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Relationship between Porphyry Copper Occurrences, Crustal Preservation Levels, and Amount of Exploration in Magmatic Belts of the Central Tethys Region

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1 Introduction

A probabilistic assessment of undiscovered resources in porphyry copper deposits in the Central Tethys region of Turkey, the Caucasus, Iran, western Pakistan, and southern Afghanistan was conducted as part of a U.S.G.S. global mineral resource assessment. The purpose was to delineate areas as permissive tracts for the occurrence of porphyry Cu-Mo and Cu-Au deposits, and to provide estimates of amounts of Cu, Mo, and Au likely to be contained in undiscovered porphyry deposits (Zürcher et al., 2013; Zürcher et al., in review).

Tectonic, geologic, geochemical, geochronologic, and ore deposits data compiled and analyzed for this assessment show that magmatism in the region can be rationalized in terms of fundamental plate tectonic principles, including mantle-involved post-subduction processes. However, uplift, erosion, subsidence, and burial of porphyry copper deposits also played an important role in shaping the observed metallogenic patterns.

2 Porphyry Occurrences, Crustal Preservation, and Exploration

Results from this study show that there is a general correlation between the number of known porphyry occurrences (the sum of prospects and deposits), the level of crustal preservation (relative permissive volcanic-to-plutonic unit ratios) and exposure (the areal extent of younger cover rocks), and the amount of exploration that has taken place in each tract.

A database of known porphyry occurrences compiled for this study served two purposes: (1) deposits were used to compare geologic characteristics and resources in tracts of the study area with porphyry deposit descriptive and grade and tonnage models; and (2) prospects were used to assist in the delimitation of tracts and the assessment of geologic favorability and uncertainty. Porphyry prospects may just be small manifestations of the same processes that generate porphyry deposits. However, they are important samples because they provide information on the location, igneous composition, metal association, and level of exhumation of a mineralized system.

Derivative maps created to group geologic units of similar age and lithological character were used to evaluate levels of preservation and extent of cover in each porphyry tract. To estimate the level of crustal preservation, the relative areal extent of: (1) older basement (igneous, sedimentary, and metamorphic) units; (2) intermediate to felsic plutonic and volcanic units permissive for porphyry-style mineralization of a given age range; (3) non-permissive (mafic or ultramafic igneous, and sedimentary) units; and (4) younger (igneous, sedimentary, and metamorphic) cover units were calculated for each tract. Permissive volcanic-to-plutonic unit ratios were also determined (VP={volcanic/ [volcanic+plutonic]}*100). These data were then used to assess whether levels of preservation across a tract were appropriate for formation of porphyry systems (VP≈33-66), too deep (VP<33), or too shallow (VP>66). These data also allowed estimation of the areal extent of younger cover rocks and the likelihood for porphyry systems to be buried or exposed. Estimation of levels of preservation and exposure in each porphyry tract show that the number of porphyry occurrences is highest where the permissive volcanic-to-plutonic unit ratios (VP) are between 33 and 66, and where the extent of cover by younger rocks is relatively reduced.

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Available information on the history, environment, and amount of exploration activity was collected to assess where, how large, and how rich undiscovered mineral resources may be in a permissive tract. The level of exploration that an area has experienced is not only guided by the favorability of the ore-forming environment and economic factors, but also by appropriate preservation and exposure of mineralized systems. Exploration typically occurs first and, if successful, is longer-lived where more mineralized systems can be identified, and thus more prospects can be generated and evaluated. Consequently, the number of known porphyry occurrences within a permissive tract is not only a reflection of the endowment and preservation and exposure levels, but also partly the result of the amount of exploration that has taken place.

3 Results

Figure 1 illustrates these relations across the 26 porphyry copper tracts identified in the Central Tethys Region (horizontal axis). The proportion of tract area of older metamorphic basement rocks (dark blue), coeval permissive plutonic and volcanic units (red and green), younger metamorphic rocks (light blue), and cover (yellow) is quantified along the left vertical axis. Not shown on the figure are the proportions of older non-metamorphic basement, and non-permissive sedimentary, mafic, or ultramafic igneous rocks. The proportions of permissive igneous units from tract to tract are also expressed as volcanic-to-plutonic ratios (gray line). The number of known porphyry copper deposits (black) and prospects (gray) is displayed by the stacked bars. Numbers or porphyry occurrences are given along the right vertical axis.

The central part of figure 1 shows that tracts with the highest number of known porphyry copper occurrences are also tracts that are underlain by sub-equal areas of coeval permissive volcanic and plutonic units, and lesser cover rocks. This reflects levels of preservation that are appropriate for porphyry emplacement (the coeval volcanic/plutonic interface where hypabyssal intrusions commonly occur) and exposure (where larger fractions of permissive units relative to younger cover occur). Compared to tracts elsewhere in the assessment region, these tracts are relatively well-explored.

The left part of figure 1 includes tracts where fewer porphyry occurrences are known. In these tracts, the proportion of permissive volcanic-to-plutonic units is high, as is the fraction of younger cover. This reflects shallow levels of preservation (where volcanic rocks are more common than coeval plutonic rocks) and inadequate exposure of porphyry systems (where smaller fractions of permissive units relative to younger cover rocks occur).

The right part of figure 1 also consists of tracts where fewer porphyry occurrences are known. Here, the proportion of permissive volcanic-to-plutonic units is generally low, and the fraction of younger cover is high. This reflects deep levels of preservation (where volcanic units are less common than coeval plutonic units) and inadequate exposure of porphyry systems (where smaller fractions of permissive unit relative to younger cover rocks occur). Deep levels of preservation are also indicated by the high proportions of metamorphic rocks in these more exhumed tracts. Metamorphic units are not only associated with older events but also with younger deformation and uplift events that occurred during or after the volcano-plutonic event delimited by a permissive tract.

4 Conclusions

Estimation of undiscovered porphyry copper deposits and associated uncertainties not only relied on available information on the intrinsic geologic environment of porphyry formation, but the inter-relationship between the geologic endowment, the levels of preservation and exposure, the numbers of porphyry occurrences, and the amount of exploration that has taken place.

The assessment team recognized that the correlation between the level of preservation and exposure and the number of porphyry occurrences contained within a tract can be measured if the age range of a tectono-magmatic episode can be adequately constrained. At the regional scales analyzed in this study, the correlation is remarkable because uplift, erosion, subsidence, and burial commonly happen at time and space scales that are an order of magnitude smaller than those of tectono-magmatic events. Furthermore, present-day preservation and exposure levels are the sum product of several partially juxtaposed exhumation and burial events.

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