were adopted in KUGLER's 1938 paper, in which, in a roughly South–North section, twelve different rock units were recognized. Amongst these, Beds 1–2 correspond with the level from which MAURY (1912) described the Paleocene mollusk fauna and which afterwards was called the "Soldado Formation", and Bed 11 includes her "Boca de Serpiente Formation". All these units are discussed in extenso in the following pages, whereby the senior author (H.G.K.) is responsible for the geological part of the present paper, and the junior author (C.M.B.C.) for the determination of the Larger Foraminifera and the age correlations based on them.

For the nomenclature of these fossils, used in the present text and fossil lists and in the Distribution Chart (see Pl. II), we refer to *Part 2* of this study on Soldado Rock. For technical reasons, publication of the paleontological descriptions had to be deferred to No. 3 of this same Volume of the "Eclogae". The new species and varieties, presented here as mere "nomina nuda", will then be fully established and the necessity of creating a new generic name (*Helicosteginopsis*) for *Helicostegina soldadensis* GRIMSDALE will be clear.

A. THE SOLDADO FORMATION

Author of name: MAURY (1925*a*, p. 42)
Original reference: MAURY (1912, p. 28–30): "Eocene fossils from Soldado Rock"
Original description: idem

Bibliographic history

MAURY (1912) published the fauna of a section from Soldado Rock, studied and sampled by A. C. Veatch who recognized 8 beds, of which Beds Nos. 2 and 8 carried a molluscan fauna. MAURY (p. 28) stated: "The basal bed, No. 2, is an extremely hard, greyish to reddish limestone containing quantities of shells which have become an integral part of the rock, from which they have been brought into high relief by the erosive action of the waves that constantly beat upon them. This bed lithologically is the exact counterpart of Midway Eocene near Ripley (Mississippi), Fort Gaines (Georgia), and Clayton (Alabama). Some samples of these various localities and Soldado cannot be distinguished from one another, and this resemblance is still more striking when fragments of rock from these widely separated places contain the same fossils." MAURY described 44 species of mollusks, several of which (amongst others *Venericardia planicosta*) formed a firm base for her correlation; 22 species and 3 varieties were new, apart from a new subgenus and species: *Veatchia carolinae*. Her complete list is given on page 375 of this paper.

MAURY (1913, p. 92–96) referred to her publication on the Paleontology of Trinidad. In a stratigraphical table she correlated the Midway fauna of Soldado Rock and Pernambuco with that of the Gulf States. A similar correlation she suggested for the next younger Lignitic fauna corresponding to the Nanafalian stage of Alabama. Both are brought into connection with a hypothetical land route between South America and Africa.

VAN WINKLE (1919, p. 19–23), from material collected by A. C. Veatch, described 7 new species of shells (see p. 376).

VAUGHAN (1919, p. 578) considered Bed 2 to be of Wilcox rather than Midway age.

KUGLER (1923) gave a new stratigraphic description of the beds exposed on Soldado Rock. His lower limestone group "A", estimated to be about 40 meters thick, is essentially a hard, crystalline rock with thick-shelled mollusks, and partly rich in glauconite. The uppermost layer, full of mollusks, such as *Venericardia planicosta* was identified with Bed 2 of MAURY. KUGLER considered the Soldado Rock to form part of a structure of which the nearby Pelican Rocks present the crestal region. The Pelican Rocks, situated between $^1/_2$ and 1 mile South of Soldado Rock, consist of almost N–S directed masses of marlstone, then thought to be of Late Cretaceous age (we now know that they are

large slip-masses of Middle Eocene Navet Formation and, like Soldado Rock, are exotic elements in much younger beds).

MAURY (1925*a*, p. 43) established the term "Soldado Formation", with Bed 2 as the type of all the Basal Eocene of Northern South America and the Antilles in general. She mentions the extension of the Soldado Formation to Trinidad, and in the other direction to the islands of Margarita (off Northern Venezuela) and Toas (at the mouth of Lake Maracaibo).

MAURY (1925*b*, p. 159) referred to the commingling of Brazilian and Alabamian species in the fauna of Bed 2.

WARING (1926, p. 40) established the name "Marac Formation" for limestones of the Marac Quarry of South Trinidad. He mentioned several guide fossils of the Midway Eocene to occur in the limestone. (Although no mention is made of the Soldado Formation it is obvious that the term Marac Formation is a junior synonym of it).

HARRIS (in WARING 1926, p. 100) equated the fauna of the Marac Quarry with that of Soldado Rock.

LIDDLE (1928, p. 223, etc.) stated: "At the Southwestern end of Isla Soldado in the Gulf of Paria, gray, calcitic, hard limestones, interbedded with calcareous shales stained reddish from limonite, are filled with comminuted shell fragments as well as recognizable fossils, which place them into the Lower Eocene about Midway or Wilcox in age." Referring to MAURY (1912) he listed the fauna described by her. However, on page 225 he described the Soldado Formation as being of Late Eocene age and stated: "At the type locality on Isla Soldado the Soldado formation overlies about 100 feet of Middle and Lower Eocene limestone, which is the lowest horizon exposed and consequently there is no means of determining if the equivalent of the Misoa-Trujillo formation of Venezuela, or the Pointe-à-Pierre formation of Trinidad, which is basal Eocene in age, underlies the Middle Eocene in the Gulf of Paria near this island. Unconformably above the Soldado formation at its type locality, and separated from it by a brecciated conglomerate, are marls, coquinas, dolomitic limestones, and shales, which are distinctly Oligocene." (LIDDLE thus erroneously included in his Soldado Formation the Late Eocene sandstone–marl group "B" proposed by KUGLER in 1923.)

JEANNET (1928, p. 16) described the new species *Linthia caraibensis* from the Jacksonian of Soldado Rock. [This echinoid came from a block (K.1317) containing mollusks belonging to Bed 2 (Midwayan), as pointed out by RUTSCH (1943, p. 148). HARRIS (1926, p. 100) mentioned *Linthia alabamensis* CLARK as being fairly common in the Marac Quarry].

WOODRING (1928, p. 39) attributed a Thanetian–Ypresian age to the faunas of Soldado Rock and of the Marac Quarry.

MAURY (1929, p. 177) pointed out the fallacy of LIDDLE's application of his term "Soldado Formation", re-established Bed 2 as the type-locality, and assigned a Montian–Thanetian age to it.

SHIMER (1934, p. 909) accepted LIDDLE's designation of the term Soldado Formation.

MAURY (1935, p. 192) criticized SHIMER's mistake and stressed the priority of the term "Soldado Formation, MAURY 1925".

SCHUCHERT (1935, p. 701), in support of LIDDLE, erroneously attributed MAURY's beds 6 and 8 to the Soldado Formation.

RUTSCH (1936*a*, p. 150–188), in his study of *Venericardia planicosta* and related forms, implies that the specimens from Soldado Rock and the Marac Quarry are to be placed in *Venericardia* cf. *parinensis* OLSSON rather than *V. planicosta*. RUTSCH correlated the Soldado Formation with the Salina Formation of Peru, with the Wilcox of the Gulf Coast, and with the Landenian of the Paris Basin.

RUTSCH (1936*b*, p. 188–207) questioned *Venericardia beaumonti* as an exclusive index fossil of the Upper Cretaceous. Forms belonging to this group occur also in the Soldado Formation. He included MAURY's *Venericardia thalassoplekta* of Bed 2 in this group (p. 201), and provisionally assigned a Wilcoxian age to it.

KUGLER (1936, p. 1443) suggested that the Soldado Formation with its glauconitic shell-bed presents shallow water conditions along zones of limited uplifts, whereas elsewhere throughout

Early and Middle Eocene times open sea conditions prevailed and produced the deposition of highly foraminiferal marls.

MACKENZIE (1937, p. 263, 280), following LIDDLE's nomenclature, correlated the Soldado Formation with the Upper Eocene Rio Caus limestone of Western Venezuela.

KUGLER (1938) described from Soldado Rock 12 different beds, which he integrated in his subdivision of 1923, and as far as possible in that of A. C. Veatch (MAURY 1912). He included Beds 1–3 in the Soldado Formation, and presented lists of mollusks and echinoids from Beds 1 and 2 according to preliminary determinations by RUTSCH. Based on a private report by VAUGHAN & COLE on the Larger Foraminifera, he established the term "Pellatispirella limestone" for the calcareous upper part of Bed 3 and that of "Discocyclina limestone" for a limestone of apparently the same age that was found as an erratic block in the Upper Eocene part of the section.

SCHILDER (1939) described from Bed 2 of the Soldado Formation the following two Cypraeacea: *Archicypraea trinidadensis trinidadensis* n. sp. and *A. trinidadensis degenerata* n. subsp.

RUTSCH (1939*d*, p. 366–368) suggested an old Paleocene age for the molluscan fauna of the Soldado Formation. The gastropod *Clinuropsis diderrichi* VINCENT from Soldado Rock has as yet only been known from the limestones of Landana, Congo.

SENN (1940, p. 1574) correlated the fauna of the limestone blocks in the Joes River mudflows of Barbados with the "Pellatispira limestone" (Bed 3) of Soldado Rock.

VAUGHAN & COLE (1941) described the Larger Foraminifera from Bed 3 [*Miscellanea antillea* (HANZAWA), *Miscellanea soldadensis* VAUGHAN & COLE, *Discocyclina* (*Discocyclina*) *barkeri* VAUGHAN & COLE, *Discocyclina* (*Discocyclina*) *grimsdalei* VAUGHAN & COLE] and from the block of Discocyclina limestone [*Pseudophragmina* (*Athecocyclina*) *soldadensis* VAUGHAN & COLE]. The fauna was compared to the Nanafalia Formation of Alabama (as was the molluscan fauna of MAURY 1912), and the age was given as "Lower Eocene" (in the terminology of the U.S. Geological Survey: in European usage it would be "Paleocene").

CUSHMAN & RENZ (1942) described the Smaller Foraminifera (exclusive of the Globigerinidae s.l.) of Bed 3. The fauna was considered as Midwayan in age, but also shows a distinct relationship to the Lower Eocene (Wilcox), especially to the Salt Mountain Formation and the Ozarks, Alabama.

RUTSCH (1943) described the mollusks of the Soldado Formation collected by H. G. Kugler (see list on p. 376 of the present paper). The age was given as Paleocene. RUTSCH on p. 187 also considered a position between the Maastrichtian and Midwayan stages.

CAUDRI (1944, p. 378, 382) listed the Larger Foraminifera from Bed 3, adding *Discocyclina aguerreverei* CAUDRI, *Discocyclina* "*crassa*" (as figured by VAUGHAN & COLE), *Hexagonocyclina meandrica* CAUDRI, *Hexagonocyclina* n. sp. and *Ranikothalia tobleri* (VAUGHAN & COLE) to the list given by VAUGHAN & COLE in 1941. She correlated the fauna with that of the Paleocene of San Juan de los Morros in Central Venezuela and the Chicontepec Formation of Mexico, the Lizard Springs Formation in Southern Trinidad, and the remnant blocks in the Joes River mudflows of Barbados. She included Bed 3 in the Soldado Formation and considered the age as Midway (Paleocene).

VAUGHAN (1945, p. 1, 19, 104) gave a list of the Paleocene Discocyclinidae of Soldado Rock and stated that the Discocyclinidae of the limestone blocks in the Joes River mudflows of Barbados can be safely put down as early Lower Eocene or late Paleocene because of their similarity to those of the Soldado Formation (meaning Bed 3 and the "Discocyclina limestone"). Again, he does not take a stand in the controversy Paleocene – Lower Eocene in America.

CUSHMAN & RENZ (1946) placed the foraminiferal fauna of Bed 3 at the level above the upper zone of the Lizard Springs Formation of Trinidad, or perhaps even at the base of the Navet Formation (Ramdat Marl), but still within the Midway.

LIDDLE (1946) brought the difinition of the Soldado Formation into line with that of MAURY 1912, KUGLER 1938 and VAUGHAN & COLE 1941.

CUSHMAN & RENZ (1948, p. 2) repeated their opinion that the Soldado Formation (Bed 3) may be the equivalent of the basal part of the Navet Formation of Trinidad.

CAUDRI (1948, p. 478) gave the first complete list of the Paleocene Larger Foraminifera in Bed 3 (mainly K.2951) and in the rubble of Bed 4, which clearly originates from the Paleocene. In modernized form, this list is presented below (Paleontology, p. 383). CAUDRI correlated the assemblage with the Joes River blocks, the limestones of San Juan de los Morros in Central Venezuela and the Valle Hondo Formation ("Guasare Formation" according to SUTTON 1946) in Western Venezuela.

VAN RAADSHOVEN (1951, p. 478) placed the Paleocene foraminiferal beds on the upper reaches of the Rio Misoa and in the Rio Carache area (Western Venezuela), which are comparable with those on Soldado Rock, in the Guasare Formation.

BOLLI (1952, p. 671, 675, Tables 1 and 2) stated that the *Globigerina–Globorotalia* fauna of Bed 3 is closely related to that of the lower zone of the Lizard Springs Formation of Trinidad.

BRÖNNIMANN (1952, p. 153, 155) described five species of *Globigerina* from 11 samples from the "type locality of the Soldado Formation". Location numbers are not given but reference to the material of VAUGHAN & COLE 1941, CUSHMAN & RENZ 1942 and BOLLI 1952 (non 1950) makes it clear that the forms are from Bed 3. In agreement with BOLLI, he correlated this bed with the lower zone of the Lizard Springs Formation of Trinidad, but there are indications of a slightly younger age (still within BOLLI's *Globorotalia wilcoxi* var. *acuta* Zone). However, the fauna also shows a great resemblance to the Lower Eocene base of the Navet Formation (Ramdat marl).

KUGLER (1953, p. 39) accepted VAN RAADSHOOVEN's correlation (1951) of some Larger Foraminifera from the upper reaches of the Misoa River in Western Venezuela with those from Bed 3 on Soldado Rock, but protested against using the term "Guasare Formation" for the beds carrying that fauna (compare: CAUDRI 1948). Extending the "Guasare" that way is not permissible, since the name was restricted by LIDDLE (1946, p. 301) the the ± 100 m thick section of glauconitic coquina on the Guasare River itself, which carries a Midwayan mollusk fauna and corresponds with Beds 1 and 2 on Soldado. KUGLER further deplored his earlier inclusion of Bed 3 in the Soldado Formation and suggested adherence to MAURY's original restricted definition. Bed 3 he placed in the Lower Eocene (Wilcox), explaining the Midwayan character of its Smaller Foraminifera as the result of reworking. On page 44 he stated: "It is still hoped that a better and more normal section of the Wilcox beds of Trinidad will be found, otherwise it may be necessary to introduce a term such as 'Serpent Formation' for Bed 3, or adopt a well defined stratigraphic term from Venezuela, but certainly not 'Guasare Formation'." (Note: even if we should ever need to distinguish the limestones of Bed 3 as a separate formation, which now seems hardly the case (see p. 378), the unfortunate term "Serpent Formation" will never be re-introduced; see DE RIVERO's objection, 1956*a*; p. 413, this paper). It was further suggested that the Soldado Formation occupies a lower level of the Paleocene than the Lizard Springs – Chaudière Formations in Trinidad.

DE RIVERO (1956*b*, p. 555, etc.) gave a very clear summary of all the various conclusions on validity and age of the Soldado Formation. Contrary to KUGLER 1953, she retained Bed 3 in that formation as a mere faunizone of a different character from the rest. She did not support a Wilcox age for this bed, nor did she agree with KUGLER's assumption that the Soldado Formation is older than the Lizard Springs – Chaudière beds of Trinidad, thus denying that there would be a large stratigraphical gap between Bed 3 and the underlying Midwayan limestone. She also suggested that the term "Soldado Formation" be used only locally for the Soldado Rock itself, and not be applied to formations of the same age anywhere else.

KUGLER (1956*b*, p. 97) referred to a meeting of geologists from Trinidad at which it was agreed that the term "Soldado Formation" should be declared valid despite the fact that its known exposures in Trinidad (including Soldado Rock) are nowhere in situ but represent nothing else but large slip-masses.

COLE (1959, p. 377 and Table) created the name of "*Operculina catenula* Zone" for the widely distributed level throughout the Caribbean area which carries a fauna dominated by that species. The fauna of Bed 3 is included in this zone. The age is given as Upper Paleocene.

TAYLOR (1960) correlated MAURY's mollusks of the Soldado Formation with the Paleocene Larger Foraminifera fauna determined by BRÖNNIMANN from the Los Bagres Formation of Margarita Island off Eastern Venezuela.

SALVADOR & STAINFORTH (1968, Fig. 3) correlated the basal limestone of the Vidoño Formation with the Soldado Formation. In Monagas (Eastern Venezuela) this basal limestone rests on the San Juan Formation of Maastrichtian age.

CAUDRI (1972*b*, p. 227) confirmed the correlation of the Joes River limestone blocks of Barbados with the "Pellatispirella limestone" of Soldado Rock; for the latter, she introduced the modernized term of "Ranikothalia limestone".

Type locality and type section

The type locality of the Soldado Formation is in the Southern part of the Soldado Rock. The section is represented by a huge rootless slipmass of limestone. In 1938, KUGLER subdivided the Soldado Formation into three beds. Additional investigations have clearly indicated that one of those, Bed 3, belongs to the Upper Eocene (see p. 388, 392) and that only Beds 1 and 2 can be assigned to thisfo rmation. Erratic blocks of Paleocene age, in Bed 3 and through the rest of the Eocene section, also represent the Soldado Formation.

Bed 1

a) Stratigraphic relationship

The *bottom* of Bed 1 is unknown on account of the fact that the limestone is only a rootless remnant. The *top* is K.2946(C-5), a dense, grey hard limestone with scattered grains of glauconite and brown, angular specks. This limestone underlies K.2947, a grey, highly glauconitic marlstone with indurated streaks full of shell remains, which forms the base of Bed 2.

b) Thickness

As far as one can observe, at least 20 meters of limestone are exposed.

c) Lithology

Bed 1 consists of massive layers of pale-brown and whitish, impure, glauconitic limestone containing scattered oysters, up to 15 cm in size, and nests of comminuted shell fragments with streaks of echinoderm breccia. The upper part of the bed is more glauconitic, which shows in the form of crimson patches and yellow specks. The limestone weathers with a rugged, sharply pitted surface on which scattered, more or less silicified fossils are visible, such as oysters showing rings of silica. The samples collected from this bed are: K.1314(C-5), 10704(D-5), 10705(C-5), 10706(D-5) and P.J.1152(C-5), of which sample K.10704 is considered to be the type sample.

- K.1314, light grey, brown speckled limestone with broken shells and echinoderm remains.
- K.10704, brown speckled limestone with some glauconite grains and a matrix full of microscopically small rhomboid calcite crystals, abundant molluscan fragments, bryozoans, echinoid spines and Smaller Foraminifera, such as Globigerinidae, but no Larger Foraminifera.
- K.10705, brown speckled limestone with the same matrix as K.10704 but with more glauconite, and less well preserved shells, with ostracods and Smaller Foraminifera.
- K.10706, grey limestone, light brown speckled, glauconitic, with rhomboid calcite crystals in the matrix. Abundant mollusks, algae and rather common Smaller Foraminifera, such as *Textularia* s.l.
- P.J.1152, brown limestone consisting of angular to rounded grains of broken shells, echinoid spines and tests of Foraminifera. Among the bivalves is a 3 cm thick oyster with a prominent umbo, possibly *Ostrea thirsae* GABB.

d) Paleontology

Noted mollusks, identified by H. G. Kugler, are:

Ostrea cynthiae MAURY
Ostrea thirsae GABB
Cucullaea (*Latiarca*) *hartii* RATHBUN
Venericardia cf. *ameliae* PERON
Tubulostium sp. (a small, flat, spirally wound form of gastropod, also known from the Marac Quarry of Trinidad)

Echinoids: *Linthia* sp., *Salenia* sp.

In general, mollusk fragments and algae are predominant. Smaller Foraminifera, bryozoans and echinoid remains occur in fair amount, but no trace of Larger Foraminifera was found.

e) Age of Bed 1: Paleocene

MAURY (1912, p. 35) correlated the mollusk fauna of the overlying Bed 2 with the Midwayan faunas of Alabama and the other Gulf States, and with that of Pernambuco. The field relationship and the general similarity of Beds 1 and 2 leave no doubt that both belong to the same formation. The age of Bed 1 is therefore also considered to be Midwayan, Paleocene.

f) Paleoecology

The presence of large oysters and common algae indicates shallow water conditions during the deposition of Bed 1, within the reach of wave action.

g) Remnant blocks of Bed 1

The remnant block, K.1317(D-5), a component of the conglomerate of Bed 4 (Upper Eocene), obviously has its origin in Bed 1. It is a dense, grey limestone, a breccia of mollusks and algae with Smaller Foraminifera and echinoid remains.

Bed 2

a) Stratigraphic relationship

The *bottom* of Bed 2 is formed by 40 cm of marly limestone [K.2947(C-5)], resting on bed K.2946 of Bed 1. The *top* of Bed 2 is indicated in the field at K.2949(C-5), where the glauconitic limestone is overlain by brown sand and silt with quartz pebbles of the size of cherry stones (K. 2950), which forms the base of Bed 3.

b) Thickness

Bed 2 ist 2 meters thick.

c) Lithology

Bed 2 consists of three separate units which form bottom to top are:

1. K.2947(C-5), 40 cm of very glauconitic grey marlstone with indurated streaks, mainly composed of leached fossils forming a shell bed.

2. K.2948(C-5), 50 cm of brown silt and sandy limestone with fossil remains. K.1315(C-5) is a good example of this siltstone; it is brown to pink mottled and non-calcareous. The same rock was also observed in the Marac Quarry of Trinidad.

3. K.2949(C-5) starts with 20 cm of leached, calcareous sandstone with fossil remains. Above this follow 90 cm of sparry, brown limestone, the top of which consists of 30 cm of hard glauconitic limestone full of fossils; this is the fauna listed by MAURY in 1912.
Z.444B(probably B-4) is a brown-grey lumachelle limestone (4 thin sections with annotation on label "Soldado Rock, Cardita Schicht, oberste Bank"):

Amphistegina? (rather coarse and
big, one or two fragments only)
Smaller Foraminifera (rare)
Pelecypods and gastropods (abundant)
Bryozoans div. (very rare)
Echinoid spines (very rare)
Dasyclad algae? (very rare)

P.J.1165(B-4) supplied a number of poorly preserved pelecypods and gastropods, together with three echinoids (*Salenia* sp.). This locality is almost identical with the locality E.L.1575, where several specimens of *Salenia* sp. were found.

K.9454(B-4) collected from the vertical wall of the cliff (Bed 2), is a white to light yellow shell limestone with burrows, in which the mollusk fauna consists of nothing but large oysters, and which carries large *Lithothamnium* s.l., and other smaller algae. It is of particular interest because it contains a few Larger Foraminifera, listed on page 377.

K.2949 is the type locality of Bed 2.

d) Paleontology

On account of their weathered state, comparatively few fossils were extracted from the type bed itself at locality K.2949. Most of them were collected from loose blocks exposed to wave action. At this spot, Bed 2 carries the famous mollusk fauna which characterizes the Soldado Formation. MAURY (1912, p. 28) determined the following species:

Pelecypods:

Ostrea crenulimarginata GABB
Ostrea cynthiae n. sp.
Ostrea cf. *percrassa* and *compressirostris* SAY
Ostrea pulaskensis HARRIS
Ostrea thalassoklusta n. sp.
Cucullaea hartii RATHBUN
Glycymeris (*Axinea*) *viamediae* n. sp.
Venericardia alticostata CONRAD
Venericardia planicostata LAM.
Venericardia thalassoplekta n. sp.
Callista mcgrathiana RATHBUN
Callista mcgrathiana var. *rathbunensis* n. var.
Chione paraensis WHITE var.

Gastropods:

Caricella ogilviana n. sp.
Caricella perpinguis n. sp.
Volutilithes pariaensis n. sp.
Lyria wilcoxiana var. *aldrichiana* n. var.
Levifusus pagoda HEILPRIN
Fusus colubri n. sp.
Fusus bocaserpentis n. sp.
Fusus meunieri n. sp.
Fusus mohrioides n. sp.
Fusus sewalliana n. sp.
Fusus sirenideditus n. sp.
Clavella harrisii n. sp.
Clavella hubbardanus? HARRIS
Latirus tortilis WHITFIELD
Strepsidura? soldadensis n. sp.
Pseudoliva bocaserpentis n. sp.
Trophon progne? WHITE
Cassis togatus var. *soldadensis* n. var.
Cypraea bartlettiana n. sp.
Cypraea vaughani n. sp.
Calyptraphorus velatus var. *compressus* ALDRICH

Veatchia carolinae n. subg., n. sp.
Cerithium soldadense n. sp.
Turritella humerosa var. *elicitatoides* n. var.
Turritella mortoni CONRAD
Turritella nerinexa HARRIS
Turritella soldadensis n. sp.
Mesalia pumila var. *allentonensis* ALDRICH
Mesalia pumila var. *nettoana* WHITE
Calyptraea aperta SOL.
Amauropsis caloramans n. sp.

VAN WINKLE (1919, p. 19–23) added to these:

Astarte mauriana n. sp.
Astarte trinidadensis n. sp.
Marcia pariaensis n. sp.
Macrocallista? veatchi n. sp.
Levifusus whitei n. sp.
Pseudoliva soldadoensis n. sp.
Erato vaughani n. sp.

SCHILDER (1939, p. 15–17) determined the following gastropods: *Archicypraea trinidadensis trinidadensis* n. sp., n. subsp., *Archicypraea trinidadensis degenerata* n. subsp.

RUTSCH (1943, p.184) listed the following mollusks collected by the senior author:

Pelecypods:

Cucullaea (*Latiarca*) *hartii* (RATHBUN)
Glycymeris viamediae MAURY
Propeamussium sp. indet.
Ostrea cf. *pulaskensis* HARRIS
Ostrea kochae GARDNER?
Ostrea sp. indet.
Astarte trinidadensis VAN WINKLE
Venericardia aff. *parinensis* OLSSON
Venericardia (*Baluchicardia*) cf. *ameliae* PERRON
Macrocallista (*Costacallista*) *rathbunensis* (MAURY)
Corbula (*Caryocorbula*) sp. indet.

Gastropods:

Mesalia scotti n. sp.
(type locality: K.1315, C-5)
Mesalia aff. *nettoana* WHITE
Mesalia sp. indet. A.
Turritella (*Torquesia*) *elicitatoides* MAURY
Turritella sylviana HARTT?
Vermetidae gen. indet.
Cerithium (*Nerineopsis*?) *buarquianum* (WHITE)
Calyptraphorus velatus compressus (ALDRICH)
Veatchia carolinae MAURY
Cromium? sp. indet.
Archicypraea trinidadensis SCHILDER
Archicypraea trinidadensis degenerata SCHILDER
Priscoficus jonhstoni nov. sp.
(type locality: K.1315, C-5)
Pseudoliva soldadensis VAN WINKLE
Pseudoliva bocaserpentis MAURY
Harpa (*Eocithara*) *soldadensis* (MAURY)
Athleta (*Volutocorbis*) *pariaensis* (MAURY)
Lyria? *wilcoxiana aldrichiana* MAURY
Clinuropsis cf. *pagoda* (HEILPRIN)
Clinuropsis diderrichi VINCENT
(mentioned in 1939)

Cephalopoda: *Hercoglossa* cf. *harrisi* MILLER & THOMPSON.

Echinoids:

JEANNET (1928, p. 16) described *Linthia caraibensis* n. sp. from the Jacksonian of Soldado Rock. However, this echinoid is derived from the block K.1317A(E-5) which carries a molluscan fauna typical of Bed 2.

KUGLER (1938, p. 12) mentioned *Salenia* sp. from Bed 1. Later on, 8 specimens of *Salenia* were found in Bed 2. Dr. Porter M. Kier of the National Museum of Natural History, Washington, received from the senior author echinoids from the Soldado Rock and wrote (private letter 29 October 1971):

"Four species are represented in the collection. One of these species is a very poorly preserved fragment that can be definitely identified as belonging to the genus *Rhopostoma*. Only one species is known of this genus, *Rhopostoma cruciferum* (MORTON), from the Paleocene Vicentown Sand (Rancocas Group, exposed in New Jersey; author's note). The Trinidad fragment may belong to this species. This fragment is numbered E.L.1575".

"There are eight specimens belonging without question to the genus *Salenia*. These specimens are distinct from any other species of this genus in the New World. In particular, they are easily distinguished from the only other Paleocene species in the New World, *Salenia tumida* CLARK from the Paleocene Vincentown Sand. Probably these specimens represent a new species. They are numbered K.2948".

"There is one crushed fragment of a spatangoid. It is too poorly preserved for generic identification. It might be a *Hemiaster*, but it is distinct from the three species that are known of the genus from the Paleocene Vincentown Sand. This fragment has been numbered K.2951". (Author's note: K.2951 is in Bed 3, but the specimen may be reworked.)

"Two fragments can be referred to *Cidaris* sp. Likewise they are distinct from any of the New World species of this genus. Their number is E.L.1575".

Foraminifera, etc.:

The sample K.9454(B-4) contains the following fossils:

Ranikothalia sp., small rolled fragments of thick-walled forms
"*Discocyclina*" (*Neodiscocyclina*?) sp. indet., very small (rare)
Textulariidae
Miliolidae
Globigerinidae
Oysters, large (abundant)
Corals (few)
Algae, large and small (abundant)

e) Age of Bed 2: Paleocene

RUTSCH (1939*d*, p. 621) suggested that the Soldado Formation indicates very old Paleocene, probably Montian. The gastropod *Clinuropsis diderichi* VINCENT, of which several specimens were found in the equivalent of the Soldado Formation in the Marac Quarry of Trinidad, was previously only known from a Paleocene limestone of Landana in the Congo.

RUTSCH (1943, p. 187) was of the opinion that the Soldado Formation might represent an intermediate position between the Maastrichtian and the Midway Formation, for the Soldado Formation contains forms such as *Venericardia* (*Baluchicardia*) *ameliae* PERON, which are known from the Upper Cretaceous of North Africa.

f) Paleoecology

The coquina layer of Bed 2 is a marine shallow water deposit. The common presence of glauconite suggests quiet sedimentary conditions along a rocky coast far from the mouth of an important river. The numerous broken shells may point to the presence of larger predators feeding on mollusks.

g) Remnant blocks of Bed 2

These are partly large blocks in Beds 4–9. The most conspicuous ones are: K.1317A(E-5), limestone, very rich in fossils but with little glauconite; K.3742(B-5), limestone with oysters which are partly replaced by hematite; a limestone sample collected by C. Joos, light grey, full of crab remains (*Callianassa*?).

Dr. P. Jung and Mr. R. Panchaud collected the following samples from blocks considered to belong to Bed 2, because they carry a more or less rich fauna of mollusks, echinoids, etc: P.J.1148, 1149, 1150, 1151, 1158(=K.1317A), and 1167.

Remnant blocks of the Soldado Formation, not directly connected with Beds 1 and 2

If we call Beds 1 and 2 the "type section" of the Soldado Formation, we should not forget that the whole complex is nothing but a rootless block which represents but a small part of the entire Paleocene section as it was originally deposited.

Apart from Beds 1 and 2, where the Paleocene appears more or less in natural sequence in the limestone mass which forms the Southern part of Soldado Rock, the whole of the islet is strewn with blocks and boulders of erratic material, many of which we can directly or indirectly trace to the same formation.

In the typical Soldado Formation of Beds 1 and 2, Larger Foraminifera are extremely rare. However, there are strong reasons for believing that the foraminiferal limestones and marls, which form the clastic material of the Upper Eocene Bed 3 belong to the same sedimentary cycle as the underlying beds. At first, this Bed 3 was considered to be a sound stratigraphical unit, grading from bottom to top from a marl with calcareous lenses into banks of dense limestone and spathic limestone, but it is now considered as a marl choked with masses of slumped older material. The marl matrix (K. 2950, 2951, C-4) is full of loose Paleocene Larger and Smaller Foraminifera, but at its top the bed consists of practically undisturbed banks of foraminiferal limestone which have slumped into this younger deposit. It is this limestone (not the marl) which deserves the name of "Pellatispirella limestone" (KUGLER 1938, p. 214) or, as we call it now in agreement with more modern nomenclature: the "Ranikothalia limestone" (T.L.L.125, C-4). Its fauna, in which *Ranikothalia* is the predominant form, is typical of the Paleocene and of a lagoonal habitat.

A shift in the quantitative relation between the components of this assemblage leads to the development of a reef limestone in which *Neodiscocyclina* predominates over *Ranikothalia*. This "Neodiscocyclina grimsdalei limestone" is linked to the former type of rock by gradual transitions. It is not known from Bed 3, but only as scattered blocks elsewhere.

Apart from the rather common foraminiferal limestones there are blocks of two other, rarer, kinds of limestone, which are mainly built up by algae. In one of them, *Athecocyclina soldadensis* (VAUGHAN & COLE) is locally abundant and, accordingly, it is called here the "Athecocyclina limestone" (= the "Discocyclina limestone" of KUGLER 1938, p. 216). The other one is a dense pseudo-oolitic limestone composed exclusively of the elements of dismembered Dasyclad algae. Also an *Amphistegina – Lithothamnium* reef deposit may have to be included in the description of the formation (K.S.25, p. 379).

The stratigraphical relationship between these limestones is anybody's guess, but because paleontologically the Dasyclad algae limestone seems to be closest to Bed 2, we put this at the bottom of the list. The Ranikothalia limestone may be a little younger than the Athecocyclina reef as here and there it contains fragments of the latter. For these reasons we have listed those remnants as follows, from bottom to top: Dasyclad algae reef, Athecocyclina reef, Ranikothalia limestone (with its lateral variant, the Neodiscocyclina grimsdalei limestone), but there cannot be a great difference in age between them.

Dasyclad algae limestone

a) Description of the samples

One of the types of old limestone, represented by erratic blocks at K.10711(D-2), K.10724(D-1), J.S.1949(D-1) and J.S.1954(C-1), is a dense "porcellaneous" rock of pseudo-oolitic aspect, exclusively built up of tiny fragments of disintegrated calcareous algae (illustrated in Part 2, Paleontology, Pl. 29, Fig. 14; Pl. 30, Fig. 1, 2). J. B. Saunders of Pointe-à-Pierre calls this a "biomicrite". Provisionally, CAUDRI considers these algae as belonging to the Dasycladaceae, but more expert investigation is necessary. From the rock sections of J. S. 1954, Dr. E. Gasche of the Basel Museum determined the following forms (which do not belong to the Dasycladaceae): *Ovulites* cf. *elongata* LAMARCK (the single tubes, loc. cit., Pl. 29, Fig. 14), *Marinella* n. sp., Corallinaceae div. gen., sp., sp. indet. More material of this type of limestone, also from localities outside Soldado Rock (San Juan de los Morros, Venezuela) is needed for a specialized study.

- K.10711(D-2), whitish highly recrystallized pseudo-oolitic limestone (one of the components of the dense limestone blocks that carry the trigonometric mark on the highest top of the Rock); Dasyclad algae (rock-building); echinoid spines (rare).
- K.10724(D-1), whitish dense recrystallized porcellaneous-looking limestone (as K.10711); Dasyclad algae (rock-building); gastropods (very rare).
- J.S. 1949(D-1), dense porcellaneous limestone (with clear crystalline matrix) (as J.S.1954, but occurring as rounded pebbles in a more opaque groundmass carrying the same fossils; deposit formed under the influence of tidal currents); Dasyclad algae (rock-building); other algae (rare); gastropods (small, rare).
- J.S.1954(C-1), dense porcellaneous limestone (with clear crystalline matrix); Dasyclad algae (rock-building).
- K.3876(F-3), blocks in the conglomeratic rubble.

  a) grey, highly crystallized limestone without glauconite.

  Pelecypods (common)
  Gastropods (common)
  Dasyclad algae (abundant)

  b) grey, highly crystallized, somewhat glauconitic algae limestone, locally full of mollusk fragments.

  Smaller Foraminifera (scarce)
  Ostracods?
  Pelecypods (common)
  Gastropods (common)
  Algae, small rounded forms of Corallinaceae? (aff. *Lithothamnium*) (abundant)
  Dasyclad algae (scarce), concentrated especially in the cavities of the Gastropods

There are also indications of the presence of these algae in the sample K.S.25(G-3), an *Amphistegina–Lithothamnium* reef of a quite unique nature for Soldado Rock: a light greenish-grey, white-spotted recrystallized limestone with a fair amount of markasite but nearly free of glauconite, which contains:

Amphistegina (abundant)
Miliolidae (scarce)
Gastropods (scarce)
Echinoids (scarce)
Lithothamnium, fairly large specimens (abundant)
Dasyclad algae? (very rare)

b) Age of the Dasyclad algae limestone

Traces of doubtful Dasyclads were found also in the main mass of the Soldado Formation (sample Z.444B, Bed 2; see p. 375), and also the lithology and the fauna of K.3876 suggest that this "pseudo-oolitic" limestone has very close links with Bed 2.

The Dasyclad algae limestone corresponds further with the pseudo-oolitic limestones carrying "tubiform ooliths" described by CAUDRI (1944) from San Juan de los Morros in Central Venezuela. In that area, the peculiar algae are accompanied by a typical Paleocene fauna of Larger Foraminifera: *Neodiscocyclina aguerreverei* (CAUDRI), *Athecocyclina* cf. *cookei* (VAUGHAN), *Hexagonocyclina meandrica* CAUDRI, *Actinosiphon barbadensis* (VAUGHAN), *Ranikothalia antillea* (HANZAWA) and *Ranikothalia tobleri* (VAUGHAN & COLE). We do not hesitate to place the blocks from Soldado Rock also in the Paleocene, though locally they lack these index fossils.

Unidentified fossiliferous limestone

Apart from the Dasyclad algae limestone, the composite sample K.10711(D-2) contained also a boulder of a different kind of recrystallized organic limestone (illustrated in Part 2, Paleontology, Pl. 30, Fig. 3, 4). The unidentified tubular organisms which fill this rock are much larger than the scattered fragments of the Dasyclads and their texture seems to be different, but also they may turn out to be algae.

Provisionally, this limestone is likewise assigned to the Paleocene, as a local development of the Soldado Formation.

The Athecocyclina limestone

Author of the name: CAUDRI (1966, private letter) suggested introducing this name to replace KUGLER's term "Discocyclina limestone" which was rendered obsolete by VAUGHAN & COLE's re-determination of the predominant "*Discocyclina*" as *Pseudophragmina* (*Athecocyclina*) *soldadensis* in 1941.

Original description (as "Discocyclina limestone"): KUGLER 1938, p. 216.

a) Bibliographic history

VAUGHAN & COLE (1941, p. 62) described *Pseudophragmina* (*Athecocyclina*) *soldadensis* from K.2851. VAUGHAN (1945, p. 101) supplied some additional information on the same material.

b) Description of the samples

The limestone is found in the form of erratic blocks only, embedded in the conglomeratic part of Bed 4 (Upper Eocene). The type sample K.2851(E-4) is the largest of these blocks, the one which furnished the material for VAUGHAN & COLE's description of *Athecocyclina soldadensis*. It is a grey, silty, somewhat glauconitic reef limestone, which weathers to a nodular cavernous mass of corrugated layers and irregular pockets through which the faunal elements are unevenly dispersed. Shells, wafer-thin tests of *Athecocyclina* (illustrated in Part 2, Paleontology, Pl. 11, Fig. 2), Smaller Foraminifera (chiefly Globigerinidae s.l.), echinoid detritus and algae are concentrated in separate nests. The sample contains:

Athecocyclina soldadensis (VAUGHAN & COLE) (locally abundant)
Neodiscocyclina aguerreverei (CAUDRI) (one specimen observed)

Smaller Foraminifera (*Nodosaria* s.l., Rotaliidae,
Globigerinidae s.l., *Textularia* s.l., etc.) (locally abundant)
Pelecypods (amongst others: "*Pecten*") (locally abundant)
Gastropods (scarce)
Echinoids, detritus (locally abundant)
Corals (scarce)
Algae (locally abundant)

Another enormous block of the same aspect as K.2851, lying in Bed 4 at K.1318 (F-3), was carefully measured. It is about 10 m long and wide, and 7 m thick.

Fig. 4. K2851(E-4) Athecocyclina limestone, 2.5 m thick. Bird (Noddy tern) in centre is about 15 cm high (photo H. G. Kugler 1934).

Other blocks of this same limestone (not studied in detail) are: K.1319, K.2850 and K.2849, all in F-3 on the map. K.10720(B-2) and Cd.22 and 23(G-3) were studied for their fossil contents by CAUDRI. A small pebble of the same kind of limestone was found embedded in the *Ranikothalia*-bearing limestone at K.3740(E-4):

- K.10720(B-2), dense whitish limestone with hardly any glauconite, full of badly preserved Larger Foraminifera (block resting on top of the Boca de Serpiente glauconite K.10719).
- Cd.22(G-3), dense grey glauconitic limestone, full of very small algae, echinoid fragments and Globigerinidae.
- Cd.23(G3), dense grey limestone, as Cd.22 but without any Larger Foraminifera:

  Rotaliidae (abundant)
  Globigerinidae and *Globorotalia* (common)
  Arenaceous foraminifera (scarce)
  Pelecypods and gastropods (scarce)
  Echinoids (common)
  Algae, very small (abundant)

- K.3740(E-4), pebble of grey glauconitic limestone, lithologically as Cd.22 and 23, with Smaller Foraminifera, numerous worm tubes and abundant small algae (enclosed in a block of glauconitic sandy limestone carrying a doubtful *Ranikothalia* fauna; see under "Ranikothalia limestone", p. 383).

c) Age of the Athecocyclina limestone

Because this limestone is known in the form of erratic blocks only, we are not sure where exactly it should be placed in the Soldado section. Though special environmental conditions have favoured the development of one single species of "orbitoid", the fauna of this reefal deposit is essentially the same as that of the Ranikothalia limestone, and its age cannot be too different.

Because of its position in the field, KUGLER (1938) originally assumed that the Athecocyclina limestone would perhaps represent a slightly higher level than the Ranikothalia limestone, but it has become clear that, if anything, it might be a little older (see enclosure in *Ranikothalia*-bearing rock at K.3740).

The Athecocyclina limestone has been compared by VAUGHAN & COLE (1941) with the upper part of the Nanafalia Formation of Alabama which VAUGHAN (1945) calls Upper Midway.

The Ranikothalia limestone

Author of name: CAUDRI 1972*b*, p. 227
Original description (as Bed 1 of group "B"): KUGLER 1923, p. 256
Type sample: T.L.L.125(C-4)

a) Bibliographic history

KUGLER (1923, p. 255) described from Soldado Rock a sandstone–marl group ("B") composed of four different beds, overlying group "A" of which MAURY's Bed 2 forms the top. Bed "B-1" is a brown, silty limestone containing *Nummulites* and *Orthophragmina*, to which an Auversian age was assigned. This limestone was grouped together with a superimposed conglomerate.

LEHNER (1935, p. 696) mentioned a Nummulite limestone resting on Venericardia limestone.

KUGLER (1938, p. 214) stated that the top part of his new Bed 3 is formed by about 50 cm of dense brown silty limestone and yellowish white dense limestone. From this limestone VAUGHAN & COLE (in a private report for Trinidad Leaseholds Ltd.) mentioned the following Larger Foraminifera:

Pellatispirella antillea HANZAWA
Discocyclina sheppardi BARKER
Discocyclina grimsdalei n. sp.

Kugler suggested that this limestone be called the "Pellatispirella limestone".

VAUGHAN & COLE (1941, p. 24–26) listed from Bed 3 (the limestone T.L.L.125 and the marls K.2950 and 2951, all in C-4) the following species:

Miscellanea antillea (HANZAWA) (new determination of "*Pellatispirella*" *antillea*)
Miscellanea sp. cf. *M. antillea* (HANZAWA)
Miscellanea soldadensis VAUGHAN & COLE n. sp.
Miscellanea sp. cf. *M. soldadensis* VAUGHAN & COLE
Discocyclina (*Discocyclina*) *barkeri* VAUGHAN & COLE n. sp.
Discocyclina (*Discocyclina*) *grimsdalei* VAUGHAN & COLE n. sp.

Like SENN in 1940, the authors compared this assemblage (in combination with the Athecocyclina limestone) with the limestone blocks in the Joes River mudflows of Barbados, and correlated the fauna with that of the upper part of the Nanafalia Formation in Alabama (Lower Eocene in U.S. terminology; Paleocene according to European usage).

CAUDRI (1944, p. 378) added *Athecocyclina soldadensis*, two species of *Discocyclina* and two species of *Hexagonocyclina* to VAUGHAN & COLE's list of Bed 3. She substituted the new name of *Ranikothalia* for their *Miscellanea*.

VAUGHAN (1945, p. 1, 19, 104) correlated, on the basis of the Discocyclinidae only, Bed 3 with the blocks in the Joes River mudflows, and with the upper part of the Midway in the Gulf States (either Lower Eocene or Paleocene).

CAUDRI (1948, p. 478) repeated the 1944 list of Larger Foraminifera of Bed 3, including the limestone banks at the top.

DROOGER (1960*b*, p. 450) reported from the Basses Plaines Formation of French Guyana a microfauna containing *Ranikothalia soldadensis* and concluded; "there is a remarkable agreement with the Paleocene fauna described from Soldado Rock".

CAUDRI (1972*b*, p. 227) changed the term "Pellatispirella limestone" to "Ranikothalia limestone" in accordance with the modernized generic name of its index fossil.

b) Description of the blocks of more or less intact limestone, slumped into Bed 3

- T.L.L.125(C-4), type sample of the Ranikothalia limestone: yellowish-brown limestone with "*Nummulites*".
- K.906(C-4), brown dense muddy limestone, greyish-green in fresh condition; matrix full of tiny calcite rhombohedrons.
- K.10701(D-4), brown recrystallized limestone with scattered small fossils and algae fragments in a matrix of minute rhomboid calcite crystals.
- K.10702(D-4), as K.10701 but highly fossiliferous: a breccia of badly preserved Larger Foraminifera in a matrix of micro-crystals of calcite; algae (*Archaeolithothamnium* and others).
- Rz.252(C-4), hard yellowish-brown muddy limestone with common Larger Foraminifera and a multitude of small algae fragments.

c) Description of the isolated blocks scattered throughout Beds 4-11

- K.3694(D-2), brown pitted limestone with abundant "*Nummulites*", up to 9 mm in diameter.
- K.3739(G-3), foraminiferous breccia.
- K.3740(E-4), block of glauconitic sandy limestone (lithologic description somewhat doubtful), enclosing pebbles of grey glauconitic recrystallized algae limestone (see under "Athecocyclina limestone", p. 381)

  Ranikothalia antillea? (scarce)
  Neodiscocyclina cf. *grimsdalei*? (scarce)

- K.3876(F-3), one of several blocks of limestone (see also under "Dasyclad algae limestone", p. 379).

  Ranikothalia sp.
  Neodiscocyclina sp.

- K.10708(D-3), dense white marble-like algae and foraminifera limestone, embedded in marl K.10707 (Bed 10); small specimens of algae only.
- K.10725(B-3), brown foraminiferal limestone, in part highly recrystallized, but partly with well preserved fossils.

d) Paleontology

The hard limestones enclosed a large amount of Larger Foraminifera in an excellent state of preservation, but the fauna has become known in all its fullness only from the detached specimens which have been washed out of pockets and layers of interbedded softer material, and are now found redeposited in the marly part of Bed 3, and the matrix of the rubble of Bed 4.

In Bed 3, the fauna of the samples K.2950 and K.2951(C-4), and Rz.255(D-4), is nearly exclusively Paleocene, so as to obscure the Upper Eocene evidence of the deposit, and also in K.2951B (Bed 4, C-4) the Paleocene forms are by far in the majority.

The combined Paleocene fauna of Larger Foraminifera in these samples consists of:

Ranikothalia antillea (HANZAWA)[4])
Ranikothalia tobleri (VAUGHAN & COLE)[4])
Ranikothalia soldadensis (VAUGHAN & COLE)[4])
Athecocyclina soldadensis (VAUGHAN & COLE)
Neodiscocyclina barkeri (VAUGHAN & COLE)
Neodiscocyclina cf. *caudriae* (VAUGHAN)

[4]) Presumably all three are varieties of *Ranikothalia catenula* (CUSHMAN & JARVIS)

Neodiscocyclina grimsdalei (VAUGHAN & COLE)
Neodiscocyclina aguerreverei (CAUDRI)
Neodiscocyclina fonslacertensis (VAUGHAN)
?*Neodiscocyclina mestieri* (VAUGHAN)
Hexagonocyclina meandrica CAUDRI
Hexagonocyclina inflata (CAUDRI)
Actinosiphon barbadensis (VAUGHAN)

Amongst the Smaller Foraminifera of the marl samples K.2950 and 2951, determined by CUSHMAN & RENZ in 1942, the following also showed a distinctly Midwayan character:

Gaudryina soldadensis CUSHMAN & RENZ
Nodosaria affinis REUSS
Vaginulina plumoides PLUMMER
Vaginulina robusta PLUMMER
Guttulina sp.
Globulina gibba D'ORBIGNY
Siphogenerinoides eleganta (PLUMMER)
Gyroidina subangulata PLUMMER
Nonionella soldadensis CUSHMAN & RENZ
Eponides elevata (PLUMMER)
Pulvinulinella obtusa (BURROWS & HOLLAND)
Anomalina acuta PLUMMER

In view of the heterogeneous nature of the material, the affinities of the other species mentioned in their paper are left out of the discussion here, but several of their new forms may likewise prove to be characteristic of the Paleocene. The same may apply to the additional species determined by T. F. Grimsdale and by K. Schmid, mentioned by KUGLER in 1938 (p. 215).

Cristellaria rotulata (LAMARCK)
Vaginulina gracilis PLUMMER
Eponides lotus SCHWAGER
Valvulineria cf. *wilcoxensis* CUSHMAN & PONTON

e) Age of the Ranikothalia limestone: Paleocene

Faunistically, the Ranikothalia limestone is linked to the coquina of Bed 2 by the contents of the oyster bed at K.9454(B-4), which carries both shells and Larger Foraminifera. Though from its position in the field it seems probable that the Ranikothalia reef was originally the highest unit of the now missing part of the section above the shell bed, there cannot have been much of a difference in time between their deposition, and we are inclined to consider the two as practically contemporaneous. The development of the foraminiferal reef seems to represent the latest phase in the cycle of sedimentation within the Soldado Formation itself.

VAUGHAN & COLE (1941), and VAUGHAN (1945) give as the age of the fauna in Bed 3 (limestone and marl combined): Upper Midway (correlative with the Nanafalia Formation).

In America, a certain controversy is still going on over the question whether this level should be called early Lower Eocene or Late Paleocene, but we follow the terminology of BOLLI (1952) and BRÖNNIMANN (1952), who correlated the planktonic foraminifera of Bed 3 with those of the lower part of the Lizard Springs Formation in Trinidad, which was placed in the Paleocene. Because of its relationship to the underlying shell beds, the Ranikothalia limestone is probably Late Paleocene in age. It is the equivalent of COLE's "*Operculina catenula* Zone" (1959).

The Neodiscocyclina grimsdalei limestone

This is a reefal variant of the Ranikothalia limestone, in which large forms of *Neodiscocyclina* predominate over the Ranikothalias and often take over as rock-building elements. In most cases the species can be identified (in rock sections) as *N.*

grimsdalei (VAUGHAN & COLE), showing the typical central depression of the test and here and there the characteristic embryonic apparatus with its "floating" protoconch. But even where these features are not evident, the determination will generally be correct or not too far off: the forms are always flat and have the same type of lateral chambers as *N. grimsdalei*. The only alternative would be *N. aguerreverei* (CAUDRI).

This Neodiscocyclina grimsdalei limestone has been found in scattered blocks only, in Bed 9 and in Bed 11. It is also known as blocks in the Upper Eocene of Point Bontour in the San Fernando area of Trinidad.

a) Typical examples of this limestone

- K.9453(G-3), large blocks of dense yellowish-brown limestone full of large flat *Neodiscocyclina* and bryozoans.
- K.10724(D-1), whitish limestone (one of the blocks at this locality; the other is a Dasyclad algae limestone).

b) Transitions

The following samples form transitions to the Ranikothalia limestone:

- K.10710(D-3), whitish algae breccia full of the fragments of Larger Foraminifera, rather large algae and other fossils; matrix full of minute rhomboid calcite crystals (compare K.10701, 10702, 10710; Rz.248).
- K.10717(B-2), huge block of light brown foraminiferal limestone; matrix as K.10710.
- Rz.248(F-3), yellowish-brown highly recrystallized algae and foraminifera limestone; matrix as K.10710.

c) Age of the Neodiscocyclina grimsdalei limestone: Paleocene

The age of the Neodiscocyclina grimsdalei limestone is the same as that of the Ranikothalia limestone. They are local variations of the same kind of reef system.

Reworking of the Paleocene fauna into the younger sediments

As can be expected, not only entire blocks and boulders of hard Paleocene limestone lie scattered throughout the younger beds of the Soldado section, but also a great many detached specimens which have their origin in the softer more marly components of the Soldado Formation.

The heaviest reworking was observed in the transgressive beds of Early Late Eocene age: the marls of Bed 3 (K.2950 and 2951; Rz.255), and the rubble and the indurated limestone lenses of Bed 4 (K.2951B; K.S.23 and 24), where the predominance of Paleocene forms over the autochthonous markers is so overwhelming that it masks the genuine age of the deposits (see p. 390–391 and 394–395). For further details of this phenomenon of reworking we refer to the "Distribution Chart".

Occurrence of equivalents of the Soldado Formation

Shell limestones and foraminiferal reefs with a Paleocene fauna comparable with the Soldado Formation have been found in several places in the Caribbean area and along the West Coast of South America.

Trinidad

Also in nearby Trinidad no continuous section of the transition from Cretaceous to Paleocene in the shallow water facies is exposed, but blocks of shell limestones of that age occur in the Southern half of the island. The Maastrichtian (in general the Guayaguayare Formation) is represented as a shallow water deposit by the Bontour Formation of HARRIS (1926, p. 97). It is, however, a "remnant formation" in the sense of SUTER (1951, p. 192) and is known only as large blocks of mainly grey calcareous quartzose sandstone, partly fine conglomeratic, with such fossils as *Roudairia*, *Psilomya*, *Ostrea tripolitana* KRUMBECK, etc. This aspect points to inner shelf conditions and it is, therefore, not surprising to find also the next younger deposit, the Soldado Formation, developed in a similar facies: as an impure glauconitic coquina of large shells. The environment may have been a little different, but the formation was likewise deposited in shallow water on the inner shelf. Since none of these Maastrichtian or Paleocene shell beds has been observed anywhere in Southern Trinidad in normal sequence, the conclusion is that the blocks have been transported from the North, either from the Central Range, or even from farther away.

The blocks of Paleocene coquina occur in the Late Eocene Plaisance conglomerate along the South foot of the Central Range from Pointe-à-Pierre in the West to near the Nariva Swamp in the East. In the Southern Range it is the Marac Quarry which has furnished the richest collection of Midwayan shells.

Apart from the typical Soldado coquina, also traces of the other units of the Soldado Formation are found in Trinidad. The best example of these are the blocks of Ranikothalia – Neodiscocyclina grimsdalei limestone embedded in the Upper Eocene at Point Bontour near San Fernando, the fauna of which consists of *Ranikothalia antillea*, *Neodiscocyclina grimsdalei*, *N. aguerreverei*, *N. fonslacertensis*, *N. barkeri*, *Athecocyclina soldadensis*, *Hexagonocyclina meandrica*, *H. inflata* and *Actinosiphon barbadensis* (CAUDRI 1944, 1948). Loose specimens of these forms are scattered throughout the Middle Eocene Navet and the Upper Eocene San Fernando Formations at several localities.

On account of the Larger Foraminifera fauna, the Lizard Springs marl at its type locality Mky 102b III is considered to be the direct age equivalent of the Ranikothalia limestone of Soldado.

Other Caribbean islands, Venezuela and elsewhere

During the excursion to Barbados, organized by the Fourth Caribbean Geological Conference in April 1965, a large block of fossiliferous limestone, reminiscent of the typical Soldado Formation, was found in the Chalky Mount Formation of Middle Eocene age.

MAURY (1925, p. 412) reported from Margarita Island "beds with *Venericardia planicosta*" belonging to the Midwayan Paleocene. These beds have, however, never since been located on the island, and it is probable that they were represented by blocks only.

SALVADOR & STAINFORTH (1968, p. 33) mentioned from the State of Monagas, Eastern Venezuela, the occurrence of a shell limestone at the base of the Paleocene part of the Vidoño Formation, overlying the Maastrichtian San Juan Formation. According to the faunal contents of this limestone, correlation with the Soldado Formation is suggested. Previously, LIDDLE (1928, p. 182) and SENN

(1940, p. 158) had already reported a similar limestone, full of shells of the *Venericardia planicosta* group, from an outcrop in the State of Anzoategui (Cerro Corazon, north of Urica). According to HEDBERG (1937, p. 1996), this limestone is believed to belong to the Caratas Member of the Santa Anita Formation.

The Stratigraphical Lexicon of Venezuela (1956, p. 155 and 233) refers to Paleocene mollusks in the Caratas Formation of Anzoategui and the Guarico Formation in the area of San Juan de los Morros.

MUÑOZ (1966, p. 139) observed a coquina carrying *Venericardia* cf. *planicosta* in the lowest part of the Humocaro Formation of the Andes in the State of Lara.

BUTTERLIN (1956, p. 188) discussed a questionable occurrence of Paleocene with *Venericardia parinensis* on Curaçao.

LIDDLE (1928, p. 184, and 1946, p. 301) equated the Soldado Formation with the Rio Guasare Formation in Trujillo. In the Rio Cachiri section (1946, p. 304) he found the Rio Guasare Formation to include at its base 350 feet of solid limestone. This limestone is also present in small outcrops on Toas Island at the mouth of Lake Maracaibo. Several mollusks are listed from this formation (1946, p. 301), amongst others *Venericardia planicosta* and *Turritella mortoni*, which, according to WEINGEIST (Stratigraphical Lexicon of Venezuela 1956, p. 377), should be identified as *Venericardia* (*Venericor*) *toaensis* DUSENBURY and *Turritella mediavia* BOWLES, respectively. RUTSCH (1936*a*, p. 172) reported other localities in Venezuela where forms of the "*planicosta* group" have been observed. Also mentioned are localities in Barbados, St. Bartholomew, Panama, Colombia, Peru and Chile.

The above refers only to the shell limestones, the direct equivalent of Bed 2 on Soldado Rock. If we do not restrict ourselves to those, but include also the foraminiferal reefs that on Soldado are represented by the Ranikothalia limestone and its variations, the Athecocyclina limestone and the reefs of Dasyclad algae, we can extend the correlation even more.

COLE's "*Operculina catenula* fauna" (1959) (to us: the *Ranikothalia* assemblage) is found in many places in the Caribbean area and around the Gulf of Mexico.

First to be mentioned are the remnant blocks in the Joes River mudflows of Barbados (SENN 1940; VAUGHAN 1945; DE CIZANCOURT 1948; CAUDRI 1948, p. 476, and 1972*b*, p. 226).

Then, there are several records from Venezuela: the reef limestones of San Juan de los Morros in Guarico, where the foraminifera are accompanied by Dasyclad algae such as are known from the blocks at K.3876, K.10711, K.10724 and J.S. 1949 and 1954 on Soldado Rock (CAUDRI 1944), the base of the middle part of the Humocaro Formation in Lara, above the Venericardia limestone (CAUDRI 1961, p. 256; MUÑOZ 1966, p. 139–140), the foraminiferal beds included in the "Guasare Formation" by SUTTON, in Trujillo (CAUDRI 1948, p. 479) and the many limestones described by DE CIZANCOURT in 1951 as belonging to her "zone des nummulites cordelées" in Western and Central Venezuela.

The fauna is also known from Jamaica (ROBINSON 1968, p. 190), Haiti (COLE 1959, p. 378), Cuba (PALMER 1934; CAUDRI 1948, p. 475, footnote 7; BRÖNNIMANN & RIGASSI 1963), Mexico (Chicontepec Formation, CAUDRI 1948, p. 377) and Georgia (COLE & HERRICK 1953).

In a reworked condition, many Paleocene forms also occur in the Middle Eocene Upper Scotland Formation of Barbados (DE CIZANCOURT 1948; CAUDRI 1972*b*).