# Evaluation of U-Th-Pb whole-rock dating on phanerozoic sedimentary rocks

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# Evaluation of U-Th-Pb Whole-Rock Dating on Phanerozoic Sedimentary Rocks

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ABSTRACT

Additional studies on the feasibility of dating limestones deposited from epeirogenic seas were not successful. The $^{206}Pb/^{204}Pb$ – $^{238}U/^{204}Pb$ isochron was most likely destroyed by fairly recent alterations in U/Pb. The $^{207}Pb/^{204}Pb$ – $^{206}Pb/^{204}Pb$ secondary isochron more closely reflects the age of the source area of the sediments than the age of sedimentation.

The usefulness of dating Precambrian granitic whole-rocks by the secondary $^{207}Pb/^{206}Pb$ isochron method has been known for some time (see SOBOTOVICH, GRASHCHENKO, ALEKSANDRUK, and SHATS, 1963, and prior papers cited therein). Difficulties, however, have been encountered in applying a $^{206}Pb/^{204}Pb$-$^{238}U/^{204}Pb$ isochron similar to that used in Rb-Sr dating (Bernard Price Institute or BPI plot) because of recent alteration of the U-Pb system. In some localities, the uranium has been enriched relative to lead (SOBOTOVICH, GRASHCHENKO, and LOVTSYUS, 1963), and in other localities uranium, but not thorium, has been depleted relative to lead (ROSHOLT and PETERMAN, 1969). This difference in behavior between the U-Pb and Th-Pb systems also suggests that values determined for Th or U on old crystalline rocks may be suspect if obtained without supporting lead isotope data. This observation is of great importance to heat flow studies. GERLING and ISKANDEROVA (1966) reviewed dating by U-Pb methods of carbonate rocks and found a number of examples with the expected age indicated by a BPI plot in good aggreement with the expected age estimated by other methods. Some marbles from Balmat, New York, appear to have undergone recent alteration of the U-Pb system (data from DOE, 1962).

Additional studies of the U-Th-Pb system have been undertaken from carbonate rocks of Nevada and other data are available from southern Missouri (DOE and M. E. DELEVAUX, unpublished data), all Late Cambrian or Early Ordovician in age, that permit further evaluation of the dating possibilities by the U-Th-Pb methods. Table 1 contains the U-Th-Pb data on surface samples for the samples of inarticulate brachiopods and whole-rock limestones in the basal part of the Goodwin Limestone from Ninemile Canyon west of the Antelope Range, Nevada; in that canyon the basal part of the Goodwin is Early Ordovician or Late Cambrian in age. The southern Missouri samples, drill cores provided by the St. Joseph Lead Company, are (1) from Texas County and Laclede County at localities far from known commercial minerali-

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Table 1. U-Th-Pb data on Lower Ordovician or Upper Cambrian limestones at the base of the Goodwin Limestone, Ninemile Canyon west of the Antelope Range, Nevada.

| | Concentration (ppm) | | | Atomic ratios | | | | |
|---|---|---|---|---|---|---|---|---|
| | U | Th | Pb | $^{206}Pb/^{204}Pb$ | $^{207}Pb/^{204}Pb$ | $^{208}Pb/^{204}Pb$ | $^{238}U/^{204}Pb$ | $^{232}Th/^{204}Pb$ |
| *Fossil from D1595-CO which constitutes about 5% of the whole rock* | | | | | | | | |
| without organic matter | 16.4 | 1.5 | 5–6 | – | – | 39.49[1] | – | – |
| with organic matter | 31.1 | 2.8 | 17 | 25.23[2] | – | – | 129.1 | 12.0 |
| whole rock, including HCl-insoluble material: 7.68% | 1.35 | 0.50 | 0.94 | 24.53 | 16.16 | 39.51 | 101.0 | 37.4 |
| *Cherty limestone, D289-CO, about 80 feet above D1595-CO; no inarticulate brachiopod* | | | | | | | | |
| HCl soluble (1) | 2.28 | 0.406 | 2.65 | – | – | – | – | – |
| HCl soluble (2) | 2.30 | 0.410 | 2.62 | – | – | – | – | – |
| Residue | 0.53 | 0.148 | 0.72 | – | – | – | – | – |
| Whole rock, including HCl-insoluble material: 47.3% | 1.45 | 0.284 | 1.74 | 25.60 | 16.21 | 40.17 | 59.9 | 12.1 |
| *Approximate analytical uncertainty (%)* | 1 | 1 | 1 | 0.29 | 0.37 | 0.58 | 2 | 2 |

[1]) From spiked run with $^{206}Pb$ tracer.
[2]) From spiked run with $^{208}Pb$ tracer.

zation and (2) from an unmineralized core from Iron County surrounded by galena mineralization. Though the Missouri samples were not subject to surface weathering, they came from below the water table and may have been affected by ground-water action. All concentrations were determined with a combined spike of purified isotopes of lead, $^{235}U$, and $^{230}Th$ to minimize pipetting and splitting uncertainties. In each area, the data for the $^{206}Pb$-$^{238}U$ system result in negative slopes on a BPI plot (Fig. 1), and calculation of individual ages on each sample assuming a 500 m.y. model lead for the lead initially in the rock gives some ages too old (i.e. – those that plot above the isochron) and others too young (i.e. – those that plot below the isochron) in each area. Such a model lead should be a reasonable approximation of the minimum value of the initial lead for sediments deposited from epeirogenic seas as indicated by the analyses by Chow (1965, 1968). In Nevada, uranium appears to have been redistributed in the rock system whereas in Missouri lead appears to have been the element redistributed because the contents of these two elements are uniform in their respective areas. The redistribution seems to have occurred fairly recently because the observed $^{206}Pb/^{204}Pb$ is unrelated to the observed $^{238}U/^{204}Pb$. Extensive sampling of each area might give a composite sample approximating a closed system and therefore yield

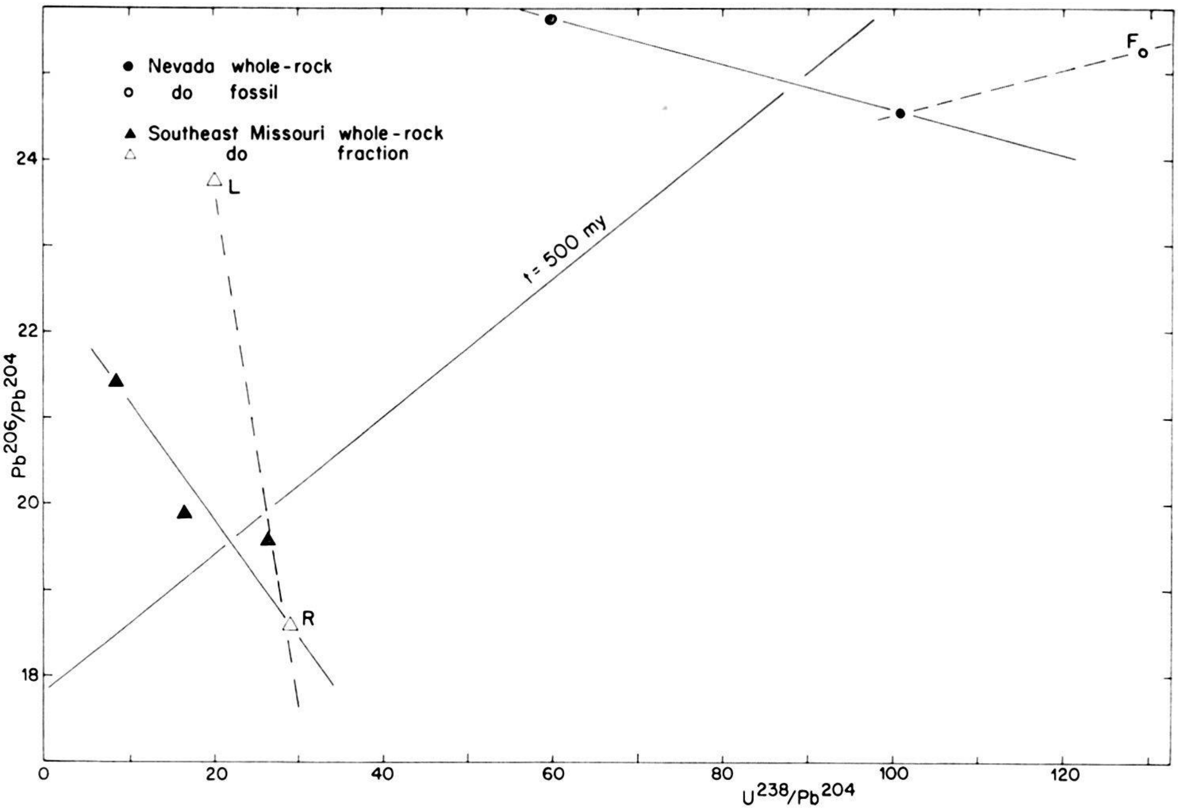


Fig. 1. $^{206}Pb/^{204}Pb$-$^{238}U/^{204}Pb$ isochron diagram for samples from Nevada and Missouri. Solid line is 500 m.y. isochron using a 500 m.y. old model lead as the initial lead. Dashed lines connect analyzed fractions of a rock with their whole rock: L- is the 6N-HCl soluble fraction and R is the residue from the acid leach; F is the inarticulate brachiopod fossils.

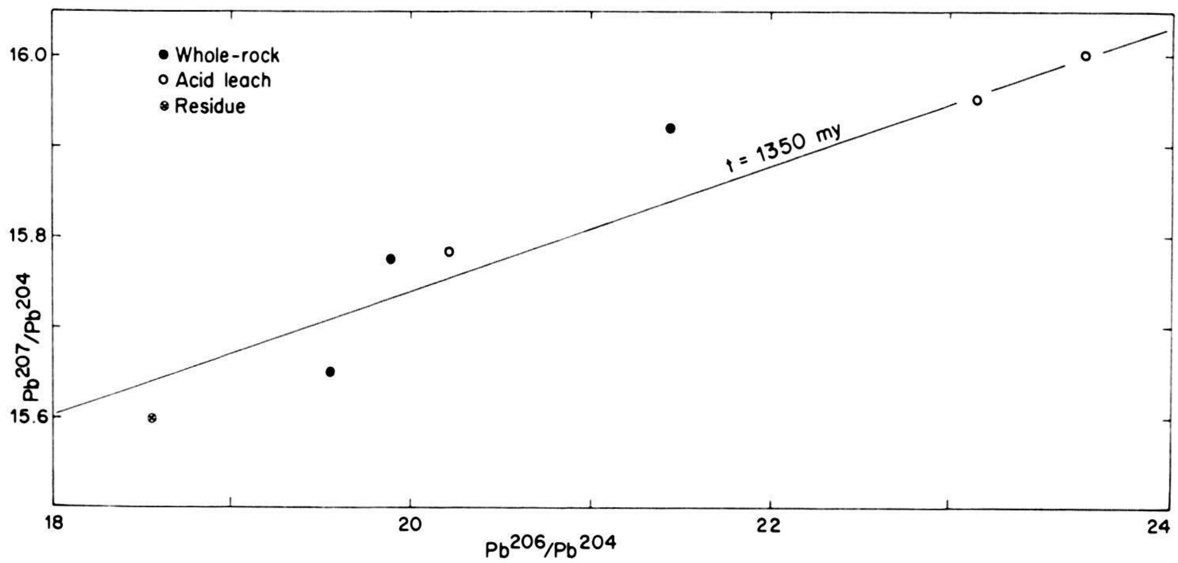


Fig. 2. $^{207}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ isochron diagram for samples from Southeast Missouri. Isochron is drawn for the age of the basement in the area. Acid leach is with 6N-HCl and residue is that fraction not dissolved by the acid.

a correct age for the rocks. If so, dating by this method might be useful for unfossiliferous limestones where an approximate age is needed. Yet serious sampling problems and the expense required severely limit its use. It is doubtful that sufficient precision could be obtained by the method, to permit refinement of the geologic time scale. Adequate range in radiogenic ratios was found in the samples from southern Missouri to permit calculation of a $^{206}Pb/^{207}Pb$ secondary isochron age of 1350 m.y. (Fig.2). This is the approximate age of the basement in the region and probably represents lead inherited from those rocks. Thus, application of this method to sediments deposited from epeirogenic seas does not appear to be useful in determining the age of sedimentation but may prove of some use in determining the source region of sediments, such as has been done by MUFFLER and DOE (1968).

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## REFERENCES

CHOW, TSAIHWA (1964): *Radiogenic Leads of the Canadian and Baltic Shield Regions*, in: *Symposium on Marine Geochemistry*. Rhode Island Univ. Narragansett Marine Lab. Occasional Publ. *3*, 169–184, 1965.

– (1968): *Lead Isotopes of the Red Sea Region*. Earth and Planet. Sci. Lett. *5*/3, 143–147.

DOE, BRUCE R. (1962): *Distribution and Composition of Sulfide Minerals at Balmat, New York*. Geol. Soc. America Bull. *73*/7, 833–854.

GERLING, E. K. and ISKANDEROVA, A. D. (1966): *Izotopny sostav svintsa karbonatytnykh porod razlichnogo vozrasta* (*Isotopic composition of lead from carbonate rocks of different age*). Akad. Nauk SSSR Doklady, *170*/4, 905–907.

MUFFLER, L. J. PATRICK and DOE, BRUCE R. (1968): *Composition and Mean Age of Detritus of the Colorado River Delta in the Salton Through, Southeastern California*. J. Sed. Petrology, *38*/2, 384–399, 1968.

ROSHOLT, J. N. and PETERMAN, Z. E. (1969): *Uranium, Thorium, Lead Systematics in the Granite Mountains, Wyoming*. Geol. Soc. America, Abstracts 1969, part 5, Rocky Mountain Section 22nd annual meeting.

SOBOTOVICH, E. V., GRASHCHENKO, S. M., ALEKSANDRUK, V. M. and SHATS, M. M. (1963): *Opredeleniye vozrasta drevneyshikh porod svintsovoizokhronnym i isotopno-spektral'nym strontsiyevym metodami* (*Determination of the age of the most ancient rocks by the lead isochronous and the strontium isotope-spectral methods*). Akad. Nauk SSSR Izv., Ser. Geol. *28*/10, 3–14.

SOBOTOVICH, E. V., GRASHCHENKO, S. M. and LOVTSYUS, A. V. (1963): *Vozrast porod Taromskogo Kariera Pridneprovia po dannym svintosovo-izokhronnogo metoda* (*The age of the Taromskoe quarry rocks in the Dnieper region according to data of lead-isochronous method*). Trudy Odinnadtsatoi Sessii Komis. po Opred. Absolyutnogo Vozrasta Geol. Formatsii, 353–356.

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# Northern Appalachian Geochronology as a Model for Interpreting ages in Older Orogens

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ABSTRACT

Isochron plots of whole-rock Rb-Sr measurements on crystalline rocks randomly collected over ancient orogens generally show a scatter of points entirely within a bounding isochron envelope. There has been controversy over the interpretation of these. A plot of isochron data from the Northern Appalachians, where correlation between the Paleozoic succession and radiometric ages has been established, is remarkably similar, so that this region may be taken as a model for interpreting the plots observed in the more ancient cases. The interpretation states that:

1. The observed age band actually consists of a complex of discrete intrusive or metasomatic events that covers the time range within the bounding isochrons.
2. The initial $Sr^{87}/Sr^{86}$ ratios given by separate isochrons on granitoid rocks are similar enough so that age values calculated on individual samples using the observed "common" initial $Sr^{87}/Sr^{86}$ ratio are more likely to be true than not.
3. Acid extrusive volcanic rocks frequently give age values less than the time of extrusion, and have higher initial $Sr^{87}/Sr^{86}$ ratios, so that they should be avoided in the sampling program.
4. A regional thermal rejuvenation of K-Ar age values in the Northern Appalachians has not affected the whole-rock Rb-Sr dating, so that a similar happening will not invalidate the above general interpretations in the case of an ancient orogenic region.

## Whole-rock Rb-Sr analyses on granitoid rocks

About 200 samples of granitoid rocks from the northern Appalachian province have been analysed by various investigators for whole-rock Rb-Sr isotopic relationships. The results are plotted in Figure 1. Coordinate scales have been chosen that will include most of the analyses; a few having too high a ratio of Rb/Sr to fall on the diagram have been reduced in scale and plotted with a tick mark. This is not a random sampling but represents a dispersed collection of samples from individual rock units that are themselves scattered throughout the province.

It can be seen that the points fall within a bounding envelope representing isochrons at 227 m.y. and 608 m.y., or roughly a 400 m.y. spread in time. From these data alone it is impossible to say anything definite about the initial ratio of $Sr^{87}/Sr^{86}$ because the apparent constriction to a limited range of $Sr^{87}/Sr^{86}$ ratio at the lower left corner of the plot may be due entirely to a different origin for the more basic, or less alkalic, rocks in the sampling. This question has been bothersome in the interpretation of whole-rock Rb-Sr ages in ancient orogens where it is not always possible to carry out the detailed work that has been done in the Northern Appalachians. We have therefore been interested in the question of whether the limited $Sr^{87}/Sr^{86}$ ratio at the low-rubidium end of such a scatter plot can be used to provide a reasonable estimate of individual whole-rock ages.