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The origin of scoriaceous rock associated with dacitic ignimbrite in the Mirannie–Mount-Rivers district, New South Wales, Australia

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SUMMARY. From field and petrographic evidence, some scoriaceous rock from the upper ignimbrite horizon of the Mount Rivers Volcanic Member of the Carboniferous Dyrring Formation in the Mirannie–Mount-Rivers District, New South Wales, Australia, is believed to have a recent origin.

By heating unaltered dacitic ignimbrite in a furnace it was possible to produce in the temperature range 600–1230 °C changes in the rock similar to those observed in specimens of scoria collected in the field. Thus a temperature range for the alterations was established. Two possible sources of heat are suggested as being responsible for the production of the scoriaceous rock, namely a bush fire and a lightning strike, with a preference for the former.

WHITE (1969) recorded the collection of several samples of scoriaceous rock at locality 431972 (Camberwell 1 : 63360 Military Sheet) in the Mirannie–Mount-Rivers District, New South Wales. They were collected from the upper ignimbrite horizon of the Mount Rivers Volcanic Member of the Carboniferous Dyrring Formation. Their origin appears to be inconsistent with that of ash-flow tuff (Ross and Smith, 1961), as a scoriaceous surface was found to be perpendicular to the plane of deposition of the ignimbrite, as indicated by compaction foliation.

The specimens collected were not *in situ*. Some were removed from a block of ignimbrite approximately 0·5×0·5×1·0 m in dimension (fig. 1), which could not have been moved more than 2 m, and others were loose pieces of scoria scattered mostly within 2 m downslope from this block. The specimen (5264) illustrated in fig. 2A is typical of the scoriaceous rock. It is white and glassy with a brown-glazed surface, and does not appear to have come from the top of the unit in the locality from which it was collected.

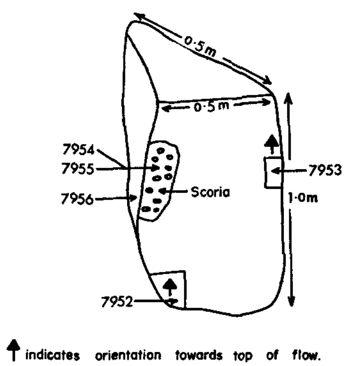

FIG. 1. Block of dacitic ignimbrite with scoria showing positions of specimens.

Petrography. Nine specimens of non-scoriaceous dacitic ignimbrite (7943–51) were collected systematically upwards from the base of a large joint block situated 2·5 m from the scoria. These and specimens 7952 and 7953, which were collected from the

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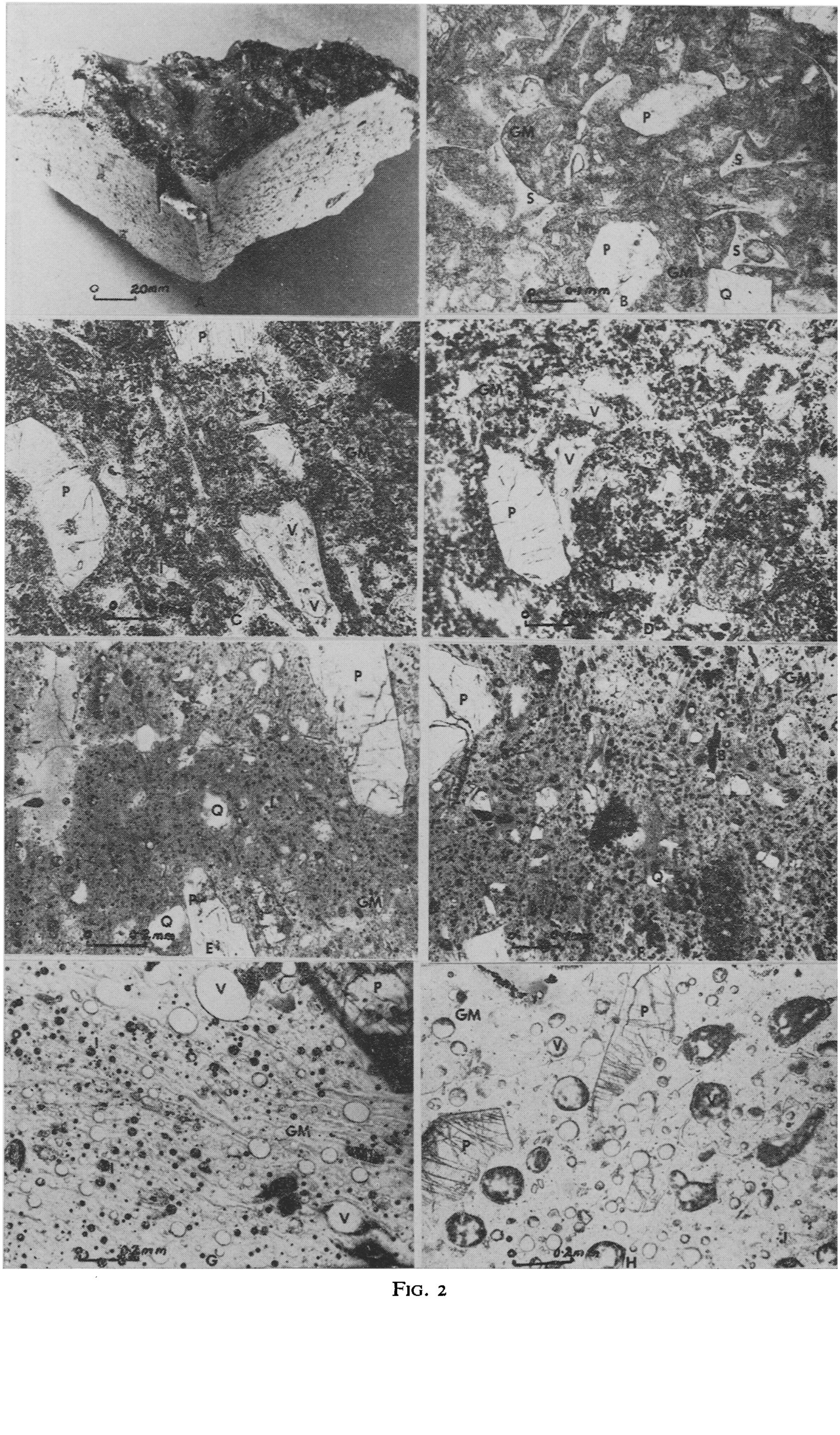

20mm
A
GM
P
S
S
P
GM
S
Q
B
P
GM
P
V
V
C
GM
V
V
P
D
P
Q
GM
Q
E
P
GM
B
Q
F
V
P
GM
V
G
GM
P
V
P
0.2mm
H

FIG. 2

block bearing the scoria illustrated in fig. 1, were buff coloured, but occasionally were reddish brown due to oxidation.

In thin section, samples 7943–53 (all numbers refer to the thin section collection, Department of Geology, University of Newcastle) consist of 20 % unwelded shards (av. length 0·3 mm) of various shapes, 15 % quartz, 2 % biotite, some of which shows pronounced kinking, 24 % plagioclase (An_{50}), 5 % K-feldspar, and 5 % lithic fragments set in a microcrystalline quartzofeldspathic groundmass. Occasionally a little hornblende is present and zircon is a common accessory mineral. The mineral fragments are angular and no orientation of the components is apparent. The shards are composed of very fine-grained (0·02 mm) clinoptilolite, which is a replacement of the original glass. In some specimens the shards are pale pink in colour as a result of ferruginous staining. Fig. 2B illustrates a thin section of the dacitic ignimbrite.

In a large thin section of specimen 5264 there is a decrease in the size and number of the circular vesicles from the ropy surface downwards. To a depth of 20 mm below the surface flow lines, closely resembling eutaxitic texture, are developed in the colourless glass (fig. 2G). The plagioclase is intensely clouded and under ×500 magnification the clouding is seen to be due to innumerable tiny needles (up to 0·02 mm in length) of tridymite arranged in criss-cross fashion. Dispersed throughout the groundmass are minute (up to 0·1 mm in diameter) black circular-shaped aggregates of microscopic grains or radiating needles of magnetite. The lithic fragments present have fused but are still angular in shape. Quartz fragments are present.

Transitional between the unaltered ignimbrite and the scoriaceous rock are specimens 7954, 7955, and 7956. Specimens 7956 collected from below the scoriaceous surface of the block shows less intense alteration. The zeolite in the shards is in the process of dehydration and is cracked. No vesicles are present. Most of the biotite is unaffected but in some there is an indication of breakdown to magnetite. Specimens 7954 and 7955 show marked alteration. Quartz crystals are fractured and in some cases their borders are diffuse. The biotite has broken down completely to magnetite. The shards are composed of colourless glass and contain vesicles, probably due to the escape of the volatiles (predominantly H_2O) as the zeolite became dehydrated and fused. The shape of the shards is preserved. The constituents of the groundmass show obvious signs of being reconstituted with aggregates of iron oxide granules scattered throughout. The grain-size of the groundmass is finer, and in specimen 7955 it has fused to a fawn-coloured glass. Specimens 7954 and 7955 are similar in appearance to

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FIG. 2. A, Typical scoriaceous rock with a glazed ropy surface (Specimen 5264). B, Dacitic ignimbrite (Specimen 7944) showing phenocrysts of quartz (Q) and plagioclase (P), and unwelded shards (S) in a microcrystalline groundmass (GM). C, Specimen 7954. Note vesicles (V) in the shards. The phenocrysts of plagioclase (P) are set in a reconstituted groundmass (GM) scattered with iron oxide granules (I). D, Specimen 7944 heated to 1000 °C. Note vesicles in shards (V) and general similarity to specimen 7954 opposite. E, Specimen 7955. Note spherules of iron oxide and phenocrysts of plagioclase (P) and quartz (Q) in hematite-stained glassy groundmass (GM). F, Specimen 7944 heated to 1100 °C. Note similarity to specimen 7955 opposite. Biotite (B) has broken down to magnetite. G, Specimen 5265—5 mm below surface. Note strongly developed flow lines in colourless glassy groundmass (GM), abundant vesicles (V), iron oxide spherules (I), and clouded plagioclase (P). H, Specimen 7944 heated to 1230 °C. Note similarity to specimen 5264 opposite. The plagioclase (P) is intensely cracked.

sections taken 50 mm and 20 mm respectively below the top of the scoriaceous specimen 5264 (fig. 2A).

Chemical composition. The scoria is associated with a single ash-flow unit approximately 3 m thick. The mineralogy of the unit (specimens 7943–51 above) classifies it as a dacite. This is supported by chemical analysis (Table I).

TABLE I. *Chemical analyses of ignimbrite and scoria*

	1	2	1′	2′		ppm	ppm
SiO_2	69·90	74·20	74·40	74·90	Rb	92	85
Al_2O_3	14·00	14·60	14·90	14·70	Sr	635	633
Fe_2O_3*	1·20	1·36	1·28	1·37	Yt	29	29
MgO	0·49	0·42	0·52	0·42	Th	22	21
CaO	3.80	4·07	4·04	4·11	Zr	170	170
Na_2O	1·32	1·31	1·40	1·32	Nb	0	0
K_2O	2·81	2·77	2·99	2·80	Ni	20	14
TiO_2	0·15	0·15	0·16	0·15	Sc	7	7
P_2P_5	0·07	0·05	0·07	0·05	V	15	14
MnO	0·02	0·02	0·02	0·02	Cr	48	37
S*	0·11	0·05	0·12	0·05	Li	8	8
BaO	0·09	0·10	0·10	0·10	Ga	23	21
Ign. Loss	6·86	0·54			Ge	3	4
					Cu	0	0
	100·82	99·64	100·00	99·99	Pb	13	19
					Zn	32	33

1. Average composition of Unit (Chips sampled at approx. 30 cm intervals). 1′ recalculated to 100 % excluding ignition loss.
2. Composition of Scoria. 2′ recalculated to 100 % excluding ignition loss.
* Total iron as Fe_2O_3 and total sulphur is recorded as S. Analyses by XRF. Details of analytical methods, precision, and accuracy are given in White, 1975.

Both the ignimbrite (chip sample across the flow) and the scoria (several discrete lumps bulked) were analysed (Table I). The two analyses are very similar, the chief difference being the high ignition loss for the ignimbrite compared with the low value for the scoria. When these analyses are recalculated to 100 % after elimination of ignition loss, the two can be seen to be essentially identical. This result is consistent with dehydration of the ignimbrite during fusion to form the scoria.

Origin of the scoriaceous rock. The field occurrence and the changes in the rocks observed under the microscope suggest that the scoria was not developed during the magmatic evolution of the rock in Carboniferous time but probably in recent time due to the application of external heat.

As petrographic evidence for the breakdown of biotite (Eugster, 1957) and the dehydration of the clinoptilolite (Mumpton, 1960) had been observed, temperatures in the order of at least 600 and 700 °C respectively were predicted. In order to determine more specifically the temperature of the changes, small chips (*c.* 800 $mm^2 \times 3$ mm) of a typical specimen of the dacitic ignimbrite (7944) were heated one at a time in a furnace for 6 hrs at 300, 600, 800, 900, 1000, 1100, and 1230 °C and allowed to cool slowly in the furnace. Thin sections were prepared for examination. Table II provides a summary of the changes produced.

The results show that it is possible to produce in the furnace changes similar to those displayed by the specimens collected in the field. It would appear that the surface of the rock has been subjected to a temperature of at least 1200 °C. As the heat penetrated the rock the temperature dropped to 1100 °C at approximately 20 mm below the surface and to 1000 °C at 50 mm.

TABLE II. *Heating experiments*

Temp.	Observed changes
300 °C	Colour of specimen became lighter shade of pink.
600	Zeolite in the shards in process of dehydration; some isotropic, some not quite so; cracking accompanies dehydration.* Biotite shows signs of breakdown to magnetite. Groundmass shows signs of reorganization.*
800	Zeolite has become amorphous and the shards are colourless. Biotite has broken down to magnetite.
900	Biotite has broken down to magnetite. Groundmass is reorganized but is still microcrystalline and stained with haematite.
1000	Biotite has broken down to magnetite. Zeolite in the shards has fused to colourless glass containing vesicles. Surface of specimen is fused; tridymite is developed in this area.†
1100	Shards are fused to colourless glass containing vesicles. Groundmass is fused but is stained with haematite. Minute (up to 0·025 mm) black spherules of radiating (?) magnetite are present.†
1230	Plagioclase is intensely clouded and cracked. Groundmass is glassy and contains abundant vesicles. Original shards have disappeared. Rock fragments have been fused to glass. Biotite is absent.§

* Similar to 7956.
† Similar effects are displayed by 7954 and 5264 (50 mm from the surface). See fig. 2C and 2D.
† Similar effects are displayed by 7955 and 5264 (20 mm from the surface). See fig. 2E and 2F.
§ Similar effects are displayed by 5264 to 5 mm from the surface. See fig. 2G and 2H.

Two possible sources of heat are suggested—a bush fire and a lightning strike. Similar rocks throughout the Hunter Valley have been subjected to bush fires from time to time and to date the development of such scoriaceous material has not been reported. Therefore, for the heat to have been derived from such a source a special set of circumstances must have pertained. This could have been a burning hollow log placed in such a position against the rock that, as it burned, a draught was created and produced a blow-torch effect. The production of rock fulgurites as a result of lightning strikes on a variety of rock types is well recorded in the geological literature. When struck by lightning the rock melts and then cools rapidly into a glassy substance similar to obsidian. It has been estimated that a temperature of 1600 °C could be involved when lightning strikes. Of the two possibilities, the burning hollow log is more likely. The area and depth of rock affected are too large to be consistent with a very transient heat source such as a lightning strike.

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