

1972-01

Age Determination of a Granite Gneiss from the Precambrian Basement of Scioto County, Ohio

Hofmann, Charles M.; Faure, Gunter; Janssens, A.

The Ohio Journal of Science. v72 n1 (January, 1972), 49-53

<http://hdl.handle.net/1811/5670>

Downloaded from the Knowledge Bank, The Ohio State University's institutional repository

AGE DETERMINATION OF A GRANITE GNEISS
FROM THE PRECAMBRIAN BASEMENT OF
SCIOTO COUNTY, OHIO^{1, 2}

CHARLES M. HOFMANN, GUNTER FAURE, AND A. JANSSENS

*Department of Geology and Mineralogy, The Ohio State University, Columbus, Ohio 43210
and Ohio Division of Geological Survey, Columbus, Ohio 43212*

ABSTRACT

Biotite and potassium feldspar from a specimen of granite gneiss from the Precambrian basement of Scioto County (Permit No. 212, Greenup Quadrangle of Green Township) have been dated by the Rb-Sr method. The model dates, calculated relative to an assumed initial ⁸⁷Sr/⁸⁶Sr ratio of 0.7040, are 898±40 million years (biotite) and 1242±46 million years (potassium feldspar). The dates are discordant, which suggests that the minerals gained or lost rubidium and/or strontium during an episode of metamorphism. The age of the metamorphism is estimated as 840±42 million years, assuming that both minerals were isotopically re-equilibrated and had the same ⁸⁷Sr/⁸⁶Sr ratio of 0.7178±0.0026. The model date of the biotite agrees with previous age determinations of basement rocks from Ohio and confirms the interpretation that the Grenville Province of the Canadian Precambrian Shield extends southward into Ohio.

INTRODUCTION

The geology of the Precambrian basement rocks of Ohio is known only as a result of deep drilling through the cover of Paleozoic sedimentary rocks. Information available to the Ohio Division of Geological Survey shows that 76 wells had been drilled to the basement by the end of 1970.

McCormick (1961) studied the petrology of the Precambrian rocks of Ohio and Summerson (1962) published a report on the topography, petrography, and structure of the Precambrian basement of Ohio and adjoining areas, based on a review of the literature and a compilation of 38 well records. Bass (1960) had previously examined samples of basement rocks recovered from 14 deep wells in

¹Laboratory for Isotope Geology and Geochemistry Contribution No. 21.

²Manuscript received October 1, 1971.

Ohio and postulated the existence of a sharp lithologic boundary between high-grade metamorphic rocks on the east and unmetamorphosed sedimentary and igneous rocks west of this line. He dated two biotites and one muscovite from two wells by the Rb-Sr method and obtained dates ranging from 930 to 980 million years. On the basis of these dates and lithologic similarities, he correlated the basement rocks east of the hypothetical boundary with the rocks of the Grenville Province of the Canadian Precambrian Shield and predicted that the rocks west of the boundary should be older.

More recently Lidiak *et al.* (1966) dated Precambrian rocks and minerals from ten Ohio wells using both the Rb-Sr and K-Ar methods, where appropriate. Their results confirmed the hypothesis of Bass, because two samples from locations west of his boundary were found to have whole-rock Rb-Sr model dates of 1280 ± 70 and of 1240 ± 120 million years. The two rocks (OH-4 and OH-5) are trachyte and rhyolite, respectively, and indicate the occurrence of volcanic activity in western Ohio approximately 1260 million years ago. The other samples came from locations east of the boundary and were found to have essentially concordant K-Ar and Rb-Sr biotite and muscovite dates ranging from 860 to 990 million years, in satisfactory agreement with the results of Bass (1960). On the basis of these age determinations, it is now generally accepted that the western boundary of the Grenville Province passes through Ohio in a north-south direction west of Columbus (Goldich *et al.*, 1966; Muehlberger *et al.*, 1967), although Rudman *et al.* (1965) placed this boundary farther west in Michigan and Indiana.

The age determinations reported here were made by the Rb-Sr method based on analyses of coexisting potassium-feldspar and biotite of a granite gneiss from the basement of Scioto County, Ohio. The sample was taken from a core drilled for USS Chemicals (Division of U.S. Steel Corporation) in the Greenup Quadrangle of Green Township, Scioto County, under Permit No. 212, issued on May 2, 1968. The well was drilled to a depth of 5617 feet and intersected the basement at a depth of 5580 feet. The specimen dated by us was taken at a depth of 5616 feet, 36 feet below the unconformity and was made available to us by the Ohio Division of Geological Survey. The location of this well in Scioto County is shown in Figure 1, which also indicates the position of the lithologic boundary in Ohio, according to Janssens (in press). It is apparent that the well in Scioto County is located east of that boundary, which suggests that mineral dates from the core should be within the range commonly observed in the Grenville Province.

The rock consists of dark-salmon-colored potassium-feldspar, quartz, biotite, hornblende, and magnetite. The feldspar and the mafic minerals are segregated into irregular layers up to several inches in thickness. Quartz is evenly distributed throughout the rock. The magnetite content of the mafic layers is approximately 10 percent. Based on its mineral composition and texture, this rock is classified as a granite gneiss.

ANALYTICAL PROCEDURES AND RESULTS

The rock was crushed in a steel mortar and screened into three fractions: 60 to 120, 120 to 200, and <200 mesh. The last fraction was discarded. Magnetite was removed from the remaining two fractions with a magnet, and biotite concentrates were prepared by repeatedly passing the rock powders through a magnetic separator. The two concentrates of biotite, containing minor amounts of hornblende and chlorite, were recombined and homogenized by rolling on a sheet of paper. Potassium-feldspar was concentrated from the non-magnetic fractions by suspension in a mixture of bromoform and acetone whose specific gravity was adjusted to float potassium-feldspar and to sink quartz. The two feldspar concentrates were combined and thoroughly mixed.

Concentrations of rubidium and strontium and the Rb/Sr ratios of the biotite and K-feldspar concentrates were determined by X-ray fluorescence analysis

using a Mo-target X-ray tube and a LiF (220) analyzing crystal. An aliquot (3g) of the potassium-feldspar fraction was reground to <200 mesh and was compressed into a pellet with a boric-acid backing. A similar aliquot of the biotite concentrate was digested in reagent-grade HF to convert the silicates to fluorides. After evaporation of excess HF, the residue was crushed in an agate mortar and compressed into a pellet as before. The concentrations of rubidium and strontium measured in the biotite fraction therefore are not representative of the silicate minerals. However, the Rb/Sr ratio, which is the desired parameter for dating, is not affected by this procedure, which avoids the practical difficulty of compressing mica concentrates into stable pellets.

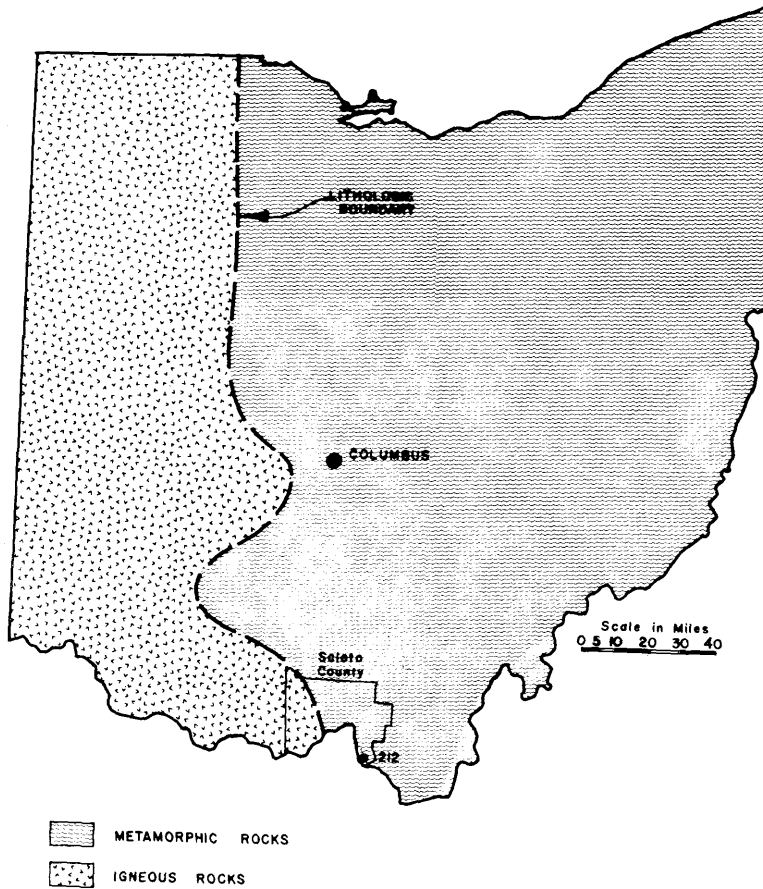


FIGURE 1. Map of Ohio showing the location of well 212 in Scioto County and the lithologic boundary of the Precambrian basement. Adapted from Janssens (1972).

The Rb/Sr ratios of the mineral concentrates were determined in two different ways. (1) Concentrations of rubidium and strontium were measured by comparison with U.S.G.S. rock standards (G-2, GSP-1, and W-1). (2) The ratios of Rb K-alpha to Sr K-alpha x-radiation, corrected for background, were measured and related to the Rb/Sr ratios by means of a separate calibration based on replicate analyses of nine rocks whose Rb/Sr ratios are known. The relationship

between $(\text{Rb}/\text{Sr})_{\text{XRF}}$ and the known $(\text{Rb}/\text{Sr})_{\text{STD}}$ ratio of the standards is a straight line through the origin of the form:

$$\left(\frac{\text{Rb}}{\text{Sr}}\right)_{\text{STD}} = k \left(\frac{\text{Rb}}{\text{Sr}}\right)_{\text{XRF}}, \quad (1)$$

where $k = 1.344 \pm 0.034$.

In order to reduce matrix effects, the Rb and Sr K-alpha X-ray intensities of both standards and unknowns were divided by the intensity of the Compton-scattered Mo K-alpha X-radiation. Counts were accumulated for 200 seconds for Rb and Sr and for 100 seconds on the baselines. Deadtime corrections were not significant for any sample analyzed in this study. The analytical results are compiled in Table 1. It can be seen that the Rb/Sr ratios obtained by the two techniques described above agree well within experimental errors.

The data in Table 1 were used to calculate dates for each of the two minerals by substitution into equation (2).

$$\left(\frac{{}^{87}\text{Sr}}{{}^{86}\text{Sr}}\right)_p = \left(\frac{{}^{87}\text{Sr}}{{}^{86}\text{Sr}}\right)_o + \frac{{}^{87}\text{Rb}}{{}^{86}\text{Sr}} \left(e^{-\lambda t} - 1 \right), \quad (2)$$

where $\left(\frac{{}^{87}\text{Sr}}{{}^{86}\text{Sr}}\right)_p$ = isotope ratio in the mineral at present,

$\left(\frac{{}^{87}\text{Sr}}{{}^{86}\text{Sr}}\right)_o$ = isotope ratio in the mineral at the time of assumed last closure to Rb and Sr,

$\frac{{}^{87}\text{Rb}}{{}^{86}\text{Sr}}$ = isotope ratio in the mineral at present,

$\lambda = 1.39 \times 10^{-11} \text{y}^{-1}$ (decay constant of ${}^{87}\text{Rb}$), and

t = time elapsed since last closure of the mineral to Rb and Sr.

By assuming a value of 0.7040 for $\left(\frac{{}^{87}\text{Sr}}{{}^{86}\text{Sr}}\right)_o$ and solving equation (2) for t , the following dates were obtained: 1242 ± 46 million years for the potassium feldspar and 898 ± 40 million years for the biotite. The limits of uncertainty of the dates were calculated from the analytical errors of the measurements in Table 1 and do not include the uncertainty of the assumed initial ${}^{87}\text{Sr}/{}^{86}\text{Sr}$ ratio. The date for the biotite is similar to dates previously reported by Bass (1960) and Lidiak *et al.* (1966) for Precambrian basement rocks of Ohio. It is clear, however, that the dates obtained by us are strongly discordant.

The discordance of mineral dates is characteristic of rocks which have experienced redistribution of rubidium or strontium among their constituent minerals during an episode of metamorphism. The discordance we observe in this case could be due to loss of strontium by the biotite and capture of strontium by the potassium feldspar to replace K^+ ions. If strontium was isotopically equilibrated as a result of metamorphism, the age of this event could be calculated from analyses of two or more coexisting mineral phases which contain rubidium and strontium. In the case at hand, we are restricted to only two minerals by

the mineral composition of the rock, and the calculation that can be made is therefore not definitive. Nevertheless, we obtained a date of 840 ± 42 million years and an initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of 0.7178 ± 0.0026 for the biotite and the potassium-feldspar by making the assumptions described above. The value of the initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio is significantly higher than is commonly observed in granitic rocks (Faure and Powell, 1972) and is consistent with the suggestion that this rock has been metamorphosed. However, the data available to us at this time do not permit us to date the metamorphism precisely.

TABLE 1

Analytical data for mineral concentrates of a granite gneiss, Scioto County, Ohio

Mineral Concentrate	Rb ppm	Sr ppm	Rb	$(^{87}\text{Sr})^*$	^{86}Sr
			Sr	(^{86}Sr)	^{88}Sr
				corr	
K-feldspar	175.6	213.8	0.822	0.7456	0.1192
	± 3.4	± 3.6	± 0.021	± 0.0005	
			0.812 [†]		
Biotite (fluoride)	317.6	53.5	± 0.021	0.9246	0.1190
	± 7.6	± 1.8	± 0.024	± 0.0005	
			5.98 [†]		
			± 0.20		

*The $^{87}\text{Sr}/^{86}\text{Sr}$ ratios have been corrected for isotope fractionation to a value of 0.1194 for the $^{86}\text{Sr}/^{88}\text{Sr}$ ratio.

[†]Based on a separate calibration, as discussed in the text.

The mineral dates reported by us, although discordant, agree with earlier age determinations of minerals from the Precambrian basement of Ohio and confirm the interpretation that the basement of Ohio can be regarded as an extension of the Grenville Province of the Canadian Precambrian Shield.

ACKNOWLEDGMENTS

The rock specimen dated in this study was obtained from the Ohio Division of Geological Survey, in Columbus, Ohio. D. A. McClain provided assistance in the laboratory. We thank C. H. Summerson for helpful discussions and critical comments which improved the manuscript.

REFERENCES

- Bass, M. N. 1960. Grenville boundary in Ohio. *J. Geol.*, 68(6): 673-677.
- Faure, G., and J. L. Powell. 1972. Strontium isotope geology. Springer-Verlag New York, Inc.
- Goldich, S. S., W. R. Muehlberger, E. G. Lidiak, and C. E. Hedge. 1966. Geochronology of the midcontinent region, United States. 1. Scope, methods, principles. *J. Geophys. Res.* 71(22): 5375-5388.
- Janssens, A. in prep. Subsurface geology of Cambrian and Lower Ordovician rocks in Ohio. Ohio Geol. Survey Bull. 65.
- Lidiak, E. G., R. F. Marvin, H. H. Thomas, and M. N. Bass. 1966. Geochronology of the midcontinent region, United States. 4. Eastern area. *J. Geophys. Res.* 71(22): 5427-5438.
- McCormick, G. R. 1961. Petrology of Precambrian rocks of Ohio. Ohio Geol. Survey Rept. Invest. 41. 60 p.
- Muehlberger, W. R., R. E. Denison, and E. G. Lidiak. 1967. Basement rocks in continental interior of United States. *Amer. Assoc. Petroleum Geol. Bull.* 51(12): 2351-2380.
- Rudman, A. J., C. H. Summerson, and W. J. Hinze. 1965. Geology of basement in midwestern United States. *Amer. Assoc. Petroleum Geol.* 49(7): 894-904.
- Summerson, C. H. 1962. Precambrian in Ohio and adjoining areas. Ohio Geol. Surv. Rept. Invest. 44. 16 p.