Jurassic Chronostratigraphic Database and the TimeScale Creator Visualization System

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ABSTRACT: A joint project of the International Commission on Stratigraphy (ICS) and CHRONOS database program is to provide detailed global and regional "reference" scales of Earth history. Such scales integrate biostratigraphy (zones, datums for marine and terrestrial realms), sea-level (curves, sequences), geochemistry (trends, events), magnetic polarity chrons and astronomical cycles. The current Jurassic scale contains over 1000 events and zones correlated to Tethyan and Boreal ammonite zones with approximate numerical ages from *Geologic Time Scale 2004* (Gradstein *et al*. 2004). This public database will be progressively enhanced through the efforts of the Jurassic Subcommission of the ICS and by other stratigraphic and regional experts. On-screen display and production of user-tailored time-scale charts is provided by the TimeScale Creator, a Java package freely available from the ICS Subcommission for Stratigraphic Information or the TS-Creator websites (*http://stratigraphy.science.purdue.edu* or *www.tscreator.org*). After specifying the time interval and vertical scale, a user selects a subset of stratigraphic columns and trends. In addition to screen views and a scalable-vector graphics (SVG) file for importation into popular graphics programs, the on-screen display also has "hot-curser-points" to open windows providing additional information on events, zones and boundaries. The database and visualization package are envisioned as a convenient reference tool, chart-production assistant, and a window into the geologic history of our planet.

INTRODUCTION

Earth history relies on a standard international language and high-resolution correlation of divisions of geologic time. There has been a progressive improvement of both the inter-calibrations of types of paleontology, sea-level oscillations and other events of Earth history, and of the assignment of numerical ages from radiometric dating and orbital-cycles tuning. One of the main goals of the International Commission on Stratigraphy (ICS) is to make this information easily accessible via the Internet and through other mediums (*e.g.*, printed compilations, posters, *etc.*).

In 1998, a team of specialists led by Jan Hardenbol (Exxon) published a detailed set of large-format charts summarizing the correlations and ages of biostratigraphy (all major marine groups), sequence stratigraphy, magnetic stratigraphy and other events through the Mesozoic and Cenozoic eras of the past 250 million years (Hardenbol *et al*. 1998). We converted the supporting databases (provided by ExxonMobil, approximately 5,000 event-age items) to the Geologic Time Scale 2004 (GTS2004; Gradstein *et al*. 2004), and included updates and additional datums from the Ocean Drilling Program and other sources. For the Paleozoic, the initial database contained all

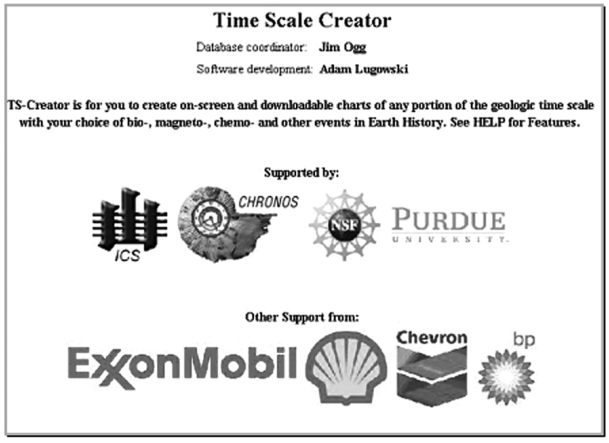

Fig. 1. Opening screen for TimeScale Creator; available as freeware from International Commission on Stratigraphy (*www.stratigraphy.org*) and CHRONOS (*www.chronos.org*)

the events tabulated in Cambrian through Permian chapters within GTS2004. Additional stratigraphic columns for the Phanerozoic were contributed by the Quaternary and other subcommission of ICS, compiled from geochemical databases (strontium, C-13, ice cores, *etc.*) and from published sea-level curves (*e.g.*, Haq and Al-Qahtani 2005; Miller *et al.* 2005), and obtained from other publications. The current (August 2006) database contains about 10,000 event-age items, plus a suite of geochemical and sea-level curves. This compilation is being progressively enhanced with contributions from the subcommissions of ICS, and all entries are annotated with details of their calibration.

For ease in updating to future enhancements of the numerical time scale, the ages of all datums are derived from relational equations of their documented or estimated inter-calibrations. For example, the age of a particular Early Cretaceous nannofossil first-appearance datum is relative to its placement with respect to a M-sequence magnetic polarity chron, and its age is derived from a Pacific spreading model for the corresponding magnetic anomalies. That spreading model, in turn, is constrained by radiometric ages on specific magnetic chrons and on orbital-scaled chron durations. The result is that the set of Early Cretaceous ages for all event datums might depend on only a few anchor points. If an anchor point is revised or a new one is added, then the numerical ages of all associated datums are automatically updated.

JURASSIC STRATIGRAPHIC SOURCES

The initial suite of Jurassic zones and datums were the extensive compilation by Hardenbol *et al.* (1998), but updated to GTS2004. Other revisions and columns have been progressively added. Listed below are the columns in August 2006 (the Jurassic Congress)(see *www.tscreator.org* for the greatly enhanced current suites):

Chronostratigraphic divisions and Global Stratotype Section and Points (GSSPs) (linked to ICS website graphics).

Magnetic polarity: marine-derived chrons and outcrop-derived zones (compiled by Ogg *in*: Gradstein *et al.* 2004).

Ammonites: zones and subzones for Boreal, Subboreal and Tethyan realms (J. Thierry *et al. in*: Hardenbol *et al.* 1998; and Groupe Français d'Étude du Jurassique 1997).

Sea-level: Boreal and Tethyan sequences and a proposed sea-level curve (Hardenbol *et al.* 1998; with partial update by Haq and Al-Qahtani 2005).

Strontium 87/86 ratio (John McArthur, Lowess version 4; used in his GTS2004 chapter).

Calcareous microfossils (planktonic foraminifers, calpionellids, smaller and larger benthic foraminifers, ostracods, charophytes) [by J. Remane, by F. Magniez-Jannin and C. Ruget, by P. Peybernes, by J. -P. Colin *et al.*, and by J. Riveline (all in Hardenbol *et al.* 1998); by C. Ruget and J-P. Nicollin and by J. -P. Bassoullet (all in Groupe Français d'Étude du Jurassique 1997].

Nannofossils: Boreal and Tethyan zones and datums (J. Bergen 1994; Bown and Cooper 1998).

Dinoflagellate cysts: Subboreal and Tethyan (Poulsen and Riding 2003; E. Monteil *in*: Hardenbol *et al.* 1998).

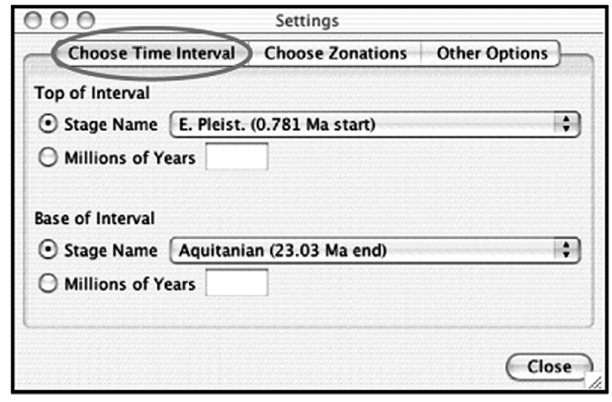

Fig. 2. User of TimeScale Creator selects time interval (set of stages, or by million of year interval).

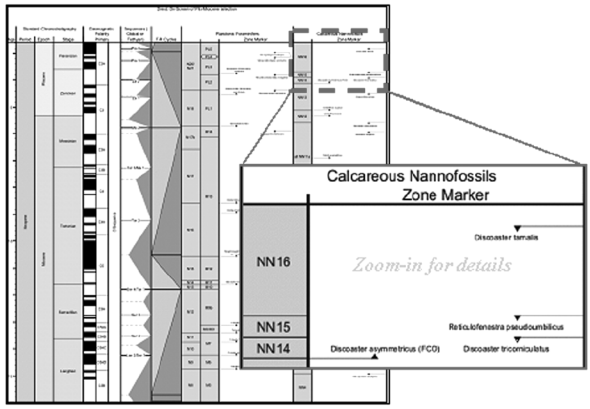

Fig. 3. Screen display of TimeScale Creator can be enlarged and panned.

Radiolarians (P. de Wever *in*: Hardenbol *et al.* 1998).

Calcareous macrofossils: belemnites, brachiopods (by R. Combemorel, and by B. Laurin, in Hardenbol *et al.* 1998).

Regional stages: New Zealand, China (compiled by R. Rohde for GeoWhen database, *www.stratigraphy.org*).

TIMESCALE CREATOR VISUALIZATION PACKAGE

An application called TimeScale Creator (Fig. 1) has been designed in Java programming language to run on all platforms that utilizes the reference Phanerozoic database to create custom graphics. The user specifies the stratigraphic interval by stage or by millions of years (Fig. 2), then selects the desired columns of stratigraphic information (Figs 3, 4). The TimeScale Creator generates an on-screen rendition. As explained above, when future enhancements are made to the database of stratigraphic scales or ages, then new graphics can be instantly produced.

Some of the features within TimeScale Creator include:

Several types of columns, including lithologic patterns and curve-fitting capabilities.

Appending the internal database with external datasets of age-event in different column formats, such as saving display settings to allow regeneration of a previous view. Exporting the graphic as SVG format (for direct importation into Adobe Illustrator or other graphics software for modification of elements, adding new text or graphics, *etc.*) or as a PDF image. Vertical scale (cm per myr) and any column width can be adjusted, fonts revised, columns re-ordered, colors changed from default system, *etc.* Numerical ages can be displayed on any desired column. These changes can be done by highlighting the column name in the menu (Figs 3, 4), which also displays the references used for that column. Paleontology datums can be displayed as FAD/LADs or as ranges (ordered by first or last occurrence). Screen views can be enlarged and panned. "Hot-cells" option can be activated. When a "hot" column title, biostratigraphic zone, sequence boundary or other datum is tapped with the mouse, then a window opens with references and additional information. These can include URL links to external sites or graphics on other websites, thereby allowing a vast amount of information to be accessed through such "hot" screen images.

It is not possible to easily present a set of Jurassic compilations and associated display charts in the limited space of this paper. Therefore, we include only a simple suite of three screen images as an example of TimeScale Creator output (Fig. 5).

FUTURE GOALS

In particular, this Phanerozoic stratigraphic database is envisioned to expand and become more authoritative as users contribute their knowledge and ideas. Some of the requested additions include additional suites of biostratigraphic columns (especially terrestrial realm), geochemical curves

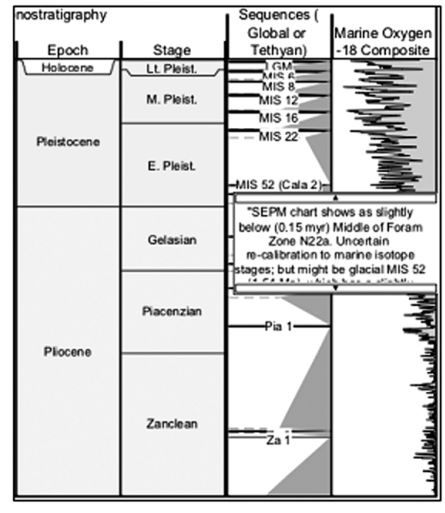

Fig. 4. The hot-cell option allows opening of windows with additional details and sources; and these can include URL links to open website pages or graphics.

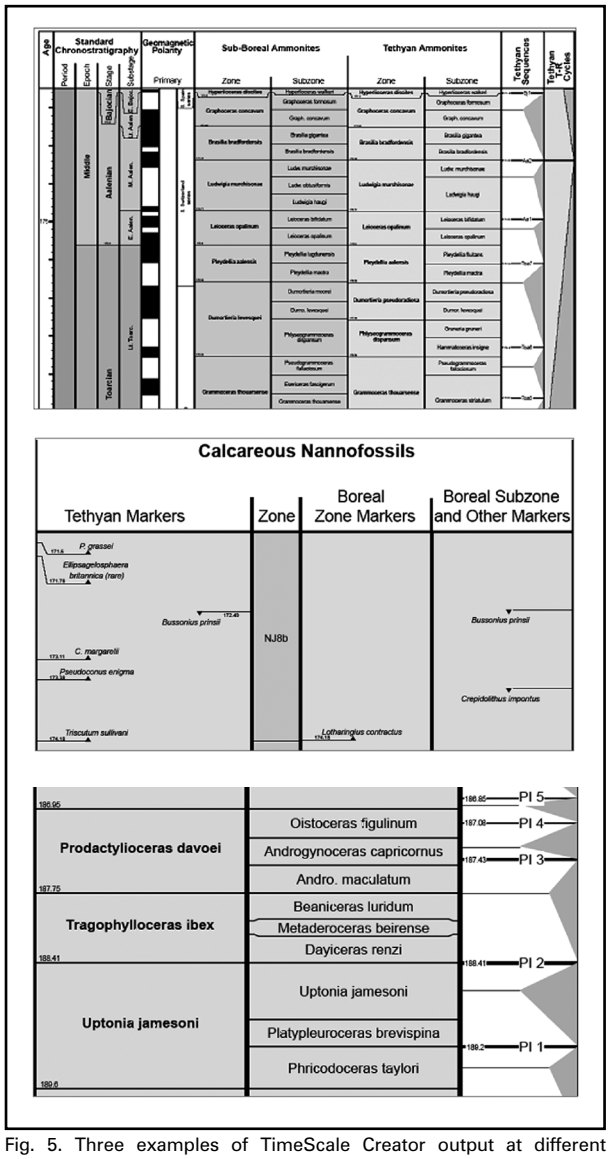

Fig. 5. Three examples of TimeScale Creator output at different magnifications for a portion of the lower Jurassic database.

(*e.g.*, Jurassic C-13, Osmium ratios, *etc.*), generalized schematic stratigraphic columns and formations for major basins, hot-links to images of marker ammonites and major fossils, regional stages and other chronostratigraphic divisions, and widespread impact and anoxic events. It is also important to include links to authoritative web documents and images for users. Assistance with these and other database improvements would be greatly appreciated and acknowledged in the sources.

For the TimeScale Creator visualization system to display and explore this Phanerozoic database, some current requests are to enable other range-chart options, additional downloading formats, and two-dimensional lithologic diagrams (interfingering or regional relationships). The most important factor is whether users can easily display and access the information that they desire.

SUMMARY

The current TimeScale Creator JAVA suite, several supplemental datapacks, manuals and other details can be downloaded from the ICS Subcommission for Stratigraphic Information or the TS-Creator websites (*http://stratigraphy.science.purdue.edu/* or *www.tscreator.org*).

The International Commission on Stratigraphy relies on volunteer efforts by specialists and other people interested in understanding Earth's complex history. The validity of any database is only as accurate as what is contributed and evaluated by such experts and users. The goal of ICS is to present the current status of our knowledge of past evolution, geochemical and climatic trends, and other episodes in Earth's history, plus provide a suite of useful reference standards for both the general public and research experts. Therefore, the ICS and its subcommissions are grateful for feedback on its products.

In some respects, the ICS database and visualization system was designed by stratigraphers for stratigraphers. However, a much larger world of students, educators, hobbyists, and general public should have a simplified graphics-rich system that presents Earth history in a more vivid manner, then leads them into the more specialized aspects. We welcome people to utilize the resources and tools of ICS and its subcommissions to reach out to this global audience.

REFERENCES

Bergen J. A. 1994. Berriasian to early Aptian calcareous nannofossils from the Vocontian trough (SE France) and Deep Sea Drilling Site 534: new nannofossil taxa and a summary of low-latitude biostratigraphic events. *Journal of Nannoplankton Research (International Nannoplankton Association Newsletter)*, **16**: 59-69.

Bown P. R. and Cooper M. K. E. 1998. Jurassic. *In*: P. R. Bown (*Ed.*) Calcareous Nannofossil Biostratigraphy, British Micropalaeontology Society Publication Series, Kluwer Academic Publ., p. 34-85.

Gradstein F. M., Ogg J. G., Smith A. G., Agterberg F. P., Bleeker W., Cooper R. A., Davydov V., Gibbard P., Hinnov L., House M. R., Lourens L., Luterbacher H-P., McArthur J., Melchin M. J., Robb L. J., Shergold J., Villeneuve M., Wardlaw B. R., Ali J., Brinkhuis H., Hilgen F. J., Hooker J., Howarth R. J., Knoll A. H., Laskar J., Monechi S., Powell J., Plumb K. A., Raffi I., Röhl U., Sadler P., Sanfilippo A., Schmitz B., Shackleton N. J., Shields G. A., Strauss H., Van Dam J., Veizer J., van Kolfschoten Th. and Wilson D. 2004. Geologic Time Scale 2004. 1-598, Cambridge University Press, Cambridge.

Groupe Français d'Étude du Jurassique (coordinated by E. Cariou and P. Hantzpergue). 1997. Biostratigraphie du Jurassique ouest-européen et méditerranéen: Zonations parallèles et distribution des invertébrés et microfossiles. *Bulletin des Centres de Recherches Exploration-Production Elf-Aquitaine, Mémoire*, **17**: 422 pp.

Haq B. U. and Al-Qahtani A. M. 2005. Phanerozoic cycles of sea-level change on the Arabian Platform. *Geoarabia*, **10**: 127-160 and 2 charts.

Hardenbol J., Thierry J., Farley M. B., Jacquin Th., de Graciansky P. -C., and Vail P. R. (with numerous contributors). 1998. Mesozoic and Cenozoic sequence chronostratigraphic framework of European basins. *In*: P. -C. de Graciansky, J. Hardenbol, Th. Jacquin and P. R. Vail (*Eds*), Mesozoic-Cenozoic Sequence Stratigraphy of European Basins. *SEPM Special Publication (Tulsa)*, **60**: 3-13, 763-781, and chart supplements.

Miller K. G., Kominz M. A., Browning J. V., Wright J. D., Mountain G. S., Katz M. E., Sugarman P. J., Cramer B. S., Christie-Blick N., and Pekar S. F. 2005. The Phanerozoic record of global sea-level change. *Science*, **310**: 1293-1298.

Poulsen N. E. and Riding J. B. 2003. The Jurassic dinoflagellate cyst zonation of Subboreal north-west Europe. *In*: Ineson J. *et al.* (*Eds*), The Jurassic of Denmark and Greenland. Special issue of the Geological Survey of Denmark and Greenland.