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 2nd and 3rd generation borehole televiewer (BTV) technology
  - 3D visualization methods for geological structures using GIS and Google Earth

NEW JERSEY GEOLOGICAL & WATER SURVEY
NJGWS
1835

March 18, 2013 G.C. Herman







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….

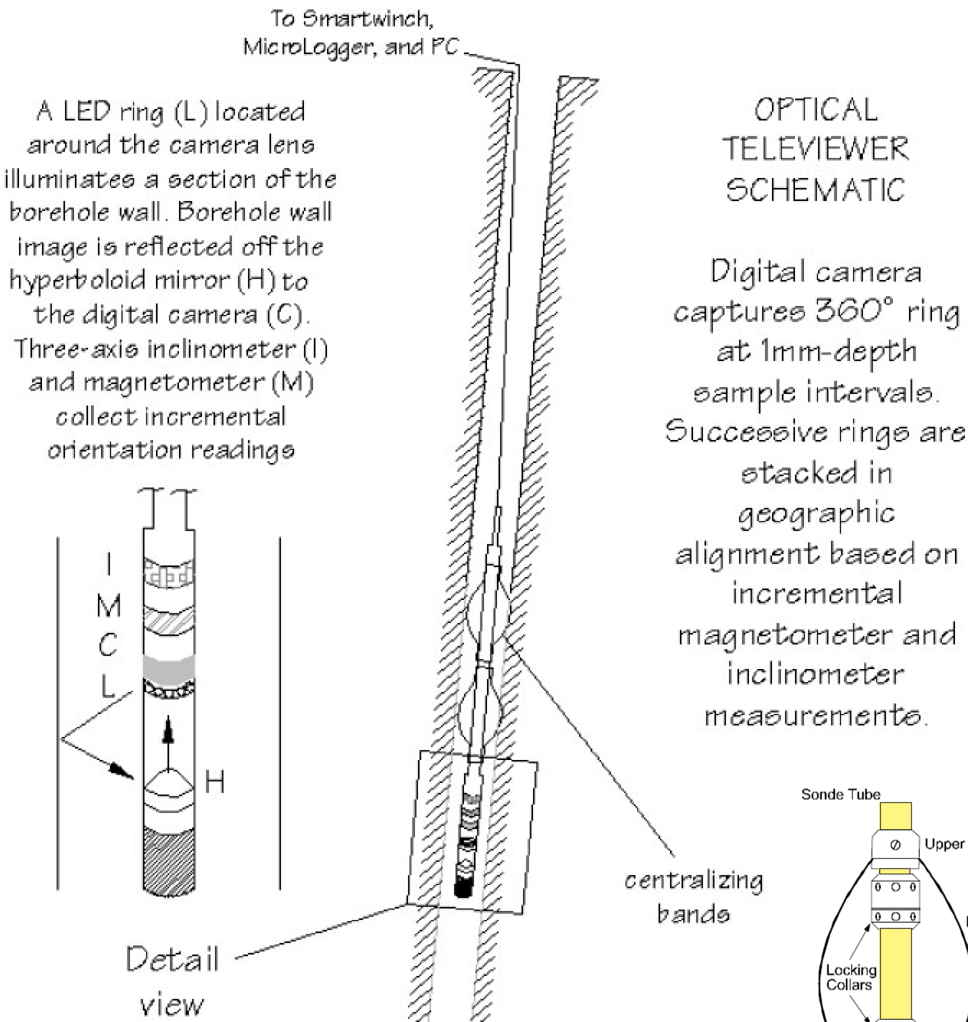
Robertson Geologging Ltd.System

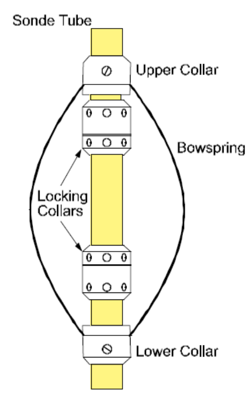
Portable Smartwinch w/ 300 m coax cable
Fluid temp and electrical conductivity
Multi-directional Color TV camera (VHS)
Optical Televiewer (OPTV)
Heat Pulse Flowmeter

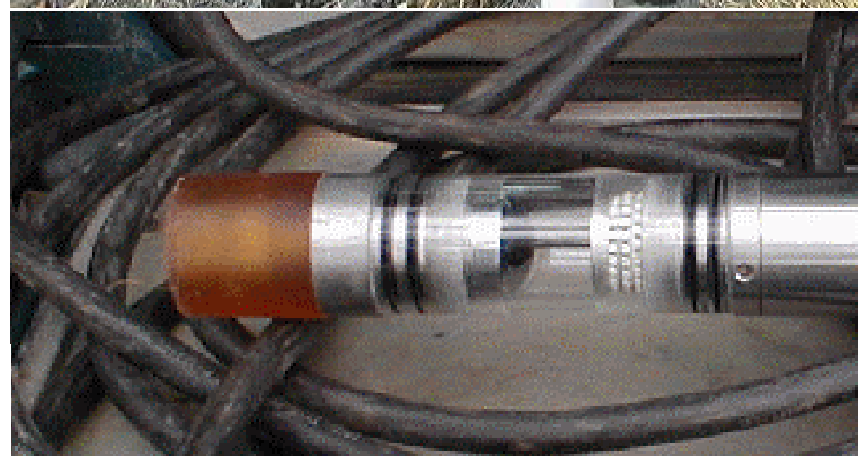
NJGS 2002-2010

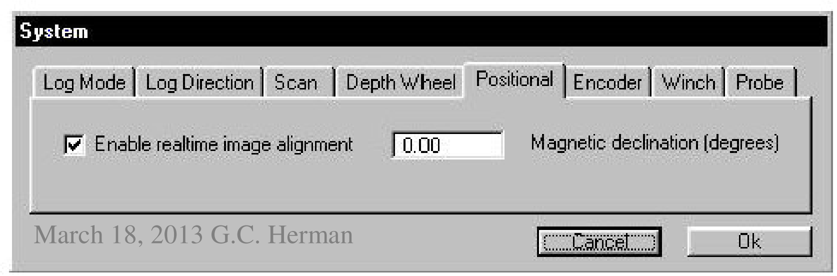
DOPTV

DIGITAL OPTICAL TELE-VIEWER

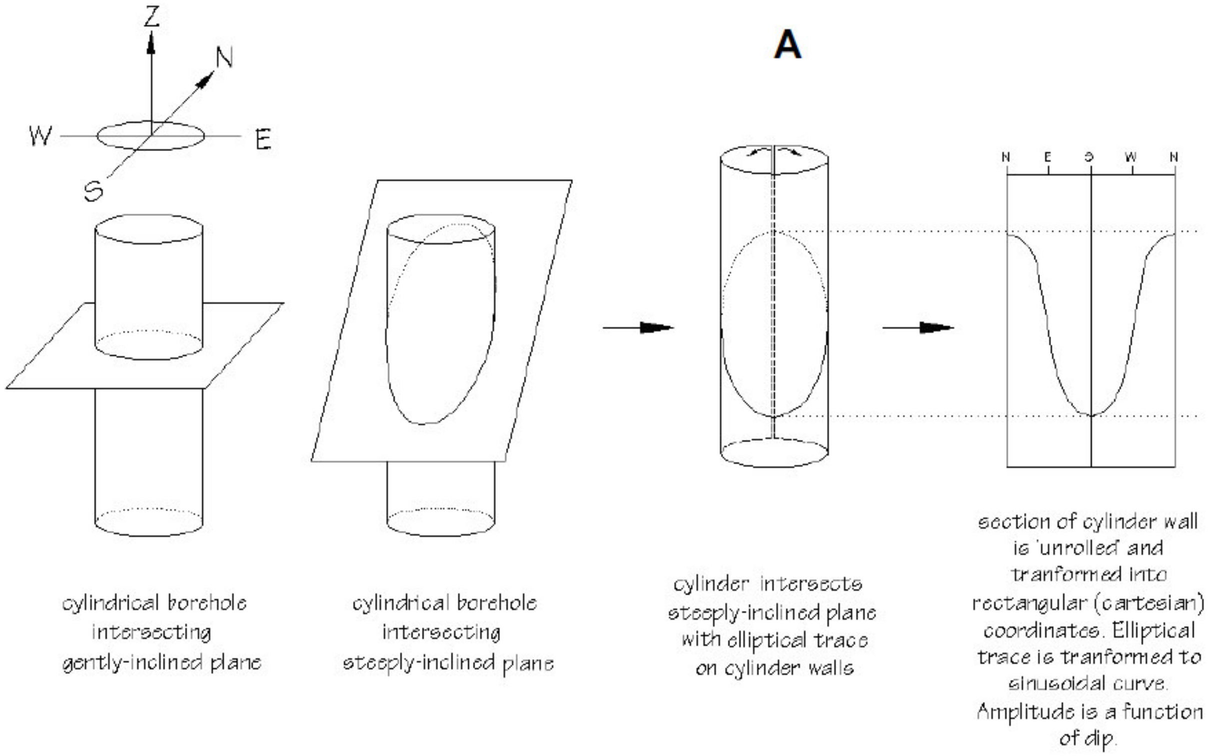






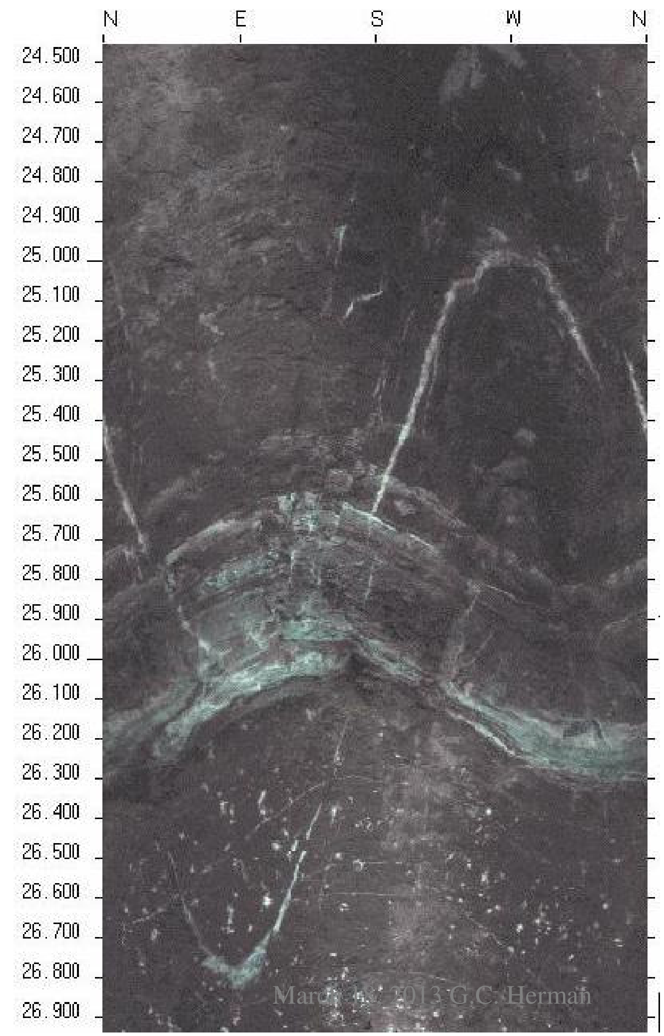


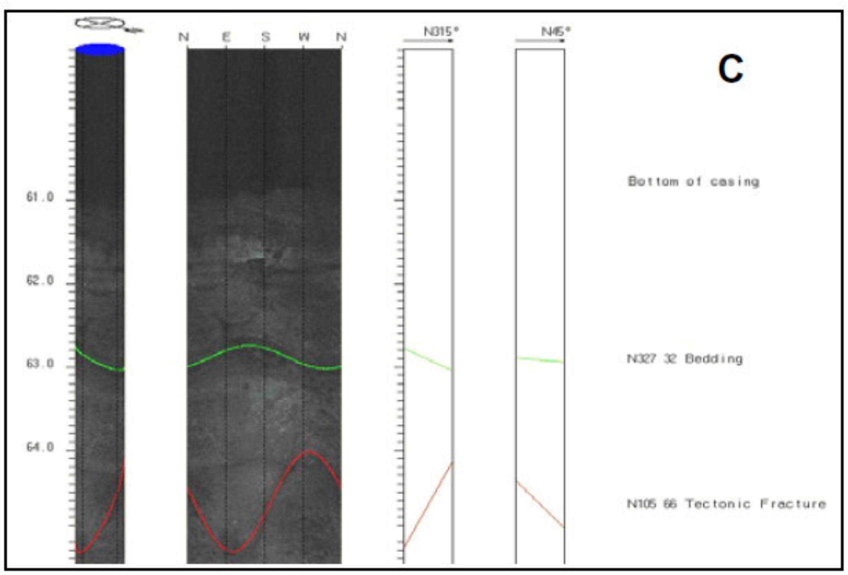
OPTV scans of 360 or 720 pixels per 1mm scan ring

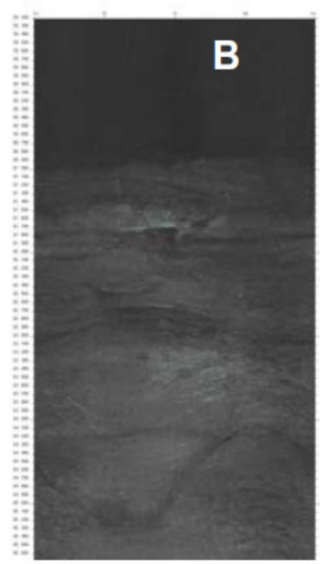


DOPTV

DIGITAL OPTICAL TELE-VIEWER







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.

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Well 46 - Brunswick middle red zone

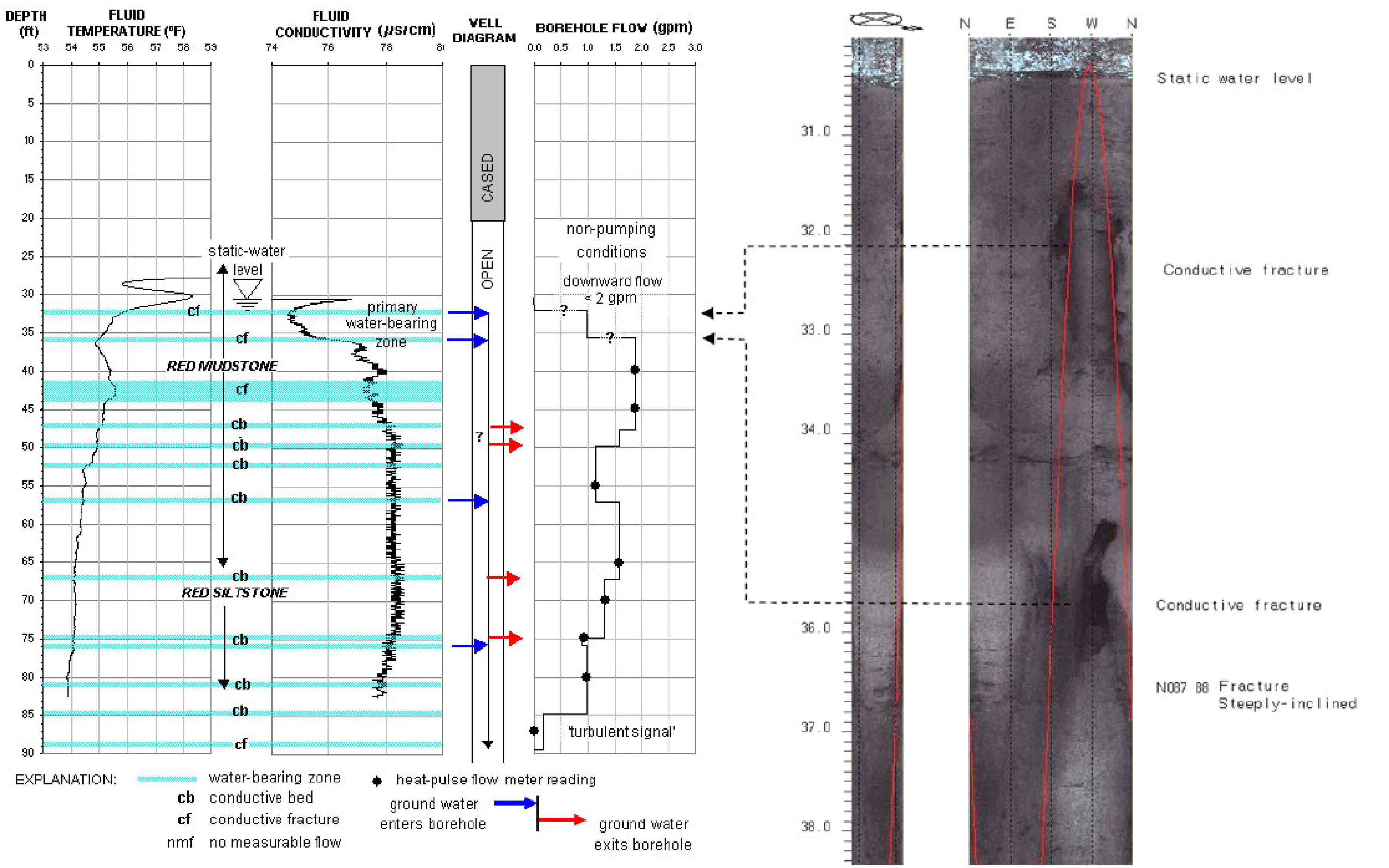
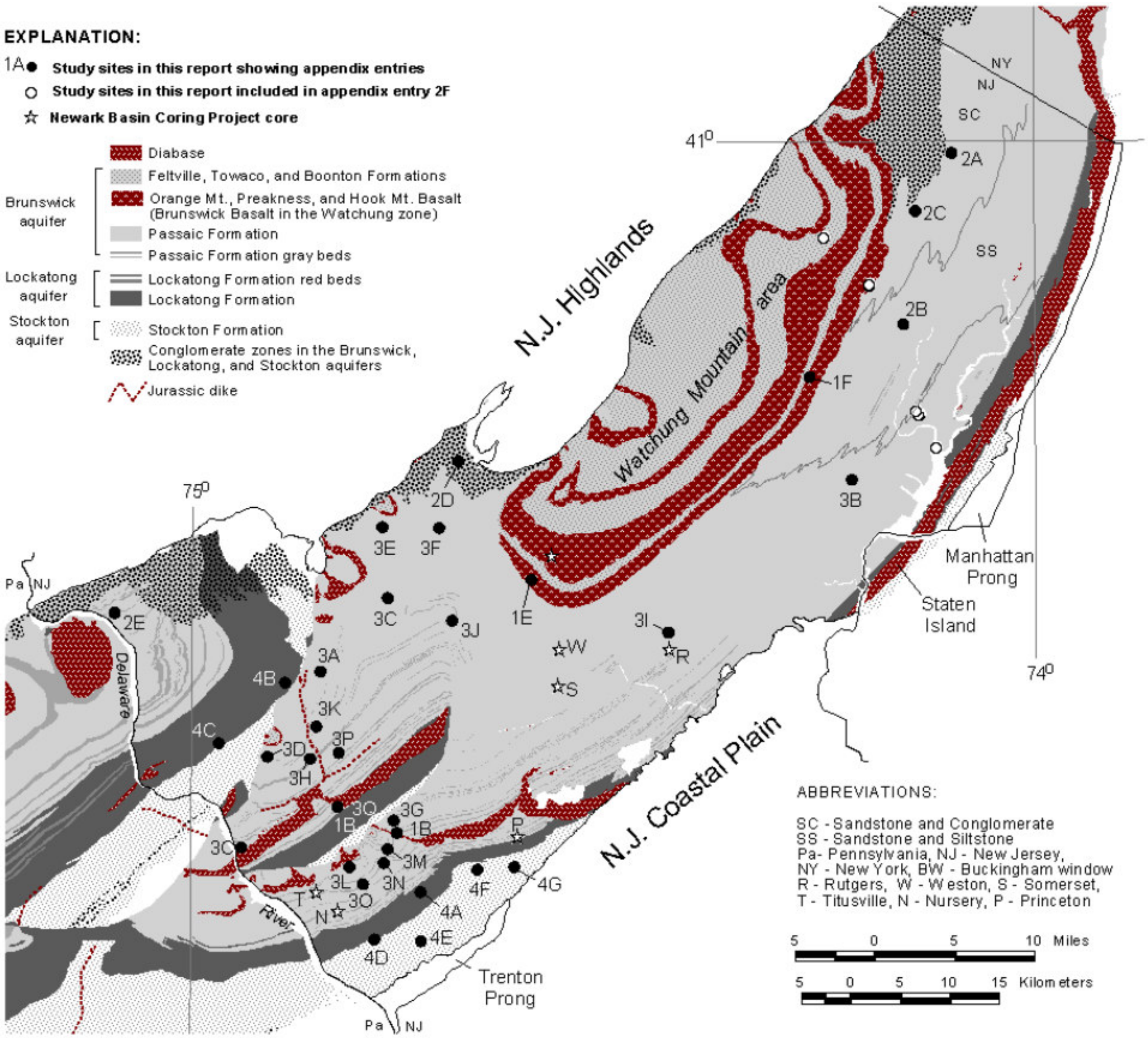


FIGURE 3C3. Hydrogeologic section based on geophysical logs (left) for well 46 at 15 Roosevelt Rd, Readington Twp, Hunterdon County, NJ. The section shows the vertical distribution and types of hydraulically-conductive features and water-bearing zones in red mudstone. An OPTV record of the 6-inch diameter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

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

Advanced Logic Technology

www.mountsopris.com MOUNT SOPRIS Instruments Geophysical Logging Systems

OBI40 Optical Borehole Imager

2 Measurement Principle

5

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).

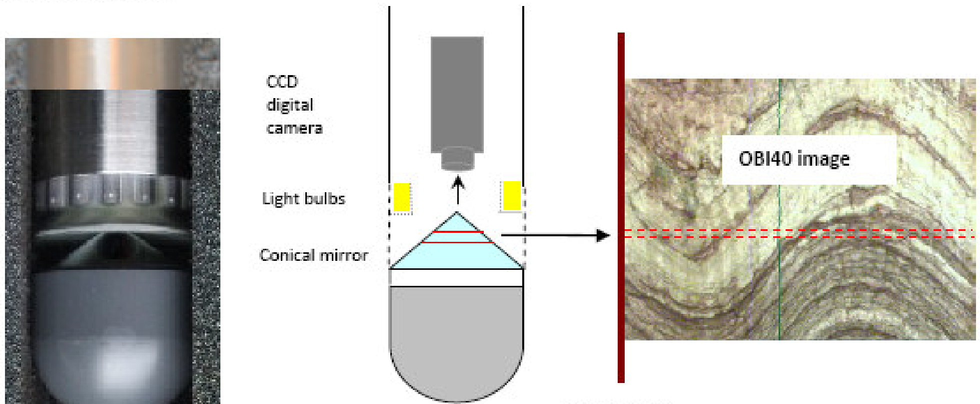
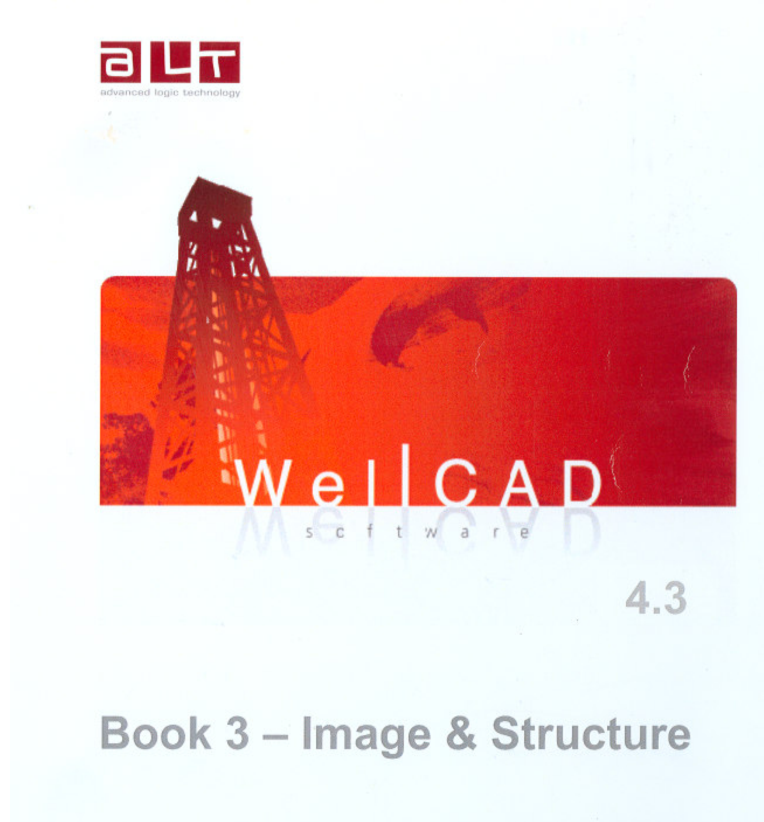
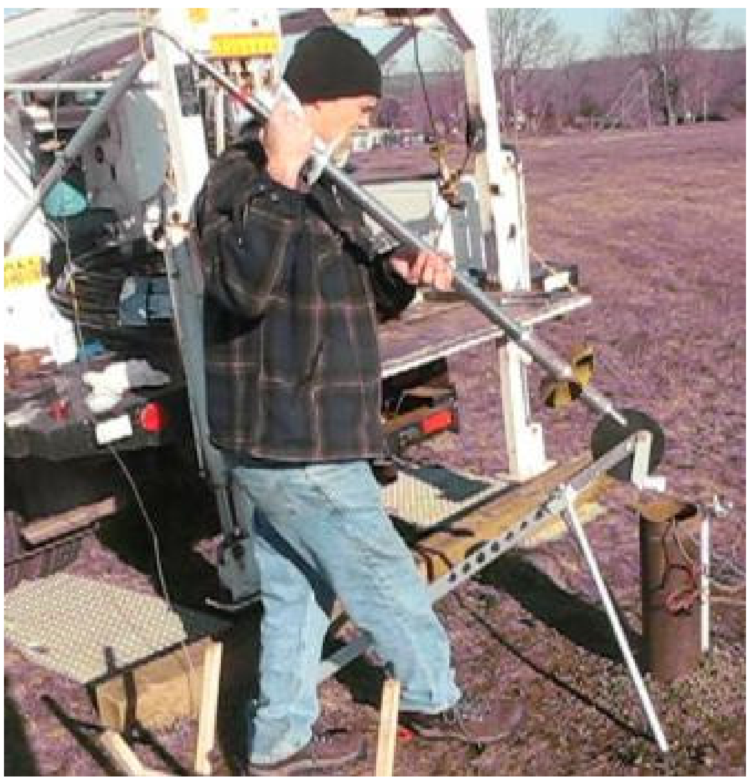


Figure 2-1 Optical assembly





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

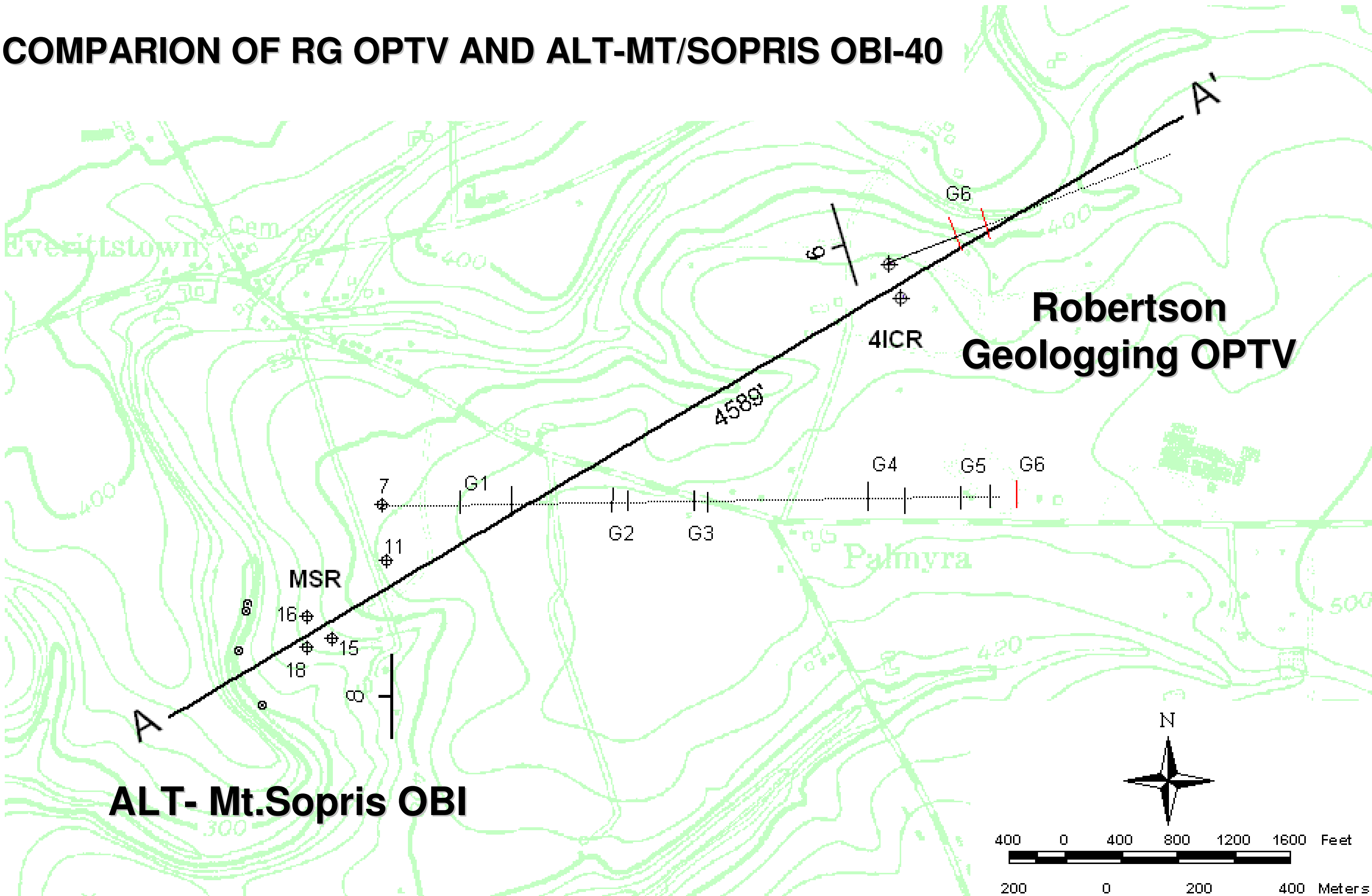
0.15 ft/min. to 13 ft/min. — 0.046 m/min. to 3.962 m/min.

Resolution	Accuracy
5%	5% (Mid-Range) to 15% (Extremes)

Pressure Rating

2000 PSI or 13789 Pascal (.43197 psi/ft ~6000 ft)

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



Base map from the US Geological Survey Frenchtown, NJ-Pa 7-1/2' Topographic quadrangle.

EXPLANATION:

Water well with line trace of penetrated stratigraphic interval

A —— A' Cross-section trace

Outcrop notes

8 Strike and dip from OBI image analysis

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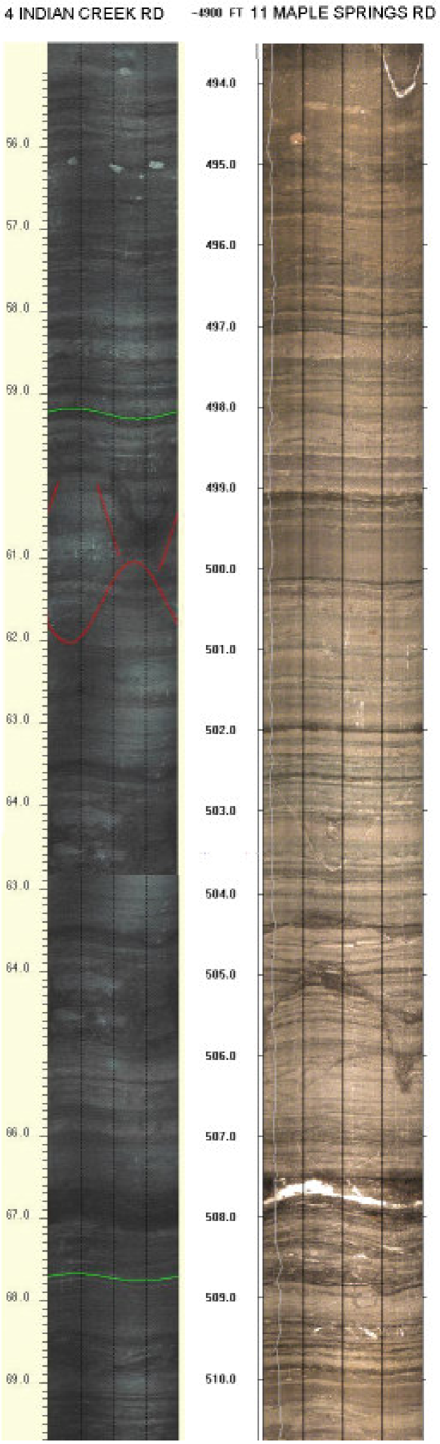
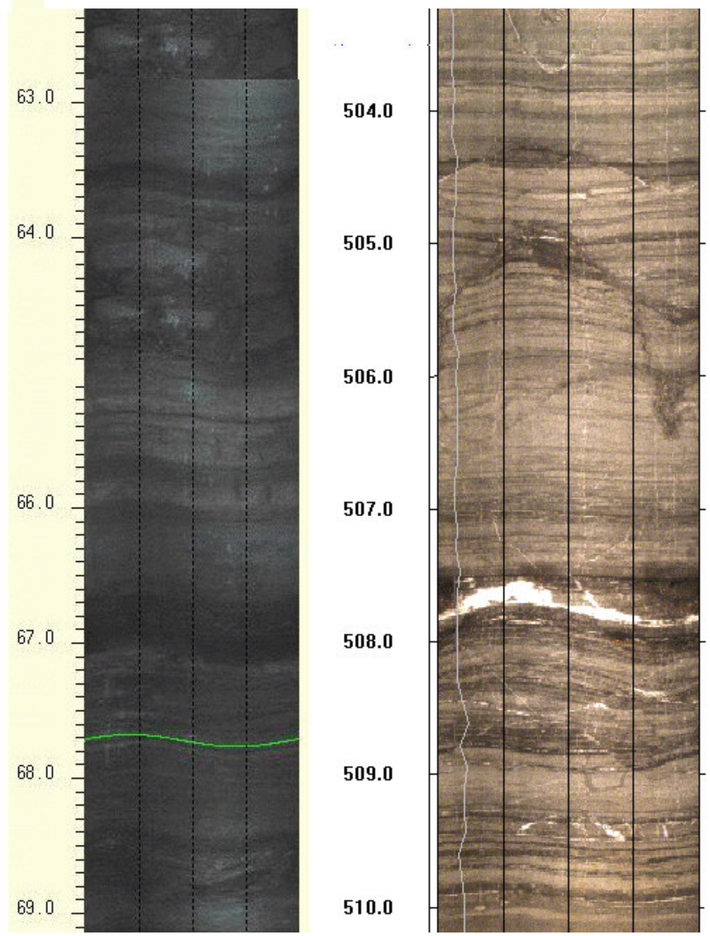
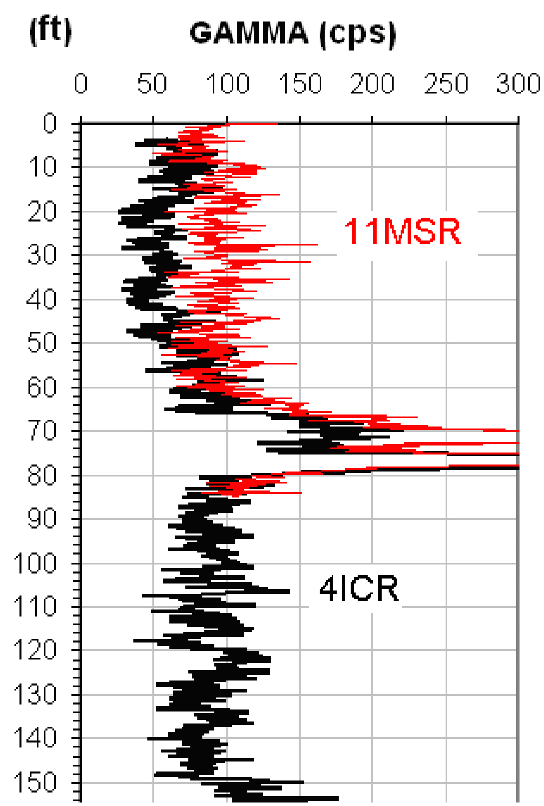
COMPARION OF RG OPTV AND ALT-MT/SOPRIS OBI-40



Correlation of the "Borrelli bed" within the lower gray zone of the Brunswick aquifer, Warford (?) member of the Passaic Formation from Olsen and others (1996), using Gamma-ray and Optical Borehole Imaging logs.





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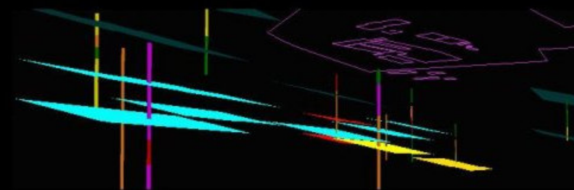
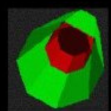
3D Well-Field Generation and Visualization

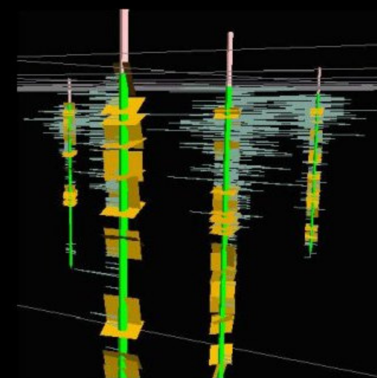
with ESRI ArcView® 3D Analyst™



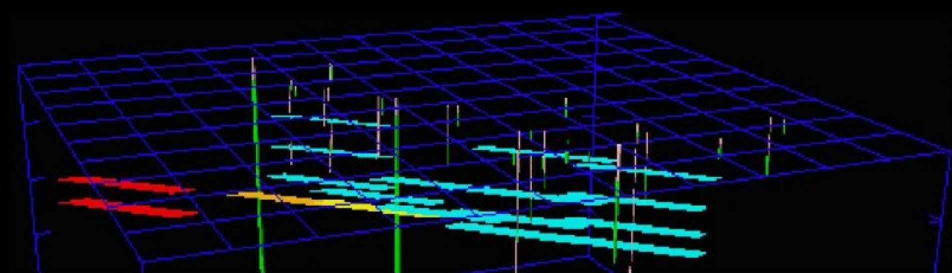
Inclined water-bearing zones indexed by estimated yield and packer-test results indexed by MTBE concentrations



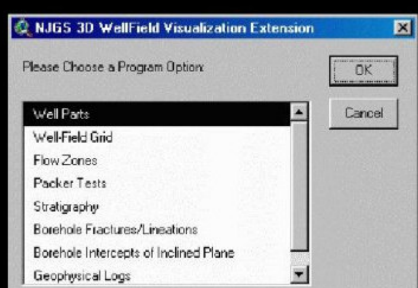
Well parts use Multipatch PolygonZ planes centered about the borehole in an octagonal arrangement

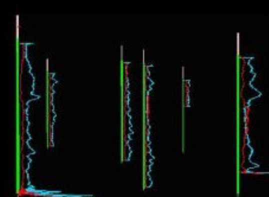


Borehole fractures and fluid-temperature-differential records from acoustic televiewer and fluid-temperature logs.



Well-field grid, inclined water-bearing zones (indexed by yield), water-production wells, and monitoring wells (pink - cased intervals, green open/screened intervals)





Electromagnetic Resistivity (red) and Conductivity Geophysical Logs

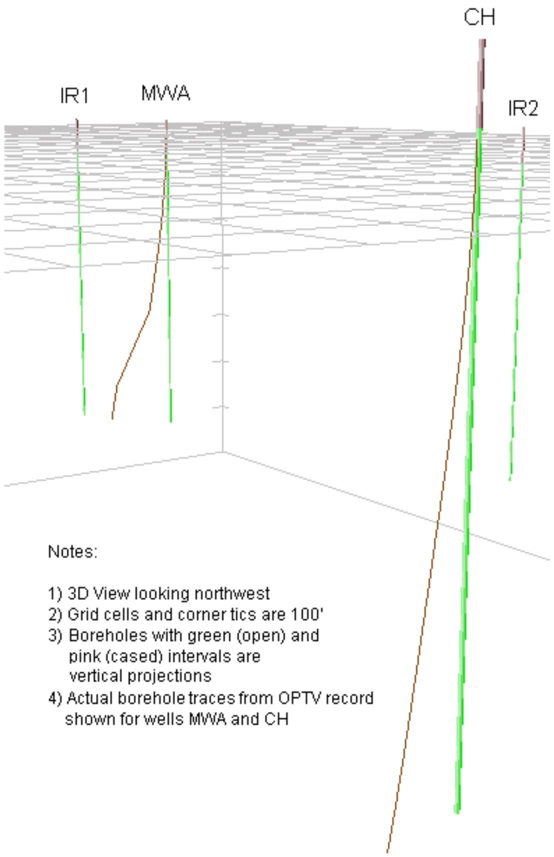
3D generation and visualization of

- *Well-field well-construction parts*
- *Inclined planes*
- *Packer-test results*
- *Borehole-fractures*
- *Borehole geophysical logs*

An ArcView ® 3DWellField Extension written by the N.J. Geological Survey for use with ESRI ArcView ® 3D Analyst™

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

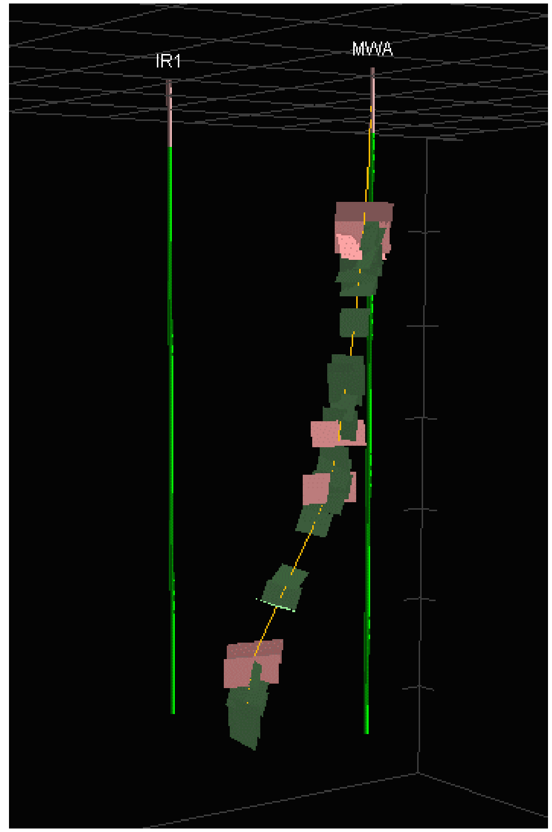
3D VIEW OF PART OF THE RIDGE GOLF COURSE WELL FIELD, EAST AMWELL TWP., HUNTERDON COUNTY, NEW JERSEY, N.J. GEOLOGICAL SURVEY, G.C. HERMAN, 2003 SEPTEMBER 19



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 traces from OPTV record shown for wells MWA and CH

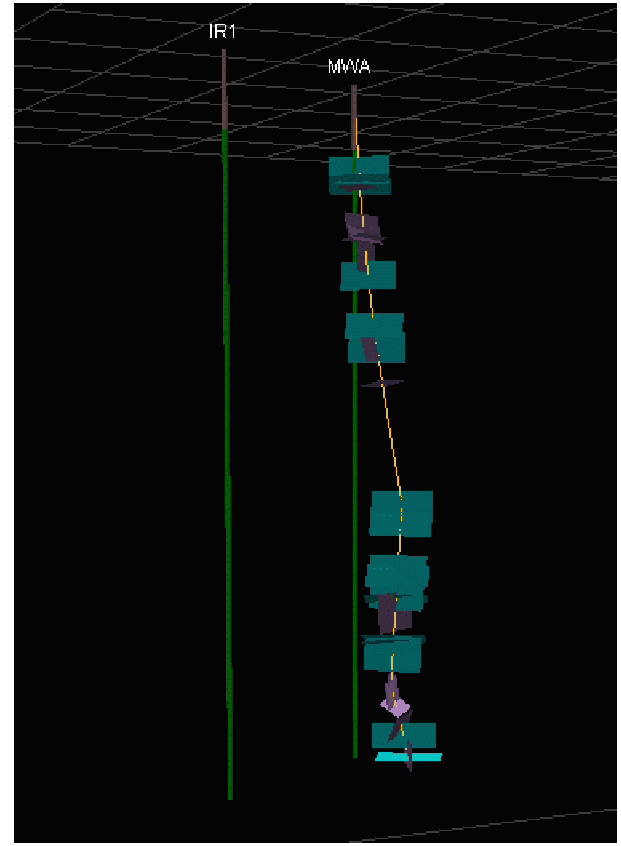
3D VIEW OF THE RIDGE GOLF COURSE WELL FIELD IN THE VICINTY OF MONITORING WELL MWA, EAST AMWELL TWP., HUNTERDON COUNTY, NEW JERSEY, N.J. GEOLOGICAL SURVEY, G.C. HERMAN, 2003 SEPTEMBER 19



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, G.C. HERMAN, 2003 SEPTEMBER 19



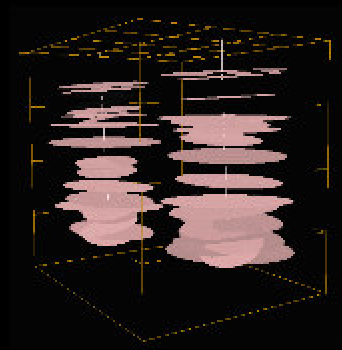
Notes:

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)

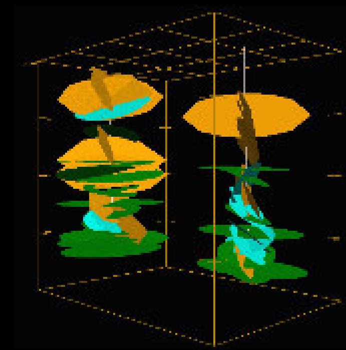
Virtual Reality Model Language (VRML) programs provide dynamic display of three-dimensional shapes using VRML viewers and Internet browsers.

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.

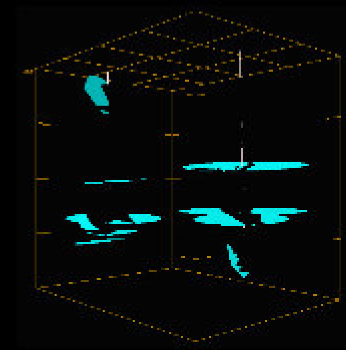


Bedding planes



Brittle fractures

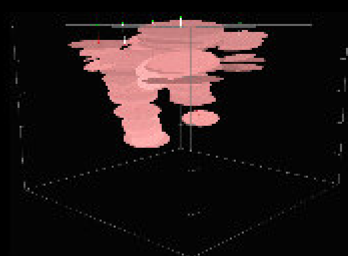
Green dips <30°
Blue dips 30-60°
Orange dips 60-90°

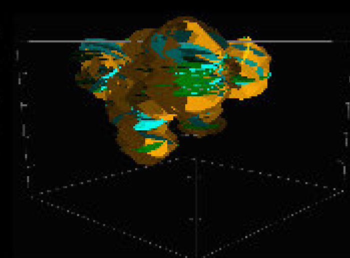


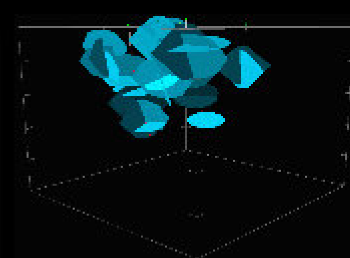
Water-bearing planes

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

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

52

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

HERMAN, Gregory C., 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 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. 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.

Session No. 52
T22. Innovations in Geoscience Education and Research Using Google Earth and Related Digital Technologies
Tuesday, 19 March 2013: 1:30 PM-5:40 PM

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

52

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Presentation Time: 4:40 PM

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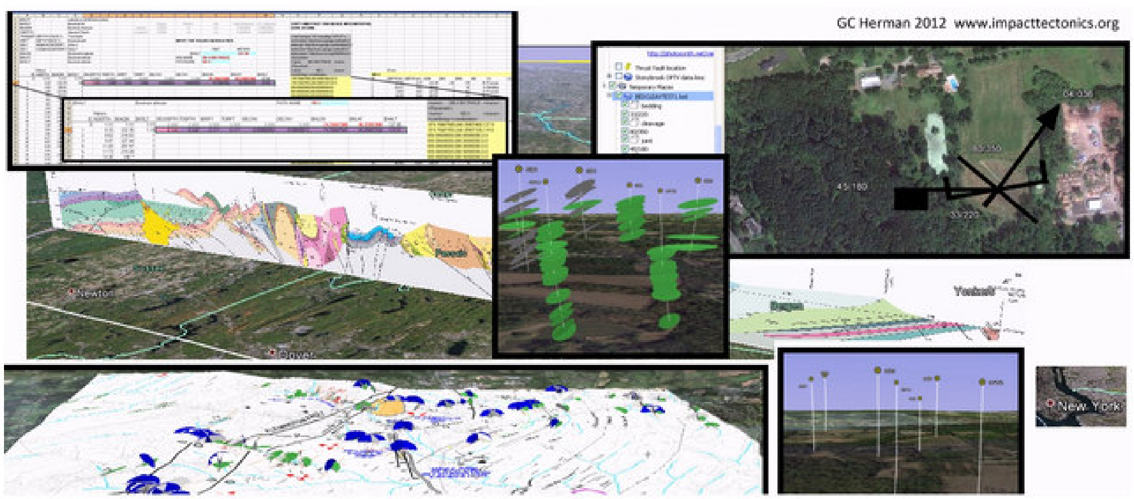
T22. Innovations in Geoscience Education and Research Using Google Earth and Related Digital Technologies
Tuesday, 19 March 2013: 1:30 PM-5:40 PM

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 Notes PDF file (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

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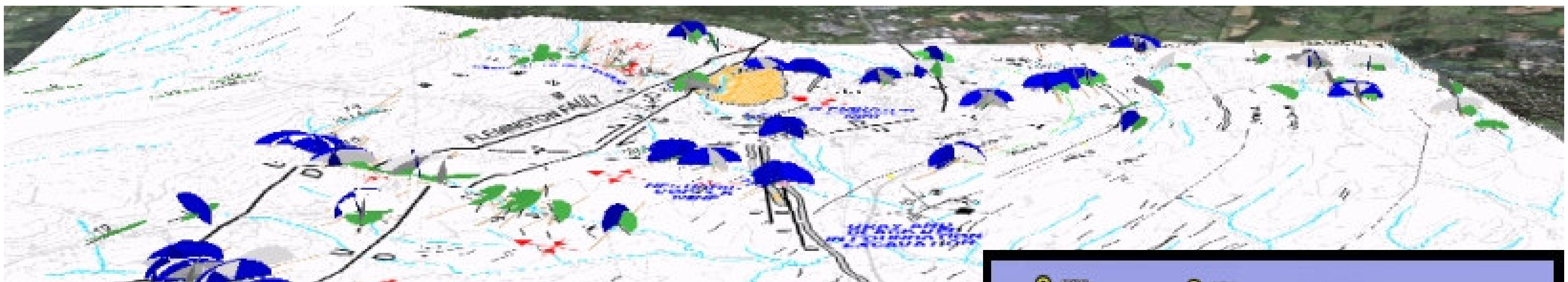
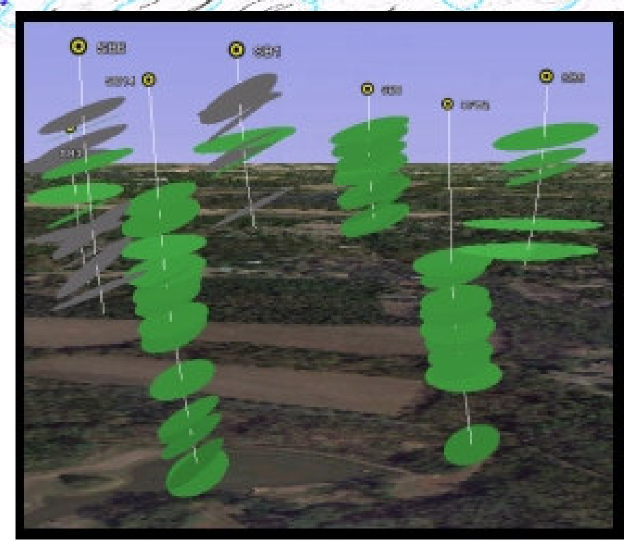
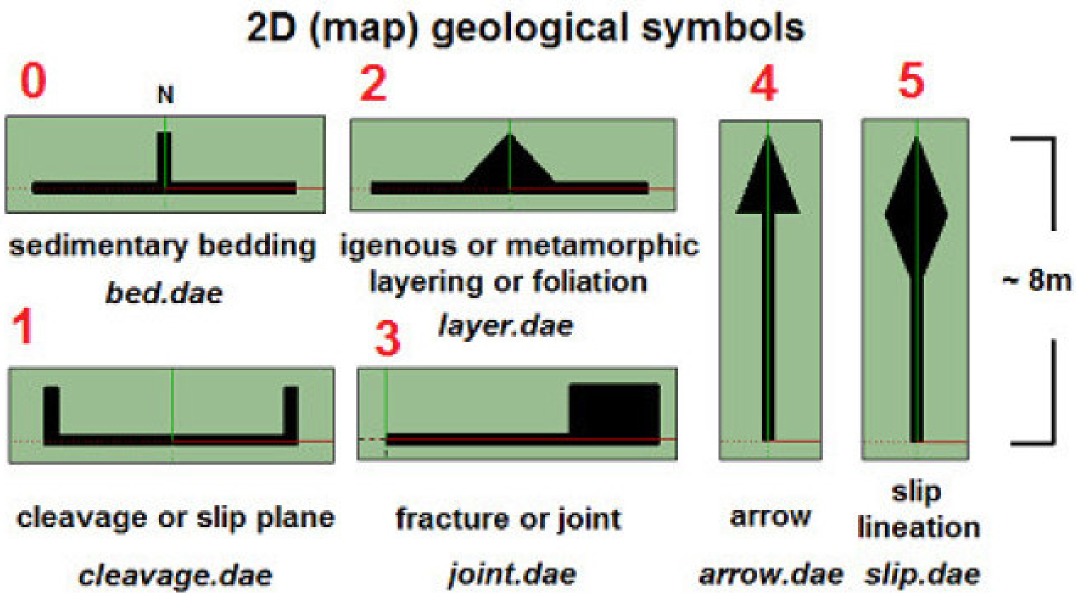


• Computerized 2D geological symbols and 3D models are generated in Trimble SketchUp, then georegistered, scaled, and annotated utilizing Microsoft Excel to generate GE keyhole-markup-language (KML) files.



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.

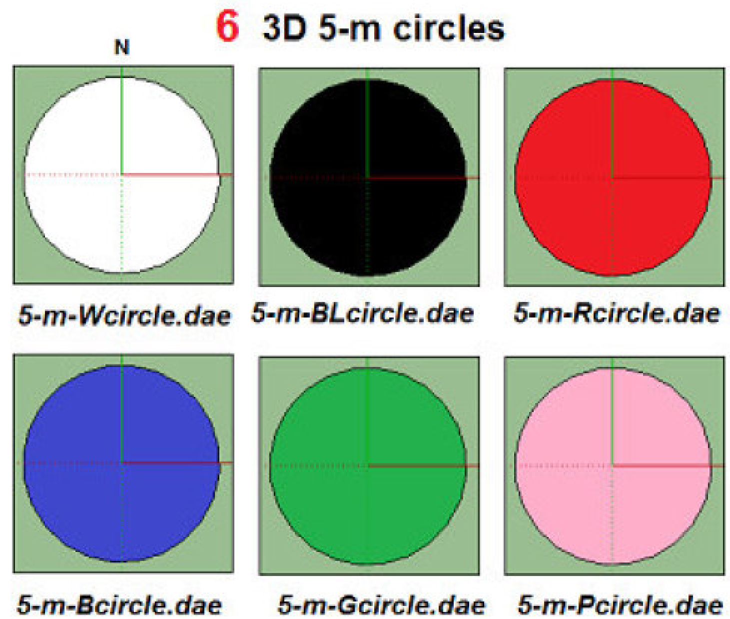


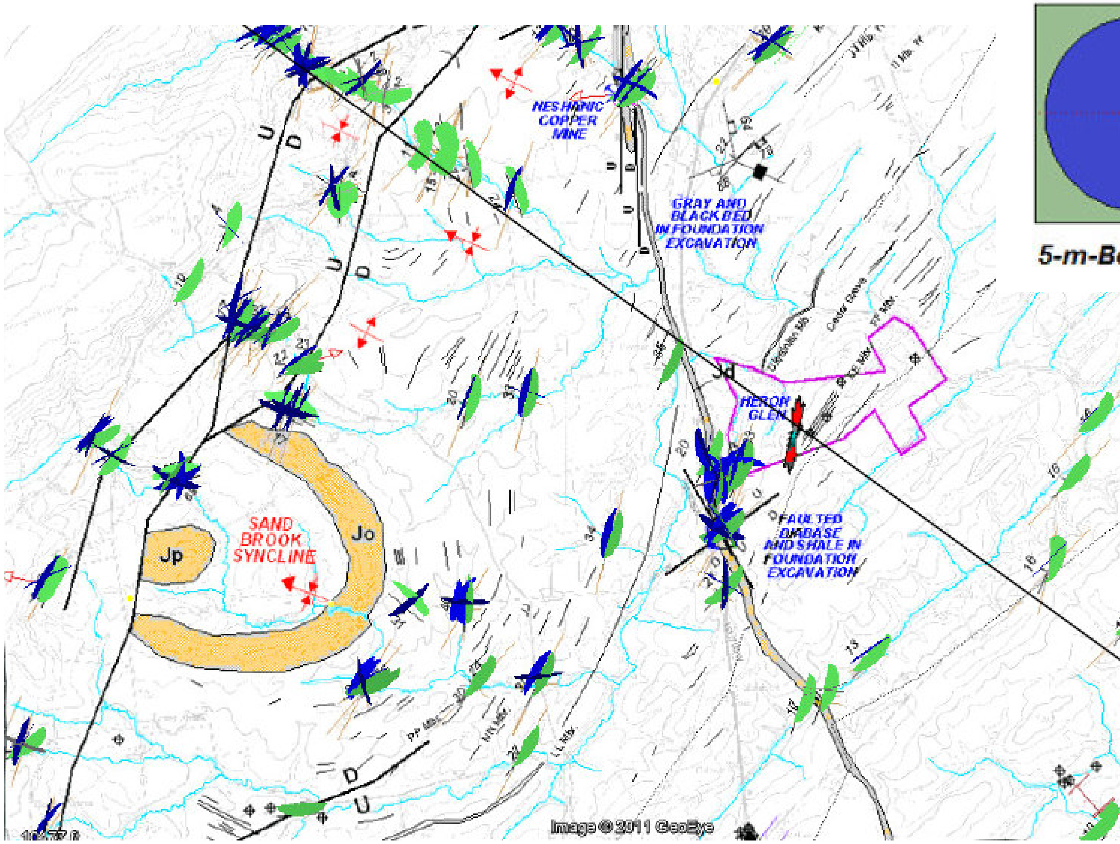
2D geological symbols and 3D colored circles (next page) are plotted in GE using KML output from Excel Worksheets shown below.

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.





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.

Geologic_symbols_and_circles_50_Flemington.xls

INSTRUCTIONS

1. Copy this worksheet, and then work with the copy
2. Enter the RED BOLD variables below
3. Select the highlighted cells starting with Line 53
4. Copy <Ctrl C> the content to the clipboard and paste <Ctrl V> them into Notepad.
5. Save the Notepad file as an *.kml file (Each kml file must have an unique filename)
6. Open the KML file in Google Earth.

SYMBOL KEY

0	Bedding
1	Cleavage
2	Layering
3	Joint
4	Arrow
5	Lineation
6	Circle

CIRCLE COLORS

0	White
1	Black
2	Red
3	Green
4	Blue
5	Light Blue
6	Pink

*Note use color 7 when using symbols other than circles

KML NAME: fractures 1

SYMBOL DIMENSIONS

Length (m) of symbol at scale = 1:

ANNO SPACING FACTOR (increase number for wider spacing)

Bed and layer dip line (~1.5 m): 3 (2D default = 3)

Joint, arrow, slip-line (~ 8.0 m) or 5-m 3D circle: 9 (2D default = 9, 3D = 3)

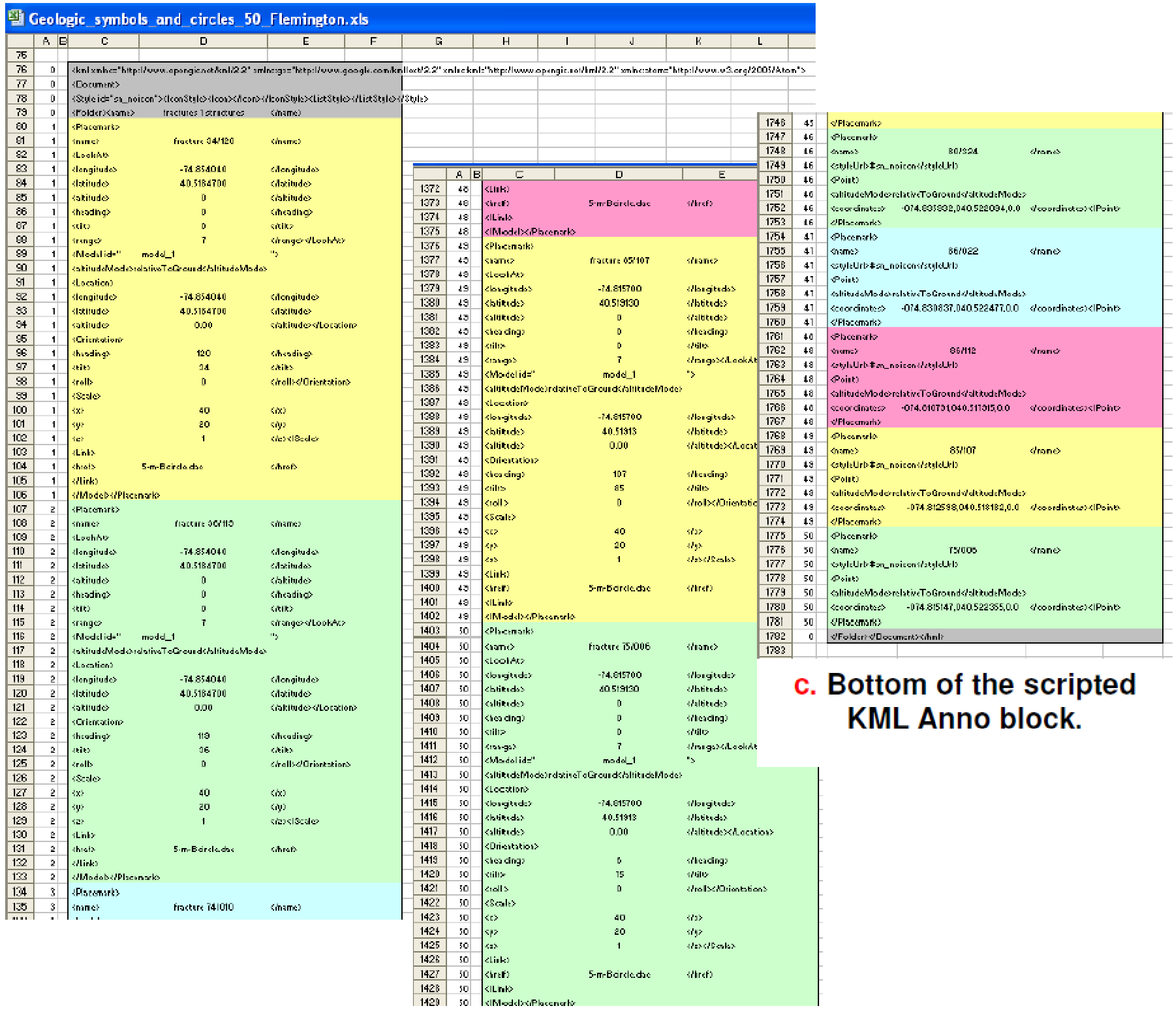
Station	Longitude	Latitude	Altitude	Azimuth	Dip/Plunge	Xscale	Yscale	Zscale	Symbol	Note	Color
58143	-74.85404	40.51847	0.00	120	34	40	20	1	6	fracture	4
58143	-74.85404	40.51847	0.00	119	36	40	20	1	6	fracture	4
58143	-74.85404	40.51847	0.00	10	74	40	20	1	6	fracture	4
58144	-74.85845	40.51619	0.00	39	74	40	20	1	6	fracture	4
58144	-74.85845	40.51619	0.00	143	83	40	20	1	6	fracture	4
58144	-74.85845	40.51619	0.00	62	74	40	20	1	6	fracture	4
58183	-74.86761	40.50273	0.00	234	80	40	20	1	6	fracture	4
58183	-74.86761	40.50273	0.00	143	68	40	20	1	6	fracture	4
58187	-74.86778	40.51766	0.00	232	87	40	20	1	6	fracture	4
58187	-74.86778	40.51766	0.00	50	81	40	20	1	6	fracture	4
58187	-74.86778	40.51766	0.00	204	73	40	20	1	6	fracture	4
58188	-74.86443	40.51670	0.00	222	80	40	20	1	6	fracture	4
58188	-74.86443	40.51670	0.00	125	68	40	20	1	6	fracture	4
58189	-74.85085	40.50994	0.00	50	70	40	20	1	6	fracture	4
58189	-74.85085	40.50994	0.00	165	74	40	20	1	6	fracture	4
58189	-74.85085	40.50994	0.00	305	70	40	20	1	6	fracture	4
58195	-74.87427	40.52176	0.00	70	62	40	20	1	6	fracture	4
58195	-74.87427	40.52176	0.00	96	68	40	20	1	6	fracture	4
58195	-74.87427	40.52176	0.00	138	83	40	20	1	6	fracture	4
58196	-74.87184	40.52154	0.00	86	58	40	20	1	6	fracture	4
58215	-74.84091	40.50364	0.00	120	61	40	20	1	6	fracture	4
58215	-74.84091	40.50364	0.00	120	61	40	20	1	6	fracture	4
58228	-74.85324	40.52197	0.00	256	63	40	20	1	6	fracture	4
58231	-74.83457	40.52480	0.00	184	83	40	20	1	6	fracture	4
58231	-74.83457	40.52480	0.00	90	66	40	20	1	6	fracture	4
58231	-74.83457	40.52480	0.00	80	57	40	20	1	6	fracture	4
58231	-74.83457	40.52480	0.00	274	82	40	20	1	6	fracture	4
58231	-74.83457	40.52480	0.00	267	47	40	20	1	6	fracture	4
58231	-74.83457	40.52480	0.00	264	63	40	20	1	6	fracture	4
58231	-74.83457	40.52480	0.00	103	78	40	20	1	6	fracture	4
58231	-74.83457	40.52480	0.00	45	76	40	20	1	6	fracture	4
58232	-74.84469	40.51395	0.00	111	60	40	20	1	6	fracture	4
58232	-74.84469	40.51395	0.00	194	77	40	20	1	6	fracture	4
58232	-74.84469	40.51395	0.00	92	52	40	20	1	6	fracture	4
58232	-74.84469	40.51395	0.00	95	49	40	20	1	6	fracture	4
58232	-74.84469	40.51395	0.00	177	72	40	20	1	6	fracture	4
58232	-74.84469	40.51395	0.00	204	71	40	20	1	6	fracture	4
58233	-74.84239	40.51534	0.00	91	80	40	20	1	6	fracture	4
58233	-74.84239	40.51534	0.00	279	88	40	20	1	6	fracture	4
58233	-74.84239	40.51534	0.00	117	58	40	20	1	6	fracture	4
58233	-74.84239	40.51534	0.00	166	82	40	20	1	6	fracture	4
58234	-74.84139	40.51599	0.00	4	90	40	20	1	6	fracture	4
58234	-74.84139	40.51599	0.00	90	87	40	20	1	6	fracture	4
58234	-74.84139	40.51599	0.00	270	87	40	20	1	6	fracture	4
58234	-74.84139	40.51599	0.00	80	75	40	20	1	6	fracture	4
58235	-74.83282	40.51947	0.00	324	80	40	20	1	6	fracture	4
58235	-74.83282	40.51947	0.00	22	86	40	20	1	6	fracture	4
58255	-74.81570	40.51913	0.00	112	86	40	20	1	6	fracture	4
58255	-74.81570	40.51913	0.00	107	85	40	20	1	6	fracture	4
58255	-74.81570	40.51913	0.00	6	75	40	20	1	6	fracture	4

Geologic_symbols_and_circles_50.xls

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1																		
2			INSTRUCTIONS						SYMBOL KEY				CIRCLE COLORS					ANNO PLAC
3																		
4	1		Copy this worksheet, and then work with the copy						0	Bedding	bed.dae		0	White		5-m-Wcircle.dae		A
5	2		Enter the RED BOLD variables below						1	Cleavage	cleavage.dae		1	Black		5-m-BLcircle.dae		B
6	3		Select the highlighted cells starting with Line 53						2	Layering	layer.dae		2	Red		5-m-Rcircle.dae		C
7	4		Copy <Ctrl C> the content to the clipboard and paste <Ctrl V> them into Notepad.						3	Joint	joint.dae		3	Green		5-m-Gcircle.dae		
8	5		Save the Notepad file as an *.kml file (Each kml file must have an unique filename)						4	Arrow	arrow.dae		4	Blue		5-m-Bcircle.dae		
9	6		Open the KML file in Google Earth.						5	Lineation	slip.dae		5	Light Blue		5-m-LBcircle.dae		
10									6	Circle	circle		6	Pink		5-m-Pcircle.dae		
11													*Note use color 7 when using symbols other than circles					
12			KML NAME	SB-1														
13																		
14			ANNO SPACING FACTOR		SYMBOL DIMENSIONS													
15			(increase number for wider spacing)								Degree	Meters	Unit	Value				
16					Length (m) of symbol at scale = 1,				Latitude		0.00001	1.11	1 m=	######				
17			2	(2D default = 3, 3D = 2)	Bed and layer dip line ~1.5 m				Longitude		0.00001	0.68	1 m=	######				
18			3	(2D default = 9, 3D = 3)	Joint, arrow, and slip-line ~ 7.5 m													
19																		

	A	Station	Longitude	Latitude	Altitude	Azimuth	Dip/Plunge	Xscale	Yscale	Zscale	Symbol	Note	Color	File	DEL_X	DEL_Y
22	1	58164	-74.75146	40.62386	0.00	11	28	20	20	1	6	bedding	7	circle	11.44853972	58.89763101
23	2	58165	-74.75207	40.62365	0.00	11	28	20	20	1	0	bedding	7	bed.dae	7.63235982	39.26508734
24	3	58166	-74.76206	40.61375	0.00	348	18	20	20	1	0	bedding	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	-5.56692404	-39.61072275
33	12	58282	-74.74989	40.57702	0.00	192	52	20	20	1	0	bedding	7	bed.dae	-8.31646763	-39.12590403
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	-25.35709570
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	-59.85384302	4.18538842
50	29	58070	-74.79979	40.58761	0.00	170	66	20	20	1	3	fracture	7	joint.dae	-59.08846518	-10.41889066
51	30	58069	-74.79118	40.58652	0.00	188	52	20	20	1	3	fracture	7	joint.dae	-59.41608412	8.35038606
52	31	58077	-74.7859	40.58619	0.00	180	70	20	20	1	3	fracture	7	joint.dae	-60.00000000	0.00000000
53	32	58210	-74.77827	40.58567	0.00	180	70	20	20	1	3	fracture	7	joint.dae	-60.00000000	0.00000000

The worksheet includes cells and cell blocks for data input and a cell block for data output.



c. Bottom of the scripted KML Anno block.

b. Bottom of the scripted KML cell block for symbols and Top of the Anno block.

Geologic_symbols_and_circles_50.xls

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
70	49		58080	-74.81211	40.56778	0.00	188	43	20	20	1	3	fracture	7		joint.dae
71	50		58169	-74.78643	40.5904	0.00	190	34	20	20	1	1	shear plane	7		cleavage.dae
73																
74																
75																
76	0		<kml xmlns="http://www.opengis.net/kml/2.2" xmlns:gx="http://www.google.com/kml/ext/2.2" xmlns:kml="http://www.opengis.net/kml/2.2" xmlns:atom="http://www.w3.org/2005/Atom">													
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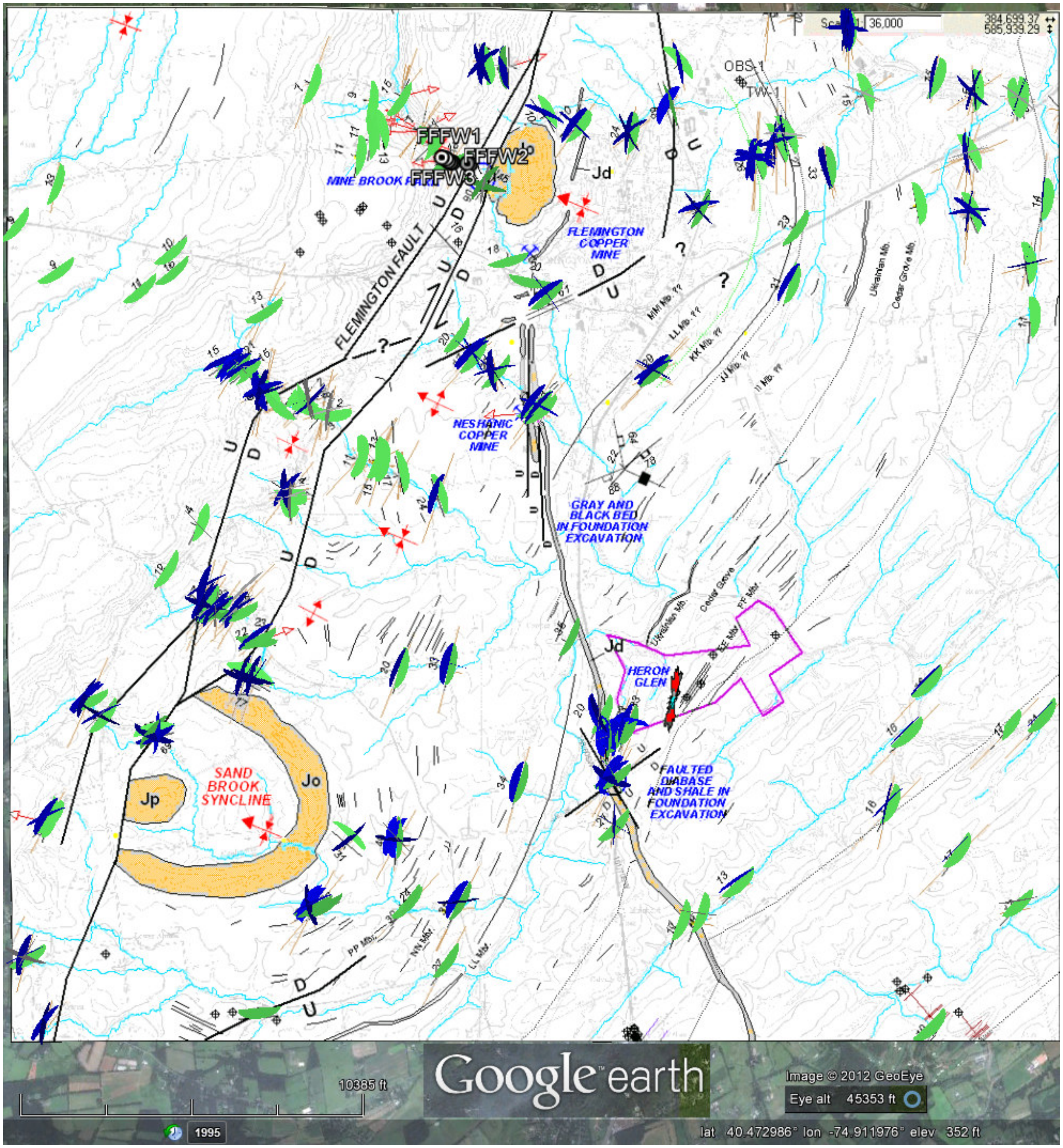
107	2		<Placemark>													
108	2		<name>	bedding 28/011	</name>											
109	2		<LookAt>													
110	2		<longitude>	-74.752070	</longitude>											
111	2		<latitude>	40.6236500	</latitude>											

Detail of KML script output block



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

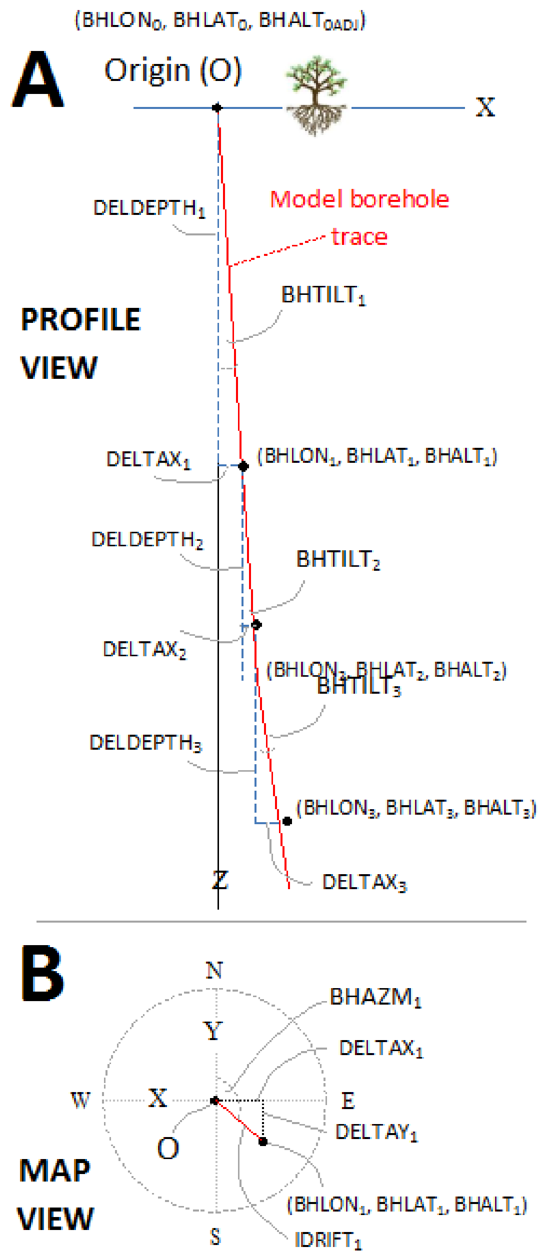
Base image is from a NJGS project map showing basalt flows (orange polygons labeled Jp and Jo), bedding strike and dips, and faults (U – up thrown, and D – down thrown fault blocks).

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.

March 18, 2013 G.C. Herman

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



C MS Excel Worksheet variables and formulas for calculating the 3D model borehole vertices and traces in decimal degrees

$BHLON_0$ – Borehole longitude

$BHLAT_0$ – Borehole latitude

$BHALT_0$ – Borehole altitude

$ADEPTH_n$ = BTV feature depth

$BHAZM_n$ = BTV incremental borehole azimuth

$BHTILT_n$ = BTV incremental borehole tilt

$DELDEPTH_n$ = Incremental vertical depth

$IDRIFT_n$ [INCREMENTAL DRIFT] =
IF (BHAZM>180, DELDEPTH *-1 * SIN (RADIANS (BHTILT)),
[ELSE] DELDEPTH * SIN (RADIANS (BHTILT)))

$DELTAX_n$ = $IDRIFT_n$ * SIN (RADIANS ($BHAZM_n$))*0.000009

$DELTAY_n$ = $IDRIFT_n$ * COS (RADIANS ($BHAZM_n$))*0.000009

$BHLON_n$ = $BHLON_{n-1}$ + $DELTAX_n$

$BHLAT_n$ = $BHLAT_{n-1}$ + $DELTAY_n$

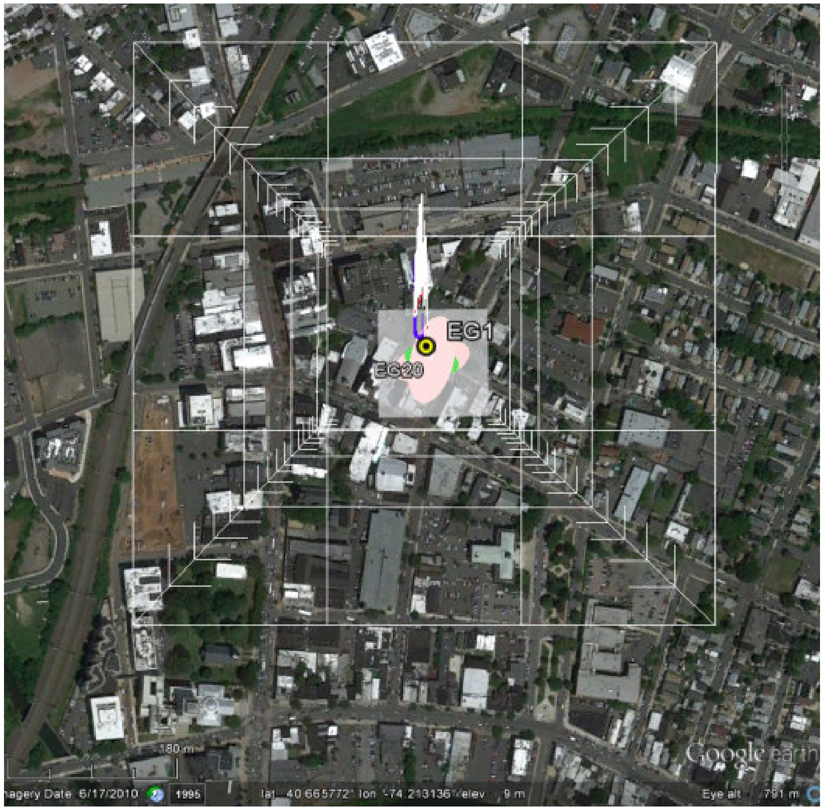
$BHALT_n$ = $BHALT_{n-1}$ + $DELDEPTH_n$

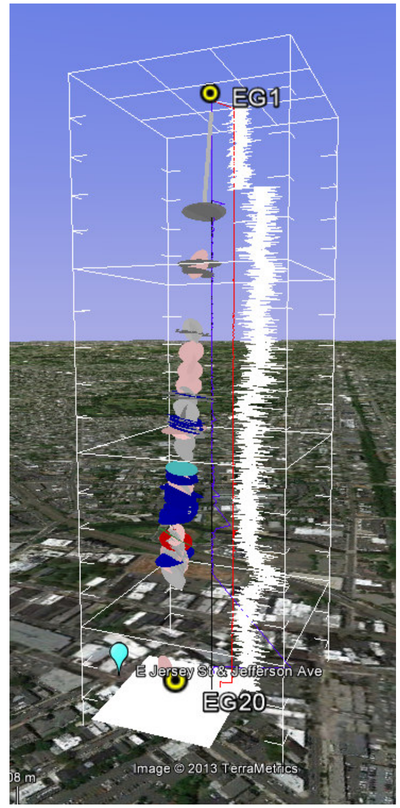
TDEPTH [TOTAL DEPTH] = Sum total of DELDEPTH(s)

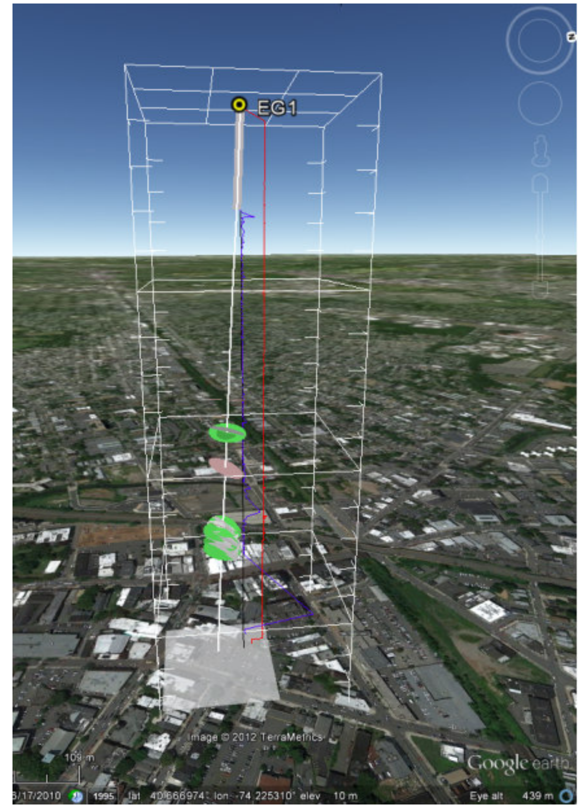
for the map example, $BAZM_1$ = 130°

2) 1 meter $\simeq$ 0.000009 degree

• 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.



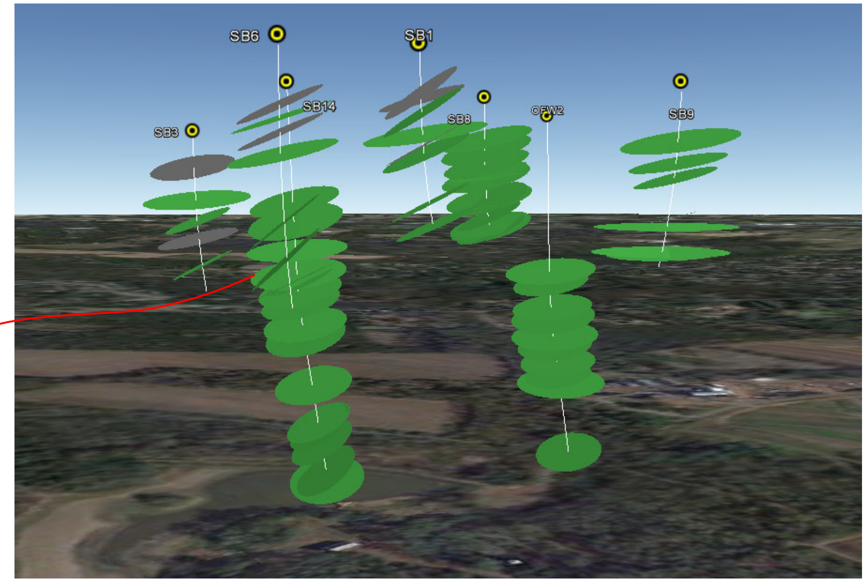


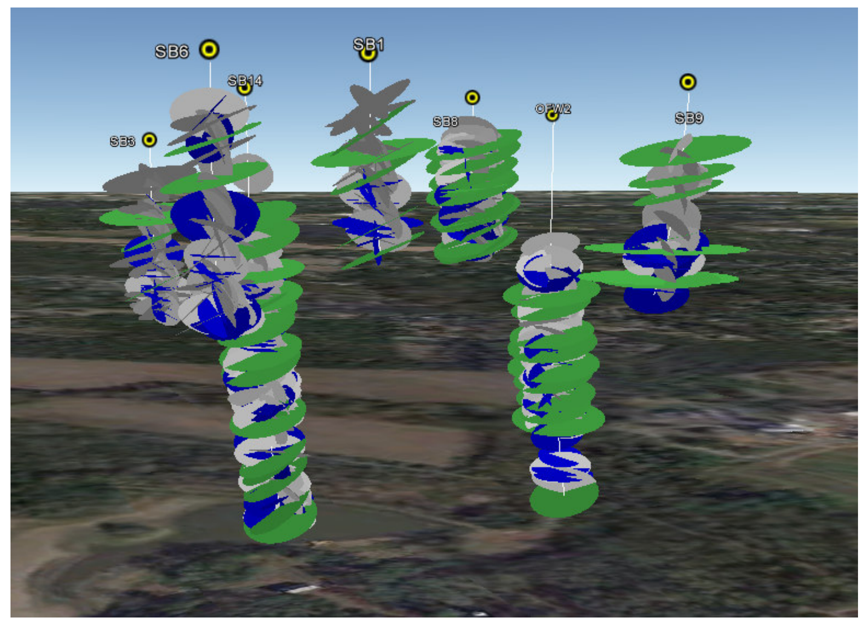


• As GE is designed for viewing the Earth's surface, 3D well-field visualization requires lifting well-field components above land surface by a distance exceeding the deepest well.

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

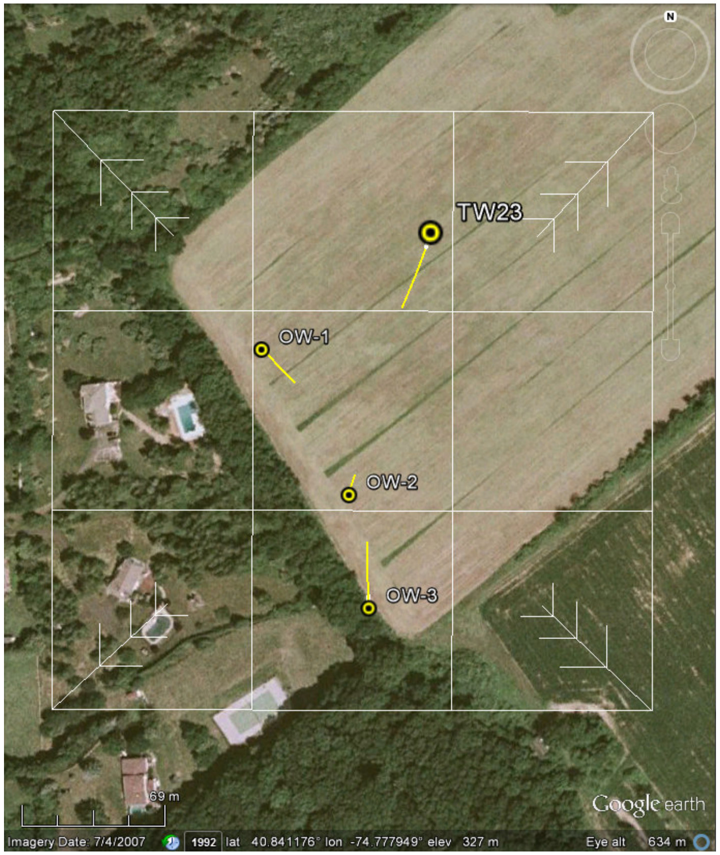
• Availability of BTV data on multiple wells in close proximity facilitates comparison of complex stratigraphic and structural relationships.

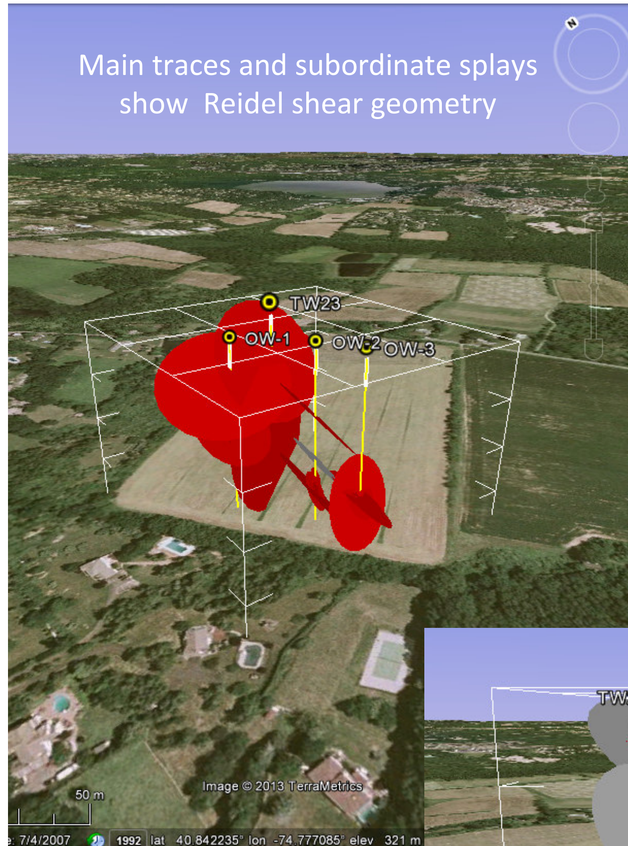




These approaches have proven useful for linking geological heterogeneity, such as **cross stratification**, to aquifer anisotropy.

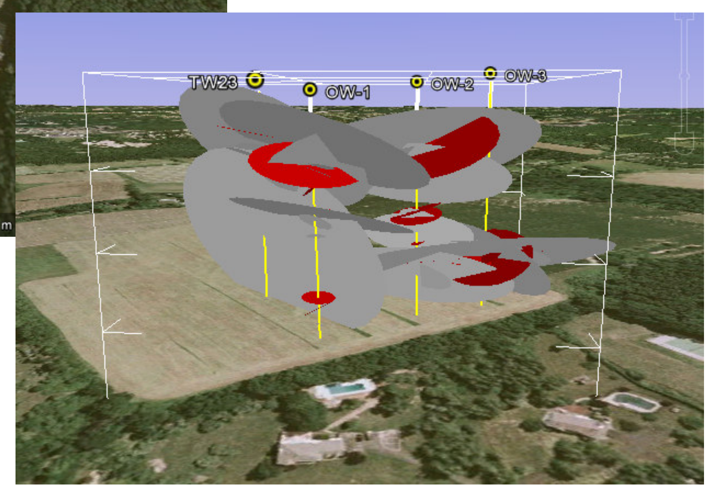
Comparative thickness values for sets of planar features, such as branching and interconnecting faults within a fault zone, can be variably scaled in a model to help assess complex structures in multiply-tectonized terrains.





Red – faults are variable scaled using aperture thickness

Green –metamorphic layering



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

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

THANK YOU