Statistical Estimation of Mineral Age\textsuperscript{1} by K-Ar Method

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Statistical estimation of age of $^{40}\text{Ar}/^{40}\text{K}$ ratios may be considered a result of convolution of uniform and normal distributions with different weights for different minerals. Data from Gul'shad Massif (Nearbalkhash, Kazakhstan, USSR) indicate that $^{40}\text{Ar}/^{40}\text{K}$ ratios reflecting the intensity of geochemical processes can be resolved using convolutions. Loss of $^{40}\text{Ar}$ in biotites is shown whereas hornblende retained the original content of $^{40}\text{Ar}$ throughout the geological history of the massif. Results demonstrate that different estimation methods must be used for different minerals and different rocks when radiometric ages are employed for dating.

KEY WORDS: convolution of distributions, uniform distribution, normal distribution, Gul'shad Massif, potassium-argon dating, geochemistry.

INTRODUCTION

The problem is a general one that is seen many places in earth science; it is not restricted to geochemistry or potassium-argon dating. However, here a massif which is divided into small blocks, each having a different transformation intensity is considered. Transformation intensity, as expressed in the loss of $^{40}\text{Ar}$, is slight and varies randomly from block to block. Some blocks have not lost their original $^{40}\text{Ar}$ content. Mineral x containing $^{40}\text{Ar}$ is desseminated over the massif. $^{40}\text{Ar}$ in mineral x is a result of decay of $^{40}\text{K}$ or a result of accumulation of $^{40}\text{Ar}$ obtained by decay of $^{40}\text{K}$ plus some excessive $^{40}\text{Ar}$ which is not distinguishable from $^{40}\text{Ar}$ obtained by decay of $^{40}\text{K}$.

Specimens obtained in the sampling process are taken at random and at a distance from one another of a size greater than the blocks with different intensity of transformation. Experimental estimation of the value of $^{40}\text{Ar}/^{40}\text{K}$ in a single specimen (a member of the sample) is accepted as an estimator of the

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parametric value of this ratio with the estimator variance ($s^2$). Rate of decay of $^{40}K$ is taken as constant.

As a result of this procedure, a series of values of $^{40}Ar/^{40}K$ for all specimens in the sample is obtained. Herein, one piece of rock is "a specimen" whereas a set of specimens taken from some population (a zone) will be referred to as "a sample" or sampling. What is an appropriate statistical operation for determining the age of the massif, or part of the massif, by measuring $^{40}Ar/^{40}K$ in $n$ specimens? The problem can be solved if each specimen contains only $^{40}Ar$ obtained as a result of decay of $^{40}K$ in this specimen. If excessive $^{40}Ar$ is present, a different problem exists for which a solution is not proposed herein.

Assume that the time of mineral generation is negligibly small compared with the time from the moment of mineral generation to the present (which is to be measured). Assume also that generation of mineral $x$ in the massif under investigation was simultaneous in all parts sampled.

The problem is examined using data from the Gul'shad Massif (Nearbalkhash, Kazakhstan, USSR) (Fig. 1) because the geological history of this massif has been investigated in detail and necessary conditions for obtaining the needed estimators exists to a greater or lesser degree in this massif (Vistelius, 1984, 1986).

**MAIN GEOLOGICAL FEATURES OF GUL'SHAD MASSIF**

Gul'shad Massif is along the Karaganda-Alma-ata highway, 434 km from Karaganda. The massif is composed of three main zones: an outer zone of monzonites, a middle zone of pyroxenites, and a core-zone of olivine gabbro. Pyroxene gabbro and pyroxene-hornblende gabbro form a thin, minor zone between the outer and middle or innermost zone (where pyroxenites are absent).

Monzonites and pyroxene and pyroxene-hornblende gabbros with small spots of olivine gabbro can be observed in outcrops. Most olivine gabbro and all pyroxenite rocks are covered by Quaternary deposits up to 20 m in thickness.

Bore-holes (Fig. 2) and geophysics indicate that monzonite thickness is some hundreds of meters; pyroxene and pyroxene-hornblende gabbro have a thickness of about 10 m; maximum thickness of olivine gabbro is 180 m; and pyroxenites are up to 270 m in thickness. The transition between gabbro and monzonites is gradual without any traces of sharp contacts or intrusive breccia.

In field work, the border between these two rocks is impossible to detect. In bore-holes, some fissures and hydrothermal alterations are observed in the zone of transition from gabbro to monzonite. The transition from one type of gabbro to another is also gradual. Terminations between gabbro and pyroxenites are usually sharp; xenoliths of pyroxenite occur in different types of gabbro. In olivine gabbro, xenoliths are angular whereas in pyroxene-hornblende gabbro they are rounded and similar to schlieren in their contacts. Xenoliths of pyroxenite reach 20–25 cm in diameter.