

### Significance of calcium sulphates in the Chuquicamata porphyry copper system, Chile

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Besides being one of the largest accumulations of copper on Earth, the Chuquicamata porphyry copper deposit in the Chilean Andes represents an even larger concentration of sulphur in the form of sulphides and sulphates. At Chuquicamata, gypsum found in the near- surface levels of the mine has been assumed to be the product of supergene oxidation of sulphides. However, ubiquitous hydrothermal anhydrite veins are accompanied by copper sulphide ores in the deeper levels of the system, well below the supergene zone, within both potassic and sericitic alteration. Consequently, it is likely that much of the gypsum in the upper levels represents hydrothermal anhydrite that has been hydrated by meteoric waters. Gypsum and anhydrite may impart different physical and chemical properties to the rocks and ores causing mining and metallurgical problems, thus the definition of the gypsum/anhydrite boundary is of practical importance. Furthermore, the presence of these minerals poses interesting questions regarding the sources and cycles of calcium and sulphate during the evolution of the magmatic-hydrothermal-supergene system.

Gypsum is associated with both supergene and hypogene sulphides, and anhydrite is found mainly with hypogene covellite, digenite, and molybdenite. The progressive

hydration of anhydrite to gypsum is texturally evident in thin section. Electron microprobe analyses show anhydrite to be simple  $\text{CaSO}_4$  with up to 2 weight % strontium. Strontium content shows no obvious correlation with assemblage, depth or location in the deposit. Sulphur isotope data confirm that much of the gypsum in the upper levels is indeed hydrated anhydrite. Isotopic equilibration temperatures calculated from sulphide-sulphate pairs in the quartz-sericitic alteration zone indicate that the vein-anhydrite formed between 330° and 375°C, which is further evidence of a hydrothermal origin for the anhydrite. Anhydrite veining in the early potassic alteration (older than 34 Ma) could have derived its calcium from the destruction of magmatic plagioclase, titanite and amphibole, but the relatively greater abundance of anhydrite veins in the later (ca. 31 Ma) quartz-sericitic assemblages makes it difficult to derive so much calcium from already calcium-depleted rocks in the potassic-altered zone. Calcite is rare in the Chuquicamata orebody, and strontium isotopes of the anhydrite-bearing ores are not compatible with a source of strontium in Mesozoic calcareous country rocks; hence, a source in a younger (ca. 31 Ma), still-unrecognised mineralising intrusion at depth can be hypothesised.