Thrust emplacement of the Hispaniola peridotite belt: Orogenic expression of the mid-Cretaceous Caribbean arc polarity reversal?

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ABSTRACT

New structural data from central Hispaniola suggest that a mid-Cretaceous orogenic event resulted in the obduction of peridotites onto the early Antillean arc. The Maimón belt, which structurally underlies the peridotites, contains a shear zone composed of mylonitic and phyllonitic schists formed by northward thrust emplacement of the peridotites. Penetrative deformation decreases progressively to the northeast and is observed in the Neocomian sedimentary and volcanic rocks of the Los Ranchos Formation. The unconformably overlying, upper Albian–Cenomanian limestones are not penetratively deformed, thus bracketing the obduction to Aptian-Albian time. This event is synchronous with chemical changes of the arc magmas in Hispaniola, Puerto Rico, and central Cuba. Thus, they may both be related to the postulated Greater Antillean polarity reversal.

INTRODUCTION

The concept of a mid-Cretaceous subduction polarity reversal of the Greater Antillean arc was first introduced by Burke et al. (1978) and Mattson (1978). Later, more elaborate tectonic models (e.g., Pindell and Barrett, 1990; Pindell, 1994) showed an early Cretaceous southwest-facing, proto–Greater Antillean arc spanning the gap between North and South America, which then "flips" to a northwest facing arc, allowing the Americas to engulf the Caribbean portion of the Farallon plate. Evidence for the mid-Cretaceous age of this event is found in the pre-Albian orogenic and metamorphic events preserved in terranes of the southern Caribbean plate boundary (Snoke, 1991; Pindell and Erikson, 1994). Compelling evidence of orogenic effects accompanying the postulated "flip" in the northern Caribbean has not previously been presented, however, especially for Hispaniola. In this paper, we suggest that the orogenic manifestation of the polarity reversal in Hispaniola was a north-directed thrust emplacement of oceanic lithosphere onto island-arc crust that took place during Aptian–early Albian time.

REGIONAL SETTING

Hispaniola is an early Cretaceous to early Eocene arc edifice, modified by Tertiary left-lateral strike-slip tectonics (Mann et al., 1991; Draper et al., 1994). The island is not a simple arc edifice, however, because its central region consists of a median belt with serpentinized peridotite flanked by metamorphic units located between two Upper Cretaceous arc terranes (Bowin, 1966; Fig. 1).

The median belt is composed of several units. The partly serpentinized Loma Caribe peridotite is flanked by two basaltic volcanic sequences, the Siete Cabezas and Peralvillo formations, which Boisseau (1987) suggested are of Cenomanian-Coniacian age. The Rio Verde complex is along strike of the peridotite belt and consists of metabasites, gabbros, diabases, and basalts. Although originally mapped as the Duarte Complex (Bowin, 1966), this unit is sufficiently different that we regard it as a separate unit.

The extensive Duarte Complex bounds the southwestern margin of median belt and consists of metamorphosed, magnesian-rich, enriched mid-ocean ridge basalts (E-MORB) that have compositions comparable with oceanic plateaus or seamounts (Draper and Lewis, 1991; Lewis and Jimenez, 1991). Minor chert bands have yielded radiolaria, which indicate a Late Jurassic age (Montgomery et al., 1994). The median belt's northeastern flank consists of the Lower Cretaceous, dominantly volcanic Los

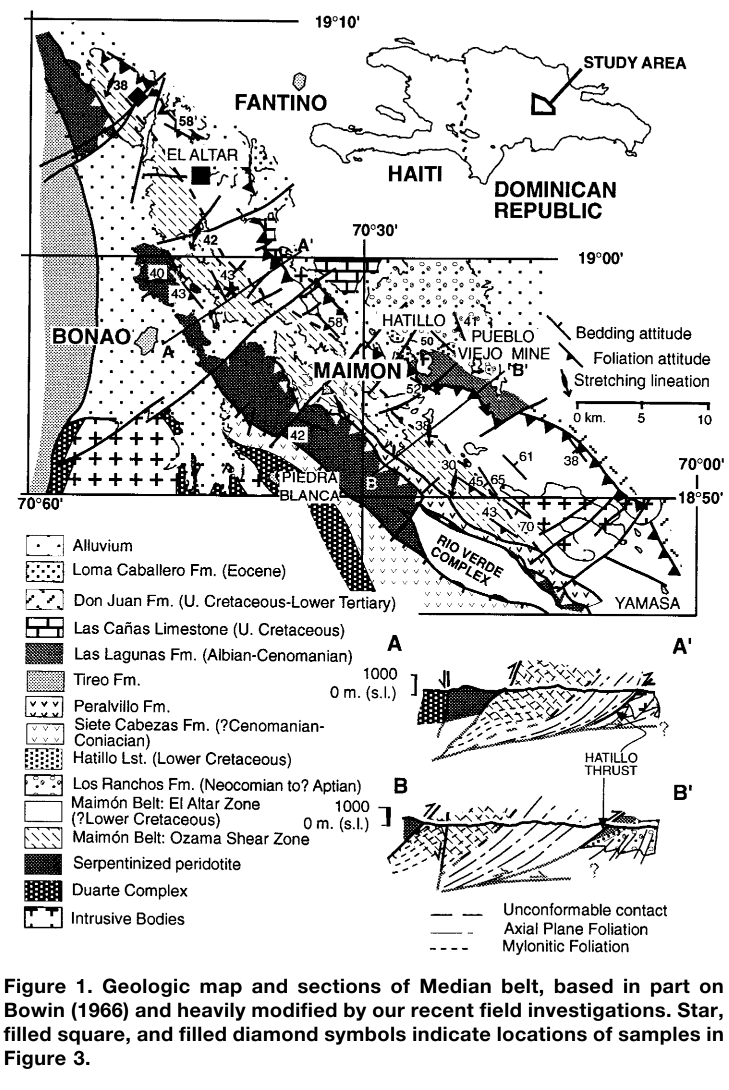

Figure 1. Geologic map and sections of Median belt, based in part on Bowin (1966) and heavily modified by our recent field investigations. Star, filled square, and filled diamond symbols indicate locations of samples in Figure 3.

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Ranchos Formation, which is unconformably overlain by Upper Cretaceous to lower Tertiary formations (see Fig. 1). The Hatillo thrust juxtaposes the metavolcanic rocks of the Maimón belt (?Lower Cretaceous) against these units (Bowin, 1966) and truncates the early Eocene limestones of the Loma Caballero Formation. At least some of the Hatillo thrust movement is, therefore, post–early Eocene.

Here, we attempt to clarify the structural relations and timing of deformation in the median belt and thus formulate a coherent tectonic interpretation of the region.

DEFORMATION OF THE MAIMÓN BELT

The protolith of the Maimón belt consists mainly of volcanic rock and minor sedimentary rocks (Kesler et al., 1991); the age of the protolith is unknown, but is probably Early Cretaceous. Our structural investigations reveal that the Maimón belt, although formed of a single unit, consists of two elongate and parallel structural-metamorphic provinces (Fig. 1). These are (a) the Ozama shear zone, which is a high-strain, greenschist-facies, ductile shear zone consisting of interlayered felsic mylonites and mafic phyllonites, and (b) the El Altar zone, which is a less-deformed, greenschist to prehnite-pumpellyite facies belt consisting of interlayered felsic and mafic tuffs with varying degrees of schistosity, but which exhibits both pure-shear and simple-shear fabrics. The sharp boundary between these two provinces has not been observed, but mapping indicates that it must be abrupt—probably a fault that dips southwest. This interpretation of the Maimón belt contrasts with that of Kesler et al. (1991), who viewed the Maimón belt as a series of interbedded, metaigneous and metasedimentary rocks. We agree that protolith lithologies can often be identified in the El-Altar zone; the extreme deformation in the Ozama zone obliterated most of the original textures.

Ozama Shear Zone

This zone is most clearly exposed in the upper Rio Ozama. Rocks consist of alternating felsic and mafic bands metres to tens of metres thick. Rocks of both compositions are L-S tectonites with the stretching lineation defined by aligned actinolite, elongate quartz, and/or epidote aggregates. The mafic bands often contain smaller, centimetre-scale layering. Thin, centimetre-scale quartz veins are common, and both veins and layering are tightly folded to form intrafolial folds. Folds are doubly verging, and we have found several sheath fold structures. In many cases the limbs of the folds are completely attenuated, leaving intrafolial fold hinges. Fold hinges lie in a great circle in the plane of foliation and there is a concentration of fold axes parallel to the stretching lineation (see Fig. 2). Such structures are indicative of ductile zones of a high degree of simple shear. The concentration of fold axes and the stretching lineation (Fig. 2) indicates that the shear is so intense that the separation angle is essentially zero. The indicated shear motion vector trends north to north-northeast, and numerous rotated porphyroclast structures indicate a top-to-the-north, or thrust, sense of shear.

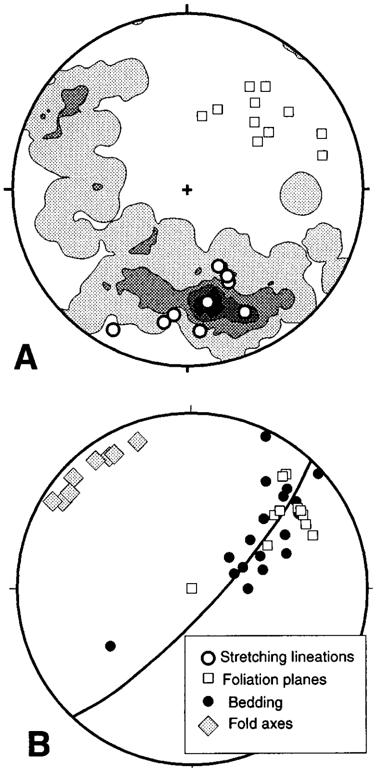

Figure 2. Lower hemisphere, equal area diagrams. A: Ozama shear zone in upper Ozama River. Contoured data show fold axes (contours at intervals of 4% points per 1% area; *N* = 98). Open circles show stretching lineations; note coincidence with maximum in population of fold axes. Open squares show poles to foliation planes, perpendicular to fold axes' great circle. B: Los Ranchos Formation at Pueblo Viejo. Black, filled circles represent poles to bedding located on best-fit great circle. Filled diamonds are fold axes, and open squares represent poles to foliations.

Petrofabric analysis on quartz ribbons or deformed quartz grains in felsic units also indicates thrust-related, ductile shear (Fig. 3, DR 9156 and DR 9148B). Ozama shear zone specimens exhibit monoclinic, small circle girdle (SG) fabrics and monoclinic type 1 crossed girdle (CG) fabrics (Schmid and Casey, 1986). These fabrics are consistent with a simple shear context and indicate ⟨a⟩ directed basal slip, typical of low-temperature (less than 350°) deformation (Blacic, 1975). This latter conclusion is compatible with the lower greenschist assemblages of the Maimón belt (Draper and Lewis, 1991), but it is not yet clear if the quartz textures developed during, or after, the peak metamorphic temperatures.

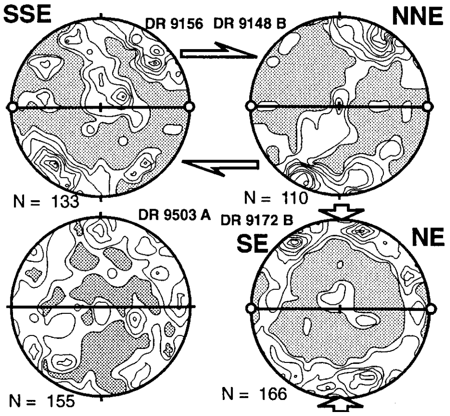

Figure 3. Lower hemisphere, quartz c-axis petrofabric diagrams of ribbons and quartz-rich domains in Ozama shear zone (DR 9156 and DR 9148 B; collected in adjacent localities indicated by star symbol in Fig. 1) and in El Altar Zone (DR 9503 and DR 9172; diamond and square symbols, respectively, in Fig. 1). Contour intervals at 0.5%, 1%, 2%, 3%, per 1% area. Lines indicate foliation planes, and white circles stretching lineation.

El Altar Zone

This part of the Maimón belt consists of greenschist to sub-greenschist grade metavolcanic and metasedimentary rocks that exhibit a lower and more variable degree of penetrative deformation than in the internal belt. Original volcanic and sedimentary features such as columnar jointing, breccia clasts, bedding, phenocrysts, and amygdules, albeit often deformed, can still be observed. The variability of deformation is illustrated by the petrofabric observations. A quartz c-axis fabric diagram (Fig. 3, DR 9503A) of a sample from Rincón shows a random pattern, indicating very little deformation of quartz by dislocation mechanisms. A similar fabric diagram (Fig. 3, DR 9172B) from a sample from El Altar, in the northern part of the belt, shows a symmetrical pattern that indicates pure shear deformation, although some simple shear deformation is usually present.

STRUCTURAL RELATIONS IN THE LOS RANCHOS FORMATION

The Los Ranchos Formation is considered to be Neocomian in age based on the fossil flora (Russel and Kesler, 1991). Excavations at the Pueblo Viejo (Fig. 1) open-pit gold mine have created excellent exposures of sedimentary and volcanic rocks of the Los Ranchos Formation (Kesler et al., 1991).

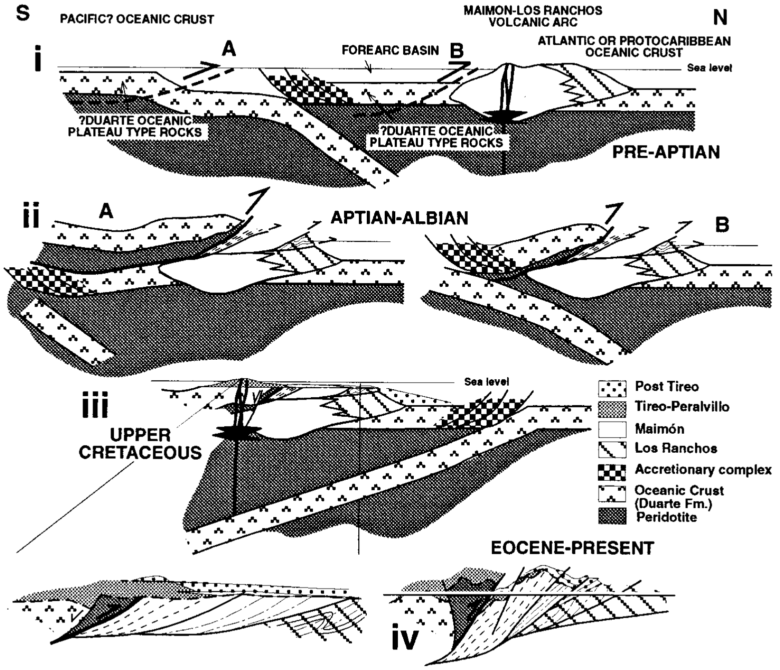

Figure 4. Cross sections illustrating the tectonic and structural evolution of Median belt. i: Arc prior to polarity reversal during pre-Aptian (Neocomian) time. A shows future site of sole thrust of Loma Caribe peridotite, if it and Duarte Complex are interpreted as having formed part of Pacific lithosphere. B shows site of sole thrust if Duarte–Loma Caribe represents the basement of forearc. ii: Obduction of the Duarte–Loma Caribe during the Aptian-Albian. A shows delamination of Pacific crust and obduction of an allochthonous Duarte–Loma Caribe over early Antillean arc. B shows an alternative scenario where forearc is thrust onto arc and the Duarte–Loma Caribe, at base of forearc, is para-autochthonous to arc. iii: Arc after polarity reversal in late Albian or Cenomanian. Magnified portion shows structural cross section of obducted peridotite, Maimón belt, and Los Ranchos. iv: Present-day configuration of Median belt following middle to late Eocene compression that reactivated and modified earlier geometry.

There, we found a penetrative cleavage that is axial planar to asymmetric, northeast-verging folds in the metasedimentary rocks of the Pueblo Viejo Member (Fig. 2B).

At Pueblo Viejo, the Los Ranchos Formation is also unconformably overlain by the Albian to Cenomanian age Hatillo Limestone (Russel and Kesler, 1991). Unlike the Los Ranchos, the Hatillo Limestone unit is not penetratively deformed (although it may be locally recrystallized), and thus its sedimentary age constrains the age of the Los Ranchos penetrative deformation. The age of the penetrative deformation in the Los Ranchos can be bracketed, therefore, as post-Neocomian, pre–late Albian to Cenomanian, or roughly between 100 and 130 Ma.

TWO-STAGE STRUCTURAL MODEL FOR THE DEVELOPMENT OF THE MEDIAN BELT

The penetrative nature of the deformation in the Maimón belt and the Los Ranchos Formation and the similarity of the orientation of the structures suggest that both units were subjected to a major thrust deformation event. Moreover, the stratigraphic relations of the Los Ranchos and Hatillo Formations suggest that this took place during approximately Aptian to early Albian time (100–130 Ma). We suggest that the tectonic mechanism for this event was a northward (in the present-day reference frame) obduction of the Loma Caribe peridotite (Fig. 4iii). Heat transfer from the sole of the thrust during obduction produced an inverted metamorphic-deformation gradient that decreased toward the north-northeast. High shear strains were thus partitioned into the hotter, more ductile parts of the Maimón belt closer to the sole. The orientation of the structures in the Los Ranchos Formation may indicate that the direction of thrusting may have changed from north to a more northeast direction in the later stages of deformation.

Such a scenario requires an adjustment of previous interpretations of what constitutes the Median belt ophiolite, because the emplacement of the peridotite must have taken place before the extrusion of the Peralvillo and Siete Cabezas basalts. We suggest, therefore, that the ophiolite may consist of either (1) a suprasubduction-zone body, stratigraphically underlying the Maimón or, more likely, (2) an association of the Loma Caribe peridotite with the metabasalts of the Duarte Complex (rather than with the Peralvillo–Siete Cabezas units as suggested by Boisseau, 1987; Draper and Lewis, 1991).

In the Late Cretaceous, after subduction had resumed on the northern side of Hispaniola (Fig. 4), the median belt was covered with volcanic and volcano-sedimentary deposits (Siete Cabezas, Peralvillo, and Las Lagunas formations) that were erupted through and deposited on top of the older, deformed rocks. West of the Median belt, in the Cordillera Central, the time-equivalent deposits were those of the Tireo Formation (Lewis and Jimenez, 1991), which represent the magmatic axis of Late Cretaceous arc activity. The arc accumulation continued until early Eocene time. In the middle to early late Eocene, Hispaniola underwent northeast-southwest contraction (Mann et al., 1991). Many of the mid-Cretaceous thrust structures were reactivated at this time, including the Hatillo thrust (Bowin, 1966), which juxtaposed the Maimón belt against lower Eocene and upper Cretaceous rocks. Reactivated thrusts emplaced the peridotites in a northeast direction over the Peralvillo Formation (Fig. 1). Horizontal axis rotation accompanying contraction steepened earlier faults and foliations (Fig. 4). The Eocene reactivation probably faulted out high-grade metamorphic rocks, which are expected to have formed adjacent to the sole thrust of the ophiolite as well as tectonically thickening the Maimón belt.

TECTONIC SIGNIFICANCE

Lebrón and Perfit (1994) demonstrated a change in composition of volcanic arc rocks in both Hispaniola and Puerto Rico, from primitive island arc to calc-alkaline in Albian time. They suggested that this change resulted from the switch from the Greater Antillean arc's consumption of Pacific lithosphere to proto-Caribbean lithosphere during the arc polarity reversal postulated by Pindell and Barrett (1990). Stanek and Cabrera (1991) reported a similar change in composition, occurring at the same, in central Cuba. The temporal coincidence of this magmatic event with Hispaniola's ophiolite obduction event suggests to us that it is highly likely that both were produced by the reversal.

Two possible tectonic-structural models (Fig. 4) explain the emplacement of the Duarte–Loma Caribe nappe in the context of a subduction polarity-reversal. The first indicates that the nappe was allochthonous to the arc and was part of the subducting Pacific plate (A in Fig. 4i). The second shows that the ophiolite might have formed part of the oceanic substrate on which the early Hispaniola forearc was formed (B in Fig. 4i), that is, was essentially para-autochthonous to the arc. In the first scenario, the Duarte–Loma Caribe nappe detached from the downgoing slab along its sole thrust and was obducted over the forearc onto the volcanic protolith of the Maimón (A in Fig. 4ii). In the second scenario, the sole thrust developed within the forearc, and the nappe along with the outer forearc was thrust over the volcanic arc (B in Fig. 4ii).

The Aptian-Albian event probably also affected Puerto Rico. Mattson (1973) reported north-directed emplacement of ophiolitic rocks, as indicated by asymmetric folding in radiolarian cherts. The timing of emplacement is poorly constrained to be definitely pre-Campanian, but later than pre-Albian. No similar orogenic event has been established in Cuba, however, but it is not clear if this is because it did not occur, or because it is masked by major Campanian and Eocene orogenic events (Pszczolkowski and Flores, 1986; Iturralde-Vinent, 1994; Draper and Barros, 1994).

The precise tectonic mechanisms that increased subduction zone coupling to produce the arc polarity reversal and accompanying orogenic events remain problematic. The idea that the reversal of the Greater Antillean arc could be caused by jamming of the early subduction zone by the entry of the central Caribbean oceanic plateau (e.g., Burke et al., 1978; Livacarri et al., 1981; Draper and Lewis, 1991; Lébron and Perfit, 1994) must be rejected, because the age of the Caribbean plateau is younger (88 to 89 Ma or Turonian-Coniacian; Duncan et al, 1994) than the Early Cretaceous age for the reversal inferred from this and other studies. Pindell (1994) suggested that the increased coupling was due to the initiation of opening of the South Atlantic, which suddenly accelerated the westward velocity of the Americas relative to the mantle. Increased spreading rates and Pacific plate buoyancy caused by the upwelling of a mantle superplume (Vaughn, 1995) may have further increased plate coupling.

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