

ESG Stranded Assets Analysis

Carbon Transition Risk in Copper Mining

Alexis Vannon, Kerrian Le Bars and Othmane Menkor

Research Emerging Topics

January 2026

Quantifying Climate Transition Risk Across 914 Global Mining Assets

Project Overview

Research Questions:

- Which copper mining assets become unprofitable under carbon pricing?
- What is the total financial exposure to carbon costs?
- How are emissions trending over time (2021-2024)?
- Can we predict stranded asset risk using machine learning?

Scope:

- 914 mining assets globally
- 56+ countries analyzed
- 51,184 monthly emission records

Data Source:

Climate TRACE v5.2.0

- Satellite + AI emissions tracking
- Monthly data: Jan 2021 - Aug 2025
- Most comprehensive global emissions database

Methodology:

- Financial risk modeling
- Machine learning predictions
- Interactive web dashboard
- Scenario stress testing

The Problem: Carbon Pricing Impact

\$19.04 Billion

Annual carbon cost exposure at \$200/tCO₂

914 Assets Global copper mines	56 Countries Worldwide coverage	259 Assets At critical/high risk	28.3% Of assets vulnerable
--	---	--	--------------------------------------

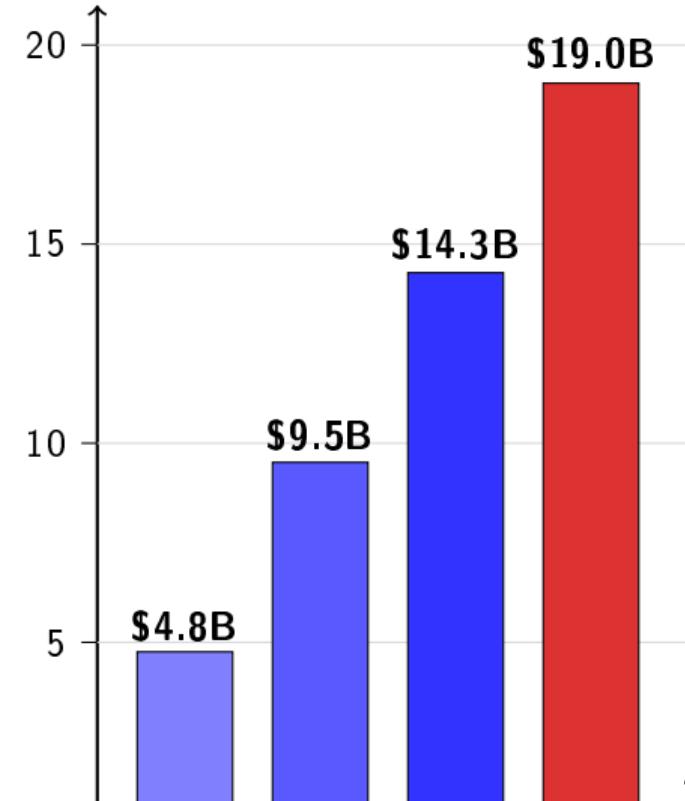
Carbon pricing will destroy value. The question is: how much?

Key Finding #1: Massive Financial Exposure

Carbon Cost by Scenario:

Scenario	Annual Cost
\$50/tCO ₂	\$4.76B
\$100/tCO ₂	\$9.52B
\$150/tCO ₂	\$14.28B
\$200/tCO ₂	\$19.04B

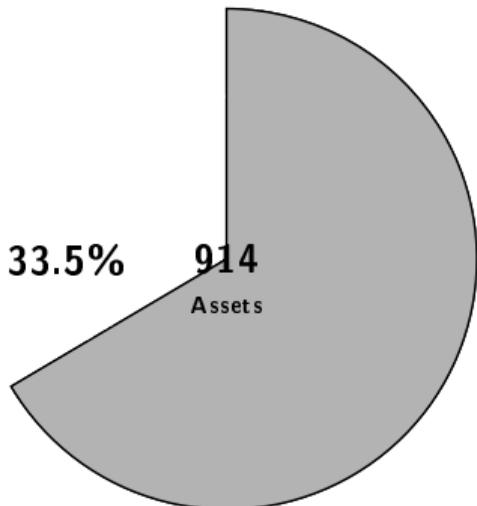
Annual Cost (Billions \$)



Key Metrics:

- \$14.28B swing between \$50 and \$200 scenarios
- Every \$10/tCO₂ = \$950M additional cost
- Top 10% of assets = 51.6% of exposure
- Median break-even: \$776/tCO₂

Key Finding #2: Risk Distribution

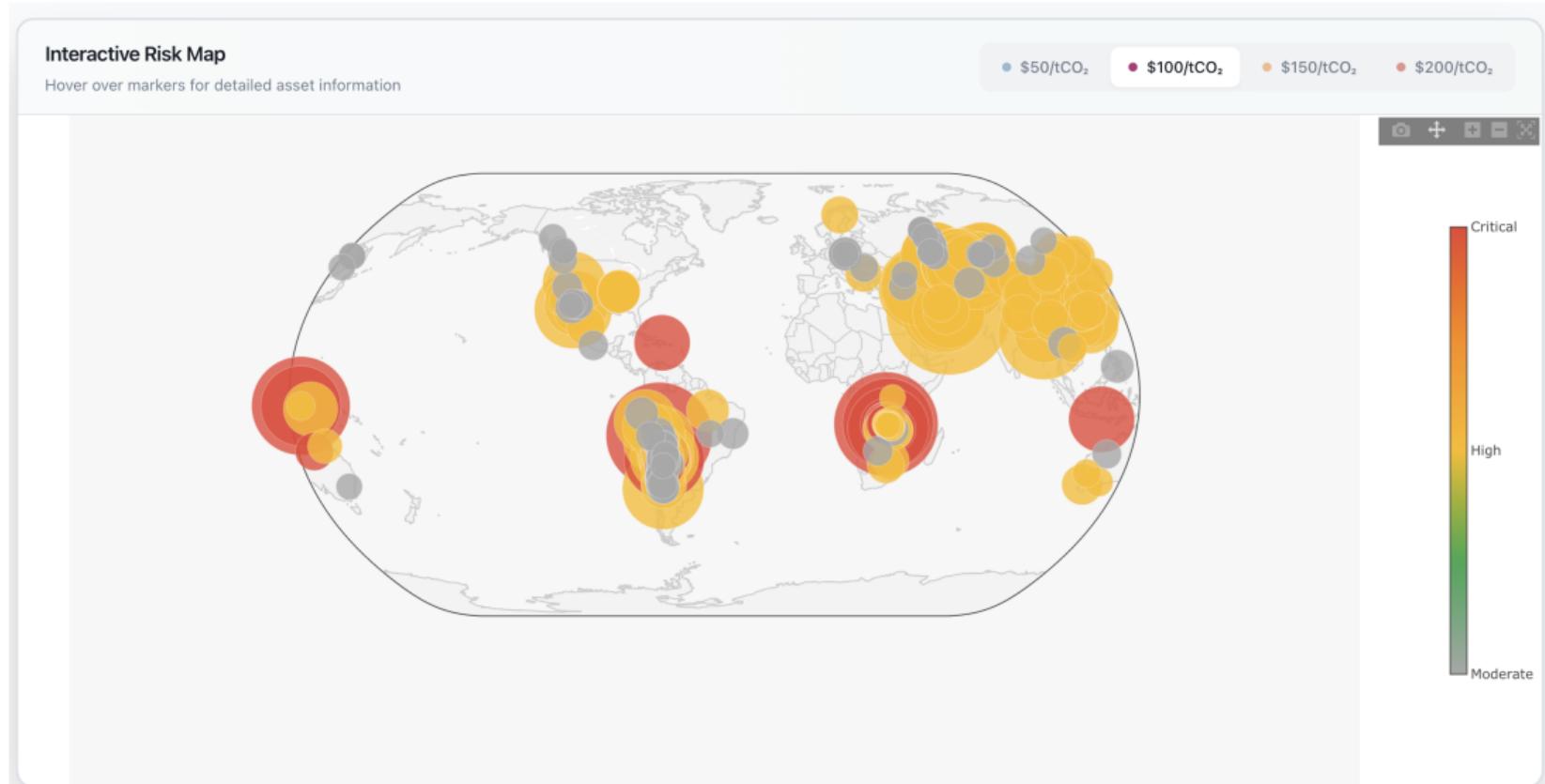


Risk at \$100/tCO₂

Key Insight

259 assets (28.3%) require immediate strategic intervention
(Critical + High risk categories)

Interactive Dashboard: Overview



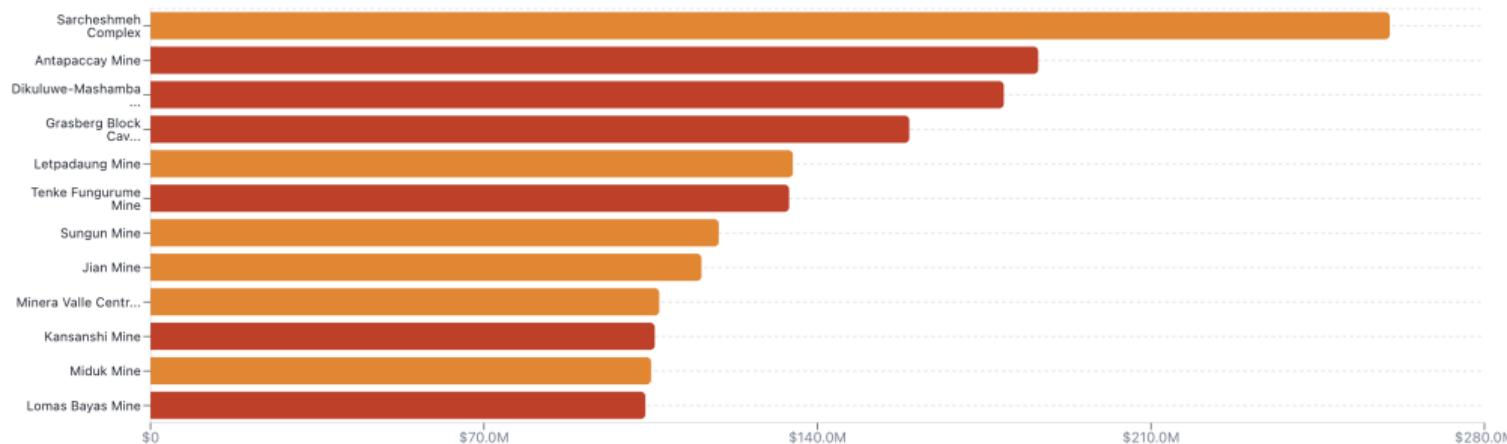
Interactive Dashboard: Asset Analysis

Asset Explorer

Browse and analyze individual mining assets

● \$50/tCO₂ ● \$100/tCO₂ ● \$150/tCO₂ ● \$200/tCO₂

Top 12 Most Exposed Assets



Interactive Dashboard: Geographic Risk Mapping

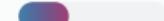
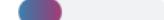
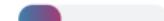
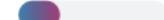
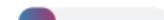
Company Portfolio Analysis

Analyze carbon exposure by parent company

● \$50/tCO₂ ● \$100/tCO₂ ● \$150/tCO₂ ● \$200/tCO₂

Top 25 Companies by Exposure

 Export

Company	Mines	Total Emissions	Exposure @ \$100/tCO ₂	Carbon Intensity
>  FreePort-McMoran Inc	11	4,858,750.02 tCO ₂	<div style="width: 100%;"><div style="width: 100%;">\$485.9M</div></div>	 0.0104
>  Government of Iran	3	4,844,845 tCO ₂	<div style="width: 100%;"><div style="width: 100%;">\$484.5M</div></div>	 0.0240
>  Qatar Investment Authority	11	2,318,213.002 tCO ₂	<div style="width: 100%;"><div style="width: 100%;">\$231.8M</div></div>	 0.0445
>  Kazakhmys Holding LLP	4	2,262,216.04 tCO ₂	<div style="width: 100%;"><div style="width: 100%;">\$226.2M</div></div>	 0.0056
>  The Vanguard Group Inc	14	2,091,091 tCO ₂	<div style="width: 100%;"><div style="width: 100%;">\$209.1M</div></div>	 0.0045
>  Zijin Mining Group Co Ltd	10	1,641,364.428 tCO ₂	<div style="width: 100%;"><div style="width: 100%;">\$164.1M</div></div>	 0.0158
>  Eurasian Resources Group SARL	5	1,400,075.296 tCO ₂	<div style="width: 100%;"><div style="width: 100%;">\$140.0M</div></div>	 0.0092
>  First Quantum Minerals Ltd	5	1,384,564 tCO ₂	<div style="width: 100%;"><div style="width: 100%;">\$138.5M</div></div>	 0.0097
>  Glencore PLC	2	1,345,730 tCO ₂	<div style="width: 100%;"><div style="width: 100%;">\$134.6M</div></div>	 0.0455
>  Government of Poland	6	1,203,982.002 tCO ₂	<div style="width: 100%;"><div style="width: 100%;">\$120.4M</div></div>	 0.0128

Interactive Dashboard: Scenario Analysis

Active Scenarios

Select All

Orderly Transition

Steady carbon price growth, early policy action

Disorderly Transition

Delayed action with sudden policy shock

Hothouse World

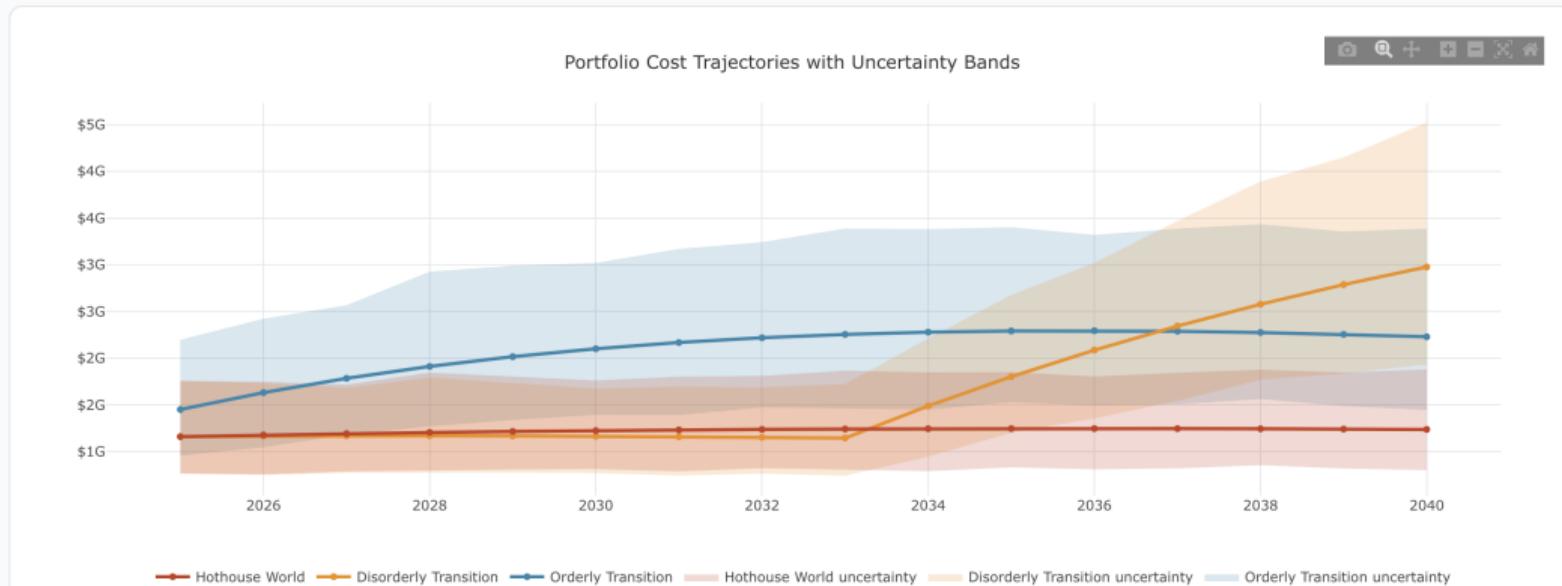
Minimal climate action, limited decarbonization

3 of 3 scenarios active

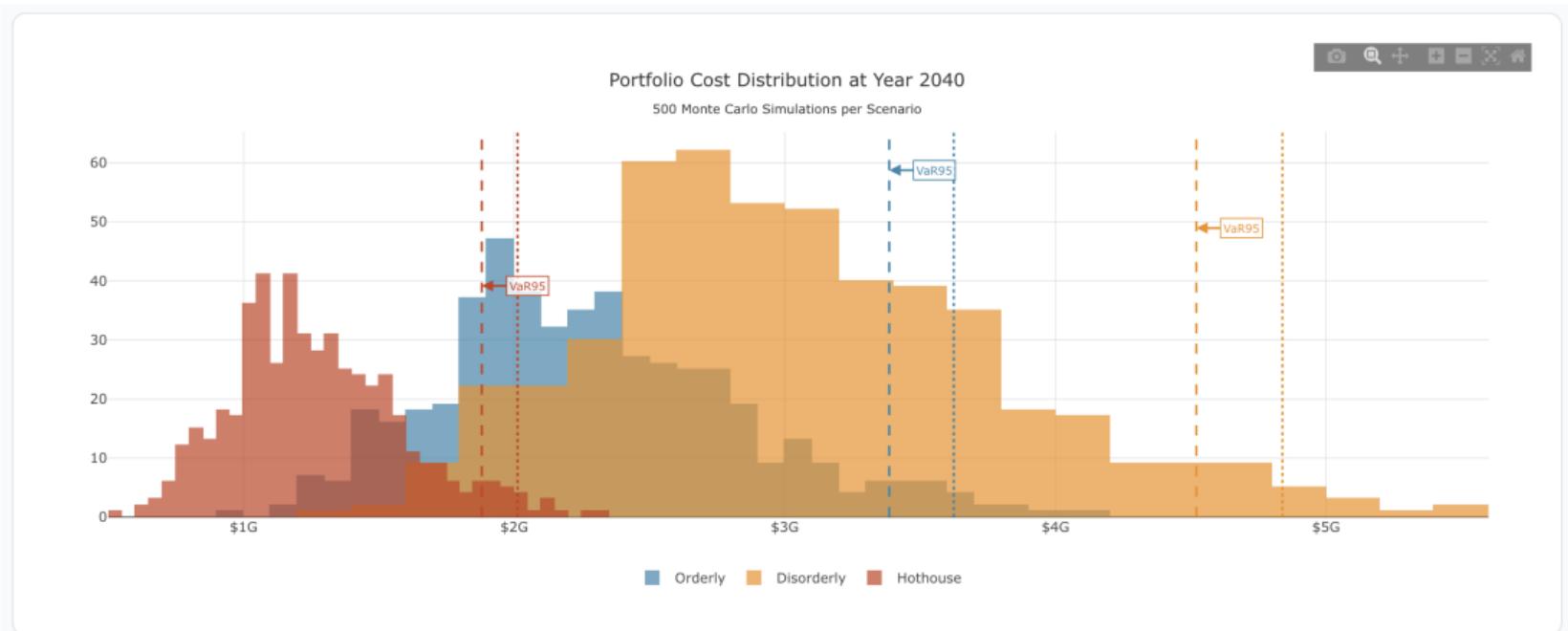


Show Monte Carlo Uncertainty Bands

VaR Horizon: 2040



Interactive Dashboard: Risk Categories



● \$50/tCO₂

\$4.76B

● \$100/tCO₂

\$9.52B

+100% from baseline

● \$150/tCO₂

\$14.28B

+200% from baseline

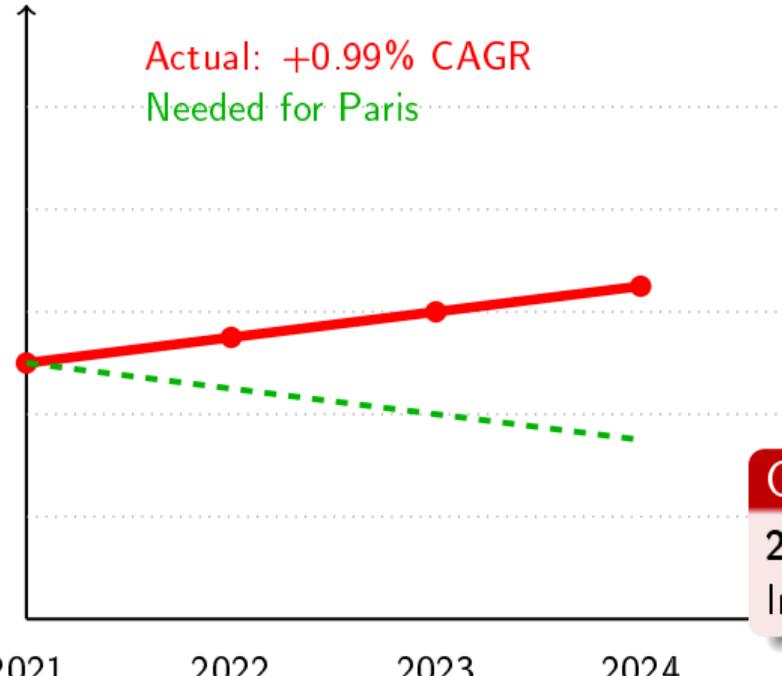
● \$200/tCO₂

\$19.04B

+300% from baseline

Key Finding #3: Emissions Trending Upward

Emissions Index



Trajectory Analysis:

Trend	Assets
Deteriorating ($>10\% \uparrow$)	202
Improving ($>10\% \downarrow$)	119
Stable ($\pm 10\%$)	208

Critical Problem

202 assets have worsening emissions
Industry moving away from decarbonization

Key Finding #4: Company-Level Exposure

Top 10 Companies by Carbon Cost

Rank	Company	\$M @ \$100
1	Freeport-McMoRan	1,245
2	Codelco	1,123
3	BHP	987
4	Rio Tinto	876
5	Glencore	845
6	Southern Copper	678
7	Anglo American	534
8	First Quantum	498
9	Antofagasta	445
10	Teck Resources	389
Top 10 Total		7,620

Concentration

Top 10 companies = **80%** of industry exposure

Investor Implications:

- Major portfolio companies at risk
- ESG ratings will reflect exposure
- Shareholder pressure mounting
- Divestment risk for worst performers

Company Response Needed:

- Asset-level decarbonization plans
- Renewable energy investment

Key Finding #5: Predictive Risk Modeling

Random Forest Model

Metric	Score
Accuracy	84.2%
Precision	79.3%
Recall	72.7%
ROC-AUC	0.87

Feature Importance:

- Carbon Intensity: 31%
- Capacity Factor: 24%
- Production Volume: 18%
- Temporal Trend: 12%
- Oil price: 15%

What This Enables:

Proactive Risk Management

Predict which assets will become stranded
before they fail

Use Cases:

- ① Portfolio optimization
Divest high-risk assets early
- ② Targeted interventions
Focus capex on saveable assets
- ③ Valuation adjustments
Price carbon risk into M&A
- ④ Insurance pricing

Recommendations

Mining Companies

① Immediate audit

Assess 259 critical/high-risk assets

② Divest underwater assets

El Salvador, Sepon already unviable

③ Decarbonization capex

Prioritize open pit electrification

④ Renewable PPAs

Lock in green power for processing

⑤ Enhanced disclosure

Asset-level carbon reporting

Investors & Lenders

① Portfolio stress testing

Model \$150-200 carbon scenarios

② Engagement campaigns

Demand decarbonization plans

③ Credit risk repricing

Adjust spreads for carbon exposure

④ Thematic opportunities

Low-carbon copper as alpha source

⑤ Voting actions

Support climate resolutions

Policymakers

- Predictable carbon price escalation

Conclusion

The copper mining industry faces a \$19B annual carbon crisis

28% of assets
at critical/high risk

Emissions rising
+0.99% CAGR

Cost multiplying
4x from \$50 to \$200



Massive value destruction unless industry acts now

This is not a distant threat. Carbon prices are already rising.

Thank You

Alexis Vannson, Kerrian Le Bars and Othmane Menkor
Research Emerging Topics
January 2026

Data: Climate TRACE v5.2.0
Assets Analyzed: 914 global copper mines