# A fourth type of myrmekite origin in early Proterozoic terrane in northeastern Wisconsin

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## ABSTRACT

Myrmekite in early Proterozoic Marinette Quartz Diorite and Hoskin Lake Granite in northeastern Wisconsin southwest of Iron Mountain, Michigan, have formed by recrystallization of altered and micro-fractured plagioclase grains in former strongly cataclastically-sheared zones. In this process Ca and Na have been removed by hydrothermal fluids from deformed lattices in the plagioclase to leave a silicate lattice enriched in residual Si that becomes quartz ovals and/or stringers when recrystallized in myrmekite. In some places the plagioclase of this myrmekite is replaced by K-feldspar to form ghost myrmekite. Hornblende is destroyed and converted to quartz as Ca, Mg, and Fe go out of the system whereas K-bearing biotite is mostly unaffected and remains without replacement because its K-content makes it stable. The loss of some Ca, Mg, and Fe from the system as Marinette Quartz Diorite and Dunbar Gneiss were converted metasomatically to Hoskin Lake Granite resulted in a volume loss that facilitated the folding of these rocks to form the Dunbar Dome and promoted cataclasis to keep the system open.

## Introduction

Until now three types of myrmekite origin have been recognized: (1) produced by K-metasomatism of primary zoned plagioclase in which quartz vermicules in the myrmekite taper toward adjacent K-feldspar (Collins and Collins 2013), (2) produced by Na- and Ca-metasomatism of primary K-feldspar in which the quartz vermicules of the myrmekite are untapered and the myrmekite may be adjacent to quartz, biotite, muscovite, plagioclase, or K-feldspar (Collins and Collins 2013) and (3) produced by Ca-metasomatism of primary relatively-more-sodic plagioclase in anorthosite in which the quartz vermicules of the myrmekite are generally of nearly constant thickness (Wager and Brown 1967; De Waard et al. 1977; Dymek and Schiffries 1987; and Perchuk et al. 1994). A fourth type of myrmekite origin is now recognized that results in rocks that have been subjected to strong cataclasis in which Ca and some Na are subtracted from deformed, primary, zoned plagioclase crystals, leaving a lattice full of holes but retaining much of the silica in the original plagioclase (Putnis et al. 2007). This altered plagioclase has an imbalance of silica with what Ca and Na remains in the plagioclase and recrystallizes to form quartz vermicules in recrystallized relatively more-sodic plagioclase, and these vermicules do not taper in thickness toward adjacent K-feldspar. This myrmekite generally occurs adjacent to other ground mass minerals (quartz, biotite, hornblende, muscovite, and plagioclase). This kind of myrmekite commonly accompanies rocks in which the plagioclase may also be replaced internally by K-feldspar (microcline or orthoclase).

Examples of this fourth type of myrmekite origin occur in three places. The first is in the Temecula, California, area where hornblende, biotite, quartz, and zoned plagioclase in the Bonsall Tonalite (quartz diorite) are converted into metasomatic microcline-bearing granite in which the primary zoned plagioclase crystals lose Ca from their cores in the tonalite and where these strongly chemically altered and structurally weakened crystals are granulated. Where this occurs, the granulated grains recrystallize as tiny myrmekite grains in which the quartz vermicules do not taper toward adjacent K-feldspar that enclose the myrmekite. See **Figures 11** and **13** in Collins and Collins (2013).

The second is in the Papoose Flat pluton in eastern California in which zoned orthoclase megacrysts grow by metasomatic replacement of strongly deformed ground mass minerals consisting of primary zoned plagioclase, biotite, and quartz. The myrmekite is produced in the deformed and chemically altered plagioclase crystals which have lost Ca and have become enriched in residual silica before recrystallizing as myrmekite. This myrmekite may or may not become enclosed by the orthoclase, and the quartz vermicules do not taper toward the orthoclase. See **Figures 46, 48**, and **52** in Collins and Collins (2013).

The third is in northeastern Wisconsin in the early Proterozoic Hoskin Lake Granite that metasomatically replaces the Marinette Quartz Diorite and the Dunbar Gneiss in the Dunbar Dome where the quartz diorite and gneiss are strongly deformed (Dutton 1971; Sims et al. 1984, 1985, 1989, 1992). The Hoskin Lake Granite is a complex, crescent-shaped unit along the northern margin of the dome (**Figure 1**).

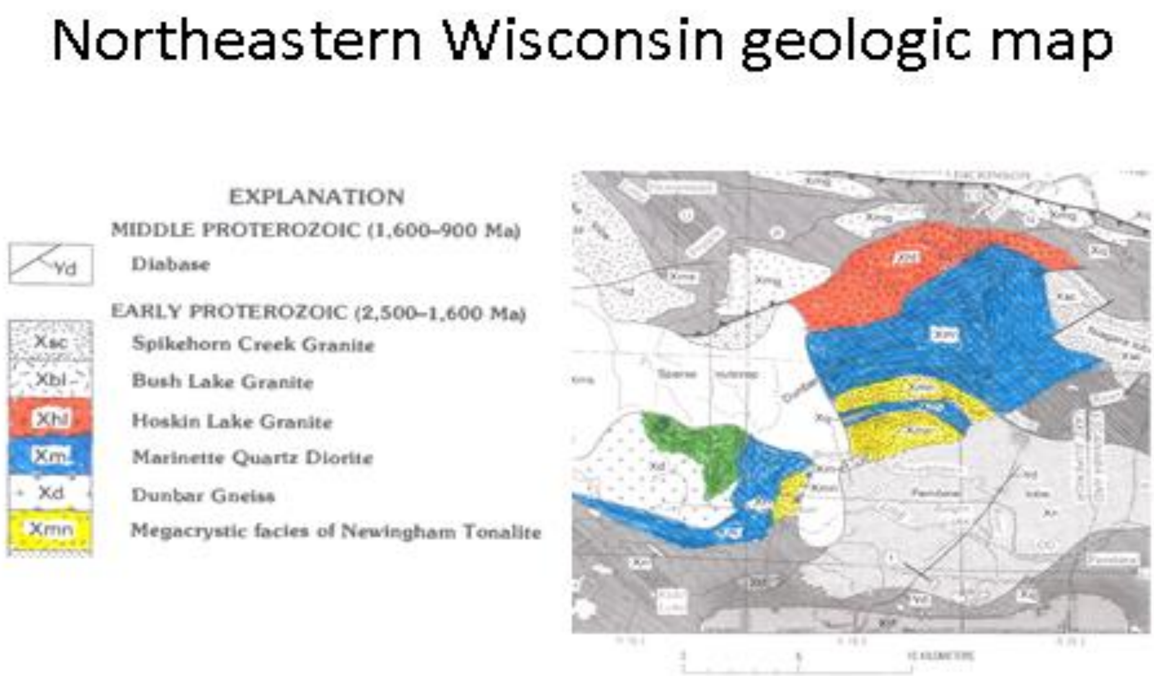


**Figure 1**. Geologic map of northeastern Wisconsin showing locations of Hoskin Lake Granite (orange), Marinette Quartz Diorite (blue), Dunbar Gneiss (white, lower left side; altered gneiss replaced by granite in green), and megacrystic facies of Newingham Tonalite (yellow; not discussed in this article). Map is a portion of **Figure 2** in Sims et al. (1992) with colors added and omitting colors for the Spikehorn Creek Granite and Bush Lake Granite.

The type Hoskin Lake Granite (Prinz, 1965; Bayley et al. 1966) is a distinctive rock characterized by oriented 1-5 cm tabular crystals of K-feldspar (microcline). The parallel alignment results from the replacement of former aligned plagioclase crystals by the K-feldspar. However, much of this facies also has K-feldspar porphyroblasts that lie athwart the foliation in the rock. K-feldspar megacrysts cutting across the foliation of the Marinette Quartz Diorite is also reported by Jeff Greenberg in the transition to the Hoskin Lake Granite (personal communication 2017). Cain (1964) noted that the southern margin of the granite is gradational into biotite gneisses of the Dunbar Gneiss (green area on **Figure 1**) and the Marinette Quartz Diorite. Where cataclastic deformation of these rocks occurs, evidence for the conversion of these rocks into granite by K-metasomatism is compelling. Dutton (1971) also noted that the Hoskin Lake Granite was formed by K-metasomatism of this quartz diorite. Therefore, the K-metasomatism that produced this granite has been known for more than 50 years since 1964. However, neither Cain nor Dutton discussed the origin of the myrmekite which occurs in both the quartz diorite and the granite, and its origin is the main theme of this article.

From chemical analyses of the Marinette Quartz Diorite and the Hoskin Lake Granite (**Table 1**), it is clear that where the quartz diorite is converted to myrmekite-bearing granite, Fe, Mg, and Ca are subtracted, K is added, Na remains about the same but slightly less, and Si is enriched. These chemical changes occur as hornblende is largely replaced by quartz. Biotite is generally not replaced because K is being introduced into the quartz diorite, making the K-bearing biotite stable. Some zoned plagioclase crystals are replaced by K-feldspar (microcline) while other zoned plagioclase crystals are replaced or overgrown by more sodic plagioclase. The amount of Na in the recrystallized rock (granite) remains about the same because the Na from the zoned plagioclase that is displaced by incoming K to form microcline moves into other nearby altered and deformed plagioclase crystal lattices to cause the plagioclase to recrystallize as more sodic facies while Ca displaced by K moves out of the system. However, some Na likely leaves the system with the outgoing Ca. The migration of Na into other nearby altered plagioclase lattices to form relatively more-sodic plagioclase was also noted in the Temecula area (Collins and Collins 2013). The altered silicate lattices of the replaced hornblende and plagioclase essentially remain in the same volumetric spaces of the original unreplaced crystals, but the net compositional result, because of the incoming K to form microcline, is to convert the quartz diorite into granite that is enriched in quartz and silica content (**Table 1**). The loss of Fe, Mg, and Ca from the cataclastically sheared Marinette Quartz Diorite likely caused a shrinkage in volume which would facilitate the formation of the Dunbar Dome as the rocks in the dome were folded and compressed into a smaller volume, and that compression in turn would cause the cataclasis to be on-going and keep the system open for fluid movements and more K-metasomatism. Shrinkage in volume where myrmekite is formed also occurs in the limb of an anticlinal fold containing garnet gneisses in the Gold Butte area of Nevada (Collins and Collins 2013) and in the limb of a steeply-plunging, isoclinal Split Rock Pond anticline in New Jersey (Collins, 1988, 2015). Although myrmekite is not mentioned in the second cited 2015 reference, large losses of Ca in plagioclase and the displacement of Fe from ferromagnesian silicates to form concentrations of magnetite with higher density had to occur in eight amphibolite layers in order for this anticline to become a tight isoclinal fold. One amphibolite layer that contained abundant biotite in this anticline was altered metasomatically to become a myrmekite-bearing garnet, sillimanite, K-feldspar, plagioclase, and quartz gneiss.

**Table 1**. Representative chemical analyses of samples from the Marinette Quartz Diorite (1 and 2) and the Hoskin Lake Granite (3 and 4). From part of **Table 2** in Sims et al. (1984).

| | **1** | **2** | **3** | **4** |
|---|---|---|---|---|
| **$SiO_2$** | 51.8 | 65.0 | 69.1 | 73.0 |
| **$Al_2O_3$** | 16.8 | 15.9 | 15.0 | 13.7 |
| **$Fe_2O_3$** | 1.97 | 0.64 | 0.56 | 0.31 |
| **FeO** | 7.77 | 3.01 | 2.67 | 1.78 |
| **MgO** | 3.50 | 1.56 | 0.91 | 0.41 |
| **CaO** | 6.18 | 3.20 | 1.91 | 1.06 |
| **$Na_2O$** | 3.88 | 4.30 | 3.45 | 3.51 |
| **$K_2O$** | 2.62 | 3.69 | 4.69 | 4.63 |
| **$TiO_2$** | 2.42 | 0.79 | 0.51 | 0.18 |
| **$P_2O_5$** | 0.64 | 0.18 | 0.11 | <0.05 |
| **MnO** | 0.15 | 0.07 | 0.05 | 0.05 |
| **$H_2O$** | 1.23 | 0.44 | 0.63 | ——— |
| **$H_2O$** | 0.07 | 0.02 | 0.13 | 0.44 LOI |
| **$CO_2$** | <0.01 | 0.04 | 0.08 | ——— |

**Figure 2** shows two representative photomicrographs of relatively coarse-grained Marinette Quartz Diorite. In other places the quartz diorite is fine-grained (**Figure 3**). In these places the fine-grained textures of the quartz diorite makes the rock harder and in these places little cataclasis and K-replacement occur.

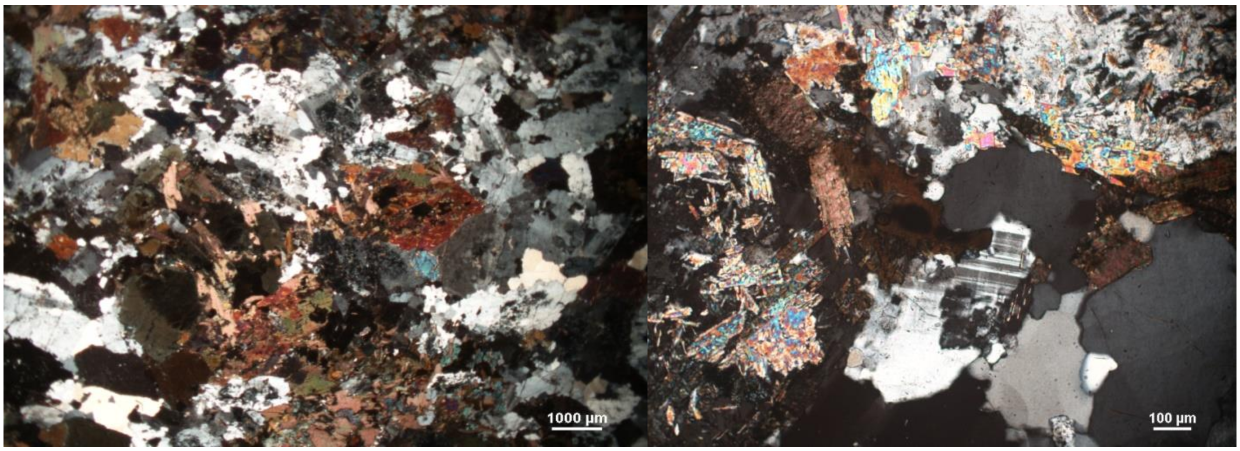


**Figure 2**. Two photomicrographs of Marinette Quartz Diorite showing quartz (white, cream), plagioclase (with albite twinning, gray), biotite (tan and bright colors), and hornblende (dark brown).

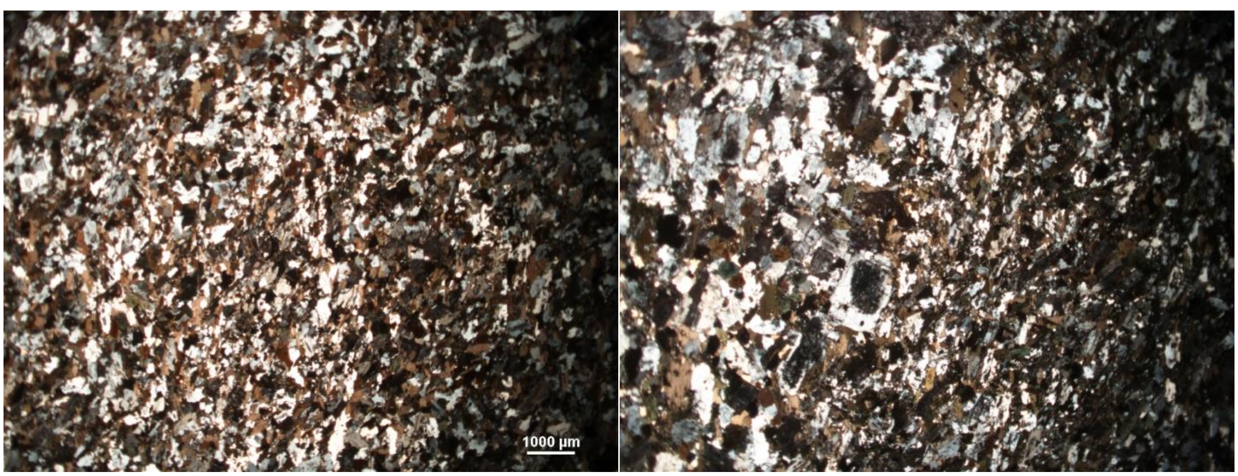


**Figure 3.** Two photomicrographs of fine grained Marinette Quartz Diorite. Zoned plagioclase shown in right image.

**Figure 4** shows early stages of interior replacement of plagioclase by islands of microcline.

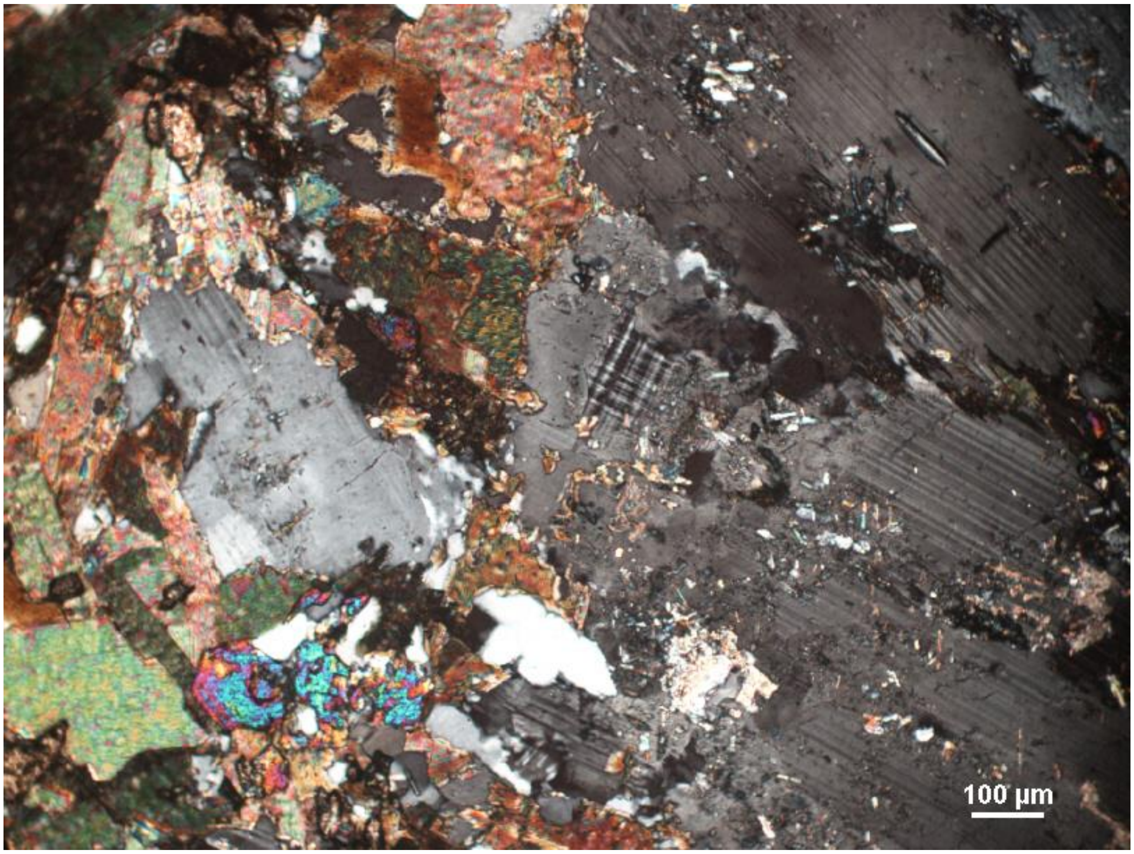


**Figure 4.** Photomicrograph of Marinette Quartz Diorite, showing early interior stage replacement of deformed faintly-albite-twinned plagioclase (light gray) by microcline (cross-hatched twinning, black and white). Biotite (light tan and bright colors), quartz (white), and hornblende (dark olive-green and brown).

**Figures 5** and **6** show myrmekite in the Marinette Quartz Diorite. Unlike myrmekite in the Temecula locality, this myrmekite occurs adjacent to quartz, biotite, hornblende, or plagioclase as well as in the Hoskin Lake Granite (**Figures 8** and **9**), and the quartz in the myrmekite occurs either as sub-round to oval blebs or as stringers instead of being tapered toward microcline away from non-quartz-bearing plagioclase. Cataclastic granulation of crystals is common in the thin sections although this is not shown in **Figures 5, 6, 8** and **9** but is shown in **Figures 10** and **11**.

**Figure 5**. Photomicrograph of Marinette Quartz Diorite, showing myrmekite (black with white quartz blebs) adjacent to microcline (cross-hatched twinning, dark gray and white). Quartz grains outside microcline (white and cream).

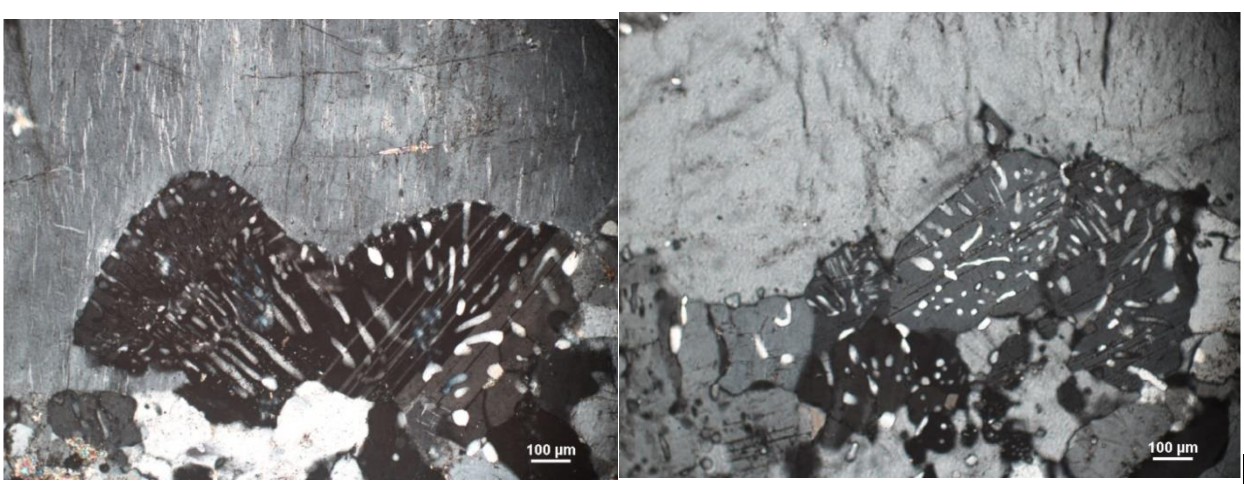


**Figure 6.** Two photomicrographs of Marinette Quartz Diorite, showing myrmekite (black; dark and light gray) with quartz blebs and stringers (white) against microcline (light gray with tiny albite lamellae in perthitic intergrowth). Quartz (white and cream).

**Figure 7** shows a portion of the northern part of the crescent area for the Hoskin Lake Granite (**Figure 1**) and the location of where two rock samples were collected in this area by Paul Sims. Thin sections were made from these samples (SIM-9-82 and SIM-12-82) and provided to me by Klaus Schulz.

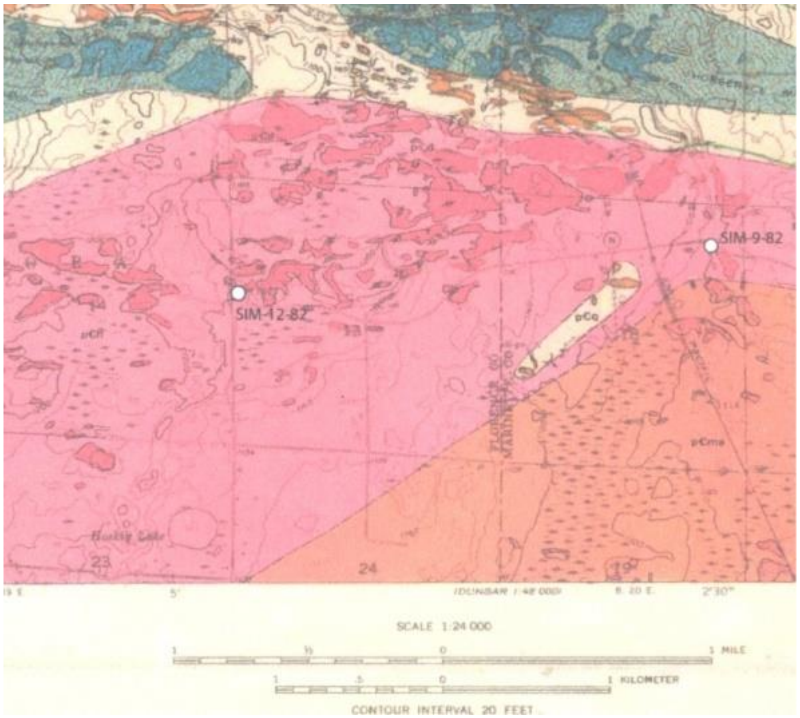


**Figure 7.** Location of Hoskin Lake Granite (outcrops in red and areal distribution in pink). Tiny white circle on right side is where a thin section of granite sample SIM-9-82 is located and tiny white circle on left side is where a thin secion of granite sample SIM-12-82 is located. Map is from Bayley et al. (1966).

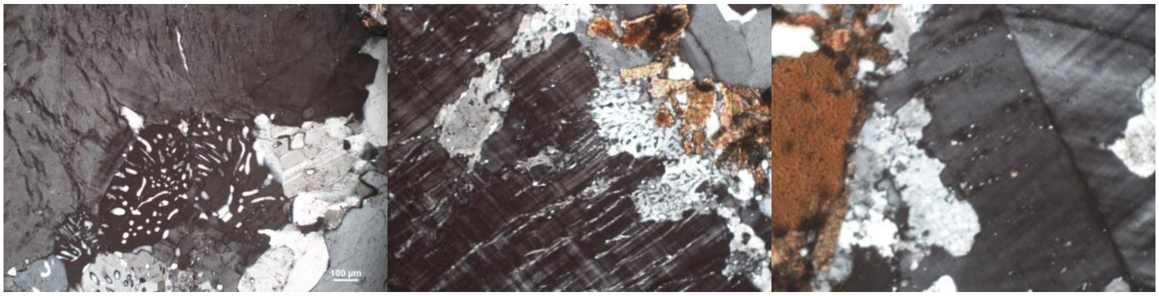


**Figure 8.** Three photomicrographs of portions of thin section SIM-9-82. **Left image** shows myrmekite (black with stringers of quartz [white]) adjacent to microcline (top left, light gray) and quartz (bottom right, white). **Middle image** shows myrmekite (white with dark quartz ovals) adjacent to microcline (grayish black with faint cross-hatched twinning) and biotite (tan and brown). Zoned plagioclase (light tan) is in left side of image inside the microcline. **Right image** shows ghost myrmekite (scattered and clustered quartz blebs [white]) in Carlsbad twinned microcline (dark gray with cross-hatched twinning). Myrmekite with dark gray quartz blebs is in white area against biotite (brown, left side).

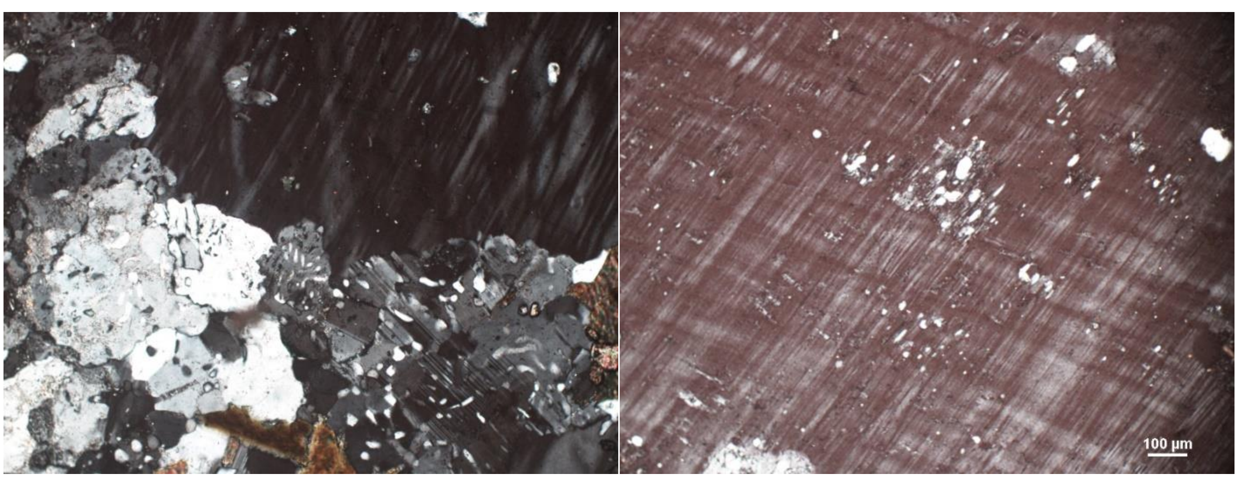


**Figure 9.** Two photomicrographs of Hoskin Lake Granite from thin section SIM-12-82. Left image shows myrmekite against biotite (brown), quartz (white), and microcline (dark gray with cross-hatched twinning). Right image shows ghost myrmekite (clustered white quartz blebs) in microcline (cross-hatched twinning).

In a field outcrop (Stop 6, Sims et al. 1983) the Hoskin Lake Granite, shown in a sample and in thin section images in **Figure 10**, looks like a granite dike that has been injected into the Marinette Quartz Diorite, but instead it is zone of cataclastic shearing along which K-replacement of plagioclase occurs to produce microcline and myrmekite. This cataclastic texture is also shown in the nearby larger outcrop of Hoskin Lake Granite in **Figure 11**.

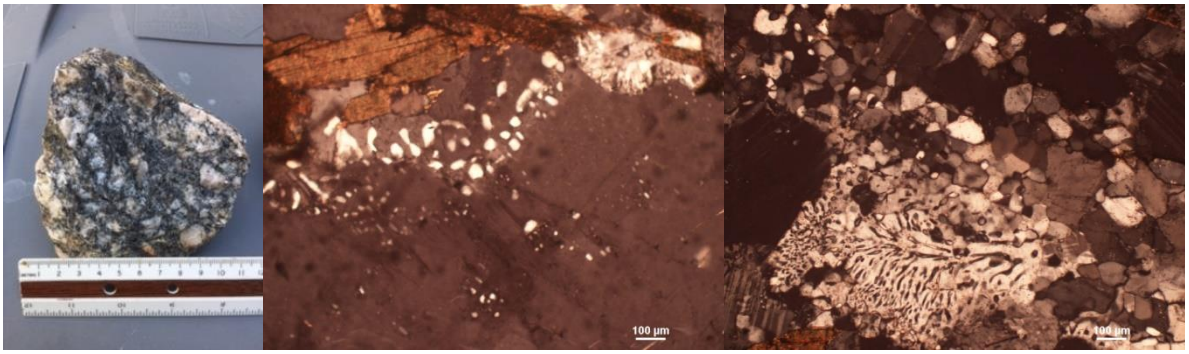


**Figure 10. Left image**: Hoskin Lake Granite dike at Stop 6 of 30th annual field trip (Sims et al. 1984). Crystals of microcline (white). **Middle image**: Myrmekite with oval quartz (white) against biotite (brown) and ghost myrmekite (clusters of tiny quartz grains; white) inside microcline (dark gray). **Right image**: Myrmekite along zone of cataclasis with small granulated grains.

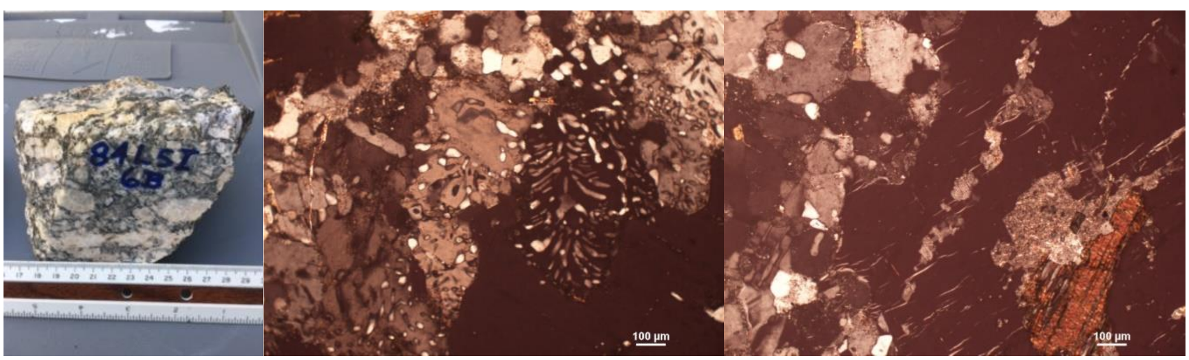


**Figure 11. Left image**: Hoskin Lake Granite at Stop 6 of 30th annual field trip (Sims et al. 1984). Crystals of microcline (white). **Middle image**: Myrmekite in granite along zone of cataclasis. **Right image**: Myrmekite adjacent to biotite (brown) in microcline (dark grayish black). Cataclastic grains of ground mass in linear alignment (slanted top to bottom) and surrounded by microcline without cataclasis of the microcline.

## Summary

Thin section images of samples of early Proterozoic rocks in northeastern Wisconsin show that myrmekite in this terrane has formed by recrystallization of chemically altered and micro-fractured plagioclase grains in former strongly-cataclastically-sheared Marinette Quartz Diorite and Dunbar Gneiss that become the Hoskin Lake Granite. This granite not only grades into the quartz diorite toward the south and southeast but also into the gneiss toward the southwest (Cain 1964; green part of white un-speckled area labeled **Xd** in **Figure 1).** In these sheared rocks Ca and Na have been removed by hydrothermal fluids from plagioclase to leave a silicate lattice enriched in residual Si that becomes quartz ovals and/or stringers in myrmekite. The removed Ca leaves the system in hydrous fluids, but Na remains behind in recrystallized more-sodic plagioclase. In some places the plagioclase of this myrmekite is replaced by K-feldspar to form ghost myrmekite. Hornblende is destroyed and converted to quartz as some Ca, Mg, and Fe go out of the system whereas K-bearing biotite is mostly unaffected and remains without replacement because its K-content makes it stable. The replacement of some of the plagioclase in the Marinette Quartz Diorite and the Dunbar Gneiss by K-feldspar (microcline) is the compositional change that converts these rocks into the Hoskin Lake Granite. The loss of some Ca, Mg, and Fe facilitates the folding of the Dunbar Dome, and this folding promotes cataclasis that keeps the system open to progressive K-metasomatism. Newly formed K-feldspar (microcline) encloses granulated ground mass minerals without itself being granulated, and in some places K-feldspar megacrysts that replace altered and micro-fractured plagioclase cross-cut the foliation.

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## References

Bayley, R.W., Dutton, C.E., and Lamey, C.A., 1966, Geology of the Menominee iron-bearing district, Dickinson County, Michigan, and Florence and Marinette Counties, Wisconsin: ***U.S. Geological Survey Professional Paper*** 513, 96 p.

Cain, J.A., 1964, Precambrian geology of the Pembine area, northeastern Wisconsin: ***Papers of Michigan Academy of Science, Art, and Letters***, v. 49, p. 81-103.

Collins, L.G., 1988, Hydrothermal Differentiation and Myrmekite – A Clue To Many Geological Puzzles: Athens, Theophrastus Publications, 387 p.

Collins, L.G., 2015, Can flood geology and catastrophic plate tectonics explain sedimentary rocks? Opposition to Creationism website. Available at: http://www.csun.edu/~vcgeo005/Collins5.pdf.

Collins, L.G. and Collins, B.J., 2013, Origin of myrmekite as it relates to K-, Na-, and Ca-metasomatism and the metasomatic origin of some granite masses where myrmekite occurs. Available at: http://www.csun.edu/~vcgeo005/Nr56Metaso.pdf.

De Waard, D., Hancock, S.A., and Robinson, J.E., 1977, Mineral variation in anorthositic rocks of eastern Paul Island, Nain complex, Labrador. ***Nederlandse Akademie van Wetenschappen, Afdeeling Natuurkunde***, in Proceedings, Ser. B, v. 80, no. 4, p. 322-335.

Dutton, C.E., 1971, Geology of the Florence area, Wisconsin and Michigan, ***U.S. Geological Survey Professional Paper 633***, 54 p.

Dymek, R.F. and Schiffries, C.M., 1987, Calcic myrmekite: possible evidence for the involvement of water during the evolution of andesine anorthosite from St-Urbain, Quebec. ***Canadian Mineralogist***, v. 25, p. 291-319.

Perchuk, L.L., Gerya, T.V., and Korsman, K., 1994, A model for charnockitization of gneissic complexes: ***Petrology***, v. 2, p. 395-423.

Prinz, W.C., 1965, Marinette Quartz Diorite and Hoskin Lake Granite of northeastern Wisconsin, *in* Cohee, G.E., and West, W.S., Changes in stratigraphic nomenclature by the U.S. Geological Survey, 1964: ***U.S. Geological Survey Bulletin 1224-A***, p. Al-A77.

Putnis, A., Hinrichs, R., Putnis, C.V., Golla-Schindler, U., and Collins, L.G., 2007, Hematite in porous red-clouded feldspars: evidence of large-scale crustal fluid-rock interaction. Lithos, v. 95, p. 10-18.

Sims, P.K., Peterman, Z.E., and Schulz, K.J., 1985, The Dunbar gneiss-granitoid dome – implications for early Proterozoic tectonic evolution of northern Wisconsin, ***Geological Society of America Bulletin***, v. 96, p. 1101-1110.

Sims, P.K., Schulz, K.J., and Peterman, Z.E., 1984, Thirtieth Annual Institute on Lake Superior Geology Field Trip 1. Guide to the geology of the Early Proterozoic rocks in northeastern Wisconsin.

Sims, P.K., Schulz, K.J., and Peterman, Z.E., 1992, Geology and geochemistry of early Proterozoic rocks in the Dunbar area, northeastern Wisconsin, ***U.S. Geological Survey Professional Paper 1517***.

Sims, P.K., Van Schmus, W.R., Schulz, K. J., and Peterman, Z.E., 1989, Tectono-stratigraphic evolution of the Early Proterozoic Wisconsin magmatic terranes of the Penokean Orogen, ***Canadian Journal of Earth Sciences***, v. 26, p. 2145-3258.

Wager, L.R., and Brown, G.M., 1967, Layered Igneous Rocks. San Francisco, Freeman and Company, 588 p.