

DDE – INTERNAL ASSESSMENT (2019-2023)

SUMMARY

This report is an assessment carried out by the DDE Secretariat on the implementation of the first 30-months of the 5-year Medium Term Plan (MTP) for 2021-2026. The end of 2023, which marked the end of 30-months from July 2021, coincided with the end of the 5th year of the 10-year (2019-2028) vision of the DDE White Paper, which serves as the overall Science and Technology Plan of DDE.

For the period, 2019-2023, the main achievements were:

- (i) A Governance structure, comprising a Governing Council (GC), Executive Committee (EC) and a Scientific Committee (SC) have been established and operational. The DDE Secretariat manages day-to-day operations under the guidance of the Chair of the Executive Committee. About 28 Working and Task groups (WTGs) provide research and networking support to promote international scientific cooperation
- (ii) DDE Platform, launched in November 2022, is fully operational. It has nearly 1500 databases and a user base of nearly 4000; harmonizes databases from sources such as PaleoBiology DataBase (PBDB), Macrostrat, GeoLexicon and includes *MyDDE* for personalized data management and analyses, DDE Cloud for scalable data storage and computing and DDE WebGplates for real-time data rotation and display.
- (iii) The number of DDE members grew from around 12 in mid-2019 to nearly 30 by the end of 2023.
- (iv) 8 research projects, at a total value of about US\$ 1 million, were supported and are making good progress. WTGs are provided annual grants of \$5,000 – 10,000 to support their DDE linked research activities. Important outcomes already delivered include: 1:5M World Digital Geological Map; China's geological maps in English; and an estimated 200 academic and scientific publications.
- (v) Networking capabilities of DDE significantly grown since the IUGS, UNESCO, IYBSSD and DDE co-organized DDE Open Science Forum in UNESCO, Paris, in November 2022; during 2022-2023 DDE has been in major regional and international geosciences events in Asia, Africa, Europe and North America.
- (vi) The DDE geoscience information metadata standard (Edition 1.0–2023) was released in November 2023. An MoU with CODATA that will enable testing the application of this standard under FAIR principles to many of the databases in the DDE Platform.
- (vii) 3 Research Centers of Excellence (RCEs) (2 in China and one in the US) have been established.

Shortfalls in meeting expected deliverables included: (a) lack of establishment of pre-determined priorities for supporting DDE financed R & D and Seed Grant funded projects; (b) delay in establishing a systematic tracking system for monitoring performance of *ddeworld.org*; (c) insufficient opportunities for research and development and capacity building initiatives for Africa and other developing regions; and (d) DDE funding sources continue to be from China based sources; the only source of funding from outside China is from IUGS.

Performance during the assessment period was constrained by COVID-19 pandemic related restrictions and some other unexpected international events. Only the last 15 of the 30-month assessment period of the MTP was constraint free for DDE to reach out internationally.

Following a brief introduction, this report describes deliverables met under each one of the 6 objectives of the MTP. It provides comments on the feasibility of meeting deliverables scheduled for the second half of the MTP period (beginning of 2024 up to June 2026).

For each of the 6 objectives, a summary of the main achievements and important follow-up activities for the next 30 months is provided. The extent to which the key performance indicators for the mid-term assessment had been met are described. The work of the DDE GC, EC and SC and WTGs and the Secretariat are briefly outlined; and a time frame for an external review of DDE 5-year performance of 2019 through 2023, including the 30month period of the implementation of the MTP, is provided.

This internal assessment report and supplementary materials will be made available to an external review team to be led by IUGS in 2024. Presentations and discussions on the past, challenges and plans for DDE's work during 2024-2030 are foreseen at the DDE theme Session 37.8 of the 37th IGC in Busan, Korea (25 to 31 August 2024). Recommendations from this and another 13 DDE theme sessions to be convened during IGC 37, and that of the IUGS led external review, expected to be available before the end of 2024, will be synthesized to finalize a DDE development plan 2025-2030 during the first quarter of 2025 which will be submitted to the DDE Governing Council for approval.

INTRODUCTION

DDE, Deep-time Digital Earth, is the first big science program recognized by the International Union of Geological Sciences (IUGS), the world's largest geological sciences organization. The IUGS Executive Committee approved the launch of DDE in December 2018 see IUGS Bulletin no: 152 for details). DDE convened its first "kick-off" meeting in February 2019 at the Fragrance Hill Hotel in Beijing. More than 40 institutions and nearly 100 scientists from all parts of the world participated in the Beijing event. This was followed by the first meeting of the DDE

Scientific Committee (SC) meeting in South Korea in January 2020. In November 2022, DDE was globally launched at the Open Science Forum convened at UNESCO, Paris, France.

A DDE White Paper (<https://dde-world.oss-cn-hongkong.aliyuncs.com/editor/2022/03/25/68e89e77927144a480be12049b79915a.pdf>) details the mission, vision, a road-map for data-driven discovery in geological sciences, the development of a data-driven cloud computing Platform for geoscience, priorities for research and development in both basic and applied geosciences, and implementation of DDE over a 10-year time horizon. The White Paper defines the 4E research priorities, i.e. evolution of materials, life, geographies and climate, as well as directions of technology development for a digital ecosystem in support of data-driven research in geological sciences.

For DDE implementation, the DDE Secretariat prepared a Medium-Term Plan (MTP; <https://www.ddeworld.org/news/detail/134>) for the period 2021-2025. MTP was adopted by the DDE Executive Committee (EC) in mid-2021 and came into operation in July 2021; hence the five-year period is from July 2021 to June 2026.

In the monitoring and evaluation of the MTP, a mid-term evaluation after 30 months of the 60 months of the implementation period was foreseen. December 2023 marks these 30 months of implementation of the MTP. The DDE EC, that met online on 20 October 2023, instructed the DDE Secretariat to prepare an internal assessment. This will be one of the sources of information for an IUGS-led team that will carry out an external evaluation of DDE up to the end of 2023. The mid-term point of MTP also marks the end of the 5th year of the 10-year (2019-2028) scientific plan visioned in the DDE White Paper and hence could serve as an evaluation of the first 5-years of work (2019-2023) of DDE.

During the preparation of the MTP and discussions on its revision and adoption, there were considerations to match the time frame of the MTP to the IUGS/IGC cycle, i.e., 4 years. This possibility will be explored after the IUGS-led, external review recommendations of DDE for the period 2019-2023 is available, sometime after the forthcoming 37th IGC to be convened from 25 to 31 August 2024, in Busan, South Korea.

This document initially provides an internal DDE assessment of the implementation of the DDE MTP for the period from July 2021 to December 2023. It provides Secretariat's reflections on the status of the deliverables identified for Year 1 (July 2021-June 2022) and Year 2 up to the end of the end of the 30 month-period (July 2022 – December 2023) for the 6 objectives (see the 6 annexes of the MTP at: <https://www.ddeworld.org/news/detail/134>). In addition, it includes comments and suggestions on deliverables foreseen for the remaining 30-month period. This is followed by: (a) Secretariat views on the key performance indicators (KPIs) identified in the MTP for the mid-term evaluation; (b) description of activities of the DDE Governing Bodies, namely the GC, EC and SC and WTGs and the Secretariat since the DDE "kick-off" meeting held in February 2019 in Beijing, China; (c) a time frame for external evaluation of DDE's mid-term performance; (d) Secretariat plans for DDE sessions at the 37th IGC in Busan, South Korea in August 2024; (e)

Secretariat views on the implementation of DDE after the 37th IGC. Secretariat plans for actions after the completion of the IUGS-review are described briefly.

DDE MTP (2021 (July) -2026 (June)): STATUS OF DELIVERABLES AT MID-TERM (END OF 2023) AND FEASIBILITY OF DELIVERABLES FORESEEN FOR THE REMAINING PERIOD ENDING IN JUNE 2026

Although, DDE kick-off meeting in Beijing was convened in 2019, the MTP was ready only in mid-2021. MTP preparation was done entirely online, due to international and face-to-face communications among experts from different parts of the world being impossible until mid-2022.

In this section, the status of deliverables for the 30-month period until December 2023 for each of the 6 objectives is described. At the end of the section on each of the six objectives, a summary of the progress made and comments on the implementation of activities for reaching the expected deliverables for the period from 2024 to 2026 is provided.

Objective 1: DDE cyberinfrastructure framework constructed based on existing knowledge base and data standards and is serving the global geoscience community

Year 1 (July 2021- June 2022) Deliverables	Secretariat assessment	Year 2-2.5 (July 2022 – December 2023) Deliverables	Secretariat assessment	Year 2.5 - 5 (foreseen for Jan. 2024 – July 2026) Deliverables	Secretariat assessment
Overall design and key technology of DDE platform DEEP Platform – version 1 tested;	COMPLETED. DDE Platform was globally launched at the 5 th session of the DDE GC held at UNESCO, Paris, on 8 November 2022.	Reconstructed geoscience knowledge system ready for treatment by big data analytics, artificial intelligence, and machine learning.	"A reconstructed knowledge system" for the whole of geoscience was too ambitious a task for the first 2.5-year period. Some WGs, like the Paleogeographic Reconstruction Alliance, One Stratigraphy and One Mineralogy, have progressed in making large datasets accessible via the cloud and hence open to big data analytics, artificial intelligence, machine learning, etc., and allow geoscientists to establish their own data-driven research workflows on the Platform.	10-15 WGs generate knowledge graphics through the application of DDE group intelligent cooperation model;	Work on knowledge graphs of petroliferous basin evaluation and sedimentology were reported at an international CGI-IUGS and DDE Standard Task Group (STG) workshop held in Kunshan, Suzhou, China from 7 to 10 November 2023. The number of knowledge graphs that could be completed by the end of 2026 has to be reassessed considering some of the initiatives that have begun to mature in 2024 and the target of 15 foreseen for the end of 2026 revised accordingly.
DDE big data integration and sharing mechanism and standards and specifications for	Work on creating DDE metadata standard initiated; an online workshop in October 2021 gathered information from	Model for generation of knowledge graphics in the geosciences	The DDE Platform provides access to a range of knowledge resources which could be useful in generating knowledge graphs. The DDE geoscience information metadata	DDE data authentication center.	The establishment of such a center is no longer considered necessary.

deep time earth big data.	several currently operational, data-standards practitioners.		standard (Edition 1.0–2023) was released at the CGI-IUGS and DDE STG co-sponsored workshop convened in Kunshan, Suzhou, China from 7 to 10 November 2023.		
Integrated communication strategy and communication standards	Discussions on the creation of an integrated communications strategy started. Full drafting and finalization of an integrated communication strategy would be best attempted when the two main communication outlets of DDE, namely the DDE website and DDE Platform, have been further developed.	DEEP central engine ready for serving as the DDE digital earth collaborative research platform.	This has been completed with the launch of the DDE Platform. However, improvement of the Platform performance based on feedback from users is ongoing and will be continued. Feedback has been obtained through the demonstration of the Platform in DDE booths and training courses conducted at several international (GSA, EGU, AGU, etc.) and regional (China) events between November 2022 and December 2023.	DDE professional/thematic databases, including regional, national, professional, industry and interest node networks.	Some thematic databases, such as Stratigraphy, Paleogeography and Mineralogy., are already available on the Platform. The construction of a national node for China is completed. Some African countries have expressed an interest to learn from China’s experience to build national or regional nodes. These requests will be given due consideration and suitable initiatives launched during 2024-2026.
		Communication activities and products for professionals, educators, and deep-time geoscience popularizers;	There are tools, data, and computing power available in the Platform that could be used by geoscience popularizers. But the use of the Platform for such purposes has not begun. This will require greater awareness among non-specialists on how the	DDE digital earth, integration, exchange, and collaborative research platform.	The DDE Platform already serves some of these expectations. Under <i>MyDDE</i> part of the Platform, researchers could use their own data and create workflows to address research questions using other data, models, and

			<p>Platform could be used to meet their goals and objectives. The DDE World Cup Competition, DDE Dinosaur World Tour, and the DDE/IGEO Olympiad in 2024 in China, that intends to test the value of the DDE Platform as a pedagogic tool, etc., could help in this regard. The DDE 3D Outcrop Model, introduced at a DDE session in Paris on 7 Nov 2022 has attracted a lot of attention from Africa, China, Europe and UK based academics and researchers and could be an important tool for popularizing research and for public education on geological sciences during 2024-2026.</p>		<p>computational power of the Platform. Collaborative research between different WTGs using the Platform could, however, be further improved. All these dimensions of the Platform would be further developed, refined, and improved to significantly increase and widen its user-base.</p>
		<p>At least 3 organizations with vision and missions like DDE become new members of DDE.</p>	<p>DONE. DDE Membership has increased by 7 from July 2022 until December 2023. Currently the number of DDE Members is nearing 30. Many of them share DDE vision and mission on promoting data-driven research.</p>	<p>DEEP Platform for professional applications such as Deep Earth, Deep Map, Deep Scholar, etc., are available for DDE Platform users</p>	<p>Some of these services are partially available and could be further developed for more mature applications by mid-2026.</p>
				<p>At least another 3 organizations become new DDE members.</p>	<p>The increase in the number of DDE Members during 2022-2023 was ahead of expectations.</p>

					During the 2024-2026 period, greater emphasis would be placed on attracting Members from regions that are currently less represented (Europe, Middle East, South America) and sectors (Industry, business, and data science/management organizations, etc.)
--	--	--	--	--	---

- **Objective 1 Summary:** The most significant achievements under this objective are: (i) Successful launch of the DDE Platform and initiation of its use by geoscientists; (ii) Effective use of the Platform by groups like the Paleogeographic Reconstruction Network to demonstrate implementation of FAIR guidelines in data-driven research; (iii) Release of the geosciences metadata standard through collaborative efforts of CGI-IUGS and the DDE Standards Task Group; and (iv) Number of new members of DDE exceeding the expected levels.

Additional information on the DDE Platform.

The DDE Platform is the online research platform built for enabling and empowering geoscientists globally to undertake collaborative innovation and discoveries. Deep-time Engine is the core module of the DDE Platform. It contains four levels of sub-engines, which correspond to computing, data, knowledge, and scenario services, respectively. Through its globally accessible DDE cloud infrastructure, the platform provides analytical tools and workflow services and large-scale, high-performance computing services. Several working platforms, such as the Dental Zircon Analysis Platform and the Global Layer Platform etc., have been created. The Platform now has nearly 4000 users with more than 50 databases which are linked to several other datasets via the internet. The deep-time.org platform harmonizes data from sources like the Paleobiology Database (PBDB), Macrostrat, and GeoLexicon, streamlining workflow and increasing efficiency for researchers. Other key advancements include myDDE for personalized data management and analysis, the DDE Cloud for scalable data storage and computing, and DDE WebGPlates, which offers real-time data rotation and display in a web browser improving user experience.

- Improvements and important focus for work during 2024 to mid-2026: (i) Launch initiatives like World Cup competition, DDE-IGEO (International Geosciences Educational Organization, a DDE Member) collaboration in the conduct of Olympiad 2024 in China, DDE Dinosaur World Tour and promoting the research and pedagogic value of the DDE 3D outcrop model to attract wider

use of the DDE Platform including students, educators, science popularizers and other target groups; (ii) Demonstrate the use of the Platform for the completion of a certain number of disciplinary knowledge graphs; (iii) Develop the work of DDE RCE in Hangzhou to further refine and improve the user-friendliness and performance of the DDE Platform; (iv) Improve DDE representation in underrepresented regions (e.g. Europe) and sectors (e.g. industry); (v) Enhance interlinked DDE professional/ thematic databases.

The White Paper identified several other Data Organizations and Open Access Data bases with whom DDE could seek collaboration (see Table 3-1, page 9 of the White Paper). As would be described later in this report, DDE already has an MoU with CODATA and has had communications with WDS. DDE has been trying to establish relationships with ICDP, IODP and EarthCube. Others, including GBDB, PBDB and OneStratigraphy are sharing data via the DDE Platform. Possibilities for collaboration with OneGeology and Mindat are being explored. While DDE shares the mission of many of these organizations and databases, DDE is an effort that has matured during its first 5 years, despite constraints that were not faced by any of these organizations during their early stages of development. DDE is ready to commit resources and effort to make the Platform to be the world’s leading digital hub for international data-driven research collaboration in solid-earth sciences.

Objective 2: DDE Web is content-rich, and DDE has developed other on-line and print information dissemination and communication channels in cooperation with its members and partners for promoting the significance of data driven discovery in geosciences.

Year 1 (July 2021 – June 2022) Deliverables	Secretariat assessment	Year 2-2.5 (July 2022 – December 2023) Deliverables	Secretariat assessment	Year 2.5 - 5 (Jan. 2023 – June 2026) Deliverables	Secretariat assessment
A thorough review of the DDE website and an updated design and plan catering to a clearly defined set of target audiences who can benefit from data driven discovery in the geosciences.	This was discussed and several suggestions and recommendations were made by GC, EC, and the Steering Committee of DDE and by the WTGs. A phased approach to the improvement of the DDE website has been put in place during Years 2 and 3.	An updated, content-rich DDE website linked to a minimum of 10 other websites of current and new members and partners.	The content of DDE website – www.ddeworld.org – has been regularly improved. Mike Stephenson’s Blog and the DDE Newsletter are now regular features. Brief reports on the outcomes of important events like the DDE Open Science Forum held on Nov. 9, 2022, in UNESCO, Paris, are made available in a timely manner.	Continued monitoring of web-site performance as described in item (ii) for years 2-3;	This is a realistic deliverable whose importance for having feedback on the DDE website during the second 30-month period of MTP would be much more critical than from the beginning till end of the first 30-month period, when website

			<p>A revised and updated version of the web (web 3.0) is planned for the end of 2023. Linking to other partner, Member and WTG sites has been possible when DDE implements specific activities with them. Greater effort is needed to sharing news relevant to DDE work from DDE Member and partner sites.</p>		<p>development had been initiated and had to progress through various upgrades and testing</p>
<p>Initiation of dialogue and communications with current members, potential new members, partners who share interests in data driven discovery for addressing land, water, ocean, energy related problems and issues to create website linkages and data sharing arrangements.</p>	<p>During the 1st year of MTP implementation, i.e., July 2021-June 2022, such communications were restricted to on-line means only as international travel was restricted. However, during that period some new Members joining DDE, such as IAH, IMA, IAEG and YES, showed that DDE was attracting attention of geological science community interested in different themes and issues..</p>	<p>Evidence for growing interest and frequency of visits to the DDE website gathered and made available to GC, EC, SC and StC, and Members and WTGs on a bi-monthly basis:</p>	<p>Regular monitoring of visits by users to ddeworld.org has not been initiated in a systematic manner and has been delayed until the current version of www.ddeworld.org is further refined and updated by the end of 2023.</p>	<p>DDE collaborates with Members and partners who have been linked to UN Decade on Sustainable Energy for All which will conclude in 2024 to issue special publications to demonstrate the importance of deep-time data in enabling energy transitions to</p>	<p>There are some emerging initiatives within DDE which are likely to mature in 2024 and which may create opportunities to generate publications and other scientific and popular outputs under this deliverable. They include the creation of a DDE Energy sub-Centre in the Hangzhou, RCE; potential partnerships between DDE and Project Inner Space, USA, focusing on geothermal energy; the Duke University (Kunshan, China and North Carolina, USA)</p>

				combat climate change.	on Sustainable materials and energy; and the Hedberg Conference on geothermal energy to be convened at Univ. of Wuhan (Oct. 2024). Establishment of a new DDE TG on Carbon Capture and Sequestration (CCS) is under consideration. The DDE Energy Group session at 37 th IGC in Busan, Korea in Aug. 2024, may deliver relevant outputs.
Attendance and participation in international, regional, and national events to promote DDE.	Between July 2021 and June 2022 attendance of DDE Members at international, regional, and national events were constrained by prevailing international travel restrictions. Nevertheless, some Members, like AAPG attended events focusing on North and South America to publicize DDE work and achievements. China based Members and WTG representatives participated in national and regional events to	With the help of IUGS and other potential partners DDE has established strong links with organizations like UNESCO, which coordinates the International Geosciences and Geoparks Program (IGGP) and similar ones on oceans, land, water, geological heritage etc., to establish mutually beneficial arrangements to	IUGS, UNESCO, IYBSSD and DDE co-organized “DDE Open Science Forum” convened in UNESCO Paris on Nov. 2022 served to globalize awareness and achievements of DDE. It was an event where many of the DDE GC, SC and EC Members had their first face-to-face interactions since early 2019. The Forum and associated events have opened new partnership possibilities. DDE and CODATA signed an MOU in Aug. 2023. A DDE.UNESCO MOU may be finalized in	DDE data driven discovery findings, data bases and approaches are used to design and launch 5 visitor and public education campaigns on “deep-time data and knowledge for society and development”,	Through contacts and networks created by DDE participation and sponsorship in many of the events in 2023, possibilities for visitor and public education campaigns are being explored. DDE-UNESCO collaboration will likely have a special component on capacity building for using digital geodata in the identification, nomination, management (including

	<p>share the results of their work carried out under the framework of DDE.</p>	<p>plan and implement joint initiatives.</p>	<p>2024 and the UNESCO General Conference, while adopting the Open Science Recommendation in Nov. 2021, referred to DDE as potential pilot project in whose implementation DDE and IUGS could collaborate. Prof. Qiuming Cheng, IUGS President during 2016-2019 has been awarded a UNESCO Chair established at the China University of Geology in Beijing on Sustainable Use of Minerals, particularly focusing on DDE work on minerals. In 2023, DDE's regional and international exposure has significantly increased through DDE and Member/WTG/Partner sponsored sessions at IPTC 2023 (Feb. – March), EGU (April), CAG29 (Sept.), GSA (Oct.) and AGU (Dec.). A list of international and regional events which were sponsored by DDE and/or where DDE was represented is in Annex 1 to this report. DDE Secretariat has established a budget-structure for supporting annual DDE engagement in</p>	<p>including in a selected number of well visited geoparks and geological heritage sites, both in China and elsewhere.</p>	<p>popularization) and monitoring of UNESCO Global Geoparks in Africa and SIDS.</p>
--	--	--	---	--	---

			3 tier-categories of events of varying scales and with financing ranging from 10.000 to 100,000 US\$.		
<p>Concept note, announcements, and planning for convening a data-driven discovery in geosciences symposium, or expert dialogue, preferably linked to some global, international event addressing geo and/or data sciences issues and problems.</p>	<p>The idea for the organization of the data-driven discovery event was discussed during some of the DDE Steering Committee sessions. Rather than organizing one-single event, it was considered preferable that the work carried out by DDE on data driven research and their contributions to DDE implementation be featured periodically in as many international, regional, and national events as possible.</p>	<p>Outcome of DDE sessions and special events organized as part of international, regional, and national conferences and symposia disseminated through web, print and other media outlets.</p>	<p>A DDE Technical Workshop convened on 7 November 2022, jointly by IUGS, CGMW and DDE at the Maison de la Geologie in Paris, France, informed DDE Members, WTGs, and the broader geological science community on the outcomes of data-driven research activities, particularly those implemented by CGMW, Marginal Seas TG, IUGS/CGI-DDE Standards TG, the Chinese Geological Survey and Palaeogeographical Reconstruction Alliance. The DDE 3D Outcrop model introduced at that meeting, has since then captured the interest of geological science academics and researchers in the UK, Europe, and Africa. Since then, DDE sessions, events, Platform demonstrations and training courses have been organized at IPTC 2023, EGU 2023, CAG 29, GSA 2022 and 2023 and AGU 2022 and 2023.</p>	<p>At least 5 popular science articles in reputed Journals (e.g., National Geographic, GEO, National Geographic Traveler, Scientific American, New Scientist etc.) sponsored by DDE Members and partners.</p>	<p>Scientific and technical publications from DDE research have already been widely disseminated (see list of publications produced during 2021-2023 in Annex 2 to this report). The production of popular science publications on DDE has not been initiated but could be assigned higher priority beginning from 2024. Discussions between DDE and Springer-Nature in Nov. 2023 could provide opportunities for DDE achievements to be disseminated among the broader science-literate public.</p>

			News about the various events sponsored by DDE in 2023 as well as major outcomes from those events are regularly provided through the DDE website (www.ddeworld.org) and, to some extent, through other social media outlets, in particular LinkedIn and Twitter (now "X").		
--	--	--	---	--	--

Objective 2 Summary:

- The most significant achievements under this objective are: (i) DDE website (www.ddeworld.org) contents improved and reaches a wide range of users; (ii) With the successful launch of the DDE Open Science Forum co-organized by IUGS, UNESCO, IYBSSD and DDE on 9 Nov. 2022, and other events in Paris, France, DDE outreach significantly improved; a UNESCO Chair on Sustainable Use of Minerals with close links to the work of DDE has been established at the China University of Geology in Beijing (CUGB); (iii) DDE signed an MoU with CODATA, one the world's largest data science organization under the framework of ISC; and (iv) DDE data-driven research demonstration in training courses and other activities at EGU 2023 (Europe), CAG 29 (Africa), GSA 2023 (USA) and AGU 2023 (USA).
- Improvements and important focus for work during 2024 to mid-2026: (i) Establishing a systematic monitoring mechanism for tracking use of www.ddeworld.org and improving website content based on user feedback; (ii) Widening and improving the use of social media outlets for disseminating news beyond www.ddeworld.org; (iii) Generating popular science publications on the work of DDE, including through the outcome of possible DDE-UNESCO initiatives in Africa and SIDS and potential collaboration between DDE and Springer-Nature.

Objective 3: Creation of a global network of Research Centers of Excellence (RCEs) for scientific research and training of a new generation of geodata scientists and for promoting interactions with policy professionals and other groups with an interest in data driven discovery in geosciences.

Year 1 (July 2021 – June 2022) Deliverables	Secretariat assessment	Year 2-2.5 (July 2022 – December 2023) Deliverables	Secretariat assessment	Year 2.5 – 5 (January 2024 – June 2026) Deliverables	Secretariat assessment
RCE, Suzhou infrastructure development completed	COMPLETED -- The physical infrastructure of Suzhou RCE has been completed by the Jiangsu Province, China. The Centre is well equipped with facilities for data-driven research.	“IGCP Google” that includes an “IGCP Google Scholar” or a similar product/service that centralizes 50 years of IGCP outputs launched in partnership with IUGS and UNESCO to commemorate IGCP-50 in 2022.	This work has not been possible to date. IUGS and UNESCO were not ready to embark on such an activity in time for its completion for IGCP-50 in 2022. In the future UNESCO and DDE have informally agreed to discuss with IUGS and IGCP potential areas of collaboration where the possibilities for creating an IGCP database as imagined under this deliverable could be one option that may be discussed.	At least one new RCE launched and networked with existing RCEs in China and in countries that established RCEs in years 2-3;	Potential candidate sites for this period include, one in Namibia (for Southern Africa) and another in Nigeria (West Africa). This potential will be further pursued during 2024. Discussions with CCOP, a DDE Member, for establishing a DDE RCE for ASEAN, were already initiated in 2022, will be further pursued.
RCE Suzhou designs, organizes, and completes (a) one training workshop for geo and data scientists from less developed countries and (b) a scientific	Due to international travel restrictions to enter China, which was only lifted in early 2023, this activity conducted in 2022 was confined only to Chinese	two new RCEs are established and operational	A DDE RCE has been established at the Earth and Planets Lab of the Carnegie Science Institute in Washington D.C., in Mar. 2023, focusing on “Geomaterials	The reception and level/extent of use of the “IGCP Google” tracked and achievements highlighted and constraints and	As noted above this activity has not been feasible. An IUGS evaluation of IGCP conducted in 2023 has suggested several ways to reimagine future IGCP Projects.

<p>workshop that includes participants bringing data from their own countries for treatment with AI, machine learning and similar technologies used by DDE geo and data scientists</p>	<p>participants. Future training events are foreseen in China as well as in other parts of the world. In 2023, a DDE Platform based training course was organized at the GSA annual meeting (Oct. 2023, Pittsburgh, USA). More training events in Africa and other developing regions of the world are foreseen during 2024-2026.</p>		<p>Informatics". A second DDE RCE in China (the first being the one in Suzhou), focusing on data sciences and technology for DDE's data driven research supported by the Zhejiang Province is nearing finalization in Hangzhou. Discussions for a DDE RCE in the Democratic Republic of Congo are underway and are progressing well and could be confirmed in 2024.</p>	<p>problems for its better use, particularly by less developed nations, addressed.</p>	<p>UNESCO has agreed to have a discussion with IUGS and IGCP and include DDE in the discussions to explore potential for collaborative initiatives with DDE. Such a discussion is expected to take place in 2024.</p>
<p>At least 5 scientific publications or reports produced by WTGs and Members to demonstrate the benefits of data-driven discovery in geosciences.</p>	<p>The list of scientific publications derived from the work of DDE Members, WTGs and projects are included as Annex 2 to this report.</p>	<p>Interest and opportunities to launch RCEs in other regions/countries, e.g., Russia, EU, Africa, Latin America and the Caribbean, Arab States etc., explored and country(ies)/region(s) with the greatest likelihood in succeeding in the creation of new RCEs identified</p>	<p>Countries interested in establishing RCEs for Southern Africa (Namibia) and West Africa (Nigeria) have been identified. Development of a DDE RCE in Russia is feasible but has been delayed due to prevailing international tensions. Possibilities in other parts of the world are being explored. In countries like the UK and Ireland, universities and academics have shown an interest to create a collaboration network; in</p>	<p>RCEs already established in China and at least in 3 other countries, together host 10 visiting scholars from member and/or partner organizations to design and launch co-operative initiatives on data-driven discovery in geosciences.</p>	<p>Based on negotiations currently underway, this deliverable appears achievable. DDE Secretariat has an agreement with the Kunshan City Government to provide accommodation for visiting scholars. Some of the discussions underway with Duke (Kunshan and North Carolina) University, CODATA, UNESCO, Botswana Geoscience Institute,</p>

			<p>particular, to widen access and use of the 3D outcrop model for research, teaching and raising public awareness of geological sites, features, and phenomena. Possibilities for linking such a network to the establishment of an RCE needs further exploration.</p>		<p>University of Lubumbashi, DRC, etc. will provide opportunities to identify scholars who could be invited to spend time and collaborate with DDE RCE scientists.</p>
<p>DDE, IUGS and UNESCO collaborate to explore outcomes and results of 50-years of IGCP Projects for designing products and services such as “IGCP Google” (including perhaps an “IGCP Google Scholar”) with open access, in particular, to less developed countries.</p>	<p>During Year 1 this possibility was explored but neither UNESCO nor IUGS were ready to pursue the idea.</p>	<p>RCE, Suzhou hosts at least 3 visiting scholars from member and/or partner organizations to design and launch cooperative initiatives on data-driven discovery in geosciences in countries and/or regions participating in China’s BRI initiative.</p>	<p>So far there has been only one scholar who had spent a full year in DDE Suzhou. His work has contributed significantly to the development of the Paleogeographic Reconstruction Alliance and Network. Another Member of the DDE Paleogeographic Reconstruction Network spent about two months in Suzhou and other parts of China during Aug-Sept. 2023. A third Scholar from the CGMW Member of DDE could not come to France due to COVID-19 related travel restrictions; he has found alternative employment in France and will not be visiting</p>	<p>A program to host geo and data science, post-doctoral fellows contributing to DDE/RCE Network Research and Training Program financed and operational</p>	<p>Efforts to encourage and facilitate scholar exchanges between DDE RCEs and DDE Members, DDE WTGs and other geoscience communities are underway and will be more operational from 2024. Funding possibilities have also been explored and the likelihood for confirming availability of financial support for such scholar exchanges would be known by the first half of 2024.</p>

			<p>Suzhou-RCE. The current Chair of the DDE SC is participating in a long-term geosciences research project in China and has been regularly visiting China and is guiding the work of DDE in 2023 and will continue to do so in 2024.</p> <p>Attracting scholars and post-doctoral candidates from countries participating in BRI will also be explored.</p>		
		<p>Concept and proposal development and fund-raising campaigns for supporting post-doctoral fellows in RCEs</p>	<p>Following the global launch of DDE at the Open Science Forum held in UNESCO Paris in Nov. 2022, a project concept and proposal to register and promote DDE as a China-based International Big Science initiative was submitted to relevant sources of potential funding in China. This proposal had attracted a favorable response from potential sources of funding. As a result, DDE funding for 2024-2026 is expected to be higher than what has been available during</p>		

			2021 (July) – 2023 (Dec.). Details of this project, the level of funding and plans for use of the funds for both China-based and international cooperation activities was presented to DDE GC session in Dec. 2023. The full approval of relevant Chinese authorities for the project and mobilization of funds are expected in the first half of 2024.		
--	--	--	---	--	--

Objective 3 Summary:

- The most significant achievements under this objective are: (i) RCE in Suzhou infrastructure development completed with the support Jiangsu Province, China, and is available for data-driven research; preparations for establishing a 2nd DDE RCE in China, in Hangzhou, is ready to serve as the technical node of DDE; (ii) The first RCE in North America established in Carnegie Science Institution in Washington D.C., USA on the theme “Geomaterials Informatics”; (iii) Well over 5 scientific publications produced from DDE linked work by Members, WTGs and project partners; and (iv) 3 post-doctoral/scholars from DDE Members, WTGs and Governing organs work with RCE in Suzhou and other China-based collaborating partners of DDE.
- Improvements and important focus for work during 2024 to mid-2026: (i) Follow-up on negotiations initiated in Namibia, Nigeria and DRC to develop and establish Africa-based RCEs; (ii) Explore creating RCEs in other parts of the world including continuing conversations with CCOP for an RCE for ASEAN and establishing links with Europe, UK and Ireland universities and academics who show interest in collaborating with 3D outcrop and other specific areas of DDE work; (iii) Use current RCEs for organizing training courses on data-driven research benefiting Africa and other less developed regions; (iv) Enhance training opportunities in data-driven research via the new RCEs to be established in Africa and through collaboration with partners like IGEO (a DDE Member) and planned activities such as DDE-IGEO Olympiad 2024 in China (see also objective 1); and (v) Initiate discussions with IUGS, UNESCO and IGCP to identify a joint project, similar to the IGCP database (foreseen but could not be started), and other mutually acceptable R&D projects.

Objective 4: Priority setting and financing of WTG and member initiatives on creating meta-databases, by harmonizing existing databases with “long-tail data”, to address questions on evolution of life, evolution of geodynamics, evolution of earth materials and evolution of climate.

Objective 5: Demonstration of the value of DDE-created databases to undertake studies, analyses and/or syntheses that inform and enable nations, local governments, industries, business, and communities to meet UN SDG targets linked to land, water, ocean, and energy.

Most of the deliverables anticipated under these two objective for the period from July 2021 to December 2023 were “process” deliverables (see Annex 4 of the MTP at: <https://www.ddeworld.org/news/detail/134>). Given the fact that the DDE global launch, originally foreseen for the 36th IGC scheduled for March 2020 in India was cancelled, and did not take place until November 2022 at the DDE Open Science Forum convened in UNESCO, Paris, the anticipated levels and frequency of communications between the Secretariat and the DDE Members, WTGs and other potential partners did not live up to expectations when the deliverables under these two objectives were defined in the period during October 2020 to June 2021 when the MTP was drafted, revised and adopted.

Nevertheless, the DDE Secretariat was able to mobilize funds through the Kunshan City agreement, which the DDE GC signed in 2020, for supporting 3 research projects on 4E (evolution of materials, life, geographies and climate) related themes in 2021. In addition, the DDE Secretariat set up a Seed Grant Fund in 2022 supported by the Kushan City Government’s Ministry of S&T which was open to proposals from DDE Members, WTGs, and the broader international geoscience community. In total, there were 13 proposals were submitted for funding under the 2022 Seed Grant Fund. The DDE SC recommended approval 4 of them and the DDE EC endorsed the recommendation of the DDE SC.

The total of 8 projects initiated in 2021 and 2022 with financial support from DDE Secretariat mobilized resources with the help of the Kunshan City Government helped to address 4E research themes as foreseen under objective 4.

In 2021, the following 4 projects were evaluated by the DDE SC and recommended for approval; the EC approved the projects and implementation has been underway since 2021. Of the 4 projects 3 were funded by DDE and 1 was jointly implemented by DDE and Chinese Geological Survey, with DDE contributions being in-kind. The four Projects are:

- **1:5M Digital Geological Mapping Project.** Proposed and implemented by CGMW. A 2-year Project (2021-2023) supported with a grant of US\$ 75,000/year. The project implementation has been timely and efficient. It has been completed in 2023 and discussions for a second phase of the project are currently underway between DDE and CGMW and other interested DDE Members.
- **Geoscience Knowledge System Standardization.** Proposed and implemented by the IUGS/CGI and the DDE Standards TG. A 3-year (2021-2024) project supported by the DDE Secretariat with US\$ 50,000 per year. The project is making sound progress and is contributing to meeting

standards related to deliverables under objective 1. An international workshop, co-organized by the project proponents was convened in Suzhou, China, from 7 to 11 Nov. 2023, and reviewed progress and suggested future directions of work for data and standards related activities beyond the end of this project. The DDE Standards TG is in communication with CODATA and CGI-IUGS and is developing a proposal which intends to seek DDE funding for 2024-2026 for continuing the collaboration between IUGS/CGI and the DDE STG within the framework of the DDE-CODATA MoU signed in August 2023 for work related to the application of FAIR principles to DDE databases.

- **Marginal Seas Project** proposed and implemented by the DDE Marginal Seas TG and Helmholtz-Zentrum Hereon, Germany. A 3-year project that is making sound progress and had been granted US\$ 150,000 for a 3-year (2021-2024) period. The project convenes regular international and regional conferences, both in-person and online, to disseminate results derived from the project. The project is expected to end in 2024.
- **China Country Node Project**, proposed and implemented by DDE and the China Geological Survey. The project is implemented through in-kind and staff support provided by the China Geological Survey with parallel support from DDE Suzhou RCE and the Secretariat. The establishment of the China Country Node, the first under DDE, has been completed and will demonstrate the process and the benefits of establishing such nodes at country, regional and disciplinary levels, foreseen as one of the deliverables during the period from January 2024 to June 2026 under Objective 1 of the MTP.

In 2022, under the Seed Grant Fund, the following proposals were approved:

- Completing the “**Evolutionary System of Mineralogy**” supported with US\$100,000 for 3 years beginning from 2023. The Project was proposed and is being implemented by the Earth and Planets Laboratory of the Carnegie Science Institute in Washington. D.C., USA, which has also, in March 2023, set up the first DDE RCE outside of China, a deliverable under objective 3 of the MTP
- **Quantifying Deformable Plate Models of Tethyan Domain with Big-Data** and supported with US\$150,000 for 3 years beginning from 2023. The Project was proposed and is being implemented by the China University of Geosciences in Beijing (CUGB).
- **On-line Comprehensive Database of Asian and Australian Stratigraphic Units (Lexicons) with Linked Display on Paleogeographic Reconstructions** supported with US\$150,000 for 3 years beginning from 2023. The project was proposed and is being implemented by the DDE WG on Paleogeography, in collaboration with the Paleogeographic Reconstruction Network that this WG has established.
- **Sand Dunes and Holocene Environmental Changes in the European Arctic (ArcDune)** supported with \$150,000 for 3 years beginning from 2023. The project was proposed and is being implemented by the Geomorphology and Environmental Systems Research Group of the University of Bonn, Germany.

Hence, a total of 7 projects addressing different 4E themes, as foreseen under objective 4, have been financed by the DDE Secretariat and provide data to enrich relevant databases on the DDE

Platform. The total funding made available, including for projects approved in 2022 and whose implementation began in 2023, and will continue until 2026, is around US\$ 1 million.

However, these project proposals were not designed and developed based on any predetermined set of priorities established by the DDE SC in consultation with Members, WTGs and partners as foreseen in the deliverables linked to Objective 4 (see annex 4 at: <https://www.ddeworld.org/news/detail/134>). The DDE SC has been able to meet only twice, after its inaugural meeting in January 2020 in the Republic of Korea. One was an on-line meeting in April 2021 when SC recommended approval of 4 projects for the period 2021-2024; and the second one was a hybrid meeting in November 2022 when the SC recommended approval of the 4 projects under the Seed Grant Fund established in 2022 and discussed, at length, criteria for future project proposals and their evaluation.

The DDE SC at its 4th session convened on 10 December 2023 in San Francisco, California, USA, the day before the beginning of the annual AGU session on 11 December where DDE hosted several activities, discussed priorities for future projects, had started discussions are expected to continue at the next (5th) session of the DDE SC in August 2024 and could lead to priorities for future DDE project financing.

Objective 4 summary: The list of publications, products (for example, maps websites, databases etc.) established from the research projects funded under this objective are provided in Annex 3 to this report. The reports of the DDE funded projects shall be made available to the external review team separately.

Regarding objective 5, no proposals that catered to meeting SDGs or other more applied and societal benefits-oriented themes have been supported. Among the 13 proposals that were received for potential funding under the Seed Grant Fund in 2022, there were 2 that had an applied science, SDG orientation: (i) Intelligent Prediction of Geothermal Energy Prospect Driven by 3D Geological Model and Big Data Analysis; and (ii) Big Data-Driven Evolution Mechanism Study on Regional Scale Groundwater Systems. However, those two proposals were not prioritized for financing by DDE SC and hence were not recommended for funding.

There have been discussions between DDE Secretariat and potential partners in Africa, Asia and the Middle East that have generated interest and opportunities for DDE to identify potential geological science R&D projects in energy, mineral, groundwater, education, and other SDGs relevant sectors. DDE activities of some working groups, like the Energy WG, where one of the co-Leaders was supervising an African doctorate student in China, developed a geothermal energy map of Africa. There have also been maps of natural disasters, groundwater, geological features etc., of the African continent, all of which were presented at the workshop jointly organized by DDE and the Geological Society of Africa (GSAf, a DDE Member since March 2023) on 25th Sept 2023, the opening day of the 29th Colloquium of African Geology, convened in Windhoek, Namibia.

The DDE Platform (www.deep-time.org), launched in November 2022, is an important digital resource library providing scientific data and knowledge and technological data, models, graphics, computational resources etc. The Platform has been recognized as one of the Open Science infrastructures in the UNESCO Compendium and has direct relevance to implementing SDG 2 (several DDE WTGs, Members, and partner organizations have established nearly 50 databases on

the Platform. Their quality and operability vary. However, some of them are quite useful for demonstrating applications of the FAIR principles. Others could have relevance to launching DDE initiatives on SDG themes, in particular SDG2 (quality education) and SDG 9 (industry, innovation and infrastructure). Platform users could in the future apply these resources to design, develop and implement research projects relevant to SDGs 6 (water), 7 (energy) and 13 (climate). Hence, databases, as they are developed and refined further in 2024 and beyond, could be used in the identification of DDE projects and initiatives under objectives 4 and 5 of the MTP. Furthermore, the DDE Energy sub-Centre, expected to be opened as part of the Hangzhou RCE in 2024, is already in communication with potential partners for launching potential R&D projects in the field of geothermal energy.

Objective 5 summary: Annex 4 includes all the Africa maps generated by the African doctoral student as part of his work for a Ph.D. at the University of Wuhan in China. Some of the publications of the DDE Working Groups on Energy, Groundwater and other SDG themes are also included.

Objective 6: DDE's financial sustainability secured through agreements and partnerships for implementing this MTP and the WP recommendations until 2029.

Deliverables under this objective (see, Annex 6 at: <https://www.ddeworld.org/news/detail/134>) need rethinking and reimagining. The only international financial contribution to DDE thus far is from IUGS, US\$ 20,000 per year. The rest of the financial contributions are all from funding sources in China. However, there are several international and Chinese geologists who make available their time and some of their project resources to the work of DDE WTGs; these contributions need to be acknowledged, though it would be rather difficult to estimate the \$ value of such contributions without launching a detailed questionnaire survey among WTG Leaders which may place additional demands on their time commitments to DDE.

From 2019 to 2023, funding from China's Provincial Government sources, predominantly from the Jiangsu Province, covered the following expenses of DDE: (i) Secretariat operations and maintenance, including staff salaries; (ii) DDE participation in and hosting of international, regional and national scientific conferences and associated events; (iii) DDE financed research projects; and (iv) development, launch and maintenance of the DDE Platform, DDE Cloud establishment and operational costs, primarily funded by the Hangzhou RCE.

Financial sustainability for the period 2024-2026 is, however, expected to be strengthened through the additional funding support for DDE implementation from China based sources. DDE Secretariat hopes to reserve 30% of such additional support for projects from China based sources for international research and development initiatives. It is hoped that such additional contribution from Chinese sources could enable the Secretariat, WTGs, Members and partners to attract matching, counterpart financing from sources outside of China.

Objective 6 Summary: All financing for the work of the DDE Secretariat and the R&D Projects so far has been provided by the Kunshan City Government in accordance with the MoU signed between the Government and the DDE GC in 2020. The only international contribution was from IUGS. It is expected that period from 2024 to mid-2026 conditions for attracting financial contributions from international sources as matching/counterpart funding for higher levels of funding expected to become available within China would significantly improve.

Having provided an assessment on DDE achievements in relation to the deliverables described under the 6 objectives of the MTP, the Secretariat would like to provide some additional information on the following to facilitate the mid-term evaluation of DDE:

(a) **Secretariat views on the key performance indicators (KPIs) identified in the MTP for the mid-term evaluation.** [Descriptions in red indicate KPI components that could not be satisfied. Those in blue indicate KPIs met to varying levels of satisfaction.]

- Fully operational cyberinfrastructure support for promoting DDE data-driven discovery research paradigm. **DDE Platform is operational, and its performance effective; user friendliness is being regularly monitored and improved**
- At least 3 new Members join DDE: significant improvements of gender and geographical diversity of representation in GC, EC and SC and the leadership of WTGs. **The DDE Membership has increased by more than 5 new Members between 2021 and 2023 and is nearing 30. GC representatives are proposed by Members and the geographical and gender distribution are satisfactory. In SC (15 Members) and EC (5 Members), the geographical distributions are fair, but gender distribution could be further improved. The same holds true for the WTGs.**
- Assurance of support and funding for implementing at least 75% of this Plan; 30% of the support mobilized originate from sources outside of China. **The increased funding expected to become available within China in 2024 assures the implementation of all aspects of the MTP. However, except the IUGS contribution of US\$ 20,000/year, all other financing so far has been from the Kunshan City Government sources and in accordance with expectations defined by the agreement signed between DDE GC and the Kunshan City Government in 2020.**
- At least 3 RCEs established and functional; financing for post-doctoral fellowships of young scientists in at least one of them secured. **2 RCEs (1 in China and 1 in the US) have been established and functional. A third one, in China, will be operational by the end of 2023. Financing for post-doctoral fellowships in the Suzhou RCE is secured.**
- Content-rich website linked to at least 10 other WTGs, Member, or partner websites; evidence for high use by academic and scientific communities and moderate-to-high use by policy and development professionals, industry and business sectors and specific public interest groups of the DDE website. **www.ddeworld.org content has blogs, a newsletter and other products that provide regularly updated information. Within www.deep-time.org well over 10 Members/WTGs and partners have begun to create databases and others are under discussion. MyDDE in www.deep-time.org allows geologists from all parts of the world to use the Platform for data-driven research. Use of the DDE Platform and DDE website by policy and development**

professionals and industry and business sectors have not been feasible and would require special attention.

- Outcome and results of collaboration between data and geoscientists demonstrated via the launch of 3-5 new/integrated databases and at least 10 scholarly, popular, and journalistic outputs based on DDE achievements. [Integrated databases in Paleogeography, Mineralogy, Stratigraphy, and 3D Outcrops are accessible via www.deep-time.org](http://www.deep-time.org) and are being regularly monitored and improved based on user feedback. Several scholarly and academic publications. Some outreach to the more general users shared via LinkedIn and Twitter. **Production of popular science and journalistic outputs need to be targeted for initiatives during 2024-2025.**
- Databases and related studies and analyses demonstrating the value of “deep-time data discovery” to the “UN Decade on Sustainable Energy for All” that ends in 2024 and follow-up. **Not achieved, but some synthesis of available data into a database in a new DDE Energy sub-Centre in the 3rd RCE (the second one in China), may be feasible in 2024.**
- 5 working partnerships with UN, business, and industry sector and/or specific public sector interests that support and help DDE to generate results and outcomes that have a global impact. [MoU signed with CODATA, one of the largest international organizations focusing on data under the auspices of ISC. An MoU with UNESCO to promote Open Science applications and capacity building in geological sciences in Africa and SIDS is in process and is expected to be finalized in 2024.](#) **No business or industry sector partnership has been feasible so far.**

Constraints and factors limiting the expected deliverables and KPI:

The COVID Pandemic, which restricted international communications and travel between early 2020 to early 2022 in most countries, was a significant limiting factor. Entry into China, where the DDE Secretariat is located, did not fully normalize until early 2023. There were also other unexpected changes in international relations between countries that lead in science and technology since the DDE, “kick-off” meeting in 2019 that appear to constrain active participation of some countries as well as fund-raising from sources outside of China. The DDE Open Science Forum, co-organized by IUGS, UNESCO, IYBSSD and DDE, was originally scheduled for June 2022 but had to be delayed until November in the same year because of the diplomatic impacts that the Ukraine-Russia war had on UNESCO intergovernmental decision-making processes.

Complete, constraint-free global environment for DDE activities became a reality only by late 2022 with the launch of the DDE Open Science Forum in November 2022. International travel to China fully normalized in March 2023. The first international DDE workshop in China, after the “kick-off” meeting in February 2019, was convened in November 2023 on “Status and Future of Geoinformation Standards” in Kunshan City, next to the DDE Secretariat Office premises.

Hence, though the mid-term evaluation of the MTP is expected to cover performance over a 30-month period from July 2021 to December 2023, a constraint-free international working environment has been in place for only about half that time horizon, i.e., 15 months, beginning from October 2022.

It is expected that progress in DDE implementation and completion of deliverables would be more on time during the 2024-mid June 2026, barring any other unexpected events imposing limitations like those experienced during 2020-2022.

(b) Description of activities of the DDE Governing Bodies since the DDE “kick-off” meeting held in February 2019 in Beijing, China.

To-date the GC has met for 6 sessions, 5 of them online. The first hybrid (5th) session, where several GC Members attended in person was convened at UNESCO, Paris, on 8 November 2022, the day before the IUGS, UNESCO, IYBSSD and DDE co-organized DDE Open Science Forum. The advantages of the face-to-face discussions during the 5th session of GC at UNESCO Paris were evident and the GC has encouraged the EC and the Secretariat to foresee at least one session of the GC per year where, as many Members as possible can attend in person. The 7th session of the GC was convened on 10 December 2023, in San Francisco, CA, USA, the day before the inauguration of the annual meeting of AGU at the same location from 11 to 15 Dec 2023. During that AGU, the DDE hosted a Town Hall meeting on 12 December from 1300 to 1400 hours; hosted a booth to display its information and demonstrate the working of the Platform and some other products and services that have been developed. Short presentations from invited speakers, including from Rob Hazen, Director of the DDE RCE in Carnegie Mellon Institute, Washington, D.C., USA and Dr. Antonio Abreu, Director of UNESCO Ecological and Earth Sciences, linked to the AGU 2023 conference theme: “Wide.Open.Science” were delivered at the DDE booth and engaged attendees in formal and informal discussions.

The EC, which is responsible for the implementation of the decisions of the GC and overseeing the work of the DDE Secretariat, has met more frequently. The EC concluded its 11th session on 20 October 2023. During 2020, 2021 and 2022, given prevailing international travel restrictions to and from China where the DDE Secretariat is housed, EC met 3-4 times a year online. In 2023 the EC met three times, including for its 12th session in San Francisco during the evening of 12th December 2023 after the conclusion of the 7th session of the GC on 10 December 2023.

During 2020-2021 and including the times leading to the adoption of the MTP, the DDE Steering Committee met frequently and guided the work of the EC and the Secretariat.

The SC convened for its 4th session, also in San Francisco, CA, USA, on the same day of the GC session, on 10 December 2023. The SC and the GC sessions in San Francisco came together for discussions on some of the common agenda items, such as priorities and guidelines for future R&D projects. The SC, which spent most of its time during its 2nd and 3rd sessions on evaluating project proposals and reviewing reports of funded projects and activities of WTGs, allocated considerable time in San Francisco to discuss DDE’s future R&D priorities and conditions and guidelines for financial support provided by DDE.

A DDE Advisory Board was established at the end of 2021 comprising the President of IUGS, Assistant Director General for Natural Sciences of UNESCO, President of IUGG, and two other

independent personalities one representing the academia and the other industry. However, the UNESCO representative changed positions in 2023 and the IUGG President and the academic representative were also Members of the DDE SC. The Advisory Board have not met even once so far. The structure, role and representation of Members of the Advisory Board need to be revisited following the external review of the implementation of DDE is completed.

The DDE Statutes, which was adopted by the DDE GC at its 3rd session in September 2021, defines term limits and guidelines for the periodic renewal of SC and EC Members. These were considered by the GC at its 7th session on 10 December 2023 and several amendments were proposed. The draft revision of the Statutes will be completed in 2024 with a view to implementing GC decisions on term-renewal of SC and EC Members soon after the conclusion of the 37th IGC in Busan, South Korea, on 31 August 2023.

(c) Meetings with WTGs

Maintaining regular communications with Leaders and Members of WTGs has been the most challenging aspect of work for the DDE Secretariat. The number of international and Chinese scientists who are engaged in WTG activities is well over 200. Each WTG is eligible for a maximum annual stipend of US\$ 5000 (in 2021-2022) which was increased to US\$ 10,000 in 2023. There were 2 online meetings for all WTGs, one each in 2021 and 2022, which attracted a reasonable number of WTG leaders, co-leaders and/or members. The attendance at the WTG online meeting on 24 July 2023 was disappointingly low. Some WTGs, such as those on Paleogeography, Dinosaur, Energy, Marginal Seas, Data and Standards, are more active than others. Most of the WTGs were established in 2019 and a mid-term assessment of those WTGs is planned in 2024.

(d) DDE Secretariat:

Since 2019, the Secretariat has maintained a team of 3-4 personnel. But members of the Secretariat team have changed frequently during the 5-year period.

The work of the Secretariat is overseen by the Chair of the DDE EC, and the Deputy Secretary General serves as the Head of the Secretariat. At the Kunshan City Secretariat office in Suzhou, China, there are currently a Science Operations Team (SOT: Head and an Assistant) and an International Relations Team (IRT: Head and an Assistant). Two positions for international staff, one each for SOT & IRT, who would be expected to work full-time based in the Kunshan City Secretariat were announced. But the Secretariat has not been able to attract suitable candidates for either of the two positions.

There are four part-time staff working with DDE based in the UK (1) and the USA (3)

Administration of budget and financial matters, including payments of salaries, reimbursement of costs incurred by invited experts, etc., must be carried out in compliance with the Kunshan City Government's rules and regulations, which are complex and time-consuming. As a result, the 4 staff Members belonging to the SOT and IRT in Kunshan City are spending too much time

on administrative and financial matters which impacts Secretariat time available for carrying out programmatic and scientific activities. A senior professional well versed with Chinese Government processes and with considerable experience in developing international cooperation initiatives from the China University of Geology in Beijing has been seconded to the Secretariat in late 2023 and the administrative performance of the Secretariat is already showing considerable improvement.

(e) A time frame for the external evaluation of DDE's mid-term performance (2019-2023).

DDE is an IUGS initiative. The Secretariat has submitted annual reports to the IUGS for 2020, 2021 and 2022. In 2022 and 2023, DDE Secretariat attended the IUGS Executive Committee sessions in Paris, France (March 2022) and in Belfast, Northern Ireland, UK (February 2023). The Chair of the DDE Governing Council during 2022-2023, Prof. Jennifer McKinley, is an IUGS Counsellor and ensures that IUGS concerns, and information are regularly transmitted to the consideration of DDE Governing Bodies. The President of IUGS, Prof. John Ludden attended one DDE GC session (online) in 2021 and was among the leading convenors of the IUGS, CGMW, DDE co-organized DDE Technical Session at the Maison de la Geologie, in Paris, France on 7 November 2022, and the IUGS, UNESCO, IYBSSD and DDE co-organized DDE Open Science Forum at UNESCO Headquarters in Paris, on 9 November 2022.

At both IUGS Executive Committee sessions in 2022 and 2023, the work of DDE received favorable remarks and comments. IUGS Commissions, namely CGMW and CGI-IUGS, have benefitted from DDE project funding. The current Chair of the DDE Science Committee, Prof. Hans Thybo, is also the Chair of the International Lithosphere Program (ILP), an IUGS affiliated Program and a DDE Founding Member. Many other IUGS Commission Members and Program participants serve as Leaders or Co-Leaders of several DDE WTGs. DDE is also making a significant commitment to the 37th IGC, the quadrennial event hosted by IUGS, convening 14 scientific sessions, hosting a booth and organizing some social and networking events to share the progress and achievements of DDE with the global IUGS community. DDE is Theme #37 at IGC 2024 (see: <https://www.igc2024korea.org/content/14403>).

Given the close and mutually beneficial relationship that DDE has with IUGS and the fact that DDE is the first-ever IUGS big-science initiative, DDE Governing Bodies have unanimously decided invite IUGS to lead a team to conduct an external review of DDE performance during the first 30 months of implementation of the MTP and the broader 5-year, time horizon encompassing 2019 to 2023. The external review team could include IUGS nominated and other independent experts who may be proposed by the DDE GC and the SC.

This draft has undergone several revisions and will be finalized for submission to the leader of the IUGS led review team before the beginning of IGC 37 on 25 August in Busan, Korea. IUGS led team intends to complete the review before the end of 2024 and submit its recommendations to the consideration of the IUGS Executive Committee meeting in the first quarter of 2025.

(f) Secretariat plans for DDE sessions at the 37th IGC in Busan, South Korea in August 2024.

Under Session 8 on "DDE – Progress, Challenges and Plans for 2024-2030", the Secretariat will host presentations and discussions that will provide insights into DDE performance during 2019-2023. Several of the other 13 sessions under the DDE theme (theme 37 of IGC 37) will also generate possible ideas and suggestions on how DDE's work during 2019-2023 has met expectations of the global geosciences community and how DDE development could serve them better in the future.

Secretariat activities after the receipt of the recommendations of the IUGS-led external review DDE mid-term performance

The Secretariat intends, after the receipt of the recommendations of the IUGS-led external review, to prepare a DDE MTP2 for the period from 2025 to 2029.

The MTP for 2025-2029 should integrate: (i) Lessons learned from DDE self-reflection on the implementation of the first 30 months of the DDE MTP as described in this report; (ii) Outcomes, recommendations and suggestions of the IUGS-led external review based on this report and other information that would be made available as requested by the external review team; and (iii) Outcomes, suggestions and recommendations deriving from DDE sessions at the 37th IGC in Busan, South Korea. These will serve as inputs for the drafting, review, finalization, and approval of the DDE MTP2 before 30 June 2025, so that implementation of DDE MTP2 could begin on 1 July 2025.

CONCLUSIONS

The DDE Platform, anchored on the DDE Cloud and launched in November 2022, has enabled DDE to initiate work in fulfilling its mission to harmonize global deep-time earth data and share global geoscience knowledge. It also marks the starting point for DDE to realize its vision to transform earth sciences by advancing a data-driven research paradigm in geological sciences.

The DDE Platform includes a variety of research tools, including models and software for big-data analytics, machine learning, AI based algorithms and DDE Cloud's computational power, to enable geologists to use their own data and create workflows to derive outputs and responses to their own research questions and problems. Beginning from 2024, the Platform's capacity to meet FAIR data principles and Open Science guidelines will be investigated and improved gradually; and the extent to which the databases hosted on the DDE Platform satisfy CGI-IUGS and DDE Standards TG metadata standards for geological science disciplines, released in November 2023, will be tested in collaboration with CODATA and other internationally recognized data science organizations.

The DDE Open Science Forum, co-organized by UNESCO, IUGS, IYBSSD and DDE on 9 November 2022, and the DDE GC and SC sessions held at the same venue on the previous day, together with the DDE/IUGS/CGMW technical workshop convened on 7 November 2022 at the

Maison de la Geologie, Paris, enhanced the global outreach and display of services and products developed by DDE since 2019. DDE GC and EC's decision to encourage DDE participation in other such international forums has led to DDE sharing data, information, and knowledge at IPTC, EGU, CAG29, GSA and AGU events in 2023. Similar efforts are foreseen and will be continued in 2024 and will peak with DDE sponsoring 14 sessions at 37th IGC in Busan, South Korea, from 25 to 31 August 2024.

DDE website and other outlets for sharing information with publics beyond the geological sciences community, via LinkedIn and Twitter, has gradually improved since 2020 and further refinements and regular monitoring of their use are foreseen in 2024. 2 DDE RCEs are now fully operational, and a third one in Hangzhou will serve as the DDE technical node beginning from 2024. Other opportunities for creation of at least another 3 RCEs, including in Africa, have been identified and will be further pursued. Networking between these RCEs, DDE Members, WTGs and project partners through exchange and visits of post-doctoral fellows, academic and research scholars, and representatives from other target groups such as industry and business sectors need greater emphasis from 2024.

Growth in the number of new Members joining the DDE community over the last 30-month period had been well-above expectations. More effort is now needed to attract new Members from under-represented regions, in particular Europe and the Middle East. The partnership established with CODATA needs to be built in a manner to bring tangible benefits from that organization's long experience on FAIR data applications to the nearly 50 databases already hosted on the DDE Platform. On-going efforts to conclude an MoU with UNESCO need to be accelerated, and collaborations and initiatives on digital geodata applications and capacity building projects, in partnership with IGCP and the UNESCO Global Geoparks Network, to benefit, in particular Africa and SIDS, need to be launched

The 7 DDE funded projects' progress will be monitored and their outputs and outcomes relevant to DDE's 4E themes shared with the broader DDE community and beyond. Initiatives on more applied geoscience projects that are relevant to DDE themes and relevant to the delivery of UN SDGs need to be identified and supported, particularly during the next phase of DDE implementation for 2024-2029 as this period overlaps with the last years of the UN 2030 agenda on SDGs. The DDE GC and EC, with the assistance of the DDE SC, will set clear priorities for the types of projects and initiatives that merit financial support from 2024 onwards.

Annexes (*To be completed*):

Annex 1: Tier categories of international, regional, national events and webinars sponsored by DDE during 2022 and 2023.

Annex 2: List of scientific publications and reports deriving from DDE WTGs, Members and Projects from mid-2021 till December 2023.

Annex 3: Products (maps, websites etc.) developed as outputs from DDE funded projects; DDE information and display materials used in DDE booths and events convened at international, regional and national conferences, workshops, etc.

Annex 4: Maps of Africa generated by the African Ph.D. student in China.