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Research Advances

Hydrothermal Zircon from a Newly Found Porphyritic Granite in the Dongping Gold Deposit in Northern Hebei, China: Evidence from Petrography and Hf Isotope Composition

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Objective

Hydrothermal zircon is altered by hydrothermal fluids and sometimes shows "hydrothermal mineral" characteristics. Studying hydrothermal zircon in gold deposits can help understand the origins of the gold mineralization. The Hf isotope composition of zircon can be used to determine the properties of the original rock. However, most zircon Hf isotope studies focus on magmatic zircon; only a few involve hydrothermal zircon. The widespread Dongping gold deposit, located in Chongli County of the Hebei Province, occurs in the Shuiquangou alkaline complex. A porphyritic granite body which extends along the northwest-trending shear zone within the Shuiquangou complex was recently discovered in the Zhuanzhilian area of the Dongping deposit. The porphyritic granite body underwent silicification or potassic alteration and the associated gold reserves are estimated at more than a ton. A number of hydrothermal zircon examples were identified under CL (Fig. 1). The zircon was generally dark black with irregular silkworm shape. Some zircon was sheared or broken into sub-grains with residual, oscillating magmatic rings.

Based on zircon U-Pb dating in porphyritic granite, 142.02±1.2 Ma is believed to be the age of the hydrothermal fluid alteration and gold mineralization, while residual zircon of the Shuiquangou alkaline complex dates to 373±3.5 Ma. Hf isotopes of hydrothermal zircon were analyzed to further understand the origin and evolution of porphyritic granite and its relationship with gold mineralization.

Methods

The Hf isotope test was performed on zircon particles of established ages in porphyritic granite. The test was performed using a Thermo Fisher Neptune multi-receiving inductively coupled plasma mass spectrometer and laser ablation system with ablation diameter of 55 μm and 20 Hz pulse repetition frequency.

Results

The porphyritic granite zircon ages are divided into three groups: 146.6–153.7 Ma, 245.3–350.6 Ma, and 372.8–387.6 Ma. The zircon $^{176}Hf/^{177}Hf$ ratios of those three groups are 0.281947–0.282022, 0.281936–0.282129, and 0.281968–0.282028, respectively. The variation ranges of $\varepsilon_{Hf}(t)$ are −23.6 to −26.1, −20.8 to −22.8, and −18.1 to −21.3. The average values of $\varepsilon_{Hf}(t)$ are −24.2, −21.6, and −19.7, with a $\varepsilon_{Hf}(t)$ change of three units in every group. The average values of the first-stage Hf mode (TDM1) ages are 1.768 Ga, 1.770 Ga, and 1.772 Ga, respectively, and the average values of the second-stage Hf mode (TDM2) ages are 2.728 Ga, 2.690 Ga, and 2.617 Ga.

Wei et al. (2018) believes that the zircon in porphyritic granite was later metamorphosed by hydrothermal fluid and the alteration and gold mineralization occurred 146.6-153.7 Ma. These grains of zircon were completely altered to hydrothermal zircon. Residual magmatic zircon of the Shuiquangou alkaline complex dates to 372.8–387.6 Ma. Partially-transformed zircon dates to 245.3–350.6 Ma and retains characteristics of the source magmatic zircon. The zircon Lu-Hf isotope system is less susceptible to fluid and thermal events than the U-Pb isotope system. Zircon Hf isotopes are often used to study properties and transformations of metamorphic rocks. The zircon Hf contents of the three groups are 5962–9221, 6055–9129, and 6356–8787, respectively. If $\varepsilon_{Hf}(t)$ is calculated using the same age, the values of the three zircon groups are approximately equal. The U-Pb isotope system of this zircon was affected by later fluid interaction, however the

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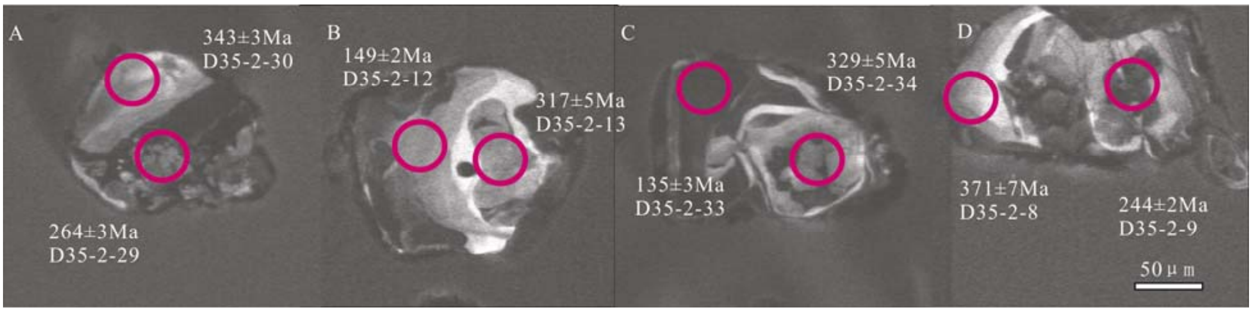

Fig. 1. The CL images of hydrothermal zircon in porphyritic granite.

Lu-Hf isotopes have not changed significantly. They can represent the zircon Lu-Hf isotope system of the original porphyritic granite alkaline complex .

Zircon of different ages is distributed along the crust evolution line in Fig. 2. Negative $\varepsilon_{\mathrm{Hf}}(t)$ values indicate that the porphyritic granite is the product of reworked ancient crust source material. TDM2 is distributed from 2.519–2.722 Ga with a average value of 2.622 Ga, similar to the zircon U-Pb age of the Archean metamorphic rocks in Zhangjiakou, Chicheng, Fengning, Chengde, and Miyun (2.5–2.6 Ga), indicating that Archean metamorphic basement participated in the diagenesis process. The Archean metamorphic rock xenoliths and inherited zircon found in the alkaline complex reinforce the possibility of Archean continental crust material influencing the magma source of the porphyritic granite. The higher gold content in the alkaline complex may be derived from the Archean continental crust.

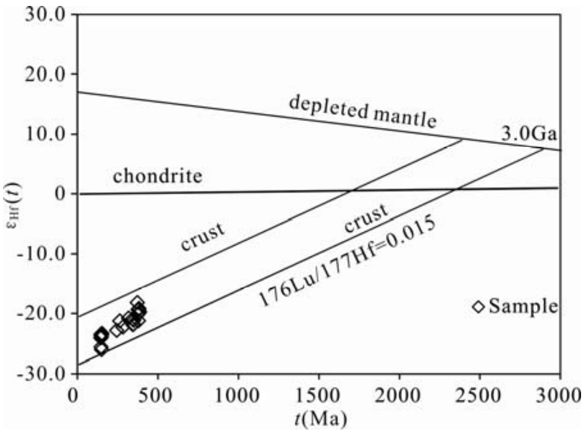

Fig. 2. Zircon $\varepsilon_{\mathrm{Hf}}(t)$ - age relationship of porphyritic granite.

The age of moyite in the Mazhangzi mineralization area is 138.24±0.82 Ma, which is close to the age of Shangshuiquan moyite (135.5±0.4 Ma). These ages are close to the time of hydrothermal fluid alteration and gold mineralization in the porphyritic granite. Moreover, the age and alteration characteristics of altered zircon show that the porphyritic granite was later altered by fluids 142.02±1.2 Ma. Therefore, we cannot disprove that hydrothermal fluids extracted ore-forming materials from the alkaline complex and deposited gold under suitable conditions during the Late Jurassic to Early Cretaceous. In summary, gold mineralization in porphyritic granite may have involved the ore-forming materials of old Archean continental crust.

Conclusions

Zircon examples are distributed along the crust evolution line with $\varepsilon_{\mathrm{Hf}}(t)$ values of −18.2 to −26.1 and TDM2 of 2.519–2.722 Ga. The zircon Lu-Hf isotope data, combined with zircon micro-petrography and U-Pb ages, indicate that the porphyritic granite was formed by late alteration and metasomatism in the Shuiquangou alkaline complex, which involved the ore-forming materials of old Archean continental crust. During the Late Jurassic to Early Cretaceous, the porphyritic granite was altered by later hydrothermal fluids and gold mineralization.

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