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The Cretaceous island-arc rocks of the Camagüey area, Central Cuba

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With 4 figures in the text

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Abstract: The island-arc units that crop out in eastern Central Cuba can be divided into four groups according to their geological position as well as their petrological, geochemical and geochronological characteristics. The oldest, Lower Cretaceous group consists of bimodal, Na-rich plutonites, which form a northern magmatic belt. In a southern magmatic belt, Upper Cretaceous calcalkaline differentiated plutonites predominate. K-rich, alkaline rocks occur as well. The youngest, Campanian magmatic rocks are stocks of biotite granites and rhyolitic flow domes.

Zusammenfassung: Die im östlichen Zentralkuba aufgeschlossenen Inselbogen-Einheiten können durch ihre geologische Position, geochemische und petrologische Charakteristika sowie geochronologische Datierungen vier verschiedenen Gesteins-Gruppen zugeordnet werden. Die ältesten, unterkretazischen PIA-Gesteine bilden eine nördlichen Gürtel aus Na-betonten, bimodal zonierten Intrusionen. Im südlich anschließenden Intrusivgürtel treten vor allem oberkretazische kalkalkaline, differenzierte Gesteinsserien, untergeordnet alkaline, K-reiche Intrusiva auf. Die jüngsten, campanen Magmatite bestehen aus biotitgranitischen Intrusionen und rhyolithischen Laven.

Resumen: En la parte este de Cuba Central afloran unidades rocosas de un arco de islas Cretácico, las cuales se pueden dividir en cuatro complejos tanto por su posición geológica, la característica petrológica y geoquímica como por dataciones geocronológicas. El complejo más viejo, rocas de un arco de islas primitivo (PIA) del Cretácico Inferior, forma un cinturón intrusivo en el norte del área, compuesto de intrusiones bimodales-sódicas. En el cinturón intrusivo del sur predominan rocas calcoalcalinas diferenciadas del Cretácico Superior, en menor cantidad aparecen rocas plutónicas alcalinas potásicas. Como formación magmática más joven afloran intrusiones de granitos biotíticos y lavas riolíticas.

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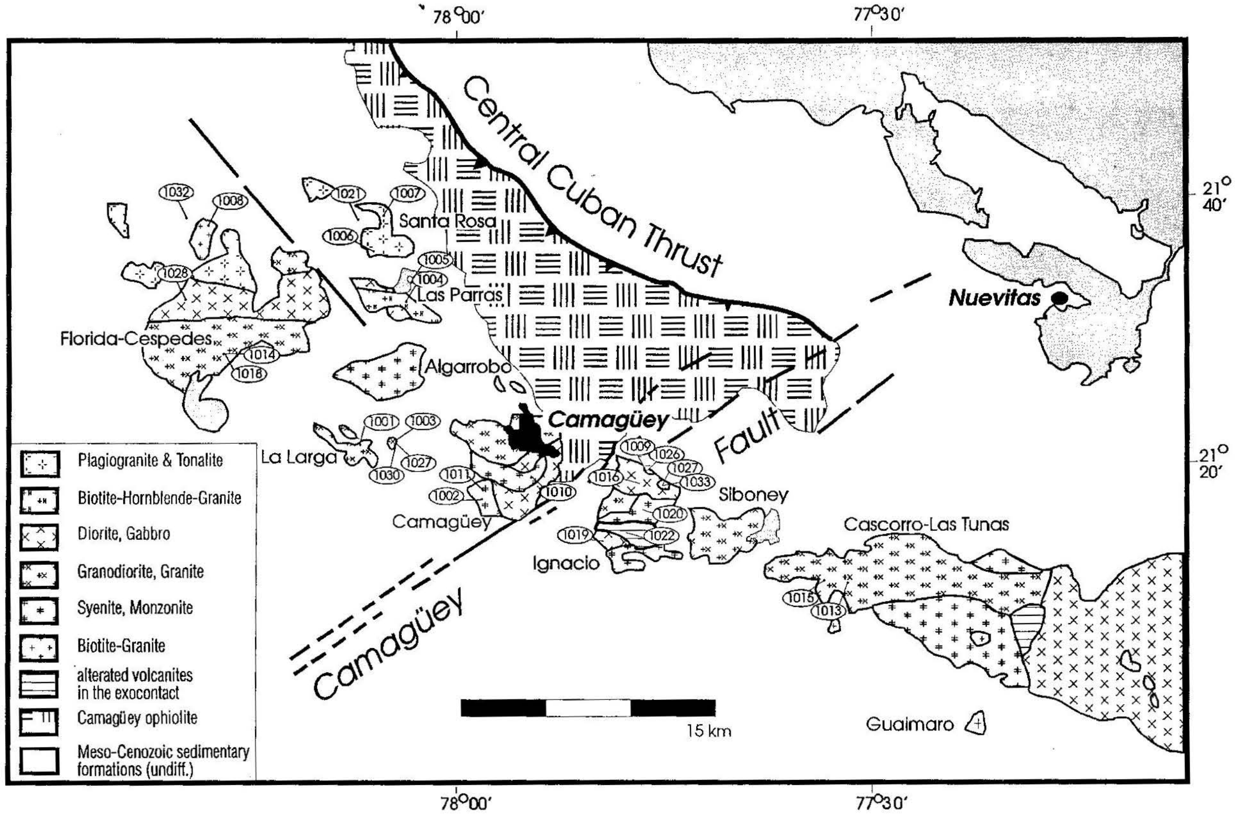

Fig. 1. Sketch map of island-arc plutonites in the region of Camagüey, based on field data of ITURRALDE-VINENT et al. (1987) and CEVCENKO et al. (1979). Encircled numbers indicate samples used in the present paper.

Introduction

The early magmatic and paleotectonic history of the northern Caribbean island arcs plays an important part in our understanding of the geotectonic development of the Caribbean microplate. In Cuba, Cretaceous island-arc rocks have been mainly exposed in two areas by Late Cretaceous to Early Tertiary thrusting and post-Eocene strike-slip faulting. West of the NE-trending Trocha fault, in Las Villas, the southern part of the island-arc suite is strongly deformed and overprinted by thrusting and uplift of the Escambray metamorphic complex. East of the Trocha fault, in the Camagüey peneplain, the rocks exhibit only a weak overprint by thrust-fault tectonics and metamorphism. Based on field observations, geochemical and geochronological data, a probably primary zonation of the Cretaceous island arc can be reconstructed. The analytical data is based on drill-hole material, sampled during regional mapping from 1985 to 1989.

Geologic setting

In the Camagüey area (Fig. 1), the Central Cuban Thrust forms the structural boundary between the southern extension of the Bahama platform and a Cretaceous island-arc terrane, the so-called Zaza zone in the south. North of Camagüey city, the thrust plane dips about 60° SW and is indicated by Eocene olistostromic units. To the west, the angle of dip decreases to about 30° (ECHEVARRIA, pers. comm. 1987). The base of the island-arc terrane is formed by the Camagüey ophiolite, in which peridotites and cumulate gabbros predominate. At its southern edge, the ultramafic complex is overlain by klippen-like bodies of island-arc volcanics.

The outcrops of the island-arc complex extend over about 80 km south of the ophiolite in a WNW-ESE striking direction. The prolongation of this geotectonic unit has been found in Las Villas, partly in Oriente (eastern Cuba) and on the eastern Greater Antillean islands. The island arc in Central Cuba has been magmatically inactive since the Late Cretaceous because of its collision with the Bahama platform.

The present tectonic structure is dominated by the NE-trending Camagüey fault. West of the Camagüey fault, two magmatic belts can be observed within the island arc. The belts are divided by NW-trending, Eocene graben-structures. East of the Camagüey fault, the northern part of the Cretaceous island arc is buried by Cenozoic sediments.

The Cretaceous island arc

Field observations

The northern, minor magmatic belt is formed by intrusions 3 to 5 km wide. As supported by aeromagnetic and gravity data (ITURRALDE-VINENT et al. 1987), the intrusive bodies show a characteristic zonation of plagiogranites, tonalites and trondhjemites in the central part, surrounded by diorite and gabbro. The light-grey, fine-grained plagiogranite

(sample 1007) in the central Santa Rosa massif consists of albite, quartz, and small amounts of euhedral amphibole. Additional, greenish biotite occurs in the granite (1004) of the Las Parras massif. Granophyric textures, synmagmatic microbrecciated feldspar and quartz, and intrusive breccias indicate a shallow level of emplacement. Similar rock types are exposed in the area north of the Florida-Céspedes massif. The basic phase of the intrusives is fine- to medium-grained. Clearly exposed contacts between leucocratic and basic rocks have not been found. The wall-rocks of the plutonites are volcano-sedimentary sequences, combined as the Caobilla Formation, which consist of tuffites, tuffs, plagiorhyolites, rare basalts and shallow marine carbonates. In the exocontact, alteration halos and magnetite skarns have been formed. On the basis of the petrological and geological data, and in accordance with DONNELLY & ROGERS (1980), the Na-rich plutonites of the northern belt will be called primitive island-arc magmatites (PIA) in the following.

The southern magmatic belt exhibits a broad variety of plutonic rocks and intrusive bodies. The largest intrusions, like the Florida-Céspedes massif or the Cascorro-Las Tunas massif, extend several tens of kilometres. On the other hand, the outcrop area of the plutonites depends on the erosional surface. In the Ignacio massif, only the "roof" part of the intrusion and overlying, altered volcanites are exposed by erosion. To the east, the outcrop areas and the depth of erosional level increase.

South of the belt of major intrusions, small "satellite" stocks of granodioritic composition like La Larga and Guaimaro are located.

The dominating rock types of this calcalkaline series (CAL) are fine- to medium-grained, grey diorite and granodiorite. Subordinate gabbro (Florida-Céspedes and Camagüey massif) and granite (Cascorro-Las Tunas massif) have been found. In thin-sections the samples reveal an equigranular texture of subhedral plagioclase laths, and euhedral to subhedral green amphibole (in some cases the amphibole shows a core of pyroxene - sample 1015). Subordinate subhedral K-feldspar, anhedral quartz and subhedral biotite occur. In the Florida-Céspedes massif, fine-grained mafic enclaves have been observed.

The second group of plutonites found here consists of K-rich, syenitic and monzonitic types (AL). Originally, these rocks were described as gabbro-syenite formation by EGUIPKO et al. (1984). In this paper, the rocks are classified after DE LA ROCHE et al. (1980). The K-rich plutonites are intimately associated with gabbroic rock types, although contacts are not exposed. The syenitic intrusions occur in the Algarrobo, the Camagüey and Ignacio massif. The largest syenitic intrusion has been mapped north of Guaimaro (CEVCENKO et al. 1979). The leucocratic to light-pink syenites have a medium- to coarse-grained, equigranular texture of subhedral K-feldspar, albite-rich plagioclase and greenish amphibole, as well as subordinate biotite. The syenites of the Camagüey and the Ignacio massif (sample 1022) exhibit autometasomatic alterations (chloritisation, replacement of plagioclase by K-feldspar, disseminated sulfides). Additional to the known K-rich magmatism in the northern part of the Caribbean (DONNELLY et al. 1990), Central Cuba forms the largest occurrence of K-rich plutonites and volcanics within the Greater Antilles.

East of Cascorro (sample 1013), north of Guaimaro and in some temporary quarries south of Florida (sample 1018), NE-trending dike swarms of granitic and granodioritic porphyries penetrate both vulcanoclastic

sequences and plutonites. The dikes, up to 20 m thick, strike for several hundred metres. Generally, the dikes are characterized by well-developed chilled margins and phenocrysts of amphibole and plagioclase, subordinate biotite and quartz.

North of the village of Florida, in the quarry of Piedrecitas, a stock of leucocratic biotite granite (sample 1008) crops out over an area of 6 km^2. Similar intrusions have been mapped on the northern edge of the Ignacio massif (the so-called Maraguan granites, sample 1009) and as dikes in the Siboney and the Algarrobo massif (ITURRALDE-VINENT et al. 1987). Leucocratic granites also occur within the Cascorro-Las Tunas massif (CEVCENKO et al. 1979). Volcanic equivalents of these granites have been mapped as the La Sierra Formation in the area between Camagüey and Guaimaro. The rhyolitic to dacitic volcanics form morphologically well-expressed flow domes and local flows. Both biotite granites and volcanics penetrate all the other island-arc rocks, but are themselves covered transgressively by Upper Cretaceous to Lower Tertiary conglomerates and limestones. Petrologically, the felsic magmatites consist of quartz, K-feldspar, albite-rich plagioclase and biotite. In contrast to the magmatites described earlier, miarolitic pockets with quartz and epidote have been observed. Due to their field relations, the biotite granites are called "late orogenic granites" (LOG) in the present paper.

The same trend of the erosional surface can be observed within the volcano-sedimentary sequences, which form the host rocks of the plutonites. In the area between Camagüey and Guaimaro, the volcano-sedimentary sequences fill a basin with a WNW-plunging axis, cut by the NE-trending Camagüey fault in the west. On the basis of the interpretation of aerophotographs, horizons of isolated carbonate bodies and conglomerates can be subdivided. Detailed paleontological dating of the carbonates is still lacking. However, west of the Ignacio massif plagiogranite pebbles have been found in Upper Cretaceous conglomerates (H. MÜLLER pers. comm. 1990); other granitoid pebbles occur in conglomerates of a stratigraphically lower level near the Loma de Caballeros south of the Carretera Central near Sibanicu. The pyroxene fraction from a basalt (drill hole 1-45i) within the same sedimentary member as the plagiogranite pebbles gave a K-Ar age of 147 ± 7 Ma. In the western part of the Ignacio massif, contact metamorphism of the youngest volcano-sedimentary formations has been observed only locally. K-Ar determinations of 76 ± 3 and 89 ± 9 Ma from fine-grained mica-quartz metasomatites (ITURRALDE-VINENT et al. 1987) indicate the Mid- to Late Cretaceous intrusion of calcalkaline and alkaline rocks of the Ignacio massif into the synchronously forming basin.

Geochemistry

Major and trace elements have been analysed by X-ray fluorescence spectrometry, the REE determined by ICP. For detailed analytical data please contact the author.

The variation of the major elements is shown as Harker diagrams (Fig. 2). Because a metasomatic overprint is weak or even absent, no major changes of the primary petrochemistry are to be expected.

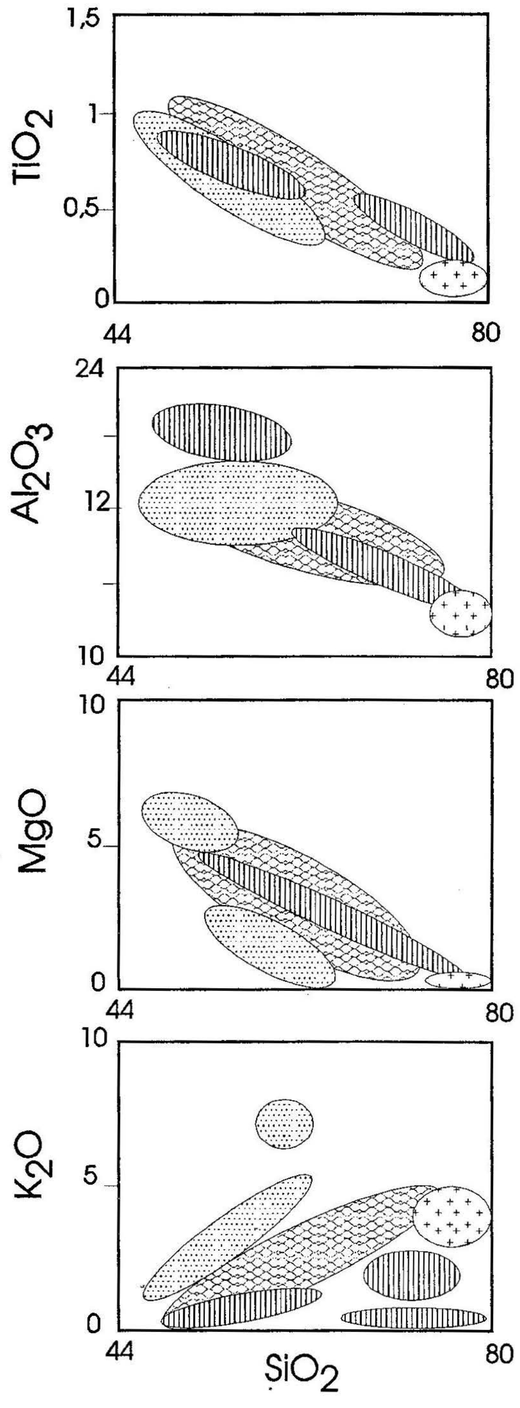

Fig. 2. Harker distribution of major elements versus SiO_2. For patterns see Fig. 4.

In comparison with the calcalkaline group, the plutonites of the northern belt (PIA) contain significantly less potassium. The SiO_2 contents permit a bimodal division of the PIA series. The bimodality is supported by enrichment of titanium in the felsic phase and by strong enrichment of aluminium and moderately of titanium in the basic phase. The contents of LILE (Rb, Sr, Ba) are extremely impoverished; the Rb/Sr ratio is similar to MORB.

In the southern belt, there is a linear correlation between the major elements and SiO_2 of the calcalkaline plutonites. Probably, these patterns are a result of fractional crystallization, a magmatic differentiation from gabbro to granite in an island arc. In contrast to the "normal" magmatic development, the alkaline, K-rich rocks (AL) are enriched in potassium, partly in magnesium (monzonitic rocks), but are moderately depleted in titanium. In comparison with CA rocks, they do not show significant differences in trace elements.

The granites of LOG generally show high SiO_2 contents, but anomalously low contents of Sr, Ti and V.

The REE patterns reveal significant differences between the various rock groups (Fig. 3) considered. The PIA have flat to very slightly LREE-enriched patterns and low total REE; Nd exhibits a negative anomaly.

The CA and AL rocks of the southern belt have LREE-enriched REE patterns, but, in common with the PIA rocks, no negative Eu-anomaly. The amount of total REE is several times higher than that of PIA.

The LOG granites exhibit patterns similar to the CA magmatics. However, there is a clear negative Eu-anomaly and a slight enrichment of the HREE. The positive Tb anomaly in all rock groups cannot be explained at present.

The magmatic development of the Cretaceous arc can be demonstrated in the diagram of BATCHELOR & BOWDEN (1985) (Fig. 4). Because of the high SiO_2 contents, the diagram is slightly modified in the R1 axis. The assumed oldest group, the PIA rocks, fall in parts into the field of tholeiites, the mafic endmembers trend to the calcalkaline field. The rocks of the southern magmatic belt occupy the calcalkaline and K-rich calcalkaline rocks of the subduction stage. Clear different from the older igneous rock groups, the field of the LOG granites (syn-collisional group) appears as the latest magmatic event during the island-arc development.

Geochronology

The first geochronological data for island-arc rocks in the Camagüey area have been published only within the last ten years (EGUIPKO et al. 1984, ITURRALDE-VINENT et al. 1989).

Stratigraphical data for the volcano-sedimentary units of the northern magmatic belt are still lacking, and therefore isotopic dating of plutonites plays an important role in clarifying the early development of the island arc. Unfortunately, K-Ar age determinations of the PIA rocks in the northern magmatic belt appear particularly problematical because of their low potassium content. Four preliminary determinations of fine-grained plagiogranite and tonalite give ages between 130 and 157 Ma (samples 1007 and 1006), in accordance with the results of ITURRALDE-VINENT et al. (1989), but the statistical errors (2δ) reach values of 12 to 49 Ma.

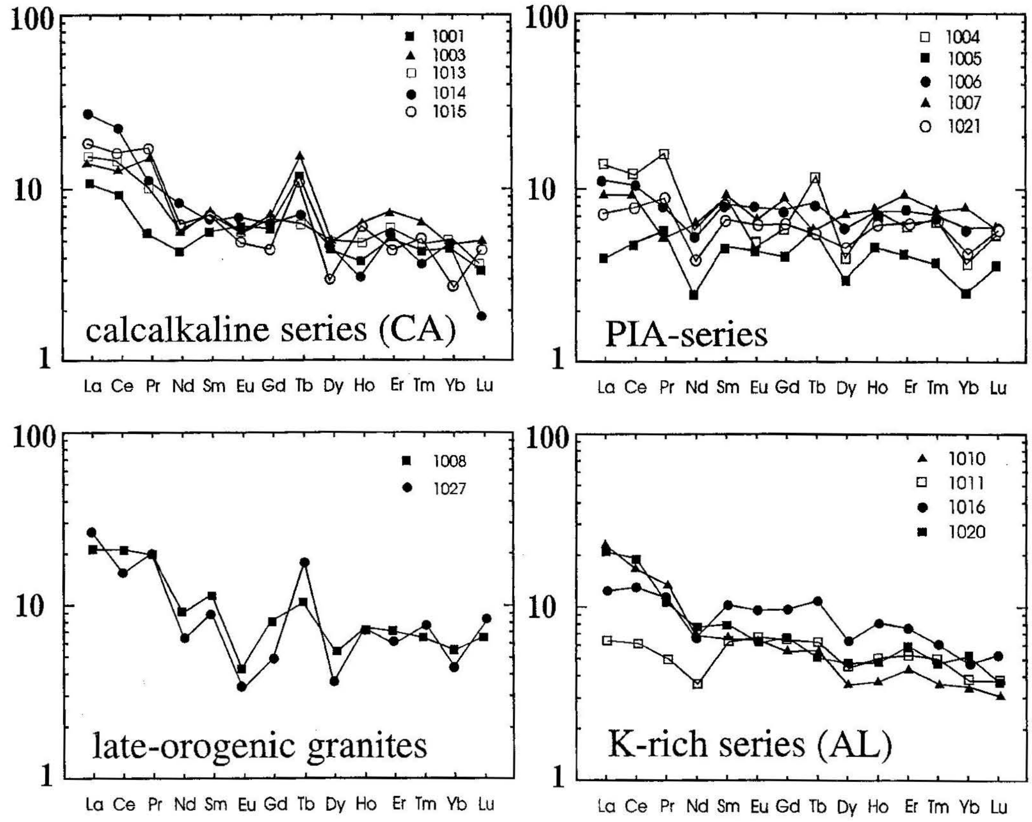

Fig. 3. Mantle-normalized REE spider plots show the different patterns for PIA, LOG and CA/AL. Note the absence of significant differences between calcalkaline and K-rich plutonites.

In Las Villas, U-Pb determinations on zircons of geochemically similar rocks gave ages of about 100 Ma (BIBIKOVA et al. 1988). In Las Villas, the stratigraphic position of the assumed PIA magmatites indicates a clear pre-Mid-Cretaceous age (DIAZ DE VILLALVILLA 1988). The geochemical similarity and the above-mentioned K-Ar ages could indicate a Lower Cretaceous age for the PIA rocks in Camagüey as well. However, a final decision will require detailed geochronological investigation.

Alkaline volcanics and plutonites in the Ignacio massif (sample 1016 - alkaline gabbro) and in the Guaimaro area (EGUIPKO et al. 1984, PEREZ et al. 1992) yield five K-Ar ages between 85 and 95 Ma. K-Ar determinations on granodioritic dykes, crosscutting the syenite, range from 76 to 82 Ma, supporting the Mid-Cretaceous age of the Guaimaro syenite. The syenites, monzonites and alkaline gabbros in the Camagüey massif give ages around 75 to 79 Ma (samples 1002, 1010, 1011). Geochronological data for the Algarrobo massif are still lacking.

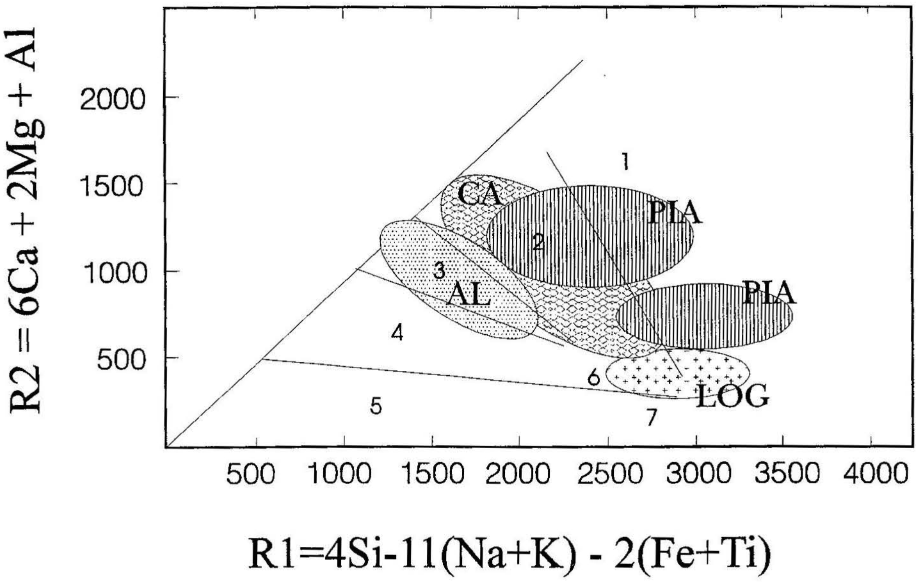

Fig. 4. Geotectonic position of island-arc plutonites after BACHELOR & BOWDEN (1985). The diagram is based on 250 analyses of major elements, sampled during regional geological mapping (ITURRALDE et al. 1987). The diagram, was slightly modified to present the felsic members of PIA.

The CA rocks appear slightly younger than the alkaline plutonites. Sixteen ages show a spectrum of 75 to 85 Ma (EGUIPKO et al. 1984, ITURRALDE-VINENT et al. 1989).

The K-Ar ages of the LOG intrusions confirm their geological position as the youngest magmatic formation. The Piedrecitas granite (sample 1008) aud leucocratic granites northeast of Las Tunas have ages of 70 to 76 Ma.

In the Las Parras and the Ignacio massif, K-Ar ages of about 60 Ma occur in the PIA and CA rocks. These ages are interpreted as "reset" ages, probably indicating the collisional uplift in this area.

$^{87}Sr/^{86}Sr$ ratios were determined for 12 whole-rock samples and mineral fractions. Because of the good correlation of the 1/Sr values, a common origin has been assumed. Both PIA, AL and CA rocks have uniform whole-rock ratios of about 0.704. The only exception is the LO granite of Piedrecitas, which yields a ratio of 0.709. The $^{87}Sr/^{86}Sr$ ratios of the mineral fractions, especially from the alkaline rocks, diverge significantly from those of the whole-rock samples, probably indicating inherited radiogenic Sr or a strong autometasomatic overprint.

Discussion

Petrographic and geochemical data suggest a similarity between the Na-rich, partly bimodal, tholeiitic plutonites in the northern magmatic

belt of Camagüey and the characteristics of primitive island-arc magmatites described by DONNELLY & ROGERS (1980). Preliminary geochronological data support the idea of an Early Cretaceous age and the probable extension of PIA magmatism during the Early Cretaceous from the Virgin Island through Puerto Rico and Hispaniola (SOLER & CHEILLETZ 1985) to the central part of Cuba (STANEK & CABRERA 1992). In Central Cuba, the proposed PIA were followed by widespread submarine basaltic and andesitic flows.

The Albian "carbonate" event throughout the Greater Antillean arc marks a change in the magmatic and geomorphological arc evolution. KACZOR & ROGERS (1990) described a phase of rapid subsidence of the arc basement during the formation of the carbonates. The developing intra-arc basins in the Camagüey region, filled by eroded island-arc rocks, support this feature. The occurrence of the plagiogranite indicates erosion of the deeper parts of the island arc by the Late Cretaceous. The crustal extension within the island arc is connected with the emplacement of calcalkaline and K-rich intrusions during Late Cretaceous. Small stocks and domes of felsic igneous rocks conclude the magmatic development in the Latest Cretaceous.

The problem of the change in magmatism during the Middle Cretaceous still remains unsolved. LEBRON & PERFIT (1994) proposed a reversal of arc polarity. Generally, such a reversal needs a collision of terranes or other crustal units, which could not be proven in the Greater Antilles up to now. Another explanation could be an increase of the subduction rate caused by the opening of the South Atlantic at this time. An assumed reversal of the island arc probably took place after the collision of the Cretaceous arc with the Bahama platform during Late Cretaceous and Early Tertiary (STANEK & VOIGT 1994).

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