Matters of interest concerning

THE EVOLUTION OF THE NATURAL ENVIRONMENT OF BELIZE

A SERIES OF LECTURES PREPARED FOR BELIZEANS

BY

THE BELIZE ZOO AND TROPICAL EDUCATION CENTER

P.O. BOX 1787
BELIZE CITY
BELIZE
CENTRAL AMERICA

(FEBRUARY 1995)
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These lectures have been prepared to help you think about matters which may have influenced the evolution of our Belizean natural environment: geology, soils, vegetation, land use, and wildlife preservation.

The topics discussed include:

1. The Geological History of Belizean landscape.
2. Evolution of the soils of Belize.
3. Evolution of the natural plant cover of Belize.
4. Possible changes in the vegetation induced by land use systems of the ancient Maya.
5. Wildlife surviving in the present Belizean environment.
   (a) Amphibia and reptilia
   (b) Birds
   (c) Mammals

The text for each topic is published as a separate chapter. This publication is Chapter 1: The Geological History of the Belizean Landscape. Education has to be an on-going process and as new knowledge and new ideas become available, our lecture texts will undoubtably be changing somewhat. For example, a new text may be needed for this present topic by 1996 or 1997, and to avoid the cost of republishing the whole volume of chapters as our education progresses, we would prefer to update the information, chapter by chapter. So, if you wish to keep up-to-date with an unfolding story, always check the publication date of your chapter. The date of this present chapter is February 1995.

It has been prepared by

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INTRODUCTION

Belizeans have inherited responsibility for looking after one specific sector of the earth’s crust. If we are to carry out this task effectively, we need to know about the geological history of our landscape, the evolution of our soils and the plant cover associated with them. We must also adequately evaluate the environmental forces that comfort or dismay the four- and two-legged creatures currently living in the Belizean geographic sector, which covers 22,963 square kilometres of land above mean sea level, and 23,675 square kilometres of land below mean sea level; giving a total of 46,630 square kilometres as the area of the earth’s crust for which Belizeans are responsible.

As the story unfolds you will note that quite a lot of scientific information is missing. That is because environmental research is a relatively new endeavour for Belizeans. To build up any kind of story at all, we have repeatedly had to draw on the scattered scientific data obtained by students and professors from overseas. The story we have concocted from such sources as we were able to locate is not expected to be the final one: it seems to fit most of the known facts, but as more research is carried out, the picture we present here must inevitably change somewhat.

The basic scientific discipline for the study of our landscape is Geology. We get most of the information for our Chapter One from the work of geologists.

CHAPTER 1

by A.C.S. Wright

THE GEOLOGICAL HISTORY OF THE BELIZEAN LANDSCAPE

As long ago as 1926, an Australian geologist, L.W. Ower, prepared the first map of the geology of British Honduras. He was followed in the 1950’s by Cecil Dixon (Scotland) and his assistant C.E. Cunha (British Guiana). Both spent eight years exploring the complex rock patterns of the Maya Mountains and the nearby Toledo District. During 1952 and 1953 I myself joined Dixon and Cunha in their camps along the Chiquibul and Machakela Rivers where amongst other things they were panning the creek for indications of gold. One day, on the top-most ridge of the Maya Mountains in this sector, we came across an unusual kind of rock. It looked like weathering granite but Dixon was suspicious and he took several samples. On my soil maps of that region I described the soils as being derived from "granitic rocks"; but reports from London where the rock samples were tested showed that they were an extrusive volcanic rock known as porphritic rhyolite. My soil report erroneously calling them "granite rocks" was written in 1954.
(published in 1959), but Dixon's correct information was published in 1956 in his book called *Geology of Southern British Honduras*. The *Geology of Northern British Honduras* by G. Flores was published in 1952, and geologists J.H. Bateson and I. Hall provided some additional information about the Maya Mountains in reports published in the early 1970's.

Currently, there are two geologists, Jean Cornec (French) and Robert J. Johnston (U.S.A.), working mainly in the Maya Mountains. I am very much indebted to these two for many of the facts in the story that now follows. One of the most helpful things they did was to introduce me to their geological time scale (Figure 1.) which shows the relative age of the different kinds of rocks, and the way geologists divide up the time scale into different ages and periods, each covering intervals of many millions of years. They also introduced me to a comparatively new geological concept called "plate tectonics" which allows geologists to visualise a large measure of mobility of fragments of the earth's crust. For example, Africa could be joined to, and later separated from, South America and even "supercontinents" could be formed for a time by many of the crustal plates jamming themselves into a single huge plate.

This new concept certainly stretches the imagination but you can quite easily get the idea if you ever watched your mother cooking marmalade or jam in a large saucepan. When she stirs in the mixture of crushed or chopped fruit into heating water, most of the lighter ingredients will come up to the top and form a crust. As the water begins to boil this crust breaks into floating islands which move around, often piling up in one corner. As the mixture gets hotter, boiling liquid comes up from below and separates the mass of crust into new islands which move away from each other, and some may come together again in another part of the pot. When this happens, they may push against each other, often forming small ridges as one island is pushed under the edge of its neighbour. The growing heat makes the whole mixture expand, but by now your mother will have grabbed a spoon and vigorously stirred up the whole potful, to ruin the plate tectonics demonstration but save her marmalade from flowing over on to the fire. The point to note is that those mobile islands of floating material have been behaving somewhat like the tectonic plates of the geologists which also form from cooler crustal material on the surface of planet earth. They also can become bunched up and separated subsequently again by the surfacing of more liquid (molten) rock pushing out from the core of the planet.

It is also worth noting that the surface of our planet has, over time, accumulated a lot of water which now completely or partially covers many of these tectonic plates. The actual land mass on which we live may be only at the extreme edge of a tectonic plate, or perhaps a relatively small island in the middle of a tectonic plate. Geologists are still arguing about the actual boundaries of some tectonic plates, and whether they are going east, west, north or south; or even spinning slowly in
## The Geologists' Time Scale

<table>
<thead>
<tr>
<th>Age in Millions of Years</th>
<th>Era</th>
<th>Period</th>
<th>Surface Rocks Found in Belize</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>Quaternary</td>
<td>Recent</td>
<td>No surface rock (\text{unconsolidated sediments only})</td>
</tr>
<tr>
<td>1.8</td>
<td></td>
<td>Pleistocene</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Pliocene</td>
<td>Limestone and unconsolidated sediments (Northern Belize)</td>
</tr>
<tr>
<td>22.5</td>
<td>Tertiary</td>
<td>Miocene</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td></td>
<td>Oligocene</td>
<td>? Not in Belize</td>
</tr>
<tr>
<td>54</td>
<td></td>
<td>Eocene</td>
<td>Limestone and calcareous sedimentary rocks (Northern Belize)</td>
</tr>
<tr>
<td>65</td>
<td></td>
<td>Paleocene</td>
<td>Southern Belize</td>
</tr>
<tr>
<td>100</td>
<td></td>
<td>Cretaceous</td>
<td>Limestone of Western Belize and Maya Foothills</td>
</tr>
<tr>
<td>141</td>
<td>Mesozoic</td>
<td>Jurassic</td>
<td></td>
</tr>
<tr>
<td>195</td>
<td></td>
<td>Triassic</td>
<td></td>
</tr>
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<td></td>
<td>Permian</td>
<td>No surface rocks found in Belize</td>
</tr>
<tr>
<td>280</td>
<td></td>
<td>Carboxiferous</td>
<td></td>
</tr>
<tr>
<td>345</td>
<td></td>
<td>Devonian</td>
<td></td>
</tr>
<tr>
<td>395</td>
<td></td>
<td>Silurian</td>
<td></td>
</tr>
<tr>
<td>435</td>
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<td>Ordovician</td>
<td></td>
</tr>
<tr>
<td>500</td>
<td></td>
<td>Cambrian</td>
<td></td>
</tr>
<tr>
<td>590</td>
<td></td>
<td>Hadryanian</td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td>Precambrian</td>
<td>Helikian</td>
<td>Not found in Belize</td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td>Aphebian</td>
<td></td>
</tr>
<tr>
<td>2600</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4600 ?</td>
<td></td>
<td>Origin of Planet Earth ?</td>
<td></td>
</tr>
</tbody>
</table>
one spot.

From here on we will focus our attention on that part of the earth’s crust for which Belizeans are now responsible. Regrettably, geologists have not yet quite settled this question. Some like to put us as a southern appendage to the very large North American tectonic plate. Others prefer to locate us on a separate Caribbean tectonic plate which was formed when a large southern continent (consisting of South America, Africa, Antarctica and Australasia, collectively known as Gondwanaland) rifted away from North America and drifted imperceptibly to the south and east. Two things seem to be agreed upon: firstly, for much of geological time we have enjoyed a median position on planet earth about equidistant from the north and south polar positions; and secondly, much of our particular tectonic plate has been submerged under the ocean for long periods of geological time.

Our first appearance above the sea may well have been an explosion of very hot lava resulting in the formation of a submarine volcano which continued to erupt until it built up a cone that rose above the level of the sea. Thus the future territory of Belize probably began as a small volcanic island (or more probably a group of small volcanic islands) that were located west and slightly to the north of the high point we now call Richardson Peak. Geologists searching for commercial mineral deposits have made deep borings near this location and they report that at times the ancient sea level appears to have risen and submerged these new islands of the Paleozoic ocean. Furthermore, for much of geologic time, from about 300 million years b.p. (before present time) to 248 million years b.p. (i.e. a period of over 50 million years) our land mass was rather restricted, and had an inconvenient habit of periodically disappearing below the waves. However, every time our territory went back under the sea, fresh marine sediment settled on, and mixed with, the continuing outpouring of volcanic ash and lava. Geologists identify our ancient volcanic rocks as the Bladen Volcanic Member of the Santa Rosa Paleozoic sediments, and it would seem that the volcanic rocks came to occupy only a relatively small sector of our eventual territory. Moreover, by their physical and chemical nature, they are naturally very susceptible to normal environmental decay processes. This could explain why they are so seldom found as surface rocks in our present landscape. Fresh rock samples are mainly known from deep bores.

By far the most common rocks found on Maya Mountain landscapes are dark-coloured siltstones, sandstones, shales, and slates. Many of these show evidence of having been twisted, sheared, and subjected to subsequent heat and compression which brought about physical and chemical changes, collectively known as metamorphism. Geologists accordingly refer to them as metamorphic sedimentary rocks of Paleozoic age. Part of the metamorphic process seems to have been caused by normal crustal movement (earthquakes produced in times long past), and in part
by the intrusion of molten granitic rock between the layers of sedimentary rock, often accompanied by silica-rich steam and hot water which subsequently formed veins of very hard quartz rock. Many of the granitic intrusions are still deeply buried by layers of sedimentary rocks but in some sectors of the Maya Mountains, this granitic rock has been exposed by subsequent erosion, and in such locations granite now exists as a surface rock. The granite rocks of the Mountain Pine Ridge sector of the Maya Mountains are probably amongst the oldest rocks to be found on a Belizean landscape since they began to be emplaced around 400 million years ago in the Devonian period of the Paleozoic era (see Figure 1).

There were other more local intrusions of granitic rock around 260 million years ago and yet another interval of invasion by granite intrusions which began around 230 million years ago in the Triassic geological period. Thus there are different kinds of granitic rock differing slightly in mineral and crystalline composition but all are characterized by a very high silica content.

The Maya Mountain mix of rock types is thus quite varied yet this mix does indicate that for most of the last 60 million years of Paleozoic geological time, our future heritage was mainly under the sea. There may have been brief intervals of a few million years when sea level fell sufficiently to allow a land mass to appear briefly. Unfortunately the fossil record from our Paleozoic rocks is very poor and needs much more investigation. Very few plant remains have been recorded and most fossils discovered indicate that a marine environment may have prevailed. This contrasts markedly with the Paleozoic fossil record from other parts of the ancient world, where ferns, cycad, horse-tail and club-moss species had evolved to the stature of low trees forming forests around the margins of parts of the Paleoozoic ocean, later to become seams of coal.

Despite the fact that primitive plant communities were rampant on fresh sediment in other parts of the world, only a very few small plant fossil have so far been found in our own Paleozoic rocks. Perhaps we just have not looked enough for fossils in our Maya Mountain rocks. So far our best known fossils are of crinoids (which are often called "sea lilies" because they look like low plants with short waving leaf fronds). They are not plants at all, but primitive colonial animals which constructed a tubular skeleton out of calcium carbonate, anchored in mud and used waving arms that gathered food by capturing free-floating marine organisms. As fossils, these crinoids appear as seams of crinoidal limestone at several locations in the Maya Mountains, especially in the Cockscomb Basin. These crinoids are very primitive, ancient animals, but strangely enough, they still can be found growing in the cold waters of the steeply sloping Pacific coasts of New Zealand and Chile.

The near absence of plant fossils and the scarcity of marine animal fossils in the Belizean geological record may be more real than apparent, and if this is true it may provide some clue to
our situation in the tectonic plate circus that was in progress in late Paleozoic geological times. Geologists are still somewhat cautious on this point, but it is now generally agreed that towards the end of the Paleozoic era, many of the continental tectonic plates of the northern half of the planet were converging to form one gigantic land mass known as the Devonian (or Old Red Sandstone) supercontinent, and that this was in turn converging on a southern supercontinent which geologists call Gondwanaland (Fig 2). Our future home was probably somewhere right in the middle of all of this, occupying a relatively depressed area of the earth’s crust, and one that was receiving a considerable amount of marine sediment derived from both the northern and southern converging supercontinents. Perhaps this was not exactly a healthy location for fossil plant remains, much less for plants to colonise stable shoreline environments—if such existed at all. Moreover, since by now most of the emergent continental land masses of the planet were arranging themselves into a single huge continent extending from the north pole to the south pole (Fig. 3), there would be every possibility that the snow and ice at either end would be slowly converging, bringing much cooler temperatures to the land and remaining pockets of sea left in equatorial regions. Crinoids seem to have managed to survive this environmental change, but many other marine organisms became extinct.

Many millions of years later the single, great supercontinent which geologists have named Pangea began to rift apart (Fig. 4) and our future Belizean territory probably occupied a central position during these exciting times. Geologists are still trying to sort out what might have happened when the South American tectonic plate of Gondwanaland pulled itself away from the North American plate of the northern amalgamation of plates, which included Europe and Asia. Some geologists think that when the South American plate rifted away from the North American plate and rotated slowly away to the east and south, it peeled off and carried away some of the land mass of Mexico (part of the Oaxaca highlands). This in turn broke off from the South American plate to become a separate Caribbean tectonic plate. Moving eastward, perhaps rotating slightly, this new Caribbean plate left the Western Ocean, passed through the gap left by the rifting supercontinents, and took up a new position as part of the Eastern Ocean. In this scenario the Maya Mountain block, and the contiguous highlands of Guatemala and Honduras, remained more or less in place as the southern tip of the North American plate. With this recent theory of the trajectory of the Caribbean tectonic plate, Paleozoic rocks from the western Oaxaca highlands are moved from the Pacific side to the Atlantic side, perhaps taking a million or so years to scrape slowly past our Maya Mountain block and then leaving the Oaxaca rocks in a position where they subsequently become part of the Sierra Mastre Mountains of southern Cuba:—all done at the amazing speed of a centimetre or two per year. All things appear to be plausible when you use the geological time scale.
Figure 2. Convergence of northern group of tectonic plates towards Gondwanaland in mid-Paleozoic geological time (about 350 million years ago). Location of future Belizean territory uncertain.

Figure 3. Joining together of most of the continental tectonic plates to form the supercontinent of Pangea about 230 million years ago.
Figure 4. Rift developing across the middle of Pangea separating North America from South America. The future Belize may have been attached to the southern tip of North America.

Figure 5. Approximate positions of continental tectonic plates in late Cretaceous geological time (about 100 million years ago).
We have so far learned that the Maya Mountains are composed of a mixture of Paleozoic sedimentary rocks interspersed with intrusive granitic rocks and some acid volcanic extrusive rocks collectively called the Santa Rosa group. From deep borings we know that they seem to have occupied an area as far north as the Yucatan Peninsula, and (on the evidence of surface exposures) as far south as Honduras. In Guatemala and Honduras the final sediments laid down in Paleozoic time were relatively thick limestone beds (the Choctal Limestone) which seem to be missing from our Maya Mountains. Limestone is relatively soluble rock and it might have once been present in Belize but could have dissolved away completely during the 35 million years of the Triassic period that followed the Paleozoic era (see Figure 1). Or, on the other hand, it could have been missing in Belize because our Maya Mountains had already been uplifted above sea level, by earth movements in late Paleozoic time, before the Choctal Limestones were deposited. The process of uplift took place between two clearly east-west defined fault boundaries, one in the north running westward from the present day position of the village of Gales Point, and a southern one roughly following the line of present-day Bladen River. Between these two boundaries, the sea-bed rose up as a block. The eastern limits of this block are not so well defined (probably because of erosion), and the true western boundary has been obscured by emplacement of younger limestone rock. It appears to have been a squareish uplifted block, of a type that geologists describe as a "horst". The first appearance of this horst may have been somewhat abrupt, perhaps accompanied by vigorous earth movements (earthquakes), but the fault zones have remained active for many thousands of years with the block rising or falling very slowly from time to time. The rates of uplift seem to have been stronger in the northeast corner, so that the surface of the block became was slightly tilted down towards the west, and early drainage patterns seem to have been mainly from east to west. The initial amount of uplift at the conclusion of the Paleozoic era may not have been very great, but it was sufficient to ensure that the Maya Mountain block stayed above sea-level for perhaps 50 million years. During this time the forces of normal erosion would have been active, especially on the eastern flank, and parts of the northern and southern flanks, where an intricate pattern of steep rivers and streams removed surface rock and soils for deposition in the surrounding ocean. The geological record confirms that no new geological material were added to this Belizean landscape, during the whole of the 35 million years of the Triassic period and much of the ensuing 50 million years of the Jurassic period. In about the final millennia of Jurassic time, some relatively shallow beds of shaley sandstone, which may have been erosion products, accumulated along the foot of the eastern end of the northern boundary fault. These have been mapped by geologists as the St. Margaret Creek formation. Exposures of these rocks are quite limited and fossil remains are very few. In other parts of the planet, where Triassic and
Jurassic rocks are present, fossil remains indicate that many new forms of life were evolving. Two families of reptiles that had survived from Paleozoic days were evolving into dinosaurs. The first bird-like creature appeared in Jurassic times. It had a reptile-like tail with feathers, a bill with teeth and claws on its wings which may have been helpful when gliding if not suited to flying. Many primitive mammalian species were also evolving at this time.

The Jurassic period ended about 140 million years ago and was followed by the Cretaceous geological period which lasted for another 85 million years, during which time the Belizian geological record resumes again. This records an almost totally different geological activity, and one which virtually continued up to the present day. The difference was not so much in the relative position of the land in respect to the sea (which continued to oscillate up and down much as in former times) but in the quality of the marine environment in Cretaceous time. For perhaps the first time the sea water was so well supplied with such basic minerals as calcium and magnesium and other nutrients that it could support copious growth of marine organisms that protected themselves with shells or skeletons fashioned out of calcium or magnesium carbonate. There was no shortage of carbon dioxide in the environment, for the evolution of plants had by now reached the stage where seed-bearing plants had come into existence, making feasible the covering of exposed landscapes with a vegetative cover that could survive and recover quickly from minor climatic variations (hot, dry summers, cold wet winter, etc) and also withstand grazing and browsing by an ever-increasing number of herbivore species. More plant life on the terrestrial environment sustains the supply of carbon dioxide for a marine environment. The Cretaceous period appears to have been characterised by a phenomenal development in free-floating single-celled marine organisms, many of which wrapped their minute bodies in a protective shell of calcium carbonate. They were usually of minute size ("nanno plankton"), feeding and reproducing mainly in the upper layers of the ocean. The constant rain of dead calcium-coated small shells produced a sediment very rich in calcium or magnesium carbonate (often referred to as "calcareous ooze"). With time, this material compressed into white or pinkish-white limestone rock, usually almost lacking in earthy impurities. This process did not require an ocean of any specific depth or require light-penetration at depth; and there was an enormous variety of plankton species adapted to a wide range of sea temperatures. Limestone from this source could accumulate in deep oceans, or on coastal shelves, or even quite shallow marine basins. Many of the mudstones or sandstones of the Cretaceous period are notably calcareous (by virtue of their high calcium content), but the most common sediment emplaced became almost pure limestone rock. By virtue of the fact that calcium or magnesium carbonate is quite readily soluble under a variety of conditions, some of the minute nanno-plankton skeletons accumulating on the sea-bed
dissolved completely and subsequently recrystallised to form a layer of evaporite or cemented limestone rock. Cretaceous limestone usually contain few fossils visible to the naked eye, but when photographed by a scanning electron microscope the fossiliferous nature of the rock can be demonstrated. Usually, mixed with the calcareous nannoplankton (which are algae—i.e. plants, not animals), there are diatoms, foraminifers and other minute organisms; some with siliceous skins. Only rarely do fragments of bivalve mollusk shells or coral fragments turn up in our Cretaceous limestones. Some beds of limestone rock exceed 2000 metres in thickness and microscopic examination is often necessary to determine whether it is of more or less uniform age or whether deposition occurred at different times during the Cretaceous period. Only towards the end of the Cretaceous time did modern coralline limestones begin to appear. Limestones with a high content of magnesium are usually called dolomites, and these are often produced under rather specific and localised environmental conditions. Figure 5 shows the approximate position of the continents 100 million years ago.

Many of the earliest limestones formed in the Cretaceous period belong to a group that geologists identify as the Coban Formation, a dominantly dolomitic, highly recrystallized massive limestone which may include some siliceous limestone and occasional thin layers of calcareous siltstone and shale. During a later period of deposition (perhaps 70-80 million years ago), the Campur Formation was formed. This is a fine-grained limestone with some incorporated primitive coral debris and has very few dolomite bands and only very minor bands of shale and siltstone. There is also a third category of limestone rocks known as the Sepur or Lacandon Group which has a very variable lithology. Sepur sediments are, in part, post-Cretaceous in age, some dating from well into the Tertiary period.

Limestone landscapes are in marked contrast to landscapes carved from Paleozoic rocks. The latter decay mainly by slow-working physical and chemical processes in which water has to penetrate into the rock before the decay processes can start. By contrast, limestone decays by a relatively rapid process of solution, which takes place not only at the rock surface but extends rapidly down the many fissures and cracks (a feature of the physical nature of most limestones) and even down root channels that the plant roots themselves create by dissolution of the rocks. Any major flow of subsurface water creates tunnels and links systems of caves that greatly speed up the progressive destruction of a limestone landscape. This results in a special type of landscape known as "karst", which is a rugged landscape of steep rocky slopes pock-marked by solution depressions and pot-holes. This type of landscape is fairly typical of Coban limestone, which still covers very large areas of Belize. In all probability, Cretaceous limestone once covered the whole of the Maya Mountain block, deposited at a time when ocean levels were high worldwide. The Maya block perhaps had been reduced considerably in elevation following the long period of erosion
in Triassic time. The Campur limestone occurs mainly to the south and north of the Maya Mountains in the Yalbac, Gallon Jug, Booth’s River escarpment and perhaps Barton Creek localities. Karst topographic features are present but on lesser scale than Coban limestone landscapes. Sepur limestones in Belize are mainly confined to the Toledo district where the weak karst features are modified by the presence of bands of calcareous sediment. In addition to Sepur limestone in the area south of the Maya Mountains, a new sequence of sedimentation began about 80 million years ago. These gave rise to a geological formation called the Toledo Beds and their sedimentary material is suspected to have originated from mineralised highlands located somewhere south and west of the Maya block. Toledo beds are characterised by alternating bands of claystone, siltstone, sandstone, and mudstone between less-frequent layers of limestone, which may be markedly silicified. No karstic features occur on Toledo bed landscapes.

It was about 65 million years ago when the Maya Mountains finally emerged above the ocean, and during this long interval of time much of the limestone covering the Paleozoic basement rocks is still in progress of dissolving away. As a result, no geologist can be sure how thick the original limestone cover might have been; or, indeed, if some of the higher parts of the Maya Mountains might have escaped submergence by the Cretaceous ocean. Because of its relatively high solubility, limestone can come and go on a landscape and leave very few signs of its temporary occupancy. No one has yet examined the surface soils of the higher parts of the Maya Mountains for relict traces of Cretaceous diatom or foraminiferan species. In the vicinity of the locality now know as "Doyles Delight" at one of the highest parts of the Maya Mountains, there are a few relatively wide flattish ridges suggestive of remnants of an ancient plateau surface which might be worth examining.

Usually, where land and sea meet, shoreline features such as beaches, caves, or wave-out platforms develop. Such features have never yet been identified along the high flanks of the Maya Mountains. However, these same mountainsides have been exposed to erosion for more than 65 million years and the question of the maximum Cretaceous sea level is still an open one.

If a limestone sheet did cover the whole Maya block one might expect some relict topographic features due to the fact that limestone on the higher parts would dissolve under the influence of rainfall alone, while at lower levels the solution process might be greatly accelerated by an input of acid ground water from lateral flow of rainfall acidified by passage through the weathering zone of the buried Paleozoic rocks. On the western "dip" slopes of the Maya Mountains (the Mountain Pine Ridge area, for example) there are many interesting minor topographic features that must have originated from sub-surface drainage problems along the contact between the limestone and the Paleozoic rocks (mainly granite in the case of the Mountain Pine Ridge). Temporary (ephemeral) swamps and even a few shallow
lakes were once a feature of that upland landscape. Little hills of relict limestone are a common feature of the landscape today. Dissolving of limestone on the higher parts of the landscape would inevitably charge the rivers draining the area with a high content of lime, which would be carried down and largely redeposited in new sediments building up in lowland situations. Thus, for many millions of years all new sedimentary materials accumulating around the Maya Mountains gave rise to rock formations that had a relatively high calcium content. With the passage of time and the increasing exposure of silica-rich Paleozoic rocks, the amount of quartz sand and smaller siliceous particles increased in the waters draining from the uplands, resulting in deposition of alluvial material notably rich in quartz sand. Thus alluvial deposition on the Belizean lowlands passed through a sequence in composition from calcareous to siliceous, and in localities subject to changing river courses, very varied patterns of deposition could occur.

At the end of the Cretaceous era, it is likely that the Maya Mountain block did not stand very high above the sea level of that time, but geologists have some evidence suggesting that the old boundary faults were still active and the Maya block was very slowly becoming more elevated. This movement continued progressively through much of the next interval of geological time, known as the Tertiary period, which lasted for some 90 million years.

The end of the Cretaceous era was clearly marked by another of those sudden, as yet unexplained, biological catastrophes. Just as at the end of Paleozoic era, some sudden environmental change killed off much of life then existing on planet earth: almost 200 million years of trial-and-error evolutionary effort were obliterated by disaster that struck with great swiftness. In the case of the Cretaceous biological extinction, evidence seems to be definitely pointing to an extraterritorial origin. Perhaps a series of collisions with a shower of meteorites, or even one large asteroid which not only might have produced toxic irradiation killing some forms of life rapidly but could have raised a mushroom cloud of dust from pulverised asteroid and terrestrial crust which, moving up into the stratosphere, would spread quickly over all the earth, cutting off sunlight and suppressing photosynthesis. Research workers in many parts of the world have recently identified a thin band preserved in some rocks of this period that contains unusual concentrations of iridium. After the Cretaceous biotic catastrophes, no more fossil remains can be found of big marine reptiles, flying reptiles, dinosaurs, many species of bony fish and many shellfish. Primitive land animals suffered less severe species losses, but countless numbers must have died in the holocaust. Amongst those who did survive were a few small species of mammals who survived after the Cretaceous world blew up to give rise to the humanoid species.

So now we are at the start of the Tertiary geologic era, with a much diminished biosphere and a landscape that is still
rising slowly between the main northern and southern fault zones of the Maya Mountains, and along the less well-defined eastern limit of the Paleozoic rocks. This was perhaps an active area of a new pattern of faulting that now became quite noticeable in this sector of the earth’s crust. Fault zones (where one sector of the earth’s crust moves upwards or downwards with respect to an adjoining sector) with a north-south alignment began to become widespread in Belizean geological record. North-south faults developed in some of the Cretaceous limestones already emplaced to the north of the Maya Mountains block’s northern boundary. The result here was that much of northern lowland Belize became bounded by highland on the south and also on the west, leaving the northeastern corner as an embayed coastal area, occupied by a shallow sea and probably floored by a wave-cut limestone platform.

Much of the rest of the geological history of Belize, (a period of only 65 million years) concerns the eroding away of the northern and eastern flanks of the Maya Mountains, the effect of the relatively minor north-south faulting systems on the former drainage pattern which was by long rivers running towards the west, and the build-up of Toledo sedimentary rocks between the older Cretaceous limestones in southern Belize (which continued for about 30 million years). Thus, in Tertiary time, drainage from part of the Maya Mountains began increasingly to flow northwards, depositing erosion products into the embayed northeastern sector of the landscape. The first major east-west river to meet its fate was one that began high in the Maya Mountains near a locality now known as Mt. Mossy. This old river was captured in several places by stream following new northeastern fault lines located along the northern fringe of the Maya Mountains. The first interception was that of the Sibun River (via the Sibun gorge); the next by Caves Branch, then by Roaring Creek and at the western end by Barton Creek. The difference in elevation between the bed of the old east-west river course, and sea level at that time was great enough to ensure that much of the eroded limestone rock came down in large chunks, giving rise to the Cayo (foothill) Formation consisting mainly of tumultuous fans built up with limestone boulders, often in a matrix of white marl. Much of the westerly drainage from the Mountain Pine Ridge became intercepted by the Raspacula, Macal and Mopan rivers which may also have developed partly along new north-south fault lines, bringing down more limestone boulders and white marl to be emplaced at the head of the embayed shoreline between Barton Creek and Arenal.

Thus, at the start of the Tertiary period, a mixture of tumultuous limestone boulders, white marl and red clay formed a shoreline around the shallow, tidal sea of the embayed coastal shelf. For many millions of years thereafter, alluvial materials transported from the higher land continued accumulating on this shelf, and the patterns formed by these varied alluvial deposits strongly suggests that they were deposited by rivers that flowed northwards and perhaps emptied into the Bay of Chetumal. The
appearance of red gypsiferous clays in the Cayo Formation suggests that in Tertiary time something new may have been added to the geological assemblage. Gypsum crystals are formed from hydrated calcium sulphate, and their formation implies that some source of sulphuric acid need be available. Sulphuric acid can be produced from the decomposition of the mineral pyrite (iron sulphide) which often occurs as a gold-coloured mineral ("fools gold") in quartz veins. However, quartz vein rock is about the last feature in a landscape to be reduced by erosion and it is difficult to imagine that erosion from the Maya Mountains could have produced enough pyrites to give rise to the layers of red gypsiferous clays of the Cayo and other sedimentary formations of this period.

A more likely source of iron to provide sulphuric acid for the gypsum process could have been basic andesitic volcanic ash from distant volcanoes in Mexico, in Guatemala, or from many islands now emerging along volcanic areas in the eastern sea. Tertiary time was in most parts of the planet an era of mountain building and extensive volcanic activity. There is some evidence that a light powdering of volcanic ash fell locally on the parts of the Cretaceous sea, and in some places drifted as a surface scum thick enough to leave traces in the limestone rock subsequently formed. It was mainly from Tertiary time onwards that red clay made common appearance on the developing lowland landscape of northern Belize. In many places red clay overlie hard white limestone that analyses out at 98% pure calcium carbonate. To accumulate a four-foot depth of red clay from such pure limestone would require the solution of many hundreds of feet of rock. Yet the uppermost layer of the limestone does not indicate that solution on such a scale did ever occur. So, we are left with a strong suspicion that volcanic ash either fell as subaerial dust directly on limestone surface during the early centuries after emerging as dry land, or was floated into place by rivers or by tidal and estuarine currents; or, perhaps from massive sheets of floating ash drifting as a scum across the open sea. The embayed shoreline of the north Belizean coast might have favoured concentrations of any such rafts of drifting ash. This last 65 million years of geological time brings us up to present day. The essential elements in the geological history of northern Belize was little more than progressive infilling of the embayed sector with the products of erosion from Maya Mountains highland. Eventually, the coastal shelf which occupies the northeast sector of Belize was converted into a plain of mainly gentle relief whose simple topographic appearance concealed a great variety of contrasting geologic materials. For many millions of years, progressive stripping of the limestone covering the Paleocene rocks of the Maya Mountains produced erosion products that were mainly powdered calcium (and some magnesium) carbonate, with some quartz sand, which today appear on the northern lowlands as sandy chalk beds (known locally as "chalk marl", or by the Yucatecan dialect name of "sascab"). These materials were mainly alluvial deposits from the north-
flowing rivers interrupted periodically by local ingressions of sea water, causing them to become estuarine in depositional nature. Occasionnally, when a shoreline became static for a few hundred years or so, coral beach gravels and siliceous boulder beds might be formed. At first most of the major rivers seem to have flowed along parallel fault zones, running from south to north towards the present Bay of Chetumal. During late Tertiary time, the extreme northern part of this shelf may have been subject to a small upward movement, exposing many of the emplaced calcareous sediments to a tidal lagoon environment allowing the uppermost layer of the "sascab" material to become hardened into a cemented crust or "carapace". Such lagoonal conditions probably persisted for about 20 million years, during which an outbreak of volcanic activity at some distant place briefly filled the lagoon system with floating volcanic ash.

As the highland of the Maya Mountains gradually became stripped of limestone surface rock, the quartz content of the erosion product gradually increased. These quartz-rich alluvia contain both sharp quartz grains and smooth, well-rounded grains, suggesting that some of the material travelled from localities far from their place of deposition, while the sharp quartz sand indicates a more local origin.

Drainage across these northern lowlands seems to have been originally from south to north. The development of the Belize River valley eventually changed much of the drainage into an west-east course and deepened to the point where a small tributary stream captured the flow of the Mopan River and turned its considerable volume of water to join the Belize River and flow eastwards to the Caribbean Sea. The high plains of the old Mopan River, above Melchor and Benque Viejo indicate that the old northern course of the Mopan River may have perhaps been impeded by upward movement of the landscape to the north, thus facilitating capture by an affluent of the Belize River.

Changes in sea level due to glaciation (ice formation in distant polar parts of our planet) have been operational throughout the Belizean geological record but subsequent erosion has just about obliterated all traces of old shorelines that may have existed in Paleozoic to late Tertiary time. Features characteristic of prolonged intervals when the sea level was high and remained high for several thousand years (or more) began to appear late in Triassic time and continued during Quaternary time (which began 2 million years ago). There must have been an old shoreline around the embayed coastline of northern Belize in Tertiary time (about 60 million years ago) when waves came in and out, planeing off a wave-cut platform from previously deposited Cretaceous rocks, but evidence of this Tertiary shoreline is somewhat fragmentary. During Quaternary time, there are some foothill caves in the Cretaceous limestone, about 50 feet above present sea level, which do show features strongly suggestive of wave and tidal action. Such caves are somewhat more common along the foot of limestone hills in the Toledo district where flint artifacts show that they may have sheltered neolithic families.
Some limestone was still being laid down on the northern lowland of Belize in early Quaternary time (about 1.5 million years ago) but these have been partially buried by younger alluvial material brought down by the larger rivers, many of which still flowed across the lowland plain moving northward towards Chetumal Bay. However, since this veneer of alluvium has had neither enough time nor the appropriate geologic forces to consolidate into rock, surface exposure of rock are uncommon. If rocks are present, they are siliceous and usually rounded. One lowland sector, a strip about 6 miles wide, parallel to the present coastline between Belize City and the general latitude of Altun Ha, does show a very thick accumulation of rounded flint stones interspersed with large boulders of flint and some clay. These flints may have originated in a former tidal zone, in part fed by siliceous waters from shallow sub-marine springs, perhaps delivering silica-rich groundwater derived from decay of fine quartz sand particles in the central sector of the lowland plain. Flint stones and boulders also occur in the Tertiary Cayo Beds and in the Neustad sector of the northwest corner of Belize in locations where an ancient coastline with silica springs might be suspected.

The quantity of quartz sand deposited on the northern lowland plain has clearly fluctuated with time. The sequence appears to be one of diminishing calcium carbonate input ("sascab") and increasing input of quartz sand. Some intervals of alluvial deposition included a high proportion of angular quartz sand; elsewhere, the quartz sand was mainly rounded. Alluvial material in the vicinity of Orange Walk Town is about 50% of each category of quartz grains. The depositional pattern of Quaternary alluvial deposits is further complicated by adjustments to the surface of the plain caused by minor faulting and slumping, which sometimes brought about reversal in direction of flow of minor rivers and streams, created new swamp areas, and sometimes directed local drainage into a line of sinkholes. The presence of remnants of red mangrove forest in a few of the larger valleys suggests that, at some point in time, the sea invaded the plain, and the mangroves have survived for several thousand years, perhaps with some assistance from local saline spring waters.

Between the present eastern coast of mainland Belize and the foothills of the Maya Mountains, lies a flattish to undulating plain which continues without a break from the present Belize River delta southwards to meet the undulating to gently rolling coastal lowlands of Toledo. The base of much of this eastern lowland plain appears to be a platform of wave-cut limestone although in some localities a subdued sub-surface landscape of granitic or Paleozoic metasediments is known to occur. Cutting of this platform by prolonged wave action may have occurred about 20 million years ago, but in the centuries that followed the whole of this wave-cut shelf has been buried in various kinds of alluvial material eroded mainly from the eastern sector of the Maya Mountains and deposited by river systems that originated
from steep and narrow headwater streams, subject to sudden, intense flooding causing tumultuous accretion at lower levels. At times the shelf on which the eroded material accumulated was dry land or subject only to minor but regular tidal ingress by the sea. During the inter-glacial periods of the four major ice ages the shelf might have been just below sealevel for many thousands of years.

During periods of marine inundation which occurred in successive inter-glacial epochs, the most recently deposited salt, sand and clay is likely to have been resorted by sea currents, producing a somewhat stratified mixed alluvium which would be further modified and stratified by on-going soil processes during the glacial epochs when the shelf was no longer below sealevel. There are some indications of very old buried topsoils (perhaps nearly a million years ago) in these largely unconsolidated alluvial beds of the Quaternary geological age. Few rocks were added to the Belizean landscape in Quaternary time, but local mounds of nodular flints (perhaps marking the sites of ancient hot springs with silica-rich waters), and local deposits of ironstone gravel ("ferricrete") may be remnants of lateralised alluvial fan material which were redistributed as a kind of beach gravel during ingress of the sea.

In the southern district of Toledo, accumulation of marine sedimentary material continued throughout most of late Tertiary and Quaternary geological time (perhaps until about 30 million years ago) burying older limestone rocks and infilling old valleys between the limestone ranges. There is one small area in Toledo where hot silica- (and magnesia-) rich springs are still active. Such springs may have been even more common in early Tertiary time, to judge by the frequent occurrence of very hard siliceous limestone, sometimes found in association with dolomite. This just about completes the geological history of Belize, with the exception of living coral which is actively growing along the barrier reef and on nearby cayes and atolls, providing calcareous material for the future limestone beds of the twenty-first century.