DIGITAL MAPPING TECHNIQUES 2020

The following was presented at DMT '20
(June 8 - 10, 2020 - A Virtual Event)

The contents of this document are provisional

See Presentations and Proceedings
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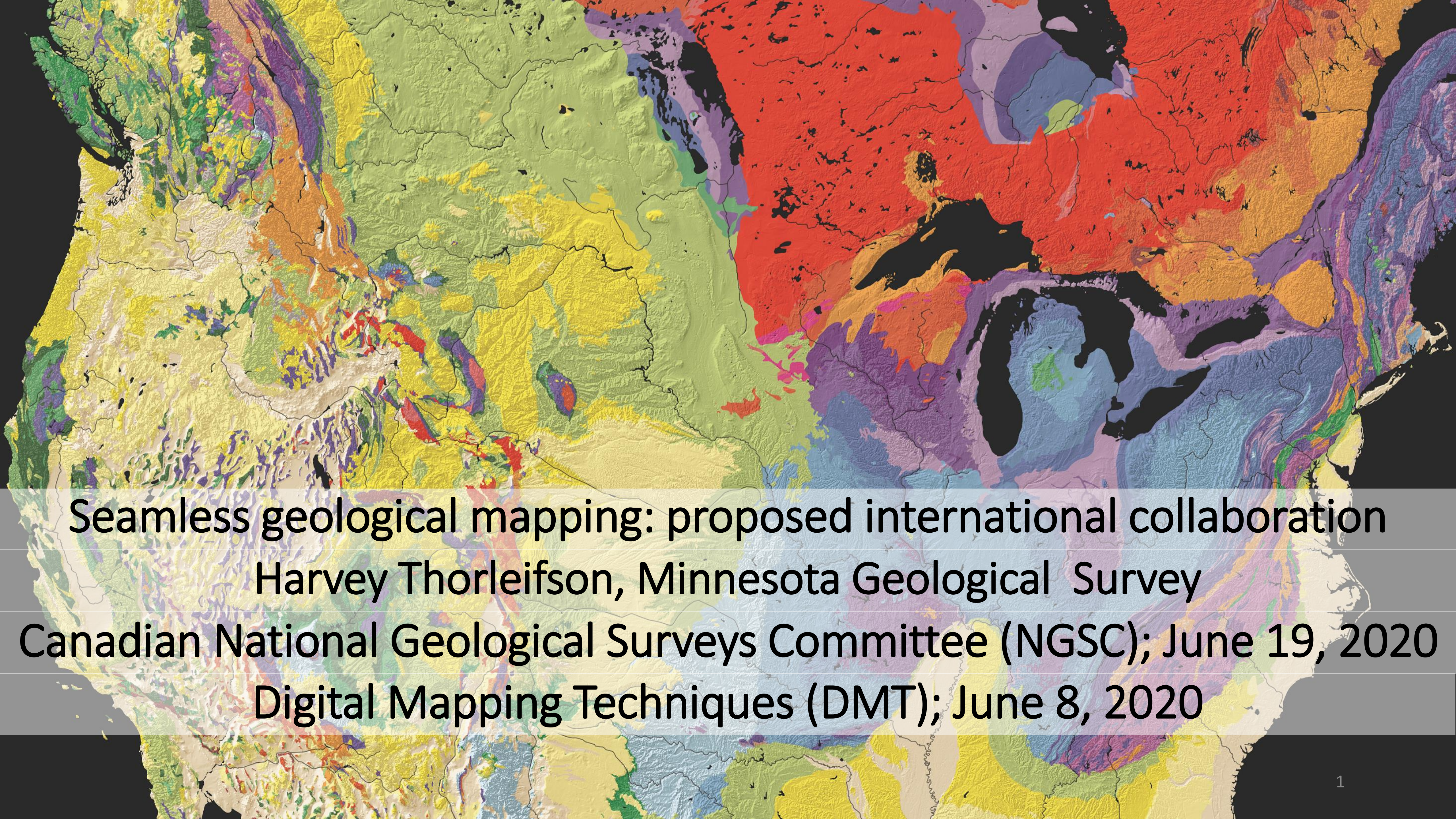
http://ngmdb.usgs.gov/info/dmt/



Seamless geological mapping: proposed international collaboration

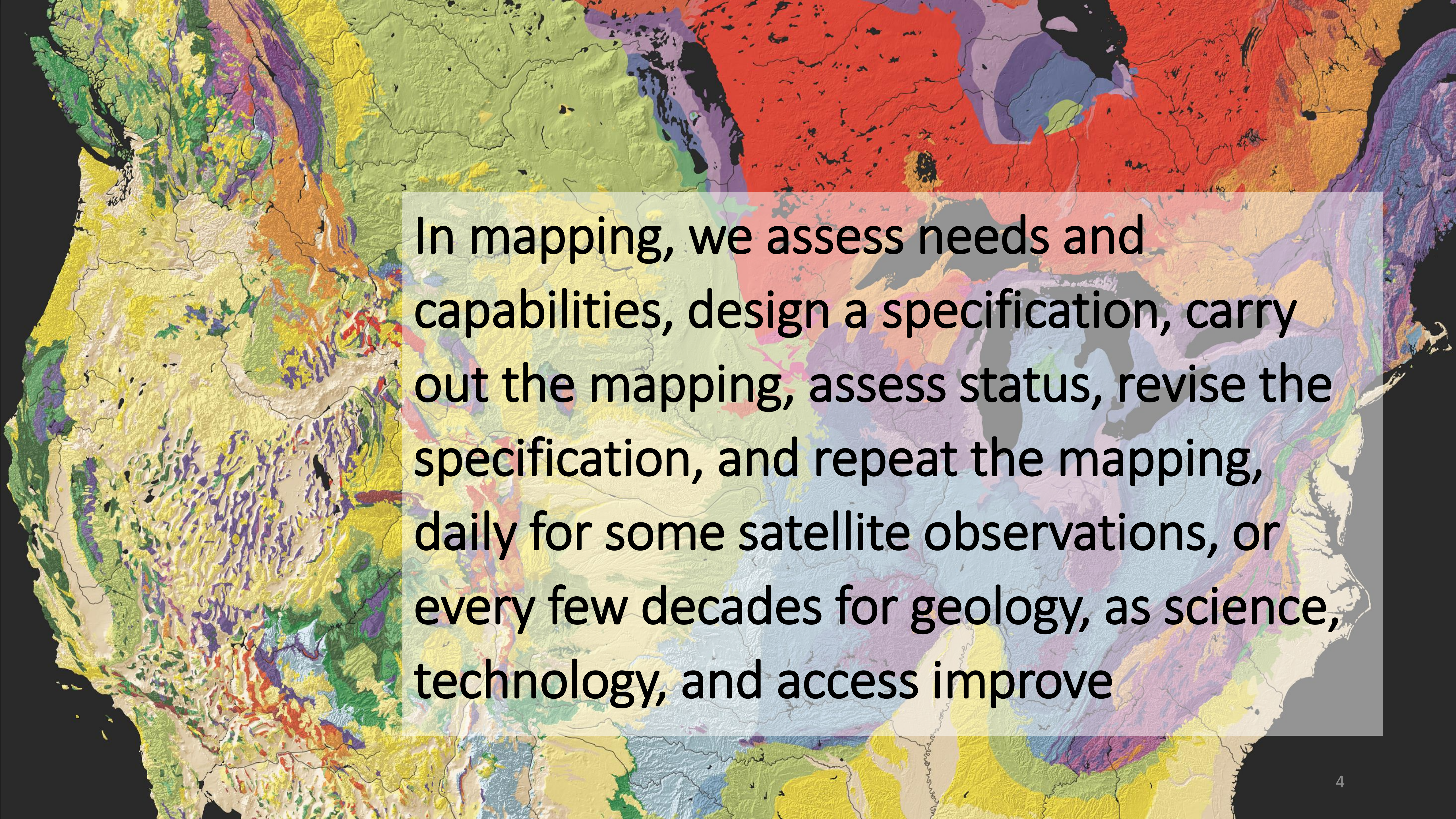
Harvey Thorleifson, Minnesota Geological Survey

Canadian National Geological Surveys Committee (NGSC); June 19, 2020

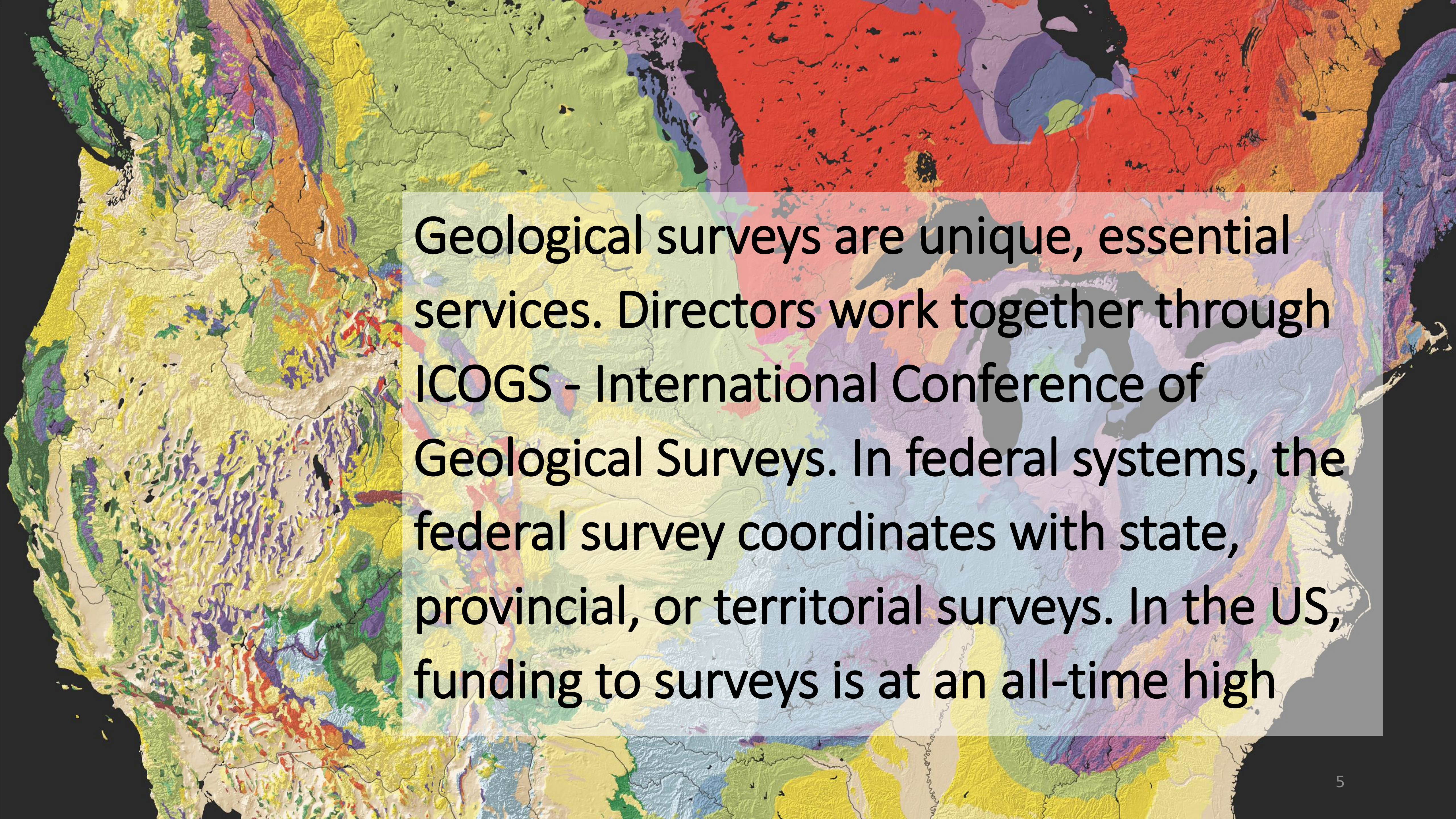
Digital Mapping Techniques (DMT); June 8, 2020

The people of our nations strive for societal benefits in the form of health, safety, wealth, and respect, while we seek to cherish and protect our human and natural heritage

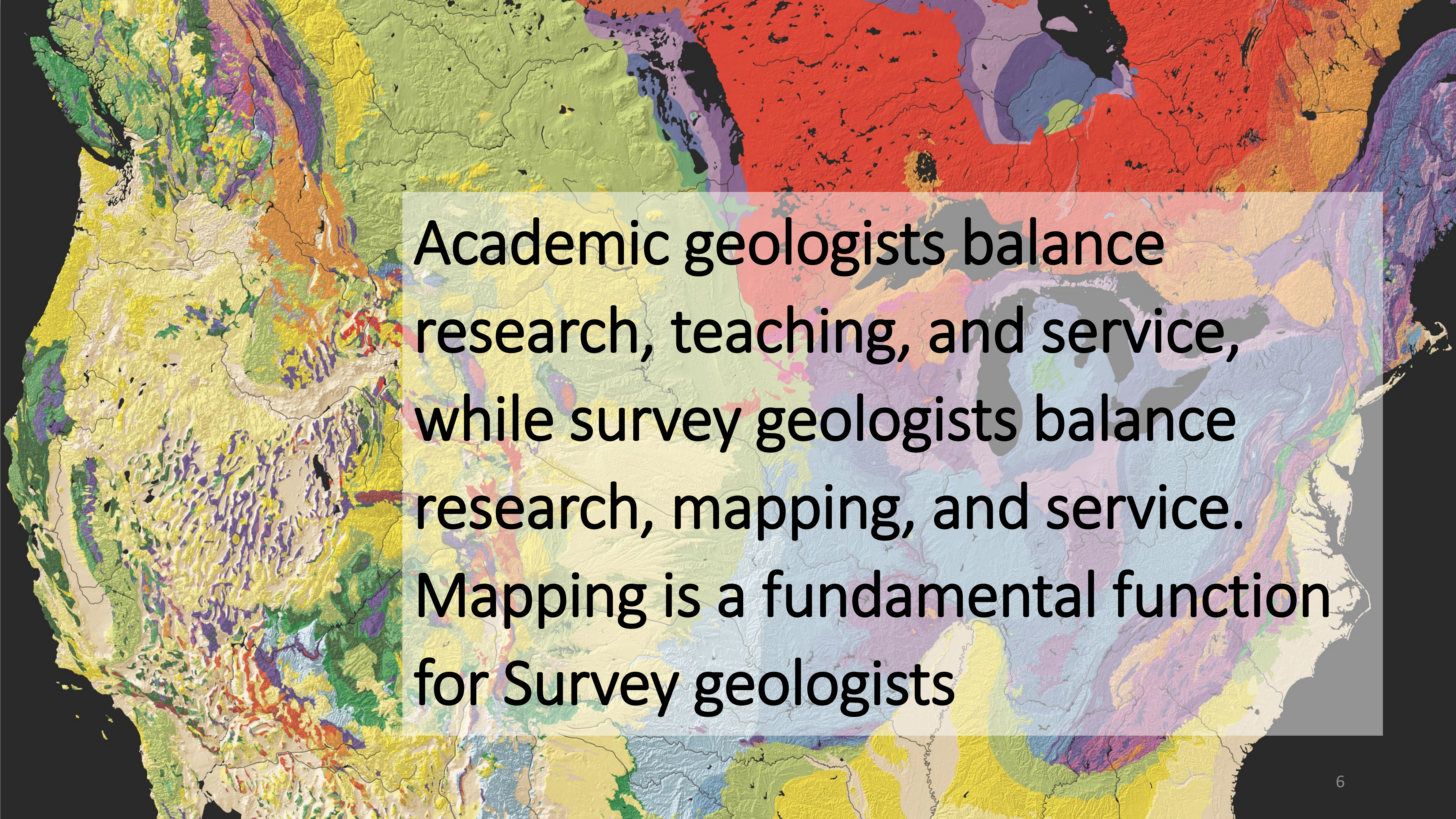
Research, mapping, monitoring, modeling, and management contribute to these benefits. Research is conceptual, mapping is spatial, and monitoring is temporal. Modeling, built from mapping and monitoring and guided by research, guides management that contributes to benefits; for geology, this includes resource management, hazards resilience, infrastructure design, and research



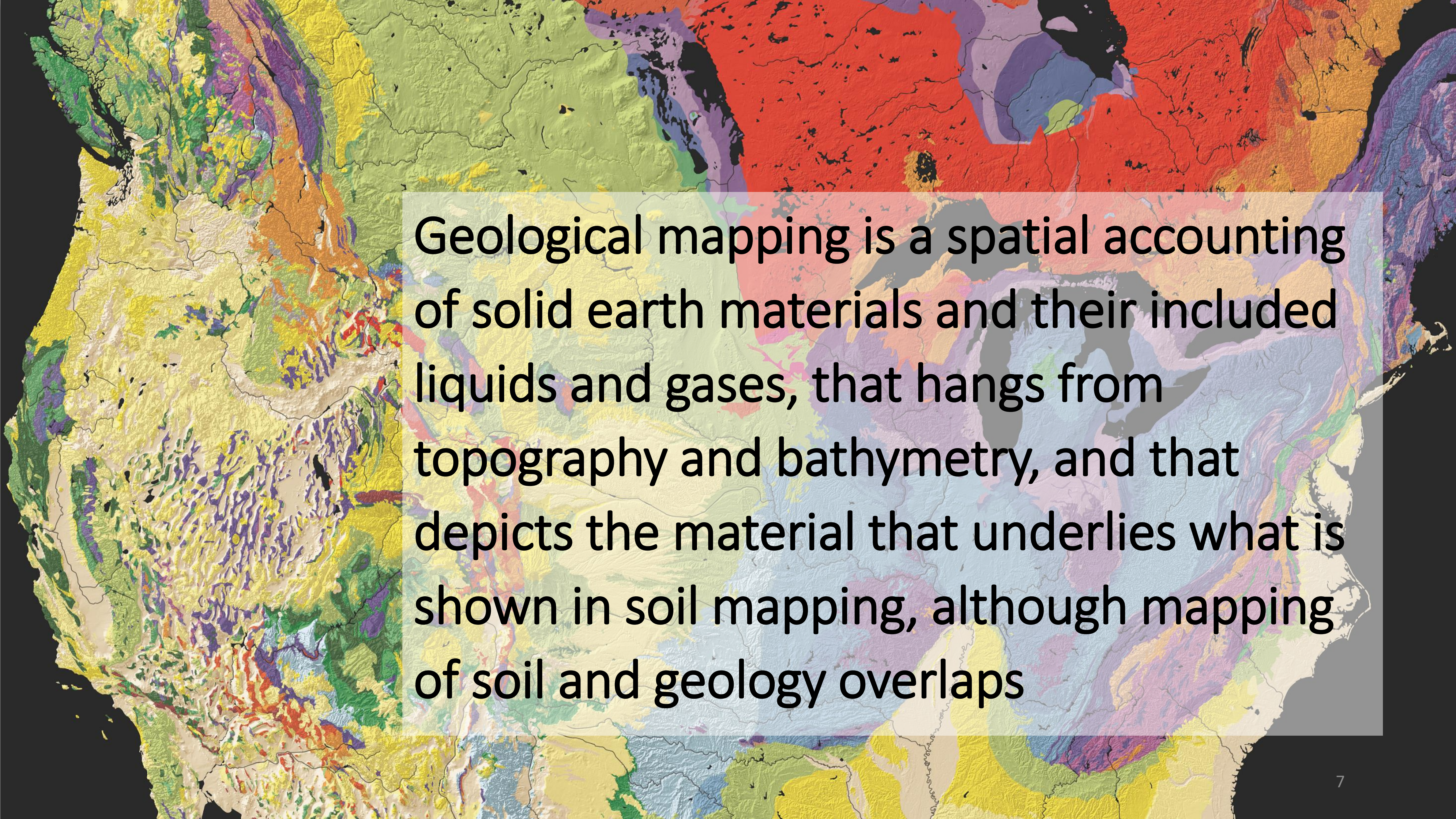
In mapping, we assess needs and capabilities, design a specification, carry out the mapping, assess status, revise the specification, and repeat the mapping, daily for some satellite observations, or every few decades for geology, as science, technology, and access improve



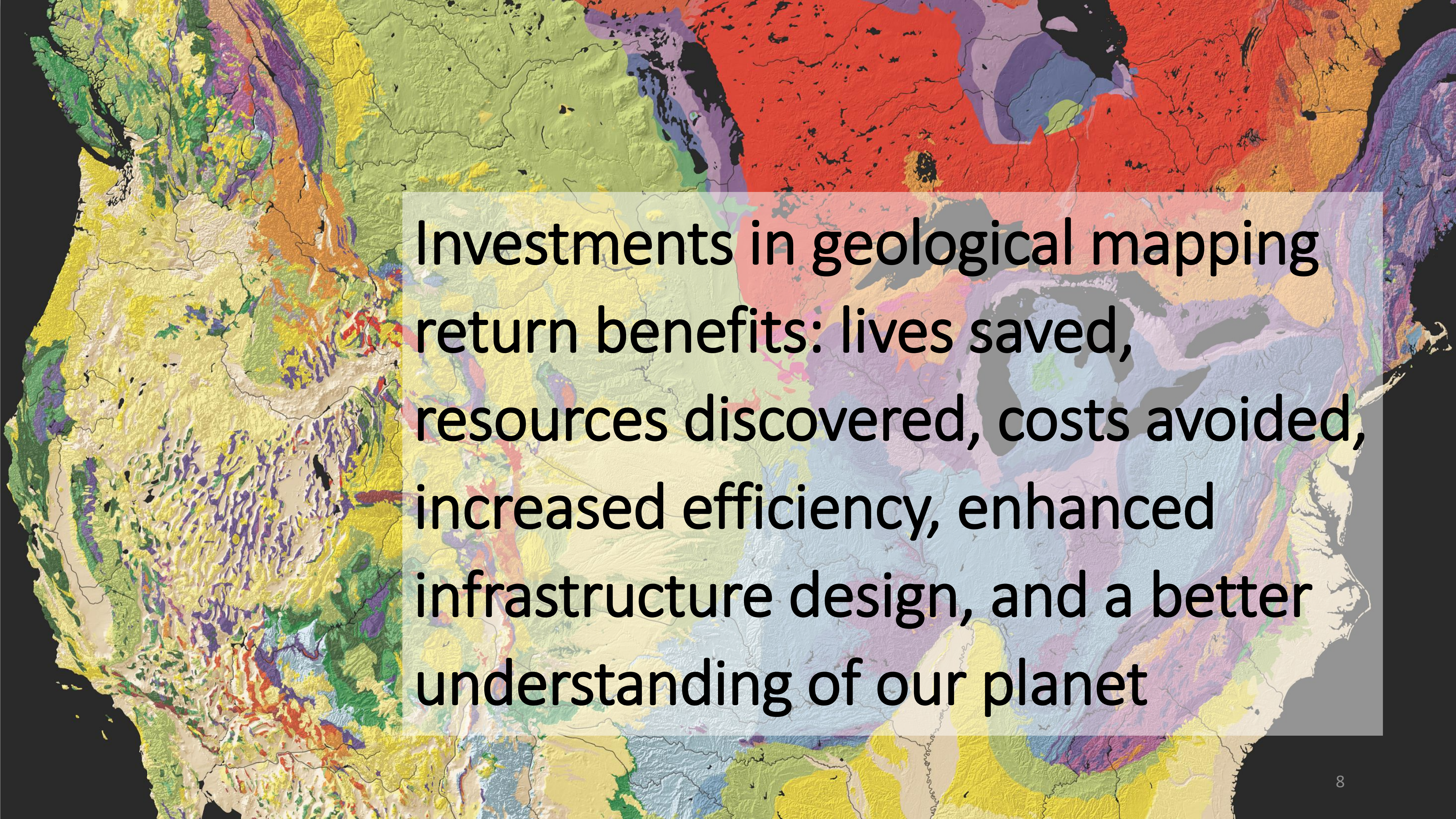
Geological surveys are unique, essential services. Directors work together through ICOGS - International Conference of Geological Surveys. In federal systems, the federal survey coordinates with state, provincial, or territorial surveys. In the US, funding to surveys is at an all-time high



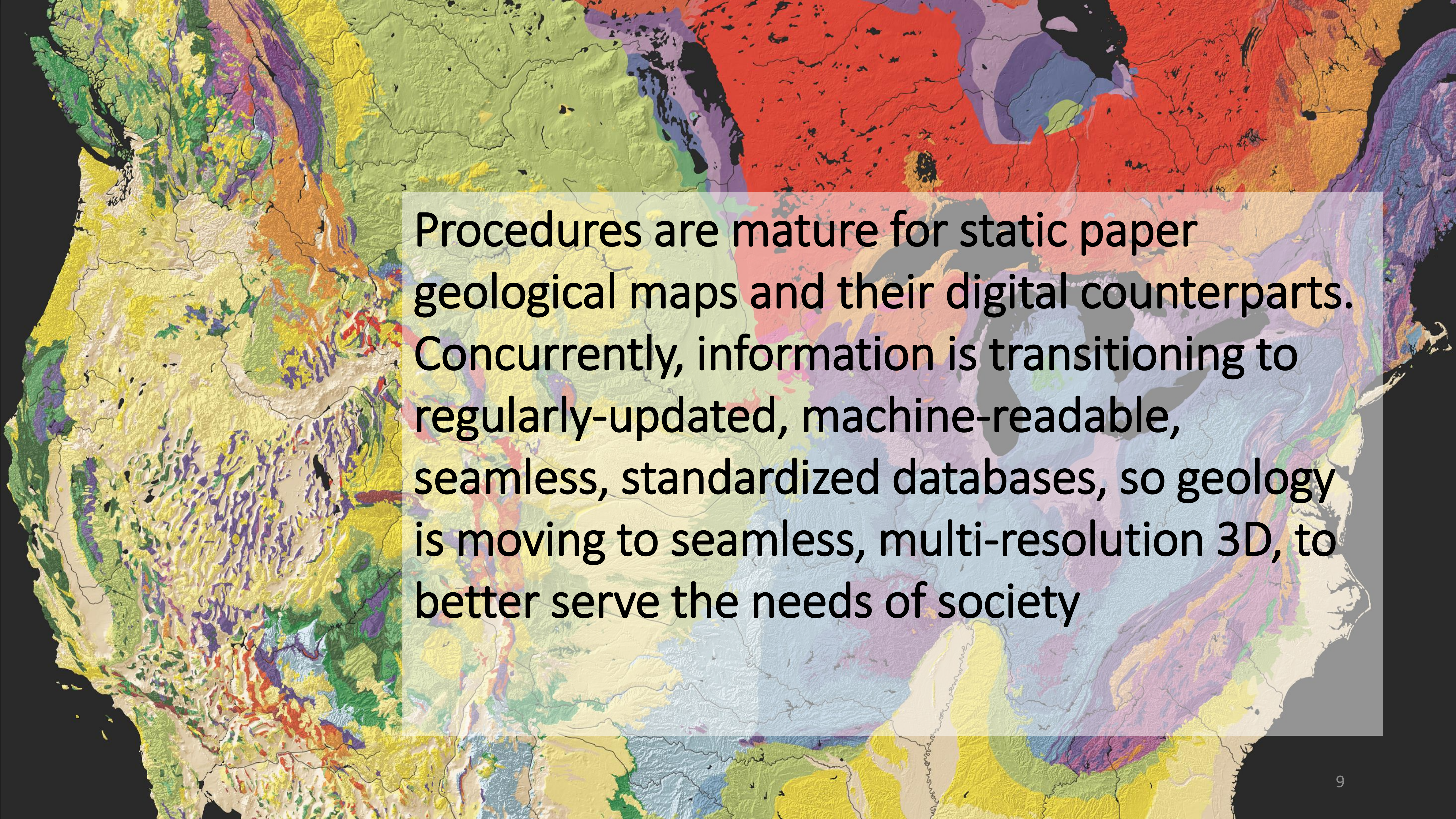
Academic geologists balance research, teaching, and service, while survey geologists balance research, mapping, and service. Mapping is a fundamental function for Survey geologists



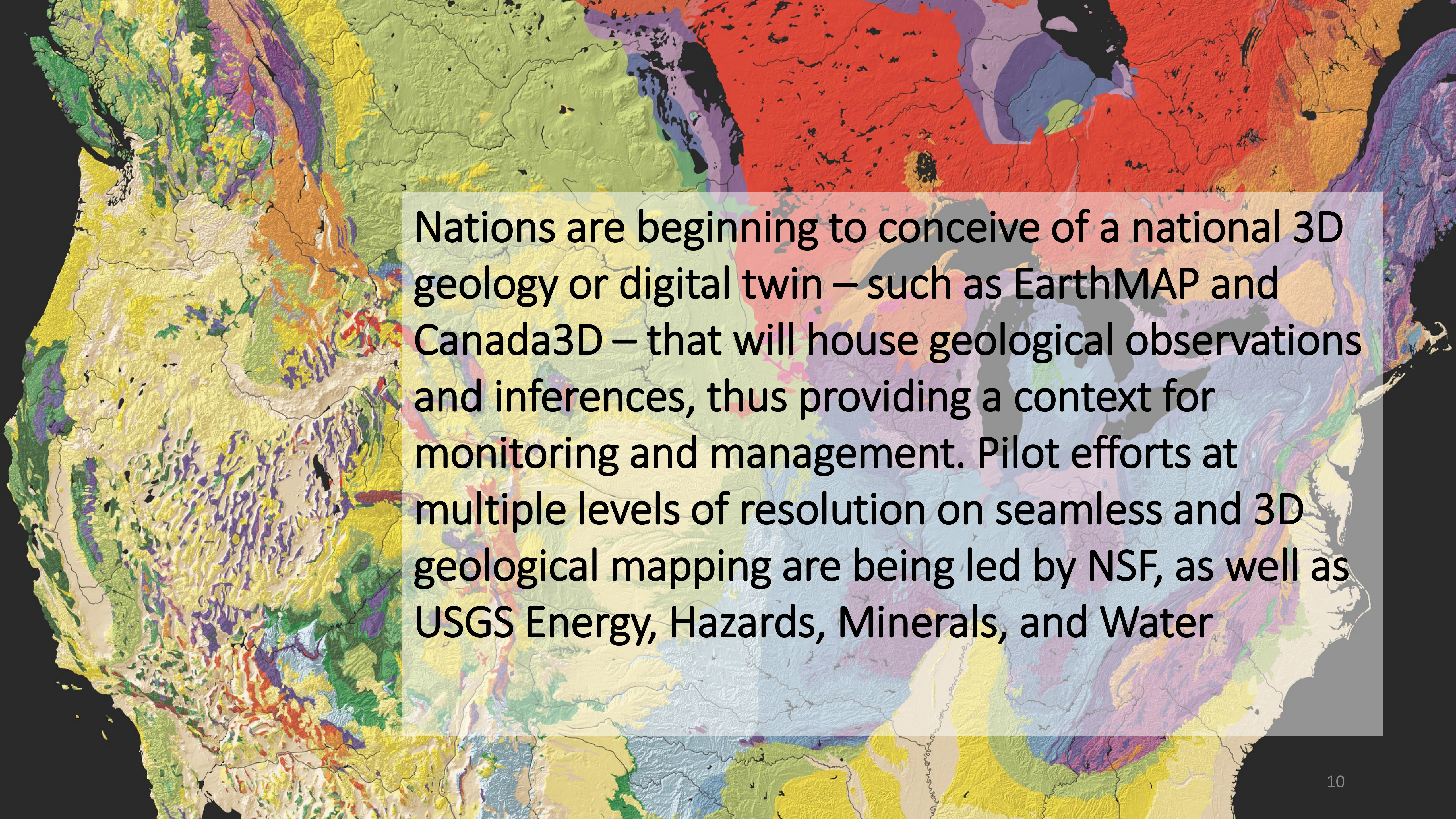
Geological mapping is a spatial accounting of solid earth materials and their included liquids and gases, that hangs from topography and bathymetry, and that depicts the material that underlies what is shown in soil mapping, although mapping of soil and geology overlaps



Investments in geological mapping return benefits: lives saved, resources discovered, costs avoided, increased efficiency, enhanced infrastructure design, and a better understanding of our planet



Procedures are mature for static paper geological maps and their digital counterparts. Concurrently, information is transitioning to regularly-updated, machine-readable, seamless, standardized databases, so geology is moving to seamless, multi-resolution 3D, to better serve the needs of society



Nations are beginning to conceive of a national 3D geology or digital twin – such as EarthMAP and Canada3D – that will house geological observations and inferences, thus providing a context for monitoring and management. Pilot efforts at multiple levels of resolution on seamless and 3D geological mapping are being led by NSF, as well as USGS Energy, Hazards, Minerals, and Water

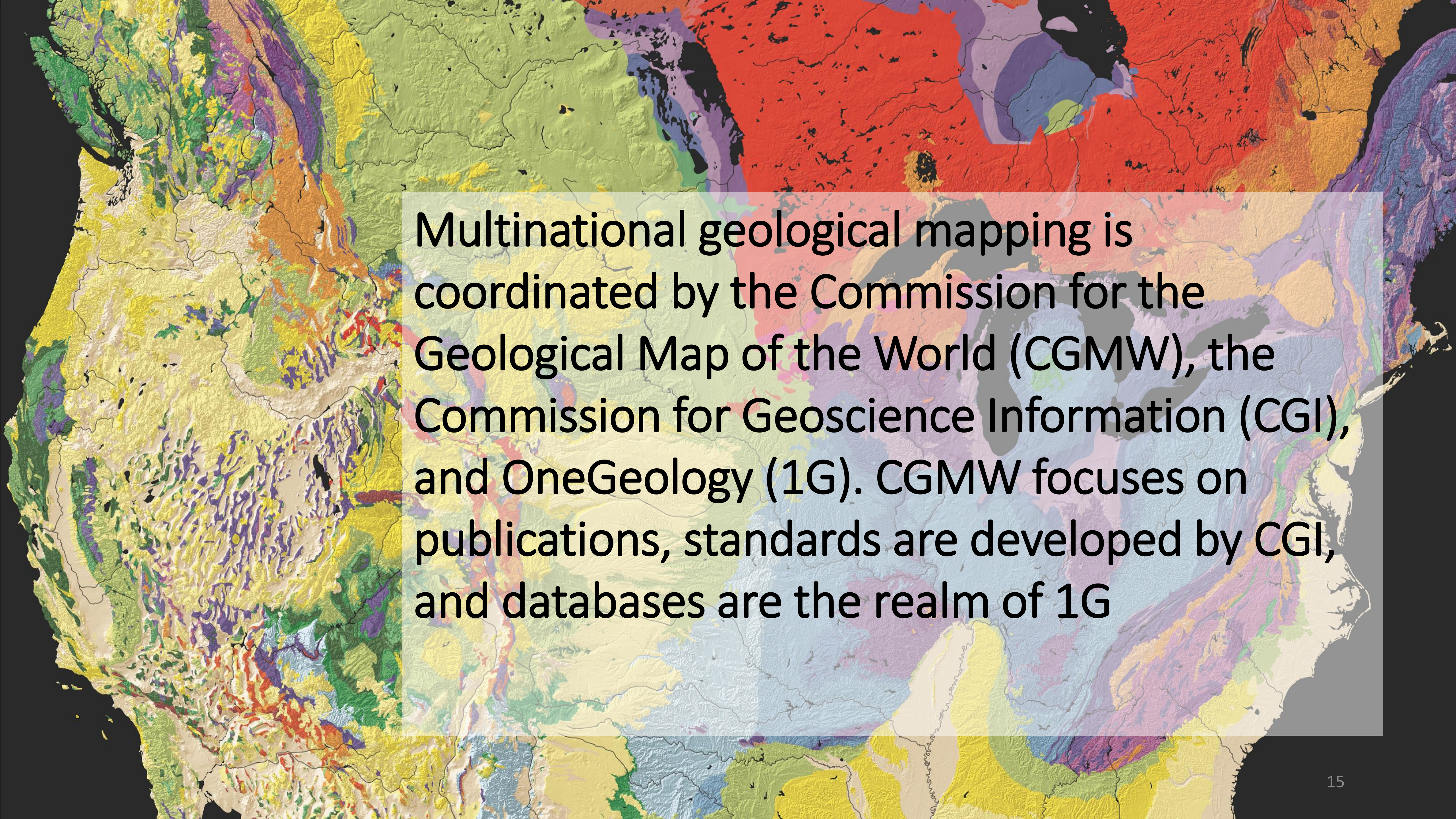
Our work thus consists of publications, standards, and databases. Each publication is based on a static database, and we also have the publications catalog and stratigraphic names database. The term database will be used here for evergreen, seamless, jurisdiction-wide geological mapping databases

Peer-reviewed, authored, innovative, published, static, paper geological maps with a thorough legend are a durable format that will remain the documentation that will underpin our databases.

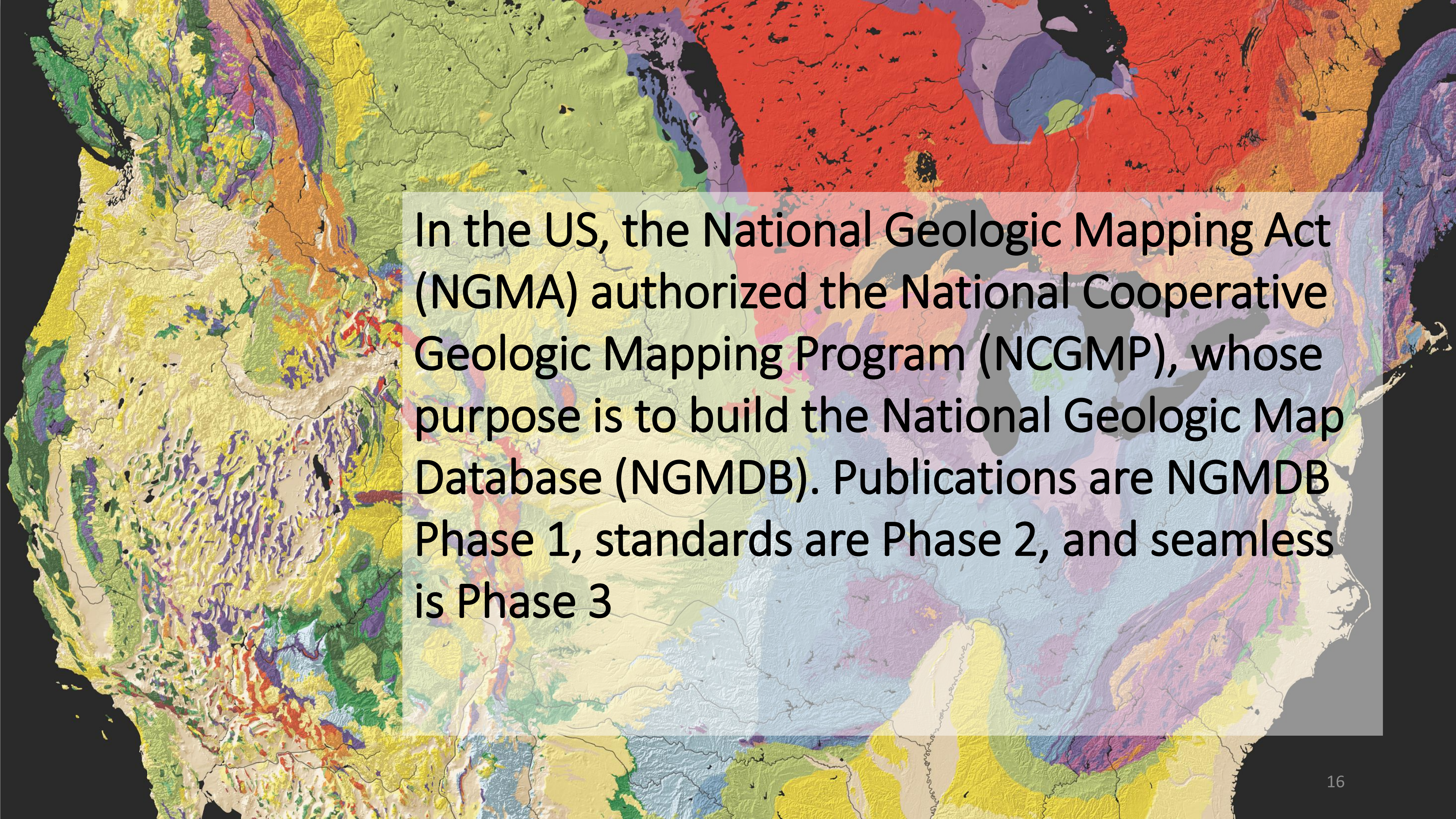
Publication procedures and policies are governed by each geological survey

Standards are procedures that ensure interoperability, that largely are developed through consensus within a professional community, and that may be guided by standards-development organizations

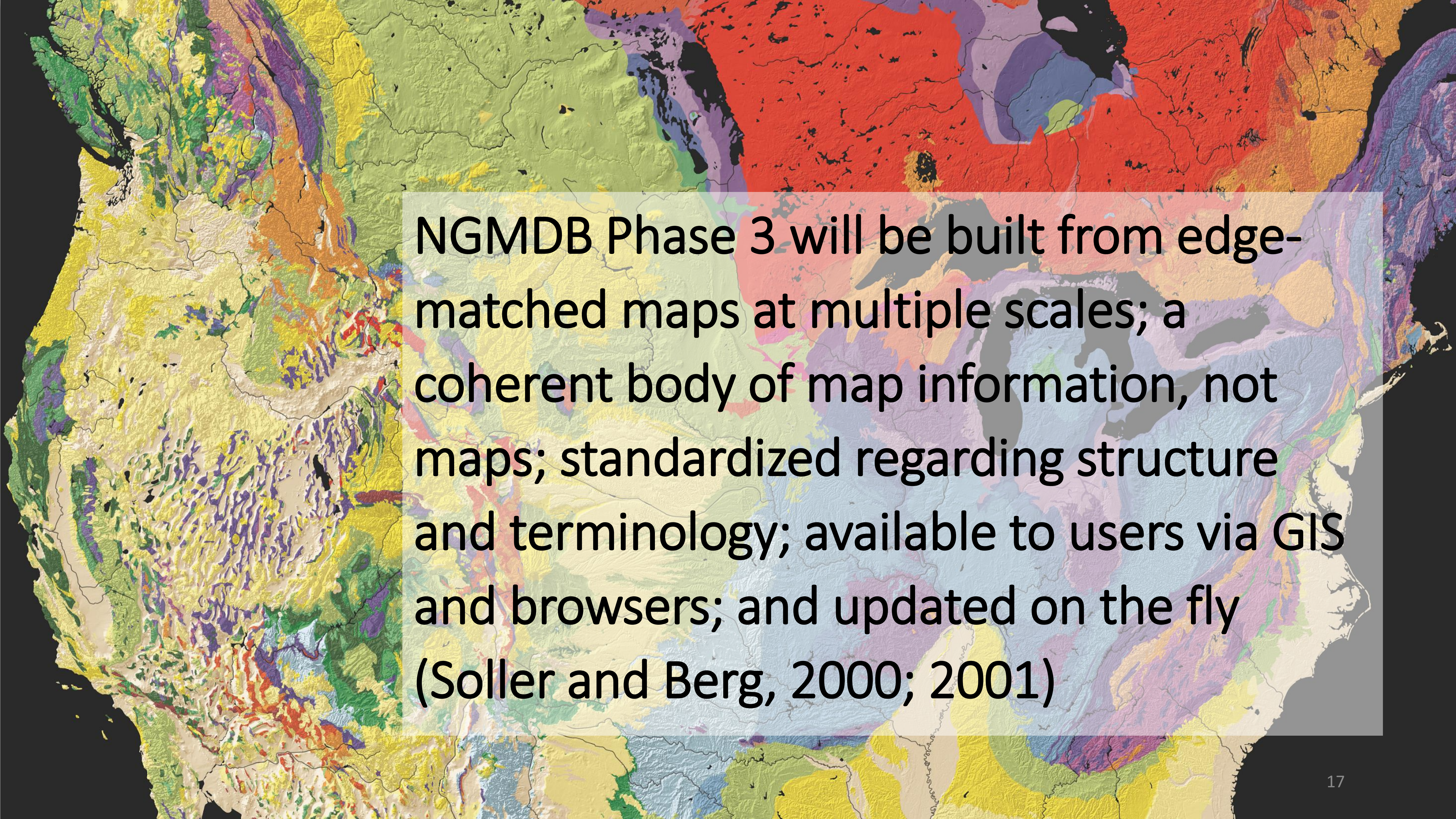
Seamless geology is a synthesis of multiple published maps, in which steps have been taken toward harmonization, and facilitation of query. Seamless is best done as a regularly-updated, jurisdiction-wide spatial database that provides an authoritative prediction for sediment and rock. Seamless will operate under database governance specified by multi-agency agreements that are needed to ensure coordination of roles in federal systems, and to ensure cross-border compatibility needed to facilitate successful applications and to sustain user confidence



Multinational geological mapping is coordinated by the Commission for the Geological Map of the World (CGMW), the Commission for Geoscience Information (CGI), and OneGeology (1G). CGMW focuses on publications, standards are developed by CGI, and databases are the realm of 1G

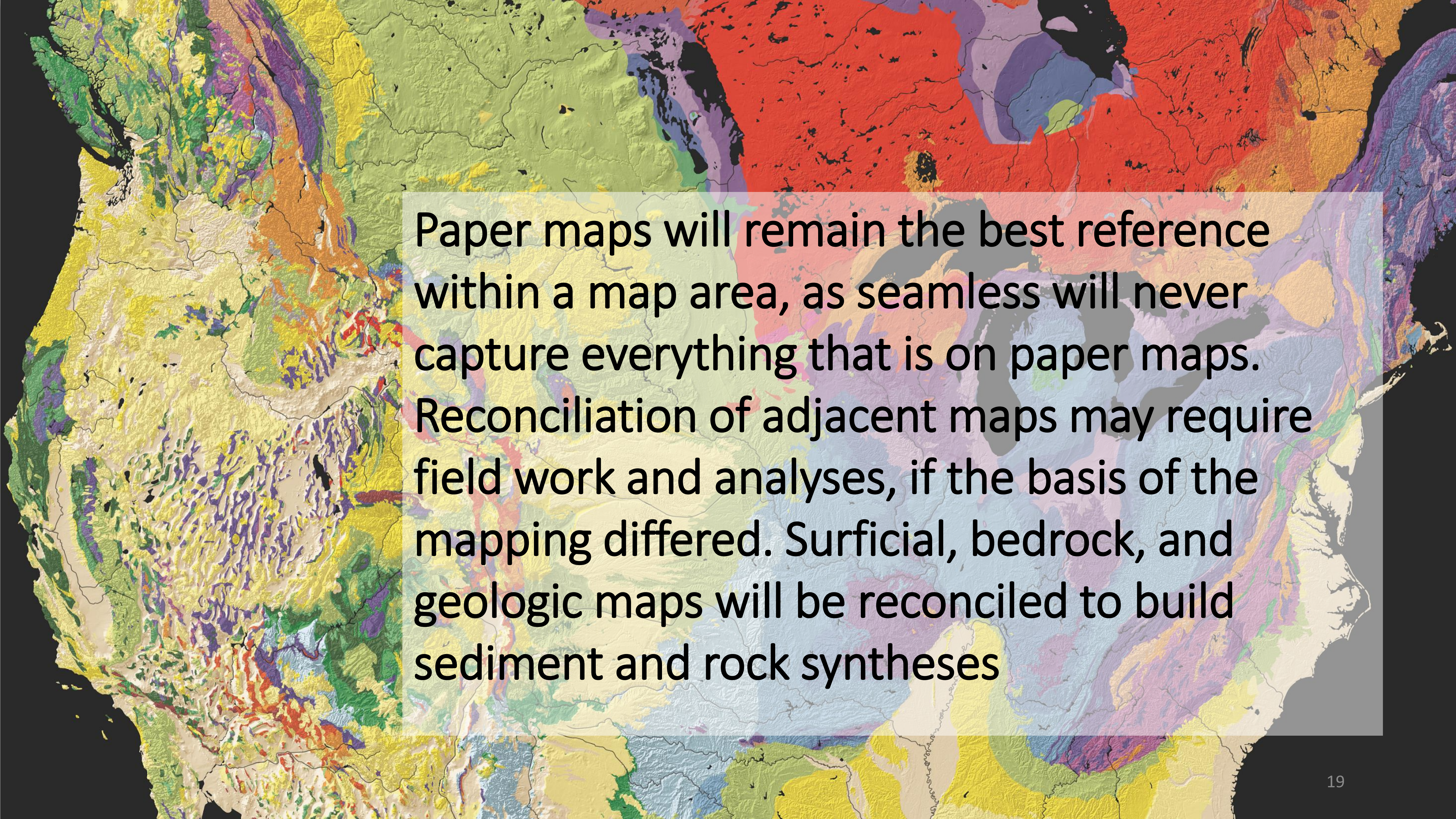


In the US, the National Geologic Mapping Act (NGMA) authorized the National Cooperative Geologic Mapping Program (NCGMP), whose purpose is to build the National Geologic Map Database (NGMDB). Publications are NGMDB Phase 1, standards are Phase 2, and seamless is Phase 3

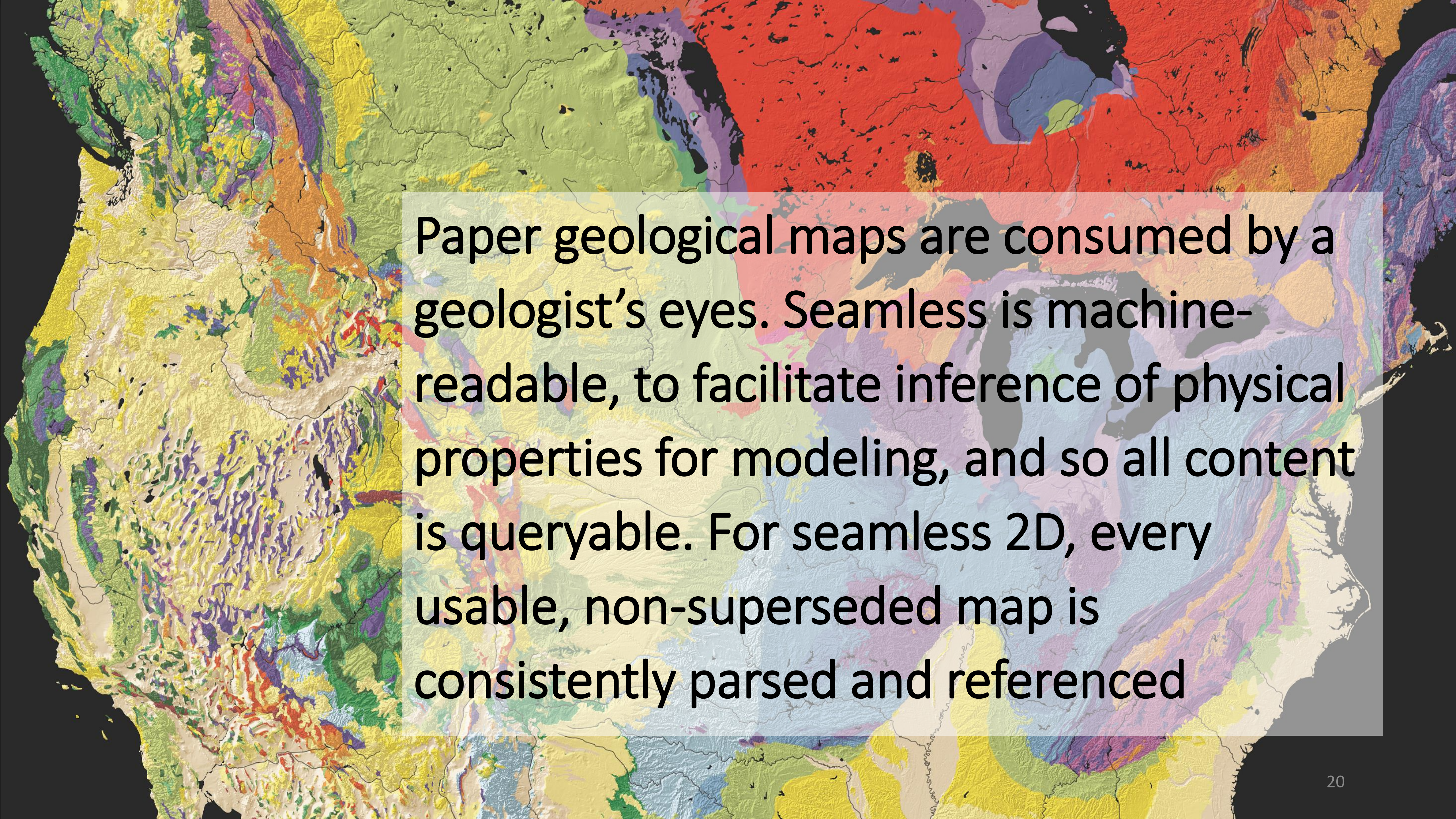


NGMDB Phase 3 will be built from edge-matched maps at multiple scales; a coherent body of map information, not maps; standardized regarding structure and terminology; available to users via GIS and browsers; and updated on the fly (Soller and Berg, 2000; 2001)

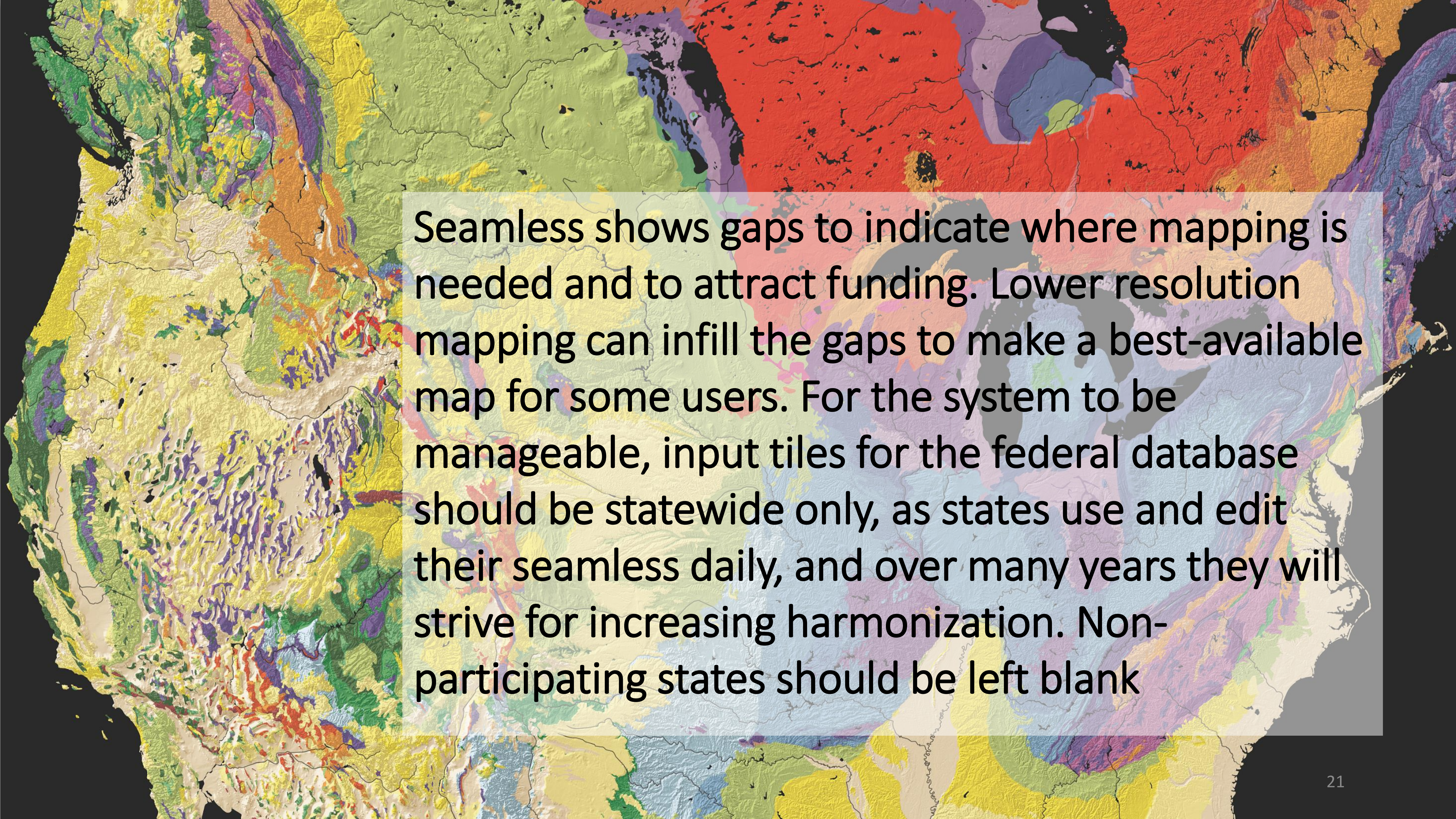
NGMDB mapping will be available as 1) the published map; 2) a coherent body of information for each scale; 3) a best available map (Soller et al., 2000). The name Earthsounder has been proposed for the Phase Three database



Paper maps will remain the best reference within a map area, as seamless will never capture everything that is on paper maps. Reconciliation of adjacent maps may require field work and analyses, if the basis of the mapping differed. Surficial, bedrock, and geologic maps will be reconciled to build sediment and rock syntheses



Paper geological maps are consumed by a geologist’s eyes. Seamless is machine-readable, to facilitate inference of physical properties for modeling, and so all content is queryable. For seamless 2D, every usable, non-superseded map is consistently parsed and referenced

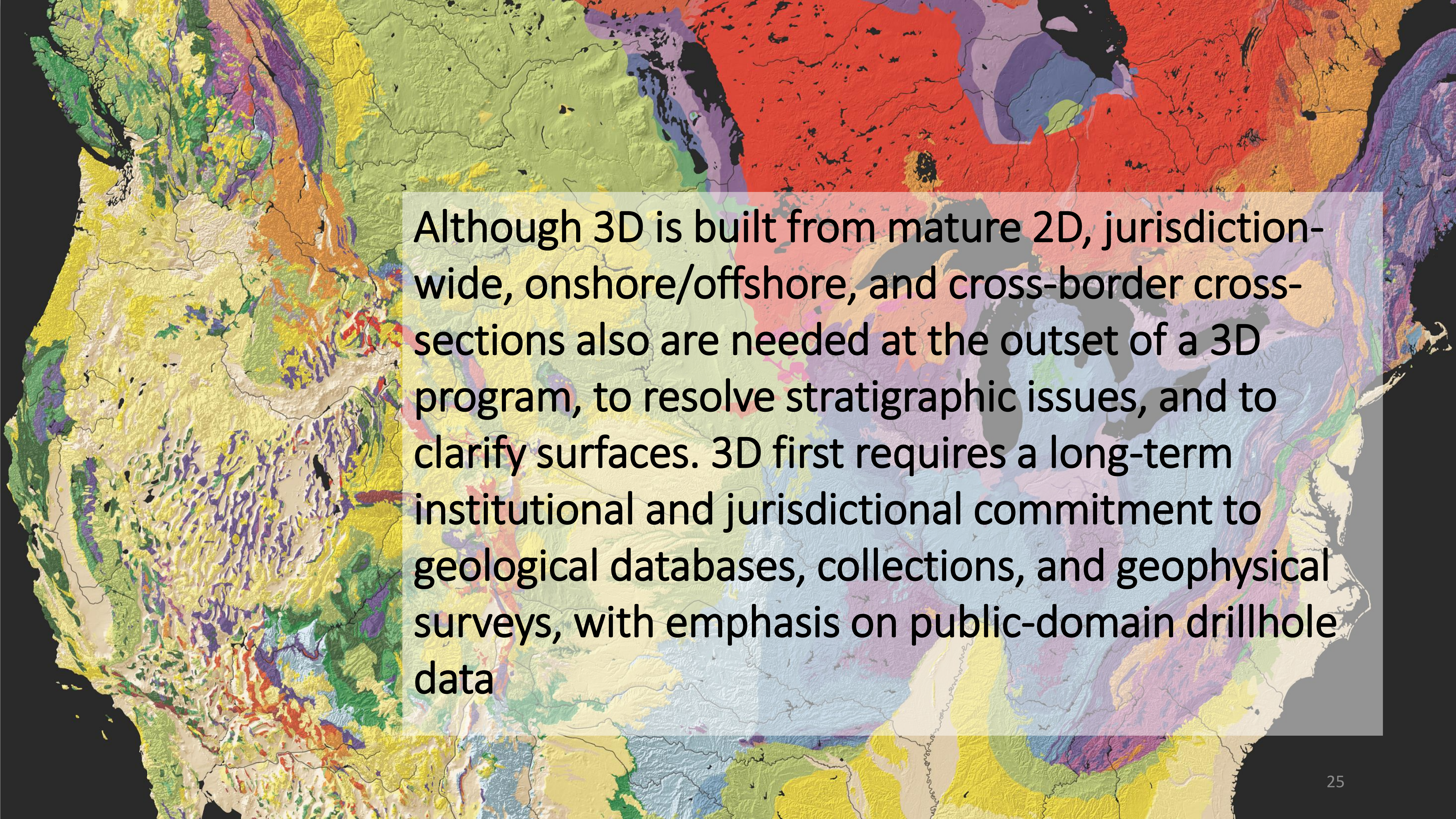


Seamless shows gaps to indicate where mapping is needed and to attract funding. Lower resolution mapping can infill the gaps to make a best-available map for some users. For the system to be manageable, input tiles for the federal database should be statewide only, as states use and edit their seamless daily, and over many years they will strive for increasing harmonization. Non-participating states should be left blank

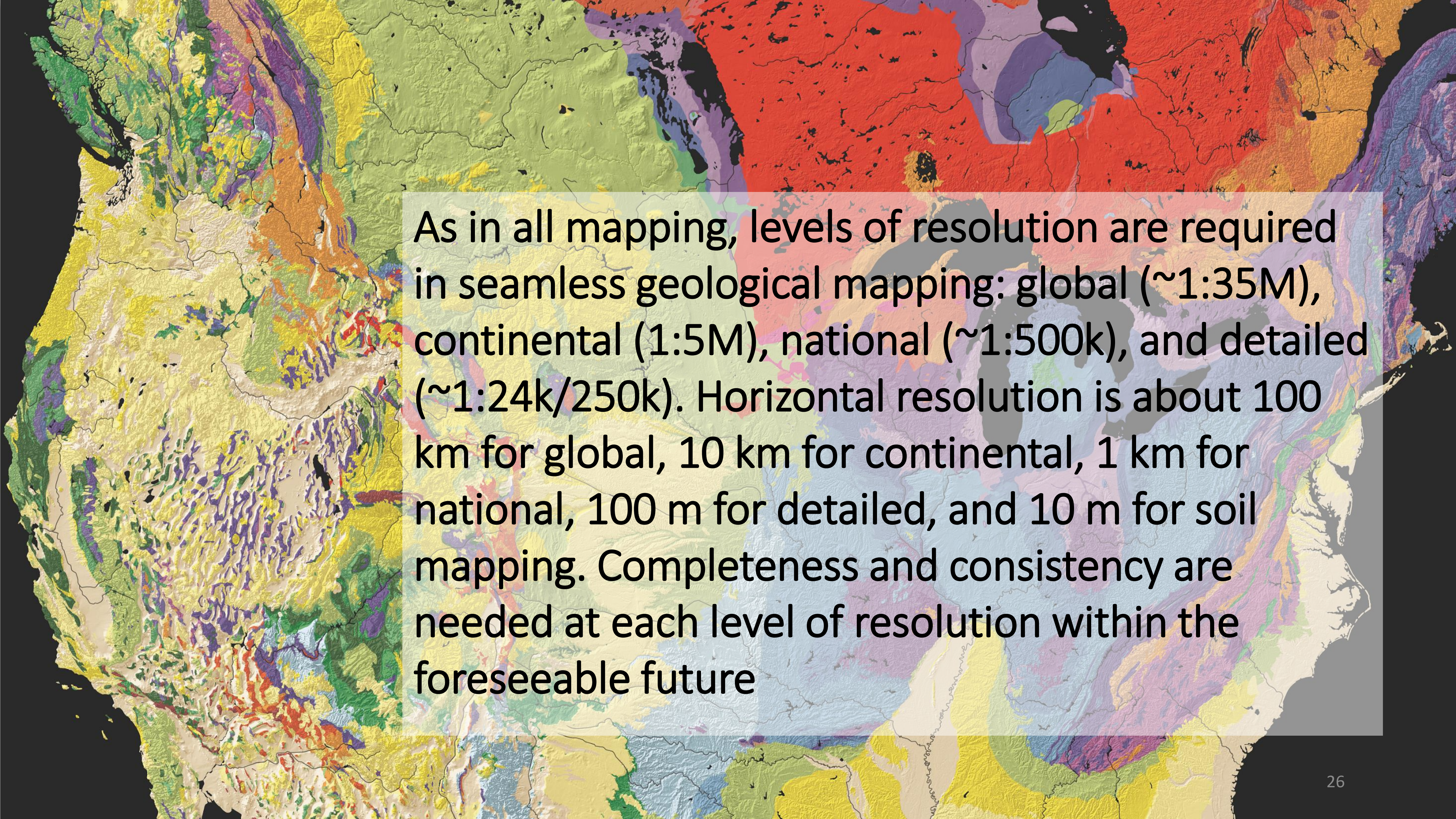
Seamless does not have authors, as it is constantly changing, and it is subjected to audits rather than peer review. Seamless should be updated every one to three years as database format, terminology, editing, and new mapping evolve. Contributors to seamless databases must receive credit toward their professional advancement

State Geologists and their staff are regional authorities, who should be held responsible for maintenance and contribution of their seamless, which may be done with partners. Federal geologists play an essential and appreciated role in broader thinking as well as specialized research and technology. While the State role can be completeness, the Federal role can be consistency. Additional federal roles will be in housing and managing the databases, leading on standards, and engaging in science that will cause the state contributions to gradually be more consistent

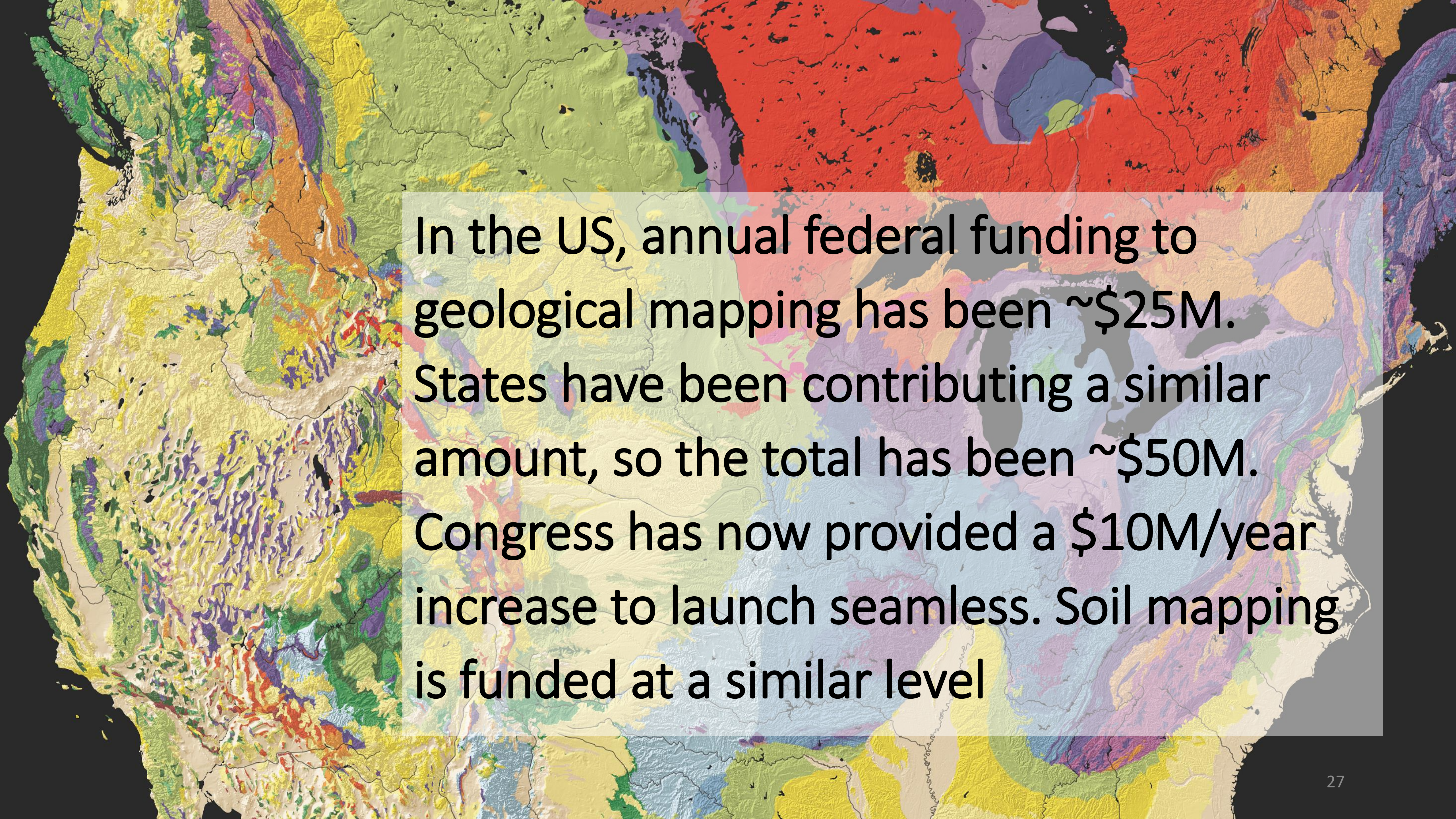
In 3D geological mapping, a layer is a 2D map polygon whose thickness can be mapped. To map removable layers, we assemble data, and map extent, thickness, properties, heterogeneity, and uncertainty. 3D can be expressed as a regular grid of synthetic drill holes. Below the layers is basement. In layers, we map strata, and in basement, we map structures, then discretized properties



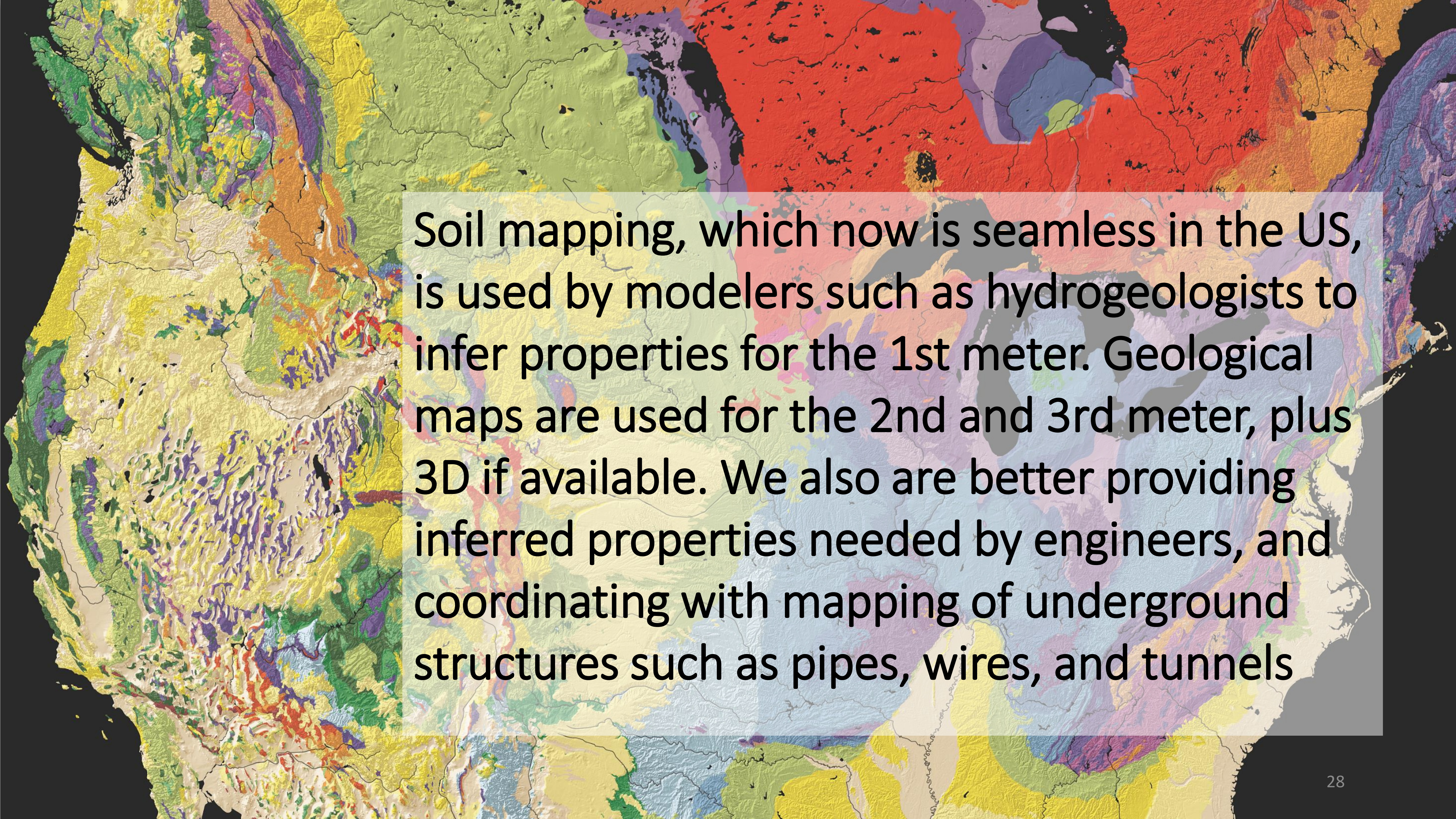
Although 3D is built from mature 2D, jurisdiction-wide, onshore/offshore, and cross-border cross-sections also are needed at the outset of a 3D program, to resolve stratigraphic issues, and to clarify surfaces. 3D first requires a long-term institutional and jurisdictional commitment to geological databases, collections, and geophysical surveys, with emphasis on public-domain drillhole data



As in all mapping, levels of resolution are required in seamless geological mapping: global (~1:35M), continental (1:5M), national (~1:500k), and detailed (~1:24k/250k). Horizontal resolution is about 100 km for global, 10 km for continental, 1 km for national, 100 m for detailed, and 10 m for soil mapping. Completeness and consistency are needed at each level of resolution within the foreseeable future

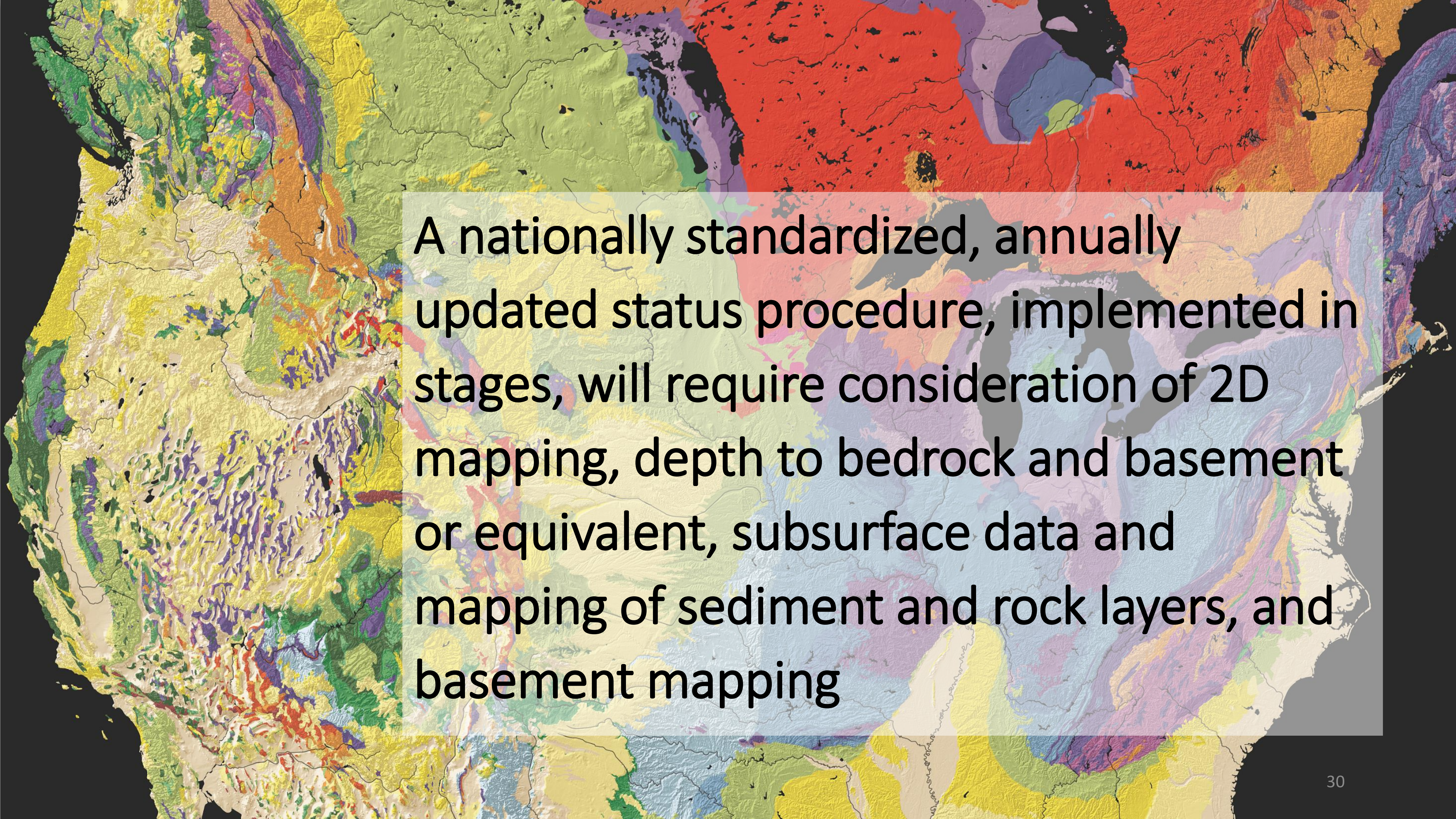


In the US, annual federal funding to geological mapping has been ~$25M. States have been contributing a similar amount, so the total has been ~$50M. Congress has now provided a $10M/year increase to launch seamless. Soil mapping is funded at a similar level

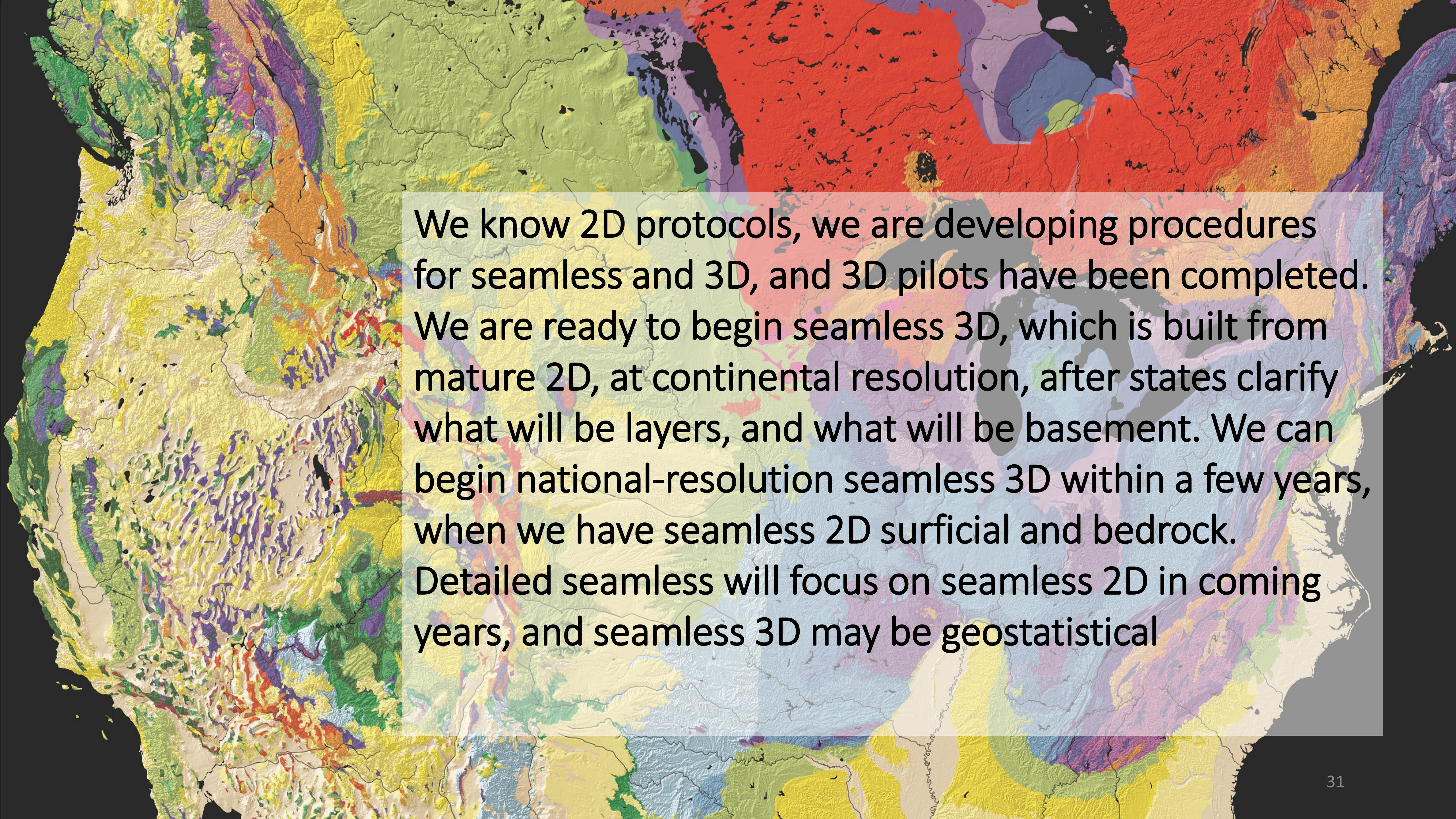


Soil mapping, which now is seamless in the US, is used by modelers such as hydrogeologists to infer properties for the 1st meter. Geological maps are used for the 2nd and 3rd meter, plus 3D if available. We also are better providing inferred properties needed by engineers, and coordinating with mapping of underground structures such as pipes, wires, and tunnels

Status mapping is required, to develop consensus on goals, to monitor and manage our progress, to stimulate funding, and to cause us all to strive. A status map differs from a publication index, which indicates the spatial footprint of published maps, including obsolete, superseded maps. Status mapping requires local knowledge, judgement about needs, a composite index, and thus an indication of progress toward goals

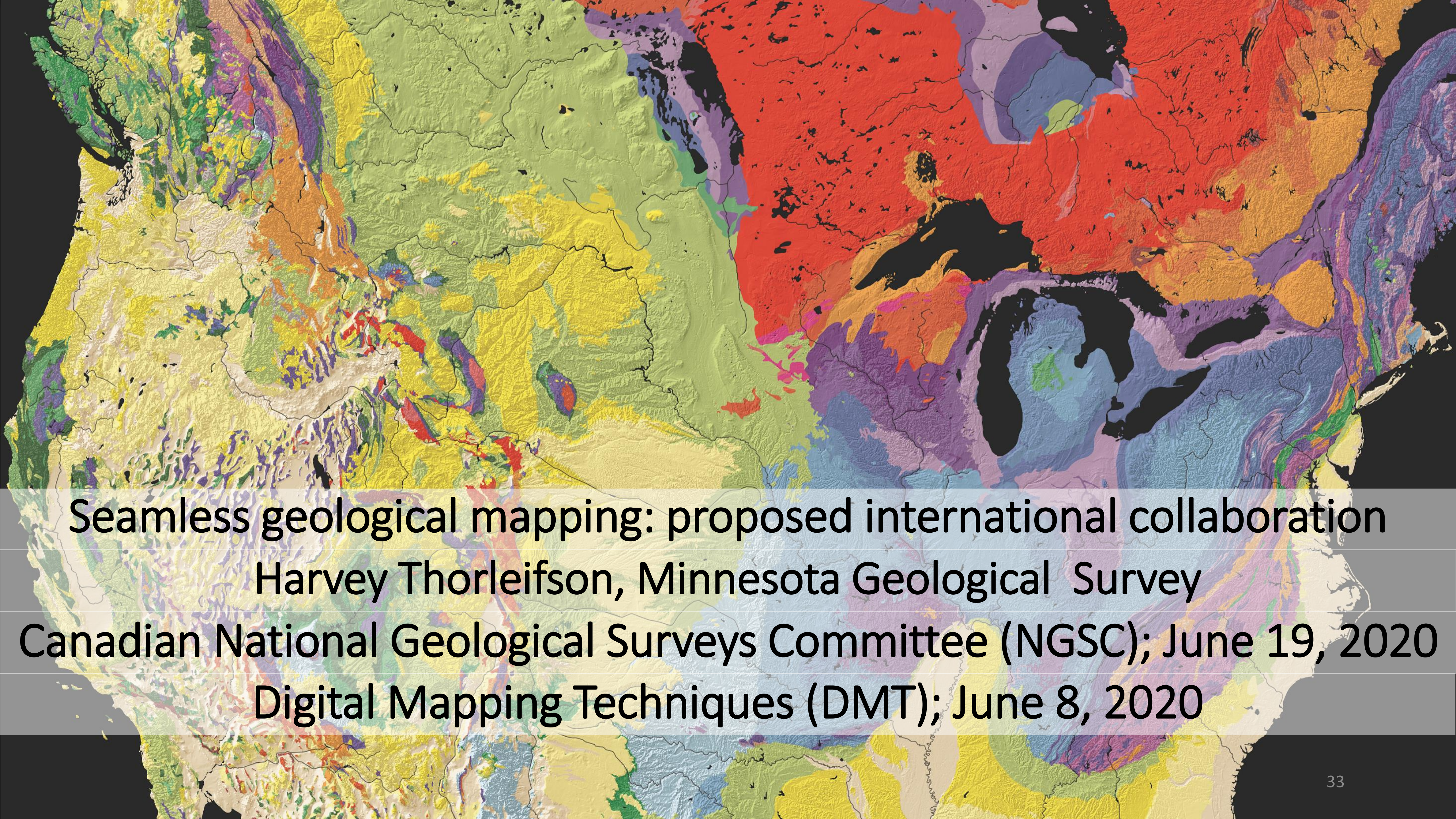


A nationally standardized, annually updated status procedure, implemented in stages, will require consideration of 2D mapping, depth to bedrock and basement or equivalent, subsurface data and mapping of sediment and rock layers, and basement mapping



We know 2D protocols, we are developing procedures for seamless and 3D, and 3D pilots have been completed. We are ready to begin seamless 3D, which is built from mature 2D, at continental resolution, after states clarify what will be layers, and what will be basement. We can begin national-resolution seamless 3D within a few years, when we have seamless 2D surficial and bedrock. Detailed seamless will focus on seamless 2D in coming years, and seamless 3D may be geostatistical

Priority actions for partners such as USA and Canada include next steps on continental 3D, work toward seamless national-resolution 2D, and coordinated effort on protocols for seamless detailed mapping and status mapping. In summary, geological surveys may now better fulfil their obligations to society by delivering, over the coming decade, a multi-resolution seamless 3D geological mapping database that will better support societal needs



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