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The Camana Formation and its Bearing on the Andean Post-Orogenic Uplift

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The Camana formation is named by the writer after the type locality at Camana, situated about 690 km due southeast of Lima, Peru (see Map 1: 1 000 000 Am. Geogr. Soc., New York, Lima sheet; and Carta Nacional, 1:200 000, Inst. Geogr. Militar, Peru, Camana sheet, 17c). The formation is a rather young-looking series which is very well exposed in the Camana district. Its thickness varies locally, being greatest along a northwesterly trend through Cerro San Cristobal, where it reaches at least 420 m, but thinning eastwards, being not more than 260 m at Cerro Sarria. However, there is a widely displayed «appendix» to the formation in the hinterland, between and along Rios Majes, Ocoña, etc. and these younger beds may reach three times the thickness around Camana.

The basal strata of the Camana formation encroached upon a clearly defined abrasion terrace of great regional extent. At different places this marine platform is cut into granite, gneiss, or Jurassic and Cretaceous sediments belonging in its greater part to Steinmann's "Formacion porfiritica". The terrace has been observed at altitudes ranging from 150 meters near the coast to 3500 meters much farther inland.

The lowermost portion of the formation is composed of epineritic sandy and calcareous, cream and variegated rocks, which are crowded with triturated fossils such as lamelibranchiates, gastropods, echinoids, corals, foraminifera etc., constituting a true breccia. Also imbedded are impure limestones and gravel-strewn sandstones. These strata lie locally on a poorly consolidated bottom conglomerate of coarse sands, sandstones and boulders of the crystalline and sedimentary substratum. The samples referred to later, R-220 and R-221, were collected from this basal part of the section at Pucchu and Huacapuy, northwest of the town of Camana.

The aforementioned portion is followed upwards by reddish and buff, medium grained to gritty sandstones which are highly cross-bedded and contain subordinate conglomeratic intercalations and calcareous flags. This turbulent accumulation of rather lenticular shape yields remains of *Tellina* sp., *Pecten* sp., *Ostrea* sp., *Arca* sp., *Anthozoa, Balanidae, Echinodermata,* etc., but the fossils are too poorly preserved to assit in age determination.

The beds overlying this sequence are gray and yellow very sandy clays and soft shales, interbedded with argillaceous sands and mudstones. They often carry iron-stained ledges, veinlets of gypsum and ashy materials and, as do the basal beds, they often show seeps of salt water or incrustations of salt and salpetre ($NaNO_3$). The aspect of these beds is already distinctly continental.

The sequence so far described forms the escarpments facing west, south and east in the vicinity of Camana; but it is also developed in incomplete sections along the coast for more than 50 km, i. e. between Pampa del Jahuay and Quilca. Its southerly extension has not been followed but from the description by different authors of the Moquegua formation *it seems unlikely that the Camana and Moquegua formations are equivalents. It is further obvious that the Camana formation and its «appendix»* (see below) *can not be correlated with any of the Tertiary formations known to exist north of the strip mentioned above.*

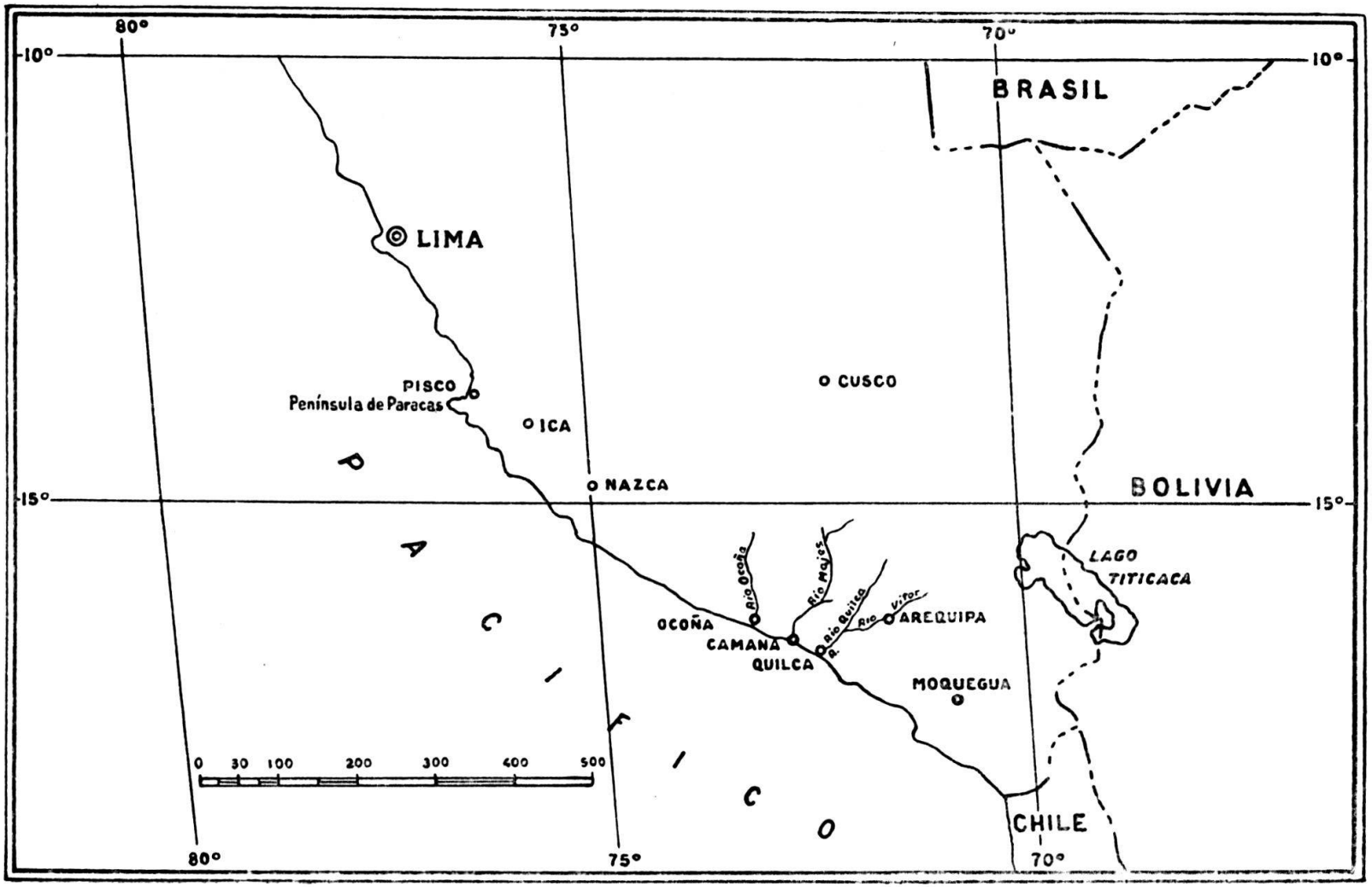

Fig. 1 Southern Peru

The whole Camana succession shows many local discontinuities. These are explained by changes and fluctuations of the source of the sediments, mode of transport, and environment of deposition. The irregular changes and the gradual change from marine up to terrestrial conditions have been clearly observed along the entire belt of outcrops. It is also apparent that the marine facies thins out gradually to the north and northeast, but its development can still be observed a fair distance up the Majes Cañon. Though the whole complex is crumpled, folded and faulted, it tends to reveal a general flat dip towards the Pacific.

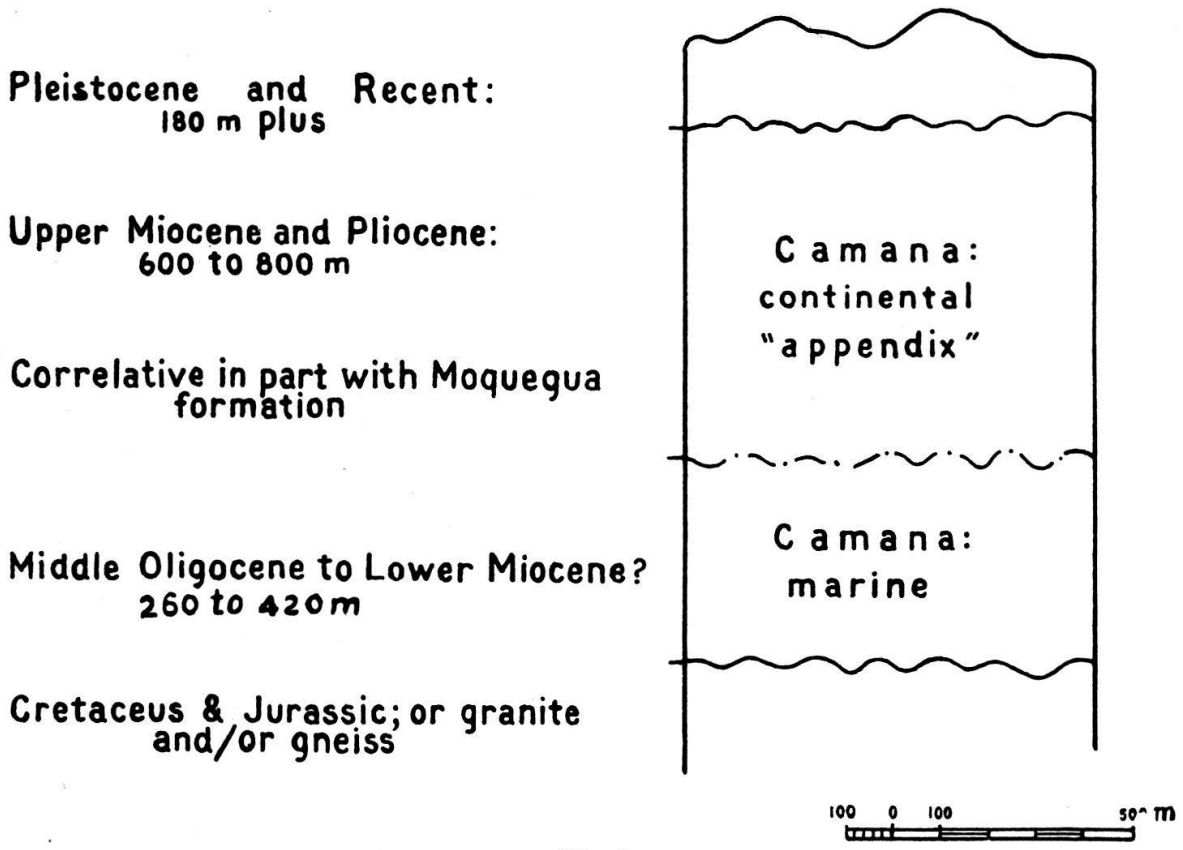

Fig. 2

STRATIGRAPHIC RELATION OF THE CAMANA FORMATION PROPER AND "APPENDIX"

This coastal sequence, the Camana formation proper, is overlain in the rugged, deeply intrenched hinterland by an almost exclusively continental sequence of lead-gray to whitish, ochre to rose coloured clays, sandy shales, sands, sandstones, conglomerates and thick pyroclastic beds—ash, tuff, lava, agglomerate, breccia—and all kinds of transitional variants. The contact between the two very different formations has not been observed directly, but no noticeable angular break has been detected. The upper beds of the inland «appendix» grade up into layers of presumed uppermost Tertiary age. As can be seen in the precipitous gorges of the terraced and blockfaulted highland (Quebradas Pacayura, Jahuay-Manga, affluents of Rio Ocoña, etc.) the thickness of the continental beds is at least six to eight hundred meters.

On purely lithologic grounds it appears that the «appendix» may, at least in part, be correlative with the Moquegua formation, though the stratigraphic position of the latter is still not at all clear. However, the various minor subdivisions seem to reflect strictly local events, confined to one or the other of the two regions and formations concerned, so that precise correlation remains difficult.

All the sediments so far discussed are in turn capped unconformably by widespread Quaternary rhyolites, tuffites (volcanic and detrital-epiclastic materials), large alluvial gravels and fanglomerates, and local eolian deposits.

It is believed that the total thickness of the whole Cenozoic sequence, i. e. of the predominantly marine Camana formation, the overlying continental series of the hinterland, and the roofing Quaternary accumulations, amounts to approximately 1300 meters.

Evidence as to the age of the two Tertiary groups is as follows. The field sample R-220 of the lowermost part of the Camana marine facies contained a moderately rich, but poorly preserved foraminiferal fauna. Forms referred to the distinctive species *Uvigerina mexicana* Nuttall and *U. topilensis* Cushman are clearly suggestive of Lower Oligocene age. Less weight is attached to a *Lepidocyclina* aff. *atascaderensis* Berry as, unfortunately, the single specimen found was poorly preserved. The species cited is known in the Upper Eocene of Peru. The sample R-221, also taken from the lower beds of the Camana formation but stratigraphically about 35 m higher than R-220, contained a very significant orbitoid fauna. Studies of thin-sections have shown the presence in fair abundance of two species of *Miogypsina,* namely *M.* (*M.*) *gunteri* Cole and *M. (Miolepidocyclina) ecuadorensis* (Tan). *Miogypsinas* have not previously been recorded in Peru but the different species form a closely-knit evolutionary pattern and are highly regarded as age-indices in the Carribbean countries and as far south as Ecuador. The two species in sample R-221 indicate an age close to the Middle/Upper Oligocene boundary[1]). Hence it is beyond any doubt that at least the basal part of the Camana formation in its marine facies is at least as old as Middle Oliogocene. Probably the upper parts of the formation extend into the Lower Miocene.

With these faunal data to consider, we may now draw the following important conclusion. From the stratigraphic studies of petroleum geologists and others it has been established that over northern South America and the West Indies there are strong signs of a regional mid-Oligocene immersion. The evidence extends down to northern Peru (Mancora and Heath formation) and it now seems reasonable to judge that our Camana transgression reflects the same regional event, i. e. *the mid-Oligocene subsidence also affected southern Peru.*

The terrestrial beds of the hinterland and uplands of Camana and the adjacent coastal strip (beds which, contrary to certain statements, seem completely barren of fossils) can on mere lithologic and magmatologic grounds be assigned provisionally to the Upper Miocene and Pliocene. The «transition» supposed to exist between this complex and the underlying (marine) Camana formation may tentatively be interpreted as an unobserved disconformity (pseudo-conformity?) representing a hiatus due to non-deposition and/or definite mid-Miocene emergence. The type of

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[1]) We are glad to acknowledge our gratitude to the International Petroleum Company, especially to Dr. A. L. Bell, head of exploration, and Dr. R. M. Stainforth, chief paleontologist, who benevolently accepted and worked over our field samples. We also wish to thank Dr. C. W. Drooger, Geol. Inst., Utrecht, Holland, specialist in the Miogypsinidae, whose cooperation was most helpful. A detailed report on the microfauna will be published separately.

break which possibly exists has not actually been spotted in the field, but gaps in mid-Miocene sedimentation are reported from northwest Peru, Ecuador, etc., and it is very probable that such a hiatus also exists in the Ica-Nasca area, where field work and paleontological studies suggest that the Upper Miocene rests unconformably on Lower Miocene.[2])

It is obvious that the foregoing interpretation of the geological conditions prevailing in the southern littoral is in marked contrast to what has heretofore been accepted. The application of the new age-determinations makes it fully clear that the aforementioned marine terrace is not Pliocene as has been reported, but is much older: it is pre-Camana, hence not younger than early Middle Oligocene. Its substratum, frequently granite and/or gneiss, is certainly not Tertiary as also has been reported, but is considerably older: these igneous rocks have locally been found in sharply unconformable contact below Jurassic and Cretaceous clastics. The wide extent, the close definition of age and the general relationships of the abrasional terrace show it to be a key feature of importance in deciphering the geological history of part of southern Peru.

The new interpretation cannot fail to modify existing concepts of the so-called Pliocene immersion, of the huge accumulation of Pliocene sediments, and of the extraordinary Pliocene-Quaternary epeirogenic uplift of a large tract of the southern coast and its hinterland. Now, admitting that the abrasion plane and its overlying strata are Oligocene and knowing that its actual position in the field varies from 150 m to 3500 m above sea level, there is absolutely no reason to state that the enormous difference in altitude is solely a matter of Plio-Pleistocene to Recent radial uplift. On the contrary, the wide variation in altitude is rather due to folding and large-scale block-faulting during the known successive diastrophisms in the relatively long interval since Oligocene-Miocene time. Net vertical movement of epeirogenic type must have been of minor magnitude.

It has been possible to check our data by comparison with true Plio-Pleistocene to Recent terraces and their remnants inland, i. e. slopes of raised shore-lines and intermediate stages of platforms, noting especially their altitudes and angles of tilt. From this comparison we conclude that the greatest displacements of the marine terrace took place during phases of active Andean orogeny, particularly when block-faulting at right-angles to the Cordilleran axis broke up the coastal belt. We further conclude that *vertical movement since the youngest Andean orogeny does not exceed an average of 800 meters or a maximum of 1600 meters. Maximum elevation due to epeirogenesis has been found in the places nearest the mountain front. Our measurements preclude any movement of the order of 3000 to 3500 meters, such as has been claimed in the literature for the total post-Pliocene uplift.*

The new views presented above deserve careful consideration, more field-work being a prime necessity. We believe that detailed stratigraphy and thorough study of the terrace-structures will furnish enough clues for interpreting the origin, interrelationships, amplitudes and rhythms of these fascinating phenomena. Solution of the problem on this classic coast will help to solve many pending questions of circum-Pacific importance.

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[2]) The author wishes to express his sincere appreciation to Mr. A. Manrique, geologist, Lima, for his excellent assistance during the field campaign in southern Peru.

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Note: Personal correspondance with Dr. R. M. Stainforth, chief paleontologist, Talara, and Dr. M. A. Rivera V., geologist, Arequipa, which improved the present study most substantially. —

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