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Convention on the Use of Units for Time in Earth and Planetary Sciences

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INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY
and
INTERNATIONAL UNION OF GEOLOGICAL SCIENCES

JOINT IUPAC-IUGS TASK GROUP ON ISOTOPE DATA IN GEOSCIENCES‡

CONVENTION ON THE USE OF UNITS FOR TIME IN EARTH AND PLANETARY SCIENCES

(IUPAC-IUGS RECOMMENDATIONS 200X)

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Convention on the Use of Units for Time in Earth and Planetary Sciences

(IUPAC-IUGS Recommendations 200x)

Abstract: The units of time (both absolute time and duration) most practical to use in Earth and Planetary Sciences are multiples of the year, or annus (a). Its proposed definition in terms of the fundamental SI unit for time, the second (s), for the epoch 2000.0 is 1 a = 3.1556925445×10^7 s. Adoption of this definition, and abandonment of the use of distinct units for time differences, will bring the Earth and Planetary Sciences into compliance with the SI standard regarding units of time.

INTRODUCTION

The International Union of Pure and Applied Chemistry, IUPAC, and the International Union of Geological Sciences, IUGS, set up a task group in October 2006 with the goal of updating the recommendations on radioactive decay constants (and half-lives) for geochronological use, last formalized in 1976.

In the course of the initial assessment, it was noticed that use of units for time in the geological literature is inconsistent both internally and with respect to SI (*Le Système international d'unités*). A source of inconsistency is the perceived contrast between "absolute time", or "age", i.e., the time difference between "now" and an event in the past, and the time difference between two events in the past. This issue is addressed immediately, as it requires neither new experiments nor extensive literature evaluations but only judgment and adherence to SI rules.

SI AND NON-SI UNITS FOR TIME

The SI unit of time, the second (s), is impractical for earth scientists and nuclear physicists alike. In such cases the SI tolerates other units. For geological applications and for use with long-lived radioactive nuclides the year, or annus (symbol, a), is used [1,2].

The definition of the year in terms of the fundamental SI unit, the second, is no trivial matter, as the year is not commensurable with the day, and is not a constant. There are several possible definitions available for the year, such as Julian, Gregorian, Tropical (or Solar) and Sidereal. Prior to the introduction of the atomic standard to define the second in 1967, SI used a definition of the second derived in terms of a fraction of a tropical year, for the epoch 1900.0, as "the second is the fraction 1/31556925.9747 of the tropical year for 1900 January 0 at 12 hours ephemeris time [3]".

In view of the necessity to define units for time in such a way that they can be considered as constant for practical purposes, it is here recommended to re-define the year on the basis of the second recommended at present by [4], effectively reversing the definition used by [3] in favour of a more precise and up-to-date definition of the second. Taking into account the astronomical decrease by 0.530 s per century, for the epoch 2000.0 the year amounts to 31556925.445 seconds.

As with other units, thousands, millions and billions of these are appropriately designated ka, Ma, and Ga, respectively. These derived units are already in widespread use in Earth and Planetary Science literature, though as noted above they lack precise definition. The departure lies in the use of different units (e.g., m.y., from the American Engineering Society) for ages and time differences, such that the interval between 90 Ma and 100 Ma, for example, is sometimes designated as 10 m.y. Instead, following correct SI usage [4], units must follow algebraic rules such as the distributive law: 100 Ma – 90 Ma = (100 – 90) Ma = 10 Ma, and so on. Similarly, half-lives should be expressed in ka, Ma, or Ga,

and rates and decay constants in $(ka)^{-1}$, $(Ma)^{-1}$ or $(Ga)^{-1}$. The definition of the second, and of the year based on the second, is that of a duration, or time interval. In order to express an age, or absolute time, the same units must be used, with the optional addition of qualifiers such as “ago” or “before present” if a disambiguation is required. Analogies on the use of absolute and relative SI units are useful: it is rarely denied that the depth difference between 100 m and 200 m below ground level in a borehole is 100 m.

It is therefore recommended that geoscientists abandon the incorrect habit of expressing time durations in distinct *ad hoc* units such as k.y., M.y., or G.y. The correct way to achieve compliance with the SI standard is expressing time durations as a, ka, Ma, Ga. When age units in geochronology are followed by the abbreviation "BP" (before present), "present" refers to a particular datum such as that of calendar year 1950.0 widely used in radiocarbon dating. As this nomenclature refers to a datum, and not to the units themselves, no recommendation is made for change in usage at this time.

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