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# PLEISTOCENE GEOLOGY AND PALEONTOLOGY OF THE TALARA REGION, NORTHWEST PERU

R. R. H. LEMON[1] and C. S. CHURCHER[2]

ABSTRACT. Three major erosion surfaces (Tablazos) and associated deposits of Pleistocene age in coastal northwestern Peru are described. The marine deposits are richly fossiliferous; the Mancora (oldest) and Talara tablazo faunas are of cooler-water type, the Lobitos (youngest) fauna is similar to that of the modern shoreline.

A terrestrial vertebrate fauna from tar seep deposits on the Mancora Tablazo is similar to that of the Carolinian of Ecuador. A provisional list of the Talaran fauna is compared with faunas from the Carolinian of Ecuador and from Rancho La Brea, California.

It is likely that the local climatic regime of the coastal plain differed little from that of the present day. However, the tar seep fauna suggests an at least moderately abundant water supply, probably provided by permanent or semi-permanent streams rising in a wetter hinterland.

## INTRODUCTION

The coastal region of northwestern Peru is underlain by extensive Pleistocene marine sediments containing a rich shelly fauna. Little detailed work has been done in the area, although Bosworth (1922) gave an account of the Pleistocene deposits. The interest of this region is further enhanced by the presence of surface tar seeps containing a varied vertebrate fauna of Pleistocene age.

A study of the tar seeps and associated deposits and of the Pleistocene geology of the area in general was made by Lemon, while extensive excavation and careful screening of the most richly fossiliferous parts of the brea deposits was carried out by A. G. Edmund and R. R. Hornell of the Royal Ontario Museum.

Laboratory preparation and study of the brea material is now being undertaken by A. G. Edmund and C. S. Churcher. The present paper is intended as a preliminary account only, and the conclusions reached may be subject to modification as work progresses.

## PRE-PLEISTOCENE GEOLOGY

The oldest rocks occurring in the area are quartzites, graywackes, argillites, and shales of the Pennsylvanian Amotape formation. They outcrop over extensive areas in the Amotape Mountains to the east and have been recognized in subsurface. The sediments have been intruded by granites in some areas and are usually considerably faulted and brecciated. The total thickness is in excess of 4600 feet.

Unconformably overlying the Amotape formation are sediments ranging from Aptian to Albian in age. These outcrop in a small fault block in the extreme east of the present area and elsewhere are known in subsurface. The lower beds include reef limestones and thin-bedded black limestones, but the greater part of the section consists predominantly of shales with associated sandstones and clonglomerates. The youngest beds pass up into sandstones and shales of Lower Eocene age.

The Cenozoic rocks present total some 15,000 feet of sediments ranging from the Salina-Negritos formation of Lower Eocene age to the Cone Hill

[1] Royal Ontario Museum, Toronto, Canada.
[2] Department of Zoology, University of Toronto, Canada.

formation of the Upper Eocene Chira Group. Shales, sandstones, and conglomerates show lateral facies changes and, sometimes, as in the Talara Group, rhythmic alternation of sands and shales. The lithologies suggest conditions of

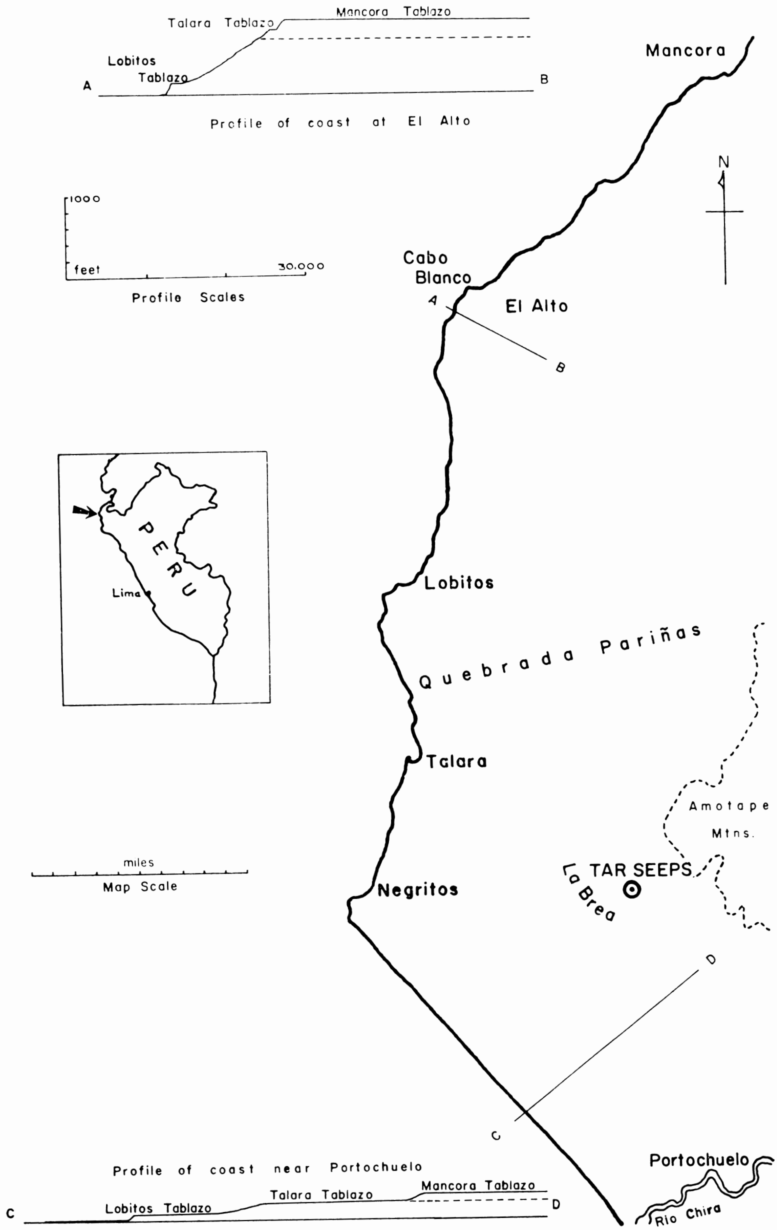


Fig. 1. Sketch map of Talara region, northwest Peru.

deposition ranging from a moderately deep water marine environment to shallow brackish water. Many of the sands, notably the Pariñas sand, are oil producers. The whole area is complexly block faulted.

Bosworth (1922) considers the geology and paleontology of the Cenozoic rocks, and a more recent summary of the pre-Pleistocene geology, with a comprehensive bibliography is given by Travis (1953).

## PLEISTOCENE MARINE DEPOSITS

Overlying a truncated surface of Cenozoic and older rocks is a thick sequence of marine quartz sands, shelly and calcareous sands, marls, coquinas, and pebble beds ranging in age from Early or Middle Pleistocene, to Late Pleistocene and Recent.

These deposits occur at three distinct levels, each one marking a period of marine encroachment followed by uplift of the coastline. These three levels or tablazo (tableland) surfaces are named from the highest and oldest to the lowest and youngest, respectively, Mancora, Talara, and Lobitos (Bosworth. 1922). The depression and uplift were not uniform along the coast, and all three surfaces attain their highest altitudes in the north and become progressively lower towards the south. Likewise the associated deposits are in each case thickest in the north.

At least three tablazo surfaces and associated deposits occur in southwestern Ecuador and have been briefly described by Sheppard (1937). In the Santa Elena peninsula, tablazos occur at 10, 250, and 350 feet above sealevel. whereas on the Isla de la Plata what are considered to be equivalent tablazo surfaces are found at 100, 500, and 740 feet above sealevel. The tablazo deposits are generally thin and said rarely to exceed 50 feet in thickness. The faunas appear to be similar to that of the Lobitos Tablazo and modern beach in northwestern Peru.

*The Mancora Tablazo.*—The Mancora Tablazo surface lies at about 900 feet above sealevel at El Alto in the northern part of the area and falls steadily to about 300 feet near the Chira River in the south, a distance of 45 miles. The Mancora Tablazo deposits reach a maximum thickness of 250 feet or more in the north and thin to less than 100 feet in the south. Some of the best exposures of the varied sands, coquinas, and pebble beds occur in the walls of the Quebrada Siches and other steep-sided valleys in the El Alto area.

Medium- to fine-grained, gray or yellowish or rusty-weathering quartz sands make up the greater part of the Mancora Tablazo deposits, particularly in the lower part of the succession. The sands are usually clean and well sorted and probably represent beach or offshore deposits laid down in water sufficiently shallow for effective winnowing by wave action, i.e., less than 30 feet (Bradley, 1958). They frequently show low-angle cross bedding and carry a scattered shelly fauna, *Ostrea megadon* Hanl. being particularly characteristic at some localities. In general the sands are only poorly consolidated, although iron-rich patches and bands are more resistant and tend to support the sands in vertical exposures. Individual sands vary from a few inches to 30 feet or more in thickness, and the thicker beds are persistent over many square miles.

The coquina bands within the succession occur mainly in the upper part and normally do not exceed 10 or 12 feet in thickness, although 25 feet has been recorded at some localities. They are more or less consolidated and relatively resistant to weathering so that they stand out as prominent ledge-forming horizons. In detail the coquinas are made up of comminuted shell debris cemented into a compact but usually quite open-textured or porous rock. Whole shells are common throughout and locally may be the dominant constituent. The barnacle *Balanus tintinnabulum* var. *concinnus* (Darwin) often occurs in conspicuous masses. *Pecten purpuratus* Lamarck, *Ostrea megadon* Hanl., and a large species of *Ostrea* measuring up to 10 inches in diameter are also typically associated. *Turritella goniostoma* Val., *Thais chocolata* Ducl., and *Glycimeris ovata* Brod. are commonly found and locally may be the dominant forms. Rounded pebbles averaging ½ to 2 inches in diameter and usually of brownish quartzite, graywacke, or pale gray or white quartz are usually present scattered throughout the coquina. Distinct pebble bands occur at some horizons and locally may form pebble beds up to several feet thick. Soft, fine-grained, gray to white marls are typically interbedded with the coquinas.

Along the face and top of the coastal cliffs between El Alto and the Quebrada Pariñas the coquinas take on a much harder and more compact character. The open saccharoidal texture typical elsewhere has been replaced by a dense texture in which the constituent comminuted shell debris is hardly discernible and where the large, intact shells present have been leached away, leaving only empty casts. The rock here is a true limestone, difficult to sample and breaking with a conchoidal fracture. This local modification of the coquina is presumably due to its exposed position on the cliffs. Although the prevailing southwesterly winds blowing off the cold Humboldt Current are practically devoid of moisture, the rapid ascent of the air over the cliffs, here over 800 feet above sealevel, does give rise to some localized condensation due to orographic effect. The moisture thus derived has been sufficient to cause solution and redistribution of the calcium carbonate in the coquina and leaching of the large shelly constituents. A similar phenomenon has been mentioned by Bosworth (1922) as occurring to the north in Ecuador where a moister climate prevails.

The abundance of unbroken and uneroded shells in the coquinas and the close association with calcareous sands and marls of extremely fine grain suggest deposition under quiet water conditions with little or no winnowing action. At some horizons, however, such features as cross bedding and pebble bands point to shallow water deposition with vigorous movement. The close association of these features would best be explained by postulating lagoonal conditions in this area in late Mancora time. There is today no direct evidence of a reef or barrier lying to the west, and protection for inshore water may have been provided, at least in part, by small reefs built up by lime-secreting colonial worms. Structures of this nature have been noted in the Mancora Tablazo deposits 8 miles east of Lobitos.

In the El Alto area the remains of numerous whales (Order Cetacea), mainly comprising vertebrae and fragments of ribs, have been found at several horizons in the upper part of the Mancora Tablazo succession. It has been suggested (Cherry, 1953) that their presence supports the case, outlined in a later paragraph, for a whole series of raised beaches in the El Alto area, assuming that each whale marks the present position of the beach on which it was stranded. There is, however, no reason to suppose that such strandlines were any more than ephemeral features. Fluctuations in the profile of the beach and the building up of storm ridges in advance of a transgressing shoreline would, it is considered, be entirely efficient in burying and preserving intact some at least of such jetsam. The fact that some of the skeletons, particularly the vertebral columns, are almost undisturbed suggests that they were buried relatively rapidly. Alternatively they came to rest in quiet water, out of reach of vigorous wave action, possibly in shallow lagoons.

The spaces within the spongy bone structure have, in many cases, become more or less infilled by calcite, although there has apparently been little or no replacement of bone material. This has undoubtedly increased the resistance to weathering and presumably accounts for the prominence of many of the skeletal fragments on the surface at the present day.

The coquinas and interbedded sands and marls occur most prominently in the upper part of the Mancora Tablazo sections, particularly in the north of the region, while further south the deposits as a whole tend to be more sandy, a trend also seen in moving inland to the east. The overall north to south thinning of the Mancora deposits and the southward tilt of the Mancora surface would indicate greater crustal movements in the northern part of the region, both subsidence and subsequent uplift presumably being more pronounced than in the south.

In the north the Mancora Tablazo extends some 12 to 14 miles inland. With continuous and progressive marine transgression this could, according to the ideal wave-cut profile limitations of Bradley (1958), mean that the platform lay at about 1000 feet below sealevel in the El Alto area, assuming the simplest picture and leaving out of account any localized subsidence or tectonic warping. The Mancora succession in the area at the present time might, therefore, represent only one-third or less of the total thickness of sediments accumulated at the time of greatest advance of the Mancora sea, the younger deposits having been removed by subsequent erosion as the sealevel fell.

Differential weathering of the alternating coquinas and soft sands and marls is very marked and gives rise to the characteristic "stepped" topography of the El Alto area. Wind erosion is very effective in causing the wholesale removal of the sands and marls, whereas the thinner and impersistent coquinas are broken up by undercutting. Erosion of the thickest coquinas, on the other hand, is relatively slow, and their surfaces have become exposed over considerable areas. In some localities large fallen blocks help to protect the coquinas from undercutting and this must considerably slow down the retreat of the scarp edge. The great regularity and extent, often amounting to many square miles, of the more persistent coquina surfaces has led to the suggestion that they are in fact themselves raised beaches, marking intermediate sealevels below that which produced the main Mancora surface. Although lower beach levels probably did exist at intervals during the post-Mancora uplift, it is unlikely that their presence could be detected in erosion surfaces at the present day. The difference in resistance between the coquinas and the sands is so marked and is so accentuated by the effects of wind erosion that the resultant topography completely masks any possible surfaces initiated originally by wave action alone.

The effects of wind erosion are also very noticeable on outcrops of Eocene rocks in the area where the varying resistance of alternating shales and thin-bedded siltstones and sandstones is reflected in a "stepped" topography in miniature.

With progressive uplift of the land the coquinas and sands not removed by erosion would have been covered by a veneer of prograded beach deposits (Bradley, 1957) laid down as the Mancora sea retreated. In view of the age of the Mancora surface the possibility of any of this veneer remaining seems small; nevertheless, intermittent but extensive patches of rounded pebbles occurring on the Mancora surface in the area north of the Quebrada Pariñas may, in fact, represent the deflated remnants of this final deposit of the Mancora sea.

*The Talara Tablazo.*—In the northern part of the area between the Quebrada Pariñas and El Alto only remnants of this tablazo surface and the associated sediments remain at the present day. In this region the Talara deposits were probably never of great east-west extent, and they now occur on narrow, disconnected ledges usually only a few hundred yards wide. At El Alto one such ledge, lying 95 feet below the Mancora surface, shows strongly cross-bedded coquinas dipping steeply towards the west and representing beach debris piled against an old sea cliff developed in deposits of Mancora age. At a locality 6 miles south of El Alto, exposures in a gulley section show cross-bedded sands deposited against an old cliff cut into Tertiary sandstones overlain by Mancora Tablazo sediments.

South of the Quebrada Pariñas the western edge of the Mancora surface swings inland in a great arc to the east and southeast, and the Talara surface occupies a large area within this shallow embayment, extending approximately 10 miles in an east-west direction at its widest. At Talara the surface lies at about 280 feet above sealevel, dropping gradually southwards to about 130 feet at the southernmost occurrences north of the Chira River. The Talara deposits are everywhere thin and even at their greatest development in the north seldom exceed 25 feet. In the Talara area 8 to 12 feet is the average and this thins to 5 feet or less in the south.

The deposits are predominantly pebbly in character and vary from pebble beds made up almost entirely of rounded graywacke, quartzite, or quartz pebbles with little or no shelly material, to pebbly and sandy coquinas interbedded with shelly marls. *Pecten purpuratus* Lamarck, *Ostrea megadon* Hanl., *Glycimeris ovata* Brod., *Arca grandis* Brod. and Sow., the large, thick-shelled species of *Ostrea*, *Turritella goniostoma* Val., and *Balanus tintinnabulum* var. *concinnus* (Darwin) are all common forms found in the coquinas. In general the fauna is similar to that found in the Mancora Tablazo deposits although other species not noted in the older formation, such as *Chama pellucida* Brod., *Pecten tumbezensis* Orb., and *Anomia peruviana* Orb., are present.

The wave-cut platform beneath the Talara deposits in places reaches 8 to 10 miles inland and, as with the Mancora Tablazo, this implies erosion during a progressive advance of the sea. In the offshore zone there was presumably deposition in the wake of the zone of active erosion during the Talara transgression but, as that zone retreated westward again in the closing stages of the Talara cycle, the sediments would have been removed.

The Talara Tablazo deposits, although varying locally, show little or no regional facies change and, compared with the deposits of Mancora age, amount only to a thin veneer. It therefore seems likely that they represent only a single cycle of deposition and were laid down during progradation of the beach deposits on the retreat of the Talara sea. This final erosion and progradational deposition would mask the effects of any minor fluctuations in sealevel during the major Talara transgression.

East and southeast of Talara are several pebble ridges aligned in a northwest-southeast direction parallel to the Talara shoreline. Usually these are barely discernible as topographic features on the ground but can be readily seen on air photographs. They may represent storm beaches on the shore of the retreating Talara sea.

*Lobitos Tablazo.*—The Lobitos transgression was short lived with a wave-cut terrace probably never more than a mile wide. As with the Talara Tablazo the Lobitos deposits are of prograded beach type laid down as the sea withdrew.

Erosional remnants, often reduced to only a few square yards of flat surface, occur at intervals along the coast from Mancora to Talara. In the northernmost localities the surface lies at about 135 feet above sealevel, falling to 72 feet at Cabo Blanco and 67 feet at Lobitos. At Cabo Blanco the tablazo occurs beneath recent guano deposits up to 1 foot thick.

Southeast of Negritos the tablazo occurs as a narrow ridge running for about 7 miles parallel to the present shore; this represents the largest portion of Lobitos Tablazo surface remaining. At its southern end the ridge is 2½ miles from the present sea margin and lies behind a broad stretch of sand dunes and salinas. The surface here is 50 feet above sealevel.

The Lobitos Tablazo deposits, like the Talara Tablazo, are largely pebbly in character. As in the older tablazos there is considerable local variation; in some areas sandy and pebbly coquinas are richly fossiliferous both in the number and variety of forms, while in others, particularly close to the old sea cliffs, coarse pebble beach deposits are practically barren of fossils. Thicknesses normally range from 4 to 10 or 12 feet with the thicker sections occurring in the more northerly localities.

The most marked features of the Lobitos fauna, when compared with the older assemblages, are the great increase in the number of gastropod species, the greater total number of molluscan species present, and the absence of such forms as *Pecten purpuratus* Lamarck and the large *Ostrea* sp. so characteristic in the Mancora and Talara Tablazo deposits. The fauna is similar to that found on the modern beaches and on the whole shows a warmer aspect than does the Mancora and Talara assemblage. As Bosworth (1922) has suggested, this change probably reflects variations in the configuration of the coastline. At the present day the cool Humboldt current tends to be deflected by the westerly-jutting points of land such as Punta Balcones. In consequence the ameliorating influence of the southward-setting warm counter current (El Niño) is felt, although with decreasing effect, as far south as Paita. During Mancora and Talara times, on the other hand, the Humboldt Current apparently carried further north before being deflected westwards, and so along this portion of the coast the influence of the counter current was negligible.

Although along the Pacific coast of North America upwelling of coldwater has been suggested as a factor in determining the distribution of Pleistocene molluscan faunas (Valentine, 1955), there is, up to the present, no evidence for any such effects along the Peruvian coast.

## RECENT SEDIMENTS

*Salina deposits.*—At the mouth of the Quebrada Pariñas and in the area south of Negritos are broad flats covered by blown sand, shells, and extensive salinas or salt flats liable to inundation at the highest tides. These are areas only recently emergent as a result of the latest phase of uplift of the coastline following the slight negative movement that caused the removal of much of the Lobitos Tablazo deposits and the erosion of the post-Lobitos cliffs.

Although apparently attributable to the same process of marine regression, the Salina deposits are markedly different from those of the Lobitos Tablazo. These differences might be explained by appeal to a rapid uplift, leaving no time for the inevitable progradation required by Bradley, but the answer possibly lies in the fact that neither the Quebrada Pariñas flats nor those south of Negritos are true emergent open beaches. Both are physiographically more in the nature of estuaries and are underlain by considerable thicknesses of alluvial sediments. In the case of the Negritos area the mouth of the river lies at the north end of the salina flats, and there are numerous records of the breaching of the coastal dunes during times of flood.

The situation is further complicated by the thick accumulations of blown sand. In the area south of Negritos, ridges of sand and shells reach over 30 feet in height. Their straight alignment parallel to the general trend of the coast suggests that they originated on a foundation of storm ridges on the early shelly and sandy beach left as the sea retreated.

*Amotape Breccia Fan.*—This is the name applied to the great fan of downwash material derived from the Amotape Mountains to the east. It blankets much of the Mancora Tablazo surface in the eastern part of the area and by successive reworking during intermittent floods has come to spread over considerable areas of the Talara surface also, reaching as a thin remnant almost to the present coast. Typically it consists of a coarse, angular gravel made up of reddish brown- and rusty-weathering graywacke and quartzite fragments. Around the flanks of the Amotape Mountains it is very coarse grained and irregularly and deeply eroded by channels gouged out in times of torrential rains. Further away from the mountains the deposit is of smaller grain size and somewhat better sorted, covering large areas as a flat stony desert pavement.

*Blown sand.*—Blown sand carried inland from the beaches by the prevailing southwesterly winds chokes many of the smaller valleys and accumulates in every hollow and in the lee of all obstructions. The most extensive areas occur where there is a scattered vegetation cover and mounds of sand pile up in the lee of the thorn bushes. Only locally near the coast, as in the area south of Cabo Blanco and near Portochuelo, are true dunes with slip faces developed.

### THE TALARA TAR SEEPS

Numerous surface tar seeps occur in the La Brea-Pariñas oil field area, the largest being in the region some 10 miles southeast of Talara. The seeps have been known since early times, and pitch was obtained there by the Indians and later by the Spaniards. Numerous pits, up to 20 feet deep, remains of the hearths and iron crucibles used for boiling off the light ends, and large numbers of earthenware shards are to be seen at the present time. It was at this locality that the first oil well in Peru was drilled in 1862.

The main seeps lie within the area of the concession or Estate of the International Petroleum Company, and the presence of bones in the brea deposits associated with the seeps had been noticed for some years. The first real attempt to collect the material, however, was made by G. H. McDonald and R. B. Fraleigh, geologists with the Company, and a representative collection was sent to the Royal Ontario Museum, Toronto in 1957.

The vicinity of the main tar seeps is known by the name La Brea (Spanish for pitch) and on the maps of the International Petroleum Company the productive area is known as the La Brea pool. In view of the possibility of confusion with the well-known Pleistocene vertebrate locality at Rancho La Brea, California (sometimes referred to only as "La Brea" in the literature), it is proposed henceforth to refer to the present locality as the Talara tar seeps.

The seeps occur upon the Mancora Tablazo surface and, as they lie only about 6 miles west of the Amotape Mountains, also in the area of the main Amotape Breccia Fan. The original surface of the seeps area has been partially destroyed by man-made excavations but enough remains to indicate that it stands at approximately the same level or a little above that of the general surface of the breccia fan, due to a gradual build up of pitch deposits assisted, in part at least, by the accretionary action of pitch exposed at fresh seeps which tends to trap blown sand and dust.

Sections exposed in man-made cuts show the tar seep deposits to consist of irregularly alternating lenses and stringers of medium to coarse, poorly sorted angular gravels and cross-bedded sands. Although, as will be seen later, there are numerous indications that permanent or semi-permanent streams were present in the area, the general aspect of the seep deposits is similar to that of the Amotape outwash sands and gravels of the present day desert surface and, in so far as their sedimentary structures are concerned, they cannot be said to provide positive evidence of deposition in a permanent stream. Detailed study of the size distribution of the gravels, shape of the pebbles, etc., may, however, show significant features not apparent in the field.

The main bone-bearing deposits occur as irregular lenses up to 6 feet thick and 20 to 30 feet in width. These may have been pools of pitch later filled with gravel and sand, or they may represent patches of tar-soaked quicksand into which the animals blundered. Most likely the seeps were covered by shallow pools of water or a stream which would, of course, provide a powerful attraction to animals.

At the present time small natural pools of pitch occur at the surface, but, unless the seep is persistently active, they are short lived and within a few days usually become sealed off as the pitch hardens, a process speeded by the smothering action of blown sand and dust.

Today large pools of pitch occur only in artificial hollows and trenches or adjacent to flowing wells. These are still active as traps of wildlife, and numerous birds, mainly water fowl, and large numbers of beetles, moths, and other insects were noted.

One of the outstanding features of the fossiliferous deposits is the great mixing and high percentage of broken bones. It is extremely improbable that any circulation of the tar could account for this; rather it is suggested that the bones became disturbed by the movement of later victims during their death struggles.

## PLEISTOCENE CLIMATES

The vertebrate fauna found in the tar seep deposits includes many forms characteristic of a habitat considerably wetter than any found in the area at the present day. Although it is not possible to say with certainty that the whole region was well watered during Pleistocene times, there must have been numerous permanent or semi-permanent streams. This much can be adduced not only from the presence of the tar seep animals but also from the evidence of the deep river valleys cut into the elevated marine terraces and in the Amotape Mountains; their origin clearly dates back to a period of greater precipitation and runoff.

Further evidence is seen in the great abundance of vegetable material found throughout the fossiliferous brea deposits, including finely comminuted fragments of woody plants, twigs, thorns, seeds, and seed cases. A proportion of this material possibly represents debris washed in from higher ground upstream, and there is evidence also that some came from the stomachs of animals trapped in the seeps; nevertheless the abundance of the material is considered ecological evidence for at least a moderate vegetation cover in the immediate vicinity.

In the case of the invertebrate faunas of the tablazo deposits, a change towards warmer water conditions is suggested by the greater variety of forms in the Lobitos Tablazo deposits and on the modern beach as compared with the Mancora and Talara faunas. However, as was mentioned earlier, this probably reflects a change in the shape of the coastline and the consequent effect on the influence of the Humboldt Current rather than on a change from a colder climatic regime.

At the present day the aridity of the coastal plain is directly proportional to the intensity of the Humboldt Current influence and it is interesting to note that, unless regional climatic factors were of over-riding importance during Mancora and Talara times, the local climate might then have been even more arid than at present as a result of the more northerly sweep of cooler coastal water.

In South America, as in North America, there is evidence from many localities of an overall wetter climate during the Pleistocene (Charlesworth, 1957, p. 1122). Whether or not the Humboldt Current influence along the Peruvian coast was sufficient to maintain the arid state of the coastal plain it is difficult to say. It does seem likely that owing to the effect of the Humboldt Current the coastal plain climate was essentially arid but that the inland region, enjoying a wetter climate than at the present day, supplied a greater run-off to west-flowing streams and thereby enabled them to cross the coastal plain as permanent or semi-permanent rivers.

The presence of shell middens and ancient Indian occupation sites several miles from the coast in the Quebrada Pariñas and elsewhere in areas now completely devoid of any permanent fresh water suggests that even within a period of possibly only the last 1000 years there has been a continuation of the progressive desiccation of the region.

## AGE RELATIONSHIPS

All the molluscs of the tablazo faunas so far identified appear to belong to species still extant. As mentioned in a previous section, the closely similar Mancora and Talara faunas differ somewhat from the Lobitos and modern assemblage, particularly in the lesser number of species present. The observed vertical intervals between the various erosion surfaces indicate that the Mancora/Talara and Lobitos/modern time intervals were relatively short, and that between the Talara and Lobitos phases was considerably longer.

The high shorelines of Pleistocene age recognized in many parts of the world as resulting from worldwide fluctuations in sealevel cannot, of course, be identified in the present series of tablazo surfaces. These owe their existence primarily to tectonic movements of the land and any effect attributable to sea-level fluctuations would have been completely masked.

Undoubtedly the most promising solution to the age problem lies in Carbon-14 analysis. Samples of shelly material from all three tablazo surfaces have been submitted for Carbon-14 analysis and it is hoped that direct dating of the tablazos will be possible. Radiocarbon dating of bone material from the tar seep deposits will also be attempted, although it is not certain how far it will be possible to eliminate the effects of the pitch with which all the bone deposits are saturated.

Relative to the tablazo surfaces a post-Mancora age for the main bone-bearing tar seep deposits is indicated by the presence, in close association with the bones, of scattered marine shells and shell fragments washed in from surface deposits of Mancora Tablazo material. At the other end of the scale it is fairly safe to assume that the main period of bone accumulation pre-dates the Lobitos Tablazo since the evidence of only a small uplift and the modern aspect of the Lobitos fauna points to a comparatively recent date for this phase.

The vertebrate fauna of the tar seeps suggests an Upper Pleistocene age. However, it is not possible to relate this assignment directly to the tablazo sequence and to say at what period within the relatively long Mancora-Lobitos interval the animals were trapped and buried.

GENERAL DESCRIPTION OF THE TAR PIT FAUNA

The collection of specimens from the Talara tar pits already shows one of the most complete faunal samples from the Upper Pleistocene of South America. This fauna will be referred to as the Talaran Fauna hereafter for brevity. The only comparable sample known at present is that from Rancho La Brea, California, and it is fortunate that two sites similar in age and formation are available for detailed faunal comparison.

The sample obtained includes remains of both plants and animals. The plant remains are divisible into two groups: large pieces of wood in varying degrees of preservation and obviously derived from fallen boughs of mature trees, and smaller pieces of wood only a few centimeters or less in length, seed pods, thorns, buds and soft ends of twigs, deposited while still green. These small pieces are from both woody and partially woody plants and probably originated in part from the remains of the stomach contents of the larger herbivores trapped in the deposits. The ends of the small twigs are often cleanly cut at an oblique angle, suggestive of the chopping action of the teeth of a sloth such as *Eremotherium*, or of the incisor teeth of some rodents. These small pieces are distributed throughout the matrix in an uneven manner, but mixing of the remains within the deposit has occurred and none of this material can be associated with the remains of any particular animal.

The animal remains include insects, molluscs, and vertebrates. The insect remains comprise scattered elytra, head and thoracic shields, mouth parts, and various parts of the abdominal segments and legs of various types of beetles. The genus *Hydrophilus*, family Hydrophilidae, has been tentatively identified, with at least ten other varieties of Coleoptera among the insect remains. Molluscan remains are represented by two shells of a small fresh water pulmonate, family Planorbidae, tentatively assigned to the genus *Gyraulus*.

The vertebrate remains include representatives of the classes Amphibia, Reptilia, Aves, and Mammalia. The amphibian remains consist of a few anuran femora and are scarce. The reptilian remains are referable to the Orders Crocodilia, Chelonia, and Lacertilia, and comprise fragments of jaws, long-bones, portions of carapaces, and bones from the skulls of crocodilians. The avian remains are mainly from the postcranial skeleton, but on the basis of both cranial and postcranial fragments identification of teal and duck (Anatidae, *Anas* ?), blackbirds (Icteridae, *Icterus* ?), finches (Fringillidae, *Paroaria* ?, *Spinus* ?), vultures (Cathartidae, *Vultur* ?, *Cathartes* ?), cormorants (*Phalacrocorax* ?), eagles and hawks (Accipitridae, *Aquila* ?), falcons (Falconidae), goat-suckers (Capromulgidae), and herons (Ardeidae) can be reported tentatively. The mammalian fauna is represented by parts of the skeletons of Marsupialia, Chiroptera, Edentata, Rodentia, Carnivora, Perissodactyla, Artiodactyla, and Proboscidea. The faunal sample is therefore fairly broad at the higher level, and although some obvious gaps are present (e.g. Squamata, Primates) at the time of writing, it is reasonable to expect further additions as new prepared material becomes available.

Owing presumably to the trampling and threshing of the larger animals trapped in the tar, a large proportion of the bones are broken and well mixed within the deposit, very few articulated bones or parts of skeletons having been found. The possibility of obtaining single individuals from this deposit is therefore small, and the construction of any skeleton will necessitate the compounding of a number of bones from different individuals. Many of the bones show damage because of exposure and weathering before they were entirely included within the matrix. Tooth-marks of rodents and carnivores are also evident, and some show striae, possibly made by disarticulated bones rubbing against each other or against stones or teeth during the struggles of the trapped animals. A marked preponderance of phalanges, metapodials, and vertebrae of the other bones of the skeleton of the larger animals in the deposit suggests some selective agency at work. This may show a preference by carnivores for the meatier parts of the bodies and for marrowbones and a distaste for the extremities which would have been covered with pitch. The extremities would then be disregarded and become entombed in the pitch in an unbroken state, while the remainder of the skeleton would be broken for its contents or in the death struggles of the dying victims.

The tar has stained all the bones and plant remains black, often filling the alveoli, sutures, and sinuses with a hardened pitch deposit. Where weathering has occurred, the color may be bleached to a dark brown, and in this latter condition the bones are often brittle and friable.

## FAUNAL RELATIONS

*Climatic evidence.*—The topography of Ecuador and Peru is divisible into three main sections, a western low-lying Pacific littoral region, a central high Andean region, and an eastern low-lying Amazonian basin region. These three regions possess different climatic environments despite their tropical latitudes, the climatic variation being dependent upon differences in altitude and rainfall peculiar to each region. The present-day faunas of these regions are highly diverse and reflect respectively a dry semi-desert along the Pacific coast, a montane environment in the Andes, and a tropical rain forest in the low Amazon basin. The Talaran fossil fauna is from an environment which is dry semi-desert today, and the extant fauna has few species in common with the Andean or Amazonian faunas. It can be reasoned that the Talaran fossil fauna should include few representatives from the other two life zones. This is borne out by the obvious tropical character of the Talaran assemblage which shows little affinity with the faunas of the tropical rainforest. Instead it suggests a relatively open grassland interspersed with some trees, such as occurs in the savannas and bushveld of southern Brazil or Africa at the present day. This type of environment is wetter than that of the Talara region today, and the presence of bones of Crocodilia and Anura, remains of Hydrophilidae, Anatidae, Phalacrocoracidae, and Ardeidae, and the presence of fragments of wood from large trees that may have been nearby all support this contention. Perhaps the climate was one in which seasonal rains and partial droughts occurred cyclicly, the faunal population migrating into the area during the wet seasons.

Probably the Talara tar pits attracted and held individuals representative of the local fauna in the same manner as did the tar pits of Rancho La Brea in California. Herbivores would have been attracted by water, some of it standing over the impermeable surface of the tar pools, and would have become trapped in the soft tar when they attempted to wade into the water. Carnivores would have gathered around the trapped herbivores to feed upon the dead and dying, and in their turn would have become trapped. Others might have been trapped in attempting to cross areas of viscous tar covered by a layer of windblown sand.

The presence of mastodonts (*Haplomastodon*) indicates that at times the hard crust on the surface of the tar pools must have been almost strong enough to support the great weight of the animal, since the caution of the living proboscideans and their habit of testing the ground before venturing to place their whole weight upon a foot is well known. During the dry weather their natural caution would be blunted by the need for water, and the animal would venture upon the crust overlying the tar pool. Such a crust might form during a prolonged drought, being made up of tar-soaked sands or of laminations of pitch and windblown sand baked hard by the sun.

The presence of various other creatures usually found associated with water supports the theory that standing water was the main attraction. Remains of crocodilians and of wading and swimming birds have been mentioned already. The crocodilians (and anurans) could have come from the nearby coastal areas or river systems during periods of heavy rains, when they are known to wander away from water, and the aquatic birds could have seen the water from the air, and tried to land upon it. In both cases, if the water coverage was only a few inches deep and the tar still soft beneath it, the force of the creatures entering the water would have been sufficient to trap as heavy a creature as a crocodilian and to have congealed the feathers of a bird so that it could not escape. Alternatively, the crocodilians may have been attracted by the carcasses present, and been trapped in the same manner as were the other carnivores. Birds and water beetles might have mistaken the shining surface of fresh tar for pools of water, as, in fact, they do today.

*Geographic evidence.*—A marked correspondence between the faunas of the Carolinian of Ecuador and the tar pits of Talara is seen when a comparison is made of the mammalian genera tentatively identified from Talara with those reported from Rancho La Brea (Stock, 1958), and from the Pleistocene of Ecuador by Hoffstetter (1952). The Carolinian fauna of Ecuador is from the coastal region between Guayaquil and Portoviejo, and is Upper Pleistocene in age. Ten genera certainly and possibly two other genera are common to both the Carolinian and Talaran deposits, and four to Rancho La Brea and Talara.

Table 1 shows a comparison by genus and subgenus of the main elements of the mammalian faunas of the tar pits of Rancho La Brea and Talara, and with the three main groupings of the Ecuadorian faunas (Hoffstetter, 1952). The nomenclature used follows Simpson (1945). A difference between the Talaran and Carolinian faunas is the absence of megalonichid remains from Talara.

The presence of marsupials in the fauna is indicated by a fragment of a left mandible with seven alveoli (approximate length 7 mm), and while it shows various didelphid characters, it is lacking teeth, symphysial, and articular areas, and therefore detailed comparison is impossible. The closest comparison is with the modern genus *Marmosa*; tentatively it may be considered

TABLE 1

Comparison of the fossil mammal faunas of Rancho La Brea, California (Stock, 1958), and Talara, Peru, and three faunas from the Pacific Coast, the Andes and the Amazon basin of Ecuador (Hoffstetter, 1952). 'X?' = tentative generic identification. The following orders and families have been omitted from this table as they appear only in the Rancho La Brea fauna: Insectivora, Lagomorpha, Ursidae, Bovidae, and Antilocapridae.

| Order: Family Genus or Subgenus | Rancho La Brea, California, North America, U. Pleistocene | The Talara tar seeps, Peru, South America | Carolinian, Pacific Coast of Ecuador, U. Pleistocene | Punian and Chichean, Ecuador, U. Pleistocene | Amazonian of Ecuador, ? Pleistocene |
|---|---|---|---|---|---|
| MARSUPIALIA | | | | | |
| *Didelphidae* | | | Gen. indet. | | |
| *Marmosa* | | X? | | | |
| CHIROPTERA | | | | | |
| *Microchiroptera* | | | | | |
| *Eptesicus* | | X? | | | |
| EDENTATA | | | | | |
| *Megalonichidae* | | | Gen. indet. | | |
| *Nothrotherium* | X | | | | |
| *Megalonyx* | X | | | | |
| *Mylodontidae* | | | | | |
| *Paramylodon* | X | | | | |
| *Glossotherium* | | X | X | | |
| *Scelidotherium* | | X | X | | |
| *Oreomylodon* | | | | X | |
| *Megatheriidae* | | | | | |
| *Eremotherium* | | X | X | X | X |
| *Dasypodidae* | | | | | |
| *Chlamytherium* | | X | X | | |
| *Propraopus* | | | | X | |
| RODENTIA | | | | | |
| *Hydrochoeridae* | | | | | |
| *Neochoerus* | | X? | X | | |
| *Capromyidae* | | | | | |
| *Drytomomys* | | | | X | |
| *Echimyidae* | | | | | |
| *Proechimys* | | | X | | |
| *Sciuridae* | | | | | |
| *Otospermophilus* | X | | | | |
| *Geomyidae* | | | | | |
| *Thomomys* | X | | | | |
| *Heteromyidae* | | | | | |
| *Perognathus* | X | | | | |
| *Dipodomys* | X | | | | |
| *Cricetidae* | | | | | |
| *Reithrodontomys* | X | | | | |
| *Peromyscus* | X | | | | |
| *Onychomys* | X | | | | |
| *Phyllotis* | | X? | | | |
| *Sigmodon* | | X? | | | |
| *Neotoma* | X | | | | |
| *Microtus* | X | | | | |

**Table 1 (Continued)**

| Order: Family Genus or Subgenus | Rancho La Brea, California, North America, U. Pleistocene | The Talara tar seeps, Peru, South America | Carolinian, Pacific Coast of Ecuador, U. Pleistocene | Punian and Chichean, Ecuador, U. Pleistocene | Amazonian of Ecuador, ? Pleistocene |
|---|---|---|---|---|---|
| CARNIVORA | | | | | |
| *Canidae* | | | | | |
| *Canis* | X | | | | |
| *Aenocyon* | X | X | | | |
| *Urocyon* | X | | | | |
| *Dusicyon* | | X | X | X | |
| *Protocyon* | | | X | | |
| *Felidae* | | | | | |
| *Panthera* | X | X | | X | |
| *Puma* | X | | X | X | |
| *Smilodon* | X | X | X | X | |
| *Lynx* | X | | | | |
| *Mustelidae* | | Gen. indet. | | | |
| *Mustela* | X | | | | |
| *Mephitis* | X | | | | |
| *Spilogale* | X | | | | |
| *Taxidea* | X | | | | |
| PROBOSCIDEA | | | | | |
| *Gomphotheriidae* | | | Gen. indet. | Gen. indet. | Gen. indet. |
| *Haplomastodon* | | X | X | X | |
| *Cuvieronius* | | | | X | |
| *Mammutidae* | | | | | |
| *Mammut* | X | | | | |
| *Elephantidae* | | | | | |
| *Elephas* | X | | | | |
| PERISSODACTYLA | | | | | |
| *Equidae* | | | | | |
| *Equus* | X | | | | |
| *Amerhippus* | | X | X | X | |
| *Onohippidium* | | | | X | |
| *Tapiridae* | | | | | |
| *Tapirus* | X? | X? | | | |
| ARTIODACTYLA | | | | | |
| *Camelidae* | | | | | |
| *Camelops* | X | | | | |
| *Tanupolama* | X | | | | |
| *Palaeolama* | | X | X | X | |
| *Cervidae* | | | | | |
| *Odocoileus* | X | X | X | X | |
| *Mazama* | | | | X | |
| *Agalmaceros* | | | | X | |
| *Tayassuidae* | | | | | |
| *Platygonus* | X | | | | |

to belong to this genus. The Order Chiroptera is represented by a number of mandibles and isolated teeth. Comparison of the mandibles and of the teeth with specimens of *Eptesicus* shows marked similarities, and provisionally the Talaran form is assigned to that genus.

The presence of a hydrochoerid rodent of the genus *Neochoerus* is attested by some phalanges. These have been tentatively assigned to *Neochoerus*, as *Neochoerus* has been reported by Hoffstetter; alternatively the genus may be *Hydrochoerus*.

The cricetid rodent remains represent a large animal, similar to *Sigmodon*, but represented only by scarce and worn material, and two smaller forms, similar to *Phyllotis*, which are more abundantly represented.

Carnivores present in both the Carolinian and Talaran are *Dusicyon* and *Smilodon*. Two carnivore genera present in the Carolinian and absent in the Talaran are *Puma*, (*Felis* (*Puma*)), and *Protocyon*. These large carnivores are replaced by *Panthera* and *Aenocyon*, a South American giant jaguar or lion and a dire wolf closely related to, if not identical with, the Californian giant jaguar and dire wolf from Rancho La Brea (Churcher, 1959). *Panthera* will be used for the form similar to *Felis atrox* as Merriam and Stock (1932) refer to this cat as *Felis* (*Panthera*) *atrox*, and Simpson (1945) raises *Panthera* to generic rank. The presence of *Aenocyon* in Peru extends its range into South America, the most southerly previous record being from Tequixquiac, north of Mexico City (Furlong, 1925), other records for South America being doubtful.

The mustelid remains comprise two mandibles, three separate teeth, and a left humerus. The dentitions are worn and further material will be required for accurate identification, but the humerus is short and heavy and resembles that of *Mephitis*, the North American skunk. The animal is therefore probably one of the genera of South American skunks. The tapirid remains comprise only a few phalanges. As in the case of Rancho La Brea (Stock, 1958), these phalanges resemble most closely those of a tapir when compared with material or illustrations, and are provisionally identified as *Tapirus*.

*Temporal evidence.*—The age of the Carolinian is given as Upper Pleistocene by Hoffstetter. In terms of the Tablazo succession, the age of the Talara tar-seep fauna is post-Mancora, possibly post-Talara, and probably pre-Lobitos, and probably within the upper half of the Pleistocene. A comparison of the two faunas shows that they are nearly identical in both ecology and composition, and from this may be deduced a close temporal relationship within the Upper Pleistocene.

The two main differences in the fauna, apart from deficiencies within the samples, are the substitution of *Protocyon* in the Carolinian by *Aenocyon* in the Talaran, and the substitution of *Felis* (*Puma*) *platensis* by *Panthera atrox*. The Pacific coastal zone is isolated from the rest of South America by the Andes, which provide a barrier to any migration of fauna from the eastern pampas of the Argentine and Brazil. Both *Protocyon* and *Felis platensis* were originally described from the eastern pampas and later identified from areas west of the Andes. *Aenocyon* and *Panthera atrox* were originally described from North America and are best known from the tar pits of Rancho La Brea. Both *Aenocyon* and *P. atrox* are larger and more massive carnivores than the South American *Protocyon* and *F. platensis* and were better adapted to prey upon the large herbivores. The explanation may be that the two larger forms entered South America by the isthmus of Panama and migrated down the Pacific coastal plain towards Talara. The immigration of these two forms displaced the other two carnivores from the region west of the Andes, but representatives of *Protocyon* and *F. platensis* survived east of the mountains. If this interpretation is correct, then the Talaran is later in time than the Carolinian of Ecuador.

There is another possible explanation which would, however, shed very little light on the temporal relationships of the two faunas. Since both *Aenocyon* and *P. atrox* are stronger and larger than *Protocyon* and *F. platensis*, it is possible that in the region of the tar pits, where meat was reasonably easy to obtain, the two pairs of carnivores competed for the carcasses. Under these conditions the stronger *Aenocyon* and *P. atrox* might be able to drive away the weaker *Protocyon* and *F. platensis*, and so have the privilege of feeding on the carcasses and becoming victims of the tar pits. This would account for the preservation of many specimens of *Aenocyon* which seems to have been primarily a scavenger. The many remains of *Smilodon* would also be accounted for, as this cat probably preyed on the large and slow herbivores, and would be attracted to the tar seep in the hope of easy prey. *P. atrox* is much scarcer, as at Rancho La Brea, and probably was a "lion" of the savannas accustomed to killing its prey by the same means as do the modern lions; consequently it would be less attracted by the trapped animals, and the number of specimens preserved would not be indicative of the total in the same way as are those of *Smilodon* or *Aenocyon*. At the time of writing, numerous bones of *Aenocyon*, *Smilodon*, and some of *P. atrox* have been rcovered, while the field fox, *Dusicyon*, is represented by bones from all parts of the skeleton found throughout the deposits. On the other hand, no specimens of *Protocyon* and *F. platensis* have yet been found and it seems improbable that either was present in the region of the tar seeps during the main period of trapping. Therefore, the explanation of the differences between the two faunas as involving an ecological separation may be discarded as unlikely.

The remaining possibility is that *Aenocyon* and *P. atrox* were originally present in the area and later were replaced by *Protocyon* and *F. platensis*. This is also unlikely since *Protocyon* is generally considered to be more primitive than *Aenocyon*, whereas *Panthera atrox*, one of the largest of the cats, is much larger than *F. platensis*. For *F. platensis* to replace *P. atrox* conditions would have had to favor the smaller form. No evidence of this can be adduced, as large herbivores of all sorts were still present, providing sufficient meat for the largest of the felids.

The presence of *Panthera* (*Jaguarius*) in the Punian and Talaran, and the absence of *Aenocyon* from the Punian suggests that the age of the Punian lies between the ages of the Carolinian and the Talaran. The sequence from older to younger would therefore be Carolinian-Punian-Talaran. To attempt to place the Chichean and other Pleistocene horizons of Hoffstetter within this series would be incautious; too little is known of their faunas to provide evidence of their temporal relations. However, it is probable that they are all Upper Pleistocene in age and that their faunal differences represent ecological variation as much as temporal differences.

## SUMMARY AND CONCLUSIONS

Successive uplifts of the coastal region of northwest Peru, with intervening periods of stillstand and negative movement occurred during the Pleistocene period. Three major erosion surfaces, the Mancora, Talara, and Lobitos Tablazos, and associated deposits are recognized. These surfaces are highest in the northern part of the area (approximately 900, 800, and 70 feet above sealevel at Cabo Blanco respectively). Traced southwards the tablazos become progressively lower and there is a corresponding decrease in thickness of the sediments.

The Mancora Tablazo deposits, up to 250 feet thick, are dominantly sandy in their lower part but with prominent coquinas and shelly marls, particularly in the north, in the upper third of the succession. The sediments are mainly of shallow water type and are considered to have been laid down as nearshore, and possibly in part lagoonal, deposits. The Talara and Lobitos Tablazo deposits, mainly pebbly sands and marls, are much thinner and are thought to represent prograded beach deposits laid down on the retreat of the Talara and Lobitos seas respectively.

All three tablazo deposits contain a prolific molluscan fauna, all specimens identified to date belonging to modern species. The Mancora and Talara faunas are closely similar and reflect a cooler water environment. The Lobitos fauna, similar to that of the modern beach, is of warmer water type and is characterized by a greater variety of species and a higher proportion of gastropods. These faunal differences suggest that the ameliorating effect of the southward-setting warmer counter current felt at the present day and in Lobitos time, was less pronounced in Mancora and Talara time.

The climate of the coastal region during Pleistocene time may have been as arid as at present. However, there were probably numerous permanent or semi-permanent streams crossing the coastal tract and fed by runoff from the mountains to the east where it is likely that a climatic regime appreciably wetter than at the present day prevailed.

Actual ages for the Tablazos have not yet been established and await the result of Carbon-14 analyses. A consideration of the relative heights of the three tablazo surfaces, supported by faunal evidence, suggests that the interval between the Mancora and Talara phases of deposition was comparatively short. This was followed by a long Talara/Lobitos interval, followed in turn by the relatively brief Lobitos/Recent period.

Tar seeps occurring in the area 10 miles southeast of Talara were active during Pleistocene time and successful in trapping a varied fauna, mainly of vertebrates. The main period of bone deposition postdates the Mancora Tablazo but is probably older than the Lobitos phase of marine deposition.

A preliminary consideration of the faunas of the Talara tar pits and the Carolinian of Ecuador shows that the Talaran deposits are probably younger than those of the Carolinian. Both possibilities of equal age and of the Talaran's being older than the Carolinian are insupportable on the evidence of the associated faunas. Both the Talaran and Carolinian faunas are of Upper Pleistocene age and must have been closely spaced within the Upper Pleistocene.

In other respects the Talaran fauna resembles that of the Carolinian so closely that the two may be treated as one when considering the general relationships of the Upper Pleistocene of the coastal regions of Peru and Ecuador. These seem to lie mainly with the faunas of Eastern and Southern Brazil, as many genera are common to both regions. *Eremotherium*, *Scelidotherium*, *Chlamytherium*, *Smilodon*, *Amerhippus*, and *Palaeolama* are present in both regions, and while differences at the specific level or less are to be expected, and have been reported by Hoffstetter for the Carolinian, the evidence points to the presence of a fairly uniform aspect to the South American Pleistocene fauna of the tree savannas. A few North American genera are found in later deposits representing this fauna, of which *Aenocyon*, *Panthera*, *Odocoileus*, and *Cuvieronius* are examples.

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