Short Articles

Zinc-bearing actinolite
from the Kakkonda geothermal system,
Iwate Prefecture, northeastern Japan

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Abstract: Zinc-bearing actinolite was found in a hydrothermal vein of a drill core retrieved at 1,223 m in depth of the deep research well, WD-1, which had been drilled in the Kakkonda geothermal area, northeastern Japan. Zinc-bearing actinolite is fibrous and occurs with sphalerite, chalcopyrite, pyrite, quartz, anhydrite, epidote and clay minerals in the vein. The ZnO content of actinolite ranges in 0.4-1.5 wt.%, relatively high compared with zinc-bearing calcic amphiboles in previous reports. The actinolite was possibly formed from zinc-rich hydrothermal fluid at early stage of geothermal activity in Kakkonda.

1. Introduction

The Kakkonda geothermal system in northeastern Japan is one of the active geothermal systems in Japan, and two geothermal power plants are in operation there (Kanazawa \textit{et al.}, 1996). The New Energy and Industrial Technology Development Organization (NEDO) drilled a deep geothermal research well (WD-1), in order to confirm and promote utilization of deep geothermal resources within the “Deep-Seated Geothermal Resources Survey” (Sasada \textit{et al.}, 1998). The well WD-1 was drilled through hydrothermally altered rocks and hornfelses, and encountered a Quaternary granitic rock (Kakkonda Granite: Kanisawa \textit{et al.}, 1994) at 2,860 m in depth. In 1995, a temperature exceeding 500°C was measured at the bottom of WD-1 (Muraoka \textit{et al.}, 1998; Ikekichi \textit{et al.}, 1998).

Some drill cores were recovered from WD-1, including the altered rocks, hornfelses and granitic rocks (Uchida \textit{et al.}, 1996). The authors found zinc-bearing actinolite in a hydrothermal vein of the core sample recovered from 1,220.8-1,223.5 m in depth of WD-1, and describe their petrography. The amphibole nomenclature conforms to that of Leake (1978).

Amphiboles of high zinc contents uncommonly occur. From the Franklin skarn, New Jersey, U.S.A.


2. Geological setting

The geology of the Kakkonda area has been studied for geothermal exploitation (e.g. Doi \textit{et al.}, 1998; Muraoka \textit{et al.}, 1998). Figure 1 shows a cross section of the Kakkonda geothermal system (Doi \textit{et al.}, 1998).

Keywords: Kakkonda geothermal system, zinc-bearing actinolite
The Kakkonda geothermal area is covered with volcanic and sedimentary rocks of Neogene (the Obonai, Kunimitoge, Takinoue-onsen and Yamatsuda formations) and Quaternary, and they are underlain by sedimentary rocks of pre-Tertiary. The geothermal reservoir of the Kakkonda geothermal system is divided into shallow and deep reservoirs, and their boundary is at about 1,500 m in depth, based on steep change of formation temperatures and permeability (Doi et al., 1988, 1998). The sedimentary rocks of pre-Tertiary and a part of the volcanic and sedimentary rocks of Neogene are thermally metamorphosed by the Kakkonda Granite of Quaternary (Kanisawa et al., 1994; Muraoka et al., 1998; Doi et al., 1998). The studied sample was from the shallow reservoir.

3. Petrography of the sample

The core sample at 1,220.8–1,223.5 m in depth of WD-1 is andesitic tuff with pyroclastic textures of the middle Kunimitoge formation, and is cut by a number of hydrothermal mineral veins (NEDO, 1995). Zinc-bearing actinolite occurs in a hydrothermal vein over 10 cm wide with 70° dip at 1,223.0–1,223.5 m deep. The core is remarkably altered around the vein. The vein consists of chalcopyrite, pyrite, sphalerite, quartz, anhydrite, epidote, actinolite and clay minerals (NEDO, 1995), accompanied by fractured and altered rock fragments. The vein is subdivided into two parts under the microscope: one is composed of coarse sphalerite, chalcopyrite, pyrite and quartz with small amounts of anhydrite and epidote, and the other is of coarse sphalerite, chalcopyrite and pyrite which are embedded in matrix of fine actinolite and epidote. The later part may be extremely altered host andesitic tuff.

Actinolite occurs as fibrous crystals less than 0.3 mm in length. Around coarse sphalerite, fibrous actinolite pierces sphalerite (Fig. 2), without reaction relations. Compositional zoning in actinolite was not observed, because of its small size. Pyrite, chalcopyrite and sphalerite are euhedral to subhedral of several millimeters in size. Epidote occurs as pools in the matrix, and possibly replaced original volcanic textures: for example, amygdules.

4. Mineral chemistry and paragenesis

Chemical analyses of actinolite around sphalerite and epidote were performed on the JEOL JCXA-8800 electron-probe microanalyzer at the Geological Survey of Japan. The accelerating voltage, specimen current and beam diameter were 15 kV, 1.2–1.3x10⁻⁸ A and 3 μm, respectively. Analytical data were reduced
using the method of Bence and Albee (1968). Selected results are given in Table 1. The actinolite contains 0.45–1.45 wt.% ZnO (0.05–0.15 per formula unit for O-23). The Mg/(Fe+Mg) ratios are 0.79–0.87, and MnO contents are 1.2–3.2 wt.%. Coexisting epidote contains no valuable ZnO.

Zn vs Fe[total]/(Fe[total] + Mg + Mn + Zn) ratios for calcic amphiboles in this study and previous reports (Palache, 1935; Borley, 1963; Klein and Ito, 1968; Stull, 1973; Treloar, 1987; Damman and Lustenhouwer, 1992; Oen and Lustenhouwer, 1992) are plotted on Fig. 3. Actinolite from the Franklin skarn (Palache, 1935; Klein and Ito, 1968) is exceptionally rich in ZnO, and is classified as “zinc-actinolite” (Leake, 1978). The studied actinolite from Kakkonda is second to that from Franklin as for ZnO content.

Bulk rock compositions of cuttings from the well WD-1 were reported by NEDO (1996) and Muraoka and Ohtani (2000), and the data show that zinc is enriched around 1,200–1,300 m deep. Hydrothermal veins of zincian minerals and sulfides are localized at the level, and heavy metals (Mn, Pb, Zn, Ba, V and Cu) are concentrated there. However, Muraoka and Ohtani (2000) suggests that the concentrated zone of the heavy metals does not correspond to present-day lost circulation zones. and the veins were probably formed prior to formation of the present permeable fractures. Thus, the zinc-bearing actinolite and other sulfides in the vein may be product of hydrothermal activity, in which geothermal fluid was enriched in the heavy metals, at early stage in the Kakkonda geothermal system.

5. Summary

Fibrous zinc-bearing actinolite occurs accompanied by sphalerite in a hydrothermal vein of a core sample at 1,223 m deep of the deep geothermal research well in Kakkonda. The ZnO content ranges from 0.4–1.5
Table 1 Chemical compositions of actinolite and epidote in the sample from 1.223 m deep of WD-1.  
* Total iron as FeO, ** Total iron as FeO.

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wt.%, relatively high. The actinolite was possibly formed from zinc-rich hydrothermal fluid which infiltrated and fractured the host andesitic tuff at early stage in the Kakkonda geothermal system.

Acknowledgments: The authors wish to express their sincere appreciation to NEDO for providing the core sample.

References


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Received February 14, 2001
Accepted July 18, 2001

東北日本岩手県葛根田地熱系に産する亜鉛鍵アキチノ閃石
佐賀幸雄・佐々木宗建・藤本光一郎・竹野直人

要旨

葛根田地熱系に掘削された深部調査井 WD-1 の、深度 1,222 m より回収されたコア試料を切る熱水性玄武岩中に、亜鉛鍵アキチノ閃石が見出された。亜鉛鍵アキチノ閃石は纖維状のものであり、亜鉛鉱鉱、黄銅亜鉛鉱、黄鉄亜鉛鉱、硫黄鉱、硬石膏、石英、粘土鉱物と共に産する。その亜鉛鉱含有量は 0.4-1.5 wt.% であり、これまでに報告されている亜鉛鉱カルシウム角閃石と比べると、亜鉛鉱含有量が高い方に属する。この亜鉛鍵アキチノ閃石は、おそらく、葛根田地熱系の熱水活動の初期段階に存在していた亜鉛に富む流体から形成されたと考えられる。