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Project 433
Caribbean Plate

IGCP Project 433 Caribbean Plate Tectonics
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FIELD GUIDE TO THE FORMER CARIBBEAN PLATE BOUNDARY CAMAGÜEY, CENTRAL CUBA

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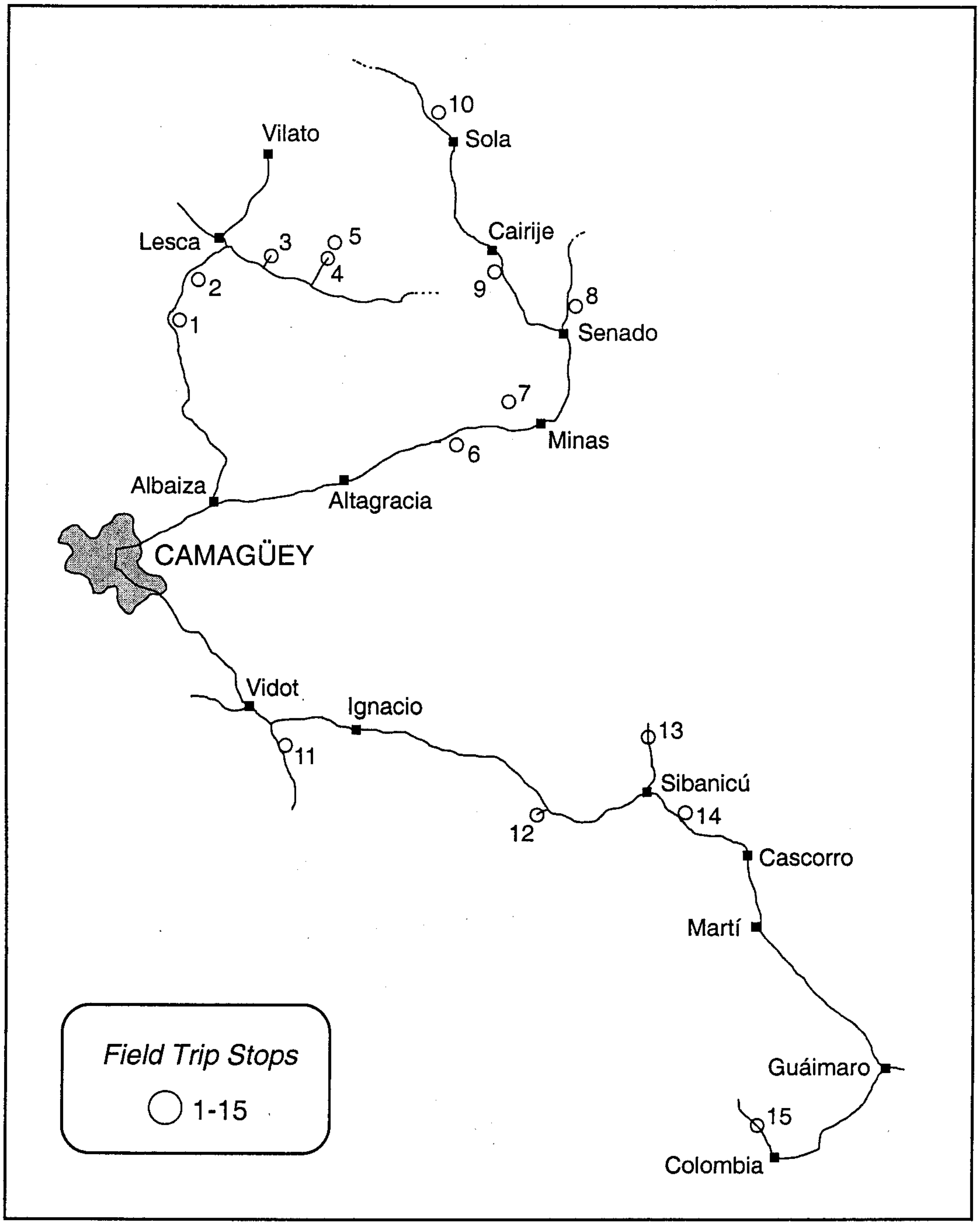
Schematic route map and stop locations for the field trip



General Geology of Camagüey, Central Cuba

Central Cuba consists of three different terranes which display the essential stages of the evolution of the contact between the North American and the Caribbean plates. These terranes are 1) the southern margin of the North American plate (Bahamas), 2) the ophiolite complex and oceanic sediments, and 3) the Cretaceous island arc suite (Fig. 1). They have been merged as a result of the collision between these terranes. The Bahamas platform on the north and the ophiolites in the south are separated by the NE-SW trending (120-140^0) Cubitas fault, which is part of the Northern Cuban suture. This suture zone is intersected by fault zones trending NE (Camagüey fault) and N-S (Banao fault), which define crustal segments with differences in composition and tectonic structure. West of La Trocha fault, (part of the Camagüey fault system) a fourth terrane is present, the Escambray metamorphic terrane (Iturralde-Vinent 1994, 1996, Iturralde-Vinent et al., 1987).

The Cubitas Fault

This fault is located south of Sierra de Cubitas, trending NW-SE (near 130^0). As the fault is a deformed thrust plane, its surficial expresion is a sinuous boundary between the ophiolites (South) and the carbonates (North) (Figs 1 and 2). The fault crops out for a distance of 68 km between the towns of Senado and Esmeralda in Camagüey province. NW-ward, near Esmeralda town, the fault vanishes below the Miocene and younger sediments, but SE-ward, near Senado town, it is interrupted by the N and NE trending Camagüey faults (Fig. 3).

Detailed investigation of the fault plane, with combined drilling, trenching and geophysical measurements, indicate that the thrust plane dips about 30^0 SE between Lesca and Las Cuevas, but reach 45^0 S-SE near Paso Paredones. Several rotary wells which cored the fault plane found overlying foliated and deformed serpentinites in contact with underlying and slightly deformed and non-metamorphosed sedimentary breccias with ophiolites and limestone clastic components (Senado Formation). Along the trend of the Cubitas fault occur a younger Montesitos system of vertical to nearly-vertical normal faults that produce steep limestone walls in the southern slope of Sierra de Cubitas, as well as a system of downward NW-SE elongated blocks toward the south, in such a way that the Cubitas thrust plane is located deeper and deeper in any cross section measured south of the Sierra de Cubitas. The plunge places the thrust plane at a depth of about 5 km near Camagüey city, according to the interpretation of the gravity and magnetic fields (Figs. 1, 2, 3).

The North American Plate

Jurassic, Cretaceous and Paleogene sediments of the passive North American Plate margin have been mapped in the northern half of Camagüey, particularly in the Guaney Hills, Sierra de Cubitas and surroundings. These rocks belong to different tectono-sedimentary facies of the Upper Jurassic to Maastrichtian, including intraplatform channel facies (Güaney Hills), carbonate platform (Sierra de Cubitas) and slope deposits (which do not outcrop in Camagüey, but west of La Trocha Fault) (Figs. 1 and 2).

The Bahamas carbonate platform section, as exposed in the Sierra de Cubitas, is strongly folded with the folds showing NE vergence. Shallow-marine carbonate grainstone, wackestone and mudstone dominate in this stratigraphic section. Two rudist banks of Cenomanian and Maastrichtian age are observed. During the Cenomanian, the carbonate platform was drowned, indicated by the occurrence of laminated hemipelagic mudstones of this age. Sediments of the Turonian to Santonian have not been identified, so the Mid Cretaceous unconformity is probably reprensed in the area.

Marginal slope sediments of the Bahamas platform (named Camajuaní zone) are probably present, according to seismic profiling, below the ophiolite allochthon, south of Sierra de Cubitas fault (Figs. 1 and 2).

Sierra de Cubitas, in general, is a stack of N-NE verging thrust sheets, separated by fault planes diping S-SE with different angles. These sheets are composed by Cretaceous carbonate platform rocks crowned by Paleogene Foreland sediments. The whole stack plunges SE-ward, in such a way that, NW-ward, the oldest sections are exposed; while in the area around Senado town, SE-ward, mostly the youngest olistostromic Senado Formation occur.

The Camagüey Ophiolite

The Camagüey ophiolite forms an arc-shaped belt of about 1,000 km (Fig. 3). Drill holes and gravimetric data show that the thicknes of the ultrabasic rocks increases to at least 5 km in the south near Camagüey city. The thrust plane dips 30° to 45° SW; towards the south the dipping angle increases up to an almost vertical position (Fig. 2). Thrusting of the ophiolite onto the NOAM carbonate platform started in the Paleocene and lasted until the Upper Eocene (Iturralde-Vinent, 1996). Above the Mesozoic carbonates of the passive margin, there is a section of Paleocene-Eocene sedimentary rocks and an olistostrome of early Upper Eocene age (Senado formation). The ophiolite tectonically overlies the former sections. In the south, the ophiolite is covered by klippen-like bodies of arc rocks, which are thrust both above a Paleocene- Lower Eocene olistostrome and the ophiolites.

The Camagüey ophiolite allochthon is represented by two nappe structures. The lower one containing tectonic inclusions of oceanic volcanics and sediments as the Camajan Hills. The upper thrust body contains inclusions of metamorphic rocks, both metavolcanics and metasedimentary (La Suncia massive). Both nappes show a similar and almost complete ophiolitic succession. The peridotite complex mainly consists of harzburgite, websterite and lherzolite, as well as some dunite. In some localities dikes of gabbroids cutting the harzburgites occur. Serpentinization varies in intensity from weakly (primary magmatic texture preserved) to rocks completely altered. The cumulate complex is also developed and represented by olivine gabbro, norite, troctolite, as well as anorthosite, intercalated with lherzolite, websterite, harzburguite and few dunites. Dikes of gabbros, plagioclasites and plagiogranites, as well as chromite veins, cut the cummulative gabbroids. Between the peridotite and the cumulate complex is a transitional zone.There are only minor scattered outcrops of the dike complex. In the area west of Minas, dikes of basalt and dolerite occur, with the structure of sheeted dikes.

The volcano-sedimentary complex of the ophiolites is represented by ?Albian-?Cenomanian basalts, hyaloclastites, radiolarian cherts and siltstones (Albaiza formation), which crop out as isolated blocks of several square kilometers. Near Esmeralda, slices of hemipelagic limestones and metacherts are included in the serpentinite (Mate Prieto Formation), NE of Camagüey city a large tectonic slice of green schists, quartz mica schists, metacarbonates and carbon rich mica schists (La Suncia Formation) is exposed. The largest of these vulcano-sedimentary inclusions occur as the Camajan Hills. The stratigraphic section of Camajan hills starts with pillow basalts and hyaloclastites of Tithonian age, which are overlain by hemipelagic limestones, cherts, shales and siltstones. The Turonian to Campanian hiatus is present and is covered by Maastrichtian clastic carbonate rocks.

Podiform chromite bodies are widespread in the ophiolites of Camagüey, some of which are medium-grade chromite ore deposits (about 30% Cr_2O_3 on the average). Host rocks of the metallurgical cromite are peridotites and dunites. Refractory chromite ores are located within the transition zone, as well as in the lower part of the cumulate complex. In the Meseta San Felipe, deep weathered ultramafic rocks occur as lateritic soil with reserves of nickel.

The Cretaceous Island Arc

In the Camagüey region, the exposures of the Cretaceous island-arc complex extend over more than 80 km with an NNW-SSE strike. These arc suites are in tectonic contact with the ophiolites in the north.The NE trending Camagüey fault (Fig. 1-3) subdivides the volcano-plutonic rocks into two areas with different erosional levels, the lower western part that is partially covered by Tertiary sediments, and the uplifted eastern part of well exposed arc-suite rocks. In Central Cuba, the Cretaceous island arc was active until the Campanian, and is disconformably overlain by late Campanian and younger sediments (Iturralde-Vinent, 1996). The island arc section of Camagüey can be subdivided into three volcano-plutonic sequences (Fig. 4): the pre-Albian IAT suite, the Albian-Turonian CA suite, and the Santonian-Campanian CA-A suite (Iturralde-Vinent et al., 1987; Iturralde-Vinent, 1996).

The IAT suite is represented by the sedimentary-volcanic rocks named Pre-Camujiro. The Albian to Turonian CA suite is mostly represented by the Camujiro Formation (about 2,000 m thick), which include basaltic, shoshonitic, trachybasaltic and trachyandesitic lavas, tuffs and tufffites with intercalations of fossiliferous limestones. The Santonian - mid Campanian rocks are dominated by volcanoclastic sediments with intercalations of andesitic to rhyodasitic lavas. Two main rudist-bearing limestone units of Santonian and Campanian age are intercalated in the section. The sequence can be subdivided into various facies. The Caobilla Formation consists of near-volcanoes dacitic to plagiorhyolitic lavas of various textures, intercalated with tuffs, tuffites and rare limestones. The Piragua Formation represents proximal volcanics and sediments, and the Aguilar

Formation represents distal fine-grained volcanoclastic sediments (Iturralde-Vinent, 1996). The last volcanic event are extrusive lavas of late Campanian age, represented by dacitic and rhyolitic necks (La Sierra formation) and columnar basalts (La Mulata Formation).

Plutonic igneous rocks are dominatly calc-alkaline, fine- to medium-grained diorites and granodiorites that form large outcrops. K-rich syenitic and monzonitic rocks are intimately associated with gabbros and crop out within the areas of Camagüey and Ignacio. K/Ar dates of the plutonic rocks show a wide range, but the cooling of the last plutons probably took place around 79 m.y ago (Iturralde-Vinent, 1996). Both volcanic and plutonic rocks were subject to metasomatic alterations with the replacement of plagioclase by K-feldespar, chloritization and formation of disseminated sulfides. Some adularia veins, probably part of the La Sierra volcanics, yield 72 m.y. Ar-Ar age (Simon et al., 1999).

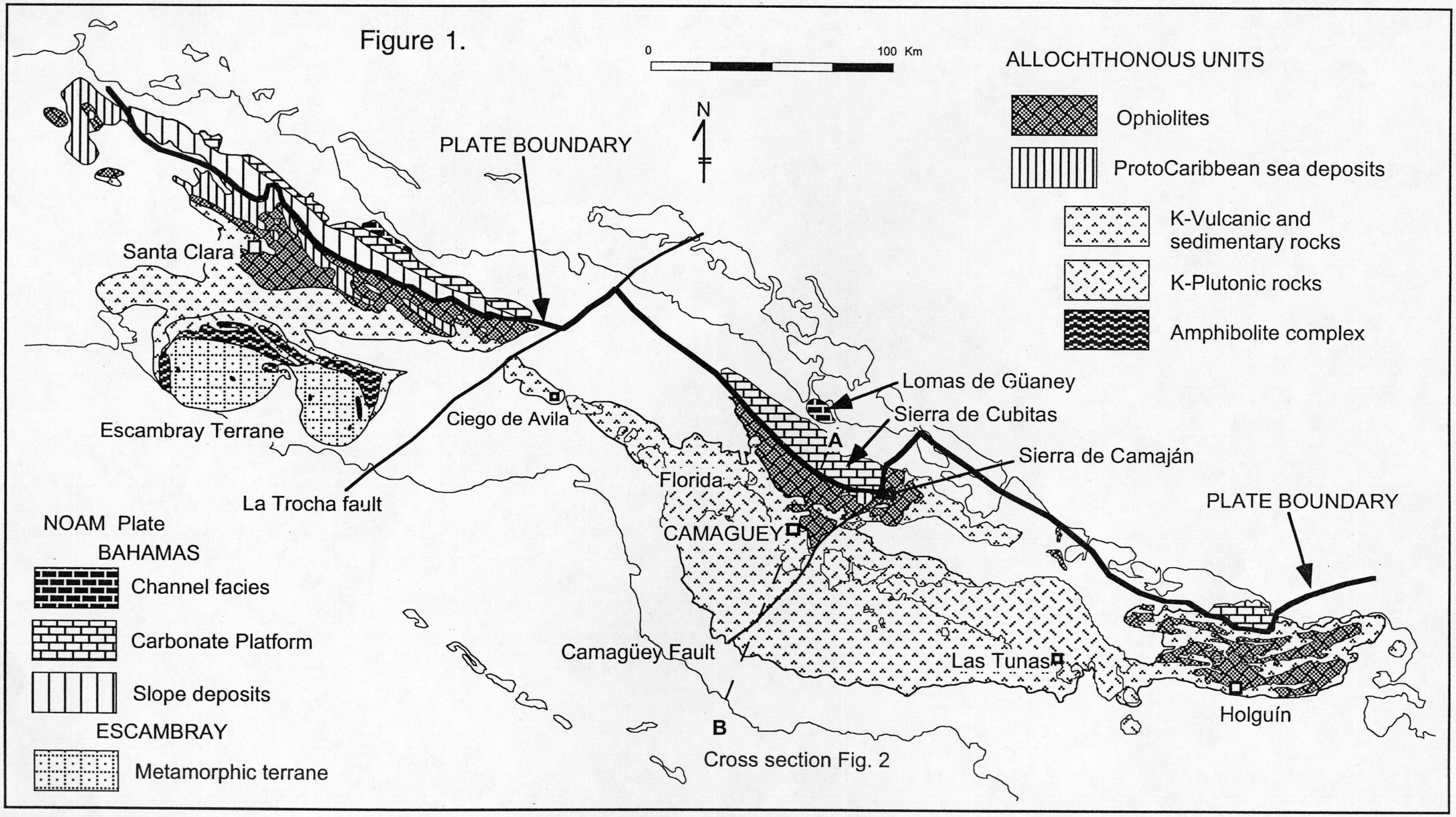
Sedimentary basins

Foreland basins: Foreland basins developed on top of the Bahamas carbonate platform. The first occurrence of ophiolitic and volcanic arc reworked debris is recorded in Paleocene deposits of the southern margin of the foreland (within the Camajuaní zone outcrop west of La Trocha fault). Generally the basin was filled with clastic sediments of Lower to Middle Eocene age. Early in the Upper Eocene the foreland basins were completely overthrust by the allochthonous ophiolites and volcanic arc suites as shown in Figure 5.

Piggyback basins: On top of the allochthonous units, several Paleocene-Eocene basins evolved. These are filled with clastic and clastic-carbonate sedimentary rocks. Some of these basins, located above the ophiolites, were strongly deformed during the late Middle and Upper Eocene thrusting event (Fig. 3 and 5).

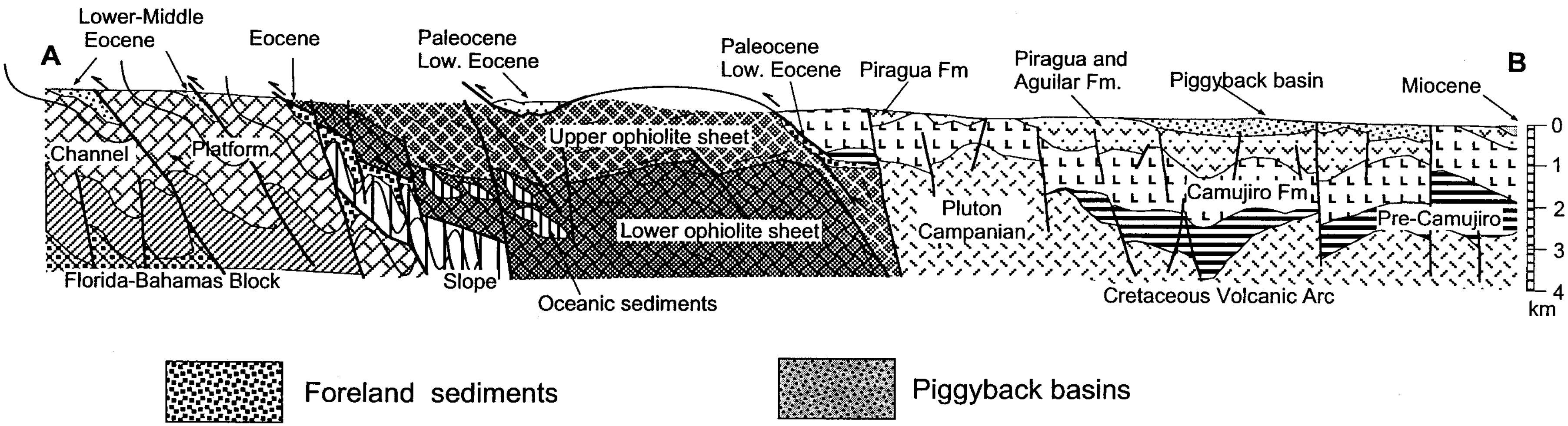
Post-orogenic basins: Since the Upper Eocene, post-orogenic undeformed basins developed on the Cuban foldbelt. Three deposition cycles can be distinguished within the sedimentary sections of these basins, one from Upper Eocene to Oligocene, another from Lower Miocene to Upper Miocene, and the last from Pliocene to Present times. Each cycle started with a transgression and the deposition of clastic sediments, and ended with shallow-marine carbonates.

Figure 1.



GEOLOGIC MAP OF CENTRAL CUBA, SHOWING MAIN TECTONIC UNITS IN THE OLD CARIBBEAN PLATE BOUNDARY.

Figure 2. Cross section of Camagüey



In this cross-section is observed the relationships among the various geologic units of the Camagüey area. From south (B) to north (A) the volcanic arc suite is found first with a general brackyfold structure. The Camagüey Campanian pluton is found underneath these units. During the collision of the arc with the ophiolites, the plutonic core acted as a deep spike preventing further thrusting of the arc. Only some of the vulcano-sedimentary section of the arc was transported above the ophiolite.

The ophiolite allochthon during emplacement became sliced into two main sheets. The upper sheet has inclusions of metamorphic rocks which were probably derived from depth. The lower ophiolite sheet contains inclusions of highly deformed non-metamorphosed oceanic volcanics and hemipelagic sediments.

Figure 3. Structure of the Camaguey ophiolites

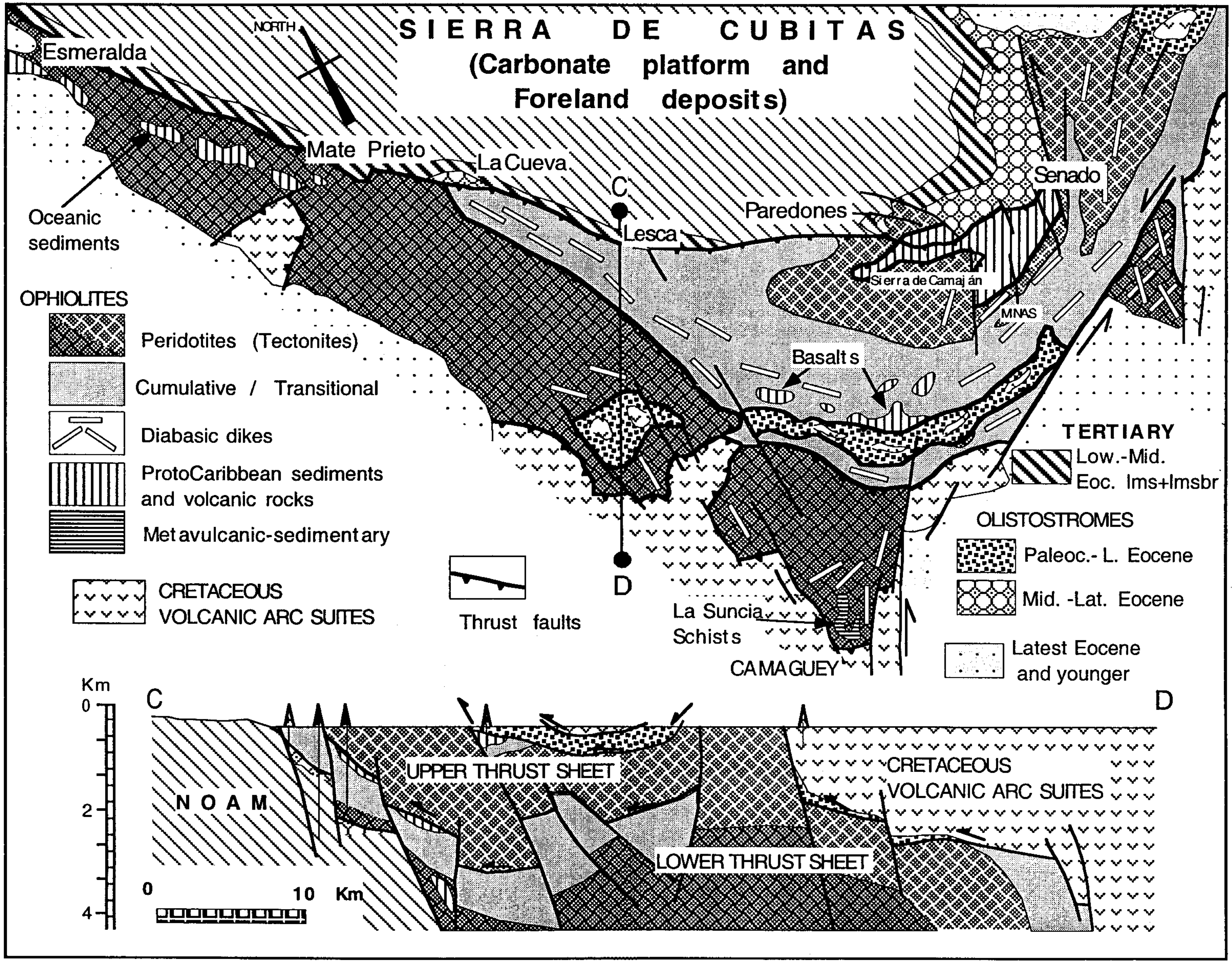


Figure 4. Stratigraphic units of the Cretaceous volcanic arc suites in Camagüey.

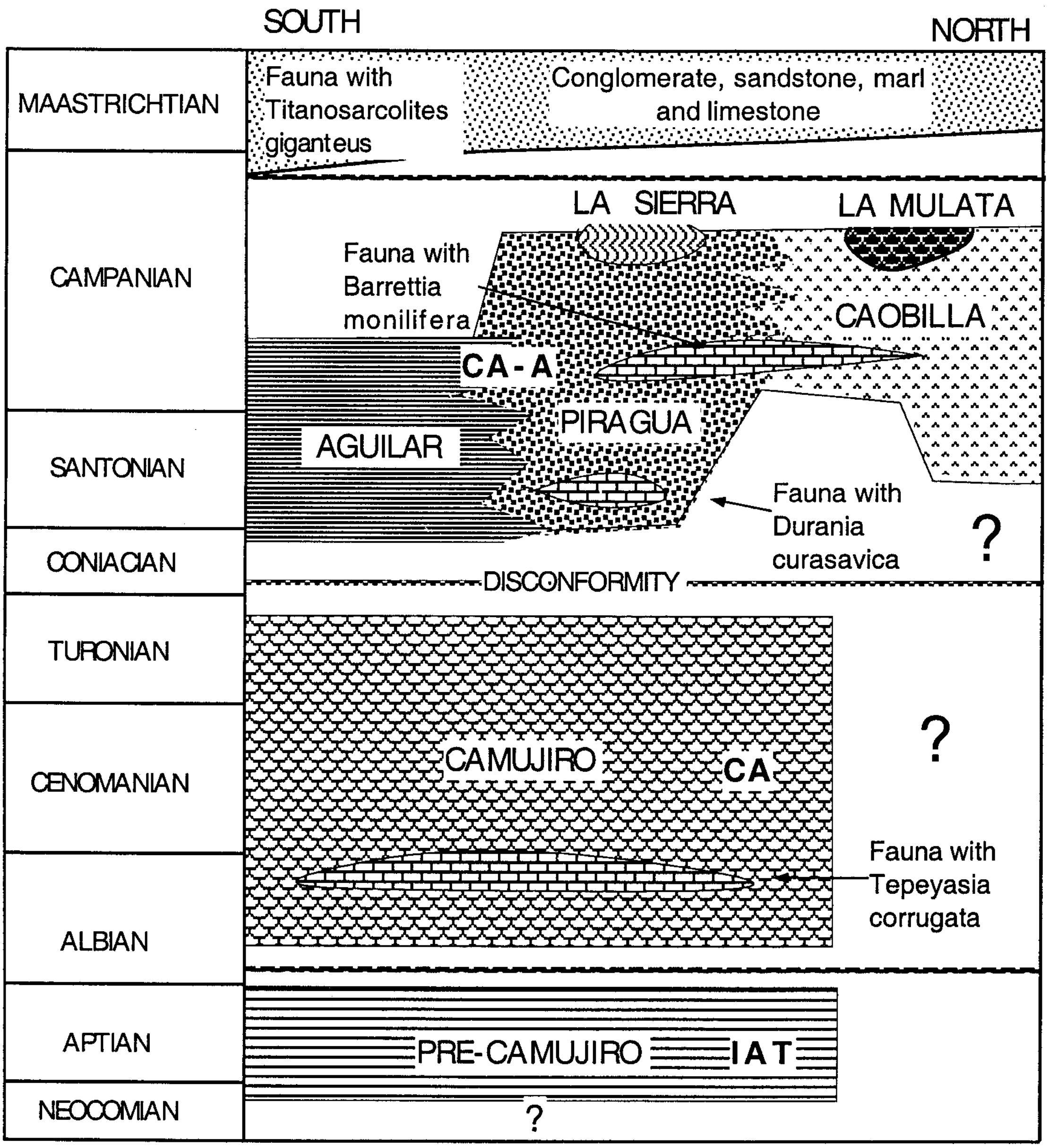
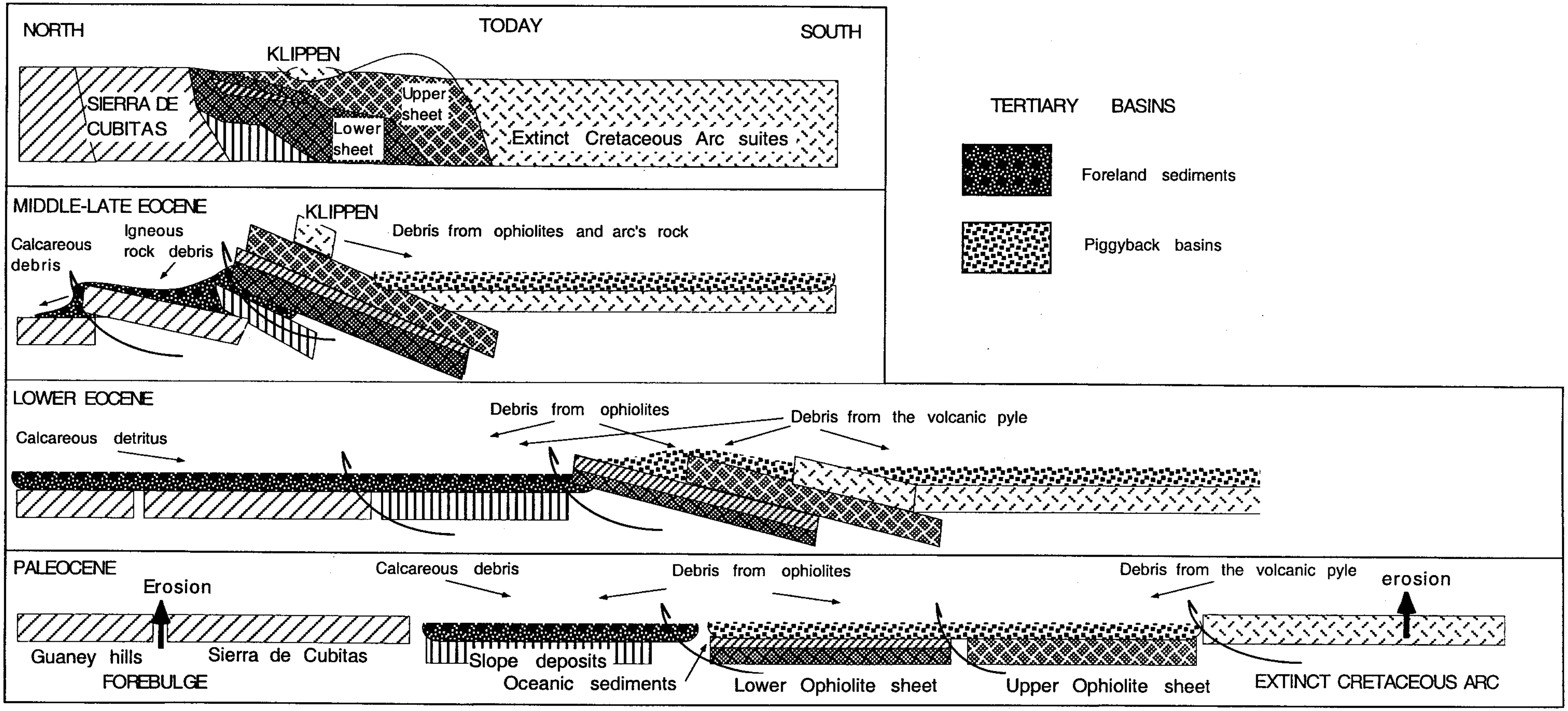


FIGURE 5. Evolutionary cross section of the plate boundary in the Camagüey area during the Tertiary



SCHEDULE AND DESCRIPTION OF STOPS

Day 1 (March 23): Transportation from Havana to Camagüey.
Hotel Horizontes Camagüey.

Day 2 (March 24): Camagüey - Lesca - Paredones - Hoyo Bonet.
Contact between the allochthonous Ophiolites and the Bahamas.

South of Sierra de Cubitas are outcrops of the Old Caribbean Plate Boundary (Cubitas fault), represented by the contact between the allochthonous ophiolites in the south, and the Cretaceous-Eocene carbonate rocks in the north. Today the contact is obliterated by a younger vertical fault system. During this part of the trip we will be visit several outcrops of the ophiolites and the Sierra de Cubitas limestones.

Stop 1: Loma del Agua. Scenic view of the Cubitas Fault
North: Sierra de Cubitas hills, where Cretaceous carbonate platform rocks and Eocene foreland sections occur. The sharp southern slope of Sierra de Cubitas coincide with a complex vertical fault system, but just south the ophiolites rest in thrust contact above Sierra de Cubitas sections. *East*: are the Camaján hills, an outcrop of Late Jurassic through Middle Eocene rocks of the former proto Caribbean sea. *West*: the Meseta de San Felipe, where lateritic ores are developed above serpentinite and gabbroids.

Stop 2: Outcrop of layered gabbroids of the transition between the tectonites and the layered cumulative gabbros. These rocks have been described as troctolites.

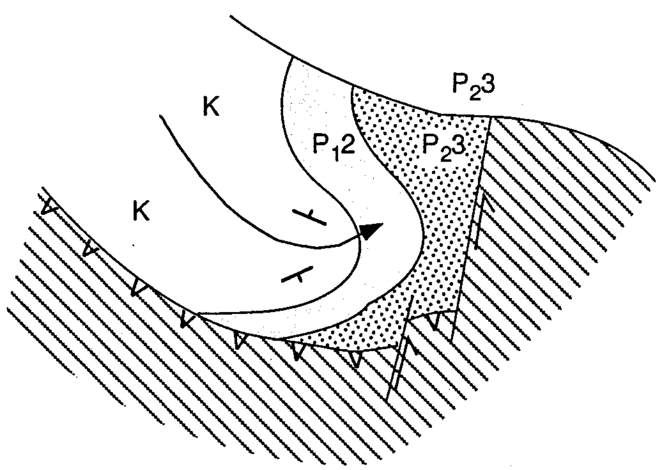
Stop 3: Sierra de Cubitas Quarry. Here the Lower to Middle Eocene, well bedded, hemipelagic limestones with intercalated shales and cherts (Lesca Formation) occur, as well as Lower Eocene carbonate breccias (Embarcadero Formation) which unconformably overlie the Late Cretaceous carbonate platform facies of the Purio Formation. Maastrichtian rudist-bearing rocks of the Purio Formation have been reported not far from this site (Iturralde-Vinent and De la Torre, 1990). The locality is at Paso de Lesca, along the road from Camagüey to Sola, where are found exposures of Maastrichtian platform margin facies, characterized by thickly bedded partially recrystallized shelly bioclastic floatstones and fine- to medium-grained grainstones, white to light greyish in colour. Some beds contain abundant large-sized *Biradiolites lombricalis* in living position, while thin floatstone layers include transported *Titanosarcolites* aff.*alatus, Antillocaprina* sp., *Mitrocaprina* sp. along with typically Maastrichtian orbitoidal foraminifera (Rojas et al., 1996).

Stop 4: Paso de Paredones. Outcrop of the Late Cretaceous Purio Formation. represented by well bedded foraminiferal limestones and dolostones. These are interior platform facies with invertebrates typical of hypersaline environments. Usually the shells have been dissolved and the rocks recrystallized as dolostones. Some thrust fault planes diping S-SE occur along the walls of the road.

Stop 5: Hoyo de Bonet (Large sink hole). Exposured are strongly folded Purio limestones, representing the deformation of the Bahamian carbonate platform due to the emplacement of the allochthon between Middle and Late Eocene. Many tight isoclinal folds are visible on the wall of the sink, with the axial plane diping SE.

Day 3 (March 25): Camagüey - Minas - Camaján hills - Senado - Sola. Relationships between the ophiolites, olistostrome and the Bahamian margin.

Today we will travel along the allochthon and will reach the eastern end of Sierra de Cubitas in the area NW of the town of Senado. In this area the Cubitas thrust unit plunges SE-ward into the Senado olistostrome, producing a pinched closure of the whole unit. The Cubitas fault is interrupted here by N-NE trending faults, and a very interesting structure is formed (sketch below and Fig. 3).



Stop 6: Cumulative gabbroids. Large body of layered dunites - gabbroids - leucogabbroids.

Stop 7: Nueva María Quarry. Exposured are oceanic basalts and hyaloclastites of Tithonian age (Nueva María Formation) and the transition into hemipelagic limestones and shales of Late Tithonian age (Velóz Formation). These rocks are part of the Camaján Hills, which represent an example of the Late Jurassic to Maastrichtian oceanic volcanic and sedimentary deposits of the Caribbean Sea.

Stop 8: Senado railroad cut. Exposured are the Middle to early Late Eocene Senado olistostrome. This unit overlies with transition the Lower to Middle Eocene Lesca Formation. The Senado olistostrome is developed just below the allochthonous ophiolite sheet.

Stop 9: Embarcadero Fm. Late Paleocene to Lower Eocene sedimentary carbonate breccia. This section rests unconformably above the Cretaceous Bahamian carbonate bank and toward the upper half gradually changes into hemipelagic limestones of the Lesca Fm.

Stop 10: Near Sola. Latest Eocene post-orogenic conglomerates and marls (Nuevitas Formation), which rest unconformably above the various terranes of the deformed Cuban foldbelt. The occurrence of these sediments demonstrate that since latest Eocene no thrust faulting took place in the Cuban foldbelt onland.

Day 4 (March 26): Camagüey - Jimaguayú - Jimbambay - Loma Caballero - Cascorro – La Sierra - Colombia. The Cretaceous volcanic arc.

The Cretaceous arc in Cuba is represented by three different suites, a lower IAT unit, a middle CA unit, and an upper CA-A unit (Fig. 4). These three suites outcrop in Camagüey province of Central Cuba and will be visited today, as well as the unconformities that separate these rock suites.

Stop 11: Jimaguayú. Small hill located just south of the village of Jimaguayú. Mid Cretaceous late Albian - Turonian calc-alkaline agglomerates and volcanic breccias (Camujiro Formation). This unit represent near-volcanic-vent facies. One andesitic block from this outcrop is characterized as andesitic clinopyroxene phyric (2-3 mm). The medium-grained groundmass consists of altered plagioclase needles, granular clinopyroxenes, oxide rhombs, and possibly small olivine relicts (Kerr et al., 1999).

Stop 12: Loma Caballero. Contact between the Camujiro and Piragua Formations. This contact somehow represents the mid-Cretaceous unconformity described elsewhere. Here occur a 40-50 meters thick limestones unit as part of a sharply transgressive sequence resting unconformably above Albian-Cenomanian volcano-sedimentary rocks (Camujiro). At the base are some 3 m of volcaniclastic conglomerates and sandstones, followed by 2 m of well-cemented, mixed volcaniclastic/bioclastic pebbly sandstones. Then follow the thick-bedded, dark grey limestones with rudists and acteonellids. Some layers are coarsely bioclastic, but most are fine-grained, although a further conglomeratic lens is intercalated in the lower part. Near the top, the unit becomes finely stratified, and fine-grained limestones are intercalated with tuffites and tuffs that dominate the upper part of the section. In the lower part of the thick limestone unit ocur abundant *Barrettia monilifera*, as well as *Biradiolites* ex. gr. *Acuticostatus, Mitrocaprin* sp. and *Macguillavria nicholasi*, together with oysters, large acteonellids (in a band a little higherup), unidentified burrowing bivalves, and rare horizontal burrow systems. In some localities, this thick limestone unit of the Piragua Formation is represented by a set of thinner limestone intercalations in the tuffaceous section.

Stop 13: N. of Sibanicú (La Sierra). Latest Cretaceous La Sierra subaerial rhyodacitic and rhyolitic flows. These rocks represent one of the latest volcanic extrusions of the Cretaceous arc. They are related with very young epithermal mineralization that have been Ar-Ar dated as 72 m.y. (Simon et al., 1999).

Stop 14: Between Sibanicu and Cascorro. Plutonic rocks. NE trending dikes of dioritoids which intersect the Cretaceous volcanic and plutonic rocks. The trend of these dikes is parallel to the Camagüey fault, a set of sinistral strike-slip faults that intersect the Cuban foldbelt. This fact means that the younger Camagüey system followed older structural weaknesses within the Cretaceous volcanic pile.

Stop 15: Near Colombia Sugar mill. The oldest well-dated basalts known from the Cretaceous arc (Colombia basalts) are intercalated with mid Albian rudist limestones. The limestone are a lens of poorly stratified, pale to dark grey but locally reddened, recrystallised bioclastic limestone, about 1 km long and 40-50 m thick. The limestone lens is embedded within basalts, but the basal contact is erosional, indicating that the rudist-bearing limestones were deposited during a magmatically quiescent period, probably on top of an eroded volcanic substrata. The rudist assemblage belongs to the mid-Albian *Tepeyacia corrugata* fauna. The basalts were geochemically characterized by Kerr et al (1999: COL 1 and COL2) transitional between IAT and CA, represented by glomerophyric clots of plagioclase and clinopyroxene in a fine-grained groundmass of plagioclase laths and clinopyroxene granules.

Day 5 (March 27) Return to Havana

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