The Mount Warning Shield Volcano

A General Geological and Geomorphological Study of the Dissected Shield

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THE MOUNT WARNING SHIELD VOLCANO

A GENERAL GEOLOGICAL AND GEOMORPHOLOGICAL STUDY OF THE DISSECTED SHIELD

ABSTRACT. A general description is given of what is now known as the Mount Warning Shield Volcano. Three distinct geomorphological features are represented—the central elevated mass, the erosion caldera, and the dissected outer remnants. The latter two features are treated with respect to their general geology and geomorphology.

A mechanism of shield formation is proposed, and the suggested evolutional development of the land form is traced from the early stages to the present day representation.

A brief survey is made of the evidence relating to the regional setting and age of the shield.

I

INTRODUCTION

The Mount Warning mountain mass and related peaks cover some 50 square miles of rugged country, the north-eastern corner of which lies 3 miles south-west of Murwillumbah in northern New South Wales. Field investigations were carried out in the area during 1958 and early 1959, at which time a direct relationship between the complex and the geological and physical features of the surrounding ranges and valleys was established. In this study, a preliminary interpretation has been made of the evolutional history—both geological and geomorphological—of these surroundings, which cover approximately 1,500 square miles.

This paper is a condensation of part of a thesis submitted for the Master of Science Degree at the Queensland University (Solomon, 1959). The second section, outlining the geology of the central igneous complex, will be presented in a subsequent publication. Investigations were completed with the aid of a Commonwealth Postgraduate Award.

The writer wishes to acknowledge the assistance and advice given by Professor W. H. Bryan, the late Dr. R. Gradwell, Dr. N. C. Stevens, and the rest of the staff of the Geology Department. He wishes to record his appreciation of the invaluable assistance given to him by Dr. R. Greet, both in the field and in the compilation of maps and text figures.

Previous literature

Richards (1916), in a pioneer work, made reference to the volcanic rocks in the area, and included them in his subdivision of the volcanic rocks of South-Eastern Queensland into a vertical succession of basalt-rhyolite-basalt of Tertiary Age. Bryan & Jones (1945) suggested that the volcanic rocks and minor interbedded freshwater sediments be called the Lamington Series and that they are of probable Pliocene age. Hill (1951) recognized that these masses "were formed in a shield volcano whose central orifice was Mount Warning".

Detailed mapping by Tweedale (1950) in the Binna Burra area supported a relationship between the emission of the Lamington Volcanics and the outpourings from the supposed central volcanic vent of Mount Warning.

Other than the above, no field information was available at the time of commencement of the investigation. Since this paper was prepared, McTaggart (1962) has contributed to the stratigraphy of the shield.

II

General description

Located within that part of South-Eastern Queensland and North-Eastern New South Wales bounded by the parallels 28°—28° 45′ S., and the meridians 153°—153° 30′ E., are the eroded remnant features of a geological entity, henceforth called the Mount Warning Shield Volcano.

In this paper the writer follows Williams (1932) in the definition and use of the term "shield volcano"—a large dome-like structure formed exogenously by the outpouring of fluid lavas—with the additional point that the exogenous build-up may be attributed to outpourings by subsidiary vents and fissures as well as from a central eruption.

The volcanic accumulations outcrop within an oval or shield-shaped area covering approximately 1,500 square miles, with the major and minor axes of the shield measuring 55 miles in a north-south direction and 35 miles in an east-west direction, respectively. As a result of the erosive forces active since the last stages of igneous activity, the Mount Warning Shield has reached a submature stage of dissection, intermediate between the planeze and residual mountain stages of Cotton (1944) and Kear (1957). Thus, representing the old shield volcano, there are now two distinct geomorphological features—the erosion caldera with Mount Warning at its centre, and the dissected outer remnants—which, taken together, exhibit a stage of dissection probably not represented on such a large scale in any other part of the world.

III

Geomorphology

The erosion caldera

According to Cotton (1944), erosion calderas are "great hollows excavated in the centres of volcanic mountains by erosion". The Mount Warning erosion caldera has an average radius of 10 miles, and covers an area of approximately 350 square miles. It resembles a large amphitheatre in form, with the Mount Warning mass a dominant feature.

The central mass has withstood the forces of erosion more markedly than the surrounding area, resulting in an extreme topographic relief. The detailed geomorphology of this central area is too complex to be discussed herein. It is sufficient to note that its presence represents a stage of volcano dissection not shown in other comparable structures.

Surrounding this mass is the relatively flat-lying floor, bounded for the greater part by an erosional escarpment forming the rim of the caldera. This escarpment wall is steep-sided, with many cliff faces extending upwards of 2,000 feet from the caldera floor. There are two gaps in this wall. North-east of the central mass, the Tweed River opens to the sea with subsequent breakdown of the rim for a distance on either side. A smaller but just as well-defined opening exists to the south-west, but this break-through is not complete for a line of maturely dissected hills still separates the eastern and south-western drainage systems.

Inside the rim the major feature is the Tweed River, which with its tributaries drains the caldera floor. There are three main tributaries—the North, South, and Middle Arms—each of which has its headwaters in the escarpment walls. These three streams assume a roughly circular arrangement around the central mass. The minor headwater streams, some of which are still in the juvenile stage, exhibit semi-dendritic patterns where they drain the caldera walls. In its lower reaches, the Tweed River has reached maturity, meandering over the surrounding flats built up by successive deposits of alluvium to form a flood plain.

The outer shield remnants

Geomorphologists have recognized four stages in shield erosion—the volcano, planeze, residual mountain, and skeleton stages. The planeze stage is that stage of erosion wherein dwindling sectors of the constructional surfaces (planezes) survive on the ridges between deeply eroded major consequent valleys (Cotton, 1944). Continued erosion causes the planezes to dwindle, and finally disappear. At this, the residual mountain stage, there are no longer any traces of the original shield surface (Kear, 1957).

The eroded remnants of the Mount Warning Shield exhibit the planeze, residual mountain, and skeleton stages of dissection. By far the greatest amount of erosion has taken place over the eastern half of the land surface, both north and south of the caldera, with the result that in these sections there is very little evidence of the original constructional surface. Radially directed spurs run outwards from the rim, but none show the flat ridge-top characteristics of the planeze. The Nightcap Range in the south forms a very sharp escarpment wall averaging some 2,200 feet in elevation, while to the north the Springbrook Plateau with an elevation of almost 3,000 feet is the dominant feature. Both these land forms represent the residual stage of erosion, while further east still they merge into a series of radial coastal foothills representing the skeleton stage.

West of the Nerang Gorge, and extending round to the south-western escarpment break, the land surface topographically represents the planeze stage. The McPherson and Tweed Ranges averaging 3,000 feet in elevation cap the caldera rim, with Mount Hobwee, 3,860 feet, the highest point. Adjoining these rim ranges are the Lamington National Park in the north-west, and to the south the Wiangaree State Forest areas, both being great plateau remnants which extend outwards and down to the outer limits of the shield.

The dissection of such plateaux has led to the development of deep narrow gorges, enclosed on either side by the radial planezes. The consequent streams that drain these gorges are swift flowing and cut back, and sideways, into the constructional surface to form towering cliff faces.

IV

General geology

The erosion caldera

Very little is known of the detailed geology of the erosion caldera. Mount Warning and related peaks form a central igneous ring-complex.

On the caldera floor, a north-south line drawn through Mount Warning represents a distinct geological division between the Palaeozoic and the Mesozoic rocks of the area.

To the east of this line, there are folded sequences of greywackes and shales which form part of the Tasman Geosyncline deposits of late Ordovician or Silurian Age. They are probably equivalent to the Neranleigh-Fernvale Group of Southern Queensland, and further mapping should prove them to be an actual extension of these rocks.

Outcropping along the line of Palaeozoic-Mesozoic junction is a relatively narrow band of tuffaceous material, with interbedded flow rhyolites, which disappears to north and south beneath the caldera rim and is also truncated by the central complex. Where these tuffs are bedded, they strike north-south and dip steeply to the west. This formation is termed the Chillingham Volcanics on the Geological Map of New South Wales (1962).

West of the tuff band, the gently folded sediments are dirty, fine-grained sandstones, with interbedded conglomerates and shales, laid down under lacustrine conditions. They are Mesozoic in age, and bear strong lithological resemblance to deposits of similar age in South-Eastern Queensland.

In many places, the junction between the early sediments and the overlying extruded volcanics is clearly visible. Preliminary field mapping indicates that, just prior to the volcanic activity, the old landscape was in a fairly mature stage of dissection with minor ridges and valleys forming a somewhat uneven land surface upon which the early lavas were poured.

The outer shield remnants

Recent investigations have shown the basalt-rhyolite-basalt sequence of shield lavas, recognized by Tweedale (1950) and earlier workers in the Lamington-Binna Burra areas, to be fairly characteristic of the whole shield. McTaggart (1962) has found that the rhyolite flows are not all equivalent, as there are two horizons of rhyolite with intervening basalt in some areas. Vertical sections through the lavas, around the caldera walls and in the gorges, show the constant elevation or horizontality of some flows at fixed distances radially outwards from the centre. Furthermore, where ideal sections are visible, the major flows at least are observed to dip away from the centre on a slope of about 3°—conformable with the planeze gradients.

It is often the case that wherever an erosion escarpment has been developed, either around the rim or within the gorges, the more resistant acid lavas form the distinctive cliff face developments, with the basalts above and below undergoing more rapid breakdown. An excellent example of this is the Springbrook rhyolite cliff.

Scattered round the shield, wherever there has been sufficient erosion to uncover them, there are small but prominent spine-like rock peaks which have proved strongly resistant to weathering. Tweedale noted several of these such as Egg Rock and Charraboomba Rock in the Binna Burra area, and the writer has recently investigated others such as Page's Pinnacle, and Mount Doughboy and Dinsey's Rock within the erosion caldera. They are made up of rhyolite flows with vertical flow layers and marginal chilling effects, and it is postulated that they represent the chilled lavas in the throats of delivery vents. In addition, many of the coastal headlands, such as Point Danger and Fingal, are basaltic prominences which show indications of their having been volcanic centres.

Evidence that there were dormant periods during the time of the build-up of the volcanic pile lies in the presence of minor interbedded freshwater deposits of water-laid tuffs, as well as of shales, clays, and diatomite. These sediments were laid down in the ephemeral lakes that were no doubt characteristic of the period. In addition, a widespread bed of freshwater conglomerates indicates the passage of streams over the surface during periods of dormancy.

V

Mechanism of shield formation

The following interpretation of the geological formation of the Mount Warning Shield is presented as a working hypothesis on which one might base further field studies.

As in like structures in other parts of the world, the initial activity involved the outpouring of a thickness of basalt lavas. These lower basalts filled the irregularities in the old land surface, and were assumed by Tweedale (1950) to have come from the centre of extrusion. However, this poses the problem of fluidity, for these basalts are made up of a large number of thin flows, and it is difficult to visualize these flows travelling far without cooling to give a coefficient of viscosity sufficient to prevent further movement. It is suggested that in the primary stages of activity, under the intense pressures being exerted by what must have been an immense crustal movement, there was developed in addition to the central vent a great number of subsidiary fissures and smaller vents along lines of crustal weakness. Through these, highly fluid lavas were poured out, filling depressions and forming a vast lava plain. The earlier mentioned minor volcanic centres, along with the Cudgen and Terranora Hills as representative of lines of fissure eruption, are cited in evidence. Irrespective of their location of outpouring, the lower basalts were probably the result of numerous intermittent eruptions rather than the product of one long continuous period of flow.

Following this, the parent magma seems to have become relatively enriched in acid differentiate and associated volatiles. As a result, the next phase of extrusive activity saw the explosive ejection of ash, tuffs, and agglomerates, followed by great outpourings of rhyolite flows, both from the focus and from centres distributed about the flanks. Eventually, lack of material or the pressure of overlying lavas sealed the subsidiary vents, choking them as outlets, and this acid phase of eruption ended with the emission from the shield centre of distinctive rhyolite flows, dipping outwards from the centre. Even at this stage the distribution of lavas was beginning to assume a shield-like form.

The final stage of extrusive activity resulted in further outpourings of basic magma—the "Upper Basalts" of Richards (1916). These are conformable in dip with the underlying rhyolites and have been built up by numerous thin flows originating from the centre. They may not prove to be as widely distributed, areally, as the underlying sequences. At the cessation of activity, the resultant volcanic pile presented a vast shield-shaped form.

Following the volcanic activity, the greater part of the shield passed into a stage of structural dormancy with minor tilting and uplift in localized areas.

VI

Evolutional geomorphology

Method of approach

The most valuable indication of the early constructional form lies in the preservation of the remnant planeze surfaces. Straight line gradients of these surfaces have been plotted, and continued as straight line projections across a distance comparable to the radius of the erosion caldera—toward the supposed shield focus, now represented by the central complex (Frontispiece).

The results obtained from these graphs are tabled as follows:

GRADIENT

Graph	*Stage of Erosion*	*Degrees (approx.)*	*Feet/Mile*	*Focus Elevation (feet)*
1	Skeleton	1° 45′	175	3,900
2	Residual mountain	5° 15′	475	8,000
3	Planeze	2° 45′	250	6,100
4	Planeze	2° 45′	260	6,550
5	Planeze	2° 45′	250	6,800
6	Planeze	2° 15′	200	5,800
7	Planeze	2° 45′	250	6,200
8	Planeze	3° 15′	300	6,200
9	Planeze	3°	275	6,250
10	Planeze	3°	270	6,300
11	Planeze	3°	300	6,300
12	Residual mountain	5° 30′	500	7,000

Considering the natural limitations, and the degree of accuracy of the graphed variables, the calculated results show a remarkable consistency. The surface gradients of the planezes average 3° 15′, and this value is in comparative conformity with the estimated gradients of the major shield flows, serving to confirm the constructional nature of such land surfaces. Furthermore, the straight line projections have indicated that the focus of eruption, at the cessation of volcanic activity, had an elevation of 6,300 ± 500 feet.

Topographic evolution

The representation of the uneroded constructional surface is of a dormant shield of low surface gradient rising to a focal height of over 6,000 feet. The first stage of erosion, i.e. the early planeze stage, is represented by the development of a radially distributed drainage pattern with numerous minor tributaries, forming a complex headwater network. In the struggle for existence, many of the minor tributaries are gathered into a major consequent master stream. This, by nature of its early head-water development, causes the excavation of an amphitheatre-headed valley. Continual expansion of these headward valleys by the major radial consequent streams leads to eventual coalescence, as the separating divides are gradually eroded and broken down. Finally, there is developed a great master valley head forming the embryonic erosion caldera. Any primary volcanic collapse cauldron or late stage central sub-surface crustal movement would emphasize such a development.

The next stage of erosion resulted in the widening of the caldera, together with dissection of the shield flanks, to represent the planeze stage of Kear (1957). Continual growth of the master valley was accompanied by a lowering of the floor, but at the same time persistence of the central prominence led to the formation of a circular drainage pattern which replaced the inner radial system. Further erosion tended to direct this central drainage towards a single outlet, resulting in the development of what is now the Tweed River.

This breakdown led to the truncation of the headwaters of the other major radial systems which have since been confined to the remnant shield flanks, where they have set about the dissection of the shield surface. The overall effect has been the formation of a caldera rim escarpment wall separating the two drainage patterns. The system receiving the breakdown products of the erosion caldera should show the more rapid trend towards maturity, and this evidently has been the case.

The present day degree of landscape evolution has reached a point intermediate between the planeze and residual mountain stages of erosion. Eventually, the flank streams, together with the central network, will cause complete breakdown of the caldera rim and destruction of the planeze surfaces. The resultant landscape will be indicative of the skeleton stage of erosion, where only the more resistant central intrusive rocks will bear testimony to the former volcanic feature.

VII

Age and regional relationships

It is not possible, as yet, to make any definite statement concerning the age of the activity.

Although the Mount Warning Shield is, within itself, a complete geological entity, nevertheless it forms a part of an extensive volcanic province in South-Eastern Queensland. This province includes the Mount Barney and Mount Alford intrusive complexes, a great number of acid and alkaline plugs, and a vast expanse of both basic and intermediate lavas along the Main Range.

The only general agreement as to age of the major features of this province is that they are all Post-Jurassic and Pre-Pleistocene, a time lapse of some 120 million years, and as a result of no more than passing value. However, evidence concerned with the relative ages of these features leads to a more accurate dating of the shield formation.

Tweedale (1950) identified freshwater conglomerate boulders, interbedded in the acid phase of the shield at Mount Cainbable, as being granophyre similar in mineral composition and texture to the Mount Barney granophyre further west. He suggested that the boulders had been transported some 30 miles from Mount Barney by a juvenile eastward flowing stream. Examination by the writer of material collected by N. A. H. Simmonds in the Upper Albert River further substantiates this idea, and the inference is that Mount Barney was already in a state of youthful topography during the time of the Mount Warning Shield formation.

The time relationships between the Mount Warning, Mount Barney, and Main Range periods of activity are not completely determined, but it should be noted that preliminary palaeomagnetic studies by Green & Irving (1958) have indicated a Pliocene age for the Main Range basalts at Toowoomba.

There remains for consideration the indications given by the stages of erosion, through which the shield has passed to reach its present form; and even here there is conflict of evidence. Within the caldera there has been upwards of 6,000 feet of erosion while, in direct contrast, round the flanks there still remain significant parts of the constructional surface. The greater reliability should be placed on the degree of dissection of the outer shield remnants, for one cannot be aware, fully, of the exact conditions responsible for the formation of the erosion caldera—conditions which may have been favourable to an extremely rapid rate of erosion. The suggestion then is that, assuming a normal rate of erosion, the presence of planeze surfaces indicates a comparatively late age, at least for the cessation of the volcanic activity.

On the basis of this scattered and as yet inconclusive information, the author agrees with Bryan & Jones (1945), but on different grounds, that the Lamington Volcanics and hence the Mount Warning Shield Volcano are of Late Tertiary Age and probably will prove to be Pliocene.

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