Pueblo Viejo High-Sulfidation Epithermal Gold-Silver Deposit,
Dominican Republic: A New Model of Formation beneath Barren Limestone Cover – A Reply

RICHARD H. SILLITOE,
27 West Hill Park, Highgate Village, London N6 6ND, England

DAVID J. HALL,
GoldQuest Mining Corp., 1480-885 West Georgia Street, Vancouver, B.C. V6C 3E8, Canada

STEWARD D. REDWOOD,
P.O. Box 0832-1784, World Trade Center, Panamá, Panama

and ALISTAIR H. WADDELL
GoldQuest Mining Corp., 1480-885 West Georgia Street, Vancouver, B.C. V6C 3E8, Canada

Corresponding author: RHS, e-mail, aucu@compuserve.com
Sir: Muntean et al. (2007) are thanked for their long-anticipated discussion of our reinterpretation of the Pueblo Viejo high-sulfidation epithermal gold-silver deposit as a product of Late Cretaceous-early Tertiary rather than Early Cretaceous magmatism. The reinterpretation is based on evidence that the gold-silver mineralization post- rather than pre-dated deposition of the thick, regionally extensive Hatillo Limestone (Sillitoe et al., 2006). Their discussion tries to diminish the significance of our new district-wide observations, reiterates the limited evidence from the Pueblo Viejo mine, and presents a previously unpublished U-Pb zircon age (regrettably, without the supporting analytical data) and its interpretation. Here we welcome the opportunity to restate the key district-scale features that lead us to conclude that the gold-silver mineralization, along with formation of the adjoining 10-km-long Loma la Cuaba advanced argillic lithocap, took place beneath the Hatillo Limestone before commenting on Muntean et al.’s (2007) main mine area observations and conclusions.

Muntean et al. (2007) infer that the silicification and associated iron oxide replacement described from the base of the Hatillo Limestone is a local feature and possibly even a replacement of an older limestone bed in the underlying Los Ranchos Formation rather than of the Hatillo Limestone itself. Although we present in some detail the drill intercept from Piedra Imán as a type example of the replacement phenomenon, we nowhere imply that the silicification is merely a localized feature. In fact, quartz-iron oxide replacement along the base of the Hatillo Limestone is district-wide and exposed intermittently for at least 3 km along the basal contact of the Limestone with the underlying Los Ranchos Formation as well as occurring as erosional remnants on the dip slope exposed after Hatillo Limestone removal (see Sillitoe et al., 2006; Fig. 2).
Although outcrop is generally poor, especially near the Pueblo Viejo mine, small exposures and contiguous float trains are more numerous and widespread farther west and reveal unambiguous partial replacement of limestone by massive fine-grained silicification plus associated magnetite and derivative hematite. Breccia texture, like that shown in our Figure 3a, and limestone cut by veins and pods of massive silicification, as illustrated by our Figure 3b, are commonplace. There is no possibility that the limestone replaced is any other than the Hatillo. Nevertheless, as clearly stated, the silicification does extend from the limestone into the uppermost parts of the underlying Los Ranchos Formation, thereby making distinction of former limestone and volcanic rocks difficult.

Muntean et al. (2007) repeat the earlier conclusion that the magnetite is the result of contact metasomatism of limestone around diorite intrusions of Eocene age (Koschmann and Gordon, 1950; Bowin, 1966; Kesler et al., 1981; Russell and Kesler, 1991). However, most of the magnetite-hematite deposits are accumulations of boulders rather than in-situ replacements (Koschmann and Gordon, 1950). Moreover, the most important ones were largely mined out decades ago, thereby removing most of the geologic evidence. It is worth pointing out, however, that no calcic skarn has been recorded in association with any of the magnetite deposits. Furthermore, no magnetite is present at limestone-diorite sill contacts drilled by GoldQuest Mining Corp. on Loma la Mina, although minor pyroxene endoskarn was observed at a single contact. The largest magnetite accumulations were at Las Lagunas – adjacent to the Pueblo Viejo mine gate – and Hatillo. The latter was almost certainly an erosional product of magnetite replacements on Loma la Cuaba, like that drilled by GoldQuest Mining Corp. at Piedra Imán, and the source of the former, if it consisted of magnetite-hematite boulders.
(Koschmann and Gordon, 1950), may be inferred to be the former Hatillo Limestone cap to the Pueblo Viejo deposit.

We reiterate the new stratigraphic evidence from drill holes southwest of Pueblo Viejo in the Margajita valley and at Loma la Mina (see Sillitoe et al., 2006; Fig. 2), which show that Hatillo Limestone conformably overlies the Los Ranchos Formation volcanic rocks rather than being separated from them by either a thrust fault or regional unconformity. The lower part of the Hatillo Limestone (or upper part of the Los Ranchos Formation) is a dark-colored, well-bedded limestone with black shale intercalations and a few tuff beds, which is gradational upward to the massive micritic limestone typical of the Hatillo. Consequently, it would be difficult, if not impossible, to generate the Pueblo Viejo orebodies and associated Loma la Cuaba lithocap between Los Ranchos and Hatillo Limestone times.

A key facet of our evidence, the identical lithogeochemistry of the quartz-iron oxide rock and the Pueblo Viejo orebodies, except for the absence of appreciable gold in the former, was studiously ignored by Muntean et al. (2007). This distinctive Cu-Pb-Mo-Bi-As-Sb-Hg-Se-Te-Ba signature is surely the best evidence for a direct connection between hydrothermal fluid associated with the Pueblo Viejo orebodies and that responsible for the Hatillo Limestone replacement. The limestone-replacing fluid is interpreted as a distal equivalent of the ore fluid, which flowed laterally beneath the Hatillo Limestone aquitard. The geochemical anomalism associated with the base of the Hatillo Limestone extends west of Hatillo Lake, beyond the main Loma la Cuaba lithocap discussed by Sillitoe et al. (2006); therefore it is unsurprising that magnetite
occurrences occur in that area too, as re-emphasized by Muntean et al. (2007). None of the massive silicification at Loma la Cuaba shows any sign of being supergene (or paleosupergene) in origin, as asserted by Russell and Kesler (1991) and Muntean et al. (2007) for an occurrence immediately beneath the Hatillo Limestone in the Pueblo Viejo mine area.

We accept the fact that the highest gold grades in the Monte Negro orebody at Pueblo Viejo were controlled by the contact between the carbonaceous sedimentary rocks and underlying volcanic sequence (Muntean et al., 1990, 2007). However, it also needs to be emphasized that the highest ground alongside the open pits, and immediately above the ore zones, is underlain by massive, cherty, hematitic silicification identical to that farther west on Loma la Cuaba. We interpret this silicification to have formed at the top of the Los Ranchos Formation, just below the Hatillo Limestone, which on geologic sections can be projected northward over the entire mine area.

Kesler et al. (1981) and Muntean et al. (2007) refer to cobbles of silicified rock in the Los Ranchos Formation within the Pueblo Viejo orebodies as evidence for broadly coeval sedimentation, alteration and, by inference, gold-silver mineralization. In the open pits, we have observed sedimentary clasts in conglomerate that were preferentially silicified (or leached to produce vuggy quartz) during the ore-forming event; late-stage, strata-bound pebble dikes containing clasts of silicified rock that were presumably derived from elsewhere in the same orebody; and true sedimentary clasts of silicified rock derived from pre-existing silicified zones. Before clasts of silicified rock can be used as evidence for broadly synsedimentary mineralization during the Early
Cretaceous, their origin must first be confidently determined. Then the clasts that are truly of pre-existing silicified rock must be shown to be gold-bearing prior to incorporation in the conglomerate horizon (no easy matter since they are part of the host rock to the gold-silver orebodies) as well as texturally identical to silicification developed during early stages of orebody formation rather than silicification that existed in some unrelated external source area. Such evidence, if it exists, has never been reported.

Muntean et al. (2007) describe a mafic dike that cuts the ore-bearing carbonaceous siltstone in the Monte Negro orebody at Pueblo Viejo as intermineral in timing because it has different alteration and a much lower gold content than the surrounding siltstone-hosted ore. These observations could, as they claim, be indicative of intermineral emplacement, following the main stage of gold-silver introduction, but they could equally well reflect the less receptive and/or less permeable nature if the dike vis-à-vis the thinly bedded and formerly carbonate-bearing siltstone. As Kirkham (1971) pointed out, intermineral dikes can only be confidently identified where they either clearly truncate veins or veinlets in the surrounding rock or contain xenoliths of previously mineralized rock. Neither of these criteria is satisfied by Muntean et al.’s description. Therefore the 109-Ma U-Pb zircon age reported by Muntean et al. (2007) is not necessarily an intermineral age, but could equally well simply reflect the age of dike emplacement during the Early Cretaceous accumulation of the Los Ranchos Formation.

Muntean et al. (2007) restate the opinion of Kesler et al. (2005) that the range of $^{40}\text{Ar}/^{39}\text{Ar}$ ages (62-77 Ma) determined previously for alunite from depth in the Pueblo
Viejo deposit must be due to different degrees of resetting of an original Early Cretaceous (~111-Ma) age by a postmineral thermal overprint, and cannot approximate the timing of the mineralization event because the hydrothermal lifespans of high-sulfidation epithermal deposits do not last for 15 m.y. Obviously, as they are well aware, we do not imply such longevity for the Pueblo Viejo system, but simply prefer the notion that the ages provide a rough estimate for the timing of the mineralization while accepting that the determinations, unlike those for alunite from most high-sulfidation deposits, fail to provide a precise age. One plausible interpretation would be that the mineralization took place at 77 Ma and that the younger ages, including the 58- and 46.1-Ma sericite ages cited by Muntean et al. (2007), are the products of subsequent argon loss or some other currently unknown factor.

Muntean et al. (2007) take issue with our assumed temperature of 285°C for the gold-silver mineralization at Pueblo Viejo and imply that the mineralization temperature may have been much lower and capable of generating only kaolinite as an alteration mineral rather than the widely observed pyrophyllite. They propose that the kaolinite (plus quartz) was subsequently transformed to pyrophyllite in response to heating by a Late Cretaceous intrusion. First, it should be emphasized that the assumed temperature was taken directly from Muntean et al. (1990), who documented gold deposition during the pyrophyllite and accompanying silicification stage. Second, the chances of billions of tons of kaolinite-bearing rock throughout the Pueblo Viejo orebodies and Loma la Cuaba lithocap being transformed to pyrophyllite during later epizonal intrusion are considered slight. We contend, of course, that the Late Cretaceous magmatic event that
Muntean et al. (2007) invoke for this mineralogic transformation is, in fact, the mineralization event itself.

Therefore, in conclusion, we suggest that the district-scale evidence for post-Hatillo Limestone alteration and gold-silver introduction at Pueblo Viejo is difficult to ignore and is certainly not outweighed by the evidence mustered by Muntean et al. (2007) from the Pueblo Viejo orebodies. Muntean et al. (2007) rather facetiously suggest that we were bewitched by some previously undocumented genus of Late Cretaceous sea nymph, whereas in fact the district-scale evidence simply spoke for itself. May we remind them that the proper understanding of any mineral deposit depends on not just a detailed analysis of the ore zone itself but also its district setting; unfortunately, their studies were confined to the open pits. Porphyry copper-related lithocaps are commonly on the order of 10 to 25 km across, a scale consistent with the regional extent of silicification and magnetite in and around the Pueblo Viejo district. This fact is especially critical for those engaged in either green- or brownfield exploration. In this regard, it is encouraging to learn that direct application of our new Pueblo Viejo model elsewhere in the Dominican Republic recently resulted in the discovery of gold mineralization at the Juan del Bosque prospect, where the associated advanced argillic alteration and contained barite reportedly occur beneath the silicified base of a Cretaceous limestone sequence (Unigold Inc., press release, 11 June 2007). As always, the proof of the pudding is in the eating.
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REFERENCES


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