



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superseded by a paper in the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

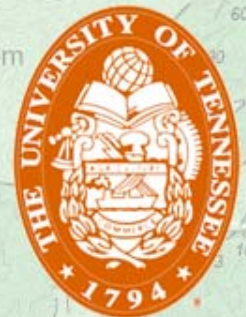
Andrew L. Wunderlich
gibbon@utk.edu

DMT11 - Williamsburg, VA

Tectonics & Structural Geology Research Group

Department of Earth & Planetary Sciences
and Science Alliance Center of Excellence

University of Tennessee, Knoxville



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...

Alt. Allocation - Inner Piedmont

- 743 1/2 Rose - bit on
- 743 Amph.
- 746 ssps or GEMS
- 740 1/2 pg.
- 745 graywacke } ortho/
- 742 1/2 mass bit. sch
- 737 80% - even grained

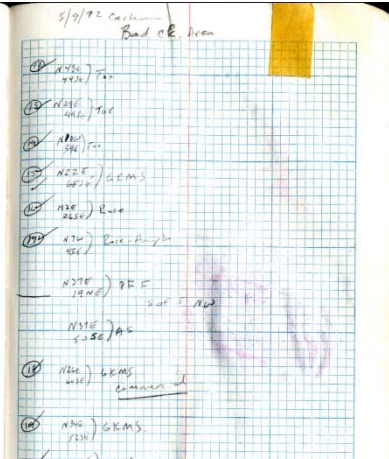
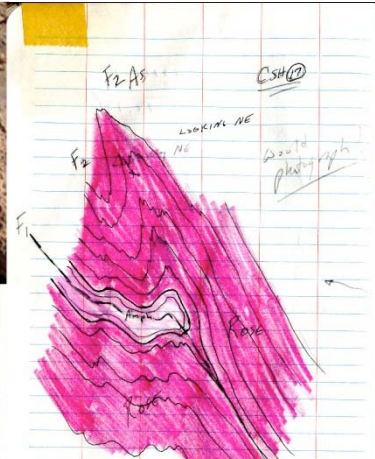
- 751 UM
- 736 calc sil. gzt.
- 747 gneiss sch
- 735 Flich
- 735 Megacryst. Zircon
- 741 1/2 RJD
- Chauga Belt

- 736 myl. } Henderson Gneiss
- 745 1/2 Augen
- 741 or 740 Figs. gzt.
- Chauga R. Fm

- | | |
|--------------|--------------------|
| 739 1/2 bp | 735 gzt. |
| 741 1/2 ore | 739 pma |
| 747 sp | 737 stp. graywacke |
| 737 1/2 myl. | 738 1/2 bpm |
| | 760 marble |

Inner Piedmont

- 743 amph.
- 740 1/2 ggn
- 736 calc sil gzt

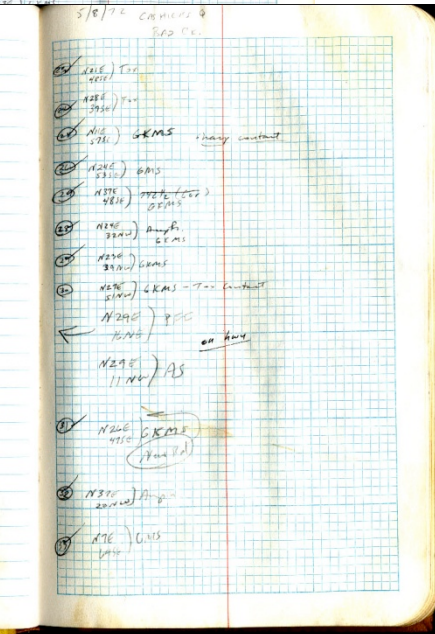
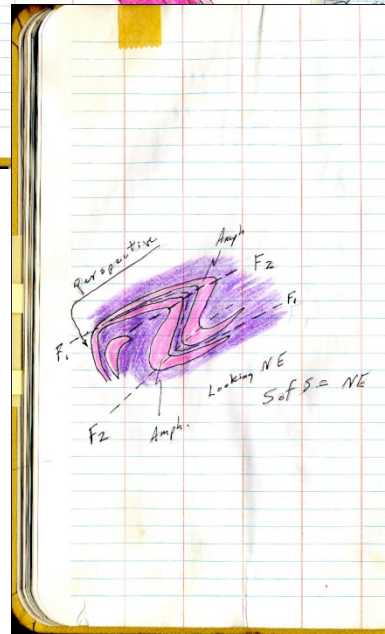


et. Quad

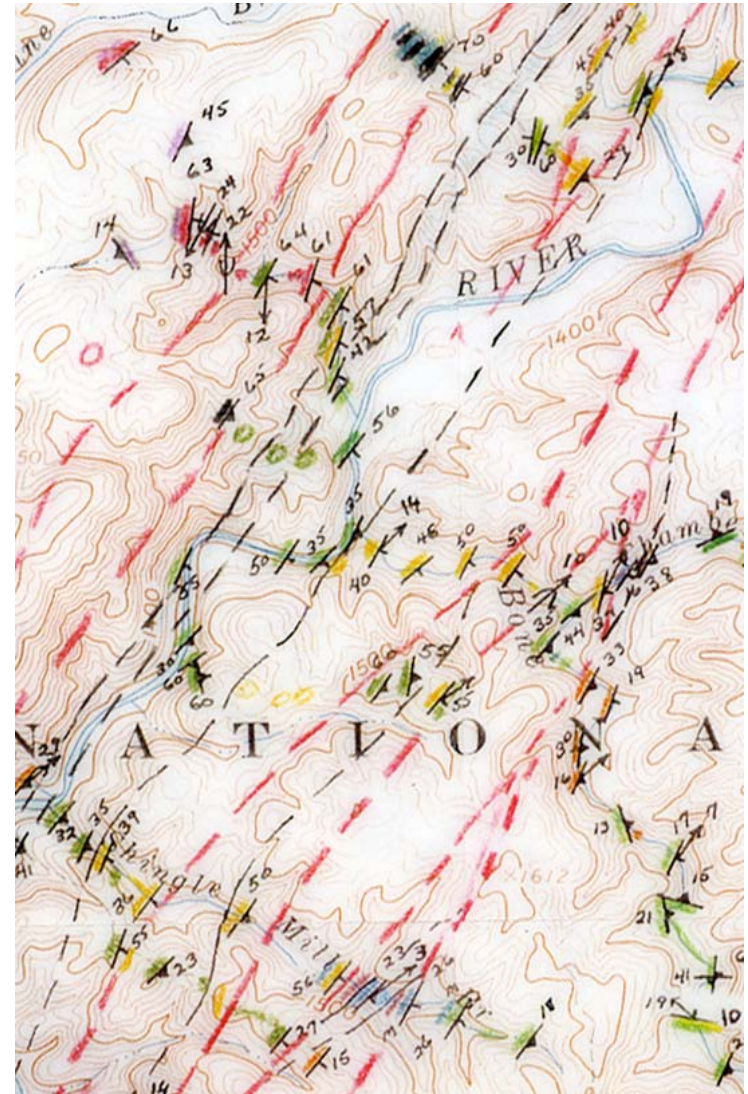
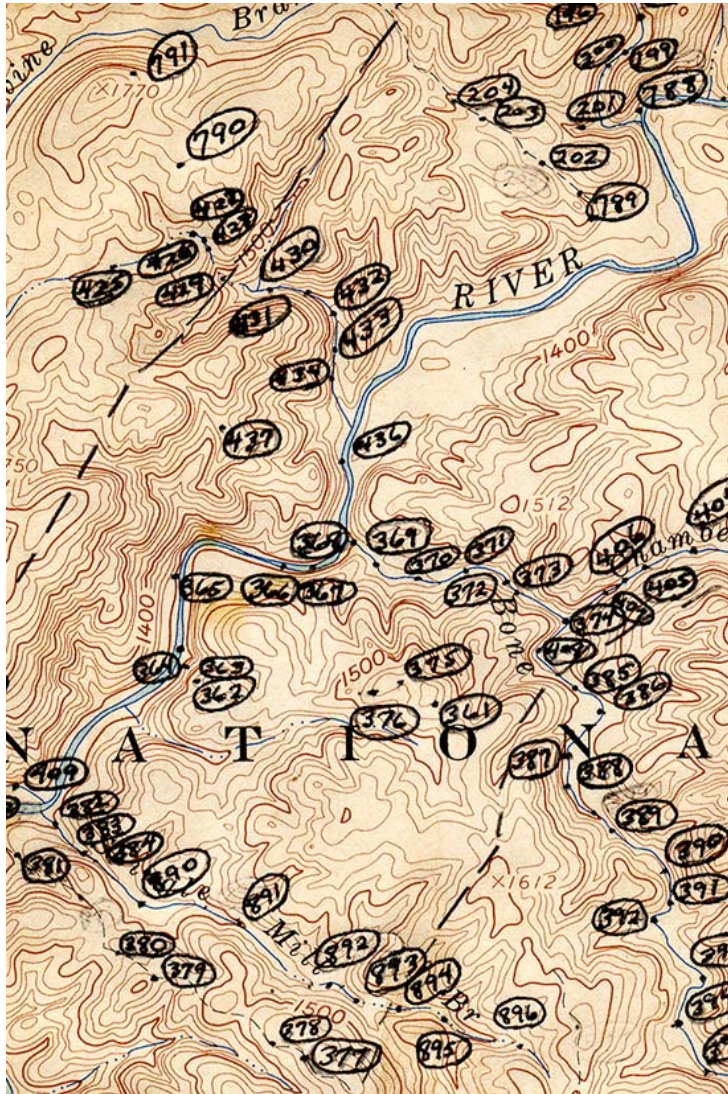
North of Fair
 top of the
 to all problem
 the solution of
 the road at
 away 170-25W
 the sandstone
 granite in
 relation of the
 to the south
 identification
 could not be
 nor could the
 be followed. Actually
 sampling that of

The Carr & sandstone of the
 Dc type appears so that there
 may be a fault in here. Perhaps
 interference has only played a trick
 on the writer.

Another possibility for the mapping
 of the Dc bands is that the rocks
 may have flattened out. Therefore gneiss
 may be a quartzite. But how
 else can we account for the Carr sheet?

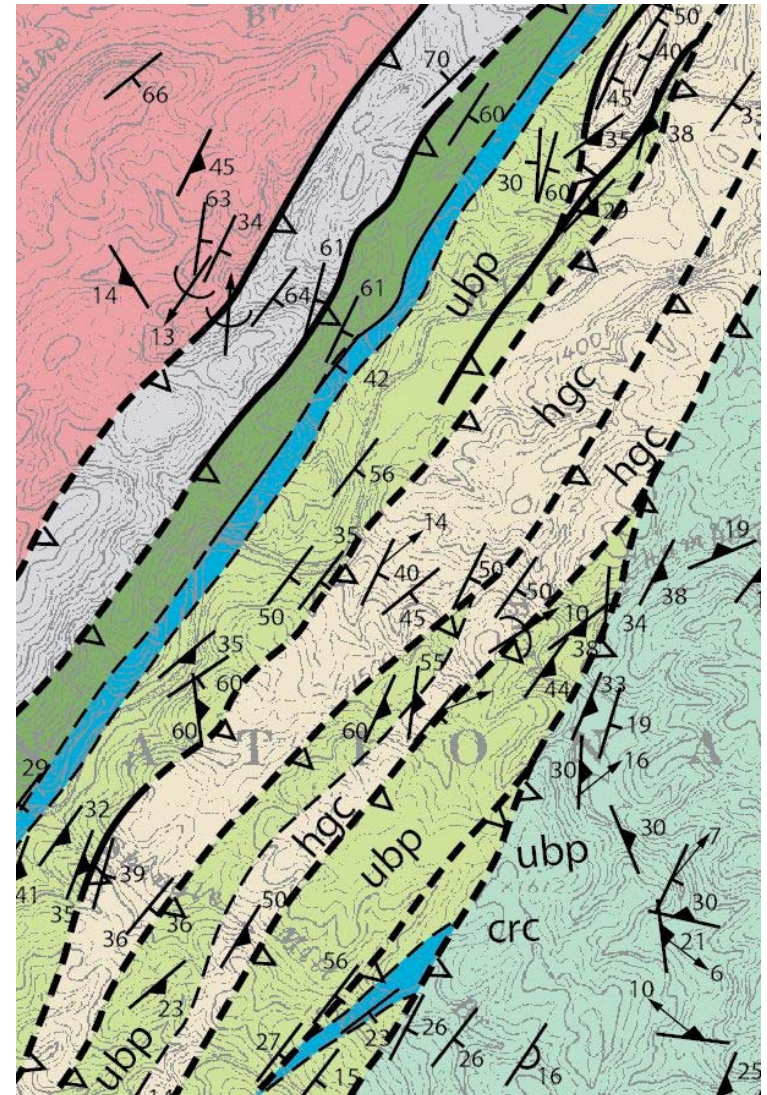


Traditional mapping...



Traditional mapping...

1	A	C	D	F	G	I	J	K
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; cherty 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 Cr?	71	46	
215	214	2/13/1990	137	bedding inclined	Cr?	53	49	
216	215	2/13/1990	138	bedding inclined	Cr	69	59	
217	216	2/13/1990	139	bedding inclined	Cr or Cr	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...



The image displays two windows from the ArcPad software suite. The left window, titled "ArcPad Studio - [ArcPad_ga-nc_2011_vbs]", shows a Visual Basic script for managing a list of rock types. The right window, titled "FieldMap_Snyder.apm - ArcPad", shows a topographic map of the Zebulon area with a "Station Information" dialog box open over it.

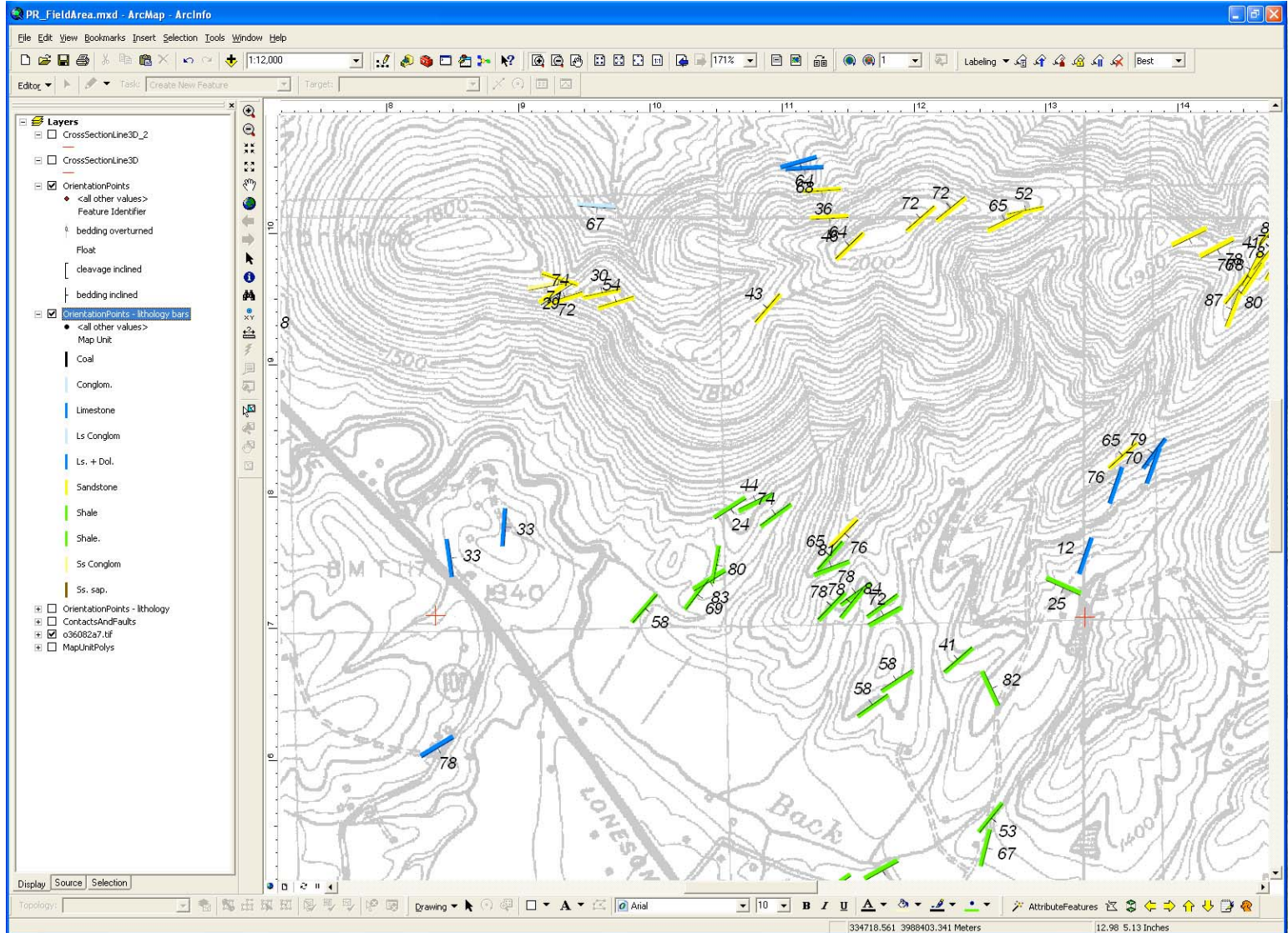
```
206 Call Leadobjs.AddItem("Layered Metagraywacke", "Layered Metagrawacke")
207 Call Leadobjs.AddItem("MS Schist", "MS Schist")
208 Call Leadobjs.AddItem("BT Schist", "BT Schist")
209 Call Leadobjs.AddItem("MS-BT Schist", "MS-BT Schist")
210 Call Leadobjs.AddItem("Grt-Mica Schist", "Grt-Mica Schist")
211 Call Leadobjs.AddItem("Biotite Gneiss", "Biotite Gneiss")
212 Call Leadobjs.AddItem("Migmatite", "Migmatite")
213 Call Leadobjs.AddItem("Amphibolite", "Amphibolite")
214 Call Leadobjs.AddItem("Calc-silicate", "Calc-silicate")
215 Call Leadobjs.AddItem("Metagabbro", "Metagabbro")
216 Call Leadobjs.AddItem("Granitic Orthogneiss", "Granitic Orthogneiss")
217 End If
218 If (Application.Forms("StationEntry").Pages("RockTypePage").Controls(
219 Leadobjs.Clear
220 Call Leadobjs.AddItem("Shale", "Shale")
221 Call Leadobjs.AddItem("Siltstone", "Siltstone")
222 Call Leadobjs.AddItem("Sandstone", "Sandstone")
223 Call Leadobjs.AddItem("Graywacke", "Graywacke")
224 Call Leadobjs.AddItem("Arkose", "Arkose")
225 Call Leadobjs.AddItem("Conglomerate", "Conglomerate")
226 Call Leadobjs.AddItem("Sed Breccia", "Sed Breccia")
227 End If
228 If (Application.Forms("StationEntry").Pages("RockTypePage").Controls(
229 Leadobjs.Clear
230 Call Leadobjs.AddItem("Mylonite", "Mylonite")
231 Call Leadobjs.AddItem("Breccia", "Breccia")
232 Call Leadobjs.AddItem("Quartz Vein", "Quartz Vein")
233 Call Leadobjs.AddItem("Colluvium", "Colluvium")
234 Call Leadobjs.AddItem("Other", "Other")
235 '*** Added by ALW 02/25/2008
236 Call Leadobjs.AddItem("Si Cataclasite", "Si Cataclasite")
237 Call Leadobjs.AddItem("Alluvium", "Alluvium")
238 '*** End
239 End If
240 End Sub
241
242 Sub CheckForNumeric 'Called by Onvalidate event of StationValue(Control)
243 Dim InclineValue
244 Dim varValue
245 varValue = ThisEvent.Object.Value
246 If (Not Isnumeric(varValue)) And (varValue <> "") Then
247 ThisEvent.Result = False
248 ThisEvent.MessageText = "This must be a numeric Value"
249 ThisEvent.MessageType = vbExclamation
250 End If
251 End Sub
252
253 Sub CheckAzimuthRange 'Called by Onvalidate event of AzimuthValue(1-5)(Control)
254 Dim AzimuthValue
255 AzimuthValue = ThisEvent.Object.Value
256 If Isnumeric(AzimuthValue) Then
257 If (AzimuthValue > 359) Or (AzimuthValue < 0) Then
258 ThisEvent.Result = False
259 ThisEvent.MessageText = "Azimuth out of range (0-359)"
260 ThisEvent.MessageType = vbExclamation
261 End If
262 End If
263 End Sub
264
```

The "Station Information" dialog box includes the following fields and options:

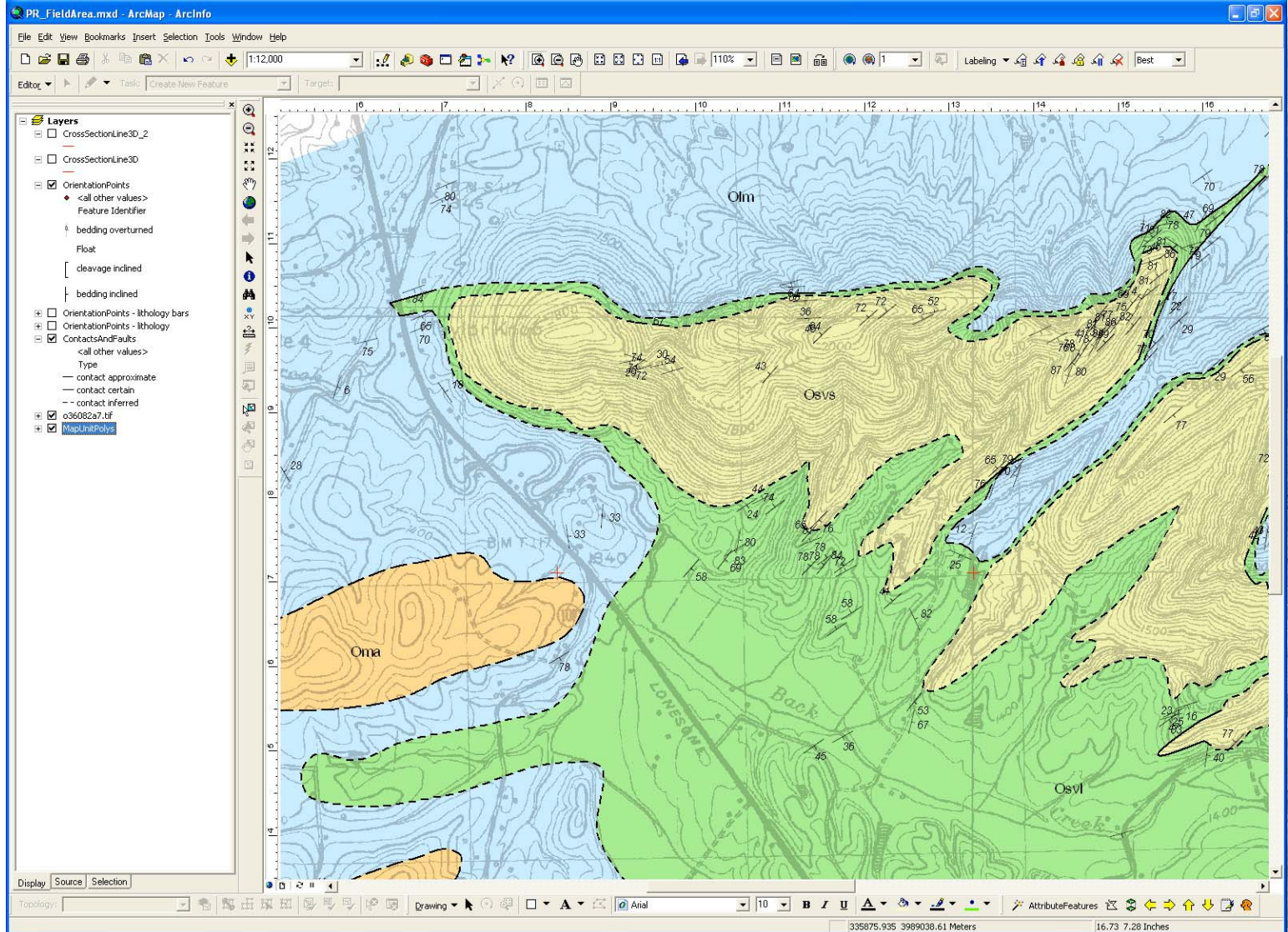
- Station ID: 1
- Modifier: [Dropdown]
- Outcrop Size: [Dropdown]
- Same as last station: [Checked]
- Layer Thickness: [Dropdown]
- Saprolite:
- Sample taken:
- Photo:



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 = difficulty 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...

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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

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(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...

The screenshot displays the ArcMap interface with the following components:

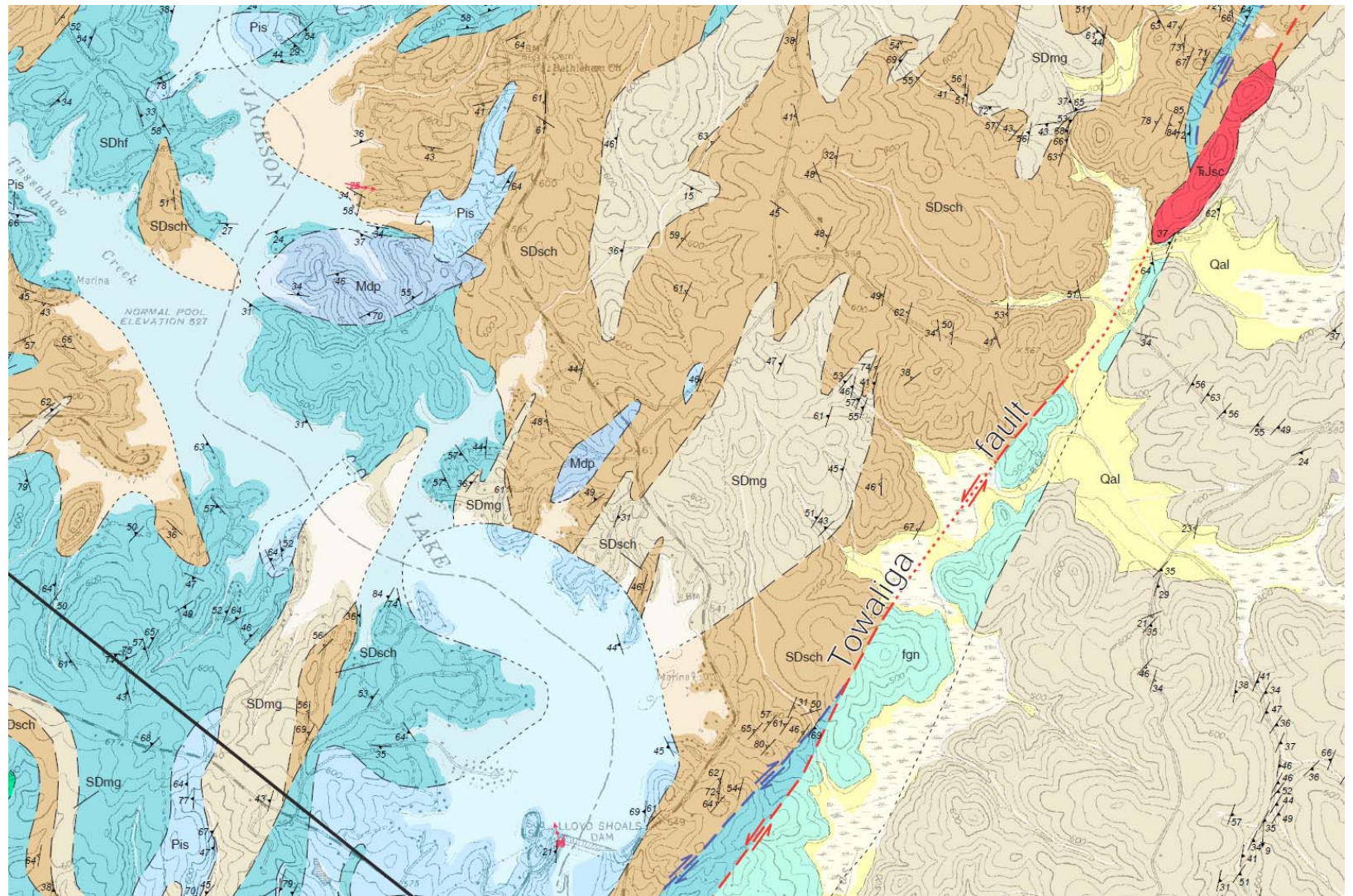
- Layers Panel:** Lists various map layers such as 'Anno_7_28', 'GeologicMap_Topology', and 'MapUnitPolys - Huebner'. The 'MapUnitPolys - Huebner' layer is selected.
- Map View:** Shows a geological map with different colored regions representing various geological units. A red polygon is highlighted on the map.
- Identity Window:** Shows the details for the selected feature (OrientationPoints - Huebner).

Field	Value
OBJECTID	1218
Shape	Point
Feature Identifier	ORP1218
Type	schistosity inclined
StationID	93
Map Unit	
FgdcSymbol	8.2.3
Label	crd3
Flx At: Scale	24000
Location Confidence (In Meters)	10
LocationSourceID	DAS1
Azimuth	209
Inclination	69
IdentityConfidence	std
Notes	Jackson
OrientationConfidenceDegrees	S
DataSourceID	DAS1
- Attributes Table:** Shows a list of map units with their properties.

OBJECTID	Shape	Feature Identifier	Map Unit	IdentityConfidence	Label	AreaSymbol	Notes	DataSourceID	Shape_Length	Shape_Area
1876	Polygon	MUP1876	SDbg	std	SDbg	<Null>	Covington	DAS1	3823.551415	643959.007994
1877	Polygon	MUP1877	Olg	std	Olg	<Null>	Covington	DAS1	6572.934134	2293080.536745
1878	Polygon	MUP1878	NotMapped	std	NotMapped	<Null>	Covington	DAS1	50302.178791	158128209.229766
1879	Polygon	MUP1879	PPis	std	PPis	<Null>	Jackson	DAS1	342.930222	5965.910098
1880	Polygon	MUP1880	SDbg	std	SDbg	<Null>	Jackson	DAS1	762.054126	15462.057036
1881	Polygon	MUP1881	SDsch	std	SDsch	<Null>	Jackson	DAS1	895.589723	26096.153145
1882	Polygon	MUP1882	PPis	std	PPis	<Null>	Jackson	DAS1	1069.868264	83627.820474
1883	Polygon	MUP1883	PPis	std	PPis	<Null>	Jackson	DAS1	1295.922162	60729.613529
1884	Polygon	MUP1884	SDsch	std	SDsch	<Null>	Jackson	DAS1	2978.095127	175126.637807
1885	Polygon	MUP1885	PPis	std	PPis	<Null>	Jackson	DAS1	2956.450794	291548.8031
1886	Polygon	MUP1886	PPis	std	PPis	<Null>	Jackson	DAS1	1792.779623	86367.494238

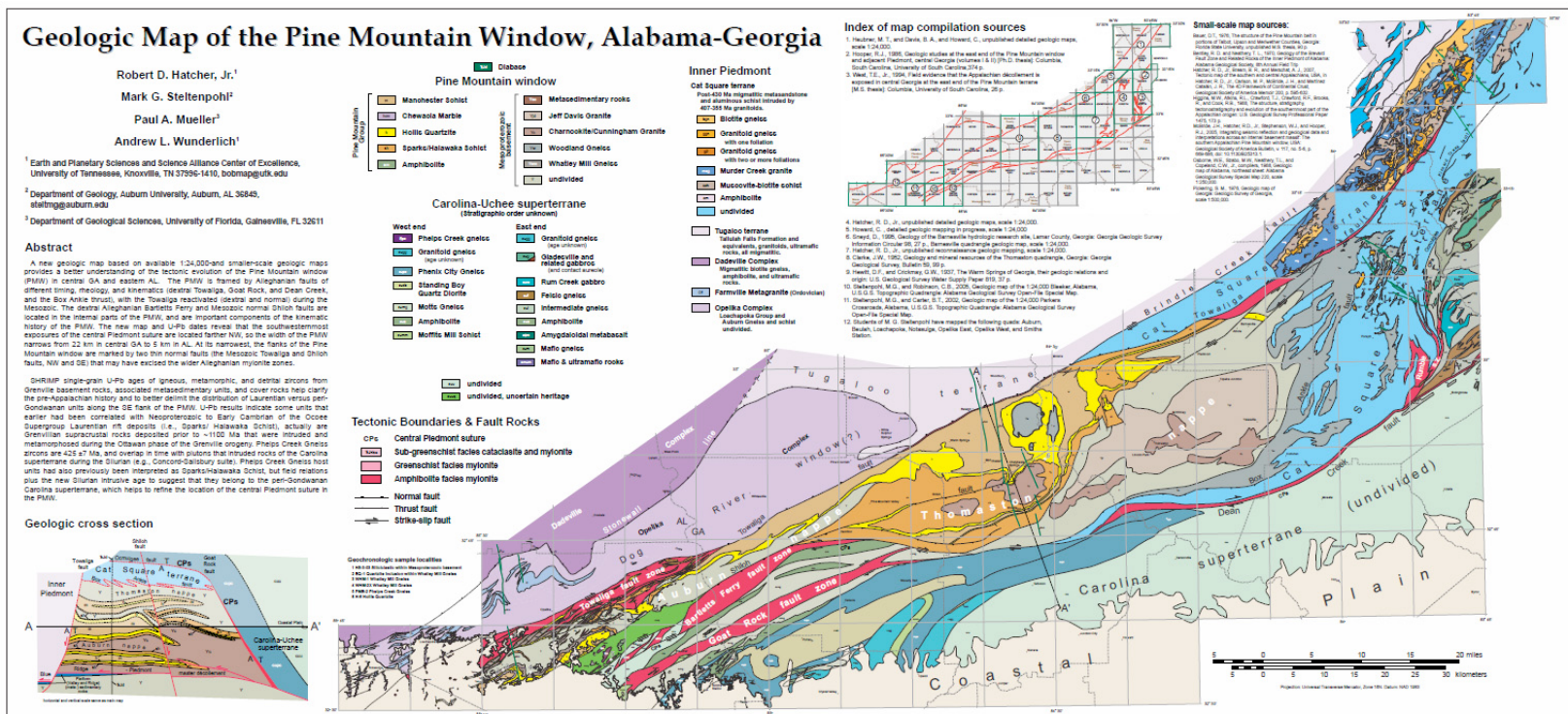


Mapping with NCGMP09...



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...

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

Ultimately allowing scientists to do...

BETTER SCIENCE!



A topographic map showing contour lines and various colored regions. The map includes labels such as 'pCtg', 'Ohgc', 'crc', 'bpm', 'uhp', 'mg', 'Opma', and 'Ot'. The text 'Thank you for your time and attention!' is overlaid in the center.

**Thank you for your time
and attention!**

Questions?