Science Group of the Anthroposophical Society in Great Britain

Newsletter
Articles Supplement

Contents:

September 1996

Science Group of the Anthroposophical Society in Great Britain

This group exists to promote an understanding of scientific method and results, broadened and deepened by spiritual science; to maintain contacts among those with similar interests; to encourage collaboration and to publish and translate important contributions. The group publishes a newsletter twice a year which includes details of forthcoming meetings and courses, reports, book reviews, information on new publications and details of articles available from members. Starting September 1995, on an experimental basis, an optional articles supplement was made available with the newsletter. As a result of the interest shown in the first issue and following subsequent receipt of sufficient additional material, this second issue has been made possible. Initially, it was intended that the supplement should appear annually, but if the need arises, it will be issued twice a year to correspond with both newsletters. Its content, in English, will comprise research and other relevant articles, short communications and any correspondence these generate. For details regarding the submission of material for publication, please see inside the rear cover.

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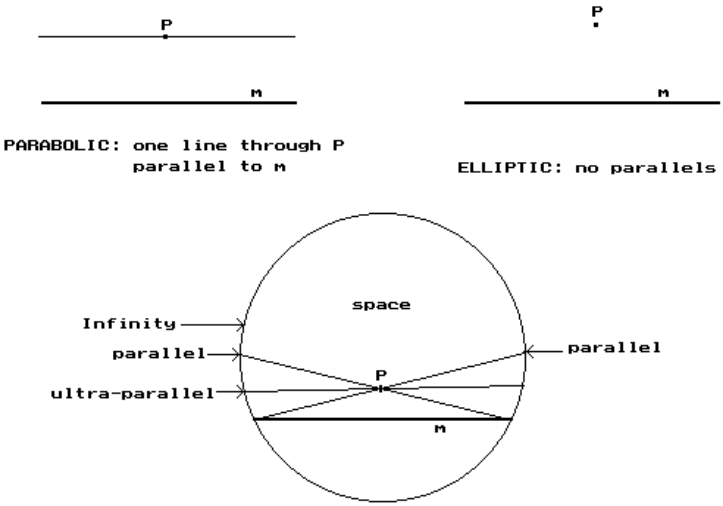
Rethinking physics

Nick Thomas

What is it like inside the Sun? In Rudolf Steiner's time the current model involving the burning of hydrogen through nuclear fusion to produce helium had not been developed extensively. Steiner maintained that were it possible by some extraordinary means to travel to the inside of the Sun a big surprise would be in store, for far from finding burning gas we would - he said - find less than nothing, not just negative matter (which is now known to physics) but negative *space*. George Adams and Louis Locher-Ernst found a way to describe such a space based on geometry, and a possible application of that to physics will be sketched in this article.



Euclid's geometry is profoundly beautiful and satisfying, but it assumes implicitly that space is of a certain kind, and in particular that our intuitive notions of parallelism are valid in it. For ordinary common sense parallel lines do not meet, and neither do parallel planes. Furthermore, given a line and a separate point, then only one line exists passing through that point which is parallel to the first (Ptolemy). Ever since Euclid's time mathematicians were unhappy about this apparently obvious axiom, but until the last century none could find any way of proving or disproving it. Gauss was the first to solve the problem, but he dared not publish, so the honour went to Bolyai and Lobachevsky who independently solved it about 40 years after Gauss. The solution was far-reaching: there can be more than one kind of geometry, and that studied by Euclid

is a very special one in which the axiom is true, but there exist other geometries where it is false. Either there are no parallels at all through the point (elliptic geometry), or there are two with all lines in between being so-called ultra-parallels (hyperbolic geometry). Euclid's lies on the border between these two with just one parallel (parabolic geometry).

These ideas were not at first welcomed, but the matter was settled in 1868 when E. Beltrami proved that if these strange geometries are inconsistent then so is Euclid's. Felix Klein gave an alternative approach illustrated above. The scene was set for the development of non-Euclidean geometries which have become well known through their use in Relativity Theory. The latter took the further step of assuming that a non-Euclidean geometry is not only a mathematical construct, but may also describe the real world of physics i.e. space itself. A central idea has been that of a *manifold* in which the nature of space varies from place to place, sometimes being "flatter", sometimes more "curved". Euclid's geometry is a uniformly "flat" geometry by contrast. However, the assumption is still made that there is *one* space. Steiner and Adams suggested otherwise.

The study of projective geometry since the 15th Century prepared the way for this revolution, but projective geometry is *not* a non-Euclidean geometry, but rather an *archetypal* one. Euclid's geometry is a metric geometry, and this distinction is most crucial in what follows. A metric geometry preserves certain types of measure as invariants, and generally non-Euclidean geometries do so too. Projective geometry does not do this, for the only quantity it preserves is a so-called *cross-ratio*. To appreciate this it is helpful to notice an important difference in the way modern geometry is conceived which differs from Euclid's approach. The latter studied fixed forms such as triangles and circles, and investigated their relationships. The former studies *transformations*. Relativity Theory is founded on such an approach. We know that a mirror may distort the scene reflected, or transmit it faithfully. Thus an initial form may retain its proportions or have them altered. If the mirror magnifies then we have a transformation that leads to an expansion. The study of perspective led to the development of projective geometry, for we all know from first hand experience that the world does not *appear* to us as it actually *is*. When observing a cube rotate we all know that actually it keeps constant its volume, the length of its sides and the angles between its lines. Also the areas of its faces. But *that is not what we observe*! We need to distinguish here between our concept of Euclidean space and what we actually see, for Euclidean space is in fact a concept. Perspective allows us to represent three dimensional scenes in two dimensions, and to explain the laws which render what we know to be the case into the form which we actually observe (trees apparently getting smaller down an avenue etc.). The rotation of a cube is regarded, in modern geometry, as a transformation which can be precisely described mathematically. This kind of transformation, which leaves lengths and angles (and volumes and areas) unchanged, is referred to not surprisingly as a Euclidean transformation, and further the kind of space in which such a transformation is possible is a Euclidean space. A well known example of a non-Euclidean transformation is that postulated by Einstein when he asserted that a body travelling close to the speed of light

becomes shorter i.e. various lengths, angles, areas and the volume all change. This way of thinking about geometry is absolutely fundamental to what will follow here.

Projective geometry studies transformations which change all measures e.g. a shadow of a triangular road sign thrown by a street lamp on the road has different proportions from the sign itself. Projective geometry does preserve straightness though i.e. if the road is flat then if an edge of the sign is straight, so will be its image in the shadow. One important property of projective geometry is that it moves infinity about! If you travel in a train you observe that nearby objects appear to go past quicker than more distant ones, while the Moon does not appear to move at all. You are undergoing a Euclidean transformation while travelling in the train (which is not harmful to health, if you have not thought like that before), and this transformation leaves things infinitely far away unmoved, as suggested in an approximate way by the Moon. Were you to undergo a projective transformation it almost certainly would be harmful to health, and you might suffer the trauma of seeing infinitely distant stars rushing up close. Quite reasonably such behaviour is regarded as eccentric, so in order to move closer to our world mathematicians restrict the full range of transformations available in a projective world to those which leave infinity well alone! The resulting geometry is called *affine* geometry. Now parallel lines are said to meet at infinity, so if infinity stays put then lines that are parallel before a transformation remain parallel after it, even if they have changed in other ways. Like projective geometry, affine geometry (remember we are now regarding a geometry as characterised by certain kinds of transformations) changes lengths, angles, areas and volumes, but it has a healthy respect for infinity. While in Euclidean geometry the cube remained the same size, an affine cube can expand or contract, but parallel faces remain parallel. Unlike the Euclidean cube, however, lines in different directions need not remain in the same ratio, so the cube could become a prismatic shape after an affine transformation, with sides in different directions changing proportion. Also its volume could change. Now there exists a special version of affine geometry where volume becomes invariant (but not proportion). For example if a column of mercury in an inverted test tube on a table is released by withdrawing the test tube, it will certainly change shape, but its overall volume remains constant. This is called *special affine geometry*. It is most important for physics to note that lengths in different directions cannot be compared in any type of affine geometry, so scalar products have no meaning in this geometry. If a force is applied to a cart at an angle to its possible direction of movement, the work done in moving it is the scalar product of the force and the displacement. Such a calculation is only possible in metric geometry, but not in affine geometry.

Finally we may restrict the allowable transformations to those which leave right angles invariant, and also the ratios of lengths in different directions. We then end up with Euclidean geometry. Technically this is accomplished by leaving an imaginary circle in the plane at infinity invariant. We find two major kinds of invariant measure: length and angle. Also volume and area.

When the possibility of non-Euclidean metric geometries was realised, Cayley replaced the above steps by a single one: choose a quadric surface to be invariant

(spheres, hyperboloids, ellipsoids and paraboloids are examples). The resulting restriction on projective geometry gives some kind of metric geometry. In the case of Euclidean geometry the quadric is degenerate, consisting of a special imaginary circle in the plane at infinity. A central thesis of this paper is that this "shortcut" hides important things, and that the four steps enumerated above are significant in themselves. They were:

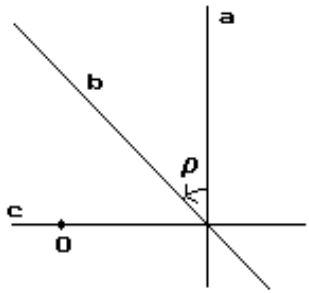
1. Start with projective geometry.
2. Obtain affine geometry by making a plane invariant (the plane at infinity).
3. Obtain special-affine geometry by disallowing expansion (or contraction).
4. Obtain metric geometry by choosing the so-called *absolute imaginary circle* in the plane at infinity.

George Adams interpreted Steiner's negative space as the polar opposite or dual of Euclid's. Thus instead of an imaginary circle in an infinite plane he chose an *absolute imaginary cone in an infinite point*. Just as an imaginary circle (with equation $x^2+y^2+r^2=0$) nevertheless lies in a real plane, so an imaginary cone (with a similar equation in terms of planes) has a real vertex. Clearly it requires a different consciousness to be able to experience a point as being at infinity, to experience an *infinite inwardness* instead of an infinite outwardness as is normal. Such a space, it seems, Steiner had in mind for the interior of the Sun.

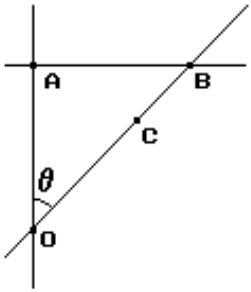
Here we will split this process up into four stages as we did for Euclidean geometry:

1. Start with projective geometry.
2. Select a point at infinity as invariant, to give polar-affine geometry.
3. Restrict transformations to those where there is no expansion or contraction, to give special polar-affine geometry.
4. Select the special imaginary cone with its vertex in the infinite point as invariant, to give polar-Euclidean geometry which characterises counter-space. It is a metric geometry.

What, in the resulting metric geometry, correspond to length and angle? We must be quite clear that counter-space is a *metric* space in contrast to polar affine space, so what is measured in it? We can only state the result here, which is derived from Cayley's formula for deriving length and angle from cross ratio for a general metric geometry. Applied to Euclidean geometry we get the well known formula $d^2 = x^2+y^2+z^2$ for length, and a formula for the cosine of the angle between two planes as a scalar product of the plane coordinates. We are now faced with an interesting decision, for we may follow the relativity-style route and seek a metric which defines a distance between any two points of counter-space. Or, we dualise this which gives a measure for the separation of any two planes which is dual to distance. There is no purely mathematical reason for choosing the one route rather than the other; it is a matter of consciousness. Here we are exploring the second route, for which the metric for planes is quite unlike an angle, varying from 0 to ¥, the latter when one plane lies in the infinite point. Also it is a vector, unlike the angle between two planes in



Turn $\rho = \infty$ if b moves to c



Shift between A and B = θ

Shift between A and C = θ

Shift between B and C = 0

Euclidean geometry. We will refer to this measure as *turn*, so two planes in counter-space are separated by a definite turn rather than an angle. Similarly the dualisation leads to the separation of two points in counter-space as being like an angle since it varies cyclically from 0 to 2p, which we will refer to as *shift*. It is not a vector.

Two points on a line through the infinite point have a zero shift (reminiscent of null lines in Minkovsky's metric), which is dual to the fact that two planes in Euclidean space sharing a line in the plane at infinity are parallel and so the angle between them is zero even though they are distinct. The shift between two points is easy to visualise if we imagine two lines joining each point to the counter-space infinite point, for then the shift equals the angle between those lines. This at first sight strange measure is critically important for an understanding of gravity, as we shall see.

The four steps from projective geometry to Euclidean geometry (which we will simply refer to as "space" henceforth) are suggestive of the four states of matter, for the metric step (4) clearly describes solids, while special affine geometry relates to liquids which are incompressible (ideally), having as it does the property of constant volume but plasticity otherwise. General affine geometry allows expansion and so may relate to gases. Heat cannot simply be related to projective geometry, however. It is further interesting that three dimensional special affine geometry does not induce special affine geometry in planes, but general affine geometry, which can be seen to relate to the gas like behaviour at the surfaces of liquids (evaporation).

The three steps to counter-space may thus relate to the ethers, with polar affine geometry related to light, special polar affine geometry to chemical action, and counter-space itself to life processes. This leads to interesting insights when followed up. Before continuing with this we will now consider the central thesis of this paper.

If indeed counter-space describes an aspect of the real world then we may ask what happens if an object is linked to both space and counter-space simultaneously? Consider a cube linked to both: if it undergoes a transformation then that transformation should be characteristic of both spaces at once i.e. lengths, angles, turns, shifts and vol-

ume should be invariant. If this is not so then we will get strain in one or both spaces, leading to stress i.e. force. If the cube behaves in a Euclidean way then its lengths and angles will be invariant, but we then find that corresponding shifts and turns must change, so it becomes stressed in counter-space. Evidence of such a linkage might be sought in an otherwise inexplicable force, one notorious candidate being gravity. For this it is natural to examine shift in view of the point-centred quality of gravity, in which case we analyse the possibility that two points may retain their Euclidean distance invariant but that the counter-space shift between them is forced to vary, giving rise to strain and hence a force. In fact gravity can be derived in this way, giving the inverse square law and proportionality to volume (and hence, via density, mass). It is too technical to describe in detail here, but further aspects will arise later. This result gives strong support to the validity of the line of thought being developed, and in particular that counter-space relates to minerals as well as living beings, especially where shift is involved. A general principle to be followed up, then, is that scientific evidence for the etheric may be sought not in contradictions to physical law, but rather in an understanding of aspects of the world that were thought to be physical but in fact are rooted in this idea that two qualitatively different spaces are simultaneously active.

It is natural to ask if any transformations are stress-free in both spaces, for such are likely to be the equilibrium conditions sought by Nature. Only four have been found:

1. A rotation about an axis through the counter-space infinite point. This may explain the ubiquitous appearance of vortices and rotary motion in general. If there is a counter-space infinitude in the centre of the Earth, this would explain why water vortices tend to behave the way they do, with an axis tending towards a line through the centre, but with instability near the tip as tangent planes related to counter-space strive to avoid "going to infinity" (very large stress) which they would if they passed though the Earth's centre.
2. A polar transformation (where points and planes are related via a quadric surface) has the property that a transformation in one space yields a stress free polar transformation in the other.
3. A reflection.
4. It is possible also to regard uniform rectilinear motion as nearly stress free given certain assumptions about the relative scaling of spatial and counter-spatial measures, but acceleration is not stress-free.

If a transformation in one space causes stress in the other, we see that work must be done to bring about the transformation. The result depends upon the situation, but broadly we can envisage two possible outcomes: first that we are left with stress in one (or even both) spaces, which is potential energy; or secondly that the relation to the spaces is changed to become stress free, in which case absorption or emission of energy must account for that change.

So far we have only considered a fully metric linkage between space and counter-space, relevant to solids. The above description of the elements may now be taken further by taking into account the possibility that a linkage between space and counter-space may be affine, or polar affine, as well as fully metric. Further, it is important to note the distinction Steiner pointed to in the *Light Course* between the kinematic and the

dynamic, for force and mass cannot necessarily be accounted for by geometry alone. In the present context we may postulate that mass is the content of a linkage between space and counter-space where the spatial metric dominates, and ether is the content where the counter-space metric dominates. The quality of these contents is not exhausted by the geometry which provides the stage, as it were, upon which matter and ether as actors play their part. In particular we should not confuse ether with counter-space. Goethean observation is necessary to win the content for which the geometry can provide a non-materialistic context. Both are needed to win through to a Michaelic science which does full justice both to the qualitative and the quantitative.

A question naturally arises at this point: how many counter-spaces are there? It is possible to consider a counter-space as fractally related to space i.e. that images of the counter-space infinitude appear in space due to a fractal linkage of the two spaces. Thus if a point is related to two such counter-space infinitude images (CSIs) a stress may arise if it then appears to have two different positions for the primal counter-space.

Returning to the Sun, spectroscopic analysis reveals hydrogen and helium and other trace elements on its surface. This does not prove that any such elements exist inside the Sun. Steiner spoke of a "tearing" of space e.g. in lightning (*Heat Course*), and we may consider the Sun's corona also as a result of such a "tearing", although we are not suggesting the corona is lightning. If there is a large stress between space and counter-space on the Sun's surface the result may be a "tearing" which results in a fractal relation between the counter-space of the Sun and ordinary space. The meaning of the "tearing" is just this fractal multiplication of CSIs. Gas is the result of this fractal "tearing", and also heat and light. The result is an affine linkage between space and counter-space expressed in fractal form. Dually there arises a polar affine linkage related to light (but which may not be fractal). Both linkages are expansive. Now an affine linkage cannot give rise to metric stress since metric quantities are not invariants, but as suggested above a point can be inconsistently related to the primal counter-space, giving stress. We will refer to this as *affine stress*. Regarding a CSI as such a point the only way this stress can be relieved is for the CSI to move away from the others. Hence we have gas pressure if it is in a metric container where the affine and metric behaviours must harmonise. Furthermore, since different directions are incomparable in affine space we can perhaps see why the kinetic theory of gases works, which considers pressure to arise from the rate of change of momentum of individual atoms travelling independently each in a definite direction (we are not espousing this view here). An analysis of the gradient of the affine strain for a point-triangle gives a force which is inversely proportional to the linear size of the triangle and passes through its circumcentre. We take triangles rather than solid structures because the affine quality restricts us to one counterspatial "direction" at a time. Summing the effects of all such triangles of CSIs in a volume of gas we find the total force on the outer surface of the metric container to be inversely proportional to its surface area, and hence in total we get pressure inversely proportional to volume. Finally, if the scaling between space and counterspace to obtain stress from strain is proportional to temperature we obtain the ideal gas law PV=RT. The important issue of how the two spaces are scaled is illustrated here, and fundamental physical constants seem to relate to this. In particular we see how heat enters into the picture in rela-

tion to scaling, noting also its effect on expansion and contraction of bodies, which are non-Euclidean transformations. If we have a given gas such as hydrogen we suppose that it has a primal counter-space of its own which becomes fractally related to space when ponderable and in the gaseous state. This agrees with Steiner's description of the existence of elements throughout the cosmos even when not materially expressed. To summarise, gas is composed of multiple CSIs under affine stress causing pressure.

When we come to the liquid state we find that we need an understanding of an aspect of gravity to explain it, so we will first consider the solid state. Only in solids do we have metric stress, and in particular we find particles suffer shift stress in counter-space, which is a development of affine stress in so far as the fractal coupling gives shift stress. A detailed calculation shows this to manifest as a force like gravity. The interesting thing is that this only appears for solids, as shift stress is not possible in affine or polar affine space, agreeing with Steiner's indication in the *Heat Course* that gravity does not affect a pure liquid. Crystal structure arises in solids through a principle of least action, where hexagonal, cubic etc. forms share and hence economise on action, a process which makes and breaks counterspace linkages. Apart from these static forms, one other class of structure seems to satisfy this requirement, namely path curves. This may explain why path curves appear in plants, and are related to geometric transformations, and yet plants do not appear actually to grow in that way.

We must account for liquid in such a way that it does have weight, as is observed. Water tends to form short range structures, and on this basis we can solve the problem for water, for if short range crystal forms occur then gravity is ushered in for those micro-structures. We envisage the fluid state as an equilibrium between the crystalline and the gaseous, between gravity which is contractive and the expansive affine stress of gas. Then special affine geometry with its constant volume character is an expression of this equilibrium. This approach indicates that a liquid must be extensively microstructured in view of its weight. However, this is not the only way of resolving the problem, and a fuller consideration of what we mean by "mineral" is required. We may perform an analysis of affine strain for a constant volume tetrahedron (following the logic applied to gases but now in special affine space), which results in a gradient which is only zero for a regular tetrahedron, and is inversely proportional to its linear size. The forces on the vertices act parallel to the opposite faces, giving shear effects. This manifests mainly in the surface of the liquid as the effects balance out in the centre of a liquid mass. We also find that a small base combined with a distant fourth vertex results in the base moving towards the vertex, not vice versa. This accounts for the tendency of a liquid drop to form a sphere. Surface tension can be seen to arise from a combination of behaviours of tetrahedra containing CSI vertices in the surface. The rich range of action of various forms of such tetrahedra seems to account well for the properties of a liquid. An interesting thing that emerges is that an analysis of affine strain is identical to that of shift strain were it to exist in liquid, and the same applies to gases. We are thus led to propose that the analysis applies to the point-wise mineral qualities of the liquid, to which gravity may also apply. The non-mineral aspect related to the constant volume property upon which the analysis is superimposed, to which gravity does not apply, is perhaps what Steiner had in mind in the *Heat Course*.

Looking at the dual situation for chemical action where we have a special polar affine linkage, we envisage an equilibrium between "short range" structure in counter-space and light (dual to gas). But what does "short range" mean in counter-space? Put quite simply it means far from infinity, so we are concerned with structures "far" from the CSI, whereas "long range" means "closer". To clarify, if we have a plane linked to both spaces then if the line through the CSI perpendicular to it (in the Euclidean sense) is of length r then it can be shown that the turn of that plane in from the Euclidean infinite plane is t = s/r where s is a scaling factor between the two spaces. "Far" from the CSI means t is small, whereas "close" means t is large and r is small. This may mirror the distinction between the nucleus of an atom where counter-space entities and structures are "long range" and the electron shells where they are relatively "short range". $\underline{s}$ needs to be determined, but this indicates it is a very small number. The difference from conventional atomic theory is *that we regard the structure and properties of elements to arise from counter-space structures rather than from particles*, in line with Steiner's indication that where we think of atoms we should look for cosmic activity. Again, as we found for gases, we start to see (dimly as yet) why atomic theory arises and why it works as a model. A cardinal question concerns the nature of the counter-space structure of a primal element. Remarkable woven patterns of planes with respect to their mutual turns suggest a structure of light, again reminiscent of Steiner's characterisation of matter as "woven light". Briefly, it is possible to construct lattices of parallel planes such that the turn between two parallel planes equals that between a plane and one rotated though a definite angle in the next array. The structure is dynamic and contains a weaving between spiral planar movements and radial parallel arrays. Hexagonal and triangular prisms are interesting as they sit in balance with infinity, having the same turn between neighbouring planes as each plane has to the plane at infinity, showing a possible transition from a mobile affine structure to a static metric one. However this is only very tentative as yet. What is clear is that "long range" counter-space structure concerns the identity of a primal element while "short range" structure concerns chemical activity, and dual to liquid there is an equilibrium between the chemical-element-forming tendency and the expansive tendency of light characteristic of polar affine space.

We have not yet considered light. It has posed some of the greatest riddles to physics this century, so we need not expect an easy answer. Light arose with gas in early evolution which is why we look to a polar affine linkage between space and counter-space dual to the affine linkage characterising gas. There is no pointwise linkage here, so the light source CSI is not located in space, which expresses the conventional idea that position may be indeterminate. Thus a plane in this counter-space is also indeterminately located, and for space only has an orientation (expressed as a line in the Euclidean plane at infinity). A more detailed account requires a closer study of polar-area i.e. the dual in counter-space to area in space. While light itself is essentially etheric, when it relates to darkness in the form of photons we obtain not particles but cones in counter-space. We get neither particles nor waves but a polar area which can express the experimental properties of photons. The fact that a polar area appears extended over a volume in Euclidean space may help explain some of the apparently paradoxical multi-path experiments carried out with photons where the latter appear to be in several places at

once. In fact they are, but not as particles or waves. A strong initial support for this approach is that it unexpectedly yielded Balmer's formula for the emission of photon cones. Reflection, refraction and diffraction can be understood, and Taylor's version of Young's double-slit experiment (more recently repeated with electrons and very recently with atoms) can be explained without paradox.

Chemical action seems to involve bonds mediated by photon cones, and as planar linkages are very "stiff" these cones do not detach easily, which is what constitutes a "bond". A stronger bond may be associated with an interesting geometrical property. Quadric surfaces cannot change "signature" in affine or metric space as their relation to infinity is invariant i.e. a surface either intersects the plane at infinity or it does not (or it touches). This relation is referred to conventionally as the signature. Thus an ellipsoid does not intersect the plane at infinity, but a hyperboloid does, so the one cannot be transformed into the other. For counter-space a similar signature arises in relation to the CSI (O say), for a quadric surface may have a real tangent cone in O in which case it is a "hyperboloid" for counter-space even if it looks like an ellipsoid to a Euclidean consciousness. If it has no real tangent cone in O then it is an "ellipsoid" for counter-space, so what looks like a euclidean hyperboloid may have a finite polar-volume, which has been confirmed by integrating polar-area over that polar-volume. The point is, this can explain why matter does not collapse, for constituent Euclidean spheres would have to change signature in counter-space for this to happen. Conversely very strong bonds are possible if signature change is required to separate the constituents of matter. It is not yet clear whether this distinguishes covalent from metallic and hydrogen bonds, or whether it goes beyond chemistry to nuclear forces.

A subtle interpretation of time is needed fully to appreciate what is said above, which explains the constancy of the velocity of light, in the sense that a photon cone apex has that velocity but not in fact the light itself. Quantisation arises as a necessity, to avoid infinite time intervals, together with what otherwise requires relativity i.e. these two aspects are quite naturally united. It also explains the sense in which we have a time organism when we consider life ether, and why the apparently "rigid" quality of counter-space as a metric space, apparently so un-life-like, does in fact express life. The implications of this approach to time are currently being explored, so these brief comments must suffice.

The "fallen ethers" have yet to be satisfactorily included, although a promising start has been made with magnetic and electric polarisation, which points the way. Briefly, the idea is that a scaling quadric forming part of a CSI may be ellipsoidal at the metric level, and thus polarised. The fractal interaction of the metrically linked members of a population may "entrain" the shapes of its affine members (for which polarisation is otherwise indeterminate), which is referred to as "affine entrainment". An example is a capacitor for which the plates are metrically polarised, the dielectric being affinely entrained into polarisation. It seems at this stage that "fields" are accounted for by the propagation of fractal effects in this way, which seems more satisfactory than fictitious "lines of force".

The indeterminacies in quantum physics seem to arise when a transition from affine to metric space occurs, for a non-strained affine configuration may end up strained if

forced by a measurement to become metric. Thus at the affine level we have indeterminacy from a metric standpoint, and only one of the complementary quantities (e.g. position and momentum) can be realised metrically with full precision.

This article is necessarily aphoristic and much will seem to be mere assertion, which is unavoidable in a short account like this of what has become a large work. It is planned to remedy this in the form of a book where the accompanying mathematics and diagrams can be presented. We are concerned with ongoing research which is developing week by week, and what has been described may have changed considerably by then. The hope was to convey something in a short article of the whole picture that is developing.

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Nick Thomas
163 Toms Lane
Kings Langley
Herts
WD4 8PA
UK

Email: nct@cix.compulink.co.uk

Radioactivity in the history of the earth

Norman Grant

Introduction

Unlike the free oxygen in the atmosphere which occurs as a result of the removal of organic carbon from the cycle of photosynthesis and respiration by burial in sediments, oxygen in the Earth's crust and mantle occurs in chemical combination with other elements as rock-forming or silicate minerals. Because oxygen and the second most abundant element in continental crust, silicon, make up about 74% of the mass of the crust, all the other elements are present in only minor or trace amounts. This means that, with the exception of potassium which is a minor element in many rocks, radioactive elements occur in the crust and underlying mantle in dilute concentrations that are measured down to a few - or even fractions - of a part per million by weight. In addition to its widespread but dilute occurrence in nature,[1] natural radioactivity is also a heat-producing or exothermic process.

Seventy-one of the ninety-two elements found in nature consist of nuclides[2] that differ in respect of their atomic masses but not in the chemical properties of each element. Such nuclides or atomic varieties are called isotopes. Almost seventeen hundred nuclides are known, and of these some fourteen hundred and forty are radioactive.[3] Many radioactive nuclides have short half lives[4] ranging from a fraction of a second to several tens of thousands of years, and are known to be produced by human manipulation of nuclear processes in the form of nuclear weapons and atomic reactors.

In the solid Earth most nuclides are stable, and radioactivity is restricted to a set of nuclides with very long half lives of the order of 10^9 to 10^{11} years. Natural radioactivity is also present in the Earth's upper atmosphere, on rock surfaces on mountains at high altitudes, and on the surfaces of meteorites, and is the result of nuclear reactions between the flux of high energy cosmic rays[5] that come from deep space with atoms of elements in the atmosphere (oxygen, nitrogen and argon), and others on the surfaces of rocks and meteorites. The chemical properties of the so-called cosmogenic nuclides determine how rapidly they are removed from the atmosphere and incorporated into the biosphere or into water and sediments on the Earth's surface. The production rates of cosmogenic nuclides are influenced by the Sun, in that the solar wind reduces the cosmic ray flux incident on the Earth, and also by variations in the intensity of the Earth's magnetic field.

With one notable exception,[6] none of the cosmogenic nuclides are known in the solid Earth. The concentrations of some cosmogenic nuclides in natural reservoirs have been altered as a result of human activities, as may be seen from the decrease in ^{14}C in the atmosphere since 1900 and the strong increase after 1945. The

decrease reflects the addition of ^{14}C-free carbon dioxide to the atmosphere produced by the burning of old carbon in fossil fuels, while the increase after 1945 reflects ^{14}C produced by nuclear weapon testing in the atmosphere.

TABLE 1

Principal radioactive nuclides

Long-lived nuclides in the solid Earth	**Decay products**	**Parent half lives (years)**	**Cosmogenic nuclides**	**Decay products**	**Parent half lives (years)**
^{40}K	^{40}Ar ^{40}Ca	1.250×10^{9}	^{3}H ^{7}Be	^{3}He ^{7}Li	12.26 53 (days)
^{87}Rb	^{87}Sr	4.88×10^{10}	^{10}Be	^{10}B	1.5×10^{6}
^{147}Sm	^{143}Nd	1.06×10^{11}	^{14}C	^{14}N	5730
^{176}Lu	^{176}Hf	3.54×10^{10}	^{22}Na	n.a.	2.6
^{187}Re	^{187}Os	4.56×10^{10}	^{26}Al	^{26}Mg	0.716×10^{6}
^{232}Th	^{208}Pb	1.401×10^{10}	^{32}P	n.a.	14.3 (days)
^{235}U	^{207}Pb	7.038×10^{8}	^{33}P	n.a.	25 (days)
^{238}U	^{206}Pb	4.468×10^{9}	^{32}Si	^{32}S	276
			^{36}Cl	n.a.	3.08×10^{5}
			^{37}Ar	n.a.	35 (days)
			^{39}Ar	^{39}K	269
			^{53}Mn	n.a.	3.7×10^{6}
			^{59}Ni	n.a.	8×10^{4}
			^{81}Kr	^{81}Br	2.13×10^{5}
			^{85}Kr	^{85}Rb	10.6 (days)

Compiled from: Faure, G., 1986. Isotope Geology, 2nd edition. John Wiley & Sons, Inc., New York, 589p.; Lal, D. and Peters, B., 1967. Cosmic-ray produced radioactivity on the Earth. In, Sitte, K. (ed.), Handbuch der Physik, Springer-Verlag, Berlin, 436, 551-612 (n.a. = not available in these sources).

The conventional understanding of the long-lived radioactivity in the solid Earth is that it was inherited from the time of the Earth's formation, and thus is very different from the cosmogenic nuclides that are continuously replenished as a result of the arrival of cosmic rays from deep space. The absence of cosmogenic nuclides in the solid Earth is conventionally taken to mean that the Earth is sufficiently old that any cosmogenic nuclides originally present have been exhausted by radioactive decay a long time ago. Furthermore, the continuous recycling and reconstitution of the Earth materials by weathering, erosion, sediment transport and deposition, metamorphism and volcanism, in the same sense that the biosphere reconstitutes Earth materials in the life cycles of living organisms, make the survival of ancient rocks or minerals containing the decay products of cosmogenic nuclides extremely unlikely, although examples of these decay products are known in one variety of meteorite. Such meteorites must, therefore, have remained unchanged in their physical and mineralogical constitution from the time when cosmogenic and other short-lived radioactive nuclides were incorporated into them.[7]

A final point to be made by way of introduction is that it is clear (Table 1) that natural radioactivity is not a phenomenon that is restricted to elements of the highest atomic mass, although this has been asserted by some anthroposophical writers.[8]

Distribution of natural radioactivity

The long-lived radioactive nuclides in the solid Earth (Table 1) are most abundant in continental crust, particularly in the upper crust on which we stand (Figure 1).[9,10] Although the average thickness of continental crust (30-40 km) is only about 0.5% of the Earth's radius, and it occupies 0.04% of the Earth's volume, the concentration of radioactive elements is so great that 30% of the Earth's radioactive heat production occurs in continental crust. If we think of the Earth in terms of its heat production, rather than its internal temperature, then the Earth appears as a heat body within which heat production is highest within the planet's outermost skin or crust. From this point of view, the Earth is almost like a tree in which growth is most active under the bark, leaving the heartwood interior - perhaps like the Earth's core - as the inner part from which the life forces have retreated. Although the crust's contribution to total heat production is less than the mantle because of the very much larger mass of the latter, nonetheless it is true to say that during the time-span through which changes in the biosphere led eventually to the appearance of human beings on Earth, the continental crust on which we were eventually to stand was enlarged, consolidated and enriched in crustal elements, including the long-lived radioactive nuclides.

A second intimate connection between radioactivity and life arises from the biochemical properties of several of the cosmogenic nuclides, for many of them belong to elements that living organisms take up in their life cycles. A notable example is ^{14}C, an isotope of the element carbon that lies at the heart of plant and tree

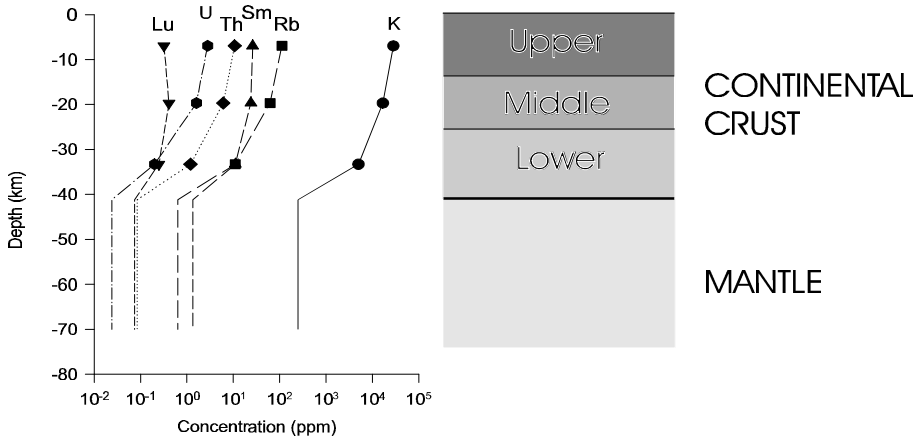

Figure 1. Estimates of the concentrations of selected radioactive nuclides in the Earth's mantle, and the lower, middle and upper continental crusts. Note the logarithmic concentration scale.

life, and which reveals a double affinity for the Sun and cosmos, through photosynthesis on the one hand and its origin through cosmic rays on the other. The low levels of radioactivity in all living vegetation is a result of the presence of ^{14}C, and means that plants and trees die twice: once visibly at the end of the plant or tree's life cycle, and then invisibly when much later the radioactivity in their carbon is exhausted. At that point the life of the plant as a heat body ends, and the carbon is given as dead carbon (ultimately coal) to the solid Earth, or returned to the atmosphere as carbon dioxide to be replenished by cosmic rays in the upper atmosphere with new ^{14}C.

Similar connections with life are apparent for other cosmogenic nuclides. The element phosphorus (^{32}P and ^{33}P) enters into nerves and bones, while sulfur (^{35}S) combines with carbon, hydrogen, oxygen and nitrogen to form proteins. Tritium, the isotope of hydrogen (^{3}H), is also present when water flows through living organisms, while the isotopes of sodium and chlorine (^{22}Na and ^{36}Cl) are important to the salinity of ocean waters. Their ability to readily ionize and form electrolytic solutions means they are important for electrical processes in the body, and in cases where salinity differences influence the osmotic transfer of fluids through membranes such as cell walls.

This intimate association between radioactivity and life is not reflected in the dread of radioactivity that arises from fear of its destructive capacities. But, such dread overlooks the distinction between the behavior of radioactive nuclides when concentrated by human intent for nuclear reactors and weapons, and the extremely

dilute concentrations of these nuclides in the Earth. Although radioactivity is the antithesis of life when artificially concentrated, we should recall that elements and substances that in high concentrations are extremely toxic (e.g., lead, arsenic, antimony, mercury), may also have curative properties at homeopathic dilutions. If this point of view can also be applied to radioactivity, then the properties of the very dilute natural radioactive nuclides present in the atmosphere, the ocean, the solid Earth and the biosphere, may be very different from anything we have so far considered.

Warmth and the evolution of life

Radioactivity and metabolism

Radioactivity and metabolism are heat producing processes, and both are based on the transformation of one form of material substance into another. In the case of radioactivity, it is the parent nuclide that is transformed, while in the case of metabolism it is food. Both processes, therefore, incorporate the principle of sacrifice, where one form of material substance gives up its being in order to become something else. Furthermore, if metabolic processes are the seat of the human will, then we may think of natural radioactivity as an expression of will-forces in the Earth.

The mutual relations between life, metabolism and heat are very varied, but in all cases they reflect life's capacity to define itself in terms of temperature. The fossil record illustrates the changing ways in which life has incorporated itself into physical substance, and the evolution of the relationship of life to heat. The clearest expression of this is to consider a phylogenetic "tree of life" based on genetic relationships between present-day living organisms[11] rather than the more familiar tree based on the morphology of living and fossil organisms first developed in the 19th century. The phylogenetic "tree" divides all living organisms into three groups: bacteria and archaea that are prokaryotic or unicellular organisms lacking a cell nucleus, and eucaryotes where a cell nucleus is present (Figure 2). The substantial numbers of thermophiles within the bacteria and archaea, living in water-filled cracks in the deep crust and in hot springs or hydrothermal systems associated with subaerial and submarine volcanism in the deep and completely dark ocean, may be examples of the earliest unicellular fossils known in Precambrian rocks.[12] Thermophiles retain a close connection to radioactivity in the solid Earth because hydrothermal heat is transformed radioactive heat transferred to hydrothermal waters by way of rising magmas.

The evolutionary innovation of photosynthesis, which is responsible for the presence of free oxygen in the Earth's atmosphere, occurred within both the bacteria and eucaryotes, and represents a shift from life centered on the solid Earth, to life centered on the Sun as the source for the heat and energy needed to sustain life. The

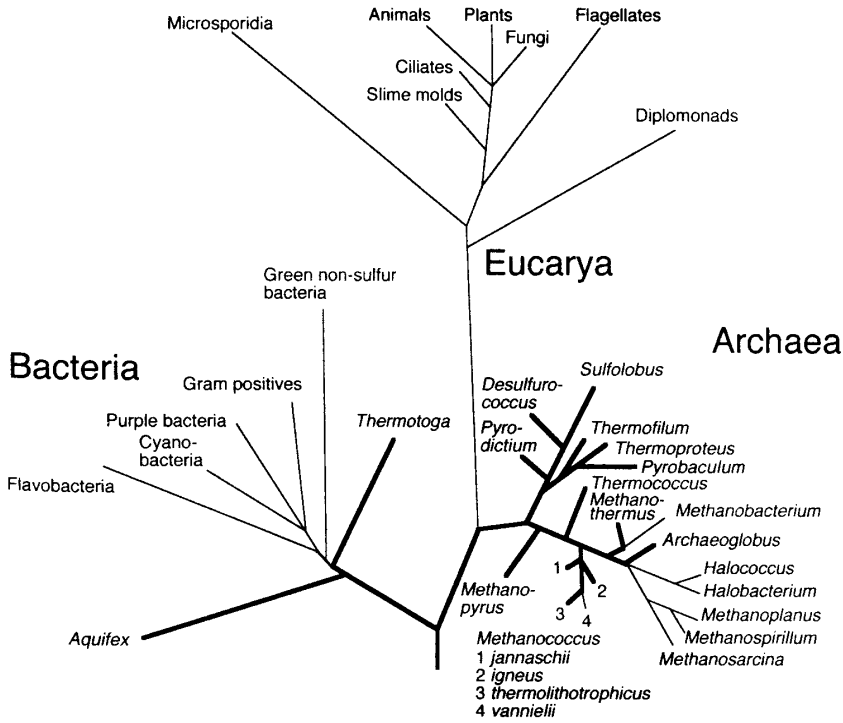

Figure 2. Universal phylogenetic tree, based on 16S rRNA genetic sequences. The thick lines identify thermophiles.

Sun remained important in the subsequent development of multicellular life, not only for plants but also for reptiles, and it is only with the appearance of mammals that life-forms developed the capacity to regulate their internal temperatures independently of radioactive heat on the one hand and the Sun on the other. Viewed in this way, the evolutionary process may be thought of as one where life-forms have changed from being wholly integrated into the environment and centered first on the solid Earth and radioactivity, then on the Sun, before becoming autonomous heat organisms. It is this autonomy that provides the basis for human thought and morality, and our realization that we have become agents in the Earth's future.

Warmth and Death

With death, life's link to temperature is broken, as in the case of a simple organism

outside it's ecological niche, or a mammal when metabolic processes end and death's coldness appears. All Earth processes also carry this relationship to temperature. In the case of the atmosphere and hydrosphere the source of the heat is outside the Earth, in the Sun, but for the solid Earth, the heat source lies inside the planet as finely dispersed radioactivity. All aspects of the Earth' activity reflect the interplay between these two heat sources, as well as the processes that mediate the balance between heat production and heat loss. For the solid Earth, as for humans, old age leads to a diminished capacity for heat generation. Ultimately, for both, death is cold. Just as our experience of our own death can be anticipated by the passing of a person close to us, so the cold Moon conveys an image of planetary death through the loss of its internal heat. This is not to say there is no radioactivity in the Moon, only that the imbalance between lunar heat production and heat loss has led to a cold Moon.[13]

Radioactive Dating

Method and Assumptions in Radioactive Dating

The belief of Christian fundamentalists, that a literal reading of the Bible resolves both the questions of the age and history of the planet, preserves dim vestiges of a once-rich tradition that reached back from medieval times to ancient Greece, and placed human beings in a hierarchical cosmos that was mirrored on Earth by the Church. In the 19th century this tradition was in an advanced state of decay, and began to be replaced by other ways of looking at time in the history of the Earth. An early step was the separation of geology from theology by the argument that the past must be interpreted in terms of what can be observed at the present day, rather than what can be learned from Biblical and other authoritative texts. Because it is clear that interpretations change radically if there is a shift in the assumptions made about the past, every historical discipline faces this question.[14] Whatever we might think about the assumption that the *present is the key to the Earth's past*, and Steiner's contrary view of Earth history stands within the tradition that conventional science abandoned by the end of the 19th century, there can be no doubt that the assumption has greatly stimulated the study of the present-day Earth. Charles Lyell (1797-1875) who was prominent in the 19th century debate that established the view that the present is the key to the past, argued that to do otherwise would:

> "... directly ... repress the ardour of inquiry by destroying all hope of interpreting what is obscure in the past by an accurate investigation of the present phenomena of nature."

His point was that the assumption that the past history of the Earth involved events and conditions quite different from those of the present day would make historical reconstructions entirely speculative, and undermine the need to make careful observations of the Earth as we see it today. It would be well for us as anthroposophists to bear his criticism in mind, for how does one make a Goethean

study of the Earth's history if at the present day the planet has little in common with the Earth in the past?[15]

The 19th century contribution to understanding the history of the Earth arose from the observation and mapping of sedimentary strata, the development of criteria - such as superposition - to determine the relative ages of different strata, and the use of fossils to correlate strata between geographically separate regions, even between continents. The outcome of this work was the Stratigraphic Column or Table, a compilation of all known strata set out in order of their relative ages and classified into *systems*. Each system was taken to represent the passage of a particular length of time, or *period*, and periods were grouped into *eras*. There was nothing in this approach to indicate how much time each period and era represented, although geologists were convinced that it must have been substantially more than the 6,000 years assigned by Biblical scholarship to the age of the Earth.

Quantitative measures of past time had to wait until the 20th century, with the application of radioactivity to age calculations. In 1902, six years after Becquerel had discovered radioactivity, Rutherford and Soddy proposed - on the basis of experiments with radioactive substances - that the rate of decay of a radioactive parent nuclide is proportional to the number of atoms (N) remaining at any time (t).[16] This can be expressed mathematically, as follows:

$$-\frac{dN}{dt} \propto N$$

In this expression, dN/dt is negative because the reduction in the number of surviving parent atoms (N) causes the rate of decay to decrease. This proportionality can be changed into an equality by the introduction of the decay constant (λ), that has a particular value for any radioactive nuclide and represents the probability that an atom will decay in unit time. Thus, we can now write:

$$-\frac{dN}{dt} = \lambda N \qquad (1)$$

If this expression is rearranged, and then integrated, we have:

$$-\ln N = \lambda t + C \qquad (2)$$

Where $\ln N$ is the logarithm of N to the base "e", and C is the constant of integration whose value can be defined from the condition $t = 0$ (when a mineral or rock was formed), when N had an original value N_o. This leads to:

$$C = -\ln N_o \qquad (3)$$

When substituted into equation (2), and then rearranged:

$$-\ln N = \lambda t - \ln N_o \qquad (4)$$

$$\ln N - \ln N_o = -\lambda t$$

$$\ln \frac{N}{No} = -\lambda t$$

$$N = N_o e^{-\lambda t} \qquad (5)$$

Equation (5) is the basic equation that describes radioactive decay, but it is not in a form suitable for age determination because not all quantities are measurable at the present day. It is possible to replace N_o by considering the number of daughter atoms that have accumulated (D^*) as a result of the decay processes. This must be the difference between N_0 and N:

$$D^* = N_o - N \qquad (6)$$

If (5) is rearranged, and substituted into (6):

$$D^* = Ne^{\lambda t} - N$$

$$D^* = N(e^{\lambda t} - 1) \qquad (7)$$

If we also take into account that a number of atoms of the daughter nuclide (D_o) may have been present at $t = 0$, then (7) can be changed into a completely general statement:

$$D = D_o + D^*$$

$$D = D_o + N(e^{\lambda t} - 1) \qquad (8)$$

If (8) is solved for time (t) in years, we have:

$$t = \frac{1}{\lambda} \ln \left[\frac{D - D_o}{N} + 1 \right] \qquad (9)$$

This expression is the fundamental equation that allows ages of rocks or minerals to be calculated on the basis of radioactivity. In some cases such ages represent the time of formation of a rock or mineral, in others - depending on the chemical properties of the parent and daughter nuclides and the particular mineral that is dated - the ages may represent a younger metamorphism, or a time when a rock or mineral last cooled through some critical temperature. There are some instances where an age has no particular significance, although this is less of a problem than it was because the criteria by which spurious results can be recognized have become increasingly well defined. Likewise, the original presence of daughter atoms incorporated into a rock or mineral at the time of its formation is not now an important problem, and can be avoided or corrected by an appropriate choice of the parent-daughter nuclides and the mineral that is dated.

From this discussion, it can be seen that the validity of radioactive ages depends only on two assumptions. The first assumption underlies the mathematical treatment of radioactive decay, namely, that the rate of decay of a radioactive parent nuclide is proportional to the number of atoms present. The second is the assumption that radioactive decay constants have remained fixed throughout the time-span of the history of the Earth. Both assumptions are part of a wider set of assumptions about the uniformity of processes in time and space that have progressively developed in science over the last three hundred years.

Rudolf Steiner and radioactivity

Steiner experienced the Earth as a living being, and understood its development in terms of organic laws that led to the late appearance of the present-day properties of material and mineral substances in the planet's history. I believe he may have stood against the conceptions of time that have arisen from radioactive dating, because organic processes do not proceed according to the constant rates assumed for radioactive decay in the past. Organic processes vary logarithmically, and conclusions about the early life stages of an organism are bound to be misleading, if they are based on observations made when the organism is at a mature or old-age stage. Steiner not only made this argument, but he stated in 1905 that the phenomenon of radioactivity was a recent one:

> "In earlier times atoms were progressively hardening; now, however, they are coming more and more apart. Previously there was no radioactivity. It has existed only for a few thousand years, because atoms are now splitting up increasingly".[17]

It is this statement that lies behind Lehrs'[18] assertion that radioactivity is an aspect of the Earth's old age, and also Wachsmuth's proposal - on the basis of astronomical criteria -that radioactivity began 15,000-14,000 years ago. Wachsmuth wrote that:

> "From this standpoint, the figures for the total evolution [of the Earth] which have been theoretically calculated in millions and billions, bear no relation to reality."

Because these statements are in such sharp conflict with what is accepted by present day scientists, it is important to examine the conflict by first considering Steiner's statement and the views of other anthroposophists on radioactivity, and by assessing the assumptions that lie behind anthroposophic and conventional views of radioactivity.

Steiner made his 1905 statement in a course of thirty-one lectures given in Berlin from September 26 to November 5, 1905, nine years after radioactivity was discovered, and less than three years after Soddy and Rutherford proposed the basis for the numerical treatment of radioactive decay. According to the editor and translators of the lectures, the course was given to an inner circle of the German Theosophical Society without the presence of a stenographer. The lectures were

reconstructed from notes taken for personal use by Mathilde Scholl that were later edited when compared with similar notes taken for most of the lectures by Marie von Sievers. The editor, Hella Wiesberger, wrote that the:

> "notes have a strongly aphoristic character which should be borne in mind if, owing to their shortened and condensed content, or also as a result of gaps in the text, they are not always entirely comprehensible. If today these notes appear in the Complete Edition it is because … they provide us with valuable aspects of human and cosmic consideration, which are not to be found in this form in Rudolf Steiner's later lectures."

Several conclusions are clear from these considerations. One is that Steiner's statement came within two to three years of physicists first grasp of the numerical description of radioactive decay. Another is that his statement is contained in a lecture course for which the textual record is abbreviated, not always comprehensible and even incomplete. Finally, this lecture course contains "human and cosmic considerations" that are not to found in later lectures by Steiner.

It is not clear whether Steiner's statement introduced the inner circle of Theosophists to the idea of the recent onset of radioactivity, or whether he was repeating something that was familiar to his audience from Theosophic sources.[19] We also do not know how to understand statements attributed to Steiner that he did not return to in later lectures, nor do we know about the popular understanding of radioactivity in Europe in the early years of this century. This may have been very different from present popular understanding, as in the early belief that radioactivity had curative medical properties. Furthermore, we do not know if Steiner was fully acquainted with the results of scientific research into radioactivity in the immediate years before 1905.

Taking these points together, it may be wisest to interpret Steiner's statement as a remark attributed to him in the notes taken by Mathilde Scholl and Marie von Sievers rather than a literal quotation of exactly what he said.[20] Although Wachsmuth took the position that radioactive ages "bear no relation to reality" because he believed radioactive decay is a phenomenon of only the last 15,000 years, not all anthroposophical writers have followed him, preferring to retain radioactive ages and find a way of representing them that is consistent with an organic origin and history of the Earth. For example, several writers[21] have proposed that an exponential (i.e., *hyperbolic* or *logarithmic*) depiction of radioactive ages would best represent the passage of time for an organic Earth, leaving only the last 3,000 years as the interval to which calendar years in the modern sense should be applied.[22]

We are lead, therefore, to the following questions. How far back in time can we recognize calendar years? How far back in time can we justify the assumption that radioactive rates of decay have been constant? Finally, what is the evidence that bears on Steiner's statement that radioactivity began only a few thousand years ago?

Recognition of Calendar Years

A calendar year contains the seasonal variations that influence the growing patterns of the biosphere. One record of calendar years is contained in trees, because a tree-ring records high growth rates in the spring and summer, and low rates in the fall and winter. Changes in the total thickness of an annual tree-ring reflects regional environmental and climatic changes, and lead to distinctive tree-ring patterns that can be correlated and meshed together to create a composite tree-ring record that extends back to about 11,500 years before present.[23] ^{14}C dating of tree rings shows that radiocarbon years are systematically different from calendar years, being too high for the last 3,000 years and too low from this point back to 11,500 years. Radiocarbon and uranium-thorium ages of corals ranging in age from 8,500 to 30,000 years show that the uranium-thorium ages[24] are consistent with the tree ring chronologies, demonstrating that the decay constants for uranium and thorium have been constant as far back as 11,500 years before present, and perhaps to 30,000 years.

Another well known record of calendar years is contained within glacial ice, for the differences between winter and summer snow form a distinctive double layer, just as in the case with a tree-ring. Counting annual accumulation layers in glacial ice has been most developed in two ice cores recently drilled through the Greenland ice sheet, where snow accumulation rates are extremely high and the layers are well preserved. Recently published studies of these ice cores demonstrate that it is possible to count annual accumulation layers back to 40,000 years before present. Chronologies developed in this way are consistent with the age of volcanic ash from historic and older eruptions in Iceland and elsewhere, and also with the results of studies of sediment cores from ocean basins dated by radiocarbon methods. It is important to note that tree rings and glacial ice place no upper limits on how far back it is valid to extrapolate calendar years. It is clear, however, that the upper limit of 3,000 years assigned to the calendar year timescale in recent Anthroposophic writings[8] is not correct.

Past Rates of Radioactive decay

It is possible to test the assumption of uniform rates of radioactive decay over the past few millions of years from two independent measurements of the rates of continental drift or plate motion. One is based on satellite laser-ranging techniques that are capable of measuring the position of fixed locations on different continents with an accuracy of a few cm. When these measurements are accumulated over a period as short as five years it becomes possible to calculate the velocities with which these fixed locations are moving away from or towards each other as a consequence of continental drift. The second method of calculating the same set of velocities comes from a knowledge of the radioactive age of oceanic crust on the sea floor. Velocities of sea-floor spreading can be calculated from the distance of ocean crust of a particular age from the mid-ocean ridge at which it was created. When the rates of continental drift are averaged over the past three million years and compared to the rates for the same continents based on laser-ranging measurements made over

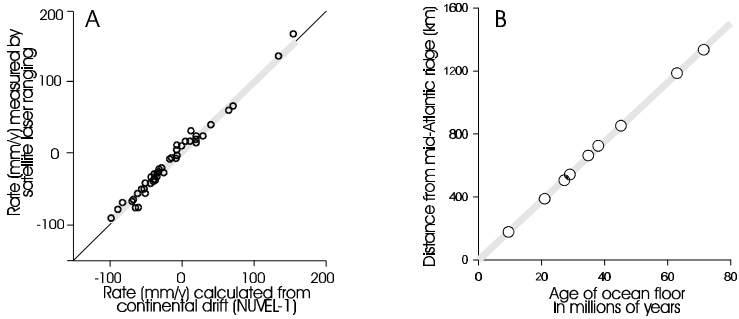

Figure 3. (A) Comparison of the rates of change of distances between fixed points on different continents made by laser-ranging measurements over 1978-88 with estimates of the same rates averaged over the past 3 million years from sea-floor spreading rates calibrated by the radioactive time-scale. The thin solid line illustrates equality between the two rates, while the stippled line shows the best-fit line to the data. The best-fit line has a slope of 0.949±0.019, showing that on average the laser-ranging rates are 5% slower than the rates based on the radioactive time-scale. NUVEL-1 is a numerical model that describes the movement of continents and plates over the past 3 million years on a radioactive time-scale. (B) The relations between age of the Atlantic ocean floor based on the radioactive time-scale and distance from the mid-Atlantic ridge, showing that the rate of continental drift, or sea-floor spreading, has remained fixed over almost the past 80 million years.

1978-88,[1] the two rates are essentially the same (Figure 3a). This equality demonstrates that radioactive decay rates have had present day values for at least the last three million years.

As in the studies of tree rings and annual layers of accumulation in glacial ice, this result places no limit on the length of past time over which it is reasonable to assume that rates of radioactive decay have been constant. That it is likely to be much longer than three million years is apparent from a comparison of radioactive ages over the past eighty million years for the Atlantic sea floor[26] with distance of sea-floor of a particular age from the Mid-Atlantic Ridge (Figure 3b). The observation that the age of the sea-floor is linearly related to distance from the Mid-Atlantic Ridge shows that sea-floor spreading in this part of the Atlantic has occurred at a uniform rate of just less than 2 cm/year. This rate is similar to the rates calculated from laser-ranging measurements at the present day. It is also possible to conclude from this linear relationship, that rates of sea-floor spreading and radioactive decay have both been constant over the past eighty million years.

Onset of Radioactive Decay

If radioactivity started at a certain point during the history of the Earth, it follows that the accumulation of daughter nuclides would have begun at that point in time. If this were true, the consequences for radioactive ages are sharply different from the conventional assumption that radioactivity has been a property of the Earth throughout its history.

This can be illustrated by the decay of ^{238}U to ^{206}Pb. If we omit the eighteen intermediate steps in the decay process, it can be shown as follows:

$$^{238}U \text{ fi } {}^{206}Pb + 8(\text{helium atoms}) + 6(\text{electrons}) + \text{energy}$$

The isotopic proportion of ^{206}Pb to the other lead isotopes can be represented by the atomic ratio $^{206}Pb/^{204}Pb$, in which ^{204}Pb is an isotope of lead that is not the outcome of radioactive decay, and whose abundance in any rock or mineral is fixed.

One way to assess whether radioactive decay began at some point in the Earth's history, or has always been a property of the Earth, is to examine the value of

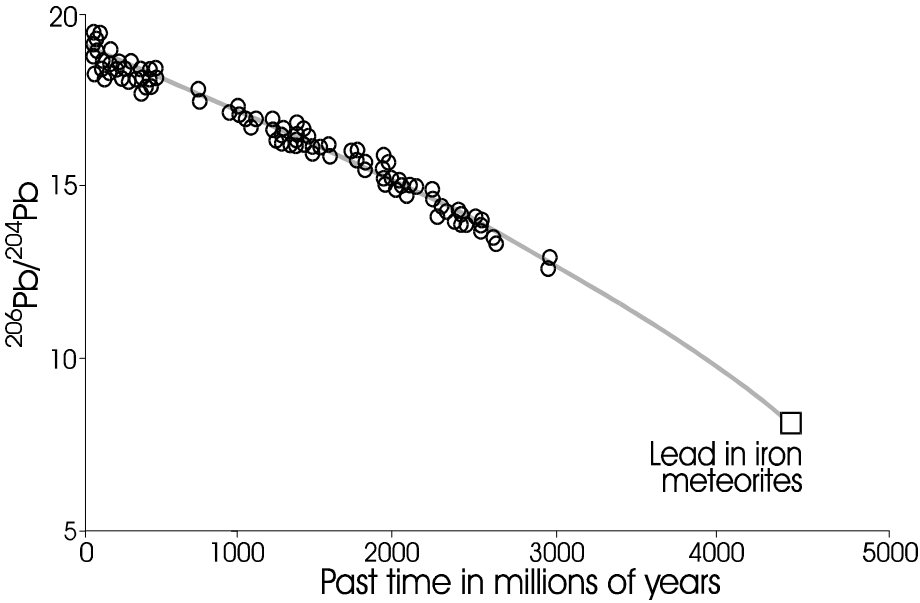

Figure 4. Plot of $^{206}Pb/^{204}Pb$ values measured on "conform-able" galena crystals of different ages. The stippled line shows the change in this ratio calculated on the basis of the $^{206}Pb/^{204}Pb$ value for lead in iron meteorites 4.55 billion years ago, an assumed $^{238}U/^{204}Pb$ value, and the present day decay constants for ^{238}U. Conformable galena, one of several types of galena deposits, occurs where sediments and associated volcanic rocks form the host to the deposit.

$^{206}Pb/^{204}Pb$ of the crust throughout the Earth's history, because this ratio would remain fixed during times when there was no radioactive decay, but increase when radioactive decay was active. This test can be accomplished by measurements of $^{206}Pb/^{204}Pb$ on the lead ore mineral galena (PbS), for galena crystallizes from fluids that have dissolved lead out of crustal rocks and minerals and precipitated it in combination with sulfur. The key to this test is that galena excludes uranium and thorium from its crystal lattice, so that lead in galena crystals retains the isotopic composition of the lead originally precipitated from the ore fluids. Because this isotopic composition has been inherited from the crustal rocks from which the ore fluids dissolved the lead, the lead in galena preserves a record of the isotopic composition of lead in the Earth's crust through past time. An example of $^{206}Pb/^{204}Pb$ values measured in galena crystals of different ages[27] (Figure 4) shows that this ratio increases from the oldest to the youngest galena crystals, as would be expected if radioactivity had been a property of the Earth throughout its history. This result would not be changed if the radioactive ages attributed to the galena are replaced by a relative time-scale based on field criteria, or if the radioactive time-scale is replaced by one with a logarithmic scale, so these observations are not consistent with Steiner's view that radioactivity began "a few thousand years" ago. These measurements also show that the atomic weight of lead is not fixed in nature, but varies according to the age of the rock or mineral and the proportion of uranium and thorium to lead.

A consideration of radioactive age calculations leads to the same assessment of Steiner's statement. The issue is not whether the ages are "correct", but that there is a well established correspondence between radioactive ages and relative chronologies based on field criteria, such a superposition of strata, fossils and cross-cutting relations. Rocks judged to be "old" on the basis of field criteria are always old from the perspective of radioactive ages. The significance of this correspondence will be clear from the age calculation equation (9):

$$t = \frac{1}{\lambda} \ln\left[\frac{D - D_o}{N} + 1 \right]$$

This shows that differences in radioactive ages arise from differences in $\frac{D - Do}{N}$ ratios.

In the absence of radioactive decay, this ratio cannot change, so that rocks and minerals formed at a time when radioactive decay was absent would have uniform radioactive ages with a maximum value reflecting the time when radioactivity started. If we adopt Wachsmuth's estimate for the onset of radioactivity, this would mean that rocks and minerals could not yield radioactive ages greater than 15,000 years before present. This is so clearly contradicted by what is observed that we can conclude that Wachsmuth was not correct on this point.

Conclusions

Although the statement about radioactivity attributed to Steiner during the lecture course of 1905 does not appear to be a fruitful line of thought for geology, it is to him we must turn if we are to get a glimpse of the spiritual realities that may underlie radioactivity. In 1911 Steiner gave six lectures in Berlin that deepened the descriptions given in *Occult Science* of the stages in the Earth's planetary development. In the lecture of October 31, Steiner described that when the Old Saturn stage was inaugurated neither space nor time existed for the Earth, and could be imagined through the presence of the Spirits of Will or Thrones existing in a "sea" of flowing courage and energy. When other members of the Hierarchies appeared, a special relationship led the Spirits of Will to make a sacrifice to the Cherubim out of which time was born and made manifest - not as an abstract concept - but as the Spirits of Personality or Archai. Steiner continued:

> "… it is only possible now, when time is born, that something else appears - something that makes it possible for us to speak of the Saturn condition as having anything in the least similar to our environment. What we call the element of heat in Saturn is as it were the sacrificial smoke of the Thrones giving birth to time. Hence I have always said, in describing the condition, that it was one of heat. Of all the elements we have around us now, the only one we can speak of as being on ancient Saturn is heat."

In these descriptions, Steiner indicated that a deep connection between sacrifice, heat and time was established in old Saturn times among the Spiritual Hierarchies. Because he envisaged that at each stage in the Earth's planetary development there is a recapitulation of the previous stages, we may understand that this deep connection was re-established at the beginning of the present Earth stage during the recapitulation of old Saturn.

But, this association between sacrifice, heat and time established among the Spiritual Hierarchies on old Saturn is the same association that arises from the modern scientific understanding of radioactivity, with the crucial difference that the modern understanding is entirely materialistic. The only hint that spiritual realms lie behind radioactivity appears in its intimate connection with life - a connection that remains without significance to modern science because of science's materialistic view of life.

If it is correct to understand that behind radioactivity there lie the deeds of the Spiritual Hierarchies on old Saturn, then we can take this to mean that the recapitulation of old Saturn at the beginning of the present stage of the Earth would have established the basis for radioactivity at the point of the material origin of the present Earth. Thus, the scientific view of radioactivity as an original property of the Earth lies much closer to Steiner's descriptions of Earth evolution, than the view that radioactivity is only a few thousand years old.

This line of thought reverses previously expressed anthroposophical views about radioactivity. Radioactivity is not an indication of the Earth's old age, but is the material expression of the deeds of the Spiritual Hierarchies that were re-enacted at the beginning of the present stage of Earth development. Radioactivity did not appear late in the Earth's history but is an original property of the Earth that was more intense in the early Earth than it is today.[28] The death of the Earth will be dissipation of the Earth's heat body arising from the exhaustion of radioactivity. The scientific view, in the light of Steiner's descriptions, places radioactivity within the creative processes active in the Earth, whereas the view arising from a literal interpretation of the statement attributed to Steiner in 1905 makes no connection between radioactivity and life, only with death.

Acknowledgements

Georg Maier assisted in the presentation of this workshop at the conference Geologie und Anthroposophie in Gespräch, and was a source of insight and sympathetic understanding without which the workshop and the subsequent development of this article would have been diminished. He will be able to identify the parts of this article that reflect his influence, as will the workshop participants[29] who offered many and varied comments. To all, in their different ways, I offer my warm thanks. Karl Setter graciously gave copyright permission to include Figure 2 in this article. If there are errors or misunderstandings in what I have written, I reserve for myself the deserved opprobrium.

References

1 Exceptions to this generalization arise from the presence of rare minerals whose crystallization has led to unusual concentrations of radioactive nuclides

2 Nuclide is an alternative term for atom. The conventional way of defining a nuclide is to specify both its atomic mass and the element to which it belongs, i. e., ^{238}U.

3 Stable nuclides of low atomic mass contain approximately equal numbers of neutron and protons in the atomic nuclei: the proportion gradually changes to 3:1 in stable nuclides of high atomic mass.

4 Half life is a measure of the rate of radioactive decay, and is defined as the time required for a number of radioactive atoms to decay to half the original number.

5 Cosmic rays consist of protons and alpha-particles, with small numbers of heavier atomic nuclei and electrons.

6 ^{10}Be occurs in lavas for which there is independent evidence for the presence of sediment in the mantle source region of the lavas.

7 Carbonaceous chondrites. The anomalous presence of the decay product of ^{26}Al (^{26}Mg) in plagioclase feldspar ($CaAl_2Si_2O_8$) from several carbonaceous chondrites is evidence that such meteorites originally contained ^{26}Al.

8 For example "We know that the naturally radioactive elements are all in a group with the highest atomic weight. This fact, seen together with the characteristics of radioactivity, tells us that in such elements gravity has so far got the upper hand of levity that the physical substance is unable to persist as a spatially extended, coherent unit. It therefore falls asunder, with the liberated levity drawn into the process of dispersion. Seen thus, radioactivity becomes a symptom of the earth's old age." See, Lehrs, E., 1951. *Man or Matter*. London, Faber & Faber, p.229:

9 The same is true for oceanic crust, but to a lesser extent than for continental crust.

10 The estimates for the mantle come from Floyd, P.A. (ed.), 1991. Oceanic Basalts. New York, Van Nostrand Reinhold, Appendix D (primitive mantle). For continental crust the estimates come from Rudnick, R. L. and Fountain, D. M. 1995. Nature and composition of the continental crust: a lower crustal perspective. Reviews of Geophysics, 33(3):267-309.

11 Setter, K.O., 1994. The lesson of Archaebacteria. In, Bengston, S., Early Life on Earth: Nobel Symposium No. 84. New York, Columbia University Press, p.143-151.

12 In the case of those living on the sea floor, the metabolic processes are mediated by sulfur rather than carbon.

13 One way of representing the balance between heat production and heat loss is to see heat production as a function of planetary mass or volume, and heat loss as a function of planetary surface area. Because volume is proportional to the cube of the radius of a spherical object, and surface area is proportional to the square of the radius, the volume increases at a faster rate than the surface area for spherical objects of increasing size. This means that heat loss dominates the balance in smaller planetary objects.

14 We face this problem in Dr. Steiner's work: should we read Anthroposophy on the assumption that its content would remain unchanged if Steiner was alive today? Should we make the assumption that a proper understanding of Anthroposophy requires that we also understand its late 19th and early 20th century context?

15 Perhaps the anthroposophic custom of studying Steiner's texts as a means of understanding the Earth's history preserves the text-based knowledge that was abandoned by 19th geologists in favor of an understanding based on observations on rocks and present-day rock forming processes, as Lyell advocated.

16This section follows the treatment of this topic in Faure, G., 1986. Principles of Isotope Geology (2nd edition). New York, John Wiley & Sons.

17 Steiner, R., Foundations of Esotericism (GA 93a), lecture of October 5, 1905, Translated by V. and J Compton-Burnett. London, Rudolf Steiner Press, 1984.

18 Lehrs, E., 1951. Man or Matter. London, Faber & Faber, p.229.

19 For example, Steiner's discussion of the sunken continents and Lemuria and Atlantis repeats concepts familiar to Theosophists from Theosophical sources.

20 It would be great interest, for example, to compare the exact language in the two

sets of notes used to attribute this statement about the onset of radioactivity to Steiner.

21 See Bosse, D., 1994. How old is the Earth? Journal of Anthroposophic Medicine, v.11, no.1, p.53-67, and references therein.

22 Note that the exponential property of radioactive decay is already accommodated in the age equation (9), because of the expression

$$\ln \left[\frac{D - Do}{N} \right]$$

in the age calculation. The logarithmic scaling of radioactive ages thus applies a second logarithmic transformation to the measured quantities, a step not discussed by anthroposophic writers advocating a logarithmic representation of radioactive ages.

23 This record, in some ways, is similar to the Stratigraphic Column for sedimentary strata.

24 Because uranium, but not thorium, can be accommodated in the crystal lattice of calcium carbonate, the re-establishment of the equilibrium concentration of ^{230}Th within the long decay series from ^{238}U to ^{206}Pb can be used in the calculation of past time. The measure of this equilibrium is the ratio $^{230}Th/^{234}U$, where ^{234}U, the immediate parent of ^{230}Th, is also an intermediate nuclide in the decay series of ^{238}U.

25 Smith, D.E. and others, 1990. Tectonic motion and deformation from satellite laser ranging to LAGEOS. Journal of Geophysical Research, v.95, p.22,013-22,045.

26 Heirtzler, J.R. and others, 1968. Marine magnetic anomalies, geomagnetic field reversals, and motions of the ocean floor and continents. Journal of Geophysical Research, v.73, p.2,119-2,136.

27 Russell, R.D. and Farquhar, R.M., 1960. Lead Isotopes in Geology. New York, Wiley Interscience.

28 This statement follows from the loss of radioactive elements by decay through time, where the magnitude of the losses reflects the nuclide half lives. This leads to the conclusion that radioactivity and radioactive heat production were more intense in the early Earth than they are today, so that the heat body of the early Earth would not only have been more vigorous but also closer to the state of old Saturn.

29 Workshop participants: Engbert Brower, Jörn Heinlein, Georg Iliev, Michael Jacobi, Ernst-August Müller, Norbert Pfennig, Sune Nordwell, Meinhard Simon and Wim Sinoo.

Department of Geology,
Lawrence University,
Appleton, WI 54912,
USA
Email: grantn@lawrence.edu

Steiner's description of the Earth's history

Norman Grant

Introduction

Why has the anthroposophical approach to geology not achieved the prominence and influence of anthroposophical work in education, curative care for children with developmental difficulties, eurythmy, medicine, agriculture and projective geometry - to name just a few examples?

The superficial answer is very obvious, because nearly every concept important to Steiner's view of the history of the Earth has been discarded by modern geology. By this I mean, Steiner's history of the Earth included concepts that were prominent in late 19th century science but which have now been discarded by modern geology and replaced by newer ones, either because they provide a more comprehensive explanation of what is known about the Earth, or because the discarded concepts are now considered to be wrong. Among the discarded concepts we may note the sunken continents of Lemuria and Atlantis, the tetrahedral structure of the Earth, the view that organic evolution was purposeful - with humans being first rather than last in the development of life, the departure of the Moon from the Earth late in the Earth's history, and the very late appearance of the present-day physical and mineral constitution of the Earth.

In consequence, a great division has opened up between Anthroposophy and modern geology, so that it is not easy for geologists to respond to Peter Heusser's call for a bridge to be built between modern science and Anthroposophy. He advocated this as a major research task for the Medical Section of the School of Spiritual Science,[1] but I take his words as also defining a major research task for all scientists.

Sources of Steiner's Descriptions

One approach to understanding how the division has come about is through a consideration of the sources of Steiner's descriptions of the history of the Earth. Anthroposophists rarely, if ever, raise this issue, taking Steiner at his word that the descriptions are entirely the result of his spiritual research on the Akashic Record. With the exception of Goethe, Steiner did not often acknowledge the influence of other people on his work, and he was adamant in the last years of his life that Theosophy provided nothing for Anthroposophy. In his autobiography he wrote that:

> *It was from what was thus given* [from spiritual research], *and not from anything borrowed from the Theosophical Movement, that the Anthroposophical Movement had its growth. If I gave my attention to the teachings carried on in the* [Theosophical] *Society when I composed my own writings on spiritual knowledge, it was only for the purpose of correcting by a contrasting statement one thing or another in those teachings which I considered erroneous.*[2]

It is not difficult to think of reasons why Steiner wished to distance Anthroposophy from Theosophy towards the end of his life, particularly after the refounding of the Anthroposophical Society in 1924. But Steiner's insistence that Anthroposophy was based only on the results of his spiritual research inclines us to think of him as a figure who created Anthroposophy entirely without influence from the political, social, scientific and spiritual cultures of the times in which he lived. If we follow this line of thought, it is only a small further step to think of Steiner as a figure who stood outside history, a step that carries the potential for Anthroposophy to become an insular movement, where insularity - among other consequences - can become an obstacle to efforts to create bridges between Anthroposophy and modern science.

I suggest the building of bridges requires that we take a very different view of Steiner, and think of him as an fully historic individual who lived intensely within the political, social, scientific and spiritual cultures of his times. If we accept this, then the task for us who are interested in building bridges between Anthroposophy and science becomes one where we must work, from a knowledge of Steiner's life and times, to mutually influence Anthroposophy and science out of our participation in the political, social, scientific and spiritual cultures of the times in which we live.

Steiner's Historic Moment

Christopher Bamford, in his introduction to the six lectures on *Occult Science, Theosophy, and the Catholic Faith* given by C.G. Harrison in 1893 that Steiner knew well,[3] wrote that:

> *Everyone, even an "initiate", incarnates in a specific time and culture, so that no matter how deep the love and wisdom they are able to infuse into their historic moment, they are nevertheless inevitably of that moment and thus express its contingent strengths and weakness to a greater or lesser extent.*[4]

Bamford's point leads to the question: in what ways does Steiner's account of the Earth's history reflect the contingent strengths and weakness of his historic moment?

Steiner's first account of the history of the Earth, one that reappeared more or less unchanged in later publications and lectures, was published in 1904 as a series of articles in the magazine *Lucifer Gnosis*[5] less than two years after he became chairman of the German Section of the Theosophical Society. These articles were republished as a book with the English title *Cosmic Memory: Prehistory of Earth and Man*, and will be referred subsequently in this article as *Cosmic Memory*. The historic moment of this account was the early years of the 20th century, when Steiner's audiences were members of the Theosophical Society. Steiner solved the problem of being understood by this audience *"by mostly using the old* [Theosophic] *terminology during the first years"* according to Günther Wachsmuth.[6,7]

But, Steiner's 1904 account of the history of the Earth contains much more than Theosophic terminology, because it follows the essentials of the cosmology described by Helena Blavatsky (1831-1891)[8] in the fundamental Theosophic book, *The Secret*

The Seven-fold Nature of Man

Blavatsky (1888)	Steiner (1904)
Body or *Rupa*	Physical body
Vitality or *Prana*-Jiv	Etheric body
Astral body or *Linga-Sarira*	Astral body
Animal soul or *Kama-Rupa*	I
Human soul or *Manas*	Spirit-self (Manas)
Spiritual soul or *Buddhi*	Life-spirit (Buddhi)
Spirit or *Atma*	Spirit-man (Atma)

Doctrine published in 1888. To anthroposophists who know *Cosmic Memory* or *Occult Science* by Steiner, a description of the seven planetary stages of cosmic evolution through which the Earth evolved to progressively draw spirit down into matter will be entirely familiar. The same is true for the view that the present Earth is the fourth and most material of these stages, and that it was preceded by a Moon stage, and will be followed by three future stages through which matter will become spiritualized. But, I have not taken this from *Cosmic Memory* or *Occult Science*, but from *The Secret Doctrine*. Furthermore, *The Secret Doctrine* describes the evolution of human beings through the progressive materialization of the human form through seven root races, of which the second, third and fourth were associated with the Hyperborean, Lemurian and Atlantean continents. Human sexuality is described as arising in Lemurian times out of an earlier state in which the male and female principles were combined, and the Atlantean inundation followed the division of Atlanteans into the righteous and the unrighteous. In *The Secret Doctrine* and other Theosophic works there are descriptions of reincarnation, the Akashic Record, karma and seven-fold nature of human beings, all of which appeared in Steiner's writings only after he became chairman of the German Theosophical Society.

This congruence between the cosmologies of Blavatsky and Steiner is recognized in scholarly circles outside Anthroposophy,[9] and leads to vital questions of how the similarities should be understood by anthroposophists. For example, can the two cosmologies be considered to be wholly independent of each other on the grounds that Steiner had no knowledge of *The Secret Doctrine* at the time he wrote *Cosmic Memory*? While this position is sympathetic to what Steiner wrote in his autobiography, it cannot be supported because in a letter of August 20, 1902, to Marie von Sievers, he thanked her for the gift of *The Secret Doctrine* by writing:

> *The Secret Doctrine has duly arrived and lies on my desk: it is very useful in my relevant studies, and I consult it continually.*[10]

Thus, in the period immediately prior to the 1904 publication in *Lucifer Gnosis* of the articles later collected under the title of *Cosmic Memory,* we know that *The Secret*

Doctrine was a prominent element in Steiner's work.

It is not possible, either, to claim that Steiner wished in later life to withdraw certain pieces of work that were completed in the early years of his Chairmanship of the German Branch of the Theosophical Society, because he reiterated many of the key concepts of his 1904 cosmology in 1924.[11]

Another view is that the congruence between Blavatsky's and Steiner's cosmologies is the result of independent occult observations of the same parts of the Akashic Record, in effect, asserting that Steiner confirmed Blavatsky's cosmology. Anthroposophists inclined towards this view need to seriously consider the dangers it carries for the anthroposophic movement, because Blavatsky's critics have demonstrated extensive plagiarism in her writing, charged her with fraud in some psychic phenomena, and questioned the veracity of her claims that she received her occult knowledge from Masters who lived in Tibet.[12] It would seem very unwise without knowledge of the details of these charges to assert that Steiner verified many of Blavatsky's occult descriptions, because it would draw Anthrosposophy into the murky issues that brought Theosophy into disrepute, and because it would revive the associations between the two that Steiner struggled in his later years to deny, even though - in his autobiography - he retained a belief in Blavatsky's spiritual powers.[13]

Although Steiner excluded Theosophic terminology from his later work, and ultimately denied any connection between Theosophy and Anthroposophy, we have inherited his description of the history of the Earth from the years when Steiner worked vigorously to establish himself with Theosophical audiences, when the Theosophic influence on his conceptions was strongest. Anthroposophic knowledge of the Earth's history comes, therefore, from the earliest years of Steiner's development within the Theosophical Society, and not from the very different period from 1914 onwards, after Steiner severed his ties with the Theosophical movement and formally began the Anthroposophical Society. It was in this latter period that the many successful anthroposophic initiatives noted at the outset of this article were begun. If this is a correct view of the circumstances under which Steiner wrote his cosmological account in *Cosmic Memory,* then it is not unreasonable to conclude that in the immediate years following 1902 Steiner made use of Theosophic concepts in formulating what later came to be called Anthroposophy. This means that the originality in Steiner's cosmology lies not in the details, but in the extraordinary range and integration of its conceptions, so that there should be nothing, in principle, to lead anthroposphists to object to the view that Anthroposophy is not only a testimony to Steiner's original vision but also to his capacity to synthesize important concepts from the political, social, scientific and spiritual cultures of the times in which he lived.

Lemuria and Atlantis

To illustrate this conclusion, let us return again to *Cosmic Memory* to consider some of the language Steiner employed in his cosmological account. For example, Steiner wrote in connection with Lemuria that:

While all possible care has been taken in the deciphering of the Akashic Chronicle it must be emphasized that nowhere is a dogmatic character claimed for these communications. If, to begin with, the reading of things and events so remote from the present is not easy, the translation of what has been seen and deciphered into the language of today presents almost insuperable obstacles.[14]

When Steiner refers to *"the language of today"* he means the language of the early 1900s from which we are now separated by more than 90 years. Language always carries within it the particular beliefs, meanings and understandings that belong to the Zeitgeist of a particular time. One measure of the many and profound differences between Steiner's historic moment and ours is the question of sunken continents, for in the late 19th century there was widespread scientific and public acceptance that the oceans were underlain by sunken continents. Moreover, the scientific basis for this belief was correctly described by Steiner in *Cosmic Memory* in terms of distribution of living and fossil forms of life among the different continents and islands. This belief in sunken continents was so strong that the British prime minister Gladstone attempted to persuade his cabinet to launch an expedition in the 1880s to find Atlantis. Yet, we must remember that these speculations about sunken continents occurred at a time when almost nothing was known about the ocean floor. The first major oceanographic study, the British Challenger Expedition of 1872-76, measured water depths with weighted lines made of piano wire some 3-4 km long, and recovered samples of ocean floor sediment with buckets tied to the end of long ropes. In three and half years, the Challenger made 300 determinations of water depths in the world's oceans. Fifty years later, the belief in sunken continents was strong enough to defeat Alfred Wegener's attempt to convince geologists of the reality of continental drift. Geologists in the 1920s could only conceive of an Earth in which vertical movements led to the rise and fall of continents, but not the horizontal movements that Wegener proposed. It will be clear from this that the references in Steiner's cosmology to Lemuria and Atlantis would not have been at odds with the beliefs held about the Earth by, scientific, esoteric and well-read public circles in 1904.

A second elaboration of the circumstances under which Steiner wrote his cosmology can be illustrated by the origin and conceptual development of the sunken continent of Lemuria. Unlike the concept of Atlantis which goes back to Plato, Lemuria has much more recent origins. In *Cosmic Memory* Steiner wrote:

We are concerned with the third human root race, of which it is said in theosophical books that it inhabited the Lemurian Continent. According to these books this continent was situated south of Asia and extended approximately from Ceylon to Madagascar.[15]

Apart from the location of Lemuria, this statement is important in that Steiner cited "*theosophical books*" as the authority for his descriptions of Lemuria. This means that we are justified in turning to Helena Blavatsky's account of Lemuria to elaborate what Steiner wrote. In *The Theosophical Glossary* published after her death, she wrote that Lemuria is:

A modern term first used by some naturalists, and now adopted by Theosophists, to indicate a continent that, according to the Secret Doctrine of the East, preceded Atlantis. Its

Eastern name would not reveal much to European ears.[16]

The Secret Doctrine provides more information:

> *The third continent we propose to call Lemuria. The name is an invention of Mr. P.L. Sclater, who asserted, between 1850 and 1860, on zoological grounds the actual existence, in prehistoric times, of a Continent which he showed to have extended from Madagascar to Ceylon and Sumatra. It included some portions of what is now Africa; but otherwise this gigantic Continent, which stretched from the Indian Ocean to Australia, has now wholly disappeared beneath the waters of the Pacific, leaving here and there only some of its highland tops which are now islands*.[17]

Helena Blavatsky's assertion in *The Secret Doctrine* that Lemuria is a mid-19th century scientific invention due to a Mr. P.L. Sclater, is confirmed by an article published by Sclater in 1864. In this he concluded that:

> *... the Mammal-fauna of Madagascar can be best explained by supposing that, anterior to the existence of Africa in its present shape, a large continent occupied parts of the Atlantic and Indian Ocean stretching out towards (what is now) America on the west, and India and its islands on the east; that this continent was broken up into islands, of which some became amalgamated with the present continent of Africa, and some possibly with what is now Asia - and that in Madagascar and the Mascarene Islands we have existing relics of this great continent, for which ... I should propose the name Lemuria!*[18]

While it might be concluded that these quotations only illustrate the origin of the name Lemuria in 1864, it is also possible that they demonstrate the birth of the concept of Lemuria as a now long-abandoned scientific speculation that became clothed in esoteric language when preserved in Theosophy and later in Anthroposophy. If no evidence, from sources prior to 1850 to avoid possible western and Theosophic influences on eastern traditions, can be found to support Helena Blavatsky's statement that Lemuria was known in eastern occult traditions under another name, then the possibility that Steiner transferred the now long-abandoned scientific invention of Lemuria into his cosmology from Theosophic doctrines must surely be taken seriously.

The presumption that Steiner followed the outlines of Theosophic cosmology releases him from the restrictive view that his work was not influenced by the political, social, scientific and spiritual cultures of the times in which he lived, and identifies him as a key figure who lived fully within the great esoteric, cultural and religious stream that began in Europe at the end of the 15th century with the translation of the Hermetic documents by Marsilio Ficini. From this point of view Steiner becomes a person whose work reflects both his intense experience of the Zeitgeist of his historic moment, and also the spiritual insights that he contributed to Anthroposophy.

It will now be clear why the great division has opened up between Anthroposophy and modern geology, because Steiner's cosmology preserves much of the Theosophic account of the history of Earth whose authenticity - as has been previously noted - has been severely undermined by Helena Blavatsky's critics.[19] To the extent that Anthroposophy functions as a museum dedicated to the preservation of Steiner's lec-

tures and writings, then Anthroposophy will lay itself open to the same criticisms that have undermined the authority of the fundamental Theosophic books.

A Question for the late 20th Century

A simple question can clarify the ways in which a reader might respond to these conclusions. How do we think Steiner would have described the history of the Earth if he had been born in 1951 and reached the full expression of his powers in 1990, if we accept that he would have been as well informed of the science of the late 20th century as he was of the science in the late 19th and early 20th centuries?

One answer is that Steiner would have responded with a cosmology what was consistent with our knowledge of the Earth at the end of the 20th century, as he did in *Cosmic Memory* for the science of his historic moment in the late 19th and early 20th centuries. The other answer is that he would have ignored contemporary understanding of the Earth in the 1990s and returned to the late 19th century as the source of his descriptions of the Earth's history.

If the second answer is favored, on the grounds that it is unthinkable that Anthroposophy could be defined in concepts and imagery that are different from those which Steiner actually chose, then it becomes necessary to understand why Steiner would have preferred the late 19th century scientific understanding of the Earth over that of the late 20th century. Would he have rejected late 20th century Earth science, but have incorporated the other sciences such as physics, chemistry and biology into his world view? Or would he have rejected the entire range of late 20th century sciences? Such considerations show that the second answer leads into a *cul de sac* of implausibilities. The second answer is also not likely to lead to bridges between modern science and Anthroposophy nor diminish the conflicts between the two, unless anthroposophists begin to consider the implications of Steiner's active and vital participation in the scientific, cultural, political and esoteric streams of the times in which he lived, and that Anthroposophy in part represents a synthesis of what he drew from his intense experience of these streams. In this case, anthroposophic understanding and scholarly work could play an important role in shaping the future assessments of Steiner that come from outside the anthroposophical movement.

If the first answer is favored, then the future of Anthroposophy lies not in the necessity to defend the literal or absolute nature of Steiner's descriptions of the Earth, but in the need to uncover the underlying meaning that he expressed in the language of his day ninety years ago, and to re-express it in the language of our day. From this point of view, Lemuria is not a fixed and literal object that we somehow have to fit into the Earth's history, but is the way Steiner chose to express a vital aspect of human evolution to Theosophical audiences.

Owen Barfield in his debate in the 1920s with C.S. Lewis clearly grasped the implications of the second answer, although he was not thinking of Lemuria or Atlantis when he wrote that words *"perpetually tend to lose their meaning"*.[20] But, this is an

apt description of what has happened to the concepts of Lemuria and Atlantis, and other aspects of Steiner's cosmology, over the past ninety years. As geologists working with Steiner's cosmology, I think we need to share Barfield's conviction:

> *... that truth lies not in "facts" that once discovered remain as certainties, but in a continuous reaching into* [the] *unknown or* [a] *re-consideration of experience*.[21]

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3 Bamford expresses the view that the ten lectures given by Steiner in 1915 and collected under the title *The Occult Movement of the Nineteenth Century*, London, Rudolf Steiner Press, 1973, amount to Steiner's commentary on the *Transcendental Universe*. See Bamford, C., 1993. Introduction to *The Transcendental Universe* by C.G. Harrison, Hudson, New York, Lindisfarne Press, p.18.

4 Bamford, C., op. cit., p.11-12.

5The English translation of these articles was published in 1959 under the title *Cosmic Memory: Prehistory of Earth and Man* (translated by K.E. Zimmer): Steinerbooks, Blauvelt, New York.

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7 Steiner's recollected these early years in his autobiography, as follows: "My first work of lecturing within the circles which grew out of the Theosophical Movement had to be planned according to the temper of the mind of the groups. Theosophical literature had been read there, and people were used to certain forms of expression. I had to retain these if I wished to be understood". See Steiner, R., 1928, op. cit., p.313.

8 Helena Blavatsky formed the Theosophical Society with others including Henry S. Olcott (1832-1907) and William Q. Judge (1851-96) in New York in 1875.

9 For example, see: Galbreath, R.C., 1970. *Spiritual Science in an Age of Materialism*. Unpublished dissertation, University of Michigan.

10 Letter from Rudolf Steiner to Marie von Sievers, August 20, 1902. *Correspondence and Documents, 1901-1925*. Anthroposophic Press, 1988, p.24.

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13 In his autobiography, Steiner wrote that Helena Blavatsky was "... a human per-

sonality in whom, by reason of a remarkable atavism, the spiritual worked as it had once worked in the leaders of the mysteries, in a state of consciousness which - in contrast with the modern state of consciousness - was dreamlike in character." See Steiner, R., 1928, op.cit. p.308.

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21 Adey, 1978, op. cit., p.122.

Dr Norman Grant
Department of Geology
Lawrence University
Appleton,

WI 54911,

USA

Email:grantn@lawrence.edu

Editor:
Dr David J Heaf
Hafan, Cae Llwyd, Llanystumdwy, Cricieth, Gwynedd, LL52 0SG, UK
Telephone/Fax: 01766 523181 Email: 101622.2773@Compuserve.Com

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