National Center for Science Education

http://www.ncseweb.org/resources/rncse_content/vol20/6061_radiometeric_dating_does_work_12_30_1899.asp

Radiometeric Dating Does Work!

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Originally published in RNCSE 20 (3): 14-19. [Reports of the NCSE May 2000] The version on the web might differ slightly from the print publication.

Radiometric dating of rocks and minerals using naturally occurring, long-lived radioactive isotopes is troublesome for young-earth creationists because the techniques have provided overwhelming evidence of the antiquity of the earth and life. Some so-called creation scientists have attempted to show that radiometric dating does not work on theoretical grounds (for example, Arndts and Overn 1981; Gill 1996) but such attempts invariably have fatal flaws (see Dalrymple 1984; York and Dalrymple 2000). Other creationists have focused on instances in which radiometric dating seems to yield incorrect results. In most instances, these efforts are flawed because the authors have misunderstood or misrepresented the data they attempt to analyze (for example, Woodmorappe 1979; Morris HM 1985; Morris JD 1994). Only rarely does a creationist actually find an incorrect radiometric result (Austin 1996; Rugg and Austin 1998) that has not already been revealed and discussed in the scientific literature.

The creationist approach of focusing on examples where radiometric dating yields incorrect results is a curious one for two reasons. First, it provides no evidence whatsoever to support their claim that the earth is very young. If the earth were only 6000–10 000 years old, then surely there should be some scientific evidence to confirm that hypothesis; yet the creationists have produced not a shred of it so far. Where are the data and age calculations that result in a consistent set of ages for all rocks on earth, as well as those from the moon and the meteorites, no greater than 10 000 years? Glaringly absent, it seems.

Second, it is an approach doomed to failure at the outset. Creationists seem to think that a few examples of incorrect radiometric ages invalidate all of the results of radiometric dating, but such a conclusion is illogical. Even things that work well do not work well all of the time and under all circumstances. Try, for example, wearing a watch that is not waterproof while swimming. It will probably fail, but what would a reasonable person conclude from that? That watches do not work? Hardly.

A few verified examples of incorrect radiometric ages are simply insufficient to prove that radiometric dating is invalid. All they indicate is that the methods are not infallible. Those of us who have developed and used dating techniques to solve scientific problems are well aware that the systems are not perfect; we ourselves have provided numerous examples of instances in which the techniques fail. We often test them under controlled conditions to learn when and why they fail so we will not use them incorrectly. We have even discredited entire techniques. For example, after extensive testing over many years, it was concluded that uranium-helium dating is highly unreliable because the small helium atom diffuses easily out of minerals over geologic time. As a result, this method is not used except in rare and highly specialized applications. Other dating techniques, like K-Ar (potassium-argon and its more recent variant $^{40}Ar/^{39}Ar$), Rb-Sr (rubidium-strontium), Sm-Nd (samarium-neodynium), Lu-Hf (lutetium-hafnium), and U-Pb (uranium-lead and its variant Pb-Pb), have all stood the test of time. These methods provide valuable and valid age data in most instances, although there is a small percentage of cases in which even these generally reliable methods yield incorrect results. Such failures may be due to laboratory errors (mistakes happen), unrecognized geologic factors (nature sometimes fools us), or misapplication of the techniques (no one is perfect). In order to accomplish their goal of discrediting radiometric dating, however, creationists are faced with the daunting task of showing that a *preponderance* of radiometric ages are wrong — that the methods are untrustworthy *most* of the time. Not only that, they have to show the flaws in those dating studies that provide independent corroborative evidence that radiometric methods work. This is a tall order and the creationists have made no progress so far.

It is rare for a study involving radiometric dating to contain a single determination of age. Usually determinations of age are repeated to avoid laboratory errors, are obtained on more than one rock unit or more than one mineral from a rock unit in order to provide a cross-check, or are evaluated using other geologic information that can be used to test and corroborate the radiometric ages. Scientists who use radiometric dating typically use every means at their disposal to check, recheck, and verify their results, and the more important the results the more they are apt to be checked and rechecked by others. As a result, it is nearly impossible to be completely fooled by a good set of radiometric age data collected as part of a well-designed experiment.

The purpose of this paper is to describe briefly a few typical radiometric dating studies, out of hundreds of possible examples documented in the scientific literature, in which the ages are validated by other available information. I have selected four examples from recent literature, mostly studies involving my work and that of a few close colleagues because it was easy to do so. I could have selected many more examples but then this would have turned into a book rather than the intended short paper.

The Manson Meteorite Impact and the Pierre Shale

In the Cretaceous Period, a large meteorite struck the earth at a location near the present town of Manson, Iowa. The heat of the impact melted some of the feldspar crystals in the granitic rocks of the impact zone, thereby resetting their internal radiometric clocks. These melted crystals, and therefore the impact, have been dated by the $^{40}Ar/^{39}Ar$ method at 74.1 Ma (million years; Izett and others 1998), but that is not the whole story by a long shot. The impact also created shocked quartz crystals that were blasted into the air and subsequently fell to the west into the inland sea that occupied much of central North

Nebraska in a thin layer (the Crow Creek Member) within a thick rock formation known as the Pierre Shale. The Pierre Shale, which is divided into identifiable sedimentary beds called members, also contains abundant fossils of numerous species of ammonites, ancestors of the chambered nautilus. The fossils, when combined with geologic mapping, allow the various exposed sections of the Pierre Shale to be pieced together in their proper relative positions to form a complete composite section (Figure 1). The Pierre Shale also contains volcanic ash that was erupted from volcanoes and then fell into the sea, where it was preserved as thin beds. These ash beds, called bentonites, contain sanidine feldspar and biotite that has been dated using the $^{40}Ar/^{39}Ar$ technique.

The results of the Manson Impact/Pierre Shale dating study (Izett and others 1998) are shown in Figure 1. There are three important things to note about these results. First, each age is based on numerous measurements; laboratory errors, had there been any, would be readily apparent. Second, ages were measured on two very different minerals, sanidine and biotite, from several of the ash beds. The largest difference between these mineral pairs, in the ash from the Gregory Member, is less than 1%. Third, the radiometric ages agree, within analytical error, with the relative positions of the dated ash beds as determined by the geologic mapping and the fossil assemblages; that is, the ages get older from top to bottom as they should. Finally, the inferred age of the shocked quartz, as determined from the age of the melted feldspar in the Manson impact structure (74.1 ± 0.1 Ma), is in very good agreement with the ages of the ash beds above and below it. How could all of this be so if the $^{40}Ar/^{39}Ar$ dating technique did not work?

The Ages of Meteorites

Meteorites, most of which are fragments of asteroids, are very interesting objects to study because they provide important evidence about the age, composition, and history of the early solar system. There are many types of meteorites. Some are from primitive asteroids whose material is little modified since they formed from the early solar nebula. Others are from larger asteroids that got hot enough to melt and send lava flows to the surface. A few are even from the Moon and Mars. The most primitive type of meteorites are called chondrites, because they contain little spheres of olivine crystals known as chondrules. Because of their importance, meteorites have been extensively dated radiometrically; the vast majority appear to be 4.4–4.6 Ga (billion years) old. Some meteorites, because of their mineralogy, can be dated by more than one radiometric dating technique, which provides scientists with a powerful check of the validity of the results. The results from three meteorites are shown in Table 1. Many more, plus a discussion of the different types of meteorites and their origins, can be found in Dalrymple (1991).

There are 3 important things to know about the ages in Table 1. The first is that each meteorite was dated by more than one laboratory — Allende by 2 laboratories, Guarena by 2 laboratories, and St Severin by four laboratories. This pretty much eliminates any significant laboratory biases or any major analytical mistakes. The second thing is that some of the results have been repeated using the same technique, which is another check against analytical errors. The third is that all three meteorites were dated by more than one method — two methods each for Allende and Guarena, and four methods for St Severin. This is extremely powerful verification of the validity of both the theory and practice of radiometric dating. In the case of St Severin, for example, we have 4 different natural clocks (actually 5, for the Pb-Pb method involves 2 different radioactive uranium isotopes), each running at a different rate and each using elements that respond to chemical and physical conditions in much different ways. And yet, they all give the same result to within a few percent. Is this a remarkable coincidence? Scientists have concluded that it is not; it is instead a consequence of the fact that radiometric dating actually works and works quite well. Creationists who wants to dispute the conclusion that primitive meteorites, and therefore the solar system, are about 4.5 Ga old certainly have their work cut out for them!

The K-T Tektites

One of the most exciting and important scientific findings in decades was the 1980 discovery that a large asteroid, about 10 kilometers diameter, struck the earth at the end of the Cretaceous Period. The collision threw many tons of debris into the atmosphere and possibly led to the extinction of the dinosaurs and many other life forms. The fallout from this enormous impact, including shocked quartz and high concentrations of the element iridium, has been found in sedimentary rocks at more than 100 locations worldwide at the precise stratigraphic location of the Cretaceous-Tertiary (K-T) boundary (Alvarez and Asaro 1990; Alvarez 1998). We now know that the impact site is located on the Yucatan Peninsula. Measuring the age of this impact event independently of the stratigraphic evidence is an obvious test for radiometric methods, and a number of scientists in laboratories around the world set to work.

In addition to shocked quartz grains and high concentrations of iridium, the K-T impact produced tektites, which are small glass spherules that form from rock that is instantaneously melted by a large impact. The K-T tektites were ejected into the atmosphere and deposited some distance away. Tektites are easily recognizable and form in no other way, so the discovery of a sedimentary bed (the Beloc Formation) in Haiti that contained tektites and that, from fossil evidence, coincided with the K-T boundary provided an obvious candidate for dating. Scientists from the US Geological Survey were the first to obtain radiometric ages for the tektites and laboratories in Berkeley, Stanford, Canada, and France soon followed suit. The results from all of the laboratories were remarkably consistent with the measured ages ranging only from 64.4 to 65.1 Ma (Table 2). Similar tektites were also found in Mexico, and the Berkeley lab found that they were the same age as the Haiti tektites. But the story doesn’t end there.

The K-T boundary is recorded in numerous sedimentary beds around the world. The Z-coal, the Ferris coal, and the Nevis coal in Montana and Saskatchewan all occur immediately above the K-T boundary. Numerous thin beds of volcanic ash occur within these coals just centimeters above the K-T boundary, and some of these ash beds contain minerals that can be dated radiometrically. Ash beds from each of these coals have been dated by $^{40}Ar/^{39}Ar$, K-Ar, Rb-Sr, and U-Pb methods in several laboratories in the US and Canada. Since both the ash beds and the tektites occur either at or very near the K-T boundary, as determined by diagnostic fossils, the tektites and the ash beds should be very nearly the same age, and they are (Table 2).

There are several important things to note about these results. First, the Cretaceous and Tertiary periods were defined by geologists in the early 1800s. The boundary between these periods (the K-T boundary) is marked by an abrupt change in fossils found in sedimentary rocks worldwide. Its exact location in the stratigraphic column at any locality has nothing to do with radiometric dating — it is located by careful study of the fossils and the rocks that contain them, and nothing more. Second, the radiometric age measurements, 187 of them, were made on 3 different minerals and on glass by 3 distinctly different dating methods (K-Ar and $^{40}Ar/^{39}Ar$ are technical variations that use the same parent-daughter decay scheme), each involving different elements with different half-lives. Furthermore, the dating was done in 6 different laboratories and the materials were collected from 5 different locations in the Western Hemisphere. And yet the results are the same within analytical error. If radiometric dating didn't work then such beautifully consistent results would not be possible.

Dating of The Mt Vesuvius Eruption

In the early afternoon of August 24, 79 CE, Mt Vesuvius erupted violently, sending hot ash flows speeding down its flanks. These flows buried and destroyed Pompeii and other nearby Roman cities. We know the exact day of this eruption because Pliny the Younger carefully recorded the event. In 1997 a team of scientists from the Berkeley Geochronology Center and the University of Naples decided to see if the $^{40}Ar/^{39}Ar$ method of radiometric dating could accurately measure the age of this very young (by geological standards) volcanic material. They separated sanidine crystals from a sample of one of the ash flows. Incremental heating experiments on 12 samples of sanidine yielded 46 data points that resulted in an isochron age of 1925 94 years. The actual age of the flow in 1997 was 1918 years. Is this just a coincidence? No — it is the result of extremely careful analyses using a technique that works.

This is not the only dating study to be done on an historic lava flow. Two extensive studies done more than 25 years ago involved analyzing the isotopic composition of argon in such flows to determine if the source of the argon was atmospheric, as must be assumed in K-Ar dating (Dalrymple 1969, 26 flows; Krummenacher 1970, 19 flows). Both studies detected, in a few of the flows, deviations from atmospheric isotopic composition, most often in the form of excess ^{40}Ar. The majority of flows, however, had no detectable excess ^{40}Ar and thus gave correct ages as expected. Of the handful of flows that did contain excess ^{40}Ar, only a few did so in significant amounts. The 122 BCE flow from Mt Etna, for example, gave an erroneous age of 0.25 0.08 Ma. Note, however, that even an error of 0.25 Ma would be insignificant in a 20 Ma flow with equivalent potassium content. Austin (1996) has documented excess ^{40}Ar in the 1986 dacite flow from Mount St Helens, but the amounts are insufficient to produce significant errors in all but the youngest rocks.

The 79 CE Mt Vesuvius flow, the dating of which is described above, also contained excess ^{40}Ar. The $^{40}Ar/^{39}Ar$ isochron method used by the Berkeley scientists, however, does not require any assumptions about the composition of the argon trapped in the rock when it formed — it may be atmospheric or any other composition for that matter. Thus any potential error due to excess ^{40}Ar was eliminated by the use of this technique, which was not available when the studies by Dalrymple (1969) and Krummenacher (1970) were done.

Thus the large majority of historic lava flows that have been studied either give correct ages, as expected, or have quantities of excess radiogenic ^{40}Ar that would be insignificant in all but the youngest rocks. The $40Ar/^{39}Ar$ technique, which is now used instead of K-Ar methods for most studies, has the capability of automatically detecting, and in many instances correcting for, the presence of excess ^{40}Ar, should it be present.

Summary

In this short paper I have briefly described 4 examples of radiometric dating studies where there is both internal and independent evidence that the results have yielded valid ages for significant geologic events. It is these studies, and the many more like them documented in the scientific literature, that the creationists need to address before they can discredit radiometric dating. Their odds of success are near zero. Even if against all odds they should succeed, it still would not prove that the Earth is young. Only when young-earth creationists produce convincing quantitative, scientific evidence that the earth is young will they be worth listening to on this important scientific matter.

Acknowledgments

I thank Chris Stassen and 2 anonymous reviewers for their thoughtful comments, which led to important improvements in the manuscript.

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Figure Caption: Figure 1. ^{40}Ar/^{39}Ar ages for 8 volcanic ash beds in the Pierre Shale. Sedimentary beds (members) are shown in their known stratigraphic order, youngest at the top. The age data for the Manson, Iowa, impact event (shaded box) is shown in the stratigraphic position of the shocked quartz, which is found in the Crow Creek Member. After Izett and others (1998).

Table 1. Radiometric ages for 3 chondrite meteorites.

Meteorite	Method	Age (Ga)	Lab
Allende	^{40}Ar/^{39}Ar	4.52 ++ 0.02	1
Allende	^{40}Ar/^{39}Ar	4.53++ 0.02	1
Allende	^{40}Ar/^{39}Ar	4.48++0.02	1
Allende	^{40}Ar/^{39}Ar	4.55++ 0.03	1
Allende	^{40}Ar/^{39}Ar	4.55++0.03	1
Allende	^{40}Ar/^{39}Ar	4.57++0.03	1
Allende	^{40}Ar/^{39}Ar	4.50 ++ 0.02	1
Allende	^{40}Ar/^{39}Ar	4.56++0.05	1
Allende	Pb-Pb isochron (27 points)	4.553++ 0.004	7
Guarena	^{40}Ar/^{39}Ar	4.44++ 0.06	2
Guarena	Rb-Sr isochron (13 points)	4.46++ 0.08	4
St Servin	^{40}Ar/^{39}Ar	4.43++ 0.04	5
St Servin	^{40}Ar/^{39}Ar	4.38++ 0.04	6
St Servin	^{40}Ar/^{39}Ar	4.42++0.04	6
St Servin	Rb-Sr isochron (10 points)<	4.51++ 0.15	3
St Servin	Sm-Nd isochron (4 points)	4.55++0.33	4
St Servin	Pb-Pb isochron (5 points)	4.543++ 0.019	3

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From compilation in Dalrymple (1991). Data from university laboratories in Germany(1), Great Britain(2), France (3), California (4), Minnesota (5), Missouri (6), and the USGS in Denver, Colorado (7).

Table 2. ^{40}Ar/^{39}Ar ages for K-T tektites and related K-T boundary deposits

Location	Material Dated	Method	Number of Analyses	Age (Ma)
Haiti (Beloc Formation)	tektites	^{40}Ar/^{39}Ar total fusion	52	64.4 ++ 0.1
Haiti (Beloc Formation)	tektites	^{40}Ar/^{39}Ar age spectrum	4	64.4 ++ 0.4

Haiti (Beloc Formation)	tektites	$^{40}Ar/^{39}Ar$ age spectrum	2	64.5 ++ 0.2
Haiti (Beloc Formation)	tektites	$^{40}Ar/^{39}Ar$ age spectrum	4	64.8 ++ 0.2
Haiti (Beloc Formation)	tektites	$^{40}Ar/^{39}Ar$ total fusion	18	64.9 ++ 0.1
Haiti (Beloc Formation)	tektites	$^{40}Ar/^{39}Ar$ total fusion	3	65.1 ++ 0.2
Haiti (Beloc Formation)	tektites	$^{40}Ar/^{39}Ar$ age spectrum	9	65.0 ++ 0.2
Mexico (Arroyo el Mimbral)	tektites	$^{40}Ar/^{39}Ar$ total fusion	2	65.1 ++ 0.5
Hell Creek, Montana (Z-coal)	tektites	$^{40}Ar/^{39}Ar$ total fusion	28	64.8 ++ 0.1
Hell Creek, Montana (Z-coal)	tektites	$^{40}Ar/^{39}Ar$ age spectrum	1	66.0++0.5
Hell Creek, Montana (Z-coal)	tektites	$^{40}Ar/^{39}Ar$ age spectrum	1	64.7++0.1
Hell Creek, Montana (Z-coal)	tektites	$^{40}Ar/^{39}Ar$ total fussion	17	64.8++0.2
Hell Creek, Montana (Z-coal)	biotite, sanidine	K-Ar	12	64.6++1.0
Hell Creek, Montana (Z-coal)	biotite, sanidine	Rb-Sr isochron (26 data)	1	63.7++0.6
Hell Creek, Montana (Z-coal)	zircon	U-Pb concordia (16 data)	1	63.9++0.8
Saskatchewan, Canada (Ferris Coal)	sanidine	$^{40}Ar/^{39}Ar$ total fussion	6	64.7++0.1
Saskatchewan, Canada (Ferris Coal)	sanidine	$^{40}Ar/^{39}Ar$ age spectrum	1	64.6++0.2
Saskatchewan, Canada (Ferris Coal)	biotite, sanidine	K-Ar	7	65.8++1.2
Saskatchewan, Canada (Ferris Coal)	various	Rb-Sr isochron (10 data)	1	64.5++0.4
Saskatchewan, Canada (Ferris Coal)	zircon	U-Pb concordia (16 data)	1	64.4++0.8
Saskatchewan, Canada (Ferris Coal)	sanidine	$^{40}Ar/^{39}Ar$ total fussion	11	64.8++0.2
Saskatchewan, Canada (Nevis coal)	sanidine	$^{40}Ar/^{39}Ar$ age spectrum	1	64.7++0.2
Saskatchewan, Canada (Nevis coal)	biotite	K-Ar	2	64.8++1.4
Saskatchewan, Canada (Nevis coal)	various	Rb-Sr (7 data)	1	63.9++0.6
Saskatchewan, Canada (Nevis coal)	zircon	U-pb concordia (12 data)	1	64.3++0.8

Data from compilation and study by Dalrymple and other (1993). Analyses done by university laboratories in Australia, Canada, France, and California, and at the USGS in Menlo Park, California.