Rocks and Landscapes of the Cairns District

W. F. WILLMOTT and P. J. STEPHENSON

QUEENSLAND DEPARTMENT OF MINES
1989

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Cover photo: *The Barron Gorge has been cut back from the escarpment bounding the eastern edge of the adjacent tablelands as the Barron Falls steadily eroded upstream over millions of years. The bridge in the foreground leads past the tunnel outlet into the underground hydro-electric generating station. (Photo courtesy of Q.E.C.)*

THIS BOOKLET

Most people are naturally curious about the spectacular topography and scenery around Cairns, and how it was formed. To try to understand the processes involved however, we must look back in time many millions of years, to trace the ancient history of the rocks of the region, the geological events that have affected them, and subsequent processes of erosion.

This booklet is a brief non-technical guide to the geological history, the rocks themselves, and the development of the landscape. The influence of the geology on man's activities is also mentioned, and there descriptions of several routes where typical examples of the local rocks and landscapes features can be seen. A history of geological investigations in the Cairns district is included in Appendix A.

Some geological terms may be unfamiliar, but the glossary at the end should assist. Appendix B explains some of the concepts of measuring geological time. The recently published Cairns Region 1:100 000 Geological Map and accompanying technical Map Commentary describe the geology in more detail.

HISTORY AND NATURE OF THE ROCKS

Most of the Cairns district is formed by one very widespread group of rocks - the Hodgkinson Formation. These rocks originated as very thick sediments (mainly sandy and muddy deposits) which accumulated in deep water off the edge of an ancient continent, about 420 to 360 million years ago. The sediments were later hardened into rocks, crumpled by earth movements and raised above sea level to form an addition to the continent. A second extensive group of rocks, mainly granites, formed later, between 310 and 230 million years ago. These 'igneous' rocks originated as molten material rising from great depth, which cooled deep beneath the earth's surface, and solidified there in huge bodies called batholiths. Because they have resisted erosion more than the surrounding sediments, they form most of the high mountains of today.

Subsequently, this region of the Australian continent remained relatively stable for a very long period. It suffered erosion and developed extensive plains, with steadily subdued mountainous features. Then, about 100 million years ago, major changes started to occur in the northeastern parts of the continent, with the Coral Sea subsiding and the adjacent continent being uplifted. Many of the major features of the present landscape began to develop from that time. Much more recently, from about 4 million years ago, volcanic activity formed numerous small volcanoes, especially nearby on the Atherton Tableland.

To explain the various rocks and how they formed, the different episodes of geological history as we understand them are described in sequence. A diagram shows this history against the geological time scale on page 12. The geological map on page 13 shows where the main rock groups now occur in the region. It will be appreciated that the further back in time we consider, the less complete becomes our knowledge of the events, as the older rocks are obscured by later rock sequences.

An understanding of the vast span of geological time is not easy to grasp, and the concept is also difficult to represent. Geologists have divided time into a sequence of 'Periods' with formal names, such as Devonian. The ages of different rocks in the region are mentioned in terms of these periods and set out against millions of years in the geological time scale.

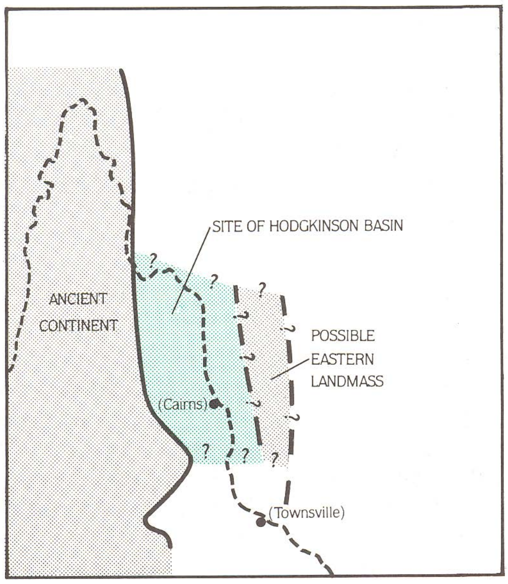
The whole question of geological time, and the ways geologists come to estimate just how old particular rocks are, must seem mysterious to many people. In an appendix at the end of this booklet some of the different methods used for dividing geological time into the periods, and for seeking to measure their actual ages in millions of years, are described.

1. THE BEGINNING OF THE CAIRNS DISTRICT GEOLOGY

Our story begins about 420 million years ago (in the Late Silurian period), when what was to become this part of the Australian continent was covered by deep water. The edge of the continent was in the Palmerville-Chillagoe area, much further west than the present coastline. We are not yet sure whether this deep water region marked the true eastern edge of the continent at that time, or whether it had developed by stretching, fracturing and sinking within the old continent, leaving other continental areas further east. Such areas would now be obscured beneath the Coral Sea, as illustrated in Sketch 1. This former region of deep water is known as the Hodgkinson Basin.

2. SEDIMENTS DEPOSITED OFF THE EDGE OF THE CONTINENT

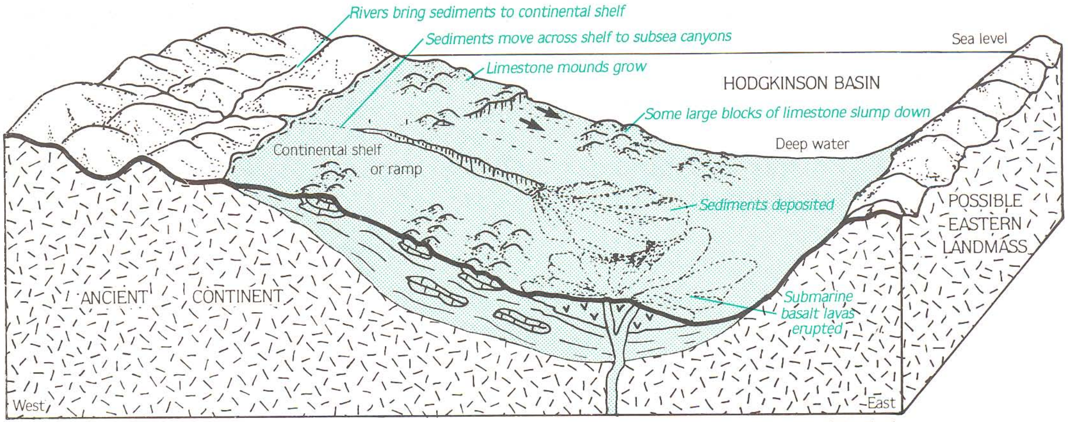
Between 420 and 360 million years ago, extensive erosion occurred on the continent further to the west. Rivers carried down gravel, sand and mud into the sea, and large volumes of sediment were deposited on the continental shelf next to the coast. Periodically, this sediment became unstable, and slumped in muddy currents down submarine canyons cut into the edge of the shelf, to be deposited in the deep water beyond the foot of the slope. The sea floor continued to subside as sediments were deposited, and over this long period of about 60 million years, a tremendous thickness accumulated, perhaps 10 kilometres thick.



1. 420 million years ago. Interpreted north-eastern margin of Australian continent, and deep-water Hodgkinson Basin, Late Silurian times.

It is not certain whether the basin formed off the true eastern edge of the continent, or whether it was a deep trough which subsided within the continent, leaving other land masses to the east

Because of the periodic slumping, somewhat irregular beds of sediments built up, rather than even, regularly stratified layers. With each slump, a layer of coarser material settled first, then was covered with finer material that took longer to settle. Some layers were many metres thick. As the sediments were progressively buried, they became consolidated into rock, mainly by compaction.



(Vertical scale exaggerated in this series of sketches)

2. 420-360 million years ago. Sediments and lavas deposited off edge of old continent in deep-water Hodgkinson Basin.

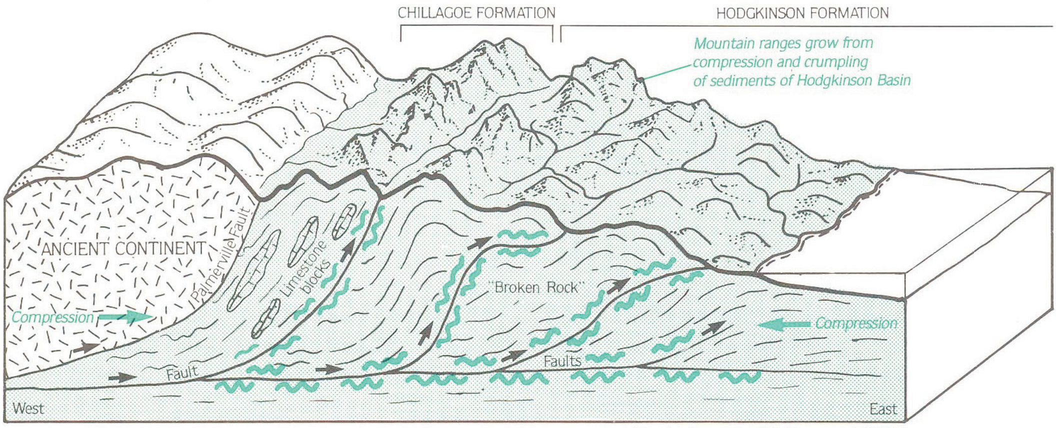
The finer muddy sediments became siltstone, mudstone and shale. Sandy sediment formed a sandstone called greywacke, which contains numerous dark rock grains. There were also some gravels which hardened to form conglomerate. Submarine volcanic activity erupted basalt lavas onto the sea floor in some areas, and these became incorporated with the thickening sediment pile. In places, layers of very silica-rich rock called chert were deposited, either from chemical precipitation from the sea water near the submarine volcanoes, or from the gradual accumulation of the skeletons of microscopic creatures called radiolaria.

Near the western margins of the basin (near Chillagoe) large masses of limestone were formed. These were parts of coral reefs which grew in the shallow marine waters on the continental shelf. Possibly some extensive masses of limestone were broken off the edge of the shelf and slumped down the slope into deeper water, adding to the other sediments already forming there.

3. MAJOR UPHEAVAL

About 360 million years ago (at the end of the Devonian period, or very early in the Carboniferous), the long accumulation in the Hodgkinson Basin ceased, and the sediments were compressed, as major movements of the earth's crustal plates closed the basin. The temperatures in these sedimentary rocks increased, and they began to change, by some minerals such as quartz and chlorite forming new grain shapes. This process of changing within the rock is known as 'metamorphism' and it produces 'metamorphic rocks'. The compression also crumpled and folded the rocks into steep inclinations, apparently as the older continental landmass to the west was pushed eastwards over the sediments of the basin.

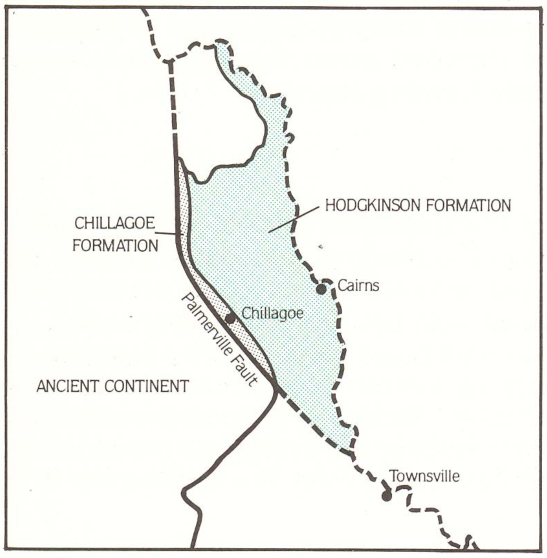
During this compression, the region was uplifted above sea level, probably forming high mountains. Although considerable erosion has occurred since then, these rocks still occupy an extensive region from Tully to north of Cooktown, and inland as far as Chillagoe. They are known as the Hodgkinson Formation, except for those in the west near Chillagoe which are called the Chillagoe Formation. In the Cairns district, some of the rocks were previously termed the ‘Barron River Metamorphics’ because they show greater metamorphic effects. However, they are very similar to the adjacent HOdgkinson Formation and because it is difficult to place any meaningful boundary between them, they are all referred to here as Hodgkinson Formation.



Sketch after work of R. Hammond JCUNQ

3. About 360 million years ago. Major compression and upheaval of sediments of Hodgkinson Basin.

Sediments progressively crumpled up as ancient continent pushed eastwards and upwards; separated from old continent by the major break of the Palmerville Fault. Major zones of faulting, or shearing resulted in 'broken rock'.



Generalised extent of Hodgkinson Formation exposed at present

Rocks in the Hodgkinson Formation

The most common rocks are relatively similar in composition. Many are meta-sedimentary, being rocks which can still be readily recognised as having formed as sediments (with features such as bedding) but which also show mild metamorphic effects, such as a toughening, and in some cases a tendency to cleave, or break along parallel surfaces. Some of them show stronger effects and are typical metamorphic rocks. The most common are:

- **Argillite** - Originally mudstone, siltstone or shale. Hardened and mildly metamorphosed, to a dark grey to black, very fine grained rock. In some places, bedding or banding is visible, but some outcrops are also closely fractured. These dark rocks commonly grade into slate.

- **Slate -** Originally shale, it is usually dark coloured. It has a strongly developed cleavage, tending to split along parallel fractures which have been induced by the metamorphism. Where such cleavage is very regularly developed, slates can be quarried to produce flat tiles for roofing and other purposes. However, no suitable materials have been developed in the Cairns region.

- **Greywacke** - Originally sandstone, composed of a mixture of different types of grains,including small fragments of dark rock, quartz and feldspar. Metamorphic effects have made the greywacke hard and tough, and the rocks generally form thick beds which may be inter-layered with argillite. As the grain sizes in greywacke increase, the rock is more easily recognised as of sedimentary origin. The coarser grains may include angular fragments of black shale, or pebbles of limestone, granite and other rocks. These coarser-grained rocks composed of pebbles and more angular shapes, are conglomerate.

- **Quartzite** - This rock is formed originally from chert (fine silica-rich rock), which has been affected by mild metamorphism. It is very hard, tough and fine grained. It can have a range of colours from white to grey, and in rare instances, ‘black’. It is commonly banded.

- **Greenstone** - This rock was originally basalt lava, which has been altered due to metamorphism. It is typically greenish-grey, fine-grained, and shows no indications of layering. In some places, small fractures are filled with the yellow-green mineral, epidote. Where outcrops have been exposed to weathering, they have a blocky appearance.

- ‘**Broken rock**’ - During the episode of compression major breaks or faults developed, and in places belts of intensely stretched-out and crushed rocks were formed. In this material (‘broken rock’) the original layering in the rock has been completely destroyed, and small elongate and stretched remnants of greywacke beds are now found to be enclosed in a crushed, finely layered background. ‘Broken rock’ varies in appearance, depending on the relative proportion of argillite and greywacke, and the intensity of the deformation. In some localities, the finely crushed material may be near black in colour where it is unweathered.

- **Phyllite** - This is a metamorphic rock which is fine grained and composed of small mica and chlorite flakes, together with quartz and feldspar grains. It was formed from shale, mudstone or siltstone. In the course of the metamorphism the mica and chlorite flakes have grown in parallel directions, imparting a cleavage, or metamorphic ‘foliation’ to the rock. The most common occurrences of phyllite are around the margins of the Tinaroo Granite, and in places in the Russell-Mulgrave Shear Zone, described below.

- **Schist** - A medium-grained, sometimes banded metamorphic rock, schist also has a well-developed metamorphic foliation due to the parallel alignment of mica minerals. Some schists are made up mainly of white mica (muscovite) but in others there is mainly black mica (biotite). Schists also contain varying amounts of quartz, feldspar and other minerals. In the Cairns district, schists are well developed around the margin of the Tinaroo Granite, where in some places they contain large crystals of andalusite.

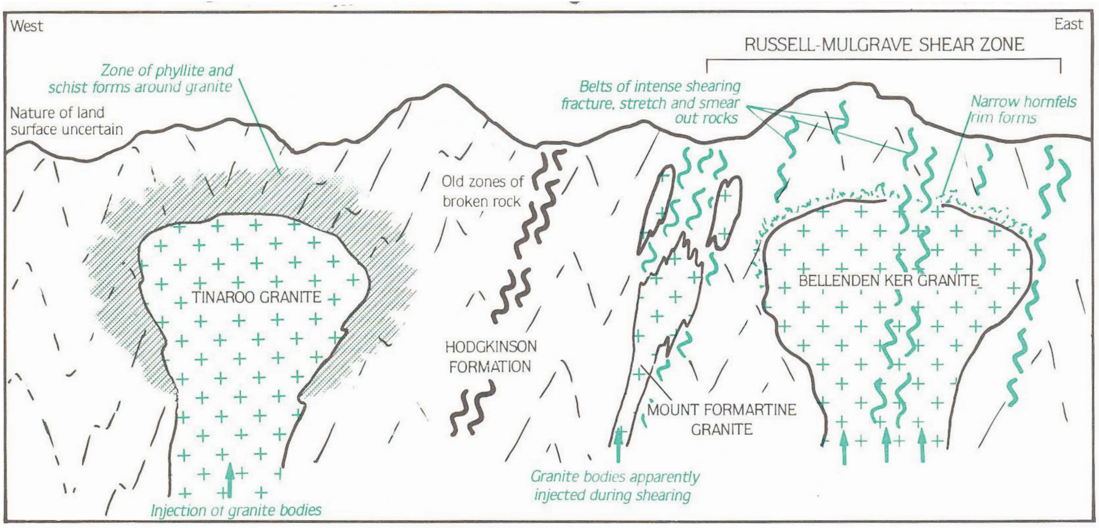
4. INTRUSION OF GRANITE BODIES

After the major upheaval, no geological events are recorded until about 310 million years ago. It must be concluded that during the intervening period the uplifted region remained stable, probably as a high mountain belt undergoing erosion.

From around 310 to about 230 million years ago (latest Carboniferous, Permian, and early Triassic time) there were several episodes of heating deep within the Earth's crust, perhaps 30 to 50 kilometres beneath the surface. This caused melting of the rocks, to give segregated pools of molten 'magma'. These pools had lower density than the solid rocks above them, and they rose up through them due to buoyancy, to form very extensive igneous intrusions. The circumstances under which this heating developed are incompletely understood; they may well have been connected with events taking place in parts of the continent further east, now obscured beneath the Coral Sea.

The magmas were granitic in composition, and they ascended to different levels, the shallowest perhaps within 2km of the Earth's surface. They formed a number of extensive masses known as 'batholiths', and smaller intrusions. They cooled as they rose, and became increasingly stiff, finally solidifying without reaching the surface. As they cooled and solidified, relatively coarse mineral grains crystallised - typically several millimetres or up to centimetres in size. This crystallisation produces the coarse igneous appearance of granitic rock. In some granites, large crystals of feldspar are conspicuous, and the details of other mineral grains allow different granite intrusions to be distinguished.

The granites in the Cairns district form five major masses. The ages at which they formed (measured by radiometric methods) become progressively younger from west to east, the oldest being the Mareeba Granite south-east of Mareeba, and the next the large Tinaroo Granite forming the mountains north of Tinaroo Dam.



4. 310-230 million years ago. Large bodies of granite magma injected into meta-sediments after several episodes of heating deep within the crust.
5. 250-230 million years ago. Major zone of movement in east, the Russell-Mulgrave Shear Zone, produces belts of sheared (crushed) rocks.

Both have been dated at between 270 and 260 million years. The large body of the **Bellenden Ker Granite** (south of Gordonvale), similar unnamed granites in the Murray Prior Range east of Cairns, and smaller bodies of the **Wangetti Granite** and the **Mount Formartine Granite** in a belt north-west of Cairns, are younger at 250-235 million years.

The granite intrusions have heated the older rocks surrounding them sufficiently to produce a zone of metamorphism, usually known as 'local' or 'contact' metamorphism. Around the Tinaroo Granite this metamorphic zone is several kilometres wide and contains phyllite and schist. Around the other granites, the metamorphism has been less severe, producing the metamorphic rock known as hornfels.

The granitic rocks

The various granitic bodies have been given different formal names. Some consist of a type of granite which can be distinguished from that in other intrusions, but many of them are quite similar. All contain abundant feldspar, recognised by its generally rectangular, elongate shape and light colour. Quartz is always present in conspicuous amounts, and can be recognised by its usually dull glass-like appearance. Biotite is also usually present, and is recognised by its very shiny black flaky appearance.

- **Coarse biotite granite with large feldspar crystals** -This type occurs mainly in the Tinaroo Granite, Bellenden Ker Granite, granites of the Murray Prior Range, and parts of the Wangetti Granite. The rocks are light grey to pink-grey, and are coarse to very coarse. They weather to form large slabs and rounded boulders with few fractures through them. Black flakes of biotite occur amongst irregular quartz and feldspar grains, and there are common large, well-formed elongate crystals of potassium feldspar (microcline or orthoclase).

- **Muscovite-biotite granite** - Forms the Mareeba Granite. This type is cream coloured, with mineral grains ranging from fine to course in size. Amongst the grains of clear quartz and cream feldspar, there are flakes of black mica (biotite) and silvery white mica (muscovite). The grain size varies and there are patches of very coarse rock, known as pegmatite, as well as white quartz veins.

- **Tourmaline-muscovite granite** - This type of granite forms the outer parts of the Wangetti Granite. It is white to cream in colour, medium grained and contains sparse but easily-seen small needle crystals of black tourmaline. Silver flakes of muscovite are also present, set in quartz and feldspar grains.

- **Sheared biotite granite** -The small bodies of granite north of Cairns are composed ofthis rock type, and are called the Mount Formartine Granite. The granites are dark grey to black, medium grained and are hard where they are fresh. They contain black biotite mica flakes, set amongst white quartz and feldspar grains, and some silver muscovite flakes also. These rocks have been affected by later deformation which has stretched or sheared them, and some specimens are strongly layered. However, their appearance varies, depending on the intensity of shearing.

- **Hornfels** - These rocks are associated with the granites, occurring adjacent to their margins. They represent the older rocks into which the granites were intruded, and which have been affected by contact metamorphism due to the high temperature of the granite magma. Various older rocks may be found affected by this metamorphism, and the 'hornfels' varies somewhat in accordance. Where originally fine grained sedimentary rocks have been affected, the hornfels is a typically tough, black rock which usually retains only vague indications of original bedding. The hornfels formed from greywacke beds is also hardened, but the general appearance of the greywacke is usually still recognisable.

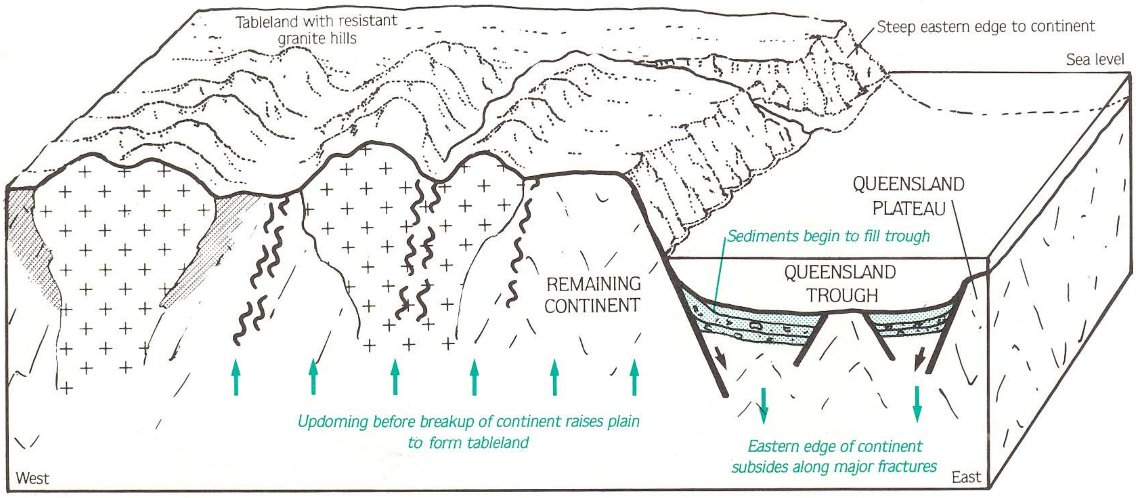
5. FURTHER DISRUPTION:THE RUSSELL-MULGRAVE SHEAR ZONE

During the early Triassic period (248-235 million years ago) new, major movements in the crust occurred. They were especially concentrated along a north-north-west trending zone which now extends from south of Innisfail to north of Mossman. This zone is known as the Russell-Mulgrave Shear Zone and it was formed by crushing and shearing of a variety of rocks along the zone.

The zone occurs in several diffuse belts with unaffected rocks between them. The various bodies of the Mount Formartine Granite are affected by intense close fracturing, and the deformation appears to have been active around the time of their intrusion. The large Bellenden Ker batholith has also been affected in part, as its rocks commonly show a parallel alignment of the minerals. Among the meta-sediments of the Hodgkinson Formation, the effects of the shear zone can be difficult to distinguish from the older zones of 'broken rock' which have been referred to earlier. However, in the Cairns area, very intense close fracturing with a vertical inclination was developed in the Shear Zone, and in places phyllite was formed.

6. CONTINUED EROSION THROUGH THE MESOZOIC ERA

From about the middle of the Triassic period (around 230 million years ago), there are no geological events recorded in the Cairns district over much of the long duration of the Mesozoic era. For over 100 million years, this part of the Australian continent appears to have remained a relatively elevated, stable region. It would have been affected by continued erosion which progressively wore down its highlands, and lowered the general level of the surface, until the deeper granitic bodies within the Hodgkinson Formation were exposed. In most places many kilometres of rock were eroded, the material being carried away as sediments to the shallow sedimentary basins which developed much further to the west (the Carpentaria Basin) and to the north (the Laura Basin).



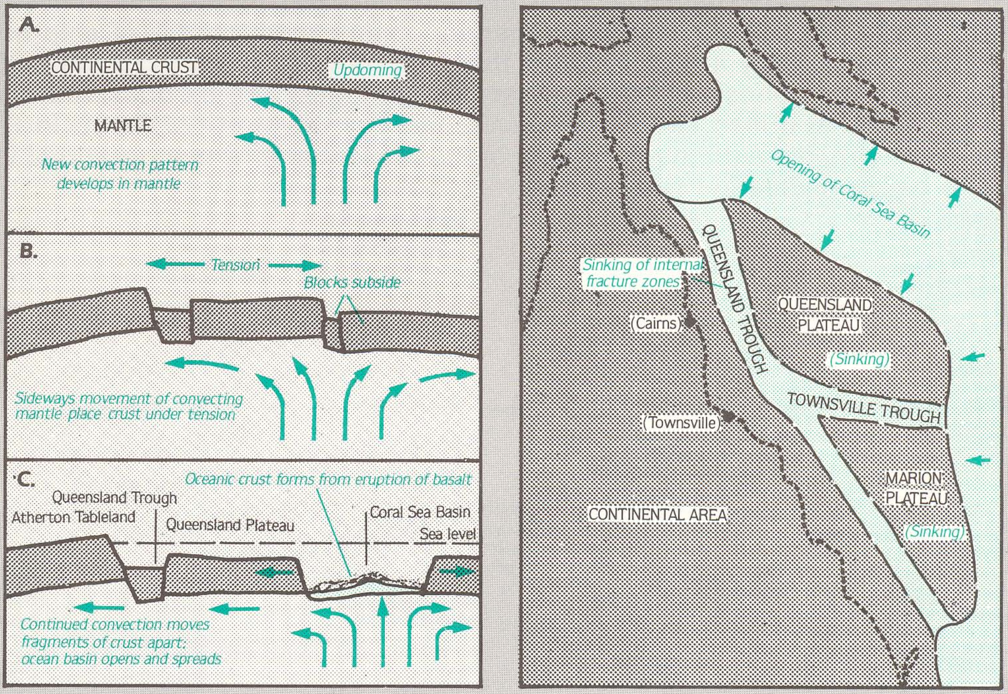
7. 100-65 million years ago. Broad plain of eroded metasediments and granites (now exposed at surface from erosion of overlying rocks) domed up to form tableland, followed by fracturing of eastern edge of continent, leaving steep eastern face.

7. BREAK-UP OF THE NORTHEASTERN EDGE OF THE CONTINENT

Up until the middle of the Cretaceous period, about 100 million years ago, the Australian continent extended much further east than at present, but then a major change started to take place which led to fracturing and eventual dispersal of much of the former land to the east of the present continent (see box). Parts of the dispersed fragments drifted much further east giving rise to the present island masses of New Zealand, new Caledonia and New Guinea.

Before the fracturing commenced, the region may have been domed up slightly; after the fracturing highlands remained on the western side but areas to the east were depressed.Thus the eastern highlands of today were essentially determined around that time (Sketch 7).

FRACTURING OF THE NORTHEASTERN EDGE OF THE CONTINENT



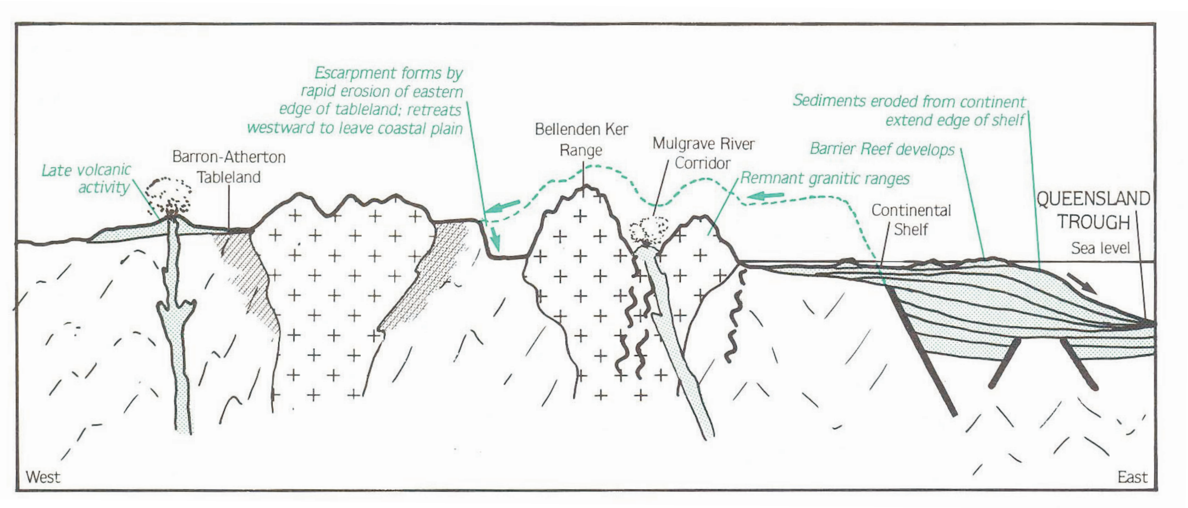
About 100 million years ago, a major change in the pattern of the convection currents circulating in the semi-molten mantle of the Earth, deep below the crust, began to break up the eastern side of the Australian continent. A current of slowly rising mantle material first domed up the continental crust. Then, as it spread sideways, it began to pull blocks of the crust apart, and some of these sank below sea level. At the place of the main upwelling, about 65 million years ago, the crust was eventually torn right apart, and oceanic crust began to form in the gap from the eruption of basalt lavas, which were derived from the mantle material. This was the beginning of the Coral Sea Basin; gradually with further spreading it opened to its present width (about 55 million years ago). Secondary fracture zones further west did not open completely but remained as depressed troughs - these are now the Queensland and Townsville Troughs not far off the present coastline. The continental fragment on the eastern side of these troughs subsided below sea level to form the area now known as the Queensland Plateau.

8. MARINE SEDIMENTS BUILD OUT THE CONTINENTAL SHELF

After the fracturing described above, the eastern edge of the continent was probably close to the Queensland Trough. Rapid erosion on this steep eastern slope led to the development of the great highland escarpment, which today is the most striking topographic feature in coastal eastern Australia. The escarpment gradually retreated westwards as erosion continued, leaving isolated mountains and the offshore islands.

Sediments were derived from this erosion, transported by streams and deposited offshore. The accumulating sediments built out from the continent, advanced over the flank of the Queensland Trough, and formed the present edge of the continental shelf of this part of Australia. This evolution is represented in the Sketch below.

These sediments were deposited over the long period from the commencement of the Tertiary period and have been mapped mainly with the use of ship-borne seismic methods. They are up to 200m thick not far east of Green Island, but up to 3900m in the Queensland trough. Only the youngest can be observed in drill holes such as that drilled 183m beneath Michaelmas Cay north of Cairns in 1926. These sediments beneath the limestone of the present and former coral reef were found to be mainly marine sandstones.



8. 65 million years ago to the present day. Erosion of steep eastern side of tableland to form present topography by retreat of escarpment; sediments deposited off-shore.

9. 4 million years ago to 900 000 years ago. Eruption of basalt lavas, build up of volcanic cones.

10. 4 million years ago to present. Valleys fill with alluvium.

9. YOUNG VOLCANIC ACTIVITY

There is a zone of relatively young volcanic activity extending from Torres Strait to Tasmania. It has recorded intermittent volcanism in certain areas, which cover the time span from the earliest Tertiary period up until almost the present day. There are several very old volcanic centres in this zone further west, near Petford, but the main volcanic area near Cairns is the Atherton Province. This contains about 50 known volcanoes, most of which were active for short periods from 3 million until probably less than 15,000 years ago. Some of the volcanoes sustained explosive eruptions, but extensive basalt lavas were also erupted and the weathering of these flows has produced the rich red soils found over much of the Atherton Tableland. The well known craters of Lakes Barrine and Eacham are two examples of explosive volcanoes. There are many volcanic cones surrounded by lavas, such as the Atherton Volcano, Bones Knob near Tolga, and closer to Cairns the two volcanoes at Twiddler Hill and Adler Hill south-east of Mareeba. In the case of these volcanoes near Mareeba, the eruptions poured lavas down the valleys of Emerald Creek and the Clohesy River, covering the thin sediments which blanketed those valleys. Other lavas ran down the valley of the upper Mulgrave River but have been partly eroded subsequently by the river. A partly explosive cone built up Green Hill (about 900,000 years ago) in the broad alluvial valley near Gordonvale.

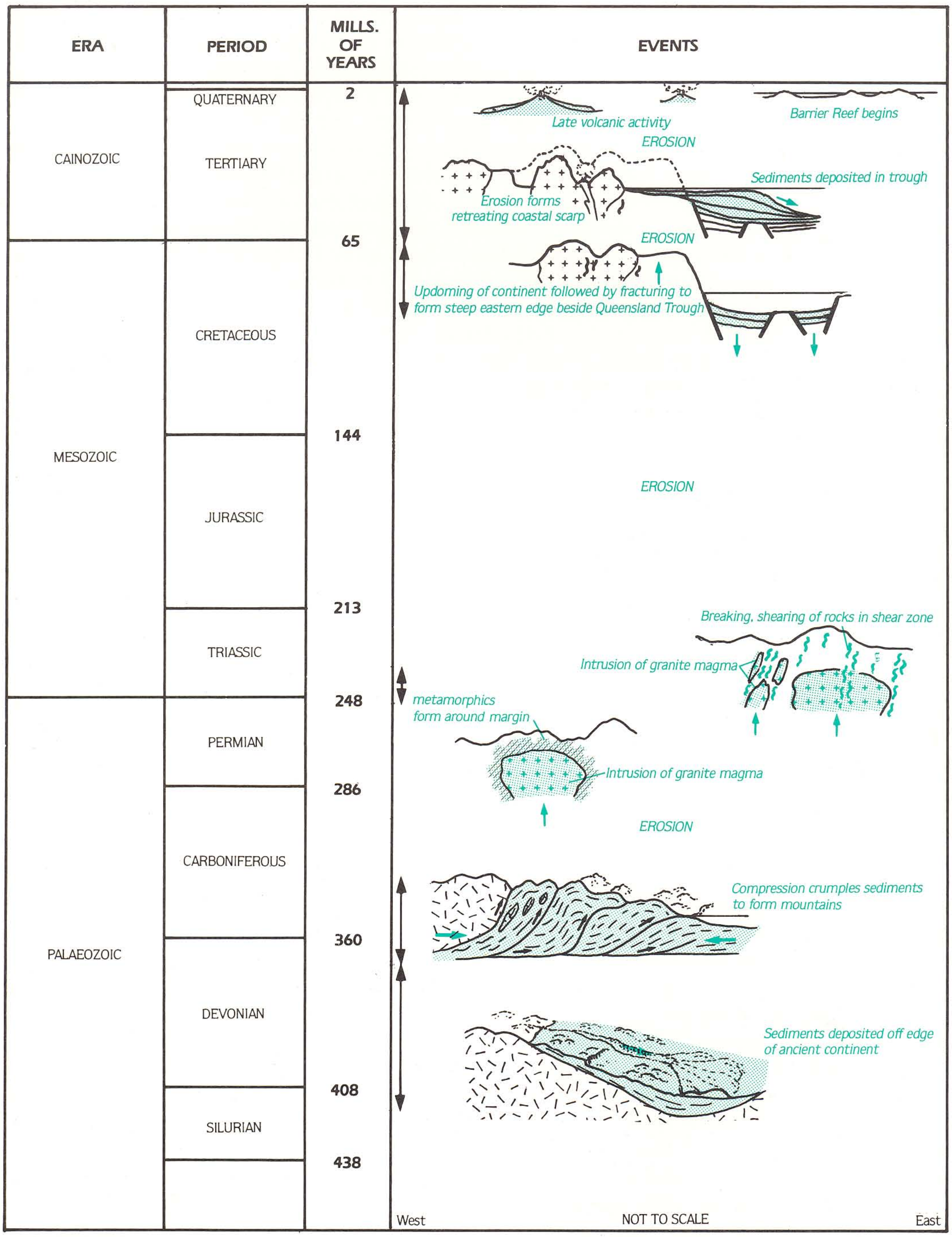
The young volcanism - the rocks

- Basalt - Dark grey to black fine-grained rock. Some basalts contain visible green crystals of olivine, and some contain light coloured feldspars, but the background is very fine grained. Many basalts contained small bubbles of gas and are said to be vesicular, with spherical or elongated cavities. Basalt flows are commonly fractured into nearly hexagonal columns, which form as the hot rocks cool and contract (eg. at Mungalli Falls).

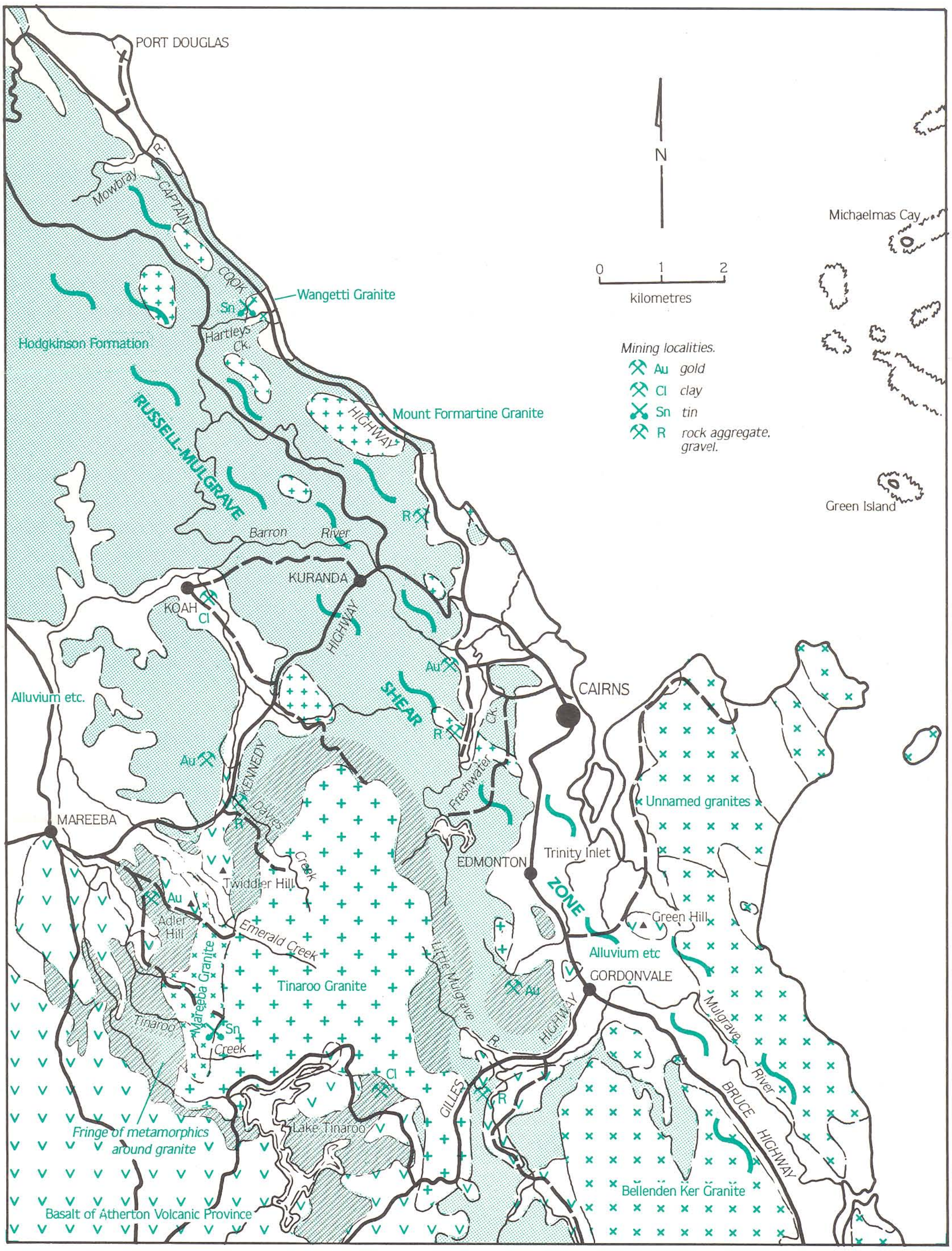
- Tuff and Agglomerate - These are made up of fragments thrown out by the volcano during explosive eruptions. The name tuff is given to deposits in which the common size of the fragments is less than 20mm. Material with coarser fragments is called agglomerate. Usually, the most common fragments are made of very vesicular basalt, called ‘scoria’.

10. VALLEYS FILL WITH ALLUVIUM

During the later part of the Tertiary period (in the last few million years,) alluvium began to accumulate in most of the river valleys in their lower courses away from the mountains. Broad plains, formed by the accumulation of pebbly, sandy sediments eroded from the Tinaroo Granite, developed beside the Clohesy River and the Barron River near Mareeba. On the coastal plain, extensive radiating fans of alluvium were disgorged onto the flat country where the streams left the mountains, especially in the Mulgrave River corridor. Towards the end of Pleistocene times in the Quaternary period, around 20 000 years ago, sea level fell considerably, causing the streams to erode down into the older alluvial sediments. Since then sea level has risen again to its present level, causing the streams to deposit new alluvial material at the lower levels. The present flood plain of the Barron River north of Cairns is an example, and many of the other rivers on the coastal plain have a high extensive upper terrace, with younger lower terraces closer to the stream channel. During this time coastal sediments were also deposited adjacent to the shore; these are described in a later chapter.



Geological time scale and sequence of geological events in the Cairns district.



GEOLOGICAL MAP. Present areas of outcrop of the various rock units.

FORMING THE PRESENT LANDSCAPE

Over the vastness of geological time, all mountains and hills are gradually worn down by the agents of erosion. However, the landscapes that result are not uniform, being very much dependent on the types of rocks present and the geological history of the district before erosion commenced.

Processes of erosion

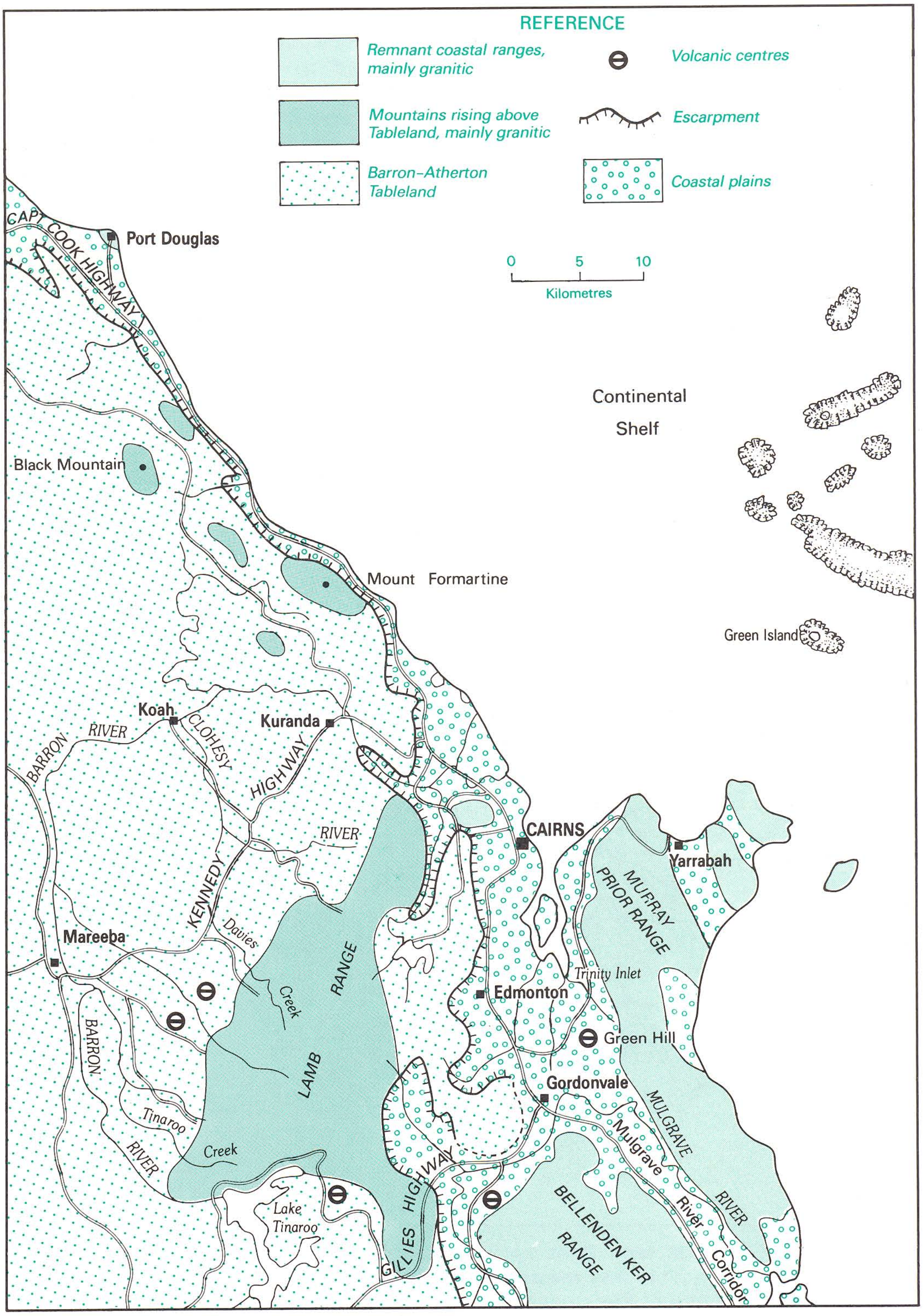
Erosion starts with the gradual softening and decomposition of the rocks (weathering) near the surface by penetrating waters, air, roots and biological activity. The wet tropical climate of Cairns has led to considerable depths of softened rocks, particularly in the meta-sediments of the Hodgkinson Formation, whose layering and close fracturing have assisted entry of percolating waters. On steep ground, bouldery soil and clay can move downhill by processes such as boulder rolling, soil creep, and small slumps and landslides; some may collect around gullies and dish-shaped slopes.

In the mountains behind the coastal plain, the velocity and steep gradients of the streams have led to erosion and removal of this softened rock in steep-sided valleys. In addition to the effects of the water itself, landslides occur on the sides of valleys, either in patches of the loose materials, or along weak planes in the layering of the bedrock. Landslides can occur naturally on the forested slopes as the rock gradually softens, but they are facilitated by disruption of the forest, such as may occur in cyclones, or by clearing by man (as has occurred around Cairns). Gradually the heads of valleys are deepened, forcing their headwaters and the edge of the coastal escarpment to retreat westward. On the tableland areas further west, gradients of streams are in contrast quite gentle, and erosion proceeds much more slowly.

On areas of granite, the coarse crystals of the rock allow water penetration from fractures along the crystal boundaries, and almost complete decomposition of the rock mass to a coarse clayey sand. However, the broad fracture spacings in the solid granite bodies means there are limited sites where this decomposition can start. As a result, the weathering process results in isolated rounded boulders, which are the remnant kernels of fracture-bounded blocks, set in a decomposed clayey sand. In general the granites tend to be more resistant to erosion than the meta-sediments, and remain as higher mountains.

History of the landscape

The landscape of the district today consists of the high tableland in the west, formed on the meta-sediments of the Hodgkinson Formation, with even higher mountains, mainly of granite, protruding in places; a steep eastern escarpment forming the edge of this tableland; a narrow coastal plain and associated alluvial river valleys; remnant coastal ranges; and, offshore, a flat continental shelf (see map opposite).

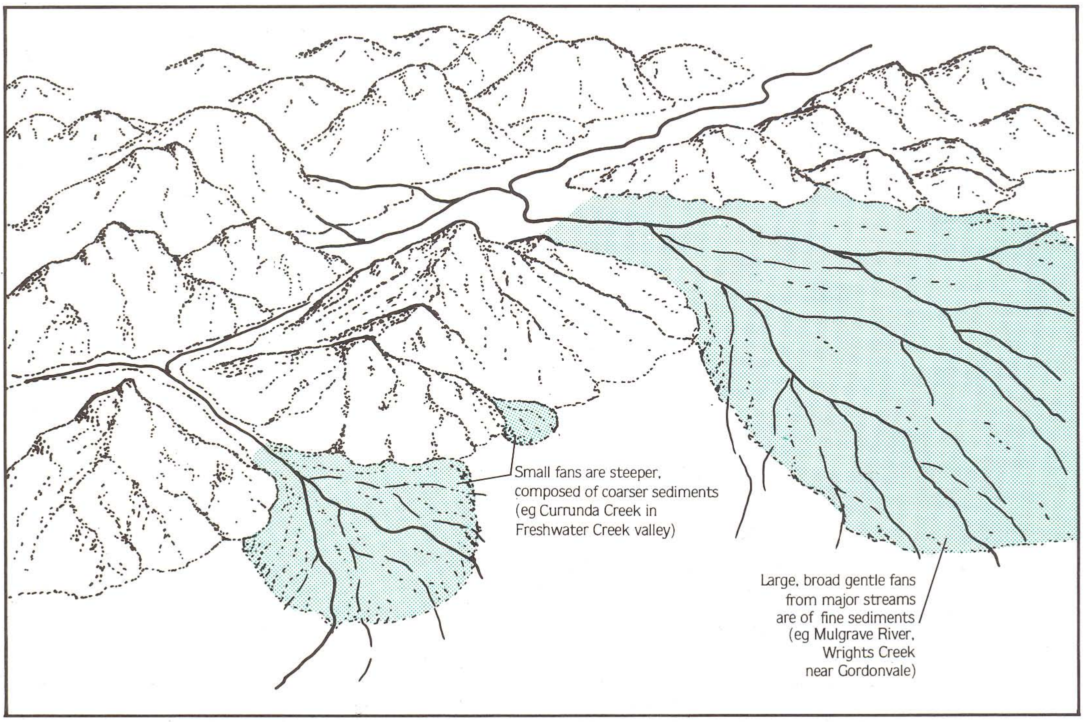


Topographic divisions of the Cairns district (Adapted from Willmott & others, 1988).

Some earlier researchers considered that the tableland could be explained by an episode of uplift of coastal regions late in the Tertiary period, possibly along fault lines, which saw some blocks of land elevated to mountains, and others depressed, such as the Mulgrave River-Trinity Inlet corridor. However, there is little evidence for such faults, and the preset escarpment marking the edge of the tableland is so intricate it is difficult to relate it to any obvious fault. Moreover, basalt lavas dated as later Tertiary have flowed down the escarpment in the Innisfail area, suggesting it was in existence long before then.

More recently it has been suggested that the tablelands formed from uplift and warping of a previously relatively flat area which existed before the fracturing of the eastern edge of the Australian continent in Cretaceous time (as described in the previous chapter). After this uplift, a relatively steep eastern face was left to the remaining continent. Streams with steep gradients rapidly eroded this, with their headwaters co-operating to form a steep escarpment. This gradually retreated westwards, to its present position, leaving behind a continental shelf, the coastal plain and the alluvial corridors separating remnant ranges.

The position of the corridors, such as the valley of the Mulgrave River, and the remnant ranges, can be explained by the process of differential erosion i.e. erosion advanced more rapidly in the meta-sedimentary rocks of the Hodgkinson Formation (especially where the streams flowed parallel to the trend of their beds, i.e. NNW-SSE), than in the more resistant rocks of the granite bodies.



Examples of alluvial fans built up where streams disgorge onto flat land from mountainous areas. This was the situation in the Mulgrave River corridor and coastal plain towards the end of the Pleistocene times (500 000 - 10 000 years ago).

These granites now form the remnant ranges of the Bellenden Ker and Murray Prior Ranges, as well as most of the Lamb Range rising above the north-western edge of the Tablelands. The southern part of the Mulgrave River corridor probably formed along a major belt of easily eroded sheared and fractured rocks with the Bellenden Ker Granite.

At the base of the slopes on the coastal plain, gravelly material has accumulated on broad alluvial fans or aprons where streams exit from the hills; the sediments gradually become finer down slope. It is believed that the main valleys and the coastal plains became choked with sediments from these fans and rivers in the Pleistocene epoch. However, when sea level was considerably lower at about 15 000 years ago, the streams eroded down into the fans and plains. With a return to high sea levels, alluvium was again deposited but in lower terraces close to the stream channels. The fans and high level plains, are no longer receiving sediments. The younger sediments can be seen adjacent to the Mulgrave River, and in the Barron River flood plain.

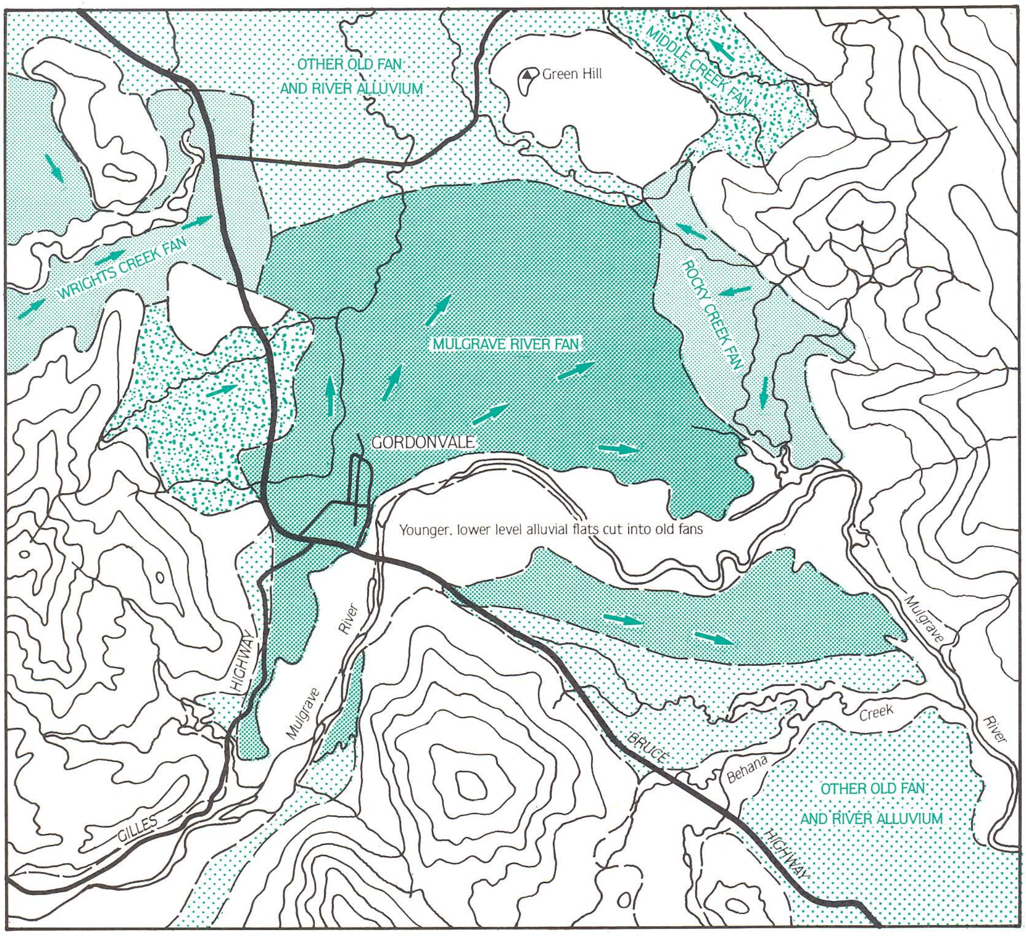
Volcanic landscapes

The volcanic activity of the Atherton Volcanic Province is sufficiently recent to allow some original volcanic land forms still to be recognised. Green Hill (900 000 years old) is a grass covered cone, about 100m high, with a high northern rim and crater open to the south-east; this was possibly caused by the prevailing south-easterly winds blowing the debris from the eruptions in the north-westerly direction. Twiddler Hill and Adler Hill south-east of Mareeba are composite double cones of lava and erupted fragmental debris built up over adjacent vents, but no craters are present on their summits. Basalt flows from these two centres form the flat valley floors of the Clohesy River and Emerald Creek; these have been subsequently cut into by the present day streams. Emerald Creek was diverted by the flows from Twiddler Hill. The basalt lavas in the upper Mulgrave River valley form less recognisable terrain because of greater erosion by the Mulgrave River, and the thick vegetation. Other volcanic centres and basalt lava in the south-west around Lake Tinaroo form part of the central area of the Atherton Volcanic Province, and are beyond the scope of this booklet.

Interesting changes in the courses of the rivers

The wide estuary of Trinity Inlet is anomalous as it lacks a major river to feed it. It has been proposed that the Mulgrave River once entered the sea here, and that it was diverted south to meet the Russell River by the damming of the valley floor by the Green Hill volcano. Evidence now available from drilling in the valley does show the Mulgrave River once flowed northwards, but it seems that the eruption of the volcano was not the cause of its diversion. The drill holes reveal basalt lavas covered by later thick alluvial deposits, showing the river continued to flow northwards after the eruption.

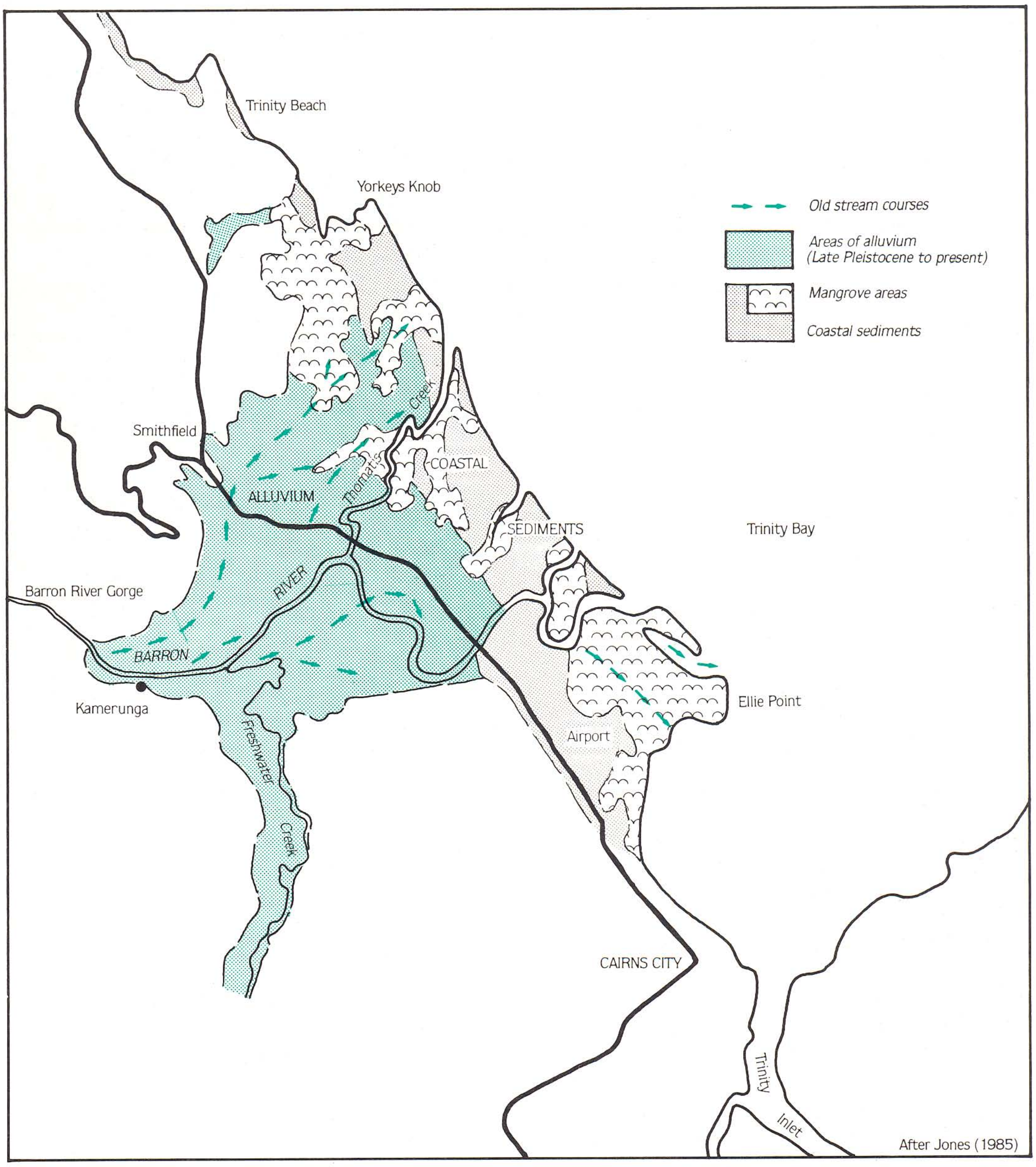
It is now believed that during late Pleistocene times the valley corridor south of Cairns became choked with alluvial sediments. In particular, a broad alluvial fan built up where the Mulgrave River exits from the mountains just west of Gordonvale.



Alluvial fans recognised in the old, high level alluvium of the Mulgrave River corridor near Gordonvale.

Falling gently to the north, east and south, this was interlaced with numerous intersecting streams rather than one major channel. At times the main part of the flow would go northwards (to Trinity Inlet), but as these channels silted up, the flow would be diverted to the south (and vice versa). Sometime later, sea levels fell, allowing the streams to erode to lower levels, and to cut down into the alluvial fan deposits. The Mulgrave River at that time was flowing mainly from the south side of its fan, and so its new lower channel was trapped on that side to flow southwards to its present mouth.

In the far west of the area between Kuranda and Mareeba the headwaters of the Barron River have gradually retreated westward. In this process they have captured first the Clohesy River near Koah, and then what were once the headwaters of the Mitchell River, near Mareeba; both streams originally flowed northwest into the present Mitchell River north of Mareeba. The increased flow in the Barron River since these relatively recent captures accounts for the steepness and narrowness of the Barron River Gorge below Kuranda. This gorge has been cut by retreat of the Barron Falls. Similar gorges have formed this way in other north Queensland coastal rivers such as the Tully and the Herbert.



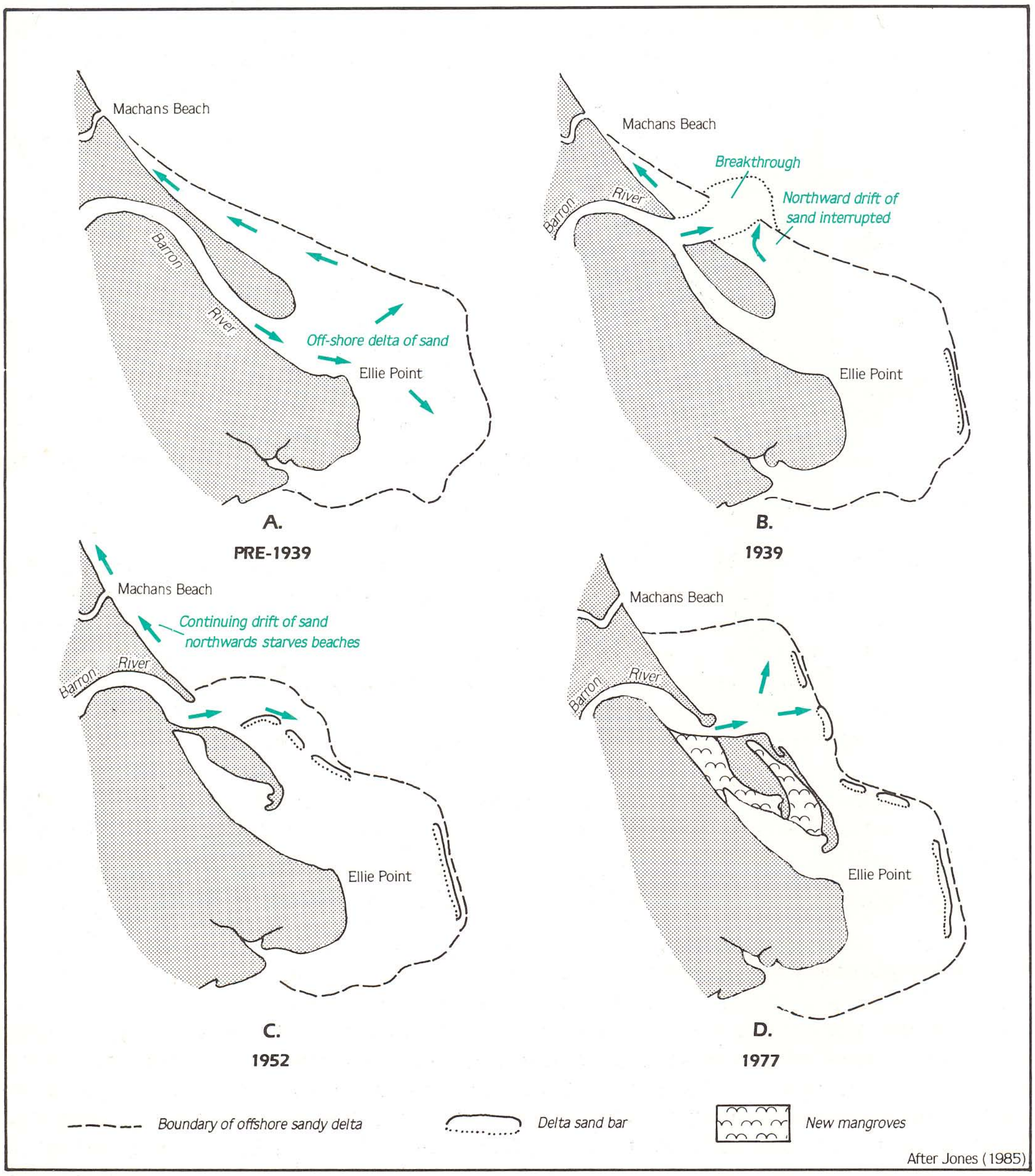
Former courses of the Barron River still visible in the alluvium of its flood plain.

Examples of recent changes in the Barron River

The alluvial sediments near the surface of the present Barron River flood plain north of Cairns have been deposited mainly since late Pleistocene times. During that time the course of the river channel has migrated across the plain, on some occasions switching courses suddenly during major floods. Some of these old courses that still can be recognised on aerial photographs are shown above. As can be seen, not only the course of the river but also its mouth have changed drastically over time.

An example of such a change in the river was witnessed during a cyclone in 1939. Before then the mouth was near Ellie Point, but during the floods the coastal sand spit south of Machan's Beach was cut through, and a new mouth formed further north (see below). This had implications for the stability of the beaches further north, as described in the next chapter.

Thomatis Creek was not connected to the Barron River until about 1932. Since then, there has been a tendency for more and more of the flow of the river to be diverted down this course (a distributary). If left to its own devices, Thomatis Creek could eventually become the new main channel of the river.

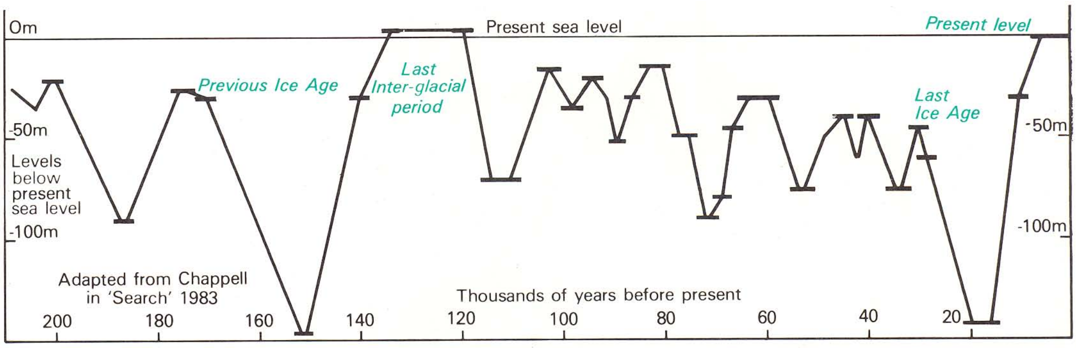


After Jones (1985)

Changes to the mouth of the Barron River since 1939. This has had a major impact on the erosion of beaches to the north (After Jones, 1985).

HISTORY OF THE COASTAL AREAS

When looking at the present coastline, we must realise that it is not static, but has migrated dramatically over the last 2 million years. This has come about by fluctuations in sea level, which in turn have been caused by variations in the Earth's climate. In colder periods (Ice Ages) of the Pleistocene epoch the polar ice caps expanded, drawing water from the oceans, and hence lowering their sea levels. At such times the coastline was much further east than at present, even beyond the edge of the Barrier Reef: Our present climate is much warmer in comparison with the colder stages of the last 2 million years. This has led to the ice caps becoming relatively small, and to sea level rising over 100 metres in the last 15 000 years, reaching its present level (or slightly higher) about 6 000 years ago. It is in fact one of the highest levels recorded during these last 2 million years.



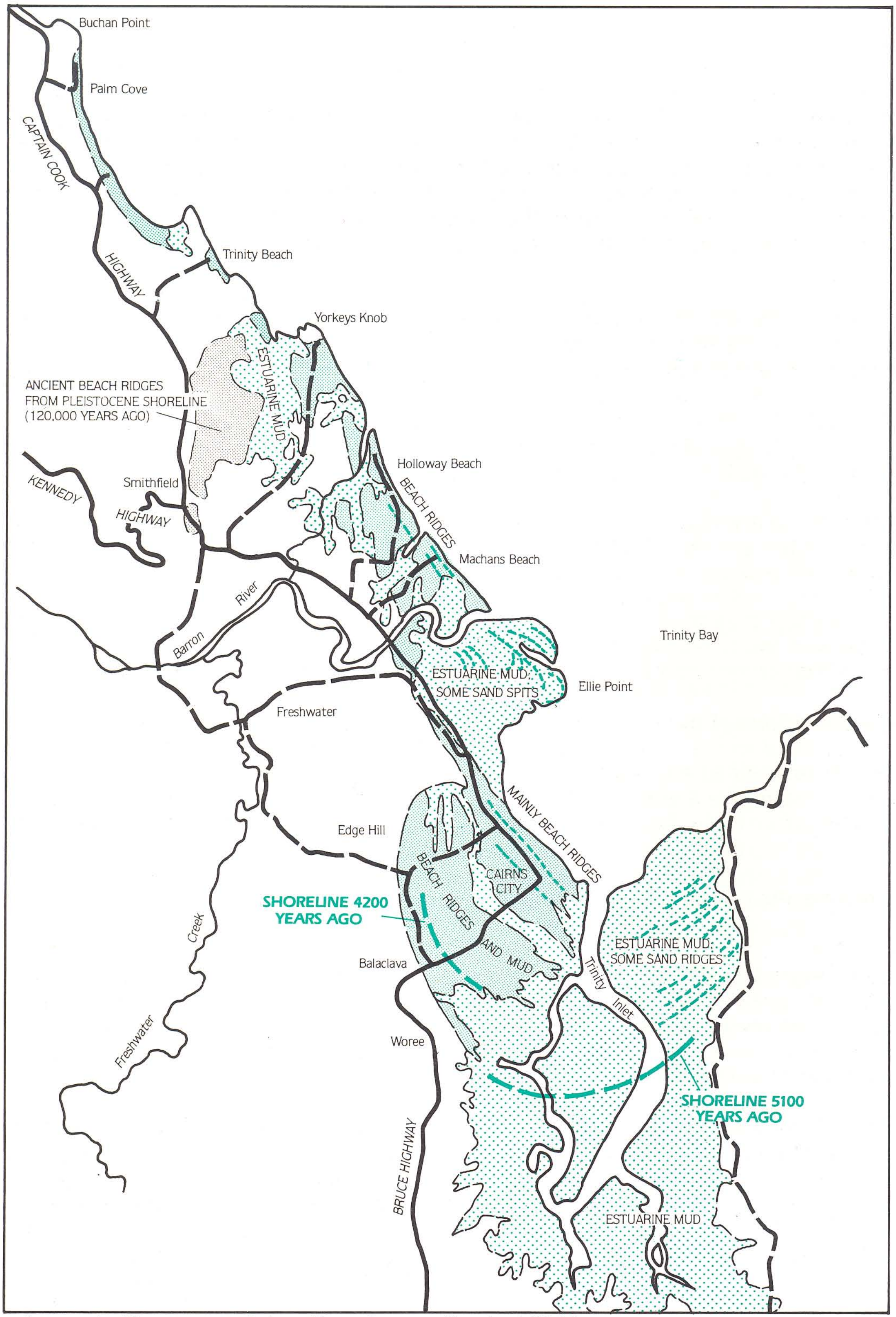
Adapted from Chappell in 'Search' 1983

Fluctuations in sea level over last 200 000 years. (Diagram courtesy of GSA-Qld Div.)

History of Trinity Bay

During periods of high sea level Trinity Bay has been flooded, and muddy sediments from the Barron and Mulgrave Rivers (when the latter was flowing northwards) have been deposited over its floor. During the low sea-level episodes, the floor of the bay has been exposed land, and the rivers have cut channels into it on their way to the shoreline farther east. Some such channels cut during the last period of low sea level (before about 10 000 years ago) have been located by geophysical methods.

Along the coastline, wind, waves and tidal currents construct long narrow ridges of beach sand. If sea level remains constant over a long period and the supply of sand is adequate, a series of beach ridges parallel to the shore may form, building the coastline out seawards. After the sea rose to its present level about 6000 years ago, beach ridges accumulated along the new shoreline, as can be seen along the coast north of Cairns. It is surprising how far the shore has been built out in Trinity Inlet; most of the central part of Cairns city is situated on a series of beach ridges, and muds of inter-ridge swamps, less than 4000 years old. An inland set of beach ridges, now very much eroded and hard to recognise beneath cane fields east of Smithfield, is probably a relic of an older, slightly higher sea level of 120 000 years ago. Since the most recent flooding of Trinity Bay (6000 years ago), muddy sediments are again being deposited over its floor, but they have not yet been redistributed as far as Green Island, where older muds and clays are close to the surface. A fan of sandier sediments in very shallow water forms an off-shore delta at the mouth of the Barron River.



Accumulation of coastal sediments over the last 6000 years.

Coastal erosion

In recent decades much erosion has occurred on the beaches north of Cairns, threatening roads and property. The problems have their origin in the change of the position of the mouth of the Barron River in 1939. There is a general movement of sand in a ‘conveyor belt’ fashion from south to north along the coastline, largely due to wave activity. An uninterrupted supply of sediments in the south is essential to maintain sand on all the beaches. The sand has been supplied to the coast by waves moving sands as they wash across the shallow delta of the Barron River.

After the river mouth switched from Ellie Point to its present position, the supply of sediment was disrupted while the river attempted to build up a new bar, but the ‘conveyor belt’ system continued to operate further north. The beaches themselves then had to contribute to the ‘conveyor belt’, and this is seen as erosion. Machan’s Beach was first affected, and in the 1950s a rock wall was constructed to protect beach-side property. This led to the disappearance of the beach in front of the wall, and transferred the problem on to Holloway Beach.

North of Holloway Beach, local beaches have been affected by the growth of the entrance bar at Thomatis Creek/Richters Creek. Since 1932, when this creek became a distributary of the Barron River, the bar has grown in size, and has intercepted much of what sand was moving northwards from the Machan’s Beach area. Erosion has thus also occurred on beaches to the north (eg. Yorkey’s Knob), as local sand there has continued to be removed northwards without replenishment. This situation will continue until sand supply is resumed from the Barron delta.

The development of the new bar of the Barron River has been inhibited by dredging for sand in the river channel, which has removed volumes far in excess of natural replenishment rates. Extraction rates are being reduced to slightly less than the replenishment rate, but it is uncertain how long it will take for the bar to stabilise and for the full supply of sand to the beaches to the north to be resumed.

Growth of the Barrier Reef

Sometime in the Pleistocene epoch (probably about 1.5 million years ago) coral reefs began to grow on high spots on the pile of sediments over the edge of the continental shelf; we do not yet know why they commenced at this time. During the low sea levels of the Ice Ages the coral reefs were periodically exposed, while subsequent higher sea levels in warm periods were followed by new reefs growing again over the old coral platforms.

The last low sea level was prior to about 10 000 years ago; at that time the channels of the Barron River in the floor of Trinity Bay wound their way eastward amongst mounds of exposed dead coral reefs between Green Island and the edge of the continental slope. After sea level rose again, the present reefs were re-established over the old platforms; they are probably less than 9000 years old, as is the whole of the present day Barrier Reef.

USEFUL ROCKS AND MINERALS

The chances of finding valuable minerals or useful rocks depend very much on the nature and history of the underlying rock units of the district. The meta-sediments of the Hodgkinson Formation around Cairns are relatively barren of minerals, apart from some small deposits of gold. Most of the large granite bodies are also barren, but traces of tin are associated with them in places. Rock construction materials are the most important products mined.

Gold

In 1915 several underground mines were opened in the Mount Peter area west of Gordonvale. The gold occurs in erratic shoots (patches) in otherwise barren veins of quartz, which cut across phyllites and schists of the Hodgkinson Formation. These rocks are thought to have developed from the effects of a small granite body not far to the north, and the quartz and gold may have originated from fluids from the granite penetrating fractures in the surrounding rocks. The mines were most active over the period 1917-1951.

Gold-bearing quartz veins cutting similar rocks were also located west of the **Clohesy River** in the 1890s. However, the grade of ore was low and productive activity on the field was short lived.

Late last century, gold was discovered in a quartz vein cutting phyllite on the **Mareeba Goldfield** several kilometres southeast of the town. Although one mine briefly produced significant amounts, mining activity ceased after 9 years.

Gold-bearing quartz veins cutting the Hodgkinson Formation were discovered near **Kamerunga** in 1931, but overall the grade of the ore was very low and only limited production occurred until closure in 1935. The mine was re-opened in 1983 but difficulties in recovery of the gold from the low-grade ore were encountered.

Tin

Important deposits of the mineral cassiterite (tin oxide, SnO_2) are associated with granite bodies of Permian age In the Herberton area to the west, but granites of similar age around Cairns carry only small amounts.

The cassiterite occurs as small grains along minute fractures and quartz veinlets cutting the granite, the result of fluids left over as the granite solidified. The veinlets are generally too scattered to be mined as such, but in places weathering and erosion of the granite has allowed the cassiterite (a resistant, heavy mineral) to be released and concentrated in the alluvium of nearby creeks.

Sizeable deposits of cassiterite of this type occurred in the alluvium of **Tinaroo and Black Rock Creeks** over the Mareeba Granite, between the Tinaroo Falls Dam and Mareeba. These were exploited by large scale workings in the late 1970s and early 1980s, and the main deposits are now nearly exhausted.

In the **Hartleys Creek** area adjacent to the Captain Cook Highway north of Cairns, cassiterite occurs in thin quartz veins and coarsely altered zones (greisens) with coarse muscovite mica which cut the Wangetti Granite; the mineral wolframite (tungsten oxide, W_3O_4) has also been reported. Several short-lived attempts have been made to mine these veins, and resulting alluvial deposits nearby, since the turn of the century, but with only minor quantities of mineral produced.

Construction materials (quarry rock, gravel, sand, brick clay)

Although hardly as glamorous as gold or some other minerals, these everyday materials are the most valuable products mined in the district. In fact, a modern city such as Cairns, with its requirements for roads, concrete construction and bricks, could not exist without them. Around Cairns deposits of these materials are relatively scarce because of the geological framework of the district, and efforts must be made to safeguard known deposits for the future.

The meta-sediments of the Hodgkinson Formation generally contain too much unsuitable soft and flaky argillite and phyllite, and are too deeply weathered to be of potential for rock aggregate. Only a few bands of greywacke are thick enough to be suitable. The coarse granitic rocks of the large intrusive bodies are also unsuitable, as any crushed aggregate made from them tends to fall apart along the boundaries of the coarse crystals. In addition, the steep topography makes siting of quarries difficult. The young basalt lavas provide some deposits, but they are usually too weathered or otherwise unsuitable.

Coarse aggregate for concrete has been obtained from gravels in the Mulgrave River west of Gordonvale, but accessible deposits there are now limited. Aggregates are also obtained from greywacke at two quarries north of Smithfield, and from basalt quarries on the highway between Kuranda and Mareeba, and in the Mulgrave River valley. Silty gravels are worked for road base from a pit in an alluvial fan in the Freshwater Creek Valley.

Several quarries around Cairns city have worked soft weathered meta-sediments for filling materials. Attempts have also been made to work quartzite bands in the meta-sediments for aggregates, but they have proved too hard to be economically crushed.

Sand for concrete has been obtained from the Mulgrave River workings, dredging the channel of the Barron River north of the airport, and from pits in nearby alluvium. The dredging operations are being scaled down, to minimise beach erosion along the northern coastal suburbs. Finer sand and loams have been obtained from pits in the beach ridges behind the coastal suburbs, and in the older beach ridges near Smithfield.

Brick clay is needed by the brickworks on the Kuranda-Mareeba road at the Clohesy River Crossing. It is won from pits nearby and at Koah which are in the old, high-level alluvial deposits that fill the Clohesy River valley. Some clay for blending purposes is derived from deeply weathered phyllite of the Hodgkinson Formation and trucked from the Mobo Creek area north of the Tinaroo Falls Dam.

Groundwater

Useful supplies of groundwater can be obtained from gravel and sand layers in the alluvial sediments of the Mulgrave River Valley and parts of the Barron River delta. Spears and bores tapping these layers are used to supplement surface supplies for both domestic use and irrigation.

The bedrock formations, comprising the Hodgkinson Formation, the granites, and the basalts of the Atherton Volcanic Province are not widely used as a groundwater source, because of poor yields. Water is available only along sporadic fractures, which are difficult to locate.

EFFECTS OF THE GEOLOGY ON HUMAN ACTIVITIES

Obviously the biggest influence on the way settlement has occurred around Cairns has been the steep topography, although it could be said that this itself was controlled by ancient geological events. This apart, the present day geological framework has many subtle and not so subtle effects on man’s activities.

For example, the soils on the north-western side of the Mulgrave River corridor (e.g. between Gordonvale and Cairns) which are formed on alluvial fans derived from meta-sediments, tend to be more fertile than those on the eastern and southern sides of the corridor, which are derived from granites. Soils on the basalts at Green Hill and in the upper Mulgrave River valley are fertile, but rapid water absorption makes them less suited for sugar cane.

The location of the Cairns city area on unconsolidated sandy beach ridges and soft inter-ridge muds means that foundations for any large buildings must be placed on piles, which are driven down to the underlying older, stiff marine clays of Pleistocene age (which extend beneath Trinity Bay and Trinity Inlet).

In the hillside suburbs, deep weathering of the rocks presents problems for foundations on the steeper slopes. In particular, pockets of colluvium (hillside debris) which have collected in certain positions, are prone to landslide if cleared of forest or undercut; they must be avoided in planning for subdivisions and house sites.

The most obvious effects are those caused by geological processes that can be seen to be active today. Flooding in the Barron River delta limits the area suitable for urban settlement north of the city. Coastal erosion is seriously affecting the beaches and properties in the northern beach suburbs (see previously), reminding us that the shoreline is a mobile zone which must be settled and built on only with caution.

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WHERE TO SEE THE ROCKS

Immediately around Cairns good examples of the rocks are difficult to find because of the intense stretching and crushing effects of the Russell-Mulgrave Shear Zone, and the deep weathering of the rocks in the tropical climate. However, suitable examples can be seen farther afield to the north, west and south.

The several driving routes suggested below are designed to show the range of rocks present and to illustrate the landscapes.

CAUTION. Road cuttings can be dangerous if not inspected sensibly. Ensure you park safely, and keep off the carriageway, particularly if a group is involved; there is no safety in numbers.

Respect our geological heritage by not damaging the outcrops, and take samples only when necessary. It is only good manners to leave the site tidy, and available for future visitors.

Hammering or collecting samples in National Parks, some of which are visited in these excursions, is prohibited.

CAPTAIN COOK HIGHWAY

(Route Map 1)

This route of about 35 km takes you along one of the most scenic coastal drives in Queensland, with many pleasant beaches passed on the way. Examples of the predominant rocks of the district, the Hodgkinson Formation, are seen, together with two different granitic intrusions. Allow at least half a day, or a day or more if combined with sightseeing/swimming at beach settlements. The highway continues on to Port Douglas, Mossman and Cooktown.

Driving north from Cairns, past the airport, the alluvial flats of the Barron River are crossed, with the coastal escarpment visible to the west.

At the intersection of the Kuranda road and the Captain Cook Highway, note odometer reading. Continue north along the highway.

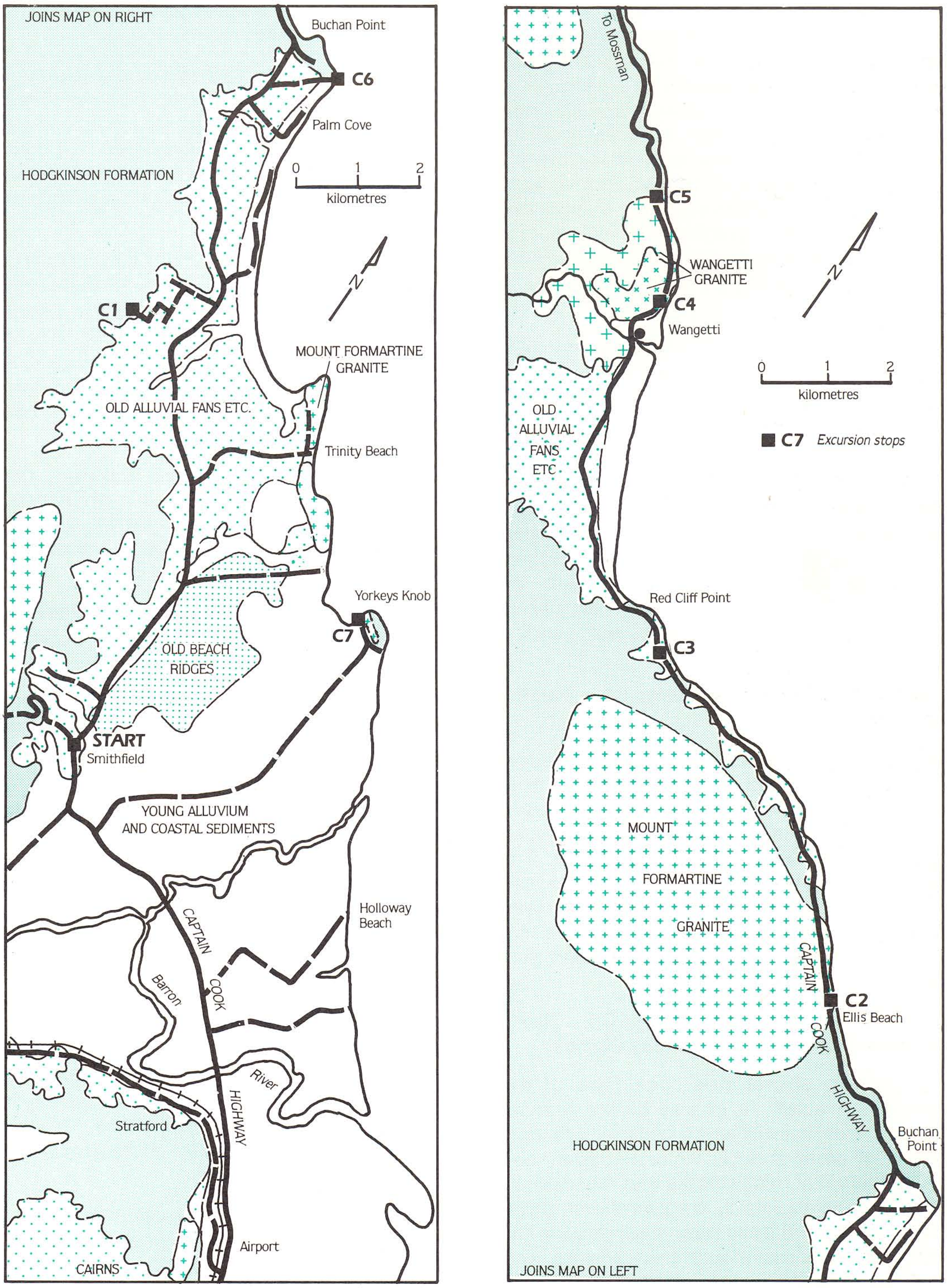
Stop C1. 8.05 km past the above intersection, turn left into Evergreen Street, then 500 m to left turn into Forrester Street, then right into Stevens Street, then left into Petricola Street, then right into the cul-de-sac of Tobias Close.

A cutting on the right shows interbedded greywacke and argillite of the Hodgkinson Formation. The beds are now almost vertical as a result of the compression and folding movements that affected the sequence. In the downhill part of the cutting, repeated patterns of sediments about 0.5 m thick can be seen. Lighter-coloured greywacke can be recognised in each pattern at the base (on the right hand side); and it grades upwards into fine greywacke and then black, fine argillite. Such a pattern is called a graded bed; it results from settling of progressively finer grains from pulses of sediments cascading down into deep water. In places you can see the top of one graded bed has been eroded before the next has been deposited.

Continue back to the highway. Note odometer here. Proceed further north along highway.

Stop C2. 7.7 km farther on. Just past Ellis Beach settlement, stop in the last parking bay on the seaward side. Waterfall in a gully above a road culvert about 100 m farther on.

The edge of a body of Mount Formartine Granite is exposed. The granite is a fine-grained, black, biotite granite. A streakiness (foliation) in the



ROUTE MAP 1 CAPTAIN COOK HIGHWAY

rock and close fracturing show it has been intruded and sheared in part of the Russell-Mulgrave Shear Zone. The granite is fine grained because of rapid cooling and crystallisation near its margin. Its heat has recrystallised the surrounding meta-sediments to hornfels. This can be seen in the southern bank immediately above the concrete culvert, and above this is the granite, containing large black angular fragments of the surrounding hornfels. The granite is cut by thin veins of quartz.

In the next cutting along the highway to the north, which is farther inside the granitic body, the rock is coarser and more easily recognisable as a granite. However, the streakiness indicating intrusion under shearing stress is still present.

Continuing, note odometer. Slabs of granite can be seen for the next kilometre, followed by accumulations of large boulders of granite which have been shed from the mountain above. Eventually the road passes back into the meta-sediments surrounding the granite.

Stop C3. 6.2 km past Stop C2. Parking space on left.

A road cutting shows a thick layer of boulders and cobbles of meta-sediments, eroded from the escarpment behind. These were deposited in alluvial fans that built up around gullies where they left the steep country. The deposits probably formed in Pleistocene times, possibly when the sea level was lower. Since then streams have cut new gullies into them and the sea has risen and eroded their toe.

Stop C4. 7.0 km past Stop C3. Rex's Lookout on the hill past Hartleys Creek.

The cutting shows one rock type of the Wangetti Granite - a coarse biotite granite, with large crystals of white feldspar amongst grains of clear quartz, white feldspar, and black and silver mica (biotite and muscovite). Small rounded black fragments of other rocks (xenoliths) have been caught up in the magma, and there are thin seams and patches of black needle-shaped crystals of tourmaline. Some veins of quartz up to 20 cm wide cut the rock, and in one place there is a spectacular pegmatite with coarse, cream feldspars, quartz crystals and needles of black tourmaline.

The patches of rusty discolouration are caused by minute grains or thin veins and seams of pyrite (iron sulphide, FeS_2), which weather to iron oxide on exposure to the air. A sample of this granite has been dated by the K-Ar radioactive decay method as 253-255 million years.

South from the lookout, the coastal escarpment can be seen close to the coast; above it is the northern end of the inland tableland. The high mountain is Mount Formartine, which being composed of granite, has been less susceptible to erosion than the meta-sediments, and hence has remained higher than the tableland.

Some 400 m north of Rex Lookout, the granite changes to a different, tourmaline-muscovite granite. Thin, needle-shaped crystals of tourmaline can be easily seen.

Stop C5. 1.6 km past Stop C4. Parking space on right just before a rocky waterfall above road culvert.

The waterfall shows the edge of the Wangetti Granite body against surrounding greywacke of the Hodgkinson Formation; the edge trends diagonally up the rock face.

To the right (north) is a very coarse greywacke containing numerous fragments of other rocks, chiefly black shale and grey-white limestone (which has recrystallised to marble). The greywacke is now very hard as it has been hornfelsed by the heat of the granite.

To the left is the tourmaline-muscovite granite variety of the Wangetti Granite. It is very light coloured, medium grained, and consists mainly of quartz, white feldspar and silver muscovite. Back along the highway it becomes coarser, and the black needle-shaped crystals of tourmaline become obvious.

Farther past this stop the cuttings mainly show very thick bands of greywacke, but usually not as coarse as here. More coarse material can be seen at Yule Point, although the cutting there is dangerous to inspect.

Sidetrips on return

Stop C6. Palm Cove: Take the northern entry to Palm Cove, along Warren Street. Continue to Palm Cove along Cedar Road (approximately

1 km). Turn north through the caravan park to the parking area at the end of the road near the pier. Walk across the sandy beach and inspect the rock outcrops on the adjacent point.

These are more examples of the Hodgkinson Formation, which show some very interesting details. Some of the beds originated as coarse gravel (conglomerate) which has since been folded and considerably deformed. The rocks can be seen to contain very elongate boulders, and constitute a 'stretched conglomerate'.

Stop C7. Yorkeys Knob: Take the Yorkeys Knob turn-off from the highway, continue until just before the headland, then left to the boat-ramp car park. A few metres around the foreshore east of the ramp a small body of biotite granite of the Mount Formartine Granite can be seen.

It is bordered on both sides by meta-sediments of the Hodgkinson Formation that have been converted to hornfels. The granite shows the streakiness (foliation) which indicates intrusion under shearing stress, and contains thin gashes of quartz which may have formed at the same time.

The surrounding meta-sediments have also been strongly sheared (before they were hardened to hornfels) to the extent that they have been smashed and drawn out to 'broken rock', consisting of angular fragments set in a fine streaky background. This may have occurred in the Russell-Mulgrave Shear Zone, just before the intrusion of the granite, but alternatively it could be much older. Examples of the 'broken rock' can be seen around the foreshore east of the granite. At one point a dyke (of basalt?) can be seen cutting the meta-sediment, just beyond the granite.

BARRON RIVER GORGE

(Route Map 2A)

This is a relatively short excursion up the scenic Barron River Gorge, ending at the Barron Gorge Power Station which is open for inspection. Allow about 2 hours for the excursion, and extra for visiting the power station or relaxing in the gorge. The Barron River Gorge has been cut back into rocks of the Hodgkinson Formation on the coastal escarpment by the erosive power of the Barron River. The unusual size and steepness of the gorge may have been caused by the additional water flow that followed the capture of the headwaters of the Clohesy and Mitchell Rivers by the ancient Barron River (see previous description). Take the Redlynch road, turn right at Redlynch to Kamerunga and cross the Barron River to the Lake Placid turn-off. Note odometer at the turn-off. Continue towards Lake Placid for 1.2 km, then continue along Barron Gorge Power Station road (Valmadre Street).

Stop B1. 4.35 km from Lake Placid turn-off.

A waterfall above a concrete culvert shows grey-green, fine-grained greenstone of the Hodgkinson Formation. This was originally basalt lava erupted on the deep ocean floor,but has since been recrystallised during the compression of folding movements. Crystals of feldspar (small dull white, elongate grains) are still visible, but patches of green material are of recrystallised chlorite. Discontinuous veins of quartz run in different directions, some cutting across earlier ones.

Stop B2. 4.9 km from Lake Placid turn-off. Parking space on left. Walk a further 100 m to rock cutting around bluff.

Very fine-grained, grey, banded quartzite, deposited as chert on the deep ocean floor, is interbedded with dark grey argillite and some fine to medium-grained greywacke (far end). In places the rocks are closely fractured (cleaved) vertically this is typical of rocks affected by the Russell-Mulgrave Shear Zone. About midway along the guard rail, look up at the steep cliff from beneath: a fold (crumple) in the beds is visible under an overhang.

Power Station. At the east end of the bridge across the Barron River, display boards give details of this hydro-electric station. Visits can be made to the underground generating chamber.

KURANDA-MAREEBA ROAD, DAVIES CREEK
(Route maps 2A, 28)

This excursion is a 90 km round trip, passing through the popular town of Kuranda onto the tablelands west of Cairns. It examines rocks of the Hodgkinson Formation which have been converted to metamorphic rocks around the margins of the Tinaroo Granite, as well as interesting features of the granite itself, younger basalt volcanoes and the landscapes of the inland tableland. The final site at Davies Creek is an attractive picnic spot in a National Park. The last 6 km is on unsealed roads. Allow at least half a day for the excursion, which can be combined with an extension to Emerald Creek Falls, sightseeing in Kuranda, or continuing onto Mareeba or the Atherton Tableland.

Drive north from Cairns to the intersection of the Kuranda road and the Captain Cook Highway. Note odometer. Distances are measured from this point.

Ascending the range, the road passes cuttings which are too dangerous to inspect because of heavy traffic on blind corners. The cuttings show ‘broken rock’, quartzite and greenstone of the Hodgkinson Formation, which have been sheared in the Russell-Mulgrave Shear Zone.

Stop K1. 7.0 km up the range. Henry Ross Lookout on the right.

Vista of landscapes. The lookout here is on the side of the coastal escarpment, which has been eroding and retreating westward into the inland tableland throughout the Tertiary and Quaternary periods. On the coastal plain below the alluvial deposits of the Barron River flood plain and delta can be seen. Beach ridges back the coastline northwards from the river mouth. Offshore Green Island is visible, and on a clear day other reefs may be visible further north.

To the south, Trinity Inlet behind Cairns city, opens southwards into the broad valley which was once occupied by the Mulgrave River, before it turned southwards and became trapped in that direction The small hump in the centre of the valley far to the south is the cone of the Green Hill volcano,which was active about 900 000 years ago.

On the far side of the valley is the Murray Prior Range, which is formed on resistant granites. It was left as a remnant after the coastal escarpment retreated back to its present position. The Whitfield Range just west of the city is a smaller remnant formed by meta-sediments.

Continuing past Kuranda, the rolling topography is the eroded surface of the old tableland, which may have been first uplifted as long ago as late in the Cretaceous period.

Stop K2. 21.2 km from start. Road cut on right, opposite Speewah road.

Interbedded argillite and greywacke of the Hodgkinson Formation have been steeply inclined by the folding earth movements, but they are west of the influence of the Russell-Mulgrave Shear Zone and are not as sheared or fractured as are the rocks closer to Kuranda.

Stop K3. 35.0 km from start. Road cutting on left just past Tichum Creek bridge.

The cutting exposes basalt, which flowed down the valley from the Twiddler Hill vent further to the west. This is believed to have been active in Pliocene-Pleistocene times (4 million to 1 million years ago), as the basalt filling the valley floor has been eroded considerably by present day creeks.

Numerous minute holes in the rock, or vesicles, were gas bubbles in the liquid lava. ‘Onion-skin weathering’ is developed in places; this is caused by water and air penetrating from intersecting fracture planes to decompose the intervening rock into successive spherical skins surrounding a remnant, rounded kernel.

Stop K4. 37.4 km from start. Landscape vista to left of road, before crest of hill.

in the background is high rugged country formed on the large body of the resistant Tinaroo Granite. The flat plain in the middle distance (over which you have been driving) is formed on the same basalt lavas as represented at Stop K3. The volcano that erupted them is the double-crested Twiddler Hill in the centre of the plain. Further to the west (right) the hummocky Adlers Hill is another vent that poured lavas westward. The hills on the other side of the road here are formed on meta-sediments of the Hodgkinson Formation.

Backtrack 1.2 km on the main road then turn off to the right to the Davies Creek National Park road (signposted). Note odometer here.

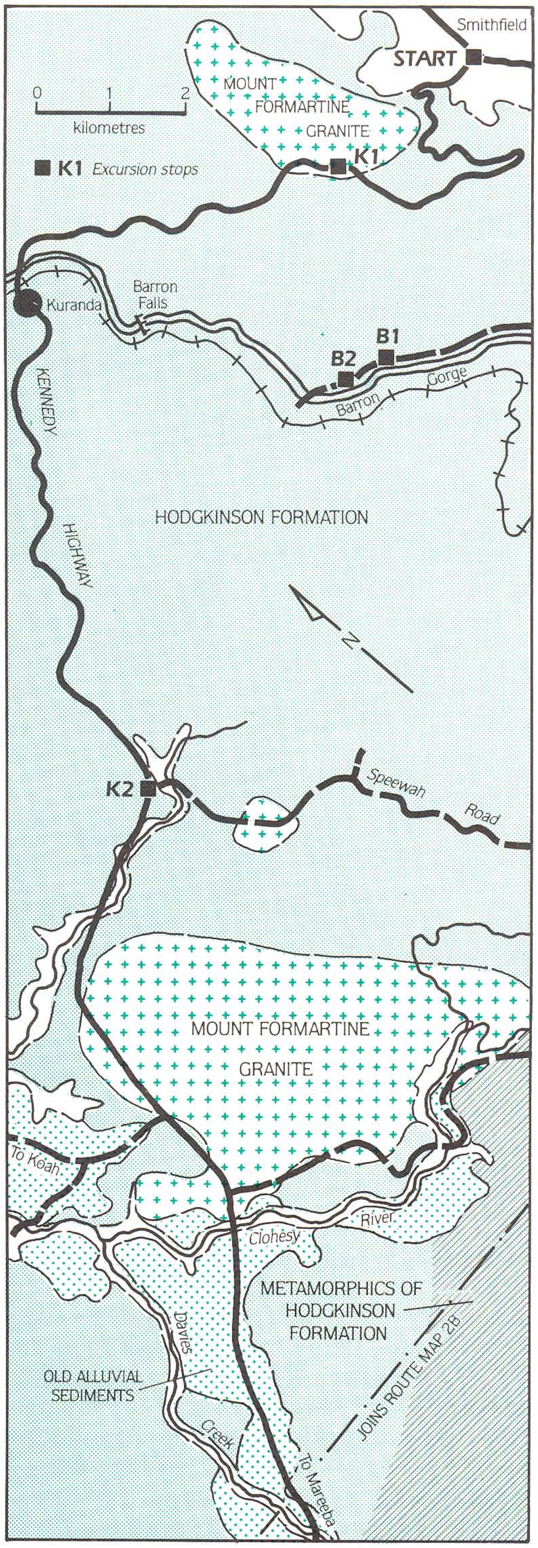
At first this road passes over the flat basalt plain.

Stop K5. Crossing of Brindle Creek, 1.6 km from turn-off.

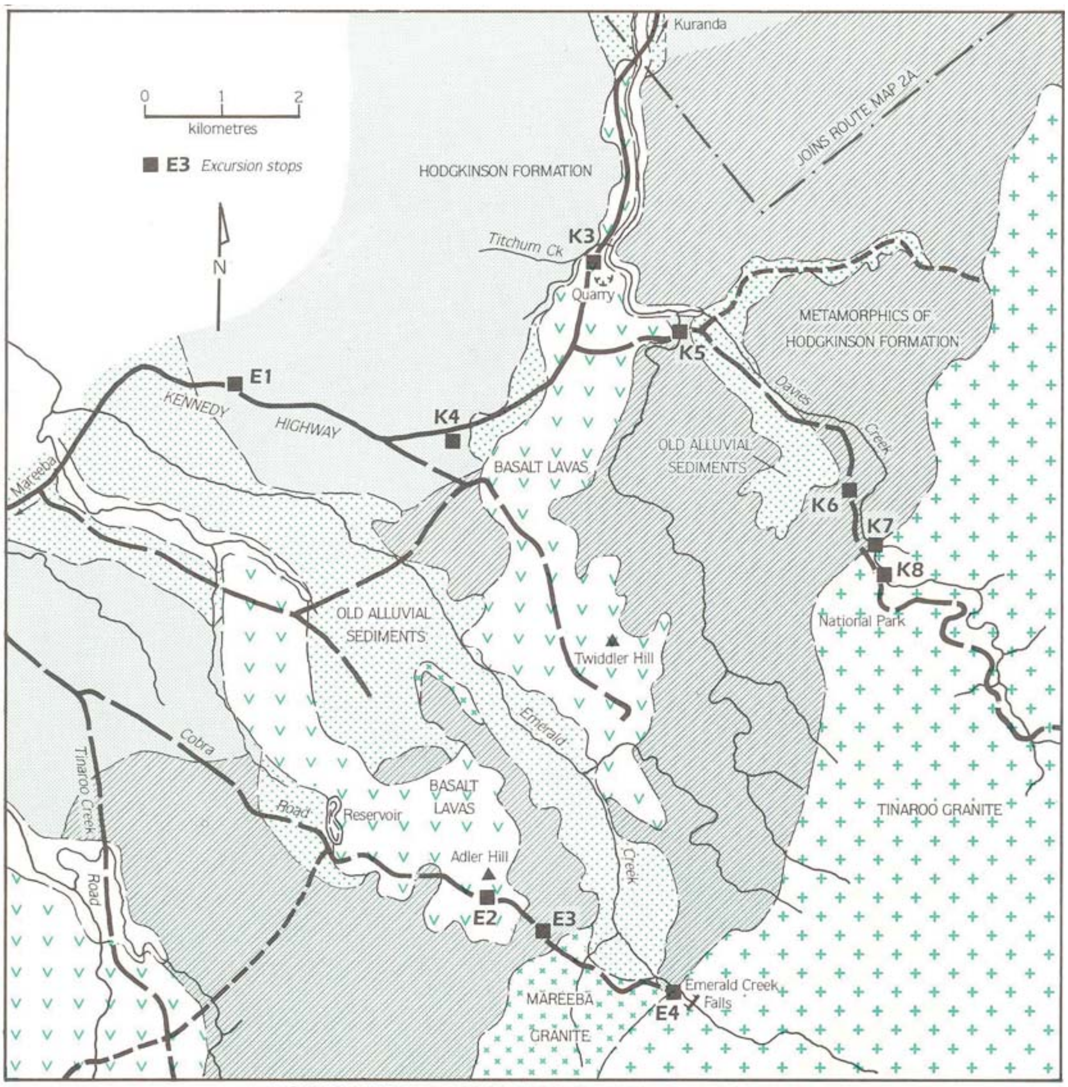
The creek has eroded through the basalt to expose the bedrock of the Hodgkinson Formation beneath; dark grey, fine mica schist crops out near the culvert. About 150 m further on, a cutting on the other side of a grid shows semi-consolidated fine gravel composed of quartz and rock fragments and coarse sand with traces of bedding (layers) visible. Such sediments were deposited hereabouts in the broad valleys of Emerald Creek, Davies Creek and the Clohesy River before the basalt lavas were erupted, probably in late Tertiary to Pleistocene times. They are composed mainly of debris eroded from the mountains of the Tinaroo Granite to the south.

Stop K6. 5.4 km past the turn-off. Road cut on right on downhill curve just past the National Park sign.

These are metamorphic rocks, which have recrystallised from the meta-sediments of the Hodgkinson Formation under the influence of heat and pressure from the Tinaroo Granite, which is not far ahead to the south. Finely banded, fine-grained muscovite and biotite mica schist is interbedded with quartzite. The banding in the schist is called foliation; it is caused by the plate-shaped mica minerals crystallising in an almost parallel alignment There are also thin quartz veins about 1 cm thick.



ROUTE MAP 2A KURANDA-MAREEBA ROAD



ROUTE MAP 2B KURANDA-MAREEBA ROAD

Stop K7. 5.95 km from turn-off, small parking space on left adjacent to Davies Creek.

Here a small exposure of the metamorphic rocks of the Hodgkinson Formation can be seen on the other side of the creek. The edge of the Tinaroo Granite can be seen in contact with the metamorphic rocks, cutting across their banding. Near the contact of the granite is a medium grained biotite granite but further away it becomes much coarser grained with large crystals of potassium feldspar. The mica schist metamorphic rocks also occur in the adjacent road cutting.

Stop K8. 6.25 km from the turn-off. Davies Creek National Park picnic area.

The broad, water-worn rock slabs beside the creek exhibit some remarkable details of the coarse biotite granite of the Tinaroo Granite. There are darker coloured inclusions (xenoliths) which are fragments of older rock carried up with the molten granite. In some places there are spectacular dark swirls in the outcrops, with more biotite. Close examination shows these formed by crystals growing inward from a solidified margin towards a molten centre (see sketches pages 36&37). The alternate crystallization of light and dark coloured minerals was repeated, forming the banding. Some bands have elongated feldspars that become wider towards the centre, indicating crystal growth in this direction. Small veins of coarser pegmatite and finer aplite cut the granite. These were injected during the last stages of solidification of the granite melt.

NOTE. Hammering or collecting specimens in the National Park is not permitted.

Extension to Emerald Creek Falls

If time permits, the trip could be extended further, along the Emerald Creek road and another 30 km, especially to see the scenic Emerald Creek Falls area, which has a good swimming area at the base of the falls, and is a pleasant picnic site. This part of the excursion visits folded meta-sediments, passes another volcano, and inspects different igneous phenomena at the falls.

Return to Kuranda-Mareeba main road, turn left towards Mareeba, note odometer.

Stop E1. 5.4 km from Davies Creek turn-off. Road cutting on right.

Here interbedded argillite and fine greywacke of the Hodgkinson Formation have been more complexly folded than usual, and slightly recrystallised. Prominent fracture planes (or cleavage planes) formed during early folding earth movements have been later crumpled, and in places small sharp folds can be seen in the cutting. The argillite beds could be called slate because of the prominent cleavage.

Continue another 2.3 km along the main road, turn off left to the Tinaroo Creek road (note odometer). Then after 2.9 km turn left again into Cobra road, and continue past the right side of the East Barron water reservoir, then left again at the end.

The road then rises onto sloping plains on basalt lavas erupted from the small vent of Adler Hill, ahead on the left.

Stop E2. 9.7 km from the turn-off on the main road. The road crosses the right flank of the Adlers Hill vent.

Boulders of basalt can be seen in the grass with numerous large gas-bubble holes (vesicles). It is uncertain whether the boulders are ‘bombs’ of lava ejected from the vent, or simply the broken-up surface of a lava flow.

Continuing, the road descends off the basalt plateau onto the older metamorphic rocks which have developed from the Hodgkinson Formation.

Stop E3. 10.2 km from main road. Lookout on left.

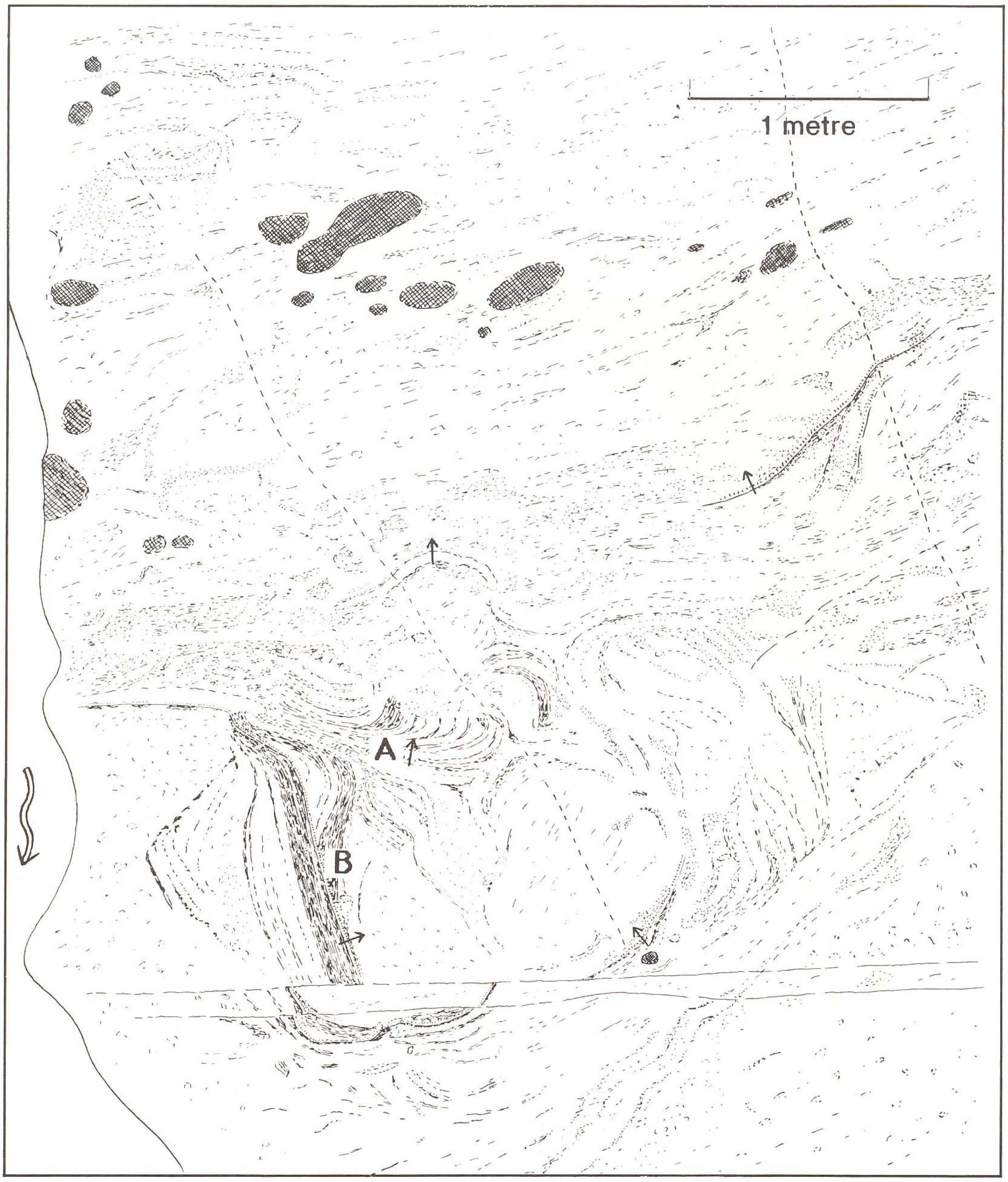
At the point where the road turns off to the lookout, the contact of the Mareeba Granite against the meta-sedimentary rocks already crossed can be seen. The muscovite-biotite granite is well weathered and decomposed. From the lookout, the rugged terrain formed on a different granite further ahead, the Tinaroo Granite again, can be seen. The base of the mountains ahead roughly coincides with the edge of this granite and large slabs of granite can be seen, illustrating the resistance to erosion of this particular granite, probably because of an absence of fractures in the massive, uniform rock.

The Mareeba Granite forming the lower country ahead and below the lookout is much more weathered and decomposed possibly because it has a more intense fracturing pattern.

Stop E4. End of road adjacent to Emerald Creek, drive through the picnic ground to the start of the walking track to Emerald Creek Falls.

There is medium-grained Tinaroo Granite at the end of the road, but along the path this changes to coarser granite. It is about 400 metres walk to the base of the falls, taking the lower track where it branches. Slabs in the creek show the very coarse granite with large potassium feldspar crystals, and small dykes of fine-grained, pink aplite can be seen cutting the granite - these dykes were probably injected during the later stages of granite solidification. In places, dark finer-grained xenoliths occur in the granite.

The face of the main waterfall is formed of a more resistant band which is another aplite dyke over 30 m thick. Some elongate crystals of tourmaline can be seen, as well as some narrow fault fractures away from the creek on the north side, and in a few places there are spectacular potholes. These deep cylindrical holes in the solid granite have been scoured out by the agitation of trapped boulders in floods.



Sketch showing some of the 'swirl' patterns in granite slabs next to Davies Creek at locality K8. Dark ovals were 'foreign' inclusions (xenoliths) carried in the molten granite. The 'swirls' were formed by an advancing front of crystals growing from the melt in successive stages. Alternating bands vary in light and dark minerals. Arrows show the growth directions evident from crystal shapes, shown opposite for examples at A and B. Small faults have displaced the banding in the lower part of the sketch. Dashes show quartz veins.

A. White crystals of feldspar widen in the direction of crystal growth.

B. A band of light coloured feldspar and quartz grew away towards the right from a 'front' of already solidified darker rock, and was followed in turn further across by a coarser granite.

LANDSCAPE DRIVE SOUTH OF CAIRNS

Leaving the city on the Bruce Highway, the beach ridge plain which has built up over the last 5000 years in Trinity Inlet is crossed. This extends as far as the ‘Marlin Statue’ outside a shopping centre on the left, but it is now difficult to recognise, as settlement has obliterated the subtle ridge and hollow topography.

Further south the road enters the Mulgrave River corridor. This was originally eroded preferentially in meta-sediments of the Hodgkinson Formation, behind the resistant granites of the coastal range, as the coastal escarpment gradually retreated westwards during the Tertiary period. Eventually it became choked with sediment, and at times the Mulgrave River found its way to Trinity Inlet via many small interlacing streams. After it became trapped flowing in a southerly direction from Gordonvale (see previous explanation) the northern part of the valley was abandoned except for small creeks flowing from the hills nearby.

After Edmonton is passed the volcanic vent of Green Hill can be seen in the middle of the valley. This was erupting about 900 000 years ago while the Mulgrave River was still flowing north, as drill holes reveal basalt lavas from the volcano buried beneath alluvial sediments (35 m thick) from the river in the middle of the valley. Along the Yarabah Road, the vent can be seen at closer quarters. A farm road off to the right crosses the lower end of one side of the crater. Further along, the interior of the crater can be seen, which is high on the northwesterly downwind end, and open to the southeast; this is probably because of the prevailing southeasterly winds blowing the debris from eruptions downward.

NOTE. The summit and interior of the crater are on private land.

Continuing on the Bruce Highway, the crossing of the Mulgrave River just past Gordonvale shows three levels of alluvium. The highest material was probably deposited in the Pleistocene when the valley became choked with sediment, and forms part of the old Mulgrave River fan extending eastward from where the river enters the corridor. The sediments in the two lower levels have been deposited since the river cut down into its old sediments, and became trapped in a southerly channel.

South of Gordonvale the spectacular peak of Walsh’s Pyramid can be seen on the right. This is formed by a small body of the Bellenden Ker Granite which is more resistant to erosion than the surrounding meta-sediments. Similar granite is exposed in a road cutting just south of Behana Creek. Between here and Babinda the corridor narrows. On the right the high Bellenden Ker Range is formed by a large body of the Bellenden Ker Granite, and on the left other resistant granites from the coastal Malbon Thompson Range.

Along the Gilles Highway west of Gordonvale, the narrow valley of the upper Mulgrave River is entered. Past the crossing of the Little Mulgrave River, the highway begins to climb the coastal escarpment (which here is developed on the Tinaroo Granite) to eventually arrive at the surface of the Atherton Tableland. Looking to the south, note how the upper valley of the Mulgrave River separates the high range of the Bellenden Ker Granite from the escarpment in the Tinaroo Granite. It has been eroded preferentially in a zone of meta-sediments between the two granites.

GLOSSARY

Agglomerate	Rock formed by accumulation of coarse fragments ejected in explosive volcanic eruptions.
Aggregate	Crushed rock pieces or gravel used in concrete and roads and elsewhere.
Alluvium	Sediments deposited by modern rivers and creeks.
Andalusite	An aluminium silicate mineral which forms elongate, well shaped crystals.
Argillite	Hardened siltstone, mud stone or shale.
Basalt	A dark grey or black, fine-grained volcanic rock usually erupted as lava flows.
Basin	A low area in the Earth's crust in which sediments have accumulated.
Bedding	The succession of beds, or layers, which result from successive pulses of sediment being deposited
Biotite	A black platy mica mineral containing silicon, aluminium, potassium, magnesium and iron
Colluvium	Weathered material transported by gravity down slopes
Carboniferous	The period of geological time extending from about 360 to 290 million years ago.
Cassiterite	Tin oxide ($Sn0_2$); the most important ore of tin.
Chert	A sedimentary rock composed of very fine-grained silica.
Cinder cone	A conical hill formed by the accumulation of fragments around a volcanic vent.
Continental drift	The process by which continents slowly move over the surface of the Earth, driven by movements of material deep within the Earth.
Cretaceous	The period of geological time extending from about 145 to 65 million years ago.
Crust	Outer layer of the Earth; about 35 km thick beneath continents and 10 km thick beneath the oceans.
Crystallisation	The process through which crystals grow and separate from a melt or solution.
Devonian	The period of geological time extending from about 410 to 360 million years ago.
Erosion	The natural processes by which rock and earth materials are loosened, worn away and removed from parts of the Earth's surface.
Escarpment	A steep face or slope abruptly terminating highlands.
Fault	A fracture in rocks along which the two sides have been displaced.
Feldspar	A family of common rock-forming minerals which contain silica, alumina, potassium, sodium and calcium.

Folding	Bending or crumpling of a rock sequence.
Foliation	Fine banding in rocks caused by segregation of different minerals into separate layers under the influence of pressure and heat.
Granite	A coarse-grained intrusive igneous rock composed mainly of quartz, feldspar and commonly mica.
Greenstone	Metamorphosed basalt.
Greisen	An altered granitic rock commonly rich in fluorine and containing coarse muscovite, quartz, topaz, tourmaline and some times cassiterite.
Greywacke	A coarse sedimentary rock composed of small fragments of other rocks, feldspar, and quartz.
Hornfels	A tough recrystallised rock which develops from heat metamorphism around an igneous intrusion. Variable in appearance, but commonly very dark and fine grained.
Igneous rocks	Rocks formed from solidification of molten material generated within the Earth. Either in intrusions (plutonic rocks) or at the surface (volcanic).
Intrusion	A body of molten rock that has penetrated into other rocks and solidified beneath the surface.
Joint	A natural crack in rock formed by fracturing under stress but without displacement along it (compare fault).
Lava	Molten rock poured out from volcanoes.
Lenses	Tapering, discontinuous patches of sediments or lavas.
Limestone	Sedimentary rock consisting mainly of calcium carbonate, often in the form of shell and coral debris.
Magma	Molten rock generated within the Earth, capable of intrusion or volcanic eruption.
Mantle	The layer of the Earth between the crust and core.
Metamorphism	Process of transformation and recrystallisation of rocks by pressure and heat; new minerals commonly develop in new directions.
Metamorphic rock	A rock recrystallised during metamorphism.
Meta-sediment	Sedimentary rocks that have undergone some metamorphism but insufficient to obliterate their sedimentary appearance.
Mica	A family of platy, sheet-like silicate minerals.
Mudstone	A fine-grained sedimentary rock consolidated from mud with little banding or bedding evident.
Muscovite	A white or silver-coloured platy mica mineral, containing silicon, aluminium and potassium.
Olivine	A green, translucent, magnesium and iron-rich silicate mineral.
Permian	The period of geological time extending from about 285 to 250 million years ago.

Phyllite	A fine-grained metamorphic rock with recrystallised mica minerals lying in one direction, giving a silky sheen to the rock.
Pleistocene	The portion of the Quaternary period of geological time lasting from 2 million to 10 000 years ago.
Quartz	Crystalline silica $Si0_2$
Quartzite	A rock composed predominantly of quartz, usually sedimentary or metamorphic in origin.
Quaternary	The period of geological time lasting from 2 million years ago to the present.
Recrystallisation	Formation of new mineral grains in a rock from the original ones, commonly by pressure and high temperature
Scoria	Fragments of volcanic rocks ejected from a volcano, generally containing many gas-bubble cavities.
Schist	A medium to coarse-grained metamorphic rock, with a well-defined layering, or foliation, of different minerals.
Seismic method	Method of determining sub-surface layering within the earth by setting up vibrations, generally by explosions, and measuring their effects.
Shale	A fine-grained sedimentary rock with a pronounced thin layering.
Shearing	Distortion or breaking of rocks by successive slices being shifted laterally over each other.
Silica	Silicon dioxide ($Si0_2$).
Siliceous	Silica-rich.
Siltstone	A fine-grained sedimentary rock intermediate in grain size between mudstone and sandstone.
Silurian	The period of geological time from about 440 to 410 million years ago.
Slate	A fine-grained meta-sedimentary or metamorphic rock containing a finely spaced fracturing, allowing it to be split easily.
Tertiary	The period of geological time extending from about 65 to 2 million years ago.
Tourmaline	A complex silicate mineral that forms long, black, needle-shaped crystals.
Triassic	The period of geological time extending from about 250 to 205 million years ago
Veins, Veinlets	Mineral-filled fractures cutting across rocks.
Vesicular	Containing small cavities originating as gas bubbles in lavas.
Weathering	The physical, chemical and biological processes that cause rocks exposed to the weather to decay and change into soil-like materials.

APPENDIX A: A CENTURY OF GEOLOGICAL INVESTIGATIONS

Studies in geology are always advancing, whenever new observations are made and specific projects are undertaken to study more detailed aspects. However, our present knowledge and understanding of the geology of the Cairns district represents the sum of the work carried out over the last hundred years.

Field work today sometimes involves relatively arduous and adventurous work In this rugged part of north Queensland, but the earliest studies by geologists were carried out by real pioneering spirits, some among the earliest explorers. One of the first was R.L.Jack, who not only explored some of the more remote Cape York region but survived serious injuries there after an encounter with hostile aborigines. A number of the earliest investigations were stimulated by gold discoveries in the region.

The first comprehensive account of the geology of the region was by H.I.Jensen in 1923, who correlated the rocks around Cairns with those of the Hodgkinson Palmer River goldfield belt. F.W.Whitehouse first named the rocks in the Barron River Gorge, the Barren River Series (later called the Barron River Metamorphics). In spite of Jensen’s ideas, something of a controversy developed with the concept that the Barron River Metamorphics were older than the Hodgkinson Formation, and possibly even as old as Precambrian.

The most systematic examination of the regional geology was made during the 1950’s and 1960’s by joint geological parties from the Commonwealth Bureau of Mineral Resources (BMR) and the Geological Survey of Queensland. This work showed the Barron River Metamorphics were, in fact, only the metamorphosed equivalents of the Hodgkinson Formation. For the first time, the ages of the granitic rocks were determined, by radioactive dating. The rubidium-strontium method (see Appendix B) was employed and the granites were found to have formed between 230 to 270 million years ago.

Almost nothing was known about the concealed geology of the offshore continental shelf until the last fifteen years. Extensive seismic surveys undertaken by the BMR and others have given a clearer picture of the break-up and subsidence of the eastern side of the continent, the considerable thickness of Cainozoic sediments under the shelf, and of the history of the Great Barrier Reef.

Modern ideas on the geological evolution of the region in terms of plate tectonic (continental drift) theories were presented in the major volume ‘Geology and Geophysics of Northeastern Australia’ published by the Geological Society of Australia in 1980. Mapping of the Cairns district itself by the Geological Survey of Queensland (Queensland Department of Mines) in 1984-85 produced the Cairns Region 1 :000 000 Geological Map, which summarises and presents all the most recent observations and conclusions.

Despite the advances in knowledge and understanding of the geological development of the region, there are many discoveries yet to be made. Geological advances are a little like an emerging jig-saw puzzle, for which the first sorting was achieved by those early geologists. New connections (and corrections!) have still to be made and fresh insights remain to be offered by the coming generations.

APPENDIX B: GEOLOGICAL TIME AND THE AGES OF ROCKS

The scale of geological time is difficult to grasp, and for some, equally difficult to accept. Geologists are in the habit of 'dropping' time terms, and speaking glibly in terms of millions of years.

How are concepts of geological time assembled, and what is the basis for being able to assert just how old some of the rocks are likely to be? How are the ages of rocks measured? Time's immensity can perhaps best be seen in parallel to a familiar span of time - such as one year. If the formation of the earth marks the beginning of such a year, then the oldest rocks found anywhere on earth (as in parts of Western Australia) were formed around the end of February. The oldest rocks described in this booklet from the Cairns region did not form until the first week of December, and the fracturing of the eastern edge to develop the shape of the continent as we now know it would not have begun until close to Christmas. Green Hill, the volcano south of Cairns erupted at about a quarter past ten on the last night of the year and the earliest humans are thought to have arrived less than 5 minutes before midnight. Cook was repairing the Endeavour at Cooktown less than two seconds before new year!

Relative Ages

The geological relationships between rock units, which can be confirmed by studying outcrops carefully 'in the field', are of fundamental importance for establishing their relative age one to another. The main essentials can be listed:

1. The principal of superposition states that relatively younger rocks are deposited on top of older ones. In an ancient rock sequence, the oldest are at the base, and progressively younger ones follow. The only contradictions occur in regions with a complicated history of subsequent disruption, which has either turned the rocks upside down, or displaced older rocks above a major 'thrust' fault, on top of younger strata.

2. Rocks which are produced by the solidification of molten material can form igneous intrusions which may be seen to have cut through adjacent rocks, and are obviously younger than them. Typically, they also cause heat effects in the nearby older rocks, which show indications of 'local' metamorphism, producing metamorphic rocks like hornfels. In some cases, the intrusive rocks may also contain inclusions (xenoliths) of the older rocks, confirming that the igneous rock formed later.

3. It is common for relatively old rocks in a region to have experienced earth movements and changes due to heat, and to show the effects of metamorphism. These metamorphic rocks contrast in appearance with younger rocks formed later than the metamorphic episode. In some cases where a junction can be found, superposition will confirm the younger rocks above the older metamorphic ones.

4. Those sedimentary rocks which are formed by the accumulation of sand or gravel will contain fragments derived by erosion of older formations. For example, a conglomerate bed in a sedimentary formation might contain boulders of granite, and careful study may be able to match these with an intrusion of granite elsewhere in the district, showing this intrusion must be older.

5. Weathering affects only the rocks adjacent to the surface of the earth, giving rise to various soils, which can develop as relatively thick formations if the conditions are

continued for a long enough period, without upheaval changes. Indications of the relative time elapsed can be seen in some areas where there has been a later upheaval, such that the older weathering profiles have been partly cut into by erosion.

6. In areas where the landscape contains certain features which have been changed by erosion, a relative sense of the time involved can be inferred from erosion rates. For example, the Barron River Gorge has a waterfall at its head and the shape of the gorge below can be explained by erosion concentrated at the waterfall itself, together with the power of the stream removing the eroded material away downstream. If the gorge is 6km long, and if the rate of erosion has been 1 mm per year at the fall, then the gorge has taken around 6 million years to be formed.

Other examples are the volcanoes on the Atherton Tableland. The youngest are scarcely affected by erosion and still have almost ideal cone and crater shapes. Progressively older ones are scarred by eroding gullies and their craters become indistinct. Still older ones are only remnants, and their once continuous lava flows no longer fill the floors of valleys they once flowed down.

These are some of the main indicators of relative time in geology, and our understanding is built upon the appreciation of all such evidence. For understanding the geology of a region, attention is also given to correlation of equivalent formations. In places like North Queensland, outcrops are discontinuous because of intermittent soil or sediment cover, and careful mapping is required to establish the extent of a particular formation. In addition, comparisons of separated rock formations are always considered to seek possible correlations. All perspectives are taken into account - the actual types of rock involved and their relative geological relationships.

Ages from fossils

A special characteristic of some sedimentary rocks (unfortunately not all) is the occurrence of fossils. Fossils have played a critical role in the development of geological science. Last century, as the early geologists studied the sequence of sedimentary strata in the various continents, they perceived that different fossils characterised particular units. The detailed study of the fossils established the traditional subdivisions of geological time:Precambrian (time prior to the appearance of organisms with hard parts which form well preserved fossils), Palaeozoic, Mesozoic and Cainozoic up to the present time. Specific details of the fossil record allowed these broad eras to be finely divided into the well known geological periods, and further subdivisions. When fossils are found in a rock unit in Australia, in most instances they can establish the age on the basis of fossil correlations with others of known age.

Actual ages

The geological periods and their subdivisions were well established before methods were developed to measure their actual ages in years. These modern laboratory methods are expensive and are based on the decay of radioactive elements.

These radioactive age determinations depend on the occurrence of a residue of a radioactive element, adjacent to the element which has formed from it since the rock was formed.

If the amounts of the two elements (the parent and daughter elements) are carefully analysed, and if the rate at which the radioactive decay occurs has been established, then the age (or duration of radioactive decay since the rock or mineral formed) can be calculated. It is generally assumed that none of the daughter element was present initially, but certain methods can determine the amount if some daughter already existed. The element analysis is complicated, since the specific chemical elements usually occur in different isotopes (the same element, but as types of atoms with slightly different weight). The analysis usually involves the use of a mass spectrometer, and other chemical techniques. Some examples of elements commonly used for age determination include the following:

Potassium-argon. One of the isotopes of potassium is radioactive and decays to form the gas argon. Some minerals are capable of retaining the argon formed inside their crystal structure (even though it is a gas), and careful analysis of the total potassium left and of the argon formed can establish the geological age. The specimens must be suitable (for example, weathering is likely to have allowed some argon to escape). Some of the rocks and minerals which have been very successfully used for age determination this way include mica, horneblende, and fresh basalt specimens. The potassium-argon age determination method can measure ages ranging from around 1 000 000 years to hundreds of millions.

Rubidium-strontium. Each of these elements occurs as several isotopes. Rubidium 87 is radioactive, and decays slowly to form strontium 87. By analysing the abundance of rubidium and strontium, and measuring the ratio of different isotopes of these elements, the ages of rocks can be measured. Usually, different minerals (such as horneblende, biotite, and feldspar) separated from one rock specimen, or sometimes a group of slightly different specimens from the same rock unit (such as a granite) are analysed to provide a more secure age determination. The rubidium-strontium age determination method can measure ages ranging from tens of millions to thousands of millions of years.

Radiocarbon. Carbon mostly occurs as the isotope 12, but a known proportion of radioactive carbon 14 is created in the atmosphere by cosmic rays acting on nitrogen. When this is assimilated in growing plants, it begins to decay back to nitrogen. Careful analysis of the two carbon isotopes in fossil carbonaceous material can provide a measure of their age. The rate at which the carbon 14 decays is relatively fast, and the radioactive method is normally used for geological materials less than 40 000 years old.

A number of other methods can be used, such as uranium-lead and the use of the rare earth elements, samarium and neodymium.

For suitable specimens the errors involved in radiometric dating usually amount to several percent of the age result. Thus, careful age determination of a rock specimen which gives a result of two hundred million years is expected to be quite close (within, say 4 million) to the true age. However, geologists always seek alternative radiometric methods as checks on each other. Also the relative ages must always be consistent with the geological evidence. For example, if it has been established in the field that the relationship between two basalt flows involves one overlying the other, then the laboratory radiometric age determinations must be consistent with this - if a contradiction occurs, then the cause of the error needs to be established, or the radiometric results are unacceptable.

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