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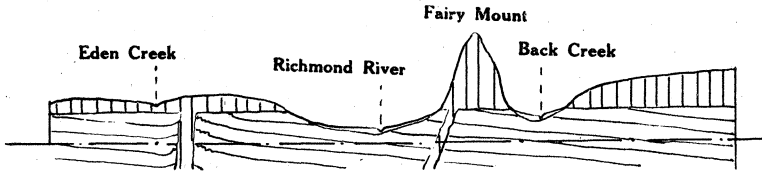
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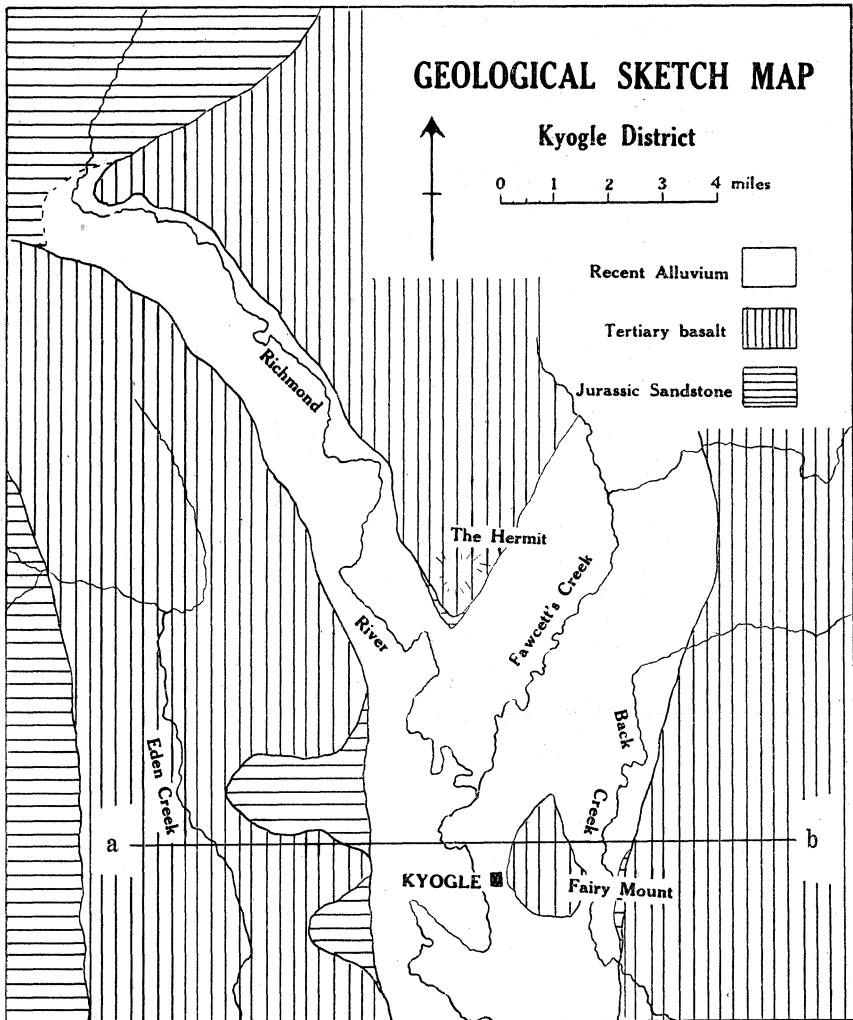
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# THE OCCURRENCE OF ZEOLITES AT KYOGLE, NEW SOUTH WALES.

By

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(Plate xlvi; Figures 1-5, and Map.)

The Kyogle Shire Council opened up a basalt quarry for the supply of road metal some years ago, but it was not until Dr. W. G. Woolnough visited the district in 1923 that it was known that this quarry was a prolific producer of zeolites and calcite. On his report the writer, accompanied by Mr. C. M. G. Friend, visited the quarry with a view to collecting and examining the occurrence. The visit was made possible by the generosity of Mr. Anthony Hordern, and over four hundred specimens, mainly chabazite, were obtained. The collection contains the finest specimens of this mineral yet obtained in Australia.

Kyogle is only 198 feet above sea level and is built on the fertile valley of the Richmond River, which has here reached a mature age. To the west of Kyogle the sandstone of Jurassic age dips under the alluvium and the basalt of Fairy Mount immediately to the east of the town. The dip of the sandstone here is  $8^{\circ}$  south-east, but, following the sandstone to the west, where it has been exposed by the denudation of the basalt (see map), the dip increases to about  $15^{\circ}$  south-east, and near its junction with the basalt to the west it shows distinct evidence of crumpling, indicating proximity to the fissure or vent from which the basalt was extruded. Fairy Mount is a residual of this basalt, and has been separated from it on the west and north by the valleys of the Richmond River and Fawcett's Creek respectively, while to the east it has been separated from the same mass of basalt by the valley of Back Creek.

The quarry face at the foot of Fairy Mount, and about thirty chains east of the Kyogle post office, discloses the fact that this mass of basalt is a complex structure. Four distinct flows can be readily recognized, as well as the presence of a dyke. The quarry face at the time was eighty feet high, and the greatest thickness of any one flow was thirty-six feet. Unfortunately the mountain is well covered with soil, and outcrops are scarce, but at a height of 900 feet vesicular basalt was observed to be overlain by solid basalt, indicating the surface of another flow. There is a marked absence

of pyroclastic rocks, suggesting that the effusion of basalt, though intermittent, was not of the explosive type, but rather in the nature of a fissure eruption. It is suggested from a study in the field that these fissures trended approximately north and south.

The basalt is typically of a very dark grey colour, and varies considerably in texture from porphyritic to even-grained. The phenocrysts consist of labradorite, and they appear to become more pronounced as one travels north from Kyogle. The basalt is generally rich in olivine. Under the microscope the basalt from the four flows at the quarry shows a very similar mineral content and fabric. The predominant mineral is labradorite, which is lath-shaped and gives distinct evidence of flow structure. Augite, which is the titaniferous variety with weak pleochroism, occurs as an interstitial mineral between the felspar laths. It is often altered to a green fibrous mineral with the fibres always at right angles to the periphery of the section. Olivine forms phenocrysts, and is sometimes very little altered. In a number of cases alteration takes place to iddingsite and a green serpentine-like mineral. Iron oxide and titaniferous iron are fairly abundant.

The basalt is obviously post-Jurassic in age. Prof. H. C. Richards<sup>1</sup> divides the tertiary volcanic rocks of south-eastern Queensland into Upper, Middle, and Lower Series. His description of the Upper Series might well have been taken from the Kyogle occurrence, and there can be no doubt that the Kyogle basalt is the equivalent of his Upper Series. He places the age of this division as Upper Cainozoic, and compares them to the Ben Lomond basalt, which Professor Sir T. W. Edgeworth David<sup>2</sup> places as probably Pliocene. These two basalts are very similar in appearance under the microscope, and it is of interest to note that both are characterized by the presence of abundant chabazite occurring in the vesicles and crevices of the rock.

For the sake of convenience, the flows exposed at the quarry have been numbered from one to four. No. 1 flow is partly exposed at the floor of the quarry, and No. 4 is the topmost flow to be seen at the time of our visit. At about the centre of the quarry the surface of No. 2 flow forms a small, rather broad, V-shaped depression, which is partly filled with irregular blocks and fragments of basalt which has been completely altered. The felspar is invariably zeolitized. The augite and olivine have been entirely replaced by a green fibrous chloritic material, zeolites, and calcite. Large cavities exist between these blocks of altered basalt, and they are nearly always lined with zeolites and calcite. Indeed, it was from here that most of the specimens were collected.

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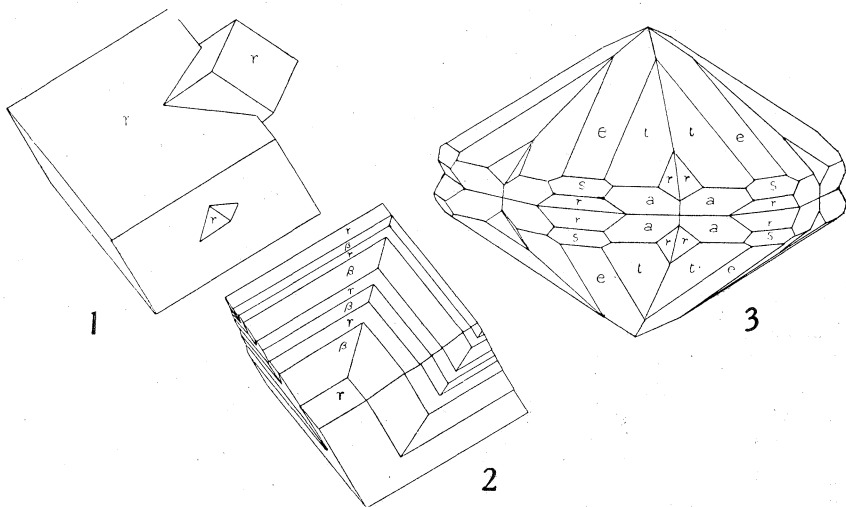
<sup>1</sup> Richards.—Proc. Roy. Soc. Q'land, xxvii, 7, 1916, pp. 117-118.

<sup>2</sup> David.—B.A.A.S., 1914, N.S.W. Handbk., p. 608A.

## CHABAZITE.

(Figures 1-3.)

No chabazite was found in No. 1 flow, but in the vesicles of No. 2 flow a number of simple rhombohedrons occur (Fig. 1). These are generally quite small, seldom measuring more than 2 mm. in diameter, and often twinned on the  $c$  axis. The faces are invariably striated and curved, giving not very satisfactory measurements; they belong to the form  $r$  ( $10\bar{1}1$ ). In one specimen (Fig. 2) the rhombohedrons were relatively large, measuring 15 mm. along the edge. These were modified by the scalenohedron  $\beta$  ( $13\cdot10\cdot\bar{2}\bar{3}\cdot13$ ). Most of the chabazite was obtained from the breccia between No.



Figures 1-3.

Chabazite from Kyogle, New South Wales. Fig. 1: Simple rhombohedron twinned on the vertical axis. Form:  $r$  ( $10\bar{1}1$ ). Fig. 2: Modified rhombohedrons. Forms:  $r$  ( $10\bar{1}1$ ),  $\beta$  ( $21\cdot2\cdot\bar{2}\bar{3}\cdot25$ ). Fig. 3: The phacolite type. Forms:  $r$  ( $10\bar{1}1$ ),  $a$  ( $11\bar{2}0$ ),  $t$  ( $11\bar{2}3$ ),  $e$  ( $01\bar{1}2$ ),  $s$  ( $02\bar{2}1$ ).

2 and No. 3 flows. Wherever a cavity was broken open it was found to contain alkaline water, and the moist chabazite was quite colourless in almost every case. On exposure to the atmosphere the chabazite became milky to almost opaque white. The temperature at the quarry during the early afternoon was never less than  $100^{\circ}$  F. On being immersed in water the chabazite regained its transparency. This property of chabazite was noted by D. A. Porter<sup>3</sup> in his description of the mineral from Ben Lomond, New South Wales.

The chabazite is mostly of the phacolite type (Fig. 3), and is very similar in habit to that found at Ben Lomond, figured by

<sup>3</sup> Porter.—Journ. Roy. Soc. N.S.W., xxii, 1, 1888, p. 88.

Dr. C. Anderson.<sup>4</sup> Unlike the phacolite (seebachite) from Richmond, Victoria,<sup>5</sup> the basal plane was not found on any of the numerous crystals examined. The majority of crystals were so modified as to be lenticular in shape, due to the fact that the individual parts of the twin are made up of a number of units in parallel growth.

Only a very few specimens were obtained from No. 3 and No. 4 flows. The crystals were of the phacolite type, but were not well developed.

Four crystals of the phacolite type and two of the rhombohedral type were selected for measurement, and the mean  $\phi$  and  $\rho$  angles as measured, together with the calculated angles are given in Table I. The measurements cannot be considered as very satisfactory, as centering was a somewhat difficult matter, and, at best, could only be considered fair. The form  $a$  ( $11\bar{2}0$ ) is always a bright face,

TABLE I.—CHABAZITE, KYOGLE, NEW SOUTH WALES.

Forms.		Measured.		Calculated.		Error.	
Goldschmidt.	Dana.	$\phi$	$\rho$	$\phi$	$\rho$	$\phi$	$\rho$
$r$ ( $11\bar{2}1$ )	$r$ ( $10\bar{1}1$ )	29 58	51 18	30 00	51 25	02	07
$b$ ( $10\bar{1}0$ )	$a$ ( $11\bar{2}0$ )	00 10	90 00	—	90 00	10	—
$t$ ( $10\bar{1}1$ )	$t$ ( $11\bar{2}3$ )	00 11	36 36	—	35 54	11	18
$e$ ( $\bar{1}122$ )	$e$ ( $01\bar{1}2$ )	29 42	31 42	30 00	32 05	18	23
$s$ ( $\bar{2}\bar{2}41$ )	$s$ ( $02\bar{2}1$ )	29 52	68 10	30 00	68 15	08	05
$\beta$ ( $13\cdot10\cdot\bar{2}\bar{3}\cdot13$ )	( $21\cdot2\cdot\bar{2}\bar{3}\cdot25$ )	25 44	47 44	25 41	48 03	03	19

but consists of four parts which are striated parallel to their intersection with  $r$ , and in consequence gave multiple signals. The faces of  $t$  ( $11\bar{2}3$ ) are invariably striated parallel to the edge  $e/t$ , and more often than not  $e$  and  $t$  alternate. The form  $s$  ( $02\bar{2}1$ ) usually has bright faces, though these are very small. No crystals were found which could be determined as belonging either to the gmelinite or levynite types.

The result of a chemical analysis is given in Table II, and is compared with that of the Ben Lomond chabazite. It will be noticed that the Kyogle mineral is richer in alkalis and correspondingly lower in lime. The specific gravity is 2.099.

<sup>4</sup> Anderson.—Rec. Austr. Mus., vi, 6, 1907, pp. 416-418, pl. lxxix.

<sup>5</sup> Rath.—Monatsber, d. k. preuss. Akad. Wiss., Berlin, 1875 (1876), pp. 523-532.

TABLE II.—CHEMICAL ANALYSIS OF CHABAZITE.

	Kyogle.	Ben Lomond. <sup>6</sup>
SiO <sub>2</sub> .. .. .	46·89	47·37
Al <sub>2</sub> O <sub>3</sub> .. .. .	19·96	19·16
CaO .. .. .	7·64	9·52
Na <sub>2</sub> O .. .. .	3·92	1·11
K <sub>2</sub> O .. .. .	0·18	0·93
H <sub>2</sub> O— .. .. .	} 22·05	3·43
H <sub>2</sub> O+ .. .. .		18·41
	100·64	99·93

CALCITE.

(Figures 4-5.)

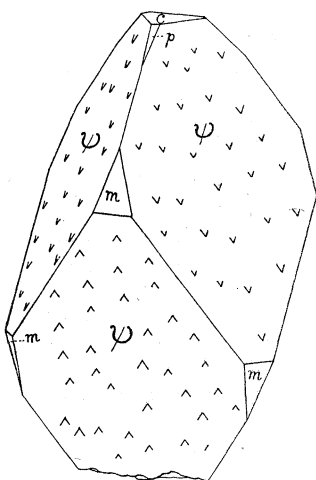
Calcite occurs in three distinct varieties, as follows:—

1. Large pale amber-coloured scalenohedrons capped by a basal plane and invariably coated with chabazite (Plate xlvi).
2. Small colourless crystals, occurring in the small vesicles of the basalt (Fig. 5).
3. Small amber-coloured rhombohedrons deposited on chabazite (Fig. 4).

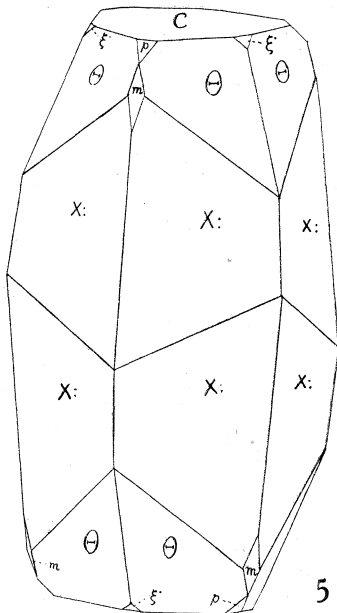
1. The large scalenohedrons invariably exhibit well marked zonal growth. As many as eight different layers have been deposited on the original crystal; each layer can be removed with ease. Incidentally, this, together with the perfect cleavage, made the collecting of these crystals a very difficult matter. No definite scalenohedron is represented, as there is an oscillation between several scalenohedrons and the unit rhombohedron. This oscillation becomes more pronounced as each additional layer is deposited. Several crystals were broken up, the original crystal mounted on a two-circle goniometer, and centered by means of the cleavage planes. Readings on the scalenohedrons were quite unsatisfactory and variations of as much as 4° were noted. They are positive forms, and, comparing them with those of the second type of crystal, which is similar though smaller and has a greater development of forms, the principal scalenohedron appears to be  $X: (19\cdot1\bar{2}0\cdot1)$ . In one of the core crystals rather better signals were obtained, giving measured  $\phi$  and  $\rho$  angles of 4° 15' and 81° 41', which correspond to an unrecorded form with very large indices (119·11·130·10), which has calculated  $\phi$  and  $\rho$  angles of 4° 22' and 82° 00'. There is no definite plane of attachment of the crystals, which may lie horizontally or project from the surface at any angle. Two fairly large crystals coated with chabazite were

<sup>6</sup> Anderson.—*Loc. cit.*

doubly terminated. Measurements taken of the thickness of the various zones of growth on twelve crystals, chosen at random from the collection, present some interesting features (Table III).



4



5

Figures 4-5.

Calcite from Kyogle, New South Wales. Forms:  $p$ : (11 $\bar{2}$ 1),  $m$ : (44 $\bar{5}$ 1),  
 $\xi$ : (4483),  $\theta$ : (4 $\bar{1}$ 51),  $\psi$ : (5 $\bar{5}$ 10 $\bar{2}$ ),  $X$ : (19 $\bar{1}$ 20 $\bar{1}$ ).

There is a remarkable agreement between the thickness of any one zone as compared to that of the same zone in any two crystals. Referring to the last column of the table, which gives the average

TABLE III.—MEASUREMENTS (MM.) OF THE ZONES OF GROWTH OF CALCITE,  
 KYOGLE, NEW SOUTH WALES.

Zone.	Crystal.												Average.	Ratio.
	1	2	3	4	5	6	7	8	9	10	11	12		
Outer	3	3	3	2	3	3	2.5	2.5	2.5	3	2	3	2.7	1
2	4.5	3.5	3	2.5	4	3	3	3	3	3.5	3	4	3.3	1.2
3	7	6	5	5	7	5	5	5	5	5.5	5.5	6	5.6	2.1
4	7	7	6.5	6	—	6	6	5	4.5	7	5.5	6.5	6	2.2
5	3.5	4.5	4	3.5	—	4	3	3	—	4	4	5	3.9	1.4
6	4	—	3.5	3.5	—	4	3	3	—	—	3.5	—	3.5	1.3
7	10	—	9	9	—	—	—	9	—	—	8	—	9	3.3
8	—	—	10.5	—	—	—	—	—	—	—	12	—	11.2	4.1



relative thickness of the various zones, assuming the outer zone to be unity, it will be seen that the zones are arranged in pairs. The outside two zones have an average relative thickness of 1 and 1.2, the next two are approximately twice as thick, while zones 5 and 6 are somewhat narrower, and the last pair are much thicker, being 3.3 and 4.1, showing a greater discrepancy than do the others. With the exception of zones 5 and 6 there is a gradual diminution of thickness from the centre outwards. In every case the outer zone is coated with chabazite. It is to be noted that, although there is this remarkable relation in the thickness of the various zones, all crystals do not possess the same number of zones. The greatest variation exists between crystal 5, with only three zones, and crystals 3 and 11, with the full complement of eight zones.

The maximum measurements made on these crystals were, length 27 cms. and diameter 11 cms.

These crystals were confined entirely to the breccia area.

2. The small colourless crystals were obtained mainly in small vesicles, either alone or with analcite. In one case a crystal of this type was found deposited on chabazite. They were not confined to any one flow, but were found in all flows, though they existed more plentifully in No. 2 flow. They were never found in the brecciated area.

Five of these crystals were measured on a two-circle goniometer, and the measured  $\phi$  and  $\rho$  angles, together with the calculated angles, are given in Table IV. The only forms to give really good signals were the positive rhombohedrons  $p'$  (11 $\bar{2}$ 1) and  $m'$  (44 $\bar{8}$ 1). The negative scalenohedrons  $\Theta$  ( $\bar{4}$ 1 $\bar{5}$ 1) is generally rounded, while  $X$  ( $\bar{2}$ 3 $\bar{8}$ 31.7) was represented in one crystal only by a full complement of faces, giving only fair signals. The positive scalenohedron  $X$ : (19.1 $\bar{2}$ 0.1) is invariably striated parallel to the edge  $p'/X$ . The basal plane is very much etched in every case, giving prac-

TABLE IV.—CALCITE, KYOGLE, NEW SOUTH WALES.

Form.	Measured.		Calculated.		Error.	
	$\phi$	$\rho$	$\phi$	$\rho$	$\phi$	$\rho$
$p'$ (11 $\bar{2}$ 1)	30 00	44 37	30 00	44 36	0	1
$m'$ (44 $\bar{8}$ 1)	30 00	75 47	30 00	75 47	0	0
$\xi$ (4483)	29 48	52 15	30 00	52 45	12	30
$\psi$ (5.5.10.2)	30 00	68 01	30 00	67 55	0	06
$\Theta$ ( $\bar{4}$ 1 $\bar{5}$ 1)	11 16	68 58	10 53	69 02	23	4
$X$ : (19.1 $\bar{2}$ 0.1)	2 38	85 05	2 32	84 51	6	14
$X$ ( $\bar{2}$ 3 $\bar{8}$ 31.7)	14 00	66 24	14 23	66 12	23	12

tically no signal of any value. The crystals are usually attached by a plane approximately parallel to the basal plane, and only very rarely are they doubly terminated.

3. The small amber-coloured rhombohedrons were found only in one place, deposited on the chabazite of the breccia, covering an area of about four square feet. They are generally much etched, the positive rhombohedrons  $p'$  (11 $\bar{2}$ 1) and  $m$  (44 $\bar{8}$ 1) being the least affected. The negative scalenohedron  $\psi'$  (5 $\bar{5}$ ·10·2) is always etched as shown in the figure. A small basal plane is developed in all crystals. The plane of attachment is approximately parallel to  $m'$  (44 $\bar{8}$ 1).

#### ANALCITE.

Analcite occurs mostly in the small vesicles of flows Nos. 1 and 2. It is generally associated with green chlorite, upon which it is deposited, and which occurs as inclusions in many of the crystals. One minute crystal was found associated with mesolite deposited on chabazite, but in every other case chabazite was deposited on analcite. The largest individual crystal of chabazite, measuring twenty-eight millimetres in diameter, found at the quarry, was deposited on analcite. The association of chabazite and analcite is quite rare, and is confined to near the surface of No. 2 flow. Calcite of the second type is often found deposited on the analcite, which is always water-clear. Two forms have been identified, the trapezohedron and the cube, though the latter appears to be extremely rare, as it was found to be present on only one crystal out of a great number examined, and then the faces were very small. The crystals did not exceed four millimetres in diameter.

An analysis of the mineral is given in Table V, and it is compared with analcite from Ben Lomond, New South Wales. A marked difference in the lime content of the two analcites is shown. Lime is absent from the Kyogle mineral, but constitutes 1·33 per cent. of the Ben Lomond mineral.

TABLE V.—CHEMICAL ANALYSIS OF ANALCITE.

	Kyogle.	Ben Lomond. <sup>7</sup>	Theoretical.
SiO <sub>2</sub> .. ..	54·23	54·39	54·5
Al <sub>2</sub> O <sub>3</sub> .. ..	23·67	21·76	23·2
Fe <sub>2</sub> O <sub>3</sub> .. ..	Absent	—	—
CaO .. ..	Absent	1·33	—
Na <sub>2</sub> O .. ..	13·81	13·77	14·1
K <sub>2</sub> O .. ..	Trace	Trace	—
H <sub>2</sub> O .. ..	8·34	8·71	8·2
	100·05	99·96	100·0

The specific gravity is 2·286.

<sup>7</sup> Anderson.—*Loc. cit.*

## MESOLITE.

Mesolite is found deposited mostly on the chabazite of the breccia. Occasionally it is deposited on calcite in spaces which have been formed by the interlacing of large calcite crystals. The basal planes of the chabazite-covered calcite crystals were coated with mesolite in almost every case, while no trace of the mineral existed on the scalenohedron faces, except where deposited directly on the calcite as noted above. Only rarely was it found on the chabazite lining the larger cavities of the brecciated zone, more commonly it occurred in the smaller cavities. Except for the basal planes of the calcite crystals, the more or less confined spaces appeared to provide the conditions most favourable for the deposition of mesolite.

It occurred as delicate somewhat diverging tufts, or forming a drusy surface. Individual crystals are acicular and rarely exceed one millimetre in length. They are colourless, but in the mass appear to be white.

The quantity of mesolite was so small that it was impossible to obtain much for analysis without destroying a large number of the specimens. Less than a quarter of a gram was used for analysis and the results are given in Table VI. The water was determined by difference, but the results obtained definitely place the mineral as mesolite.

TABLE VI.—CHEMICAL ANALYSIS OF MESOLITE.

	Kyogle.	Ben Lomond. <sup>8</sup>
SiO <sub>2</sub> .. .. .	44·40	43·88
Al <sub>2</sub> O <sub>3</sub> .. .. .	26·53	27·14
CaO .. .. .	11·48	7·03
Na <sub>2</sub> O .. .. .	3·72	10·48
K <sub>2</sub> O .. .. .	—	Trace
H <sub>2</sub> O (diff.) .. .. .	13·87	11·86
	100·00	100·39

## CHLORITE.

No attempt was made to analyse this mineral and it is not possible to state to which particular member of the chlorite group it belongs. It is a fibrous green variety and therefore belongs to the leptochlorite of Tschermak. Besides being an interstitial mineral of the rock itself, it often forms an extremely thin lining on the walls of the vesicles of the rock.

<sup>8</sup> Anderson.—*Loc. cit.*

## PARAGENESIS.

The distribution of the minerals in the different flows as exposed in the quarry face is shown below.

Flow No. 4.—Chabazite (2), calcite (1).

Flow No. 3.—Chabazite (2), calcite (1).

Breccia under Flow No. 3.—Clayey zeolitic material (3), chabazite (5), calcite (2), chabazite (1), mesolite (4), analcite (7), calcite (6).

Flow No. 2.—Chlorite (3), analcite (1), chabazite (4), calcite (2).

Flow No. 1.—Chlorite (3), analcite (2), calcite (1).

The numeral after each mineral indicates approximately the order of abundance in which the mineral was found in the respective flows. The breccia contained more zeolites and calcite than all the flows combined. The vesicular portion of No. 4 flow was not exposed, and only two specimens were obtained from here, consequently the distribution of the minerals in this flow as given above may be subject to alteration.

The sequence of the minerals in flows No. 1 and No. 2 is quite normal, but in the case of the breccia this is not so. The clayey zeolitic material appears to be the first to be deposited, though there is definite evidence that it was also deposited after the first crop of calcite and immediately before the second chabazite. The first chabazite rests either on the amorphous material or else directly on the decomposed basalt of which the breccia is composed. Occasionally it is seen to form veins in the brecciated material, but more often it is overlain by calcite. It does not appear to attain a thickness of more than six millimetres, while the overlying calcite forms crystals of more than twenty centimetres in length. This calcite is the zonal variety previously described. In some cases the zeolite can be definitely identified as chabazite, but in other cases its identification is somewhat doubtful, but it is probably all chabazite. The zeolite has been deposited from solutions which have been injected between the zones subsequent to the deposition of the calcite and probably contemporaneously with the main deposit of chabazite. Mesolite is invariably deposited on the main chabazite. The evidence of the analcite having formed after the mesolite is based on the occurrence of one crystal of analcite, and there is no direct evidence that the calcite is later than the analcite as the two were never found in association.

## THE ORIGIN OF THE ZEOLITES AND ASSOCIATED MINERALS.

It has already been noted that in the vesicles of the various flows the normal order of the sequence of the zeolites and calcite

occurs, and this is accompanied by very little alteration of the basalt. While it is maintained that the sequence of the minerals in the breccia is not normal, the basalt forming this material has been so altered that it is possible to scrape it into powder very easily by means of an ordinary pocket-knife, and the basalt which encloses the breccia has been intensely altered for a distance of at least three centimetres. It is at once obvious that the solutions acting on the breccia have had a much more severe action on it than the solutions in the vesicles of the basalt itself. It therefore becomes necessary to seek the cause for this difference. Bailey and Grabham<sup>9</sup> have suggested that magmatic solutions rich in sodium carbonate, accompanying the extrusion of lava, attack it shortly after the consolidation of the groundmass. The breccia is found only where a marked irregularity of the surface of No. 2 flow forms a rough kind of basin. This would form an excellent reservoir for such a magmatic solution, while, owing to the nature of the breccia, a relatively large surface of the material would be exposed to the action of the solutions. Further, it is to be noted that the vesicles occur near the surface of the flow, where the loss of heat is most rapid, and in consequence the rate of decrease of temperature of the solution would be greater than in the breccia. The action of sodium carbonate on a labradorite-rich rock would be to form calcium carbonate, sodium silicate, and aluminium silicate, the two latter interacting to form a double silicate of sodium and aluminium, with further partial replacement of sodium by calcium in the presence of excess of calcium carbonate. The crystallization of minerals from such a solution would depend on saturation due to either addition of the solute, evaporation, or lowering of the temperature. Pressure would not be an important factor in this case. If saturation were mainly due to a lowering of the temperature, it would be expected that the minerals would be deposited in their normal order. It might be argued that they have been so deposited. Thus the clayey material, chabazite, and calcite being crystallized from one solution, the second deposit of chabazite and mesolite would be due to the introduction of another solution, while the crystallization of the analcite and second deposit of calcite would be the result of a third injection of water. However, it must be remembered that the most favourable period for the introduction of magmatic solutions into the breccia would be at the time of the actual flowing of the lava immediately above, that is No. 3 flow. It is thus apparent that the quantities of the various minerals must be taken into account. With the exception of the second deposit of chabazite, calcite occurs in far greater quantity than all the other minerals together. The first deposit of chabazite is exceedingly small compared with the calcite. This is exactly the opposite from what one would expect

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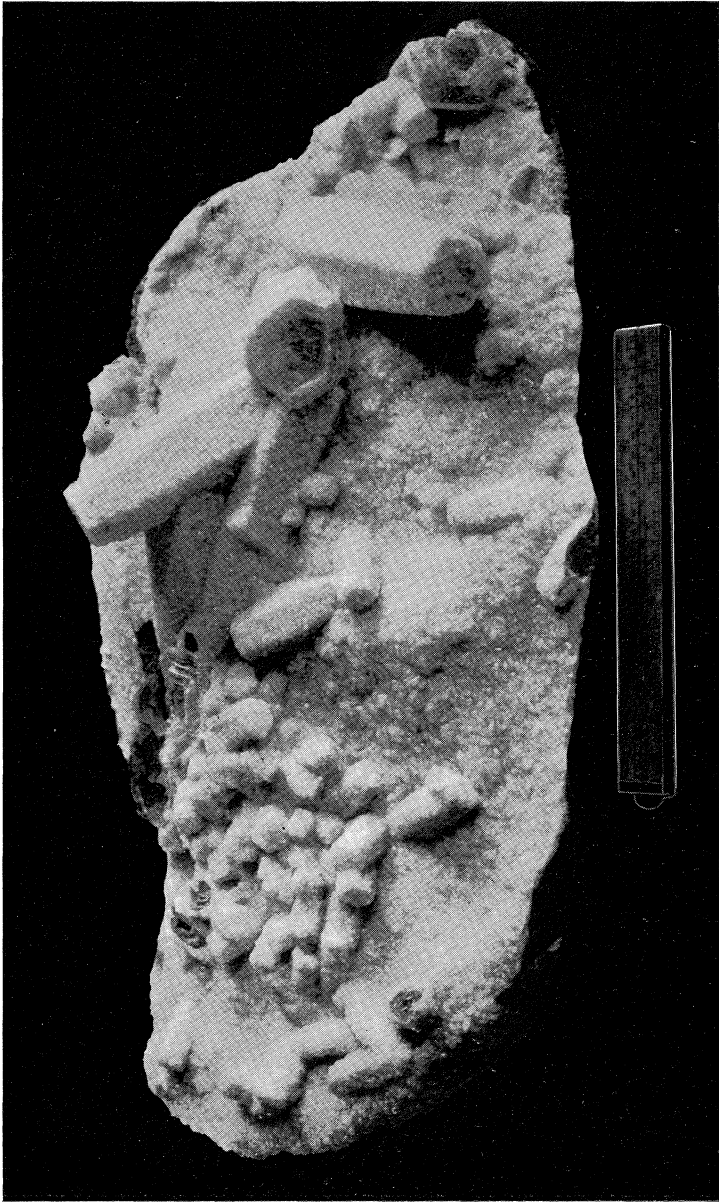
<sup>9</sup> Bailey and Grabham.—*Geol. Mag.*, vi, 1909, pp. 250-256.

if these minerals were the result of different injections of magmatic water derived from overlying flows. It seems more probable that they were deposited from the one solution, that is the magmatic water accompanying the extrusion of the basalt of No. 3 flow. In this case it is reasonable to suppose that the solution would contain calcium carbonate and silicates before reaching the breccia. A comparatively rapid initial loss of temperature of the solution owing to contact with the relatively cool breccia and underlying solidified flow, would be sufficient to cause the deposition of the first series of minerals, consisting of the clayey zeolitic material, chabazite, and calcite. This would be followed by a slow gradual lowering of the temperature, permitting a sufficient time for the solution to effect the complete deposition of the basalt of the breccia. During this period the principal accession would be calcium carbonate, and saturation would be controlled not so much by temperature as by this fact. Two processes would be going on simultaneously, one, the decomposition of the basalt, and the other, the deposition of calcite. It is suggested that these conditions would be favourable to the rhythmic deposition of calcite so characteristic here. After the decomposition of the basalt had been completed or nearly so, temperature would be again the most important factor in any further crystallization of minerals, so that the normal sequence of the minerals would occur. This is precisely what is found here, that is, chabazite followed by mesolite, analcite and calcite.

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EXPLANATION OF PLATE XLVI.

Chabazite coating scalenohedrons of calcite from Kyogle, New South Wales. At the top centre of the specimen, a broken section of a calcite crystal is seen showing the characteristic zonal structure.



G. C. CLUTTON, photo.