Geological time units are the *lingua franca* of earth sciences: they are a terminological convenience, a vernacular of any geological conversation, and a prerequisite of geo-scientific writing found throughout earth science dictionaries and textbooks. Time units include terms formalized by stratigraphic committees as well as informal constructs erected *ad hoc* to communicate more efficiently. With these time terms we partition Earth’s history into utilitarian and intuitively understandable time segments that vary in length over seven orders of magnitude: from the 225-year-long Anthropocene (Crutzen and Stoermer, 2000) to the ~4-billion-year-long Precambrian (e.g., Hicks, 1885; Ball, 1906; formalized by De Villiers, 1969).

Given the importance of such chronostratigraphic units (*sensu* Zalewicz et al., 2004), it is surprising that the key event in the Earth’s history, the first appearance of life, is not recognized as a major time boundary. This omission may reflect the relative youth of the field of Precambrian paleobiology. The earliest definitive reports of pre-Ediacaran fossils date to the 1950s (Tyler and Barghoorn, 1954), and only in the last few decades have details of life’s early history begun to emerge (e.g., Schopf, 2001; Knoll, 2004). This recent progress in the understanding of early life sets a foundation for augmenting the geological time scale into two more recent geological past.

In recognition of the importance of life in the Earth’s history and the efficiency offered by chronostratigraphic terms, we propose to divide the geological time scale into two informal super realms: Progeozoic (the abiotic superon) and Geozoic (the biotic superon).

**DEFINITION OF THE GEOZOIC**

The Geozoic denotes the time of life’s existence on our planet. Its lower and upper boundaries are defined by the first and last appearance of life, respectively. The upper boundary cannot be defined until life has gone extinct on our planet. However, ample precedent exists for open-ended boundaries. For example, the Cenozoic and the Quaternary are formal units that potentially (and continually) transcend the present. Yet, their top boundaries are set at 0 yrs on geological time scales, which is not only permissible, but also conservative. The end point of the Geozoic can be only younger than today: life is still unequivocally present on Earth.

The lower boundary is uncertain due to controversies surrounding the earliest records of life. Molecular clock analysis places the divergence between archaeabacteria and the archaeabacterial genes in eukaryotes at 3.97 ± 0.32 Ga (Hedges et al., 2001), but such estimates are not without problems. The oldest proposed direct geological evidence for life comes from geochemical signatures in ca. 3.8 Ga rocks.
ETYMOLOGY AND ALTERNATIVE TERMINOLOGY

The term Geozoic denotes the time of life on Earth (Geo = Earth and zoic = life). To be semantically precise, -zoic denotes animal life. However, in geological terminology, the suffix -zoic is used more broadly to denote any life. Thus, textbooks and dictionaries translate Phanerozoic as the time of visible, obvious, evident, or well displayed life (e.g., Whitten and Brooks, 1978; Stanley, 2009), and not the time of visible animal life. The largely abandoned term Cryptozoic is defined as the time of hidden or obscure life (e.g., Prothero and Dott, 2010), and not the time of obvious animal life. Although some of the -zoic terms were originally proposed to denote animals, usage of the suffix has evolved to denote all life.

Following our conference presentation on the Geozoic (Kowalewski et al., 2009), multiple colleagues inquired why we had not considered the term Biozoic. This term is problematic. First, the suffix -zoic is used by geologists to denote all life, which makes Biozoic redundant. Also, the prefix bio, could be misread as an emphasis of the strict meaning of the word Zoic, equating Biozoic with the time of animal life. Finally, Biozoic does not make any reference to earth, which makes it vague from the geocentric perspective of stratigraphy (Zalasiewicz et al., 2004). For example, if conclusive evidence of Pregeozoic life is found on Mars, the lower boundary of the Geozoic would not be affected, but a case could be made for redefining the Biozoic. Others suggested the term Zoic, but this term also does not make any reference to earth, which makes it vague. The largely abandoned term Cryptozoic is defined as the time of hidden or obscure life (e.g., Prothero and Dott, 2010), and not the time of visible animal life. Although some of the -zoic terms were originally proposed to denote animals, usage of the suffix has evolved to denote all life.

Following our conference presentation on the Geozoic (Kowalewski et al., 2009), multiple colleagues wondered why we had not considered the term Biozoic. This term is problematic. First, the suffix -zoic is used by geologists to denote all life, which makes Biozoic redundant. Also, the prefix bio, could be misread as an emphasis of the strict meaning of the word Zoic, equating Biozoic with the time of animal life. Finally, Biozoic does not make any reference to earth, which makes it vague from the geocentric perspective of stratigraphy (Zalasiewicz et al., 2004). For example, if conclusive evidence of Pregeozoic life is found on Mars, the lower boundary of the Geozoic would not be affected, but a case could be made for redefining the Biozoic. Others suggested the term Zoic, but this term also does not make any reference to earth and may be more appropriate for denoting the time of life in the universe. The term Gaiazoic was also proposed, but this is a politically charged term that we chose to avoid.

The term Pregeozoic is derived based on the same logic that had been used to coin the term Precambrian (but see Martinson, 1973). Pregeozoic is synonymous with Azoic (Martinson, 1973; see also Goldblatt et al. [2009] for discussion of pre-Archean, non-biotic time units). The term Azoic does not make any reference to Earth and could serve as a counterpart to the term Zoic to denote the prebiotic history of the Universe. Admittedly, the terms Zoic and Azoic sound like...
Successful terms are invented because they are needed for a specific reason and then propagate because they prove useful beyond their original need. The term Geozoic was invented because the NESCent abstract, these entries represented blogger names, e-Bay postings, and other obscure hits, including a Trojan virus that delayed somewhat the preparation of the manuscript.

PRACTICAL JUSTIFICATIONS

Successful terms are invented because they are needed for a specific reason and then propagate because they prove useful beyond their original need. The term Geozoic was invented because the NESCent abstract, these entries represented blogger names, e-Bay postings, and other obscure hits, including a Trojan virus that delayed somewhat the preparation of the manuscript.

1. A purely pragmatic reason for introducing new terminology is linguistic parsimony. Terms save words and characters, allowing for shorter titles and succinct abstracts. Brevity is not just desirable, but often required: many journals set stringent limits on the length of titles, abstracts, or text. The published literature offers many cases that illustrate potential utility of the term Geozoic. For example: “...little evolution at the macroscopic level took place for half of the entire history of life on Earth” (Schulze-Makuch and Irwin, 2004, p. 39) could be “...little evolution at the macroscopic level took place for half of the Phanerozoic;” “We would argue that it is simplistic to expect only one pattern of stability in the entire fossil record” (Tang and Bottjer, 1997, p. 475) could be “We would argue that it is simplistic to expect only one pattern of stability in the Geozoic;” and “...together comprise <20% of the total duration of life on Earth” (Payne et al., 2009, p. 24) could be “...together comprise <20% of the Geozoic.” The time terms are particularly useful in titles, which are often more effective when brief. For example, the title: “Biotic enhancement of weathering and surface temperatures on earth since the origin of life” (Schwartzman and Volk, 1991, p. 357) could be shortened as “Biotic enhancement of weathering and surface temperatures in the Geozoic.”

2. The need for Geozoic is illustrated by inadequacy of existing terms, often used due to lack of appropriate terminology. An ISI Web of Knowledge search (12/02/2009) for the subject “Phanerozoic” revealed that the journal *Precambrian Research* published 119 papers apparently focused on post-Precambrian times (only four journals published more papers on the Phanerozoic). Very likely, those papers dealt with both the Precambrian and Phanerozoic, but lacked a single subject tag to denote such a long time interval. The Geozoic tag could allow one to highlight papers (whether published in *Precambrian Research* or elsewhere) that deal with both the Precambrian and the Phanerozoic.

3. Temporal units are indispensable indexing tags for identifying publications that deal with specific time intervals or target temporal scales of a given magnitude. Anyone interested in large-scale patterns in the evolution of multicellular life can use the Phanerozoic tag to find many relevant publications, while those interested in recent changes in ecological communities can use the Holocene tag to assemble their initial bibliography. Why then, having such efficient terms for biologically relevant time scales and time intervals, do we lack the most important tag? We have a special name for the time of old life on Earth (Paleozoic). We have a name for the time of obvious life on Earth (Phanerozoic). However, absurdly, we lack a name for the time of life on Earth (Geozoic).

4. The Geozoic-Precambrian terminology could also facilitate a more transparent organization of introductory geological textbooks. Currently, textbooks are organized lucidly for the Phanerozoic part of the Earth’s history, often having time-parallel sections on biological and geological processes (e.g., Paleozoic Life and Paleozoic Earth), but their Precambrian parts are less intuitive chronologically. In particular, the text dedicated to the origin of life and earliest life is often buried in chapters that deal with the whole Archean or even Archean and Hadean. This problem relates to the lack of explicit separation of the prebiotic and biotic Earth. The Geozoic offers a convenient tool for presenting the Precambrian history of life in a more structured manner in textbooks and in classrooms.

5. Finally, the term Geozoic may become increasingly useful as the perspective of evolutionary research continues to expand, especially with the discovery of water-bearing worlds in our own Solar System.
(e.g., Lunine et al., 2003; Clark, 2009) and the arrival of new technology for detecting Earth-scale planets elsewhere in our galaxy (e.g., Gaidos et al., 2007). The notion that life exists on other planets, and that it might be accessible to scientific inquiry, has gained scientific credibility, culminating in the creation of the field of exobiology. It is thus possible that in the not-too-distant future we will come to think of the history of life on Earth comparatively, that we will start discussing origins, durations, and trajectories of evolution on life-bearing planets generally, not just on Earth. We may become interested in the frequency of certain kinds of events affecting life over its various histories or the differences in the sorts of evolutionary trends occurring on different planets. When we do so, we will need a convenient way to refer to the relevant time period on Earth as well as corresponding terms for other worlds. It may be too soon to develop a full vocabulary for making these comparisons. But it is not too soon to recognize, in our use of language, that our thinking has expanded to encompass a larger context: all of life, including its whole duration on Earth, the Geozoic.

Note that the Geozoic will be validated if future users find any of the above arguments compelling. Some may agree that the Geozoic offers a useful tag, but dismiss the linguistic parsimony argument. Others may find it useful for structuring syllabi, but scorn the idea of extraterrestrial terms. Even we do not support all the above arguments with equal enthusiasm, but all of us find at least some of those points compelling enough to campaign for the Geozoic.

One may raise objection that new terms such as Geozoic cannot be used without explaining what they mean, which defeats the idea that they would become useful. Using this type of logic, it would be impossible to ever invent a new term. Of course, you will need an explanation at first: this is true for all new terminology. But presumably, as the term becomes more known over time, the need for an explanation will go away. Moreover, if anything, Geozoic is more self-explanatory than existing terms. If you asked someone what the Geozoic refers to, he or she might be able to figure it out etymologically without knowing the definition. But there’s no way someone could figure out precisely what the Mesozoic refers to without explanation.

Another objection may be the issue of the vagueness of the lower boundary of the Geozoic. Again, this would be true for all time intervals, and if this argument had been taken seriously in the past we would not have been able to name any time units at all. At least for the Geozoic, the time encompassed is conceptually clear, even if the lower boundary is imprecisely estimated.

Finally, an understandable reaction would be to ask why use the term if one can simply say “time span of life on Earth.” We are certain that similar criticisms must have been voiced when successful terms such as if one can simply say “time span of life on Earth.” We are certain that similar criticisms must have been voiced when successful terms such as Paleozoic, the time encompassed is conceptually clear, even if the lower boundary is imprecisely estimated.

In the world of components there are no equivalents,” noted Erofeev (1994, p. 68), when discussing substitute alcoholic drinks that Russians enjoyed during the Soviet Era. We believe that this dictum applies to the Geozoic; a supereon that denotes the entire documented history of life on our planet with just one seven-letter word. None of the currently used time units offers comparable terminological expedience. None recognizes the historical importance of life as concisely.

ACKNOWLEDGMENTS

The concept of the Geozoic originated during meetings of a Working Group (Phanerozoic body size trends in time and space: macroevolution and macroecology) supported by the National Evolutionary Synthesis Center (NESCent), Durham, North Carolina (National Science Foundation EF-0423641). We thank a legion of colleagues for moral encouragement and etymological discussions.

REFERENCES


