

The following was presented at DMT'09
(May 10-13, 2009).

The contents are provisional and will be
superseded by a paper in the
DMT'09 Proceedings.

See also earlier Proceedings (1997-2008)

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



**NCGMP09 --
A proposed standard format for
publication of geologic maps**

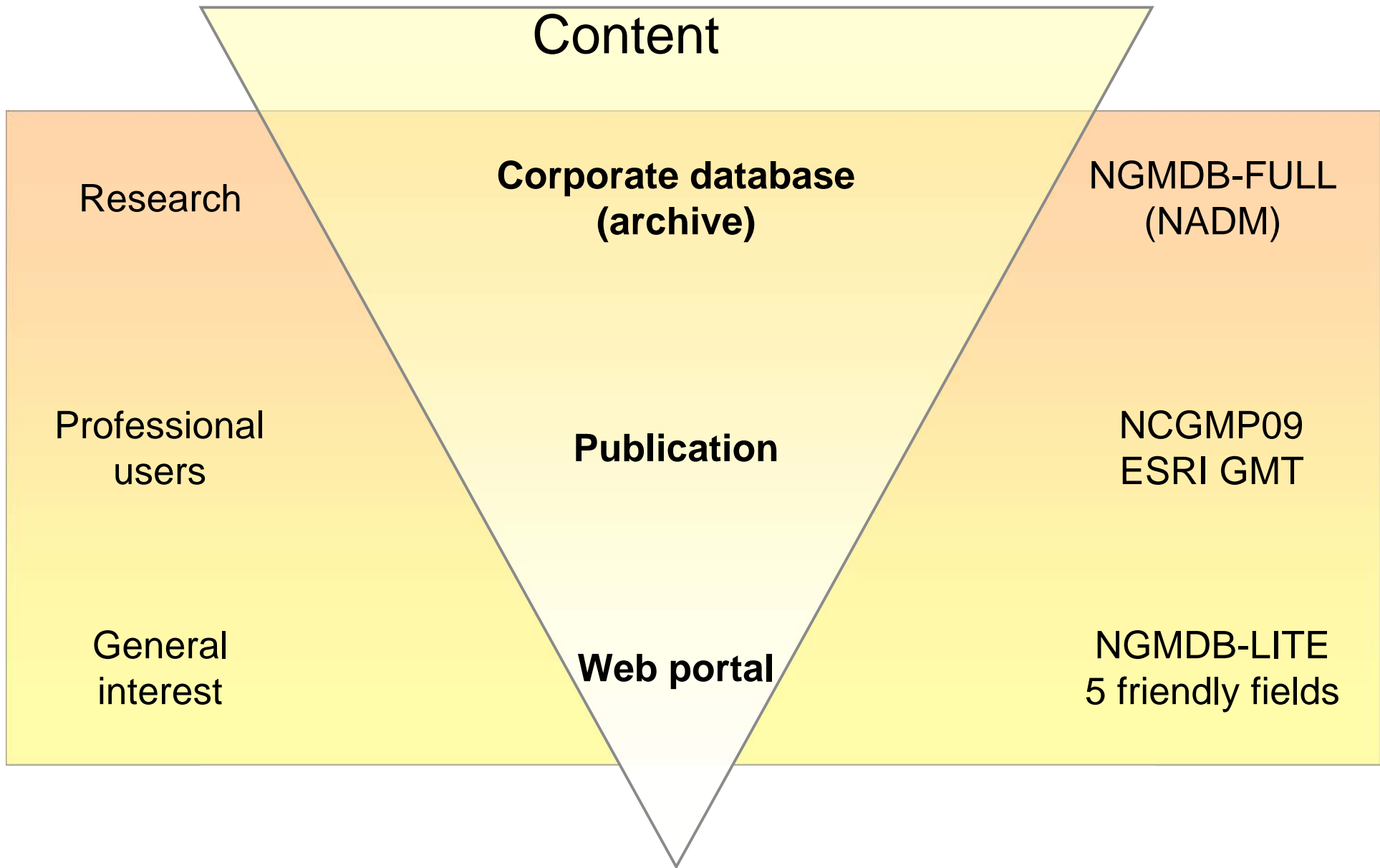
National Geologic Map Database and
Pacific Northwest Geologic Mapping projects

U.S. Geological Survey

Some background

- ☀ AASG/USGS Geologic Data Model Working Group formed in August, 1996
produced data model “v.4.3” in 1998
- ☀ ca. 1998-2000 -- test-implement the data model
- ☀ North American Data Model (NADM) Committee formed in March, 1999
produced conceptual model “NADM-C1”, and science language “NADM-SLTT”
- ☀ ca. 2004-present -- test-implement the data model and science terminology, encode it in GeoSciML

ngmdb.usgs.gov/info/standards/



Publication-quality cartography

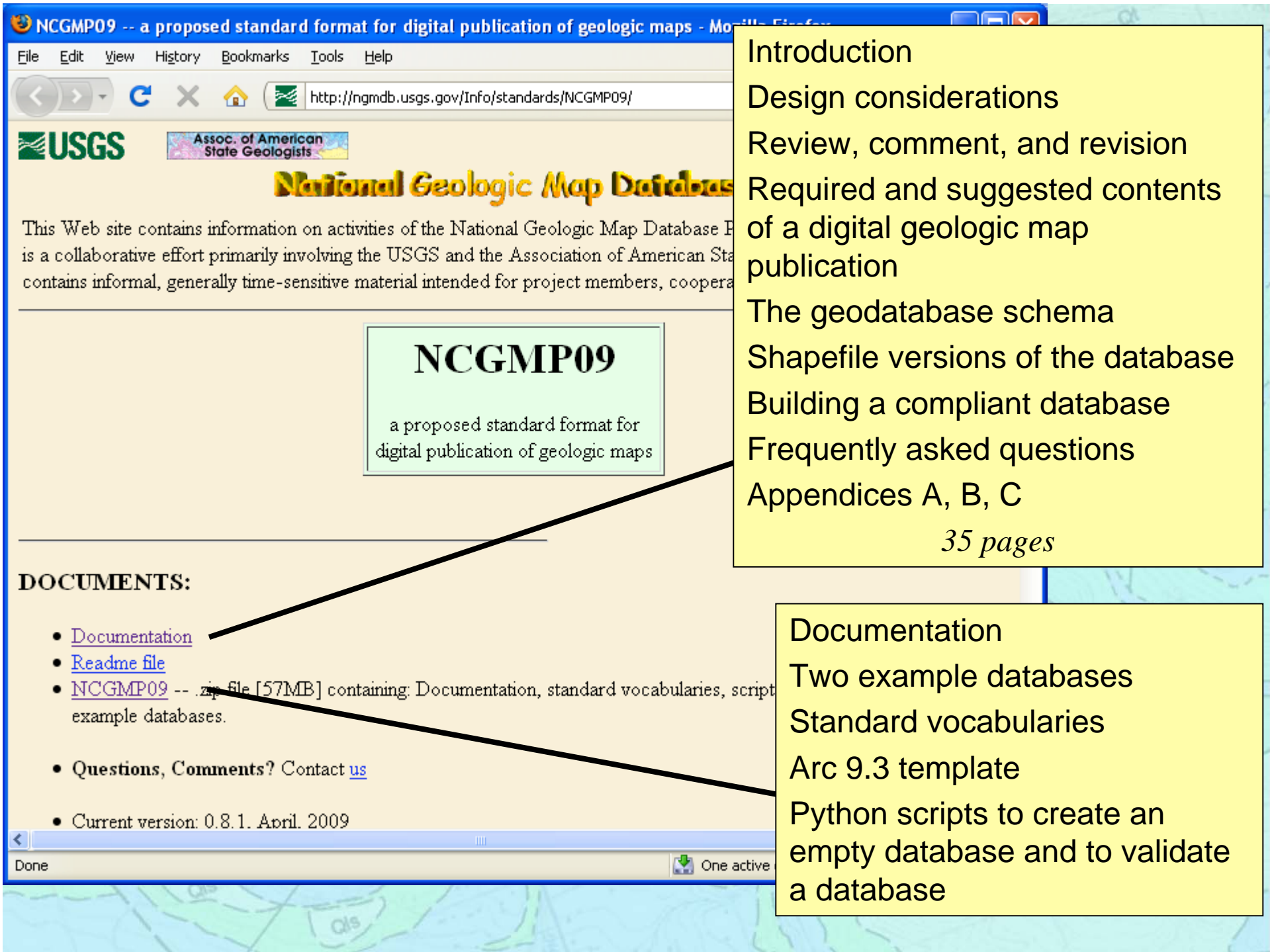
Enterprise multi-map database

Create (compile and edit) a map

Our problem: transfer and archive (publish) a single map

Field data collection

A world of database schemas



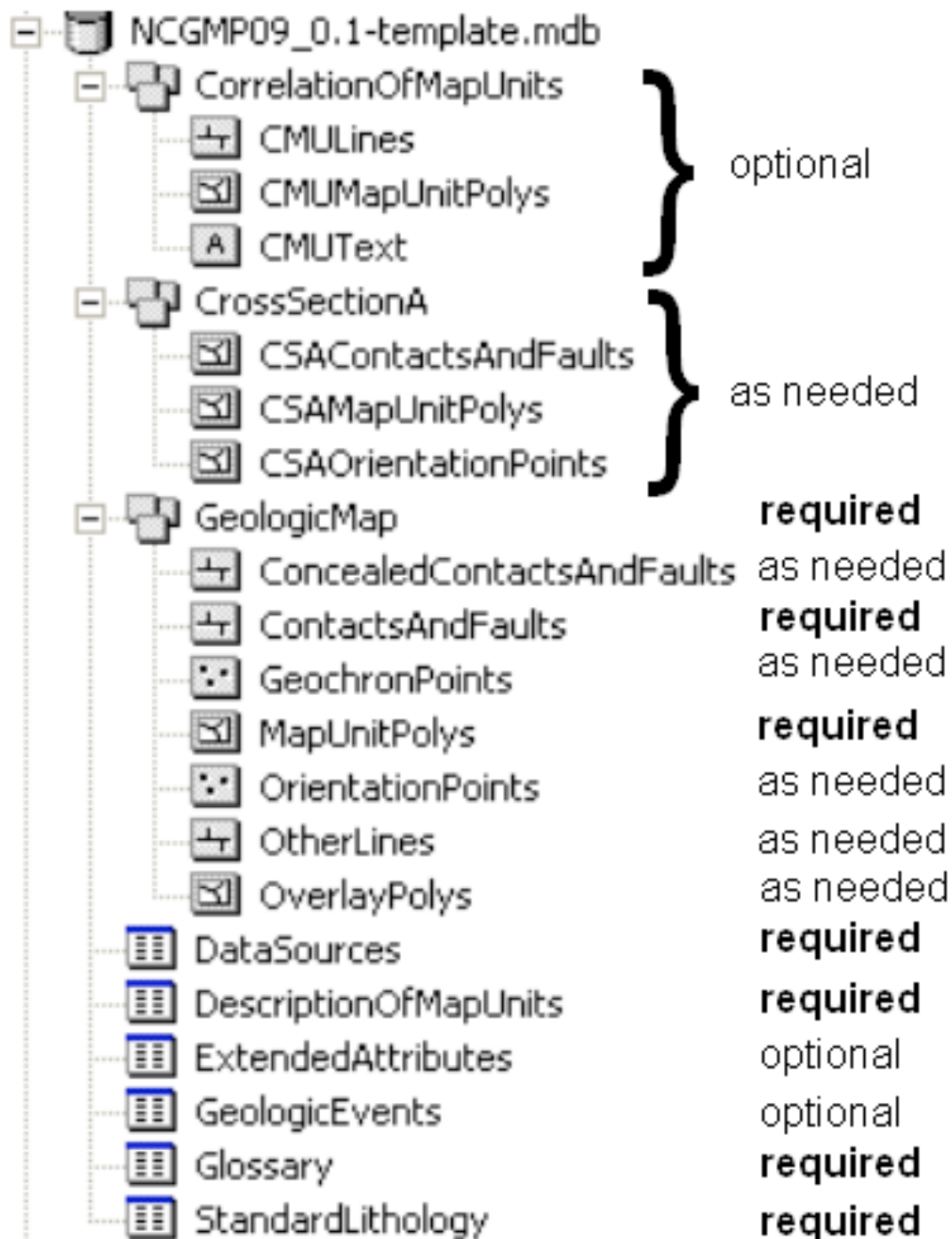
Introduction

- Design considerations
- Review, comment, and revision
- Required and suggested contents of a digital geologic map publication
- The geodatabase schema
- Shapefile versions of the database
- Building a compliant database
- Frequently asked questions
- Appendices A, B, C

35 pages

Documentation

- Two example databases
- Standard vocabularies
- Arc 9.3 template
- Python scripts to create an empty database and to validate a database



- Arc-native
- Simple structure
- Strong naming conventions
- Complete DMU
- StandardLithology
- Feature-level metadata
- Vocabulary definitions
- Extended Attributes
- FGDC symbology

ArcGIS-native

- .gdb or .mdb
- Implementations and (some) tools exist!
- Prescribed translations to shapefile format (*simple* and *open* versions)
- A documented, stable file format would sure be nice

Simple structure

- Features grouped by spatial reference framework
 - Earth's surface (GeologicMap)
 - Cross-section space (CrossSectionA, CrossSectionB, ...)
 - Page units (CMU)
- 1 required feature dataset: GeologicMap
- Within GeologicMap, 2 required feature classes
 - **MapUnitPolys**
 - **ContactsAndFaults**
 - OverlayPolys (as needed)
 - ConcealedContactsAndFaults (as needed)
 - OtherLines (as needed) *fold axes, cross-section lines...*
 - OrientationPoints, GeochronPoints, ... (as needed)
- Optional feature datasets for Correlation of Map Units and cross sections
- 4 required non-spatial tables, 2 optional tables

Strong naming conventions

- All names are prescribed
- Names make geologic sense

Goal is to
facilitate
collective
development
of tools

ThisReport.zip

ThisReport.gdb *geodatabase*

GeologicMap *feature dataset*

MapUnitPolys *feature class*

MapUnitPolys_ID *field*

MapUnit

Label

IdentityConfidence

AreaSymbol

...

DescriptionOfMapUnits table

MapUnit	Name	Age	Description (free-format)
Tbh	Blakely Harbor Formation (Miocene)		—Volcanic-lithic sandstone, siltstone, conglomerate, and peat. Orange-brown weathering; pervasive clayey alteration. Conglomerate rich in basaltic clasts and without granitic clasts. Abundant wood and, locally, peat as thick as 3 m. Stream and flood-plain deposits

- One row per map unit
- Headings and headnotes represented as additional rows in DescriptionOfMapUnits
- Row attributes include ParagraphStyle and HierarchyKey
- This is a complete representation of traditional USGS-style DMU

StandardLithology table

- Structured, queryable, description of each map unit using NGMDB-sanctioned list of standard lithologic terms
- Units can be described as mixtures (interbedded, block-in-matrix, ...) with definite (93%) or indefinite (mostly, rare, ...) proportions

Dr Jekyll to the free-text Mr Hyde of the traditional DMU

Feature-level metadata

- LocationConfidenceMeters
- IdentityConfidence
- ExistenceConfidence
- OrientationConfidenceDegrees
- DataSource
 - DefinitionSource
 - AnalysisSource
 - LocationSource

as
appropriate

Vocabulary definitions

- Certain terms **MUST** be defined internally or in referenced external vocabulary
 - Any Type term
 - Lithology and part terms in StandardLithology
- **Glossary** table for internal definition
- *Except for StandardLithology, we sidestep issue of controlled vs. uncontrolled science language*
- Have tool to check for undefined terms and unused definitions

ExtendedAttributes table

- A thread-style database table to store most anything in structured, queryable form

- Each row has attributes

OwnerID *the entity that has this attribute*

Property *e.g., typical seismic velocity*

PropertyValue *e.g., 150 m/sec*

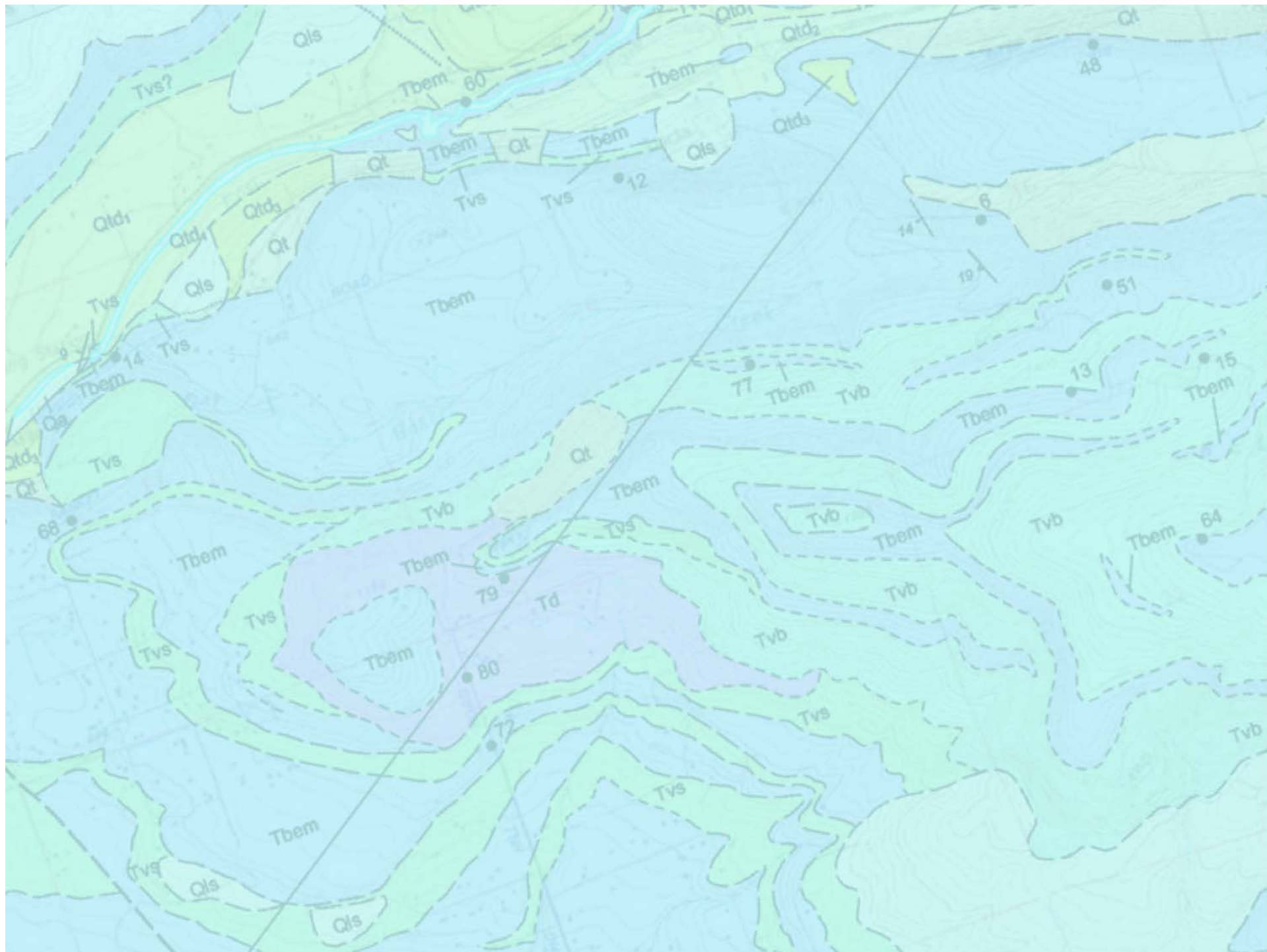
- Particularly useful for sparse data

e.g., we know that this polygon of alluvium is particularly sandy

FGDC Symbology



- We wish to encourage a common graphical vocabulary
- We build on the good work done by the Digital Cartographic Standard group and folks at ESRI
- Implementation is incomplete: we need an FGDCGeology.style

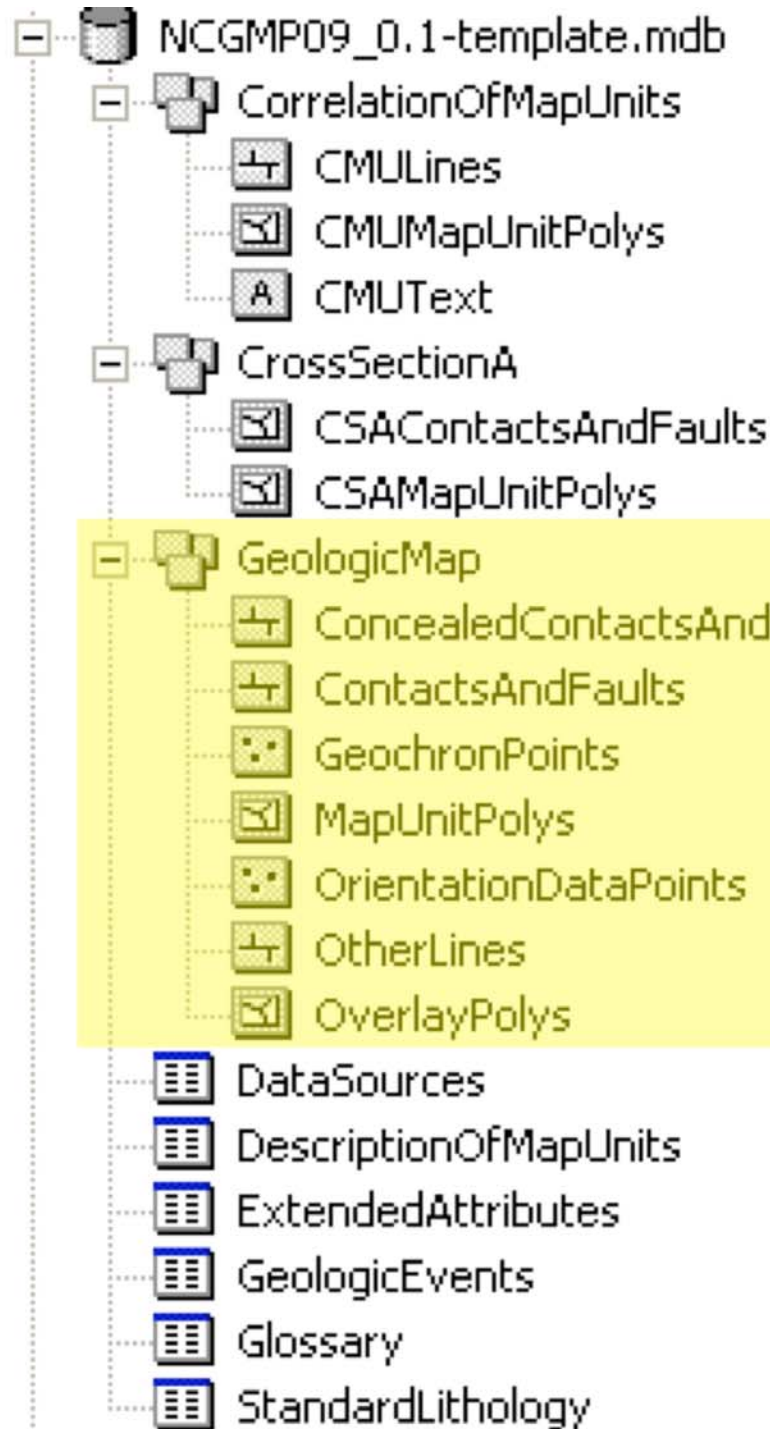


Framework of schema

- Feature classes:
 - Have geometry
 - Link to geoscience thematic tables (foreign key)
 - Other properties are observation-related metadata
- Thematic tables
 - Map unit definition, lithology, age
 - Metadata
 - Pattern for extension to add other information

Catalog
view of an
example
DB

The geologic
map itself



optional

as needed

required

as needed

required

as needed

required

as needed

as needed

as needed

required

required

optional

optional

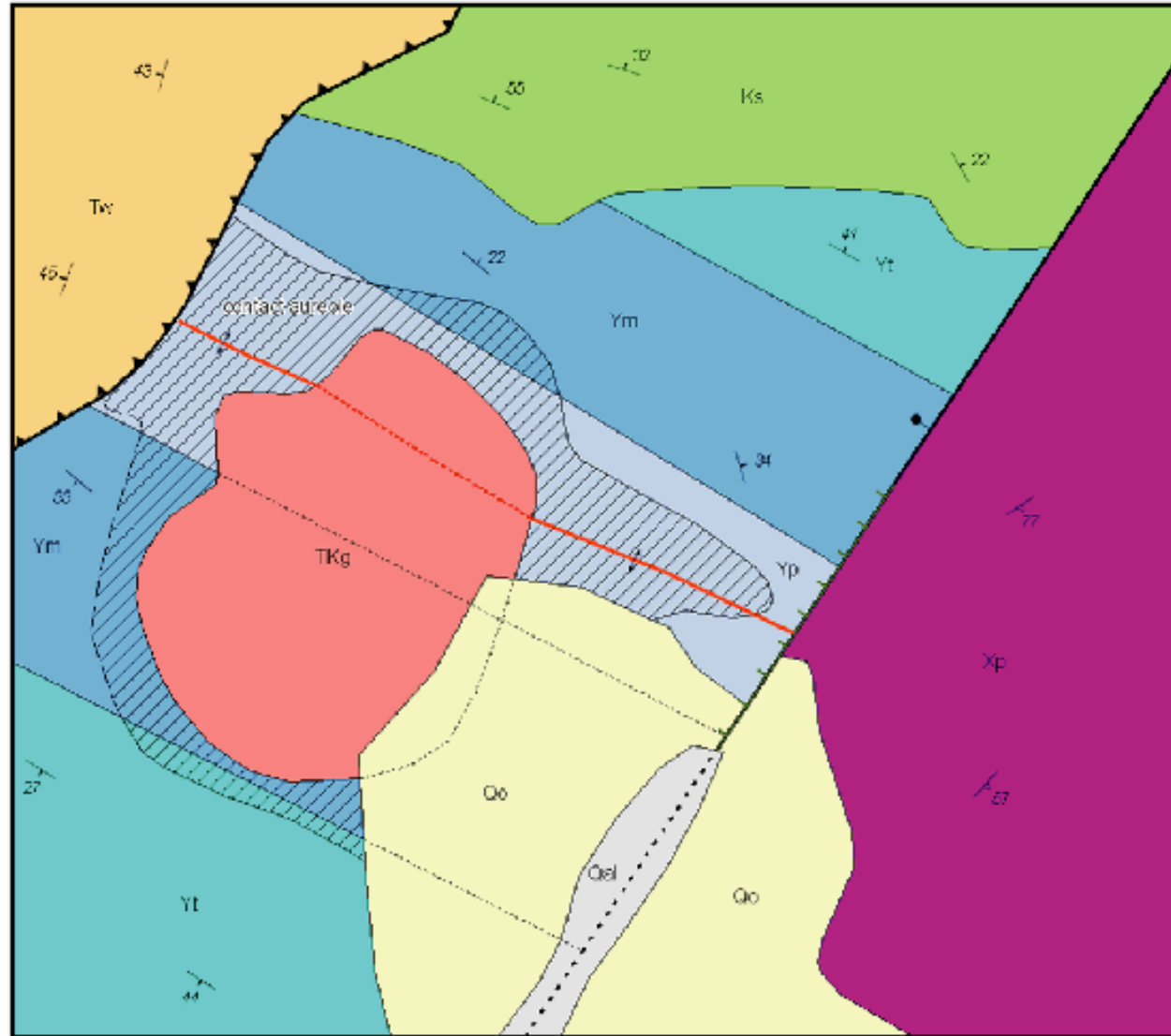
required

required

Feature classes

- Tables that have a ‘shape’ field—georeferenced location that can be plotted.
- Required
 - MapUnitPolygons, ContactsAndFaults
- Optional
 - Overlay polygons
 - ConcealedContactsAndFaults, OtherLines
 - Point data (e.g. OrientationDataPoints)

A simple geologic map:

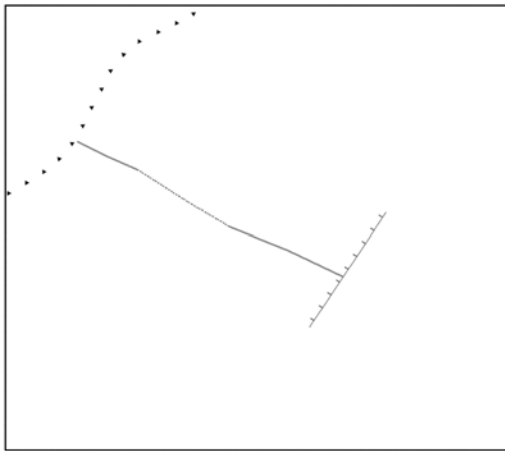




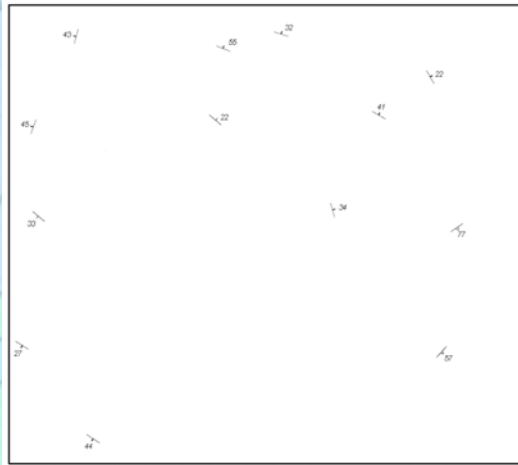
Map Unit Outcrops



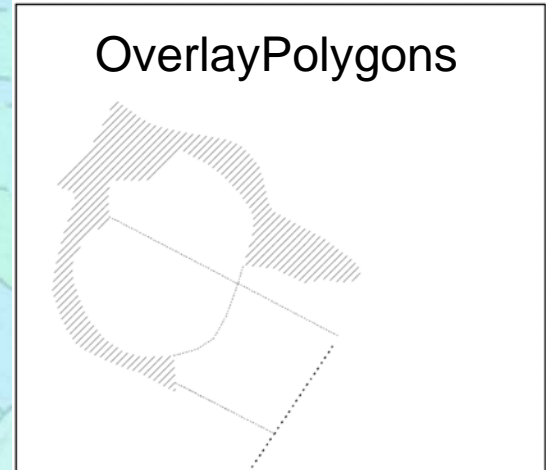
ContactsAndFaults



OtherLines



OrientationDataPoints



ConcealedContactsAndFaults

Follow same pattern: cross sections, correlation of units

- [-] NCGMP09_0.1-template.mdb
 - [-] CorrelationOfMapUnits
 - [+] CMULines
 - [+] CMUMapUnitPolys
 - [+] CMUText
 - [-] CrossSectionA
 - [+] CSAContactsAndFaults
 - [+] CSAMapUnitPolys
 - [-] GeologicMap
 - [+] ConcealedContactsAndFaults
 - [+] ContactsAndFaults
 - [+] GeochronPoints
 - [+] MapUnitPolys
 - [+] OrientationDataPoints
 - [+] OtherLines
 - [+] OverlayPolys

optional

as needed

required

as needed

required

as needed

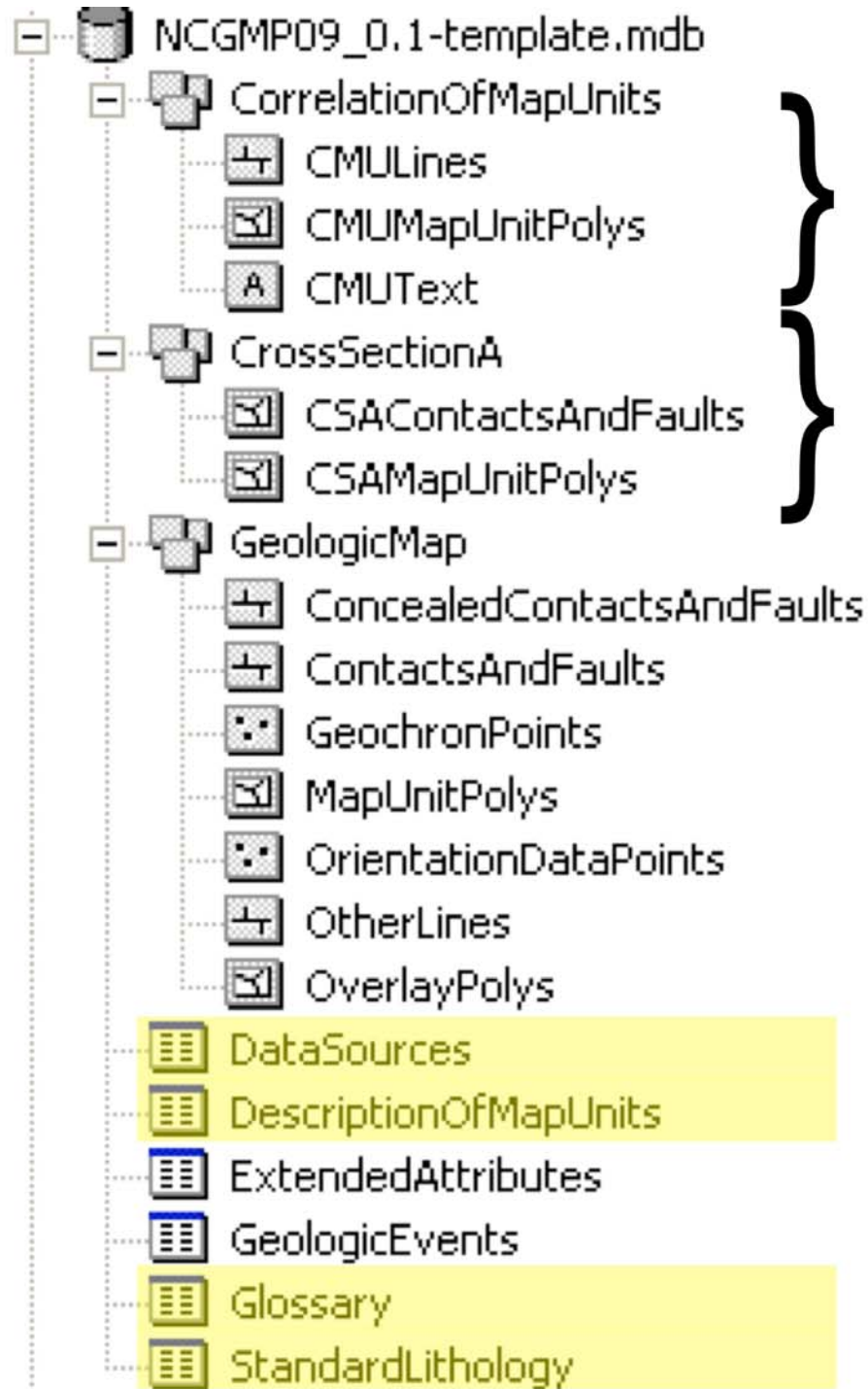
required

as needed

as needed

as needed

Catalog view of an example DB



optional

as needed

required

as needed

required

as needed

required

as needed

as needed

as needed

required

required

optional

optional

required

required

DescriptionOfMapUnits

(required) Provides basic text definition of unit as found in map - surround 'explanation of map units'

MapUnit (e.g. TKg) abbreviation used to identify the unit in links to lithology

HierarchyKey (1, 1.1, 1.2, 2, 2.1, 2.1.1, 2.1.2) use for sorting units for legend display

ParagraphStyle defines formatting of text based on legend rank

AreaFillRGB and PatternFillDescription describe symbolization of polygons

DescriptionOfMapUnits

Map Unit	Label	Name	FullName	Age	Description	HKey	Paragra. style	RGB	Pattern	Source
		Surficial deposits	Surficial deposits	Quaternary		01	Heading 1			DS0001
Qal	Qm	Younger Alluvium	Younger Alluvium	Late Holocene	Unconsolidated sandy gravel and sand	01-01	Map Unit	225,225,225	Solid fill	DS0001
Qo	Qo	Older Alluvium	Older Alluvium	Early to Middle Pleistocene	Unconsolidated to weakly consolidated gravel and sandy gravel	01-02	Map Unit	245,247,189	Solid fill	DS0001
aureole	<Font=symbol>m (μ)	contact aureole of Schultze granite	contact aureole of Schultze granite	Paleocene	Zone of skarn and hornfels development; character varies rapidly with protolith rock type and distance from granite	02	Map Unit	0,0,0	black diagonal line hatch, 45, 0.2 mm, sp. 1 mm	DS0001
TKg	TKg	Schultze granite	Schultze granite	Paleocene	Fine grained equigranular biotite granitoid	03	Map Unit	244,126,127	Solid fill	DS0002
Ym	Ym	Mescal Formation	Mescal Formation of Apache Group	Middle Proterozoic	Very light gray, medium bedded limestone, locally laminated; reddish terra rosa zones common near top.	04	Map Unit	116,175,210	Solid fill	DS0003

StandardLithology

(required) Provides list of lithologic constituents of geologic unit based on standard vocabulary

PartType how constituent is related to whole
(e.g. blocks, interbedded, stratigraphic part...)

Lithology categorization of kind of rock

Proportion term or numeric value for
fraction of unit composed of this constituent

StandardLithology example

Standard-Lithology_ID	MapUnit	PartType	Lithology	ProportionTerm	ProportionValue
STL26	Tx	Interbedded	Sandstone	Dominant	
STL327	Tx	Stratigraphic part	Siltstone	Minor	
STL579	Tx	Stratigraphic part	Tuff	Minor	
STL264	Txt	Interbedded	Tuff	Dominant	
STL265	Kit	Only part	Tonalite	Dominant	
STL266	KJz	Interbedded	Limestone		.55
STL770	KJz	Interbedded	Mudstone		.45

Standard lithologies

Earth material

Breccia

Soil

Unconsolidated material

Igneous rock

Metamorphic rock

Sedimentary rock

Hierarchical

Sedimentary rock

heading is expanded
at right

Sedimentary rock

Clastic sedimentary rock

Mudstone

Shale

Sandstone

Conglomerate

Wackestone

Diamictite

Carbonate sedimentary rock

**Calcareous carbonate
sedimentary rock**

**Dolomitic or magnesian
sedimentary rock**

*Carbonate rocks defined by
depositional fabric (~Dunham
classification)*

Carbonate boundstone

Carbonate mudstone

Grainstone

Packstone

Crystalline carbonate

Framestone

Carbonate wackestone

Organic-rich sedimentary rock

Coal

Chert

Iron-rich sedimentary rock

Phosphorite

Evaporite

ExtendedAttributes

(optional) Provides mechanism to associate attributes with any other data element.

Cost is that unusual content will be less likely to be understood and used.

Associates property and property value pair with an 'owning' record representing an item the property applies to or the target of a relationship.

ExtendedAttributes Example

Extended-Attribute_ID	Owner-Table	Owner-ID	Property	Property-Value	Value - Link	Qualifier	Notes	Data SourceID
EA306096	Description OfMapUnits	DMU3	Permeability	Low		Typical	Rock is full of alteration clays	DS2140
EA308062	Description OfMapUnits	DMU3	Permeability	High		Rare		DS0001
EA338396	Description OfMapUnits	DMU 27	Metamorphic Grade	Low		Uncommon		DS0364
EA306358	Description OfMapUnits	DMU27	Metamorphic Grade	Medium		Typical		DS2069
EA306066	Description OfMapUnits	DMU27	MetamorphicAge	Early Proterozoic		Probable		DS2106
EA306906	Description OfMapUnits	DMU27	MetamorphicAge	Middle Cretaceous		Possible		DS045
EA375796	Geologic-Events	Slip-Event1	Displacement	4 km		None		DS1045
EA352796	Geologic-Events	Slip-Event1	Displacement Type	Right-lateral strike slip		None		DS1130
EA306334	Geologic-Events	Slip-Event1	Successor		GE266	None		DS1205
EA302476	Geologic-Events	GE266	Displacement	200 km		None		DS1135
EA304996	Geologic-Events	GE266	Displacement-Type	Right-lateral strike slip		None		DS0980
EA306765	Contacts-AndFaults	COF22	ContactCharacter	Gradational		None		DS3656

A geological map with various colored regions (green, blue, yellow) and labels like 'Qls', 'Tbem', 'Qtd2', 'Qtd3', 'Tvs', 'Qt', 'Qa', 'Tvb', 'Tvm', 'Tvd', 'Tve', 'Tvf', 'Tvg', 'Tvh', 'Tvi', 'Tvj', 'Tvk', 'Tvl', 'Tvm', 'Tvn', 'Tvo', 'Tvp', 'Tvq', 'Tvr', 'Tvs', 'Tvt', 'Tvu', 'Tvv', 'Tvw', 'Tvx', 'Tvy', 'Tvz'. The text is overlaid on the map.

GeologicEvents

(optional) Use for greater precision in describing geologic age and history

Associate an event with a minimum and maximum bounding age (term or numeric)

Sequence events to describe a history

Event vocabulary examples: deposition, intrusion, folding, Laramide orogeny...

Example GeologicEvents

Geologic-Events_ID	Event	Age-Display	Age-Younger-Term	Age-Older-Term	Age-Younger-Value	Age-Older-Value	Notes	Data-Sources-ID
GE00001	FaultSlip	Early Miocene	Early Miocene	Early Miocene	20	22		DS26904
GE00022	FaultSlip	Pliocene to Quaternary	Quaternary	Pliocene	0	4		DS62016
GE2465	Deposition of Tvt	Miocene Deposition	Miocene	Miocene	8	22		DS105
GE23609	Laramide orogeny	Laramide age	Early Eocene	Cenomanian	40	80		DS20656

Glossary



- **(Required) Simply a listing of terms with definitions and source information**

- **Term**

- **Definition**

- **DataSource_ID**

Feature-level metadata

- **LocationConfidenceMeters**

- Data type = float
- Diameter or width of 95% confidence zone for spatial position
- Relative to other geologic data and base map, not necessarily relative to ITRF2005
- Estimates with 2X uncertainties are OK!

- **IdentityConfidence, ExistenceConfidence**

- Typically “STANDARD” or “LOW”

- **DataSource**

- Foreign key to DataSources table (text description and citation for provenance)
- For some point data: LocationSource, AnalysisSource

Summary

- Designed for data delivery / sharing
- With some minor additions, could use for single project data production
- Standardized vocabularies are key to facilitating data interchange using the schema
- Please try it out and give us feedback!

<http://ngmdb.usgs.gov/Info/standards/NCGMP09/>