Copper Deposits – Summary of Formation Models

Copper deposits form through **distinct geological processes** tied to **tectonic setting, fluid sources, and metal transport mechanisms**. Over 70% of the world's copper are derived from just a few deposit classes.

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1. Porphyry Copper Deposits (≈60–65% of global Cu)

Tectonic Setting

- **Convergent margins** (subduction zones)
- Continental or island arcs

Formation Process (Genetic Model)

1. Subduction introduces **H_2O, S, Cl, metals** into mantle wedge
2. Partial melting generates **hydrous, oxidized magmas**
3. Magma stalls at upper crust (1–5 km depth)
4. **Exsolution of magmatic-hydrothermal fluids**
5. Copper transported as **Cu–Cl complexes**
6. Deposition due to:
    - Cooling
    - Fluid mixing
    - Sulfur saturation
    - Pressure drop

Key Features

- Stockwork veinlets
- Large tonnage, low grade (0.3–1% Cu)
- Zoning, alterations:
  Potassic → Phyllic → Argillic → Propylitic

Typical Minerals

- Chalcopyrite
- Bornite
- Molybdenite (common byproduct)

2. Sediment-Hosted Stratiform Copper (≈20–25%)

Tectonic Setting

- Intracratonic basins
- Rifted continental margins

Formation Process

1. Oxidized basinal brines leach Cu from basement
2. Fluids migrate along permeable red beds
3. Copper precipitates when fluids encounter:
    - Reduced sediments
    - Organic matter
    - Sulfides

Controls

- Redox boundary is critical
- Stratabound geometry

Examples

- Kupferschiefer (Europe)
- Central African Copperbelt (Zambia–DRC)

Minerals

- Chalcocite
- Bornite
- Chalcopyrite

Academic Model

- Redox-controlled basin fluid flow
- Comparable to MVT processes

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3. Volcanogenic Massive Sulfide (VMS) Copper

Tectonic Setting

- Mid-ocean ridges
- Back-arc basins
- Island arcs

Formation Process

1. Seawater penetrates oceanic crust
2. Heated by magma chamber
3. Leaches Cu, Zn, Fe
4. Discharged as black smokers
5. Rapid sulfide precipitation on seafloor

Ore Geometry

- Lens-shaped massive sulfides
- Stringer (feeder) zones below

Minerals

- Chalcopyrite (Cu)
- Sphalerite (Zn)
- Pyrite

Academic Significance

- Modern analogs observed at seafloor vents
- Strong link between volcanism and ore formation

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4. Iron Oxide Copper Gold (IOCG)

Tectonic Setting

- Craton margins
- Extensional or transpressional zones

Formation Debate (Academic)

Still controversial:

- Magmatic-hydrothermal
- Crustal brine-dominated
- Mixed sources

Key Characteristics

- Abundant hematite/magnetite
- Weak association with intrusions
- Enriched in Cu, Au, U, REE

Fluids

- High salinity
- Oxidized
- Often Na-Ca rich

Example

- Olympic Dam (Australia)

5. Skarn Copper Deposits

Tectonic Setting

- Intrusion into carbonate rocks

Formation Process

1. Magmatic fluids interact with limestone/dolomite
2. Metasomatism forms calc-silicate minerals
3. Copper precipitates at reaction fronts

Minerals

- Chalcopyrite
- Magnetite
- Garnet, pyroxene (gangue)

Genetic Link

- Often peripheral to porphyry systems

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6. Magmatic Sulfide Copper (Minor Global Contribution)

Setting

- Mafic–ultramafic intrusions

Process

- Sulfur saturation in magma
- Immiscible sulfide melt scavenges Cu, Ni, PGE

Examples

- Norilsk (Russia)
- Voisey’s Bay (Canada)

Comparative Academic Summary

Deposit Type	Main Cu Source	Transport Mechanism	Trap
Porphyry	Magma	Hydrothermal fluids	Cooling + sulfide saturation
Sed-hosted	Basement	Basinal brines	Redox boundary
VMS	Oceanic crust	Convecting seawater	Seafloor precipitation
IOCG	Mixed	Saline fluids	Structural + chemical
Skarn	Magma	Reactive fluids	Carbonate replacement

Academic References

- Lowell & Guilbert (1970)
- Sillitoe (2010)
- Seedorff et al. (2005)

END of SUMMARY