The San Fernando formation

Objekttyp: **Chapter**

Zeitschrift: **Eclogae Geologicae Helvetiae**

Band (Jahr): **68 (1975)**

Heft 2

PDF erstellt am: **13.09.2024**

B. THE SAN FERNANDO FORMATION

The Upper Eocene part of the Soldado section is correlated with the San Fernando Formation of Trinidad. It comprises Beds 3 through 10 of KUGLER's 1938 section, as well as the blackish Asterocyclina marl (9a), which originally was included in Bed 9, but which we now consider as a separate unit. Bed 11 does not belong to the San Fernando Formation: it is a slump mass of older material which has become embedded in the Upper Eocene.

In 1938, KUGLER included Bed 3 in the Soldado Formation, because in the field no definite break was visible between this marly deposit and the Paleocene coquina (Bed 2), and also because the preliminary determination of the Larger Foraminifera by T. W. Vaughan and W. S. Cole seemed to indicate this age. Continued work on both Larger and Smaller Foraminifera by C. M. B. Caudri and by J. B. Saunders has since brought to light that there are also minor amounts of Late Eocene Foraminifera in the marls and calcareous silts, which proves that Bed 3 belongs to the San Fernando Formation, and not to the Paleocene.

Bed 3

a) Bibliographic history

Apart from the literature already mentioned on p. 269–373 and 382–383, the following publications refer more specifically to Bed 3:

KUGLER (1938, p. 214, 220) described Bed 3 as a series of marls and calcareous silts including calcareous lenses, and towards the top even whole banks of limestone. After the predominant fossil in it, determined by VAUGHAN & COLE as "*Pellatispirella antillea*", this limestone was given the name of "Pellatispirella limestone" (now modernized to Ranikothalia limestone, see above). A few Larger and Smaller Foraminifera were listed.

VAUGHAN & COLE (1941) studied some of the Larger Foraminifera from the type section of Bed 3 (K.2950, K.2951, T.L.L.125, all in grid C-4 of the map). They described *Miscellanea* ("*Pellatispirella*") *antillea* (HANZAWA), *M.* cf. *antillea*, *M. soldadensis* n. sp., *M.* cf. *soldadensis*, *Discocyclina grimsdalei* n. sp. and *D. barkeri* n. sp. and, from a block of "Discocyclina limestone" (K.2851, E-4): *Pseudophragmina* (*Athecocyclina*) *soldadensis* n. sp. The age of these fossils was given as Lower Eocene (see discussion of the Paleocene/Lower Eocene controversy on p. 371 and 384 of this paper).

RENZ (1942, p. 533) listed 18 Smaller Foraminifera from Bed 3 and suggested a ?Maastrichtian to Lower Paleocene age for the assemblage.

CUSHMAN & RENZ (1942, p. 1814) described 36 Smaller Foraminifera, nearly all benthonic, from sample K.2950. The fauna was determined as Midwayan (Paleocene), but also showed affinities to the Wilcox (Lower Eocene).

CAUDRI (1944, p. 378) gave a more complete and modernized list of the Larger Foraminifera of Bed 3 (including in it the Athecocyclina limestone K.2851, and a "tubiform oolith", which do not belong to it but are older erratic blocks). She erroneously included Bed 3 in the Soldado Formation, the type deposit of the Paleocene in the Caribbean region, but the age determination of the reworked assemblage as Paleocene is correct.

CUSHMAN & RENZ (1946, p. 2) placed the Soldado Formation (meaning Bed 3!) above the upper part of the Lizard Springs Formation of Trinidad as possibly equivalent to the Lower Eocene base of the Navet Formation.

LIDDLE (1946, p. 310) referred to KUGLER's 1938 paper and concluded: "Conglomerate and rubble from various sources, with silt, sand, shale and marl comprises the base of the Upper (Jacksonian) Eocene which rests on the Soldado Formation. At least 2000 feet of Middle Eocene which are found in Venezuela and Trinidad are not present on Isla Soldado. Of the possibilities non-deposition, removal by erosion, or concealment by folding and faulting, erosion is the most satisfactory explanation." In this context is it not quite clear whether he considered the broken banks of "Pellatispirella limestone" of Bed 3 as belonging to the Paleocene Soldado Formation, or to the rubble of the Jacksonian transgression.

CUSHMAN & RENZ (1948, p. 1, 2) again mentioned the correlation of the Soldado Formation (Bed 3!) with the base of the Navet Formation (Ramdat marl) of Trinidad.

CAUDRI (1948, p. 478) gave a still more extensive list of the Paleocene Larger Foraminifera of Bed 3, including the forms redeposited in the rubble of Bed 4. The unnamed new *Hexagonocyclina* was determined as *Bontourina inflata* n. sp., *Discocyclina "crassa"* was changed to *D. fonslacertensis* VAUGHAN, and *"Lepidorbitoides* cf. *planasi"* and *Discocyclina caudriae* VAUGHAN were added to the 1944 list. She repeated the error of including Bed 3 in the type deposit of the Caribbean Paleocene.

GRIMSDALE (1951, p. 471) stated that the planktonic form determined as *Globorotalia wilcoxensis* var. *acuta* TOULMIN by CUSHMAN & RENZ (1942) is so close to *Globorotalia velascoensis* (CUSHMAN) from Mexico that he was inclined to unite these two forms entirely. He remarked that "*Globorotalia velascoensis* is not found in the oldest layers of the Velasco Formation in eastern Mexico. Nor does it reach down as far as the base of the Tertiary column in Syria. On the other hand, specimens very close to the typical form are recorded (as *G. wilcoxensis* var. *acuta*) from the Salt Mountain limestone (supposedly of Wilcox age) in Alabama and from the top of the Soldado Formation on Soldado Rock (correlated with the Midway). It is worthy of note that GLAESSNER records his *Globorotalia aragonensis* var. *caucasica* from Lower Eocene and not from Paleocene, and this is a typical *G. velascoensis*." Further, the variety *G. wilcoxensis* var. *acuta* "has not been separated from *G. velascoensis* in the range chart. Its range in the Western Hemisphere is early Lower Eocene; in the Middle East it is very rare, but provides occasional examples in the Lower Eocene, associated with *G. aragonensis* and *G.* aff. *globigeriniformis*."

BRÖNNIMANN (1952, p. 155) placed the planktonic fauna of sample K.2950 in the *Globorotalia wilcoxensis* var. *acuta* Zone.

BOLLI (1952, p. 671, 674, 675, Tables 1 and 2) reported from sample K.2950: *Globorotalia wilcoxensis* var. *acuta* and *G. grassata* var. *aequa*. He concluded: "The Soldado Formation considered by CUSHMAN & RENZ (1942, 1946) to be the top of the Lizard Springs Formation, is in fact an age equivalent of the lower zone of the Lizard Springs Formation."

KUGLER (1953, p. 39, 42–44) discussed the Paleocene and Eocene of Soldado Rock in connection with similar units in Trinidad, Venezuela and Barbados. He separated Bed 3 with its (possibly reworked) foraminiferal fauna of Wilcox age from the Soldado Formation (Beds 1–2) and tentatively proposed the term "Serpent Formation" for it. The whole mass of Beds 1 to 3 was described as a rootless block slipped into Upper Eocene silts comparable to various slipmasses in Southern Trinidad, for instance, the Paleocene Marac limestone.

BOLLI (1957*a*, p. 65) stated: "The *Globorotalia* species from the type sample (K.2950) of Bed 3 from Soldado Rock off Trinidad (KUGLER 1938; CUSHMAN & RENZ 1942) have been reinvestigated and determined as follows:

G. velascoensis (CUSHMAN) (determined as
G. wilcoxensis var. *acuta* TOULMIN by CUSHMAN
& RENZ 1942, and by BOLLI 1950, 1952*b*)
G. aequa CUSHMAN & RENZ
G. whitei WEISS
G. elongata GLAESSNER

These species correspond with those characterizing the *Globorotalia velascoensis* Zone, which is the highest zone of the lower Lizard Springs Formation. CUSHMAN & RENZ compare the 'Bed 3' foraminifera with Midwayan faunas from Alabama, but also point to a relationship with the Salt Mountains and the Wilcox of Ozark, Alabama. A stratigraphic position of 'Bed 3' of Soldado comparable with that of the uppermost lower Lizard Springs agrees also with the views of BRÖNNIMANN (1952)."

VAN DEN BOLD (1957, Table 1) listed 25 ostracods from K.2950 and K.2951. He stated: "The Ostracoda from KUGLER's Bed 3 on Soldado Rock, from Marac Quarry, and from the core samples from wells FC-98 and Rochard-1 show affinity to the Midway fauna of the United States Gulf Coast and to the Guasare limestone of Western Venezuela."

BOLLI (1966, p. 9) suggested a possible correlation of the planktonic foraminifera of Bed 3 with the *Globorotalia pseudobulloides* and the *Globigerina eugubina* Zones.

b) Type section of Bed 3

On the South side of the Southern top, from K.2950 to K.2951(C-4) and beyond.

c) Stratigraphic relationship

Bottom: there is no conspicuous break between Bed 2 and Bed 3, but the contact between the coquina and the marl is considered to be the bottom of Bed 3.

Top: the top is formed by the banks of Ranikothalia limestone which are covered by the rubble of Bed 4.

d) Thickness

2.2 meters.

e) Lithology

For the lithology of Bed 3 we have to rely on KUGLER's description of 1938. When visiting Soldado Rock in 1951, KUGLER found that target shooting of the Royal Air Force during the Second World War had blown away the entire section.

According to the original observation, Bed 3 consisted of two layers of silty marl, described as follows from bottom to top:

- K.2950(C-4) represents the lower bed of 70 cm thickness. It is a light yellowish-brown highly fossiliferous marl and calcareous silt with fine sand, in part finely bedded, containing scattered quartz pebbles the size of cherry stones and pieces of decalcified Soldado Formation. Indurated streaks with quartz grains were noticed to the West of the trench cut from K.2950 to K.2951.
- K.2951(C-4), 1.5 m thick, is essentially an irregular rubbly layer of flat-lying lenticular masses of Ranikothalia limestone embedded in light yellowish-brown fossiliferous marl and partly calcareous silt and sand with grains of bluish quartz. Towards the top, the limestone lenses grade into whole banks of solid limestone, which are partly brecciated on account of weathering. The horizontal banks of Ranikothalia limestone formed the flat top of the southern peak of Soldado Rock.
- Rz.255(D-4) was taken from the same marl as the previous numbers. The Ranikothalia limestone is represented by the samples: T.L.L.125(C-4), K.906(C-4), K.10701(D-4), K.10702(D-4) and Rz.252(C-4). Samples Rz.254(D-4) and Rz.256(C-4) are taken from grey barren silts.

f) Paleontology

The microfauna of Bed 3 (K.2950, K.2951 and the hard Ranikothalia limestone) was divided into four groups, each studied separately by different specialists: the Larger Foraminifera by GRIMSDALE, by VAUGHAN & COLE, and by CAUDRI, the mainly benthonic Smaller Foraminifera by CUSHMAN & RENZ, the planktonic foraminifera by BOLLI and by SAUNDERS, and the ostracods by VAN DEN BOLD.

1. The list of Larger Foraminifera runs as follows:

Ranikothalia antillea (HANZAWA)
Ranikothalia tobleri (VAUGHAN & COLE)
Ranikothalia soldadensis (VAUGHAN & COLE)
Neodiscocyclina grimsdalei (VAUGHAN & COLE)
Neodiscocyclina aguerreverei (CAUDRI)
Neodiscocyclina barkeri (VAUGHAN & COLE)

Athecocyclina soldadensis (VAUGHAN & COLE)
Hexagonocyclina inflata (CAUDRI)
Hexagonocyclina meandrica CAUDRI
Operculinoides soldadensis VAUGHAN & COLE (one specimen in K.2950)
Lepidocyclina pustulosa (H. DOUVILLÉ) forma *trinitatis* H. DOUVILLÉ (one specimen in K.2951)
Amphistegina cf. *undecima* CAUDRI n. sp. (one specimen in K.2950)

2. CUSHMAN & RENZ (1942) listed the following Smaller Foraminifera:

Ammomargulina sp.
Gaudryina soldadoensis CUSHMAN & RENZ
Quinqueloculina sp.
Robulus cf. *rosetta* (GÜMBEL)
Robulus sp.
Marginulina cf. *scitula* (BERTHELIN)
Nodosaria affinis REUSS
Vaginulina plumoides PLUMMER
Vaginulina robusta PLUMMER
Guttulina sp.
Globulina gibba D'ORBIGNY
Pseudopolymorphina sp.
Sigmomorphina soldadoensis CUSHMAN & RENZ
Nonionella soldadoensis CUSHMAN & RENZ
Gümbelina trinitatensis CUSHMAN & RENZ
Siphogenerinoides eleganta (PLUMMER)
Bulimina kugleri CUSHMAN & RENZ
Augulogerina cf. *parvula* (CUSHMAN & THOMAS)
Trifarina herberti CUSHMAN & RENZ
Ellipsonodosaria sp.
Spirillina sp.
Discorbis midwayensis CUSHMAN var. *soldadoensis* CUSHMAN & RENZ
Discorbis midwayensis CUSHMAN var. *trinitatensis* CUSHMAN & RENZ
Gyroidina subangulata PLUMMER
Eponides elevata PLUMMER
Cancris mauryae CUSHMAN & RENZ
Pulvinulinella obtusa (BURROWS & HOLLAND)
Globorotalia crassata (CUSHMAN) var. *aequa* CUSHMAN & RENZ
Globorotalia wilcoxensis CUSHMAN & PONTON var. *acuta* TOULMIN
Anomalina acuta PLUMMER
Anomalina basilobata CUSHMAN & RENZ
Anomalina sp.
Cibicides praecursorius (SCHWAGER)
Cibicides howelli TOULMIN
Cibicides cf. *semiplectus* (SCHWAGER)
Cibicides cf. *williamsoni* GARRETT

In 1972 (private communication), J. B. Saunders spotted in sample K.2950: *Bulimina jacksonensis* CUSHMAN.

3. The planktonic foraminifera of K.2950 were re-determined by BOLLI (1957*a*) as follows:

Globorotalia velascoensis (CUSHMAN)
Globorotalia aequa CUSHMAN & RENZ
Globorotalia whitei WEISS
Globorotalia elongata GLAESSNER

SAUNDERS stated in 1972 (private letter) that the planktonic fauna of K.2950 consists mainly of Middle to Lower Eocene forms of *Globorotalia* and *Truncorotaloides*, but he also found: *Globorotalia centralis* CUSHMAN & BERMUDEZ (some specimens trending towards *Globigerina ampliapertura* BOLLI).

4. Ostracods are not numerous in K.2950 and K. 2951, but represented by many different species. VAN DEN BOLD (1957) listed:

Platella kellettae MUNSEY
Cytherella sp. sp.
Cytherelloides sp.
Propontocypris sp.
Paracypris communis VAN DEN BOLD
Bairdia dolicha VAN DEN BOLD
Bairdia soldadensis VAN DEN BOLD
Bairdia aff. *hondurasensis* VAN DEN BOLD
Bairdia sp.
Eucythere sp.
Cytheromorpha sp.
Munseyella kyalokystis (MUNSEY)
Buntonia alabamensis (HOWE & PYEATT)
Puriana sp.
Trachyleberis ? *spinisissima* (JONES & SHERBORN)
Pterygocythereis sp.
Hermanites ? *collei* (GOOCH)
Hermanites ? *grimsdalei* VAN DEN BOLD
Brachycythere kugleri soldadensis VAN DEN BOLD
Brachycythere kugleri var.
Cytheretta arrugia VAN DEN BOLD
Eucytherura decorata WEINGEIST
Loxoconcha nuda ALEXANDER
Xestoleberis mauryae VAN DEN BOLD

The above microfauna of Bed 3 is supplemented by small amounts of bryozoans, brachiopods, echinoids and algae. Part of those are doubtlessly also reworked. Mollusks are absent in the marl.

g) *Age of Bed 3: Late Eocene*

In 1938 KUGLER included Bed 3 in the Soldado Formation, mainly because there is no visible break between this marly deposit and the Paleocene coquina of Bed 2. The determination of the rich microfauna at first confirmed this age. The larger Foraminifera determined by VAUGHAN & COLE (1938, in KUGLER; 1941) were comparable to the fauna of the Paleocene Lizard Springs Formation of Trinidad, and also the Smaller Foraminifera seemed to indicate the same age (CUSHMAN & RENZ 1942). These latter authors compared their faunal lists with the Lower Lizard Springs Formation and with the Midway Group of Alabama and Texas, and came to the conclusion that Bed 3 must be of Midway age, although they also drew attention to a certain relationship with the Wilcox of the Salt Mountain Formation and the Ozarks in Alabama and, through this, to the Middle Eocene of North Africa. BOLLI (1957*a*) determined the level of K.2950, on account of the planktonic species, as the *Globorotalia velascoensis* Zone, the top zone of the Lower Lizard Springs Formation.

Subsequent studies of the fauna by CAUDRI (Larger Foraminifera, present paper, Part 2), and SAUNDERS (Smaller Foraminifera, 1972, private correspondence) have, however, unmistakably proved the presence of Late Eocene foraminifera in the marls and calcareous silts of this bed. The overwhelming amount of forms, suggestive of the Lower Lizard Springs Formation, against the negligible traces of Late Eocene Larger Foraminifera have lead both KUGLER and CAUDRI to believe for years that the occurrence of the latter was unreliable and caused by contamination, either in the field through dry season cracks, or in the laboratory, where so much rich Late Eocene material was being processed at the same time. But after SAUNDER'S observation on the planktonic forms, this assumption can now be ruled out. An important stratigraphical break between Bed 3 and the Paleocene coquina is, to a certain extent, supported by the presence of the small quartz pebbles in Bed 3, near the contact, and by the conspicuous absence of all shell material.

Both the Larger and Smaller post-Paleocene Foraminifera indicate a Late Eocene age (*Operculina soldadensis*, *Lepidocyclina pustulosa* forma *trinitatis*, *Bulimina jacksonensis*, *Globorotalia centralis*), but at the same time, side by side with the flood of Paleocene detritus, the influence is noticed of reworking from the Middle Eocene (*Amphistegina* cf. *undecima*, Middle Eocene species of *Globorotalia* and *Truncorotaloides*). SAUNDERS' impression is that there was heavy reworking of Navet Formation (Middle Eocene of Trinidad) into shallow water Late Eocene sediments. These Middle Eocene specimens must have been washed in from somewhere else (compare Bed 11!) but the horizontal lenses and banks of Ranikothalia limestone, together with all the loose material of Paleocene foraminifera, have slumped into the Late Eocene marl on the spot, practically without any lateral transportation. The stratigraphic relationship between the Paleocene and Bed 3 is further discussed below (p. 428).

Bed 4

a) Bibliographic history

JEANNET (1928) mentioned K.1321 as one of the localitites of newly described echinoids.

KUGLER (1938, p. 215, 220) gave a detailed description of this conglomeratic rubble bed and correlated it, on the basis of its stratigraphical position, directly with the conglomerate at Mount Moriah (Trinidad), which there rests on the Middle Eocene, and forms the base of the San Fernando Formation in its type area.

b) Type section

At K.2951B(D-4).

c) Stratigraphic relationship

Bottom: Bed 4 distinguishes itself from Bed 3 by its more rubbly and conglomeratic aspect. Although at the type locality the rubble likewise consists mainly of detritus from the Ranikothalia limestone, the conglomerate itself grades laterally into a mixed assortment of blocks of different origin, irregularly laid down and not in horizontal layers like the limestone lenses and banks in Bed 3.

Top: marked off by the contact with the sands of Bed 5.

d) Thickness

Variable and difficult to ascertain because of lateral silt interdigitations. At the type locality only 1.5 meter of section is exposed, but the block conglomerate further to the NNE is more than 10 meters thick.

e) Lithology

At the type locality (K.2951B) the matrix of Bed 4 is a yellowish-brown, finely sandy, slightly glauconitic marl full of fragments of yellow and brown Ranikothalia limestone, and with a very rich fauna of Larger Foraminifera. Towards the West, this rubble changes into a weathered breccia and thin conglomerate, in which there are occasional pebbles of mudstone with *Pholas* holes, and which is almost completely covered by low vegetation and guano (Rz.253, D-4). At K.1321(B-3) the marl is indurated to a limestone lens with the same mixed fauna as in the type sample. The typical marl bed of K.2951B(D-4) can also be traced to the East and NE, but there it becomes more silty and its nature changes from a rubble bed to a block conglomerate of considerable thickness, which stretches right down to the East point of the islet. Common interdigitations of sand, glauconitic sand, silt and clay represent the matrix, which in general is less fossiliferous here than at the type locality. An exception forms the indurated lens of grey glauconitic, somewhat markasitic limestone Rz.247(F-3) which carries a very rich nearly pure Late Eocene fauna. Such limestone lenses occur also at K.3739, K.S.23 and K.S.24 (all in G-3), but their fauna is predominantly composed of reworked Paleocene forms. To a great extent, this local induration of the marl may be ascribed to the abundance of "spathic" calcite particles, reworked clastic material from the Paleocene (K.3739). Locally, Bed 4 carries mollusks, e.g. at K.3877 (G-3), a dark grey, non-calcareous siltstone of the same lithological aspect as the Mount Moriah siltstone of Trinidad (San Fernando area).

The erratic components range from small pebbles to blocks weighing several tons and reaching dimensions of $10 \times 10 \times 7$ meters. The deposition of the bigger blocks is chaotic, but the partly rounded smaller boulders and pebbles are sometimes arranged in definite beds separated by sandstone layers 20 to 40 centimeters thick. The average dip of these beds is 60° NNW. The blocks and boulders are derived from various deposits, mainly (or exclusively) from the Soldado Formation (Beds 1 and 2): coquinas, pseudo-oolitic Dasyclad algae limestone, Athecocyclina limestone, Ranikothalia limestone, Neodiscocyclina grimsdalei limestone, etc. Special attention is called to the conspicuous and lithologically peculiar remnants of the Athecocyclina reef: K.2851(E-4), K.1318(F-3), K.2850(F-3), K.1319(F-3), Cd.22(G-3) and Cd.23(G-3), which are arranged in a roughly continuous SW–NE line and seem to have come from the same bed. None of the blocks found here is representative of the Lower Middle Eocene (see Beds 10 and 11).

These erractics can be grouped as follows:

Beds 1-2 (chiefly Bed 2, coquina):
K.1317(D-5), K.1317A(F-4), K.1318(F-3, in part), K.1319(F-3), K.2653(E-4), K.2849(F-3), K.3736(F-3), K.3742(B-5) and K.3875(G-3).

Dasyclad algae limestone:
K.3876(F-3, part of the blocks), ?K.S.25(G-3).

Athecocyclina limestone:
K.1318(F-3, in part), K.1319(F-3), K.2850(F-3), K.2851(E-4), K.3740(E-4, in part), Cd.21(F-3), Cd. 22 and 23 (G-3), and P.J.1159 and 1160(E-4).

Ranikothalia limestone:
K.2951(D-4, solid component of rubble), K.3739(G-3, in part), K.3876(F-3, one of the blocks).

Discocyclina grimsdalei limestone:
K.9463(G-3).

Odd samples:

- K.1317(D-5), boulder of fine-grained sandy algae- and mollusk-limestone, full of *Pholas* holes.
- K.3876(F-3), part of the blocks from this locality, a fine-grained, dark crystalline limestone common on the East point of the Rock.
- K.10714(B-3), quartzitic sandstone.
- Cd.24(G-3), highly recrystallized, finely markasitic coral limestone with some mollusks (a rarety on Soldado Rock).
- K.S.27(G-3), barren, non-calcareous, hematitic mudstone nodule.

f) Paleontology

At the type locality (K.2951B, D-4) the matrix of the rubble bed carries a wealth of Larger Foraminifera. The overwhelming part of these represent a reworked Lizard Springs fauna, even more complete than that which we have found in Bed 3. However, in contrast to Bed 3, the autochthonous fauna of Late Eocene Larger Foraminifera, although far in the minority, is well established here. There are also traces of reworking from the Middle Eocene.

In the following complete faunal list of this heterogeneous assemblage (K.2951B), the Paleocene forms are marked with an asterisk(*) and the Middle Eocene ones with two asterisks (**); the relative frequency of the Larger Foraminifera is given in the "Distribution Chart".

**Ranikothalia antillea* (HANZAWA), with transitions to *R. tobleri* (VAUGHAN & COLE)
**Ranikothalia tobleri* (VAUGHAN & COLE), A-form
**Ranikothalia soldadensis* (VAUGHAN & COLE) (diameter 4–9 mm)
**Neodiscocyclina grimsdalei* (VAUGHAN & COLE), A-form and large B-form
**Neodiscocyclina ? aguerreverei* (CAUDRI)
**Neodiscocyclina fonslacertensis* (VAUGHAN), A- and B-form

**Neodiscocyclina barkeri* (VAUGHAN & COLE), typical A-form
**Neodiscocyclina barkeri* (VAUGHAN & COLE), B-form
**Hexagonocyclina inflata* (CAUDRI)
**Athecocyclina soldadensis* (VAUGHAN & COLE), A- and B-form
**Actinosiphon barbadensis* (VAUGHAN)
***Neodiscocyclina ? bullbrooki* (VAUGHAN & COLE), B-form
***Proporocyclina tobleri* (VAUGHAN & COLE)
Operculinoides soldadensis (VAUGHAN & COLE)
Asterocyclina asterisca (GUPPY), large and small A-forms
Asterocyclina asterisca (GUPPY), B-form
Lepidocyclina pustulosa (H. DOUVILLÉ), A- and B-form
Lepidocyclina peruviana CUSHMAN
Helicolepidina spiralis TOBLER, A- and B-form

Smaller Foraminifera: benthonic species determined by H. H. Renz as Late Eocene (private report 1941); J. B. Saunders (private communication 1972) encountered Early Eocene Globorotalias but no Late Eocene planktonics.

Gastropods (scarce), brachipods (scarce), echinoderms (scarce), algae (scarce).

The other samples collected from the marl and silt matrix of the bed have not contributed anything new:

- Rz.253(D-4) carries *Ranikothalia antillea*, common *Neodiscocyclina barkeri* and some *Neodiscocyclina grimsdalei*, in combination with small but typical *Asterocyclina asterisca* and some non-foraminiferal fossils: the washed residue was flooded with recent fish remains from the guano.
- K.3877(G-3) does not carry a microfauna and the gastropods it contains are inconclusive.

As to the hard limestones of Late Eocene age:

- K.1321(B-3) is a breccia full of Ranikothalia limestone fragments and its Larger Foraminifera fauna seems to be directly comparable with K.2951B(C-4).
- Rz.247(F-3) is the only sample in which the Late Eocene fauna predominates and the Paleocene elements are rare. It contains common *Operculinoides* sp. sp., *Asterocyclina asterisca, Lepidocyclina* cf. *pustulosa* forma *trinitatis* (and *L. peruviana*?),), perhaps also some *Helicolepidina spiralis* and abundant *Amphistegina* (presumably *A. grimsdalei*), as against rare specimens of *Neodiscocyclina barkeri* (A- and B-forms).

The other limestones contain a predominantly Paleocene fauna.

- K.3739(G-3) yielded various boulders, one of which seems to be a straight Ranikothalia limestone; in another one, only *Lepidocyclina* was observed, but its matrix consists entirely of minute calcite rhombohedrons which are probably washed in from the disintegrating Ranikothalia limestone.
- K.S.23(G-3) is an unevenly recrystallized rock in which the fauna is also chiefly Paleocene, with some rare *Lepidocyclina* cf. *pustulosa;* in K.S.24, from the same locality, no *Lepidocyclina* was observed but paleontologically as well as lithologically it is so much like K.S.23 that it can be considered as coming from the same lenticular limestone body.

The contents of the limestone blocks of Paleocene origin have been described above, in the chapter on the Soldado Formation.

g) *Age of Bed 4: Late Eocene*

Although the Late Eocene fauna in Bed 4 is sparse and not fully developed, there is little doubt that this deposit belongs to the Upper Eocene. The absence of *Helicosteginopsis soldadensis* seems to be significant for a more refined age determination (see below, under "Geological History", p. 428), but none of the samples yielded an autochthonous pelagic fauna which would permit correlation with an exact planktonic zone.

Bed 5

a) Bibliography

KUGLER (1938, p. 217, 220) correlated this bed, along with Beds 6 to 9, with the San Fernando Formation of Trinidad. At the time he also included in this bed the conglomerate at K.1317(D-5), which today is considered as belonging to Bed 4.

b) Type section of Bed 5

This bed, like beds 6 to 9, has been exposed by a trench cut along the crest of the saddle between the Southern point of the Rock, formed by Beds 3 and 4, and the foot of the cliff which bears the trigonometric signal on the Northern summit.

c) Stratigraphic relationship

Bed 5 is a lenticular sand body between the rubble bed (Bed 4) and the well-bedded silts of Bed 6. Its type locality is K.2956(D-4).

d) Thickness

About 5 meters.

e) Lithology

A fine-grained, bright yellow calcareous quartzose sandstone, with large quartz grains, some chert particles and a layer of white non-calcareous grit. To the West (K.1495, D-4) the colour changes to light-grey and the sandstone becomes non-calcareous and contains a layer of quartz grains with vugs. Similar quartz sandstone lenses are found all along the SE slope of the Rock.

f) Paleontology

The deposit is barren.

Bed 6

a) Bibliography

KUGLER (1938, p. 217, 220).

b) Type section

As Bed 5: type locality K.2955(D-4).

c) Stratigraphic relationship

The bed separates the sandstone of Bed 5 from the fossiliferous marl of Bed 7.

d) Thickness and dip

The bed has a thickness of 4 meters and dips 50 degrees to the North.

e) Lithology

Bluish-grey silt with intercalated thin layers of muddy sand, and a band of glauconitic sand of about 20 cm thickness. A few blocks of limestone lie scattered in the silt. Such silts occur in many spots along the SE slope of the Rock.

f) Paleontology

The deposit is barren.

Bed 7

a) Bibliography

KUGLER (1938, p. 217, 220) gave a lithological description and a list of Smaller Foraminifera, including such forms as *Bulimina jacksonensis* and *Hantkenina alabamensis* var. *primitiva* (see below). The marl represents a more open sea facies than the surrounding silts and was compared with the Late Eocene "Hantkenina marl" of the San Fernando area of Trinidad.

b) Type section

As Bed 5: type locality K.2954(D-4).

c) Stratigraphic relationship

This marl is intercalated between the bluish-grey silts of Bed 6 and the silver-grey carbonaceous silts and clays of Bed 8.

d) Thickness and dip

The bed is about 3 meters thick and has an almost vertical dip.

e) Lithology

The type sample K.2954 is a yellowish-brown calcareous clay with scattered Larger Foraminifera. Its washed residue is full of fibrous calcite.

Following the strike to the NE, we also include in this bed the dark-brown glauconitic orbitoidal marl K.2855(F-3), which in its residue proves to be full of minute calcite rhombohedrons probably derived from the disintegrating Ranikothalia limestone (compare K.3739, Bed 4).

f) Paleontology

The marl at K. 2954 is highly fossiliferous, especially rich in excellently preserved Smaller Foraminifera. The Larger Foraminifera fauna is rather poor; the fossils are white or brown in colour and in a weathered crumbly condition. On the other hand, K. 2855 is very rich in Larger Foraminifera.

KUGLER (1938, p. 217) listed the following benthonic Smaller Foraminifera from K.2954, determined by H. Naegeli, H. H. Renz and K. Schmid:

Bulimina jacksonensis
Cassidulina subglobosa
Robulus cf. *arcuato-striatus* var. *carolinianus*
Pseudoglandulina conica
Plectofrondicularia cf. *mexicana*
Plectofrondicularia vaughani
Vaginulina elegans mexicana
Nonion cf. *pompilioides*
Gyroidina soldanii
Hantkenina alabamensis var. *primitiva*
Textularia cf. *pala*
Sigmoidella elegantissima
Saracenaria aff. *italica*

as well as undetermined forms of the genera *Uvigerina*, *Cibicides*, *Bolivina*, *Cristellaria*, *Buliminella*, *Textularia*, *Nodosaria*, *Siphonodosaria*, *Triloculina*, *Globorotalia*, *Globigerina*, *Massilina*, *Marginulina*, *Ellipsoglandulina*, *Vulvulina*, *Haplophragmoides*.

CAUDRI later determined the Larger Foraminifera in the samples K.2954 and K.2855. A difference in facies between the deposits at these two localities finds its expression in the composition of their fossil assemblages (see "Distribution Chart"). The combined fauna of Bed 7 is as follows:

Operculinoides soldadensis VAUGHAN & COLE
Operculinoides ocalanus (CUSHMAN)
Operculinoides kugleri VAUGHAN & COLE
Operculinoides trinitatensis (NUTTALL)
Proporocyclina mirandana (HODSON)
Asterocyclina asterisca (GUPPY)
Asterocyclina soldadensis CAUDRI n. sp.
Lepidocyclina peruviana CUSHMAN
Lepidocyclina pustulosa s.s. (H. DOUVILLÉ)
Lepidocyclina pustulosa forma *trinitatis* (H. DOUVILLÉ)
Lepidocyclina pustulosa forma *tobleri* (H. DOUVILLÉ)
Lepidocyclina pustulosa var. *compacta* CAUDRI n. var.
Lepidocyclina sp. indet. 1
Lepidocyclina sp. indet. 2
Helicolepidina spiralis
Amphistegina grimsdalei CAUDRI n. sp.
Helicosteginopsis soldadensis (GRIMSDALE)
Sphaerogypsina globulus s.l.
Cycloloculina jarvisi CUSHMAN

SAUNDERS (private correspondence 1972) reported that the assemblage of planktonic and calcareous/arenaceous benthonic Smaller Foraminifera in K.2954 includes:

Bulimina jacksonensis CUSHMAN
Vaginulina mexicana NUTTALL
Globorotalia cerroazulensis COLE (small, but with acute periphery)
Globorotalia centralis CUSHMAN & BERMUDEZ
Globigerinatheca tropicalis (BLOW & BANNER)
Globoquadrina venezuelana (HEDBERG)

The Smaller Foraminifera of K.2855 were determined as Late Eocene by H.H. Renz.

g) Age of Bed 7: Late Eocene (Globorotalia cerroazulensis Zone)

With the help of the Larger Foraminifera, Bed 7 can be correlated with the Upper Eocene of the San Fernando area in Trinidad, and the planktonics of K.2954 pin the age down to the *Globorotalia cerroazulensis* Zone (*G. cocoaensis* Zone of BOLLI)[5]).

The difference in preservation between the Larger and the Smaller Foraminifera in sample K.2954 suggests that the marl was deposited at some distance from the shore, and that the former were swept in by turbidity currents or slumping. At K.2855 everything seems to be in place (fore-reef facies).

Along with the autochthonous fauna, a small amount of reworked material was also deposited in the sediment: *Ranikothalia* from the Paleocene in K.2954, and *Proporocyclina tobleri* and *Neodiscocyclina bullbrooki* from the Lower to Middle Eocene in K.2855. We have no information on the Smaller Foraminifera in this respect, but also there the influence of reworking must be insignificant.

Bed 8

a) Bibliography

KUGLER (1938, p. 218, 220).

b) Type section

As Bed 5; type locality K.2953(D-4).

c) Stratigraphic relationship

Bed 8 is a silty deposit in sharp contrast with the marl of Bed 7. It is separated from Bed 9 by a layer of glauconitic sand.

[5]) According to COLE (1960*b*, p. 57), the name *cerroazulensis* COLE has priority over *cocoaensis* CUSHMAN by about four months. BOLLI (1957*b*, p. 169) chose *cocoaensis* as the valid name for his planktonic zone.

d) Thickness and dip

The bed is about 4 meters thick and dips with 80 degrees to the North.

e) Lithology

Silver-grey silts with clay layers, showing carbonaceous specks, the joints coated with yellow powdery jarosite.

f) Paleontology

The deposit is barren.

Bed 9

a) Bibliographic history

KUGLER (1938, p. 218, 220) attached much more importance to Bed 9 than at present. He wrote: "This bed resembles typical Mount Moriah silt (of Trinidad) and is well exposed all along the SE shore of Soldado Rock, where it can best be studied at low tide." Since then the "silts" (actually marls) along the SE shore have been recognized as a separate stratigraphical unit distinguished under the name of "Asterocyclina Marl" (see below, Bed 9a).

Apart from the type sample K.2952, KUGLER also mentions K.1316, K.1499 and K.2854, and gives the list of Larger Foraminifera in this mixed lot as determined by VAUGHAN & COLE. Of these samples only K.1499 is now considered as belonging to Bed 9, and the fossil list is of no value.

VAUGHAN & COLE (1941) determined the following Larger Foraminifera from the sample K.1499:

Operculinoides ocalanus (CUSHMAN) HANZAWA
Operculinoides kugleri VAUGHAN & COLE (type material!)
Operculinoides trinitatensis (NUTTALL)
Discocyclina cubensis (CUSHMAN)
Discocyclina (Asterocyclina) asterisca (GUPPY)
Discocyclina (Asterocyclina) vaughani (CUSHMAN)
Pseudophragmina (Proporocyclina) flintensis (CUSHMAN)
Lepodocyclina (Pliolepidina) pustulosa (H. DOUVILLÉ)
Lepidocyclina (Pliolepidina) pustulosa forma *trinitatis* (H. DOUVILLÉ)
Lepidocyclina (Pliolepidina) pustulosa forma *tobleri* (H. DOUVILLÉ)
Lepidocyclina sp. indet. No. 2
Helicolepidina spiralis TOBLER
Helicostegina soldadensis GRIMSDALE (abundant)
Amphistegina sp. indet. n. (= *Amphistegina grimsdalei* CAUDRI n. sp.)

COLE (1961, p. 137) mentions material from his "locality 2" which is a mixed sample from Soldado Rock: K.1316 and K.1499 (K.1316 belongs to Bed 9a!).

b) Type section of Bed 9

As Bed 5, at the North end of the trench: type sample K.2952(D-3).

The lateral extension of Bed 9 is rather vague. The sandstone lens at K.905(D-3) lies interbedded in it. The bed can further be followed towards the NE, where the samples K.1499(E-2), K.2856(E-2), K.3678(E-1), Rz.249(E-1), E.L.1441(E-1) and E.L.1571(E-1) were collected from it. The fauna in K.3677(E-1) proved to be quite different from K.1499 and more like that of Bed 10; the sample is considered to be a block of Bed 10 which has fallen down from the steep cliff formed by that bed. Further to the East, on the slope down towards the shore, the bed merges into the undifferentiated mass of beds 4–9.

c) Stratigraphic relationship

Bed 9 is separated from the silt of Bed 8 by a layer of glauconite. It is sharply set off against the marlstone and marls of Bed 10.

d) Thickness and dip

At the type locality (K.2952, D-3) the thickness is about 10 meters, and dips varying from 80 degrees (E.L.1441, E-1) to 90 degrees (Rz.249, E-1), to the WNW, were measured.

e) Lithology

At the type locality (K.2952) the bed consists of prismatically jointed silt and silty sand with finegrained quartzose sandstone lenses and thin layers of glauconitic sand. The deposit resembles the Mount Moriah silt of the San Fernando Formation in its type area. The quartzose sandstone at K.905(D-3) is similar to that in Bed 5 (K.1495, D-4), but it is gritty and does not show vugs. A similar assemblage of streaks and lenses occurs at E.L.1441(D-3), where a brown weathering sandstone with a bluish core rests on a calcareous silt. Such barren calcareous silts were also observed at Rz.249(E-1); they are associated with foraminiferal marls (K.1499, E-2).

f) Paleontology

The only foraminiferal sample that was collected from Bed 9 is the brown-grey marl K.1499(E-2) which carries a rich Larger Foraminifera fauna and a fair amount of Smaller Foraminifera:

Ranikothalia antillea (HANZAWA), one specimen
Operculinoides soldadensis VAUGHAN & COLE
Operculinoides ocalanus (CUSHMAN)
Operculinoides kugleri VAUGHAN & COLE
Operculinoides trinitatensis (NUTTALL)
"*Discocyclina*" sp. indet., very small (VAUGHAN & COLE's "*Discocyclina cubensis*")
Asterocyclina asterisca (GUPPY)
Asterocyclina vaughani (CUSHMAN) (determination by VAUGHAN & COLE 1941), one specimen
Asterocyclina aff. *monticellensis* COLE & PONTON, one specimen
?*Proporocyclina* cf. *tobleri* (VAUGHAN & COLE)
Proporocyclina mirandana (HODSON)
Lepidocyclina pustulosa (H. DOUVILLÉ) s. s. (megalospheric form, abundant)
Lepidocyclina pustulosa (H. DOUVILLÉ) (microspheric form, common)
Lepidocyclina pustulosa forma *trinitatis* (H. DOUVILLÉ) (common)
Lepidocyclina pustulosa forma *tobleri* (H. DOUVILLÉ) (scarce)
Lepidocyclina spatiosa CAUDRI n. sp.
Helicolepidina spiralis TOBLER
Amphistegina grimsdalei CAUDRI n. sp. (abundant)
Helicosteginopsis soldadensis (GRIMSDALE) (common)
Helicosteginopsis soldadensis (GRIMSDALE), microspheric form (one specimen)

Smaller Foraminifera: *Gaudryina*, Miliolidae, *Robulus*, *Lenticulina*, *Nonion*, *Bolivina*, *Uvigerina*, *Valvulineria*, *Eponides*, *Cibicides*, *Globigerina*, *Globorotalia*, etc.

g) Age of Bed 9: Late Eocene

The Larger Foraminifera fauna of Bed 9 is typical of the Upper Eocene, and is directly comparable with that of the San Fernando Formation of Trinidad. We have no information on the planktonic foraminifera. Reworking from older deposits (*Ranikothalia*, "*Discocyclina*", *Proporocyclina* cf. *tobleri*) has been observed but is of minor importance.

Bed 9a («Asterocyclina marl»)

a) Bibliographic history

KUGLER (1938, p. 218) showed on the geological map a belt of foraminiferal marly clay exposed along the SE coast (samples K.2651, K.2854, K.1316, K.2650, K.3741 and others) which, at the time, was not recognized as a separate unit but was included in Bed 9.

VAUGHAN & COLE (1941) did not make any differentiation either. From this particular marl they had at their disposal only the sample K.1316 (mixed with material from K.1499, Bed 9), and K.2854. They determined from these: *Operculinoides ocalanus*, *Asterocyclina asterisca*, *Lepidocyclina pustulosa* s.s. and forma *trinitatis*, *Lepidocyclina ocalana* var. *pseudocarinata* and *Lepidocyclina macdonaldi*. Many of their photographs of *Lepidocyclina pustulosa* illustrate specimens from K.2854.

GRIMSDALE (1941, appendix to VAUGHAN & COLE 1941, p. 86) described the new foraminiferal species *Helicostegina soldadensis* from "black silts exposed on the south shore of Soldado Rock" (the type locality has now been traced to Gr. 33 = K.2854(E-5); see Part 2 of present paper).

COLE (1960*a*, p. 133) discussed the variability of *Lepidocyclina pustulosa*, using in part material from K.2854.

COLE (1961, p. 137, etc.) described *Operculinoides trinitatensis* and other forms from mixed material of K.1316 and K.1499 (Bed 9).

COLE (1963, p. 10, plates 1, 2, 3, 5, 10) included many specimens from K.2854 in his study of the embryonic chambers of *Lepidocyclina pustulosa*.

b) Type section of Bed 9a

No actual type section was established. The type sample is K.2854(E-5) and dips of 70–80 degrees were measured around K.1316 and K.2650(D-5).

c) Stratigraphic relationship

No clear-cut contacts with the surrounding beds could be established for the Asterocyclina marl. To the SE and South it is cut off by the sea, and on the land side it is smothered in loose blocks of various origin which we have in part called the block conglomerate and described as one of the lateral derivates of Bed 4 (see p. 393). Paleontologically, however, there is no close relationship to Bed 4.

d) Thickness

Unknown.

e) Lithology

The Asterocyclina marl is a dark-coloured (brown to blackish) deposit which differs from the other foraminiferal marls of Soldado Rock by the almost complete absence of clastic material. It hardly contains any silt at all, and reworked Early or Middle Eocene Foraminifera, which are so commonly mixed with the fauna in the other Upper Eocene beds, are extremely rare here.

For paleontological reasons, i.e. because it contains the most complete combination of Larger and Smaller Foraminifera, K.2854 is designated as the type sample of this bed.

f) Paleontology

As soon as the importance of this marl as a separate sediment had been realized, a number of additional samples were collected by J. B. Saunders, who also undertook to study the planktonic elements in them. Most of the samples carry a rich fauna of planktonic as well as calcareous benthonic forms. For the planktonic fauna, the following samples were examined: J.S.1030(F-3), J.S.1029(E-4), K.2651(E-4), J.S.1223(D-5), J.S.1224(E-4), K.2854(= Gr. 33, E-5), K.1316(D-5), K.3741(D-5) and K.2650(D-5). J. B. Saunders determined the following foraminifera from this material:

Globorotalia cerroazulensis (COLE)
Globorotalia cerroazulensis, transition to *G. centralis* CUSHMAN & BERMUDEZ
Globorotalia centralis CUSHMAN & BERMUDEZ
Globorotalia centralis transition to *G. ampliapertura* (BOLLI)
Globorotalia opima nana BOLLI
Globorotaloides suteri BOLLI
Globigerinatheka tropicalis BLOW & BANNER
Globigerinatheka dissimilis (CUSHMAN & BERMUDEZ)
Globigerinatheka lindiensis BLOW & BANNER
Globigerina angustiumbilicata BOLLI
Globigerina tripartita tripartita KOCH
Globigerina parva BOLLI
Globigerina ciperoensis ciperoensis BOLLI
Globigerina ciperoensis angulisuturalis BOLLI
Globigerina anguliofficinalis BLOW
Globigerina cf. *G. trilocularis* D'ORBIGNY
Hantkenina alabamensis CUSHMAN
Hantkenina primitiva CUSHMAN & JARVIS
Globoquadrina venezuelana (HEDBERG)
Bulimina jacksonensis CUSHMAN
Vaginulina mexicana NUTTALL

During the routine picking of K.1316 for Larger Foraminifera, CAUDRI noted down the following genera:

Robulus div. (large)
Frondicularia
Glandulina (large)
Guttulina (large)
Sigmoidella
Bolivinopsis
Bulimina jacksonensis CUSHMAN
Uvigerina (small)
Pullenia
Nonion
Eponides (large)
Cibicides
Miliolidae (large, elongate)
Textularia

The sample P.J.1147 yielded *Bathysiphon;* P.J.1162 contained *Bulimina jacksonensis* and common *Glandulina*, subglobular Miliolidae and *Haplophragmoides* (the latter also present in P.J.1146 and 1147). Other samples contained: *Gypsina*, *Carpenteria* and *Rupertia.*

Larger Foraminifera were obtained from the following samples: K. 1316, K.2650, K.2651, K.2854, K.3737, K.3741, J.S.1223 and P.J.1146, P.J.1147 and P.J.1162. The richest concentration of these fossils occurs at K.1316, K.2651 and K.2854. The sample J.S.1223 contains essentially a Smaller Foraminifera assemblage, but also a certain number of small specimens of Larger Foraminifera, abundant *Helicosteginopsis soldadensis*, common *Amphistegina grimsdalei*, a few non-typical juventile specimens of *Helicocyclina paucispira* and many initial stages of *Lepidocyclina pustulosa.*

The Larger Foraminifera fauna of the Asterocyclina marl as a whole consists of:

Asterocyclina asterisca (GUPPY), A-form
Asterocyclina asterisca (GUPPY), B-form
Asterocyclina soldadensis CAUDRI n. sp.
Proporocyclina mirandana (HODSON)
Lepidocyclina peruviana CUSHMAN
Lepidocyclina pustulosa s. s. (H. DOUVILLÉ)
Lepidocyclina pustulosa forma *trinitatis* (H. DOUVILLÉ)
Lepidocyclina pustulosa forma *tobleri* (H. DOUVILLÉ)
Lepidocyclina pustulosa (H. DOUVILLÉ), B-form
Lepidocyclina spatiosa CAUDRI n. sp.
Lepidocyclina subglobosa NUTTALL (one specimen in K.3741)
Lepidocyclina ? *sanfernandensis* VAUGHAN & COLE, B-form
Helicolepidina spiralis TOBLER, A- and B-form
Operculinoides soldadensis VAUGHAN & COLE
Operculinoides ocalanus (CUSHMAN)
Operculinoides kugleri VAUGHAN & COLE
Operculinoides trinitatensis (NUTTALL)
Operculinoides, transition between *O. trinitatensis* and *O. kugleri*
Operculinoides spiralis CAUDRI n. sp.
Amphistegina grimsdalei CAUDRI n. sp.
Helicosteginopsis soldadensis (GRIMSDALE)
Helicosteginopsis soldadensis, transition to *Helicocyclina paucispira*
Helicocyclina paucispira (BARKER & GRIMSDALE) (not typically developed)

The relative frequency of all these forms is given in the "Distribution Chart".

Accessory, mostly scarce organisms are further: pelecypods (very small specimens, sometimes abundant, for instance at K.2854), gastropods, scaphopods, brachiopods, bryozoans, echinoderms, corals, fish otoliths, crab remains, and locally common worm tubes. The last three may in part be Recent additions.

Traces of reworking of older material into this extremely rich Late Eocene assemblage are restricted to an obviously reworked specimen of *Proporocyclina tobleri* in K.1316, one specimen of *Amphistegina undecima* in P.J.1146 and another doubtful one in K.2854, both species originally from the Proporocyclina tobleri limestone zone (see Bed 11). At K.3737, pebbles and blocks from older formations got mixed up with the marl (surface contamination). J. B. Saunders pronounced the Asterocyclina marl the cleanest of all the Upper Eocene deposits, also with reference to the planktonic fauna.

g) *Age of the Asterocyclina marl (Bed 9a): Late Eocene (G. cerroazulensis Zone)*

According to SAUNDERS, the Asterocyclina marl is the equivalent of the *Globorotalia cerroazulensis* Zone (= *Globorotalia cocoaensis* Zone; see footnote on p. 398). The work of TOUMARKINE & BOLLI (1970) suggests that it would be the lower part of the zone. SAUNDERS declares that he has seen nothing that can with confidence be put in the upper part: nothing can be proved to be as high in the section as the *Globorotalia cocoaensis cunialensis* Zone of TOUMARKINE & BOLLI. In other words: no great difference was found between this marl and Beds 7 and 10, as far as the planktonic foraminifera are concerned. Unfortunately there is no information on Bed 9 in this respect.

This is a rather puzzling result (as we shall see from the discussion of the geological history of Soldado Rock, p. 429), because the information obtained from the Larger Foraminifera is somewhat at variance with it.

The Larger Foraminifera assemblage contains such forms as *Lepidocyclina subglobosa* and *Helicocyclina paucispira*, perhaps *Lepidocyclina sanfernandensis*, and even a variety of *Lepidocyclina pustulosa* with thin-walled rhomboid equatorial chambers reminiscent of *L. yurnagunensis* (P.J.1147, P.J.1162). These species characterize, in the San Fernando area of Trinidad, the uppermost part of the Upper Eocene as encountered on the Vistabella Estate (in a surface section and in the calyx wells), in the highest part of the section at Point Bontour (where the Eocene merges into the Oligocene Cipero Formation) and in the marl exposed behind the former San Fernando Railway Station. The junior author is, therefore, under the impression that the Asterocyclina marl can, at least in part, be correlated with this very high Eocene level and that it is definitely the youngest of all the beds of the Soldado section. Unfortunately, the most important samples in this respect (K.3741, J.S.1223, P.J.1147 and P.J.1162) are all essentially Smaller Foraminifera marls in which, probably on account of greater depth or perhaps through passive selection, Larger Foraminifera are very rare and represented chiefly by juvenile specimens and fragments. Apart from the convincing but isolated specimen of *Lepidocyclina subglobosa* in K.3741 (illustrated in Part 2, Paleontology, Pl. 26, Fig. 10, 11) the evidence for this correlation with Trindidad is slim.

Bed 10

a) Bibliography history

MAURY (1912, p. 30, 31) described as "Bed 6" of her section a highly fossiliferous horizon, which in accordance with later studies should be placed within our Bed 10 (KUGLER 1938). This horizon "contains myriads of Foraminifera, especially Orbitoids, Echinoids and one imperfect *Ostrea* shell, probably of *Ostrea crenularimarginata*" (a species also mentioned by her from the Paleocene, Bed 2).

R. M. Bagg (in MAURY 1912, p. 31) determined the Orbitoids as follows:

Orbitoides papyracea (BOUBÉE)
Orbitoides aspera GÜMBEL (*O. faujasii*)
?*Orbitoides mantelli* (= *O. forbesii*)
Tinoporus vesicularis
Tinoporus baculatus

MAURY stated: "The evidence furnished by both Foraminifera and mollusks points definitely to Lower Eocene".

Remark: with our present knowledge of the Soldado section and its various faunas, both Bagg's faunal list and the age determination are easily challenged. A deposite of this type, so much higher in the section than the Paleocene, can only have come from what we now call Bed 10, and we can safely take Bagg's list as referring to a Late Eocene *Lepidocyclina–Asterocyclina* assemblage. The oyster (if correctly identified) may be reworked, as perhaps also some of the Orbitoids in as far as they are not Lepidocyclinas (*O. papyracea* = *Proporocyclina tobleri* ?).

DOUVILLÉ, H. (1917, p. 844) described Larger Foraminifera collected by F. Zyndel in Trinidad and Soldado Rock. From the latter he mentioned *Asterodiscus asteriscus* and the new species *Isolepidina pustulosa*, two characteristic species which he placed into the basal Stampian and not into the Lower Eocene as suggested by R. M. Bagg.

MAURY (1925*b*, p. 160) changed her opinion on the age: "Bed 6, characterized by Foraminifera, is now thought to be Upper (Jacksonian) Eocene, ..."

JEANNET (1928) described from the indurated lowest orbitoid reefs in this bed (K.903; and also from K.1321, Bed 4) the following new echinoids: *Oligopygus zyndeli* and *Oligopygus kugleri* (together with *Oligopygus christi*, which was already known from Venezuela).

GORTER & VAN DER VLERK (1932, p. 107) mention "from San Fernando and Soldado": *Lepidocyclina (Lepidocyclina) pustulosa* H. DOUVILLÉ, *Lepidocyclina (Pliolepidina) tobleri* H. DOUVILLÉ, *Discocyclina (Asterocyclina) asteriscus* (GUPPY), *Camerina floridensis* HEILPRIN. According to RUTSCH (1939), their material came (at least in part) from Bed 10 of Soldado Rock.

KUGLER (1938, p. 218, 220) gave a short description of Bed 10, mentioning MAURY's *Ostrea* and the echinoids of JEANNET. From the soft silty marl of the uppermost layer he mentioned the common occurrence of the fine-ribbed brachiopod *Terebratulina kugleri* RUTSCH which at the time had not yet been published officially (see below). No foraminifera were determined. Good pictures of the outcrop and the general lithological aspect of the bed accompany the description. Six samples were listed but no type sample was designated.

RUTSCH (1939*b*, p. 517) described *Terebratulina kugleri* n. sp. from a mollusk-bearing horizon (K.3692) near the top of the bed, situated in the section between the two main mollusk faunas, the Soldado Formation and the Boca de Serpiente Formation (see under Bed 11). This is the horizon called "Bed 6" by MAURY and "Bed 10" by KUGLER. Unfortunately, the mollusks proved to be indeterminable. The genus *Terebratulina* is very rare in the Eocene and cannot yet be used as an age indicator. RUTSCH used GORTER & VAN DER VLERK's Larger Foraminifera, which he claimed came from Bed 10, to determine the age of the *Terebratulina* as Late Eocene.

VAUGHAN & COLE (1941, p. 14, 15, 18–23) had material from several samples of Bed 10: K.296 (= K.903), K.1500, K.3689, K.3691, and K.3692. The very incomplete fauna they mentioned from these include:

Operculinoides ocalanus (CUSHMAN)
Operculinoides soldadensis n. sp.
(type locality: K.3692)
Operculinoides kugleri n. sp.
Discocyclina (*Asterocyclina*) *asterisca* (GUPPY)
Discocyclina (*Asterocyclina*) *vaughani* CUSHMAN

Pseudophragmina (Proporocyclina) tobleri n. sp.
Helicolepidina spiralis TOBLER
Lepidocyclina pustulosa (H. DOUVILLÉ) s.s.
Lepidocyclina pustulosa (H. DOUVILLÉ) forma *trinitatis* (H. DOUVILLÉ)

COLE (1962*a*, p. 30, 38), in his study of the variability and systematic value of the embryonic chambers of *Lepidocyclina*, mentioned and figured specimens from Bed 10 (K.903, K.3677 and K.3692). The material from K.903 contained forms of *Lepidocyclina pustulosa* with an abnormal embryonic development, but no typical *Lepidocyclina pustulosa* forma *tobleri* was found.

COLE (1962*b*, p. 146, 147, 149, 150) discussed the nepionic development of *Helicolepidina spiralis* in sample K.3692 in comparison with others. The larger Foraminifera of this sample were listed as follows:

Asterocyclina asterisca (GUPPY)
Camerina floridensis (HEILPRIN)
Camerina trinitatensis (NUTTALL)
Helicolepidina spiralis TOBLER
Lepidocyclina pustulosa (H. DOUVILLÉ)
Pseudophragmina (Proporocyclina) tobleri VAUGHAN & COLE (one reworked specimen)
Cycloloculina jarvisi CUSHMAN

This assemblage indicates a Late Eocene age.

The planktonic species in this sample, determined by Miss Ruth Todd, were:

Globigerina yeguaensis WEINZIERL & APPLIN
**Globigerapsis kugleri* BOLLI, LOEBLICH & TAPPAN
Catapsydrax dissimilis (CUSHMAN & BERMUDEZ)
**Globorotalia aspensis* (COLON)
Globorotalia bolivariana (PETTERS)
**Globorotalia bullbrooki* BOLLI
Globorotalia centralis CUSHMAN & BERMUDEZ
Globorotaloides suteri BOLLI
**Truncorotaloides rohri* BRÖNNIMANN & BERMUDEZ
Truncorotaloides topilensis (CUSHMAN)

According to COLE, the species marked with an asterisk(*) seem to indicate that the planktonic fauna represents the *Globigerapsis kugleri* Zone of BOLLI (corresponding with the Middle Eocene Navet Formation of Trinidad), but the assumed that, along with the specimen of *Proporocyclina tobleri*, also the planktonics are reworked into the Late Eocene deposit of Bed 10.

COLE (1963, p. 10, 24, 25) included *Lepidocyclina pustulosa* from K.903 in his comparative study of the measurements of that species in various localities, resulting in the diagram on p. 25.

KIER (1967) redescribed JEANNET's echinoids (on p. 61 and 69, respectively).

b) *Type section of Bed 10*

On the South side of the highest top, including the type sample K.3692(D-3).

c) *Stratigraphic relationship*

Both the upper and lower contact of Bed 10 is abnormal; their true nature is discussed in extenso below (p. 428–429).

The transition from Bed 9 to Bed 10 is marked by an abrupt change from silts, silty marls and sands to a series of rugged marlstone and marls full of orbitoids and algae. In the Northern area (E-1, D-1) the base of Bed 10 is a breccia with a dip of 40 degrees, resting on the sandstone E.L.1441(E-1) of Bed 9, which has a dip of 80 degrees. In the steep wall at K.2652(D-1) indications of a mylonite were observed.

At the top, the well-bedded marlstone series of Bed 10 is clearly set off against Bed 11 which consists of masses of glauconite ("greensand") and autoclastic breccia of highly glauconitic limestone.

The sample K.3692(C-3) is, for stratigraphical as well as paleontological reasons, chosen as the type sample of Bed 10.

d) Thickness and dip

Bed 10 is 11 meters thick. No dip was established in the Southern part of the exposure (area B-3, C-3, D-3), but in the area D-1 and E-1 a dip of 40 degrees was measured. This observation is probably of very little importance as the sediments do not seem to be in place (see p. 428–429).

e) Lithology

Bed 10 is built up mainly of layers of grey glauconitic orbitoid marlstone with intercalated softer marls. The lowest 4 meters are composed almost entirely of the tests of orbitoids and colonies of calcareous algae (*Lithothamnium* s.l.), fine brecciated rubble of the same material and echinoids. Typical of the lower part are the samples Rz.251, J.S.1024, K.903, K.1500 (all in square B-3 of the map).

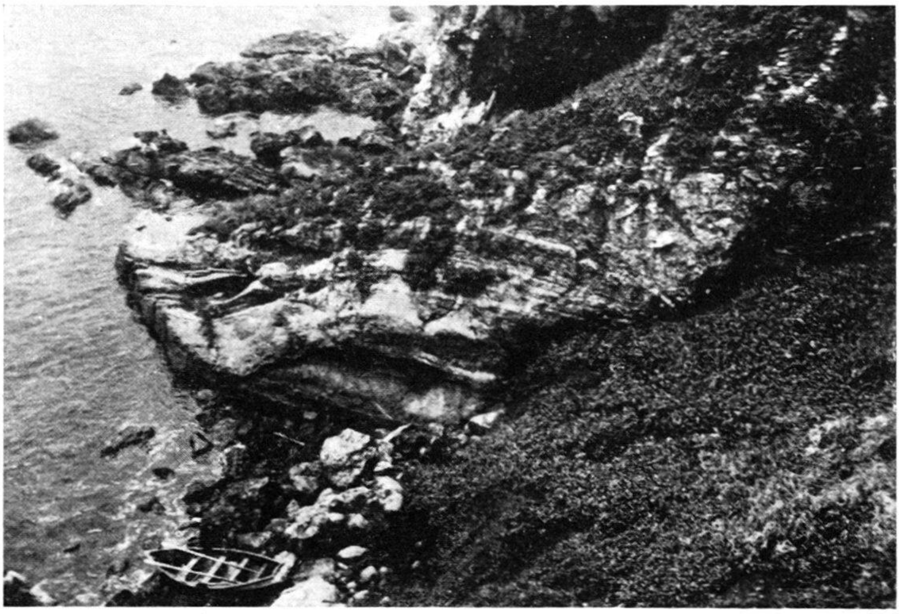

Fig. 5. Landing place with orbitoidal limestone (B-3) of Bed 10 (photo E. Ganz 1922).

In the upper part (about 7 meters) layers of marlstone, varying in thickness from a few centimeters to more than a meter, alternate with soft silty marl and occasional layers of glauconitic "sand". The uppermost layer (1.5 meter) is a soft foraminiferal marl, the contents of which lent themselves particularly well for a detailed study. The type sample K.3692(C-3), situated about 1 meter below the contact with Bed 11, comes from this marl. This sample also yielded an, unfortunately, indeterminable mollusk fauna and it is the type material of the brachiopod *Terebratulina kugleri* Rutsch (1939*b*).

The repetition of beds of different resistivity to weathering increases the already rugged appearance of the orbitoid and algal reef marlstones in themselves. Moreover, numerous erratic blocks of Ranikothalia limestone, Proporocyclina tobleri limestone (see Bed 11), fine-grained crystalline limestone, quartzites, etc. are scattered throughout the bed.

The rugged and heterogeneous nature of Bed 10 should not, however, lead to the conclusion that it was deposited under turbulent water conditions. Apart from those blocks, and a fair amount of reworked finer calcareous matter, there is very little

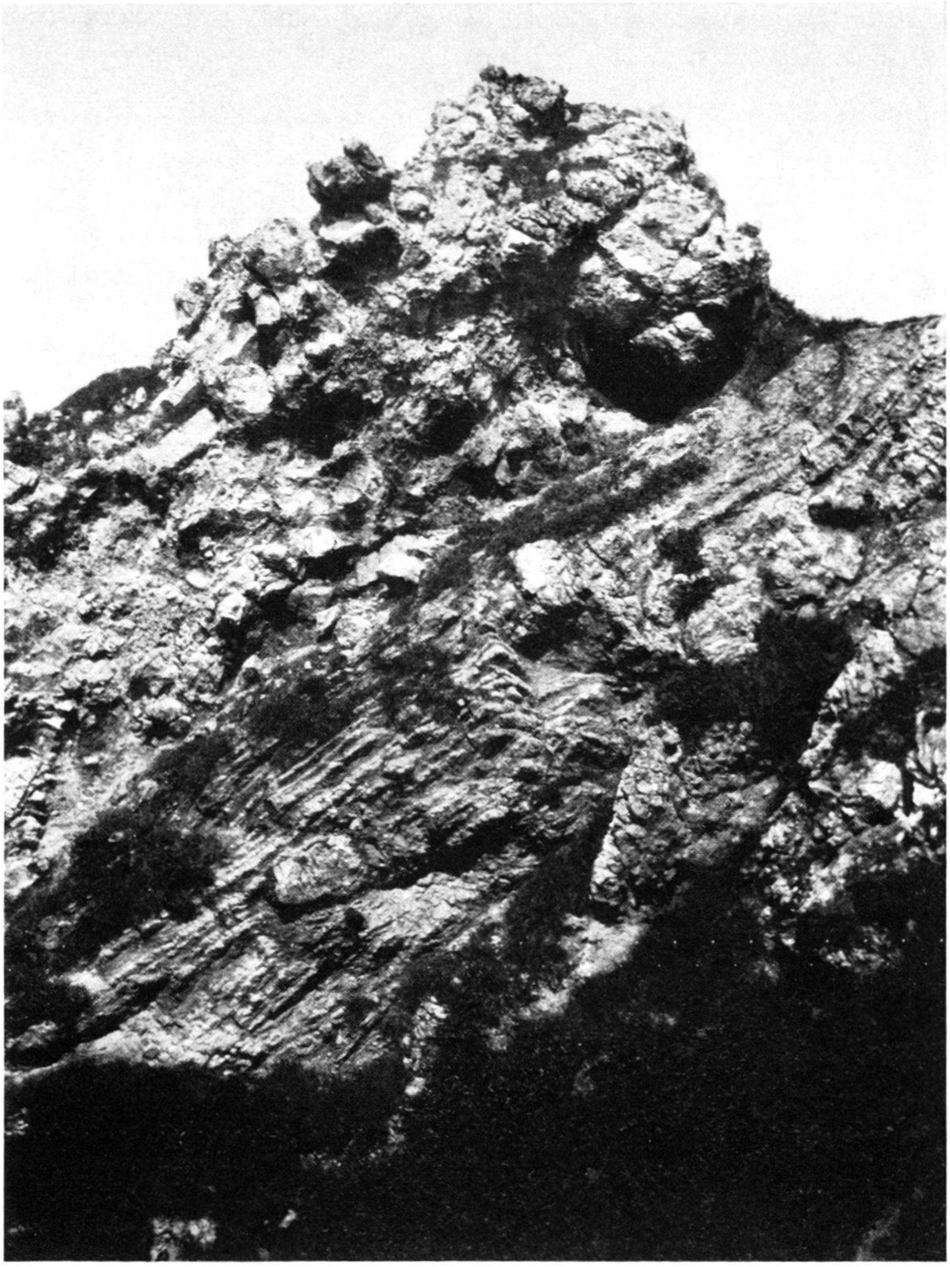

Fig. 6. Bed 10 of well-bedded Late Eocene marls with Paleocene and Middle Eocene remnant blocks superimposed by slump mass of Bed 11 (D-3) of Middle Eocene age (photo H. Buess 1936).

clastic material in the residues. The matrix is marly, mixed at the most with some fine silt, but there are no sands. In several samples, the most important Larger Foraminifera (*Asterocyclina asterisca*, *Lepidocyclina pustulosa*, *Lepidocyclina peruviana*, *Helicolepidina spiralis*, *Operculinoides soldadensis*) are represented by entire populations, unsorted or graded according to size or to shape, which points to an undisturbed sedimentation in their own habitat. The foreign material, large and small, was not introduced by strong lateral currents, but most have fallen and slid into the organic ooze from a nearby exposure. The presence of glauconite would suggest the nearness of a steep unbroken rocky coast, but more possibly these grains got somehow washed in from the Boca de Serpiente Formation (see Bed 11). J. B. Saunders' observations on the planktonic foraminifera in Bed 10 suggested shallow water conditions during sedimentation (private information).

f) Paleontology

The following samples were studied for Larger Foraminifera: Area A-2, A-3, B-3, C-3 and D-3: K.3689, Rz.251, K.903 (= old sample number K.296, mentioned by VAUGHAN & COLE in 1941), K.1500, K.3690, K.10718, K.10716, K.3691, K.3692, K.10707, J.S.1956 (K.10715, in this same area, is an erratic block originating from Bed 11).

Area D-1 and E-1: K.2652, J.S.1950, Rz.250, K.3677 (a block of Bed 10 fallen from the cliff onto Bed 9). The rich orbitoid fauna of Bed 10 is obviously of Late Eocene age. It is, however, heavily mixed with reworked material, not only in the form of the large blocks mentioned above, but also as detached Larger Foraminifera, and especially also planktonic forms which must have come from totally disintegrated marl deposits. In those planktonic forms, the Middle Eocene element predominates, and reworking is in places so overwhelming as to obscure the genuine age of the bed. Amongst the Larger Foraminifera both the lower Middle Eocene and the Paleocene are represented. The difference between the autochthonous fauna and the foreign material is often traceable by the state of preservation. This is particularly clear in the sample K.10716(B-3): the Late Eocene specimens are porous and tend to disintegrate, and boiling them in Canada balsam turns their colour to deep brown, whereas the reworked ones are solidly recrystallized and retain a light whitish brown colour. In sample Rz.250(D-1), on the other hand, the well preserved members of the true fauna are yellowish-grey and the sugary recrystallized older forms are dark brown.

The autochthonous fauna of Larger Foraminifera of Bed 10, all samples combined consists of:

Operculinoides soldadensis VAUGHAN & COLE
Operculinoides ocalanus (CUSHMAN)
Operculinoides kugleri VAUGHAN & COLE
Operculinoides trinitatensis (NUTTALL)
Operculinoides ? *spiralis* CAUDRI n. sp.
Asterocyclina asterisca (GUPPY); also rare B-forms
Asterocyclina vaughani (CUSHMAN)
Proporocyclina mirandana (HODSON), A- and B-forms
Helicolepidina spiralis TOBLER, A- and B-forms
Lepidocyclina pustulosa (H. DOUVILLÉ), s.s.
Lepidocyclina pustulosa (H. DOUVILLÉ), forma *trinitatis* (H. DOUVILLÉ)
Lepidocyclina pustulosa (H. DOUVILLÉ) forma *tobleri* (H. DOUVILLÉ)
Lepidocyclina pustulosa (H. DOUVILLÉ), B-form (undifferentiated)
Lepidocyclina peruviana CUSHMAN
Sphaerogypsina globulus s.l.
Amphistegina grimsdalei CAUDRI n. sp.
Amphistegina cf. *lessonii* ?
Cycloloculina jarvisi CUSHMAN

Reworked from the Paleocene are:

Ranikothalia antillea (HANZAWA)
Ranikothalia cf. *tobleri* (VAUGHAN & COLE)
Neodiscocyclina grimsdalei (VAUGHAN & COLE)
Neodiscocyclina cf. *aguerreverei* (CAUDRI)
Neodiscocyclina fonslacertensis (VAUGHAN)
Neodiscocyclina barkeri (VAUGHAN & COLE)
Neodiscocyclina ? sp. (thickwalled specimen in K.10707)
Hexagonocyclina inflata (CAUDRI)

Reworked from the lower Middle Eocene (see Bed 11) are:

Proporocyclina tobleri (VAUGHAN & COLE), A- and B-forms
Neodiscocyclina bullbrooki (VAUGHAN & COLE), A- and B-forms
Amphistegina undecima CAUDRI n. sp.
Amphistegina pauciseptata CAUDRI n. sp.

The relative frequency of these species in the various samples is indicated in the "Distribution Chart".

Benthonic Smaller Foraminifera are comparatively scarce in Bed 10, and they have not been given much attention. Around 1941, H. H. Renz in Pointe-à-Pierre determined those in sample K.3692 as being of Late Eocene age, and also J. B. Saunders mentions forms like *Bulimina jacksonensis* from a couple of samples (private information). Locally, forms of *Rupertia* and *Carpenteria* have been observed in the reef limestones.

More emphasis was laid on the planktonic foraminifera. The first determinations were given by Ruth Todd in 1962 (see p. 405). J. B. Saunders studied 15 samples from Bed 10, some of which carried a great number of planktonic forms whilst others were very poor. His general conclusion was that Bed 10 was a shallow water deposit, heavily contaminated with reworked material from the Middle Eocene. Specially mentioned in his letter are:

- K.1500(B-3): crushed *Globorotalia centralis*
- K.3677(B-1): strong *Uvigerina* assemblage and planktonics; *Bulimina jacksonensis*, *Bolivina*, etc.; planktonics Middle Eocene
- K.3690(B-3): common Middle Eocene planktonics, rounded *Globorotalia cerroazulensis* and *Globigerinatheca tropicalis*
- K.10716(B-3): strong Middle Eocene, weak Upper Eocene, *Globorotalia cerroazulensis*, *Globorotalia spinulosa*, *Globigerinatheca tropicalis*
- K.10718(B-3): planktonic foraminifera small and almost all Middle Eocene
- Rz.250(D-1): Middle Eocene planktonics
- Rz.251(B-3): *Truncorotaloides rohri*
- J.S.1024(B-3): small planktonic foraminifera common, mainly Middle Eocene, but also Upper Eocene present (probably *Globorotalia cerroazulensis* Zone)
- J.S.1026(B-2): strong planktonic fauna, mainly Middle Eocene, but also Upper Eocene present (probably *Globorotalia cerroazulensis* Zone)
- J.S.1032(B-3): small planktonic forms, mostly Middle Eocene, some Upper Eocene present (probably *Globorotalia cerroazulensis* Zone)
- J.S.1220(B-3): mixed Middle and Upper Eocene planktonics (probably *Globorotalia cerroazulensis* Zone)
- J.S.1950(D-1): poor in planktonics, mainly poorly preserved Middle Eocene forms

Apart from the foraminifera, the fauna of Bed 10 also comprises a certain amount of mollusk material (of both pelecypods and gastropods, especially near the top, K.3692; see RUTSCH 1939*b*). MAURY reported an oyster of doubtful origin (p. 404). Further, there are a few brachiopods, especially in the uppermost layer (*Terebratulina kugleri* RUTSCH in K.3692 and K.10716), bryozoans, ostracods, echinoids (JEANNET 1928, KIER 1967). Locally there are great concentrations of calcareous algae of the *Lithothamnium* type.

General remarks on the Larger Foraminifera

The most remarkable observation made on the very rich, complete and undisturbed fauna of Bed 10 is the total absence of *Helicosteginopsis soldadensis* (GRIMSDALE), so common and conspicuous an element in several of the other beds of the Soldado section, and also in the Upper Eocene of Trinidad and of many other places in the Caribbean Region.

Further, it is worth mentioning that several species of Larger Foraminifera are represented in flood abundance and as complete populations, ranging from embryos to fully developed large specimens in all their morphological variations, in both megalospheric and microspheric form. This is, for instance, the case with *Lepidocyclina pustulosa* (sensu stricto and forma *trinitatis*), *Lepidocyclina peruviana*, *Helicolepidina spiralis*, *Asterocyclina asterisca* and *Operculinoides soldadensis*. The bed thus provides excellent material for a specialized paleontological study of these forms. Also *Cycloloculina jarvisi*, both in the megalospheric and microspheric form, is consistently present in the marls, and is particularly frequent in the sample K.3692 from the top layer. Noteworthy is that practically all the specimens of *Asterocyclina asterisca* in this bed (apart from the rare B-forms) are 4-rayed.

Typical *Lepidocyclina "tobleri"* (*L. pustulosa* forma *tobleri*, in terms of VAUGHAN & COLE) was found (common!) only in one rather excentric spot: K. 2652(D-1), considered to be the top of Bed 10. The cases of a "multilocular embryonic apparatus" recorded by COLE from K.903(B-3) and K.3692(D-3) (1962*a*, p. 38, Pl. 7, Fig. 6 and 1962*b*, Pl. 27, Fig. 3, respectively) are too doubtful to be determined as such. Similar deviations from the normal embryonic pattern in this species were also observed at K.1500(B-3) and K.10707(D-3), but they do not go further than the development of irregular gigantic periembryonic chambers, or of twin bilocular nucleoconchs. In sample K.1500 some tricarinate monstrosities of *Helicolepidina spiralis* were encountered.

g) Age of Bed 10: Late Eocene

The first age determination of this bed proposed by MAURY has already been discussed and dismissed above (p. 404).

In spite of the above mentioned differences with the Vistabella fauna of the San Fernando area in Trinidad, there can hardly be a doubt that the Larger Foraminifera assemblage in Bed 10 belongs also to the Late Eocene. None of the samples contains any forms that would point to a late Middle Eocene age (*Polylepidina*, *Helicolepidina polygyralis*, *Neodiscocyclina* cf. *marginata*, Asterocyclinas of the group characterized by radiating rods of solid shell material, etc.).

The main difference with the typical Upper Eocene of San Fernando (Vistabella, Point Bontour) lies in the total absence of *Helicosteginopsis soldadensis*. As all the other forms with which this species is usually associated are present in abundance, we must assume that in principle the habitat in which the fauna was developed was favourable also for *Helicosteginopsis*. The most logical explanation for its absence is that it just had not come into being at the time Bed 10 was deposited. In other words, Bed 10 is slightly older than the San Fernando Formation at Vistabella and corresponds more closely to the glauconitic silt that used to be exposed on the top of the Mount Moriah hill in San Fernando before the locality was walled up. This silt, stratigraphically at the base of the Upper Eocene directly overlying the Middle Eocene Navet Formation, is likewise devoid of *Helicosteginopsis soldadensis*. Bed 10 and this Mount Moriah silt also have in common an abundance of *Lepidocyclina peruviana* and *Operculinoides soldadensis*.

This would mean that Bed 10 is older than Beds 7, 9, and 9a of the Soldado section itself. Another indication may be found in the monotony of the 4-rayed pattern of *Asterocyclina asterisca* in comparison with the increased frequency of 5-rayed forms and the general morphological variability of the species both at San

Fernando and in the Asterocyclina marl (Bed 9a) of Soldado Rock. In its lack of *Helicosteginopsis*, Bed 10 corresponds with Bed 4. This correlation is further discussed below, in the chapter on the "Geological History of the Rock".

The planktonic foraminifera do not offer much support to these detailed correlations. On their evidence J. B. Saunders states that he "would place Bed 10 in the *Globorotalia cerroazulensis* Zone (= *G. cocoaensis* Zone) rather than lower in the Upper Eocene, but it is not the topmost Eocene". On the other hand, also many samples of Beds 7 and 9, and the Asterocyclina marl are assigned to this zone, in some cases rather to the lower than to the upper part of it.

C. THE BOCA DE SERPIENTE FORMATION

Author of name: MAURY (1929, p. 180)
Original description: idem

Bed 11

a) Bibliographic history

MAURY (1912, p. 28–31) described the highest of Veatch's fossiliferous horizons on Soldado Rock (his Bed 8) as an indurated rock noticeable from being stained deep red with hematite, and greenish and purplish with other forms of iron, and gave a list of 28 species of mollusks and one brachiopod, most of them new (see under "Paleontology", p. 418). Mainly on the abundant presence of *Ostrea thirsae* GABB, this fauna was correlated with the "Lignitic" fauna of the Gulf Coast of the United States; G. D. Harris considered this Soldado horizon to be the equivalent of the Nanafalia Formation (Wilcox) of Alabama.

KUGLER (1923, p. 258) failed to locate MAURY's "Bed 8" during his short visit to the Rock, but assumed it to form part of his "Limestone Complex C", which included the yellowish and red, nodular, in part sugary deposit forming the highest top of Soldado, and which rests on the well-bedded orbitoidal Bed B-4a; their contact is shown in Fig. 3. Since this Bed B-4a was recognized as being of Priabonian age, the "Complex C" was assigned a possible Oligocene age on the assumption that it would later prove to carry an *Isolepidina–Eulepidina* assemblage such as was known from Trinidad (an assumption that was not confirmed).

MAURY (1925*c*, p. 160) stated: "The age of Bed 6, characterized by foraminifera, is now thought to be Upper (Jacksonian) Eocene, and that of Bed 8 either uppermost Eocene or, less likely, basal Oligocene. Its fauna is not very decisive".

LIDDLE (1928, p. 227) wrote: "Though there is no discordance of dip between the Eocene and Oligocene on Isla Soldado, an angular brecciated conglomerate indicates that considerable erosion has occurred between these two periods". On p. 231 a translation of KUGLER's description of the upper "Limestone Complex C" is given, whereby "knaurig" was erroneously translated as "lenticular conglomerate" instead of "nodular". LIDDLE's reproduction of Kugler's photo of the contact between the "Orbitoidal Marlstone B" and the "Limestone Complex C" is of much better quality than that in the original paper. Also LIDDLE assumed that the fossiliferous Bed 8 of VEATCH and MAURY has to be included in the upper limestone formation, but his conception of MAURY's faunas is rather confused.

MAURY (1929, p. 180) stressed the marked difference between the fauna of her Bed 2 (Soldado Formation) and that of Bed 8. For Bed 8 she established the term "Boca de Serpiente Formation" and the age was given as "Uppermost Eocene, equivalent to the European Ludian". No type locality was specified.

MAURY (1935, p. 192) repeated her age determination of Bed 8 as Ludian, and compared its fauna to a horizon East of El Carmen in Northern Colombia (later described by CLARKE & DURHAM in 1946).

KUGLER (1938, p. 219–221) distinguished the upper "Limestone Complex C" of his previous paper as Bed 11 of his new detailed subdivision of the Soldado section. This bed starts with a zone