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# Increased Magmatic Water Content—the Key to Porphyry Cu-Mo ± Au Formation in the Gangdese Belt, Tibet

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The Gangdese magmatic belt in Tibet preserves a series of Cenozoic collision-related igneous rocks that have formed since the start of the Indo-Asian collision at ~55–50 Ma (Yin and Harrison, 2000; de Sigoyer et al., 2000). Oligocene and Miocene magmatic rocks crop out as smallvolume intrusions in the eastern Gangdese belt (to the east of 89°E; Fig. 1), and are associated with several large porphyry ± skarn deposits (Hou et al., 2009). In contrast, few deposits are associated with earlier, more voluminous Eocene magmatism. One explanation for the lack of significant porphyry deposits in Eocene rocks might be that they have been eroded away. However, Paleocene–Eocene volcanic rocks (the Linzizong volcanic sequence) are well preserved in many parts of Tibet (Fig. 1), so subvolcanic porphyry systems should also have been preserved if originally present.

Data compiled from the literature and our own analyses indicate that Eocene magmatic rocks have calc-alkaline continental arc-like compositions with medium to high-K contents, intermediate [La/Yb]N ratios (1.15 to 34.3, average = 9.9 ± 8.1, n = 50), intermediate-to-low Sr/Y ratios (mostly <40), and negative Eu anomalies (0.24 to 1.33, average $Eu_n/Eu^*$ = 0.79 ± 0.24, n = 50). They show decreasing Sr concentrations and increasingly negative Eu anomalies with increasing $SiO_2$, while Y content increases steadily until ~66 wt.% $SiO_2$, then decreases. These granitoids are mainly composed of pyroxene, plagioclase, and quartz, with minor interstitial amphibole and biotite. These data are consistent with early fractionation mainly of pyroxene and plagioclase, with hornblende fractionation only occurring in more evolved (≥66 wt.% $SiO_2$) magmas (as reflected by Y and REE behavior; Green and Pearson, 1985; Rollinson, 1993). In contrast, the Oligo-Miocene granitoids are mostly medium- to high-K calc-alkaline in composition. They have high [La/Yb]N ratios (11.6 to 93.2, average = 31.9 ± 12.3, n = 130), high Sr/Y ratios (>40), Y contents that decrease with $SiO_2$, and listricshaped (MREE-depleted) rare earth element patterns. Their mineralogy consists of plagioclase, quartz, and amphibole. They start from much higher Sr contents and lower Y contents than the Eocene rocks (at equivalent $SiO_2$ concentrations), suggesting early hornblende fractionation and delayed plagioclase fractionation from hydrous magmas.

The Paleocene–Eocene plutons and Linzizong volcanic successions are interpreted to be the final products of Andean-type Neo-Tethyan continental subduction (Mo et al., 2007). The lower water contents of the Eocene magmas inferred from their mineralogy and geochemistry might reflect the final dehydration of the remnant Neo-Tethyan slab. Late-collisional medium- to high-K calc-alkaline Oligo-Miocene magmas were emplaced through collisionally thickened crust along N–S normal faults (Williams et al., 2001; Mitsuishi et al., 2012), and intrude or crosscut the older Gangdese intrusive rocks and volcanic successions. Following Richards (2009) and Hou et al. (2011), we propose that hydrous calc-alkaline to mildly alkaline magmas with the potential to form porphyry Cu-Mo±Au deposits were generated during late collisional processes in the India–Asia orogen by partial melting of previously subduction-fertilized and thickened lithosphere. We suggest that slab break-off triggered asthenosphere upwelling and underplating, which led first in the Oligocene to occurrence of small volumes of asthenosphere-derived mafic enclaves (Zheng et al., 2012), and later on the Oligo-Miocene to partial melting of subduction modified Tibetan lithosphere to generate hydrous and fertile melts. The high water contents and oxidation states of these remobilized arc magmas would have made them ideal transportation agents for chalcophile and siderophile elements, as for normal arc magmas (Candela and Holland, 1984; Hamlyn et al., 1985; Richards, 2009). The Oligo-Miocene Gangdese porphyry deposits are similar in many respects to those in arc

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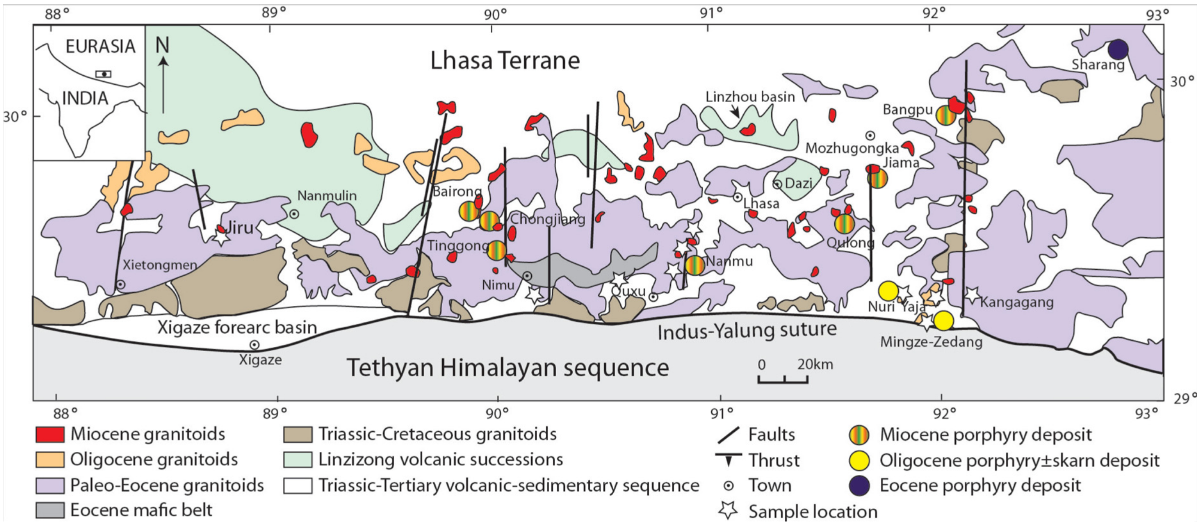


Fig. 1. The eastern Gangdese magmatic and metallogenic belt on the southern margin of the Lhasa terrane (modified from Hou et al., 2004; Dong et al., 2006; Gao et al., 2008)

settings (i.e., mineralization style, alteration zoning, and metal association; Hou et al., 2009). Thus, it is concluded that postsubduction porphyry deposits can be generated in collisional orogenic belts tens of millions of years after subduction has ceased, by remobilization of fluids and metals previously introduced into the lithosphere by prior subduction events.

**Key words**: magmatic water, porphyry deposit, Miocene, Oligocene, Eocene, Gangdese, Tibet, Hornblende

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