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NOTAS TECNICAS Y CIENTIFICAS

ZEOLITE ALTERATION AND FORMATION OF GOLD ORE IN A TERTIARY GEOTHERMAL FIELD, LA LIBERTAD, NICARAGUA

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The Tertiary volcanic rocks in central Nicaragua have been affected on a regional scale by burial diagenesis at low-temperature zeolite facies (mordenite subfacies), with inferred thermal gradients of <50°/km. Towards epithermal precious metal deposits the secondary mineralogy gradually changes to a geothermal field type of alteration at a higher grade of the same facies, with thermal gradients of ca 150°C/km (Darce et al., 1989). The La Libertad gold mining district and its surroundings can be used to illustrate the mineralogical and chemical alteration patterns.

Five alteration zones based on mineralogical criteria have been defined in the La Libertad region (Darce, 1990; Fig.1). The rocks in the outermost zone (zone I; regional burial diagenesis at mordenite subfacies; temperature attained <100°C) are unaltered except in originally permeable parts where the volcanic glass and most olivine are replaced by secondary phases. The influence from the fossil geothermal system (zones II to IV) reaches more than 5 km from the outer limit of the mining district, and unaltered rocks are found only locally as patches in massive parts of basic lava flows. The alteration ranges from heulandite subfacies (zone II; temperature ca. 100-120°C) to the transition between laumontite and wairakite subfacies with appearence of epidote at depth (zone IV; temperature about 215 to 260°C).The temperatures are inferred from comparison with data from active geothermal fields (Darce, 1990, table 2). Zone V is a 30-40 m thick illite-kaolinite-bearing cap covering most of the mining district. The aureoles around the auriferous quartz veins consist at depth of quartz, chlorite, adularia, illite and pyrite. The alteration of the country rock, and the formation of the quartz veins and aureoles appear to be expressions of the same geothermal process, with the illite cap as a late-stage development. La Libertad can be classified as an adularia-sericite type of deposit (Darce, 1989,1990).

Major and some minor elements have been determined in ca. 100 samples (gold in half of them) from zones I to V. Analytical procedures are described in Darce (1991). The calculation of chemical gains and losses during the alteration is made by using the average composition of six unaltered samples of basalt from zone I as background values, i.e. the composition of the unaltered rock. The analytical data for each sample is normalized against Ti in order to compensate for density and volume changes during the alteration. Titanium was selected as normalization element

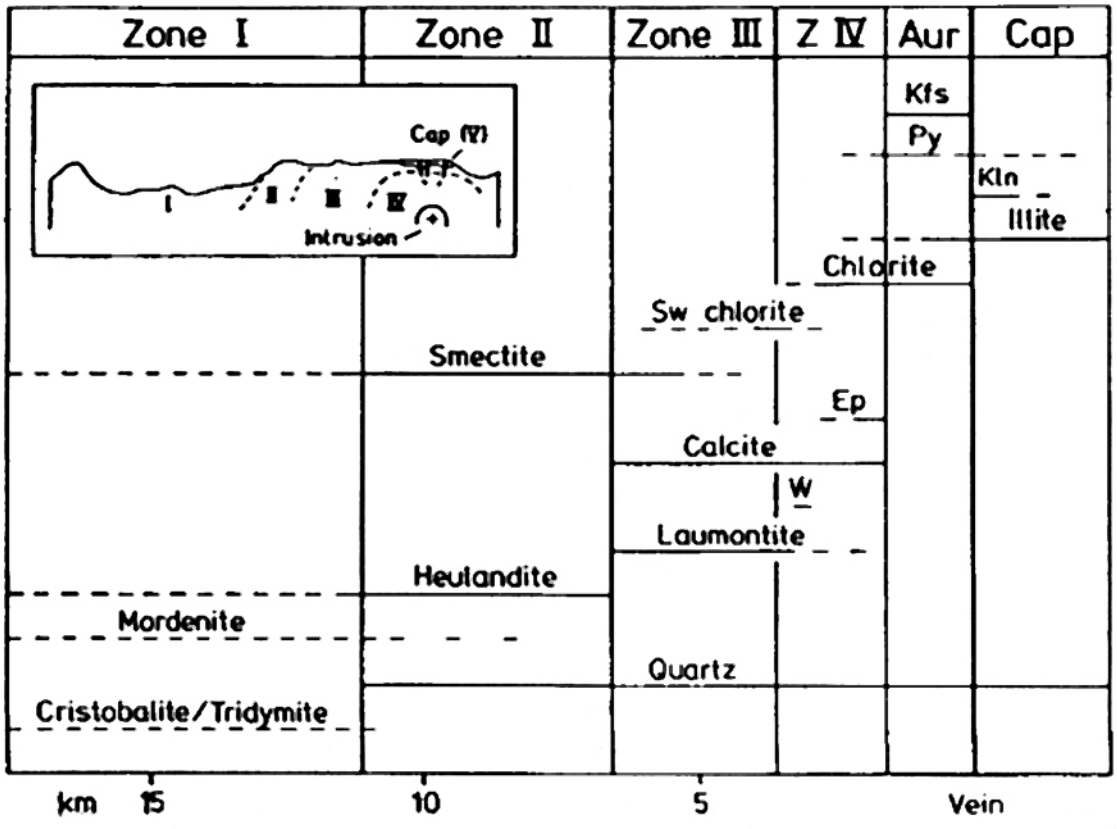

Fig.1. Distribution of secondary minerals in the La Libertad region. The kilometer scale is schematic; the relative scale for aureoles below the cap (=Aur) is stronly exaggerated.
Abbreviations: Ep= epidote, Kfs= K feldspar (adularia), Kln= kaolinite, Py=pyrite, Sw= swelling, W=wairakite. A southwest-northeast profile through the region is given as an inset.

because it appears to have been inmobile in the La Libertad region, and in other areas characterized by geothermal alteration at zeolite facies (e.g. Henneberger & Browne, 1988).

Comparation between the background and the alterated basic lavas from the different alteration zones shows that H_2O, CO_2, K and S have been added and Ni, Mg and Cl partly lost from the fossil geothermal system; Si, Al, Fe, Mn, Na and Cu show only a limited variation (disregarding aureoles and cap), and outcrop samples are low in Ca and Sr (Darce, 1991). The K, probably derived from breakdown of volcanic glass in zone I, became incorporated in heulandite, mordenite and smectite in zone II. The formation of the zeolites suggests oxidizing conditions and neutral to slightly alkaline solutions which is consistent with the absence of kaolinite here. In zone III laumontite takes the place of the K-bearing zeolites, and K is largely bound in swelling chlorite or smectite. The formation of laumontite is controlled by an increase in temperature, a moderately high pH, and a high Ca activity due to breakdown of the original plagioclase and augite. Less alkaline and more reducing conditions prevailed in zone IV, as suggested by the presence of illite and chlorite. Potassium occurs in illite and swelling chlorite, and Ca occurs in the same minerals as in zone III, with a local appearance of epidote and wairakite where the temperature was higher.

An estimate shows that partial leaching of Au from the basic volcanic rocks in the fossil geothermal field released a sufficient quantity to form the La Libertad gold deposit (Darce, 1991). The following reasons suggest that the Au

originally was concentrated in the glass of the basic rocks. The strongest depletion of Au has taken place in zone II and should therefore be related to the most important alteration reactions here: replacement of glass by zeolites and smectite, and olivine by smectite. A lack of correlation between extent of alteration of olivine and Au content argues against olivine as a significant Au source. Since Au commonly follows Cu during magmatic differentiation (Romberger, 1988), its presence in the glass is consistent with the ocurrence of native copper here. Careful inspection of freshly prepared thin sections of unaltered basic lavas from La Libertad region and Recent lavas from western Nicaragua (including samples from historic eruptions at the Masaya volcano) reveals tiny, up to 5 μm large grains of native copper locally in interstitial groundmass glass and melt inclusions in phenocrysts. We believe that the Au was transported as a colloid and precipitated with silica in fractures, forming veins in the center of the geothermal field. Concentration of Au in residual silicate melt (glass) in basic volcanic rocks from Iceland has been reported by Zentilli et al. (1985), who also showed that Au was mobilized during alteration at zeolite facies conditions.

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