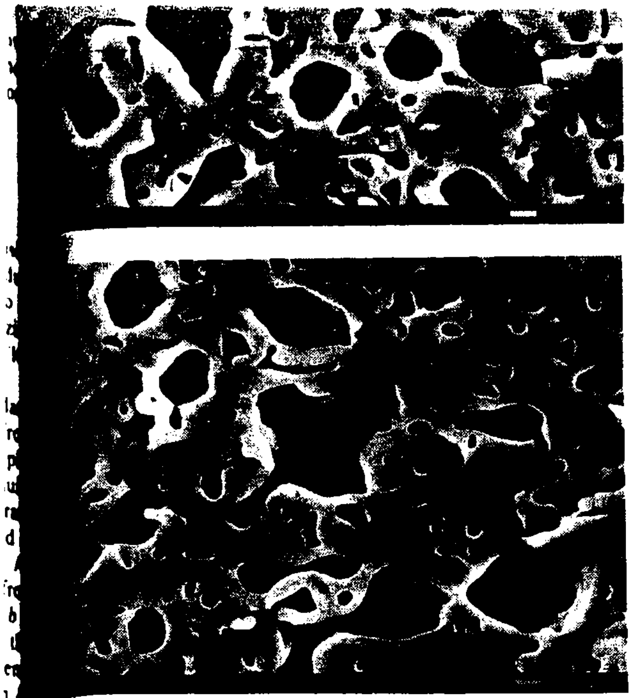
POTTER 1984



Scanning electron micrographs showing cleavage sections mposed regions of AP in *a*, a pure crystal and *b*, a crystal h the reaction was initiated by NH_4NO_3. No difference in could be discerned in a series of careful comparisons of reas of both types. We suggest that the texture of the posed salt is that of reactant remaining after penetration by gular migration of small particles of an active phase within nd which decomposition occurs, presumably including O_4 intermediate and possibly in the form of liquid. ed reaction occurs when droplets coalesce, resulting in the larger pore spaces. Scale bars, 1.0 μm.

linked by two or more pores, may be ascribed to a nhancement of reaction when two active reaction drop- during their irregular wanderings. Perhaps there is y growth of the active reaction zone by bubble or froth n. As nuclei grow hemispherically, there must also be of active droplets[17] into two or more which thereafter independently. Unfortunately, the identification of the ion of NO_2ClO_4 within partly decomposed crystals was cable as it hydrolyses so readily.

action mechanism described above does not take into the initiation of reaction in pure AP, where no source zed nitrogen is available. Although we have not yet n detail the slow reactions occurring during the induc- iod, we have observed that nucleus generation often ithin grooves on roughened surfaces (see, for example, Such surface retexturing occurs during sublimation umably is accompanied by other slower decomposition , such as Cl_2O_7 breakdown[16], capable of oxidizing . Any volatile NO_2ClO_4 produced can only participate s growth when it is effectively retained within pores nels, progressively formed at the inner surfaces of Thus again[17,18] we identify nuclei as specialist structures d particularly to retain (temporarily) a fluid participant

decomposition. Permanganate and chromium containing anions may participate similarly by oxidizing ammonia, the reduced oxyanion being reoxidized through ClO_4^- breakdown.

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South African modern beach sand and plate tectonics

"Fly by night... glorified abstracts" - RVI on 'Nature'

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South America is the ideal continent for baseline studies on how the framework composition of modern sands relates to reconstruction of palaeoplates—it has well-defined active and passive margins, great contrasts in climate and relief and is free of continental glaciation (Fig. 1). I report here petrographical studies of its beach sands which show two active margin associations rich in volcanics and plagioclase—one along its Pacific coast and one along the Argentine coast—and two associations rich in quartz—a passive margin association from Argentina to Trinidad and a moderately, quartz-rich association along the Caribbean coast. Tectonic control is thus overwhelming but complications exist along the Argentine coast where a dry, narrow continent permits active margin sand to mantle a passive margin. Another surprising result is that quartz-rich sands border the crystalline rocks of much of the Sera do Mar in Brazil.

Sandstone has long been used[1] to help identify the tectonic setting of ancient basins for many reasons. It is present in almost every basin, including some of the very oldest, and it occurs in almost every sedimentary environment with the possible exception of the abyssal plains of some deep sea basins. Each grain also carries its own provenance history, which is easy to study with both microscope and microprobe. However, the idea that the petrographic study of 10–30 sandstone samples from an ancient basin, perhaps a sample of only 10^{-12} to 10^{-16} of its entire volume, can reveal a plate tectonic setting, and thus infer major crustal processes, may be considered audacious.

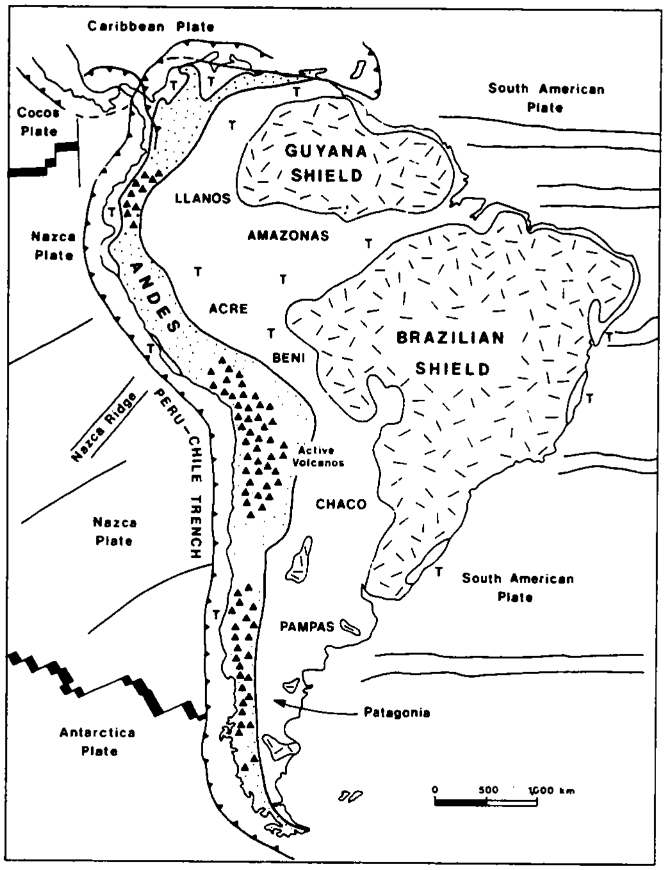

Fig. 1 Major tectonic elements of South America and adjacent ocean basins.

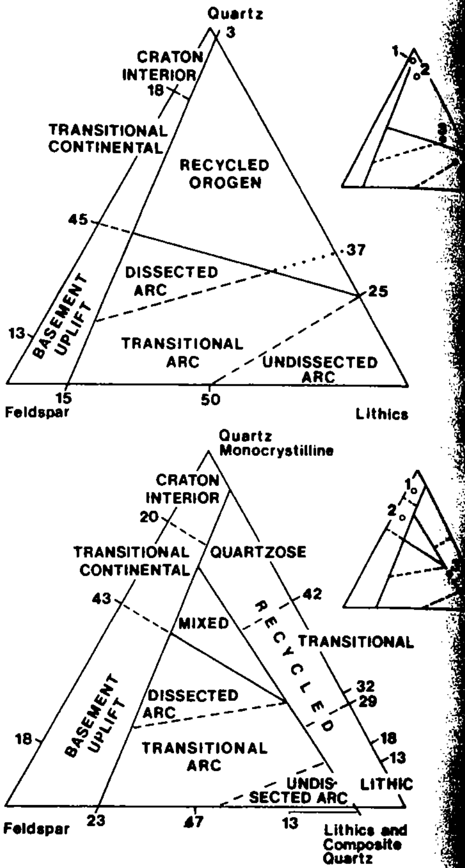

Fig. 2 Plate tectonic classification of sandstone minera ref. 6, Fig. 1). Numbers in the small triangles indicate composition of passive margin sands from the Rio d Trinidad; 2, beach sands from Trinidad westward along t bean coast; 3, Argentine beach sands; and 4, the sands America's Pacific coast (see Fig. 3).

Present themes of the plate tectonic control on framework mineralogy come from studies of Mesozoic and Cenozoic basins[2–7] supplemented by studies of modern deep sea[8–11] and alluvial sands[12–15]. More than 40 papers on the plate tectonic interpretation of sandstone mineralogy have appeared since 1970, and virtually all of these recognize three different major tectonic settings with seven to nine subdivisions using standard compositional triangles (Fig. 2).

South America, the fourth largest continent, forming 12% of all the Earth's land surface, is the most elegantly asymmetric of all the continents from a plate tectonic standpoint—the entire west coast is an active margin, all of the eastern coast from Tierra del Fuego to Trinidad is a passive margin and only its Caribbean border, where translation seems important—is moderately complex (Fig. 1). South America is also free of continental glaciation; continent-wide provenance studies of modern sands are difficult to interpret where Pleistocene continental glaciation was widespread, because it blurs the continent-wide distribution pattern of sand. The climate of South America ranges from arid, with extremely dry deserts along coastal Peru and Chile, through temperate to tropical, with up to 10 m of rainfall in northwestern Colombia. Furthermore, major climatic trends are transverse to the Andes. Physiographic contrasts are equally impressive. The Andes Mountains, the world's longest mountain range with a length of almost 9,500 km, have towering peaks, an average elevation second only to that of the Himalayas, and many high, vast, dry plateaus. Additionally, South America has sweeping plains and low plateaus—some dry and grass covered, some covered by vast jungles. Also present along much of the Brazilian coast are jungle covered mountains composed of Precambrian rocks that rise from a narrow coastal plain. The coastal physiography and climate for the entire continent is summarized in ref. 16.

Another reason to study South America is that there are data available on the petrography and chemistry of the modern river sands of the Amazon and Tocantins basins[14], an area that covers about 40% of South America plus some for the
Orinoco, Parniba do Sul, Paraná and Sao Francisco
well as for small rivers on the Peruvian coast. To
river sands come from basins that drain about
continent. There are also published data on deep-s
sands of the Peru–Chile trench bordering South A
addition to the sands of Atlantic shelf[18].

This study reports on the first-ever effort to study
cally the sand of a single environment, the beach
entire continent. The technique used in sampling
sands of South America was based on that of Du
showed how the petrology and chemistry of mo
beaches become more mature as litoral drift tra
away from the southern edge of the Baltic Shield.

Why study modern beaches? The beach is th
between marine and non-marine environments so tha
sands have passed through it and, with recycling,
same is true for many, if not most, ancient sandsto
the beach environment is one of high kinetic energy
a strong test of another factor: modification of
mineralogy by abrasion. In other words, if petro
correctly identify the tectonic setting of a landm
beaches, surely they could do so from its fluvial
the beach is an easy environment to reach and
important factor when an entire continent with a
50,000 km is to be sampled. More than 200 sampl
sand were collected in 116 field days. Beaches we
points of convenient access and the 27 samples re
were selected because of their geographical repres
each major mineral association.

Where possible, fine- to medium-sand was colle
match the dominant size classes with midpoints
350 mm (2.5 and 1.5ϕ) as reported by Shea[20] ba

ation of 11,212 analyses chiefly of onshore sands and bnes, but including some sands from modern continental . These two size classes include ~35% of his present e grain-size distribution. Because grain sizes of samples study are coarser than those of most deep-sea sands, ock fragments with their greater provenance information expected than in studies of typical fine-grained, deep-sea derived from the same source. To avoid the pitfalls of ng only a narrow size fraction and missing important stic grains[21], the entire sand was impregnated and studied standard counting procedures[15] after staining for potash r.

trasts in the beach sands of South America are dramatic ged by variations of quartz (Q), feldspar (F), and rock nts (Rf) and dominant types of rock fragments (Fig. 3). sands of South America's leading margin, the Pacific have an average Q:F:Rf ratio of 19:13:68, whereas the ent's trailing margin coastline from the Rio Plata to ad, a coastline bordering the Brazilian and Guyana s, averages 95:3:2, a staggering difference which is even impressive when it is realized that mountains composed cambrian crystalline rocks border much of the South ic coastline of Brazil. A petrographical count of each size n from a beach at Huacho in Peru and one from Natal zil confirm these contrasts (Fig. 4). Downstream increase artz content in both the Amazon and Orinoco rivers vely eliminates significant Andean contributions to beach from the mouth of the Amazon to Trinidad (Fig. 5). The ragments of the two major mineral associations are also different—volcanics predominate along most of the coast whereas rare alterites and igneous and metamorphic are characteristic of beach sands between Rio de la Plata rinidad.

smaller mineral associations are present and both are of interest. All the Argentine coast from Rio de la Plata to del Fuego has an Andean, leading edge composition only y more mature than that of Pacific beach sands—the Rf ratio averages 33:15:52—and again volcanics are its ant rock fragments. Although the entire Argentine coast railing margin, its beach sands have a leading edge osition because Patagonia is narrow and its bedrock near oast is largely Tertiary molasse itself derived from the s. In addition, rainfall is scant, thus minimizing increase turity downstream from the Andes. One important implica- mmediately follows—use of sandstone mineralogy alone ntify palaeoplate setting can result in tectonic misclassifi- unless the basin's characteristics and regional setting are onsidered.

fourth and smallest association occurs from Trinidad to outh of the Magdalena River in Colombia. Here beach have an average Q:F:Rf composition of 78:5:17, although y rock fragments are more abundant. This predominance artz—as along the southwestern coast of Brazil—is surpris- ven the proximity of metamorphic highlands close to the ine. Dominant rock fragments are metamorphics derived the Venezuelean Andes.

liminary results based on thin section study of light als indicate four major mineral associations for South ican beaches: two immature leading edge associations and ailing margin association, one from the Rio de la Plata to dad and the other along the Caribbean coast from Trinidad Magdalena River. Compositionally, west coast beaches n the boundary between undissected and transitional arc ckinson and others[6] and Argentine beaches plot as a ed orogen (back arc basin), although near the boundary nsitional arc; Venezuelan beaches plot as a recycled orogen he boundary of the craton–interior field and beaches from o de la Plata to Trinidad plot in the craton–interior field 2, inset). Thus my preliminary results confirm the fields sted by Dickinson and others[6].

se preliminary results pose several interesting questions: ere a leading edge of a continent becomes narrow, its

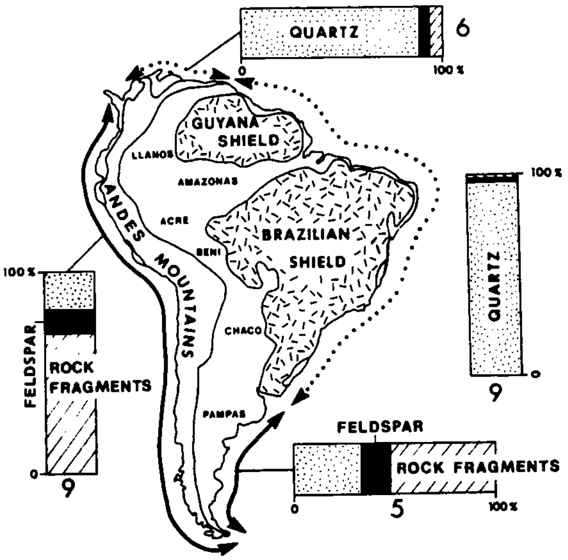

Fig. 3 Major, broad, mineral associations of South American beach sands.

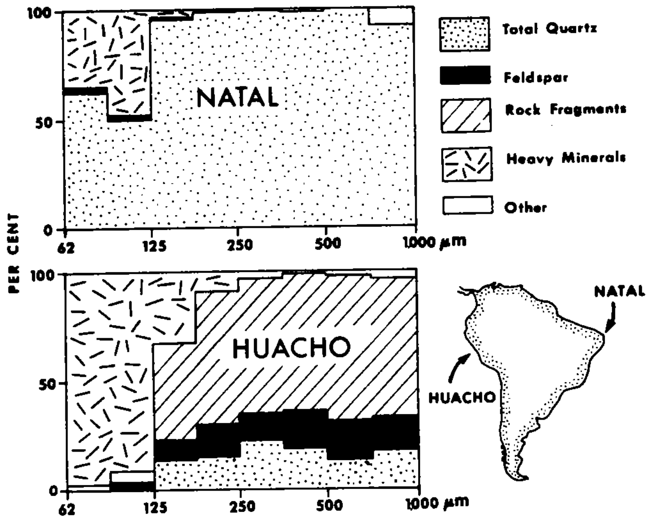

Fig. 4 Fraction analysis of beach sand at Huacho, Chancay Province, Peru and Natal, Rio Grande do Norte, Brazil shows great contrast in composition between each size grade.

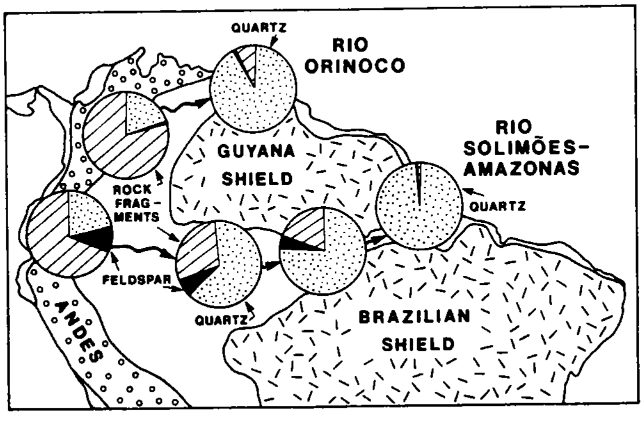

Fig. 5 Downstream increase in compositional maturity—more quartz and fewer rock fragments—in Orinoco and Solimões-Amazonas Rivers. Data for Solimões-Amazonas from ref. 14.

characteristic composition can also occur on its 'backside', passive margin, especially where a dry climate prevails, as in Patagonia in Argentina. What implications does this have for the palaeogeographic reconstructions of ancient basins? How will a wet versus dry climate on the backside of a continent affect the mineralogy of its sandy detritus reaching the sea?

Abrasion on the beaches of South America's western leading edge does not reduce our perception of the towering land mass on shore; on the other hand, the low feldspar content of beaches bordering Brazil's Serra do Mar commonly gives little hint of these Precambrian mountains. Would this be true if the coastal climate were arid rather than humid?

Why do some of the continent's larger rivers show such a great change in mineralogy from Andean source to Atlantic mouth? Would this happen if their river basins had a subarctic, temperate or arid climate?

How commonly do the boundaries of major mineral provinces along a continental margin coincide with the mouth of a large river and produce contrasts like that on opposite sides of the Rio de la Plata, whose estuary separates sand of leading edge composition in Argentina from sand of trailing margin composition in Uruguay?

How carefully can we recognize subprovinces al Andean leading edge, either on- or offshore, and relate onshore geology?

The effect of tectonic control on sandstone compositio to be overwhelming, but how much relief is needed to o the effects of high rainfall? Could there be areas where w sample a 'controlled experiment'?

As more samples are reported from modern beach sa the adjacent offshore, how well will they agree? Will o sands have a different composition than their borderi or deep seas?

Are we near the stage in regional studies of moder that we can deduce the sand composition of an entire co If so will computer modelling add a new dimension t enance studies in the not too distant future.?

This research was funded by NSF grant EAR-80-1 received much help in every coastal country of South A which will be fully acknowledged when final results a lished but, until then, I thank W. R. Dickinson (Unive Arizona) L. J. Suttner and A. Basu (Indiana University) Emery (Woods Hole Oceanographic Institute) and J. Maynard, (University of Cincinnati) for helpful advice.

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A new method for environmental analysis of particle size distribution data from shoreline sediments

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The study of particle size distributions is commonly used to investigate sedimentary processes and environments. Originally such work concentrated on typifying these distributions by their sample moments, while more recent statistical studies have proposed fitting parametric models to sample data and then using the resulting parameter estimates. We have investigated the use of log-hyperbolic and skew log-Laplace models to distinguish between beach and dune sands, with the aim of classifying the depositional environment of some mesolithic middens. We found that the former models were unsatisfactory for various numerical and physical reasons, while the latter provide a simple and robust method which is useful for the classification of sand sediments.

Barndorff-Nielsen[1,2] and Bagnold and Barndorff-Nielsen[3,4] demonstrated the statistical and geological advantages of using log-hyperbolic distributions to interpret particle size distributions. The method eliminated[1] the mathematical arbitrariness and unreliable assumption of normality associated with the use of low-order moment measures (such as, mean, median, skewness, kurtosis and developments of them[5-7], and (2) used a mathematical distribution that had been directly related to the geological processes of transportation and deposition responsible for the sediments[3,4]. Four parameters were utilized to describe the log-hyperbola: ϕ, γ, μ and δ (Fig. 1). Bagnold[1-4] suggested that the gradient ϕ was related to the significa the particle size distribution of saltation, and that the g γ corresponded to the significance of coarser grains 'creep'.

We have employed this statistical procedure to chara the particle mass-size distributions with data obtained intervals obtained by standard procedures[8,9] from coastal salting and dune environements in the Inner Hebrides, and South Wales; and, in particular, to identify the depo environments, and hence the palaeogeography, represe shell sands of unknown origins obtained in trial pits and beneath late mesolithic shell middens investigated on t coast of Oronsay, Inner Hebrides[10-13] (Fig. 2). In thi study, samples were taken from along four transects c several depositional environments.

The fitting of the log-hyperbola was satisfactorily a both on our reworking of the published Bagnold and Ba Nielsen[2,3] data and on a substantial proportion of ou data[14]. However, in four out of our 15 attempts to u procedure no numerically stable solution was obtained. D numerical investigation of these four cases revealed t likelihood function was virtually flat with respect to the meter δ. The physical explanation is that there are many d log-hyperbolic distributions, differing only in curvature peak of the distribution, which fit the data equally wel arises because of the coarse sequence of sieves used collection of our data: $\frac{1}{2}\phi$ rather than the $\frac{1}{4}\phi$ intervals u the Bagnold and Barndorff-Nielsen data. The transitio 'fine-grade fraction' to 'coarse-grade fraction' typically over a range rather less than $\frac{1}{2}\phi$. Consequently, if the p the distribution occurs close to a mesh size of any of the then the available data provide little information on the of this parameter δ which essentially measures the curvat the distribution at its peak. Use of alternative numerical niques, in particular the programs used by Barndorff-N and his colleagues[15], did not alleviate the numerical pro Note also that the computation, using any of the num