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CAINOZOIC BASALTS OF THE MT. FOX AREA, NORTH QUEENSLAND

F. L. SUTHERLAND
Department of Mineralogy and Petrology
The Australian Museum, Sydney

SUMMARY

The Mt. Fox basalt field encompasses late Tertiary plugs and flow remnants and the Pleistocene Mt. Fox volcano. The flow remnants suggest an earlier largely westerly flowing plateau drainage, captured by southerly flowing drainages which cut through the old valley fills.

The basalts are mostly undersaturated types, basanitic and alkali basaltic rocks, but include transitional olivine tholeiite. Geochemically, the younger Mt. Fox lavas are the most undersaturated and show relative enrichment in alkali and alkaline earth elements.

INTRODUCTION

Cainozoic basalts in north Queensland form a number of provinces ranging up to 7,500 km^2 in area (Twidale, 1956; Branch, 1969; Stephenson and Griffin, 1973). The Mt. Fox field, west of Ingham, is a sparsely scattered province covering about 2,500 km^2 (Figs. 1 and 1a). It flanks the extensive voluminous McBride Province (5,500 km^2) to the north-west. Its westernmost occurrences have been referred to as the Older McBride Province and assigned late Miocene (?) to early Pliocene ages on the association with diatomite deposits (Best, 1959, 1960).

Basalts form older denuded plugs and dissected flows as well as youthful pyroclastics and lavas of the extinct Mt. Fox volcano. These lie on a dissected Tertiary plateau, which slopes gently westwards from about 800 m to 480 m a.s.l. at the Burdekin River, where it skirts the flank of the McBride basalt shield. Study of the flow remnants is important in reconstructions of the old plateau drainage; some basalts appear to trend across the Douglas River valley which has captured much of the present drainage.

Specimens and thin sections of the rocks are held in the collections of The Australian Museum. Analysed rocks are registered from DR9426 to DR9434 and thin sections are registered from AM6716 to AM6744.

Records of The Australian Museum, 1977, **Vol. 30, No. 19,** 532-543, Figures 1-3.

DENUDED PLUGS

Two small adjacent plugs intrude Silurian-Devonian beds west of Camel Creek Homestead. They probably represent the oldest basalts as they differ petrologically from the surrounding flow remnants. The southern plug contains sporadic lherzolite xenoliths and conspicuous glomeroporphyritic clinopyroxene; it approaches an ankaramitic potassic basanite (Analysis 1, Table 1). The northern plug consists of dense, alkali olivine basalt (Analysis 2). Between them lies a poor exposure of partially fused and fractured banded quartz-labradorite granofels. This appears to represent a metamorphic xenolith, of at least amphibolite facies, brought up by the ascending magma from underlying Precambrian basement, which outcrops 35 km to the north-east.

FLOW REMNANTS

The distribution of the flow remnants and associated sub-basaltic sediments (including stanniferous leads and silicified quartz sands) is summarized in Figs. 1 and 1a. The remnants, individually up to 45 m in thickness, are mostly alkali basalts, but include basanite and transitional olivine tholeiite.

Mildly alkaline olivine basalts (Analyses 3 and 4), closely similar in petrography, extend eastwards from the "Red Hill" area, dropping in elevation to form a pedestal under Mt. Fox (1 in 75 average gradient) and isolated occurrences at Mt. Dora (1 in 250) and The Knobs (1 in 350). Previous workers considered Mt. Fox as the source, but the elevations suggest an eruptive point further east near the edge of the plateau. These remnants outline a westward to south-westward flowing pre-basaltic drainage, assuming no significant post-basaltic tilting. Where basalt overlies silicified sandstones near Kallanda, the bedding is practically horizontal (Shepherd, 1943; Ridgway, 1944, 1947).

Closely similar basalts, associated with silicified quartz sands west and north-west of Camel Creek Homestead are slightly more potassic (Analysis 5). They reach their highest elevation near Lucy Creek and appear to represent lavas which filled and overtopped its tributaries to flow south into the Hopewell and Camel Creek drainages. Their source is unknown, but they may have emanated from the McBride Province near Lake Lucy prior to headward erosion and downcutting of the present Burdekin headwaters.

Petrographically different basalts disconformably overlie the lower flow to cap The Knobs (augite-olivine basalt), extend from near Mt. Fox to west of Camel Creek Homestead (transitional olivine tholeiite) and descend the coastal scarp into the Stone River valley as an erosionally inverted valley fill (lherzolite-bearing basanite). The age of the Stone River basanite relative to the plateau flows is uncertain because of the potentially greater erosion from higher rainfall and steeper gradients on the coastal scarp. The Knobs basalt is mildly alkaline (Analysis 6), but is enriched in groundmass olivine and contains glomeroporphyritic augite. Its source is unknown; similarly textured basalts occur in the McBride Province, but are chemically quite different (T. J. Griffin, pers. comm.). The olivine tholeiite (Analysis 7) is highest near Michael Creek, but it would be unwise to assume that Mt. Fox nearby was the source for such a dissected basalt. It overlies stanniferous deep leads 5 km WSW of Mt. Fox (Morton, 1946) and at Black Cow Creek (de Keyser, *et al*, 1964) and calculated average pre-basaltic gradients give approximate drops eastwards of 1 in 75 (Michael Creek to Mt. Fox lead), 1 in 150 (Mt. Fox lead), 1 in 350 (Mt. Fox lead to Black Cow Creek) and 1 in 750 (Black Cow Creek to Camel Creek Homestead).

The extensive dissection, deep weathering and apparent flow paths across the well established valley of the Douglas River, suggest considerable ages for the plateau flows, comparable to or older than those for mesa and plateau flow remnants found in the McBride Province (isotopically dated at 7-8 m.y.; T. J. Griffin and I. McDougall, pers. comm.).

THE MT. FOX VOLCANICS

The Mt. Fox cone, over 120 m high, has a shallow infilled crater. Crudely bedded coarse pyroclastics are interbedded with minor scoriaceous lava tongues. Scoriaceous bombs, ranging to over a metre across, show tails and surface flow features indicative of rotational flight. Below a small erosional breach on the southern crater rim, a flow extends southwards filling in an old tributary of Four Mile Creek cut down below the older flow remnants (Fig. 1). Over 10 m thick, this flow displaced and laterally twinned the drainage, which has now re-cut through parts of it.

Similar craters in the McBride Province are dated isotopically at approximately 200,000 years, but the Mt. Fox cone may have suffered a more rapid rate of erosion because of higher rainfall; it may be as young as 100,000 years, within an error of at least 50,000 years (T. J. Griffin and P. J. Stephenson, pers. comm.). It is almost certainly older than the youngest McBride Kinrara crater dated around 50-70,000 years (loc. cit.).

The Mt. Fox volcanics are undersaturated glassy basanites. The pyroclastics (Analysis 8) show high water content coupled with relatively low Na_2O and $FeO : Fe_2O_3$ ratios. They are presumably partly leached and altered from their original composition, which probably matched a potassic basanite. The main lava flow is an even more undersaturated and alkaline poikilitic rock with a glassy base (limburgite) and is high in normative nepheline.

MINERALOGY AND PETROLOGY

Compositions of phenocrystic minerals in the ankaramite plug, west of Camel Creek Homestead were determined by electron micro-probe analysis. Glomeroporphyritic titaniferous clinopyroxene shows oscillatory zoning from a core of diopsidic augite ($Ca_{50}Mg_{38}Fe_{12}$; 7% Al_2O_3, 2.5% TiO_2) to less calcic more magnesian rims with lower Al_2O_3 and TiO_2 ($Ca_{45-47}Mg_{44}Fe_{9-11}$; 5-5.6% Al_2O_3, 1.3-1.6 TiO_2); it encloses some of the phenocrystic olivine ($Mg_{76-77}Ca_{0\cdot5}Fe_{22-23}$). With laths of zoned plagioclase ($Ca_{58}Na_{39}K_3$), these lie in a groundmass of more sodic plagioclase, titaniferous augite, granular iron-titanium oxides and some poikilitic analcime. Nepheline is a groundmass mineral in the Stone River basanite.

The bulk of the olivine basalts grade from finer grained intergranular basalts to coarser sub-ophitic to ophitic rocks with more strongly pleochroic titan-augite, more bladed opaque oxides and greater amounts of late-stage and/or secondary zeolites, carbonate, silica and serpentinic and chloritic mineraloids. The transitional olivine tholeiite is characterised by sporadic phenocrysts of andesine ($\sim An_{42}$, with patchy zoning and corroded interiors) and a darkish brown mesostasis containing bladed iron oxide, crystallites and glass.

Chemically, the older denuded plugs show slightly lower SiO_2 and higher TiO_2 than the basalt flow remnants. The basalt flows are mildly alkaline and their norms contain minor nepheline or hypersthene. Certain classifications (Yoder and Tilley, 1962) would regard some of the rocks with normative hypersthene as tholeiitic, but the author follows the scheme of Poldervaart (1964) which allows for alkali basalts with normative hypersthene, providing that $Ab - 2En_{(hy)} - 1.50\ Fs_{(hy)}$ is positive. On this basis, Analyses 2, 4, 5 and 6 are alkali basaltic and Analysis 7 is tholeiitic. This is confirmed by plotting the basalts on an alkalis v silica diagram (Figure 2) in relation to the tholeiitic-alkali basalt boundaries of Macdonald and Katsura (1964) and Irvine and Baragar (1971). The lack of significant petrographic differences between the Ne — and low Hy — normative basalts, the presence of titaniferous clinopyroxene and occurrence of considerable secondary minerals, including silica, also suggest a single group of alkali basalts grading into transitional olivine basalts and hawaiites. The Michael Creek tholeiite with higher SiO_2 and lower K_2O and P_2O_5 and high normative hypersthene is petrographically quite distinct. It is termed a transitional tholeiite as it plots close to the dividing lines in Figure 3 and no sub-calcic clinopyroxene has been identified in it. The Mt. Fox lavas are more undersaturated and alkaline with much higher normative nepheline and higher MgO, CaO and P_2O_5 than the older lavas.

Few trace element data are published for north Queensland basalts and some results from the Mt. Fox field are given in Table 2. In general, the more undersaturated basanitic rocks tend to show the highest values of Ba, Sr and Rb, with the young Mt. Fox lavas being highest in Ba but less high in Ni and Cu. In comparison, the tholeiitic basalt shows lower values of Rb, Sr, V and Zr, but higher Ga.

DISCUSSION AND SUMMARY

The morphology of the field, apart from the Mt. Fox volcano, suggests eruptions mostly older than the main part of the McBride shield which was built during the last 3 m.y. (isotopic dating, T. J. Griffin and I. McDougall, pers. comm.). Some of the eruptions probably correspond in age with or pre-date the oldest basalts of the McBride Province (7-8 m.y.). This may reflect the apparent westward migration in the focus of volcanism across eastern Australia at a rate of 5 mm/year (Wellman and McDougall, 1974), but it is not clear-cut in north Queensland.

A westerly to south-westerly drainage pattern preserved under the older flow remnants appears to have been disrupted by considerable later headward erosion and capture by southerly drainages. The main lines of longitudinal incision across the basalt fillings developed along Douglas River, Camel Creek and Perry Creek as the Burdekin with its tributary drainage extended northwards. The strongest evidence of old basalt flow lines across the present Douglas River is provided by the very characteristic petrography of the olivine tholeiite which is generally consistent from outcrop to outcrop. The alkali basalts across the Douglas River are also consistent in their petrography, but are a common type of basalt and more difficult to correlate. The divergence of the alkali basalt and tholeiite flows westward across the Douglas seems to reflect overtopping and deflection of the thick tholeiite into a separate tributary drainage.

Reassembly of the flow remnants indicates that some of the lavas travelled at least 40 km and possibly 60 km or more. Long flows exceeded 80 km are known in some north Queensland provinces (Stephenson and Griffin, in press) and are attributed mainly to high continued effusion rates and favourable topography. Some of the flows in the Mt. Fox field match these long flows in chemistry and low average slopes (less than 5°), but in contrast show fluidal and/or more porphyritic textures. This would suggest advanced crystallization at distances under 80 km, in keeping with relatively sparser and presumably less voluminous effusions in the Mt. Fox field.

Some structural control on the eruptive sites in the eastern part of the field may be exercised by a strong WNW-ESE trending line downfaulting Carboniferous (?) volcanics against Precambrian (?) metamorphics and passing through the suspected source areas for the "Red Hill" and Stone River lavas. The restricted young activity at Mt. Fox may have picked out a particularly favourable weakness where this line would intersect NNW-SSE fault lines.

Undersaturated and mildly alkaline lavas dominate the field, but it includes tholeiitic lava, a relatively rare feature of the post-Oligocene provinces in north Queensland. The adjacent McBride and Nulla Provinces include some transitional basalts with low-normative hypersthene (P. J. Stephenson, pers. comm.), but not high-normative hypersthene basalts of the Michael Creek type. $Sr^{87}:Sr^{86}$ ratios for the Michael Creek tholeiite fall within the range of alkali basalts of the Nulla Province (0.7041-0.7046; A. W. Webb, pers. comm.) suggesting that no significant crustal contamination was involved in its generation. The more undersaturated and alkaline Mt. Fox lavas are in keeping with an isolated burst of activity tapping a deep source, well after the main activity had ceased.

Compared with the limited trace element data available for other Queensland provinces, the Mt. Fox field contains higher Sr, Ni, Cr and Cu than found in the alkali basalts of the Main Range and Lamington Volcanics (Stephens, *et al*, 1973), but generally lower Ba, Sr and Rb than found in the alkali basalts interbedded with tholeiitic basalts in the Peak Range area (Mollan, 1965). Detailed investigations in the adjacent McBride, Nulla and Walleroo Provinces by T. J. Griffin and P. J. Stephenson will provide geochemical data for comparisons between sparse and voluminous basalt provinces in north Queensland.

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TABLE 1. MAJOR ELEMENT ANALYSES AND C.I.P.W. NORMS OF THE MT. FOX FIELD VOLCANIC ROCKS

1. Ankaramite (basanitoid). Southern plug, 8 km W of Camel Creek Homestead, Einasleigh Sheet (lat. 145°23.6′E, long. 18°50.8′S). DR9426.
2. Alkali olivine basalt (transitional hawaiite). Northern plug, 8 km W of Camel Creek Homestead, Einasleigh Sheet (145°23.5′E, 18°50.7′S). DR9427.
3. Alkali olivine basalt (transitional hawaiite). West side, below base of Mt. Fox, Ingham Sheet (145°48.0′E, 18°50.4′S). DR9428.
4. Alkali olivine basalt (transitional hawaiite). Mt. Dora, Ingham Sheet (145°36.5′E, 18°55.7′S). DR9429.
5. Alkali olivine basalt (transitional hawaiite). West side of Basalt Dam, Einasleigh Sheet (145°24.1′E, 18°51.5′S). DR9430.
6. Alkali olivine basalt (transitional hawaiite). Top of northern knob, The Knobs, Clarke River Sheet (145°24.8′E, 19°04.6′S). DR9431.
7. Transitional olivine tholeiite. Michael Creek crossing, Mt. Fox Road, Ingham Sheet (145°47.5′E, 18°49.1′S). DR9432.
8. Basanite. Pyroclastics, north side of Mt. Fox cone. Ingham Sheet (145°48.1′E, 18°50.5′S). DR9433.
9. Basanite (limburgite). Flow, south side near base of Mt. Fox cone. Ingham Sheet (145°48.1′E, 18°50.6′S). DR9434.

Analyst: F. L. Sutherland.

Analyses 1-8 mainly by x-ray fluorescence, with Na_2O by flame photometry and FeO by dissolution with HF in the presence of excess ammonium metavanadate and titration against standardised ceric sulphate. Earth Science Laboratories, Macquarie University. Analysis 9 mainly by Atomic Absorption Spectroscopy, on an HF-Boric Acid dissolution, using natural rock standards, Geochemistry Laboratory, James Cook University, with FeO determined as in Analyses 1-8.

Table 1. Major Element Analyses and C.I.P.W. Norms Mt. Fox Field Volcanic Rocks

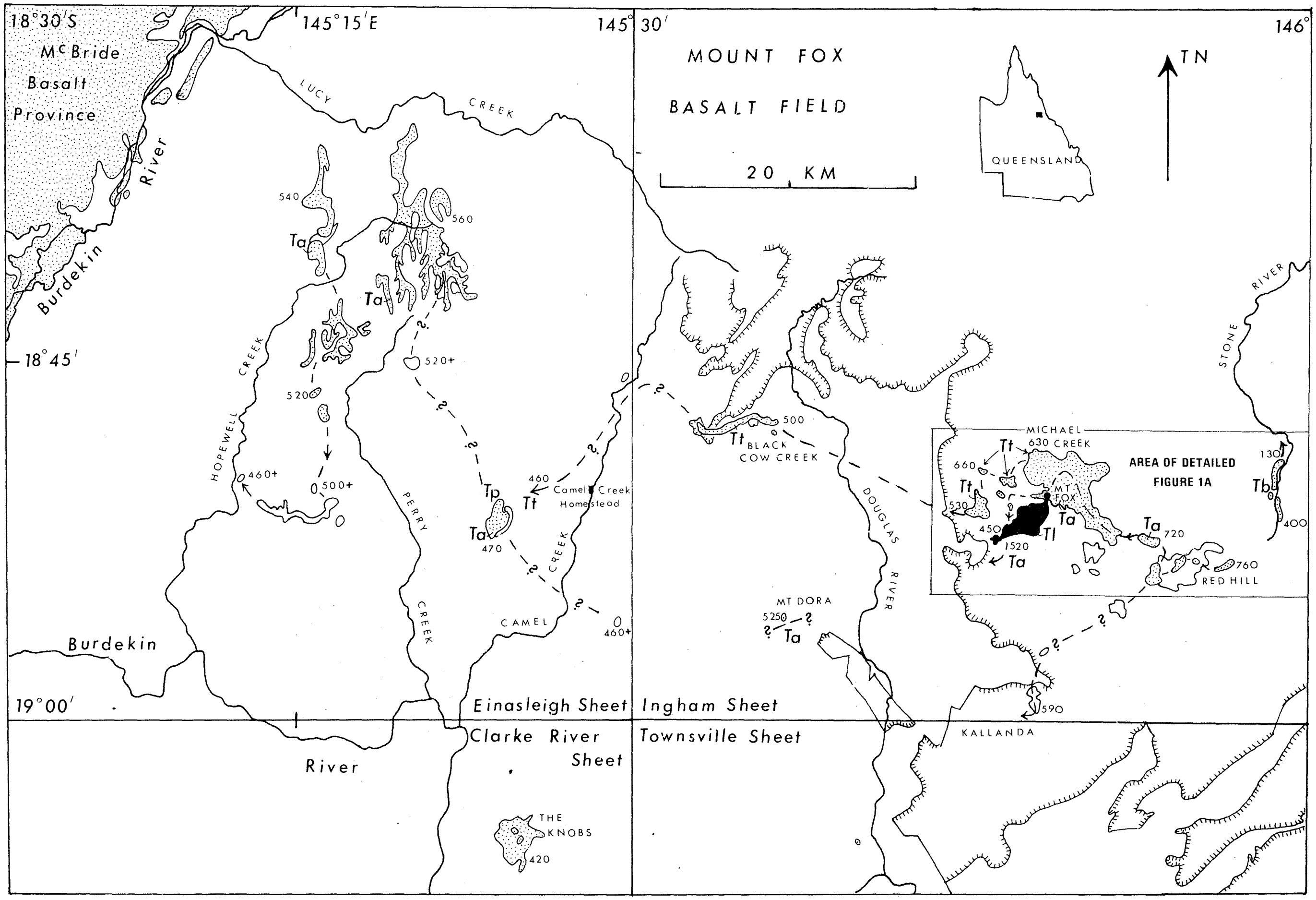
Analysis	1	2	3	4	5	6	7	8	9
SiO_2	44.74	46.98	48.30	48.95	49.00	47.96	50.34	44.66	43 6
TiO_2	2.79	2.28	1.84	1.99	1.81	2.08	1.47	1.98	1.61
Al_2O_3	13.19	14.38	14.86	15.05	15.12	14.16	15.27	12.67	13.60
Fe_2O_3	3.23	3.56	2.41	2.89	1.96	2.73	3.85	5.05	3.39
FeO	8.43	8.66	8.19	8.00	8.32	8.38	6.80	5.48	7.28
MnO	0.17	0.19	0.15	0.16	0.16	0.17	0.17	0.18	0.16
MgO	9.97	8.89	8.06	8.41	7.93	9.36	7.94	10.38	10.20
CaO	9.43	8.76	8.90	7.86	8.04	8.74	7.93	10.26	10.87
Na_2O	3.31	3.21	3.69	3.25	3.37	2.86	3.50	2.52	4.30
K_2O	1.97	1.08	1.27	1.22	1.59	1.16	0.74	1.81	2.15
P_2O_5	0.86	0.59	0.52	0.47	0.51	0.49	0.31	0.89	0.99
Loss	1.60	0.84	1.79	1.74	1.37	2.21	2.58	4.70	0.82
Total	99.69	99.42	99.98	99.99	99.18	100.30	100.90	100.58	99.0
CIPW Norm	1	2	3	4	5	6	7	8	9
Or	11.64	6.38	7.50	7.21	9.39	6.85	4.37	10.69	12.70
Ab	14.06	27.15	27.42	27.49	28.50	24.19	29.60	17.27	2.12
Ne	7.55	—	2.05	—	—	—	—	2.19	18.55
An	15.32	21.64	20.24	22.88	21.44	22.38	23.77	17.92	11.46
Di	20.72	14.48	16.62	10.52	12.27	14.33	10.07	21.39	28.81
Hy	—	0.84	—	10.48	2.82	8.02	18.86	—	—
Ol	16.83	17.23	16.17	10.62	15.92	13.28	2.35	13.28	14.23
Mt	4.68	5.16	3.49	4.19	2.84	3.96	5.58	7.32	4.92
Il	5.30	4.33	3.49	3.78	3.44	3.95	2.79	3.76	3.06
Ap	1.99	1.37	1.20	1.09	1.18	1.14	0.72	2.06	2.29
Loss	1.60	0.84	1.79	1.74	1.37	2.21	2.78	4.70	0.82
Total	99.69	99.42	99.97	100.00	99.17	100.31	100.89	100.58	99.0
Plag. An	52.15	44.36	42.47	45.42	42.93	48.05	44.54	50.92	84.38
Oliv. Fo	79.30	75.29	71.94	74.72	70.29	75.36	78.32	92.00	80.27

Table 2. Trace Element Data, Mt. Fox Field Volcanic Rocks

Analysis	1	2	3	7	8	9
Ba	310	148	147	158	455	505
Sr	885	637	643	348	142	992
Rb	30	15	14	11	39	38
Zr	250	173	180	143	151	180
Y	28	30	24	25	25	28
U	<1	1	<1	1	2	1
Th	7	4	2	2	7	5
Pb	11	10	8	8	11	11
Ga	22	21	24	47	20	22
Zn	116	127	102	109	113	112
Cu	82	42	56	46	77	87
Ni	229	112	152	151	242	208
Cr	337	253	286	252	341	281
V	192	197	155	127	194	206
Mn	1272	1296	1175	1107	1328	1349

Analysis numbers correspond with those given in Table 1. Element values are given in parts per million and were determined by X-ray fluorescence, using mass absorption data derived from major element analyses; F. L. Sutherland, analyst. The rocks were powdered using a tungsten carbide mill and were not analysed for Co which is a contaminant in this process.

Figs. 1,1a. Maps showing distribution of lavas in the Mt. Fox field, distinguishing the Mt. Fox cone and flow (black and shaded) and older remnants (stippled), with adjacent plugs (Tp), alkali basalts (Ta), olivine tholeiite (Tt) and basanite (Tb). Sub-basaltic silicified quartz sands and related sediments are shown as enclosed unstippled areas. Approximate elevations on the base of basalts are shown in metres, while elevations of silicified quartz sands are indicated with pluses (from the National Topographic 1 : 100,000 mapping, 1973-1974). Dashed lines and arrows represent the approximate drainage courses of sub-basaltic leads. The edge of the coastal range granite batholith is shown as a barbed line, with fault contacts unbarbed. The basalt boundaries are modified from the Bureau of Mineral Resources 1 : 250,000 Ingham, Einasleigh, Clarke River and Townsville geological sheets and include areas of dark soils and basalt float which may not represent true outcrop.



MOUNT FOX
BASALT FIELD
20 KM
QUEENSLAND
TN
18°30′S
145°15′E
145°30′
146°
18°45′
19°00′
McBride
Basalt
Province
Burdekin
River
LUCY
CREEK
HOPEWELL
CREEK
PERRY
CREEK
CAMEL
CREEK
Camel Creek
Homestead
BLACK
COW CREEK
DOUGLAS
RIVER
STONE
RIVER
MICHAEL
CREEK
MT
FOX
AREA OF DETAILED
FIGURE 1A
RED HILL
MT DORA
KALLANDA
THE
KNOBS
Burdekin
River
Einasleigh Sheet
Ingham Sheet
Clarke River
Sheet
Townsville Sheet
Ta
Tp
Tt
Tl
Tb
540
560
520
520+
500+
460+
460
470
500
630
660
530
450
1520
720
760
130
400
525
590
420

Fig. 1.

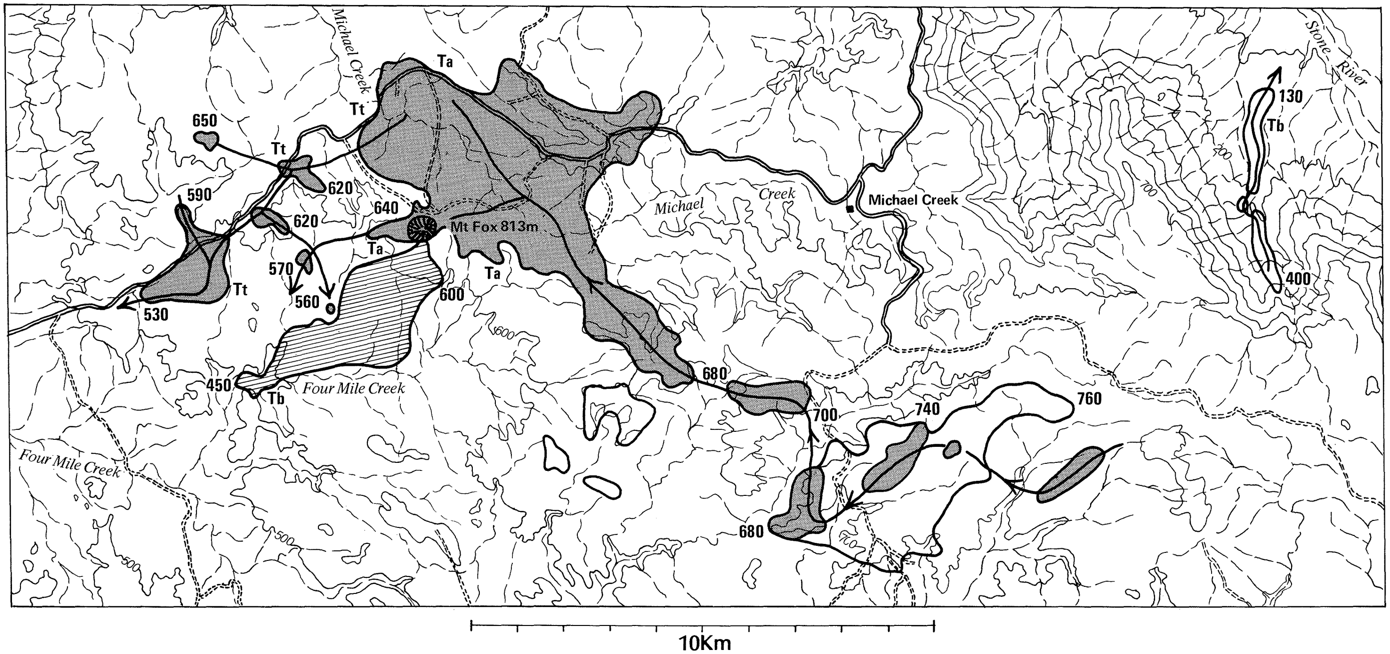

Michael Creek
Ta
Tt
650
Tt
620
590
620
640
Mt Fox 813m
Ta
Ta
570
Tt
560
530
600
450
Tb
Four Mile Creek
Four Mile Creek
Michael Creek
Michael Creek
680
700
740
760
680
Stone River
130
Tb
400
10Km

Fig. 1a.

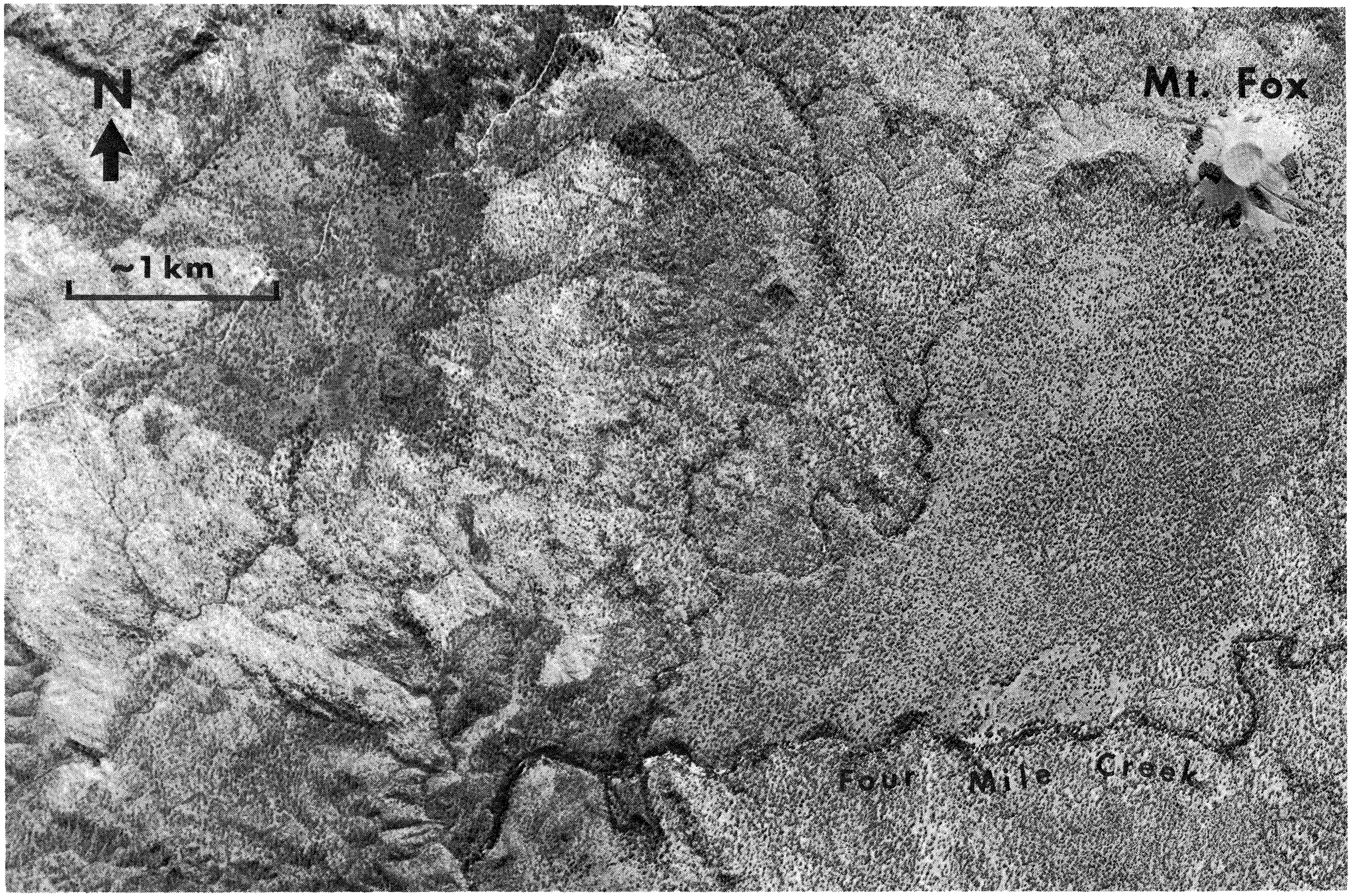


Fig. 3. Aerial view of Mt. Fox cone crater (top right) and an associated flow infilling an old tributary of Four Mile Creek to the south-west. The ridge immediately west (left) of the cone is an older underlying and unrelated flow residual. The enlargement is taken from aerial photograph No. 5060, Ingham Run 8 DWG Series.

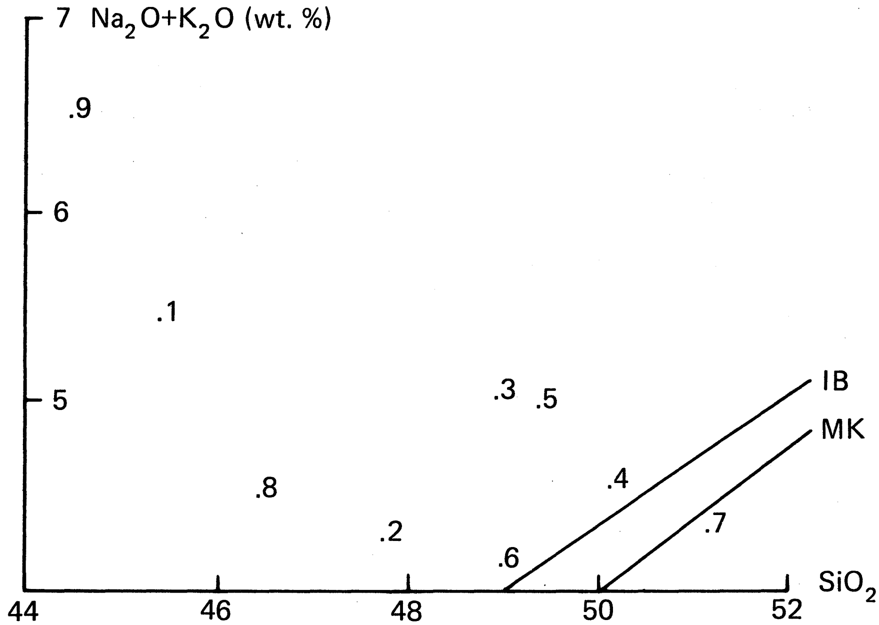


Fig. 2. Silica v. Alkalis diagram showing plots of the volcanic rocks of the Mt. Fox field (Analyses 1-9 recalculated to anhydrous compositions) in relation to the alkali basalt-tholeiite dividing lines of Macdonald and Katsura (1964) and Irvine and Baragar (1971).