COMMENT

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Zalasiewicz et al. (2004) propose that it is time to end the distinction between the dual stratigraphic terminology of chronostratigraphy and geochronology. Their proposal is based on observations that: (1) it is difficult for the greater part of the professional geological community to distinguish between chronostratigraphy and geochronology; (2) stratigraphic concepts, dating methods, and practices used on stratified rocks are supplemented by techniques such as magnetostratigraphy and radiometric dating, which can be used on nonstratified rocks; (3) stratigraphic principles are now used to map Earth, the Moon, and other solid planets; and (4) that boundary stratotypes or global stratotype section and points (GSSPs) are widely used in defining formal geological time units. We consider the proposal of Zalasiewicz et al. (2004) to be timely, constructive, and significant for the further development and enhancement of stratigraphy. We also believe that the proposal of Zalasiewicz et al. (2004) needs some further clarification and perfection.

We agree that ending the distinction between the parallel units of chronostratigraphy and geochronology will not only simplify stratigraphic practice for use by the wider geologic community, it will also, we believe, provide an opportunity to extend the geochronological terminology to the commonly used anthropological time scale (millennium, century, etc.). With the development of geosciences and related science and technology, it is recommended that geologic-time units should not only have the eon, era, period, epoch, age, and chron, which are well known, but should also be extended to include shorter-term time units such as eccentricity year, obliquity year, precession year, millennium, century, year, and so on (see Bai, 1995; House, 1995; Gong and Li, 1999; Hinnov, 2000; Gong et al., 2001).

It is well known that formally defined geologic-time units and their boundaries are exclusively anchored in classical strata by global stratotype sections and points (GSSPs) (e.g., Yin et al., 2001) and by numerical dating methods (e.g., Bowring et al., 1998). Together the GSSPs and geochronology are designed to maintain precision and stability of geologic-time units. These geologic-time units can be used to study the time recorded in both classical strata and other geologic bodies and establish a high-resolution geologic-time scale based on a single set of stratigraphic terms.

Compared with chronostratigraphic units (eonothem, erathem, system, series, stage, chronozone) that, by definition, exclude nonstratified rocks (Hedberg, 1976), geologic time units (eon, era, period, epoch, age, chron, etc.) can be used to encompass both stratified and nonstratified rocks. For example, the term Late Devonian epoch not only contains all sedimentary strata laid down during the Late Devonian epoch, but also comprises the processes and products of magmatic, metamorphic, tectonic, and other geologic events that have taken place during that epoch. This example also shows how the simplification of the terminology used will allow greater flexibility and integration of stratigraphic disciplines, which in turn would greatly extend the applications of stratigraphic theories.

We are in favor of the idea of being able to refer to both stratified and nonstratified rocks on the one time scale. In conducting our stratigraphic research and geologic mapping in some orogenic belts of China, we have found that the classical paradigm of stratigraphy based on William Smith's original concept (which we call Smith stratigraphy) is not suitable for orogenic belts. In structurally complicated geological settings such as fold belts and suture zones, typically there are both stratified and nonstratified rocks. In dealing with these cases it has been our practice to use a number of different stratigraphic techniques including: Smith stratigraphy, non–Smith stratigraphy, and numerical dating methods (e.g., Gong et al., 1996; Yin et al., 1999; Zhang et al., 2000). Zalasiewicz et al.'s (2004) proposed chronostratigraphy will allow us to report field mapping results from both the stratified and nonstratified rocks in orogenic belts on the one time scale.

In summary, we support the proposal of Zalasiewicz et al. (2004) to terminate the distinction between the dual stratigraphic terminology applied to chronostratigraphy and geochronology. A unified (integrated) chronostratigraphic-geochronologic scale will allow both stratified, nonstratified rocks, and geological processes to be referred to together on the one time scale, and it also has the potential to extend current stratigraphic theories and techniques to a wider range of geological applications (e.g., mapping in orogenic belts). In addition, we would like to suggest that the unified chronostratigraphic-geochronologic scale be extended into, and combined with, anthropological time units such as millennium, century, year, etc.

REFERENCES CITED

Bai, S.L., 1995, Milankovitch cyclicity and time scale of the Middle and Upper Devonian: International Geological Review, v. 37, p. 1109–1114.

Bowring, S.A., Erwin, D.H., Jin, Y.G., Martin, M.W., Davidek, K., and Wang, W., 1998, U/Pb zircon geochronology and tempo of the end-Permian mass extinction: Science, v. 280, p. 1039–1045, doi: 10.1126/SCIENCE.280.5366.1039.

Gong, Y.M., and Li, B.H., 1999, High resolution stratigraphy, Milankovitch cycle and ENSO event deposits: Geological Science and Technology Information, v. 18, p. 32–36.

Gong, Y.M., Du, Y.S., Feng, Q.L., Yan, J.X., and Liu, B.P., 1996, Thinking about non-Smith stratigraphy: Earth Science, v. 21, p. 19–26.

Gong, Y.M., Li, B.H., Wang, C.Y., and Wu, Y., 2001, Orbital cyclostratigraphy of the Devonian Frasnian-Famennian transition in South China: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 168, no. 3–4, p. 237–248, doi: 10.1016/S0031-0182(00)00257-1.

Hedberg, H.D., 1976, International stratigraphic guide: New York, John Wiley, 200 p.

Hinnov, L.A., 2000, New perspectives on orbitally forced stratigraphy: Annual Review of Earth and Planetary Sciences, v. 28, p. 419–475, doi: 10.1146/ANNUREV.EARTH.28.1.419.

House, M.R., 1995, Orbital forcing timescales: An introduction, *in* House, M.R., and Gale, A.S., eds., Orbital forcing timescales and cyclostratigraphy: Brassmill, Geological Society [London] Special Publication 85, p. 1–18.

Yin, H.F., Zhang, H.T., Qihe, R., Yu, Q.W., Zhang, K.X., Ren, J.Q., and Gu, F.B., 1999, Discussion on non-Smith stratigraphy: Chinese Geology, v. 265, p. 24–29 (in Chinese).

Yin, H.F., Zhang, K.X., Tong, J.N., Yang, Z.Y., and Wu, S.B., 2001, The global stratotype section and point (GSSP) of the Permian-Triassic boundary: Episodes, v. 24, no. 2, p. 102–114.

Zalasiewicz, J., Smith, A., Brenchley, P., Evans, J., Knox, R., Riley, N., Gale, A., Gregory, F.J., Rushton, A., Gibbard, P., Hesselbo, S., Marshall, J., Oates, M., Rawson, P., and Trewin, N., 2004, Simplifying the stratigraphy of time: Geology, v. 32, no. 1, p. 1–4, doi: 10.1130/G19920.1.

Zhang, K.X., Huang, J.C., Yin, H.F., Wang, G.C., Wang, Y.B., Feng, Q.L., and Tian, J., 2000, Application of radiolarians and other fossils in non-Smith strata—Exemplified by the Anyemaqen mélange belt in East Kunlun Mts: Science in China, v. 43, p. 364–374.

COMMENT

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Stratigraphy and Time

Zalasiewicz et al. (2004) have proposed fundamental changes in the definition and application of stratigraphic terminology involving time-rock and geologic-time units that fly in the face of widely accepted principles that have been tried and tested in establishing an international unified stratigraphic hierarchy and nomenclature. Their adoption would create major disruption to established procedures.

The principal problem with the paper is that the authors appear to be confused about how time is related to stratigraphy; this misunderstanding starts with the title, it permeates the whole paper, and confuses arguments. Major dictionaries (e.g., Oxford, Webster's, Chambers) define stratigraphy as the study of strata and their succession and relative position; there is no mention of time there. Time itself cannot have a stratigraphy as implied in their title, which is why we do not use it in our comments and we cannot agree with their use of simplifying in this context.

The authors' failure to grasp the essential difference between time and rock is demonstrated by their Table 1, where the features labeled Chronostratigraphy are in fact units of standard chronostratigraphy, that is classification of rocks by age measured on a standard time scale (i.e., the geological column comprising units of system, series, stage rank, etc.), commonly referred to as time-rock units. The hierarchy of units applied here is defined ultimately by the bases of the units set by marker points (golden spikes) in rock within type-sections in a global stratotype section and point (GSSP); the defined base of each unit of a higher rank corresponds automatically with the base of the lowest unit at the next lower rank of the hierarchy. Thus the marker point coinciding with the lowest occurrence of *Monograptus uniformis* in the type-section at Klonk, Czech Republic, marks the base of the Lochkovian Stage, and also the bases of the Lower Devonian Series, the Devonian System, and the Upper Paleozoic Suberathem. The important point about all these units is that they apply to rocks, can be examined in the field, and one can hammer a golden spike into them.

The items under the heading Geochronology in Table 1 are geologic-time units; these are arranged in a chronologic order and have a hierarchy of units (in the same way as year, day, hour, minute, etc.). Geochronology, on the other hand, is an arrangement of events by age that has nothing to do with time itself nor with a hierarchy of units. Geologic-time units include the familiar periods, epochs, etc., but they do not have an exactly corresponding stratigraphy. How stratigraphy at any point relates to time is a matter of interpretation. Each unit in every part of the geologic-time unit hierarchy is bounded by time instants (i.e., points on a linear time scale) and comprises a total record of time without gaps or overlaps. These units can neither be seen in the field nor can you hammer a golden spike into them. The only point at which there is known correspondence with time-rock boundaries is at the golden spikes. Thus these geologic-time units differ in principle from time-rock units and their distinction is necessary for the purposes of language and communication.

Having thus defined units, it is possible to appreciate why a dual terminology is needed. It is to maintain clarity of thought. The Zalasiewicz et al. (2004) proposal that a GSSP should define both the base and the top of a unit clearly reveals why it is important to maintain a difference between chronostratigraphy and time units. A GSSP is a point in rock coinciding with a point in time that defines the base of a unit at one locality and provides a standard with which other sections can be correlated and calibrated. A GSSP is thus defined at a point at which some event occurred, believed to be time diagnostic; this may be based on such factors as a biostratigraphic criterion (e.g., the appearance of a time-significant fossil), or on time-significant lithostratigraphic criteria (e.g., an iridium-enriched clay band signifying an impact event). In selecting a point for a GSSP, the event should be chosen preferably to allow the possibility of correlation as closely as possible with other sections across the same time interval.

Even if the rock successions at GSSPs are believed to be "in continually [continuously] deposited sections," it would be remarkable if this were so; time is inevitably unrepresented by sediments at some part of any section, whether on land, in an Ocean Drilling Program core, or wherever. Bedding planes themselves may represent a break in sedimentation, so that time is likely to be unrecorded there. Such appreciation led to the decision to fix GSSPs by their bases only. In fact, long before the concept of a GSSP was introduced for the base of the Devonian System (McLaren, 1977), the same method had been used in Jurassic stratigraphy for a great number of years (Callomon, 1995). GSSPs cannot thus define tops as well as bases of time units, but they may correlate with the tops of chronostratigraphic units. It should also be pointed out that they need not be used to define the tops of standard chronostratigraphic units because these coincide automatically with the bases of the succeeding standard chronostratigraphic units.

The authors refer to Hedberg's (1976) stratigraphic guide, and the principles of distinction between rocks and time have also been enunciated clearly by other authors (e.g., Callomon, 1995). The rock-time duality has been seen to be essential for over 150 years; its evolution has led to a stratigraphic classification that has been both practical and broadly accepted internationally. To abandon that duality now would be a retrograde step that will simply confuse stratigraphic thought. Zalasiewicz et al. (2004) may well be correct in saying that the distinction between the duality of time and rock is "not clear to the greater part of the professional (or student) geological community," but this is no reason to abandon it! What is needed is clearer understanding of the principles, and not an abandonment of methodologies and definitions that now do so much in promoting global correlation of geological events.

REFERENCES CITED

Callomon, J.H., 1995, Time from fossils: S.S. Buckman and Jurassic high-resolution geochronology, *in* Le Bas, M.J., ed., Milestones in geology: Geological Society [London] Memoir 16, p. 127–150.

Hedberg, H.D., ed., 1976, International stratigraphic guide: A guide to stratigraphic classification, terminology, and procedure: New York, John Wiley and Sons, 200 p.

McLaren, D.J., 1977, The Silurian-Devonian Boundary Committee. A final report, *in* The Silurian-Devonian boundary, International Union of Geological Sciences Series A, Volume 5: Stuttgart, E. Schweizerbart'sche Verlagsbuchhandlung, p. 1–34.

Zalasiewicz, J., Smith, A., Brenchley, P., Evans, J., Knox, R., Riley, N., Gale, A., Gregory, F.J., Rushton, A., Gibbard, P., Hesselbo, S., Marshall, J., Oates, M., Rawson, P., and Trewin, N., 2004, Simplifying the stratigraphy of time: Geology, v. 32, no. 1, p. 1–4, doi: 10.1130/G19920.1.

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