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DISCUSSION

Stephen E. Kesler · Norman Russell

Discussion of: Nelson, C.E., 2000, Volcanic domes and gold mineralization in the Pueblo Viejo district, Dominican Republic. *Mineralium Deposita*, vol. 35, pp. 511–525

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Introduction

The recent description by Nelson (2000) of the Pueblo Viejo gold deposit in the Dominican Republic indicates that ore is spatially and temporally related to previously unrecognized volcanic domes. This varies from our interpretation (Russell and Kesler 1991) that ore is the product of hydrothermal systems driven by concealed intrusions deep in the basin or maar that hosts mineralization. The difference between these interpretations is important, because Pueblo Viejo is one of the largest and most economically rewarding acid-sulfate (high-sulfidation) precious metal deposits in the world. Better knowledge of its geologic setting could aid exploration for similar deposits and help place Pueblo Viejo in the continually evolving spectrum of models for mineralization of this type (Heald et al. 1987; Sillitoe 1993; Arribas 1995). Our concern with the geologic setting presented by Nelson centers on the geographic scope of the study, the evidence provided for the proposed domes, and the possible role of these domes in gold mineralization.

Geographic scope

Geologic mapping that forms the basis for Nelson's report covers the 15 km^2 Pueblo Viejo district, which is a very small part of the 500 km^2 that we have mapped in the ore-hosting Los Ranchos Formation (Kesler et al. 1981, 1991). On the basis of his work, Nelson (2000) suggests that our "layer-cake stratigraphy" for the Los Ranchos Formation should be revised because of interfingering of lithologic units. However, he provides information on the stratigraphy of only the uppermost Los Ranchos Formation and ignores stratigraphically lower units that make up at least 80% of the formation. We have shown that this upper part is characterized by interfingering of the upper part of the Meladito Member with the generally overlying Platanal, Zambrana, and Pueblo Viejo Members (Kesler et al. 1991, Fig. 5) and recently discussed changes in stratigraphic relations in this part of the section that might be indicated by new exposures (Kesler 1998). While we are certain that increased exposure and more detailed mapping will lead to revisions of our stratigraphic column for the Los Ranchos Formation, they should be based on a more complete coverage of the Los Ranchos Formation than provided by Nelson (2000). As noted below, this lack of regional perspective might also have led to misconceptions about the presence of volcanic domes at Pueblo Viejo.

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Geological evidence for domes at Pueblo Viejo

The main focus of the work by Nelson (2000) is the presence of volcanic domes in the Pueblo Viejo area, which were apparently not recognized as such in our earlier mapping. Curiously, Nelson (2000) presents poor and, in some cases, no evidence for the presence of these domes of both mafic and felsic compositions, which he claims to have been the source of mineralization.

Seven orebodies at Pueblo Viejo are proposed to be underlain by andesite domes. These domes are in the Platanal Spilite Member of the Los Ranchos Formation, which Nelson (2000) suggests should be renamed andesite. We have already pointed out that these rocks are andesite (Kesler et al. 1991, p. 190) and noted that the term spilite is retained because other important, correlative units in the Caribbean region are referred to by this name (Donnelly 1966; Donnelly et al. 1990; Lebron and Perfit 1993). Platanal Spilite is exposed westward from Pueblo Viejo for at least 5 km and beyond that is covered by the Hatillo Limestone. Nelson (2000) does not show that his proposed domes differ in any way from this extensive unit. The spilite thins abruptly at the edge of the Pueblo Viejo basin or maar and irregularities at this transition might be interpreted as domes if the regional context is ignored.

Most of the andesite domes proposed by Nelson are simply not shown in his cross sections or are not described in sufficient detail to evaluate their existence or relation to orebodies. The *Cumba orebody* is hosted entirely by Platanal Spilite at the edge of the basin. Our drilling here intersected spilitic agglomerate that could be breccia marginal to a dome, but is more reasonably interpreted to be fragmental rocks deposited on the margin of the basin, at least until its three-dimensional relation to a dome is made clear. The *Bench 5 orebody* is hosted by carbonaceous sediments at the southern edge of the district. Our mapping and drilling in this area did not find spilite (andesite) at depth, although Eocene-age diorite is widespread immediately to the south and west. As noted below, Nelson (2000) misidentifies Eocene diorite dike material as Cretaceous-age andesite in Monte Negro and might have done so here, although after stating that the Bench 5 orebody is associated with an andesite dome, he does not mention it again. Similarly, Nelson (2000) states that the two orebodies at *Arroyo Hondo* are associated with andesite domes that we did not recognize, but does not comment further on evidence for the domes.

The *Mejita and East Mejita orebodies* are also alleged to be associated with andesite domes, but these are not described or illustrated by Nelson (2000). Our interpretation of these orebodies is that they are simply eastward continuations of the large Moore orebody that have been separated from it by erosion (Kesler et al. 1981, Fig. 3; Russell and Kesler 1991, Fig. 2), an interpretation that is supported by the gold grade contours of Nelson (2000, Fig. 4). Drilling at both Mejita and East Mejita confirms that these orebodies are shallow and do not appear to have any roots. At Mejita the orebody is underlain by a thin layer of spilite that does not have a domal shape and the spilite is underlain in turn by conglomerate containing coral fragments, which we have correlated with the Meladito Member.

At *Monte Negro*, Nelson (2000, Fig. 6) shows the South Monte Negro dome and a "buried dome" beneath the southern part of the orebody. Note that these domes merge to form a single contact between spilite (below) and sediments (above), that the contact is sloped in the direction of the sedimentary basin or maar, and that only one drill hole shows sediment below the inferred domes. Essentially equivalent cross sections in Kesler et al. (1981, Fig. 3) and Russell and Kesler (1991, Fig. 2) show that the spilite forms an irregular basement for carbonaceous sediments. In the most southerly of the two sections shown by Russell and Kesler (1991, Fig. 2), the spilite does appear to have a domal shape, but a north–south section through the same location (Russell et al. 1986, Fig. 3) shows that there is no domal geometry and that the spilite has a smooth, gently sloping upper surface that continues into the main mass of the Platanal Spilite to the north.

Nelson (2000) proposes that the large *Moore orebody* is related to an intrusive dacite dome that we consider to be an allochthonous block of lapilli tuff. We have referred to this unit in previous publications as quartz porphyry agglomerate (Kesler et al. 1981) and lapilli-ash tuff (Russell and Kesler 1991) and will refer to it below as "quartz-eye unit" because it is identified by large quartz grains. Nelson (2000) claims that the quartz-eye unit consists of massive, flow-banded dacite with unsorted breccia on its margins. In thousands of meters of core, we have observed only fragmental quartz-eye material with no well-developed flow banding. Nelson (2000, Fig. 4) also claims that the unit has a feeder zone that extends into deeper parts of the basin or maar. This possibility was of interest to us from the beginning of exploration and the first detailed drill program was designed to search for such a feeder zone. Approximately 25 diamond drill holes and another 50 rotary holes confirmed that the basal contact of the quartz-eye unit is flat and that there was no evidence for a feeder zone below it (Fig. 1). Nelson depicts the western edge of the quartz-eye unit as flaring out over the carbonaceous sediments, whereas our detailed drilling shows that the contact is almost vertical. Nelson (2000) claims to have detected a 5-m-wide baked zone at the northern contact of the unit, but the only characteristic that he describes is a brown color. Considering that the contact is between intensely silicified, mineralized carbonaceous sedimentary rocks and pyrophyllitic, unbedded fragmental rocks, color is not good evidence of a baked zone. Nelson (2000) states that the quartz-eye unit contains abundant xenoliths of carbonaceous sedimentary rock, whereas all of the fragments that we have seen consist of other igneous rocks. This distinction is important because it precludes emplacement of the quartz-eye unit by intrusion through the carbonaceous sediments. We consider it more likely that the apparent xenoliths of carbonaceous sedimentary rocks described by Nelson (2000) reflect interfingering or faulting of adjacent sedimentary rock and quartz-eye unit.

We described quartz eyes in the carbonaceous sedimentary rocks that border the quartz-eye unit on its western margin and interpreted this as clear evidence that the quartz eyes were shed from the quartz-eye unit during its burial beneath continuing sedimentation (Russell and Kesler 1991). Nelson (2000) also says that quartz eyes in the sedimentary rocks were derived from the quartz-eye unit, but does not explain how these same rocks were apparently intruded by the quartz-eye unit. We conclude that there are two possible explanations for the origin of the quartz-eye unit: either it was erupted into the basin from the south, or it represents a large block of an original lapilli tuff ring (i.e., quartz-eye unit) that collapsed into the basin. We favor the latter explanation, because the central, deeper part of the basin is filled with coarsely fragmental rocks, containing quartz eyes (Fig. 1). These rocks are not identical to the quartz-eye unit, because they are poorly sorted and locally layered. However, they do contain the same lithologic components, except for lenticular, ragged-ended, mafic clasts, whose shape would have been altered during transportation (Russell and Kesler 1991). There is only one known rock type in the Pueblo Viejo area that could have supplied the quartz eyes in this

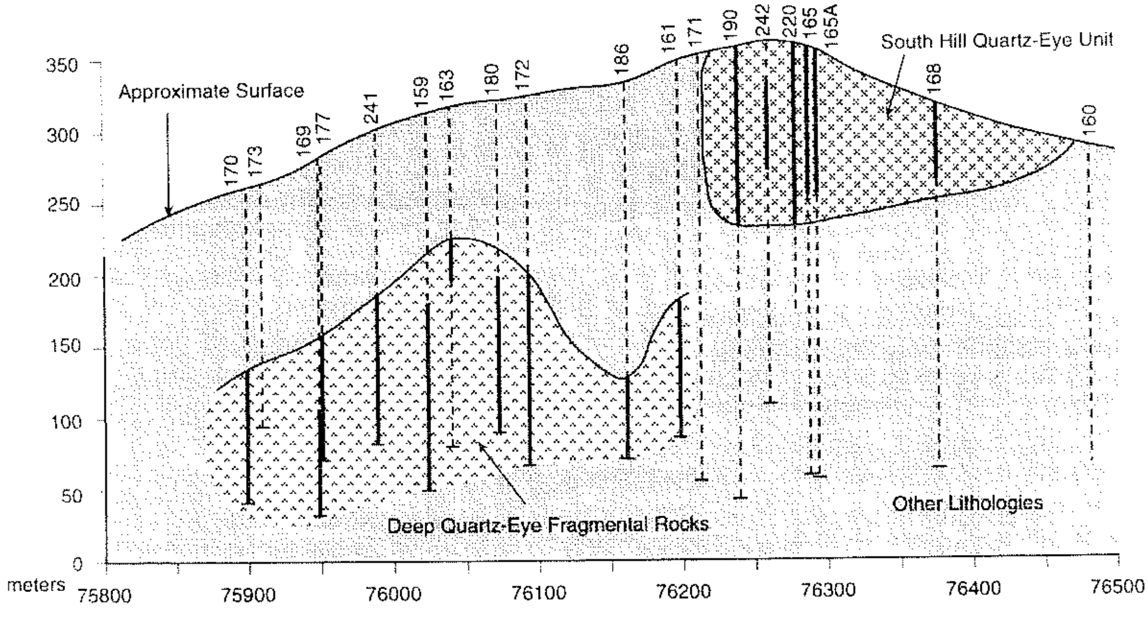

Fig. 1 North-looking geologic cross section through the Moore orebody showing core holes from adjacent sections as distant as 300 m on both sides, projected to section 94,600N. Note that the base of the South Hill Quartz-Eye Unit (i.e., dacite dome) is roughly planar and that numerous holes make it impossible to place a feeder zone beneath the quartz-eye unit or to connect it to the quartz-eye fragmental rocks found at depth in the basin or diatreme

material and that is the quartz-eye unit. We therefore concluded that the basin was originally surrounded by volcanic debris that was eroded into the basin, forming quartz-eye conglomerate in the central, deeper part of the basin (Russell and Kesler 1991). We interpreted the quartz-eye unit at Moore as a large remnant of the tuff ring that foundered into the maar as a block. Nelson (2000) mostly ignores the drill hole records of the rocks deep in the central part of the basin and makes no attempt to relate the quartz eyes in these rocks to the quartz eyes in the fragmental unit at Moore.

Although the presence or absence of andesite dikes at Pueblo Viejo is not critical to his dome model, Nelson (2000) states that we have misidentified the large diorite dike in the Monte Negro deposit as one of the many dikes and sills of Eocene-age diorite that cut the Pueblo Viejo area. The Monte Negro dike cuts mineralized and altered carbonaceous sedimentary rocks and spilite at Monte Negro, yet the dike itself is barren of ore. Nelson (2000) claims that the presence of sericite in the dike is proof of hydrothermal alteration associated with gold deposition. However, rocks surrounding the dike are mainly altered to quartz and pyrophyllite, and lack sericite. It is unlikely that a single episode of mineralization would produce such different alteration–mineralization suites in the dike and surrounding rocks. Contact iron deposits of the Las Lagunas district, which formed when the Eocene-age diorite dikes intruded the Hatillo Limestone (which overlies the Los Ranchos Formation), are found immediately south of the Pueblo Viejo mine. Formation of these magnetite deposits required that the diorite intrude the Pueblo Viejo Member at numerous locations in this area. Nelson (2000) also suggests that the contact between the Pueblo Viejo Member and Hatillo Limestone is a thrust fault, presumably in an attempt to explain why diorite dikes cutting the limestone do not continue at depth into the Pueblo Viejo Member. Although this contact might be thrusted locally, it is clearly a depositional contact as described by Russell and Kesler (1991, Fig. 4) in outcrops that were covered by tailings before Nelson's fieldwork. We have also identified elements of these basal beds in the area between Moore and Monte Negro (Russell and Kesler 1991, Fig. 1), which are evidence that thrust faulting at the base of the Hatillo Limestone was of minor importance at Pueblo Viejo.

Role of domes in mineralization at Pueblo Viejo

Nelson (2000) suggests that "gold mineralization is spatially and temporally related to ... volcanic domes" and that "exploration efforts within the Los Ranchos Formation should focus on volcanic dome fields." We are concerned by two aspects of this implied relation.

First, almost no evidence is shown to support an association between ore and domes. Our grade contours (Russell and Kesler 1991, Fig. 2) show that the quartz-eye unit at Moore is essentially barren and ore is hosted largely by carbonaceous sedimentary rocks. Nelson (2000, Fig. 4) shows that the quartz-eye unit is essentially barren and his figure also shows continuity of gold grade between two orebodies that he claims were formed separately by a dacite dome (Moore) and an andesite dome (Mejita). As noted above, these are parts of a single orebody that was dissected by erosion along a stream valley. Nelson (2000) provides information for comparison of grade and andesite domes only at Monte Negro, where he shows a root of ore extending into the "buried andesite dome." Nelson (2000) does not refer to our description of Monte Negro, which shows distributions of Au, Ag, Te, Hg, Cu, Sb, Zn, and Ba in the unoxidized ore (Russell et al. 1986, Fig. 5). The sections clearly show that Monte Negro mineralization forms a single lens along the gently dipping contact of the spilite and overlying sedimentary rocks. It is inconceivable that the distribution of these elements reflects three separate mineralizing events from three domes.

Second, we have difficulty envisioning geologic processes in which volcanic domes of widely different chemical composition (mafic and felsic) could play (simultaneously) an active role in formation of epithermal mineralization. Nelson (2000, p. 524) notes that "Volcanic domes at Pueblo Viejo are too small to drive the hydrothermal cells that were responsible for gold mineralization." We heartily agree with this statement. But, if the alleged domes did not provide clear structural or lithologic control and did not drive the systems, then what did they do? We think that they did nothing, simply because they do not exist.

Reassessment of the maar–diatreme setting for Pueblo Viejo mineralization

The key question here is not whether Pueblo Viejo contains domes but whether it is hosted by a maar–diatreme complex. New outcrops, changing perceptions of global geology, and a distinct swing of the maar–diatreme pendulum (Henley 1995) make it appropriate to reassess this question here. Rampino and Caldiera (1993) have shown that there was a global anoxic event in the world ocean at about 116 Ma, which coincides approximately with the age of carbonaceous sedimentary rocks at Pueblo Viejo, as indicated by Neocomian plant fossils (Smiley 1982, unpublished). Thus, a restricted maar basin might not be necessary to account for these anomalous sediments. The southern margin of the basin (or maar) at Pueblo Viejo is concealed beneath Hatillo Limestone, leaving open the question of whether the basin was isolated or open to the sea. There is also uncertainty about the age of mineralization, as measured by ^{40}Ar–^{39}Ar on alunite from the core of the system. Ages of 61.6 to 67.8 Ma were originally reported by Kesler et al. (1981) for alunite from the Moore deposit and additional Ar–Ar measurements by Greg Arehart and Ken Foland on alunites from DDH-170–176 m in the Monte Negro deposit yield similar, but not identical, total fusion ages of 77.0 ± 0.3 Ma and 77.7 ± 0.6 Ma. Both sets of alunites are from clearly primary, main stage alunite–pyrite-quartz assemblages deep in the deposit. The Late Cretaceous ages that they yield are much younger than the age of the Los Ranchos Formation, which is of Early Cretaceous age.

These anti-diatreme observations must be considered in the context of other constraints. First, two-stage model lead ages for vein minerals at Pueblo Viejo range from 144 to 115 Ma (Cumming et al. 1982), connecting mineralization with Los Ranchos-age volcanism. Second, Kettler et al. (1992) showed that siderite and sulfide minerals in the Pueblo Viejo Member carbonaceous sedimentary rocks formed during diagenesis of fresh water sediments rather than marine sediments, making its correlation with global oceanic anoxia unlikely. Third, Muntean et al. (1990) and Vennemann et al. (1993) showed that mineralization at Pueblo Viejo formed from fluids that were strongly magmatic in composition and that the hydrothermal system was isolated from surrounding rocks by an impermeable zone in which fractures were filled by calcite and gypsum. Fourth, all mapping in the area confirms that rocks beneath the carbonaceous sedimentary rocks differ from "stratigraphically equivalent" rocks elsewhere in the Los Ranchos Formation. Finally, although traces of similar mineralization are found in other correlative rocks in the Greater Antilles (Donnelly and Rodgers 1980; Kesler et al. 1991), high-grade, large orebodies have only been found at Pueblo Viejo, which consists of highly fragmented volcanic rocks underlying an isolated, fresh water sedimentary basin that was permeated by magmatic fluids.

Conclusions

We conclude that the mineralized area of Pueblo Viejo was not the result of emplacement of scattered andesite and dacite domes, with mineralization associated with each dome overlapping and interfingering with mineralization from neighboring domes. Instead, the geology of the area shows that mineralization is associated with the perimeter of a basin that probably formed as a maar–diatreme complex. Nelson (2000) states that the domes are surrounded by pyroclastic aprons, but his own illustrations show that what he interprets as pyroclastic aprons are invariably distributed with a strong bias toward the center of a single circular structure. It is perhaps significant that the most important new rock type that he introduces to Pueblo Viejo, namely "massive andesite porphyry domes", does not appear in any illustration prior to his final Fig. 9, which is a geologic model. Thus, if the domal features exist at all, they are simply incidental to the formation of a large gold deposit that owes its formation to deep magmatic processes indicated by geologic, geochemical, and isotopic data. Whether or not the underlying magmatic processes are related to a buried porphyry copper system, as we suggest, cannot be determined at this time, but we invite comparison of Fig. 3 in Kesler et al. (1981) to Fig. 4 in Hedenquist et al. (1998), keeping in mind that DDH-161 (Fig. 1) cut sections of massive enargite–pyrite rock as thick as 8 m and averaging 4.4% Cu.

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DISCUSSION

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Reply to Discussion of: Nelson, C.E., 2000, Volcanic domes and gold mineralization in the Pueblo Viejo district, Dominican Republic. *Mineralium Deposita*, vol. 35, pp. 511–525

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Introduction

In their discussion of Nelson (2000), Kesler and Russell argue that the evidence presented for volcanic domes is weak, that the geographic scope of the study is limited, and that a maar–diatreme is still the preferred geologic setting for the Pueblo Viejo district. I accept the comments in the constructive spirit that they are offered and I welcome this opportunity to reply.

Geologic evidence for domes at Pueblo Viejo

Kesler and Russell point out that a color change in the carbonaceous sedimentary rocks adjacent to dacite porphyry in the Moore deposit is insufficient evidence for intrusion. If this were the only evidence presented, I would certainly agree. However, the comments by Kesler and Russell ignore much of the evidence I cited. These observations, listed below, together provide convincing evidence of an intrusive origin for the massive dacite porphyry. Specifically:

- The contact between massive dacite porphyry and carbonaceous sedimentary rocks is crosscutting rather than conformable.
- Xenoliths of carbonaceous sedimentary rock occur within the massive dacite porphyry.
- Carbonaceous sedimentary rocks adjacent to the contact are hardened and recrystallized, as opposed to hydrothermally altered, forming a contact metamorphic aureole that extends for as much as 5 m into the surrounding sedimentary rock section.
- Carbonaceous sedimentary rocks, horizontally bedded throughout most of the district, tilt steeply away from their contact with the dacite porphyry.

Kesler and Russell go on to point out that numerous drill holes document a flat basal contact for the dacite porphyry and that a flat contact is inconsistent with intrusion. However, Kesler and Russell's own cross section shows *both* a flat contact *and* a near-vertical contact. Given a near-vertical contact with subhorizontal sedimentary rocks, options for the dacite porphyry (their South Hill quartz-eye unit) include faulting or intrusion. Which option they prefer is not clear because the figure presented by Kesler and Russell shows no structure at all, surprising in an ore deposit (Moore) that contains in excess of 20 M oz. Au (Ruiz 1997). My cross section (Nelson 2000, Fig. 4) is drawn through the dacite porphyry vent area, where *inclined* drill holes document a funnel-shaped crosscutting contact. This funnel-shaped contact, shown as near vertical on Kesler and Russell's Fig. 1, is located directly beneath outcrops that expose a crosscutting contact and contact metamorphic aureole.

Kesler and Russell, in their Fig. 1, refer to the dacite porphyry as the "South Hill quartz-eye unit." This same rock unit was identified as "quartz porphyry agglomerate" by Kesler et al. (1981) and was referred to as "lapilli tuff" by Russell and Kesler (1991). Such variety and ambiguity of rock names suggest that Kesler and Russell are not sure themselves of what to call the dacite porphyry. The uncertainty is resolved by recognition of a volcanic dome – a rock unit that includes *both* intrusive *and* extrusive facies. Massive dacite porphyry and dacite porphyry vent breccia intrude surrounding epiclastic sedimentary rocks in the vent area. Dacite porphyry flows, dacite porphyry debris flows, and a dacite porphyry pyroclastic apron exhibit flat-lying, conformable contacts with surrounding epiclastic sedimentary rocks. Mapping of separate volcanic facies within the dacite porphyry and recognition of the contact metamorphic aureole in surrounding sedimentary rocks resolve the objections raised by Kesler and Russell over flat-lying contacts and evidence for intrusion.

Kesler and Russell argue that my maps fail to identify volcanic domes and that no domes appear until a schematic section (Fig. 8; Nelson 2000) provided near the end of the article. I must point out that six volcanic domes appear and are clearly labeled as domes on the regional geologic map (Fig. 3; Nelson 2000). Also, two volcanic domes appear on the geologic map and section of the Moore deposit (Fig. 4; Nelson 2000), and two more volcanic domes are shown on the Monte Negro map and section (Fig. 6; Nelson 2000). Unfortunately, some of the patterns used to distinguish between andesite flows, domes, and pyroclastic aprons did not show up clearly on the regional geologic map (Fig. 3; Nelson 2000). To clarify this omission, the regional geologic map is reprinted here (Fig. 1).

Geographic scope

Kesler and Russell argue that my revision of their stratigraphy ignores 80% of the Los Ranchos section. I would counter that a stratigraphy that does not work in the Pueblo Viejo district is bound to be inadequate for the rest of the Los Ranchos Formation. There is no better exposure anywhere in the Los Ranchos For-

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mation than that provided by a quarter century of mining at Pueblo Viejo. With respect to the area of coverage, my regional-scale geologic map of Pueblo Viejo (Fig. 1) covers the same area as the maps published by Kesler et al. (1981) and Russell and Kesler (1991). As to the 500 km^2 that Kesler and Russell claim to have mapped, I can only note that the entire Los Ranchos Formation in the Dominican Republic does not approach 500 km^2 (Toloczyki and Ramirez 1991).

The revised volcanic stratigraphy that I define for the Pueblo Viejo district avoids the inconsistencies inherent in the four-member layer-cake stratigraphy proposed by Kesler et al. (1981) and later revised to six members by Russell and Kesler (1991). Specifically, Kesler and Russell's Platanal Spilite overlies what they map as stratigraphically higher Pueblo Viejo Member in the Monte Negro deposit (Fig. 6; Nelson 2000). In addition, the Meladito Member overlies what they map as stratigraphically higher Platanal Spilite in the Upper Mejita deposit (Fig. 4; Nelson 2000). Given numerous such inconsistencies, I decided to simply map rock units (1:2,000 scale pit maps built bench by bench) and let the stratigraphy construct itself. What evolved was a series of separate volcanic centers each of which is surrounded by epiclastic carbonaceous sedimentary rocks of similar composition. Given this

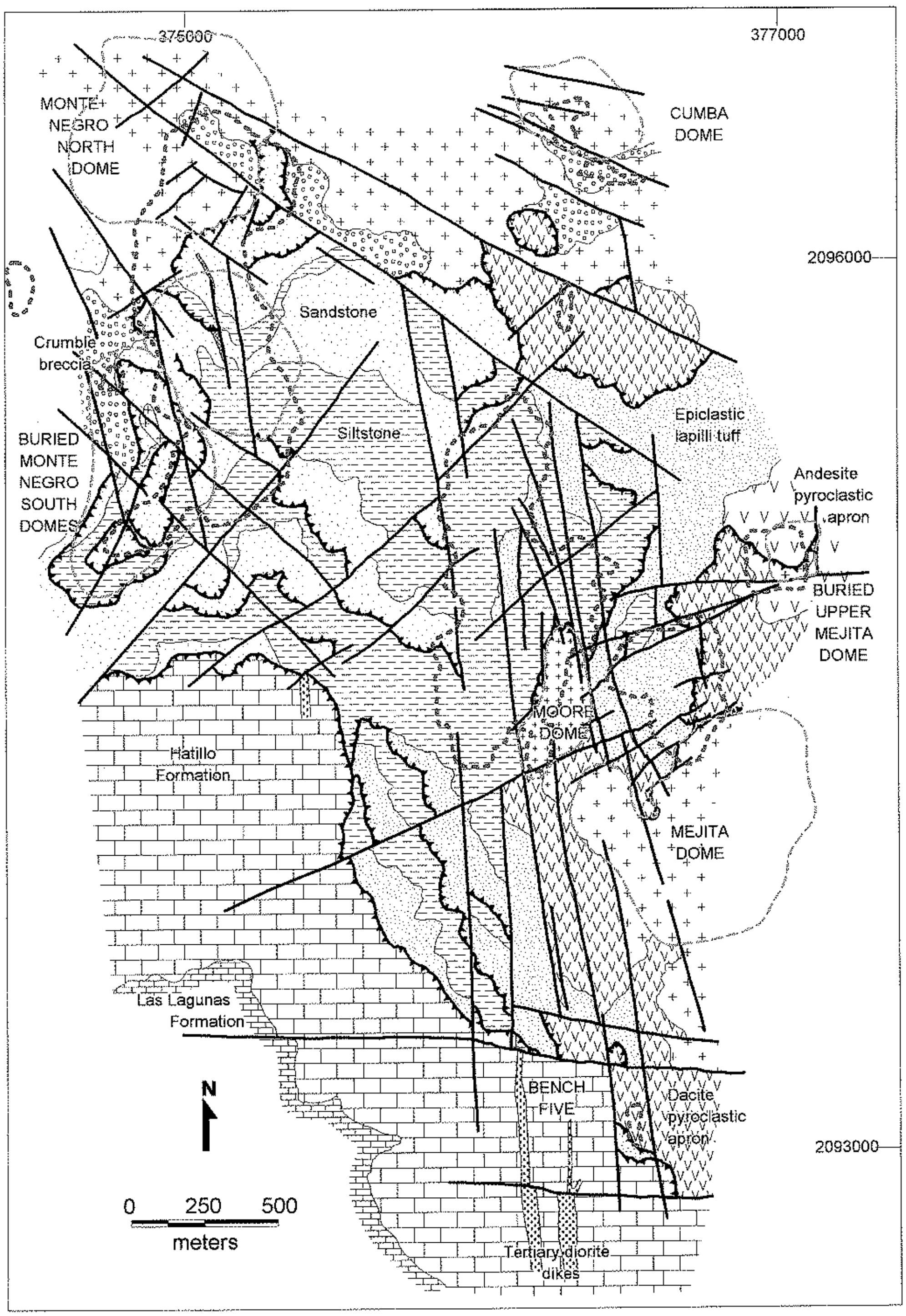

Fig. 1 Geologic map of the Pueblo Viejo district showing the location of volcanic domes within the Los Ranchos Formation (*green dashed line*) and open pit outlines (*red dotted line*). Strike and dip symbols are omitted for clarity; sedimentary units are subhorizontal. A stratigraphic section appears in Fig. 2 of Nelson (2000). This figure was originally published as Fig. 3 (Nelson 2000)

revised stratigraphy, sedimentary intervals are no longer constrained to the uppermost Pueblo Viejo Member. They can (and do) overlie and underlie andesitic volcanic domes previously mapped as Platanal Spilite. In similar fashion, the Moore dacite porphyry dome, previously referred to as lapilli tuff, is younger than some and older than other nearby volcanic centers of andesitic composition.

Thinly bedded, carbonaceous sedimentary rocks are present at a number of other prospects in the Los Ranchos Formation (e.g., Guaimarote and Managua in the Bayaguana district, Loma de Payabo east of Pueblo Viejo). Together with mapping in the Pueblo Viejo district, these exposures define the arcuate margin of an Early Cretaceous coastline. In addition, volcanic domes have been mapped at a number of high sulfidation epithermal prospects in the Los Ranchos Formation, including at Managua, Trinidad, and Dona Amanda. Regional geologic mapping in the Los Ranchos Formation supports, rather than contradicts, the link between volcanic dome fields and gold mineralization. It also supports, rather than contradicts, the volcanic stratigraphy that I describe for the Los Ranchos Formation.

With respect to nomenclature, I abandon the terms spilite and keratophyre and refer to these rock units using the terms andesite and dacite. In support of this change, I offer the recommendation of Cas and Wright (1995, pp. 18–19) who cite spilite and keratophyre as examples of terms that should be abandoned in favor of a classification scheme based on modal mineral composition. They favor, as I have adopted, the classification of the IUGS Subcommission on the Systematics of Igneous Rocks (Cas and Wright 1995, Fig. 2.1, p. 17). The terms andesite and dacite avoid the ambiguity of the terms spilite and keratophyre, are in accord with the volcanic rock classification scheme advocated by Cas and Wright (1995), and are consistent with the geochemical data provided by Kesler et al. (1991).

Role of domes in mineralization

With respect to Kesler and Russell's comments on the role of domes in mineralization and their "reassessment" of the maar–diatreme setting for Pueblo Viejo – their own comments reflect uncertainty as to whether a maar–diatreme is present. I refer to statements such as, "Thus, a restricted maar basin might not be necessary ..." (Kesler and Russell, previous discussion) and, "Thus it might be argued that the carbonaceous sediments did not form in an enclosed basin (or maar) and, instead, were deposited in an arm of the sea ..." (Kesler 1998). I agree heartily with this "reassessment" of the problematic maar–diatreme and offer what I believe is convincing evidence for an alternative geologic setting, a volcanic dome field on the flank of an Early Cretaceous stratovolcano.

The domes themselves do not provide a unique source for the gold or the heat that drove the hydrothermal cells responsible for mineralization at Pueblo Viejo. I do not suggest, nor intend to imply, that any individual dome (e.g., the Moore dacite porphyry) was responsible for any individual ore deposit (e.g., the Moore or Mejita orebodies). Instead, I describe a setting in which volcanic domes and hydrothermal fluids avail themselves of the same structural conduits.

Recognition of volcanic domes strengthens the link between Pueblo Viejo and other high sulfidation epithermal deposits. On a local scale, volcanic domes have been found at high sulfidation prospects throughout the Los Ranchos Formation, including the Managua, Doña Amanda, and Trinidad prospects in the Bayaguana district and the Domenica prospect in the Miches district. On a worldwide scale, very large high sulfidation deposits are more often than not associated with volcanic domes. Examples include the Yanacocha district in Peru (40 M oz. Au) and the Rosia Montana district in Romania (11 M oz. Au).

Conclusion

My description of volcanic domes in the Pueblo Viejo district and stratigraphic section emphasizing separate volcanic centers differs from the maar–diatreme setting and layer-cake stratigraphy presented by Kesler et al. (1981) and Russell and Kesler (1991). I do not mean to imply that information presented by Kesler and Russell during their long association with Pueblo Viejo is incorrect. I do offer an alternative interpretation based on detailed geologic mapping, previously unrecognized volcanic domes, and a revised volcanic stratigraphy.

Evidence for an underlying pluton at Pueblo Viejo includes the volcanic dome field itself and a buried magnetic high revealed in an aeromagnetic survey completed as part of the SYSMIN program (1996). However, evidence for an underlying pluton is not necessarily evidence for an underlying porphyry copper deposit. I object to the underlying porphyry copper deposit proposed by Kesler (1998), and to deeply buried sources of metal in general, only in so far as they blind the observer to important evidence available in outcrop.

Exploration for new deposits, especially within the Los Ranchos Formation, should focus on volcanic dome fields rather than the problematic maar–diatreme advocated by Russell and Kesler (1991). However, I doubt that resolution of our differences will come through written comment and reply. I look forward to comparing our respective geologic maps in the field.

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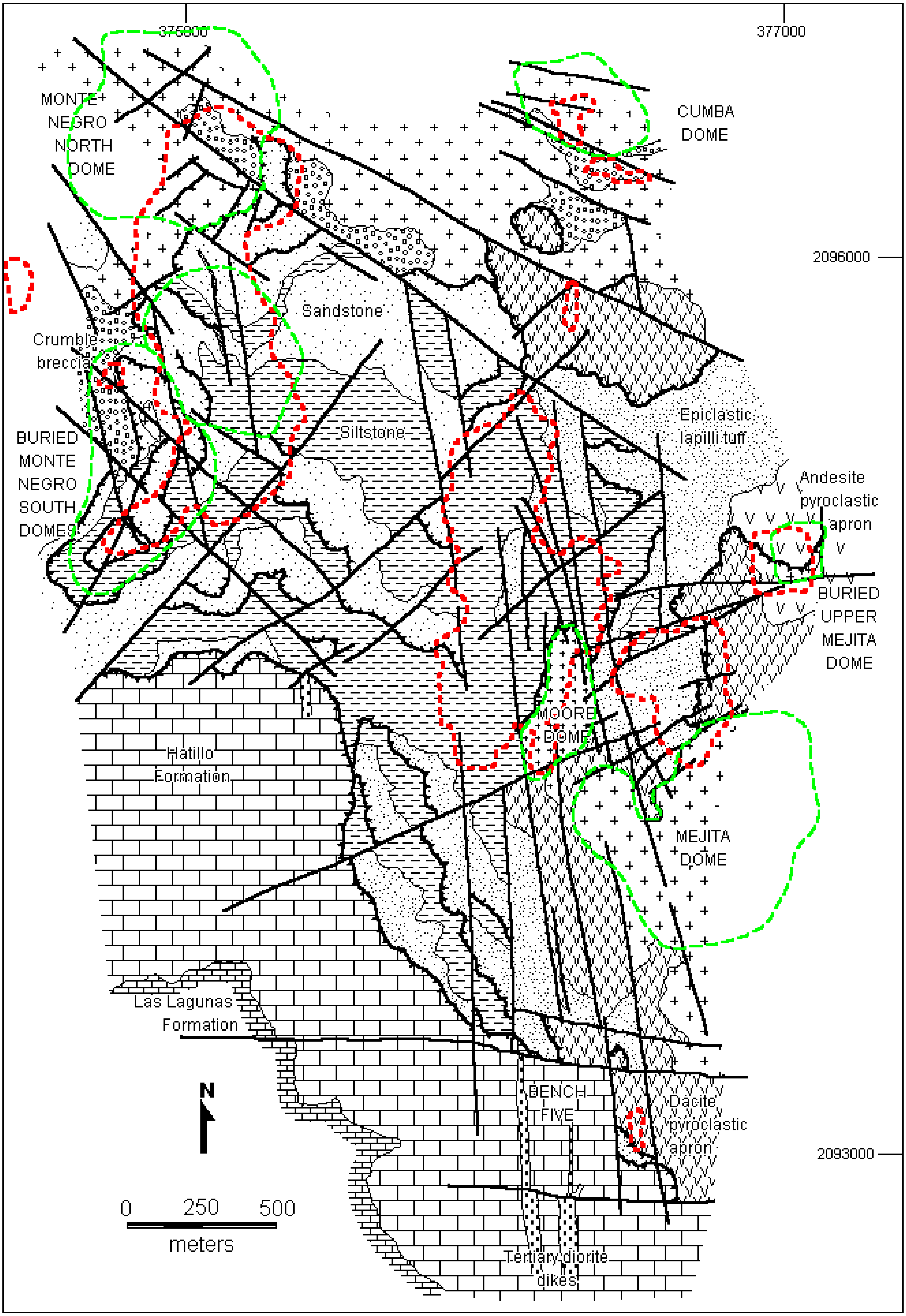
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377000
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MONTE NEGRO NORTH DOME
CUMBA DOME
Sandstone
Crumble breccia
Siltstone
Epiclastic lapilli tuff
BURIED MONTE NEGRO SOUTH DOMES
Andesite pyroclastic apron
BURIED UPPER MEJITA DOME
MOORE DOME
Hatillo Formation
MEJITA DOME
Las Lagunas Formation
N
BENCH FIVE
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