



The Geological Potential of Central America and the Caribbean: A USGS Report

World Bank Workshop

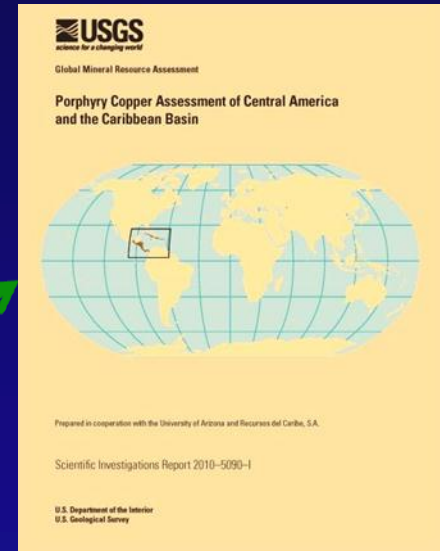
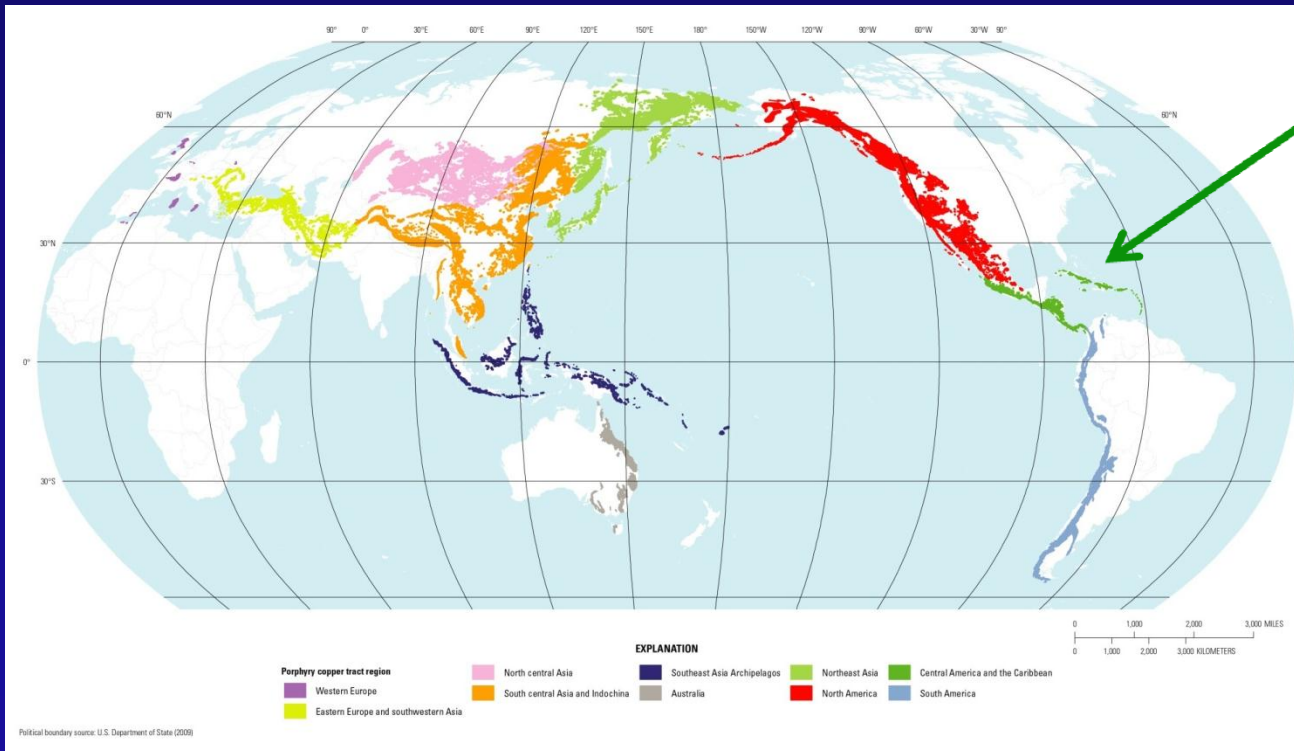
“Recent Developments in Mining and Sustainable Development in Latin America”

March 5, 2014

Jane Hammarstrom

Assessment of undiscovered copper resources associated with porphyry copper deposits in the Central America and Caribbean Region (part of a Global Mineral Resource Assessment)

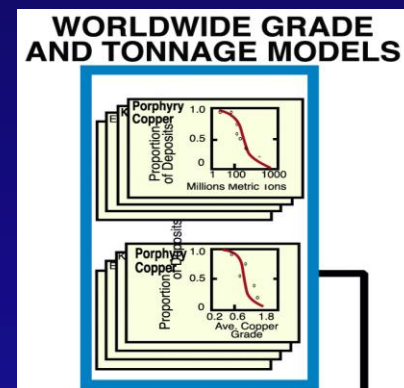
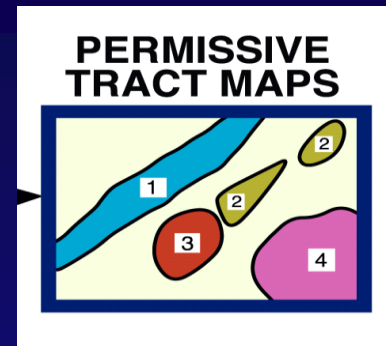
- A cooperative international effort to assess undiscovered copper resources to provide all nations with unbiased, science-based information on the geologic availability of mineral resources for resource development, land-use planning, and decision making
- Probabilistic estimates of undiscovered porphyry copper resources for 10 world regions



Gray, F., Hammarstrom, J.M., Ludington, S., Zürcher, L., Nelson, C.E., Robinson, G.R., Jr., Miller, R.J., and Moring, B.C., 2014, *Porphyry copper assessment of Central America and the Caribbean Basin: U.S. Geological Survey Scientific Investigations Report 2010-5090-I*, 81 p., and GIS data, <http://dx.doi.org/10.3153/sir20105090I>.

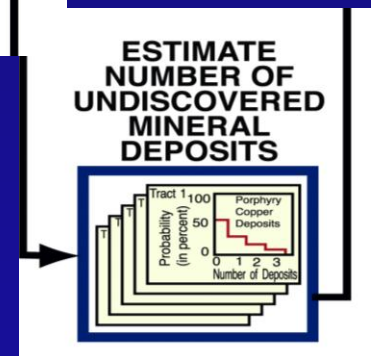
How? USGS 3-Part Form of Assessment

- Delineate areas that are permissive for the deposit type based on mineral deposit models (Permissive tracts)
- Use grade and tonnage models based on known deposit of the type as analogs for undiscovered resources
- Make probabilistic estimates* of numbers of undiscovered deposits of each types within each permissive tract
 - * *Combine estimates with grade and tonnage models to estimate undiscovered resources*



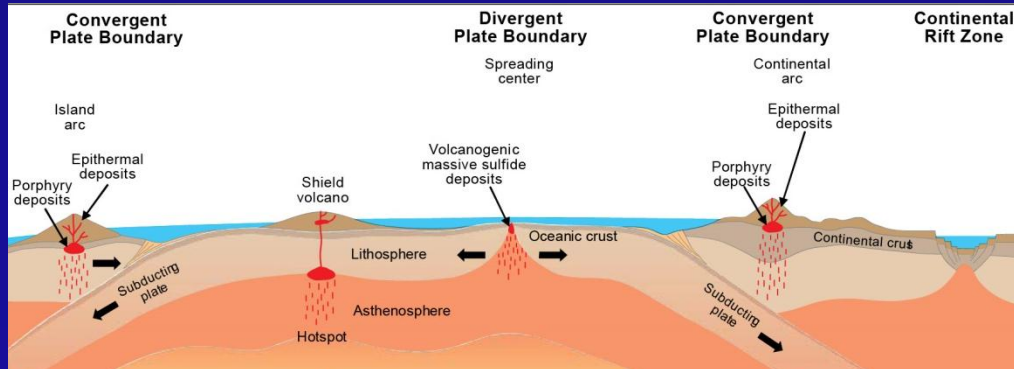
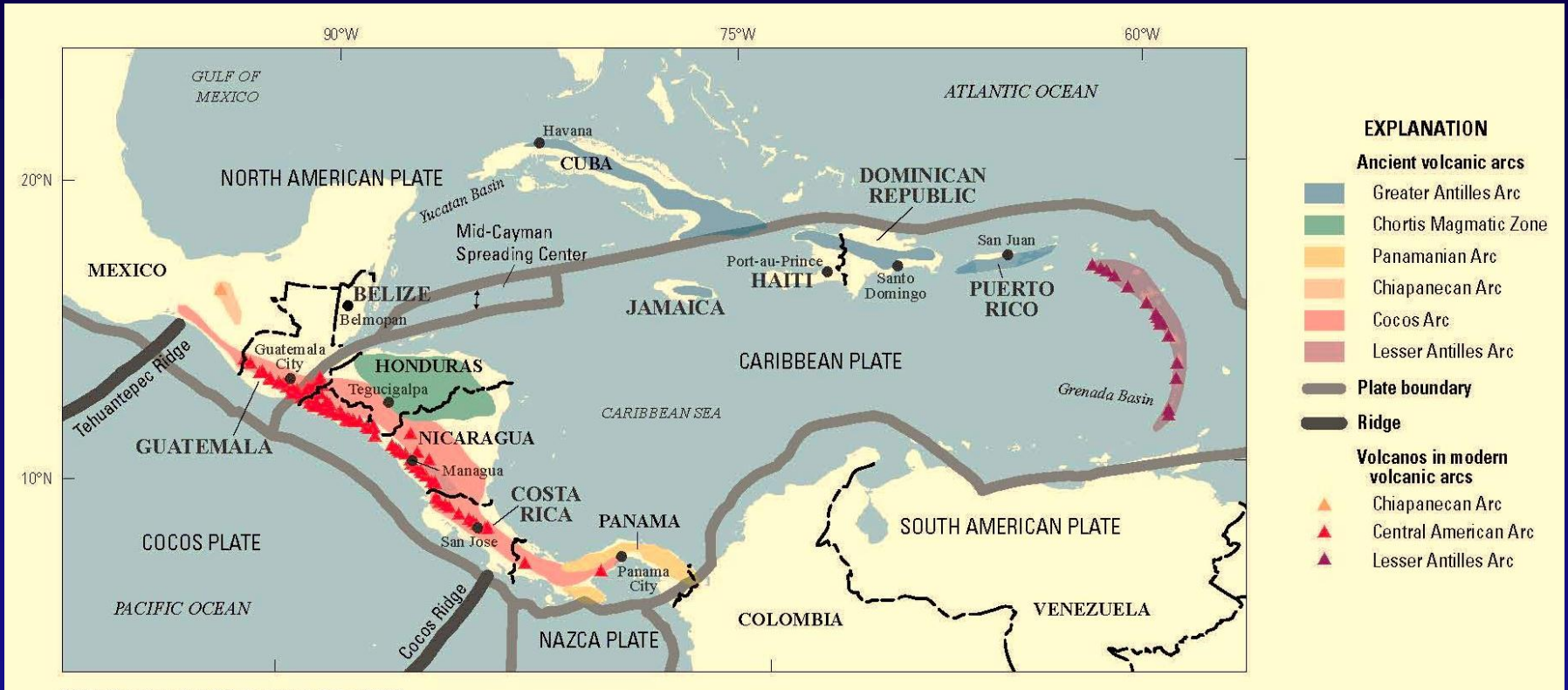
Descriptive model

- Rock type
- Age range
- Tectonic setting
- Depositional environment
- Associated deposit types



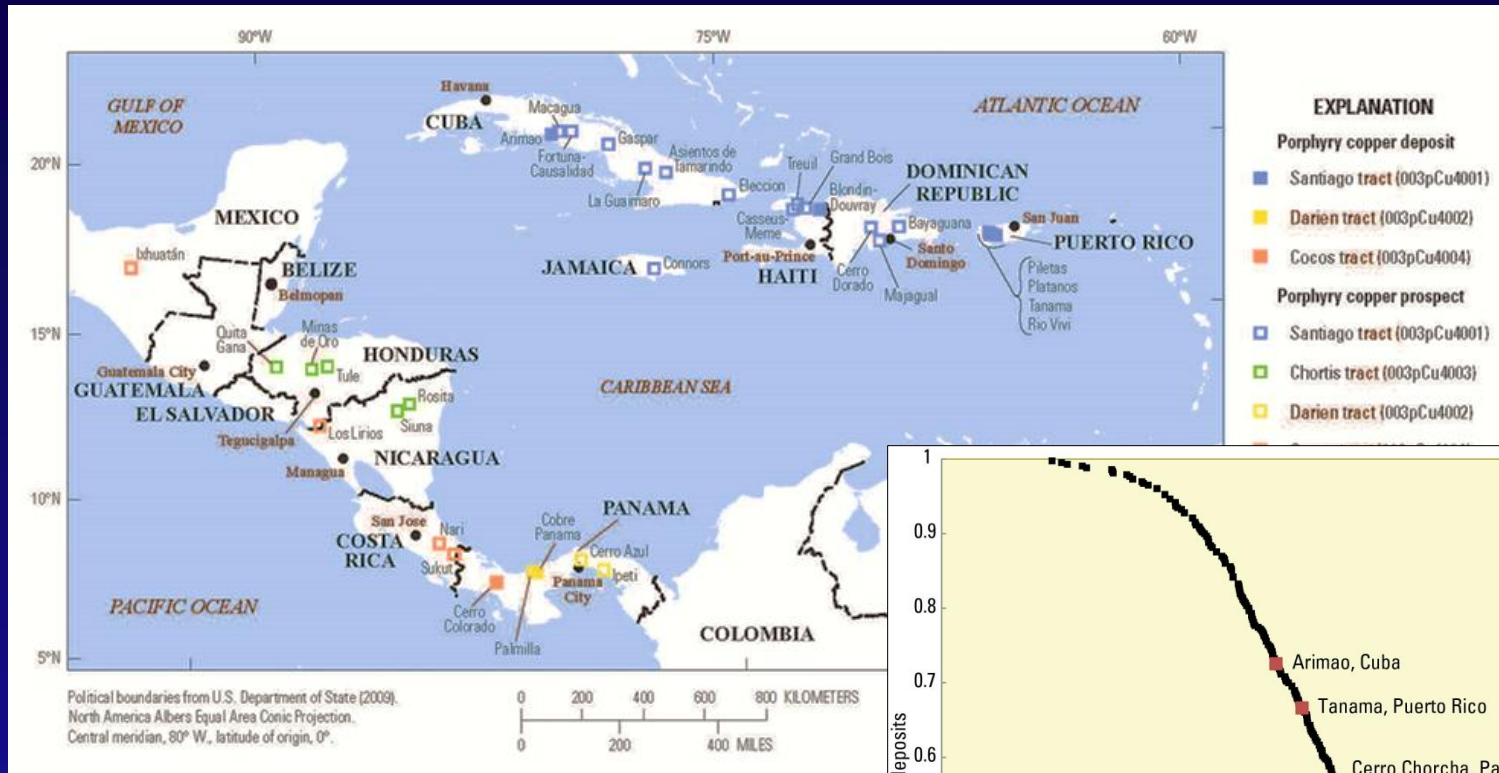
Singer, D.A., 1993, Basic concepts in three-part quantitative assessments of undiscovered mineral resources: Nonrenewable Resources, v. 2, no. 2, p. 69-81.

Geologically permissive settings for porphyry copper deposits

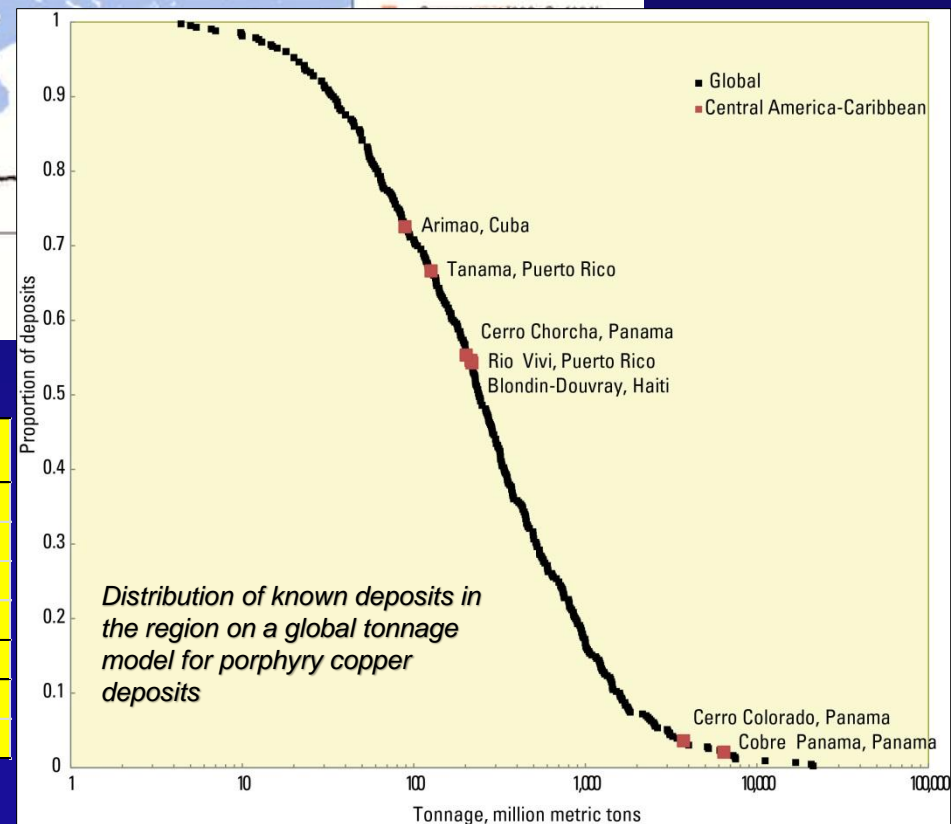


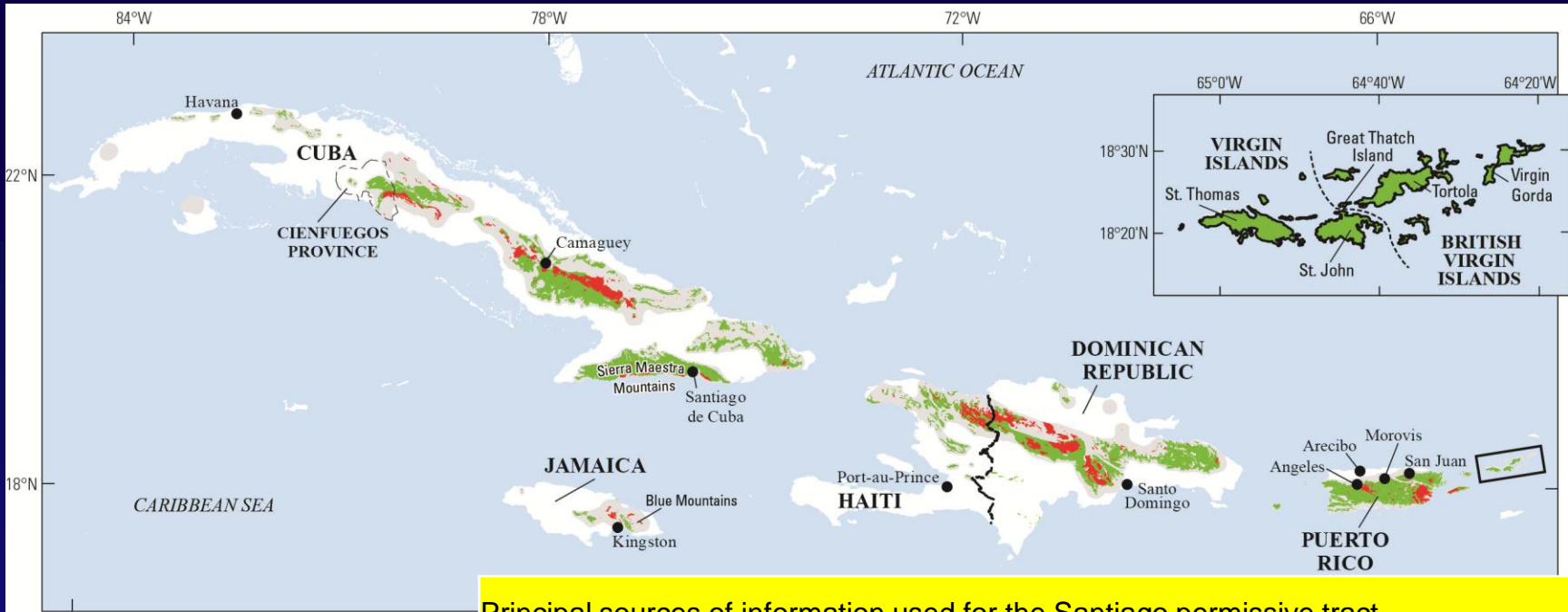
Permissive areas for porphyry copper deposits include permissive areas for related deposit types such as Au-rich epithermal deposits

Porphyry copper deposits and prospects in the region



Tract	Name	Country	Tonnage (Mt)	Cu (%)	Au (g/t)	Contained copper (Mt)
Santiago	Arimao	Cuba	88.8	0.27	1	0.24
	Blondin-Douvray	Haiti	215.4	0.45	0.3	0.98
	Rio Viví	Puerto Rico	218	0.73	0.3	1.59
	Tanamá	Puerto Rico	126	0.64	0.38	0.81
Darien	Cobre Panama	Panama	6,405	0.301	0.05	19.28
Cocos	Cerro Chorchá	Panama	201.9	0.49	0.07	0.99
	Cerro Colorado	Panama	3,730	0.39	0.075	14.55





Political boundaries from U.S. Department of State (2009).
 North America Albers Equal Area Conic Projection.
 Central meridian, 74° W., latitude of origin, 0°.

EXPLANATION

- Assessed porphyry copper tract 003pCu4001
- Permissive intrusive rocks
- Permissive volcanic rocks

Principal sources of information used for the Santiago permissive tract

[NA, not applicable]

Theme	Name or Title	Scale	Citation
Geology	CBMap--Digital geologic map of the Caribbean Basin	1:500,000	Available for purchase from www.cbmap.net
	Geologic map of Cuba	1:250,000	Pushcharovskiy and Mossakovskiy (1986)
Mineral occurrences	Porphyry copper deposits of the world: database, map, and grade and tonnage models	NA	Singer and others (2008)
	Geology, Geochemistry, Geophysics, Mineral Occurrences and Mineral Resource Assessment for the Commonwealth of Puerto Rico	1:200,000	Bawiec (1999)
	CBMap--Digital geologic map of the Caribbean Basin	1:500,000	Available for purchase from www.cbmap.net
	U.S. Geological Survey Mineral Resources Data System	NA	U.S. Geological Survey (2005)
Geochemistry	Commercial databases	NA	http://www.metalseconomics.com/default.htm
	United Nations Development Program	NA	UNDP (1969)
	Geochemistry of stream sediment samples, Puerto Rico	NA	Marsh (1992), Learned and others (1973)
Exploration	Company websites	NA	See table A4 and Prospects, Mineral Occurrences, and Related Deposit Types section of text

Geology and data sources for the Santiago permissive tract

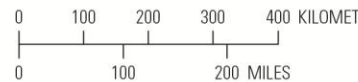
Geology and assessment results for the Cocos permissive tract



EXPLANATION

- Assessed porphyry copper tract 003pCu4004
- Permissive intrusive rocks
- Permissive volcanic rocks

Political boundaries from U.S. Department of State (2009).
North America Albers Equal Area Conic Projection.
Central meridian, 87° W., latitude of origin, 0°.



Results of simulations of undiscovered resources for the Cocos Region

[Cu, copper; Mo, molybdenum; Au, gold; and Ag, silver; in metric tons; Rock, in million metric tons]

Material	Probability of at least the indicated amount					Mean
	0.95	0.9	0.5	0.1	0.05	
Cu	2,200,000	6,100,000	39,000,000	120,000,000	160,000,000	53,000,000
Mo	5,700	67,000	830,000	3,500,000	5,100,000	1,400,000
Au	20	110	970	2,900	3,800	1,300
Ag	0	550	9,400	41,000	62,000	18,000
Rock	480	1,300	8,400	24,000	30,000	11,000

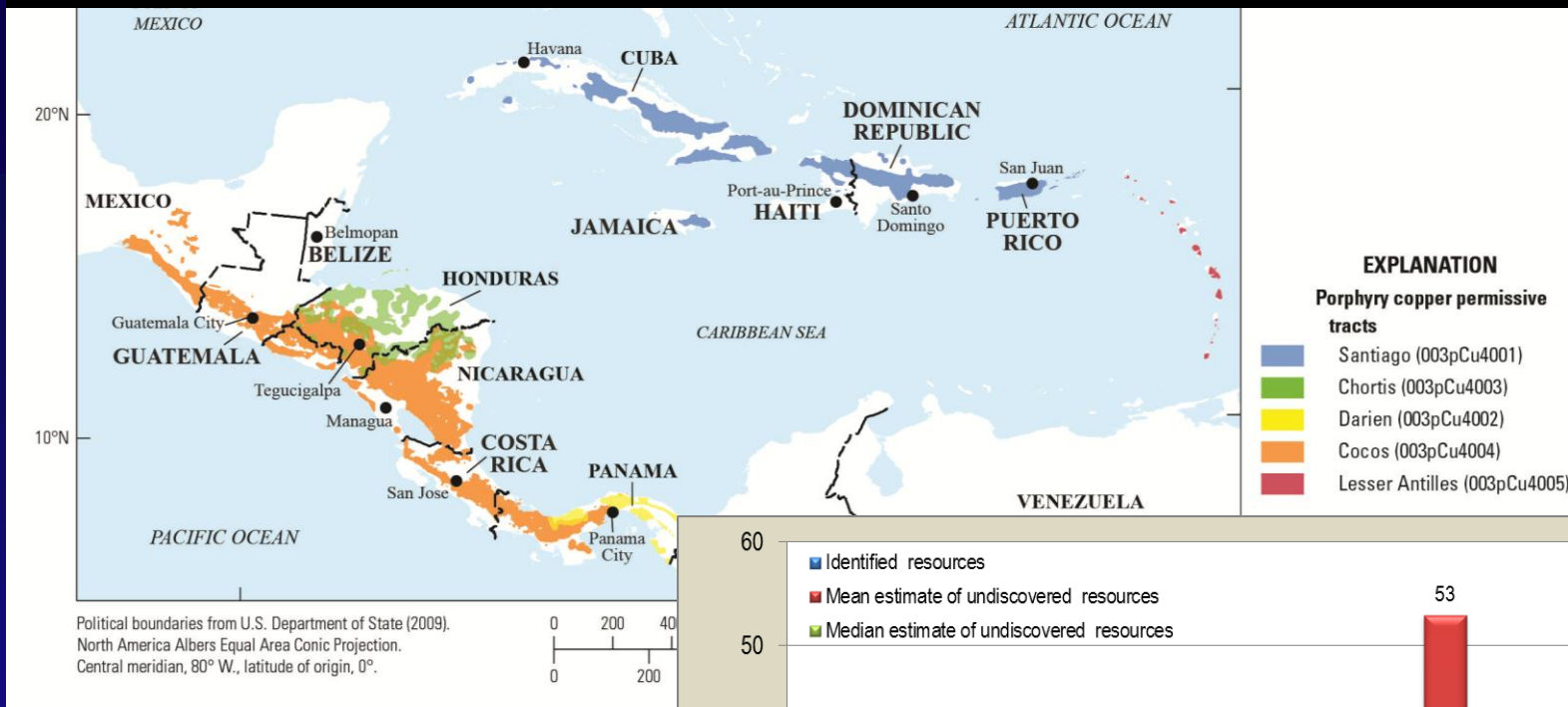
Estimated numbers of undiscovered deposits

90 % chance of 4 or more

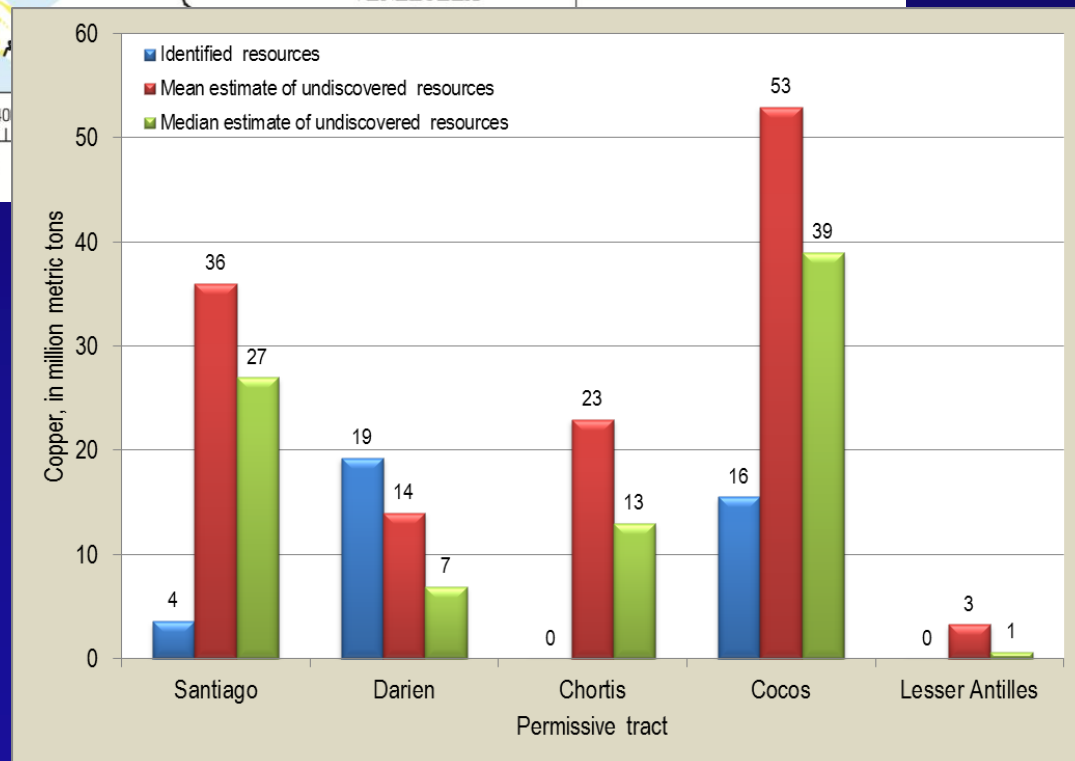
50% chance of 14 or more

10% chance of 24 or more

5 permissive tracts for porphyry copper deposits in the region

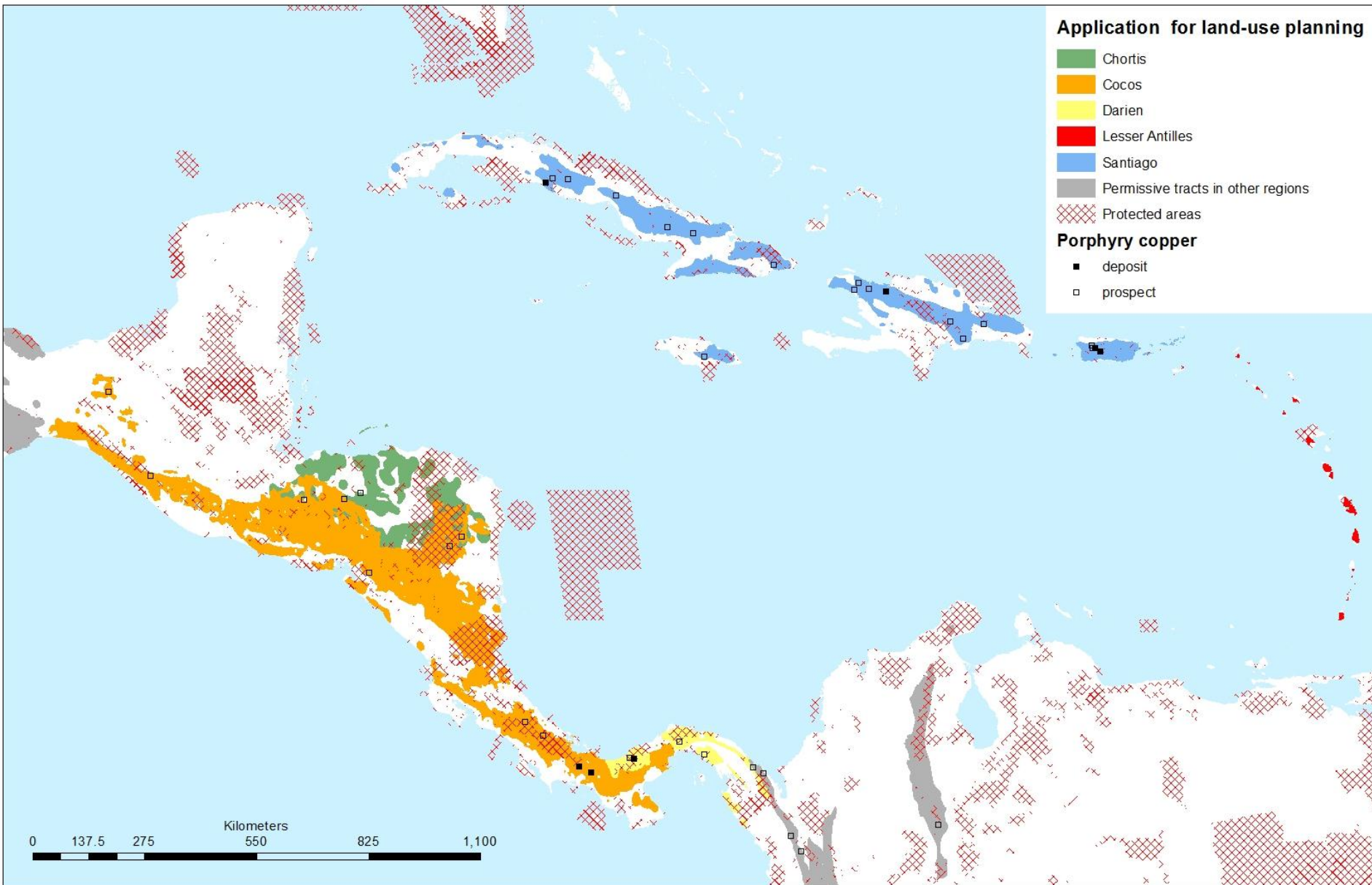


Mean undiscovered copper resources > identified copper resources for 4 of the 5 tracts



Example of an application of the assessment data

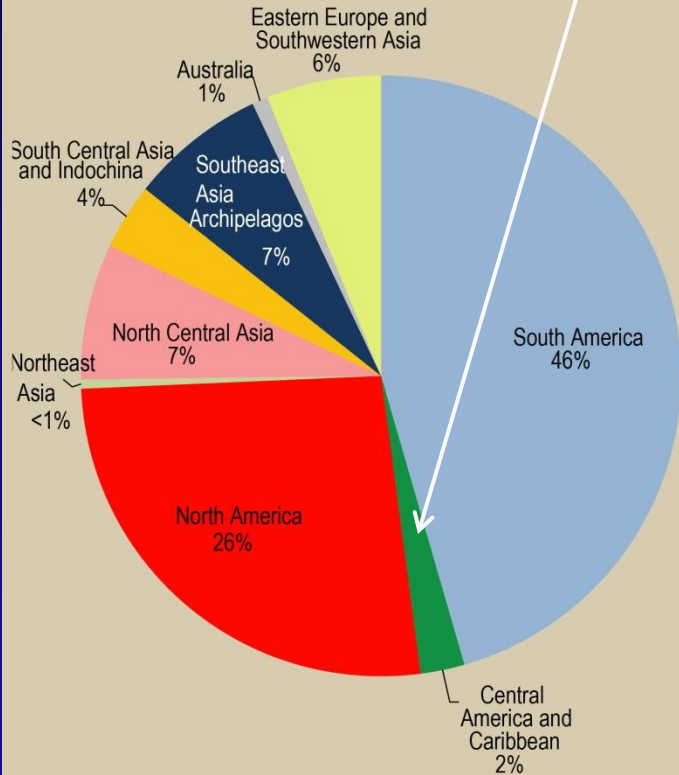
What areas are already off-limits for mineral exploration and development?



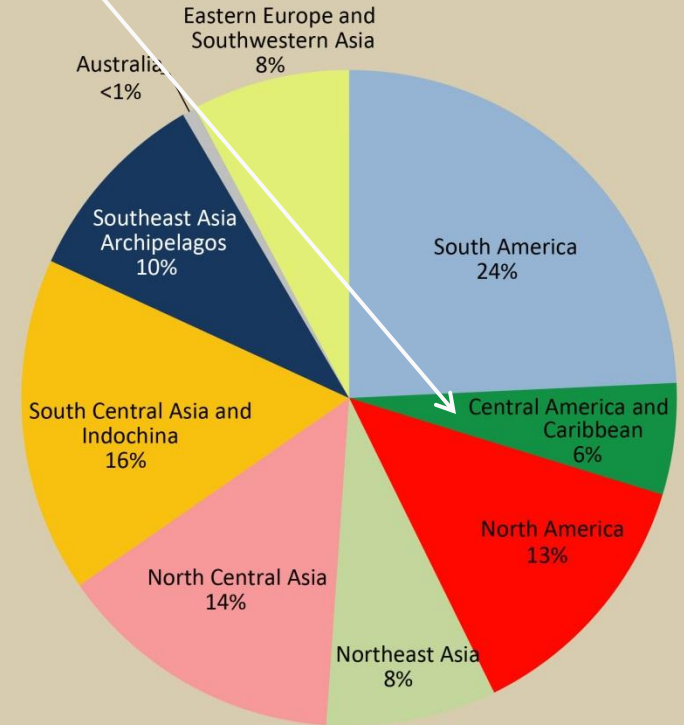
Importance of the region on a global scale

2% of identified, 6% of undiscovered

Regional distribution of identified porphyry copper resources



Regional distribution of undiscovered porphyry copper resources



Estimate of Undiscovered Copper Resources of the World, 2013

Using a geology-based assessment methodology, the U.S. Geological Survey estimated a mean of 3,500 million metric tons of undiscovered copper among 225 tracts around the world.



Introduction

Informed planning and decisions concerning future mineral supplies, sustainability, and resource development require a long-term global perspective and an integrated approach to land use and to resource and environmental management. This integrated approach further requires unbiased information on the global distribution of identified and undiscovered mineral resources, the economic factors influencing their development, and the environmental consequences of their exploitation.

The U.S. Geological Survey (USGS), the principal Federal provider of research and information on nonfuel mineral resources, has completed a geology-based, cooperative international assessment of copper resources of the world. Collaborators in this assessment include mineral resource experts from national geological surveys and from industry and academia worldwide.

This assessment indicates that in addition to identified copper resources of 2,100 million metric tons (Mt), a mean of 3,500 Mt of undiscovered copper

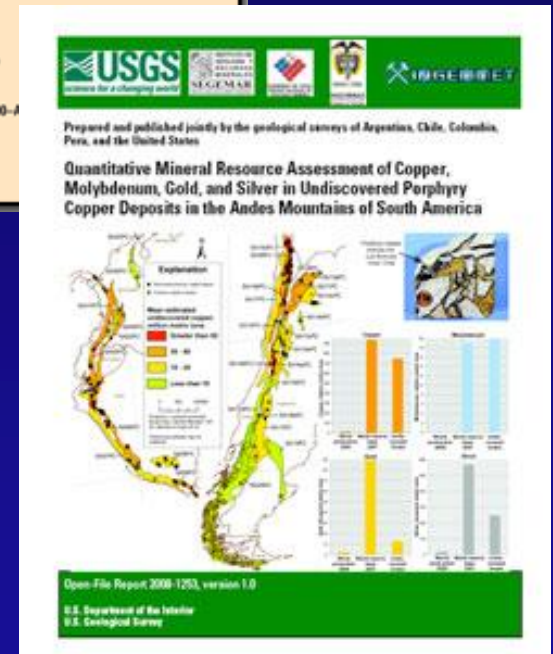
is expected in 11 regions spanning six continents (table 1 and fig. 1). Annual U.S. copper consumption is 2 Mt; global consumption is 20 Mt (Edelstein, 2013).

The methodology for the assessment consisted of (1) compilation of geologic data and characterization of identified deposits for each area considered, based mainly on published literature, (2) delineation of geographic areas (tracts) in which the geology is permissive for specific types of copper deposits defined in mineral deposit models, (3) evaluation of amounts of metal in typical deposits by using grade-tonnage models, and (4) probabilistic estimation of numbers of undiscovered deposits. Probable amounts of undiscovered resources were computed by combining estimates of numbers of undiscovered deposits with grade and tonnage models using Monte Carlo simulation. Finally, results for individual tracts were aggregated into regional groups, assuming independence between tracts.

Table 1. Assessment results for identified and undiscovered copper worldwide, by region.

[km², square kilometers; Mt, million metric tons; "90" indicates a 90-percent chance of at least the amount shown, with other percentiles similarly defined. Columns may not add to total because of rounding. Gray shading indicates no quantitative assessment]

Region	Deposit type	Tract extent (km ²)	Undiscovered resources (Mt)				Identified resources (Mt)
			90	50	10	Mean	
South America	Porphyry	1,200,000	500	730	1,000	750	810
	Sediment-hosted	99,000					0.51
Central America and the Caribbean	Porphyry	540,000	78	150	280	170	42
North America	Porphyry	3,200,000	250	370	540	400	470
	Sediment-hosted	450,000	15	48	110	57	18
Northeast Asia	Porphyry	2,300,000	76	220	500	260	8.8
North Central Asia	Porphyry	3,200,000	210	360	590	440	130
	Sediment-hosted	180,000	22	49	90	53	48
South Central Asia and Indochina	Porphyry	3,800,000	280	490	770	510	63
	Sediment-hosted	29,000					4.5
Southeast Asia Archipelagos	Porphyry	850,000	180	290	430	300	130
Australia	Porphyry	580,000	1.9	14	54	21	15
Eastern Europe and Southwestern Asia	Porphyry	1,200,000	130	220	370	240	110
	Sediment-hosted	4,800	0.052	4.8	36	13	6.4
Western Europe	Porphyry	73,000					1.6
	Sediment-hosted	190,000	38	110	230	120	77
Africa and the Middle East	Sediment-hosted	200,000	81	150	260	160	160
Total copper						3,500	2,100



Muchas gracias!