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Chapter 11

Generation of Postcollisional Porphyry Copper Deposits in Southern Tibet Triggered by Subduction of the Indian Continental Plate*

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Abstract

Oligocene to Miocene postcollisional porphyry Cu deposits in the Gangdese belt in southern Tibet contain total resources of >20 million metric tons (Mt) Cu and are genetically associated with granodioritic-quartz monzogranitic porphyry intrusions with adakite-like signatures (e.g., Sr/Y >40). The adakite-like magmatic rocks in the southern sub-belt of the eastern Gangdese belt (east of 87° E) range in age from ca. 38 to 18 Ma, whereas those in the northern sub-belt range in age from ca. 21 to 10 Ma. Mineralization ages of the porphyry Cu deposits in the eastern Gangdese belt also show a decreasing trend from south to north, with the deposits in the southern sub-belt being ca. 30 Ma and the deposits in the northern sub-belt, 21 to 13 Ma. Many more of the adakite-like intrusions in the northern part are associated with porphyry copper deposits, compared with those in the southern part. The adakite-like intrusions exhibit high SiO_2 (>60 wt %), Al_2O_3 (mostly >15 wt %), K_2O (>2 wt %), and Sr (>300 ppm); low Y (<15 ppm); enrichment in large ion lithophile elements (LILE); and depletion in high field strength elements (HFSE). These data are consistent with partial melting of a subduction-modified lower crust. However, the extremely variable Sr-Nd isotope compositions (initial $^{87}Sr/^{86}Sr$ = 0.7037–0.7120; $\varepsilon_{Nd(t)}$ = +5.7 to –10.6) of the intrusions require incorporation of lower crust with an end member having extremely enriched Sr-Nd isotope compositions, and the anhydrous character of the eclogitized lower crust in turn requires melting via addition of exogenous H_2O and/or heat. These features, together with the northward younging of adakite-like magmatism and associated porphyry Cu mineralization in the eastern Gangdese belt, indicate that the intrusions and mineralization could have been caused by H_2O-added melting of the lower crust. Such melting would have been triggered by the late Eocene to Miocene northward relatively hot (~15°C/km geotherm) subduction of the Indian continental plate. Under hot subduction conditions, the main hydrous minerals (e.g., phengite, epidote, chlorite, biotite) in the upper crust of the Indian continental plate would have lost most of their mineralogically bound water before reaching a depth of 100 km. This devolatilization would have resulted in progressive fluid-fluxed melting of the metasomatized wedge of subcontinental lithospheric mantle and part of the lower crust; the former produced ultrapotassic-like and/or alkaline mafic magmas. Underplating of such mafic magma, rising from their source area (>80 km) into the lower part (~60–70 km) of the lower crust, together with direct input of fluid liberated from the subducting Indian continental plate, resulted in H_2O-added melting of the Tibetan lower crust, generating H_2O-rich adakite-like magmas in the eastern Gangdese belt.

The adakite-like rocks in the western Gangdese have very similar geochemical compositions to those in the eastern Gangdese, and their generation can also be explained by the melting of subduction-modified mafic lower crust with input of ultrapotassic melt. However, in contrast, colder (5°–8°C/km geotherm) subduction of the Indian continental plate and the opposite younging trend from north to south for the postcollisional adakite-like and ultrapotassic rocks in the western Gangdese belt suggests that the generation of the adakite-like rocks in the west was triggered by a different geodynamic process, which is most likely roll-back and gradual break-off of the northward subducting Indian slab from north to south.

We suggest that H_2O in the postcollisional ore-related magmas originated from dehydration reactions in the upper parts of the subducting continental plate. Thermal structure of the continental subduction zone and the amount of continental crust subducted to depth seem to be two critical controls on the generation of porphyry Cu deposits in the Tibetan postcollisional setting.

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