IGCP Project 433: Caribbean Plate Tectonics

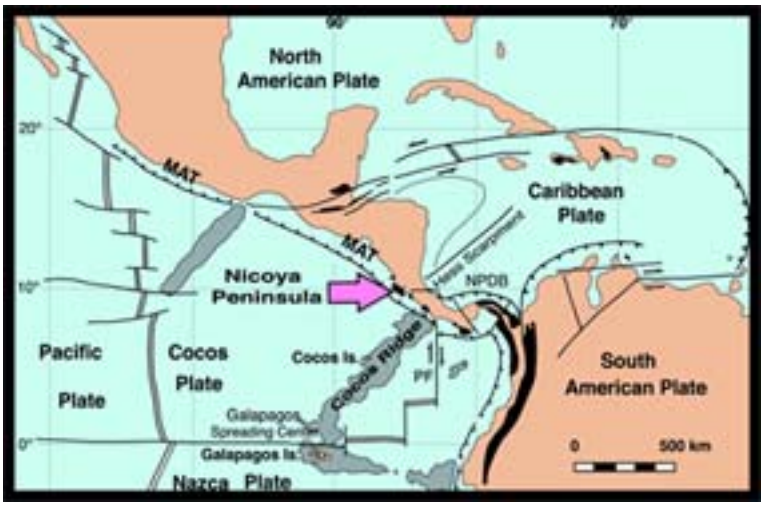
Scientific Report of Field Workshop to the "Nicoya Complex" in Costa Rica

M. Iturralde-Vinent and the field workshop group

The Field workshop (March 1-7th, 2004) was organized by Percy Denyer (Escuela Centroamericana de Geología, Costa Rica), who did a great job taking the group to well chosen exposures of the so-called "Nicoya Complex" and related rocks. The workshop was attended by 11 persons, 3 from Puerto Rico (W. Ramírez, H. Schellekens, I. Carre), 3 from USA (J. Lewis, C. Greene, K. Johnson), one from Guatemala (S. Bonis), Nicaragua (M. Valle), Germany (K. P. Stanek), Spain (A. García Casco) and Cuba (M. Iturralde-Vinent).

The first day four lecturers from de Escuela Centroamericana de Geología (ECG), addressed the group with important presentations concerning the Geotectonic of Central America (Walter Montero), the stratigraphy and tectonics of Costa Rica (Alain Astorga), the geology of the Nicoya Complex (Guillermo Alvarado), and an introduction into the Field workshop (P. Denyer). Dr. Tourist Aguilar, director of ECG, welcomes the IGCP group.

The next six days were dedicated to visit outcrops from north to south, along the Pacific margin of Costa Rica, including the Santa Elena peninsula, the Nicoya peninsula, and the Osa peninsula (see map below). The last day in the afternoon there was a group discussion, organized by the project's co-leader, in order to summarize our observations and experiences. Some of these are described in the following paragraphs.



Tectonic setting of Costa Rica.

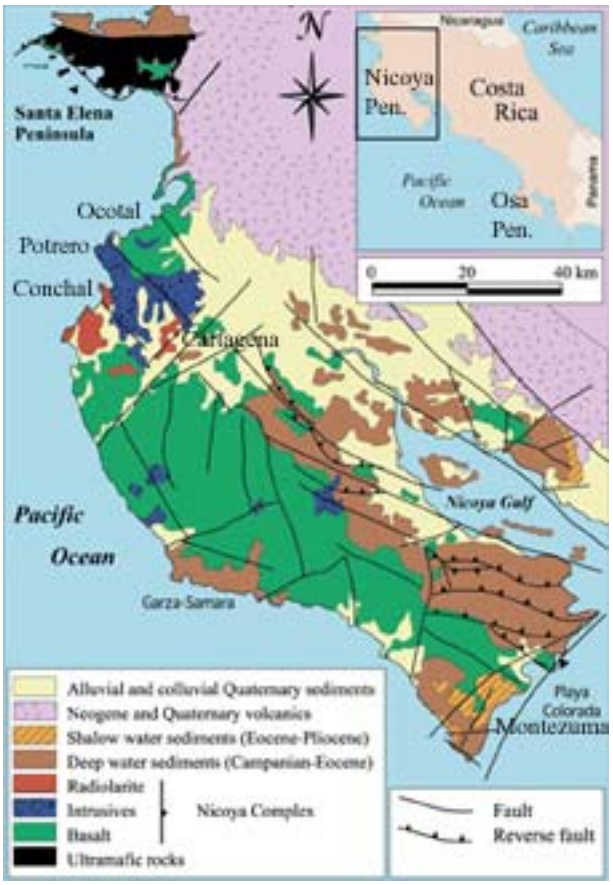
Before visiting the area, our view of the region was delineated by Percy Denyer as follow: "*The Nicoya Peninsula has been studied since the sixties, because of its outcrops of oceanic crust and its importance for the understanding of the origin and*

geotectonic history of the Middle American convergent margin. It consists of a Jurassic-Paleogene basaltic ophiolitic sequence, mainly composed of basalts that occur as massive and pillow flows, dykes, and hyaloclastic breccias. Subordinated rocks include komatiites, alkali-olivine basalts, gabbros, ferrogabbros, diabases, picrites and plagiogranites. The age of the igneous sequence corresponds to the Upper Cretaceous sill event.

Deep-sea radiolarian cherts were deposited from the Middle Jurassic to Late Cretaceous. No Jurassic oceanic basement has been identified so far at the outcrop level in the Nicoya Peninsula, but could be buried beneath the surface. The Jurassic-Cretaceous chert sediment pile became disrupted and detached from its original basement by multiple intrusions during the formation of the Caribbean Plateau.

Hemipelagic and pelagic rocks, rich in epiclastic elements (shards, pumice, plagioclases and amphiboles) are circumstantial evidence of a paleo-magmatic arc of Albian to Late Santonian age.

In the Santa Elena peninsula, crops out a peridotitic nappe composed by diopside-bearing harzburgites and lherzolites, scarce plagioclase peridotites, dunites and orthopyroxenites. This nappe is cut by dykes of diabases, ultramafic cumulates, clinopyroxenites and pegmatitic gabbros. The relatively autochthonous series consists of radiolarites, cherts and basaltic breccias.

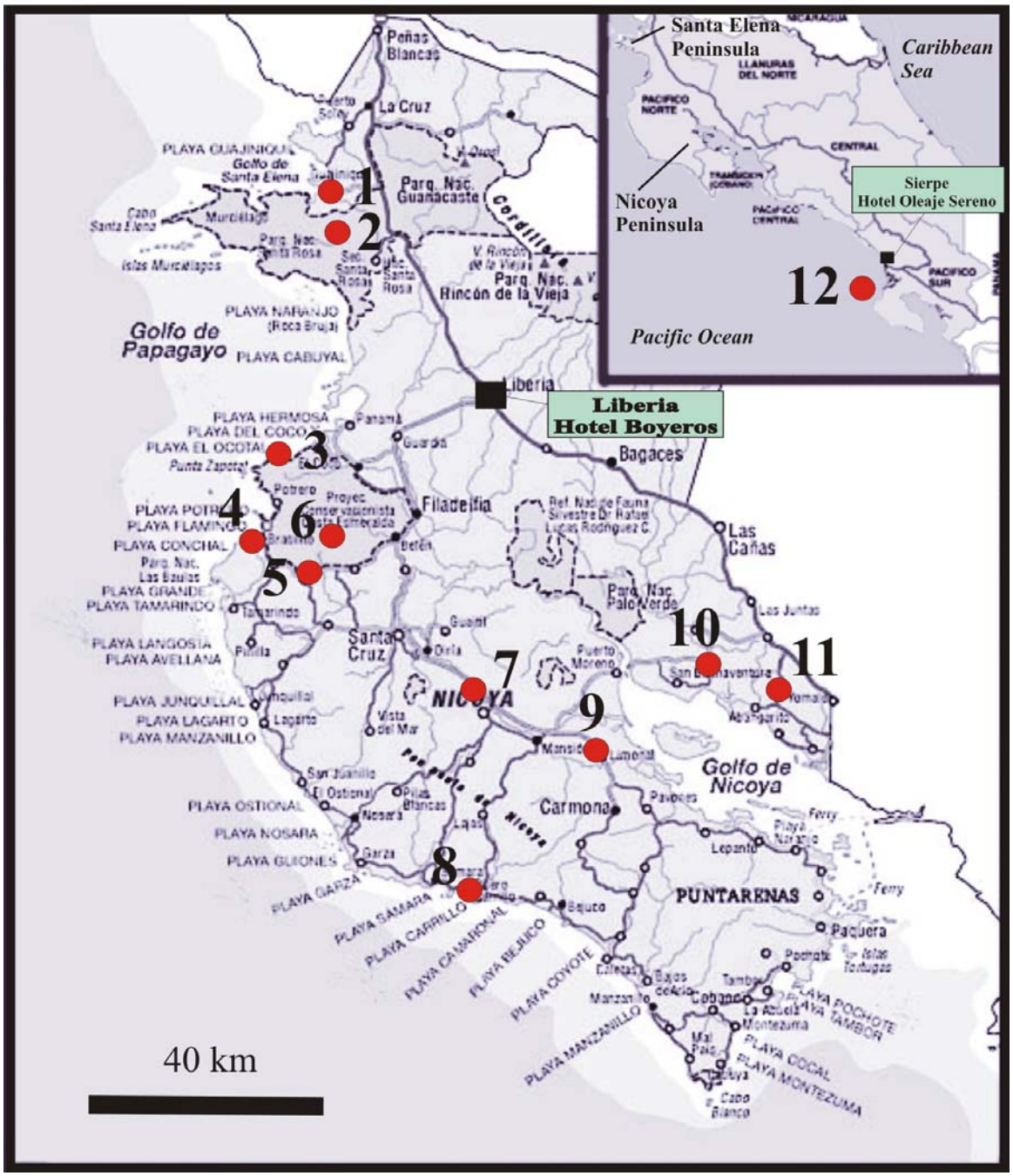


Generalized geologic map of Costa Rica

The Nicoya peninsula consists of different terranes, the Nicoya terrane accreted to the edge of the Caribbean plate during Cretaceous to Late Eocene, and now is cropping out of the outer part of the peninsula of Nicoya and the Santa Elena peninsula. The Shortage terrane constitute the inner part of the Nicoya"

With this overview in mine we visited as much as twelve outcrops and reached the following conclusions:

Overview



Stops visited during the field trip.

Summary of the field observations

Although these observations are in general the opinion of the participants and field trip leader, the author take full responsibility for them, as there are some minor discrepancies.

St Elena is the only area that has most of the rock types, including mantle peridotites, which are found in ophiolite associations. In the Santa Elena peninsula (Stops 1 and 2) crops out a thrust sheet composed of diopside-bearing harzburgites and lherzolites, scarce plagioclase peridotites, dunites and orthopyroxenites. This mantle peridotite nappe is cut by dykes of diabases, ultramafic cumulates, clinopyroxenites and pegmatitic gabbros. We were able to visit outcrops of the peridotites, and in blocks along the river were also found layered gabbroids, plagiogranites? and amphibolites. This last lithology was not reported before, but appears to be quite abundant. Work on the nature, age and origin of the amphibolites within the Santa Elena peridotites should be addressed in the future in order to decipher the thermal history of this peridotite sheet. This mantle sheet, a few hundred meters thick, overlies a strongly deformed basaltic complex with radiolarites, which outcrop in a tectonic window along the seashore and within a river valley. Samples of these basalts has an arc geochemical signature and were dated as Lower Cretaceous (110-96 Ma) (Hauff et al., 1997, 2000). Radiolarian cherts of Middle Jurassic (Bajocian) to Late Cretaceous (Cenomanian) age have been found within the basaltic complex. Latest Cretaceous (Campanian-Maastrichtian) limestones overlie the deformed basement, indicates that the emplacement of the peridotites took place before the Campanian.

Some authors suggest that Santa Elena is part of the Nicoya complex, while others concluded that they represent an independent oceanic terrane attached to the Chortis block. Mantle plume igneous rocks have not yet been properly identified in the area. We believe that in Santa Elena may be present, intermingled, several relatively independent elements: 1. The Mesozoic radiolarites and basalts as fragments of the Pacific ocean crust; 2. The arc-related rocks probably as part of a volcanic arc, and 3. The ultramafic-mafic rocks as a sliver derived from the mantle. In the future more dates and geochemistry of the basalts associated with the radiolarites needs to be done. The Lower Cretaceous arc-related rocks can be either a fragment of the present Antillean basement (at the eastern [Antillean] edge of the Caribbean plate), or may be part of the pre-Campanian arc developed in the Nicoya peninsula (on the western edge of the Caribbean plate). Will come back to this matter below.

As in the Santa Elena peninsula, in the Nicoya peninsula crops out strongly deformed Lower Jurassic to Cenomanian radiolarian cherts embedded in basalts and related rocks. Originally the age of the basalts was identified according to the age of the associated radiolarites. But in recent years, several samples of the basalts have been radiometrically dated as Late Cretaceous (92.5 - 83.2 Ma; Turonian-Santonian), suggesting that they belong to the Caribbean plateau basalts (mantle plume). As a consequence, the relationship of the radiolarites with the igneous rocks was revisited, finding that the contacts are magmatic (Punta El Encanto, Playa Potrero). This means that probably much of the extensive outcrops of gabbroids, dolerites, plagiogranites, and pillow and massive basalts of the Nicoya peninsula may be a representative of the Caribbean Late Cretaceous plateau basalt province. The fact that only some radiolarites (but certainly not all of them) are found embedded in the igneous complex, may be due

to the very limited assimilation of highly siliceous rocks by mafic magmas. On the other hand, the Mesozoic radiolarites embedded in this igneous complex, can be interpreted as punctuated remnants of the original Pacific crust, generally amalgamated with the magmatic bodies produced by the activity of the mantle plume. Similarly, the rare occurrence of original Jurassic-Cretaceous basalts of the Pacific crust can be explained by their incorporation into the newly formed large magmatic bodies. We considered Nicoya peninsula as an excellent example of an exposed plateau basaltic crust.

In the Rivas-Tempisque area including Nicoya peninsula (northwestern part of Costa Rica), outcrop sedimentary and igneous rocks of Albian (or older) to Santonian age, which encompass the Loma Chumico, Berrugate, Sabana Grande and related Formations. These units were generally deposited in deep-water environments, and include cherts and well-bedded turbidites represented by conglomerates, sandstones and shales. These rocks contain glass, grains and crystals of amphibole and plagioclase derived from a contemporaneous volcanic arc source. Up to the present it is not evident if the Late Cretaceous mantle plume event somehow overprinted these rocks. The ?Albian-Santonian arc-derived sections of the Rivas-Tempisque area may be interpreted in two ways. First, it can be considered as autochthonous remnants of a pre-Campanian volcanic arc originally located along the southwestern Pacific edge of the Caribbean plate. In the coast of Manzanillo beach outcrop pillow basalts (with large number of small pillows) overlain by (and probably intercalated with) cherts and turbidites, including conglomerates with poorly sorted clasts of basalts and other volcanic rocks. The geochemical signature of the basalts is not known for certain, neither the precise age of the section. If the section can be ascribed to the Cenomanian-Turonian Berrugate Fm. (Flores 2003), and the basalts are MORB, it may probe that the ?Albian-Santonian arc is autochthonous in the Caribbean plate. Second, the Rivas-Tempisque ?Albian-Santonian sections can also be interpreted as an allochthonous suspected terrane, originated somewhere along the Pacific margin of the Chortis block, which later became amalgamated as part of the Chorotega block. In favor of this interpretation are two points: 1. The location of the sections only within the Rivas-Tempisque area, northwest of Costa Rica; and 2. The observation that in the locality of Loma Chumico outcrops a well-bedded section of Albian quartz sandstone with mica, which probably derived from a mixture of continental and volcanic arc sources. The hypothetical continental crust source may be the Chortis block, probably the Todos Santos Formation or older units. In the future more detailed research is needed of the Loma Chumico Formation, in order to verify if it really had a continental crust source; and if it does, where it may have been originally located. The problem with this suspected terrain is the age of its hypothetical emplacement. Such emplacement into the Chorotega block, may have happened only very recently, when the western edge of the Caribbean plate was in line with the Chortis block.

One of the most outstanding tectonic events in Costa Rica, a general deformation, uplift and exposure, is recorded by the pre-Campanian regional unconformity, which can be observed in many localities. Above the unconformity rest transgresional sections of Campanian to Eocene sedimentary rocks composed by red breccias, conglomerates, sandstones and limestones, representing a variety of environments from terrestrial to deep marine. These rocks contain volcanic-derived materials, which suggest the near-by co-evolution of a volcanic arc source. As with the ?Albian-Santonian volcanic-derived turbidites, no traces of the actual arc rocks (arc plutons' and calc-alcaline lavas) have

been found in Costa Rica. A mid-Maastrichtian unconformity and hiatus is recorded in these sections, which were also deformed in the Eocene.

The are several difference between the ?Albian-Santonian and Campanian-Eocene volcaniclastic sections. The first probably include volcanic arc basaltic rocks (Santa Elena), was overall deposited in deeper waters, probably contain continentally derived sediments, and it may represent a suspected terrane derived from the north. The second include terrestrial deposits, more limestones, and overlie the Caribbean plateau basaltic complex, so it was originally deposited above the Caribbean crust.

The Osa-Caño accretionary complex is developed in the Osa peninsula and surroundings. It is composed by a Late Paleocene to Middle Eocene melange including probable a trench-derived complex that includes Late Cretaceous to Early Eocene blocks of basalts, andesites, tuffs and sediments (graywakes?) of centimeter to tens of meters in size. It may represent the accretionary complex of the Campanian-Eocene volcanic arc.

Plate tectonic implications of the field observations

As preliminary conclusions of the field observations, and from previous research in the area, we concluded that the following tectonostratigraphic units are present in Costa Rica:

(1) A Lower Jurassic to Late Cretaceous radiolarian cherts and basaltic complex representing an oceanic crust segment of the Pacific Ocean. These rocks have been included in the Nicoya complex, or named the Lower Nicoya complex, or the Matapalo Formation along with other rocks. Probably all these names have to be abandoned to avoid confusion.

(2) An ?Albian-Santonian oceanic arc complex including arc-related basalts, radiolarian cherts and volcanic-derived turbidites, which may be either autochthonous to the Caribbean crust, or an allochthonous suspected terrane derived from the Chortis block. Usually these rocks were included in the Nicoya complex, but this usage should be abandon to avoid confusion.

(3) A latest Cretaceous (92.5 - 83.2 Ma) igneous complex derived from a mantle plume, known as the Caribbean plateau basaltic province. Usually these rocks were included in the Nicoya complex, but this usage should be redefined to avoid confusion.

(4) A Campanian-Eocene arc-related complex, autochthonous to the Caribbean plate,

(5) The Osa-Caño accretionary complex of the previous arc.

These conclusions have important implications for the plate tectonic evolution of the Caribbean Plate:

First, now can be hypothesized that the Caribbean plate may encompass Lower Jurassic to Late Cretaceous crust. If this is the fact, it is interesting to underline that, associated to mafic-ultramafic rocks, have also been found radiolarian cherts of similar antiquity in Cuba (Late Jurassic), Dominican Republic (Middle Jurassic), Puerto Rico (Lower Jurassic), La Desirade (Late Jurassic), and Venezuela/Siquisiqui) (Middle Jurassic).

Second, the occurrence of ?Albian-Santonian arc-derived rocks, in the Rivas-Tempisque area, may suggest that already since the Lower Cretaceous the Caribbean plate was independent, and its westernmost edge was a convergent one with an active arc-subduction system. Although this is the more simple and parsimonious explanation, still there is the possibility that these rocks may be allochthonous, in which case, they may represent a fragment of the Antilles arc basement later incorporated into the Chorotega block. We believe that this is a major question to be addressed, in order to reach an agreement about the ?Albian-Santonian evolution of present Central America.

Third, in the area of the so-called Chorotega block occurs arc-derived rocks of at least four distinct stages: ?Albian-Santonian, Campanian-Maastrichtian, Maastrichtian-Eocene, Miocene to Present. These stages are separated by tectonic events including deformations, unconformities, hiatus, and modification of the orientation of the arc.

Fourth, the Osa-Caño subduction complex suggests that tectonic erosion of the Caribbean plate was not a permanent event, but took place also in the past. The occurrence of Late Cretaceous to Early Eocene blocks probably derived from seamounts, suggest that tectonic erosion may have taken place in the past. Therefore, erosion and accretion may be common events along a subduction front.

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Hot Picks

In several localities visited during the field trip we have observed very interesting sections and/or outstanding features which we would like to share in the following pictures and paragraphs – *Coming soon!*