CORDILLERA DE LA COSTA, VENEZUELA: GEOLOGICAL FIELD TRIP

By Franco URBANI, Luis CAMPOSANO, Franck AUDEMARD & Hans AVÉ LALLEMANT (Guides)

Abstract

For the October 2005 Annual Meeting of the "Southeast Caribbean Continental Dynamics Project (BOLÍVAR: Broadband Ocean-Land Investigation of Venezuela and the Antilles arc Region)" and "GEODINOS (Geodinámica del Norte de Sur América)" project, a two day field trip was prepared grossly to cross the Cordillera de la Costa of Northern Venezuela at 67°W longitude. The route will traverse the following major nappe units: Ávila (Paleozoic-Proterozoic continental crust units. Epidote amphibolite → green schist facies), Caracas (Late Jurassic-Early Cretaceous metasedimentary units of passive continental margin. Green schist facies), Loma de Hierro (Cretaceous ophiolitic complex. Green schist facies – Sub-green schist facies), Villa de Cura (matatuffs and metalava of island arc affinity. High P - low T metamorphism), San Sebastián (island arc volcanics). One place in Villa de Cura units will be used to explain the multiple phases of deformation (ductile and brittle), metamorphic facies and P-T-t paths. Some stops in the Villa de Cura area will be used to explain neotectonic features related to the Río Guárico fault.

Resumen

Para la reunión anual de octubre 2005 del proyecto "Southeast Caribbean Continental Dynamics Project (BOLÍVAR: Broadband Ocean-Land Investigation of Venezuela and the Antilles arc Region)" y "GEODINOS (Geodinámica del Norte de Sur América)", se preparó una excursión de dos días en el campo para cruzar la Cordillera de la Costa del norte de Venezuela, aproximadamente en el meridiano de longitud 67°O. La ruta atraviesa las siguientes napas principales: Ávila (unidades de corteza continental de edad Paleozoico-Proterozoico. Facies de la anfibolita epidótica → esquisto verde), Caracas (unidades metasedimentarias del Jurásico Tardío – Cretácico Temprano de margen continental pasivo. Facies del esquisto verde), Loma de Hierro (complejo ofiolítico del Cretácico. Facies del esquisto verde o facies sub-esquisto verde), Villa de Cura (principalmente matatoba y lava de afinidad de arco de isla. Metamorfismo de alta P - baja T), San Sebastián (volcánicas de arco de isla). Un lugar en la faja de Villa de Cura será utilizado para explicar las múltiples fases de deformación tanto dúctil como frágil, así como las facies metamórficas y las trayectorias P-T-t. Algunas paradas del área de Villa de Cura serán utilizadas para explicar características geotectónicas relacionadas con la falla del Río Guárico.

This field trip was prepared to partially follow the on-land portion of "Profile 67W" (Fig. 1).

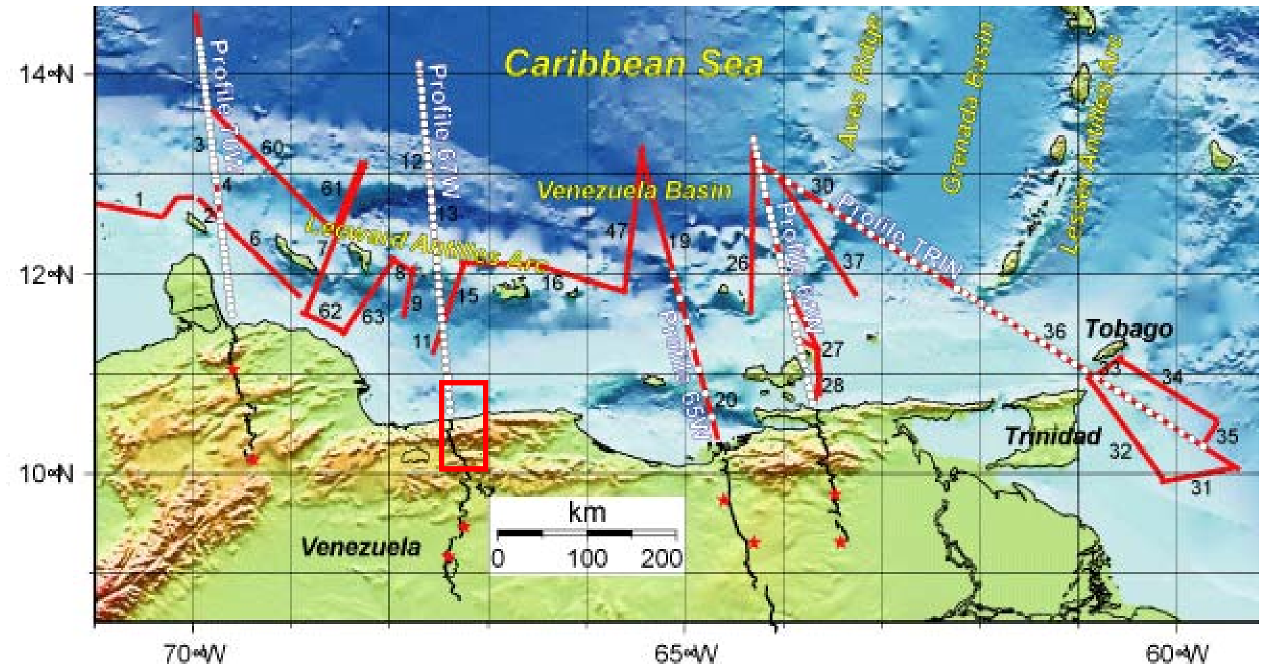


Fig. 1. BOLIVAR and GEODINOS transects. The red rectangle shows the area to be visited.

Due to the heavy rains of 2005 there is still an uncertainly if it will be possible to make the whole planned route of Caracas – Tiara – El Pao de Zárate – San Sebastián – San Juan de los Morros – Villa de Cura – La Victoria – Colonia Tovar. This will only be clarified a couple of days before by calling the Agency that is clearing some of the landslides that are currently blocking the El Pao de Zárate – San Sebastián dirt road. Therefore to cover the possibilities we have written this guide in different legs to be ready to different possibilities.

Contents

INTRODUCTION

By Franco URBANI

Since the times of KARSTEN (1850, see cover) geologists have pointed out to the E-W trending configuration of the geological units of the Cordillera de la Costa.

By the mid 1930´s Dr. Harry H. Hess and coworkers discovered an extensive negative gravity anomaly in the Caribbean that he tried to explain through different models (Fig. 2), which somehow were very relevant to the future development of the plate tectonics ideas.

After the Second World War in order to understand the geophysical uncertainties H. Hess started the ambitious field geology "Caribbean Research Project" (1947-1976) in which several tens of PhD students of the University of Princeton and other universities, mapped several tens of thousands of square kilometers of continental and island lands. Such works at least for some areas of the Venezuelan Cordillera de la Costa are still an unsurpassed source of hard information.

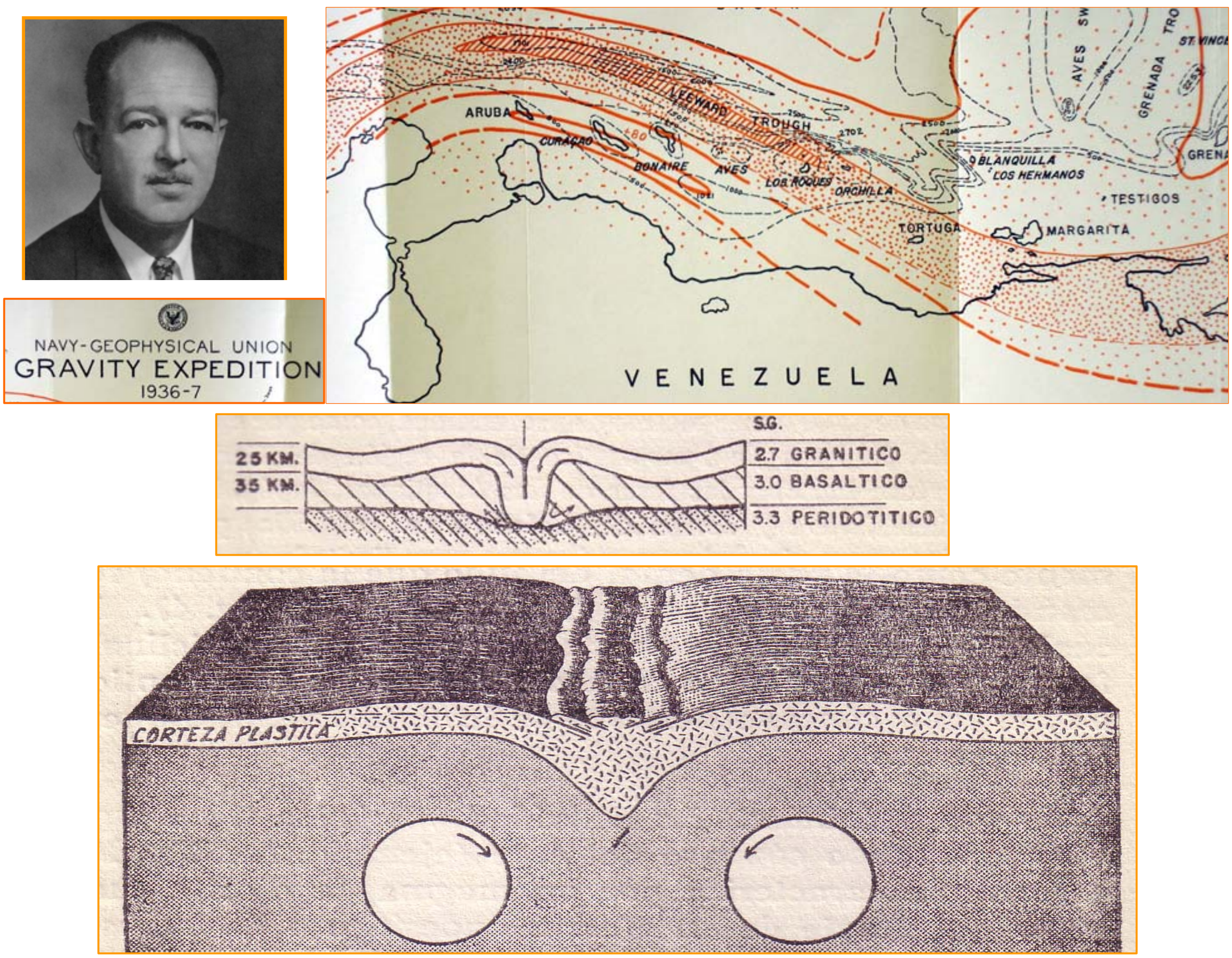
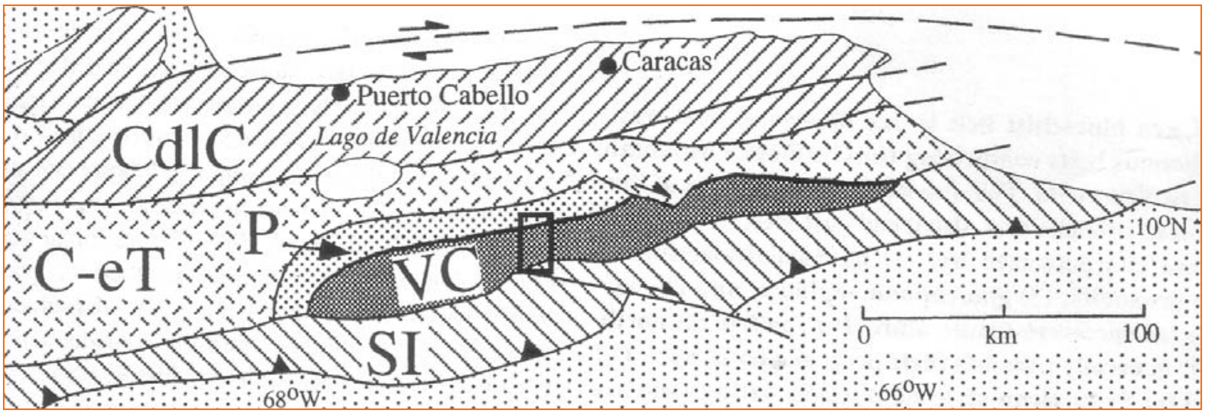


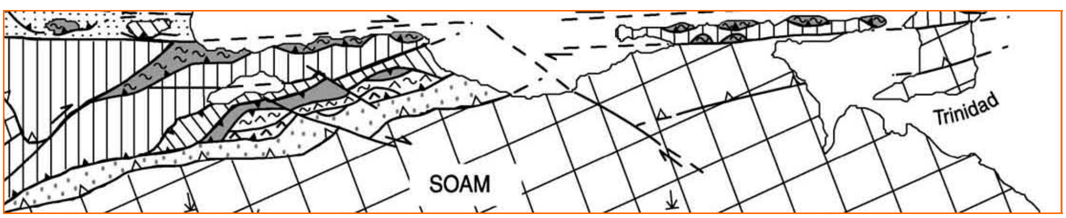
Fig. 2. *Harry Hammond HESS (1906-1969) and a view of his gravimetric maps and models.*

One of the disciples of H. Hess, Alfredo MENÉNDEZ (1966) formally divided the Cordillera in "belts", a concept much improved and reinterpreted by BELL (1968), STHEPHAN (1982) and many others (Fig. 2, 3). The usefulness of these synthesis is that it allows to see the different environments of formation of each rock assemblage for proper fitting into global models of the interaction of Caribbean – South America plates.



CdlC - Cordillera de la Costa, C-eT - Caucagua El Tinaco belt, P - Paracotos belt, VC - Villa de Cura belt, SI - Serranía del Interior foreland and thrust belt.

Fig. 3. Simplified maps of the Cordillera de la Costa belts:
Above = From SMITH et al. (1999). Below = From GIUNTA et al. (2000).



After the December 1999 catastrophic floods in Vargas, an inter-institutional effort was carried out to integrate and update the geological map of the Cordillera de la Costa totaling 146 sheets at scale 1:25.000 with a total area of about 14,500 km^2 (URBANI & RODRÍGUEZ 2004). Also as part of such project the descriptions of 145 igneous and metamorphic units have been up-dated (URBANI 2000) for the "Venezuelan Stratigraphic Lexicon" following the rules for lithodemic units of NACSN (1983), so all igneous and metamorphic units previous named Group, Formation or Member were changed accordingly. The first consequence of this compiled map is the clear distinction of the previous undivided "Cordillera de la Costa Belt" (Serranía del Litoral, geographically speaking), into three different sub-belts: Coastal, Ávila and Caracas.

From a geographic point of view the Cordillera de la Costa in central Venezuela is divided into two parts, the "Serranía del Litoral" in its northern half, and the southern "Serranía del Interior" (Fig. 5), separated by a series of intermontane valleys mainly controlled by the La Victoria fault system.

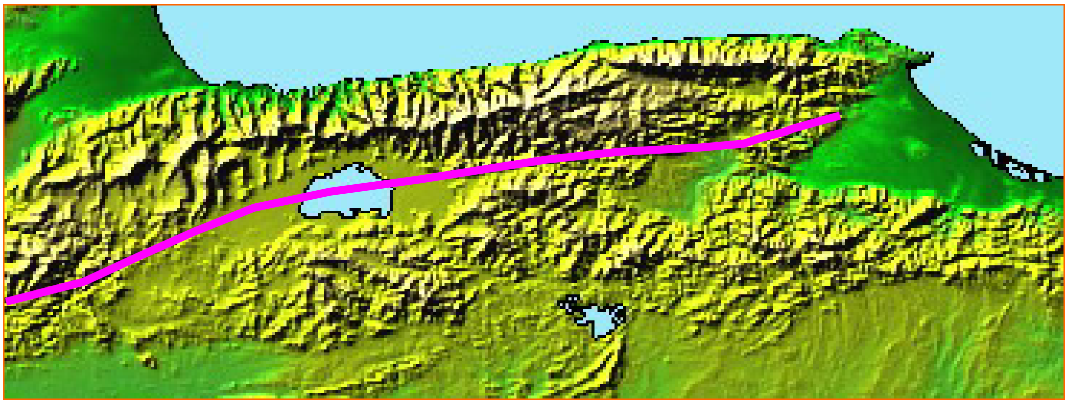


Fig. 5. DEM Image of the Cordillera de la Costa (SRTM-NASA-USGS).
The line separates the Serranía del Litoral (north) and Serranía del Interior (south)

To spatially visualize and interpret the distribution of rock units (belts) we have rather used the structural conceptualization of nappes/terranes formally introduced by BECK (1986), but adapted to the new geological map of the Cordillera de la Costa (Fig. 6), as follows:

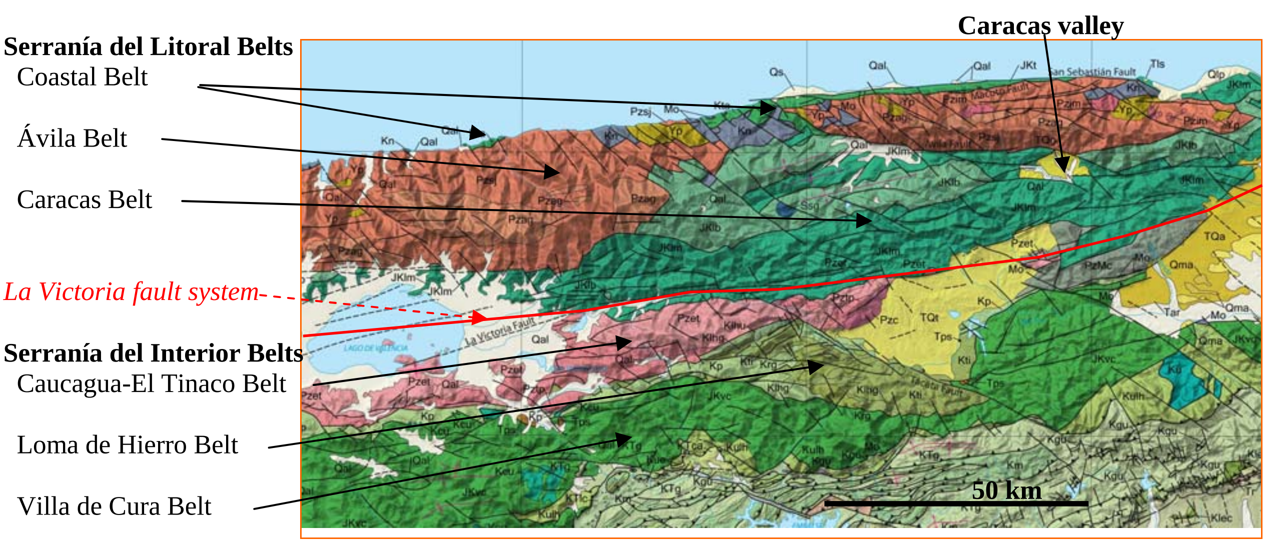


Fig. 6. Geological map of northern Venezuela. From HACKLEY et al. *(2005).*

A synthesis of the lithology, age and some interpretations of the rock units belonging to each nappe is presented in Table 1.

Table 1. Geological synthesis of the igneous and metamorphic rock units in the "Profile 67W" (Summarized from URBANI & RODRÍGUEZ 2004).

1st. division	2nd. division	Rock units + observations
Serranía del Litoral belts	**Coastal** terranes	**Coastal** terranes: **Tacagua** Schist: graphite schist and metatuff. Metamorphosed to green schist facies and differently from the two other units it never has undergone high P / low T metamorphism. Fore-arc setting. **Nirgua** Complex: Subduction melange with gabbro and basalt of MORB affinity **Antímano** Marble: marble with eclogite and amphibolite boudins. **Serpentinite** (unnamed): Phacoidal serpentinized peridotite bodies along major faults. The mafic elements of Nirgua and Antímano show high P / low T metamorphism retrograded to green schist facies (chlorite). The whole suite belongs to a subduction complex melange. Elements of oceanic lithosphere mixed with contemporaneous marine sediments and tectonically incorporating continental crust elements. Age: probably Early Cretaceous but Nirgua incorporates older elements.
	Ávila belt	**Ávila** belt: **Colonia Tovar** Gneiss: metagranite, strongly deformed. Pre-Mesozoic. **San Julián** Complex: metasediments, metaplutonic rocks: granite, tonalite, trodhjemite, diorite; metamafic rocks: amphibolite. Pre-Mesozoic. **Peña de Mora** Augengneiss. Metamorphosed and strongly deformed porphiritic granite (rapakivi?). Precambrian. Continental crust units: igneous (plutonic mainly granitic-tonalitic and hipoabissal diabase?) and sedimentary (pelitic and psamitic) protolith.
	Caracas belt	**Caracas** belt. **Chuspita** Schist. Graphite schist/phyllite and metasandstone of probable turbiditic origin. Early Cretaceous. **Las Mercedes** Schist: Graphite schist and marble. Black shale formed in an anoxic and/or high-productivity sedimentary basin. Late Jurassic to Early Cretaceous. (Leg 1, View Point 2.) **Las Brisas** Schist. Quartz muscovite schist, metasandstone, metaconglomerate and hectometric sized marble bodies. Late Jurassic (Kimmeridgian) to Early Cretaceous. (Leg 1, View Point 1.) Low grade metamorphosed sediments of a passive continental margin. **Sebastopol** Gneiss. Granitic. Silurian. Basement of Las Brisas Schist.
Serranía del Interior terranes	**Loma de Hierro** terranes	**Paracotos** Phyllite. Late Cretaceous. Unit included in this nappe by BECK (1886) as a sedimentary cover of the ophiolite units (Leg 2, Stop 1.) **Loma de Hierro** Ophiolitic Complex. **Tiara** Metavolcanics. **Mesia** Gabbro. **Loma de Níquel** Ultramafics (Leg. 1, Stops 3 to 5.) Interpreted as a sliver of oceanic lithosphere and its sedimentary cover. Late Jurassic? - Cretaceous age. The basalt and gabbro show MORB affinity.
	Caucagua-El Tinaco terranes	**La Guacamaya** Metadiorite. **Curiepe** Tonalitic Gneiss. **El Tinaco** Complex. **Tinapu** Schist. Quartz mica feldspar metasedimentary rocks (Leg. 1, Stop 1 and 3.) **La Aguadita** Gneiss: tonalitic-dioritic rocks (Leg 1, Stop 2.) This belt contains crystalline basement (Proterozoic -La Aguadita- to Paleozoic units), mixed with units of plutonic, volcanic and sedimentary origin of probably Late Jurassic to Early Cretaceous age. All units belong to continental crust affinity. Some metabasalt samples show within plate tholeite affinity.

1st. division	2nd. division	3rd. division	Rock units + observations
Serranía del Interior terranes	**Villa de Cura** terranes	Northern terrane: rocks with high P and low T metamorphism	**Villa de Cura** Metavolcanosedimentary Suite **El Caño** and **El Chino** metatuffs , undivided (Divided by SHAGAM 1960 but undivided by further workers). Mainly matatuff (Leg 2, Stop 2) **El Carmen** Metalava. Same metatuff as previous units but with distinctive piroxene metabasalt interlayered. **Santa Isabel** Granofel. Mixture of granofel, varied schists, metasediments, chert (Leg 2, Stop 3 and 4) El Caño, El Chino and El Carmen units form an assemblage distinctive than Santa Isabel. Due to the pyroclastics predominance those units probably were formeed in a fore- or back-arc setting, latter incorporated in an island arc subduction complex.
		Southern terrane: rocks with very low metamorphism (or no metamorphic)	**San Sebastián** Igneous Suite. **Las Hermanas** Volcanics (Late Cretaceous) (Leg 2, Stops 5 and 6) **Chacao** Ultramafics. Usually with metamorphism no higher that prehnite-pumpellyite, no penetrative structures. The basalt show island arc affinity and ages from middle to Late Cretaceous. Mainly lava. These units are part of an unsubducted island arc.

LEG 1

GEOLOGY OF CARACAS – BOCA DE CAGUA – TIARA

By Franco URBANI & Luis CAMPOSANO

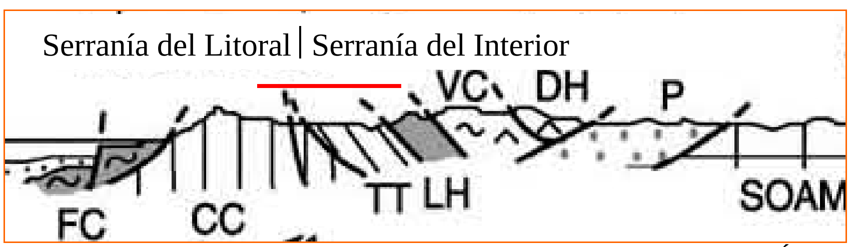


Fig. 7. Rough geological cross-section at 67W. Red line: section covered by this leg. CC: Ávila and Caracas nappe. TT: Caucagua – El Tinaco nappe. LH: Loma de Hierro nappe. From GIUNTA et al. *(2000).*

8:00 Depart from Hotel Las Americas, Caracas.

Due to the limited time of the field trip, while driving we ask you to see the road cuts but without stopping.

VIEW POINT 1: La Brisas Schist. Caracas Metasedimentary Suite

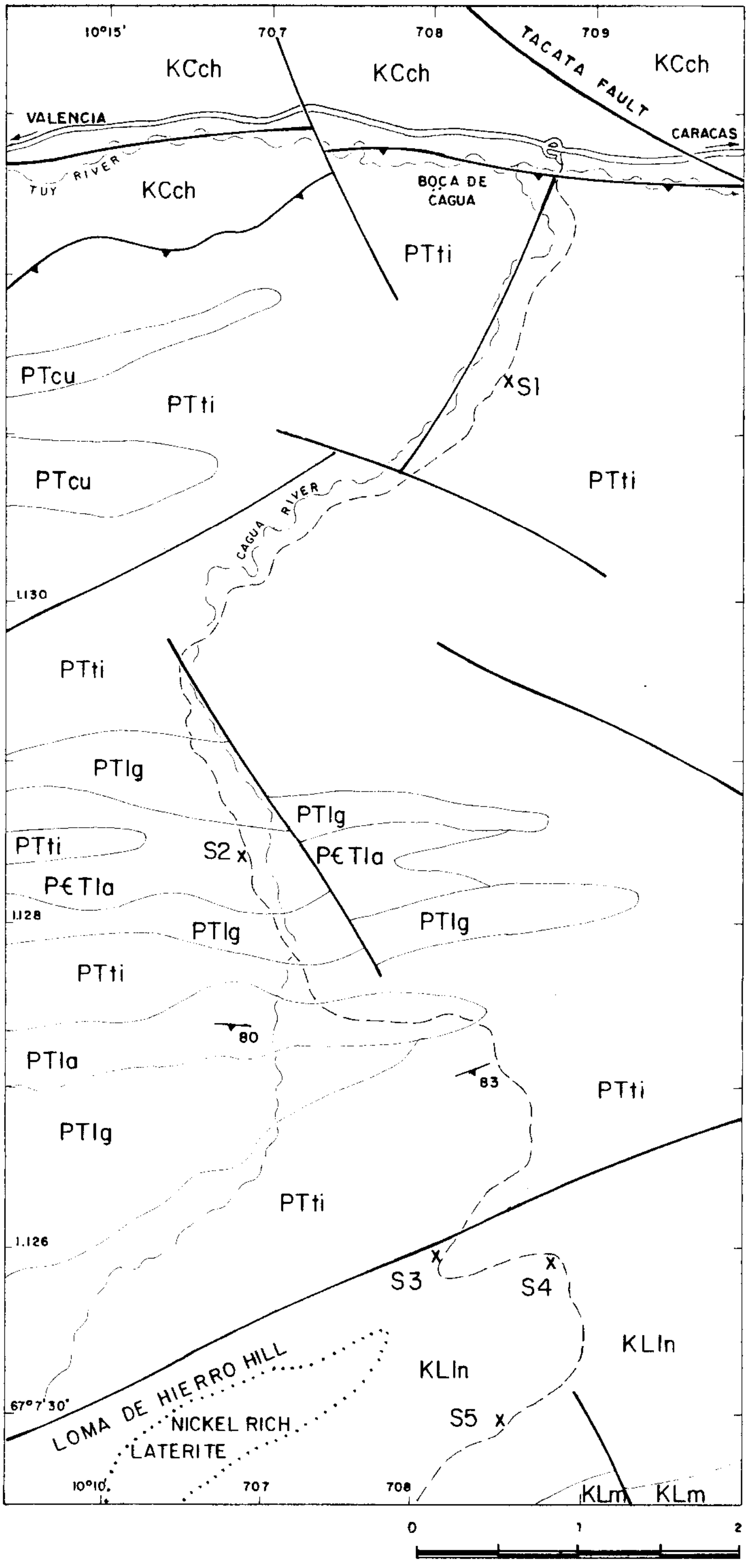
Locality: "Bajada de Tazón". Highway right talus.

This site is very near the "type locality" of Las Brisas Schist, mainly quartz mica schist, metasandstone and metaconglomerate. One marble body has Late Jurassic (Kimmeridgian) mollusks (*Nanogyra virgula*).

VIEW POINT 2: Las Mercedes Schist. Caracas Belt

Locality: From "Hoyo de La Puerta" toll station to Los Anaucos.

This unit shows very conspicuous dark gray to black graphite schist (quartz muscovite chlorite calcite).From "Los Anaucos" to the place we abandon the Highway we follow a valley controlled by the La Victoria Fault System, the one that physically divides the serranías del Litoral and Interior.



Geological units from North to South

SERRANÍA DEL LITORAL

Caracas Nappe
KCch **Chuspita** Schist (Caracas Belt), Cretaceous

SERRANÍA DEL INTERIOR

Caucagua-El Tinaco terranes
PTcu **Curiepe** Tonalitic Gneiss (Paleozoic-Mesozoic?)
PTlg **La Guacamaya** Metadiorite (Paleozoic-Mesozoic?)
Complejo **El Tinaco**
PTti **Tinapú** Schist (Paleozoic?)
pCTla **La Aguadita** Gneis (Precambrian - Proterozoic)

Loma de Hierro terranes
Loma de Hierro Ophiolitic Complex (Cretaceous)
KLm **Mesia** Metagabbro (metagabbro)
KLln **Loma de Niquel** Peridotite (Harzburgite, serpentinite)

Fig. 8. Geological map of Boca de Cagua – Tiara section. Simplified from sheet 67 and 70 of URBANI & RODRÍGUEZ (2004), with original data from SMITH (1953) and BECK (1985).

STOP 1: TINAPÚ SCHIST

Setting-Units:
Serranía del Interior
Caucagua – El Tinaco terranes
El Tinaco Complex
Tinapú Schist

Location: Road between Boca de Cagua and Loma de Niquel Mine. UTM, PSA56 datum, zone 19, E 708.180 N 1.131.370.

Lithology: Mainly quartz-albite-muscovite schist mixed with albite-quartz-chlorite schist. Also decimetric layers of metaconglomerate. Probably metamorphosed at the Epidote-Amphibolite facies later overprinted by green schist facies.

Age: Unknown. Considered Paleozoic due to its association with El Tinaco Complex.

Interpretation: Metasediments probably of a passive continental margin. It is one of the less studied units in the Serranía del Interior. There are also some green schist levels whose protolith may include volcanic elements (pyroclastics)

Fig. 9. Tinapú Schist outcrop.

STOP 2: GNEIS DE LA AGUADITA

Setting-Units:
Serranía del Interior
Caucagua – El Tinaco terranes
El Tinaco Complex
La Aguadita Gneiss

Location: Road between Boca de Cagua and Loma de Niquel Mine.
UTM, E 706.860 N 1.128.410.

Lithology: The unit in general shows banded gneisses with felsic bands of quartz-plagioclase gneiss and mafic bands (hornblende-plagioclase-quartz gneiss, biotite-plagioclase-quartz gneiss). Metamorphosed at the epidote-amphibolite facies later overprinted by green schist facies.
The current outcrop is a fine grained hornblende-oligoclase-biotite-quartz rock (probably a quartz diorite).

Age: Proterozoic (Rb/Sr isochron by OSTOS 1990).

Interpretation: The whole unit mainly metaigneous rocks (with protolith as quartz diorite, tonalite, trondhjemite) of Continental Crust affinity.

Fig. 10. La Aguadita Gneiss

STOP 3: FAULT CONTACT BETWEEN TINAPÚ SCHIST AND LOMA DE HIERRO OPHIOLITIC COMPLEX

Setting-Units:
- Serranía del Interior
  - Loma de Hierro terranes
    - Loma de Hierro Ohiolitic Complex
      - Loma de Níquel Peridotite

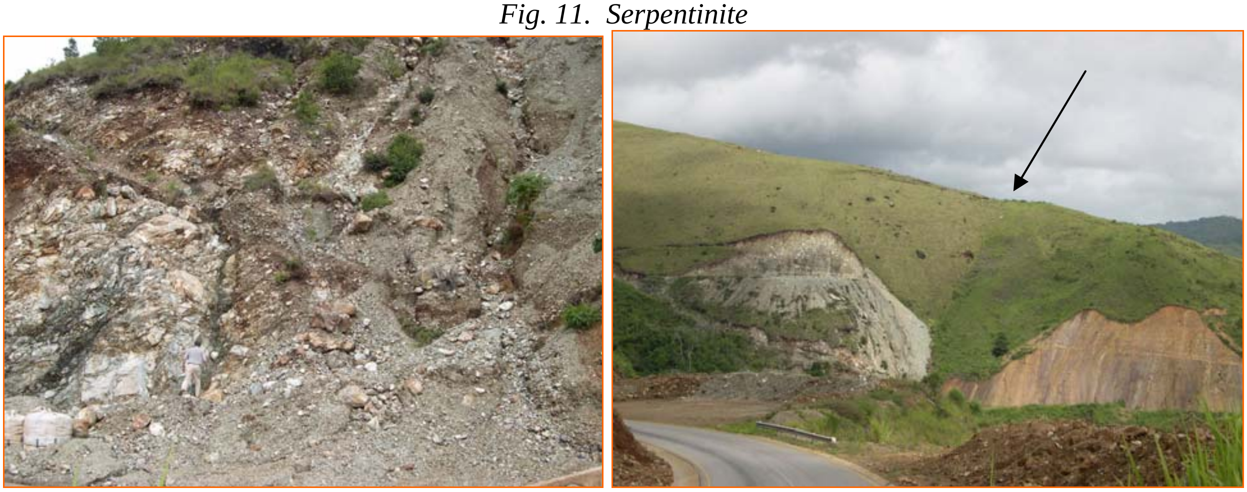
Location: Road between Boca de Cagua and Loma de Niquel Mine.
UTM, 19, E 708.100 N 1.125.990.

Lithology and fault: Outcrop of serpentinite at the contact with the previous Tinapú Schist. Serpentinite composed mainly of antigorite at the microscope there are relicts of pyroxene. The fault plane is vertical. Notice the abundance of slickensides and polished fault surfaces.

Age: Probably Early Cretaceous.

Interpretation: The peridotite is a mantle sliver of an oceanic lithosphere later serpentinized.

Fig. 11. Serpentinite



Left: Serpentinite ourcrop. Right: Notice the color difference in vegetation between both units: Serpentinite at left and Tinapú Schist at right.

STOP 4: LOMA DE NÍQUEL PERIDOTITE

Setting-Units:

Serranía del Interior
Loma de Hierro terranes
Loma de Hierro Ohiolitic Complex
Loma de Níquel Peridotite

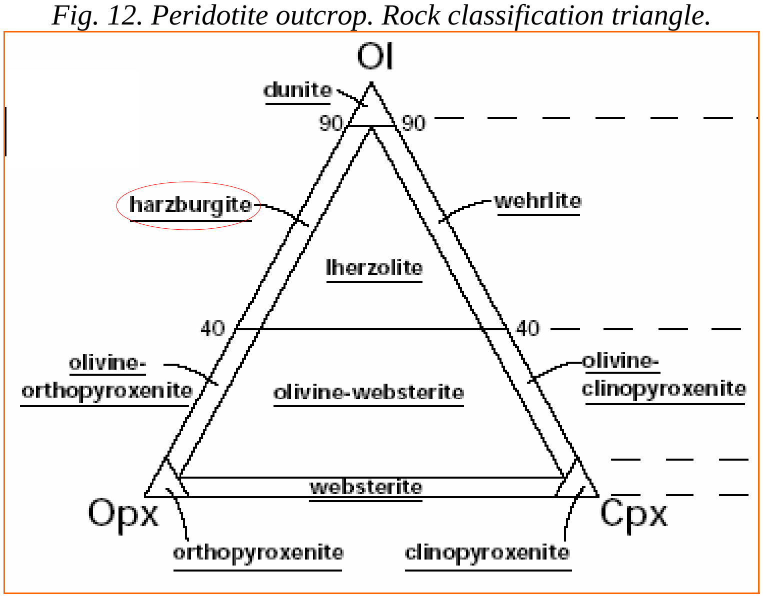
Location: Road between Boca de Cagua and Loma de Niquel Mine.
UTM, E 708.646 N 1.125.976.

Lithology: The main rock type of the unit is the peridotite (harzburgite) partially serpentinized. There are vein of crysotile (asbestos). It is coarse grained with olivine and enstatite (orthopyroxene) with black to very deep green color varying according to the degree of serpentinization.

Age: Probably Early Cretaceous.

Interpretation: The peridotite is part of the mantle of an oceanic lithosphere later serpentinized.

Fig. 12. Peridotite outcrop. Rock classification triangle.



STOP 5: LOMA DE NÍQUEL PERIDOTITE

Setting-Units:
Serranía del Interior
Loma de Hierro terranes
Loma de Hierro Ohiolitic Complex
Loma de Níquel Peridotite

Location: Road between Boca de Cagua and Loma de Niquel Mine.
UTM, E 707.433 N 1.124.350.

Lithology: Outcrop of peridotite (harzburgite) crosscutted by several dikes of gabbro. Some gabbro bodies have very large grain size with a pegmatitic texture. Many faults cross the outcrop.

Age: Probably Early Cretaceous.

Interpretation: The peridotite is part of the mantle of an oceanic lithosphere later partially serpentinized. It is crossed by later gabbro dikes that by its geochemistry show a MORB affinity environment.

Part of a section of an oceanic lithosphere is exposed in the area: peridotite (Loma de Níquel Peridotite, this one and the two previous stops), gabbro (Mesia Gabbro) and basalt (Tiara Volcanics.)

Fig. 13. Peridotite outcrop with gabbro dikes.

Left: Pegmatitic gabbro. Right: Slickensides and polished fault surfaces are seen in the serpentinized peridotite produced by friction on fault planes and joint faces.

LEG 2 a
GEOLOGY OF EL PAO DE ZÁRATE – SAN SEBASTIÁN – SAN JUAN DE LOS MORROS

By Franco URBANI & Luis CAMPOSANO

Fig. 14. Rough geological cross-section at 67W. Red line: section covered by this leg. VC: Villa de Cura Metavolcanosedimentary Suite. DH: Las Hermanas Volcanics. P: Cretaceous-Tertiary sedimentary units. From GIUNTA et al. *(2000).*

STOP 1: PARACOTOS PHYLITE

Setting-Units:

Serranía del Interior
  Loma de Hierro terranes
    Paracotos Phyllite

Location (S1 of fig. 15): Dirt road between El Pao de Zárate and San Sebastián, Aragua state.

Lithology: LUGO (1982) described this unit with phyllite (60%), marble, metasiltstone and metaconglomerate (with basalts Tiara-type and metasedimentary boulders). The outcrop visited shows the graphite-muscovite-calcite phyllite with some centimeter wide marble layers

Age: Some marble samples show a rich microfauna that point to a Maastrichtian age.

Interpretation: BECK (1986) considers this unit as the sedimentary cover of the Loma de Hierro Ophiolitic Complex, perhaps formed under turbiditic environments during the nappes advance.

STOP 2: EL CAÑO AND EL CHINO METATUFFS (UNDIVIDED)

Setting-Units:

Serranía del Interior
  Villa de Cura terranes
    Northern terrane with rocks of high P / low T metamorphism
      Villa de Cura Metavolcanosedimentary Suite
        El Caño and El Chino metatuffs (undivided)

Location (S2 of fig. 15): Dirt road between El Pao de Zárate and San Sebastián, Aragua state. At the crossing of Río Pao from right to left margin. UTM, E 695.205, N 1.112.090

Geological units from North to South

Qal **Alluvium** (Quaternary)

SERRANÍA DEL INTERIOR

Caucagua-El Tinaco terranes (Paleozoic units)
Pt **Tucutunemo** Phyllite
Ptln **Los Naranjos** Metavolcanics

Loma de Hierro terranes (Cretaceous units)
Mp **Paracotos** Phyllite
Mt **Tiara** Metavolcanic
Loma de Hierro Ophiolitic Complex
Mlh **Loma de Niquel** Peridotite (Harzburgite, minor serpentinite)
Msp **Loma de Niquel** Peridotite **(**Serpentinit**e)**

Villa de Cura terranes
Villa de Cura Meta-volcanosedimentary Suite (Cretaceous)
Mcc **El Caño** and **El Chino** Metatuffs, Undivided
Mca **El Carmen** Metalava
Msi **Santa Isabel** Granofel

Doted lines are approximate boundaries between metamorphic mineral assemblages (from NAVARRO 1983)
Z1 Lawsonite-albite
Z2 Lawsonite-glaucophane
Z3 Glaucophane-Epidote
Z4 Barroisite

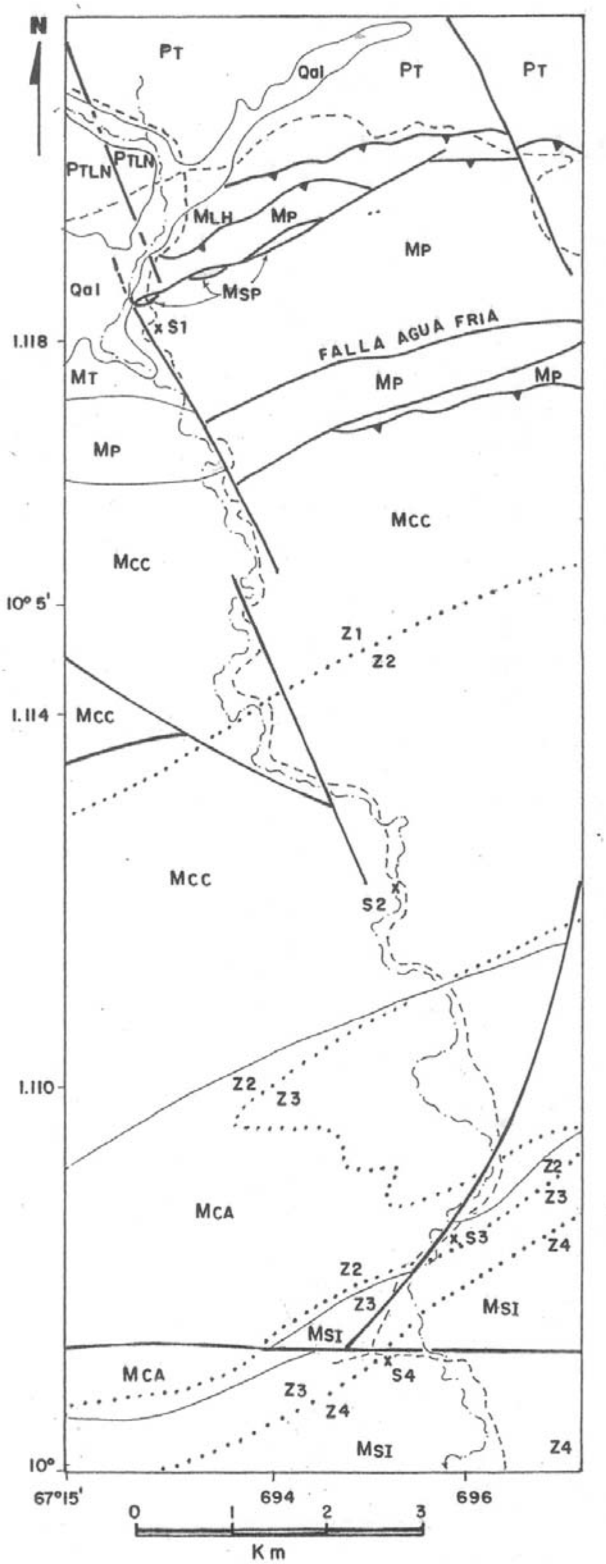


Fig. 15. Geological map of the Río El Pao section, between El Pao de Zarate and San Sebastián.

Lithology: LUGO (1982) and NAVARRO *et al*. (1988) described this unit as mainly ash metatuff from laminated to massive, also with quartz-sericite-chlorite granofel, lawsonite-sericite-quartz schist, quartz-graphite phyllite all usually well foliated. Less that 5% of metachert, metasandstone and pyroxene metalava.
In this particular outcrop mainly laminated metatuff strongly ductile folded.
According to NAVARRO (1983) this site in included in his lawsonite-glaucophane metamorphic zone (high P – low T.)

Interpretation: Laminated tuff due to subaqueous sedimentation with a large proportion of reworked island arc material, interlayered with fine grained marine sediments.
Those island arc related materials later were involved in a subduction process and metamorphosed in a high P – low T environment.

Fig. 16. Strong ductile deformation in El Caño-El Chino unit.

STOP 3 AND 4: SANTA ISABEL GRANOFEL.

Setting-Units:

Serranía del Interior
- Villa de Cura terranes
  - Northern nappe with rocks of high P / low T metamorphism
    - Villa de Cura Metavolcanosedimentary Suite
      - Santa Isabel Granofel

Lithology: LUGO (1982) and NAVARRO (1983) describe this unit as mainly composed of granofel with quartz-feldspars-epidote, occasionally with stilpnomelane, chlorite, clinozoisite, glaucophane, crossite and barroisite, monotonously intermixed with chlorite schist, feldspar-epidote schist, and narrow intervals of metachert and pyroxene metalava.

STOP 3: Location (S3 of fig. 15): Dirt road between El Pao de Zárate and San Sebastián, Aragua state. UTM, E 695.825, N 1.108.412
In this particular outcrop mainly chlorite schist probably of pyroclastic protolith.
Acording to NAVARRO (1983) these rocks fall in the glaucophane-epidote zone.

Fig. 17. Stop 3. Santa Isabel. Notice the shiny foliation surfaces of the chlorite schist showing two fold phases. Below-right: undulated "roof-top" second generation folds.

STOP 4: Location (S4 of fig. 15): Dirt road between El Pao de Zárate and San Sebastián, Aragua state. UTM, E 695.174, N 1.107.120

Lithology: Quartz-albite-epidote-chlorite granofel. Interlayered with quartz feldspar rich horizons. Acording to NAVARRO (1983) these rocks fall in the barroisita zone.

Fig. 18. Stop 4. Santa Isabel unit.

Age: SMITH *et al.* (1999) for Santa Isabel obtains an Ar-Ar age of 96.3±0.4 Ma which represents the peak of metamorphism. In El Caño, El Chino y El Carmen obtain a peak metamorphism age of 79.8±0.4 Ma. The Villa de Cura belt was probably exhumed in two stages, first by Late Cretaceous arc-parallel extension, and second by Miocene south-ward thrusting onto the South American continent

Interpretation: OSTOS & NAVARRO (1986) consider that the Villa de Cura units belong to a subduction complex (arc-trench). To STILES *et al.* (1999) they were formed in a mid-Cretaceous island arc imbricated, subducted and exhumed. GIUNTA *et al.* (2002) retakes the same ideas of a Cretaceous subduction complex in with the basaltic lavas have an island arc tholeitic affinity.

STOP 5. LAS HERMANAS VOLCANICS

Setting-Units:

- Serranía del Interior
  - Villa de Cura terranes
    - Southern nappe: rocks with very low metamorphism (or no metamorphic)
      - San Sebastián Igneous Suite
        - Las Hermanas Volcanics

Location: Quebrada Las Hermanas at its crossing with a road that come from San Sebastián. Type locality of the unit. UTM: E 704.890 N 1.102.655

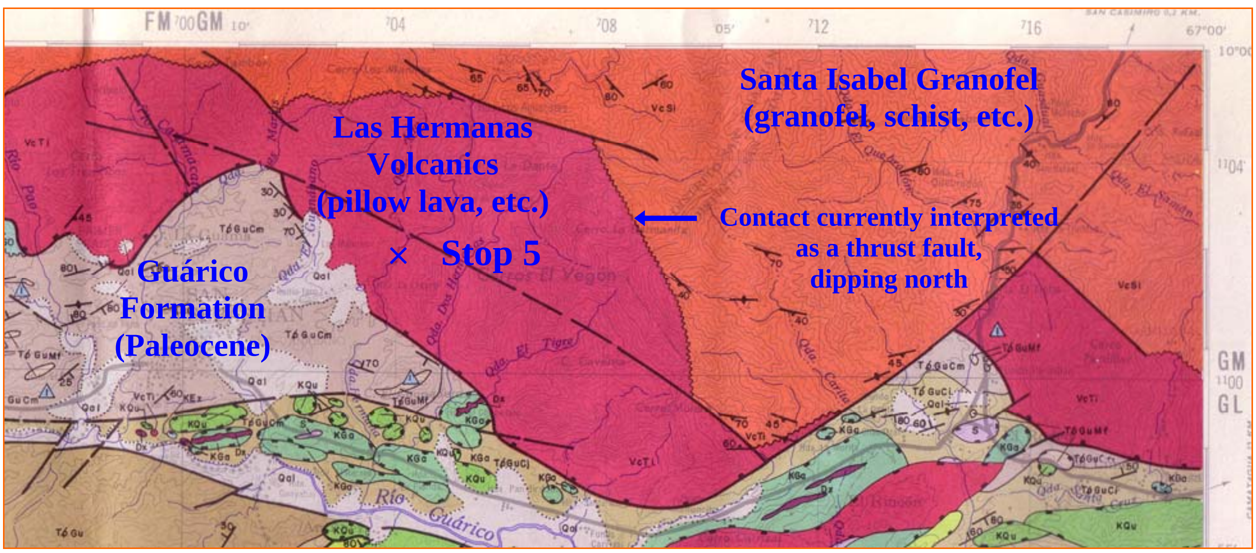


Fig. 19. Map of the San Sebastián area. From GONZÁLEZ-SILVA & PICARD (1971).

Lithology: Basalt and andesite (sometimes with pillow structures), tuff and volcanic agglomerates. The lava shows plagioclase and pyroxene phenocrysts, with recrystallized matrix to chlorite, albite, calcite and epidote. Some lava types are amigdaloid (filled with quartz, chlorite and calcite). Tuffs show different grain size from cinder, lapilli and even blocks.
Metamorphism no higher that prehnite-pumpellyite, no penetrative structures.

Age: Radiometric and paleontological data point to mid to Late Cretaceous age.

Interpretation: Since GIRARD (1981) (the author of the unit name) all authors agreed that the basaltic lava of this unit shows an island arc affinity. The nature of its contact with Santa Isabel has been in debate but now it is accepted that it is a thrust fault.

Fig. 20a. Pillows.

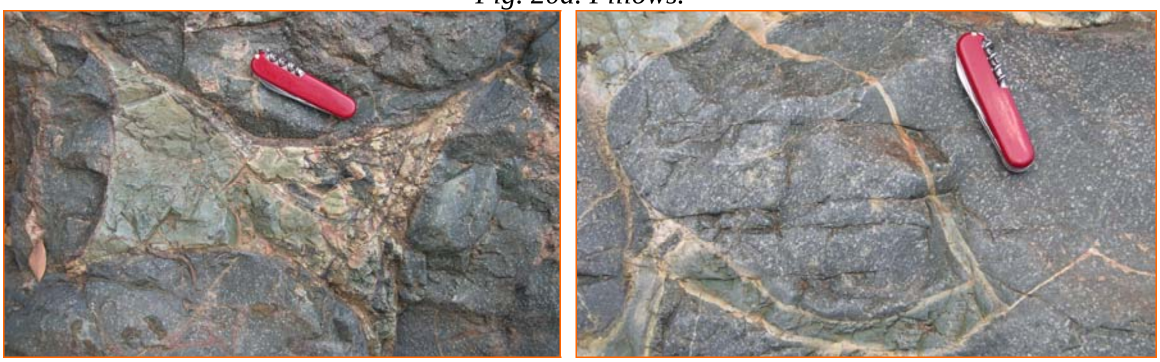


Fig. 20b. The interstices between individual pillows are afanitic composed by quartz, epidote and pumpelleyite probably formed as hyaloclastites.

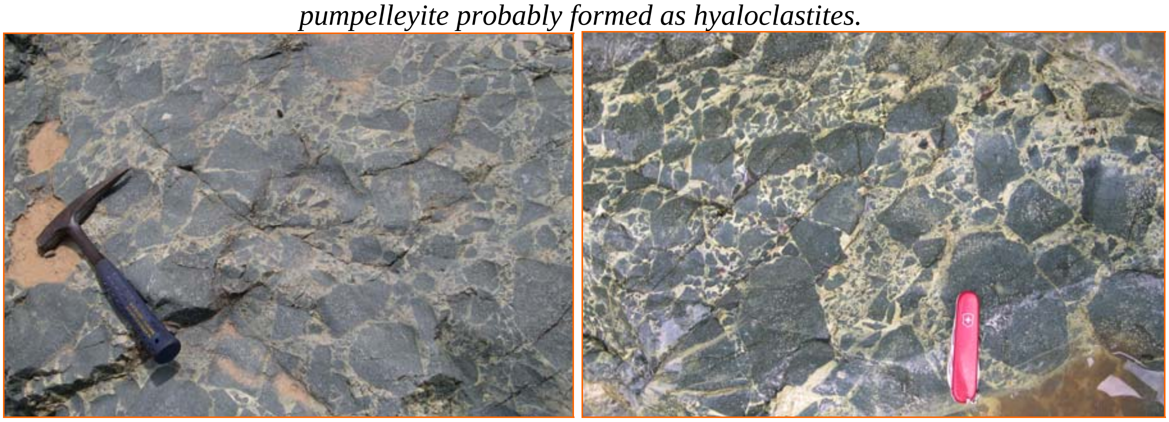


Fig. 20c. Volcanic agglomerates.

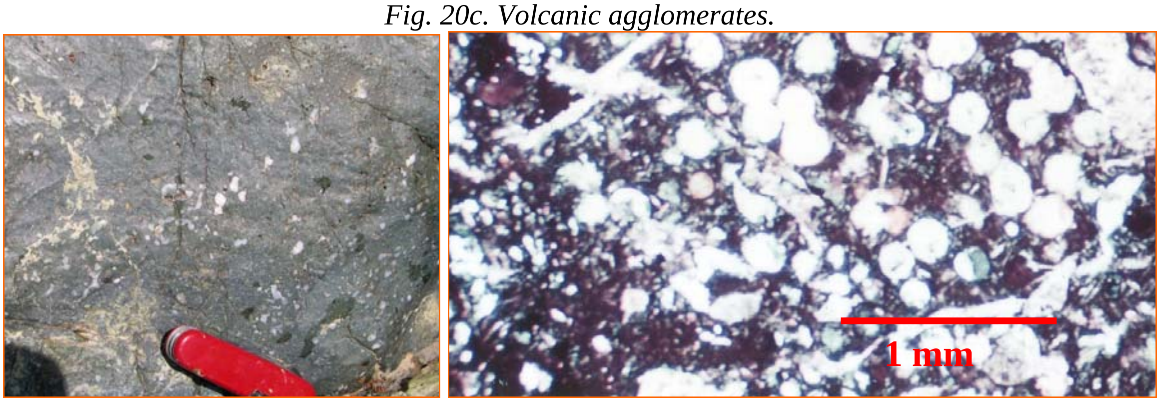


Fig. 20d. Amigdaloid lava. Right from a thin section: vesicles filled by quartz chlorite calcite and pumpellyite (LUGO 1982:140)

STOP 6. SANTA ISABEL AND LAS HERMANAS VOLCANICS

Setting-Units:

Contact between Santa Isabel and Las Hermanas (as described previously in stops 3 to 5).

Location: Western side of the "Morro del Faro". UTM: E 675.656 N 1.098.873 (Fig. 21).

Description: In the trail that takes to the summit of the "Morro del Faro" (Fig. 21) we can see the tectonic contact between the Santa Isabel and Escozonera units.

Also enclosed in Escorzonera Formation there are several bodies of fosiliferous limestone. The paleontological evidence gave an age of Late Cretaceous, as specimens of Mollusca (gastropoda): *Actaeonella* sp. (identified by Dr. Oliver Macsotay). In thin sections numerous fragments of gastropoda, pellecypoda and echinoids are seen indicating a very shallow marine environment with energy for fragmentation and rounding the fossil fragments (identified by Dr. Maximilian Furrer). The chambers of some gastropoda are filled with volcanic ash.

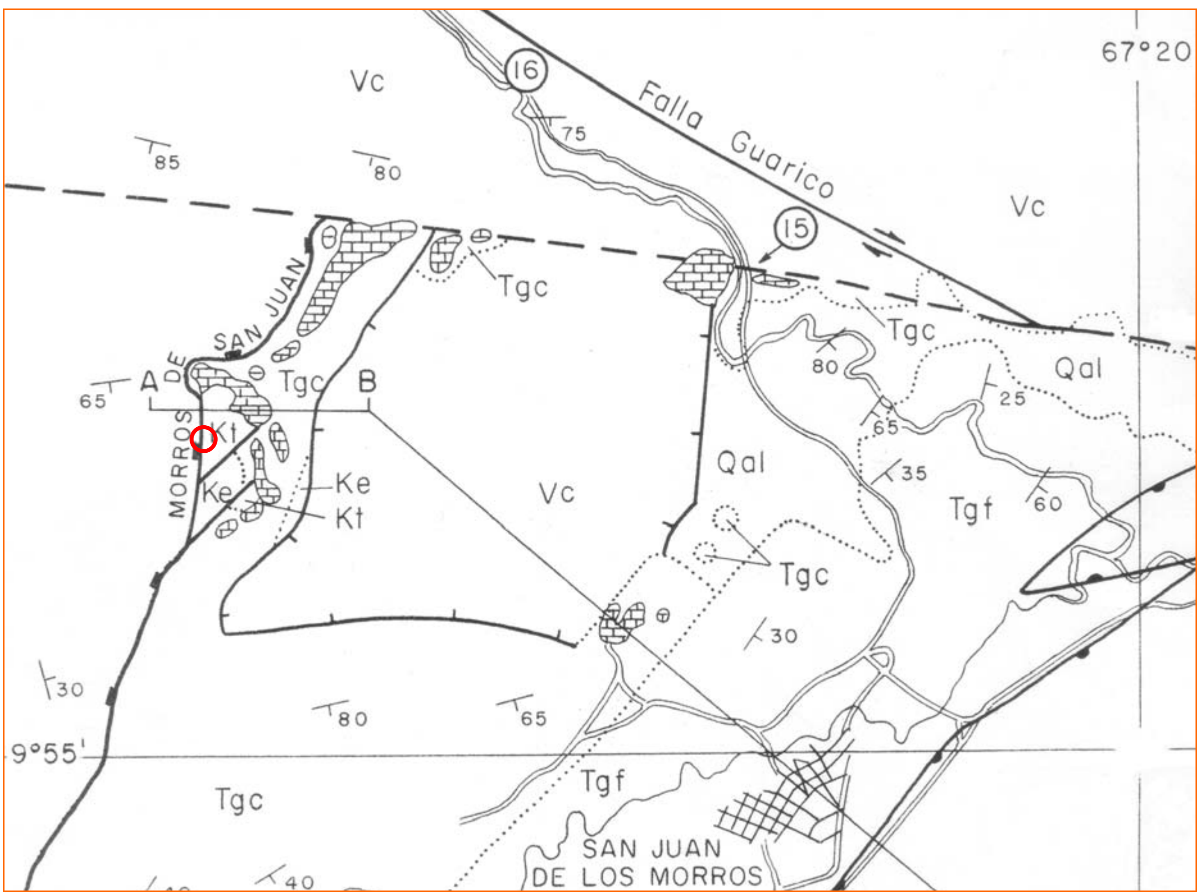


Fig. 21. Geological map of the San Juan de los Morros area after B*ELL (1968), modified with the information of* G*ONZALEZ*-S*ILVA &* P*ICARD (1971). Red circle locates the stop.*

Fig. 22. Trail to the summit of Morro del Faro.

Fig. 23. Schistose rocks from Santa Isabel Granofel.

Fig. 24. Spheroid weathering in the lava included in Escorzonera Formation.

Fig. 25. High angle reverse fault contact between Santa Isabel (darker, left, west) and Escorzonera Formation (lighter, right, East). Strike almost N-S, dips west.

Fig. 26. Actaeonella sp. (identified by Oliver Macostay, 2004. Late Cretaceous).

Fig. 27. View to the southwest where it crops out the Chacao Ultramafics.

LEG 2 b

DEFORMATION AND METAMORPHISM OF THE VILLA DE CURA UNITS

By Hans AVÉ LALLEMANT

Stop 2 of Leg 2a will be used for an extended explanation of the deformation stages and metamorphism el the Villa de Cura units:

Stop 2: Setting-Units:

Villa de Cura Terranes

Villa de Cura Metavolcanosedimentary Suite [El Caño and El Chino metatuffs (undivided)]

Location (S2 of fig. 15): Dirt road between El Pao de Zárate and San Sebastián, Aragua state. At the crossing of Río Pao from right to left margin. UTM, E 695.205, N 1.112.090

Strong ductile deformation in El Caño-El Chino unit.

The Villa de Cura blueschist belt is one of several east-west trending allochthonous belts comprising the Caribbean Mountain system of northern Venezuela. This blueschist belt consists of four structurally coherent sub-belts that also trend east-west; from north to south these are characterized by: (1) pumpellyite-actinolite, (2) glaucophane-lawsonite, (3) glaucophane-epidote, and (4) barroisite. The retrograde pressure-temperature (P-T) path of the northern three sub-belts generally parallels their prograde path. Such P-T paths are typical for Franciscan-style subduction settings and are characterized by relatively low geothermal gradients indicative of refrigeration during subduction-zone-parallel ascent and exhumation of these rocks. The barroisite sub-belt formed at high pressures similar to those of the glaucophane-epidote sub-belt, but at substantially higher temperatures, and followed a counterclockwise P-T path. New 40Art39Ar ages record peak metamorphism at 96.3 ± 0.4 Ma for the barroisite sub-belt and 79.8 0.4 Ma for the northern three sub-belts.

The Caribbean plate is thought to have been a fragment of the Farallon plate, which together with the "Great Arc of the Caribbean" (Greater Antilles-Ares Ridge-Lesser Antilles-Leeward Antilles) migrated northeastward after a subduction polarity reversal and over-rode the young Proto-Caribbean lithosphere that had formed by spreading between North America and South America. The more silicic barroisite sub-belt may have been part of the arc that was subducted immediately after polarity reversal, whereas the other three belts formed much later when the geothermal gradient had decreased substantially. The Villa de Cura belt was exhumed in two stages, first by Late Cretaceous arc-parallel extension, and second by Miocene south-ward thrusting onto the South American continent.

Abstract from SMITH *et al*. (1999).

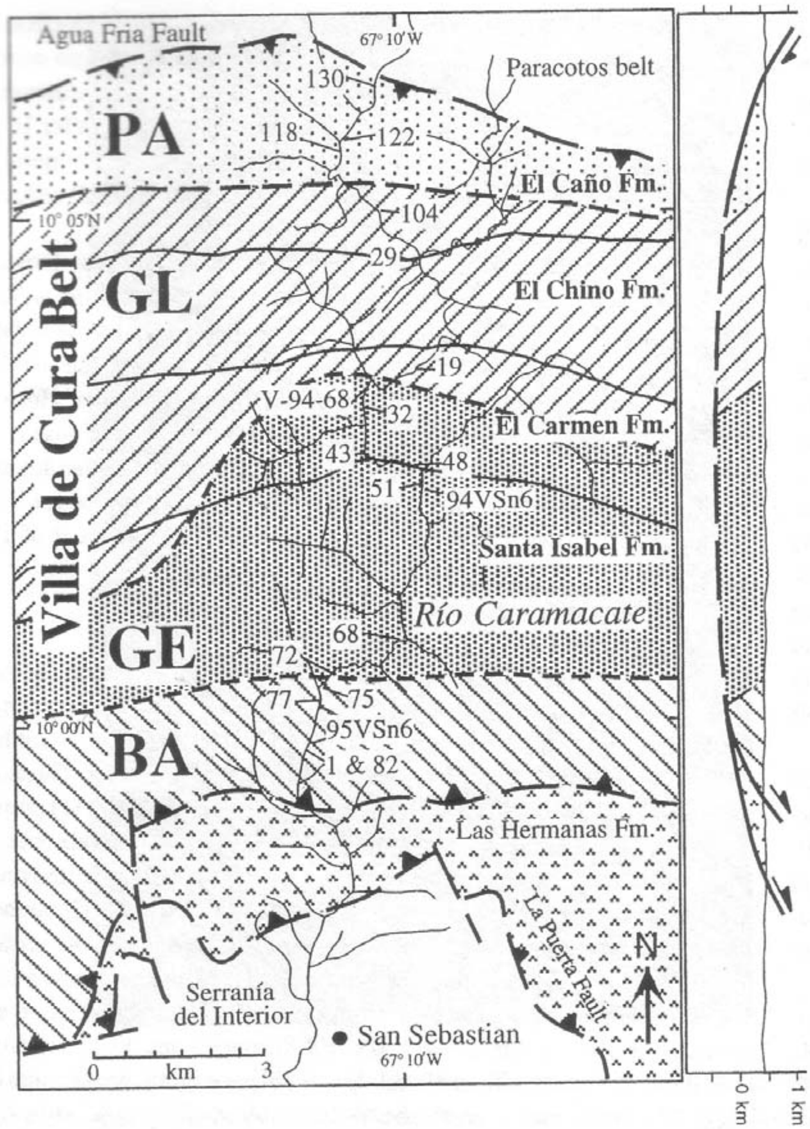


Figure 2. Simplified geologic and sample map of the Río Caramacate transect north of the town of San Sebastian and cross section through the Villa de Cura belt. Dashed lines indicate approximate positions of boundaries between different subbelts: PA—pumpellyite-actinolite; GL—glaucophane-lawsonite; GE—glaucophane-epidote; BA—barroisite. Solid lines are approximate contacts between lithologic units of Shagam (1960). Dashed lines with barbs are thrust faults that define the southern and northern boundaries of the Villa de Cura belt. Isograds modified from Navarro (1983). Cross section is aligned north-south through long 67°10′W with no vertical exaggeration.

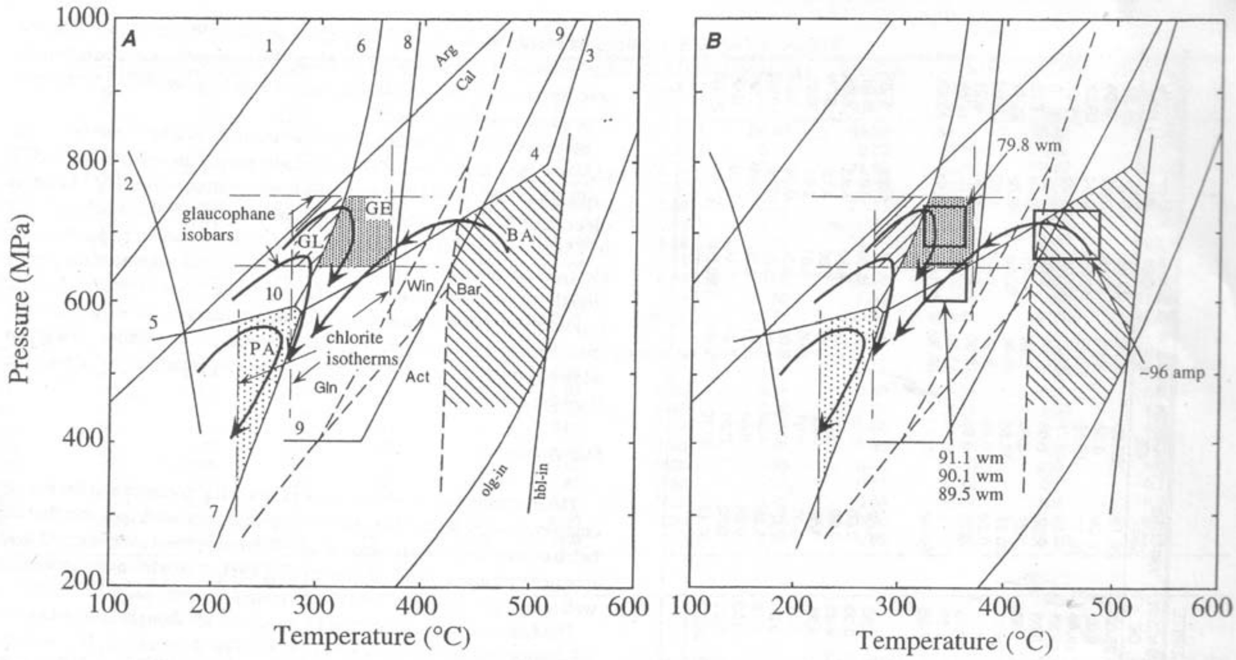


Figure 6. Pressure-temperature (*P-T*) diagram showing relative positions of the subbelts of the Villa de Cura belt. (A) Mineral stability curves 1–10 are given in Table 6. Inferred amphibole stability fields are shown by short-dashed lines (from Miyazaki et al., 1996; Otsuki and Banno, 1990). Mineral abbreviations after Kretz (1983). Patterned regions show the four subbelts: PA—pumpellyite-actinolite; GL—glaucophane-lawsonite; GE—glaucophane-epidote; BA—barroisite. Dashed lines show *P-T* estimates determined by chlorite geothermometry and sodic amphibole geobarometry. (B) *P-T* paths for the different belts shown by heavy lines with arrows. Estimated *P-T* conditions for the various geochronometers are shown by boxed regions for amphibole (amp) and white mica (wm).

Fig. 30.

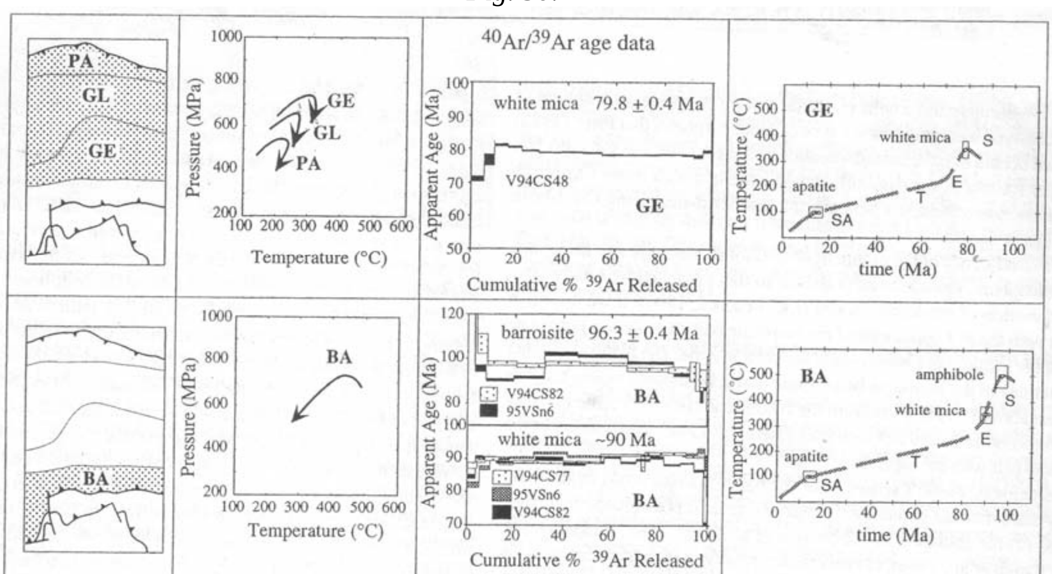


Figure 7. Summary of pressure-temperature-time (*P-T-t*) relations for the two regions of the Villa de Cura belt subdivided by differences in their *P-T* paths as discussed in text. The first column shows the distribution of the two regions (see text for abbreviations). The second column shows the different styles of *P-T* path for each region. The third column summarizes the ^{40}Ar/^{39}Ar plateau data for each region. The fourth column indicates the difference in *T-t* evolution for each region. S—subduction, E—exhumation, T—eastward transport, SA—emplacement on South America.

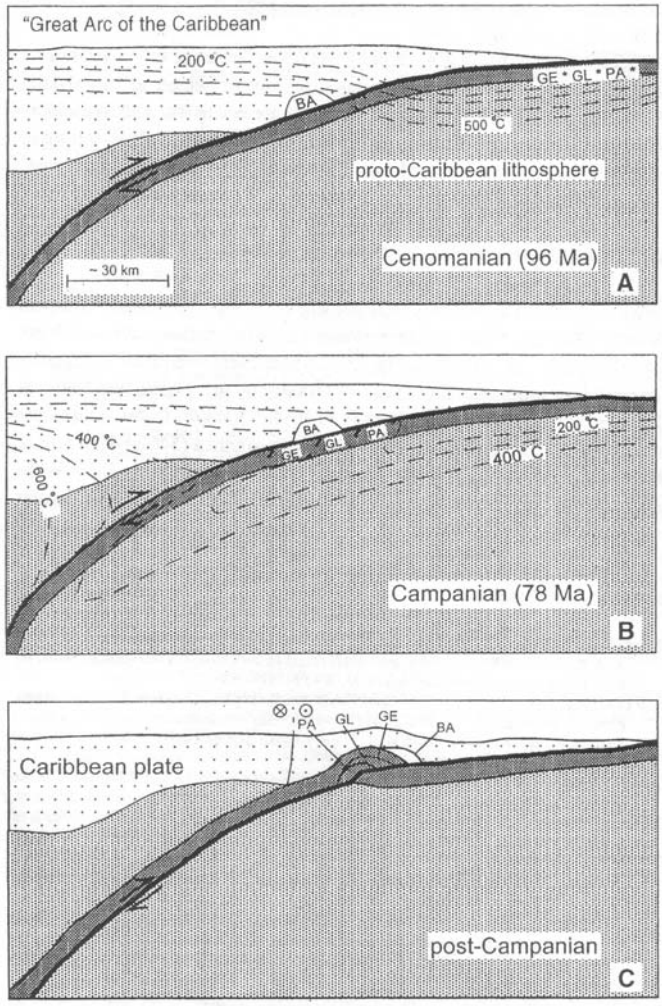


Figure 8. Schematic model for the metamorphism, tectonic imbrication, uplift, and exhumation history of the Villa de Cura belt. Dotted pattern indicates Great Arc of the Caribbean. Dark shading represents oceanic crust. Intermediate shading shows upper mantle. (A) At 96 Ma, the peak metamorphic conditions are attained in the BA belt. The geothermal gradient is high because subduction has just started. The protolith of the barroisite (BA) belt is as yet unknown, but the lithologies suggest that it is related to the Caribbean arc. The protoliths of the glaucophane-epidote, glaucophane-lawsonite, and pumpellyite-actinolite belts are far to the east (shown as GE*, GL*, and PA*, respectively). (B) At 78 Ma, the geothermal gradient has become relatively low (isotherms of van den Beukel and Wortel, 1987), because of continued subduction. The GE, GL, and PA belts are juxtaposed to the BA belt. (C) Shortly(?) afterward, the four belts were stacked upon each other in a foreland-dipping duplex (Boyer and Elliott, 1982), resulting in the present-day stacking order of the BA, GE, GL, and PA belts (see cross section in Fig. 2). The thickness of all belts has decreased because of arc-parallel (out of the plane) stretching. Subsequently, in Cenozoic time, the Villa de Cura belt was rotated clockwise (Skerlec and Hargraves, 1980) and obducted onto the South American continent (not shown).

LEG 3

NEOTECTONICS OF THE RÍO GUÁRICO FAULT

By Franck AUDEMARD

The Río Guárico fault (most commonly known as the Guárico fault) extends transversely across the Interior Range between the Carrizal hill, located 10 km east of San Sebastián, and the southeastern coast of Lake Valencia. This WNW-ESE trending fault displays the most conspicuous evidence of Quaternary activity near the town of Villa de Cura. Along this stretch, between the towns of San Francisco de Asis and San Juan de Los Morros, the fault comprises two subparallel fault strands (Fig. 1), with a 3-km-wide right-stepping at Villa de Cura. The fault essentially runs at the foot of the relief, bounding the Villa de Cura depression, which has been interpreted as a small pull-apart basin (AUDEMARD *et al.* 1989).

In this N120º-running portion of the fault, the geomorphic evidence of Quaternary activity indicate a righ-lateral sense of slip. Two places deserve mention, where offset drainages and crestlines, coupled with fault scarps, support such motion in Quaternary times.

STOP 1

Near Campo Alegre, located 5 km southeast of Villa de Cura, the Quaternary activity of the southern strand of the Río Guárico fault is attested by a set of nicely-developed landforms, being the most common ones: shutter ridges, fault trenches, offset crestlines, fault saddles and faceted spurs (Fig. 2b). This features support right-lateral motion, and a minor normal component.

STOP 2

Between San Francisco de Asis and Villa de Cura, and near to an Edelca power substation, the Quaternary activity of the northern strand of the Río Guárico fault is highlighted by: a fault trench, shutter ridge, fault benches, and an offset drainage with a righ-lateral shift of about a 100 m (Fig. 2a).

STOP 3

This stop corresponds to a roadcut on the Villa de Cura-Cagua road, located outside the Villa de Cura pull-apart basin. This outcrop exposes a sequence of Quaternary (Early Pleistocene?) deposits of colluvial and alluvial origin (Fig. 3). The sequence is faulted several times. One of the most prominent fault planes yuxtaposes coarse colluvial deposits against less coarser alluvial beds. Faults show essentially normal-slip and trend roughly east-west. Also few right-lateral strike-slip, WNW-ESE striking faults cut this Quaternary sequence.

BIBLIOGRAPHY

AUDEMARD Franck, Feliciano DE SANTIS & André SINGER. 1989. Evidencias geomorfológicas de una actividad tectónica reciente a lo largo de la falla del Río Guárico. *Memorias VII Congreso Geológico Venezolano,* S.V.G., Caracass 12-18 nov., 3: 988-998.

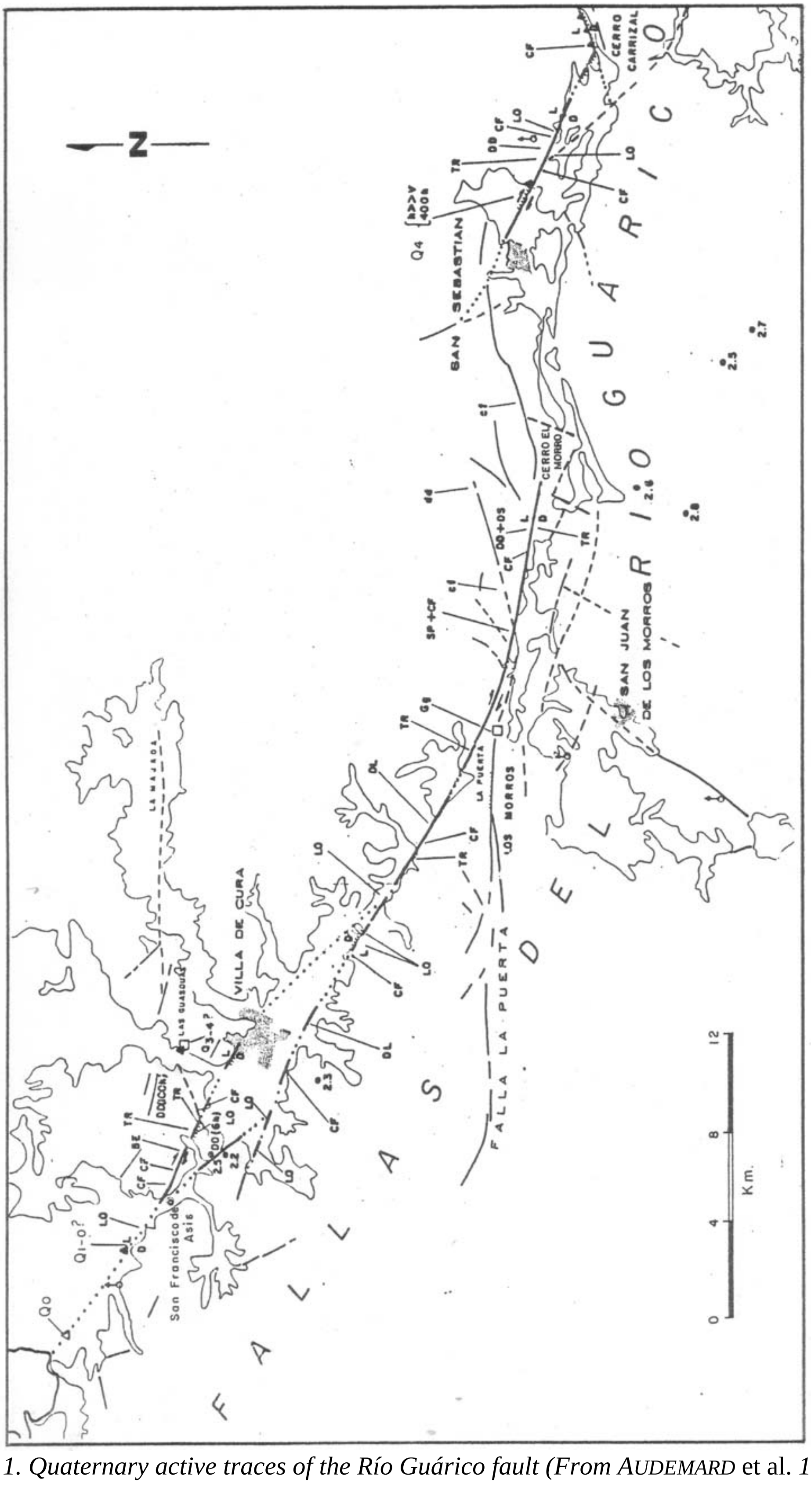
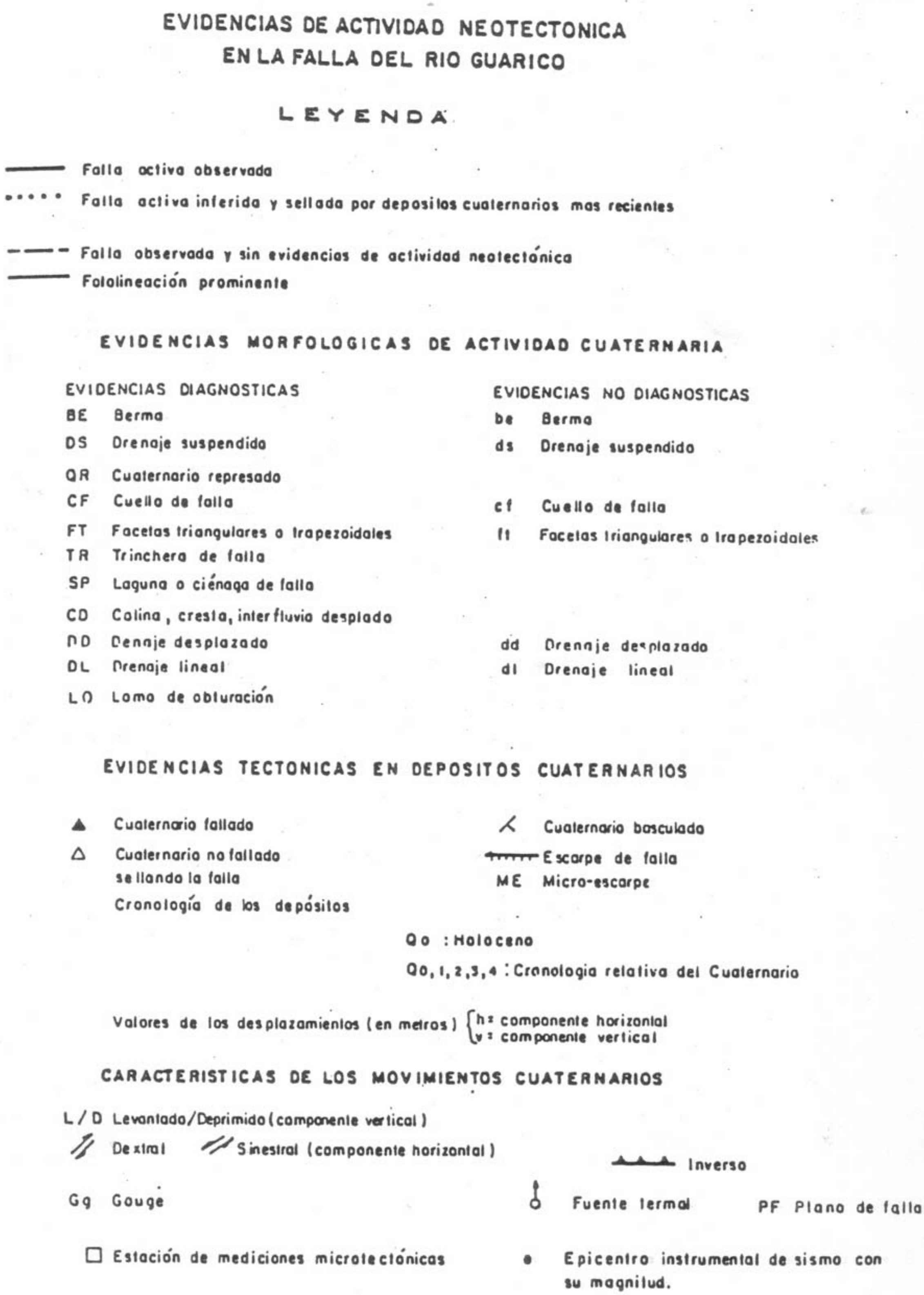


Fig. 1. Quaternary active traces of the Río Guárico fault (From AUDEMARD et al. *1989).*



Legend to Fig. 1 (From AUDEMARD et al. *1989).*

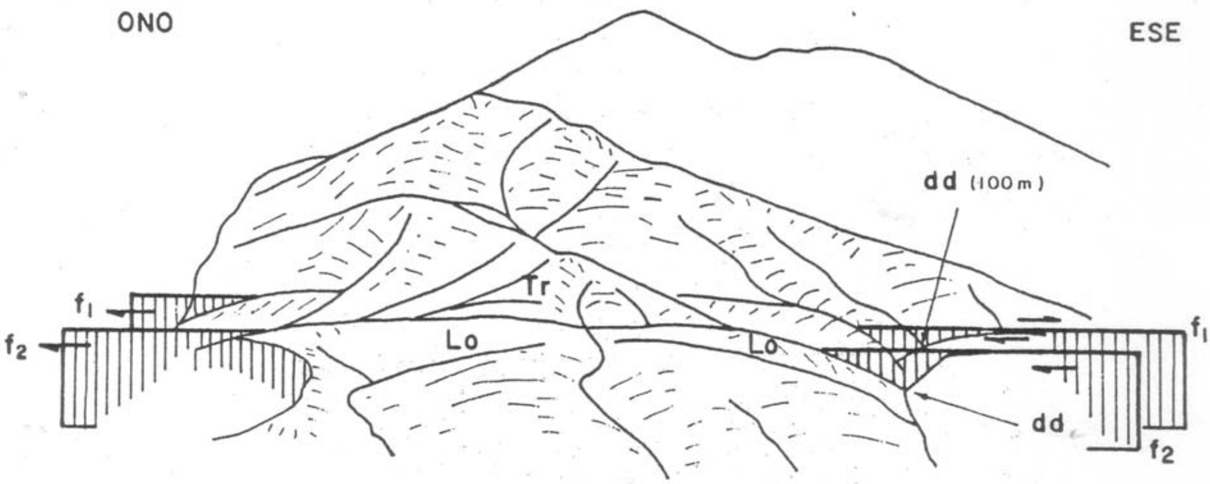


Fig. 2b

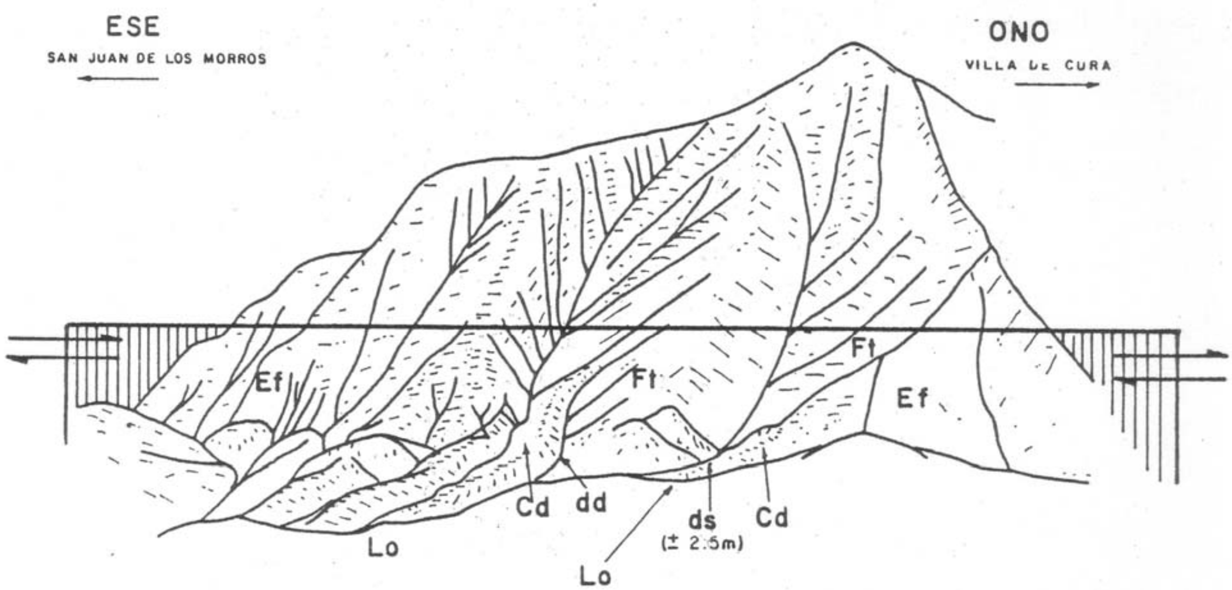


Fig. 2. Geomorphic evidence of recent tectonic activity along the Río Guárico fault (From AUDEMARD et al. *1989).*

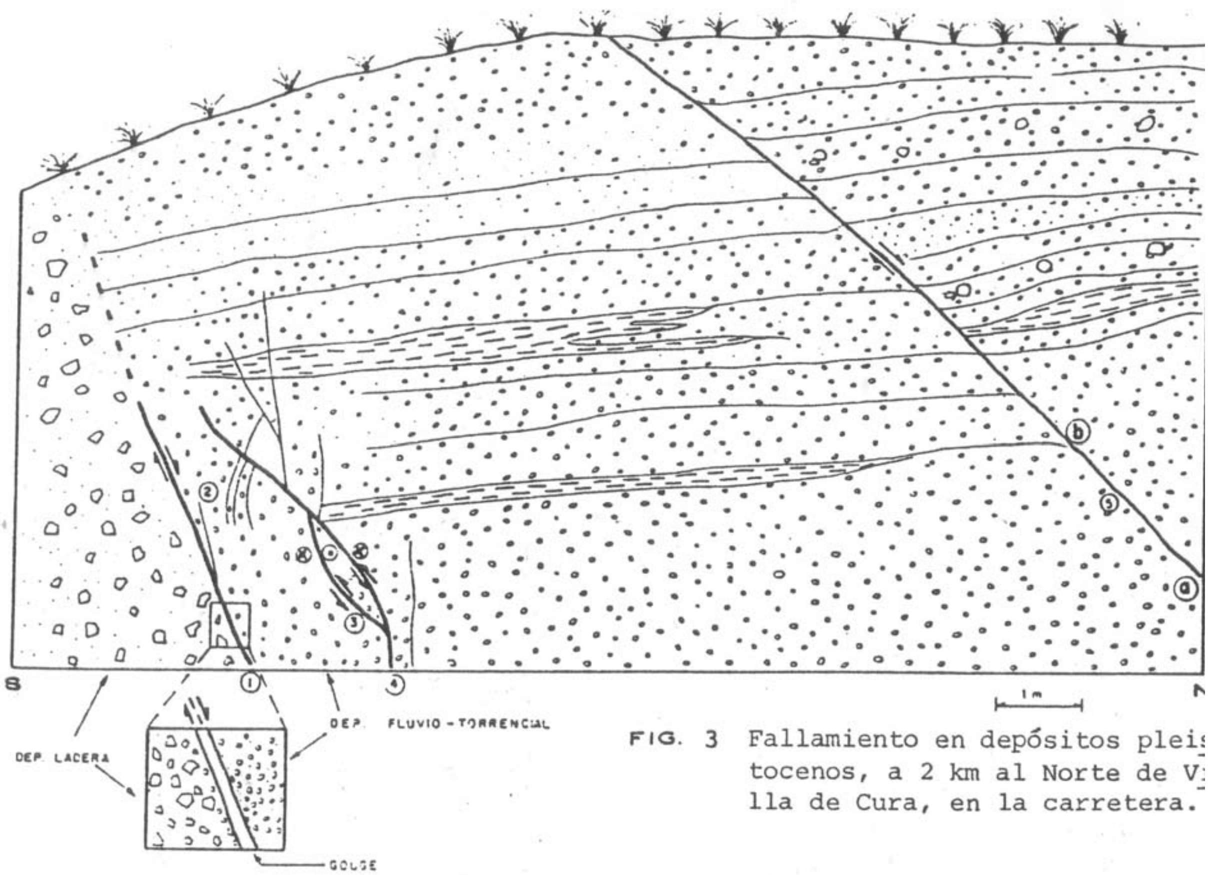


FIG. 3 Fallamiento en depósitos pleistocenos, a 2 km al Norte de Villa de Cura, en la carretera.

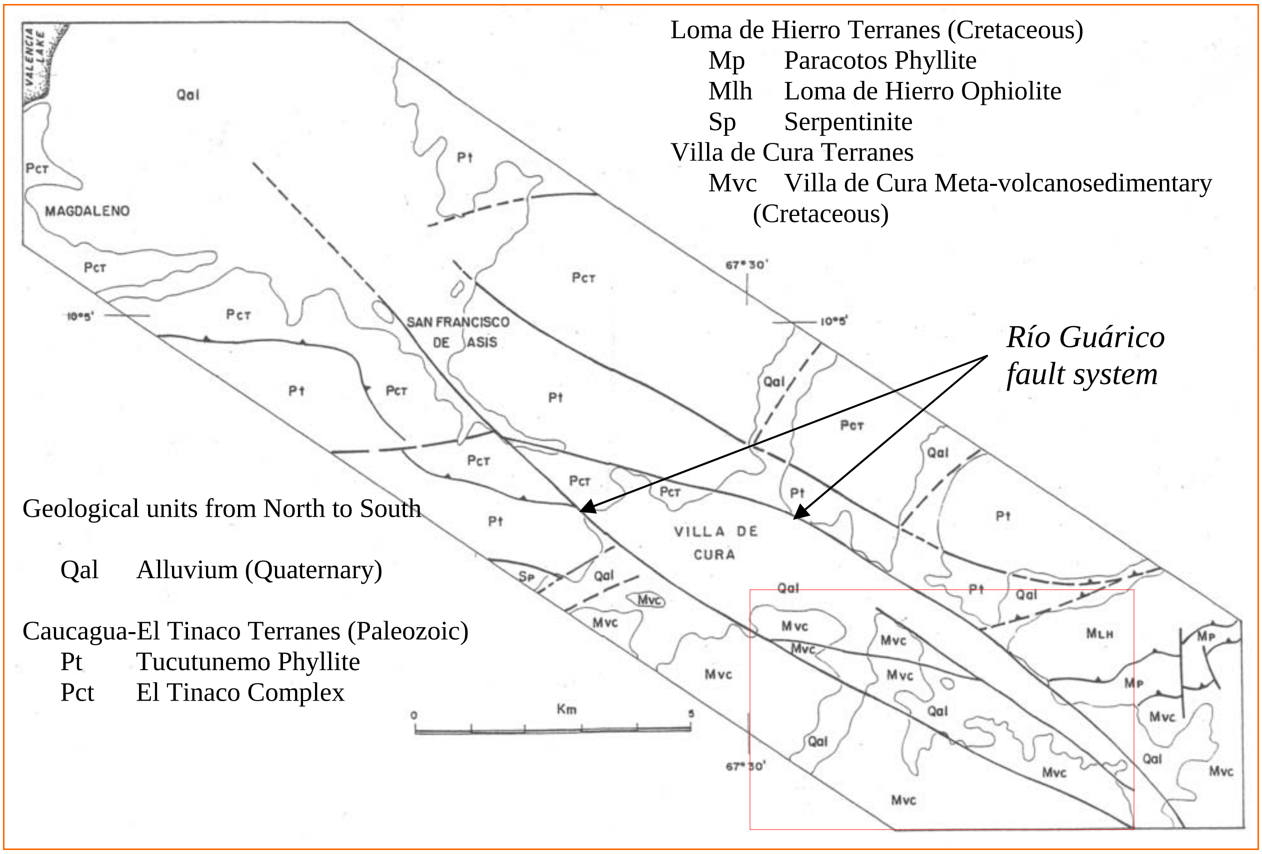
FALLAS

Rumbo y	Buzamiento	Estría
1. E-O	67° N	74° N Normal
2. N 118°	62° N	50° O Inversa Dextral
3. N 302°	25° N	12° N Dextral Inversa
4. N 55°	54° N	66° N Inversa
5a. N 100°	33° N	74° SE Normal
5b. E-O	46° N	73° E Normal

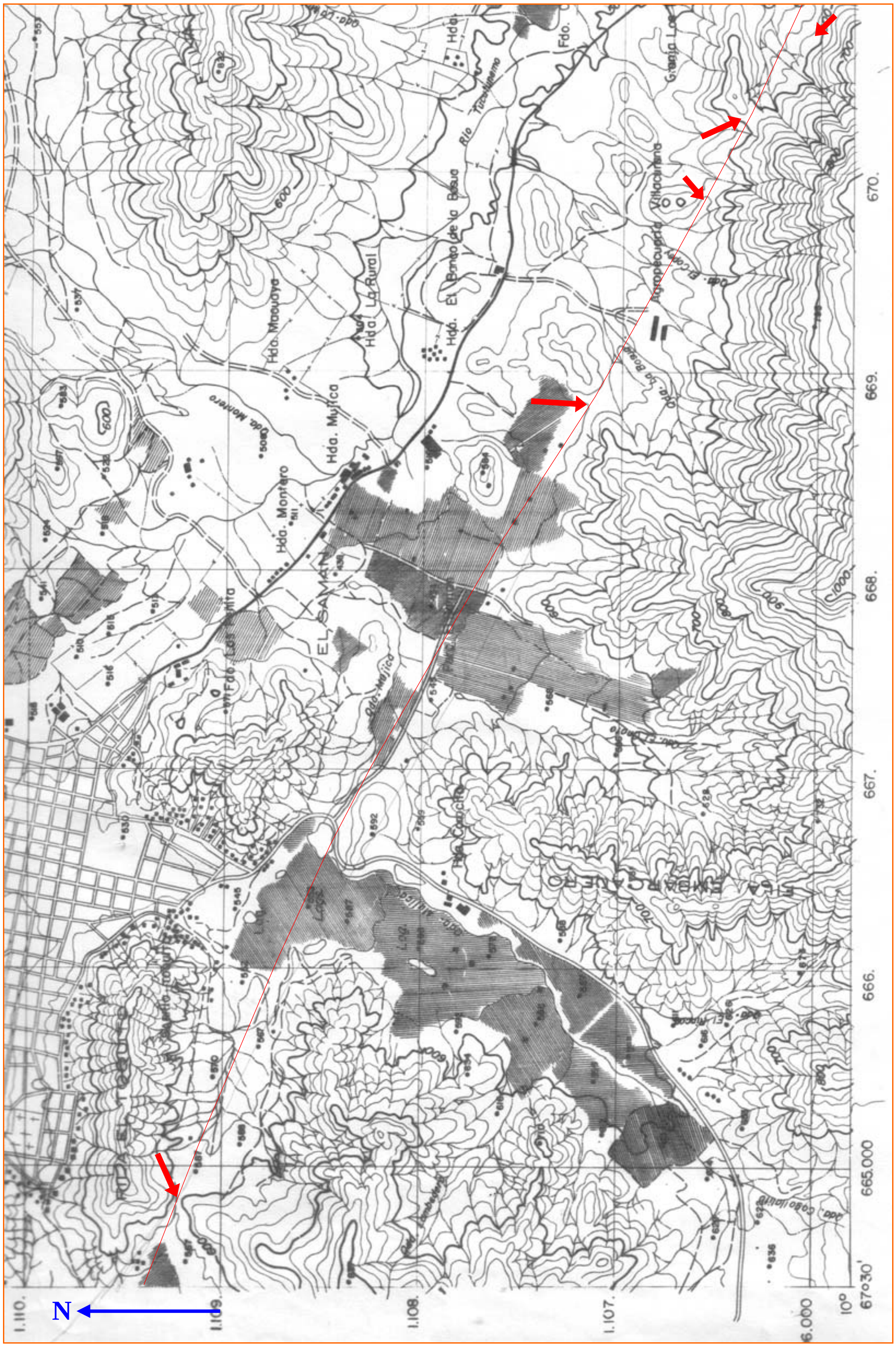
Fig. 3. Faulting of Pleistocene deposits, road at 2 km North of Villa de Cura
(From A*UDEMARD* et al. *1989)*

BEDROCK GEOLOGY OF THE VILLA DE CURA AREA

By Franco URBANI



Geological map of the Villa de Cura area.
From sheets 41, 42 and 76 of URBANI & RODRÍGUEZ (2004).
Red rectangle shows location of next map.



Fault necks (red arrows) in the southern branch of Río Guárico fault around the city of Villa de Cura. Topographic map 6746-III-SO, Villa de Cura, D.C.N., 1979.

LEG 4
GEOLOGY OF LA VICTORIA – COLONIA TOVAR

By Franco URBANI

We will travel from La Victoria to Colonia Tovar, apparently there will be no time for formal geological stops but at any rate here we enclose the geological map of the transect.

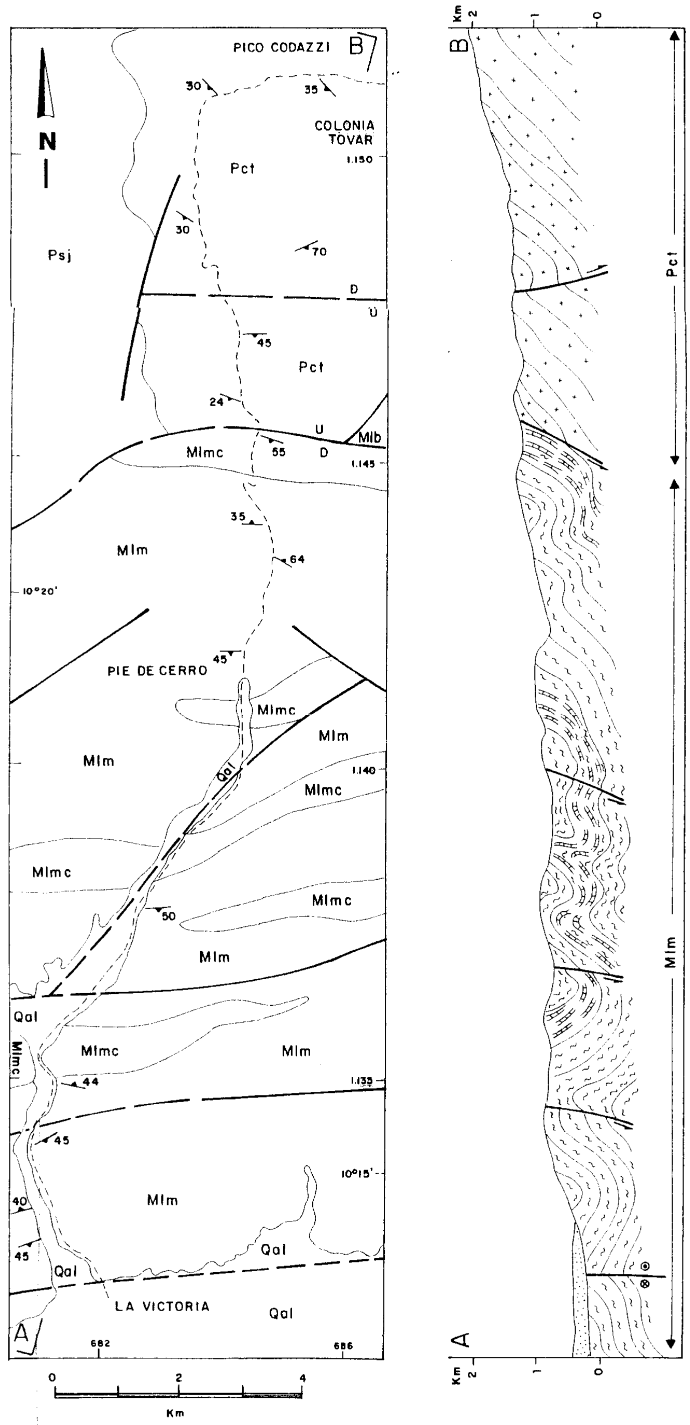
Legend

Qal Alluvium (Quaternary)

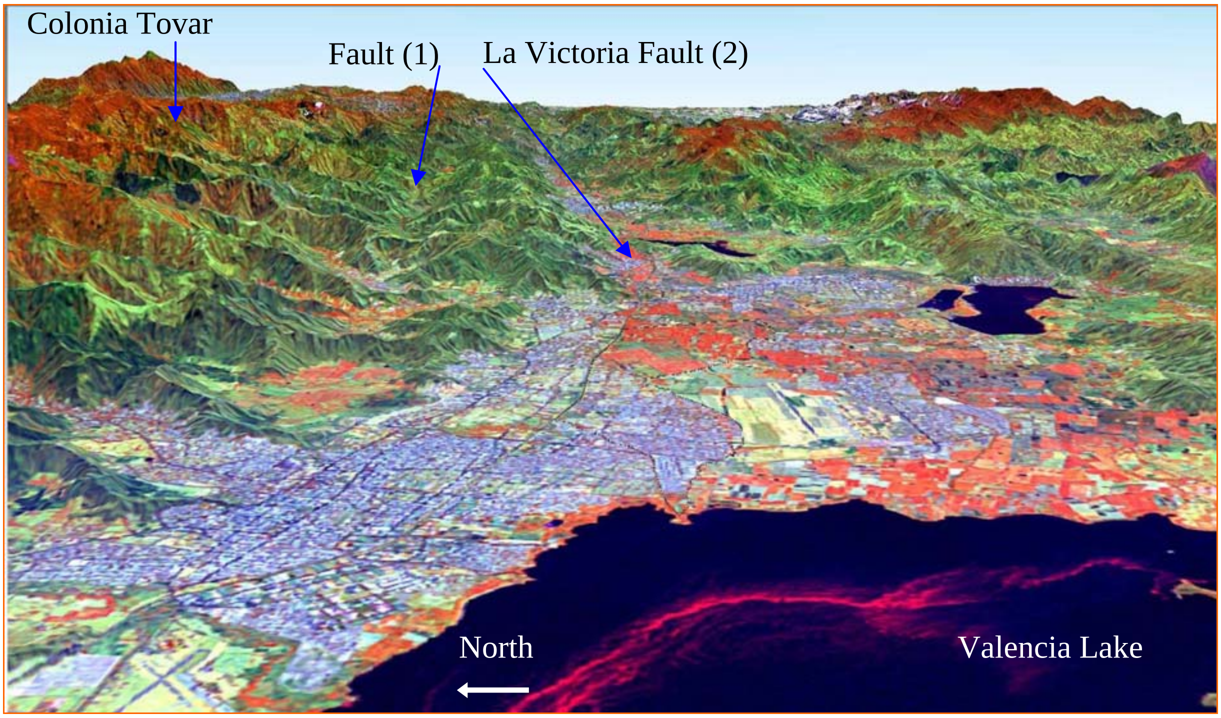
Caracas Belt
Mlm Las Mercedes Schist
Mlmc Los Colorados Marble
Mlb Las Brisas Schist

Ávila Belt
Pct Colonia Tovar Gneiss
Psj San Julián Complex

Geological map compiled from Sheets 61, 78 and 79 of URBANI & RODRÍGUEZ (2004). Original data from MACLACHMAN *et al.* (1960), RODRÍGUEZ (1972) and WEHRMANN (1972). Cross section adapted from OSTOS (1990).



Geological map and cross-section of La Victoria - Colonia Tovar, Aragua state.



Landsat TM image on a DEM. Courtesy of CPDI, 2005. Faults (1) and (2) are located in the previous geological map.

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BIBLIOGRAPHY

AUDEMARD Franck, Feliciano DE SANTIS & André SINGER. 1989. Evidencias geomorfológicas de una actividad tectónica reciente a lo largo de la falla del Río Guárico. *Memorias VII Congreso Geológico Venezolano*, S.V.G., Caracas 12-18 nov., 3: 988-998.

BECK C. 1986. *Geologie de la chaine Caraïbe su meridien de Caracas (Venezuela).* Soc. Geol. de Nord, Villeneuve s'Ascq, Francia, Public. No. 14, 462 p.

BELL J. S. 1968. Geología del área de Camatagua, estado Aragua, Venezuela. *Bol. Geol*., Caracas 9(18): 291 - 440.

CIEN-COMISIÓN INTERFILIALES DE ESTRATIGRAFÍA Y NOMENCLATURA. 1997. *Léxico Estratigráfico Electrónico de Venezuela*. INTEVEP-PDVSA, edición electrónica www.pdvsa.com/lexico. Consulted October 2005. Also version in CD-ROM (1997).

GIRARD D. 1981. *Pétrologie de quelques séries spilitiques mésozoïques du domaine Caraïbe et des ensembles magmatiques de l'île de Tobago.* Univ. de Bretagne Occidentale, Brest. 3rd. cycle Dr. degree thesis, 229 p.

GIUNTA G., L. BECCALUVA, M. CONTORTI, F. SIENA & C. VACCARO. 2002. The southern margin of the Caribbean Plate in Venezuela: tectono - magmatic setting of the ophiolitic units and kinematic evolution. *Lithos* 63: 19 - 40.

GONZÁLEZ-SILVA & PICARD 1971. *Mapa geológico de San Juan de los Morros*. Min. Energía y Minas. Dir. Geología. Sheet 6745, 1:100.000, color.

LUGO J. 1982. Geología de una zona uibicada al nortte de San Sebastián de los Reyes. edo. Aragua. UCV. Escuela de Geología. Trabajo Especial de Grado, 233 p.

MACLACHLAN J. C., R SHAGAM & H. H. HESS. 1960. Geología de la región de La Victoria, estado Aragua, Venezuela. *Bol. Geol.*, Caracas, *Public. esp*. 3, 2: 676 - 684. English version: Geology of the La Victoria area, Aragua, Venezuela. *Bull. Geol. Soc. Am.* 71(3): 241 - 248.

MENÉNDEZ A. 1966. Tectónica de la parte central de las montañas occidentales del Caribe, Venezuela. *Bol. Geol.*, Caracas 8(15): 116-139.

NACSN - NORTH AMERICAN COMMISSION ON STRATIGRAPHIC NOMENCLATURE. 1983. North American Stratigraphic Code. *AAPG Bulletin* 67(5): 841-875.

NACSN - NORTH AMERICAN COMMISSION ON STRATIGRAPHIC NOMENCLATURE. 2001. Application for amendment of the North American Stratigraphic Code concerning consistency and updating regarding electronic publishing. *AAPG Bulletin* 85(2):366-375.

NAVARRO E. 1983. Geología y petrogénesis de las rocas metavolcánicas del Grupo de Villa de Cura. *Geos* (UCV, Caracas) 28: 170 - 317.

NAVARRO E., M. OSTOS & F. YORIS. 1988. Revisión y redefinición de unidades litoestratigráficas y síntesis de un modelo tectónico para la evolución de la parte Norte - central de Venezuela durante el Jurásico Medio - Paleogeno. *Acta Científica Venezolana* 39: 427 - 436.

OSTOS M. 1990. Tectonic evolution of the south-central Caribbean based on geochemical data. Rice University, Ph.D. dissertation, 459 p. Full text published in: *Geos* (UCV, Caracas) 31: 1-320, 1990.

OSTOS M. & E. NAVARRO. 1985. Faja de Villa de Cura. Realmente un complejo de arco de isla alóctono? *Bol. Geociencias* (UCV, Caracas) 1: 1-23.

RODRÍGUEZ D. 1972. Geología de la región de Choroní - Colonia Tovar y lago de Valencia. *Bol. Geol*., Caracas, *Public. esp.* 5, 3: 1783 - 1784.

SEYLER M., J. L. PAQUETTE, G. CEULENEER, J. R. KIENAST & M. LOUBET. 1998. Magmatic underplating, metamorphic evolution and ductile shearing in a Mesozoic lower crust - upper mantle unit (Tinaquillo, Venezuela) of the Caribbean Belt. *Journal of Geology* 106(1): 35 - 58.

SHAGAM R. 1960. Geología de Aragua central (Venezuela). *Bol. Geol.*, Caracas, *Public. esp.* 3, 2: 574 - 675. English version: Geology of central Aragua, Venezuela. G*eol. Soc. Amer. Bull*. 71(3): 249 - 302.

SMITH C. A., V. B. SISSON, H. G. AVÉ LALLEMANT & P. COPELAND. 1999. Two contrasting pressure-temperature-time paths in the Villa de Cura blueshist belt, Venezuela: Possible evidence for Late Cretaceous initiation of subduction in the Caribbean. *GSA Bulletin* 111(6): 831-848.

SMITH R. J. 1952. Geología de la región de Los Teques - Cúa, *Bol. Geol.*, Caracas, 2(6): 333 - 406. Versión en inglés: Geology of the Los Teques - Cúa region, Venezuela. *Bull. Geol. Soc. Amer*. 64(1): 41 - 64. 1953.

STEPHAN J. F. 1982. *Evolution géodynamique du domaine Caräibe : Andes et chaine Caräibe Sur la transversale de Barquisimeto (Vénézuéla).* Universite de Pierre et Marie Curie (Paris VI). Doctoral dissertation. 512 p.

STEPHAN J. F. 1985. Andes et chaine Caräibe sur la transversale de Barquismeto (Vénézuéla): Évolution géodynamique. In: A. MASCLE, Ed., *Symposyum Geodinamique des Caraibes*. Paris, Ed. Technip, p. 505-530.

URBANI F. 2000. Revisión de las unidades de rocas ígneas y metamórficas de la Cordillera de la Costa. *Geos* (UCV, Caracas) 33: 1 - 170.

URBANI F. & J. A. RODRÍGUEZ. 2004. *Atlas Geológico de la Cordillera de la Costa, Venezuela*. Edic. Fundación GEOS, UCV y FUNVISIS, 148 geological sheets at scale 1:25,000.

WEHRMANN M. 1972. Geología de la región de Caracas - Colonia Tovar. *Bol. Geol.*, Caracas, *Public. esp.* 5, 4: 2093-2121.