Single-crystal $^{40}\text{Ar}/^{39}\text{Ar}$ age variation in muscovite of the Gassetts Schist and associated gneiss, Vermont Appalachians

WILLIS E. HAMES,†,* JOHN T. CHENEY, 2 AND ROBERT J. TRACY 3

1Department of Geology and Geography, Auburn University, Auburn, Alabama 36849, U.S.A.
2Department of Geology, Amherst College, Amherst, Massachusetts 01002, U.S.A.
3Department of Geological Sciences, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061, U.S.A.

ABSTRACT

An exposure near Gassetts, Vermont, contains lithologies varying from staurolite-kyanite grade aluminous schists with paragonitic muscovite to potassic gneiss with phengitic muscovite. Single-crystal laser fusion $^{40}\text{Ar}/^{39}\text{Ar}$ ages for paragonitic and phengitic muscovite yield similar distributions with ranges between $366 \pm 4$ and $326 \pm 4$ Ma. Intracrystalline ages vary from ca. $394 \pm 4$ to $330 \pm 4$ Ma. Thus, we find that the intracrystalline (core-rim) age distribution of relatively large single crystals essentially encompasses the range of ages obtained through total fusion of smaller crystals, consistent with models for development of diffusion profiles and $^{40}\text{Ar}$-closure during cooling with a diffusion dimension controlled by the physical grain size. However, some of the larger crystals studied, particularly those with prominent microscopic defects (features readily evident such as internal grain boundaries and twin planes), yield relatively young ages and lack significant core-rim age discordance. Furthermore, the overall distribution of single-crystal ages in the two samples is bimodal, and we suggest that this age distribution reflects metamorphic deformation and recrystallization event(s) superimposed on early generation muscovite. Thus, the mean age of muscovite in these samples (typical of K/Ar and $^{40}\text{Ar}/^{39}\text{Ar}$ incremental heating analysis of bulk mineral separates) has little relationship to any single, hypothetical closure temperature. In view of the similar results we obtain for muscovite of contrasting composition, the net effects of variations in grain size, deformational character, and growth history are interpreted to be more important in forming the observed variations in age than are the chemical substitutions in these samples.

Keywords: Muscovite, paragonite, phengite, $^{40}\text{Ar}/^{39}\text{Ar}$, geochronology, laser analysis, Appalachians, Acadian

INTRODUCTION

Variations in size, major-element composition, intracrystalline structure, and relative growth history are generally present among crystals of a given mineral in metamorphic rocks. The extent to which these factors influence the retention of radiogenic isotopes, and thus affect the apparent ages of minerals, must be known to effectively sample, analyze, and interpret minerals and isotopic data. This is particularly true for studies of muscovite in schists, where crystals may have diameters varying from micrometer- to centimeter-scale, muscovite-paragonite-phengite solid solutions are prevalent (Guidotti 1984), and crystalization may occur at different times of the metamorphic and deformational history (e.g., Dempster 1992). Microanalytical techniques enable age determinations to be made in the context of individual crystals and areas within crystals, and thus can test the influence of different parameters on $^{40}\text{Ar}$-retention during metamorphism and cooling. As these tests are applied at the scale of, or within, single crystals, they also permit investigation into the range of behavior for a population of crystals.

CHEMICAL SUBSTITUTIONS TYPICAL OF MUSCOVITE IN SCHISTS

Although there is considerable variation in the composition and structure of micas (Bailey 1984; Guidotti 1984), metamorphic white micas permit relatively restricted polytypism and ionic substitution. Substitution of Na, Ca, and K in the interlayer sites of micas is similar to the cation substitutions in feldspars (Fig. 1). Asymmetric solvi exist between muscovite-paragonite and paragonite-margarite, such that muscovite in typical green-schist- to amphibolite-facies rocks contains 5–30% paragonite, and there is essentially no solid solution between muscovite and margarite. Incorporation of Ca into paragonite also limits paragonite-muscovite solid solution. Thus, in terms of the ideal NaAlO$_2$-CaAl$_2$O$_4$-KAlO$_2$ system, the [Na][K]$_3$ substitution is all that need be considered for micas with more than a fraction of a weight percent of K$_2$O.

Natural muscovite deviates considerably from the ideal end-member composition, principally by the “phengite substitution” $[(\text{Mg,Fe}^{2+})\text{Si}^4\text{+}]_2[(\text{Al}^3\text{+Al}^2\text{+})]$ which is the reverse of the Tschermak substitution (Fig. 2a), substitution of Fe$^{3+}$ for $\text{Al}^3\text{+}$, and incorporation of octahedral Ti by mechanisms such as $[(\text{Mg,Fe}^{2+})\text{Ti}^{4\text{+}}][2\text{Al}]$. Phengite substitution in muscovite tends to increase with pressure, but this effect also depends on mineral assemblage.