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RECONNAISSANCE OF THE PERUVIAN COAST FROM LIMA TO TALARA

By
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July 1959

Division of Raw Materials, AEC
Washington, D. C.

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GEOLOGY AND MINERALOGY

U. S. ATOMIC ENERGY COMMISSION
DIVISION OF RAW MATERIALS
IN COOPERATION WITH THE
JUNTA DE CONTROL DE ENERGIA ATOMICA DEL PERU

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RECONNAISSANCE OF THE PERUVIAN COAST

FROM LIMA TO TALARA

ABSTRACT

A geologic and radiometric traverse of about 1,100 kilometers along the Panamerican Highway, northward from Lima to Talara, Perú, disclosed no positive evidence of economic uranium deposits.

In several isolated areas various rock types have undergone intense hydrothermal alteration, accompanied by replacement deposition of certain metallic and nonmetallic minerals. Some anomalous radioactivity is associated with lower temperature alterations but not with higher temperature alterations. Additional and more detailed examination of lower temperature alteration in the Chiclayo-Guadalupe area seems advisable.

INTRODUCTION

An auto trip along the Panamerican Highway from Lima, Lima Department, to Talara, Piura Department, Perú, was made from May 8 to May 17, 1959, by Sr. Cesar Rangel Z. of the Junta de Control de Energía Atómica del Perú (JCEA) and the writer. The purpose of the trip was to reconnoiter the lithology, regional structure, and mineralization characteristics of the narrow coastal strip bordering the Peruvian Andes on the west, and to determine, if possible, the favorability of environments for uranium deposits.

The interpretations of the tectonic and mineralization environments presented herein are based largely on data obtained from more thorough examinations in the coastal Cañete, Río Chancay, and Fortaleza areas, which are discussed in other reports.

Principal changes in lithology were noted in passing. Obvious major structures, intrusions, and all visible areas of alteration were plotted on 1:200,000-scale topographic maps. Occasionally outcrops near the highway were examined to guide or verify interpretation.

Three generally different geologic environments in the region traversed will be described separately. These are: the narrow coastal strip between Lima and Chiclayo; the Sechura Desert between Chiclayo and Sullana; and the Talara area in northwesternmost Peru. Any geographic map of northern Perú can be consulted for reference.

THE COASTAL STRIP

Physiography

The segment of coastal strip considered here extends from Pisco northwestward to Chiclayo as an unusually straight, narrow, unbroken physiographic, and probably structural, unit. It is confined between the equally straight coastline and the Cordillera Occidental which arises abruptly to extreme elevations on the east. The strip is characterized by highly planar surfaces at varying elevations within a relief of 250 meters above sea level. These either slope gently upward from the sea as pediments or are flat terraces; they are coalescent or separated by low scarps of 30 to 50 meters' relief. The surfaces generally are rock-cut and are veneered with relatively thin (5 to 50 meters thick) layers of outwash gravel; they are crossed and entrenched as much as 75 meters by major gravel-laden valleys issuing from the Andes. Isolated hills or small mountain chains rise abruptly and precipitously as much as 800 meters above the surfaces; many are rudely aligned to the northwest, and others are randomly distributed.

Lithology

On the geologic map of Perú (Bellido, Narvaez, and Simons, 1956) the Andean granodiorite batholith underlies the precipitous west slope of the Andes as far north as Trujillo, beyond which it is expressed as small isolated intrusions that become rare north of Chiclayo. The gradual northward termination of the batholith is matched by a gradual decrease in the height and ruggedness of the Cordillera Occidental. Between Casma and Trujillo the batholith extends westward to the sea; elsewhere the coastal strip is underlain by the Jurassic-Cretaceous marine(?) volcanics of the Porfirítica formation and overlying Lower Cretaceous marine shales and sandstones. North of Trujillo the surfaces are underlain by Quaternary gravels through which protrude isolated hills of the same volcanics and shales.

Modifications noted by the writer are as follows: (1) marine shales dominate between Lima and Chancay; (2) mafic volcanics dominate between Chancay and south of Huarmey; (3) interbedded sandstone, shale, and volcanics dominate between Huarmey and south of Casma; (4) the batholith contact between Casma and Chimbote is near the Panamerican Highway, but a narrow strip of intruded volcanics intervenes between the batholith and the coast; (5) near the batholith contact and in a 20-kilometer interval about 25 kilometers north of Barranca swarms of basic dikes, younger than the batholith, illustrate classic fracture patterns; (6) basic volcanics dominate between Chimbote and Pacasmayo; and (7) Lower Cretaceous shales, limestones, and sandstones dominate between Pacasmayo and Chiclayo although volcanics are common.

Structure

The structure of the coastal strip, as interpreted from excellent exposures, is that of Porfirítica formation volcanics and Cretaceous

sediments thrown into large, locally sharp folds which trend generally north-northwest, parallel to the coast. These folds are transgressed by the main body, or outliers, of the Andean batholith, which, in turn, is cut by basic dikes that probably were feeders for upper Tertiary volcanics. The absence of volcanoes or flows from the present landscape indicates the lack of Quaternary volcanism. The strip was then cut by many block faults along which the segments rose differentially and vertically in conjunction with the late Tertiary and Quaternary uplift of the Andes.

Block faulting has contributed most to the present configuration of the landscape, but in reconnaissance it is indicated only by physiographic features of which the most important are the isolated hills and the shape of the coastline in detail.

Although the isolated hills and mountains could be simply monadnocks residual from the erosion of the coastal surfaces and their precipitous slopes could represent the scarp retreat typical of arid climates, strong lithologic variations and the elongation and alignment of many hills suggest that they are eroded remnants of differentially uplifted fault blocks.

The shape of the coastline indicates a regional north-northwest, remarkably straight trend paralleling the axis of the Cordillera Occidental. In detail, however, the coastline is composed of many short segments of varying orientation that commonly trend northwest or west-northwest and terminate in a "point," north of which is a northwest-facing bay bringing the coastline eastward to the beginning of another northwest segment. The whole effect is that of many northwest segments which, en echelon, form the north-northwest trend and are separated by bays. The land projections have flat surfaces normally no more than 50 meters above the sea, but their "points" characteristically terminate in isolated, rocky, precipitous hills rising several hundred meters above the sea. Some "points" are exaggerated by high, northwest-trending ridges. This coastal configuration cannot be explained by the building of bay-forming bars by the northwest-flowing Humboldt current because the points normally terminate in rocky outcrops. Echelon block faulting probably controls the coast and has caused the differential uplift of small blocks which have been moderately eroded to form the isolated hills and point terminations. Individual faults probably originate near the mountain front and extend northwestward into the sea. Together the faults indicate a gigantic shear zone separating the continent from the neighboring ocean deeps.

Cessation of the most active phase of block faulting is indicated by the absence of little-modified fault scarps on the hills. Common earthquakes and rising coastline characteristics, including multiple terrace dislocation at San Juan south of the region described and the tilting of surfaces, suggest that the principal fault zone is still active, probably off the coast, and that the coastal region is rising in response to broad regional uplift.

Mineralization

Distribution

No economically significant metal deposits in the coastal strip are known to the writer, but hydrothermal activity is indicated by numerous areas of altered shales, sandstones, limestones, volcanics, and intrusives.

Altered rocks have characteristic anomalous colors. Rocks have been altered in isolated, irregular but generally rounded areas which are believed to have pipelike extensions at depth. From brief distant views it was not possible to determine whether altered areas contain controlling structures, but no obvious faults were noted in many altered areas, either in road cuts or in hills with excellent exposures.

About 85 percent of the altered areas visible from the highway were plotted. Such areas are irregularly distributed and long intervals contain none. The strongest concentration of altered areas is between Barranca and Huarmey in an interval north of Fortaleza. Moderately strong concentrations were noted near Samanco (between Chimbote and Casma), between Chimbote and Santa, and between Pacasmayo and Guadalupe. Minor concentrations were observed south of Casma and near Chiclayo.

Three types of control over concentrations were noted. In the Barranca-Huarmey and Chimbote-Santa concentrations isolated altered areas occur in narrow belts that trend northwest parallel to the earlier mentioned northwest segments of the coastline, and control by block faults is suggested. The former area is best illustrative of this feature although even in this area no controlling faults were identified. This area is also one of volcanic feeding. From south of Casma to Samanco (two concentrations) alteration probably is controlled by the contact zone of the Andean batholith which probably provided solution channels. The contact is visible from the highway for many kilometers. Its position and trend appear to be locally influenced but not broadly determined by faulting. The contact is composed of many short segments whose trends suggest a reticulate fracture pattern. Both granodiorite and intruded rocks have been altered, but the alteration associated with the batholith is not as strong as that in the narrow fault-controlled belts. The concentration of alteration in the Pacasmayo-Guadalupe area apparently is not confined within a belt but coincides with an increase in the quantity of volcanic rock, suggesting control by volcanic feeder structures. Near Chiclayo alteration pipes appear to be randomly distributed and are not obviously associated with faults or volcanics, but several coincide with small intrusive plugs.

Alteration

Alterations noted are chloritization, argillization, and a little-known alteration of ferromagnesian minerals in volcanic rocks and to a lesser extent in intrusives. These alterations are locally pervasive, but the amount of rock affected per unit volume and the total volume of altered

rock varies greatly with the strength of mineralization. Chloritization imparts a noticeable green color and softness to the rocks. Argillization bleaches and softens rocks. Ferromagnesian alteration is easily recognized by the peculiar, but characteristic, dark brownish-yellow color of limonite-after-ferromagnesian minerals. The limonite results from surficial oxidation of original or altered minerals and cannot be considered a primary alteration. In this case laboratory work may identify a primary alteration product; however, none has been recognized from brief field examination. An intermediate primary alteration mineral is suspected because this variety of limonite is found only in or near rocks that have been otherwise hydrothermally altered and does not occur in fresh ferromagnesian-rich rocks.

Metallization

Metallization products are characterized principally by replacement of original minerals, usually disseminated cavity fillings. Some minerals are nonmetallic. Magnetite, specularite, and pyrite occur as replacement disseminations and are the only common minerals; chalcopyrite, quartz, calcite, and possibly a uranium mineral occur as rare cavity fillings.

Magnetite is recognized from a distance by its oxidation to red earthy hematite (not to be confused with primary red earthy hematite which has a more purple tinge). Specularite is recognized by its oxidation to red hematite with a noticeable pink and slightly purplish tinge. Pyrite is recognized by its limonite product, which ranges in color from dark wine red to orange yellow depending on the distance of migration.

Mineral associations and zoning

Chlorite, clay, ferromagnesian alteration, magnetite, and specularite are the most abundant and commonly the only mineralization products in most of the altered areas in the entire coastal strip; ferromagnesian alteration is the most common product. Areas with this mineralization assemblage normally do not contain other types.

Areas of clay-pyrite mineralization, locally with silica, are rare and small. Most are on the outer fringes of areas of the first type; some occur independently. Clay is more common in the former than in the latter assemblage.

Chalcopyrite and vein quartz were observed at only one locality, Kilometer 246, in an area of clay-silica-pyrite mineralization.

The geometric relations between mineralization products are rudely indicative of lateral zoning in which the former assemblage suggests the highest temperature environment. Both environments typify higher temperatures than those of most base- or precious-metal districts. The great preponderance of the first type indicates the persistence of very high-temperature environments throughout most of the coastal strip, significantly on the west side of the Andean batholith.

It cannot be supposed that the presence of only high-temperature products west of the batholith indicates that hydrothermal solutions did not pass through cooling stages, especially near the surface. The implication is that these solutions lost their capacity for mineralization (corrosiveness and mineral content) while still at elevated temperatures. They did not deposit lower temperature products at their respective temperatures, suggesting that they carried only high-temperature components in this region, and that the coastal strip (north of Lima at least) represents either a distinct high-temperature metallogenic province or an isolated high-temperature zone within a more complex metallogenic province which would include belts of lower temperature mineralization east of the batholith.

Uranium

The highest temperature mineralization assemblages, containing chlorite, magnetite, specularite, and ferromagnesian alteration, have no anomalous radioactivity. It is believed that uranium will not be found in this environment except possibly in trace quantities.

About 90 percent of the rocks mineralized with clay, silica, and pyrite are anomalously radioactive to as much as 4 times background, and almost universally to $1\frac{1}{2}$ times background. The average is $2\frac{1}{2}$ times background. The anomalous radioactivity is most closely associated with pyrite.

Even if uranium is completely responsible for the anomalous radioactivity, the quantity of uranium represented is insignificant except as indicating an uncommon environment of uranium mineralization. Greater quantities of uranium may be suggested only by the presence of strong surface leaching or by discovery of greater concentrations at the surface. Oxidation and leaching are present but are indicated to be moderate by the relatively arid climate, small annual precipitation, and the ease with which unoxidized sulfides can be found at the surface. Mineralized areas in the coastal strip have not been examined completely or thoroughly, but the weak radioactive anomalies are so common and so universally near the same level of intensity that greater concentrations of uranium are considered improbable. The absence of significant concentrations of uranium characterizes the high-temperature environment west of the Andean batholith and its metallogenic zone or province.

Uranium is known to have been deposited in high-temperature pegmatitic environments in the Andean batholith. Sr. César Rangel Z. of the JCEA has reported an anomaly of 0.7 mr/hr in a granite pegmatite at the Adan mine, about 11 kilometers southeast of Casma (Perú, Junta de Control de Energía Atómica, 1960). Pegmatitic uranium is not expected to be economically important because of its very limited and erratic distribution.

Barranca-Huarmey area

The most strongly altered area in the coastal strip is between kilometers 210 and 248 along the Panamerican Highway. High-temperature alteration occurs in two relatively narrow echelon strips which extend from the foothills of the Andes to the sea, parallel to short segments of coastline separated by Gramadal Point and Gramadal Beach. This area has been examined closely and is considered unfavorable for uranium.

Chiclayo area

The area between Chiclayo and Guadalupe contains many small exposures of rocks affected by moderately strong alteration. Most of the alteration pipes coincide with a concentration of volcanic rocks near Guadalupe; alteration becomes weaker and less extensive northward toward Chiclayo. Alteration is principally argillic, silicic, and pyritic. Near and northwest of Chiclayo the surface is a flat, gravel-veneered plain, but alteration is evident locally in small isolated hills that rise above the plain. Alteration persists as far north as Tucume village. The area northwest of Chiclayo is a part of the Sechura Desert, but it is considered here because the alteration appears zonally related to the stronger alteration near Guadalupe.

Of the several altered hills between Chiclayo and Tucume only the hill in the eastern part of Tucume was examined carefully. The entire hill has been so argillized, then silicified, that the original character of the rock is difficult to determine; it probably was a fine-grained shaly sandstone or sandy shale. Poorly preserved, silicified marine pelecypods suggest a Cretaceous age. Before and possibly during alteration the rock was strongly shattered by faulting. Weak to moderate pyritization is indicated by indigenous limonite; gypsum and jarosite(?) are present. The entire hill is anomalously radioactive to 2 and locally 3 times background. Cerro Purgatorio, about 2 kilometers east of Tucume, is larger and has a similar altered appearance although limonite is lacking. On a generalized geologic map of northwestern Peru (Quiroga and Petersen, 1954) both hills are shown as part of a small stock of Jurassic-Cretaceous granite, which is one of ten in a narrow northwest-trending belt northeast of Chiclayo.

At a small altered area between Chiclayo and Mocupe argillized and pyritized shales are radioactive from $1\frac{1}{2}$ to 2 times background, whereas fresh shales and earthy hematite associated with basic pyroclastics are not anomalously radioactive.

The area between Chiclayo and Guadalupe has been studied by Sr. Rangel but without special emphasis on alteration. Several anomalies ranging to $2\frac{1}{2}$ times background were noted in fresh sediments; east of Mocupe small specks of a mineral believed to be autunite were found in calcite veinlets cutting fresh limestone. Sr. Rangel has recommended additional examination of the area east of Mocupe, and it is here

suggested that the reconnaissance be extended northwest to Tucume for a brief study of the argillic-silicic-pyritic alteration.

THE SECHURA DESERT

Physiography

The Sechura Desert is a plain of minimum relief in the departments of Lambayeque and Piura, extending from the foothills of the Andes westward to the coast where it is broken locally by small mountain uplifts. It is actually an extension of a complex surface which forms the narrow coastal strip but here widens to form the only large area of low relief and elevation west of the Andes in Perú.

Widening of the coastal strip to form the desert is matched by the gradual northwestward termination of the Cordillera Occidental; thus, physiographic definition of the Andes is much less pronounced east of the desert and elevations rarely exceed 3,000 meters. Here clouds are able to retain their moisture as they are blown westward across the Andes, providing the only area of natural luxuriant vegetation on the western slope of the Peruvian Andes.

The Panamerican Highway crosses the area on the western side of the Sechura Desert with the physiography that of isolated mountains rising abruptly and precipitously to heights of 1,000 meters above the plain.

Lithology

Limited exposures of Jurassic-Cretaceous volcanics and sedimentary rocks occur on the western margin of the Sechura Desert, but most outcrops are of Tertiary and Quaternary sediments and early Paleozoic metamorphic rocks. The stratigraphic configuration of the area is essentially that of a basin bottomed by the metamorphosed basement, filled with early Tertiary sediments, and veneered with Quaternary detritus from the Andes.

Structure

The Sechura Desert occupies a large north-northwest-trending basin formed during Laramide (Cretaceous-Eocene) folding, then filled by early Tertiary marine sedimentation. It has been little modified by late Tertiary block faulting and Tertiary-Quaternary vertical uplift, apparently having been largely unaffected by the late deformation responsible for the present configuration of the Andes.

It is significant that compressive folding throughout most of the Cordillera Occidental was apparently not severe enough to bring the early Paleozoic basement to the level of the present surface. However, the basement was elevated by folding at the northern end, where the cordillera loses structural distinction in the cores of several large folds. Apparently the cordillera dies out structurally by branching into several

smaller but more severely folded individual axes. Drilling by the International Petroleum Company in the Sechura basin indicates that in much of the basin the basement directly underlies Tertiary marine sediments. Thrusting was probably prominent during the early compressive folding.

The prominent island mountains in the western part of the desert, like the isolated hills of the coastal strip, could be interpreted as erosional remnants and their very steep sides attributed to the scarp retreat of arid climates. However, most of them are composed of basement rocks totally unrelated to the marine deposits through which they protrude. These mountains and those on the eastern margin may have resulted from block faulting. The mountains do not appear to be drowned in their own detritus because coarse-grained facies are apparently absent from their bases. The few exposures seen at mountain bases are composed of fine-grained sediments that probably resulted from marine sedimentation.

Mineralization

Except for the hydrothermal alteration of small isolated hills near Tucume, rock exposures seen in the Sechura Desert are devoid of mineralization. The absence of altered exposures from that part of the desert traversed strongly suggests its nonexistence in most rocks available for study because in most areas of even very weak mineralization some alteration is readily visible. The presence of lithologic environments favorable for uranium in some of the Tertiary formations is not an important factor if uraniferous solutions were absent.

A lateral decrease in deformation and igneous activity, such as noted in the northern Cordillera Occidental, is usually matched by diminished strength of mineralization. It is remarkable that no transition was found from the high-temperature mineralization of the coastal strip, through lower temperature types, to the absence of mineralization in the Sechura Desert. The alteration at Tucume is the closest known representative of such a transition, but a transition may exist closer to the cordillera axes.

THE TALARA AREA

Physiography

This small area of northwesternmost Peru is essentially an extension of the Sechura Desert. It is bounded on the east by the Amotape Mountains at the northwest end of the Sechura Desert and on the west by the sea. A planar, gravel-veneered surface slopes gently away from the uplift to the coast, truncating moderately deformed Tertiary sediments. Physiographically the area resembles the coastal strip, but its lithology and structure are more similar to the Sechura Desert.

Lithology

The formations consist mostly of Tertiary marine shales and sandstones deposited in a small central basin of unusually great depth. The Tertiary formations are underlain by Upper Cretaceous sediments which may be part of the basin sequence and unconformably overlie a basement of early Paleozoic schists. The eastern part of the Amotape Mountains is reportedly underlain by granite intruded through Paleozoic rocks which constitute the remainder of the mountains. The generalized geologic map of north-western Peru (Quiroga and Petersen, 1954) designates this granite as Jurassic-Cretaceous and older than the Cretaceous sediments through which it apparently projects as stocks east of the Amotape Mountains.

Structure

The Talara area is underlain by the small north-northwest-trending asymmetric La Brea basin, bounded on the east by the Amotape uplift and on the west by several small domal uplifts.

Some question remains whether the Amotape uplift is residual from Larimide folding, thus forming a natural east boundary for the basin, or was raised along middle or late Tertiary faults after basin formation. Block faulting is the more accepted interpretation because of the straight, angular segments of mountain front, but faults are not obvious. R. Travis (personal communication), of the International Petroleum Company, suspects a shoreline facies in some of the early Tertiary formations marginal to the uplift.

The original western boundary of the basin is not apparent along the present coastline, and it is not established that a well-defined border existed. According to Travis, the basin was probably open, or at least accessible, on the west.

The present coastline between Negritos and El Alto, near Talara, has a general trend of just east of north, and is the westernmost extension of land in South America. It also marks the latitude where the general axial trend of the Andean chain swings from north-northwest to north-northeast. This segment of coastline is characterized by three small but prominent points jutting into the Pacific, separated by two broad embayments. The points are south to north: Punta Pariñas, Punta Lobos, and Punta Pena Negra (El Alto). Because folds are truncated by the coast the coastline maintains the same characteristics of a complex fault boundary although more obscure than to the south. Each point coincides with a small, generally domal uplift folded in early Tertiary sediments, intricately block-faulted, and truncated on the west. The uplifts are separated by similar-sized basins, and the entire area is separated from the larger Sechura basin by the small Lagunitos basin, southeast of Negritos, and by La Brea uplift.

Although not specific, the general trend of large folds and faults is east-west, essentially bisecting the angle between the principal Andean

trends and parallel to the axis of the Amazonas basin. This trend is more obvious here than elsewhere in Perú, where it probably significantly governs the general east-west trend of several mineral belts.

Development drilling in the oil fields has demonstrated an extremely large number of small block faults on the uplifts, which form an intricate pattern that is resolvable into principal stress directions. No particular orientation can be proved to be earlier or later than any other direction, suggesting near-contemporaneity; all are steeply dipping and straight. Displacements are commonly so small, on all except the large east-west faults, that faults cannot be indicated even on large-scale structure contour maps.

Petroleum accumulation

Petroleum probably originated in Chacra (Eocene) and related source shales deposited in the small marine basins and, after moderate middle(?) Tertiary folding, migrated into the Paríñas reservoir sandstones on the flanks of small uplifts on the west side of the area. As a significant reflection of the influence of the east-west structures, aggregates of small petroleum pools occur in short, generally east-west belts coincident with each of the three coastal uplifts. Although faulting is locally influential in barring the migration of petroleum in some areas, and offering flow conduits in others, folding rather than faulting controls the localization of petroleum. As late Tertiary and modern tectonic adjustments have shifted the positions of structural highs, petroleum accumulations have also shifted, leaving large reservoir volumes occupied only by "dead oil." Other migration routes are similarly marked by dead oil. It is common for oil to escape from some pools along faults in which it is trapped within a few meters of the surface by the caliche-sealed gravel veneer of the flat modern erosion surface. The traces of such faults are locally marked by oil seeps and mud volcanoes, the activity of which is attributable to seismic activity in the area.

Possibilities of uranium mineralization

Although most Tertiary marine sediments in this area do not possess the variable and strongly carbonaceous lithology commonly most favorable for the localization of uranium, dead-oil accumulations in permeable sandstones are equally or more favorable, as suggested at Ambrosia Lake, New Mexico, U.S.A. The other essential factor for uranium deposition is the passage of uraniferous hydrothermal or lateral secretory solutions through such an environment.

The presence of hydrothermal activity in any region is reliably indicated by altered rocks which are commonly visible from a distance. Although virtually all the central basin and most of the western uplifts are concealed beneath the modern gravel-veneered surface, no hydrothermal alteration was seen in the southern portion of the area where the Paríñas and Chacra formations are extensively exposed by dissection of the surface,

and in the Paleozoic rocks of the Amotape uplift where alteration would be most expected because of associated stronger deformation and intrusion. The only area which appeared to contain anomalous alteration of Chacra shale and mudstone (northwest of Amotape) was examined carefully and seems to be rather surficial differential mottling in the normally limonite-yellow shale although the lack of alteration is not definitely established. The radioactivity of this shale is 0.005 mr/hr, no higher than the low background of other areas along the coast. When the obvious lack of visible alteration here is compared with the readily visible alteration of many Peruvian areas that are not even known to be mineralized, the conclusion that this area was not mineralized seems to be justified.

The lithologic and structural environment for lateral secretion in La Brea basin is ideal if sufficient uranium could have been leached from the Paleozoic metamorphic or Mesozoic(?) intrusive rocks of the Amotape uplift. Uranium-laden solutions could then have migrated in aquifers down the sides of the basin and possibly into the petroliferous areas. Accordingly, the possibility of even small amounts of uranium in the Amotape uplift could be estimated from exposures in the uplift. The uplift was not visited, but similar Paleozoic schists on the northeast side of the Sechura Desert between Piura and Chiclayo contained no radioactivity above the areal background.

Even if it were established that metamorphic, intrusive, or volcanic rocks marginal to the basin contained sufficient uranium for lateral secretion and it were assumed that laterally secreted deposits existed, there would still remain the problems of location and depths of the deposits. Dr. Guillermo Cox R., of the JCEA, measured no radioactivity in core from International Petroleum Company's development holes in the Talara fields, and the company has examined the surface thoroughly with scintillation counters. To eliminate the entire Talara field as a uranium producer would require much additional drilling for pockets of dead oil, and the poor indications from this area do not warrant such expenditures.

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