CORRESPONDENCE

THE EVIDENCE FOR COSMIC UPWARD PULL IN MOUNTAIN AND LAND UPLIFT

SIR,—It is admitted that lunar or tidal pull or gravitation has an effect on the solid surface of the earth, but it is always stated that the surface returns to its original level. I have examined evidence in various regions and conclude that such a pull has been effective and accumulative and is responsible for much of the uprise and maintenance of land surfaces we see to-day. Briefly stated the reasoning is as follows:—

1. Gravitational pull of the moon and other celestial bodies acts continually on the higher or more massive parts of the earth's surface, tending to pull them upwards, the higher parts more strongly than those below.
2. Cohesion or mass gravitation causes the mountain mass to be attracted together as it comes up.
3. Pressure of water in adjacent oceans tends to reinforce the upward movement and to depress the sea bed in a reverse manner.
4. Metamorphism and crystalline changes in certain rocks below causes heating and softening and makes the pull up more effective. At the same time, it produces a great contraction in volume and this can lead to folding and disturbance in the rocks concerned.

The regions I have examined mainly are England, the Alps, Jamaica, Barbados, Trinidad, and New Zealand. This theory is based on observable evidence and is not mere " wishful thinking ". In this " Geophysical Year " it may be of interest to present such evidence.

EVIDENCE FROM RAISED BEACHES

Raised beaches are generally seen on rocky platforms and not on flat lying adjacent land at lower levels. The one I know best is north of Easington on the Durham coast; a patch of shelly gravel resting on brecciated Magnesian Limestone at the foot of the Shell Limestone Knoll of Beacon Hill. The beach would seem to mark a mild interval after the initiation of the Cheviot Northern or last glaciation. It is overlain by calcreted glacial gravel and by thin glacial drift. On the shore for about a mile round the base of the Knoll, the cliffs are in places strongly slickensided up and down. Among the breccia there have been several fissures filled with late Tertiary or early Glacial red marl and pieces of upper Magnesian Limestone. Some of these have been caught in the movement and are crushed and slickensided, especially on the side facing the Knoll, and they tend to bend over upwards towards the Knoll. The Knoll itself is slickensided vertically on a small scale as I used to see years ago when the railway cutting was being made. The red fissures are seen only in the cliff near the Knoll, and do not occur between tide marks.

If the beach had been due to a temporary rise of sea level it should have left traces on the lower ground, but it has not. It was deposited at sea level, then a rise of the brecciated rock occurred. There are in the beach no pebbles of the fossiliferous rock from the Knoll which rises immediately to the west. The inference would seem to be that the Knoll was then not so prominent as it is now. During post-glacial time the Knoll may have risen and dragged up the platform of brecciated rock on its seaward flank, the red fissures acting as a sort of lubricant in the process.

A curious piece of negative evidence is that, with the exception of a mass from the higher part of the reef in the railway cutting between Castle Eden and Hesleden, I have never found a piece of Shell Limestone in the drift, never a fossil such as *Productus horridus*. One would have supposed that if the knolls such as Humbledon and Tunstall Hills were as prominent as they are now, they would have provided many pebbles to the glacial drift. I think that after the removal of the ice sheet the landscape was improved upon or exaggerated, and I can see no way this could have come about, except by a differential pull up on the more elevated masses, leaving the lower parts to stay where they are or to go down under pressure of sea water. The Beacon Hill raised beach at 80 feet is almost in view of the submerged forests of Hartlepool and Roker, which continue under the North Sea.

The Permian of East Durham has in the Tertiary period been covered by Trias, Lias, Jurassic, and Chalk, a series possibly 5,000 feet thick. As this was denuded away most of North and Central England remained a land surface, the uprise keeping place with the denudation. It has never been 5,000 feet high and then denuded down. During the same period in the Isle of Wight and on the South Coast, the Chalk and Eocene have been turned up on end, but with much less denudation and much less rise. To my mind some explanation other than the crude one of a cooling and contracting earth must be sought to explain these facts.

The Alps

The structure of the Alps is reasonably clear if the writers since 1900 will only allow it to be so. Starting on the Molasse near Lucerne the Rigi conglomerate is raised against the Alpine rocks, then the Klippen Masses of the Mythen, Pilatus, and others rest on Flysch. The Cretaceous and Jurassic follow, often back-folded as one sees along the Axenstrasse. The high calcareous Alps and the St. Gothard massif have infolded masses of Secondary strata, generally represented as down loops. Those I have seen look more like slices of strata with the higher beds facing towards the greater Alpine uplift. Almost flat-lying gneiss and schist of Tessin is followed southwards by infolded Carboniferous at Manno, and then near Lugano the Permian and Trias are turned over towards the south, and finally the Tertiary on the southern edge.

I wrote a paper dealing with the so-called exotic granite blocks in the Habkerenthal near Interlaken. After examination I concluded that the specimen often figured had been a pocket of pebbles of granite, pegmatite, limestone, and nummulitic green-sand that had been welded together and turned up on end in the Wild Flysch.[1] The rounded base and the three partly detached upper pieces suggested some drawing-up process.

Before I accept the Klippen as relics of vast overthrust sheets of the last period of Alpine movement I should like some borings, such as are put down in oil-bearing countries, to show on what they rest and whether the Molasse passes under them as present-day sections generally show. They may have belonged to some earlier period of slumping in or on the Flysch and have been raised in the general uplift in Miocene times.

The fossils reported from the Mythen and those I sometimes collect on Mt. Pilatus need not have travelled far; they look like local types. The idea of far-transported Nappes is not supported by fossil evidence, whatever the argument may be from facies peculiarities.

The Alps are a range that has a metamorphic core. On the north side the Jurassic and Cretaceous rocks are not schistose, and on the south side near Lugano, at Monte Salvatore, the Trias Esino limestone, and at Monte Generoso the Lias is unaltered. In the central Alps the Jurassic has been involved and metamorphosed. Schists at Griespass and Nufenen with Belemnites, crinoid stems, Liassic Cardinias, etc., are seen and I notice that in the metamorphic knotted schist the Belemnites are not broken or stretched; it is in the less altered shale that they are torn apart and the spaces filled with calcite.

The Furka Pass involvement is one I have seen. The higher or Lias Beds are on the north side facing the high Alps. The Rauchwacke and Verrucano on the south merge into schist and gneiss on which they were deposited. Some of the strata are metamorphosed and closely resemble rock from the northern range of Trinidad. It looks to me like a one-time escarpment that has become turned up on end between gneiss and granite; both have come

[1] This was confirmed in 1952 by Walter Gigon. Verhandlungen de Naturforschenden Gesellschaft in Basel, p. 105, Fig. 17.

up, but that on the north side has risen much more than that on the south side.

At the Joch Pass on the north side of the Alps a similar arrangement, but in reversed order, seems to exist; the Nummulitic Beds are on the south facing the high uplift, the Permian Beds being towards the north.

At the Jungfraujoch, the rock one sees on coming out from the tunnel has been described as gneiss and as granite. Pieces of it closely resemble samples from the northern range from Trinidad, which are metamorphosed sedimentary series. It merges down in the form of thin streaks into the almost unaltered Jurassic limestone below. It has apparently been over-turned towards the north. In none of these localities can I see any reason to suppose that they have been overlain by horizontal Nappe Sheets, now supposedly weathered away. In fact, I know of no section in the Alps where undoubted Protogine gneiss has been thrust over secondary strata.

The Alps are commonly supposed to have been shortened across by 60 or 120 miles. In my last conversation with our lamented friend Doctor G. M. Lees, I said I would be satisfied with about 2 miles. The involved secondary beds, now schistose, must have undergone great contraction with removal of calcite, as one observes in Jamaica or in the Delabole Slates of Cornwall. Internal cohesion rather than any rock pressure from outside could draw them together during the process of uplift with resulting contortion of the strata.

As regards the so-called fan-like structure. This refers to the feature that on the north and south sides the strata tend to be dipping in a reverse direction, The higher east end of Jamaica shows a similar disposition, the marginal beds being over-turned and then flattened out again. The Alps came up out of a Miocene Sea as Jamaica is coming up out of the Caribbean.

The West Indies

Geologists in the past have been fond of representing the West Indies as a uniform uplift with a great but imaginary fault passing through the arc and dividing the outer stratified from the inner volcanic islands. It has to pass of course between the volcanic western part and eastern limestone part of Guadeloupe. Suess, vol. 1, p. 544, makes the erroneous statement that the inner arc is wholly of recent volcanic origin. There are older Tertiary sediments on Martinique and Carriacou. He and others also refer to the West Indies as a sunken mountain chain. When I see Cretaceous shale with fossils at 7,000 feet in Jamaica, I tend to take the opposite view and to look on it as a rising mountain range in process of coming up out of the sea.

It is an arc, but so are most mountain uplifts. Far from being uniform, parts of one and the same island, though made of the same rocks, have a different geological story to tell. The high eastern part of Jamaica differs in its state of metamorphism from the lower western part. The south part of Barbados is a later uplift than the higher main part. The northern range of Trinidad is highly metamorphic while the central range is unaffected. Antigua, on the other hand, looks like a piece of continental land; the old igneous part may have risen and the sedimentary beds gone down round the edges of the island. It has no raised coral rock.

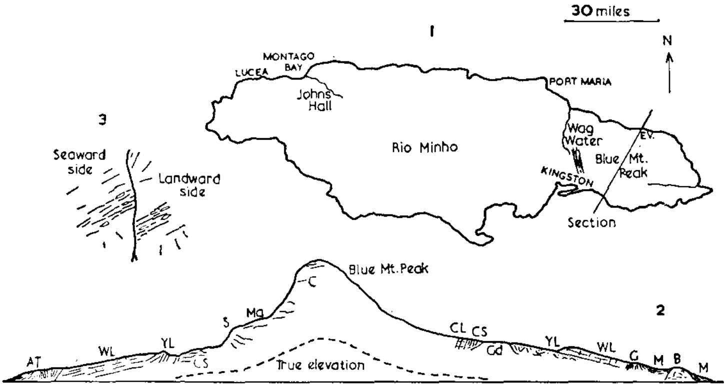
Jamaica

Jamaica is 144 miles from east to west and 49 miles north to south at the widest part and rises to 7,402 feet[1] at Blue Mountain Peak, towards the eastern end, where it is only 25 miles across. All the island was probably covered by white limestone in early Miocene times. It then began to come up in the form of an elongate dome, when the marginal August Town, Bowden, and Manchioneal beds began to be laid down in gradually deepening sea around the edges of the rising land. At the eastern end, measured from

[1] Sawkins in 1865 gives the height of Blue Mountain Peak as 7,385 feet. Like Barbados there is a suggestion that it has risen.

the marginal beds on the north and on the south, Jamaica is a more abrupt uplift than the Alps.

The larger and wider western part rises to not much above 2,000 feet, and a long east to west valley has been eroded down to the Eocene and Cretaceous beds, the Rio Minho Valley. The marginal beds dip off the white limestone at low angles, but at two places on the north coast at Lucea and at Port Maria, the older Eocene shales and conglomerates touch the coast.



TEXT-FIG. 1.—(1) Sketch map of Jamaica to show localities and the position of the Wag Water dislocation and of the section.

(2) Section across Jamaica about 23 miles from the extinct volcano at Low Layton, though Blue Mountain Peak, to 12 miles east of Kingston. It shows the tilting, up-ending, and partial reversal of dip of the marginal beds, north and south of the highest uplifted part of the island.

M. Manchioneal beds, Pliocene. B. Vesicular pillow lavas. G. Globigerina marls, Miocene. W.L. White limestone. Y.L. Yellow limestone, Middle Eocene. C.S. Carbonaceous shale or flysch, Lower Eocene. Gd. Granodiorite. C.L. Cretaceous limestone and shale at Fruitful Vale. C. Cretaceous mudstone at the Peak. Ma. Marble at Abbey Green. S. Serpentine and Westphalia schists. A.T. August Town beds, Upper Miocene, at the south coast.

(3) A section about 6 feet high near the north coast of Jamaica, east of Swift River. The beds are flinty white limestone with *Lepidocyclina*. They dip seawards but a small fault has displaced a band of flint on the north side upwards. This suggests that there has been upward pressure from the direction of the submarine slope.

The higher eastern end of Jamaica is formed of similar beds, but they show a different state of metamorphic alteration. It is separated from the lower lying western area by a band of dislocation called the Wag Water Fault which passes from east of Kingston in a north-westerly direction. This is a complicated band of dislocation which brings up and involves slices of granodiorite. It can be traced for about three-quarters of the distance to the north coast in a north-westerly direction.

Below the western area, the rocks are in places altered by metasomatism. At Johns Hall, in the Montego Bay region, a fossiliferous Eocene conglomerate with limestone pebbles seems to change, with elimination of the calcite and by growth of ferromagnesian crystals, into an andesitic tuff or agglomerate, and this into a basic andesitic lava which becomes intrusive. At Harkers

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Hall, granodiorite is exposed and adjacent to it is a hornfelsed conglomerate in which the pebbles have been drawn out as streaks and over-folded forming a rock which Sawkins called petrosilex. This granodiorite comes up to the base of the white limestone which it seems to marmorize, patches of white crystalline limestone are found in the granodiorite. Below the higher eastern end of Jamaica, the metamorphism is more varied and of a different character. Conglomerates of the Cretaceous and Eocene carbonaceous shale series can be seen passing into Serpentine at Moy Hall and Arntully ; into Chinese steatite up the Rio Grande; into schist at Abbey Green. These changes can be traced in the field and specimens collected. The actual Blue Mountain Peak is formed of scarcely altered shale and conglomerate and Cretaceous fossils are found at 7,000 feet. I attribute the higher uplift of Eastern Jamaica to a different condition of metamorphism, a plastic softening which allows a pull up but a less liability to fall back again. This material has undergone great internal contraction with removal of limestone and is often much slickensided.

Jamaica, like the Alps, exhibits what is called " Fan Structure ". The solid compact mass of white limestone is rarely disturbed or tilted, but the Blue Mountain Cretaceous formation has risen more than 3,000 feet since the white limestone was denuded off it.

The marginal beds round the flanks of the eastern part are often raised on end so as to dip vertically or become slightly reversed. Later beds further away from the raised mass have remained flat. This condition of the rocks is seen on both north and south sides of the Blue Mountain uplift.

Text-fig. 1 is intended to represent a cross-section from the so-called extinct volcano on the north coast to the Cane River, east of Kingston, on the south coast. The volcano is a ridge of basaltic lava which has flown out into globigerina marls, probably early Miocene. It is no part of a crater, but is a dead mass that was below sea level and was overlain by Manchioneal beds of Pliocene age. It has come up possibly because the rock is magnetic or because it is a solid mass, and has tilted the covering beds on both its seaward and landward sides. Going south down a depression and up the slope away from the basalt, we find late Tertiary globigerina marls dipping to the north, while a little further up these beds stand on end, and where they adjoin the thick white limestone they are slightly reversed. The white limestone with *Lepidocyclina* has been dragged up as a compact mass and has tilted the less solid marginal beds on its flank. The white, with the yellow limestone at its base, ends in an escarpment at about 2,000 feet, when the Blue Mountain complex of early Eocene Flysch and Cretaceous beds appears uncomformably below the covering beds.

South of the Blue Mountain mass the succession is repeated. A north-facing scarp of yellow and white limestone, with lower down, near the sea, August Town and marginal late Tertiary beds. In a quarry near Cane River, they are turned up on end or slightly reversed, but they are flattened out when they are well away from the upraised mass of white limestone.

On the flatter south and south-west parts of Jamaica are three or four minor subsidiary uplifts of white limestone. West of Kingston Harbour is the Port Henderson mass, with its much discussed section at the Lazaretto. It has a core of hornblende schist and amphibolite with hornfelsic material. I concluded this to be metamorphic Eocene carbonaceous shale series overlain by white limestone with *Dictyoconus*. There is a marble layer at the top in which I found remains of the *Dictyoconus* still recognizable. The softened mass below may have enabled it to be pulled up, and in doing so, it has tipped up a series of August Town beds which now dip away from it on the north-east side.

The Santa Cruz ridge of white limestone overlooks the sea on the south-west coast. Near Malvern College, at about 1,800 feet, a boring for oil has recently been put down. It went down over 8,000 feet and met with a quite unexpected thickness of about 6,000 feet of white limestone, below which came rocks resembling lava and tuffs and near the base a dark green serpentinous diabase, slightly slickensided. This is suggestive of some of the material below the Port Henderson ridge, at the Lazaretto.

Long Mountain is an elongate NW–SE dome of white limestone that overlooks Kingston on the east. Near Mona the rock appears to be broken up into great masses, as if it had been forcibly lifted and moved. On the north-east side it has raised up a typical series of August Town beds which dip steeply away off the mass.

On the north-east coast of Jamaica at Hope Bay, up the east side of the Swift River, there are thin bands of flint in the white limestone with *Lepidocyclina*. There is a small fault but it is the seaward side that has been thrust upwards and has displaced a layer of flint a distance of a few feet. This suggests that there has been pressure from the oceanic slope that has assisted the uplift while the adjacent sea bed on the north has gone down.

These various disturbances in Jamaica are not due to any pressure of rock from on either side, nor is there any evidence of intrusion from below. I attribute them to gravitational pull up of the massive white limestone aided by " sticky " metamorphism of parts of the rock below. As the island rose, later Tertiary sediments were deposited in the deepening sea around the coast. At the higher eastern end the massive white limestone tilts and contorts in various ways the later softer beds that happen to lie on its adjacent rising flank, while further away they lie flat or dip slightly seaward.

Barbados

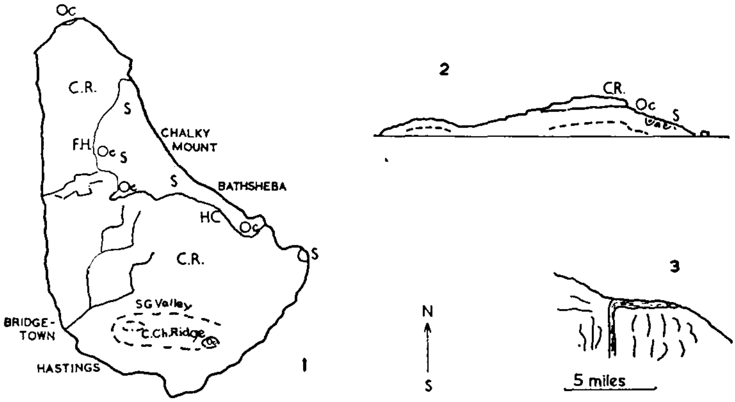
Barbados is unique among islands. It stands well away from the Antillean arc, being 100 miles east of St. Vincent, the nearest volcanic island. It is surrounded by deep water, the 100 fathom line averaging about a mile off the coast. Jukes Brown thought it might have been forced up by some igneous mass below, but deep borings for oil to 10,000 feet go down only into Eocene Scotland beds.

It is 21 miles north to south and 14 miles wide and was completely under the sea in Pleistocene times. The larger or main part on the north rises to 1,105 feet at Mt. Hillaby, formed of oceanic chalks; but a recent survey reports that Castle Grant, on coral rock, is higher. The southerly Christ Church anticline, extending east and west, is a later uplift and rises to 400 feet near its western end. Between these uplifts is the St. George's Valley, a depressed undulating area. The *Natural History of Barbados*, by Revd. Griffith Hughes (1750), gives the highest point of Barbados as 915 feet taken from high-water mark. This is about the position where Castle Grant now is, and if the old measurement is reliable, the island may have risen 100 feet in 200 years.

The oldest beds are shales, grits, and conglomerates well folded, striking generally east and west parallel with the northern range of Trinidad and Venezuela. They are middle to upper Eocene in age, now exposed in the Scotland area and a few small patches. They are shallow-water beds and contain both marine and freshwater shells, the latter including a large *Ampullaria* resembling some that now live in Central Africa, but not in South America. This and several river bivalves have lived in a large river draining some continental land mass that may have lain in the Atlantic in the direction of Africa. The pebbles, however, of the conglomerate are merely quartz and clay-ironstone and give no clue to the nature of the land.

The Scotland beds have been folded and contorted in an almost Alpine manner and at Chalky Mount (by the way, there is no chalk on it) a high and wide vertical faulted surface faces west. At the north and south ends of Barbados, the folding seems to be less acute than across the middle region. This folding cannot be attributed to any particular cause and we scarcely know which are the lower and which are the higher beds, but probably the Ragged Point grits in the south are the oldest. This folded mass of rocks does not seem to have been raised very high above the sea. The oceanics rest unconformably on its edges and in the lower beds *Hantkenina* is reported. As this is an Eocene genus the interval between the folding and planation of the Scotland Series and deposition of the lower oceanics must have occurred during some interval in the upper Eocene.

Above the Scotland beds, the oceanics occur in patches. They are supposed to have been lain down in deep water. They now form the highest point of Barbados, Mt. Hillaby. At Bissex Hill, 800 feet, the formation is very soft and crumbles in the fingers, and consists of unbroken foraminifera and radiolaria. Though these beds have been raised below a heavy cover of limestone and coral rock, they are not compressed, and the small fossils are



TEXT-FIG. 2.—(1) A sketch map of Barbados indicating the zig-zag course of some of the stream gorges on the area covered by coral rock.

C.R. Coral rock. Oc. Oceanics. S. Scotland beds. S.G.V. St. George's Valley. C.Ch.R. Christchurch Ridge. H.C. Hackleston's Cliff. F.H. Fortress Hill.

(2) Section from near Hastings to Chalky Mount across the Christchurch Ridge and St. George's Valley and the main uplifted part of the island. The wave-cut terraces at higher levels have been further raised to form fault scarps.

(3) A section below Highgate Signal Station, on the south-west side of the Christchurch uplift, at about 250 feet altitude. The post-coral rock *Helix* bed has been turned down and caught between rising masses of coral rock. Just below 3 a perfect freshwater *Chilina* was found but where the bed is turned down all the shells are crushed and the rock sheared. The adjacent coral rock is fine-grained and shows surfaces movement of dislocation ; the sheared faces tend to bulge out in the direction of the sea and stand at acute angles to one another.

undamaged. This is always the case where the uplift has been purely vertical and suggests that the rise was a sort of release rather than compression. But at the edge of the rising terraces, where two forces have come into action the result is different. Below the terrace at Fortress Hill, on the north-west of Barbados, the base of the coral rock rests on oceanics. At this high level, further rise of the terrace has been considerable enough to expose a strip of the oceanic beds, which are here a dense yellow limestone, more or less veined, in which the globigerinae are crushed but still recognizable in places. The direct uplift has no crushing effect, but where a terrace has been further raised the combined uplift and cohesional mass attraction has produced hardening and crushing of the rock.

A similar effect has occurred in connection with the post-coral-rock *Helix* bed at the south end of the island, as will be described later.

Coral rock covers about four-fifths of Barbados and reaches 220 feet in

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thickness. On the north-east side it has been removed and exposes the oceanic and Scotland beds, which have quite a different surface topography. The edge of the coral rock forms a curving scarp rising from sea-level on the north-east, going up to 1,000 feet, and sinking to sea-level again on the south. On the main part of the island, facing north, west, and south up to about 500 feet, the coral rock rises as a series of four or five successive wave-cut terraces. In front of the lower two of the terraces the terrain is flat as it would be to-day on a shore line, but at the foot of the higher terraces the surface is jumbled and has sloping surfaces as if the rock has been raised irregularly.

At the highest three terraces we see lines of vertical cliff scarps 80 or 100 feet high, separated by gaps and looking like a row of decayed teeth. At the foot of two of these, at Fortress Hill, and at another place, an extra rise has exposed the oceanics at the base. On the west side and on the south side, facing St. George's Valley, many steep gulleys, often with vertical sides, pass downwards. The vertical sides of these gulleys often go down to below the level of the base of the adjacent scarp that faces the sea and they often take sudden right-angle turns to the left or right on descending the slope and scarps. Schomburgk, writing on Barbados long ago, noticed these gulleys and said they are not the result of water action as there is not enough gathering ground above, and compared them with earthquake rifts in Calabria. They are evidently connected in some way with the mode of uplift of the island. They may be some sort of submarine topography that has come up.

The coral rock of Barbados had been practically all formed before the island uplift began. At the base, in several places from sea-level up to 1,000 feet and in the southern later uplifted ridge, I found a peculiar basal bed. The fossils in it are *Haliotis barbadensis*, *Pleurotomaria quoyana*, *Cavolinia*, *Terebratula*, and often thousands of *Amphistegeina*. These do not occur in the main coral rock above. *Haliotis* is not found on the western coast of the Atlantic to-day, but a deep water form was dredged off Florida, but was destroyed by fire at a Chicago exhibition. This basal bed may be Pliocene in age. The southern or Christ Church anticline is a later uplift aligned east and west. It has no deep gulleys and the soil is still black and not reddened by weathering as it is at levels above 600 feet. On the sides facing the sea it has wave-cut, often sinuous terraces and scarps, but these show less later uplifting than on the main part of the island. Nevertheless, the terraces have been further raised and have in the process involved some quite late post-coral rock beds. On the seaward sides of the Christ Church ridge there are some deposits later than the coral rock, which have been called the *Helix* beds. They are marly limestones with rolled pebbles of coral and marine shells, especially at lower levels, noticeably the large blotched periwinkle, *Livonia pica*. At all levels we find land shells, especially the now living *Helix isabella*, *Helicina* sp., *Buliminus* sp., and *Geomelania* sp. These beds were deposited in swamps a little above high-water mark as each terrace rose. This is the only formation on Barbados which, where involved, has been sheared and the fossils crushed and broken and this very late deposit is the one which we would least expect to have suffered thus.

On the south-east coast at Whitehaven this bed is unusually thick, some 20 feet, and rests on oceanics, but has been banked up against coral rock. The island had attained more or less its present state of erosion before the *Helix* bed was deposited. Even so, it is not quite recent because here and at Silver Sands it is being undercut by the sea. The *Helix* bed was deposited on each terrace as it came up, so each higher terrace is older than the one below. At Silver Sands it contains marine gasteropods as well as *Helix*; it forms a veneer on the coral rock and is banked up against the base of a stack of that rock. It dips gently seawards, but at the next higher terrace it dips more steeply. Behind the Marine Hotel marl about 6 feet thick has been caught up between masses of coral rock and contains crushed *Livonia* and land shells. Further east, at the base of the third scarp, is a band of broken *Livonia* in crushed marl, the mottled outside of the shells contrasts with the pearly interior on the smashed specimens.

At the foot of and up the slope of the terrace below Highgate Signal Station, at about 250 feet, one sees the veneer of post-coral-rock passing up the slope on the surface; but it suddenly turns vertically downwards and becomes involved between masses of coral rock, which themselves show cleaved surfaces. In a quarry here it can be traced to a depth of over 20 feet, it is quite vertical, about 18 inches thick, and contains a few marine shells and plentiful land mollusca. These are crushed to pieces but one can recognize *Helix*, *Helicina*, and *Geomelania*. Just above the point where it turns down I found a sharp-pointed, smooth freshwater shell, like a *Limnaea*, but with a pleated columella. It is not crushed and looks like some form of Chilina now living in Peru and Chile but apparently not on Barbados.

These vertically involved *Helix* beds occur only near the western or more highly uplifted part of the Christ Church ridge where it rises to 400 feet. They are not mere fissures filled with late material because the bed is distinctly stratified as it is before it turns down into the coral rock.

The top of the broad Christ Church ridge is undulating with swallow holes formed by solution of the coral rock. On the north side it slopes irregularly down to the St. George's Valley and there are no wave-cut terraces as there are on the seaward sides. How then did it come up? The coral bank that gave rise to Barbados started to grow in deep water; the fossils in the basal bed died out and the reefs grew upwards till they came near to the surface. It may then have come under the influence of some upward tidal pull. On the main part of the island the upward urge has been strong enough to form the terraces into lines of vertical cliffs. On the lower Christ Church ridge the upward urge was less strong, but the terraces, so to speak, chased one another up, with the result that at the inner angle of the higher terraces the post-coral-rock beds have been caught up and sheared and the enclosed shells broken into pieces.

The north-east end of Barbados is flat, the coral rock is thin and has not the usual basal bed. Its growth here seems to have been hindered by being mixed up with underlying oceanic chalk. It has stayed low, while just to the south where the rock is massive it rises in a series of terraces.

All these features suggest that gravitational vertical pull-up is a powerful though distantly acting force and the soft material below had to follow up beneath the heavy cover as a sort of release and in consequence is uncrushed. The cohesional side pressure is a less powerful but more immediate force and the two acting together produce a hardening and crushing effect.

The whole island is an uplift and all the faults are double up-faults and the rise continued when the island was well above sea-level and presumably out of the reach of any pressure of rock from the sides.

The age of cataclysmic geology is suppoed to be over, but is it? At Hackles-tons Cliff, 997 feet above the sea, on the south-east of the coral rock escarp-ment, one looks down on to Bathsheba, about a mile away on the coast. There are many undercut masses of coral rock on the shore and I used to think they had rolled down from the escarpment. Examination of most of them shows they are rooted *in situ* on Scotland beds and have the usual *Amphiste-gina* bed at the base. It looks as if the coral rock had been forcibly dragged up and raised to 900 feet in the distance of a mile, but no doubt the process was slower than would appear.

Trinidad

The northern range of Trinidad, 45 miles from east to west, rises to just over 3,000 feet. It is an amazing display of a geological late-bedded series of sandstone, limestone, and shale, very largely altered to quartz, calcite, chalybite, with haematite, talc, sericite, gypsum, etc., fossils in the less altered parts in the south-west at Laventille and on the north-east at Toco date from Upper Jurassic to Upper Cretaceous.

Lenses among the schist consist of crystalline calcite, chalybite, and quartz, and often have ragged interior cavities lined with talc, but at the edges the grit frequently remains unaltered, passing abruptly into the crystalline material in the interior. It is at these narrow edges of the lenses that one might have expected the pressure to have been greatest. Another noticeable feature is that the quartz forms round the calcite rhombs as narrow partitions like the sides of a box, as if the quartz had crystallized out later than the calcite, as it does in a granite with respect to the feldspar crystals. In one place I found ferruginous grit turning into quartz crystals and talc near Morvant. The northern range is much folded and contorted but not compacted. It looks like a case of metamorphism without apparent pressure. There is only one minor occurrence of igneous basic rock, at Sans Souci, on the north-east coast. The northern range rises to three times the height of the central range, 20 miles to the south. This is formed of Cretaceous and early Tertiary rocks quite unmetamorphosed. A boring at Mt. Harris to 10,000 feet was still in dark Barremian shale only slightly slickensided.

The nearness of the northern range to an old shore line and the drawing up may have induced penetration by metamorphosing liquids and gases and caused its extra rise. I should prefer to attribute the gravity diminution over mountains to some such loosening or porosity rather than to any hypothetical down folding of lighter rock below them.

New Zealand

This is a country of great uplifts of the massive pre-Tertiary rocks and involvements of very thick covering beds, generally aligned parallel to the present coast lines, suggesting some influence of the sea. There is no evidence of any rock pressure from either side and apparently there is no granite claiming to be Tertiary in age. The most ancient rocks occur in the Nelson Province, Fiordland, and the Bluff on the south. A long fault separates them from the high Alpine backbone, which consists of Maitai or Permo-Carboniferous and Triassic beds, which are very thick; the upper Trias is estimated at 20,000 feet. These become metamorphic, principally in Otago. The covering beds range from middle Cretaceous to Pliocene.

In the Kaikoura Ranges, on the north-east of the South Island, and the Clarence Valley, the NE–SW ranges of the Kaikoura rise from 8,500 to 9,500 feet and over-top the Cretaceous and Tertiary beds of the Clarence and Awatere Valleys. The grain or structure of the Permo-Carboniferous of the Kaikoura is said to be independent of the direction of the involved strips. In the Clarence Valley, the newer or Amuri beds are on the west, dipping towards the more elevated Kaikoura Range.

On the north shore of Lake Whakatipu, at Bob's Cove, is the great involved strip of Oamaru Tertiary covering beds, about 1,500 feet thick. It extends to the north for about 25 miles and crosses Mt. Silverhorn at an altitude of 5,300 feet, where it has become narrowed to 75 to 100 feet, and dips 75° W. This slice of Tertiaries is enclosed by schist. On the lake I thought the highest beds were on the west and the schist must have risen much higher on this side than on the east, the side on which the Oamaru beds rested. Fossils are only moderately broken. At Lake Te Anau, further south, the Tertiaries are tilted up on the flank of mountains of older rock of each side of the lake.

New Zealand is a type area of what is called block faulting, which I prefer to call block uplift or pull-up of more massive beds, leaving the softer and more easily denuded strata below but tilting them in various directions.

The outbreak of volcanoes in the North Island seems to have had a pacifying effect so far as further uplift is concerned. The dormant cone of Mt. Egmont, in the south-west of the North Island, has a great thickness of Miocene beds on its flank and probably beneath it, they were bored to 8,260 feet.

A number of these features were mentioned in a paper I had printed by Messrs. B. T. Ord, of West Hartlepool, in 1950, entitled " New Zealand and My Forbidden Theory of Mountain Uplift ".

Reduction in Volume of Rocks by Metamorphism

In Devonian slates at Holbeach, in North Cornwall, the one-time thick spirifers are reduced to ghost-like films of sericite, while Crinoid ossicles in the same piece show that the bed was once calcareous.

At Os, in Norway, in the Bergen Arches, masses of Ordovician corals are slightly flattened while bands of mica schist pass through the actual coral.

In Jamaica, at Moy Hall, on approaching the serpentine at Arntully, conglomerate with limestone pebbles enclosing Rudist remains and Foraminifera occur. Patches of serpentine develop while the pebbles become reduced in size till they are mere pellets. The pebbles become impregnated from the outside inwards by green infiltration and in some pieces are drawn out into streaks but still retain fossil traces, in a sort of ophicalcite.

The wholesale removal of calcite is obvious, but I can assign no reason for it, except that the process is chemical and mineralogical rather than dynamical. Such contraction occurring through a considerable thickness of rock could account for local folding and thrusting as the mass becomes drawn together as it is drawn upwards.

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HUDWORTH TOWER,
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6th March, 1958.

ULTRABASIC PILLOW LAVAS FROM CYPRUS

SIR,—Preliminary accounts of the Troödos massif and igneous complex were given by the writer in *Nature*, 1952, and in the Transactions of the XIXth International Geological Congress (1952), published in 1954, as well as in unpublished official records. The subdivision of the massif into its main groups and the recognition of more than one series of lava flows had in fact been accomplished and demonstrated by the writer before 1953; since when the Geological Survey has been steadily continuing its investigation of the island.

It is incorrect, therefore, that in the second paragraph of his paper " Ultrabasic Pillow Lavas from Cyprus " (*Geol. Mag.*, xcv, No. 3, 1958), Mr. I. G. Gass should ascribe this early work to the present organization; while he omits my two short but fundamental papers of 1952–54 from his bibliography. In fact, the general reconnaissance of the whole area and pioneer mapping of over 250 square miles of this rough and then geologically unknown region was done by the writer (1950–53) with the assistance of Mr. R. A. M. Wilson during 1952 and the end of 1951.

There are some further points of interest which have not yet received the attention they deserve.

Mr. Gass records a difference of opinion as to whether the Diabase Formation represents a huge series of north-south dykes or a set of isoclinally-folded lava-flows. Both of my papers cited above give the evidence on which I named this formation the " Folded Diabase ", whose component sheets vary from a few centimetres to a metre or so in thickness, and whose total breadth of exposure across the strike is some 50 miles. The strike does not vary more than a few degrees either side of north and south, and is frequently north-north-west, thus lining up with the Red Sea direction. On the evidence I have interpreted the structure as a great anticlinorium of which the heart has been filled by the basic plutonic core described. There is a lot of dyke-matter intruded lit-par-lit into this diabase; but if the whole thing is a huge series of dykes in groups inclined at various angles it becomes enormously difficult to explain the structures by any theory of faulting; or the emplacement of a pack of dykes of such small thickness and huge extent like the leaves of a book. Each dyke must have had time to solidify before an adjacent one came in beside it and displaced the existing wall-rocks for dozens of miles all told. The dips of the various limbs of the supposed folds run as a rule between 45 and 60 degrees either to east or west; and the turnover at the bottom of a syncline is unusually sharp if not angular, while the slopes from valley-bottom to crest may be as uniform as a roof for several thousand feet. But this is not inconsistent with the rigid, non-plastic, competent character of the diabase which shows low-grade metamorphism.