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Mixing Lines: Considerations Regarding Their Use in Creationist Interpretation of Radioisotope Age Data

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Considerations Regarding their Use in Creationist Interpretation of Radioisotope Age Data

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ABSTRACT

Radioisotope daughter/parent ratios may be interpreted on the basis of a model for daughter accumulation, an isochron diagram, or a mixing line. Each of these interpretive treatments is evaluated for its constraint on resolution of apparent disagreement between radiometric age and the chronological specifications in the Pentateuch. A mixing-line interpretation gives no direct specification regarding time, and consequently avoids conflict between Biblical specifications and radioisotope data for minerals associated with fossils and geologic features that were formed after the beginning of Creation Week.

However, a mixing line places limits on the model age for the source material components that are required for mixing to form these minerals. Consequently, when a mixing line interpretation is used for radioisotope data associated with geologic features and fossils formed during and following the Flood, i.e., within the last 5500 years, there remains a need for a corresponding treatment of the model age limits indicated by the mixing line. Treatment of radioisotope model ages for inorganic material from a short-chronology (young earth) creationist viewpoint will be determined by the interpretor's exegesis of Genesis 1:1,2,8-10. One viewpoint constrains the terms *heaven* and *earth*, as used in connection with the Creation Account, within the definitions given in Genesis 1:8-10; and allows model ages to have a relationship with time between an uspecified primordial creation and the creation episode described in Genesis. Another viewpoint infers the entire physical universe, or at least the Solar System, to be designated by these terms; and requires radioisotope model age relationships to be design features expressed at or subsequent to the beginning of the Genesis One Creation Week.

INTRODUCTION

One of the greatest challenges in the development of a credible scientific Biblical creationism is the need for models that provide compatibility of the chronological data in the Pentateuch and scientific evidence that has chronological significance, giving proper recognition to each source of data. Unfortunately, many well-meaning attempts to establish such compatibility and maintain a direct grammatical-historical exegesis of the Pentateuch have fostered disrespect for Biblical creationism within the scientific community at large, and have failed to reduce the influence of unrestricted historical-critical exegesis among Christians and Jews.

Creationist apologists have suggested that a mixing-line interpretation of inorganic radioisotope data would provide an academically sound treatment from a Biblical short-chronology perspective. See [9] and [10], e.g. A mixing-line interpretation has been used to resolve difficulties over radiometric ages inconsistent with the conventional geologic time scale, as noted in [1], [2], [8], [11], [3], [13], [12], and [6, pp. 141-153], e.g., and has promise for similar success in resolution of difficulties with respect to a Biblically-based time scale. The purpose of this treatment is to critically examine the mixing-line concept and its significance to scientific Biblical creationism.

For an efficient development of this treatment, I will first clarify three concepts: radioisotope model age, radioisotope isochron, and mixing line. These concepts are then used in an analysis of a mixing-line interpretation of radioisotope data.

MODEL AGE

A radioisotope daughter/parent model age requires two measurements and is based on three assumptions. The measurements are the concentration of a radioactive parent, and the associated concentration of a stable daughter. The three necessary assumptions are:

1. Isolation from exchange of both parent and daughter with the sample environment throughout the time indicated by the measurements.

2. Rate of transformation of parent into daughter is constant throughout the time indicated, and equal to the presently-measured value of this rate.

3. The concentration of daughter in the sample at the beginning of the indicated time span. This is usually assumed to be equal to the concentration of daughter isotope in material that gives no evidence of having been associated with the parent element.

Using subscript o to indicate initial values of parent and daughter, p_o and d_o, with values at any subsequent time indicated by p and d, $d - d_o = p_o - p$. Representing the half-life for spontaneous transmutation of parent into daughter by $T_{½}$, $p = p_o e^{-(\ln 2)t/T_{½}}$. From combination of these two relationships $d = d_o + p[e^{(\ln 2)t/T_{½}} - 1]$, which can be used to calculate t from a pair of values for d and p.

$$t = (T_{½}/\ln 2)\ \ln[1 + (d-d_o)/p] \qquad [1]$$

ISOCHRON AGE

Figure 1 is a sample isochron taken from [4, p. 149]. In this figure the relative concentration of daughter ^{87}Sr is plotted against the relative concentration of parent ^{87}Rb in a suite of gneiss samples from Isua, West Greenland. An isochron plot requires several measurements of radioactive parent and stable daughter concentration in related specimens that have varying concentrations of the parent isotope. If a plot of daughter concentration against parent concentration can be satisfactorily represented by a straight line, as in Figure 1, this line has been called an isochron because it appears to provide evidence for equal time of daughter accumulation in each sample.

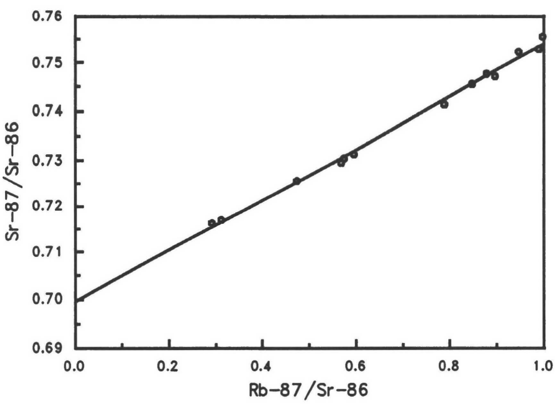

FIGURE I. Linear-array plot of daughter ^{87}Sr plotted against parent ^{87}Rb for gneisses from Isua, West Greenland. [Replotted from Dalrymple (1991), p. 149.] If interpreted to be an "isochron", the sloping line indicates an age of 3.6 billion years.

Because the daughter concentration d_o corresponds to zero parent concentration, the slope of an isochron line, designated by m, is equal to $(d-d_o)/p$, and the time span indicated by an isochron plot is obtained from Equ. [1] as

$$t = (T_{½}/\ln 2)\ \ln(1 + m)\ . \qquad [2]$$

An isochron determination has several advantages over a model age.

1. It represents an average of several independent determinations of apparent daughter increase in proportion to parent concentration.

2. It may provide freedom from the need for an estimate of the initial daughter concentration (The initial daughter concentration is assumed to be specified by the y-intercept.)

3. The linearity of the plot provides supporting evidence for the assumption of isolation from exchange with the sample environment.

For more detailed treatment of model age and isochron age see [6, pp. 141-153], or [4, Chapter 3].

MIXING LINES

To develop the concept of a mixing line, consider two sources of material, A and B, each having characteristics p and q. A portion from A is mixed with a portion from B to form the material from which sample S (see Figure 2) is obtained. The fraction f of S is obtained from A, and the fraction (1−f) is obtained from B. On a plot of q against p the coordinates of A and B are q_a,p_a and q_b,p_b, respectively. The coordinates of S are $[fq_a + (1-f)q_b]$ and $[fp_a + (1-f)p_b]$.

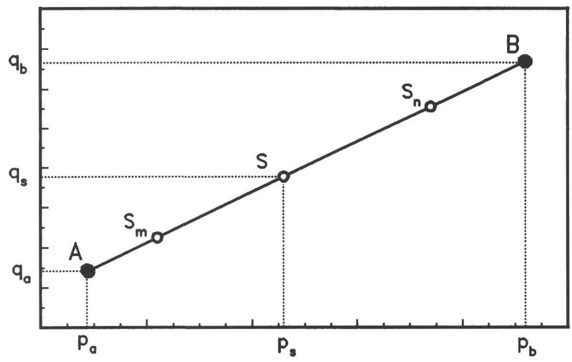

FIGURE 2. Mixing coordinates for samples S with fraction f from source A and fraction (1−f) from source B, each with characteristics p and q.

Incomplete mixing of material from A and B will produce samples of varying mixing fraction f. For two samples S_m and S_n with mixing fractions f_m and f_n the q-axis (ordinate) increment will be
$[f_nq_a + (1-f_n)q_b] - [f_mq_a + (1-f_m)q_b] = (f_m - f_n)(q_b - q_a)$, providing mixing does not influence q_a and q_b in any other way than by dilution.

Similarly, the p-axis (abscissa) increment will be $(f_m - f_n)(p_b - p_a)$.

The ratio of these increments is independent of f, and specifies a straight line of slope $(q_b - q_a)/(p_b - p_a)$ for a plot of S on the p,q plane. The ordinate intercept for this line, q_o, is given by $(q_a - q_o)/(p_a - 0) = (q_b - q_a)/(p_b - p_a)$, or $q_o = q_a - p_a(q_b - q_a)/(p_b - p_a)$.

Accordingly a two-component mixing-line equation in p,q coordinates may be written

$$q = (q_a p_b - q_b p_a)/(p_b - p_a) + p[(q_b - q_a)/(p_b - p_a)], \quad [3]$$

with the subscripts designating characteristics of the source material.

MIXING-LINE OR ISOCHRON?

The p,q characteristics for a mixing-line plot can be the concentrations of a radioactive parent and its stable daughter, the same as for an isochron plot. How can one be certain that a linear plot of daughter concentration versus radioactive parent concentration is an isochron rather than a mixing-line? A linear plot may indicate partial melting, rather than simple mixing. A decision between these possibilities will be determined largely by the perspective of the individual making the judgement. If the slope of the line does not correspond with an age that can be fitted into the conventional geologic time scale, reports in the professional literature usually resort to a mixing-line interpretation. See [1], [7], [3], [13], [12], [6, pp. 145-147], e.g.. Choice for a mixing-line interpretation is made also when the ordinate intercept (initial daughter concentration d_0) is outside the range of values for minerals that have no indication of association with the parent element.

It must be emphasized that the slope of a mixing line does not have time significance. The time at which mixing occurred must be inferred from other considerations. As stated by Zheng, "... an observed isochron does not certainly define a valid age information for a geological system, ..." [12, p. 14]. "A negative slope ... can be yielded by a mixing where the Rb/Sr ratio of high $^{87}Sr/^{86}Sr$ component is less than that in the low $^{87}Sr/^{86}Sr$ end-member. This situation has been observed for minerals ... in the Eifel, F.R.G. ..." [12, pp. 10,11].

Figure 4 is a plot of a negative slope mixing line for the Newer Volcanics in Victoria, Australia. The data for Figure 4 are taken from Table 1 and Figure 3 of reference [5].

MIXING-LINE INTERPRETATION FROM THE PERSPECTIVE OF BIBLICAL CREATIONISM

If uniformitarian scientists can comfortably resort to a mixing-line interpretation when an isochron interpretation gives an age inconsistent with the geologic time scale, there should be equal freedom to choose a mixing-line interpretation for data which give an isochron interpretation that contradicts a Biblically-based time frame.

For a closer analysis of mixing-line interpretation as it may be used in Biblical creationism modeling, consider Figure 3. This figure represents seven distinct samples S_1 to S_7 from an incomplete mixture of material from two sources A and B. Each sample S_n corresponds to a mixing fraction f_n, as used in the development of Equation 3. S_1 could represent source A, with $f_1 = 1$; and S_7 could represent source B, with $f_7 = 0$. All that the data indicate for certain is either that S_1 and S_7 represent the sources A and B, or that the mixing line at those locations points toward p and d values which represent the sources.

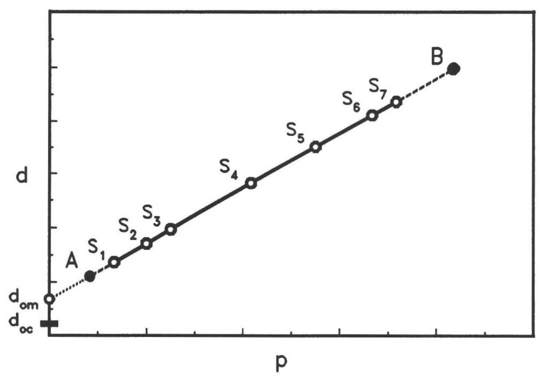

FIGURE 3. Mixing line for a suite of samples S_n (n = 1-7) formed by varying degrees of incomplete mixing of material from sources A and B, each with characteristics p (radioisotope parent) and d (daughter).

There is associated with the p and d values for S_1 a model age T_m (Equation 1) based on d_{om}, the value for d_o given by the ordinate intercept of the extended mixing line. If the p and d values for the source A were known, they would specify a model age T_c based on d_{oc}, the primordial daughter concentration conventionally assumed for model age calculations. T_m will be <, =, or > T_c for source A, depending on whether d_{om} is >, =, or < d_{oc}. The same comparisons apply to a T_m based on S_7 and a T_c for source B, but the difference between the two model ages will be less with respect to source B than with respect to source A; i.e., a mixing-line-based model age estimate derived from the upper terminus of a mixing line will be closer to the conventional model age for source B, than a similar estimate derived from the lower terminus will be to the conventional model age for source A.

For a horizontal mixing line $T_m = 0$, but the relationship between T_c and T_m is the same as for a line with positive slope.

For a negative-slope mixing line T_m is negative and has no significance with respect to real time, but the associated T_c values for the sources can be positive, zero, or negative. A model age interpretation of the data extremes represented in Figure 4 specifies for T_c a Rb-Sr age $\geq$ 3.10 Gy for source A, and $\leq$ 1.36 Gy for source B.

The two sources assumed in a simple mixing-line treatment of a radioisotope data set may have the same model age characteristic. Mixing of source materials that have differing concentrations of a specific daughter/parent ratio (a common radioisotope model age characteristic) can produce a range of incompletely mixed specimens which plot on a mixing line (pseudoisochron) that has no time significance as to when the mixing occurred. Such specimens have been described as samples from a heterogeneous source that has a characteristic inherited model age. The inherited age concept recognizes that a radioisotope age may be a characteristic of material, without providing an indication of the time at which that material was placed in its present association with a geological formation or a fossil.

The mixing-line considerations outlined above are illustrated by plutons in the central Idaho area of the Clearwater River South Fork [7]. Conventional geological considerations place the age of these formations in the vicinity of 80 million years. Since they are present-surface features of our planet, the record in Genesis places their origin during or following the late stages of the Flood, and restricts their real-time age to less than 6000 years (most probably less than 5500 years). The 1640 m.y. Rb-Sr isochron obtained from these formations is accounted for in [7] by proposed mixing of melted wall rocks with rising magma at the time of pluton formation. Exposed Precambrian wall rocks in the area have isochron and model ages in the range between 1500 m.y. and 1800 m.y. Various suggestions for the interpretation/explanation of these model ages, or any radioisotope model age in excess of 10,000 years, may be found in the creationist literature.

Most coordinated daughter-parent sample sets probably represent initial mixing followed by daughter buildup from radioactive decay of the parent. A major concern is the degree to which the slope of a linear-array plot represents radioactive decay rather than mixing. After the mixing that initially formed the sample suite, the daughter concentration in each unit will increase with time by the amount that the parent concentration is reduced. This change will rotate the plot counterclockwise about d_{om} as the center point, effectively adding an isochron to the initial mixing line. The resulting line interpreted as an isochron will indicate a greater time lapse than has occurred since the initial mixing. Interpreted as a mixing line it will not indicate either the time of initial formation or the additional time since formation. An illustration of such rotation is given in Figure 3a of [3].

It is important to emphasize that a mixing-line interpretation provides no direct indication of the length of time mineral specimens have been in existence, or in the association with which they are found (a geological formation or a fossil, e.g.). But a mixing-line interpretation does provide an indication of, and sets limits on, the radioisotope model age of the components that were partially mixed to form the suite of samples which define the mixing line. Thus the mixing-line interpretation gives freedom to fit fossils and geological features into a Biblical time frame, into what creationists often refer to as a young-earth short chronology; but it does not remove the challenge for an explanation of radioisotope model ages associated with primary inorganic material.

Within the constraints of a conservative grammatical-historical exegesis of the Bible there are two categories of approach for dealing with this challenge.

The first category is presumption that universally one or more of the three conditions necessary for the establishment of a radioisotope model age has/have not been met. One can assume that present-day observations of radioisotope decay provide no basis for estimating daughter-isotope accumulation in the past, i.e., that there have been multiple-order-of-magnitude changes in the factors which determine nuclear stability (half-life). And one can assume that the daughter/parent ratios indicated by mixing line termini are features of God's design, and have no more relationship to real time than does mixing line slope. According to this assumption isotope ratios essentially are features of initial creation, and may or may not have been modified by mixing and isotope separation processes since the creation of elementary matter.

In the second category the indications associated with mixing line termini are considered to be evidence outside the restrictions of chronological data in the Bible. For this approach to be effective, interpretation of Genesis 1:1 to 2;4a must be constrained within the definitions given in Genesis 1;8-10, and not based on modern designations of the terms *heaven* and *earth*. On this basis the model age implications associated with a mixing line can be related to time between a primordial creation of "the foundations of the earth" (Job 38:4; Psalm 102:25; Isaiah 48:13; 51:13,16; Zechariah 12:1), and the subsequent creation of "the earth" (Genesis 1:9,10).

Both of these categories are represented among "young earth" Biblical creationists, and there is no prospect for achievement of unanimity. Adherents to straightforward grammatical-historical exegesis of the Bible can have Christian unity in diversity of approach to radioisotope age challenges, each holding the approach which best secures his/her confidence in the historical witness of the Bible, and which is most effective in reaching those with whom he/she wishes to share that confidence.

CONCLUSIONS

A mixing-line interpretation of a related set of radioisotope daughter/parent ratios for a group of specimens removes any time significance of this data for the source of those specimens (associated fossil or geologic formation). But a mixing-line interpretation requires an explanation for the isotope ratios indicated by the mixing line terminii. An interpreter is free to hypothesize the time of mixture according to his viewpoint, but is constrained by the implications of the model ages indicated for the mixture components, whatever relationship there may be between those model ages and real time.

A Biblical creationist can propose that mixture was created at the beginning of Creation Week, occurred in the modification of the planet's surface on Day Three of Creation Week (Genesis 1:9), or occurred in connection with the crustal breakup and reformation associated with the Flood (Genesis 7,8) and its aftermath. If only one radioisotope age determination is available, or there is insufficient data for delineation of a mixing line, the model age established by one determination may be classified as a characteristic of emplacement material, rather than an indication of the time at which the material was placed in association with a geological formation or a fossil. [For example, 250 m.y. Rb-Sr age for fresh sediment on the floor of Ross Sea, Antarctica. (See Proceedings of the First International Conference on Creationism, Vol. II, p. 36.)]

Options for "young earth" explanations of radioisotope model ages, whether from single daughter/parent isotope ratio determinations, or indicated by termini of a mixing line, include: (1) consideration of model ages as having no time significance, on the basis of presumption that in no case has the requirements of the essential assumptions been met; (2) considering the isotope ratios on which model ages are based to be essentially design features exhibited at the time of creation, and mixtures of the initial ratios; but not determined in large measure by radioisotope decay; and (3) associating model ages exceeding the range of Biblical chronology with material derived from a primordial creation that preceeded the creation of *heaven*, *earth* and *sea* as defined in Genesis 1:8-10. The effectiveness of each of these options in the establishment and the retention of confidence in a grammatical-historical exegesis of the Bible is the paramount concern. There can be Christian unity in diversity, without controversy as to which option is "correct".

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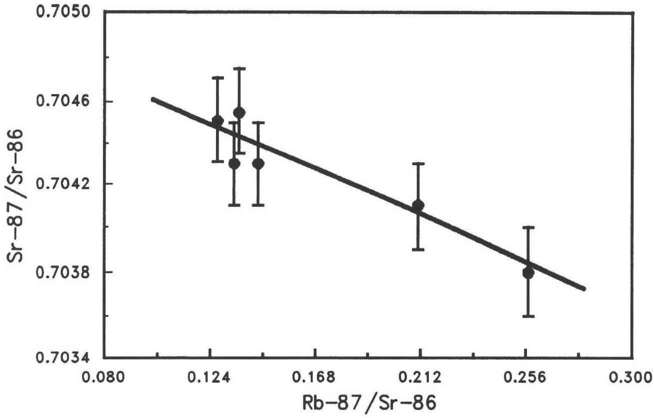

FIGURE 4. $^{87}Sr/^{86}Sr$ vs $^{87}Rb/^{86}Sr$ for Newer Volcanics in Victoria, Australia. Error bars designate the 95% confidence interval. Linear regression line is $0.7051 - 0.00490(^{87}Rb/^{86}Sr)$.

APPENDIX A

Excess, and presumably radiogenic, ^{26}Mg in certain mineral inclusions (Ca-Al-rich chondrules) of the carbonaceous chondrite classification of meteorites may be accounted for from either an isochron or a mixing-line viewpoint [11]. The excess ^{26}Mg over the concentration characteristic of minerals for which there is no indication of prior association with aluminum, plots on a straight line against the aluminum with which it is associated. The plot is against ^{27}Al, since aluminum from natural sources is monoisotopic. As would be expected on the basis of its 740,000 year half-life, ^{26}Al, the parent of ^{26}Mg, exists at present only in relatively insignificant quantities where it can be continually produced by nuclear reactions with cosmic ray particles. Accordingly the pseudoisochron of ^{26}Mg against ^{27}Al is actually a correlation line that indicates the initial $^{26}Al/^{27}Al$ ratio, rather than time since meteoroid formation or creation. The absence of ^{26}Al in these meteorites suggests that they, or the materials of which they are composed, have been in existence more than five million years ($10T_{1/2}$ = 7.3 m.y.).

A two-component mixing-line interpretation places no restraint on the time the meteorite has been in existence, and allows the ^{26}Mg to either come from mature aluminum in a component of material from which the meteoroid was formed, or be a design feature expressed in a recent creation of meteoroids.

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