C O P P E R - S O U R C E C O M P A N I O N

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How to read this companion

Every bracketed number in the book - [C1], [C2] and so on - resolves to one entry below. Each entry gives the source, how fully it was read, what it supports in the text, and its limits. Read levels: FULL (read end to end), EXCERPT (substantial portions read), ABSTRACT (abstract or summary only), SEARCH (search-result highlights and snippets, not the full document). Where sources conflict, the conflict is stated rather than smoothed over.

Section C - Core sources

C1 - USGS Mineral Commodity Summaries 2026: Copper (February 2026)

Read level: FULL. The United States Geological Survey's annual copper chapter: US production, use and trade statistics for 2021-2025; world mine and refinery production and reserves by country; price averages; the November 2025 addition of copper to the US critical minerals list.
Supports: world mine production ~23.0 Mt (2025, estimated); Chile 5.3 Mt, DRC 3.2, Peru 2.7; China refinery output 14.0 Mt of ~29 Mt world; reserves 980 Mt; US end-use split (construction 42%, electrical/electronic 23%, transportation 18%, consumer 10%, industrial machinery 7%); scrap ~30% of US supply; US 2025 refined import surge; COMEX 2025 average $4.80/lb record; critical-minerals listing (Federal Register 90 FR 50494, 7 November 2025); USGS global resource assessment (1.5 Gt identified, 3.5 Gt undiscovered, as of 2015 assessment).
Limits: 2025 figures are estimates (marked 'e'); reserve figures carry each country's own definitions and reporting dates; the resource assessment is dated 2015/2019.
URL: https://pubs.usgs.gov/periodicals/mcs2026/mcs2026-copper.pdf

C2 - Copper properties: standard reference values

Read level: SEARCH (datasheet and reference excerpts; direct Copper Development Association pages could not be retrieved in this pass).
Supports: density 8.96 g/cm3; melting point 1,085 C; thermal conductivity ~400 W/mK; face-centred cubic structure and workability; qualitative alloy family descriptions.
Limits: values are standard reference data quoted across metallurgical literature; the specific CDA web pages cited in draft could not be loaded and the claims resting on them were kept to values also covered by C50 and C51.
URL: https://copper.org/resources/properties/ (unreachable in this pass; values cross-checked against C50/C51)

C3 - Antimicrobial copper: EPA registrations and clinical evidence

Read level: ABSTRACT/SEARCH (via research compilation; EPA registration label and AJIC 2023 review abstract).
Supports: EPA registration of copper alloys with public-health antimicrobial claims (registrations from 2008 onward, hundreds of alloys); systematic review finding reduced microbial burden on copper surfaces in healthcare settings.
Limits: clinical-outcome effect sizes (versus surface bioburden) remain debated; the book claims only the registration facts and the burden-reduction finding.
URLs: https://www3.epa.gov/pesticides/chem_search/ppls/082012-00001-20100209.pdf ; https://www.ajicjournal.org/article/S0196-6553(23)00081-0/fulltext

C4 - Great Lakes native copper and the Old Copper Complex

Read level: EXCERPT (peer-reviewed articles read in substantial part via open access; chronology papers).
Supports: native copper working in the western Great Lakes from roughly 8500-3000 years before present; production beginning 9000-8000 RCYBP by radiocarbon/OLE modelling; an independent, cold-hammered metallurgical tradition that never developed smelting; the abandonment of copper tool production around 3000 BP and its status as a near-unique technological reversal.
Limits: dating remains model-dependent and debated among archaeologists; the book presents dates as approximate.
URLs: https://doi.org/10.1017/rdc.2021.7 ; https://doi.org/10.1017/aaq.2021.121 ; https://pmc.ncbi.nlm.nih.gov/articles/PMC6453894/ ; https://pmc.ncbi.nlm.nih.gov/articles/PMC9041870/

C5 - Origins of copper smelting: Roberts et al., Antiquity 2009, and the Catalhoyuk reassessment

Read level: EXCERPT (Roberts et al. read via search excerpt of full PDF; Catalhoyuk paper abstract-level).
Supports: copper ores used as beads/pigments from the 11th-9th millennium BC (Shanidar and neighbours); native copper working with annealing at Cayonu Tepesi c. 8000 BC; earliest smelting late 6th/early 5th millennium BC at Tal-i Iblis and Belovode; single-core-invention (probably Anatolia) argued more probable than parallel invention, explicitly unsettled; Catalhoyuk's supposed slag reclassified as non-metallurgical (2017).
Limits: the invention debate is open; the book presents both positions and does not assert a single origin as fact.
URLs: https://os.pennds.org/archaeobib_filestore/pdf_articles/Antiquity/2009_83_Robertsetal.pdf ; https://doi.org/10.1016/j.jas.2017.07.001

C6 - The Uluburun and Cape Gelidonya shipwrecks

Read level: EXCERPT (review article citing Bass, Pulak and Gale's isotope work).
Supports: Uluburun (c. 1300 BC): ~10 tonnes of copper in 354 ingots of oxhide and other shapes, ~1 tonne of tin, the ~10:1 bronze recipe; lead-isotope attribution toward Cypriot ores (Apliki area, with caveats); Gelidonya (c. 1200 BC): 34 ingots of ~25 kg with bronze-working scrap - an itinerant smith's cargo; refutation of the cattle-value explanation of ingot shape.
Limits: isotopic attribution carries caveats about depleted source signatures; dating of Uluburun within the late 14th century BC is approximate.
URL: https://doi.org/10.21550/sosbilder.1414674

C7 - ICSG World Copper Factbook 2020

Read level: EXCERPT (Intergovernmental body statistics).
Supports: world mine production growth from <0.5 Mt (1900) to 20.5 Mt (2019), ~3.2% compound; SX-EW rise from <1% of refined output in the late 1960s to 16% (3.9 Mt) in 2019; secondary refined ~17% of world refined output in 2019.
Limits: 2020 edition; later structural figures in the book use C1 (2026 edition).

URL: https://internationalcopper.org/wp-content/uploads/2021/01/2020_10_13_ICSG_Factbook_2020.pdf

C8 - Richard Schodde: long-run analysis of the copper industry (grades)

Read level: EXCERPT (conference paper; exact series not quoted figure-by-figure).
Supports: secular decline of copper ore grades for over a century; typical porphyry grades now well under 1% versus >2% a century ago; grade decline as the industry's best-documented secular trend.
Limits: precise historical grade series not reproduced in the book; the claim is directional.
URL: https://www.uvm.edu/~shali/Schodde.pdf

C9 - USGS Mineral Commodity Summaries 2025: Copper (January 2025)

Read level: FULL.
Supports: 2024 world mine production 23.0 Mt; DRC overtaking Peru (3.3 vs 2.6 Mt, 2024 estimates); China 12.0 Mt refined, ~44% of world; reserves by country (Chile 190 Mt in that edition); Escondida/Bingham production context.
Limits: superseded by C1 for 2025 estimates; retained for the 2024 ranking detail.
URL: https://pubs.usgs.gov/periodicals/mcs2025/mcs2025-copper.pdf

C10 - BHP: Escondida overview

Read level: FULL (company page).
Supports: Escondida ownership (BHP 57.5% operator, Rio Tinto 30%, JECO 12.5%); two pits, three concentrators, two leach operations; discovery 1981, production from 1990; significance to Chilean GDP (company framing).
Limits: company source; ownership and configuration facts are stable, economic-significance framing is the owner's own.
URL: https://www.bhp.com/what-we-do/global-locations/chile/escondida

C11 - Codelco 2023 results coverage (Reuters) and Codelco annual report

Read level: SEARCH/EXCERPT.
Supports: Codelco 2023 production decline to 1.325 Mt (lowest in decades); 2023 gross profit down 34% to $3.12bn; delayed structural projects.
Limits: 2023-era; 2025 finals are in C46.
URLs: https://www.reuters.com/markets/commodities/chile-copper-miner-codelcos-2023-production-declines-recovery-seen-this-year-2024-02-07/ ; https://www.reuters.com/markets/commodities/chiles-codelco-posts-2023-profit-dip-production-falls-2024-03-29/

C12 - Chilean nationalization of copper: US government primary documents

Read level: EXCERPT (FRUS documents and declassified CIA memo).
Supports: Frei's 1964 Chileanization terms; 1969 forced sale of Anaconda stakes; 11 July 1971 unanimous constitutional amendment, effective 16 July; the "excess profits" deduction leaving Anaconda and Kennecott uncompensated (Cerro $13m); Kennecott's litigation against Codelco shipments in European courts; NSDM 136 context.
Limits: US-government vantage; Chilean legal texts not directly read; the book uses these for the sequence of events, not for Chilean constitutional detail.
URLs: https://history.state.gov/historicaldocuments/frus1969-76ve16/d86 ; https://history.state.gov/historicaldocuments/frus1969-76v04/d149 ; https://www.cia.gov/readingroom/document/cia-rdp85t00875r001600030048-6

C13 - CIPEC: contemporary assessment

Read level: FULL (contemporary journal article, PDF).
Supports: CIPEC founded Lusaka 1967 by Chile, Zambia, Congo, Peru; HQ Paris; failure to achieve price control due to insufficient supply coverage and quota defection.
Limits: period source; membership and mechanisms described as of its writing; later history (decline into research body) is standard record presented qualitatively.
URL: https://www.econstor.eu/bitstream/10419/138878/1/v08-i08-a12-BF02927699.pdf

C14 - Zambia: Copperbelt history and resource nationalism

Read level: FULL/EXCERPT (three peer-reviewed/working-paper sources).
Supports: independence 1964; Kaunda's 1969 51% state participation; ZCCM consolidation; output peak around 1969; quarter-century decline under state ownership; privatization 1997-2000 under donor pressure; Konkola Copper Mines liquidation saga (2019+).
Limits: interpretation of causes varies across the sources; the book presents the sequence and attributes the welfare-state diagnosis as argument, not consensus.
URLs: https://scielo.org.za/scielo.php?pid=S2225-62532016000600003&script=sci_arttext ; https://www.tandfonline.com/doi/full/10.1080/03057070.2022.2083853 ; https://www.wider.unu.edu/sites/default/files/Publications/Working-paper/PDF/wp2018-166.pdf

C15 - DRC: CMOC, Kamoa-Kakula and the Chinese-led rebuild

Read level: SEARCH/EXCERPT.
Supports: CMOC's 80% of Tenke Fungurume and 71.25% of KFM; stated ambition of 800 kt-1 Mt/yr DRC copper by 2028; the Chinese-financed character of Congo's production surge; Kamoa-Kakula developed by Ivanhoe with Zijin.
Limits: company statements and trade press; production ambitions are targets, not output; cobalt coupling described qualitatively.

URLs: https://www.mining.com/web/cmoc-to-double-copper-output-at-congo-mines-to-1-million-tons-by-2028/ ; https://en.cmoc.com/html/Business/Congo-Cu-Co/ ; https://www.reuters.com/markets/commodities/chinas-cmoc-boosts-cobalt-output-congo-mines-despite-export-ban-2025-04-08/

C16 - Grasberg 2018 divestment

Read level: SEARCH/EXCERPT (Reuters plus company releases).
Supports: Freeport ceding majority control to Indonesian state interests in a $3.9bn transaction; Rio Tinto's exit; framing as negotiated resource nationalism.
Limits: deal terms simplified; book claims only majority transfer and price.
URLs: https://www.reuters.com/article/us-indonesia-freeport-deal/freeport-to-cede-control-of-indonesian-copper-mine-in-3-9-billion-deal-idUSKBN1K202D/ ; https://investors.fcx.com/investors/news-releases/news-release-details/2018/Freeport-McMoRan-Announces-Successful-Completion-of-Transaction-with-the-Government-of-Indonesia-Marking-the-Beginning-of-a-New-Partnership/default.aspx

C17 - The Sumitomo copper affair

Read level: SEARCH/EXCERPT (NYT 1996, Washington Post 1996, CFTC 1998, Federal Reserve testimony 1996).
Supports: Yasuo Hamanaka's decade-long unauthorized accumulation; June 1996 revelation; admitted $1.8bn loss later reckoned near $2.6bn; CFTC action; systemic-risk testimony; "Mr. Copper"/"Mr. Five Percent" nicknames; contested degree of management tolerance.
Limits: 1990s press accounts; the book avoids adjudicating the rogue-trader-versus-tolerance question.
URLs: https://www.nytimes.com/1996/06/14/business/sumitomo-says-it-found-loss-of-1.8-billion.html ; https://www.cftc.gov/sites/default/files/opa/enf98/opa4144-98.htm ; https://www.federalreserve.gov/boarddocs/testimony/1996/19960918.htm

C18 - IEA, The Role of Critical Minerals in Clean Energy Transitions

Read level: EXCERPT (chapter via search excerpt; scenario figures quoted with scenario names).
Supports: grid expansion requirements in STEPS/SDS scenarios; transmission and distribution growth attributable to renewables; grid copper demand roughly doubling by 2040 in the SDS; framing of electrification as minerals demand.
Limits: scenario outputs, not forecasts; the book attributes them to their scenarios.
URL: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/mineral-requirements-for-clean-energy-transitions

C19 - International Copper Association: substitution research (2022)

Read level: EXCERPT.
Supports: the finding that the substitution driver is the absolute copper-aluminium price difference, not the ratio; partial reversal when prices fall.
Limits: industry-association research; direction of the finding corroborated by market behaviour but the survey is the ICA's own.
URL: https://internationalcopper.org/wp-content/uploads/2022/03/Substitution.pdf

C20 - Reuters (30 June 2026): why companies are swapping copper for aluminium

Read level: SEARCH.
Supports: record 2024-2026 prices pushing manufacturers toward aluminium qualification; substitution wave of the mid-2020s.
Limits: news report; extent and permanence of substitution unquantified.
URL: https://www.reuters.com/business/autos-transportation/why-companies-are-swapping-copper-aluminium-2026-06-30/

C21 - Butte and the Berkeley Pit: EPA record

Read level: EXCERPT (EPA site pages and Superfund document).
Supports: Butte as "the Richest Hill on Earth"; Berkeley Pit abandoned 1982, flooding with acidic metal-laden water; Superfund (Butte Mine Flooding Operable Unit); requirement to manage water below the critical level protecting groundwater, with treatment in perpetuity.
Limits: EPA framing; the pit's full hydrology and consent-decree detail are simplified.
URLs: https://www.epa.gov/butte/background ; https://semspub.epa.gov/work/08/100006199.pdf

C22 - Otzi's axe: provenance studies

Read level: FULL/EXCERPT (PLOS One 2017 full text; Springer reassessment excerpt).
Supports: axe blade ~99.7-99.8% copper with trace arsenic and silver; lead-isotope attribution to southern Tuscan ores (mainstream reading); evidence of long-distance Copper Age metal trade; later reassessment challenging the attribution and noting the unusually high purity.
Limits: provenance debated; the book presents the Tuscany reading as mainstream but challenged. (Used as background for the trade-routes argument.)
URLs: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0179263 ; https://link.springer.com/article/10.1007/s00501-018-0782-0

C23 - Etymology of "copper"

Read level: EXCERPT (etymological references).
Supports: late Latin cuprum (first attested 301 AD, Diocletian's Edict) from aes Cyprium, "metal of Cyprus"; scholarly caution that the island-metal naming direction should not be glibly assumed.
Limits: etymology; the book uses the mainstream derivation with the caution.
URLs: https://www.etymonline.com/word/copper ; https://magazine.hmc.edu/summer-2015/copper-and-mudd/

C24 - Westmetall LME market data, 30 October 2026

Read level: FULL (market data table).
Supports: LME copper cash settlement $14,449/t and 3-month $14,250/t on 30 October 2026; LME copper stocks 274,000 t; comparable base-metal prices.
Limits: single-day official prices; market data without interpretation.
URL: https://www.westmetall.com/en/markdaten.php?action=table&field=LME_Cu_cash&year=2026

C25 - Discovery Alert: copper price and exchange stocks, October 2026

Read level: SEARCH.
Supports: price near record in late October 2026 (~$14,441/t on 21 October); cathode stocks rising on LME, COMEX and SHFE; 2026 average cited as 40% above 2025 in that piece.
Limits: industry-analysis site; the 40% figure differs in basis from C39's ICSG-reported +35% YTD average (different windows); the book uses C39 with attribution and C24 for spot levels.
URL: https://discoveryalert.com/analysis/copper-price-record-stockpiles-october-2026/

C26 - Mining.com: ranked world's biggest copper mines (2024 production)

Read level: SEARCH.
Supports: Escondida first at 1.28 Mt in 2024 (+16% y/y); ranking context for the giant mines.
Limits: trade press ranking; company-reported production basis.
URL: https://www.mining.com/featured-article/ranked-worlds-biggest-copper-mines/

C27 - Codelco operational and financial report, December 2024

Read level: SEARCH.
Supports: 2024 total production including stakes (El Abra, Anglo American Sur, Quebrada Blanca) of 1,442 kt, +1.2% y/y; own-versus-consolidated definitional distinction.
Limits: company reporting; the own/total distinction matters and is flagged in the text wherever Codelco tonnages appear.
URL: https://www.codelco.com/sites/site/docs/20240426/20240426181050/operational_and_financial_report_december_31_2024.pdf

C28 - EV copper intensity: ICA E-Mobility factsheet and Transportation report

Read level: FULL for the factsheet numbers (read verbatim); report excerpt.
Supports: ICE car 23 kg; HEV 40 kg; PHEV 60 kg; BEV 83 kg; hybrid bus 89 kg; battery bus 224-369 kg; chargers 0.7 kg (up to 8 kg fast); "BEVs require three times more copper than ICE vehicles" (ICA Transportation report).
Limits: industry-association figures based on IDTechEx data from the late 2010s; vehicle designs have since thrifted copper; the book presents these as ICA reference figures with that dating, not as current universal intensities.
URLs: https://internationalcopper.org/wp-content/uploads/2017/06/2017.06-E-Mobility-Factsheet-1.pdf ; https://internationalcopper.org/wp-content/uploads/2022/02/ICA-IR-Transportation-202202-R3.pdf

C29 - CIA declassified memo on copper pricing (1970)

Read level: EXCERPT (declassified document).
Supports: two-tier pricing 1964-66; US producer prices held at 30 then 42 cents/lb while LME ran to 85; collapse of the system in 1966 when Chile ordered producers to LME pricing.
Limits: intelligence-agency vantage written for policy purposes; used for the price sequence, which is uncontested.
URL: https://www.cia.gov/readingroom/document/cia-rdp85t00875r001600030048-6

C30 - Roman copper industry background

Read level: NOT DIRECTLY READ in this pass; claims narrowed accordingly.
Supports: qualitative framing only - Roman workings at Rio Tinto and the Sierra Morena, waterwheel dewatering (see C58), large slag accumulations, post-Roman contraction.
Limits: precise figures originally drafted (wheel-train counts, slag tonnages, annual output estimates) were removed from the text for lack of a directly read source; only claims also covered by C58/C59 remain.
URL: (see C58, C59)

C31 - Mining methods and costs: block caving and C1

Read level: SEARCH/EXCERPT (Resolution Copper block-caving description PDF; Penn State course notes; C1-cost glossaries).
Supports: block-caving mechanism (undercut excavated below the orebody, ore collapsing into drawpoints, cave propagating upward); method developed in the US after WWI for weak, massive, low-grade orebodies; C1 cash cost as the standard cross-industry comparison metric for direct cash costs of producing payable metal.
Limits: method descriptions kept qualitative; no cost figures claimed.
URLs: https://resolutioncopper.com/wp-content/uploads/2024/02/RTRC-Block-Caving-FINAL.pdf ; https://courses.ems.psu.edu/mng230/node/911 ; https://quoteddata.com/glossary/c1-costs/

C32 - Smelting and refining process descriptions

Read level: EXCERPT (EPA AP-42 copper smelting chapter; peer-reviewed flash-smelting review; anode-slime study).
Supports: flash furnace combining roasting and smelting of dried concentrate and flux into high-grade matte (EPA); reaction-shaft operation with oxygen-enriched air at ~1300 C (MDPI review); anode slime as the insoluble electrorefining residue containing Cu, Ni, Se, Te, Ag, Au and platinum-group metals; matte and blister grades; acid-plant sulphur capture.
Limits: capture-rate figures ("over 95%") remain stated as typical of well-run modern smelters, not a measured average; the flash-smelting date rests on C60.
URLs: https://www.epa.gov/sites/default/files/2020-11/documents/c12s03.pdf ; https://www.mdpi.com/2075-4701/10/9/1229 ; https://doi.org/10.1179/174328509x431463

C33 - Negative treatment-charge regime 2024-2026

Read level: SEARCH (Reuters column, June 2025; Benchmark Mineral Intelligence).
Supports: smelters so short of concentrate in 2025 that they paid miners for conversion - treatment charges negative; margin survival on byproduct credits; the market-pricing crisis framing for smelters.
Limits: spot prints vary weekly; the book quotes direction only.
URLs: https://www.reuters.com/markets/commodities/copper-smelters-are-facing-both-market-pricing-crises-2025-06-20/ ; https://source.benchmarkminerals.com/article/copper-concentrate-tc-rcs-for-smelters-flatten

C34 - Telegraph and cable application history

Read level: EXCERPT (atlantic-cable.com histories; submarine cable record).
Supports: early land telegraph lines used iron wire; the first international submarine telegraph cable of 1851 and the 1851-66 buildout of the submarine industry used gutta-percha-insulated copper conductors; cables as copper's first large electrical market.
Limits: specialist-history site; the iron-first detail corrected the manuscript's original copper-first phrasing. No tonnage figures claimed.
URLs: https://atlantic-cable.com/CableCos/Bolton/index.htm ; https://atlantic-cable.com/Article/Origins/index.htm ; https://en.wikipedia.org/wiki/Submarine_communications_cable

C35 - Plumbing substitution (PEX and plastics)

Read level: SEARCH (Home Innovation Research Labs builder-practices data).
Supports: copper fallen from its dominant first position in new-home supply plumbing, displaced by PEX; two decades of tracking behind the trend claim.
Limits: US new construction specifically; the book claims nothing about other regions or renovation.
URLs: https://www.homeinnovation.com/insights/trends_data/big-changes-underway-in-whole-house-re-piping-market/42689 ; https://www.homeinnovation.com/services/market_research/market-demand-data/builder-practices/p_pipe

C36 - Reuters (22 May 2024): the COMEX squeeze

Read level: FULL.
Supports: May 2024 COMEX short squeeze; LME then-record nominal high of $11,104.50/t on 20 May 2024; metal shipped to CME warehouses to cover shorts.
URL: https://www.reuters.com/markets/commodities/copper-squeezed-united-states-china-has-plenty-2024-05-22/

C37 - Reuters (8 July 2025) and Straits Times: the tariff announcement spike

Read level: FULL/SEARCH.
Supports: 8 July 2025 announcement of a planned 50% copper tariff; COMEX all-time high $5.8955/lb (over $12,330/t); one-day move reported variously as >12% intraday and up to 17% (record one-day move).
Limits: intraday percentage differs between reports; the book quotes the price level, not the percentage.
URLs: https://www.reuters.com/business/comex-copper-hits-record-after-trump-says-he-will-impose-50-tariff-copper-2025-07-08/ ; https://www.straitstimes.com/business/companies-markets/us-copper-prices-surge-to-record-as-trump-calls-for-50-tariff

C38 - Reuters (31 July 2025): tariff scope and the COMEX collapse

Read level: FULL.
Supports: September futures -22% in one session to $4.376/lb ($9,647/t); COMEX premium over LME collapsing from ~$3,000/t to ~$27/t; LME that day -0.8% at $9,620.5/t; months of tariff anticipation having drawn enormous tonnage into the US since February 2025.
URL: https://www.reuters.com/markets/commodities/trumps-watered-down-copper-tariffs-crush-comex-premium-2025-07-31/

C39 - S&P Global Commodity Insights at LME Week (October 2026)

Read level: FULL.
Supports: LME 2026 high $14,850/t on 17 August 2026; August 2026 average $14,353/t; ICSG's September 2026 release putting the 2026 year-to-date average at $13,395/t, 35% above the 2025 average (as reported in this October 2026 article; the ICSG observation window was not stated in the report); ING attribution of drivers (disruptions, lower guidance, permitting, grades).
Limits: the YTD figure's exact observation window is unconfirmed; the book carries the attribution ("ICSG September 2026 release, as reported at LME Week, October 2026").
URL: https://www.spglobal.com/energy/en/news-research/latest-news/metals/102026-lme-week-copper-supply-struggles-to-keep-pace-with-electrification-demand

C40 - Mining.com: US stockpile distortion study (GEM Mining Consulting)

Read level: SEARCH.
Supports: ~70% of visible exchange stocks in US warehouses by October 2026; global visible inventories ~1.04 Mt, +83% y/y; “tightness” coexisting with a US overhang from the tariff trade.
Limits: consultancy study via trade press; “visible stocks” are exchange-registered inventories, not total world stocks.
URL: https://www.mining.com/us-copper-stockpiles-conceal-growing-global-supply-crunch/

C41 - Section 232 copper proclamation and White House fact sheet (2025)

Read level: FULL (Federal Register text and fact sheet).
Supports: 50% tariff on semi-finished copper products and intensive copper derivatives listed in the Annex, effective 1 August 2025; application to copper content; non-stacking with auto 232 tariffs; EXEMPTION of refined copper (cathodes, anodes), ores, concentrates and scrap; the Commerce recommendation of phased refined-copper tariffs (15% from 2027, 30% from 2028) and a 25% domestic sales requirement being recommendations in the proclamation text, not implemented duties as of 1 November 2026.
Limits: implementation status of the phased recommendations unverified at publication; the book states them as recommendations only.
URLs: https://www.federalregister.gov/documents/full_text/html/2025/08/05/2025-14893.html ; https://www.whitehouse.gov/presidential-actions/2025/07/adjusting-imports-of-copper-into-the-united-states/

C42 - Treatment-charge benchmark record 2024-2026

Read level: FULL/SEARCH (Reuters twice; Mining.com; Mining Weekly).
Supports: 2024 benchmark $80/t and 8.0c/lb; 2025 benchmark $21.25/t and 2.125c/lb (Antofagasta-Jiangxi, 5 December 2024, -73.4%); mid-2025 settlement at $0 (June 2025); 2026 benchmark $0/0c (Antofagasta with a Chinese smelter); Antofagasta’s mid-2026 push to index term TCs to spot, resisted by Chinese smelters.
Limits: other miner-smelter pairs may have settled differently; spot prints vary weekly and are deliberately not quoted.
URLs: https://www.reuters.com/markets/commodities/antofagasta-jiangxi-agree-major-drop-2025-copper-tcrcs-sources-2024-12-05/ ;
https://www.reuters.com/world/china/chinas-copper-smelters-win-better-than-expected-0-tcrc-deal-antofagasta-sources-2025-06-27/ ;
https://www.mining.com/web/antofagasta-agrees-zero-copper-processing-charges-for-2026-with-chinese-smelter/ ;
https://www.miningweekly.com/article/chinese-copper-smelters-baulk-at-spot-indexed-ore-pricing-proposal-2026-06-29

C43 - Grasberg mud rush (September 2025) and restart plan

Read level: FULL (Reuters 18 November 2025); SEARCH (Bloomberg force-majeure report).
Supports: 8 September 2025 incident: ~800,000 tonnes of wet mud breaching from the retired open pit into the Grasberg Block Cave; seven workers killed; force majeure declared around 24 September; phased restart aiming at July 2026; 2026 PTFI guidance ~1bn lb copper + ~900 koz gold; 2027-29 average ~1.6bn lb copper and ~1.3 Moz gold per year; CEO statement (“no indications of human error”); PTFI 51.2% controlled by Jakarta; Grasberg as world’s second-largest copper mine and largest gold mine (company/industry framing).
Limits: guidance is guidance; actual ramp status at publication is in C52.
URLs: https://www.reuters.com/world/asia-pacific/after-deadly-accident-freeport-aims-restart-grasberg-copper-production-by-july-2025-11-18/ ;
https://www.bloomberg.com/news/articles/2025-09-24/copper-jumps-after-freeport-declares-force-majeure-at-grasberg

C44 - Kakula flooding (May-June 2025)

Read level: ABSTRACT (Reuters paywalled beyond summary).
Supports: May 2025 seismic activity and water inflows flooding sections of Kakula; partial restart 12 June 2025 with output guidance cut.
Limits: revised tonnage guidance not captured; the book makes no numeric claim.
URL: https://www.reuters.com/world/africa/ivanhoe-restarts-part-congo-copper-mine-cuts-output-guidance-2025-06-12/

C45 - Cobre Panama: closure and the October 2026 commission report

Read level: EXCERPT (substantial read of the Interministerial Commission Final Report, October 2026).
Supports: closure since 27 November 2023 (Supreme Court ruling on Law 406); preservation-and-maintenance regime at operator cost; the October 2026 report recommending assessment of a new contract, settlement of arbitration, and a restart designed around an eventual closure plan with six non-negotiable criteria; mine NOT restarted as of that report.
Limits: the report is hosted by First Quantum (it is the government commission’s document, but framing was not cross-checked against Panamanian coverage in this pass); the book presents it as the commission’s recommendation, not a decision.
URL: https://www.first-quantum.com/wp-content/uploads/2026/10/Interministerial_Commission_Final_Report_Eng.pdf

C46 - Codelco and Chile 2025 finals

Read level: SEARCH/EXCERPT.
Supports: Codelco own production 2025: 1,334,445 t (+0.5%) per company press release; total incl. stakes 1,439,732 t; Cochilco Anuario 2025: Codelco own-division output 1,307,200 t (-1.6%, lowest since 2000, 24.3% of national output) - a disclosed conflict of basis/revision between the company and the state commission; Chile total 2025: 5,415,200 t (-1.65%); El Teniente 31 July 2025 tremor/collapse, six workers killed.
Limits: the two Codelco series cannot be reconciled from the available documents; the book cites them side by side with their sources.
URLs: https://www.codelco.com/prensa/2026/codelco-reafirma-solidez-operativa-y-rol-estrategico-para-el-desarrollo ;
https://www.cochilco.cl/web/download/1036/2026/16853/anuario-de-estadisticas-del-cobre-y-otros-minerales-2025.pdf ;

https://www.df.cl/empresas/produccion-de-cobre-de-chile-cae-casi-2-en-2025-y-escondida-por-si-sola ; https://www.reuters.com/world/americas/codelco-ends-el-teniente-rescue-effort-after-five-miners-found-dead-2025-08-03/

C47 - DRC 2025 exports

Read level: SEARCH (Bloomberg via Mining.com, February 2026).
Supports: DRC copper exports 3.4 Mt in 2025, up from 3.1 Mt in 2024 (provisional government data).
Limits: EXPORT tonnage, not measured mine production; the book uses it only for direction and scale, with the production ranking resting on C1.
URLs: https://www.bloomberg.com/news/articles/2026-02-11/congo-copper-exports-rose-10-last-year-as-china-drives-output ; https://www.mining.com/web/congo-copper-exports-rose-10-last-year-as-china-drives-output/

C48 - ICA per-vehicle copper content (see C28)

Read level: FULL (factsheet numbers).
Supports and limits: as C28; the book attributes the 23/40/60/83 kg figures to the ICA factsheet and flags their vintage.
URL: https://internationalcopper.org/wp-content/uploads/2017/06/2017.06-E-Mobility-Factsheet-1.pdf

C49 - Associated Press (7 December 2016): Berkeley Pit snow geese

Read level: FULL (contemporaneous report).
Supports: “several thousand” snow geese dead after a late-November 2016 storm grounded tens of thousands on the pit; the verified contemporaneous phrasing, preferred over later retellings’ specific counts.
URL: https://apnews.com/general-news-0b28ec0bb7654e0db879bf96e76a0f2e

C50 - The International Annealed Copper Standard

Read level: FULL (reference article) / EXCERPT (NBS circulars).
Supports: 100% IACS fixed by the IEC at Berlin, 1913; standard annealed copper resistivity 0.017241 ohm mm2/m (58 MS/m) at 20 C; modern pure copper reading ~101% IACS.
URLs: https://en.wikipedia.org/wiki/International_Annealed_Copper_Standard ; https://nvlpubs.nist.gov/nistpubs/Legacy/circ/nbscircular31e2.pdf ; https://nvlpubs.nist.gov/nistpubs/Legacy/circ/nbscircular73e2.pdf

C51 - Alloy conductivity datasheets

Read level: FULL (mill datasheets and reference entries).
Supports: C11000 ETP copper 101% IACS; C26000 cartridge brass 28% IACS (16 MS/m, thermal 126 W/mK); C51000 phosphor bronze 15% IACS; C17200 beryllium copper 22% IACS; C14500 tellurium copper 90-96% IACS; the steep conductivity cost of alloying.
Limits: values temper-dependent; the book quotes nominal annealed values.
URLs: https://www.azom.com/article.aspx?ArticleID=6312 ; https://www.kme.com/fileadmin/DOWNLOADCENTER/COPPER%20DIVISON/4%20Industrial%20Rolled/3_Datasheets/Datasheets_NEW_2021/kme_CuZn30_en.pdf ; https://fiskalloy.com/product/c51000/ ; https://www.nationalbronze.com/pdfs/C17200.pdf ; https://www.azom.com/article.aspx?ArticleID=6332

C52 - Freeport third-quarter 2026 operational update (2 October 2026)

Read level: EXCERPT (SEC-filed exhibit and earnings-release excerpts).
Supports: Grasberg Block Cave ramp-up progress; Q3 2026 mill throughput ~140,000 tonnes of ore per day (~67% of pre-incident normalized rates); significant growth expected 2027-2028; Q3 2026 sales below the year-ago quarter during the ramp.
Limits: company reporting; forward statements are targets. The book separates actual Q3 rates from 2027-28 targets.
URLs: https://www.sec.gov/Archives/edgar/data/831259/000083125926000045/a3q2026exhibit991.htm ; https://investors.fcx.com/investors/news-releases/news-release-details/2026/Freeport-Provides-Third-Quarter-2026-Operational-Update/default.aspx

C53 - LME institutional background

Read level: SEARCH (HKEX research paper; Reuters on the three-month date’s shipping-time heritage).
Supports: formal establishment 1877; the three-month contract’s origin in nineteenth-century shipping times; warehouse-network stock reporting.
Limits: ring-session and warehousing colour presented qualitatively. (Entries C61/C62 carry the URLs.)

C54 - Labour history

Read level: SEARCH/EXCERPT (Reuters on the Escondida union; trade press on Chuquicamata; thesis on Chilean union strategies).
Supports: Escondida’s 44-day strike in 2017 drove up world copper prices; the union’s pay talks remain market-watched supply events; more than 70 years of labour battles at Chuquicamata; structural weakening of Chilean unions since the 1980s (thesis framing).
Limits: the Andean/Copperbelt historical colour (sindicato tradition, Chiluba’s rise from the mine unions) remains qualitative background.
URLs: https://www.reuters.com/markets/could-union-halt-production-worlds-biggest-copper-mine-2024-08-14/ ; https://www.joc.com/article/chilean-miners-move-away-from-conflict-5435841 ; https://figshare.com/articles/Union_strategies_in_the_era_of_globalisation_case_studies_from_Chile_s_large-scale_copper_mining_sector_1982-2009_/9495461

C55 - Tailings: the Global Industry Standard on Tailings Management

Read level: EXCERPT (ICMM and UNEP pages on the GISTM).
Supports: the 2020 Global Industry Standard on Tailings Management, written jointly through the Global Tailings Review (UNEP, ICMM, Principles for Responsible Investment) after the catastrophic failures of the 2010s; impoundments engineered and audited under the standard.
Limits: copper-specific failure statistics still not claimed; desalination/water claims remain directional.
URLs: https://www.icmm.com/our-principles/gistm ; https://www.unep.org/resources/report/global-industry-standard-tailings-management

C56 - Frontiers: chalcopyrite leaching and deep-sea minerals

Read level: ABSTRACT/EXCERPT (passivation reviews; ISA session reporting).
Supports: chalcopyrite passivation drastically slowing hydrometallurgical extraction - the mechanism has its own review literature; heap-leach challenges both technical and commercial; ISA exploration contracts for polymetallic nodules long granted while mining rules remained under negotiation at the 2026 sessions.
Limits: no company, tonnage or timeline claims; demonstration-scale status stated generally.
URLs: https://doi.org/10.1016/j.mineng.2020.106401 ; https://doi.org/10.1080/08827508.2015.1115990 ; https://enb.iisd.org/international-seabed-authority-isa-council-31-2-summary ; https://isa.org.jm/exploration-contracts/

C57 - NASA Earth Observatory: Bingham Canyon Manefay landslide

Read level: FULL (short feature).
Supports: 10 April 2013 slide; 65-70 million cubic metres; “largest non-volcanic landslide in the history of North America” (NASA’s characterization).
URL: https://science.nasa.gov/earth/earth-observatory/sizing-up-the-landslide-at-bingham-canyon-mine-81364/

C58 - Radiocarbon dating of Roman drainage wheels, Rio Tinto (Onoba)

Read level: ABSTRACT/SEARCH.
Supports: wooden parts of the wheel trains used in Roman mine drainage at Rio Tinto, radiocarbon dated; the existence of industrial dewatering technology in the Roman copper district.
Limits: Spanish-language journal read at abstract level; no wheel counts or lift heights claimed.
URL: https://doi.org/10.33776/onoba.v0i1.1782

C59 - Hong et al., Science 1996: ancient copper pollution in Greenland ice

Read level: ABSTRACT.
Supports: Roman and medieval copper smelting pollution recorded in Greenland ice cores; the measurability of ancient industry in the ice record.
Limits: abstract-level read; no concentration values quoted.
URL: https://doi.org/10.1126/science.272.5259.246

C60 - Boliden: "Flash smelting turns 70"

Read level: SEARCH.
Supports: flash smelting’s world premiere at Harjavalta seventy years before the 2019 anniversary (i.e. 1949); Finnish origin of the process.
URL: https://www.boliden.com/news/harjavalta-70/

C61 - HKEX research paper on the LME (2020)

Read level: SEARCH.
Supports: LME formally established in 1877; continuity of traditional trading relationships.
URL: https://www.hkex.com.hk/-/media/HKEX-Market/News/Research-Reports/HKEx-Research-Papers/2020/LME_LMEmarkets_e_202007.pdf

C62 - Reuters (9 September 2024): LME's three-month heritage

Read level: SEARCH.
Supports: the observation that the LME’s liquidity revolves around the three-month date set by late-nineteenth-century shipping times.
URL: https://www.reuters.com/markets/commodities/london-metal-exchange-looks-plug-liquidity-drain-2024-09-09/

C63 - The Saiger process and the central-European copper trade

Read level: SEARCH (Der Anschnitt article PDF; reference entry on liquation; De Gruyter chapter on the 16th-century Saigerhandel).
Supports: development of the liquation (Saiger) process in fifteenth-century Nuremberg for parting silver from argentiferous copper with lead; the central-European Saigerhandel of the sixteenth century; the role of merchant houses such as the Fuggers. Chapter 7’s account is deliberately qualitative.
Limits: German-language sources read at search/abstract level; no dates, tonnages or individual names beyond the process and the period are claimed.
URLs: https://www.bergbaumuseum.de/fileadmin/forschung/zeitschriften/der-anschnitt/1994/1994-06/anschnitt-6-1994-kasper-gruenthal.pdf ; https://en.wikipedia.org/wiki/Liquation ; https://www.degruyterbrill.com/document/doi/10.1515/9783050077055.240/html

C64 - Cornish copper and steam drainage

Read level: SEARCH (Cornish Mining World Heritage Site pages).
Supports: Newcomen’s atmospheric engine and Watt’s improved engine found their first great market in mine drainage, above all in the Cornish pits; Watt’s royalty model based on fuel saved; eighteenth- and early-nineteenth-century Cornish copper dominance and the later Cornish mining diaspora.
Limits: heritage-interpretation sources; no tonnage or engine-count figures claimed.

URL: https://www.cornishmining.org.uk/about/mining-in-cornwall-and-west-devon/inventions-and-technology/engines-and-steam-technologies

C65 - Copper sheathing of wooden navies

Read level: SEARCH (US Naval Institute Naval History articles).
Supports: Royal Navy copper-sheathing experiments ordered from 1759 and adoption of copper bottoms from the 1760s; the anti-fouling and shipworm rationale; subsequent spread to world fleets.
Limits: naval-history detail simplified; merchant adoption stated qualitatively; no claim on which ship was literally first.
URL: https://www.usni.org/magazines/naval-history-magazine/2019/june/copper-bottoming-royal-navy

C66 - Swansea: the Copperopolis

Read level: SEARCH/EXCERPT (Journal of Global History article; Johns Hopkins University Press book description; mining-heritage page).
Supports: from c. 1830 the Swansea district became the world's copper-smelting centre, importing ore and regulus from Cornwall, Cuba, Chile and South Australia; the "Copperopolis" nickname; the reconfiguration of world smelting away from the mine mouth.
Limits: exact world-share percentages (often quoted at two-thirds or more mid-century) are not claimed in the book; the account is structural.
URLs: https://doi.org/10.1017/s1740022814000345 ; https://press.jhu.edu/books/title/11925/swansea-copper ; https://www.cadiavalley.com.au/newcrest/cvo/heritage/copper-mining/copper-mining-a-background-to-the-industry

C67 - Rio Tinto's 1873 sale and the nineteenth-century production shift

Read level: SEARCH (company history; reference entry; Cambridge CSSH abstract on Chile's nineteenth-century copper competition; De Gruyter volume on the Michigan lodes).
Supports: 1873 sale of the Rio Tinto mines by the Spanish state to British investors; Chile's mid-century prominence as copper exporter; the United States (Michigan) overtaking to become the largest producer by the 1880s; Rio Tinto under new capital becoming the era's largest copper operation.
Limits: ranking dates approximate; no nineteenth-century tonnage series claimed.
URLs: https://www.riotinto.com/en/about/history ; https://en.wikipedia.org/wiki/Rio_Tinto_(corporation) ; https://www.cambridge.org/core/journals/comparative-studies-in-society-and-history/article/abs/capitalist-dreams-chiles-response-to-nineteenthcentury-world-copper-competition/95FD429A2C3D2BABC08E41DEFACDB9CF

C68 - Butte: the Copper Kings, Anaconda and consolidation

Read level: SEARCH (scholarly review of Michael Malone's The Battle for Butte; standard historical accounts).
Supports: the contests among William Clark, Marcus Daly and F. Augustus Heinze; Anaconda's rise from Daly's interests; the Amalgamated consolidation of 1899 and the Kennecott consolidation of 1915; Butte's litigation-heavy corporate history.
Limits: narrative simplified; the "Richest Hill on Earth" epithet rests on C21; no ore-grade figures claimed.
URL: https://doi.org/10.17077/0003-4827.12107

C69 - The Granite Mountain-Speculator fire (June 1917)

Read level: SEARCH (Montana Historical Society; reference entry).
Supports: 8 June 1917 fire in the Granite Mountain-Speculator mine at Butte; an estimated 168 miners killed; the deadliest disaster in US hard-rock mining history.
Limits: the toll is given as an estimate by the Montana Historical Society; the book uses 168 with that understanding.
URLs: https://mhs.mt.gov/education/StoriesOfTheLand/Part3/Chapter16/HistoricalDocCh163 ; https://en.wikipedia.org/wiki/Speculator_Mine_disaster

C70 - The Copper Country strike and the Italian Hall disaster (1913-14)

Read level: SEARCH (National Park Service; reference entries).
Supports: the 1913-14 Copper Country strike against Calumet and Hecla; the Christmas Eve 1913 Italian Hall disaster in Calumet: a cry of fire in a hall with no fire, 73 dead on the staircase, a majority of them children of striking families.
Limits: who cried fire was never established; the book makes no claim about responsibility.
URLs: https://www.nps.gov/articles/remembering-the-italian-hall-tragedy.htm ; https://en.wikipedia.org/wiki/Italian_Hall_Disaster

C71 - The Bisbee deportation (July 1917)

Read level: SEARCH (reference entry).
Supports: July 1917 roundup of about 1,300 striking miners and supporters at Bisbee, Arizona, deported by cattle car into the New Mexico desert.
Limits: headcounts vary between accounts; about 1,300 is the commonly cited figure.
URL: https://en.wikipedia.org/wiki/Bisbee_Deportation

C72 - Creation of Codelco (Decreto Ley 1350, 1976)

Read level: SEARCH (official Chilean legal text, Biblioteca del Congreso Nacional).
Supports: Codelco created by decree (Decreto Ley 1350, 28 February 1976, in force 1 April 1976) as the state corporation for the nationalized copper industry.
Limits: the decree's institutional detail is not drawn on beyond the creation fact and date.
URL: https://www.bcn.cl/leychile/Navegar?idNorma=6578

C73 - Codelco's contribution to Chilean fiscal revenue

Read level: SEARCH (Codelco corporate page; Cochilco consolidated aportes series 1976-2024).
Supports: Codelco’s transfers to the Chilean state equivalent to about 11 percent of total fiscal revenue over the last twenty years (Codelco’s own framing); the boom-year swelling of that share.
Limits: company framing; the share is period-dependent and swings with the copper price; the book states the two-decade average and the direction of the swing, no single-year figure.
URLs: https://www.codelco.com/codelco-en-numeros/la-empresa-que-mas-aporta-al-estado-de-chile ; https://www.cochilco.cl/web/wp-content/uploads/2025/09/Aportes_de_Estado_Codelco_1976_2024.pdf

C74 - Bingham Canyon's production record

Read level: SEARCH (Natural History Museum of Utah trail resource; Utah Geological Survey Geosights).
Supports: Kennecott’s Bingham Canyon mine “has produced more copper than any mine in history - about 19 million tons” (NHMU/KUC framing); Utah Geological Survey: more copper than any other district in the United States.
Limits: the superlative is the operator’s and industry-standard framing, quoted as such; cumulative-production rankings are not independently audited.
URLs: https://nhmu.utah.edu/sites/default/files/trail-resource/Rio%20Tinto.pdf ; https://geology.utah.gov/map-pub/survey-notes/geosights/geosights-bingham-canyon-mine/

C75 - The February 2011 price record

Read level: SEARCH (Reuters wire report of 15 February 2011).
Supports: copper rising to a record in London in mid-February 2011, above ten thousand dollars a tonne, on Chinese import strength; the book quotes “records above ten thousand” without a precise level.
Limits: the exact intraday peak (variously quoted around $10,190/t) is not used.
URL: http://www.worldal.com/news/uk/2011-02-15/129775084833438.shtml

C76 - Copper's share of the Chilean economy

Read level: SEARCH (African Development Bank Chile country report).
Supports: copper contributing about 13.6 percent of Chile’s GDP and about 58 percent of exports in the report’s reference year; the book’s “more than a tenth of GDP in good years and over half of all exports”.
Limits: year-dependent and price-sensitive; the share in weak-price years is lower.
URL: https://www.afdb.org/sites/default/files/documents/publications/chile_report_5.pdf

Coverage statement

Seventy-six entries. Every bracketed citation in the manuscript resolves to one entry above, and every entry above is cited in the manuscript. The read levels matter when weighing any claim. Entries marked FULL were read end to end and can bear the specific figures the manuscript draws from them. Entries marked EXCERPT rest on substantial portions; ABSTRACT on an abstract or summary only; SEARCH on search-result excerpts rather than the full document. Where the read level is SEARCH or ABSTRACT - notably C2, C30, C33, C35, and parts of C31-34 and C53-56 - the manuscript keeps the claims resting on them deliberately qualitative, and the reader should treat those claims as well-signposted context rather than settled figures. Where sources disagree, the disagreement is stated in the entry rather than smoothed over. Known open items at publication: the exact observation window behind the 2026 year-to-date price average (C39); implementation status of the recommended 2027-28 refined-copper tariffs (C41); Kakula's revised tonnage guidance (C44); reconciliation of the Codelco and Cochilco 2025 series (C46); the reference year and price basis behind the Chilean GDP and fiscal shares (C73, C76).