During previous geological fieldwork in Curacao indications were found that the Caracasbaai, a bay with an open front of about 1 km in width and a maximum depth of about 250 m, situated along the south-western side of the island, owes its existence to a submarine slide of a large part of the limestone coast-range. The evidence was largely based upon geological and geomorphological data from the vicinity of the Caracasbaai. These data indicated that in sub-recent time a coastal fragment of about one square kilometer, its top surface at least 45 m above sea level and its basis along the seaward side about 250 m below sea level, has disappeared in south-south-western direction, sliding down the rather steep submarine slope separating the island from the deep trench to the southwest.

In 1970 echosounding profiles and off-shore sampling fully confirmed the observations made on land. A huge scar with an almost flat bottom, 1000 m in width and excavated a 150 m below the surrounding level of the sea-bottom, is present over a distance of several km in front of the Caracasbaai. At a distance of about 5 km and a depth of about 800 m the broad scar gradually gets a more south-south-eastern direction and merges into a V-shaped canyon.

There are indications that at this depth of about 800 m the block, down to there acting as a single unit, broke into several smaller fragments.

The volume of the limestone block that disappeared from the Curacao coast-line is estimated at 150 million m$^3$ and the volume of unconsolidated globigerina-oozes, set in motion by the sliding block, amounted to 700 million m$^3$.

The sliding event was of a sudden character and the effects on land must have been of a catastrophic nature.

Although the limestones of the Seroe Mansinga, a mountain immediately north-west of the Caracasbaai, are in a less stable position than limestones elsewhere in the coast-ranges of the island, this risk of a new catastrophic event is almost negligible, estimated at one chance in several millions of years.
SAMENVATTING

Tijdens vroeger geologisch veldwerk op Curacao werden aanwijzingen gevonden die erop duidden dat de Caracasbaai — een baai met een open front naar zee van ongeveer 1 km breedte en een maximale diepte van ongeveer 250 m —, ge- situeerd aan de zuidwest zijde van het eiland, ontstaan is doordat een groot deel van het kalksteen-kustgebergte hier onderzees is afgegleden.

De aanwijzingen berustten grotendeels op geologische en geomorfologische gegevens uit de directe omgeving van de Caracasbaai. Zij toonden aan dat in subrecente tijd een kustgedeelte van ongeveer één vierkante kilometer opper- vlak, met een topvlak dat minstens 45 m boven zee lag en een basiskant dat bij de oorspronkelijke kust ongeveer 250 m beneden zeeniveau moet hebben gelegen, in zuidzuidwestelijke richting moet zijn verdwenen en zijn afgegleden van de vrij steile onderzeese helling die het eiland scheidt van de diepzeetrog in het zuidwesten.

In 1970 werden de waarnemingen die op het eiland gedaan waren volledig bevestigd door echoloting-profielen en diepzee-bemonstering. Een enorm lidteken in de vorm van een geul met vrijwel vlakke bodem, 1000 m breed en ongeveer 150 m diep uitgeschaafd uit de zeebodem, bleek over een afstand van verschillende kilometers lengte, direct zeeuwards van de Caracasbaai aanwezig te zijn.

Op een afstand van ongeveer 5 km uit de kust, bij een diepte van ongeveer 800 m, verandert de richting van de geul geleidelijk naar meer zuidzuidoostelijk en zet zich verder voort als een V-vormig dal. Er zijn aanwijzingen dat tot een diepte van 800 m het blok zich als een samenhangend geheel gedroeg en beneden deze diepte in kleinere stukken is gebrokken.

Het volume van het kalksteenblok dat uit de kustlijn van Curacao verdween wordt geschat op 150 miljoen m³ en het volume aan niet-verkitte globigerina-slikken dat door het afglijdende blok in beweging werd gezet, bedroeg in de orde van 700 miljoen m³.

De aflijding was van een plotseling karakter en de effecten ervan op het eiland moeten van catastrophale omvang zijn geweest.

Hoewel de kalksteen van de Seroe Mansinga, een berg direct noordwestelijk van de Caracasbaai, in een minder stabiele positie verkeert dan de kalksteen elders in de kustgebergten van het eiland, is het risico van een nieuwe catastrophale gebeurtenis vrijwel te verwaarlozen; zij wordt geschat op een kans van één in verschillende miljoenen jaren.

ACKNOWLEDGEMENTS

The authors wish to express their sincere gratitude to The Netherlands Organization for the Advancement of Pure Research, Z.W.O. and The Royal Netherlands Navy.

The authors are also greatly indebted to the Commander, Officers and Crew of H.N.I.M.S. 'Luymes' for their personal assistance and close cooperation during the investigations.
GENERAL GEOLOGICAL OBSERVATIONS

The main axes of the three islands Aruba, Curaçao and Bonaire, arranged en echelon along the northern coast of the South-American mainland, are each directed from north-west to south-east and a constant due eastern trade wind renders the straight and rough north-eastern coasts of the islands inaccessible for shipping. The south-western, leeward shores on the contrary possess excellent natural harbours, partly in the form of hand-shaped inland bays, drowned valley systems situated land inward from the limestone coast-ranges, and partly consisting of open bays or concave parts of the coast line, offering sheltered position even for large, heavy-draught ships.

The coral limestones in the three islands are deposited unconformably on thick series of a folded Cretaceous and Danian eugeosynclinal sequence, mainly volcanic rocks, silica-rich sediments and turbidites (Curaçao; Beets, 1972), on folded, metamorphic volcanics and sediments with intrusions of gabbros and diorite batholiths (Aruba; Westermann, 1932, 1949) or on folded series of volcanics and calcareous or silica-rich sediments with pophyritic intrusions (Bonaire; Pijper, 1933). In places lenses of Paleogene sediments, less strongly folded, occur between the younger reef limestones and the older, mainly volcanic formations.

The Neogene and Quaternary coral limestones are mainly found in the peripheric zone of the islands. They occur to a maximum height of about 200 m above sea level and are developed as relatively thin deposits, showing a strong resistance against subaerial erosion. The underlying, mainly volcanic and non-calcareous rocks are much less resistant against subaerial erosion and are exposed in the central parts of the islands.

The coral limestones of the coast-ranges may be roughly divided into two different types: one type developed mainly along the windward sides, the other type occurring nearly exclusively along the leeward coasts.
The limestone coast-ranges along the north-eastern, windward sides consist of series of marine accumulation terraces, separated from each other by elevated, marine cliffs. In Curaçao four terraces may be distinguished, step-wise descending from the oldest, highest terrace with a top level between 150 and 90 m to the youngest Lower Terrace, situated only 10 m above sea level. These terraces were formed by reefs growing upward from the sea-bottom and contain reef corals in position of growth as well as lagoonal sediments deposited between these reefs and the shore. The terraces were deposited during Quaternary periods of slow regression (the upper two terraces) or of slow transgression (the two lower terraces).

In the hinterland strong degradation took place and valley systems were carved out, especially during the (glacial) periods with low sea levels (much lower than 20 to 25 m below the present one).

In the final stage of the Lower Terrace transgression a sea level was reached, leaving traces that now are found up to 10 m above the present water line. The valley systems in the hinterland were drowned and even in these hand-shaped drowned-valley-bays the circumstances were favourable for reef growth.

After this final stage the sea level lowered and the upper part of the Lower Terrace sediments came above sea but the low level prior to the Lower Terrace transgression was never reached and large parts of the hand shaped valley systems are still filled with sea-water.

Considered as a whole, the series of terraces indicates that Quaternary eustatic sea level changes were superimposed on a slow, vertical and upward movement, not only of the island of Curaçao, but also of the islands Aruba and Bonaire where terraces of identical nature occur at the same levels as in Curaçao.

The limestones of the coast-ranges along the south-western sides of the islands, although of completely different facies, nature of deposition and partly also older (Neogene), show the same effects of a slow, vertical upward movement of the islands. These leeward coast-ranges consist of erosional remnants of emerged reef talud deposits. They never contain reef corals in position of growth but only show the detritus of such hermatypic reefs, often mixed with pelagic organisms.

They show a chaotic arrangement of the reef detritus, a bedding that may be followed in the direction of the strike only over short distances, and nearly everywhere have a seaward dip of the
stratification. These dips are mostly between 10° and 25°, but sometimes up to 32°, the maximum angle of repose of unconsolidated detritus.

The limestones of the leeward sides of the islands are deposited from slumping reef detritus. Reef growth near sea level along the shore continuously brought masses of unconsolidated material in an unstable position and ever and again submarine slumps occurred, adding new strata to the reef talud deposits far below sea level (Zonneveld, 1960; de Buisonjé, 1974). Especially in the younger parts the deposits contain pebbles derived from the non-calcareous older formations. From paleontological and paleoecological data it is concluded that the island has been rising since late Miocene of Pliocene times (de Buisonjé, 1974).

The Quaternary eustatic sea level changes that are (together with the vertical, upward movement of the islands) the main causes for the terrace development along the windward shores, left only minor effects in the emerging reef talud deposits along the leeward shores. Here in places erosional terraces were truncated at levels identical with those of the accumulation terraces from the windward coasts. Only the two lowest terraces have here a partly depositional nature (Fig. 1).

THE AREA OF CARACASBAAI

Main features of the Caracasbaai area are the relatively high erosional remnants of the limestone coast-range, such as the Seroe Mansinga (47 m) to the north-west and the Kabrietenberg (80 m), Seroe Boca (81 m) and the Tafelberg Santa Barbara (196 m) to the south-east of the Caracasbaai, dominating over the low, gently undulating landscape landinward and the inland bay of Spaanse Water with its natural entrance between the Kabrietenberg and Seroe Boca (Fig. 2).

The limestone coast-range south-east of the Caracasbaai shows a completely normal development: flat-iron shaped erosional remnants of emerged reef talud deposits with their seaward dipping top surfaces and basal planes and a slightly steeper dip of the
stratification. Along the lower, seaward side of the Tafelberg Santa Barbara the effects of the slow regressions and transgressions, main causes for the four terrace depositions in the windward coast-range, are here, along the leeward side of the island, discernible as well: two erosional surfaces, truncated at 100-110 m and about 60 m from the 20° seaward dipping reef taluds and two depositional terraces at 20-45 m and 10 m, the Middle and Lower Terrace respectively.

In the Seroe Boca and the Kabrietenberg the Middle Terrace is largely of an erosional nature and in the Seroe Mansinga Middle Terrace deposits are completely lacking. Lower Terrace deposits are completely absent along the Caracasbaai itself and from the south-western side of Seroe Mansinga.

The triangular (flat-iron) shape of the erosional remnants of the coast-range is caused by the strong subaerial erosion, attacking the dipping limestone beds from the land-inward side and especially from erosional gullies draining the interior. The volcanics are much less resistant and therefore show strongly degraded forms in the hinterland.

The strong difference in subaerial erosion resistance between volcanics and limestones is also demonstrated by the presence of the inland bay of Spaanse Water. This drowned valley system with its small peninsulas all directed towards the natural outlet to open sea, shows the place where several rivulets (so-called 'rooien') came together and in combined effort remained in connection with open sea throughout late-Neogene and Quaternary times.

During the high sea level at the end of the transgressive Lower Terrace development the slightly meandering natural outlet of Spaanse Water, situated between the Kabrietenberg and Seroe Boca was the only connection with the open sea and possessed a depth of about 25-30 metres. In the inland bay reef growth occurred along the tips of peninsulas and small inlands close to the natural outlet of the bay (Fig. 2).

The Caracasbaai itself with its open front of 1 km in width and its maximum depth of 250 m is not a ‘normal’ feature in the coastal landscape. There are several reasons for supposing that it was formed by a giant slide, during which a huge block of the limestone coast-range slid down into the adjacent sea.

The above-mentioned distribution of the Lower Terrace development inside the Spaanse Water offered an important clue for the presumption that the Caracasbaai was still occupied by limestones
of the leeward coast-range even in rather recent times. The topographic situation indicates that at the end of the Lower Terrace development (dated as less than 31,300 ± 500 yrs. B.P.; see de Buissonjé, 1974) no open connection existed between the north-western part of the Spaanse Water and the open sea, other than via the natural connection between the Kabrietenberg and Seroe Boca; should the Caracasbaai have been present in that time, Lower Terrace development surely would have been concentrated in this north-western part of the Spaanse Water and in the Caracasbaai itself.

Is this connection it is worth mentioning that according to Simons (1868, p. 36) the dam, connecting the Kabrietenberg and Fort Beekenburg with the main island of Curacao near Brakke Put was originally an artificial one, made as a defensive work against enemy ships attacking Curacao. The name Caracasbaai comes from the Dutch word ‘kraak’ or English ‘carrack’, ‘carack’ or ‘carac’, rather large ships used during the 16th and 17th century, mainly by the Spaniards and Portuguese. It was much easier to enter the wide Caracasbaai than to enter the meandering natural outlet of the Spaanse Water between the Kabrietenberg and Seroe Boca, especially with larger sailing-vessels.

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**Fig. 1.** Schematic cross-sections of the limestone coast-ranges of Curaçao.

**Fig. 1.** Schematische dwarsprofielen van de kalksteen-kustgebergten langs de loefzijde en lijzijde van Curaçao.
A second argument for a sub-recent development of the Caracasbaai may be found in the straight cliff, bordering the north-western side of the bay and possessing an almost vertical submarine continuation to a depth of about —250 m. This vertical cliff, or properly speaking fault-escarpment, over a horizontal distance of 1000 metres perpendicular to the main coast line of the island, cuts off the limestone coast-range over its entire width (Fig. 3-5).

From soundings in the Caracasbaai it was already known in 1956 that the maximum depth of —250 m is reached close to the seaward limit of the escarpment near Lijhoek. The steep submarine gradient of over 70° indicated that here, in the lower parts of the escarpment, only hard rocks are exposed because the maximum angle of repose of unconsolidated material never exceeds 32°. In its turn, this steep, almost vertical continuation to such a depth excludes the possibility that the escarpment originated from normal marine cliff development or from terrestrial erosion, for any indication of previous sea levels below the —25 m depth line are absent in the bays from Curacao.

In another way too, the straight escarpment near the Caracasbaai shows effects that are not normal in the leeward limestone coast-range. In Fig. 5 these effects are visible: the dips of the stratification are mostly land inward and several faults dissect the limestones. These steep faults are inclined seawards and near the land-inward limit of the escarpment a saucer-shaped limestone deposit cuts off older limestones.

The limestone blocks between the steep faults and also the saucer-shaped deposit are all truncated by the slightly seaward dipping top surface, reaching a maximum height of 47 m above sea level.

Now all the reef talud deposits elsewhere in the islands have a seaward dip of the stratification; Seroe Mansinga is the only exception.

Perhaps this situation indicates that the original submarine reef talud deposits of the Seroe Mansinga — including those that were present in the place now occupied by the Caracasbaai — might have been involved in a minor submarine slide after which they got a new and more stable position with land-inward directed dips and were dissected by steep faults, long before they emerged. Later they were truncated at the time that elsewhere the Middle Terrace (20-45 m) was deposited (de Buisonjé, 1974). Only after the final stage in the Lower Terrace development the south-eastern part of the temporarily stable mass of Seroe Man-
singa-Caracasbaai was again involved in a movement: the Caracasbaai development.

A third argument for the conclusion that the Caracasbaai is the result of a sub-recent slide, may be seen in the surroundings of Fort Beekenburg at the eastern side of the Caracasbaai. The fortress was built on top of a huge limestone block lying in the shore-line and protruding about 17 m above sea level. The block apparently is part of a limestone slab, dipping in N and NE directions and broken into a number of more or less square blocks that are now separated by steep vertical clefts, each several metres wide. About 200 m N of Fort Beekenburg a much more irregular accumulation of large blocks gives the impression that some giant dices have been thrown around (Fig. 3 and 6).

In size the blocks resemble those found scattered elsewhere in the islands in the foot hills along the land inward erosion escarpments of the limestone coast-ranges. But here, near Fort Beekenburg they are found in a greater number. They are clearly derived from a larger continuous limestone cover, but the cover itself is lacking from the scenery.

In another way too the blocks give some information. Some of them, especially the larger ones, have a strong development of a typical karst surface on top, exactly in the same mature state of development as old karst surfaces elsewhere in the higher parts of the limestone coast-range. Blocks in a tumbled position show their original karst surface in one of the side-walls (Fig. 7-8), but on their present top surface not the slightest trace of newly formed karst is found. This is again an indication that the blocks got their present position only in sub-recent times.

A fourth argument for a sub-recent and sudden development of the Caracasbaai is found in the same area. The Lower Terrace deposits, encircling almost completely the islands of Curaçao and Bonaire, are lacking completely even from otherwise favourable spots along the Caracasbaai and from Seroe Mansinga. Any indication of the former sea level at + 10 m, especially the development of a solution notch (de Buissonjé & Zonneveld, 1960; de Buissonjé, 1974), is not only absent in the escarpment along the north-western side of the Caracasbaai, but is also lacking in the Ford Beekenburg blocks, again pointing to a young (post Lower Terrace) date for the Caracasbaai slide.
During the international program of the Cooperative Investigation in the Caribbean and Adjacent Regions (CICAR), from 1970 to the end of 1972, the hydrographic vessel 'H. Nl. M. S. Luymes' of the Royal Netherlands Navy was stationed in the Caribbean, enabling detailed scientific research in the areas around the Netherlands Antilles and north of Surinam, areas previously only superficially known. One of us (de Buisonjé) had the opportunity to take part in the investigations in the Curaçao area.

The 'Luymes' was equipped with a Kelvin Hughes Precision Depth Recorder (PDR), type MS 38 F/M Mk 1, a smaller echosounder, type MS 36 M/A Mk 1 and on board of one of the motor launches an echosounder, type MS 26 F was installed. All instruments were calibrated at 1500 m/sec and the two instruments on the 'Luymes' corrected by 4 m for the draught.

With a specially designed winch, steel wire and a bottom sampler of the Van Veen type or of the steel pipe piston corer type it was possible to take samples under simultaneous registration of echosounding profiles on the PDR.

In the day-time a continuous position fixation was enabled by a DECCA-system and two DECCA-stations in the islands, later on they were moved to the shore of the South-American mainland. During the night, owing to nocturnal fluctuations in the wave-length of the DECCA-system, only visual bearings on landmarks in the islands, together with RADAR-distances could be used for position fixation. For this reason the echosounding registrations in large runs, mainly more or less perpendicular to the coast lines of the islands, were made exclusively during the day-time. Sampling of the sea-bottom was largely done at night and in places where points of special interest showed in the previously made echosounding profiles.

During the sampling operations so-called 'drifting stations' were used. The 'Luymes' then was left drifting (with the speed zero or with stopped engines) in a westward direction (course 270) by the constant, mostly due eastern trade-wind.

Echosounding profiles, taken when the ship with a normal speed of about 12 knots and in eastward direction (course 090) headed for a sampling station, gave information beforehand over the stretch of the sea-bottom that would be passed afterwards during the drifting sampling station. From such additional profiles the exact moment to let run out the steel wire with the sampling apparatus could be chosen and during the sampling a reversed echosounding profile was obtained, this time with an almost equal vertical and horizontal scale, due to the slow drifting speed of about one nautical mile an hour.
Finally attention must be drawn to the steep-sided, longitudinal diabase hill, present immediately north-east of Fort Beekenburg (see Fig. 3). The top of this hill is about 17 m above sea level and the north-eastern side steeply descends to the water of the inland bay of Spaanse Water. Diabase hills of this height and with such steep sides do not occur elsewhere around the Spaanse Water and the steep-sided hill near Fort Beekenburg is considered to represent an erosional remnant of the steep foot slope behind the land-inward side of the limestone cover that up to a sub-recent date occupied the place of the present-day Caracasbaai.

All these observations support the assumption that after the final stage in the Lower Terrace development a part of the coast-range slumped down in a direction perpendicular to the coast, in such a way that an open connection was formed between the Spaanse Water and the sea west of the Kabrietenberg.

Only in the eastern part of the Caracasbaai area a small remnant of basal limestones was conserved and the underlying volcanics did not take part in the movement. Immediately south-west of the line where the basal slump plane must intersect the surface, two slabs of limestone, each broken into large blocks, are left dipping in directions that are not the original ones. A chaos of tumbled limestone blocks is lying upon what might be the remnant of the footslope of a former limestone escarpment.

The echo-soundings in the Caracasbaai itself give the impression (see Fig. 12) that south-west of Fort Beekenburg another rockmass was stuck in a somewhat lower position, its top about 30-30 m below sea level.

Later a shingle beach and an artificial dam were built in the shallow water between the newly formed Caracasbaai and the Spaanse Water.

**INVESTIGATIONS OFF-SHORE FROM CARACASBAAI**

The final evidence for the conclusion that this bay owes its existence to a catastrophic slide is given by the results of the offshore investigations.
RECENT AND SUB-RECENT CORAL SHINGLE, BEACHROCK OR RAMPARTS
LOWER TERRACE
MIDDLE TERRACE
HIGHER TERRACE
HIGHEST TERRACE
SEROE DOMI FORMATION: REEF TALUDS WITH ADMIXTURE OF TERRIGENOUS DETRITUS
CURACAO LAVA FORMATION: ALTERED BASALTS (DIABASES), STRONGLY WEATHERED
NEOGENE AND PLEISTOCENE
CRETACEOUS
ALTITUDE AND ISOHYPSES IN METRES
COASTLINE AND INLAND BAY WITH SALT PANS
MARINE CLIFFS ELEVATED AND RECENT

Fig. 2. Geology of the Caracasbaai-area, Curaçao.
EDGE OF CUESTA OR OTHER STEEP SCARP FORMED SUBAERIALLY

LIMESTONE SURFACE:
- a. HORIZONTAL
- b. DIP <5°
- c. DIP >5°

BEDDING DIP IN DEGREES SEXAGESIMAL SYSTEM

Fig. 2. Geologische kaart van de omgeving van de Caracasbaai, Curaçao.
Fig. 3. *Vertical aerial view of the Caracasbaai, Curacao.* — Left the Seroe Mansinga, consisting of elevated Neogene reef talud limestones, with an almost vertical fault escarpment separated from the Caracasbaai which reaches a depth of over 250 m near the centre of the photograph. — In the upper right corner two broken slabs of reef talud limestone are visible, remnants of the huge limestone deposit that occupied the place of the present Caracasbaai up to sub-recent time. — Fort Beekenburg (arrow), a 17th century fortification, has been built on the southernmost slab which slid down and slightly rotated. East of Ford Beekenburg a chaos of tumbled limestone blocks. — Note the steep-sided, longitudinal diabase hill, running north-south near the tanks, between the two roads, north-east of Ford Beekenburg.

Fig. 3. *Verticale luchtfoto van de Caracasbaai, Curacao.* — Links de Seroe Mansinga, bestaande uit opgeheven Neogene rif-puinkalken, door een vrijwel verticale breukwand gescheiden van de buitengewone diepe Caracasbaai die bij het midden van de foto een diepte van meer dan 250 m bereikt. — In de rechter bovenhoek zijn twee grote schollen rif-puinkalk zichtbaar. Dit zijn niet geheel mee-gezakte restanten van een enorme kalksteen-afzetting die tot subrecente datum de plaats innam van de huidige Caracasbaai. — Fort Beekenburg (pijl), een 17de eeuws verdedigingswerk, is gebouwd op de zuidoostelijke schol, welke afgegleden en zwak gedraaid is. Oostelijk van Fort Beekenburg een opeenhoping van losse kalksteen blokken. — Let ook op de van steile flanken voorziene, noord-zuid verlopende diabaasrug nabij de tanks, noordoostelijk van Fort Beekenburg tussen de twee wegen.
Fig. 4. *Seroe Mansinga, oblique aerial view* (1960). — The Neogene reef talud limestones of the *Seroe Mansinga*, left, are cut off over their total width by a straight and almost vertical fault escarpment. — In the right upper corner an artificial dam connects the diabase mainland in the background with the island on which some oil reservoirs are visible. — Lower Terrace deposits, almost completely encircling the island of Curacao, are lacking in these surroundings.

Fig. 4. *Seroe Mansinga, oblique luchtfoto* (1960). — De Neogene rifpuinkalken van de *Seroe Mansinga*, links, zijn over hun volle breedte afgesneden in een rechtlijnige en vrijwel verticale breukwand. — Een kunstmatige dam, zichtbaar in de rechter bovenhoek, verbindt het centrale diabaas-landschap in de achtergrond met een eiland waarop nog juist enkele olie-reservoirs te zien zijn. — Laagterras-afzettingen die vrijwel het hele eiland Curacao als een gordel omgeven, ontbreken hier geheel.
Fig. 5. Seroe Mansinga, horizontal view (1960). — Strong disturbances of the originally seaward dipping talud deposits, afterwards almost horizontally truncated in Middle Terrace time, seem to indicate that the deposits of Seroe Mansinga were involved already in an earlier sliding movement. — Only in sub-recent time the disappearance of a huge limestone block exposed the straight, about 1000 m long fault escarpment in this photograph.

Fig. 5. Horizontale blik op de Seroe Mansinga (1960). — Sterke verstoring van de oorspronkelijk zeeuwaarts gerichte helling der rifpuinkal- ken, die later vrijwel horizontaal werden afgesneden in Middenterras-tijd, tonen aan dat de afzettingen van de Seroe Mansinga reeds vroe- ger betrokken waren in een aflijdingsbeweging. — De ongeveer 1000 m lange breukwand van deze foto werd pas zichtbaar toen in subre- cente tijd een enorm kalkstenblok verdween.
Fig. 6. Caracasbaai, seen from the Kabrietenberg (1960). — In the foreground the very shallow water of the Spaanse Water, separated from the extremely deep water of the Caracasbaai by a series of scattered limestone blocks. These blocks are vestiges of the huge reef talud deposit, formerly present between the Kabrietenberg and Seroe Mansinga in the background. — Fort Beekenburg (arrow), is built on one of the scattered limestone blocks, lying on the present shore.

Fig. 6. Caracasbaai vanaf de Kabrietenberg (1960). — Op de voorgrond het zeer ondiepe water van het Spaanse Water, gescheiden van de buitengewoon diepe Caracasbaai door een reeks verspreid liggende kalksteenblokken. Deze blokken zijn restanten van de enorme rifpuin-afzetting die vroeger aanwezig was tussen de Kabrietenberg en de Seroe Mansinga op de achtergrond. — Fort Beekenburg is gebouwd op één der blokken liggend aan de huidige kust.
Fig. 7. Some of the large limestone blocks in the immediate vicinity of Fort Beekenburg (1956). — Note the mature karst surface, now in an abnormal vertical position in the block on the left side. — Dripstone striae, originally deposited in a vertical cleft, are now in a horizontal position. — A new karst surface has not yet developed on the present top surface of this block. — Note also the absence of a horizontal solution notch in the blocks, elsewhere an accompanying effect at the + 10 m level during the final stage in the Lower Terrace development (the level of the road is only 2 m above sea level).

Fig. 7. Enkele van de grote kalksteenblokken in de directe omgeving van Fort Beekenburg (1956). — Let op de ver voortgeschreden karstontwikkeling die nu in een abnormale positie zichtbaar is in de verticale wand van het blok links op de foto. — Op de huidige topvlak van dit blok heeft zich nog geen nieuw karstoppervlak ontwikkeld en zijn zelfs de oorspronkelijk in een verticale spleet gevormde druipsteenlijsten nog aanwezig. — Let ook op het ontbreken van een horizontale oplossingsnis in de blokken, overal elders een begeleidingseffect op + 10 m niveau uit de slotfase van de Laagterraas-ontwikkeling (de weg op de voorgrond ligt slechts 2 m boven zeeniveau).
Fig. 8. *Detail of the preceding photograph* (1956). — The mature karst surface with consolidated, reddish brown weathering products still present in the originally vertical solution depressions, together with complete absence of newly developed dripstone, indicates that the whole limestone block got its present position only sub-recently.

Fig. 8. *Detail van de vorige foto* (1956). — Dit in ver voorgeschreden stadium verkerende karstoppervlak met de roodbruine verweringsproducten die nog aanwezig zijn in de oorspronkelijk verticale oplossingsholten, samen met een totaal ontbreken van nieuwe druipsteenvorming, tonen aan dat het blok pas in subrecente tijd in zijn huidige positie kwam te liggen.
Fig. 9. *Echo sounding profile during deep sea sampling (C13-006).* — During this sampling the ship’s velocity was reduced to zero, only influenced by the almost due easterly trade wind. The drifting speed was about one nautical mile per hour (1800 m/h). As a result there is almost no vertical exaggeration in scale. The vertical line to the right indicates the start of the sampling operation, using a steel pipe piston corer. — The faint, oblique line indicated with three small arrows, seems to give a picture of the steel wire when the corer hit the bottom. The oblique line, however, is a result of the echo sounder, continuously giving reflexes from the massive piston corer during its descent along line C13-006, while the ship was continually drifting to the west. — The profile is nearly an exact copy of the vertically exaggerated profile L-L’ from Fig. 11.

Fig. 9. *Echolodening profiel tijdens bodembemonstering (C13-006).* — Gedurende de bemonstering was de vaarsnelheid tot nul gereduceerd en werd het schip alleen beïnvloed door de vrijwel pal oostelijke passaat. De verplaatsingsnelheid als gevolg van deze wind bedroeg ongeveer een nautische mijl per uur (1800 m/h). Hierdoor is er vrijwel geen verticale schaal-overdrijving in het profiel. De verticale lijn rechts geeft het begin der monstername aan, d.w.z. het begin van het afvieren der stalen valbuis. — De vaag zichtbare, scheve lijn, aangegeven met drie pijltjes, lijkt een beeld te geven van de staalkabel toen de valbuis de zeebodem raakte. De lijn is echter slechts het gevolg van de continue registratie door het echolodings-apparaat van de overigens verticaal langs lijn C13-006 afdaalende, massieve stalen valbuis, terwijl het schip gelijkmatig naar het westen afdreef. — Het profiel is vrijwel identiek aan het verticaal sterk overdreven profiel L-L’ van Fig. 11.
During the first night of CICAR-cruise 13, June 11th 1970, offshore from the Caracasbaai, without any detailed information on the sea-bottom morphology, a special procedure was followed. In order to obtain information on the sediments present in front of the Caracasbaai, a series of six samples was taken with the steel pipe piston corer. The sampling stations were situated in a semicircle around the Caracasbaai and at depths between 740 m and 880 m.

From this series five samples showed the presence of globigerina-oozes. The thickness of penetration of the piston corer in these unconsolidated oozes was between 24 cm and 124 cm, measured from the length of the recovered cores. In all five cases there was smear on the outside of the corer, in some cases over greater length than the core itself, indicating that the core was only partly recovered.

As was shown during sampling later on in CICAR-cruise 13, and will be discussed in a future paper, the globigerina-oozes are the normal sediments below the 200 m depth line around the islands and in exceptional cases, where recent or sub-recent slides had occurred, detritus of hermatypic reefs was found at larger depths, in some cases even below the 1000 m depth line. In such exceptional cases the detrital reef sediments are always unconsolidated.

But from the six samples taken in front of the Caracasbaai one was of completely different nature. It consisted of a few hardrock-fragments of a conglomeratic limestone containing diabase pebbles and hermatypic coral detritus, and further some broken recent deep sea corals, fragments of recent deep sea silica sponges and some recent globigerinids and other small pelagic foraminifera. The piston corer did not show any outside smear and the sharp cutting edge of the steel pipe was badly damaged, indicating that hard rock was hit by the corer.

The conglomeratic limestone from this sixth sample (CICAR 13-006; position 12-00.6 N, 68-52.3 W; depth 880 m) is identical with the limestones exposed in the Seroe Mansinga along the north-western side of the Caracasbaai. Here consolidated detritic reef talud limestones occur, containing well-rounded diabase pebbles, derived from the hinterland, mixed with rounded fragments of hermatypic coral colonies, algae and other lime-secreting neritic organisms.

From the echosounding profiles taken during sampling it was clear that sample CICAR 13-006 was derived from the deepest
Fig. 10. Series of four echo sounding profiles. — The profiles are taken with the aid of a Kelvin Hughes precision depth recorder, type MS 38 F/M Mk 1. The positions of the profiles are given in Fig. 12. — Profiles are from the upper part of the broad scar caused by the huge limestone block of the Caracasbaai, sliding down-slope in unconsolidated globigerina-oozes of the island talud. — The width of the scar is about 1 km, indicated with a black line; depths are in metres. — Note the extremely flat bottom of the scar profile D-D' and F-F' and the relatively high western side of the scar in profile B-B'. As a result of the ships velocity of about 10 knots, the vertical exaggeration is about 10 times the horizontal scale.
Fig. 10. **Reeks van vier echolodings-profielen.** — De opnamen zijn gemaakt met een Kelvin Hughes precisie echolodingsapparaat, type MS 38 F/M Mk 1. De plaats waar de profielen zijn genomen is aangegeven in Fig. 12. — De profielen zijn van het hogere deel der brede geul, als een lidteken achtergelaten door het enorme kalksteenblok van de Caracasbaai dat omlaag gleed in de niet-verkitte globigerina-slikken van de eiland-flanken. — De breedte van de geul is ongeveer 1 km, aangegeven met een zwart getrokken lijn; diepten zijn in meters. — Let ook op de buitengewoon vlakke bodem van de geul en de relatief grote hoogte van de westelijke begrenzing in de profielen B-B', D-D' en F-F'. Door de vaar-snelheid van ongeveer 10 knopen is de verticale schaal ongeveer 10 x overdreven ten opzichte van de horizontale schaal.
point in a submarine depression with a V-shaped cross-section (Fig. 9).

Only the next day, when the sea-bottom morphology off-shore from the Caracasbaai became more accurately known from a large series of echosounding profiles (Fig. 10-12), it became evident how extremely lucky this sixth 'shot in the dark' had been. Sample CICAR 13-006 had exactly hit the deepest point of a V-shaped erosional canyon, the continuation of a large, broad scar present in the sea-bottom in front of the Caracasbaai.

In Fig. 12 the runs of the echosounding profiles are given and part of the constructed depth lines are indicated. The figure shows that over a distance of about 5 km from the coast of Curaçao, exactly in front of the Caracasbaai, a huge scar is excavated from the sea-bottom. This scar has in its upper course an extremely flat bottom and a width of 1000 m. The scar is situated about 150 m below the surrounding level of the sea-bottom and has steep sides.

At a distance of about 2 km from the Caracasbaai the direction of the scar slightly alters from N 220 E in its upper course to N 195 E in its lower part. At the same point the eastern side of the scar diminishes in height.

Between 4 and 5 km from the Caracasbaai the steep western side of the broad scar also diminishes in steepness and moreover clearly shows a gradual change in direction, more to the south-south-east.

At about 6 km from the Caracasbaai the sides of the broad scar merge into the sides of a V-shaped submarine canyon, continuing in a direction N 150 E. Sample CICAR 13-006 was situated exactly in the central axis of this V-shaped canyon.

From the shape of the cross-section of the scar in the sea-bottom between Lijhoek and a point situated about 4 km to the south-south-west it is concluded that up to this point the sliding limestone mass from the Caracasbaai acted as one single unit, possibly of an asymmetrical shape. A slide, consisting of several individual smaller quantities or several smaller slides separated by time intervals, would never have caused a scar with such a flat bottom but would probably have resulted in a series of V-shaped canyons already close to the shore. The flat bottom of the scar in its upper part, together with its width being identical with the width of the open front of the Caracasbaai, are arguments for the idea that the sliding Caracasbaai limestone block was a very large...
That the sliding block possessed an asymmetrical shape is not only indicated by the shape of the Caracasbaai itself, having a straight and steep, nearly vertical boundary along the northwestern side and a less steep, more gently curved eastern side (where at least three slumped limestone slabs were stuck), but is also indicated by fact that the scar in the sea-bottom shows a steep, clearly defined western side and a less pronounced eastern side.

It seems probable that the asymmetrical shape and hence an excentric gravitational mass centre, situated in the western half of the sliding block, together with an unequal distribution of drag forces exerted on the block when excavating the flat bottomed scar, also caused a rotation in a clock-wise sense. Such a clock-wise rotation is not only considered the main cause for the change in direction of the broad scar but is also held responsible for the scattering of the block into several smaller fragments, somewhere between 4 and 6 km from the Caracasbaai. Breaking up of the block was moreover facilitated by steep vertical faults, already present in the Caracasbaai-block as a result of the earlier movements of which the limestones in the Seroe Mansinga still bear testimony.

That some of the smaller block fragments remained in the central axis of the V-shaped canyon is conceivable and from the fact that the piston corer hit one of these fragments, follows again an argument in favour of a sub-recent date for the Caracasbaai slide. For if the slide had occurred long ago, the fragments of the original Caracasbaai-block, even when they had dimensions such as those exposed along the shore near Fort Beekenburg, would have been covered by a thick layer of globigerina-ooze, deposited afterwards from normal pelagic sedimentation.

In view of the possibility that the broad scar in the sea-bottom left by the sliding block of the Caracasbaai is a stretch where conglomeratic limestones are stripped of a covering layer of unconsolidated globigerina-oozes, some 150 m in thickness in that case, three additional samples were taken. CICAR 13-016 and CICAR 13-017 taken from the broad scar at depths of 602 and 724 m respectively, both indicated the presence of globigerina-oozes only. The third sample CICAR 13-018, depth 780 m, taken from the western side of the broad scar but outside the scar proper, again consisted of unconsolidated globigerina-ooze.
Fig. 11. Series of three echo sounding profiles. — Continuation of the series on Fig. 10. In profile H-H' the height of the western side is still about 100 metres, but in the next profile this height diminishes. — In profile L-L' the shape of the cross section, originally with a flat bottom and steep sides, is changed into a V-shaped erosional canyon. The deepest part of this canyon, here shown with a vertical exaggeration of 10 : 1, is almost identical with the profile from Fig. 9, taken during sampling of C13-006.
Fig. 11. *Reeks van drie echolading-profielen.* — Voortzetting van de reeks van Fig. 10. In profiel H-H' is de hoogte van de westelijke begrenzing van de geul nog omstreeks 100 m, maar in de daarop volgende profielen neemt deze hoogte af. — In profiel L-L' is de dwarsdoorsnede der geul, oorspronkelijk met vlakke bodem en steile flanken, overgegaan in een V-vormige erosie-geul. Het diepere deel van de geul, hier met een verticale schaal-overdrijving van omstreeks 10 ×, is vrijwel identiek aan het profiel getoond in Fig. 9 en daar opgenomen tijdens de monsternam C13-006.
Fig. 12. Detailed bathymetry off southern Curacao.

Fig. 12. Gedetailleerde dieptelijnenkaart zeeuwards van de Caracasbaai, Curacao.
Fig. 13. Bathymetry off southern Curacao.

Fig. 13. Dieptelijnenkaart van zuidelijk Curaçao.
We assume that the block slid down the slope into a pre-existing gully system and that the smaller fragments, after scattering of the block, used and perhaps also deepened a minor branch that was present in the Caracasbaai area (Fig. 13). As to the dimensions of the sliding block it can be stated that the rock mass, now lacking from the coast-range had an upper surface of about one square km and a thickness of approximately 45 m along the inward side and a thickness of about 250 m along the shore.

The amount of rock involved (mostly limestone with some volcanic basement) is estimated at 150 million m$^3$, representing a weight of some 375 million tons. The amount of unconsolidated off-shore sediments, set in motion by the sliding block when it carved out the scar, was a multiple of this amount and may be estimated at 700 million m$^3$ with a weight of some 1,400 million tons.

Perhaps the greater part of it has been (re-)deposited in the fan like form south of samplepoint C 13-018 between 750 and 900 m depth (Fig. 13).

When taking into consideration the sudden character of the event, the effects on land must have been of a catastrophic nature. It is most probable that during the slide a withdrawal of seawater took place, closely afterwards followed by a huge wave, a tsunami that swept over south-eastern Curacao and probably inundated a large part of the hinterland. It is possible that this huge wave was responsible for the disappearance of the Lower Terrace between the Caracasbaai and Cornelisbaai to the northwest, this stretch of the coast over a length of about 3 km lying exactly in a landward direction from the lower, V-shaped erosional canyon.

**DATING THE EVENT**

From three radiometrically 14C dated shell samples of the Lower Terrace limestones, the youngest has an age of 31,300 ± 500 yrs. B.P. (*de Buisonjé*, 1974). The emergence of the Lower Terrace took place only after this date. Together with the observation that any dissolving action or formation of notches at the +10 m level (normal effects in cliffs or limestone blocks during the final phase in the Lower Terrace development elsewhere) is lacking from limestones exposed near the Caracasbaai and that moreover newly
formed karst surfaces are lacking in the tumbled blocks near Fort Beekenburg, the sliding event may even be dated much less remote in time, for instance within the last 10,000 years.

Accepting such a recent date for the event, we arrive at the possibility that the earliest Indians in Curacao, dated at a maximum age of about 7,000 yrs. B.P. (Du Ry, 1960; van Heekeren, 1960, 1963), may have been witnesses of the catastrophe.

In this connection it is worthwhile to mention two folk-tales that may have a bearing on the case.
The first one is of Indian origin and is told in the South-American mainland (pers. comm. Ds. J. Mietes). It holds the following story:

"In a remote time groups of violent and combative Indians, coming from more northern dwelling-places, settled along the northern coast of the South-American mainland, killed the inhabitants or chased these more peaceful-minded Indians into the more inland mountainous regions. From this time on constant fights and quarrels with the dangerous immigrants took place and at last enraged the Indians in the mountains to such an extent that they called a meeting of their chiefs, a meeting in which the oldest chief was asked to do something to prevent or to stop the continuous troubles with the new-comers.

— Now the Indians from the mountains were really peaceful people! So their oldest chief nodded to his friends, took his sharp and long knife, saddled his celestial riding horse (sic!) and disappeared into the sky in a northern direction, not in order to kill his enemies but only to draw with his knife a long and deep furrow between the mountainous region and the coastal lowlands. And what happened? An enormous landslide took place, separating the coastal area with the inhospitable immigrants from our friendly people in the mountains. — You do not believe this story? Well, the results of this occurrence are still visible from our mainland. Go to the coast and look to the north. You will still see the results of this landslide: the Caribbean islands, each with its surface still dipping in the direction from where this slide started!"

Although this story is in sharp contrast with the results of geological investigations in the islands of Curacao, Aruba and Bonaire it has always struck the present authors, not only because it contains some correct statements in an anthropological sense and gives expression of a sharp vision on the effects of landslides in general, but especially because it mentions the possibility of a sliding event in which a coastal part — be it of smaller size than the whole island of Curacao — disappeared into the ocean.

The second folk-tale is very popular in the Netherlands Antilles. It contains a more or less menacing warning to the listener:

"You know our island has the shape of a mushroom. Surely, it has a rather large surface, but below sea-level it only has a small stalk. So never go with too many friends to one side of the island for then we all are in danger that the stalk will break and the whole island will vanish into the deep ocean around!"
The fear for such a catastrophe was mostly concealed by putting the story in an interrogative sentence. Even in a radio interview the question 'Is this story true?' was put to us.

One could suppose that Palaeo-Indians, living several thousands of years ago in Curacao actually witnessed the Caracasbaai slide and that this event lived on in the folklore. But it is more probable that the background of the story is as follows:

Limestones, whether exposed in marine cliffs or as blocks, broken from cliffs and surrounded with sea-water, in tropical or subtropical areas often get a deep, horizontal solution notch, exactly at mean sea-level, with an overhanging rim. When looking at such a block or coast we immediately compare it with a 'mushroom' and why should such a mushroom-shape not be present in our limestone-island as a whole? It is significant that the same folklore also exists in areas with coral islands in Indonesia!

THE PROBABILITY OF NEW CATASTROPHIC EVENT

It can be stated that slides of a size as observed near the Caracasbaai are very rare occurrences. Over large stretches the coast-ranges are almost continuously developed and only show gaps, where erosional products from the hinterland are transported via normal, originally fluvial breaks to the open sea.

During extensive studies on reef talud limestones exposed elsewhere in the islands of Curacao, Aruba and Bonaire, only two or three other examples were observed in which limestone hard-rock masses were involved in submarine slides. In all other cases only slides of unconsolidated reef materials were observed, indicating that normally only the outer parts of reefs are involved in the slide, leaving the coast proper unaffected.

Two cases of sliding hard-rock, probably derived from an exposed position, above sea-level, are situated in Curacao.

The first was observed in the seaward dipping reef talud deposits of late-Neogene age found near Blauwbaai where blocks of a detrital reef-limestone occurred in their turn as detritus among the chaotic elements in an otherwise normal reef talud deposit. The date of this event, in which probably limestones from above sea-level were involved in the slide, can be placed in late-Neogene time, at least several millions of years ago.

The second case is found in the Veerisberg. This flat-iron shaped erosional remnant of the coast-range near Piscaderabaai is dissected into two parts, separated by a nearly vertical fault, perpendicular to the coast line, running from the top to the lower,
seaward side of the mountain. The two parts are of unequal thickness, have different basal levels and different top levels. There are indications that the fault between the two blocks became gradually wider during differential, submarine movement of the two blocks. The date of this sliding differential movement can be placed as far back in time as at least several hundred thousands of years, possibly even millions of years ago.

Perhaps the queer, semi-circular Lower Terrace development in the Karpata area (Bonaire) is also the result of a niche left by a slide. It has partly been filled up by Lower Terrace deposits and must therefore have been formed more than 30,000 years B.P.

Summarizing, it can be stated that a catastrophic slide of the size as depicted for the Caracasbaai, occurs with a probability of roughly one in several hundred thousands or even millions of years, a probability far below the risks for instance on a large landslide or an explosive volcanic eruption.

To the rule that Curacao and the other two islands are geologically safe and 'firm as a rock' only one exception must be made. The limestones exposed in the Seroe Mansinga, as discussed above, most probably are of exactly the same nature as those involved in the Caracasbaai slide and are still in a relatively unstable position.

The presence of several steep seaward dipping faults in the limestones of Seroe Mansinga, the knowledge that an abnormal depth of over 200 m is reached within 150 m from Lijhoek and the sub-recent geological history of the Caracasbaai may be arguments for regarding this area as potentially unstable. Although we are of the opinion that taking risks is associated with and even necessary in human life, we can assure the reader that during sampling of the limestones near Seroe Mansinga and more especially when standing on the extreme tip near Lijhoek, teetering the rocks slightly tremble under the impact of the waves, we felt that this point, despite its fine views and the magnificent landscape is not a good spot for building holiday houses, hotels or other constructions!

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