Petrochemistry and tectonic significance of Cretaceous island-arc rocks, Cordillera Oriental, Dominican Republic

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ABSTRACT

Cretaceous island-arc rocks of the Caribbean island-arc system have been exposed by Cenozoic faulting in the Cordillera Oriental in eastern Hispaniola. High-K, O intermediate to felsic volcanic rocks (Loma la Vega volcanics) are interbedded with marine epiclastic sedimentary rocks and tuffs (Las Guajabas tuffs) and unconformably overlie pre-Aptian sedimentary rocks, low-K, O volcanic rocks (Guamira volcanics) and a granodioritic to tonalitic intrusion (El Valle pluton). The petrology and geochemistry of these units, in conjunction with regional stratigraphic data, are used to speculate on the tectonics of the newly developing Caribbean island-arc system during Early and Late Cretaceous time.

The Loma la Vega volcanics are characterized by the presence of large phenocrysts of sanidine, and minor amounts of clinopyroxene, opaque oxides, and rare leucite in a devitrified matrix of chlorite and clay. Although the volcanic rocks have undergone some low-temperature alteration/metamorphism, which redistributed some major elements and large-ion-lithophile trace elements, the high-field-strength elements, rare-earth elements, and radiogenic isotopes appear to have been minimally affected. Based on abundances of the relatively immobile elements, trace-element enrichment patterns and isotopic compositions, the Loma la Vega volcanics are considered part of the high-K, calc-alkaline (CA) or shoshonitic island-arc volcanic series. In contrast, pre-Aptian (Early Cretaceous?) volcanic and plutonic rocks of the underlying Los Ranchos Formation have chemical characteristics similar to rocks in the island arc tholeiitic or "primitive island arc" (PIA) series that form coeval and along-strike sections of the Early Cretaceous Caribbean island arc in other parts of present-day Hispaniola, Cuba, Puerto Rico and the Virgin Islands.

An abrupt and regional change in composition from island-arc tholeiites to high-K, calc-alkaline rocks is coincident with a hypothesized reversal in subduction polarity in pre-Aptian time. As inferred from previously published tectonic models, polarity reversal may have been triggered by attempted subduction of the Caribbean oceanic plateau beneath this segment of the Caribbean island arc. The observed magmatic and tectonic effects of the proposed Cretaceous Caribbean arc reversal are similar to the better documented Neogene subduction reversal event in the Solomon Islands arc in the southwest Pacific.

Introduction

The early tectonic and magmatic histories of most mature island arcs are poorly understood because later arc growth can bury, erode, metamorphose, deform and/or assimilate early arc products. In the Cretaceous–Cenozoic circum-Caribbean island-arc system, there are few exposures of relatively undeformed sections of Cretaceous island-arc rocks (Fig. 1). In this paper, we describe the petrographic and geochemical characteristics of island-arc rocks in the Cordillera Oriental of eastern Hispaniola where 875 km² of early to late Cretaceous island-arc rocks are exposed. These rocks are not severely overprinted by Cenozoic strike-slip faults, as in many areas of the Caribbean, and provide new and important stratigraphic and petrochemical information regarding the development of the Cretaceous circum-Caribbean arc system. Here we present geochemical and stratigraphic data from arc-related rocks exposed in the eastern Dominican Republic and compare them with data from coeval and along-strike sections of the Cretaceous arc in other parts of Hispaniola, Cuba, Puerto Rico, and the Virgin Islands. These stratigraphic and
geochemical data support a tectonic model for arc polarity reversal in the Cretaceous Caribbean island arc that has previously been proposed by researchers such as Mattson (1979) and more recently by ourselves (Lebrón and Perfit, 1993).

**Tectonic setting**

**Present-day plate boundaries**

Hispaniola is the second largest island after Cuba in the Greater Antilles island chain but exposes the largest and most deeply eroded area of Cretaceous–Eocene arc rocks in the northeastern Caribbean. Hispaniola is presently located within a 200-km-wide plate-boundary zone of post-Eocene strike-slip deformation separating the North America and Caribbean plates (Fig. 1A). A minimum of 1100 km of post-Eocene, left-lateral offset along the North America–Caribbean plate boundary has produced the Cayman trough, an elongate east–west striking, pull-apart basin floored by oceanic crust (Perfit and Heezen, 1978; Rosencrantz et al., 1988). The Caribbean plate is presently bounded on the east and west by subduction zones. In the east, Atlantic ocean floor is subducted beneath the Lesser Antilles island arc. In the west, the Cocos and Nazca plates are being subducted beneath Central America at the Middle America trench.

The physiography of the central and western part of Hispaniola is dominated by northwest to west-northwest-striking valleys and mountain ranges which are defined by reverse or left-lateral strike-slip faults related to convergent North America–Caribbean plate motions (Mann et al., 1991). Cretaceous island-arc rocks of the Cordillera Oriental have been exhumed in late Cenozoic time by strike-slip faulting and oblique subduction below this segment of the North America–Caribbean plate boundary (Sykes et al., 1982).

**Cretaceous–Oligocene island-arc rocks of the Caribbean**

Island-arc rocks of Hispaniola form one segment of a Cretaceous–Eocene island-arc chain that extends from Cuba to the northern coast of South America (Fig. 1B). The Greater Antilles segment of the arc, from Cuba to the Virgin Islands to the east of Puerto Rico, has been volcanically inactive since its Eocene collision with the Bahamas carbonate platform. The Lesser Antilles segment of the arc has remained active because this segment of the arc passed between the Bahamas Platform and the northern continental margin of South America as the Caribbean plate moved eastward. Because many segments of the arc were initiated in the Early Cretaceous and are lithologically similar, most workers now interpret the arc rocks as part of a once continuous intra-oceanic arc that swept into the Caribbean from the eastern Pacific (e.g., Bouysse, 1988; Pindell et al., 1988; Pindell and Barrett, 1990). Burke (1988) has named this once continuous arc the “Great Arc of the Caribbean”. The arc is associated with back-arc basins in the Yucatan basin adjacent to Cuba (Rosencrantz, 1990) and the Grenada basin adjacent to the Lesser Antilles arc (Bouysse, 1988) (Fig. 1B). Both back-arc basins appear to have opened in earliest Cenozoic time and may have formed a single, continuous basin prior to disruption by Eocene to Recent strike-slip faults of the North America–Caribbean plate boundary (Mann et al., 1991).

**Cretaceous–Tertiary compositional stages of the circum-Caribbean island arc**

**MORB series**

Donnelly and Rogers (1980) and Donnelly et al. (1990) have attempted to relate three distinct igneous rock series to stages in the development of the circum-Caribbean island arc. The first stage of arc development is characterized by mid-ocean ridge basalt (MORB) series that is interpreted as a widespread “basalt event” of Aptian to Coniacian age. MORB-type basalts produced during this event often form part of larger, ophiolite-like stratigraphic sections containing serpentinite, plagiogranite, amphibolite, chert and pelagic limestone. These basalts have low concentrations of large-ion-lithophile elements (LILE), Sr, non-radiogenic Pb and Sr isotopes, depleted light rare-
earth-element (LREE) patterns, and moderate concentrations of Ti and Mg. The MORB series is generally characterized by the absence of intermediate to siliceous rocks.

**PLA series**

The primitive island-arc (PIA) series, characteristic of the second stage of arc development, is

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Fig. 1. (A). Present-day plate structure of the Caribbean region modified from Jordan (1975); rates of plate motion relative to the Caribbean plate are from Stein et al. (1988). The island of Hispaniola straddles the active left-lateral strike-slip zone separating the North America and Caribbean plates. (B). Main tectonic elements of Late Cretaceous–Eocene circum-Caribbean island-arc system: (1) Late Cretaceous oceanic plateau in a back-arc position; (2) Late Cretaceous–Eocene island arc; (3) Late Cretaceous–Eocene back-arc basin; arrows indicate inferred direction of opening in the Yucatan back-arc basin (Rusencrantz, 1990) and the Grenada back-arc basin (Bouysse, 1988); and (4) Jurassic–Eocene Bahama carbonate platform. Note presence of Cretaceous–early Tertiary island-arc rocks in eastern Hispaniola. (Map is modified from Mann et al., 1991.)
contemporaneous with the MORB series and is interpreted by Donnelly et al. (1990) as a record of early subduction and submarine arc development of the Cretaceous circum-Caribbean island arc. Rocks in the PIA series are similar in composition, origin and tectonic setting to "island arc tholeiites" of Jakes and Gill (1970) and Gill (1981, 1988) and are characterized by low concentrations of Th, U, Ba, K, Rb, Ni, Cr, Ta, Zr and Nb. The PIA series also has relatively non-radiogenic Pb isotopic compositions, low rare-earth-element abundances, and flat REE patterns (Donnelly et al., 1990). The PIA series is mainly represented by spilitized basalts but these have also been found with felsic rocks, including keratophyres and rare plutonic rocks. Donnelly et al. (1990) suggest the PIA series developed from contaminated mantle-derived magmas produced in the early stages of island-arc evolution.

**CA series**

The third stage of arc development in the Caribbean is represented by Late Cretaceous to Early Oligocene calc-alkaline (CA) volcanic, pyroclastic and plutonic rocks. This series is characterized by enrichments in LILE and LREE relative to the PIA series, and depletions in high-field-strength elements (HFSE) relative to these other elements. The CA series has more radiogenic Sr isotopic ratios than the MORB or PIA series and distinctive Pb isotopic compositions. The CA series, mainly represented by andesites, is proposed to have developed from more evolved,
fractionated magmas formed within a mature arc (Donnelly et al., 1990). Included in the CA series is a sub-series commonly known as the "shoshonitic" series characterized by very high contents of K and other LIL elements and relatively low contents of Ti and HFSE. Donnelly et al. (1990) suggest that in the Caribbean the shoshonitic series developed as a late-stage product of the CA series as the arc crust matured and thickened.

Geologic setting of the Cordillera Oriental

Bourdon (1985) divides the Cordillera Oriental of eastern Hispaniola (Dominican Republic) into two fault-bounded tectono-stratigraphic units: the Aptian–Late Cretaceous volcanic and sedimentary El Seibo unit to the southwest, and the Coniacian sedimentary El Oro unit to the northeast (Fig. 2). The focus of our study, the Loma la Vega volcanics, form part of the El Seibo unit. Bourdon (1985) estimates that the El Seibo unit is over 2 km thick and that the Loma la Vega volcanics are 50–70 m thick (Fig. 3). These are minimum thickness estimates as the rocks exhibit regional-scale folding and faulting. The basement underlying the El Seibo unit is lithologically similar to and considered by us to be stratigraphically equivalent to the Los Ranchos Formation of Kesler et al. (1991a), which crops out 50–70 km to the west and along the regional strike of our study area (Lebrón and Mann, 1991) (Fig. 2).

Pre-Aptian island-arc stratigraphy

The oldest Cretaceous island-arc rocks of the El Seibo unit are composed of: (1) deformed chert; (2) sedimentary breccia, primarily composed of volcanic fragments; (3) epiclastic tuff; (4) conglomerate with volcanic clasts (andesite, dacite and aphyric lava) and a tuffaceous matrix; (5) basaltic to andesitic flows (Guamira basalts); and (6) minor dacitic to rhyolitic flows (Bourdon, 1985; Lebrón, 1989) (Fig. 3). All rock types are slightly metamorphosed to prehnite-pumpellyite or lower greenschist grade.

Toward the northwestern boundary of the exposed area of the El Seibo Unit, the El Valle pluton crops out in a 55 km² circular topographic depression formed by preferential tropical weathering of the pluton (Fig. 2). Rock types within El Valle pluton include abundant granodiorite or tonalite with minor amounts of granite and diorite (Bourdon, 1985; Lebrón, 1989).

Unconformably overlying the oldest volcanic and sedimentary rocks of the El Seibo unit is a 1–5 m thick, basal conglomerate mainly composed of boulder- to gravel-sized volcanic rocks derived from the underlying rocks. The conglomerate marks a period of uplift and erosion and forms the base of a 100–150-m thick, carbonate platform sequence of Aptian–Albian age (approximately 119–97.5 Ma). Bourdon (1985) correlates this shallow-water limestone to the Hatillo limestone described by Bowin (1966) in an area 100 km to the west of Bourdon's locality. Douglas (1961) first dated the Hatillo limestone as Albian
based on rudist and *Orbitolina* fauna. More recent paleontological dating and detailed studies by Bourdon (1985) have confirmed the Aptian–Albian age and shallow-water origin of the limestone section.

**Post-Albian island-arc stratigraphy**

The Aptian–Albian limestone gradationally passes into a southeastward to southward-dipping section of Upper Cretaceous volcaniclastic marine sedimentary rocks primarily composed of conglomerate with volcanic and sedimentary clasts that are overlain by epiclastic tuffs (Las Guajabas tuffs) (Fig. 3). In the lower part of the Las Guajabas tuffs, Bourdon (1985) and Lebrón (1989) mapped a horizon of volcanic flows—the Loma la Vega volcanics—of late Cretaceous age that are well exposed on the Loma la Vega (“Vega Hill”) to the west of the town of El Seibo (Fig. 2). A series of upper Cenomanian to lower Turonian pelagic limestones conformably overlies the Las Guajabas tuffs. (Fig. 3).

**Field and petrologic description of igneous rocks**

**Pre-Aptian Guamira basalts**

The Guamira basalts were sampled at their type section along a 1 km segment of the Rio Guamira 24 km west-northwest of the town of El Seibo (Fig. 2). Fresh exposures of massive lavas

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Fig. 4. Geologic map of the Loma la Vega–El Seibo area of the Cordillera Oriental. (Geology is based on compilation map of Bourdon, 1985; and field observations by Lebrón, 1989.)

Fig. 5. (A), Outcrop of the Guamira basalts in the Rio Guamira (locality of samples 87-3A and 87-3B in Fig. 2). Note poorly developed columnar jointing and fracturing. (B), Roadcut exposure of the Las Guajabas tuffs south of Loma la Vega (see Fig. 4 for location). Note bedding, faulting, high degree of fracturing, and hammer for scale. (C), Hand-sample of volcanic breccia (autobreccia) within Loma la Vega volcanics. Note plastic texture and sanidine phenocrysts in a fine-grained devitrified matrix. (Top scale of ruler is in centimeters.)
are present in continuous exposures along the incised river channel. The basalts and associated andesites are aphyric, grayish to black in color on fresh surfaces, and greenish to red in color on weathered surfaces. In one outcrop on the Rio Guamira, a massive 2-m thick flow unit of aphyric basalt exhibits weakly developed columnar jointing (Fig. 5A). Vesicular, aphyric lava flows with rare pyroxene phenocrysts were also sampled along the Rio Guamira. Weathered and oxidized volcanic breccias, containing angular to subangular clasts 3–10 cm in size, conformably overlie the Guamira basalts. Clast types include amygdaloidal basalts and other altered aphyric lavas.

In thin section, the Guamira basalts are fine-grained, holocrystalline basalts that have been metamorphosed to greenschist facies. The lavas contain rare, small relict phenocrysts of clinopyroxene and altered olivine (?). The matrix is microcrystalline and composed of chlorite and plagioclase microlites, commonly altered to epidote. Some of the samples contain calcite-filled amygdalae. These lavas have petrologic characteristics similar to the low-grade Cretaceous metavolcanics in Puerto Rico described by Lidiak (1965) and Jolly (1971).

El Valle pluton

Outcrops of the pluton along the Rio Guamira are tonalitic to granitic, highly fractured and weathered to gray or pinkish colors. Two adjacent compositional phases were noted in outcrops; a darker gray, medium- to fine-grained, more mafic phase intruding a pink to white, coarser-grained granitic phase. The lighter-colored, granitic phase is more typical in the outcrops we observed in the field.

A thin section of a sample from a highly fractured outcrop reveals an inequigranular, micro-brecciated texture. The major minerals in this fractured sample include: anhedral quartz with undulatory extinction; subhedral plagioclase laths partially altered to sericite; and significantly lesser amounts of subhedral orthoclase. Chlorite is present as fine, anhedral crystals replacing mafic minerals and filling microfractures. Brecciated samples also appear to be silicified, with quartz commonly filling microfractures. A chemical analysis of one of these samples shows that it has a low potassium content, more similar to some trondhjemites than true granites.

Samples from less fractured outcrops of the El Valle pluton have slightly different compositions than fractured samples. More felsic samples have equigranular textures and contain anhedral quartz, subhedral K-feldspar and plagioclase as major minerals. Euhedral biotite and pseudomorphs after mafic minerals (hornblende?) are tabular in shape and usually account for less than 5% of the mode. Slightly more mafic samples only differ from felsic varieties by containing higher modal percentages of mafic minerals and having finer-grained textures. Similar tonalitic intrusive rocks have been described by Kesler et al. (1977) and Kesler et al. (1991b) from the Cordillera Central in west-central Hispaniola (Dominican Republic).

Post-Aptian (Late Cretaceous) Las Guajabas tuffs

The Late Cretaceous Las Guajabas tuffs are greenish- to red-colored, medium- to fine-grained epiclastic tuffs. Well-defined beds range from 10 to 20 cm in thickness. The tuffs are not resistant to weathering and consequently form lowlands between more resistant volcanic and limestone lithologies. Outcrops of tuff in the study area (Fig. 4) were found only in roadcuts or stream banks (Fig. 5D). In the Loma la Vega region, the...
tuffs are slightly folded, highly fractured, and generally dip at moderate angles to the southwest (Fig. 5B). In the eastern part of the study area, around El Seibo, large-scale folds are obvious on aerial photographs and have been mapped at a scale of 1:50,000 by Bourdon (1985) and compiled on a map at a scale of 1:150,000 by Lebrón and Mann (1991).

The tuffs are fine-grained (< 1 mm), composed of devitrified glass shards, volcanic clasts and primary minerals that include: subhedral plagioclase, euhedral biotite, subhedral potassium feldspar crystals, and mafic minerals altered to carbonate and clay. Volcanic clasts in the tuffs are rounded and completely chloritized. The matrix of the tuffs is composed of chlorite and cryptocrystalline silica that probably formed as a result of devitrification of the glassy matrix.

Post-Albian (Late Cretaceous) Loma la Vega volcanics

Based on textural differences, outcrops of the Loma la Vega volcanics found on the slopes of Loma la Vega, 15 km to the west of the town of El Seibo, are divided into: (1) trachytic lava flows; (2) volcanic breccias; and (3) vitroclastic tuffs (Lebron, 1989). Contact relationships between the three textural units are difficult to determine because of the discontinuous nature of the outcrops on Loma la Vega but may be gradational. We observed that the trachytic flows largely underlie the breccias and the vitroclastic tuffs.

Lava flows

Trachytic lava flows, the most common rock type in the Loma la Vega volcanics, are massive, dark gray, porphyritic rocks with conspicuous euhedral phenocrysts of pink sanidine (Fig. 6A, C). The phenocrysts range from 1 to 3 mm in length and tend to weather to clay minerals. The sanidine phenocrysts are usually arranged in clusters and occasionally exhibit reaction rims composed of orthoclase. Smaller, less common, subhedral phenocrysts of clinopyroxene are not well preserved (Fig. 6B) They are commonly altered to chlorite and rarely exhibit opalite rims. Amphibole is rarely present as euhedral to subhedral microphenocryst. A few samples contain euhedral leucite pseudomorphs (Fig. 6B) with feldspar reaction rims. The matrix is composed of fine-grained minerals, including anhedral chlorite, subhedral biotite, feldspar microlites, rare anhedral analcime and minor anhedral opaque minerals. The matrix is fractured and some of these fractures are filled with pink zeolites.

Sanidine- and leucite-bearing volcanic rocks are rare in the Caribbean and relatively unusual in convergent margin settings world-wide. Mineralogically, however, the lavas from Loma la Vega are quite similar to high-K trachytes, tephrites and phonolites from the Roman volcanic province in Italy (e.g., Cundari, 1977) and the Tabar-to-Feni chain in Papua New Guinea (Wallace et al., 1983) Although the Loma la Vega lavas have been slightly altered, the inferred primary mineralogy suggests they were derived from K-rich, slightly silica-undersaturated magmas.

Volcanic breccias

The volcanic breccias are greenish-brown, coarse grained, poorly-sorted and characterized by a conglomeratic appearance produced by irregular to rounded volcanic clasts (3–8 cm in diameter) made of the same material that forms the matrix (Fig. 5C). The monolithic nature of the breccias and their textures suggest they formed contemporaneously with consolidation and can, therefore, be considered autobreccias.

The interclast matrix in all the breccias examined is cryptocrystalline and appears to have formed from the devitrification of glass fragments and shards. Devitrified glass shards (less than 0.5 mm in diameter) are very common and are primarily comprised of cryptocrystalline silica, sericite and chlorite with minor amounts of epidote. Some of the devitrified glass shards contain relatively well-preserved sanidine crystals in their core. Less commonly, small, subhedral clinopyroxene crystals are present but are usually corroded, fractured and altered to chlorite. Epidote grains are commonly clustered with biotite that is typically altered to chlorite and iron oxides. Anhedral opaque minerals are present in small
amounts (approximately 1% of the mode). The observed textures, abundance of glass shards and vitric clasts in some of the breccias suggests they may have formed as pyroclastic flows in or near an aqueous environment (Cas and Wright, 1987). Similar features have also been described in subaqueous, rhyolitic dome-top tuff cones by Cas et al. (1990).

**Vitroclastic tuffs**

Weathered vitroclastic tuffs are green to brown in color and contain pink, prominent, 2–3 mm long sanidine phenocrysts (Fig. 6C). The matrix contains angular, devitrified glass shards up to 1 mm in length. Clay minerals (sericite) form alteration rims around the glass shards. As in the flows and breccias, the tuffs are characterized by the presence of euhedral to subhedral sanidine crystals and subhedral to anhedral clinopyroxene, usually replaced by carbonate, chlorite and/or epidote. Subhedral amphibole is rarely present.

The matrix in these rocks is mainly composed of angular glass shards that are partially or completely devitrified. Devitrification features of these rocks include radial, fibrous spherulites that are amalgamated or arranged in trains of connected, overlapping spheroids. Anhedral chlorite is common in the devitrified matrix but some parts of the matrix consist of fine-grained recrystallized quartz and feldspar.

**Geochemical methods**

In order to investigate the chemical evolution of the Hispaniola island arc before and after the pre-Aptian erosional event, we analyzed samples of the Guamira basalt and El Valle pluton beneath the pre-Aptian erosional surface and samples of the Loma la Vega volcanics and the Las Guajabas tuffs above the pre-Aptian erosional surface. Compositional comparisons were then made to other Caribbean volcanic rocks of similar age that have previously been described.

**Major and trace elements**

Major elements were determined by spectrometric methods at the Dirección General de

### TABLE 1

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All analyses done by atomic absorption, Dirección General de Minería, Santo Domingo, Dominican Republic.
All analyses normalized to 100 wt% volatile free.

n/d  = not determined.

* Total iron as Fe³⁺.

* Analysis from Bourdon (1985).
### TABLE 2
Major element compositions of Loma la Vega volcanics and related rocks from the Cordillera Oriental, Dominican Republic

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<th>LLV tuff 87-14</th>
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<th>El Valle pluton X7-1</th>
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<td>2.70</td>
<td>9.53</td>
<td>2.15</td>
<td>6.73</td>
</tr>
<tr>
<td>MnO</td>
<td>0.21</td>
<td>0.18</td>
<td>0.24</td>
<td>0.10</td>
<td>0.19</td>
<td>0.07</td>
<td>0.10</td>
</tr>
<tr>
<td>MgO</td>
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<td>0.91</td>
<td>0.58</td>
<td>0.34</td>
<td>3.56</td>
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<tr>
<td>CaO</td>
<td>0.73</td>
<td>0.91</td>
<td>1.65</td>
<td>0.45</td>
<td>3.31</td>
<td>1.63</td>
<td>4.90</td>
</tr>
<tr>
<td>Na₂O</td>
<td>2.77</td>
<td>2.95</td>
<td>2.72</td>
<td>5.20</td>
<td>6.29</td>
<td>5.72</td>
<td>4.36</td>
</tr>
<tr>
<td>K₂O</td>
<td>11.49</td>
<td>10.01</td>
<td>11.44</td>
<td>8.13</td>
<td>0.08</td>
<td>0.91</td>
<td>2.95</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.06</td>
<td>0.07</td>
<td>0.06</td>
<td>0.05</td>
<td>0.05</td>
<td>0.00</td>
<td>0.51</td>
</tr>
<tr>
<td>LOI</td>
<td>2.07</td>
<td>2.13</td>
<td>2.80</td>
<td>1.17</td>
<td>2.83</td>
<td>1.30</td>
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</tr>
<tr>
<td>Total</td>
<td>100.75</td>
<td>100.47</td>
<td>102.71</td>
<td>100.17</td>
<td>101.49</td>
<td>100.44</td>
<td>100.18</td>
</tr>
</tbody>
</table>

All analyses done by X-ray fluorescence spectrometry at the University of Florida.

LOI = loss on ignition.

* Total iron as Fe³⁺.

Mineria in Santo Domingo, Dominican Republic (Table 1) and by X-ray fluorescence spectrometry at the Department of Geology, University of Florida (Table 2). Trace-element analyses were performed by X-ray fluorescence techniques at the University of Florida following the procedure.

### TABLE 3
Trace-element compositions of Loma la Vega volcanics (LLV) and related rocks, Cordillera Oriental, Dominican Republic

<table>
<thead>
<tr>
<th></th>
<th>LLV flow 87-20</th>
<th>LLV flow 87-14</th>
<th>LLV tuff 87-10</th>
<th>LLV tuff 87-7</th>
<th>LLV tuff 87-1</th>
<th>LGT epiclastic tuff RU-52</th>
</tr>
</thead>
<tbody>
<tr>
<td>TiO₂</td>
<td>0.36</td>
<td>n/d</td>
<td>0.30</td>
<td>0.38</td>
<td>0.36</td>
<td>0.37</td>
</tr>
<tr>
<td>Sc *</td>
<td>1.0</td>
<td>1.0</td>
<td>2.0</td>
<td>n/d</td>
<td>n/d</td>
<td>1.0</td>
</tr>
<tr>
<td>V</td>
<td>60</td>
<td>63</td>
<td>70</td>
<td>n/d</td>
<td>n/d</td>
<td>62</td>
</tr>
<tr>
<td>Cr</td>
<td>6</td>
<td>7</td>
<td>9</td>
<td>n/d</td>
<td>n/d</td>
<td>3</td>
</tr>
<tr>
<td>Ni</td>
<td>23</td>
<td>n/d</td>
<td>5</td>
<td>22</td>
<td>21</td>
<td>15</td>
</tr>
<tr>
<td>Cu</td>
<td>27</td>
<td>40</td>
<td>31</td>
<td>24</td>
<td>26</td>
<td>34</td>
</tr>
<tr>
<td>Zn *</td>
<td>115</td>
<td>140</td>
<td>109</td>
<td>n/d</td>
<td>n/d</td>
<td>110</td>
</tr>
<tr>
<td>Rb</td>
<td>234</td>
<td>213</td>
<td>164</td>
<td>225</td>
<td>229</td>
<td>204</td>
</tr>
<tr>
<td>Sr</td>
<td>92.7</td>
<td>238.0</td>
<td>179.0</td>
<td>239.0</td>
<td>95.9</td>
<td>76.6</td>
</tr>
<tr>
<td>Y</td>
<td>45.0</td>
<td>24.5</td>
<td>22.6</td>
<td>34.4</td>
<td>45.7</td>
<td>35.7</td>
</tr>
<tr>
<td>Zr</td>
<td>176</td>
<td>212</td>
<td>144</td>
<td>179</td>
<td>172</td>
<td>163</td>
</tr>
<tr>
<td>Nb</td>
<td>8.8</td>
<td>7.0 *</td>
<td>6.5</td>
<td>8.4</td>
<td>7.8</td>
<td>8.2</td>
</tr>
<tr>
<td>Ba</td>
<td>163</td>
<td>763</td>
<td>150</td>
<td>257</td>
<td>160</td>
<td>n/d</td>
</tr>
<tr>
<td>Be *</td>
<td>5.5</td>
<td>5.0</td>
<td>5.0</td>
<td>n/d</td>
<td>n/d</td>
<td>n/d</td>
</tr>
<tr>
<td>Cs *</td>
<td>1.9</td>
<td>5.7</td>
<td>0.2</td>
<td>n/d</td>
<td>n/d</td>
<td>1.3</td>
</tr>
<tr>
<td>Li *</td>
<td>9.8</td>
<td>9.9</td>
<td>5.1</td>
<td>n/d</td>
<td>n/d</td>
<td>12.0</td>
</tr>
<tr>
<td>Co</td>
<td>2.3</td>
<td>3.1</td>
<td>3.5</td>
<td>n/d</td>
<td>n/d</td>
<td>2.6</td>
</tr>
<tr>
<td>Ga *</td>
<td>17</td>
<td>17</td>
<td>n/d</td>
<td>n/d</td>
<td>n/d</td>
<td>21</td>
</tr>
</tbody>
</table>

All values in ppm except TiO₂ in wt.%

n/d = not determined.

* Analysis performed by Ian Ridley using ICP mass spectrometry, U.S. Geol. Surv. Denver, Colo. All other analyses done by X-ray fluorescence spectrometry at the University of Florida.
### TABLE 4

Trace-element compositions of Guamira volcanics and El Valle pluton, Cordillera Oriental, Dominican Republic

<table>
<thead>
<tr>
<th></th>
<th>Guamira andesite 87-3A</th>
<th>Guamira basalt 87-3B</th>
<th>El Valle pluton 87-1D</th>
<th>El Valle pluton 87-1A</th>
<th>El Valle pluton 87-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>TiO₂</td>
<td>1.04</td>
<td>0.66</td>
<td>0.02</td>
<td>0.19</td>
<td>0.2</td>
</tr>
<tr>
<td>Sc *</td>
<td>41.0</td>
<td>n/d</td>
<td>5.0</td>
<td>n/d</td>
<td>n/d</td>
</tr>
<tr>
<td>V *</td>
<td>193</td>
<td>n/d</td>
<td>5.0</td>
<td>n/d</td>
<td>n/d</td>
</tr>
<tr>
<td>Cr</td>
<td>2</td>
<td>372</td>
<td>4</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Ni</td>
<td>n/d</td>
<td>72</td>
<td>n/d</td>
<td>n/d</td>
<td>n/d</td>
</tr>
<tr>
<td>Cu</td>
<td>35</td>
<td>28</td>
<td>5</td>
<td>7</td>
<td>31</td>
</tr>
<tr>
<td>Zn *</td>
<td>79</td>
<td>n/d</td>
<td>26</td>
<td>n/d</td>
<td>n/d</td>
</tr>
<tr>
<td>Rb</td>
<td>2.8</td>
<td>11.6</td>
<td>14.3</td>
<td>13.7</td>
<td>9.7</td>
</tr>
<tr>
<td>Sr</td>
<td>72.5</td>
<td>83.6</td>
<td>95.1</td>
<td>81.5</td>
<td>63.5</td>
</tr>
<tr>
<td>Y</td>
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<td>16.8</td>
<td>23.5</td>
<td>29.3</td>
<td>25.3</td>
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<tr>
<td>Zr</td>
<td>68.9</td>
<td>54.6</td>
<td>157</td>
<td>159</td>
<td>163</td>
</tr>
<tr>
<td>Nb</td>
<td>0.5</td>
<td>0.5</td>
<td>3.7</td>
<td>3.8</td>
<td>3.7</td>
</tr>
<tr>
<td>Ba</td>
<td>48.5</td>
<td>111</td>
<td>268</td>
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<td>n/d</td>
</tr>
<tr>
<td>Be *</td>
<td>0.5</td>
<td>n/d</td>
<td>1.0</td>
<td>n/d</td>
<td>n/d</td>
</tr>
<tr>
<td>Cs *</td>
<td>n/d</td>
<td>n/d</td>
<td>0.1</td>
<td>n/d</td>
<td>n/d</td>
</tr>
<tr>
<td>Li *</td>
<td>11.6</td>
<td>n/d</td>
<td>2.70</td>
<td>n/d</td>
<td>n/d</td>
</tr>
<tr>
<td>Co *</td>
<td>18.5</td>
<td>n/d</td>
<td>1.60</td>
<td>n/d</td>
<td>n/d</td>
</tr>
<tr>
<td>Ga *</td>
<td>17</td>
<td>n/d</td>
<td>14</td>
<td>n/d</td>
<td>n/d</td>
</tr>
</tbody>
</table>

All values in ppm except TiO₂ in wt%.  
* Analysis performed by Ian Ridley using ICP mass spectrometry, U.S. Geol. Surv., Denver, Colo. All other analyses done by X-ray fluorescence spectrometry at the University of Florida.

### TABLE 5

Rare-earth-element and additional trace-element abundances (ppm) of the Loma la Vega volcanics and related rocks, the Guamira volcanics, and the El Valle pluton

<table>
<thead>
<tr>
<th>ppm</th>
<th>LLV flow RU-20</th>
<th>LLV flow 87-20</th>
<th>LLV tuff 87-14</th>
<th>LLV tuff 86-1</th>
<th>Guamira basalt 87-3A</th>
<th>El Valle pluton 87-1D</th>
</tr>
</thead>
<tbody>
<tr>
<td>La</td>
<td>35.3</td>
<td>45.1</td>
<td>26.6</td>
<td>36.3</td>
<td>2.3</td>
<td>8.3</td>
</tr>
<tr>
<td>Ce</td>
<td>69.6</td>
<td>76.9</td>
<td>53.3</td>
<td>69.0</td>
<td>6.4</td>
<td>19.4</td>
</tr>
<tr>
<td>Pr</td>
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<td>9.4</td>
<td>6.4</td>
<td>8.6</td>
<td>1.01</td>
<td>2.9</td>
</tr>
<tr>
<td>Nd</td>
<td>31.5</td>
<td>35.6</td>
<td>23.0</td>
<td>30.9</td>
<td>5.4</td>
<td>11.4</td>
</tr>
<tr>
<td>Eu</td>
<td>0.96</td>
<td>1.00</td>
<td>0.99</td>
<td>1.1</td>
<td>0.9</td>
<td>0.8</td>
</tr>
<tr>
<td>Sm</td>
<td>0.8</td>
<td>7.6</td>
<td>5.3</td>
<td>6.6</td>
<td>2.0</td>
<td>2.9</td>
</tr>
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<td>Gd</td>
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<td>7.1</td>
<td>4.6</td>
<td>5.5</td>
<td>2.8</td>
<td>3.0</td>
</tr>
<tr>
<td>Tb</td>
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<td>0.8</td>
<td>0.9</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>Dy</td>
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<td>4.8</td>
<td>5.5</td>
<td>3.7</td>
<td>3.9</td>
</tr>
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<td>Ho</td>
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<td>1.0</td>
<td>1.1</td>
<td>0.8</td>
<td>0.9</td>
</tr>
<tr>
<td>Er</td>
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<td>4.2</td>
<td>3.0</td>
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<td>2.5</td>
</tr>
<tr>
<td>Tm</td>
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<td>0.64</td>
<td>0.52</td>
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<td>0.46</td>
</tr>
<tr>
<td>Yb</td>
<td>3.7</td>
<td>4.5</td>
<td>3.5</td>
<td>3.4</td>
<td>2.7</td>
<td>3.1</td>
</tr>
<tr>
<td>Lu</td>
<td>0.49</td>
<td>0.66</td>
<td>0.43</td>
<td>0.44</td>
<td>0.37</td>
<td>0.42</td>
</tr>
<tr>
<td>Hf</td>
<td>5.9</td>
<td>6.1</td>
<td>5.2</td>
<td>6.4</td>
<td>2.4</td>
<td>1.7</td>
</tr>
<tr>
<td>Ta</td>
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<td>0.4</td>
<td>0.5</td>
<td>0.13</td>
<td>0.3</td>
</tr>
<tr>
<td>W</td>
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<td>7.3</td>
<td>3.5</td>
<td>0.6</td>
<td>1.0</td>
</tr>
<tr>
<td>Pb</td>
<td>21.5</td>
<td>23.4</td>
<td>24.2</td>
<td>24.9</td>
<td>1.6</td>
<td>1.6</td>
</tr>
<tr>
<td>U</td>
<td>3.0</td>
<td>2.5</td>
<td>3.3</td>
<td>2.2</td>
<td>1.0</td>
<td>0.4</td>
</tr>
</tbody>
</table>

All analyses by ICP-MS at the USGS in Denver, Colo.
<table>
<thead>
<tr>
<th></th>
<th>LLV flow RU-20</th>
<th>Zeolite in LLV flow 86-1A</th>
<th>Sanidine crystal in LLV flow 86-1B</th>
<th>LLV tuff 86-1M</th>
<th>LLV tuff 87-10</th>
<th>LLV tuff 87-20</th>
<th>El Valle Pluton 87-1D</th>
</tr>
</thead>
<tbody>
<tr>
<td>(^{87}\text{Rb}/^{86}\text{Sr})</td>
<td>3.2347</td>
<td>0.00378</td>
<td>4.3795</td>
<td>7.2903</td>
<td>n/d</td>
<td>n/d</td>
<td>n/d</td>
</tr>
<tr>
<td>(^{87}\text{Sr}/^{86}\text{Sr})</td>
<td>0.709163</td>
<td>0.705248</td>
<td>0.710069</td>
<td>0.714131</td>
<td>n/d</td>
<td>n/d</td>
<td>n/d</td>
</tr>
<tr>
<td>(^{87}\text{Sr}/^{86}\text{Sr}\text{int}^*)</td>
<td>0.705256</td>
<td>0.705243</td>
<td>0.704780</td>
<td>0.708526</td>
<td>n/d</td>
<td>n/d</td>
<td>n/d</td>
</tr>
<tr>
<td>(^{147}\text{Sm}/^{144}\text{Nd})</td>
<td>0.1306</td>
<td>n/d</td>
<td>0.13796</td>
<td>0.1394</td>
<td>n/d</td>
<td>n/d</td>
<td>n/d</td>
</tr>
<tr>
<td>(^{147}\text{Nd}/^{144}\text{Nd})</td>
<td>0.512831</td>
<td>n/d</td>
<td>0.512677</td>
<td>0.512616</td>
<td>n/d</td>
<td>n/d</td>
<td>n/d</td>
</tr>
<tr>
<td>(\epsilon\text{Nd}_{1,8})</td>
<td>+4.25</td>
<td>n/d</td>
<td>+1.16</td>
<td>-0.04</td>
<td>n/d</td>
<td>n/d</td>
<td>n/d</td>
</tr>
<tr>
<td>(^{207}\text{Pb}/^{204}\text{Pb})</td>
<td>15.667</td>
<td>15.644</td>
<td>15.650</td>
<td>15.616</td>
<td>15.633</td>
<td>15.568</td>
<td>15.603</td>
</tr>
<tr>
<td>(^{208}\text{Pb}/^{204}\text{Pb})</td>
<td>39.133</td>
<td>38.793</td>
<td>39.027</td>
<td>38.980</td>
<td>39.052</td>
<td>38.269</td>
<td>38.330</td>
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</tbody>
</table>

n/d = not determined.
All measured Nd isotopic ratios are better than ±20 in the last two significant figures; La Jolla Nd = 0.511836. \(\epsilon\text{Nd}\) based on present day CHUR = 0.511836 and \(^{147}\text{Sm}/^{144}\text{Nd} = 0.1967\). Sr values are better than ±20 in the last two significant figures (2\(\sigma\)). NBS 987 = 0.710240 ± 12.
NBS 981 values used for Pb: \(^{208}\text{Pb}/^{204}\text{Pb} = 2.1664 ± 12; ^{207}\text{Pb}/^{204}\text{Pb} = 0.91482 ± 20; ^{206}\text{Pb}/^{204}\text{Pb} = 0.05931 ± 20.
Procedural blanks for Sm, Nd and Pb < 1 ng and < 2 ng for Sr.
* Initial ratios based on an age of 85 m.y.b.p.
** Lead isotopic ratios are present-day values and are corrected for 0.0005 per AMU; procedural blanks for Pb were < 0.7 ng.

Lead, strontium and neodymium isotopes

Sr, Nd and Pb isotopic ratios as well as Rb, Sr, Sm and Nd concentrations were determined by thermal ionization mass-spectrometry at the University of Florida using a VG Micromass 354 mass-spectrometer. \(^{87}\text{Sr}/^{86}\text{Sr}\) and Rb/Sr of six samples from the Loma la Vega volcanics and tuffs and one sample from the El Valle pluton are presented in Table 6 together with \(^{143}\text{Nd}/^{144}\text{Nd}\) values for three of these samples. Four whole-rock and two sanidine crystals were also analyzed for common lead isotopic ratios (Table 6). Methodology for the determination of Pb isotopes is similar to that of Mukasa et al. (1987) and methodology for Nd and Sr isotopes is described by Lebron (1989).

Geochemical results

Major-element analyses of samples from the Loma la Vega volcanics are presented in Tables 1 and 2, where we also include the composition of one tuff (sample VSD-155) reported by Bourdon (1985). Harker variation diagrams in Fig. 7 show selected major-element data relative to published results from Cretaceous igneous rocks in Puerto Rico and the Virgin Islands. Major-element analyses of an andesite from the Guamira basalt unit and a leucocratic tonalite from the El Valle pluton are also presented (patterned squares in Fig. 7).

It should be noted that the samples analyzed have undergone some degree of low-grade metamorphism and/or hydrothermal alteration. Extensive alteration has been shown to cause major changes in the primary major-element chemistry of volcanic rocks because of element migration and metasomatism (Gunn and Roobol, 1976;...
Wood et al., 1976; Schellekens et al., 1989). However, the relative coherency of elemental abundances, particularly those considered to be immobile during low-temperature alteration, in the Loma la Vega volcanics suggests only minor changes have occurred. In particular, the high-field-strength elements (HFSE) and rare-earth elements (REE) appear to have been little affected and are believed to reflect primary compositional affinities.

There is also a relative coherency of elemental abundances in the igneous and tuff samples analyzed. This coherency suggests that whole-rock analyses of tuffs provide a good representation of their igneous parent materials despite mechanical fractionation and other volcanogenic processes affecting tuffs.

**Major-element geochemistry**

The Loma la Vega volcanics have high aluminum and alkali concentrations (particularly K₂O), and low magnesium and titanium contents at intermediate silica concentrations (Table 1). Based on alkali-silica variations alone, the Loma la Vega samples could be classified as potassic trachytes or latites. Comparisons between the compositions of these rocks and samples from the primitive island-arc (PIA) and calc-alkaline (CA) volcanic rock series from the Caribbean island arc (Donnelly et al., 1971; Donnelly and Rogers, 1980; Donnelly et al., 1990) are shown in Fig. 7. The geochemically depleted nature of the PIA series is indicated by their low K₂O values typical of low-K, island-arc tholeiites. Both the Guamira and El Valle samples plot within the low-K, PIA field. Their high Na₂O contents is typical of spilitized samples in the PIA series. In contrast,
the Loma la Vega volcanics have some of the highest K₂O concentrations in the northern Caribbean Cretaceous arc and have distinctively lower values of CaO, TiO₂ and MgO and higher Al₂O₃ compared to other Caribbean calc-alkaline, intermediate volcanic rocks.

Fig. 8. (A). Primitive mantle-normalized trace-element diagram of Loma la Vega volcanics from Cordillera Oriental, Dominican Republic. Light rare-earth- and LIL-elements enrichments and HFSE depletions are characteristics of calc-alkaline (CA) arc rocks worldwide. Relative depletions of Sr and Eu, and possibly Ba, are a consequence of feldspar fractionation in some samples and are not indicative of primitive values. Sample number TD-17 is from the Lapa Lava Member of the Robles Formation of Puerto Rico. The Lapa Lava Member is a Cretaceous high-K, calc-alkaline andesite (Donnelly and Rogers, 1978, and unpublished data) that shows a similar trace-element pattern to the Loma la Vega volcanics. Mid-ocean ridge basalt (N-MORB) and ocean island basalt (OIB) from Sun and McDonough (1988) are shown for comparison. (B). Mantle-normalized trace-element diagram of pre-Aptian andesite (Guamira basalt unit) and a low-K granitic sample from El Valle pluton from the Cordillera Oriental, Dominican Republic. (Representative primitive island-arc (PIA) samples and data are from Donnelly and Rogers, 1980; and Donnelly, unpublished 1977 data).
The high K\textsubscript{2}O concentrations and K\textsubscript{2}O/Na\textsubscript{2}O ratios coupled with the high Al\textsubscript{2}O\textsubscript{3} and low TiO\textsubscript{2} values in the Loma la Vega volcanic rocks are characteristic of high-potassium calc-alkaline and shoshonitic magma series found in some other arcs and continental margins (cf., Edgar, 1980; Morrison, 1980; Gill, 1981; Venturelli et al., 1984). Classification of these rocks solely based on labile major elements must be considered speculative because of their possible redistribution during alteration. Unusually low CaO contents and increasing K\textsubscript{2}O contents with decreasing Na\textsubscript{2}O and CaO suggest metasomatic replacement of Na and Ca by K during alteration and metamorphism. Lidiak (1965) discusses similar elemental variations in calc-alkaline lavas in Puerto Rico (included in data plotted in Fig. 7) and suggests metasomatism was a consequence of post-consolidation deuteric alteration by alkali-rich fluids. Regardless of the extent of K-metasomatism in the Loma la Vega volcanics, the presence of leucite in some of the lavas and ubiquitous sanidine phenocrysts are indicative of a high-K parental magma.

Trace-element geochemistry of the Loma la Vega volcanics

Trace elements, particularly those considered immobile during alteration, are potentially more useful in identifying the rock series to which the Loma la Vega volcanics belong and in deciphering the magmatic processes that may have affected the evolution of the observed rock compositions. Trace-element abundances are presented in Tables 3, 4 and 5 and plotted relative to primitive mantle abundances (Sun and McDonough, 1989) in Fig. 8A.

Large-ion-lithophile elements (LILE)

LILE in arc volcanic rocks generally show a positive correlation with potassium and silica concentrations. Alteration of the Loma la Vega volcanics has probably remobilized the LILE to some extent and produced a wider range of values than would be expected from magmatic processes alone. In spite of this, certain trends and characteristics remain distinguishable.

Rubidium. Rubidium values range from 164 to 255 ppm (Table 3) in samples of the Loma la Vega volcanics and there is a crude correlation between K and Rb (K/Rb varies from 406 to 448). In comparison, evolved volcanic rocks from Puerto Rico and the Lesser Antilles have Rb contents that vary from about 10 to 128 ppm and K/Rb ratios mostly between 200 and 1000 (Donnelly and Rogers, 1980; White and Dupré, 1986; Davidson, 1987). Calc-alkaline rocks in other "mature" arc settings, such as the Fiji Islands, have similar ranges (Jakes and Gill, 1970; Gill, 1988), whereas fractionated arc shoshonites have slightly smaller ranges (98–590 ppm) (e.g., Morrison, 1980; Venturelli et al., 1984, Foley and Wheller, 1990).

Barium. Aside from a high value of 763 ppm in one lava, barium contents in the Loma la Vega volcanics are relatively low (150–257 ppm; see Table 3) relative to their high K\textsubscript{2}O contents. Consequently, these rocks have high K/Ba values. Although somewhat erratic, the barium contents of the Loma la Vega volcanics plot within the wide range of the barium contents of intermediate calc-alkaline volcanic rocks from Puerto Rico and the Lesser Antilles (i.e., values from 122 to 2030 ppm) (Donnelly and Rogers, 1980; Davidson, 1987) but tend to be on the low side. It is possible that Ba in the Loma la Vega volcanics was removed during hydrothermal alteration or potassium feldspar fractionation but this is opposite to the effect predicted from the observed K\textsubscript{2}O enrichment.

Lead. Lead concentrations in the Loma la Vega volcanics vary from 21.5 to 24.9 ppm (Table 5). These lead values are higher by a factor of 4 to 20 compared to Pb values reported from Puerto Rico and the Lesser Antilles (Donnelly and Rogers, 1978, 1980; White and Dupré, 1986) and other intermediate calc-alkaline rocks from mature arcs such as the Fiji or Aleutian Islands (DeLong et al., 1985; Gill, 1981; 1988). Such high concentrations and high Pb/Nd values are typical of marine sediments (White and Dupré, 1986). The elevated abundances of lead appear as a
characteristic positive “spikes” on mantle-normalized diagrams (Fig. 8A).

**Strontium.** Strontium ranges from 76.6 to 238 ppm in the Loma la Vega volcanics (Table 3). Compared to other intermediate arc volcanic rocks from the Caribbean and circum-Pacific, the Loma la Vega volcanics have relatively low Sr contents. In many island arcs, Sr generally exhibits a positive correlation with K O (Perfit et al., 1980; Foley and Wheller, 1990) but this correlation is not observed in the Loma la Vega volcanics. In part, the low Sr concentrations may be a consequence of extensive feldspar fractionation during magma evolution. Significant europium anomalies in chondrite-normalized REE patterns and relatively low Ba values support this hypothesis.

**Cesium.** Cesium contents in the Loma la Vega volcanics vary from 0.2 to 5.7 ppm (Table 3) are typical of the range of Cs values reported from Puerto Rico, Lesser Antilles and other intermediate calc-alkaline rocks from mature arcs such as the Fiji Islands (Jakes and Gill, 1970) and the Aleutian Islands (DeLong et al., 1985). In both the Fiji and the Aleutian arcs, Cs values increase with differentiation. Slightly higher values in some of the Loma la Vega volcanics samples may indicate a higher degree of fractionation than in Fiji or Aleutian Islands or inherently higher LILE abundances.

**High-field-strength elements (HFSE) and rare-earth elements (REE)**

HFSE and REE are considered immobile during low to moderate grades of metamorphism or metasomatic alteration (Pearce and Norry, 1979). Floyd and Winchester (1978) have shown that Ti, Zr, Y and Nb are immobile elements in igneous rocks of intermediate composition that have experienced low-grade metamorphism.

Zirconium concentrations range from 144 to 212 ppm and Nb ranges from 6.5 to 8.8 ppm in the Loma la Vega volcanics and both show positive correlations with other HFSE (Table 3). The concentrations are similar to those in other evolved arc rocks and the observed variations follow intermediate to felsic compositional trends of volcanic arcs such as Tonga, South Sandwich, New Hebrides and the Lesser Antilles (Pearce and Norry, 1979). Such trends are probably the result of the fractional crystallization of feldspar, olivine, clinopyroxene, and magnetite. Low Zr/Y, Nb/Y and Ta/Y ratios are a consequence of relatively normal Y values but low Zr, Nb and Ta contents (Ta > 0.5 ppm). Depletions of HFSE relative to LILE in the Loma la Vega samples, typical of orogenic volcanic rocks world-wide (e.g., Perfit et al., 1980; Gill, 1981), are obvious on a mantle-normalized trace-element diagram (Fig. 8A). Negative Ti, Nb and Ta anomalies, even in fractionated lavas, are characteristic of calc-alkaline and shoshonitic igneous rocks in other mature arcs (Pearce and Norry, 1979; Foley and Wheller, 1990) but the abundances of the HFSE in the Loma la Vega volcanics are not as high as those measured in some shoshonitic suites (e.g., Venturelli et al., 1984; Pecceirillo et al., 1984).

Rare-earth-element concentrations of the Loma la Vega Volcanics are presented in Table 5. The Loma la Vega volcanics are moderately enriched in LREE, have negative europium anomalies, and exhibit flat HREE patterns. La/Yb ratios for the Loma la Vega volcanics range from 7.6 to 10.7. These ratios and the chondrite-normalized REE patterns are similar to those reported in intermediate calc-alkaline rocks from the Caribbean (Donnelly and Rogers, 1978; Donnelly, unpublished data, 1977; White and Dupré, 1986) and for calc-alkaline suites around the world (e.g., Perfit et al., 1980; Gill, 1981, 1988; Reid and Cole, 1983; DeLong et al., 1985). The REE abundances and patterns are not as enriched and LREE-fractionated as many rocks from high-K or shoshonitic suites (e.g., Peccerillo et al., 1984; Venturelli et al., 1984).

**Trace-element chemistry of the pre-Aptian El Valle pluton and Guamira basalts**

Trace-element concentrations of the Guamira basalts and the El Valle pluton are presented in Table 4. Trace-element abundances are shown on a mantle-normalized diagram (Fig. 8B) together with two representative low-K spilites from the primitive island-arc (PIA) series of Donnelly and
Rogers (1978, 1980). In contrast to the high K$_2$O contents in the Loma la Vega volcanics (and most calc-alkaline suites), the Guamira andesite and El Valle granite have very low K$_2$O concentrations which correspond to their relatively low Cs, Rb, Ba, Pb and Sr contents. However, the LILE are enriched relative to the REE and HFSE in these samples (Fig. 8B) — a characteristic of arc rocks in general. In particular, the large positive anomalies in Ba and Pb and negative anomalies in Nb and Ta seem characteristic of the Caribbean PIA series. The overall higher abundances of incompatible elements in the El Valle pluton is likely a consequence of its extremely differentiated nature. We also ascribe the negative Sr, Eu and Ti anomalies shown in Fig. 8B largely to the effects of extensive fractional crystallization of plagioclase and iron oxides.

Low concentrations of REE and the flat to only slightly LREE-enriched patterns distinguish these rocks from those of the calc-alkaline series. Trace-element patterns of the Cretaceous PIA rocks and the Guamira basalts suggest that both belong to the island-arc tholeiitic magmatic series (see Gill, 1981) and that both are petrogenetically distinct from rocks of the overlying Loma la Vega volcanics.

**Isotopic age of the Loma la Vega volcanics**

The $^{87}$Rb/$^{86}$Sr and $^{87}$Sr/$^{86}$Sr ratios from four whole-rock samples, one sanidine phenocryst, and a zeolite vein from the Loma la Vega volcanics are presented in Table 6. These ratios define an isochron whose slope gives an age of 84.3 ± 17.9 Ma and an initial $^{87}$Sr/$^{86}$Sr ratio of 0.70512 (Fig. 9A). Although some of the major and LIL elements in the Loma la Vega volcanics have been redistributed by alteration, evidence suggests alteration was either syn-magmatic or occurred soon after the Loma la Vega volcanics were deposited. There are several lines of evidence that support a relatively closed system with respect to Rb/Sr isotopic systematics:

1. Well-preserved glassy textures and no evidence of penetrative deformation in the Loma la Vega volcanics indicate that these rocks have not undergone major regional metamorphic events that would have completely reset the isotopic system.
2. The zeolite vein plots along the isochron slope and suggests that alteration/mineralization occurred as the Loma la Vega volcanics formed.
(3) Rb and Sr values in the LLV volcanics are relatively coherent and systematic suggesting that they have not been greatly affected by secondary alteration.

(4) Loma la Vega volcanics and the Las Guajabas tuffs are stratigraphically above Aptian-Albian limestone and the pre-Aptian Guamira basalts, and stratigraphically below Turonian pelagic limestones (Bourdon, 1985; see Fig. 3). The age of this section based on microfossils (97.5–91 Ma) is statistically indistinguishable from the isotopic age determined here (84.9 ± 17.8 Ma).

Strontium, lead and neodymium isotopes

Measured strontium, lead and neodymium isotopic compositions of representative samples from the Loma la Vega volcanics together with the calculated initial values for Sr and Nd at 85 m.y.b.p. are presented in Table 6. Lead isotopic

![Diagram](image-url)
ratios of one sample of the El Valle pluton are also presented in Table 6. Initial \(^{87}\text{Sr}/^{86}\text{Sr}\) values of the Loma la Vega volcanics range from 0.70478 to 0.705326 and \(\varepsilon\text{Nd}\) values range from +4.25 to −0.04 and lie within the “mantle array” defined by MORB and ocean island basalts (Fig 9B). The fact that the volcanic rocks plot within the mantle array, rather than to the right of it, suggests the Sr isotope systematics have not been significantly affected by seawater alteration. Although only a few Sr-Nd isotope values are available for rocks from the Cretaceous Caribbean arc (Fig 9B), the Loma la Vega samples are more radiogenic than calc-alkaline volcanic rocks from Puerto Rico (Perfit, unpublished data, 1989) but similar to the more radiogenic Neogene samples from the Lesser Antilles (White and Dupré, 1986; Davidson, 1987). The Loma la Vega samples plot within the concave arcuate Sr-Nd trend defined by lavas from the central Lesser Antilles; a trend believed to result from the contamination of depleted mantle with subducted sediment from the Atlantic seafloor (White and Dupré, 1986).

Lead concentrations of the Loma la Vega samples are high and their present-day isotopic compositions are moderately radiogenic (Table 5 and 6). On Pb-Pb plots, they lie within a fairly restricted field that overlaps with that of MORB and the field defined by volcanics from the central Lesser Antilles (White and Dupré, 1986; Davidson, 1987) (Fig. 10). Samples of El Valle pluton and Guamira andesite have distinctly lower \(^{206}\text{Pb}/^{204}\text{Pb}\) values than the Loma la Vega volcanics and plot in the field defined by rocks in the PIA series (Fig 10). Similar differences in Pb-isotopes between pre- and post-collisional volcanic rocks from the West Philippine arc have been noted by Mukasa et al. (1987).

Discussion

Original composition and affinity of the Guamira basalts and El Valle pluton

Petrographic, trace-element and isotopic data suggest the Guamira basalts and El Valle pluton are similar to rocks belonging to the island-arc tholeiitic (IAT) series; frequently interpreted to be characteristic of early or primitive island-arc volcanism (e.g., Donnelly and Rogers, 1978, 1980; Gill, 1988). In addition, both the Guamira basalts and the El Valle pluton appear to represent a magmatic episode that is distinct from that of the Loma la Vega volcanics. This interpretation is consistent with regional stratigraphy which indicates the pre-Aptian Guamira basalt unit is significantly older than the Loma la Vega volcanics. We assume that the El Valle pluton was intruded sometime prior to the Aptian.

Original composition and affinity of the Loma la Vega volcanics

The petrography and geochemistry of the Loma la Vega volcanic rocks suggest they originated as moderately alkaline lavas and pyroclastics of intermediate composition (high-K andesites and dacites or trachytes). Evidence for a high-K parental magma is based on the presence of euhedral phenocrysts of sanidine (Fig. 6A, C) and rare fergusonite in the volcanics (Fig. 6B). However, we believe the rocks have experienced some degree of metasomatism that enriched them in K and possibly Si and depleted them in Ca, Na and probably Mg. Immobile trace-element abundances and patterns suggest the original volcanics were part of the high-K calc-alkaline series not the shoshonitic series.

The textures and secondary mineralogies observed in the Loma la Vega volcanics may have been produced by autobrecciation, devitrification or autometamorphism (i.e., residual hydrothermal solutions reacted with the glass and minerals that crystallized while the flows were still cooling). The presence of recrystallized pelagic foraminifera in tuffs (Las Guajabas) interbedded with the Loma la Vega volcanics suggest there was a marine environment proximal to the eruption site which may explain the variety of vitroclastic textures observed in some of the the Loma la Vega volcanics (Cas and Wright, 1987).

Comparison of Loma la Vega volcanics to other circum-Caribbean volcanic rocks

High K\(_2\text{O}\) and low MgO and CaO contents of the Loma la Vega volcanics distinguishes them
A. PRESENT-DAY OUTCROPS: CRETACEOUS PRIMITIVE ISLAND ARC ROCKS

B. PRESENT-DAY OUTCROPS: CRETACEOUS OLIGOCENE CALC-ALKALINE ARC ROCKS

Fig. 11. (A). Present-day outcrops of Cretaceous primitive island-arc rocks in the Greater Antilles (map modified from Donnelly et al., 1990). (B). Present-day outcrops of Cretaceous to Oligocene calc-alkaline (map modified from Donnelly et al., 1990). See text for discussion.
from other circum-Caribbean calc-alkaline volcanic rocks. Although the LIL elements in the Loma la Vega volcanics have been remobilized to some extent, the LIL values tend to be in the range of many calc-alkaline arc rocks. In addition, the HFSE and REE follow trends similar to other fractionated calc-alkaline suites in island-arc settings worldwide. Variations in the abundances of Sr, Ba, Zr, Ti, Nb, Y and REE suggest that feldspars, clinopyroxene (± hornblende) and magnetite were the principal fractionating phases responsible for the observed evolutionary trends of the Loma la Vega volcanics. Strontium, neodymium and lead isotopic compositions of the Loma la Vega volcanics are similar to other calc-alkaline rocks in the Caribbean. The relatively radiogenic nature of the samples, coupled with their high LIL/REE characteristics, suggest subducted sediments were a minor but significant component in the petrogenesis of parental magmas (cf., White and Dupré, 1986; Davidson, 1987).

Compared to volcanic rocks from other island arcs, the Loma la Vega volcanic rocks are most like those associated with calc-alkaline volcanism and the subduction of continentally-derived sediments. The Loma la Vega samples are not as radiogenic as K-rich volcanics from the Roman region of Italy, but have similar Sr-Nd isotopic values to shoshonitic lavas from Papua New Guinea and Sunda arcs (Wallace et al., 1983; Varne, 1985).

Donnelly et al. (1971) and Donnelly and Rogers (1978, 1980) first noted that lead isotopes in the PIA series in the Caribbean are less radiogenic than those in the calc-alkaline series. Our data support their observations and suggest that differences in compositions of the PIA and calc-alkaline series may reflect different compositions of sources and/or contaminants of those sources. One explanation for major differences in the source compositions of the two series may be that a greater component of subducted sediment was involved in the formation of calc-alkaline magmas or that this sediment was more radiogenic. Pre-Aptian subduction may have been dominated by Pacific pelagic sediment, whereas post-Albian subduction involved the consumption of more radiogenic, terrigenous sediments from the Atlantic ocean basin derived from continental rocks in North and South America.

In summary, the Loma la Vega volcanics are high-K, intermediate to felsic calc-alkaline lavas and pyroclastic rocks that probably were erupted in or proximal to a marine environment prior to approximately 85 Ma (Santonian). Flows underwent autometamorphic or post-magmatic hydrothermal alteration that affected their texture, remobilized some major and LIL elements, but did not appreciably affect their HFSE, REE or isotopic signatures. We suggest that the Loma la Vega volcanics represent the first stages of a changing magmatic environment in the Hispaniola segment of the circum-Caribbean island arc. In contrast, the older, underlying Guamira basalts and El Valle pluton appear to represent late-stage island-arc tholeiitic magmatism that characterized PIA volcanism in the early Caribbean arc.

Regional correlation of PIA and CA rocks in the Cretaceous–Early Tertiary Caribbean island arc

Igneous rocks in the Cordillera Oriental confirm the existence of a pre-Aptian transition between primitive island-arc (PIA) series represented by the Guamira basalts and the El Valle pluton and calc-alkaline (CA) series volcanism represented by the Loma la Vega volcanics and Las Guajabas tuffs (Fig. 3). We have shown that the Loma la Vega volcanics are high-K, calc-alkaline magmas and not shoshonites as proposed by Bourdon (1985) and that the extremely high values of potassium in these rocks can be attributed to potassium metasomatism that occurred during hydrothermal alteration. In this section, we point out some regional correlations between the PIA to CA transition in the Cordillera Oriental and similar transitions in other parts of Hispaniola, Cuba, Puerto Rico and the Virgin Islands.

Distribution of PIA rocks

Rocks of the PIA series have mainly been studied in Puerto Rico and the Virgin Islands (Fig. 11A). In central Cuba, Pardo (1975) and
Iturralde-Vinent (pers. commun., 1992) note a major change in Aptian-Albian time that separates an “old volcanic section” from a distinct Late Cretaceous section. Díaz de Villalvilla (1988) and Stanek and Cabrera (1991) describe the geochemistry of both sections and indicates the pre-Aptian “old volcanic section” is tholeiitic, whereas the overlying post-Albian section is calc-alkaline to shoshonitic. Torrez and Fonseca (1990) report the presence of tholeiites in the Teneme Formation of Aptian-Albian age in eastern Cuba but more trace element and isotopic analyses of Cuban rocks are needed before correlations can confidently be made to other areas of the Caribbean arc.

In central Hispaniola, the Maimon Formation consists of undated, fault-bounded siliceous and mafic schists (Fig. 11A). The Amina and Tortue schists, more to the northwest, are lithologically similar and possibly correlative. The protoliths of all three of these units are proposed to be mafic to felsic volcanic rocks, graywackes, and carbonaceous shales (Draper and Lewis, 1991). Donnelly et al. (1990) tentatively propose that the igneous units in both the Maimon Formation and the Amina schists are part of the PIA suite on the basis of sparse geochemical data from metavolcanic rocks in the Maimon Formation. More recent geochemical studies of metavolcanic rocks from the Amina schist and Maimon Formation, support this hypothesis (S. Horan, pers. commun., 1993).

In east-central Hispaniola, the Los Ranchos Formation is a 3-km-thick Early Cretaceous section of spilites and keratophyres that we correlate with the nearby pre-Aptian Guamira basalts. The

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**Fig. 12.** Stratigraphic correlation of island-arc rocks in Cuba, Hispaniola, Puerto Rico and the Virgin Islands. See Fig. 11 for outcrop locations and text for discussion.
Los Ranchos Formation is unconformably over-lain by the Aptian–Albian Hatillo limestone. Kesler et al. (1991a) document depletions of LIL elements of the Los Ranchos Formation in comparison to more typical island-arc magmatic rocks. They correlate the lower part of the Los Ranchos Formation with the PIA series of the Virgin Islands (Water Island Formation) (Fig. 11A).

In the Virgin Islands, the PIA series is represented by the Water Island Formation, a thick, bimodal, Early Cretaceous section consisting mainly of submarine lavas (Donnelly et al., 1990) (Fig. 11A). In Puerto Rico, Donnelly et al. (1990) propose that the Pre-Robles Formation, consisting mainly of Early Cretaceous andesites, also belongs to the PIA series.

**Distribution of CA rocks**

Rocks of the CA series have been studied in Cuba, Hispaniola, Puerto Rico and the Virgin Islands (see Donnelly et al., 1990) (Fig. 11B). The CA section in these areas ranges from 1000 to 5000 m in thickness and is intruded by dioritic to granodioritic stocks and plutons of Late Cretaceous to Early Tertiary age; a period when the most extensive arc-related activity occurred in the Greater Antilles (Lewis et al., 1991; Kesler et al., 1991b). In Puerto Rico, CA rocks include the Robles Formation, which is composed of basaltic to andesitic lava and tuffs, interbedded with minor quantities of limestone (Donnelly et al., 1990). High-K andesites in the Robles Formation have been described as shoshonites by Jolly (1971).

In central Cuba, the CA series is represented by the Zaza Group which is Cenomanian to Maestrichtian in age and consists of andesites, basalts and rhyodacites (Pardo, 1975; Díaz de Villalvilla, 1988). The most abundant rock types are tuffs and volcaniclastic rocks (Haydoutov, 1986). In eastern Cuba, the correlative Aptian to Campanian Santo Domingo Formation is composed mainly of tuffs (Torrez and Fonseca, 1990) and the correlative Berrocal Group of east-central Cuba consists of Upper Cretaceous andesitic flows. The lack of trace-element or isotopic studies of all of these Cuban rocks makes their correlation with CA rocks in other areas of the Caribbean arc tentative.

**Timing and nature of PIA–CA transition**

Although the local stratigraphy and structure of arc rocks in the Greater Antilles are complex, some striking correlations exist between the timing and nature of the PIA to CA transition in Hispaniola and Puerto Rico. On both islands, a major erosional unconformity separates underlying PIA rocks from overlying CA rocks (Fig. 12). This unconformity is overlain in both areas by a shallow-water, recrystallized Aptian-Albian limestone.

**Hispaniola.** In the northeast Cordillera Central of Hispaniola, the limestone is generally less than 100 m thick and overlies a basal conglomerate that is generally less than 10 m thick. Open-pit excavations at the Pueblo Viejo gold and silver mine in the Dominican Republic reveal that the conglomerate overlies the 1000–3000 m thick, PIA volcanic rocks of the Los Ranchos Formation (Kesler et al., 1991a). Russell and Kesler (1991) document a period of phreatic or phreatomagmatic eruptions and shallow water deposition at the top of the PIA section of eastern Hispaniola.

In the Cordillera Oriental of eastern Hispaniola, PIA rocks of the Guamira basalts are unconformably overlain by a similar 100–200 m thick, shallow-water limestone containing upper Aptian–lower Albian ammonites, rudists and microfauna indicative of a shallow-marine environment (Bourdon, 1985) (Fig. 3). Microfauna in overlying Upper Cretaceous limestone interbedded with subaqueous tuffs of the CA series suggest a deepening-upwards, pelagic depositional environment.

**Puerto Rico.** In central Puerto Rico, Berryhill and Glover (1960) and Kaczor and Rogers (1990) have mapped the Rio Matón limestone separating a lower, 5-km-thick PIA volcanic unit (Pre-Robles Fm.) from an overlying Albian–Turonian CA volcanic unit (Robles Fm.). The Pre-Robles Formation is thought to have been deposited in a subaerial and shallow marine environment while the Robles Formation is believed to have been deposited in a deep marine environ-
The Rio Matón limestone, which ranges in thickness from several meters to 60 m, consists of shallow water limestone facies formed near rudist reefs and inter-reef areas. Samples of the Rio Matón limestone have yielded Albian microfauna (Douglas, 1961) and early Albian rudists (Sohl, 1976). Because of the rapid deepening suggested for rocks above the Rio Matón limestone, Kaczor and Rogers (1990) suggest the limestone drowned during a phase of rapid subsidence of the underlying arc.

**Cuba.** In Cuba, biogenic, clastic and shallow marine carbonates of Albian age show similarities to the Rio Matón limestone in Puerto Rico. They overlie a bimodal tholeiitic rock series believed to be analogous to the PIA series and are associated with volcanic sandstones and conglomerates (Stanek and Cabrera, 1991).

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![Diagram](image_url)

**Fig. 13.** (A). Distribution of Cretaceous–Recent island arc and Late Cretaceous oceanic plateau crust in the Caribbean. (B). Cenomanian reconstruction of the Caribbean island arc and oceanic plateau (modified from Pindell and Barrett, 1990).
**Other areas.** Although similar Aptian–Albian limestone has not been identified in the Cretaceous arc sequences in the western Cordillera Central of Hispaniola nor the Virgin Islands, these areas exhibit an early to late Cretaceous transition from the PIA to CA volcanic series (Donnelly et al., 1990) (Fig. 3). The unconformity and limestone in eastern Hispaniola and Puerto Rico suggests the abrupt pre-Aptian PIA to CA transition may have also affected these adjacent areas.

**Tectonic model for PIA and CA rocks of the Caribbean island arc**

The close coincidence of the PIA to CA magmatic transition with a major uplift event in the Caribbean arc during Aptian–Albian time suggests that the two events may be related to a single tectonic mechanism (Lebron, 1989; Lebron and Perfit, 1993). A possible mechanism may have been the attempted northward subduction of buoyant Caribbean seafloor and subsequent reversal of subduction polarity as suggested by Mattson (1979) and later restated by Pindell et al. (1988), Burke (1988) and Pindell and Barrett (1990). We speculate that the transition from PIA to CA magmatism in the Greater Antilles may also be related to flipping from northward to southward dipping subduction.

In earliest Cretaceous time, a south-facing Caribbean island arc, composed primarily of submarine PIA rocks arrived along the western margin of North America and began to move north-

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**Fig. 14.** (A and B). Cartoon depicting Neogene subduction polarity reversal along the western margin of the Pacific Ocean in the Solomon Islands (modified from Johnson et al., 1978) compared to proposed Aptian–Albian subduction polarity reversal along the eastern margin of the Pacific Ocean in the Caribbean region. See text for discussion.
eastwards into the gap created by the separation
of North and South American plates (Pindell et
al., 1988; Pindell and Barrett, 1990) (Fig. 13A).
Remnants of this early Caribbean island arc are
recognized as PIA volcanics now found in His-
paniola, Puerto Rico, the Virgin Islands and pos-
sibly Cuba (Fig. 12). By Cenomanian time, sea-
floor spreading at the site of the present-day
Caribbean Sea had widened the gap between
North and South America to approximately
1000–2000 km and allowed the northeastward
and eastward moving arc system to enter the area
of the present-day Caribbean and consume a
proto-Caribbean Sea of Late Jurassic and Early
Cretaceous age (Pindell et al., 1988; Pindell and
Barrett, 1990) (Fig. 13B). Collision between the
young Caribbean island arc and the buoyant,
non-subductable oceanic plateau that comprised
the crust of the Caribbean Sea during Cenoma-
nian times (Burke, 1988; Pindell and Barrett,
1990) caused regional uplift, lead to the cessation
of early PIA volcanism and resulted in the depo-
sition of shallow-water limestone over an exten-
sive area of the arc massif (Fig. 14B). Continued
eastward movement of the Caribbean plate re-
sulted in a reversal in subduction polarity and the
oceanic crust of the proto-Atlantic began to be
subducted beneath the proto-Greater Antilles
(Pindell and Barrett, 1990). New melts were de-
derived from a mantle source chemically modified
by the subduction of Atlantic sediments and pos-
sibly slab-derived fluids from the earlier north-
dipping subduction. Enrichments in arc magmas
due to delayed partial melting of subduction-
modified mantle have been discussed by Johnson
et al. (1978). Magmatism associated with the new
south-dipping subduction became relatively more
enriched and radiogenic and, therefore, more
characteristic of the CA magma series as the arc
continued to grow and mature.

Comparison of the Caribbean and Solomon Islands
arc

We propose that several stratigraphic and
petrochemical similarities exist between the tec-
tonic evolution of the Cretaceous Caribbean arc
and the better documented Neogene Solomon
Islands arc in the southwest Pacific (Fig. 14). Geologic and geophysical evidence suggest that a
reversal of subduction polarity occurred along the
northeast-facing Solomon arc during Late
Miocene time (Dunkley, 1983; Musgrave, 1990).
Initial southwestward subduction of the Pacific
plate beneath the Australian plate during
Oligocene—early Miocene time resulted in deforma-
tion of the oceanic arc basement and eruption
of island-arc tholeiites, many of which are of
submarine origin and arc similar in composition
to the Caribbean PIA series (Dunkley, 1983).
Polarity reversal resulted from attempted subduc-
tion of the Ontong–Java oceanic plateau, a sub-
marine feature with a similar crustal thickness
and composition to the Caribbean oceanic plateau
(Bowland and Rosencrantz, 1988). During this
collisional event, PIA volcanism ceased; the now
dormant island arc was uplifted; a broad fold belt
of igneous and sedimentary material accreted
along the border between the oceanic plateau
and the arc, and the arc massif became the site of
widespread shallow-water limestone deposition
(Coulsen and Vedder, 1986). By Pliocene time,
subduction polarity had completely reversed,
forming the New Britain–San Cristobal trench on
the southwest side of the island arc, and magma
compositions abruptly changed to more felsic
types with CA characteristics.

Dunkley (1983) interpreted the change to more
enriched magma compositions as a result of mod-
ification of the sub-arc mantle by slab-derived
fluids remaining from the previous period of
west-dipping subduction. This process of enrich-
ment, originally proposed by Johnson et al. (1978)
for Cenozoic magmatism in the highlands of
Papua New Guinea, has also been invoked by
Barsdell et al. (1982) to explain the distribution of
geochemically distinct Cenozoic volcanic rocks in
the northern New Hebrides (Vanuatu) arc and by
Wallace et al., (1983) to explain the unusual
alkalic rocks in the Tabar-to-Feni arc north-west
of the Solomon Islands.

We emphasize the similarity of the Neogene
history of arc reversal in the Solomon Islands to
the Aptian–Albian transition between PIA and
CA volcanic series in Hispaniola and the coinci-
Petrochemistry and Tectonics of a Cretaceous Island Arc, Cordillera Oriental, Dominican Republic

We propose that the abrupt transition between the Caribbean PIA and CA volcanic rock series may have occurred as a result of arc polarity reversal rather than gradual arc “maturation” through time as proposed by Bourdon (1985) and Donnelly et al. (1990). In this model, compositional differences in PIA and CA rock suites may be attributed to a sudden change in subducted source materials (e.g., subduction of an old oceanic plate with thick pelagic sediment cover versus subduction of a younger oceanic plate with thin, continentally-derived, terrigenous sediment cover) and to renewed partial melting of previously subduction-modified mantle.

Conclusions

(1) The geochemistry and petrology of the late Cretaceous Loma la Vega volcanic rocks and Las Guajabas tuffaceous rocks from the Cordillera Oriental, eastern Dominican Republic, indicate that these rocks are intermediate to felsic rocks with calc-alkaline (probably high-K) affinities. The Loma la Vega volcanic flows are interbedded in a thick sequence of marine-deposited epiclastic, calc-alkaline tuffs that overlie Albian–Aptian limestone and pre-Aptian primitive island-arc basalts and granitic plutons.

(2) The texture and secondary mineralogy of many of the Loma la Vega volcanic rocks suggest autometamorphism and/or hydrothermal alteration occurred during or shortly after eruption. Low-temperature alteration processes were partially responsible for the high concentrations of potassium in these rocks as well as depletions in sodium, calcium and possibly magnesium. Alteration affected some of the LIL trace elements to different extents but the HFSE, REE and isotopic compositions of the rocks appear to have remained largely unaffected. Based on the concentrations of relatively immobile elements, these volcanics are considered to be part of the high-K calc-alkaline series common in other island arcs rather than the shoshonitic series as previously proposed.

(3) Sr, Nb and Pb isotopic signatures of the Loma la Vega volcanics are similar to other calc-alkaline rocks in the Caribbean and suggest the contribution of an “enriched” component (most likely from Atlantic sediment subduction) in the petrogenesis of parental magmas.

(4) The stratigraphic sequences present in the Hispaniola (Cordillera Oriental), Puerto Rico, and Cuban segments of the circum-Caribbean island arc (Fig. 12) indicate a period of magmatic quiescence, uplift and erosion during late Early Cretaceous to early Late Cretaceous time.

(5) Based on previous plate tectonic models for the evolution of the Caribbean (e.g., Mattson, 1978; Burke, 1988; Findell and Barrett, 1990), we interpret the Cretaceous stratigraphic sequences and abrupt transition from PIA to CA magmatism in the Greater Antilles area as consequences of attempted subduction of the Caribbean oceanic plateau and subsequent arc polarity reversal. A Neogene tectonic analogy is the collision of the Ontong–Java Plateau with the Solomon Islands arc along the western margin of the Pacific Ocean (Fig. 14). In the Caribbean region, collision of the oceanic plateau with the proto-Greater Antilles during pre-Aptian (< 119 m.y.b.p.) time ended north-dipping subduction which produced the early volcanic PIA arc basement. Uplift after collision resulted in the deposition of shallow-water limestone and further convergence resulted in a new, post-Albian (> 97 m.y.b.p.) south-dipping subduction zone beneath the proto-Greater Antilles. The mantle source of the renewed magmatism was modified by slab derived fluids from the previous north-dipping subduction and subduction of North Atlantic sediments which resulted in the generation of enriched rocks of CA affinities.

(6) This study has documented the existence of a late Early Cretaceous (Aptian–Albian) transition from PIA (Guamira basalts and El Valle pluton) to CA (Loma la Vega volcanics and related rocks) in eastern Hispaniola. We emphasize the similarity of this transition to others in the Greater Antilles and to abrupt changes from tholeiitic to calc-alkaline magmatism in other arcs. We propose this tectonically-instigated change from PIA to CA rocks as an alternative possibility to the generalized models of gradual magmatic evolution in arc systems.
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