ZONING OF HYDROTHERMAL ALTERATION IN THE WESTERN PART OF THE HISHIKARI EPITHERMAL GOLD DEPOSIT, SOUTHERN KYUSHU, JAPAN

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SUMMARY – This study aims to clarify the alteration zoning in the Hishikari deposit from the view of temperature at which host rocks reacted with hydrothermal solutions. The study of the western area of the Hishikari deposit is based on mineral determination by X-ray diffraction of 203 samples obtained from drill holes. Powdered bulk rock and oriented clay samples were examined to identify clay minerals. We distinguished three types of chloritehmectite mixed-layer minerals by the degree of the shift of basal reflections by ethylene glycol treatment. The clay mineral zoning indicates that favorable conditions for gold mineralization extend west of the present Hishikari deposit.

1. INTRODUCTION

The Hishikari epithermal vein-type gold deposit is located in southern Kyushu, Japan (Figure **1).** It was discovered by Metal Mining Agency of Japan in **1981** (Izawa et al., **1990;** Sillitoe, **1995)** and developed by the Sumitomo Metal Mining Co., Ltd. and is known as one of the richest gold deposits in the world (Ibaraki and Suzuki **1993).**

This study aims to clarify the alteration zoning in the western part of the Hishikari deposit from the view of temperature at which host rocks reacted with hydrothermal fluid to interpret the ore fluid pathways.

2. GEOLOGIC SETTING

Geologically, the Hishikari deposit and the surrounding area consist mainly of basement sedimentary rocks of the Cretaceous Shimanto Super-group, Pliocene-Pleistocene volcanic rocks and alluvial deposits (Izawa et al., **1990)** (Figure 2).

The Shimanto Supergroup consists of sandstone, shale and their alternations. The Honko-Sanjin

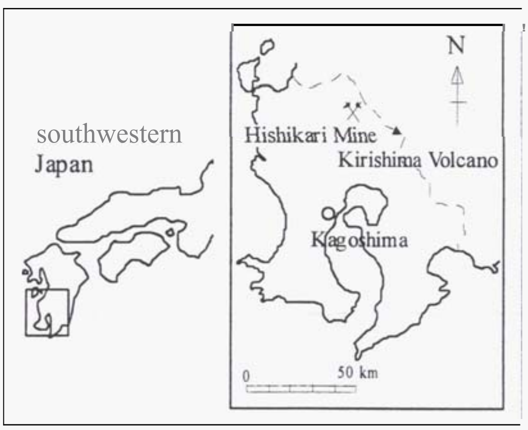

Figure 1. Location map **of** the Hishikari deposit

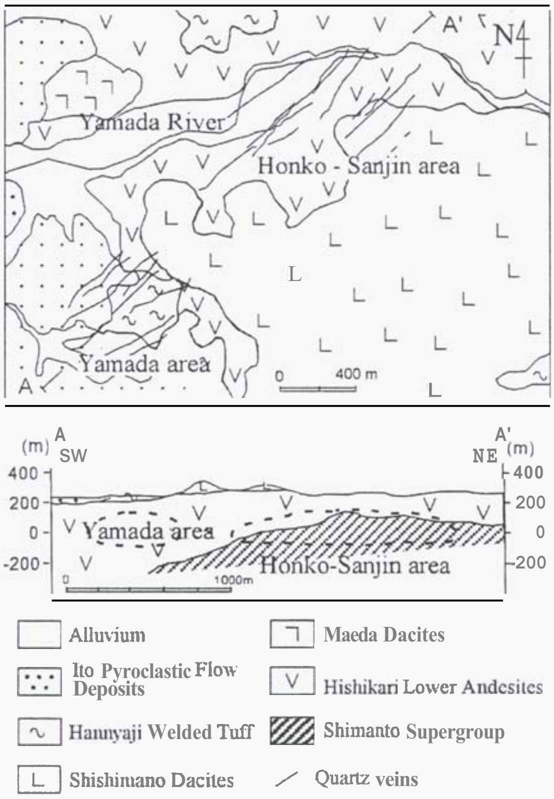

Figure 2. Geological **map of the Hishikari area and longitudinal section along A -A'. Modified from Ibaraki and Suzuki (1993) and** Etoh **et al.,** ***(2002).***

area, the eastern part of the Hishikari deposit, rises to 120 m above sea level and hosts more than *60* % of mineable veins (Izawa et al., **1990).** The volcanic rocks, which unconformably cover the Shimanto Supergroup, are Hishikari Lower Andesites, Maeda Dacites, Shishimano Dacites, Hannyaji Welded Tuff and Ito Pyroclastic Flow Deposits, in ascending order. The Hishikari Lower Andesites are the host rock of about 40 % of ore in the Honko-Sanjin area and of the entire veins in the Yamada area. (Figure **2).**

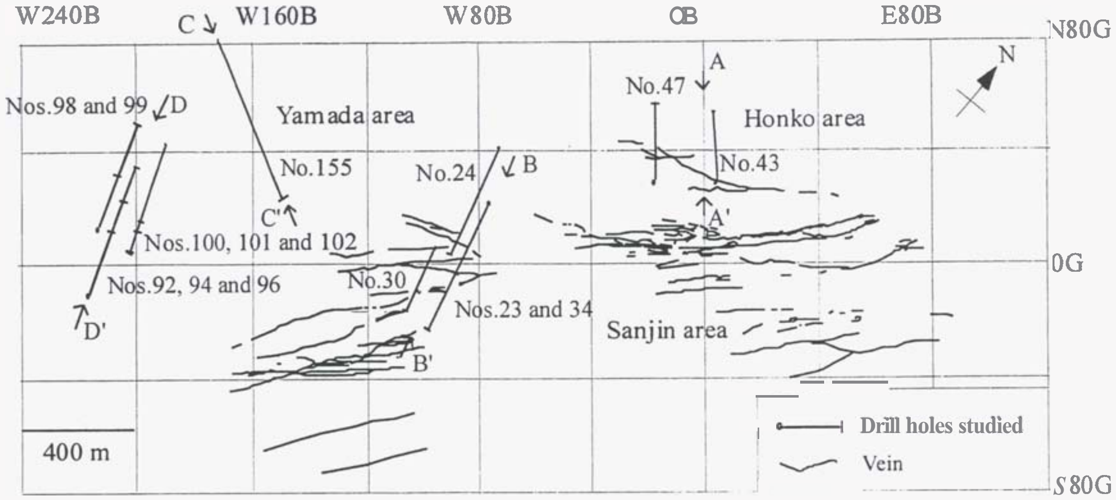

Figure 3. Location of drill holes sampled in this studied

3. METHODS AND MATERIALS

Hydrothermal alteration was studied between -100 m and 200 m above sea level in the north central and western areas of the Hishikari deposit using **203** samples from drill holes (Figure 3). The minimum sampling interval of drill cores is 20 m.

Hydrothermal minerals were identified using X-ray diffractometry for powdered bulk rocks and clay fractions collected by sedimentation. Oriented clay samples were prepared by pipetting clay suspensions onto glass slides. Air-dried and ethylene glycol treated samples were examined. Among the clay minerals identified in this study, smectite, chlorite and chloritehmectite mixed layer minerals are examined in detail.

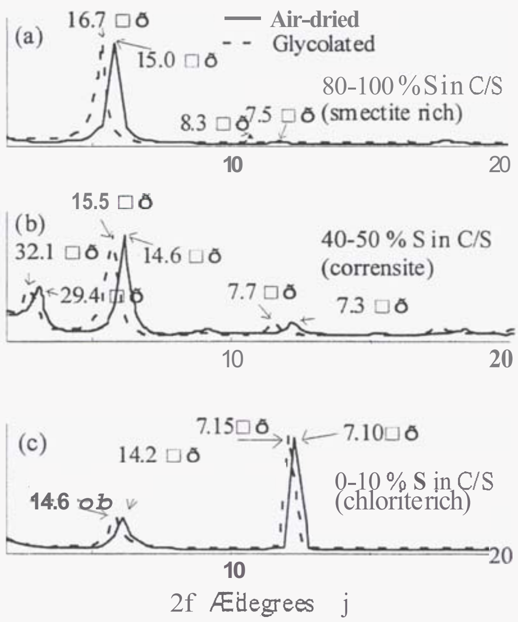

Figure 4. X-ray diffraction patterns of chlorite/smectite mixed-layer minerals. (a) Smectite rich mixed-layer minenrals. (b) Corrensite. (c) Chlorite rich mixed-layer minenral. S = smectite, C/S = chlorite/smectite.

Trioctahedral chlorite/smectite (C/S) mixed-layer minerals are common minerals of hydrothermally altered andesitic rocks under near-neutral pH condition. The smectite component (% S) decreases discontinuously with increasing temperatures from 80-100 % (smectite-rich C/S) through 40-50 % (corrensite) to 0-10 % (chlorite-rich C/S) (Inoue, 1995).

X-ray diffraction patterns for chloritehmectite mixed-layer minerals are shown in Figure 4. Smectite-rich C/S resembles smectite in diffraction patterns of air-dried samples, but a slight difference is caused by ethylene glycol treatment. Whereas the peak of the pure smectite shifts from 14° to 17° by this treatment, the peak of the smectite-rich C/S moves to 16.8° or less. An ordered trioctahedral chloritehmectite mixed-layer mineral, corrensite, is identified by a superlattice reflection with d = **29-30** Å. Chlorite-rich C/S resembles chlorite in diffraction patterns of air-dried samples, but slight layer expansion was caused by ethylene glycol treatment. Figure 4 shows the X-ray diffraction patterns of air-dried and glycolated samples for the chlorite/smectite mixed layer minerals from the Hishikari deposit.

4. RESULTS AND DISCUSSION

Least-altered andesitic volcanic rocks (the Hishikari Lower Andesites) consist of plagioclase, cristobalite, tridymite and small amounts of hypersthene and augite. Quartz and K-feldspar occur in the Shishimano Dacites. Clay minerals (smectite, kaolinite, mixed-layer clay minerals, chlorite and illite), zeolite minerals (stilbite, mordenite and laumontite), adularia, calcite, gypsum and pyrite were formed by hydrothermal alteration.

Using assemblages of clay minerals with silica minerals, the hydrothermal alteration zones in the

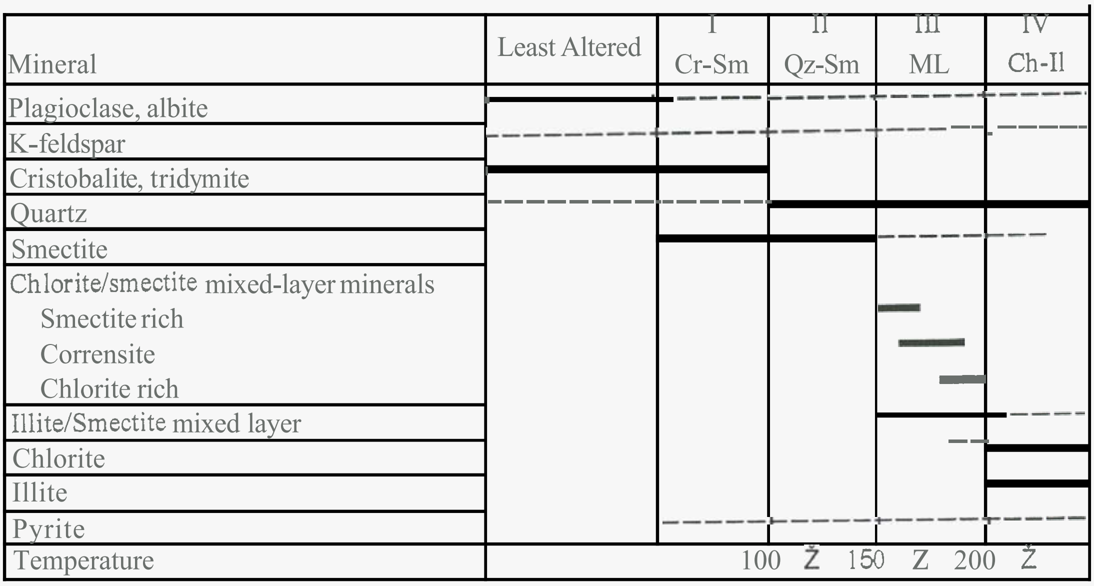

Figure 5. Alteration zoning by mineral assemblages and temperature conditions.

Cr-Sm = cristobalite-smectite zone, Qz-Sm = quartz-smectite zone,
ML = Mixed- layer mineral zone, Ch-Il = chlorite-illite zone.

Hishikari deposit is defined as follows; cristobalite and smectite for zone I, quartz and smectite for zone 11, quartz and mixed layer minerals for zone III, and quartz and chlorite and/or illite for zone IV. This classification was defined by Izawa et al. (1990) and these alteration zones were considered to correspond to following temperature conditions; less than 100°C for zone I, 100-150°C for zone 11, 150-220°C for zone III and higher than 220°C for zone IV (Ibaraki and Suzuki, 1993). However, the temperature of zone IV indicated by chlorite may be lower than 220°C judged fiom data on active geothermal fields and is about 200°C (e.g. Nakagawa et al., 1985; Inoue, 1995), although chlorite minerals provides somewhat ambiguous temperature information (Hulen and Nielson, 1986).

This study revealed that three types of chloritehmectite mixed-layer minerals occur in the Hishikari deposit reflecting various temperature conditions. Figure 5 shows the alteration zoning and temperature conditions indicated by clay minerals.

Figure 6 shows the distribution of clay minerals in longitudinal section in the north central and western areas of the Hishikari deposit. The smectite content in mixed-layer minerals is low in deeper levels indicating higher temperatures. Corrensite tends to occur near **quartz** veins. Comparing the east with the west, chlorite tends to be abundant on the same level in the Honko-Sanjin area and in the eastern part of the Yamada area.

Izawa et al. (1990) considered that zone IV is the principal alteration directly associated with high-grade gold mineralization. Later, Ibaraki and Suzuki (1993) showed that the Yamada veins occur in zone **IV** and also in zone 111.

The vertical distribution of alteration zones shown by the longitudinal section B–B' (Figure *6)* was previously studied by Izawa et al. (1990) and zone III was not found in the northern part of the section indicating a steep thermal gradient. However, zone III was recognized in this study by detailed examination of three types of chloritehmectite mixed-layer minerals. *So* the thermal gradient is not as steep as previously thought.

As zone III exists above sea level in the sections C-C' and D-D’, we conclude that hydrothermal fluid (>150°C) flowed through the western part of the Yamada area and that the favorable condition for gold mineralization exists on the western side of the Yamada area.

5. CONCLUSIONS

Clay minerals, in particular three types of chlorite/smectite mixed-layer minerals, show the temperature distribution during hydrothermal alteration in the Hishikari deposit.

Temperature conditions deduced by clay minerals range fiom 150°C to above 200°C in the Yamada area.

Corrensite and chlorite-rich mixed-layer minerals occur near quartz veins.

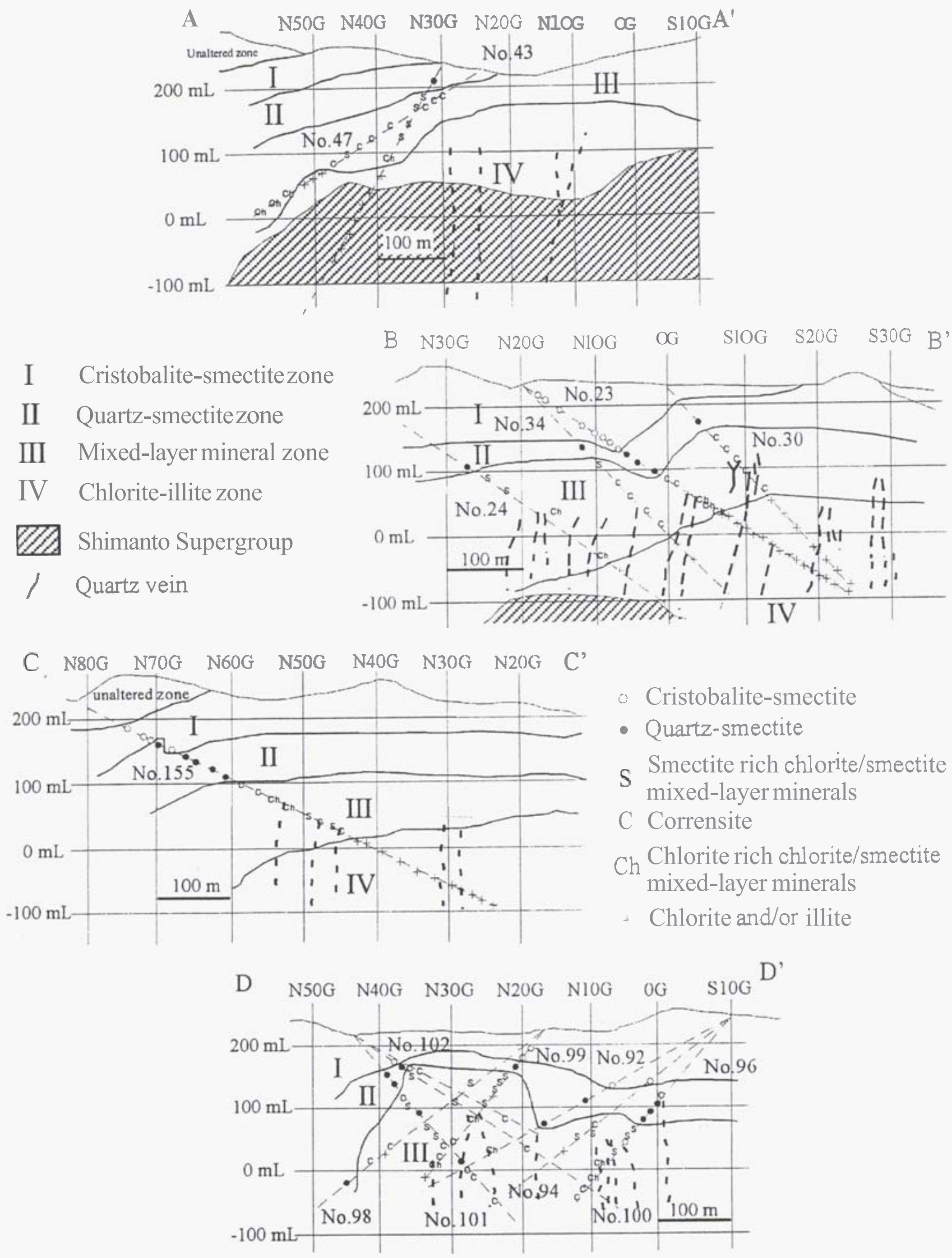

Figure *6*. Vertical alteration zoning on **A - A'**, B - B', **C - C'** and D - D' cross sections.

It is expected that the favorable condition for gold mineralization exist on the western side of the Yamada area.

6. ACKNOWLEDGMENTS

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