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DISCUSSIONS

COMPARATIVE ELEMENTAL AND OXYGEN ISOTOPE GEOCHEMISTRY OF JASPEROID IN THE NORTHERN GREAT BASIN: EVIDENCE FOR DISTINCTIVE FLUID EVOLUTION IN GOLD-PRODUCING HYDROTHERMAL SYSTEMS—A DISCUSSION

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Sir: Discriminating productive jasperoids associated with economic gold mineralization from barren jasperoids, those with no known gold association, has long been an objective of Great Basin explorationists. Holland et al. (1988) use factor analysis of a multielement geochemical data set to compare jasperoids associated with Carlin-type gold mineralization with jasperoids in barren systems. They go on to propose a genetic model for Carlin-type deposits based on their interpretation of the factor analysis results. There are problems with their approach, several of which the authors acknowledge. The geologic control for their samples is inadequate, the analytical technique used is inaccurate for several critical elements, and their statistical analysis of the data could be much simpler, easier to interpret, and useful.

The samples of jasperoid, the analyses of which form the database used by the authors, were gathered by "over a dozen different geologists" in a variety of circumstances, ranging from mine tours to project work. Thus, the geologic context of the samples must range from well established to very poorly established, which creates a host of interpretive pitfalls. For example, the effects of lateral and vertical geochemical zoning, which are pronounced in most mineral deposits, cannot be accounted for. Holland et al. (1988) briefly acknowledge this, as well as the fact that only field descriptions of the samples are available, which may be limited with a material as fine grained as jasperoid. No petrography or quantitative mineralogy (e.g., X-ray diffraction, microprobe analysis of minerals) were done on the samples, so the geochemistry of a sample cannot be directly related to its mineralogy.

The authors note that "the aqua regia digestion used for ICP trace element analyses . . . was reported by the laboratory to be only partial for some of the elements used in this study (B, Ba, Mn, and W)." While it is possible that the relative difference in the concentration of these elements between productive and barren jasperoids may still be valid even though the absolute concentrations are not accurate, inductively coupled plasma (ICP) analyses of these elements should obviously be interpreted with great caution. Hill et al. (1986) sampled eight of the ten gold deposits sampled by Holland et al. (1988), but used dc arc emission spectroscopy for a broad spectrum of elements supplemented with standard wet chemical methods. A comparison of the two data sets shows significant differences in both the median value and range of values of Ba, As, Sb, V, Cu, Ni, Mo, B, W, Ag, and Au.

Holland et al. (1988) use factor analysis of the multielement geochemical data to develop a seven-factor model for the data set. They then interpret the factors to give the petrology and paragenesis of the jasperoids from which the samples were taken, instead of using petrography for that purpose. Unfortunately, the factor upon which Holland et al. (1988) rest the bulk of their subsequent genetic hypothesis is factor 3, which is heavily loaded with W, B, and Mn, three of the least accurately measured elements in the data set. Factor 3 (W, B, V, Zn, Co, Ni, Au, CaO, Mn, Cu, in order of decreasing factor scores) is interpreted to be related to carbonate alteration associated with gold mineralization. High factor 3 loadings are contended to represent derivation of the jasperoids and their host deposits from boiling, high CO_2 fluids. This then is the basis of Holland et al.'s (1988) genetic model. An alternative and equally plausible interpretation of factor 3, briefly mentioned by the authors, is that it is a scheelite factor. In fact, the deposits with high factor 3 loadings (Gold Quarry, Maggie Creek, Pinson, and Preble) are in areas where scheelite-bearing skarn occurs. The appropriate interpretation of the geochemical data presented by the authors can be made only when these data are firmly grounded in their geologic context, at all scales, with detailed mapping and petrography. Standing alone, the factor model of Holland et al. (1988) and their interpretation of it is hardly a foundation for the far-reaching genetic model that they propose.

Given that the geologic context of the analytical data presented by Holland et al. (1988) is not established in other than the grossest sense, the data set may still be of some use in a general way for attempting to discriminate between gold-mineralized and gold-barren systems. Holland et al. (1988) state that, "because unaltered host rocks were not analyzed to obtain reference compositions for mass balance computations . . . simple univariate or bivariate statistical methods were not used to analyze the data because these might have produced equivocal or misleading results." This qualm caused them to skip over what many statisticians recommend as the first step in analyzing a multivariate data set (see Tukey, 1977) and miss some simple geochemical associations that are obscured as a result of the factor analysis. Box plots of the trace elements in Holland et al.'s (1988) appendix I data set are shown in Figure 1 and plots for the major oxides in Figure 2. These graphs show that the concentrations of gold, potassium, and aluminum are distinctly different in the gold-mineralized systems versus the barren systems. Further, antimony, strontium, copper, molybdenum, lanthanum, and tungsten show some separation as well.

From a purely empirical exploration standpoint we find these simple statistical differences between the barren and mineralized jasperoids extremely interesting. By comparing geochemical populations found in the known productive jasperoids with geochemical populations from jasperoids with undetermined po-

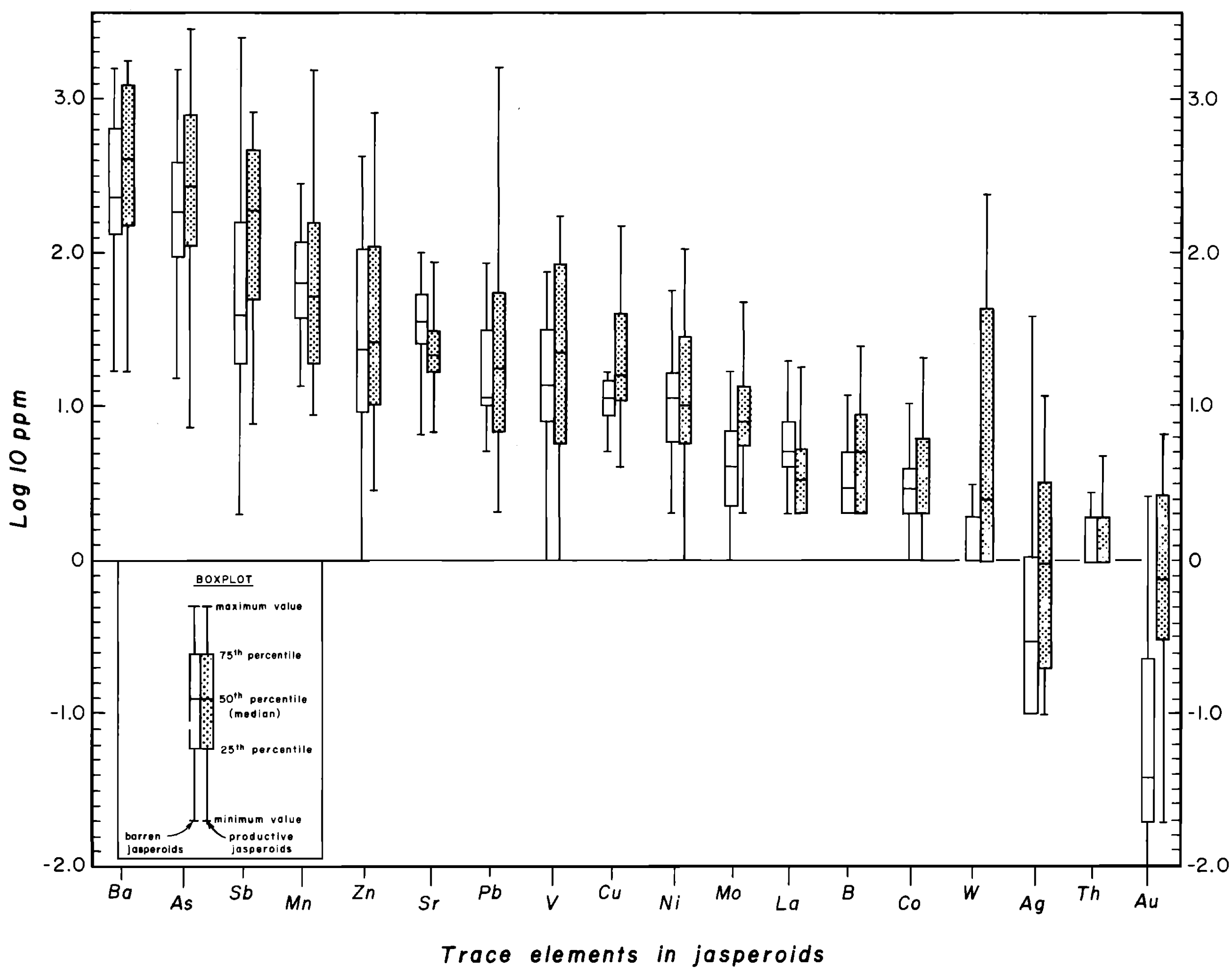

FIG. 1. Multiple box and whisker plot of trace element geochemical data from Holland et al. (1988), appendix I, plotted in order of descending median concentration, from left to right. Stippled box in each pair of boxes represents distribution of values of a given element in 32 samples of gold deposit-associated jasperoids, open box shows distribution in 33 samples taken from gold-barren systems. Box plots with no median bar in the box have a median that plots on the bottom line of the box.

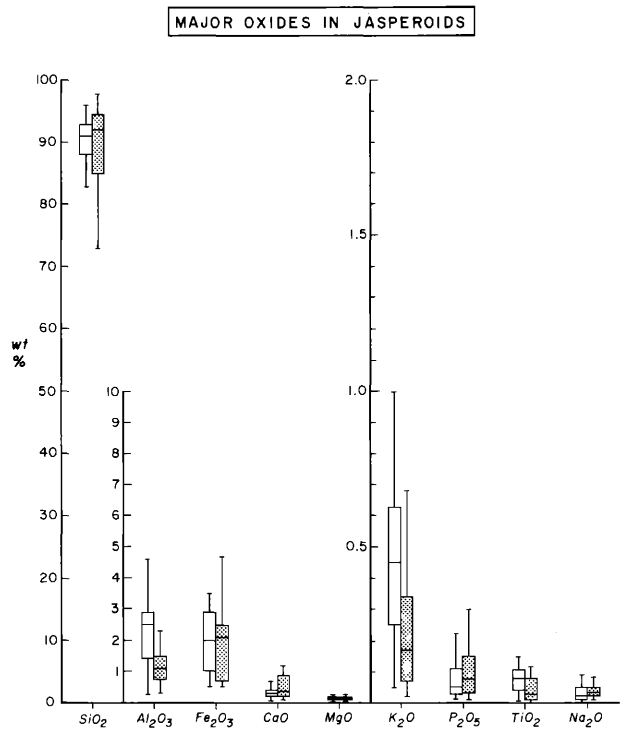

FIG. 2. Multiple box and whisker plot of major oxide data from Holland et al. (1988), appendix I, plotted in order of descending median concentration. Note scale changes. See Figure 1 for explanation of box plots.

tential, it may be possible to screen gold-favorable prospects from unfavorable ones. Based on Holland et al.'s (1988) data set, a gold concentration of greater than about .3 ppm in a jasperoid is the best univariate discriminator of jasperoids associated with Carlin-type gold mineralization. Whether or not this is a trivial observation depends upon the location of the samples relative to the orebodies, and we are given no spatial information. Further, the data suggest that analyzing samples for K, Al, Sr, Mo, La, and possibly W can be useful in evaluating jasperoids. These elements are not routinely run by mining companies exploring for Carlin-type gold deposits. The data also demonstrate that arsenic, which is commonly analyzed along with gold and silver, appears to be a poor indicator for productive jasperoids.

Holland et al. (1988) provide a valuable geochemical data set, but their use of factor analysis obscures several fundamental and useful characteristics of jasperoids associated with gold-barren versus gold-mineralized deposits. These characteristics are best demonstrated with simple (to do and to interpret) graphical univariate statistical techniques, and they may be easily applicable to gold exploration. Holland et al.'s (1988) conclusions for the genesis of Carlin-type gold deposits are not justified by the data that they present. Their genetic model can certainly be viewed as a viable genetic hypothesis that is testable with detailed field and laboratory studies of jasperoids, as well as of other aspects of Carlin-type gold systems.

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Sir: Brian K. Jones and Richard A. Leveille raise a number of points regarding the way in which our comparative study of jasperoid geochemistry (Holland et al., 1988) was framed and the implications that might be drawn from our results. Their primary concerns are with (a) the lack of geologic control for samples, (b) the accuracy of analyses for several critical elements, (c) the specific interpretation of factor 3 and its subsequent use in a discussion of genetic implications, and (d) the evaluation of analytical data by