SEDIMENTOLOGICAL STUDY OF BEACHES FROM CENTRAL ECUADOR

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ABSTRACT

Four central Ecuadorian beaches were studied from a sedimentological point of view, using a total of three samples for each one. In each beach, the infra, meso and supra literal zones were sampled. The beach profiles and the granulometric analysis suggest that the northern most and the southern most beaches are not accretional, while the two other are in accretion. According to the petrographyc analysis, the principal constituents are rock fragments and feldspar plagioclases. One exception was the supralitoral sample from the Pasado Cape beach that was rich in black sand content with 63.85% Fe_2O_3 and 30.20% TiO_2. The data distribution in the Q-F-RF triangle suggests that tectonically the studied samples belong to an arc. This inference agrees with the fact that the studied beaches are located in the margin of the Nazca and South America Plates.

KEY WORDS: Beaches, Ecuador, Sedimentology.

RESUMEN

Se estudiaron cuatro playas de la porción central de la República del Ecuador, desde un punto de vista sedimentológico. En cada playa se colectaron muestras de las zonas infra, meso y supralitoral. Los perfiles de playa, así como el análisis granulométrico sugieren que las playas de los extremos norte y sur del área de estudio no son acrecionales, en tanto que las otras dos playas si lo son. Según el análisis petrográfico los constituyentes más abundantes fueron los fragmentos de roca y los feldespatos (plagioclasas), con excepción de la muestra de arena supralitoral de la Playa Cabo Pasado, la cual fue rica en arena negra, con una concentración de 63.85% de Fe_2O_3 y 30.20% de TiO_2. Por la distribución de datos en un diagrama triangular, con polos cuarzo-feldespatos-fragmentos de rocas, se infiere que las muestras corresponden a un ambiente tectónico de arco, lo cual es congruente con el hecho de que las playas muestreadas se ubican en el límite de la Placa de Nazca que se introduce por debajo de la Placa Sudamericana.

PALABRAS CLAVE: Playas, Ecuador, Sedimentología.

INTRODUCTION

Litoral sedimentological studies are particularly interesting due to the fact that the literal is a fringe in dynamic equilibrium where the terrestrial, marine and atmospheric processes interact. The materials that arrive to the beach coming through rivers will be selected during weathering and transportation processes; at the end of a long way, only the more resistant materials will remain. Among the materials more frequently found on clastic deposits are quartz, feldspar and rock fragments. Their relative abundance has been used for diverse authors in order to characterize the sand composition (Pettijohn *et al*. 1972, Folk, 1974; Potter, 1986). In particular cases of high energy conditions is feasible to find sandy bodies known as black sand which may be composed by magnetite, ilmenite, rutile, garnet, and so on. Sometimes those accumulations can be of economic interest (Mero, 1965; Cronan, 1980; Kunsendorf, 1986).

The study of recent sedimentary environments has been important for the interpretation of ancient analogous environments. According to Dickinson and Suczek (1979) the detrital framework modes of sandstone suite from different kinds of basins are function of provenance types governed by plate tectonics.

The quartz rich rocks are associated typically with passive continental margins, and the quartzpoor rocks are mainly volcanogenic (Crook, 1974; Schwab, 1975). This paper is focused to characterize and analyze the sedimentological aspects of litoral sediments from central Ecuador as well as to establish possible inferences related to tectonism of the oceanic Nazca Plate that is subducting under the South America Plate.

STUDY AREA

The study area is located on the central equatorial coast (Fig. 1) and it is comprised between 0.34º S and 0.94º S. The cold Humbold current that runs south-north changes its heading to the west at Pasado cape (Fig. 2) going to Galapagos Islands (Garrison, 1992; IGPCP-246, 1992).

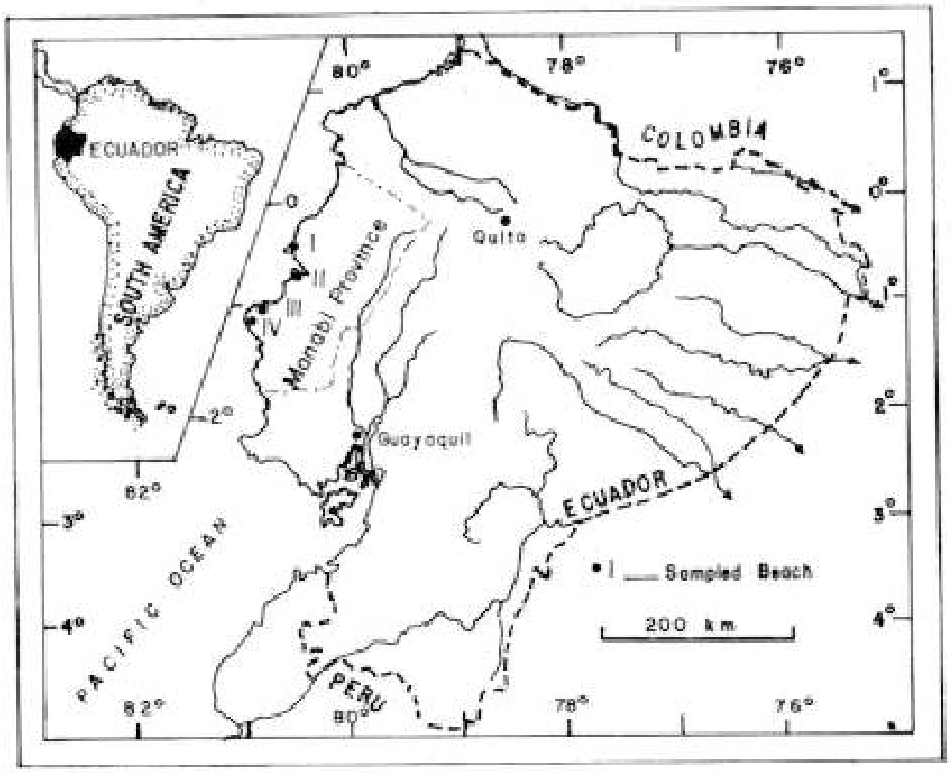

Figure 1. Location map. I) Pasado Cape, II) Caraquez Bay, III) Tarqui beach at Manta, IV) La Barca Point.

The sampled beaches are located in the Manabí Province. The beaches I and II (Fig. 2) are on the northeastern portion of Manabí Province, while beaches III and IV are located at the southwest of Manabí Province.

Manabí Province (18,830 Km^2) is one of the five coastal provinces of Ecuador. Its capital is Porto-viejo and is situated 355 km southwest from Quito. The Manabí Province has a tropical climate, being dry between May and November and rainy from December to April.

There are four major geomorphological units in Ecuador: Orient, Sierra, Coast and Islands. The study area is located in the Coast Province, that according to Baldock (1982) comprises the whole region west of the Andes and corresponds to a late Cretaceous to Tertiary fore-arc basin underlain by tholeiitic volcanism (Piñon Fm., fig. 3), probably of Lower Cretaceous age. The Piñon Fm. represents oceanic crust or may be underlain by Mesozoic oceanic crust accreted into the South American Plate.

During Eocene, sedimentation started and continued in block faulted troughs. In the central coast a Neogene uplift of the marshal hills caused an eastward migration of the axis of the sedimentary trough (Baldock, 1982). There are not granite out-crops in the studied area.

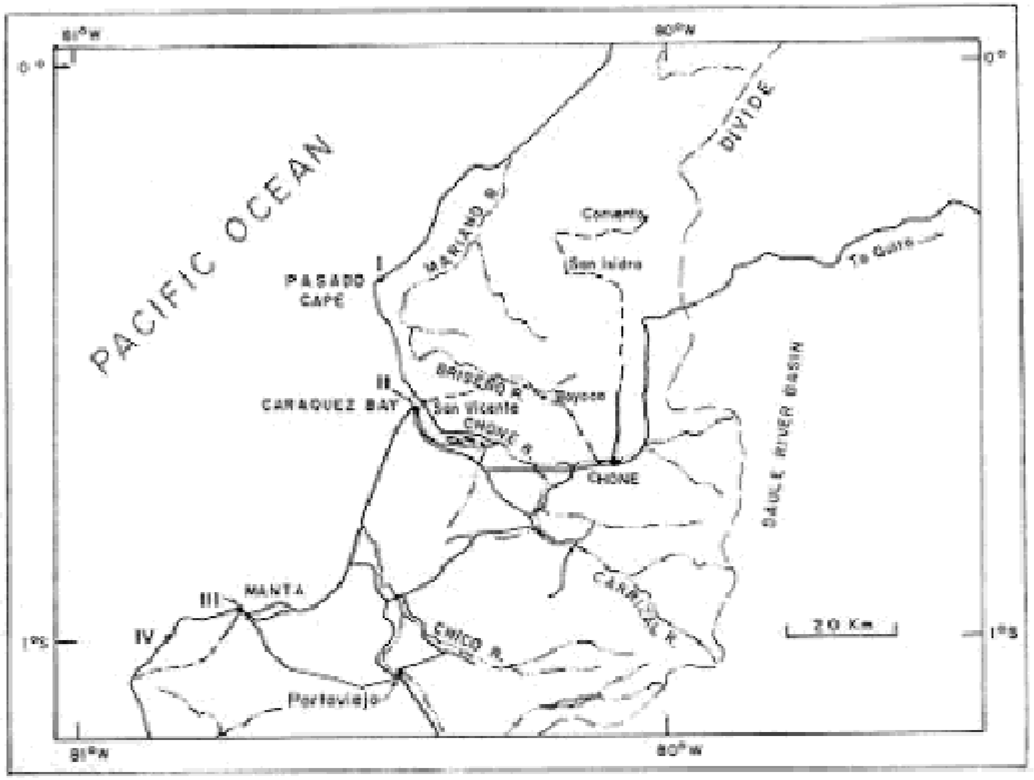

Figure 2. Main rivers at the study area. I) Pasado Cape, II) Caraquez Bay, III) Tarqui beach at Manta, IV) La Barca Point.

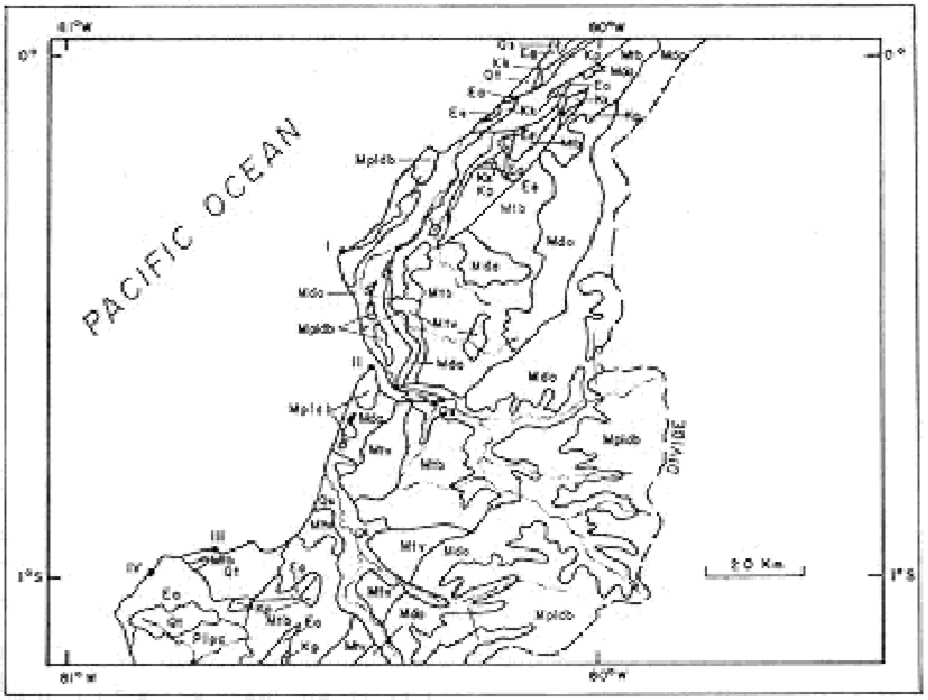

Figure 3. Geologic map modified from the Geologic Map of Equator (Mapa Geológico Nacional de la República del Ecuador, 1982). Qs: quaternary sediments (estuarine and marine clays); Qt: pleistocene bioclastic marine deposits (Tablazo fm.); Plpc: Pliocenic sands, clays and conglomerates (Canoa-Cachabi Fm.) Mpldb: conglomerates, sands and calcareus muds (Borbón Fm.), Mda: conglomerates, sandstones and mudstones (Angostura Fm.); Mtv: white shales, diatomites and silty shales (Villingota Member of Tosagua Fm.); Mtb: chocolate shales (Dos Bocas Member from Tosagua Fm.); Ea: sandstones, shales, limestones and clays (San Mateo-Punta Blanca-Zapallo Fms.); Ee: limestones and shales (San Eduardo Fm.); Kk: shales, tuffs, breccias and lava (Cayo Fm.); Kp: basaltic lavas, tuffs and breccias (Piñon Fm.); M: Miocene, E: Eocene, K: Cretaceous.

MATERIAL AND METHODS

Litoral clastic sediments were collected in the central coast of Ecuador in four sampled beaches (Fig. 4). Three surficial samples were taken in each beach: in the infralitoral, mesolitoral and supralitoral zones. The sample location is shown in the profiles shown in Fig. 4.

After organic matter and salt were eliminated in the samples, they were dried and sieved each 1/4 *f*, following procedures suggested by Folk (1974). In order to obtain the textural parameters, the formules from table 1 were used. The granulometric limits considered in this work are those from table 2. With the obtained percentils (Table 3), the textural parameters of the samples were calculated.

The sediment samples were mounted in thin section, in order to establish their petrographic composition and 300 grains were identified and counted, using a petrographic Olympus microscope. The identified constituents are: quartz, feldspar, rock fragments, biogenic detritus, mica and heavy minerals. The heavy minerals were identified using the criteria followed by Potter (1978). The quartz-feldspar-rock fragment were normalized to 100% in order to construct the Q-R-RF triangle that is related to tectonics by Dickinson *et al.* (1983).

Sample Ic from the supralitoral zone of Pasado Cape beach, was grinded and fused with lithium tetraborate (0.1:9.9) at 1150 ºC. The fused pellet obtained was studied by XRF in order to know the concentration of Fe_2O_3 and TiO_2.

TABLE 1

FORMULES APPLIED IN THE TEXTURAL ANALYSIS

(AFTER FOLK, 1974)

$$Mz = (f16 + (150 + f84) / 3$$

St. Dev. = ((*f*84 - *f*16)/4) + ((*f*95 - *f*5)/6.6)

Ski = ((*f*16 +*f* 84-2*f* 50) / 2 (*f*84 - *f*16)) +((*f*5 + *f*95 -2*f* 50) / 2 (*f*95 -Ø 5))

Kg = (*f*95 - *f*5) / 2.44 (*f*75 - *f*25)

Mz:size , St. Dev.: sorting, Ski:skewness, Kg:kurtosis.

RESULTS AND DISCUSSION

The Pasado Cape beach, has 15º of face slope, and is the beach with the higher slope. The upper limit is given by rocks from the miocenic Angostura Formation. The supralitoral zone is covered with black sand (Fig. 4). There are some logs and scattered pebbles on the beach that suggest recent influence of heavy weather conditions.

More than 20% of the grains population from sample Ia, can be related to traction movement as it inferred from the shape of the cumulative curves on fig. 5. This sample, has the worst sorting coefficient (Table 4) and according to the textural limits suggested by Folk (1974) its inclusive graphic standard deviation is bad sorted. On the other hand, the black sand on the supralitoral zone of this beach has the highest heavy mineral concentration (Table 5) among the sampled beaches, as was expected.

TABLE 2

TEXTURAL LIMITS CONSIDERED IN THIS PAPER

(AFTER FOLK, 1974)

Mean graphic size

Gravel: bigger than 2mm

Very coarse sand: -1*f* to 0*f* (2 to 1 mm)

Coarse sand: 0*f* to 1*f* (1 to 0.5 mm)

Medium sand: 1*f* to 2*f* (0.5 to 0.25 mm)

Fine sand: 2*f* to 3*f* (0.25 to 0.125 mm)

Very fine sand: 3*f* to 4*f* (0.125 to 0.0625 mm)

Silt: smaller than 0.0625mm

Inclusive graphic standard deviation

Very well sorted: less than 0.35

Well sorted: 0.35*f* to 0.50*f*

Moderately well sorted: 0.50*f* to 0.71*f*

Moderately sorted: 0.71*f* to 1.00*f*

Bad sorted: 1.00*f* to 2.00*f*

Very bad sorted: 2.00*f* to 4.00*f*

Extremely bad sored: more than 4.00*f*

Inclusive graphic skewness degree

Very skewned to fine: 1.00 to 0.30

Skewned to fine: 0.30 to 0.10

Not skewned: 0.10 to -0.10

Skewned to coarse: -0.10 to -0.30

Very skewned to coarse: -0.30 to -1.00

Graphic kurtosis

Very platikurtic: smaller than 0.67

Platikurtic: 0.67 to 0.90

Mesokurtic: 0.90 to 1.11

Leptokurtic: 1.11 to 1.50

Very leptokurtic: 1.50 to 3.00

Extremely leptokurtic: bigger than 3.0

TABLE 3

PERCENTILS FROM THE BEACH SAND SAMPLES

Sample	5	16	25	50	75	84	95
Ia	-1.48	0.75	2.33	2.85	3.13	3.29	3.49
Ib	0.26	0.84	1.10	1.64	2.18	2.45	2.85
Ic	0.71	1.48	1.82	2.39	2.77	2.92	3.21
Iia	1.35	1.99	2.30	2.78	3.04	3.18	3.49
Iib	2.21	2.54	2.64	2.85	3.05	3.19	3.44
Iic	1.51	1.85	2.04	2.42	2.73	2.90	3.31
IIIa	2.54	2.69	2.78	2.91	3.25	3.39	3.63
IIIb	2.47	2.63	2.75	2.89	3.12	3.29	3.48
IIIc	1.84	2.15	2.32	2.62	2.85	2.96	3.27

IVa	-2.93	-1.62	-1.24	-0.64	-0.20	-0.05	0.30
IVb	1.28	1.78	1.99	2.27	2.54	2.63	2.75
IVc	0.34	1.14	1.43	1.95	2.31	2.47	2.70

I.- Pasado Cape; II.- Caraquez Bay; III.- Manta; IV.- La Barca Point.

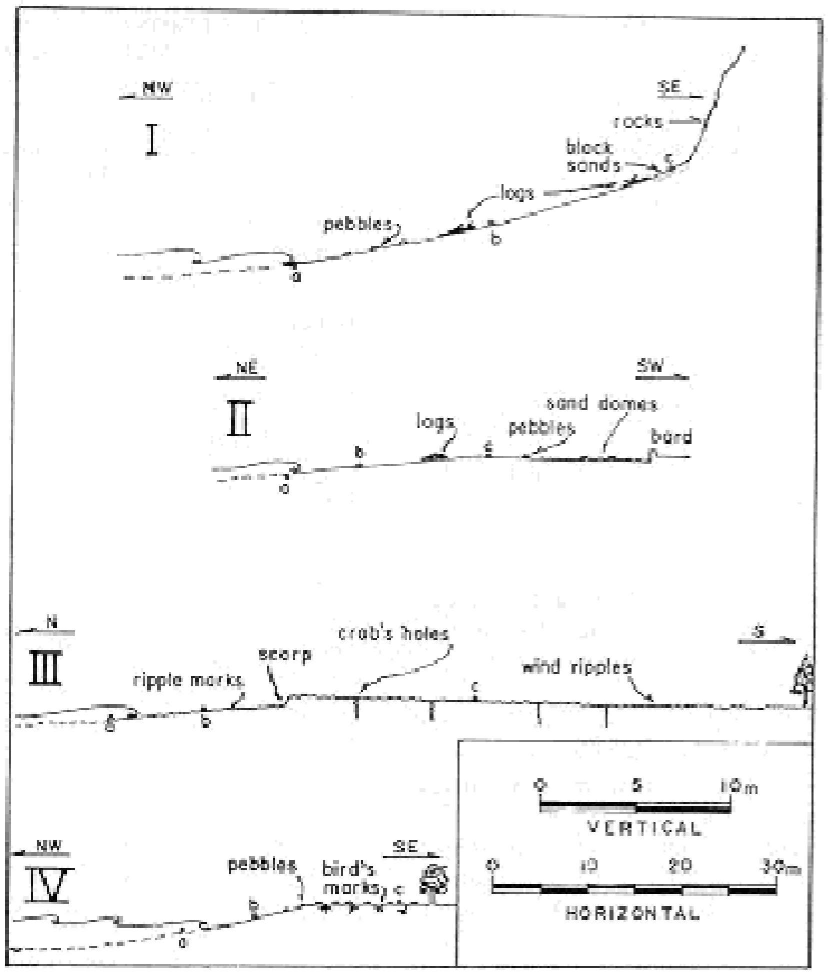

Figure 4. Profiles of the studied beaches. I) Pasado Cape, II) Caraquez Bay, III) Tarqui beach at Manta, and IV) La Marco Point. The sampling points a, b and c represent infralitoral, mesolitoral and supralitoral zones. The scales bars are only valid for the beach prorofiles, and not for details

The beach from Caraquez Bay (II in Fig. 4) is located at the mouth of the Chone River estuary and has a 3º beach face slope. The breaking waves are small and the presence of sporadic logs suggest influence of the Chone River.

The cummulative granulometric curves (Fig. 5) give information of the energy level of the literal environment as well as the uniformity on the processes that act in the environment. In the sublitoral zone the traction population deduced from the commutative curves of figure 5 is notoriously more important than in zones b and c, the mean graphic size is in the range of fine sand for the three zones, the best sorting was found on the mesolitoral zone (b samples).

TABLE 4

TEXTURAL PARAMETERS

Sample	Mz	St. Dev.	Ski	Kg
Ia	2.295	1.388	-0.698	2.538
Ib	1.642	0.793	-0.034	0.985
Ic	2.265	0.738	-0.303	1.081
IIa	2.651	0.623	-0.335	1.202
IIb	2.859	0.348	0.001	1.238
IIc	2.390	0.537	-0.045	1.070
IIIa	2.995	0.337	0.354	0.926
IIIb	2.939	0.318	0.191	1.116
IIIc	2.576	0.419	-0.122	1.116
IVa	-0.767	0.881	-0.330	1.274
IVb	2.227	0.435	-0.247	1.103
IVc	1.855	0.693	-0.294	1.107

I.- Pasado Cape; II.- Caraquez Bay;

III. Tarqui beach at Manta; IV.- La Barca Point.

TABLE 5

PETROGRAPHIC ANALYSIS OF THE BEACH SANDS

Sample	Q(%)	F(%)	RF(%)	B(%)	HM(%)	M(%)	Mi	Pi
Ia	4.5	37.5	47.2	5.6	4.5	0.7	0.06	0.79
Ib	11.0	34.3	39.7	1.0	9.7	4.3	0.15	0.86
Ic	0.0	2.3	3.3	0.0	94.3	0.0	0.00	0.70
Iia	9.3	36.3	46.3	3.0	3.3	1.7	0.11	0.78
Iib	6.3	29.3	48.7	1.7	8.3	6.0	0.08	0.60

Iic	1.1	42.4	35.1	1.5	15.6	4.2	0.01	1.20
IIIa	3.7	30.0	64.0	0.3	1.0	1.0	0.04	0.47
IIIb	10.0	20.0	60.3	4.0	3.0	2.7	0.12	0.33
IIIc	8.0	28.0	55.7	2.0	3.0	3.3	0.09	0.50
Iva	0.0	3.7	96.3	1.2	0.0	0.0	0.00	0.04
IVb	12.3	19.0	59.4	6.3	2.7	0.3	0.16	0.32
IVc	3.0	29.3	62.0	2.7	2.7	0.7	0.03	0.47

I) Pasado Cape, II) Caraquez Bay, III) Tarqui beach at Manta, IV) La Barca Point. Q = quartz, F = fdeldspar, Rat = rock fragments, B = diverse biogenic debris, HM = diverse heavy minerals, M= mica. Mi = Q/F+RFand Pi = F/RF.

The curves from the Tarqui beach at Manta (IIIa, IIIb and IIIc) are the more similar among themselves, the saltation population, defined by range of the higher slope of the curve, is also similar, they show a very low traction component and low suspended population, as can be seen in the low percent of the low slopes near to the 0 and 100 commulative percent.

The scarp observed in the Tarqui beach profile corresponds to a berm scarp that suggest accretion. Low wave energy was observed during the sand sampling (see profile III in fig.4) and the beach face had 5º slope. In Tarqui beach the sand is find sand, well sorted to sorted and mesokurtic. The symmetry changes from very skewned to fine to skewned to coarse sizes from infralitoral to supralitoral zone.

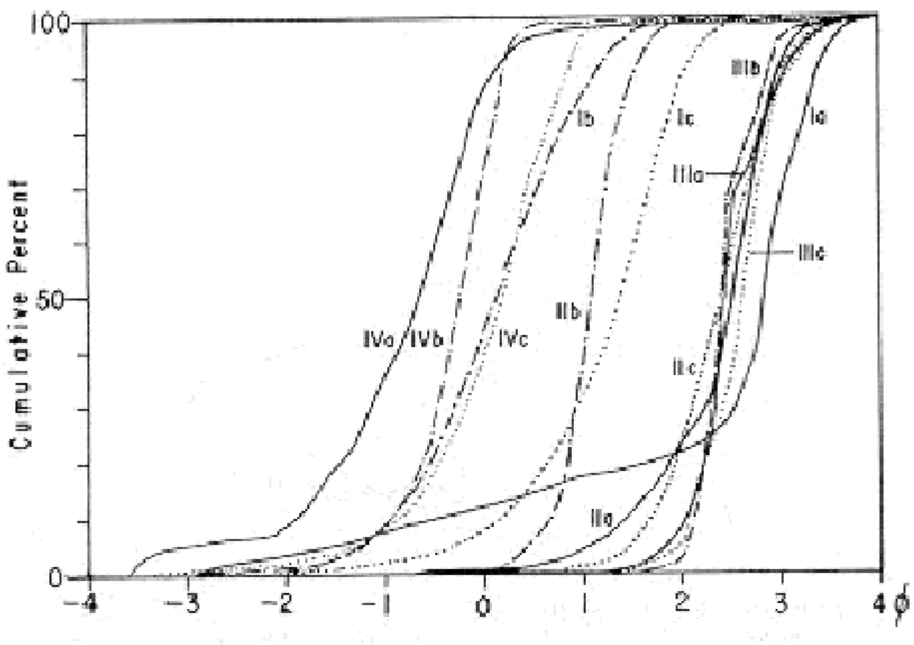

Figure 5. Cumulative granulometric curves. Solid lines: infralitoral zones; discontinuous lines: mesolitoral zone; dotted lines: supralitoral zones.

A higher energy beach is that of La Barca Point beach (Fig. 4), that has a 7º beach face slope and is the narrowest one. The samples of this beach have cumulative granulometric curves charged to the coarser sizes (Fig. 5). The sample IVa was the coarser one, with very coarse sand as mean graphic size (Table 4). This beach was richer in rock fragments than the others (Table 5) and shows beach cusps associated to rip currents. The petrographic analysis shows a relative great abundance of rock fragments and feldspars. The feldspars were plagioclases and showed frequently oscillatory zoning that suggest a volcanic source (Helmold, 1985). The abundance of rock fragments and feldspars are related to Ethology and tectonics of the study area, that usually exerts an important control. According to the geologic map (Fig. 3) the most abundant rock outcrops are from sedimentary rocks and sediments aging from Tertiary to Recent. There are few scattered and small cretacic basaltic lavas, tuffs and breccias outcrops from Cayo Fm. and Piñón Fm. (see Fig. 3). The great majority of rock fragments observed in thin section are composed by chert, siltstone, sandstone and volcanics. Although there are important shales outcrops in land, the resistance of this kind of fragments is too low to be preserved in the beach environment.

Essentially the rock fragments were more abundant in the infralitoral zone (zone a) than in the supralitoral zone (zone c). This is probably due to the fact that the aqueous media is more efficient in load transport than the wind agents.

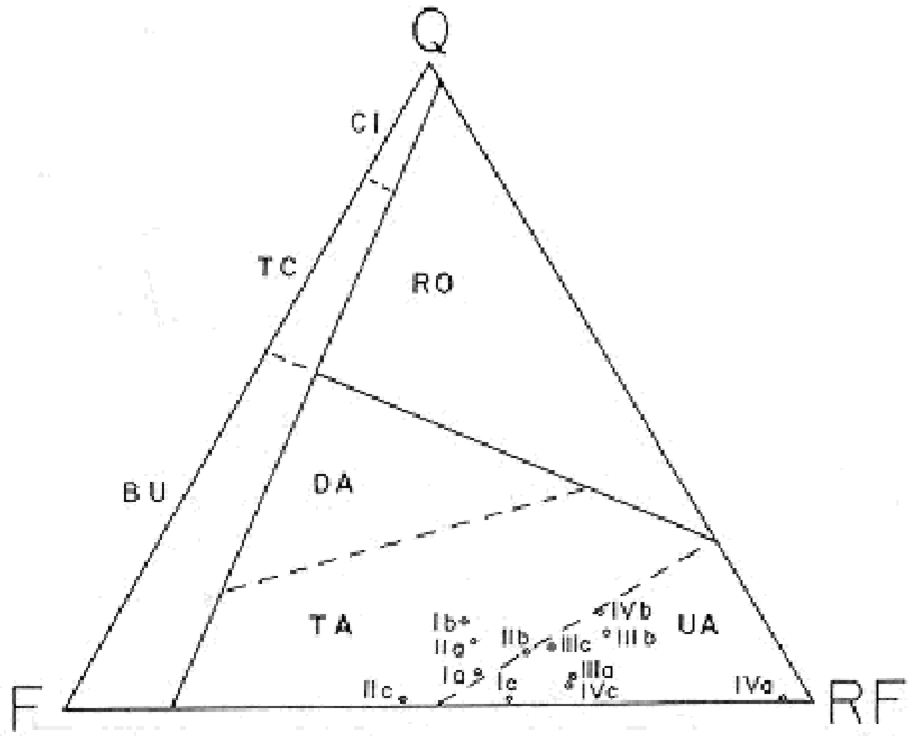

Figure 6. Q-F-RF Dickinson's Triangle (Dickinson et al., 1983). The empty circles represent the sand composition of the studied beaches. CI: craton interior, TC: transitional craton, RO: basement uplift, RO: recycled orogen, DA: dissected arc, TA: transitional arc, UA: undissected arc. I) Pasado Cape, II) Caraquez Bay, III) Tarqui at Manta and IV) La Barca Point. The infralitoral, mesolitoral and supralitoral zones are represented by a, b and c, respectively.

Both quartz and biogenic debris were not abundant and their distribution don't show a preferential pattern. Mica was also not abundant and the lowest values were found on the infralitoral zone where more energy of transport is available.

Low heavy minerals concentration were found on the studied samples with exception of sample Ic, which has 94% of heavy minerals according to the petrographic analysis.

This particular sample is composed notably by magnetite and Ilmenite. The sample was analysed by x-ray fluorescence; showing 63.85% of Fe_2O_3 and 30.20% of TiO_2. Also high values of magnetite in black sands have been found by Carranza-wards (1980,1986) in the south east pacific coast of Mexico where the Tertiary volcanic rocks are the main source for magnetite. The sample Ic is probably derived from the cretaceous volcanic rocks that outcrop in the studied area.

On the other hand, the observed maturity index (Mi = Q/F + RF) varies from 0.00 to 0.16 (Table 5) with 0.07 average. This low value for the maturity index can be explained by the fact that the distance between the source and the deposition area is short, in such a way that both feldspar and rock fragments have not been exposed to weathering for a long time. The observed variations (Table 5) in the provenance index (Pi = F/RF) are probably associated to the energy conditions present in each litoral zone.

The provenance index, on the other hand, suggests a supracortical provenance (Pettijhon, 1975). This is supported by the position of the samples in the triangular diagram (Fig. 6), given that the majority of the samples are located near the RF pole, and also by the fact that samples with range of fine sands were rich in rock fragments. This happen when the rock fragments are related with a supracortical origin, otherwise instead of rock fragments, quartz or unzonned feldspars will be more abundant.

According to the triangle of Dickinson et al. (1983) the samples fall in the sectors of transitional and undissected arc (Fig. 6). This reflects the influence of the subduction of the oceanic Nazca Plate under the South America Plate. The Q-F-RF values obtained for this sector of the ecuatorian beaches are contrasting with those obtained for Oaxaca in South Mexico (Carranza et al., 1988) where high ratios of plutonic and metamorphic feldespar characterize a transitional and diseccted arc, due to the exposed deep-seated crust.

CONCLUSIONS

1) Physical characteristics of the studied beaches show amplitud intervals from 25 m to 70 m and beach face slope from 3º to 15º. The lower slope is for Caraquez Bay and the higher for Pasado Cape Beach. The beach profiles suggest non deposit conditions for Pasado Cape and La Barca Point beaches, while Caraquez Bay and Tarqui beaches seem to be in accrecional status, specially Tarqui Beach at Manta, that has a very well developed berm. On the other hand the sorting was better for the sands of the beaches from Caraquez Bay and Tarqui at Manta.

2) Seventy five percent of the studied beach samples are fine sands, two samples correspond to medium sand size and the coarsest sample was a very coarse sand located in the infralitoral zone of the Pasado Cape beach, that also show the highest traction population according to the granulometric cumulative curve. This seems to supports the idea of a non acretional beach. The inclusive graphic skewness didn't show a particular or preferential pattern and the kurtosis was mainly mesocurtic or leptocurtic, but also without a specific distribution.

3) The most abundant constituents of the sand samples were the rock fragments and the feldspars (plagioclase type) that suggest a volcanic origin due to the abundance of oscillatory conning in plagioclases.

4) The sample Ic, from the supralitoral zone of Pasado Cape, was constituted by high values of iron and titanium present in magnetite and limenite derived probably from basic laves of cretaceous age (Piñón Fm.).

5) The position of the quartz-feldspars-rock fragments data positioned in the Q-F-RF Triangle from Dickinson's et al (1983) suggest that the samples were taken in a terrain represented by an arc tectonic setting. This is notably transitional arc for samples from northern beaches and undisected arc for southern studied beaches.

ACKNOWLEDGMENTS

We appreciate the support given by the authorities of the Universidad Nacional Autónoma de México (through Institute de Ciencias del Mar y Limnología and Instituto de Geología) and Universidad Central del Ecuador. Also to Mr. Gabriel Sánchez Lara for granulometric sieving and Susana Santiago Pérez and Patricia Altuzar Coello for XRF analysis.

We thank Ing. Rodrigo Tirado and Dr. Tsuchi, as well to the IGPCP-246 (UNESCO) group for their support during the field trip.

LITERATURE CITED

BALDOCK, J.W.,1982. Geology of Ecuador. Explanatory Bulletin of the National Geological Map of the Republic of Ecuador. Ministerio de Recursos Naturales y Energéticos and Institute of Geological Science, London, 70 p.

CARRANZA-EDWARDS, A., 1980. Ambientes sedimentarios recientes de la Llanura Costera Sur del Istmo de Tehuantepec. *An. Centro de Cienc. del Mar y Limnol., Univ. Nal. Autón. México, 7 (2)*:13-66.

CARRANZA-EDWARDS, A., 1986. Estudio sedimentológico regional de playas del estado de Chiapas, México. *An. Inst de Cienc. del Mar y Limnol., Univ. Nal. Autón. Mexico, 13 (1)*: 331-344.

CARRANZA-EDWARDS, A., L. ROSALES-HOZ and R. LOZANO-SANTA CRUZ, 1988. Estudio sedimentológico de playas del Estado de Oaxaca. *An. Inst. de Cienc. del Mar y Limnol., Univ. Nal. Autón. México, 15 (2)*: 23-38.

CROOK, K.A.W., 1974 Lithogenesis and geotectonics: the significance of compositional variation in flyssch arenites (graywackes), in Modern and ancient geosynclinal sedimentation: *SEPM Spec. Pub., 19*: 304-310.

CRONAN, D.S., 1980. Underwater Minerals. Academic Press, London, 362 p.

DICKINSON, W.R., and C. A. SUCZEK 1979. Plate tectonics and sandstone composition. *Amer. Assoc. Petrol. Geol. Bull. 63 (12)*: 2164-82.

DICKINSON, W.R, L. S. BEARD, G.R. BRAKENRIDGE, J.L. ERJAVEC, R.C. FERGUSON, K.F. INMAN, R.A. KNEPP, F. A. LINDBERG and P. T. RYBERG, 1983. Provenance of North American phenerozoic sandstones in relation to tectonic setting. *Geol. Soc. Amer. Bull., 94*: 222-235.

FOLK, R.L, 1974. Petrology of Sedimentary Rocks. Hemphill Pub. Co., Austin, Texas, 182 p.

GARRISON, R. E., 1992. Neogene phosphogenesis along the eastern margin of the Pacific Ocean. *Revista Geológica de Chile, 19 (1)*: 91-111.

HELMHOLD, K. P. 1985. Provenance of feldspathic sandstones - the effect of diagenesis on provenance interpretations: A review. G.G. Zuffa (ed.), Provenance of Arenites: 139-163. D. Reidel Publishing Company, Dordrecht, Holland.

IGPCP-246, 1992. Pacific Neogene events in the tropical South America. Guide book for Excursion Neogene at Cabo Pasado and Cabo San Mateo. International Simposium for IGPCP-246. November 18-20, 1992, 32 p. Quito, Ecuador.

KUNZENDORF, H., 1986. Marine Mineral Exploration. Elsevier New York, 300 p.

MERO, J. L, 1965. The Mineral Resources of the Sea. Elsevier, New York, 312 p.

PETTIJOHN, F. J., P. E. POTTER and R. SIEVED, 1972. Sand and Sandstone. Springer-Verlag, New York, 618 p.

PETTIJOHN, F. J., 1975. Sedimentary Rocks. Harper and Row Publ., New York, 628p.

POTTER, P. E., 1978. Petrology and chemistry of big river sands. *Jour. Geology*. *86:* 423-449

POTTER, P. E., 1986. South America and a few grains of sand: Part 1-Beach sands. *Jour. Geology, 94 (3)*: 301-319.

SCHWAB, F. L., 1975. Framework mineralogy and chemical composition of continental margin-type sandstone. *Geology, 3*: 487-490.

2.- Trabajo recibido 19, 2, 1993; aceptado 10, 3, 1993