Deep-time Digital Earth:

Introduction and progress in 2019

Junxuan Fan

Director, DDE secretariat

What is IUGS?

Deep-time Digital Earth
IUGS Big Science Program

- Founded in 1961 non-political & non-governmental UNION
- 123 National Committees (NC) and 56 affiliated organizations and serves millions of geoscientists
- Largest member of the International Science Council (ISC)
- Supports and facilitates international and interdisciplinary cooperation in the earth sciences for tackle global geological problems

International Science Council

What is an IUGS Big Science Program?

Deep-time Digital Earth
IUGS Big Science Program

Global and major issues

International collaboration

Transdisciplinary

Global – Free – Open – Sharing - Service

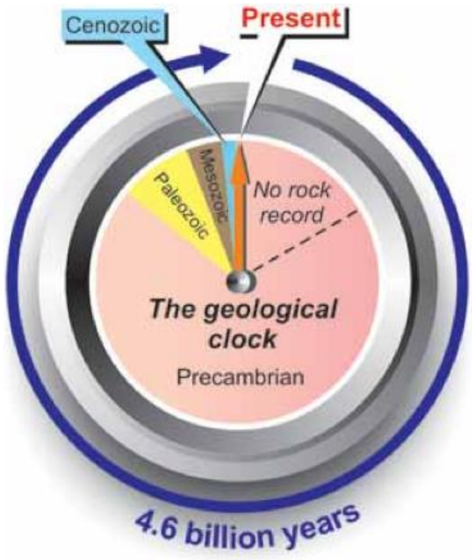
Collaboration with ISC, UNESCO etc.

Promotion in underrepresented nations

Background

"Deep-time Digital Earth" (DDE) is built on

- the International Geosphere-Biosphere Programme (IGBP)
- the Global Sedimentary Geology Program (GSGP)
- International Geoscience and Geopark Program (IGGP)
- Global Geochemical Baseline (GGB)
- International Lithosphere Program (ILP)
- OneGeology
- …



Kick-off meeting at Beijing, Feb. 26-28, 2019

- Representatives of 40 geoscience organizations attended the meeting
- 12 founding organizations signed the accord to initiate the DDE program

DDE Steering Committee

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- Regular virtual meetings every two weeks
- First face-to-face meeting:
  - Oct. 16-17, Beijing
  - Review annual progress
  - Finish the draft of Statutes and Bylaws
  - Discuss the construction of DDE Board, Governing Council, Science Committee, and Executive Committee

Statutes and Bylaws

- Draft: November 2019
- Statutes: 63 items
- Bylaws: 51 items

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IUGS

STATUTES

PREAMBLE

With its mission of integrating Earth evolution data and sharing global geoscience knowledge, and vision for promoting the transformation of the GEO-scientific research paradigm, the Deep-time Digital Earth (DDE) programme aims to harmonize deep time geological data facilitating data-driven and knowledge-driven data discovery for earth science innovation. Through DDE, a data and knowledge engine will be available in easily used 'hubs' providing insights into the distribution and value of earth resources and materials, as well as earth hazards. Data brought together in new ways may provide novel glimpses into the Earth's geological past and its future.

The Deep-time Digital Earth programme is an international consortium aiming to develop open digital platforms with full **F**indable, **A**ccessible, **I**nteroperable, and **Re**-usable (FAIR) data linking the various spheres of Earth's of geological history

The Deep-time Digital Earth programme will provide a digital earth with multidisciplinary and multidimensional earth science data as well as facilities for Deep-time Digital Data Discovery for investigating the complete evolution of earth from past to present, and towards the future.

The DDE program will build on several decades of programs promoted by IUGS in collaboration with UNESCO and other organisations including the International Geosphere-Biosphere Programme (IGBP), the Global Sedimentary Geology Program (GSGP), the International Geoscience and Geopark Program (IGGP), the Commission of the Geologic Map of the World (CGMW), the Global Geochemical Baseline (GGB), the International Lithosphere Program (ILP), and OneGeology.

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Founding members

1. International Commission on Stratigraphy (ICS)
2. International Palaeontological Association (IPA)
3. International Association for Mathematical Geosciences (IAMG)
4. International Association of Sedimentologists (IAS)
5. Commission for Geological Map of the World (CGMW)
6. Commission on the Management & Application of Geoscience Information (CGI)
7. International Association of Geomorphologists (IAG)
8. International Association on the Genesis of Ore Deposits (IAGOD)
9. American Association of Petroleum Geologists (AAPG)
10. British Geological Survey (BGS)
11. China Geological Survey (CGS)
12. Russian Geological Research Institute (VSEGEI)
13. Russian Federal Geological Foundation (FBGU)

Potential founding members

- Geological Society of Canada (GSC)
  - GC member: Linda Richard
- India Ministry of Earth Sciences， Geological Survey of India， Indian Institute of Science
- International Heat Flow Commission (IHFC)
- Integrated Ocean Drilling Program (IODP)
  - Observer in GC
- Northern European Geological surveys (NAG)
- Korean Geological Society
- Committee on Data (CODATA)

Collaboration with international organizations

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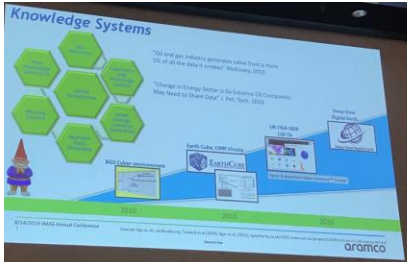
- Northern European Geological surveys (NAG)
  - Mike Stephenson: keynote, France
- Integrated Ocean Drilling Program (IODP)
  - Junxuan Fan: invited talk, Japan
- International Association of Sedimentologists (IAS)
  - Junxuan Fan: keynote, Italy
- International Association for Mathematical Geosciences
  - Qiuming Cheng: keynote, USA



Committee on Data (CODATA)

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COMMITTEE ON DATA
CODATA
INTERNATIONAL SCIENCE COUNCIL

CODATA exists to **promote global collaboration to advance Open Science** and to improve the availability and usability of data for all areas of research. CODATA works also to advance the interoperability and the usability of such data: research data should **be FAIR**

- **CODATA-DDE joint project on FAIR data**
- **MOU for future collaboration**

Barend MONS (President), Jianhui LI (Vice-president), John BROOME (Treasurer) , Simon HODSON (Executive Director)

Visiting IODP

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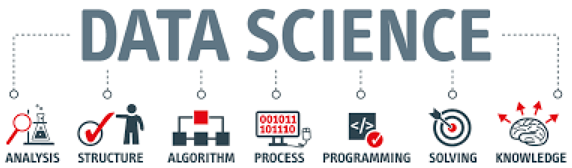
IODP is an international marine research collaboration that explores Earth's history and dynamics using ocean-going research platforms to recover data recorded in seafloor sediments and rocks and to monitor subseafloor environments.



Would start a **SOD Data Science Working Group within DDE**

- Opportunity to organize data projects
- Corral the ongoing projects such as e-IODP
- Interface/ laisse with IODP platforms
- Might even function as a SEP- style review panel

https://www.datanami.com/

Visiting IODP: viewpoint of IODP people

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Another look at Deep- Time Digital Earth

Beth Christensen
September 13, 2019

Science Advisory Structure includes SOD scientists

Danis Nurgaliev	Russia	Geophysics
David Cohen	Australia	Geochemistry
Guy M. Narbonne	Canada	Paleontology
Hans Thybo	Denmark	Geophysics
Harsh Gupta	India	Geophysics
Kathy Whaler*	UK	Geomagnetism
Kiyoshi Suyehiro	Japan	Marine science, Tectonics
Robert Hazen	US	Mineralogy
Robin Bell*	US	Glaciology
Shanan E. Peters	US	Sedimentary stratigraphy
Sierd Cloething	Netherlands	Geophysics, Geodynamic
Taras Gerya	Switzerland	Geodynamic
William Cavazza	Italy	Tectonics
Zengqian Hou	China	Economic geology

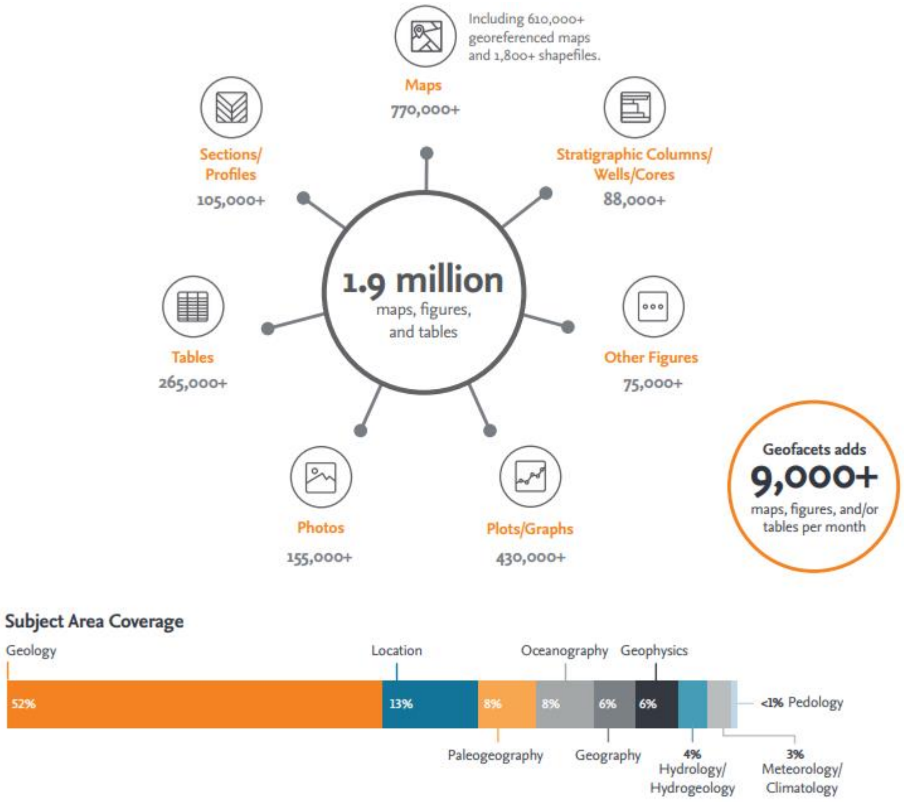
DDE is Global in structure

- IUGS is hosting this effort *http://iugs.org*
  - Non- political organization with 121 nations
    (121 - 26 = 95 possible expansions for SOD membership, maybe join E-SOD?/ e-IODP?)
  - The INTERNATIONAL UNION OF GEOLOGICAL SCIENCES is a 501 c (3) non-profit organization registered in the USA.
    - Secretary General in the US, Secretary in Bejing
- IGCP is a joint effort between IUGS and UNESCO
  - "International Geoscience Programme (IGCP) is a 45-year long joint-venture between UNESCO and the International Union of Geological Sciences (IUGS)"
  - *UNESCO and https://en.unesco.org/news/unesco-and-iugs-are-looking-new-members-join-council-international-geoscience-programme*
- *This would be parallel to IGCP (likely too big to fit into IGCP)*
  - *Early admission means a position on a governing board*

- **Website releasing in October**

Talk to publisher: database; data mining collaboration

- Elsevier
- Wiley
- Science Press



How could founding members get involved?

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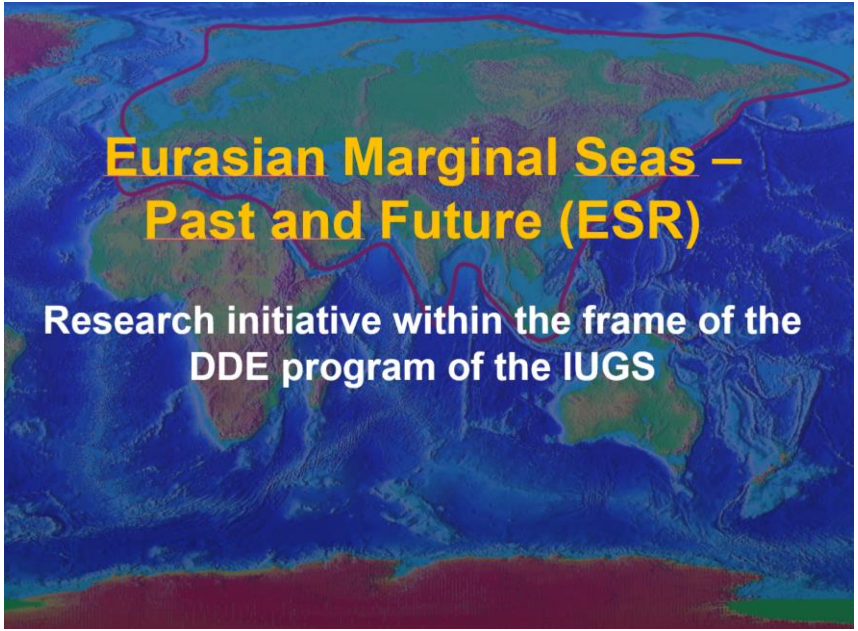
International Association for Mathematical Geosciences

IAMG can **facilitate construction and automation of discovery flow** from representation, analysis, modeling and visualization of large and growing data resources, **become core member** of a dynamic, diverse, and engaged international community of earth sciences and data science

- **Organize Task group of Eurasian Marginal Seas**
- **IAMG EC agrees to put $20,000/yr as IAMG-DDE seed funding**



How could founding members get involved?

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IUGS Big Science Program

Proposal for Eurasian Marginal Seas

Rational – a short description

The landmass of "supercontinent" EURASIA hosting 70 % of the human population is surrounded by a chain of marginal seas forming a belt of transition between land and ocean. This chain, crossing all types climate zones, formed under most different tectonic and geological conditions plays a crucial role providing people with habitat, food, trade ways, and facilitated socio-economic networking. However, marginal seas are increasingly threatened by rising sea-level, floods, storms, tsunamis, coastal erosion and environmental hazards that endanger livelihoods. These threats have become even more visible in recent times in the face of climate change and anthropogenic impact on the natural environment.
To diminish the threats cross-bordering sustainable management is becoming a unifying task for the Eurasian community and beyond. Management strategies need to consider the “geo-environmental” change in the past and future to separate natural and anthropogenic driving forces. Advanced numerical models of complex geo-systems parameterized by multidisciplinary data will help to generate time-space environmental scenarios on the global, regional and local level. An international and interdisciplinary project jointly supported by the Deep-time Digital Earth (DDE) program of the IUGS and the International Association for Mathematical Geosciences (IAMG) is proposed to answer - based on model sharing and Big Data analysis - three general questions.

Questions to be answered by the EMS project:

- How did Eurasian marginal seas of different climatic zones and tectonic settings change their paleo-geography, -oceanography and environment during the natural climate and environmental variation of the Last Glacial Cycle?

- What are the future expectations for the development of Eurasian marginal seas and their coastal zones facing the challenge of climate change and increasing human activities?

- What strategies for sustainable development of the marine and coastal realm can help to keep a balance between the protection of the environment and the economic use of marginal seas' resources?

Multi-scale model approach

The EMS project is planned to be structured into five research steps:

(1) Model design: Mirroring complex systems of meteorological, fluid, solid earth and environmental dynamics by multi-scale systems of partial differential equation systems to describe mixed conduction convection problems,

(2) Big Data Analysis: Advanced statistical methods for process identification and prediction using machine learning methods from existing data sources to determine parameters (transport coefficients) of the partial differential equations systems,

(3) Model validation: Comparison of model test results with geoscientific measured data,

- *Regional models* will be designed and applied to treat key areas representing different types of marginal seas. To study key areas, global processes have to be downscaled to regional levels describing, for instance, regional oceanographic systems, sediment-dynamics, coastline migration, and eco-dynamics.

Despite the fact that the initiative is focused on Eurasia, marginal seas of other areas will be included in the future.

Potential key study areas

The following key areas have the potential to serve as key areas in a first project approach (Fig. 1):

- Marginal seas in low latitudes (not GIA affected): East China Sea, South China Sea
- GIA-affected marginal seas in high latitudes: Baltic Sea
- Polar marginal seas: Laptev Sea
- Basin-to-basin transit: Gulf of Cadiz, Strait of Malacca
- Gulf-like marginal seas: Adriatic Sea
- Delta-ruled systems: Andaman Sea
- Marginal seas of active continental margins: Sea of Ochotsk

Implementation:

At a meeting held at State College, Pennsylvania, USA on August 12, 2019, during the annual conference of the IAMG 2019, attended by representatives of the IAMG, the IUGS and the signee it was proposed to implement the EMS Initiative as a joint Task Force jointly participated and supported by DDE and IAMG. The aim of the Task Force shall be to prepare the EMS project in order to develop and to apply mathematical models and information techniques to processing big data and to solve Eurasian Marginal Seas issues.

Financial sources for the EMS research should be provided jointly by DDE and IAMG to cover the costs for coordination, networking, scientific meetings, educational programs and publications. National funds should be added for national operational capabilities to manage the program and to support individual EMS projects. The involvement of Early Stage Researchers (ESR) and PhD students in the project will have high priority.

Road Map:

(i) *Establishment of a scientific network*

started in May 2019, status of August 2019:

China: Jinpeng Zhang (CGS/GMGS Guangzhou)
Ping Yin (CGS/QIMG Qingdao)
Di Zhou (SCSIO, Guangzhou)
Xinong Xie, Tao Jiang (CUG Wuhan)
Jiaxue Wu, Junjie Deng (Sun Yat-Sen University, Guangzhou)
Chao Li (University of Xiamen)

(4) Model application for the reconstruction of the geological past: Generation of paleogeographic, oceanographic and environmental scenarios for the time span of the Last Glacial Cycle with special focus on the Holocene and Anthropocene,

(5) Model application for future projection based on IPCC climate scenarios for a time span up to 2100 AD:

- Generation of sea-level -, coastline migration -, and environmental change scenarios
- Risk assessment of flooding, coastal erosion, ecological hazards
- Numerical cause-effect simulation in order to derive strategies for sustainable environmental and economic management.

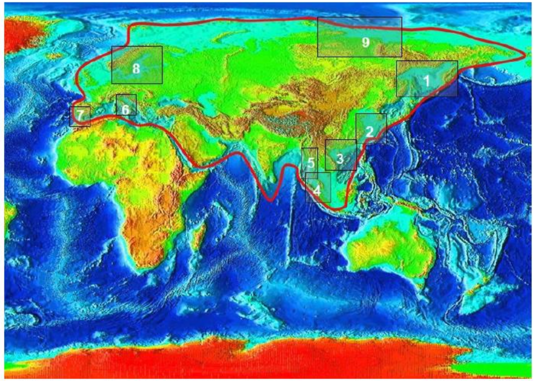


Fig. 1, Eurasia and its marginal seas, potential key areas of the EMS Research Initiative

1 Sea of Ochotsk, 2 East China Sea, 3 South China Sea, 4 Strait of Malacca
5 Andaman Sea, 6 Adriatic Sea, 7 Gulf of Cadiz, 8 Baltic Sea, 9 Laptev Sea

Spatial 2-level modeling

Spatially a two-level approach is foreseen:

- *Global models* are needed to describe processes that affect Eurasia as a whole, such as isostasy and the effects of climate dynamics.

How could founding members get involved?

Commission on Geoscience Information

- Beijing meeting 19-20 Sep. for the group setting up …

Task Group founding meeting
attend DDE, CGI-IUGS and CODATA

How could founding members get involved?

Deep-time Digital Earth
IUGS Big Science Program

First face-to-face meeting of DDE Standards Task Group

◆ January 12-13, 2020

Draft Terms of Reference for IUGS DDE Big Science Programme Standards Task Group
(Draft as 13 Jan,2020)

1. **Mission**

Jointly set up with the **CGI, CODATA, OneGeology and DDE**, the DDE Standards Task Group (DDE STG) is responsible for standards to the IUGS-recognized International Big Science Programme of 2019-2028 titled Deep-time Digital Earth (DDE). Supporting the DDE programme by providing access to efficient digital interoperable cross disciplinary geoscience standards, knowledge systems, tools and methodologies in convenient forms for DDE geoscience data for science, public and industry, for better insights into the distribution and value of earth's resources and materials.

2. **Task**

To actively organize and participate in the evaluation of DDE related standards issues for the DDE Science Programme.

How could founding members get involved?

AAPG – DDE collaborations

◆ Susan Nash from AAPG becomes the DDE International Ambassador

◆ Activities arranged based on the collaborations

Date	Event	Activity
Jan 2020	AAPG Learn! Blog	Interview
Jan - Feb 2020	Planning Machine Learning Certificate	Planning when / how to hold courses (F2F)
Mar 2020	Planning infrastructure / econ development	Identifying and planning a revenue generating project (for example, using data to help stimulate bid rounds / planning data rooms)
Jun 7-10, 2020	AAPG Annual Convention (ACE)	Booth
Jun 10, 2020	AAPG Annual Convention (ACE)	Special session on DDE
Jul 20-22, 2020	URTeC - Austin	Participation in U-Pitch New Technology Showcase
Aug 1-2, 2020	Beijing, China	Participation in AAPG Hedberg Research Conference
Sept 20, 2020	China	Offer first course for Machine Learning certificate
Sept 15 - 17, 2020	Aberdeen, UK	Participation in ENGenious / on digitization of geology
Sept 28 - Oct 1, 2020	AAPG International Conference	Participate in special session
Jan 2021	IPTC - Thailand	Present papers / participate

Mission and vision

Deep-time Digital Earth
IUGS Big Science Program

Previous version:

- Mission: Integrate Earth evolution data and share global geoscience knowledge
- Vision: Promote the innovation of geoscience research paradigm

New version: 2019.10.16

- **Mission**: harmonise global Deep-time Digital Earth data, and share global geoscience knowledge
- **Vision**: transform Earth science

SHARE

IN DEPTH | DATA SHARING

Earth scientists plan a 'geological Google'

Dennis Normile
+ See all authors and affiliations

Science 01 Mar 2019:
Vol. 363, Issue 6430, pp. 917
DOI: 10.1126/science.363.6430.917

Article | Figures & Data | Info & Metrics | eLetters | PDF

The British Geological Survey (BGS) has amassed one of the world's premier collections of geologic samples. Housed in three enormous warehouses in Nottingham, U.K., it contains about 3 million fossils gathered over more than 150 years at thousands of sites across the country. But this data trove "was not really very useful to anybody," says Michael Stephenson, a BGS paleontologist. Notes about the samples and their associated rocks "were sitting in boxes on bits of paper." Now, that could change, thanks to a nascent international effort to meld earth science databases into what Stephenson and other backers are describing as a "geological Google."

Open in new tab

Deep-time Digital Earth aims to liberate data from collections such as the British Geological Survey's.

PHOTO: BRITISH GEOLOGICAL SURVEY

Program Structure

Deep-time Digital Earth
IUGS Big Science Program

LEADERSHIP	DDE Board	Governing Council (GC)
		Executive Committee (EC)
		Science Committee (SC)

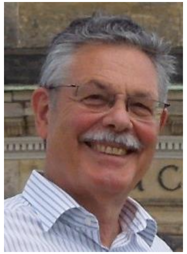
SCIENCE COMMUNTIES	Evolution of Life	Evolution of Geography
	Evolution of Earth materials	Evolution of Climate

CROSS-COMMUNTY GROUPS& TEAMS	Secretariat	Center of Excellence
	Working Group	Task Group

DDE Science Committee

Deep-time Digital Earth
IUGS Big Science Program

NAME	NATION
Roland Oberhänsli	Germany
Robert M. Hazen	US
Shanan E. Peters	US
Guy M. Narbonne	Canada
Zengqian Hou	China
Harsh K. Gupta	India
Sierd Cloetingh	Netherlands
Danis Nurgaliev	Russia
Kiyoshi Suyehiro	Japan
Hans Thybo	Denmark
William Cavazza	Italy
Dietmar Muller	Australia
Nicholas Arndt	France
Kathryn A Whaler	UK
Muhammad Asif Khan	Pakistan















Program Structure

Working groups (WG) and task groups (TG): provide the operational capabilities to manage the program and to support individual DDE projects

Working group

Paleontology | Stratigraphy | Tectonics | Sedimentology | Paleomagnetism

Geophysics | Mineralogy | Geochemistry | Hydrogeology | Geothermics

Geomorphology | Geochronology | Metamorphic petrology | Igneous petrology

Petroleum geology | Paleogeography | Geo-education | Geological mapping

Data science | Mathematic Geology | Big data | Platform

Task group

Dinosaur | Paleoclimate modelling | Marginal sea

Southeast Asia | Central Asia | Standards

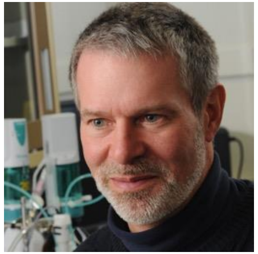
Program Structure

Deep-time Digital Earth
IUGS Big Science Program


Michael Stephenson
GC chair

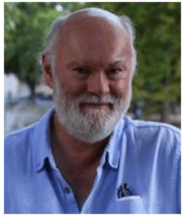

Roland Oberhänsli
SC chair


Chengshan Wang
EC chair


Robert Hazen
GC member


Kerstin Lehnert
Big data WG


Peter Fox
Data science WG

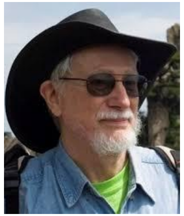

Dave Harper
Stratigraphy WG


Shuzhong Shen
Paleontology WG


Isabel Montañez
Sedimentology WG


Michael Gurnis
Tectonics WG


Sabin Zahirovic
Paleogeography WG


James Ogg
Paleogeography WG


Kris King
GeoEducation TG

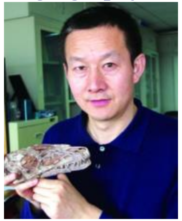

Bruce Eglington
Petrology WG


Oleg Petrov
Petrology WG


Shaunna Morrison
Petrology WG


Matthew Harrison
Big data WG


Tim Lenton
Modelling TG


Xing Xu
Dinosaur TG


Junxuan Fan
Secretary general

Executive Director of DDE CE (Suzhou)

Deep-time Digital Earth
IUGS Big Science Program

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Harvard University
- Ph.D., 1988, Geology
- A.M., 1987, Geology

Oxford University
- Honors B.A., 1982, Philosophy, Politics and Economics

Yale University
- M.S., 1980, Geology and Geophysics
- B.S., 1980, with distinction in Geology and Geophysics and in Economics and Political Science

EXPERIENCE

Carnegie Institution for Science
- Director, Deep Carbon Observatory (DCO), 2011-2019

Geological Society of America
- Director for Geoscience Policy, 2007-2011

National Council for Science and the Environment
- Director of Science Policy, 2002-2007

Yale University
- Alan M. Bateman Distinguished Lecturer, 1999-2000

National Academy of Sciences / National Research Council
- Commission on Geosciences, Environment, and Resources Associate Executive Director for Special Projects, 1998-1999
- Director, Board on Earth Sciences and Resources, 1995-1998

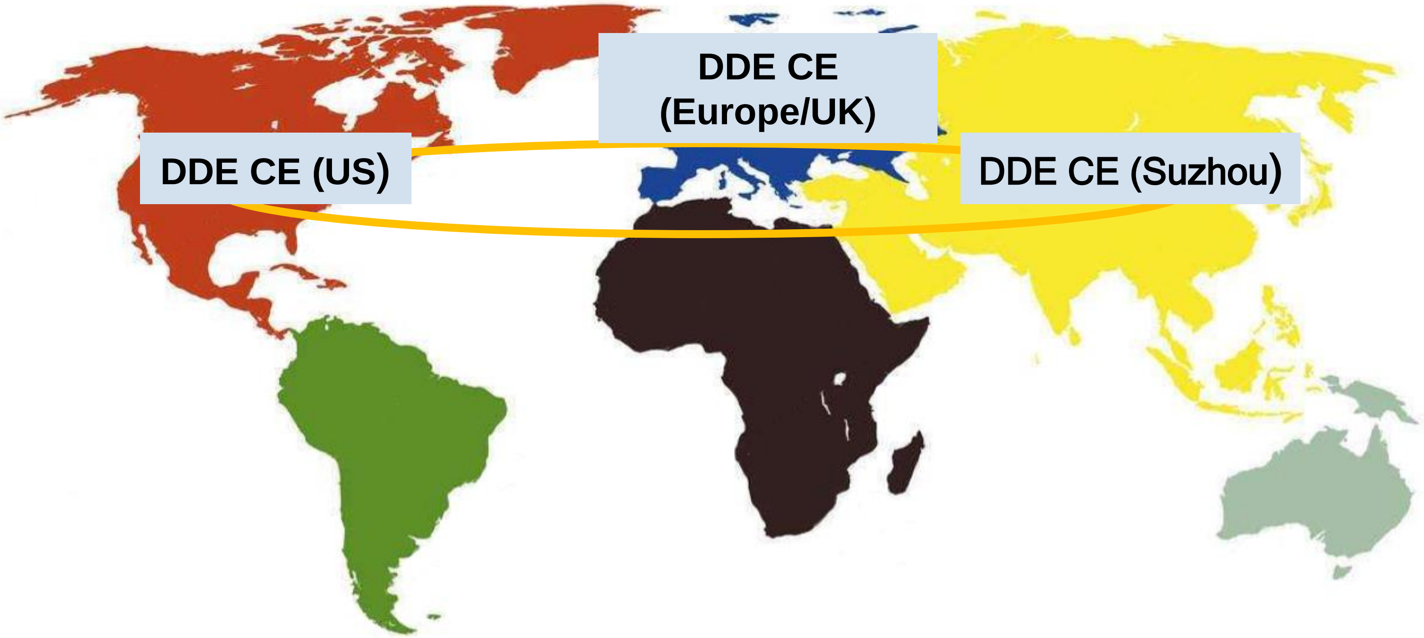
American Geological Institute
- Director of Government Affairs, 1994-1995
- Coordinator of Government Affairs, 1992-1993

United States Senate
- Subcommittee on Technology and the Law, Senate Judiciary Committee Professional Staff Member, 1991
- Congressional Science Fellow, 1990-91

Carnegie Institution of Washington
- Carnegie Fellow, Geophysical Laboratory, 1988-1990

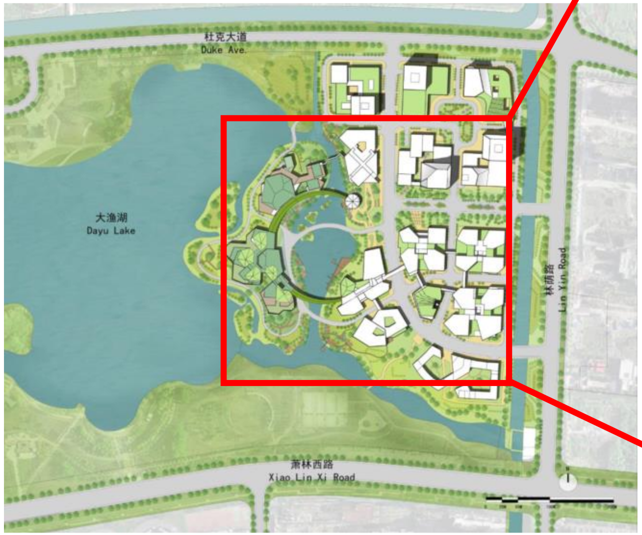
Program Structure

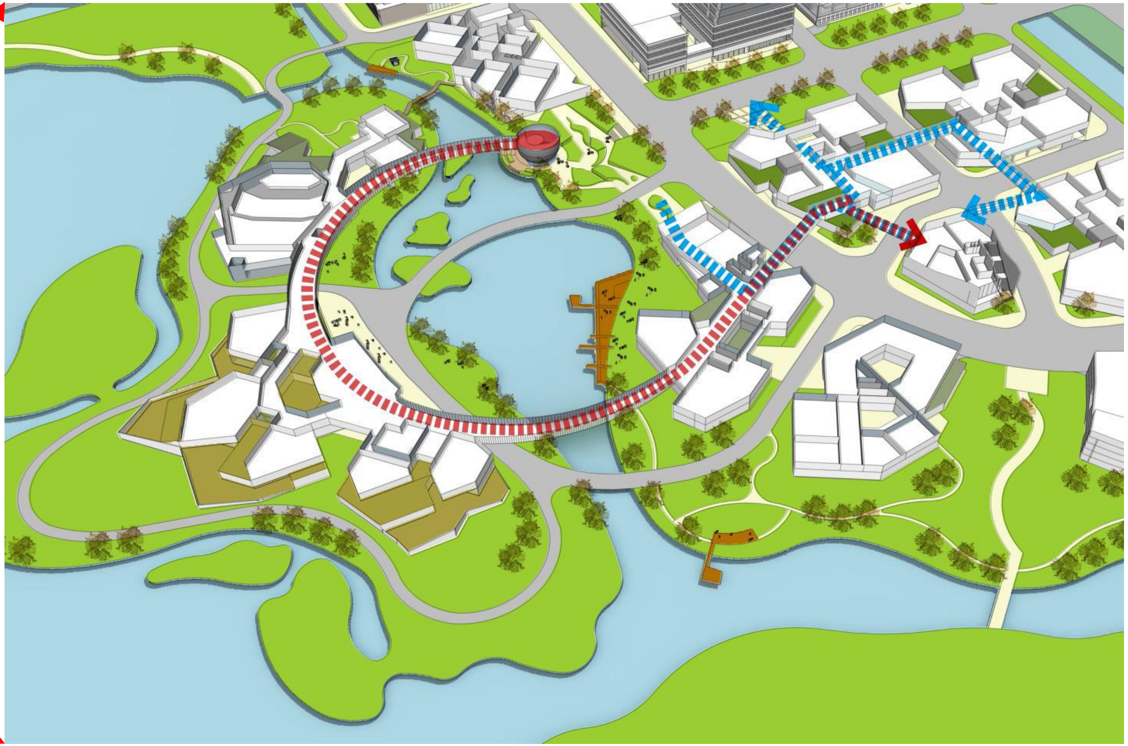
- At least three DDE Centres of Excellence (CE): China, Europe/UK and US
- Linking all the existed, independent databases in the world, and providing long-term, sustainable online service



DDE Centres of Excellence

Deep-time Digital Earth
IUGS Big Science Program





DDE Centres of Excellence: Suzhou

- 300,000 m²: Research, Conference, Technology Application, Popular Science…

DDE Centres of Excellence: Suzhou

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DDE Centres of Excellence: Suzhou

Deep-time Digital Earth
IUGS Big Science Program

DDE Centres of Excellence: Suzhou

DDE Centres of Excellence: Suzhou

DDE Centres of Excellence: USA

- 4D project (Carnegie Institute)
- Consortium by University of Texas and Purdue University

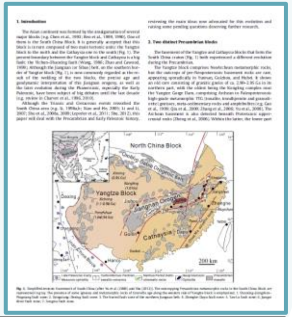
Why DDE Needs Geoscience Knowledge System?

CHALLENGES in integrating earth science big data：

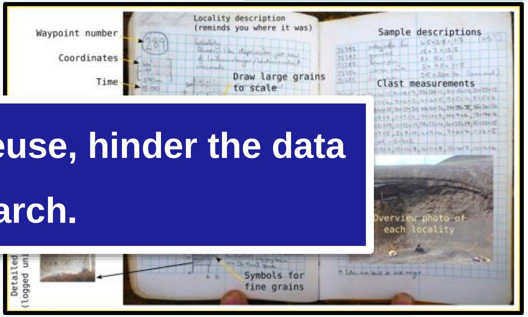
- **Highly complicated terminology in earth science**

various research methods make the data ‘fragmented’ and hard to be integrated

Articles



fieldbooks

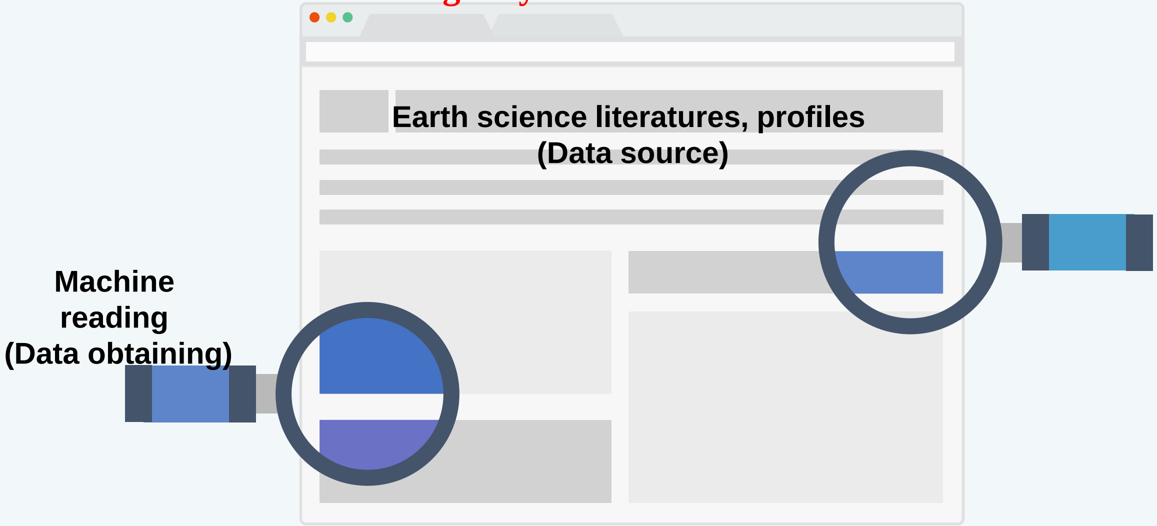


making great barriers for data integration and reuse, hinder the data mining and deep learning in Earth Science research.

The first and fundamental step: to built a machine understandable knowledge system.

Train the computer to read and digest the geoscience literature

Extract data intelligently from unstructured literature to structured data.

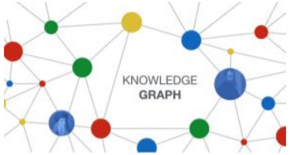


One of the fundamental part of DDE initiatives is to establish a comprehensive Geoscience Knowledge System to facilitate data finding, accessing, integration and reuse.

A hierarchical nested structure of knowledge for smart data processing

Deep-time Digital Earth
IUGS Big Science Program

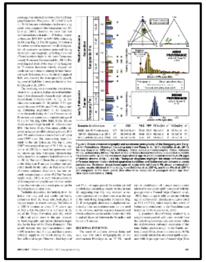
Artificial Intelligence powered by
Geological knowledge system



Data collection

Data storage& curation

Data analysis & visualization



Data mining and visualization

— Text to annotate —

consistent with its palaeo-connection into the thicker and more extensive Carboniferous succession to the north-west, in the Midland Valley.

— Annotations — named entities ✕ openie ✕ — Language — English ▾ Submit

Named Entity Recognition:

1 Apart from several named and extensively worked coal seams , the succession consists mainly of sandstone , siltstone , mudstone and seatearth , with ironstone ribs in places .

2 As with the underlying Scottish Lower Coal Measures [LEXICON] , there is a general thinning of the succession towards the eastern part of the Sanquhar Basin [LOCATION] , consistent with its palaeo-connection into the thicker and more extensive Carboniferous [CHRONOSTRAT] succession to the north-west , in the Midland Valley [LOCATION] .

text1 = ("The fauna consists of seven genera/subgenera, Agastograptus, Gothograptus, Holoretiolites, Paraplectograptus, Plectograptus (Plectograptus), Plectograptus (Sokolovograptus) and Spinograptus")

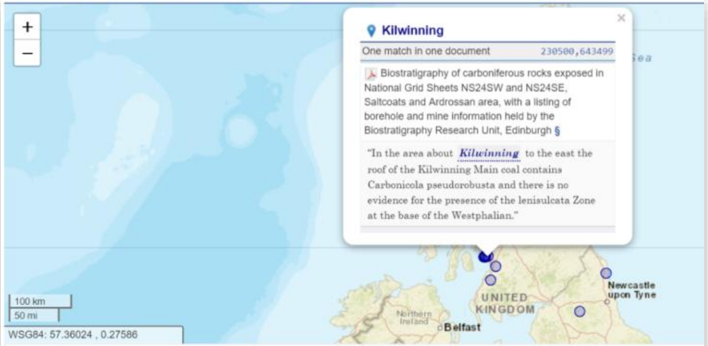
tag1 = ['O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'U-FOSSIL', 'O', 'U-FOSSIL', 'O', 'U-FOSSIL', 'O', 'U-FOSSIL', 'O', 'B-FOSSIL', 'I-FOSSIL', 'I-FOSSIL', 'L-FOSSIL', 'O', 'B-FOSSIL', 'I-FOSSIL', 'I-FOSSIL', 'L-FOSSIL', 'O', 'O', 'U-FOSSIL', 'O']

3 Geochronological Divisions found in *WH88282R_29453_000177*

Divisions matched sort by Match Count (9-1) ▾

Code	Name	Min Age (MYBP)	Max Age (MYBP)	Matches	Division frequency
C	Carboniferous Period	298.9 ±0.2	358.9 ±0.4	3	C 3
CW	Westphalian Stage	308 approx. ± 0	319 approx. ± 0	2	CW 2
CN	Namurian Stage	319 approx. ± 0	329 approx. ± 0	2	CN 2

15 Locations found in *WH88282R_29453_000177*



Found 15 Gazetteer Places   Found 0 BNG Grid References

Data mining and visualization

Deep-time Digital Earth
IUGS Big Science Program

GeoDeepDive

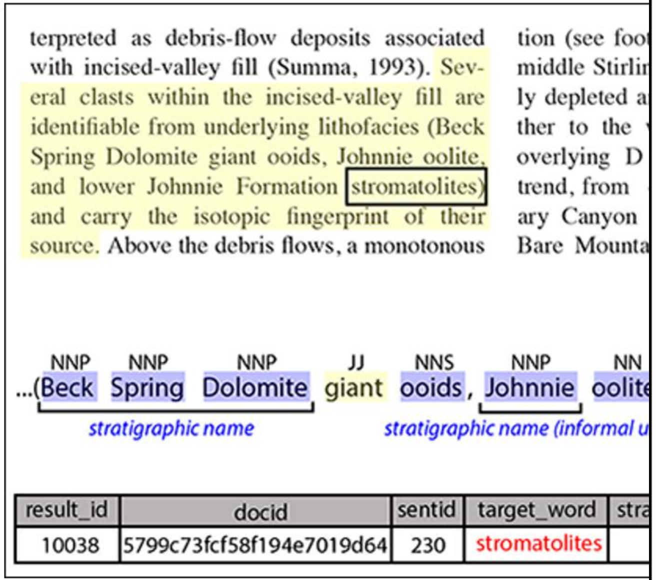
Temporal and spatial distribution of stromatolites in North Ame

Algorithm:

- Search sentences with "stromatolite" and related names, record all t
- Supercomputer: Analysis more than 8000 articles and feedback stru

Analysis process

extraction

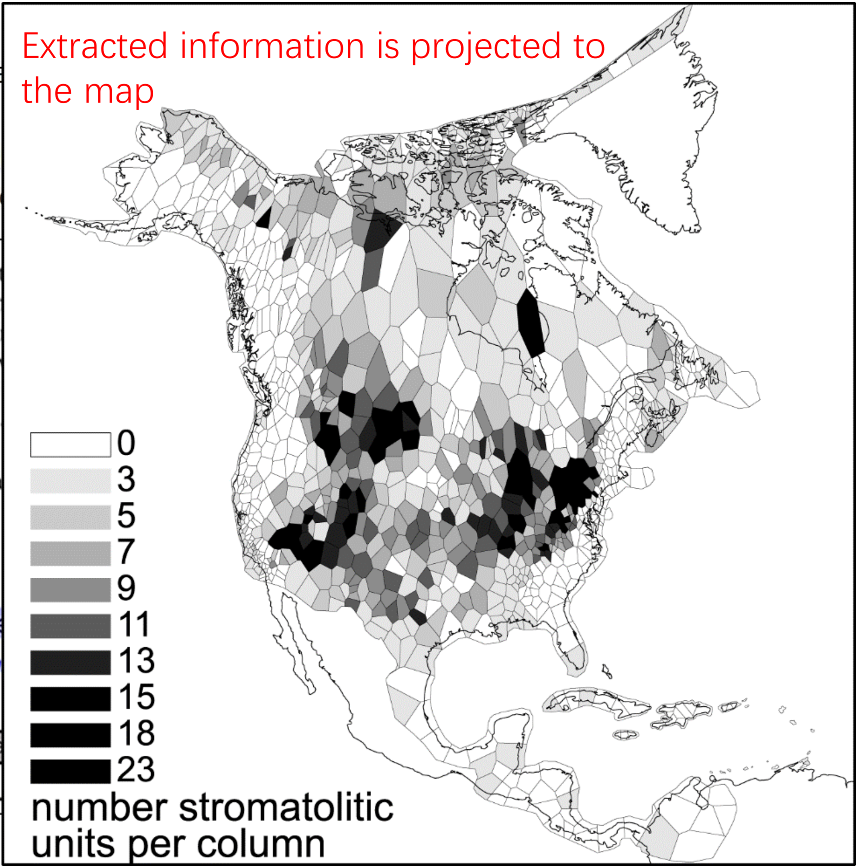


terpreted as debris-flow deposits associated with incised-valley fill (Summa, 1993). Several clasts within the incised-valley fill are identifiable from underlying lithofacies (Beck Spring Dolomite giant ooids, Johnnie oolite, and lower Johnnie Formation stromatolites) and carry the isotopic fingerprint of their source. Above the debris flows, a monotonous

tion (see foot
middle Stirlin
ly depleted a
ther to the
overlying D
trend, from
ary Canyon
Bare Mounta

result_id	docid	sentid	target_word	stra
10038	5799c73fcf58f194e7019d64	230	stromatolites	

(Wilcots et al., 2015, GSA abstract program;



An open platform with FAIR data

- **Create a 5-star open platform**

★ Available on the web (whatever format) but with an open license, to be Open Data

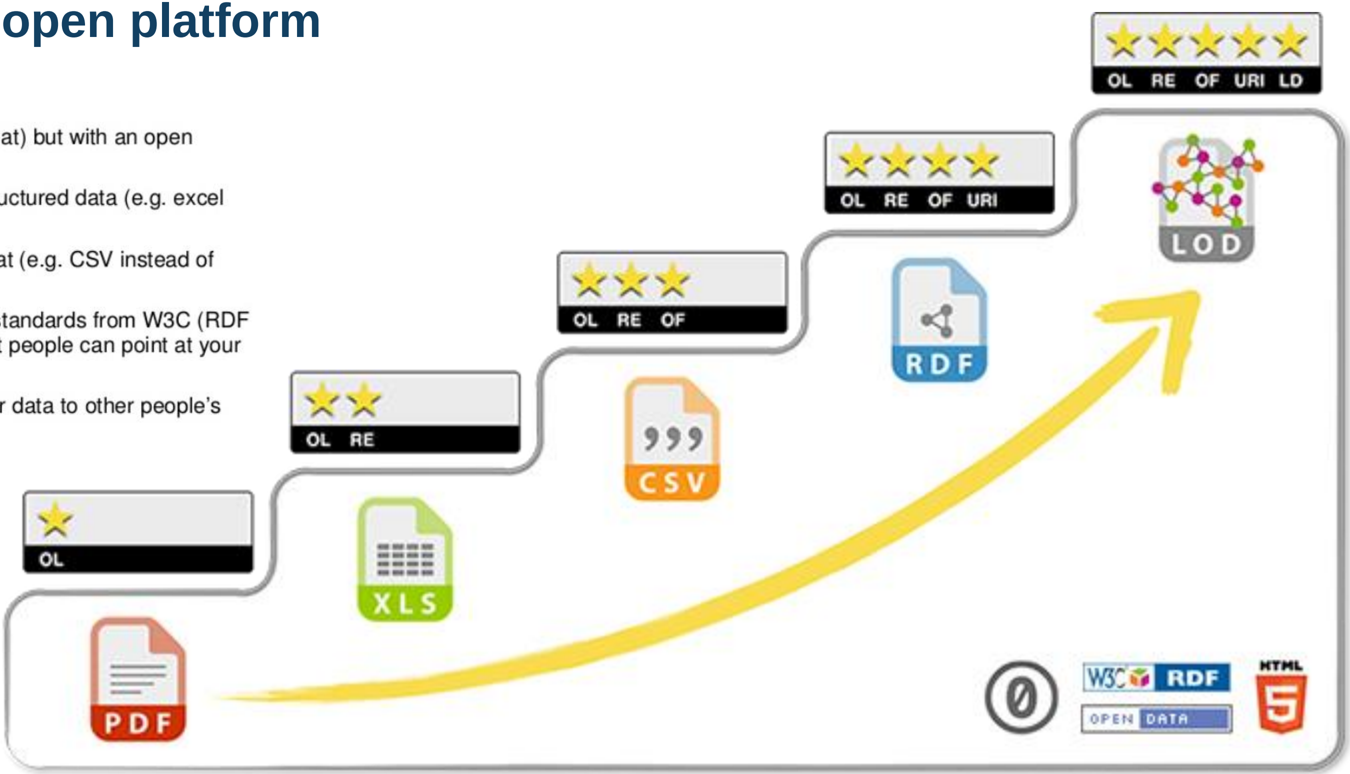
★★ Available as machine-readable structured data (e.g. excel instead of image scan of a table)

★★★ as (2) plus non-proprietary format (e.g. CSV instead of excel)

★★★★ All the above plus, Use open standards from W3C (RDF and SPARQL) to identify things, so that people can point at your stuff

★★★★★ All the above, plus: Link your data to other people's data to provide context

Linked Open Data



Berners-Lee (2006) (Image sources: w3c.org and 5stardata.info)

What is DDE-Knowledge System

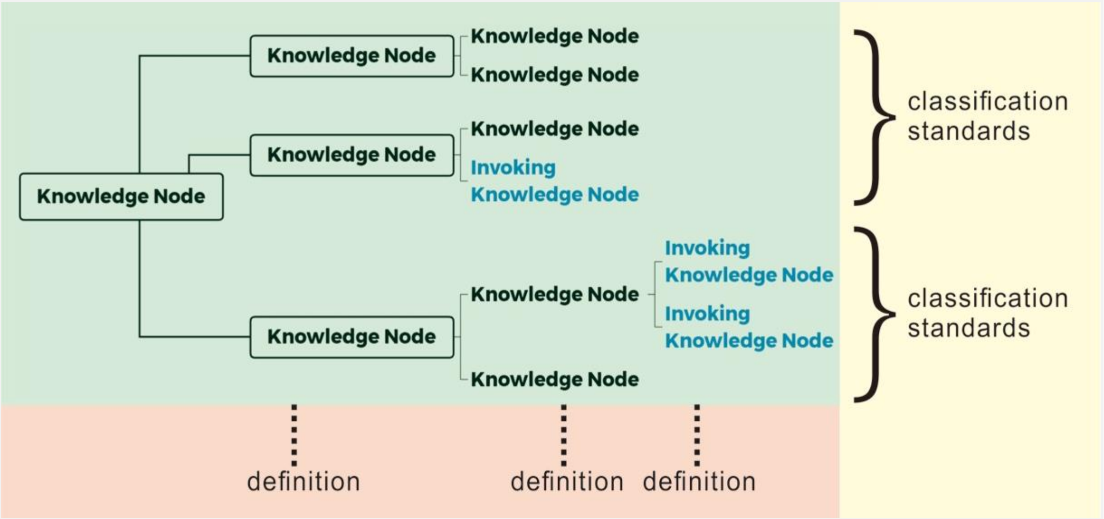
- A series of explicit and formal definitions for the concepts that fall with the DDE project’s domain, along with specification of internal conceptual relations;
- Acting as a mediator to reconcile heterogeneous geoscience data collected from different disciplines globally to meet the requirements of the FAIR data principles and play an important role in earth science research enhanced by Artificial Intelligent technologies.

Conceptual map of Knowledge System

- The whole DDE-Knowledge system has a wide coverage of Earth Science disciplines.
- All concepts within a discipline will treated as a knowledge node and would be organized into a hierarchical structure.
- Each node in the hierarchical structure would be described explicitly and formally.
- Semantic relationships among nodes (e.g. “is-a”, “part-of”, “consisting of”, “including”, etc.) would be described as well.

↓Knowledge Tree

↓Knowledge standard

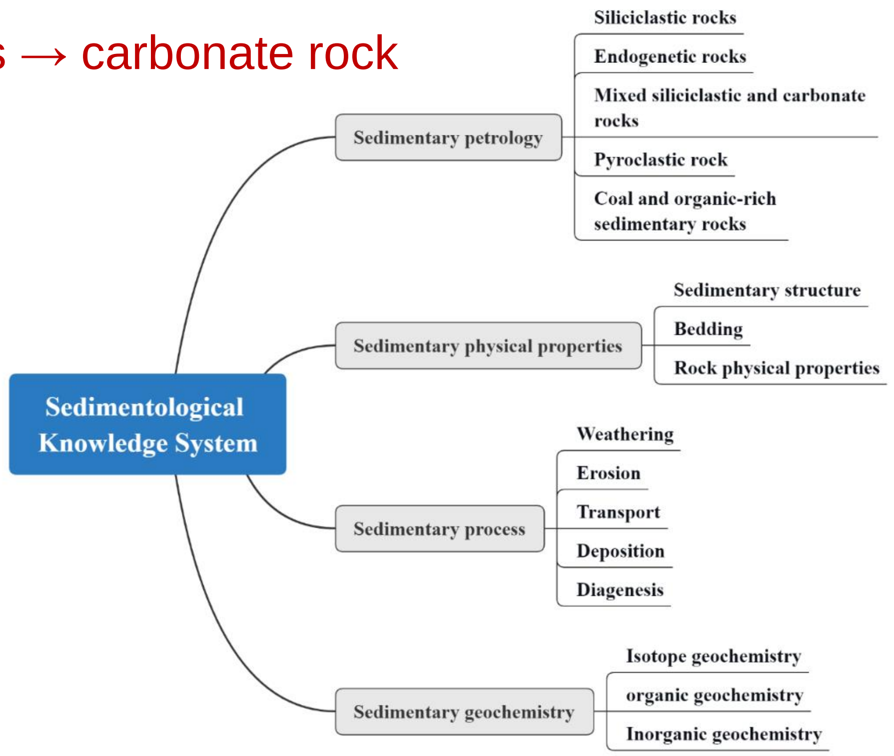


↑Knowledge definition

Example of the Sedimentology Knowledge System

Sedimentology→Sedimentary petrology→

endogenetic rocks → carbonate rock



Efficient cooperation among geoscientists, data scientists and computer scientists

Computer scientists

- **Implement a knowledge system editor to store, manage, visualize and search the knowledge system online**

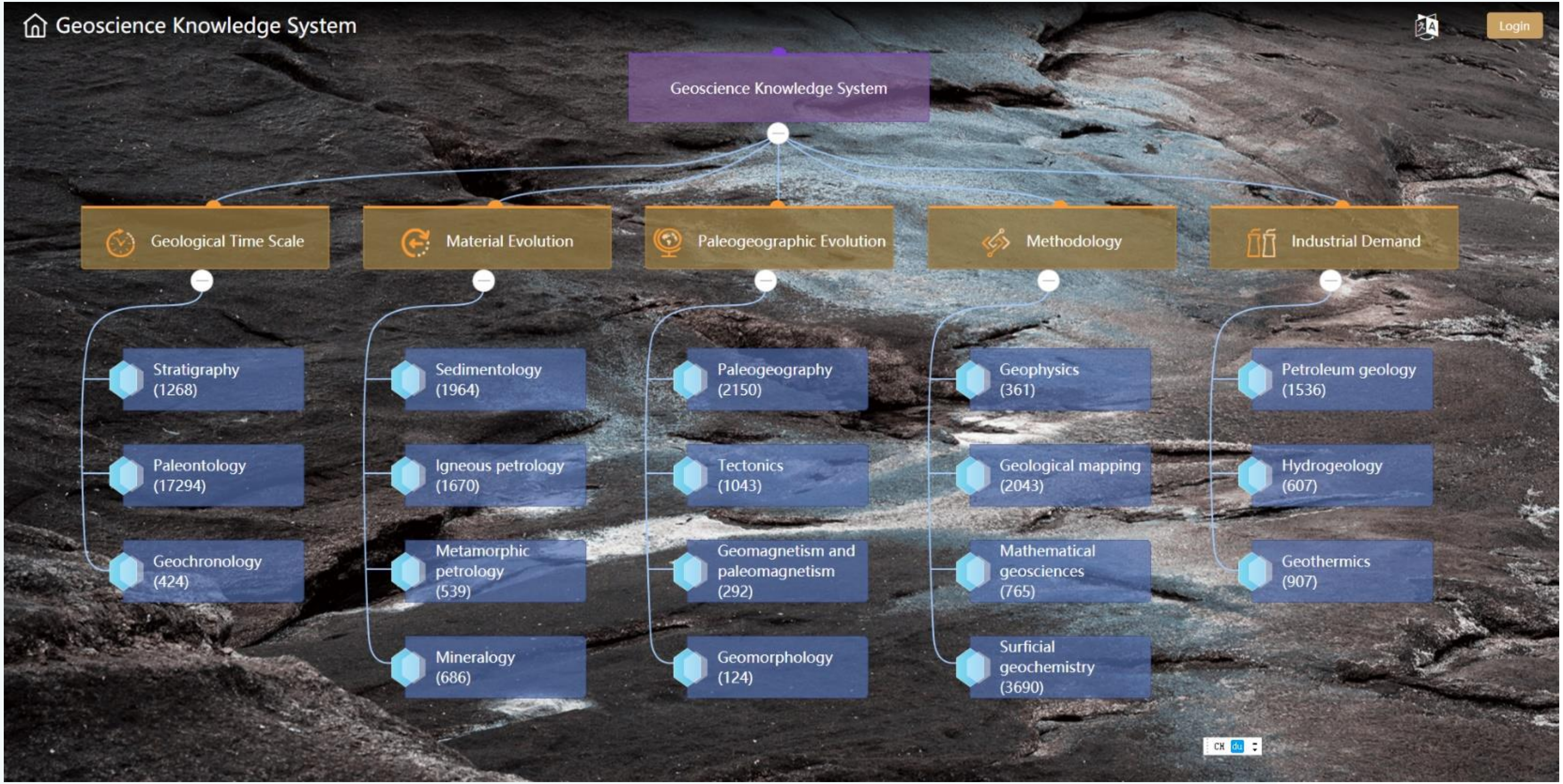
Data scientists

- **Set up mandatory and optional terms to describe the knowledge system in a pre-defined format recommend by W3C**

Geoscientists

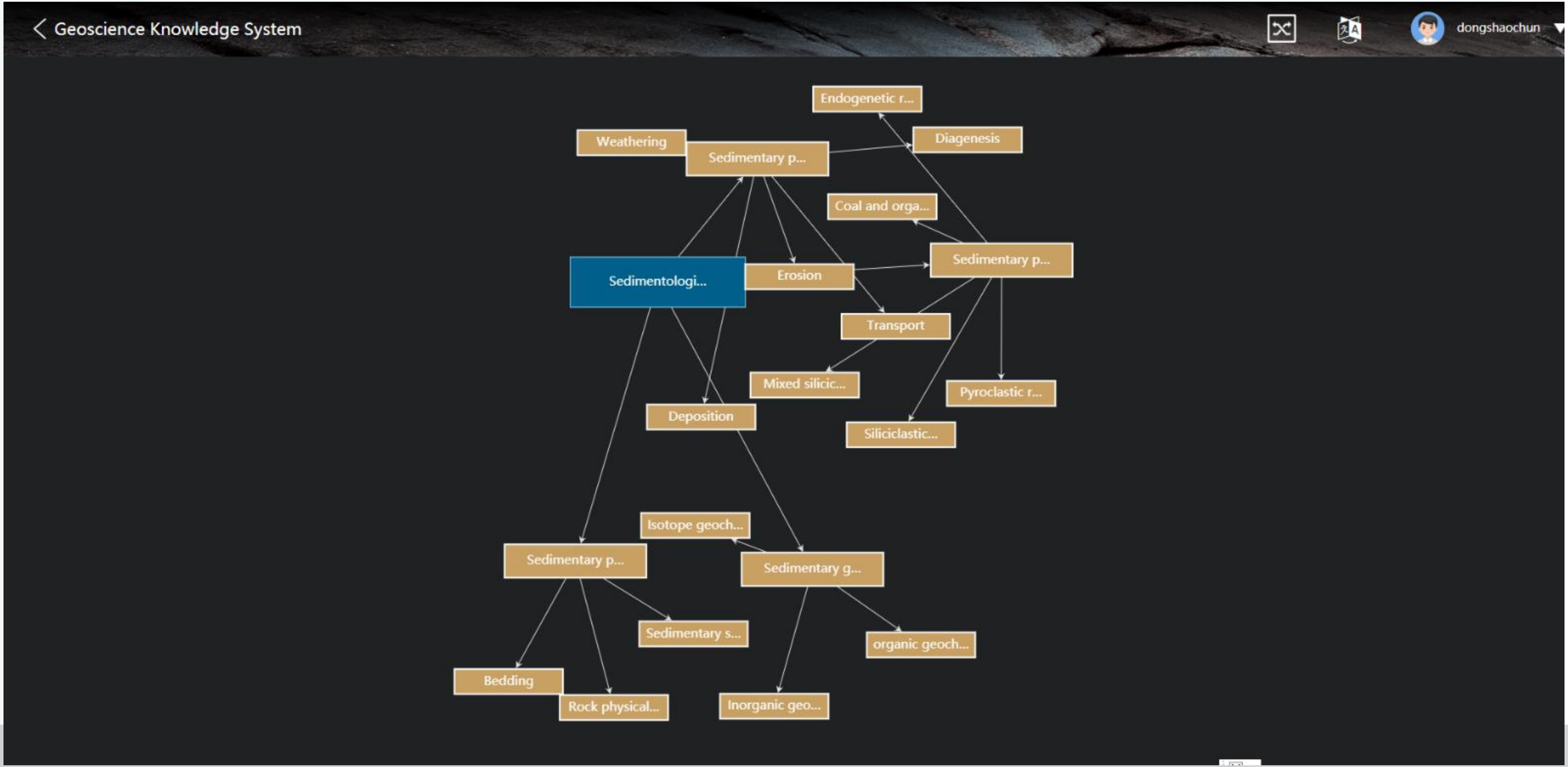
- **Describe the knowledge system in a hierarchical way.**

Construction platform: A cloud-based cooperation platform developed by DDE



http://222.79.57.25:10139/

The graph mode



Nodes that has already constructed

Each working group had conduct more than two-round of “construction-review-modification”

Total knowledge nodes：
37467

Till Jan.8, 2020

- **1212 CGI nodes are downloaded from GeoSciML Vocabularies and EarthResourceML Vocabularies**
- **Most of the them are adopted by DDE-KS, only 129 nodes are not.**

Discipline	Number of nodes
Stratigraphy	1268
Palaeontology	17383
Geochronology	424
Igneous petrology	1670
Metamorphic petrology	539
Sedimentology	1964
Mineralogy	686
Geomorphology	124
Palaeogeography	2150
Tectonics	1043
Palaeomagnetism	292
Mathematical geology	765
Geologic mapping	2058
Surfacial geochemistry	3690
Geophysics	361
Petroleum geology	1536
Hydrogeology	607
Geothermics	907

Why some CGI definitions are not adopted?

Examples in sedimentology：Packstone

More precise definition are found

DDE：Packstone is a carbonate-dominated lithology containing carbonate mud (<63 μm) in a fabric supported by a sand grade (63 μm to 2 mm) grain-size fraction and where less than 10% of the volume is comprised of grains >2 mm. (Lokier S W, Al Junaibi M. The petrographic description of carbonate facies: are we all speaking the same language?. Sedimentology, 2016, 63(7): 1843-1885)

CGI：Carbonate sedimentary rock with discernible grain supported depositional texture, containing greater than 10 percent grains, and constituent particles are of intrabasinal origin; intergranular spaces are filled by matrix.

Embry & Klovan Classification system

<table>
<tr><td colspan="6">Allochthonous Limestones - No evidence that the original components were bound together at the time of deposition</td></tr>
<tr><td colspan="4">Less than 10% of the components are >2 mm</td><td colspan="2" rowspan="2">Greater than 10% of the components are >2 mm</td></tr>
<tr><td colspan="3">Contains lime mud (<30 µm)</td><td>No lime mud</td></tr>
<tr><td colspan="2">Mud-supported</td><td colspan="2" rowspan="2">Grain-supported</td><td rowspan="2">Matrix-supported</td><td rowspan="2">Grain-supported by the >2 mm size fraction</td></tr>
<tr><td>Less than 10% grains (>30 µm – 2 mm)</td><td>Greater than 10% grains (>30 µm – 2 mm)</td></tr>
<tr><td>Mudstone</td><td>Wackestone</td><td>Packstone</td><td>Grainstone</td><td>Floatstone</td><td>Rudstone</td></tr>
</table>

Lokier and Junaini, 2016 Sedimentology

The definition of CGI doesn’t include:

1) The size of carbonate grains, which is important to distinguish packstone to rudstone

2) The size of matrix (carbonate mud)

The next step

- To Continue the construction of DDE-KS
- To carry out International review organized by CGI
  - CGI + CODATA + international associations or committees of each discipline
  - CGI + CODATA + DDE working group
  - The review process, including the evaluation and the election of reviewers must by approved by CGI
  - Our platform provides online review service and can be accessed all over the world
- To conduct research based on knowledge system

CGI
Commission for the Management and Application of Geoscience Information

COMMITTEE ON DATA
CODATA
INTERNATIONAL SCIENCE COUNCIL

Databases in Geoscience

Deep-time Digital Earth
IUGS Big Science Program

NEOTOMA PALEOECOLOGY DATABASE

VertNet

IGSN

UNAVCO

IEDA

IRIS

MORPHOBANK
HOMOLOGY OF PHENOTYPES OVER THE WEB

ePANDDA API
enhancing Paleontological and Neontological Data Discovery

TreeBASE

EARTHTIME
ACCELERATING ADVANCES IN GEOCHRONOLOGY SINCE 2003

iDigBio
@iDigBio

DRYAD

The Paleobiology Database

DataONE
Data Observation Network for Earth

BCO-DMO
Biological & Chemical Oceanography Data Management Office

HYDROSHARE

GBIF Global Biodiversity Information Facility

Geochron

earthlife CONSORTIUM

Macrostrat

SEAD

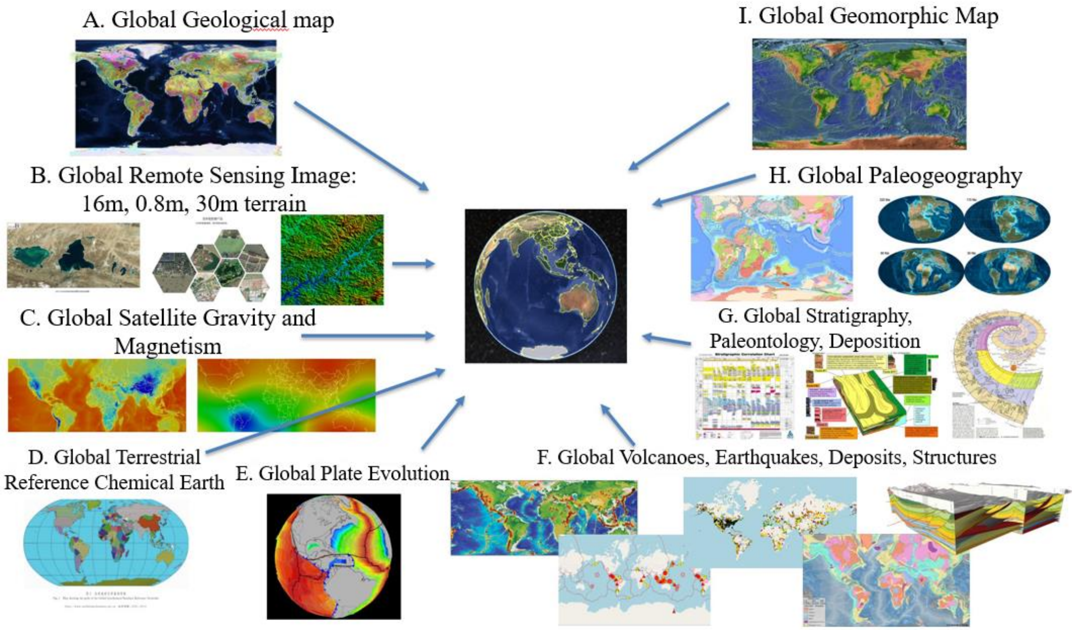
GBDB Geobiodiversity Database

EarthChem

DDE platform: *Geological google*

Deep-time Digital Earth
IUGS Big Science Program

Distributed, not a centralized system



Data sharing

&

collaboration

IEDA

The Paleobiology Database

iDigBio
@iDigBio

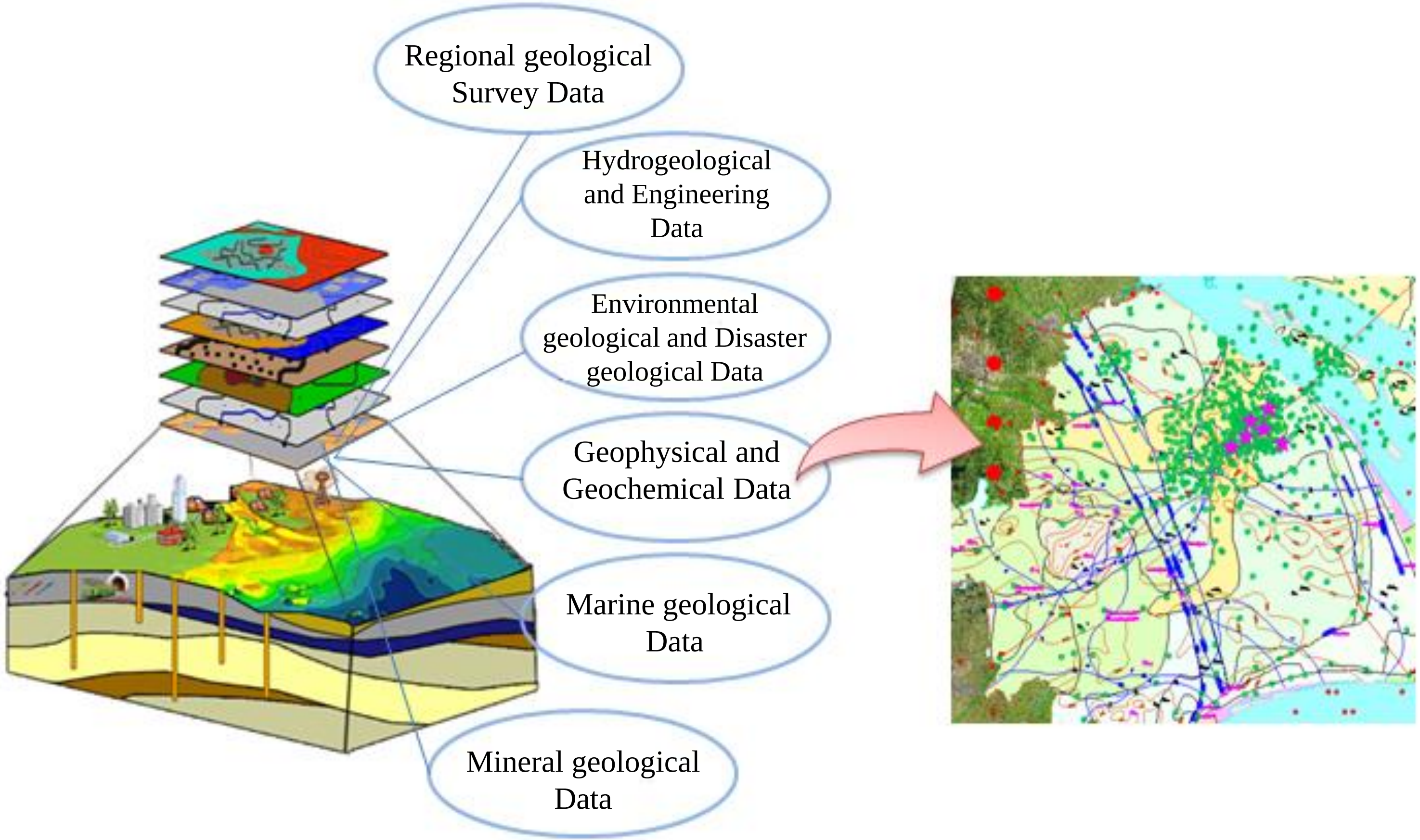
Geochron

GBDB
Geobiodiversity Database

EARTHTIME
ACCELERATING ADVANCES IN GEOCHRONOLOGY SINCE 2003

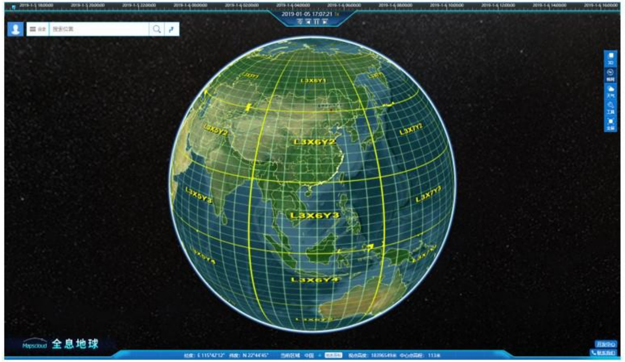
DDE platform: *Geological google*

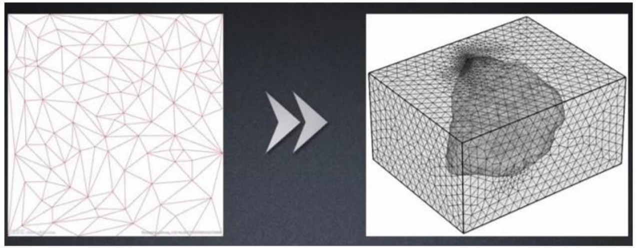
Deep-time Digital Earth
IUGS Big Science Program



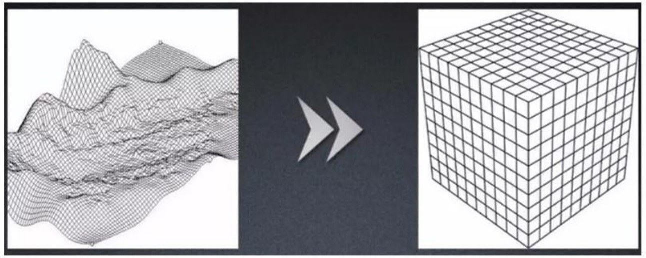
3D Modeling and Visualization of Solid Earth under Unified Space-time Reference

Uniform Depth Reference Design

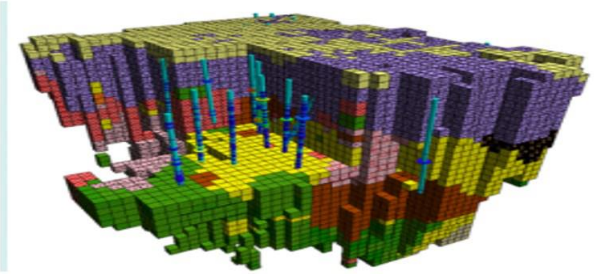




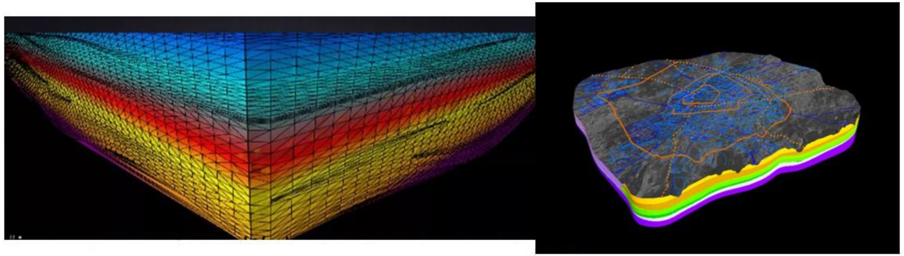
3D Modeling of Geological Bodies: Irregular Tetrahedral Grids Express Geological Structures



3D Modeling of Geological Bodies: Voxel Grids Express Geological Structures



Modeling and Visualization of Borehole and Profile Data



Modeling and Visualization of Geological Bodies Data

DEEP platform development plan (App, middle platform, intelligent platform three-step strategy)

Deep-time Digital Earth
IUGS Big Science Program

The first stage: research and development of DEEP Earth, Map, GeoTools, APPStore, extensive integration of existing tools and systems, integration of existing data based on the cloud database provided by the platform, construction of deep Earth data cubes, development of DEEP Portal to provide unified deep time Space-based global geological information service.

Deep Earth Information Service Platform

Deep earth data cube
（2019-2020.3）

Deep Earth Holographic Big Data Platform

Deep time holographic cube
（2020.4-2021）

The second stage: research and development of spatio-temporal data warehouse, deep knowledge database, DEEP Engine. Form the ability to analysis big data. Extensively correlate data results to build deep-time holographic cubes. Provides scientists with convenient data-intensive scientific research and knowledge discovery services supported by online and super-computing capabilities.

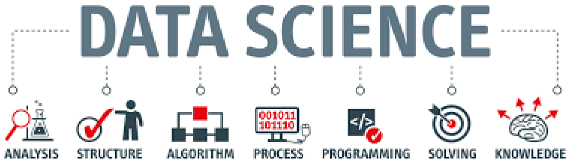
Intelligent platform

Deep Earth Intelligent Cube
（2022—）

The third stage: combined with artificial intelligence technology to build a smart data cube for the earth, providing intelligent services.

Primary Goals

- An international consortium
- Linking isolated databases into an open system
- Make scientific data and information **FAIR** (Findable, Accessible, Interoperable, and Re-usable)
- Linking various Earth's spheres (hydrosphere, geosphere, atmosphere, biosphere)
- Promoting innovative research on 4E (Evolutions of life, Earth materials, geography and climate)



https://www.datanami.com/

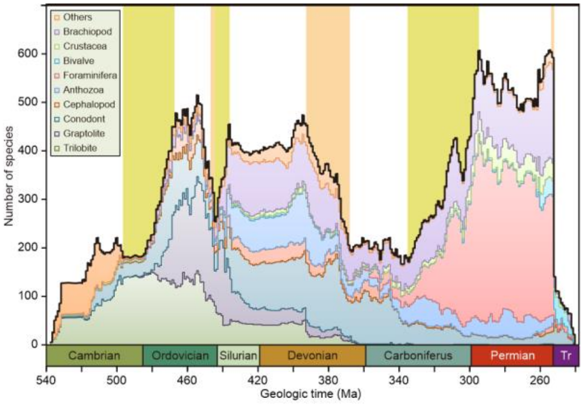
Data-driven knowledge discovery

Deep-time Digital Earth
IUGS Big Science Program

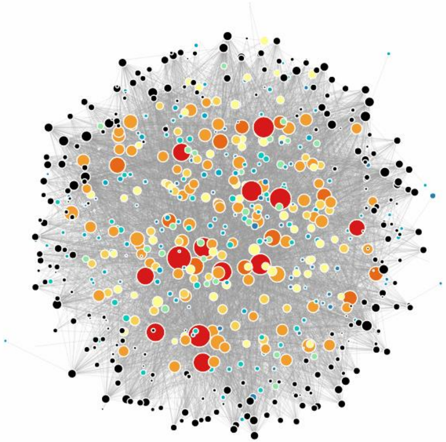
"transform geoscientific research"

Four major questions:

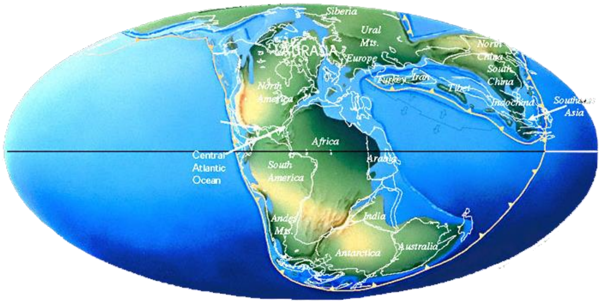
- Evolution of Life
- Evolution of Earth materials
- Evolution of Geography
- Evolution of Climate



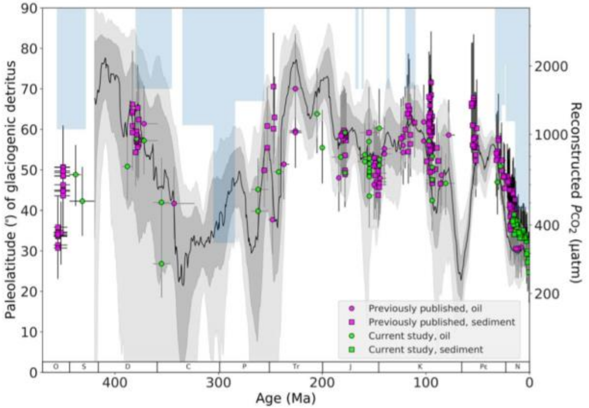
Paleozoic marine diversity



Mineral network analysis



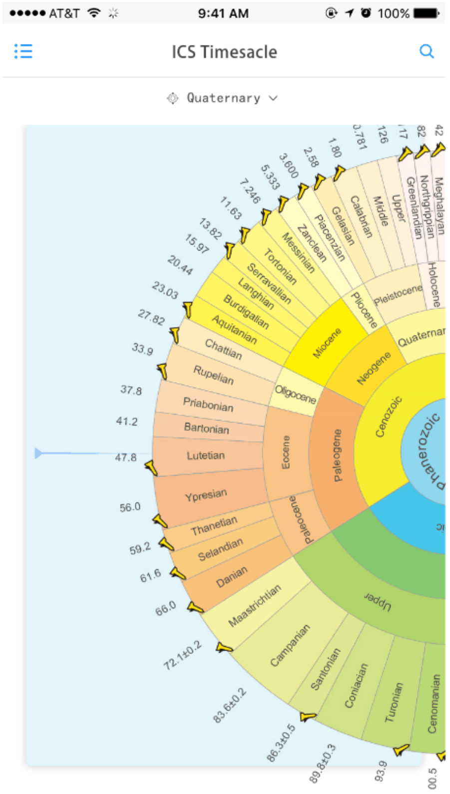
Paleogeographic reconstruction



Reconstructed Pco_2

Data-driven knowledge discovery

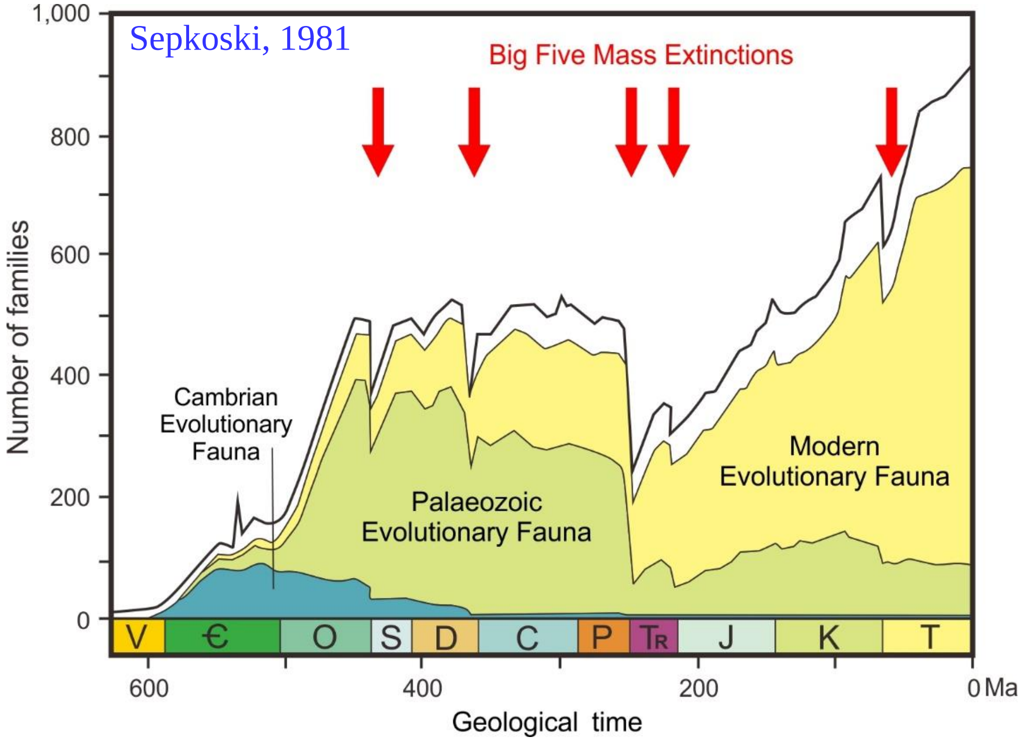
Deep-time Digital Earth
IUGS Big Science Program

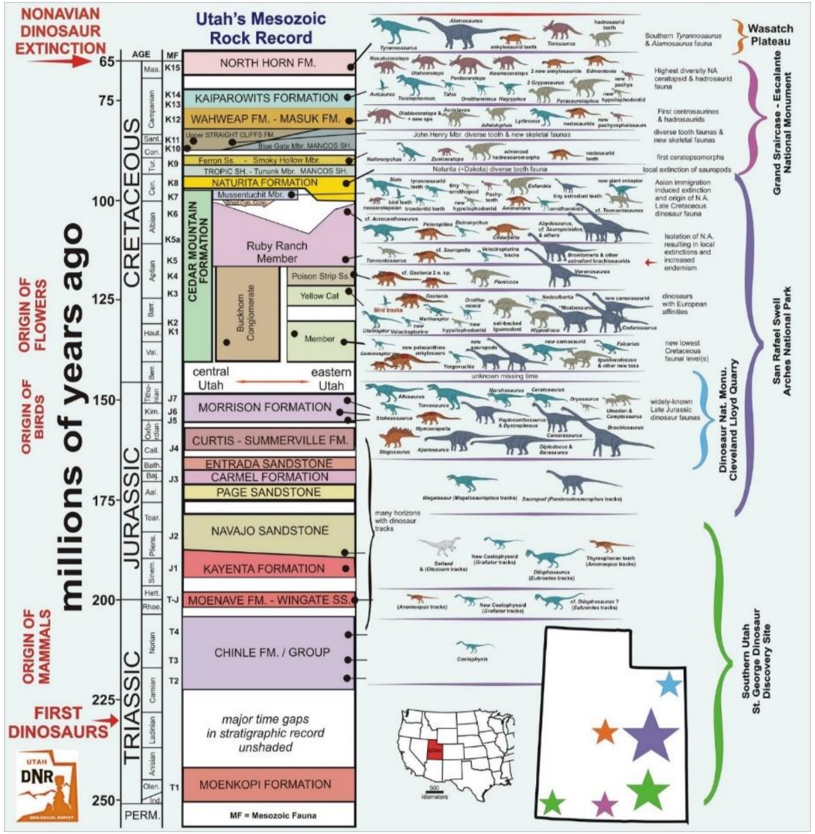


Top 10 scientific research directions

1. Integrating a uniform high-resolution earth time system
2. Origin and evolution of life and biodiversity
3. How did the sedimentary matter evolve and cycle?
4. Reconstructing earth climate and atmosphere history from big data of multiple geochemical indices
5. Global sea-level change through deep time
6. Quantifying plate tectonics and deformation in four dimensions
7. 4D architecture and evolution of deep-earth materials and dynamics
8. Mineral evolution beyond 4D
9. Establishing a globally shared big-data energy resource system for sustainable development
10. Big data system of geophysical fields for prediction of seismic hazard

Origin and evolution of life and biodiversity

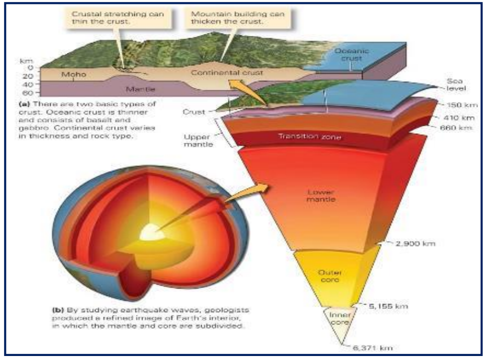


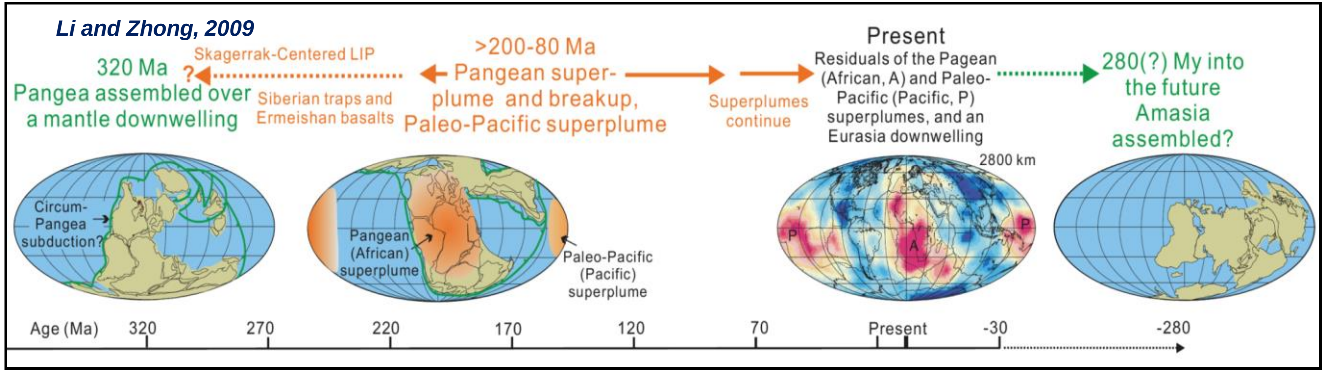


4D architecture and evolution of deep-earth materials and dynamics

Deep-time Digital Earth
IUGS Big Science Program

1. **3D architecture and evolution of deep-earth materials**
2. **Deep dynamics of assemblage-breakup and cycle of super-continent**
3. **Recycle of crustal-mantle material and development of metallogenic system**





Mineral evolution on Earth and other planets

The changing diversity and distribution of minerals in near-surface environments of Earth and other terrestrial planets and moons through deep time

Three Eras and Ten Stages of Earth's Mineral Evolution

Era/Stage	Age (Ga)	Cumulative no. of species
Prenebular "Ur-Minerals"	>4.6	12
Era of Planetary Accretion (>4.55 Ga)		
1. Primary chondrite minerals	>4.56 Ga	60
2. Achondrite and planetesimal alteration	>4.56 to 4.55 Ga	250
Era of Crust and Mantle Reworking (4.55 to 2.5 Ga)		
3. Igneous rock evolution	4.55 to 4.0 Ga	350 to 500*
4. Granite and pegmatite formation	4.0 to 3.5 Ga	1000
5. Plate tectonics	>3.0 Ga	1500
Era of Biologically Mediated Mineralogy (>2.5 Ga to Present)		
6. Anoxic biological world	3.9 to 2.5 Ga	1500
7. Great Oxidation Event	2.5 to 1.9 Ga	>4000
8. Intermediate ocean	1.9 to 1.0 Ga	>4000
9. Snowball Earth events	1.0 to 0.542 Ga	>4000
10. Phanerozoic era of biomineralization	0.542 Ga to present	4400+

* Depending on the volatile content of the planet or moon

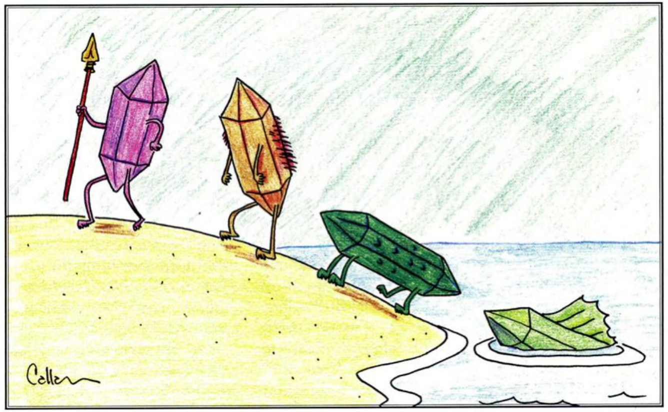
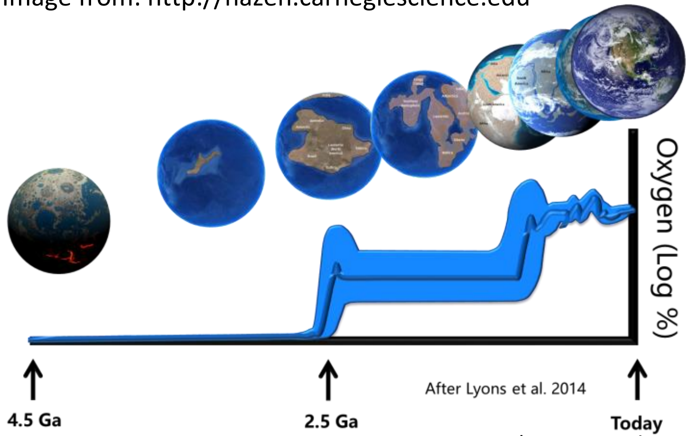


Image from: http://hazen.carnegiescience.edu

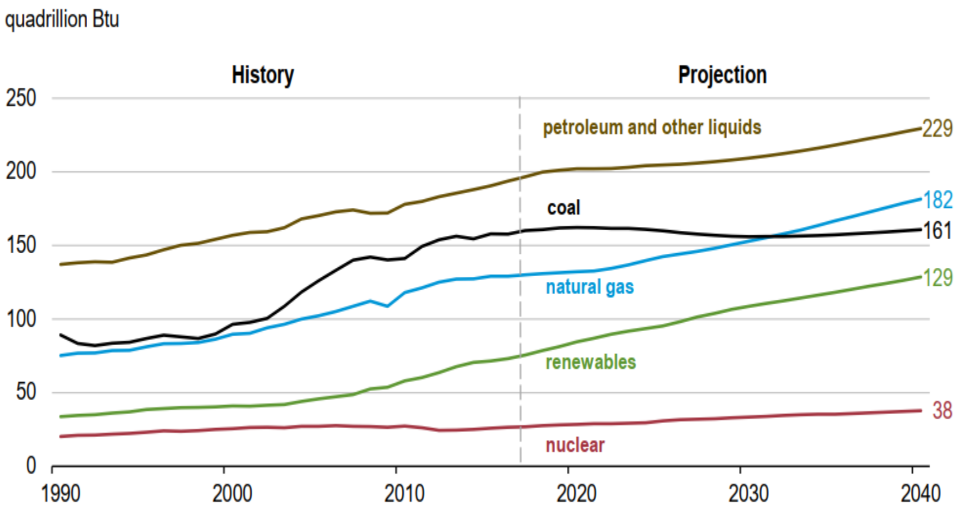


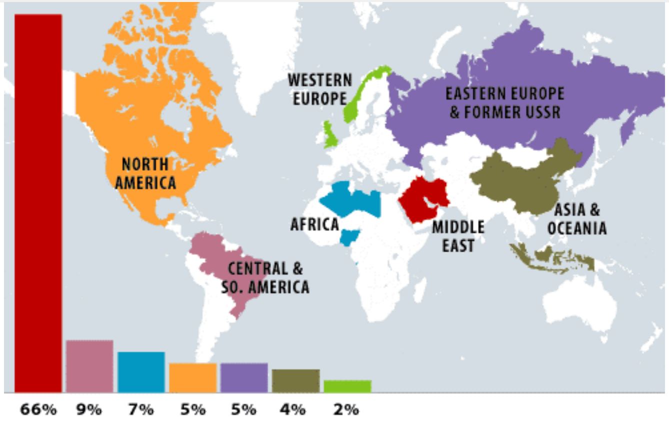
(Hazen and Ferry, 2010)

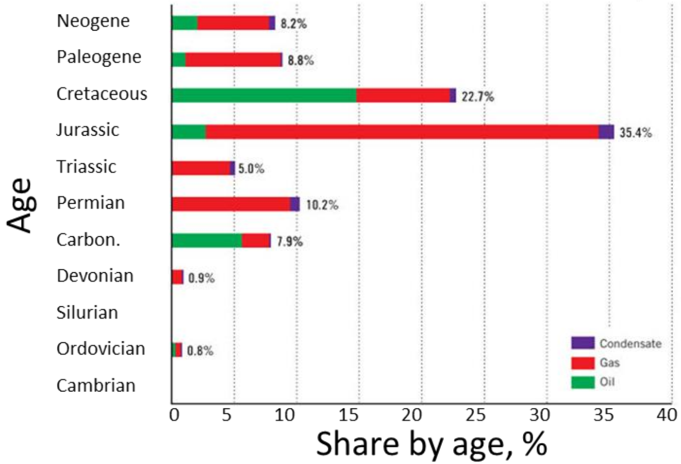
Energy resources for sustainable development

Deep-time Digital Earth
IUGS Big Science Program

- Present consumption of fossil energy is around 85%;
- Global energy demand is still increasing fast;
- Can the fossil fuels meet the global energy demand in the future?

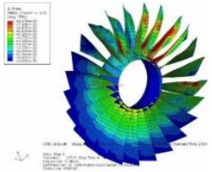






10 innovative techniques of DDE

1. Machine reader of literature legacy and information retrieval
2. Digitization and comparison of map and image materials
3. Characterization and intelligent detection of geological entities
4. Cleansing and spatio-temporal annotation of massive data
5. Interoperability and spatio-temporal coordination of cross-platform databases
6. Deep-time knowledge base management and automatic configuration of knowledge graphs
7. Intelligent engine for information search and crawling
8. Holographic visualization and mapping of deep-time digital earth
9. High performance computation and deep-time digital earth analysis engine
10. Data synthesis and deep-time digital earth reconstruction engine



Schedule

Roadmap and deliverables (2019-2028)

- Accord signed at the 73th IUGS EC in Beijing, February 25-27, 2019.
- Formal launch meeting at the 36th IGC 2020.
- A midterm progress with significant deliverables at the 37th IGC 2024.

- A final report at 38th IGC 2028

36th International Geological Congress
March 2-8 , 2020, Delhi, India

Deep-time Digital Earth
IUGS Big Science Program

Theme 45.7 *The IUGS Big Science Program: Deep-time Digital Earth (DDE)*

- *45.7.1 Evolution of life and biodiversity changes through deep time*
- *45.7.2 Evolution of sedimentary and paleoclimate system*
- *45.7.3 Quantifying plate tectonics and deformation in four dimensions*
- *45.7.4 Exploring the evolution of materials and environments through deep time*
- *45.7.5 Open and Big Data, Artificial Intelligence, and Geoinformatics: New Paradigms that Advance Discovery and Knowledge of Earth in Deep-time*
- *45.7.6 DDE in Geological Survey Organizations and industry*
- *45.7.7 Dinosaur macroevolution and building an integrated database for both academia and the public*
- *45.7.8 Orogenic architecture and crustal growth from accretion to collision (IGCP-662)*

First Governing Council meeting

March 3, 2020, Radisson Blu Hotel

Town hall meeting

March 4, 2020, Radisson Blu Hotel

DDE Booth


36TH INTERNATIONAL GEOLOGICAL CONGRESS
2 - 8 MARCH 2020, DELHI, INDIA

Home | About | Program | Field Trips | Registration | Sponsorship & Exhibitions | More | General Information | Events

Super Early Bird Registration: Now Open | Abstract Submission: Now Open | GeoHost Application: Now Open | Workshops/Short

SCIENCE PROGRAM

The Science Program of the 36th IGC comprises 266 Symposia under 44 Themes. The details of such symposia with their summary can be viewed below. The call for abstracts is based on this program. The schedule will be finalised after all the abstracts are received.

The symposium / session proposals received, and expected to be received from National and International Scientific organisations/fora are placed under a special theme (Theme 45). This excludes symposia already incorporated in the relevant science themes. The submission of abstracts under Theme 45 is only through normal system of abstract submission of 36 th IGC but presentations under Theme 45 is only by invitation of the respective conveners of the organisations.

The entire Science Program will be open to all delegates with full IGC registration. All Symposia in the Scientific Program are expected to include both oral and e-poster presentations. Participants will be permitted to deliver only one oral presentation in the program, but they may co-author multiple oral presentations and may make multiple poster presentations. Invited keynote speakers and presenters in IUGS-related symposia under Theme 45 may deliver a second oral paper in the science program. The official language of the Congress will be English; translation services will not be provided. Any questions or requests for further information should be addressed to the Communicating Theme Coordinators or Symposium Conveners, whose email addresses are listed in the program, with intimation to the Convener, Science Program.

The maximum word limit of abstract is 250 words without any illustrations, table and references and the last date for submission of Abstracts is 31st August, 2019.

Booth

- *6m X 12m*
- *Design plan: October*

36th International Geological Congress
March 2-8 , 2020, Delhi, India

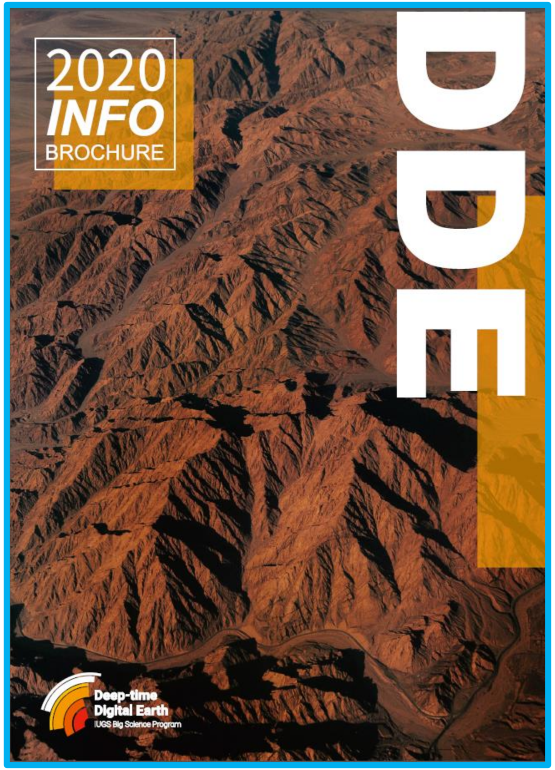
Deep-time
Digital Earth
IUGS Big Science Program

DDE Booth

- 75 m^2

Brochures

Deep-time Digital Earth
IUGS Big Science Program



MISSION AND VISION

MISSION

Harmonise global Deep–time Digital Earth data, and share global geoscience knowledge.

VISION

Transform Earth science.

WHAT IS DDE ?

Modern Earth systems science requires harmonised global Deep–time Earth data. This harmonisation is now possible through the digital revolution, but new protocols, platforms and programs are needed to secure compatible and interoperable databases, so that the vast amounts of existing (and new) geoscience data can be linked for the benefit of global society. Big Data analytics, internet cloud computing, data mining, machine learning and artifi–cial intelligence, will lead to innovation in understanding the Earth's evolution and applications including the Sustainable Development Goals.

Deep-time Digital Earth

WHY DDE ?

A grand challenge for geoscience is to secure interoperability of databases, as well as improve accessibility. Better or–ganised data will transform Earth sci–ence.

A huge amount of digital and ma–chine–readable data is held by geologi–cal surveys and in other large big the–matic databases. Collective efforts are needed to develop internationally ac–cepted protocols for standardization, harmonisation and association of diverse data so that hubs within a net–work can be interconnected. While geological survey data generally has wide geographic coverage it has limited diversity of types of data. In contrast, data held by academic institutions and supplementary government data is often wider ranging including a huge resource of information such as pic–tures and scanned images, tables, notes, sketches, cross sections, videos, samples, measurements scattered in documents and even geoscientists' notebooks. Much is not currently ma–chine–readable and searchable. Freeing this 'volunteer' generated information is fundamental to creating big Earth data. Appropriate mechanisms and artificial intelligence techniques need to be sought to motivate, facilitate and assist organizations and geoscientists to make their data FAIR (Findable, Accessible, Interoperable, and Re–usable).

DDE website: http://www.ddeworld.org/

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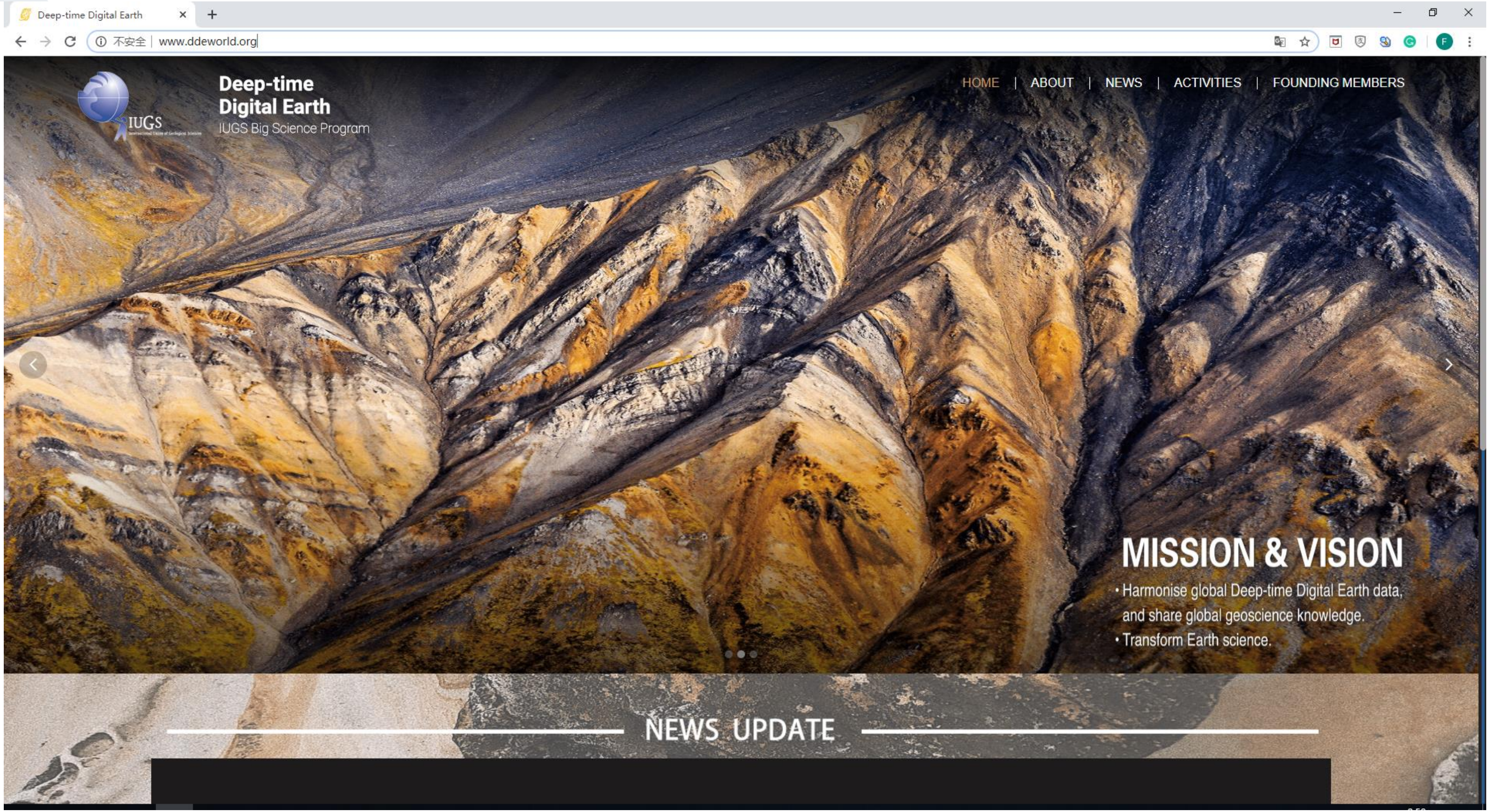


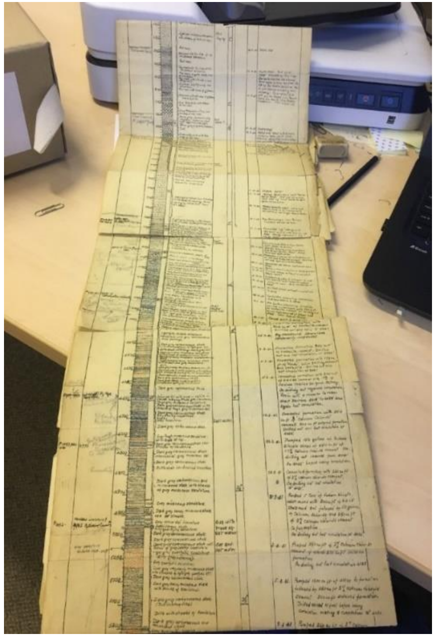
What can we do? Opportunities for the community

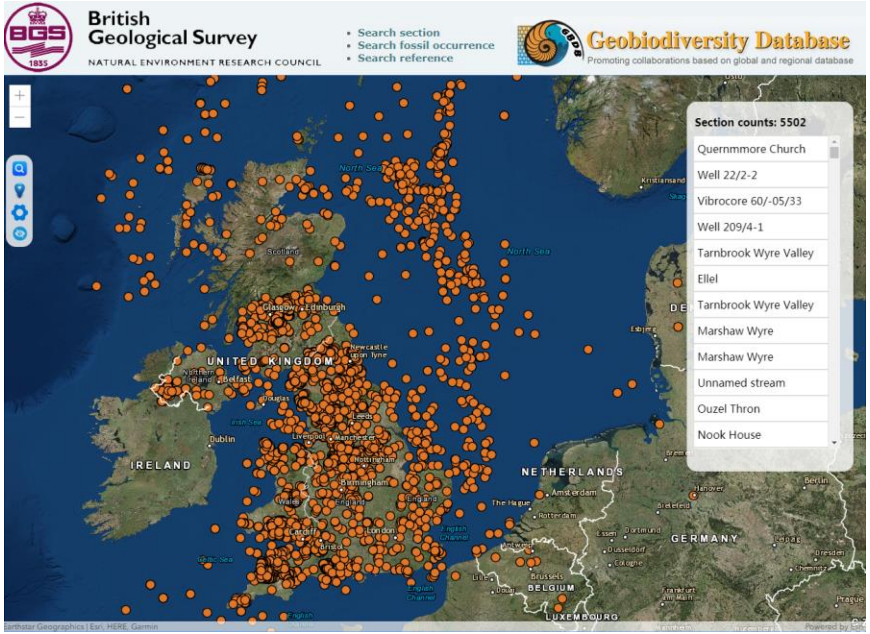
Deep-time Digital Earth
IUGS Big Science Program

◆ Digitization of legacy data: publications, dark data; open and share

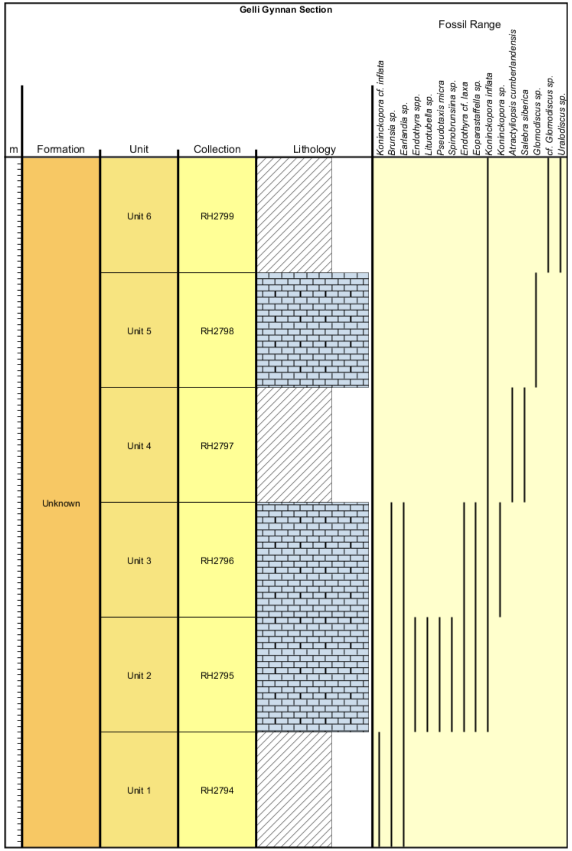
- ◆ 5-10 year's long-term project
- ◆ digitization of huge data sources in BGS
  - ◆ Dark data

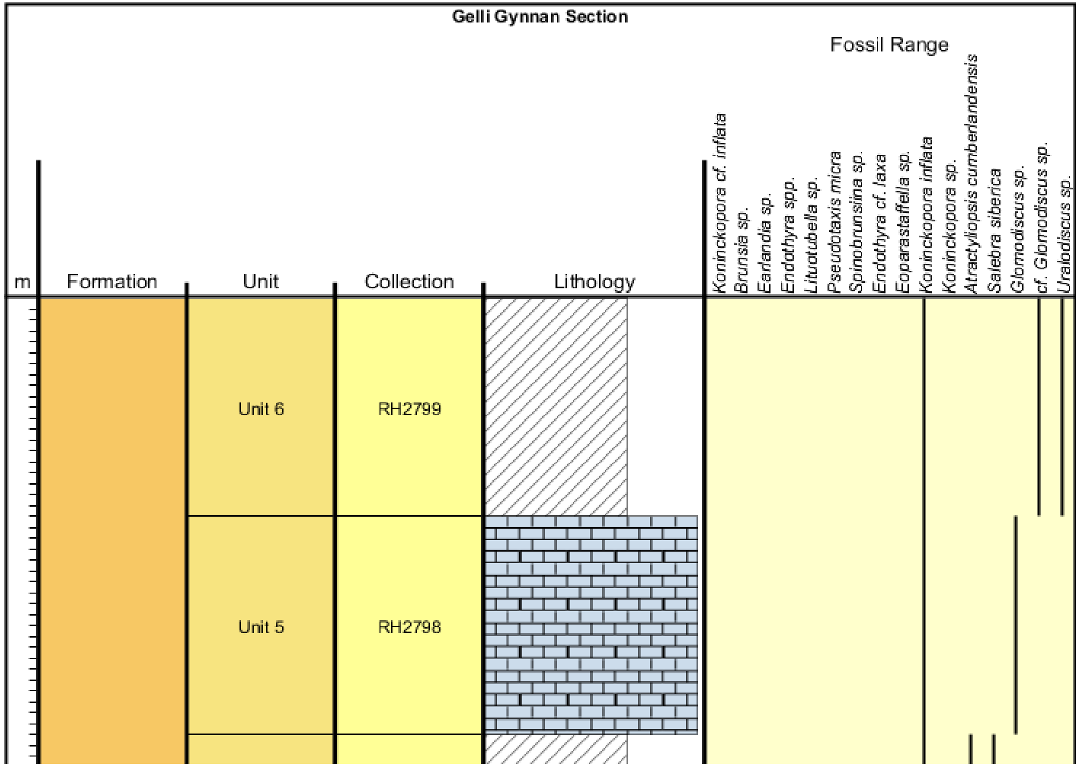
Digitization in ~ 6 months
- ◆ 5502 outcrops/drillcores; 13588 references
- ◆ FAIR data: online, open access





Potential collaborations

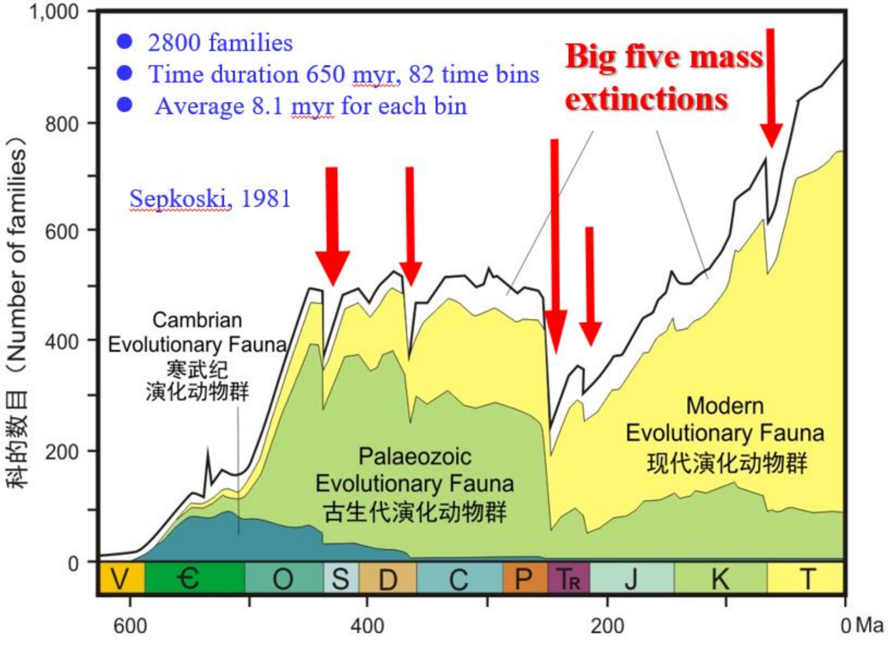




Opportunities for the community

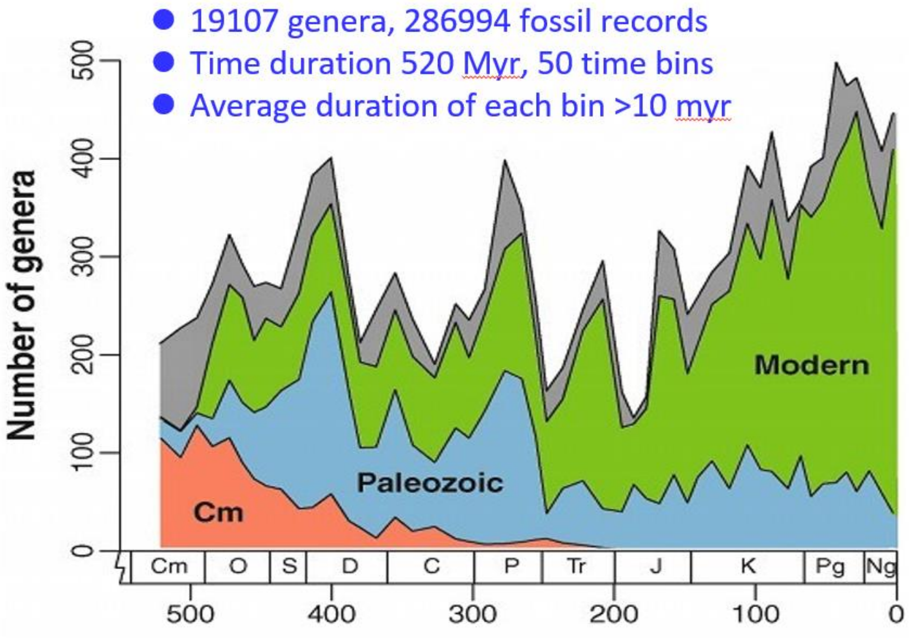
◆ Data analysis: Big data analysis and visualization, HPC

Phanerozoic diversity pattern at family level



Are the Big Five and the exponential post-Paleozoic rise real?

Phanerozoic history of marine genera



Alroy et al., 2008, *Science*

Opportunities for the community

Deep-time Digital Earth
IUGS Big Science Program

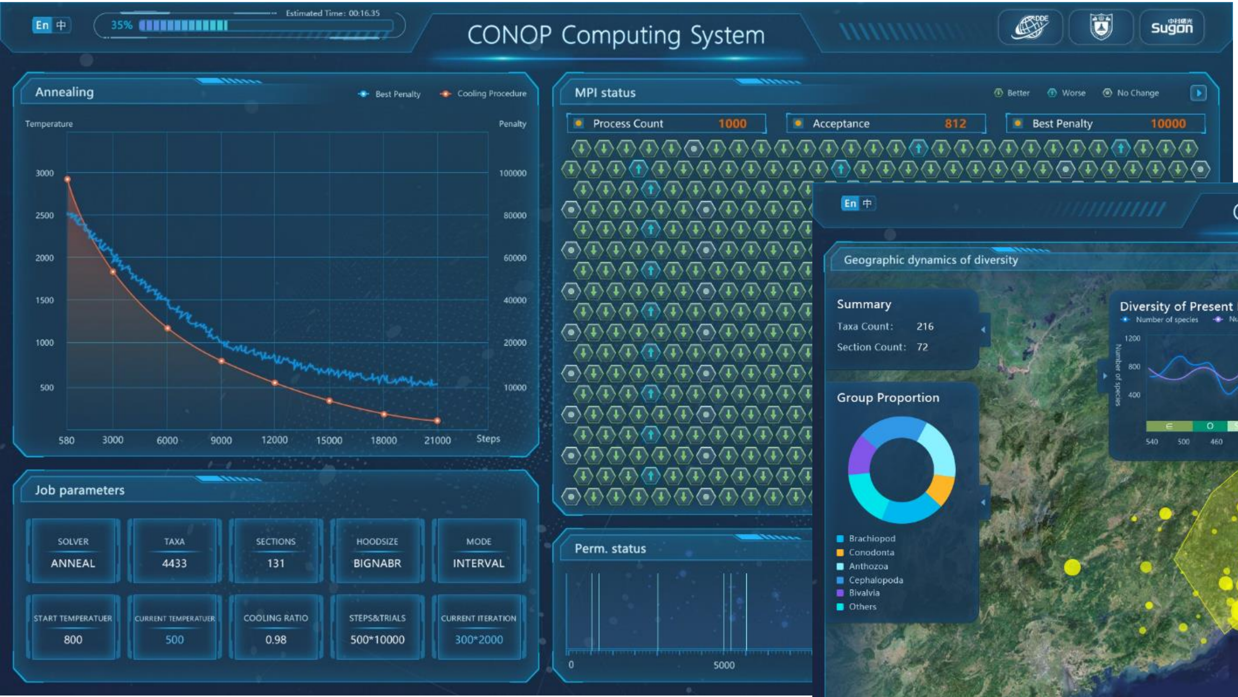
- High temporal resolution: Traditional 8-10Ma --> CONOP 30Ka
- Big computing power: 10,000 species → 17 years!

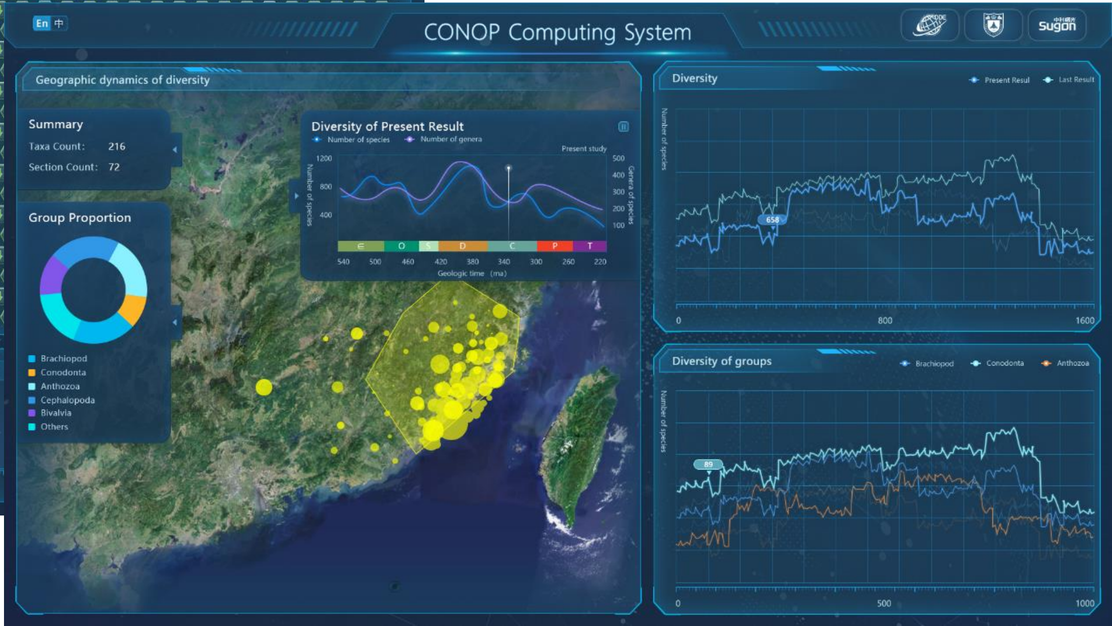
- First supercomputer program for quantitative stratigraphy
- Successfully tested on "Tianhe II"
- Accelerate rate=**5/10** cores

Opportunities for the community

◆ **Data analysis: High Performance Computing (HPC)**

Simulated annealing
Genetic algorithm





Opportunities for the community

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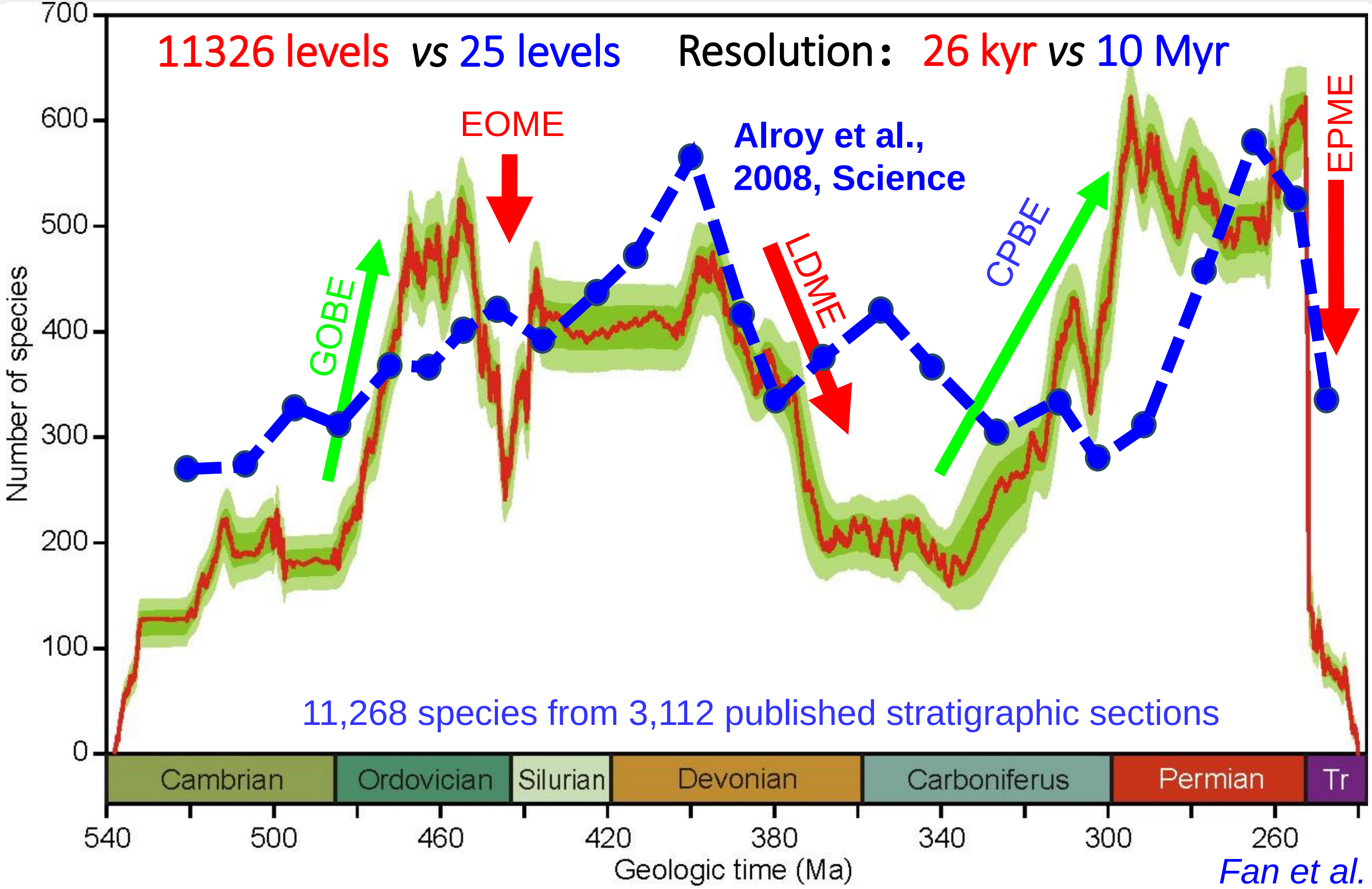

Fan et al. 2020, Science

Opportunities for the community

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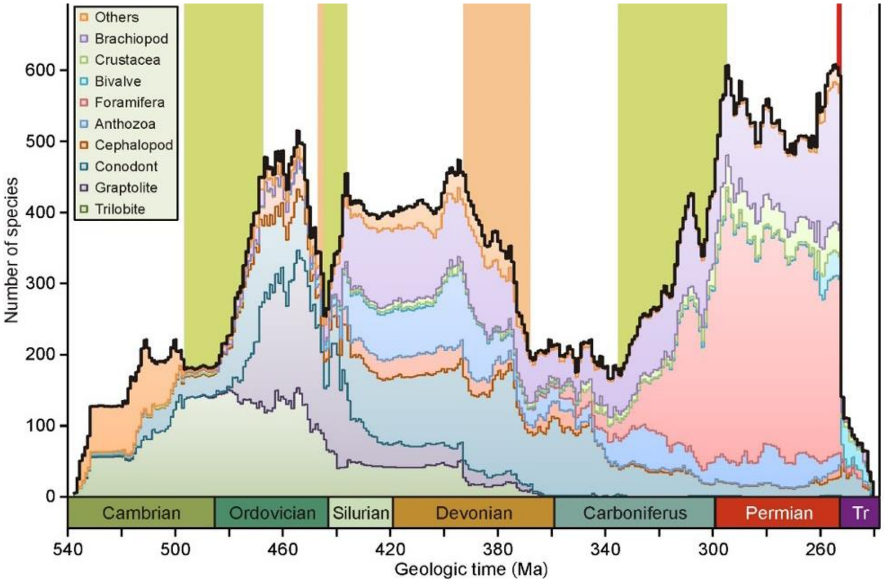
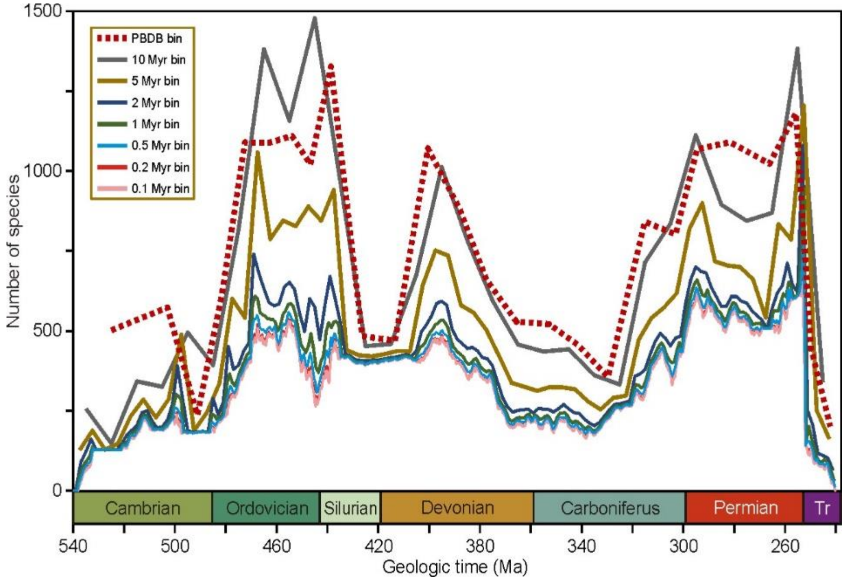


Diversity of different fossil groups

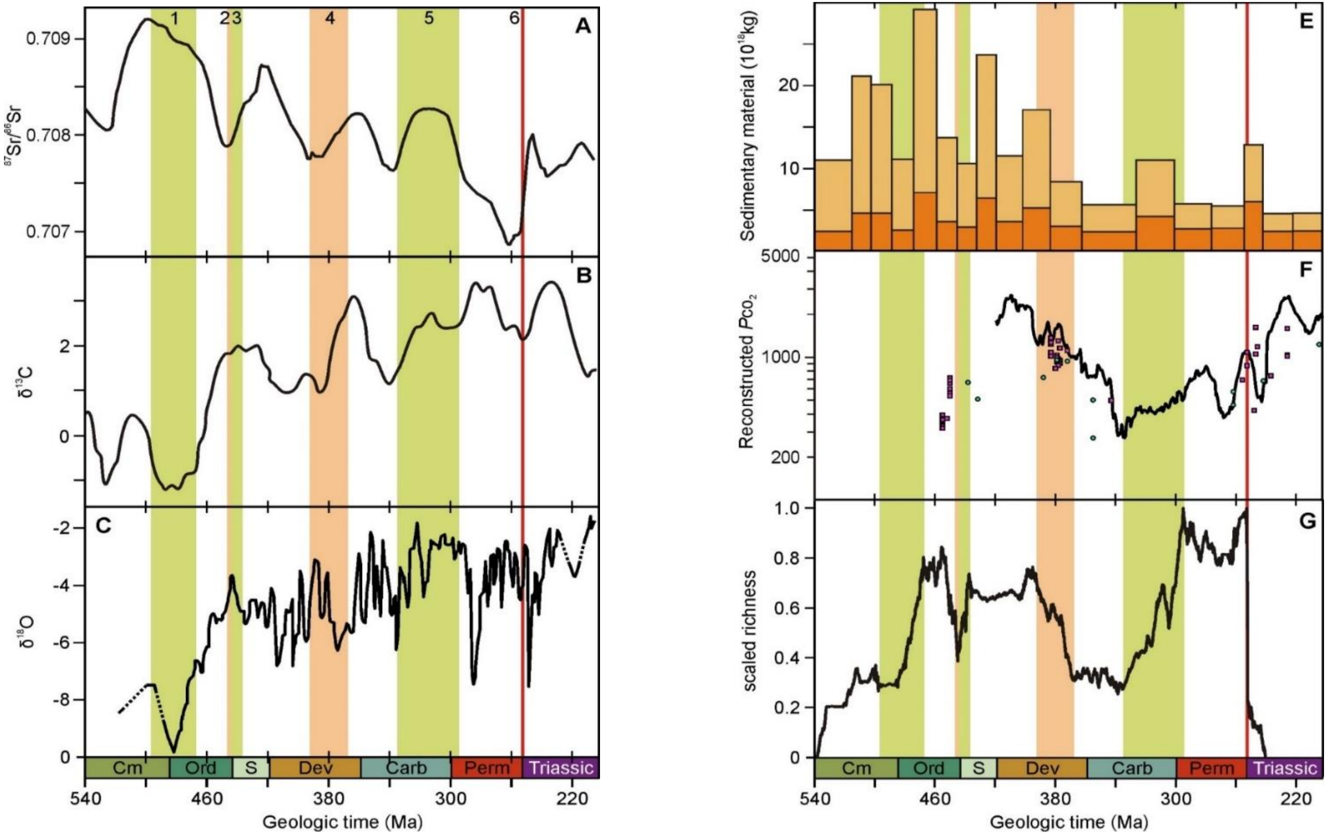


Composite diversity patterns produced in different evenly-divided time bins (from 0.1 to 10 Myr; solid lines)

Fan et al. 2020, Science

Opportunities for the community

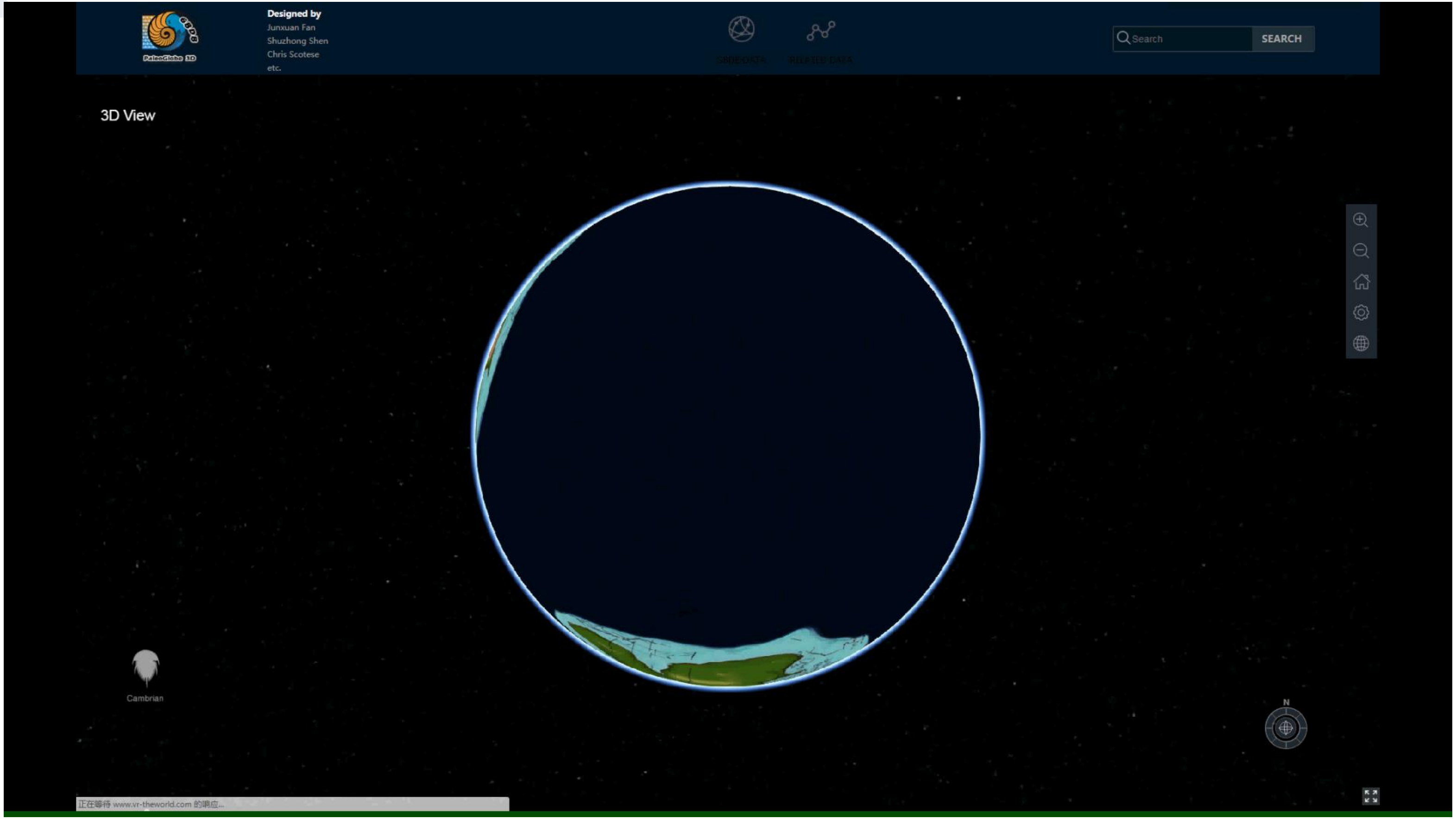
Exploring the coupling or decoupling between life and environment



Opportunities for the community

Linking geoscience, data science and computer science

Opportunities for the community



Opportunities for the community

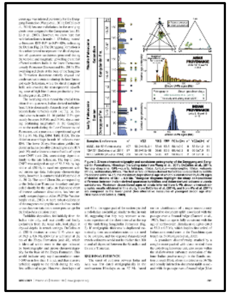
◆ Artificial intelligence and machine learning

Knowledge System

Collection

Storage& management

Analysis & visualization



Data source

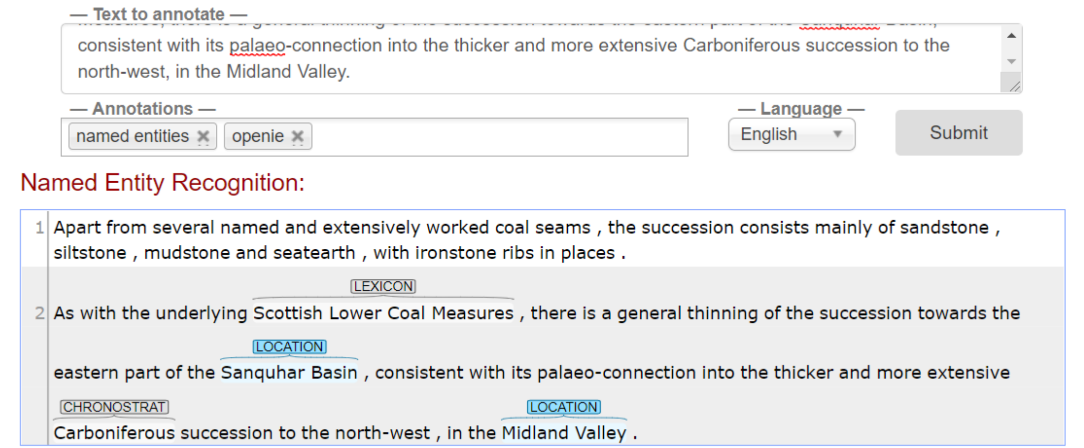
Input

Database and Platform

Output

Opportunities for the community

◆ Artificial intelligence and machine learning



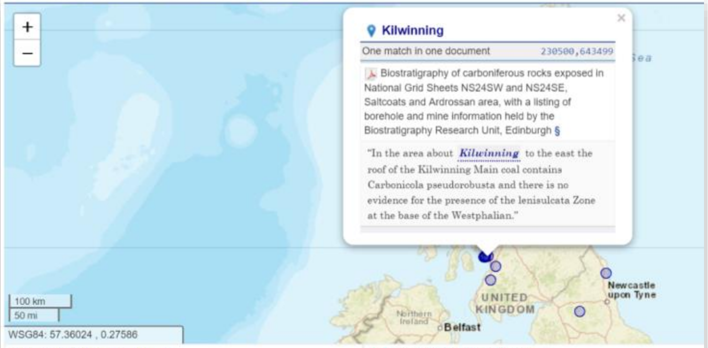

```
text1 = ("The fauna consists of seven genera/subgenera, Agastograptus, Gothograptus, Holoretiolites, Paraplectograptus, Plectograptus (Plectograptus), Plectograptus (Sokolovograptus) and Spinograptus")

tag1 = ['O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'U-FOSSIL', 'O', 'U-FOSSIL', 'O', 'U-FOSSIL', 'O', 'U-FOSSIL', 'O', 'B-FOSSIL', 'I-FOSSIL', 'I-FOSSIL', 'L-FOSSIL', 'O', 'B-FOSSIL', 'I-FOSSIL', 'I-FOSSIL', 'L-FOSSIL', 'O', 'O', 'U-FOSSIL', 'O']
```

3 Geochronological Divisions found in *WH88282R_29453_000177*

Divisions matched sort by Match Count (9-1)

Code	Name	Min Age (MYBP)		Max Age (MYBP)		Matches	Division frequency
C	Carboniferous Period	298.9	±0.2	358.9	±0.4	3	C 3
CW	Westphalian Stage	308	approx. ± 0	319	approx. ± 0	2	CW 2
CN	Namurian Stage	319	approx. ± 0	329	approx. ± 0	2	CN 2

15 Locations found in WH88282R_29453_000177

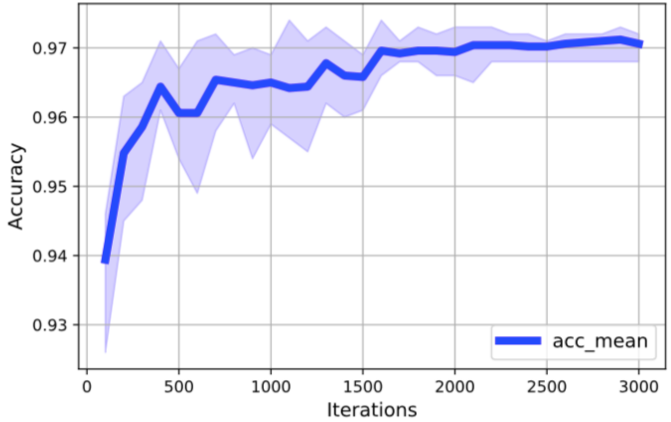


Found 15 Gazetteer Places

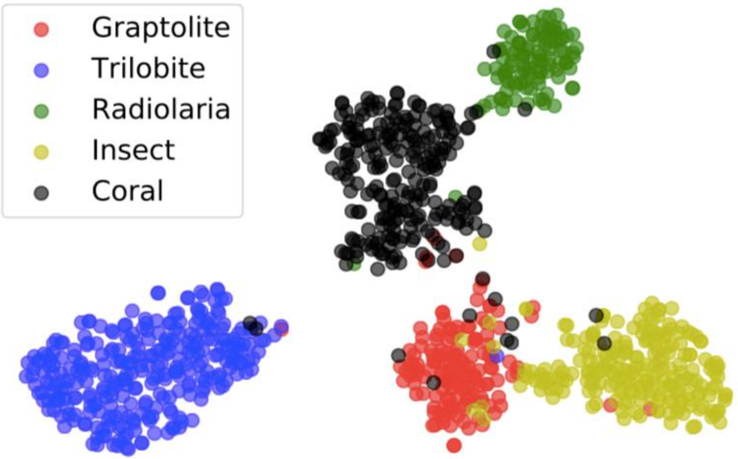
Found 0 BNG Grid References

Opportunities for the community

◆ Artificial intelligence and machine learning

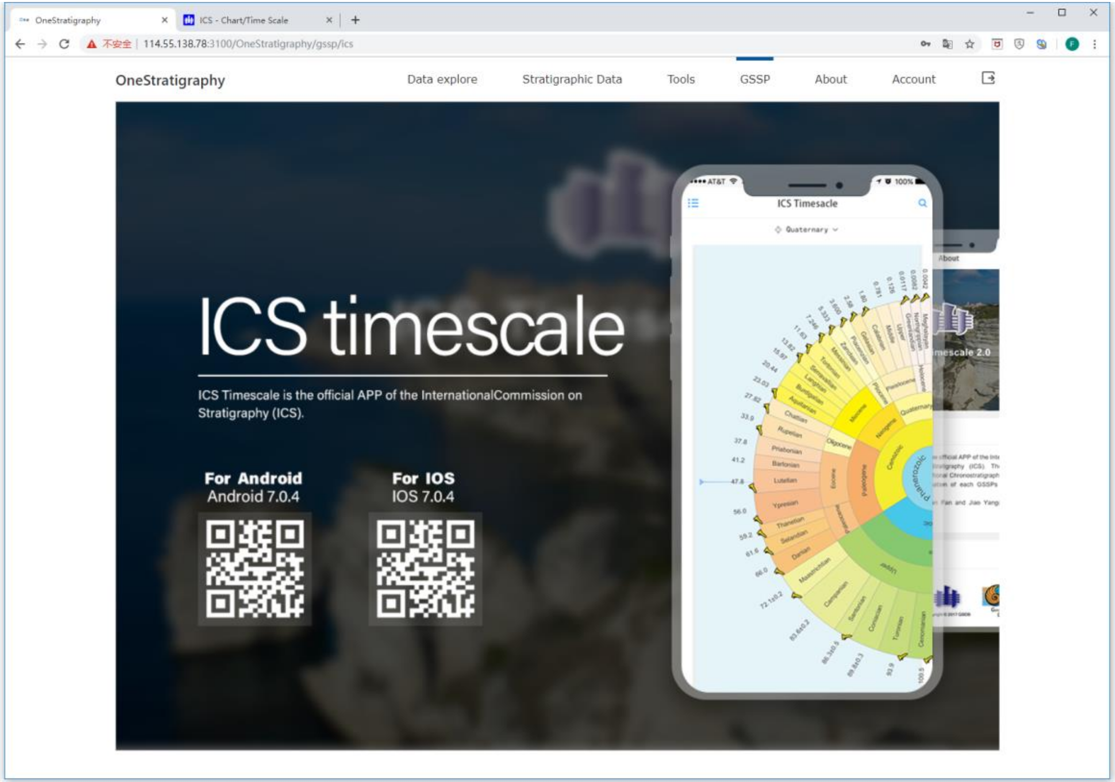


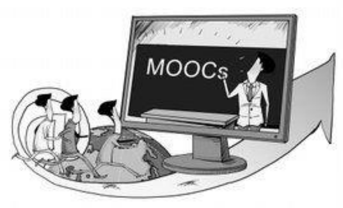
- 5 high-rank taxonomy, 4000 images
- VGG16 model
- 97% accuracy: top 1 catalogue
- Next:
  - ✓ more groups
  - ✓ Species level



Opportunities for the community

◆ Innovative technology in research, education and training





Opportunities for the community

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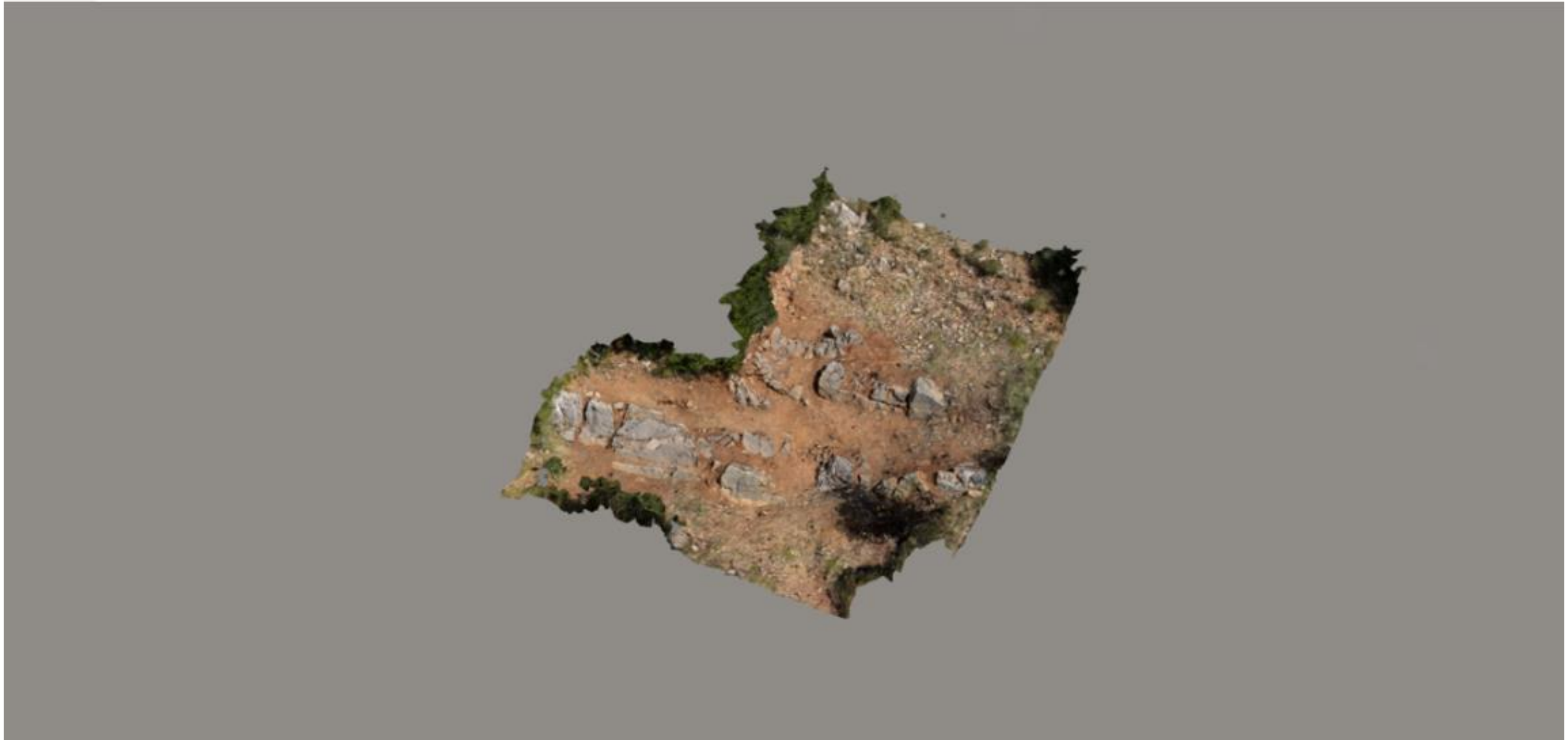
◆ **Innovative technology in research, education and training**

Opportunities for the community

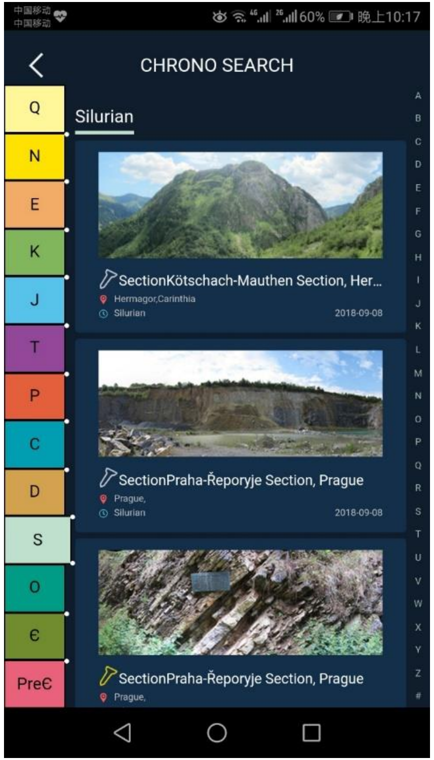
Permian/Triassic GSSP, Changxing, China

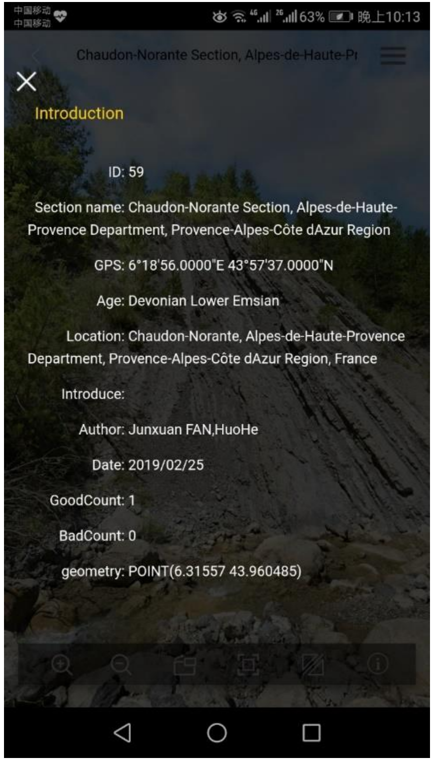
Opportunities for the community


Devonian/Carboniferous GSSP, La Serre, Montagne Noire, France

Opportunities for the community

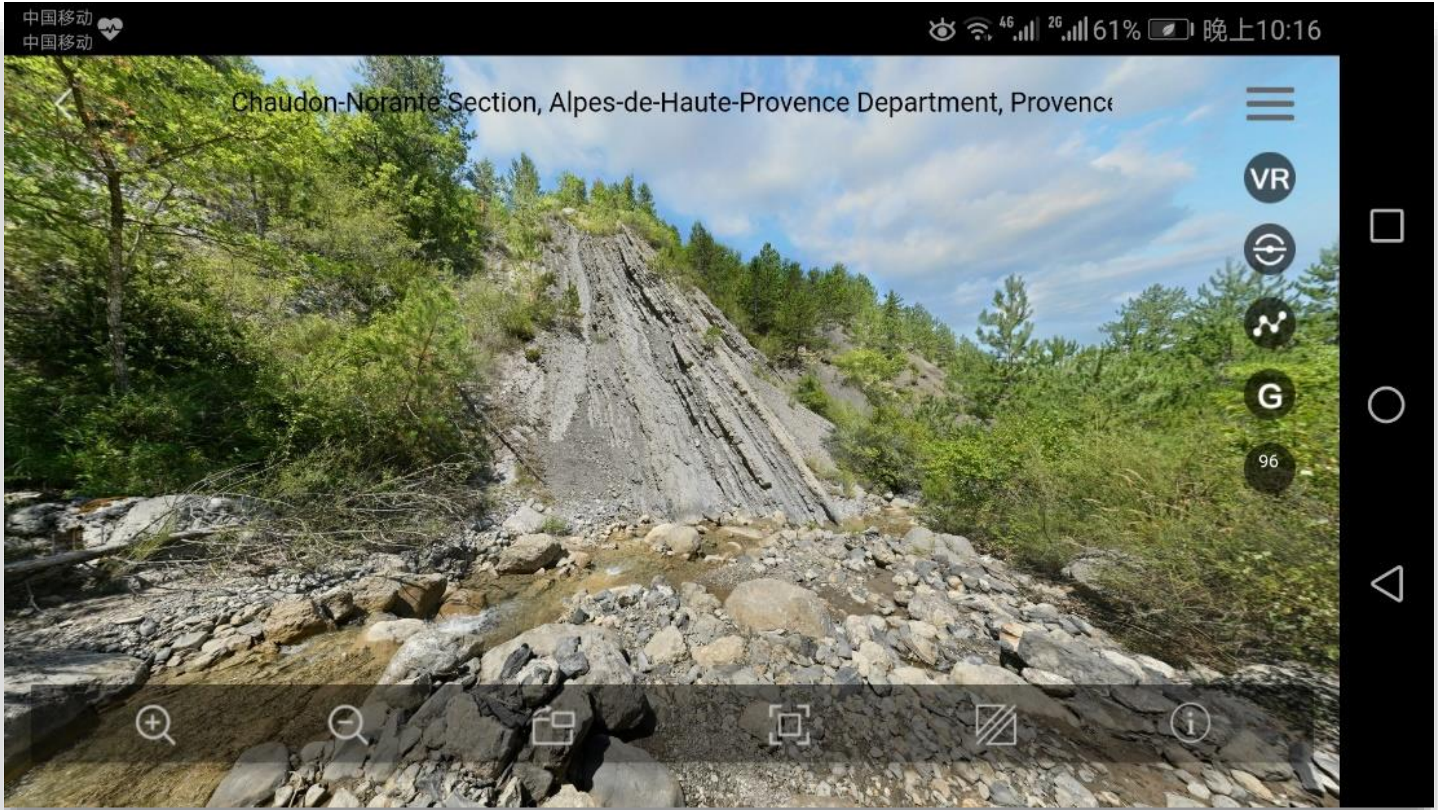
◆ Innovative technology in research, education and training





Opportunities for the community

◆ Innovative technology in research, education and training



Opportunities for the community

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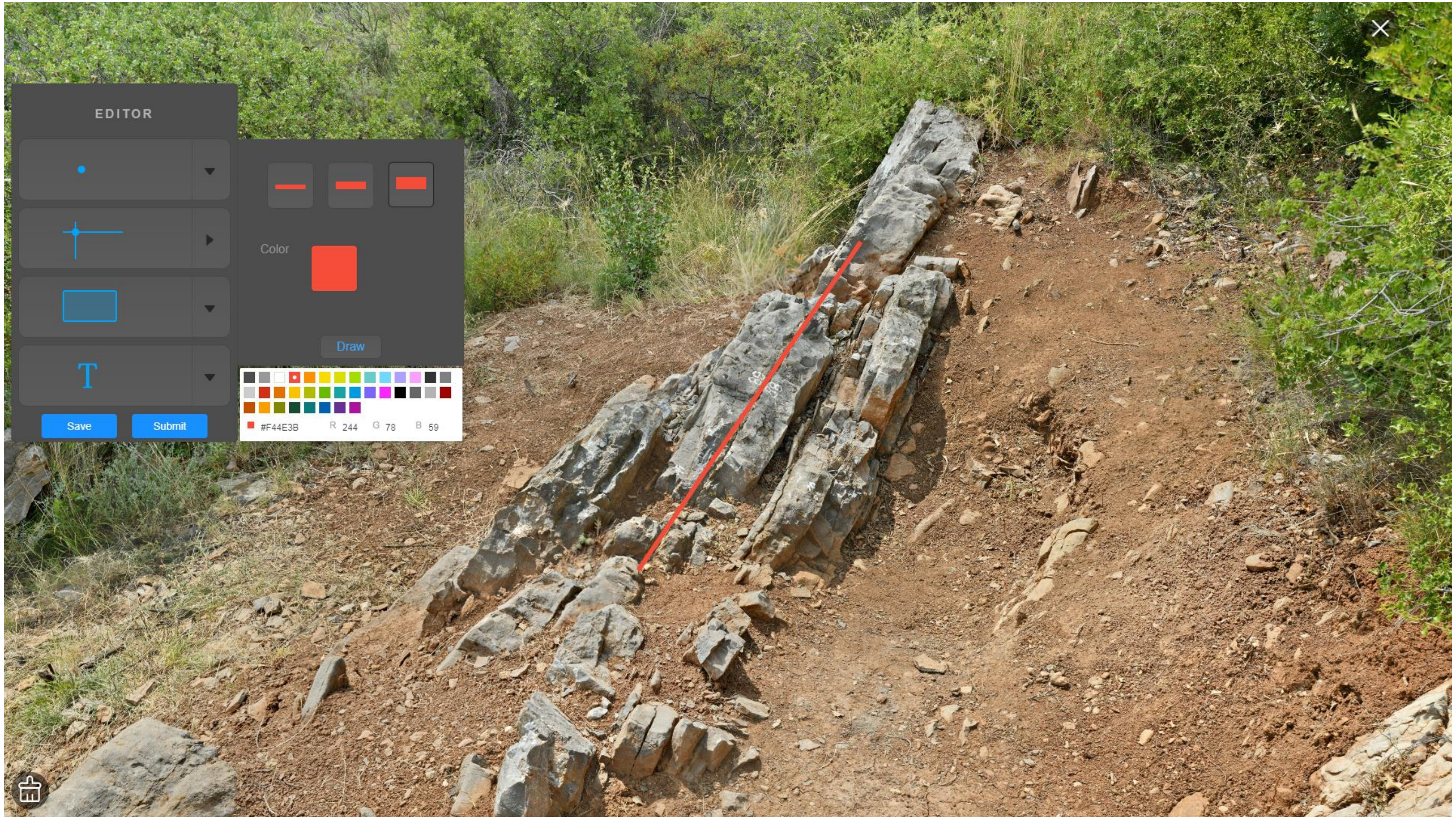

Opportunities for the community

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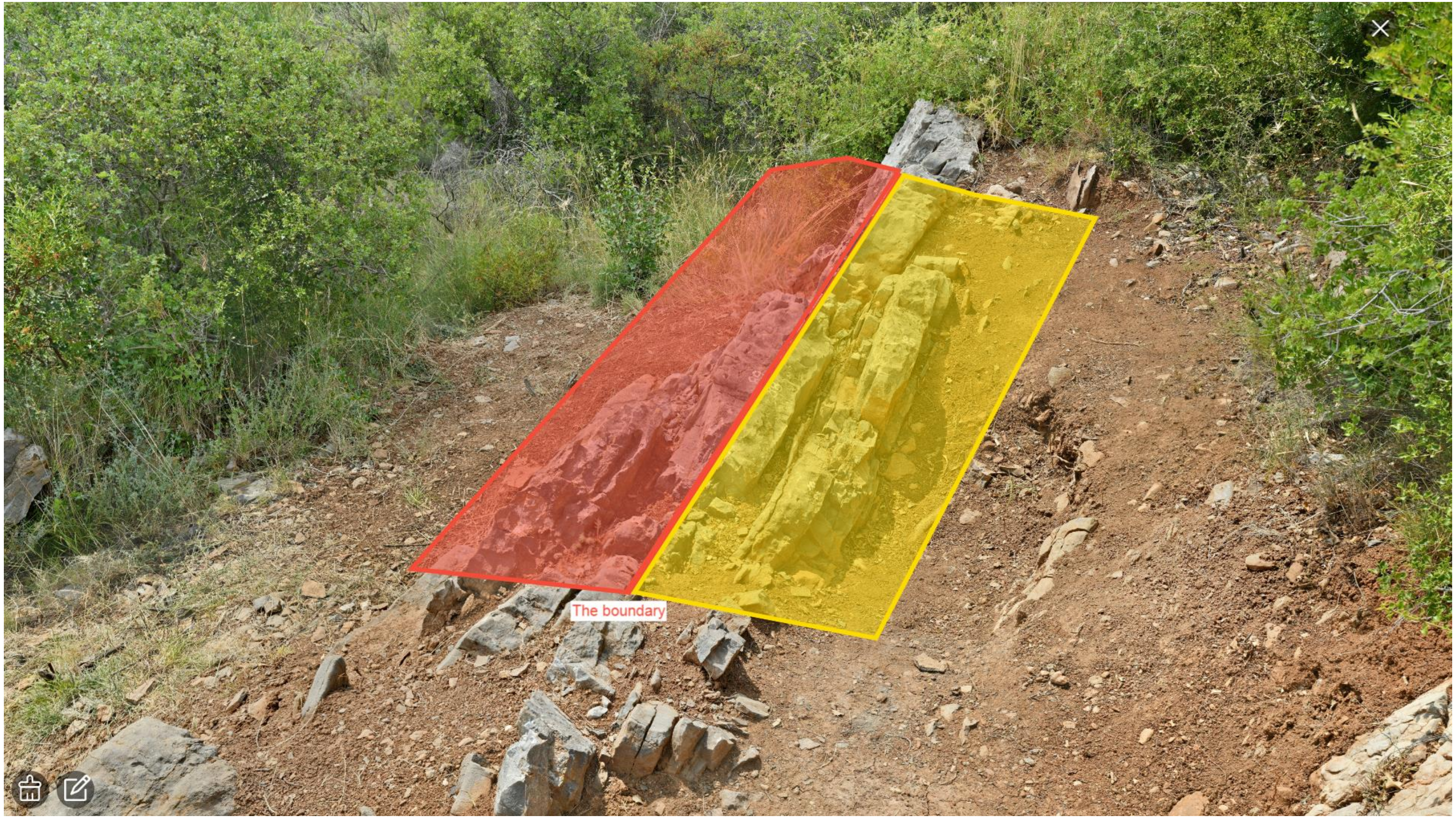

Opportunities for the community

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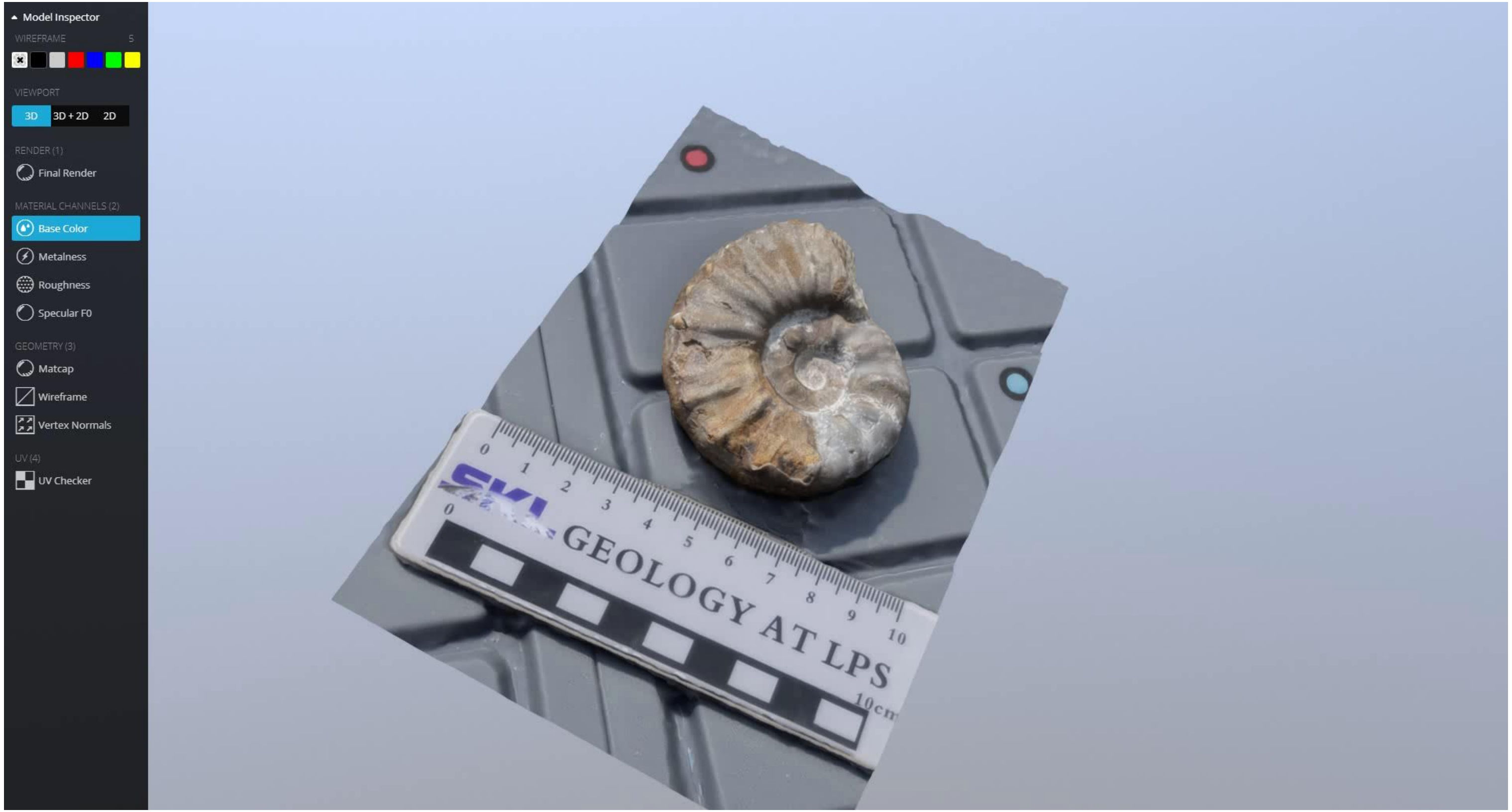
◆ Innovative technology in research, education and training



The future: *Geo-cyberspace*

Deep-time Digital Earth

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Let us work together for the success of DDE!