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Artikel: Contribution to the geology and paleontology of the area of the city La Habana, Cuba, and its Surroundings

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younger than the others, although the evidence is inconclusive. SÁNCHEZ ROIG (1949, p. 246) recorded *Ostrea haitensis* SOWERBY from a cut at the railroad from Habana to Marianao, Estación de Ceiba. This is the same locality from which this author described *Pericosmus roigi* LAMBERT.

As pointed out earlier, discoasters and coccoliths so common in the older Tertiary appear to be destroyed through recrystallization in all of the Cojímar samples examined by us. The planktonic Foraminifera, however, indicate that the Cojímar formation is part of the *Globorotalia fohsi* zone which overlies the *Globigerinatella insueta* zone and underlies the *Globorotalia mayeri* zone. Not all of the subzones of the *Globorotalia fohsi* zone were recognized. The type section of the Cojímar formation is within the *Globorotalia fohsi fohsi* subzone, and only three samples, one from the Cojímar beds at the road cut at the Autopista del Mediodía, BR station 549, and the others from the Marianao area, BR stations 907 and 908, are from the younger *Globorotalia fohsi lobata* subzone. The *Globorotalia fohsi robusta* subzone, the youngest of the subzones of the *Globorotalia fohsi* zone was not recognized, either because it is not represented, or because, and from the field evidence this seems to be more probable, a distinct facies change occurs from the chalky deeper water beds to the hard fragmental limestones of relatively shallow-water character from which globorotalias either could not be isolated or where they are practically absent. In terms of larger Foraminifera, the Cojímar formation is part of the *Operculinoides* zone, which is extended from the *Globorotalia fohsi* zone to the end of the Miocene.

TECTONICS OF THE HABANA AREA

The over 80 km long east–west trending Habana–Matanzas uplift or anticlinorium plunges near Matanzas axially eastward into the sea. Southwest of Habana it sharply turns toward the west-southwest and also shows a distinct axial plunge. Pre-Capdevila beds are not exposed between the highway from Habana to Rancho Boyeros and the Guanajay–Mariel uplift immediately to the west of the mapped area. Approximately halfway between Habana and Matanzas, in the vicinity of Central Hershey, a northwest trending saddle filled with Oligocene and younger sediments covers the steeply folded and broken core of the anticlinorium. This saddle is possibly caused by a fault trend in older sediments.

To the south of the Habana anticlinorium lies the also east–west trending relatively flat Vento syncline with beds of Miocene and ?younger age. Farther south follows the Bejucal uplift with a core of steeply folded Lower Eocene beds, probably Apolo, Alkàzar and Capdevila formations. Between the Bejucal uplift and the Caribbean sea to the south, the Miocene to younger beds are gently dipping southward. The flattening of the dips in the southernmost exposures of this area is suggestive of a third apparently less pronounced east–west trending uplift located off-shore.

The northern rim-rock od the Habana anticlinorium

The entrance to the Bahía de la Habana is dividing the northern rim-rock into two segments. The west-southwestern segment, made up mainly of post-Capdevila beds, dips throughout Vedado and Marianao toward the northwest, and toward the north-northwest in the vicinity of Arroyo Arenas and Punta Brava. The dips range from 5° to 25° with average values of 10° to 11°. There is only one major tectonic feature disturbing the western segment of the northern rim-rock, that is the about N 10° E trending fault which is followed in part by the Río Almendares. This fault is probably of the wrench type, with a relative displacement of the eastern side toward the north-northeast. Very likely the fault was active during different geological periods. The segment of the northern rim-rock east of the entrance to the Bahía de la Habana is dipping in general to the north, with dips ranging from 5° to 34°. The average value of the dips is about 18°. Formations of post-Vía Blanca and pre-Cojímar age are only locally preserved. Some minor tectonic accidents occurred in the eastern segment such as the small east-southeast trending anticline cut by the road just east of the Hospital Naval, where the cotype locality of the Cojímar formation is exposed.

As suggested by R. H. PALMER (1934), it seems very probable that the steep cliff along the northeast side of the entrance to the Bahía de la Habana corresponds to a northwest trending fault. Morphologic expressions of a fault were encountered during the construction of the tunnel across the Bahía de la Habana (personal communication by Ing. J. F. DE ALBEAR). Such a fault would explain the differences of both stratigraphic and structural character between the western and the eastern side of the entrance to the Bahía de la Habana.

The southern rim-rock of the Habana anticlinorium

From Punta Brava to the highway from Habana to Rancho Boyeros, the southern rim-rock is dipping 5° to 12° toward the south. Farther east between Arroyo Naranjo and the Carretera Central, the inclinations of the dips are similar, their azimuths however are directed toward the south-southeast. South of Santa María del Rosario, the dips are virtually identical with those between Punta Brava and the highway from Habana to Rancho Boyeros. The post-Capdevila to pre-Güines beds are by far not as well preserved as in the northern rim-rock. The Universidad formation is known to us only by a single outcrop in the quarry about 1.5 km west-southwest of Santa María del Rosario. The Cojímar formation is missing. The Husillo formation, on the other hand, is rather well but not continuously developed along the southern rim-rock.

The core of the Habana anticlinorium

As shown by the interpretive geological map (plate II) and the cross sections I to IV (fig. 75), the core of the Habana anticlinorium is sharply contrasting with the rim-rock by its steep and often overturned beds and by its numerous faults. The strikes of most of the beds are in east–west direction.

The axial plunge of the anticlinorium toward the west is reflected by the successive disappearance in that direction of the serpentinites, which within the studied area do not outcrop west of the Bahía de la Habana, and of the pre-Vía Blanca, Vía Blanca, Peñalver, Apolo and Alkázar formations. West of Alta Habana–Los Pinos, the oldest exposed beds belong to the Capdevila formation. A few kilometres west of the here described area, the anticlinorium is higher again as witnessed by the occurrence of Upper Cretaceous beds, probably pertaining to the Peñalver and Vía Blanca formations. Because of the scarcity of good outcrops not much can be said about the actual tectonic conditions below the Capdevila formation. Water wells drilled in 1913 on the grounds of Cervecería La Tropical, Puentes Grandes, Marianao, coordinates 364.60 N and 355.30 E, are reported to have reached "serpentinite" at the shallow depth of about 60 feet (DeGolyer, 1918, p. 138). In a general way it appears safe to state that the tectonic pattern of the covered core must be very similar to that of the deeper exposed core east of La Habana. The structurally highest portion of the anticlinorium is the Regla–Guanabacoa–Bacuranao serpentinite body. South of the Regla–Guanabacoa–Bacuranao uplift, the folds have generally vertical or overturned northern flanks. The dips at the south flanks of the folds range from about 50° to 60°. North of the uplift, the southern flanks of the folds are steeper than to the south and often overturned as can be seen in the detailed geological map of the rim-rock between Casa Blanca and Cojímar (plate III).

The core of the Habana–Matanzas anticlinorium is characterized by a sequence of very incompetent beds. It displays similarities with many areas of flow tectonics as for instance with the Préalpes Médianes Plastiques and the Ubaye–Embrunnais nappes of the Swiss and French Alps, and with the Basle–Argovian Jura of northern Switzerland. In all these regions we are dealing with a sedimentary sequence folded and displaced on some very plastic layers, as for instance the shales and evaporites of Triassic age on which the Jura Mountains were folded, and which are resting in their turn on a relatively undisturbed substratum. In the Habana area, where the displacement through a gliding or plastic flow mechanism was directed to the north, no evidence was found for low-angle thrusts with large horizontal displacement. According to W. H. Bucher (personal communication) the mode of folding as expressed by the Peñalver formation (fig. 75) implies that a major gliding plane must exist at a depth of approximately 500 m deeper than the bases of the synclinal folds of the Peñalver formation. One of the writers (D. R., 1961) has expressed the opinion that this gliding plane is separating highly disturbed sediments and serpentinites from non-disturbed peridotites of the mantle. Some authors suggested that the central Cuban structure is the result of the superposition of several low-angle thrust sheets, at the base of which serpentinites are found (Brönnimann and Pardo, 1956; Wassall, 1956). In our opinion, however, the only regions of Cuba where large-scale low-angle thrust sheets are clearly developed are the Organos Mountains of Pinar del Río Province, southwest of a line connecting La Palma and San Diego de Los Baños, with Jurassic to Lowermost Eocene rocks forming magnificent thrust sheets displaced to the north or northwest, and the Trinidad–Sancti Spiritus mountains, where metamorphics of yet unknown age are folded into large, probably northward displaced nappes (Rigassi, 1961, pp. 3–7). For such movements as those which produced the steep folds of the core of the Habana anticlinorium, the term "rheogenetic movements" has been proposed.

Age of deformation

In the Habana area, the lower and upper time limits of the gliding or plastic flow phase can be traced as follows:

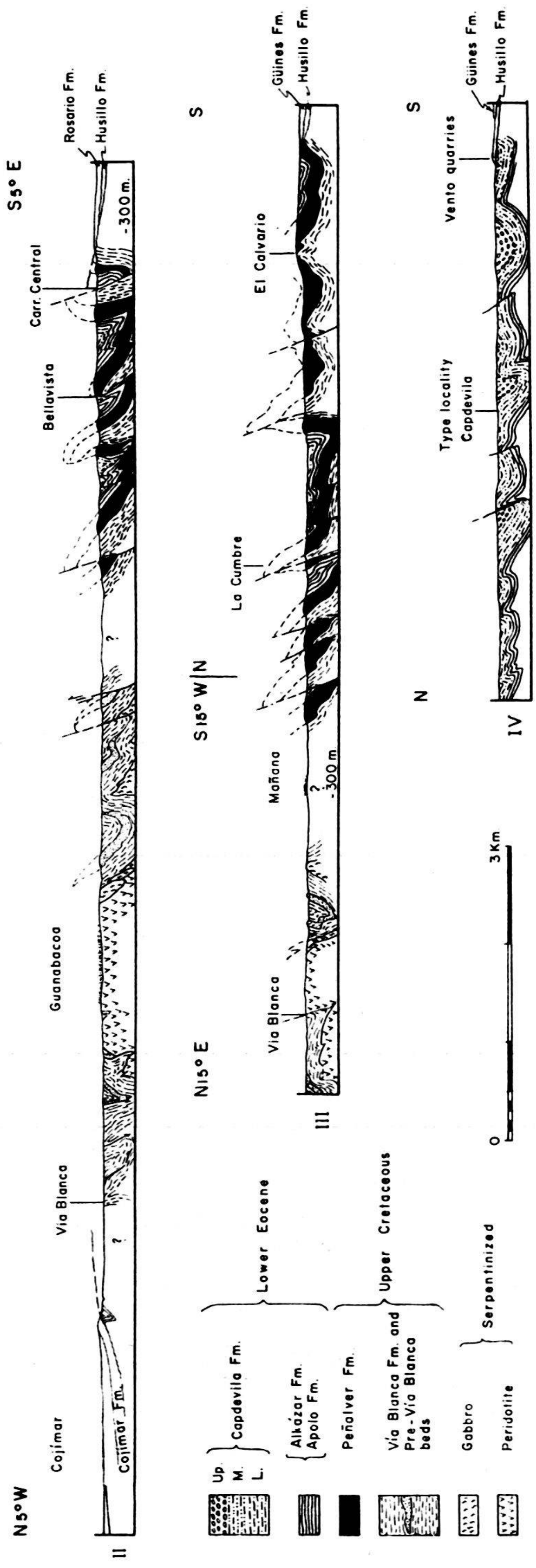

Fig. 75. Cross sections I to IV, Habana area.

The beginning of the flysch-type deposition represents also the beginning of tectonical instability in the source areas. The pre-Vía Blanca beds are not yet adequately known in order to decide whether or not they have all the characteristics of a flysch series. The Vía Blanca sedimentation, on the other hand, is definitely of flysch-type. The age of the oldest Vía Blanca beds is Campanian and their clastics were probably mostly of southern origin. The Universidad formation, the base of which is late Lower Eocene, was not affected by gliding movements. It is true that some instability persisted throughout the Tertiary as witnessed by slumped beds and numerous disconformities and unconformities, but it appears that the regional tectonical expression of this instability is restricted to gentle folds with dips usually not exceeding 20°. The gliding or rheogenetic movements in the Habana area are thus of mid-Laramid age, with their paroxysmal phase during the late Upper Cretaceous and the early Tertiary (Campanian to Lower Eocene).

Faults

The north-northeast striking faults west of the highway from Habana to Rancho Boyeros are believed to be the attenuated surface expression in beds of Capdevila and younger age of an important wrench fault trend with a relative displacement of the eastern side toward the north-northeast. It is pointed out that this interpretation is based on regional considerations rather than on actual field observations. Physical evidence of faults is rarely seen in this area. Several faults have been clearly identified on aerial photographs in the region between Central Toledo and the highway to Rancho Boyeros, but could not be investigated in the field because of the political situation at the time of our survey. The fault followed by the Río Almendares, east of Marianao, is still seen in post-Cojímar beds. Its last displacement was of late Miocene or younger age. As expressed by the paleogeological map of the Cojímar formation (plate VI), an important movement occurred in post-Cojímar time. The paleogeological study of the Husillo formation (plate V) indicates that there was already in Husillo time a depression along the present fault line. In the vicinity of Loma Príncipe, the dips in the Capdevila formation at the moment of the Universidad transgression were 12° to 19° toward the west-northwest. This could be interpreted as a very early indication of the north-northeast trending wrench faults. Wrench movements apparently occurred over a very long period of time with alternating phases of relative tectonic quietness and of activity. This is the case for many of the wrench faults with which the authors are familiar, such as those in California, the Jura Mountains, the Appennin, and the Near East (Red Sea–Dead Sea–Hatay fault trend).

N 10° W to N 35° W trending faults east of the highway from Habana to Rancho Boyeros are regarded as old faults, because none can be followed into the southern rim-rock, and because the two lips are definitely disymmetric. A good example of this type of fault occurs between coordinates 360.7 N and 368.4 E and coordinates 359.1 N and 368.85 E. These faults must have been active before the end of the mid-Laramid folding, i.e. before late Lower Eocene time. Better exposed faults of similar direction in other Cuban regions, in particular those in the Coliseo area, Matanzas Province, must have originated during the Lower Eocene. They underwent, however, reactivation in younger geological periods.

A third fault trend is directed toward the northwest and the west-northwest. Representative of this fault group are those in the area of Vieja Linda, Los Pinos and Arroyo Apolo, and the hypothetical fault at the entrance of the Bahía de la Habana. These fractures are possibly antithetical faults caused by the north-northeast trending wrench faults.

The folding of the rim-rock

The basal unit of the rim-rock proper, the Universidad formation, is either transgressive on beds ranging in age from the Vía Blanca formation to the Capdevila formation or it is transitional on the Capdevila beds. It never shows the steep dips affecting older formations. The Punta Brava and Consuelo formations are so restricted geographically that they cannot furnish any general idea on the diastrophism which occurred during the time interval from the Universidad formation to the Husillo formation. At the moment of the Consuelo transgression, the dip of the underlying Universidad beds was at Tejar Consuelo, Reparto Cerro, La Cienaga, about 7° toward the south-southwest. The dip in the Punta Brava beds, in the quarry east of Punta Brava was probably 14° to 15° toward the northwest. The paleogeological map of the Husillo formation shows that there was a very weak reactivation of some east–west trending folds after the deposition of the Universidad beds and before the Husillo transgression. The scant information available from the paleogeological map of the Cojímar formation does not afford any significant conclusions on movements during its time of deposition.

Post-Cojímar sediments are of two types, i.e. sediments transgressive on Cojímar beds and involved in later movements, such as the Morro formation, and marine terraces, both above and below sea level, and not visibly affected by later movements. During late Neogene time, the area was gently uplifted and folded in what constitutes the Habana anticline proper of former authors. Possibly compression due to meridian forces reactivated the folds of the core but did not affect the rim-rocks of massive carbonates of the Marianao group. During the Quaternary, there were apparently no measurable tectonic movements in the Habana area, because the above mentioned marine terraces are not tilted and their elevations are continuous. Hence it seems that the occurrence of different levels of marine terraces which may be found on any formation from the Vía Blanca upwards, must be attributed to the effects of the glacial period and not to epeirogenetic movements. These observations are in contrast with those made in other Cuban areas, especially in southern Oriente Province and in the Trinidad Mountains, where the terrace pattern suggests rather strong Recent uplift movements (L. RUTTEN, 1941; DEL CORRAL, 1944). The slumped masses of Peñalver clastics found for instance near coordinates 363.7 N and 371.6 E are believed to have occurred in Recent time.