1 Introduction

The completion of the USGS’s Global Mineral Resource Assessment for porphyry copper deposits (Hammarstrom and others, 2013; Johnson and others, 2014) provides a new worldwide database of porphyry copper deposits and prospects that allows examination of how the resource characteristics of porphyry-style deposits vary by tectonic setting and other spatial and temporal characteristics.

The new database is distinctly larger than the one published by Singer and others (2008), which contained 422 deposits. The new database contains 452 deposits (and excludes Precambrian deposits). Most of the newly compiled deposits are in Australia, Turkey, Iran, and China. These new data allow us to explore how some of the traditional classifications of porphyry-style deposits present taxonomic challenges.

2 Metals Present in the Deposits

The most important secondary metals in porphyry copper deposits are molybdenum, gold, and silver. Although gold- and molybdenum-rich deposits have been long recognized as important subclasses (Cox and Singer, 1992; Singer and others, 2008), the new compilation allows the analysis of deposit metallogeny of the deposits as a function of their tectonic setting (Ludington and others, 2013). We classified the settings of the magmatic arcs that contain the deposits as continental-margin arc (56% of the deposits), island arc (22%), or postconvergent arc (15%).

We used analysis of variance, Student’s t-test, and discriminant analysis to evaluate the proposition that these tectonic divisions result in distinct metal contents.

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Tonnages and copper grades are not significantly different between any of the three tectonic groups. With respect to molybdenum, all three types (continental-margin arc, island arc, and postconvergent environments) are distinct from each other, although there is considerable overlap (Fig. 1). The postconvergent deposits have the highest average Mo grade, followed by the continental-margin and island arc groups. With respect to gold, deposits of the postconvergent and island arc tectonic groups have significantly higher gold grades than the continental-margin group. Again, the postconvergent group has the highest grades, but the postconvergent and island arc groups cannot be distinguished from each other.

The higher molybdenum contents probably reflect interaction with continental crust and our data are consistent with that speculation. The relatively large contrast between gold grades in deposits from postconvergent (primarily in thick continental crust) vs.
continental-margin environments is more difficult to understand.

Cox and Singer (1992) developed an empirical way to classify gold- and molybdenum-rich porphyry copper deposits. They used the Au:Mo ratio as a discriminant. The use of this ratio for classification leads to the curious situation where deposits with very low abundances of gold or molybdenum are termed, for example, “gold-rich” really on the basis of their low molybdenum contents. A somewhat more useful, although still not satisfactory, method is to use decile measurements independently. The 90 deposits (~20%) in the database that contain more than 0.019% Mo can be termed Mo-rich and the 90 deposits that contain more than 0.31 g/t Au can be termed Au-rich. There are 10 deposits that are both Mo- and Au-rich. Three of them are in Armenia, 3 in China, 2 in the United States, and 2 in the Andes of South America. At least 6 of those 11 formed in a postconvergent environment.

3 Value of Metals in the Deposits

There are many factors, in addition to gross value of contained metal, that affect the economic viability of mineral deposits. However, we evaluated the relative importance of the secondary metals in porphyry copper deposits by calculating gross values for the deposits in the database using representative prices during the last 12 to 18 months. Those prices are: Cu, $7,000/t; Mo, $22,000/t; Au, $47/g; and Ag, $0.75/g. The percentage contribution to the total value for each metal was then calculated by dividing by the total value.

For 9 of the deposits (about 2%), Mo contributes more than 50% of the value and it is the most valuable metal in 10 of the deposits. For 27 of the deposits (about 6%), Au contributes more than 50% of the value and it is the most valuable metal in 29 of the deposits. For 17 of the deposits (about 4%), Ag contributes more than 10% of the value. In fact, for 12 of the deposits, Cu makes up less than a third of the total value. If molybdenum or gold is the most valuable mineral in a deposit, should it be called a porphyry copper deposit?

4 Porphyry Molybdenum Deposits

The presence of a class of molybdenum deposits that resemble porphyry copper deposits and are characteristically found in continental-margin arcs was recognized long ago (Mutschler and others, 1981; Westra and Keith, 1981; White and others, 1981). These are distinct from Climax- or high-fluorine-type deposits that will not be considered here. Similarly, we will not discuss whether the porphyry molybdenum deposits in the Qinling belt of China (Mao, 2012) are Climax-type or not.

During the compilation of the new porphyry copper database, we noticed that some of the deposits called porphyry copper deposits had higher molybdenum grades than some of the deposits traditionally called porphyry molybdenum deposits. When the original low-fluorine grade and tonnage model (Menzie and Theodore, 1992) was compiled, copper grades were not included. In researching these 33 deposits, we found that several of them had higher Cu grades than Mo, and 7 of them are now included in our compilation of porphyry copper deposits (4 from the U.S. and 1 each from Canada, Mexico, and Australia). Most of the low-fluorine molybdenum porphyry deposits however, have no copper data.

A similar situation characterizes the many newly discovered porphyry molybdenum deposits of eastern Asia. Zeng and others (2013) have recently compiled a database of molybdenum deposits that includes 34 molybdenum-rich porphyry deposits, most of them discovered since 2000. None of them (except Jinduicheng) have reported copper grades, yet 14 of the 33 are described to have chalcopyrite as a “major ore mineral.”

5 Data Quality

The differences between some of these types of deposits are quite subtle, which suggests that issues of data quality are quite important.

Leaving aside the issue of different reporting standards for mineral resources in different countries, the fact that so much data is missing limits research on the taxonomy of porphyry deposits. Only about 25% of the deposits in our database have grade numbers for all 4 metals and 20% have data only for copper. Whereas about 56% of the deposits have a molybdenum grade and 60% have a gold grade, nearly two-thirds (64%) lack one or the other and thus cannot be classified by any of the numerical means used in the past.

Similarly, the prevalence of missing copper data in the porphyry molybdenum deposits means that the question of whether there is a logical or natural boundary between porphyry molybdenum and porphyry copper deposits cannot be answered with any certainty using grade characteristics.

6 Conclusions

The tectonic environment of emplacement, long thought to affect porphyry deposit genesis, is associated with significant differences in gold and molybdenum contents. A substantial proportion (more than 10%) of porphyry
copper deposits are more valuable for their gold or molybdenum than for their copper. Largely because of missing data, it is not possible to properly define a boundary between porphyry molybdenum and porphyry copper deposits.

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