DECREPITATION CHARACTERISTICS OF SOME HIGH GRADE METAMORPHIC ROCKS

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Abstract

The decrepitation characteristics of several types of high grade metamorphic rocks from 17 localities were determined. A similar stage of decrepitation was found in every specimen, starting at temperatures from 565 to 710° C., the average value being 633° C. The cause of this stage of decrepitation tentatively is interpreted to be due to the misfit of crystalline inclusions in the constituent minerals when they are heated above the temperature at which they crystallized.

Introduction

The decrepitation characteristics of a number of varieties of garnet were reported recently (Smith, 1952b). Several stages of decrepitation were recognized, and one, ascribed to differential thermal expansion of crystalline inclusions, was found to begin at some temperature between 300 and 700° C. This stage of decrepitation (here designated as the D2 stage) was found to be a function of the abundance of crystalline inclusions in the garnet. Grossularite and andradite were found to have a much lower D2 temperature than almandite and pyrope. Garnets of different composition from the one locality were found to have the same D2 temperature, and hornblende closely associated with almandite was found to have a D2 temperature very similar to that of the garnet.

The above data suggest the possibility that metamorphic minerals, which usually contain a great abundance of crystalline inclusions, may be found to have decrepitation characteristics which reflect the conditions during growth. Stated in another way, if decrepitation of metamorphic minerals beings at a temperature below that of formation, and continues above it, some change would be expected in the rate of decrepitation when the minerals are heated above the maximum temperature which they had already experienced. If a mineral be heated to some temperature, t, in the laboratory, then cooled, crushed, and heated again, a sudden increase in rate of decrepitation takes place at the temperature t. This fractional increase in rate of decrepitation at t is greater when the fractional degree of comminution after preheating is smaller. When the specimen is crushed before preheating and not afterward, there is practically no decrepitation until the temperature t is reached, and there is a very rapid increase immediately above t. Similarly, if a mineral encloses other minerals as it grows at temperature t, decrepitation should be greater above this temperature than below it (Smith, 1952a), and if all the minerals in one rock crystallized (or recrystallized) at the same temperature, they should have similar temperatures of D2 decrepitation. Taking this as a working hypothesis, it is unnecessary to separate single minerals of metamorphic rocks for decrepitation analysis, and the rock as a whole may be studied.

The interpretation of complex decrepigraphs is not simple and the criteria of cause of each stage have not been determined exactly. At the present time in this laboratory, the following criteria are being employed in the case of metamorphic minerals.

1) Decrepitation starting below 350°, usually between 200 and 300°, and not very vigorous, is due to filling of complex inclusions by the liquid phase. This is somewhat analogous to decrepitation of hydrothermal minerals due to filling of simple two-phase fluid inclusions by the liquid phase, and is virtually absent in garnet of regionally metamorphosed rocks. The symbol being used for this type of decrepitation is D1.

2) Decrepitation which starts fairly sharply at 300–700° C., rises within about 100° to its maximum rate, and continues for several hundred degrees, may be due to solid inclusions if no other facts conflict with this interpretation. Decrepitation beginning above 450° C. cannot be D1, if the solutions are aqueous. Below this temperature, ambiguity may be removed by use of a heated microscope stage. The symbol being used for decrepitation due to solid inclusions is D2.

3) Decrepitation which starts indefinitely, and continues to accelerate until nearly the peak rate is reached at 360–450° C. is characteristic of the soft hydrothermal minerals, and especially the carbonates. The cause has not been determined, but the facts that a) the curve of rate *vs* temperature resembles the curve of pressure *vs* temperature for water solutions, and b) the peak rate is near the critical temperature of water and salt solutions, both suggest that water in imperfections of the minerals may be responsible. The symbol being used for this type of decrepitation is D3.

4) Decrepitation due to inversion should begin and reach its peak rate within a few degrees, but in the case of quartz, there appears to be a preliminary decrepitation which is evident at least 70° before the inversion, continues to accelerate to a sharp peak rate at the α-β inversion ($573 \pm 3°$ C.), and then falls very rapidly. The symbol being used for decrepitation due to inversion is D4.

5) Decrepitation due to decomposition, such as dehydration of gypsum and goethite, usually is too faint to detect, unless the water condenses and boils on the walls of the heating device. Exfoliation of micaceous minerals, such as chlorite, usually can be detected by the apparatus now in use. This gives a rapid increase in rate, with a well-defined peak and rapid decrease in rate. When decomposition is suspected, the responsible

mineral can be determined by running the component minerals of the rock and comparing the peak rates. The symbol being used for decrepitation due to decomposition is D5.

6) The decrepitometric and microscopic data on metamorphic minerals recently obtained in this laboratory suggest that if liquids are present during growth, they are siliceous rather than aqueous, although water may be present as a component; the temperatures of formation are approximately 300–700° C.; contact metasomatism of limestone with formation of silicates takes place at approximately 300–500° C.; formation of garnetiferous granite gneiss takes place at approximately 600–700° C.

When a new technique is developed to study an old problem, there arises a choice of methods of use of the new data. One may set out to test each of the older hypotheses and theories by a suitable set of critcial experiments, or one may build a new set of internally consistent hypotheses to satisfy the new data. In the field of physical chemistry of metamorphic processes, for a long time dominated by abstruse and cyclic logic, the second course is indicated. The critical reader will have noted the mass of unwarranted speculations which have become interlocked and taught as fact. Temperatures of metamorphic grades are given, without a measurement having been made. Shearing stress is stated to be a phase determinant, without facts. Water solutions as interstitial catalysts are postulated, but the distinctive metamorphic minerals such as cordierite, almandite, staurolite, kyanite, etc., have not been synthesized in water solutions. Accordingly, generalizations made on the basis of the following decrepitation results will not be within the framework of any current theory of metamorphism.

The rocks selected for this series of tests contain minerals which have been found in preliminary studies to give fairly vigorous decrepitation. Very fine grained minerals, and soft minerals, generally give too faint or infrequent decrepitation for good rate analysis and recording by the present equipment. Therefore, the metamorphic rocks which give easily resolvable decrepitation are those of high grade regional and contact metasomatic type. While these types cover only a limited range of metamorphic conditions, they would serve to establish some limits of temperature during metamorphism, if the temperature during crystallization is reflected in their decrepitation.

Decrepitation Data

The decrepitation method has been described several times in the past by Scott (1948), Peach (1949), and Smith (1952a). A more complete description of the electronic system and heating apparatus is being prepared for publication.

The present standard method of treatment includes the following steps: a) crushing and sieving to −40+80 mesh, b) digestion in hot hydrochloric acid to remove carbonates if present, c) heating 1–3 cc of the preparation in the decrepitation apparatus at 10–20°C per minute, d) electronic analysis of the rate of decrepitation, recorded as a curve of rate *vs* time, with or without supplementary cumulative summation of the number of detected explosions, e) automatic temperature fiducial marks made on the rate/time curve at 20° intervals, and f) corrections applied to the interpolated temperature of discontinuities on the rate/time curves by a calibration chart prepared in October, 1950.

The probable error of reading a discontinuity on electronic decrepigraphs is about ±5°, and the accuracy of any one reading is about ±10°, determined by the scatter of values during the original calibration tests. Unless the discontinuities on the curves are very sharp, wider limits of accuracy, ±20°, are given below.

The following decrepitation data are grouped in several ways to answer a number of obvious questions which would arise as to the probable meaning of the results.

Different minerals in the same rock

Barton Mine, New York. Red garnet and green hornblende from the Barton Mine, New York, were previously reported to have a high temperature decrepitation beginning at 613±30 and 603±20° C., respectively (Smith, 1952b).

Willsboro, New York. An intergrowth of andradite garnet and white wollastonite from Willsboro, New York, obtained from Ward's, was separated into pure components after coarse crushing. The garnet was reported to have compound decrepitation, one curve starting between 300 and 400°, and another starting at 594±10° (Smith 1952b).

The Wollastonite decrepitated very vigorously starting at 275±20°, with a peak rate near 375°, and on the downward slope, an increase began at 581±20°. Considering the uncertainty of interpreting the complex curves, the high temperature decrepitation of both the garnet and wollastonite probably starts at the same temperature (590±20°, weighting in favor of the garnet results).

Different rock compositions in the same locality

O'Connor Lake, N.W.T., Canada. Two highly metamorphosed rocks from a band of schist and gneiss at O'Connor Lake. N.W.T. (Lat. 61°15′N, Long. 111°50′W) were available for testing. One specimen is a course grained garnetiferous gneiss, containing abundant pink feldspar, a little dark mica and pink garnet, and not much quartz. This began to decrepitate feebly at about 255°, increased somewhat after 330°, and reached a peak rate near 430°. The quartz inversion curve was evident but not high. A vigorous stage of decrepitation began at 635±20°, reached a peak rate near 700° and then fell rather rapidly. The other specimen is a coarse grained hornblende gneiss, containing dark green hornblende and clear, colorless, plagioclase. This began to decrepitate at 370±10°, and rose to a peak rate near 540°. Another increase began at 632±20°, with a peak rate near 730°. The temperature of beginning of the last stage of decrepitation of the two rocks is measurably the same (633±20°).

Similar rocks from different localities. a) Amphibolite

Barton Mine, New York. The decrepitation temperatures of garnet and hornblende from the Barton Mine, New York, may be taken to represent that of the rock in which they occur, since they are the principal minerals. The mean D2 temperature, weighted in favor of the value for the more abundant hornblende, is 606±30°.

Bryce Township, Ontario. A specimen of amphibolite from a small xenolith in granite was obtained from a suite collected by W. W. Moorhouse. The occurrence is in a granitic intrusion breccia, 50 feet from the contact with metamorphosed basalt, in Range 6, Lot 12, Bryce Township, 25 miles south of Kirkland Lake, Ontario (Map 50j—*Ontario Department of Mines*).

Very little decrepitation was detected below 500°. A rate curve began feebly at 525±30°, and increased at 640±20°, with a peak rate at 720±20°.

Cadillac Twp., Quebec. Two specimens of amphibolite schist from the O'Brien Gold Mine, Kewagama, Quebec, were obtained from a suite collected by R. Blais. Specimen A contains actinolitic hornblende, brown tourmaline, and some biotite. Apparently it has been derived from the regional greenstone by metasomatism. Specimen B contains less tourmaline, more biotite, and some chlorite. It occurs in close association with lenses of dark colored albite porphyry. Both specimens were treated with warm hydrochloric acid after grinding, to remove a small amount of a carbonate mineral.

Specimen A gave a complex decrepigraph. The first evident rate curve began at 342±20° and reached a peak rate near 440°. Another increase began sharply at 581±20° and this curve continued to increase in rate to 750°, the limit of heating.

Specimen B gave a somewhat similar complex decrepigraph, but the rate was only about one fifth of that of Specimen A. The first curve began at 425±40°, and the second, at 620±20°.

Calumet Island, Quebec. A specimen of amphibolite was obtained from a suite collected by W. W. Moorhouse from the property of New Calumet Mines, Ltd. This locality contains a complex group of rocks which have been interpreted to be due to metasomatic alteration of sediments by pegmatitic solutions (Moorhouse, 1941).

Decrepitation was very feeble until 652±20°, when a well-defined stage began fairly abruptly. The peak rate was above 750°, the limit of heating. The decrepigraph, corrected for heating rate lag, is shown in Figure 1.

Hybla, Ontario. A specimen of massive black amphibolite interbedded with crystalline limestone near Hybla, Ontario, was obtained from a suite collected by P. A. Peach, who interprets the occurrences as amphilolite developed in limestone due to pegmatitic metasomatism. The locality , 10 miles due north of Brancroft, is well known for a number of large bodies of granite pegmatitite (Ellsworth, 1932).

The decrepitation of this specimen (cleaned with hot hydrochloric acid to remove a small amount of carbonate), started at 335±20°, reached a peak rate near 420°, and began to increase again at 475±20°. This curve reached a flat maximum rate near 540°, began to increase again at 612±10°, and reached a peak rate near 720°. Some of the same preparation was treated with warm dilute hydrofluoric acid to remove most of the quartz and feldspar. The decrepigraph showed a decrease in the maximum rates, the curve starting at 335° was missing, the curve starting at 475° was of low intensity, and the highest temperature stage started at 625±10°, which probably is higher than the first value obtained.

Lake Athabaska, N.W.T. Two specimens of schistose amphibolite from the north shore of Lake Athabaska (Lat. 59°35′N, Long 108°40′W) were obtained from a suite collected by H. G. Harper. Both specimens are from different bands of amphibolite within garnetiferous granite, both of which may be metamorphosed sediments. Specimen A was from an underground working, and specimen B, from the surface, about 125 feet from specimen A.

Specimen A began to decrepitate vigorously starting at 370±20°, and reached a peak rate near 450°. An even more vigorous stage began less definitely at 595±20°, with a peak rate near 750°, the limit of heating.

Specimen B decrepitated less vigorously, starting at 360±20°. The rate reached a minor peak near 510°, then soon started up on a quartz inversion curve with a peak at 575±10°. On the fall in rate, an increase began at 595±20°., and the peak rate appeared to be near 750°, the limit of heating.

Long Lake, Olden Twp., Ontario. A specimen of gneissic amphibolite

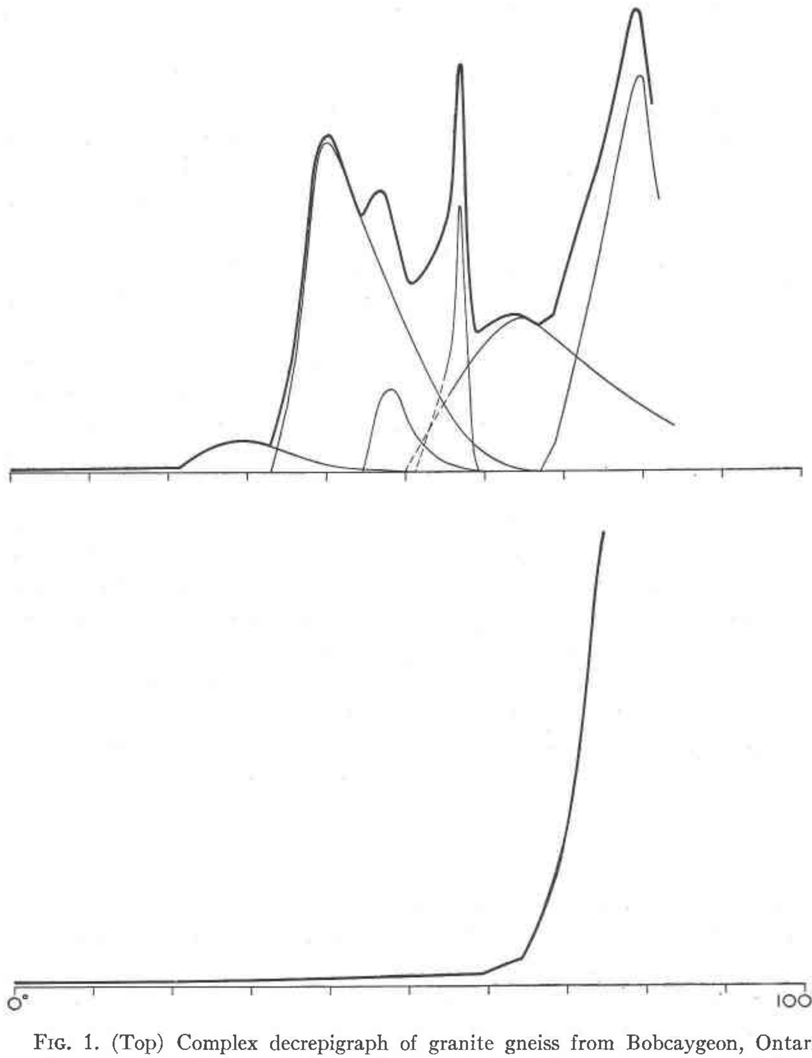

Fig. 1. (Top) Complex decrepigraph of granite gneiss from Bobcaygeon, Ontario, showing six stages of decrepitation and deduced simple rate curves. (Bottom) Simple decrepigraph of amphibolite from Calumet Island, Quebec.

was obtained from a suite collected by P. A. Peach. The locality is on the north side of Long Lake, Olden Township, Ontario, about one half mile west of the east end of the lake, and near a large batholith of granite and/or syenite. The specimen was taken one inch away from a dike of aplite, 10 inches wide, of which there are a number intruding the amphibolite. The geology of the area, which lies north of Kingston, was described by Harding (1947).

Decrepitation began sharply at 133 ± 10° and reached a peak rate near 240°. An increase began at 333 ± 20, and appeared to consist of several unresolved curves until 650 ± 20°, when a well-defined rate increase began. The peak rate was near 730°.

Yellowknife, N.W.T. Several specimens of greenish black amphibolite from Yellowknife, N.W.T., were obtained from a suite collected by R. W. Boyle. The location is north and west of the town, between the large granite batholith to the west of, and the sedimentary series to the east of, a belt of metamorphosed basalt and other extrusives. The geology of the area is shown in Maps 709A and 868A, Geological Survey of Canada.

A stage of decrepitation began at 355–410°, reached a peak rate between 400 and 500°, but sometimes increased again between 500 and 600°, probably due to quartz. A vigorous stage began at 610°–665°, with a peak rate above 720° in all cases. Variations within these limits are described below.

Wilberforce, Ontario. A coarse grained amphibolite from Wilberforce, Ontario, was obtained from a suite collected by W. W. Moorhouse. The specimen occurs one inch away from a pink pegmatite which contains large hornblende crystals with fluorite and calcite. The occurrence was described by Ellsworth (1932, pp. 213–227).

The decrepitation was found to be complex. The first rate curve began at 332 ± 10° and reached a peak rate near 400°. A small rate increase typical of quartz inversion obscured the start of a vigorous stage, but it appeared to begin at 575 ± 20°. The peak rate of this curve was at 700 ± 20°.

Similar rocks from different localities. b) Paragneiss

Bobcaygeon, Ontario. A specimen of coarse grained granite gneiss, probably a metamorphosed sediment, was obtained from a glaciated outcrop 30 miles south-west of Bobcaygeon, Ontario (Lat. 44°25′N, Long. 78°35′W). Under the microscope, the rock was seen to be composed of clear colorless microcline, nearly clear plagioclase, quartz, and a small amount of biotite. After crushing, the specimen was acid washed to remove a slight rusty stain, and all but traces of the biotite were removed by jigging and panning.

The decrepitation was vigorous and complex. The first stage began at 216 ± 20°. The second stage, apparently composite, began abruptly at 320 ± 20°, and reached a peak near 460°. A quartz inversion rate curve rose on the descent of the second rate curve. Another stage began sharply at 610 ± 20° and another began at 690 ± 20°. The last stage of decrepitation was vigorous, with a peak rate above 750°, the limit of heating.

In order to determine the effect of the mica alone, a concentrate containing mostly mica was prepared. This gave feeble decrepitation. All of the stages described above appeared, except the one at 690±20°. Considering the relative peak rates of the various stages in the two runs, it was deduced that the small amount of mica impurity in the sample was not responsible for any of the recorded stages of decrepitation.

Several runs were made, varying instrumental settings of gain and integration characteristics, and grain size and mineralogy of the specimen, in order to obtain maximum resolution of the complex series of rate curves starting between 500 and 700°. It was found that the D3 curve is much less evident using a finer grain size, such as −80+200, and, since the high temperature curves are easier to deduce and subtract from the composite when the base line is flatter, this grain size was used in most of the tests. In the decrepigraphs, the quartz inversion curve is considerably greater than the one immediately following, which makes resolution uncertain. Accordingly, some of the quartz was removed by heavy liquid separation from the slightly lighter feldspar. The remainder, free from mica and any other heavier minerals, if present, and containing only a small amount of quartz, gave the best rate curves for analysis.

The complex decrepigraph is shown in Figure 1. This is derived from one run, but qualitatively is representative of all of them. The curves are corrected for heating rate lag. Six component curves are show in the figure, but these are only tentative solutions.

Barry Bay, Ontario. A specimen of coarse grained banded grey paragneiss was obtained from a road cut one mile south of Barry Bay, Ontario (Lat. 45°30′N, Long. 77°40′W). In hand specimen, the rock is composed of nearly equal amounts of white feldspar and black hornblende, with a small amount of black biotite and quartz. After crushing, the specimen was digested in hot hydrochloric acid, and most of the biotite was removed by jigging and panning.

The decrepitation was fairly vigorous, and also complex. The first stage began at 340±20° and reached a peak near 410°. Another stage began between 400 and 500°. A very small quartz inversion curve was evident. The high temperature stage began abruptly at 700°±20°, and rose to a peak rate at about 820°.

Bracebridge, Ontario. A specimen of grey paragneiss, very similar to the above specimen from Barry Bay, was obtained from a road cut near Bracebridge, Ontario (Lat. 45°0′N, Long 79°20′W). In hand specimen it appeared to contain a little more feldspar than the former. It was cleaned and washed in a similar manner.

The decrepitation was vigorous and complex. The first feeble stage began between 200 and 300°. The first vigorous stage began at 340±20° and rose to a peak rate near 430°. Possibly another stage began between 400 and 500°. A good quartz inversion curve appeared. The high temperature stage began at 705±20° and rose to a peak rate near 810°.

Whitney, Ontario. A specimen of coarse grained, banded, grey, granitic gneiss was obtained from a road cut six miles east of Whitney, Ontario (Lat. 45°30′N, Long. 78°05′W). This rock varies in texture and composition and would be classed as a paragneiss, or migmatite, or gneissic intrusive by competing theorists of origin of granitic rocks. The ferromagnesian minerals are black biotite and hornblende, and quartz is present. The ratio of dark to light minerals is about that of granodiorite.

Decrepitation was fairly vigorous and very complex. The first stage started at 350±20° and reached a peak rate near 440°. Another stage, possibly compound, began near 490°. The quartz inversion curve was very evident. The high temperature stage began at 710±20° and reached a peak rate near 820°.

Similar rocks from different localities. c) Chlorite Schist

Soft minerals have been found to give very little detectable decrepitation, except at decomposition temperatures in some cases. Therefore chlorite schist is not suitable for decrepitation studies, unless it contains brittle metacrysts, which may be removed and treated separately.

Snow Lake, Manitoba. A specimen of garnetiferous chlorite schist from the 580 Level, Snow Lake Mine, Snow Lake, Manitoba (Lat. 54°50′N, Long. 100°00′W) was made available by F. Ebbutt. The garnet metacrysts are pale red in color, with abundant crystalline inclusions. They have mirror-smooth faces against the schist matrix, which consists of chlorite and a small amount of amphibole and white minerals. The rock is metamorphosed dike, and, from the abundance of dark minerals, probably was originally a diabase.

A preparation of the pure garnet gave a very little low temperature decrepitation. A small quartz inversion rate curve was recorded, near the peak of which a fairly vigorous stage began, at 580±20°. There appeared to be another increase at 678±20°, with a peak rate near 740°.

A preparation of the matrix, not chemically treated, gave very little decrepitation until a rate curve began at 563±10°. This seemed to be composite, and at 691±20° a very vigorous stage began.

Probably the highest temperature stage of decrepitation is due to decomposition of chlorite. The stage beginning at 580° (garnet) and 563° (matrix) may be the D_2 stage. A weighted mean value for the rock is 565±20°.

Similar rocks at different distances from intrusives

Renfrew, Ontario. Several specimens of impure crystalline limestone, near a large body of granite, were available in a suite collected by the writer several years ago. The locality is 4 miles south of the town of Renfrew, Ranges III and IV, Lot 1, Admaston Township. The geology of the area is shown on Map 53b, Ontario Department of Mines. The first tests gave no useful decrepitation results, due to the extremely vigorous effect of the carbonates, starting near 300°, which masks decrepitation of the various silicate minerals present. Therefore all carbonate minerals were removed with boiling concentrated hydrochloric acid before heating in the decrepitation apparatus.

Specimen A (F.G.S. No. 2) began to decrepitate at $210 \pm 30°$, reached a minor peak rate at $320 \pm 30°$, began to increase again at $340 \pm 30°$, reached another peak rate at $495 \pm 20°$, increased again to the quartz inversion temperature, and then began a vigorous stage which, when projected back, appeared to start between 525 and 620°. The sharpest positive change of rate was at $615 \pm 10°$.

Specimen B (F.G.S. No. 9) began to decrepitate indefinitely about $355 \pm 30°$, and the rate curve was obviously composite, with a peak rate at 590 ± 20. A more vigorous stage began at $608 \pm 20°$, reaching a peak rate at $695 \pm 10°$.

Specimen C (F.G.S. No. 35) began to decrepitate feebly about $275 \pm 30°$. Another stage began at $365 \pm 30°$, with a peak rate near 480°. A slight increase typical of quartz was evident, but a definite increase began at $585 \pm 20°$, with a peak rate at $715 \pm 10°$.

The temperatures of beginning of the highest temperature stage of decrepitation, and shortest distances of the specimens from the granite contact, are shown below in the table.

TABLE 1

Specimen	Distance from Contact	Temp. of D2
A	2100 ± 200 Feet	$615 \pm 10°$ C.
B	1550 ± 150	608 ± 20
C	100 ± 40	585 ± 20

Evidently there is no increase of the D2 temperature approaching the granite contact, and probably there is a decrease.

Yellowknife, N.W.T. Ten specimens of metamorphosed basalt, collected by R. W. Boyle along two east-west traverses in the vicinity of Yellowknife, were prepared in identical manner, including cleaning in hydrochloric acid, and were heated in the decrepitation apparatus with special precautions to keep all variables as constant as possible. The results are shown below in the table, which also includes the shortest horizontal distance of each specimen from the large granite batholith to the west, and brief petrographic notes.

TABLE 2

Line	No.	Decrepitation Temperatures			Dist. from Granite	Petrographic Notes
C	1	358±20	500±20	609±20	350 Feet	Amphibole, sodic plagioclase, quartz, magnetite.
C	3	398±20	(500)	623±20	2550	Amphibole, sodic plagioclase, epidote, magnetite.
C	5	360±30		668±20	4100	Amphibole, plagioclase, epidote-zoisite, carbonate
F	1		527±30	649±20	500	Similar to C 1
F	2	367±20	(530)	619±20	1200	Similar to C3 and C5
F	3	408±30		616±20	2000	Similar to C3 and C5
F	4	(450)		626±30	4000	Similar to C3 and C5
F	5	(317)		608±30	5000	Similar to C3 and C5
F	7a			659±20	6500	Similar to C3 and C5
F	9	411±10		664±20	9000	Chloritic, little amphibole.

Miscellaneous Tests. a) Granodiorite

A specimen of massive pinkish grey granodiorite from the Jervis Inlet area, B.C., was obtained from a suite collected by W. R. Bacon. It occurs along the south coast of Nelson Island. The mineral composition, including complex zoning of the plagioclase, has been described by Bacon (1952). While field evidence is not conclusive that this rock had an igneous origin, there are no contrary facts, and most field geologists would classify it as igneous by intuition.

Decrepitation was found to be very complex. A feeble stage began at 340±20°, and increased to a vigorous stage starting at 375±20°, with a peak rate near 450°. Another feeble stage began at 475±30°, and about 535° the quartz pre-inversion curve started to rise. There was a rapid rise and fall of rate at 575±10°. Two small increases in rate, not fully resolved, appeared between 585° and 660°. A vigorous stage began at 750±20°, with a peak rate near 775°. No other stage of decrepitation was evident to 1050°, except one of inversion or decomposition type at 970±20°.

Comparison of the decrepigraphs of para-gneiss and the above granodiorite indicated a general similarity, except that the highest temperature stage (D2)? is at a higher temperature in the latter case (635–710° for para-gneiss, 750° for granodiorite).

Miscellaneous Tests. b) Diabase

A specimen of diabase from a large dike was available in a suite collected by the writer from the south shore of Great Slave Lake, 26 miles west-south-west from the trading post of Snowdrift (Lat. 62°15′N, Long. 111°30′W). The specimen was taken 8 inches away from the contact which was found to contain a glassy selvage. Under the microscope, the grain size was found to be somewhat seriate, from approximately 0.5 mm to 0.02 mm. The largest crystals are 1) plagioclase, somewhat altered to an aggregate of unidentified minerals, and 2) pale greyish green pyroxene. Smaller crystals of plagioclase, pyroxene, bright green (pleochroic) amphibole, magnetite, and traces of quartz, carbonate and biotite are intimately intergrown. The crushed rock was treated with hot hydrochloric acid before heating.

Decrepitation was found to be too feeble to give a resolvable rate recording. An electronic scalar was attached to the ratemeter and the detected noises were totalled in 20° intervals. From these values were subtracted equivalent values obtained with no charge in the heating block. No significant residual was found up to 750°. This rock, undoubtedly igneous, has decrepitation characteristics very different from those of metamorphic rocks of similar chemical composition, *i.e.* greenstone and amphibolite.

Discussion of the Results

The decrepitation temperatures of the metamorphic specimens studied are shown in Table 3, classified tentatively as to the cause of each stage.

Too few specimens gave enough low temperature decrepitation (below 300°) to allow any quantitative generalizations to be made. However, the fact that hydrothermal minerals generally give vigorous decrepitation in this range, and also contain abundant multiphase fluid inclusions, while the reverse is true in the case of the metamorphic minerals, suggests that crystallization of the latter is not from aqueous solutions.

The peculiar D3 stage of decrepitation can be detected in most of the rate curves described above, but the meaning of this was not determined.

All of the specimens gave more or less vigorous high temperature decrepitation which started at 565° to 710°. The average value of the results from 17 localities is 633°, giving the mean of all values from one locality the same weight as single values. These results are quantitatively similar to those obtained with metacryst almandite garnet (Smith,

TABLE 3. SUMMARY OF RESULTS

Locality	Metamorphic Mineral or Rock	Probable Original Rock	Decrepitation Temperatures (° C.) D1	D2	D3	D4	Remarks
Barry Bay, Ont.	Hornblende Gneiss	Sediment	—	700±20	340±20	Quartz	
Barton Mine, N. Y.	Garnetiferous Hornblendite	—	—	606±30	—	—	
Bobcaygeon, Ont.	Granite Gneiss	Sediment	216±20	690±20	320±20	Quartz	Also 610±20, and 440±20.
Bracebridge, Ont.	Hornblende Gneiss	Sediment	(250)	705±20	340±20	Quartz	
Bryce Twp., Ont.	Hornblendite	Basalt	—	640±20	—	—	Also 525±30.
Cadillac, Que., A	Amphibolite	Basalt	—	581±20	342±20	—	
Cadillac, Que., B	Amphibolite	Basalt	—	620±20	—	—	Also 425±40.
Calumet Is., Que.	Amphibolite	—	—	652±20	—	—	
Hybla, Ont.	Amphibolite	Sediments	—	625±10	335±20	—	Also 475±20.
Lake Athabaska, N.W.T.	Hornblende Schist	—	—	595±20	365±25	Quartz	
Long L., Ont.	Amphibolite	—	133±10	650±20	333±20	—	Near aplite
O'Connor L., N.W.T.	Garnet Gneiss	Shale	(255)	635±20	(330)	Quartz	
O'Connor L., N.W.T.	Hornblende Gneiss	Basalt	—	632±20	370±10	—	
Renfrew, Ont.	Crystalline Limestone	Limestone	210±30	615±10	340±30	Quartz	2100′ from granite.
Renfew, Ont.	Crystalline Limestone	Limestone	—	608±20	355±30	—	1550′ from granite.
Renfrew, Ont.	Crystalline Limestone	Limestone	275±30	585±20	365±30	—	100′ from granite.
Snow L., Man.	Chlorite Schist	Diabase	—	565±20	—	—	
Whitney, Ont.	Granite Gneiss	Sediment	—	710±20	350±20	Quartz	Also 440°.
Wilberforce, Ont.	Amphibolite	—	—	575±20	332±10	Quartz	Near pegmatite.
Willsboro, N. Y.	Garnet	Limestone	—	594±10	(350)	—	Contact metasomatic rock.
Willsboro, N. Y.	Wollastonite	Limestone	—	581±20	275±20	—	
Yellowknife, N.W.T.	Amphibolite	basalt	—	634±40	(375)	Quartz	

1952 b). In the case of garnet, it was shown that the rate of decrepitation of this stage is directly related to the abundance of crystalline inclusions. By analogy, but with less certainty, the D2 stage of decrepitation of the high grade metamorphic rocks is due to crystalline inclusions in the constituent minerals. If this is correct, it may further be assumed that the majority of the inclusions were trapped during the primary crystallization. The present tentative interpretation of the decrepitation rate curves is that the beginning of the D2 stage represents the temperature of this crystallization, correctable for the effect of pressure during crystallization.

Internally, the results do not conflict with the above interpretation. The lowest D2 temperature (565°) was found in a garnet-chlorite schist, and the highest (near 700°) were found in gneisses which probably would initiate a petrological dispute as to whether they are very high grade metamorphic or igneous rocks.

In two cases (Renfrew, Ontario, and Yellowknife, N.W.T.) no gradient of D2 temperature was found outward from the granite contact. Probably facts such as this will be important in theories of formation of granite, if the D2 stage of decrepitation represents the maximum temperature to which the rock was subjected during metamorphism and intrusion (or granitization). Interpretation will be reserved until more detailed studies have been made around other batholiths.

Conclusions

High grade metamorphic rocks from 17 localities have a stage of decrepitation beginning between 565 and 710°, with an average value of 633° C. These results are qualitatively and quantitatively similar to those previously reported for metacryst almandite garnet, and probably are due to misfit of crystalline inclusions in the constituent minerals when they are heated above the temperature at which they crystallized, or when they are heated above the maximum temperature which they have experienced.

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