



International Commission on Stratigraphy

ANNUAL REPORT 2021

1. TITLE OF CONSTITUENT BODY

The International Commission on Stratigraphy (ICS)

Summary and compilation of subcommission reports submitted jointly by:

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2. OVERALL OBJECTIVES AND FIT WITHIN IUGS SCIENCE POLICY

Objectives

The International Commission on Stratigraphy (ICS) is a body of expert stratigraphers founded for the purpose of promoting and coordinating long-term international cooperation and establishing standards in stratigraphy. Its principal objectives are:

- (a) Establishment and publication of a standard global stratigraphic time scale and the preparation and publication of global correlation charts, with explanatory notes.
- (b) Compilation and maintenance of a stratigraphic database centre for the global earth sciences.
- (c) Unification of regional chronostratigraphic nomenclature by organizing and documenting stratigraphic units on a global database.
- (d) Promotion of education in stratigraphic methods, and the dissemination of stratigraphic knowledge.
- (e) Evaluation of new stratigraphic methods and their integration into a multidisciplinary stratigraphy.
- (f) Definition of principles of stratigraphic classification, terminology and procedure and their publication in guides and glossaries.

Fit within IUGS Science Policy

The objectives satisfy the IUGS mandates of:

- Fostering international agreement on nomenclature and classification in stratigraphy.
- Facilitating international co-operation in geological research.

- Improving publication, dissemination, and use of geological information internationally.
- Encouraging new relationships between and among disciplines of science that relate to geology worldwide.
- Attracting competent students and research workers to the discipline.
- Fostering an increased awareness among individual scientists worldwide of what related programmes are being undertaken.

In particular, the current objectives of ICS relate to three main aspects of IUGS policy:

- (a) Development of an internationally agreed scale of chronostratigraphic units, fully defined by Global Stratotype Sections and Points (GSSPs) where appropriate and related to a hierarchy of units to maximize resolution throughout geological time.
- (b) Promotion of international consensus on stratigraphic classification and terminology, which is essential for advancement of earth-science research and education.
- (c) Establishment of frameworks and systems to encourage international collaboration in understanding the evolution of the Earth.

3. ORGANISATION

ICS is organised in two types of constituent bodies: Subcommissions for longer-term study, and Executive Task Groups (working groups) for more limited, shorter-term tasks. ICS is managed by the Executive Committee, which consists of elected and appointed officers. The current structure of ICS consists of the Executive Committee of three voting and three non-voting members, and 17 Subcommissions that deal with the major chronostratigraphic units and aspects of stratigraphic classification. The ICS Executive has initiated a new Executive ex-officio position of Treasurer and appointed a new webmaster. The webmaster is revising the ICS website and transferring the webpages of the subcommissions to the main ICS site.

Subcommissions:

Quaternary
 Neogene
 Paleogene
 Cretaceous
 Jurassic
 Triassic
 Permian
 Carboniferous
 Devonian
 Silurian
 Ordovician
 Cambrian
 Ediacaran
 Cryogenian
 Pre-Cryogenian
 Stratigraphic Classification
 Timescale Calibration

- (a) Establishment and publication of a standard global stratigraphic time scale and the preparation and publication of global correlation charts, with explanatory notes.
- (b) Compilation and maintenance of a stratigraphic database centre for the global earth sciences.
- (c) Unification of regional chronostratigraphic nomenclature by organising and documenting stratigraphic units on a global database.
- (d) Promotion of education in stratigraphic methods, and the dissemination of stratigraphic knowledge.

INTERNATIONAL UNION OF GEOLOGICAL SCIENCES

The reports of each Subcommittee are appended to this ICS summary compilation. The ICS subcommittees together include approximately 350 titular members. When the corresponding members of Subcommittees are added, several thousand stratigraphers worldwide participate in the activities of ICS, and several thousand more over the 60-year history of ICS. In addition, ICS maintains contacts with many national stratigraphic committees. The members of the Full Commission (i.e. the 3 voting members and 3 non-voting members of the Executive, and the chairs of the 17 Subcommittees) represent 12 countries: United Kingdom (5 members), Canada (1), Italy (2), USA (3), China (4), Sweden (1), France (1), Netherlands (1), Spain (1), Austria (1), Australia (1) and Czechia (2). Among all subcommittee officers and the ICS executive, 18 countries are represented: United Kingdom (7 members), Canada (3), USA (7), China (11), Italy (7), Australia (1), Spain (3), Poland (2), Russia (1), Czech Republic (2), France (3), Belgium (1), Germany (3), Brazil (3), Sweden (2), Austria (2) and Norway (1). The voting members of ICS, i.e. all voting members of all subcommittees who replied to our request to report include officers, represent over 42 countries: USA (69), China (38), United Kingdom (25), Ireland (1), Russia (29), Canada (15), Germany (24), Italy (25), Australia (12), Spain (8), France (11), Japan (9), New Zealand (4), Argentina (3), Belgium (8), Netherlands (7), Brazil (10), Poland (10), Czech Republic (5), Denmark (3), Sweden (8), Switzerland (5), United Arab Emirates (1), Hungary (2), India (4), South Africa (3), Austria (4), Slovenia (1), Tunisia (1), Swaziland (1), Estonia (2), Finland (3), Iran (2), Jordan (1), Korea (1), Mexico (1), Croatia (1), Algeria (1), Namibia (1), Greece (1), Turkey (1) and Columbia (1). The ICS subcommittees are in the process of reinstalling their websites on the main ICS site (noted last year), and some continue to maintain their own websites; the URLs of the websites are as follows:

Websites:

ICS main site:	www.stratigraphy.org
Quaternary:	www.quaternary.stratigraphy.org
Neogene:	www.geo.uu.nl/SNS
Paleogene:	wzar.unizar.es/isps/
Cretaceous:	www.univ-brest.fr/geoscience/?ISCS/
Jurassic:	www.jurassic.stratigraphy.org
Triassic:	paleo.cortland.edu/sts/
Permian (newsletter):	www.permian.stratigraphy.org
Carboniferous	www.stratigraphy.org/carboniferous/
Devonian:	www.unica.it/sds/
Silurian:	www.silurian.stratigraphy.org

Ordovician:	www.ordovician.stratigraphy.org
Cambrian:	www.palaeontology.geo.uu.se/ISCS/ISCS_home.html
Ediacaran:	www.paleo.geos.vt.edu/Ediacaran/
Cryogenian:	being established
Precambrian:	www.precambrian.stratigraphy.org
Stratigraphic Classification:	issc.uni-graz.at/
Timescale calibration	being established

3a. ICS Executive Officers for 2020-2024:

Chair: David Harper (Durham, England)

Vice-Chair: Shuzhong Shen (Nanjing, China)

Secretary General: Philip Gibbard (Cambridge, England)

Non-voting officers:

Information Officer: Nicholas Car (Brisbane, Australia)

Graphics Officer: Kim Cohen (Utrecht, Netherlands)

Treasurer: Stuart Jones (Durham, England)

ICS Subcommission officers:

A full listing of current officers (with addresses) is given at the end of this main ICS report. The individual subcommission reports include a listing of all voting members (typically *c.* 20 in each subcommission).

4. EXTENT OF NATIONAL/REGIONAL/GLOBAL SUPPORT FROM SOURCES OTHER THAN IUGS

Few of the subcommissions have formal financial contributions from external sources other than IUGS (through ICS), and they are very limited and listed in the individual reports. Some activities that are associated with ICS goals, such as distributing charts of the Geological Time Scale and placing this information onto public websites, have received some minimal support from private companies and professional organisations. Informally, every officer and member of ICS donates their own time, office space, institutional facilities, and other components to the activities of the organisation. No officer nor executive receives any salary compensation from IUGS or other ICS funds. Indeed, most officers personally contribute towards their own travel and operational expenses.

5. INTERFACES WITH OTHER INTERNATIONAL PROJECTS

Active and highly fruitful interfaces with many international organisations and geo-projects are a standard feature of ICS activities. ICS maintains a strong link with the International Quaternary Association (INQUA) Commission on Stratigraphy regarding the stratigraphy of the Quaternary, and with the Commission for the Geological Map of the World (CGMW) in Paris regarding standardisation of chronostratigraphy and its colour scheme on charts, as well as producing the ICS International Chronostratigraphic Chart. In addition, ICS is collaborating with the IUGS Commission on Geoscience Information (CGI) as it develops GeoSciML as an

interchange format for geoscience data. ICS subcommissions are traditionally affiliated with a considerable number of IUGS and IGCP activities. For example, ICS members lead or participate or have participated in numerous, active IGCP projects and others serve on IGCP national committees and the scientific board. ICS members maintains active links with international research groups, including The Micropalaeontology Society (TMS), the North American Micropaleontology Society (NAMS), International Nannoplankton Association (INA) and the Association of American Stratigraphic Palynologists (AASP), and international palaeontological research groups on Graptolites, Conodonts, Ammonites, Radiolarians (Interrad), Nannofossils, Foraminifers, etc., and many ICS members serve on national stratigraphic commissions and as editors of journals. There are close links between many ICS stratigraphers and the International Ocean Drilling Project (IODP). ODP cores routinely test the global correlation potential of a great number of bio-events since the Jurassic, and this record is vital to develop integrated timescales at several scales of resolution, and global palaeo-climate models. The designation of GSSPs necessitates close interaction with local and international groups concerned with conservation, such as UNESCO (Geoparks Programme), IUGS (Geosites Programme) and ProGEO (Geosites and Geoparks initiatives).

6. CHRONOSTRATIGRAPHIC STAGE AND SERIES NAMES AND DEFINITIONS ESTABLISHED IN ICS

Quaternary:

- Base Meghalayan Stage (= Base Upper Holocene Subseries)
- Base Northgrippian Stage (= Base Middle Holocene Subseries)
- Base Greenlandian Stage (= Base Lower Holocene Subseries)
- Base Holocene Series
- Base of Lower and Upper Pleistocene Subseries
- Base Chibanian Stage (= base Middle Pleistocene Subseries)
- Base Calabrian Stage
- Base Gelasian Stage (= Base Pleistocene Series and Base Quaternary System)

Neogene:

- Base Piacenzian Stage
- Base Zanclean Stage (= Base Pliocene Series)
- Base Messinian Stage
- Base Tortonian Stage
- Base Serravallian Stage
- Base Aquitanian Stage (= Base Miocene Series and Base Neogene System)

Paleogene:

- Base Chattian Stage
- Base Rupelian Stage (= Base Oligocene Series)
- Base Priabonian Stage
- Base Lutetian Stage
- Base Ypresian Stage (= Base Eocene Series)
- Base Thanetian Stage
- Base Selandian Stage
- Base Danian Stage (= Base Paleocene Series and Base Paleogene System)

Cretaceous:

- Base Maastrichtian Stage
- Base Santonian Stage
- Base Coniacian Stage

- Base Turonian Stage
- Base Cenomanian Stage (= Base Upper Cretaceous Series and Base Cretaceous System)
- Base Hauterivian Stage
- Jurassic:
 - Base Kimmeridgian Stage
 - Base Bathonian Stage
 - Base Bajocian Stage
 - Base Aalenian Stage (= Base of Middle Jurassic Series)
 - Base Toarcian Stage
 - Base Pliensbachian Stage
 - Base Sinemurian Stage
 - Base Hettangian Stage (= Base Lower Jurassic System and Base Jurassic Series)
- Triassic:
 - Base Carnian Stage (= Base Upper Triassic System)
 - Base Ladinian Stage
 - Base Induan Stage (= Base Triassic System)
- Permian:
 - Base Changhsingian Stage
 - Base Wuchiapingian Stage (= Base Lopingian Series)
 - Base Capitanian Stage
 - Base Wordian Stage
 - Base Roadian Stage (= Base Guadalupian Series)
 - Base Artinskian Stage*
 - Base Sakmarian Stage
 - Base Asselian Stage (= Base Cisuralian Series and Base Permian System)
- Carboniferous:
 - Base of Bashkirian Stage (= Base Lower Pennsylvanian Series and Base Pennsylvanian Subsystem)
 - Base Viséan Stage
 - Base Tournaisian Stage (= Base Lower Mississippian Series and Base Mississippian Subsystem and Base Carboniferous System)
- Devonian:
 - Base Famennian Stage
 - Base Frasnian Stage (= Base Upper Devonian Series)
 - Base Givetian Stage
 - Base Eifelian Stage (= Base Middle Devonian Series)
 - Base Emsian Stage
 - Base Pragian Stage
 - Base Lochkovian Stage (= Base Lower Devonian Series and Base Devonian System)
- Silurian:
 - Base Pridoli Series
 - Base Ludfordian Stage
 - Base Gorstian Stage (= Base Ludlow Series)
 - Base Homerian Stage
 - Base Sheinwoodian Stage (= Base Wenlock Series)
 - Base Telychian Stage
 - Base Aeronian Stage
 - Base Rhuddanian Stage (= Base Llandovery Series and Base Silurian System)
- Ordovician:
 - Base Hirnantian Stage
 - Base Katian Stage
 - Base Sandbian Stage (= Base Upper Ordovician Series)

Base Darriwilian Stage
Base Dapingian Stage (= Base Middle Ordovician Series)
Base Floian Stage
Base Tremadocian Stage (= Base Lower Ordovician Series and Base Ordovician System)

Cambrian:

Base Jiangshanian Stage
Base Paibian Stage (= Base Furongian Series)
Base Guzhangian Stage
Base Drumian Stage
Base Wuliuan Stage (= Base Miaolingian Series)
Name Terreneuvian Series
Base Fortunian Stage (= Base Terreneuvian Series and Base Cambrian System)

Neoproterozoic:

Base Ediacaran System

* for approval at this of writing.

7. CHIEF ACCOMPLISHMENTS IN 2021

Full commission

- The 2021 version of ICS Chronostratigraphic Chart, which includes revised numerical ages, was posted on the ICS website (there were about 3 versions of the chart in 2021). An interactive chart is also available on the website and the iPhone timescale app was updated.
- Several authors, university teachers and other educators and professional societies were granted permission to use and reproduce the ICS International Chronostratigraphic Chart in their productions.
- The GSSP for the base of the Jurassic Kimmeridgian Stage, and the formal status for subseries/subepoch divisions was approved for inclusion in the stratigraphic guide. Following this subseries/subepoch divisions proposed for the Neogene System/Period (i.e. the Miocene and Pliocene Series/Epochs) were ratified by IUGS. They have been published in *Episodes*.
- The continued impact of the COVID19 Pandemic, many of the potential accomplishments have again been postponed to 2022 at the earliest.

Quaternary Subcommission.

- Holding of the successful INQUA-SQS GELSTRAT International Symposium, Palazzo Steri, Palermo, Sept 1-2 2021, on Neogene–Quaternary boundary and Gelasian GSSP, followed by a field workshop (originally planned for June, 2020 but postponed due to the COVID pandemic) (see below: SNS report). The workshop inaugurated a multidisciplinary multi-year research programme to constrain more precisely the Gelasian (and Pleistocene/Quaternary) GSSP, using material obtained from the Gelasian stratotype in fieldwork following the Symposium. There was strong media interest.
- Holding of the ‘Anthropogenic Markers’ meeting, Haus der Kulturen der Welt, Berlin, September 22-24, for presentation of the (highly promising) initial

analytical results of stratigraphic proxy data for the 12 Anthropocene GSSP candidate stratotypes.

Neogene Subcommittee

- Formalisation of Neogene Subseries/Subepochs. The International Commission on Stratigraphic Classification (ISSC) voted to recognise the rank of subseries as formal and to be integrated in the International Chronostratigraphic Chart (ICC). The SNS subsequently voted to designate Neogene Subseries as formal chronostratigraphic units. The vote for formal Neogene subseries, initiated on 20 May 2021, followed by a vote in which 81% of the members voted for formalisation. On 13 October 2021, the Executive Committee of the IUGS approved the proposal for formalisation of the Neogene subseries. A paper announcing the results and discussing their implications is submitted to *Episodes* by the entire SNS.
- INQUA-SQS-GELSTRAT Symposium (1–2 September, 2021, Palazzo Steri in Palermo, Italy) followed by a Field Trip (3 September, 2021) to the boundary stratotypes for the Piacenzian and Gelasian stages and the unit stratotype for the Piacenzian and Zanclean stages at Capo Rossello, Sicily. Lively discussions focusing on the Neogene/Quaternary boundary (= base of Gelasian Stage) provided a plan for high-resolution sampling (5 cm) of the Gelasian GSSP section, followed by a one-day field trip for participants and a subsequent 2-day sampling. The Matuyama/Gauss magnetic reversal is located ~1m below the GSSP (Rio *et al.*, 1988), sample resolution was 1 m, allowing possible near coincidence (but not coincidence since the GSSP is in a reversed interval) of the GSSP and the reversal. Sampling was proposed to improve the stratigraphic resolution and particularly to resolve the stratigraphic relationship between the magnetic reversal and the GGSP. In the process of sampling, however, one fact became apparent: the outcrops provide a stunning visual record of the sapropel-chalk ‘bar codes’, but are weathered to greater than 1 m depth into their faces, limiting high resolution sampling and data quality. Drilling of the section will be proposed to resolve this and other challenges posed by the weathering of the outcrops.
- Planned preproposal to the ICDP Caruso, Miller, Hilgen, Herbert and Head are planning to present a preproposal to the International Continental Scientific Drilling Program (ICDP) to drill the boundary stratotypes at Capo Rossello and Gela. As stated above, the moderate to heavy weathering of the outcrops inhibits high-resolution (cm-scale) sampling particularly for palaeomagnetism and stable isotopes.
- GSSP Progress. In 2020 the Langhian and Burdigalian GSSP Working Group (chair: Frits Hilgen) succeeded in finding a consensus on a proposal to place the Langhian GSSP in the La Vedova section in Italy close to the top of C5Cn, the selected guiding criterium to recognize the base of the Langhian (Turco *et al.*, 2017). Uncertainty related to the choice of calcareous plankton events associated with the top of C5Cn, and useful for the recognition of the Langhian base at low-latitudes, is still matter of debate. As an example, the taxonomic issues related to the *Praeorbulina* datum (the historical criterium for recognising the base of Langhian) are overt, as well as the low reliability for global correlation of the Last Common Occurrence (LCO) of *Helicosphaera ampliaperta*, an event proposed for the best approximation of the top of C5Cn in the Mediterranean.

- Potential problems in correlation to the pending La Vedova GSSP requires an auxiliary boundary stratotype in a Pacific IODP core, at the equivalent stratigraphic level, providing direct correlation to the open ocean benthic isotope record and low-latitude calcareous plankton events. Site U1337 will be designated as auxiliary open-ocean boundary stratotype, as its continuous succession across the Burdigalian-Langhian boundary provides a good-quality benthic isotope record that has been astronomically tuned (Holbourn et al., 2015). The lack of magnetostratigraphy for Site 1337 can be overcome by through detailed cyclostratigraphic correlations (stable isotopes, CaCO₃) to Site U1336 that has a reliable magnetostratigraphy across the boundary interval and is in good agreement with La Vedova section. However, these detailed correlations highlighted a missing 100-kyr cycle in the splice of Site U1337 just above the level that corresponds to the GSSP. The revision of the splice and the age model of Site U1337 has delayed the completion of a GSSP proposal and its formal submission. However, the proposal for the Langhian GSSP will be submitted soon with the purpose of reaching a final decision within the SNS. The discussion on the definition Burdigalian GSSP is still open since until now no good candidate section (astronomically tuned deep marine section, possibly in the Mediterranean, that would guarantee the stratigraphic contiguity with the other GSSP sections) is available.

Paleogene Subcommission

- The working group (WG) on the Bartonian, the only stage of the Paleogene pending formal definition, submitted to ISPS a proposal for the Bartonian GSSP. The board of ISPS raised some fundamental issues related to the completeness, continuity and exposure of the section, magneto and cyclostratigraphy. The WG decided to proceed with further stratigraphic analyses through the optimal interval of the Bottaccione section, and possibly also that of the Contessa Highway section. Depending on the new data, they will decide if these issues can be overcome and a formal proposal be resubmitted to ISPS. Ongoing studies to find an appropriate section also include those in Navarra (Spain; by Larrasoana et al.) and the Italian Torrente Caravello section (by Dinarés-Turell and colleagues). A paper with a multidisciplinary analysis and discussion of the base of the Bartonian in the Alum Bay section (Barton area in England) has been published by members of ISPS (Cotton et al., 2021).
- Image and video filming of the GSSPs for the bases of the Selandian and Thanetian (Itzurun Beach, Zumaia) and the Lutetian (Gorrondatxe), to construct 3D models of the outcrops that will be accessible for the scientific community and the general public through the ISPS website.
- Publication of the formal definition for the base of the Priabonian Stage (Agnini et al., 2021). Additionally, numerous studies have been carried out on the Paleogene successions of the Caucasus, Baltic, East and West Russia pointing out the importance of this area for interregional correlation.

Cretaceous Subcommission

- Memberships have been updated continuously by inviting active scientists who are willing to collaborate to the WG activities.
- Campanian GSSP: The first draft of the GSSP proposal for the base of the Campanian Stage at the magnetic reversal C33r (221.6 m) in the Bottaccione

section, Gubbio (Italy) circulated among WG members in August 2021. Responses were collected and the proposal is currently (November 2021) under revision prior to further circulation. The auxiliary sections include: 1) Seaford Head, UK (Thibault et al. 2016); 2) Postalm, Austria (Wolfgring et al. 2018); 3) Bocieniec, Poland (Dubicka et al. 2017) and 4) Smoky Hill, Kansas, USA. Correlation with the Tepeyac section in Mexico is also discussed. Restudy of a previously proposed GSSP at Waxahachie (Texas), demonstrates the presence of a major hiatus in the succession.

- Coniacian GSSP: The GSSP proposal for the base of the Coniacian Stage in the Salzgitter-Salder section (Germany) was approved by SCretS and ICS in early 2021, and ratified by IUGS on May 2021. Primary criterion is the appearance of the inoceramid *Cremnoceramus deformis erectus* at the base of bed 46, further information is included in the paper below:
- Albian GSSP: Finalisation of the official steps with the local authorities for the protection and easy accessibility of the GSSP site at Col de Pre-Guittard in the Commune of Arnayon (Département of Drôme) and planning of the official GSSP ceremony for the placement of the golden spike.
- Aptian GSSP: The WG is evaluating two options: GSSP defined by (1) bio-, magneto- and chemostratigraphy at Gorgo a Cerbara (Italy), or by (2) ammonite stratigraphy and, hopefully, chemo- and magnetostratigraphy (historical stratotype for Bedoulian, Cassis-La Bedoule, and, possibly, a new location in the Vocontian Trough). New preliminary data on magnetostratigraphy (statistical treatment of measurements with unclear pattern) from French ammonite-dated sections by C. Frau suggest that the base of CM0r is just below the base of the *I. giraudi* Zone, and it extends upward into the lower part of the *M. sarasini* Zone. If correct, the Barremian/Aptian boundary shifted into C34n, and the top of the *M. sarasini* zone falls near the negative C-isotope spike. This corresponds to an upward shift of the boundary by around 600 ky. Debatable remains the ammonite stratigraphy of the lowermost Aptian and C-isotope stratigraphy will need complete revision (if the ammonite and magnetostratigraphy turn out to be correct). In a first round of discussions most WG members agreed to choose a physical marker for the definition of the base of the Aptian (e.g. negative C-isotope spike at the base of OAE1a). Few ammonite experts prefer to keep ammonite stratigraphy as primary tool.
- Barremian GSSP: The drafting of the formal proposal of the Río Argos section (Caravaca, SE Spain) as GSSP of the Barremian Stage has been completed. The primary marker discussed and approved by the working group is the first appearance of the ammonite *Taveraidiscus hugii*. The proposal includes data on biostratigraphy (mainly ammonites, calcareous nannofossils and foraminifera), chemostratigraphy (organic matter and stable isotopes) and cyclostratigraphy. Correlations are discussed and a new calibration of the Hauterivian/Barremian boundary against the magnetostratigraphic scale is proposed. The protection of the Río Argos section is ensured by the current urban planning regulations of the municipality of Caravaca, and its recognition at the regional and national level is also being processed. The proposal is currently (November 2021) in the final phase of internal review and will be sent to the members of the WG for discussion by the end of this year.
- Hauterivian GSSP: The GSSP for the base of the Hauterivian Stage at the FO of the ammonite genus *Acanthodiscus* at La Charce (SE France) was ratified

by IUGS in December 2019. The department and the municipality of La Charce established an exceptional and world-renowned geological interpretation circuit for the public and planned the official GSSP ceremony.

- Valanginian GSSP: The WG approved the first appearance of the calpionellid *Calpionellites darderi* as the primary marker for the base of the Valanginian. Cañada Luenga (Cehegín, SE Spain) and Vergol (Montbrun-les-Bains, SE France) are considered as possible candidates for the GSSP. Integrated analyses of the Cañada Luenga section with biostratigraphic (ammonites, calpionellids and calcareous nannofossils) and magnetostratigraphic data are published. Preliminary data on the distribution of ammonites and calpionellids were published for the Vergol section. A complete cyclostratigraphic analysis is also available. Calpionellids are currently being studied. An integrated biostratigraphic study (ammonites and calcareous nannofossils) has been published:
- Berriasian (J/K boundary) GSSP: The new Berriasian WG began work in February 2021 focusing on the organization of database and ideas concerning possible definitions and placing the Tithonian/Berriasian boundary, and its palaeoenvironmental context. The WG meets online approximately once a month, usually with two keynote talks and discussion as follows: 1st meeting (11.02.2021), Grabowski J.: in the search of the J/K boundary stratotype: state of art – beginning 2021; Aguirre-Urreta B.: the J/K boundary in the Andes. 2nd meeting (24.03.2021), Petrova S., Reháková D.: Calpionellid evolution and biostratigraphy during the Late Jurassic – Early Cretaceous; Grabowski J.: My doubts about Tre Maroua section (previous WG proposal). 3rd meeting (27.04.2021), Rogov M.: Boreal J/K boundary; Li G.: Jurassic/Cretaceous boundary in China. The 4th meeting (19.05.2021), Casellato C.E., Erba E.: 1) Reliability of calcareous nannofossil events in the Tithonian – early Berriasian time interval: implications for a revised high-resolution zonation; 2) Jurassic/Cretaceous boundary interval: Palaeoceanography and Palaeoclimatology of the Tethys; Szives O., Fözy I.: New data from the Tithonian/Berriasian interval from Hungarian ammonitico rosso sections: problems and possibilities of ammonite zonations. 5th meeting (22.06.2021), Price G.: Stable isotopes across the Jurassic-Cretaceous boundary; Grabowski J. (& Research Team): Integrated stratigraphy of the Volgian section in the Polish Basin: implications for correlation with Tethys area and NW European basins. 6th meeting (12.10.2021), Deconinck, J.-F.: Clay minerals around the J/K boundary; Grabowski J.: WG after summer season: New activities and concepts. The 7th meeting is scheduled for November 2021. The presentations and short reports of the meetings are archived and accessible only to WG members on a dedicated web page. The WG does not plan to start investigations of new sections, given the huge amount of work performed by the previous WG that logged and established stratigraphic frameworks in many sections, mostly located in SE France, Italy, Spain, Slovakia, Hungary and Ukraine. We aim to re-investigate existing sections by applying new methods, and by using archival samples within a well-established stratigraphic context. Torre de Busi (Lombardy basin, Italy) is regarded as a promising section with complete magneto-, carbon isotope and calcareous nannofossil stratigraphy, but slightly problematic calpionellid stratigraphy. A re-study of calpionellid stratigraphy at Torre de Busi was initiated in September 2021.
- Killian Group. The WG was inactive in 2021.

- Publication of a *Cretaceous Research* Virtual Special Issue titled “Cretaceous integrated stratigraphy, greenhouse climate change and events” edited by Petrizzo M.R., Wagreich, M., Falzoni F., and Haggart, J. The Special Issue collects papers presented in the Cretaceous Subcommission scientific session held at STRATI 2019 (Milano, Italy, July 2019). The special issue is available at: <https://www.sciencedirect.com/journal/cretaceous-research/special-issue/10LTDCL3HZ0> and includes 11 papers published in 2020 and 2021

Jurassic Subcommission

- The ISJS proposal for the Kimmeridgian GSSP was unanimously accepted by ICS on the 23rd January 2021 and by IUGS on the 15th February 2021. This GSSP will be placed in the upper part of Bed 35 of the Staffin Shale Formation, 1.25 ± 0.01 m below the base of Bed 36 in block F6 in the foreshore at Flodigarry, Staffin Bay, Isle of Skye, Scotland. In partnership with Scottish Natural Heritage (<https://www.nature.scot/>) and other local bodies work has begun on promoting the GSSP to the scientific community and general public.
- Preparations are now well underway for the next Jurassic conference and we are delighted that the Hungarian Jurassic team have kindly agreed to host this in Budapest, Hungary from the 29 August to 2 September 2022.
- The Oxfordian Working Group has been reformed to meet the challenge of selecting a candidate GSSP. The new working group comprises 25 specialists across at least 10 different stratigraphical disciplines. Whilst other candidate sections might be located, the three candidate sites being considered at present are: Redcliff Point, Weymouth, England; Thuoux and Saint-Pierre d’Argençon, Serres, SE France and Dubki, Saratov Region, Russia. The Callovian Working Group have documented correlation of the chosen guide fossil in other faunal provinces and constructed a higher resolution ammonite stratigraphy at several sites. The Tithonian Working Group have also been furthering correlations and interpretation of ammonite stratigraphy. Work has started through the new voting members, to rejuvenate the Tithonian and Callovian working groups and expand the search for candidate GSSPs by considering promising sections outside of Europe.
- The ISJS were the first Subcommission to create webpages on the new ICS website setting the agenda and structure for others to follow. We hope that this website will offer us a stable and easily findable web-platform.
- ISJS Newsletters in stratigraphy: This valuable resource is often requested and referenced so we are delighted that *Volumina Jurassica* agreed to give the scanned versions of these newsletters a permanent and secure online home. We are also particularly grateful to ISJS member Eckhard Mönnig for meticulously digitising the newsletters.
- Research with the International Subcommission on Cretaceous Stratigraphy (Berriasian Working Group): ISJS members Veronica Vennari and Pierre Pellenard have been interacting with members of the Berriasian Working Group to gather new geological and biostratigraphical data on some Upper Jurassic-Lower Cretaceous sections of the Argentinean Andes. The Berriasian working group are meeting regularly and making good progress.

Triassic Subcommission

- A total of 349 papers that are closely related to stratigraphy and extreme biotic, environmental and climatic events within the Triassic have been published by STS members in 2021. The issue of *Albertiana* (#46) was published, and it is available for download from STS website.
- New achievements in C-N and I-O boundaries: The definition and selection of the GSSP of the Carnian-Norian boundary (CNB) have been hotly debated among STS members through e-mail conversations in 2020-2021. Most advancements of the CNB came from the Black Bear Ridge section of Williston Lake, British Columbia, Canada, which is also one of candidates of GSSP for NCB, and records relatively continuous carbonate successions near the stage boundary. Lei et al. (2021) undertook analysis of $\delta^{13}\text{C}_{\text{carb}}$ from the NCB beds, and recognized a pronounced negative $\delta^{13}\text{C}_{\text{carb}}$ excursion interval with an anomalously low negative values near the CNB, which is defined by the base of the *Metapolygnathus parvus* Subzone of the *Primatella primitia* conodont Zone, together with the first occurrence of bivalve *Halobia austriaca*. McRoberts (2021) provided emendation of *H. austriaca* from the Black Bear Ridge section. Reappraisal of *H. austriaca* places the lower occurrence of the species in Bed 22, slightly higher than the traditional NCB in the same section. The updated Lower Triassic conodont biostratigraphic studies show that the I-O boundary defined by the first occurrences of conodont *Novispathodus waggeni waggeni* coincides with the upper part of the positive shifting excursion of $\delta^{13}\text{C}_{\text{carb}}$ in Kashmir of northern India and the Salt Range of Pakistan, and conodonts are much more poorly preserved around the IOB than the previously reported). In contrast, two substage boundaries within the Induan (Griesbachian-Dienerian boundary) and the Olenekian (Smithian-Spathian boundary) have been much better defined based on conodont and ammonoid biostratigraphy, and chemostratigraphy.
- Primary publications: Stable carbon isotope record of carbonate across the Carnian–Norian boundary at the prospective GSSP section at Black Bear Ridge, British Columbia, Canada. *Albertiana* 46, 1–10. McRoberts, C.A., 2021. *Halobia austriaca* in North America with a reappraisal of its distribution across the Carnian-Norian boundary interval at Black Bear Ridge (northeastern British Columbia, Canada). *Albertiana* 46, 13–46. Lyu, Z., et al., 2021. Lower Triassic conodont biostratigraphy of the Guryul Ravine section, Kashmir. Improved taxonomic definition based on the ontogenetic series of Griesbachian-Dienerian conodonts from the Early Triassic of northwestern Pakistan. Calibrating the late Smithian (Early Triassic) crisis: New insights from the Nanpanjiang Basin, South China. Abundant conodont faunas from the Olenekian (Early Triassic) of subsurface British Columbia, Canada and diversification of the Neogondolellinae around the Smithian-Spathian boundary. Smithian and Spathian (Early Triassic) conodonts from Oman and Croatia and their depth habitat revealed. Smithian (Olenekian, Early Triassic) conodonts from ammonoid-bearing limestone blocks at Crittenden Springs, Elko County, Nevada, USA. Carbon isotope chemostratigraphy and conodont biostratigraphy around the Smithian-Spathian boundary in the Panthalassan carbonate succession (SW Japan).

- Terrestrial PTB mass extinction: modelling ecosystem collapse and possible causes: Great advancements have been achieved on the modelling of terrestrial ecosystem collapse across the PTB mass extinction and possible causes, including large igneous province volcanism and associated deleterious catastrophe and increase in atmospheric CO₂.
- Primary publications: Chu, D.L., et al., 2021. Metal-induced stress in survivor plants following the end-Permian collapse of land ecosystems. *Geology* 49, 657-661. Huang, Y.G., et al., 2021. Ecological dynamics of terrestrial and freshwater ecosystems across three mid-Phanerozoic mass extinctions from northwest China. *Proc. Roy. Soc. B* 288, 20210148. Kaiho, K., et al., 2021. Pulsed volcanic combustion events coincident with the end-Permian terrestrial disturbance and the following global crisis. *Geology* 49, 289-293. Wu, Y.Y., et al., 2021. Six-fold increase of atmospheric pCO₂ during the Permian-Triassic mass extinction. *Nat. Comms.* 12, 2137.
- Two field workshops/excursions and one indoor workshop: Covid-19 pandemic makes large international symposium impossible. Thus, STS organized or sponsored partly three events in various regions. 1) STS organised a long field excursion to eastern Tibet, western China from 01 August to 03 September, 2021. A total 21 participants from China University of Geosciences, China Geological Survey (Wuhan Centre), Tibetan local geological survey and two Ph.D. students from Pakistan investigated the Triassic strata in the eastern Tibet Plateau, with emphases on integrated stratigraphy and biotic and environmental changes over the mid-Carnian event and end-Triassic extinction. 2) The 16th International P-Tr Field Workshop in Ardeche, France (10-13 Sept., 2021) organized by the STS members of the European P-Tr Association (Association des Géologues du Permian et du Trias). 3) International Workshop on Microbialites (M-Fed; 13-15 Oct. 2021; Paris) organized by the STS members from the Muséum National d'Histoire Naturelle (MNHN). Workshop reports are attached.

Permian Subcommittee

- The proposal for the Global Stratotype Section and Point (GSSP) for the base-Artinskian Stage (Lower Permian) has been published in the ISPS Newsletters Permophiles 71 by Chernykh *et al.* (2021). A call to vote on this GSSP was sent to the SPS Voting Members on October 2021. Based on the large majority of positive votes (15 out of 16), the proposal for the GSSP for the base of the Artinskian Stage at the point indicated by the FAD of the conodont *Sweetognathus asymmetricus* at the Dal'ny Tulkas section, Russia was accepted by the Subcommittee on Permian Stratigraphy. A formal proposal of the Artinskian-base GSSP will be soon submitted to the International Commission on Stratigraphy.
- A professional video was produced to advertise SPS at <https://www.youtube.com/watch?v=s2f1647pCpI> and two webinars were organized live online through Zoom: <https://www.youtube.com/watch?v=dzkjP84kvfI> <https://permian.stratigraphy.org/Interests/Giovanni>
- A call to fund small projects of young researchers on Permian correlation

was organised and four projects were selected. The Permian Time Scale was updated and two issues of *Permophiles* were published (SPS Newsletters *Permophiles* 70 and 71).

Carboniferous Subcommittee

- Activities of the Working group for the revision of the Devonian-Carboniferous boundary have still been impacted by the pandemic crisis and all planned field workshops have been postponed to undefined dates. One of the major this year results has been the publication of the special Issue entitled “*Global review of the Devonian-Carboniferous Boundary*” in *Palaeobiodiversity and Palaeoenvironments* (volume 101(2): 1-377). This volume, co-edited by the working group leaders M. Aretz and C. Corradini. Overall, fifteen regional synthesis written by 55 experts present not only descriptions of key regions for the stratigraphic subdivision of the Devonian-Carboniferous Boundary Interval, but also give a truly global view on this time interval in various facies realms and on palaeocontinents. The work to establish a global correlation chart has been started with the presentation of a rough draft by the working group leaders during a half-day online discussion in October. The working group maintains the aim to send a formal proposal to the subcommission for the boundary criterion early in 2022.
- The Subcommittee on Carboniferous Stratigraphy held a meeting, “The Kasimovian Workshop,” on May 24-27, 2021. The meeting was organized by William DiMichele, Spencer Lucas, Xiangdong Wang, and Stanislav Opluštil. The pandemic restrictions made impossible the original plan for an in-person meeting in Albuquerque, New Mexico, USA. Consequently, the meeting was run on a Zoom platform sponsored by the Smithsonian Institution. The meeting brought together about 40 scientists from North America, Europe, Asia, and South America to discuss diverse aspects of the Middle-Late Pennsylvanian transition, much of it focused on the Kasimovian Age of the Late Pennsylvanian. The Geological Society, London, recently approved publication of an edited volume based on the Kasimovian Workshop in their Special Publications series. This volume will be titled “*Ice Ages, Climate Dynamics and Biotic Events: The Late Pennsylvanian World*” and will be edited by Spencer G. Lucas, William A. DiMichele, Joerg W. Schneider, Stanislav Opluštil, and Xiangdong Wang.
- The Carboniferous Timescale. Geological Society, London, Special Publications 512. Much progress has been made during the past three decades by the SCCS in defining a Carboniferous time scale based on marine bioevents. This GSL Special publication 512 is edited by Spencer G. Lucas, Joerg W. Schneider, Svetlana Nikolaeva, and Xiangdong Wang, which is to bring together state-of-the-art reviews of the non-biostratigraphic and biostratigraphic evidence that are used to define and correlate Carboniferous time intervals, including comprehensive analyses of Carboniferous radio-isotopic ages, magnetostratigraphy, isotope-based stratigraphy and timescale-relevant marine and non-marine biostratigraphy.
- The volume includes 21 chapters: 1, The Carboniferous chronostratigraphic scale: history, status and prospectus (by Lucas et al.); 2, Russian regional Carboniferous stratigraphy (by Alekseev et al.); 3, Proposed chronostratigraphic units for the Carboniferous and early Permian of the southwestern Gondwana margin (by Gonzalez and Saravia); 4, Carboniferous

numerical timescale (by Ramezani); 5, Carboniferous isotope stratigraphy (by Chen JT et al.); 6, A geomagnetic polarity timescale for the Carboniferous (by Hounslow); 7, Current synthesis of the penultimate icehouse and its imprint on the Upper Devonian through Permian stratigraphic record (by Montanez); 8, Carboniferous smaller Foraminifera: convergences and divergences (by Vachard and Coze); 9, Carboniferous fusulines: taxonomy, regional biostratigraphy, and paleobiogeographic faunal development (by Ueno); 10, Global Carboniferous brachiopod biostratigraphy (by Angiolini et al.); 11, Carboniferous crinoids (by Ausich et al.); 12, Carboniferous biostratigraphy of rugose corals (by Wang XD et al.); 13, A global review of Carboniferous marine and non-marine bivalve biostratigraphy (by Amler and Silantiev); 14, Carboniferous ammonoid genozones (by Nikolaeva); 15, Carboniferous conodont biostratigraphy (by Barrick et al.); 16, The biostratigraphy of Carboniferous chondrichthyans (by Ginter); 17, Appalachian coal bed palynofloras: changes in composition through time and comparison with other areas (by Eble); 18, Carboniferous macrofloral biostratigraphy: an overview (by Oplustil); 19, Improved blattoid insect and conchostracan zonation for the late Carboniferous, Pennsylvanian, of Euramerica (by Schneider et al.); 20, Carboniferous tetrapod footprint biostratigraphy, biochronology and evolutionary events (by Lucas et al.); 21, Carboniferous tetrapod biostratigraphy, biochronology and evolutionary events (by Lucas).

Devonian Subcommission

- SDS meeting took place via the Zoom platform in October 19, we were able to inform directly about current situation in the Devonian community, on-going Devonian projects (accumulation of data in the Eifel Mountains, the Rhenish Mountains, the Carnic Alps and the Prague Synform, special ICS project for Pyrenees), publications and future meetings, We had 35 participants from all over the globe (18 countries). The meeting was successful, we recruited six new Corresponding members from Czechia, Germany and China.
- Launching of the new SDS webpage – housed on the ICS webpages (stratigraphy.org).
- Publications: Two announced important Devonian-related volumes have appeared: A special volume of *Palaeobiodiversity and Palaeoenvironments* “*Global Review of the Devonian-Carboniferous Boundary*” (Guest-editors: M. Aretz & C. Corradini) with 15 contributions on 370 pages, and a special volume of the Scientific Journal of the Hassan II Academy of Science and Technology “*Devonian to Lower Carboniferous stratigraphy and facies of the Western Moroccan Meseta: implications for palaeogeography and structural interpretation*” (Guest-editors: R.T. Becker, A. El Hassani & Z.S. Aboussalam) of 194 pages.

Silurian Subcommission

- Silurian Times No 28 was edited by the secretary, David Ray, and distributed in April, 2021, posted on the web site for the ISSS, and circulated as an email attachment to all titular, corresponding and interested members of the Subcommission. It contained the reports on previous meetings, announcements of planned meetings, the latest news and recent publications

on Silurian research.

- The restudy of the Rheidol Gorge section has not yet been submitted for publication due to delays in geochemical analyses. Submission of the paper by Melchin et al. (in prep) presenting the proposal of Rheidol Gorge as a candidate section for the base of the Aeronian Stage was planned for 2021.
- Chinese working group documented a new borehole situated near the proposed base Aeronian GSSP candidate section at Yuxian and collected samples for both biostratigraphy and chemostratigraphy purpose.
- Melchin, M.J., Davies, J.R., Boom, A.R.A., Zalasiewicz, J.A., De Weirtdt, J., Vandenbroucke, T.R.A., Russell, C.T., McIntyre, A.J., Morgan, G., Phillips, S. (in prep.). Integrated stratigraphic study of the Rhuddanian-Aeronian (Llandovery, Silurian) boundary succession at Rheidol Gorge, Wales: A proposed GSSP candidate for the Base of the Aeronian Stage.

Ordovician Subcommission

- Due to the Covid-19 pandemics, the initial plans for activities in 2021 could not be respected, similar to 2020. The 36th International Geological Congress, originally scheduled in 2020 and postponed, was finally cancelled, together with the official meeting of the ICS and the take-over of the new subcommission and its officers (no SOS budget spent in 2021)
- The official inauguration of the second Auxiliary Boundary Stratigraphic Section and Point (ASSP) for the base of the Ordovician System in the Dayangcha section (Northern China), originally scheduled for May 2020, was postponed to May 2021, and is currently postponed again to a later date, possibly in 2022 (no SOS budget spent in 2021).
- In accordance with ICS Rules, the Voting Members of SOS were replaced in 2020, and the Voting Membership voted to select a new Executive and Voting Members for the term 2020-2024. The Voting Membership was increased to 20. An online meeting organized in March 2021 allowed all (for the first time in the history of the SOS) 20 voting members to join for a business meeting.
- The Subcommission decided to co-opt an Internet Officer as an additional member of the Executive. For the first time in the history of the SOS, a female voting member joined the Executive in 2021.
- The final meeting of the International Geoscience Programme (IGCP) 653 ‘*The onset of the Great Ordovician Biodiversification Event*’ took finally place as a successful videoconference congress, September 13th-16th 2021, with about 300 participants, with the Ordovician subcommission being a co-organising body. The excursions (Belgium and France; Wales and Welsh Borderland) have been cancelled (and are postponed to be held as a regional field meeting of IGCP 735). The Lille online meeting was the largest meeting of Ordovician workers ever organised, including a wide attendance by the Voting Members of the SOS.
- Ordovician News 38 (for 2020) was published in April 2021 and is available from the SOS webpage (<http://ordovician.stratigraphy.org/>).
- The SOS webpage changed its host, and is now managed as a separate page of the webpage of the ICS (<http://stratigraphy.org/>).

Cambrian Subcommission

- A vote on whether the Furongian Series/Epoch should be subdivided into four

rather than three stages/ages (with provisional stages/ages 10 and 11 in addition to the already ratified Paibian and Jiangshanian stages/ages) was conducted in April–May 2021. 59% of those who voted were in favour of a threefold subdivision of the Furongian (the Paibian and Jiangshanian stages/ages + provisional Stage/Age 10). The Subcommittee will therefore continue to subdivide the Furongian Series/Epoch into three stages/ages.

- Two options are being considered for defining the base of Stage 10: 1) at the lowest occurrence (LO or evolutionary appearance, FAD) of *Lotagnostus americanus*, or 2) at the LO (or FAD) of *Eoconodontus notchpeakensis* just below the onset of the HERB/TOCE excursion. The two options have been extensively discussed during three periods in 2021. The results of a balloting among the voting members conducted in June–July 2021 were inconclusive. 55% voted for *L. americanus* as the primary marker and 45% preferred that we should proceed with two candidates for the level. For approval all decisions require 60% of the delivered votes.
- Officers of the Subcommittee (Zhu et al. 2021) and Landing et al. (2021) attempted to clarify the carbon isotope stratigraphy in the uppermost Cambrian and the concept of the TOCE and HERB excursions in two separate papers published in *Geological Magazine*, albeit with different views (see <https://doi.org/10.1017/S0016756820001120> and <https://doi.org/10.1017/S001675682100090X>).

Ediacaran Subcommittee

- The Subcommittee is working to offer a field workshop to examine Ediacaran successions in Brazil and Argentina in July 2022. All logistical work is completed.
- New website: As part of the Executive transition, we wished to transfer the website to new ownership. We also solicited our colleague Dr. Tara Selly to act as web-developer.
- Two virtual meetings were scheduled and highly attended by the voting members.
- A database of known late-Ediacaran sections is currently being constructed, with input from all voting members. Construction of a database of all known end-Ediacaran sections worldwide. This includes fact-finding searches concerning the geology, geochemistry, and palaeontology of each section. This is currently underway and will continue into the new year.
- Two of our corresponding members (Drs. Dunn and Kenchington) held an important virtual and in-person meeting in October 2021 at Oxford University to discuss issues of Ediacaran Taxonomy. Given the difficulties of assigning proper biostratigraphic tools in the Ediacaran, these kinds of meetings are extremely important. Several voting members were present.

Cryogenian Subcommittee

- In June a key paper was published in the *Journal of the Geological Society*. A template for an improved rock-based subdivision of the pre-Cryogenian timescale. This paper shows the consensus understanding of many Precambrian stratigraphers who make up the ICS working group on pre-Cryogenian subdivision, chaired by Graham Shields (voting member). The working group involves ~35 Precambrian researchers globally who worked out how the first 85% of Earth history can best be subdivided so that the

names and ages of periods, eras and eons match known tectonic, environmental and palaeobiological events recorded in the rock record. The hope is that this will allow more intuitive appreciation of our planet's formative years for future scientists, students and the general public. A global debate ensued that resulted in surprising consensus. The figure shows the proposed timescale, along with some explanation, which forms the basis of a white paper that the working group will submit formally to the International Commission on Stratigraphy for their consideration.

- During May a two-day virtual conference was held via Zoom: Cryogenian glaciation: the extraordinary Port Askaig record, followed by a voting member meeting. 26-27th May, more than 7 hours in total, 13 research talks showcased the research results based on decades of study on the 1100 m thick Port Askaig Formation in Northwest Scotland. The conference was organised by Tony Spencer and Ian Fairchild (voting member), and it has attracted over 150 participants worldwide. Now the recordings or all four sessions are on the Cryogenian subcommission website for the interested to watch.

The meeting was followed by a voting members' meeting on the 28th May, during which a working plan for a criteria working groups were drafted.

- Cryogenian Webinar Series. As planned last year, this year in total three webinars were presented by experts from or outside of the Cryogenian subcommission, the topics covers Tonian/Cryogenian transition and Cryogenian records of the Tambien Group in Ethiopia and of the Flinders Ranges in South Australia. The information of the webinars and the speakers are on the Cryogenian subcommission website.
- The first draft of the criteria to define the base of the Cryogenian System. During this summer and autumn, at least three working groups on different criteria have come up with a document. These documents will be discussed and voted early 2022.
- Greater internet visibility and community building. The Cryogenian twitter account @cryogenian has been used to promote the events of the Cryogenian/Tonian research community. The twitter account is managed by Ying Zhou.

Precryogenian Subcommission

- The Subcommission discussed the Hadean/Archean boundary and potential candidates to receive the GSSP. Guided by new data, the members attended virtual meetings in course of 2021, to address their considerations and to build a concise document that will serve as base for the voting process in 2021. The discussion has produced surprising new approaches. The Subcommission has presented results at the Annual Meeting of the Geological Society of America, Portland, USA 2021. One manuscript is in preparation. Collaboration with colleagues outside of ICS, who work on Hadean and Archean Earth questions, was fruitful.
- The Subcommission has discussed various ways to subdivide the Hadean. Based on recently published data, the discussions concerned about the subdivision numbers, possible names (following the subdivision names of other eons) and ages. The Subcommission revisited also the existing subdivisions for the Archean. This discussion is summarised in a report and will serve as base for the voting process to be held in 2021.

- The Acting Chair presented the current discussion of the Subcommittee at the Annual Meeting of the Geological Society. The abstract and the presentation were composed in collaboration with all members of the Subcommittee.
- Chief problems encountered in 2021. Due to the continuation of Covid 19 crisis into 2021, no field workshop could be conducted as originally planned.

Stratigraphic Classification Subcommittee

- Subseries/subepoch project. On 19 January 2021 ISSC submitted a proposal to the ICS for Subseries/Subepochs to be accorded the status of formal chronostratigraphic units in a new/revised version of the International Stratigraphic Guide. The voting result on 23 March 2021 was: 17 yes, 2 no, 1 abstention (20 votes) representing a supermajority with 89.47% (with abstention) and 85% yes. On 1 May 2021 the IUGS Executive Committee ratified this proposal and Subseries can now be defined as chronostratigraphic units in a formal rank intermediate between stage and series. Following this ratification, Aubry and Piller revised the online version of the “*International Stratigraphic Guide – an abridged version*” (<https://stratigraphy.org/guide/>; online: 17 November 2021). This outcome was also the starting point for ISNS to discuss and vote positively on this topic.
- Auxiliary boundary stratotype project. A small working group (Leader: M. Head; M.-P. Aubry, W. E. Piller, M.J.C. Walker) deals with the topic of Auxiliary Boundary Stratotypes. More and more auxiliary stratotypes are currently published to support GSSPs but representing different approaches. To standardise auxiliary stratotypes the authors work on a proposal to introduce Standard Auxiliary Boundary Stratotypes to support GSSPs with reference sections which represent, e.g., different facies or palaeogeographic context. The manuscript will be finished early 2022 and submitted to *Episodes*.
- New developments in stratigraphic classification project. The final goal of ISSC is to update, upgrade and implement the *International Stratigraphic Guide* (Hedberg, 1976 [1st edition]; Salvador, 1994 [2nd edition]; Murphy and Salvador, 1999 [abridged edition]). The ISG is a most important official document with a large distribution, which requires revisiting because of the fundamental advances of stratigraphy in the last 30 years. A project was developed by ISSC under the Chairmanship of Maria Bianca Cita following a workshop organised during the 32nd IGC in Florence, entitled “*Post-Hedberg Developments in Stratigraphic Classification*”. Background and motivation of this ambitious project “*New Developments on Stratigraphic Classification*” are clearly expressed in the introductory article (Cita, 2007) printed in *Newsletters on Stratigraphy* where the various review articles are being published. After all the various review articles in the coordinated series are published, the reprinting of the various articles in a textbook is foreseen, after passing the prescribed check points for approval in order to obtain the permission to use the ICS and IUGS logos.
- Lithostratigraphy. The working group is making good progress. It is expected, that the manuscript will be submitted in spring 2022.
- Biostratigraphy. In 2021 new working group members have been approached and invited to work on this topic. As the concepts and approaches of biostratigraphy vary between fossil groups and stratigraphic systems, this

turns out to be rather difficult. The core team of authors will held a video-conference to define a thematic skeleton of the manuscript. The manuscript, however, will not be finalised before end of 2022.

- Chronostratigraphy. A new working group has been established. The manuscript should be finalised in summer/spring 2022.
- A business meeting was planned to be held during EGU (Vienna, Austria) or/and GSA Annual Meeting (Portland, Oregon). Due to the COVID 19 pandemic no meeting took place in person. We plan a meeting for EGU 2022 (Vienna).
- North American Commission on Stratigraphic Nomenclature (NACSN). The chair of ISSC, Werner Piller, was again invited and attended the 76th annual meeting of the NACSN on 5 October 2021 which has been a digital meeting in conjunction with the GSA Annual Meeting in Portland (Oregon, USA). The major general topics of this meeting were: Subseries have been formalised in the North American Stratigraphic Code as already published by
- Aubry, M.-P., Fluegeman, R., Edwards, L., Pratt, B.R., and Carlton E. Brett, 2020: *North American Commission on Stratigraphic Nomenclature Report 14 – Revision of Articles 73, 81, 82 and Table 2 of the North American Stratigraphic Code to Formalise Subseries and Subepochs*. *Stratigraphy*, 17 (4), 315-316. A proposal on formalisation of chemostratigraphy has again been discussed. Although it is still in a very immature state some proponents urge for submitting the proposal to the NACSN. It is, however, still unclear how formal chemostratigraphic units could be defined. Some members of the NACSN want also that Chemostratigraphy will formally be included in the upcoming new version of *International Stratigraphic Guide*. In this respect many questions have to addressed before.
- The session SSP2.3 “Integrated Stratigraphy - Recent advances in stratigraphic systems and geochronology” was digitally held at the EGU General Assembly 2021 (EGU 2021), 19-30 April 2021, Vienna, Austria.

Timescale Calibration

- Due to the inability to travel due to COVID, our subcommission put out a call for proposals among the membership for novel application of available funds. This was highly successful and the finances were used to support the creation of teaching materials for the Cyclostratigraphy Intercomparison Project (CIP).
- Presentation given to the Subcommission on Permian Stratigraphy and work begun with them to identify challenges and opportunities for timescale calibration of the Permian System.
- Used our 2021 funds to continue support for the Cyclostratigraphy Intercomparison Project (CIP) in their creation of online learning resources and tools for researchers and teachers of cyclostratigraphy.

Graphics Officer (Cohen) and Web Officer (Car) contributions

- The ICS Chronostratigraphic Chart, which included newly ratified GSSPs and subseries division and revised numerical ages, was kept actual on www.stratigraphy.org (versions released: 2021/05, 2021/07, 2021/10), as was a changelog.

- The ICS website since 2020 also features digitally generated web chart representations, based on its Semantic Web representation, which was kept up to date to the 2020 chart.
- Eight out of seventeen Subcommissions are operating their own websites within the new website system: Precryogenian; Cambrian; Ordovician; Devonian; Permian; Jurassic; Cretaceous; Neogene. The status of Subcommissions' website standardisations can be seen online.
- The Stratigraphic Guide online (<https://stratigraphy.org/guide/>) has been updated with changes from the Stratigraphic Classification subcommission (Piller & Aubry, Eds.).
- The following translated versions of the ICS chart were updated to the 2021 versions:
 - Iberian Portuguese; Catalan; Spanish; American Spanish; Chinese; Japanese; Finnish; Hungarian; French; Belgium Dutch; Netherlands Dutch; Norwegian. A Slovak version was newly translated in 2021. Archived chart translations established in earlier years, have been imported as layers in a single master file, now allowing to release updated versions faster.
- As in earlier years, several authors, university professors and other educators, and professional societies were granted permission to use and reproduce the ICS International Chronostratigraphic Chart (and translations) in their productions (9 instances).
- The chart colour legend, which follows that of the Commission of the Geological Map of the World (CCGM/CGMW), has been updated for the Late Pleistocene and Holocene stages (cf. Table 2 in Head et al. (2020, Episodes) and for the Pennsylvanian, in coordination with CCGM/CGMW. Since 2021 files containing the colour coding are for download on the website.
- Keeping the ICS chart up to date with GSSP status and numeric age developments. This may include a formal cross-check between GTS-2020 and the ICS Chart. This was last formally performed against the GTS-2012 (in 2012 and 2013) and it has since been left to ICS Subcommission chairs to call updates to numeric ages on the ICS chart.
- Keeping the ICS website up to date with chart status and downloads, ICS activities and news items, ICS output, ICS subcommission activities and content, stratigraphic guide text and downloads, statutes and annual report archives, and so on.
- Further integrating the workflows that follow each IUGS ratification, ICS Executive and ICS subcommission chair approved requests to change chart content, namely cross-check if with a new GSSP also the numeric age is wished to be amended the updating of the chart PDF/JPEG (editing and exports from graphics software) the updating of the chart in Semantic Web representation (pushing edits on GitHub) the uploading of the chart on the websites (emailing and web-admin) updating the interactive chart connection to the latest GitHub-stored version.
- Release of updated translations of the ICS chart.
- Improved digital representation (structuring and accessibility of the chart
- Data remodelling work on the Semantic Web representation of the Chart (<http://resource.geosciml.org/vocabulary/timescale/gts2020>) to better represent stratigraphic and temporal typologies has commenced with a new Knowledge Graph of Chart and related information being built at <https://github.com/i-c->

stratigraphy/geologic-timescale-kg. Co-authoring this remodelling with Nicholas Car is Steve Richard, one of the two main contributors of the Semantic Web form of the Chart.

- Remodelling work is expected to be complete by Q1, 2022; Data display will occur after remodelling (Q2, 2022); after data display (e.g. interactive chart on the ICS website), we will attempt to generate a like-for-like version of the PDF chart from the Semantic Web form of the Chart (Q3+, 2022).
- *Episodes* paper on developments on the ICS chart last 10 years, to succeed the 2013 paper (i.e. a paper at meta-level: formal administrative, distribution-technical, digital-era representation-diversity and diversity-of-usage orientated).

8. SUMMARY OF EXPENDITURE IN 2021:

The IUGS Executive Committee awarded ICS a budget of \$40,000 for 2018 (a reduction on previous years, limiting significantly the requests of the 16 subcommissions and the ICS Executive. Thus, \$40,000 was available for ICS activities in 2018. Expenditure is detailed in the appended financial spreadsheet (Expenditure_Budgets).

9. SUMMARY OF INCOME IN 2021:

The IUGS Executive Committee awarded ICS a budget of \$40,000 for 2020, reducing significantly the requests of the subcommissions and the ICS Executive. No additional income to the ICS is declared.

10. BUDGET PROPOSALS FROM ICS IN 2021

These have been itemised in detail in the attached spreadsheet ((Expenditure_Budgets).

10. WORK PLAN, CRITICAL MILESTONES, ANTICIPATED RESULTS AND COMMUNICATIONS TO BE ACHIEVED NEXT YEAR:

Quaternary Subcommission

- The priority for SQS is the selection of a GSSP for the Upper Pleistocene Subseries and its corresponding stage. Two potential candidates have already been identified (Fronte Section, Taranto, Italy; and an ice core in Antarctica). The aim is to have proposals developed for these potential candidates during the coming year. The Upper Pleistocene Working Group is being reformed under the co-convenership of Martin Head.
- A field workshop on the Neogene–Quaternary boundary and Gelasian GSSP, originally meant to be held in Palermo in June, 2020. This workshop will inaugurate a multidisciplinary multi-year research programme to re-investigate the Gelasian stratotype section.
- The SQS website is being updated under the direction of Martin Head as Vice-Chair with explicit responsibility for this task.

Neogene Subcommission

- The major plan is to present to ICS the official proposal for the Langhian GSSP, that is on a reliable/reproducible guiding criterium, complemented by additional criteria useful for correlation, and reach a decision on the GSSP section and auxiliary deep-sea core.

Paleogene Subcommission

- Full support will be given to studies related to the Bartonian GSSP, the last stage pending definition. Fieldwork is planned in several Italian and Spanish sections, and on-going studies of the Bartonian WG will probably lead to the resubmission of an improved proposal in 2022.
- A variety of sections from different palaeogeographical areas and depositional settings will be assessed for the proposal of auxiliary sections for the base of the Ypresian (Paleocene/Eocene boundary), and a publication will be submitted to *Episodes*.
- Contribute to a new edition of the international meeting on ‘Climatic and Biotic Events of the Paleogene’ (CBEP 2022, cancelled in 2020 and 2021), which will be held in Bremen (Germany). This is the main meeting event for the Paleogene community, and is celebrated every 4 years.
- Potential funding sources external to IUGS: most of the research that is currently being undertaken by the ISPS members is financially supported by their home countries’ research grants.

Cretaceous Subcommission

- Campanian GSSP: The WG will complete the review of the proposal for the Campanian GSSP by the end of 2021 and submit the revised proposal to SCS for voting in early 2022. Providing the Campanian GSSP is approved and ratified by IUGS, the WG will produce an article for *Episodes* in 2022.
- Aptian GSSP: The discussion on the upward shift of the *M. sarasini* ammonite zone by around 600 kyr will continue. Other stratigraphies calibrated with ammonite stratigraphy will need revision, if they were correlated with magnetostratigraphically dated sections with the top of the *M. sarasini* zone corresponding to base of M0r.
- Barremian GSSP: The discussion and voting of the GSSP proposal by the members of the WG will take place during the first months of 2022. If approved, the proposal will be sent to SCS. If the proposal is ratified by IUGS, a publication will be prepared with the most relevant data concerning the Hauterivian/Barremian boundary and the Río Argos section. Official contacts with the local authorities will also continue to increase protection and facilitate accessibility of the GSSP site.
- Valanginian GSSP: The WG is currently studying the stratigraphic distribution of the calpionellids and the magnetostratigraphy of the Vergol section; the fieldwork was delayed due to the covid-19 crisis. This work should be finished during 2022 and results available by the end of the year. Pending studies will be completed by the end of 2022 with the proposal ready for circulation to the members of the WG. Once the decision has been made within the working group, the final proposal will be sent to SCS.
- Berriasian (J/K boundary) GSSP: The WG attempts to decide which level (not

yet the primary marker) will be the best choice for the J/K boundary definition. The base of the *Calpionella alpina* Subzone proposed as primary marker by the previous WG is very consistent and well documented in the pelagic and hemipelagic successions of the Tethys, but it may hardly be identified elsewhere. Thus, an effort should be made to seek for alternative stratigraphic levels more easily transferred to Boreal basins (NW Europe, Russia and Siberia) and South America. Our field of interest covers the interval from the lower part of the upper Tithonian (upper part of M20n) to the upper part of the lower Berriasian (base M17r).

- A detailed integrated stratigraphic framework based on calpionellid and magnetostratigraphy in multiple sections with significant implementation of calcareous nannofossil stratigraphy is available from the base of the upper Tithonian to the Berriasian/Valanginian boundary of the western Tethys area. The WG will integrate these data with chemostratigraphy, climatostratigraphy (arid/humid cycles), eurybathic sea-level changes, astrochronology and radiometric dating. Preliminary data indicate that humid/arid cycles documented in the NW European basins with palynology, clay minerals and chemostratigraphy might be correlated with the excellent chronostratigraphic calibration of Tethyan sequences. However, palaeoclimatic variations in the Tethyan sequences are not as well studied, owing to the deep marine paleoenvironment. Our plan is to supply more palaeoenvironmental evidence from the Tethyan sections and to date more precisely the NW European sections. The recently discovered $\delta^{13}\text{C}_{\text{org}}$ excursion (VOICE event) in the upper part of the lower Tithonian (middle Volgian) in some Boreal sections (the South American sections – under study) seems promising. Astrochronological and radiometric studies, quite advanced in the South American sections (Neuquen basin) are planned in the Tethyan successions. A special project application to ICS devoted to these topics will be considered after pilot investigations.
- Kilian Group: The upper Aptian, lower-middle Albian zonal schemes will be in focus at the forthcoming Kilian meeting.

Jurassic Subcommittee

- The 11th Jurassic congress in Hungary: The organisation and running of a successful blended face-to-face and online conference enabling researchers to present their results, network and build new collaborations through the conference fieldtrips and sessions will be a primary focus of ISJS this coming year.
- Oxfordian, Callovian and Tithonian GSSPs: The Oxfordian Working Group will focus on establishing the primary taxa for correlation, and agreeing terminology and interpretation of taxa as this has been an issue in previous discussions because of different philosophies. The group will also continue with their preparation of proposals and the aim is to vote on these in 2022. Revitalisation of the Callovian and Tithonian working groups and discussions at the 11th Jurassic congress should enable more rapid progress and a broader perspective on these remaining GSSPs.
- Kimmeridgian GSSP: With the lifting of C-19 restrictions we aim to celebrate and promote the Kimmeridgian GSSP on the Isle of Skye, Scotland.
- Jurassic/Cretaceous boundary and the Berrasian GSSP: The 11th Jurassic Congress and the 11th Cretaceous Symposium have been planned to run

consecutively in Poland and Hungary to facilitate discussions on the placement of the Berrriasian GSSP which has proved to be particularly challenging. Three of the ISJS voting members (including the chair of the Berrriasian Working Group, Jacek Grabowski) aim to make significant contributions to formulating a proposal for this GSSP and hence the top of the Jurassic.

Triassic Subcommission

- Organising the International Symposium on Triassic Integrated Stratigraphy and Bio-Environmental Events in Wuhan on 03-07 November, 2022, in which STS business meeting is held, progresses on GSSPs for Olenekian, Anisian, and Norian are reported.
- GSSPs: The plan is to move towards a vote on the boundary marker and section for Norian GSSP in late 2022 or early 2023. Both Anisian and Olenekian GSSPs move towards preparing a discussion document among the working group members at the Wuhan meeting in 2022, as a prelude to moving towards a vote on the candidate markers and sections.
- Launching serial books “*Triassic of the World*”: the Covid-19 pandemic has significantly prevented international travels and field activities. To attract more members to be involved in the STS activities, TST hopes invite Triassic workers from around the world to join us to complete comprehensive summaries on the Triassic stratigraphy of the World. A total of six volumes are planned to summarise integrated stratigraphy, palaeontology, as well as environmental and biotic evolutions and global correlations, and this book series covers Europe (except for Russia), Russia, China, Asia (outside China), northern high-latitude region, Oceania-Africa-Antarctic, North America, and Middle-South America.

Permian Subcommission

- We plan to have the base Artinskian GSSP ratified and start to work on the base Kungurian GSSP.
- We plan to organise several webinars.
- We plan to start a new working group on Gondwana Correlation.

Carboniferous Subcommission

- A special volume entitled ‘*The Carboniferous Timescale*’ will be officially published in Geological Society, London, Special Publication in 2021.
- Due to the COVID-19 pandemic, many events have been deleted or postponed to new dates. In 2021, the SCCS executive committee plan to organise several online workshops about the progresses of the Carboniferous studies around the world.
- Task group leaders for the establishments of four Boundaries will be re-appointed and related works will be carried out to facilitate the definitions of the bases of the Serpukhovian, Moscovian, Kasimovian and Gzhelian.
- A detailed proposal for the GSSP defining the base of the Moscovian and Gzhelian stages needs to be prepared and voted by the task groups and SCCS in the next year, and the result should be submitted to the ICS.

Devonian Subcommission

- Work on formal proposals or progress reports submitted for the revision of the basal Emsian Stage GSSP from several areas.
- Continuation of Devonian subprojects aimed at GSSP redefinition.
- Revision of the D/C boundary with the D/C Boundary Task Group in close collaboration with the Carboniferous Subcommittee. Progress towards selection of candidate stratotypes.
- Real or virtual SDS business meeting and Devonian symposia.

Silurian Subcommittee

- Two ISSS groups working on restudy of the base of the Aeronian GSSP and base of the Telychian GSSP will be hopefully able to complete their work by submission of the formal proposals of the candidate sections (Štorch *et al.*, Hlasna Treban, Czech Republic and Melchin *et al.*, Rheidol Gorge, UK for Aeronian GSSP and David Loydell *et al.*, El Pintado Reservoir, Spain, for Telychian GSSP).
- ISSS online discussion and formal voting on the Aeronian and Telychian GSSP replacement candidate sections.
- Update of the website for Silurian Subcommittee by webmaster Huang Bing. We gratefully acknowledge this work and the support provided by the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences.

Ordovician Subcommittee

- Support of the Annual Meeting of IGCP 735 to be held in Marrakech, Morocco (19-25 October, 2022), including field excursions to the Ordovician of the Anti-Atlas.
- Support of the Seminar on Regional Stratigraphic Classification Standard in China in Baishan, Jilin Province, in summer 2022 (organised by the Chinese Commission on Stratigraphy), to include an inspection and unveiling ceremony for the Xiaoyangqiao ASSP section (originally planned to be organised in May 2020 and postponed to early 2021).
- Further work is needed to compile an updated summary on Ordovician regional stratigraphy and geology: A Global Synthesis of the Ordovician System. A meeting of editors and contributors is planned (probably in Lille, or Lyon, in early 2022).
- Data will be gathered for Ordovician News 39 (to be published in March 2022).

Cambrian Subcommittee

- In 2022 the Cambrian Subcommittee will continue work toward defining GSSPs for its remaining provisional stages.
- Arrival at a decision on how to define Stage 10 in 2022; then to arrive at decisions on stages 2, 3, and 4 in subsequent years.
- Continue examining issues surrounding definition of the Cambrian GSSP.

Ediacaran Subcommittee

- Field workshop to examine Ediacaran successions in Brazil and Argentina. This trip will hopefully be run in the summer of 2022 (Previously 2020). Focus will be on the Corumba and Bambui groups in Brazil, and the La

Providencia Group in Argentina. The Corumba and Bambui groups contain Cloudina and other tubular fossils that are being considered as key biostratigraphic criteria to define the terminal Ediacaran stage (TES), and thus they are highly relevant to the missions of the Subcommittee. The field workshop will be organised and led by Subcommittee Secretary Lucas Warren and his colleagues in Brazil and Argentina.

- Developing and managing a special issue (most likely in *Episodes*) that brings our membership up to speed on the progress made over the past 5 years (since Xiao et al., 2016. Towards an Ediacaran time scale: problems, protocols, and prospects. *Episodes*, 39, 540-555). This special issue will also summarize regional Ediacaran stratigraphy and potential criteria for the definition of the terminal Ediacaran stage (TES). Each manuscript will be formatted identically and designed as a facts-only short format where all proposed defining characters of the Series and Stages are identified and compared across sections. Importantly, recent recalibration and dating of the global Shuram negative excursion (Rooney *et al.*, 2020, Calibrating the coevolution of Ediacaran life and environment. *Proceedings of the National Academy of Sciences*. 2020;117, 16824-30) may finally provide a strong correlative character for the base of the Series and Stage. We believe we are close to a final vote and wish to have all the facts in one place before voting. With the change in leadership, we also require a change in our subcommittees. These committees will be tasked with setting realistic boundaries within both proposed Series.
- Improved Subcommittee Exposure and Branding: In order to reach out to our members and to breathe new life into the subcommittee, we are rebranding with a new logo and new website. We also hope to purchase and distribute “swag” (such as coffee mugs, USB sticks, lapel pins) amongst voting and corresponding members, and distribute at conferences. We (Schiffbauer and Laflamme) have used similar approaches with other committees (Geobiology and Geomicrobiology division of the Geological Society of America), and have seen a direct increase in attendance and participation (especially by junior/student members) at international meetings.
- Construction of a database of all known end-Ediacaran sections worldwide. This includes fact-finding searches concerning the geology, geochemistry, and palaeontology of each section. This is currently underway.

Cryogenian Subcommittee

- Cryogenian Webinar Series. The webinar series are proven to be a great way to introduce the up-to-date research of the Tonian/Cryogenian records worldwide, and offer good opportunities for discussion among researchers. Each time, we have up to 50 attendees. The subcommittee has decided to carry on the webinar series, and aim to cover another 3-4 key Cryogenian groups. The webinar series will be organised by Ying Zhou.
- Voting for criteria to define the base of the Cryogenian System before February 2022.
- Field Trips and meetings. Three field trips/meetings will be organized if the pandemic situation permits, including (1) Scotland field trip, followed the virtual meeting in May 2021, the field trip, led by Tony Spencer, is aim to look at some key transitions on Garbh Eileach in person by at least some of the voting members of the subcommittee, aim for discussion on Port Askaig

Formation as a GSSP candidate; (2) Utavi, Namibia field trip, mid-July, 2022, organised by Karl-Heinz Hoffman and Galen Halverson. The field trip is planned as a 5-day physical trip in case the Covid-19 situation eases. (3) Uralian field trip, later 2022 or early 2023, led by Anton Kuznetsov, this trip is planned as a 7-8 days physical trip.

Precryogenian Subcommission

- Proceed with the ICS vote on the Archean and Hadean subdivisions, as well as the major boundary of the Hadean and Archean.
- Establish candidate sections for GSSPs, where warranted.
- Defining a representative major geological conference for the next update of the Subcommission's activity to continue community involvement.
- Finalising a manuscript on the problematic and possible resolution on Hadean and Archean stratigraphy.
- Continuing the expansion of the Subcommission membership to include currently underrepresented areas, especially east and south Asia.
- Organising the workshop on Archean sites in South Africa or Australia. The workshop was planned for last years, however, it was postponed due to the global Covid-19 health crisis. The current omicron variety of SARS-CoV-2 is prevalent in South Africa. The development is not foreseeable at this point in time. Dependent on future international travel regulations the workshop will take place either in the Barberton Greenstone Belt, South Africa (visit planned for March 2022), or in the Pilbara, West Australia (visit planned for June/July 2022). Permits are in hand and travel logistics organised.

Stratigraphic classification

- For the chapter Biostratigraphy new members of the workgroup have been invited but not fully established. The old concepts have still to re-evaluated and/or new concepts have to be developed. A video conference will be organised early in 2022.
- The session SSP2.3 “*Integrated Stratigraphy - Recent advances in stratigraphic systems and geochronology*” will be held at the EGU General Assembly 2021 (EGU 2021), 3-8 April 2022, Vienna, Austria.
- The Subcommission does not envisage being able, as an organisation, to obtain significant funding from outside IUGS/ICS sources. Some financial support could be obtained by individual members from their host institutions and/or their personal research funds. There is, however, a considerable amount of in-kind funds supporting the activities of all ISSC members.

Timescale Calibration

- Second session of the ISTC to be organised at GSA.
- Planning and organisation for the first ISTC subcommission meeting to be held online in 2022.
- Acquisition of funding at the national/international level to support community building globally for the ISTC.

11. OBJECTIVES AND WORK PLAN FOR NEXT 4 YEARS (2020-2024)

The following is a summary of objectives of the ICS Executive Commission and a selection of key goals noted in the detailed reports of each subcommission.

ICS Executive

- Define a substantial number of GSSPs, particularly for stages in the Carboniferous, Triassic, Jurassic, Cretaceous, and Cambrian systems; re-evaluate GSSPs for the several Silurian stages and the Devonian-Carboniferous boundary, and of the Cambrian System (Paleozoic Erathem, Phanerozoic Eonothem), and select GSSP-defined subdivisions of the Precambrian.
- Maintain website (and the ICS App) and its formal, permanent archive of the global geostandards - GSSPs and the ICS International Chronostratigraphic Chart.
- Continue coordinating websites and the information they contain among all subcommissions and the Commission in order that they become the primary global web-based entry point to information on the activities and accomplishments of the subcommissions and ICS.
- Encourage subcommissions to re-assess regularly GSSPs and to develop new initiatives and projects that utilise the refined International Stratigraphic Chart.
- Encourage the recruitment by subcommissions of members from under-represented countries/regions and of those at early career stages.
- Promote the preservation of GSSPs by local communities and national stratigraphic commissions and dedication ceremonies, including the placement of permanent markers, at all ratified GSSPs.
- Produce a new edition of the *International Stratigraphic Guide* with its joint publication by IUGS and the Geological Society of America
- Continue development of a strong link between ICS and the Geobiodiversity DataBase (GBDB) at the Nanjing Institute of Geology & Palaeontology
- Maintain close collaboration with all national stratigraphic commissions.
- Cooperate with One-Geology and the Commission on the Geologic Map of the World to ensure that these projects continually incorporate the latest revisions to the International Stratigraphic Chart.
- Serve as the primary international body setting global standards and illustrating best practices in stratigraphy.
- To continue to integrate fully the new Subcommission on Timescale Calibration (ISTC) under the leadership of Dr Brad Cramer (cf. below) into the ICS structure.

Quaternary Subcommission

- Develop and submit a GSSP proposal for definition of the Upper/ Late Pleistocene and its respective Stage/Age.
- Analyse candidate GSSPs for the Anthropocene, and submit a proposal for formalisation to the SQS
- Re-investigate the GSSP for the Gelasian Stage (and Lower Pleistocene Subseries, Pleistocene Series, Quaternary System) at Monte San Nicola, Sicily.
- Explore the possibility of a second stage for the Middle Pleistocene, based around the increasingly well-recognised Mid-Brunhes Transition.

- Continue to examine the fine-scale subdivision of the Quaternary.
- Continue to develop/update detailed correlation charts for the Quaternary (Cohen & Gibbard, 2019, *Quaternary International*, is the latest version).

Neogene Subcommission

- We will hold a virtual meeting with members in spring 2022 and a tentative field trip to La Vedova section Conero Riviera, Italy after Sept. 2022. As noted above, we have three action items to:
- submit the final proposal for La Vedova as the Langhian boundary stratotype and to subsequently vet and vote on the proposal;
- evaluate possible boundary stratotypes and criteria for the definition of the base of the Burdigalian Stage;
- submit a preproposal to ICDP to drill the Gelasian, Piacenzian, and Zanclean stages in Sicily.

Paleogene Subcommission

- To advance the definition criteria for identifying the base of Bartonian Stage, choose a type section and submit a GSSP proposal to the Paleogene Subcommission voting members.
- To prepare the report on the Bartonian GSSP proposal to be submitted to the ICS and the IUGS.
- To celebrate the official ceremony to place the Golden Spike at the GSSP for the base of the Priabonian in Alano di Piave section, Italy.
- To produce an updated version of an integrated Paleogene Time Scale.
- Preparation of standardised regional correlation charts and paleogeographic maps by the regional Committees.
- To support studies for the completion of the Paleogene astronomical time scale. This will contribute to filling the so-called “middle Eocene astronomical timescale gap” and will help to connect existing floating calibrations with the astronomically tuned standard Neogene time scale.
- Update the status of Paleogene working groups, creating new working groups as necessary and closing those which have completed their task and/or are inactive.
- Revisit existing GSSPs and, if necessary, define new GSSPs and/or ASSPs in order to characterise better the following boundaries:
 - Thanetian/Ypresian (P/E) boundary (i.e., Alamedilla, Caravaca and Zumaia sections in Spain; Forada and Contessa Highway sections in Italy; Polecat Bench in Wyoming);
 - Danian/Selandian boundary: Contessa and Bottaccione sections in Italy; Caravaca and Sopelana sections in Spain;
 - Selandian/Thanetian boundary: Contessa, Italy
 - Base of the Rupelian (E/O boundary): Monte Cagnero and Monte Vaccaro sections in Italy.

Cretaceous Subcommission

- Spring 2022: official ceremonies for the inauguration and placement of the golden spikes of the Albian and Hauterivian GSSPs.
- 2022: Finalisation of the GSSP proposals for the base Barremian and base Campanian and vote within the WG.

- 2023: Finalisation of the GSSP proposals for the base Valanginian and base Aptian and vote within the WG.
- 2022–2024: Research activities toward the preparation of the GSSP proposal for the base of the Berriasian Stage by the new Berriasian WG.
- 2022-2024: Continue preparation of proposals for the definition of substages for discussions at the forthcoming meeting: 11th International Symposium on the Cretaceous (Poland, 2022).
- 2022-2023. Vote by the SCS of the Barremian and Campanian GSSPs.
- 2023-2024. Finalisation of the GSSP proposal for the base Berriasian and vote within the WG.
- 2023-2024. Vote by the SCS of the Valanginian and Aptian GSSPs.

Jurassic Subcommittee

- Achieve ratification of the Kimmeridgian GSSP.
- Complete or significantly advance the defining of the remaining Jurassic GSSPs (Calloviaian, Oxfordian, and Tithonian) through revitalizing the working groups and facilitating progress by encouraging constructive collaboration and raising funds.
- Increase diversity and facilitate research aspirations at all career stages by championing representation through the new official positions, providing a diversity of opportunities, role models and subject specialist champions.
- Facilitate communication on the Jurassic for both specialist and non-specialist audiences. including promoting the Jurassic GSSPs. This will be achieved through meetings, workshops, *Volumina Jurassica*, outreach activities and maintaining an up-to-date and informative subcommittee website.
- Facilitate a successful and inclusive Jurassic congress in Budapest, Hungary in 2022.
- Improve resolution and correlation of the integrated stratigraphy for the Jurassic.
- Further our understanding of the Earth system during the Jurassic especially palaeoclimate change.
- Provide support to IGCP 655 (Toarcian) and future IGCP projects related to the Jurassic.
- Work with the Cretaceous Subcommittee to help them define the base of the Berriasian and the Jurassic/Cretaceous boundary.
- Work with national and international bodies to protect Jurassic geological sites, assess and promote their natural capital.

Triassic Subcommittee

- A total of two international symposia, 2-3 STS sessions, 1-2 thematic issues, significant progresses on 4 GSSPs (2 of them can be ratified) are anticipated to be achieved:
- Organisation of the International Symposium on Triassic Integrated Stratigraphy and Bio-Environmental Events in Wuhan, China on 03-07 November, 2022.
- Organisation of the International Symposium and Field Workshop on Triassic Stratigraphy and Bioevents in Albuquerque, New Mexico, USA in June-August, 2024.

- Launching global Triassic book series: *Triassic of the World*, and inviting the Triassic workers from around the world to write various volumes and chapters in 2022-2024.
- Organisation of the STS sessions in major conferences, and journal special issues in 2022-24.
- Norian GSSP: This GSSP is anticipated to move towards a vote in late 2022.
- Olenekian GSSP: Completing the GSSP proposal and submitting to STS for ratification in 2023.
- Anisian GSSP: The GSSP of OAB is to be voted in 2023-2024.
- Rhaetian GSSP: A long-time stasis in this group has seen no significant prospects of change. If this continues into early 2022, a new chair of this working group will be sought to move forward at a faster pace.

Permian Subcommission

- Establish the Artinskian (currently under consideration for approval by ICS) and Kungurian GSSPs.
- Revise the Permian timescale where it needs to be improved (Guadalupian stages, replacement GSSP section of the base-Lopingian).
- Establish a robust palaeogeographic frameworks for the Permian and focus on N-S correlations.
- Propose DDE-sponsored informatics support for biostratigraphic data management and palaeogeographic reconstructions.
- Organise webinars to increase the size, diversity and international coverage of the Permian Community
- Publish at least two *Permophiles* issues each year

Carboniferous Subcommission

- Within the next 4 years, it will be possible to select the defining events for all of the stage boundaries and progress toward selecting candidate sections for the GSSPs. We intend to use high-resolution biostratigraphy and combine it with a multi-discipline approach (use of sedimentology, geochemistry, and geological events) to establish as many of the remaining GSSPs as possible. The realistic objective is to have two remaining GSSPs ratified in the next four years and redefine the Devonian-Carboniferous boundary.
- We will encourage and pay more attention to finding volcanic ash beds for radiometric dating, in order to establish a more precise Carboniferous time scale and facilitate the correlation of important Carboniferous events at global scale.
- Using multi-discipline methods including palynological studies, U-Pb dating and stable isotope studies, we will further promote marine and non-marine correlation.
- We are going to organise at least one academic activity each year, either a workshop (maybe combined with conferences) or joint workshop/field excursion. However, this plan might be delayed or cancelled due to the COVID-19 situation, and we will probably have more video meetings and try to make progresses through internet.
- To establish working groups on dividing the Tournaisian and Viséan stages because both of them represent too long time interval.
- To strengthen and to vivify the SCCS website, with membership lists revised,

tasks and newsletters updated in time, making it a genuine platform to bring Carboniferous specialists together for collaboration and exchange of new ideas and results.

- Integrate the Carboniferous databases from the entire world, combining the Geobiodiversity Database (GBDB, a large compilation of data about sections) at Nanjing Institute of Geology and Palaeontology, the Palaeobiology Database (a large compilation of data about fossils) at the University of Wisconsin-Madison, DDE (Deep Time Digital Earth) and other major databases, to facilitate the studies on Carboniferous biota and stratigraphy.

Devonian Subcommission

- Redefine the base of the Emsian Stage.
- Redefinition of the Devonian/Carboniferous Boundary with the joint Task Group.
- Annual meetings.

Silurian Subcommission

- Principal work will be devoted to GSSP-related research activities – restudy of some previously ratified but currently inadequate basal stratotypes. Delayed formal proposals of the Aeronian and Telychian GSSP replacement candidates will be completed in 2021 and new stratotypes will be chosen. We aimed to vote on these candidate sections in 2019 in Milano, but the deadline had to be postponed due to delayed work on some of the candidate sections and subsequent Covid-related restrictions.
- Homeric working group will be established and restudy of the Homeric GSSP will join the programme, together with never ending search for potential sections suitable for new GSSP of the Wenlock Series.
- Application of astronomically tuned cyclostratigraphy integrated with radiometric data and high-resolution biostratigraphy in conjunction with IGCP no 652 “Reading geological time in Palaeozoic sedimentary rocks”.
- We will take part in further development of databases that would bring together and make available information from all sources associated with the Silurian researchers. One such database, operated by the Nanjing Institute of Geology and Palaeontology (Geobiodiversity Database, GBDB) is the official database of the ICS.
- ISSS bi-annual field-meeting and business meeting organised in Sofia, Bulgaria in August 2021 in collaboration with Geological Institute of Bulgarian Academy of Sciences may be postponed until the end of international travel restrictions, most likely until 2022.

Ordovician Subcommission

- For further advancement and increased precision in correlation we need to focus on regional stratigraphy, regional scales and regional chronostratigraphic schemes. We recognise that many biotic, chemical and physical changes are not always synchronous, and that local and regional signals may vary from trends evident in global compilations. This is especially true for the Ordovician, where strong provincialism can mask biostratigraphic-based correlation. Ordovician regional stratigraphy and

geology will therefore be the main goal for the period 2020-2024.

- To compile and publish an updated summary on Ordovician regional stratigraphy and geology: A Global Synthesis of the Ordovician System. Special attention is going to be paid to precise correlation of the Ordovician depositional sequences and sea level curves as well as stable isotope and regional biodiversity curves. Though work has been proceeding on this aim, regrettably it is at a glacial pace.
- To better correlate Ordovician depositional sequences throughout the World.
- To design and execute a program of radiogenic dating of key Ordovician horizons (using Pb-Pb isotopes and CA-IDTIMS dating of zircons).
- The Ordovician website will be updated including development of a database for GSSPs and ASSPs.

Cambrian Subcommittee

- The principal objective of the Subcommittee is to narrow possibilities for horizons and GSSP stratotypes for the remaining undefined stages, which are provisionally identified as stages 2, 3, 4, and 10. The ISCS has developed a prioritised plan for formalising definition of the remaining undefined GSSPs. The plan is:
 - Provisional Stage 10 is expected to be defined next, and a decision on a GSSP will likely be made in 2021.
 - Following a decision on Stage 10, provisional stages 2, 3, and 4, are expected to be defined in rapid succession. A decision on the preferred GSSP horizon of any one of the three stages will restrict choices for the remaining two stages, so the ISCS is approaching work toward definition of the three stages as closely linked.
 - A more long-term objective is re-examination of the Cambrian GSSP (Terreneuvian Series, Fortunian Stage). Imprecision in correlating the lower boundary of the Cambrian System has been encountered on all palaeocontinents, and the ISCS is now engaged in seeking a practical solution to remedy the problem (Babcock, L.E. *et al.* 2014: Proposed reassessment of the Cambrian GSSP. *J. of African Earth Sci.* 98, 3–10). A decision on how to proceed with the Cambrian GSSP is expected to be made following ratification of GSSPs for stages 2, 3, and 4.

Ediacaran Subcommittee

- Subcommittee annual newsletter will be distributed in December 2021 or January 2022. Secretary Dr. Lucas Warren will be leading the effort to compile and edit the newsletter.
- Building on several previous trips in Brazil sponsored by members of the Ediacaran Subcommittee, the Subcommittee will sponsor an extended field trip to examine Ediacaran successions in Brazil and Argentina. The field trip will be led by TES-WG voting member Dr. Lucas Warren and his colleagues, and it is tentatively scheduled on June or July 2022.
- A field workshop is being planned to visit and examine Ediacaran successions in Siberia.
- A vote will be called to decide what criterion or criteria will be the most useful in dividing the Ediacaran System into series and stages (particularly the

second and terminal stages of the Ediacaran System). Our goal is to finalise the discussion on TES by 2022 (previously 2020).

Cryogenian Subcommission

- Voting for criteria to define the base of the Cryogenian System (2021)
- Call for proposals for basal Cryogenian GSSP candidates (2022).
- Voting and ratification of basal Cryogenian GSSP (2023).
- Establishment of working groups on Cryogenian subdivision (2022)
- Voting and ratification of Cryogenian series (2023-2024).
- Interface with other international projects / groups.
- Field trips planned: (1) Utavi, Namibia field trip, mid-July, 2021 (organised by Karl-Henz Hoffman and Galen Halverson); Scotland field trip, May 2021 (virtual and already in planning, organised by Ian Fairchild and Tony Spencer); Tonian Urals field trip, 2022 (organised by Anton Kuznetsov); South China field trip, 2023 (organised by Maoyan Zhu).

Precryogenian Subcommission

- The Subcommission has made significant progress in evaluating the possible venues of subdividing the Hadean and Archean stratigraphy. The subcommission is finalising a manuscript that will discuss the problematic and present possible solutions. Submission is geared towards the beginning of 2022. The commission will submit also a proposal to fund a virtual field trip programme to a major funding agency in the USA and in Brazil. After final voting on the Hadean and Archean on the ICS level, the Subcommission will re-organise to focus specifically onto the Mesoproterozoic. Several colleagues, including Linda Kah, University of Tennessee, have expressed interest in leadership roles.

Stratigraphic Classification

- All the remaining review papers on the various branches of Stratigraphy will be published in 2021.
- The series of papers may form the core of a textbook. Publication details, including arrangements with Nägele & Obermiller, Stuttgart (the publishers of *Newsletters on Stratigraphy*) remain to be worked out.
- The subcommission will take the initiative to encourage special sessions and symposia at conferences that advance stratigraphic principles, in collaboration with other ICS subcommissions.
- The subcommission will continue to participate in GSSP discussions with ICS subcommissions.
- The subcommission continues to interface with national stratigraphic commissions although only in an advisory capacity.
- The ultimate goal is the publication of a new, multi-authored, really multinational International Stratigraphic Guide - a guide not a code, simple, clear, concise, user-friendly, for worldwide distribution and acceptance (post-2021).

Timescale Calibration

- Create the full subcommission with both voting members and corresponding members. We have completed the list of voting members and are now in the process of filling out the list of corresponding members.
- Organising the first subcommission meeting to physically bring the ISTC together for the first time
- Organising a major position volume to be focused on current best practices in timescale calibration as well as where we see the future of timescale calibration. This is to be a printed volume following on from the first subcommission meeting.
- Integrate the ISTC with other international as well as national and regional organizations. For example EARTHTIME, EARTHTIME EU, EARTHTIME China, Geochronology Division of the GSA, SEPM, The Palaeontological Association, The Paleontological Society, etc.

APPENDIX 1: ICS DIRECTORY OF OFFICERS 2020-2024

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PL Gibbard
Cambridge University
4.12.21

DAT Harper
Durham University
4.12.21

APPENDICES: REPORTS OF INDIVIDUAL SUBCOMMISSIONS

These were edited by the respective officers of the named subcommissions and are presented here as submitted.