DIGITAL MAPPING TECHNIQUES 2023

The following was presented at DMT'23
May 21 - 24, 2023

The contents of this document are provisional

See Presentations and Proceedings
from the DMT Meetings (1997-2023)

http://ngmdb.usgs.gov/info/dmt/

Department of Environment & Conservation
Division of Mineral and Geologic Resources

TENNESSEE GEOLOGICAL SURVEY
ESTABLISHED 1831

Geologic Mapping in Tennessee and the Development of TNGeMS

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May 21-24, 2023

The TGS: Our Mission

- The Tennessee Geological Survey was established in 1831. It is one of the oldest geologic service and research organizations in the country.

- The survey advises other state agencies and federal and local organizations on matters relating to Tennessee geology.

"The mission of the Tennessee Geological Survey is to encourage and promote the prudent development and conservation of Tennessee's geological, energy, and mineral resources by ***developing and maintaining databases***, maps and technical services; providing accurate geologic hazard assessments; and disseminating geologic information through publications and educational outreach activities."

TGS: Status of Current Collections

- 460+ published 7.5-minute quadrangle geologic maps listed and viewable via NGMDB
- 50+ publications (Bulletins, Reports of Investigations, Special Charts, etc.) available on the TGS website
- 17 geoscientific collections are inventoried on ReSciColl/ScienceBase:
  - 9 are richly populated, with several in progress
- 12,500+ metadata records, 10,000+ files available for public viewing/download on TDEC FileNet

NOT ONE MAP DATABASE!

Map databases… Where to Begin?

- Limitations:
  - Small staff
  - Smaller budget
  - Lack of IT resources
  - GIS skills of geologists are not advanced

- But our geologists have continued to map and publish!

THEN CAME GeMS!

- Problem: Skill gap too great for geologists to overcome
- Solution: Hire a dedicated GIS professional

TGS has had a long road within the TN State govt: Once a proud division within the Dept of Environment, demoted to a working group within water resources, now part of the newly formed Division of Mineral and Geologic Resources. Along comes GeMS and the forecasted mandate of its use for new mapping funded under STATEMAP as well as other NCGMP-funded programs.

Map databases… Where to Begin?

Map databases are a priority for all new publications

- BUT…
  - NO existing enterprise GIS for maps or collections
  - NO existing single map schema
  - NO standards for the organization or storage of GIS projects
- HOWEVER,
  - Large collection of published maps
  - Loose set of GIS methodologies shared by geologists
  - Standards exist for the storage of single map databases

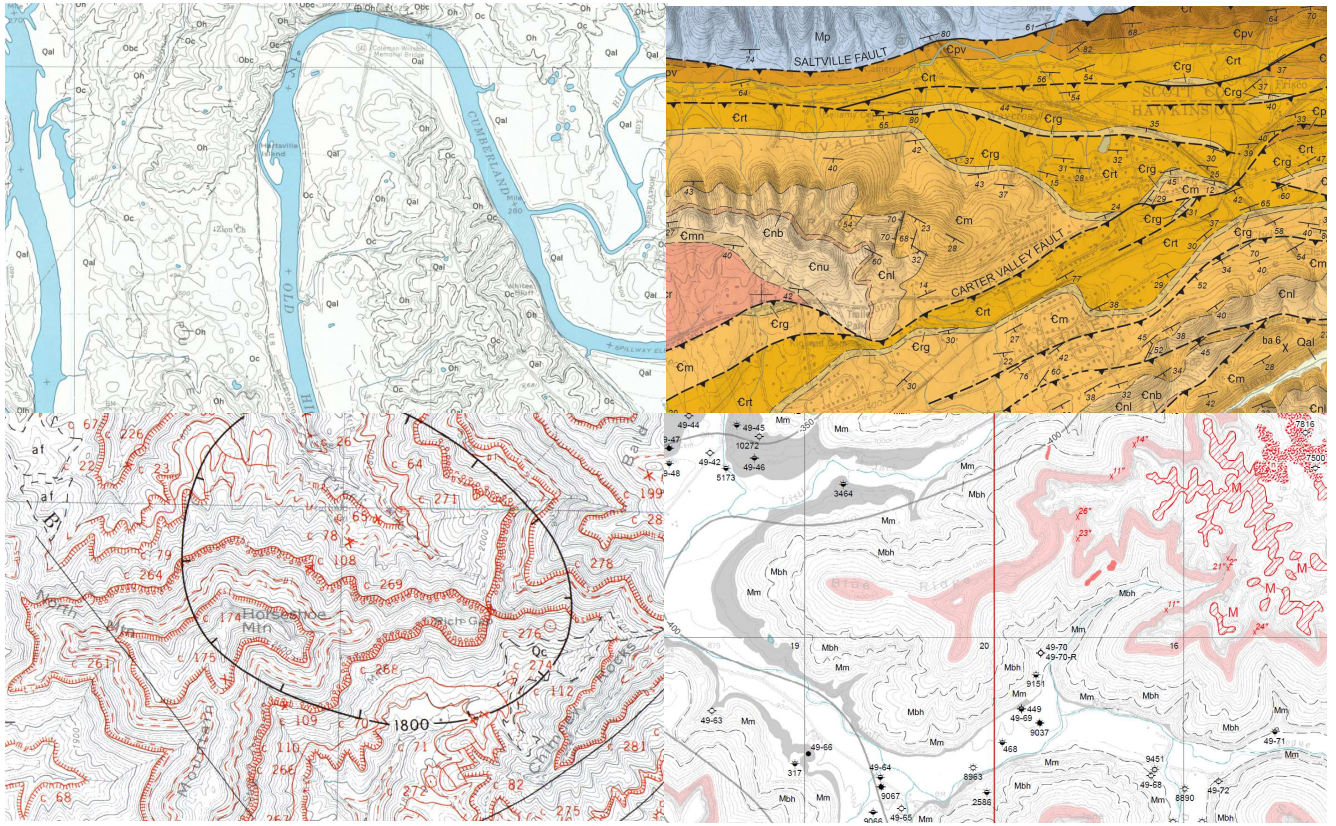
GeMS… to the Rescue(!?)

- Sort of… The framework is there, but isn't an off-the-shelf solution
- We can use GeMS, but need to assess our maps and decide how extend it to meet our requirements

TGS maps: Building a data dictionary

- Examined 450+ 7.5-minute geologic quadrangle maps by the TGS (as well as a few by the USGS) published between 1962 and 2022
- Map explanations were parsed for representations of geologic map features
- Symbols and written descriptions were compiled into a spreadsheet containing ~1500 entries
- Removed very similar or near-duplicates which resulted in a list of around 400 unique cartographic representations and accompanying descriptions
- Also compiled mineral (natural) resource symbols:
  - 175 unique commodity/mineral resource “letter codes” and descriptions
  - 50+ symbols related to various processing plants, mills, storage facilities, etc.
  - 30+ oil and gas symbols

To inform the extension of GeMS we had to figure out what additional information we wanted to store within a map database. The Visual Guide To TGS Geologic Map Feature Storage Locations in the TNGeMS Database Data Model is the product of this comprehensive assessment of our geologic and mineral resource publications.



Geologic and mineral resource map examples

TGS map symbols: FGDC…

Source Quad	Exp. ID	TGS (or USGS) Symbol	Descriptions from TGS published maps	FGDC Ref. No.	FGDC Symbol
					CONTACTS AN
Adams	1.01		Contact, dashed where approximate	1.1.1	
Athens (USGS)	8.01		Contact; Dashed where approximately located	1.1.3	
Fairmount	45.03		Contacts very approximately located, includes gradational contacts	1.1.5	
McEwen		?	Contact indefinite	1.1.6	?- - - -
Ausmus	9.03		Contact, dashed where approximate, dotted where concealed	1.1.7	
				1.1.17	
Soddy	75.01		Contact showing dip, dashed where approximate	1.4.1	35
Mount Airy	67.04	22 30	Contact showing dip; overturned contact	1.4.5	85
Fork Ridge	49.08	mag	Magoffin zone	1.2.3	
				1.4.12	ds
Billingsley Gap	16.18	ba	Coal cropline [seam name], dashed where approximate	1.2.25	
Roddy	74.22	h	Coal cropline [seam name]	1.2.27	
				1.2.31	
				1.4.15	lg

TGS map symbol > Match to FGDC symbol

While compiling the data dictionary I also compiled a visual guide to the features and matched them to FGDC symbols where applicable

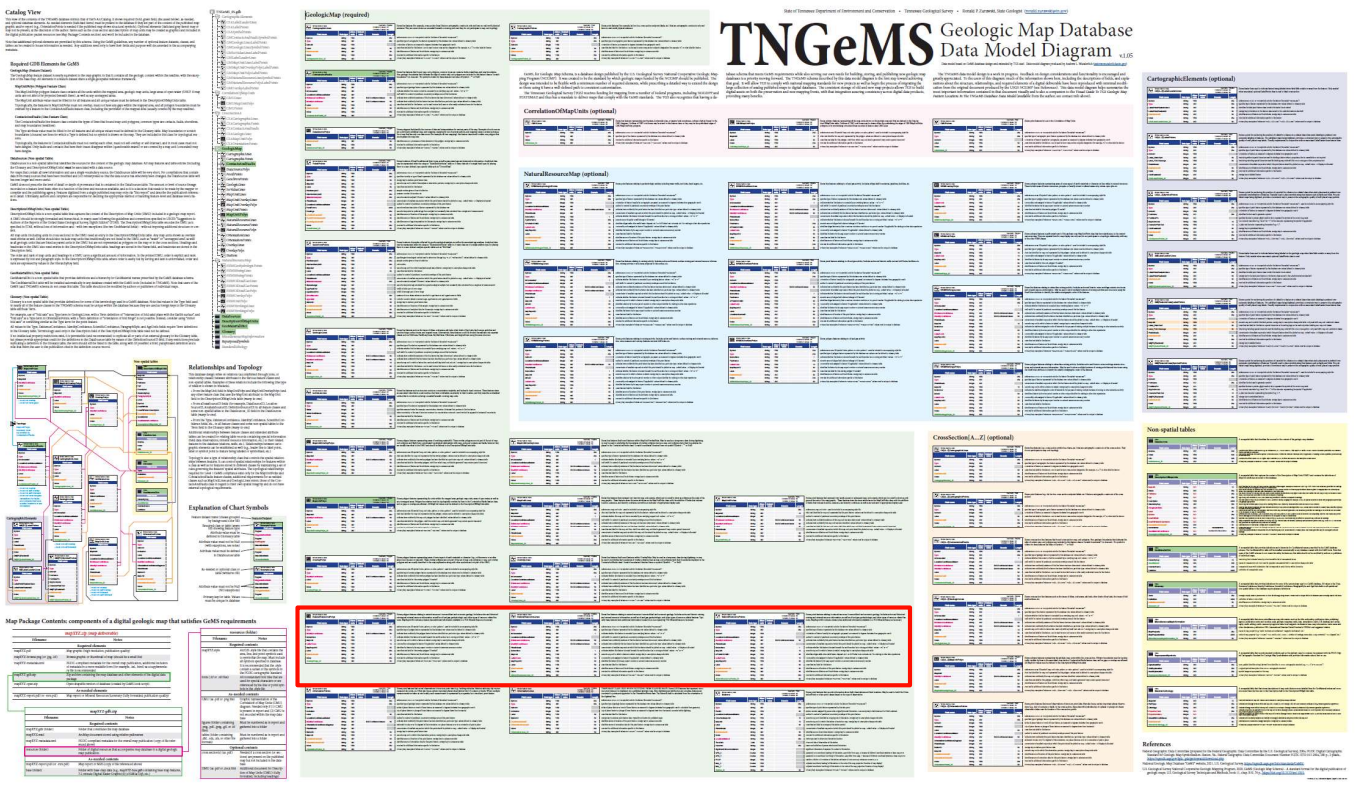
TGS map symbols: …and GeMS

	A	B	F	J	K	L	M
1	ID	Map #	Description	Symbol	Type	FDataset	FClass
2	1	1	Contact, dashed where approximate	01.001.001	contact certain	GeologicMap	ContactsAndFaults
3	2	1		01.001.003	contact approximate	GeologicMap	ContactsAndFaults
4	3	1	Abandoned quarry [point]	19.003.005	mine or quarry; abandoned	GeologicMap	NaturalResourcePoints
5	4	1	Oil and gas test (gas show)	19.005.019; 19.005.050	dry hole (gas show)	GeologicMap	NaturalResourcePoints
6	5	1	Map numbers refer to descriptions in Mineral Resources Summary	N/A	N/A	CartographicElements	NR[Geometry]Text
7	6	2	Contact, dashed where approximate	01.001.001	contact certain	GeologicMap	ContactsAndFaults
8	7	2		01.001.003	contact approximate	GeologicMap	ContactsAndFaults
9	8	2	Strike and dip of beds:	N/A	N/A	N/A	N/A
10	9	2	Normal	06.000.002	bedding inclined	GeologicMap	OrientationPoints
11	10	2	Horizontal	06.000.001	bedding horizontal	GeologicMap	OrientationPoints
12	11	2	Active quarry [point]	19.003.004	mine or quarry	GeologicMap	NaturalResourcePoints
13	12	2	Abandoned quarry [point]	19.003.005	mine or quarry; abandoned	GeologicMap	NaturalResourcePoints
14	13	2	Abandoned quarry [area]	19.003.006	open pit or quarry (area); abandoned	GeologicMap	NaturalResourcePolys
15	14	2	Map numbers refer to descriptions in Mineral Resources Summary	N/A	N/A	CartographicElements	NR[Geometry]Text
16	15	3	Contact, dashed where approximate	01.001.001	contact certain	GeologicMap	ContactsAndFaults
17	16	3		01.001.003	contact approximate	GeologicMap	ContactsAndFaults
18	17	3	Strike and dip of beds	06.000.002	bedding inclined	GeologicMap	OrientationPoints
19	18	3	Strip mine (inactive) [line]	TGS NEW CODE	strip mine bench; abandoned	GeologicMap	NaturalResourceLines
20	19	3	Abandoned adit	19.003.012	adit or tunnel; abandoned	GeologicMap	NaturalResourcePoints
21	20	3	Shut-in gas and oil well	19.005.064	oil and gas well; suspended	GeologicMap	NaturalResourcePoints
22	21	3	Shut-in gas well	19.005.052	gas well; suspended	GeologicMap	NaturalResourcePoints
23	22	3	Abandoned location [well]	19.003.029	well; abandoned	GeologicMap	NaturalResourcePoints
24	23	3	Dry and abandoned [well]	19.005.019	dry hole	GeologicMap	NaturalResourcePoints
25	24	3	Coal test hole [drill hole]	19.003.025	drill hole for mineral exploration	GeologicMap	NaturalResourcePoints
26	25	3	Map numbers refer to descriptions in Mineral Resources Summary	N/A	N/A	CartographicElements	NR[Geometry]Text
27	26	4	Contact, dashed where approximate	01.001.001	contact certain	GeologicMap	ContactsAndFaults
28	27	4		01.001.003	contact approximate	GeologicMap	ContactsAndFaults

TGS map symbol > Match to FGDC symbol > Find a home in GeMS…

With a match to FGDC symbol, we can find the feature a home in GeMS. The features we felt didn't fit an existing class meant we needed to create a class for them.

TNGeMS data model development



We created a traditional geodatabase data model diagram poster. It hangs on the wall and allows the geologists (and others in our division) to inspect and comment on the data structure and see how geologic map information is organized in a GeMS database.

TNGeMS: Feature classes for MRS data

Simple feature class
NaturalResourcePoints

Geometry *Point*
Contains M values *No*
Contains Z values *No*

Field name	Data type	Allow nulls	Default value	Domain	Length	
Symbol	String	YES			254	References an FGDC or TGS symbol code for the feature (formatted "00.000.000")
Type	String	*NO*			254	Specifies type of feature represented by this database row. Values defined in Glossary table
Azimuth	Single	YES				Orientation of feature (usually for cartographic purposes), as measured in degrees clockwise from geographic North
LocationConfidenceMeters	Single	*NO*				Radius (in meters) of positional-uncertainty envelope of this point feature

Stores point features relating to natural resources (commodities) and economic geology. Includes active and historical mining and mineral resource information, as well as oil and gas, geohydrologic, and other types of resource-related features. MapReportIDs indicate a feature has additional information available in a TGS Mineral Resource Summary

Simple feature class
NaturalResourceLines

Geometry *Polyline*
Contains M values *No*
Contains Z values *No*

Field name	Data type	Allow nulls	Default value	Domain	Length	
Symbol	String	YES			254	References an FGDC or TGS symbol code for the feature (formatted "00.000.000")
Type	String	*NO*			254	Specifies type of feature represented by this database row. Values defined in Glossary table
IsConcealed	String	*NO*			1	Indicates whether this feature is concealed by an overlying feature. Values = "N" or "Y"
LocationConfidenceMeters	Single	*NO*				Half-width (in meters) of positional-uncertainty envelope around this line feature

Stores line features relating to natural resources (commodities) and economic geology. Includes active and historic mining and mineral resource information, as well as oil and gas, geohydrologic, and other types of resource-related features. Typically these features have additional information located in an accompanying TGS Mineral Resource Summary

Simple feature class
NaturalResourcePolys

Geometry *Polygon*
Contains M values *No*
Contains Z values *No*

Field name	Data type	Allow nulls	Default value	Domain	Length	
Symbol	String	YES			254	References an area-fill symbol (color, pattern, or color+pattern). Must be included in accompanying .style file.
Type	String	*NO*			254	Specifies type of polygon feature represented by this database row. Values must be defined in Glossary table
IdentityConfidence	String	*NO*		ExIDConfidenceValues	50	Indicates how confidently this polygon feature has been identified as a particular type. Values defined in Glossary table
Subsurface	String	YES			1	Indicates whether this feature is located beneath the Earth's surface (as in mining activities). Values = "N" or "Y"
MapUnit	String	YES			10	Records map unit to which a feature is related. Foreign key to DescriptionOfMapUnits table
LetterCode	String	YES			10	Commodity code assigned to feature (if applicable). Values defined in Glossary table
MapReportID	String	YES			50	Identifies the feature by its Map Report number or Mineral Resources Summary number
Label	String	YES			254	Describes text label for this overlay polygon (if needed)
DataSourceID	String	*NO*			50	Identifies source of feature and its attributes. Foreign key to DataSources table
Notes	String	YES			254	Free text for additional information specific to this feature
OverlayPolys_ID	String	*NO*			50	Primary key. Examples of values are "NRPL001", "NRPL002". Values must be unique in database

Stores polygon features relating to natural resources (commodities) and economic geology. Includes active and historical mining and mineral resource information, as well as oil and gas, geohydrologic, and other types of resource-related features. MapReportIDs indicate a feature has additional information available in a TGS Mineral Resource Summary

The NaturalResource feature classes are examples of custom GeMS-compliant extensions to the original GeMS schema designed using the criteria defined within the GeMS documentation but with attributes specific to TGS-style geologic and mineral resource maps.

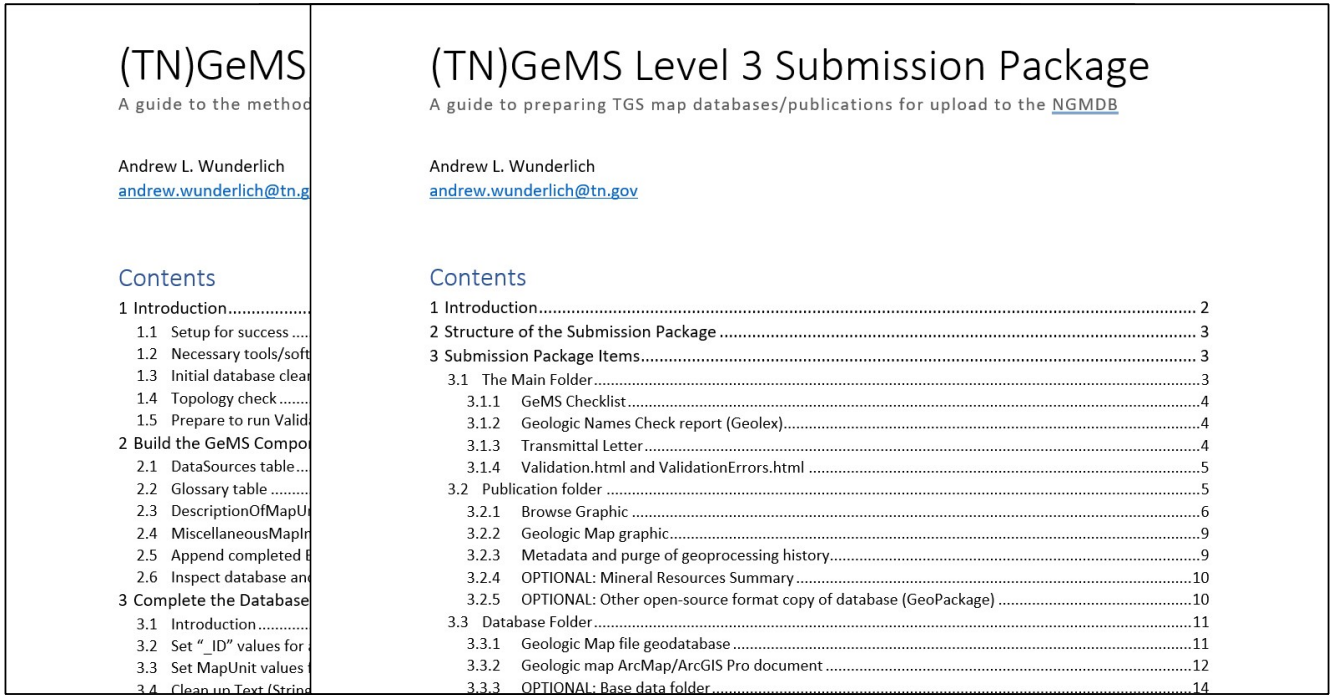
TNGeMS implementation

- The schema was tested on a handful of projects:
  - Unfinished (mothballed) geologic quadrangle maps that needed to be digitally re-compiled
  - Conversions of recently published non-GeMS maps with GIS data

- Building and testing TNGeMS led to the development of guidance documents intended to help train TGS geologist how to build GeMS databases, including TN-specific content

More streamlined workflows = more consistent products

TNGeMS documentation



(TN)GeMS

A guide to the method

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Contents

(TN)GeMS Level 3 Submission Package

A guide to preparing TGS map databases/publications for upload to the NGMDB

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Contents

With TGS-developed documents and supplemental information from the FGDC and GeMS publication, we have step-by-step software-specific information for geologist to follow. Documentation like this gets us to a really good place with the databases on the first pass, meaning a less arduous QC process and more consistent products.

TNGeMS: Current and future applications

- Mapping:
  - All current and future NGGDPP and STATEMAP funded conversions and compilations
  - All future new mapping STATEMAP projects
- Non-mapping:
  - Features related to the development of spatial components of our new historical collection ArcGIS Online portal
  - Features related to other data collection/compilation projects (e.g., NIBI, CORE-CM, and Earth MRI)

What about publishing maps???

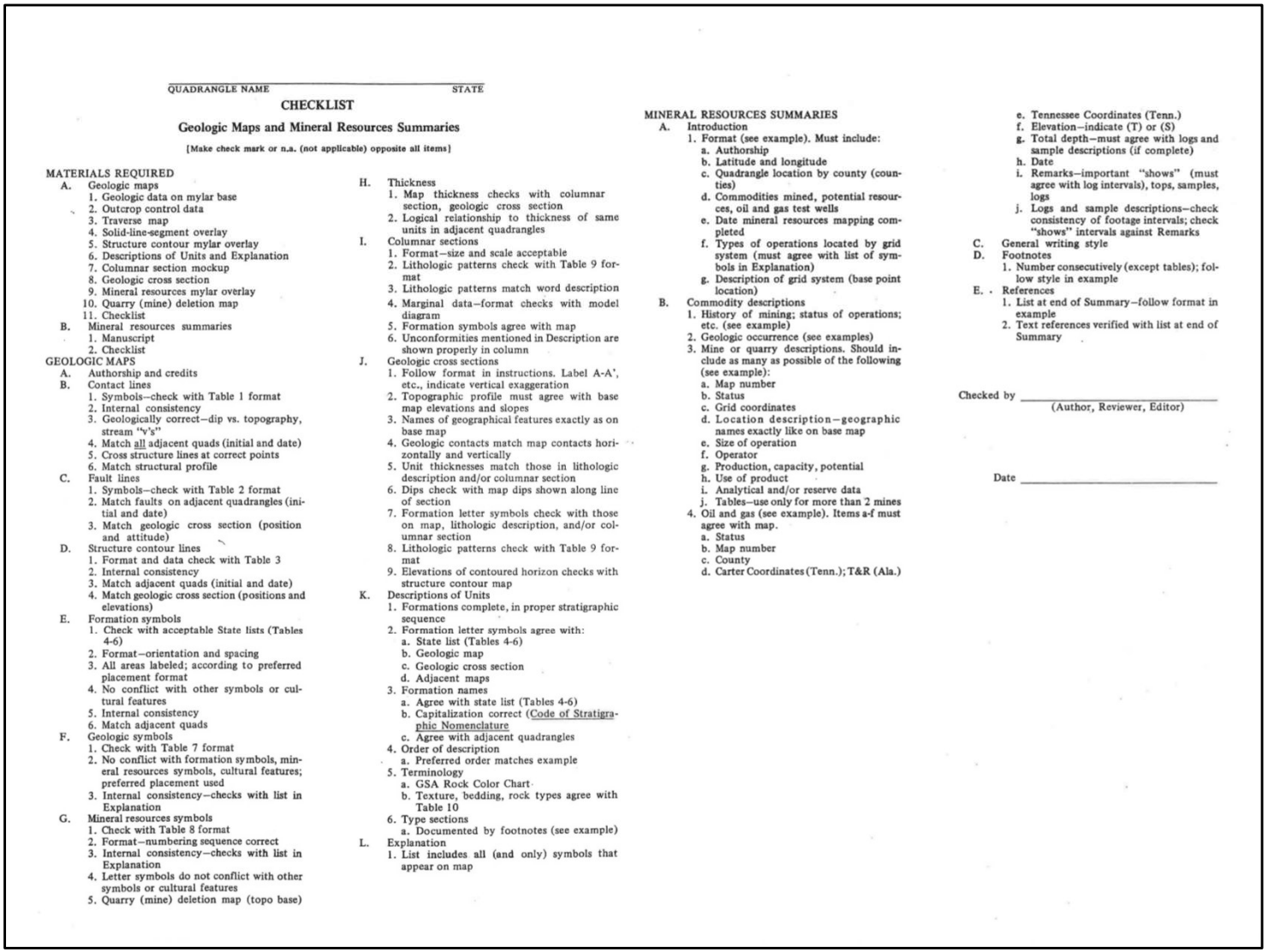
TNGeMS and… Publishing?

"The mission of the Tennessee Geological Survey is to encourage and promote the prudent development and conservation of Tennessee's geological, energy, and mineral resources by ***developing and maintaining databases***, maps and technical services; providing accurate geologic hazard assessments; and ***disseminating geologic information through publications*** and educational outreach activities."

Through TNGeMS development:

- Led us to assess the current methods used to make maps, review them, and prepare them for publication
- Published maps will be accompanied by the database, i.e., the GeMS package becomes the ***complete*** publication.
- We (re)created a set of criteria to inform the review of a map and its content…

Note the second emphasized text. The GeMS package is a well-defined and repeatable product for single map publications. But what's the connection with the development of TNGeMS and publishing our maps? Over the last 20 years, budget cuts, staff reductions, retirements, have all led to a loss of rigor in our review process and intuitional knowledge. We are now taking a hard look at how we've been building and reviewing our more recent products.



QUADRANGLE NAME STATE

CHECKLIST

Geologic Maps and Mineral Resources Summaries

[Make check mark or n.a. (not applicable) opposite all items]

MATERIALS REQUIRED
- A. Geologic maps
  1. Geologic data on mylar base
  2. Outcrop control data
  3. Traverse map
  4. Solid-line-segment overlay
  5. Structure contour mylar overlay
  6. Descriptions of Units and Explanation
  7. Columnar section mockup
  8. Geologic cross section
  9. Mineral resources mylar overlay
  10. Quarry (mine) deletion map
  11. Checklist
- B. Mineral resources summaries
  1. Manuscript
  2. Checklist

GEOLOGIC MAPS
- A. Authorship and credits
- B. Contact lines
  1. Symbols—check with Table 1 format
  2. Internal consistency
  3. Geologically correct—dip vs. topography, stream "v's"
  4. Match all adjacent quads (initial and date)
  5. Cross structure lines at correct points
  6. Match structural profile
- C. Fault lines
  1. Symbols—check with Table 2 format
  2. Match faults on adjacent quadrangles (initial and date)
  3. Match geologic cross section (position and attitude)
- D. Structure contour lines
  1. Format and data check with Table 3
  2. Internal consistency
  3. Match adjacent quads (initial and date)
  4. Match geologic cross section (positions and elevations)
- E. Formation symbols
  1. Check with acceptable State lists (Tables 4-6)
  2. Format—orientation and spacing
  3. All areas labeled; according to preferred placement format
  4. No conflict with other symbols or cultural features
  5. Internal consistency
  6. Match adjacent quads
- F. Geologic symbols
  1. Check with Table 7 format
  2. No conflict with formation symbols, mineral resources symbols, cultural features; preferred placement used
  3. Internal consistency—checks with list in Explanation
- G. Mineral resources symbols
  1. Check with Table 8 format
  2. Format—numbering sequence correct
  3. Internal consistency—checks with list in Explanation
  4. Letter symbols do not conflict with other symbols or cultural features
  5. Quarry (mine) deletion map (topo base)
- H. Thickness
  1. Map thickness checks with columnar section, geologic cross section
  2. Logical relationship to thickness of same units in adjacent quadrangles
- I. Columnar sections
  1. Format—size and scale acceptable
  2. Lithologic patterns check with Table 9 format
  3. Lithologic patterns match word description
  4. Marginal data—format checks with model diagram
  5. Formation symbols agree with map
  6. Unconformities mentioned in Description are shown properly in column
- J. Geologic cross sections
  1. Follow format in instructions. Label A-A', etc., indicate vertical exaggeration
  2. Topographic profile must agree with base map elevations and slopes
  3. Names of geographical features exactly as on base map
  4. Geologic contacts match map contacts horizontally and vertically
  5. Unit thicknesses match those in lithologic description and/or columnar section
  6. Dips check with map dips shown along line of section
  7. Formation letter symbols check with those on map, lithologic description, and/or columnar section
  8. Lithologic patterns check with Table 9 format
  9. Elevations of contoured horizon checks with structure contour map
- K. Descriptions of Units
  1. Formations complete, in proper stratigraphic sequence
  2. Formation letter symbols agree with:
     a. State list (Tables 4-6)
     b. Geologic map
     c. Geologic cross section
     d. Adjacent maps
  3. Formation names
     a. Agree with state list (Tables 4-6)
     b. Capitalization correct (Code of Stratigraphic Nomenclature
     c. Agree with adjacent quadrangles
  4. Order of description
     a. Preferred order matches example
  5. Terminology
     a. GSA Rock Color Chart
     b. Texture, bedding, rock types agree with Table 10
  6. Type sections
     a. Documented by footnotes (see example)
- L. Explanation
  1. List includes all (and only) symbols that appear on map

MINERAL RESOURCES SUMMARIES
- A. Introduction
  1. Format (see example). Must include:
     a. Authorship
     b. Latitude and longitude
     c. Quadrangle location by county (counties)
     d. Commodities mined, potential resources, oil and gas test wells
     e. Date mineral resources mapping completed
     f. Types of operations located by grid system (must agree with list of symbols in Explanation)
     g. Description of grid system (base point location)
- B. Commodity descriptions
  1. History of mining; status of operations; etc. (see example)
  2. Geologic occurrence (see examples)
  3. Mine or quarry descriptions. Should include as many as possible of the following (see example):
     a. Map number
     b. Status
     c. Grid coordinates
     d. Location description—geographic names exactly like on base map
     e. Size of operation
     f. Operator
     g. Production, capacity, potential
     h. Use of product
     i. Analytical and/or reserve data
     j. Tables—use only for more than 2 mines
  4. Oil and gas (see example). Items a-f must agree with map.
     a. Status
     b. Map number
     c. County
     d. Carter Coordinates (Tenn.); T&R (Ala.)
     e. Tennessee Coordinates (Tenn.)
     f. Elevation—indicate (T) or (S)
     g. Total depth—must agree with logs and sample descriptions (if complete)
     h. Date
     i. Remarks—important "shows" (must agree with log intervals), tops, samples, logs
     j. Logs and sample descriptions—check consistency of footage intervals; check "shows" intervals against Remarks
- C. General writing style
- D. Footnotes
  1. Number consecutively (except tables); follow style in example
- E. References
  1. List at end of Summary—follow format in example
  2. Text references verified with list at end of Summary

Checked by _____
(Author, Reviewer, Editor)

Date _____

It turns out we had a solid basis for reviewing of our products all along! Our rich history of geologic mapping, compilation of natural resource info, and publication of those data was a well-defined, highly controlled process guided by a very detailed document called “The Authors’ Guide for Preparing Geologic Maps and MRSs” internally referred to simply as “The Authors’ Guide”. Created by the TVA in the early 1970s to help those involved in “cooperative programs between the Tennessee Valley Authority and state agencies. Information presented is directed mainly to authors but will also be used as a reference for editors and cartographers involved in the program.”

Reviving/Revising *The Authors' Guide…*

Creating maps (QA):

- Integrate the TNGeMS data model diagram elements, map symbols/data dictionary, and how-to guides to create a comprehensive document for our geologists and GIS analysts to reference
- Checklist provides measurable criteria for project tracking purposes

Editing/reviewing maps (QC):

- One of the major hurdles we have as a small survey is publishing with appropriate peer review
- Checklist provides clear guidance for internal and ***external*** reviewers

The plan is to update "The Authors' Guide": it will once again be the primary resource to make and review our geologic and mineral resource maps. One of the major hurdles we have as a small survey is publishing with appropriate peer review. For many projects, the solution was to simply stamp the product as a "DRAFT Open File Map/Report"… and that is certainly less than ideal. It may undermine the perception users have regarding the quality/credibility of the work and in a way violates our mandate to truly "publish" maps!

Final thoughts

- The NEW Authors' Guide will become the TGS standard for building map databases (TNGeMS)
- The updated checklist provides a useful tool for QA/QC; particularly for establishing guidelines for pre-publication review
- With an aging staff we are desperate to preserve our institutional knowledge
- We are looking to establish partnerships with other states to review map publications

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TENNESSEE GEOLOGICAL SURVEY

ESTABLISHED 1831

Thank you!

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