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The Santa Elena Peninsula : an ophiolitic nappe and a sedimentary volcanic relative autochthonous

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Abstract

The Santa Elena peninsula, northern Pacific coast of Costa Rica, is formed by three structural units: a relative autochthonous unit, an allochthonous peridotitic unit and a sedimentary cover (Campano/Maastrichtian to Paleogene in age). The autochthonous unit crops out as tectonic windows in the Center and the South of the peninsula. It consists of strongly folded layered radiolarites and cherts, Lias-lower Dogger to Cenomanian in age. Various sequences of dykes and pillowed basaltic flows display alkaline compositions. The allochthonous unit is a 35 km long peridotitic massif. Most peridotites are diopside bearing harzburgites and lherzolithes and correspond to relatively poorly depleted mantle rocks. Plagioclase peridotites and scarce dunites also occur. Pyroxenitic layers parallel the foliation of the enclosing peridotites. The mantle sequence is cut by dykes composed of ultramafic cumulates, pegmatitic gabbros and very abundant dolerites. A layered sequence made of cumulates, gabbros and scarce plagiogranites is overthrust by the peridotites. The allochthonous unit does not present the stratigraphy of a classical ophiolitic complex and the various sequences of mafic rocks are not cogenetic. Similar mantle peridotites occur in the Río San Juan area. The possible occurence of a 150 km long East-West peridotitic suture is discussed. Such a structure could be the result of the Senonian closure of an "oceanic Basin" by convergence between the Southern Central American block and the Chortis block.

INTRODUCTION

The Santa Elena peninsula, North Costa Rica, is 30 km long with hilly terrain and an E-W orientation oblique in relation to other Costa Rican orographic systems. HARISSON (1953) first noticed extensive outcrops of peridotites intruded by mafic rocks and overlain by a Late Cretaceous cover. DENGO (1962) described radiolarites and diabases regarded as lateral equivalents of the Nicoya Complex and suggested that the emplacement of the ultramafic massif was linked to the Clipperton Fracture Zone. DEBOER (1979) interpreted the peridotitic massif as the lowest unit of a "Nicoya Ophiolitic Complex". Radiolarites which crop out in lower areas of the peninsula were regarded as the upper unit of an ophiolitic pile collapsed by normal faulting (SCHMIDT-EFFING, 1979). AZÉMA & TOURNON (1980, 1982) proposed an alternative interpretation involving tangential tectonic and nappe emplacement of the ultramafic massif onto a relative autochthonous unit made of sedimentary and volcanic rocks. Petrological studies were carried out by WILBERG (1984), TOURNON (1984), DESMET et al. (1985), DESMET & ROCCI (1988). Chronology of the sedimentary formations was supported by determinations of radiolarian fauna (SCHMIDT-EFFING, 1980; DEWEVER et al., 1985).

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AZÉMA & TOURNON (1980, 1982) distinguished several structural units from base to top (Fig. 1, 2):

- a sedimentary and volcanic unit which crops out out in low areas of the peninsula, the Potrero Grande Valley and the Southern Coast. These outcrops are regarded as tectonic windows.
- megabreccias
- an allochthonous unit mostly made of peridotites and cutby mafic dykes
- a Late Cretaceous-Paleogene cover
- an ignimbritic slab originated from the Guanacaste Volcanic Cordillera
- off the southern coast, Islas Murcielago are made of basaltic flows.

THE SEDIMENTARY AND VOLCANIC AUTOCHTHONOUS UNIT

This lowest structural unit crops out at the bottom of the Potrero Grande valley and at the sea level along the southern coast (Fig. 1). It is covered directly by the ultramafic unit.

The Potrero Grande series include radiolarites, massive cherts, pelagic siliceous limestones,tuffs and scarce pillow basalts. Radiolarian fauna were assigned to Callovian, Hauterivian and Cenomanian (SCHMIDT-EFFING, 1980, DEWEVER et al., 1985).

Along the southern coast, at the present sea level, sedimentary and volcanic units crop out over 6 km of coastal cliffs. The succesion shall be described from West (Playa Carrizal) to East (Playa Respingue).

At playa Carrizal crop out alkaline pillow lavas, tuffs, schists and radiolarites bearing Upper Aptian-Lower Albian fauna. This sequence is faulted and strongly deformed. Eastward of Punta Danta, made of peridotites, are extensive outcrops of alkaline pillowed and massive basaltic flows. Along the coast called Sitio Santa Rosa crops out a regular succesion, the most complete found in Costa Rica for Jurassic and Lower Cretaceous. Chronology is supported by radiolarian fauna (DEWEVER et al., 1985). Dips are subvertical. Thick radiolaritic breccias alternate with thin homogeneous radiolaritic layers. Fauna are Lower Albian with reworked Neocomian and Malm species. Then outcrops a thick sequence of radiolarites made of centimetric layers interlaminated with thin argillaceous intercalations. This radiolaritic unit is cut by numerous sills of alkaline basalts. An homogeneous radiolaritic sample furnished a Lias-Lower Dogger fauna, the oldest documented in Costa Rica. The series follows with thick succesion of radiolaritic breccias with minor intercalations of cherts and radiolarites. Fauna are from Barremian to Cenomanian with reworked Malm species. These breccias are made of blocks of radiolarites and basalts. The symetrical disposition of the Santa

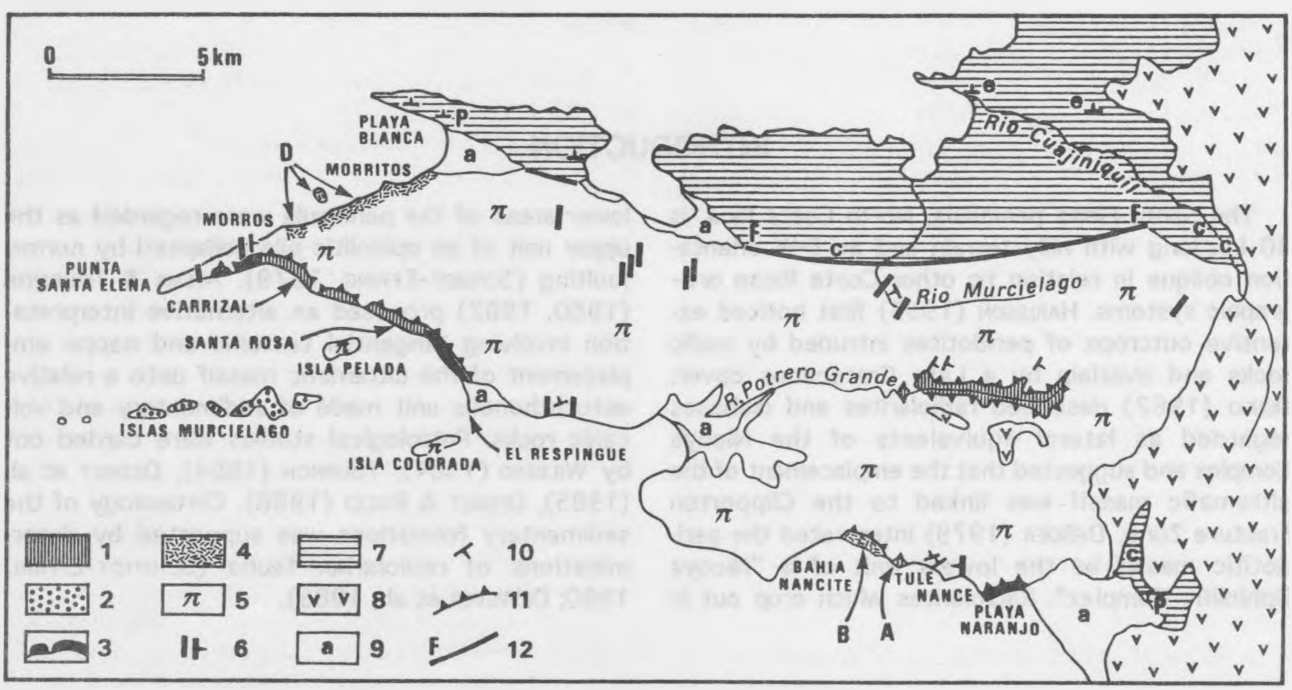

Fig. 1: The Santa Elena Peninsula: localization of structural units. 1: Autochthonous unit. Volcanic ans sedimentary series: Potrero Grande Valley and Southern Coast. A: detrital formation, Playa Tule. 2: ferrobasalts, Islas Murcielago. 3: megabreccias. Allochthonous units. 4 B: layered sequence, Bahia Nancite; 4 D: dyke swarm, western coast; 5: peridotites cut by dykes; 6: direction of doleritic dykes cutting the peridotites; 10: dips of foliation planes within the peridotites. 7: sedimentary cover. c: Late Campanian-Maastrichtian, p: Paleocene, e: Eocene, 8: Quaternary ignimbrites. 9: alluvial deposits. 10: dips of strata. 11: thrust contacts; 12: normal faults.

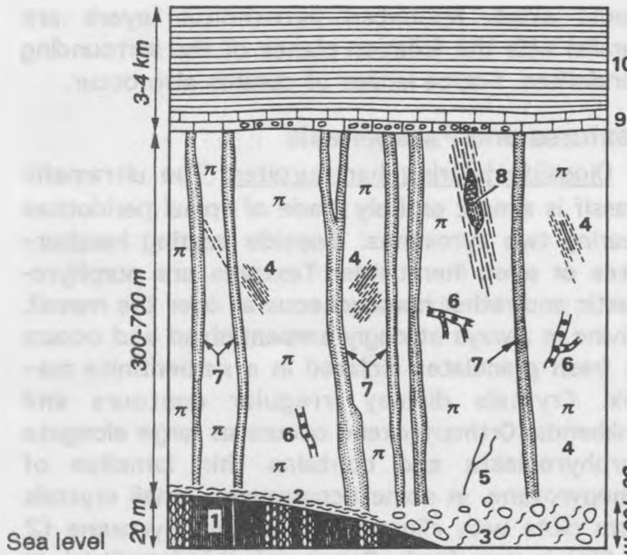

Fig. 2: Schematic column: relations between the structural units. Scales are not respected.
1: volcanic and sedimentary authochtonous unit, Lias-Lower Dogger to Cenomanian. 2: schistosed serpentinites. 3: megabreccis. 4: peridotites, foliation and thin pyroxenitic layers. 5: dykes of clinopyroxenites. 6: dykes of pegmatitic gabbros. 7: doleritic dykes with chilled margins. 8: lenses of foliated amphibolites. 9: reef limestones bearing pebbles of serpentinite, Late Campanian. 10: detrital series, Paleocene to Eocene. The layered igneous sequence of Bahia Nancite, which occurs as a tectonic slice, is not figured.

Rosa sequence suggest an anticline.

Eastwards, near Playa Respingue crops out a thick volcanic pile without any sedimentary intercalation and made up of alternating massive and pillowed basalts cut by basaltic dykes, tuffs and scarce trachytes.

In the eastern region of the peninsula (Playa Tule), a sedimentary formation crops out, it is intruded by microgabbros bearing ortho- and clinopyroxenes. The whole formation is overlain tectonically with ultramafics. The sediments are sandstones and microconglomerates. They contain clasts of radiolarites and lavas which bear large plagioclase phenocrysts, idiomorphic crystals (zoned plagioclases, euhedral quartz, clinopyroxene, green and brown hornblende) and organic fragments (algae, bryozoans, echinoidea, inoceramus) within a a calcareous matrix. The clasts suggest the proximity of an andesitic to acidic volcanism. At Playa Naranjo, the megabreccias unit covers conglomerates which also bear pebbles of radiolarites and lavas.

Mineralogy and chemistry of the lavas

Sills of K rich basalts and lamprophyres within radiolarites

The radiolaritic series of Sitio Santa Rosa are intruded by numerous sills. They are 1 to 20 m thick and display symmetric chilled margins. Some sills are heterogeneous and cumulates of mafic minerals occur in their central parts. The thikest sills are composite and contain lamprophyric veins parallel to sill orientation.

Textures of basalts are porphyritic with large pseudomorphozed olivine, pyroxene and plagioclase (An 66-60) phenocrysts. Matrix contains abundant kaersutite, clinopyroxene, scarce biotite, plagioclase, titanomagnetite and apatite. Mesostasis is made of small K-feldspars in altered glass.

Lamprophyres bear abundant phenocrysts of kaersutite, scarce clinopyroxenes in a devitrified matrix with dentritic crystals of K-feldspars.

Clinopyroxenes from basalts are strongly zoned (Fig. 1), from cores to rims occur:

1 - scarce green cores of Fe rich augites (Wo46-En24-Fs30);
2 - colorless augite (Wo48-En39-Fs12);
3 - high Al and Ti brown augite (Al_2O_3: 10%, TiO_2: 5%, SiO_2: 41%);
4 - thin rims of Ti aegyrine (TiO_2: 5%).

Compositions 2 and 3 are normal trends for mafic alkaline rocks, with strong Al and Ti enrichment. Evolution toward peralkaline paragenesis is emphasized by late crystallization of aegyrine, however presence of this phase is rather unusual in basaltic rocks. Green cores are not in equilibrium with the Mg/Fe contents of enclosing rocks and are likely xenocrysts from more evolved rocks.

Basalts are strongly undersaturated and show high K contents (K_2O: 2%) and high light REE enrichment.

Alkaline basaltic flows from Playa Carrizal and Playa Danta

Pillowed flows from the western part of the southern authochthonous contain very abundant ocelli of calcite. Textures are porphyric with large euhedral pseudomorphozed olivine. Matrix is made of plagioclase (An 55-44) generally albitized, Al and Ti rich brown augite (Al_2O_3 and TiO_2 respectively up to 8% and 6%), titanomagnetite.

Although primary compositions may be modificated by secondary processes (albitization of plagioclase), pyroxene compositions and REE patterns display alkaline trend.

The Playa Respingue volcanic series

In the eastern part of the southern autochthonous (west of Playa Respingue) occurs a very thick sequence of pillowed and massive basalts. Large phenocrysts are chromian diopsides (Cr_2O_3: 0.7%) and microlites show low or moderate Al contents. Large plagioclase phenocrysts are partially fresh (An 70-30), but microlites are recrystallized into albite.

Two outcrops of trachytes were also observed. Textures are porphyric with K-felspar and green hedenbergite phenocrysts, acicular hedenbergite microlites in a recrystallized matrix made of alkali-feldspar and quartz.

Scarce chemical data are available for these series of basalts. High Contents of TiO_2 (3%) and LREE enrichment suggest alkaline trend. Trachytes (SiO_2: 68%) are Quartz normative (20%). The playa Respingue series may correspond to a weak alkaline series with slighly undersaturated basalts and over-saturated differentiates.

These three alkaline series display distinct mineralogical and chemical features and probably are not contemporaneous. The K rich sills are possibly the oldest because they intrude radiolarites Lias-Lower Dogger in age and are not observed in more recent sediments.

MEGABRECCIAS

Discontinuous megabreccias crop out along the Southern coast from sea level to 20 or 50 m high. They display large exposure at Punta Santa Elena, Respingue and Playa Naranjo and are covered with the allochthonous ultramafic unit. They are made of blocks with various sizes, some up to 5 m of dolerites, gabbros and serpentinites in a crushed serpentinite matrix. At Respingue occur also blocks of cherts and of magmatic rocks unknown elsewhere in the peninsula. Mafic cumulates, gabbros, plagiogranites and olivine basalts similar to those from the layered complex of Bahia Nancite occur within breccias at Playa Naranjo.

The megabreccias are interpreted as a tectonic mélange accumulated on the front of the thrust.

THE ULTRAMAFIC AND MAFIC ALLOCHTONOUS UNIT

This allochthonous unit crops out over 180 km2 area.It is made of ultramafic rocks cut by mafic dykes from sea level to the highest points (500 to 700 m).

A layered igneous complex in the form of a tectonic slice occurs beneath the peridotites at Bahia Nancite, Southern Coast.

The Ultramafic Sequence

The Santa Elena peridotites are partially serpentinized but are totally in shear zones and at the contact with the autochthonous unit. They are mostly diopside bearing harzburgites. A coarse foliation is marked on elongation of the orthopyroxenes. The direction of foliation planes changes through the massif and the dips display high angles, 50 to 80° (Fig.1). Along the Potrero Grande valley, foliation planes are parallel over 3 km area, suggesting that a 2.5 km thick peridotitic section would exist. Repeated pyroxenitic layers are parallel with the foliation planes of the surrounding peridotites. Scarce lenses of dunites also occur.

Textures and Paragenesis

Diopside bearing harzburgites: The ultramafic massif is almost entirely made of spinel peridotites bearing two pyroxenes: diopside bearing harzburgites or even lherzolites. Textures are porphyroclastic and rather homogeneous all over the massif. Olivine is always strongly serpentinized and occurs as fresh granulates isolated in a serpentinite matrix. Crystals display irregular contours and kinkbands. Orthopyroxene occurs as large elongate porphyroclasts and contains thin lamellae of clinopyroxene. In some occurrences, small crystals form clots with clinopyroxenes. Clinopyroxene (2 to 9%) is very fresh. Brown spinel is interticial. In totally serpentinized rocks, orthopyroxene recrystallized into bastite.

Plagioclase bearing peridotite: Plagioclase lherzolites can be found in some areas of the massif. The plagioclase (An 90) generally pseudomorphed, occurs as clots which often rim Al poor spinel.

Dunites: Dunites are rather scarce and generally crop out in patches ten meters across. In rare occurences, spinel rich layers are parallel to the contact with the enclosing harzburgites. Dunites are generally totally serpentinized. Spinel is euhedral. Some dunitic patches contain podiform-chromitite deposits (JAGER, 1977).

Orthopyroxenites: Scarce layers of orthopyroxenites occur parallel to the foliation of enclosing diopside-bearing harzburgites and display boudinage. Generally various orthopyroxenitic layers, 1 to 5 cm thick, are separated by thin peridotitic intercalations. Large crystals of orthopyroxene are strongly deformed and contain lamellae of clinopyroxene. Olivine is rare. Clinopyroxene occurs as large crystals and also as clots of small crystals which are undeformed. Abundant brown spinel sections are elongated parallel to the foliation. Some orthopyroxenitic layers lack spinel but contain scarce interstitial Ni sulfides.

Chemistry

Analysis of ultramafic rocks were published by WILBERG (1984) and display variations, especially for Al and Ca contents (Al_2O_3: 1.4 - 3.4%; CaO: 0.2 - 2.9%). On the other hand seven analysis (DESMET et al. 1985) from diopside bearing peridotites, recalculated dry, are homogeneous with SiO_2 44.6 to 45.7% and MgO 39.6 to 41.6%. Ca and Al contents are high for all samples (Al_2O_3: 1.9 - 3.3% and CaO: 2.4 - 3.3%). Ti and Na are relatively high (TiO_2: 0.05 - 0.10%; Na_2O: 0.06 - 0.10%). DESMET (1984) emphasized the peculiar compositions of these peridotites called harzburgites-lherzolites.

Olivine: In diopside-bearing harzburgites the forsterite content varies from 89.2 to 90.4. The NiO contents are between 0.25 and 0.33% and CaO is always below 0.01%. Olivine from dunites are more magnesian (Fo 90.9 - 91.1).

Orthopyroxene: Orthopyroxenes from peridotites and pyroxenitic layers have the same En contents (89-88). Punctual analysis show high Al contents (Al_2O_3: 4.5 - 5.3%) and relatively high Cr (Cr_2O_3: 0.4 - 0.7%) and Ca (CaO: 0.4 - 0.8%) contents. A scanning microprobe analysis integrated lamellae of clinopyroxene and thus allows us to estimate composition before exsolution occurred: CaO reaches 2%.

Clinopyroxene: Clinopyroxenes from harzburgites (1 to 2%) and lherzolites (5%) are fairly homogeneous in terms of Wo contents (Wo 50 - 48). Contents are variable but generally high for Na (Na_2O: 0.5 - 0.9%), Al (Al_2O_3: 4.5 - 5.8%), Cr (Cr_2O_3: 0.6 - 1.1%) and Ti (TiO_2: 0.2 - 0.5%). Clinopyroxenes from orthopyroxenitic layers are also diopside, but with lower contents of Na and Cr. According to the two pyroxene thermometer (Bertrand & Mercier, 1987), temperatures of equilibration in three localities are: 1059-1052°C, 1015-1006°C, 994-977°C at 10 kbs. Temperatures for exsolution of diopside lamellae within orthopyroxene and of equilibration for clots of small undeformed orthopyroxene-clinopyroxene crystals are between 885 and 864°C.

Spinel: Brown spinel sections have the same compositions in one sample of diopside-bearing peridotite.Spinel from orthopyroxenitic layers are similar with those of the enclosing peridotites (Fig. 4). Contents of Al are high (Al_2O_3: 44 - 58%). Cr is low (Cr_2O_3: 10 - 21%). In contrast, spinels from dunites are euhedral and have low Al contents (Al_2O_3: 23 - 24%; Cr_2O_3: 36 - 39%).

Layered Mafic Complex and Plagiogranites

Along the Southern coast near Bahia Nancite, a layered complex crops out approximately 1 km in length. The verticle drop is 50 m to sea level.It is covered by peridotites and low angle contacts are marked by schistosed serpentinites. Such an occurence suggests that the complex is a tectonic slice overlain tectonically by the peridotites.

The layers differ from one another by the relative abundance of ferromagnesian minerals and the grain size. Their thickness ranges from a few centimeter is to several meters, and the direction of layers are N-S. Dips of the layers are weak in the eastern outcrops but are more than 50° in the western ones and suggests a synclinal arrangement. The thickness of the exposed section probably does not exceed 500 m.

Acidic veinlets cross cut the gabbros and are conected upwards with pockets of quartz rich plagiogranites.

Two generations of dykes with chilled margins cut the layered complex as follows:

- dolerites, similar to those which cut the peridotites
- olivine basalts which emplaced later than the dolerites.

Blocks made of similar rocks are present in the breccias from Playa Naranjo.

Layering is marked by the more or less abundant plagioclase (10 to 70%) and clinopyroxene (18 to 60%), always present, and the occurence of olivine and orthopyroxene. The more mafic rocks display the following crystallization succession: euhedral olivine, abundant small euhedral clinopyroxene, xenomorphic orthopyroxene including clinopyroxene, poikilitic plagioclase enclosing clinopyroxene crystals. Olivine is exceptionally abundant (42%) in very scarce layers, but generally not exceed 2% and lacks in plagioclase rich layers. Zoned amphiboles always occur (5 to 14%). Oxydes are only represented by very scarce chromiferous spinels.

Chemistry

Olivine (Fo 84, NiO: 0.20-0.25%) is partially serpentinized. Orthopyroxene is not zoned (En 81-82). Clinopyroxenes from mafic layers are diopside and show variable chromium contents (Cr_2O_3: 0.30 to 0.80%), low Al (Al_2O_3: 2-2.5%) and Ti (TiO_2: 0.10-0.15%) contents. Clinopyroxene from plagioclase rich layers are quite similar,although with slightly higher Fe and Ti contents. Amphiboles are strongly zoned.Cores are light brown magnesian Al rich hornblendes (Al_2O_3: 10-11%). This chromium rich (Cr_2O_3: 1-1.5%) magmatic amphibole is rimed with colorless tremolitic amphiboles (Al_2O_3: 3-4%). Oxydes are almost totally absent, only very scarce Cr rich spinels (Cr_2O_3: 35-39%) are present in mafic layers as euhedral crystals or inclusions in clinopyroxene (Fig. 4). Plagioclase are quite similar in mafic layers (An 94-92) and more felsic layers (An 94-86).

Plagiogranites are made of very abundant quartz, Ca rich plagioclase (An 58-56) and scarce green amphibole.

Chemical datas are scarce for the layered sequence of Playa Nancite and for similar rocks from the breccias of Playa Naranjo. Mafic cumulates and plagioclase-rich gabbros display high Mg/Mg+Fe values (0.76 to 0.60) and very low Ti contents (TiO_2: 0.12-0.14). Plagioclase-rich gabbros are strongly depleted for incompatible elements. Plagiogranites are very acidic (SiO_2 up to 70%), relatively high Ca (1.8-4%) and low K (K_2O: 0.3%) (Tournon, 1984, Wilberg, 1987).

Mafic Dykes

Clinopyroxenites

Dykes of clinopyroxenites cut the serpentinized peridotites in the South East of the massif. They are ramified upwards and lack chilled margins. Thickness varies from several centimeters to one meter. Textures vary from coarse-grained to pegmatitic and the size of clinopyroxene crystals often reaches several centimeters. Clinopyroxenes are diopsides with low Al, Na, and Ti contents.

Euhedral crystals of pseudomorphozed olivine are enclosed within clinopyroxene. Small interstitial orthopyroxenes recrystallized into bastite. Scarce spinels are enclosed into the clinopyroxene.

Pegmatitic Gabbros

In the whole massif,peridotites are intruded by scarce, thin (5 to 50 cm thick) dykes of pegmatitic gabbros (Fig. 2). In general they are recrystallized into low T assemblages. Some occurences display partially preserved high T paragenesis with large plagioclases (An 90), and in exceptional cases, relics of orthopyroxene enclosed within amphibole. Chemical analysis (DESMET et al., 1985) are unlikely significant for the grain size, although they display tholeiitic features, high Mg and very low Ti contents as noticed for the gabbros from the layered sequence of Bahia Nancite.

Dolerites

The doleritic dykes are abundant within the peridotites with thickness ranging from 1 to 10 m.They display high angle dips and are sometimes ramified near the top (Fig. 2). Directions of dykes are mainly NS, except in the northeastern part of the massif where they are N 30° (Fig. 1). The doleritic dykes are not deformed, except along the Southern Coast where they display folds recumbent toward the South.The abundance of the dykes increases along the Western Coast until the region is swarmed with dykes (Fig. 3). This area suffered multistage intrusions and peridotites are enclosed as xenoliths. Chilled margins occur around peridotitic xenoliths and around coarse gabbroic masses. Shear zones within the peridotites are marked by schistosed serpentinites with squeezed lenses of foliated amphibolites. In the doleritic dyke swarm, strongly foliated amphibolites occur as narrow corridors within preserved dolerites.

Textures are doleritic to subophitic in dykes cutting the peridotites, doleritic to microgabbroic in the dyke swarm from the Western Coast. Chilled margins are marked by smaller grain size and sometimes even by microlitic textures. Plagioclase, generally fresh, occurs as elongate euhedral zoned crystals (An 54-30). Relic crystals of clinopyroxene often occur enclosed within amphibole. They are Ca Mg rich augites with low Al (Al_2O_3: 0.5-1.5%) and Ti (TiO_2: 0.10-0.30%) contents. Amphibole (45-60%) is zoned: brown green (Al_2O_3: 8%), green hornblende (Al_2O_3: 5%) to light green colorless actinolite (Al_2O_3: 2%) in rims. Opaque minerals are ilmenite and scarce sulfides.

In narrow shear zones, dolerites recrystallized into foliated amphibolites and magmatic textures are totally oblitered. Amphibole is brown green hornblende (Al_2O_3: 7-8%) or green hornblende (Al_2O_3: 5%). Plagioclase is labrador (An 54-51). Ilmenite also occurs. A 88,8 +-4.5 my K/Ar age was obtained for the amphibole of a gneissic amphibolite (BELLON & TOURNON, 1978). Within amphibolites are lenses of pyroxenites made of diopside (Wo 49-En 40-Fs 11), plagioclase (An 88-86) and

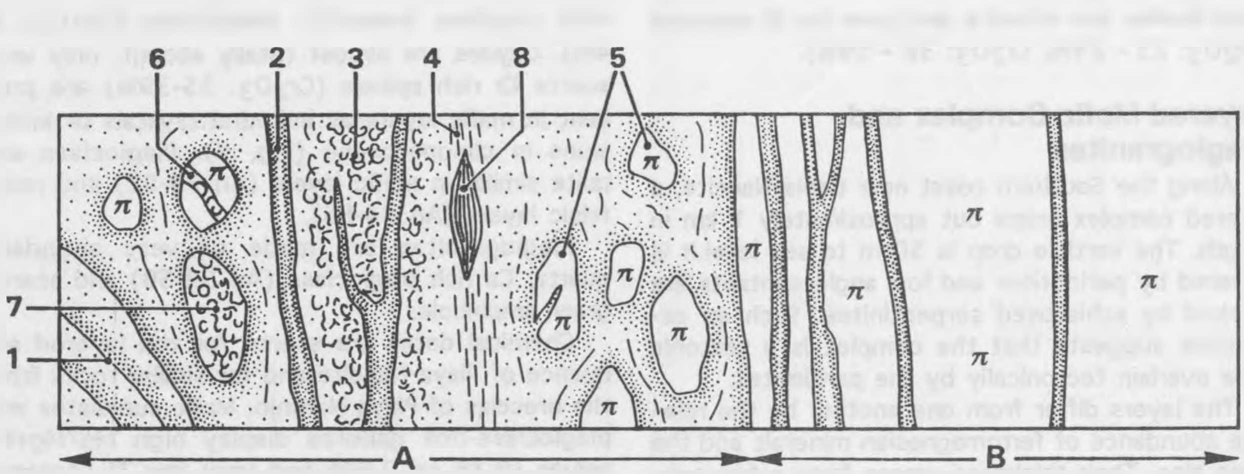

Fig. 3: Schematic section of the dyke swarm, western coast.
1: multiple intrusions of doleritic dykes. 2: doleritic dykes with symetrical chilled margins in coarse grained dolerites and gabbros. 3: coarse grained dolerites, microgabbros and gabbros. 4: foliated amphibolites. 5: xenolits of peridotites within dolerites. 6: dyke of pegmatitic gabbros within peridotitic xenoliths. 7: xenoliths of pegmatitic gabbros.8: schistosed xenoliths of serpentinites within foliated amphibolites. A: from Playa Morros to Playa Gringos; B: West of Playa Gringos.Scales are not respected.

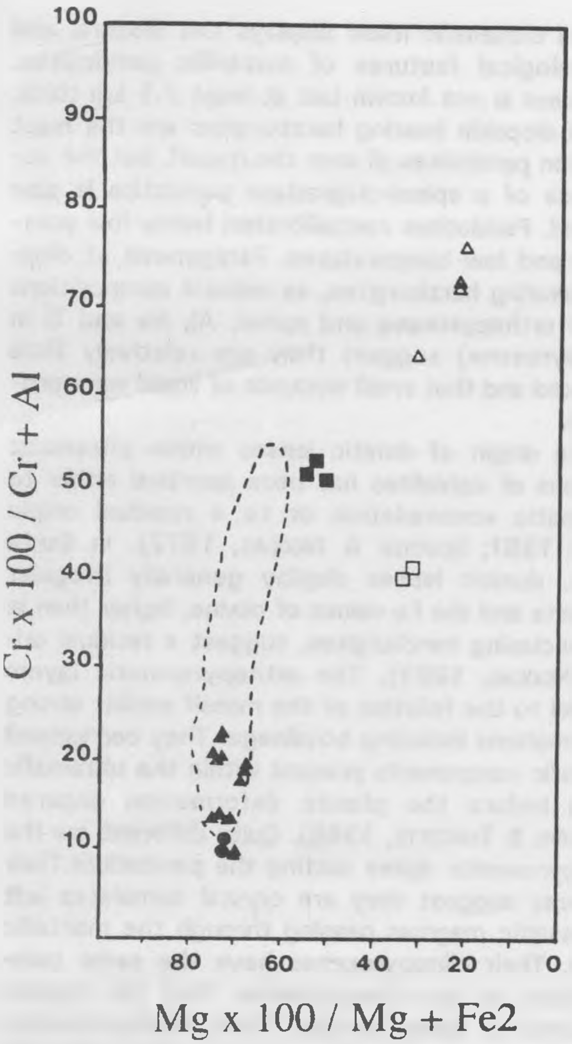

Fig. 4: Compositions of spinels.
Solid triangles: diopside bearing harzburgites. Solid circles: orthopyroxenitic layers. Solid squares: dunites. Open squares: clinopyroxenites, dykes cutting the peridotites. Open circles: mafic cumulates, layered sequence of Bahia Nancite. Dotted line: field for abyssal peridotites, DICK and BULLEN (1984).

sphene. Their bulk composition (CaO: 20%) suggests a metasomatic origin.

In the dyke swarm from the western coast, dolerites and gabbros are locally recrystallized into low T paragenesis with chlorite, epidote, actinolite and albite. Dykes of dolerites within the peridotites and the dyke swarm from the western coast have not only similar mineralogy but also the same chemical compositions (DESMET & ROCCI, 1988). Thus, they can be related to the same intrusive event and the two occurences differ only for the dolerite abundance versus enclosing peridotites. Dolerites have relatively high Si (SiO_2: 51-52%) and Al (Al_2O_3: 15%) contents, and are characterized by low K and Sr, Rb enrichment and low contents of elements of high ionic potential (Nb, Ti, Zr, Y, Yb). These features suggest that dolerites are island arc tholeiites.

Basalts

Basaltic dykes,0.5 to 4 m thick, intrude the layered gabbros from Bahia Nancite. They also occur as blocks in the breccias of Playa Naranjo. Textures are porphyric with abundant phenocrysts of totally pseudomorphozed olivine. Large pyroxene phenocrysts are strongly zoned. Cores are chromiferous diopside (Wo43-En53-Fs5; Cr_2O_3: 0.6%) with very low Al and Ti contents.Rims are augite (Wo31-En41-Fs22). Matrix is made of augite and plagioclase (An 80). These basalts, called low Ti basalts by WILBERG (1984) are the latest magmatic rocks from the allochthonous unit. They display rather primitive features: high Mg, Cr and Ni contents.

BASALTS FROM THE MURCIELAGO ISLANDS

Structural setting of the Murcielago archipelago, off the Southern coast of Santa Elena, is not known. The islets are made entirely of tholeiitic ferrobasalts. Magmatic paragenesis are well preserved with augite (Wo39-En36.6-Fs28.5) and plagioclase (An75-65). Chemical features are different from the dolerites in the allochthonous unit as from basalts in the autochthonous unit which are alkaline. On the other hand, basalts from Murcielago archipelago are reminicent of tholeiites from Northern Nicoya peninsula, although they are more depleted in incompatible el ements (DESMET & ROCCI, 1988).

THE SEDIMENTARY COVER

The sedimentary cover begins with underlying reef limestones containing pebbles of serpentinites. Abundant macrofauna (rudists, nerineas, corals) and forams are Late Campanian-Maastrichtian in age. A thick (about 4 km) Lower Paleocene to Middle Eocene detrital series is well exposed in the northern part of the peninsula (AZÉMA et al., 1981; SEYFRIED & SPRECHMANN, 1986).

DISCUSSION AND CONCLUSIONS

The autochthonous unit displays siliceous sedimentary series, Lias-Lower Dogger to Cenomanian in age. Radiolarian fauna allow to iden-tify Lias-Lower Dogger, Callovian-Oxfordian, Barremian, Aptian, Albian and Cenomanian. It is not actually possible to assert if this unit correspond to a tectono-sedimentary mélange or to an unique stratigraphical succession deposited during aproximatively 90 my. Although the Santa Rosa sequence displays rather coherent outcrops. BOURGOIS et al.

(1984) regarded this unit as a possible lateral equivalent of the Matapalo unit, lower Nicoya Complex. The Nicoya Complex includes radiolarites rather similar in age (from Callovian to Santonian) and large basaltic outcrops. However the Santa Elena autochthonous unit displays peculiar characteristics unknown in the Nicoya peninsula: distinct sedimentary features, such as the important radiolaritic breccias intercalations, the abundance of alkaline lavas. This suggests that the Santa Elena autochthonous unit formed in a seamount environement and rules out it corresponds to the highest sequence of the ophiolitic allochthonous.

Paleontological data are available to assign an interval during which the ophiolitic nappe emplaced. This event occured between Cenomanian, latest age known in the autochthonous unit and Late Campanian, age of the lower reef limestones of the cover.

Direction and vergence of the thrust are to be considered. In the Potrero Grande Valley are observed within the radiolarites and just below the serpentinites, horizontal fault mirrors with "crenulations" and strias (N 170°). Thurthermore, on the Southern Coast, doleritic dykes within the ultramafics display recumbent folds towards the South. TOURNON (1984) suggested that the nappe emplacement was from North to South and that deformation of the autochthonous unit occured prior to the nappe emplacement. On the other hand FRISCH et al. (1992) consider the nappe emplacement was NE to SW and produced deformation of the autochthonous unit.

Interpretation of a so complex assemblage is still matter to debate and the paleogeographic reconstructions are conditioned by the Late Cretaceous paleopositions, whether quite similar to the present ones or located in equatorial position or even in the Southern Hemisphere (GOSE, 1983, FRISCH et al., 1992).

The Santa Elena allochthonous unit displays mantellic peridotites, layered gabbroic rocks, doleritic and basaltic dykes. Such assemblage is in accordance with an ophiolite as generally defined (Anonymous 1972, COLEMAN, 1977; NICOLAS, 1989). However, the rock types do not occur in the classical sequence starting from the bottom and working up: ultramafic rocks, gabbros, dyke complex, mafic volcanic rocks. The allochthonous unit is mostly made of mantellic peridotites and the mafic rocks occur as following: 1) gabbroic and later doleritic dykes cutting the peridotites, 2) a layered complex tectonically overlain by the peridotites, this complex includes also plagiogranites and is cut by doleritic and later basaltic dykes. Thus, the normal limit peridotites-gabbros (paleo-Moho) is not observed.

The ultramafic mass displays the textural and mineralogical features of mantellic peridotites. Thickness is not known but at least 2.5 km thick. Spinel diopside bearing harzburgites are the most common peridotites all over the massif, but the occurence of a spinel-plagioclase peridotite is also noticed. Peridotites reequilibrated below low pressures and low temperatures. Paragenesis of diopside bearing harzburgites, as mineral compositions (Al in orthopyroxene and spinel, Al, Na and Ti in clinopyroxene) suggest they are relatively little depleted and that small amounts of liquid were produced.

The origin of dunitic lenses within ultramafic sections of ophiolites has been ascribed either to magmatic accumulation or to a residual origin (QUICK 1981; BOUDIER & NICOLAS, 1972). In Santa Elena, dunitic lenses display generally irregular contacts and the Fo values of olivine, higher than in the enclosing harzburgites, suggest a residual origin (NICOLAS, 1989). The orthopyroxenitic layers parallel to the foliation of the massif exhibit strong deformations including boudinage. They correspond to mafic components present within the ultramafic mass before the plastic deformation occured (ALLEGRE & TURCOTTE, 1986). Quite different are the clinopyroxenitic dykes cutting the peridotites.Their textures suggest they are crystal cumulates left by basaltic magmas passing through the mantellic mass. Their clinopyroxenes have the same compositions as the clinopyroxenes from the layered sequence of Bahia Nancite. Thus, clinopyroxenitic dykes are a possible link between the magmatic chamber and the mantellic mass.

The layered cumulate-gabbro sequence is strongly differentiated. Plagioclase rich gabbros have compositions of tholeiites depleted for incompatible elements, composition not expected for generation from a relatively slightly depleted peridotites. On the other hand, the doleritic dyke sequence shows island arc tholeiites features and is likely not cogenetic with the layered sequence. Presence of chilled margins and lack of rodingitization suggest that dolerites intruded within cooled peridotites and that serpentinization already occurred (GIRARDEAU et al., 1985). Mineral compositions indicate that metamorphic recrystallization occurred in the amphibolite facies (600 to 650°C).

Compared to most ophiolitic complexes,the allochthonous unit of Santa Elena displays peculiar features:

- dominance of diopside bearing harzburgites in the ultramafic unit.
- small amount of the cumulate-gabbroic section, however we do not know if it corresponds to a primary feature or if it is the result of tectonic denudation.
- large development of the doleritic dyke section

cross cutting the ultramafic rocks and which likely correspond to secondary basaltic intrusions.

The ultramafic section shows characteristics intermediate between the common harzburgite ophiolite type and the more restricted lherzolite ophiolite type as defined by BOUDIER & NICOLAS (1985). Such intermediate and unusual characteristics have been emphasized for the Xigaze ophiolite, Tibet (NICOLAS et al., 1981; GIRARDEAU & MERCIER, 1988). This ophiolite type with relatively little depleted ultramafic section and small amount of gabbroic rocks is expected to be formed at low spreading centers (GIRARDEAU et al., 1985; NICOLAS, 1989).

The Santa Elena allochthonous unit correspond to the lower parts of an ophiolitic complex which suffered denudation of its upper sequences.This ophiolitic basement,likely generated in a small bassin,was later intruded by island arc tholeiitic magmas,then obducted onto deep sea series accumulated from Lias-Lower Dogger to Upper Cretaceous.

Possible eastward extension of the Santa Elena ultramafic massif is to be considered because peridotites were recently discovered in the Rio San Juan area, at almost the same latitude (ASTORGA, 1992). The outcrops are located near the border in Costa Rica (VARGAS & ALFARO, 1992) and in Nicaragua (Astorga, 1992). The peridotites are generally totally serpentinized. Exceptionally the primary phases of diopside bearing harzburgites are preserved.The texture and the mineral compositions are similar with those of the Santa Elena diopside bearing harzburgites (TOURNON & ASTORGA, to be published). Thus one may ask if the Santa Elena ultramafic massif and the Rio San Juan peridotitic outcrops belong to the same unit. In this case, a 150 km long East-West peridotitic suture would occur.

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