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THE GRANITE, PEGMATITE, AND REPLACEMENT VEINS IN THE SHEAHAN QUARRY, GRANITEVILLE, MISSOURI*

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INTRODUCTION

Graniteville, Iron County, Missouri, has been for some time the most important granite quarrying center in the state. The Sheahan quarry located just north of Graniteville village is at present the most active one in the district. The quarry product is the distinctive "Missouri red granite" of pre-Cambrian age. The granite, a pegmatite, and replacement veins exposed in the quarry afforded material for a petrographic and chemical study presented in this paper.

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GRANITE

Feldspar and quartz make up 96 to 97 per cent of the granite. The feldspar includes two generations of albite, orthoclase and microcline. Both orthoclase and microcline are intergrown with albite forming several types of perthite. Microcline-albite intergrowths are usually of the type described by Andersen[1] as "vein" perthite. The orthoclase-albite intergrowths are much less regular and are of the "patch" type. A third perthitic development is "poikilitic"; allotriomorphic to hypidiomorphic crystals of albite are included in larger crystals of vein and patch perthite.

The earliest feldspar of the granite is an albite near oligoclase which occurs in crystals up to an inch or more in length. Albite also appears to be the last feldspar, a second generation of this

* Published by permission of the State Geologist of Missouri.
[1] Andersen, Olaf, *Norsk. Geol. tidsskrift*, vol. **10**, pp. 116–203, 1928.

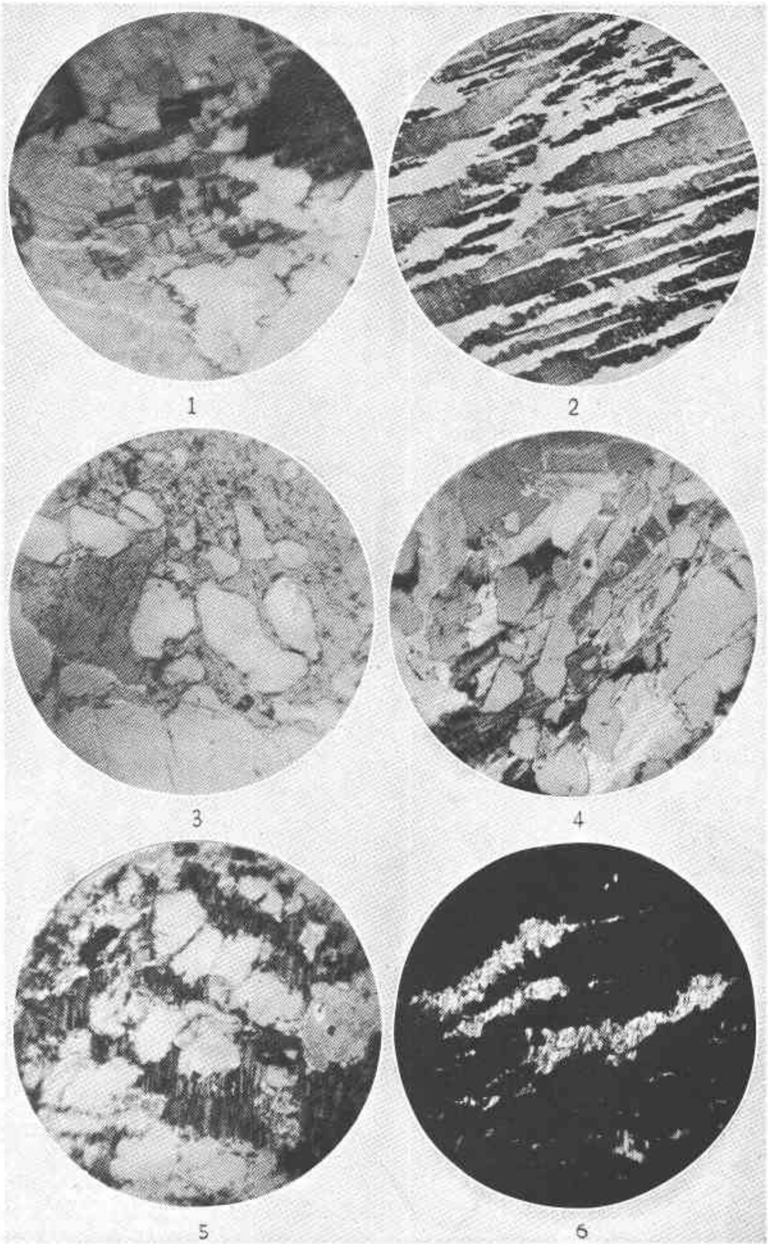


FIG. 1. Sheahan quarry granite. The late "blocky" albite is shown. Crossed nicols. ×43; fig. 2. Perthite of the vein type from the pegmatite. Crossed nicols. ×38; fig. 3. Topaz (light) replaced by beryl (dark). Crossed nicols. ×43; fig. 4. Topaz replaced by muscovite. Crossed nicols. ×43; fig. 5. Topaz and muscovite replaced by albite. Crossed nicols. ×43; fig. 6. Feldspar (light) replaced by fluorite (dark). Crossed nicols. ×43.

mineral occurring in small unaltered grains interstitial to the larger minerals and sometimes as a "blocky" fringe bordering earlier feldspar (Fig. 1). Other minerals, some of which are secondary products, include apatite, biotite, calcite, chlorite, fluorite, hematite, leucoxene, magnetite, muscovite, pyrite, sericite, and zircon. Apatite is very rare, and only a few scattered crystals were noted. Biotite is not common and has been largely altered to "green-biotite" and chlorite. A few grains of zircon with characteristic haloes are found as inclusions in the biotite.

Magnetite is of interest because it occurs both as an early and as a late mineral. In the second occurrence it is usually associated with muscovite which replaces feldspar and to a lesser extent quartz. It is possible that the muscovite is deuteric and was derived from an earlier iron-bearing mineral such as biotite by the action of late magmatic juices. Such a reaction might produce a mica more closely allied to muscovite at the same time liberating iron which became fixed as magnetite. The muscovite is colorless or has a faint olive-green to colorless absorption. It is probably a closely related if not the same mica which occurs abundantly in the pegmatite and veins.

Although pyrite was not observed in thin sections prepared from chips taken from the material used for chemical analysis, this mineral is present in the granite near joint planes. The chlorite apparently derived from biotite is blue-green in color and is characterized by blue-grey interference colors. 2V is small and negative, and the mineral is probably negative-penninite or delessite.

Chemical Analysis

A chemical analysis was made of a sample prepared from several pounds of chips representing the massive granite. The results of the analysis and the calculated normative minerals are shown in Table 1. Normative albite exceeds normative orthoclase, a feature in keeping with the usual high soda content of the acid igneous rocks of the St. Francois Mountains. Phosphorus and other minor constituents were found only in small amounts.

PEGMATITE

Abnormally large developments of quartz and feldspar which locally result in pegmatitic granite can be observed in a number of places in the Sheahan quarry. Recently, however, a lens of peg-

TABLE I

Chemical analysis and classification of Missouri red granite from Sheahan quarry, Graniteville, Missouri. S. S. Goldich, analyst.

	Per cent	*Mol. No.*	*Norm*	
SiO_2	76.81	1.280		
Al_2O_3	12.23	.120		
Fe_2O_3	0.52	.003		
FeO	0.41	.006		
MgO	0.12	.003		
CaO	0.98	.018	Quartz	35.14
Na_2O	3.85	.062	Zircon	0.05
K_2O	4.59	.049	Orthoclase	27.24
H_2O+	0.26		Albite	32.49
H_2O-	0.01		Anorthite	2.50
CO_2	0.07	.0016	Diopside	1.14
TiO_2	0.08	.001	Magnetite	0.70
ZrO_2	0.02	.0003	Ilmenite	0.15
P_2O_5	Trace		Fluorite	0.35
S	0.01		Calcite	0.16
Cr_2O_3	0.00			
MnO	0.00 (.004)			99.92
BaO	0.01			
F	0.17	.0045		
	100.14			
Less O	.07			
	100.07			

Specific gravity 26°/4° = 2.607
Class I, Subclass 1, Order 4, Rang 1, Subrang, 3.
Rock name: LIPAROSE.

matite distinctive in its mineral assemblage was discovered. The pegmatite is exposed on the upper bench of the north face of the quarry near its western end. The outcrop is about 10 feet in length and has a maximum thickness of about 18 inches. Though it appears to be roughly lens-shaped, the pegmatite thins and swells irregularly. The strike is parallel to the prominent joint system of the quarry (N. 65° E.), and the dip is about 60 degrees to the northwest.

Large blocks of pegmatite found on the quarry floor below the outcrop indicate that considerable material may have been removed in the quarrying operations. However, because of the steepness of the dip, any portion of the pegmatite continuous with the outcrop would have been truncated within a short distance by the present erosion surface.

Mineralogy

Most of the pegmatite in the outcrop is composed of feldspar and quartz. Topaz, mica, fluorite, and a few other minerals are present, but of special interest is beryl, a mineral hitherto not described in any Missouri occurrence.

Perthite. An intergrowth of massive quartz and feldspar represents the early or magmatic phase of the pegmatite. The feldspar which attains a maximum length of 8 inches is a perthitic intergrowth of microcline and albite of the "vein" type (Fig. 2). The mineral is red in color, and in thin section a small amount of finely dispersed hematite is visible. An analysis by Goldich gave the following results:

SiO_2	65.85
Al_2O_3	18.85
Fe_2O_3	0.11
FeO	Trace
MgO	0.00
CaO	0.05
Na_2O	3.91
K_2O	11.15
H_2O+	0.24
H_2O-	0.01
	100.17

Specific gravity 26°/4° = 2.553

The analysis of the perthite calculated into feldspar molecules gave the following percentages:

K-feldspar	65.6
Na-feldspar	33.0
Ca-feldspar	0.3

Topaz. The topaz is colorless or light yellow with a vitreous luster. It occurs in coarsely granular aggregates, and crystal faces are rare. Topaz is always in close association with beryl and muscovite, and replacement by these minerals (Figs. 3 and 4) and by albite (Fig. 5) is so general that the original relationships of the topaz could not be determined. Topaz is considered to be the earliest hydrothermal mineral.

Beryl. Massive beryl is common, but there is a greater tendency for this mineral to develop crystal forms than is true of the topaz. Hexagonal prisms two inches in length were found. The beryl varies from colorless or a faint blue to a fine aquamarine color, but none is of good gem quality. Indices of refraction are: $\epsilon = 1.571 \pm .002$; $\omega = 1.578 \pm .002$.

The best material was carefully selected for chemical analysis by hand picking. The mineral was crushed and sieved to a uniform size (1/4 to 1/8 mm.), and was separated from topaz with which it is intimately associated by means of bromoform (specific gravity, 2.83). The beryl was recovered as the float fraction and after being washed and dried was further cleaned by hand picking under a binocular microscope. The chemical analysis of this material by Goldich follows:

SiO_2	65.23
Al_2O_3	17.99
Fe_2O_3	0.96
FeO	0.57
BeO	13.39
MgO	0.06
CaO	0.03
Na_2O	0.52
K_2O	0.01
H_2O (Ignition)	1.20
H_2O-	0.03
	99.99

Specific gravity 24°/4° = 2.682

Beryllium was separated from aluminum and iron by 8-hydroxyquinoline.[2] Total iron was determined on a separate portion by fusing the sample with sodium carbonate, dissolving the melt in HCl and determining the iron by potentiometric titration with dichromate following reduction with stannous chloride. Alumina was then obtained by difference. Incipient alteration of the beryl to a clay-like substance was observed, and this may be a hydrated secondary product contributing to the observed loss on ignition. The beryl is also replaced by a dark-green mica which has been oxidized to a yellowish to reddish oxide of iron, probably goethite, and this mineral likewise may account for some of the water as well as for part of the ferric iron.

[2] Kolthoff, I. M., and Sandell, E. B., *J. Am. Chem. Soc.*, vol. **50**, p. 1900, 1928.

The beryl is of the low alkali type, the specific gravity and optical data being in accord with the chemical data. Beryl replaces topaz and feldspar (Fig. 3) and is replaced chiefly by mica.

ALBITE. Albitization affected both the granite and the pegmatite and possibly the late albite of the rock is related to that which replaces the perthite, quartz, topaz and early muscovite of the pegmatite. The perthite, itself, may represent an early (deuteric) replacement of massive microcline.

The albite is pink to deep red in color and in thin section is characterized by sharply defined twinning lamellae which are not continuous but broken to give a patch-like appearance between crossed nicols.

Albite is also found in veinlets one to two millimeters in width. This albite is somewhat unusual because of the absence of prominent twinning. Powdered material showed the composition to be near $Ab_{95}An_5$. Extinction on the basal pinacoid, X to (010), is 3–4 degrees. Indices of refraction are: $\alpha=1.529$; $\beta=1.533$; $\gamma=1.539$; all $\pm.002$.

BIOTITE. A number of micas are present in the pegmatite. An early mica is dark-green in color and is strongly pleochroic, dark green to light greenish-yellow. 2V is small, 10° or less, and the mineral is optically negative. The birefringence is high and is about that of the normal brown biotite.

MUSCOVITE. The most abundant mica in the Sheahan quarry is an iron-bearing muscovite which varies in color from light yellowish-brown to almost black. Optical properties also vary, and these variations are probably controlled by the tenor of ferrous and ferric iron. Only the light brown mica which is found in booklets measuring an inch or more in diameter was studied in any detail. Dr. Ellestad of the Laboratory for Rock Analysis at the University of Minnesota determined the alkalies on this muscovite. Chemical data are shown in Table II. The combined figures of the partial analyses yield a total of 98.69 per cent. The low summation may be due to the presence of fluorine which was not determined or to an error in the figures for water. The hydroxyl was therefore omitted in the calculation of molecules. The analysis gives a $K_2O:SiO_2$ ratio of 1:6 making it necessary to use Hallimond's[3] formula for phengite ($K_2O.2Al_2O_3.RO.6SiO_2.2H_2O$)

[3] Hallimond, A. F., On the chemical classification of the mica group: *Mineral. Mag.*, vol. **XX**, pp. 305–318, 1925.

rather than the one suggested by Winchell[4] ($K_2O.2Al_2O_3.RO.7SiO_2.2H_2O$). The calculated molecules are

Phengite	52.4%
Fe''' Muscovite	19.7
Muscovite	26.4
	98.5

Beta was found to be $1.596 \pm .002$; 2V is about 30°. The optical data agree fairly well with the position a muscovite of the above composition would have on Winchell's diagram except that 2V is too small. The diagram, however, is based on data for phengite high in MgO, and according to Winchell,[5] ferrous iron is more effective in reducing the optic angle than is magnesia.

TABLE II

Chemical data on muscovite occurring in large books in pegmatite and veins in the Sheahan quarry.

	1	2	*Mol. No.*		*Ratios*
SiO_2	45.92		.763	.768	6.00
TiO_2	0.36		.005		
Al_2O_3	29.07		.285		
Fe_2O_3	3.94		.024		
FeO	3.58		.050	.380	2.97
MnO	0.06		.001		
MgO	0.79		.020		
CaO	Trace				
Li_2O	n.d.	0.29	.010		
Na_2O	n.d.	0.27	.005	.128	1.00
K_2O	n.d.	10.68	.113		
H_2O above 110°C.	3.20				1.62
H_2O below 110°C.	0.53			.207	
F	n.d.				

1. S. S. Goldich, Analyst.
2. R. B. Ellestad, Analyst.

SERICITE. Felted aggregates of sericite compose greenish masses which in hand specimens have an appearance like that of serpentine. The sericite seems to be later than the muscovite and in part replaces it.

FLUORITE. Fluorite is abundant in the pegmatite and replaces feldspar, mica, and beryl. The replacement of feldspar by fluorite

[4] Winchell, A. N., Further studies in the mica group: *Am. Mineral.*, vol. **XII,** pp. 267–279, 1927.

[5] *Op. cit.*, p. 269.

and likewise by beryl resulted in a structure in which stringers of albite are found as remnants in the invading mineral (Fig. 6). These elongated residuals of albite may have resulted from a selective replacement of perthite.

Other Minerals. Rutile and cassiterite were noted in a few thin sections of pegmatite minerals. Only a few small crystals were found, and their position in the mineral sequence could not be determined. Magnetite, specularite, and pyrite occur in scattered grains. Polished sections showed some of the pyrite is replaced by chalcopyrite which is in turn replaced by galena.

REPLACEMENT VEINS

A number of quartz veins are present in the north face of the Sheahan quarry. These veins have the same general strike as the joints, but some differ in dip. The largest observed is four inches in width. The veins are of a replacement nature, and the walls are often indefinite. Fragments of granite in all stages of replacement are included. Quartz in terminated crystals and thuringite were found in vugs.

The granite wall rock in many places along the quartz veins has been mineralized with magnetite. Octahedrons of magnetite two millimeters in size also occur in the quartz. Some pyrite is present.

Joint-Veinlets

Secondary minerals, the most prevalent of which are muscovite, fluorite, and pyrite, have been developed rather generally along the joint planes. In most places these minerals represent a thin film replacing the granite, but locally these replacements are several inches in thickness.

PARAGENESIS

The pegmatite is of the complex type with both magmatic and hydrothermal stages present. The first stage is represented by the coarse feldspar and quartz. The development of these minerals was undoubtedly influenced by the presence of mineralizers. As these mineralizers became concentrated as a consequence of crystallization, the magmatic stage gave way to a hydrothermal stage.

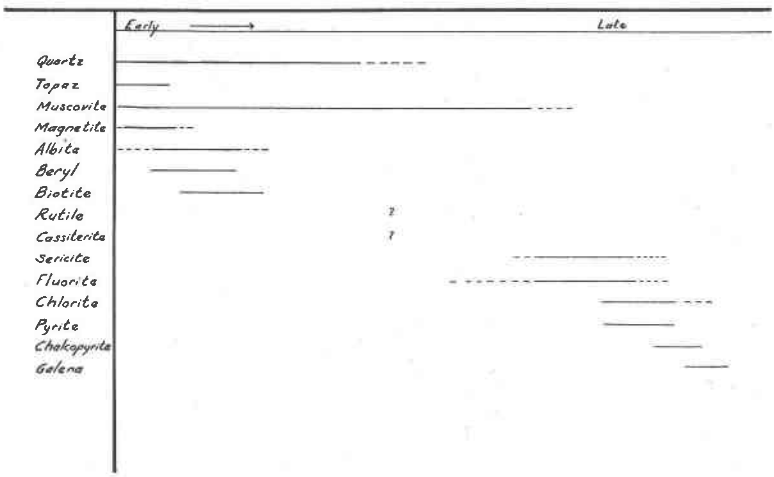
The hydrothermal stage of the pegmatite is marked by the deposition of a series of minerals, by progressive replacement of early minerals by later ones. The hydrothermal minerals in the order of their development as determined from replacement relationships shown in thin sections are topaz, muscovite, beryl and albite, biotite, muscovite, rutile and cassiterite (?), sericite and fluorite, pyrite, chalcopyrite, and galena.

Throughout the granite mass deuteric and hydrothermal activity resulted in albitization and replacement of feldspar and quartz by magnetite, muscovite, fluorite and other secondary minerals. Hydrothermal solutions in their ascent became more or less restricted to channels and developed the quartz veins and the joint-veinlets described.

The paragenesis of the hydrothermal minerals found in the pegmatite and veins in the Sheahan quarry is shown in a generalized manner in Table III.

TABLE III

Relative Age of Hydrothermal Minerals in Pegmatite and Veins



SUMMARY AND CONCLUSIONS

1. Granite, pegmatite, and replacement veins in the Sheahan quarry, Graniteville, Missouri, are genetically related.

2. The granite is composed of quartz, albite, orthoclase, microcline, and a small amount of accessory minerals. The feldspar shows much perthitic intergrowth and some late albitization. Secondary minerals include magnetite, muscovite, fluorite, sericite, chlorite, calcite, hematite, and pyrite.

3. The pegmatite is of the complex type. Perthite and quartz represent the magmatic stage. The hydrothermal minerals are topaz, muscovite, albite, beryl, biotite, rutile, cassiterite, sericite, fluorite, pyrite, chalcopyrite, and galena.
4. Quartz, magnetite, muscovite, fluorite, specularite, pyrite, and chlorite are found in replacement veins and in joint-veinlets.
5. Chemical data for the granite, perthite, beryl, and muscovite are given. Optical data for the minerals are also included.
6. The Sheahan quarry pegmatite is the only complex pegmatite so far encountered in the St. Francois Mountains.