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Gartronite, a new zeolite,
from Ireland and Iceland

BY

G. P. L. WALKER

WITH CHEMICAL ANALYSES BY

I. S. E. CARMICHAEL

IMPERIAL COLLEGE, LONDON S.W. 7

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Garronite, a new zeolite, from Ireland and Iceland.

By G. P. L. WALKER, Ph.D.

With chemical analyses by I. S. E. CARMICHAEL, M.A.
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[Read 22 March 1962.]

Summary.—A new zeolite closely related to phillipsite and gismondine is recorded from thirty localities in the Tertiary basalts of Antrim and eastern Iceland, and the name garronite is proposed. Four chemical analyses indicate a composition of $\text{NaCa}_2\text{Al}_6\text{Si}_6\text{O}_{32}\cdot 13\text{H}_2\text{O}$. Garronite differs chemically from phillipsite in having a very low content of potash, and from gismondine in containing less lime, alumina, and water; optically garronite is intermediate between these two zeolites.

SPECIMENS of a zeolite similar to, but not identical with, phillipsite were collected by the writer in 1950 from several localities in the Tertiary basalts of Antrim, Ireland. It was not possible to make an adequate study of this mineral at the time, but it was described in a Ph.D. thesis¹ as a probable new zeolite, and the name *garronite* was tentatively assigned, from the occurrence of the mineral in the Garron Plateau area.²

Subsequent field work in Antrim has resulted in the same mineral being found at several other localities. In the summer of 1957 specimens of the same mineral were collected from Tertiary basalts in eastern Iceland, and during field work since then the mineral has been found at a further twenty localities in Iceland and is locally quite abundant. The mineral has since also been identified in specimens from four additional localities in Antrim: one from a borehole at Langford Lodge, in the collec-

¹ Presented at the University of Leeds in 1955.

² When the name was first applied, the writer was unaware that D. L. Reynolds had suggested the name garronite (from Slievegarron, Co. Down) for a rock variously described as an augite-biotite-diorite, a hybrid sodi-potassic gabbro, a gabbro-diorite, and a biotite-essxite-gabbro (Geol. Mag. 1937, vol. 74, p. 476 [M.A. 7-35]). This use does not seem to have been accepted.

tion of the Geological Survey of Northern Ireland; and three from the collection of Antrim zeolites bequeathed to the British Museum (Natural History) by the late F. N. Ashcroft. The following description is based on the examination of specimens from a total of 30 localities in the two countries (fig. 6).

In 1958 the writer supplied a specimen of garronite to Prof. Barrer for his studies on the harmotome family; an X-ray powder pattern was published,¹ indexed to the tetragonal system with a 10.01 Å and c 9.87 Å, and shown to be almost identical with that of a tetragonal synthetic zeolite referred to as species *P*. A synthetic calcium zeolite referred to as CASH II was prepared by M. Koizumi and R. Roy,² at temperatures of 225 to 290°C and pressures of 15 000 lb/in.²; the powder pattern and optical properties appear to be identical with those of garronite. A sodium analogue was also reported.

The occurrence of garronite in Antrim.

Garronite is found fairly abundantly in screes on the steep western slopes of the Glenariff valley, in eastern Antrim, locality³ G. 1. Zeolites are abundant in amygdalae in thin olivine-basalt lavas at this locality; they include chabazite, thomsonite (färöelite), analcime, levyne, natrolite, and phillipsite. Phillipsite forms well-shaped crystals lining amygdalae, and is quite distinct from garronite, which forms radiating aggregates completely filling the amygdalae—these measure up to 2 cm in diameter—that it occupies. Phillipsite and garronite sometimes occupy amygdalae less than 1 cm apart. One specimen of garronite from this locality has been analysed chemically (table II, G. 1) and, on account of the close relationship that clearly exists between garronite and phillipsite, a specimen of phillipsite from the same locality has also been analysed (table II, B), and proves to be a normal phillipsite. This is the locality at which garronite was first found, and is regarded as the type locality on this account.

Garronite at this and other localities forms compact radiating aggregates and alone, or with other zeolites, normally completely fills the amygdale in which it occurs. Crystal faces have not yet been observed. Amygdalae up to 2 cm. have been observed at several localities completely infilled with garronite. Occasionally it is accompanied by färöelite or

¹ R. M. Barrer, F. W. Buttkide, and I. S. Kerr, Journ. Chem. Soc., 1959, vol. 294, p. 1521.

² M. Koizumi and R. Roy, Journ. Geol., Chicago, 1960, vol. 68, p. 41.

³ A complete list of localities is given in the appendix.

other zeolites, and when incompletely filling an amygdale phillipsite characteristically coats the surface of the garronite aggregate. Garronite is white or colourless, with a vitreous to greasy lustre. The aggregates are distinguished from those of phillipsite, färöelite, gismondine, or other zeolites on account of garronite possessing a series of concentric fractures normal to the length of the individuals in the aggregate.

Five other localities for garronite in the eastern coastal strip of Antrim are listed in the appendix. In addition, garronite has been found in specimens from the Langford Lodge borehole from depths of 290 to 1000 ft, associated with chabazite, färöelite, levyne, calcite, and saponite.¹ The writer is indebted to the Director of the Geological Survey for Northern Ireland for permission to examine specimens from this borehole and to publish this note. Small amounts of garronite have also been detected in specimens from three localities in the Antrim zeolite collection of the late F. N. Ashcroft, now in the British Museum (Natural History). The writer is indebted to the Keeper of Minerals for permission to examine these specimens, and to publish this note.

The occurrence of garronite in Iceland.

Garronite is readily collected from screes from the Graenavátn porphyritic group² on the mountain Skessa, near the head of Reyðarfjörður in eastern Iceland. Specimens from this locality fill amygdalae commonly measuring 1–2 cm in diameter. The garronite is usually alone in its amygdale, but occasionally it is accompanied by färöelite or heulan-dite. Other minerals in the basalts at this locality are chabazite, levyne, and a little hair-like mesolite. One specimen of garronite from this locality has been analysed chemically (table II, G. 18).

Two other specimens of garronite from eastern Iceland have been analysed. One is from the mountain Hånefúr, Seyðisfjörður, where the mineral occurs in olivine-basalt lavas associated with chabazite, färöelite, and levyne (table II, G. 11). The other is from Baejarhundur, Breiddalur, where the mineral occurs in olivine-basalt lavas and is associated with chabazite and färöelite (table II, G. 26). Other Icelandic localities for garronite are listed in the appendix.

¹ The geology and location of this borehole are discussed by Fowler (Summ. Progr. Geol. Surv. for 1956, 1957), and the general distribution of zeolites by Walker (Min. Mag., 1960, vol. 32, p. 526).

² This prominent group of feldspar-porphyrific basalt lavas has been mapped over a wide area of eastern Iceland; the group was named from its occurrence at Graenavátn (G. P. L. Walker, Journ. Geol. Soc., 1959, vol. 114, p. 367).

Description of garronite.

As noted above, garronite characteristically forms compact radiating aggregates and, usually alone, fills the amygdale in which it occurs. Crystal faces have not yet been observed. Two cleavages at about 90°, both parallel to the length of the individuals, are sometimes clearly seen.

At the proximal end of the individuals in the aggregates, the garronite is uniaxial, with the optic axis parallel to the length of the individuals, and gives straight extinction. At the distal end extinction is often oblique and the mineral appears to be biaxial and twinned, although the extinction angle is difficult to determine on account of the branching and fern-like nature of the aggregates. Phillipsite often appears as an outer zone to the aggregates, and it is difficult to be certain where garronite ends and phillipsite begins. Although phillipsite has in general a lower refringence than garronite, the fields for the two minerals overlap (fig. 2), and where they overlap the two minerals cannot reliably be distinguished optically, and recourse must be had to X-ray methods. It was this very close relationship between garronite and phillipsite that prompted the chemical analysis of phillipsite from one garronite locality. This phillipsite proves to be chemically normal, and quite unlike garronite in composition. The X-ray powder patterns for the two minerals are also different (fig. 4).

A number of typical refractive index figures for garronite are given in table I; these and others are plotted on fig. 1, in which garronite that is length fast is distinguished from garronite that is length slow, and an envelope drawn around the well-defined distribution field. The aggregates of garronite are almost invariably zoned, and the zoning tends to follow a constant pattern, with steadily decreasing refringence outwards from the proximal to the distal ends of the individuals. Very frequently the refractive index parallel to the length of the individuals (ϵ) falls less steeply than that normal to the length (ω), in which case there may be a change-over in the middle from length fast (optically negative) to length slow (positive), with a point in between at which the mineral is sensibly isotropic. Typical values are (for two specimens from locality G. 18): ω 1.507 (core) to 1.500 (rim), ϵ 1.505 (core) to 1.502 (rim), and ω 1.512 (core) to 1.502 (rim), ϵ 1.509 (core) to 1.504 (rim).

A plot of 40 new determinations of Antrim and Icelandic phillipsite, together with published data, is also given in fig. 1. In fig. 2 the envelopes for phillipsite, garronite, and gismondine (Walker, this vol., p. 192) are plotted on the same diagram to show the small amount of overlap

TABLE I. Density and optical properties of garronite.

Locality	Density	n_1^*	n_2^\dagger	Birefringence	Length
G. 1	2.16	$\left\{ \begin{array}{l} 1.510 \\ 1.506 \end{array} \right.$	1.512 1.504	0.002 0.002	fast slow
G. 3	2.14	—	—	—	—
G. 6	—	$\left\{ \begin{array}{l} 1.512 \\ 1.505 \end{array} \right.$	1.515 1.501	0.003 0.004	fast slow
G. 8	—	1.507	1.505	0.002	slow
G. 9	—	1.506	1.504	0.002	slow
G. 10	—	1.507	1.505	0.002	slow
G. 11	2.16	$\left\{ \begin{array}{l} 1.506 \\ 1.504 \end{array} \right.$	1.503 1.502	0.003 0.002	slow slow
G. 12	2.14	1.503	1.501	0.002	slow
G. 13	2.17	$\left\{ \begin{array}{l} \text{prox. } 1.506 \\ \text{dist. } 1.510 \end{array} \right.$	1.507 1.514	0.001 0.004	fast fast
G. 14	2.15	$\left\{ \begin{array}{l} 1.506 \\ 1.505 \end{array} \right.$	1.507 1.503	0.001 0.002	fast slow
G. 15	—	1.506	1.504	0.002	slow
G. 17	—	1.504	1.501	0.003	slow
G. 18	2.14	$\left\{ \begin{array}{l} \text{prox. } 1.505 \\ \text{dist. } 1.502 \end{array} \right.$	1.507 1.500	0.002 0.002	fast slow
	—	$\left\{ \begin{array}{l} \text{prox. } 1.509 \\ \text{dist. } 1.504 \end{array} \right.$	1.512 1.502	0.003 0.002	fast slow
G. 20	2.15	1.506	1.504	0.002	slow
G. 25	2.15	$\left\{ \begin{array}{l} \text{prox. } 1.506 \\ \text{dist. } 1.505 \end{array} \right.$	1.505 1.503	0.001 0.002	slow slow
G. 26	2.15	1.502	1.502	0.001	fast and slow
G. 27	2.13	1.507	1.508	0.001	fast
G. 28	—	$\left\{ \begin{array}{l} \text{prox. } 1.505 \\ \text{dist. } 1.508 \end{array} \right.$	1.503 1.510	0.002 0.002	slow fast
G. 29	2.16	$\left\{ \begin{array}{l} \text{prox. } 1.504 \\ \text{dist. } 1.502 \end{array} \right.$	1.502 1.500	0.002 0.002	slow slow
G. 29	2.16	1.508	1.509	0.001	fast
G. 30	2.15	$\left\{ \begin{array}{l} 1.510 \\ 1.505 \end{array} \right.$	1.512 1.503	0.002 0.002	fast slow
G. 31	2.15	1.502	1.500	0.002	slow
G. 32	—	$\left\{ \begin{array}{l} \text{prox. } 1.506 \\ \text{dist. } 1.503 \end{array} \right.$	1.504 1.501	0.002 0.002	slow slow

* n_1 , refractive index for light vibrating parallel to length; for uniaxial garronite, $n_1 = \epsilon$.

† n_2 , refractive index for light vibrating normal to length; for uniaxial garronite, $n_2 = \omega$.

prox., proximal end of individuals in zoned aggregates.

dist., distal end of individuals.

of the first two, and the contiguity of the second two. The trend of zoning in zoned crystals is also shown. In gismondine, phillipsite, and other zeolites (thomsonite, chabazite, heulandite) the refringence normally increases outwards in zoned crystals, and in some cases this can safely be assumed to mark an outward increase in CaAl at the expense of NaSi. In garronite, on the other hand, the trend is reversed. The arrow

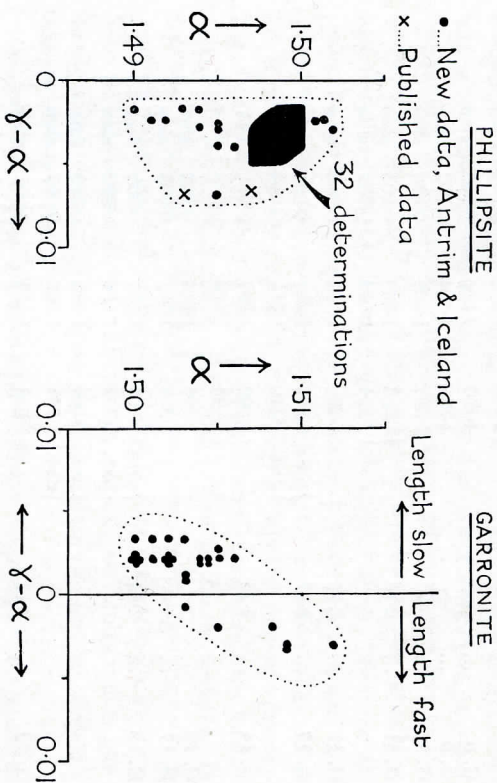


FIG. 1. Left: Variation in optical properties of phillipsite, based on new data for Antrim and Iceland material and published data. Right: Variation in optical properties of garronite. Some of the points refer to separate determinations on different parts of the same zoned aggregate.

indicating the zoning trend for garronite is extended beyond the confines of the garronite envelope to include the phillipsite rim sometimes encountered.

Density determinations on garronite from 14 localities by suspension in mixtures of bromoform and a mineral oil give values ranging from 2.13 to 2.17; 8 specimens of phillipsite from Antrim and Iceland give values from 2.13 to 2.17, and the two minerals thus overlap. Clear gismondine, which ranges from 2.20 to 2.26, is distinctly higher, although the density of white gismondine falls as low as that of garronite. Refractive indices calculated by the Rule of Gladstone and Dale¹ are, for the analysed

¹ E. S. Larsen, U.S. Geol. Surv. Bull., no. 679, 1921. Also H. W. Jaffe, Amer. Min., 1956, vol. 41, pp. 457-477.

specimens, 1.504 (G. 1), 1.505 (G. 11), 1.501 (G. 26), and 1.500 (G. 18), in close agreement with the measured values of 1.511, 1.503, 1.502, and 1.503 respectively.

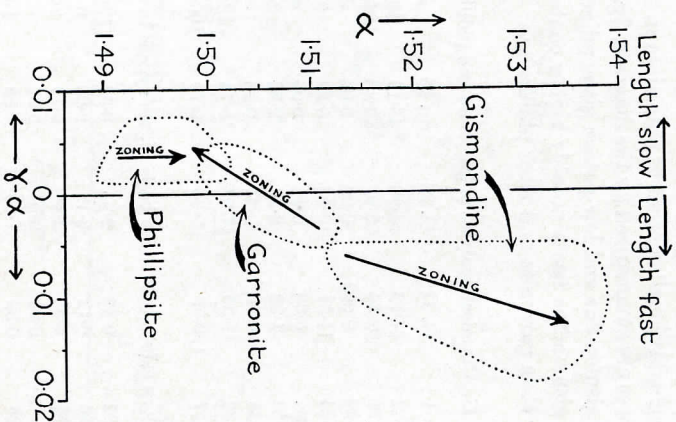


FIG. 2. Comparison of the optical properties of garronite, phillipsite, and gismondine. The arrows give the normal zoning trend in each case.

Chemical composition.

Four samples of garronite—one from Antrim and three from Iceland—from different localities have been analysed chemically. All were handpicked under a stereoscopic binocular microscope and the purity of the powder checked optically. Each specimen was zoned and the refractive indices in each case show a range in value; the estimated average values have been given in table II. The atomic proportions have been calculated on the basis of 32 oxygen atoms.¹ It can be seen that the four analyses are very similar; the variation is too small to enable any

¹ With the cell dimensions given by Barrer, Barltreide, and Kerr (*loc. cit.*), the four garronite analyses and densities cited in table II lead to 30.75, 31.04, 31.06, and 30.67 oxygen atoms per unit cell respectively; these low values remain unexplained.

reliable deductions to be made of the nature of the ionic substitutions responsible for this variation. The analyses indicate the formula $\text{NaCa}_{0.2}\text{Al}_6\text{Si}_{10}\text{O}_{32}\cdot 13.5\text{H}_2\text{O}$. The outstanding difference between garronite and phillipsite is the very much lower content of alkalis, and in particular the negligibly small content of potassium in the former. The chemical differences are summarized by the diagram, fig. 3, in which the fields for potash gismondine and low-potash gismondine are also shown for comparison; gismondine has a notably higher content of lime, alumina, and water than garronite and most phillipsite.

TABLE II. Chemical analyses of garronite and phillipsite.

	G. I				A.		B.	
	G. 1	G. 11	G. 26	G. 18				
SiO_2	43.21	44.75	44.96	45.15	45.48	45.60		
Al_2O_3	24.20	23.54	23.61	23.35	23.15	22.54		
Fe_2O_3	0.02	0.003	0.02	0.02	—	0.02		
CaO	10.64	11.31	10.52	10.32	10.61	7.72		
BaO	tr.	0.06	0.14	0.09	—	0.22		
Na_2O	2.94	1.38	2.52	2.96	2.35	1.50		
K_2O	0.54	0.70	0.21	0.16	—	5.63		
H_2O	18.62	18.35	17.97	18.74	18.41	16.58		
Sum	100.17	100.09	99.95	100.79	100.00	99.81		

Atomic proportions calculated on the basis of 32 oxygens to the unit cell:

Si	9.62	9.88	9.88	9.92	10.00	10.10
Al	6.35	6.12	6.12	6.05	6.00	5.89
Ca	2.54	2.68	2.48	2.43	2.50	1.84
Ba	—	0.01	0.01	0.01	—	0.02
Na	1.26	0.59	1.08	1.26	1.00	0.64
K	0.15	0.20	0.06	0.04	—	1.59
H_2O	13.82	13.50	13.17	13.73	13.50	12.25
Si+Al	15.97	16.00	16.00	15.97	16.00	15.99
D	2.16	2.16	2.15	2.14	2.217†	2.13
n_1 *	1.510	1.504	1.502	1.504	1.503	1.503
n_2 †	1.512	1.502	1.502	1.502	1.498	1.498

G. 1 Garronite from original locality, Glenariff, Antrim.

G. 11 Garronite, Hånefur, Seyðisfjörður, Iceland.

G. 26 Garronite, Bæjarindur, Breiddalur, Iceland.

G. 18 Garronite, Skessa, Reyðarfjörður, Iceland.

A. Theoretical composition, $\text{NaCa}_{0.2}\text{Al}_6\text{Si}_{10}\text{O}_{32}\cdot 13.5\text{H}_2\text{O}$.

B. Phillipsite from same locality as garronite, G. 1.

Analys: I. S. F. Carmichael.

* n_1 refractive index for light vibrating parallel to length.

† n_2 ditto normal to length.

‡ Calc. for Barrer, Bultitude, and Kerr's cell-dimensions and 32 oxygens.

All of the analysed samples are zoned, with a range of refractive index; the figures given above are estimated average values.

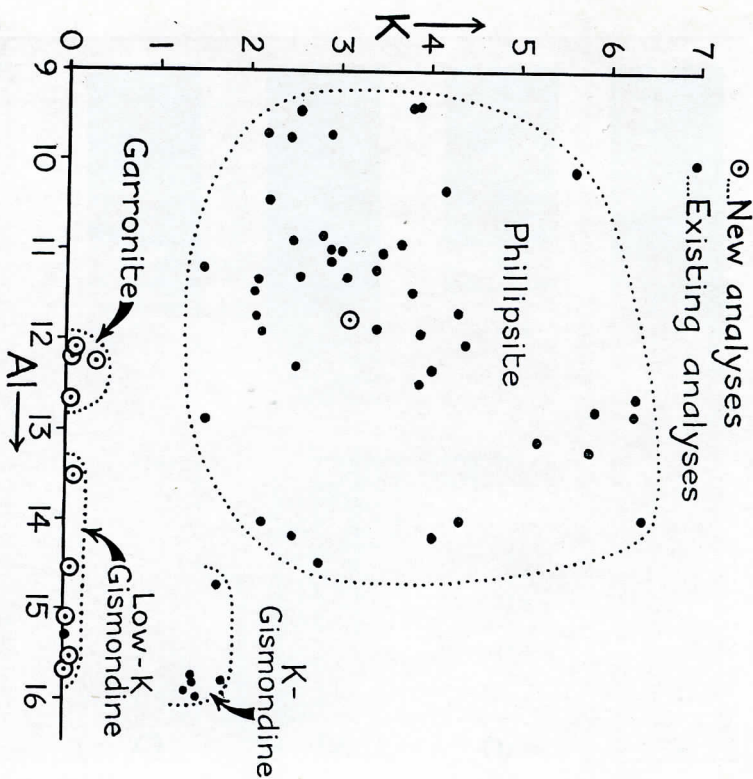


FIG. 3. Comparison of the chemical composition of garronite, phillipsite, low-potash gismondine, and gismondine.

X-ray powder pattern.

The identity of garronite from each locality has been checked by X-ray powder photographs, using material from Glenariff, Antrim, as the type material. Powder photographs of garronite, phillipsite, and gismondine from Antrim localities are compared in fig. 4, and it may be seen that there are small but distinct differences between them. Garronite from the proximal and distal ends of the individuals in zoned aggregates sometimes shows slight differences in the powder pattern, which are correlated with optical differences; a powder photograph of each is reproduced in fig. 4. As noted above, indexed powder data for garronite and for a synthetic zeolite with which it is almost identical have been published elsewhere by Barrer *et al.*, 1959.

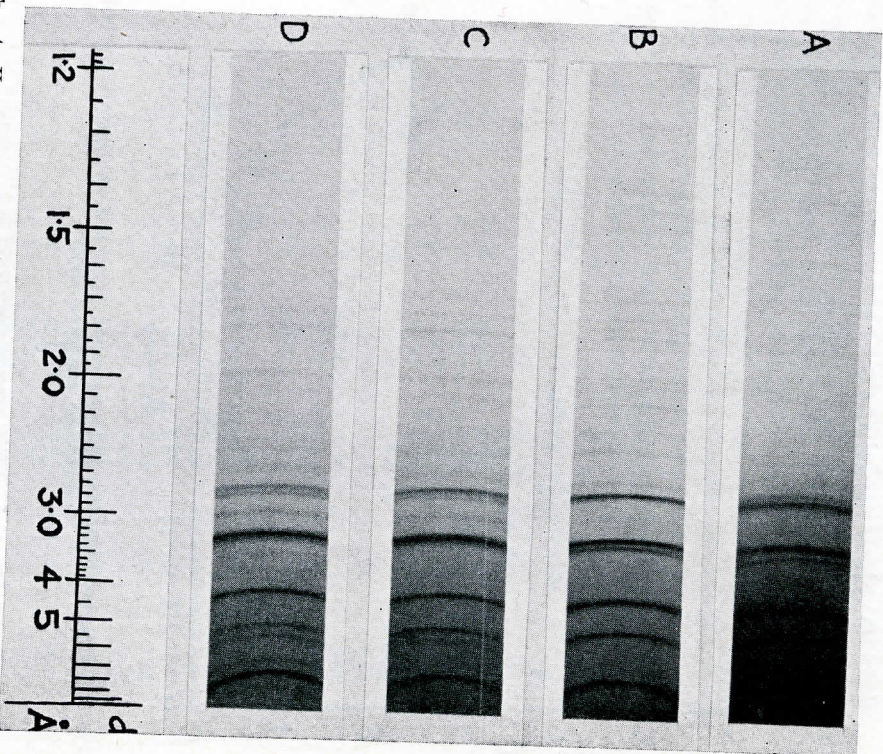


FIG. 4. X-ray powder photographs of garronite and related minerals, taken with filtered Cu radiation on a 9 cm camera. A: Gismondine, Hyrarfall, East Iceland (specimen no. 308). B: Garronite, proximal end of zoned aggregate, Glenariff, Antrim. C: Garronite, distal end of the same zoned aggregate as B. D: Phillipsite, Islandmagee, Antrim.

Paragenesis.

Garronite in Antrim has been found only in olivine-basalt lavas. In Iceland it has been found in lavas rich in phenocrysts of hytownite in which a small amount of olivine is also present, and also to a lesser extent in non-porphyrific olivine-basalt lavas. All of these rocks are silica-undersaturated. The amygdale minerals with which garronite is associated in these basalts are for the most part relatively silica-poor species such

as thomsonite, chabazite, levyne, phillipsite, and gismondine, but analcime, natrolite, stilbite, heulandite, mesolite, and scolecite occur at some localities.

In two recent papers¹ a regular distribution of zeolites in flat-lying zones of regional extent has been described from Tertiary basalt lavas in Antrim and Iceland. The uppermost zone in each area is charac-

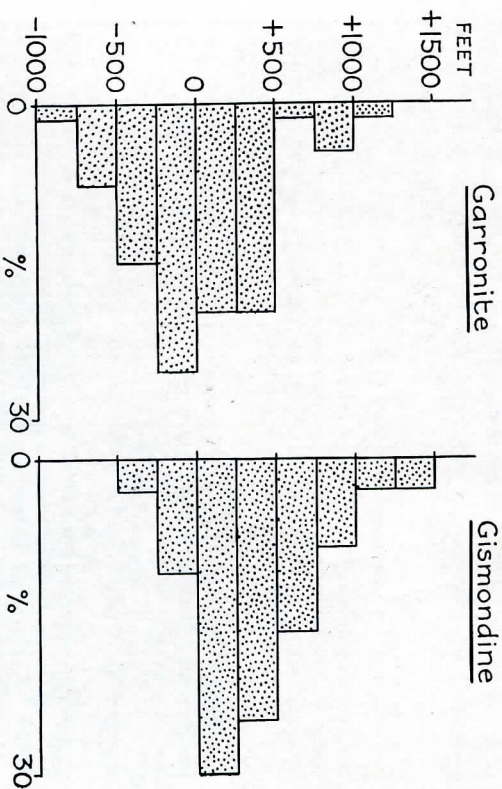


FIG. 5. Histogram of the height distribution of garronite and gismondine in the sequence of zeolite zones, the datum line being the top of the analcime zone. The garronite histogram is based on 30 localities in Antrim and Iceland, the gismondine on 40 localities.

terized by an assemblage in which chabazite and thomsonite are predominant, accompanied by smaller amounts of phillipsite, levyne, and gismondine, and sparse apophyllite and gyrolite. Below the chabazite-thomsonite zone comes a zone in which these minerals are joined by analcime and other zeolites. The mineral assemblages in these zones are interpreted as indicators of the temperature attained during zeolitization of the basalts, although it is not yet possible to assign reliable temperature values; the zone boundaries are interpreted as marking geosotherms for the period when zeolitization took place. The garronite localities in Antrim and Iceland are almost equally distributed between the analcime

¹ G. P. L. Walker, *Min. Mag.*, 1960, vol. 32, p. 503; and *Journ. Geol.*, 1960, vol. 68, p. 515.

zone and the lower half of the chabazite-thomsonite zone, as is shown by the histogram of fig. 5, in which height is measured above or below the top of the analcime zone, taken as the datum line. The histograms show that garronite occurs systematically lower by about 250 ft than gismondine, and is probably formed at a somewhat higher temperature. When

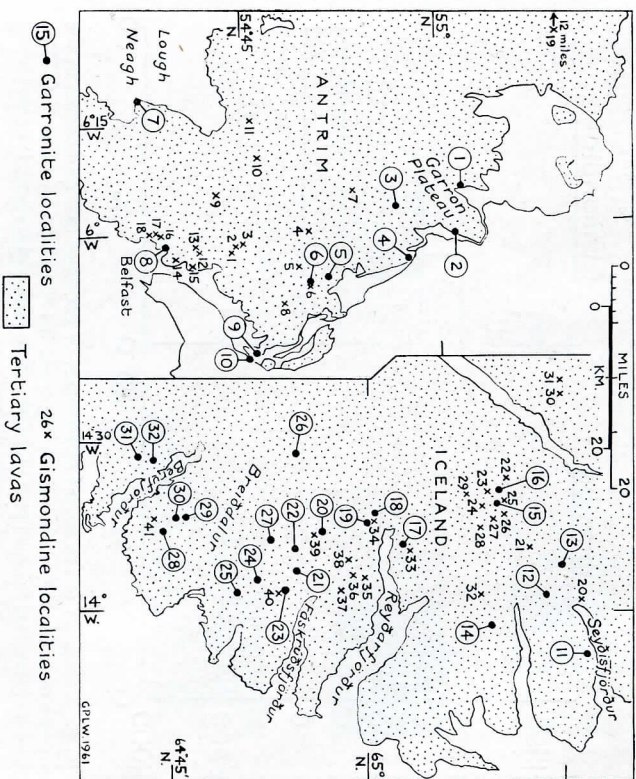


Fig. 6. Sketch-maps showing the location of the garronite localities given in this paper.

searched for, garronite is found at a substantial proportion of the exposures at the optimum height shown by the histogram.

There are insufficient data presently available to assign reliable temperature limits to the zeolite zones, but Barrer *et al.* (*loc. cit.*) synthesized a sodium zeolite almost identical in structure with garronite over a temperature range of 60 to 250° C, with an optimum yield at 110° C; the figure of 110° C is tentatively assigned to the geotherm that marks the top of the analcime zone. A figure of 2000 ft was given by Walker for the estimated average depth of the top of the analcime zone below the original basalt lava surface in eastern Iceland. Subsequent work has indicated that this figure may be 500 to 1000 ft too low, and

that the optimum depth for the formation of garronite was 2500 to 3000 ft. Shallow wells in the non-thermal areas of Iceland—the areas in which zeolitization may still be proceeding at depth—give a temperature gradient of 0.03 to 0.16° C/m, which on extrapolation gives a temperature of 110° C at a depth of 3000 to 600 m. The higher gradient is perhaps more likely to be expected in areas of active zeolitization. The synthesis of garronite-like material at 110° C and the geological evidence for the formation of garronite at an optimum depth of 2500 to 3000 ft are thus compatible with the observed present-day temperature gradient elsewhere in Iceland.

Appendix: List of garronite localities.

Locations shown on map, fig. 6. On list below, locality or specimen number given in parentheses. Assoc: associated minerals (*an* analcime; *ap* apophyllite; *ch* chabazite; *gi* gismondine; *gm* gmelinite; *gy* gyrolite; *he* heulandite; *le* levyne; *me* mesolite; *na* natrolite; *ph* philipsite; *st* stilbite; *th* thomsonite (*faröelite*)).

Antrim:

- G. 1 (14.151) Type locality; one specimen of garronite, and one of philipsite, analysed, table II. Screens on steep western side of Glenariff Valley, eastern Antrim, at a point 1 mile SE. of trig. point 1304 ft, Crookalough. Lat. 55° 02' N; long. 6° 05½' W. Assoc: *ch, th, an, le, na, ph*.
- G. 2 (14.115) Path exposure at 700 ft, ¼ mile S. of Black Burn, N. of Carnlough. Assoc: *ch, th, le*.
- G. 3 (20.90) Small exposure in field just W. of Tickle dolerite plug at 600 ft in Tickle Water, 5 miles SW. of Carnlough. Assoc: *ch, le, th, ph*.
- G. 4 (20.82) Coastal cliffs 1 mile E. of Glenarm. Assoc: *an, na, gm*.
- G. 5 (20.95) Stream at 820 ft, 1 mile NW. of Kilwaughter Castle, Larne. Assoc: *ch, th, na*.
- G. 6 (20.112) Quarry ¼ mile SW. of Kilwaughter crossroads, ¾ mile S. of Kilwaughter Castle. Assoc: *ch, na, an, th, gi*.
- G. 7 Langford Lodge borehole (Fowler, 1957), in specimens from depths ranging from 290 to 1000 ft. Assoc: *ch, th, le*, and also some scolecite and much calcite and saponite.
- G. 8 Ashcroft collection, locality 56/5; quarry high on NE. slope of Squire's Hill. Garronite identified in one specimen. Assoc: *th, ch, an, gi, ap, gy*.
- G. 9 Ashcroft collection, locality 47/19; roadside quarry at 300 ft, ½ mile W. of Whitehead village. Garronite identified in one specimen. Assoc: *ch, th*.
- G. 10 Ashcroft collection, locality 47/3; large quarry on N. side of White Head. Garronite identified in one specimen. Assoc: *na, an, gm, ch, th, he*.

Iceland:

(Note: Gr. P. = Grænavatn Porphyritic basalt group, a stratigraphic unit named by Walker, 1959, p. 382; the feldspar-porphyratic basalts of this group often contain garronite.)

- G. 11 (E. 658) In olivine-basalt at 1200 ft on W. side of Hánefur (= Hánesstaðafjall), S. of Seyðisfjörður. Lat. 65° 16½' N; long. 13° 53' W. One specimen from this locality analysed, table II. Assoc: *ch, th, le*.

¹ G. Bodvarsson and G. Palmason, Exploration of subsurface temperature in Iceland. U.N. Conference on New Sources of Energy. Rome, 1961, p. 21.

- G. 12 (p. 961) In feldspar-porphyrific basalt at 1200 ft on S. of Fjardar valley, Seydisfjörður. Assoc: *ch, th, an, le, me*.
- G. 13 (p. 694) In olivine-basalt at 2300 ft, 1 mile E. of Heidarvaan, W. of Seydisfjörður. Assoc: *ch, th, ph, le*.
- G. 14 (p. 949) In olivine-basalt at 2400 ft, N. side of Gaesadalur, S. of head of Mjólfjörður. Assoc: *ch, an, th, le, me, st*.
- G. 15 (p. 694) In Gr. P. at 1700 ft on NW. ridge of Skagafell, W. of Fagradalur and NW. of Reydarfjörður. Assoc: *ch, th, le, gi*.
- G. 16 (p. 696) In Gr. P. at 1700 ft on W. of Fagradalur, opposite G. 15. Assoc: *ch, ph, th, le, gi*.
- G. 17 (p. 225) In olivine-basalt at 1050 ft on SW. of Teigargerdistindur, N. of Reydarfjörður. Assoc: *th, me, an, gy*.
- G. 18 (p. 711) In Gr. P. on N. face of Skessa, at head of Reydarfjörður. Lat. 65° 09' N; long. 14° 17' W. One specimen of garronite from this locality analysed, table II. Assoc: *ch, th, le, me, he*.
- G. 19 (p. 708) In Gr. P. on W. side of Fossdalur, at head of Reydarfjörður. Assoc: *ch, th, me, he, gi*.
- G. 20 (p. 574) In Gr. P. at 1900 ft on E. side of Lambadalstindur, W. of the head of Fáskrúdsfjörður. Assoc: *ch, th, me, he, le*.
- G. 21 (p. 822) In feldspar-porphyrific basalt at 900 ft in corrie W. of Digrintindur, SW. of head of Fáskrúdsfjörður. Assoc: *st, he, an, le*.
- G. 22 In Gr. P. at 2200 ft, 3½ miles W. of the head of Fáskrúdsfjörður. Assoc: *ch, th, le, gi, st, he, me, ph*.
- G. 23 (p. 825) In Gr. P. on N. face of Háöxl, S. of head of Fáskrúdsfjörður. Assoc: *ch, th, ph, gi*.
- G. 24 (p. 846) In feldspar-porphyrific basalt at 2000 ft on E. face of peak between Gunnarstindur and Klófatindur, W. of Stöðvarfjörður. Assoc: *ch, ph, th, me, an, le*.
- G. 25 (p. 851) In feldspar-porphyrific basalt at 2700 ft on SE face of Götutindur, 3 miles W. of Stöðvarfjörður. Assoc: *ch, th, ph, le*.
- G. 26 (p. 488) In olivine-basalt at 3300 ft on SE ridge of Bæjarfjörður, N. of Breiddalur. Lat. 64° 54½' N; long. 14° 28½' W. One specimen of garronite from this locality analysed, table II. Assoc: *ch, th*.
- G. 27 (p. 297) In olivine-basalt associated with Gr. P. at 2200 ft on SE. side of Smáindafjall, N. of Breiddalur. Assoc: *le, ch, th, an, me, he, ap*.
- G. 28 (p. 210) In Gr. P. at 2800 ft on W. ridge of Hrossatindur, N. of the entrance to Bernfjörður. Assoc: *ch, th, le, ph, he*.
- G. 29 (p. 927) In Gr. P. at 2000 ft on NE. ridge of Graenafell, NW. of the entrance to Bernfjörður. Assoc: *ch, th, ph, gi*.
- G. 30 (p. 930) In Gr. P. at 2100 ft on Mýrafjallstindur, 1 mile S. of G. 29. Assoc: *ch, th, le, ph*.
- G. 31 (p. 625) In olivine-basalt at 2600 ft on S. slopes of the Sanddalur corrie, between Godaborg and Balandstindur, S. of Bernfjörður. Assoc: *ph, an*.
- G. 32 (p. 627) In olivine-basalt at 2400 ft on N. side of Sanddalur corrie, opposite locality G. 31. Assoc: *ph, ch, an, th, le, ap*.