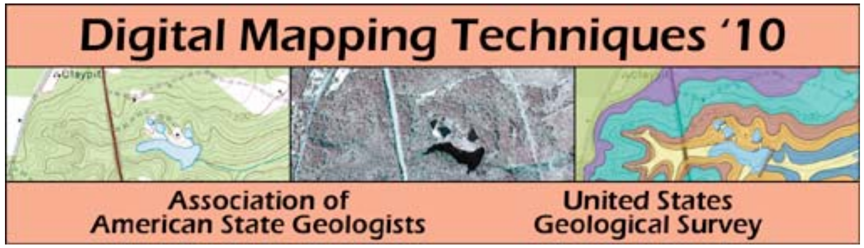

The following was presented at DMT'10
(May 16-19, 2010).

The contents are provisional and will be
superseded by a paper in the
DMT'10 Proceedings.

See also earlier Proceedings (1997-2009)
http://ngmdb.usgs.gov/info/dmt/

Digital Mapping Techniques 2010
NPS Geologic Resources Inventory

The NPS GRI: Data Model Concepts and Implementation, and a Programmatic Approach to Digital Map Production

by

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Sacramento, California

May 16-19, 2010

Outline of Our Talk

Part I: Data Model Concepts and Implementation

- The Geologic Resources Inventory (GRI) Program
- GRI Data Model Design Requirements, Factors and Challenges
- GRI Data Model Implementation

Part II: A Programmatic Approach to Digital Map Production

- GRI Digital Map Production Workflow
- Our Mode of Programming
- Show GRI Production Tools

Canyon de Chelly NMON (photo by Ron Karpilo)

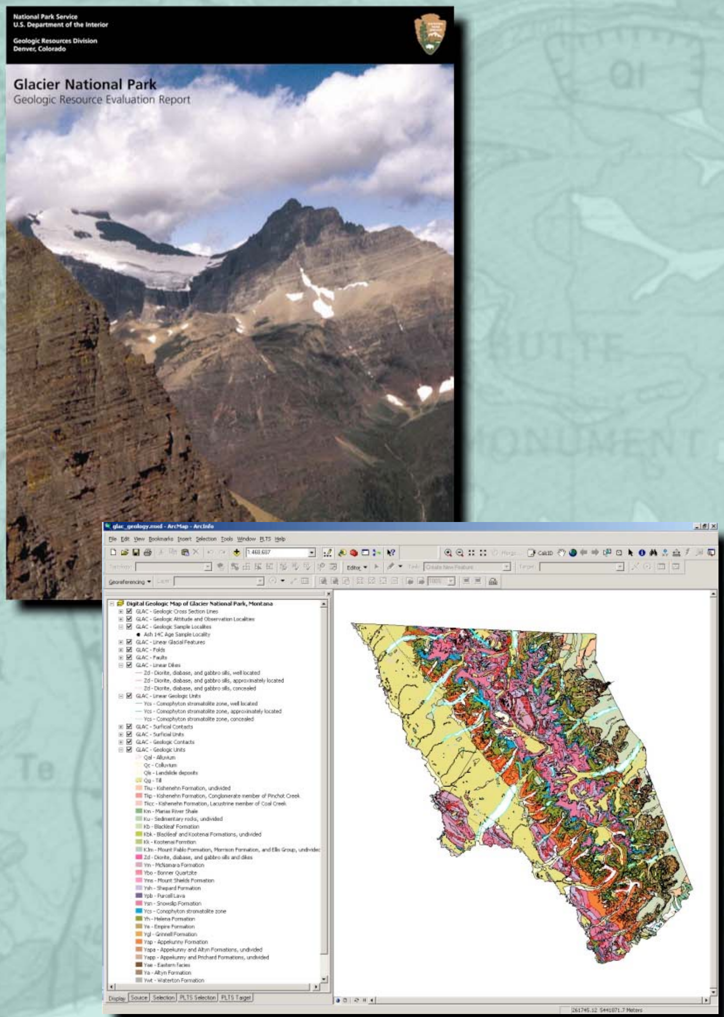
The Geologic Resources Inventory (GRI) Program

- The GRI is tasked with producing geologic information for 270 National Park Service (NPS) parks with natural resources.
- The GRI relies heavily upon cooperative relationships with other agencies and institutions such as the U.S. Geological Survey, state geologic surveys, and academia to produce our products.
- Colorado State University (CSU) is an integral partner in designing and producing GRI products.

Grand Canyon NP (photo by Ron Karpilo)

GRI Products

- A Scoping Meeting to discuss park geologic features, processes and issues, as well as to identify the best source geologic map(s) for the park. The meeting is summarized in a scoping report.
- A Geologic Report, written for resource managers, that explains the geology of a park, and how geology is relevant to park resource management.
- Digital Geologic-GIS Map that conveys useful information about the park's geologic features, yet is also user-friendly and true to the source map(s).



GRI Geologic Report and Digital Geologic-GIS Map (ArcMap Document) for Glacier NP (GLAC).

Data Model Design: Requirements and Challenges

The GRI Data Model had several design requirements, including addressing our intended users and their needs to ensure that we are providing useful geologic-GIS data to them.

Our Base Requirements:

- The GRI data model needed to be implementable in standard GIS software. The GIS software widely employed by the NPS is ESRI ArcGIS.

- The intended end users of our data are park resource managers, most of whom are scientists, but not geologists!

- To preserve and effectively communicate all geologic information present on a source map as GIS data (as features and tables) or as ancillary documents (as report text, metadata or graphics).

Data Model Design: Requirements and Challenges

Geology Across the NPS is Varied and Diverse:

- Each geologic terrain often has its own set of geologic features and observations, and such geologic diversity requires a data model that is flexible and can accommodate new features.

  - Igneous and/or metamorphic geology (Yosemite NP and Shenandoah NP)
  - Sedimentary and stratified geology (Grand Canyon NP and Canyonlands NP)
  - Volcanic terrains (Yellowstone NP, Craters of the Moon NMON & NPRES, and Hawaii Volcanoes NP)

Grand Canyon NP (photo by Ron Karpilo)

Data Model Design: Requirements and Challenges

Geology Across the NPS is Varied and Diverse:

- Glacial terrains (Glacier NP, and Glacier Bay NP & NPRES)
- Coastal geomorphic and barrier island terrains (Cape Hatteras NS and Cape Cod NS)
- Historic mining districts (Death Valley NP and Klondike Gold Rush NHP)

** Surficial geology and special derivative maps (e.g., hazard probability, erosion susceptibility).

Glacier Bay NP & NPRES
(photo by Ron Karpilo)

Data Model Design: Requirements and Challenges

Map Scale and Map Compilation Considerations:

- On large–scale maps, features are frequently more abundant and diverse, particularly point features (preferred GRI source map scale is 1:24,000 for most parks).

- Features often vary in their spatial representation (i.e., polygon, line or point) depending on map scale and their extent.

- Many GRI park maps are a compilation of multiple source maps.

  - Frequently involves the integration of many geologic features.
  - Line and point features are not omitted in compilations.

Data Model Design: Summary

- As there is varied and diverse geology across the NPS, our anticipated data users are not geologists, their uses of our data vary, we often use large-scale source maps, and we frequently produce map compilations:

  Our data model needed to be flexible, not too technical, yet preserve all source map information, and present geologic features in data layers and attribution that can easily be understood and used in a GIS by our users.

Mount Rainer NP
(photo by Ron Karpilo)

Data Model Implementation: GIS Format and Design

GIS Data Format and Architecture:

- Geologic-GIS data is implemented in an ESRI 9.X personal geodatabase as polygon, line and point feature classes.

  - We continue to evaluate a move to an ESRI 9.X file-based geodatabase format.

- Feature class attribute tables are comprised of just those attribute fields necessary to fully capture all applicable attribution.

- Geologic features are often grouped into data layers (feature classes) based upon the geologic processes that created them (e.g., deformation/structural, volcanic, glacial) for ease of presentation for our intended users.

Data Model Implementation: Feature Classes

- Many data model feature classes can be repeated if warranted (e.g., for different structure contour lines or for different area hazards).

- To implement many feature classes our data model employs the use of shared schema. Feature classes share the same schema when they have the same:

  - spatial geometry (i.e., polygon, line or point).
  - attribute fields (the minimum required to fully attribute) .
  - table-to-table relationships.
  - topological rules.

- Shared data model schema are referred to as a "Template Feature Class Definition" in our data model. 7 template feature class definitions are employed to represent 44 of the 56 possible feature classes.

Data Model Implementation: Feature Classes

Data Model Template Feature Class List:

Polygon

Geologic Units

Other Area Units*

Other Area Types*

Line

Geologic Contacts

Other Area Contacts and Boundaries*

Geologic Line Units*

Faults

Folds

Structure Contour, Other Value and Related Subsurface Lines*

Geologic Cross Section Lines

Linear Geologic Features and Extent Lines*

Point

Geologic Point Units

Geologic Attitude Observation Localities

Geologic Observation Localities

Geologic and Other Point Features*

Geologic Sample Localities

Geologic (Non–Attitude) Measurement Localities

Seismic Localities

Map Symbology

Cape Hatteras NS
(photo by US ACE FRF)

* Indicates a template feature class definition

Data Model Implementation: Feature Classes

- Example: The "Other Area Types" template feature class definition is used to implement 8 data model feature classes.

Feature Class Definition Attribute Table Parameters

Field Name	Field Alias	Data Type	Allow Nulls	Implemented Domain	Precision	Scale	Length
OBJECT_ID*	NA	Object ID	–	–	–	–	–
SHAPE*	NA	Geometry	Yes	–	–	–	–
FUID	Unique Feature ID	Long Integer	No	–	0	–	–
FTYPE	Feature Type	Short Integer	No	Variable (Coded)	0	–	–
NOTES	Notes	Text	No	–	–	–	254
LBL	Label	Text	Yes	–	–	–	60
GMAP_ID (1)	Source Map ID	Long Integer	No	–	0	–	–
SHAPE_Length*	NA	Double	Yes	–	0	–	–
SHAPE_Area*	NA	Double	Yes	–	0	–	–

* Standard ESRI 9.X personal geodatabase feature class attribute field (see ESRI ArcGIS software).
(1) Relationship class foreign key field to MAP table (see Relationship Classes below).

Feature Class Definition List

Alteration and Metamorphic Areas (AMA)

Aquifers (AQU)

Deformation Areas (DEF)

Glacial Area Features (GAF)

Hazard Area Features (HZA)

Mine Area Features (MAF)

Outcrops (OCR)

Weathered Area Features (WTH)

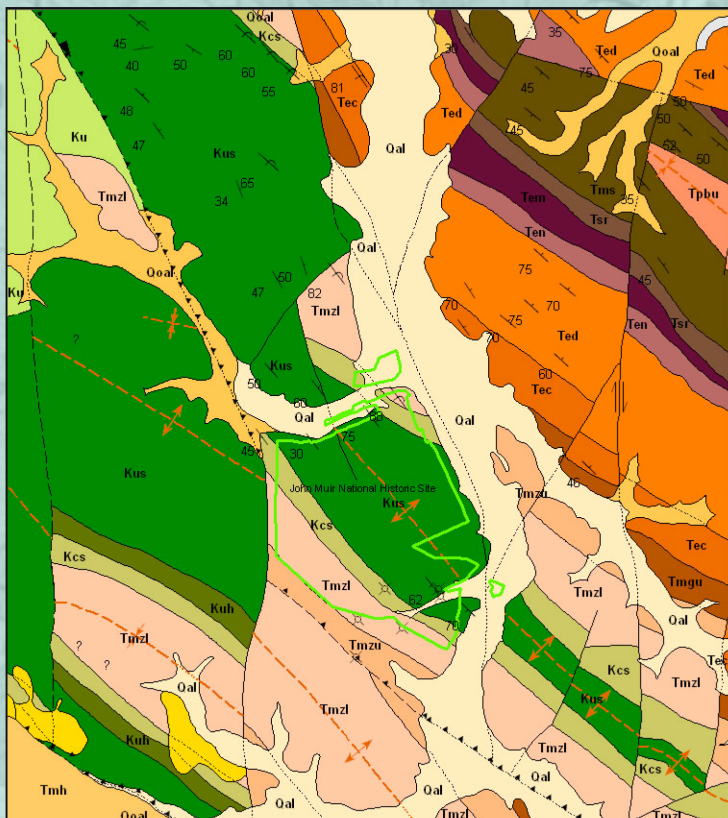
Deformation Areas (DEF) Feature Type (DEF_FTYPE) Domain List

Coded Domain Value	Definition
1	fault zone
2	shear zone
3	mylonite zone
4	ductile deformation
5	ground–crack zone
6	structural zone
7	high-strain zone
8	breccia zone

** Data model feature class abbreviations are in parentheses.

John Muir NHS (JOMU) Map

JOMU Geology (park is outlined in apple green)



Source Map: Haydon, Wayne D., 1995, Landslide Hazards in the Martinez-Orinda-Walnut Creek area, Contra Costa County, California, Landslide Hazard Identification Map No.32, OFR 95-12, Division of Mines and Geology, California Department of Conservation, 4 plates, 1:24,000 scale

JOMU Feature Class List

- **Digital Geologic Map of John Muir National Historic Site and Vicinity, California**
  - JOMU - Geologic Attitude Observation Localities
  - JOMU - Mine Point Features
  - JOMU - Map Symbology
  - JOMU - Folds
  - JOMU - Faults
  - JOMU - Hazard Point Features
  - JOMU - Hazard Feature Lines
  - JOMU - Hazard Area Feature Boundaries
  - JOMU - Hazard Area Features
  - JOMU - Relative Landslide Susceptibility
    - JOMU - Relative Landslide Susceptibility Boundaries
    - JOMU - Relative Landslide Susceptibility Areas
  - JOMU - Relative Debris-Flow Susceptibility
    - JOMU - Relative Debris-Flow Susceptibility Boundaries
    - JOMU - Relative Debris-Flow Susceptibility Areas
  - JOMU - Geologic Contacts
  - JOMU - Geologic Units

JOMU Hazard Feature Classes (expanded to show features)

- JOMU - Relative Landslide Susceptibility
  - JOMU - Relative Landslide Susceptibility Boundaries
  - JOMU - Relative Landslide Susceptibility Areas
    - least susceptible (1)
    - marginally susceptible (2.1)
    - marginally susceptible (2.2)
    - generally susceptible (3)
    - most susceptible (4.1)
    - most susceptible (4.2)
    - not classified (cf)
- JOMU - Relative Debris-Flow Susceptibility
  - JOMU - Relative Debris-Flow Susceptibility Boundaries
  - JOMU - Relative Debris-Flow Susceptibility Areas
    - least susceptible (A)
    - marginally susceptible (B)
    - most susceptible (C)
    - not classified (cf)

- JOMU - Hazard Point Features
  - small mass movement
- JOMU - Hazard Feature Lines
  - landslide direction, known or certain
  - landslide escarpment/scarp, known or certain
  - debris flow, known or certain
  - gully, known or certain
  - earthflow, known or certain
- JOMU - Hazard Area Feature Boundaries
- JOMU - Hazard Area Features
  - landslide area
  - earthflow
  - gully

Data Model Implementation: GIS Building Blocks

Attribute Fields:

- Only 25 data model attribute fields are employed for data model feature classes. Custom attribute fields can also easily be added.

Feature Class Attribute Field and Field Parameters Table

Field Name	Field Alias	Data Type	Allow Nulls	Implemented Domain	Precision	Scale	Length
AM_ROT	ArcMap Rotation	Short Integer	No	Range	0	–	–
DEPTH	Depth	Double	No	–	8	3	–
DP	Dip/Plunge	Short Integer	No	Range/Coded	0	–	–
FNAME	Feature Name	Text	No	–	–	–	60
FSUBTYPE (2)	Feature Subtype	Short Integer	No	Subtype	0	–	–
FTYPE	Feature Type	Short Integer	No	Coded	0	–	–
FUID	Unique Feature ID	Long Integer	No	–	0	–	–
FVALUE	Feature Value	Long Integer	No	Coded	0	–	–
GLG_SYM (1)	Unit Symbol	Text	No	–	–	–	12
GMAP_ID (1)	Source Map ID	Long Integer	No	–	0	–	–
LBL	Label	Text	Yes	–	–	–	60
LOC_ID	Location ID	Text	No	–	–	–	40
MAG	Magnitude	Float	No	–	4	2	–
NOTES	Notes	Text	No	–	–	–	254
OBJECT_ID*	NA	Object ID	–	–	–	–	–
PLUNGE	Plunge	Short Integer	No	Coded	0	–	–
POS	Position	Short Integer	No	Coded	0	–	–
SAM_AGE	Sample Age	Text	No	–	–	–	40
SAM_NO	Sample Number	Text	No	–	–	–	40
SEC_ABRV	Section Abbreviation	Text	No	–	0	–	6
SENS	Sensitivity	Short Integer	No	Coded	0	–	–
SHAPE*	NA	Geometry	Yes	–	–	–	–
SHAPE_Area*	NA	Double	Yes	–	0	–	–
SHAPE_Length*	NA	Double	Yes	–	0	–	–
SORT_NO	Sort Number	Float	No	–	6	3	–
SRC_ABRV	Source Abbreviation	Text	No	–	0	–	6
SRC_SYM	Source Unit Symbol	Text	No	–	–	–	12
ST	Strike/Trend	Short Integer	No	Range/Coded	0	–	–
UNITS	Units	Short Integer	No	Coded	0	–	–

* Standard ESRI geodatabase feature class attribute field.
(1) Relationship class foreign key field.
(2) Denotes a Subtype field.

Geologic Units (GLG) Feature Class Attribute Table Parameters

Field Name	Field Alias	Data Type	Allow Nulls	Implemented Domain	Precision	Scale	Length
OBJECT_ID*	NA	Object ID	–	–	–	–	–
SHAPE*	NA	Geometry	Yes	–	–	–	–
FUID	Unique Feature ID	Long Integer	No	–	0	–	–
GLG_SYM (2)	Unit Symbol	Text	No	–	–	–	12
SRC_SYM	Source Unit Symbol	Text	No	–	–	–	12
SORT_NO	Sort Number	Float	No	–	6	3	–
NOTES	Notes	Text	No	–	–	–	254
LBL	Label	Text	Yes	–	–	–	60
GMAP_ID (1)	Source Map ID	Long Integer	No	–	0	–	–
SHAPE_Length*	NA	Double	Yes	–	0	–	–
SHAPE_Area*	NA	Double	Yes	–	0	–	–

* Standard ESRI 9.X geodatabase feature class attribute field.
(1) Relationship class foreign key field to MAP table.
(2) Relationship class foreign key field to UNIT table.

Data Model Implementation: GIS Building Blocks

Attribute Domains:

- Both coded and ranged attribute domains are implemented.

Strike/Trend (STRIKE_ROTATION) Ranged Domain List

Ranged Domain Value	Definition
1	minimum value
359	maximum value
999	not applicable (NULL) value

Fault Feature Type (FLT_FTYPE) Domain List

Coded Domain Value	Definition
1	thrust fault
2	reverse fault
3	low–angle normal fault
4	normal fault
5	right–lateral strike–slip fault
6	left–lateral strike–slip fault
7	reverse right–lateral strike–slip fault
8	reverse left–lateral strike–slip fault
9	normal right–lateral strike–slip fault
10	normal left–lateral strike–slip fault
11	unknown offset/displacement fault
12	high–angle reverse fault
13	detachment fault/decollement
14	high–angle fault
15	right–lateral fault, vertical displacement/offset unknown
16	left–lateral fault, vertical displacement/offset unknown
17	gravity slide plane
18	overturned thrust fault
19	high–angle right–lateral strike–slip fault
20	high–angle left–lateral strike–slip fault
21	overturned detachment fault/decollement
22	vertical fault
23	thrust right–lateral strike–slip fault
[illegible]	thrust left–lateral strike–slip fault
	ductile fault
	normal fault, horizontal displacement/offset unknown
	fault scarp
	shear zone
	tear fault
	tectonic slide

Bryce Canyon NP (BRCA) Fault Layer (Feature Class) Attribute Table**

Attributes of BRCA - Faults

Unique Feature ID	Feature Type	Feature Subtype	Positional Accuracy	Feature Name
33	normal fault	Fault	approximate	Paunsaugunt Fault Zone (northeast segment)
21	thrust fault	Fault	concealed	Ruby's Inn Thrust Fault
35	normal fault	Fault/Contact (GLGA)	known or certain	NA
36	normal fault	Fault/Contact (GLGA)	approximate	Paunsaugunt Fault Zone (southwest segment)
37	normal fault	Fault	known or certain	NA
38	normal fault	Fault	approximate	NA
39	left-lateral fault, vertical displacement/offset unknown	Fault	approximate	NA

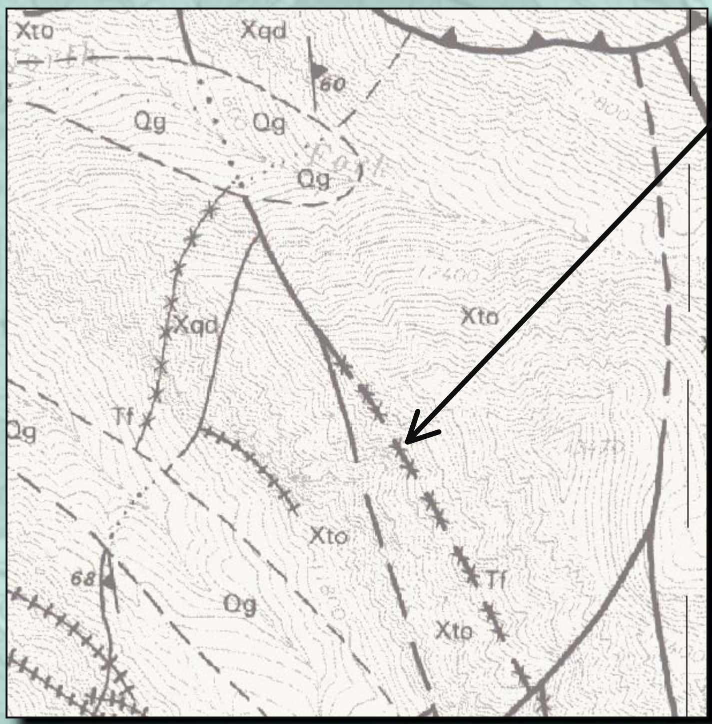
Record: 118 Show: All Selected Records (0 out of 351 Selected) Options

**partial attribute table, many attribute fields are not shown.

Data Model Implementation: GIS Building Blocks

Geodatabase Topology:

- Implemented to ensure no gaps, no overlaps, and no dangles, and to ensure feature coincidence between features where appropriate.



Dike intruded along a fault

Feature coincidence is maintained between the Linear Dikes (DKE) and Faults (FLT) feature classes via topology rules.

**If either line is spatially edited using topology edit tools then both features are edited.

Source Map: Johnson, Bruce R. and Bruce, Robert M., 1991, Reconnaissance Geologic Map of parts of the Twin Peaks and Blanco Peak Quadrangles, Alamosa, Costilla and Huerfano Counties, Colorado, U.S. Geological Survey, Miscellaneous Investigations Series Map MF-2169, 1:24,000 scale

Data Model Implementation: GIS Tables

Ancillary Tables and Table Relationships:

- Two standard ancillary tables: the Geologic Unit Information (UNIT) and Source Map Information (MAP).
- Feature classes are linked to ancillary tables via relationship classes using a common key field.
- Additional GIS tables, if present in the source data, are easily accommodated.

Shenandoah NP (SHEN) Geologic Unit Information (UNIT) Table

Attributes of shenunit

Unit Symbol *	Unit Name	Group	Formation	Member	Sort Number	Age Text
Ob	Beekmantown Group, undivided	Beekmantown Group	---	---	16	Middle and Lower Ordovician
Os	Stonehenge Limestone	---	Stonehenge Limestone	---	17	Lower Ordovician
OCc	Conococheague Limestone	---	Conococheague Limestone	---	18	Lower Ordovician and Upper Cam
Ce	Elbrook Limestone	---	Elbrook Limestone	---	19	Upper and Middle Cambrian
Cwa	Waynesboro Formation	---	Waynesboro Formation	---	20	Lower Cambrian
Ct	Tomstown Formation	---	Tomstown Formation	---	21	Lower Cambrian
Cca	Antietam Formation	Chilhowee Group	Antietam Formation	---	22	Lower Cambrian
Cch	Harpers Formation	Chilhowee Group	Harpers Formation	---	23	Lower Cambrian
Cchs	Harpers Formation, ferruginous metasandstone	Chilhowee Group	Harpers Formation	ferruginous metasandstone	24	Lower Cambrian
Ccw	Weverton Formation	Chilhowee Group	Weverton Formation	---	25	Lower Cambrian

Record: 15 Show: All Selected Records (0 out of 64 Selected) Options

Attributes

SHEN - Bedrock Units
Cch
Source Map Information
Geologic Unit Information
Harpers Formation

1 features

Property	Value
OBJECTID	23
Unit ID	7129
Unit Symbol	Cch
Unit Name	Harpers Formation
Group	Chilhowee Group
Formation	Harpers Formation
Member	---
Sort Number	23
Age Text	Lower Cambrian
Period Age	Cambrian
Minimum Age	Lower Cambrian
Maximum Age	Lower Cambrian

Data Model Implementation: Summary

- The GRI geology-GIS data model is implemented in an ESRI 9.X personal geodatabase and makes use of much of the functionality (i.e., attribute domains, topology, relationship classes) this format provides.

- Many data model feature classes are implemented using shared schema.

- Our data model preserves all source map geologic information, and presents this information in data layers and attribution that can easily be understood and used by our users.

- As a result of our design and implementation methodology, our data model is highly flexible and can easily accommodate the addition of new features as well as new data layers as these are recognized.

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- GRI Data Model Implementation

Part II: A Programmatic Approach to Digital Map Production

- GRI Digital Map Production Workflow
- Our Mode of Programming
- Show GRI Production Tools

GRI Digital Map Production Workflow

→ **Project set up** → **Capture/ Conversion** → **Quality Checking** → **Data Finalization**

Project set up

Create geodatabase
Add topology

Capture/ Conversion

Parse features
Custom field mapping and data loading
Compile
Clip

Quality Checking

Append features to new geodatabase
Batch frequency report
Quality control tool

Data Finalization

Repath layer files
Create metadata
Create relationship classes
Finalize MXD
Calculate unique identifiers
Export shapefiles
Zip GRI product

Our Mode of Programming

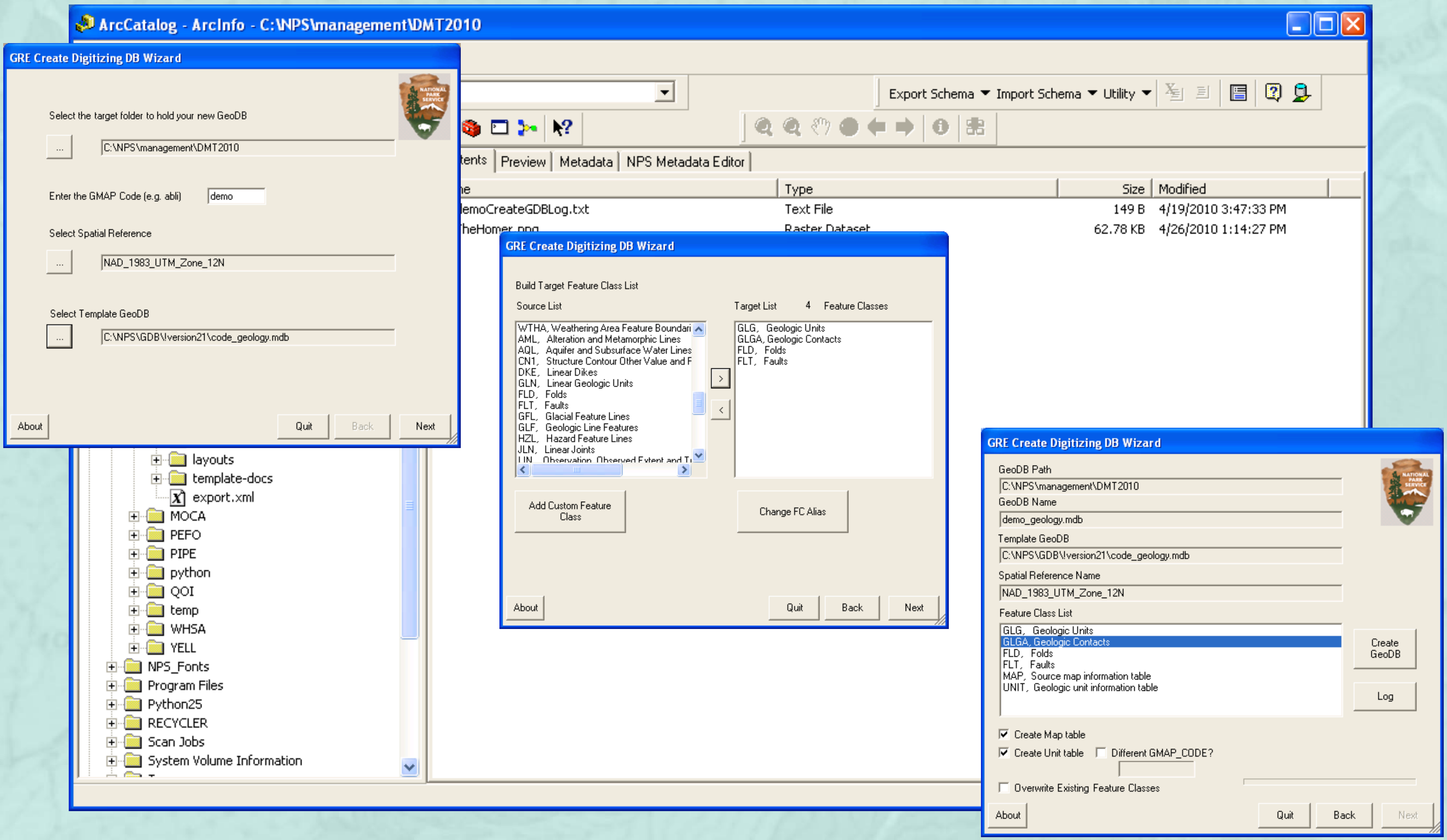
- Tasked with creating data products, not tool sets
  - Planning is key
  - Recycle/Reuse?
- Employ an iterative approach
  - Keep it simple to start
  - Forces us to think modular

Our Mode of Programming

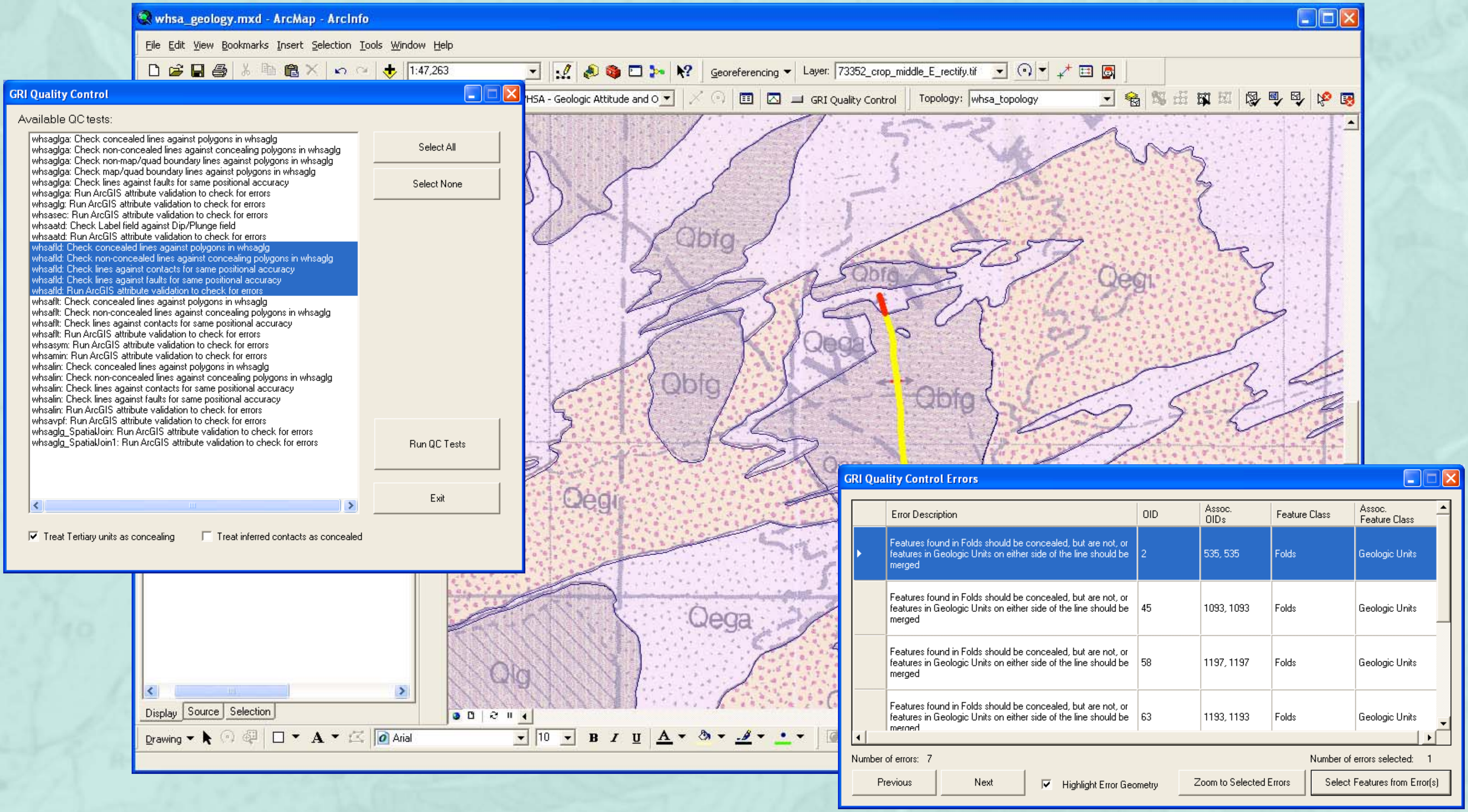
What we don’t want…

“The Homer”

GRI Create Geodatabase Tool



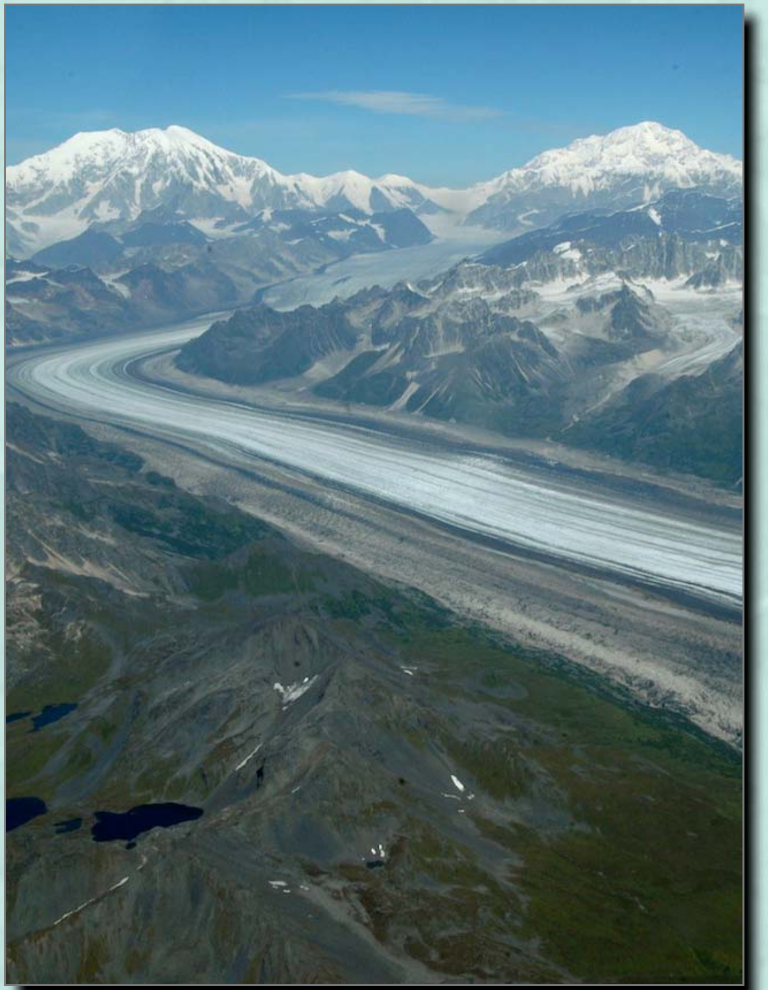
GRI Quality Control Tool



Summary and Conclusion

- Designed and implemented a data model that is:
  - Very flexible – accommodates varying terrains and map scales
  - Communicates effectively to intended users

- Continue to utilize custom tool development to aid in map production:
  - Streamlined digital map production process
  - Ensured quality and consistent geologic map datasets



Denali NP & NPRES (photo by Ron Karpilo)

GRI Product Information and Status

GRI Digital Map Product:

- GIS Readme file
- 9.x GIS data (personal geodatabase and shapefiles
- 9.x ArcMap document and layer files complete with symbology
- FGDC-compliant metadata file
- GRI Map Help PDF document containing geologic unit descriptions, as well as ancillary information from all source maps

GRI Completed Map Data (as of May, 2010):

- Parks: 173 (plus 10 non-resource parks)
- Maps: 614
- Source maps used: 672

Grand Canyon NP (photo by Ron Karpilo)

URLs:
NPS Geology-GIS Data Model documents: http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm
Digital Geologic-GIS data available at the NPS Data Store: http://science.nature.nps.gov/nrdata/
Geologic Resources Inventory products: http://www.nature.nps.gov/geology/inventory/publications