The following was presented at DMT'11
(May 22-25, 2011).

The contents are provisional and will be
superseded by a paper in the
DMT'11 Proceedings.

See also earlier Proceedings (1997-2010)
http://ngmdb.usgs.gov/info/dmt/

Utilizing NCGMP09 for student mapping projects:

Advancing the techniques of tomorrow's geologic mappers

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DMT11 - Williamsburg, VA

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Introduction

This presentation summarizes our implementation of the NCGMP09 database design in student mapping projects in our research group at UTK

Highlighting:

- Increased productivity in the field
- Interoperability of the datasets, ease of compilation
- Furthering the technological development of the future geologic mapping community
- Use of a standardized data model allows the students to focus on geology, not the technical aspects of geodatabase design.

User Profile

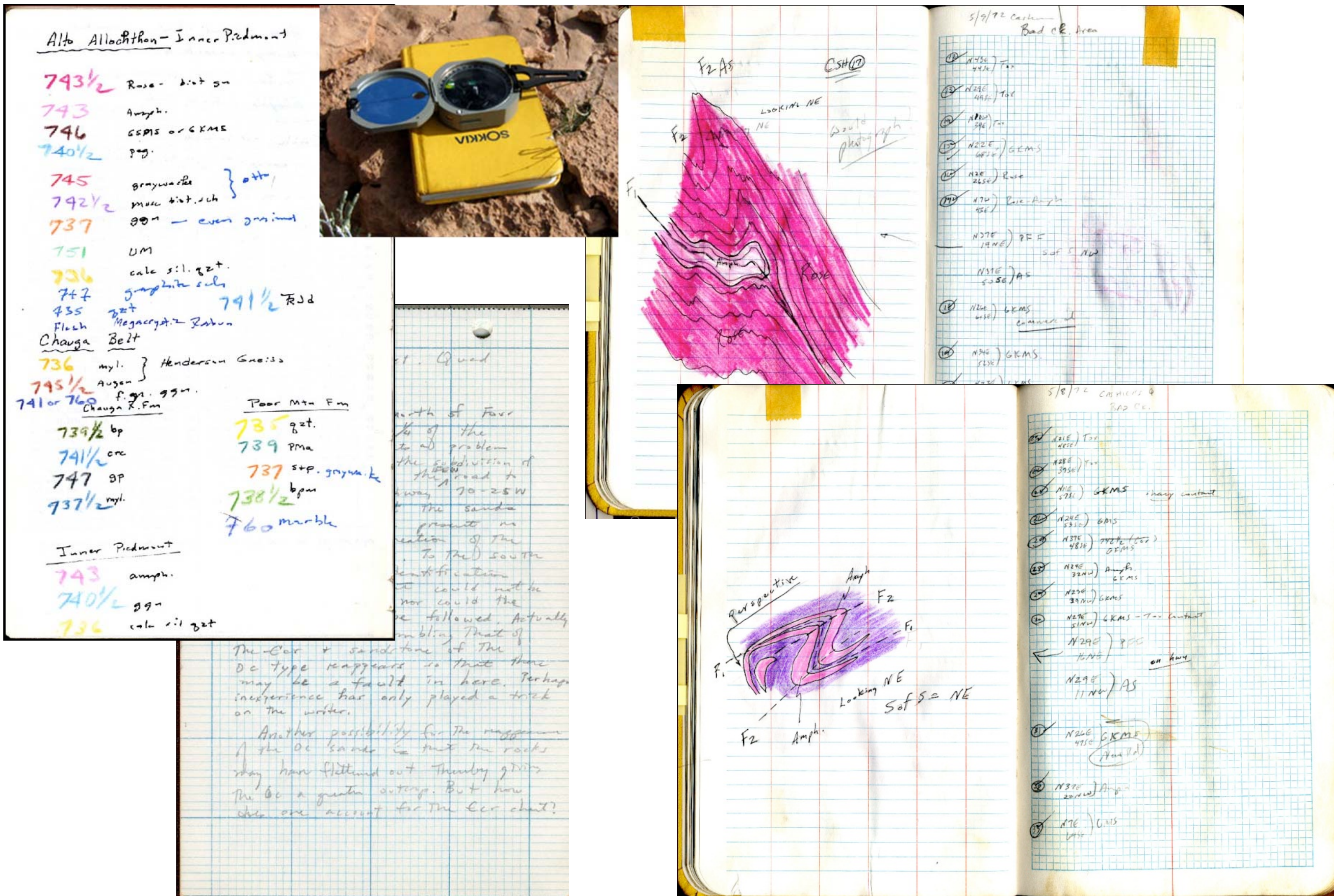
- Incoming graduate student
  (occasionally an advanced undergraduate student)
  - Strong interest in structural geology
    - Completed courses in structural geology and tectonics
  - Focus on field mapping techniques
    - Completed an accredited field camp to learn basic skills associated with gathering measurements and how to interpret them
  - Basic understanding of GIS
    - Completed an undergraduate course in GIS

My goal

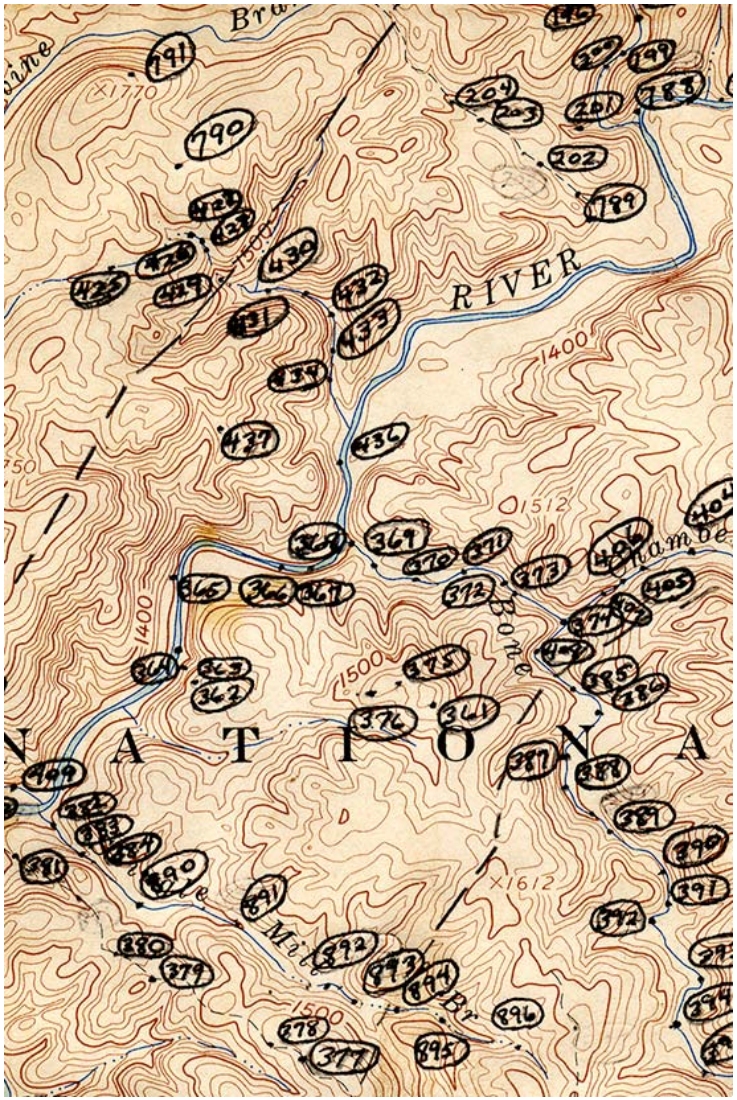
I strive to educate students on the best methods, techniques, and technology to accomplish the detailed mapping portion of their research.

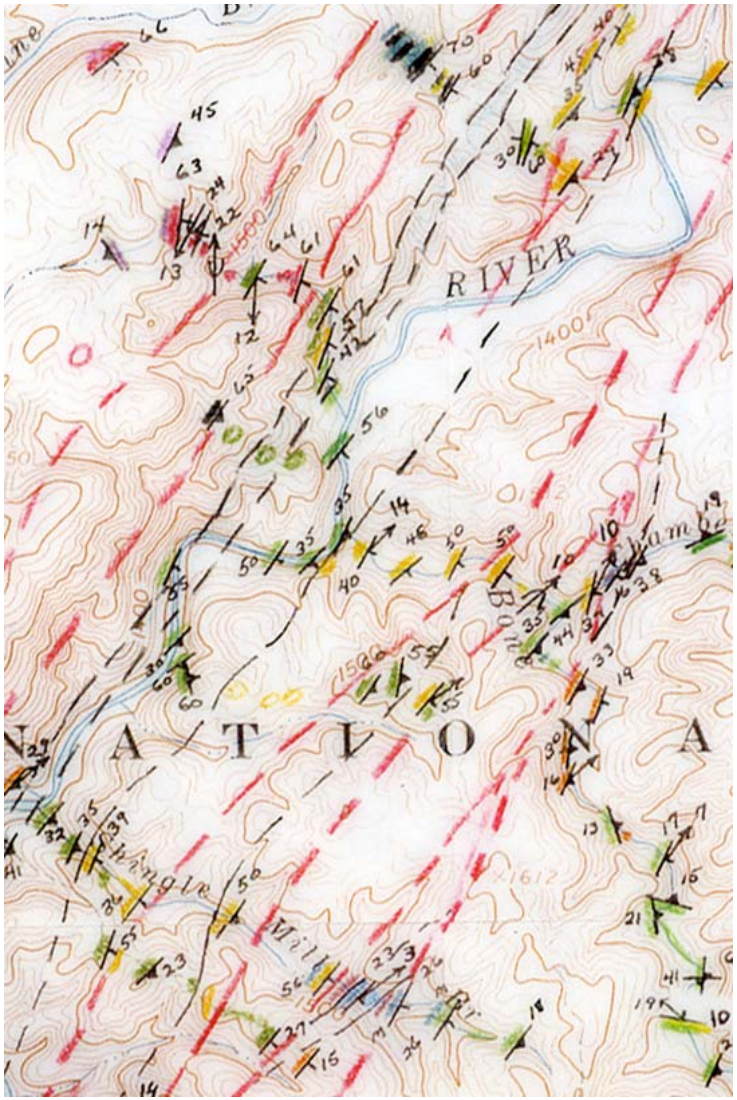
Over the last 4 years, our mapping program has transformed from a very traditional style (employed for over 40 years by our mentor Dr. Robert D. Hatcher Jr., with the addition of computer drafting in the last 15-20 years), to a modern system of capture, plot, draft, analyze, and publish.

Traditional mapping…



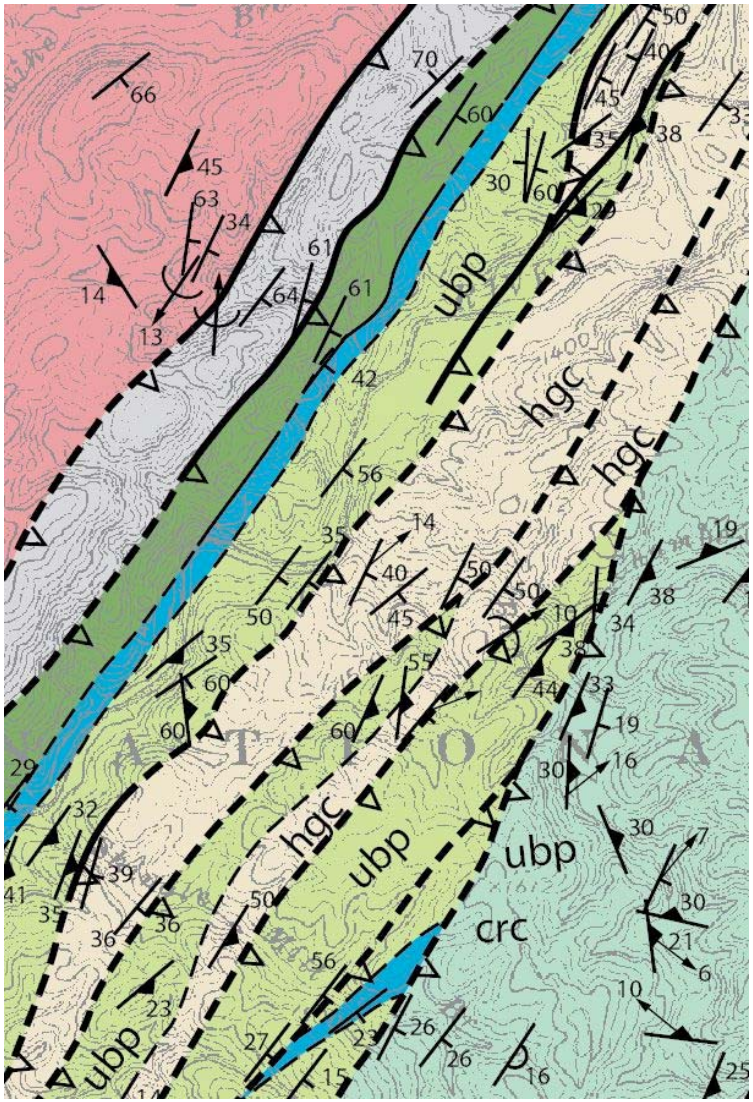
Traditional mapping…





Traditional mapping…

	A	C	D	F	G	I	J	K
1	FID	Date	StationID	Type	MapUnit	Azimuth	Inclination	Notes
164	163	1/11/1990	106	bedding inclined	Cr	53	37	
165	164	1/11/1990	106	joint inclined		263	69	
166	165	1/11/1990	106	joint inclined		234	44	
167	166	1/11/1990	106	joint inclined		131	74	
168	167	1/11/1990	106	cleavage inclined	Och	64	83	2mm spaced cleavage
169	168	1/11/1990	106	bedding inclined	Och	83	26	
170	169	1/11/1990	106	joint inclined	Och	168	75	
171	170	1/11/1990	106	joint inclined	Och	222	39	
172	171	1/11/1990	106	joint inclined	Och	288	59	
173	172	1/11/1990	106	joint inclined	Och	132	86	
174	173	1/11/1990	107	bedding inclined	Och	43	43	thin nod/shaly ls w/ interlayered red beds
175	174	1/11/1990	108	bedding inclined	Och	61	49	thin nod/shaly ls w/ interlayered red beds
176	175	1/11/1990	109	bedding inclined	Och	57	48	mostly ls (med mass to sh.) w/ minor red
177	176	1/11/1990	110	bedding inclined	Och	57	43	
178	177	1/11/1990	111	bedding inclined	Och	58	42	nod/shaly ls w/ red
179	178	1/11/1990	112	bedding inclined	Och	63	43	shaly w/ red
180	179	1/11/1990	113	bedding inclined	Cr	57	47	Haw Ridge near Bull Run
181	180	1/11/1990	114	bedding inclined	Och	57	43	
182	181	1/30/1990	115	bedding inclined	Och	53	49	Off Edgemoor Rd opposite boat lake access
183	182	1/30/1990	116	bedding inclined	Och	67	51	thin bedded
184	183	1/30/1990	117	bedding inclined	Och	57	52	massive
185	184	1/30/1990	118	bedding inclined	Och	69	32	red & silty
186	185	1/30/1990	119	bedding inclined	Och	52	53	thin bedded
187	186	1/30/1990	120	bedding inclined	Olv	64	69	
188	187	1/30/1990	121	bedding inclined	Olv	59	44	
189	188	1/30/1990	122	bedding inclined	Oma	59	51	
190	189	1/30/1990	123	bedding inclined	Oma	58	47	
191	190	1/30/1990	124	bedding inclined	Oma	61	42	NW of Edgemoor Rd
192	191	2/13/1990	125	bedding inclined	Och	56	41	Haw Ridge Park; chirty ls, silty shaly ls, ls
193	192	2/13/1990	126	bedding inclined	Och	53	43	silty red & nodular ls
194	193	2/13/1990	127	bedding inclined	Cr	52	31	
195	194	2/13/1990	127	FSF		41	31	tight; SE limb 65 SE, NW limb 75 NW
196	195	2/13/1990	127	axial surface		42	74	V=NW
197	196	2/13/1990	127	joint inclined		326	83	
198	197	2/13/1990	128	bedding inclined	Cr	56	69	
199	198	2/13/1990	128	joint inclined		138	79	
200	199	2/13/1990	128	joint inclined		273	70	
201	200	2/13/1990	129	bedding inclined	Cr	62	42	
202	201	2/13/1990	130	bedding inclined	Cr	69	44	
203	202	2/13/1990	131	bedding inclined	Cpv	63	36	
204	203	2/13/1990	132	bedding inclined	Cpv	68	71	
205	204	2/13/1990	133	bedding inclined	Cpv	84	56	
206	205	2/13/1990	134	bedding inclined	Cr	63	37	
207	206	2/13/1990	135	bedding inclined	Cpv	53	57	
208	207	2/13/1990	135	joint inclined		142	87	
209	208	2/13/1990	135	joint inclined		193	34	
210	209	2/13/1990	135	joint inclined		238	72	
211	210	2/13/1990	135	joint inclined		112	89	
212	211	2/13/1990	135	joint inclined		147	78	
213	212	2/13/1990	135	joint inclined		108	73	
214	213	2/13/1990	136	bedding inclined	Cpv or Crt?	71	46	
215	214	2/13/1990	137	bedding inclined	Crt?	53	49	
216	215	2/13/1990	138	bedding inclined	Crt	69	59	
217	216	2/13/1990	139	bedding inclined	Crg or Crt	63	52	



… has its disadvantages

- Can often be long period of time between field observations and compilation/interpretation
- Disparate repositories of info: field book, several field sheets, spreadsheet, graphics file, etc.
- Time consuming to extract information from maps and tables
- Difficult to repurpose or compile information from multiple resources

The modern approach…

ArcPad Studio - [ArcPad_ga-nc_2011.vbs]

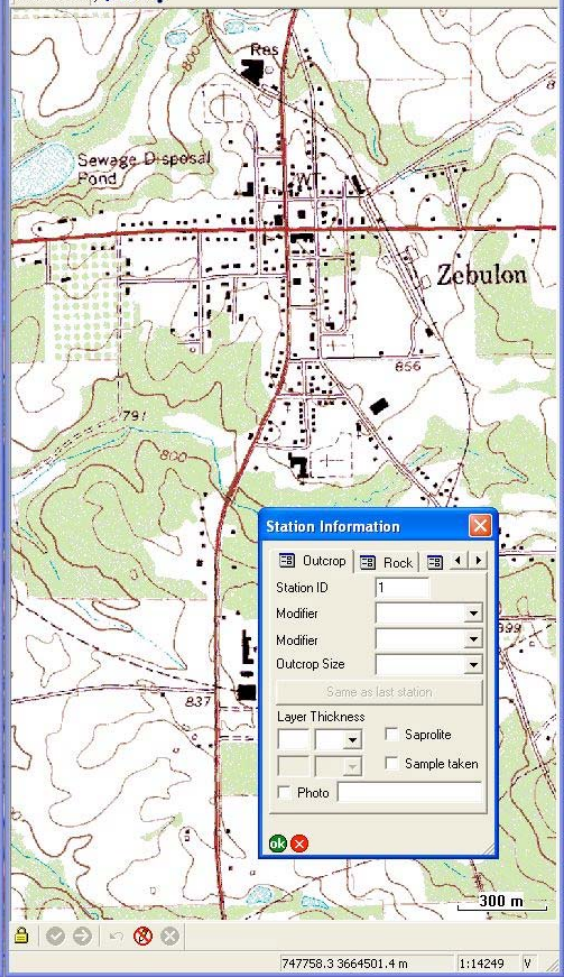
```
            Call Leadobjs.AddItem("Layered Metagraywacke","Layered Metagrawack
            Call Leadobjs.AddItem("MS Schist","MS Schist")
            Call Leadobjs.AddItem("BT Schist","BT Schist")
            Call Leadobjs.AddItem("MS-BT Schist","MS-BT Schist")
            Call Leadobjs.AddItem("Grt-Mica Schist","Grt-Mica Schist")
            Call Leadobjs.AddItem("Biotite Gneiss","Biotite Gneiss")
            Call Leadobjs.AddItem("Migmatite","Migmatite")
            Call Leadobjs.AddItem("Amphibolite","Amphibolite")
            Call Leadobjs.AddItem("Calc-silicate","Calc-silicate")
            Call Leadobjs.AddItem("Metagabbro","Metagabbro")
            Call Leadobjs.AddItem("Granitic Orthogneiss","Granitic Orthogneiss
        End If
        If (Application.Forms("StationEntry").Pages("RockTypePage").Controls(
            Leadobjs.Clear
            Call Leadobjs.AddItem("Shale","Shale")
            Call Leadobjs.AddItem("Siltstone","Siltstone")
            Call Leadobjs.AddItem("Sandstone","Sandstone")
            Call Leadobjs.AddItem("Graywacke","Graywacke")
            Call Leadobjs.AddItem("Arkose","Arkose")
            Call Leadobjs.AddItem("Conglomerate","Conglomerate")
            Call Leadobjs.AddItem("Sed Breccia","Sed Breccia")
        End If
        If (Application.Forms("StationEntry").Pages("RockTypePage").Controls(
            Leadobjs.Clear
            Call Leadobjs.AddItem("Mylonite","Mylonite")
            Call Leadobjs.AddItem("Breccia","Breccia")
            Call Leadobjs.AddItem("Quartz Vein","Quartz Vein")
            Call Leadobjs.AddItem("Colluvium","Colluvium")
            Call Leadobjs.AddItem("Other","Other")
            '*** Added by ALW 02/25/2008
            Call Leadobjs.AddItem("Si Cataclasite","Si Cataclasite")
            Call Leadobjs.AddItem("Alluvium","Alluvium")
            '*** End
        End If
    End Sub

Sub CheckForNumeric 'Called by Onvalidate event of StationValue(Control) a
    Dim InclineValue
    Dim varValue
    varValue = ThisEvent.Object.Value
    If (Not Isnumeric(varValue)) And (varValue <> "") Then
        ThisEvent.Result = False
        ThisEvent.MessageText = "This must be a numeric Value"
        ThisEvent.MessageType = vbExclamation
    End If
End Sub

Sub CheckAzimuthRange 'Called by Onvalidate event of AzimuthValue(1-5)(Cor
    Dim AzimuthValue
    AzimuthValue = ThisEvent.Object.Value
    If Isnumeric(AzimuthValue) Then
        If (AzimuthValue > 359) Or (AzimuthValue < 0) Then
            ThisEvent.Result = False
            ThisEvent.MessageText = "Azimuth out of range (0-359)"
            ThisEvent.MessageType = vbExclamation
        End If
    End If
End Sub
```

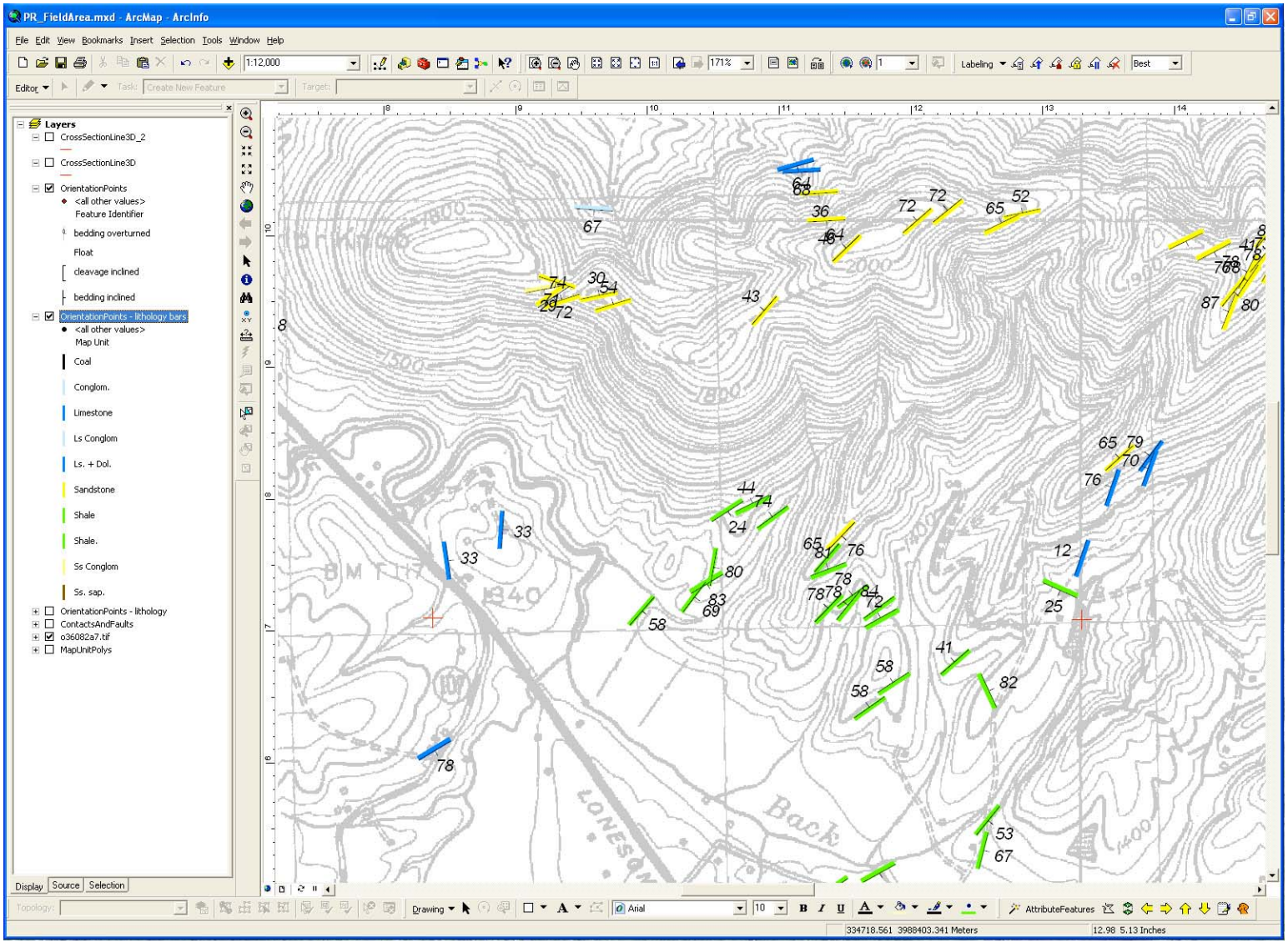
For Help, press F1 | Ln 1, Col 1 | NUM

FieldMap_Snyder.apm - ArcPad

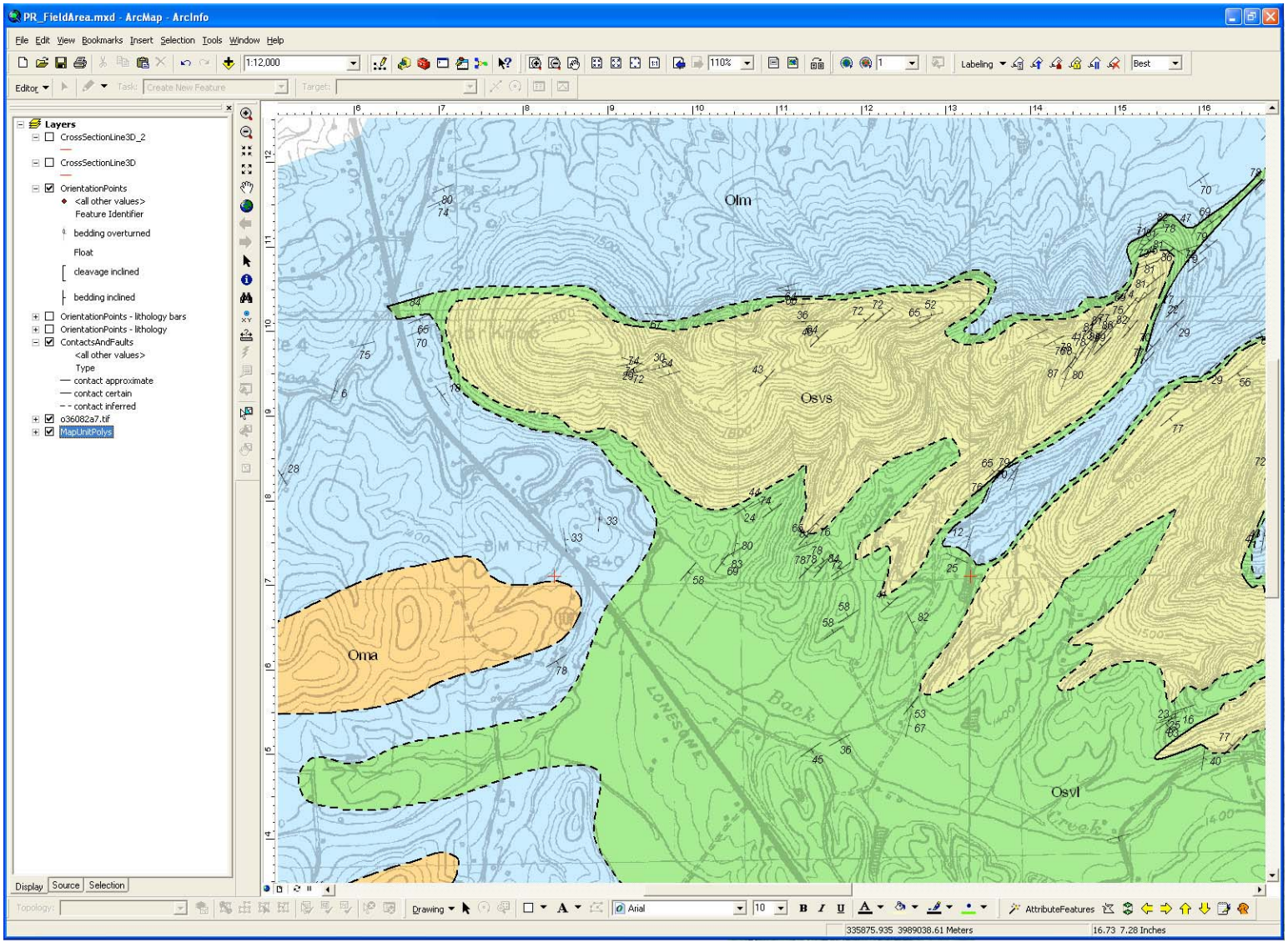


747758.3 3664501.4 m | 1:14249

The modern approach…



The modern approach…



…also had disadvantages

- Lack of structure after capture
  - Lots of shapefiles, folders, ancillary files, etc.
  - No naming conventions being used
  - No consistent schema for derived datasets: contacts and faults, map unit polygons, etc. were a mess.
- Still difficult to compile
  - Incorrect or unknown spatial references
  - Schema and attribution differences = difficultly applying consistent symbology
- OVERALL => INCONSISTENT

Why NCGMP09?

- GDB design “heavy lifting” has been done! Well-vetted structure, created by geologists for geologists
- Relatively easy for students to read documentation and understand where the pieces go
- Less time spent trying to learn technical aspects of database design
- Geodatabase allows for better data management, helps keep project data organized
- All student mapping projects are built using same schema:
  - Students are speaking the same language
  - Interoperability: eases collaboration, compilation
  - Teaches them good habits for future projects

Mapping with NCGMP09…

values of Label commonly are very different from Type values or are formed by convolving Type and IdentityConfidence (e.g. "Me" and "questionable" to show "Me?"); (2) special characters, inappropriate for Type values, may be used to enable labeling; and (3) for line features, Symbol is determined by the combination of Type, LocationConfidenceMeters, ExistenceConfidence, and IdentityConfidence.

Polygons, lines, and topology: what goes where?

By convention, a geologic map depicts the distribution of earth materials on a particular map horizon, commonly the earth's surface. Map unit polygons (including water, snowfields, and glaciers) are bounded by contacts, faults, shorelines, snowfield boundaries, scratch boundaries, or the map boundary. With some exceptions, which are unusual enough to require mention, contacts do not separate polygons of the same map unit, though faults may do so. Map-unit polygons may be partially bisected by a fault (i.e., using GIS jargon, the fault "dangles").

The distribution of map units on the particular map horizon is recorded in the polygon feature class "MapUnitPolys". Contacts between map units, faults that bound map units, and associated dangling faults are recorded in the line feature class "ContactsAndFaults". Elements of these feature classes participate in topological relations that are described below. Elements are assigned to these feature classes to simplify enforcement of the topological relations (when constructing a geodatabase) and to facilitate topological queries (when using a geodatabase).

Some maps show contacts and faults that are concealed beneath covering units (e.g., beneath thin unconsolidated deposits, or beneath open water). These concealed contacts and faults should be recorded in the feature class "ContactsAndFaults", and be coded as IsConcealed = "Y". Such concealed contacts and faults are not involved in topology with MapUnit polygons. Some concealed contacts and faults may dangle.

Many, but not all, geologic maps contain other classes of features that do not participate fully in map topology (e.g., fossil localities, fold axes, bedding orientation measurements). Feature classes for encoding such features are described below under "As-needed elements".

We understand that some producers of geodatabases will choose to create polygons and edit linework in the absence of a topology relationship class. For instance, rather than using topology editing tools to synchronously edit shared boundaries between lines and polygons, many users prefer to edit using a procedure involving lines, polygon attribute label points, and the creation of polygons when the linework is finished, without the use of geodatabase topology rules. For the purposes of this design (data delivery), the method used to produce the feature classes does not matter, only that the feature classes in the published database follow the topology rules outlined below.

Directional lines

Many geologic lines have directionality, equivalent to handedness. Examples are thrust and normal faults, which by convention have ornaments (teeth, tics, bar-and-ball symbols) that point towards the upper (overlying) plate. We prescribe the right-hand rule to store this directionality: such lines should be created or edited (e.g., using the 'flip' tool in ArcMap) such that any ornament, or the

DRAFT -- To be published in DMT'09 Proceedings
(see http://ngmdb.usgs.gov/Info/dmt/)

upper direction in the case of U-D labels on faults, is to the right of the line while traveling from the start of the line to the end of the line.

Required elements

GeologicMap (feature dataset)

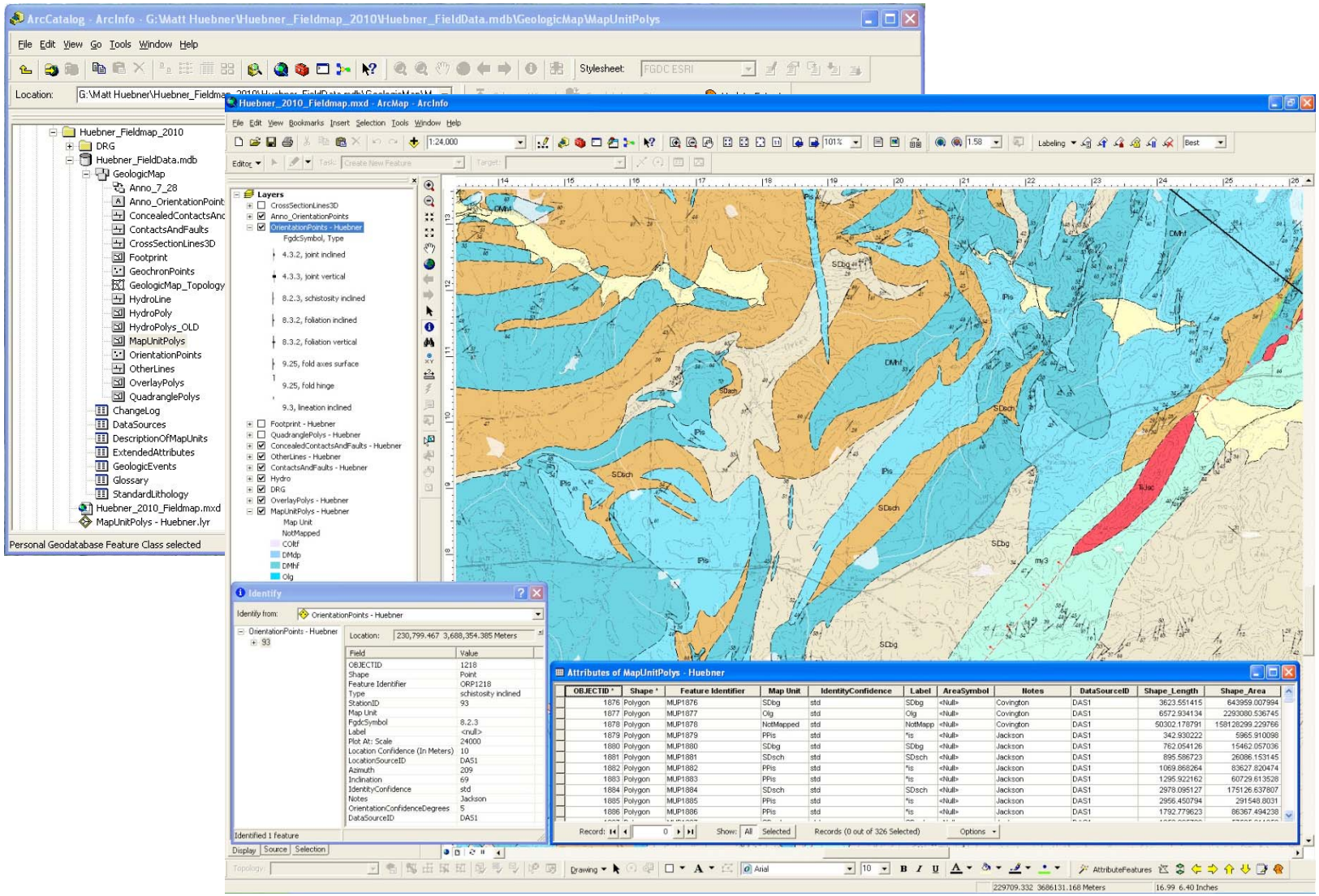
This feature dataset is equivalent to the map graphic: it contains all the geologic content (but not the base map) within the neatline. All elements share a single spatial reference framework. Blue highlighting indicates fields whose content must be defined in the Glossary table.

MapUnitPolys (polygon feature class)

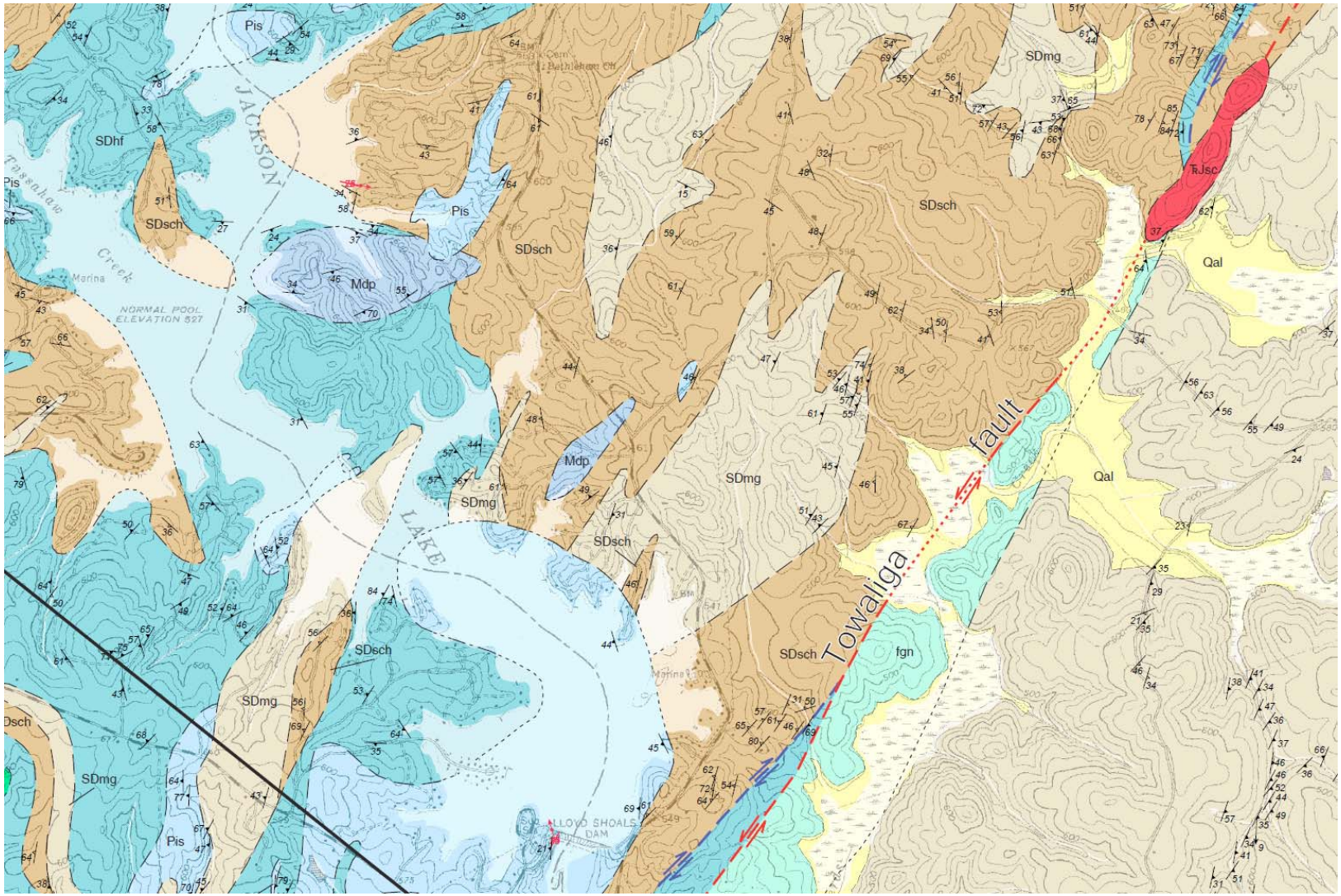
Fields:

MapUnitPolys_ID	*Primary key. Example Values = MUP1, MUP2, MUP3, etc. Values must be unique in database as a whole*
MapUnit	*Short plain-text key (identifier) for the map unit. Example values: Qal, Tg, Kit, water, Trc3, etc. Foreign key to DescriptionOfMapUnits table. Null values not permitted—a mapped polygon must have an assigned map unit*
IdentityConfidence	*How confidently is this polygon identified as MapUnit? Value is usually "certain", "questionable", or "unspecified". Null values not permitted. Suggest setting default value to 'certain'*
Label	*Calculated from MapUnit//Label and IdentityConfidence: if IdentityConfidence = "questionable", then append "?" to MapUnit//Label. Allows for subscripts and special characters. Null values OK*
Symbol	*References an area fill symbol (background color + optional pattern). Area fill symbols must be defined in an accompanying style file. If cartographic representations are used to symbolize map units, the value may be null or blank. Null values permitted*
RuleID	*Data type = integer. If Cartographic Representations are used, this field is required; otherwise it is not included in the table (see* Symbolization *section, below).*
Override	*Data type = blob. If Cartographic Representations are used, this field is required; otherwise it is not included in the table (see* Symbolization *section, below).*
Notes	*Null values OK. Free text for additional information specific to this polygon*
DataSourceID	*Foreign key to DataSources table, to track provenance of each data element. Null values not permitted*

Mapping with NCGMP09…

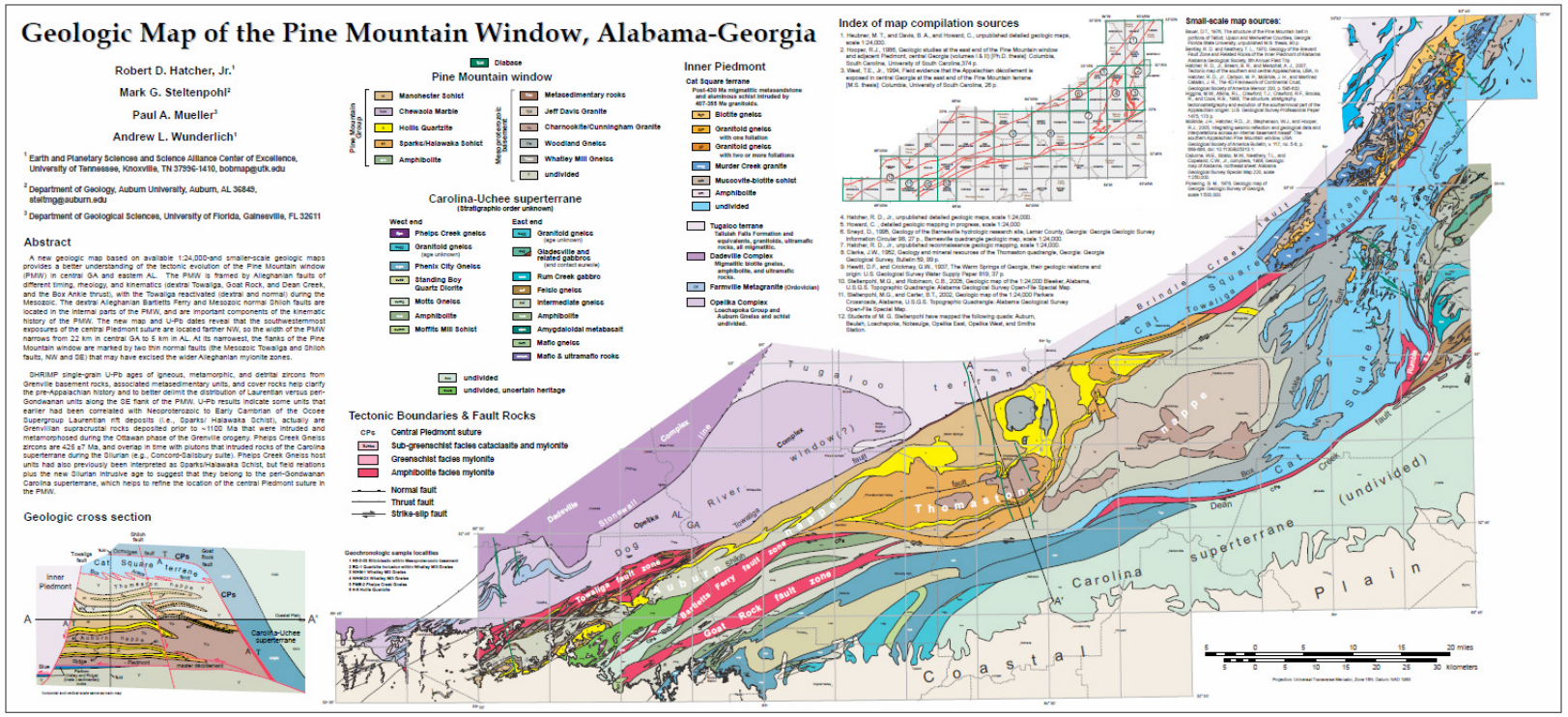


Mapping with NCGMP09…



Mapping with NCGMP09…

Compiled from over a dozen individual maps, all of which were digitized in, or converted to, an NCGMP09-compliant geodatabase. Thanks to matching schemas and consistent attribution, preparing the compiled map was sped up considerably.



Final thoughts on NCGMP09…

- Interoperability!
- Collaboration!
- Reinforces good data organization habits!

Final thoughts on NCGMP09…

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Ultimately allowing scientists to do…

BETTER SCIENCE!

Thank you for your time and attention!

Questions?