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FORAMINIFERAL CORRELATION OF TERTIARY MOLLUSC HORIZONS OF THE SOUTHERN CARIBBEAN AREA

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ABSTRACT

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Correlations of conspicuous Tertiary mollusc horizons described from the southern Caribbean area are attempted on associated micropalaeontological evidence. By this method the rich mollusc horizons characteristic of the Springvale Formation of Trinidad, the Punta Gavilán Formation of Venezuela, and the Tubará Formation of Colombia are considered time-correlatable at the Early Pliocene level. The Cantaure mollusc horizon of the Paraguaná Peninsula of northern Venezuela contains an Early Miocene (Burdigalian) microfauna and is correlatable with that of the basal part of the Castilletes Formation of the Guajira Peninsula of northern Colombia and the Quiroz horizon of the La Rosa Formation of the Maracaibo Basin. The '*Raetomya* Shales' of the Jarillal Formation of western Venezuela correlate with similar macrofaunas found in the Caus Formation and other transitional facies units associated with the contact of the Middle Eocene Misoa and Pauji Formations of the Maracaibo Basin, and those of the Ceru Mainsji Formation of the island of Curaçao. These horizons can be clearly calibrated with the *Truncorotaloides rohri* and *Orbulinoides beckmanni* zones of Bolli's (1966) planktonic foraminiferal zonation. There is also micropalaeontological evidence to suggest that the *Hannatoma* horizon of western Venezuela can be associated with the final regressive depositional phase of the Middle Eocene throughout northwestern South America.

INTRODUCTION

Fossil Mollusca are relatively common throughout the Tertiary of the southern Caribbean and northern South America region but often locally concentrated at distinctive horizons which have attracted the attention of palaeontologists since the early years of geological exploration. These include the '*Venericardia* limestones' of the Palaeocene Guasare Formation of Venezuela and the Soldado Formation of Trinidad; the '*Raetomya* shales' of the Jarillal and Santa Rita Formations of Venezuela; the '*Hannatoma* horizon' of the La Victoria Formation of Venezuela and the Carbonera Formation of Colombia; the 'Cantaure beds' of the Paraguaná Peninsula of Venezuela; and the younger rich mollusc horizons of the Springvale Formation of Trinidad, the Punta Gavilán Formation of Venezuela, and the Tubará Formation of Colombia.

Early correlations were based essentially on general stratigraphic position, percentage of living species, and ratio of species in common with other rich Tertiary assemblages. These correlations were necessarily tentative due to the indeterminate palaeo-environmental factors influencing the faunal composition of the assemblages, and the variable quality of published data. The study of associated microfaunas, particularly the planktonic foraminifera, has more recently permitted a further refining of Tertiary stratigraphic correlations and an additional reference by which to analyse faunal variations of time-correlatable mollusc assemblages in terms of palaeo-environmental controls.

This paper is intended as a preliminary presentation of the basic microfaunal data so far assembled and which will be incorporated into a broader stratigraphic analysis of Caribbean Tertiary mollusc assemblages in conjunction with Dr Peter Jung of the Basel Natural History Museum.

BASAL TERTIARY VENERICARDIA LIMESTONES

The basal Tertiary section of the southern Caribbean area, like that of the Gulf Coast province of the United States, is locally characterized by limestone horizons containing rich mollusc assemblages dominated by the *Venericardia planicosta* group. The most distinctive and extensive horizon carrying this fauna in the southern Caribbean region is the

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Guasare Formation of northwestern Venezuela and northeastern Colombia, which has commonly been referred to informally as the '*Venericardia* limestone' because of the abundance of specimens of *Venericardia* species in the closely-packed coquinas of that formation.

MAURY (1925) was the first to mention the presence of '*Venericardia planicosta,* smooth variety' from the type locality of the Guasare Formation on Toas island. She had already described this form from the Soldado Formation of Soldado Rock off the west coast of Trinidad. RUTSCH (1936) also collected from Toas Island, as well as in the Rio Guasara and the Rio Cacharí of the adjacent mainland area of northwestern Venezuela, and identified most of the species of *Venericardia* as *V. parinensis,* which had originally been described by OLSSON (1928) from the Parinas Formation of Peru. Olsson was later (in SUTTON, 1946) reported to consider the Guasare species as identical to those from Soldado Rock and Marac quarry of Trinidad but belonging to a new species which Dusenbury (also in Sutton, 1946) described under the name *Venericardia (Venericor) toasensis.* SUTTON (1946) reported Guasare limestone containing *Venericardia* outcropping in the upper Rio Rancheria valley, between Fonseca and Arroyo Cerrejon, Department of Magdalena, northeastern Colombia. MAURY (1925) also mentioned '*Venericardia planicosta,* smooth variety' on the island of Margarita off the north coast of Venezuela, but this occurrence has never been confirmed by later workers in the area.

Other Venezuelan records of Venericardia limestones at the base of the Tertiary section include those reported from the lowest part of the Humocaro Formation of Lara (MUÑOZ, 1966) and the Cerro Corazon limestone of LIDDLE (1928), outcropping north of Urica in the State of Anzoategui. The latter is now considered to belong to the basal part of the Vidoño Formation. More questionable occurrences include BUTTERLIN's (1956) reference to the possible presence of *V. parinensis* in the Palaeocene of the island of Curaçao. RUTSCH (1936) had previously made a sweeping reference to basal Tertiary *Venericardia* limestones occurring over a wide part of the South America and southern Caribbean region including Barbados, St. Barts, Panama, Peru, and Chile, without referring to specific geological horizons.

MAURY (1912, 1925) originally considered the Soldado and Guasare *Venericardia* limestones to be Eocene in age following the generally accepted view of that time that the Midway, although representing the basal Tertiary stage of the Gulf Coast region, was no older than Lower Eocene. Later, the Midway became generally accepted as being equivalent to the European Palaeocene, although the latter term was not always adopted on the western side of the Atlantic, except by vertebrate palaeontologists.

SCOTT (1926, 1934) was the first to challenge the presence of any considerable time break between the basal Tertiary (Midway) and the Upper Cretaceous (Navarro) of the Gulf Coast region and, by determining the local Nautiloid species *Enclimatoceras ulrichi* White as synonymous with *Hercoglossa danica* (Schlotheim), considered the basal Midway of the Gulf Coast province to be Danian in age. However, the Danian at that time was considered to be the closing epoch of the European Cretaceous and consequently Scott's correlations temporarily removed the basal Midway from the Cenozoic into the top of the Mesozoic. Some authors followed Scott (SIMPSON, 1932; STEPHENSON, 1941; FOX & ROSS, 1942; etc.) but others, such as GARDNER (1933), whilst accepting the Midway as equivalent to the European Palaeocene, considered Scott's data to be insufficient evidence for the presence of marine deposits of Danian age in either of the Americas.

BROTZEN (1948) offered the first strong biostratigraphic evidence, largely based on benthonic foraminifera, in favour of a Danian age for the lower Midway (Kincaird). Later studies of the planktonic foraminifera have now confirmed that this stratigraphic level is Danian (LOEBLICH & TAPPAN, 1957), and this stage has now also been generally accepted as the basal stage of the Tertiary.

A Palaeocene age for the Soldado Formation was first determined by RUTSCH (1939) although KUGLER (1936) had previously broadly referred to "The stratigraphic position of the Paleocene Soldado Formation" in his 'Summary digest of the geology of Trinidad'. SUTTON (1946) later listed a fauna of larger foraminifera from the 'Guasare Formation of northeast Trujillo, Venezuela' which he correlated with a Palaeocene fauna described by CAUDRI (1944) from the San Juan de Los Morros limestones of the Guárico Formation of central Venezuela. SUTTON (1946) also lists a rich fauna of smaller foraminifera, identified by Dusenbury, from the Guasare Formation of well DM-1 of the Mara field and from Toas Island, including such species as *Discorbis midwayensis soldadensis* Cushman and Renz, *Spiroplectammina laevis cretosa* Cushman, *Dorothia alabamensis* Cushman, and *Ammobaculites midwayensis* Cushmen, known only from the Palaeocene.

A Danian age is possible for the Guasare Formation as it conformably overlies proven Maastrichtian strata (Colon Formation) and is overlain in a similar manner by the Marcelina Formation which contains a rich palynomorph assemblage clearly indicating a Palaeocene age.

The only sediments so far clearly dated as Danian within the southern Caribbean area are those of the Midden-Curaçao Formation of Curaçao. However, because there is strong lithological evidence in favour of depositional continuity over the Cretaceous-Tertiary boundary throughout most of the region, it is assumed that the Danian stage is well represented but difficult to define. In many cases, such as the Lizard Springs Formation of Trinidad, the Vidoño Formation of eastern Venezuela, and the Trujillo Formation of Falcón and Lara, microfaunas are dominated by arenaceous foraminiferal assemblages and lack the necessary diagnostic planktonic species for more accurate definition.

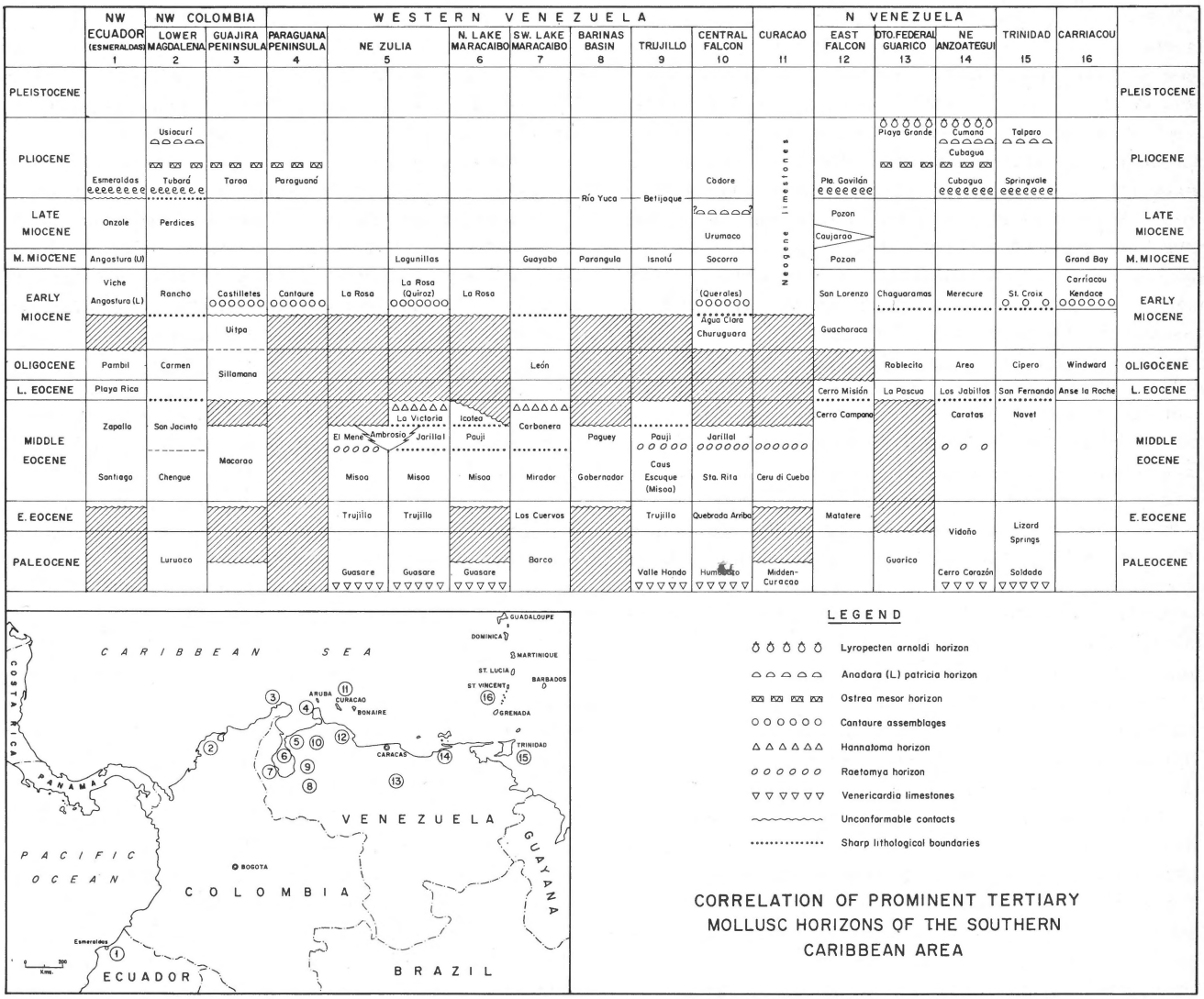

Fig. 1
Correlation of prominent Tertiary mollusc horizons of the southern Caribbean area.

RAETOMYA SHALES

The two mollusc species *Mya (Raetomya) scheinfurthi falconensis* Rutsch and *Rimella (Ectinochilus) gaudichaudi alauda* Olsson were identified by SEITZ & RUTSCH (1930) and RUTSCH (1930) respectively as the most characteristic components of a rich mollusc assemblage occurring within the top of the Santa Rita Formation and the lower part of the overlying Jarillal Formation of northern Lara and south-central Falcón, Venezuela. These two formations, together with a younger unit, the Churuguara Formation, were originally described by SENN (1935) as the Santa Rita conglomerate, the Jarillal shale, and the Churuguara beds of his Agua Negra Formation. The latter was later given group ranking by RIVERO (1956) and the three members promoted to formations.

The lower 50 metres of Senn's Jarillal shale were distinguished by that biostratigrapher as the *'Raetomya* shales' due to their rich mollusc faunas. He considered the underlying Santa Rita conglomerate to be Late Eocene in age largely based on the rich faunas of larger foraminifera identified by GORTER & VAN DER VLERK (1932) and GRAVEL (1933). The conglomeratic nature of that unit also influenced him to interpret it as the basal beds of a Late Eocene (Jacksonian) transgression. Tentative correlations were made with the Ceru di Cueba limestones of Curaçao which had previously been described and dated as Late Eocene by KOCH (1928). Comparisons were also made with the Paloma Alta Formation of the Maracaibo Basin which was then also considered to belong to the Late Eocene.

There is now increasing evidence that this *Raetomya* fauna belongs to the upper part of the Middle Eocene within the time interval represented by the *Orbulinoides beckmanni* zone and the lower part of the succeeding *Truncorotaloides rohri* zone of BOLLI's (1966) planktonic foraminiferal zonation. The writer (HUNTER, 1974) has described a homogeneous Middle Eocene planktonic foraminiferal fauna from marls interbedded with the more conglomeratic and limestone levels of the Santa Rita Formation in its type locality. The overlying Jarillal Formation of the type section carries a poorly preserved benthonic foraminiferal assemblage but GUEVARA (1967) erected a reference section further to the west, in the area of the old Paloma Alta Formation, which contains a rich planktonic fauna no younger than the Middle Eocene *Truncorotaloides rohri* zone. The Jarillal Formation is also identified in well Pica Pica -1 and contains the same rich planktonic foraminiferal assemblage as that of the reference section.

JUNG (1974) has now described a rich mollusc fauna from the Ceru Mainsjie Formation of Curaçao which included *Raetomya falconensis* (Rutsch) and other species in common with the Santa Rita assemblage of Venezuela. HERMES (1968) had previously described Middle Eocene planktonic foraminifera from the Curaçao horizon and Jung (personal communication) has more recently confirmed that the rich mollusc fauna of the Santa Rita and Jarillal Formations, although not yet systematically described, is identical to that he found in the Ceru Mainsjie Formation.

The *Raetomya* fauna is also known from the Maracaibo Basin of western Venezuela and again appears to lie consistently at the transitional zone between the Middle Eocene Pauji and Misoa Formations. This mollusc horizon has been identified in such transitional facies units as the Las Flores and Potreritos Formations of northeast Zulia, the Omuquena Formation of Táchira, and the Caus Formation of Trujillo.

SUTTON (1946) listed the following fauna identified by Hodson, Hoffmeister, and Winkler from the Las Flores Formation.

Ectinochilus gaudichaudi alauda Olsson
Rimella knappiana Maury
Alectrion terebratula Olsson
Amauropsis smithiana Olsson
Diastoma americanum Olsson
Epitomium cf. *multiliniferum* Aldrich
Cardium tuomeyi Aldrich
Meretrix subimpressa var. *golfotristensis* Maury
Nuculana lisbonensis Aldrich
Ostrea sellaeformis Conrad
Ostrea tacalensis Hodson

Molluscs are rarer in the Potreritos Formation but among the identifications of Hoffmeister and Winkler (in SUTTON, 1946) are *Ectinochilus gaudichaudi alauda* Olsson and *Arca cf. rhomboidella* Lea.

SALVADOR (1950) lists the species *Raetomya falconensis, Rimella gaudichaudi alauda* and *Athleta (Volutospira) ochsei* as having been identified by Rutsch from the Caus Formation of the Chejendé area of the State of Trujillo. The first reference to this mollusc horizon was probably that of SUTTON (1946) who mentioned identifications by Winkler of *Ectinochilus* sp. and *Raetomya* sp. in a fauna of a sandy limestone bed near the top of the 'Lower Pauji' in the Rio Caus near Las Pavas, and *Ectinochilus gaudichaudi alauda* Olsson and *Nuculana lisbonensis* (Aldrich) from sandy limestone and shale outcrops of the 'Lower Pauji' in the vicinity of Pone Mesa in southwest Trujillo. These levels probably represent the Caus Formation which is a glauconitic, calcareous sandstone unit transitionally located between the shaly Pauji Formation above and the sandy Escuque (Misoa) Formation below. The Pauji Formation is clearly no younger than the *Truncorotaloides rohri* zone of the Middle Eocene and, although the underlying sandy beds of the Escuque Formation do not carry diagnostic faunas, rich planktonic assemblages of the *Orbulinoides beckmanni* zone have been identified by the writer in the thin shale zone immediately below the Caus level of the Los Baños anticline section and elsewhere in the Valera area of the State of Trujillo.

The species *Athleta (Volutospira) ochsei* is apparently a nomen nudum. According to Jung (personal communication) a type specimen was selected by Rutsch from the Santa Rita Formation but never formally described and published.

SUTTON (1946) also lists *Ectinochilus gaudichaudi alauda* Olsson, *Architectonica sultana* Olsson, and *Cardium cf. C. restinensis* Olsson, as having been identified by Olsson from a mollusc collection made by J. W. Nance from a sandy shale zone about 107 metres above the base of the Misoa Formation in the northeastern part of Trujillo.

Elsewhere in the Maracaibo Basin reference has been made by SUTTON (1946) to forms identified by Winkler in Táchira which could well correlate with the *Raetomya* level. These come from the Omuquena Formation which is now recognized as being equivalent to the upper part of the Middle Eocene Misoa Formation. *Raetomya* species are listed from the Rio Omuquena; *Psammosolen cf. P. sanctidominici* Maury from the Rio Escalente; and *Venericardia cf. V. simillina* Olsson, *Lucina cf. L. conventa* (Olsson), and *Cardium samanicum* Olsson from Mérida.

SUTTON (1946) has also reported "numerous species of *Raetomya*" in MACKENZIE's (1937) El Mene Formation of the Barinas Basin. This formation has since been renamed the Altamira Formation by Sutton and, more recently, the Paguey Formation by PIERCE (1960). This unit was always considered to be Late Eocene until FURRER (1971) described rich Middle Eocene planktonic foraminiferal faunas from the type section.

Outside western Venezuela and Curaçao there is some limited evidence to suggest that the same *Raetomya* fauna could have extended over a much wider geographic area during Middle Eocene time. *Rimella (Ectinochilus)*

knappiana Maury and *Ostrea golfotristensis* Maury have been recorded from Bed 11 (Boca de Serpiente Formation) of Soldado Rock which has recently been confirmed as Middle Eocene in age by KUGLER & CAUDRI (1975). There is also a reference in the Venezuelan Stratigraphic Lexicon (DUSENBURY, 1956) to a *Raetomya* fauna in the Mundo Nuevo (Caratas) Formation of the Quiriquire Field of eastern Venezuela whose microfaunas indicate a Middle Eocene age (LAMB, 1964).

Thus the consistency of biostratigraphic evidence within at least the western Venezuela region, including the island of Curaçao, indicates that the *Raetomya* horizon is no younger than Middle Eocene in age and is probably time-correlatable at a level equivalent to the upper and lower parts respectively of the *Orbulinoides beckmanni* and *Truncorotaloides rohri* Middle Eocene planktonic foraminiferal zones. This places the *Raetomya* horizon at a slightly older time level than the *Hannatoma* horizon. The latter appears to represent a brackish-water facies associated with the shallowing end phase of the Middle Eocene, whilst the *Raetomya* faunas are interpreted as open marine assemblages occupying the transitional facies zone between the Misoa deltaic-marine and the Pauji prodeltaic provinces of the preceeding transgressive phase.

THE HANNATOMA HORIZON

The *Hannatoma* fauna is probably the most widely known Tertiary mollusc horzion of the northern South American region principally due to the controversial opinions concerning its exact age and chronostratigraphic value. This mollusc horizon is a highly facies controlled assemblage of dominantly brackish-water species which cannot be directly correlated with any age-diagnostic marine macro- or microfaunal horizons. Consequently age determination has always been speculative as demonstrated by the variety of opinions which range from Middle Oligocene (OLSSON, 1931, 1934; SUTTON, 1946) to Late Eocene (Durham, Dusenbury, Kehrer, Stainforth, and Stone in DURHAM ET AL., 1949; STAINFORTH, 1955).

The assemblage, including the key species *Hannatoma emendorferi,* was first described by OLSSON (1931) from the Mirador (Mancora) Formation of the Chira Group of northwestern Peru, and the initial Middle Oligocene age determination was partly based on a supposed direct correlation with the mollusc assemblages of the Antigua Formation of the island of Antigua, and partly by accepting a Late Eocene age for the underlying Talara and Samán Formations following Cushman's determination of *Discocyclina peruviana* as a Late Eocene species. However, in correlating the *Hannatoma* horizon with the Antigua Formation, Olsson placed greater time-stratigraphic value on associated mollusc species such as *Ampulinopsis spenceri* Cooke and *Hemisinus sp. aff. H. antiguaensis* which are common to the two formations but were then considered to be Oligocene markers. WIEDEY & FRIZZELL (1939) later reclassified *Discocyclina peruviana* as a Middle Eocene species and placed the Chira shale and part of the Mancora Formation of Olsson in the Late Eocene, but Olsson still continued to consider the *Hannatoma* fauna to be Oligocene up to the time it was identified in the Carbonera Formation of the Colombia-Venezuela border area (NOTESTEIN ET AL., 1944; SUTTON, 1946).

In an attempt to clarify the anomaly R. M. Stainforth contacted several geologists and palaeontologists familiar with the faunas and associated local stratigraphy for their opinions on the age of the *Hannatoma* fauna throughout its known geographic occurrence in Peru, Ecuador, Colombia, and Venezuela. The general concensus of opinion, summarized in DURHAM ET AL. (1949), was that the fauna occurred mainly in Late Eocene strata but could represent a diachronous facies-controlled assemblage ranging locally into the Oligocene. The writer believes that, principally based on a micropalaeontological study of the La Victoria Formation of northeast Zulia, Venezuela, the *Hannatoma* fauna could be as old as uppermost Middle Eocene in age, and also finds supporting evidence in the published literature to suggest that it could also be time-correlative at this level throughout most of its recorded geographic occurrence.

Much of the supporting evidence comes from the listings of Durham and Dusenbury (in DURHAM ET AL., 1949) of mollusc species from the *Hannatoma* horizon of the Carbonera Formation which had previously been described from the San Jacinto Formation of northwestern Colombia. This latter formation is clearly Middle Eocene in age as shown by the rich planktonic foraminiferal faunas of overlying marls at the type locality in the Rio San Jacinto. Durham and Dusenbury list many species common to the two sections, inclusing the following.

Crommium palmerae Clark
Pitar (Pitarella) colombiana Clark
Neverita bolivarensis Clark
Tagelus bolivarensis Clark
Mactra sp. syn. *Mactra* sp. Clark
Transennella bolivarensis Clark
Agaronia harrisi Clark

The coral species *Turbinolia olssoni* Wells is also common to the Mancora and San Jacinto Formations.

The above list is also fortified by the Samán species *Arca (Arginia) samanensis* Olsson, *Harrisianella sp. cf. H. peruviana* Olsson, *Lagunitas (?) sp.* related to *Tescopium (?) samanense* Olsson, *Cerithium (Perucerithium) cf. negritoense* Woods (in BOSWORTH, 1922), *Melanatria aff. acanthica* Woods (in BOSWORTH, 1922), and the Claiborne species *Cerithiella sp. cf. C. heckscheri* (Palmer).

The *Hannatoma* fauna is also found in the western part of the State of Táchira, Venezuela, in the lower part of the 'Sandy Shale Formation' (Carbonera Formation) which conformably and transitionally overlies the Middle Eocene

Mirador Formation. Kehrer (in DURHAM ET AL., 1949) also lists the Samán species *Turritella* aff. *T. samanensis* Olsson and *Harrisianella* cf. *peruviana* Olsson in association with *Hannatoma emendorferi* in a fauna which Woodring considered late Middle to early Late Eocene, with "some fossils similar to Middle Eocene species".

According to Hedberg (in DURHAM ET AL., 1949), H. S. Ladd of the former Venezuelan Gulf Oil Company considered the *Hannatoma* fauna of the Carbonera Formation to be Late Eocene in a private report of 1931. This determination, at a time when Olsson considered the fauna to be Middle Oligocene, was based on correlation with similar faunas reported from the Barinas Basin associated with the Pauji shale. The Pauji was at that time considered to be Late Eocene following WOODRING's (1927) similar dating of the Masparrito Limestone at the base of that shale unit in the Barinas Basin. The latter shale interval, later renamed the Paguey Formation, is now accepted as Middle Eocene (FURRER, 1971). As the majority of species studied by Ladd had not previously been described no specific identifications were given but many of his observations clearly point to a probable Middle Eocene age for the *Hannatoma* fauna. These include such comments as:

"other species from the Santander collections are related to (but not identical with) forms described from the older Eocene rocks in other parts of South America. The *Diastoma,* for example, is of the type *D. americanum* described by Woods from the Negritos formation (Wilcox and Claibourne) of Peru and the *Turritella* is related to *T. anceps* Woods from the same formation. The occurrence of both of these species, coupled with the absence of the common *Corbicula* and *Melanatria* in locality 167-31 suggest that it may be pre-Jacksonian in age"

"The species identified as *Ostrea cf. inca* are related to the species originally described by Woods (1922) from the Negritos formation of Peru"

"The *Mya (Raetomya) sp.A* is identical with species collected from the Upper Eocene Boconó series . . . in the area north of Barinas"

" . . . the *Rimella valerensis* is identical with species from the Upper Eocene of Trujillo"

All these observations refer to correlations with stratigraphic horizons which can now be clearly dated on microfaunal evidence as Middle Eocene.

Hedberg (in DURHAM ET AL., 1949) correlates the same Carbonera horizon with the Esmeraldas Formation of Santander which GERMERAAD ET AL. (1968) have found in their *Retitricolporites guianensis* zone and the lower part of the succeeding *Verrucatosporites usmensis* zone, which can also now be calibrated with uppermost Middle Eocene time.

The type locality of the La Victoria Formation, in the District of Miranda, northeast Zulia, Venezuela, is a *Hannatoma* limestone containing an abundance of the species *Hannatoma emendorferi* Olsson. However, this limestone represents only one horizon of a dominantly clay, silt, sandstone sequence broadly defined by SUTTON (1946) as the La Victoria Formation. The transitional nature of its lower contact with the underlying Jarillal Formation has been more recently described in some detail by GUEVARA (1967) in redefining and establishing a reference section for Senn's Agua Negra Formation in northeast Zulia.

As described in the previous section on the *Raetomya* horizon, and also in HUNTER (1974), the Jarillal Formation of Guevara's reference section contains a rich planktonic foraminiferal fauna indicating an age no younger than the Middle Eocene *Truncorotaloides rohri* zone. More detailed studies of the microfaunas of this shale sequence could reveal that at least the lower part belonged to the underlying *Orbulinoides beckmanni* zone. The marker species for the latter zone is only rarely present in this part of the Maracaibo Basin and it is consequently often difficult to separate the two zones.

The upward transition of the Jarillal shale facies into the La Victoria coarser clastics clearly represents progressive shallowing of the palaeoenvironment. Consequently the more diagnostic planktonic foraminifera rapidly disappear from the microfaunal assemblages with a complementary increase in palynomorph abundance. However, there is no specific change in the microflora from the underlying Jarillal Formation which influences the writer to believe that the *Hannatoma* horizon of the La Victoria Formation could still be within the top of the Middle Eocene time interval. The palynomorph assemblage contains more species in common with the Middle Eocene than with proven Late Eocene and younger sections. The three most common diagnostic species are:

Spinozonotricolpites echinatus Muller
Echitriporites trianguliformis van Hoeken-Klinkenburg
Retibrevitricolpites triangulatus van Hoeken-Klinkenburg

These three species are commonly recorded throughout the section as throughout the Early and Middle Eocene of the Maracaibo Basin in general. The first two species are only rarely recorded from Late Eocene and younger beds while the third species has as yet to be described from well dated post-Middle Eocene sediments.

Supporting evidence comes from less common but equally diagnostic species such as:

Psilatricolpites minutus Gonzalez
Retitricolpites magnus Gonzalez
Retitricolpites minutus Gonzalez

These also have yet to be recorded from Late Eocene or younger levels.

The direct micropalaeontological study of the La Victoria Formation, supported by the above reanalyses of published biostratigraphic data, convinces the writer that the *Hannatoma* horizon is of uppermost Middle Eocene age in Venezuela and Colombia and could be roughly time-correlatable with the type locality of *Hannatoma emendorferi* in the Mirador (Mancora) Formation of northwest Peru. As

indicated by STAINFORTH (1968) the overlying Cone Hill Formation is clearly Late Eocene in age as indicated by the presence of *Hantkenina primitiva*. The sandy facies and associated brackish-water molluscan fauna of the Mirador Formation, transitional to the underlying shale of the Chira Formation, could well represent the similar litho- and biostratigraphic relationship depicted by the La Victoria and Jarillal Formations of western Venezuela.

At one stage the writer considered the possibility that the *Hannatoma* fauna represented the lateral brackish-water equivalent of the marine *Raetomya* faunas of the Jarillal Formation. However, it appears that the *Hannatoma* faunas are younger and probably related to the shallowing end phase of the Eocene depositional cycle which is not always preserved due to the erosional character of the Early Miocene transgression.

THE CANTAURE FAUNAS

The oldest Tertiary sediments of the Paraguaná Peninsula of northern Venezuela appear to be those of the Cantaure Formation. The rich mollusc faunas of this horizon were first described within a series of publications by F. HODSON (1926), F. HODSON, H.K. HODSON & G.D. HARRIS (1927), and F. & H.K. HODSON (1931) on Venezuelan Tertiary Mollusca. F. & H.K. HODSON (1931) considered the Cantaure faunas as Early Miocene in age and, in private reports, correlated this level more specifically with the Cerro Pelado Formation of Central and Western Falcón. SENN (1932) writes that "Dr. F. Hodson correlates it (the mollusc fauna from 'Cantaura') with the Cerro Pelado Formation. The writer's opinion, which is based on an examination of quite rich collections, is that the Cantaure fauna has to be placed with the Lower Socorro (Querales shales) . . . I think that the Cantaure fauna shows us how the rich cast faunas of the Querales type locality would look if they could have preserved their shells".

As the Querales shales are now considered to be the upper part of the Cerro Pelado Formation both Senn's and Hodson's determinations are not far apart.

SCHILDER (1939) supported Hodson's Early Miocene age for the Cantaure shell beds by comparing fossil Cypraeacea from the Cantaure locality with forms from the St. Croix Member of the Brasso Formation of Trinidad.

These initial Lower Miocene age determinations have never been popular with geologists familiar with the geology of the Paraguaná Peninsula, probably mainly due to the more widespread occurrence of other obviously younger Tertiary fossil mollusc faunas throughout the area. The outcrop of the Cantaure Formation is of very limited geographic extent and there has also been a tendency to include it with the more widespread younger sediments because of lithological similarities.

Support for the latter interpretation appeared to be given by INGRAM (1947) who described two new fossil Cypraeidae from the Cantaure beds which were considered indicative of a late Miocene age. Other geologists were in favour of a Middle Eocene age. These included Natera (1956 Creole private report) who regarded the age as "early Middle Miocene" on molluscan evidence, but noted a "surprising number of endemic species".

JUNG (1965) also preferred a Middle Miocene age, finding more species in common with the Gatún Formation of Panama and Costa Rica and the Cercado and Gurabo Formations of the Dominican Republic than with younger levels such as the Bowden of Jamaica, the Punta Gavilán of Venezuela, and the Springvale of Trinidad. However, he did note similarities to the Early Miocene Quiroz assemblage of the La Rosa Formation of the Maracaibo Basin, listing 12 species in common with the Cantaure level, but preferred to consider the Quiroz assemblage as younger than then generally believed.

More recently, THOMAS & MACDONALD (1970) collected two samples from what they believed to be two localities within the Cantaure Formation. One sample, from USGS locality 23888 (6.2 km WNW of San Jose de Cocodite), was sent to Jung who identified the fauna and suggested a Middle Miocene age. The other sample, from USGS locality 23889 (3.6 km WSW of Pueblo Nuevo) was sent to W.P. Woodring who indicated a Middle to Late Miocene age. Thomas and MacDonald finally chose to compare and correlate the Cantaure Formation lithologically and faunally with the Castilletes Formation of the Guajira Peninsula which was then considered to be Middle Miocene in age.

Samples collected by the writer on several visits to the type locality of the Cantaure mollusc horizon have consistently yielded a rich foraminiferal fauna referrable to the Early Miocene *Globigerinatella insueta* zone of BOLLI (1957). Additional sampling of the basal part of the overlying shale sequence has supported these conclusions by yielding rich foraminiferal faunas belonging to the succeeding *Praeorbulina glomerosa* zone.

The following planktonic species were identified in the foraminiferal faunas of the mollusc beds:
Globigerinoides diminutus Bolli
Globigerinoides quadrilobatus sacculifera (Brady)
Globigerinoides obliquus (Bolli)
Globigerinoides subquadratus Bronnimann
Globorotalia peripheroronda Blow and Banner
Globigerina venezuelana Hedberg
Globoquadrina altispira altispira (Cushman and Jarvis)
Globoquadrina dehiscens dehiscens (Chapman, Parr, & Collins)

This fauna is clearly Early Miocene (Burdigalian) in age. The absence of *Praeorbulina glomerosa* Blow s.l. and *Praeorbulina transitoria* (Blow) suggests that the mollusc level belongs principally to the *Globigerinatella insueta* zone. However, these species are found in the basal part of the overlying shale sequence.

Identical microfaunas have now been identified from the type section of the Querales Shales, thereby confirming Hodson's mollusc correlation.

A rich mollusc fauna, identical to that of the Cantaure Formation, has recently been described by THOMAS (1972) from the Jimol Formation and the basal part of the conformably overlying Castilletes Formation of the Guajira Peninsula of Colombia. Foraminiferal data also confirm that these horizons span the same Early Miocene (Burdigalian) *G. insueta* and *P. glomerosa* zones as do the Cantaure beds of the Paraguaná Peninsula.

A reinvestigation of the Cantaure mollusc faunas may also indicate more species in common with other Early Miocene faunas than previously estimated. JUNG (1965) listed 12 species in common with the Early Miocene Quiroz assemblages of the La Rosa Formation of the Maracaibo Basin. His figured chart actually shows 13 species in common and a 14th species from another La Rosa locality which bridges the total up to that listed in common with the supposed Middle Miocene Gatún Formation of Panama. Also, future studies may well prove several of the Caribbean and Central American stratigraphic units listed by Jung to be older than presently believed.

The two samples collected by Thomas and MacDonald do not both come from the Cantaure Formation. The sample from locality USGS 23888 does indeed come from this level and the Middle Miocene determination by Jung is in accordance with his 1965 publication. That from locality USGS 23889 appears to have come from the overlying limestone beds and was correctly identified as Middle or Late Miocene by Woodring.

All biostratigraphic data therefore indicate that the Cantaure Formation of the Paraguaná Peninsula represents the basal mollusc-rich facies unit of a Burdigalian transgression which can be traced throughout the western Venezuela and northern Colombia region and directly correlated with other rich mollusc levels including those of the La Rosa Formation of the Maracaibo Basin, the Jimol and Castilletes Formations of the Guajira Peninsula, and the Cerro Pelado Formation of Falcón.

EARLY PLIOCENE MOLLUSC HORIZONS

The Springvale Formation of Trinidad

Rich fossil mollusc horizons are common within the upper Tertiary section of the Northern Basin of Trinidad. These are principally encountered in the Brasso, Manzanilla, and Springvale Formations of which those of the latter formation have undergone the greatest scrutiny since the publication of the first faunal descriptions by GUPPY (1910, 1911).

The Springvale, Manzanilla, and Brasso Formations were all originally classified as Miocene in age but progressive faunal studies indicated the Springvale to be the youngest of the three stratigraphic units. MANSFIELD (1925) clearly demonstrated the Springvale fauna to be younger than the Brasso and VOKES (1938) later indicated that it could also be clearly separated as a younger unit from the Manzanilla beds. However, the Springvale Formation is still retained within the Miocene and generally considered to be Late Miocene in age, as determined by MAURY (1931), RUTSCH (1942), RENZ (1942), and JUNG (1969). This determination has also been supported by the ostracod studies of VAN DEN BOLD (1963).

Precise direct dating of the Springvale Formation is still not possible as the marginal shallow-marine, palaeoenvironment precluded the entry of the more diagnostic planktonic microfaunas. Those planktonic species so far encountered in the microfaunas serve only to indicate an age no older than Late Miocene. However, indirect support for an Early Pliocene age comes from the benthonic foraminifera of the Springvale horizon itself and macro- and microfaunal assemblages of associated facies units. Planktonic foraminifera representing the basal Pliocene *Globorotalia margaritae* zone have been reported from the lower part of the Talparo Formation of southeast Trinidad (BOLLI, 1970). This horizon is most probably the Palmiste Clay horizon of KUGLER's 1959 Geological Map of Trinidad and correlates westward with the Lot Silt Member of the Morne L'Enfer Formation which, in turn, can be traced northward into the Springvale Formation.

The benthonic forminiferal faunas of the Springvale Formation contain abundant specimens of the genera *Poroeponides* and *Sestronophora*. These two genera have as yet not been found at pre-Pliocene levels in the southern Caribbean and northern South America region.

The lower part of the overlying Talparo Formation contains a distinctive mollusc horizon characterized by the dominant presence of *Anadara (L) patricia* (Sowerby) which can be traced westward into northern Venezuela where it immediately overlies shales containing rich microfaunas belonging to the basal Pliocene *Globorotalia margaritae* zone.

The Punta Gavilán Formation of Venezuela

The Punta Gavilán Formation of the eastern part of the State of Falcón, western Venezuela, can be more directly dated as belonging to the basal Pliocene *Globorotalia margaritae* zone. RUTSCH (1934) originally determined the mollusc faunas as being Late Miocene or Early Pliocene in age. SENN (1935) preferred an Early Pliocene age. SUTER (1937) followed Senn but more recently STAINFORTH (1969) considered the Punta Gavilán Formation to be younger in age (Late Pliocene - Pleistocene) and correlatable with the Playa Grande and Cumaná Formations of eastern Venezuela.

BOLLI (1970) makes first reference to the presence of *Globorotalia margaritae* in the microfaunas of the Punta Gavilán Formation. GAMERO (1970) confirmed this

observation which correlates the Punta Gavilán Formation with the Cubagua Formation rather than with the younger Cumaná Formation of eastern Venezuela. The writer has also collected rich microfaunas belonging to the uppermost Miocene *Neogloboquadrina dutertrei* zone from the youngest levels of the Huso Clay Member of the Pozón Formation, which immediately underlies the Punta Gavilán Formation in the Punta Gavilán area.

Micropalaeontological data therefore strongly suggest direct correlation of the Punta Gavilán Formation with the Springvale Formation of Trinidad. Macrofaunal comparisons are less obvious, but this can be explained by the different palaeo-environmental conditions which existed at the two sites during Early Pliocene time. The benthonic foraminifera indicate a more open and clear-water marine environment for the Punta Gavilán faunas in contrast to more marginal marine and slightly brackish conditions at the site of the Springvale facies.

The Tubará Formation of Colombia

The rich mollusc horizons of the Tubará Formation of northwest Colombia appear to correlate both in time and palaeo-environment with those of the Springvale Formation of Trinidad. Similarly, the Tubará Formation has also generally been considered as Miocene in age since the original faunal and lithological descriptions were published by ANDERSON (1927, 1929). ROYO y GOMEZ (1942) determined a Middle to Late Miocene (Langhian-Tortonian) age based on further mollusc studies as did succeeding foraminiferal, ostracod, and palynological investigations by REDMOND (1953), VAN DEN BOLD (1966), and GERMERAAD ET AL. (1968) respectively. Only BURGL ET AL. (1955) have suggested an older Miocene (Helvetian-Tortonian) age for the Tubará Formation.

As with the Springvale microfaunas planktonic species are relatively rare in the Tubará Formation, but the presence of benthonic foraminifera such as *Buliminella elegantissima* and the genus *Poroeponides* suggests an Early Pliocene or younger age. This assumption is supported by the rich microfaunas of the underlying Perdices Formation which clearly belong to the uppermost Miocene *Neogloboquadrina dutertrei* zone. The stratigraphic relationship of the Tubará to the Perdices is therefore identical to that of the Punta Gavilán to the Pozón Formation of western Venezuela. However, direct comparison of the Tubará fossil mollusc assemblages to those of the Punta Gavilán and Springvale Formations is still handicapped by the quality of the published data so far available.

Foraminiferal studies clearly indicate that the Tubará, Punta Gavilán, and Springvale mollusc horizons are time equivalent and correlatable within the Early Pliocene *Globorotalia margaritae* zone. These new micropalaeontological studies, combined with field observations, can also link the Tubará and Punta Gavilán horizons through the Taroa Formation of the Guajira Peninsula, the Chiguaje Member of the Codore Formation of central Falcón, and the El Hato Member of the Paraguaná Formation of the Paraguaná Peninsula. Eastward the same horizon is traceable through the Cubagua Formation of the Araya Peninsula and the islands of Cubagua and Margarita.

OLSSON (1964) described a rich mollusc fauna from the Esmeraldas Formation of coastal northwest Ecuador which he considered to be of "late Neogene" age. A micropalaeontological analysis by F. Rogl of material more recently collected by Jung has also yielded an Early Pliocene *Globorotalia margaritae* zone age for this horizon (Jung, pers. comm.). This appears to be a deeper water facies than the Tubará, Punta Gavilán, and Springvale horizons as Olsson described the faunal assemblage as having been "deposited along the outer shelf in waters of 200 fathoms or more depth".

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