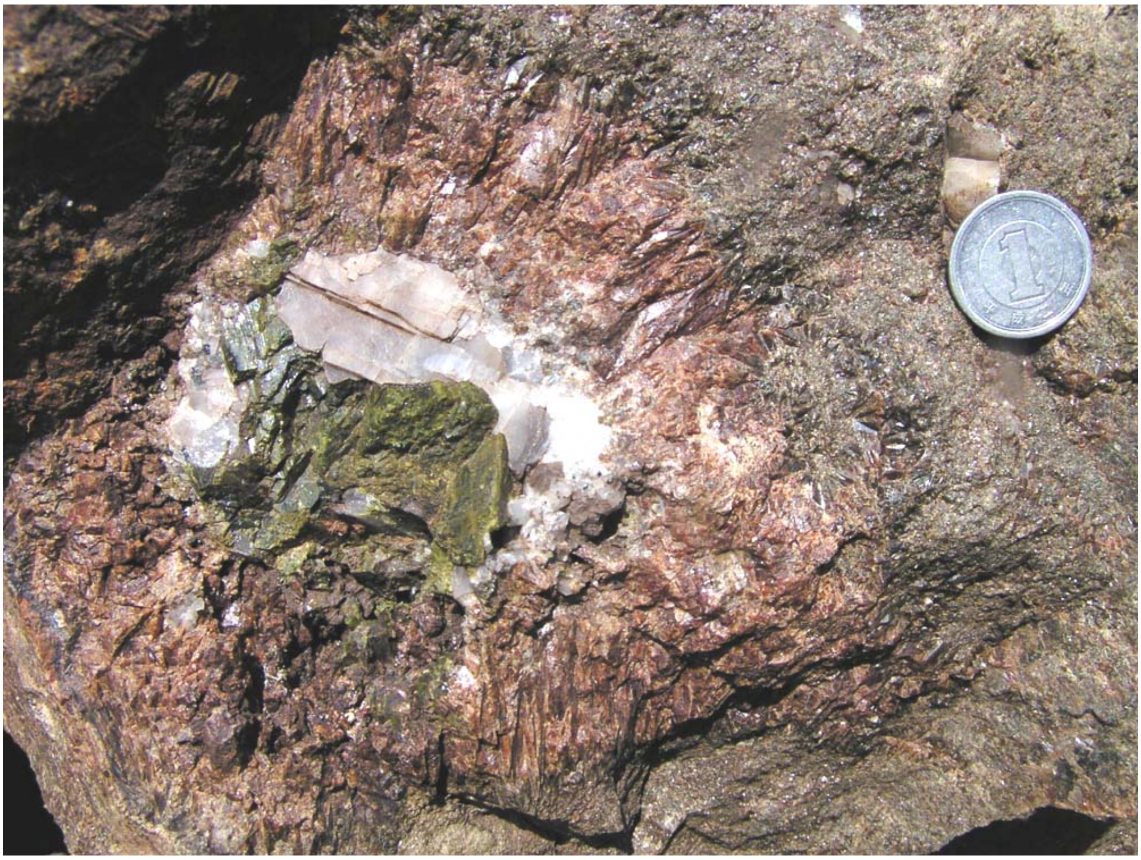
How to Study skarn type Deposits



Hiroyasu Murakami

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A short term expert seminar, submitted to:

Remote Sensing Center, MTA

1 h-murakami@aist.go.jp

Preface

This paper aims to understand how to study (method and procedure of mapping) skarn. This report is intended to have been included a necessary matter in order to understand skarn in the field. However, there are many parts which need more detailed supplements. This is mentioned as simplely as possible to be easy to understand. But in a common sense, the system of skarn formation is very complicated in a real investigation. I hope that this paper will be able to help future work for skarn deposits in Turkey.

I am very grateful to Mrs. Tekin Arıkal and Sahset Küçükefe who contributed much to the investigation together to presents for assistance of various kinds. Without their help, I would have nothing.

How to map zoning patterns of skarn minerals

The check list for mapping in the field should contain at least following features.

1. identification of minerals of skarn
2. texture and mode of occurrence of skarn
3. color of skarn minerals
4. grain size of skarn and constituent minerals of host rock (not only exoskarn but endoskarn)
5. lithology and structure of host rock (ex; dolomitic or calcareous, bedding plane, schistosity, and joint)
6. presence of vein

If you have a lot of time to observe skarn zone, you had better concentrate on only one feature from the above list. In particular, in case of core observation, you must do that. It is most important to observe repeatedly all through the skarn zone. If you do so, you may understand a system considerably in detail, and your understanding of skarn deepens too. The reason for this is because standards of judgment can always be kept uniform by concentrating on one feature, and it does not become vague of understanding system. But, if you do NOT observe so, you may misunderstand a system. Therefore, your understanding of skarn becomes poor too.

Identification of minerals of skarn

Among a lot of skarn minerals, not only garnet and pyroxene but also epidote and amphibole group minerals are the most important minerals to recognize in a skarn formation system. By knowing the mineral which skarn forms, we can estimate various conditions: temperature, pressure, oxygen fugacity, and distance from ore body. According to temperature, presence of garnet and pyroxene indicate high temperature: >400℃, epidote and amphibole group minerals are indicative of relatively low temperature: around <400℃. In most skarns, there is a general zonation pattern of proximal garnet, distal pyroxene, and wollastonite at the contact between skarn and marble. In particular it is important to ascertain relationship between skarn mineral and ore mineral. Because understanding at which skarnization stage an ore mineral was deposited at, is very efficient for mineral exploration.

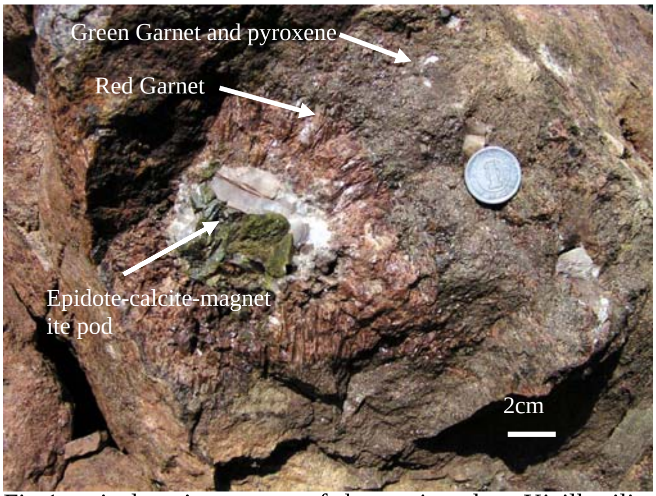

Fig.1 typical zoning pattern of skarn minerals at Kizilkesili. Retrograde epidote-calcite-magnetite-quartz skarn filled pod in the massive prograde garnet-pyroxene skarn. Coin=2cm.

The typical zoning pattern which is observed in Kizilkesili is given in Figure 1. If you find such skarnized rock, you might be confused as to how skarn minerals were formed? But, If you know these minerals were deposited at different stages and temperatures, and could not coexist with each other, based on the general idea of chemical equilibrium, you can correctly understand the formation of skarn. In other words, retrograde skarn, in the form of epidote, amphibole, and chlorite, is typically structurally controlled and overprints the prograde zonation sequence such as garnet and pyroxene. These retrograde skarn minerals sometimes show vein structure (Figure 2). In the Figure 2, it is obvious that quartz-calcite veins, which are related to retrograde skarnization, cut massive prograde garnet skarn. Furthermore, you can also observe the relationship between ore mineral (magnetite here) and skarn minerals, which suggests that magnetite is dominant in retrograde skarn stage.

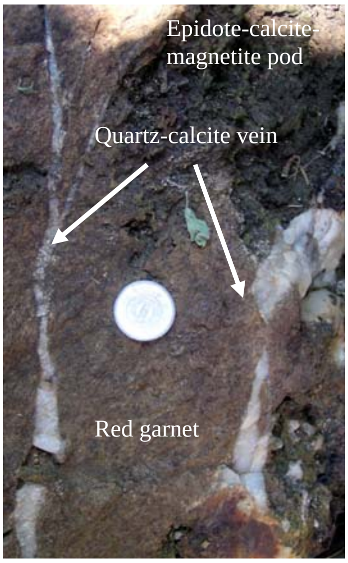

Fig. 2 explanation sees text

Sometimes, pyroxene showing prismatic texture, extraordinarily resembles amphibole: actinolite or tremolite. Even geologist who have mastered the skills can sometimes make a mistake in identification of these. The simplest and easiest method to distinguish these two minerals is to observe a cleavage. Pyroxene mainly has two cleavages which intersect by 88 degrees. On the other hand, amphibole usually also has two cleavages which intersect by around 120 degrees. It is often very convenient for the identification of minerals in various kinds of rocks, to observe a cleavage.

Color of skarn minerals

Individual skarn minerals may display systematic color variations within the zonation pattern, from intrusive rocks to marginal host rocks. Particularly, garnet is commonly dark red brown in proximal to the intrusion or center of hydrothermal activity, but becomes lighter brown in more distal occurrences, and is pale green near the marble front (Atkinson and Einaudi, 1978). The change in pyroxene color is less pronounced, but typically reflects a progressive increase in iron and/or manganese toward the marble front (Harris and Einaudi, 1982). For some skarn systems, these zonation patterns can be "stretched out" for several kilometers and can provide a significant exploration guide (Meinert, 1987).

Fig.3 typical red garnet skarn at Kizilkesili. Garnet showing dark reddish brown and/or reddish brown. This sample was located about 100m of intrusion outcrop.

In the Kizilkesili skarn outcrops, garnet displays systematic color variations within the zonation pattern from intrusive rock to marble. Variation in color of garnet is quite conspicuous, as shown in figure 3 to 6.

Fig.4 garnet-pyroxene skarn at Kizilkesili. Garnet showing two different colors of reddish brown and green. It is thought that this is a transitional zone of skarnization This sample was located about 200m from the intrusion outcrop, at the boundaries of red garnet and green garnet zones .

Fig.5 garnet-pyroxene skarn at Kizilkesili. Garnet showing green in color tends to be dominant relative to red, by getting closer to marble. This sample was located about 250m from the intrusion outcrop.

Fig.6 pyroxene-garnet skarn near marble contact at Kizilkesili. Almost garnet showing green coexists with mega-phenocryst of calcite that is considered to be marble relict. This sample was located about 400m from the intrusion outcrop.

It is thought that the skarn system may be small when such a color change of garnet is recognized by a very narrow range in distance.

Fig.7 garnet skarn suffered by epidotization of retrograde at Kizilkesili. Garnet showing pale yellow (honey like) color. This sample was located about 50m from the intrusion outcrop.

In some cases, garnet may display various color changes due to retrograde alteration. Figure 7 shows garnet having pale yellow (honey like) color is replaced by retrograde epidote. Seemingly such an occurrence is resembled to garnet, you can simply distinguish by careful observation of crystal system and mineral hardness.

Texture and mode of occurrence of skarn

The depth of a skarn formation is closely related to its mode of occurrence. If this can be recognized definitely, time/space distribution of skarn can be understood. If examination of erosion level is added, you may precisely estimate whether there is potential for exploration or not. The formation of skarn deposits such as iron or copper progress as bimetasomatic by supplying elements from magmatic solution and limestone. In such a process, the volume that a mineral occupies easily changes, due to difference of specific gravity between skarn minerals and minerals which occupied

Fig.8 garnet skarn has a lot of cavities at Kizilkesili. Some cavity fills with retrograde skarn minerals.

protolith. In particular, such a change may become conspicuous with prograde skarn, that calcite replaced by garnet (Figure 8). When there are many elements including metals supplied from magmatic solution, formation of skarn minerals provide enough volume to fill an original volume of protolith. Skarn tends to be massive and homogeneous. Adversely, if there is not enough element supply, it results in forming considerable cavities in the skarn. From this point of view, mode of occurrence of skarn will become very useful information to estimate the size of deposit.

Fig.9 garnet-pyroxene skarn showing banding structure. That may form along joints or clack of marble, at Kizilkesili.

In a deep skarn environment, rocks will tend to deform in a ductile manner, rather than fracture. Intrusive contact with sedimentary rocks at depth, tends to be sub-parallel to bedding. In occurrences such as these, skarn is formed along bedding planes or clack of the sedimentary rocks (Figure 9). In contrast, host rocks at shallow depths will tend to deform by fracturing and faulting rather than folding. Where intrusive contacts are sharply discordant to bedding, skarn cuts across bedding and massively replaces favorable beds, equaling or exceeding the exposed size of the associated pluton (Meinert, 1992). In such an environment, skarn develops in areas where fissures intersect limestone as vein like structures (Nitta et al., 1971; Kawasaki et al., 1985). Figure 10 shows a lot of veins which cut prograde skarn. The sample was taken from Samli iron skarn deposit.

Fig. 10 a lot of veins which cut prograde skarn. The sample taken from Samli iron skarn deposit.

Grain size of skarn and constituent minerals of host rock

In general skarn zonation, a grain size of mineral has various changes, and there are many difficult to recognize general trends. However, in each deposit, some local tendencies can be found. At Kizilkesili, it is likely to be recognized as a difference of grain size of calcite in marble (Figures 11 and 12).

Fig.11 fresh limestone (marble) at Kizilkesili. Compare grain size of calcite with a right figure.

Fig.12 crystalline limestone (marble) in the vicinity contact between skarn .at Kizilkesili. Compare grain size of calcite with left figure.

Moreover, a change of color is also recognized. In my experience, change in color of calcite reflects compositional change due to contact metamorphism or hydrothermal activity. According to Schuiling and Oosterom (1966), concentrations of Sr and Ba in regionally metamorphosed limestone on Naxos, Greece, decrease with increasing metamorphic grade. It is, therefore, expected that the limestone in skarn deposits would vary in composition, with a change in grain size of calcite. It is indicative for exploration to observe geochemical and mineralogical information about limestone which have grain size variation connecting with a hydrothermal system in the skarn deposits. Furthermore, they will help to develop more highly precise exploration methods.

Lithology and structure of host rock

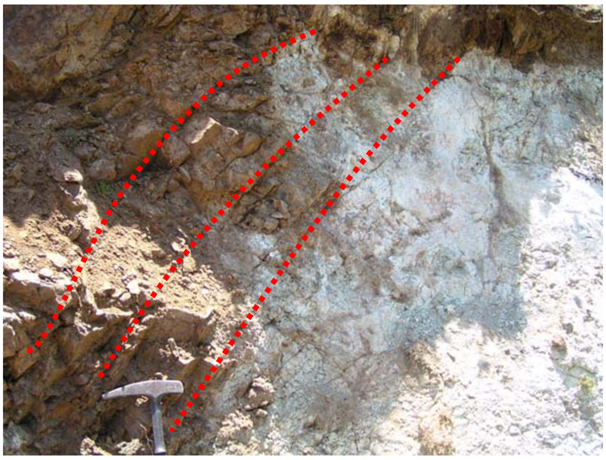

Fig.13 Intrusive contact with skarn tend to be sub-parallel to joints, at Demirlitepe(Icica).

As stated above, in a deep skarn environment, rocks will tend to deform in a ductile manner, rather than fracture. Intrusive contact with skarn at depth, tends to be sub-parallel to joints (Figure 13). In occurrence such as these, skarn is formed along bedding planes or clack of the sedimentary rocks (Figure 9).

Interpretation of igneous texture may serve as clue to solve a depth at which not only intrusive rocks are emplaced, but also skarn is formed. If you find intrusive rocks having equigranular texture (Figure 14), it may indicate a deep formation level. Therefore, the formation of skarn at depth in which lithostatic pressure is dominant strongly controlled by structure of host rock, which results in "strata-bounded" deposits. Higher ambient temperatures at depth could be affected by the crystallization history of a pluton, and minimize the amount of retrograde alteration of skarn minerals. At a depth of 12 km, with ambient temperature of approximately 400 ℃, skarn may not cool below garnet and pyroxene stability without subsequent uplift, or other tectonic changes (Meinert, 1992).

Fig.14 Intrusive rock (Eybec granodiorite) showing equigranular texture, at Kizilkesili.

Presence of vein

The presence of veins is one of the distinctive features of skarn formation in a shallow environment. In such an environment, fault and fracture are more likely to control hydrothermal activity accompanied with the formation of skarn and ore minerals (Figure 15). The strong hydrofracturing associated with shallow intrusions greatly increase the permeability of the host rocks, not only for igneous-related metasomatic fluids, but also for later, possibly cooler, meteoric fluids (Meinert, 1992). In your field around promising skarn occurrences, you can find veins constituent retrograde skarns, you must check dip and direction of veins (Figures 16, 17). Based on the observed dip and direction of veins, you might want to investigate around these veins, because retrograde alteration is generally more intense, and more pervasive in shallower skarn systems. In some shallow porphyry copper-related skarn systems, extensive retrograde alteration almost completely obliterates the prograde garnet and pyroxene (Einaudi, 1982a, 1982b).

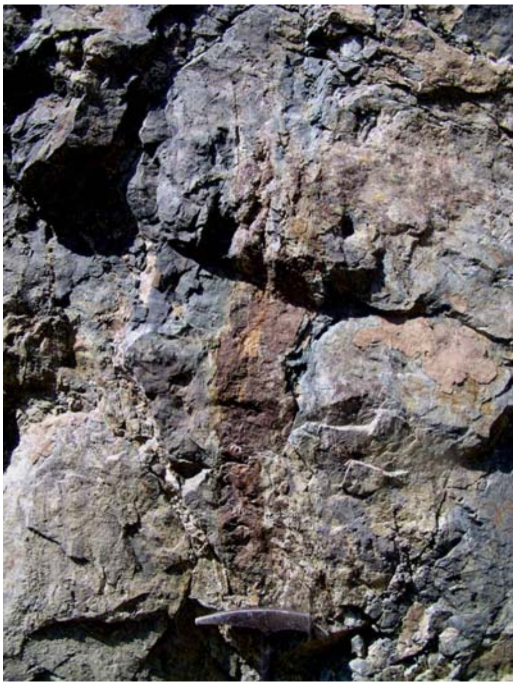

Fig.15 garnet vein cuts prograde pyroxene skarn in meta-basic rocks, Samli iron skarn deposit.

Fig.16 magnetite vein cuts prograde garnet skarn in meta-basic rocks, Samli iron skarn deposit. It is indicated that magnetite mineralization is continued in the retrograde stage of skarnization.

Fig.17 epidote vein accompanying sulfides cuts prograde pyroxene-garnet skarn in meta-basic rocks, Samli iron skarn deposit.

Limonite and amorphous silica veins originated in supergene process in some epithermal deposits. They also occur on the surface of skarn deposits, and resulted from weathering of skarn and sulfide minerals (Figure 18). It is considered that these iron oxides within some metallic elements,

Fig.18 supergene limonite and amorphous silica vein develops along the clack of prograde skarn, Samli iron skarn deposit.

Fig.19 limestone (marble) showing limonite alteration, near Samli iron skarn deposit.

can spread as ions through a present ground water. The alteration products are likely to be present at the surface in and around skarn type deposits (Figure 19). I hope that satellite image analysis can be detected thelimonite alteration including metallic anomalies on the surface (Figure 20).

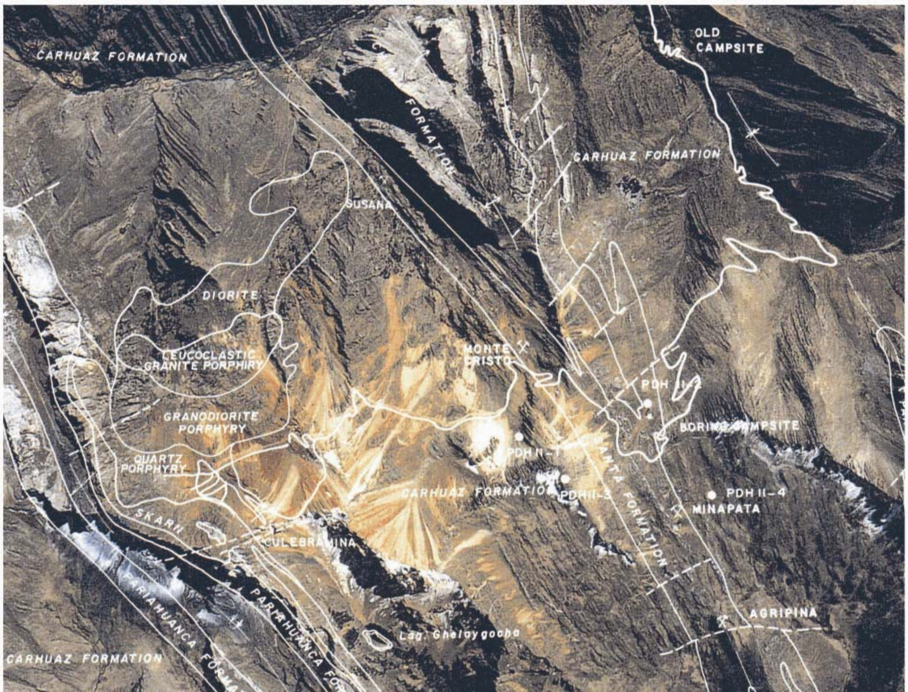

Fig.20 satellite image of Zn-Pb skarn deposit in Peru, south America. Note extensive iron-oxide alteration around skarn deposits can be distinguished from other geology.

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Postscript

If we may find some skarn minerals in a field, you must check the contact between host rock of skarn and intrusive rocks. If you can find host rocks, at next step you must confirm color of skarn minerals at contact between host rocks. You may find also intrusive rocks, you should observe character of intrusive rocks; texture, grain-size, and magnetic susceptibility. Most important thing is to ascertain relationship between skarn mineral and ore.

Postscript 2

If We could observe that skarn minerals accompanied with mineral assemblage characterized vein and alteration system of porphyry copper mineralization, we are more likely to discuss about difference and relationships between skarn and porphyry copper mineralization. In order to classify such a deposit into skarn or porphyry copper, it needs to ascertain which stage is related to the mineralization. There is critical criteria for classification of vein and alteration mineralogy resulted from porphyry copper mineralization, however, it is general that such a distinct criteria is different in skarn in each type of deposits. In this point, there are difference of criteria between both will need to be taken into consideration. In this paper, it is distinguished brief criteria of porphyry copper style mineralization from skarn system definitely here, and it will be a guide of future exploration.

	Porphyry copper	Skarn
Alteration	potassic alteration phillic alteration advanced argillic alteration propylitic alteration	Prograde Retrograde
Vein system	A vein:biotite vein B vein:Quartz-molybdenite (no alteration halo along vein) C vein:chlorite (or green smectite bearing mixed layer clay) + sulfides (partly pyrite +molybdenite) D vein: phillic alteration (sericite alteration along Quartz vein)	Dominant in sallower part of skarn system
Related intrusion	Generally, porphyry, sometimes depend on depth of formation	Depend on depth of formation