácico
JKi-vA	Vulcanismo de Arco del Jurásico al Cretacico Inferior
JK-dcm TA	Depósitos de Cuenca Marginal de Trasarco del Jurásico-Cretácico
TJi-dPCM RTA	Depósitos de Plataforma Carbonatada Marina de Rift de Trasarco del Triásico-Jurásico
PET-pE	Plutonismo Extensional
PET-dC RTA	Depósitos Continentales de Rift de Trasarco del Permotriásico
CpPi-dPC TA	Dep. de Plataforma Carbonatada Marina de Trasarco del Carbonífero Pensilvaniano-Pérmico inf.
C-dcTA	Depósitos de Cuenca Trasarco del Carbonifero
C-pA	Plutonismo de Arco del Carbonifero
SD-dcTA	Depósitos de Cuenca Trasarco del Silúrico-Devónico
NPP-Bm	Basamento Metamórfico del Neoproterozoico-Paleozoico

Tipo de Yacimiento

- Epitermal indiferenciado
- Epitermal de alta sulfuración
- Epitermal de intermedia sulfuración
- Polimetálicos con superposición epitermal
- Skarn
- Pórfidos
- Cr tipo alpino
- Au (Pb-Zn-Cu) relacionados con intrusivos
- Sedex en rocas carbonatadas
- Red Bed (Capas Rojas)
- Mississippi Valley (MVT)

- Au-Pb-Zn
- Ag-Pb-Zn
- Cu-Au-Fe
- Cu-Mo-Au
- Cu-Pb-Zn
- Pb-Zn-Ag
- Zn-Pb-Ag

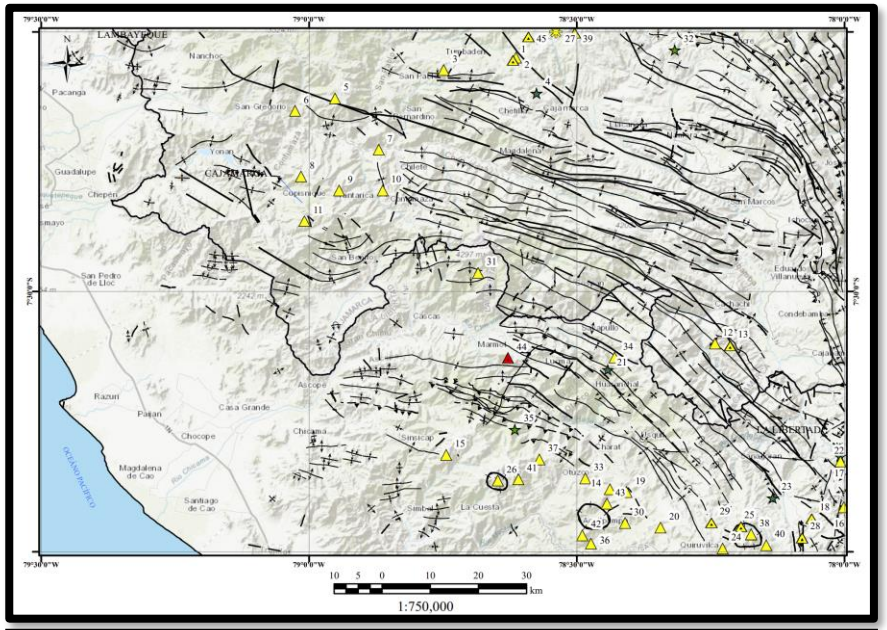
VOLUMEN DEL DEPÓSITO MINERAL (tf)

Elemento	Proyecto	Pequeño	Mediano	Grande	Muy Grande
Au	---	< 25	25 - 250	250 - 5 000	> 5 000
Ag	---	< 250	250 - 5 000	5 000 - 10 000	> 10 000
Cu	---	< 50 000	50 000 - 1 000 000	1 000 000 - 10 000 000	> 10 000 000
Mo	---	< 2 000	2 000 - 200 000	200 000 - 500 000	> 500 000
Pb	---	< 50 000	50 000 - 1 000 000	1 000 000 - 5 000 000	> 5 000 000
Zn	---	< 50 000	50 000 - 1 000 000	1 000 000 - 5 000 000	> 5 000 000
Fe	---	$< 10^{7}$	$10^{7} - 10^{8}$	$10^{8} - 10^{9}$	$> 10^{9}$
Sn	---	< 5 000	5 000 - 50 000	50 000 - 500 000	> 500 000
W	---	< 500	500 - 10 000	10 000 - 50 000	> 50 000
U	---	< 1 000	1000 - 5 000	5 000 - 50 000	> 50 000

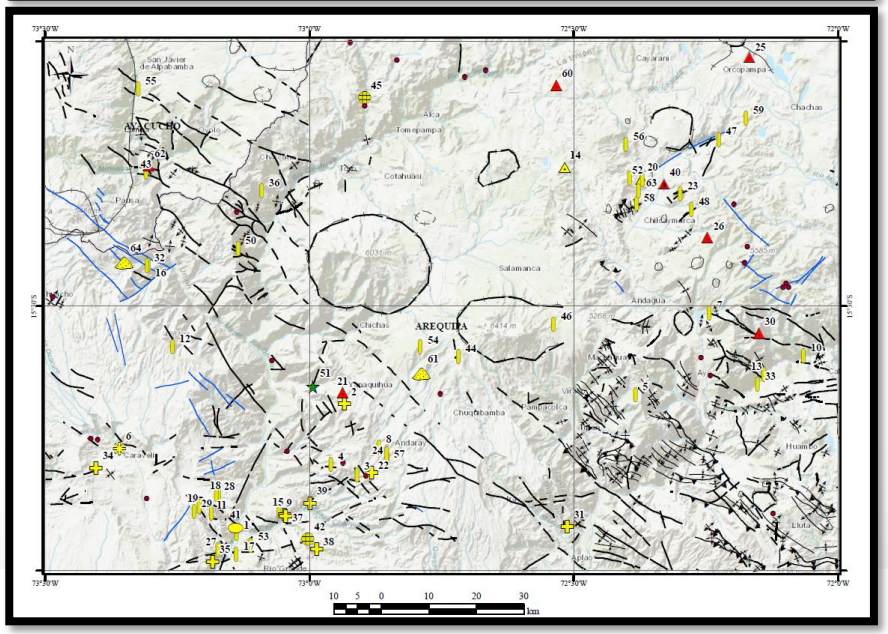
3. METALLOGENETIC CHART AT A SCALE OF 1 : 250,000

b. Structural map at scale 1 : 750 000

SHEET SB1716



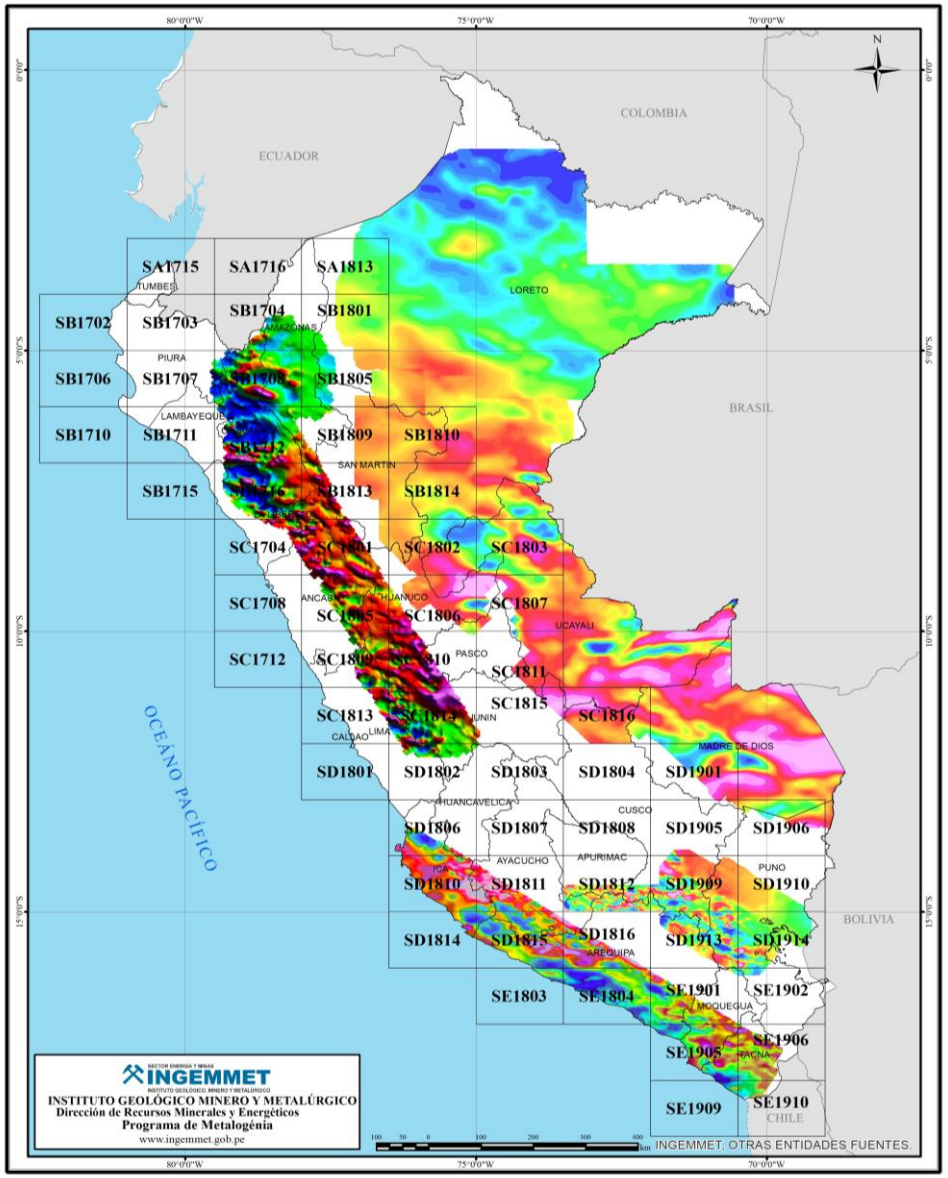
SHEET SD1816



SIMBOLOGÍA

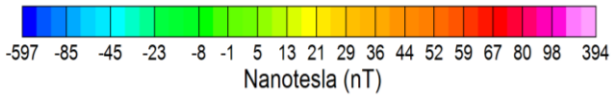
- Corredores estructurales
- Estructuras Circulares
- Fallas principales

c. Geophysical map at scale 1 : 750 000

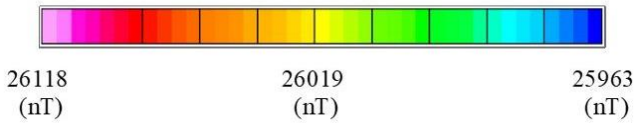


51 Metallogenic Maps at a scale of 1:750,000 with geophysical data

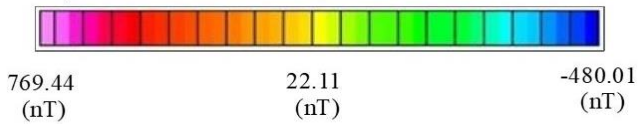
Total Magnetic Field, South Zone



Reduction to the Pole, North and Center



Reduction to the Pole, South Zone



Hojas con Geofísica		
Reducción al Polo Norte y Centro	Reducción al Polo Sur	Campo Total
SB1704	SD1806	SA1813
SB1801	SD1810	SB1801
SB1707	SD1811	SB1805
SB1708	SD1814	SB1806
SB1805	SD1815	SB1809
SB1712	SD1816	SB1810
SB1809	SE1803	SB1813
SB1716	SE1804	SB1814
SB1813	SE1901	SC1801
SC1801	SE1905	SC1802
SC1704	SE1906	SC1803
SC1805	SE1909	SC1806
SC1806	SE1910	SC1807
SC1809		SC1810
SC1810		SC1811
SC1813		SC1815
SC1814		SC1816
SC1815		SD1901
SD1802		SD1905
		SD1906
		SD1907
		SD1812
		SD1909
		SD1910
		SD1913
		SD1914
		SE1902

X SIMEXMIN

SimeXmin
X SIMPÓSIO BRASILEIRO DE EXPLORAÇÃO MINERAL
X BRAZILIAN SYMPOSIUM ON MINERAL EXPLORATION

d. Stream sediment geochemical maps at a scale of 1:750,000

- Stream sediment geochemistry database with 22071 samples.

N° of elements	N° of samples	%
30	2	0.01%
31	6	0.03%
32	3417	15.48%
43	7	0.03%
44	11	0.05%
45	9551	43.27%
49	5	0.02%
50	4676	21.19%
54	3616	16.38%
56	505	2.29%
58	275	1.25%
Total	**22071**	

Armor et al. (1998):
Variable standarization:
1° Normalization of the data, log10 (a)
2° Geometric mean of the normalized values (x)
3° Standar deviation
4° X = (a-x) / d

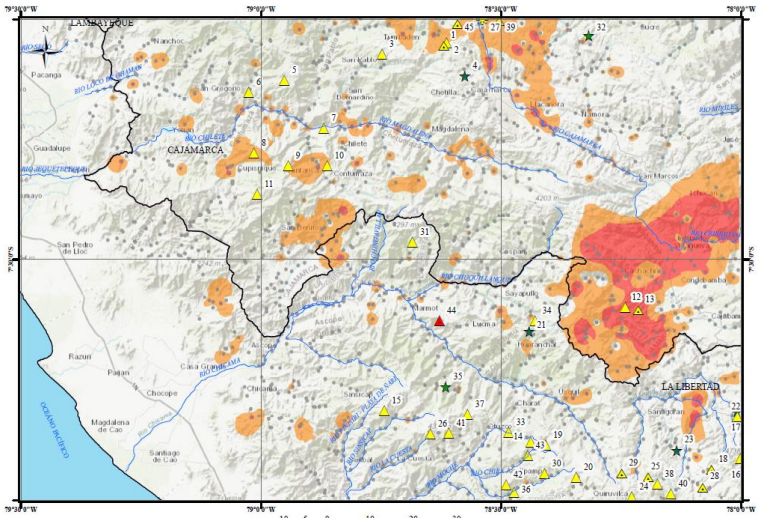
PCI: (Porphiry Copper Index): Cu + Mo + Te + Au

EPMI: (Epithermal Precious Metal Index): Au + As + Sb + Hg + Ag

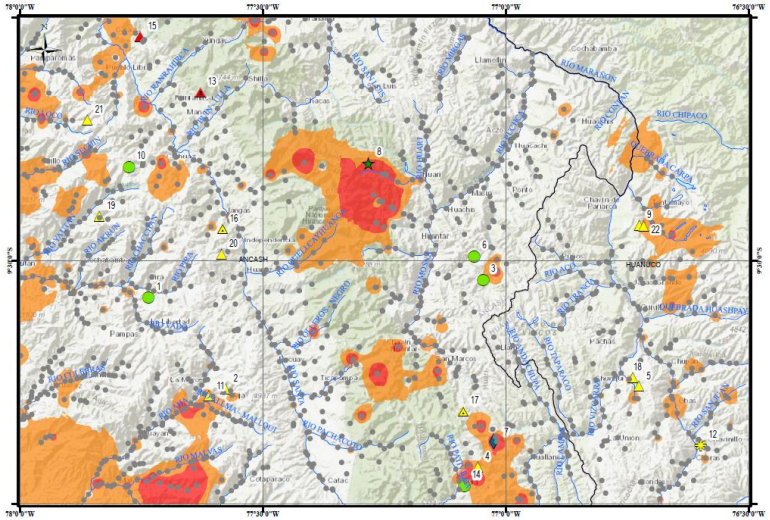
BMI: (Base Metal Index): Pb + Zn + Ba + Cu

BMI2: (Base Metal Index 2): Pb + Zn + Ba + Cu + Cd + Ag

Geoquímica Stream Sediment -Índices de Mineralización
Pórfidos de Cu (Cu, Au, Mo,Te)

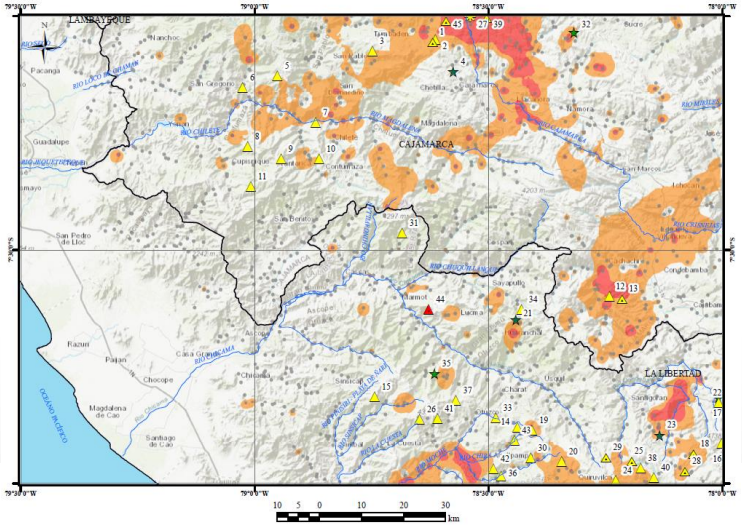


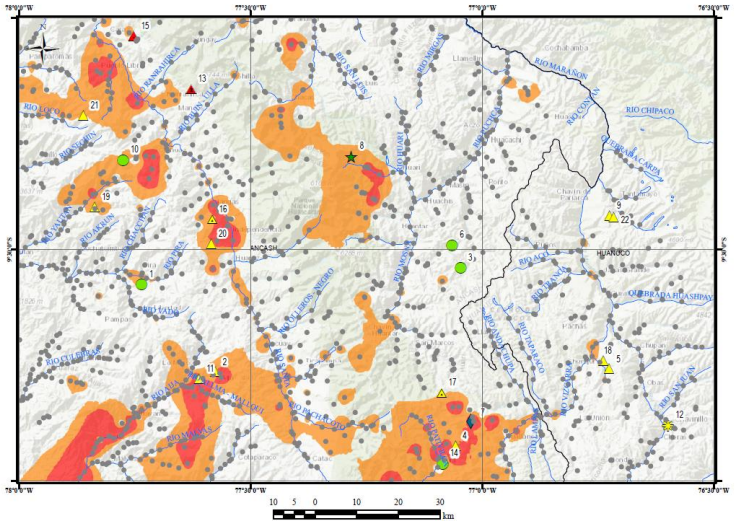
Sheet SB 1716



Sheet SC 1805

Geoquímica Stream Sediment -Índices de Mineralización
Epitermal (Au, Ag, As, Hg, Sb)

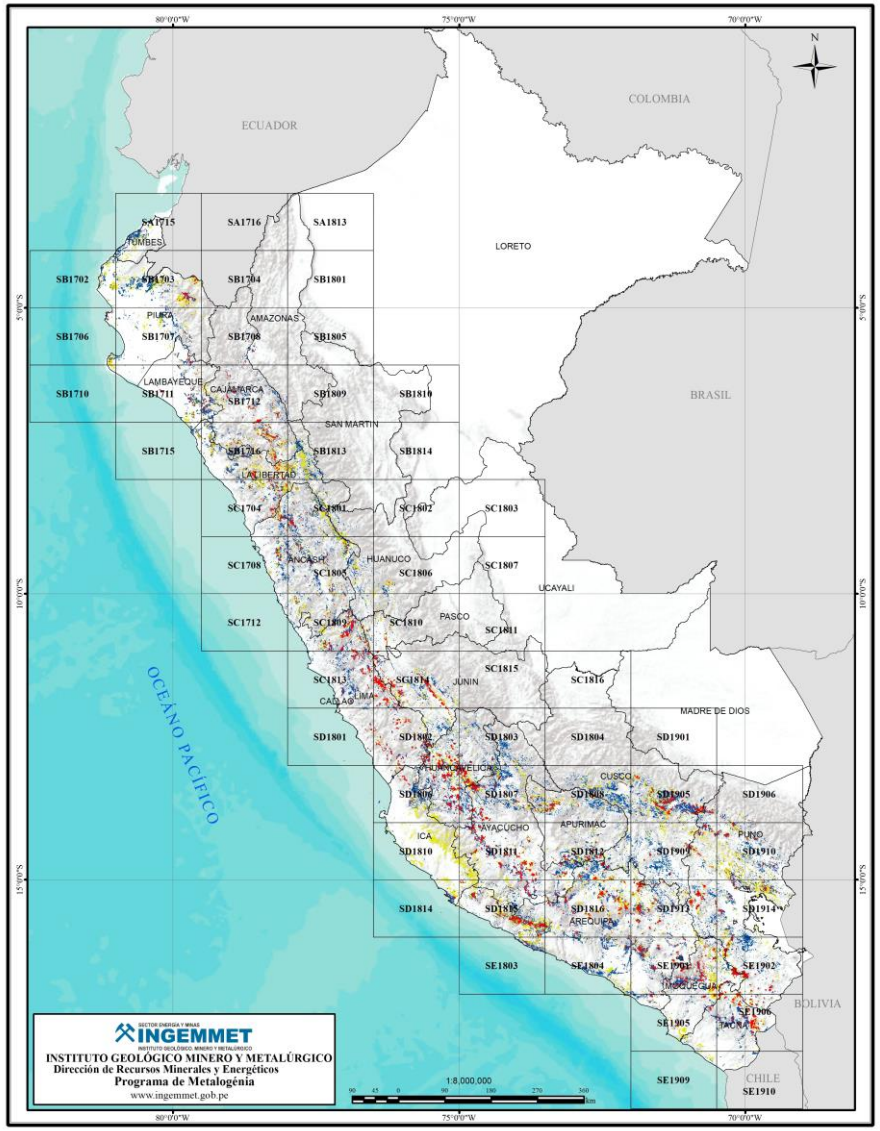


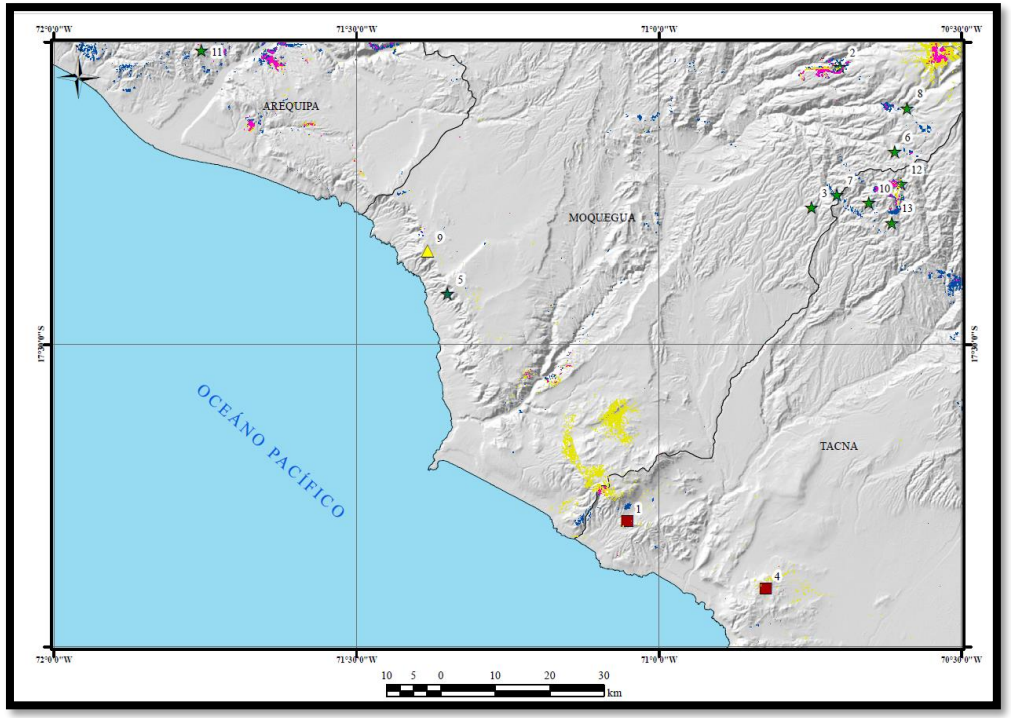


X SIMEXMIN

3. METALLOGENETIC CHART AT A SCALE OF 1 : 250,000

e. Map of spectral anomalies at a scale of 1:750,000





Listado de Yacimientos Minerales

1. Corvina
2. Cuajone
3. El Chorro
4. Hierro Morrito
5. Ilo Norte
6. Pedregal
7. Puca Urkku
8. Quellaveco
9. Sami
10. Simarrona
11. Tía María
12. Toquepala
13. Totoral

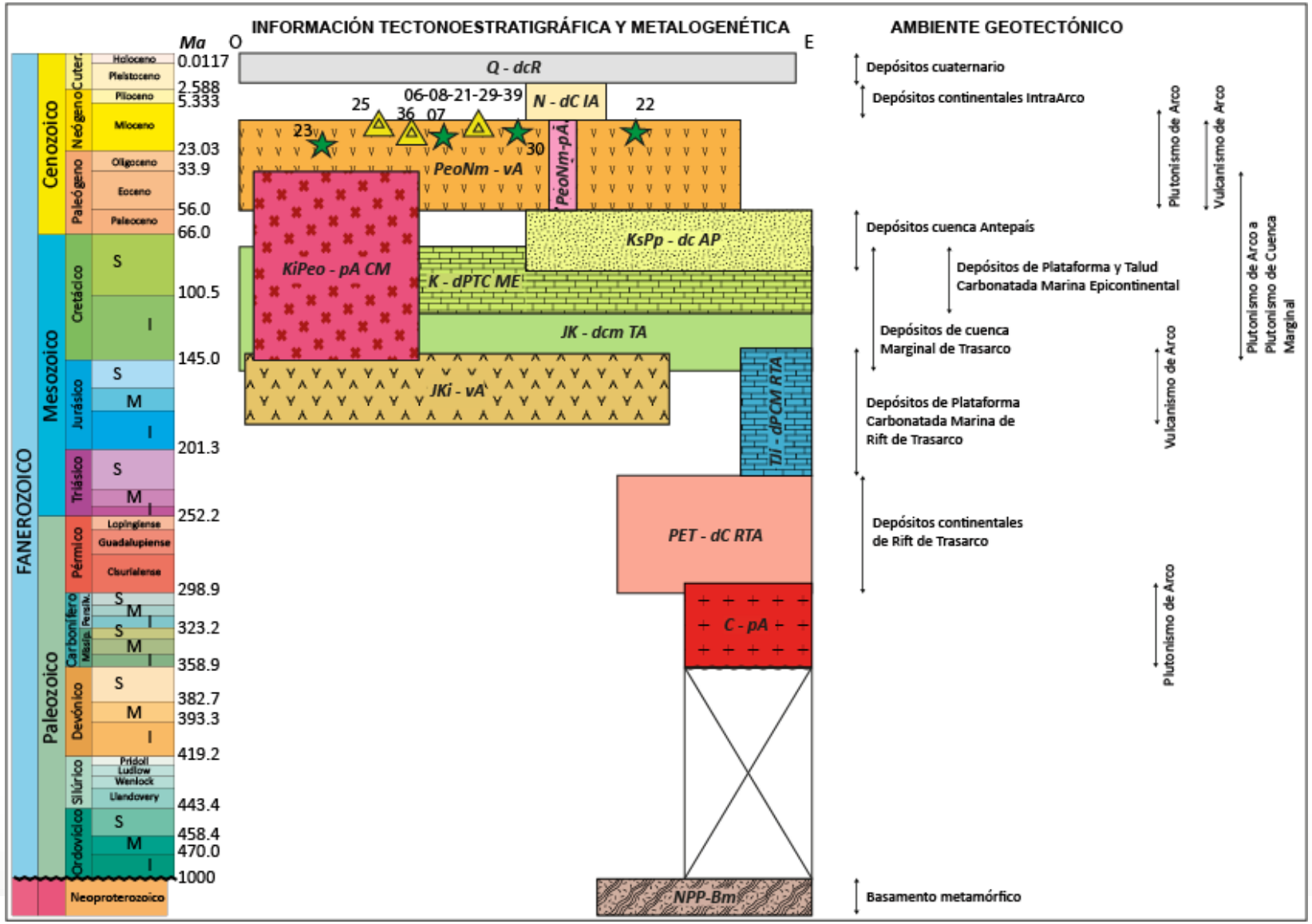
Anomalías Espectrales LANDSAT-8

- Óxidos, Arcillas
- Óxidos
- Arcillas

3. METALLOGENETIC CHART AT A SCALE OF 1 : 250,000

f. Tectono-stratigraphic chart at scale 1 : 750 000

- Spatial and temporal relationships of each of the Tectono-stratigraphic units.
- Age of the deposit, generator or discoverer metallotect .
- Tectonic environment.

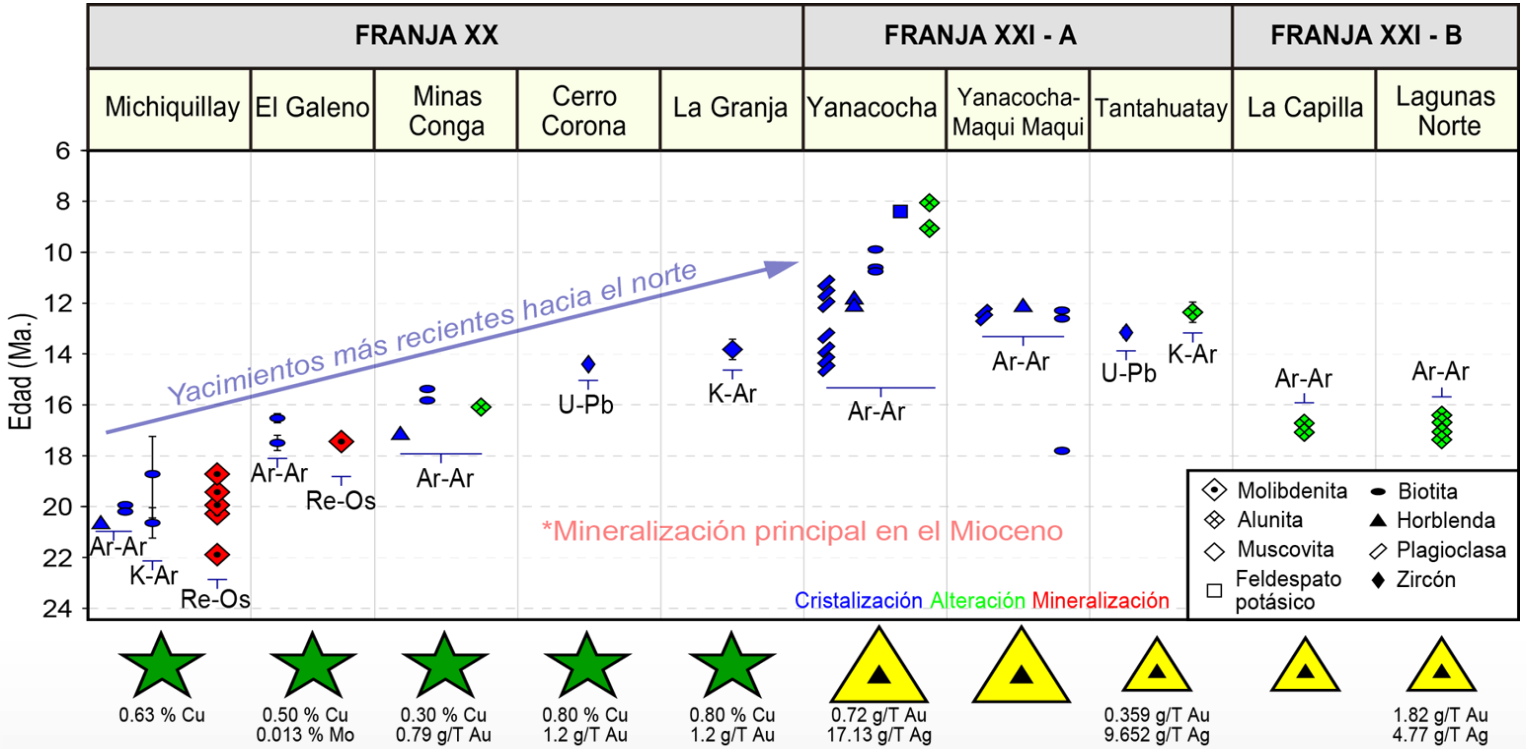


X SIMEXMIN

g. Table of radiometric ages of the main ore deposits at a scale of 1: 750,000

Vulcanismo de Arco del Eoceno-Mioceno -PeoNm-vA

N°	Depósito	CRISTALIZACIÓN	METALOTECTO PROMOTOR	ALTERACIÓN	MINERALIZACIÓN
2	Antakori	BtArAr 9.59 ± 0.06 [17]		AlArAr 11.01 ± 0.08 - 12.4 ± 0.4 [17,9]	
5	Castrejon	ZrUPb 17.55 ± 0.72 - 35.89 ± 0.93 [1]		BtKAr 13.35 ± 0.27 [10]	MoReOs 18.5 ± 0.08 [1]
7	Cerron Corona	ZrUPb 14.3 ± 0.1 - 14.4 ± 0.1 [18]			
15	El Galeno	HbArAr 29.4 ± 1.4 [5]	BtArAr 16.53 ± 0.18 [5]	BtArAr 17.5 ± 0.3 [5]	MoReOs 17.43 ± 0.09 [11]



Radiometric dating methods:

ArAr:	Argón - Argón
UPb:	Uranium – Lead
KAr:	Potassium - Argon
ReOs:	Rhenium - Osmium
RbSr:	Rubidium – Strontium
SmNd:	Samarium - Nediomium

Dated minerals:

Wr:	Total Rock
Zr:	Zircon
Plg:	Plagioclase
Hb:	Hornblende
Mus:	Muscovite
Bt:	Biotite
Fk:	Potassium Feldspar
San:	Sanidine
Al:	Albite
Mo:	Molybdenite

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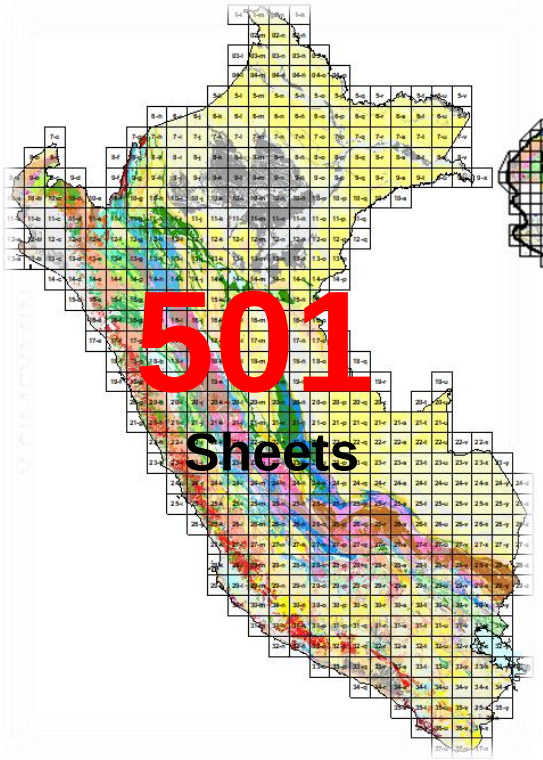
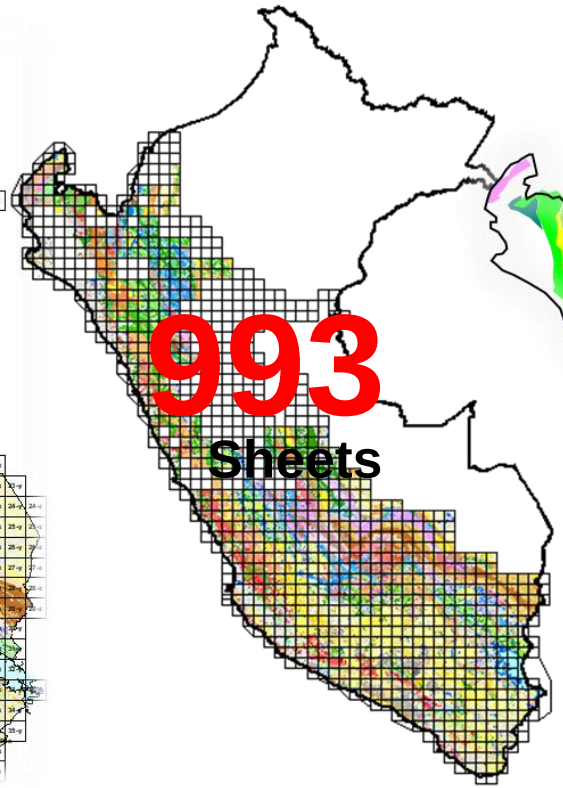
METALLOGENETIC MAP OF PERU, GEOLOGICAL MAPS AND MINING POTENTIAL

Application of the metallogenic map of Peru and geological and mining potential maps

Geologic Maps

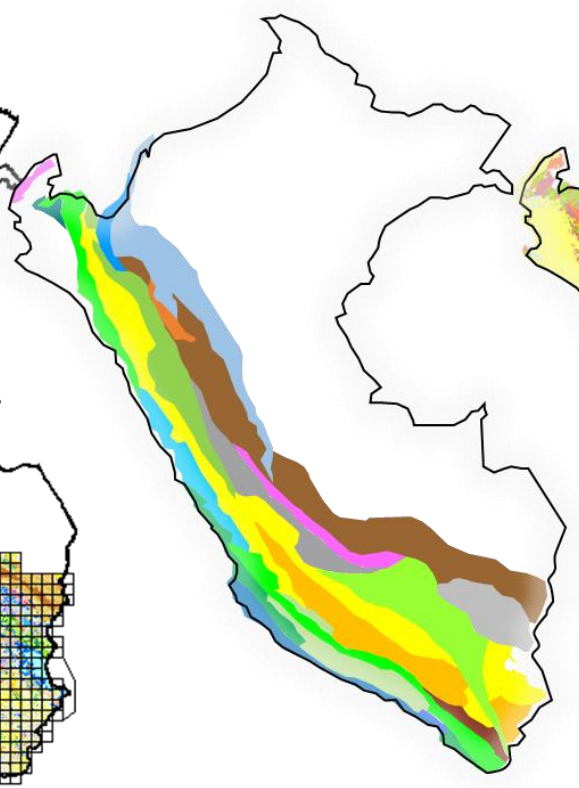


100K



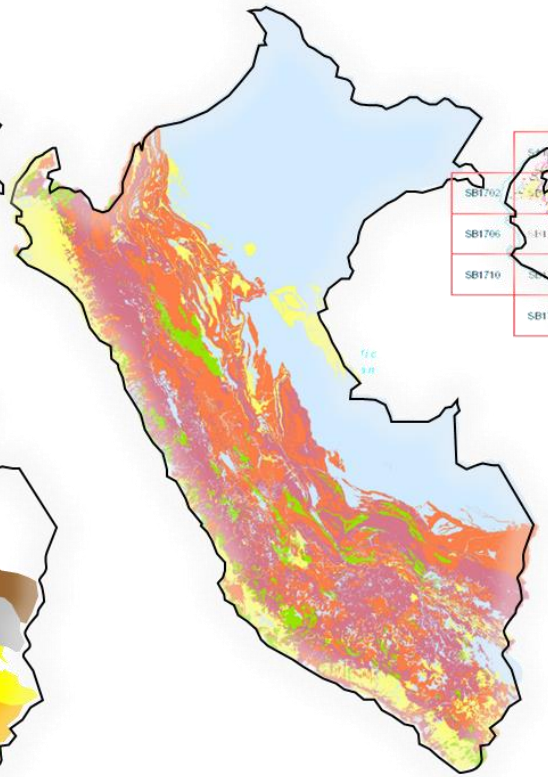
50K

Metallogenic Map



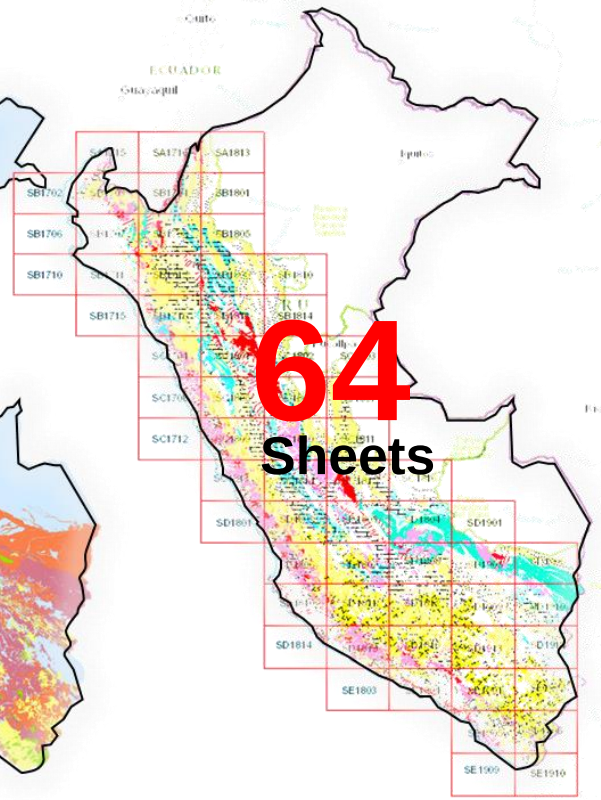
3M

Mining Potential Map



3M

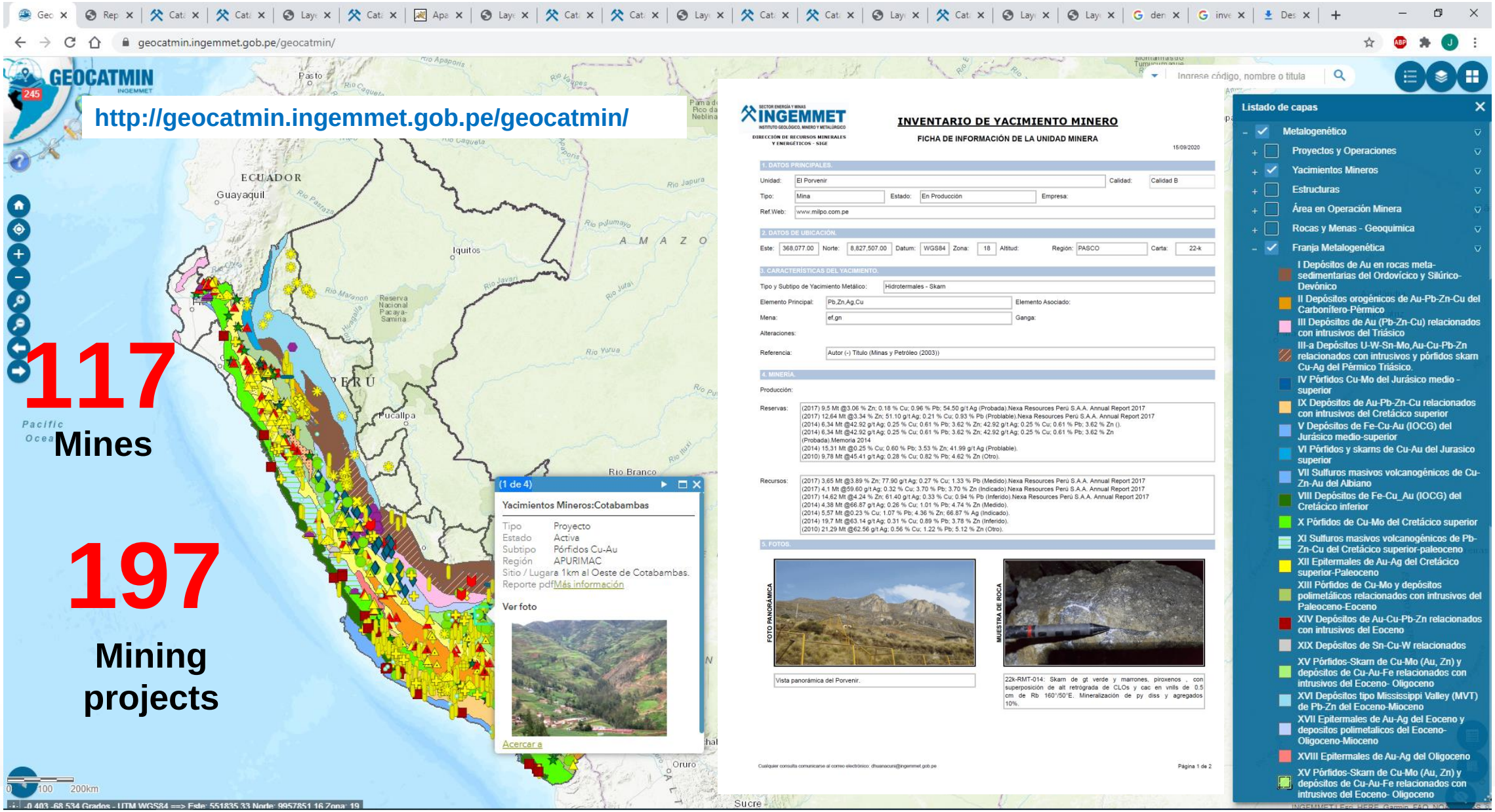
Metallogenic Chart



250K

1961-1999 → 2000….. 2024 (1093) → 2007 → 2016 → 2021

UPDATING OF THE METALLOGENIC MAP ON THE WEB



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Obrigado!

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INGEMMET
INSTITUTO GEOLÓGICO, MINERO Y METALÚRGICO