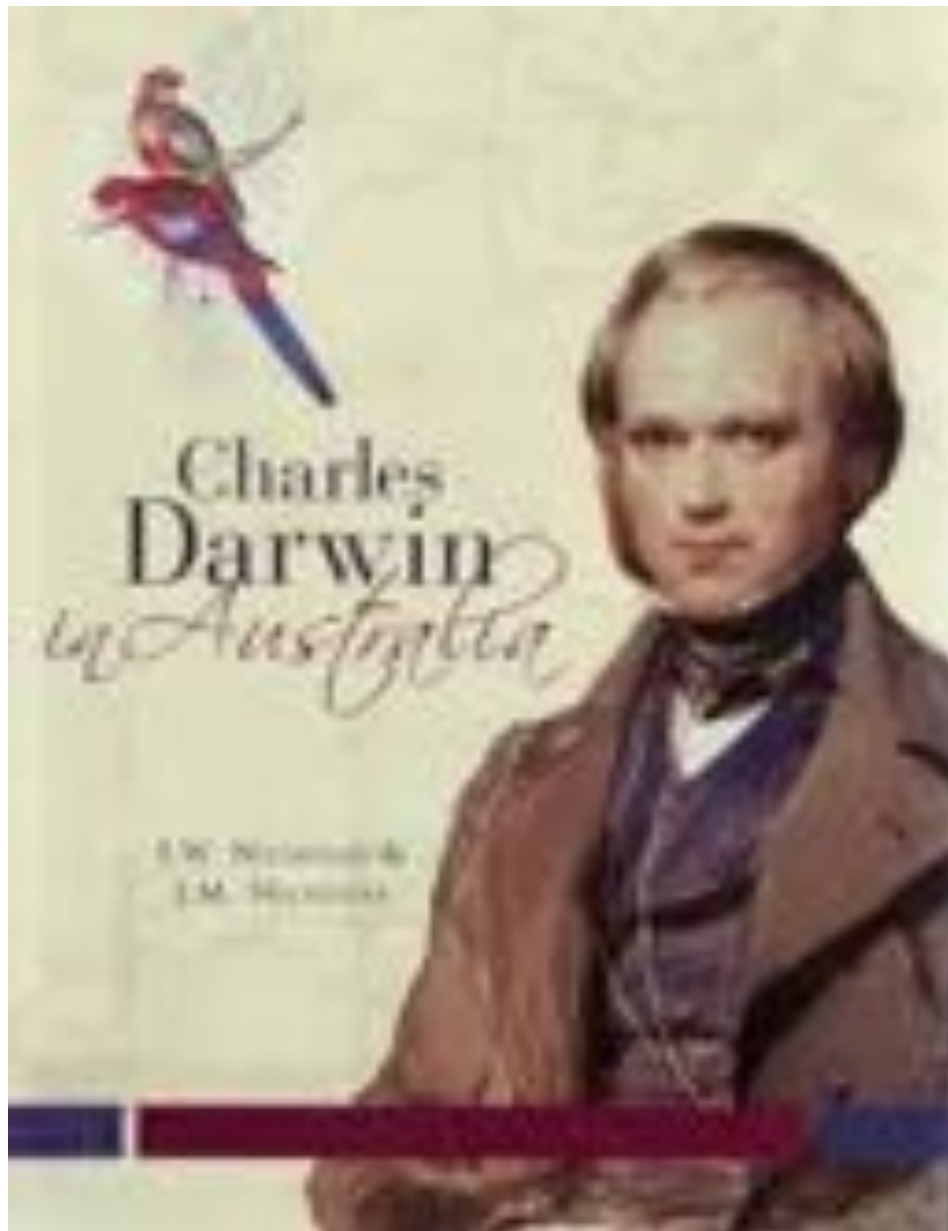


Darwin in Australia

Jan.-Feb. 1836

Coral Reefs 1842

Robert Bender
February 2020





Captain Francis Beaufort and his wind scale

Before we got onto Darwin:

Beaufort was the navy hydrographer, and very interested in meteorology, as was Robert Fitzroy.

In 1805 (4 years before Darwin was born), he developed the first version of his wind-force scale. A later version is still in use.

He trained Fitzroy in its use and recommended the young Charles Darwin as “naturalist” and companion for the 2nd Beagle voyage – its first commander, Pringle Stokes, had suicided off South America in 1828.

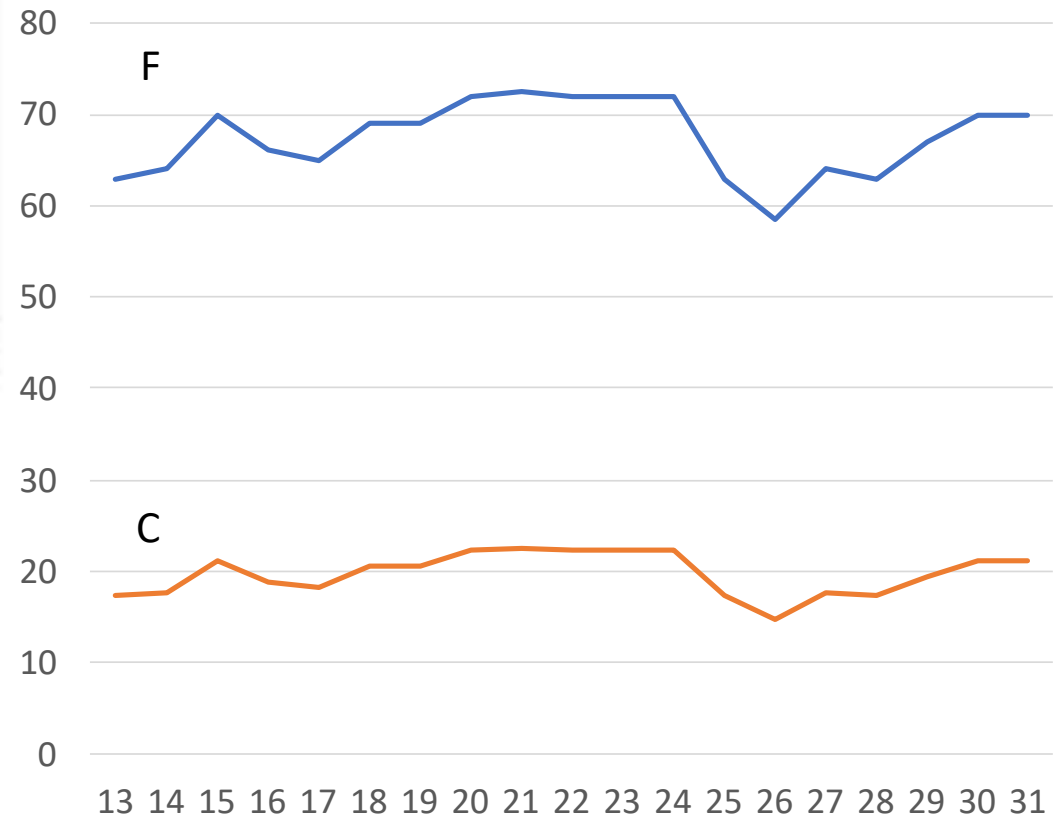
Fitzroy was a meticulous recorder (he later developed pioneering weather forecasting when Governor of New Zealand) so there is a precise record of Sydney weather for their entire 4-week stay



Beaufort's scale

A mild summer on the coast, but a scorcher inland, as Darwin found at Bathurst

Sydney temperature January 13-31 1836



Chronometers and longitude on the Beagle

Fitzroy took 22 chronometers on his voyage.

The first Harrison chronometer was used by Cook on his Endeavour voyage.

Part of Fitzroy's instructions was to get accurate longitude values for each place they stopped, to develop a worldwide set of longitudes for use of later ships.

So he had to stop at many places to get a good set of data from the entire circumference of Earth

Chronometers from the Beagle



John
Harrison,
clock-
maker

Subject of
Dava
Sobel's
book
Longitude





Conrad Martens, Beagle artist in South America
He and Darwin met again in Sydney, where Martens had settled

Sydney in 1836, about the
time the Beagle visited



CHAPTER XIX

AUSTRALIA

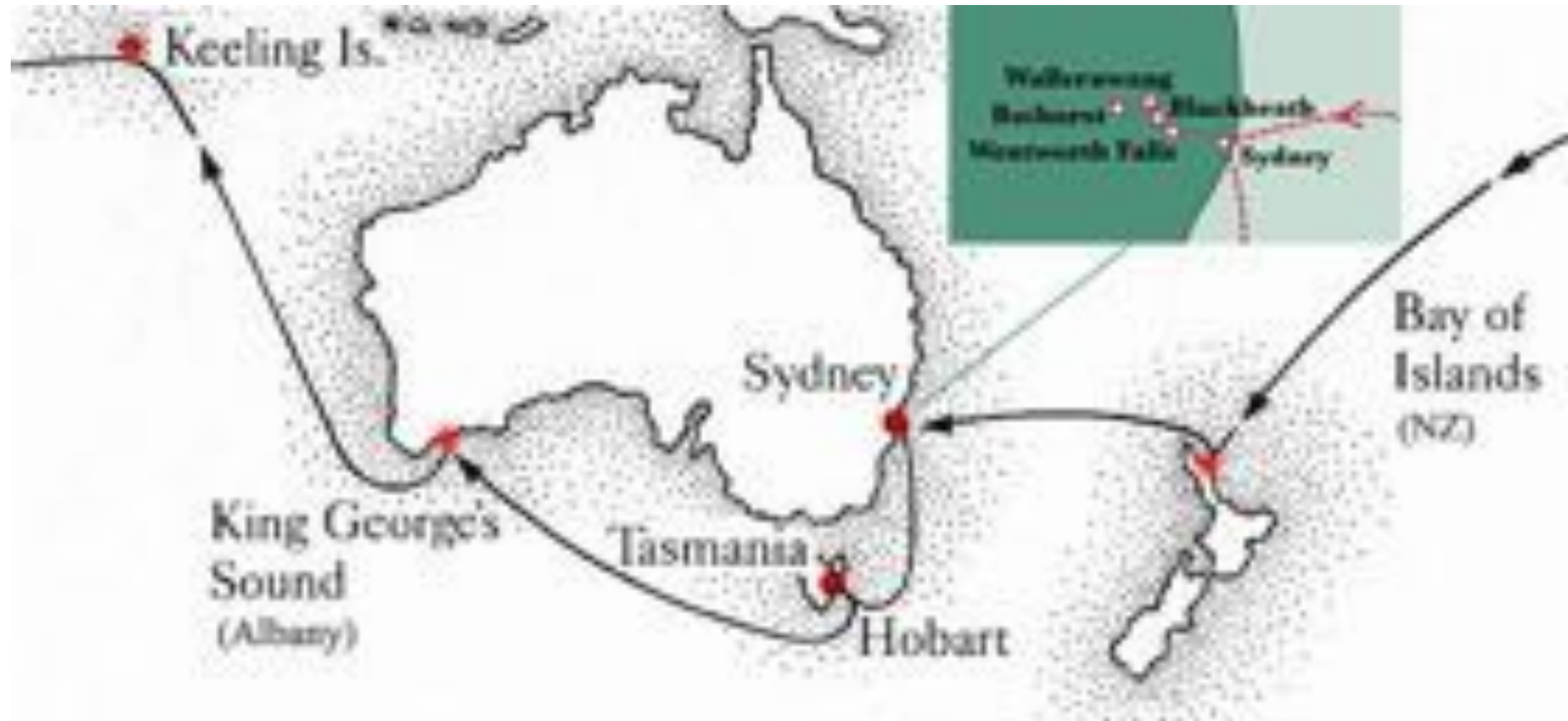
Sydney—Excursion to Bathurst—Aspect of the Woods—Party of Natives—Gradual Extinction of the Aborigines—Infection generated by associated Men in health—Blue Mountains—View of the grand gulf-like Valleys—Their origin and formation—Bathurst, general civility of the Lower Orders—State of Society—Van Diemen's Land—Hobart Town—Aborigines all banished—Mount Wellington—King George's Sound—Cheerless Aspect of the Country—Bald Head, calcareous casts of branches of Trees—Party of Natives—Leave Australia.

JANUARY 12th, 1836.—Early in the morning a light air carried us towards the entrance of Port Jackson. Instead of beholding a verdant country, interspersed with fine houses, a straight line of yellowish cliff brought to our minds the coast of Patagonia. A solitary lighthouse, built of white stone, alone told us that we were near a great and populous city. Having entered the harbour, it appears fine and spacious, with cliff-formed shores of horizontally stratified sandstone. The nearly level country is covered with thin scrubby trees, bespeaking the curse of sterility. Proceeding further inland, the country improves: beautiful villas and nice cottages are

Journal of the
Beagle

There is a short
chapter on the visit
to Australia – a
mere four weeks
out of the six-year
voyage

The Beagle visited Australia from 12 January to 7 February 1836, with 3 stops



CHARLES DARWIN'S TRAVELS IN SOUTHEAST AUSTRALIA



South Head



Sydney harbour

“Having entered the harbour, it appears fine and spacious, with cliff-formed shores of horizontally stratified sandstone.”



Sydney in 1836.

What is now just the CBD



To Bathurst

“I hired a man and two horses to take me to Bathurst, a village about one hundred and twenty miles in the interior; and the centre of a great pastoral district.

By this means I hoped to gain a general idea of the appearance of the country. On the morning of the 16th January I set out on my excursion.

Bathurst NSW
Painted by Joseph Backler 1847-57

Convict labour and roads



“The iron gangs, or parties of convicts who have committed here some offence, appeared the least like England; they were working in chains, under the charge of sentries with loaded arms.

The power which the government possesses, by means of forced labour, of at once opening good roads throughout the country, has been, I believe one main cause of the early prosperity of this colony.



“The extreme uniformity of the vegetation is the most remarkable feature in the landscape of the greater part of New South Wales.

Everywhere we have an open woodland, the ground being partially covered with a very thin pasture, with little appearance of verdure.

The trees nearly all belong to one family, and mostly have their leaves placed in a vertical, instead of, as in Europe, in a nearly horizontal position; the foliage is scanty, and of a peculiar pale green tint, without any gloss.

Hence the woods appear light and shadowless... The leaves are not shed periodically: this character appears common in the entire southern hemisphere, namely South America, Australia and the Cape of Good Hope.

The inhabitants of this hemisphere, and of the inter-tropical regions, thus lose perhaps one of the most glorious, though to our eyes common, spectacles in the world – the first bursting into full foliage of the leafless tree...

The bark of some of the Eucalypti falls annually, or hangs dead in long shreds which swing about with the wind, and give to the woods a desolate and untidy appearance.”

Aborigines



“At sunset, a party of a score of the black aborigines passed by, each carrying, in their accustomed manner, a bundle of spears and other weapons.

By giving a leading young man a shilling, they were easily detained, and threw their spears for my amusement.

They were all partly clothed, and several could speak a little English: their countenances were good-humoured and pleasant, and they appeared far from being such utterly degraded beings as they have usually been represented.

In their own arts they are admirable. A cap being fixed at thirty yards distance, they transfixed it with a spear, delivered by the throwing stick with the rapidity of an arrow from the bow of an experienced archer...

They will not, however, cultivate the ground, or build houses and remain stationary, or even take the trouble of tending a flock of sheep when given to them.

Aboriginal tribal conflict



“As the white man has travelled onwards, he has spread over the country belonging to several tribes.

These, although thus enclosed by one common people, keep up their ancient distinctions and sometimes go to war with each other.

In an engagement which took place lately, the two parties most singularly chose the centre of the village of Bathurst for the field of battle.

This was of service to the defeated side, for the runaway warriors took refuge in the barracks.

Immunity, carriers and transmission of disease



“The Rev. J. Williams, in his interesting work [*Narrative of Missionary Enterprise*], says, that the first intercourse between natives and Europeans, ‘is invariably attended with the introduction of fever, dysentery, or some other disease, which carries off numbers of the people.’

Again, he affirms, it is certainly a fact, which cannot be controverted, that most of the diseases which have raged in the islands during my residence there, have been introduced by ships; and what renders this fact remarkable, is that there might be no appearance of disease among the crew of the ship which conveyed this destructive importation.’

This statement is not quite so extraordinary as it at first appears; for several cases are on record of the most malignant fevers having broken out, although the parties themselves, who were the cause, were not affected.

In the early part of the reign of George III, a prisoner, who had been confined in a dungeon, was taken in a coach with four constables before a magistrate, and although the man himself was not ill, the four constables died from a short putrid fever; but the contagion extended to no others.



Weatherboard Inn

“In the middle of the day we baited our horses at a little inn, called the Weatherboard. The country here is elevated 2800 feet above the sea.”

Darwin stayed in the old building at left with skillion roof. The double storey one was built much later.



Wentworth Falls

“About a mile and a half from this place there is a view exceedingly well worth visiting. Following down a little valley and its tiny rill of water, an immense gulf unexpectedly opens through the trees which border the pathway, at the depth of perhaps 1500 feet.

Walking on a few yards, one stands on the brink of a vast precipice, and below one sees a grand bay or gulf, for I know not what other name to give it, thickly covered with forest.

The point of view is situated as at the head of a bay, the line of cliff diverging on each side, and showing headland behind headland, as on a bold sea-coast.

These cliffs are composed of horizontal strata of whitish sandstone, and are so absolutely vertical, that in many places a person standing on the edge and throwing down a stone, can see it strike the trees in the abyss below. So unbroken is the line of cliff, that in order to reach the foot of the waterfall, formed by this little stream, it is said to be necessary to go sixteen miles around.

This kind of view was to me quite novel, and extremely magnificent.”

“18th. – Very early in the morning, I walked about three miles to see Govett’s Leap; a view of a similar character with that near the Weatherboard, but perhaps even more stupendous. So early in the day, the gulf was filled with a thin blue haze, which, although destroying the general effect of the view added to the apparent depth....”



Govett's Leap



Wallerawang

“At Hassan’s Wells, I left the high road, and made a short detour to a farm called Walerawang; to the super-intendent of which I had a letter of introduction from the owner in Sydney. Mr. Browne had the kindness to ask me to stay the ensuing day, which I had much pleasure in doing....”



The farm has since been drowned by an artificial lake to supply a hydro power station



Rat kangaroo (Potoroo)
and Gould's painting of one

"Early on the next morning, Mr. Archer, the joint superintendent, had the kindness to take me out kangaroo-hunting. We continued riding the greater part of the day, but had very bad sport, not seeing a kangaroo, or even a wild dog.

The greyhounds pursued a kangaroo rat into a hollow tree, out of which we dragged it; it is an animal as large as a rabbit, but with the figure of a kangaroo. A few years since this country abounded with wild animals; but now the emu is banished to a long distance, and the kangaroo is become scarce; to both, the English greyhound has been highly destructive.

Ornithorhynchus anatinus

“In the dusk of the evening I took a stroll along a chain of ponds, which in this dry country represented the course of a river, and had the good fortune to see several of the famous *Ornithorhynchus paradoxus*.

They were diving and playing about the surface of the water, but showed so little of their bodies that they might easily have been mistaken for water-rats.

Mr. Browne shot one; certainly it is a most extraordinary animal; a stuffed specimen does not at all give a good idea of the appearance of the head and beak when fresh; the latter becoming hard and contracted.



A SEPARATE CREATION



Discovery of Wild Australia
by Explorers and Naturalists
Selected and annotated by
Graham Pizzey

In the dusk of the evening I took a stroll along a chain of ponds, which in this dry country represented the course of a river, and had the good fortune to see several of the famous Platypus or Ornithorhynchus paradoxus. They were diving and playing about the surface of the water, but showed so little of their bodies that they might easily have been mistaken for water-rats . . .

A little time before this I had been lying on a sunny bank, and was reflecting on the strange character of the animals of this country as compared with the rest of the world. An unbeliever in every thing beyond his own reason might exclaim, "Two distinct Creators must have been at work; their object, however, has been the same, and certainly the end in each case is complete."

How could Australia's
fauna be SO different?

From Charles Darwin's Journal of Researches into the Geology and Natural History of the Various Countries Visited by HMS Beagle (1845).

Ant lion (*Myrmeleontidae*)
*What convinced Darwin the world
is a unity after all?*



“I was interested to find here the hollow conical pitfall of the lion-ant, or some other insect; first a fly fell down the treacherous slope and immediately disappeared; then came a large but unwary ant; its struggles to escape being very violent; those curious little jets of sand, described by Kirby and Spence [*Entomology, vol 1*] as being flirted by the insect’s tail, were promptly directed against the expected victim.

But the ant enjoyed a better fate than the fly, and escaped the fatal jaws which lay concealed at the base of the conical hollow. This Australian pitfall was only about half the size of that made by the European lion-ant.



Bathurst and the sheep/wool industry

“20th. – A long day’s ride to Bathurst... In the afternoon we came to view the downs of Bathurst. These undulating but nearly smooth plains are very remarkable in this country, from being absolutely destitute of trees. They support only a thin brown pasture. We rode some miles over this country, and then reached the township of Bathurst, seated in the middle of what may be called either a very broad valley, or narrow plain.

The secret of the rapidly growing prosperity of Bathurst is, that the brown pasture, which appears to the stranger’s eye so wretched, is excellent for sheep-grazing. The town stands, at the height of 2000 feet above the sea, on the banks of the Macquarie.

This is one of the rivers flowing into the vast and scarcely known interior. The line of watershed, which divides the inland streams from those on the coast, has a height of about 3000 feet, and runs in a north and south direction at the distance of from eighty to a hundred miles from the sea-side.



Drought
in sheep
country

Drought at Bathurst 1836

“We experienced this day the sirocco-like wind of Australia, which comes from the parched deserts of the interior. Clouds of dust were travelling in every direction, and the wind felt as if it had passed over a fire. I afterwards heard that the thermometer out of doors had stood at 119° [48.3°C] and in a closed room at 96°. [35.6°C]

The season, it must be owned, had been one of great drought, and the country did not wear a favourable aspect; although I understand it was incomparably worse two or three months before.

The two main exports are wool and whale-oil, and to both of these productions there is a limit. The country is totally unfit for canals, therefore there is not a very distant point, beyond which the land-carriage of wool will not repay the expense of shearing and tending sheep.

Pasture everywhere is so thin that settlers have already pushed far into the interior: moreover the country further inland becomes extremely poor. Agriculture, on account of the droughts, can never succeed on an extended scale.”

The railway was invented the year the Beagle reached Australia and disproved Darwin's prediction of the short-lived success of agriculture in this country.

Insect-collector



“At some time during the Beagle’s stay in Sydney, Darwin went beetle-collecting. Darwin and Syms Covington between them captured ninety-seven different species representing five different orders in the environs of Sydney...

Although Darwin was a keen entomologist, he was not expert at identification, and left this task to others to whom he gave his insect collection once he had returned to England.

...forty-two species were previously unknown. Included among these new species were a leaf beetle (*Idiocephala darwini*), a seed bug (*Ontiscus darwini*), a gasteruptiid wasp (*Foenus darwinii*) and a bee (*Halictus darwiniellus*) that were each named after Darwin.

Nicholas, *Charles Darwin in Australia*

BEES COLLECTED BY CHARLES DARWIN ON THE VOYAGE OF THE "BEAGLE"

BY T. D. A. COCKRELL.

Several years ago I noticed among the undetermined bees in the Hope Museum at Oxford two species of *Halictus* collected by Charles Darwin. Last summer, being again in Oxford, I made descriptions of them, with the kind permission of Professor E. B. Poulton. One specimen, a female, was collected at Sydney, N. S. W.; the other, a male, came from Hobart Town, Tasmania. Both are black species of ordinary appearance. I went through all the collection of Australian *Halictus* in the British Museum, but neither of Darwin's species was represented. Returning home, I similarly went over my own collection, and found that the male differed in no essential respects, so far as I could make out, from *Halictus repens* Cockrell. The female I was still unable to place, nor could I identify it with any of the few species shown both from my collection and that of the British Museum. If it seems singular that a bee collected at Sydney so long ago should still be new, it must be remembered that very little attention has ever been paid to *Halictus* in New South Wales, the list of species known from that state being very much shorter than the lists for Tasmania, Victoria, or Queensland. In fact, when I was in the vicinity of Sydney I caught only a single species of *Halictus*, and it proved to be new. This was in 1928.

Halictus (Erythronis) darwiniensis new species.

♀. Black; anterior wing 5.5 mm. long; wings long, flagellum longish, broad except basally; base of head and thorax in poor condition, but pale; head rather large, ordinary; white covering below; clypeus convex, shining, with sparse punctures, the upper part with a shining median groove; squallyped; eyes dull, top of head unusually hairy interspersed; clypeus poorly developed, in lateral profile not so wide as eyes; mouthparts coarse, with no distinct median groove, moderately shining, with very numerous minute punctures; mentum shining and finely punctured, basal area of mentum large, dull and granular, as also with distinct though delicate lines, and a little shining; posterior lacinia not sharply be-

Darwin's bee, *Halictus*

Australian society: the opinion of a gentleman

“On the whole, from what I heard, more than from what I saw, I was disappointed in the state of society. The whole community is rancorously divided into parties on almost every subject.

Among those who, from their station in life, ought to be the best, many live in such open profligacy that respectable people cannot associate with them. There is much jealousy between the children of the rich emancipist and the free settlers, the former being pleased to consider honest men as interlopers.

The whole population, poor and rich, are bent on acquiring wealth: amongst the higher orders, wool and sheep-grazing form the constant subject of conversation.

There are many serious drawbacks to the comforts of a family, the chief of which, perhaps, is being surrounded by convict servants.

How thoroughly odious to every feeling, to be waited on by a man who the day before, perhaps, was flogged, from your representation, for some trifling misdemeanour. The female servants are of course, much worse: hence, children learn the vilest expressions, and it is fortunate, if not equally vile ideas.

South to Hobart for ten days



One of Earle's 6 paintings for his panorama (above)
Burford's print based on them (left)

Darwin had seen a panorama of Hobart displayed in London, based on paintings by Augustus Earle (also a Beagle artist in the voyage's first year)



Brachiopod: *Terebratula* (above), Bryozoans: *Fenestella*, *Stenopora* (below)

Hobart and geology

Darwin spent several days exploring both shores of the Derwent, collecting fossils and rock samples all the way.

He found several new species, hitherto unknown to science, but all obviously related to known species.



The Salamanca Place warehouses had just been built

“Round the Cove, there are some fine Warehouses & on one side a small Fort”



Darwin & Covington climbed Mt Wellington: it took all day
“From the number of dead trees & branches, the labor of ascent was almost as great as in T. del Fuego... It cost us five & a half hours before we reached the summit.”



Tasmania and the aborigines after the Black War (1824-31)



Aborigines and Wybalenna, Flinders Island

“All the aborigines have been removed to an island in Bass’s Straits, so that Van Diemen’s Land enjoys the great advantage of being free from a native population. This most cruel step seems to have been quite unavoidable, as the only means of stopping a fearful succession of robberies, burnings, and murders, committed by the blacks, and I fear there is no doubt that this train of evil and its consequences originated in the infamous conduct of some of our countrymen.

Thirty years is a short period, in which to have banished the last aboriginal from his native island – and that island nearly as large as Ireland. The correspondence on this subject, which took place between the government at home and that of Van Diemen’s Land, is very interesting.

Although numbers of natives were shot and taken prisoners in the skirmishing, which was going on at intervals for several years, nothing seems fully to have impressed them with the idea of our overwhelming power, until the whole island, in 1830, was put under martial law, and by proclamation the whole population commanded to assist in one great attempt to secure the entire race.

The plan adopted was nearly similar to that of the great hunting-matches in India: a line was formed, reaching across the island, with the intention of driving the natives into a cul-de-sac on Tasman’s peninsula.

The attempt failed; the natives, having tied up their dogs, stole during one night through the lines. This is far from surprising, when their practised senses, and usual manner of crawling after wild animals is considered.”

Aboriginal round-up continued

“...the natives understanding this kind of warfare, were terribly alarmed, for they at once perceived the power and numbers of the whites. Shortly afterwards a party of thirteen belonging to two tribes came in; and, conscious of their unprotected condition, delivered themselves up in despair.

Subsequently by the intrepid exertions of Mr. Robinson, an active and benevolent man, who fearlessly visited by himself the most hostile of the natives, the whole were induced to act in a similar manner.

They were then removed to an island, where food and clothes were provided them. Count Strzelecki states, that ‘at the epoch of their deportation in 1835, the number of natives amounted to 210.

In 1842, that is, after the interval of seven years, they mustered only fifty-four individuals; and while each family of the interior of New South Wales, uncontaminated by contact with the whites, swarms with children, those of Flinders’ Island had during eight years an accession of only fourteen in number!’



Cemetery at
Wybalenna,
Flinders Island



Unmarked graves
of 100 aborigines

MANNA ARGENIA

LAST CHIEF OF PORTLAND TRIBE

DIED DEC. 4TH 1885

ERECTED BY FURNEAUX HISTORICAL

RESEARCH ASSOCIATION

The only
one with
a name



The settlement only lasted 12 years.

The few aborigines left were transferred to Oyster Cover, Hobart.



Geologising around Hobart

“The Beagle stayed here ten days, and in this time I made several pleasant little excursions, chiefly with the object of examining the geological structure of the immediate neighbourhood.

The main points of interest consist, first in some highly fossiliferous strata, belonging to the Devonian or Carboniferous period; secondly, in proofs of a late small rise of the land; and lastly, in a solitary and superficial patch of yellowish limestone or travertine, which contains numerous impressions of leaves of trees, together with land-shells, not now existing.

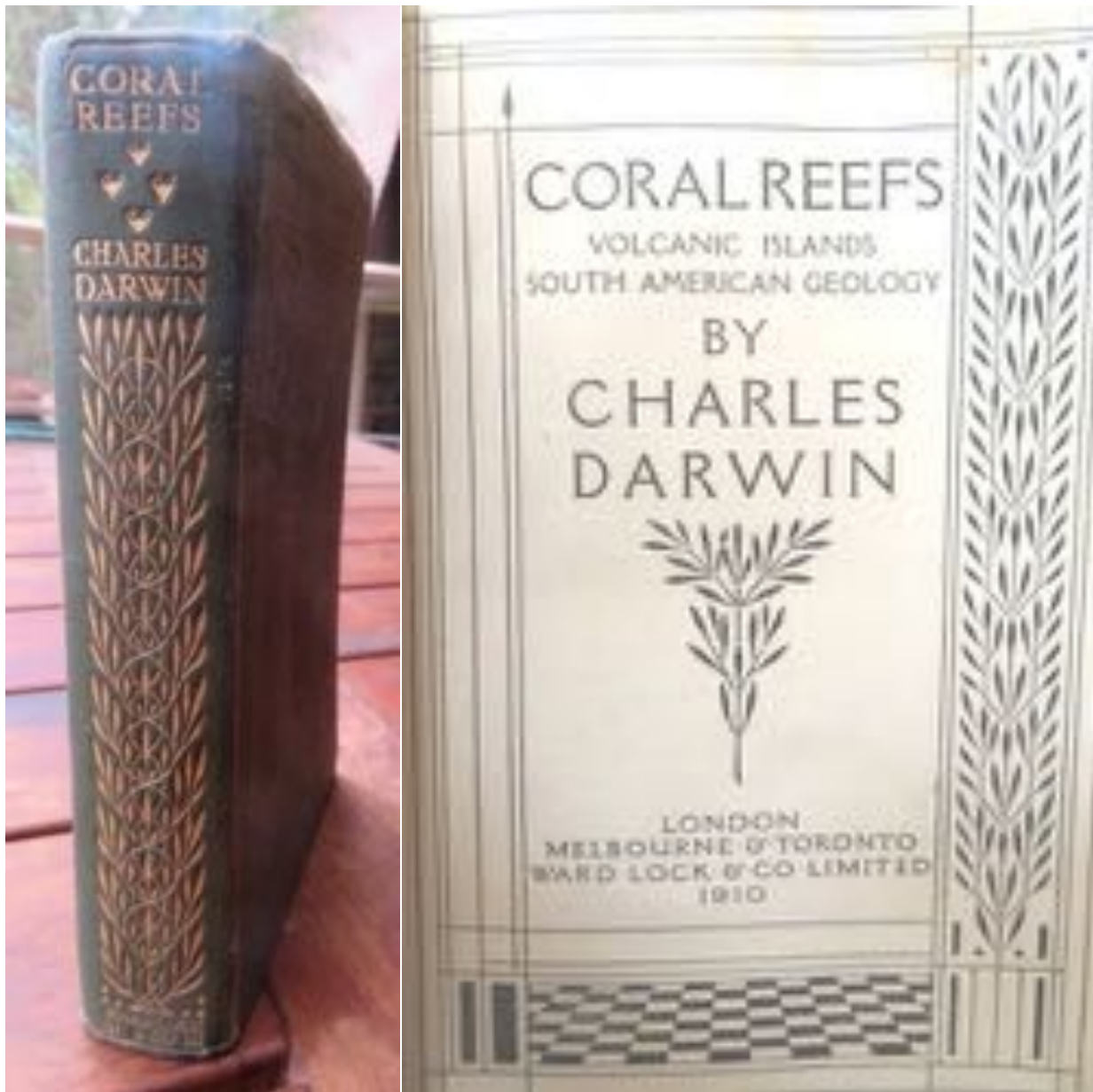
It is not improbable that this one small quarry includes the only remaining record of the vegetation of Van Diemen’s Land during one former epoch.



Permian
mudstone fossils

Below: clam
shells, Maria
Island





Published 1842

6 years after the Beagle
returned to England

17 years before *The Origin of
Species*

CHAPTER XX

KEELING ISLAND:—CORAL FORMATIONS

Keeling Island—Singular appearance—Scanty Flora—Transport of Seeds—Birds and Insects—Ebbing and flowing Springs—Fields of dead Coral—Stones transported in the roots of Trees—Great Crabs—Stinging Corals—Coral-eating Fish—Coral Formations—Lagoon Islands, or Atolls—Depth at which reef-building Corals can live—Vast Areas interspersed with low Coral Islands—Subsidence of their foundations—Barrier Reefs—Fringing Reefs—Conversion of Fringing Reefs into Barrier Reefs, and into Atolls—Evidence of changes in Level—Breaches in Barrier Reefs—Maldiva Atolls; their peculiar structure—Dead and submerged Reefs—Areas of subsidence and elevation—Distribution of Volcanoes—Subsidence slow, and vast in amount.

APRIL 1st.—We arrived in view of the Keeling or Cocos Islands, situated in the Indian Ocean, and about six hundred miles distant from the coast of Sumatra. This is one of the lagoon-islands (or atolls) of coral formation, similar to those in the Low Archipelago which we passed near. When the ship was in the channel at the entrance, Mr. Liesk, an English resident, came off in his boat. The history of the inhabitants of this place, in a few words as possible, is as follows. About the year 1791, a

Across the Indian ocean Fitzroy's instructions included expectations he would investigate coral atolls, to gather data that might explain their formation

He stopped at Tahiti, Keeling, Mauritius.





Keeling atoll

West of
Christmas Island
South of Sumatra

Keeling (Cocos) atoll
Sketch in *Coral Reefs*, modern map



Arrival at Keeling atoll



“The ring-formed reef of the lagoon-island is surmounted in the greater part of its length by linear islets. On the northern or leeward side, there is an opening through which vessels can pass to the anchorage within.

On entering, the scene was very curious and rather pretty; its beauty, however, entirely depended on the brilliancy of the surrounding colours. The shallow, clear and still water of the lagoon, resting in its greater part on white sand is, when illumined by a vertical sun, of the most vivid green.

This brilliant expanse, several miles in width, is on all sides divided, either by a line of snow-white breakers from the dark heaving waters of the ocean, or from the blue vault of heaven by the strips of land, crowned by the level tops of the coconut trees. As a white cloud here and there affords a pleasing contrast with the azure sky, so in the lagoon bands of living coral darken the emerald green water.”

“the strips of land, crowned by the level tops of the coconut trees”



Flora



“The cocoa-nut tree, at first glance, seems to compose the whole wood; there are however five or six other trees. One of these grows to a very large size, but from the extreme softness of its wood, is useless; another sort affords excellent timber for ship-building.

Besides the trees, the number of plants is exceedingly limited, and consists of insignificant weeds.”

One of the standard discoveries of biogeographers, is the depauperate flora and fauna of oceanic islands as so few species can reach them. Darwin was much interested to explain the distribution of species.

Keeling atoll, 16 km on its long axis. Darwin was keen to understand the island-forming processes, learned to identify coral species, and waded out to B to learn about coral species distribution – most vigorous on the windward side, facing the tides. Island formation is a net result of creation vs destruction. All coral grows below low-tide mark, between B and A. From A, a steep descent to the ocean floor



A.—Level of the sea at low water : where the letter A is placed, the depth is twenty-five fathoms, and the distance rather more than one hundred and fifty yards from the edge of the reef.

B.—Outer edge of that flat part of the reef, which dries at low water : the edge either consists of a convex mound, as represented, or of rugged points, like those a little farther seaward, beneath the water.

C.—A flat of coral-rock, covered at high water.

D.—A low projecting ledge of brecciated coral-rock washed by the waves at high water.

E.—A slope of loose fragments, reached by the sea only during gales : the upper part, which is from six to twelve feet high, is clothed with vegetation. The surface of the inlet gently slopes to the lagoon.

F.—Level of the lagoon at low water.

The corals



Porites

“...the reef-building polypifers, not being tidal animals, require to be constantly submerged or washed by the breakers.

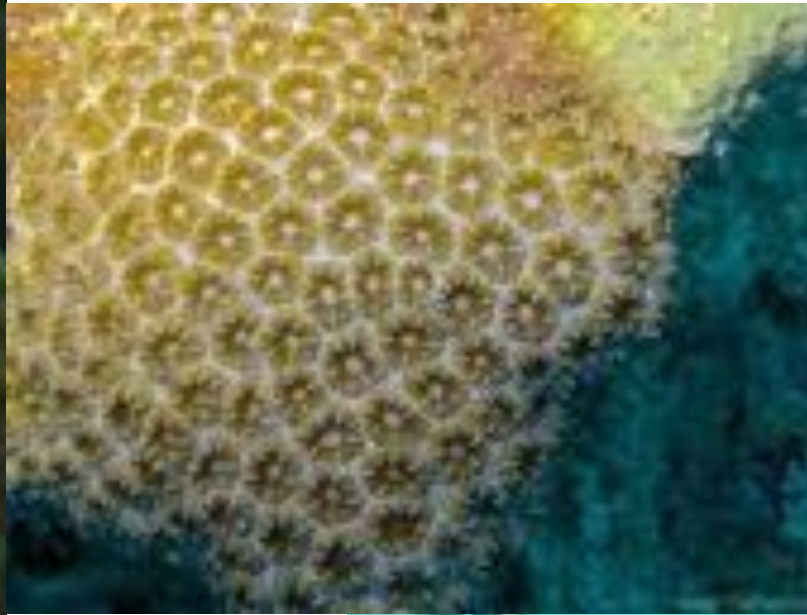
Hence it is possible only under the most favourable circumstances afforded by an unusually low tide and smooth water, to reach the outer margin, where the coral is alive.

I succeeded only twice in gaining this part, and found it almost entirely composed of a living *Porites*, which forms great irregularly rounded masses (like those of an *Astraea*, but larger) from four to eight feet broad, and little less in thickness....

On the furthest mound, which I was able to reach by the aid of a leaping-pole, and near which the sea broke with some violence, although the day was quite calm and the tide low, the polypifers in the uppermost cells were all dead, but between three and four inches lower down on its side they were living, and formed a projecting border round the upper and dead surface.



*Millepora
alcicornis*



Astraea

Corals
“Next but
much inferior
in importance
to the Porites,
is the
*Millepora
complanata*.”



Millepora complanata

How fast do reefs grow?



“In an old-standing reef, the corals, which are so different in kind on different parts of it, are probably all adapted to the stations they occupy, and hold their places, like other organic beings, by a struggle, one with another, and with external nature; hence, we may infer that their growth would generally be slow, except under peculiarly favourable circumstances.

Almost the only natural condition, allowing a quick upward growth of the whole surface of a reef, would be a slow subsidence of the area in which it stood;

if, for instance, Keeling atoll were to subside two or three feet, can we doubt that the projecting margin of live coral, about half an inch in thickness, which surrounds the dead upper surface of Porites, would in this case form a concentric layer over them, and the reef thus increase upwards, instead of, as at present, outwards?

The Nulliporae are now encroaching on the Porites and Millepora, but in this case might we not confidently expect that the latter would, in their turn, encroach on the Nulliporae?”

Madrepora now
Lobophylla
corymbosa



How deep can coral organisms “polypifers” live?

At Mauritius, on the leeward side are a few miles of coast with reefs, Darwin managing the lead. The doughy material in the lead brought up impressions of the corals below, which Darwin examined on board, trying to identify species.

Different species at different depths

Above 20 fathoms: coral;

below: clean sand

Rolled fragments on beaches were of the same species, so he hadn't missed any.



Madrepora
pocillipora



Astraea



Pocillipora
verrucosa



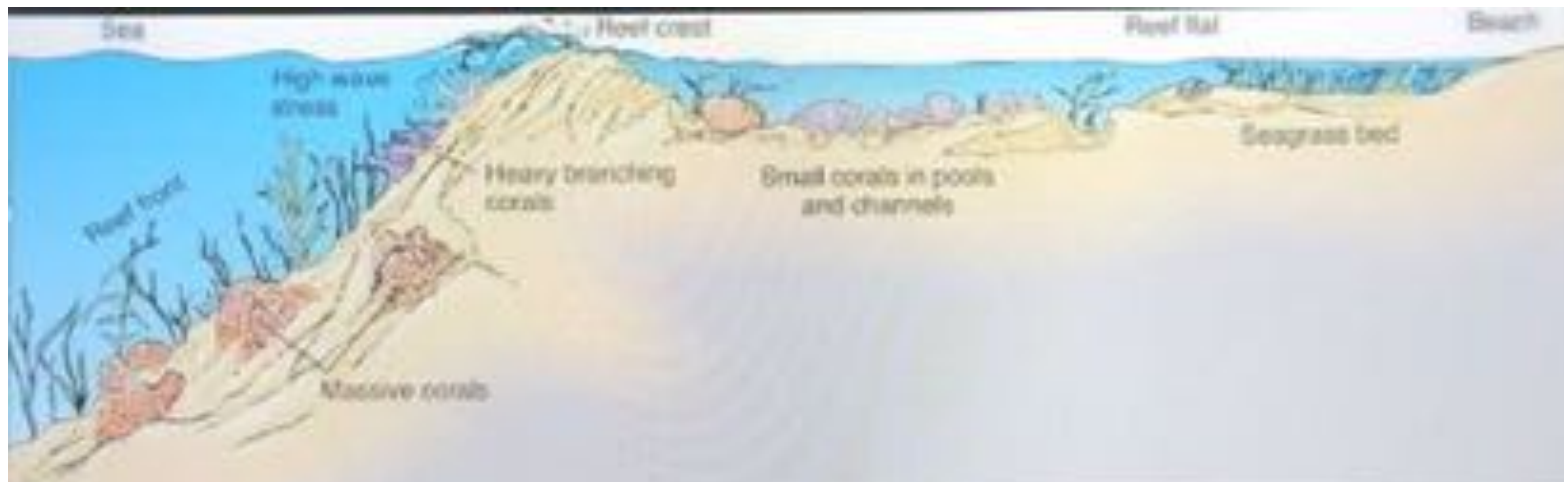
“The circumstance of the arming having invariably come up quite clean, when sounding within a certain number of fathoms off the reefs of Mauritius and Keeling atoll (eight fathoms in the former case, and twelve in the latter) and of its having always come up (with one exception) smoothed and covered with sand, when the depth exceeded twenty fathoms, probably indicates a criterion, by which the limits of the vigorous growth of coral might in all cases be readily ascertained.

I do not, however, suppose that if a vast number of soundings were obtained round these islands, the limit above assigned would be found never to vary, but I conceive the facts are sufficient to show, that the exceptions would be few.

The circumstance of a *gradual* change, in the two cases, from a field of clean coral to a smooth sandy bottom is far more important in indicating the depth at which the larger kinds of coral flourish than almost any number of separate observations on the depth, at which certain species have been dredged up. For we can understand the gradation, only as a prolonged struggle against unfavourable conditions.

I have endeavoured to collect every fact, which might either invalidate or corroborate this conclusion.” — typical Darwin caution to avoid bias in his conclusions.

And all of this done on board ship, with just a sounding lead.



How deep do corals grow?



Detour: Captain Robert Moresby 1794-1854

Moresby spent 1829-33 charting the Red Sea.

After the completion of the Red Sea Survey, Robert Moresby was sent to chart various coral island groups lying across the track of India-to-Cape trade.

In 1834–1836 Moresby, assisted by Lieutenants Christopher and Young, undertook the difficult cartography of the Maldivé Islands, drawing the first accurate maritime charts of this complicated Indian Ocean atoll group.

These charts were printed as three separate large maps by the Hydrographic Service of the Royal Navy.

Moresby's survey of the Atolls of the Maldives was followed by the Chagos Archipelago where he conducted a thorough scientific survey.

Wikipedia

Darwin used Moresby's maps extensively to develop his theory of coral reefs.



Moresby was also a competent landscape painter



Theory of the formation of the different classes of coral reef

“The theory most generally received on the formation of atolls, is that they are based on submarine craters;

but where can we find a crater of the shape of Bow atoll, which is five times as long as it is broad;

or like that of Menchikoff Island, with its three loops, together sixty miles in length...

or like the northern Maldiva atolls, made up of numerous ring-formed reefs, placed on the margin of a disc – one of which discs is eighty-eight miles in length, and only from ten to twenty in breadth?”

Reefs: uplift or subsidence?

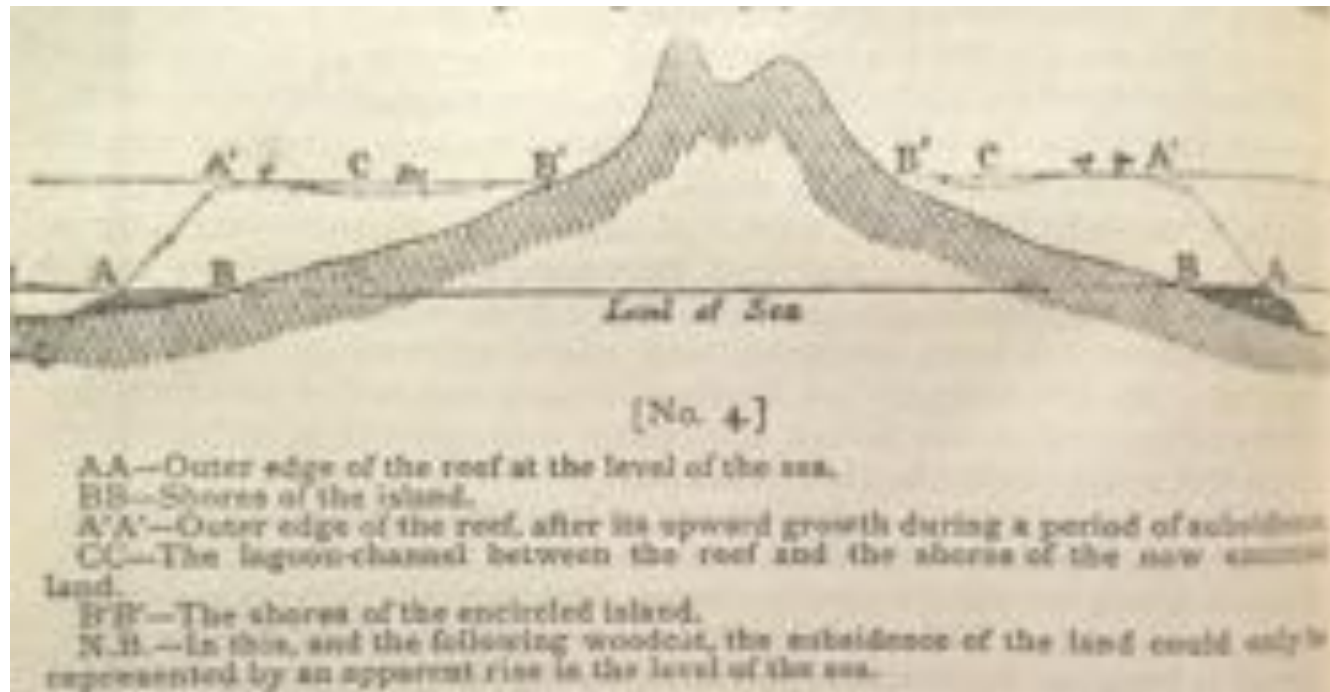
He described a theory of accumulation of huge banks of sediment along the 5,000 miles of atolls crossing the Pacific to India, dismissed it as impossible.

He compared strings of atolls with mountain ranges on continents: “Where can we find a single chain several hundred miles in length and of considerable breadth, much less several such chains, with their many broad summits attaining the same height within from 120 to 180 feet?”

“It is almost equally improbable, that as many submarine mountains, as there are low islands in the seven great and widely separated areas...should all rise within six hundred feet of the surface of the sea, and not one above it.”

“If, then, the foundations of the many atolls were not uplifted into the requisite position, they must of necessity have subsided into it; and this at once solves every difficulty, for we may safely infer... that during a gradual subsidence the corals would be favourably circumstanced for building up their solid frameworks and reaching the surface, as island after island slowly disappeared.”

“Thus areas of immense extent in the central and most profound parts of the great oceans, might become interspersed with coral islets, none of which would rise to a greater height than that attained by detritus heaped up by the sea, and nevertheless they might all have been formed by corals, which absolutely required for their growth a solid foundation within a few fathoms of the surface.”



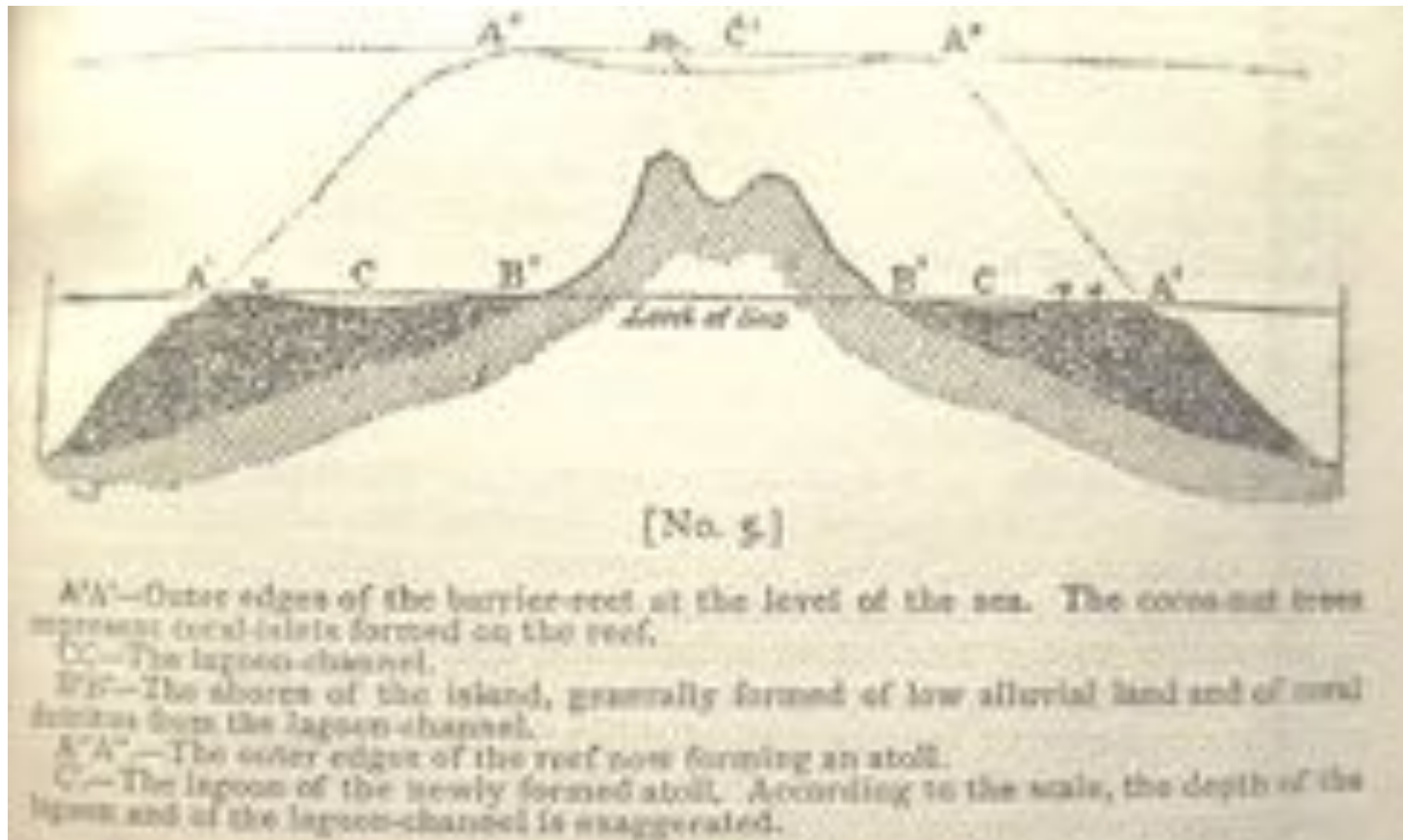
Uplift offset by subsidence

Illustration of a volcanic crater with a fringing reef, the island slowly subsiding, the reef slowly growing upwards to remain near the water surface and creating a lagoon

“...when we consider how many parts of the surface of the globe have been elevated within recent geological periods, we must admit that there have been subsidences on a corresponding scale, for otherwise the whole globe would have swollen.”

He gathered some evidence of such subsidence, much of it circumstantial:

“Whitsunday Island is described by Wallis as ‘about four miles long, and three wide,’ now is only one mile and a half long.”



Island subsides further

Illustration of island having subsided into the ocean, the coral slowly growing higher, burying the volcanic crater under dead coral, forming an atoll: a ring of coral sand and rock with coconut trees

“...let the work of subsidence go on, and the doubly pointed hill will form two small islands (or more, according to the number of the hills) included within one annular reef. Let the island continue subsiding and the coral reef will continue growing up on its own foundation, while the water gains inch by inch on the land until the last and highest pinnacle is covered, there remains a perfect atoll.”

Keeling earthquakes and barely detectable subsidence

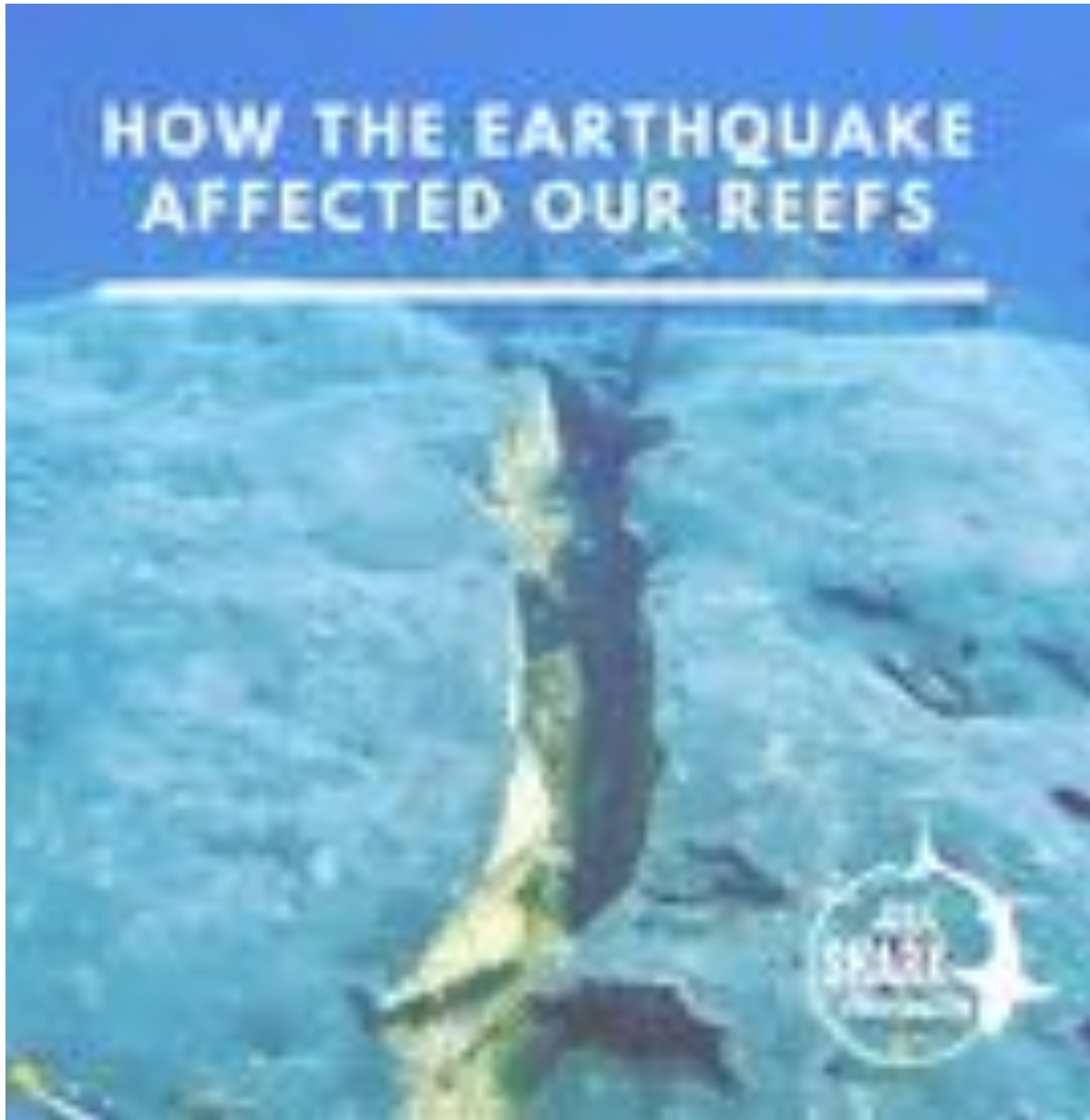
“Captain Fitzroy pointed out to me, near the settlement, the foundation posts of a shed, now washed by every tide, but which the inhabitants stated, had seven years before stood above high watermark.

In the calm waters of the lagoon, directly connected with a great and therefore stable ocean, it seem very improbable that a change in the currents, sufficiently great to cause the water to eat into the land on all sides, should have taken place within a limited period.

From these considerations I inferred, that probably the atoll had lately subsided a small amount; and this inference was strengthened by the circumstance, that in 1834, two years before our visit, the island had been shaken by a severe earthquake, and by two slightly smaller ones during the ten previous years.”

Later in his book he considered carefully the relationship between uplift and subsidence in island chains across the Pacific and Indian oceans, and on the west coast of the Americas.

HOW THE EARTHQUAKE AFFECTED OUR REEFS



Keeling atoll and subsidence

“It struck both Lieutenant Sullivan and myself, from the manner in which the trees were being washed down, that the surf had lately recommenced an attack on this line of coast.

Appearances indicating a slight encroachment of the water on the land, are plainer within the lagoon: I noticed in several places, both on its windward and leeward shores, old cocoa-nut trees falling with their roots undermined, and the rotten stumps of others on the beach, where the inhabitants assured us the cocoa-nut could not now grow.”



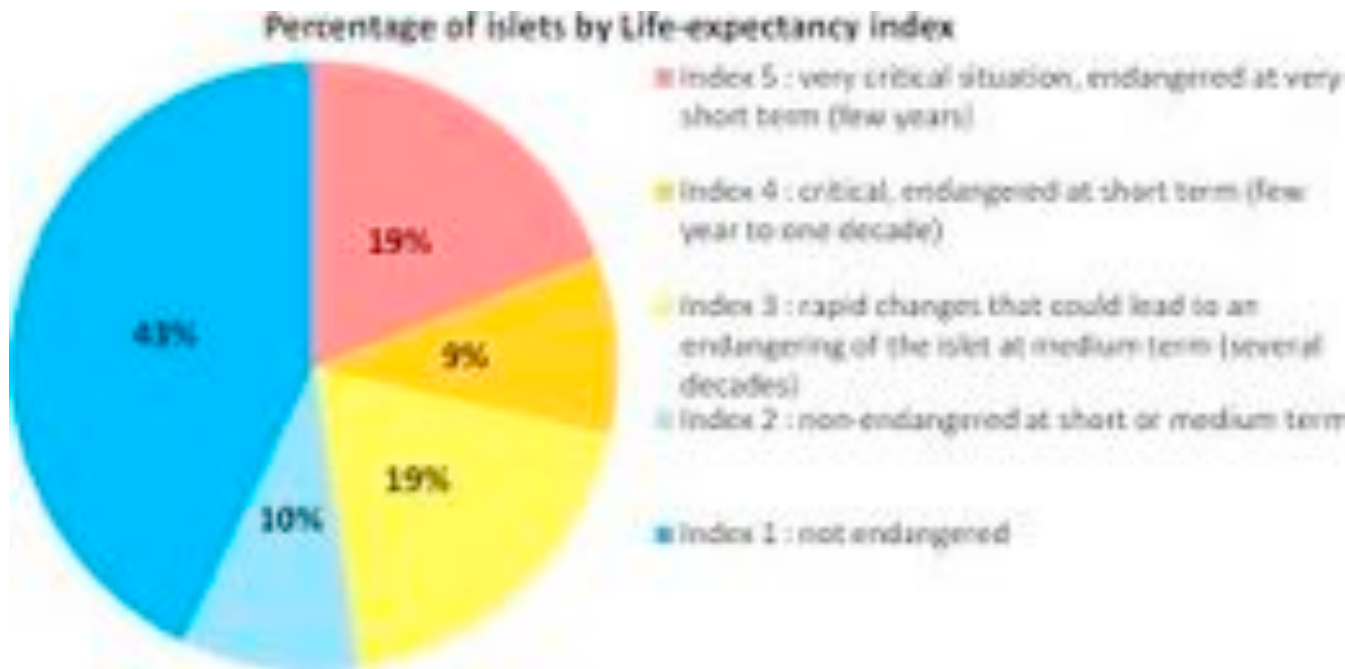
New Caledonia barrier reef & subsidence

“At New Caledonia, the barrier reefs extend for 150 miles on each side of the submarine prolongation of the island; and at their northern extremity they appear broke up and converted into a vast atoll-formed reef, supporting a few low coral islets: we may imagine that we here see the effects of subsidence actually in progress.”

The sea level map shows he was exactly right



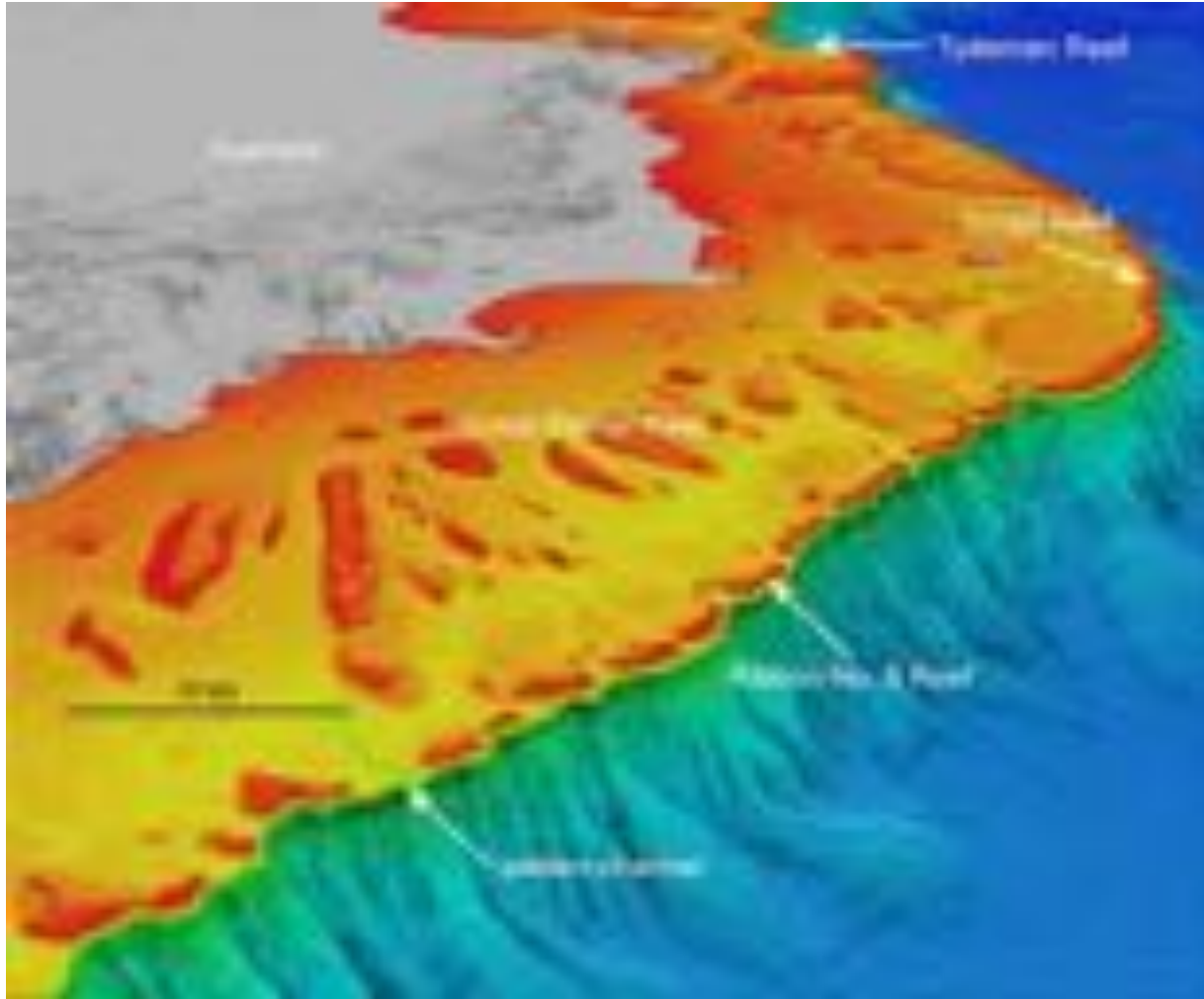
New Caledonia future



A 2016 study of 21 islets around New Caledonia by Manuel Garcin's team produced a pie chart showing life expectancy of the islets (*Continental Shelf Research July 2016*).

In the short-to mid-term the main danger is erosion by storm waves and sea level rise.

Climate change with its alteration of ocean currents, storm intensity and frequency, and sea level rise are much more immediate threats to New Caledonian islets and atolls than the very long-term subsidence Darwin postulated.



Australia's barrier reef

“The great reef which fronts the coast of Australia has been supposed, but without any special facts, to rest on the edge of a submarine precipice extending parallel to the shore.”

That's exactly right – deep ocean surveying since the 1940s has produced the modern map.

Three classes of reefs, or just one?



Volcanic Island



Fringing Reef



Barrier Reef

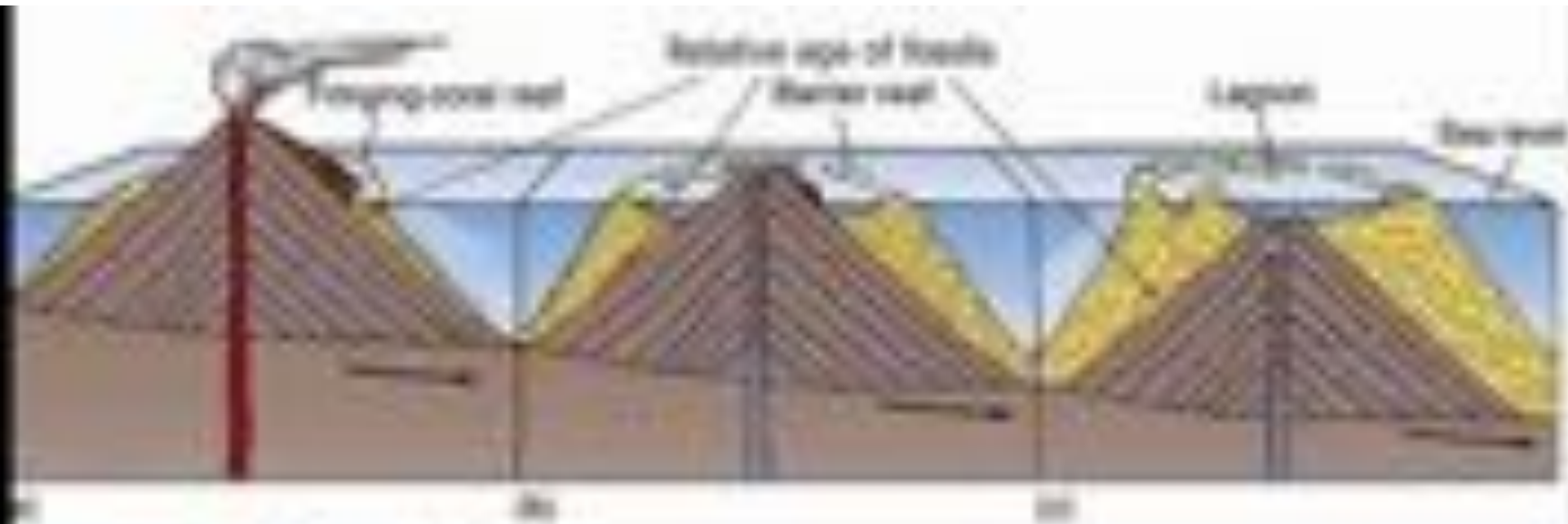


“We are now able to perceive that the close similarity in form, dimensions, structure and relative position between fringing and encircling barrier-reefs and between these latter and atolls, is the necessary result of the transformation, during subsidence of the one class into the other. On this view the three classes of reefs ought to graduate into each other.

Between barrier reefs, encircling either one lofty island or several small low ones, and atolls including a mere expanse of water, a striking series can be shown.

In proof of this, I need only refer to the first plate in this volume, which speaks more plainly to the eye, than any description could to the ear.”

Darwin was ever keen to link together different phenomena in causal series, accepting that Earth is old and has had plenty of time for all to happen.



Drowned atolls

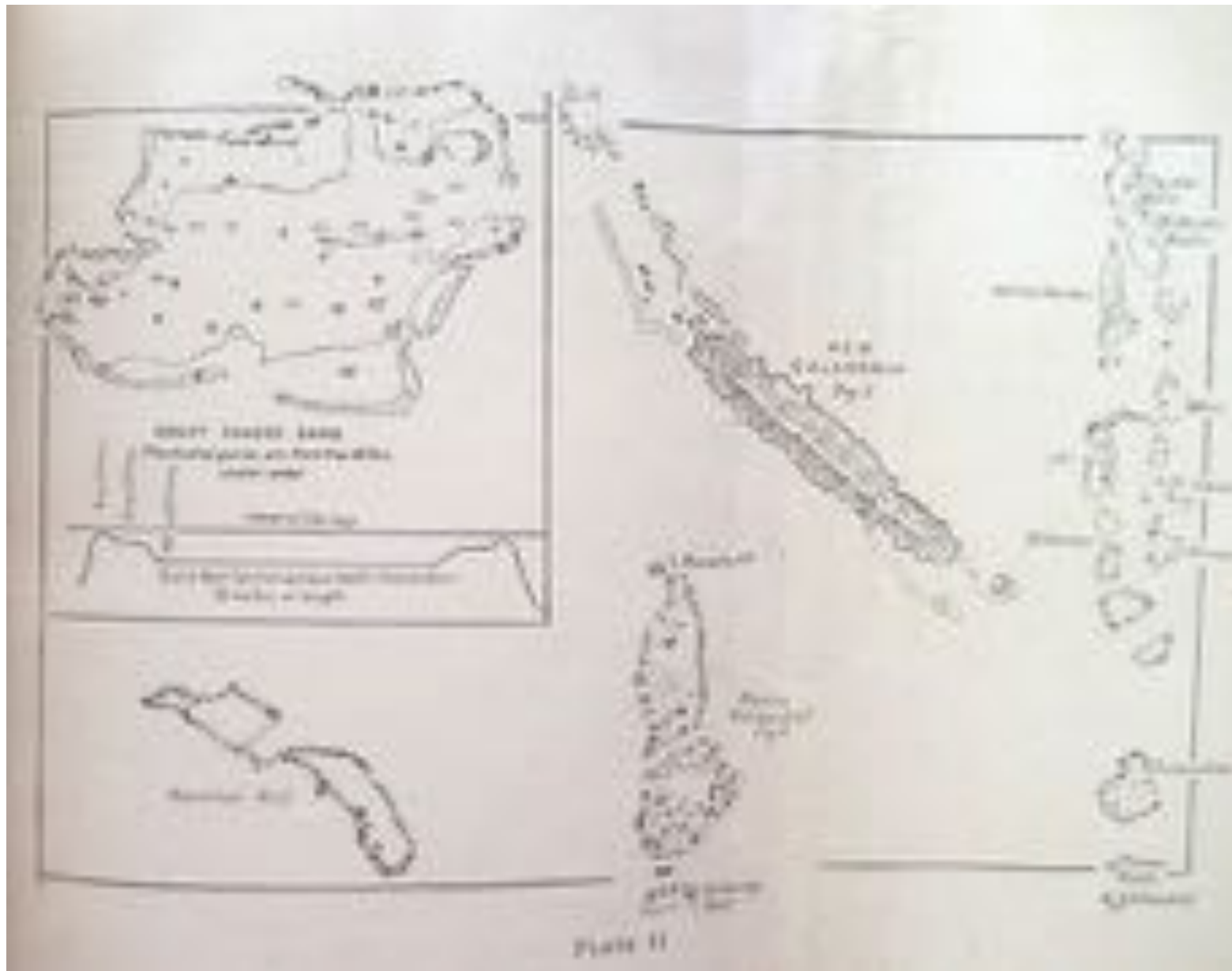
“...there are in the neighbourhood of atolls, some deeply submerged banks, with level surfaces; that there are others less deeply but yet wholly submerged, having all the characters of perfect atolls, but consisting merely of dead coral-rock; that there are barrier-reefs and atolls with merely a portion of their reef, generally on the leeward side, submerged;

and that such portions either retain their perfect outline, or they appear to be quite effaced, their former place being marked only by a bank, conforming in outline with that part of the reef which remains perfect.

These several cases are, I believe, intimately related together, and can be explained by the same means....

It is then, not improbable that the corals should sometimes perish either on the whole or on part of a reef; if on part, the dead portion, after a small amount of subsidence, would still retain its proper outline and position beneath the water. After more prolonged subsidence, it would probably form, owing to the accumulation of sediment, only the margin of a flat bank, marking the limits of the former lagoon....

In the Chagos group of atolls within an area of 160 miles by 60, there are two atoll-formed banks of dead rock (besides another very imperfect one) entirely submerged; a third with merely two or three very small pieces of living reef rising to the surface, and a fourth, namely Peros Banhos with a portion nine miles in length dead and submerged...



Great Chagos
(surveyed by Moresby)

New Caledonia
(barrier reef)

Maldiva group

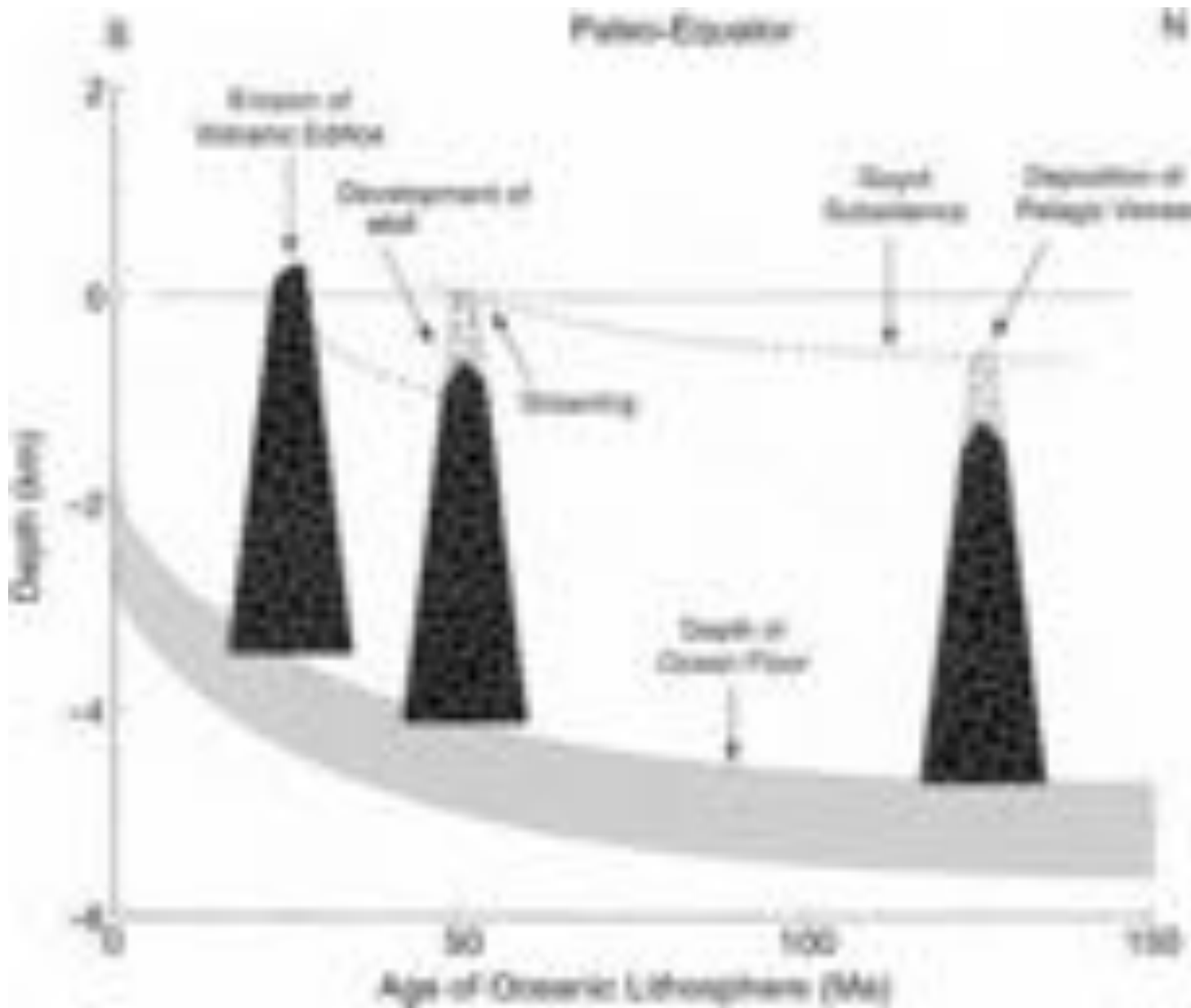
Menchikoff

Great Chagos Bank

south of Sri Lanka,
Indian Ocean

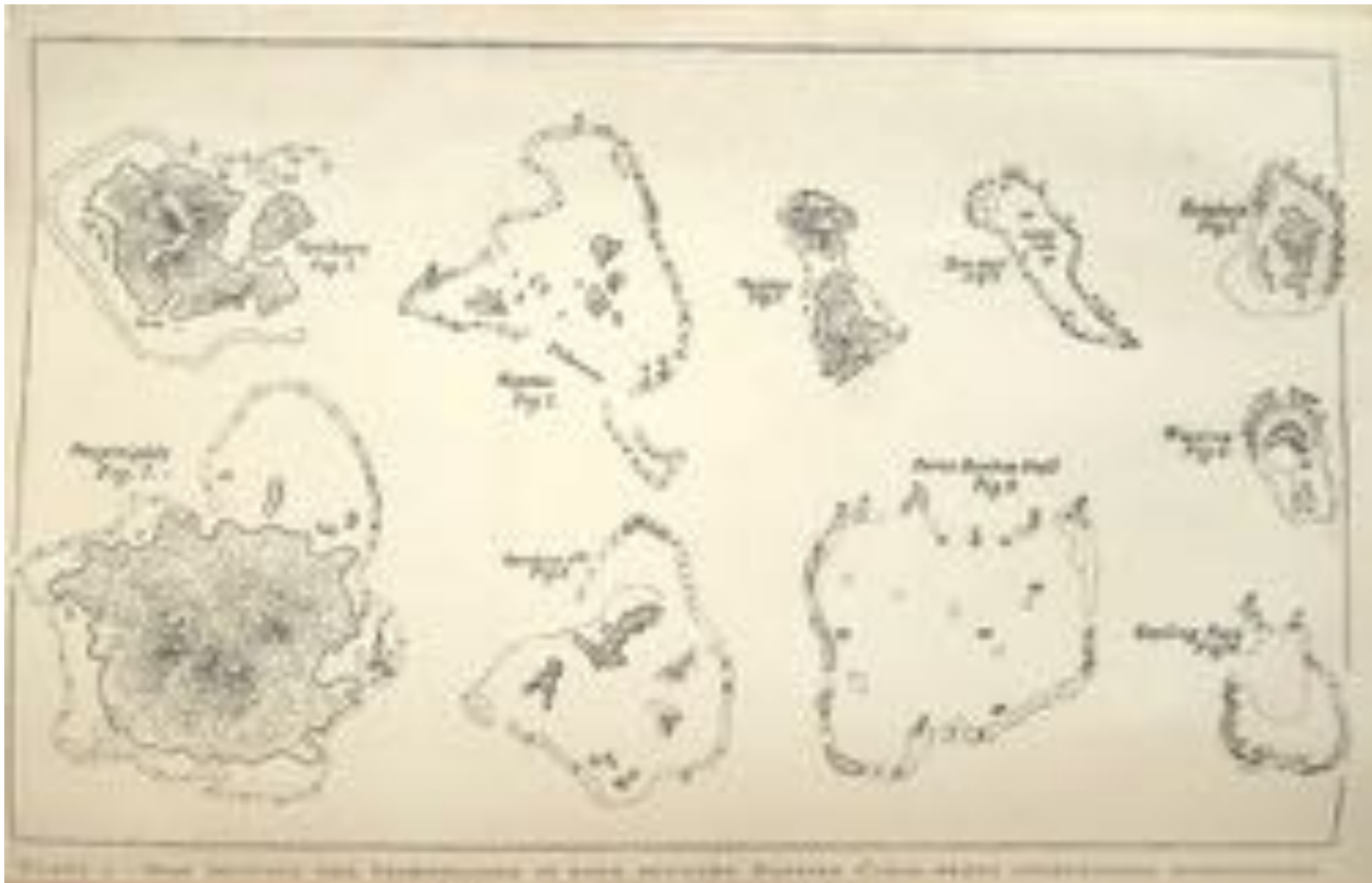


“The external rim or upper ledge consists of dead coral-rock thinly covered with sand; it lies at an average depth of between five and eight fathoms, and perfectly resembles in form the annular reef of an atoll.”



Illustrating how atolls develop atop seamounts, then subside and die.

Darwin offered no numbers on the relative ages of uplift and subsidence as he had no basis for making any estimates. Radioactivity which makes dating possible was discovered by Bequerel in 1896, 54 years later



Ten atolls

Keeling
lower
right

Some
have
islands,
some
don't

A
sequence
as islands
slowly
subside
into the
sea, leave
atolls

Distribution of atolls and reefs (*from my copy of the book*):
None on Americas west or east coast, nor on Africa's west coast.
Bermuda the only one in the Atlantic
All between 30° N and 30° S



The original 1842 publication had coral atolls and reefs coloured blue
And fringing reefs coloured red



Uplift vs subsidence on island chains and continents

On the absence of active volcanoes in the areas of subsidence, and their frequent presence in the areas of elevation.

“It is impossible not to be struck, first with the absence of volcanoes in the great areas of subsidence tinted pale and dark blue, - namely in the central part of the Indian Ocean, in the China Sea, in the area between the barrier reefs of Australia and New Caledonia, in the Caroline, Marshall, Gilbert and Low Archipelagoes; and, secondly, with the coincidence of the principal volcanic chains with the parts coloured red, which indicates the presence of fringing reefs, and, as we have just seen, the presence in most cases of upraised organic remains of a modern date.

There is not one active volcano within several hundred miles of an archipelago, or even a small group of atolls...

“...nearly the whole line of the west coast of South America, which forms the greatest volcanic chain in the world, from near the equator for a space of between 2,000 and 3,000 miles southward, has undergone an upward movement during a late geological period. The islands on the northwestern shores of the Pacific, which form the second greatest volcanic chain, are very imperfectly known; but Luzon, in the Philippines, and the Loo Choo Islands, have been recently elevated; and at Kamtschatka there are extensive tertiary beds of modern date.”

He was SO close to developing a theory of plate tectonics! Always looking at the big picture.



Red zones
fringe
continental
plates, blue
ones are
mid-ocean.

Australia is
pushing
north,
uplifting
New Guinea
and
surrounding
island chains



The Americas, recently joined by the isthmus, have a line of volcanoes right along the west coast.

And a tangle in the Caribbean, where a mess of plate boundaries indicates ongoing movement.

He was SO close!

Darwin and tectonic plate theory



“It is also, not a little improbable, that there should have existed as many craters of immense size crowded together beneath the sea, as there are not in some parts atolls.”

1960s surveys revealing vast mid-ocean ridges at the edges of tectonic plates, all lined with volcanoes, occurred 120 years after Darwin’s theory. Keeling, Maldives, Mauritius all occur on such plate boundaries.

“Some of the archipelagoes of low coral-islands are subject to earthquakes... Chamisso states, that earthquakes are felt on the Marshall atolls, which are far from any high land...”

It is just this sort of evidence which was later the basis for ocean-spreading and tectonic plate theory.

*Uplift and subsidence is part of **horizontal** movement of plates and their continents. Darwin only considered movement up or down.*

RESEARCH ARTICLE | OCTOBER 2011

Drilling on Eniwetok Atoll, Marshall Islands I

by S. L. LAM, Edgeworth, R. T. TAYLOR, Mark R. HARRIS, R. J. DICK, Christopher

APPLIED GROUNDWATER SCIENCES (2011) 26(4) 229–236

ISSN 1546-8271/11/0000-0000\$15.00/0 © 2011 American Society of Civil Engineers

ABSTRACT

Drilling on Eniwetok Atoll, Marshall Islands, revealed the presence of shallow basalt beneath shallow water. Basaltic rocks were found at depths of 1,114 feet.

Two holes were put down on opposite sides of the atoll. Hole 1 on the northeast where a good flat (ground surface) adjoins the reef at 700 feet, and Hole 2 on the southwest where a good flat is present. In Hole 1, basaltic rocks were struck at 4,200 feet, but no sample recovered. In Hole 2, unweathered basalt cuttings were obtained from a depth of 4,154 feet and basalt core from 4,200 to 4,211 feet.

Each hole penetrated some 1,000 feet of soft, Quaternary reef limestone before entering a thick, Tertiary section of dense rocks. The Tertiary rocks generally consist of massive amounts of basaltic and andesitic lavas. Some of the lavas are made up of clay-rich and silty sand particles and are calcareous. Most of the rocks are soft or weakly consolidated. The two holes are similar to depths of 1,000 feet; below this point there are striking differences in lithology that reflect, in part, the contribution, and the distribution of basaltic and andesitic

The drilling data indicate that the atoll is a thick cap of limestone resting on the surface of basaltic that must be below the floor of the ocean.

Geological Subject

Eniwetok Atoll; Eniwetok Atoll; Eniwetok Atoll; Eniwetok Atoll; Eniwetok Atoll; Eniwetok Atoll

Was Darwin right?

A series of expeditions to test Darwin's theory by drilling on Funafuti atoll in the Ellice Islands (now part of Tuvalu) was conducted by the Royal Society of London for the purpose of investigating whether basalt or traces of shallow water organisms could be found at depth in the coral.

Drilling occurred in 1896, 1897 and 1898, attaining a final depth of 1,114 feet 6 inches (339.70 m), still in coral. Professor Edgeworth David of the University of Sydney was a member of the 1896 expedition and leader of the 1897 expedition.

At the time these results were regarded as inconclusive and it was not until the 1950s when, prior to carrying out nuclear bomb tests on Eniwetok, (Marshall Islands) deep exploratory drilling through 4,200 feet (1,300 m) of coral to the underlying basalt finally vindicated Darwin's theory.

However, the geologic history of atolls is more complex than Darwin (1842) and Davis (1920 & 1928) envisioned.

Wikipedia

Darwin: right or wrong?



In assessing the geology of the reef, Darwin showed his remarkable ability to collect facts and find patterns to reconstruct geological history on the basis of the very limited evidence available. He gave attention to the smallest detail.

Having heard that parrotfish browsed on the living coral, he dissected specimens to find finely ground coral in their intestines. He concluded that such fish, and coral eating invertebrates such as *Holothuroidea* [sea cucumbers], could account for the banks of fine grained mud he found at the Keeling Islands; it showed also "that there are living checks to the growth of coral-reefs, and that the almost universal law of 'consume and be consumed,' holds good even with the polypifers forming those massive bulwarks, which are able to withstand the force of the open ocean."

His observations on the part played by organisms in the formation of the various features of reefs anticipated later studies. To establish the thickness of coral barrier reefs, he relied on the old nautical rule of thumb to project the slope of the land to that below sea level, and then applied his idea that the coral reef would slope much more steeply than the underlying land. He was fortunate to guess that the maximum depth of coral would be around 5,000 ft (1,500 m), as the first test bores conducted by the United States Atomic Energy Commission on Enewetok Atoll in 1952 drilled down through 4610 ft (1,405 m) of coral before reaching the volcanic foundations.

In Darwin's time no comparable thickness of fossil coral had been found on the continents, and when this was raised as a criticism of his theory neither he nor Lyell could find a satisfactory explanation. It is now thought that fossil reefs are usually broken up by tectonic movements, but at least two continental fossil reef complexes have been discovered to be about 3,000 ft (1,000 m) thick. While these findings have confirmed his argument that the islands were subsiding, his other attempts to show evidence of subsidence have been superseded by the discovery that glacial effects can cause changes in sea level.



Eniwetok atoll

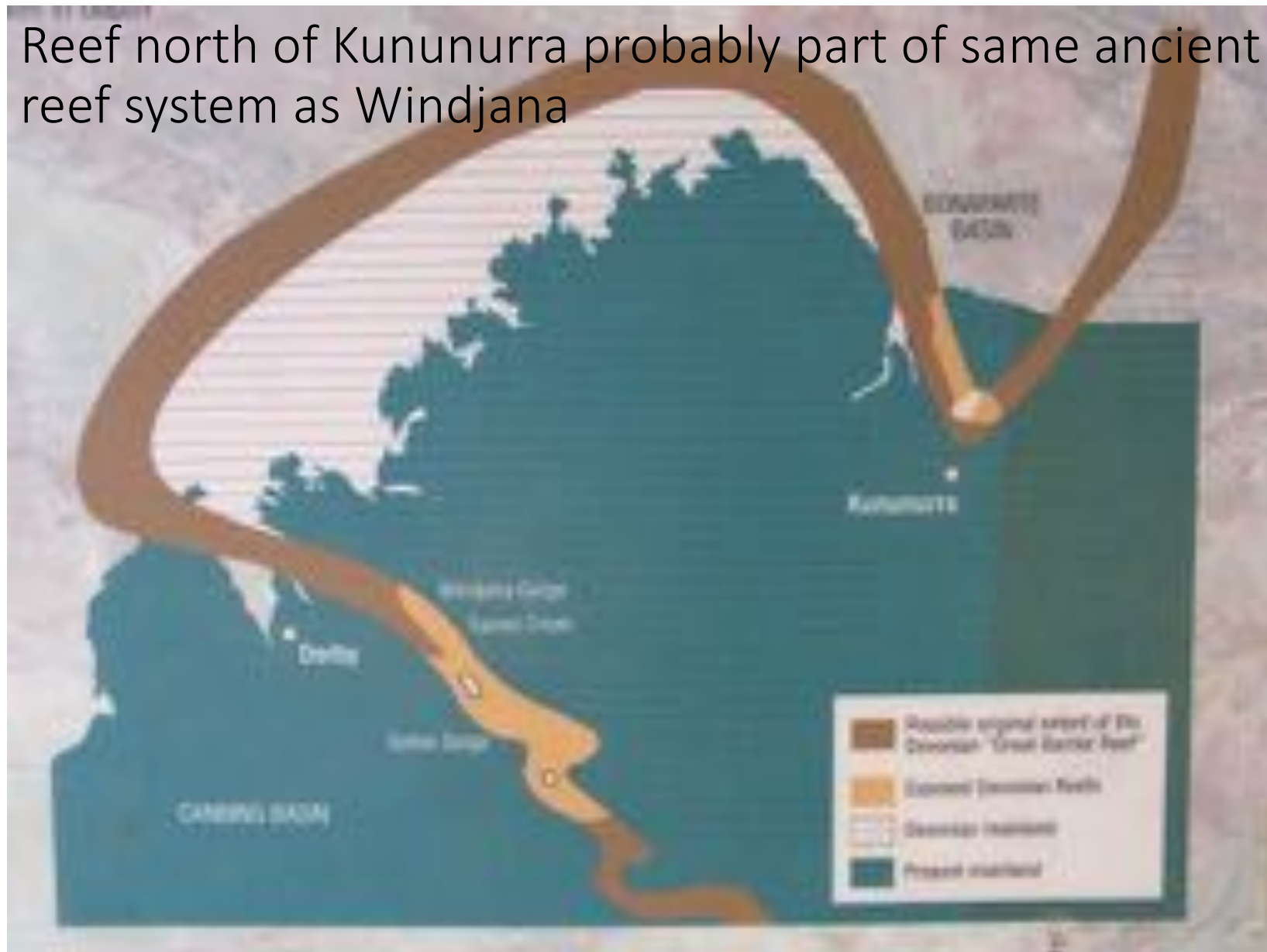
A-bomb test 1959

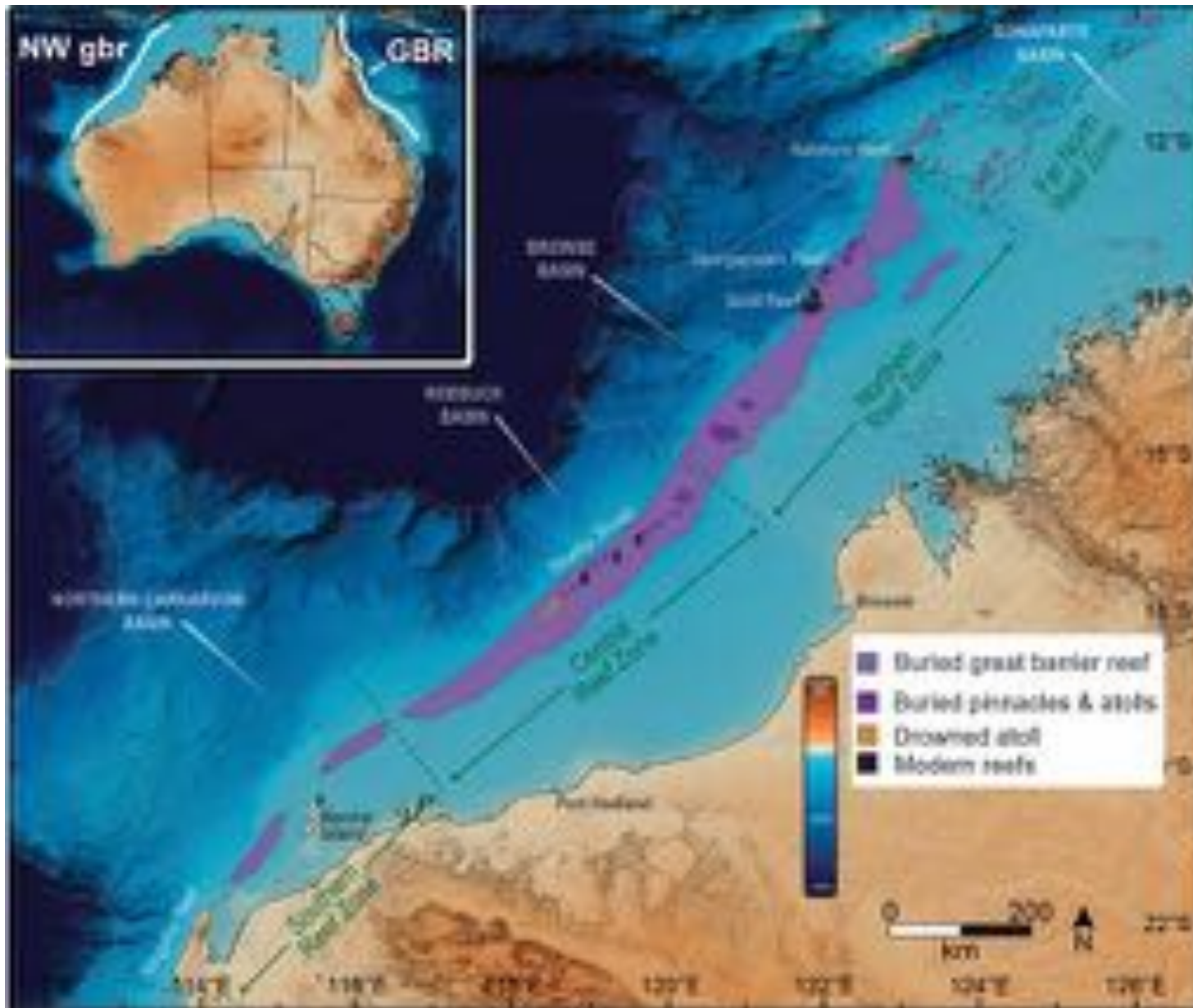




Windjana gorge
in the Kimberley,
a fossil coral reef

Reef north of Kununurra probably part of same ancient reef system as Windjana





Windjana Gorge is part of an ancient reef system off the north-west coast, recently discovered.

Small parts of it have survived sea level rise and ocean subsidence.

The Beagle's 3rd voyage

J. Wickham, who'd been on the Darwin voyage, was made captain of the ship for its third cruise to map Torres Strait and the Kimberley, 1837-43.

In 1839 the ship was surveying the coastline around Port Essington. J. Lort Stokes (2ic) and Charles Forsyth (both had sailed on the previous voyage) took a ship's boat and explored an opening into a harbor. On 9 Sept., wrote Stokes: "a wide bay appearing between two white cliffy heads, and stretching away within to a great distance, presented itself to our view."

On one of the heads they discovered "a fine-grained sandstone - a new feature in the geology of this part of the continent, which afforded us an appropriate opportunity of convincing an old shipmate and friend, that he still lived in our memory; and we accordingly named this sheet of water Port Darwin."

A settlement there from 1869 was initially named Palmerston, after the recently deceased English Prime Minister, but from 1911 the name was changed to Darwin.





“In Darwin's global hypothesis, vast areas where the seabed was being elevated were marked by fringing reefs, sometimes around active volcanoes, and similarly huge areas where the ocean floor was subsiding were indicated by barrier reefs or atolls based on inactive volcanoes.

These views received general support from deep sea drilling results in the 1980s.

His idea that rising land would be balanced by subsidence in ocean areas has been superseded by plate tectonics, which he did not anticipate.”

Darwin had a wonderful diversity of interests, and great patience in pursuing complex subjects - ever looking for the big picture, with barnacles, orchids, the expression of the emotions, the descent of man, volcanic islands, and coral reefs.

There is so much to celebrate in the work of this great man.



Down House, Kent, where Coral Reefs and all the other books were written