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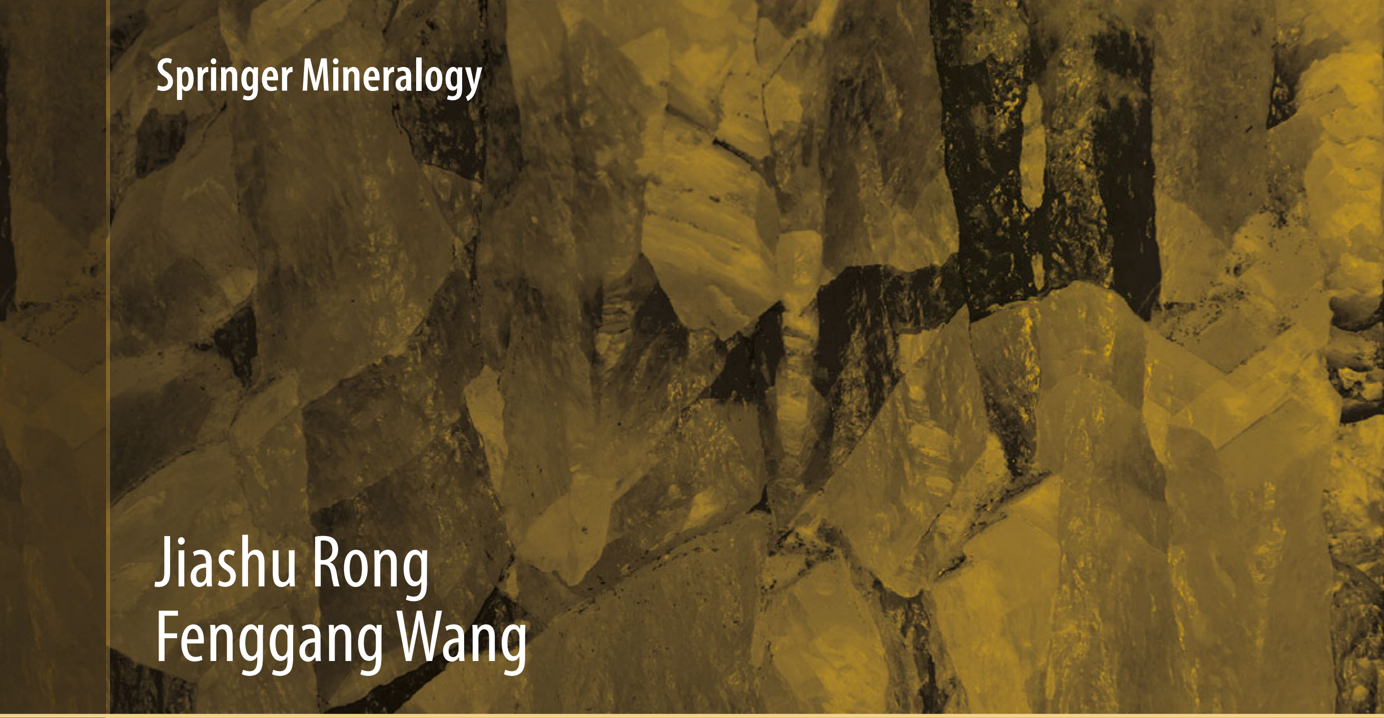

Jiashu Rong
Fenggang Wang

Metasomatic Textures in Granites

Evidence from Petrographic Observation

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Jiashu Rong
Beijing Research Institute of Uranium Geology
Beijing
China

Fenggang Wang
Beijing Research Institute of Uranium Geology
Beijing
China

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Foreword 1

The book “Metasomatic Texture in Granites” is an atlas, in which the authors stress on the exposition of metasomatic textures and their formation mechanisms than other atlases both at home and abroad. In the book the metasomatism of various minerals, including albite, K-feldspar, muscovite, biotite, quartz, beryl, calcite, apatite, etc., is systematically discussed with clear, colored, microscopic pictures and explanations.

As a new attempt and development, the authors advance both hetero-oriented and co-oriented patterns of monomineral replacement in granites. The hetero-oriented replacement pattern includes the albitization and the K-feldspathization occurring at grain boundary of plagioclase with K-feldspar and of two K-feldspars, the muscovitization and biotitization at grain boundary of K-feldspar with mica and of two biotites, etc. The co-oriented replacement pattern includes mainly the deanorthitization of plagioclase, co-oriented albitization of K-feldspar, co-oriented muscovitization and chloritization of biotite, etc. The classification of mineral replacement reflecting the objective facts is of important significance.

The authors elaborate systematically the formation mechanism of mineral replacement, its genetic hypotheses, the passage for hydrothermal fluids, the replacement mechanism (dissolution-precipitation and ion-exchange), etc. Myrmekite is the most visible texture in granite. So far there are six genetic hypotheses about its formation mechanism, including nibble replacement. After quoting extensively to discuss the possibilities and contradictions of the other hypotheses, the authors prove that myrmekite is actually formed from K-feldspar replaced by Na plus Ca bearing fluid, forming the replacive plagioclase leaning against a feldspar crystal either plagioclase or K-feldspar. As the SiO_2 content needed to compose replacive plagioclase is less than that contained in the replaced K-feldspar, the surplus SiO_2 remaining in situ produces the vermicular quartz grains.

The book is written by Prof. Jiashu Rong on the basis of ample material collected by all means after his retirement with the encouragement given by Prof. Lorence Collins. Rong hopes that his knowledge and judgement obtained in his study on metasomatic textures in granites reflect the objective situation. However, whether it is a perfect reflection requires practical inspection and extensive review by all experts on the line. There might be different viewpoints about some phenomena for our further discussion and in-depth study before we get a scientific explanation.

The research on metasomatic textures in granites is a supplement for igneous petrography. Moreover, it is of valuable reference to the study of formation mechanism of granite. I hope the book would be published as soon as possible, so as to promote an intensive communication and a deeper study on it.

May 2015

Qihan Shen
Academician of the Chinese
Academy of Science

Foreword 2

The monograph "Metasomatic Texture in Granites" is a research achievement of researcher Dr. Jiashu Rong and his team through their hard working for years. The phenomena described in the book can commonly be found by those who deal with identification of granite and gneiss.

Based on detailed observation on granite, the authors emphasize that metasomatic textures are basically classified into two patterns: (1) hetero-orientation (nibble) replacement; (2) co-orientation replacement. This brand-new idea is helpful to understanding of metasomatic texture under microscopic observation.

I had no concept of co-orientation or hetero-orientation in my teaching and research work in previous years, so I could not clearly explain the metasomatic texture in granites. For instance, some plagioclase inclusions in K-feldspar phenocryst have got clear rim while the others have not. I had no idea to explain it without consideration of coherence of the crystallographic orientation between plagioclase with K-feldspar. After reading the book, at once I have become clear minded.

Besides clear rim, many problems are involved in the book, such as myrmekite, perthite, antiperthite, especially the historical analysis of metasomatic processes, which provides a new viewpoint on the superposition of multiple metasomatic processes in granite and on the relationship of rare metal mineralization with metasomatism in granite.

Petrologists have been discussing the origin of myrmekite for 140 years since its discovery and had been formulating various presumptions on it. In this book, many examples are enumerated, indicating that myrmekite appears mainly in the rim of plagioclase contacted with differently oriented K-feldspar as well as at the boundary between two K-feldspars, forming the swapped myrmekite. The authors also discovered the existence of residue of perthitic albite, even K-feldspar with their original orientation preserved in myrmekite. Therefore, it gives a firm support to the theory of hetero-orientation metasomatic genesis of myrmekite.

It is appreciable that the authors submit their academic ideas on metasomatism on the basis of a scientific analysis to the viewpoints of previous geologists, so as to create a good atmosphere for an academic exchange. For example, the authors advance their practical ideas on disputed areas of granite as the genesis of perthite, the difference between phenocryst and porphyroblast, etc. The authors also make an analysis on the genesis of chloritization of biotite in accordance with data referring to high-precision transmission electron microscopic images, and convincingly point out the two kinds of mechanism for chloritization. Though the question of whether plagioclase may be replaced by co-oriented K-feldspar is still in debate, in the book the authors also refer it with experiment data published by Lobatka (2004), thus bringing a new way toward its resolution.

In brief, the authors show us the phenomenological characters of metasomatic texture in an all-round way by analyzing them cautiously and systematically and making a penetrating explanation, thus guiding us to see the essence through the phenomena. So it is a valuable monograph about petrography, which is of great practical reference to the people dealing with the identification of rocks and minerals and the study on granite-related rocks.

Origin of granite has been a puzzling topic in the field of geology, while the study of metasomatic texture in granite is exactly one of the keys to the mystery. As far as I know that the anatexis has been regarded as a main factor of genesis of migmatite at present. In this regard, the monograph is surely interesting for those who engage in research on either magmatic granite or metamorphic rocks.

June 2015

Zhendong You
China University of Geosciences

Foreword 3

Dr. Jiashu Rong is a senior petrologist in our Institute.

Since 1970s he has been making creative achievements in petrological study of granites in Southern China (uranium ore-field of Zhuguang, Gui-dong, Taoshan, Huichang, Jingtan, Motianling, etc.), in application of the method of induced fission tracks in uranium geology, in the survey of ura-ninite of 300 granite bodies in China, in the study of uraninite deposits of pegmatic granite of Hongshiquan and Danfeng, as well as in the petrological study of mantle xenoliths sponsored by China Natural Science Fund. In recent years he has been devoting his whole mind to metasomatic textures in granites. I think the following major points he proposed deserve to be emphasized.

1. Metasomatic texture in granites should be divided into hetero-oriented and co-oriented replacement patterns. The former is predominant. Its formation mechanism is of dissolution–precipitation. K-feldspar is the most easily replaced mineral for hetero-oriented albitization, K-feldspathization, quartzification, and muscovitization. The formation mechanism of co-oriented replacement of biotite by chlorite or muscovite is of ion-exchange. As for the co-oriented albitization of plagioclase or K-feldspar, the formation mechanism is to be explored.
2. The process of hetero-oriented replacement does not occur at random. It is controlled by two prerequisite conditions: a mineral prone to be replaced on the one side, and a same or similar kind of replacive mineral on the other side as nucleation substrate for replacive growth. Only when metasomatic process should have occurred, while the same or similar kind of the replacive mineral is absent, then an impurity may act as a nucle-ation substrate for the growth of a replacive mineral.
3. Co-oriented albitization is easy for plagioclase, but hard for K-feldspar. However, once K-feldspar is co-oriented albitized, it happens so rapidly and thoroughly, that the transition zone would be hardly observable.
4. The albite formed by co-oriented albitization of K-feldspar and the per-thitic albite may still be distinguished by their different forms and occurrences.
5. K-feldspar may be subjected to both hetero-oriented and co-oriented albitization. Although the former develops intensely, the latter does not happen at all. On the contrary, when the latter develops strongly, the former is still not enhanced. It implies that not only they took place

successively and individually, but also their formation conditions and environments are quite different. Therefore, it is reasonable and necessary to divide them and describe them separately rather than lump them together.

6. Inserting a quartz plate under crossed polars is a helpful procedure to determine the consistence of crystallographic orientations of tiny relics with surrounding minerals, in order to identify either hetero- or co-oriented replacement phenomena.
7. The small platy albite minerals in Li-F granites are of primary rather than "chaotic" metasomatic in origin.
8. Myrmekite is produced from K-feldspar replaced by plagioclase, as the SiO_2 content needed to compose replacive plagioclase is less than that contained in K-feldspar and the surplus SiO_2 remaining in situ produces the vermicular quartz grains.

Besides, he has got the following tendentious conclusions, such as (a) Quartz can not be replaced by alkali-feldspar (albite or K-feldspar); (b) Similar to the condition in magma, the growth ability of replacive albite along the axes *a* and *c* is much greater than along the axis *b*; (c) Perthitic albite in K-feldspar is mainly formed by either unmixing of solid solution or simultaneous crystallization of K-feldspar rather than replacement origin; (d) The idiomorphic interlocking crystal of K-feldspar with albite is primary rather than metasomatic origin; (e) Megacryst of K-feldspar in granitic rocks is basically of phenocryst or its residue rather than porphyroblast; (f) It is possible to distinguish the successive sequence of multiple superimposed metasomatic processes according to the rule of mineral replacement.

What is mentioned above is only my understanding. And I believe in the book there must be many valuable viewpoints for readers to find.

In conclusion, the book represents a creative research achievement on metasomatic textures in granites. It is a rare high-level petrography monograph in recent years and worth to publish in both Chinese and English languages.

July 2015

Letian Du
Beijing Research Institute of Uranium Geology

Preface

After completion of crystallization from a magma, under subolidus at about 500 °C along with slow decrease of temperature and reaction of residual fluids, the primary minerals in granite may undergo a change either in composition or in structure. Thus, K-feldspar may exsolve albite lamella and may be transformed from orthoclase into microcline. These changes are of subsolidus re-organization, but not metasomatic phenomena, and the bulk compositions are not modified.

However, after formation of granite, the hydrothermal fluid, either relevant or irrelevant to magmatic processes, can penetrate into solidified granitic rocks, resulting in the instability or change of an individual primary mineral followed immediately by precipitation or crystallization of a more stable new mineral, thereby partly changing the primary mineral into a new one.

Lindgren (1925) stated: "Replacement in solid rocks consists in solution of the host mineral, followed immediately by deposition of an equal volume of the guest mineral……The volume of the replacing mineral equals the volume of the mineral replaced. Deposition follows so closely upon solution that at no time can any open space be discerned under the microscope."

Mineral replacement, such as cation exchange, deuteric alteration, as well as pseudomorphism, chemical weathering, leaching, diagenesis, and metamorphism are all linked by common features in which one mineral is replaced by a more stable one (Putnis 2002).

Besides, under new physical–chemical circumstances, the compositional transformation of an old mineral locally or wholly into a new one by ion-exchange, without dissolution–reprecipitation, is also a reaction product of metasomatism.

Generally speaking, the metasomatic process is characterized by the following features:

1. A rock remains in solid state as the whole metasomatic process proceeds.
2. Transformation (reformation) or dissolution of a previous mineral occurs almost simultaneously with formation of regenerated minerals without any evidence of open space.

3. The volume of the replacive guest mineral is equal to the volume of the host mineral that is replaced.[1]

The process and the phenomenon of a primary mineral replaced by a newly formed mineral are always indicated by the name of replacive mineral plus -ization or -ification. For example, the replacement of K-feldspar by albite is called albitization of K-feldspar; the replacement of biotite by chlorite is chloritization of biotite, the replacement of K-feldspar by quartz is quartzification of K-feldspar, etc. The degree of replacement, i.e., the degree of -ization or -ification may be described as weak, medium, intense, and complete.

If one mineral is partially dissolved by one solution, resulting in presence of a free space where new minerals may be deposited later rather than simultaneously, this process should not be treated as a replacement but as a type of filling.

Metasomatism is conceptionally different and distinguished from the isomorphism that occurs during magmatic crystallization. Metasomatic phenomena are similar to cotectic ones when two minerals simultaneously crystallize, so they may often be confused. Moreover, metasomatism is easily indistinguishable from unmixing (exsolution) in a solid solution.

Key evidence of replacement is the presence of relics of replaced minerals in the replacive mineral. However, such relics should be distinguished from the crystals formed by simultaneous crystallization and from normal inclusions in igneous rocks. The relics also should be determined as a real residue from the replacement seen at present rather than an inherited relict from the previous replacement.

On the basis of hundreds of thin sections from granites in China, new recognition of metasomatic phenomena has been obtained. According to the consistency of orientations between replaced and replacive minerals, metasomatic textures are basically classified into two patterns: (1) hetero-oriented replacement; (2) co-oriented replacement. Hetero-oriented albitization of K-feldspar is quite distinct from co-oriented albitization of K-feldspar. They occurred separately and individually without a transition. Their formation conditions must be different from each other, although both of them generally are all called albitization of K-feldspar.

Origins of clear albite rim, intergranular albite, small platy albite, K-feldspathization, quartzification, chloritization, muscovitization, beryllization, myrmekite (myrmekitization), perthitic albite, antiperthite, as well as K-feldspar megacryst are comprehensively discussed and reasonably explicated. Metasomatic regulations and superimposed metasomatic processes are clearly illustrated by a series of color microphotos taken with quartz plate inserted under crossed polars.

[1]There is another point of view for "unequal volume replacement": during metasomatism, the introduction of a large amount of K_2O, Na_2O, SiO_2 is proceeded without carrying out of the matching volume of CaO, MgO, FeO, Fe_2O_3, resulting in upswelling and transformation of geosyncline sedimentary rocks to large-scale alkaline-rich acidic granite bodies (Geological department of Nankin University 1981; Granitoids of various ages in southern China and their relationship with metallogenesis (in Chinese) p. 381).

The metasomatic phenomena discussed in this book apply to single individual mineral replacements in granites. The recrystallization and the replacement of a primary mineral by an aggregate of new minerals are more complicated and not discussed here.

Beijing Research Institute of Uranium Geology — Jiashu Rong
February 2015 — Fenggang Wang

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Putnis A (2002) Mineral replacement reactions: from macroscopic observations to microscopic mechanisms. Mineral Mag 66:689–708

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Professor Lorence Collins, Department of Geological Sciences, California State University-Northridge, has been studying metasomatic phenomena in granites and shows his unique ingenuity in discussing the origin of myrmekite. The senior author had not known him until the senior author's short essay about metasomatic texture was transmitted to him in 1987 by an American participant in Guangzhou International Granite Congress. Soon the author received a reply from him, in which he expressed that he would like to communicate with those who have different points of views for in-depth discussion. With his constant encouragement and assistance, the senior author wrote two short articles entitled "Myrmekite formed by Ca- and Na-metasomatism of K-feldspar" (2002) and "Nibble metasomatic K-feldspathization" (2003) which were published on his website (http://www.csun.edu/~vcgeo005/ Myrmekite and Metasomatic Granite, ISSN 1526-5757). In 2006, the senior author accompanied by his son, Shenwen

Rong, visited Prof. Collins. With his warm invitation and guidance we made an on-the-spot investigation to Temecula and observed interesting thin sections. Afterwards, the senior author wrote the initial version of the book, i.e., a paper entitled "Two patterns of monomineral replacement in granites," which was published on his website in 2009 with his careful editorial handling. The above three papers were transformed by him into PDF documents (Nr45Rong1.pdf, Nr46Rong2.pdf and Nr55Rong3.pdf) in 2012.

The English version of this book was also attentively revised and carefully corrected by Prof. Lorence Collins. The authors would like to extend their special sincere thanks to Prof. Lorence Collins for his friendly assistance and frank communication.

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Contents