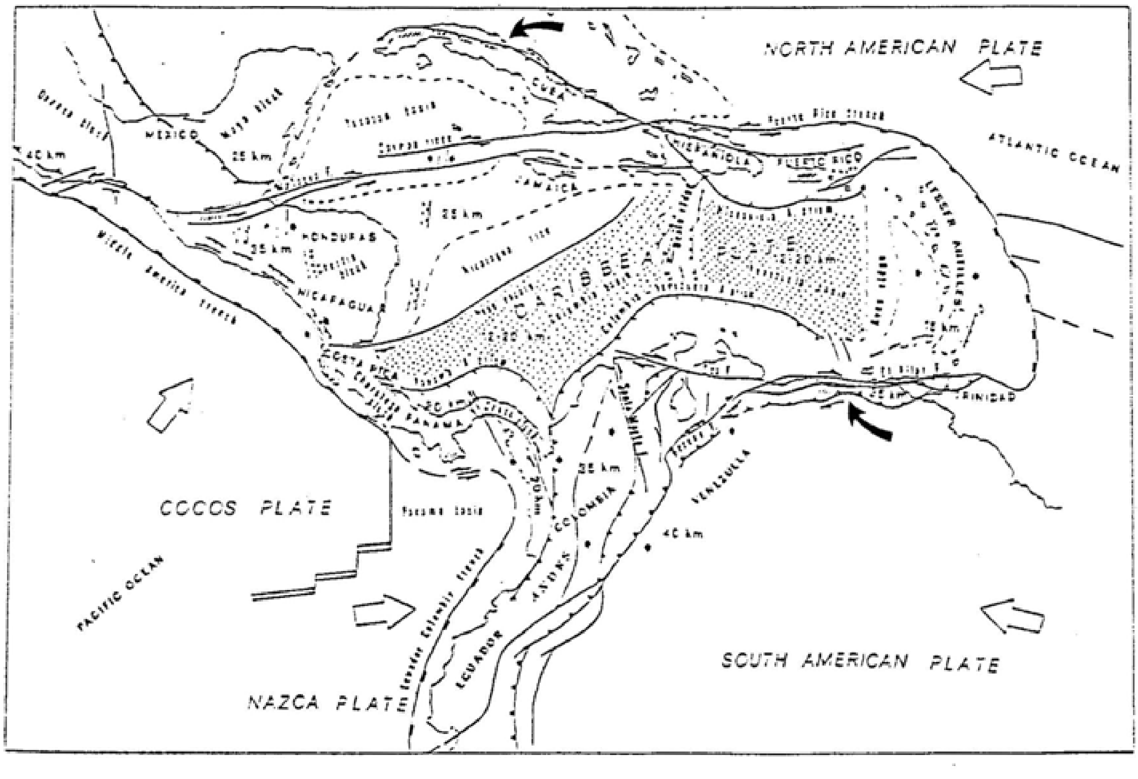
1st ITALIAN-LATIN AMERICAN GEOLOGICAL MEETING

Venezuela - Cuba, January 9-16, 1995

OPHIOLITES OF THE CARIBBEAN PLATE MARGINS



PROGRAMME AND FIELD TRIP GUIDE

OPHIOLITES OF THE CARIBBEAN PLATE MARGINS

1st ITALIAN-LATIN AMERICAN GEOLOGICAL MEETING

Venezuela - Cuba, January 9-16, 1995

Organized by:

- Gruppo di Lavoro sulle Ofioliti Mediterranee, CNR - Italy
- Escuela de Geologia, Universidad Central de Venezuela (UCV) - Caracas
- Instituto de Geologia, Ministerio Industria Basica (MINBAS) - La Habana
- Academia de Ciencias, La Habana - Cuba

Conveners: L. BECCALUVA (Ist. Mineralogia, Università di Ferrara)
G. GIUNTA (Dip. Geologia e Geodesia, Università di Palermo)

Organizing Committee:

E. Navarro (UCV, Caracas); F. Urbani (UCV, Caracas); M. Iturralde Vinent; (AC, La Habana); J. Hernandez F. (MINBAS, La Habana); R. Flores (IGP, La Habana); V. Bortolotti (Università di Firenze); F. Siena (Università di Ferrara); P. Spadea (Università di Udine); M. Coltorti (Università di Ferrara); S. Bellia (Università di Palermo).

Financial Support:

CNR Italy (L. Beccaluva) and CNR Bilateral Project (G. Giunta - E. Navarro)

PROGRAMME

Monday, 9th January - 9.00: Opening of the meeting at the Escuela de Geologia (UCV) in Caracas. Oral presentations. Geological overview of the field trips (night in Caracas)

SOUTH-NORTH TRANSECT OF THE SOUTHERN MARGIN OF THE CARIBBEAN PLATE IN THE NORTHERN CORDILLERAS OF VENEZUELA

Tuesday, 10th January - Caracas-Charallave-Cua-San Sebastian-La Candelaria-La Victoria-Caracas (night in Caracas or La Victoria)
The flyschoidal sequences of Piemontine Unit and the IAT volcanism of Dos Hermanas Unit; the subduction complex of Villa de Cura Units; the tholeiitic sequence of Caucagua-El Tinaco Unit.

Wednesday, 11th January - Caracas-Paracotos-Tacata-Altagracia de la Montaña-Caracas (night in Caracas)
Section of the ophiolitic complex (basement to MORB-type volcanics and sedimentary cover) of the Loma de Hierro Unit.

Thursday, 12th January - Caracas-Maiquetia-Catia la Mar-Arrecife-Chichiriviche-El Tigre-Colonia Tovar-Caracas-Flight to La Habana (night in La Habana
Volcano-sedimentary and ophiolitic rocks of the Franja Costera Unit; continental basement and sedimentary covers of the Cordillera de La Costa Unit.

Friday, 13th January - Day in La Habana. Organization of the field trips.

NORTH-SOUTH TRANSECT OF THE NORTHERN MARGIN OF THE CARIBBEAN PLATE IN CENTRAL CUBA

Saturday, 14th January - La Habana-Santa Clara-Camajuanì-Placetas-Santa Clara-Mataguà-Santa Clara (night in Santa Clara)
The Northern Ophiolitic Melange Unit and the Cretaceous Arc Unit.

Sunday, 15th January - Santa Clara-Mataguà-Manicaragua-Escambray-Hanabanilla-La Habana (night in La Habana)
Cretaceous Arc Unit and arc basement of the Mabujina Unit; continental lithotypes of the Escambray Unit.

Monday, 16th January - 9.30: Closure of the meeting at the Academia de Ciencias in La Habana. Oral presentations. Discussion and conclusion.

CROSS SECTIONS THROUGH THE OPHIOLITIC UNITS OF THE SOUTHERN AND NORTHERN MARGINS OF THE CARIBBEAN PLATE IN VENEZUELA (NORTHERN CORDILLERAS) AND CENTRAL CUBA

[1]Beccaluva L., [1]Coltorti M., [2]Giunta G., [3]Iturralde Vinent M., [4]Navarro E., [5]Siena F., [4]Urbani F.

with the collaboration of
[6]Alvarez H., [7]Bellia S., [6]Flores R., [7]Rotolo S., [6]Vazques C.

1 - Istituto di Mineralogia, University of Ferrara - Italy
2 - Dipartimento di Geologia, University of Palermo - Italy
3 - Academia de Ciencias, AC, La Habana - Cuba
4 - Escuela de Geologia, Facultad de Ingegneria, Universidad Central del Venezuela, UCV, Caracas - Venezuela
5 - Istituto di Scienze della Terra, Università di Catania - Italy
6 - Instituto de Geologia y Paleontologia, IGP, La Habana - Cuba
7 - Istituto di Mineralogia, University of Palermo - Italy

ABBREVIATIONS FOR THE GEOLOGICAL UNITS

PU = Piemontine Units

DH = Dos Hermanas Unit

VC = Villa de Cura Units

LH = Loma de Hierro Unit

TT = Caucagua-El Tinaco Unit

FC = Franja Costera Unit

CC = Cordillera de La Costa Unit

BU = Bahamas Unit

NO = Northern Ophiolitic Unit

AC = Cretaceous Arc Units

MU = Mabujina Unit

ET = Escambray Terrains

INTRODUCTION

In the last few years the interest in the geology of the Caribbean area has increased, as can be seen in a number of papers. However, among these, only few approach the problem from a regional point of view Mascle (1985), Dengo and Case (1990). The main problems which can be pointed out from these papers and from a preliminary field work are: a) the peculiar geophysical characteristics of each lithospheric sector; b) the type and affinity of the magmatic associations which occurred, from Mesozoic to Present, along the margins and within the Caribbean Plate; c) the geometry and structure of the plate margins in some key areas; d) the kinematic evolution of the Caribbean Plate, within the context of the surrounding Pacific, North and South American Plates.

In order to highlight some of these points, a bilateral Italian-Latin American research team has been working for several years on the ophiolitic units which are involved in the deformed margins of the Caribbean Plate. Along these margins, ophiolites consist of mantle, crustal and sedimentary sequences of Jurassic-Cretaceous age. These rocks are often covered by more recent calc-alkaline lavas.

The main magmatic features of these ophiolites, summarized in Donnelly et al. 1990a, 1990b (and references therein), are still under debate In fact, the various ophiolitic units present, besides different metamorphic facies, also different magmatic affinities (High-Ti and Low-Ti ophiolites). Moreover, these Jurassic-Cretaceous oceanic basins might have constituted the western termination of the Thetys (Auboin et al., 1977; Auboin and Tardy, 1980).

A more thorough knowledge of these units would undoubtedly give a substantial contribution to the interpretation of the complex kinematic evolution of the Caribbean Plate, starting from its nucleation.

The main ophiolitic units in Venezuela and Cuba may be considered more representative than those outcropping in Guatemala, Costarica or Hispaniola, even though some data related to the latter are now available (Carnemolla et al., 1990; Giunta et al., 1992; Beccaluva et al., 1994).

The field trips are aimed at showing the main Jurassic-Cretaceous ophiolitic units involved in the southern (Venezuela) and northern (Cuba) deformed margins of the Caribbean Plate, across the northern Venezuelan and the Central Cuban Cordilleras.

The magmatic affinities are based on both petrographical and geochemical characteristics, using the discrimination diagrams after Beccaluva et al. (1979) and Pearce (1982).

GEOLOGICAL FRAMEWORK

The Caribbean Plate is the result of the interaction between several neighbouring plates - Nazca, Cocos, North and South America (Fig. 1) - from Mesozoic to Present. Its evolution, characterized by a continuous kinematic process (although variable in space and time), is linked to that of the Atlantic Ocean, starting from the nucleation of several elements of Atlantic affinity (protoCaribe) up to the definition of an independent lithospheric unit (eoCaribe).

The present-day drifting of the Caribbean Plate is constrained by the relative motions of the North American (westward) and South American (northwestward) Plates, respectively (McDonald, 1990).

The Caribbean Plate consists of a poorly deformed central portion (Colombia and Venezuela Basins) delimited by two pairs of active systems. The northern and southern margins mainly consist of transpressive or strike-slip shear zones (Motagua, Cayman, Great Antilles, Northern Andes, Oca, S.Sebastian, El Pilar), while the western and eastern margins are represented by collisional systems with B-type subduction which generates island arcs (Central American Isthmus and Lesser Antilles). According to the crustal models reported in Case et al. (1990), an oceanic to transitional crust may be inferred for the Colombia and Venezuela Basins, whereas a transitional to continental crust can be considered for the margins of the Plate (apart from the oceanic rifting of the Cayman Trough). In the present plate border, large sectors of pre-Cambrian or Paleozoic continental crust are sometimes included, which originally belonged to the North and South American Plates.

The margins of the Caribbean Plate are constituted by large, deformed belts resulting from a series of compressive phases, superimposed by tensional and/or strike-slip phases, starting from Cretaceous. These deformations affect large portions of the Caribbean and adjoining Plates. Broadly speaking, the Caribbean lithosphere has been deformed and piled up onto the Pacific and Atlantic oceanic crusts (giving rise to the western and eastern island arc systems), as well as onto the south and north American continental crusts

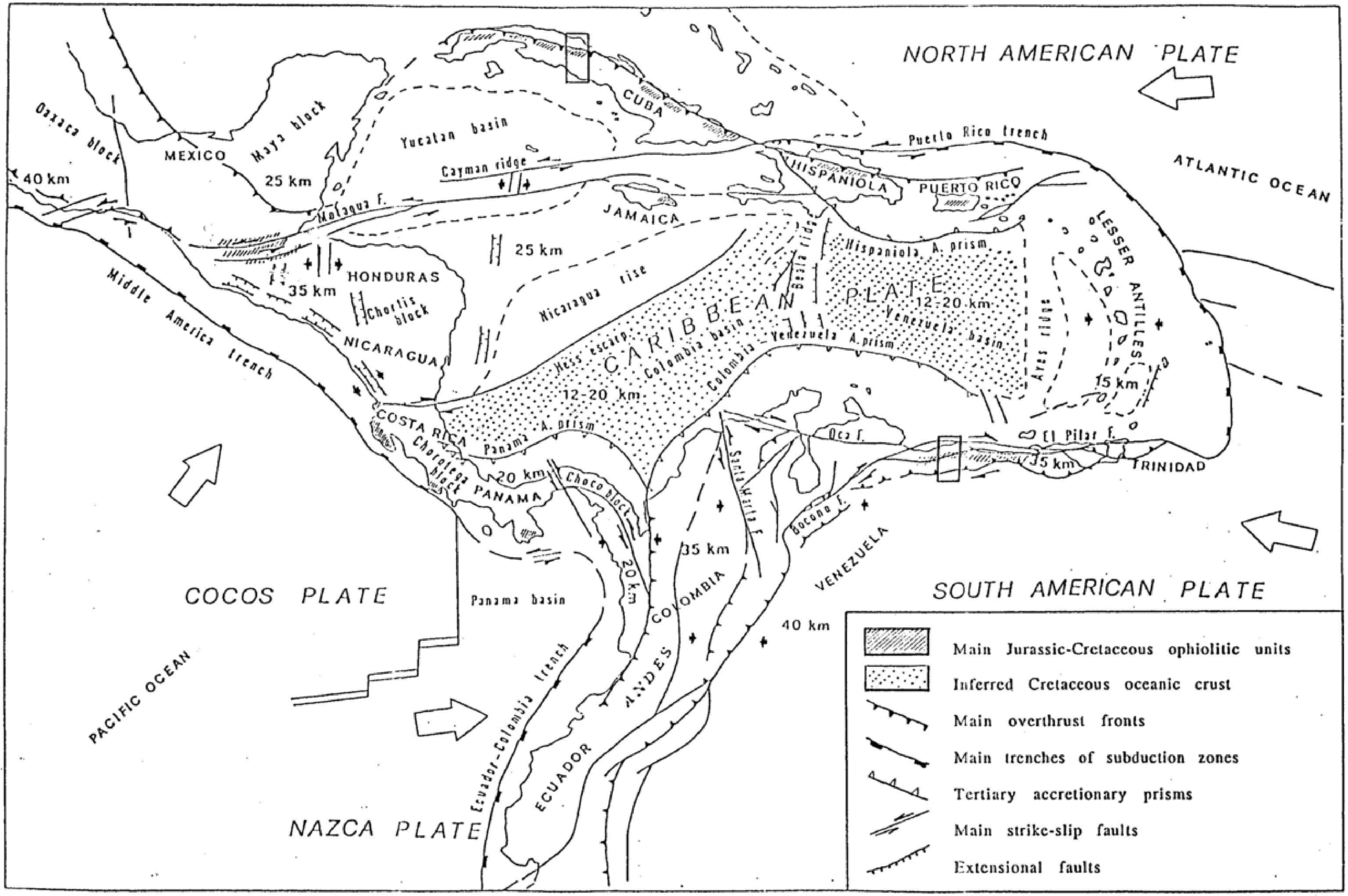


Fig. 1 - Structural sketch map of the Caribbean area. Black arrows show the regional stress-field; white arrows show the movement direction of the main plates; Km show the inferred crustal thickness; boxes indicate the studied areas.

(forming suture zones in the northern and southern cordilleras respectively). The more internal Caribbean crust was successively deformed, and the originally stable sectors were involved in a series of accretionary prisms (Venezuela, Colombia, Panama, Hispaniola, etc.), referred to as "pseudo-subduction" processes induced by the main collisions along the margins (Stephan et al., 1986).

On the whole, various "flower structures" with opposite vergence may be identified on the northern and southern Caribbean margins. The preferential shortening directions are often induced by oblique, diachronous movements with respect to the original geometry of the elements involved.

The present-day borders of the Caribbean Plate correspond to the deformed belts described above. Strike-slip shears - sinistral and dextral respectively - occur on the northern and southern margins. As a consequence, portions of the deformed eo-Caribbean lithosphere are now incorporated into the crust of the adjacent plates, and should no longer be referred to as the Caribbean domain s.s. (e.g. Cuba, the northern Motagua system in Gautemala and the northern Venezuelan Cordilleras).

Within the framework of the deformed Caribbean margins l.s., suture zones or "accreted terrains" are also present, where Jurassic-Cretaceous ophiolitic tectonic units may be found. The largest outcrops of these units are in Venezuela, Costarica, Guatemala and Greater Antilles.

Several studies have been developed on these units since Dengo (1972), but many aspects remain to be clearified with regard to structure, metamorphism and magmatic affinity. These units represent the oldest deformed fragments created during the alpine, proto-Caribbean and eo-Caribbean phases, thus recording the evolutionary history from Mesozoic to Present.

Several models have been proposed in relation to the geotectonic evolution of the Caribbean Plate (Anderson and Schmidt, 1983; Beck, 1986; Dengo, 1985; Morris et al., 1990; Pindell and Barret, 1990; Ross and Scotese, 1988; Stephan et al., 1990; Giunta, 1993), which start from different interpretations of the significance of the present Caribbean oceanic lithosphere. In particular:

a - the present-day Caribbean lithosphere belongs to the Pacific domain; it progressively crept eastward between the North and South American Plates, ultimately colliding with the Atlantic lithosphere. During this evolution it was deformed and obducted onto the two American continental margins;

b - the present-day Caribbean lithosphere mainly represents the evolution of back-arc marginal basins of the eastern and western subduction systems, variably contributing to the construction of the northern and southern collisional margins;

c - the Caribbean lithosphere might be divided in two portions: an older one related to the western termination of the Jurassic-Cretaceous Thetys through the central Atlantic; and a more recent one, which probably constitutes the present seafloor of the Caribbean sea, with unclear relationships either with the Altantic or Pacific domains.

Undoubtedly, none of the three hypotheses outlined above can be preferred, partly because some essential analytical data are missing. A hypothesis based on more data shall probably be more reliable, even if more intricate, due to the objective complexity of the area. We shall therefore confine the present discussion to the main points, only attempting to offer some tentative models.

THE CARIBBEAN OPHIOLITES

As mentioned above, large masses of Jurassic-Cretaceous ophiolitic complexes outcrop along the Caribbean margins, outlining the eo-Caribbean suture zones. The most important ophiolitic outcrops are located:

a - on the northern margin, with sinistral strike-slip movements, along the Motagua, Polochic and Chamelcon structures in Guatemala, and in the Greater Antilles Cordilleras (Donnelly et al., 1990a, 1990b; Lewis and Draper, 1990).

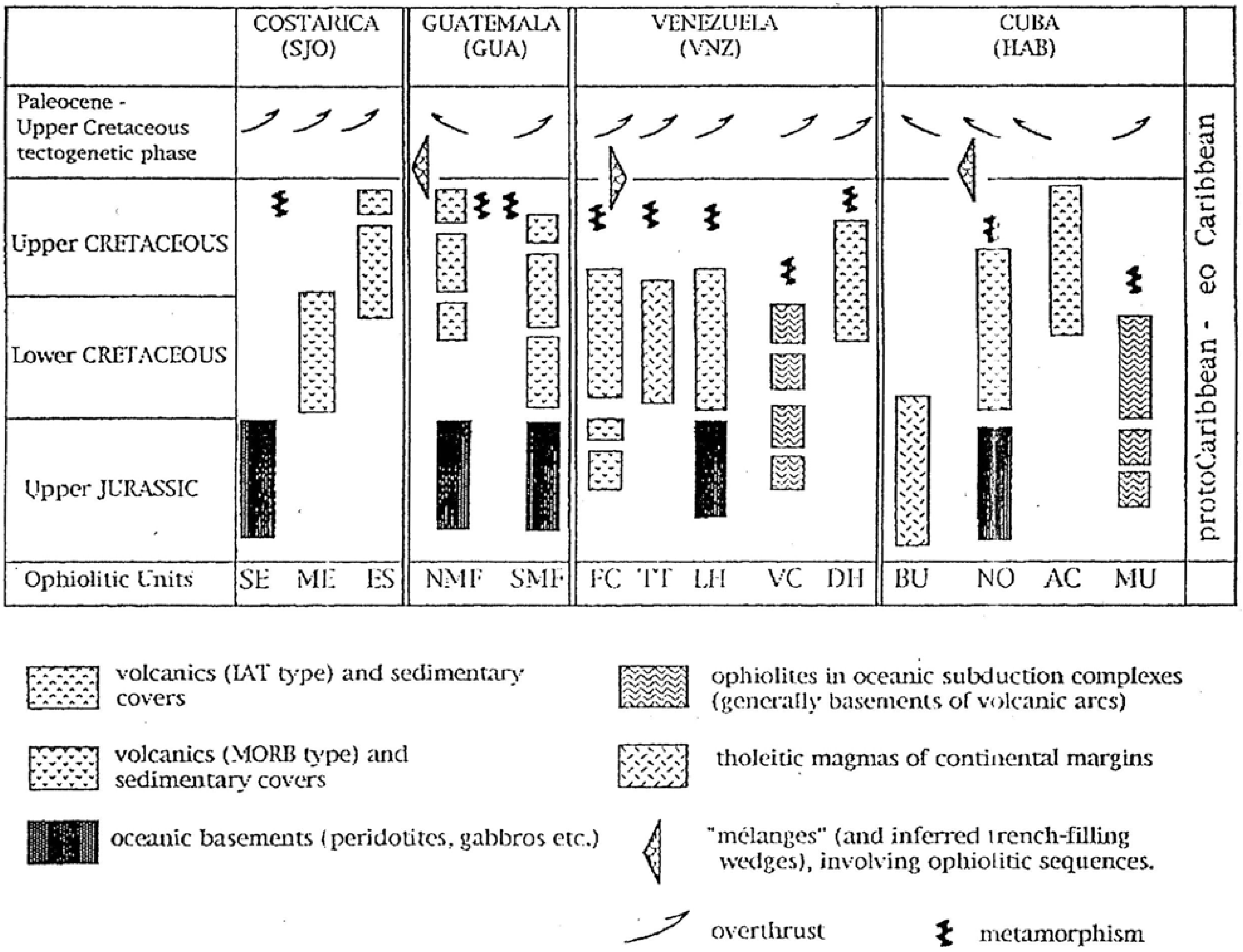
In Guatemala, they are represented by large, boudin-like bodies, overthrust northward onto the Maya block basement and cover, and southward onto the Chortis block basement.

In Cuba, ophiolites are represented by tectonic units overthrust northward onto terrains of the North American Plate, and southward onto the continental rocks of the Escambray-Guaniguanico Complex.

On Hispaniola, the ophiolitic units show a remarkable double vergence. It should be noted that the eo-Caribbean elements in Cuba outcrop well beyond the present margin of the Caribbean Plate. In the islands of Jamaica and Portorico, ophiolitic units partly similar to those of Hispaniola are found.

b - on the western margin, along the Pacific coastline of the Central American Isthmus, in the S.Elena, Nicoya and Osa Peninsulas of Costarica

Fig. 2 - Tectonostratigraphic pattern of the main Mesozoic Ophiolitic Units of the Caribbean Plate margins (from GIUNTA et alii, 1995; in prepar.).



SE= Santa Elena U.; ME= Metapalo U.; ES= Esperanza U.; NMF= North Motagua Faults U.; SMF= South Motagua Faults U.; FC=Franja Costera U.; TT= Caucagua El Tinaco U.; LH= Loma de Hierro U.; VC= Villa de Cura U.; DH= Dos Hermanas U.; BU= Bahamas U.; NO= Northern Ophiolitic U.; AC= Cretaceous Arc U.; MU= Mabujna U.

and the Azuero Peninsula of Panama (Bourgois et al., 1982; Escalante, 1990). Broadly speaking, they could be considered as structures related to the active subduction along the meso-American trench of the Cocos and, partly, Nazca Plates. Otherwise, they could be attributed to eo-Caribbean shortening, oblique with respect to the direction of the trench. In this case, the present-day position along the Central American Isthmus would be related to tectogenetic phases, creating second order blocks (Chortis, Chorotega), just before the better known cenozoic disposition.

c - on the eastern margin, in restricted zones, among which the most famous is the Desirade Island (Maury et al., 1990). On such a margin, active subduction of the north- and south-America Atlantic oceanic lithosphere occurs, underneath the Barbados accretionary prism and the Lesser Antilles volcanic arcs.

d - on the southern margin, along the Northern Cordilleras in Venezuela (Beck, 1985; Bellizia, 1986; Bellizia and Dengo, 1990); such a margin, affected by dextral strike-slip movements, represents a link between the northern termination of the Andean chain and the Lesser Antilles volcanic arcs. Here, ophiolites are generally constituted by eo-Caribbean units obducted onto the continental margin of the South America Plate, characterized in some places by double vergence. The tectonostratigraphic relationships of some Mesozoic Caribbean ophiolitic units are shown in Fig. 2.

The ophiolitic units of the Caribbean margins generally consist of serpentinized mantle peridotites, ultramafic and mafic cumulitic rocks, effusive basaltic sequences (massive and pillow lavas), and sporadic variably-sized sedimentary covers (radiolarian cherts and preflyschoidal sediments). They occur as tectonic slices, with poorly defined thrust planes, and may be divided into various subunits. In places, they are present as boudins inside "melange complexes".

Where remarkably deformed, the more ductile lithotypes are affected by at least two penetrative events; in most cases isoclinal folds F1, with axial plane foliation S1, are bent by tight or open folds F2, with crenulation cleavage S2, variably oriented.

The Caribbean ophiolites are often metamorphosed; facies may vary from prehnite-pumpellyite, through higher pressure facies with glaucophane and lawsonite, up to green-schist and amphibolite facies. The relationships between metamorphism and deformation are not always clear, even if there are, in general, evidences suggesting that metamorphic events partly

occurred under the same dynamic conditions which caused deformation. Penetrative deformations and related metamorphic effects appear to be linked to both subduction and obduction processes.

THE SOUTHERN MARGIN OF THE CARIBBEAN PLATE IN VENEZUELA

REGIONAL OUTLINES

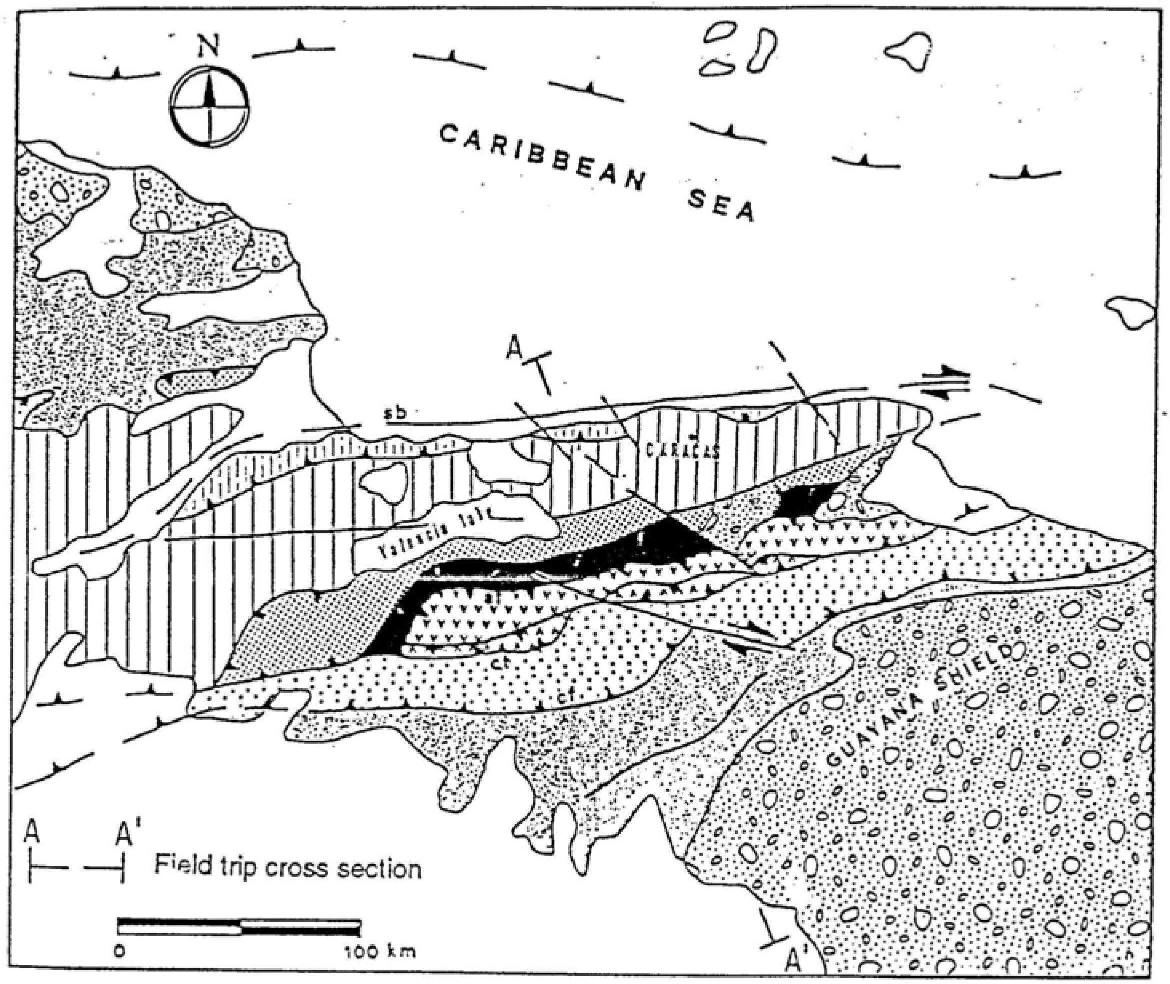
The investigated cross section is situated across the northern Venezuelan Cordilleras (Cordillera de la Costa and Serrania del Interior), westward of the Caracas longitude (Figs. 3 and 4). The northern Venezuelan Cordilleras represent the orogen linking the northeastern Andes (Ande di Merida) with the Lesser Antilles volcanic arc in W-E direction (Bellizzia, 1986; Bellizia and Dengo, 1990), and are about 1000 km in length and 100 km in width.

This system is considered to extend from the so-called Barquisemeto depression, to the west, as far as the Trinidad and Tobago Islands to the east. Southwards, it is delimited by the Guayana foreland, belonging to the stable cratonic area of the South-American Plate, onto which the external frontal units of the mobile parts of this system overthrust. The northern limit is not clearly defined, due to the presence of the Caribbean Sea and the accretionary prisms of Colombia and Venezuela; indicatively, such limit may be set north of the Goajara Peninsula - Dutch Antilles - Venezuelan Islands alignment.

Cordillera de la Costa and Serrania del Interior are made up of several tectonic units with generally southward vergence. They are affected by dextral W-E strike-slip faults (S.Sebastian, El Pilar, La Victoria) with major conjugated synthetic, and minor antithetic, systems (Tacata, Charallave), which sometimes mask the remarkable axial ondulations of the deformed portions. The resulting tectonic style, represented by structural highs and lows, displays a nappe synform (Serrania del Interior), or pull-apart basins (Lago Valencia) located between the Cordillera de la Costa and Serrania del Interior.

The crust thickness, according to geophysical data (Case and Holcombe, 1980; Graterol and Fonseca, 1978) is estimated around 25-35 km.

Along the proposed transect, from south to north, several units are recognized (Navarro, 1983; Beck, 1985; 1986; Bellizzia, 1986; Navarro, 1989; Navarro et al., 1988; Carnemolla et al., 1990; Ostos, 1990).



LEGEND

DH	Dos Hermanas Unit (DH): volcano-andesitic sequences (Cretaceous)
VC	Villa de Cura Units (VC): basalts and volcanoclastic sequences of subduction complex (Jurassic-Cretaceous)
LH	Loma de Hierro Unit (LH): ultrabasic rocks, basalts and siliceous carbonatic sequences (Jurassic-Cretaceous)
TT	Caucagua-El Tinaco Unit (TT): continental basement, basalts and carbonatic sequences (Paleozoic-Cretaceous)
FC	Franja Costera Unit (FC): terrigenous and carbonatic sequences, basalts and volcanoclastics (Cretaceous)
CC	Cordillera de la Costa Unit (CC): continental basement, carbonatic and siltitic sequences, intrusives (Paleozoic-Cretaceous)
	Piemontine flysch thrust sheets (Cretaceous-Paleogene)
	Folded terrigenous sequences (Oligo-Miocene)
	Terrigenous sequences (Mio-Pleistocene) of the stable Guayana shield

Fig. 3 - Tectonic skecht map of part of Northern Cordilleras of Venezuela (from BECK, 1986; BELLIZZIA, 1986; modified)
(sb) falla S.Sebastian; (lv) falla La Victoria; (af) falla Agua Fria; (ct) corrimiento Cantagallo; (cf) corrimiento frontal.

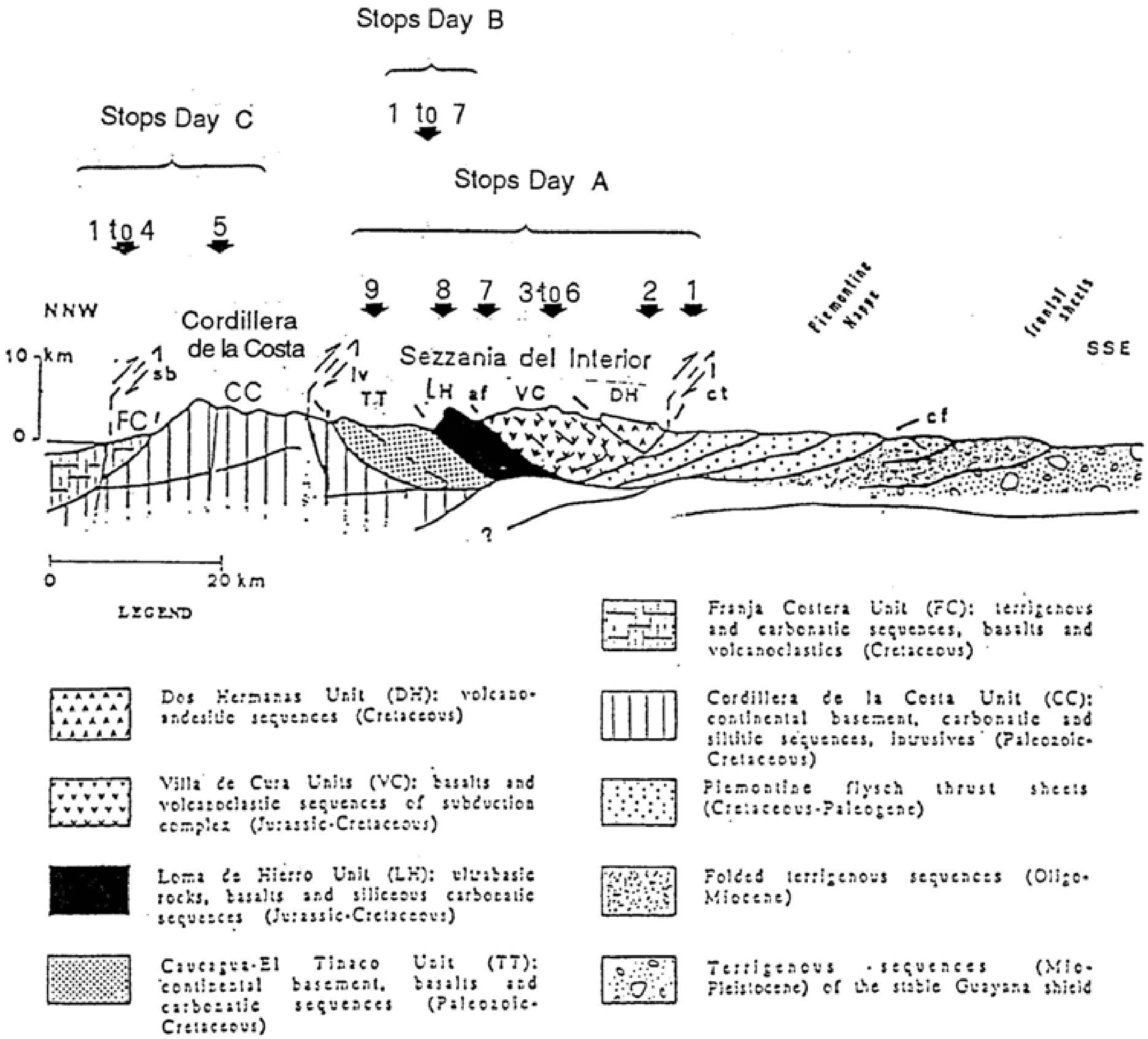


Fig. 4 - Cross section through the Northern Cordilleras of Venezuela

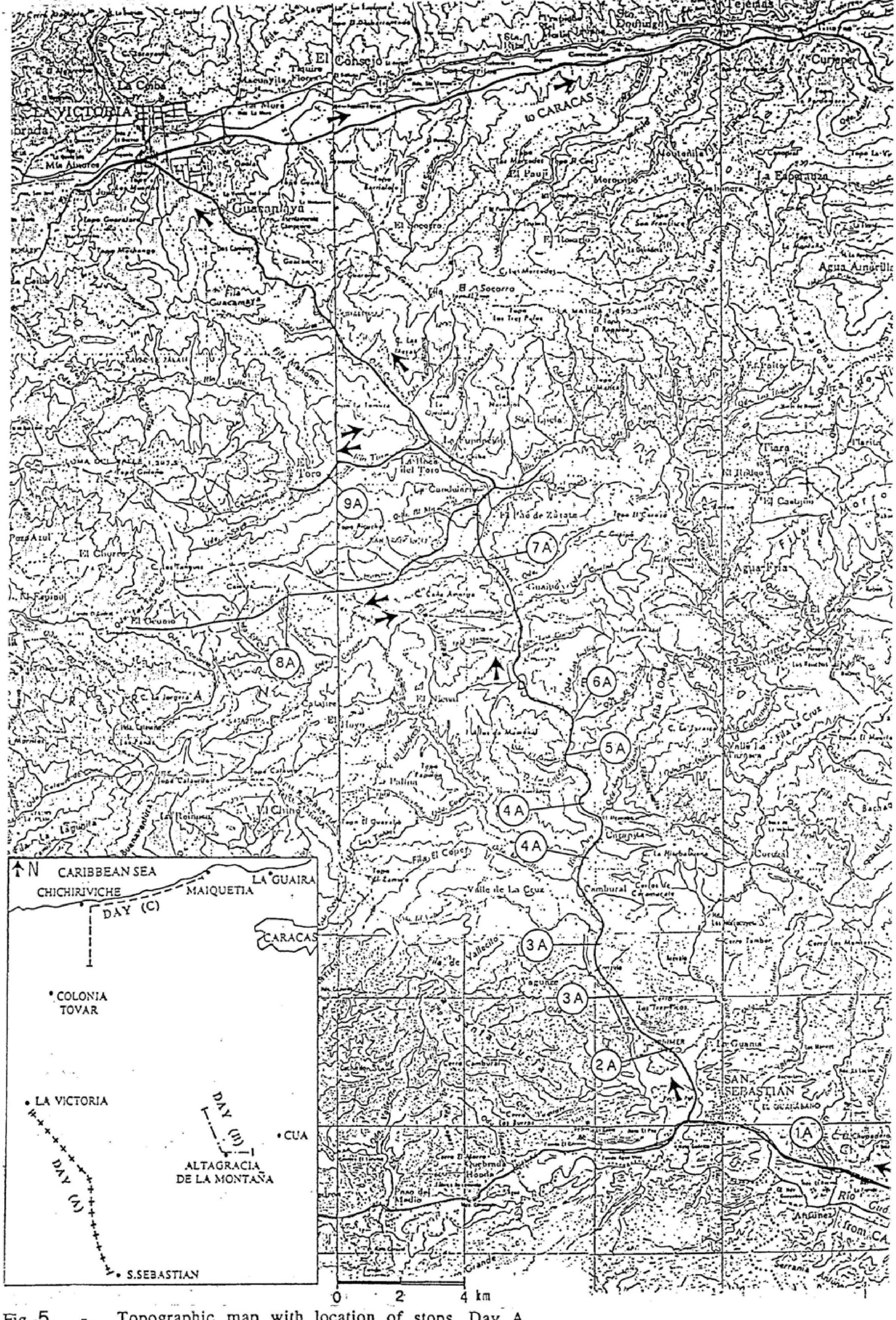


Fig. 5 - Topographic map with location of stops, Day A.

1st DAY (A) FIELD TRIP - CARACAS - CHARALLAVE - CUA - SAN SEBASTIAN - LA CANDELARIA - LA VICTORIA-CARACAS - (FIG. 5)

Stop 1A - *Eastward of San Sebastian*

Panoramic view of the tectonic contact between **Dos Hermanas** (Cretaceous volcanic arc) and **Piemontine Units** (Cretaceous-Paleogene foredeep sequences). Original relationships between Dos Hermanas volcanics and Piemontine terrigenous sediments (Garrapata Formation).

The **Piemontine Units (PU)** tectonically underlie the units of Serrania del Interior complex, and overthrust the Guyanese Craton through a series of frontal slices, which mark the southern border of the Northern Cordilleras in Venezuela. They are constituted by a series of embricated unmetamorphosed allochthonous units, with southward vergence; mesoscopic ductile deformations are constituted by tight, up to chevron, often reverse, folds. They contain terrigenous and carbonate sequences of the Cretaceous, followed by emipelagic and turbiditic arkosic sediments of the Cretaceous - Eocene.

Stop 2A - *Lower Rio Pao, northwestward from San Sebastian* **(Dos Hermanas Unit - DH)**

The **Serrania del Interior Complex** comprises the following units (Fig. 6): **Dos Hermanas, Villa de Cura, Loma de Hierro** and **Caucagua-El Tinaco**. This complex is in tectonic contact, to the north with the Cordillera de La Costa through La Victoria Fault; in places it overthrusts the Cordillera de La Costa Unit, with the thrust plane dislocated by La Victoria Fault. Southward, it overthrusts onto the Piemontine Units. It constitutes a narrow, asymmetric "nappe synform" with a larger northern limb. The thrust planes are southward rotated, thus, along the southern front, the highest units of the complex directly overlie the most external ones. The "en echelon" disposition from west to east is related to the strike-slip tectonics which affect the Cordilleras. The overthrust contacts between the various units are partially obliterated by subvertical structures (Santa Rosa, Agua Fria, etc. Faults).

The **Dos Hermanas Unit (DH)** represents the highest unit of the nappe series of Serrania del Interior. It overlies the Villa de Cura Units (S. Isabel Subunit or "Granofels" Subunit) along a poorly defined, generally mechanical contact and overthrusts, with variable northward inclination, onto the most external Piemontine units; however, an original lateral continuity with some terrigenous sequences of the latter can be envisaged (Garrapata Formation).

Dos Hermanas Unit is constituted by basaltic-andesitic lava breccias and volcanoclastites, metamorphosed in the prehnite-pumpellyite facies. Geochronological data indicate a Middle-Upper Cretaceous age for these rocks (Navarro, 1983; Ostos and Navarro, 1986). No significant ductile deformative structures have been observed.

Petrographically, the basaltic-andesitic breccias are composed by rounded clasts which show porphyritic texture. Phenocrysts consist of iddingsitic olivine, abundant augitic clinopyroxene, brown amphibole, and plagioclase, set up in a microcrystalline groundmass strongly affected by metamorphic recrystallization. The prevailing metamorphic paragenesis consists of prehnite and chlorite, mainly developed in the groundmass. The chemical analysis of sample VNZ 20, reported in Table 1, indicates a basaltic-andesite composition with transitional arc tholeiitic (IAT)/calc-alkaline (CA) serial affinity, in accordance with the main primary mineralogical assemblage. Sample VNZ 103 shows a typical basaltic composition.

Stop 3A, 4A, 5A, 6A

Cretaceous subduction complex of **Villa de Cura Units (VC)**

The Cretaceous subduction complex of the **Villa de Cura Units** lies in tectonic contact on the more northern Loma de Hierro Unit along a high-angle structure (Agua Fria Fault). The Villa de Cura Units are traditionally subdivided into several subunits (Navarro, 1983; Ostos and Navarro, 1986; Loubet et al., 1985), with poorly defined relationships: the geometry of the single slices were probably obliterated by the intense folding which affected the whole complex. It is made up of (Fig. 7 and 8): a) massive or foliated meta-lavas (El Carmen Subunit or "Metalavas" Subunit) with high-pressure metamorphism (glaucophane and clinozoisite blue-schists); b) meta-tuffs and subordinate foliated meta-lavas (El Chino-El Caño Subunit or "Metatobas" Subunit) metamorphosed in the glaucophane-lawsonite blue-

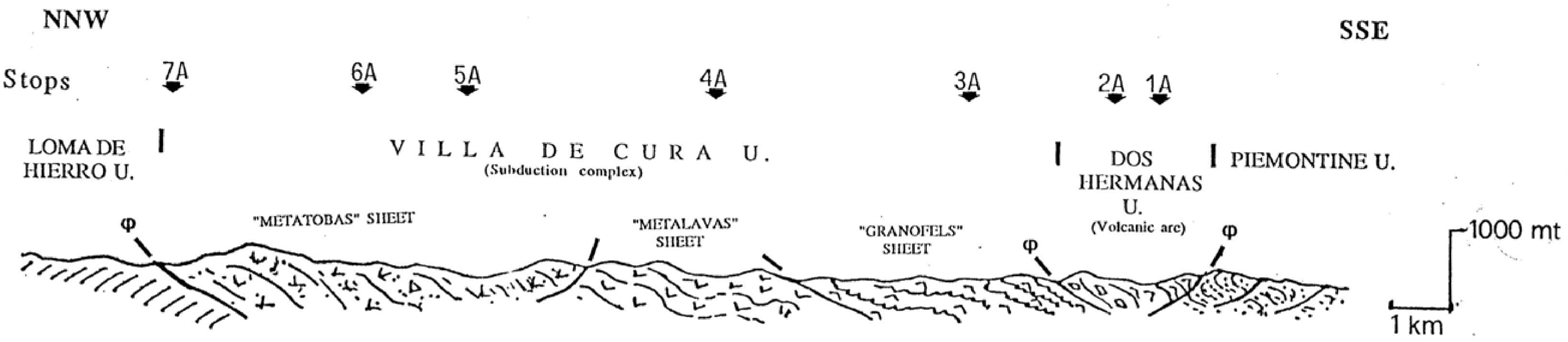


Fig. 6 - Schematic cross section of the Villa de Cura and Dos Hermanas Units, subdivided in several sheets.

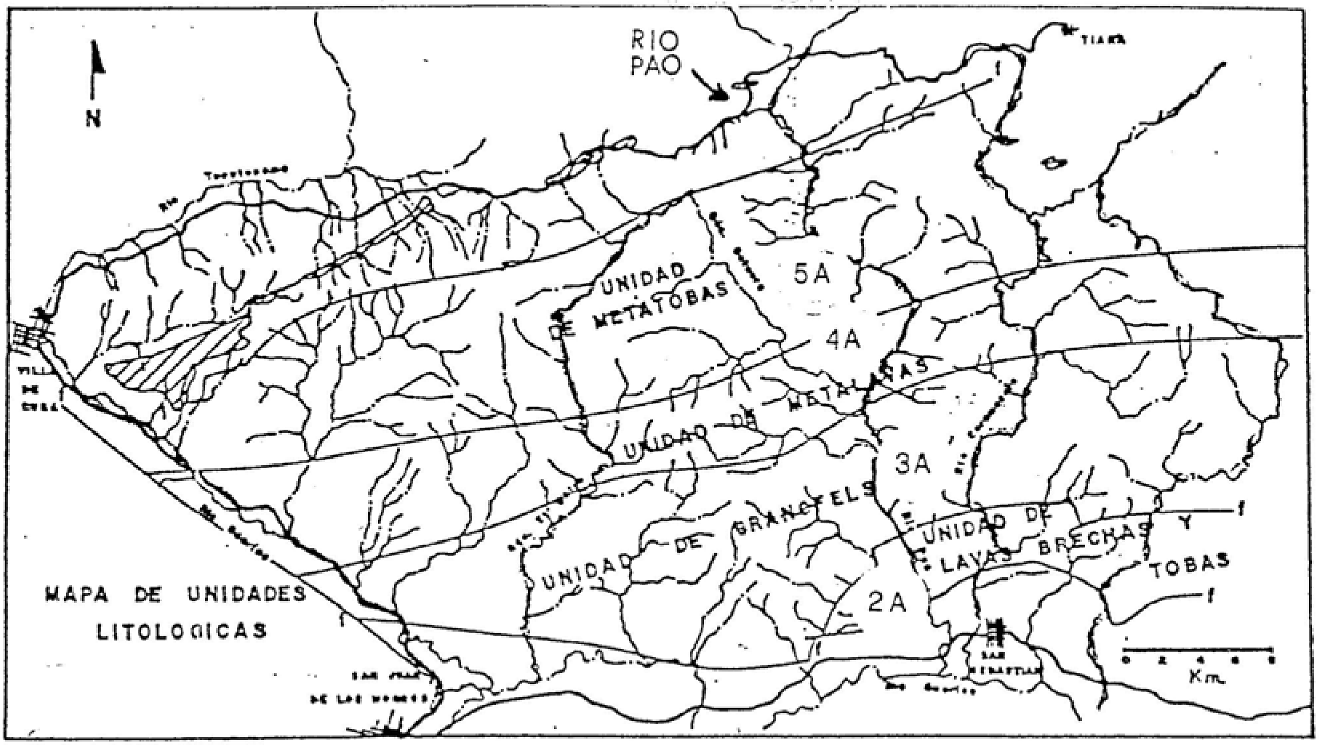


Fig. 7 - Tectonic sketch map of the different units of Villa de Cura (from Navarro, 1983), and location of stops.

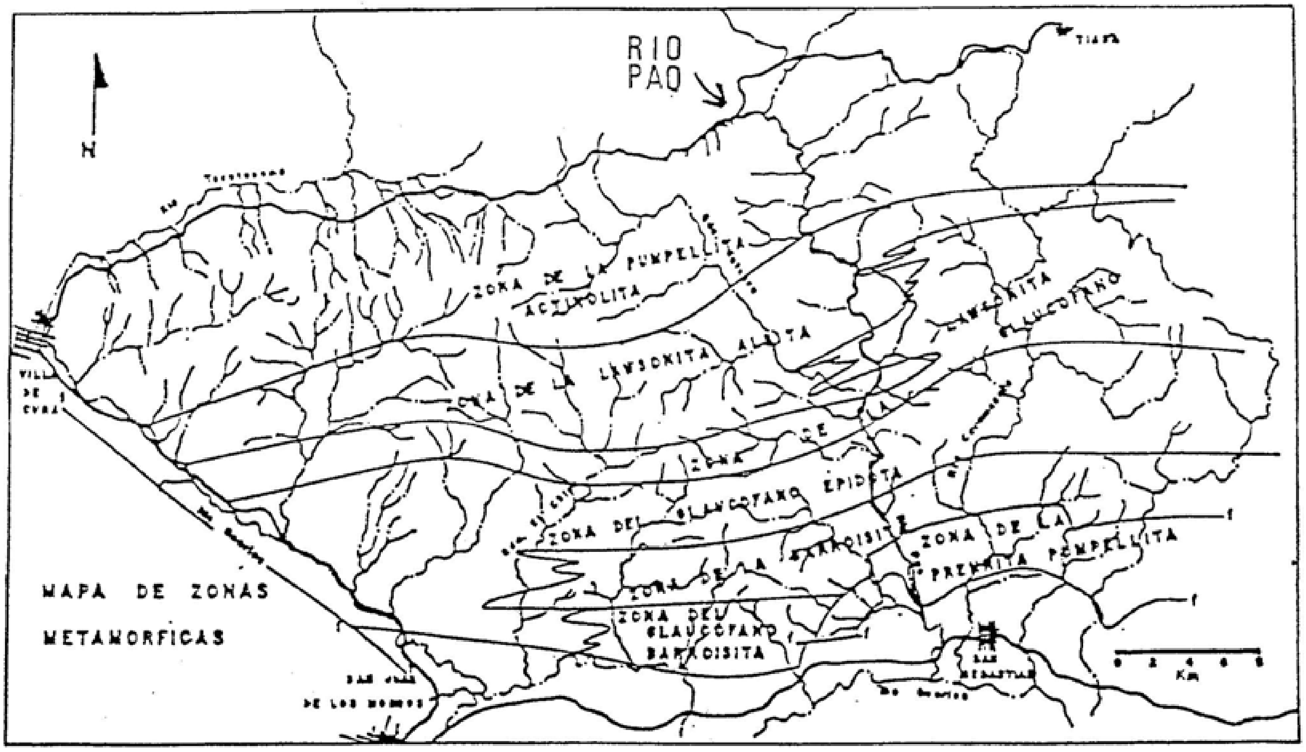


Fig. 8 - Sketch map of the metamorphic zones of Villa de Cura Unit (from Navarro, 1983).

Table 1

	Dos Hermanos Unit		Villa de Cura Units				Caucagua-El Tinaco Unit				Loma de Hierro Unit			
	Stop 2A		*Stop 3A*	*Stop 4A*			*Stop 9A*				*Stop 1B*			
	VNZ 20	VNZ 103	*VNZ 104	*VNZ 24	VNZ 111	VNZ 112	VNZ 35	VNZ 67	VNZ 97	VNZ 101	*VNZ 58	*VNZ 59	*VNZ 60	*VNZ 64
	Bas-And	Bas	Rhy	Bas	Bas	Bas	Bas	Bas	Bas	Bas	Hz	Hz	Hz	Gb
SiO2	52.91	48.22	79.67	40.89	46.50	44.83	48.00	49.16	45.06	50.53	41.78	40.35	41.09	47.58
TiO2	0.85	1.03	0.31	1.67	0.62	0.63	1.37	1.14	2.37	1.88	0.00	0.00	0.00	0.19
Al2O3	16.87	15.85	9.98	16.18	10.87	12.51	12.70	14.09	13.46	14.23	0.26	0.04	0.09	21.19
Fe2O3t	7.81	10.02	1.96	11.46	10.55	10.98	10.32	9.32	9.76	9.25	7.61	8.16	8.23	3.52
MnO	0.11	0.17	0.04	0.14	0.21	0.16	0.13	0.17	0.13	0.17	0.11	0.11	0.12	0.06
MgO	3.90	7.39	0.51	6.15	14.57	13.70	7.33	8.55	6.12	7.63	40.62	42.11	42.00	7.47
CaO	8.69	9.61	1.40	11.26	11.04	10.90	12.62	11.04	11.17	9.60	0.86	0.65	0.76	12.79
Na2O	5.06	3.43	4.90	2.02	1.20	1.09	2.81	2.62	3.82	3.80	0.00	0.00	0.00	3.59
K2O	0.32	0.01	0.63	0.79	0.96	0.87	0.87	0.01	0.05	0.14	0.01	0.00	0.00	0.32
P2O5	0.11	0.09	0.01	0.39	0.15	0.14	0.13	0.09	0.28	0.22	0.00	0.00	0.00	0.09
LOI	3.55	4.15	0.76	10.04	3.21	4.06	4.73	3.64	7.72	2.46	9.42	9.29	8.42	3.52
Tot	100.2	100.0	100.2	101.0	99.9	99.9	101.0	99.8	99.9	99.9	100.7	100.7	100.7	100.3
Cr	106	105	2	366	729	607	294	427	138	294	2970	2493	2751	775
Ni	16	36	4	61	276	316	106	102	78	120	2032	2293	2311	212
Rb	9	5	n.d.	8	19	22	26	4	6	7	n.d.	n.d.	n.d.	2
Sr	155	97	52	74	45	170	184	99	156	192	6	2	n.d.	251
Ba	252	123	212	93	419	409	12	2	47	102	n.d.	n.d.	n.d.	25
Zr	63	54	74	110	33	22	97	96	122	130	n.d.	n.d.	n.d.	n.d.
Y	23	28	2	33	17	17	35	35	50	40	n.d.	1	n.d.	3
La	2	3	11	-	4	n.d.	-	9	13	7	n.d.	n.d.	n.d.	n.d.
Ce	2	7	14	-	4	5	-	30	31	27	n.d.	n.d.	n.d.	n.d.
Nd	4	9	-	-	7	8	-	12	20	15	-	-	-	-

The following abbreviations refer to protolith nomenclature, irrespective of the metamorphic facies: Bas = basalt; Bas-And = basaltic andesite; Rhy = rhyolite; Gb = gabbro; Dn = dunite; Hz = Harzburgite.
* = XRF Analyses carried out at Istituto di Mineralogia, Ferrara University; + = XRF Analyses carried out at Istituto di Mineralogia, Petrografia e Geochimica, Palermo University; all the others from Giunta et al. (1992). n.d. = not detected; - = not determined.

Table 1 cont.

								Franja Costera Unit						
			Tiara Fm. *Stop 2B*					Tacagua Fm. *Stop 1C*			Nirgua Fm *Stop 3C*			
	*VNZ 65 Gb	*VNZ 66 Gb	VNZ 62 Bas	VNZ 63 Bas	VNZ 72A Bas	VNZ 72B Bas	VNZ 73 Bas	VNZ 75 Bas	VNZ 82 Bas	*VNZ 123 Bas	VNZ 78 Bas	VNZ 80 Bas	+VNZ 126 Dn	+VNZ 127 Dn
SiO2	47.15	47.23	51.27	50.55	50.25	51.04	50.15	46.56	50.09	42.56	45.92	46.37	45.34	39.62
TiO2	0.21	0.29	1.80	0.97	1.68	1.16	1.37	1.23	1.92	1.71	1.69	1.11	0.02	0.02
Al2O3	18.10	16.19	12.92	13.96	13.74	12.16	13.46	13.43	12.96	12.60	11.43	13.15	0.38	0.70
Fe2O3t	5.31	5.11	9.47	8.15	9.00	8.02	8.76	9.68	11.94	12.55	10.04	8.34	11.65	5.98
MnO	0.08	0.09	0.16	0.15	0.19	0.12	0.15	0.14	0.17	0.21	0.17	0.15	0.19	0.14
MgO	11.04	12.35	7.95	9.56	8.84	9.09	9.10	8.98	7.24	10.40	8.64	11.16	34.01	37.30
CaO	12.93	13.80	10.03	11.41	9.12	12.45	10.84	12.74	9.09	12.95	14.33	11.27	0.23	0.00
Na2O	1.76	1.58	2.03	2.41	3.30	2.12	2.72	2.30	3.35	1.59	1.92	1.86	0.06	0.03
K2O	0.16	0.07	0.01	0.22	0.14	0.03	0.53	0.12	0.08	0.00	0.10	0.01	0.00	0.00
P2O5	0.07	0.08	0.24	0.08	0.19	0.11	0.15	0.10	0.16	0.14	0.13	0.12	0.00	0.00
LOI	3.65	3.65	4.09	2.45	3.48	3.64	2.72	4.65	2.97	5.32	5.54	6.35	8.14	16.32
Tot	100.5	100.4	100.0	99.9	99.9	99.9	100.0	99.9	100.0	100.0	99.9	99.9	100.0	100.1
Cr	1101	782	168	493	300	365	241	363	161	340	338	365	2623	2043
Ni	224	228	79	111	118	110	87	101	62	98	136	146	2643	2105
Rb	n.d.	n.d.	5	6	4	4	7	6	6	n.d.	5	5	n.d.	n.d.
Sr	354	215	29	128	84	32	133	170	45	410	222	164	n.d.	n.d.
Ba	74	71	12	25	21	3	34	11	11	26	9	n.d.	n.d.	n.d.
Zr	4	n.d.	138	67	56	63	75	56	100	95	116	60	n.d.	n.d.
Y	5	7	45	28	28	24	29	29	45	23	43	24	n.d.	n.d.
La	n.d.	n.d.	17	5	7	3	7	n.d.	8	2	5	3	n.d.	n.d.
Ce	n.d.	n.d.	44	26	27	18	22	13	18	20	20	18	n.d.	n.d.
Nd	-	-	24	14	20	12	12	11	13	-	13	11	-	-

schist facies; c) foliated, aphanitic to granular, metavolcanics and meta-volcano-sedimentary sequences up to siltites and cherts (S.Isabel Subunit or "Granofels" Subunit), metamorphosed in the glaucophane-barroisite blue-schist facies.
Even in the absence of precise stratigraphic data, the age of the complex is presumably Upper Jurassic - Cretaceous.
The characteristics of the deformations are comparable with many units of the Venezuela Cordilleras, with axial plane foliation S1, often folded (SE-NW) and re-folded by crenulation cleavage S2 (NE-SW).
Westward of this transect, serpentinized peridotites and gabbros (Chacao Complex) outcrop, which may be considered a basement fragment involved in the subduction complex. Moreover, carbonate bodies (Upper Mesozoic), in reef and forereef facies, outcrop with mechanical contacts near S. Juan de los Morros.

Stop 3A - *Rio Pao, southward from Cambural and near Corralito*

Cretaceous subduction complex of the **Villa de Cura Units**: "Granofels" of Santa Isabel sheet. Volcano-sedimentary sequence, with intermediate to acidic volcanics, metamorphosed under high pressure-low temperature conditions, in bue schist facies.

Metavolcanics consist of meta-tuffs and meta-lavas with schistose texture and development of metamorphic assemblages of albite, epidote, actinolite (sometimes transformed into barroisite), chlorite, sphene, stilpnomelane, and glaucophane. Calcite, as a dispersed phase or filling cavities and/or veins, is widespread. Sample VNZ 104 (Table 1) is a metarhyolite with porphyritic texture; phenocrysts of albitized plagioclase, quartz, and alkali feldspar are set in a fine-grained, sometimes spherulitic, groundmass.

Stop 4A - *Rio Pao, near Carapita*

Cretaceous subduction complex of the **Villa de Cura Units**: meta-lavas of El Carmen sheet (or "Metalavas" sheet). Massive or foliated basaltic meta-lavas with high pressure-low temperature metamorphism (blue schist facies).
Chemical composition of metabasalt VNZ 24 is rather ambiguous, also due to the very high LOI; its relatively high TiO_2 and Zr contents may be attributed either to arc tholeiitic magmatic fractionation or to Mid Ocean

Ridge Basalt (MORB) affinity. Petrographically, this sample shows aphyric, intersertal texture with small albitized skeletal plagioclase laths and the primary mafic phases completely transformed into chlorite, pistacitic epidote, actinolite, and sphene; calcite, together with albite, represent the main fillings of veins and vesicles. Instead, chemical analyses of samples VNZ 111 and 112 unambiguously indicate Island Arc Toleiite (IAT) affinity. Petrographically, these samples are markedly porphyritic with large idiomorphic, nearly undeformed, phenocrysts of clinopyroxene set in a schistose recrystallized groundmass, made up of chlorite, actinolite, epidote, glaucophane, sphene, and albite. Sometimes glaucophane is growing around the clinopyroxene phenocrysts.

Stop 5A - *Rio Pao, near Altos de Mamonal*

Cretaceous subduction complex of the **Villa de Cura Units**: meta-tuffs of El Chino-El Caño sheet (or "Metatobas" sheet). Meta-tuffs and subordinate foliated meta-lavas in blue schist facies. The rocks generally show schistose texture with development of metamorphic assemblage consisting of glaucophane-crossite, epidote, albite, chlorite, actinolite, and calcite.

Stop 6A - *Rio Pao, near Altos de Mamonal*

Cretaceous subduction complex of the **Villa de Cura Units**. Outcrop of meta-tuff and meta-lava sheets where it is possible to observe the deformative phases, consisting of an axial main foliation and a crenulation cleavage.

Stop 7A - *Upper Rio Pao, southward of El Pao de Zarate*

Panoramic view of the tectonic contact between the **Villa de Cura** and **Loma de Hierro Unit.** The contact is represented by a high-angle fault (Agua Fria Fault) southward dipping. The Villa de Cura Units overthrust the Loma de Hierro Unit. Here, the top of the Loma de Hierro terrains is constituted by Upper Cretaceous sedimentary sequences (carbonatic and terrigenous) with rare layers of volcanoclastic material (Paracotos Formation)(Fig. 9).

Stop 8A - *Quebrada San Francisco, westward of El Pao de Zarate*

Panoramic view of the Santa Rosa strike-slip Fault, where it is possible to observe the tectonic contact between **Loma de Hierro Unit** and **Caucagua-El**

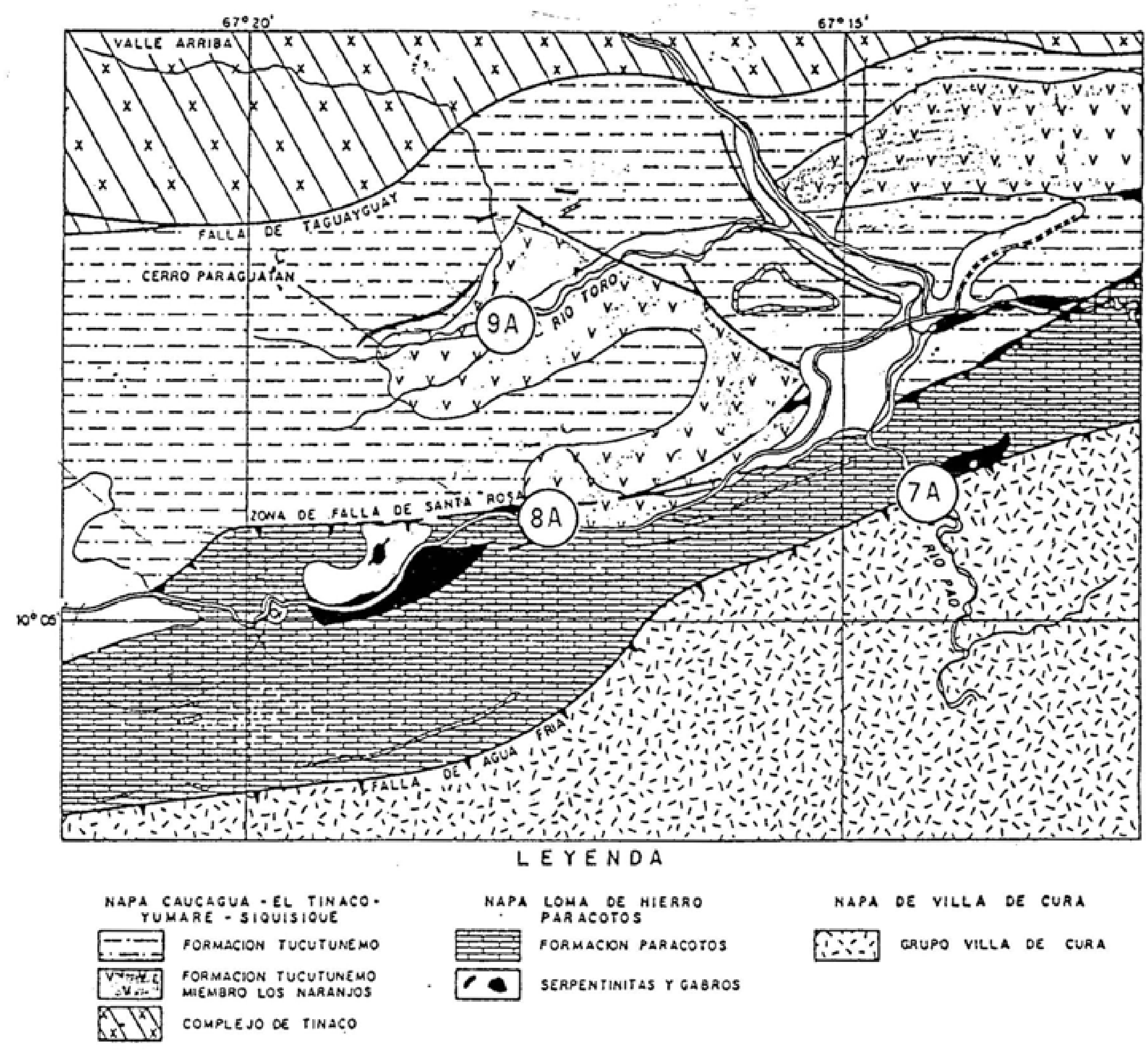


Fig. 9 - Geological sketch map of upper Rio Pao and Rio Toro areas (from OSTOS, 1990).

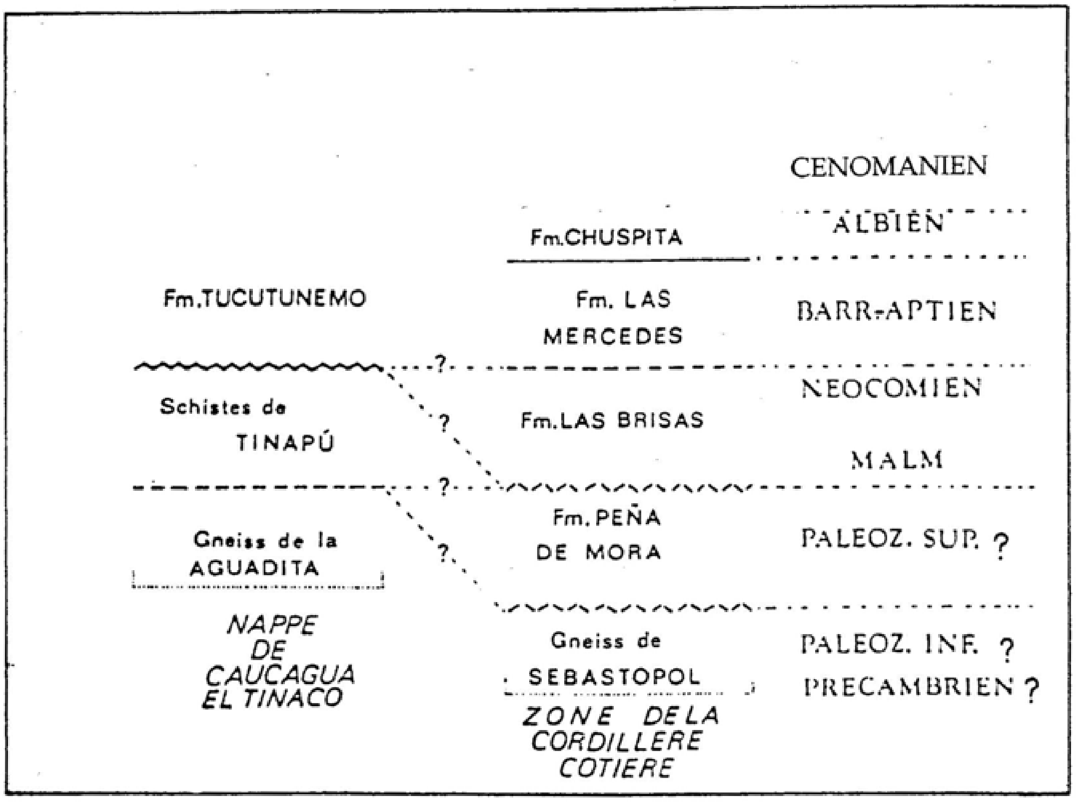


Fig.10 - Stratigraphic relationships between the Caucagua-El Tinaco nappe and the Cordillera de la Costa zone (modified from BECK, 1986).

Tinaco Unit with interposed boudins from the basement of the former unit (Fig. 9).

Stop 9A -*Rio Toro, near El Toro, northwestward of La Candelaria*

Cretaceous (?) rifted continental margin of the **Caucagua-El Tinaco Unit**

The **Caucagua-El Tinaco Unit (TT)** (Fig. 9) overthrusts onto the Cordillera de la Costa Unit, particularly to the west of the transect, or is in fault contact with this unit, along the subvertical dextral strike-slip La Victoria Fault. According to previous works, this unit comprises terrains and formations observed in several localities of the Venezuelan Northern Cordilleras (Fig. 10). It is made up of a pre-Mesozoic basement (El Tinaco Complex), constituted by metasediments and minor metavolcanics metamorphosed in amphibolite facies (Aguadita Gneiss), and schists, metaconglomerates and meta-arkoses in green-schist facies (Tinapù Schists). Westward, the basement is in tectonic contact with serpentinized peridotites (Tinaquillo Peridotite). Upward, a volcano-sedimentary sequence of Middle-Upper Cretaceous age (with great variability along the orogen axis) lies in discordance directly on the basement, often through a tectonized contact. It consists of proximal terrigenous sequences (arkosic sandstones and conglomerates), followed by allodapic limestones and calcarenites. Within this sequence, breccias and basaltic pillow lavas of various thickness are intercalated. From west to east, along this unit, differences can be observed, particularly as regards metamorphism: Pilancones, Queraqual, La Luna and Sabana Larga Breccias formations, to the west, do not show any metamorphism; laterally and to the east, Las Placitas and Araguita formations show low-grade metamorphism; further to the east, the Tucutunemo Formation, consisting of meta-arenites, metaconglomerates and marbles with intercalated basaltic metalavas (Membro Los Naranjos), displays penetrative metamorphic effects in green schist facies. These basaltic lavas are tholeiites, as indicated by the chemistry of samples VNZ 35, 67, 97, 101 (Table 1). Petrographically, they generally show schistose texture with development of a green schist facies assemblage consisting of albite, epidote, chlorite, and actinolite. In the coarsest-grained sample VNZ 97, the doleritic texture of the protolith is preserved.

From La Boca del Toro to Guacamaja.

Panoramic view on the **Caucagua-El Tinaco Unit** and observation of some lithotypes of the same unit along the road. Panoramic view of the La Victoria strike-slip Fault and contact between Caucagua-El Tinaco Unit and Cordillera de La Costa Unit.

2nd DAY (B) FIELD TRIP - CARACAS - PARACOTOS - TACATA - ALTAGRACIA DE LA MONTAÑA - CARACAS - (FIG. 11)

Stop 1B, 2B, 3B, 4B, 5B, 6B, 7B

Lithostratigraphic sequence and geometric settlement of the Jurassic-Cretaceous oceanic complex of the **Loma de Hierro Unit (LH)**.

The **Loma de Hierro Unit** (Fig. 12) overthrusts onto the Caucagua-El Tinaco Unit, which outcrop further northward, with a high-angle tectonic contact (S. Rosa Fault), along which LH is affected by shear with formation of boudins. In places, as already stated, such unit tectonically underlies the VC Units along the Agua Fria Fault. In the studied zone, a series of tectonic slices occur.

LH is made up of a sequence of serpentinized peridotites and cumulitic gabbroic rocks of Upper Jurassic age, in places followed by metabasalts with intercalated silicified metalimestones and scarce radiolarites ("Capas del Rio Guare": Beck, 1985) of the Lower Cretaceous; they are, in turn, in mechanical contact with the massive lavas of the Tiara Formation, mostly represented by metabasalts and metadolerites, sometimes cut by microgabbroic dikes, of Middle-Upper Cretaceous age. Upward, Upper Cretaceous phyllitic metapelites and meta-arenites with intercalated greyish-white meta-limestones, and minor conglomerates and volcanoclastic siltites occur (Paracotos Formation) (Fig. 13).

The Tiara Formation lavas show a clear MORB affinity (Girard et al., 1982). Metamorphic character varies inside this unit, but generally the rocks are in green-schist facies with at least two deformative phases (foliation and crenulation cleavage) in the less competent lithotypes.

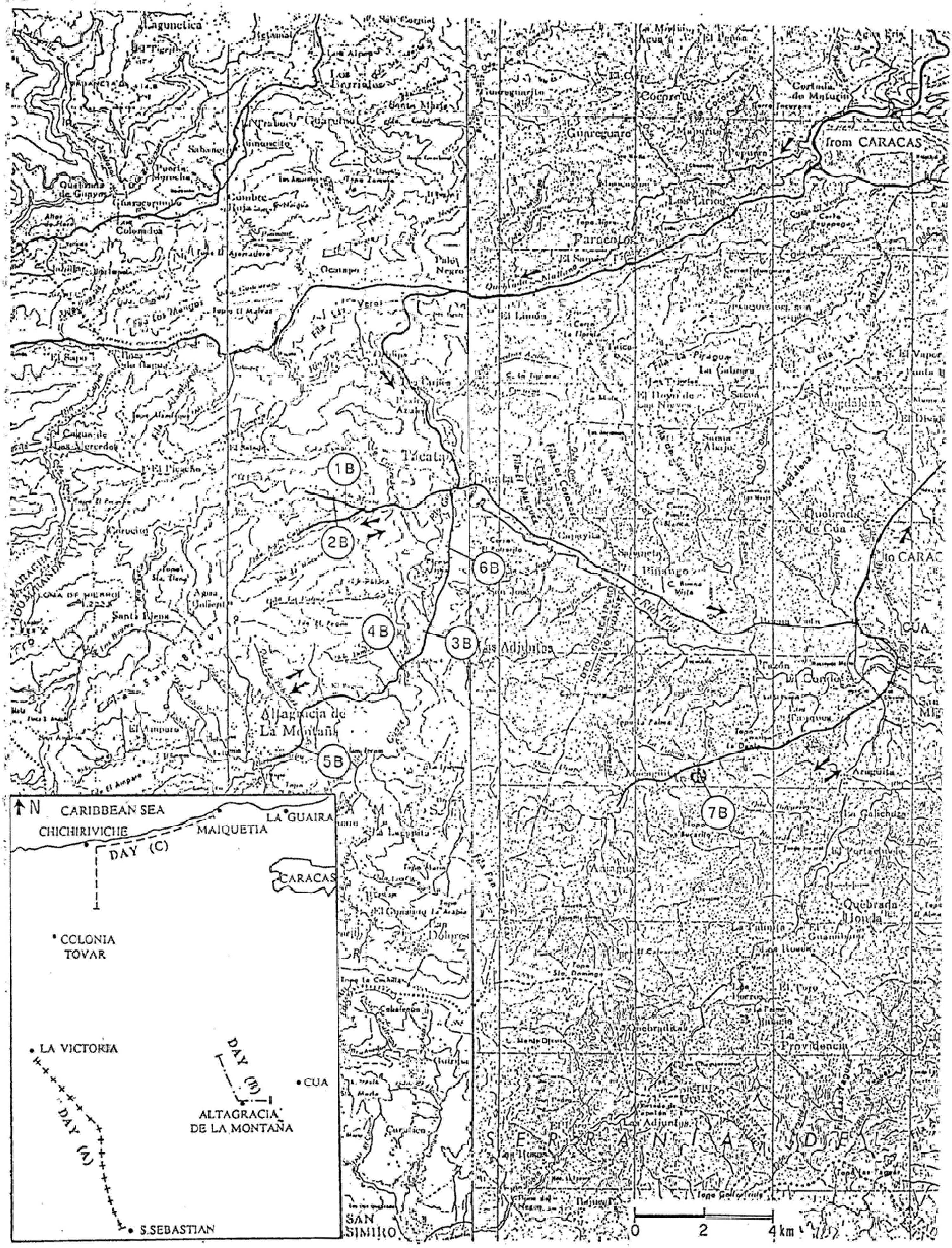


Fig. 11 - Topographic map with location of stops, Day B.

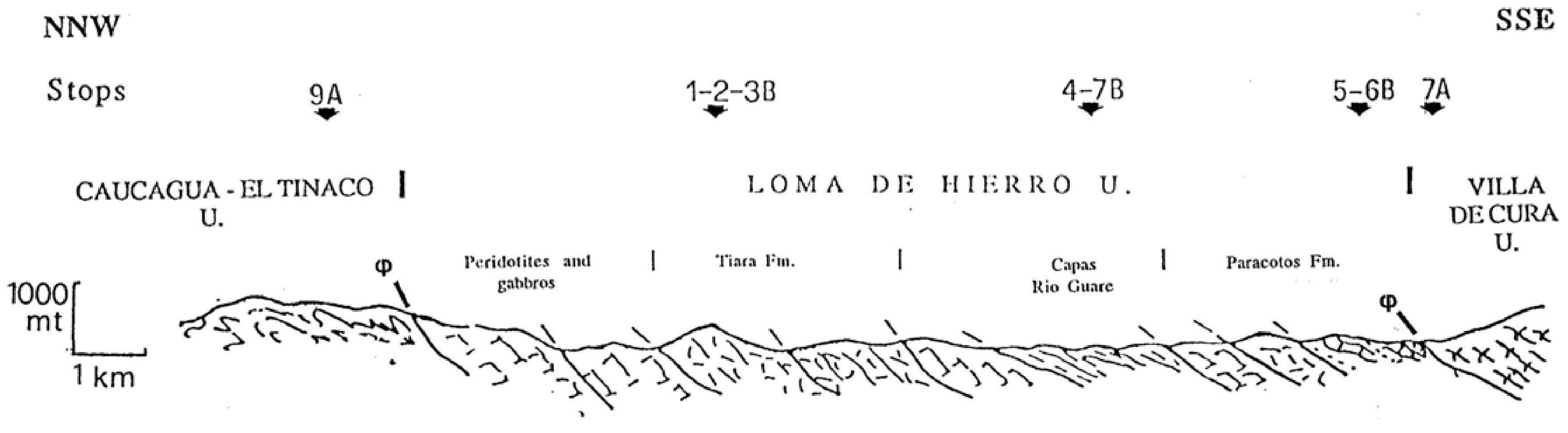


Fig.12 - Schematic cross section of the Loma de Hierro Unit (between Caucagua - El Tinaco U. and Villa de Cura U.) subdivided in several sheets.

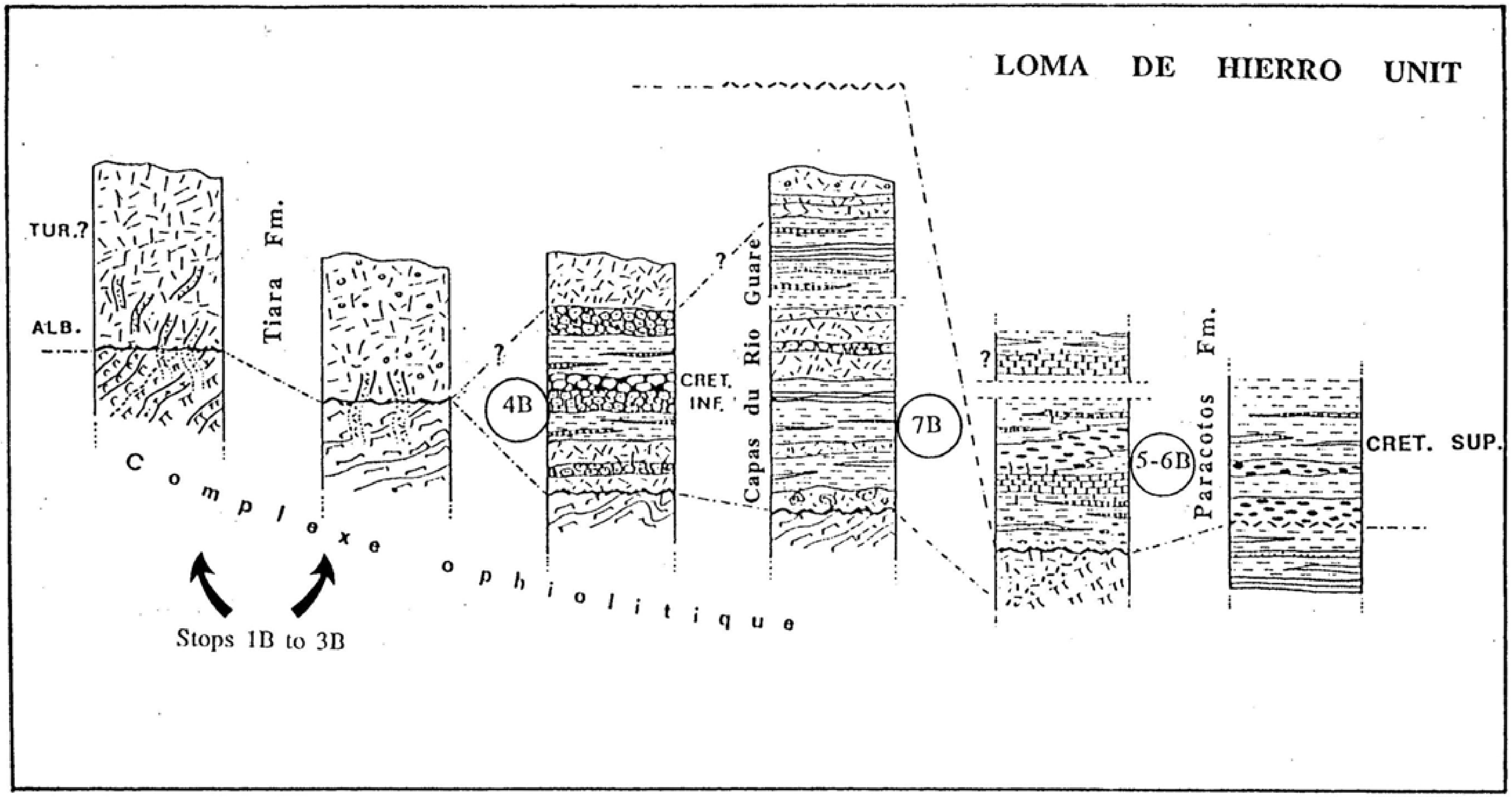


Fig. 13 - Stratigraphic relationships within Loma de Hierro Unit (modified from BECK, 1986).

Stop 1B - *Rio Mesia, westward of Tacata, near Casa Trujillo and Hacienda Los Mijados.*

Serpentinized harzburgites and layered gabbros with variable size from micro-gabbro to pegmatitic. Decimetric dikes cutting the main body are also visible.

Chemical analyses of serpentinized harzburgites (VNZ 58, 59, 60) and gabbros (VNZ 64, 65, 66) are reported in Table 1. In spite of serpentinization, harzburgites still retain the original mantle protogranular texture and relics of the primary mineralogy which consists of strongly kinked olivine and unmixed orthopyroxene, and "holly-leaf" brown Cr-spinel in interstitial position.
Gabbros vary from coarse- to fine-grained. Plagioclase is prehnitized, and clinopyroxene partly pseudomorphosed by actinolite ($\pm$ prehnite). The crystallization order (plagioclase followed by clinopyroxene) is typical of oceanic meata-gabbros with MORB affinity. The green schist facies metamorphic assemblage mainly consists of actinolite, epidote, chlorite, and albite.

Stop 2B - *Rio Mesia, westward of Tacata.*

Mechanical contact between the basaltic lavas of the Tiara Formation and the gabbroic rocks. Massive meta-basalts with MORB affinity, variably metamorphosed into green schist facies without evident ductile deformation (Tiara Formation).

Petrographycally, textures of metabasalts vary from intersertal to doleritic, sometimes porphyritic for plagioclase phenocrysts. The crystallization order of primary minerals is plagioclase followed by clinopyroxene. The green schist facies metamorphic assemblage consists of prehnite after plagioclase, and actinolite plus epidote plus chlorite after clinopyroxene. Opaque minerals and sphene are widespread.
The chemistry of all analyszd basalts (VNZ 17, 62, 63, 72A, 72B, and 73) consistently indicates a MORB affinity, in agreement with the observed petrographic characteristics of the whole association.

Stop 3B - *from Tacata Arriba to Altagracia de la Montana*

Panoramic view of the tectonic sheets within the **Loma de Hierro Unit** and of the regional contact of the Tiara lavas on the Loma de Hierro serpentinized peridotites and gabbros.

Stop 4B - *Rio Guare, southward of Tacata, near Rio Arriba*

Volcano-sedimentary covers (Lowermost Cretaceous) of the oceanic complex of the **Loma de Hierro Unit** (lower section of the "Capas del Rio Guare" Formation) (Fig. 14).
Lava-breccias and volcanoclastites with pelites and rare radiolarites, followed by basaltic lava flows.

Stop 5B - *near Altagracia de la Montana*

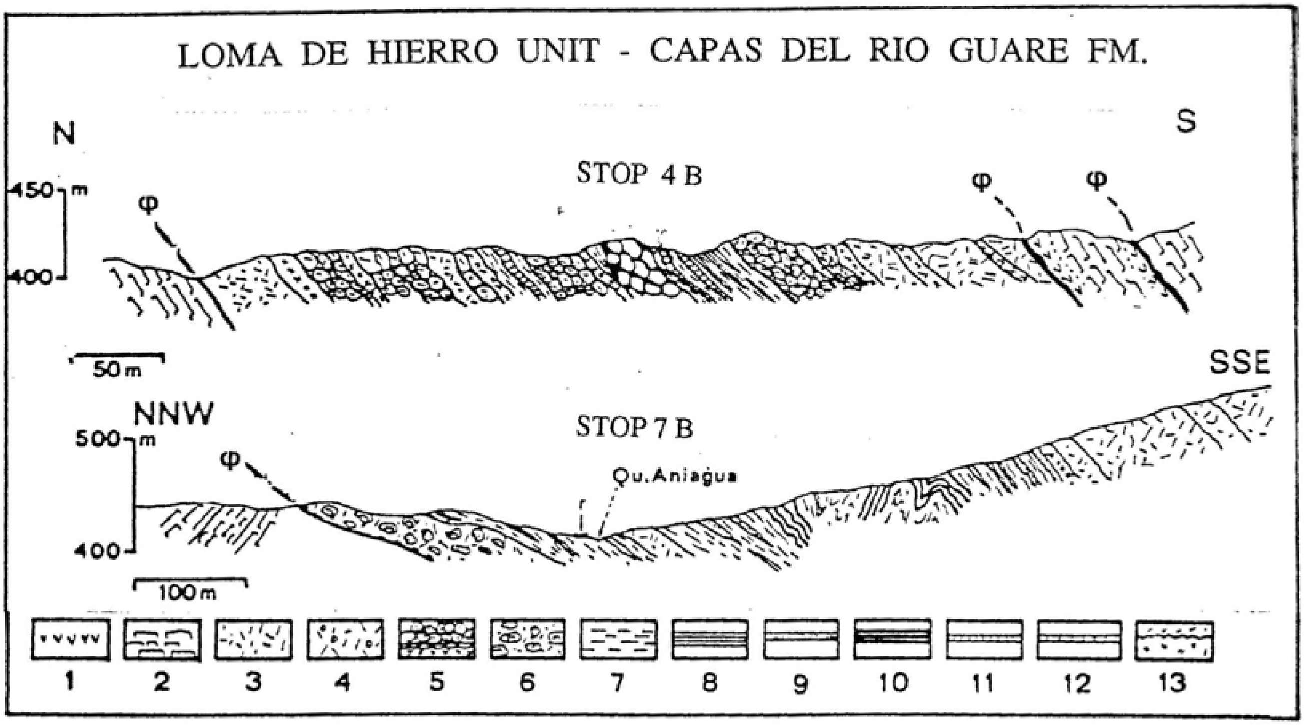
Cretaceous sedimentary sequence of the Paracotos Formation, composed by allodapic limestones, siltites and microconglomerates with volcanoclastic elements. The formation is metamorphosed in green schist facies and deformed with at least two ductile phases. The attribution of this formation to the uppermost levels of the Loma de Hierro Unit is still a matter of debate.

Stop 6B - *between Tacata Arriba and Tacata*
(possibly in alternative to Stop 5B)

Sedimentary covers (Upper Cretaceous) of the oceanic complex of the **Loma de Hierro Unit**: some lithothypes of the Paracotos Formation (see Stop 5B)

Stop 7B - *near Macaguita, southwestward from Cua*
(possibly in alternative to Stop 4B)

Volcano-sedimentary covers (Lowermost Cretaceous) of the oceanic complex of the **Loma de Hierro Unit**: volcanic breccias and basaltic lavas with intercalations of radiolarian cherts, pelites, and siltites (upper section of the "Capas del Rio Guare Formation") (Fig. 14).



Leyenda : 1. serpentinita; 2. gabros cumulados anfibolizados; 3. lavas básica afíricas; 4. lavas básicas con vacuolas de calcita; 5. tobas y brechas volcánicas; 6. brecha volcánica con fragmentos de gabro; 7. lutitas, filitas; 8. siltita, a menudo en laminatas; 9. graywacka de grano fino; 10. radiolarita y chert, a veces dolomíticos; 11. caliza negra piritosa con Radiolarios; 12. graywacka calcárea de grano fino; 13. tobas estratificadas y lavas, metamorfizadas (Gr. Villa de Cura); r. carretera, carretera de verano.

Fig. 14 - Cross sections through the volcano-sedimentary sequence of Capas Rio Guare Fm., Loma de Hierro Unit (modified from BECK, 1986).

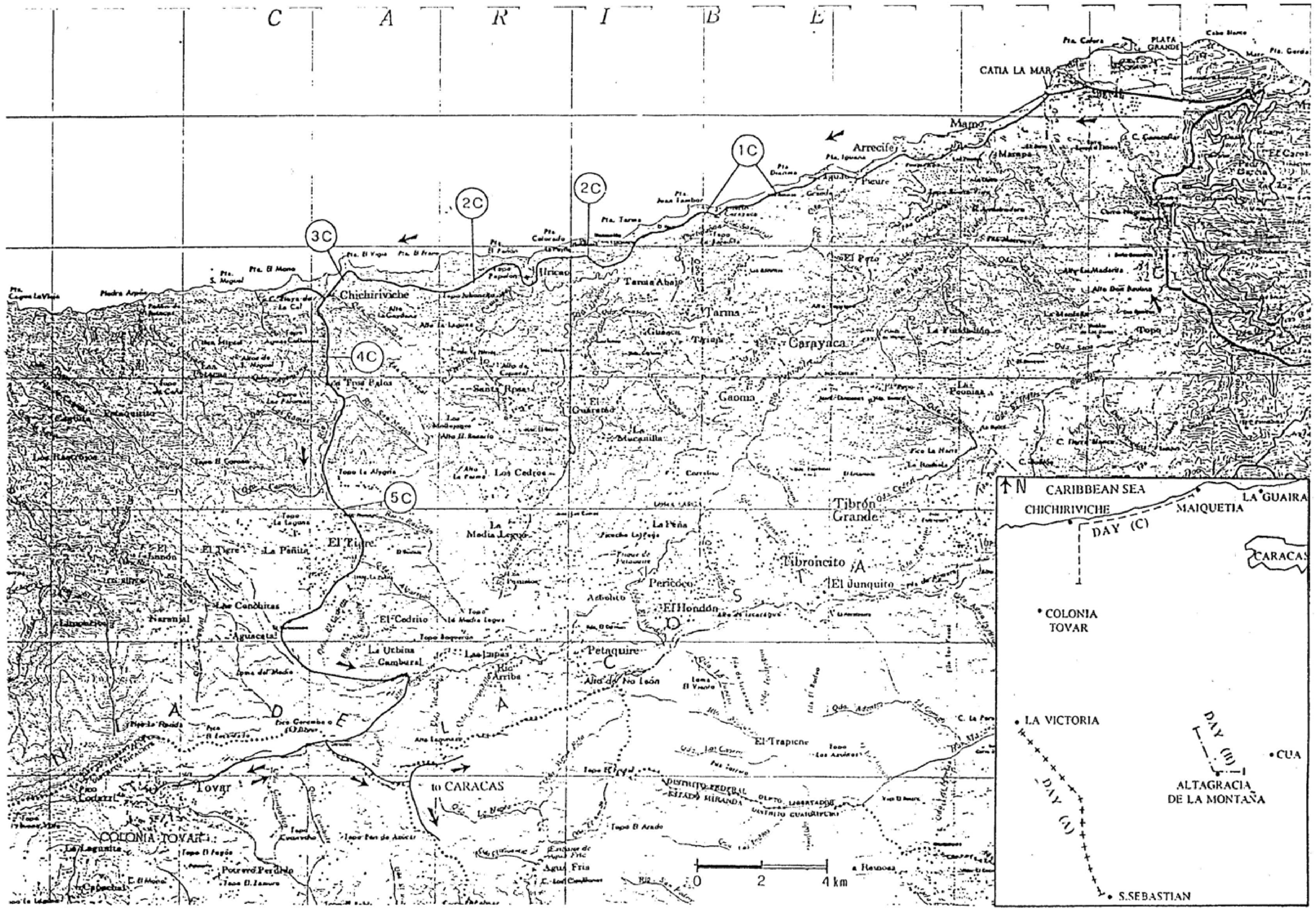


Fig.15 - Topographic map with location of stops, Day C.

3rd DAY (C) FIELD TRIP - CARACAS-MAIQUETIA - CATIA LA MAR - ARRECIFE - CHICHIRIVICHE - EL TIGRE - COLONIA TOVAR - CARACAS - (FIG. 15)

Stop 1C, 2C, 3C, 4C

Main lithotypes of the ophiolitic melange of the **Franja Costera Unit (FC)** of probable Cretaceous age.

The **Franja Costera Unit** is delimited northward by the San Sebastian Fault, and southward overthrusts, with a high angle-contact, onto the Cordillera de La Costa Unit. It consists of volcano-sedimentary and carbonate terrigenous sequences (with intercalated basic lavas), containing variably-sized boudins of mafic-ultramafic rocks (Tacagua and Nirgua Formations.; Navarro et al., 1988; Ostos, 1990) (Fig. 16). All sequences are metamorphosed in green schist facies and show the ductile deformation already observed in the above described units. The Tacagua and Nirgua Formations may be considered as "melanges" similar to those of some Franciscan units in North California.

Stop 1C -*westward of Arrecife.*

(Calc-)schists with intercalation and boudins of epidositic metabasites (Tacagua Formation).

Many litothypes of this formation record a metamorphic history from amphibolite facies re-equilibrated under green schist conditions. The ductile deformation is represented by at least two phases, the former with axial plane foliation folded by crenulation cleavage, particularly well-developed in calc-schists. Petrographically, these latter consist of calcite, muscovite, albite, epidote (± quartz). Sample VNZ 123 is a metabasalt with schistose texture and green schist facies paragenesis represented by epidote, actinolite, albite, and minor chlorite; calcite, as vein filling, is abundant. Its chemical analysis (Table 1) indicates a MORB affinity, confirming previous data by Giunta et al. (1992) (see samples VNZ 75 and 82, also in Table 1).

Stop 2C - *between Punta Tarma and Punta El Fraile*

Outcrops of boudins of serpentinites within the volcano-sedimentary sequence of the **Franja Costera Unit**.

Stop 3C - *Punta El Vigia, northeastward of Chichiriviche*

Meta-volcanics, meta-sandstones and meta-siltites with carbonatic intercalations, and layers and boudins of serpentinized dunites (Nirgua Formation).

Chemical analyses of variably serpentinized dunites (VNZ 126 and 127) are reported in Table 1. Petrographically, they show cumulitic texture and are constituted by olivine partly transformed into serpentine and blastic antophyllite.
In the same table, analyses of samples VNZ 78 and 80 refer to foliated metabasalts with MORB affinity. These metabasalts are petrographically quite similar to those already described for the Tacagua Formation (see Stop 1C).
Some samples represent meta-tuffs with typical green schist facies metamorphic assemblage consisting of albite, epidote, chlorite, actinolite, and calcite.
The metamorphism and deformation style are the same of the Tacagua Formation.

Stop 4C - *lower Rio Chichiriviche*

Panoramic view of the overthrust of the **Franja Costera Unit** onto the continental **Cordillera de La Costa Unit**.

Stop 5C - *from Rio Chichiriviche to El Tigre and Colonia Tovar*

Observation of some lithotypes of the Paleozoic-Cretaceous **Cordillera de la Costa Unit (CC)**.

The **Cordillera de la Costa Unit** outcrops as high ridge running parallel to the coast and forming a structural "dome" which separates the costal unit, to the north, from those of the Serrania del Interior. It is delimited southward by the La Victoria Fault subvertical strike-slip structure. The existence of

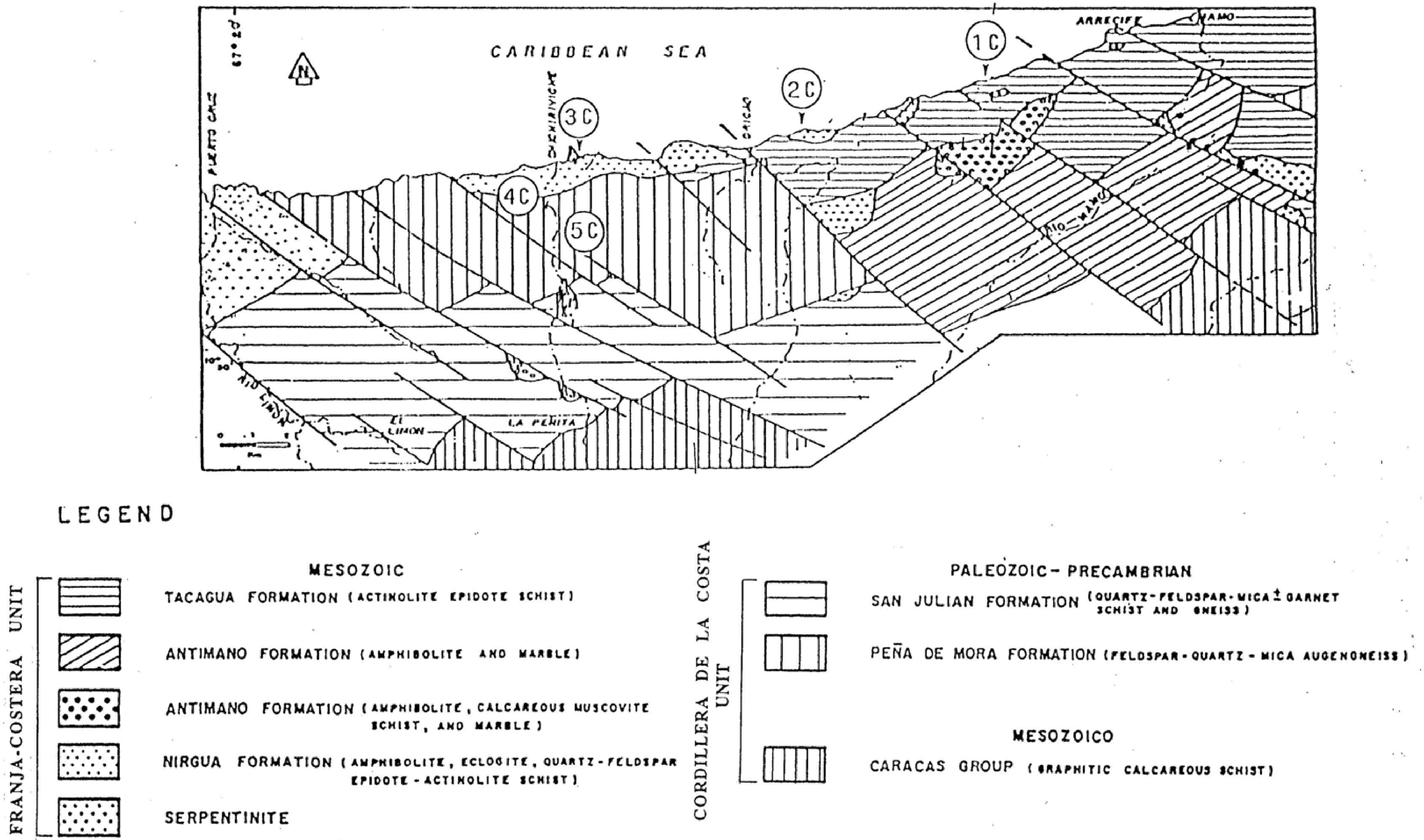


Fig. 16 - Simplified geological map of part of the Cordillera de la Costa Belt (from URBANI and OSTOS, 1987) and location of stops.

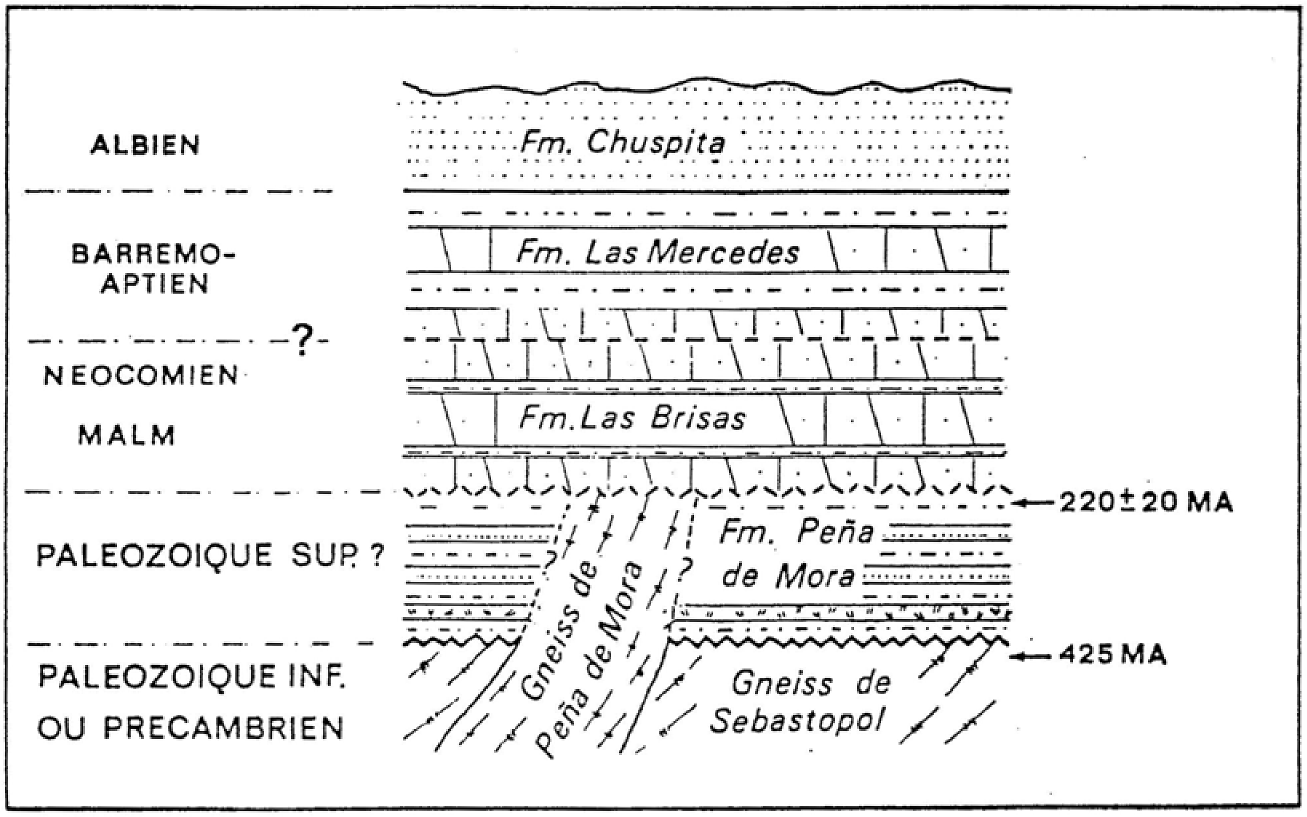


Fig.17 - Stratigraphical sketch of the Cordillera de la Costa Unit (modified from BECK, 1986).

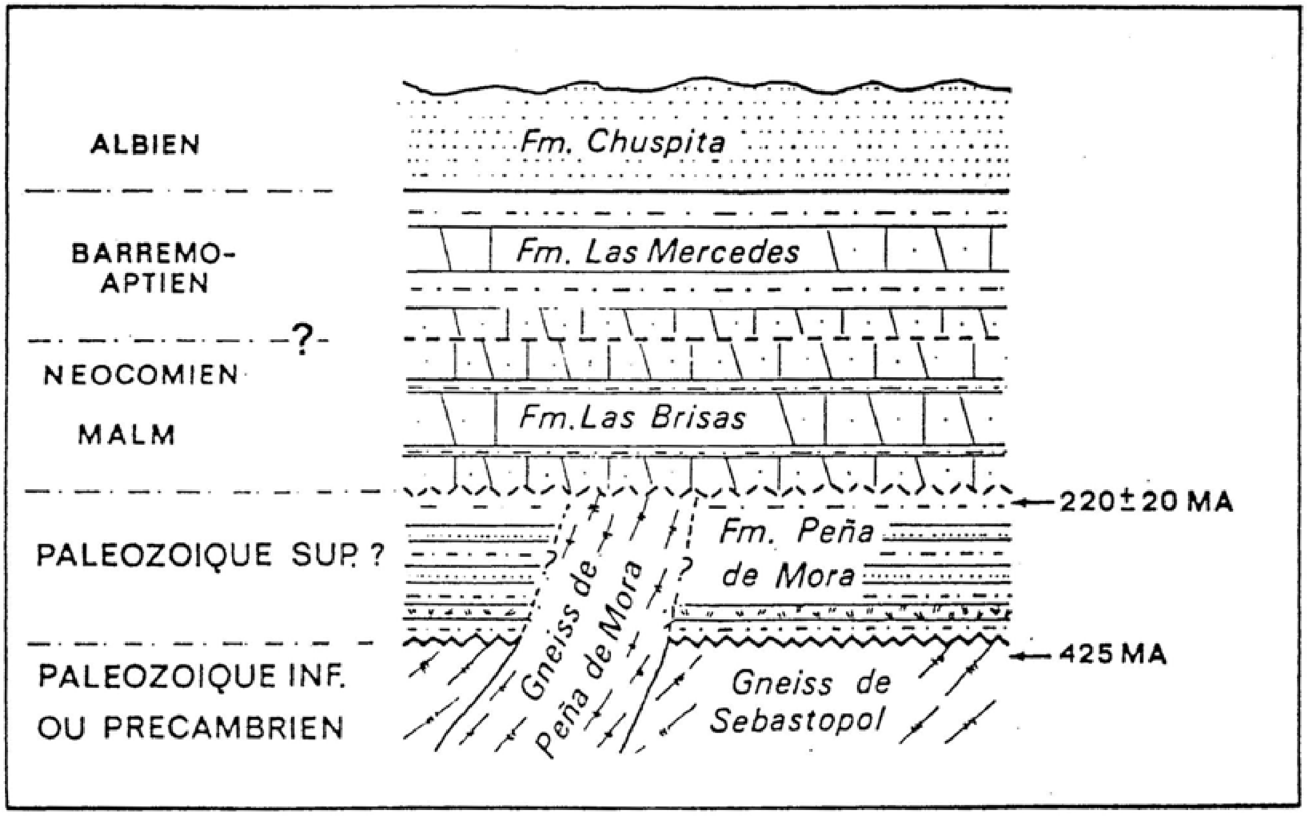


Fig. 17 - Stratigraphical sketch of the Cordillera de la Costa Unit (modified from BECK, 1986).

deep detachments are suggested by geophysical data, thus indicating the allocthonous character of the unit. It consists of (Fig. 17) a Precambrian-Paleozoic continental basement (Basal Complex of Sebastopol, Avila, Peña de Mora S.Julian) and an Upper Jurassic-Cretaceous carbonate and terrigenous-carbonate discordant cover, with volcanic intercalations (Las Brisas, Antimano, Las Mercedes, Chuspita Formation ; Urbani and Ostos, 1987). These terrains are metamorphosed in green schist facies and pervasively deformed with axial plane foliation (S_1) and crenulation cleavage (S_2).

THE NORTHERN MARGIN OF THE CARIBBEAN PLATE IN CUBA

REGIONAL OUTLINES

The cross section extends approximately in a NW-SE direction, in the Villa Clara region, Central Cuba.

Generally speaking, the Cuban Archipelago is composed of both "folded belt" and "neoautochthonous" complexes (Pardo, 1975; Hatten et al., 1988; Iturralde Vinent, 1989, 1994). The folded belt presents a series of Mesozoic-Tertiary, generally allochthonous units of continental and oceanic type (Figs. 18 and 19). The neoautochthonous complex consists of sedimentary sequences deposited onto the folded complex from Upper Eocene time, both contributing to the building of the Island.

In Cuba, the northernmost portion of the Caribbean Plate margin outcrops, today overthrust, with northward vergence, onto the North American Plate. It is separated from the more eastern Greater Antilles by the Bartlett sinistral strike-slip structure, which represents one of the transcurrent margins forming the Tertiary Cayman transtension.

The Cuban orogen is about 1000 km long, and only a few tens of kilometres wide. The main body of the orogen is subdivided into at least four sections from west to east, separated by subvertical, sinistral strike-slip structures (Pinar, La Trocha, Nipe Faults).

The most important tectonic units of the folded belt complex are shown in the cross section (Fig. 20). This complex is constituted by two continental elements, belonging to the Bahamas platform (the northernmost) and to the Guaniguanico-Pinos-Escambray Terrains (the southernmost), both overthrust by the oceanic elements of the Northern Ophiolitic Melange Unit and the Cretaceous and Paleogene Island Arc Units (Fonseca et al., 1990;

Iturralde Vinent, 1994). The Paleogene Arc Units outcropping in eastern Cuba are not considered here.
The deformation front of the folded belt complex extends upon a Tertiary foredeep, through a series of frontal slices with northern vergence, associated to flyschoid sequences and olistotromes with clasts of northern (Bahamas) and southern (ophiolites) provenance.

1st DAY (D) FIELD TRIP - LA HAVANA - SANTA CLARA - CAMAJUANI' - PLACETAS - SANTA CLARA - MATAGUÀ - SANTA CLARA - (FIG. 21)

Stop 1D, 2D, 3D, 4D, 5D, 6D, 7D, 8D, 9D

Contact between the Bahamas continental paleo-margin and the Northern Ophiolitic Unit. Jurassic-Cretaceous "melange" of the Northern Ophiolitic Unit.

Bahamas Units (BU) - these are the lowest units of the folded system and consist of at least four tectonic units: Cayo Coco, Remedios, Camajunì, Placetas, from the outermost to the innermost respectively (see Iturralde Vinent, 1994). They consist of Jurassic-Cretaceous sequences of carbonate platform and intraplatform channels. The sequences of the Camajuanì Unit represent slope deposits, while those of Placetas include deep water basin sediments. Both are interpreted as the original termination of the North America Plate continental margin. In the Placetas Unit, Upper Jurassic tholeiitic lavas are also present. It is to be noted that the Placetas facies represent the Caribbean equivalent of the deep water facies of the Gulf of Mexico and part (Rosario Units) of the southern continental element (Guaniguanico-Escambray).

Northern Ophiolitic "melange" Unit (NO) - This unit occurs in the northern half of the transect and has been overthrust north- and northeastward onto the foreland basin and Bahamas units. A complete lithostratigraphic section comprises a peridotitic and a cumulitic gabbroic complex of Upper Triassic (?) -Lower Cretaceous age, cut by dikes and diabases, and followed by basaltic lavas, hyaloclastites, radiolarites and volcanoclastites of Hauterivian-Turonian age.

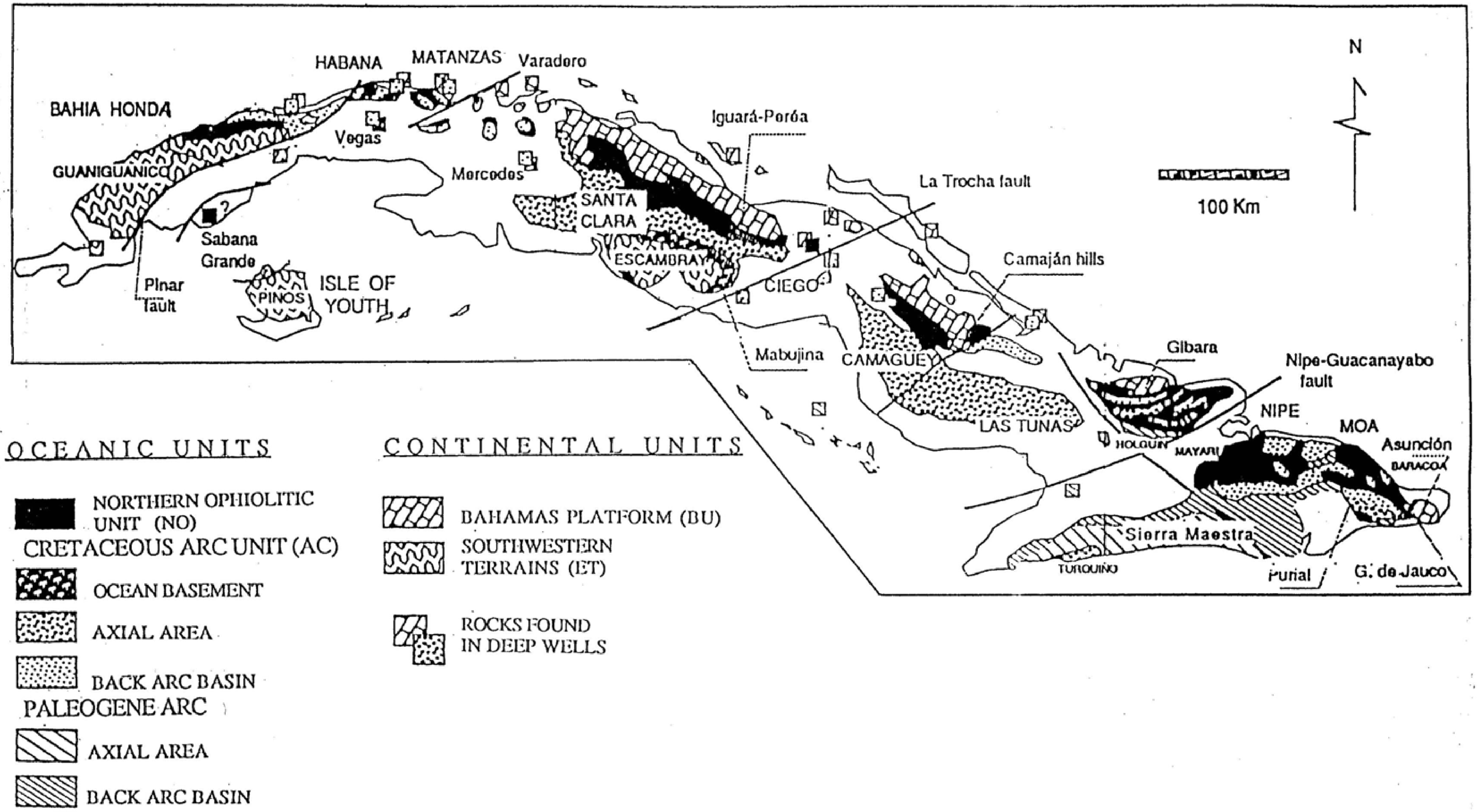


Fig. 18 - Geological sketch map of Cuba. Areas without pattern are latest Eocene to Recent deposits of the neo-autochthon (from ITURRALDE VINENT, 1994).

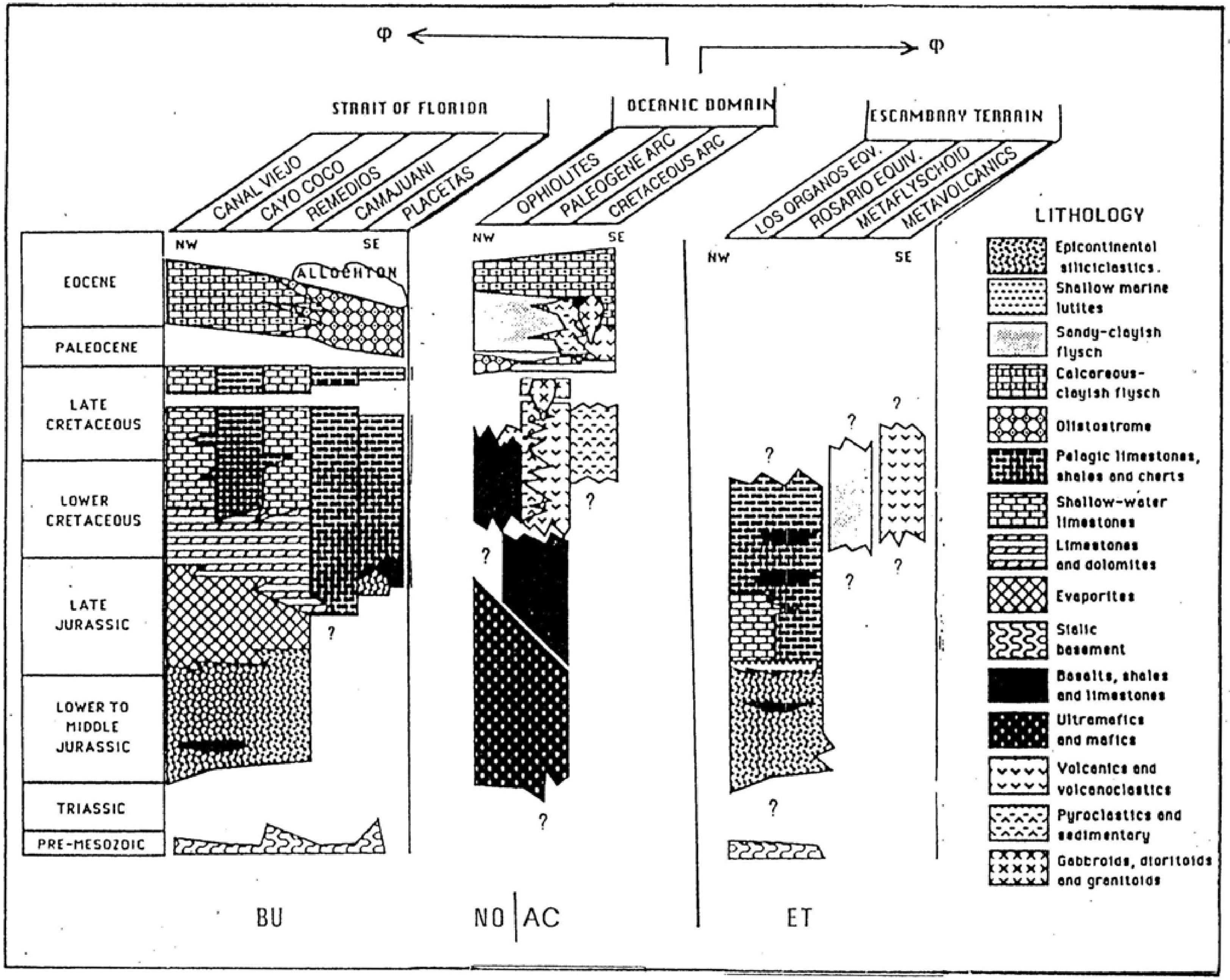


Fig.19 - Tectonostratigraphic sketch of Central Cuba (modified from ITURRALDE VINENT, 1994).

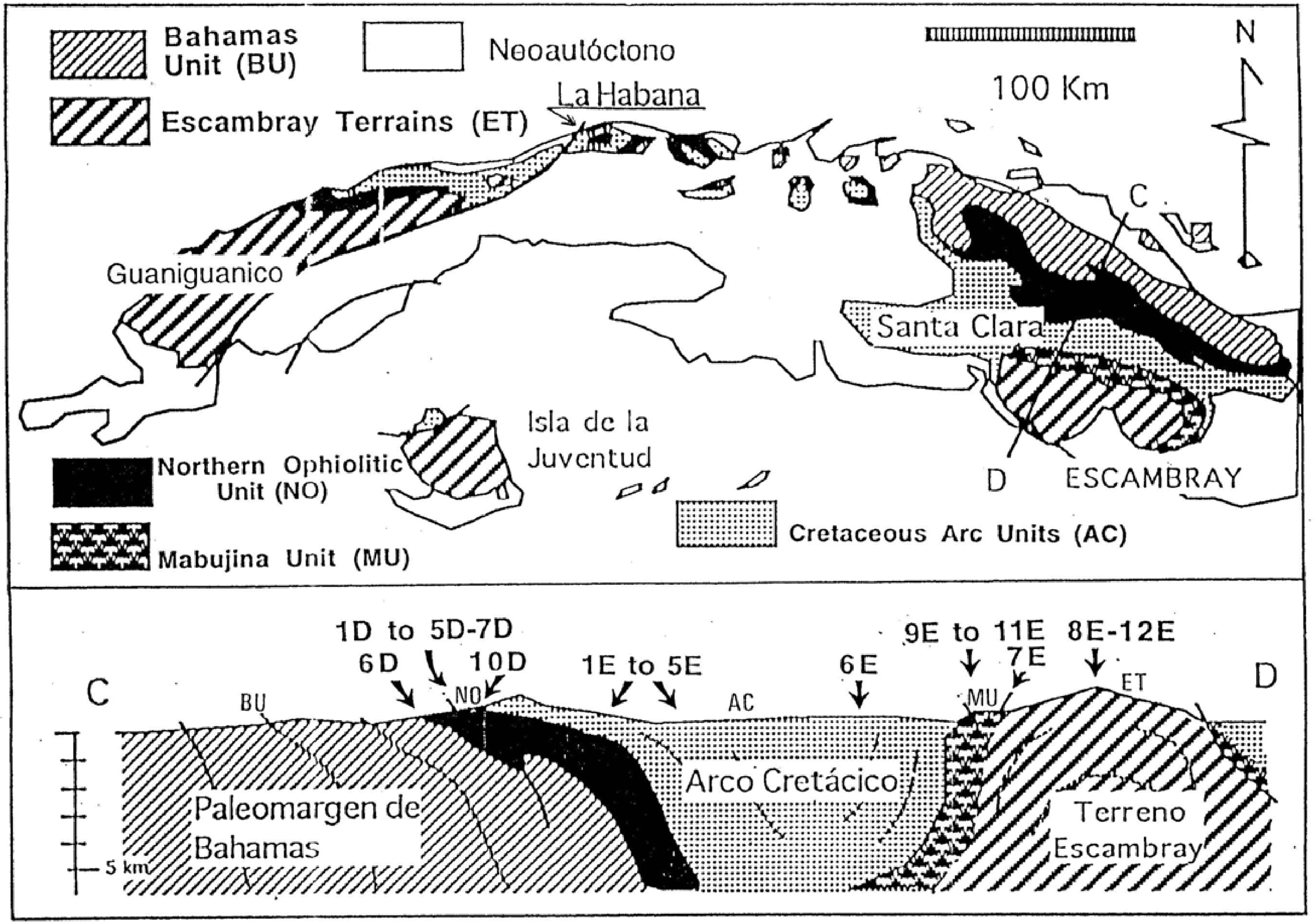


Fig. 20 - Field trip cross section through Cuba Central and location of stops.

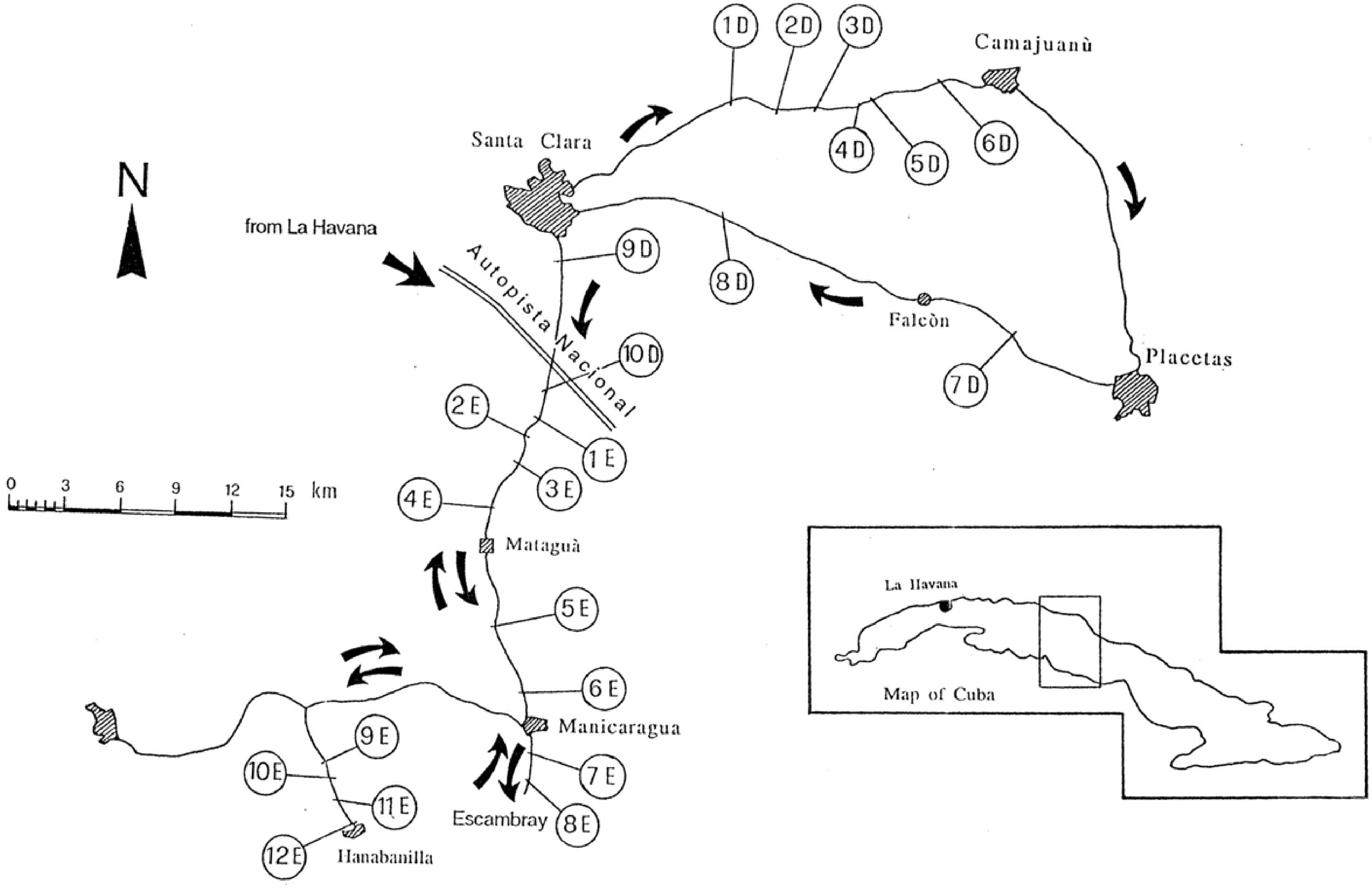


Fig. 21 - Location of stops during field trip in Central Cuba

Stop 1D -*Las Minas, northeastward of Santa Clara*
(Northern Ophiolitic Unit)

Foliated serpentinites, with harzburgitic portions. These serpentinites represent the matrix of the melange.

Stop 2D -*Loma Bonachea, northeastward of Santa Clara*
(Northern Ophiolitic Unit)

Outcrop of large blocks of Lower Cretaceous limestones and radiolarian cherts within the melange. The inferred provenance of these blocks is from the Bahamian continental paleo-margin.

Stop 3D -*El Barro, northeastward from Santa Clara*
(Northern Ophiolitic Unit)

Boudins of garnet-amphibolite within the melange.

Stop 4D - *Rio Sagua La Chica, westward of Camajuanì*
(Northern Ophiolitic Unit)

Spilitized oceanic basaltic breccias.

Stop 5D - *Crucero Carmita, eastward of Camajuanì*
(Northern Ophiolitic Unit)

Basic dikes cutting the serpentinites.

Stop 6D -*Lomas de Santa Fé, near Camajuanì*
(Northern Ophiolitic Unit)

Panoramic view of the Northern Ophiolitic Unit overthrust onto the Bahamas continental margin Units.

Stop 7D -*Ferrocarril central, westward of Placetas*
(Northern Ophiolitic Unit)

Layered cumulitic sequence from peridotites to leuco-gabbros. Chemical analyses of peridotite (HAB 5B), olivine gabbro (HAB 6) and leuco-gabbro (HAB 5A) are reported in Table 2.

Petrographically, the sequence is characterized by the following crystallization order of the primary minerals, referable to MORB magmatism: olivine, plagioclase, clinopyroxene. The rocks are only slightly metamorphosed in green schist facies.

Stop 8D -*Cerro Pelo Malo, eastward of Santa Clara*
(Northern Ophiolitic Unit)

Very large inclusions of serpentinite breccias within the melange.

Stop 9D -*Cerro Calvo, southward of Santa Clara*
(Northern Ophiolitic Unit)

Meta-volcanics in green schist facies, as "boudins" within the serpentinite matrix of the melange. Petrographically, metabasites show schistose texture and metamorphic assemblage consisting of albite, chlorite, epidote, and actinolite. Secondary quartz, in veins, vesicles and patches, is very common.

Stop 10D -*Monterola, southward of Santa Clara*
(Northern Ophiolitic Unit and **Cretaceous Arc Units)**

Panoramic view of the tectonic contact between the Northern Ophiolitic Unit and the Cretaceous Arc Units.

2nd DAY (E) FIELD TRIP - SANTA CLARA - MATAGUÀ - MANICARAGUA - ESCAMBRAY - HANABANILLA - LA HAVANA - (FIG. 21)

Stop 1E, 2E, 3E, 4E, 5E, 6E
(Cretaceous Arc Units - AC)

Cretaceous Arc Units - These units are widely represented in Central Cuba, overlying the ophiolitic melange to the north and the Escambray terrains to the south. Within this units three complexes can be distinguished: Volcano-sedimentary Complex, Mabujina Subduction Complex, and Granitoid Intrusive Complex.

Volcano-sedimentary Complex - it represents the central part of the transect, outcropping in at least three belts with different significance: back-arc basin to the north, axial segment of the arc (including plutonic bodies) to the

Table 2

	Northern Ophiolitic Unit			Cretaceous Arc Units			
						Mabujina Unit	
	Stop 7D			*Stop 2E*	*Stop 5E*	*Stop 10E*	
	HAB 5A	HAB 5B	HAB 6	HAB 12	HAB 11	HAB 8	HAB 9
	Lc-Gb	Pd	Ol-Gb	Mc-Gb	Rhy	Bas	Bas
SiO2	41.08	36.64	43.53	54.62	68.45	46.71	48.76
TiO2	0.03	0.02	0.11	1.40	0.26	0.83	0.58
Al2O3	26.45	3.14	18.56	14.56	14.48	15.74	11.46
Fe2O3	0.53	2.42	1.00	1.48	0.29	1.58	1.55
FeO	3.19	14.55	5.99	8.87	1.76	9.48	9.31
MnO	0.10	0.10	0.12	0.21	0.05	0.18	0.19
MgO	8.52	30.78	13.73	4.29	0.83	6.73	8.68
CaO	12.73	0.26	13.08	6.10	3.26	12.58	13.23
Na2O	1.08	0.01	0.58	5.66	2.94	2.16	1.60
K2O	0.53	0.00	0.00	0.43	3.59	0.86	2.47
P2O5	0.00	0.00	0.00	0.33	0.04	0.17	0.29
LOI	5.39	10.51	2.68	1.07	3.83	1.91	0.85
Tot	99.6	98.4	99.4	99.0	99.8	98.9	99.0
V	6	10	57	481	13	341	218
Cr	4	22	149	17	4	155	501
Ni	108	567	237	7	5	41	88
Rb	13	n.d.	2	7	19	27	29
Sr	295	28	121	332	39	420	545
Ba	119	5	15	179	234	409	680
Zr	7	n.d.	n.d.	101	28	29	34
La	n.d.	n.d.	3	16	n.d.	3	3
Ce	10	11	12	47	5	20	12

The following abbreviations refer to protolith nomenclature, irrespective of the metamorphic facies: Lc-Gb = Leuco-gabbro; Pd = peridotite; Ol-Gb = olivine gabbro; Mc-Gb = microgabbro; Rhy = rhyolite; Bas = basalt.
XRF Analyses carried out at Istituto di Mineralogia, Petrografia e Geochimica., Palermo University. n.d. = not detected.

south, and deposits of a hypothetical forearc trench-slope to the south. This complex consists of volcanic sequences in the form of lava flows, pyroclastites and, more generally, volcanoclastic rocks, sometimes overlaid by carbonatic sequences.

The composition of the volcanic and subvolcanic bodies varies, from bottom to top, from tholeiitic (Aptian-Albian) to calc-alkaline (Albian-Turonian) and typical mature arc associations (up to Campanian). Emergence of the volcanic arc and intense erosion are evident from Campanian time. A transgression has favoured the deposition of marine sediments in small satellite basins, starting from Campanian-Maestrichtian.

Stop 1E -*Monterola, between Santa Clara and Mataguà*

Volcano-sedimentary Complex of the **Cretaceous Arc Units.**
Acidic lavas and pyroclastic rocks.

Stop 2E -*Loma La Bruja, between Santa Clara and Mataguà*

Volcano-sedimentary Complex of the **Cretaceous Arc Units.**

Trachytic and andesitic lavas and pyroclastic rocks (Cenomanian-Turonian). Chemical analysis of micro-gabbro (HAB 12 in Table 2) displays a relatively Fe-Ti-V-rich composition, compatible with differentiated members of the arc tholeiitic trend. Petrographically, this rock shows seriate texture with large plagioclase laths, augitic clinopyroxene, and skeletal magnetite. The crystallization order, characterized by clinopyroxene plus magnetite before plagioclase, furtherly supports the arc-tholeiitic affinity of this magmatism. The secondary mineral assemblage consisting of chlorite, epidote and albite, is mainly developed in interstitial positions.

Stop 3E -*Lomas Provincial, between Santa Clara and Mataguà*

Volcano-sedimentary Complex of the **Cretaceous Arc Units.**

Rudistic limestones, marls, siltstones and tuffaceous intercalations (Upper Albian). These rocks are the inferred sedimentary cover of the volcanic islands.

Stop 4E -*Matagua̎*

Volcano-sedimentary Complex of the **Cretaceous Arc Units.**
Basic pyroclastitites, basalts and andesitic basalts (Albian).

Stop 5E -*Los Pasos, between Matagua̎ and Manicaragua.*

Volcano-sedimentary Complex of the **Cretaceous Arc Units.**

Rhyolites and rhyodacites (Albian-Aptian). Chemical analysis of rhyolite (HAB 11) is reported in Table 2. Petrographically, this rock appears porphyritic with altered feldspar, biotite and quartz phenocrysts, set in a quartz-feldspatic, widely recrystallized groundmass; abundant calcite occurs in patches and vesicles.

Granitoid intrusive complex - It intrudes the arc sequences of the Mabujina Unit, with clear original relationships. A variably thick cornubianitic-metasomatic aureola may be observed at the contact. The complex is made up of granitoid bodies with calc-alkaline, and in places alkaline, affinity. The age is Aptian-Campanian.

Stop 6E -*Rio Arimao, between Matagua̎ and Manicaragua.*

Granitoid intrusive Complex of the **Cretaceous Arc Units.**

Granitoid intrusion mainly composed by tonalites (Campanian). It represents the main plutonic phase of the arc activity.

Stops 7E , 8E, 9E, 10E, 11E, 12E

Arc basement of the **Mabujina Unit (MU)** and relationships with the continental **Escambray Terrains (ET).**

Mabujina subduction complex unit (MU) - it outcrops in the southern half of the transect below the volcanic arc sequences and overthrusting onto the Escambray continental terrains. It consists of meta-volcanics and meta-plutonics with arc affinity, irregularly associated to oceanic ophiolitic portions. They are metamorphosed in amphibolite facies. This unit is considered the structural basement of the Cretaceous arc, consisting of a

subduction complex where Mesozoic intra-arc oceanic crust is also involved (Iturralde Vinent, 1994).

Escambray Terrains (ET) - these form the southern continental part of the Cuban orogen, considered equivalent to the more western Guaniguanico and Los Pinos terrains. This formation tectonically underlies the Cretaceous Arc Units, and outcrops in a large dome-shaped structure, in which a complex thrust system can be observed.
These sequences generally consist of Mesozoic, mostly carbonatic, continental margin deposits. Slices of metavolcanites have been observed in some localities. These terrains are not younger than Upper Cretaceous, with paleomagnetic datings from Upper Jurassic. The whole complex underwent several intense ductile deformations and was metamorphosed in high pressure facies, with inverted zoning from the inner part outward. The last metamorphic event is thought to be late Cretaceous and probably refers to underthrusting of the terrains below the volcanic arc during subduction.

Stop 7E -*toward Escambray, southward of Manicaragua.*

Panoramic view of the Mabujina arc basement overthrust onto the continental sequences of the Escambray Units.

Stop 8E -*Escambray, southward of Manicaragua*
(Escambray Terrains)

Jurassic-Cretaceous sequence of marbles and calcareous schists.

Stop 9E -*Carretera Hotel Hanabanilla, westward of Manicaragua*
(Mabujina Unit)

Meta-basalts and meta-andesites in amphibolite facies.

Stop 10E -*Loma Madera, northward of Hanabanilla*
(Mabujina Unit)

Layered meta-gabbros and ophiolitic meta-basalts in amphibolite facies, intruded by Cretaceous felsic dikes. Chemical analyses of amphibolites (HAB 8 and 9) reveal a basaltic nature of the protolith with arc magmatic affinity.

Petrographically, these samples show porphyritic texture for clinopyroxene and minor plagioclase phenocrysts. Amphibolite facies metamorphic assemblage is mainly represented by green hornblende, after clinopyroxene, and epidote.

Stop 11E -*near Hanabanilla*

(Mabujina Unit)

Banded amphibolites similar to those of Stop 10E.

Stop 12E -*Hanabanilla*

(Escambray Terrains)

Jurassic quartz-micaceous schists.

DISCUSSION

The geological and petrographical characteristics of the above described transects in Venezuela and Cuba allow us to establish the following:

- The southern and northern margins of the Caribbean Plate are collisional with opposite vergences, where ophiolitic "suture zones" obducted onto the continental South and North America Plates are involved. These margins have been successively affected, during Tertiary, by dextral (southern) and sinistral (northern) strike-slip - generally transpressive - tectonics, which caused a remarkable shifting of the rock bodies from west to east.
- The ophiolitic units tectonically lie on the partly deformed continental margins within a collisional systems of "foredeep-deformation front couple" type. Pre-Mesozoic-Upper Cretaceous metamorphic continental crust units (CC, ET) are involved in the innermost parts of the deformed belts.
- Ophiolitic units with MORB (FC, NO, LH), or IAT (VC, MU), or else IAT to CA (DH, AC) magmatic affinities are present.

Tholeiitic magmatic associations have been found within thinned continental crust units (TT, BU). FC and NO represent ophiolitic melanges. The inferred age of the main ophiolitic units are Jurassic-Lower Cretaceous for LH, NO, VC, MU p.p. basements; Lower-Middle Cretaceous to Upper Cretaceous for the FC, LH, NO, VC, MU, DH, AC as well as TT and BU volcanic and sedimentary covers.

- The ophiolitic units are often metamorphosed (prehnite-pumpellyite, green-schist, blue-schist, amphibolite facies) and affected by ductile

deformation due to at least two penetrative phases, the first (S^{n-1}) with axial plane foliation folded by a second phase with crenulation cleavage S^n.
- The age of the first deformation and related metamorphism is presumably Middle - Upper Cretaceous, with formation of "subduction complexes".
- the age of the second deformation may be linked to the tectogenetic phases responsible for the collision with the neighbouring continental crusts and, successively, for the obduction onto them (Upper Cretaceous-Paleocene).

On the basis of the available data, it is possible to point out the following sequence of events:
- The existence during Jurassic-Middle Cretaceous of one or more oceanic areas (protoCaribbean) variably located with respect to the continental paleo-margins of the North and South American Plates; these margins are in places thinned and affected by tholeiitic magmatism.
- The existence during Middle-Upper Cretaceous of one or more intra-oceanic subduction zones, giving rise to subduction complexes and melanges (early eoCaribbean). Sometimes the position of the intra-oceanic subduction may have isolated still active "remnant oceanic areas".
- The formation during Middle-Upper Cretaceous of volcanic arc systems developed on the subduction complexes.
- The deformation and collision of volcanic arc systems with the continental margins (eoCaribbean), and the onset of obduction onto the latter from Upper Cretaceous to Paleocene.
Successively, the deformation continues with generation of a "foredeep-deformation front couple", toward the continental areas, and of volcanic arcs as a result of oceanic lithosphere subduction, inward.

However, several problems arise when considering these observations in the framawork of geodynamic evolutionary models.
The paleomagnetic results on Atlantic Ocean (Ladd, 1976) indicate that the drifting of the North and South American Plates generates, during Jurassic-Middle Cretaceous, one or more oceanic areas between the two main continents. These areas (protoCaribbean), affected by rifting processes, may have been connected through the Atlantic to the western Tethys (Auboin et al., 1977; Auboin and Tardy, 1980), but at the same time, westward, they must have been linked with the eastern Pacific Plate crusts (now Nazca and Cocos): this problem remains to be further investigated.

According to Biju-Duval et al. (1978) and Holcombe et al. (1990) the crust of the Colombia and Venezuela Basins could be coeval with the oceanic magmatism occurring in most of the observed units (Cretaceous), partially corresponding to the so-called "Great Caribbean Basaltic event". In this hypothesis, a proto-Caribbean area with wide portions of almost undeformed oceanic crust of the above mentioned basins would be identified.

On the contrary, if the substratum of Colombia and Venezuela Basins were more recent, or with different magmatic affinity, with respect to the above described ophiolitic units, the whole protoCaribbean oceanic lithosphere would be recycled and/or deformed and obducted onto the plate margins. Accordingly, the basins mentioned above would play a role of renmant marginal basins or oceanic segments linked to the Atlantic Ocean, after an initial deformation of oceanic crust, or else linked to the Pacific Ocean and only later included into Caribbean areas. This problem is still under debate.

When the South Atlantic Ocean started opening (from Lower to Upper Cretaceous), the North and South American Plate movements would have changed, with consequent establishment of compressional stress fields in the Caribbean region (eoCaribbean). In most cases, collisions would have occurred in intra-oceanic environments, where the various units were deformed and often metamorphosed in subduction zones, generating accretionary prisms and underplating.

The models concerning subduction and direction of dipping of the lithospheric sinking are conflicting. The most likely interpretation hypothizes early-eoCaribbean subductions dipping toward the continental margins, often separating portions of remnant oceanic areas of various size, in a back-arc position. The distance of the subduction zones from the continental margins cannot have been very large, because continental elements (CC, ET) occur between the deformed units; such continental blocks are, nowadays "incertae sedis", but are problably linked to the North and South American Plates.

Successively, upon these subduction zones, variably distributed island arcs would have developed, being involved in collision zones and suffering deformation and/or metamorphism. During this phase, it is very important to understand the role played by the Colombia and Venezuela Basins.

Afterward (Upper Cretaceous), the northern and southern eoCaribbean Plate margins would have been more clearly defined as deformed and sutured

elements, being obducted onto the old continental crusts of the two Americas. At this stage, the eastern (Lesser Antilles) and western (Central American Isthmus) margins of the Caribbean Plate were defined.

During Upper Cretaceous-Paleocene (Laramide), the obduction of the Caribbean lithosphere s.l. took place onto the North and South American Plates with deformation of these in transpressional stress fields, sinistral and dextral respectively. The kinematics of these events is under debate, but the most widely accepted opinion indicates a gradual prograding toward the continental stable areas of a "foredeep-deformation front couple", transporting piggy-back basins onto the orogen units. It is not clear if these events occurred starting from a unique compressional front, linking the northern with the southern Caribbean margin, which twisted and, ultimately, split in two segments, or if the northern (Guatemala, Greater Antilles) and southern (Venezuela) margins had different kinematic histories from the beginning.

On this matter, most evolutive models suggest that the southern and northern Caribbean Plate margins were formed from an original unique subduction zone with a position subparallel to that of the present Central American Isthmus. This implies that the studied ophiolitic units would have been generated from an oceanic area with relative volcanic arcs of Pacific type which was dismembered and deformed by the insertion of a hypothetical "Pacific promontory", into the Caribbean area. As a consequence, the Colombia and Venezuela Basin crusts would be Pacific. This is obviously in contrast with the more likely "protoCaribbean" hypothesis shown in Fig. 22. At the moment, however, we consider premature to present any conclusive interpretation and prefer to leave the question open owing to scarcity of objective data.

During Cenozoic, the Caribbean margins would be clearly defined with formation of calc-alkaline volcanic arcs to the east and west, and with the definition of discrete shear structures along the northern and southern margins, increasing the scattering of the deformed elements in E-W direction.

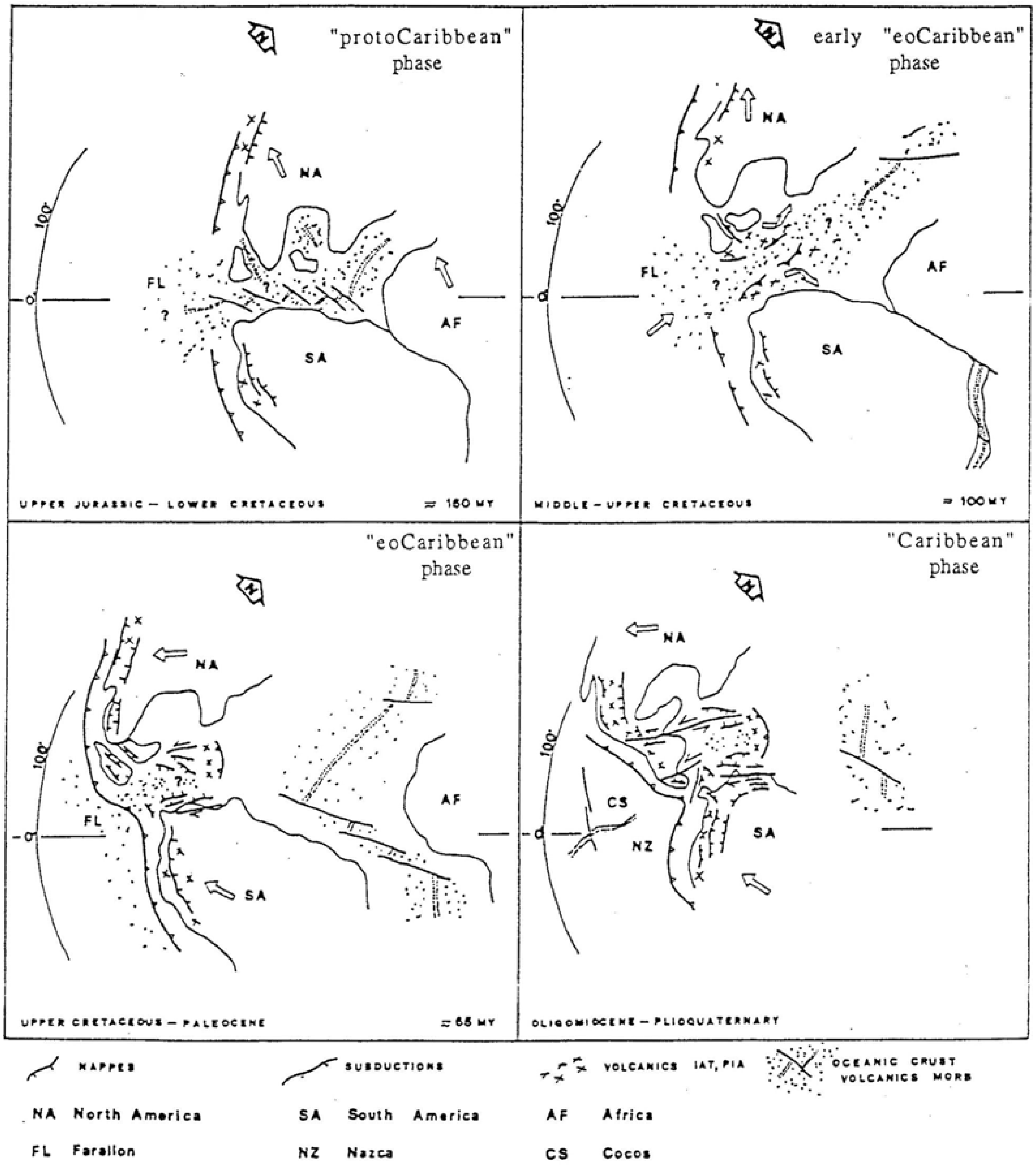


Fig. 22 - Geodynamic evolutionary model of the Caribbean area (from GIUNTA, 1993).

REFERENCES

Anderson T.H. and Schmidt V.A., 1983. The evolution of Middle America and the Gulf of Mexico-Caribbean Sea region during Mesozoic time. Geol.Soc.Am.Bull., 94.

Auboin J. and Tardy M., 1980. L'Amerique alpine: le domaine Caraibe et ses liasions avec les Cordilleres nord et sur-americaines: introduction. XXV[e] Congr.Intern., C 5, Paris.

Aubouin J., Blanchet R., Stephan J.F. and Tardy M., 1977. Tethis (Mésogée) et Atlantique: donnée de la gèologie. C. R. Ac. Sc., 285, (D), Paris.

Beccaluva L., Ohnenstetter D. and Ohnenstetter M., 1979. Geochemical discrimination between ocean-floor and island-arc tholeiites - application to some ophiolites. Can.Jour. Earth Sci. 16/9, 1874-1882.

Beccaluva L., Bellia S., Coltorti M., Dengo G., Giunta G., Mendez J., Romero J., Rotolo S. and Siena F. 1994. The northwestern border of the Carribean Plate in Guatemala: new geological and petrological data on the Motagua ophiolitic belt. Ofioliti in press.

Beck C., 1985. Las napas de Aragua-Cadena Caribe central y la historia mesozoica del margen Sur del Caribe a lo largo del meridiano de Caracas. Géodynamique des Caraibes. Mascle ed. Editions Technip.

Beck C., 1986. Caribbean colliding, Andean drifting and the Mesozoic-Cenozoic Geodynamic evolution of the Caribbean. Soc.Ven.Geol., Mem. VI Congreso Geologico Venezolano, 10, Caracas.

Bellizzia A., 1986. Sistema Montanoso del Caribe, una cordillera aloctona en la parte Norte de America del Sur. Soc.Ven.Geol., Mem. VI Congreso Geologico Venezolano, 10, Caracas.

Bellizzia A. and Dengo G., 1990. The Caribbean mountain system, northern South America; a summary. Geol.Soc.Am., 2, The Caribbean Region.

Biju-Duval B., Mascle A., Montadert I. and Wanneson J., 1978. Seismic investigations in the Colombia, Venezuela and Grenada Basins and on the Barbados Ridge for future IPOD drilling. Geologie en Mijnbouw, 57, 2.

Bourgois J., Azema J., Tournon J., Belon P., Calle B., Parra E., Toussaint J.F., Glacon G., Feinberg H., De Wever P., Origlia I., 1982. Ages et structures des complexes basiques et ultrabasiques de la facade pacifique entre 3°N et 12°N (Colombie, Panama et Costa Rica). Bull.Soc.Geol.France, 7 XXIV, 3.

Carnemolla S., Cusimano G., Di Natale R., Giunta G., 1990. La Cuenca hidrografica del Rio Tuy (Venezuela): Introduction a la geologia del Sistema Montañoso del Caribe. Quad.IILA-ROMA, Serie Scienza 2.

Case J.E. and Holcombe T.L. 1980. Geologic-tectonic map of the Caribbean. Scale 1:250.000. U.S.Geol.Surv., Miscell.Invest.Ser.Map 1/1100.

Case J.E., McDonald W.D. and Fox P.J., 1990. Caribbean crustal provinces; seismic and gravity evidence. Geol.Soc.Am. Vol H. The Caribbean Region.

Dengo G., 1972. Review of Caribbean serpentinites and their tectonic implications. Geological Society of America Memoir, 132.

Dengo G. 1985. Mid America: tectonic setting for the Pacific margin from Southern Mexico to North western Colombia. The Ocean Basin and Margins, 7, Nairn A.E.M., Stehli F.G., Uyeda S. eds, New York.

Dengo G. and Case J.H., Eds. 1990. The Caribbean region. Geological Society of America. Vol H, Decade of North America Geology.

Donnelly T. W., Beets D., Carr M.J. Jackson T., Klaver G., Lewis J., Maury R.C., Schellekens H., Smith A.L., Wadge G. and Westercamp D., 1990a. History and tectonic setting of Caribbean magmatism. Geol. Soc. Am. Vol. H. The Caribbean Region.

Donnelly T.W., Horne G. S., Finch R. C. and Lopez-Ramos E., 1990b. Northern Central America; The Maya and Chortis bloks. Geol. Soc. Am. Vol. H. The Caribbean Region.

Escalante G. 1990. The geology of southern Central America and western Colombia. Geol.Soc.Am. Vol H. The Caribbean Region.

Fonseca E., Castillo F., Uhanov A., Navarrete M. and Correa G. 1990. Geoquimica de la associacìon ofiolitica de Cuba. Trans. 12th Caribbean Geol.Conference, St.Croix, U.S. Virgin Islands.

Girard D., Beck C., Stephan J.F., Blanchet R., Maury R.C., 1982. Pétrologie, géochimie et signification géodynamique de quelques formations volcaniques crétacées péri-caraibes. Bull.Soc.Geol. France 7, XXIV, 3.

Giunta G., 1993. Los margenes mesozoicos de la Placa Caribe: problematicas sobre nucleacion y evolucion. 6° Congreso Colombiano de Geologia, 3.

Giunta G., Navarro E., Beccaluva L., Bellia S., Comin-Chiaramonti P., Dengo S., Montero W., Urbani P. and Carnemolla S. 1992. Geologia de los margenes de la placa Caribe: generalidades en Guatemala, Costarica, Hispaniola y resultados preliminares del analisis de un transecto en el Sistema Montanoso del Caribe en Venezuela. Geological Congress of Central America, Guatemala City.

Graterol V. and Fonseca A. 1978. Gravimetria en Venezuela. Bol. de Geol., M.M.H. v. XIII, n. 24, Caracas.

Hatten C.W., Somin M., Millan G., Renne P., Kistler R.W. and Mattinson J.M. 1988. Tectonostratigraphic units of central Cuba. Baker ed., Trans XI Caribbean Geol. Conference 35, 13.

Holcombe T.L., Ladd J.W., Westbrook G., Edgar N.T. and Bowland C.L., 1990. Caribbean marine geology; ridges and basins of the plate interior. Geol.Soc.Am., Vol H. The Caribbean Region.

Iturralde Vinent M.A., 1989. Las Ofiolitas en la constituciòn geologica de Cuba. Geotectonics 4.

Iturralde Vinent M.A., 1994. Cuban Geology: a new plate-tectonic synthesis. Journ.Petrol.Geol., 17, 1.

Ladd J.W., 1976. Relative motion of South America with respect to North America and Caribbean tectonics. Geol.Soc.Am. Bull., 87, 7.

Lewis J.F. and Draper G., 1990. Geology and tectonic evolution of the northern Caribbean margin. Geol.Soc.Am. Vol H. The Caribbean Region.

Loubet M., Montigny R., Chahati B., Duarte N., Lambret B., Martin C., Thuizat R., 1985. Geochemical and geochronological constraints on the geodynamical development of the Caribbean chain of Venezuela. Géodynamique des Caraibes. Edition Technip.

Mascle A. Ed. 1985. Géodynamique des Caraibes. Editions Technip.

Maury R.C., Westbrook G.K., Baker P.E., Bouysse P. and Westercamp D. 1990. Geology of the Lesser Antilles. Geol.Soc.Am., Vol H. The Caribbean Region.

McDonald W.D., 1990. Survey of Caribbean paleomagnetism. Geol.Soc.Am. Vol H. The Caribbean Region.

Morris A.E.L., Taner I., Meyerhoff H.A. and Meyerhoff A.A. 1990. Tectonic evolution of the Caribbean Region; alternative hypothesis. Geol.Soc.Am. Vol H. The Caribbean Region.

Navarro E., 1983. Petrologia y petrogenesis de las rocas metavolcanicas del Grupo de Villa de Cura. Geos, 28, Caracas.

Navarro E. 1989. Antiguas y nuevas teorias sobre el origen y emplazamiento de la faja de Villa de Cura. Soc.Ven.Geol., Congreso Geologico Venezolano, 1989.

Navarro E., Ostos M. and Yoris F., 1988. Revision y redefinicion de unidades litoestratigraficas y sintesis de un modelo tectonico para la evoluciòn de la

parte norte-central de Venezuela durante el Jurasico medio-Paleogeno. Acta Cientifica Venezolana. Geologia, 39.

Ostos M. 1990. Evolucion tectonica del margen Sur-Central del Caribe, basados en datos geoquimicos. Geos, 30.

Ostos M. and Navarro E., 1986. Faja de Villa de Cura. Realmente un complejo de arco de isla aloctono ? Soc.Ven.Geol.Mem. VI Congreso Geologico Venezolano.

Pardo G., 1975. Geology of Cuba. In "The Ocean basins and margins". Caribbean & Gulf of Mexico, Plenum Press, New York.

Pearce J. A. 1982. Trace element characteristics of lavas from destructive plate boundaries. "Andesites" Ed. R.S.Thorpe, 525-548.

Pindell J.L. and Barrett S.F., 1990. Geological evolution of the Caribbean region: a plate-tectonic perspective. Geol.Soc.Am. Vol. H. The Caribbean Region.

Ross M.L. and Scotese C.R., 1988. A hierarchical tectonic model of the Gulf of Mexico and Caribbean region. Tectonophysics, 155.

Stephan J.F., Blanchet R. Mercier De Lepinay B., 1986. Northern and Southern Caribbean Festoons (Panama, Colombia, Venezuela, Hispaniola, Puerto Rico) interpreted as subductions induced by the East West shortening of the Pericaribbean continental frame. "The Origen of Arcs" Ed. Wezel F.C., Development in Geotectonics, 21, Elsevier.

Stephan J.F., Mercier De Lepinay B., Calais E., Tardy M., Beck C., Carfantan J.C., Olivet J.L., Vila J.M., Bouysse P., Mauffret A., Bourgois J., Thery J.M., Tournon J., Blanchet R. and Dercourt J., 1990. Paleogeodynamic maps of the Caribbean: 14 steps from Lias to present. Bull.Soc.Géol. France, 8, VI, 6.

Urbani F. and Ostos M., 1987. El Grupo Avila, Cordillera de la Costa. Mem.Jornadas 50^ Ann.Erc.Geologia, UCV, Caracas.