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Contributions to the Coastal Geomorphology of Latin America

The scope of coastal geomorphology as practiced in Latin America by geographers from the United States spans a wide range of interests. Among the topics encompassed by their studies are:

1. shoreline configuration
2. beach accretion and erosion
3. deltaic plain development
4. coastal plain stratigraphy
5. identification of coastal forms, such as beach rock, terraces, beach ridges, and sand dunes
6. wave and current processes
7. sea level fluctuations
8. coastal ecology

Although these several divisions appear to cover the range of possible lines of inquiry, additional avenues do exist and the amount of data acquired thus far is minute compared to the potential for coastal geomorphological research. Prior to a historical analysis of the contributions of coastal geomorphological investigations, the forthcoming statements should be put in proper perspective. Restriction of this subject to only these contributions made by United States geographers would provide a totally misleading impression of the status of coastal research in Latin America and would especially misrepresent the areal distribution of recent activities. In order to overcome this dilemma, the approach used in this paper will be to stress the efforts of the United States geographers and also to indicate the supplementary and complementary projects undertaken in Latin America by the local scientists and others on the international level.

Review of contributions

Many of the early expeditions to Latin America recorded observations of phenomena that could be broadly described as being within the realm of coastal geomorphology but as these early observations were not specifically directed to the problems of coastal processes and coastal landforms, they need not receive

additional mention. In the latter part of the 19th century and early decades of the 20th century, coastal observations had not really progressed to the point of geomorphological investigations. Rather, coastal areas were being included in regional physiographies (Bengston 1926; Sheppard 1930) and often disguised in geological reconnaissance reports. It was not until the post-World War II era that physical geographers began to look seriously at the margins of the Latin American land mass by directing studies at the types of landforms found in the coastal regions and at the processes responsible for their formation. Of the approximately 40 entries in the bibliography that are the product of recognized "geographers," fully 80 percent are associated with but two geography departments in this country the University of California at Berkeley and Louisiana State University in Baton Rouge. It is no coincidence that both departments were initially directed toward this pursuit by the then fledgling Office of Naval Research - Geography Branch. The efforts of these two geography departments have been somewhat spatially restricted. Berkeley has directed many of its students to Baja California (Hammond 1954; Arnold 1957) and to the general Middle America area (Doran 1955; Vermeer 1959; Radley 1960; Alexander 1961), whereas the L.S.U. projects, under the auspices of the Coastal Studies Institute, were primarily restricted to the Caribbean and Mexico (Russell 1958, 1959, 1962; Psuty 1965, 1966). There are several notable exceptions to this areal preference by personnel indirectly or directly associated with L.S.U. but not necessarily with the Coastal Studies Institute (West 1954; Vann, 1959; Delaney 1963; Craig and Psuty 1968) but the data indicate that more than 70 percent of the publications produced by United States geographers focus within the Middle America area.

Review of the subject matter

The most revealing statistic concerning the potential contribution of United States geographers to coastal geomorphology is the proportion of investigators contributing more than one publication in this field of inquiry. Of the sixty-three writers listed in the United States division of the bibliography, only fourteen, or 22, are designated as preparing more than one publication and only three, 5 percent, have more than two publications to their credit. The most immediate product of these short-lived interests is the lack of a well-defined program of inquiry either in a methodological or topical sense. Despite the dominance of the California and L.S.U. departments, there is little evidence to suggest that either program had an underlying philosophy of coastal geomorphological inquiry that is reflected in the contributions of their students. The only example of a concerted

program with long term objectives is the beach-rock study undertaken by R. J. Russell (1958-1962, 1968). The following synopsis of other lines of inquiry will point out the variety of research efforts as well as the independent nature of the research.

The greatest quantity of contributions may be categorized as descriptive coastal geomorphology beginning with Vaughn (1916) and extending to the more recent publications of Russell and McIntire (1968). Many of these works contain excellent geomorphological maps and provide very basic data. Some, however, fail to fulfill this geographic principle and tend to be mere tabulations of geomorphological phenomena.

A raft of publications concentrate on what may be termed paleogeomorphologic features and introduce the dimensions of the geologic time scale. In some cases, the subject matter is the presentation and discussion of coastal terraces and a relative time scale (Ives, 1951; Alexander 1961; Craig and Psuty 1968), whereas other papers are more concerned with the recognition of a fluctuating relative sea level (Barrett 1962; Delaney, 1963; Curray, 1964; Richards, 1967). It is somewhat academic to distinguish between those papers which attempt to stress sea level fluctuations versus those which attempt to measure tectonic instability of the shoreline for both must be considered in terms of each other. What is important is that there is little to bind these efforts together. Certainly the absence of isotopic dating relegates many of these efforts to a relative chronology, but all too often the unifying principle of universal Pleistocene fluctuations of sea level is ignored.

There is a paucity of publications which attempt to detail the Quaternary development of some coastal plain in Latin America (Kaye 1995; Stoddart 1962; Delaney 1963; Psuty 1966b; Craig and Psuty 1968; Walker and Thompson, 1968). These papers are of uneven quality and succeed to varying degrees but they do have a common Quaternary framework and nearly each presents more than adequate morphologic maps depicting the spatial association of the landforms.

A few of the United States contributions have a sufficiently broad base so as to be classified as ecology rather than pure coastal geomorphology. It is significant to note that each of these articles, although some may have only one author, is the product of field research teams (Newell 1951; Brand, 1957-1958; Vann 1959; Storr 1964; Thom 1967; Craig and Psuty 1968). In each case considerable basic data is reported in map and tabular form.

Only two publications attempt to introduce the man-land relationship within a geomorphologic framework and it is no surprise to see the writers are Arnold (1957) and Parsons (1965), both from the California school.

It is odd that in an environment so dynamic and subject to considerable change in short periods, only one paper is specifically directed toward this problem (Vermeer, 1963). One other paper (Psuty, 1966a) stressed and documented seasonal beach changes but not in the same context. There is no doubt that the lack of a continuing program of investigation by a particular researcher or organization fosters this paradoxical situation. Perhaps this is not a practical program to be undertaken by United States researchers due to their spatial separation from the study area, but perhaps it should be given more serious consideration as a specific project.

The final area of emphasis is twofold and together these topics may contain the primary direction for additional geomorphological research in Latin America. They involve the use of aerial photography in shoreline mapping and interpretation of coastal geomorphology (Vest, 1931; Goosen 1962, 1964) and the synthesis of coastal geomorphology on a continental scale (McGill, 1958; Putnam, Axelrod, Bailey and McGill, 1960). These publications contain the challenge of accumulating coastal geomorphologic data in Latin America as well as the means to accomplish the task. All too few publications contain detailed geomorphologic maps and too many are dependent on out-of-date topographic maps with contour intervals of such magnitude so as to exclude most of the coastal geomorphic features. Since the topographic maps do prove to be inadequate in most of Latin America for the purpose of coastal geomorphology, the logical, and perhaps preferable, alternative is to make increased use of the growing aerial photo coverage of the shoreline.

Were the coastal investigations in Latin America conducted only by the United States geographers, extensive portions of Latin America would be totally without a coastal data base. Fortunately, however, Latin American and European scientists have been completing coastal studies in these areas and have accumulated an impressive list of references. In fact, the non-United States contributions attained scientific quality at least one decade earlier judging by the performances of Basadre (1900) and Halle (1908-1909). In addition to the slightly earlier interest in coastal geomorphology by the non-United States researchers, an analysis of the data reveals that the Latin American area was provided with a much more

uniform study and a greater quantity of research activities, at a ratio approximating 2.5 to 1. The southern portion of Latin America was certainly not neglected as is indicated by the 22 non-United States reports on Argentina, 48 on Brazil, 10 on Chile, and 22 on Peru. Furthermore, there has been a sustained interest in the coastal regions as evidenced by the continuing series of publications since 1900 in Peru, since 1909 in Argentina, since 1915 in Brazil, and since 1937 in Chile. A considerable amount of the coastal exploration was in conjunction with oil prospecting and accounts of this nature have been culled from this report, but numerous worthwhile contributions from this general milieu have been retained (Oppenheim, 1937; Grantham, 1938).

The contributions by the non-United States group were generally quite varied but a few projects do arise that are distinguishable. One of the longest spans of "foreign" interest stems from the Cambridge University Expedition initially under the direction of J. A. Steers. Steers early established an interest in the Caribbean and particularly toward coral cays (1940z, 1940b, 1940c). This eventually led to the excellent and recent contributions by Stoddart on the cays of British Honduras (1962a, 1962b, 1963, 1955). Another example of a continuing series of publications on a specific topic by a foreign scientist is the list compiled by Gierloff-Emden on coastal El Salvador (1958a, 1958b, 1959a, 1959b). Few other areas can claim a continuing program, although the Guianas, especially Surinam, have intermittently borne field parties and the resulting spate of related publications (Zonneveld, 1950, 1953, 1954; Geyskes, 1952; Brouwer, 1953).

Review of the subject matter

A greater continuity of subject matter in the publications by the non-United States group may be anticipated by the fact that 27 writers, 23 percent of the total, have contributed more than one publication and 12, or 10 percent, have more than two publications on coastal geomorphological research. Some of these publications have very restricted circulation and, therefore, their value is somewhat reduced, but they are probably available in the study area or the regional capital. The several avenues of geomorphological inquiry are summarized in the following sections.

Unlike the United States writers, the non-United States group has contributed many regional coastal geomorphologies (Munoz 1941; Bigarella, 1946; Ab'Saber, 1955; Zubieta, 1955; de Silveira, 1964). Most of these publications provide rather elementary identification and description and are handicapped by poor

cartographic work. However, they are contributing a geomorphological data base for later comparison and analysis. Many areally-restricted regional studies have been accomplished, especially in Brazil and the Guianas, and with a purposeful program, this could be a major contribution to geomorphological knowledge.

Deltaic studies have occupied an important position relative to the effects of fluvial sedimentation on coastal progradation (Cabrera la Rosa, 1938, 1946; Zonneveld, 1950; Pomar, 1962; Sioli, 1966). Pomar has interpreted the shifts of river channels and the subsequent modifications of the shoreline topography. Another group of publications is more directly concerned with the processes of sediment accumulation and the specific geomorphological features produced by these processes (Grantham, 1938; Geyskes, 1952; Brouwer, 1953; Zonneveld, 1953, 1954, 1968; Choubert, 1959). Most of these writers have attempted to correlate seasonal changes of energy levels, pulses of available sediment and types of sediments and the production of beach characteristics, beach ridges, and cheniers.

Terrace identification in pure geomorphological terms characterized the earlier works in this category (Feruglio, 1937, 1947; Broggi, 1946; Fuenzalida, 1951; Cotton, 1962), whereas subsequent efforts attempted to incorporate Quaternary chronology, primarily in relative terms. Feruglio (1950), Fuenzalida (1965), and Urien (1968) developed a terrace sequence for their study on the Pacific Coast but the sequences appears not to be utilized or compared in other areas. On the Atlantic coast, Guerra (1950), Chebataroff (1955), and Regairaz and Bozzolo (1964) interpreted the Quaternary development of portions of the coastal plain as the area was subjected to fluctuating sea levels and shifting locations of sedimentary erosion and deposition.

Geomorphology and ecology of coral reefs and islands has been highlighted in the Caribbean by the British and local investigators as in the numerous publications by Steers, Stoddart, and Zans. These studies have stressed the current geomorphological manifestations and the interpretation of sea level fluctuations based on stranded coral reef platforms. It is quite interesting that this group of investigators has made a considerable contribution to storm effects on coastal stability (Stoddart, 1962a, 1963, 1965b). These data have significance for documentation of the effects of storm erosion and accretion on beaches as well as sand islands and coral cays.

In view of the and coasts in Latin America, it is quite logical to encounter several

publications that stress eolian processes and desert features. The coasts of Chile (Fuenzalida, 1956) and Peru (Broggi, 1961; Dresch, 1961) have the greatest number of publications about the desert features but the dunes are more the product of persistent winds on the arid coastal plain than any characteristic of coastal dunes. Although many of the regional coastal physiographies contain descriptions and identification of coastal dunal types, only one article is specifically directed to the development of coastal dunes (Diaz). The puzzling question concerning the absence of coastal dunes in the tropics has apparently escaped the interest of the Latin American coastal geomorphologists.

Similar to the United States geographers, the non-United States group has made use of aerial photography and has discussed its particular applications (Guzman, 1966). Tricart (1967) has contributed several air photo interpretations of Latin American shorelines (see the 1967 issue of *Photo Interpretation*). These articles are examples of the type of work that could be accomplished but as yet there is no particular program to develop photographic keys for geomorphologic phenomena. However, there is a regional specialization within particular issues and this concentration forms some type of structural areal coverage.

Summary of research

If we were to restrict this summary of research to the approximately 40 publications by United States geographers, few geomorphological questions would be answered and, indeed, few questions would even be asked. The inclusion of the non-United States researchers assists a critical summary but merely highlights the paucity of coastal geomorphological data.

The only two beach questions that have been attacked as process-response models have been the development of beach rock and the construction of beach ridges. Although neither question has been totally resolved, collaborative investigations in other coastal locations have substantiated their conclusions. Other detailed beach sedimentation studies have been conducted in Peru recently, but replicable process-response models have not been produced to date. Accretionary and erosional beach topography have been noted and discussed in many other of the publications but the pertinent observational data are usually lacking in the reports, although they are found in the coral platform and cay studies of Middle America.

The terrace chronology for the west coast of Latin America is basically a measure

of tectonic mobility and with isotopic or relative dating, terrace sequences can be correlated over short distances. Unfortunately, the many small fault-block units complicate a universally-applied sequence and thus the sequences are of limited applicability. Despite this shortcoming, a systematic approach to terrace chronology could contribute comparable data and could be especially instructive in studying sequences on the Atlantic coast.

Prognosis

The most severe criticism of the coastal geomorphological accomplishments is evidenced in McGill's coastal landform map (1958) and bibliography (1960). The lack of precise data on the most elementary level is appalling and emphasizes the helter-skelter nature of the investigations. Without attempting to fit all geomorphologists into one mold, there is a distinct need for fundamental data on detailed maps such as wave and current observations, sediment types on beaches and geomorphologic features, dimensions and spatial arrangement of coastal forms, and distribution of Quaternary deposits. Distribution and magnitude are the key attributes here. Process-response models and coastal morphological theory are needed also and should be structured toward replicable procedures.

Recommendation

The coastal geomorphological data bank is very thin and needs considerable distributional information if it is to be useful to other geographers, to other disciplines, and can contribute to the general upgrading of coastal information. Data accumulation as accomplished by Brand (1953) and detailed geomorphologic maps such as those produced by Psuty (Craig and Psuty, 1968) are a necessity. Psuty's maps are based on aerial photo interpretation and identification in conjunction with field work in order to quickly accomplish the mapping. This procedure could produce keys which have far wider application, and basic mapping could be done from aerial photos with a modicum of field identification. These procedures could be improved with a wider variety of photographic and non-photographic data gathering systems. Remote sensing techniques would be especially helpful in closing gaps between studies areas and in extending known data. Furthermore, there should be some sort of agency for data collection, storage, collation, and retrieval. There should be a final product or goal to be achieved - such as the production of a map of coastal types, differentiated according to forms and evolutionary status, at some stated scale. Perhaps our committee could handle the task, or an appropriate organization like

the American Geographical Society since it presently holds most of the pertinent manuscript data but, unfortunately, has little photographic coverage. On the other hand, an international agency such as the PAIGH could underwrite the task of serving as the collector of Latin American geomorphological data. McGill's map (1960) provides an illustration of the kind of product that could be accomplished but as more detail becomes available, the categories could become more distinctive and its value increased. The initial efforts would take on the appearance of a compendium, but it would be surprising if this data bank did not lead to the development of additional coastal geomorphological theory and increased awareness of the value of coastal research. The establishment of a "center" for aerial photographs, procuring additional imagery and coastal geomorphological maps would amount to a very definite step toward the eventual utilization of these data rather than merely constituting a collection of miscellaneous documents concerning the coasts of Latin America. The acquisition of data would be a long-term venture and should probably have priority levels to facilitate its progress.' Despite the problems of organization, I would regard it as beneficial that some agency be empowered, directed, and financed to accomplish the task of bringing coastal photography and imagery, maps and charts, and geomorphological manuscripts together.

A second recommendation involves the type of coastal data required to convey information and strengthen coastal theory. When studying beach ridges, *cheniers*, coastal terraces, erosional headlands, vegetated dunes and other features which may be regarded as static, profile data are usually an adequate base on which to describe the phenomena or to add other variables. Given an ample supply of such point or line data, numerical analysis can be accomplished and representative descriptive statistics achieved. Furthermore, it would be beneficial to other geomorphologists if this information were also summarized in some sort of data matrix and preferably incorporated by geographical position on the geomorphological map. This philosophy has been utilized by Russell in his beach studies and has proved invaluable in communication.

I have previously suggested that the dynamics of beach sedimentation have been mysteriously overlooked by the geomorphologists studying Latin America. This gap is one of practicality rather than lack of interest, for a single beach profile or observation is not too meaningful because it is ephemeral. The study of beach processes necessitates a temporal span of inquiry which permits the investigator an opportunity to compare observations and relate beach changes to the variables

of environmental conditions. Thus, beaches should be studied through a tidal cycle or through a season or a "spell of weather" before the information has comparative value. This problem is one of considerable magnitude because only small areas can be studied by research teams and their observations should be extended over long periods - similar to the establishment of meaningful climatological data. Rather than aim at the complete data base for all of the Latin American shoreline, the study of the dynamic beach could be directed toward the formulation of process-response models that may be tested in other areas. The establishment of procedures and the recognition of significant variables would be a considerable contribution but perhaps too esoteric and of little immediate value beyond areas which are undergoing rapid change.

Although the accumulation of coastal geomorphological data is of obvious benefit to the geomorphologist, a greater stress should be directed toward the further application of this information. For example, geomorphological data, in detail, would be valuable for land use planning, especially in areas that lack land capability studies and engineering reports. In a sedimentary context, the distinction between *cheniers* and beach-ridge topography would assist in evaluating agricultural potential, trafficability, and flood hazard. Furthermore, potential erosion and deposition could be predicted from sequential aerial photography and then provide an evaluation of the coastal equilibrium. Environmental perception could be applied to the geomorphological base as a method for considering local value judgments.

A further practical application of geomorphological study and mapping should consist of an association with archaeologists and cultural geographers working portions of the coastal plain. Archaeologists are interested in learning more about the depositional and erosional origins of coastal phenomena and whether morphological processes have remained stable and whether specific archaeological sites pre-dated, post-dated, or were contemporaneous with critical morphological processes. This line of inquiry could involve Quaternary modification of geomorphological processes and shifts of fluvial channels, for example. The coastal geomorphologist is in the position of contributing valuable information to the comprehension of paleoecologic association and the eustatic-tectonic history of the coastal areas. The coast has been an important site for the study of early man in Latin America. The combination of archaeology and geomorphology has proven invaluable in North America, Europe, and North Africa, but has seen limited application in the Quaternary geography of Latin America.

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