Multiple igneous-related hydrothermal systems and related IOCG mineralization, near Copiapó, Chile

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Context

• Why study Copiapó region and the American Cordillera?
  – diversity, youth, exposure, context of IOCG systems
  – allows comparison and contrast of various deposit types

• Today: focus on case study of IOCG system diversity near Copiapó, Chile
  – based on extensive field work, petrology, geochemistry, and geochronology
  – time-space evolution of magmatism and tectonism as well as hydrothermal systems

Copiapó area and coastal batholith transect

• Region has:
  – Multiple IOCG systems
    • within & near coastal batholith
    • different deposit types
  – Porphyry-type systems

• Survey district-scale geology and regional transect
  – mention Sr isotope data bearing on material sources

• Key conclusions
  1. Hydrothermal systems formed with all major plutons in batholith
  2. Recognizable, repeated, predictable patterns – based on paths, igneous compositions, water contents
  3. Magmatic-hydrothermal systems are distinct from IOCG systems, though hybridization (overlap) can occur
  4. Significant non-magmatic Sr in all IOCG occurrences

Copiapó area time-space framework

• Relationships projected to NW-SE section

Main geologic units

Supercrustal rocks
**Time-space geologic framework**

**Framework rocks**
- Late Jur to early Cret volcanic rocks
- Cretaceous sedimentary rocks

**Principal geologic units**

**Superficial rocks**
- Marine emergent area
- Shallow or restricted marine back-arc basin
- Shallow marine active volcanic area

**Time-space framework – Magmatism**

- Hbl(-Px) diorites and gabbros
- (Qz-)Bi-Hbl monzodiorites

Age constraints from multiple sources, including Robert Marschik, Carlos Arevalo, and this study (~20 U-Pb)

Age constraints from multiple sources, particularly dates generated by Robert Marschik and Carlos Arevalo
**Time-space framework – Magmatism**

- Tonalite / granodiorite to granodiorite porphyry

**Igneous units**

Same base map in all figures

Age constraints from multiple sources, including Robert Marschik, Carlos Arevalo, and this study (~20 U-Pb)

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**Hydrothermal alteration – Overview**

Based on extensive district-scale field work with a focus on cross-cutting relationships

- Present with each pluton
- Ca, Na(Ca), K, H(Na,K) broad types
- IOCG and porphyry styles readily distinguished
- **Consistent, predictable patterns**

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**Hydrothermal alteration – Predictable**

What would be expected (predicted) about magmatic fluids and their products?

- Many factors, but melt H2O content increases from pyroxene to biotite to hornblende
- Differs with pluton type (cf. crystallization sequence)

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**Alternative flow paths**

- SiO2, wt %, 0.1%, 0.2%, 0.3%, 0.5%, 20%
- Pressure (bars), 0.1, 0.5, 1.0, 2.0
- Temperature (°C), 200, 300, 400, 500, 600, 700

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**Temperature (°C)**

- 1100
- 900
- 700

**Wt. % H2O**

- 0, 2, 4, 6, 8, 10, 12

**Early hornblende ± pyroxene ± biotite, in tonalite-granodiorites**

Naney (1983)
Hydrothermal alteration – Calcic assemblages

- Calcic suites form near or in sed rocks
- calcic alt’ n & (exo)skarn

Aureole & Ca alt’n

Calcite in SKD calcite–skarn

Hydrothermal alteration – Sodic(calcic)

- Strongest nr contacts; style varies w/ pluton

Na(Ca) alteration

Scapolite-Actinolite
Oligoclase-Actinolite

Hydrothermal alteration – Potassic

- Constrasting styles; some clearly high-T

K-silicate alteration

Tur-Qz-Kf
early Bi (foliated)

Hydrothermal alteration – Acid(-K-Na)

- Diverse types, all with Fe; commonly shallow

H(KNa) alteration

Hm-CuOx-Qz-Co
vein in batholith

Hm-Chl after Hbl

Qz-Kf cut by Bi-Qz-Cpy
overprinted by Act-Olig
Key points from mapping
– only field work can deconvolve systems

- Na(Ca) ± IOCG styles developed with all Copiapó batholith phases
  - Na(Ca) and IOCG best developed with largest (diorite)
  - represent many 10s of km³ alteration
- High-T K-silicate alteration distributed predictably in abundance and type
  - occurs only with more felsic plutons
  - some porphyry Cu style
- Implies distinct processes

**Na(Ca) alteration**

- Regional in extent (in >50% of igneous exposures examined)
- Most intense near pluton contacts and along faults

**K-silicate alteration**

- High-T and low-T types
- High-T types localized on felsic (H₂O-rich) plutons
IOCG-type & porphyry-type systems

- **IOCG:** near intrusive contacts and along structures; correlates with well-developed Na-Ca ± distributed K(±Ca)
- **PCD-type:** dlocalized with felsic plutons as disseminated, breccias, veins; correlates with high T K(±H) alteration

Regional patterns analogous to district

- Nearly all plutons have hydrothermal systems
- Intermittent over >100 Ma, most ~135 to 100 Ma
- Clearly defined time-space association of distinctive, well-developed alteration types with different types of mineralization: 1) IOCG – Na-Ca>K>H, 2) PCD – K>H>Na

Many other insights into hydrothermal systems: for example, Sr isotopic results

- Non-magmatic Sr prominent in all IOCG alteration (in contrast to igneous values in PCD type alt’ n)
  - these and petrologic data require involvement of high-salinity external (basinal?) fluids
- In comparison: other isotope data (e.g., Os, Pb, S, O, H, C) have multiple possible interpretations

Summary: Copiapó batholith & transect

- Batholith and host rocks are associated with major IOCG and minor porphyry Cu-style mineralization
  - Multiple distinguishable (mappable) systems
  - Hydrothermal systems form with all plutons (compositions)
  - Recognizable, repeated, predictable patterns in alt’ n
  - Porphyry-Cu type systems distinct from IOCG systems
  - Significant non-magmatic Sr in all IOCG systems (Cu & Fe)

Only through extensive, careful geologic mapping combined with key lab and theoretical studies will we make progress in understanding IOCG systems.