# UTILIZING GOOGLE EARTH FOR GEOSPATIAL, TECTONIC, AND HYDROGEOLOGICAL RESEARCH AT THE NEW JERSEY GEOLOGICAL AND WATER SURVEY

- •The talk is divided into two parts
  - Borehole Imaging tools used by NJGS before 2010 and after as NJGWS 2011 including a comparison of the results of 2<sup>nd</sup> and 3<sup>rd</sup> generation borehole televiewer (BTV) technology
  - •3D visualization methods for geological structures using GIS and Google Earth





# Geological Research & Support Section of the Bureau of Water and Geoscience

2 Licensed well drillers, and the good faith of the State of New Jersey.

March 18, 2013 G.C. Herman



# **Borehole Imaging Review**

# • Borehole imaging tools developed from industry's need for borehole inspection devices, for fracture detection and for use in well remediation.

source: Lowell, M.A., Williamson, G., & Harvey, P.K., (eds) 1999, Borehole Imaging: applications and case histories. Geological Society of London Special Publication 159, 1-43.

- First devices introduced in the 1950's with rigged photographic cameras.
- Downhole TV introduced in the 1960's.
- First acoustic borehole televiewer's in the late 1960's, resistivity shortly after
- First generation optical imaging, including the Raax BIPS system, late 1980s and early 1990's.
- Second generation microresistivity and high-resolution devices late 1990 to mid 2000's.
- Mid 2000's on, the third generation devices have increased logging speed from increased computing power, electronic refinements, and more data processing capabilities....

### Robertson Geologging Ltd.System

Portable Smartwinch w/ 300 m coax cable Fluid temp and electrical conductivity Multi-directional Color TV camera (VHS) Optical Televiewer (OPTV) Heat Pulse Flowmeter





### **DOPTV** DIGITAL OPTICAL TELE-VIEWER

0

Lower Collar

#### To Smartwinch, MicroLogger, and PC.

OPTICAL A LED ring (L) located around the camera lens TELEVIEWER illuminates a section of the SCHEMATIC borehole wall. Borehole wall image is reflected off the Digital camera hyperboloid mirror (H) to captures 360° ring the digital camera (C). Three-axis inclinometer (I) at 1mm-depth and magnetometer (M) sample intervals. collect incremental Successive rings are orientation readings stacked in geographic alignment based on incremental M magnetometer and С inclinometer measurements. Sonde Tube Ø Upper Collar centralizing 000 bando 000 Bowspring ATTENDED IN THE OWNER OF THE OWNE Detail Locking Collars view 000 000

> OPTV scans of 360 or 720 pixels per 1mm scan ring



Magnetic declination (degree
_



cylindrical borehole intersecting gently-inclined plane

- cylindrical borehole intersecting steeply-inclined plane
- cyl prehole ste sing wi ed plans





section of cylinder wall is 'unrolled' and tranformed into rectangular (cartesian) coordinates. Elliptical trace is tranformed to sinusoidal curve. Amplitude is a function of dip.





### **DOPTV** DIGITAL OPTICAL TELE-VIEWER



Α

# **Example of RG OPTV results**

#### Wells 95 and 96 - Brunswick lower red zone



FIGURE 3M12. OPTV records of 6-inch diameter wells 95 (left) and 96 (right) at the Stony Brook-Millstone Watershed Association well field showing geologic structures and hydraulically-conductive features in red and gray mudstone and gray shale. Depth values are in feet below land surface. March 18, 2013 G.C. Herman



#### Well 46 - Brunswick middle red zone

FIGURE 3C3. Hydrogeologic section based on geophysical logs (left) for well 46 at 15 Roosevelt Rd, Readington Twp, Hunterdon County, NJ. The section shows the vertical distribution and types of hydraulically-conductive features and water-bearing zones in red mudstone. An OPTV record of the 6-inch diameter well (right) shows primary inflow zones. Depth values are in feet below land surface.

3C3

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# The NJ-NY parts of the Newark basin



## Borehole Geophysics and Hydrogeology Studies in the Newark Basin, New Jersey

By Gregory C. Herman and John F. Curran, N.J. Geological Survey

#### Appendixes 1 to 4 of

Contributions to the Geology and Hydrogeology of the Newark Basin N.J. Geological Survey Bulletin 77

State of New Jersey Department of Environmental Protection Water Resource Management New Jersey Geological Survey 2010

State of New Jersey Chris Christie, Governor

Department of Environmental Protection Bob Martin, *Commissioner* 

Water Resource Management John Plonski, *Director* 

New Jersey Geological Survey Karl Muessig, State Geologist

# Some conclusions from this research:

- 1) Borehole cross flows in well are systematic and commonly related to red and gray bed stratigraphic layering control on aquifer heterogeneity
- 2) WBFs and WBZs in gray beds are more concentrated in non-bedding fractures whereas those in red beds and especially coarser-grained units have more bed-parallel WBFs and Zs.
- 3) The massive mudstone units have about an equal number, but the bed-parallel WBZs are higher transmissivities over longer distances.
- 4) Gray and Black shale units are confining beds to the red-bed aquifers.
- 5) The depth of weathering in bedrock is commonly 60 100 ft below land surface, so having more than 50-ft of casing for supply wells is advised

# ALT & Mt. Sopris System 2011-

800 m 4MX2 Winch with 1/8" single conductor cable

Matrix data processor

Optical Borehole Image (OBI-40) Tool

Heat-Pulse Flowmeter HPFM-2293





# **OBI40** Optical Borehole Imager

#### 2 Measurement Principle

The OBI incorporates a high resolution, high sensitivity CCD digital camera with matching Pentax optics. The CCD camera, located above a conical mirror, captures the reflection of the borehole wall. The light source is provided by a light ring assembly located in the optical head (Figure 2-1).







5





# The ALT- Mt.Sopris HPFM

### **Operational range with diverter/centralizer**

#### Measuring Range

 0.03 gpm to 1.0 gpm
 0.113 lpm to 3.785 lpm

 0.15 ft/min. to 13 ft/min.
 0.046 m/min. to 3.962 m/min.

ResolutionAccuracy5%5% (Mid-Range) to 15% (Extremes)

#### Pressure Rating

2000 PSI or 13789 Pascal

(.43197 psi/ft <u>~</u>6000 ft)



 EXPLANATION:
 Image: Water well with line
 A ----- A'
 Cross-section trace
 8

 March 18, 2013 G.C. Herman
 trace of penetrated
 8
 8

 Stratigraphic interval
 Outcrop notes
 8

4 INDIAN CREEK RD

-4900 FT 11 MAPLE SPRINGS RD



### **COMPARION OF RG OPTV AND ALT-MT/SOPRIS OBI-40**

the Passaic Formation from Olsen and others Gamma-ray and Optical Borehole Imaging logs.





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### ESRI ArcView 3.2 Avenue scripts and extensions no longer supported in ARC GIS

3D VIEW OF PART OF THE RIDGE GOLF COURSE WELL FIELD, EAST AMWELL TWP., HUNTERDON COUNTY, NEW JERSEY, N.J. GEOLOGICAL SURVEY, G.C. HERMAN, 2003 SEPTEMBER 19



3D VIEW OF THE RIDGE GOLF COURSE WELL FIELD IN THE VICINTY OF MONITORING WELL MWA, EAST AMWELL TWP., G.C. HERMAN, 2003 SEPTEMBER 19



Notes:

- 1) 3D view looking northwest
- 2) Grid cells and corner tics are 100'
- 3) Boreholes with green (open) and pink (cased) intervals are vertical projections
- 4) Actual borehole trace for well MWA from OPTV data
- 5) Inclined colored planes show tectonic fracture orientations measured from the OPTV record and projected 100' along stike and 25' up- and down-dip along their respective orientations.
- 6) Tectonic fractures are only shown for strikes ranging between 176° to 20° (pink) and 86° to 110° (green) (Intrabasin fault orientations)

3D VIEW OF THE RIDGE GOLF COURSE WELL FIELD IN THE VICINTY OF MONITORING WELL MWA, EAST AMWELL TWP., HUNTERDON COUNTY, NEW JERSEY, N.J. GEOLOGICAL SURVEY, HUNTERDON COUNTY, NEW JERSEY, N.J. GEOLOGICAL SURVEY, G.C. HERMAN, 2003 SEPTEMBER 19



Notes:

1) 3D View looking north-northeast

- 2) Grid cells are 100'
- 3) Boreholes with green (open) and pink (cased) intervals are vertical projections
- 4) Actual borehole trace from OPTV data shown for well MWA
- 5) Inclined colored planes show tectonic fracture orientations measured from the OPTV record and projected 100' along strike and 25' up- and down-dip along their respective orientations.
- 6) Tectonic fractures are only shown for strikes ranging between 111° to 150° (blue) and 21° to 60° (purple) (border-fault orientations)

Virtual Reality Model Language (VRML) programs provide dynamic display of three-dimensional shapes using VRML viewers and Internet browsers.

Two wells in **Brunswick aquifer** sandstone near Pittstown, NJ.

Ellipses are 200 ft long by150 ft wide. Grid tick are 100 ft. Grid arrow points North.



Bedding planes



Blue dips 30-60° Orange dips 60-90°

### Water-bearing planes

Eight wells in **Brunswick** aquifer mudtsone, Stony **Brook Watershed** Preserve, Hopewell Twp, NJ.

Ellipses are 200 ft long by150 ft wide. Grid tick are 100 ft. Grid arrow points North.



http://www.impacttectonics.org/gcherman/vrml.htm



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Northeastern Section - 48th Annual Meeting (18–20 March 2013)

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UTILIZING GOOGLE EARTH FOR GEOSPATIAL, TECTONIC, AND HYDROGEOLOGICAL RESEARCH AT THE NEW JERSEY GEOLOGICAL AND WATER SURVEY

Paper No. 52-11

Presentation Time: 4:40 PM

#### UTILIZING GOOGLE EARTH FOR GEOSPATIAL, TECTONIC, AND HYDROGEOLOGICAL RESEARCH AT THE NEW JERSEY GEOLOGICAL AND WATER SURVEY

<u>HERMAN, Gregory C.</u>, NJ Department of Environmental Protection, NJ Geological & Water Survey, PO Box 420, 29 Arctic Parkway, Trenton, NJ 08822, greg.herman@dep.state.nj.us

The New Jersey Geological and Water Survey uses Google Earth (GE) to help research the physical properties of fractured-bedrock aquifers. GE provides a flexible, practical, and popular software platform to help organize, display, and share 2D and 3D geological data collected in outcrop and with borehole geophysical logging tools. Computerized 2D geological symbols and 3D models are generated in Trimble SketchUp, then georegistered, scaled, and annotated utilizing Microsoft Excel to generate GE keyholemarkup-language (KML) files. 2D geological map symbols are available for stratigraphic layering, cleavage, joints, fractures, faults, and lineation, utilizing an approach based on Whitmeyer's on-line orientation-symbol generator. 3D map symbols use elliptical planes centered on outcrop locations that help tie geological structures to crustal physiography. Excel worksheets are currently designed for groups of as much as 50 structures, and have been successfully used in structural geology laboratory exercises to help students visualize their field work. As GE is designed for viewing the Earth's surface, 3D well-field visualization requires lifting well-field components above land surface by a distance exceeding the deepest well. Well-head positions are established utilizing global-positioning systems (GPS) and digital elevation models. Interpreted borehole televiewer (BTV) records provide incremental structural orientation readings, associated borehole telemetry, and a measure of plane aperture, or thickness, Well-field components include borehole traces with cased and open intervals, geophysical logs, and 3D ellipses representing structural planes that can be dynamically viewed with graduated reference grids. Availability of BTV data on multiple wells in close proximity facilitates comparison of complex stratigraphic and structural relationships. Comparative thickness values for sets of planar features, such as branching and interconnecting faults within a fault zone, can be variably scaled in a model to help assess complex structures in multiply-tectonized terrains. These approaches have proven useful for linking geological heterogeneity, such as cross stratification, to aquifer anisotropy. Assessments are planned of the dimensional accuracy of the 3D well-field models.



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## This work builds on a concept used for a 300-level structural geology class, Rider University, Lawrenceville, NJ

IMPACTTECTONICS.ORG

Google Earth 2D structural geologic symbols, and 3D planes, cross sections, and borehole traces.

The <u>Notes PDF file</u> (8 MB) explains the MS Excel applications and illustrates the results for the different symbols, cross-sections, and borehole KMZ files.



Unzip the symbols file into a folder that you download all files to. The KMLs that you write must be in the same directory as the symbols (\*.dae) files in order for the scripts to work

GCH GE Notes 2012.pdf (10.8 MB)
 DAE Symbols.zip (23 KB)
 Four structures.txt (4 KB)
 N A-A'.txt (1 KB)
 NJ Bedrock cross section A.kmz (253 KB)
 NJ Bedrock Geology North.kmz (14.2 MB)
 Geologic symbols and circles 50 Flemington.xls (1.62 MB)
 Geologic symbols and circles 50 Flemington.kmz (157 KB)
 Stonybrook Millstone Wellfield OPTV data 2012.xls (2.26 MB)
 Stonybrook Millstone Wellfield OPTV data 2012.kmz (28 KB)
 GC Herman 04-2012

http://www.impacttectonics.org/gcherman/downloads/GEO310/GCH\_GESymbols/GCH\_GE\_Geology\_Apps.htm

- The New Jersey Geological and Water Survey uses Google Earth (GE) to help research the physical properties of fractured-bedrock aquifers.
- GE provides a flexible, practical, and popular software platform to help organize, display, and share 2D and 3D geological data collected in outcrop and with borehole geophysical logging tools.



• Computerized 2D geological symbols and 3D models are generated in Trimble SketchUp, then georegistered, scaled, and annotated utilizing Microsoft Excel to generate GE keyhole-markup-language (KML) files.



2D geological map symbols are available for stratigraphic layering, cleavage, joints, fractures, faults, and lineation, utilizing an approach based on Whitmeyer's on-line orientation-symbol generator.





2D geological symbols and 3D colored circles (next page) are plotted in GE using KML output from Excel Worksheets shown below.

The red numbers are the symbol numbers used in the worksheet.

The Collada object files (\*.dae files) must reside in the directory that the KML script is opened from in order for GE to be able to read them. 3D map symbols use circular or elliptical planes centered on outcrop locations that help tie geological structures to crustal physiography.











5-m-Bcircle.dae

5-m-Gcircle.dae 5-m-Pcircle.dae

Excel worksheets are currently designed for groups of as much as 50 structures, and have been successfully used in structural geology laboratory exercises to help students visualize their field work.

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24		58143	-74.85404 -74.85845	40.51847	0.00	10	74	40	20	1	6	fracture	4	5-m-Beirela.daa	\$2.51994996 855.56288264	554.55875188 -56.31648741	8.88522854	1.00010007	48.52155332	-24.85512865	airale
26		58144	-74.85845	40.51619	0.00	143	83	40	20	1	6	fracture	4	5-m-Beirelo.dao	216.65348855	-217.51071552	1.11311511	-8.88253847	48.51555585	-24.85526392	nicale
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29		58183	-74.86761	40.50273	0.00	143	68	40	20	1		fracture	4	5-m-Beirelo.dao	216.65548855	-217.51071352	8.88348688	-8.88255817	48.58845585	-24.85442352	aicale
30		58187	-14.86778	40.51766	0.00	50	81	40	20		6	fracture	4	5-m-Bairale.dae 5-m-Bairale.dae	-289.58987498	-221.65815112	-8.88417182	-ILII1133574	48.51565926	-74.87195182	airale
32	- 11	58187	-74,86778	40.51766	0.00	204	73	40	20	1	6	fracture	4	5-m-Bairale.dae	-146.42513151	-928.87695475	-8.88245334	-8.88255285	48.51463745	-74.85333391	airale
34	1	58188	-74.86443	40.51670	0.00	125	68	40	20	1	1	fracture	4	5-m-Beirela.daa	234.83473534	-215.41754713	1.10354245	-0.10201020	48.51483975	-24.85757245	niente
35	- 14	58189	-74.85085	40.50994	0.00	50	70	40	20	1		fracture	4	5-m-Beirela.daa	275.77533352	211.48353343	8.89485555	L.11211672	48.51282472	-74.84579447	sirale
37	10	58189	-74.85085	40.50994	0.00	305	70	40	20	1		fracture	1	5-m-Beirela.daa	-294.89479594	246.48254783	-8.884335653	-0.10315273	48.51188825	-24.85548653	sirale
38	- 17	58195	-74,87427	40.52176	0.00	70	62	40	20	1	6	fracture	4	5-m-Beirela.daa	81424228334348	123.12725168	1.11437414	1.11111325	48.52286925	-74.85523516	sirale
40		58195	-74.87427	40.52176	0.00	138	83	40	20	1	÷.	fracture	4	5-m-Beirele.dae	248.88784825	-267.59249747	8.88354246	-8.88241828	48.51534388	-24.82822754	airale
41	21	58196	-74.87184 -74.84091	40.52154	0.00	120	58	40	20	1	1	fracture	4	5-m-Beirelo.dao	858.42885888 844.25844585	25.44299855	L10521422	E.88822824	48.52176524	-74.86555178	airale
43	22	58215	-74.84091	40.50364	0.00	120	61	40	20	1	6	fracture	4	5-m-Bairale.dae	311.76314536	-111.1111111	LINSHIE	-8.88452452	48.58281898	-74.83532515	sicale
44	25	58228	-74.85324 -74.83457	40.52197	0.00	184	63 83	40	20	1	6	fracture	4	5-m-Beirelo.dao 5-m-Beirelo.dao	-343.38646146	-07.03100242	-0.00313505	-0.00070461	48.52118593	-74.85857585	airale
46	25	58231	-74.83457	40.52480	0.00	90	66	40	20	1	6	fracture	4	5-m-Bairale.dae	358.88888888	1.11111111	8.88525412	1.11111111	0.5201111	-74.82927588	sirale
41	25	58231	-74.83457	40.52480	0.00	274	82	40	20	1		fracture	1	5-m-Bairale.dae 5-m-Bairale.dae	-558.12985889	62.51394395 25.41299855	8.88524969	8.88855948	<pre>48.52535348 48.52582624</pre>	-74.82595591	airale
49	28	58231	-74.83457	40.52480	0.00	267	47	40	20	1	6	fracture	4	5-m-Beirelo.dao	-959.58669251	-18.84834425	-0.00520000	-8.83846374	40.52463026	-74.83585686	sirale
50	23	58231	-74.83457	40.52480	0.00	103	78	40	20	1		fracture	4	5-m-Beirelo.dao 5-m-Beirelo.dao	-558.82788255	-17.51124571	-IL.III526512 IL.III515041	-0.00033301	41.52445199	-74.83983512	airale
52	31	58231	-74,83457	40.52480	0.00	45	76	40	20	1	6	fracture	4	5-m-Beirele, dae	254.55844422	254.55844423	8.88374351	56665588.1	48.52783332	-74.83182545	airale
54	33	58232	-74.84463	40.51395	0.00	194	77	40	20	1	i i	fracture	4	5-m-Bairale.dae	47.1241242	-342.38545145	-8.88428876	-8.88914631	48.51888985	-24.84597875	sirate
55	34	58232	-74.84463	40.51395	0.00	92	52	40	20	1	6	fracture	4	5-m-Beirele.dae	153.78863773	-12.55381881	L.11523113	-0.110111213	48.51919511	-74.83333311	airale
57	36	58232	-74.84463	40.51395	0.00	177	72	40	20	1	6	fracture	4	5-m-Beirele.dae	18.84834425	-959.59659251	1.11827717	-1.113231111	48.51871128	-74.84441223	airale
58	37	58232	-74.84463	40.51395	0.00	204	71 80	40	20	1	6	fracture	4	5-m-Beirele.dae	-145.42519151 959.94517825	-858.58669254	8.88827787	1222001.0	48.51871128	-74.84441233	airale airale
60	33	58233	-74.84239	40.51534	0.00	279	88	40	20	1	6	fracture	4	5-m-Bairale.dae	-155.56788261	58.31548741	-8.88522834	1.11151735	48.51584735	-24.84751834	sirale
62		58233	-74.84239	40.51534	0.00	117	58	40	20	1		fracture	4	5-m-Beirele.dae 5-m-Beirele.dae	\$28.75234874 \$7.85488242	-163.43657331 -343.38646146	8.8842428	-8.88947248	48.51385758	-74.89767291	airale
63	- 62	58234	-74.84133	40.51593	0.00	4	90	40	20	1	6	fracture	4	5-m-Beirele.dae	25.11233855	959.42985889	1.111215331	1.112222214.1	48.51322534	-74,14102171	aïcale
65		58234	-74.84133	40.51533	0.00	270	87	40	20	1		fracture	4	5-m-Beirelo.dao	-358,0000000	1.11111111	8.88525442 -8.88525442	LIIIIIII	40.51555000	-24.04660412	airale
66	- 65	58234	-74.84139	40.51599	0.00	08	75	40	20	1		fracture	4	5-m-Beirelo.dao	154,51873588	62.54334336	8.88524969	L.11155341	48.51655318	-74.83517531	sinate
68	6	58235	-74.83282	40.51341	0.00	22	86	40	20	1	1	fracture	1	5-m-Beirelo.dao	114.45837363	333.78648764	1.1111111	1.41311711	48.52247788	-24.83883675	airate
69	- 0	58255	-74.81570	40.51913	0.00	112	86	40	20	1	6	fracture	4	5-m-Bairale.dae	333,78648764	-134.45837363	LINGHER	-8.18121024	48.51751585	-24.11123131	airate airate
71	51	58255	-74.81570	40.51913	0.00	6	75	40	20	1		fracture	1	5-m-Bairale.dae	37.63824678	151.42241233	1.11055393	1.111222541	(0.5223554)	-74,81514661	sicale
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4	1	Lopy this w	orksheet, and then wo	ork with the c	ору			0	Bedding	bed.dae		0	White		5-m-Weireleidae		<u> </u>
5	2	Enter the RE	D BOLD variables below	¥				1	Cleavage	cleavage.dae		1	Black		5-m-BLcircle.dae		B
6	3	Select the h	ighlighted cells starting	with Line 53				2	Layering	layer.dae		2	Red		5-m-Reircle.dae		C
<u>(</u>	4	Copy «Ctrl C	C> the content to the cli	pboard and pa	ste «Ctrl ¥	> them into	Notepad.	3	Joint	joint.dae		3	Green		5-m-Geireleidae		
8	5	Save the No	tepad file as an ".kml fil	e (Each kml fi	le must hav	/e an unique	filename)	4	Arrow	arrow.dae		4	Blue		5-m-Beirele.dae		
3	6	Open the KN	1L file in Google Earth.					5	Lineation	slip.dae		5	Light Bl	ue	5-m-LBcircle.dae		
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22	1	58164	-74.75146	40.62386	0.00	11	28	20	20	1	6	beddina	7		circle	11.44853972	58.89763101
23	2	58165	-74.75207	40.62365	0.00	11	28	20	20	1	0	beddina	7		bed.dae	7.63235982	39,26508734
24	3	58166	-74.76206	40.61375	0.00	348	18	20	20	1	0	beddina	7		bed.dae	-8.31646763	39,12590403
25	4	58124	-74.78581	40.60838	0.00	14	34	20	20	1	0	bedding	7		bed.dae	9.67687582	38.81182905
26	5	58283	-74.76731	40.60736	0.00	19	15	20	20	1	0	bedding	7		bed.dae	13.02272618	37.82074302
27	6	58168	-74.78602	40.5942	0.00	147	74	20	20	1	0	bedding	7		bed.dae	21.78556140	-33.54682272
28	7	58170	-74.7854	40.59057	0.00	351	15	20	20	1	0	bedding	7		bed.dae	-6.25737860	39.50753362
29	8	58171	-74.7847	40.59056	0.00	351	15	20	20	1	0	bedding	7		bed.dae	-6.25737860	39.50753362
30	9	58071	-74.80109	40.58857	0.00	190	34	20	20	1	0	bedding	7		bed.dae	-6.94592711	-39.39231012
31	10	58072	-74.79843	40.58738	0.00	170	66	20	20	1	0	bedding	7		bed.dae	6.94592711	-39.39231012
32	11	58073	-74.79688	40.58676	0.00	188	52	20	20	1	0	bedding	7		bed.dae	-5.56632404	-39.61072275
33	12	58282	-74.74989	40.57702	0.00	192	52	20	20	1	0	bedding	7		bed.dae	-8.31646763	-33.12530403
34	13	58178	-74.8081	40.57487	0.00	16	10	20	20	1	0	bedding	7		bed.dae	11.02549423	38.45046784
35	14	58050	-74.81781	40.57025	0.00	198	61	20	20	1	0	bedding	7		bed.dae	-12.36067977	-38.04226065
36	15	58108	-74.81515	40.57005	0.00	185	27	20	20	1	0	bedding	7		bed.dae	-3.48622971	-39.84778792
37	16	58111	-74.80518	40.56986	0.00	185	27	20	20	1	0	bedding	7		bed.dae	-3.48622971	-39.84778792
38	17	58107	-74.81871	40.56757	0.00	188	43	20	20	1	0	bedding	7		bed.dae	-5.56692404	-39.61072275
39	18	58212	-74.76818	40.6199	0.00	22	28	20	20	1	3	fracture	7		joint.dae	55.63103127	-22.47639560
40	19	58214	-74.77499	40.6156	0.00	22	28	20	20	1	3	fracture	7		joint.dae	55.63103127	-22.47639560
41	20	58205	-74.7513	40.60871	0.00	348	18	20	20	1	3	fracture	7		joint.dae	58.68885604	12.47470145
42	21	58206	-74.7543	40.60857	0.00	14	34	20	20	1	3	fracture	7		joint.dae	58.21774358	-14.51531374
43	22	58167	-74.76292	40.606	0.00	19	15	20	20	1	3	fracture	7		joint.dae	56.73111454	-19.53408927
44	23	58208	-74.7666	40.60141	0.00	25	34	20	20	1	3	fracture	7		joint.dae	54.37846722	-25.35703570
45	24	58127	-74.79208	40.6011	0.00	25	34	20	20	1	3	fracture	7		joint.dae	54.37846722	-25.35709570
46	25	58207	-74.76157	40.60086	0.00	147	74	20	20	1	3	fracture	7		joint.dae	-50.32023408	-32.67834210
47	26	58126	-74.78869	40.60022	0.00	207	67	20	20	1	3	fracture	7		joint.dae	-53,46039145	27.23942998
48	27	58209	-74.77219	40.59256	0.00	184	59	20	20	1	3	fracture	7		joint.dae	-59.85384302	4.18538842
49	28	58172	-74.7837	40.5919	0.00	184	59	20	20	1	3	fracture	7		joint.dae	-53.85384302	4.18538842
50	29	58070	-74.79979	40.58761	0.00	170	66	20	20	1	3	fracture	7		joint.dae	-53.08846518	-10.41883066
51	30	58069	-74.79118	40.58652	0.00	188	52	20	20	1	3	fracture	7		joint.dae	-53.41608412	8.35038606
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53	32	58210	-74.77827	40.58567	0.00	180	70	20	20	1	3	fracture	7		joint.dae	-60.00000000	0.00000000

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Google Earth KMZ file of the bedrock geology of the Flemington, NJ area.

Base image is from a NJGS project map showing basalt flows (orange polygons labeled Jp and Jo), bedding strike and dips, and faults (U – up thrown, and D – down thrown fault blocks).

Green (bed) and blue (fracture) ellipses are 3D Collada models that are 400 m long and 200 m wide with respect to strike and dip length (for a 2:1 aspect ratio).

Light blue lines are hydrography digital line graph shapefiles.

Interpreted borehole televiewer (BTV) records provide incremental structural orientation readings, associated borehole telemetry, and a measure of plane aperture, or thickness.



• Well-field components include borehole traces with cased and open intervals, geophysical logs, and 3D ellipses representing structural planes that can be dynamically viewed with graduated reference grids.



• As GE is designed for viewing the Earth's surface, 3D well-field visualization requires lifting well-field components above land surface by a distance exceeding the deepest well.

• Well-head positions are established utilizing global-positioning systems (GPS) and digital elevation models.

• Availability of BTV data on multiple wells in close proximity facilitates comparison of complex stratigraphic and structural relationships.



These approaches have proven useful for linking geological heterogeneity, such as **cross stratification**, to aquifer anisotropy.





Comparative thickness values for sets of planar features, such as branching and interconnecting faults within a fault zone, can be variably scaled in a model to help assess complex structures in multiply-tectonized terrains.



Red – faults are variable scaled using aperture thickness

A water-supply well and three observation wells drilled into a fault zone.

Image: constrained state s



March 18, 2013 G.C. Herman

Assessments are planned of the dimensional accuracy of the 3D well-field models

THANK YOU

