Global Copper Mining and Processing

Environmental and Social Impacts

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About this Presentation

- **There is a large amount of information available about the sustainability impacts—both environmental and social—associated with global copper production (mining and processing).** To create this presentation, I reviewed about 75 papers, news articles, and web pages specifically relating to copper, and another 50 or so relating to mining in general
- **Despite the wealth of information, though, there are no consistent frameworks to quantitatively compare or weigh these risks.** For example, one set of researchers* found 95 different environmental sustainability factors in the literature relating to copper mining, only 35 of which are present in LCA calculations (although LCA is a common measurement system referenced in academic papers). They did not attempt to choose favorites, however, they did point out that many of these measurements were more related to present risks and less related to future risks
- Less focus in this presentation is given to social and governance issues, based on research published in Nature which found that **environmental risks are the biggest category of sustainability impact for copper** (as opposed to cobalt, where social and governance issues are the highest risks).
- Given all this information, in the interests of keeping this presentation brief but impactful, I have attempted to **focus on a few things**:
  - Primarily, describing **environmental issues which are unavoidable in copper production due to chemistry of copper ores and the natural locations deposits**, rather than the laundry list of every single environmental issue (of which there are plenty)
  - Secondarily, **significant environmental risks which—while perhaps theoretically possible to be engineered around—rarely are addressed in practice (i.e. tailings)**, and especially with severe natural events (such as earthquakes and flooding) are extremely difficult to control
  - **Human health issues resulting from these environmental issues**, to help make the impact more concrete
  - More focus on the mining—**the part of the process that is avoided when you use recycled materials** (as opposed to smelting, etc., which is present in both scenarios)

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Agenda

- Copper's Sustainability Risks
- Mining and the Environment
- Copper: from Ore to Electronics Components
- Tailings: Outdoor mine waste storage
- Copper Tailings
- Environmental and Human Health Impacts of Copper Mining
- Copper Processing
- The Future of Copper Supply
- Recycling Copper

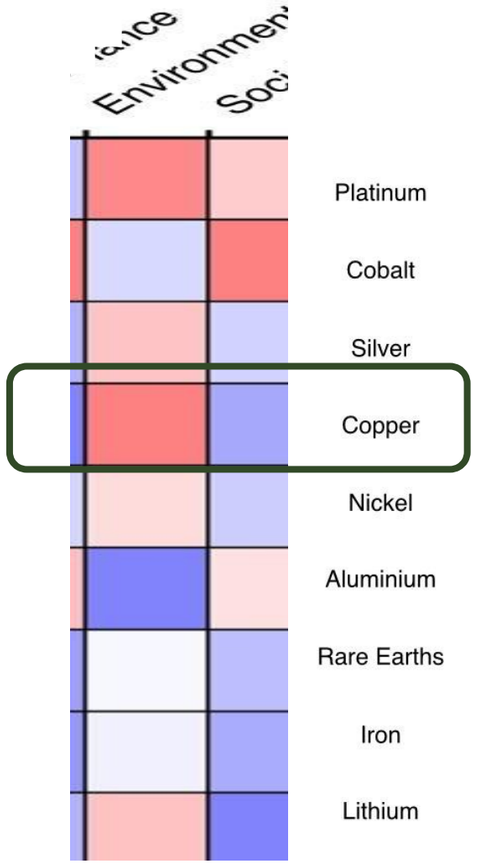
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Copper's Sustainability Risks

When compared with other metals, researchers ranked copper 1st among 64 metals in human health/ecosystem damage and 4th in global warming potential contributions[1].

A study published in Nature[2] determined that the sustainability risks related to copper are highest with regards to the environment, as opposed to social or governance issues. Cobalt, in comparison, is the opposite (see illustration).

Nonetheless, the report Material Insights[3] (sponsored by the Responsible Business Alliance) states that in addition to high pollution risk in the environmental category, copper does have high risk in the social and governance categories of: child labor, community rights violations, company/community conflicts, and corruption.



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Mining and the Environment

Unlike other production activities which can be controlled by the design and location of the facility in which they occur, **mining—by its very nature—happens outside in the environment itself, with ore located in places not chosen by humans** but rather dictated by the planet's formation processes.

In 2003, the World Resources Institute conducted an analysis of mines which revealed the following[4]:

- More than one quarter of active mines and exploration sites overlap with or were within a 10-kilometer radius of a strictly protected environmental area.
- Nearly one third of all active mines and exploration sites were located within intact areas of high conservation value.
- Nearly one third of all active mines were located in stressed watersheds.
- Nearly three quarters of active mines and exploration sites were located in areas deemed by conservation organizations to be of high ecological value.

In addition, as many of these mines are in remote areas, infrastructure to transport and further refine the materials offsite create their own set of environmental risks.

The impact of mining on important ecosystems and human rights of course isn't limited to currently active mine sites, but applies to future sites as well. **One of the largest untapped copper reserves in the world—what would become Pebble Mine in Alaska, for example—is currently being blocked from operating by the US government due to significant environmental concerns.**

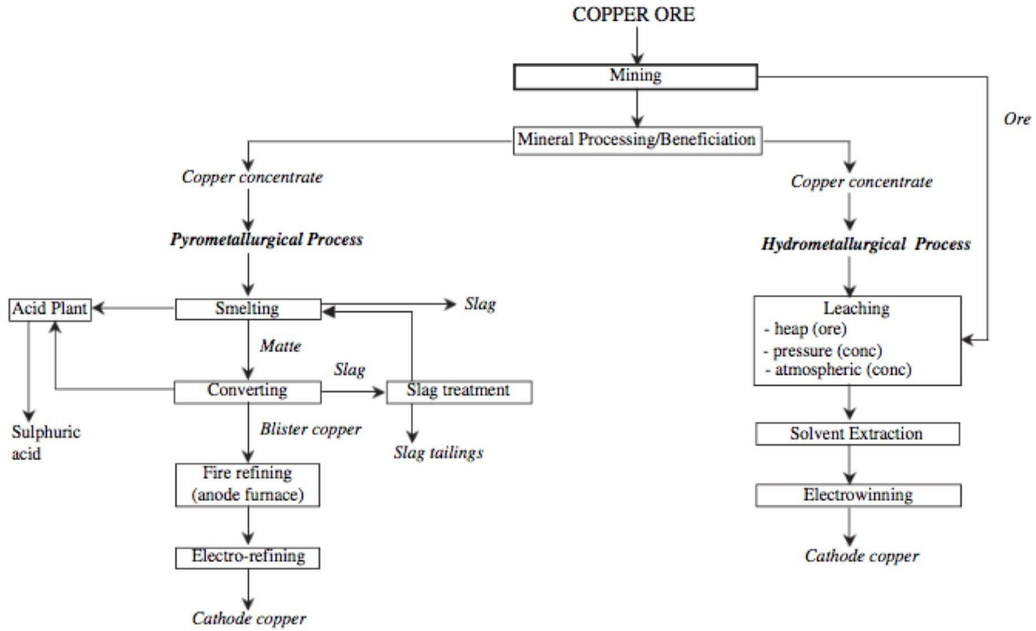
Specific to copper, researchers at the University of Queensland in Australia stated that "Our research from 2019 found **65% of copper ore bodies that haven't been mined are in areas with high water risk**: too little water means miners compete for it among other local water users, and too much means waste [acidic materials and heavy metals stored in tailings ponds] can be difficult to contain. **Almost half (47%) of these ore bodies occur on or close to Indigenous peoples' lands, and 64% within or near areas critical to biodiversity conservation. 50% are in socially and politically fragile countries, such as the Democratic Republic of Congo.**"[5]

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Copper: from Ore to Products

Excavated material doesn't usually immediately generate a human-usable form of a mineral. Instead, the ore must be extracted and separated through a cascade of processes, generating a large amount of the waste in the process.

In the case of copper, **currently the quality of ores is about 1% copper,[6] and the desired end-product for many applications ("cathode copper") is 99.5-99.9% pure copper[7,8]**.



Source: Norgate et al, 2006

Thus, for every 1 kg of copper extracted from the ground, there are over 99 kgs of waste material generated—a problem which increases with the addition of water and other chemicals. **Many of the environmental problems associated with mining stem from the management and extraction of this large amount of undesired, often toxic, material.**

Per the World Resources Institute[4], environmental challenges having the greatest impact on ecosystems include:

- *Sedimentation*: Sediments from waste dumps and tailings (remnants of ore after the desired materials are extracted) may be disposed of or erode into waterways, harming fish and other aquatic wildlife.
- *Metals Deposition*: Tailings often contain heavy metals as well as reagents used in processing. Poor tailings management may result in the release of metal-laden waste into the environment. In addition, heavy metals may be leached as a result of acid drainage.
- *Acid Drainage (AD)*: AD occurs when sulfide-bearing rock reacts with air and water, producing acidic waters containing dissolved metals that may drain as runoff into water bodies, killing aquatic flora and fauna. AD is arguably the most severe environmental impact associated with mining because once it occurs, costly and perpetual water treatment is often the only solution."

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Tailings: Outdoor Mine Waste Storage

- An **unavoidable consequence of the extraction of most copper is the exposure of sulfide-bearing rock to the air and water, which triggers a chemical reaction generating large quantities of acid**. Perpetual treatment of the acid is required until the chemical reactions are complete[8]. Roman mine sites in the UK continue to generate acid drainage—nearly 2000 years after mining ceased.
- Today, these tailings are stored in the open in tailings ponds/dams, which are constructed of an impermeable barrier into which materials are dumped.
- Additional chemicals such as diluted sulfuric acid are often added to the mixture to help precipitate out additional copper over the course of several years—a process called dump or heap leaching. Extraction of one tonne of copper from ore with a grade of 1 percent requires 4400 liters of 96 percent sulfuric acid, and generates sulfur dioxide in the process[8].



The tailings pond of the Antamina Tailings Dam at the Atamina Dam in Peru.
Photo by Xtremizta - https://www.flickr.com/photos/locoperucho/4658256759/in/photostream/ CC-BY-SA 2.0

- Copper dump leaches are massive, ranging in height from 20 to hundreds of feet, covering hundreds of acres and containing millions of tons of ore[9].
- As lower grades of ore are pursued, copper is increasingly recovered by solution methods including dump and in situ leaching (where the acid is poured into the underground mine)[9].

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Copper Tailings

Most tailings ponds have acidic pH values of less than 3.5. Heavy metals from the ore also leach into the tailings pond, making the water extremely toxic. **In the case of copper, arsenic is a primary co-present material in ore and presents an environmental and health risk from leaching all the way through processing.** To give you an idea of the toxicity of tailings ponds: in November 2016, a migrating group of approximately 10,000 snow geese landed on a copper tailings pond in Montana. Mine employees did their best to scare off the birds, but many landed in the tailings anyway—and thousands of them died within days[10].

Unfortunately, tailings dam failures and other leakages into the environment are common in the mining industry. Even in the most regulated countries, accidents are commonplace. **Earthworks.org's 2012 research[11] of operating U.S. copper mines (accounting for 89% of U.S. copper production) found that**

- 100% had pipeline spills
- 92% failed to control mine wastewater and
- 28% had tailings impoundment failures—polluting drinking water, destroying fish & wildlife habitat, harming agricultural land, threatening public health

Earthworks.org stated "For example, the Tyrone and Chino mines – the two largest copper mines in New Mexico, will generate an estimated 2 billion gallons of acid and metals contaminated seepage every year, requiring water treatment in perpetuity. These two mines resulted in severe surface and groundwater contamination, and the State of New Mexico and U.S. Department of Justice have filed natural resource damage claims against the company for damages to water and wildlife resources."

As climate change impacts continue, increased risks of flooding (overflowing tailings dams, creating further erosion and spreading of acid and metals contaminants) and earthquakes (destroying tailings dam barriers, and risking the human lives involved in the mining operations), will make tailings dams accidents more likely.

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Environmental and Human Health Impacts of Copper Mining

There are countless examples of environmental contamination from copper mines. According to the OECD[6], they can be extensive, as demonstrated by the following examples illustrating problems from both routine releases of contaminants over the course of production, and accidental releases:

- The Marcopper mining disaster of 1996 in the Philippines, involved the failure of a drainage tunnel, leading to the release of 1.6 million m^3 into the local river system. A national disaster was declared by the government, after villages were inundated with sludge. Coastal fisheries collapsed after coral reefs were smothered with wastes.
- In 2014, sulphuric acid from the Buenavista copper mine in Mexico impacted a 40 mile stretch of the Sonora River and contaminated the drinking water supply for 20,000 people. Agricultural production was significantly affected.
- In 2015, mine operators were sued by local residents with respect to contamination of drinking water supplies and of agricultural land around the Konkola mine in Zambia. An estimated 93,000 tonnes of industrial waste are generated in the area annually, with the mine regarded as the major polluter. Release of sulphuric acid is highlighted as a particular problem."

And the results of the copper mine operations on the humans living by them is significant:

- Release of acid from the Mopani mine in Zambia into the local water network following failure of a pump in 2008, is said to have affected over 1,000 residents with abdominal pains, diarrhoea and vomiting[6]
- In Peru, in 2013, the National Center for Occupational Health and Environmental Protection for Health, the government agency tasked with detecting toxic metals, took blood and urine samples from 180 people from the area of a copper mine to test for 17 toxic metals. All 180 had at least one toxic metal detected in their samples, and 52 people had levels above the World Health Organization's maximum limit.[12]



Carmen Chambi Surco Photo: Diego Cárdenas Sedano / Amnesty International 2017

Carmen Chambi Surco in Peru, whose son had lung surgery to remove a cyst the size of an apple. A test revealed that his blood contained 17 toxic metals, including arsenic, mercury and lead. She can see the copper mine tailings dam from her home.[12]

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Copper Processing

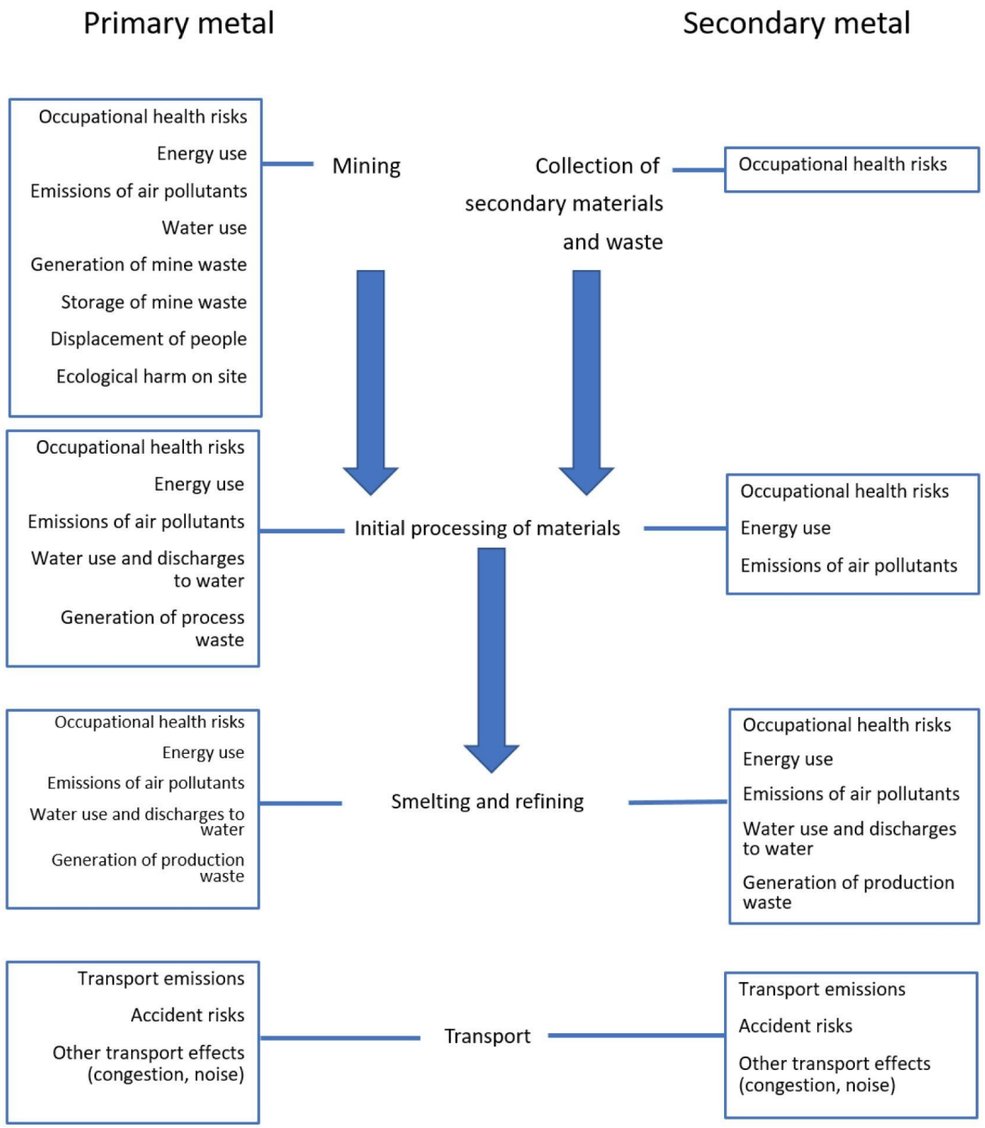
The further processing of the copper—once removed from the mining sites—has its own set of environmental and human health risks, including sulfur dioxide emissions when not properly controlled.

Health risks from copper smelters can be significant. Some examples[13]:

- Studies on the exposure of children to toxic elements carried out within a radius of 1.5 km around the copper and arsenic smelter in Sant Luis Potosi (Mexico) revealed that children's urine and blood had elevated levels of lead and arsenic
- In Chile, near the contaminated site of the Ventanas smelter, dusts have been found to pose a greater health risk than soil due to the high concentrations of toxic elements that enter the body by inhalation. A high risk of developing cancer in children was found due to the presence of arsenic, whose content significantly exceeded the acceptable norm

Note that many categories of sustainability risks to process copper after mining are also present with secondary production (i.e. recycling). Comparative quantification of each of these impacts would vary with the type of operations, locations, etc..[6]

Figure 2-1. Burdens generated during primary and secondary metal flows through to production of finished metal.



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The Future of Copper Supply

While there are ways of mitigating—but never to eliminate—the environmental impacts of mining, **unfortunately it is likely that mining's environmental impacts will only get worse over time, not better.** Barring geopolitical and other factors, generally mining of minerals began with the closer-to-the-surface and higher quality ores, so as time goes on, **in order to continue to mine we will unavoidably need to dig deeper, seek out reserves in more protected and fragile ecosystems, and try to extract more diluted materials from ores (generating even more mining wastes and tailings)**.

As certain countries enforce more stringent regulations (e.g. the stopping of Pebble Mine in the US), **the pressure for lower-regulated areas to produce copper will increase** (e.g. the likely re-opening of the Panguna copper mine in Papua New Guinea, formerly the flashpoint for a civil war resulting in approximately 20,000 deaths). If more areas of the world are opened to mining, social impacts, such as indigenous peoples displacement, will likely also increase.

Given the critical importance of carbon in the low-energy economy transition, it might be assumed that the need for copper would raise prices and could lead to the development of additional copper mining opportunities. However, given increasing environmental and social opposition to mining, money likely won't overcome the projected future issues of copper supply availability. According to researchers from the Sustainable Mining Institute at the University of Queensland Australia who study risks to future copper supply,[14] "The traditional view has been that increases in copper prices would cover increased production costs and so make now-inaccessible mines viable. We found low copper grades was the sole challenge in only three or four per cent of the undeveloped orebodies we analysed." Instead, they say, **other issues such as social and environmental impacts are in the future more likely to keep copper mines from being developed**. Pebble Mine is just one of many examples of increasing pushback around the world against copper mine development.

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Recycling Copper (i.e. Secondary Production)

Secondary production (i.e. recycling) is one of the ways in which to mitigate the environmental impact of mineral use. While the LCA data for metals is unfortunately incomplete, various estimates do support the common sense assumption that recycling should have less environmental impact than mining raw materials:

- Data from researchers indicates roughly a **60% reduction in environmental burdens through recycling for copper**[6].
- Up to **85% and 95% of energy is saved when copper is recycled instead of producing from ores**[1].
- **The environmental impact of refined copper was higher than that of reclaimed copper in almost all categories except for human toxicity** because of the direct atmospheric arsenic emission during the copper recycling stage**.** In particular, the overall environmental impact for the refined copper production was mainly attributed to metal depletion, freshwater ecotoxicity, marine ecotoxicity, and water depletion potential impact. By contrast, that for the reclaimed copper production was mainly caused by human toxicity impact[15].

Environmental and social sustainability improvements through copper recycling do depend on the type of recycling operations in place.

> "In well-regulated environments, the initial processing of secondary materials will have little impact on the health of workers, the public or the environment. Activities will include sorting of materials, perhaps separation of individual components from electronics, shredding or grinding, and mixing of materials. The complexity of operations is dependent on the materials used. Relatively pure wastes, such as copper pipe, will need little treatment, whilst complex wastes, such as electronics, will need more."[5]

Of note, **e-waste is estimated to be the largest secondary source of (not in current use) copper**[1].

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Summary

- Copper's sustainability risks are primarily in the area of environmental pollution (including the associated human health impacts)
- The majority of copper reserves unavoidably overlap with areas of significant environmental and social value
- Copper must be converted from 1% ore to 99.5%+ pure copper for most applications, a process requiring the addition of solvents and/or heat
- Copper ore excavation exposes ores to air and water, triggering an acidic reaction that requires perpetual treatment
- Tailings ponds/dams—outdoor storage and processing locations to extract copper from unwanted ore waste—commonly leak or fail, with disastrous consequences, even in the most regulated countries
- People living in the areas of copper mines and processing facilities such as smelters have been exposed to toxic chemicals, including arsenic (a by-product of many copper ores)
- As time goes on, sustainability issues with copper are only likely to get worse, as the need for copper increases and we dig deeper, push into more protected areas, etc.
- Recycling copper has significant environmental improvements, primarily from the avoidance of mining. E-waste is considered to be the primary source of recycled copper

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Thank you

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Recommended reading in green

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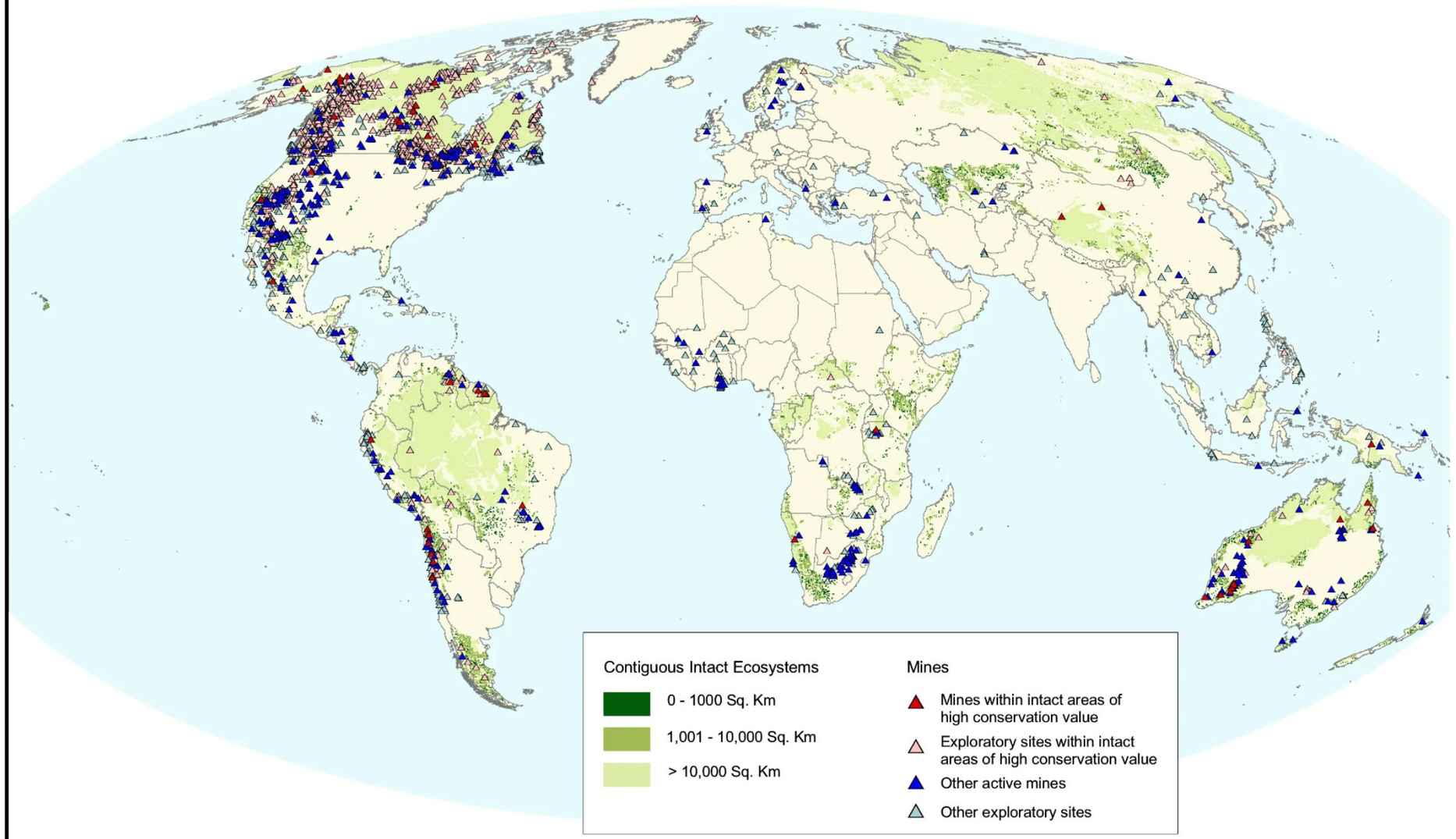
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MAP 2: Intact High Conservation Value Areas



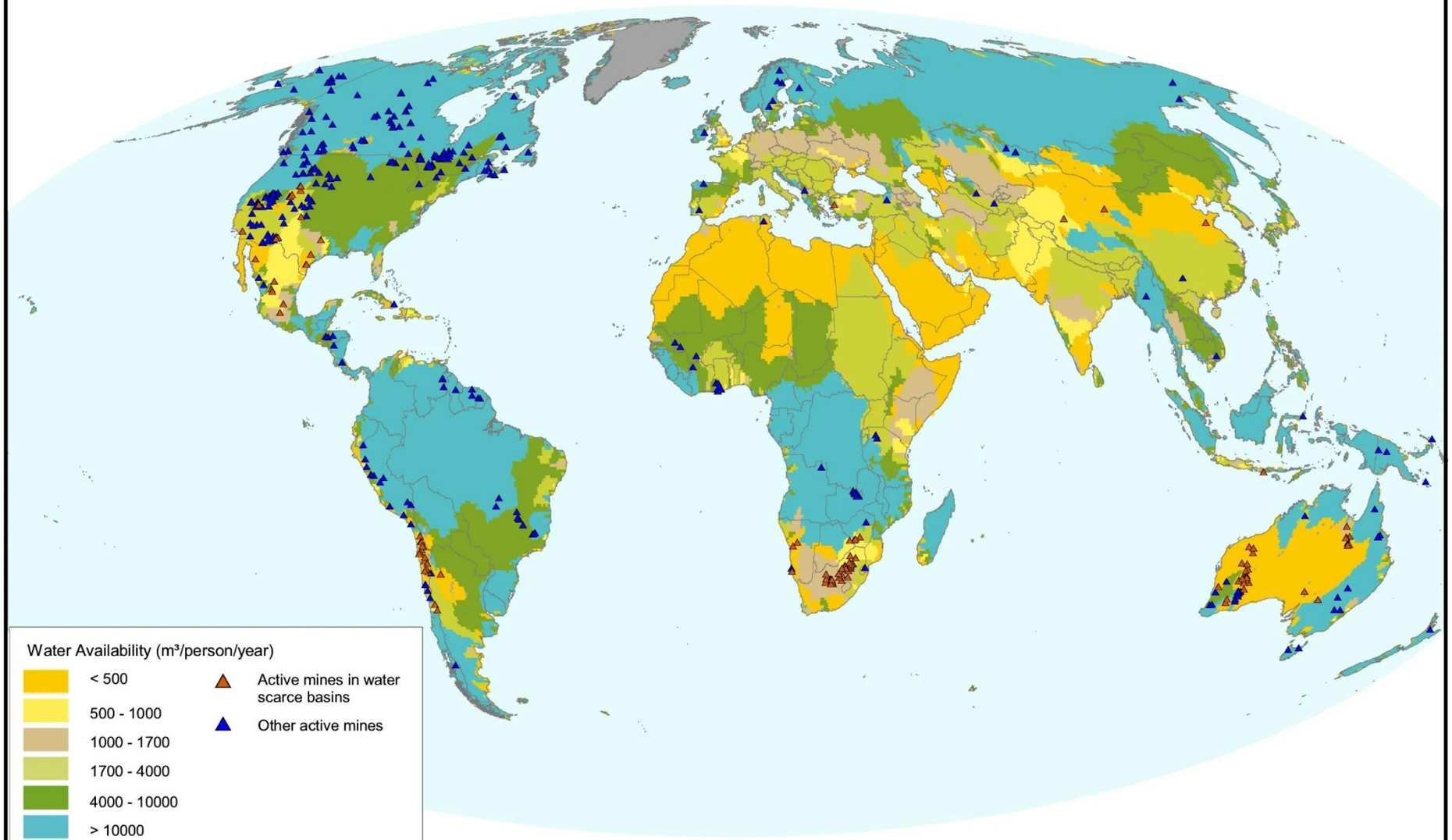
This map shows that about 10 percent of active mines and 20 percent of exploratory sites are located in areas of high conservation value, with clusters occurring in the boreal forests and arctic landscapes of North America, the northern coastal and Andean regions of South America, and northeastern and southwestern Australia.

Sources: Dinerstein et al., 1995; Sanderson et al., 2002; CI, 2001; Bryant et al., 1997; Strattersfield et al., 1998. Last of the Wild Data version 0, 2002. Wildlife Conservation Society (WCS) and Center for International Earth Science Information Network (CIESIN). Note: Degree of human influence is over-estimated on the island of New Guinea.
Mining Data ©1994-2003 InfoMine Inc. All Rights Reserved.

World Resources Institute, 2003[4]

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MAP 5: Mining in Water Scarce Basins



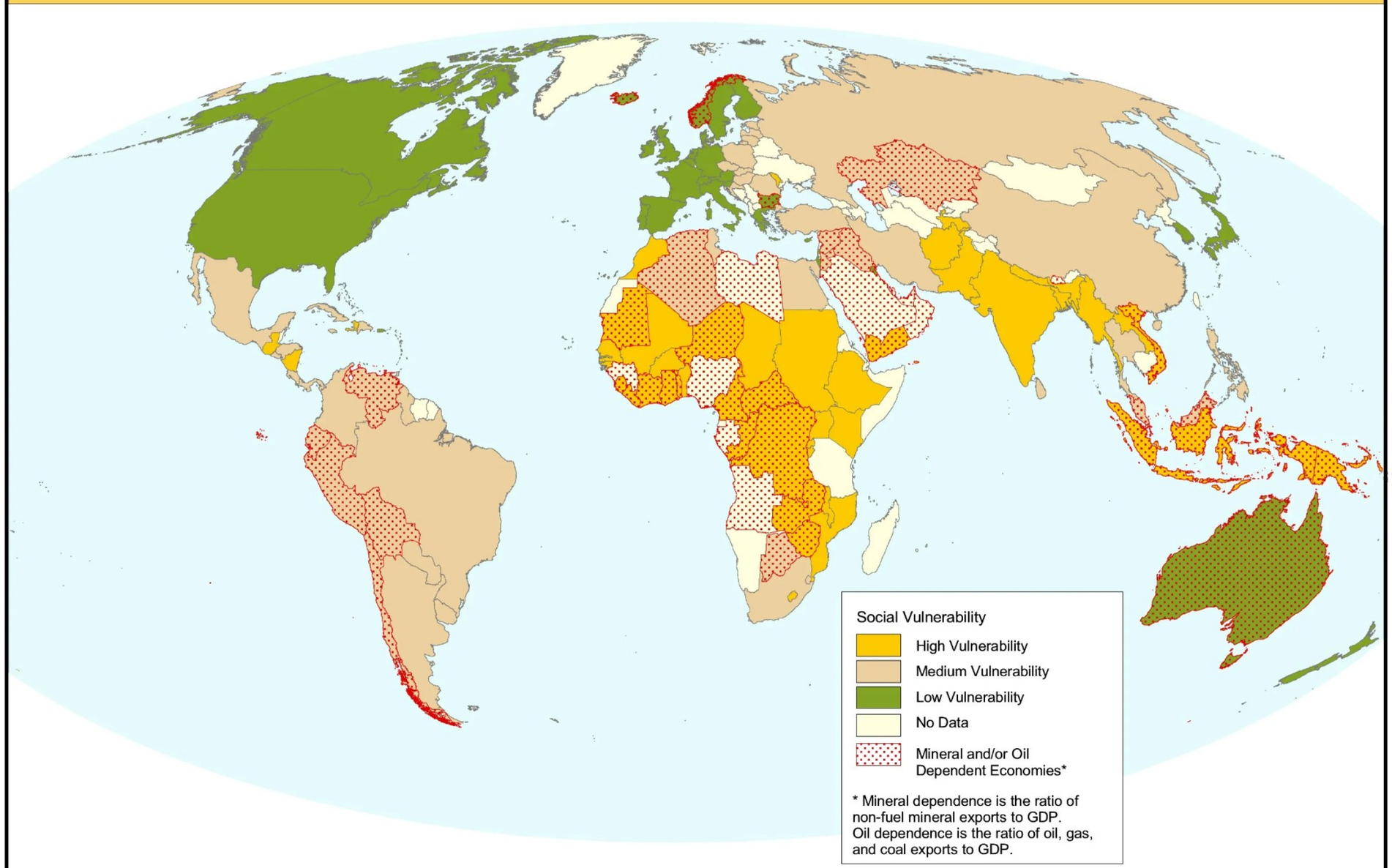
This map shows that nearly 30 percent of active mines are located in water-stressed areas where demand for water from the mining sector competes with other water uses. Of these mines, about two thirds are found in highly stressed areas where water scarcity is particularly acute (i.e., supplies of less than 1,000 cubic meters of water per person per year).

Sources: CIESIN et al., 2000; Fekete et al., 1999. Mining Data ©1994-2003 InfoMine Inc. All Rights Reserved.

World Resources Institute, 2003[4]

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MAP 8: Mining in Socially Vulnerable Areas



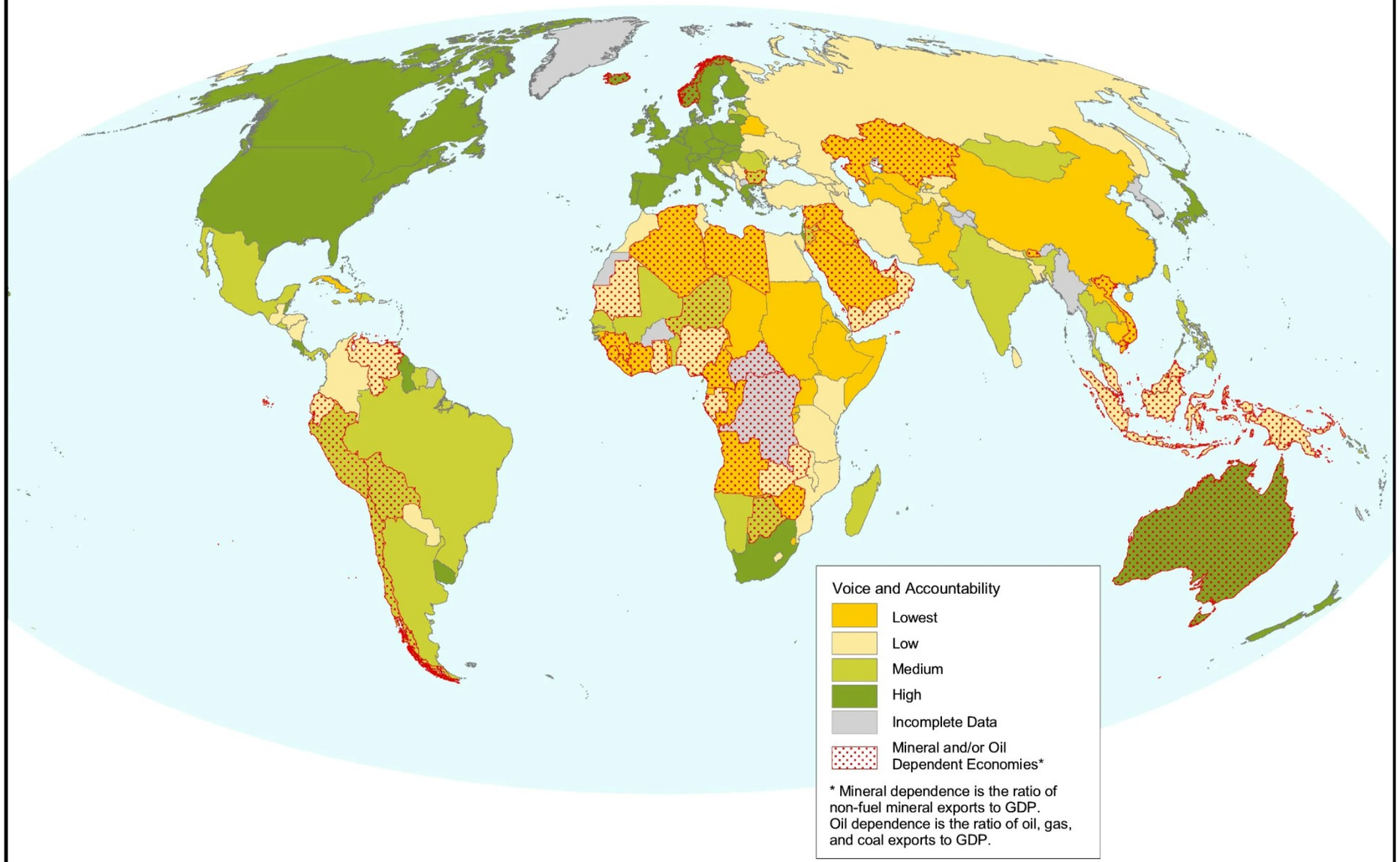
Many countries that are highly dependent on revenues from oil and/or mineral development, including in Central and Southern Africa and Southeast Asia, also are socially vulnerable to the impacts of mining. In this analysis, high social vulnerability refers to low levels of educational attainment and high poverty rates, which limit people's capacity for informed decision-making and their ability to negotiate effectively in their own best interests.

Sources: Barro and Lee, 2002; World Bank, 2003; Ross, 2001.

World Resources Institute, 2003[4]

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MAP 15: Voice and Accountability



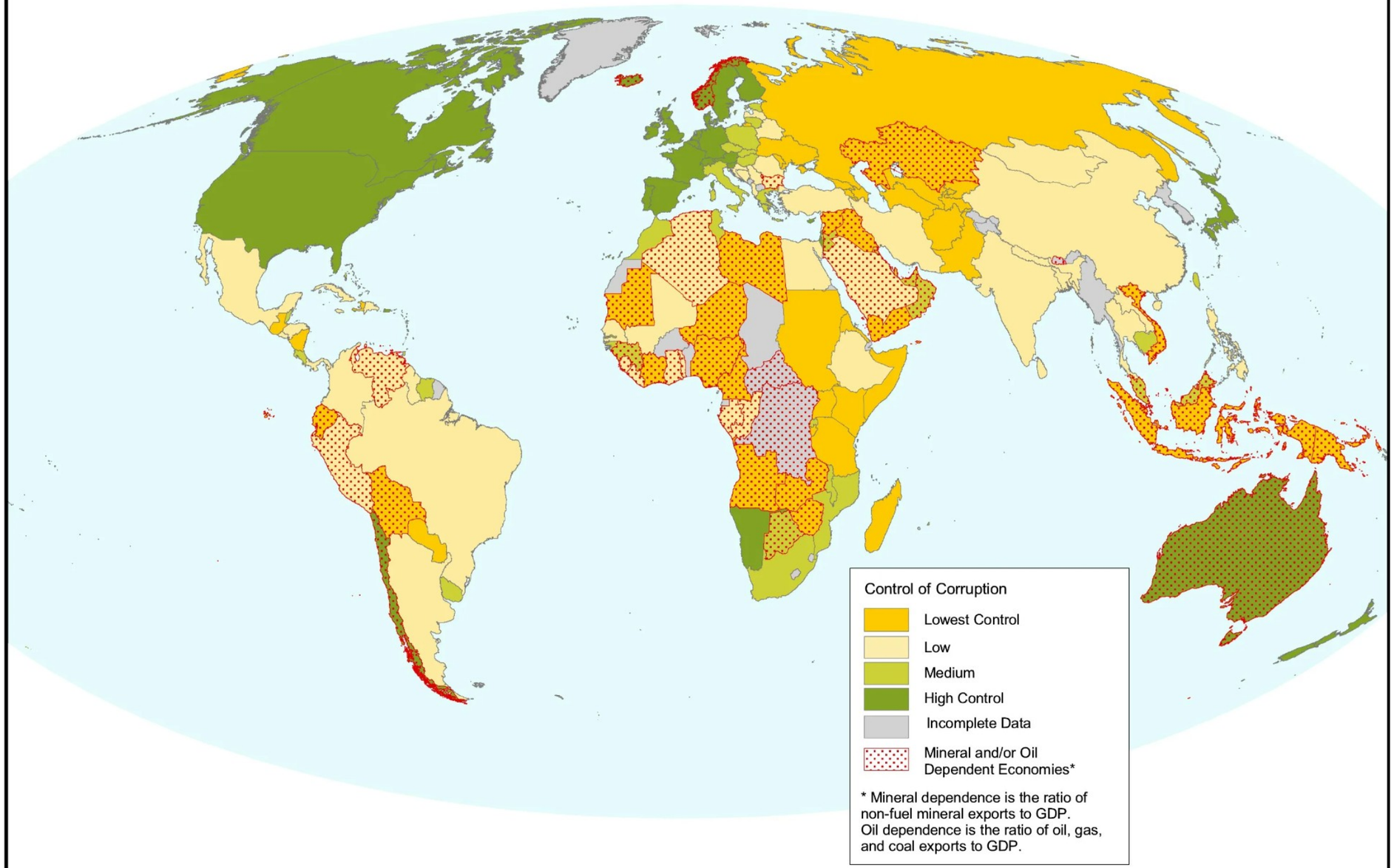
Citizens have little voice in public decision-making or ability to hold governments accountable in several oil- and mineral-dependent economies in Africa, the Middle East, and Southeast Asia. Civil and political liberties appear to be more advanced in many Latin American countries, with the exception of Cuba and Haiti.

Sources: Kaufmann et al., 1999; Ross, 2001.

World Resources Institute, 2003[4]

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MAP 14: Control of Corruption



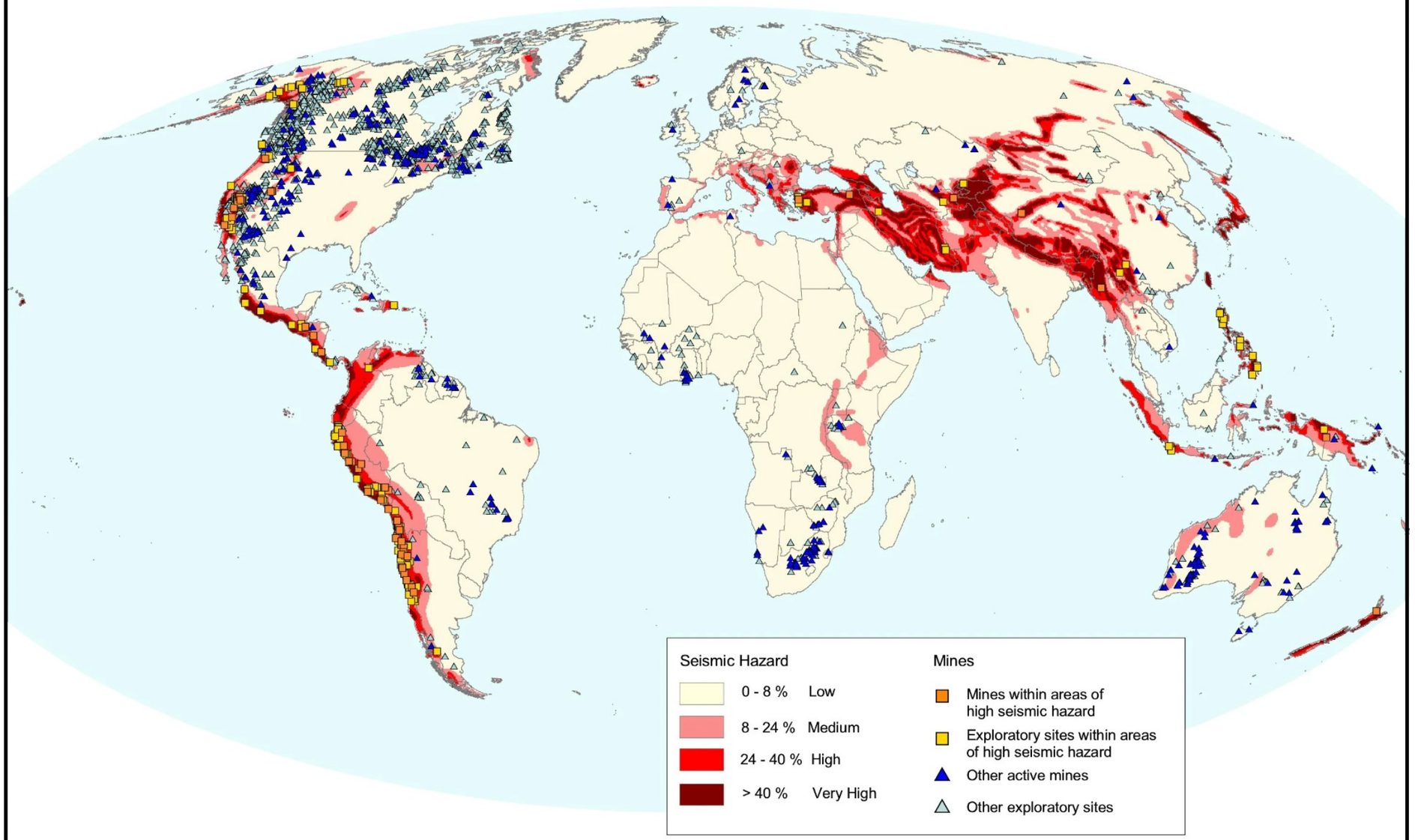
Many economies that are dependent on revenues from oil and mineral development also have difficulty controlling corruption, including clusters of countries in Africa, the Andean region of South America, the Middle East, and Southeast Asia.

Sources: Kaufmann et al., 1999; Ross, 2001.

World Resources Institute, 2003[4]

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MAP 11: Seismic Hazard



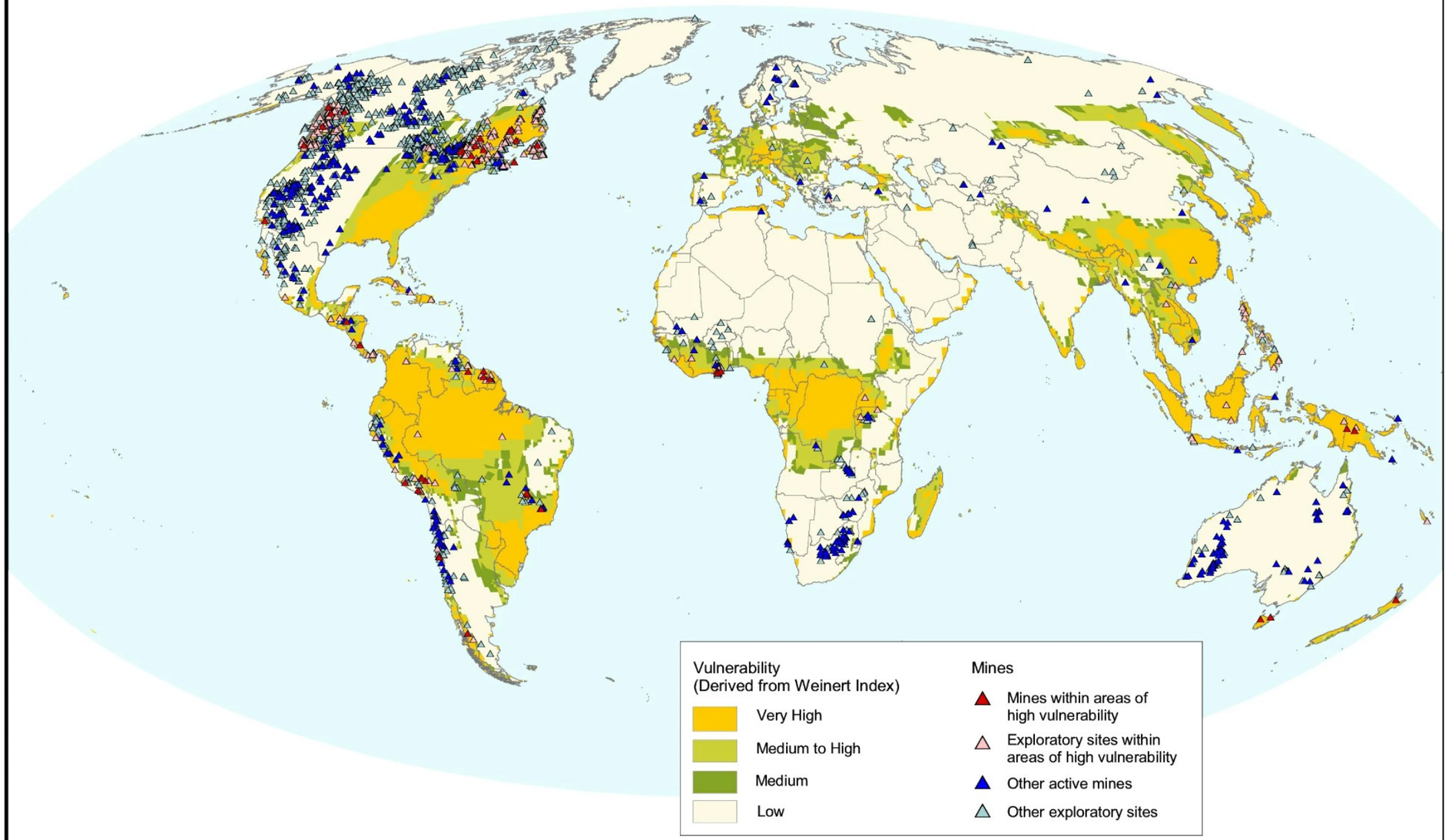
Twelve percent of active mines and 7 percent of exploratory sites occur in areas of geological instability that pose high or very high seismic hazards, an important safety concern for mine development. Such mining and exploration sites are clustered around the Pacific Rim and in a band running through Central Asia.

Sources: Giardini et al., 2000. Mining Data ©1994-2003 InfoMine Inc. All Rights Reserved.

World Resources Institute, 2003[4]

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MAP 13: Areas Predisposed to Water Quality Problems



The data used in this map were derived from the Weinert Index, which can be used as a proxy for areas that are predisposed to water quality problems from mining. High rainfall can cause mining waste impoundments to fail and produce serious water quality problems. Active mines and exploratory sites overlapping areas predisposed to mining-related water quality problems are found primarily in the tropics and in the humid coastal zones.

Sources: Legates and Willmott, 1990; NOAA, 2003; Mining Data ©1994-2003 InfoMine Inc. All Rights Reserved.

World Resources Institute, 2003[4]

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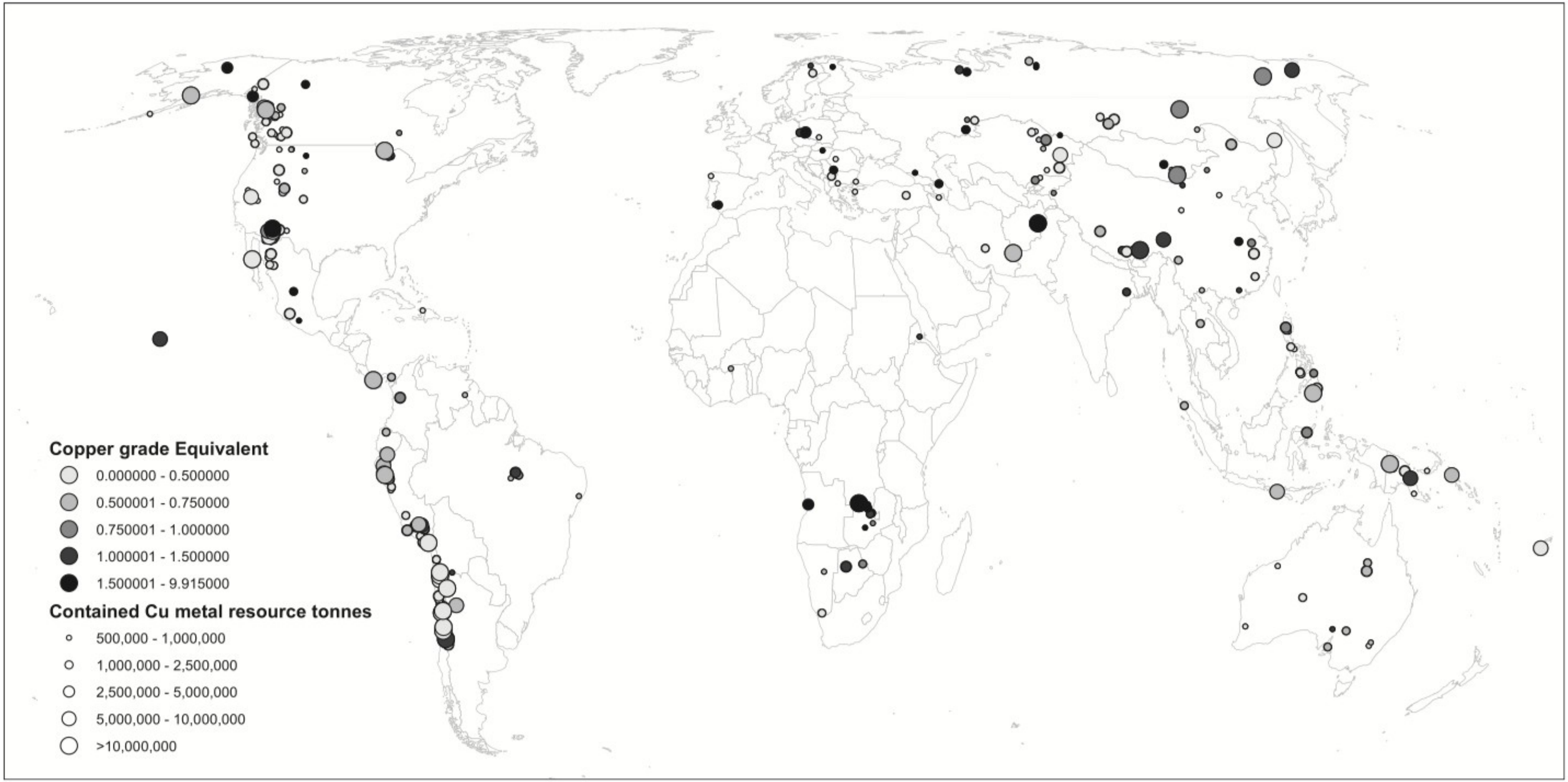


Fig. 2. Orebody location and size.

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Valenta et al, 2019[14]