Digital Photogrammetry Component of an Experimental Project to Monitor Rock Slope Activity at Multiple Sites in the Valley and Ridge, Virginia.

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2 – Virginia Dept. of Transportation (VDOT)
3 – Virginia Transportation Research Council (VTRC)

- Project Description
- Digital Photogrammetry
- Rock Slope Descriptions
- Preliminary Results
- Preliminary Conclusions

Project Context

- Geohazards in Virginia include rock slopes and karst.
- Rock slopes not inventoried or quantified.
- What is best approach to assessing risk posed to public safety and infrastructure?

Project Context

- Assessment of various monitoring technologies can suggest strategies to protect public safety and infrastructure.

- Employing multiple technologies to monitor variety of features over same time in same area allows for direct comparison of results.

Technologies Tested

- Interferometric Synthetic Aperture Radar Images (InSAR)
- Light Detection and Ranging (LIDAR)
- Digital photogrammetry (DPG)

Digital photogrammetry (DPG) presented here is a supplemental part of a larger project:

"Sinkhole Detection and Bridge/Landslide Monitoring for Transportation Infrastructure by Automated Analysis of Interferometric Synthetic Aperture Radar Images (InSAR)"

Scott Acton, *University of Virginia*
Edward Hoppe, *VTRC;* Brian Bruckno, *VDOT*
Adrian Bohane; Giacoma Farloni, TRE

Goals of larger project:

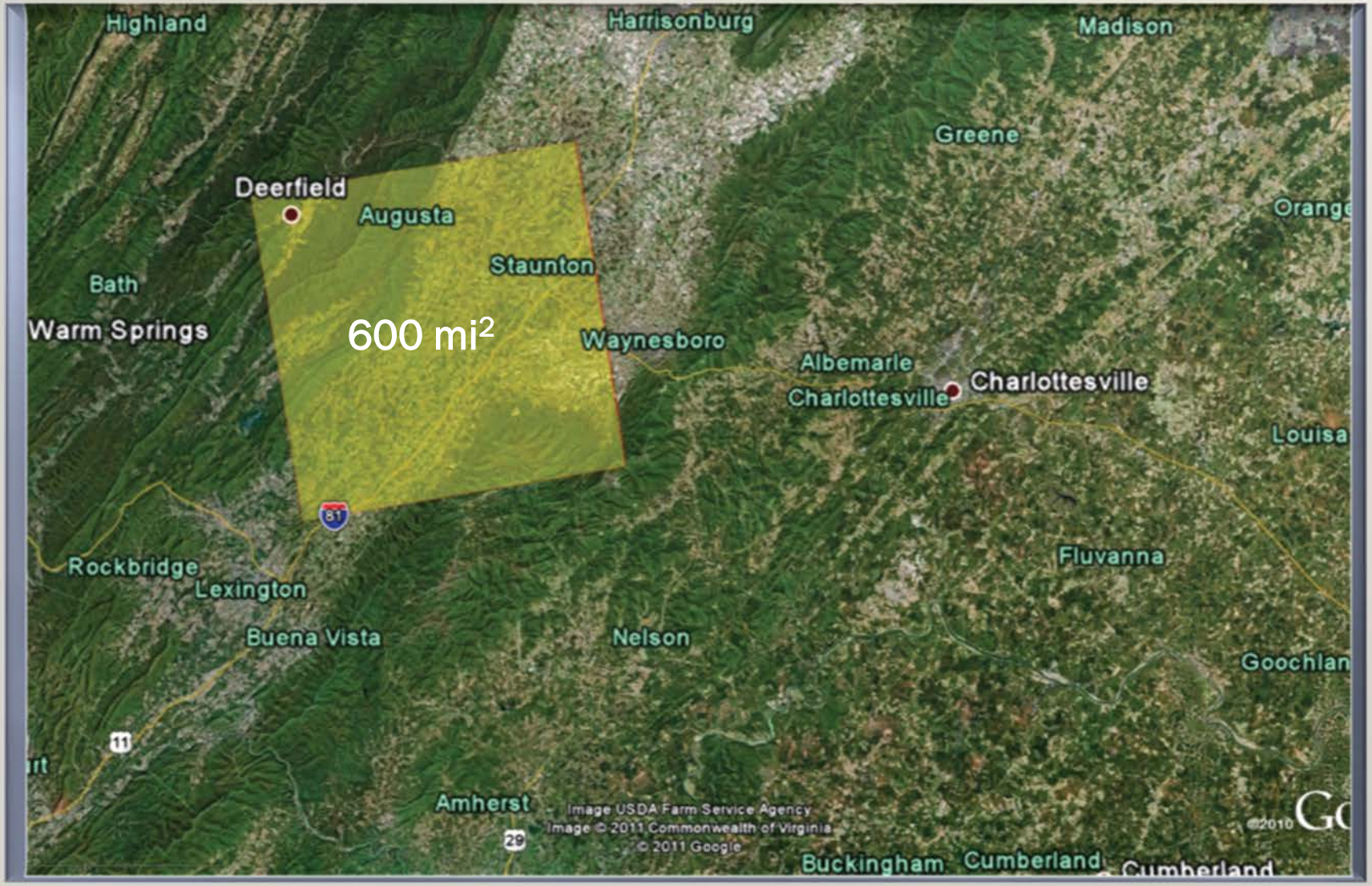
"…study the feasibility of implementing the leading edge InSAR technology* in the transportation community, with specific applications to the detection and monitoring of sinkholes, landslides, and bridge displacements."

* "…deformation data measurements with accuracies on order of tenths of an inch."

Goals of DPG and LIDAR:

- Provide ground-truthing of InSAR results on rock slopes (DPG and LIDAR) and bridge displacements (LIDAR).

- Direct comparison of results (DPG vs. LIDAR).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Staunton
Bath
Warm Springs
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Waynesboro
Albemarle
Charlottesville
Charlottesville
Louisa
Rockbridge
Lexington
Fluvanna
Buena Vista
Nelson
Goochlan
Amherst
Image USDA Farm Service Agency
Image © 2011 Commonwealth of Virginia
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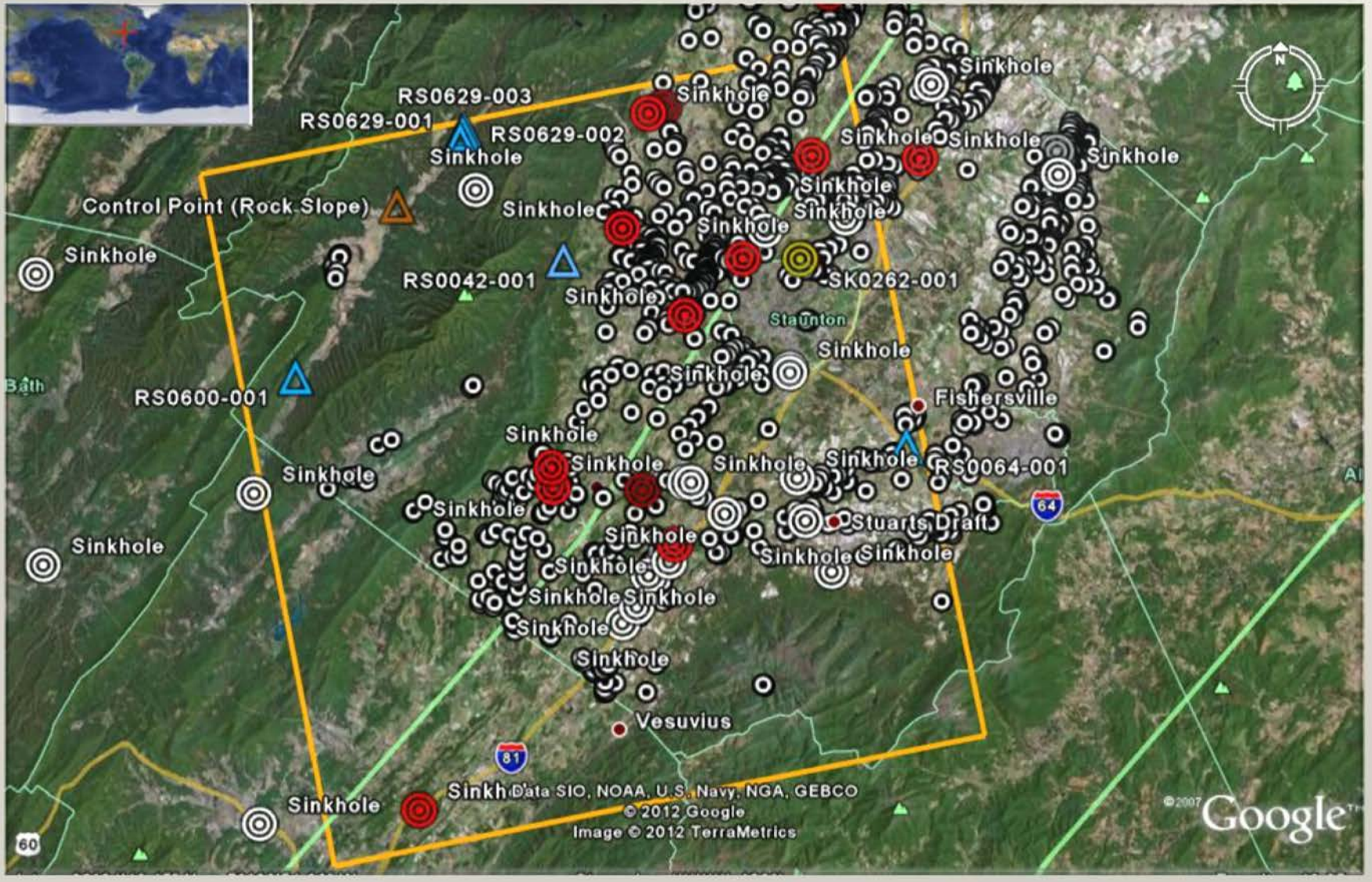
©2010
Buckingham
Cumberland
Cumberland

Features to be monitored:

- +1,000 sinkholes
- 100 bridges
- 6 rock slopes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RS0629-001
RS0629-002
Control Point (Rock Slope)
RS0042-001
SK0262-001
RS0600-001
RS0064-001
Staunton
Fishersville
Stuarts Draft
Vesuvius
Bath
Sinkhole
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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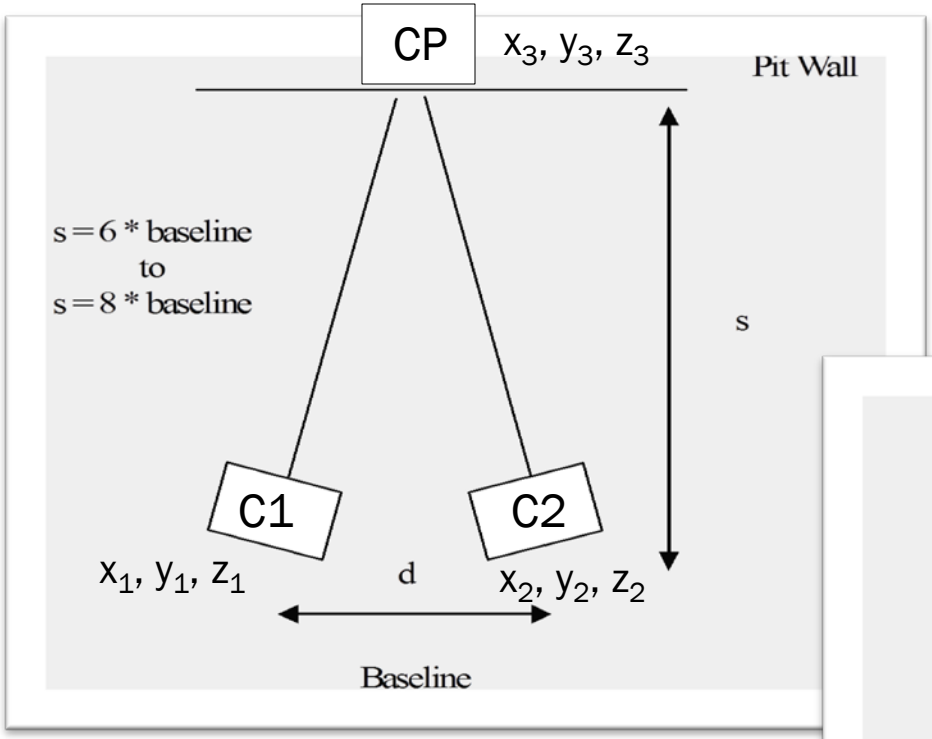
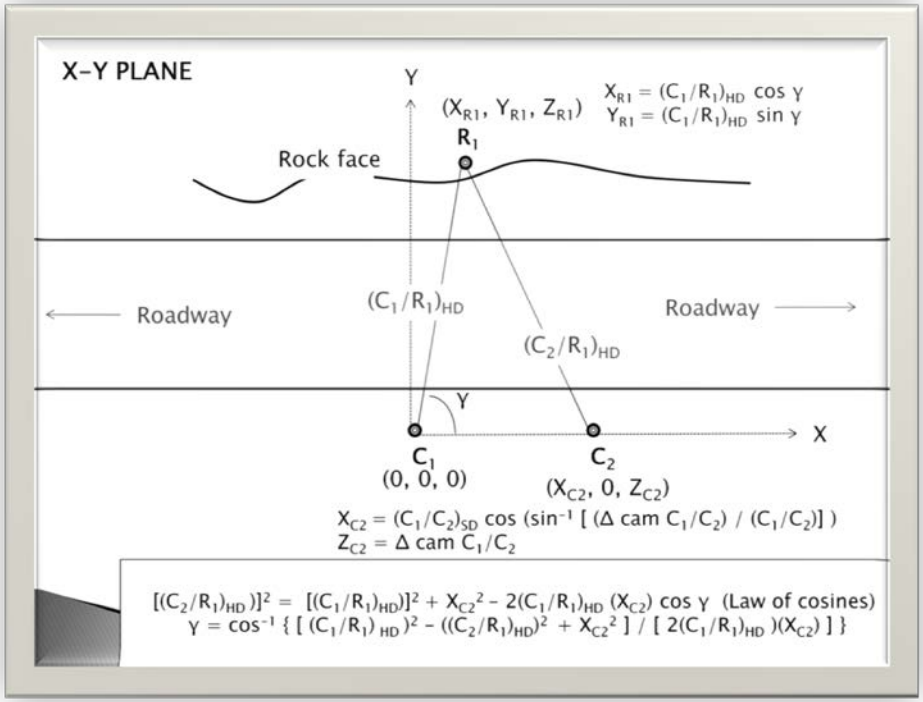
Ground-based Digital Photogrammetry

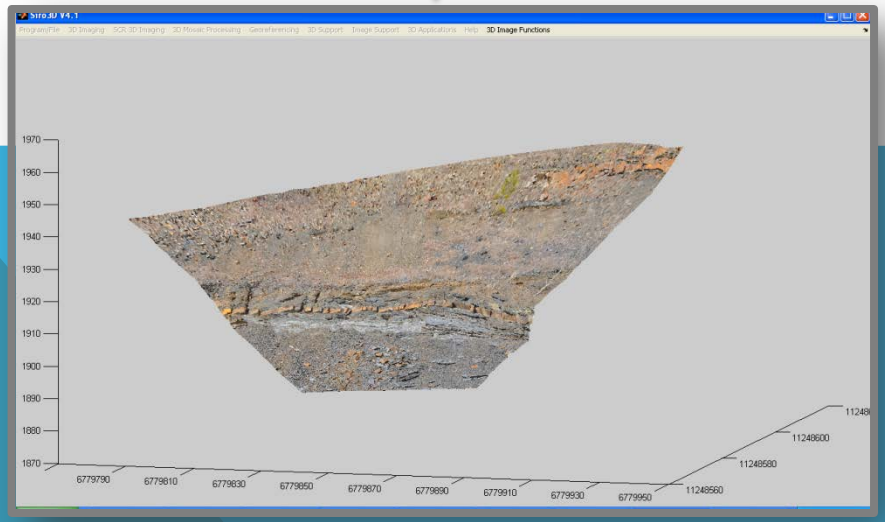


- Qualitative vs. Quantitative DPG
- Coordinates (relative versus absolute)
- Accuracy



Latitude	Longitude	Northing	Easting	Elevation, ft	Code	Locality	Intuitive Name
38.18690463	-79.23869578	6751973.3930	11270600.0640	1757.771	C1	0042-001	Route 42 C1
38.18689732	-79.23866231	6751970.6540	11270609.6630	1757.602	C2	0042-001	Route 42 C2
38.18698469	-79.23851201	6752002.1230	11270653.1170	1769.104	RSF	0042-001	Route 42 Rock Slope Face
38.18684191	-79.23842806	6751949.9320	11270676.8290	1757.077	HDS1	0042-001	Route 42 HDS 1
38.18691234	-79.23896211	6751976.8150	11270523.5410	1760.525	HDS2	0042-001	Route 42 HDS 2
38.11643084	-79.44372383	6726850.7440	11211408.7510	1571.637	C1	0600-001	Route 600 C1
38.1164582	-79.44371343	6726860.6770	11211411.8450	1571.562	C2	0600-001	Route 600 C2
38.11652167	-79.44392219	6726884.4060	11211352.0260	1603.452	RSF	0600-001	Route 600 Rock Slope Face

Sirovision®


3D Image Functions
1970
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6779950
11248560
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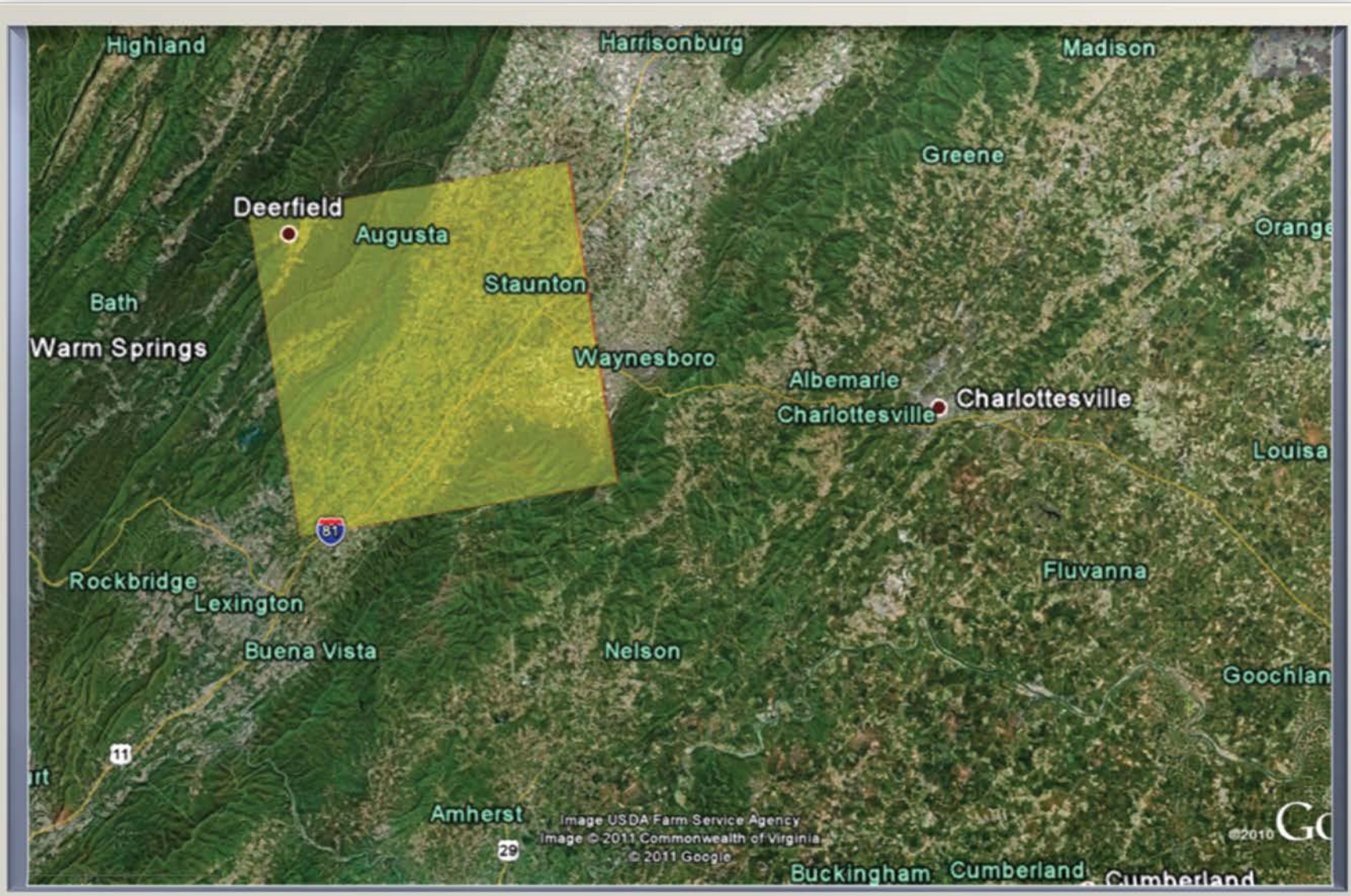
Limitations of DPG:

- Affected negatively by non-reflective surfaces:

vegetation, horizon, shadow, irregularities, shallow slope angles, etc.

- The above can also limit success of LIDAR.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Harrisonburg
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Deerfield
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Staunton
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Waynesboro
Albemarle
Charlottesville
Charlottesville
Louisa
81
Rockbridge
Lexington
Fluvanna
Buena Vista
Nelson
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Amherst
Image USDA Farm Service Agency
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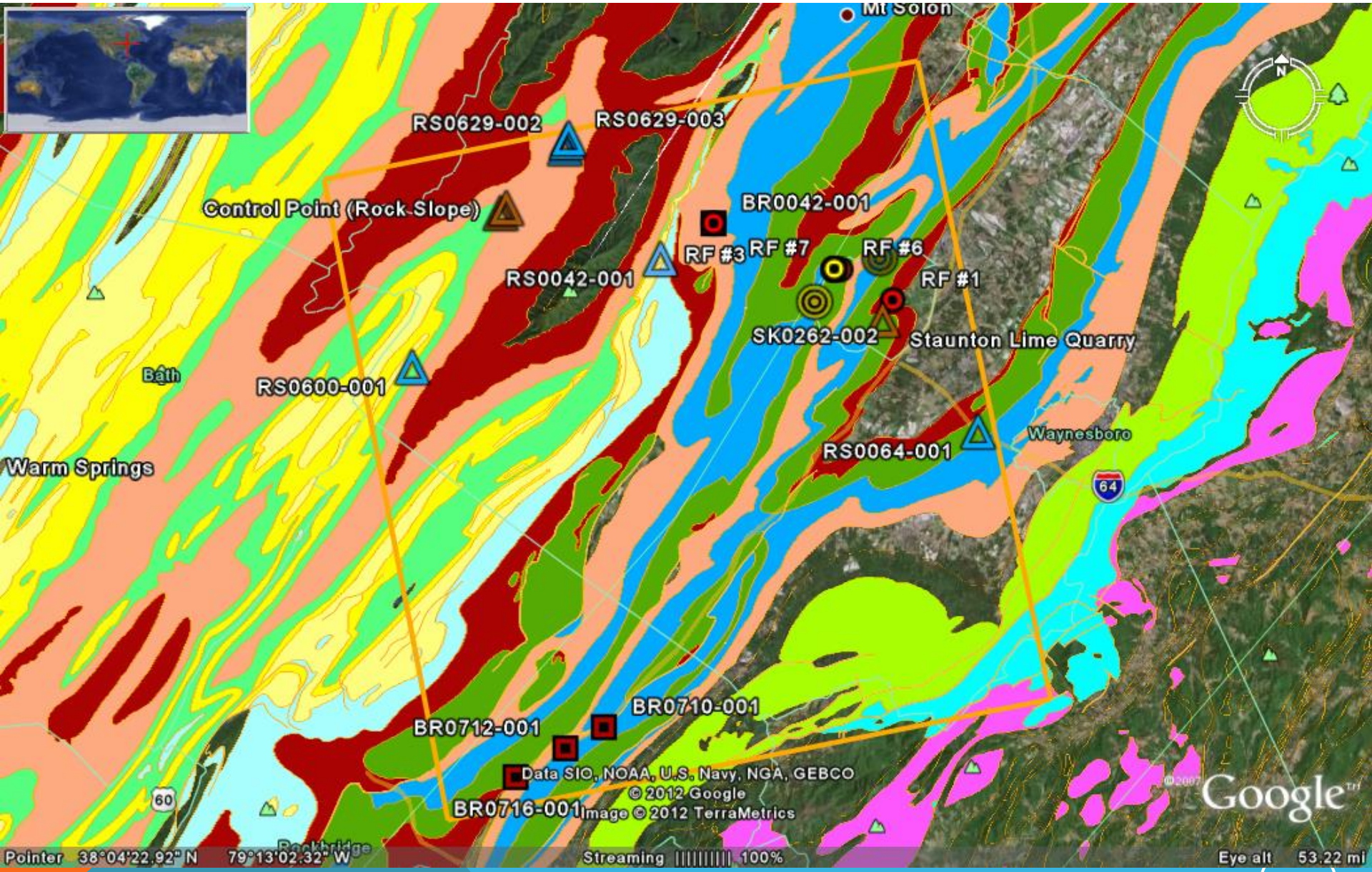
Buckingham
Cumberland
Cumberland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RS0629-003
Control Point (Rock Slope)
BR0042-001
RF #3
RF #7
RF #6
RF #1
RS0042-001
SK0262-002
Staunton Lime Quarry
Bath
RS0600-001
Waynesboro
RS0064-001
Warm Springs
64
BR0710-001
BR0712-001
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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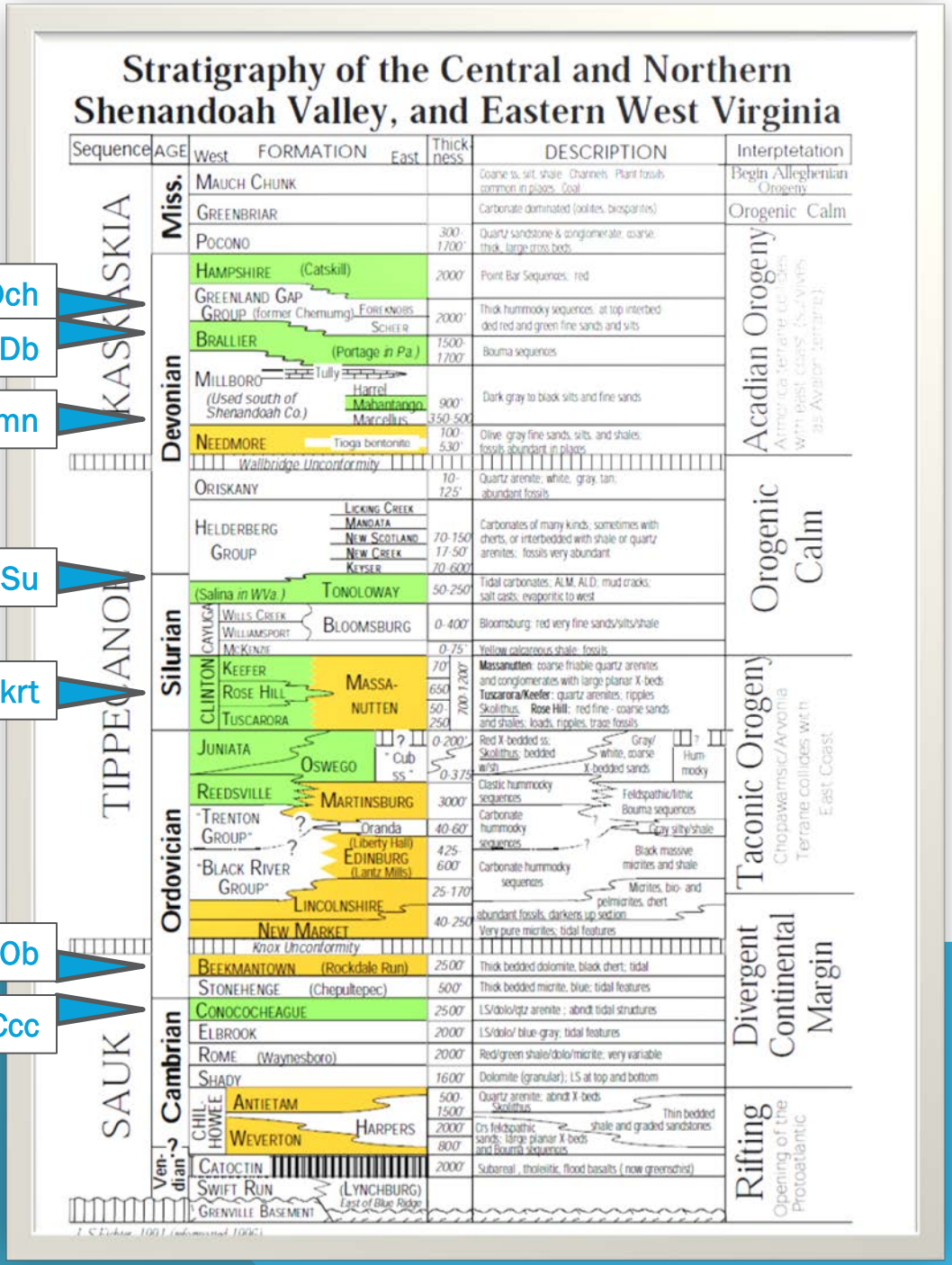
BR0716-001
Image © 2012 TerraMetrics
60
Rockbridge
Google
Pointer 38°04'22.92" N 79°13'02.32" W
Streaming 100%
Eye alt 53.22 mi


Stratigraphy of the Central and Northern Shenandoah Valley, and Eastern West Virginia
Sequence
AGE
West FORMATION East
Thick-ness
DESCRIPTION
Interpetetation
KAISKA
TIPPECANOE
SAUKIA
Miss.
Devonian
Silurian
Ordovician
Cambrian
Ven-dian
Mauch Chunk
Greenbriar
Pocono
Hampshire (Catskill)
Greenland Gap Group (former Chemung)
Foreknobs
Scheer
Brallier (Portage in Pa.)
Millboro (Used south of Shenandoah Co.)
Tully
Harrel
Mahantango
Marcellus
Needmore
Tioga bentonite
Wallbridge Unconformity
Oriskany
Helderberg Group
Licking Creek
Mandata
New Scotland
New Creek
Keyser
(Salina in WVa.)
Tonoloway
Cayuga
Wills Creek
Williamsport
Bloomsburg
McKenzie
Clinton
Keefer
Rose Hill
Tuscarora
Massa-nutten
Juniata
Oswego
"Cub ss."
Reedsville
Martinsburg
"Trenton Group"
Oranda
(Liberty Hall)
Edinburg
(Lantz Mills)
"Black River Group"
Lincolnshire
New Market
Knox Unconformity
Beekmantown (Rockdale Run)
Stonehenge (Chepultepec)
Conococheague
Elbrook
Rome (Waynesboro)
Shady
Chil-howee
Antietam
Harpers
Weverton
Catoctin
Swift Run
(Lynchburg)
East of Blue Ridge
Grenville Basement
Coarse ss, silt, shale. Channels. Plant fossils common in places. Coal.
Carbonate dominated (oolites, biosparites)
Quartz sandstone & conglomerate; coarse, thick, large cross beds
Point Bar Sequences; red
Thick hummocky sequences; at top interbed ded red and green fine sands and silts
Bouma sequences
Dark gray to black silts and fine sands
Olive gray fine sands, silts, and shales; fossils abundant in places
Quartz arenite; white, gray, tan; abundant fossils
Carbonates of many kinds; sometimes with cherts, or interbedded with shale or quartz arenites; fossils very abundant
Tidal carbonates; ALM, ALD; mud cracks; salt casts; evaporitic to west
Bloomsburg; red very fine sands/silts/shale
Yellow calcareous shale; fossils
Massanutten: coarse friable quartz arenites and conglomerates with large planar X-beds
Tuscarora/Keefer: quartz arenites; ripples Skolithus. Rose Hill: red fine - coarse sands and shales; loads, ripples, trace fossils
Red X-bedded ss; Skolithus; bedded w/sh
Gray/ white, coarse X-bedded sands
Hum-mocky
Clastic hummocky sequences
Feldspathic/lithic Bouma sequences
Carbonate hummocky sequences
Gray silty/shale
Carbonate hummocky sequences
Black massive micrites and shale
Micrites, bio- and pelmicrites, chert
abundant fossils, darkens up section
Very pure micrites; tidal features
Thick bedded dolomite, black chert; tidal
Thick bedded micrite, blue; tidal features
LS/dolo/qtz arenite ; abndt tidal structures
LS/dolo/ blue-gray; tidal features
Red/green shale/dolo/micrite; very variable
Dolomite (granular); LS at top and bottom
Quartz arenite; abndt X-beds Skolithus
Thin bedded shale and graded sandstones
Crs feldspathic sands; large planar X-beds and Bouma sequences
Subareal, tholeiitic, flood basalts (now greenschist)
Begin Alleghenian Orogeny
Orogenic Calm
Acadian Orogeny
Orogenic Calm
Taconic Orogeny
Divergent Continental Margin
Rifting
Opening of the Protoatlantic
300-1700'
2000'
2000'
1500-1700'
900'
350-500
100-530'
10-125'
70-150
17-50'
70-600'
50-250'
0-400'
0-75'
70'
650'
50-250'
700-1200'
0-200'
0-375'
3000'
40-60'
425-600'
25-170'
40-250'
2500'
500'
2500'
2000'
2000'
1600'
500-1500'
2000'
800'
2000'
Dch
Db
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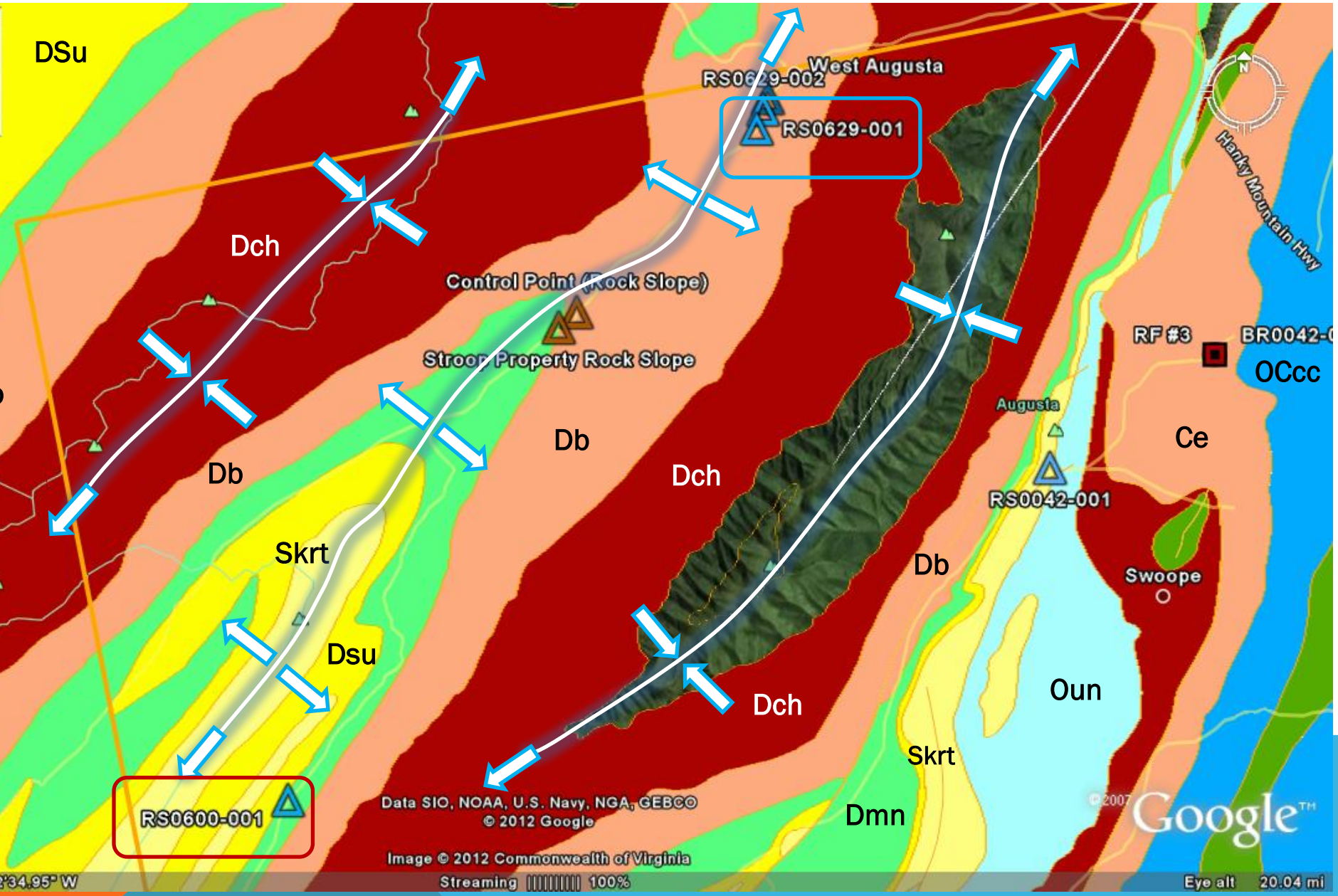
Skrt
Ob
OCcc
RS-00629-001
RS-00600-001


DSu
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RS0629-002
West Augusta
RS0629-001
Control Point (Rock Slope)
Stroop Property Rock Slope
RS0600-001
RS0042-001
Augusta
RF #3
Swoope
Hanky Mountain Hwy
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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Streaming 100%
Eye alt 20.04 mi
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Rock Slope Descriptions

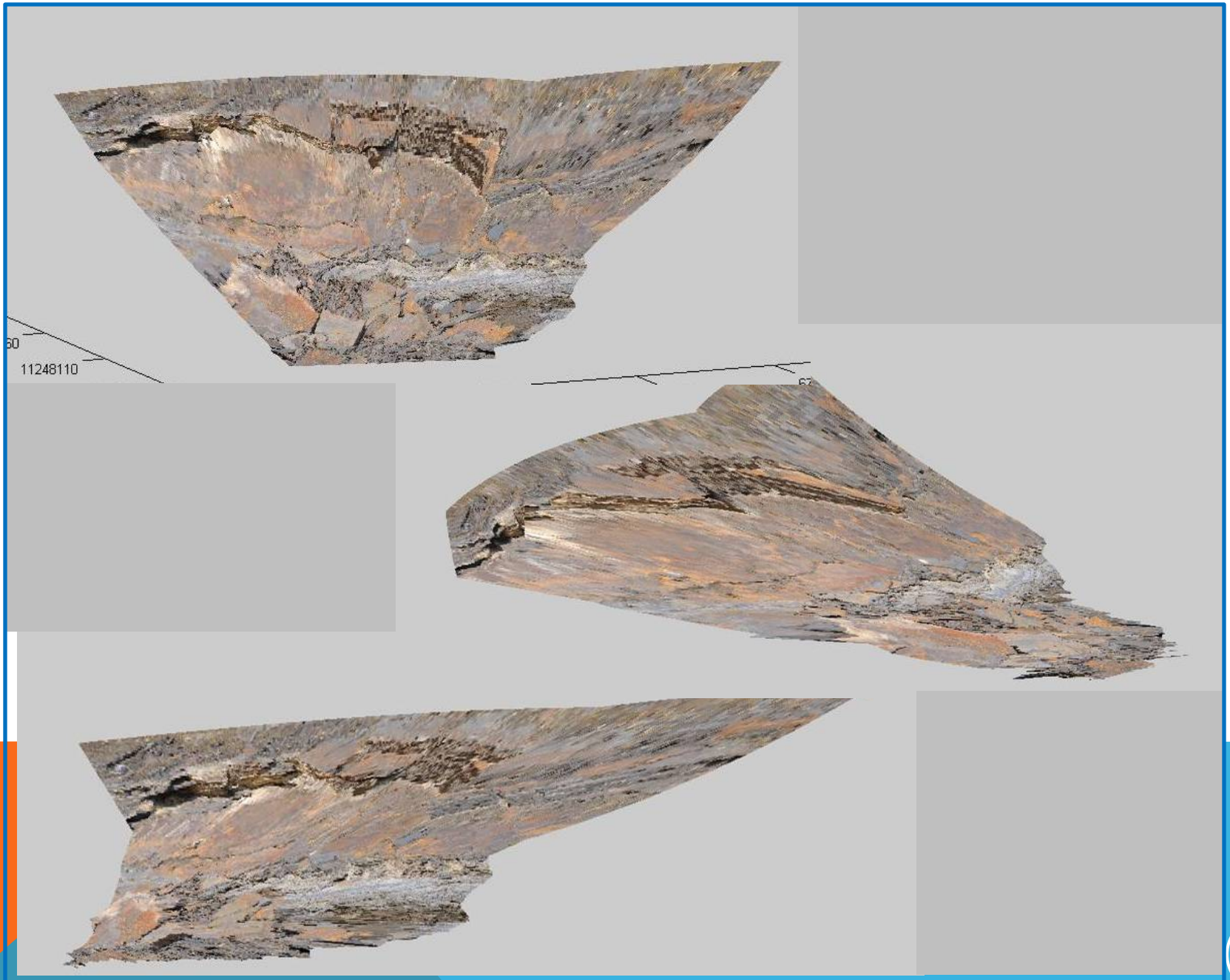
- RS-00629-001
- RS-00600-001

RS-00629-001

- Catastrophic slope failure in 2009 (10K yds^3).
- Folded and jointed beds.
- Clastic metasediments of Brallier Formation (Devonian).
- Dip slope (35 deg.) on lower cut.
- Upper and lower slopes imaged separately.

RS 00629-001

Catastrophic slope failure in 2009 (10K yds^3)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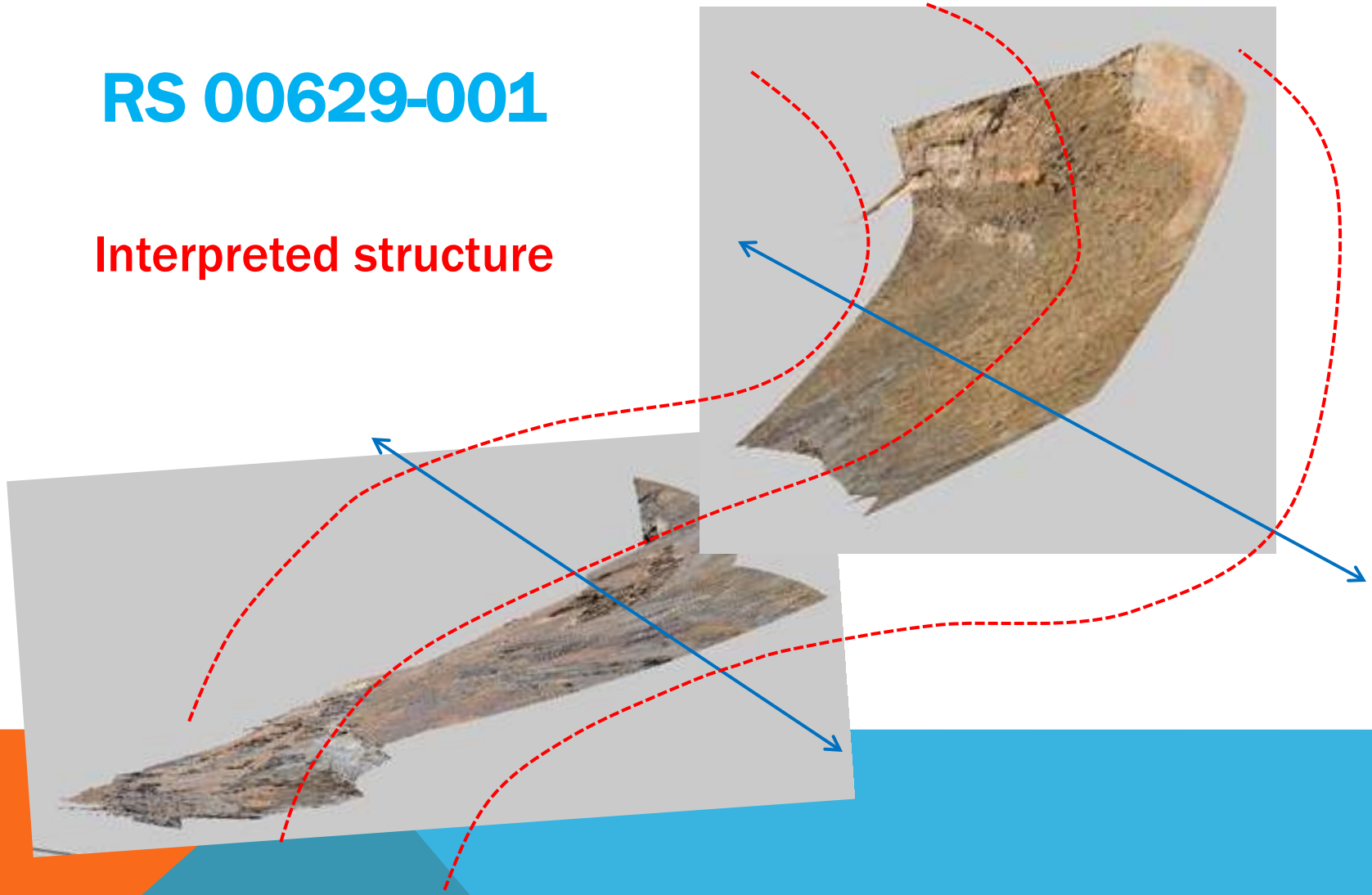
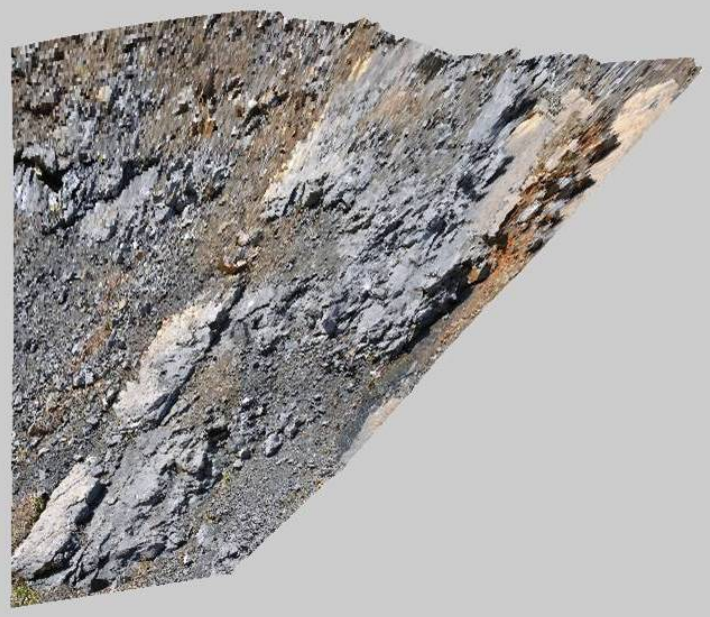
RS 00629-001

Interpreted structure

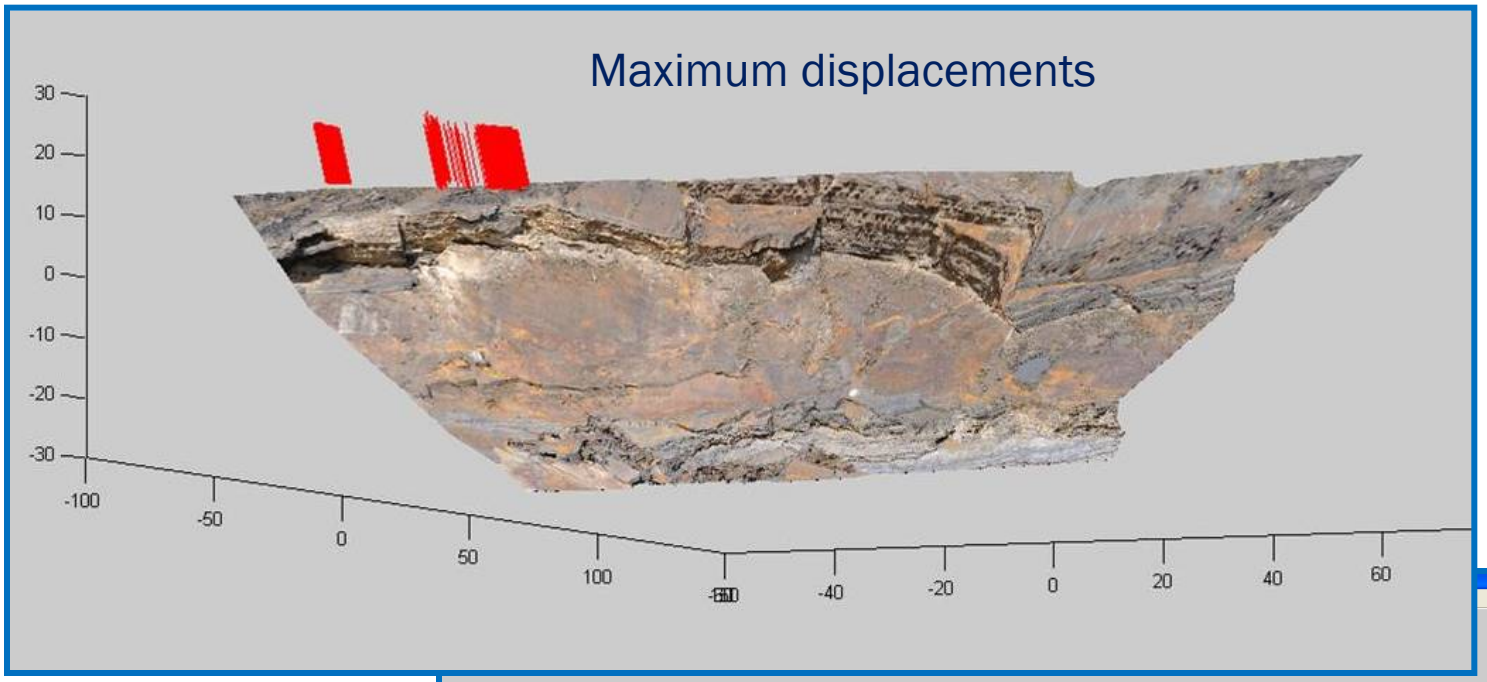


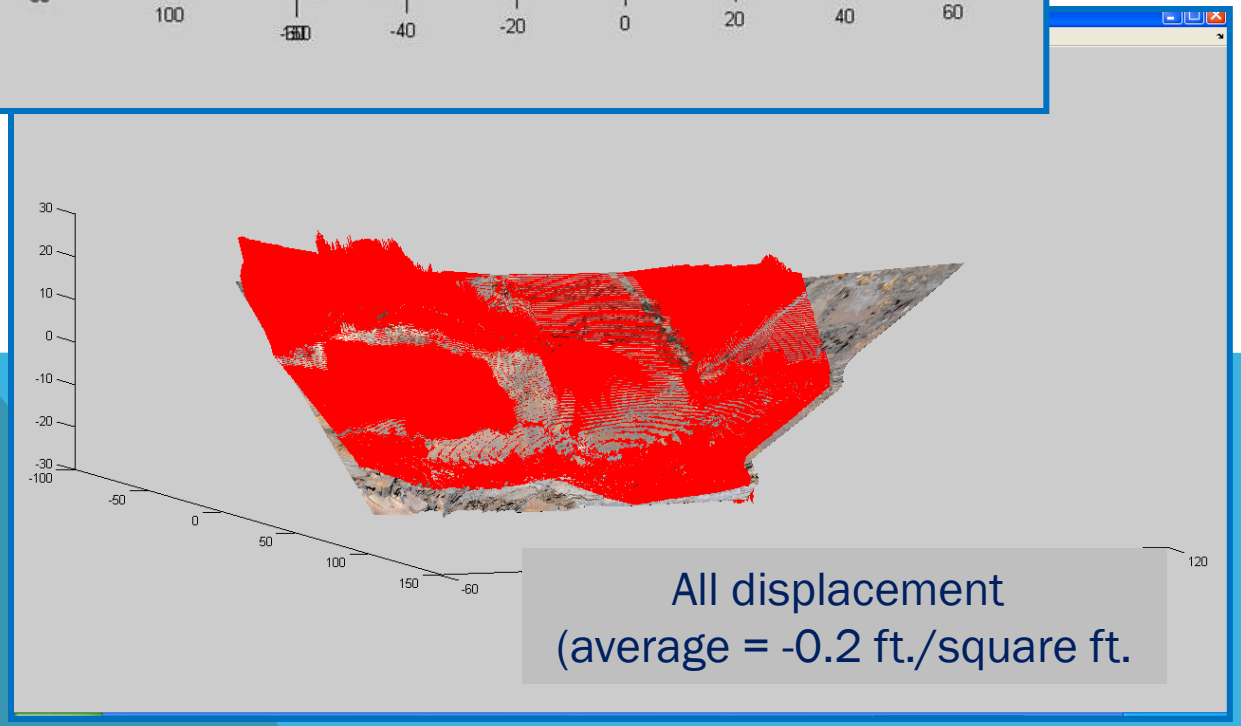
RS-00600-001

- Dip slopes (40 deg.) of cherty, wavy-bedded limestone.
- Helderberg Group (Devonian-Silurian).
- High-angle joints intersect bedding and slope, form blocks.



RS-00629-001 displacement vectors, March to June 2012

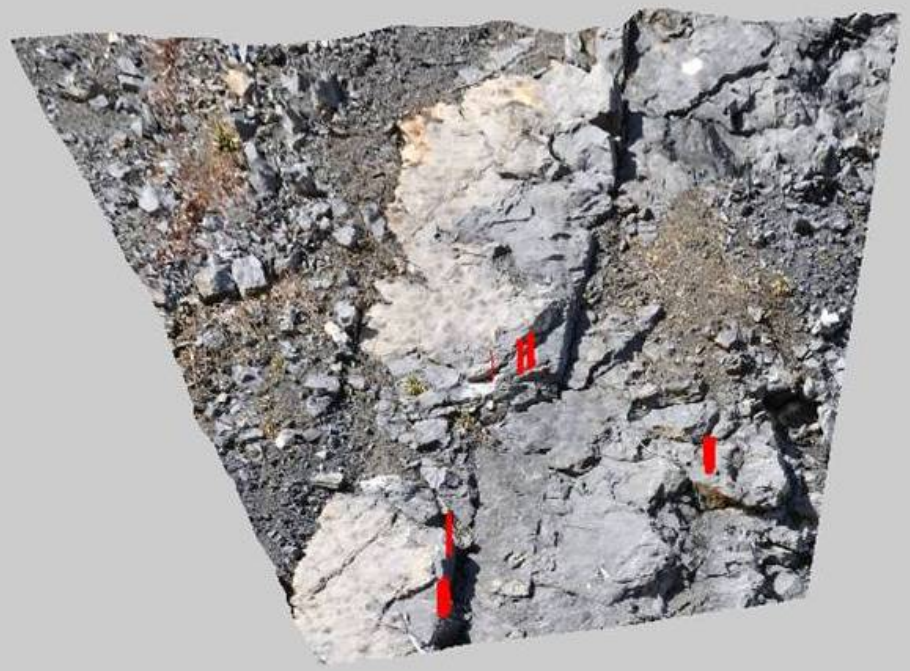




All displacement
(average = -0.2 ft./square ft.

RS-00600-001 displacement vectors, March to June 2012

Maximum displacements



All displacement
(average = +0.3 ft./square ft.

Preliminary Results

PARAMETER ▶ / METHOD ▼	AREA	SINK-HOLES	INFRA-STRUCTURE	ROCK SLOPES	COST
InSAR	Broad	Maybe	Yes	No	$$$
LIDAR	Focused	No	Maybe	Yes	$$
DPG	Focused	NA	NA	Yes	$

Preliminary Results

- +InSAR: Covers broad area, shows infrastructure well under right conditions, potentially useful for karst.

- - InSAR: Did not resolve rock slopes well.

- +LIDAR: Covers focused area, shows slopes well, potentially useful for bridges.

- -LIDAR: Poor results for karst, expensive, kinematic analysis difficult.

Preliminary Results

- +DPG: Covers focused area, shows slopes well, moderate cost, amenable to kinematic analysis.

- - DPG: Ability to yield reliable quantitative results for displacement on rock slopes not proven.