MEMOIRS OF THE COLLEGE OF SCIENCE, UNIVERSITY OF KYOTO, SERIES B,
Vol. XXXII, No. 4 Geology and Mineralogy, Article 3, 1966

Studies on Sandstones in the Maizuru Zone, Southwest Japan IV

Gamma Irradiation Effect on Quartz and its Application to the Study of Provenances

By

Tsunemasa SHIKI

Geological and Mineralogical Institute, University of Kyoto

(Received October 30, 1965)

Abstract

Research on provenance of the sandstones in the Maizuru Zone is very important for the study of geologic history during the Permian and the Triassic Periods in Japan. In this paper, the method and the results of application of gamma-ray irradiation effect on quartz for this study were reported.

Results of the experiments by HAYASE of the gamma irradiation effect on various rock quartz were first explained. Practical method adapted for the present study was stated. And, the results and their significances were expressed.

As stated by HAYASE, the smokiness grade of quartz is related to the amount of natural and artificial irradiation which permeated through the quartz, and to its original crystallization temperature and thermal history experienced after the primary crystallization. Quartz grains of low smokiness grade are the dominant constituent of quartz samples from the sandstones in the Maizuru Zone. These quartz grains originated, possibly, from the Yakuno intrusive rocks which intruded under low teperature condition, and/or from the Komori metamorphic rocks.

Introduction

The Maizuru Zone is a remarkable tectonic belt, 20 km to 30 km wide, which extends southward from Maizuru, north of Kyoto, obliquely crossing the general trend of the Sangun metamorphic belt, and turns westward near the Setouchi coastal region.

This zone is characterized by zonal arrangement of the Upper Permian, the Scytho-Anisian, the Upper Triassic, and the Yakuno Complex including the so-called Yakuno intrusive rocks and the Komori (-Maizuru) metamorphic rocks. Researches on the Maizuru Zone are of peculiar interest because of the importance of the geologic history of the Zone in studying the orogenic movement which occured during the Permian and the Triassic Periods in Japan.

The main part of this zone is inferred to have been formed as a result of the tectonic movements in the Permian and the Triassic Periods. It has been noticed that the Late Permian conglomerates contain pebbles which may be correlated with the Yakuno intrusive rocks and the Komori metamorphic rocks. On the other hand, several rock bodies which belong to the Yakuno intusives are intruded into the Late Permian formations. Some granites are unconformably coverd by the Triassic Shidaka group. Thus, the mutual relation between the sedimentary strata and the Yakuno intrusives accompanied by the Komori metamorphics is one of the most interesting problems concerning the Maizuru Zone.

As is well known, the provenance is one of the most important factors affecting the properties of sandstones and other sedimentary rocks. In the former paper, the results of the study of the source rocks, by heavy mineral analysis and by examination of gamma-ray irradiation effect on quartz, were briefly stated. The details of the study, however, were not presented there. In this paper, the methods and the results of the application of the gamma irradiation effect on quartz to the study of the provenance of sandstones will be explained rather in detail. The method itself is the same as that which has been discovered and developed by I. HAYASE (1961) and applied to studies on various igneous and metamorphic rocks.

Before going further, the writer wishes to express his gearty gratitude to Assist. Prof. I. HAYASE who gave him kind guidance on the principles and the techniques of the study by gamma-irradiation effect on quartz, and read his manuscript.

The gamm-ray used are of 2000 Curie coblat-60 gamma-ray source and in this connection the present writer wishes to thank Mr. KATANO of the Institute for Chemical Research, Kyoto University for all the troubles he has taken for the writer.

Acknowledgements are also due to Dr. D. SHIMIZU of Kyoto University and Dr. S. MIZUTANI of Nagoya University for their kind encouragement and valuable suggestions.

This paper was writen in commemoration of the near retirement of Prof. S. MATSUSHITA, to express the writer's gratitude for his continuous encouragement and guidance in various ways.

Gamma Irradiation Effect on Quartz

It has been well known that X-ray and gamma-ray irradiation account for smoky quartz. Fine crystals of smoky quartz, which are very common in pegmatite druse have been studied physically. Recently, HAYASE (1961) applied the gamma irradiation to the quartz of various rocks and detected the different geological occurrences by the wide range of the quartz smokiness grades.

Remarkable and geologically interesting is the difference of the smokiness grades of quartz grains of divergent origin. It can be easily understood that, the grade of smokiness depends upon the amount of natural and artificial irradiation (which permeated through the quartz), and upon the sensitivity of the quartz to the irradiation.

According to HAYASE, the smokiness of natural granite quartz of almost similar geological age depends mainly upon the radioactivity of granites. In granite samples of fairly high radium content ($2\text{-}3\times 10^{-12}$ g/g), *i.e.* 10 gram per ton uranium, their quartz is considerably smoky, and on the contrary, quartz included in feeble radioactive granite (under 10^{-12} g/g radium) shows no appreciable smokiness. It might be needless to say that the smokiness grade of quartz after the artificial irradiation is closely related with amount of the irradiation.

On the other hand, HAYASE found that, when irradiated artificialy by gamma-ray, quartz susceptivity is highest in volcanic rock quartz, intermediate in granite, and lowest either in schist quartz or in low temperature quartz of hydrothermal condition. After heating at 900-1000°C for 30 minutes (and irradiation of sufficient amount), quartz grains which have been affected by some hydrothermal solutions show marked increase of smokiness grade. Schist quartz also shows increase of its smokiness grade after heating under the same condition, although the degree of increase is not so large as in the case of the quartz of hydrothermal origin. Thus, smokiness grade seems to be related to its original crystallization temperature and thermal history experienced after the primary crystallization, which controls the imperfectness of the crystal structure of that quartz.

Naturally smoky quartz can be decolored by heating at 400°C for several hours, at 500°C for 30 minutes, or at 600°C for 5 minutes. The samples thus decolored can be smoked again by irradiation. After a test by gamma-rays of dosages of 10^5, 10^6, 10^7, and 10^8 roentgen, HAYASE found that, 10^7 roentgen is the dosage of saturation in case of cobalt 60 gamm-rays, That is, smokiness grade does not increase any more when irradiation reaches 10^7 roentgen.

The repetition of such decoloring and coloring by sufficient dosages (10^7 roentgen) does not change the degree of quartz smokiness in that irradiated state. If heated at over 900°C for 30 minutes, however, the degree of smokiness in that state is increased in quartz of any smokiness grade, as already stated.

From these experiments, HAYASE devised a generally applicable process of study by gamma irradiation on the susceptivity and the crystallization condition of rock quartz. This process can be applied to the study of quartz of various rocks in the Maizuru Zone, and to the study of the relations between the Yakuno intrusives (including the Komori metamorphics) and the sedimenary rocks,

Practical Method Adapted for this Study

Quartz grains were selected from the rocks by hand-picking and crushed to the size of 16-32 mesh. In the case of many sandstones, finer sizes than this mesh were used owing to the difficulty of getting together such coarse samples. Stains of the quartz colored by ferric or by manganese oxide were leached by immersing in concertric HCl for 24 hours.

Generally quartz grains thus leached mostly remain smoky as a result of natural radioactivity. These naturally smoky quartz grains were decolored by heating it at 600 °C for 5 minutes, for the purpose of eliminating the smokiness of the time effect of geological ages. The samples thus decolored, as well as the naturally colorless samples, were irradiated by cobalt-60 gamma-rays (as a rule 10^7 roentgen).

Smokiness in this state is peculiar to each quartz sample, mainly depending on its crystallization temperature. In the following pages, the degree of smokiness of quartz in this state will be called "Smokiness Grade".

Sometimes, the stains of quartz colored by ferric or by manganese oxide appeared again after the heating treatment. In these cases, dissolution of the oxide by immersing in HCl were performed after the heating or after the last irradiation.

For the purpose of making a comparative study of "Smokiness Grade", the quartz samples were stored in holes made in pasteboards which are usually used in foraminiferal study in general in Japan. The color of the floors of the holes, however, has to be white. Only 0.2 to 0.5 gram of quartz samples was sufficient for naked eye comparison of their Smokiness Grades. For the exact quantative measurment of their reflection, however, much greater amount of quartz is needed.

Results and their Singnificances

In the cases of Yakuno intrusive rocks, quartz grains leached by immersion in HCl were colorless, and the heating and also the gamma irradiation did not change, or hardly changes their color. It is remarkable that, even the quartz from quartz-porphyry was not colored or smoked. This result coincides well with the results of other authors concerning petrogenesis of these rocks. That is, the so-called Yakuno intrusive rocks are protoclastic rocks which intruded under the condition of low temperature, and by some pressure, into (and through) deep tectonic fissure zone, accompanied by the so-called Komori metamorphic rocks.

In the cases of the sediments in the Maizuru Zone, results of irradiation are a little more complex. In the former paper, it has been stated that the quartz grains selected from the sandstones of Maizuru, Yakuno and Nabae Group were not smoked by gamma irradiation at all. As a result of more detailed study, however, many sandstones which include the quartz having susceptivity by the irradiation were found. Several irradiated samples from the sandstones of the Permian Maizuru Group include a small amount of quartz of high Smokiness Grade and large amount of quartz of very low Smokiness Grade or colorless quartz. In a few cases, irradiated quartz of the Group shows faint smokiness in general. And in other samples of the Group, quartz is entirly colorless like that of the Yakuno intrusives.

In the cases of the Lower to Middle Triassic Yakuno Group, irradiation by gamma-rays produces quartz of various Smokiness Grades, most of them being low Grade or nearly colorless, as in the cases of the Maizuru Group. Many irradiated quartz grains of the Carnian Nabae Group show generally very low Smokiness Grade or are nearly colorless, and so they are of the monogenic origin.

From the above data, it can be said that, sandstones in the Maizuru Zone involve mostly quartz grains which have their origin in rocks intruded under low temperature condition or in metamorphics. Around the Maizuru Zone almost no outcrop of acidic rock is known except the Yakuno intrusives (and the Komori metamorphics) containing low temperature quartz. It may be said with reason that, the quartz grains of low Smokiness Grade that are the dominant constituent of quartz samples from the sandstones originated possibly, from the Yakuno inrtusive rocks and/or Komori metamorphic rocks.

Problems Remaining

1) Difference related with geological ages.

There is a working hypothesis that the Yakuno intrusives are some reactivated rocks as stated by READ (1955, 1957). It is highly probable that the primary intrusions of the rocks were under higher temperature condition than the later reaction rocks, and that the Smokiness Grade of quartz differs in accordance with their succession. In this case, the Smokiness Grades might show significant difference between the Maizuru Group and the Triassic Formations. Further studies based on a great many more samples are required.

2) Difference owing to divergence of localities also remains unexamined.

3) Effect of the thermal metamorphism by the intrusion of younger granite.

This is another interesting and important problem. The effect of the thermal metamorphism may probably differ in accordance to the temperature of the granite, the distance from the granite, and the time during which the quartz stayed under that condition. Studies are required on this direction also.

References

COHEN, A. T. and G. SUMNER (1958): Relationship among impurity contents, color centers and lattice constants in quartz., *Am. Min.*, **43**, pp. 58—68.

FRONDEL, C. (1962): The system of Mineralogy of James Dwight DANA and Edward Salibury DANA, Yale University, 1837—1892, 7th ed., Vol. III: Silica Minerals., New York, John Wileys and Sons, 334p.

HAYASE, I. (1961a): Gamma irradiation effect on quartz. -I. A mineralogical and geological application. *Bull. Inst. Chen. Research, Kyoto Univ.*, **39**, pp. 133—137.

HAYASE, I. (1961b): Quartz of the granite from Mt. Hiei and other localities, with special reference to artificial gamma-ray coloring phenomena and its geological and mineralogical significances. Hieizan, Kyoto Press, pp. 253—259. (in Japanese)

HIROKAWA, O., F. TOGO, & N. KAMBE (1954): Geological map sheet "Oyaichiba" and its explanatory text. (1 : 50,000) (in Japanese with English abstract)

HIROKAWA, O., H. ISOMI, & K. KURODA (1957): Geological map sheet "Obama" and its explanatory text. (1 : 50,000) (in Japanese with English abstract)

IGI, S. (1959): So-called "Yakuno intrusive rocks" in Maizuru District, Japan. *Bull. Geol. Surv. Japan*, **10**, pp. 1053—1061, (in Japanese with English abstract)

IGI, S., K. KURODA, & H. HATTORI (1961): Geological map sheet "Maizuru" and its explanatory text. (1 : 50,000) (in Japanese with English abstract)

Каменцеь, М. Е. (1963): О влиянии температуры кристаллизации на количество примесей входящих в структуру кварца, и изменение параметров элементарной зчеейки. Геохимия, **1963**, 6, 586-589. (An English translation is in *Geochemistry*, **1963**, no. 6 published by The Geochemical Society of U. S.)

KANO, H. (1961): On the "porphyroid"-like gneiss pebbles found in some conglomerates from the Maizuru District and their origin, *Jour. Geol. Soc. Japan*, **67**, pp. 49—57. (in Japanese with English abstract)

KANO, H., K. NAKAZAWA, S. IGI, & T. SHIKI (1959): On the high-grade metamorphic rocks of the matamorphic rocks of the Maizuru Zone. *Jour. Geol. Soc. Japan*, **65**, pp. 267—271. (in Japanese with English abstract)

KANO, H., K. NAKAZAWA, & T. SHIKI (1961): Considerations on the Permian back grounds of the Maizuru districts judging from the conglomerates. *Jour. Geol. Soc. Japan*, **67**, pp.463—475. (in Japanese with English abstract)

MURTY, R. C. (1965): Metamorphism and mineral identification by gamma-ray methods, *Nature*, London, **205**, (4966), pp. 60—61.

NAKAZAWA, K. (1958): The Triassic System in the Maizuru Zone, Southwest Japan. *Mem. Coll. Sci. Univ. Kyoto*, Ser. B., **24**, pp. 265—313.

Пузанов, Л. С. & Л. П. Кудакоьа (1964): К вопросу об определении относительных п авсолютных температур образавания горных рород., Геохимия, **1964**, 12, 1319—1324. (An English translation is in *Geochemistry*, **1964**, no. 12, published by The Geochemical Society of U. S.)

RITTER, C. J. & W. H. DENNEN (1964) : Color center zonation in quartz. *Bull. Geol. Soc. Amer.*, **75**, pp. 915—916.

SHIKI, T. (1959): Studies on sandstones in the Maizuru Zone, Southwest Japan -I, Importance of some relations between mineral composition and grain size. *Mem. Coll. Sci. Univ. Kyoto*, Ser. B., **25**, pp. 239—245.

SHIKI, T. (1961): Studies on sandstones in the Maizuru Zone, Southwest Japan -II, Graded bedding and mineral composition of sandstones of the Maizuru Group., Ibid., **27**, pp. 293—308.

SHIKI, T. (1962): Studies on sandstones in the Maizuru Zone, Southwest Japan -III, Graywacke and arkose sandstones in and out of the Maizuru Zone., Ibid., **29**, pp. 291—324,

SHIMIZU, D. (1962): The Permian Maizuru group, its stratigraphy and syntectonic faunal succession through the latest Paleozoic orogeny., Ibid., **28**, pp. 571—609.
The Association for Geological Collaboration of Japan (1965): The geologic developments of the Japanese Islands, Tsukiji Shokan, Tokyo, 442 p.

Errata of Part 3, (Graywacke and Arkose Sandstones in and out of the Maizuru Zone)

Page	Line (Place)	For	Read
294	10	develope	develop
294	24	is	in
294	3 from the base	racks	rocks
296	18	10	10^7
296	10 from the base	and quartz grains were picked and crushed.	and crused, and quartz grains were picked.
297	18	quarts	quartz
300	2	the size in	the size is
303	21	rock fragment	rock fragments
305	17	proevious	previous
306	2	frakment	fragment
307	25 (title)	Formation	Formations
310	24	develope	develop
310	28	develope	develop
310	4 from the base	develope	develop
313	8	developes	develops
314	Fig. 12 (explanation)	Mizutani	MIZUTZNI
316	3 from the base	cata clastic	cataclastic
317	26	soting	sorting
317	9 from the base	plutionic	plutonic
318	10	grawackes	graywackes
318	6 from the base	surpentine	serpentine
320	13	develope	develop
320	24	adamerite	adamellite
322	4 from the base	in (Japanese	in japanese

Explanation of Plate 1

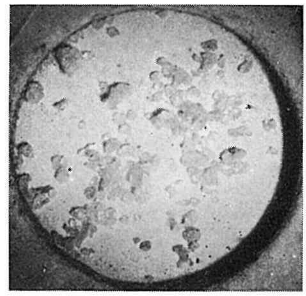
Fig. 1. Storage of irradiated quartz sample

Figs. 2-14. Irradiated quartz of various rocks

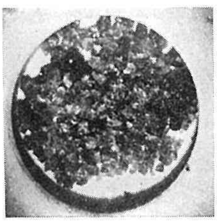
2. Quartz-porphyry: Kitashirakawa, Kyoto, (Paleogene) ×3
3. Quartz-schist; Wakayama Prefecture. ×3. Exposure time is ½ in comparison with other figures.
4. Kitashirakawa granite; Kitashirakawa, Kyoto, (Paleogene), ×2
5. Rokko gramite; Kobe, (Late Cretaceous?), ×2
6. Sanin granite; Kinosaki, Kyogo Prefecture, (Late Cretaceous?), ×2
7. Ryoke gneissose granite; Kasagi, Kyoto Prefecture, (Cretaceous?), ×2
8. Yakuno intrusive rock ("Older granite"); Okadayuri, Maizuru, Kyoto Prefecture, col. no. 571117-3a, (Latest Permian), ×2
9. Yakuno intrusive rock ("Older granite"); Okadayuri, Kyoto Prefecture, 571117-3b, (Latest Permian), ×2
10. Yakuno intrusive rock ("Older granite"); Miharaiyama, Hyogo Prefecture, 211, (Latest Permian), ×2
11. Porphyritic dike of "Older granite"; Sugasaka, Maizuru, Kyoto Prefecture, (Latest Permian or Triassic), ×2
12. Yakuno intrusive rock ("Older granite"): Okadayuri, Kyoto Prefecture, 571117-3c, (Latest Permian), ×3
13. N_2 formation, Nabae group; Sugasaka, Kyoto Prefecture, 581019-6, >32 mesh, (Carnian), ×3
14. N_2 formation, Nabae group; Sugasaka, Kyoto Prefecture, 581019-6, <32 mesh, (Carnian), ×2

1

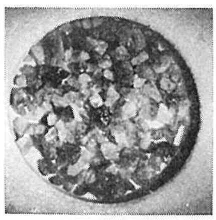
2



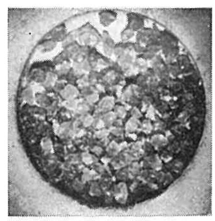
3



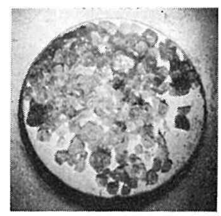
4



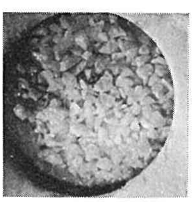
5



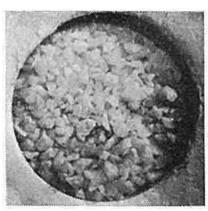
6



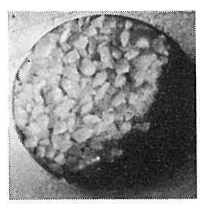
7



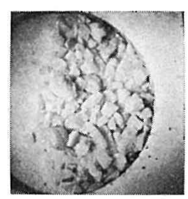
8



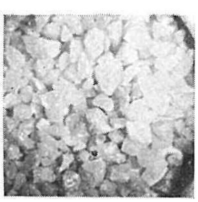
9



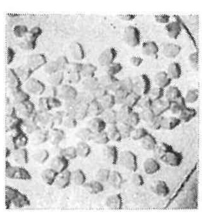
10



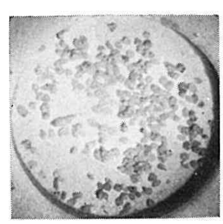
11



12



13

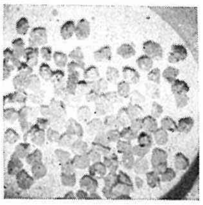


14

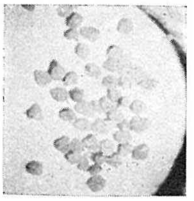
Explanation of Plate 2

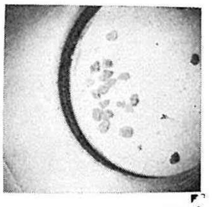
Figs. 15-30. Irradiated quartz of various rocks

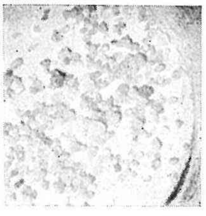
15. N_2 formation, Nabae group; Sugitani, Ayabe, Kyoto Prefecture, (Carnian), ×3
16. N_2 formation, Nabae group; Monobe, Ayabe, Kyoto Prefecture, col. no. 571131-12a, (Carnian), ×2
17. N_2 formation, Nabae group; Monobe, Ayabe, Kyoto Prefecture, 571131-12b, (Carnian), ×3
18. Heki formation; Yakuno, Kyoto Prefecture, N705, (Carnian), ×2
19. Yakuno group; Narawara, Kyoto Prefecture, 55316-1, (Lower Triassic), ×3
20. Yakuno group; Narawara, Kyoto Prefecture, 54111-2-2, (Lower Triassic), ×2.2
21. Yakuno group; Okuyama, Kawahigashi, Kyoto Prefecture, 54111-5, (Lower Triassic), ×3
22. Yakuno group; Kawahigashi, Kyoto Prefecture, 560307-5, ×2.2
23. Shidaka group; Okadayuri, Maizuru, Kyoto Prefecture, 59223-2, (Lower Triassic), ×2
24. Maizuru group; Narawara, Kyoto Prefecture, 55316-5a, (Upper Permian), ×2. Exposure time is ½ in comparison with other figures.
25. Maizuru group; Shidaka, Maizuru, Kyoto Prefecture, 610294, (Upper Permian), ×2
26. Maizuru group; Okuyama, Kawahigashi, Kyoto Prefecture, 54317-1, (Upper Permian), ×2
27. Maizuru group; Kawahigashi, Kyoto Prefecture, 54112-1'a, (Upper Permian), ×3
28. Maizuru group; Kawahigashi, Kyoto Prefecture, 54112-1'b, (Upper Permian), ×2
29. Maizuru group; Kawahigashi, Kyoto Prefecture, 54318-2, (Upper Permian), ×2. Exposure is ½ in comparison with other figures.
30. Maizuru group; Narawara, Kyoto Prefecture, 55316-5b, (Upper Permian), ×3

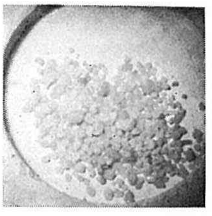

15

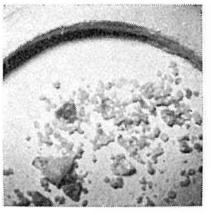

16

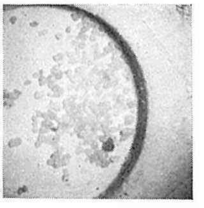

17


18

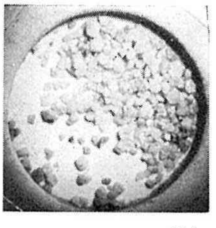

19

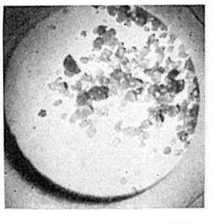

20

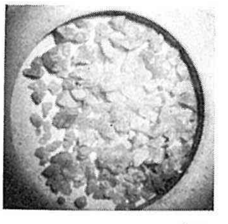

21

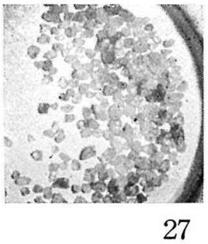

22

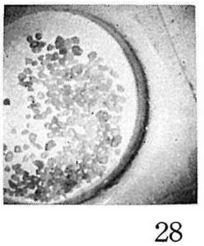

23

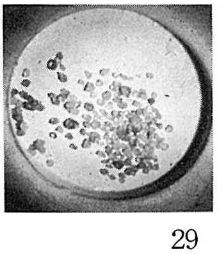

24

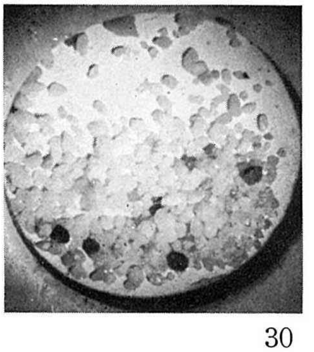

25


26


27


28


29


30