DECREPITATION CHARACTERISTICS OF IGNEOUS ROCKS

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ABSTRACT

Decrepitation during heating of igneous intrusive rocks is complex, but one stage (D2) appears to be due to misfit of solid inclusions. This stage begins at 615 ± 30° C in simple granite pegmatite and aplite, 705 ± 30° C in granite, 765 ± 50° C in granodiorite and quartz norite, and 1010 ± 60° C in gabbro and related rocks. The D2 stage of pegmatite and aplite in an area of migmatitic gneiss, with no exposed batholiths, starts at a lower temperature than the corresponding stage of decrepitation of the country gneiss.

Introduction

The rationale of decrepitation due to misfit of solid inclusions in minerals, when heated above the temperature of crystallization, was outlined previously (Smith, 1952*a*). A stage of decrepitation of several types of garnet was interpreted to be due to solid inclusions, because the frequency of decrepitation was found to be directly related to the abundance of solid inclusions (Smith, 1952*b*). A similar stage of decrepitation of high grade metamorphic rocks was found (Smith, 1953). The measured temperatures of the beginning of this stage of decrepitation of metamorphic minerals are internally consistent, and are not at variance with the small amount of synthetic data. As a further test of the rationale, a few rocks representing several igneous rock clans were heated in the decrepitation apparatus. The results can be interpreted in an analogous manner to give the temperature of crystallization of the constituent minerals. These data, which should be considered as only tentative because of the small number in each clan tested, are given below, uncorrected for the effect of pressure.

In previous papers the methods of preparing specimens, heating in the electronic decrepitation apparatus, and interpretation of decrepigraphs have been outlined. Therefore most of the details of the decrepitation results are omitted, and only the temperatures of the high temperature decrepitation stages are given in most cases.

In this series, the grain size selected for heating in the decrepitation apparatus was −80+200 mesh (0.18 to 0.075 mm.). Corrections for thermal lag and instrumental effects were of the order of 10°C, negative. The decrepitation temperatures recorded below are given large uncer-

TABLE 1. DECREPITATION TEMPERATURE OF SOME IGNEOUS ROCKS

Rock	Mineral Fraction	Temperature of D2
Granite Pegmatite	Potash Feldspar	612 ± 20
	Plagioclase	608 ± 20
Granite Pegmatite	Two Feldspars + Quartz	640 ± 30
	Magnetite	605 ± 20
Granite Aplite	Two Feldspars + Quartz	602 ± 20
Granite Aplite	Two Feldspars + Quartz	617 ± 20
Granite Aplite	Two Feldspars + Quartz	610 ± 20
Granite	(Minus Mica + Magnetite)	695 ± 20
Granite	(Minus Mica + Magnetite)	690 ± 30
Quartz Syenite	(Minus Mica, etc.)	710 ± 20
Quartz monzonite		720 ± 20
Granodiorite	(Minus Ferromagnesians)	750 ± 20
Granodiorite	(Minus Ferromagnesians)	715 ± 20
Quartz Norite		830 ± 20
Norite		1000 ± 20
Gabbro		980 ± 30
Anorthosite		1030 ± 20
Diabase		1070 ± 20
Olivine Gabbro		960 ± 30

tainties of 20° or more, but relatively, the values probably are within 10° uncertainty. They are the temperatures at which the first derivative of decrepitation with temperature has a second order discontinuity, derived graphically. Temperatures above 1000° are less certain than those below, due to the instrumentation.

Decrepitation Data

Granite Pegmatite. Discussion of pegmatites with igneous rocks is somewhat arbitrary, but the simple granitic type (consisting of two alkali feldspars, quartz, and minor amounts of other minerals) is so evidently related to granite that most geologists would agree that if one is igneous, the other is also igneous. The following data on pegmatites refer to the simple granitic type. A study of the more exotic pegmatite minerals is in progress.

A coarse-grained simple pegmatite was obtained from a small dike cutting across migmatitic gneiss near Gravenhurst, Ontario (Lat. 44°55′N, Long. 79°20′W). No batholith of granite is known in the vicinity. The pink potash feldspar and white plagioclase were separated from each other and from quartz and magnetite. Both feldspars gave complex decrepigraphs. The D2 stage began at 612±20° (pink feldspar) and at 608±20° (white feldpsar).

The grey gneiss country rock of the above pegmatite was crushed, sieved, and separated into a light fraction, mostly feldspars, and a heavy fraction, mostly hornblende. Both gave complex decrepigraphs. The D2 stage began at 624±20° (light fraction) and 626±20° (heavy fraction).

Another similar pegmatite in similar country rocks, but containing a distinct core of magnetite, was obtained from a road cut in Algonquin Park, Ontario (Lat. 45°35′N, Long. 78°25′W). The D2 stages of decrepitation began as follows: 697°±20° (grey bands of migmatite), 654±30° (pink bands of migmatite), 640±30° (pegmatite minerals minus magnetite), and 605±20° (magnetite).

Granite Aplite. A specimen of pink aplite, forming a central part of a coarse pink pegmatite, was obtained from a road-cut between Bracebridge and Gravenhurst, Ontario (Lat. 45°05′ N, Long. 79°20′W). The minerals of the aplite appeared to be similar to those of the pegmatite (microcline, plagioclase, quartz, and biotite). The biotite was removed by acid treatment and jigging after grinding. The D2 stage of the remaining quartz and feldspar started at 602±20°.

A specimen of pinkish grey aplite, which forms one type of band in migmatite, at the same locality, was prepared as above. The D2 stage began at 617±20°. This type of aplite veins the dark bands of migmatite, but is older than the pegmatite-aplite dike.

Granite. A specimen of massive pink granite was obtained from a stone quarry in the Methuen batholith, at the west end of Stony Lake, Ontario (Lat. 44°35′N, Long. 78°00′W). It was prepared for decrepitation by acid treatment and magnetic separation after grinding and sieving, to remove biotite and other micaceous minerals, magnetite, and sulphides. The decrepitation was quite complex, but a vigorous D2 stage began at 695±20°.

A specimen of somewhat gneissic grey granite was obtained from the Elzevir batholith, about 3 miles NE of the town of Actinolite, Ontario (Lat. 44°44′N, Long. 77°20′W). This batholith has xenoliths of mica schist and gneiss, not restricted to its outer zone. The specimen was taken three-quarters of a mile inside the margin of the batholith. It was prepared as above. The decrepitation was complex, starting fairly abruptly at 360±20°C. A definite quartz inversion curve was evident, also another of the D5 type with a peak rate near 630°. A vigorous stage of the D2 type began at 690°±30° and rose to a peak rate near 790°. The only other important stage was of the D5 type, starting about 940° with a peak near 990°.

Granodiorite. The decrepitation characteristics of a specimen of pinkish-grey granodiorite from Nelson Island, B.C. (Lat. 49°40′ N, Long. 124°05′ W) were given previously (Smith, 1953). The D2 stage began at 750±20°.

A specimen somewhat similar to the above, but considerably coarser in texture, was obtained from the Skookumchuck intrusive, Sechelt

Inlet, B.C. (Lat. 49°45′N, Long. 123°50′W). Bacon (1952) gave the following mineral composition (from two micrometric analyses): quartz, 17, 23%, plagioclase (An_{24}) 60, 68%, microcline 12, 11%, altered ferromagnesians 5, 4%. The ferromagnesian minerals were removed after grinding. The D2 stage began at 715±20°.

Quartz Syenite. Two specimens from a quartz syenite intrusive 3 miles NE of Nelway, on the boundary between British Columbia and Washington were obtained from W. W. Moorhouse, who also supplied the petrographic data from micrometric counts.

The buff colored quartz syenite is coarse grained and has the following mineral composition: plagioclase (zoned, core An_{44} to border An_{10})—44%; cryptoperthite—31%; biotite—12%; quartz—9%; hornblende—3%; apatite and chlorite—1%. The micaceous minerals were removed by acid treatment and jigging.

The decrepigraph shows an anomalous (D3) and a quartz inversion (D4) curve. There appears to be an indefinite beginning of the D2 type curve soon after the quartz inversion, but there is a substantial acceleration starting at 710±20°.

The second specimen is from an aplite dike which cuts the above quartz syenite, but probably is genetically related to it. The rock is medium grained and has the following mineral composition: plagioclase (near An_{10}, zoned)—28%; potash feldspar—44%; quartz—24%; biotite (altered)—3%; micropegmatite—0.8%; apatite—0.2%; magnetite—0.2%. The decrepigraph shows a small anomalous (D3) and a normal quartz inversion (D4) curve. A D2 type rate curve began soon after the quartz inversion, probably at 610±20°C.

Quartz Monzonite. A specimen of light buff-grey colored medium-grained quartz monzonite was obtained from the Nelson stock, 1 mile west of Rossland, British Columbia.

The decrepitation started indefinitely between 300 and 400° and increased in rate to the quartz inversion temperature (575°), but this curve may be multiple. A definite increase began at 720±20° and no other stage was evident up to 1100°, the limit of heating. The last stage, while not very vigorous, had the characteristics of the D2 type of decrepitation.

Quartz Norite. A specimen of dark grey medium-grained quartz norite from Sudbury, Ontario, basic intrusive was obtained from a study suite. It was collected by E. S. Moore from the Creighton area. (U.T. No. P1–027).

The decrepitation of this specimen was complex. An anomalous (D3) type was the first stage, with a peak rate near 450°. A distinct but not strong quartz inversion stage was evident, and soon after this fell, a number of partly resolved stages were detected, with peak rates from 700° to 810°. These are of the D5 or decomposition type, and may be due to chloritic and micaceous minerals. The strongest stage began very abruptly at 830±20°, rose to a peak rate near 1000° and was still rapid at 1100°. From the shape of the rate curve, the last stage probably is of the D2 type.

Norite. A specimen of light brown norite from the Bushveldt Complex of South Africa was obtained from a study suite (U.T. No. PO–435).

The decrepitation of this specimen was unusual. The first stage of low rate started at 580±30° and rose to a peak rate near 660°. Another weak increase appeared to start on the descent of the first curve, near 750°. A very vigorous stage began at 1010±20° and rose to a peak rate near 1050° but was still fairly vigorous at 1100°, the limit of heating. The cause of the first stage is unknown but the last stage probably is of the D2 type, due to solid inclusions.

A preparation of the above rock was separated with bromoform into a light fraction (nearly pure white) and a heavy fraction (light brown). Decrepitation of the separate fractions showed similar rate curves up to 1000°. The light fraction showed the stage starting near 750° more distinctly, with a sharp peak at 780±20°.

Gabbro. A specimen of grey medium-grained gabbro from the Stillwater Complex, Montana, was obtained from a study suite (U.T. No. PO–512).

Decrepitation was found to be very complex. A feeble stage of the D3 type began near 400°, and a weak quartz inversion peak appeared. A fairly vigorous stage began at 600–700°, with a peak rate near 750°. This may be due to chlorite decomposition. Two sharper peaks near 800 and 825° may be due to micas. A very vigorous stage, also of the D5 type, had a peak rate near 940° and may be due to decomposition of amphibole. On the downward slope of this curve, a new stage, possibly of the D2 type, began abruptly at 980°±30° and was still rising in rate at 1100°, the limit of heating.

Diabase. The diabase from the south shore of Great Slave Lake described previously (Smith, 1953, p. 460) was retested up to a higher temperature. Substantially no decrepitation was detected up to 900°C. Thereafter a very weak stage was detected, and a very vigorous stage began abruptly at 1070±20° and was still rising in rate at 1140°, the limit of heating. Presumably this is the D2 stage, but other causes were not eliminated.

Olivine Gabbro. A specimen of olivine gabbro from Carsaig Bay, Isle of Mull, was available for testing. This was collected by W. W. Moorhouse (U.T. No. Pl–322) from a dolerite sill, 6 feet thick, in sandstone.

It contains abundant plagioclase, with pyroxene and some olivine. There is a little alteration evident; the pyroxene contains some patches of felted crystals, possibly amphibole, and some carbonate is present. Most of the crystals are fresh and inclusions are scarce; a few of greenish brown (partly devitrified) glass were seen in the plagioclase.

Decrepitation was found to be relatively slow, starting indefinitely near 550°. A D5 type increase with a peak rate at 915±20° possibly is due to decomposition of amphibole. A definite start of a D2 type curve began at 960°±30° on the descent of this curve, and reached a peak rate near 1030°. No other increase was evident up to 1120°, the limit of heating.

Discussion and Conclusions

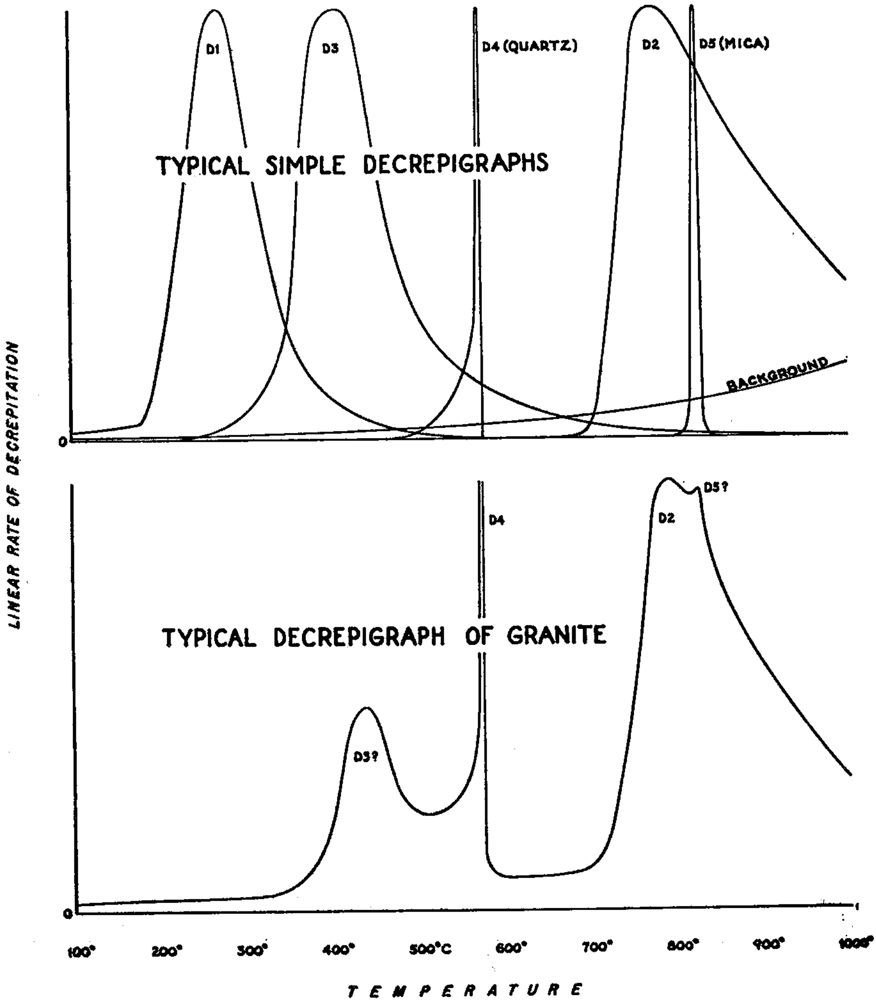
Decrepigraphs of igneous rocks are complex and a considerable amount of careful investigation would be necessary before the several causes could be given with certainty. In this preliminary study, the knowledge gained from decrepitation of metamorphic minerals and rocks (Smith 1952*b*, 1953*a*) was applied qualitatively to igneous rocks, but there are no new facts presented which aid in the identification of the various stages.

The accompanying figure shows the general shape of decrepigraphs discussed below.

Decrepitation due to filling of two-phase fluid inclusions by the liquid phase (D1) is not a characteristic of the igneous rocks tested. However, it has been detected in pegmatitic quartz (Peach, 1951) and secondary two-phase fluid inclusions have often been noted in quartz of granite (Smith, 1953). Therefore absence or presence of the D1 stage is not critical in this discussion.

Decrepitation due to inversion of quartz (D4) is readily detected, and therefore is typical of the acid igneous rocks. Presumably the sounds are due to the volume increase (below and at 573°C) which breaks multi-mineral fragments.

Decrepitation due to thermal decomposition (D5) often occurs in igneous rocks which contain phyllosilicates such as muscovite, biotite, chlorite, and serpentine, and other hydrous minerals such as epidote and amphibole. Each has a characteristic range of temperature at which decomposition gives detectable sounds. This might prove to be a useful petrographic method for determining the mineral types present in deuterically altered ferromagnesian minerals, for example. This effect was greatly reduced in the rocks studied, first by selecting relatively fresh rocks, and second by treatment of the pulverized rock with hot hydrochloric acid before heating in the decrepitation apparatus.



It was not determined with certainty whether anomalous decrepitation (D3) (Smith & Little, 1953) is present in the decrepigraphs of igneous rocks. Some of the acid rocks have a stage of decrepitation which begins indefinitely between 300 and 400°C and reaches a peak rate between 400 and 500°C. This might be due to the anomalous effect which is characteristic of minerals which have crystallized from a water solution, or more probably might be due to primary or secondary solid or complex inclusions (Smith, 1953, 1954) trapped in the minerals in a late stage of magmatic crystallization.

To some extent, the selection of one stage of decrepitation as being due to primary solid inclusions, and therefore representing in some way the temperature of crystallization, was arbitrary. For example, decrepitation at an elevated temperature could be caused by melting instead of misfit of solid inclusions. Decrepitation due to melting is caused by the increase of volume when a silicate liquid forms at a mutual boundary of several minerals. Specifically, a ternary boundary between quartz, orthoclase, and plagioclase would begin to melt at 900–1000°C, probably far above the temperature during crystallization of these minerals in magmas, assuming the presence of water and other fluxes. Therefore decrepitation above 900°C in rocks of granitic composition was not considered to be due to misfit of solid inclusions. In some cases, the selection of the D2 stage was on the basis of being in accord with other facts, such as the melting temperature of basic rocks being higher than of acid rocks, and the maximum temperature experienced by minerals in igneous rocks being higher than of similar minerals in metamorphic rocks. However, in most cases the selection was because of the shape of the rate curve. The characteristic shape of the D2 rate curve of garnet and other high grade metamorphic minerals and rocks, and presumably of igneous minerals also, is a fairly rapid acceleration soon after the stage begins, followed by a more or less linear increase of rate to a peak 100°–200° above the beginning, and finally a slower decrease of rate, with continuous deceleration, to many hundreds of degrees above the beginning.

Keeping in mind the uncertainties of interpretation of the decrepigraphs, the D2 temperatures reported here, and previously, indicate the following relations in plutonic rocks.

(1) Acidic igneous rocks have D2 temperatures from 690° to 750° whereas acidic high grade metamorphic rocks have D2 temperatures below 710°, and generally between 600° and 700° (Smith, 1952*b*, and 1953*a*).

(2) Simple granitic aplites and pegmatites have D2 temperatures considerably below those of acidic plutonics, and in the general range of 600°–650°.

(3) Simple granitic aplites and pegmatites have D2 temperatures lower than those of the high grade gneisses which form the country rock in areas in which igneous batholiths are not exposed.

(4) Igneous intrusive rocks with compositions near gabbro have D2 temperatures near 1000°C.

(5) Quartz-bearing igneous intrusive rocks with composition between granite and gabbro have D2 temperatures between those of granite (700°) and gabbro (1000°).

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