ISSN 2616-5872 Vol.7, Issue 5: 77-85, DOI: 10.25236/AJEE.2025.070510

Review on Myrmekite Structure: A Case Study in Lingshan Granite, China

Muhammad Talha[1,2,*]

[1]School of Mining Engineering, Jiangxi University of Science and Technology, Ganzhou, Jiangxi, 341000, China
[2]Graduate School, Jiangxi University of Science and Technology, Ganzhou, Jiangxi, 341000, China
talhatariq827@gmail.com
**Corresponding author*

Abstract: *Myrmekite, a quartz-plagioclase symplecticite commonly developed in granitic and metamorphic rocks, is widely recognized as a key indicator of sub-solidus reactions and metasomatic processes. Despite extensive research, its origin remains debated, particularly in complex magmatic-hydrothermal systems associated with rare-metal mineralization. Myrmekite in the Lingshan granitic pluton provides a clear record of fluid-rock interaction during the late magmatic to hydrothermal transition associated with rare-metal mineralization. Petrography shows two distinct types: (1) fine-grained myrmekite formed by early Na-Ca metasomatism along K-feldspar-plagioclase contacts, and (2) coarser myrmekite produced by partial replacement of matrix quartz by plagioclase. Both types were subsequently modified by K-rich fluids that generated wart, ghost, and other types of myrmekite textures. These features collectively demonstrate that myrmekite formation reflects sequential pulses of magmatic fluids, first Na-Ca rich, then K-rich released during cooling of the Lingshan intrusion.*

Keywords: *Myrmekite; Magmatic fluids; Metasomatism*

1. Introduction

Myrmekite is a mineral intergrowth characterized by vermicular quartz embedded within plagioclase. It is a microscopic texture widely developed in igneous rocks (especially granites) and metamorphic rocks. Revealing its origin and formation processes is of great significance for constraining or indicating the petrogenesis and metallogenic evolution of its host rocks [1-5]. Since Michel-Lévy first discovered it in 1874 and Sederholm formally named it "myrmekite" in 1897 [6], this texture has attracted extensive attention worldwide from geologists [7-18] and has become one of the most frequently described [19], yet most debated, rock textures in geology [20-22]. Based on observations of its occurrence and analyzes of geological and geochemical factors affecting its formation, previous researchers have proposed a variety of genetic hypotheses, including crystallization, metasomatism, exsolution, recrystallization, deformation-related strain, anatectic co-crystallization, and composite origins [18,20-22]. This paper synthesizes previous research on myrmekite and, through a detailed case study of the Lingshan granitic pluton, demonstrates that myrmekite formation reflects multiple metasomatic episodes rather than a single mechanism, thereby offering new constraints on both its genetic interpretation and its significance in granite-related metallogenic systems.

2. General characteristics of myrmekite

Phillips defined myrmekite as a symplectitic intergrowth of vermicular quartz and sodic plagioclase that is always in contact with K-feldspar or shows clear pseudomorphs after K-feldspar. He emphasized that such intergrowths occur only between adjacent plagioclase and K-feldspar crystals, or between two or more contiguous alkali-feldspar grains [20]. Myrmekite is widely developed in granitic rocks [1,2,4,15 -18], granodiorite [3], monzodiorite [7], granodioritic porphyry [8], gabbro [9], porphyroblastic metamorphosed granite [11], felsic gneiss [6], granitic mylonitic gneiss [10], migmatites [12], granitic mylonite [13-14], and mylonitized syenogranite [19], among various igneous and metamorphic lithologies.

Its abundance often correlates with the Ca content of the rock: it is well developed in granodiorite but absent in albite-orthoclase leucogranites [20].

ISSN 2616-5872 Vol.7, Issue 5: 77-85, DOI: 10.25236/AJEE.2025.070510

Myrmekite commonly forms fringes, skirts, or fan-shaped aggregates along boundaries between plagioclase and K-feldspar, or appears as cauliflower-like, knobby, or vein-like bodies along the margins of K-feldspar (rarely along internal fractures), or at the junctions of two K-feldspar grains [21]. It typically ranges from 0.1–0.3 mm wide but may reach 1 mm in coarser-grained granites or pegmatites. Its modal abundance in a rock is usually 3–5% but may reach up to 20%.

The vermicular quartz shows diverse morphologies, droplet-like, worm-like, finger-like, hockey-stick-like, rod-like, or dendritic and may exhibit one or multiple crystallographic orientations. In some cases, the orientation matches that of adjacent non-vermicular quartz or quartz included within perthite lamellae [20-22]. The arrangement of vermicular quartz is controlled by the morphology of the interface between the host plagioclase and adjacent K-feldspar: when the interface is bulbous and convex toward the K-feldspar, the quartz vermicules fan outward and radiate within the plagioclase; whereas if the boundary is planar, the vermicules grow perpendicular to the interface [20]. Cross-sections of quartz vermicules are circular to sub-circular, with diameters typically <0.005–>0.015 mm [22]. Toward the margin of the myrmekite (where Na content increases), the vermicules commonly taper; pure albite (quartz-free) may locally form a normal rim-zoned boundary. Rarely, anomalous reverse zoning occurs where quartz rims the albite margin [20].

In general, finer vermicules are more numerous and occupy a smaller proportion of the myrmekite volume, whereas coarser vermicules are fewer but volumetrically more significant [21]. The quartz proportion within myrmekite is positively correlated with the An content of the plagioclase [23], and the maximum vermicule diameter increases with the initial An content of the primary plagioclase [4]. in some gneisses the compositions may be nearly identical between plagioclase with and without myrmekite [20,21].

3. Different hypothesis on the formation of myrmekite

Numerous hypotheses have been proposed for myrmekite genesis. Phillips [20]summarized them as: (1) co- or direct crystallization, (2) plagioclase replacing K-feldspar, (3) K-feldspar replacing plagioclase, (4) solid-state exsolution, (5) recrystallized quartz enclosed by metamorphic plagioclase, (6) other mechanisms.

Rong Jiashu [21] summarized eight mechanisms, and Zhang Yuyan et al. [18]synthesized seven major hypotheses (crystallization, metasomatism, exsolution, recrystallization, deformation, anatectic co-crystallization, and composite origins). Zachar et al. [25] further grouped them into: (1) magnetic crystallization, (2) solid-state exsolution, (3) prograde metamorphic reactions, (4) Retrograde reactions, (5) metasomatism, and (6) deformation.

The major models are summarized below:

(1) Co-crystallization or direct crystallization

Quartz and plagioclase crystallize simultaneously or directly from magma or hydrothermal solutions during late-magmatic to post-magmatic stages [20,21,24,25].

(2) Plagioclase replacing K-feldspar

Late-magmatic Na- and Ca-rich fluids ("pneumatolytic" fluids or hydrothermal solutions) react with K-feldspar, producing plagioclase + quartz intergrowths (myrmekite) via the following reactions [15,20,21,24,25]:

$$KAlSi_3O_8\,(K-feldspar) + Na^+ \rightarrow NaAlSi_3O_8\,(albite) + K^+ \quad (1)$$

$$2KAlSi_3O_8 + Ca^{2+} \rightarrow CaAl_2Si_2O_8\,(anorthite) + 4SiO_2\,(quartz) + 2K^+ \quad (2)$$

(3) K-feldspar replacing plagioclase

K-rich, silica-bearing alkaline fluids metasomatize plagioclase. The infiltrated SiO_2 crystallizes together with plagioclase to produce myrmekite [15,20,21,24,25].

(4) Solid-state exsolution

High-temperature K-feldspar is a solid solution dominated by $KAlSi_3O_8$ with subordinate $NaAlSi_3O_8$ and a small amount of a Ca-rich, Si-rich component (Schwantke molecule). Upon cooling, exsolution occurs: Na- and Ca-components exsolve to form plagioclase, while the Schwantke component decomposes to $CaAl_2Si_2O_8$ + $4SiO_2$, producing vermicular quartz. These exsolved phases accumulate along plagioclase–K-feldspar boundaries, forming myrmekite [15,20,21,24,25].

(5) K-, Na-, and Ca-metasomatism

Three situations are included:

(a) K-metasomatism of primary plagioclase: K-rich fluids alter plagioclase to secondary K-feldspar ("volume-for-volume" replacement). Ca and Al are partially removed, and residual components recrystallize into albite + quartz (myrmekite) [1,3,4].

$$Plagioclase + K^{+} \rightarrow K - feldspar + myrmekite\,(recrystallized\,albite + quartz) + loss\,of\,Al^{3+} + Ca^{2+} \quad (3)$$

(b) Na- and Ca-metasomatism of mesoperthite: Na- and Ca-bearing fluids react with mesoperthite; incorporation of Ca requires additional Al, resulting in excess Si, which forms vermicular quartz in myrmekite [4].

(c) Ca-metasomatism of plagioclase: Reaction (4) describes Ca-rich fluids altering sodic plagioclase to more calcic plagioclase + quartz [4,9]:

$$2NaAlSi_3O_8(albite) + Ca^{2+} \rightarrow CaAl2Si_2O_8(anorthite) + 4SiO_2(quartz) + 2Na^{+} \quad (4)$$

(6) Recrystallization of altered plagioclase

In fractured plagioclase within strongly sheared zones, hydrothermal fluids promote recrystallization. Ca and Na are leached from the distorted plagioclase lattice, producing Si-rich residual silicate structures that recrystallize into ellipsoidal or microvein quartz vermicules. Locally, the plagioclase in myrmekite may be replaced by K-feldspar, producing ghost myrmekite [26].

(7) Polygenetic or composite mechanisms

Some authors argue that different types of myrmekite form by different processes depending on morphology, environment, and distribution.

- In high-level, undeformed granites, marginal, intergranular, and included myrmekites are attributed mainly to exsolution.

- In deformed granitic metamorphic rocks, large fan-shaped or knobby myrmekites, or those with a volume equal to or exceeding that of the adjacent K-feldspar, are attributed to plagioclase replacing K-feldspar [15,21,23,24,27].

Other studies suggest that myrmekite forms under subsolidus or magma–hydrothermal transitional conditions, where exsolution and metasomatism jointly participate in forming a single myrmekite body [6].

4. Geological setting of Lingshan granitic pluton

Previous studies of myrmekite have mostly focused on its crystal chemistry, micro-textures, and genetic models at the scale of individual plutons or deformational zones, but relatively few have attempted to integrate these models with a well-constrained magmatic-hydrothermal system hosting large rare-metal deposits. The Lingshan granitic pluton in northern Jiangxi provides an excellent natural laboratory for such an integrated study: it exhibits abundant myrmekite and related feldspar microstructures (perthite, snowball textures, rapakivi rims), is spatially and temporally associated with super-large Nb-Ta-W-Sn deposits, and records both magmatic differentiation and intense fluid-mediated metasomatism. The Lingshan granitic pluton lies in the northern part of the Qin-Hang belt (also referred to as the Gan-Hang rift). It is one of the largest Late Mesozoic multi-phase granite intrusions in this region, with an exposed area exceeding 200 km² [28-29]. The pluton intrudes Neoproterozoic metasedimentary rocks, Cambrian carbonates, and Triassic shales and sandstones; among these, Cambrian carbonates and Precambrian metamorphosed sedimentary-volcanic successions form the main country rocks [30].

Petrographically, the Lingshan pluton comprises porphyritic coarser-grained biotite granite, albite–biotite granite, pegmatite, and associated mafic microgranular enclaves (MMEs) enclosed mainly in the porphyritic granite. The petrogenesis of the Lingshan pluton has long been debated. Based on lithological characteristics and isotopic data, Chen [31]divided the intrusion into three stages, interpreting the earliest phase as in-situ granitization of the country rocks and the later phases as magmatic crystallization linked to mineralization. Yuan et al. [32]emphasized extensive dissolution and metasomatism within the pluton and argued that rare-metal mineralization is closely related to fluid-induced replacement. In contrast,

ISSN 2616-5872 Vol.7, Issue 5: 77-85, DOI: 10.25236/AJEE.2025.070510

Zheng et al. [33] attributed the formation of MMEs to magma mixing between basaltic and felsic magmas.

Geochemically, the Lingshan granites are characterized by high SiO_2, Al_2O_3, Ga/Al, and total alkali contents [34 -37]. They have been variably classified as A-type or I-type granites, reflecting contributions from both felsic and mafic components and pointing to magma mixing coupled with crustal partial melting [38]. Isotopic data (Sr-Nd-Hf and zircon Hf-O) reveal high $^{87}Sr/^{86}Sr$ ratios, negative εNd(t) and εHf(t) values, and elevated zircon $\delta^{18}O$, consistent with derivation from ancient crustal sources modified by mantle-derived or juvenile inputs [38].

Numerous Nb-Ta-W-Sn deposits are distributed around the margins of the pluton, including the well-known Huangshan and Songshugang super-large Nb-Ta deposits [30,35,39]. Zircon U-Pb dating yields consistent Early Cretaceous ages of 132-134 Ma for both granitic phases and MMEs [35,37,40], which are nearly identical to the ages of the Huangshan Ta-Nb and Songshugang Nb-Ta-W-Sn mineralization [40], implying a close temporal and genetic relationship.

5. Petrographic Characteristics of Myrmekite in the Lingshan Granite

Myrmekite is widespread in the Lingshan granitic pluton and occurs mainly in two textural forms: typical fine-grained myrmekite and coarser-grained myrmekite. These two varieties differ in morphology, mineral associations, and their inferred formation mechanisms, suggesting that more than one metasomatic process operated during the magmatic-hydrothermal evolution of the pluton. Fine-grained myrmekite is the most abundant type and typically forms along the boundaries between plagioclase and K-feldspar or plagioclase and perthite. Its position near feldspar contacts, together with its extremely fine quartz vermicules, usually only 0.05-0.20 mm in size indicates that it most likely formed by Na-Ca metasomatism, with Ca present in only small amounts. Na-Ca-bearing fluids infiltrated microfractures, pores, and grain boundaries, reacted with K-feldspar or perthite, and produced secondary plagioclase together with vermicular quartz. Silica released during this reaction precipitated as the fine worm-like quartz aggregates that define myrmekite. Ca is required for this process; if the metasomatic fluid were too Na-rich, most silica would be consumed in forming secondary albite, leaving no excess silica to crystallize as vermicular quartz. All analyzed myrmekite in Lingshan contains measurable Ca, which supports this metasomatic mechanism. The reaction can be represented by:

$$2KAlSi_3O_8 + Ca^{2+} + 2Na^+ \rightarrow CaNa(Al_2Si_2O_8) + 2SiO_2 + 2K^+ \quad (5)$$

Several well-defined morphological varieties of fine-grained myrmekite occur in the has been observed in the Lingshan granitic pluton such as Rim myrmekite, which is the most abundant type and develops along the margins of plagioclase in contact with K-feldspar, where replacement by newly formed albite produces a straight to slightly irregular boundary lined with extremely fine quartz vermicules (Figs. 1a-c). The constant thickness of these myrmekite bands and the uniform fineness of the vermicular quartz demonstrate that they formed by Na-Ca metasomatism. Wart-type myrmekite occurs where earlier rim myrmekite has been partially dissolved, embayed, or deformed during later K-metasomatism, creating bulbous and irregular margins (Figs. 1d-f). Ghost myrmekite consists of isolated quartz vermicules enclosed within K-feldspar (Figs. 1g-i), showing that fine myrmekite is metastable and readily destroyed during feldspathization. These overprinting textures, combined with the presence of biotite and sericite relicts inside some altered plagioclase grains (Figs. 1c, f), indicate that micro-fractures and phyllosilicate remnants acted as fluid pathways that facilitated K-rich replacement.

Enclosed myrmekite provides additional evidence for sequential metasomatism. Albite inclusions within K-feldspar contain quartz-plagioclase intergrowths along their rims (Figs. 2a-c), recording an early Na-Ca metasomatic event prior to their engulfment and subsequent modification by K-metasomatism. Small detached albite fragments displaying identical interference colors to the larger albite grains further confirm that they originated from the same plagioclase crystal before being incorporated into K-feldspar (Fig. 2c). Intergranular and lotus-type myrmekite, though less common, reinforce the fluid-replacement origin. Intergranular myrmekite forms along narrow boundaries between adjacent K-feldspar or perthite grains, where silica-rich fluids infiltrate thin interfacial zones and precipitate minute quartz crystals during feldspar replacement (Figs. 2d-g). Lotus-type myrmekite exhibits lobate vermicular aggregates developed within or at the margins of perthitic feldspar (Figs. 2h-i), reflecting uneven and localized fluid penetration fronts.

ISSN 2616-5872 Vol.7, Issue 5: 77-85, DOI: 10.25236/AJEE.2025.070510

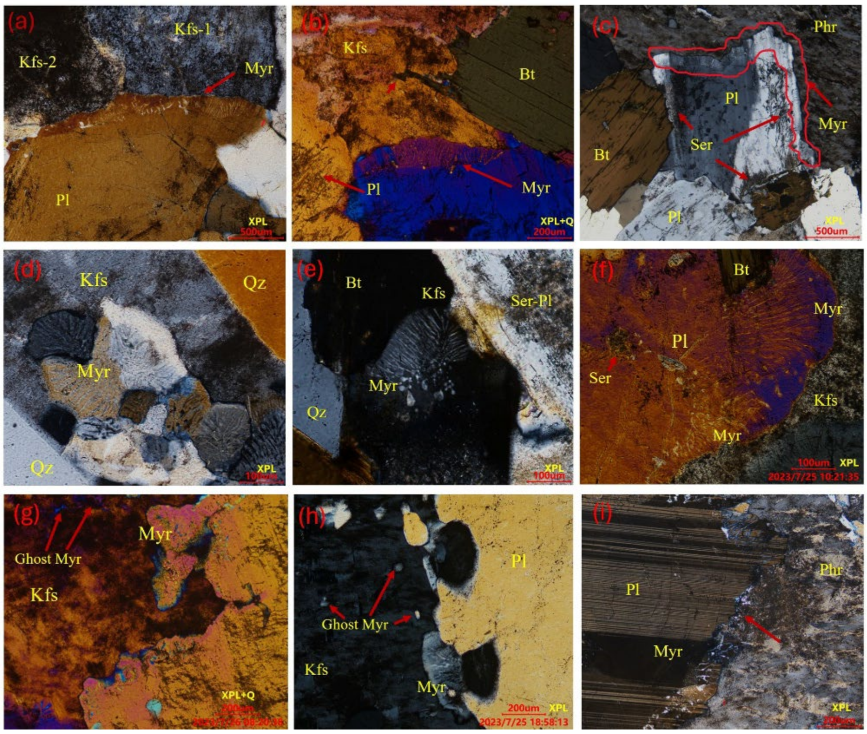

Figure 1: Rim, wart and ghost myrmekite in Lingshan granitic pluton. Potassium feldspar (Kfs); Perthite (Phr); Mica (Mca); Myrmekite (Myr); Biotite (Bt); Plagioclase (Pl); Quartz (Qz); Albite (Ab); Sericite (Ser); Cross Polarized Light (XPL); Cross Polarized Light with quartz plate (XPL+Q).

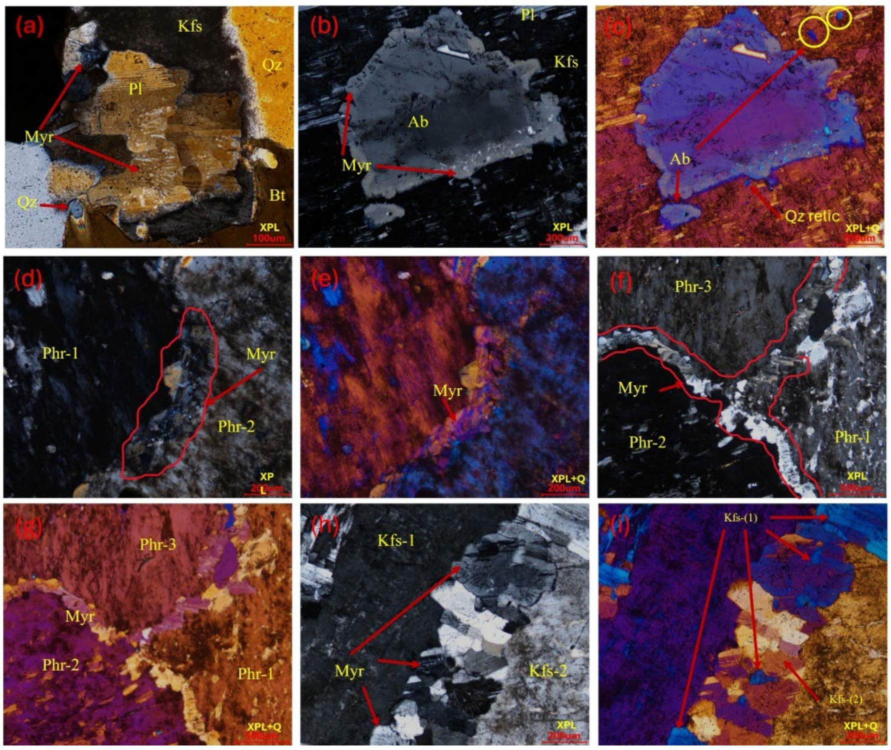

Figure 2: Enclosed, intergranular and lotus-type myrmekite in Lingshan granitic pluton. Potassium feldspar (Kfs); Perthite (Phr); Mica (Mca); Myrmekite (Myr); Biotite (Bt); Plagioclase (Pl); Quartz (Qz); Albite (Ab); Sericite (Ser); Cross Polarized Light (XPL); Cross Polarized Light with quartz plate (XPL+Q).

The second type which has been largely observed in the Lingshan granite is the coarserr grained myrmekite, earlier interpretations often treated coarserr myrmekite as simply a larger version of fine-grained myrmekite, with its vermicule size attributed to coarser exsolved K-feldspar [41]or to residual

ISSN 2616-5872 Vol.7, Issue 5: 77-85, DOI: 10.25236/AJEE.2025.070510

quartz left behind after plagioclase replaced K-feldspar Rong [15] However, the Lingshan petrographic evidence suggests that coarser myrmekite has a fundamentally different genesis. Coarser myrmekite frequently occurs on the surfaces of plagioclase phenocrysts that are not in contact with K-feldspar, indicating that its formation is unrelated to K-feldspar breakdown (Figs. 3a-c). Its shapes and sizes differ greatly from the cauliflower- or fan-shaped bands typical of fine-grained myrmekite. Instead, coarser myrmekite appears as irregular clusters within or surrounding plagioclase. In some thin sections, coarser myrmekite within plagioclase is optically continuous with quartz in the matrix, showing a transitional relationship between them (Fig. 3c). The matrix also contains abundant vermiform and dendritic quartz intergrown with fine plagioclase (Fig. 3e), closely resembling the internal textures of coarser myrmekite but at a different scale.

These observations strongly suggest that coarser myrmekite formed by metasomatic replacement of matrix quartz by plagioclase. Quartz grains that were not completely replaced became trapped within plagioclase, where they now appear as coarser vermicular quartz similar to myrmekite (Fig. 3f). After being enclosed, these quartz vermicules continued to undergo metasomatic alteration, developing finer-grained internal textures and reaction rims (Figs. 3g-h). During later K-metasomatism, coarser myrmekite domains were partly replaced, leaving behind ghost-like relics of vermicular quartz enclosed within K-feldspar (Fig. 3i). Rong [21] referred to similar textures as “angular quartz” where K-feldspar was absent, but this interpretation does not fully explain the Lingshan textures, because most plagioclase crystals in the area do not contain coarser myrmekite. Instead, the Lingshan evidence shows that fine-grained and coarser myrmekite have distinct origins. Fine-grained myrmekite formed by Na-Ca metasomatism at feldspar boundaries and was later modified or partly dissolved by K-feldspathization, whereas coarser myrmekite formed independently by plagioclase replacing matrix quartz and was later overprinted or destroyed by K-metasomatism.

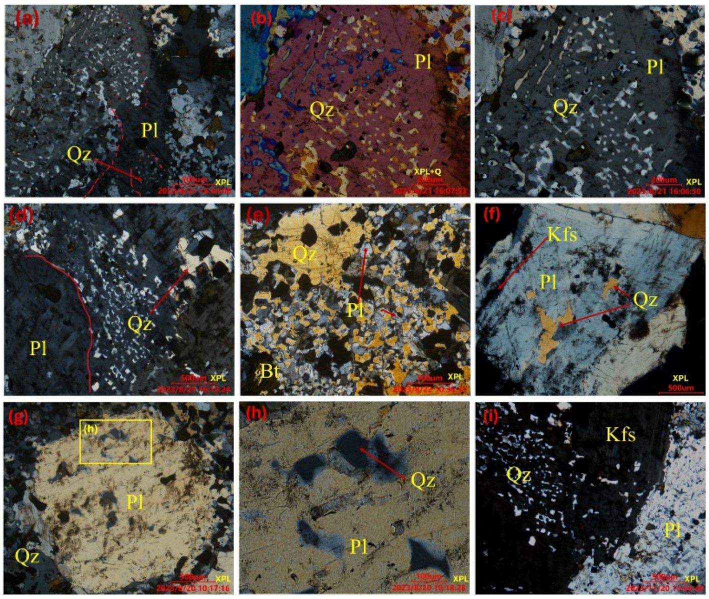

Figure 3: Coarserr myrmekite in Lingshan granitic pluton. Potassium feldspar (Kfs); Biotite (Bt); Plagioclase (Pl); Quartz (Qz); Cross Polarized Light (XPL); Cross Polarized Light with quartz plate (XPL+Q).

6. Discussion

The combined magmatic, structural, and current petrographic evidence support that myrmekite in the Lingshan granitic pluton is formed by internally sourced magmatic fluids which released during late-stage cooling of the intrusion. Oscillatory-zoned zircon [34] and magmatic tourmaline [42] in the Lingshan granitic pluton confirm that crystallization from a volatile-rich melt, whereas the marginal rocks contain murky or spongy texture zircon [34] and hydrothermal tourmaline [42] shows a transition from magmatic to fluid-dominated conditions. As crystallization proceed, Na-Ca-K-rich fluids exsolved from the residual melt, migrated upward during sub-solidus uplift, and were focused along ring faults and microfractures that surround the pluton. The earliest Na-Ca-rich fluid pulse formed fine-grained myrmekite along plagioclase K-feldspar contacts, as recorded by constant-thickness myrmekite rims, extremely fine vermicular quartz. A subsequent influx of K-rich hydrothermal fluids partially dissolved and overprinted this early myrmekite, generating wart and ghost textures and exploiting biotite- and sericite-rich microfractures as reaction centres. In contrast, coarser-grained myrmekite formed independently through partial replacement of matrix quartz by plagioclase within the groundmass, as evidenced by optical continuity between matrix quartz and coarser vermicules, dendritic quartz-plagioclase intergrowths, and reaction-rimmed quartz trapped inside plagioclase. These coarser domains were later modified or removed by K-metasomatism. Thus, Lingshan pluton experienced multiple metasomatic events, with an early Na-Ca phase and a later K-rich phase, both sourced from magmatic fluids. Myrmekite in Lingshan therefore serves as a sensitive microstructural record of the fluid evolution.

7. Conclusions

Myrmekite in the Lingshan granitic pluton is polygenetic and records multiple metasomatic episodes rather than a single origin. Myrmekite in the Lingshan granitic pluton formed through two separate metasomatic processes driven by late-stage magmatic fluids. Early Na-Ca fluids produced fine-grained myrmekite along feldspar boundaries, whereas coarser myrmekite resulted from plagioclase replacement of matrix quartz. Later K-rich fluids overprinted both generations, creating characteristic wart, ghost, and enclosed textures. These sequential metasomatic stages show that myrmekite accurately records the transition from melt-dominated to fluid-dominated conditions in the pluton. The texture therefore serves as a key microstructural tracer for reconstructing fluid evolution and metasomatic pathways in rare-metal-related granitic systems.

Acknowledgement

This study was financially supported by the National Natural Science Foundation of China (Grant No. 41963005).

References

[1] Collins L G. Origin of myrmekite and metasomatic granite. Myrmekite electronic journal, 1997, Nr. 1, in http://www.csun.edu/~vcgeo005/Nr1Myrm.pdf.
[2] Collins L G. Myrmekite as a clue to metasomatism on a plutonic scale: origin of some peraluminous granites. Myrmekite electronic journal, 1997, Nr. 6, in http://www.csun.edu/~vcgeo005/Nr6Waldoboro.pdf.
[3] Collins L G. and Collins B J. K-metasomatism of plagioclase to produce microcline megacrysts in the Cathedral Peak granodiorite, SierraNevada, California, USA [EB/OL]. Myrmekite Electronic Journal, 2002. Nr. 41, in http://www.csun.edu/~vcgeo005/Nr41K-metalsomatism.pdf
[4] Collins L G. and Collins B J. Origin of myrmekite as it relates to K-, Na-, and Ca-metasomatism and the metasomatic origin of some granite masses where myrmekite occurs[EB/OL]. Myrmekite Electronic Journal, 2013. Nr. 56, in http://www.csun.edu/~vcgeo005/Nr56Metaso.pdf.
[5] Collins L G. Significance of myrmekite [EB/OL]. Myrmekite Electronic Journal, 2021. Nr. 59, in http://www.csun.edu/~vcgeo005/Nr59Significance.pdf.
[6] Ren L., Han J. Formation of myrmekite in high-grade gneisses from the Zhongshan Station area, Antarctica [J]. Geology in China, 2006, 33(6): 1226–1235. (In Chinese).
[7] Song Y, Zhao S, Xu C. Crystallographic orientation relationships between quartz and feldspar in myrmekite [J]. European Journal of Mineralogy, 2021, 33(4): 317–332.
[8] Chen Y., Wang H. Formation of myrmekite in Yanshanian granodiorite porphyry and its relation to mineralization [J]. Journal of Shijiazhuang Institute of Economics, 1982, (C1): 123–125, 165. (In Chinese).
[9] Efimov A A, Flerova K V, Maegov V I. The first find of calcic myrmekite (quartz–plagioclase symplectites) in Uralian gabbro [J]. Doklady Earth Sciences, 2010, 435(1): 1450–1455.
[10] Zhu Y., He S. Characteristics and genesis of myrmekite in the Dawangshan dynamometamorphic zone [J]. Journal of Central South Institute of Mining and Metallurgy, 1991, 22(1): 9–17. (In Chinese).
[11] Chakrabarty A, Karmakar S, Dutta U, et al. Evidence of fluid-induced myrmekite formation after alkali-feldspar megacrysts: an example from a meta-porphyritic granitoid in Makrohar, Madhya Pradesh, India [J]. Mineralogical Magazine, 2024, 88: 262–276.
[12] Chen Y. Characteristics of myrmekite in migmatites from the Huoqiu area, western Anhui Province [J]. Geological Review, 1980, 26(6): 499–504. (In Chinese).
[13] Cisneros-Lazaro D G, Miller J A and Baumgartner L P. Role of myrmekite and associated

ISSN 2616-5872 Vol.7, Issue 5: 77-85, DOI: 10.25236/AJEE.2025.070510

deformation fabrics in controlling development of granitic mylonites in the Pofadder Shear Zone of southern Namibia[J]. Contributions to Mineralogy and Petrology, 2019, 174: 1–20.

[14] Ceccato A, Menegon L, Pennacchioni G. Myrmekite and strain weakening in granitoid mylonites [J]. Solid Earth, 2018, 9: 1399–1419.

[15] Rong J., Wang F. Granitic metasomatic structures — Evidence from petrography [M]. Beijing: Science Press, 2017: 37–42. (In Chinese).

[16] Pandit D. Geochemistry of feldspar intergrowth microtextures from Paleoproterozoic granitoids in central India: implications to exsolution processes in granitic system [J]. Journal of the Geological Society of India, 2015, 85(2): 163–182.

[17] Abart R, Heuser D, Habler G. Mechanisms of myrmekite formation: case study from the Weinsberg granite, Moldanubian zone, Upper Austria [J]. Contributions to Mineralogy and Petrology, 2014, 168: 1074–1089.

[18] Zhang Y., Li Z., Huang Z., Li X. Characteristics and preliminary discussion on the genesis of myrmekite in granitoid plutons of eastern Guizhou [J]. Minerals and Rocks, 2016, 36(2): 17–26.

[19] De Toni, G. B., Bitencourt, M. F., Nardi, L. V. S. Strain partitioning into dry and wet zones and the formation of Ca-rich myrmekite in syntectonic syenites: A case for melt-assisted dissolution-replacement creep under granulite facies conditions [J]. Journal of Structural Geology, 2016, 91: 88–101.

[20] Phillips E R. Myrmekite—one hundred years later [J]. Lithos, 1974, 7(3): 181–194.

[21] Rong J. Genesis of myrmekite [J]. Acta Petrologica et Mineralogica, 1992, (4): 324–331. (In Chinese).

[22] Rong J. Myrmekite formed by Na- and Ca-metasomatism of K-feldspar [EB/OL]. Myrmekite electronic journal, 2002, Nr. 45, in http://www.csun.edu/~vcgeo005/Nr45Rong1.pdf.

[23] Ashworth J R. Myrmekites of exsolution and replacement origins [J]. Geological Magazine, 1972, 109(1): 45–62.

[24] Liu C., Chen H. New advances in the study of myrmekite genesis [J]. World Geology, 1996, 13(1): 7–12. (In Chinese).

[25] Zachar J and Toth T M. Myrmekite-bearing gneiss from the Szeghalom Dome (Pannonian Basin SE Hungary). PartI: Myrmekite formation theories[J]. Acta Mineralogica-Petrographica, 2001, 42: 33-37.

[26] Collins L G. A fourth type of myrmekite origin in early Proterozoic terrane in northeastern Wisconsin[EB/OL]. Myrmekite electronic journal, 2018, Nr. 57, in http://www csun.edu/~vcgeo005/Nr57Wis.pdf.

[27] Phillips ER. On polygenetic myrmekite [J]. Geological Magazine, 1980,117(1):29-36.

[28] Gilder S A, Gill J, Coe R S, et al. Isotopic and paleomagnetic constraints on the Mesozoic tectonicevolution of south China[J]. Journal of Geophysical Research-solid Earth,1996,101: 16137-16154.

[29] Zhou X M, Sun T, Shen W Z, et al. Petrogenesis of Mesozoic granitoids and volcanic rocks in South China: A response to tectonic evolution[J]. Episodes Journal of International Geoscience,2006,29(1): 26-33.

[30] Xiang Y X, Yang J H, Chen J Y, et al. Petrogenesis of Lingshan highly fractionated granites in the Southeast China: Implication for Nb-Ta mineralization[J]. Ore Geology Reviews,2017,89: 495-525

[31] Chen, Z. Z. Study on the stage division of the Lingshan pluton in northeastern Jiangxi and its relationship with tungsten–tantalum mineralization[J]. Geotectonica et Metallogenia, 1984, (1): 59–70. (in Chinese).

[32] Yuan, Z.X., Bai, G., Yang, Y.Q. Discussion on the genesis of rare-metal granite-type deposits[J]. Mineral Deposits, 1987, 6(1): 88–96. (in Chinese).

[33] Zheng, J. P., Li, C. N., Xue, Z. S., et al. Genesis of mafic enclaves in the Lingshan granite, Jiangxi Province[J]. Geological Science and Technology Information, 1996, 15(1): 19–24. (in Chinese).

[34] Wang, C., Zhao, X., Huang, Z., Xing, G., & Wang, L. Early Cretaceous extensional-tectonism-related petrology of the Gan-Hang Belt SE China: Lingshan A-type granite at ca. 130 Ma[J]. Geological Journal, 2017: 1–20.

[35] Wang, X., Chen, X., Zou, S., Jia, Z., Li, B., Wang, H., & Xu, D. Geochronology, geochemistry, and mineral chemistry of the Lingshan-Huangshan complex, South China: Insights into Nb and Ta enrichment[J]. Ore Geology Reviews, 2023, 157: 105433.

[36] Wu, X. L., Fan, X. J., & Gong, Z. Y., et al. Geological characteristics and genetic discussion of the Lingshan complex, Jiangxi Province[J]. Geological Journal of China Universities, 2016, 22(3): 459–466. (in Chinese).

[37] Ye, M. Petrogenesis and magma mixing of the Lingshan granite and its mafic microgranular enclaves in the Gan–Hang tectonic belt[M]. Wuhan: China University of Geosciences, 2018. (in Chinese).

[38] Xiang, Y. X., Yang, J. H., Chen, J. Y., et al. Magma evolution of highly fractionated I-type granites in the Lingshan pluton and its relationship to Nb–Ta mineralization[C]. In Proceedings of the 2013

ISSN 2616-5872 Vol.7, Issue 5: 77-85, DOI: 10.25236/AJEE.2025.070510

National Petrology and Geodynamics Symposium, 2013, 691–692. (in Chinese).
[39] Nowak, I., & Ziolek, M. Niobium compounds preparation, characterization, and application in heterogeneous catalysis[J]. Chemical Reviews, 1999, 99(12): 3603–3624.
[40] Che, X. D., Wu, F. Y., Wang, R. C., et al. In situ U–Pb isotopic dating of columbite-tantalite by LA–ICP–MS[J]. Ore Geology Reviews, 2015, 65(4): 979–989.
[41] Schwantke, A. Die Beimischung von Ca im Kalifeldspat und die Myrmekitbildung[J]. Centralblatt für Mineralogie, 1909, 311–316.
[42] Liu, T., Jiang, S. Y., Su, H. M., et al. Tourmaline as a tracer of magmatic-hydrothermal evolution and potential Nb–Ta–(W–Sn) mineralization from the Lingshan granite batholith, Jiangxi Province, southeast China[J]. Lithos, 2023, 438–439.