solubility of gold owing to a change in pH (Henley, 1984). Gold solubility relations at 250 °C, a temperature considered by many to approximate thermal conditions in most Au-bearing skarns during paragenetic stage(s) of gold deposition, culminate at oxygen activity-pH conditions compatible with pyrite stability (Romberger, 1988). As Romberger (1988) further noted, if most gold is transported as a bisulfide complex, gold deposition may be accomplished by any chemical reaction or physicochemical process that decreases chemical activity of sulfur components dissolved in aqueous fluids circulating through skarn, including deposition of sulfide minerals and loss of sulfur components because of boiling.

Geophysical Signatures

Well-developed, local magnetic highs result from increased abundance of pyrrhotite and (or) magnetite in some Au-skarn systems (see Wotruba and others, 1987a, b). However, other Au-skarn systems are associated mostly with pyrite in their unoxidized parts (McCoy) and show no distinctive magnetic signatures (Bruce A. Kuyper, oral commun., 1987).

Ore Controls/Exploration Guides

In established mining districts zoned from mostly proximal copper-dominant deposits to distal precious-metal-dominant and base-metal-dominant veins, all stratigraphic sequences favorable for development of skarn in the zone of precious-metal deposits should be considered as permissive hosts for development of Au-bearing skarn. Polymetallic veins and polymetallic replacement deposits showing geochemical signatures and sulfide mineral assemblages similar to those at many Au-bearing skarns (for example, the Fe-As-Zn-Cu-Bi-Au- and Sb-bearing ores at the Matsuo Mine, Japan; Matsukuma, 1962) may be high-level or lateral reflections of Au-bearing skarn. Other guides include: reported gold in base- and ferrous-metal skarn systems; gold placers in regions permissive for the formation of skarn (R.G. Russell, written commun., 1989), especially if the placer gold is intergrown with bismuth minerals, including bismuth oxides or bismuth tellurides (Theodore and others, 1987; Theodore and others, 1989). Anomalous values of bismuth, tellurium, arsenic, selenium, and cobalt are useful geochemical signatures for some gold-bearing skarns (tables 2, 3; Brooks and Meinert, 1989).

Metal ratios in jasperoids, which commonly occur in or on the fringes of gold skarn systems, may also provide useful geochemical signatures for exploration. Faults cutting skarns and intersecting structures are important pathways along which retrograde assemblages and associated ores are concentrated. R.G. Russell (written commun., 1989) distinguishes between barren, early, high-temperature contact skarn formed adjacent to intrusive rocks and mineralized, fracture-enhanced exoskarn developed in Au-skarn systems.

Although pyroxene (hedenbergite)- and pyrrhotite-rich distal skarns host gold mineralization in some deposits, such as the Fortitude, garnet-pyroxene (diopsidic) and chalcopyrite or pyrite-rich proximal skarns are the locus of gold mineralization at other deposits, such as McCoy. Further studies on Au-bearing skarn deposits may reveal relatively reduced (Fortitude) and oxidized (McCoy) types of gold-bearing skarn, such as have been recognized for tungsten skarns (Einaudi and others, 1981).

GRADES AND TONNAGES OF GOLD–BEARING SKARNS

Graphs of grades and tonnages of 40 Au-skarns from table 2 and 50 byproduct Au-skarns from table 3 are shown in figures 1, 2, and 13. Gold grade must be 1 g/t or higher to be included, as described above. Median tonnage for the Au-skarn subtype is about 213,000 tonnes (fig. 1*C*), and median tonnage for the byproduct Au-skarn subtype is about 330,000 tonnes (fig. 1*D*). For the Au-skarn subtype there is a strong negative correlation between gold grade and tonnage (linear correlation coefficient = -0.69); this relation is slightly weaker for the byproduct Au-skarn subtype (linear correlation coefficient = -0.54). The Au-skarn subtype has a median gold grade of about 8.6 g/t and a median silver grade of about 5.0 g/t (figs. 2*C* and 13*A*). The determination of median silver grade for the Au-skarn subtype is based upon values of silver grade available for 29 of 40 deposits (table 2). Meinert (1988a) tabulated Au, Ag and Cu grades for various types of skarns. The fourteen deposits he classified as gold skarns all have gold grades greater than 1 g/t Au and largely overlap our data set. Median gold grade for Meinert's gold skarn set is 6.5 g/t; median silver grade for the nine deposits that report silver is 9 g/t. For the byproduct Au-skarn subtype, the medians are 3.7 g/t gold and approximately 34 g/t silver. Nearly 90 percent of the byproduct Au-skarns report silver (table 3). Silver content appears to have a strong correlation with base-metal content. As a comparison, the median gold grade for 14 porphyry copper-related Cu skarns, as reported by Meinert (1988a), is approximately 0.3 g/t and the median silver grade is approximately 8 g/t (note that these values are higher than those reported by Singer, 1986) for gold in porphyry copper-related skarns.

We found wide variations in gold grade distributions. In fact, values of gold grade reported during various stages of exploration and development of many deposits typically show significant adjustments, usually in a descendent manner. Furthermore, tests of the gold grade distribution for Au-skarns indicate that the addition of approximately 40 deposits with grades less than 3.7 g/t would be required to change the median to a value approximately the same as that of the byproduct Au-skarn subtype.

As already described, skarns that contain byproduct gold show no statistically significant differences in tonnage distributions from Au-skarns exploited almost exclusively for their precious-metal content (figs. 1, 2). This relation is primarily a reflection of the highly variable exploitability of many polymetallic skarn systems under a wide range of economic circumstances. Tonnages of deposits that comprise the Au-skarn subtype vary widely, from approximately 9 tonnes to 15 million tonnes (table 2), primarily because of a combination of both differing economic circumstances and advances in metallurgical techniques over the many years these types of deposits have been mined. However, there is a marked difference in cumulative distributions for gold and silver grades of Au-skarn and byproduct Au-skarn as defined previously: Au-skarns have a median gold grade of 8.6 g/t and byproduct Au-skarns have a median grade of 3.7 g/t. Median silver in Au-skarns is 5 g/t as compared to 37 g/t in byproduct Au-skarns (fig. 13). Both gold (greater than 1 g/t) and silver grade populations as currently reported are significantly different between the Au-skarn and byproduct Au-skarn subtypes. Median silver grades were determined from silver data available for 29 of 40 deposits included in the Au-skarn subset, and for 44 of 50 deposits included in the byproduct Au-skarn subset. It should also be noted that in element-versus-element plots for byproduct Au-skarn and Au-skarn subtypes, byproduct Au-skarns (or Au-rich Cu-skarn deposits in the terminology of many others), for instance, plot in a cluster spatially separate from most Au-skarns and tend to represent the Cu-rich part of the domain with gradational and overlapping relations with other skarns; these types of relations hold for many other elements (fig. 14*A*). However, as shown by the graph of these data (fig. 14*A*), strengths of association of gold grade for copper grade in the two subsets of Au-bearing skarn seem to show extremely weak correlations between gold grade and copper grade; correlation coefficients for the two subsets of types of Au-bearing skarn are less than 0.2. Gold and copper grades are available only for 20 of 40 Au-skarn deposits (table 2), which may in part be an indication of an underreporting of copper contents for some deposits because of its economic insignificance during the time many of those deposits were being mined. Nonetheless, very significant gold grades can occur in some very Cu-rich skarns. Many Au-skarn deposits show a strong spatial association between gold and copper within the deposits themselves. A plot of gold grades versus silver grades for both subsets of Au-bearing skarn shows that most Au-skarns have silver grades lower than byproduct Au-skarns (fig. 14*B*). Gold grades compared with silver grades for the Au-skarns have a correlation coefficient of approximately +0.4, and for the byproduct Au-skarns a correlation coefficient of approximately +0.2. One important exploration implication is that economically viable Au-bearing skarn deposits may be associated with Cu, Pb-Zn, Fe, or W skarn, and although the median gold grade of these byproduct Au-skarns is lower, the highest grades are similar to those of the Au-skarn subtype. Perhaps the only types of metal-bearing skarn that might be excluded from consideration as permissive for the occurrence of significant concentrations of gold and silver are tin-skarn and lithophile-element (beryllium, fluorine, tungsten, molybdenum, tin, and zinc) skarn associated with two-mica granite. Significant gold or silver mineralization is not known in classic Sn-skarn regions in Cornwall (Hosking, 1964) or Malaysia (Hosking, 1977, 1979). However, some Au- and Bi-bearing skarns (Stormant) are

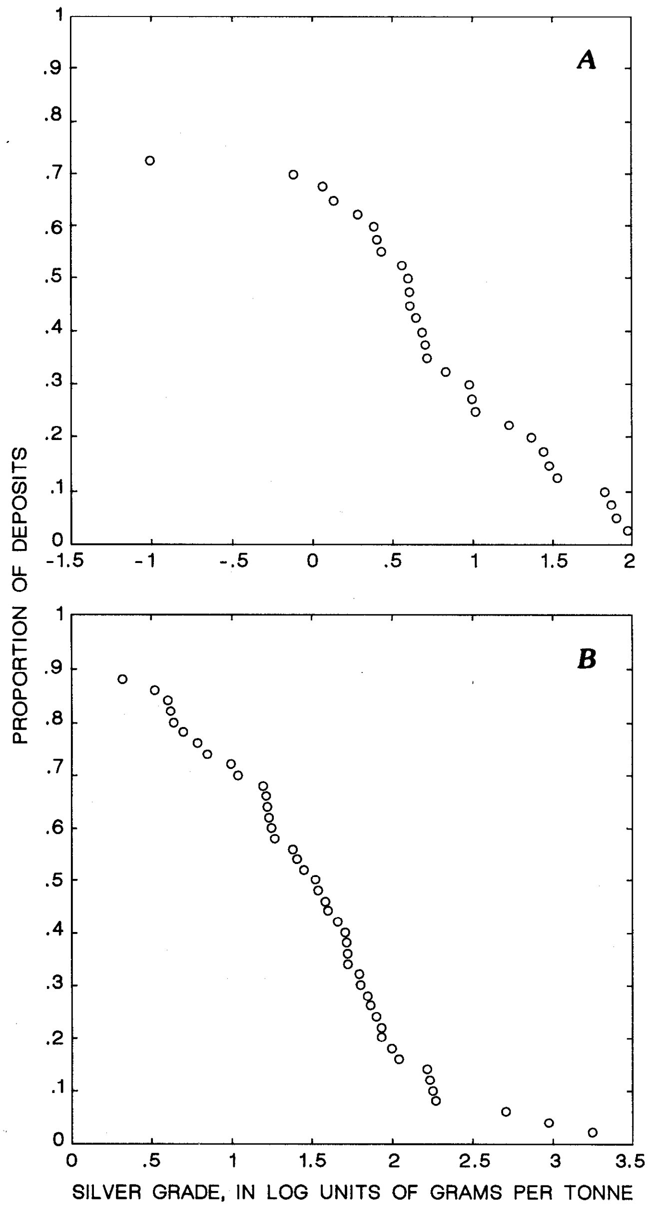

Figure 13. Distributions of silver grade for Au-bearing skarns. *A*, Silver grade model for 29 Au-skarn deposits. *B*, Silver grade model for 44 byproduct Au-skarn deposits.

known in the Moina Mining District, Tasmania, Australia, which is largely known for its Sn-W skarn and greisen deposits (Collins and Williams, 1986). Lithophile-element skarn is associated with numerous Late Cretaceous, peraluminous, two-mica granitoids across a broad region in the eastern Great Basin of the United States (Barton, 1987; Barton and others, 1988). Significant concentrations of gold have not been reported from this lithophile-element-skarn environment. However, silver is present in many of these lithophile-element skarns in apparently genetically associated silver-base-metal, quartz-carbonate veins (Barton, 1987).

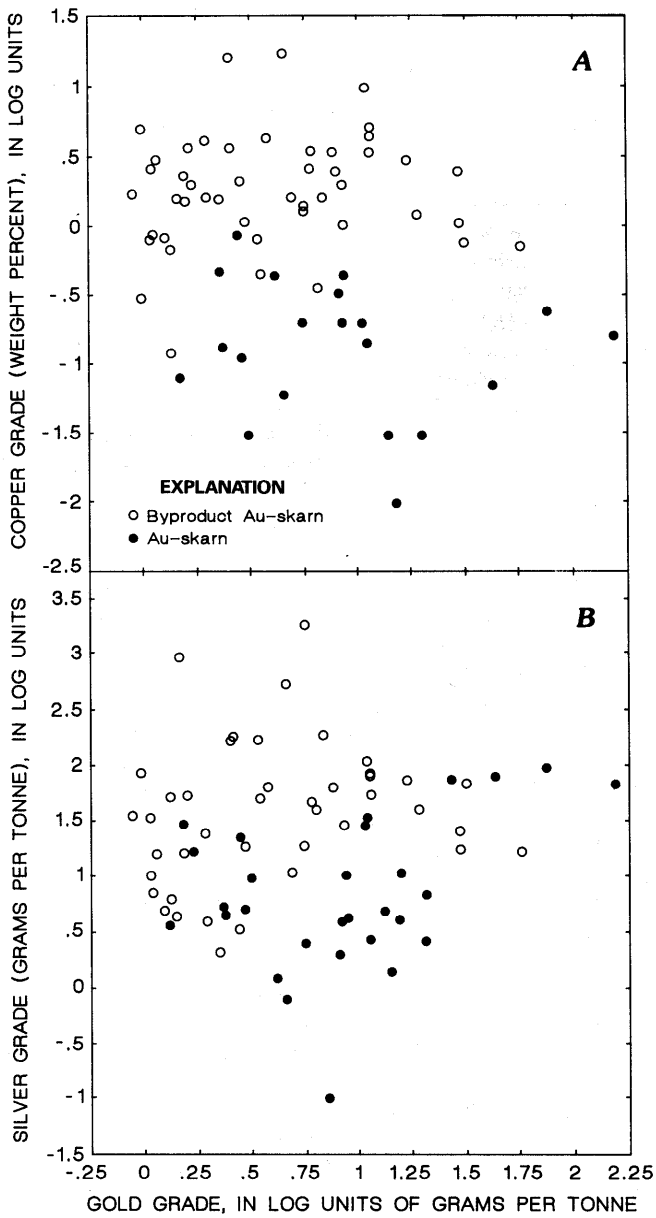

Figure 14. Gold grade compared with copper grade and silver grade. *A*, Gold grade compared with copper grade for Au-skarns and byproduct Au-skarns; *B*, Gold grade compared with silver grade for Au-skarns and byproduct Au-skarns.

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