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Overcoming Cartographic and Technical Challenges in Developing an Interactive Mapping System for the Appalachian Basin Tight Gas Reservoirs Project

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OBJECTIVES OF THE APPALACHIAN BASIN TIGHT GAS RESERVOIRS PROJECT

A major objective of the Appalachian Basin Tight Gas Reservoirs Project (ATG; http://www.wvgs.wvnet.edu/atg/) was to design and implement an interactive mapping system (IMS) website that consolidates a broad range of information about 6 main groups of tight gas reservoirs, and can be extended to any gas reservoir in the future. Data for this project came from a wide variety of sources, however the vast majority of the data layers used were converted into GIS format from *The Atlas of Major Appalachian Gas Plays* (Roen and Walker, 1996). This project was supported by U.S. DOE contract DE-FC26-05NT42661.

This objective presented many unique cartographic and technical challenges, which were further complicated by the need to switch the software platform from ESRI's newer ArcIMS© ArcMap Image Server, that uses ArcMap© MXD files to show the maps online, back to the original, older ArcIMS© Image Server which uses maps rendered in AXL code, for final implementation of the website. Initially, ArcGIS© Server was considered for the project, however at the time the mapping application was developed, ArcGIS© Server did not meet the needs of the project. The WVGES is planning to migrate the system to ArcGIS© Server in the future.

COLOR CODING THE PLAY-BASED LAYERS: WE FOUND THE RAINBOW CONNECTION

Due to the overwhelming amount of data to be presented as point, line, and polygon based layers for *each* of the 6 main Tight Gas Plays (260 IMS layers were rendered), it was decided to color code the plays into the main color 'families' that make up the rainbow: Red, Orange, Yellow, Green, Blue/Indigo, and Violet. See available color "families" in the ArcMap© color palette in Figure 1. This way there would be enough hues and shades within each color group to uniquely symbolize each data layer within the play, but still indicate to the viewer that layers were geologically related to each other in the same play because they were of the same general color.

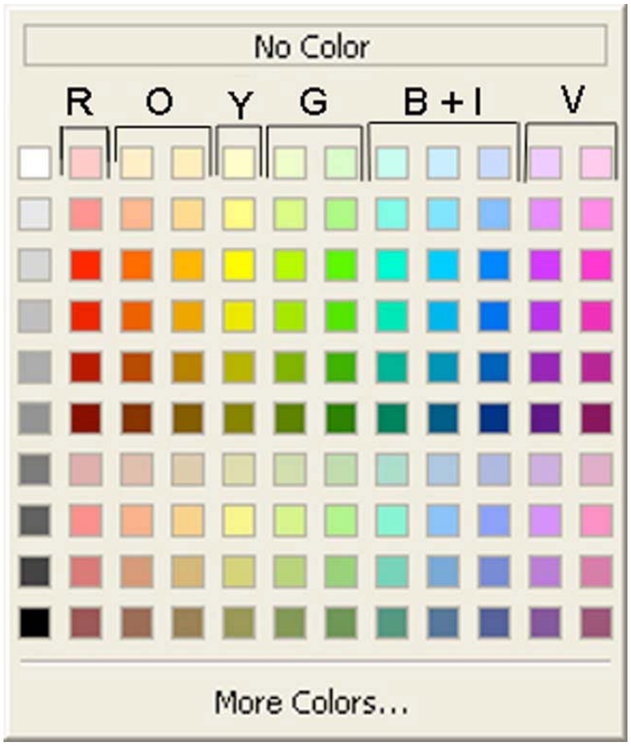

Figure 1. ArcMap© Color Palette showing main color "families" available for rendering layers. R=Red, O=Orange, Y=Yellow, G=Green, B+I=Blue/Indigo, and V=Violet.

Also, since it was expected that the viewer might wish to mix and match the data from different plays together in the display to make comparisons, it was important to be able to distinguish similar-looking data layers that were repeated in each play, such as isopach lines or gas field polygons, as belonging to the same or different plays.

The play with the fewest data layers, the Medina/"Clinton", was assigned yellow since it is the color with the fewest discernable shades (Figure 2). The play with the most layers, the Elk (Figure 3), was assigned the combined color families of blue and indigo, since these colors had the most hues from which to choose for cartographic rendering. The other plays (Berea, Venango, Bradford, and Tuscarora) were assigned to their respective color families for similar reasons (Figures 4 through 7).

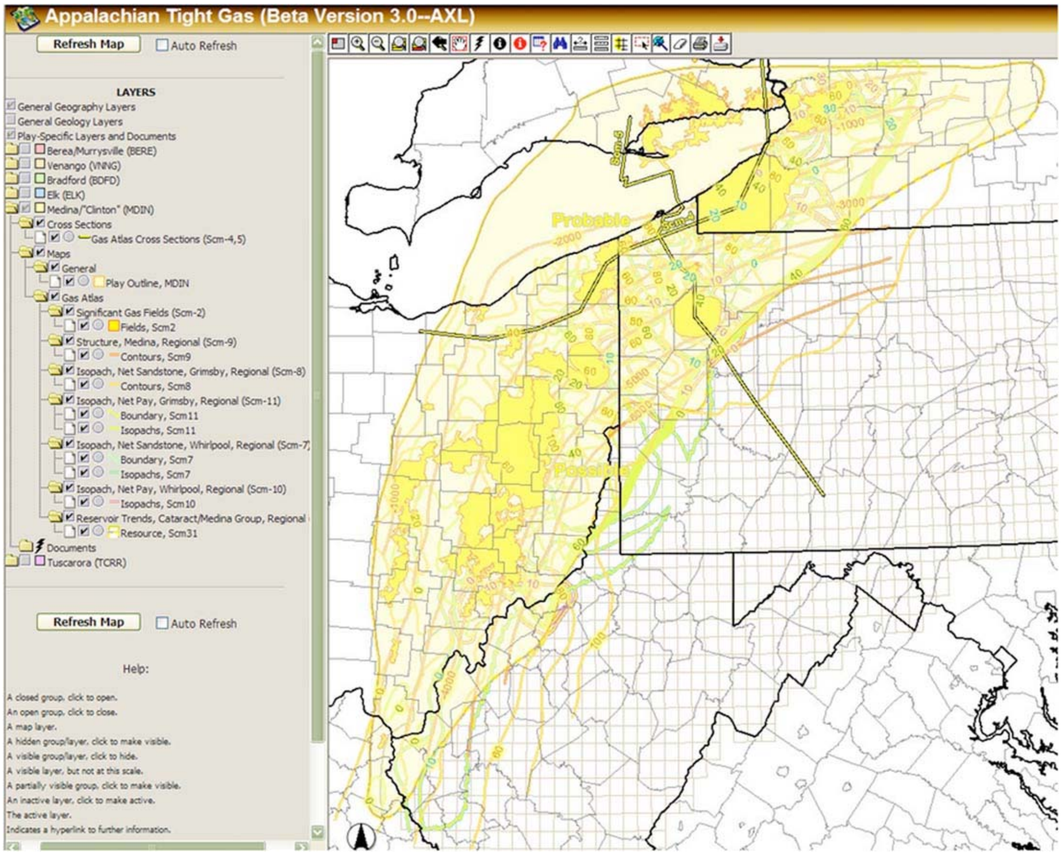

Figure 2. The Medina/“Clinton” Play of the ATG IMS contains 11 data layers and was assigned colors in the yellow family.

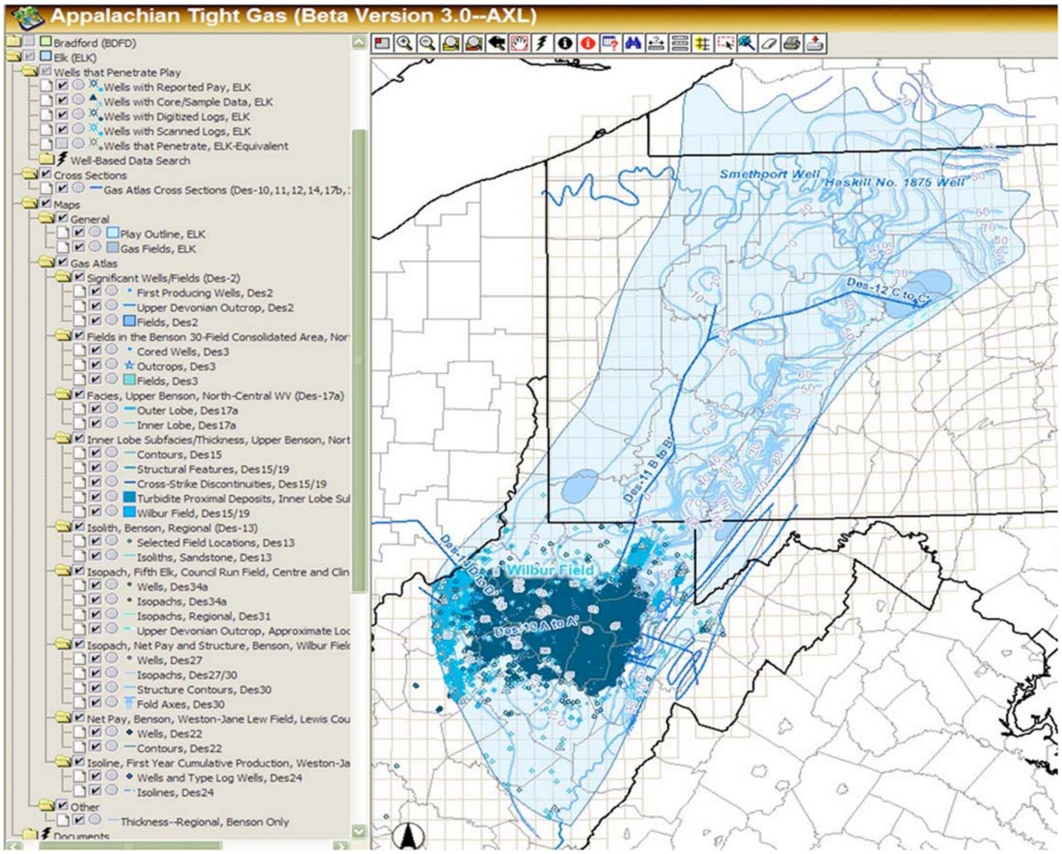

Figure 3. The Elk Play of the ATG IMS contains 36 data layers and was assigned blue and indigo colors.

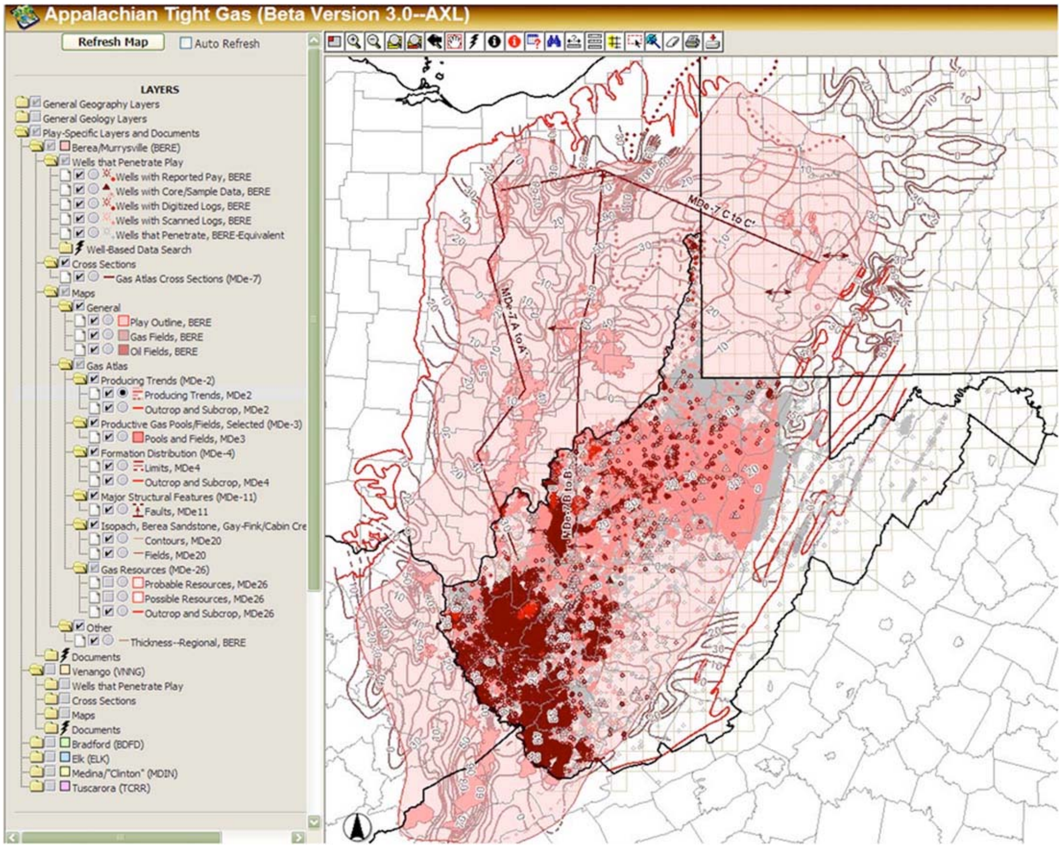

Figure 4. The Berea Play of the ATG IMS contains 21 data layers and was assigned red colors.

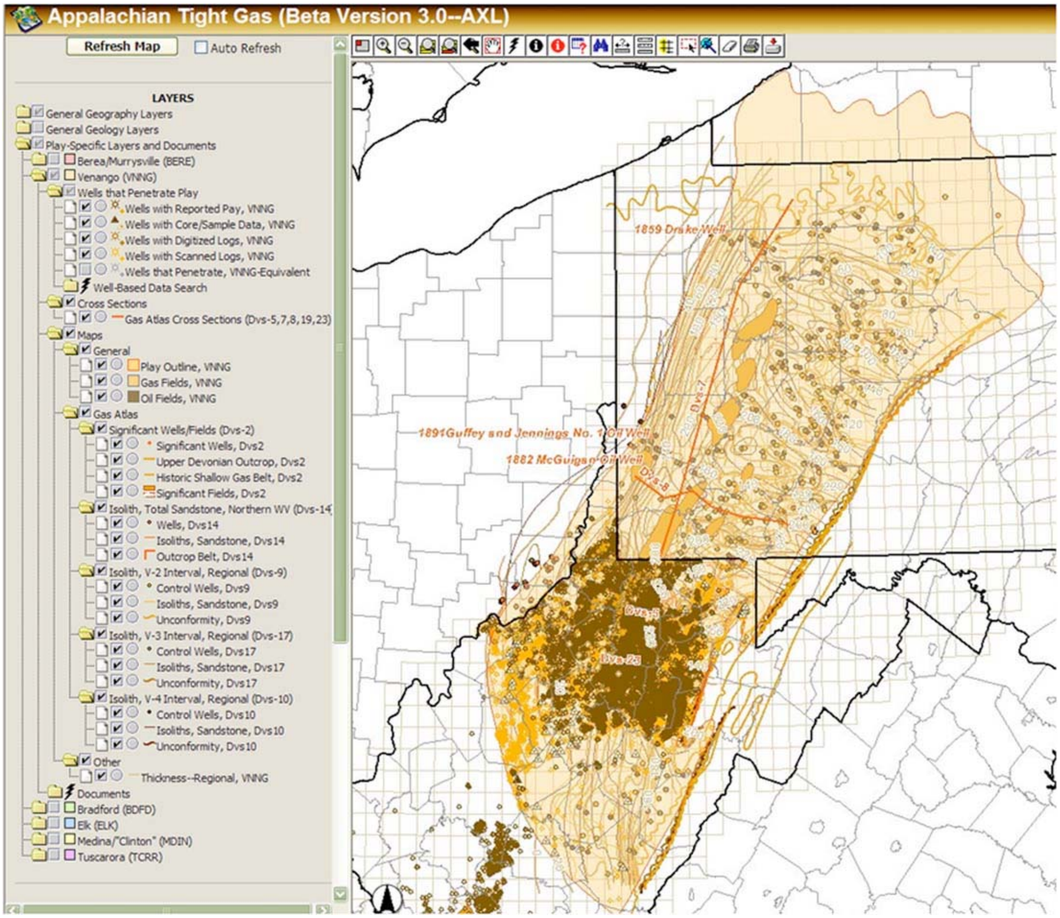

Figure 5. The Venango Play of the ATG IMS contains 26 data layers and was assigned orange colors.

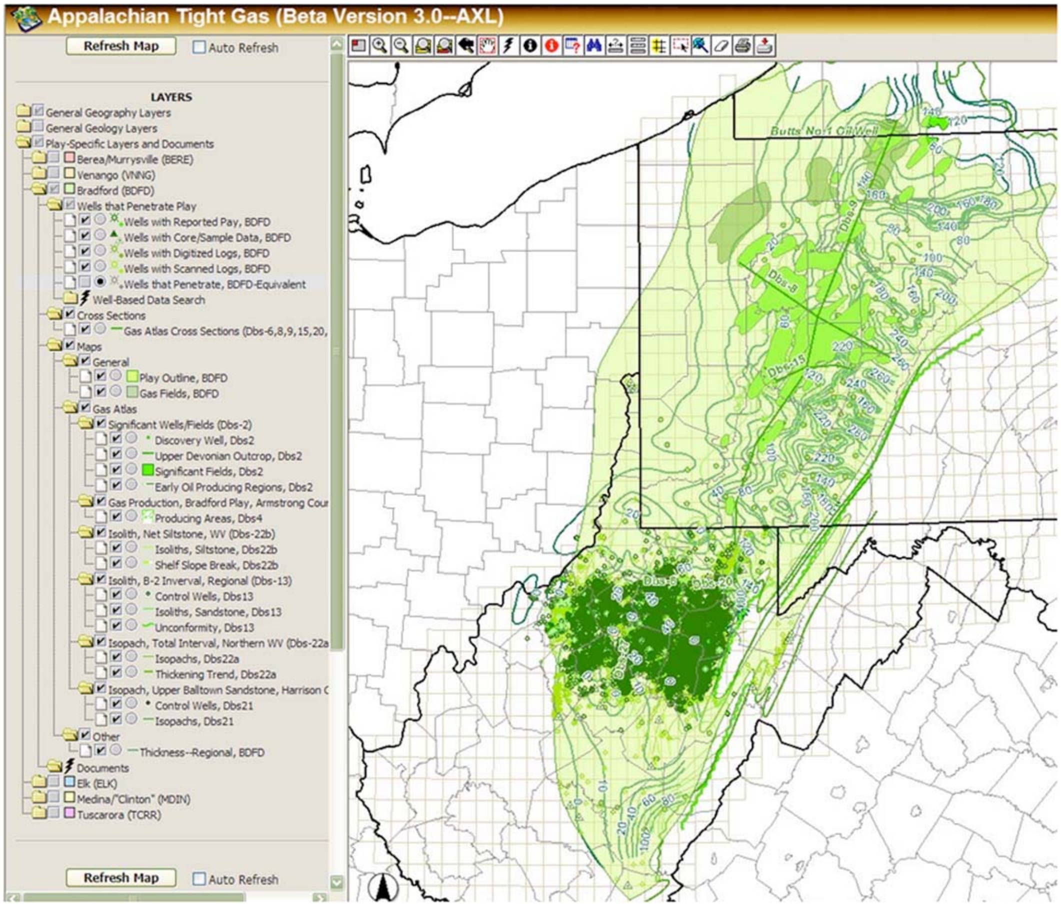

Figure 6. The Bradford Play of the ATG IMS contains 23 data layers and was assigned green colors.

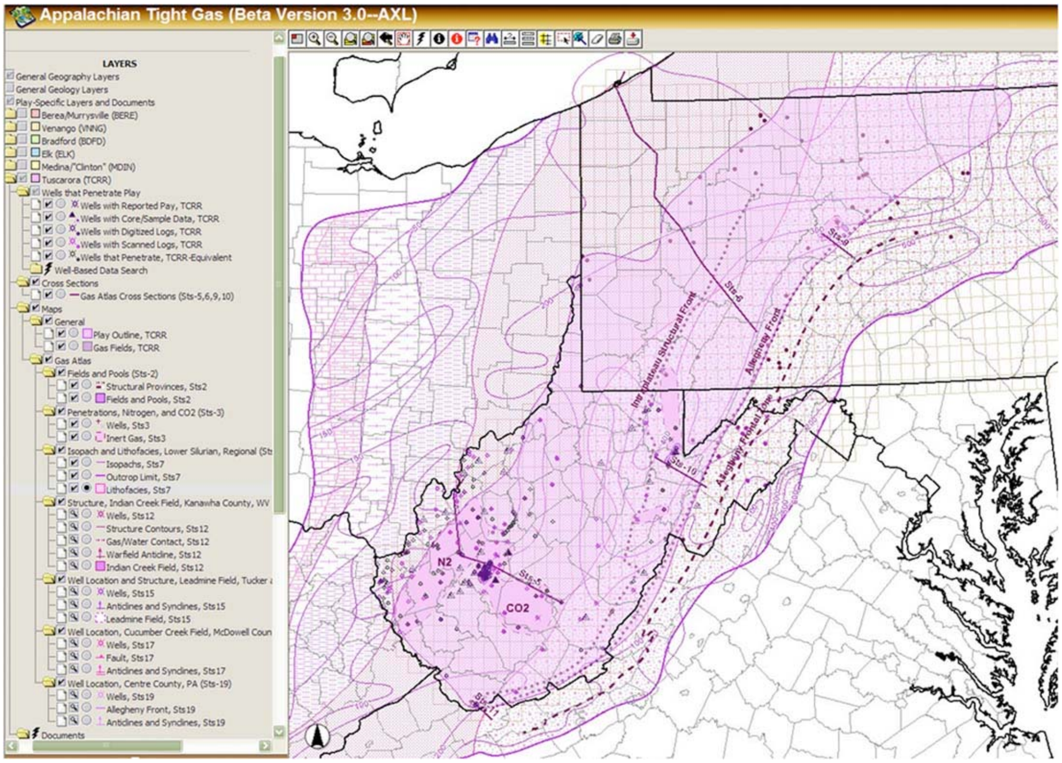

Figure 7. The Tuscarora Play of the ATG IMS contains 29 data layers and was assigned violet colors.

FORM VS. FUNCTION

Functional Differences between the Two Versions of ArcIMS©: AXL-based vs. MXD-based

There were several important functional advantages to be gained by switching the IMS platform to the original ArcIMS© Image Server.

Overall speed was vastly improved, as shown in the "Speed Comparison Table" (Table 1) below. The entire application was more stable and robust, in that the interactive maps will still function should one or more layers become unavailable in the AXL version, whereas this would cause the MXD version of the application to crash. A summary of main differences between the two versions of IMS, showing positives and negatives for each version, is shown in Table 2.

The ability to use the buffer tool to select and buffer features from the same layer in order to perform data queries and display information was considered a vitally important function of this IMS application (Figure 8). In the WVGES' other Oil & Gas applications, users commonly employ these tools to select, query, and extract data subsets from well point layers.

Scale-dependent rendering of data layers, particularly well point symbols, was advantageous in this Web application due to the sheer number of well points and well point data layers. At large scales, a smaller point symbol is shown, and as the user zooms in, the detailed well type information appears as the point symbol gets larger and the point label appears.

Table 1. Speed comparison of AXL and MXD versions of ATG IMS.
Numbers are averages of 5 trials for each version.

	ATG_AXL (AXL)			ATG2 (MXD)			AXL (ATG_AXL) is faster than MXD (ATG2) by:				
Task	Firebug (s)	Real Feel (s)	Difference (s)	Firebug (s)	Real Feel (s)	Difference (s)	Firebug (s)	Real Feel (s)	Difference (s)	Firebug (s)	Real Feel (s)
Initial open	14.47	16	1.93	27.85	29	1.15	**13.39**	**12.60**	**-0.79**	**48.06%**	**43.45%**
Zoom to the city of Morgantown	1.32	1	-0.52	15.28	17	1.32	**13.96**	**15.80**	**1.84**	**91.35%**	**95.18%**
Add All Oil and Gas Wells Layer from General Geology	6.44	7	0.56	33.83	34	-0.23	**27.39**	**26.60**	**-0.79**	**80.96%**	**79.17%**
Zoom to Osage quadrangle	2.73	3	0.27	20.63	22	1.17	**17.90**	**18.80**	**0.90**	**86.77%**	**86.24%**
Add all layers in General Geology	2.75	3	0.25	20.80	22	1.40	**18.05**	**19.20**	**1.15**	**86.78%**	**86.49%**
Add all layers (everything)	13.43	14	0.37	150.00	150	0.00	**136.57**	**136.20**	**-0.37**	**91.05%**	**90.80%**
Zoom to the city of Morgantown	9.47	10	0.13	150.00	150	0.00	**140.53**	**140.40**	**-0.13**	**93.69%**	**93.60%**

Metrics of Table 1:

The MXD (ATG2) and AXL (ATG_AXL) versions of the ATG IMS application exist on the same IMS server at WVGES. Five trials were done using the Firefox browser for each version on a laptop computer (see computer specs, below) via a wireless connection in Morgantown, WV. Table 1 shows the averages of those trials with times in seconds. The Firebug tool provided a means to measure the elapsed time for feature downloads. A "real feel" time using a watch was also taken—from the moment the "enter" key is pressed to when the eye sees the finished view loaded into the browser window.

Simple and standard IMS tools were used for the metrics: loading of single or multiple layers at once and then zooming to varied extents. The selection of "adding all layers" at once provided maximum stress to both server and client machines. The MXD (ATG2) version failed at this point, timing out at 2 ½ minutes (150 seconds) after the attempted load. This point of time-out was used to calculate values for the "all layers" test and for the "zoom to Morgantown" test.

Performance of the AXL-based application was far superior to the MXD version. Although it took time and effort to construct the 4,600+ lines of AXL code, the results justified the investment for this large (260+) layer IMS application. The ATG_AXL application is available at http://www.wvgs.wvnet.edu/atg/; the ATG2 version is no longer available.

Specifications of the client Machine (laptop): Acer Aspire 4730z; MS Windows Vista, SP1; 3 GB RAM; Processor - Intel(R) Pentium(R) Dual CPU T3400 @ 2.16GHz: L2 cache 32 Kbx2; Video - Mobile Intel(R) 4 Series Express Chipset Family, 1309 MB total available graphics memory; Wireless - b/g/n, Ralink 802.11n wireless LAN card; Setting - Other than MS Paint, Firefox was the only directly user-called program running on the client system; access was via a Morgantown wireless "hotspot" (avg. 11MB/s).

Table 2: Summary of IMS Version Differences

Negatives in red Positives in green	**MXD Version** **ArcMap Image Server**	**AXL Version** **ArcIMS Image Server**
Speed	Noticeably slow	Significantly faster!
Stability	One 'bad' layer will crash whole IMS	Robust: if >= one layer unavailable, it still works
Cartographic capabilities	Full range of ArcMap rendering available	Simple line styles only
Labels	Full range of ArcMap labeling available	Limited labeling capabilities
Buffer tools	Does not function as desired in IMS (buffer and select from same layer)	Fully functional
Scale-dependent rendering	Labels only	Fully functional for both cartography and labels

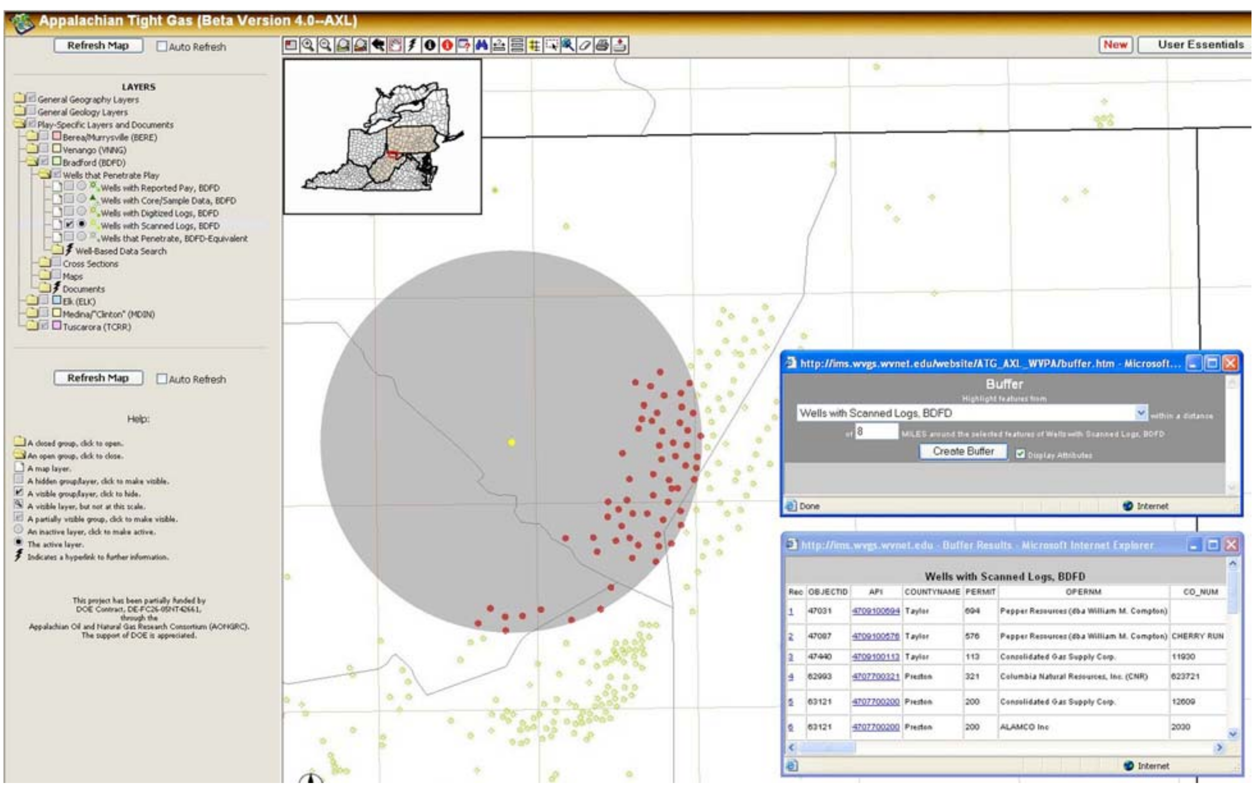

Figure 8. Example of buffer tools. View of Monongalia County, WV, showing a well point (in yellow) selected and buffered to a distance of 8 miles (gray circle) in order to select other well points in the same layer that are of interest to the user (selected points shown in red). The lower pop-up window shows the

attributes of the selected wells. For the Bradford Play, the "Wells with Scanned Logs" layer of the ATG IMS is shown.

Cartographic Differences Between the Two Versions of ArcIMS©: AXL-based vs. MXD-based

The ATG maps were originally rendered in ArcMap© and the native MXD files were served to the web using ESRI's newer ArcIMS© ArcMap Image Server. This method allowed the complex cartography required to show the geologic features such as thrust faults, anticlines and synclines, multi-layered symbols, and complex labeling of features to be displayed online as originally intended by the cartographer.

Unfortunately, some functions vital to the project, such as the ability to use the buffer tool to select and buffer features from the same layer in order to display information (Figure 8), and the ability to render layers differently dependent on scale, were not available in the ArcIMS© ArcMap Image Server version. Thus it was decided to switch the maps to the original ArcIMS© Image Server which uses maps rendered in AXL code, for final implementation of the website.

The AXL code cannot symbolize data as elegantly as the MXD file, especially with respect to line symbology, but the advantages of the AXL file functionality far outweighed the cartographic disadvantages (Table 2).

Some Specific Examples:

Some creative tweaking of AXL code was required in order to emulate some vitally important geologic symbology. Line symbols available in the AXL version were limited to solid, dashed, dot, and various dash-dot combinations. These line styles were insufficient to symbolize geologic features such as thrust faults and fold axes, which usually are shown with line decorations such as arrows for folds and "teeth" for thrust faults (compare the fault lines shown in Figures 9 and 10).

It was unacceptable for a geological survey to host a Website that cannot display common geological symbols, so a method was devised to customize the road layer symbology in the AXL code using the <RASTERSHIELDSYMBOL> tag and to use custom-made 'shield' .gif images of fold arrows to display these symbols (Figures 10 and 12). The custom fold arrow images were created individually in PaintShop Pro© for each fold type (anticline, syncline, overturned anticline, etc) and also for each fold type in the color group required per Play in the IMS. Then the road layer symbology AXL code was repurposed by replacing the road shield symbol .gif in the code (for Interstates, U.S. Highways, etc.) with the specific fold arrow symbol required for each individual layer, as the following examples show (highlighted in red). The thrust fault line symbology could not readily be modified except by using a thick, solid line style (Figure 10), but at least the fold axes could be properly symbolized for the Web. However, the rotation of the fold axis symbol relative to the fold line could not be controlled, and so the symbol remains horizontal to the page/screen, not perpendicular to the fold line as it should be (compare Figures 11 and 12).

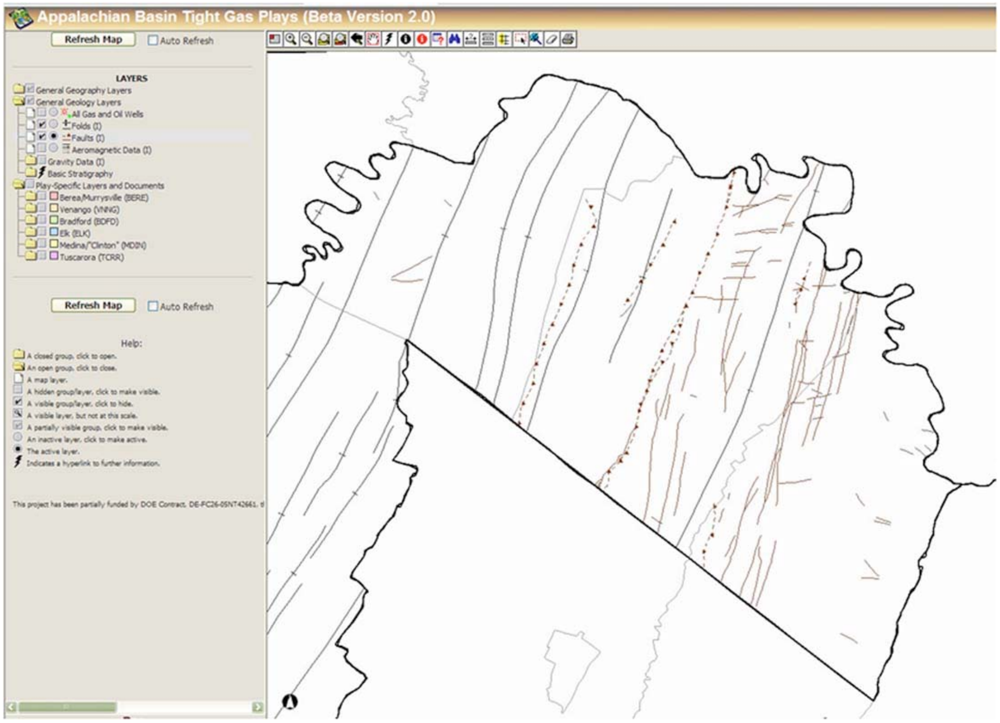

Figure 9. "Before" – lines in the MXD version: view of the Eastern Panhandle of WV showing the "General Geology Folds and Faults" layers of the ATG IMS symbolized with the standard geological line symbols for fold axes and thrust faults available from the ArcMap symbol palette.

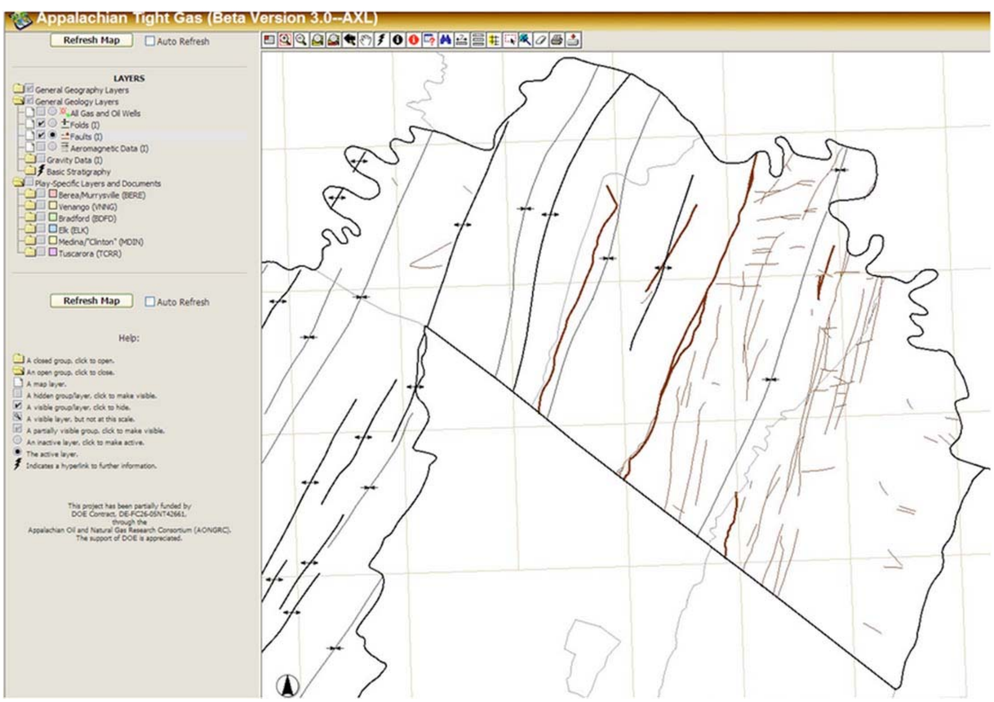

Figure 10. "After" – lines in the AXL version: same view as in Figure 9, showing the fold axes symbolized with the customized <RASTERSHIELDSYMBOL> tag and thrust faults symbolized with thick/thin line styles. Note how the custom .gif image of the fold arrows cannot be rotated relative to the fold axis line, remaining horizontal relative to the screen.

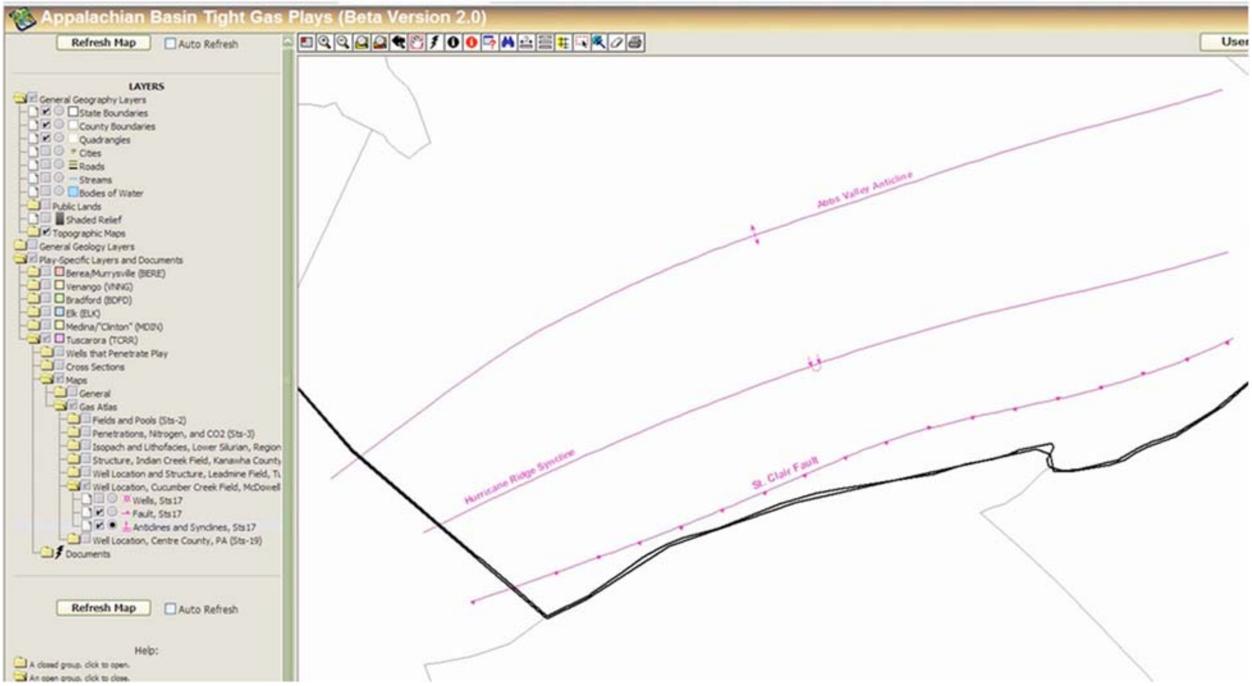

Figure 11. “Before” – line decorations in the MXD version: view of Tuscarora Play in Mercer County, WV, showing the standard geological symbols for fold axes and thrust faults available from the ArcMap© symbol palette. (Tuscarora Play Fig. Sts-17 layer of the ATG IMS shown.)

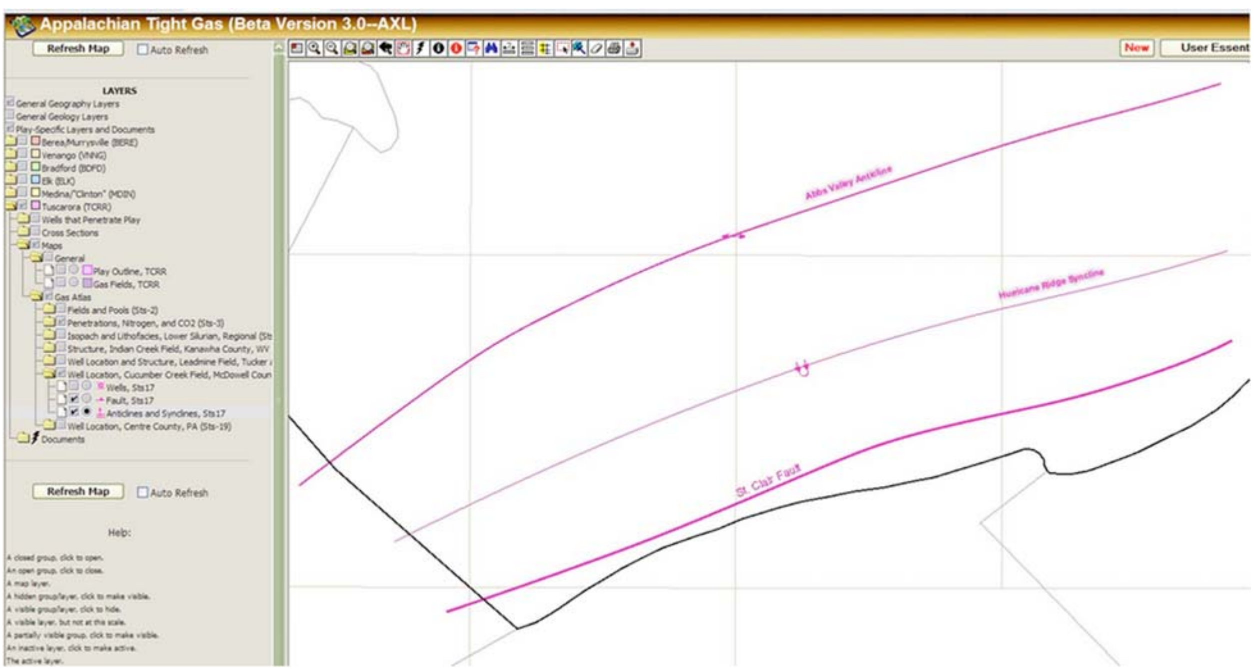

Figure 12. “After” – line decorations in the AXL version: same view as in Figure 11, showing the fold axes symbolized with the customized <RASTERSHIELDSYMBOL> tag and thrust fault symbolized with thick, solid line style. Note how the custom .gif image of the fold arrows cannot be rotated relative to the fold axis line, remaining horizontal relative to the screen.

AXL code for customized use of the <RASTERSHIELDSYMBOL> tag and specially-created fold-arrow .gif images applied to the fold layer produced the symbols shown in Figure 10. The following example shows a generic anticline and syncline fold symbol used in the "General Geology" IMS Layer:

```
<VALUEMAPLABELRENDERER lookupfield="Type" labelfield="Type"
linelabelposition="placeontophorizontal">
   <EXACT value="Anticline" label="Anticline">
        <RASTERSHIELDSYMBOL font="Arial" fontcolor="0,0,0" fontsize="1"
                image="anticline_general2.gif" transparency="1"/>
    </EXACT>
    <EXACT value="syncline" label="Syncline">
        <RASTERSHIELDSYMBOL font="Arial" fontcolor="0,0,0" fontsize="1"
image="syncline_general2.gif"    transparency="1"/>
    </EXACT>
</VALUEMAPLABELRENDERER>
```

The following AXL code for customized use of the <RASTERSHIELDSYMBOL> tag and specially-created fold-arrow .gif images was applied to "Tuscarora Play" fold layers in Figure 12. This example uses the fold arrow symbols that had to be uniquely created in the Tuscarora Play color (purple shades) and also for an overturned fold:

```
<VALUEMAPLABELRENDERER lookupfield="TrendName" labelfield="TrendName"
linelabelposition="placeontophorizontal">
   <EXACT value="Anticline" label="Anticline" method="IsContained">
        <RASTERSHIELDSYMBOL font="Arial" fontcolor="255,0,197" fontsize="1"
                image="anticline_Sts17.gif" transparency="1"/>
    </EXACT>
    <EXACT value="Syncline" label="Syncline" method="IsContained">
        <RASTERSHIELDSYMBOL font="Arial" fontcolor="255,0,197" fontsize="1"
image="overturnedsyncline_Sts17.gif"    transparency="1"/>
    </EXACT>
</VALUEMAPLABELRENDERER>
```

Some of the more complex and creative labeling that ArcMap© is capable of serving to the Web in the MXD version unfortunately had to be sacrificed for the final AXL-based version of the IMS. For example, superscripts and subscripts are not supported by the AXL code, so inert gases such as Carbon Dioxide and Nitrogen cannot be correctly scientifically labeled, (compare Figures 13 and 14) which, for an internet application publishing scientific data, is obviously not ideal.

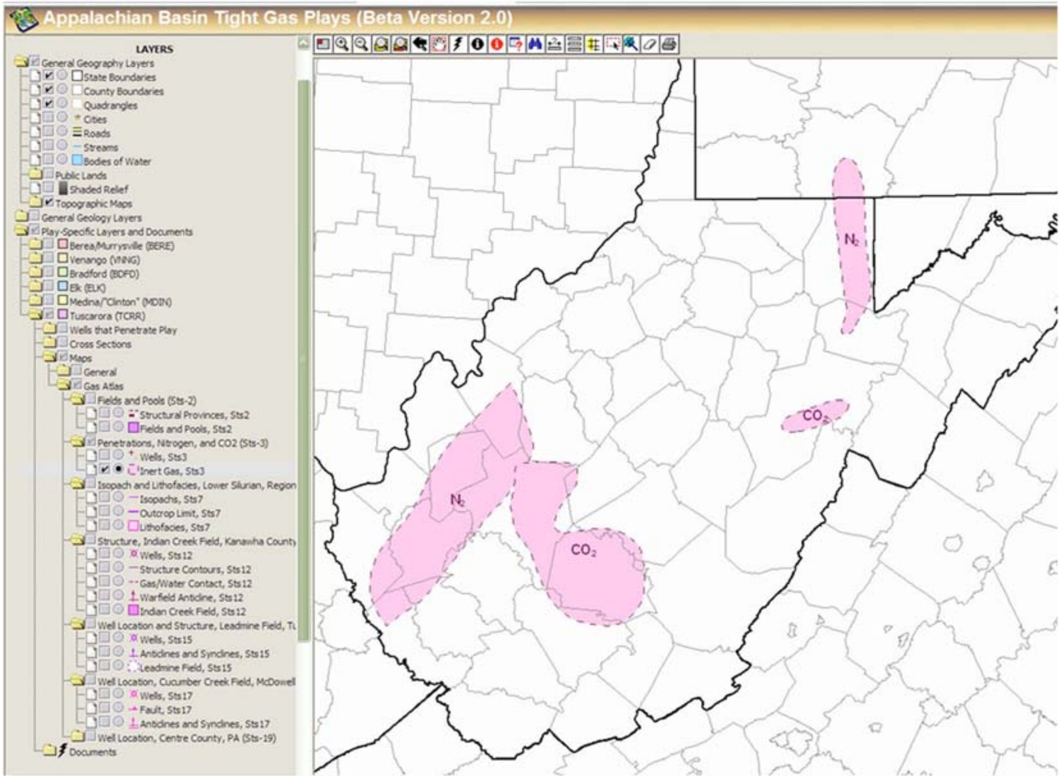

Figure 13. "Before" – the MXD version: view of WV showing some of the complex labeling options available in ArcMap© and applied to the Tuscarora Play (Fig. Sts-3 layer of the ATG IMS shown). The inert gas fields are correctly scientifically labeled using subscripts.

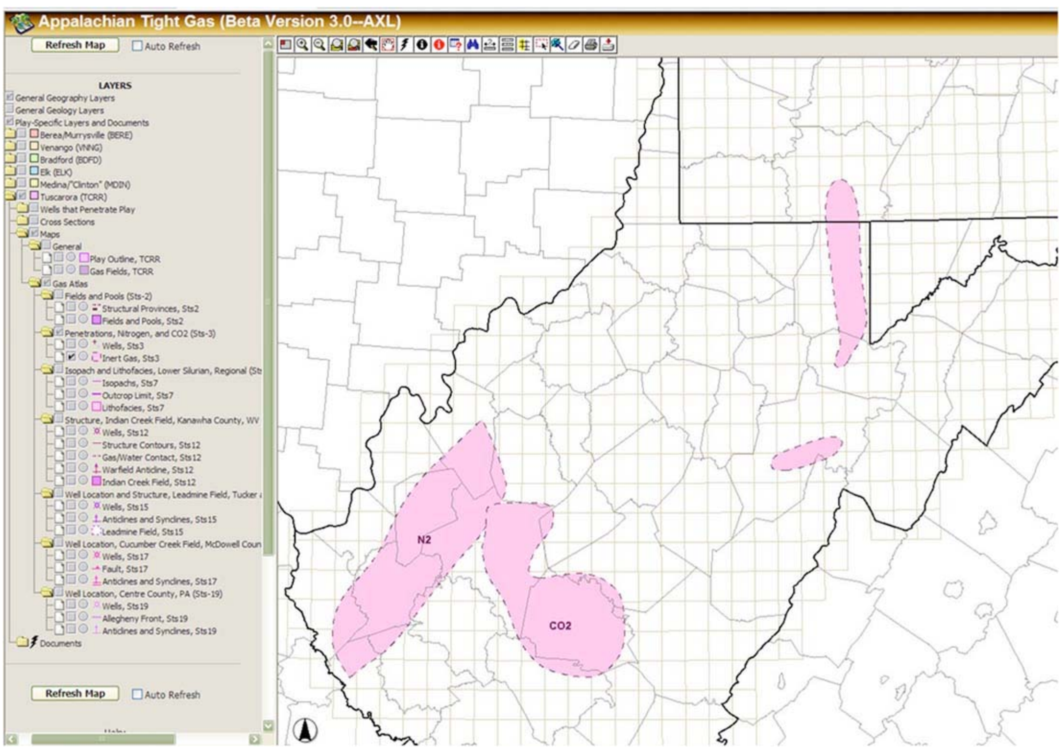

Figure 14. "After" – the AXL version: same view as in Figure 13. Subscripts and superscripts are not supported in the AXL code.

Layered labels (labeling a feature with more than one label at a time using two or more attribute fields) and label classes that define and uniquely label different features based on attributes also are not supported in AXL code. Nor are specialized label placement functions such as defining label offset from its line feature, or the ability to control its placement and/or orientation to the line (compare the "Rome Trough" label in Figures 15 and 16).

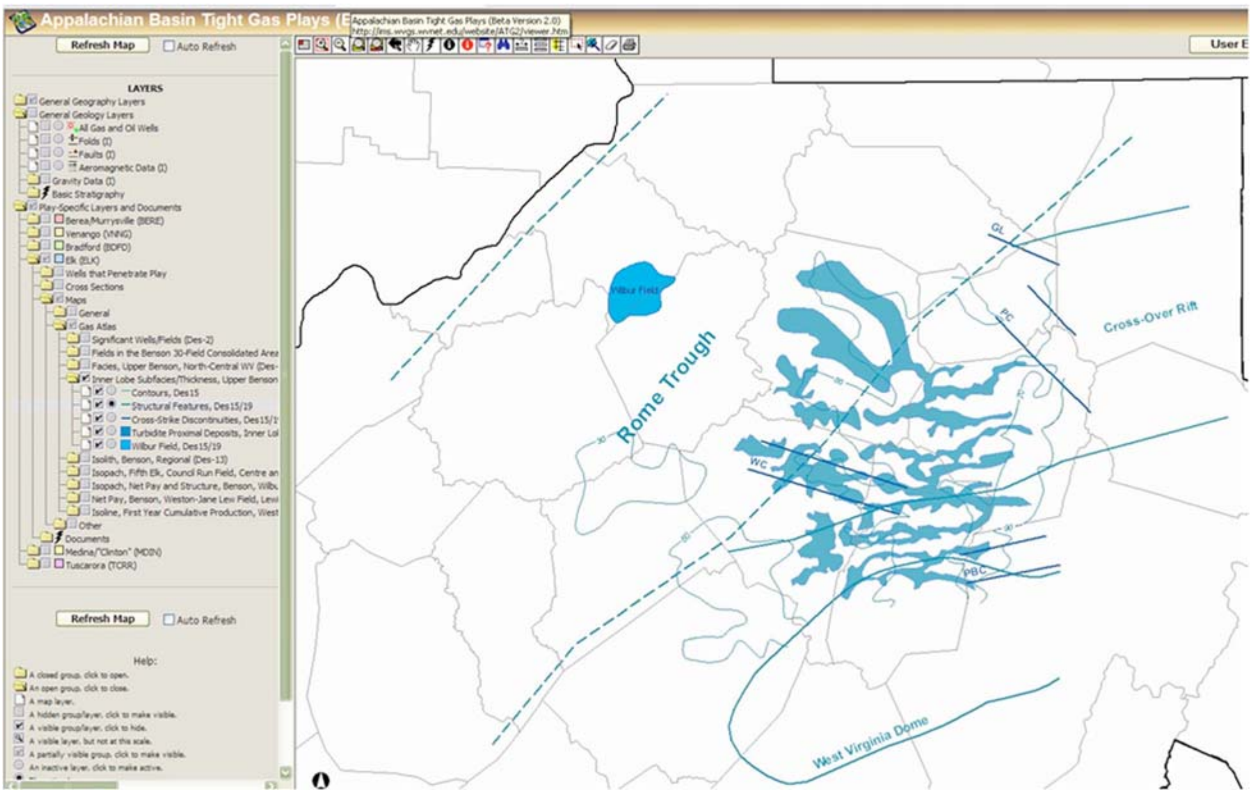

Figure 15. "Before" – the MXD version: view of WV showing some of the complex labeling options available in ArcMap©. The structural features are labeled differently based on attribute classes, and specialized label placement and orientation is employed, e.g. "Rome Trough" label. (Elk Play Fig. Des-15/19 layer of the ATG IMS shown.)

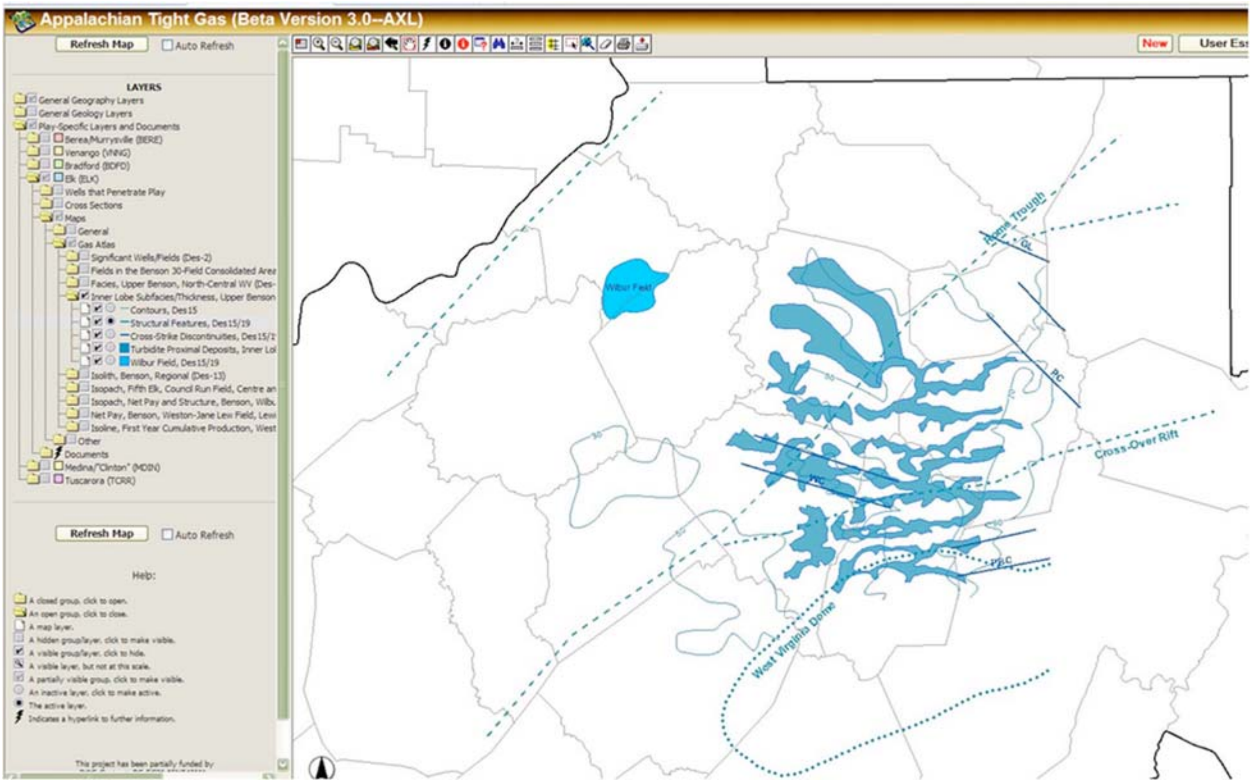

Figure 16. “After” – the AXL version: same view as in Figure 15, showing examples of the limited labeling options that are supported in the AXL code.

ArcMap© includes the capability to symbolize lines that include decorations (e.g., fault teeth), and to use graphic elements to create complex line styles. For example, lines for regional unconformities can be rendered with the standard geologic “squiggly” line style using an “S”-shaped graphic element. In Figure 17, the outcrop belt is shown with a hachured line style, but the lines themselves (with one exception) were digitized as straight lines. To show the unconformity lines in the AXL version, which cannot support complex line styles, the lines had to be completely re-digitized as “squiggles” (Figure 18) and the outcrop belt had to be symbolized as a plain, straight line.

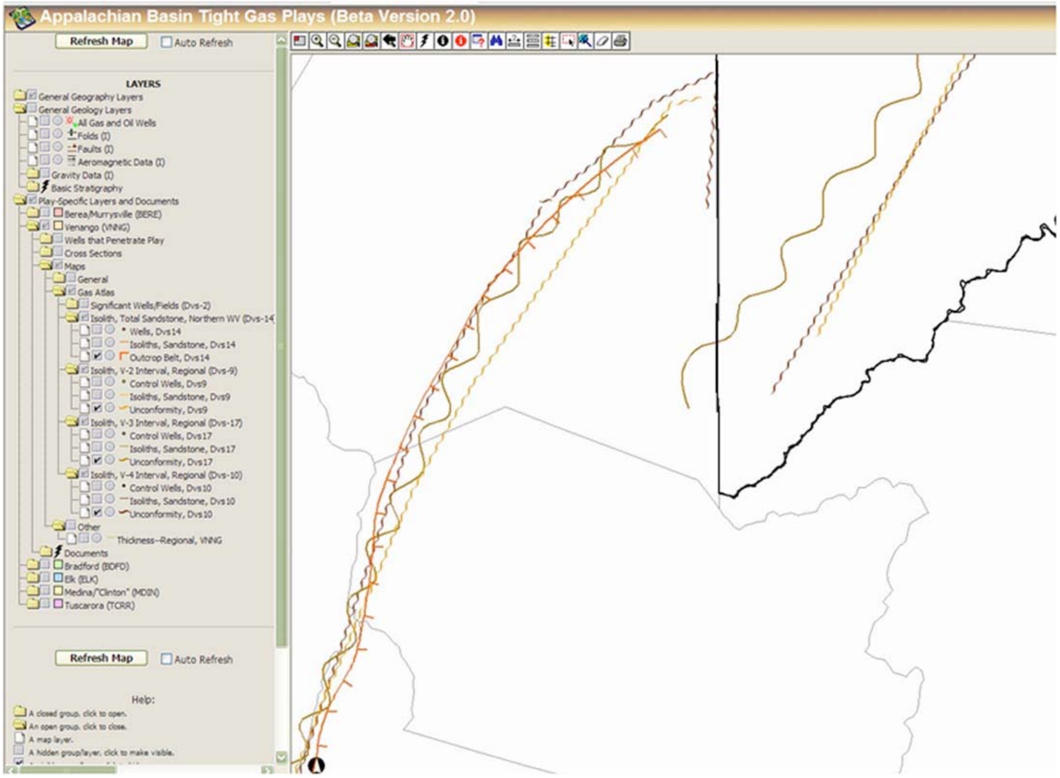

Figure 17. "Before" – the MXD version: view of Preston County, WV, showing some of the complex line rendering options available in ArcMap©. The unconformities are symbolized (with one exception) using an "S" shaped graphic element to mimic the standard geologic symbol. The outcrop belt (in orange) was symbolized with a hachured line style. (Venango Play Figs. Dvs-9, -10, -14 and -17 layers of the ATG IMS shown.)

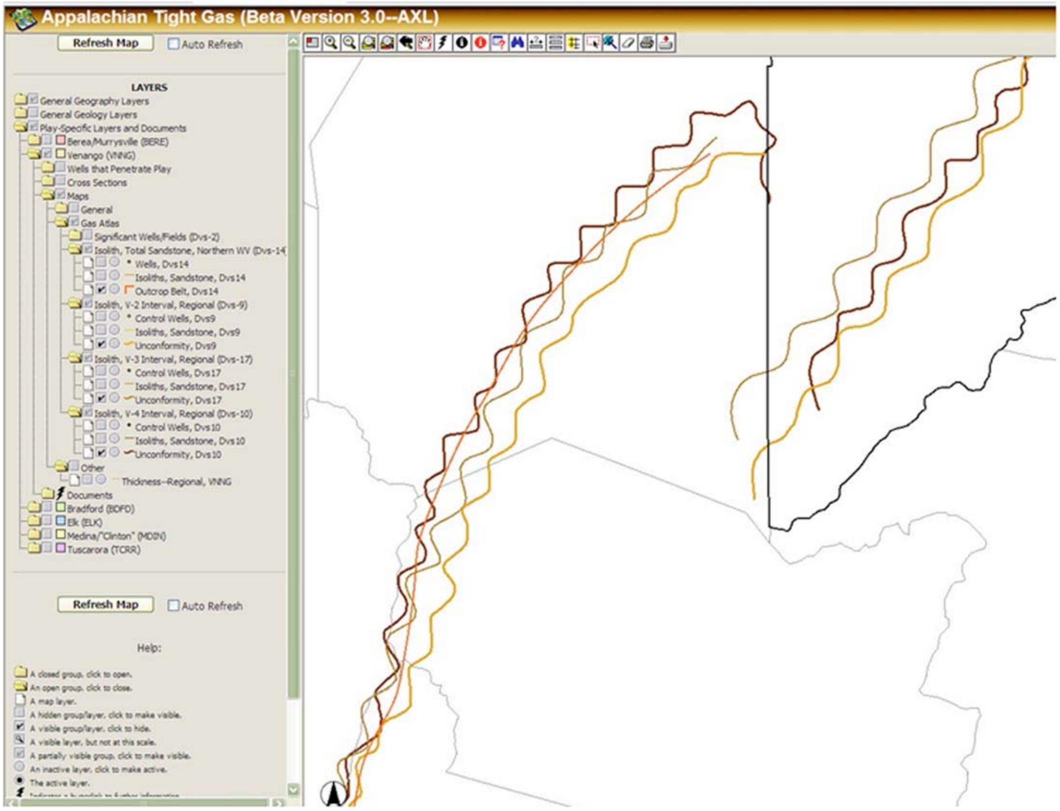

Figure 18. "After" – the AXL version: same view as in Figure 17, showing the lines completely re-digitized as "squiggles" in order to properly symbolize the regional unconformities. The outcrop belt (in orange) had to be shown with a plain, straight-line style.

A page-sized version of the poster presented at DMT'09 is shown in Figure 19. A full-resolution image can be viewed online at http://ngmdb.usgs.gov/Info/dmt/docs/DMT09_Gooding.pdf.

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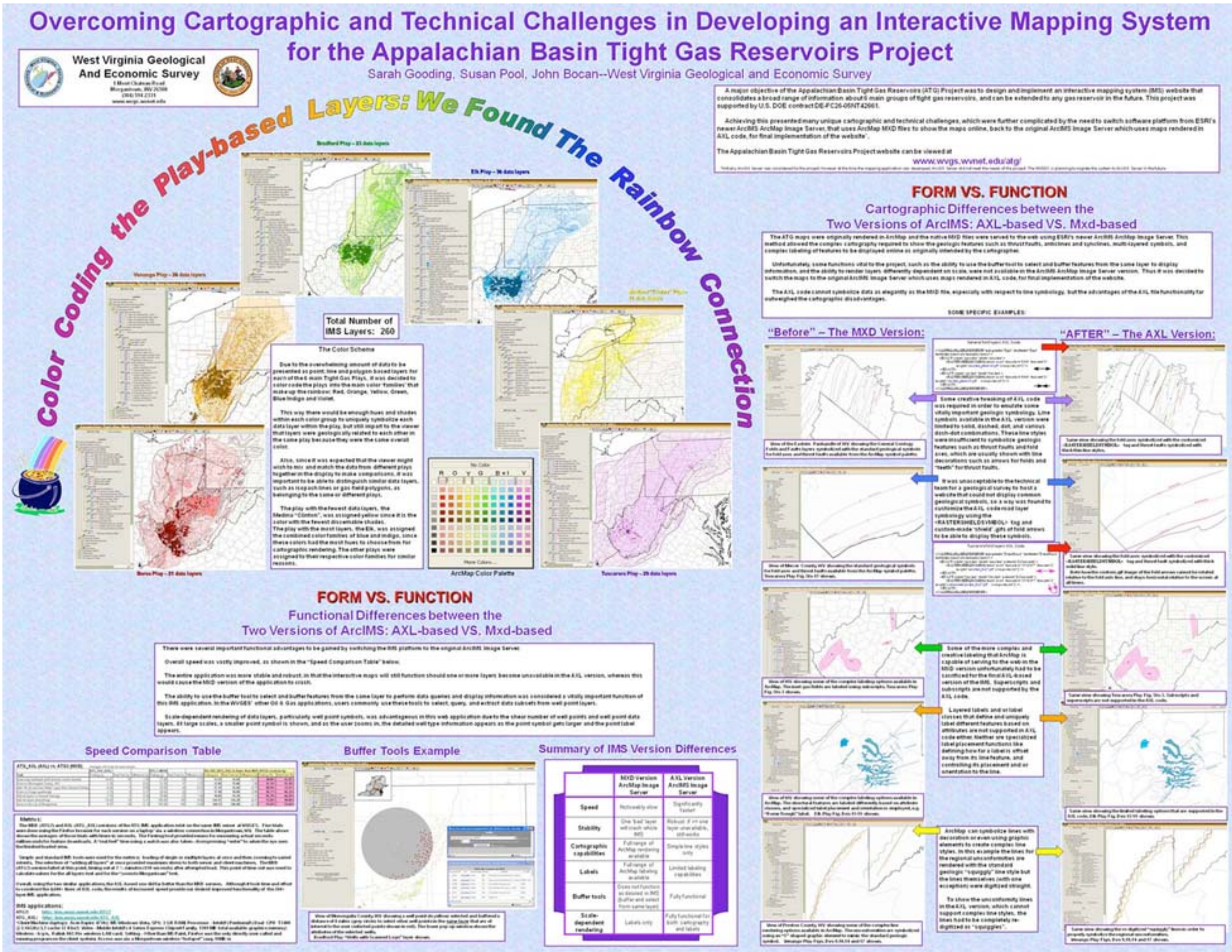

Figure 19. Overcoming Cartographic and Technical Challenges in Developing an Interactive Mapping System for the Appalachian Basin Tight Gas Reservoirs Project (presented as a poster).

REFERENCES

ArcGIS© - Environmental Systems Research Institute, Inc., 380 New York St., Redlands, CA 92373-8100 USA, (909) 793-2853, http://www.esri.com/.

Roen, J.B. and B.J. Walker, editors, 1996, The Atlas of Major Appalachian Gas Plays: Morgantown, WV, West Virginia Geological and Economic Survey.