25 Jan 2021

Dear TSCreator Pro supporter:

We are pleased to announce the release of **TSCreator Pro 8.0** with the just-published *Geologic Time Scale 2020* (GTS2020) age model applied to all datasets. In addition, most of the external datapacks (about 20 of them) have also been re-standardized to the GTS2020 age model, plus we have added additional ones.

We have mounted your **TSCreator Pro 8.0** with its completely revised GTS2020 internal dataset for you in the password-protected site:
(*https://timescalecreator.org/tscpro/login.php*)

There are both a **.jar** (for Mac/Linus) and an **.exe** (for Windows) version. *[NOTES: If you have a problem opening the .exe; then first try updating your Java; and, if that doesn't work, then contact us] In case you are wondering what happened to TSC 7.4 of last year with the GTS2016 age models, it has been retained on that download page, including the suite of older external datapacks.]*

TSC 8.0 **internal dataset** now includes 480 columns grouped into ca. 200 directory/subdirectory clusters; a total of 59,000 lines (or 2008 pages if printed in Courier 10.5pt). The full listing of columns and hierarchy (a PDF table) is included as an Appendix to this "What's New" document and is posted on the TSCreator website.

The Geologic TimeScale Foundation board **officers** were partly rotated with the expiring of term limits.

Brian Huber (Smithsonian) is Chair of the Foundation; and he is also the Vice-chair of ICS.

Linda Hinnov (George Mason Univ.) is Secretary; and Gabi Ogg continues as Treasurer.

Felix Gradstein and Erik Anthonissen are the other board members; and Jim Ogg continues as executive director (and the main *TSCreator* coordinator).

A new and extensive **TS-Creator Manual** (zip of PDFs, 108Mb, July 2019) is on the Download page (*https://timescalecreator.org/download/download.php*; Item #3). This package includes 4 sections (Reference, Exercises, Makers, Crossplot). Some sections include folders with example exercises. Each section is independent of the others.

This letter briefly describes some of the main features:

(I) TSC 8.0 updated age model (GTS 2020)
(II) Major new/revised data columns; and newly created external datapacks (selected)
(III) TSC 8.0 software program enhancements (*data-mining tools; micro-evolution within macro-evolution graphics*.)
(IV) Attachments: (1) Flyer for GTS2020 2-volume book (Gradstein, Ogg, Schmitz, Ogg; Elsevier); (2) Comparison of ages for stages among GTS2012-GTS2016-GTS2020; (3) Table of contents of internal datapack.

(I) TSC 8.0 age model (GTS 2020).

"Geologic Time Scale 2020" (Felix Gradstein, James Ogg, Gabi Ogg, Mark Schmitz as editors/coordinators with ca. 80 contributors; Elsevier Publ., ca. 1300pp in 2 volumes) was released on-line Nov'2020.

This major work includes details on new ratified GSSPs (three Holocene stages, Chattian, Albian, Hauterivian, Kimmeridgian – just ratified this week by ICS, Sakmarian, Wuliuan in Cambrian, etc.); verified cycle-scaling for nearly the entire Cenozoic and much of the Mesozoic; consensus enhanced biozonations/datums for microfossils, conodonts and other fossil groups; a major synthesis of carbon and oxygen isotope curves for the entire Phanerozoic; mini-chapters on the evolution of major biostratigraphic groups; a major review of sea-level and sequences (by Mike Simmons); etc.

PALEOZOIC -- The GTS2020 age model is based on a statistical fit that incorporates an abundance of high-resolution ID-TIMS dates published since 2012 that replaced less-accurate ones. This larger radio-isotopic database with the new CONOP fit for Ordovician-Silurian graptolites and enhanced conodont zonations for Devonian implied a shift of over 1 Myr for about half of those stages.

MESOZOIC – The main revision in the Late Jurassic through Early Cretaceous age model was also caused by exciting new dates from radioisotopic workers. They concluded that Ar-Ar dates from ODP and some previous published U-Pb dates from Argentina in Tithonian through early Aptian as used in GTS2012 were not reliable. These previous dates seemed to be systematically too old (by nearly 4 Myr) when compared to post-GTS2012 new dating methods. After a dedicated GSA session on this problem with radioisotopic and biostratigraphic workers in 2018, it was decided to ignore essentially all dates published prior to 2012. The result is that the Aptian Stage, which had a base (126 Ma; GTS2012) calibrated to ODP Ar-Ar dates from Ontong Java Plateau and MIT Guyot, is now beginning at ca. 121 Ma (5 million years shorter in duration; Geology, in press); and the Valanginian-Hauterivian stages become slightly longer in duration (and shifted younger) while the Middle Jurassic is "stretched" by about 2 to 3 million years. It is not yet known why the ODP-based Ar-Ar dates of Late Jurassic-Early Cretaceous oceanic basalts/seamounts seem to be systematically too old. Geochronologists are now working to develop ways to use different minerals in ocean basalts to investigate this offset.

CENOZOIC – The IUGS ratified the Chattian GSSP at a microfossil event that is about 1 myr younger than the former "traditional" boundary at a major sea-level lowstand. This does not significantly change any biostratigraphic ages; but the bio-magnetic scale is nearly entirely tied to astronomical cycles with higher precision. The Holocene Epoch is now officially subdivided into the Greenlandian, Northgrippian and Meghalayan stages defined by GSSPs. The ICS recently voted to give official status to sub-epoch nomenclature (e.g., the "Middle Miocene" or "Late Oligocene" are now capitalized formal units).

A full list of the difference in stage boundary ages of GTS2020 (TSC 8.0) compared to GTS2016 (TSC 7.0) and GTS2012 (TSC 6.0) is an appendix at the end of this newsletter.

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(II) Major new/revised data columns; and newly created external datapacks (selected)

(1) Internal – Microfossils have popups linked to Mikrotax and Dinoflaj3

ALL planktonic foraminifer, calcareous nannofossil, dinocyst and Cenozoic radiolarians have mouse-over popups that include hot-URL links to Mikrotax and Dinoflaj3. Calibrations were enhanced by many colleagues, including Isabella Raffi, Bridget Wade and Brian Huber.

(2) Internal – Sequence stratigraphy and sea-level curve recalibration

Paleozoic -- Late Paleozoic sequence stratigraphy of Haq and Schutter (2008) has been carefully recalibrated to biozones and anoxic events by Thomas Becker (Devonian), Markus Aretz (Carboniferous) and Charles Henderson (Permian) for GTS2020. The Devonian chapter has a very detailed high-resolution set superimposed on the main sequence graphics by Thomas Becker (working with Jim Ogg), and these detailed graphics will later be digitized into TSCreator for 8.1.

Mesozoic – The sequence and sea-level curves incorporate the revisions by Bilal Haq for Triassic (GSA Today, 2018), Jurassic (GSA Today, 2017) and Cretaceous (2014). All Phanerozoic sequences use the recommended standardized nomenclature.

Cenozoic – The isotope-based sea-level curves of Ken Miller et al. (2020, Science Advances) are in two columns: (a) Smoothed for entire Cenozoic, and (b) high-resolution for Plio-Pleistocene. [NOTE: Their high-resolution Cenozoic was not incorporated, because they did not publish their age-calibration details (microfossil datums, etc.) to enable an accurate migration to the GTS2020 age model.]

(3) Internal and External – Geochemical trends and excursions

Carbon isotopes – Brad Cramer and Ian Jarvis contributed a synthesis for the Proterozoic through Cretaceous. The internal datapack retained the Cramer et al. version, but migrated to the GTS2020 age model.

Oxygen isotopes – Ethan Grossman and Michael Joachimski compiled a Paleozoic-Mesozoic synthesis with separate scales from calcite and from apatite (conodonts) with estimated temperatures. The internal datapack retained the Cramer et al. version migrated to the GTS2020 age model.

Temperatures – We migrated an extensive in-press (Chris Scotese et al., Earth-Science Reviews) synthesis of temperature proxies to the GTS2020 age model. The column has superimposed global and tropical temperatures.

EXTERNAL -- **Cenozoic** Global Reference benthic foraminifer carbon and oxygen isotope dataset [CENOGRID] curves as compiled in Westerhold et al. (24 authors; Nov, 2020, "An astronomically dated record of Earth's climate and its predictability over the last 66 million years". Science, 369: 1383–1387), includes last 1 Myr of Maastrichtian. The datapack (text file, 800 kb of ca 50,000 values) has their ca. 1.25-Myr smoothed trend superimposed on the high-resolution (5 kyr) oscillations. [NOTE: This file is high-resolution, and viewing with at least 10 cm/myr is needed to see the Plio-Pleistocene MIS labels.]

(4) External -- North Sea and Norwegian Sea

We applied the GTS2020 age model to the extensive NORLEX Biostratigraphy (zones, ranges, datums) for the North Sea. The source version had been coordinated by Felix Gradstein (Univ. Olso) and includes all major microfossil taxa (over 80 columns). The inclusion of 1000 images implies that the datapack is approximately 250 Mb.

(5) External -- Cenozoic macroperforate planktonic foraminifera phylogeny of Aze & others (2011): Corrected Version, July 2018 and enhanced in late 2019 [Under GTS2016 set]

This set applies the integrated species–phenon tree function of the TimeScale Creator platform to bring together the morphospecies and lineage trees of the Cenozoic macroperforate planktonic foraminifera of Aze & others (2011), calibrated against GTS2016. When displaying, this integrated species–phenon version defaults to the combined tree, but the individual morphospecies and lineage trees can also be viewed individually (Choose Columns, Choose tree structure, Side by Side Tree). The detailed were published in Zehady, A. K., Fordham, B. G., & Ogg, J. G. (2019) Integrated species–phenon trees: visualizing infraspecific diversity within lineages. Scientific Reports, 9:

e18968. https://doi.org/10.1038/s41598-019-55435-w. The 50 Mb zip file includes 4 individual datapacks (ecogroups, morphogroups; with or without labels), plus a settings file and the source articles.

(6) External -- Gulf of Mexico Neogene ("BP" datapack; Bergen et al., GSA Bull., 2019)

Jim Bergen, Eric de Kaenel, and their colleagues published their results of a decade of careful calibration of Gulf of Mexico and central Atlantic microfossil-nannofossil datums to astronomical cycles. They provided us their data tables, and we should have a TSCreator datapack version mounted next month (Feb, 2021) after they review it. [NOTE: Their cycle-age calibrations for many datums/zones differ from the Neogene GTS2020 compilation by Raffi, Wade et al. which used global ODP records relative to polarity zones.]

(7) External -- Africa and South America Basins

This major "*Western Gondwana*" datapack with map interfaces currently includes most major basins in Africa (15 basins, 114 columns) and in eastern South America (especially Brazil and Colombia; 33 basins, including biostratigraphy columns with 500 images in popups). Rebecca Bobick coordinated the project and compiled most of the African basins (with many more to go), and visiting students from Brazil and Colombia compiled those regions. The current age model is GTS2016; but we will migrate these to the GTS2020 model in the future.

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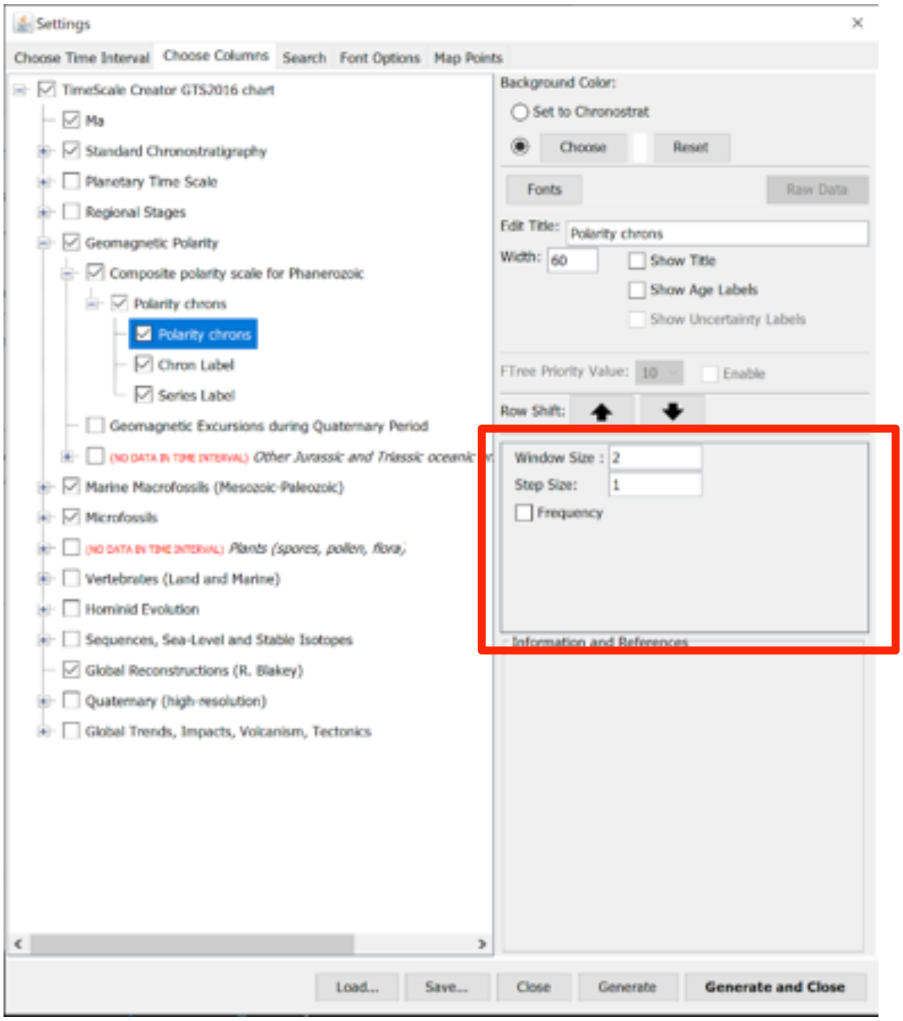
(III) TSC 8.0 software program enhancements

(1) Data-mining within TSCreator of datasets

Last year, two computer-engineering students (Eric Langbert, Garret Cagle) working with Andy Zehady (finishing his PhD at Purdue) added some simple data-analysis routines within TSCreator.

(a) FREQUENCY of Events/Zones – When one highlights a column of event (datum) or block (zone) type, then one can obtain a sliding-window analysis of the frequency per unit time. The next figures is applying this to Magnetic Polarity, using two settings:


Settings
Choose Time Interval
Choose Columns
Search
Font Options
Map Points
TimeScale Creator GTS2016 chart
Ma
Standard Chronostratigraphy
Planetary Time Scale
Regional Stages
Geomagnetic Polarity
Composite polarity scale for Phanerozoic
Polarity chrons
Polarity chrons
Chron Label
Series Label
Geomagnetic Excursions during Quaternary Period
(NO DATA IN TIME INTERVAL) Other Jurassic and Triassic oceanic
Marine Macrofossils (Mesozoic-Paleozoic)
Microfossils
(NO DATA IN TIME INTERVAL) Plants (spores, pollen, flora)
Vertebrates (Land and Marine)
Hominid Evolution
Sequences, Sea-Level and Stable Isotopes
Global Reconstructions (R. Blakey)
Quaternary (high-resolution)
Global Trends, Impacts, Volcanism, Tectonics
Background Color:
Set to Chronostrat
Choose
Reset
Fonts
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Edit Title:
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60
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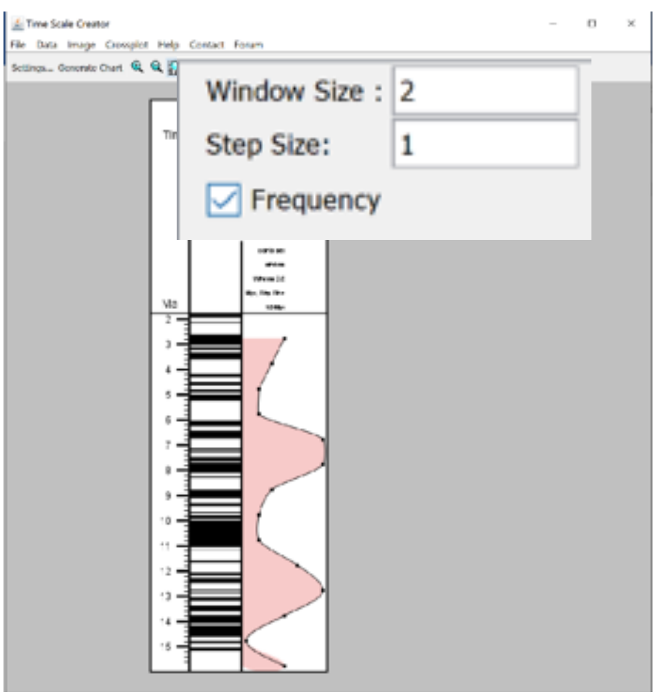
Show Age Labels
Show Uncertainty Labels
FTree Priority Value:
10
Enable
Row Shift:
Window Size :
2
Step Size:
1
Frequency
Information and References
Load...
Save...
Close
Generate
Generate and Close


Time Scale Creator
File
Data
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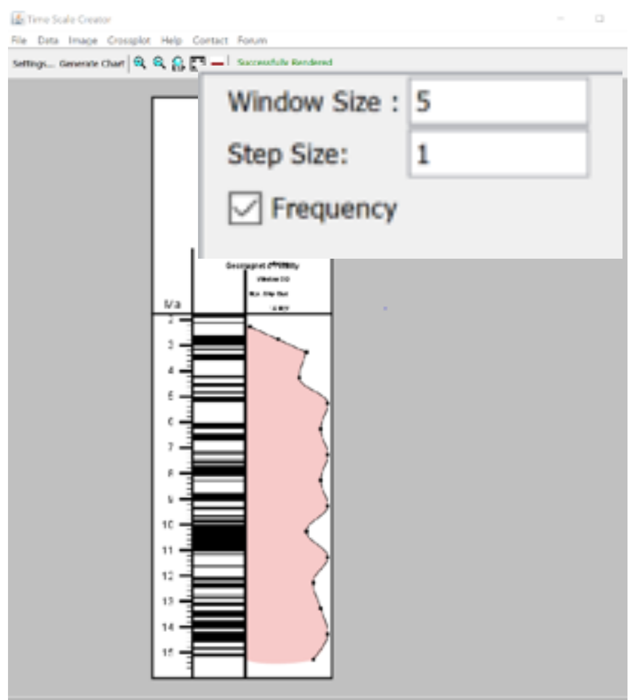
Crossplot
Help
Contact
Forum
Window Size :
2
Step Size:
1
Frequency
Ma


Window Size :
5
Step Size:
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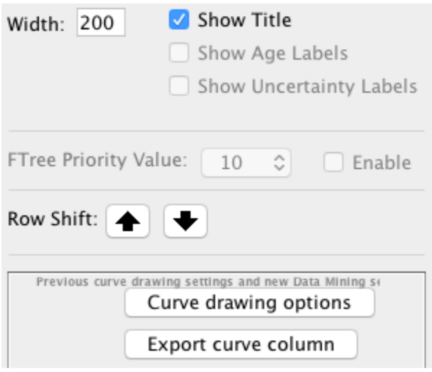
(b) CURVES – Smoothing, Rate of Change

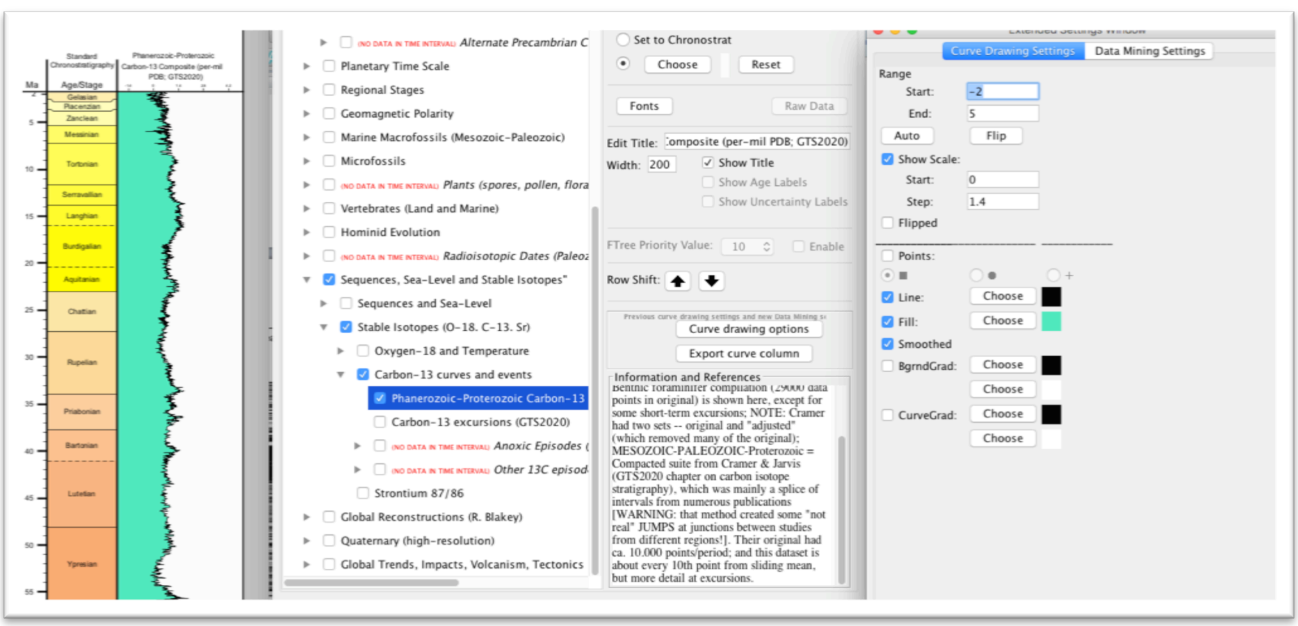
When one selects a Curve column, then the right-panel has a separate "Curve drawing options" button.



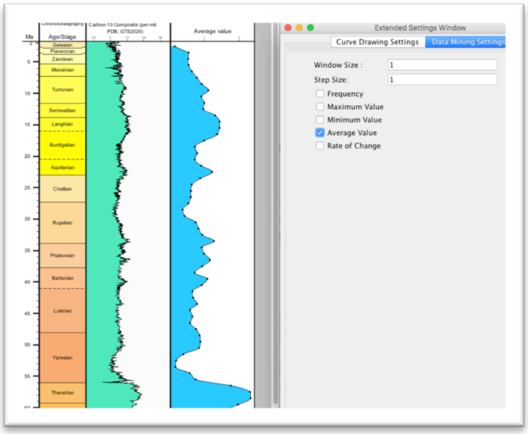
Click this to access the previous suite of scale, color and background settings; but there is an additional "Data Mining Settings" with options on a sliding window to obtain minimum, maximum, average and "rate of change".

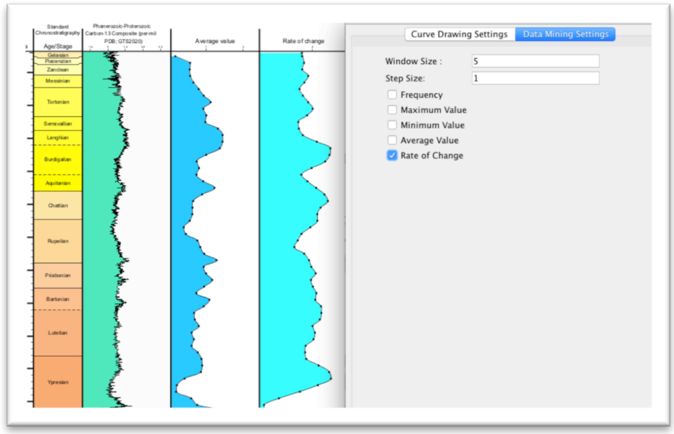
Note on the main right-panel that one can then later highlight the resulting data-analysis curve to export the values for later statistical analysis.

The following figures have chosen the Carbon-isotope curve to (1) obtain the *average* values using a 1-Myr window, and then (2) compute the average *rate-of-change* over a 5-Myr window. Clicking the "Curve drawing" button opens a new Window with two top menu bottoms. Select "Data-mining" to see the options; then, after clicking Generate on the main set, it will ADD a resulting data-analysis curve next to the one you had selected. Warning: You must de-activate the data-analysis options when satisfied, otherwise it will continue to add new curves each time you click "generate".

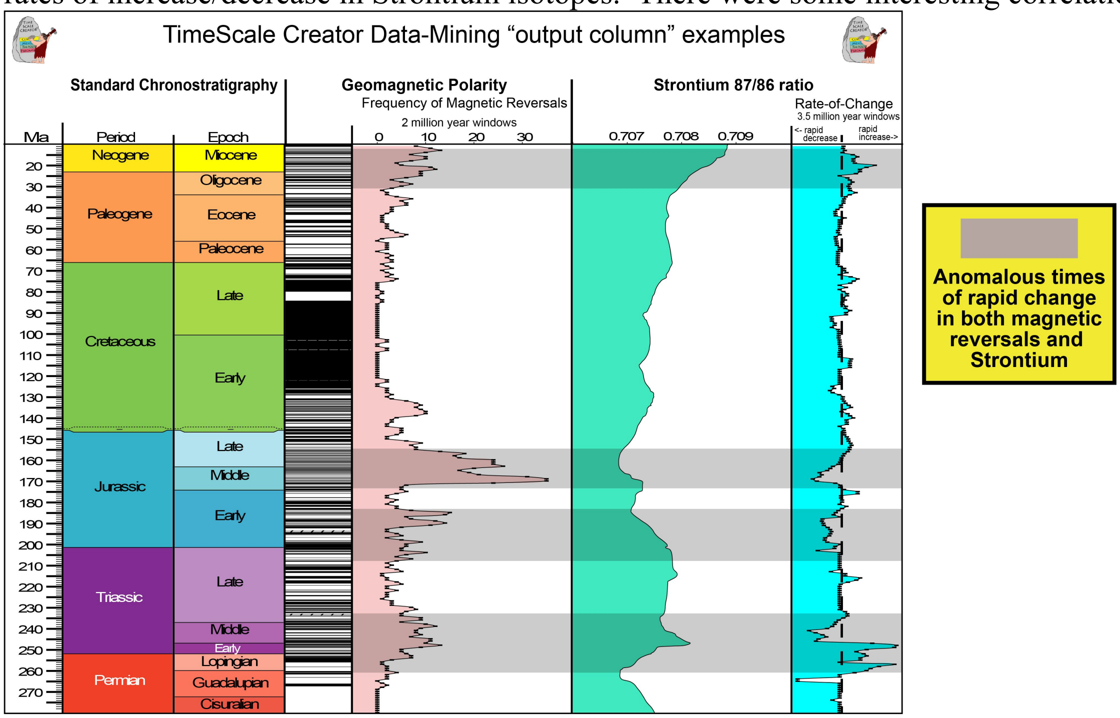


BLUE = Smoothing with 1-Myr window; then Cyan = Rate of change over 5-myr window





The students applied these to Mesozoic-Cenozoic magnetic polarity (frequency) to compare to rates of increase/decrease in Strontium isotopes. There were some interesting correlations:



(2) Micro-evolution within Macro-evolution display

A two-year project by Abdullah (Andy) Zehady and Barry Fordham to enable TSCreator to superimpose "micro-evolution" of species within their macro-evolution lineages was recently published (Zehady et al., 2019, Scientific Reports, 9:18968 *https://doi.org/10.1038/s41598-019-55435-w)*. This report includes example datapacks, and a manual on constructing datasets for this type of state-of-art display of evolution.

SCIENTIFIC REPORTS
natureresearch

Integrated species–phenon trees: visualizing infraspecific diversity within lineages

Abdullah Khan Zehady[1], Barry G. Fordham[2*] & James G. Ogg[3,1]

From Abstract: "Our integrated species–phenon tree merges ancestor–descendant trees for fossil morphotaxa (phena) into reconstructed phylogenies of lineages (species) by expanding the latter into "species boxes" and placing the phenon trees inside."

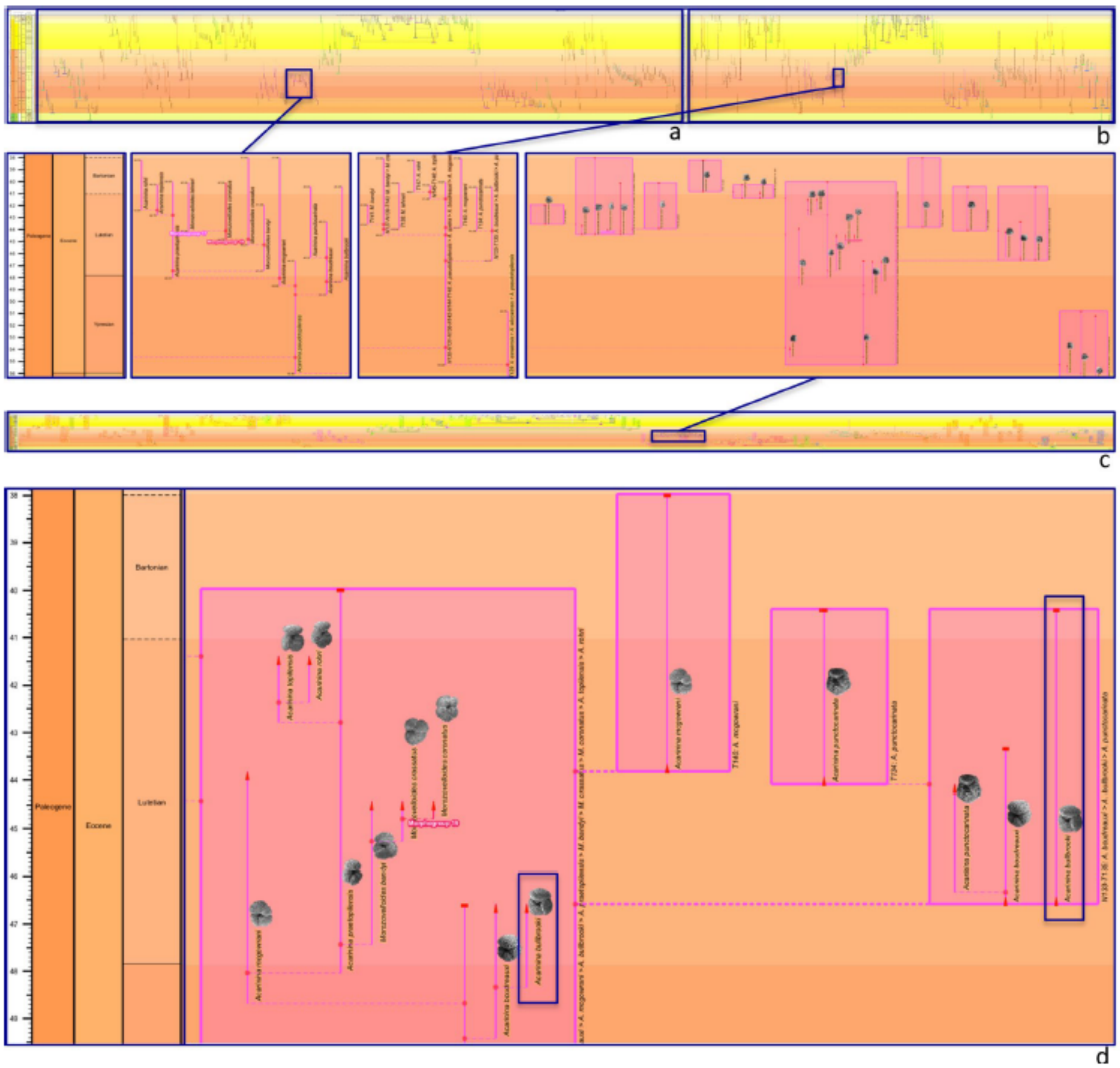


Figure 3. Derivation of an integrated species–phenon tree for the case study of Cenozoic macroperforate planktonic foraminifera[1]. Evolutionary-tree charts drawn by *TimeScale Creator* datapacks, (**a–c**) against entire Cenozoic time scale (the last 66 Myr), with insets of a Ypresian–Bartonian (Eocene) clade which begins with a

(3) Reminder – Previous "What's New"

See previous "What's New" (at *https://timescalecreator.org/download/download.php*; item #8) for details on 7.4 and earlier version enhancements. These include cross-plots, search capabilities (only in Pro), gradient-backgrounds, synonyms, map-pack usage, depth-to-age conversions, and many other developments from our enthusiastic computer-engineering students working with geology users.

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Current projects that you are helping support (a subset):

(1) Datapack makers (browser-based)

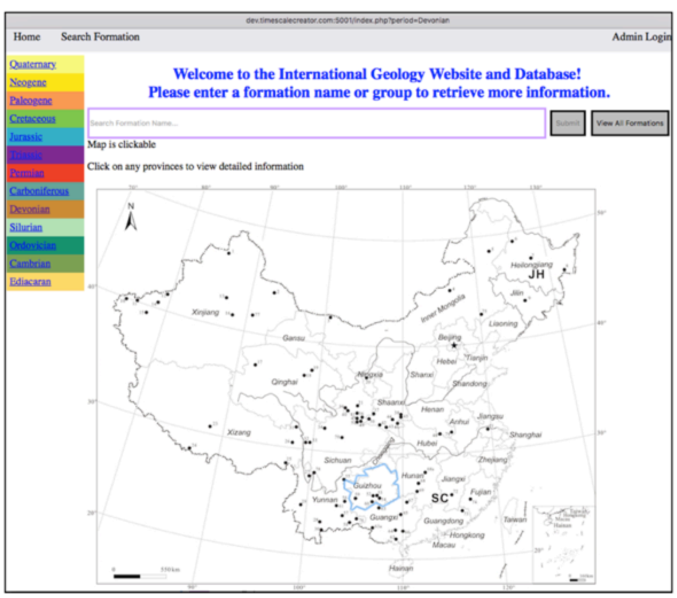
We have functioning browser-based “Transect Maker” which also has options for outputting map-pack format for the transect reference wells and segments.

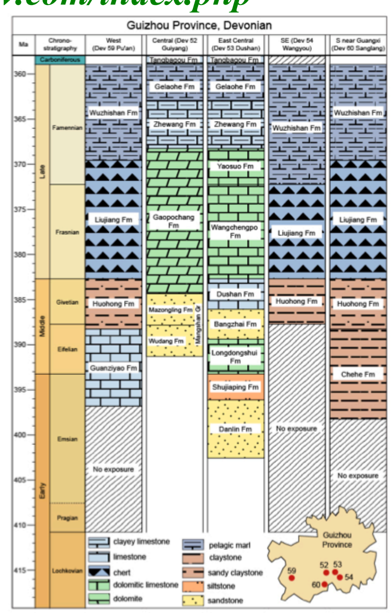
The release of this “transect-maker” was accompanied by a convenient “Curve Maker”; and these are explained in the new manuals (see first page of this letter). These should enable a more streamlined error-free method of making your own datapacks and mappacks. Our goal is an integrated set of datapack makers using browser-based interfaces.

(2) Southeast Asia regional datapacks

We are working with local experts to assemble detailed datapacks for basins and margins of southeast Asia: India-Pakistan and offshore, Thailand, Vietnam, China. The details on each regional geologic formation are being simultaneously uploaded to new "Lexicons" with a database generated page for each. The current software project is accessing the Lat-Long "GeoJSON" of a Formation with its age to project its position onto an appropriate GPlate reconstruction for that same age.

Partial demo set at: *http://china.oada-dev.com/index.php*





Gaopochang Fm

ID: 56
Period: Devonian
Age Interval: D2-3 (52), Middle to Late Devonian
Province: Guizhou

Type Locality and Naming
The type section is located at Shuitangzhai, about 3 km south of Gaopochang of Huaxi District, Guiyang City, Guizhou Province. It was named by Guizhou Team of Regional Geological Survey in 1978 and Quoted formally by Guizhou Bureau of Geology and Mineral Resources in 1978.

Lithology and Thickness
Dolomite. The formation is a set of carbonate rocks subdivided into four lithologic members: clayey dolomite, vuggy dolomite, dolomite and pisolitic limestone members, respectively.The formation is 479 m in thickness

Relationships and Distribution
Lower Contact: Conformably on the underlying thick-bedded quartz sandstone of the Mangshan Group or Mazongling Fm.
Upper Contact: This formation is overlain by grayish-black thin-bedded clayey limestone of Zhewang Fm.
Regional Extent: It is restrictedly distributed in Guiyang to Kaili area.

Fossils
The clayey dolomite of the lower part yields brachiopods Schizophoria excellens, Ambocoelia sinensis.

Age: Middle to Late Devonian

Depositional setting
It is interpreted as a lagoonal depositional environment.

(3) Known "bugs"

(a) Sometimes (randomly?), the top labels are not fitting the columns. For now, one usually just "Generates" a second time to fix the offsets; and/or widens columns to re-center the titles.

(b) The "priority" in Evolution trees seems to have stopped working. We're fixing this.

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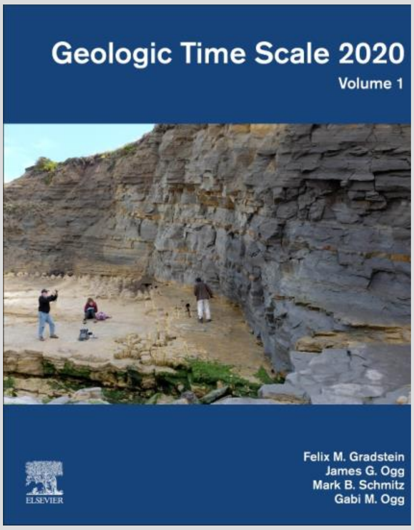
As always, we appreciate any requests that you may have for software enhancements, user interfaces or reference datapacks.

Thank you,

James Ogg (TSCreator coordinator; etc.)
Gabi Ogg (TSC website; etc.)
Aaron Ault (Purdue Computer Engineering)
Brian Huber (GTS Foundation, new Chair)
Felix Gradstein (GTS Foundation, former Chair)

With: Andy, Suyash, Sree, Joshua, Peter, Nicki, Wendy, Wen Du, and other Purdue computer-engineering and geoscience students



Geologic Time Scale 2020

Edited by: **Felix M. Gradstein**, University of Oslo, Norway; Chronostratigraphy, paleontology; **James G. Ogg**, Chengdu University of Technology, Sichuan, China; Integrated Earth history, paleomagnetics; **Mark B. Schmitz**, Boise State University, Idaho, USA; Geochronology; and **Gabi M. Ogg**, Geologic TimeScale Foundation, West Lafayette, Indiana, USA; Paleontology, geo-graphics

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TRIM: 8.5w x 10.875h
PAGES: c. 1268
AUDIENCE: Academic and professional geoscientists. Both text and illustrations are directly useful to teachers, to students, and to practicing geoscientists

https://www.elsevier.com/books/geologic-time-scale-2020/gradstein/978-0-12-824360-2

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Update on the standard international framework for deciphering the history of our planet, providing a complete stratigraphy of all periods and stages

KEY FEATURES

- Completely updated geologic time scale
- Provides the most detailed integrated geologic time scale available that compiles and synthesize information in one reference
- Gives insights on the construction, strengths and limitations of the geological time scale that greatly enhances its function and its utility

DESCRIPTION

Geologic Time Scale 2020 (2 volume set) contains contributions from 80+ leading scientists who present syntheses in an easy-to-understand format that includes numerous color charts, maps and photographs. In addition to detailed overviews of chronostratigraphy, evolution, geochemistry, sequence stratigraphy and planetary geology, the GTS2020 volumes have separate chapters on each geologic period with compilations of the history of divisions, the current GSSPs (global boundary stratotypes), detailed bio-geochem-sequence correlation charts, and derivation of the age models.

The authors are on the forefront of chronostratigraphic research and initiatives surrounding the creation of an international geologic time scale. The included charts display the most up-to-date, international standard as ratified by the International Commission on Stratigraphy and the International Union of Geological Sciences.

As the framework for deciphering the history of our planet Earth, this book is essential for practicing Earth Scientists and academics.

EARTH & ENVIRONMENT
Geology
www.elsevier.com

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Appendix 1. Color code according to the Commission for the Geological Map of the World
Appendix 2. Radioisotopic dates used in GTS2020

ELS

	Age/Stage	GTS2012	GTS2016 *(if updated from GTS2012)*	GTS2020	GTS2020 uncertainty in myr (95%)	**Snapshot comments on selected levels.** Stages or series that changed boundary age by 0.5 Ma or more in GTS2020 compared with GTS2012 are shown in red.
Quaternary	TOP	0 (2000)				
	Meghalayan			**0.004250**		New Holocene stage
	Northgrippian			**0.008236**		New Holocene stage
	Greenlandian	0.0118		**0.01170**		Base of Holocene Epoch; New Holocene stage
	Upper Pleistocene	0.126		**0.129**		
	Chibanian	0.781	0.773	**0.774**		GSSP and new stage name ratified in 2020; just slightly lower than working definition in GTS2016.
	Calabrian	1.806	1.80	**1.80**		Revised correlation of GSSP horizon to astronomical cycles
	Gelasian	2.59	2.58	**2.58**		Revised correlation of GSSP horizon to astronomical cycles
Neogene	Piacenzian	3.60		**3.60**		
	Zanclean	5.333		**5.335**		
	Messinian	7.246		**7.25**		
	Tortonian	11.63	11.625	**11.625**		
	Serravallian	13.82		**13.82**		
	Langhian	15.97		**15.99**		Enhanced magneto-cyclostratigraphic accuracy
	Burdigalian	20.43	20.44	**20.45**		,, ,,
	Aquitanian	23.03		**23.04**		,, ,,
Paleogene	Chattian	28.09		**27.29**		Ratified GSSP uses a higher marker and with revised magneto-cyclostratigraphic correlation
	Rupelian	33.89	33.90	**33.90**		
	Priabonian	37.80	37.99	**37.71**		Enhanced magneto-cyclostratigraphic accuracy; and Priobonian GSSP is slightly different than working definitions in GTS2012/2016
	Bartonian	41.20	41.03	**41.03**		Enhanced magneto-cyclostratigraphic accuracy
	Lutetian	47.82	47.84	**48.07**		,, ,,
	Ypresian	55.96		**56.00**		
	Thanetian	59.24		**59.24**		
	Selandian	61.61		**61.66**		,, ,,
	Danian	66.04		**66.04**	0.1	Precise lower stage boundary age date
Cretaceous	Maastrichtian	72.05		**72.17**	0.2	
	Campanian	83.64	84.19	**83.65**	0.5	
	Santonian	86.26		**85.70**	0.2	Revised marker and cyclostratigraphy
	Coniacian	89.77	89.75	**89.39**	0.2	Revised radioisotopic dating and cyclostratigraphy
	Turonian	93.90		**93.90**	0.2	Precise lower stage boundary age date
	Cenomanian	100.50		**100.50**	0.1	,, ,,
	Albian	112.95	113.14	**113.20**	0.3	Ratified GSSP uses slightly older marker
	Aptian	126.30		**121.40**	0.6	Major change in GTS2020 = New radioisotopic dating and magnetostratigraphy near base-Aptian boundary.
	Barremian	130.77		**126.50**	0.7	Revised cyclostratigraphic duration of stage (ca. 5 myr) relative to base-Aptian and new radiometric date for upper Hauterivian
	Hauterivian	133.88	134.69	**132.60**	0.6	Early Cretaceous spline fit with Hauterivian stage duration set as 6.1 myr (French cyclostrat)
	Valanginian	140.18	139.39	**137.70**	0.5	Spline fit to radiometric dates with Valanginian stage duration set as 5.1 myr (French cyclostrat)
	Berriasian	145.01	145.01 or 145.73	**143.10**	0.6	Base-Berriasian working definition (older option in 2016 and used in 2020) uses new marker compared to GTS2012. Spline fit to new radiometric dates with Berriasian stage duration as ca. 5.4 myr.
Jurassic	Tithonian	152.06		**149.24**	0.7	Tithonian through Bajocian from magnetostrat correlations to a spline-fit of M-sequence spreading rates as constrained by the base Berriasian age and stage durations from cyclostratigraphy.
	Kimmeridgian	157.30	157.25	**154.78**	0.8	See above, plus GSSP being voted (early 2020) uses a younger level.
	Oxfordian	163.47	163.10	**161.53**	1.0	See explanation for Tithonian; plus GSSP working definition uses a slightly younger level. No GSSP yet.
	Callovian	166.07		**165.29**	1.1	*See explanation for Tithonian*
	Bathonian	168.28		**168.17**	1.2	,, ,,
	Bajocian	170.30		**170.90**	0.8	Implied by revised Aalenian stage duration (3.8 myr) from cyclostratigraphy relative to base-Aalenian
	Aalenian	174.15		**174.70**	0.8	Implied by revised Toarcian stage duration (9.5 myr) from cyclostratigraphy relative to base-Toarcian
	Toarcian	182.70	183.70	**184.20**	0.3	Revised extrapolation of new radiometric dates to base-Toarcian
	Pliensbachian	190.82	191.36	**192.90**	0.3	Revised Pliensbachian stage duration (8.7 myr) from cyclostratigraphy relative to base-Toarcian
	Sinemurian	199.30	199.40	**199.46**	0.3	Implied by Hettangian stage duration (1.8 myr) from cyclostratigraphy relative to base-Hettangian
	Hettangian	201.30	201.36	**201.36**	0.2	Precise lower stage boundary radiometric date
Triassic	Rhaetian	209.46	205.81 / 209.56	**205.74**	0.1	Revised stage "working" boundary correlation to Newark cycle-scaled magnetostratigraphy. No GSSP yet; used proposed Italian candidate marker that is older than Austrian candidate (in GTS2012; older option in GTS2016).
	Norian	228.35	228.45	**227.30**	,,	Revised stage "working" boundary correlation to Newark cycle-scaled magnetostratigraphy. No GSSP yet.
	Carnian	237.00		**237.00**	0.5	
	Ladinian	241.50		**241.46**	0.3	Precise lower stage boundary radiometric date
	Anisian	247.06	246.80	**246.70**	0.2	Cycle-duration (3.2 myr) relative to revised base-Induan date used in GTS2016/2020, plus radiometric dating of potential GSSP

	Age/Stage	GTS2012	GTS2016 *(if updated from GTS2012)*	GTS2020	GTS2020 uncertainty in myr (95%)	**Snapshot comments on selected levels.** Stages or series that changed boundary age by 0.5 Ma or more in GTS2020 compared with GTS2012 are shown in red.
	Olenekian	250.01	249.81	**249.88**	0.2	Cycle-duration (2.0 myr) relative to revised base-Induan date used in GTS2016/202. No GSSP yet; used S.China candidate with conodont
	Induan	252.16	251.90	**251.90**	0.3	Revised precise radiometric dates on GSSP relative to GTS2012.
Permian	Changhsingian	254.20		**254.24**	0.4	
	Wuchiapingian	259.81		**259.55**	0.4	Revised spline fit
	Capitanian	265.14		**264.34**	0.4	,, ,,
	Wordian	268.80		**269.21**	0.4	New radioisotopic dating
	Roadian	272.30		**274.37**	0.4	,, ,,
	Kungurian	279.33	282.00	**283.30**	0.4	Revised working definition in GTS2020 uses a younger marker and new spline fit
	Artinskian	290.06		**290.51**	0.4	Updated marker, revised spline fit
	Sakmarian	295.53	295.50	**293.52**	0.4	Ratified GSSP definition in GTS2020 uses a younger marker, revised spline fit
	Asselian	298.88		**298.89**	0.4	Precise lower stage boundary age date
Carboniferous	Gzhelian	303.67	303.40	**303.68**	0.4	in GTS2016 different makers were used for the base. GSSP marker not yet decided.
	Kasimovian	306.99	306.65	**307.02**	0.4	in GTS2016 different makers were used for the base. GSSP marker not yet decided.
	Moscovian	315.16	314.60	**315.15**	0.4	in GTS2016 different makers were used for the base. GSSP marker not yet decided.
	Bashkirian	323.23		**323.40**	0.4	
	Serpukhovian	330.92		**330.34**	0.4	revised spline fit
	Visean	346.73		**346.73**	0.4	,, ,,
	Tournaisian	358.94		**359.30**	0.3	,, ,,
Devonian	Famennian	372.24		**371.10**	1.1	Pragian through Famennian spline fit to new or updated correlation of radioisotopic dates
	Frasnian	382.69		**378.90**	1.2	,, ,,
	Givetian	387.72		**385.30**	1.2	,, ,,
	Eifelian	393.25		**394.30**	1.1	,, ,,
	Emsian	407.57		**410.50**	1.1	,, Future Emsian GSSP gives 407.3 Ma age
	Pragian	410.78		**412.40**	1.1	
	Lochkovian	419.20		**419.00**	1.8	
Silurian	Pridoli *(Epoch)*	422.96		**422.73**	1.6	Tremadocian through Pridoli with spline fit to new or updated correlation of radioisotopic dates and improved composite standard
	Ludfordian	425.57		**425.01**	1.5	,, ,,
	Gorstian	427.36		**426.74**	1.5	,, ,,
	Homerian	430.45		**430.62**	1.3	,, ,,
	Sheinwoodian	433.35		**432.93**	1.2	,, ,,
	Telychian	438.49		**438.59**	1.1	,, ,,
	Aeronian	440.77		**440.49**	1.0	,, ,,
	Rhuddanian	443.83		**443.07**	0.9	,, ,,
Ordovician	Hirnantian	445.16		**445.21**	0.9	,, ,,
	Katian	452.97		**452.75**	0.7	,, ,,
	Sandbian	458.36		**458.18**	0.7	,, ,,
	Darriwilian	467.25		**469.42**	0.9	,, ,,
	Dapingian	469.96		**471.26**	1.0	,, ,,
	Floian	477.72		**477.08**	1.2	,, ,,
	Tremadocian	485.37		**486.85**	1.5	New radioisotopic dating and spline-fit
Cambrian	Age 10	489.5		**491.0**		,, ,,
	Jiangshanian	494.0		**494.2**		
	Paibian	497.0		**497.0**		
	Guzhangian	500.5		**500.5**		
	Drumian	504.5		**504.5**		
	Wuliuan	509.0		**509.0**		New Cambrian stage and GSSP ratified (was "Age 5" in GTS2012/2016
	Age 4	514.0		**514.5**		
	Age 3	521.0	ca. 520	**521.0**		
	Age 2	529.0	ca. 530	**529.0**		
	Fortunian	541.0		**538.8**	0.6	Revised radioisotopic dating
Ediacaran		635.0		**635.0**		
Cryogenian		850.0	720.0	**720.0**		

TimeScale Creator datasets *(thematically ordered)* *GTS2020 age models*

59,000 datalines; in 480 columns (are curves) that are grouped into a 200 directory-subdirectory hierarchy as given below. Most text entries have pop-ups with calibrations, sources and comments. *Mouse-Over option brings up windows with details on zones/events; which include direct URL hot-links to GSSP documentation (Geologic TimeScale Foundation), Microfossil taxonomy (Planktonic Forams, Nannofossils, Radiolarians, Dinoflagellate Cysts), Large Igneous Provinces, and Impacts*

Category Group and sub-group	Subsets	*Columns*	Sources (selected major ones)
Standard International Chronostratigraphy		17 columns	
Standard Chronostratigraphy		*Eon, Era, Sub-Era, Period, Sub-Period, Epoch, Sub-Epoch, Age/Stage, Substage*	International Commission on Stratigraphy [http://www.stratigraphy.org/. Details on boundaries/GSSPs are at Geologic TImeScale Foundation [http://timescalefoundation.org/gssp].
			Sub-Epochs are a special Cenozoic set with divisions as suggested by ICS subcommissions (but official for Pleist-Holocene). Color-usage here are of their lower Stage division.
	Lt. Pleistocene-Holocene detail	*Lt.Pleist-Holocene Epochs, Sub-Epoch, Stages, GSSPs*	***Use 20cm/myr to see details.***
GSSPs *(boundary stratotypes)*		*GSSPs*	The base of each unit of the geologic time scale is defined at a specific location and point (Global Boundary Stratotype Section and Point, GSSP), where it coincides with an array of paleontological, geochemical, paleomagnetic or other markers for high-resolution global correlation. The current status of currently ratified GSSPs (with strat section, images, etc.) and possible markers for the other geologic units are summarized with updated GTS2020 tables (with images) at Geologic TimeScale Foundation [http://timescalefoundation.org/gssp/] or at the main International Commission on Stratigraphy website [http://www.stratigraphy.org] .
Alternate Precambrian Chronostratigraphy		*Alternate Era / Period / Marker events*	Van Kranendonk et al. (2012), In: The Geologic Time Scale 2012
Planetary Time Scale		*10 columns*	Harald Hiesinger and Kenneth L. Tanaka. (2020) Planetary time scale. In: Geologic Time Scale 2020 (Gradstein, Ogg, Schmitz and Ogg; compilers; Elsevier Publ.)
	Moon	*Periods / Epochs / Events*	Events are from Tanaka, K.L., Hartman, W., 2012. The Planetary Time Scale. In: The Geologic Time Scale 2012; therefore may be slightly offset from the GTS2020 ages for Epochs.
	Mars	*Periods / Epochs / Events*	
	Venus	*Periods / Events*	
	Mercury	*Periods / Events*	
Regional Stages		59 columns	From GTS2020 period-chapters, plus other selected regions. [See extensive pop-up windows explaining disagreements or uncertainties in calibrations.]
Jur-Cret boundary regional stages - British and Boreal	**British** regional	*Stages / Substages*	Jur-Cret boundary = From different sources; especially articles by Bill Wimbledon, by Mikail Rogov, and the Jurassic-Cretaceous boundary working group through 2020
	Boreal regional	*Stages / Substages*	
North America regional units		*Series / Stages*	CRET (and PreCamb) = GeoWhen (compiled by R. Rohde; http://timescalefoundation.org) ; Permian from Henderson (2020); Carboniferous from Heckel (2015) and Davydov (1996; GTS2004; GTS2012), Silurian from GeoWhen (compiled by R. Rohde; at http://timescalefoundation.org); Ordovician from Goldman (GTS2020); Cambrian from Peng and Babcock (GTS2020)
	Type Mississippian Lithostratigraphy (USA)	*Lithostrat w/ Salem Lms wedge / N.Amer. Mid-Continent marker in Mississippian*	Generalized from Heckel et al., 2005; with additional correlations by Paul Brenckle, written commun., October 2006)
	California		GeoWhen (compiled by R. Rohde; at *http://timescalefoundation.org)*
European regional units	**Western European and British regional units**	***W. Europe-British*** *Series*	Cret = Traditional series-level divisions; Perm-Carb = GTS2020 and German Stratigraphic Commission (2002); Ordovician = Goldman (GTS2020), Cambrian = Shanchi Peng (GTS2020)
		East Avalonian *Series (Cambrian)*	Shanchi Peng and Babcock (GTS2020)
		W. Europe *Stages / Substages*	Cret = Traditional series-level divisions; Perm-Carb = Henderson (GTS2020), Aretz (GTS2020) and German Stratigraphic Commission (2002); Ordovician = Goldman (GTS2020); Cambrian = Shanchi Peng and Babcock (GTS2020)
		British *Substages (lower Carb)*	Aretz (GTS2020); Menning et al (2006), plus advice of Peter Jones (Aust. Natl. Univ.). *[See extensive pop-up windows explaining disagreements or uncertainties in calibrations.]*
	German Basin Triassic Lithostratigraphy	*Main Germanic Facies (generalized) / Folge divisions or Members*	LithDesc (partly Feist-Burkhardt, S., et al., 2008. Triassic. In: The Geology of Central Europe. See also Triassic Fossils (with strat) at www.palaeo-online.de. Early Triassic Folge are considered to be 100kyr periodicity by Backman, Menning, Kozur, Szurlies and others
Baltoscania regional units		*Series / Subseries / Stages / Substages*	Based on Regional Stage correlation chart of Dan Goldman, Apr 2019; and he advised (July 2019) to calibrate to Ordov. Stage Slices
Paratethyan Stages	Central Paratethys	*Stages / Defining events (FADs)*	Sources = Neogene chapter of GTS2020, which updated and enhanced W. Piller (Neogene chapter of GTS2012)

Category Group and sub-group	Subsets	Columns	Sources (selected major ones)
	Eastern Paratethys	*Stages/Substages for the **Dacian** / **Euxinian** / **Caspian** sub-basins; plus Defining events (FADs)*	Source = Neogene chart in GTS2020
Iberian-Morocco regional units (Cambrian)		*Series / Stages*	ORDOV (Iberian-Bohemia): Based on Regional Stage correlation chart of Dan Goldman, Apr 2019; and he advised (July 2019) to calibrate to Ordov. Stage Slices; CAMB: Geyer, G. & Landing, E. 2004. A unified Lower - Middle Cambrian chronostratigraphy for West Gondwana. Acta Geologica Polonica, 54 (2), 179-218; plus Peng and Babcock (GTS2020)
Russian and Ural regional units	**Russia Platform** regional units (Perm-Carb; Camb)	*Series / Stages / Substages or horizons / Permian horizons (pre-2005) and Carb sub-horizons*	Main sources are Perm-Carb = Henderson (GTS2016/2020, plus Davydov, GTS2012) and Aretz (GTS2020); Ordovician = Goldman (GTS2020); Cambrian = Shanchi Peng and Loren Babcock (GTS2020) *NOTE: See the extensive RUSSIAN BIOSTRAT DATAPACK for Russian regional zones and stages.*
	Donets Basin sub-units (Carb.)	*Substages or horizons / Sub-horizons*	Parlty from Menning et al. (DCP 2006) inter-calibrations to Russian stages
	NE Siberia regional units	*Carboniferous / Cambrian stage/substage*	Carb = Davydov (GTS2012) with partial revisions by Aretz (GTS2020); Cambrian = Peng and Babcock (GTS2016; GTS2020)
	Kazakhstan		Cambrian = Shanchi Peng (chair of subcommission, to J. Ogg, Dec. 2005), revised by Peng and Babcock (GTS2020)
Tethyan regional units (Permian)		*Stages **(Pamirs)** / Stages **(Salt Range)***	Henderson and Shen (GTS2020) and Davydov (GTS2012)
East Asian regional units	**South China**	*Series / Stages*	Permian-Carb from from Henderson (GTS2012, GTS2020) and from Menning et al, 2006; except Late Carboniferous from Zhang and Zhou (2007; Carb-Perm Congress); CHINA Ordovician stage names and calibrations are from Nat. Comm. Strat. China chart (2014). A modified set is in Zhang Yuandong, Zhan Renbin et al. (2019; Science China: Earth Sci. 62: 61-88) -- plus see other chapters in that special volume "Integrative strataigraphy and timescale of China" (Shuzhong Shen et al.). Cambrian series from Shanchi Peng (2003) Chronostratigraphic subdivision of the Cambrian of China. Geologica Acta, 1: 135-144 and Peng and Babcock (GTS2020). Older Jurassic-Triassic and Devon from GeoWhen (compiled by R. Rohde; at http://timescalefoundation.org).
	Yangtze Platform Triassic Lithostratigraphy	*Formations / **South China** cycles*	Late Triassic = Longchang, Guizhou (mainly Enos et al., 2006 GSA SpecPaper); Middle = Yongningzhen and Guandao, Guizhou (mainly Lehrmann et al., 2015 Jour Asian Earth Sci.); Early = Chaohu, Anhui (calibration by Mingsong Li et al., 2015. EPSL)
	North China / E. Yunnan	*Epoch / Age-Stage*	From Shanchi Peng (2003) Chronostratigraphic subdivision of the Cambrian of China. Geologica Acta, 1: 135-144. with updates from Peng-Babcock'19 Cambrian chapter of GTS2020.
	Japan	*Stages*	GeoWhen (compiled by R. Rohde; at http://timescalefoundation.org). Uncertain -- not mentioned by GTS2020 authors
Australia and New Zealand	**Australia**	*Stages (Cenoz; E.Paleoz.)*	Cambrian from Shanchi Peng and Loren Babcock (GTS2012/2016/2020); others from John Laurie (GeoScience Australia, to Jim Ogg, May 2007) and GeoWhen (compiled by R. Rohde; at http://timescalefoundation.org).
	New Zealand chronostratigraphy --	*Epochs, Stages, Substages, abbreviations, boundary markers*	Modified from Raine et al. (2015) "Revised calibration of the New Zealand Geological Timescale: NZGT2015/1" (GNS Science Report 2012/39; published Feb 2015); originally from Geological Timescale (Cooper et al., 2004) with Cenozoic and Cretaceous updated to the 2004 GPTS (Hollis et al, 2010). Ordov-Camb ages made consistent with same-name Australian stages
African regional units		***South Africa** (Precambrian)*	GeoWhen (compiled by R. Rohde; at http://timescalefoundation.org).
Geomagnetic Polarity		*5 columns*	
Composite polarity scale for Phanerozoic		*Polarity chrons*	GTS2020 composites: Quat = Channell-Singer-Jicha, 2020; C-sequence: Neogene-Paleogene = synthesis of many sources by Palicke for GTS2020; Maast-Camp = Husson et al. (2011) and Thibault et al. (2012); M-Seq with M-Sequence Extension [deep-tow upward projection to surface (M27r-M37r or 3km mid-depth for M38n-M44n) = GTS2020 GeomagChapter with spline-fit by Ogg-Agterberg incorporating Andy Gale's EarlyCret assigned stage-ages; Middle-Early Jurassic outcrop compilation with cycle-scaling by Hounslow-Mischa (see GTS2020 chapter); Late Triassic Newark from Kent et al (their 2018 updates) tied to CAMP basalts at top and candidate base-Norian GSSP (Pizza Mondello) for E8, then uncertain below. Triassic-outcrop based sets after Hounslow and Muttoni (2010), Zhang et al. (2020, Carnian), Muttoni et al. (various), Li (2016 with Yan Chen revisions 2020) etc. Late Permian after Steiner (2006). Early Permian-Ordovician = modified slightly from compilations GTS2012 and the Concise GTS 2016. NOTE that Hounslow et al. (2018 for Permian; 2019 for Paleozoic; 2020 pending for Carboniferous) has proposed other versions that should be incorporated; but most are similar to what is shown here.
Geomagnetic Excursions during Quaternary Period		*Events*	Use VERTICAL SCALE of 5x or higher! Compilation by Channell-Singer-Jicha (2020) that updated Brad S. Singer (2014; A Quaternary geomagnetic instability time scale. Quaternary Geochronology, 21: 29-52)
Other Jurassic and Triassic oceanic and outcrop reference scales	Secondary scales to main composite	***Pre-M26 Deep-Tow** at depth*	Marine magnetic anomaly series from M27r to M44n are rescaled from deep-tow surveys on Japanese lineations (Sager et al.; 1998; Tominaga and Sager, 2008). These anomalies are also projected upward (bottom table) to sea surface (M27r-M37r) or mid-depth (3km; M38n-M44n)
		Crussol. Poland, England Kimm-Oxf-Callov, Spain Bath-Bajo	Polish-England Oxf-Kimm composite from Przybylski, Ogg et al. (2010. with unpublished uppermost Kimm continuation at Crussol, and Callov from Rachel Gipe (2013. Purdue Univ. thesis), and Spain Bath-Bajo from Steiner-Ogg 1987
		***Late Triassic** outcrop magnetostratigraphy*	Modified from Hounslow and Muttoni (2010), Maron et al. (2019) and Zhang, Ogg et al. (2020)
Marine Macrofossils (Mesozoic-Paleozoic)			
Ammonoids		*19 columns*	

Category Group and sub-group	Subsets	Columns	Sources (selected major ones)
Ammonoids (Mesozoic)	**Tethyan** Ammonoids	*Zones / Subzones*	Revised using Klug et al. (2015) "Ammonoid Paleobiology" book (Springer); with initial sources being CRETACEOUS = Thierry et al. (in Hardenbol et al., SEPM charts, 1998), with GTS2004 and Kilian Group (2004-2015) revisions; JURASSIC = Groupe Francais d'etude du Jurassique (1997); TRIASSIC = Mietto and Manfrin (in Hardenbol et al., SEPM charts, 1998), with considerable revisions in GTS2004 using Kozur (2003 and pers. commun., 2006. 2010), plus Marco Balini (2010) and Mike Orchard (in GTS2020 Triassic chapter)revisions; Permian = Low-Latitude suite from Kozur (2003) and Henderson (GTS2020), but see Permian suite (under Paleozoic ammonoids) by Henderson (GTS2012/2020).
	North American Western Interior	*Zones / Close-spaced zones*	W.A. Cobban (2006), with GTS2008/2012 and Andy Gale (GTS2020) revisions. Intervals with close-spaced (less than 0.3 myr) zones have a separate column to avoid over-crowding.
	Sub-Boreal (Cret-Jur) and **Arctic** (Tri) Ammonoids	*Zones / Subzones*	Revised using Klug et al. (2015) "Ammonoid Paleobiology" book (Springer); with initial sources being CRETACEOUS = Thierry et al. (in Hardenbol et al., SEPM charts, 1998), with GTS2020 (Kennedy, Gale and Mutterlose) and Kilian Group (2004-2019) revisions; JURASSIC = Groupe Francais d'etude du Jurassique (1997) with GTS2020 (Hesselbo et al.) revisions, plus Mikail Rogov (pers. commun., etc., 2010-2011); TRIASSIC = Orchard-Tozer'97 (with M. Orchard revisions, GTS2020); PERMIAN = Henderson (2020).
	Boreal (Mesoz.) Ammonoids	***Russian Platform** ammonoids (zones/subzone)*	Mainly from Konstantinov and Klet as modified by Jenks et al. chapter in Klug et al. (2015) "Ammonoid Paleobiology" book (Springer). Initial sources include GTS2004 Jurassic chapter (original was compiled by Sven Backstrom, via Felix Gradstein, ~1995), and Groupe Français d'Étude du Jurassique (1997); Triassic Ammonites Zones of Siberia (Boreal realm) are compiled by Paul van Veen (in Hardenbol et al., SEPM 1998) from Kazakov & Kurushin (1992), Dagys & Weitschat (1989), Dagys & Konstantinov (1992) and Dagys (1991).
		***High Boreal (Siberia)** ammonoids (zones/subzone)*	
Ammonoids (Paleozoic)		*SuperZones abbreviation / Zones abbreviation*	Revised using Klug et al. (2015) "Ammonoid Paleobiology" book (Springer); with initial sources being PERMIAN = Henderson (2005, GTS2020), Davydov et al.,GTS 2004, Kozur, 2003; CARBONIFEROUS = GTS2004 and GTS2012 diagrams (Davydov et al., 2004, 2012) with revisions by Aretz (GTS2020) and Boardman-Work (2013) for USA; DEVONIAN = Becker (GTS2020). NOTE: Paleozoic zonations are not as well-standardized as for the Jurassic.
	Devonian	*Zones name / subZones name*	Devonian zonations, taxa names and relative age-calibrations (relaive to conodont "master" scale) are based on Thomas Becker's detailed chart (2010/2011; which was partly incorporated in GTS2012)
	Major ammonoid markers	*events*	
	Boreal (Perm-Carb Cis-Urals)	*Zones*	Revised using Klug et al. (2015) "Ammonoid Paleobiology" book (Springer); see above for other sources
	Russian Standard Carboniferous	*ammonoid Zones*	Zones are from Russian chart (2006) which referenced: Postanovlenia MSK É, 2003
	Carboniferous USA mid-continent	*ammonoid Zones / subzone*	David Work for GTS2008; and Boardman-Work (2013) for USA Pennsylvanian
	Mid-continent USA (late-Penn)	*subzones*	
Conodonts		*24 columns*	Main suites are TRIASSIC = Tethyan zones of Kozur'03 with modifications by Mike Orchard (in GTS2020); PERMIAN-CARBONIFEROUS = GTS2012 diagrams of Henderson and of Davydov (zones used for Spline-fit of this age scale); DEVONIAN = Becker (GTS2012/GTS2020) suite used for spline-fit age model; SILURIAN = "Standard" of Mike Melchin in GTS2012/GTS2020; ORDOVICIAN = Goldman (GTS2020) with earlier sources including North Atlantic conodont zones (Figure 2.2 in Webby et al. (2004; The Great Ordovician Biodiversification Event) and Roger Cooper (chart of Nov'2010 for GTS2012). Goldman-Sadler's (GTS2020) placement relative to Australia "CONOP/spline-fit" graptolie zones are used here.); CAMBRIAN = Peng and Babcock (GTS2020 graphics). See GTS2016/GTS2020 for additonal sources.
Conodont zones (general)		*Conodont zonation (selected)*	
		Conodont subzones (Ordovician)	Goldman (GTS2020)
		Conodont major markers	TRIASSIC = mainly Orchard and Tozer (1997) and Kozur (2003); PERM-CARB = GTS2012 diagrams of Henderson and of Davydov; DEVONIAN = Thomas Becker (GTS2012)
Conodont zones (regional and alternate)	**Triassic** other zonations	***West Tethys** zones (Lt. Tri.; Rigo et al., 2018)*	West Tethys (especially Italy and adjacent regions) Modified from Rigo, M., Mazza, M., Kar‡di, V., Nicora, A., 2018. New Upper Triassic conodont biozonation of the Tethyan Realm. In: Tanner, L.H. (Ed.) The Late Triassic World: Earth in a Time of Transition, Topics in Geobiology, 46, Springer Publ., p. 189-235)
		***South China** generalized zones*	South China generalized zones: Early Tri = Chaohu modified; Mingsong Li cycle-scalings -- but it seems each S. China section uses a variant; very confusing! Middle Tri = Guandao (Lehrmann et al., 2015); Carnian = lower from Haishui Jiang. Nor-Rhaet from Tong et al. (2018)
		Arctic/Panthalassan	Orchard's "Arctic/Panthalassia" as used in GTS2020, with his Calibrations to Western Canada Basin (British Columbia, "Boreal") zones tied to ammonoid zones by Orchard (pers. commun., Oct'19), who also provided references. GTS2012/2016 used (Orchard & Tozer '97; Orchard '07 and '10; with Early and Middle Triassic as diagrammed by Orchard (Fig. 9 in Lehrman et al., 2015)
	Permian-Carboniferous other zonations	*Numbered Zones (Carb-Perm; Davydov'04)*	Zone abbreviations used by Davydov (GTS04) for his graphical correlation results (mainly Eurasia)
		Permian zones of Davydov'04; Carboniferous of Lane'08 and Russian'06	Zones are from GTS2008 update to Davydov'04 using recommendations of Rich Lane (2008) and Russian biostratigraphy chart (2006) which referenced: Postanovlenia MSK ..., 2003
		***North American Mid-Continent** zones and datums (Carb.)*	Mississippian from Lane (2005); Pennsylvanian from Barrick et al. (2013; Stratigraphy); revised by Aretz (GTS2020)
	Devonian other zonations	***MN** (Montagne Noire) set*	Compiled and correlated by Thomas Becker for GTS2020
		Former pre-GTS2020 Devon. Zonations	Based on Thomas Becker's detailed chart (2010; delivered to Gradstein and Ogg); which had older zonal nomenclatures
	Ordovician other zonations	***Baltica** Ordov. Zones / Subzones*	Based on Goldman's (GTS2020) adjacent graptolite-conodont diagrams for Baltic (source of some U-Pb dates calibrated to those conodonts); even though he warns that there are very few conodont-graptolite calibrations for any region. NOTE: This set is also used in the Main Zonation synthesis
		***North American Midcontinent** Ordov Zones / Subzones*	Based on Goldman's (GTS2020) adjacent graptolite-conodont diagrams of N.Amer. mid-continent relative to Baltic conodonts
		***China** Ordov. Zones (N. / S. China)*	Based on Goldman's (GTS2020) adjacent graptolite-conodont diagrams of China relative to Baltic conodonts
	Cambrian Australia	*Zones / Subzones*	

Category Group and sub-group	Subsets	Columns	Sources (selected major ones)
Graptolites		15 columns	
Graptolite Zones (composite)		*Graptolite Zones (general) / Markers*	This hybrid Ordovician Australian and "standard" Silurian suite was used to scale the Ordovician-Silurian by CONOP method (Cooper, Melchin, Goldman, Sadler). Devonian zonations (relaive to conodont "master" scale) are based on Thomas Becker's detailed chart (2020; delivered to Ogg and Gradstein)
Regional Graptolite zones	Australian Ordovician	*Zone/SubZones abbreviation / Name / Markers / Other datums*	Numerical ages = Tied to Spline-CONOP2020 table (Sadler-Goldman, GTS2020) with Base of Silurian assumed for top of Bo5 zone. Biostratigraphy: Goldman-Cooper (GTS2020) with sources of VandenBerg & Cooper 1992; Cooper and Lindholm 1990. Age assignments for regional zonations of N.Amer., S.China, Britain and Baltoscandia are based on Dan Goldman's zonal-comparison chart for GTS2020 relaive to Australian zones; partly based on Cooper-Sadler (GTS2012).
	North American	*Zones*	
	South China	*Zones*	
	British	*Zones / Subzones*	
	Baltoscandia	*Zones / Subzones*	
Trilobites and pre-Trilobite biostratigraphy		11 columns	Zonal schemes from Peng and Babcock (2016 to J.Ogg for Concise GTS; and 2019 to G.Ogg for GTS2020); Ages based on placement relative to S.China trilobite zone "primary" (2019 to G.Ogg) NOTE: Includes Small Shelly Fossils, and some Archaeocyaths
South China trilobites		*Pelagic trilobites (**Agnostids**)*	
		*Benthic trilobites (**Polymerids**)*	
		Merged SSF-trilobite zones	
Siberia trilobites		*Main Siberia set / Alternate Siberia set*	
Australia trilobites		*zones*	
Laurentia trilobites		*Main Laurentia set / Alternate Laurentia set*	
Archaeocyaths (Austr., M.Camb.)		*zones*	
Early Paleozoic Biotic Events and Divisions		5 columns	
		Devonian crisis episodes	Becker GTS2020
		Silurian Major Biotic Events	Bioevents -- graptolite (G) and conodont (C) from Melchin (Aug'11; updated in GTS2020) using (Jaeger, 1991; Jeppsson, 1998; Melchin et al. 1998, Jeppsson et al., 2006)
		Ordovician-Silurian Stage Slices	*Silurian-Ordovician Stage Slices (Cramer et al., Lethaia, 2011; Stig Bergstrom & Chen Xu, Lethaia, 2007)*
		Ordovician time slice	*Ordovician Time Slices (Berry et al, 2004)*
		Major Cambrian markers	Peng and Babcock (GTS2020) with ages based on placement relative to S.China trilobite zone "primary" (graphic to G.Ogg)
Other Marine and Lacustrine Macrofossils		30 columns	
Belemnites		*NW Europe Zones / Subzones*	Main source = R. Combemorel (in Hardenbol et al., SEPM charts, 1998)
		Balto-Scandia Zones (Lt. Cret.); Tethyan (Oxf-Haut)	
		Tethyan subZones (Lt.Jur.)	
		Russian Platform Zones (Lt. Cret.)	
Bivalves (Inoceramids, Pelecypods, etc.)	**Cretaceous Inoceramids**	***N.Amer.** inoceramid Zones / Close-spaced Zones*	N.Amer. U.Cret. = Cobban et al., 2006, USGS report, with revisions by Andy Gale (GTS2020). Europe-Russia = A.V. Dhondt (Inoceramids) and Paul van Veen (Triassic pelecypods) (in Hardenbol et al., SEPM charts, 1998); Other columns from A.V. Dhondt (Inoceramids) and Paul van Veen (Triassic pelecypods) (in Hardenbol et al., SEPM charts, 1998)
		***Western European** Inoceramids*	
		***Aquitaine** Inoceramids*	
		***Central European/ Russian** Platform Inoceramids Zones / Markers*	
	Triassic Bivalves	***West Tethys** zones*	Ranges are from Chris Roberts, pers. commun., Aug 2007; for Triassic time scale special publication of 2010; Zones are McRoberts'10; but problem fitting zone names and ranges (many inconsisent usages?)
		***North America** zones*	
		***Boreal** zones*	
		***Ranges** - Genera / Species*	Ranges are from Chris Roberts, pers. commun., Aug 2007; for Triassic time scale special publication of 2010
	Siberian Pelecypod	*Zones / Subzone*	Paul van Veen (Triassic pelecypods) (in Hardenbol et al., SEPM charts, 1998)

Category Group and sub-group	Subsets	Columns	Sources (selected major ones)
Conchostracans		*Conchostracan Zones / Zonal markers*	Kozur and Weems (2010) and Kozur (pers. commun. to J.Ogg, 2011); as modified by Weems and Lucas (2015) and Geyer and Kelber (2018)
Brachiopods		***Tethyan** Zones / Subzone*	B. Laurin (in Hardenbol et al., SEPM charts, 1998)
		***Boreal** Zones / Subzone*	
Rudists		***Western Europe** datums*	J.-P. Masse and J. Philip (in Hardenbol et al., SEPM charts, 1998)
		***Periadriatic** datums*	
Ostracodes and Dacryonarids		***Boreal** Ostracode datums*	J.-P., Colin et al. (in Hardenbol et al., SEPM charts, 1998)
		***Tethyan** Ostracode datums*	
		***French** Ostracode Zones / Subzones / Datum*	J.-P., Colin et al. (in Hardenbol et al., SEPM charts, 1998)
		Devonian Ostracode Zones / SubZones / Datum	Devonian Pelagic ostracode zones are from Groos-Uffenorde et al (2000; Cour. Forsch.-Inst.Senckenberg 220:99-111; http://www.jstor.org/view/00223360/ap040327/04a00090/0). Relative calibration to conodont zones was revised by Thomas Becker (2019; diagram to J.Ogg for GTS2020)
		***Dacryoconarid** Zones (Devonian)*	Devonian Dacryonarid scale from Becker (GTS2020). Dacryoconarids are tentaculites -- an extinct genus of molluscs. The taxonomic classification is uncertain, but some group them with pteropods.
Microfossils			
Planktonic and Benthic Foraminifers		*35 columns*	
Planktonic Forams			All datums have popups with URL links to Mikrotax. Cenozoic = from Wade et al., 2011 (with revisions in Concise GTS2016/GTS2020). CRETACEOUS = May 2011 meeting of Late Cretaceous microfossil working group (UCL) modifying ODP Leg 171 and other scales, plus later revisions by Brian Huber and others (GTS2016/GTS2020). JURASSIC = Gradstein et al. (2017; J.Swiss Palaeo); update of B. Stam, 1986, G. Bignot and M. Janin, 1984
		Sub-Tropical Zones / Subzone	Cenozoic Sub-Tropical Zones from Wade et al., 2011 (with revisions in Concise GTS2016/GTS2020); Cretaceous from GTS2020 composite (different contributors)
		N,P Zones (Cenozoic)	Zonation of Blow, 1979; Berggren & Miller, 1988; Berggren et al'1995
		Formal Foram Zones name / SubZones name (Cenozoic)	
		Foram Zones Marker	
		Other Foram FAD/LAD	
		Additional Neogene and lesser Paleogene Foram FAD/LAD	Mainly these are events not in Wade et al'11; but were tabulated in Lourens et al'04 (esp. Medit.) or Berggren et al'95. Plus, a few of the events in Wade et al'11 that seemed relatively minor.
Benthic Foraminifers		*27 columns*	
Larger Benthic Forams		*Tethyan Shallow Benthic Zones (SBZ, etc.) / Markers*	Various authors in Hardenbol et al (SEPM charts, 1998): [SBZ set of Oligocene-Miocene = B. Cahuzac and A. Poignant. plus detailed Paleocene-Eocene = J. Serra-Kiel and L. Hottinger -- Larger foram vs Planktonic zone diagram sent by R.Speijer, Feb'11 for GTS2012. Cenozoic zone details from Working Group on Larger Foraminifera (SBZ zones): http://cenozoicforaminifera.com/. Upper Cretaceous = M. Bilotte. Lower Cretaceous = Annie Arnaud Vanneau. Jurassic & Triassic = B. Peybernes.]
		Other Larger Benthic Foram datums (Ceno-Cret)	
		Jurassic Larger Benthic Foram datums (Bassoullet'97)	Jean-Paul Bassoullet -- chapter on "Les Grands Foraminiferes"; in Groupe Français d'Étude du Jurassique (1997)
	Benthic Foram Letter stages (East Indies)	*Letter-stage / Benthic Foram Stage Datum (Philippines) / Other datums*	Matsumaru, Kuniteru, 2011. A new definition of the Letter Stages in the Philippine Archipelago. Stratigraphy, 8 (no. 4): 237–252.
Fusulinids and Benthic Forams (Carb-Perm)		*Benthic Foram Zones Abbreviation / Name*	Scheme of Davydov (GTS04)
		***Standard Permian-Carboniferous** fusulinid zone*	PERM = Shen and Henderson (Perm. Subcomm. Chart, 2013; assuming names of events are also names of zones), revised by Henderson and Shen (GTS2020); CARB = Zones are from Aretz (GTS2020) and some from Russian chart (2006) which referenced: Postanovlenia MSK …, 2003
		Benthic Foram Zones abbreviation of Davydov for Mississippian	
		Major Benthic-Foram Markers	Perm = Henderson and Shen (GTS2012, GTS2020); Carb = Aretz (GTS2020) and Davydov, 2004
	Regional Benthic-Foram scales (Carb-Perm)	*Boreal (Urals) Benthic Foram Zone*	Davydov (1996, Carb-Perm chapters in GTS2004, unpublished zonation table to GTS2004, and unpublished Permian correlation chart), with Mississippian revised by Aretz (GTS2020)
		Tethyan Benthic Foram Zone	
		N.Amer. Mid-Continent Zones / Assemblage / Marker	MISS = Paul Brenckle (pers. commun., October 2006; and in Lane and Brenckle, 2005), PENN = unpublished ExxonMobil'01, PERMIAN = Davydov (1996; 2001)
		Other N.Amer. Mid-Continent	Ross and Ross (1988, 1995b)

Category Group and sub-group	Subsets	Columns	Sources (selected major ones)
		North American Cordilleran Zones / Assemblages / marker	Paul Brenckle (pers. commun., October 2006; and in Lane and Brenckle, 2005)
Smaller Benthic Forams	Boreal Cret Smaller Foram	*Markers / Datums*	F. Magniez-Jannin (in Hardenbol et al., SEPM charts, 1998)
	Tethyan Jurassic (Ruget&Nicollin'97)	*Zones / Subzones / Markers*	Christiane Ruget and Jean-Pierre Nicollin -- chapter on "Les Petits Foraminiferes Bentiques Degages"; in Groupe Français d'Étude du Jurassique (1997)
	Tethyan Jurassic (SEPM'98)	*Zones / Markers / Other Datums*	F. Magniez-Jannin and C. Ruget (in Hardenbol et al., SEPM charts, 1998)
North Sea Microfossil Zones		*4 columns*	Gradstein et al. 2011 (partly based on Gradstein, Kaminski and Agterberg; 1999) -- see NORLEX datapack for extensive update, images, etc.
		Zones / Event	
		Deep-water agglutinated foraminifers	
Calpionellids		*4 columns*	J. Remane (in Hardenbol et al., SEPM charts, 1998), with GTS2004 revisions.
		Zones / SubZones / Abbrev. / Datums	
Calcareous Nannofossils		*19 columns*	All calcareous nannofossil datums have popups with URL links to Nannotax for individual images, etc.
Tropical and Mid-latitude Calcareous Nannofossils	CN, CC, NJT, NT	*Zones / SubZones / Zones name*	CENOZOIC (low and middle latitudes) = Backman-Agnini et al. (2012; 2014) with direct cycle-ages from Raffi et al. (Neogene GTS2020). Paleogene events reviewed and enhanced by Paul Bown, June 2011. Late CRETACEOUS = mainly Late Cret. working group (London, June2011), which modified Burnett (1999) and Erba et al (1995) as tabulated by ODP Leg 171B Init. Repts. (Table 2, p. 17-18). Middle and Early CRETACEOUS = compiled by Jim Bergen (while at BP-Amoco), based on publications by Tim Bralower et al (1995), J. Bergen (1994) and Eric de Kaenel. Tethyan Early-Middle Jur zones from Mattioli and Erba (1999); Late Jur zones from Casellato, 2011.
	NN,NP	*Zones / Subzone*	
	CN,CP,NC	*Zones / Subzone*	
	UC (Lt. Cret.)	*Zones / Subzone*	
	Tethyan Nanno Zone Marker		
	UC Tethyan Subzone Marker (if not NC-CC)		
	Other Tethyan Nanno FAD/LAD		
	Additional Plio-Pleist datums		High-resolution *(need expanded vertical scale)*; mainly Lourens et al. (GTS2004/GTS2012 tables)
Boreal Nannofossils	Boreal UC,BC,NJ,NT Nanno	*Zones / Subzone*	Upated from Paul Bown's book (1998). NEOGENE = updated in Raffi et al. (GTS2020); PALEOGENE = Composite of ODP studies -- reviewed and enhanced by Paul Bown, June 2011. Late CRETACEOUS = mainly Burnett (1998); Early CRETACEOUS = mainly Bown et al. (1998); JURASSIC = Bown and Cooper (1998); TRIASSIC = Bown (1998).
	Boreal NK Zones / KN Zones		
	Boreal Nanno Zone Marker		
	Boreal Nanno subzonal and other markers		
Dinoflagellate cysts, Acritarchs and Chitinozoans		*22 columns*	
Dinoflagellate cysts			All datums have popups with URL links to Dinoflaj3.
	N.Atl./Boreal	*Zones / SubZones / selected Markers*	CENOZOIC = King, C., 2016 -- In Geol.Soc.London Spec.Report 27 (2 chapters, and back-of-book Appendix); CRETACEOUS = mainly J.-C. Foucher and E. Monteil (in Hardenbol et al., SEPM charts, 1998). JURASSIC = Poulsen and Riding (2003). TRIASSIC = P.A. Hochuli (in Hardenbol et al., SEPM charts). SEPM Boreal Dinoflagellate Cysts compiled in SEPM chart by J.-C. Foucher and E. Monteil (1998 publ. Date)
		Costa & Manum'88 (Powell'04) Zones / subzone	D biozones of Costa and Manum (1988). Migrated and enhanced by Powell in GTS2004; Calibrations are based upon placement of FAD/LADs by Powell in GTS2004 figures.
		Other Boreal, NW Europe datums	
	***North Sea** (NORGES project*	*Zones / Events*	From the NORGES project sent in Nov. 2005. See the separate NORGES DATAPACK
	*Cenozoic of **NW Europe***	*Events (SEPM'98)*	Williams et al. (Cenozoic charts in Hardenbol et al., SEPM 60, 1998)
	Tethyan	*Cenozoic datums (high-res.)*	"W" = Low-lat, w. N.Atl., "I" = Italy; Williams et al. (Cenozoic chart in Hardenbol et al., SEPM charts, 1998); Neogene: Mediterranean and North Atlantic; Paleogene: Mediterranean
		E.Cret.-Jur. Zones	E. Monteil (in Hardenbol et al., SEPM charts, 1998)
		Tethyan Mesozoic zonal and other major markers	*(Triassic is mainly S.Hemis.)*; E. Monteil (in Hardenbol et al., SEPM charts, 1998)
		Other E.Cret. Tethyan markers	E. Monteil (in Hardenbol et al., SEPM charts, 1998)
Chitinozoa			DEVONIAN = from Becker (GTS2020 figures); SILURIAN = Standard Chitinozoan Zone (from subcommission); ORDOV = Goldman's (GTS2020) adjacent chitiniozoan-conodont diagrams for Baltic chitinozoans relative to Baltic conodonts
	Ordov-Silur-Devon	*Zones*	
	Other Devonian zones	*Zones / Datums*	Calibrations based on T. Becker table (Mar'19 for GTS2020)

Category Group and sub-group	Subsets	Columns	Sources (selected major ones)
	Other Ordovician Regional zones	*North American Chitinozoa Zone*	Figure 2.2 in Webby et al. (2004; The Great Ordovician Biodiversification Event); North America was in main zonal scale.
		North Gondwana Chitinozoan Zone	Based on Goldman's (GTS2020) adjacent chitiniozoan-conodont diagrams for Baltic chitinozoans relative to North Gondwana chitinozoans
Acritarchs	Acritarchs (Devonian)	*Events*	Becker (GTS2020 charts to J.Ogg)
Siliceous Microfossils		*21 columns*	
Diatoms			Based mainly on recommendations and datum reviews by John Barron and his colleagues in 2019-2020. Cenozoic radiolarian datums have popups with URL links to Mikrotax for taxonomy and images.
	Cenozoic **low-latitude** Diatoms	*Zones / Subzones / zonal Marker / other Events*	Low-Latitude zones and polarity calibrations from J. Barron (2015; 2006 - Site 1219) and Scherer, R.P., Gladenkov, A.Y., Barron, J.A. (2007) Methods and applications of Cenozoic marine diatom biostratigraphy, Paleont. Soc. Short-course; Main age calibration and other events/zones for Plio-Mio are revised using Raffi et al. GTS2020 (Table 29.6); although their Early Miocene calibrations are ca. 1 to 2 myr older than Barron (2006; Site 1219, used here). Additional Neogene events from earlier Barron-Baldauf papers used in GTS2012 version. Eocene zones/datums from Barron (2015; Palaeo-3); with some revisions after Witkowski et al (2020)
	North **Pacific mid-latitude** Diatoms (with global Paleoc-Eoc & Arctic Late Cret)	*Zones / SubZones / Abbrev. / zonal Marker / other Events*	Scherer-Gladenkov-Barron (2007) update of Neogene of Maruyama and Shiono (ODP Leg 186 Sci. Results; which was largely based on Maruyama (2000; ODP Leg 167, Sci. Results; which also suggested "NPD" abbreviations for zones modified from Yanagisawa and Akiba, 1998). Paleogene zones and boundary markers include Lt.Eoc. of Barron (2015). Zonal names abbreviated for convenience. Late Cret = Arctic zones/markers (Tapia & Harwood, 2002)
	South Ocean Diatoms	*Zones / Subzones / zonal Marker / other Events*	Scherer et al. (2007) for zones/datums. Other non-marker events from Baldauf, Barron, ODP 119/ Harwood Leg120 converting their ages from Berggren et al'95 scale - BUT VERY UNCERTAIN ON THIS LIST. Late Eocene from Barron (2015; Palaeo-3)
Radiolarians			CENOZOIC = Mainly Chris Hollis (GTS2020). MESOZOIC = partly from P. de Wever (in Hardenbol et al., SEPM charts, 1998), but Triassic includes some of Kozur (2003). Cenozoic radiolarian datums have popups with URL links to Mikrotax for taxonomy and images.
***Cenozoic-Jurassic** Radiolarians*	Radiolarians **(Low Latitude)**	*Zones / Marker / other major Datums*	
		Other Neogene Radiolarian datums (not used on PEAT table)	
	Southern mid-latitude zRP and Antarctic zRP zones	*Zones / SubZones (southern mid- and high latitude)*	Mainly from Chris Hollis (GTS2020; and pers. commun. to J.Ogg in 2019). Cenozoic radiolarian datums have popups with URL links to Mikrotax for taxonomy and images.
***Triassic-Permian** Radiolarians*	**Tethyan** Radiolarian	*Zones / Subzones*	Triassic-Permian Radiolarian zones are from Kozur'03 tables. Correlations are shown here relative to ammonite zones or his conodont zones in the same tables. Kozur (Jan 2006) provided additional details, especially onTriassic zonal boundary datums.
	N.Amer. (Triassic)	*Zones / Subzones*	Carter (1993), Kozur (2003)
	Major radiolarian events (Triassic)		
	Cis-Ural Radiolarians	*Zone (Permian)*	Kozur (2003)
Charophytes and Calcareous Algae		*4 columns*	Charophytes from J. Riveline (in Hardenbol et al., SEPM charts, 1998), and Early Cretaceous Green Algae from J.-P. Masse (in Hardenbol et al., SEPM charts, 1998)
	Charophyte	*Zones / Markers*	
	W Europe Calc. Algae	*horizons*	
	W Periadriatic Calc. Algae	*horizons*	
Plants (spores, pollen, flora)		*8 columns*	
Triassic spores and pollen	Pollen / Spores **(Germanic/Alpine)**	*Events*	Kürschner, W.M., and Herngreen, G.F.W., 2010. Triassic palynology of central and northwestern Europe: a review of palynofloral diversity patterns and biostratigraphic subdivisions. In: Lucas, S.G. (editor), The Triassic Timescale. The Geological Society, London, Special Publication, 334: 263-283; and P.A. Hochuli (in Hardenbol et al., SEPM charts, 1998)
	Pollen / Spores **(Arctic)**	*Events*	From SEPM chart (1998; converted to GTS2012)
Silur-Devon-Carb spores, pollen, flora	**Flora Macro**	*Zone (Dev-Carb)*	Plant macrofossils. Carboniferous = GTS2004 diagrams (Davydov et al., 2004). Devon = Becker (GTS2020); See http://www.devoniantimes.org/who/pages/archaeopteris.html and other pages at Devonian Times
	Western Europe Miospores	*Zones name / Abbreviation*	Devonian zonations relative age-calibrations (relaive to conodont "master" scale) are based on Thomas Becker's detailed chart (2020; delivered to Ogg and Gradstein); Abbreviations from Davydov et al. (GTS2004)
	Eastern Europe Miospores	*Abbreviation / EE zone*	Devonian zonations relative age-calibrations (relaive to conodont "master" scale) are based on Thomas Becker's detailed chart (2020; delivered to Ogg and Gradstein)
	Australian Spores (Devon)	*Zones / Subzones*	Australian: relationships to conodonts scheme taken from Young (in Young & Laurie, 1996) Price et al. 1985; Young in Young & Laurie 1996. Southeast Standard: Partridge 2006 & Backhouse, assorted). NOTE: Needs revision. Use detailed versions in Australian Datapack (TSCreator website)
		Zones (Southeast Std.)	Southeast Standard: Partridge 2006 & Backhouse, assorted
Vertebrates (Land and Marine)		*21 columns*	GTS2020/2016 diagrams
Fish and Reptiles (Silurian-Cretaceous)			

Category Group and sub-group	Subsets	*Columns*	Sources (selected major ones)
Amphibians-Reptiles (Carboniferous-Cretaceous)			Lucas, S.G., Sullivan, R.M., and Spielmann, J.A., 2012. Cretaceous vergtebrate biochronology, North American Western Interior. J. Strat., 36: 436-461.; Lucas, S.G., 2009. Global Jurassic tetrapod biochronology. Volumina Jurassic 6: 99-108"; Lucas, S.G., 2010d. The Triassic timescale based on nonmarine tetrapod biostratigraphy and biochronology. In: Lucas, S.G. (editor), The Triassic Timescale. The Geological Society, London, Special Publication, 334: 17-39. AND Perm-Carb from Lucas publications. SEE ALSO: http://www.devoniantimes.org/who/pages/densignathus.html and other pages on Tetrapods at Devonian Times
	Land Vertebrates	*Zones (faunachrons)*	
	Vertebrate Datum	*event*	Devonian zonations, taxa names (relative to conodont "master" scale) are based on Thomas Becker's detailed chart (2020; delivered to Ogg and Gradstein for his GTS2020 chapter).
Devonian-Silurian Fish	Sharks	*Zones (Devon)*	
	Armored Fish (Placoderm)	*Zones (Devon)*	
	Acanthodian-Thelodont	*Zones (Devon-Silur)*	
	Australian Early Fish	***Phoebondont** Assemblages*	
		***Turinid** Assemblages*	
Mammals			J. Hooker (GTS2020, GTS2012; and pers. commun. to J.Ogg, 2019) and Woodburne (2004)
North American Mammals	NALMA (Zones) / Subzones	*Zones / Subzones / Bioevents / other Bioevents*	
Europe Mammals	ELMA / MN-MP / Other	*Zones*	European Land Mammal Ages (ELMA). "an interesting quote from my communication with by Jerry Hooker last year: Oh dear. It's all rather a mess. MP levels aren't meant to span time, they are intended to be points in time and are defined on the whole fauna of the reference locality and ordered on evolutionary grade. So they are not really biostratigraphy, which is why I dislike them a great deal. " (Robert Speijer to J.Ogg, 3Sept2019)
		Bioevents / other Events	
Asian and China Mammals	ALMA / China LMA	*Zones*	
		*S.Asia **Neogene** bioevent*	
South America Mammals	SALMA	*Zones*	Neogene zonal ages are from J.A. Van Dam in Neogene chapter of GTS2012. Paleocene are from Hooker (GTS2012 chart); and Eocene-Paleocene from Woodburne et al. (Jour S.AmerEarthSci2014) with additional revisions by R. Speijer (GTS2020)
Australia		*Zones*	Neogene zonal ages are from J.A. Van Dam in Neogene chapter of GTS2012. All ages given as rounded Ma (implies no ties to polarity, etc.)
Hominid Evolution		*5 columns*	Main sources (from 2016 datapack) = Primate Fossil Record (Cambridge Univ Press; 2002); Tattersall & Schwartz (Evolution of Genus Homo; Ann. Rev. Earth & Planet. Sci., 2009); Australian Museum website; NOVA Human evolution website; Smithsonian website . NOTE: **Humanoid datapack** at TSC download page has images and active links.
Tool intervals (3 Ma, generalized)	Paleo-Neolithic / Tool cultures / Europe tool cultures	*Zones*	
	Main Homo and Australopithecus species	*Ranges*	
	Primate Evolution Major Events		
Radioisotopic Dates (Paleozoic)		*1 column*	Paleozoic dates used for GTS2020 age model spline-fits are positioned at the center of their biostratigraphic assignments. Popups have only a brief summary. Details are in GTS2020 Appendix (Mark Schmitz et al.) and relevant period chapters of the Paleozoic. Abbreviations for age control: C = conodont zone, F = benthic foraminifer zone, G = graptolite zone, Sub = within substage.
Sequences, Sea-Level and Stable Isotopes			
Sequences, Onlap and Sea-Level Curves		*38 columns total*	
Phanerozoic Sequences and Major Trends		*10 columns*	Paleozoic = Haq and Schutter (2008, Science) with Seq-stage-nomenclature ExxonMobil group (Chengjie Liu et al., Jan'08. who also modified some of the previous SEPM nomenclature for Ceno-Mesozoic; and I applied Bilal Haq's later (2018) Period-Stage-Number philosophy). Triassic = Haq (2018, GSA Today); Jurassic = Haq (2017, GSA Today); Cretaceous = revised from Haq (2014); Cenozoic = Hardenbol et al. (SEPM charts, 1998) with revisions by Chenglie Liu (2008). *[See GTS2020 chapter by Mike Simmons on Eustacy for a comprehensive review and critique.]*
		Sequences (Global, Tethyan)	
		Paleozoic Seq of Haq-Schutter'08 "Age-name"	Haq, B.U., and Schutter, S.R., 2008. A chronology of Paleozoic sea-level changes. Science (3 Oct 2008), 322: 64-68.
		Phanerozoic T-R Cycles	

Category Group and sub-group	Subsets	*Columns*	Sources (selected major ones)
		Mega T-R Trends	
Period-level Sequences	**Boreal Jurassic** *(SEPM98)*	*Sequences / T-R Cycles*	Hardenbol et al. (1998; SEPM); because they were uncertain on calibration to Tethyan sequences in parts of Jurassic.
	Paleozoic Sloss Sequences	*Mega- / Super-sequences*	Haq, B.U., and Schutter, S.R., 2008. A chronology of Paleozoic sea-level changes. Science (3 Oct 2008), 322: 64-68.
Perm-Carb-Dev *Sequences*	Major Perm-Carb-Dev sea-level trends	*Major* ***North American*** *Pennsylvanian glacials*	Heckel, 2013; and Ross-Ross'95
		Perm-Carb Main T-R episodes	
		Permian-Carb Major T-R Trends	
	E.Carboniferous Eurasian	*3rd-order sequences*	Mississippian (Early Carboniferous) 3rd-order from Aretz chart of 25Mar'19 for GTS2020
	Medium and High-resolution cycles	***Donets Basin*** *400-kyr cycle (Penn-earliest Perm)*	Schmitz-Davydov'12 drew saw-tooth sequences, with SB schematically as 1/16th (1/4th of 100kyr cycle) below MFS.
		Mid-Continent *400kyr or medium Devon-Carb-Perm Sequences*	Permian = Ross-Ross'95 plus Henderson (GTS2020, and pers.commun. to J.Ogg); lowermost Permian = Wardlaw (unpubl.); Upper Carb = Heckel, 2013; Heckel et al., 2007; Lower-Middle Carb = Ross-Ross'87/88; Devonian = Johnson et al. (1985)
		High-Resolution *Carb-Perm Sequences*	Heckel, 2013; and Ross-Ross'95
	Devonian *(Johnson'85)*	*T-R episode / cycles / trend / schematic curve*	Calibrations according to Becker (GTS2020 charts to J.Ogg)
Silurian-Ordovician *Sea Level*		***Silurian*** *Oceanic episodes (Jeppsson'06)*	Jeppsson (1998) as shown in Johnson (2006)
		Ordovician-Silurian Sea Level and Intervals (Nielson '04; Johnson '06)	Silurian = Johnson (2006); Ordovician = Nielsen (2004)
		Late Ordovician *Sequences (Central USA; Holland '08)*	Steven Holland (3 Mar'08; stratum@uga.edu ; to J.Ogg). See www.uga.edu/strata/ordoss and www.uga.edu/strata/cincy/strata/strata.html for details and references
	Ordovician Sealevel (Baltoscandia) *(Nielsen'04)*	*Events / Curve*	Silurian = inter-regional (Johnson, 2006); Ordovician = Baltoscandia (Nielsen, 2004)
		Silurian *schematic Sealevel (Loydell '98)*	Loydell (1998) as drawn and calibrated to graptolite zones by Mike Melchin (Aug'11 for GTS2012 charts)
Coastal Onlap (schematic)		*Coastal Onlap segmented (synthetic)*	Coastal onlap for CENOZOIC = offsets from long-term curve are directly from Hardenbol et al. (SEPM charts, 1998). MESOZOIC-PALEOZOIC = Schematic with SB Falls set from Bilal Haq's diagrams as Minor SB = 20m, Medium = 45m, Major = 80m relative to long-term envelope, based on advise from B. Haq to J.Ogg. [Cret = Haq'2014; Jur = Haq'2017; Tri = Haq'2018; Paleozoic = Haq and Schutter, 2008]
		Coastal Onlap (synthetic)	
Sea-level (m relative to present)	**Phanerozoic** synthesis *(Hardenbol-Haq)*	***Short-Term*** *Phanerozoic*	CENOZOIC = offsets from long-term curve are directly from Hardenbol et al. (SEPM charts, 1998). MESOZOIC-PALEOZOIC = Schematic with SB Falls set from Bilal Haq's diagrams as Minor SB = 20m, Medium = 45m, Major = 80m relative to long-term envelope, based on advise from B. Haq to J.Ogg. [Cret = Haq'2014; Jur = Haq'2017; Tri = Haq'2018; Paleozoic = Haq and Schutter, 2008]
		Mean *Sea Level (intermediate term; synthetic)*	Computed as mid-point of Coastal-onlaps. See above for method.
		Long-Term *Phanerozoic*	CENOZOIC = offsets from long-term curve are directly from Hardenbol et al. (SEPM charts, 1998). MESOZOIC-PALEOZOIC = Schematic with SB Falls set from Bilal Haq's diagrams as Minor SB = 20m, Medium = 45m, Major = 80m relative to long-term envelope, based on advise from B. Haq to J.Ogg. [Cret = Haq'2014; Jur = Haq'2017; Tri = Haq'2018; Paleozoic = Haq and Schutter, 2008]
	Cenozoic sealevel *(Miller et al., 2020)*	***Cenozoic*** *smoothed*	Miller, K.G., Browning, J.V., Schmelz, W.J., Kopp, R.E., Mountain, G.S., and Wright, J.D. 2020. Cenozoic sea-level and cryospheric evolution from deep-sea _18O and continental margin records. Science Advances. 6 (20), article #eaaz1346: 15 pp. https://advances.sciencemag.org/content/6/20/eaaz1346.full. Based on conversion of oxygen-isotope data. ["Smoothed sea-level estimates are from _18O and Mg/Ca (obtained by interpolating to 20-ka intervals and using a 49-point Gaussian onvolution filter, removing periods shorter than 490 ka)}. Timescale is GTS2012 (not migrated to GTS2020; because Miller et al., 2020, did not indicate whether biozones (or type) or chrons were used) => some excursions may be shifted by up to 1 myr?
		High-Res Plio-Pleist *Sea Level*	Miller, K.G., Browning, J.V., Schmelz, W.J., Kopp, R.E., Mountain, G.S., and Wright, J.D. 2020. Cenozoic sea-level and cryospheric evolution from deep-sea _18O and continental margin records. Science Advances. 6 (20), article #eaaz1346: 15 pp. https://advances.sciencemag.org/content/6/20/eaaz1346.full. Based on conversion of oxygen-isotope data
Stable Isotopes (O-18, C-13, Sr)		*28 columns (including overlays)*	
Oxygen-18 and Temperature			
	Plio-Pleist Marine Oxygen-18 composite	*Plio-Pleist Oxygen-18 composite (Benthic Foraminifera)*	Lisiecki, L. E., and M. E. Raymo (2005), A Pliocene-Pleistocene stack of 57 globally distributed benthic d18O records, Paleoceanography, 20, PA1003, doi:10.1029/2004PA001071. [scale = +2.5 to +5.2 per-mil PDB]. (Needs 20 cm/myr !! to see details).
		Marine Isotope Stages *-- Warm MIS / Cold MIS*	***(Needs 20 cm/myr !! to see details).*** Numbering, including Pliocene extension, from Crowhurst (2002) -- see above curve for relatively placement to their O-18 curve. Warm/interlacial MIS (odd numbers), and Cold/glacial MIS (even numbers) listed in seoparate columns to avoid over-crowding.
	Cenozoic-Campanian Marine Oxygen-18 Composite		Derived from Cramer (2009) and migrated to GTS2020 assuming his data was calibrated to Cande-Kent'95 polarity chrons. But only every 10th item from 9-point averaging of Benthic foraminifer compilation (29000 data points in original) is shown here, except for some short-term excursions; NOTE: Cramer had two sets -- original and "adjusted" (which removed many of the original)

Category Group and sub-group	Subsets	Columns	Sources (selected major ones)
	Miocene-Paleocene Oxy-18 **events**		Miocene-Oligocene event suite from Boulila-Galbrun-Millet et al. (2011) based on definitions by Miller et al. (1991, 1998) and additional calibrations by Pekar et al (2002); Eocene-Paleocene events after Zachos et al. (2008), Westerhold et al. (2008, 2014, 2015) and Dinares-Turell et al. (2014), with additional revisions by Robert Speyer (GTS2020)
Paleozoic-Mesozoic Oxygen-18 and tropical/subtropical marine temperature (Grossman & Joachimski, GTS2020)	Calcite-derived	*Oxy-18 calcite (per-mil VPDB)*	Grossman & Joachimski (Oxygen Isotope stratigraphy chapter of GTS2020): Paleozoic to early Cretaceous red curve = Brachiopods and bivalves, Jurassic-early Cretaceous blue curve = Belemnites, Cretaceous curves = Planktonic foraminifera (black = non-glassy; green = glassy)
		Isotopic temperature (calcite; ¡C)	
	Apatite-derived	*Oxy-18 apatite (per-mil VSMOW)*	Grossman & Joachimski (Oxygen Isotope stratigraphy chapter of GTS2020): Paleozoic to Triassic black curve = Conodont apatite; Jurassic-Cenozoic green curve = Fish apatite
		Isotopic temperature (apatite; ¡C)	
Tropical (red) and Global Average (black) Temperature			Scotese, C., Song, Mills (2021, Phanerozoic Paleotemperatures: The Earth's changing climate during the Last 540 million years; in press, Earth Science Reviews). Red = Tropical; Black = overlay of Global average
Cryogenian-Ediacaran Glaciations			Sturtian, Marangoan "Snowball Earth" episodes; plus mid-Ediacaran Gaskier's glaciation -- Rooney, A.D., Strauss,, J.V., Brandon, A.D., and Macdonald, F.A., 2015. A Cryogenian chronology: Two long-lasting synchronous Neoproterozoic glaciations. Geology, 43: 459-462.
Carbon-13 curves and events	*per-mil PDF*		*[scale = +5 to -0.3 per-mil PDB]*
	Phanerozoic-Proterozoic Carbon-13 Composite	*detailed curve*	MESOZOIC-PALEOZOIC-Proterozoic = Compacted suite from Cramer & Jarvis (GTS2020 chapter on carbon isotope stratigraphy), which was mainly a splice of intervals from numerous publications [WARNING: that method created some "not real" JUMPS at junctions between studies from different regions!]. Their original had ca. 10,000 points/period; and this dataset is about every 10th point from sliding mean, but more detail at excursions. CENOZOIC (0-70 Ma) = Derived from Cramer (2009) and migrated to GTS2020 assuming his data was calibrated to Cande-Kent'95 polarity chrons. But only every 10th item from 9-point averaging of Benthic foraminifer compilation (29000 data points in original) is shown here, except for some short-term excursions; NOTE: Cramer had two sets -- original and "adjusted" (which removed many of the original);
	Carbon-13 excursions (GTS2020)	*events*	
	Anoxic Episodes (Jur-Cret; Silur-Devon)	*events*	CRETACEOUS OAE's = modified from Gale (GTS2020) and Cramer & Jarvis (GTS2020); JURASSIC (145-200 Ma) = Jenkyns et al. (2002) enhanced by Glowniak and Wierzbowski (2007) for mid-Oxf, Kemp et al. (2005) for early Toarcian, and Palfy et al (2001) for Tri-Jur boundary
Other 13C episodes - Cambrian, Silurian-Devonian; Aptian	**Aptian** Stage 13C intervals	*Apt zones (Herrle) / C-segments (Italy)*	Aptian segments from Herrle et al'04 ("Ap-Al") and Bottini-Erba-et al'15 ("C-intervals; approx.)
	Devonian detailed 13C named events	*detailed curve*	Devonian = Becker (GTS2020); Silurian = Melchin (GTS2020)
	Cambrian isotopic intervals		by Loren Babcock (originally derived from Zhu et al. (2006), then enhanced and rescaled by Peng-Babcock for GTS2020. Most names seem to relate to China, therefore tied to their China zones where possible.
***Strontium** 87/86*	*[scale = 0.7068 to 0.7093]*	*detailed curve*	John McArthur (2020, Lowess version 6, supporting compilation for GTS2020) [NOTE: He rescaled graphics from his GTS2012 (which had no table) ?] GTS2016 had included Becker (2012); and part of SILURIAN from Cramer (2011; as indicated by Melchin in GTS2012"
Global Reconstructions (images		*1 column*	
	Versions by Ron Blakey	*images*	Late Precambrian to Recent globes by Ron Blakey [*https://deeptimemaps.com/global-series-thumbnails/*] , based on Chris Scotese's reconstructions [at *http://www.scotese.com*]
Quaternary (high-resolution)		*19 columns*	From Phil Gibbard and Martin Head's chart "Global chronostratigraphical correlation table for the last 2.7 million years; ICS Quat. Subcomm. for GTS2020 chapter)
Quaternary Regional Stages			
	Italian marine	*Stages / Substages*	
	North America	*Stages / Substages*	
	NW Europe	*Stages / Substages*	
	British	*Stages / Substages*	
	Russian Plain	*Stages / Horizons / Sub-horizons*	
	Ukrainian Loess Plain	*Stages*	
	New Zealand	*Stages*	

Category Group and sub-group	Subsets	Columns	Sources (selected major ones)
Chinese Loess	Divisions	*detailed L - S intervals*	Based on ties of Gibbard-Head (GTS2020) to Marine Isotope Stages (MIS) glacial (Loess) and interglacial (Soil) on chart; and ages are often fixed to those MIS ones. NOTE: Soil formation (high MagSusc) overprints upper portion of previous Loess (glacial); therefore base of "S" might be in what was originally the Loess deposited in last cold stage of the previous glacial. The actual "S" formation "onset" is therefore younger than the age of the altered Loess.
	Magnetic Susc.		An Zhisheng et al. (1990) [measured from their diagram; Magnetic susceptibility (SI units) = 0 to 230]. Gibbard-Head GTS2020 chart has a much more detailed version to 2.7 Ma. Before 1 Ma, the Zhisheng An (1990) version is too vague; so not reproduced here.
Antarctic Ice Cores	delta-Deuterium	*detailed curve*	Jouzel, J., et al. 2004. EPICA Dome C Ice Cores Deuterium Data. IGBP PAGES/World Data Center for Paleoclimatology Data Contribution Series # 2004-038. NOAA/NGDC Paleoclimatology Program, Boulder CO, USA. Accessed from NCDC Paleoclimatology Program. [scale = -450 to -360 per-mil]
	CO2	*detailed curve*	CO2 curve accessed from NCDC Paleoclimatology Program, and spliced together -- Gas Ages 0-11 ka = Taylor Dome (Indermuhle et al., 1999a; depth 356 to 86 m); 11-27 ka = Taylor Dome (Smith et al., 1999; depth 388.195 to 120.25 m); 27-60 kyr = Taylor Dome (Indermuhle et al., 1999b; depth 470.915 to 380.820 m). 64-417 kyr = Vostok (Barnola et al., 2003; depth 3304.4 to 986.2 m); 417-649 kyr = Dome C (Siegenthaler, 2005; depth 3059.61 to 2771.68 m) *[scale = 180 to 1300 ppmv]*
Milankovitch curves			Analyseries 2.0 output using: Laskar, J., Robutel, R., Joutel, F. Gastineau, M., Correia, A.C.M., Levrard, B. (2004). A long-term numerical solution for the insolation quanties of the Earth. Astronomy & Physics. 428, 261 - 285]
	Insolation 65N	*detailed curve*	[W/m2] function of time and true longitude (season). From time = 0 to 2500 kyr BP. With starting season = 0 deg. from vernal point. With ending season = 180 degrees. With latitude = 65 degrees (north>0, south<0). using the Laskar 2004 solution. And with solar constant = 1365 W/m2. *[scale = 335 to 410 Watts/m2]*
	Eccentricity	*detailed curve*	
	Obliquity	*detailed curve*	
	Precession	*detailed curve*	
Impacts, Volcanism, Tectonics		*Total of 49 columns*	
Carbonate Trends		*5 columns*	Data from Kiessling et al., 1997 -- as summarized by Markello, J.R.; Koepnick, R.B.; Waite, L.E.; and Collins, J.F., 2006, The Carbonate Analogs Through Time (CATT) Hypothesis and the Global Atlas of Carbonate Fields- A Systematic and Predictive look at Phanerozoic Carbonate Systems, in Lukasik, J. and Simo, T. eds., Controls on Carbonate Platform and Reef Development, SEPM Special Publication
	Carb Platform Reefs		
	Carb Platform Organisms		
	Carb Platform - Platform Types		
	Carb Platform - Carbonate builders		
	Major Reef builders		Based on Hallam and Wignall (1997) and James (1983) -- as summarized by Lowell Waite (author) and Roger Gilcrease (compiler), 2002. Phanerozoic Cycles and Events (NV PXD Global Stratigraphic Chart 02.DSF), March 27, 2002 (printed by Pioneer Natural Resources; permission provided by L. Waite).
Hydrocarbon System overviews		*6 columns*	Mainly from Lowell Waite (author) and Roger Gilcrease (compiler), 2002. Phanerozoic Cycles and Events (NV PXD Global Stratigraphic Chart 02.DSF), March 27, 2002 (printed by Pioneer Natural Resources; permission provided by L. Waite); with additional items from Markello et al. (2006)
	Icehouse / Greenhouse		after Fisher, 1981 (from Waite, 2002)
	Anoxic Intervals		Markello, J.R.; Koepnick, R.B.; Waite, L.E.; and Collins, J.F., 2006, The Carbonate Analogs Through Time (CATT) Hypothesis and the Global Atlas of Carbonate Fields- A Systematic and Predictive look at Phanerozoic Carbonate Systems, in Lukasik, J. and Simo, T. eds., Controls on Carbonate Platform and Reef Development, SEPM Special Publication
	Major Source Rocks		Markllo et al. (2006)
	Global Source Rocks		With % of world's total generated: Ulmashek and Klemme, 1990 -- as summarized by Lowell Waite (author) and Roger Gilcrease (compiler), 2002.
	Reservoir Intervals		With % of world's trapped reserves: Ulmashek and Klemme, 1990 -- Lowell Waite (author) and Roger Gilcrease (compiler), 2002.
	Major Evaporite Seals		Major evaporite packages (seal facies) from Sun, 1994 -- as summarized by Lowell Waite (author) and Roger Gilcrease (compiler), 2002.
Impacts		*14 main columns:*	*Mainly from Earth Impact Database, 2008 (2018 revised website). [Impacts].. Meteor Impacts [dashed => estimated; arrow UP => younger than this level; DOWN => older]. Popups have URL links for details on every event, Includes a column for impact-icon.*
	Global effects (>50 km crater)		
	Regional Impacts (<50 km crater)	*Europe, Russia-Asian, Australian, African, North American, South American*	Pairs of columns (5-50 km, and <5 km) for each region
	Recent impacts		
Large Igneous Provinces (LIPs)		*9 columns*	Mainly from Large Igneous Provinces Commission website -- Large Igneous Provinces (LIPs) Through Time.. For details click [LIPs]. All events have popups with URL links to their maps and summaries; plus "LIP of the Month" as appropriate.
	Super LIPs; Major LIPs		
	Regional LIPs of smaller extent	*Asia, Europe to Urals, Africa, N.America, S.America, India and Indian Ocean, Australia-Antarctica*	Columns for each region
Passive Margins		*13 columns*	

Category			
Group and sub-group	**Subsets**	***Columns***	**Sources (selected major ones)**
	Modern margins	*General / Arctic / Atlantic / Pacific / Indian / Southern*	Bradley, D.C., 2008. Passive margins through earth history. Earth-Science Reviews, 91: 1Ð26. doi:10.1016/j.earscirev.2008.08.001. (Especially the on-line supplement tables.)
	Past margin history (by region)	*North American / European / Middle east and South Asia / Russian-Chinese / South American / African / Australian-Indonesian*	
Precambrian Crust Formation		*2 columns*	
	Crust Formation curve / events		Modified from Van Kranendonk, GTS2012