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FURTHER INFORMATION ON THE GEOLOGY OF CHROMIAN MUSCOVITES[1]

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INTRODUCTION

In a recent paper Leo *et al.* (1965) noted that chromian muscovites in quartzites can originate in one or more of three ways: 1. Cr is released by the destruction of detrital chromite during regional metamorphism of the sandstones and combines with silica, alumina and alkalies available in the rock to form chromian muscovite. 2. Cr is introduced into metamorphic rocks by hydrothermal solutions that leached it from nearby mafic or ultramafic rocks, and (presumably) Cr replaces Al in preexisting ordinary muscovite. 3. The chromian muscovite is entirely metasomatic in origin, being a component of hydrothermal quartz-ankerite-sulfide-gold deposits. The authors cited the conclusions of Whitmore *et al.* (1946), who regarded all chromian muscovites as secondary and hydrothermal, and also the paper by Geijer (1963) who emphasized the same conclusions but in modified form.

For the origin of the Serra de Jacobina chromian muscovite Leo *et al.* (1965) were unable to decide between 1 and 2 above and state (p. 401) "Available evidence thus suggests that detrital and/or hydrothermally introduced chromium may have contributed to the formation of chromian muscovite in the Jacobina range."

Neither Geijer (1963) nor Leo *et al.* (1965) were apparently aware of the studies by Heinrich *et al.* (1953) who concluded (p. 73)

"The chrome micas variously classed as chromiferous muscovite, fuchsite and mariposite occur chiefly in two types of geological environments: (1) hydrothermal veins and replacement deposits and (2) metamorphic schists, gneisses and quartzites . . . there are numerous examples of the occurrences of chrome micas in regional metamorphic rocks, particularly schists and quartzites in which there is no evidence of metasomatism. Chromiferous muscovite quartzites have been encountered by the writer in several districts in southwestern Montana. The rocks are fine-grained, well foliated quartzites whose color varies from very pale green to deep blue green. The depth of the color is directly proportional to the amount of chromiferous muscovite present. No peridotites lie close to the bands and lenses of green quartz, nor is there any evidence of hydrothermal alteration of these rocks."

In addition it has been pointed out that the chrome micas called mariposites, at least those for which analyses are available, are in reality high-silica muscovites and that the term mariposite should be restricted therefore to signify a *chromian phengite*, i.e., a chromian muscovite in which

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the ratio of Si to tetrahedral Al is 7:1. In contrast, fuchsites are *chromian muscovites* in which this ratio is 6:2 (Heinrich *et al.*, 1953; Heinrich and Levinson, 1955). Some mariposites have crystallized as the 1M polymorph, whereas only the 2M structure has been found in fuchsite (Heinrich and Levinson, 1955; Clifford, 1957). To my knowledge, all mariposites (in this sense) are hydrothermal in origin, whereas fuchsites may be either hydrothermal or metamorphic.

The purpose of this note is not to argue against the validity or importance of hydrothermal processes in the origin of many chrome micas, but rather to nudge the pendulum in the other direction by noting the widespread occurrence of strictly metamorphic chrome micas which have received lesser attention, largely because their host rocks are of no economic significance. Indeed the amount of *metamorphic* fuchsite probably exceeds considerably that of *hydrothermal* fuchsite plus mariposite.

Chromian Muscovite in Montana

The occurrence of chromian muscovite in Precambrian quartzites of Montana was first noted by Heinrich (1958) near the Bear Trap corundum deposit in Madison County. Shortly thereafter several green quartzites containing chromian muscovite were found in the southern Ruby Mountains, east of Dillon, in Madison and Beaverhead Counties (Heinrich, 1950, p. 8): "The writer considers this green quartzite to be diagnostic of Cherry Creek rocks. . . ." Continuing studies in the Prebeltian areas of southwestern Montana by the writer and his students have shown that the green quartzites are widely distributed (*e.g.* Levandowski, 1956). Green quartzites with chromian muscovite also occur near the type section of the Cherry Creek group south of Ennis, Madison County (Heinrich and Rabbitt, 1960).

The complete list of Montana occurrences found by the writer follows:

Prebeltian area	*No. of occurrences*
Lima Peaks	1
Tendoy	1
Madison Range-Centennial Valley	1
Blacktail Range	1
Ruby Mountains	8
Southern Tobacco Root Mountains	1
Gallatin River-Madison Canyon	1
Cherry Creek	3
Beartooth Mountains	1

The area encompassed by these occurrences is 180 miles long (E–W) and as much as 50 miles wide (N–S). This distribution, on a regional scale, is a cogent argument, *per se*, for a nonmetasomatic origin of the mica.

Other features noteworthy in a discussion of the genesis of the green mica are:

1. The mica is confined to quartzites, which are relatively poorly foliated rocks. These would not be as readily penetrable by solutions as some of their neighboring, more highly foliated, micaceous schists. These, however, contain only ordinary muscovite.
2. The green quartzites show no relation, in their distribution, to faults or fracture systems.
3. There is no evidence of hydrothermal mineralization near any of the occurrences, except a few barren quartz veins at one occurrence south of Cherry Creek.
4. Although small peridotite bodies, including several known to carry very minor amounts of chromite, have been intruded into Cherry Creek rocks in several of the Prebeltian areas, the green quartzites are not spatially related to these intrusive bodies, except the one in the Beartooth Mountains which is near the eastern end of the Stillwater Complex. Moreover nearly all quartzites that *do* occur close to the peridotite bodies do not contain chromian muscovite, but have normal, colorless muscovite.
5. The green quartzites form independent beds and lenses as much as 10 feet thick and as long as several hundred feet or they occur as local phases in layers of white or gray quartzites into which they grade.
6. Microscopic examination shows that although most of the chrome mica flakes occur along the boundaries of quartz grains, many penetrate the grains and a sufficient number are "enclosed" in quartz grains to suggest that they were formed at the same time that the quartz was being metamorphically recrystallized.

The mineral assemblages of the green quartzites are:

quartz, chromian muscovite
quartz, chromian muscovite, microcline
quartz, chromian muscovite, sillimanite (one example)

Accessories are hematite, magnetite, sphene, zircon and rutile. Sulfides and carbonates are absent. The content of chromian muscovite ranges from 3–15%. By neutron activation analysis fuchsite from the Cherry Creek area contains $3.3\pm0.4\%$ Cr. A single *x*-ray determination of a chromian muscovite from Copper Mountain in the southern Tobacco Root Mountain shows that it has the 2M muscovite structure (Levandowski, 1956).

Other Occurrences

Chromian muscovite quartzites in the Rocky Mountains are not confined to Montana, for Blackwelder (1926) described them from the Medicine Bow Mountains of Wyoming. He states (p. 633), in describing the Medicine Peak metaquartzite:

> "There is one bed of a bright emerald green, about 60 feet thick, that is conspicuous in the upper third of the formation northwest of Big Telephone Lake, and boulders of it are common in the glacial drift to the southeast. The microscope shows that this green color is due to the presence of a micaceous mineral."

The occurrence of fuchsite in a New Hampshire conglomeratic quartzite also is of metamorphic origin (Clifford, 1957).

Several occurrences in Tanganyika of quartzite colored green by fuchsite are reported by Bassett (1956) who states (p. 104) "As such quartzite seems to occur over a wide area and is a striking and easily identified rock it may prove to be of considerable value in the geological mapping of the mid-northern parts of Tanganyika"—an echo of our experience in Montana.

Green quartzite which owes its color to chromiferous muscovite occurs in the Hospital Hill quartzites of the Witwatersrand System of South Africa (Frankel, 1940)[1]. Chromite also is present in the quartzites, and Frankel (p. 16) states: "The intensity of the green colour of the mica increases as the amount of associated chromite becomes greater. Nearly all the chromite grains are coated with mica . . .".

Conclusions

Chromian muscovites in quartzites, which are widespread in the Prebeltian Cherry Creek Group of Montana, show no evidence of other than a regional metamorphic origin. The associated rocks are of kyanite- or sillimanite-grade. Certainly in the Rocky Mountain area hydrothermal chromian muscovite is greatly subordinate to metamorphic fuchsite.

It should also be noted that, in addition to the three modes of origin listed by Leo *et al.* (1965) for chromian muscovites, two other parageneses have been reported:

1. Fuchsite in granodiorite at Gazma, Armenian S.S.R. The granitoid contains up to 5% fuchsite with 3.65% Cr_2O_3 (Babadzhanyan, 1960) (Metasomatic?).
2. The hydrothermal metamorphism of chromite ores at Tatarcik, Eskisehir region, Turkey, by granodiorite has converted these to hematite, magnetite, chlorite, kammererite and "chromiferous phengite" (Ergunalp, 1944; see also, Bryhni, 1964).

References

Babadzhanyan, A. K. (1960) Fuchsite from the granodiorite intrusion at Gazma (Armenian S.S.R.). *Mem. All-Union Min. Soc.* **189,** 232–233 (in Russian). *Mineral. Abs.* **15** (6), 455, 1962.

Bassett, H. (1956) Chromiferous muscovite mica in Tanganyika. *Rec. Geol. Survey Tanganyika* **4** (1954), 103–104.

Blackwelder, E. (1926) Pre-Cambrian geology of the Medicine Bow Mountains. *Bull. Geol. Soc. Am.* **37,** 615–658.

Bryhni, Inge (1964) Chromian muscovite in meta-anorthosite. *Norsk Geol. Tidssk.* **44,** 353–363.

Clifford, T. N. (1957) Fuchsite from a Silurian (?) quartz conglomerate, Acworth Township, New Hampshire. *Am. Mineral.* **42,** 566–568.

Ergunalp, Falik (1944) The chromite deposits of Turkey. *A.I.M.E. Tech. Publ.* **1746,** *Min. Tech.* Sept. 1944, 1–11.

Frankel, J. J. (1940) The green colour of the Hospital Hill quartzite. *Trans. Geol. Soc. South Africa* **42,** 15–17.

Geijer, Per (1963) On the source of chromium in micas. *Arkiv. Mineral. Geol.* **3,** 415–422.

[1] Not cited by Leo *et al.* (1965), who state (p. 399) " . . . in descriptions of the gold-uranium districts of . . . Witwatersrand . . . there is no mention of chrome mica. . . . "

Heinrich, E. Wm. (1948) Deposits of the sillimanite group of minerals south of Ennis, Madison County, with notes on other occurrences in Montana. *Mont. Bur. Mines Geol. Misc. Contrib.* **10.**

——— (1950) Sillimanite deposits of the Dillon region, Montana. *Mont. Bur. Mines Geol. Mem.* **30.**

——— and A. A. Levinson (1955) Studies in the mica group; polymorphism among the high-silica sericites. *Am. Mineral.* **40,** 983–995.

———, A. A. Levinson, D. W. Levandowski and C. H. Hewitt (1953) Studies in the natural history of micas. *Univ. Mich. Eng. Res. Inst., Final Rpt. Project* **M 978.**

——— and John C. Rabbitt (1960) Pre-Beltian geology of the Cherry Creek and Ruby Mountains areas, southwestern Montana. *Mont. Bur. Mines. Geol. Mem.* **38.**

Leo, G. W., H. J. Rose, Jr. and J. J. Warr (1965) Chromian muscovite from the Serra de Jacobina, Bahia, Brazil. *Am. Mineral.* **50,** 392–402.

Levandowski, Donald W. (1956) Geology and mineral deposits of the Sheridan-Alder area, Madison County, Montana. Univ. Mich. Ph.D. Thesis.

Whitmore, D. R. E., L. G. Berry and J. E. Hawley (1946) Chrome micas. *Am. Mineral.* **31,** 1–21.

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PHASES IN THE SPINEL REGION OF THE SYSTEM CuO_x-MnO_y-FeO_z

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The region of the quasiternary system CuO_x-MnO_y-FeO_z, in which the occurrence of phases with spinel structure is known (Weil *et al.* 1950; Toropov and Borisenko, 1950; Kordes and Röttig, 1951; Delorme, 1958; Goodenough, 1963), was investigated by means of thermogravimetric, dilatometric and *x*-ray measurements in air at temperatures between 20–1200° C. The samples were prepared from pro analysi (p.a.) pure oxides by mixing, preheating at 500° C., wet milling, and sintering at 1150° C. for five to six hours. The compositions investigated are listed in Fig. 1. The dilatometric measurements were repeated five times, the thermogravimetric measurements three times, in both directions, using the same sample. The *x*-ray powder patterns were exposed for 6 hours after the samples had been heated an adequate time for attaining equilibrium.

The following structures were found by *x*-ray to be formed at temperatures between 20 and 1200° C.: 1. cubic spinel in all samples, 2. tetragonally deformed spinel in all samples except samples 4 and 5; 3. hematite (αFe_2O_3) in samples 4 and 5, lying on the $CuFe_2O_x$-$MnFe_2O_x$ join and in sample 3, lying nearer to Fe_3O_x; 4. a monoclinic phase with the diffraction lines of tenorite (CuO) at higher manganese content, near the join $CuFe_2O_x$-$CuMn_2O_x$; 5. a hexagonal phase of the type of delafossite