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SOME CAINOZOIC BASALTIC VOLCANOES IN NORTH QUEENSLAND

by

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FIGURES AND PLATE

SOME CAINOZOIC BASALTIC VOLCANOES IN NORTH QUEENSLAND ✯

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SUMMARY

Tertiary basalt covers more than two and a half thousand square miles of an area in North Queensland between latitudes 17 and 19 degrees South, and longitudes 144 and 146 degrees East.

The area is on the western side of the Tasman Geosyncline and has been the site of much igneous activity in upper Precambrian, upper Palaeozoic/lower Mesozoic, and Tertiary times. There are extensive outcrops of Proterozoic granite, Carboniferous granite and rhyolite, Permian granite and rhyolite, and ?Triassic rhyolite dyke-swarms; and their emplacement appears to have been largely controlled by linear and ring-fractures; the linear fractures have developed mainly within the site of the geosyncline, and the ring-fractures mainly within the confines of the Precambrian basement.

Basic lava extrusion began in the ?Upper Miocene and continued intermittently until Recent time. The lava is mainly olivine basalt, commonly iddingsitised, and was erupted through many vents. The basalt has been mapped as three provinces, ranging in area from thirty square miles to two thousand square miles; one hundred and nine vents have been recognised in the largest province, two vents in the smallest, and twenty four vents in the third province.

The basalt in the largest and in the smallest provinces was all effusively erupted; in contrast, in the third province, late stage explosive activity has mantled the flows with up to one hundred feet of basaltic pyroclasts.

Within the largest province there are at least three shield volcanoes, and they have omitted much of the basalt; but a considerable amount of lava was also erupted from pit craters, fed into lava tunnels and ducted long distances; one tunnel has been traced for about twenty four miles. Numerous scoria cones dot the surface of the province, but there are no pyroclastic deposits, the youngest crater within the province (probably Historical) is a pit crater and contains abundant relics of its former lava-lake; siliceous sublimation products adhering to the inner walls of the crater testify to its youth. The volcanoes in this province are grouped in the region of the contact between Archaean metamorphics and intrusive granites; the older granite is Proterozoic and the younger granite is upper Palaeozoic.

The northern province is a confined lava field of about five hundred square miles, and contains four explosion craters; it is thought that the eruptions which produced the mantle of pyroclastics were mainly phreatic.

✯ This paper was prepared for presentation at the Helsinki meeting (1960) of the International Union of Geodesy and Geophysics.

There is one diatreme, in granite, on the western side of this province. Differential vertical movement on faults trending north-west and north-east has determined, in this area, (a) the distribution of upper Palaeozoic acid extrusives, (b) the disposition of Tertiary volcanoes and (c) to a large extent, the present-day topography.

INTRODUCTION

There are extensive outcrops of Tertiary Basalt in North Queensland; this paper deals with the basalts in the area between latitudes 17° and 19° South and longitudes 144° and 146° East.

The area includes the western side of the Tasman Geosynclinal zone and the eastern side of the Precambrian Georgetown Massif (Hill, 1951) and lies about an area where the trend of the eastern edge of the Precambrian basement changes rather abruptly. From 19° to about 17°30' South latitude the eastern edge of the basement trends about 020°; north of this there is a pronounced swing to the west; near Chillagoe, in the north-west of the area, the trend is about 315°. The Palaeozoic sediments east of the basement, in general, reflect this change in trend; the contact between the Precambrian basement and Palaeozoic sediments is largely obscured, but where visible it is faulted.

The history of the igneous activity of this area ranges from Upper Precambrian to Recent and shows a marked periodicity; the magma injected into and through the crust has alternated between basic and acid (the volume of intermediate igneous rocks is insignificant) and the total volume of acid magma injected greatly exceeds the volume of basic magma.

The igneous activity began in the Upper Precambrian with the intrusion of basic magma, dominantly doleritic, into metamorphosed sediments; this activity was extensive but not on a very large scale. At the end of the Precambrian or early in the Palaeozoic, granite was intruded on a large scale into the Precambrian basement; these rocks crop out in the south-west of the area. Igneous activity was slight in the middle Palaeozoic (?Upper Silurian) and appears to have been confined to ultrabasic and basic magma; there were minor intrusions of dolerite, serpentine and gabbro and some local basalt extrusions; the basalts are commonly associated with limestone reefs and suggest island arcs.

The upper Palaeozoic saw a marked increase in igneous activity with the extrusion of large quantities of acid volcanics and the intrusion of large granite batholiths, both phases were derived from the same magma. In Carboniferous time acid volcanics, flows and pyroclasts, preceded a granite batholith which subsequently intruded them; the granite is considered to have been emplaced at a high level. A similar pattern of igneous activity was repeated in Permian time, but the volume of the volcanics appears to have been much greater than in the Carboniferous extrusions.

The final phase of igneous activity began in ?upper Miocene and continued through until Recent. During this period of igneous activity the magma erupted was all basic, at least 2,800 square miles of country have been inundated with basalt up to perhaps, 2,000 feet thick, but generally 100 to 500 feet thick. A rough estimate suggests that 200/250 cubic miles of basalt were erupted during this time.

The history of the igneous activity of this area is summarised in Table I.

Period	Type of Activity	Extent and Magnitude of Activity
	Basic:	
Recent / ?Upper Miocene	Extrusion of basalt; mainly flows with some pyroclasts.	Extensive, medium scale.
	Acid:	
Upper Palaeozoic	Extrusion of rhyolites, flows and pyroclasts. Intrusion of granite batholiths.	Extensive and large scale.
	Basic:	
Middle/Lower Palaeozoic	Intrusion of dolerite, serpentine and gabbro, extrusion of local basalt flows.	Limited and minor.
	Acid:	
?Upper Precambrian	Intrusion of granite	Extensive and large scale.
	Basic:	
Precambrian	Intrusions of dolerite	Extensive, medium scale.

Within the confines of the Precambrian basement, ring fractures appear to have been the dominant control in the emplacement of the granite and rhyolite, particularly during the Upper Palaeozoic period of activity.

East of the Precambrian basement there appears to be two dominant directions of faulting, roughly N.E. and N.W.; differential vertical movement on these faults produced grabens which have controlled to a considerable extent:

(a) the distribution of the Upper Palaeozoic acid extrusives,

(b) the distribution of Tertiary basaltic volcanoes (particularly in the Atherton Basalt Province),

(c) the present-day topography particularly in the eastern side of the area.

PREVIOUS INVESTIGATIONS

These basalts have been investigated sporadically over the past one hundred years.

Ludwig Leichhardt and party in 1845 were the first Europeans to see the basalts, he named Mt. Lang, the most conspicuous volcano in the McBride Province.

Daintree (1872) recognised two divisions in the Tertiary volcanic rocks and noted that they were both basic; this was a departure from the pattern in Southern Queensland where the Tertiary volcanics include some acid lavas.

Allport (in Daintree 1872, p.313) recorded the alteration of the olivine to what he called "iron oxide".

Maitland (1891) carried out a close study of the basalts of the McBride Province and recorded many pertinent observations:

(a) his estimate of the extent of the basalt accords well with present-day knowledge from air photographs,

(b) he opined that the basalt plateau was built of superimposed basalt flows which emanated from numerous volcanic foci,

(c) he noted the presence of younger basalts and drew attention to the absence of "fragmental deposits",

(d) he recorded the alteration of the olivine phenocrysts to iddingsite and noted that this alteration was commonly only partial.

Jack and Etheridge (1892) considered that there were an Older and Newer Volcanic Series in Queensland but coul find no direct evidence for their ages.

Marks (1911) drew attention to the obvious age difference of basalts on "Carpentaria Downs" Station, where mesas capped with basalt stand about 400 feet above valleys floored with younger basalt.

Twidale (1956) proposed names for some of the basalt provinces and suggested three ages for the basalts. Twidale's work was based on reconnaissance and naturally he relied to a great extent on his interpretation of air-photo patterns, some of which he misinterpreted; these cases will be noted in the description of the relevant areas.

White & Crespin (1959) recorded two ages of diatomite associated with the basalts: this is the only definite evidence obtained so far for ageing the basalts.

The material for this paper was gathered during the winters of 1958 and 1959 when I, as a memberof a joint Commonwealth Bureau of Mineral Resources and Queensland Geological Survey Party, was engaged on Regional Mapping of the Einasleigh and Atherton 4-mile Sheets (a 4-mile Sheet covers $1\frac{1}{2}^{o}$ longitude by 1^{o} latitude). The accuracy of this type of mapping is mid-way between reconnaissance and detailed mapping and involves ground traverses coupled with air-photo interpretation. The McBride, the Wallaroo, and the western side of the Atherton Basalt Provinces were mapped on Regional Scale. Most of the Atherton Basalt Province is on the Innisfail 4-mile Sheet east of the Atherton

Sheet and the mapping of the basalt on it was mainly by reconnaissance traverses (air-photo cover of this area is incomplete).

East of the meridian through the town of Atherton the rainfall is high and increases towards the coast; most of this area is covered in thick rain forest and air-photo interpretation is difficult. West of the meridian through Atherton the rainfall diminishes rapidly and the rain forest is replaced by open savannah woodland; here the photo patterns are more reliable and the basalt is conspicuous.

The basalts of North Queensland fall naturally into geographic provinces and Twidale (1956) named several; the McBride was the northern-most province examined by him and is the southern-most dealt with in this paper. Twidale included the basalt around the Herbert River in the McBride Province, but as it is not connected to the McBride Province, I have given it a separate name, the Wallaroo Basalt Province.

The third province dealt with in this paper is the Atherton Basalt Province, named from common usage and obviously after the Atherton Tableland and the town of Atherton at the northern end of the province.

In all three provinces the basalts are petrologically similar and in general cover the same time range, but each province exhibits different features, and for this reason it is proposed to describe the basalts by provinces rather than chronologically. Hitherto little petrological work has been done on the basalts, and this paper deals primarily with the morphology of the volcanoes and their products.

McBride Basalt Province

The province (Plate 1) was named by Twidale (1956) from an extinct volcano situated on the north side of the road from "Kinrara"to the Hann Highway (geographic co-ordinates 144°51' E., 18°23'S.).

The province is an "extensive lava field" (Keble 1918); in the north there are a few inliers of Palaeozoic granite, but elsewhere the old land surface is completely concealed by basalt; the province is about 2,000 square miles in area and roughly oval in plan; the long axis trends east.

The basalt is domed. The doming appears to be due to an accretion of basalt flows erupted from many vents; the edge of the McBride Province ranges from 1,500 feet to 2,000 feet above sea level and the maximum altitude of 3,000 feet is attained by two shield volcanoes, Mt. Munana and Racecourse Knob. Tyrrell's (1937) definition of "multiple-vent basalts" describes this province fairly aptly; but there is a difference; Tyrrell's definition*suggests that the large number of small volcanoes erupted roughly equal volumes of lava, whereas in the McBride Province most of the basalt was erupted through a relatively few large vents and the large number of small vents are mostly parasitic scoria cones which contributed little more than the material which built the cones.

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* Tyrrell (p.92) states - "In lieu of a better term I use the designation 'multiple-vent' basalts to indicate accumulations arising from the confluence of lava flows from a large number of small and closely-spaced volcanoes".

One hundred and nine volcanoes have been located on the air photographs; twelve of these, representative of the different types, were examined on the ground in 1958.

Age of the Basalts.

Obvious age difference in the basalts have been noted by previous investigators and the ages proposed by them have been derived by analogy with Tertiary Basalts elsewhere in Australia.

Twidale (1956) proposed three ages for the basalts of the McBride Province:-

1. Kinrara - late Pleistocene to early Recent.
2. Newer McBride - early to mid Pleistocene.
3. Older McBride - late Pliocene to early Pleistocene.

White & Crespin (1959) described Pliocene diatomite deposits from both the McBride and Wallaroo Provinces and Pleistocene/Recent diatomite from the McBride Province; the older diatomites are overlain by basalt, the younger are marginal to a lake dammed by basalt.

The 1958 mapping suggested that there have been at least four main periods of volcanism in the McBride Province; accordingly I have modified Twidales groups and proposed the following:-

1. Kinrara - Recent
2. Undara - Pleistocene
3. Newer McBride - mid Pliocene to late Pliocene
4. Older McBride - ?late Miocene to early Pliocene.

The units are dealt with below and evidence for their ages discussed.

Older McBride Basalt

The diatomites (Fig.10) were deposited in lakes formed by basalt dams: Pliocene diatomites would require an early Pliocene or late Miocene basalt to impound the lakes; Twidale's (1956) name "Older McBride" has been retained for these basalts. Their extent is not known, though undoubtedly they underlie much, if not all, of the present-day basalt plateau; in addition there are numerous outliers of basalt beyond the edge of the plateau which are obviously old and could be included in this category.

On the south-west of the province a basalt-capped mesa stands about 400 feet above the level of the Copperfield River (Marks, 1911). The Copperfield flows over basalt which is obviously much younger than that capping the mesa. The plan of the mesa (Plate 1) clearly indicates that the old basalt formerly occupied an old stream channel; from this can be obtained some idea of the amount of denudation that has taken place in this area since the eruption of the older basalt.

South-east of the McBride Province, between the "Valley of Lagoons" and "Camel Creek" Homesteads there are further relics of the early basalt flows; esker-like ridges of silicified quartz sand (known in Australia as "billy"), in places up to 100 feet high, indicate former stream patterns; in a few places they are capped with basalt. About ten miles north of the "billy" ridges black-soil flats occupy the floors of broad, shallow valleys and show as antler-like patterns on the airphotos; these are fossil streams preserved by basalt. In this region denudation has been slight but the depth of weathering great.

In general, the older outliers are around the southern edge of the basalt plateau and suggest that the McBride Basalt Plateau was formerly more extensive, or alternatively that the focus of activity was in this area. The prevalence of Skeleton Stage volcanoes (Kear, 1957) near and beyond the southern edge of the basalt plateau suggests that the focus of early activity was in this area and migrated north during later activity.

Newer McBride Basalts (mid Pliocene - late Pliocene)

In both the McBride and Wallaroo Provinces the Pliocene diatomite deposits are overlain by basalt; (Fig.10) Twidale's name "Newer McBride" has been retained for this basalt. It is difficult to delineate and no attempt has been made to map it in the McBride Province. In the Wallaroo Province it is the youngest basalt, but its outcrop has not been mapped; its surface has been greatly subdued by erosion and weathering and it is obviously older than much of the basalt in the McBride Province.

Undara Basalt (Pleistocene) is the name of the basalt which is younger than the Newer McBride Basalt but older than the Kinrara Basalt: it is named from the well defined pit crater in about the centre of the McBride Province (geographic co-ordinates 144°43'E, 18°18'S).

Four main centres appear to have been active during the extrusion of the Undara Basalt. They were not strictly contemporaneous; undoubtedly the activity migrated from centre to centre during this period. The centres are dealt with briefly in order of assumed ascending age:-

(i) Racecourse Knob (Fig.1, Plate 1) poured out vast quantities of basalt which flowed radially out and built a shield volcano; this vent may be late Newer McBride or early Undara age.

(ii) Chubber's Hill, Razorback and Round Hill, two to three miles north-east of "Meadowbank" Homestead, erupted large quantities of basalt, which appears to have flowed mainly to the north-east and the west.

(iii) Undara Crater, located in about the middle of the McBride Province, extruded vast quantities of basalt which flowed mainly to the north and north-west, around the base of Racecourse Knob, and extended beyond the site of the village of Mt. Surprise.

(iv) Murronga Crater (Fig.12) about twelve miles south-south-west of Racecourse Knob, erupted a large quantity of basalt which flowed mainly to the south, into the Einasleigh River.

Kinrara Basalt (Figs. 8, 9, 11; Plate 1)

This basalt shows very clearly in the air photographs, and consequently is easy to map. The Kinrara Basalt was erupted through two vents, one major and one minor, situated close together near the north-west edge of the flow. The basalt flowed south-east into stream channels incised in older basalt; near the vents the stream channels were completely buried beneath a sheet of lava. About six miles from the vents the stream channels were sufficiently incised to confine the lava, and so the "extensive" lava field split into three "confined" lava fields (Keble, 1918); two of these subsequently re-united in the valley of the Burdekin River near the "Valley of Lagoons".

The Kinrara Basalt flow is about thirty miles long and covers an area of about one hundred square miles; it is undoubtedly the youngest, possibly the smallest, and definitely the most spectacular basalt in the entire area.

Age of the Volcanoes

Kear (1957) has proposed a method of ageing volcanoes by their "erosional stage"; his four erosional stages, Volcano, Planeze, Residual Mountain, and Skeleton, are all evident in the McBride Province, but because of large discrepancies in climate it is unlikely that a direct correlation with Kear's ages would be reliable. During the examination of the younger basalts an unsuccessful search was made for fossil wood for carbon 14 dating, apart from this no attempt has yet been made to derive an absolute time scale for these volcanoes; so, with a few exceptions, it is not possible to assign definite ages to the volcanoes even though there are obvious differences in their ages.

Types of Volcanoes

(i) Shield Volcanoes

Racecourse Knob (144°18'E. 18°18'S.) is a broad symmetrical cone near the western side of the McBride Province (Fig.1). It appears to be identical with the Icelandic Shield Volcanoes even to the extent of having a small apical crater similar to that on Skjaldbreit (Cotton, 1952 p.88,89); in addition it supports four scoria cones (Twidale 1956, erroneously referred to this volcano as Mt. Tabletop). Mt. Munana, about eight miles south-south-west of Racecourse Knob, is an older, partly dissected shield volcano (Fig.12)

These two are the obvious shield volcanoes in the McBride Province; there may be others buried beneath later basalt flows.

(ii) Pit Craters (Figs. 11 & 12)

Pit craters are normally apical on shield volcanoes and the one on Racecourse Knob is a good example of this type; but throughout the McBride Basalt Province there are a number of roughly circular depressions, two to five hundred yards in diameter and ranging from 50 to 100 feet deep, which can best be described as pit craters and yet do not appear to be apical on shield volcanoes.

<u>Kinrara Crater</u> (144°55'E, 18°25'S) is the youngest crater in the McBride Province. It is a pit crater with a rim about 400 yards wide and 150 feet high. This rim has been built by overflow and spatter; the overflow was not voluminous (Cotton, p.90) and consequently the rim has a steep outer wall. The inner wall is sheer except on the western side, where basaltic scoria and pyroclasts are draped over it (Figs.3,4 & 5).

Two lava tunnels lead away from the crater, one to the north-east and the other to the south-west; near the crater the roofs of these tunnels have collapsed and made them conspicuous. (Fig.11). These tunnels drained the basalt from this volcano and ducted it long distances down valleys incised in the older basalts.

Within the crater a ledge of basalt about 10 feet wide (Fig.11) is attached to the sheer inner eastern wall, 20 to 30 feet below the rim; it is a remnant of a former level of a lava lake. In the north-east portion of the wall, just above the level of this ledge, there is the entrance to a lava tunnel 8 to 10 feet in diameter and about 6 to 8 feet deep; this tunnel is about 100 feet above the major tunnels outside the rim and appears to be younger than they.

Late-stage explosive activity has reamed out a crater 150 feet deep in the floor of the pit crater and exposed the underlying older horizontal basalt flows and part of the throat of the volcano (see Fig.5.); the fragmented material and scoria have been draped over the western wall of the pit crater and provide a route into an otherwise sheer-sided crater.

Siliceous sublimation products adhere to parts of the walls in the crater and their presence indicates that it is not very long since solfataric activity ceased at this vent.

Small fragments of quartz up to half an inch in diameter were found included in the basalt in the upper crater rim.

<u>Undara</u> is a pit crater, older than Kinrara and the well preserved features which make Kinrara so spectacular have all been destroyed by weathering and erosion; but it is particularly interesting because from this vent a very long lava tunnel originated (Fig.13). The lava tunnel can be traced on the air photos for an aggregate distance of at least 33 miles. Twidale (1956) misinterpreted it as "a clear arcuate fissure some 25 miles in length".

Undara Crater is difficult to find on the ground because the crater is apical in a low tumid mound indistinguishable from countless other mounds and ridges surrounding it; it is possible that it was an embryonic shield volcano which had its growth stunted by a too efficient plumbing system. Had the lava tunnel become blocked early in the history of this vent, the lava would have been forced to flow over the rim of the crater and so form a cone by accretion of countless thin fluid basalt flows; as it was the lava tunnel ducted large volumes of lava great distances and so prevented Undara from growing into a shield volcano.

The walls of Undara Crater are covered with matted vegetation, but open savannah woodland covers the floor; this contrasting pattern makes it obvious on the air photos.

About three miles west-north-west of Mt. Lang is an unnamed pit crater obviously very much older than Undara. It is clothed in open savannah woodland and is not obvious on the air photographs: whether it is the crest of a buried shield volcano or is another of the Undara type could not be determined.

(iii) Scoria Cones

Scoria cones are built by "fire-fountaining" and mildly explosive activity in the declining stages of a cycle of volcanic activity. Many of these vents are almost perfectly preserved in the McBride Province. The younger members of this type are symmetrical cones 300 to 400 feet high and 300 to 400 yards wide at the rim; all have shallow apical craters and the rim is usually highest on the western side, owing to the influence of the prevailing wind. The cones are built of basalt scoria with subordinate flows and pyroclasts.

The porosity and permeability of the scoria cones leaves them particularly unaffected by "channelling". Consequently they retain their pristine form far longer than cones built of more impervious forms of lava, such as flows and fine grained pyroclasts.

In a number of places three or four scoria cones are grouped together and these groups commonly trend 020°. Several of these groups are adventive on shield volcanoes, Racecourse Knob is the best example of this association with four adventive scoria cones trending about 020° across the crest. The Tabletops about ten miles south-south-east of Racecourse Knob are three very symmetrical scoria cones, aligned at 020°, and adventive on the flanks of Murronga Crater; in this case the parasitic vents are more prominent than the host, which may be a partly buried shield volcano. Elsewhere there is no obvious reason for the location of the scoria cones, but doubtless they are related to fractures in the underlying basement.

(iv) Composite Cones

True composite or strato-cones, that is those made up of alternating layers of effusive and pyroclastic lava, appear to be absent in both the McBride and Wallaroo areas. However, some cones have too much effusive lava to be classified as scoria cones, and have therefore been classified as composite cones.

Mt. Lang, the most prominent volcano on the eastern side of the McBride Province, is the best example of a composite cone. It is now deeply dissected, particularly on the norther, western and southern sides, and part of the inner structure is revealed; near the crest, a thick deposit of ash and lapilli containing a few volcanic bombs is exposed. About 100 feet below the crest, on the western side, a lava tunnel about 8 feet wide, 4 feet high and 20 feet long is exposed; the flow-basalt surrounding it is now deeply weathered.

Chubber's Hill two miles north-east of "Meadowbank" is a smaller, more recent composite cone. The cone itself appears to be built essentially of scoria, but the late activity from this vent was almost purely effusive; the lava welled up through the central vent, filled the apical crater, and then overflowed on the low, north-east, side of the cone.

Features of the Basalts

Throughout the history of the McBride Province it is evident that the basalt has generally been extruded in a very fluid state. Most of the obvious flow structures on the older basalts have been erased by weathering; in marked contrast to this is the Kinrara Flow, with all structures perfectly preserved. Parts of this flow were closely examined, and the knowledge gained was of considerable assistance in evaluating the more weathered structures in the older basalts.

(i) Kinrara Basalt

The direction of flow of the basalt extruded from Kinrara Crater has been controlled by a pre-existing drainage pattern; the gradient of the channels, down which the basalt flowed, was sufficient to ensure rapid draining of the fluid basalt from beneath the chilled lava surface, commonly only a foot or so thick. Subsequent collapse of much of this surface has led to the formation of a chaotic assemblage of sinks, depressions and open fissures. Below Saltern Lagoon, in the Burdekin Valley, the distal portions of the Kinrara Flow contain few collapse structures; their absence indicates that the basalt was becoming sluggish in its movement and was not drained from beneath the chilled crust.

Some of the distinctive features of the Kinrara Basalt are:-

(a) Edge of the Flow

In both the "extensive" and "confined" lava-field tracts the Kinrara Basalt stands above the immediate surrounding country; the difference in elevation is usually about 4 to 6 feet. In the "extensive" lava field the edge of the flow is usually marked by a jumble of boulders of pahoehoe basalt, obviously broken from the chilled margin of a slowly advancing flow.

In the "confined" areas this litter of boulders is generally more pronounced and is similar to a lateral moraine. In some sections of the "confined" lava field the litter of lateral boulders is buried beneath the edge of the flow, which has slabbed off. This slabbing is obviously caused by fracturing of the solidified crust, a few feet in from the edge and parallel to it; the edge of the flow then collapses outwards under its own weight, much in the manner of soil turned by a single furrow mouldboard plough.

(b) Sinks

The sinks range from small circular holes a few feet in diameter to large irregular holes hundreds of square yards in area; the smaller sinks are the more common. Those investigated ranged in depth from a few feet to about twenty feet; the depth is obviously a function of the thickness of the flow. The floors of the sinks are usually covered with a litter of pahoehoe boulders. (Fig.8)

(c) Depressions

These are similar to the sinks, but in them the roof has only sagged rather than completely collapsed; the sinks are the more common form.

(d) Rectangular Pavements and Pressure Ridges.

Sub-crustal drag by the flowing basalt fractured the solidified skin and in many places rucked it up into a jumble of irregular blocks of pahoehoe basalt; in other places there is little rucking and the skin was only broken into rafts, commonly rectangular, 80 to 100 square feet in area and bounded by ridges of broken lava 6 to 8 inches wide and 2 to 3 inches high.

Possibly the severe rucking resulted from turbulent flow of the basalt over irregular parts of the channel bed, and the pavements reflect the smoother parts of the old channel.

(ii) The older basalts.

Most of the lava in the McBride Province was erupted and distributed as flows, and now countless basalt boulder barriers impede travel across the area.

Skeats & James (1932) described basalt boulder barriers from the Newer Basalt areas of Western Victoria as predominantly ring-shaped and extending outward and down from a central vent, in a series of concentric steps. Obviously much of the basalt of the McBride Province has been distributed as sheet-flows, and possibly detailed mapping would reveal basalt boulder barriers such as described by Skeats & James. But the prominent boulder barriers in this province are not obviously ring-shaped; they meander across the country in the form of irregular stone walls; in general they can be classified as lava tunnels or lava tongues. Erosion subdues these features, and in the older basalt areas meandering lines of rounded basalt boulders protruding through black soil flats mark the course of old lava flows.

(a) Lava Tunnels (Fig.13, Plate 1).

Very fluid basalt poured out on a near-horizontal surface spreads extensively and solidifies to a sheet of fairly uniform thickness; if, before solidification is completed, the liquid lava is drained from beneath the crust, the crust collapses and a chaotic assemblage of sinks and depressions is formed. The proximal portion of the Kinrara Flow is an excellent example of this; and the area between "Spring Creek" and Murronga Crater is another, older, more subdued example.

Where very fluid basalt is constrained to flow in a channel it develops a solidified skin which is constantly breached by the weight of contained lava; the tunnel grows by accretion at the snout and the flanks become littered with angular boulders of basalt. If the gradient is steep enough the lava drains out of the tunnel when the supply of basalt ceases, and subsequently parts of the roof may collapse and so reveal the tunnel.

Undara Lava Tunnel is the most prominent in the McBride Province; the collapsed portions of this tunnel contain a tangled mass of dark green vegetation which is conspicuous both on the ground and on the air photographs. The tunnel from Undara Crater trends north-north-west for about three miles and bifurcates; the northern branch can be traced in the same general direction for about another ten miles, and the main branch, the western one, can be traced for more than twenty miles towards Mt. Surprise.

Undoubtedly there are numerous lava tunnels with no surface expression; a hole drilled for water, several miles north of Kinrara Crater, passed through a number of "large holes" and was finally abandoned at a depth of about 375 feet after the churn drill bit had "dropped about twenty feet" (Mr. J. Champney, "Kinrara" Station, personal communication). It seems safe to assume that these "holes" are lava tunnels and it is interesting to note that the drill passed through a number of them in attaining a depth of 375 feet.

(b) Lava Tongues

Esker-like ridges of basalt 5 to 15 feet high and 20 to 40 yards wide meander for long distances across the surface of the McBride Province; undoubtedly they were distributed in a similar manner to the lava tunnels but were not subsequently drained. Externally they are identical; but either the basalt was more viscous or the gradient was not sufficient to drain them and so they solidified as solid ridges rather than as hollow tubes. In some places short breaks in the lava tongues suggest that they have, in places, been breached and drained through the flank; but for the most part they are solid ridges of basalt mantled with irregular basalt boulders.

WALLAROO BASALT PROVINCE

Wallaroo Province has been named from Wallaroo Hill, an old extinct volcano about three miles west of "Glen Eagle" Homestead. There are two volcanoes in the province, both in the "Residual Mountain/Skeleton Stage" of erosion (Kear, 1957). One is Wallaroo Hill, the other is an un-named feature about two miles west of "Glen Ruth" Homestead. The Wallaroo Basalt covers about 50 square miles and is a "confined" lava field (Keble 1918); its surface has been subdued by erosion and it is much easier to traverse than the McBride Province. Many outliers of basalt surround the province; those on the south side of the Herbert River are now separated from the parent body by a gorge about 1,000 feet deep.

There are two ages of basalt in the Wallaroo Province equivalents of the Older and Newer McBride Basalts, and no evidence of late-stage activity.

ATHERTON BASALT PROVINCE (Plate 1)

The Atherton Province is named from common usage, and was derived from the Atherton Tableland and the town of Atherton at the northern end of the province; it is a confined lava field (Keble, 1918) with an area of about 800 square miles.

About 80 percent of the province lies within a high rainfall area and was originally covered with thick rain forest, much of which has been felled to provide land for agricultural and dairying pursuits. Most of the province is mantled with basaltic pyroclasts up to 100 feet thick on which has developed a dendritic drainage pattern, which is much more deeply incised in the southern end of the province. The result is that the surface ranges from gently to steeply undulating and contrasts strongly with the essentially flat surfaces of the McBride and Wallaroo Provinces.

Most of the basalt is confined to a north-north-west valley about 50 miles long and up to 20 miles wide. This valley was formerly drained northwards by the westerly-draining Walsh River, and southwards by the easterly-draining ancestral Johnstone River. After the outbreak of volcanic activity in, probably, mid-Tertiary time the valley was partly filled by flows of basalt, the distal portions of which coursed down these stream valleys. Along the western side the flows over-topped several low parts of the watershed and coursed down the valleys of adjoining streams; the most notable of these are the flows that coursed down the Herbert River headwater tributaries and joined the McBride Basalt Province about four miles east of "Gunnawarra" Homestead.

The fine grained pyroclasts, erupted towards the end of the activity in this province, are not as extensive as the flows; except on the south and south-east sides the distal portions of flows are not mantled with pyroclasts, and in general there is very little pyroclastic basalt north-west of Tolga and west of Ravenshoe.

Age of the Basalts

So far no definite evidence of the age of the Atherton Basalts has been obtained, because there are no associated diatomite deposits as in the McBride and Wallaroo Provinces; they have a similar lithology and appear to have a similar age-range to the basalts in the McBride Province - ?Upper Miocene to Recent.

In several valleys on the western side of the province, in particular the Wild River and Oakey Creek (a small northern tributary of Blunder Creek), small weathered outliers of basalt crop out on hillsides 200 to 300 feet above basalt-floored valleys; these inliers are possibly equivalents of the Older McBride Basalt and the basalt in the valley floor equivalent to the Newer McBride Basalt. The pyroclastic basalt is probably equivalent to some if not all of the Undara Basalt, and the Kinrara stage (McBride Province) is probably represented by Mt. Quincan (a scoria cone, Fig.16), and Hyipamee Crater (a diatreme).

Basaltic Pyroclasts

The thick mantle of basaltic pyroclasts which covers most of the Atherton Province is the only significant difference between this province and the McBride and Wallaroo Provinces. But this mantle and the high rainfall have combined to produce a deep rich soil suitable for agriculture and dairying; consequently the Atherton Province with an area of about 800 square miles supports a population of more than 10,000 people. Whereas the McBride and Wallaroo Provinces with over 2,000 square miles support only about 500 people.

There are at least seven volcanoes in the Atherton Province which have erupted explosively (this does not include the scoria cones), they are Bromfield Swamp, Lynch's Crater, Lake Eacham, Lake Barrine, Lake Euramo, Bones Knob and Hypipamee Crater. Most of the pyroclasts were erupted from the first five of the above-named craters; four of these are large (up to a mile in diameter) and are distributed around the centre of the province, the fifth, Lake Euramo, is much smaller and is near the northern end of the province.

Most of the pyroclastic basalt was distributed subaerially, but some of it arrived at its present site as lahars; this mode of distribution was particularly active in the southern portion of the province. Eleven miles south-south-east of Ravenshoe unlithified, massive, fine-grained basaltic pyroclasts with sporadic basalt bombs have been penetrated by bores to a depth of more than 60 feet, material from this deposit has been used as a pozzolan in the construction of Koombooloomba Dam on the Tully River.

Twenty-four volcanoes have been recognised in the Atherton Province; six of them are explosion craters, one is a diatreme, and the rest are scoria cones, and vents formed by effusive eruptions.

<u>Explosion Craters</u>

(i) <u>Bromfield Swamp</u>, as the name implies, has been breached and drained, but it must formerly have contained a lake similar to Lakes Eacham and Barrine. It is the largest of the old explosion craters and is about four miles south-west of Malanda and towards the western side of the province. It is about a mile wide, roughly circular in plan and about 200 feet deep; it has been greatly subdued by erosion and is obviously much older than Lakes Eacham, Barrine, and Euramo to the north.

(ii) <u>Lynch's Crater</u>, ten miles east of Bromfield Swamp has also been breached and drained; it is smaller than Bromfield Swamp (about 700 yards in diameter and 150 feet deep), and was probably contemporaneous with it. Rounded boulders of metamorphics up to a foot long were found inside this crater; they must have been derived from the underlying Barron River Metamorphics.

(iii) <u>Lake Eacham</u> (Fig.15), five miles north-north-east of Malanda, is a young explosion crater and contains a lake. It is roughly circular, about 1,100 yards in diameter, and has an embayment on the south-east side; possibly this embayment is the former effusive vent. The crater is steep-sided and about 500 feet deep.

(iv) <u>Lake Barrine</u> is about 2½ miles north-north-east of Lake Eacham and is the largest explosion crater in the province. It is about twice the area of Lake Eacham, but about 100 feet shallower. Lake Barrine has an embayment in the north-east side.

(v) <u>Lake Euramo</u>, about six miles north of Lake Barrine smallest of the explosion craters; it consists of two small joined craters. Dimensions are about 500 yards long and 150 yards wide; the long axis trending north, and in shape it resembles the print of a boot.

<u>Diatreme</u>

The only diatreme in the whole area is the crater known as Hypipamee on the western side of the Atherton Province about ten miles south of Atherton. Here explosive activity has blasted through granite a sheer-sided hole about 200 feet wide and 450 feet deep (now partly filled with water). Basalt lapilli and small fragments of Upper Palaeozoic granite are scattered all around this vent; it is obviously very young and must have been formed by one violent explosion.

Twidale (p.11) claimed that some of the McBride Province volcanoes contained diatremes, some of which were "occupied by lakes". It is probable that he mistook the pit craters for diatremes, and the thick vegetation in the younger ones (which show dark-grey on the air photographs) for water. The only lakes in the McBride Province have resulted from impeded drainage and are marginal to the basalt.

Scoria Cones

(i) Mt. Quincan seven miles south-east of Atherton is the most spectacular scoria cone in the area; it is about 700 feet high and has a crater about half a mile wide. It is markedly asymmetrical; the west side of the rim is about twice as high as the east side; the prevailing wind blows from the east. The cone is composed of basalt scoria that has been well winnowed and contains many olivine bombs.

(ii) The Seven Sisters two miles north of Mt. Quincan are a group of scoria cones 150 to 200 feet high; they lack Mt. Quincan's well developed apical crater and are probably older.

Adler Hill and an unnamed hill south-east of Mareeba are old scoria cones from which minor basalt flows have emanated.

Shield Volcano

Bones Knob west of Tolga is one of the oldest vents in the Atherton Province. Early effusive activity built up a shield volcano and subsequent explosive activity reamed out the apical crater and constructed within it a dome of fine-grained pyroclasts (Fig.14). The pyroclasts are bedded and contain numerous volcanic bombs. Basalt dykes up to eight feet wide are exposed in the valley north of the dome, and undoubtedly fed the old vent.

Composite Volcanoes

There are several composite cones in the Atherton Province: Mt. Weerimba, west of Bromfield Swamp, is an old vent of this type, and Glen Allyn Crater, six miles south-east of Malanda, is another somewhat younger one.

DISTRIBUTION OF THE VOLCANOES

(i) In the McBride Province most of the vents fall into groups which coincide fairly well with the contact between Precambrian granite, Palaeozoic granite, and ? Archaean metamorphics. Within the groups lineations commonly striking 020° are apparent. This direction is prominent in the underlying ?Archaean basement, the edge of the basement, and the Palaeozoic sediments east of the basement.

(ii) In the Wallaroo Province, with only two vents there is no obvious grouping, but both vents appear to be located on strong faults which bound the east and west sides of the confining valley.

(iii) In the Atherton Province strong faulting again appears to have been the major control in the location of the vents. Two prominent directions of faulting about N.N.W. and N.E., have been mapped in the area west of the Atherton Basalt Province and the evidence suggests that differential vertical movement (up to 2,000 - 3,000 feet) of blocks bounded by these faults gave rise to grabens, which in Upper Palaeozoic time were filled with acid lavas. Subsequent movement and erosion has inverted the topography and produced valleys, one of which now houses most of the Atherton Province. The marked concentration of vents along the western side is undoubtedly due to the strong fault which bounds this side of the valley. The group of vents in the centre of the province is probably located along a strong north-easterly fault.

RELATIONSHIP TO PLUTONS.

In all three provinces the basalts have been extruded through areas which have formerly been the site of extensive intrusions and extrusions of acid magma. In southern Queensland the Tertiary volcanism had a three-fold cycle with an acid phase in the middle, but in north Queensland the activity was all basic.

Possibly in southern Queensland the basalt had ascended to a high level and had assimilated some of the country rock before the magma chamber was tapped; consequently basic and then acid lavas were erupted, and a fresh accession of basalt to the chamber provided the third basic phase; whereas in northern Queensland, the faulting was profound and tapped an uncontaminated basic magma at great depth - the absence of an acid phase, the prevalence of olivine bombs, and the large throws on the faults could be construed as confirmatory evidence.

CONCLUSION

This paper records only some of the many interesting aspects of the North Queensland basalts, and stems from a brief examination of parts of them. Much work remains to be done on them, particularly on the petrology and age of the basalts. It is possible that the early aboriginal inhabitants of this area witnessed volcanic activity at the younger Kinrara vent; but their detribalised descendants have no knowledge of such activity.

ACKNOWLEDGEMENT

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McBRIDE BASALT PROVINCE

Figure 1. Racecourse Knob, a shield volcano on the western side of the province; note the adventive scoria cones on the flanks of the main structure. View east-south-east from the Hann Highway/Mt. Surprise road; Palaeozoic granite in the foreground, granite/basalt contact in the middle distance. J.G. Best, photo.

McBRIDE BASALT PROVINCE

Figure 2. The Tabletops, three adventive scoria cones near the centre of the province. Note how they descend northward down the flank of Murronga Crater, the apical crater of which is the dark patch partly obscured by the tree in the right foreground. View south from Mt. Murronga.

J.G. Best, photo.

McBRIDE BASALT PROVINCE.

Figure 3. Kinrara Crater. View east-south-east across the crater; note the sheer inner wall and the narrow platform, a remnant of a former lava lake.

J.G. Best, photo.

McBRIDE BASALT PROVINCE

Figure 4. Kinrara Crater. View north-west from the south rim of the crater; note the gentle slope on the western side and the sheer wall on the north: late-stage explosive activity reamed out the throat of this vent and deposited pyroclasts and scoria over the western wall. Mt. Lang, a partly eroded composite cone, is silhouetted in the left background.

K.G. Lucas, photo.

McBRIDE BASALT PROVINCE

Figure 5. Kinrara Crater. The remnant of the throat of the volcano exposed by late-stage explosive activity which reamed out a lower crater about 150 feet deep.

C.D. Branch, photo.

McBRIDE BASALT PROVINCE.

Figure 6. Thin superimposed flows of basalt on the south side of the crater. This demonstrates how limited overflows of basalt constructed the rim around this crater. The figure is standing on the platform visible in Figure 3.

K.G.Lucas, photo.

McBRIDE BASALT PROVINCE

Figure 7. Kinrara Crater. Basalt spatter adhering to the inner eastern wall of the crater; a further relic of the lava lake.

C.D. Branch, photo.

McBRIDE BASALT PROVINCE

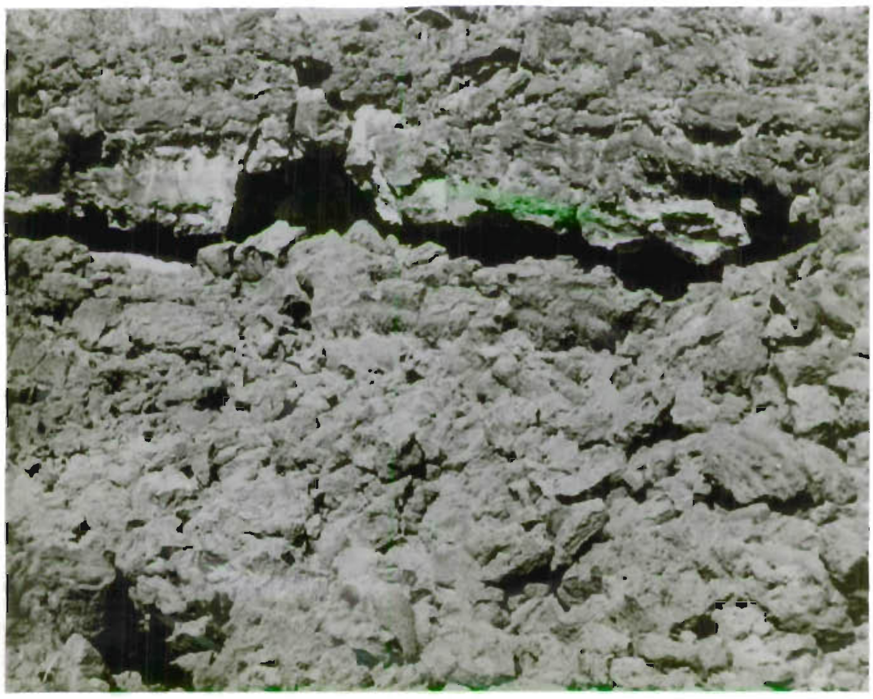


Figure 8. A "sink" in Kinrara Basalt Flow in OB Creek; note the lava tunnel exposed by the sink and the litter of pahoehoe basalt boulders.

J.G. Best, photo.

McBRIDE BASALT PROVINCE

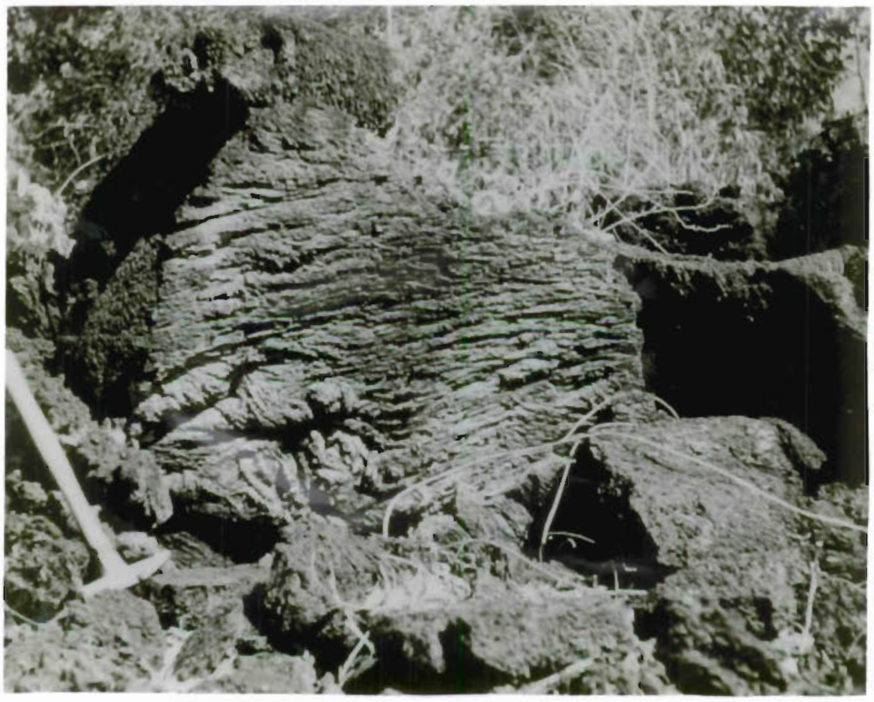


Figure 9. A pahoehoe basalt fragment on the flank of Kinrara Flow in OB Creek.

J.G. Best, photo.

McBRIDE BASALT PROVINCE

Figure 10. Diatomite deposit overlain by Newer McBride Basalt, exposed in Wyandotte Creek about 5 miles north-east of "Conjuboy" Homestead.

J.G. Best, photo.

McBRIDE BASALT PROVINCE   Figure 11.

[illegible]
south-east from the crater is the Kinrara Basalt. Note the collapsed lava tunnels leading away from the crater, one to the north-east and the other to the south-west. (The black circles are ringed centre and wing-points on the air photographs).

Three scoria cones about 2 miles south of Mt. Munana are the Table-tops. The dark-grey circle west of the centre Tabletop is Murronga Crater (a pit crater); note the collapsed lava tunnel leading south from it. The oval depression west of Mt. Munana is probably an old pit crater; it was not examined on the ground.
(The black circles are ringed centre and wing-points on the photos)

Air photograph of part of Undara Lava Tunnel, note how the thick tangled vegetation growing in the collapsed portions of the tunnel accentuates it. The scoria cone north of the lava tunnel is Kalkani cone; that south of the tunnel is un-named.
(The black circle is a ringed centre-point on the air photograph).

ATHERTON BASALT PROVINCE

Figure 14. Bones Knob near the northern end of the province appears to be a shield volcano which has had its apical crater reamed out by explosive activity; the dome within the crater is composed entirely of pyroclastic basalt, mostly fine-grained, and laps over the rim of the old crater on the south-eastern side.

K.G. Lucas, photo.

ATHERTON BASALT PROVINCE

Figure 15. Lake Eacham, an explosion crater near the centre of the province, is 2450 feet above sea level, has an area of 131 acres and an average depth of 480 feet. Note the embayment on the south-east side, possibly marking the site of mildly explosive activity, or of the original effusive vent of this volcano.

K.G. Lucas, photo.

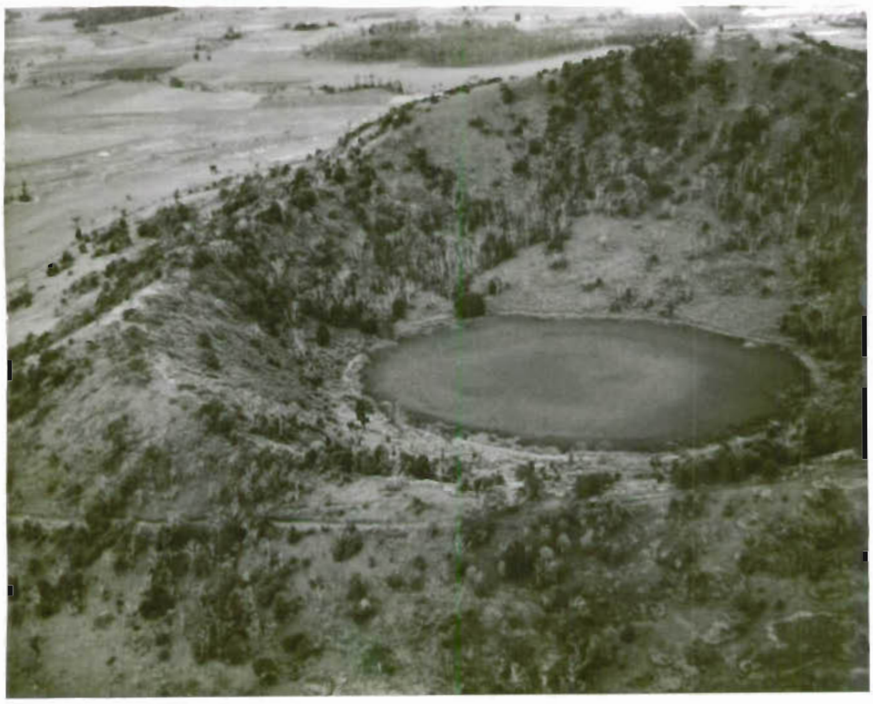
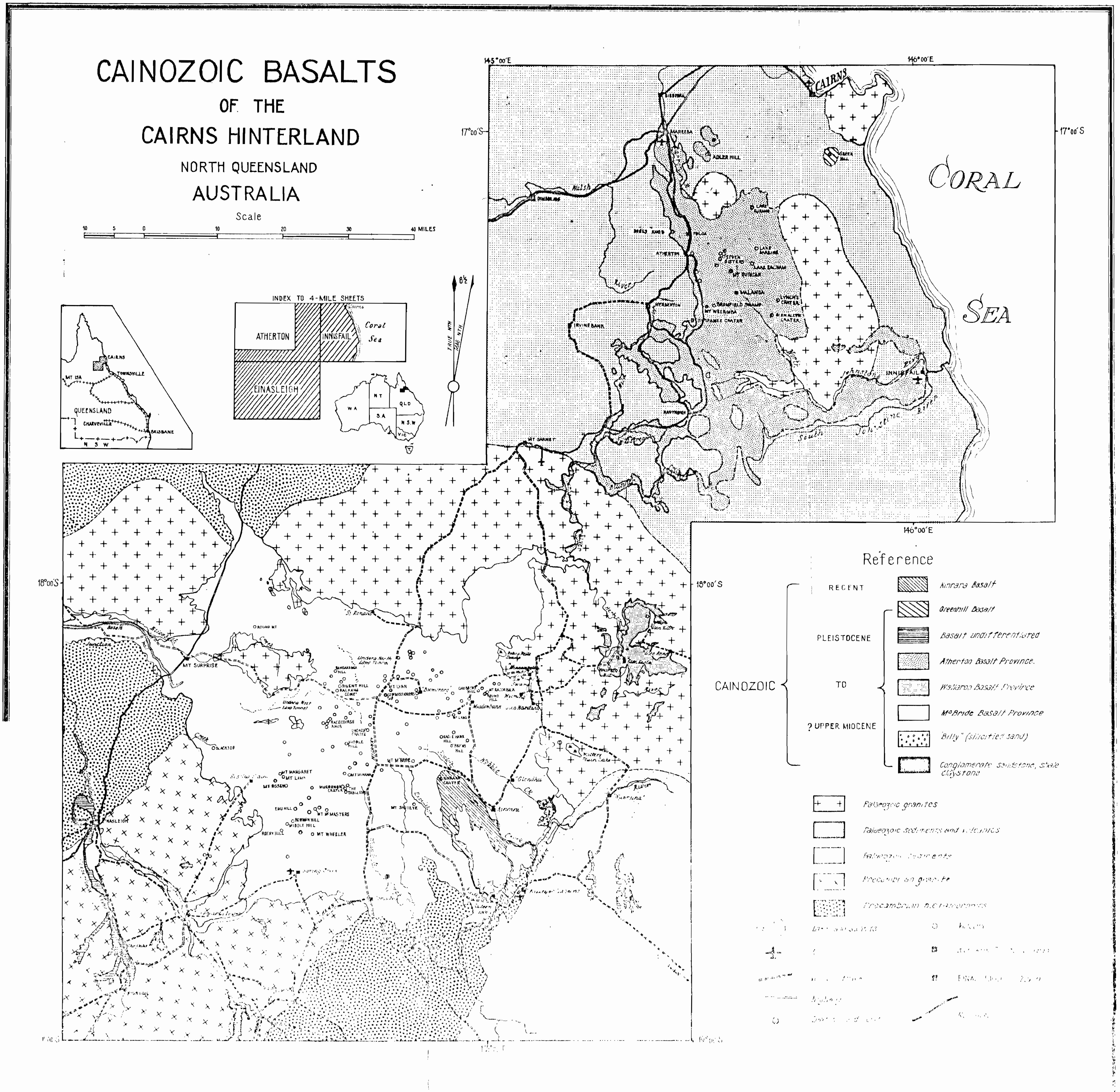


Figure 16. Mt. Quincan, a young basalt scoria cone about 7 miles south-east of Atherton township. The western side of the rim is almost twice as high as the eastern side; the prevailing wind blows from the east. Olivine bombs abound in the scoria at this vent.

K.G. Lucas, photo.

PLATE 1


CAINOZOIC BASALTS
OF THE
CAIRNS HINTERLAND
NORTH QUEENSLAND
AUSTRALIA
Scale
40 MILES
INDEX TO 4-MILE SHEETS
ATHERTON
INNISFAIL
EINASLEIGH
Coral Sea
CAIRNS
TOWNSVILLE
MT ISA
QUEENSLAND
CHARLEVILLE
BRISBANE
N S W
W A
N T
S A
QLD
N S W
VIC
CORAL
SEA
145°00'E
146°00'E
17°00'S
18°00'S
MAREEBA
ADLER HILL
ATHERTON
HERBERTON
IRVINE BANK
INNISFAIL
MT GARNET
MT SURPRISE
EINASLEIGH
MT McBRIDE
MT MARGARET
MT WHEELER
Reference
CAINOZOIC
RECENT
PLEISTOCENE
TO
? UPPER MIOCENE
Kinrara Basalt
Greenhill Basalt
Basalt undifferentiated
Atherton Basalt Province
Wallaroo Basalt Province
McBride Basalt Province
"Billy" (silicified sand)
Conglomerate, sandstone, shale claystone
Palaeozoic granites