Thinking of deep time

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ABSTRACT: Geological time is one of the most difficult concepts to comprehend, and its measurement is expressed both in relative and numerical terms. The modern geological time scale constitutes a framework for historical geology, and provides numerical ages in two forms. One is date; the other is duration. Most geoscientists use distinctive abbreviations (commonly 'Ma' and 'Myr') to specify date and duration, but some geochemists do not, using 'Ma' (mega-annus) interchangeably and are pressuring journals to follow suit. In an attempt to determine the usefulness of distinct symbols, the concept of geological time and its different expressions is reviewed, and the methodology used to determine numerical ages of crucial datum levels in chronostratigraphy is discussed. Despite the important place given to dates, geological time scales are foremost about duration of intervals between dates, from which the age of key datum points are deduced. Durations are quantities, and it may someday be suitable to express them in terms of a non-SI unit. Dates, on the other hand, are merely geological instants, not quantities, and are not concerned with the SI.

INTRODUCTION

Earth Science is concerned with geological time, the double facetted concept that renders geology a sister-science of astrophysics. The two disciplines overlap in their interest in the solar system while astrophysics alone addresses the ultimate question of cosmic time. One facet of geological time deals with the unfolding of Earth (and planetary) history, in its multiple aspects, including the chronicle of continents, oceans, climates, and, of prime significance to us, life. The other facet is the recovery of time itself, the elusive concept that is only available to us through the material evidence of its passage, in the outer shell of our planet. While the expression "deep time" McPhee (1981) is appropriate for the concept generally thought to have arisen during the Scottish enlightenment (Hutton 1795), but which has roots as far back as the 11th century with such philosophers as the Islamic scholar Ibn Sina, also known as Avicenna (Al Rawi 2002) and his Chinese contemporary Sen Kuo (Nathan 1995). It was, however, in Western Europe that the systematic study of rock successions as markers of time took hold, starting with the seminal works of Lyell (1830-33) and d'Orbigny (1850). In the brief time since geologists began to think of the age of the Earth as reckoned not in centuries but in tens to hundreds of million years—Lyell (1830), for example, reasoned from molluscan evidence that 240 million years had elapsed since the Ordovician—considerable progress has been made in extracting ages and durations from the stratigraphic record. Today the Earth is comfortably dated at ~4.54 billion years (Dalrymple 2001, 2004) and uncertainty in chronologic resolution for most of geological history has been reduced to a few thousand years.

Progress in measuring geological time has been incremental, with advances at different times in different geological disciplines, resulting in parallel developments of overlapping, often irreconcilable concepts, and leading to miscommunication and misunderstood terminology. One area of significant misunderstanding concerns the terminology used to denote various expressions of geological time, as exemplified by editorial inconsistencies in major research journals. This paper attempts to reconcile some of these contentious concepts, as background to recommendations for a logical and consistent terminology for describing geological time (Aubry et al., this volume).

MEASURING TIME

Of the four dimensions with which Earth scientists frame Earth history, time is the most difficult to comprehend. We lack intuition with regard to the immensity of geological time—how is it possible to actually imagine what 1million years represent, let alone 4 billion? As Gould wrote (1987, p. 3), "An abstract, intellectual understanding of deep time comes easily enough—I know how many zeroes to place after the 10 when I mean billions. Getting it into the gut is quite another matter. Deep time is so alien that we can only comprehend it as a metaphor". The mountain building cycle, as strata are gradually deposited and then raised into massive peaks, only to slowly wear away over the eons until they are below the sea again—as told in Hutton's unconformity at Siccar Point—is possibly the only means to grasp a time span of such magnitude. In itself, however, there is nothing in an unconformity, or any other feature of the rocks, that gives us, *a-priori* an intuitive sense of duration. It may therefore be useful to review briefly our human experience of time as a primer to characterizing geological time.

Our everyday experience is informative as to the nature of time, which comprises two components: dates and durations. It also shows that time can be measured in two fundamentally different ways. A relative method consists in discriminating successive intervals of time according to natural or assigned components that occur in sequential and recognizable order (e.g., Spring-Summer-Autumn-Winter; Dark Ages-Middle Ages-Renaissance; Classicism-Impressionism-Fauvism-Cubism), or in pre- or post-relation to a unique event (e.g., the Fall of Rome; or a given war).

A quantitative, "absolute", measurement of intervals of time is also required to synchronize the complex web of interactions in developed societies, as well as to accurately measure time dependent activities. Various methods (standing stones, obelisks, sundials) were contrived in early civilizations to count the phases of astronomical cycles *regardless* of duration in order to recognize specific moments (e.g., solstice, lunar months, approximate rhythms of the day). The first semi-quantitative methods were probably developed in ancient Egypt (Curry, 1990; Richard, 1998; Lippincott et al., 1999) where the clepsydra, or water clock, divided the day into 24 hours of equal duration. The invention of the pendulum-regulated escapement by Huygens (1656) led to the development of reliable, and soon portable spring-powered clocks and watches which were vital to the industrial revolution. While the piezoelectric properties of quartz crystals were first discovered by Jacques and Pierre Curie in 1880, the first quartz clock was not constructed until 1927 (Marrison and Horton 1928) and the quartz wristwatch, now in almost universal use, first appeared in the 1930s (Astron 1969; http://www.ieee.org/web/aboutus/history_center/seiko.html). The microsecond range was reached with atomic beam magnetic resonance (Rabi et al. 1939) and nanoseconds are now counted by atomic clocks (see review in Sullivan 2001).

If passing time is difficult to measure accurately without sophisticated instruments, then it might be expected that passed time is even more difficult to apprehend. To wit, it took 126 years from the enunciation of the fundamental trio of stratigraphic principles by Steno (1669) to the discovery of "deep time" by Hutton, 38 years more to the first division of the sedimentary record of the European Tertiary into temporal units (Lyell, 1833), another 143 years for the international geological community to endorse a *guide* to stratigraphy (Hedberg 1976). It took 139 years to first give numerical dates to Lyell's early divisions of time (Berggren 1972), another 10 years to construct the first integrated time scales (Lowrie et al. 1982; Berggren et al. 1985a), and 20 more years to achieve a relatively stable astronomically derived Neogene time scale (Lourens et al. 2004). In sum, more than 200 years elapsed between the first understanding of what we are looking at when we see strata, to reliably measure the extent and duration of time involved since their formation. Technological developments have been crucial, but their application had to follow key conceptual shifts, with the most significant being the recognition that the history of the magnetic field (Heirtzler et al., 1968) and astronomical time (Hays et al., 1976) could be imposed on the stratigraphic record for independent determination of the age of specific stratigraphic horizons.

Relative time in Earth Sciences

Clepsydras are no longer in use, and sundials and obelisks now occupy a decorative role, but the passage of time is still evaluated in relative terms, even though the means of knowing every single moment of it now exist. Although the dates of occurrence of many historical events are known with precision, it remains useful to express time in relative terms (see above) in order to communicate concepts and knowledge. If all we knew of human history were the numerical date of each event, we would have nothing but a list of disconnected facts. The same is true for Earth history. Even though we now have the means, in theory, to numerically date every stratigraphic horizon, relative time conveys information that numbers do not. The Cretaceous/Paleogene boundary is tied to a time of ~66 million years ago, but that number in itself does not resonate like the description of what happened then. Likewise, the term Eocene carries a meaning that is far more meaningful than when we simply cite the interval between ~55.8 and ~33.9 million years ago.

Different relative measures of time are available. Several concern specialty fields, for instance biostratigraphy, leading to biochronology (from biozones to biochrons), magnetostratigraphy, leading to magnetochronology (from magnetozones to magnetochrons), isotope stratigraphy (with isotopic stages and ages). Appropriate terminology in these different fields is discussed in other papers of this volume.

Universal relative time in geology is expressed by chronostratigraphy, a science in itself, founded on clear principles (Hedberg 1976; Salvador 1984) and more recently regulated and codified (Remane et al. 1996). Its fundamental concept is the spatial (geometric) relationships between rock units following the principle of superposition (see Aubry 2007). Not by right, but by educated consensus (Hedberg 1976), the *stage* is the basic unit in the superpositional hierarchy. Its definition establishes that of the derived series, which in turn defines the limit of system, and so on to erathem and eonothem. Stages are the only units defined in the rocks by bounding horizons, in which physical boundary points in stratotype sections, originally called "golden spikes", have morphed into the Global Standard Stratotype-section and Point or GSSP (Cowie 1986). A boundary horizon corresponds to a geological moment—the moment when the horizon was deposited. The interval between two successive physical boundaries is thus the embodiment of an inferred interval of time, or "age" (see discussion in Aubry, 2007). In a hierarchy that parallels that of the stage to eonothem, the corresponding ages, epochs, periods, eras and eons are defined, at base, by the corresponding time horizons taken from the rocks.

Disconcertingly, the introduction of regulation (Remane et al. 1996) increasingly threatens chronostratigraphic hierarchy by ignoring stages in standard definitions (Aubry et al. 1999), in favor of an inverted top-down hierarchy based on *a-priori* definitions of higher ranked units, mainly as a convenience (McGowran et al. 2009). The consequences of abandoning the stratotype-based hierarchy (Hilgen et al. 2006; Aubry 2007; Gladenkov 2007) can be seen in the recent ratification by the IUGS (International Union of Geological Sciences) of a proposal to create a System/Period for the Quaternary with a self-defined boundary at 2.6 Ma that is related only to the concept of "first glacial climate"—a concept that has moved repeatedly as opinions have changed (Hilgen 2008). In so doing, the component Pleistocene Series/Epoch was expanded by 44% with no justification other than conforming to the imposed top -down hierarchy, and without regard for the stability of the many disciplines from paleontology and paleoanthropology to paleoceanography and paleoclimatology, in which Pleistocene is a key concept and Quaternary is hardly used (Van Couvering et al., in press)—an essentially political maneuver likened to a "land grab" (see Mascarelli 2009) with a potential for increased rather than resolved conflict.

But should boundary definitions take full precedence in chronostratigraphy? Common sense in everyday life tells us that what happens at 12 noon and 12 midnight is not as important as what happens in the time between. Certainly chronostratigraphic boundaries of rank higher than stage boundaries are associated with extraordinary events. Sometimes the cause of the event is abrupt, and its evidence is paramount in locating the boundary. In the bolide impact interpretation of the Cretaceous/Paleogene boundary, for example, what happened just at the moment the Cretaceous ended [the equivalent of midnight in our comparison] is obviously the essence of the boundary. But for most other boundaries, the transforming event is usually more prolonged, with its beginning to be found in older time and its final end at some younger point as well (e.g., Cao et al. [2008] for the Permian/Triassic boundary; Aubry and Bord [2009] for the Eocene/Oligocene boundary), such that the defining stage boundary may represent some element or interval of the event, that is hardly significant in itself.

The recent emphasis placed on chronostratigraphic boundaries of high rank (above stage) may be linked to the recognition that each is associated with a major change in the Earth system, as documented in the fossil record (Raup and Sepkoski 1982; see Aubry et al. 2009). The ICS has considered it essential to provide firm numerical age and correlation tools for such major chronostratigraphic boundaries *per se* creating a false impression that boundaries are dated in isolation from stage-stratotypes (which indicate durations), although in reality this is not the case.

Numerical time in Earth Sciences

Much of stratigraphy deals with the integration of various datasets that, through correlation of stratigraphic successions, leads to establishing relative temporal frameworks for geological reconstructions (see for instance McGowran 2005). These temporal frameworks (biomagneto chemostratigraphic and alike) are tied to chronostratigraphy. Yet, despite its essential role in Earth history, chronostratigraphy is lacking in one aspect: it is mute with regard to numerical time, without which the rates of geological processes cannot be known.

Numerical time is accessible in three principal ways. One is radio-isotopic chronology, based on decay of relatively unstable isotopes in geological and archeological materials. Isotopic chemistry measures radiometric quantities that are converted into durations, from which, in turn, a (averaged or estimated) geological age is determined. Radio-isotopic ages are often referred to as "absolute" ages despite the inherent uncertainty of measurement as well as differences in controls, calibration and exponential decay (Faure 2004; Dickin 2005). Different isotopes in different minerals may yield different ages for the same stratigraphic horizon, prompting stratigraphers to specify the nature of the radioisotopic age (e.g., a plateau age) and the nuclides involved (e.g., a ^{40}Ar/ ^{39}Ar age of X Ma, a ^{238}U/^{235}U age of Z Ma). Another methodology is astrochronology, which interprets Milankovich –derived cyclicity in sedimentary sections.

Astrochronology proceeds with the direct measurement of time in the stratigraphic record through the duration of orbital cycles. Most remarkable is the fact that astrochronology now *assists* the intercalibration of the ^{40}Ar/^{39}Ar system (Kuiper et al. 2008; Hilgen and Kuiper 2009). A third methodology obtains an indirect, if constrained, age by interpolation between horizons of known ages (e.g., Aubry 1995; Aubry and Van Couvering 2004). This is not a measured age, but an indirect/estimated age derived from the former. The advantage of the first two methodologies lies in their independence from sedimentation rates; whereas such rates are needed to adjust the values of indirect ages.

Datums in geological time

The objective of numerical methods is to determine the age of specific horizons. These may be chronostratigraphic boundaries, or the stratigraphic expression of widely correlatable features such as magnetic polarity reversals, isotopic signatures, and the FAD (first appearance datum) and LAD (last appearance datum) of biotic elements (Berggren and Van Couvering 1978).

The concept of geohistoric 'datum' may not be well understood in broader circles, as the following statement suggests: "There are really *no such things as 'datums in geological time'* except relative to time of measurement or some arbitrarily defined benchmark" (P. R. Renne, Paul de Bievre, Maro Bonardi, Igor M. Villa; written communication, 29 June 2009; emphasis added). The concept was defined for paleontological events, and it remains mostly used in this field (see McGowran 2005). To paraphrase Holland (1984, p. 149) in his description of a GSSP, a paleontological datum is simply a biostratigraphic horizon where "time and rock coincide". An example would be the lowest occurrence of a taxon corresponding to the taxon's evolutionary appearance (see Aubry 1995). Datums are thus expressed interchangeably in terms of stratigraphic position, with regard to distance from a 0-reference point, and in terms of time, with regard to the age of the horizon from which the age of the specified event is deduced.

As a stratigraphic horizon, a datum also exists independently of whatever date may be applied. Radio-isotopic dating is important, however, *precisely* because it provides ages for datums, which in the broader sense can be defined as stratigraphic horizons that have acquired a specific significance for their geohistorical, paleontological, isotopic, or other character. A chronostratigraphic boundary itself is comparable to a datum: a point in the rock (*no thickness*) that represents a point in time (*no duration*) (Harland 1978; see discussion in Aubry et al. 1999; Aubry 2007; emphasis added).

The inherent uncertainty of radioisotopic dates thus has no consequence on what stratigraphers refer to as a datum in terms of relative spatial succession. Numerical ages are regularly improved, but the best dated mineral would be useless unless it was precisely placed in its specific stratigraphic context. Like a fossil, a date once extracted from the rock without reference to its location, is lost for science (see Aubry 2007a).

Ages and ages

In the Earth sciences, as in every day life, the term 'age' refers to duration. Being 'age 15' means being in existence for a duration of 15 years. Chronostratigraphic age, either *sensu stricto* (i.e., equivalent of "stage") or *sensu lato* (broadly applied to a chronostratigraphic unit of any rank) also designates duration—for instance being of "Eocene age" implies existing within a span of time of about 22 million years and a Cretaceous age denotes a span of about 80 million years corresponding to this period (cf. Gradstein et al. 2004).

Duration is the inherent property of that which endures, even if we are unable to measure the duration beyond a certain point. Each chronostratigraphic entity has its own duration, established not by decree or by observation but by tying its beginning and its end to a specific moment, defined by a single physical point in the rock record, while realizing that the numerical ages given to the bounding points can only be less accurate than the true limits of the age in question. The age of the Cretaceous/Paleogene (C/P) boundary, for example, is approximately 66 Ma (Kuiper et al. 2008), which means that the stratum marking the boundary datum was deposited, as far as we know, about 66 million years ago. The precise year may never be known, but it has been proposed that the bolide held responsible for the end Cretaceous mass extinction may have impacted the Earth in early June (Wolfe 1991) of that indeterminate year. The LAD of planktonic foraminiferal genus *Hantkenina*, the criterion for the Eocene/Oligocene boundary, is presently characterized in the GSSP section of Massignano (Italy) at ~33.9 Ma (Hilgen and Kuiper 2009) meaning that these extinctions occurred ~33.9 million years ago. The Brunhes/Matuyama polarity reversal boundary is placed at 0.778 Ma (Lourens et al. 2004), indicating that the magnetic field reversed 0.778 million years ago. Each age in these different cases expresses the *timing* of an event, whether sedimentologic, cosmic, evolutionary or magnetic.

Chronostratigraphic ages and numerical ages thus differ in a fundamental way. One refers to a duration, the other to a discrete stratigraphic horizon. They also differ in their stability. Once a chronostratigraphic unit has been defined by physically fixed boundaries, its true duration remains unchanged. In contrast, numerical ages may vary considerably, even in measurements on the same material, let alone in different samples measured in different laboratories with different tools (see above). For this reason numerical ages are often explicitly characterized by method, whether radio-isotopic, astronomical, or estimated. As the numerical ages of chronostratigraphic datum points are progressively adjusted and with astrochronology being extended to older and older time (Hinnov and Ogg 2007), the estimated duration of chronostratigraphic units changes as well, asymptotically approaching the actual value.

Numerical ages of stratigraphic horizons (and by inference events; see Aubry 2007) are the equivalent of dates in a calendar because they refer to a time counted in years from a starting point. 1 Ma, as a date, is constructed in the same way as Year AD 1 (*Anno Domini*), or year AD 1669, or 15 June 2009. In vernacular language'year' is often omitted in the writing of dates, which can be simply AD 2009 when the context is clear, but 'Ma' is, so far, customary for all geological dates.

Ma means Mega-annus (from Greek: *megas* large; and Latin: *annus* year, Berggren and Van Couvering 1979) – not Mega-annum, and also not Million years ago (see Aubry et al. this volume). The symbol 'Ma' is used expressly in stratigraphy to differentiate 'date' from 'duration' which is commonly noted as 'Myr', 'my' or 'm.y.', based on abbreviations for 'million years'. As a formal term, the symbol Myr is preferable, since in SI symbology lower case 'm' stands for 'milli' or thousandth. The importance of the distinction between date and duration, rather than to use a symbol such as 'Ma' for both is important to clarify.

Points and duration

To restate the obvious, *duration* is an interval of time between two moments, i.e., two *points* in time. It follows that any consideration of time involves three parameters, a proximal point, an interval, and a distal point. The greatest duration for Earth sciences is 4.54 billion years, from the time of the formation of the solar system to the time of today. Intermediate points in this 4.54 billion years temporal continuum are necessary to comprehensively describe Earth history. These points are the counterparts of the dates in day, month and year of calendars upon which historians rely to recount the human adventure. How are these intermediate points determined?

In the time scale some of the intermediate points are the direct products of radio-isotopic dating (see discussions in Berggren et al. 1985b, 1995). In radio-isotopic dating two parameters are known: 1) the Present, or 0 million year, which is the *proximal* Point [a], and 2) the *duration* [b], which is the age calculated from the amount of the subject radio-isotope in the sample and the half life of the radio-isotope. The date of the distal Point [c] is resolved by algebra with the formula (b-a=c). As [a] = 0, [c]=[b]. Thus in radio-isotopic dating the same value in years describes both, duration, a quantity, and the distal point, which is not a quantity. As noted previously, most Earth scientists would use 'Ma' for the distal point and 'Myr' with the calculated value, to distinguish the two components of time.

There can be only one distal point that is 66 Ma with reference to a proximal point set at 0 Ma. On another hand, a literally infinite number of other durations of 66 million years are included in the Earth's 4.6 billion years because there is an infinity of possible reference points. This is generic duration, in contrast to specified (or ear-marked) duration. Radioactive decay is unidirectional (i.e., non-repetitive) albeit non-linear, explaining why radio-isotopic dates and durations, both being measured from the present, are seen as interchangeable.

Other durations are based on mathematically predictable cycles, and thus have constant uncertainty values, rather than percentage error that increases in absolute value with the increase of measured time. Astrochronology, which depends on well-documented long-term orbital interactions, is the most advanced and exact of such cycle-based time scales. Where the sedimentary record can be firmly tuned to the computed astronomical solutions, the evidence of orbital cycles can be numbered in a linear sequence starting from cycle 0, in the present day (Lourens 2004; Pälike et al. 2006). In other parts of the record, however, long series of orbital cycles have been identified in sections that can only be provisionally related to the anchored sequence, providing temporary but still useful local frameworks (Olsen and Kent 1999; Cramer et al. 2003; Westerbroek et al. 2007). These floating time scales are methodological proof that durations and points are two independent variables. As they await to be anchored by satisfactory astronomical solutions, floating time scales are also indication that the future of the geological time scale lies at least equally well with the powerful resolution of orbital periodicities as with the improvements in radio-isotopic dating.

Even in radio-isotopic dating it is possible to demonstrate that duration and points are different. Using a strict logic, the zero point of a historical progression should be at its beginning. Placing Year 0 of geological time at the beginning of the solar system, a duration of 4.54 billion years (4.54×10^3 million years) means that today would be 4.54 Ga (giga-annus; 4.54×10^3 Ma). The oldest rocks on the planet (O'Neil et al. 2008) would be 26 Ma, not 4.28 Ga. A duration of 66 Myr, measured from today, would date the C/P boundary at 4.474 Ga. This makes clear one (and perhaps the least problematic) of the difficulties associated with the logical measure of time from the birth of the solar system: i.e., the inconvenience of the very large numbers for the Phanerozoic Eon, which would begin at 3.998 Ga. Nevertheless, there are some interesting illogical consequences when Earth scientists instead measure time back from the present, but do not assign negative numbers to the past dates. For instance, an event that occurred 3 million years after the C/P boundary is 63 Ma. This is a smaller value than 66 Ma, even though a duration of 3 Myr has been created. Obviously, our geological calendar does not obey a distributive law. But durations do: 3 Myr before and 3 Myr after the C/P boundary add up to 6 Myr. Comparable illogic occurs in our dealing with the passage of time. By setting Year 1 of calendars some time in the past—e.g., 2009 years ago in the year AD when Jesus was born— we measure passing time correctly as an increasing number of years. Yet, a 30 year old person is not a person who was born in Year AD 30, but one born in AD 1979 — one more example of the difference between date and duration.

'Myr' and 'Ma'

The distinction between durations that are specified with respect to beginning (0 Ma) and durations that are not is extremely important, and far from being a whim of stratigraphers it is a matter of scientific logic and rigor. The year is the unit of time in both cases, but it is constrained as a specific date in the first instance, while in the latter it is unconstrained. This calls for the use of two distinct symbols, one for duration, *any* duration, the other for dates. While the symbol 'a' has been widely proposed, if never formally adopted in SI, to simply mean 'year' (cf. Aubry et al., this volume), the use of 'Ma' to denote dates (age of a point in millions of years before present) is so ingrained in the Earth sciences (including in geochemistry) that it would be wise to retain it for this purpose. The symbol 'Myr' and other multiples of 'yr' are available for duration, whether specified or unspecified, and could be used as the symbol for a non-SI unit if agreement is ever reached on the meaning of 'year'.

CONCLUSIONS

Our relationship with passing time is a learned experience beginning in childhood. However, as soon as a watch is attached to a wrist, the illusion sets in that time has become tamed, and the essence of time is no longer a concern. Yet, the passage of time helps us understand the nature of past time, and the meandering ways that have led to increasingly precise measurements of passing time also assist us in understanding the tortuous ways that made it possible to grasp the immensity—not the eternity of Earth and planetary time. The measurement of past time is not a blue ribbon dotted with check marks every so many million of years depending on the availability of datable radioactive elements in rocks. Its measurement is a web of interconnected (correlated) stratigraphic horizons and units, each endowed with a precise significance, contributing to a mixed calendar of relative and numerical time, just as in a calendar of years and holidays. Radio-isotopic dating, no longer the unique means of accessing numerical time, has been largely supplanted by astrochronology for measuring more recent geological time, and increasingly more of the earlier record as well.

Contrary to first impression time scales are not made of dates, but of durations. Durations are identified by delimiting datum points so that other durations can be known. Quantification of Earth history by the conversion of datums into numerical dates that are referenced to the present put durations into a common frame of reference. To sum up, the numerical ages on the left side of time scales —the ages of GSSPs, biostratigraphic events, magnetic reversals, isotopic peaks, mass extinctions, i.al., are a special class of durations that extend backwards from the present as a proximal date, to a unique instant of geological time at the end (logically the beginning) of the specified duration. Considering the rates of geological processes, these are measured in periods with specified durations of millions or thousand years, and here again these durations cannot be described or calculated based on a single point with the value 'Ma'. The distinction, then, is fundamental and openly clear: that when duration is not confused with age, as in normal geohistorical contexts where the measurement of a quantity of years can begin at some datum other than the present day, then the distinction between date and duration is clear. The advantage of two ways of perceiving time, as we reconstruct Earth history, is felt by every professional, and to discard, in the name of uniformity, the intellectual tools that have evolved to manage this information is hardly an act of progress.

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