

Geology 310 Structural Geology

Gregory C. Herman, PhD



Email: ggherman@rider.edu

Lectures: Science Hall Rm. 112

Tuesday and Thursday 8:30 – 9:30 am

LABS Thursday 10:00-12:30 pm

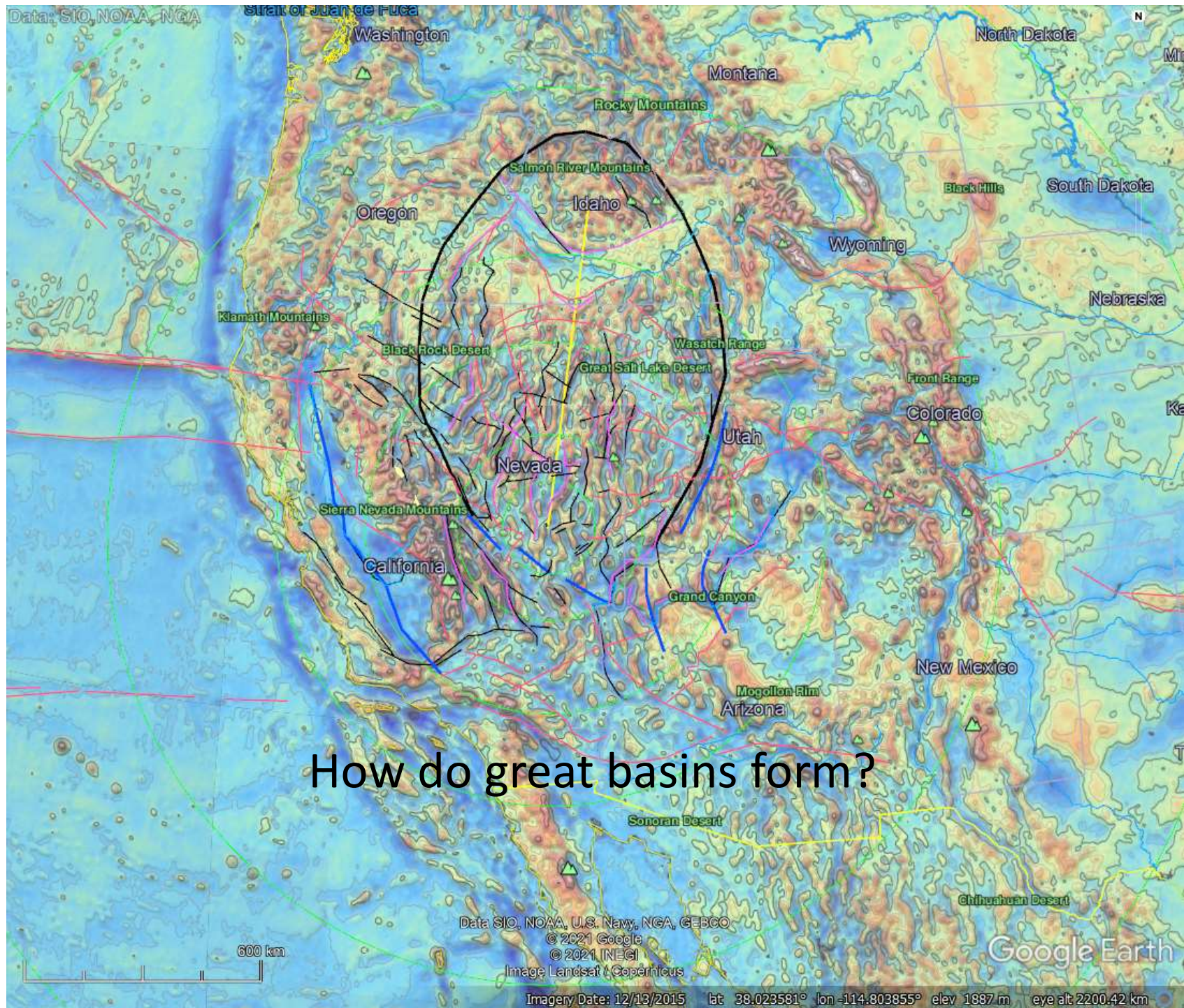
Office Tue or Thurs after lectures by appointment

WEBSITE: <http://www.impacttectonics.org/GEO310/>

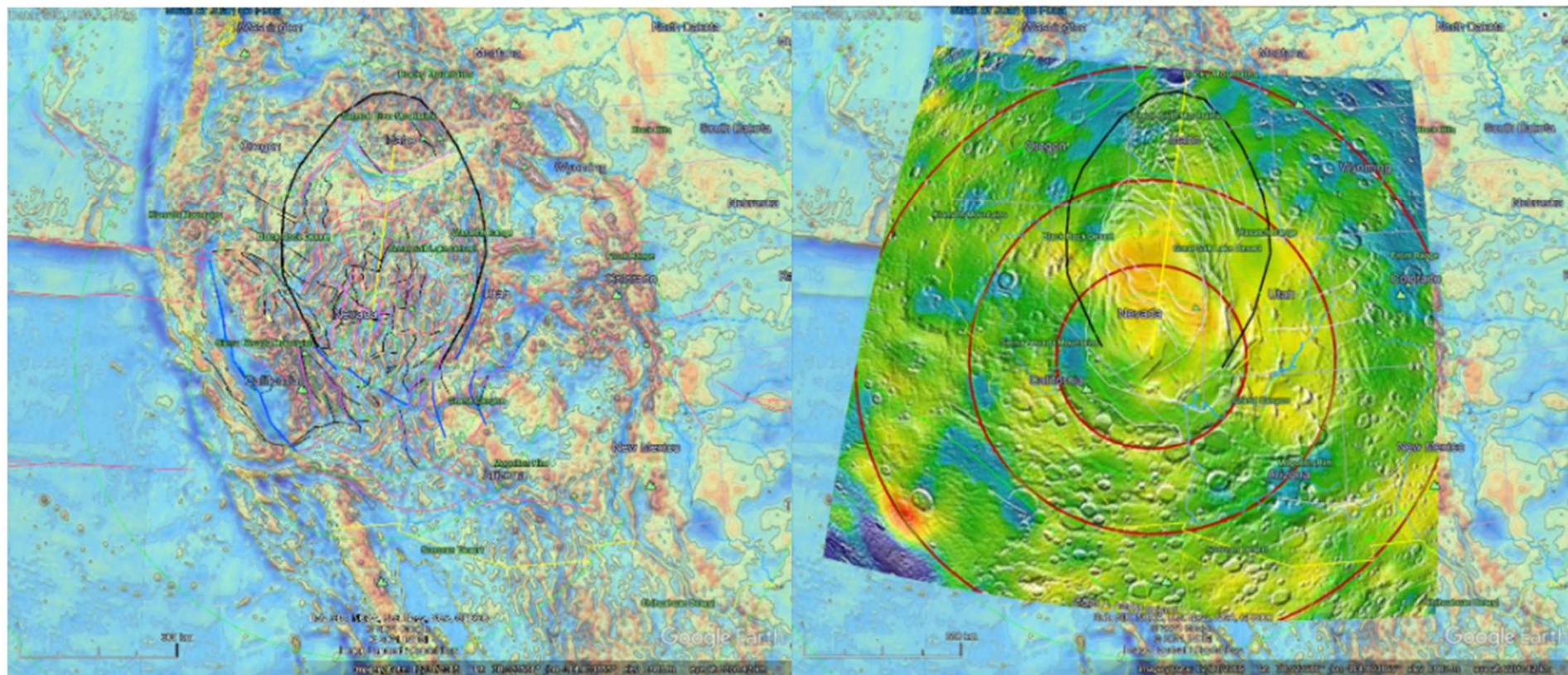
How do mountains rise and fall?



Image: <http://i.imgur.com/poKTTTq.jpg>



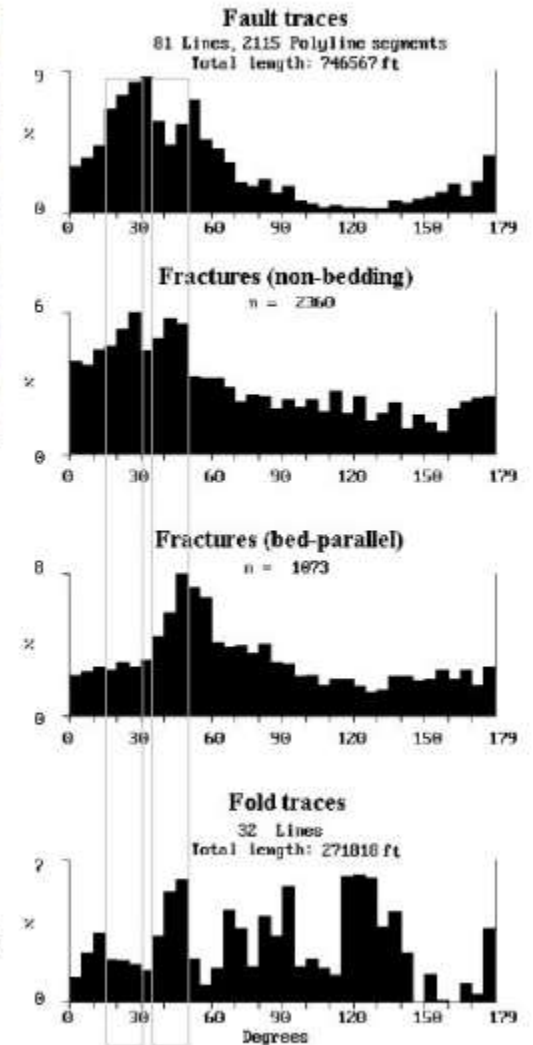
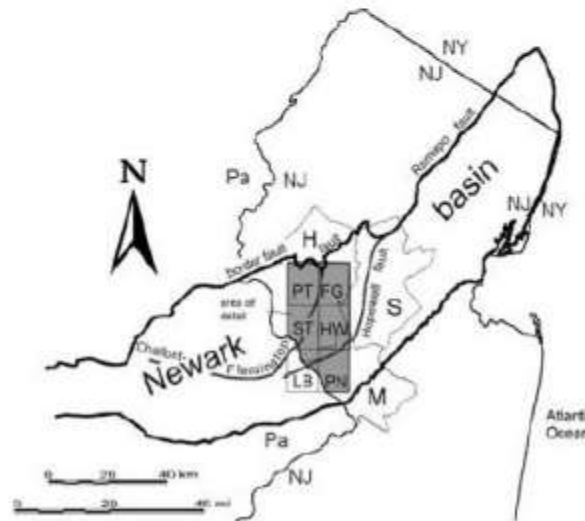
Size and structural comparison of two, similar-sized astroblemes on Earth (Alamo) and Mars (South Pole) using their gravity signatures



Structural Geology

Wikipedia - **Structural geology** is the study of the three-dimensional distribution of rock units with respect to their deformational histories. The primary goal of structural geology is to use measurements of present-day rock geometries to uncover information about the history of deformation (strain) in the rocks, and ultimately, to understand the stress field that resulted in the observed strain and geometries. This understanding of the dynamics of the stress field can be linked to important events in the regional geologic past; a common goal is to understand the structural evolution of a particular area with respect to regionally widespread patterns of rock deformation (e.g., mountain building, rifting) due to plate tectonics.

Structural Geology Laboratory.



“The whole point of geology is to figure out what happened in the past based on the rocks from that time which are still around today. It isn’t actually about the rocks. It’s about the story. The rocks are just the publishing medium. And the craft of geology is learning to read the language of stones.”

Lounge of the Lab Lemming blog



Geology sub disciplines

Name	Subject of Study
Engineering geology	The stability of geologic materials at the Earth's surface, for such purposes as controlling landslides and building tunnels, dams, mines, roads, or foundations
Environmental geology	Interactions between the environment and geologic materials, and the contamination of geologic materials
Geochemistry	Chemical compositions of materials in the Earth and chemical reactions in the natural environment
Geochronology	The age (in years) of geologic materials, the Earth, and extraterrestrial objects
Geomorphology	Landscape formation and evolution
Geophysics	Physical characteristics of the whole Earth (such as Earth's magnetic field and gravity field) and of forces in the Earth
Hydrogeology	Groundwater, its movement, and its reaction with rock and soil
Mineralogy	The chemistry and physical properties of minerals
Paleontology	Fossils and the evolution of life as preserved in the rock record
Petrology	Rocks and their formation
Sedimentology	Sediments and their deposition
Seismology	Earthquakes and the Earth's interior as revealed by earthquake waves
Stratigraphy	The succession of sedimentary rock layers
Structural geology	Rock deformation (bending and breaking) in response to the application of force
Tectonics	Regional geologic features (such as mountain belts) and plate movements and their consequences
Volcanology	Volcanic eruptions and their products

A few things that shouldn't have to be said, ... but nevertheless,

- Please arrive to class on time
- Cheating and plagiarism are not acceptable!
- PC laptops or tablets that you can take notes on or conduct lab exercises are permitted.
- Social media sites can only distract you. Please refrain from opening or using them during class.
- There will be no use of cell phones during class or lab....
please set the ringer to vibrate, for emergencies only.
- Check your messages before, after, or between classes.

- Absences from class are handled between students and instructors. I can ask for substantiating documentation for the absence.
- I'll provide make-up opportunities for student absences caused by illness, injury, death in the family, observance of religious holidays, and similarly compelling, personal reasons including physical disabilities.
- Cases of absence for a week or more will be reported by the student to the Office of Records and Registration. The Office will notify the instructor of the student's absence. The notification is not an excuse but simply a service provided by the Office of Records and Registration. Notifications cannot be acted upon if received after an absence.
- For lengthy absences, make-up opportunities might not be feasible and are at the discretion of the instructor.
- Students have the responsibility of notifying the instructors in advance of expected absences.
- In every instance, the student has the responsibility to initiate arrangements for make-up work.
- Email me.

RIDER UNIVERSITY GEO-310 Structural Geology Fall 2020

Dr. Gregory C. Herman email: gherman@rider.edu

Science Hall Room 112 Lectures Tuesdays and Thursdays 8:00 - 9:30 am
Labs. Thursdays 10:00 - 12:30 pm. Three field trips in New Jersey

CALENDAR & GRADING

Revised 11/8/2019

SYLLABUS

TEXTBOOK

APPARENT DIP

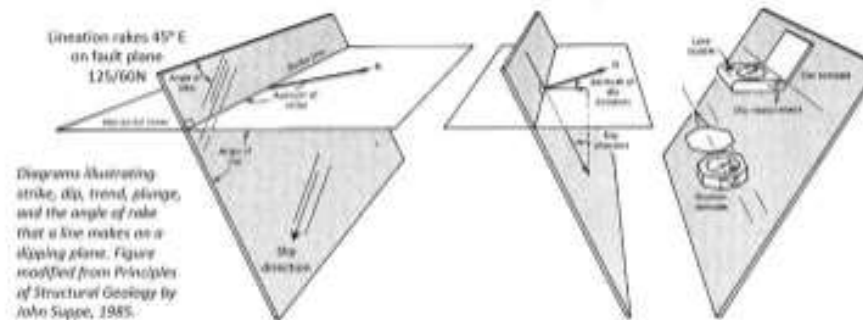
GREEK ALPHABET

VISIBLEGEOLOGY.COM

STRUCTURAL NOTATION

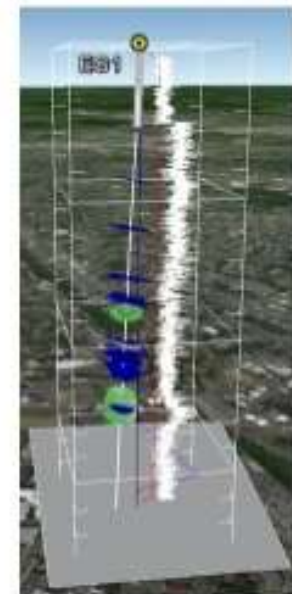
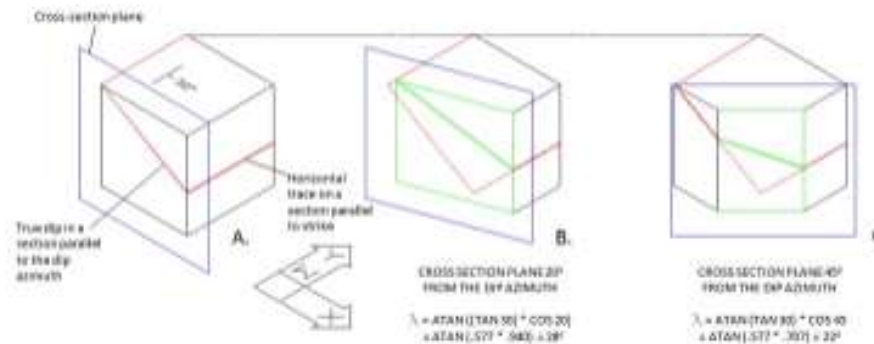
GEOLOGIC WEB UTILITIES

GE STRUCTURAL GEO APPS



$$\text{APPARENT DIP } (\lambda) = \text{ATAN} \{ (\text{TAN (DIP)} * \text{COS } \alpha) \} \text{ where ATAN} = 1/\text{TAN} \text{ or } \text{TAN}^{-1}$$

where α = the angle between the dip azimuth and the profile trace



GC Herman, Rev. 01/02/2014

Professor Gregory C. Herman
Syllabus, Lectures

Thu. Sep. 10
Tue. Sep. 15
Thu. Sep. 17
**RIDER UNIVERSITY GEOLOGY
Science Room 112, Tue. and**

Tue. Sep. 22
Thu. Sep. 24
Professor Gregory C. Herman

Sat. Sep. 26
Tue. Sep. 29
Thu. Oct. 1

Tue. Oct. 6
Thu. Oct. 8

Tue. Oct. 13
Thu. Oct. 15

Tue. Oct. 20
Thu. Oct. 22

Tue. Oct. 27
Thu. Oct. 29

Tue. Nov. 3
Thu. Nov. 5

Tue. Nov. 10
Thu. Nov. 12

Tue. Nov. 17
Thu. Nov. 19
Tue. Nov. 24
Thu. Nov. 26
Tue. Dec. 1
Thu. Dec. 3

Tue. Dec. 8
Thu. Dec. 10

Thu. Dec. 17

Tue. Oct. 6		EXAM 1	
Thu. Oct. 8	Lecture 8	Geologic faults.pdf (10.6 MB)	
	LAB 4	4A Borehole_3-Point_Problems.ppt (3.04 MB) 4B-Outcrop_Pattern_Cross-Section_Profiles.ppt (1.32 MB) 4C NASA WorldWind 3-pt problem solver	
Tue. Nov. 10		EXAM 2	Review questions
Thu. Nov. 12	Lecture 16	Caledonian-Appalachian Mountains (9.7 MB) Mid-Atlantic tectonics (13.8 MB) 8A-Hope to Jenny Jump cross section.ppt (9.53 MB) 8B-Hope to Jenny Jump Fielddata.xls (41 KB) 8C-Jenny Jump Mt.kmz (929 KB) Homework 8 Jenny Jump joint analysis.pptx (8.0 MB)	
Thu.	LAB 8		
Tue.	Tue. Nov. 17	Lecture 17	Oblique and Strike-slip Tectonics (9.9 MB) and Introduction to borehole geophysics.
Thu.	Thu. Nov. 19	Field Trip 3	Moore's Creek compound transtentional structures and Byram Lockatong Fm., Jurassic diabase, and shattercones
Thu.	Tue. Nov. 24	Lecture 18	Earth Structure and Plate Tectonics (20.3 MB)
	Thu. Nov. 26	No class	Thanksgiving Recess
	Tue. Dec. 1	Lecture 19	Neotectonics and GANJ 32 Data
Tue.	Thu. Dec. 3	Lecture 20	Unconformities & Igneous rocks (2.7 MB) Balanced_Cross_Sections.pdf (6.0 MB)
		LAB 9	9A-Unconformities_and_Igneous_Rocks.ppt (5.0 MB) 9B_Structural_profiling (5.3 MB) GANJ33 Teacher'sWorskshop (8.3 MB)
	Tue. Dec. 8	Lecture 21	Impact Tectonics
Thu.	Thu. Dec. 10	Lecture 22	Borehole geophysics and fractured aquifers.pdf (10.0 MB) Dolostone aquifer (44 MB PDF) Basalt and shale aquifer (14.7 MB PDF) Granite_and_gneiss_aquifer (22MB PDF)
		LAB 10	
Tue.	Thu. Dec. 17	FINAL EXAM	9:00-11:00 am. Final exam review questions.pdf (332 KB)
Thu. Sep. 30	Lecture	LAB 7	7C-Herman_Monteverde_1989.pdf (6.19 MB) Homework 7 Cleavage diagram.ppt (6.66 MB)
	Field Tri		
Tue. Nov. 10		EXAM 2	Review questions
Tue. Oct. 5		EXAM 1	

RIDER UNIVERSITY GEO-310 Attendance and Grading Policy

Fall semester 2016

- **Lectures attendance is kept.**
23 lectures count for 7% of your grade
- **Laboratory attendance is mandatory and there are no makeups.**
If you miss a Lab, it's up to you to gather and cover the material that you missed and submit any assignments.
- *Field labs are not mandatory for student athletes that are in season, but attendance is strongly encouraged.*
- **The final grade for the student is determined using the point system and grading scale listed to the right.**
- *The laboratory points are heavily weighted toward the final grade (>1/2 of the class).*
- The exams will include True/False, Multiple Choice, and Problem solving.
- Assignments and tests results will be presented to students the following week after their completion.
- Students will have the opportunity in class to ask questions on individual test questions and concepts.
- Students will have the opportunity at the end of the course to evaluate the instructor and course by college standardized evaluation questionnaires.

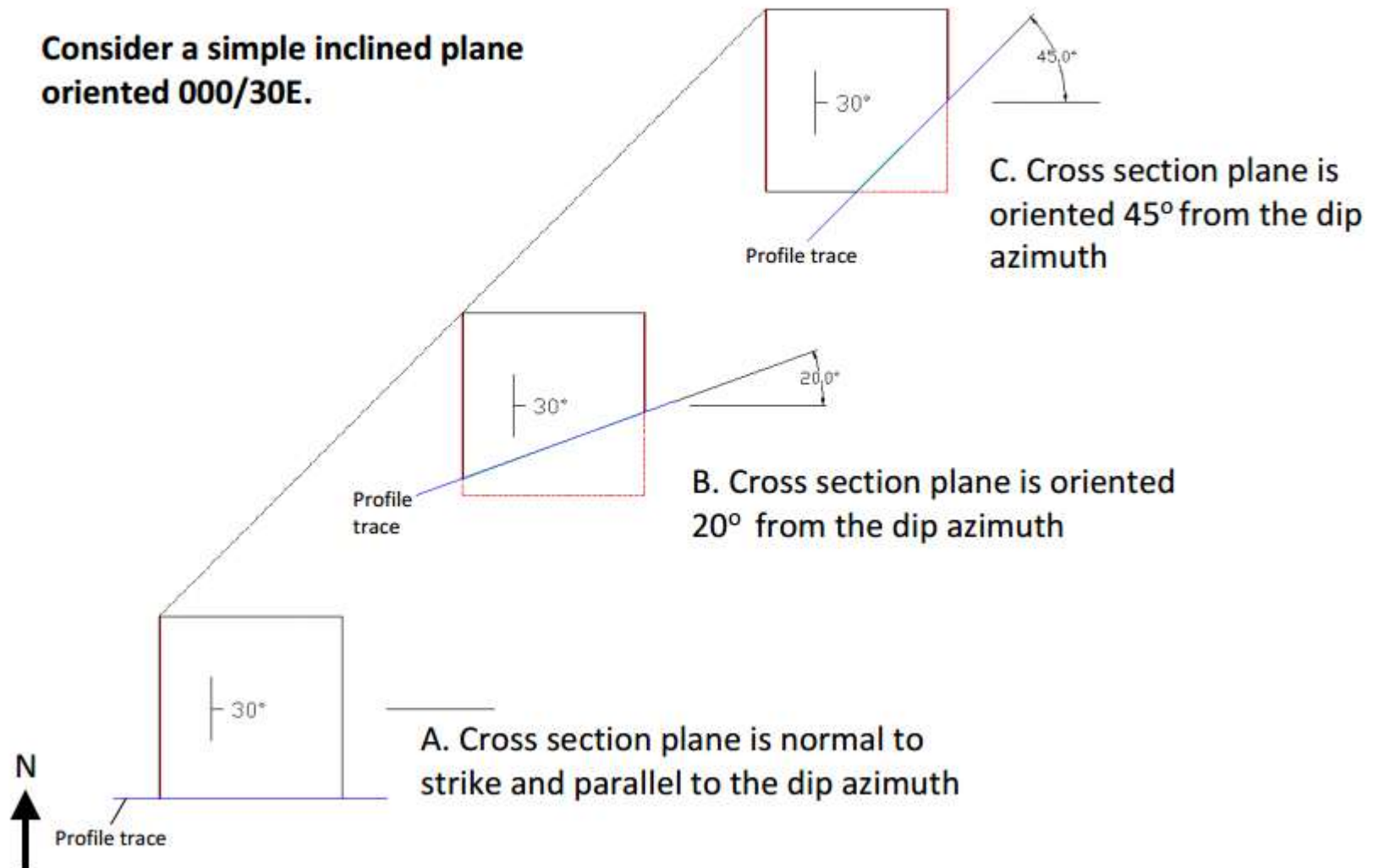
Point System	Points
11 Inside Labs (10 pts. Each <u>xcpt</u> L1)	104
3 Field-Trip Labs (10 pts each)	30
2 interim exams (25 pts. each)	50
Comprehensive final exam	50
Lecture attendance	<u>46</u>
TOTAL	280

Grading scale (%)

A = 95 - 100	C = 73 - 76
A- = 90 - 94	C- = 70 - 72
B+ = 87 - 89	D+ = 67 - 69
B = 83 - 86	D = 65 - 66
B- = 80 - 82	F = 64 or less
C+ = 77 - 79	

APPARENT DIP OF SIMPLY INCLINED PLANES

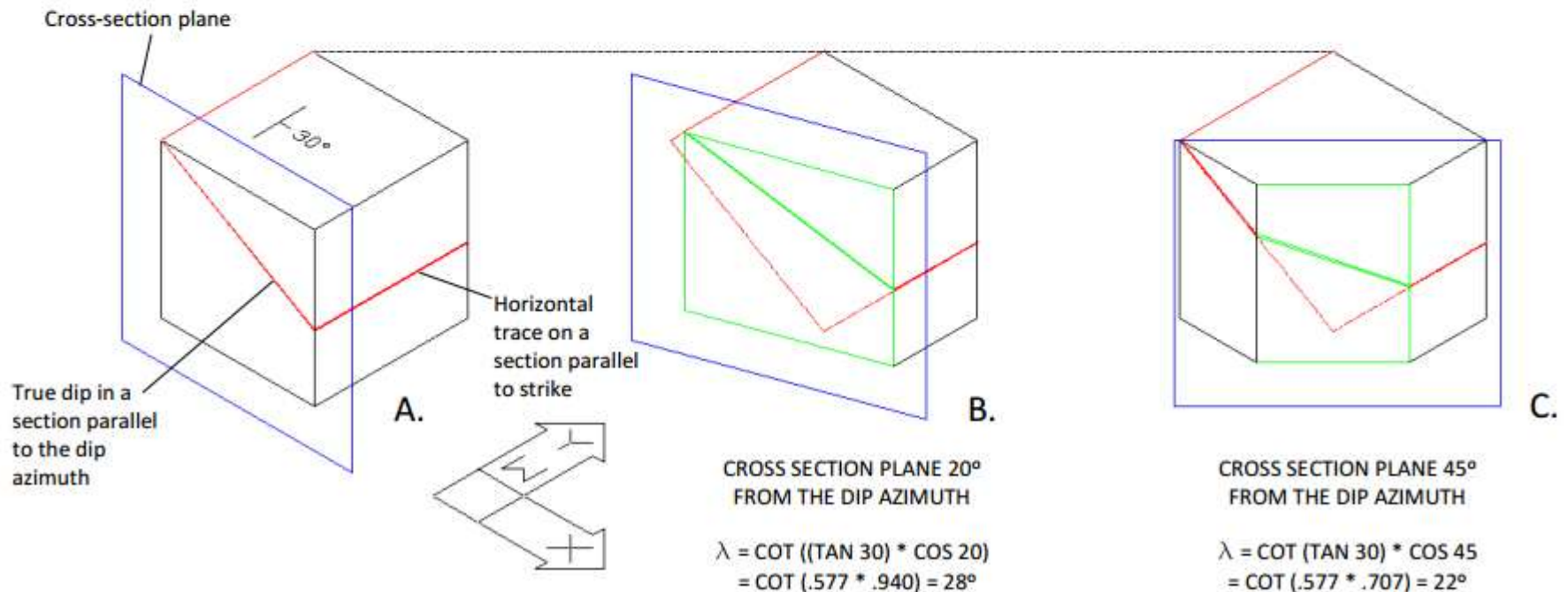
Consider a simple inclined plane oriented 000/30E.



- A. Because the plane of cross section is parallel to the dip azimuth, the plane dips in profile at its true value of 30° . Also notice that the trace of the dipping plane in the plane of section that is parallel to strike is horizontal.
- B. and C. For the cross section planes oriented 20° and 45° relative to the dip azimuth, the plane has an apparent dip less than the true dip:

$$\text{APPARENT DIP } (\lambda) = \text{COT} ((\text{TAN (DIP)}) * \text{COS } (\alpha))$$

where α = the angle between the dip azimuth and the profile trace



LINE AND PLANE RECORDING CONVENTIONS

POINT: X_n, Y_n, Z_n where n is 1.....to infinity and beyond
(Remember that Latitude is a Y-coordinate, and Longitude is an X-coordinate)

LINE: Plunge (0-90°) and Trend (000-359°) (ex. 45/287)

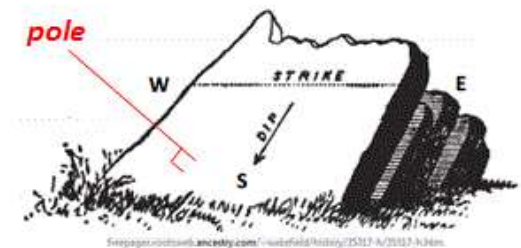
PLANE: Strike (000-179°), Dip (0-90°), and Dip Direction (N-S-E-W)

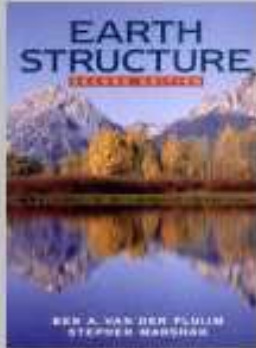
This is the *Strike, Dip, and Dip Direction notation*

example: 125/79 SW *that is the same as* 79/215 in line notation as a *dip line* (0-90/000-359°) .
other examples: plane 003/89 SE = 89/093 dip line, and plane 015/33 NW = 33/285 dip Line

The latter is *dip-azimuth notation* for a plane, that is easiest for computer systems to read as it discretely describes the plane orientation as numbers, as does the **planes pole (normal vector to the plane)**

Some geologist prefer to record planes in outcrop using dip azimuth but we will use strike, dip, and dip direction to reduce the chance of mixing plane and line readings when noting both or multiple readings at one location.





Earth Structure An Introduction to Structural Geology and Tectonics

www.globalchange.umich.edu/Ben/ES/

Ben van der Pluijm and Stephen Marshak

WW Norton & Company
Second Edition, 2004
ISBN 0-393-92467-X

GC Herman Rev. 09/13/2014

[Home](#)
[Information](#)
[Contents](#)
[Corrections](#)
[Media](#)
[Links and More ...](#)



<http://globalchange.umich.edu/ben/ES/#powerpoints>

About the Authors

Ben A. van der Pluijm is Bruce R. Clark Collegiate Professor of Geology and Professor of the Environment at the University of Michigan, Ann Arbor. He is (co-)author of more than 140 research articles and editor/board member of several international journals. His research focuses on fault rocks and processes, crustal architecture of collisional belts, intraplate deformation, microstructures and textures, and geochronology, with main field areas in North America, South America and Europe. In addition to teaching undergraduate and graduate courses in Geological Sciences and Program in the Environment, he directs U-M's interdisciplinary Global Change Program and is involved in various technology-supported educational initiatives.

vdpluijm@umich.edu

Stephen Marshak is Professor of Geology and Director of the School of Earth Society and Environment at the University of Illinois, Urbana-Champaign. He holds a Ph.D. from Columbia University, an M.S. from the University of Arizona, and a B.A. from Cornell University. He has served as Chair of the Division of Structural Geology and Tectonics of the Geological Society of America. He has written numerous research articles on topics in structural geology and tectonics, and has authored or co-authored three other books: *Basic Methods of Structural Geology*; *Earth: Portrait of a Planet*; and *Essentials of Geology*.

smarshak@illinois.edu

Contents

PART A FUNDAMENTALS

Chapter 1 Overview
Chapter 2 Primary and Nontectonic Structures
Chapter 3 Force and Stress
Chapter 4 Deformation and Strain
Chapter 5 Rheology

PART B BRITTLE STRUCTURES

Chapter 6 Brittle Deformation
Chapter 7 Joints and Veins
Chapter 8 Faults and Faulting

PART C DUCTILE STRUCTURES

Chapter 9 Ductile Deformation Processes
Chapter 10 Folds and Folding
Chapter 11 Fabrics: Foliations and Lineations
Chapter 12 Ductile Shear Zones, Textures, and Transposition
Chapter 13 Deformation, Metamorphism, and Time

PART D TECTONICS

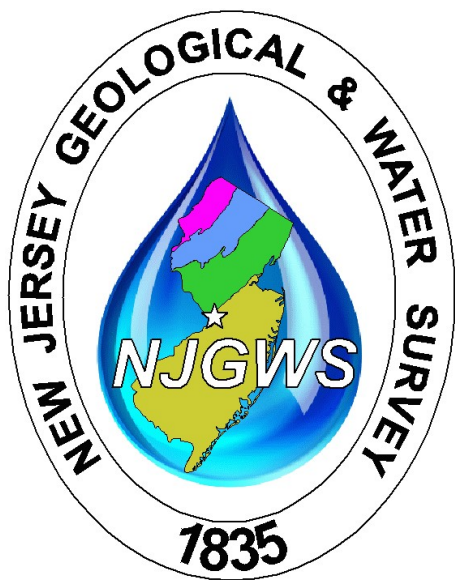
Chapter 14 Whole-Earth Structure and Plate Tectonics
Chapter 15 Geophysical Imaging of the Continental Lithosphere—An Essay by Frederick A. Cook
Chapter 16 Rifting, Seafloor Spreading, and Extensional Tectonics
Chapter 17 Convergence and Collision
Chapter 18 Fold-Thrust Belts—An Essay by Stephen Marshak and M. Scott Wilkerson
Chapter 19 Strike-Slip Tectonics

PART E REGIONAL PERSPECTIVES

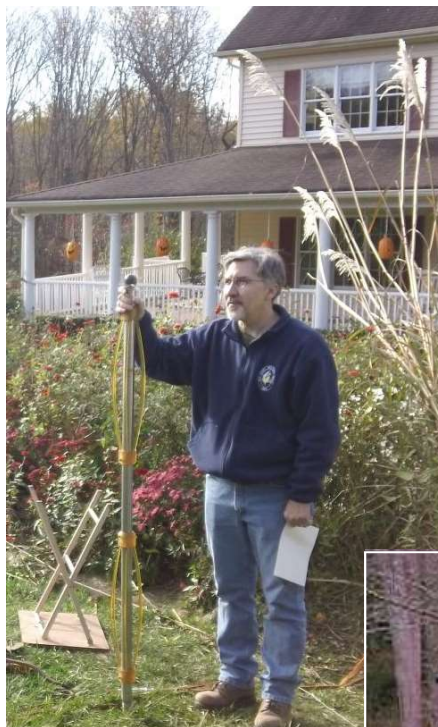
Chapter 20 A Global View
Chapter 21 Eastern Hemisphere
Chapter 22 Western Hemisphere

Appendix 1 Spherical Projections

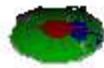
Appendix 2 Geologic Timescale



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[KMLZs](#)

[SKPs](#)

[Video](#)

[DWGs](#)

[HTML](#)

[Podcasts](#)

[Tectonics](#)



13 Martian
astroblemes
superimposed

Argyre

Cassini

Chryse

Greely

Hellas

Hyugens

Isidis

Margaritifer Chaos

North Pole

Promethei

Secchi

Syria & Sinai Planum

Utopia

G.C. Herman, PhD

NEW



[Google Mars version 2.0](#); 13 Large astroblemes with a 0-m sea



⚠ Not secure | impacttectonics.org/gcherman/Index.html

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PUBLICATIONS LIST WITH LINKS

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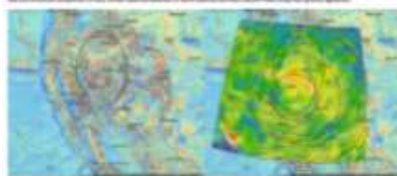
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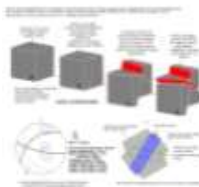
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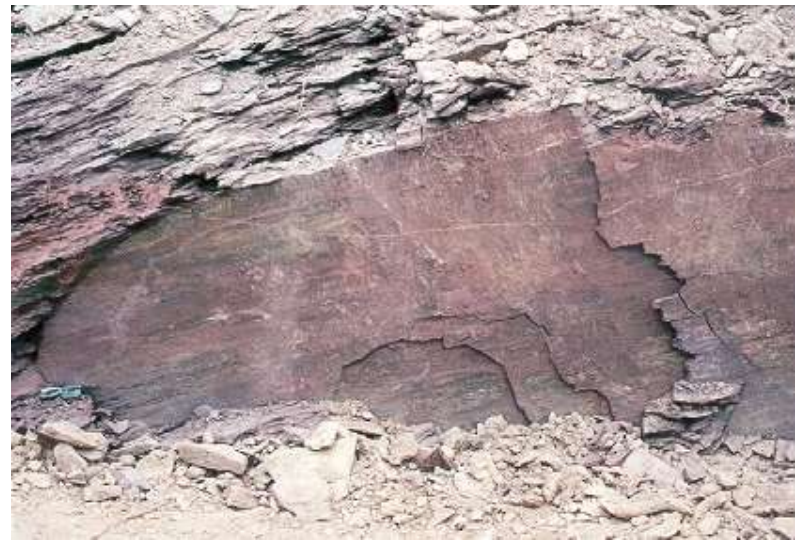
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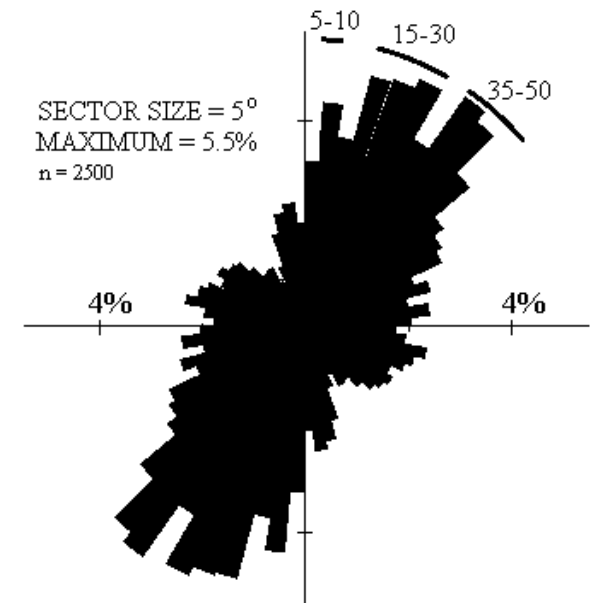
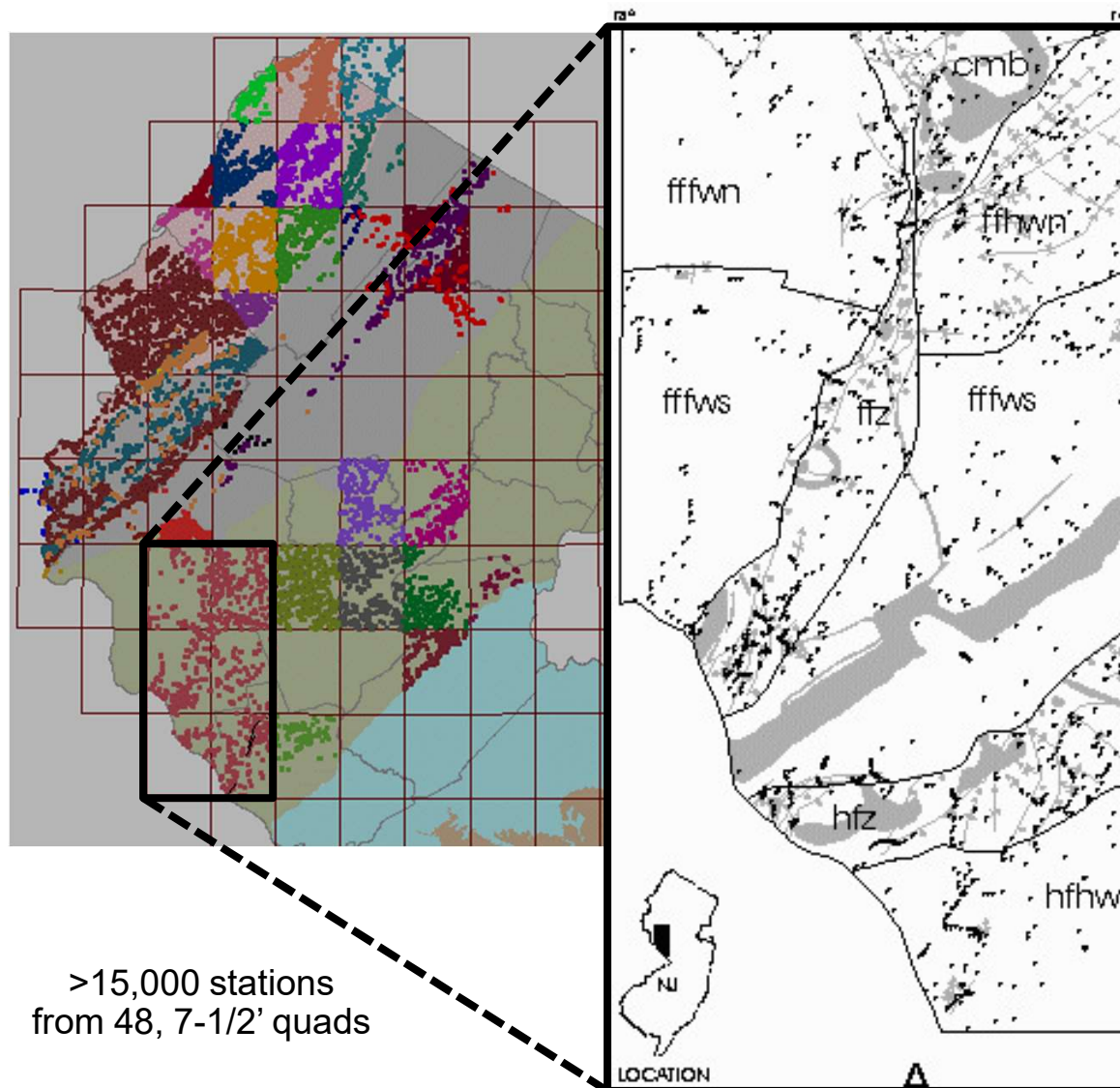


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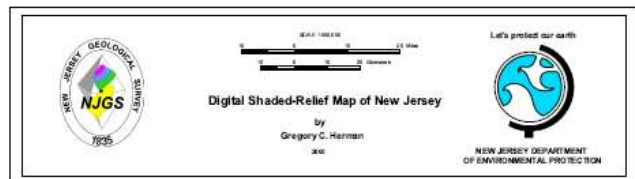


STRUCTURAL HETEROGENEITY AND AQUIFER ANISOTROPY

Bedrock Mapping and Structural Analysis of Fractured-Bedrock Aquifers



1073 Bed-parallel fractures
2360 Non-bedding fractures
1339 Stations

[illegible]

Langford, C.W. 1990. Nitrate in ground-water of the Magalloway and Hingham Formations in Cranston and Warrington, Cranston, New Jersey. U.S. Geological Survey Water Resources Division Report 90-14, 18 p.

Neuvil, W.J., Powers, D.C., Griesbach, J.P., Tinkler, J.B., 1980. Surficial Geology Map of Middlesex-New Jersey. U.S. Geological Survey Bulletin 1349-B, 10 p.

Truesky, J.P., Griesbach, J.P., Smith, R. and O'Connell, P. C. 1985. Surficial Geology Map of Middlesex-New Jersey. U.S. Geological Survey Open-File Report 85-54, 110x100x130mm.

Truesky, J.P., Griesbach, J.P., Smith, R. and Fowler, R. K., 1988a. Hydrogeology Map of Middlesex-New Jersey. U.S. Geological Survey Open-File Report 88-54, 110x100x130mm.

Truesky, J.P., Smith, R. A., Jones, A. J., and Fowler, R. K., 1988b. Hydrogeology Map of Middlesex-New Jersey. U.S. Geological Survey Open-File Report 88-54, 110x100x130mm.

Varley, M. E. 2004. Natural gas and water quality in bedrock of the Newark Basin, New Jersey. New Jersey Department of Environmental Protection Report 04-25, 59 p.

Varley, M. E., 2005. Predicted ground-water quality in the Middlesex-New Jersey Principal aquifer beneath the Newark Basin in Valley Forge geologic Province of New Jersey. New Jersey Department of Environmental Protection Report 05-25, 59 p.

Aquifer Type	Median Yield (kg/ha)
(A)	> 100
(B)	> 100 to 500
(C)	> 500 to 250
(D)	> 25 to 100
(E)	< 25

Guest Souther and Confined Ints

Should scientific education avoid such all-out war?

Tree (2)	Slender, decumbent or trailing, green, waxy, warts, not seen when flowers first open. All Aquifoliaceae composed of climbing and ground plants confined to the subnival to subalpine zone and tree line, and mesic to mesic, capitate, long and slender, greenish, glaucous, firm to drab, firm, and waxy, and waxy, and waxy.
Meristematic (epiphytic) (2)	Slender, decumbent or trailing, green, waxy, warts, not seen when flowers first open. All Aquifoliaceae composed of climbing and ground plants confined to the subnival to subalpine zone and tree line, and mesic to mesic, capitate, long and slender, greenish, glaucous, firm to drab, firm, and waxy, and waxy, and waxy.
Leafy (decumbent) (2)	Slender, decumbent or trailing, green, waxy, warts, not seen when flowers first open. All Aquifoliaceae composed of climbing and ground plants confined to the subnival to subalpine zone and tree line, and mesic to mesic, capitate, long and slender, greenish, glaucous, firm to drab, firm, and waxy, and waxy, and waxy.
Spinal and Quercus (2)	Slender, decumbent or trailing, green, waxy, warts, not seen when flowers first open. All Aquifoliaceae composed of climbing and ground plants confined to the subnival to subalpine zone and tree line, and mesic to mesic, capitate, long and slender, greenish, glaucous, firm to drab, firm, and waxy, and waxy, and waxy.

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Subtidal sediments thicker than 100 ft, averaging Coastal Plain oolites and coralline units (C₂)—includes beach, river, estuarine, and marine sands; and recent alluvium. Sediments are considered part of the underlying aquifer or a minor aquifer and a confining unit.

Early larval water-bearing zone [2] Water-tolerant adults composed of small, green, soft, and sticky elongate eggs (0.5 mm) in aquatic, beach, dune, debris, and marine environments, and recent shorelines. Uncommon by Eurytemora Clap (common) and not found by Eurytemora Clap (primary intertidal, primary and peripatetic). Water to fresh, acidic, conductive, and has low dissolved solids. Occurrence decreases in confined areas. High pH and temperature (above 20°C) severely restricts in confined areas near littoral zones. Soft in chronic egg water to common.

Kirkwood-Cohasset aquifer system (KCA) - Below-table aquifer composed of sand and gravel with lenses of silt and clay. Cohasset aquifer confined in Upper Helderberg. Underlies bylained Kirkwood aquifer (underlies City BQ test area) and Rio Grande water-bearing sand. Porous intergranular porosity and permeability, leakage to confined part prevents water. Water in fresh aquifer, largely unmineralized and low in chemical and toxic substance matter is confined in confined aquifer. Iron and manganese levels are usually elevated. Salinity may be elevated in confined part to near

Composite (centering on 35.5E, 50E and only with localized sand lenses). Confining units include the Thick Ness, Middle Ness, Hornsdown, and Thin Ness Formations, and the lower part of the Gladly Ness Member of the Red Ness from localities westward of the Red Ness. The composite is composed of medium to coarse sandstone as the Vinnodden section. The composite is composed of medium to coarse sandstone as the Vinnodden section. The composite is composed of medium to coarse sandstone as the Vinnodden section.

Warning: The Finley Flint aquifer occurs near the top of the composite unit in the subsurface only. After the aquifer is breaching good, but low and long-term levels may slowly elevated and require chemical treatment. Calcium-sulfate-type wellbore cements.



Question Mandibular premolars commonly have [C] - 2RS, cing and the bases of roots. When a premolar is used for a facially rotating cervical treatment, they are also depicted Mandibular premolars.

Answer Enlargement of the root system [B] - Upper and lower root with enlarged the base. Primary intermandibular pressure and permeability in roots. When is tooth moderately hard and is shallow. Surface texture, and permeability.

Parasitic flatworms: *Monostomum* spp. and *Platystrongylus* spp. commonly occur in the sediment. Local infections have also been reported from the sediment.

and they represent the outer world and social aspects, influence the Rankin ranking and composed of inorganic sand, silt, and clay. Primary inorganic concepts and permeability. Water is high, moderately hard with a near neutral pH. Salinity increased towards the coastline near Davao and Marikina bays. Elevated iron and manganese are common. Calcium and magnesium levels decrease and sulfur and potassium were generally increase to the southeast. Calcium flux for the study waters decrease

Fractured-rock Aquifers of the Newark Basin Part of the Piedmont

	Basal (B): Hard, dense, and highly fractured igneous rocks. Ground water stored and transported in fractures. Water is mostly hard, slightly to highly phreatic, incrustant (acid) and of the calcium-magnesium type.
	Dioritic (D): Hard and dense igneous rocks. Ground water stored and transported in fractures. Water is mostly hard, slightly to highly phreatic, incrustant (acid) and of the calcium-magnesium type.

Brinewick aspen (F3) – Sawtooth, ribbon, and Mule of the Woods, Spearhead, and Ribbon Firs. Colored water glass and handcut in heart cuts. Stone is extremely hard, slightly acidic, nonporous and hard. Calcium hydroxide type waters dissolve it. Substrate calcium sulfate waters are associated with high iron-fluoride and sulfur. Includes conglomerate lenses that contain the northernmost crop of the Idaho.

Lactation Fermentation (C) – Silage available, metabolites and free organic acids and amino acids low. Contains a large amount of water-soluble carbohydrates. Voids completed in the rumen/reticulum. Bacteria (SC) generally allow increased capacities. Voids are relatively fresh, slightly acidic, non-fermentative post heat. Cationic carbohydrates (type water) dominate.

Fractured rock Aquifers of the Valley and Ridge, Highland and Benton and Marathon Prongs of the Piedmont

[illegible]

Manure Management and Control Sequence (3) - Classrooms visit, planning, practice, with minor insurance and delivery. Ground water level and contaminated in structure. Water is high, slightly alkaline, noncorrosive, and moderately toxic. Calcium hydroxide is added to the water.

argaceous and metamorphic rocks [3]. Emerald, garnets, zircon, and monazite. Ground water is often and concentrated in fractures. Fractures are mostly and locally affected by chemical weathering. Heavy water from them makes an

is thick, slightly viscous, colorless and odorlessly flat. Water from melting has higher VDS, smaller pH, fewer ions, and is less viscous.

Chemical treatment layer uniformly distributed.

Chemical treatment may be too slow for thickness, ion, and strength.

Stratford, S. G., and Macdonald, G. D., 1982, *Glacial Geology and Geomorphology of the Fraser Valley, British Columbia*, Geological Survey of Canada, Geological Series Paper 82-10, 107 p.

Stewart, C. B., D. B. Stewart, H. Brown, P. H. and Ryan, J. J. 1981. Ground-Water Site Inventory (United, Utah's Coast). U.S. Geological Survey Water Resources Division, New Agency (Ed.). Salt Lake City, Utah, 138 p.

ALT & Mt. Sopris System 2011- ~ \$66,000

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

Matrix data processor

Optical Borehole Image
(OBI-40) Tool

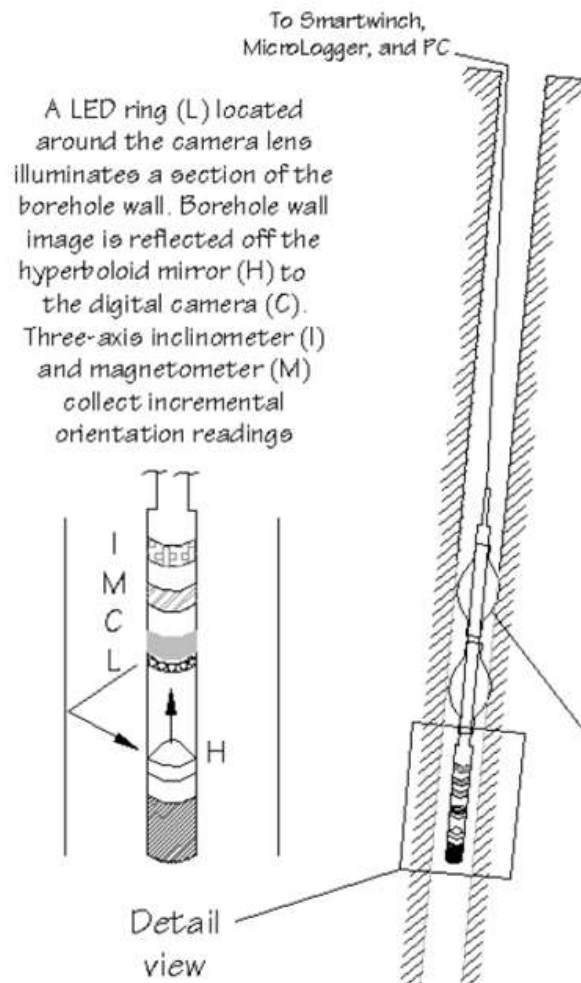
Heat-Pulse Flowmeter
HPFM-2293



ALT
Advanced Logic Technology



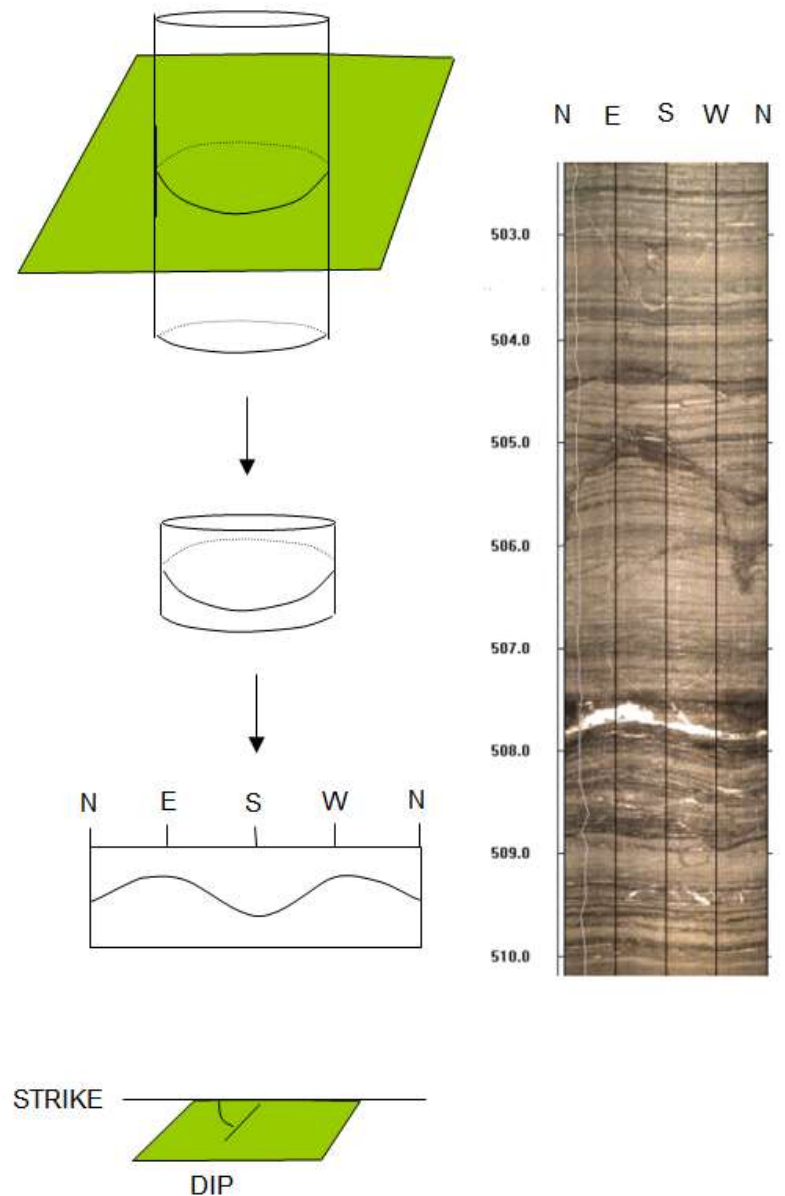
GC Herman Rev. 09/13/2014



OPTICAL TELEVIEWER SCHEMATIC

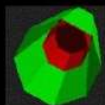
Digital camera captures 360° ring at 1mm-depth sample intervals. Successive rings are stacked in geographic alignment based on incremental magnetometer and inclinometer measurements.

centralizing bands



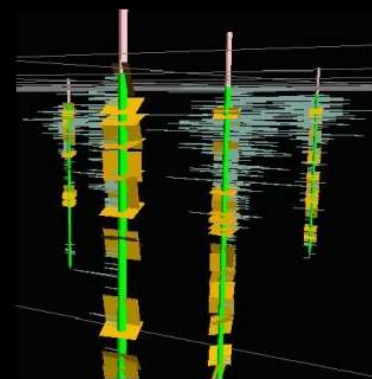
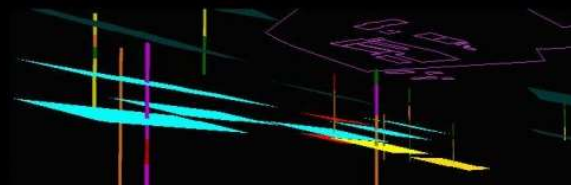
3D Well-Field Generation and Visualization

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

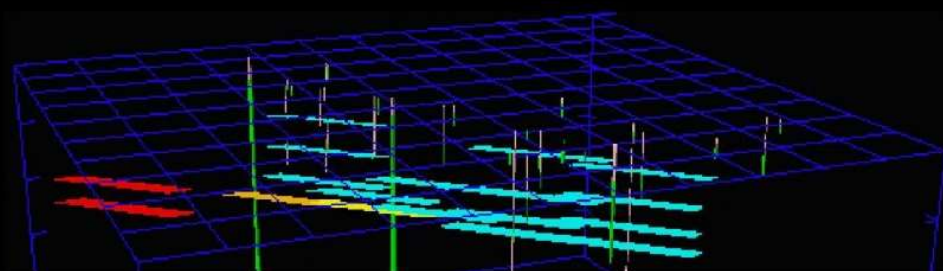


Well parts use Multipatch PolygonZ planes centered about the borehole in an octagonal arrangement

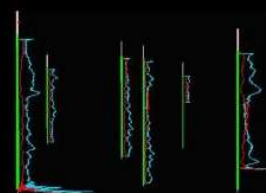
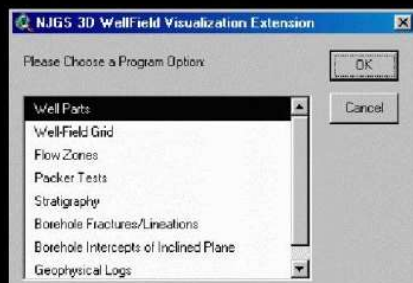
with ESRI ArcView® 3D Analyst™



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

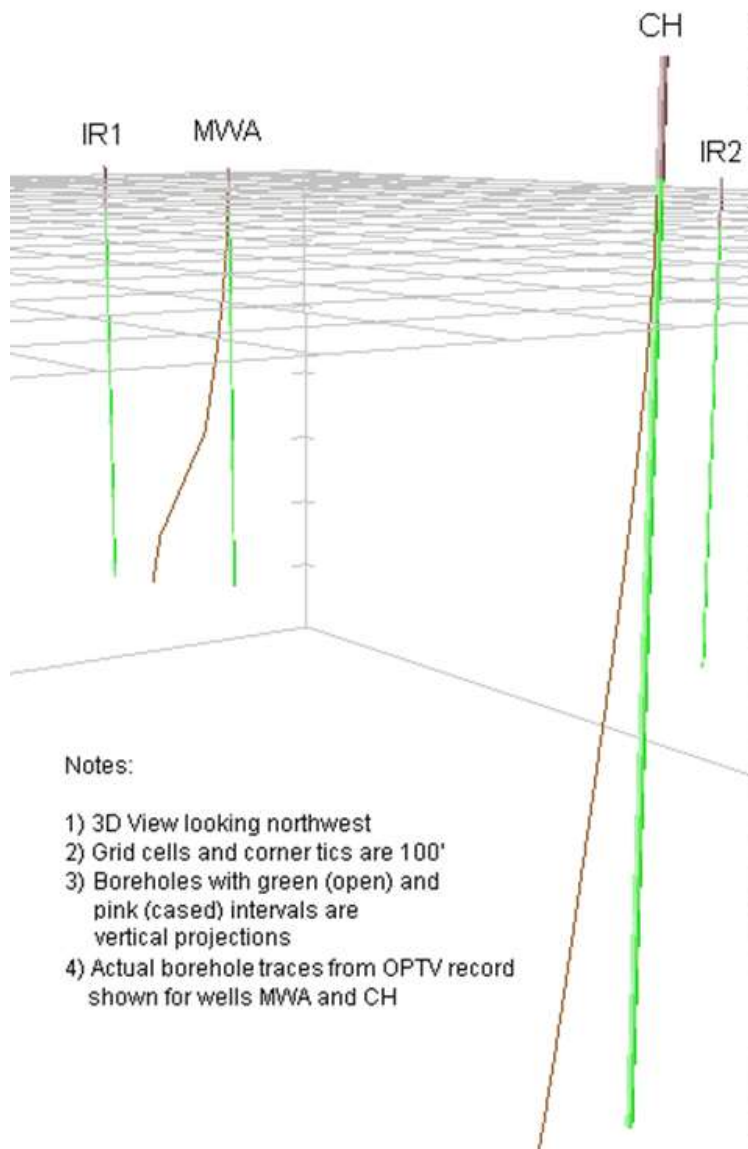
- *Well-field well-construction parts*
- *Inclined planes*
- *Packer-test results*
- *Borehole-fractures*
- *Borehole geophysical logs*



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



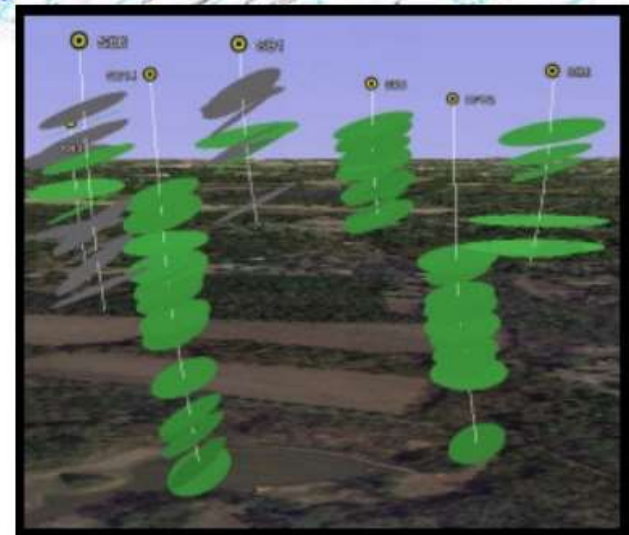
3D VIEW OF PART OF THE RIDGE GOLF COURSE WELL FIELD,
EAST AMWELL TWP., HUNTERDON COUNTY, NEW JERSEY,
N.J. GEOLOGICAL SURVEY, G.C. HERMAN, 2003 SEPTEMBER 19



- 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.



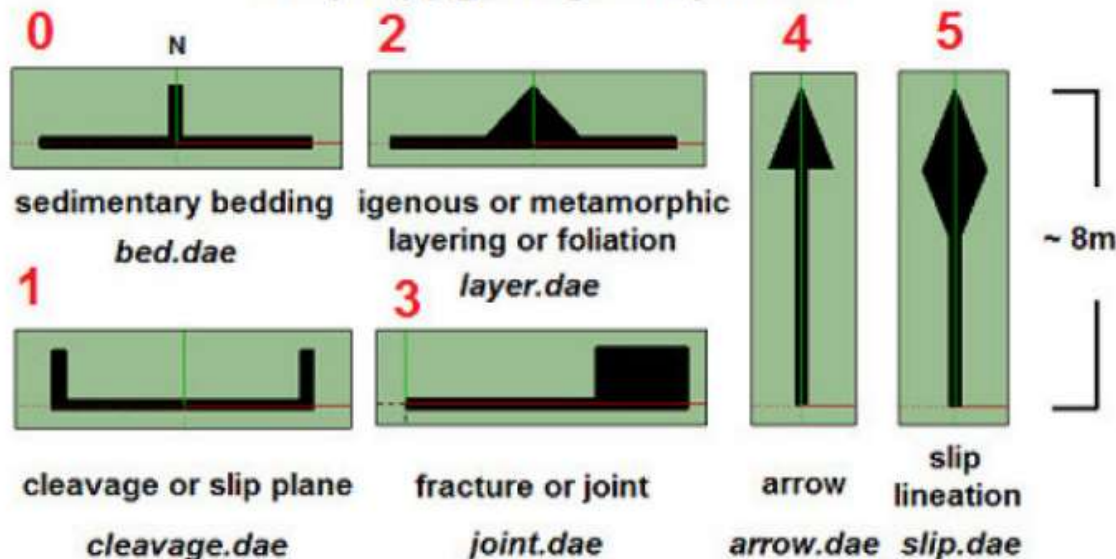
- Computerized 2D geological symbols and 3D models are generated in Trimble SketchUp, then georegistered, scaled, and annotated utilizing Microsoft Excel to generate GE keyhole-markup-language (KML) files.



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 (map) geological symbols

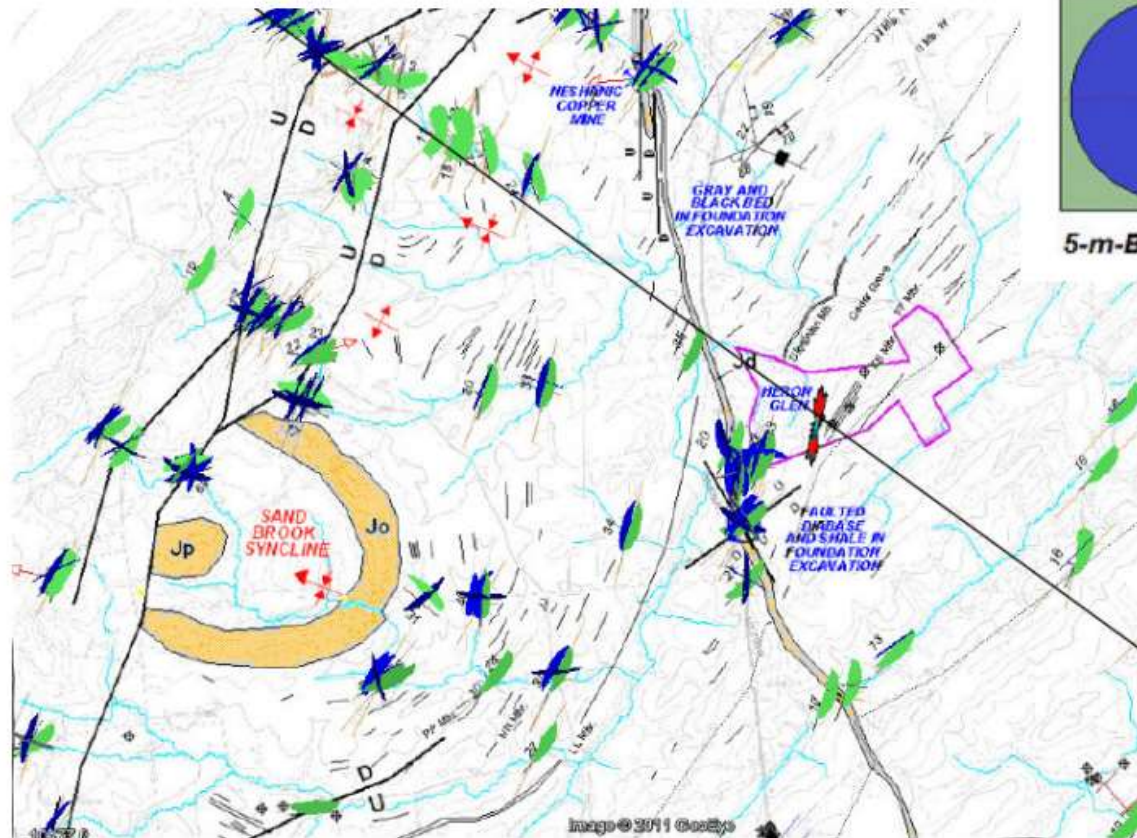


2D geological symbols and 3D colored circles (next page) are plotted in GE using KML output from Excel Worksheets shown below.

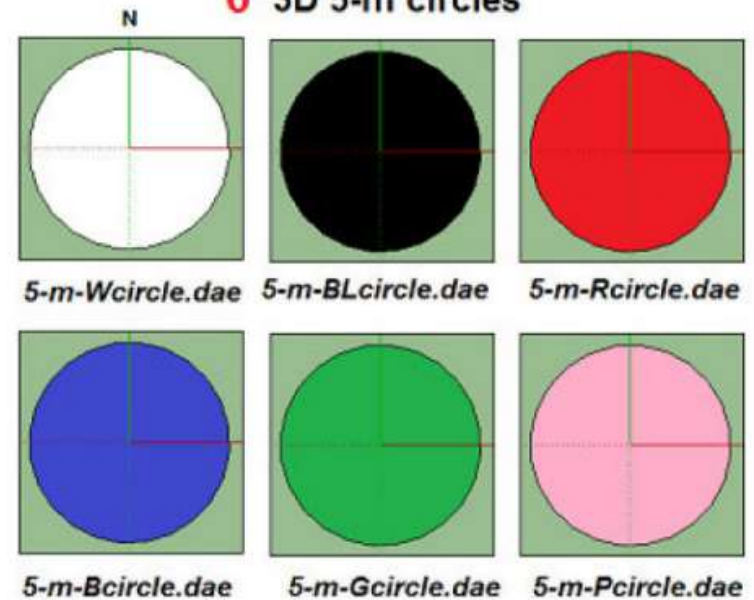
The red numbers are the symbol numbers used in the worksheet.

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.

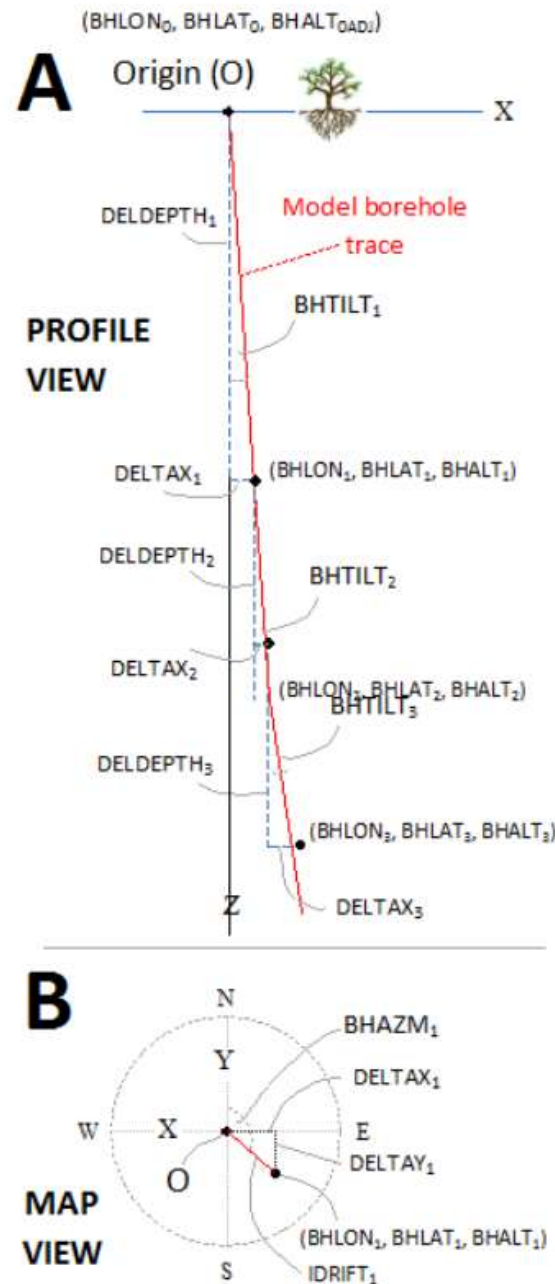


6 3D 5-m circles



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.

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] $DELDEPTH * SIN(RADIANS(BHTILT))$)

$DELTA X_n = IDRIFT_n * SIN(RADIANS(BHAZM_n)) * 0.000009$

$DELTA Y_n = IDRIFT_n * COS(RADIANS(BHAZM_n)) * 0.000009$

$BHLON_n = BHLON_{n-1} + DELTA X_n$

$BHLAT_n = BHLAT_{n-1} + DELTA Y_n$

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

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

for the map example, $BAZM_1 = 130^\circ$

2) 1 meter ≈ 0.000009 degree

Northeastern Section - 48th Annual Meeting (18-20 March 2013)**UTILIZING GOOGLE EARTH FOR GEOSPATIAL, TECTONIC, AND
HYDROGEOLOGICAL RESEARCH AT THE NEW JERSEY GEOLOGICAL AND
WATER SURVEY***Geological Society of America Abstracts with Programs*, Vol. 45, No. 1, p.110

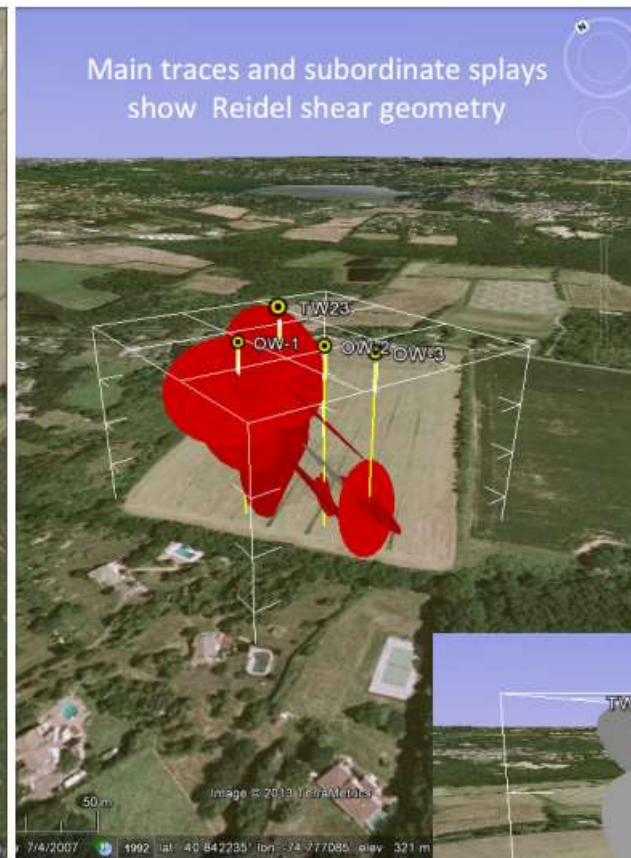
HERMAN, Gregory C., NJ Department of Environmental Protection, NJ Geological & Water Survey, PO Box 420, 29 Arctic Parkway, Trenton, NJ 08822, greg.herman@dep.state.nj.us

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.

Handouts:

-  [GCH_52-11_NEGSA2013.pdf](#) (8.4 MB)

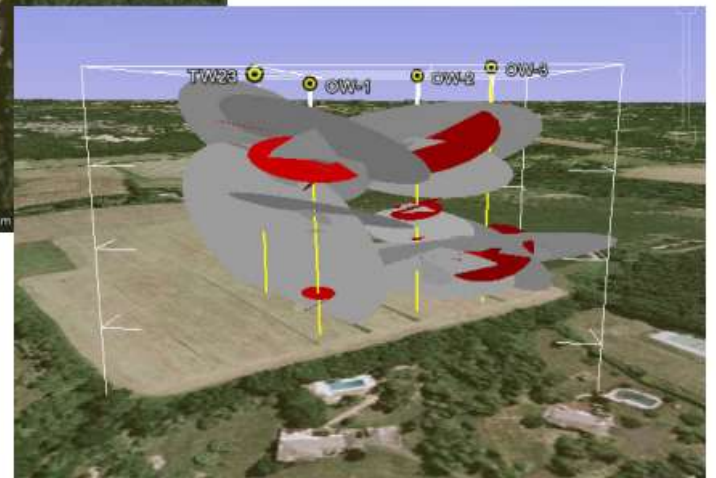
Comparative thickness values for sets of planar features, such as branching and interconnecting faults within a fault zone, can be variably scaled in a model to help assess complex structures in multiply-tectonized terrains.



Red – faults are variable scaled using aperture thickness

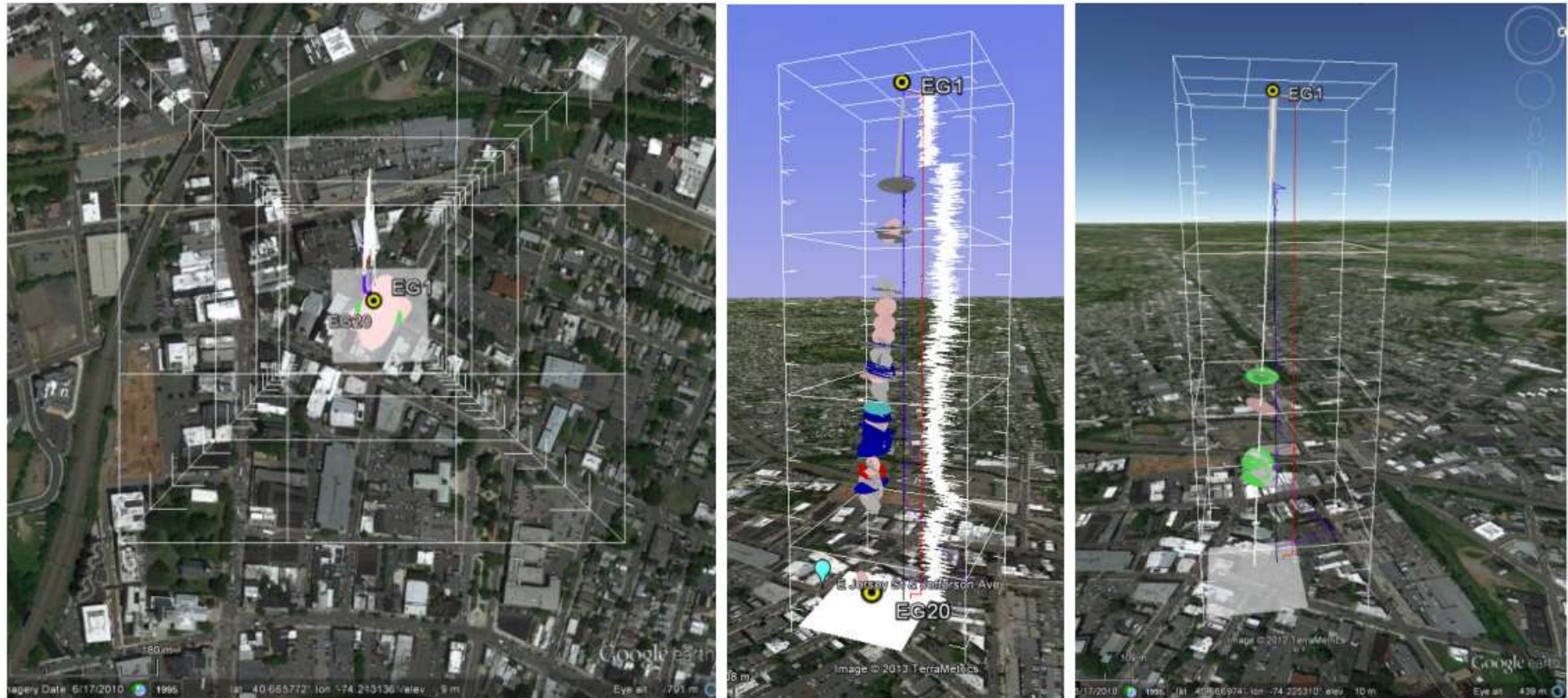


Green – metamorphic layering

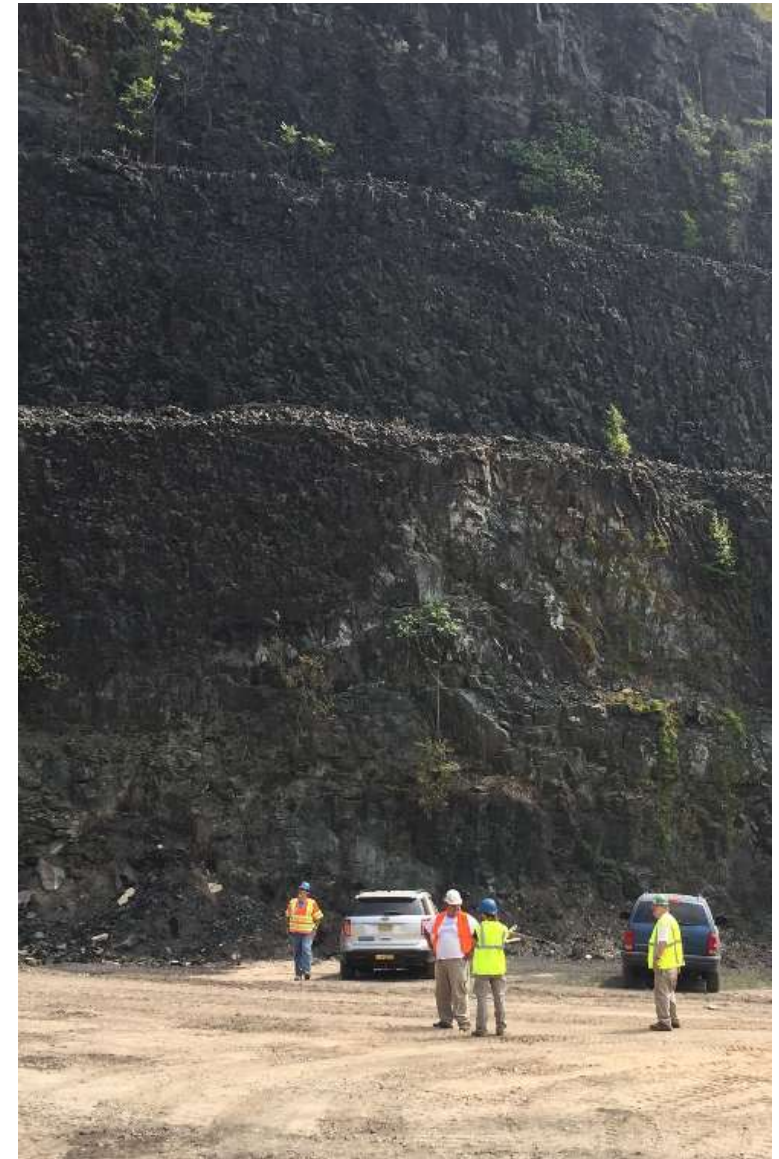
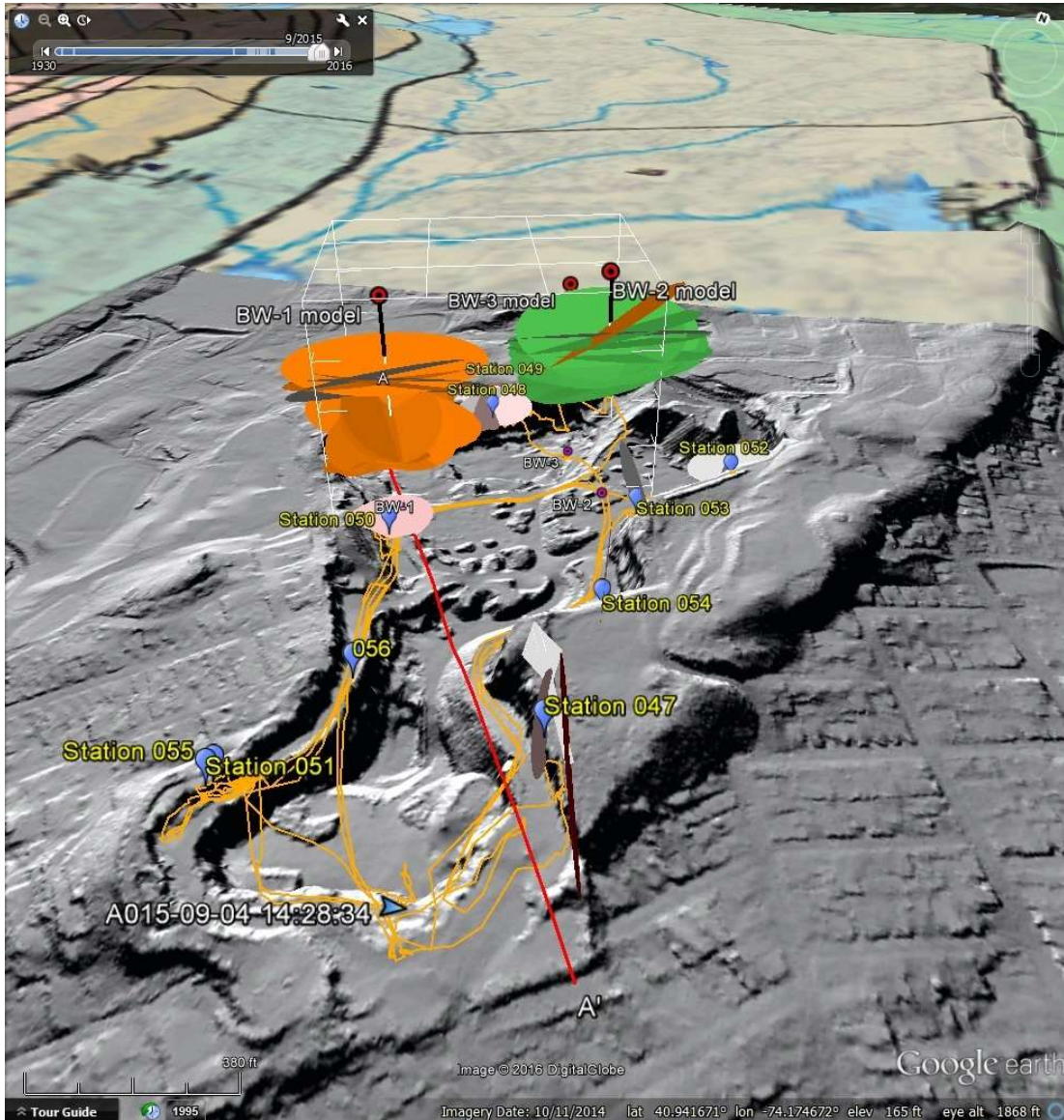


A water-supply well and three observation wells drilled into a fault zone.

- 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.





Dynamic 3-Point Geological-Plane Solver

This tool solves a 3 point problem interactively. **Alt+Click 3 points where you want to solve the problem.** The points will be plotted along with the symbol chosen below. The symbol will be placed at P2, along with Dip/Dip Azimuth.

If you need help navigating this tool, please consult the [help file](#).

Fly to:

URL Import:

P1 x	<input type="text"/>	y	<input type="text"/>	a	<input type="text"/>
P2 x	<input type="text"/>	y	<input type="text"/>	a	<input type="text"/>
P3 x	<input type="text"/>	y	<input type="text"/>	a	<input type="text"/>

Symbol to plot:

3D Symbol Dimensions (meters):

x y

Elevation: N/A

Latitude: N/A

Longitude: N/A

Strike:

Dip:

Quadrant:

Dip Azimuth:



Dynamic 3-Point Geological-Plane Solver

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Fly to:

URL Import:

P1 x	<input type="text"/>	y	<input type="text"/>	a	<input type="text"/>
P2 x	<input type="text"/>	y	<input type="text"/>	a	<input type="text"/>
P3 x	<input type="text"/>	y	<input type="text"/>	a	<input type="text"/>

Symbol to plot:

3D Symbol Dimensions (meters):

x y

Elevation: 279.72 meters

Latitude: 40.96011256166719

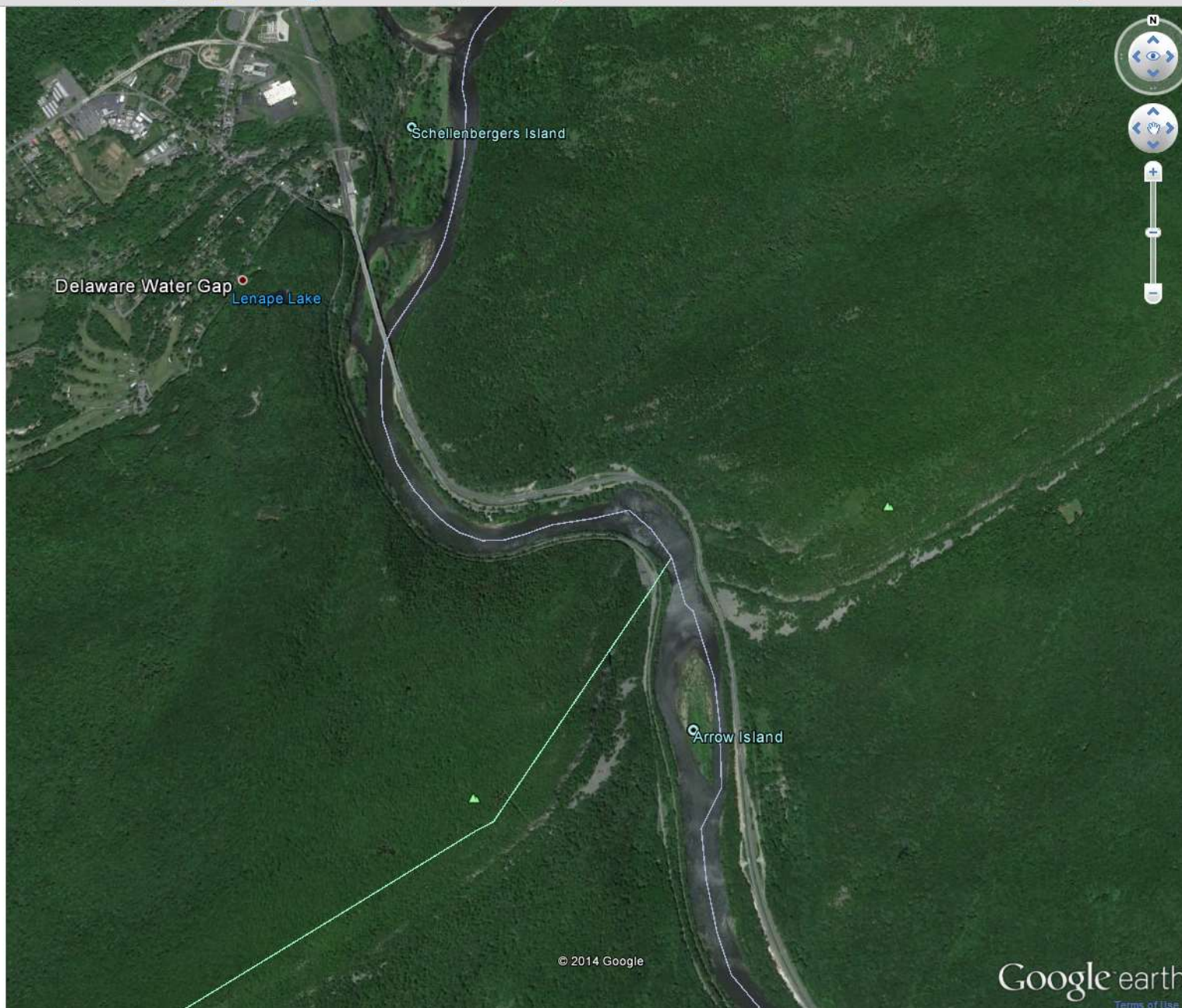
Longitude: -75.15158737814882

Strike:

Dip:

Quadrant:

Dip-Azimuth:



Dynamic 3-Point Geological-Plane Solver

This tool solves a 3 point problem interactively. **Alt+Click 3 points where you want to solve the problem.** The points will be plotted along with the symbol chosen below. The symbol will be placed at P2, along with Dip/Dip Azimuth.

If you need help navigating this tool, please consult the [help file](#).

Fly to: Delaware Water Gap

URL Import:

P1 x	<input type="text"/>	y	<input type="text"/>	a	<input type="text"/>
P2 x	<input type="text"/>	y	<input type="text"/>	a	<input type="text"/>
P3 x	<input type="text"/>	y	<input type="text"/>	a	<input type="text"/>

Symbol to plot: White Circle (3D) ▾

3D Symbol Dimensions (meters):

x y

Elevation: 305.21 meters

Latitude: 40.95438559320618

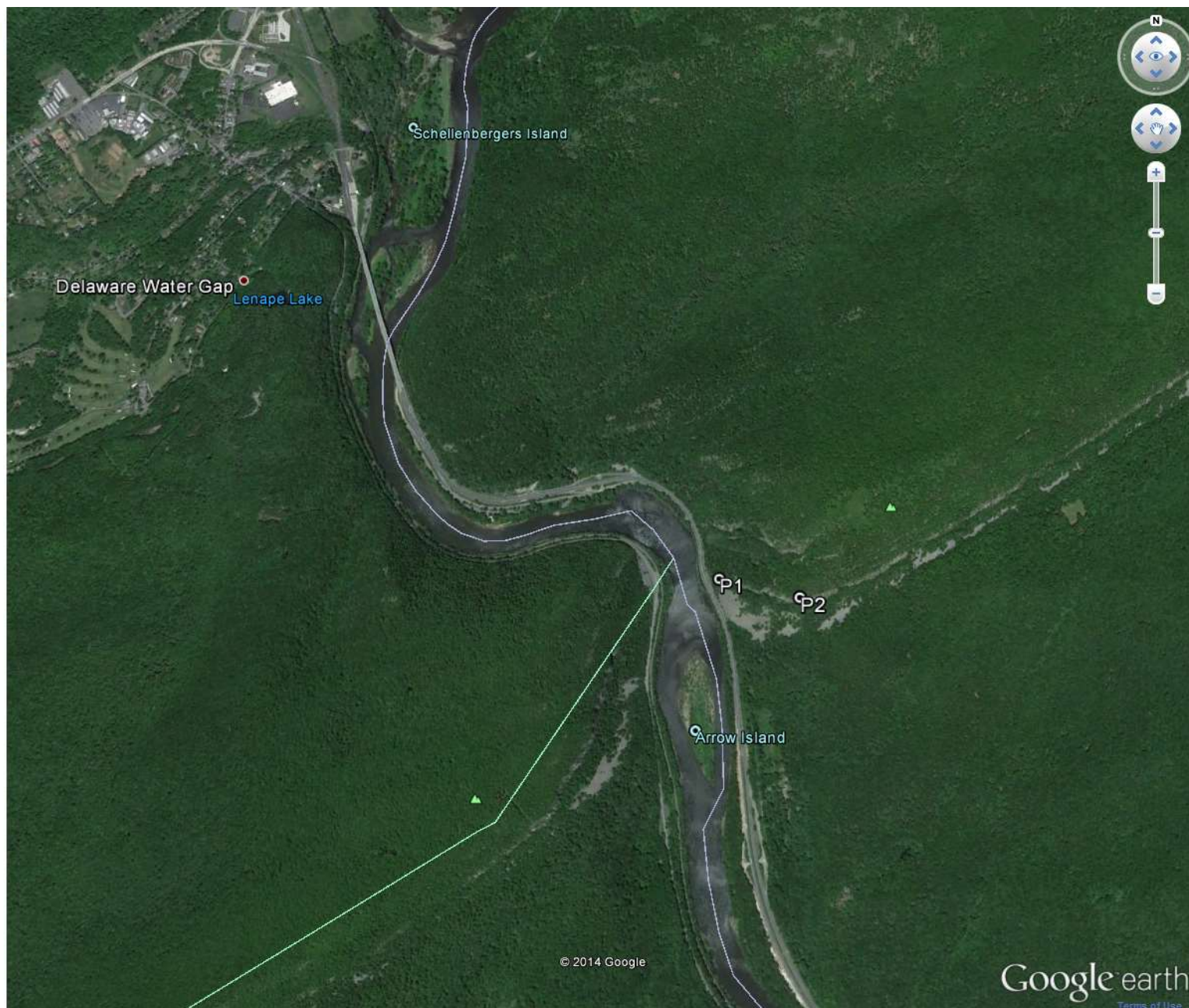
Longitude: -75.15116971637616

Strike:

Dip:

Quadrant:

Dip-Azimuth:



Dynamic 3-Point Geological-Plane Solver

This tool solves a 3 point problem interactively. **Alt+Click 3 points where you want to solve the problem.** The points will be plotted along with the symbol chosen below. The symbol will be placed at P2, along with Dip/Dip Azimuth.

If you need help navigating this tool, please consult the [help file](#).

Fly to:

URL Import:

P1 x	<input type="text"/>	y	<input type="text"/>	a	<input type="text"/>
P2 x	<input type="text"/>	y	<input type="text"/>	a	<input type="text"/>
P3 x	<input type="text"/>	y	<input type="text"/>	a	<input type="text"/>

Symbol to plot: ▼

3D Symbol Dimensions (meters):

x y

Elevation: 429.02 meters

Latitude: 40.95338587540719

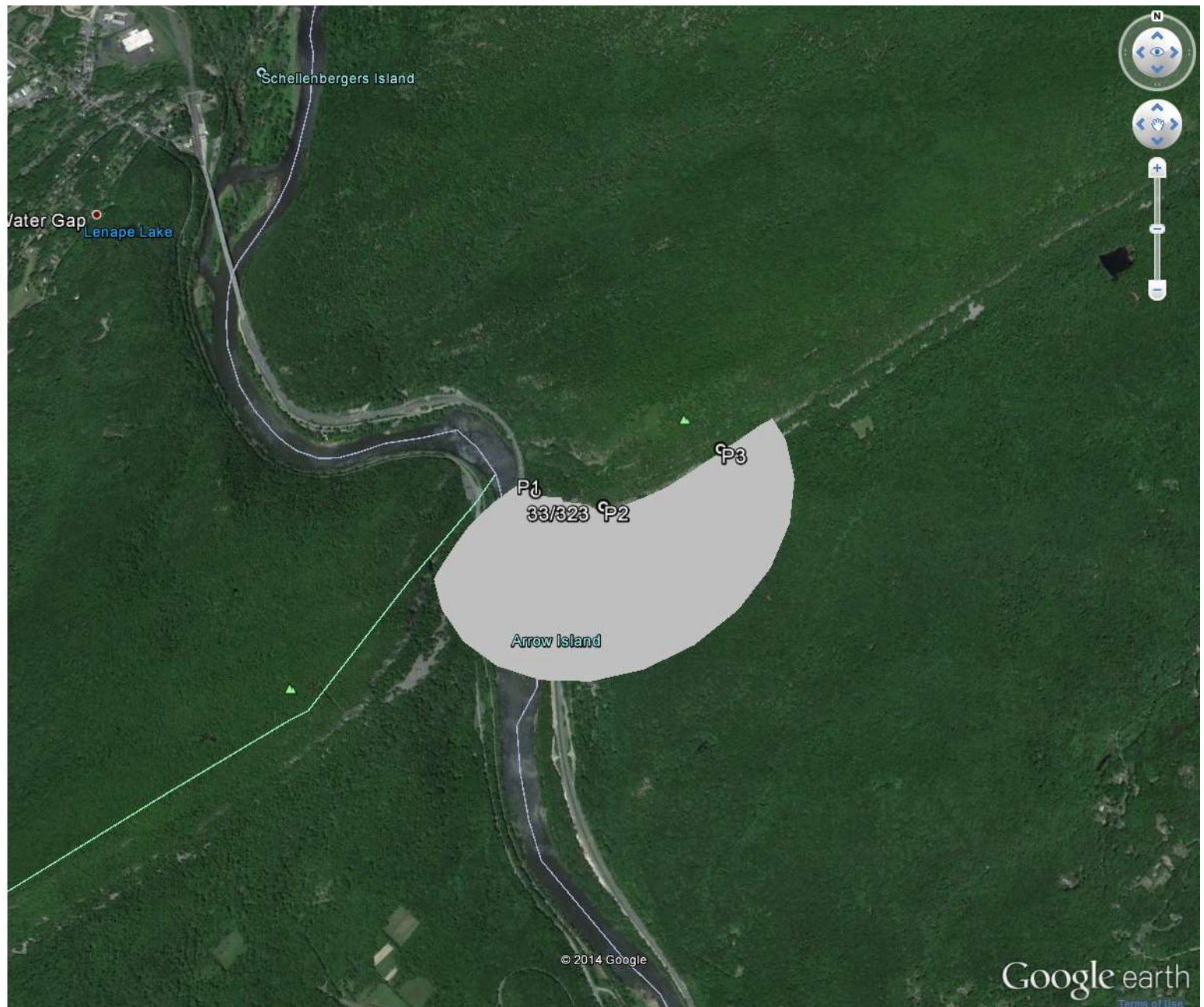
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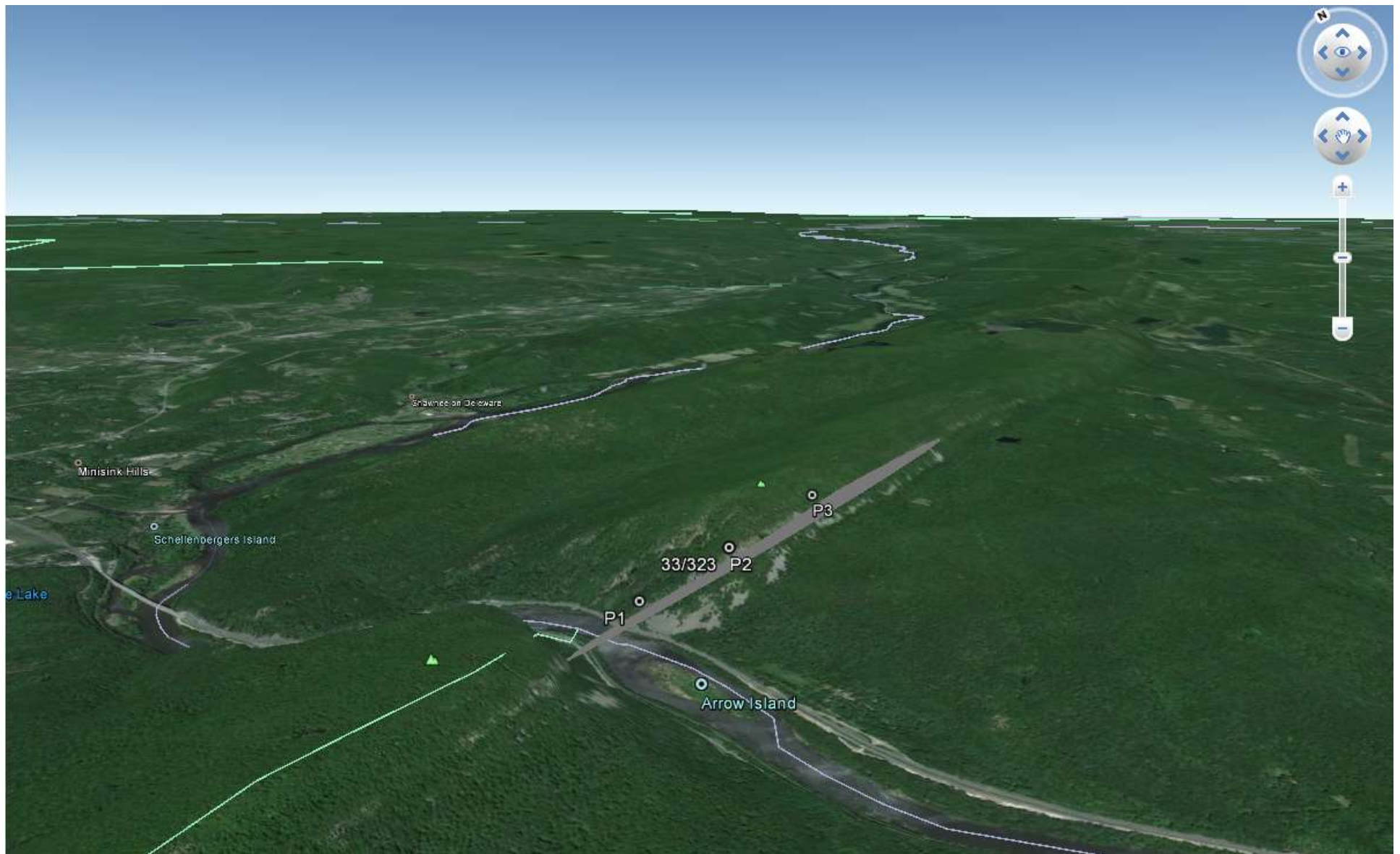
Strike: 53.35765840513042

Dip: 33.505701478540544

Quadrant: W

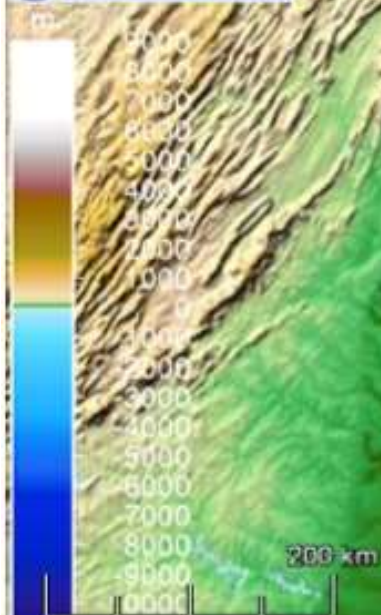
Dip-Azimuth: 323.35765840513045







ETOPO1 Ice Surface



NEW
YORK
RECESS

Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat

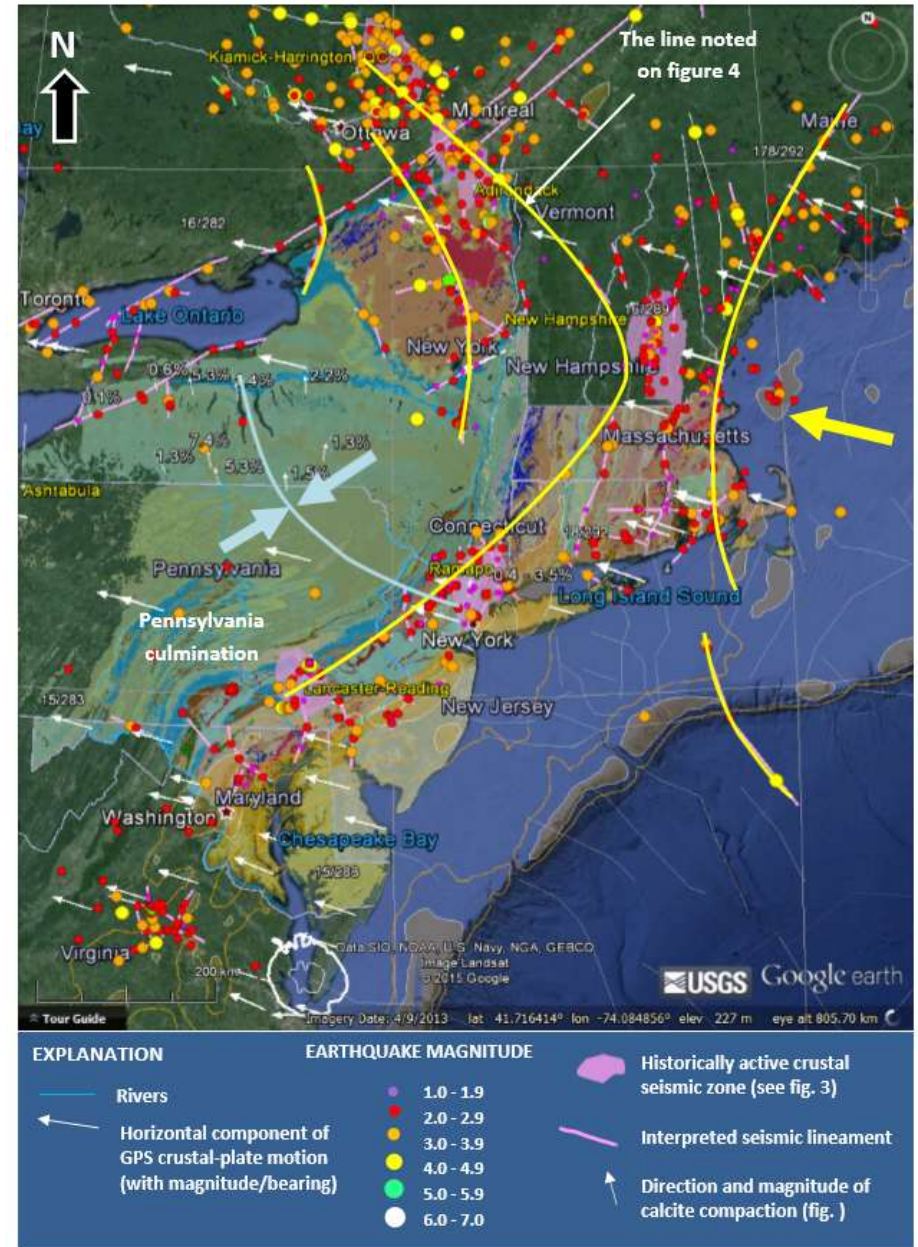
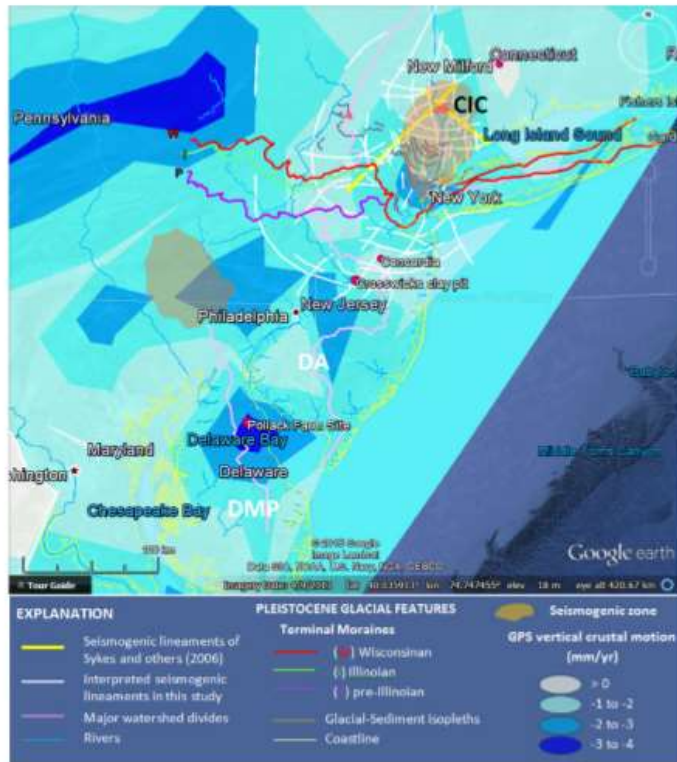
Google earth

Neotectonics of the New York Recess

MEETING PROCEEDINGS AND FIELD GUIDE FOR THE 2015 CONFERENCE
OF THE GEOLOGICAL ASSOCIATION OF NEW JERSEY

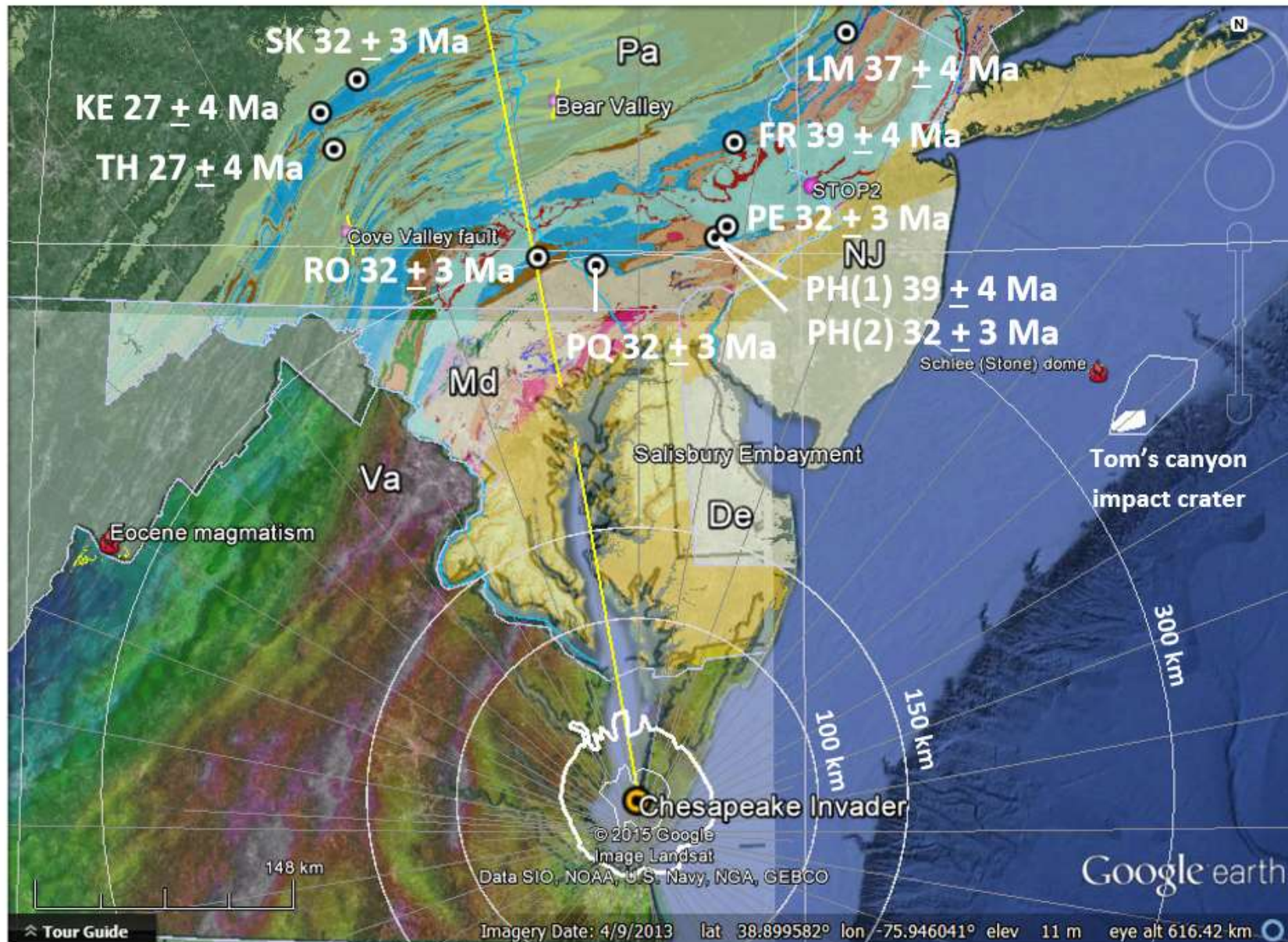
EDITED BY

Gregory Charles Herman and Suzanne Macaoay Ferguson
NEW JERSEY GEOLOGICAL & WATER SURVEY PENNJERSEY ENVIRONMENTAL CONSULTING



GEOLOGICAL ASSOCIATION OF NEW JERSEY
XXXII ANNUAL CONFERENCE AND FIELD TRIP
OCTOBER 16-17, 2015, LAFAYETTE COLLEGE, EASTON, PENNSYLVANIA

GANJ XXXII Chapter 3. Re-Os isotope evidence an Early Tertiary crustal faulting and sulfide-mineralization in Pennsylvania with probable ties to the Chesapeake Bay bolide impact in Maryland, USA





*Earth continental
geology by Era and
grayshade seafloor
physiography*



Chicxulub crustal-fracture model

2020-20 Impact experiments using an air gun, steel projectile, and 60mm glass balls.

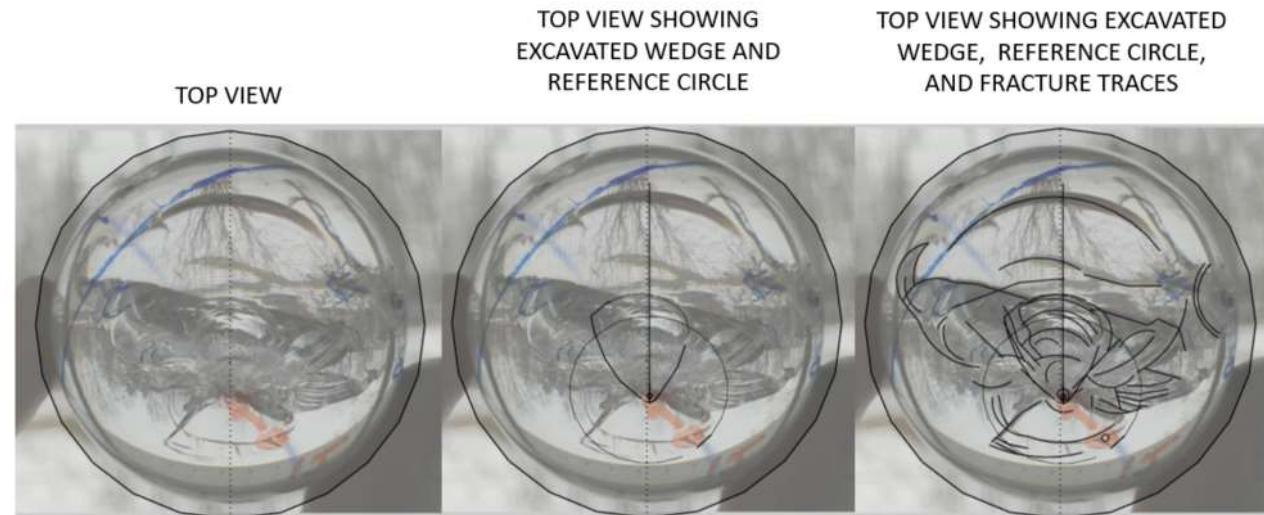


Figure 9. Mapped results of the strain field resulting from a high-angle impact (85°) near the gun's threshold velocity. The impact conditions were just right to produce a 3D foreland strain field that descends down toward the ball center from the impact point at the surface, then returns upward following an irregular path as further profiled in figure 8.

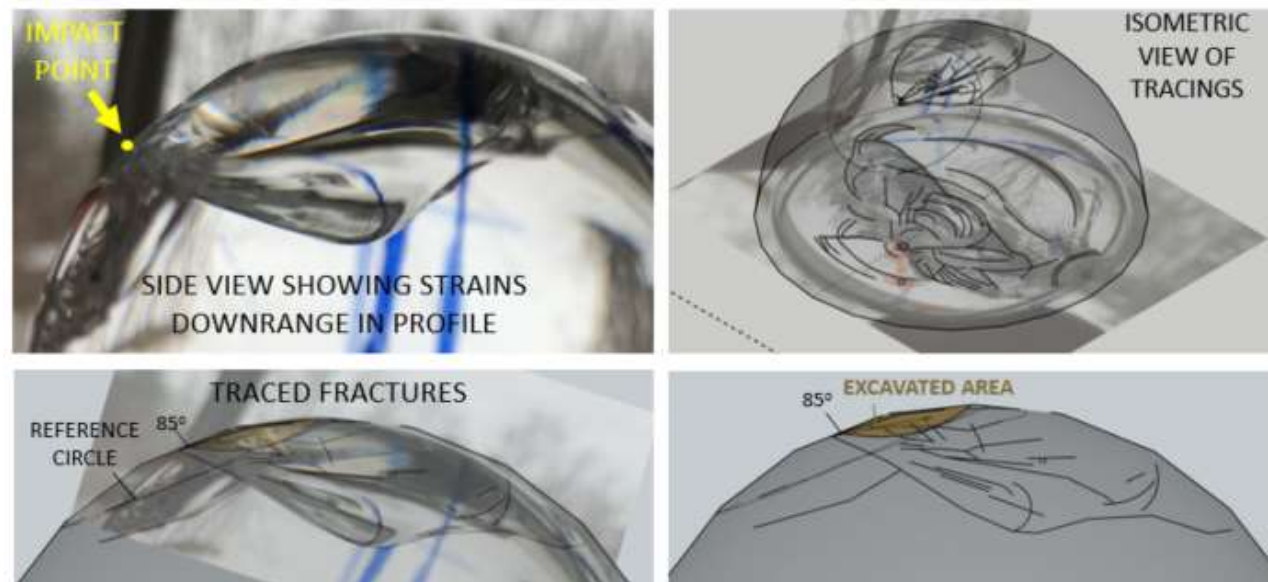


Figure 10. Test results showing a high-angle impact near the gun's threshold velocity. Three-dimension (3D) line tracings of spherical strain fields including the map depictions in figure 7.