

Porphyry copper: Grade and tonnage models revisited

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Grade and tonnage models are frequency distributions of tonnages and average grades of well-explored deposits of a given type that are used as analogs for undiscovered deposits in resource assessments and as tools to distinguish among deposit types. Compilations of porphyry copper grades and tonnages have been done since the 1980s (Cox and Singer, 1986; Singer et al., 2002, 2005, and 2008 (<https://pubs.usgs.gov/of/2008/1155/>)). An update of the 2008 dataset resulted in a compilation of 488 Phanerozoic deposits and 24 Precambrian deposits. The updated compilation preserves the spatial rules and criteria for defining Cu-Au, Cu-Mo, and Cu subtypes used previously, with the addition of a designation of apparent tectonic setting for each Phanerozoic deposit (island arc, continental margin, postconvergent, or mixed). Analysis of the updated database shows that:

- Most of the new deposits reporting resources since the 2008 compilation are in Chile, Peru, and Argentina.
- Tonnage and grade distributions are similar to the previous compilation. Median ore tonnage increased to 250 million metric tons (Mt) from 240 Mt in 2008, median copper grade decreased slightly to 0.39% Cu from 0.44 % Cu. Only 61% of the deposits have reported Au grades; 56% have Mo grades, and 40% have Ag grades.
- The large numbers of deposits included in the 2008 database and the slight changes based on updates and additions over a 9-year period indicate that the models are relatively robust over time and should continue to be useful as analogs for resources in undiscovered porphyry copper deposits. Average grade of contained resources (total ore tonnage/total contained copper) decreased from 0.525% Cu in 2008 to 0.482% Cu in the 2017 update.
- Precambrian deposits, many of which are polymetallic and may represent superimposed or misclassified deposit types, tend to be smaller (70 Mt median ore tonnage) and have lower median Cu grades (0.22% Cu) than Phanerozoic deposits.
- Statistical analysis of the Phanerozoic data (log-transformed) using one-away analysis of all pairs shows that the tectonic classes are not discriminated by Cu grade characteristics, but are discriminated by tonnage, Mo, Au, and Ag grades at the 99% confidence level using a Tukey-Kramer honestly significant difference (HSD) test.
- Deposits in postconvergent settings (e.g., Gangdese belt, Tibet) have the highest mean Au, Mo, and Ag grade values.
- Analysis of a smaller subset (N=113) of deposits with no missing grade values shows the same correlation with tectonic setting.
- A third of the postconvergent deposits occur in China. About a third of all recognized postconvergent deposits are world-class deposits (>2 Mt contained Cu), including the supergiant deposits (>20 Mt contained Cu) at Grasberg in Indonesia, Bingham in the United States, and Almalyk in Uzbekistan.
- The postconvergent setting may be an attractive exploration target for deposits that are enriched in Au and Mo as well as Ag.