GEOLOGY OF THE MOUNT GILLIES RHYOLITIC VENTS, SOUTHEASTERN QUEENSLAND, AUSTRALIA

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ABSTRACT
This paper describes the geology of a major rhyolitic vent area in which dykes were the main feeders for the rhyolitic eruptives of the Mount Gillies Volcanics. The dykes occur predominantly in postulated grabens in a structurally complex area lying on the margin of the Mount Barney Central Complex.

GEOLOGICAL SETTING

A BROAD and discontinuous belt of Tertiary to Recent eruptives and intrusives occurs in eastern Australia and the Tasman Sea[1,2]. The eruptives in eastern Australia are composed largely of alkali, transitional and tholeiitic basalts, trachytes and rhyolites. Peralkaline and metaluminous† trachytes and rhyolites occur.

The extinct Focal Peak Shield Volcano occurs in southeastern Queensland and northeastern New South Wales, Australia[3-5], and forms part of the above belt. The eruptives and associated intrusives of this shield volcano are late Oligocene in age. The shield volcano's stratigraphy, on its eastern margin, from bottom to top, is the Albert Basalt (mostly alkali and transitional basalts), the Mount Gillies Volcanics (previously called the Mount Gillies Rhyolite) and the Chinghee Conglomerate. Unlike the Albert Basalt, the latter two formations tend to be patchy in occurrence. The age of the Mount Gillies Volcanics is about 24 Ma and the time span of volcanic activity is probably < 2 Ma[4,6,7].

MOUNT BARNEY CENTRAL COMPLEX

At the centre of the shield volcano is the Mount Barney Central Complex[4,5,8,9] (figure 1). The diameter of the Complex is 15–20 km and the area of the Complex is about 240 km^2. It contains numerous intrusives and subordinate eruptives, ranging in composition from mafic (eruptives, dolerite, gabbro), through intermediate (trachyte, syenite, monzonite), to acidic (rhyolite, granophyre). Major doming over the breadth of the Complex has occurred and, on the basis of dips in sedimentary country rocks, uplift due to doming alone is estimated to be up to around 3000 m; the volume of rock uplifted is therefore about 400 km^3. Its margin is marked by a notable flexure zone in which, to the near west of Mount Gillies, the sedimentary country rocks have been tilted from originally low dips of around 5–40° to the west to dips averaging 43° to the east and ranging up to 90°.

An important intrusive body is the Mount Barney Granophyre, the volume of which is at least about 20 km^3. (An average of chemical analyses of the Mount Barney Granophyre is presented in table 2.) It is faulted on three sides and has suffered uplift[8] of the order of 2400 m. Incomplete ring dykes of granophyre are associated with the Mt Barney Granophyre.

At Focal Peak a caldera, 4 km in diameter, is believed to have existed. The margin of the caldera is marked by an incomplete ring dyke of syenite and at the centre is a gabbro-monzonite-syenite body which has metamorphosed a capping of mafic eruptives. Doleritic cone sheets, centred on the caldera, occur in an area with a 6.5 km diameter.

Around the periphery, and sometimes lying on the outside (on the side furthest away from the Complex), of the flexure zone noted previously are numerous large intrusive bodies of rhyolites which form sills and/or laccoliths and the rhyolitic vents of the Mount Gillies-Campbell's Folly area.

THE MOUNT GILLIES VENTS

Introduction

The Mount Gilllies-Campbell's Folly area is rugged with many rocky ridges and cliffs composed mostly of rhyolites belonging to the Mount Gillies Volcanics. In particular, the cuesta of Campbell's Folly possesses cliffs on its eastern and northern

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† The terms "peralkaline" and "metaluminous" are based upon the shand classification which uses silica and alumina saturation[2].

margins up to about 200 m in height. Mount Gillies and Campbell's Folly are respectively 680 and 660 m high, about 350-500 m about the surrounding valleys. The mountains and ridges occupy an area of about 17 km^2. The country rocks are mafic eruptives of the Albert Basalt and sediments of the Jurassic Walloon Coal Measures, composed mostly of labile sandstones, siltstones, mudstones and coal.

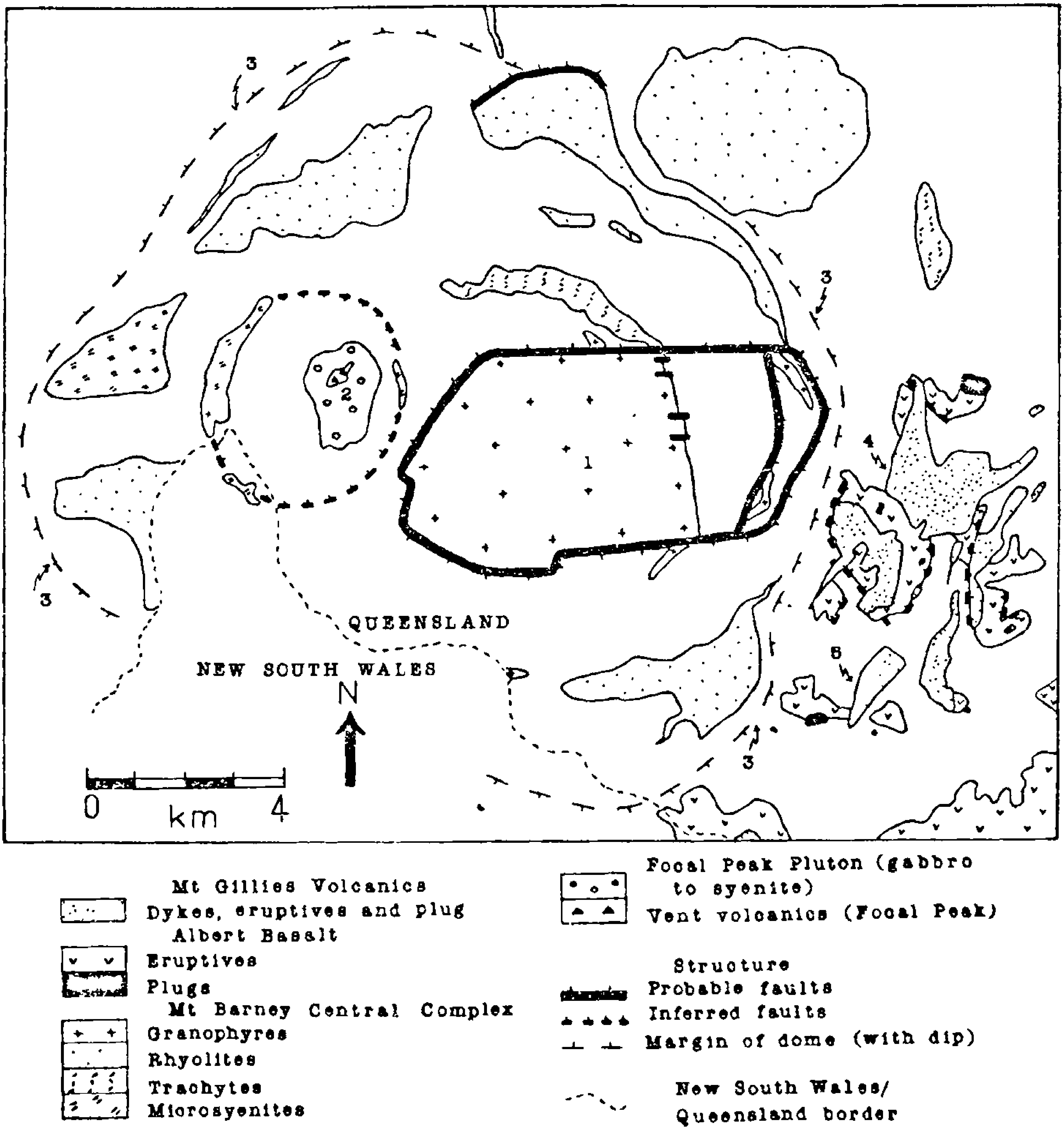

Figure 1. Geology of the Mount Barney Central Complex. Probable and possible faults in the Mount Gillies–Campbell's Folly area are shown in figure 3. Much scree occurs in the Mount Gillies–Campbell's Folly area (see figure 2) and consequently, rhyolite and basalt in that area is slightly more extensive than shown. Mount Barney is indicated by 1, Focal Peak by 2, the flexure zone to the Mount Barney Central Complex by 3, Mount Gillies by 4, and Campbell's Folly by 5.

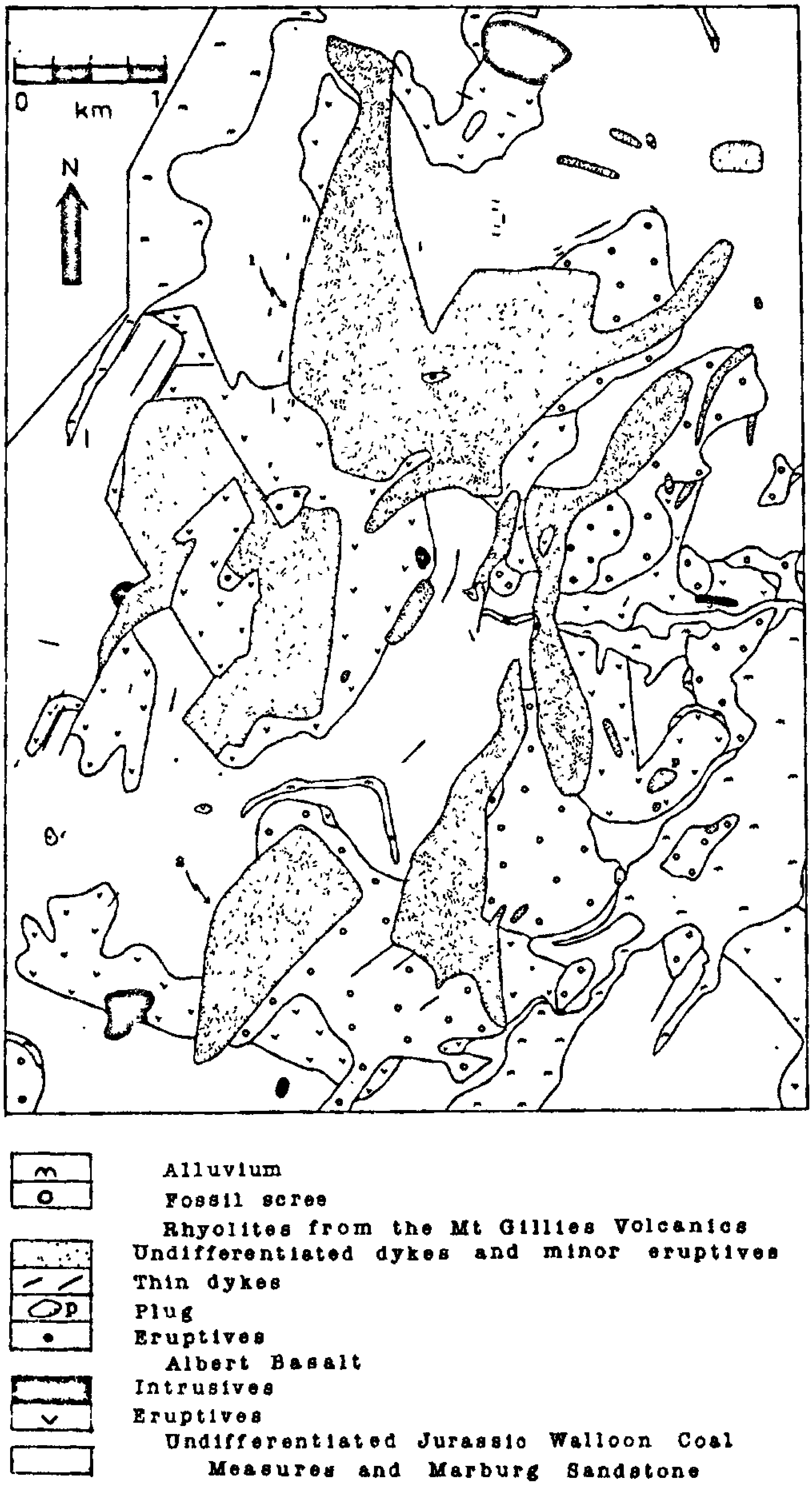

Figure 2. Geology of the Mount Gillies–Campbell's Folly area. Possible and probable faults are shown in figure 3. Mount Gillies is indicated by 1, and Campbell's Folly by 2.

Rhyolitic dykes and eruptives

Field mapping reveals that most of the rhyolites in the Mount Gillies-Campbell's Folly area are thin dykes with widths generally less than 20 m. The dykes tend to occur en masse with very few intervening mafic eruptives and sedimentary country rocks (figure 2). These masses range up to about 3 and 2 km in length and width respectively, Relatively few rhyolitic dykes occur by themselves and they seldom, if ever, cut across any other dyke. Only one plug has been positively identified while patches of rhyolitic eruptives occur.

Unfortunately, it is not always easy to identify separately dykes and eruptives in this area because of the common lack of tell-tale characteristics (e.g. fluidal banding, geological boundaries), the complicated nature of the area arising primarily from the large number of thin dykes (estimated to be in the range[4] of 700 to 2800), and scree. The presence of many different rhyolitic eruptives belonging to the Mount Gillies Volcanics, in the nearby McPherson Ranges and elsewhere, indicates that many eruptions have occurred. Although much of the formation has been removed by erosion, the volume erupted is estimated to be up to about 105 km^3 and the ratio of the volume of erupted rhyolite to erupted mafics[4] of the Albert Basalt is probably around 1:10 to 1:40. The maximum recorded thickness of rhyolitic eruptives is 270 m at Mount Lindesay[10].

For both rhyolitic dykes and eruptives, fluidal rhyolites, breccias and agglomerates predominate over uncommon tuffs and rare tuff-lavas. The fluidal rhyolites are often devitrified although black pitchstones are moderately common. Colours include black, white, green, red, pink and yellow either singularly or in combination.

The rare tuff-lavas consist of co-existing bands and patches of lava or conduit lava and pink porous ash, and are interpreted as representing an intermediary stage in the creation of tuff from lava or conduit lava through violent vesiculation[11]. It should be noted that such an intermediary stage should exist, albeit rarely, because of very nature of the particular tuff-creation process being discussed; its non-existence would suggest that the process occurs instanteously in time and in infinitesimal space. The textures are not consistent with secondary flow or rheomorphism. One example of tuff-lava, to the near north of Cashell's Gap, is suspected as being in a dyke within a few tens of metres of its surface eruptive orifice.

Mineralogy of the rhyolites

All rhyolites are porphyritic (for pitchstones: average phenocrystic content = 17.5%, range 6.3–26.1%). Phenocrystic phases are sanidine (and minor anorthoclase) +/- quartz +/- ferrohedenbergite (and minor ferroaugite) + fayalite + ilmenite +/- ferrohypersthene +/- partially resorbed plagioclase in order of decreasing abundance. Pyroxenes, fayalite and ilmenite in devitrified rhyolites are nearly always altered to chlorite, haematite and maghemite. Such alteration is less common in the pitchstones. An average modal analysis and some examples of modal analyses are presented in table 1.

Geochemistry of the rhyolites

Based upon the Shand classification and allowing for silicification (see discussion below), the rhyolites are believed to be all metaluminous in composition. Notably, unaltered rhyolites tend to be low in MgO, Sr and Ba compared to rhyolites from provinces in which tholeiitic basalts and calc-alkaline andesites occur[12–18]. Incompatible elements, such as Nb and the rare earth elements, are generally low compared to peralkaline rhyolites[19–22]. Unaltered rhyolites plot at, or close to, the ternary minimum in the $NaAlSi_3O_8$–$KAlSi_3O_8$–SiO_2 melt system and are believed to be derived by fractional crystallization of parental transitional or alkali basalts[4,23]. The geochemistry is discussed in greater detail in other papers[24,25]. An average analysis and examples of analyses are presented in table 2. Interestingly, the average analysis of the pitchstones, when recalculated with loss of ignition equal to zero, resembles analyses of the Mount Barney Granophyre to such an extent that it is likely that the granophyre and many of the rhyolites are co-magmatic despite

Table 1 *Modal analyses of pitchstones from the Mount Gillies Volcanics*

	Average (N=42)	Individual Sample: HV4	96	Pitchstones 95
Glass	82.5	93.7	85.0	79.3
Quartz	3.5	0.4	1.5	7.2
Alkali feldspar	13.3	5.7	12.0	13.1
Clinopyroxene	0.7	0.2	1.3	0.4
Fayalite	0.2		0.2	n.d.
Ilmenite	tr.	tr.	tr.	tr.

Modal analyses based upon 2500 points; Grid spacing was 1/6 mm; tr. means trace (<0.1%); n.d. means not detected; N = number of analyses.

Mount Barney and Mount Gillies occurring about 6 km from each other (table 2). It should be noted that Mount Barney has a maximum altitude of 1362 m, some 680 m above Mount Gillies and yet the former is a batholith and the latter is a mixture of dykes and eruptives.

Some rhyolites have been subjected to secondary silicification with SiO_2 contents ranging up to nearly 81%. SiO_2 is believed to have increased because of the preferential leaching of the majority of the other oxides, in particular Al_2O_3, total Fe expressed as FeO, CaO, TiO_2, MgO and K_2O. Trace elements which are significantly depleted during silicification are Ba, Sr, Zn, Zr and rare earth elements. It is not clear whether silicification occurs during the cooling of rhyolitic eruptives and intrusives through the action of volatiles or by another process involving groundwaters circulating through solidified rhyolites in the 24 Ma since eruption[26]. An analysis of a silicified rhyolite is presented in table 2.

Table 2 *Chemical analyses of some rhyolites from the Mount Gillies Volcanics and the Mount Barney Granophyre*

	Average of Selected Pitchstones (N=12)	Pitchstones Sample: 28	96	144	Silicified Sample: 4	Average of the Mt Barney Granophyre (N=8)
(wt %)						
SiO_2	73.26	73.89	73.48	73.05	80.04	75.89
TiO_2	0.18	0.12	0.22	0.19	0.12	0.18
Al_2O_3	11.98	11.59	12.37	12.28	9.43	12.28
Fe_2O_3	0.54	0.97	0.29	0.40	0.45	1.10
FeO	1.06	0.64	0.86	1.13	0.25	0.49
MnO	0.03	0.02	0.02	0.02	0.01	0.02
MgO	0.09	1.04	0.08	0.15	0.14	0.16
CaO	0.71	0.33	0.71	0.67	0.32	0.43
Na_2O	3.22	3.07	3.07	3.51	2.21	3.37
K_2O	5.32	5.04	5.07	5.46	4.88	5.46
P_2O_5	0.01	0.00	0.02	0.01	0.01	0.02
LOI	3.23	3.57	3.45	3.27	1.29	0.75
Total	99.62	100.28	99.64	100.14	99.15	100.13
(ppm)						(N=6)
Rb	154	159	162	135	142	144
Sr	12	6	25	23	n.d.	7.5
Ba	108	64	148	77	57	143
Pb	22	19	19	20	26	27
Th	20	20	19	17	18	19
Zr	351	298	382	419	267	396
Nb	35	36	37	31	31	30
La	75	118	96	63	26	72
Ce	169	225	202	130	91	160
Nd	81	137	105	76	46	73
Y	71	105	78	65	27	~ 67
V	2.4	1	3	3	1	2
Cr	~1.5	–	n.d.	2	–	2
Co	~0.8	–	–	–	–	1.5
Ni	~6.0	8	5	6	6	6
Cu	8.8	10	6	7	7	11
Zn	142	150	130	111	91	131

Note: the similar compositions of the averages of pitchstones and the Mount Barney Granophyre. The similarity is enhanced if the averages are recalculated on the basis of LOI being zero; N = number of analyses; ~ means number of analyses for particular trace elements less than N; n.d. means not detected; – means not analysed; LOI means loss on ignition; Na_2O analysed by flame photometry and atomic absorption, FeO by wet chemistry, and other major oxides and trace elements by xrf.

Structure

Dykes predominately strike northerly (0–15°) conforming to the direction of the nearby margin of the Mount Barney Central Complex. A few dykes strike northeasterly (45–60°), easterly (90–105°) and northwesterly (120–135°). The northerly strike direction also corresponds closely to the direction of the regionally important South Moreton Fault, occurring about 7 km to the east of Mount Gillies, which forms the eastern boundary to a horst which may pass through the Mount Gillies area. Although movement along the fault is possibly entirely pre-volcanic, sub-volcanic topography indicates the presence of a partially dissected fault escarpment and a major valley, paralleling the escarpment to the east of Mount Gillies, which was locally infilled by mafic eruptives of the Albert Basalt. Differing directions for the strikes of the dykes are more common on the western side of the Mount Gillies-Campbell's Folly area than on the eastern side. This can be interpreted as reflecting the weakening of faults and fracture structures, occurring within the sedimentary country rocks, by movements associated with the doming of the Mount Barney Central Complex; the weakening being more pronounced towards either the centre of the Complex or along the zone of flexure of the dome. Such structures have probably been utilized in the Mount Barney Central Complex where mafic and trachytic dykes tend to strike northwesterly and northeasterly respectively[8].

Dips of the strata in the sedimentary country rocks, not obviously affected by the doming of the Mount Barney Central Complex, in the Mount Gillies-Campbell's Folly area do not conform to the pattern seen along the flexure of the dome where strata dip radially away from the Complex. Generally, dips of up to 40° (average 18°; strike often northerly) occur for the former whereas along the flexure of the Dome dips are generally higher ranging up to 90° (average 43°; strike often northerly) in the area to the immediate west of Mount Gillies and Campbell's Folly.

On the basis of field relationships between eruptives (both rhyolitic and from the Albert Basalt) and the country rocks and the fact that rhyolitic eruptives occur up to about 600 m below rhyolites belonging to the same formation, the Mount Gillies Volcanics, in the nearby McPherson Ranges, subsidence of up to 600 m at Mount Gillies could have occurred. It could be argued that part of the McPherson Ranges (specifically Mount Lindesay) has been uplifted by about 300 m by doming and/or faulting associated with the Mount Barney Central Complex, and consequently the maximum value for possible subsidence could be over-estimated by up to 300 m.

The above evidence can be interpreted tentatively as indicating the presence of fissure vents existing in at least four grabens orientated approximately north-south, up to 5 km in length and generally polygonal in shape (figure 3). It appears that a near-surface magma chamber(s) occurred in the area and subsidence of the roof rocks into the chamber(s) occurred during numerous eruptions, the subsidence being due to decreased support for roof rocks in a manner similar to that proposed for successive stages in the development of a caldera[27,28]. The major difference between the model presented by Cotton[27] and that proposed for

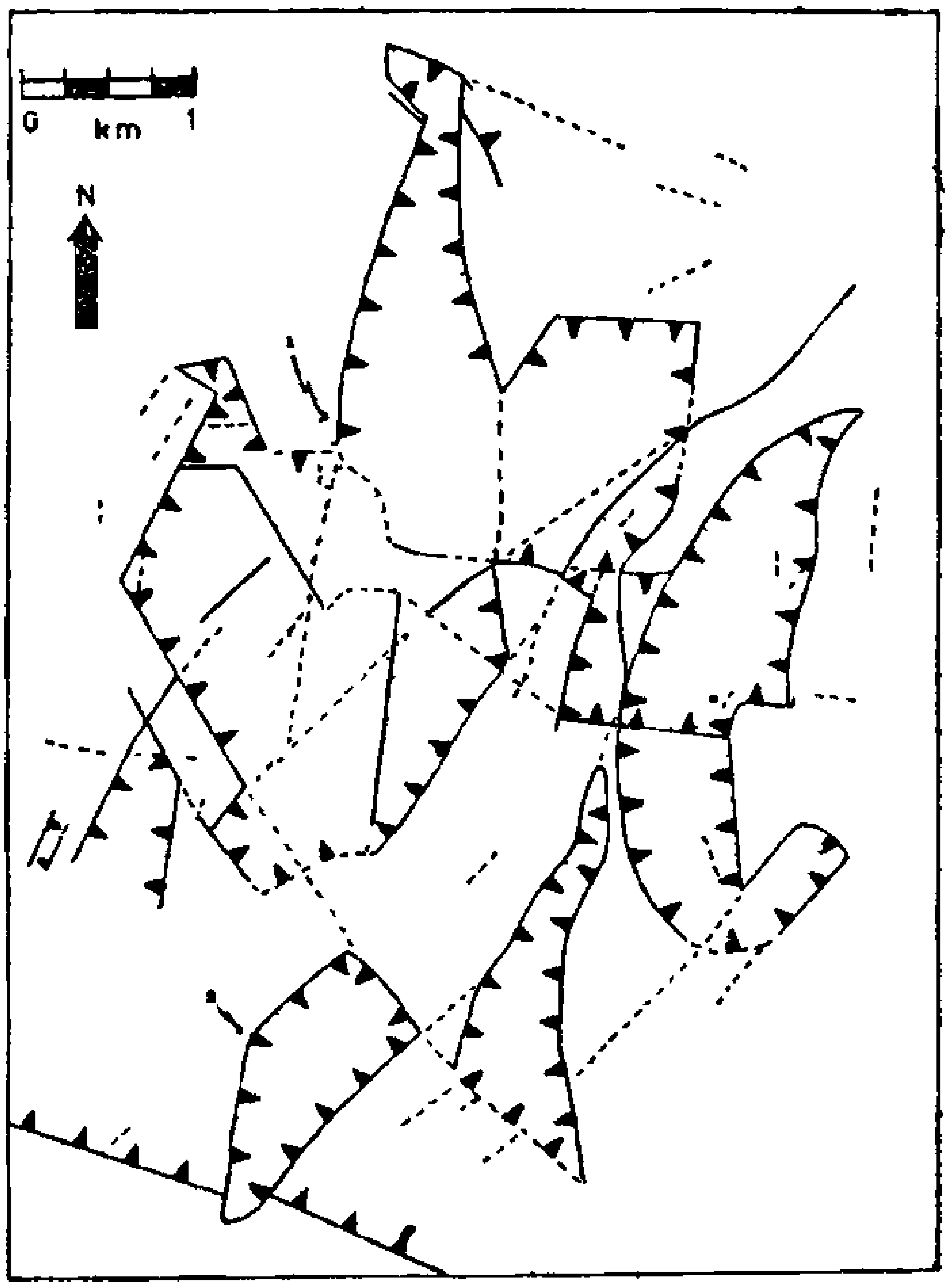

Figure 3. Postulated volcanic grabens (vents) and faults in the Mount Gillies–Campbell's Folly area. Note that the figure is biased deliberately towards an interpretation based upon faults. Mount Gillies is indicated by 1, and Campbell's Folly by 2. --- Possible fault; ▲—▲ Probable fault; [symbol] Probable graben-shaped vent.

the Mount Gillies-Campbell's Folly area is that for the latter subsidence did not occur along ring faults but along fractures bordering grabens. Fissure vents of the type observed in the Mount Gillies-Campbell's Folly area are unique or very uncommon in southeastern Queensland and northeastern New South Wales and their presence may owe much to deformation associated with the Mount Barney Central Complex.

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1. Brown, D. A., Campbell, K. S. W. and Crook, K. A. W., *The geological evolution of Australia and New Zealand*, Pergamon Press, New York, 1968.
2. Carmichael, I. S. E., Turner, F. J. and Verhoogen, J., *Igneous petrology*, McGraw-Hill, New York, 1974.
3. Ross, J. A., *Proc. R. Soc. Qld.*, 1974, **85**, 111.
4. Ross, J. A., *The Tertiary Focal Peak Shield Volcano, South-East Queensland—a geological study of its Eastern Flank*, Ph. D. thesis, University of Queensland, Australia, 1977, (unpublished).
5. Ewart, A., Stevens, N. C. and Ross, J. A., (in press).
6. Webb, A. W., Stevens, N. C. and McDougall. I., *Proc. R. Soc. Qld.*, 1967, **79**, 79.
7. Wellman, P. and McDougall, I., *J. Geol.. Soc. Aust.*, 1974, **21**, 247.
8. Stephenson, P. J., *The geology and petrology of the Mt Barney Central Complex*, Ph. D. thesis, University of London, London, 1956, (unpublished).
9. Stephenson, P. J., *Geol. Mag.*, 1959, **96**, 125.
10. Exon, N. F., Records Bureau of Mineral Resources, Geology and Geophysics, Australia, 1972(17).
11. Ross, J. A., *Curr. Sci.*, 1985, **54**, 272.
12. Gill, J. B., *Contrib. Mineral. Petrol.*, 1970, **27**, 179.
13. Ewart, A., Bryan, W. B. and Gill, J. B., *J. Petrol.*, 1973, **14**. 429.
14. Carmichael, I. S. E. and McDonald, A., *Geochim. Cosmochim. Acta*, 1961, **25**, 189.
15. Ewart, A., Taylor, S. R. and Capp, A. C., *Contrib. Mineral. Petrol.*, 1968, **17**, 116.
16. Pichler, H. and Zeil, W., Bull. Volcan., 1972, **35**, 424.
17. Gunn, B. M. and Mooser, F., *Bull. Volcan.*, 1971, **34**, 557.
18. Morgan, W. R., *J. Petrol.*, 1974, **15**, 97.
19. Cox, K. G., Gass, I. G. and Mallick, D. I. J., *J. Petrol.*, 1970, **11**, 433.
20. Weaver, S. D., Sceal, J. S. C. and Gibson, I. L., *Contrib. Mineral. Petrol.*, 1972, **36**, 181.
21. Abbott, M. J., *Contrib. Mineral. Petrol.*, 1969, **20**, 115.
22. Barberi, F., Ferrara, G., Santacroce, R., Treuil, M. and Varet, J., *J. Petrol.*, 1975, **16**, 22.
23. Ross, J. A., *Curr. Sci.*, 1984, **53**, 76.
24. Ewart, A., Mateen, A. and Ross, J. A., In: *Volcanism in Australasia*, (ed.) R. W. Johnson, Elsevier, Amsterdam, 1976, p. 21.
25. Ewart, A., Baxter, K. and Ross, J. A., *Contrib. Mineral. Petrol.*, 1980, **75**, 129.
26. Ross, J. A., *Curr. Sci.*, 1985, **54**, 1168.
27. Cotton, C. A., *Volcanoes as landscape forms*, Whitecombe & Tombs Limited, 1944.
28. Smith, R. L. and Bailey, R. A., *Mem. Geol. Soc. Am.*, 1968, **116**, 613.