Intraformational Slip Surfaces in the Marcellus and Overlying Hamilton Group*

Terry Engelder¹ and Murat Aydin¹

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Abstract

Detachment is very common in the Penn State ABBSG core collection of Marcellus gas shale and greater Hamilton Group from south of the Allegheny Front. The Hamilton section is populated with a variety of bedding-parallel slip surfaces that range in thickness from individual bedding planes to cleavage duplexes up to a meter thick. The bedding-plane slip surfaces are decorated with a variety of structures that include mainly tails, streaks, fibers, and striations by Means' (1987) classification. These fall into a class of ductile structures by Petit's (1987) classification. Bedding slip surfaces are clustered in local zones of more intense slip. Bedding slip surfaces in the Hamilton Group above the Marcellus honor a simple flexural-slip fold model with sense of slip limb-dependent. The major composition of the fibers includes one or more of four minerals: calcite, quartz, clay, and pyrite. In all cases it seems that the material was deposited by a diffusion-mass transfer mechanism rather than a brittle comminution and in situ recrystallization. Fibers were deposited in several layers which are not necessarily parallel, layer-by-layer. The mineralogy of the fibers reflects mineralogy of the host rock, with calcite fibers more commonly associated with a calcareous matrix. Slip surfaces consuming multiple beds usually form as cleavage duplexes with scaly surfaces of anastomosing slip whose character is similar to single-bedding slip surfaces. Cleavage duplexes commonly verge toward the foreland regardless of the flank of the structure on which they form. Core is weakest along these slip surfaces which may mean that they are ripe for loading with proppant when the Marcellus gas shale is stimulated.

References

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^{*}Adapted from oral presentation at AAPG Annual Convention and Exhibition, Long Beach, California, USA, April 22-25, 2012

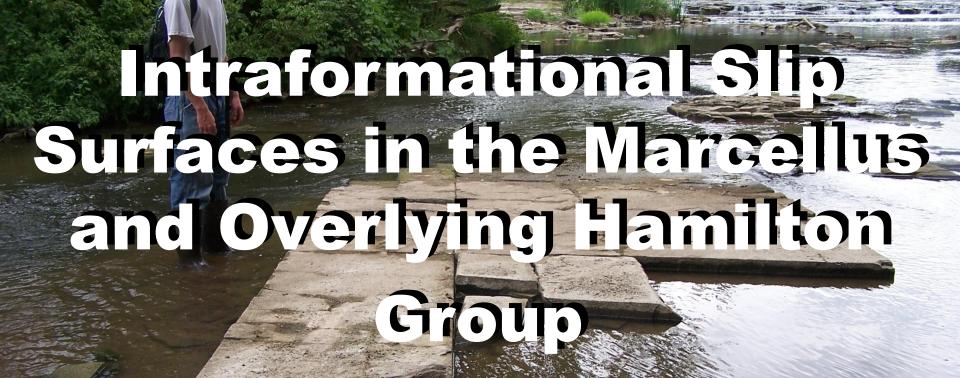
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¹Department of Geosciences, Penn State, University Park, PA (jte2@psu.edu)

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Terry Engelder & Murat Aydin
Department of Geosciences
The Pennsylvania State University



2011 ACE*: Rules concerning natural hydraulic fractures (NHF) in gas shales

- Natural hydraulic fractures (NHF) are driven by maturation-related high pressure gas (<u>pore</u> <u>pressure</u>).
 - not a tectonic stress
- 2. The orientation of NHFs are controlled by the superposition of gravity-related stress and tectonic stress yoked to **pore pressure**.
 - poroelastic deformation ultimately controls state of stress
- 3. NHF are not uniformly developed throughout the Appalachian Basin.

 * And earlier papers

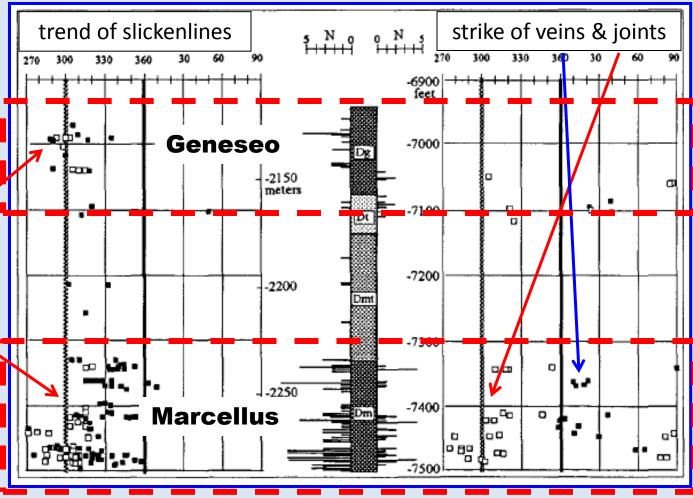
2012 ACE*: Rules concerning NHF and intraformational slip surfaces (ISS)

- 1. NHF and intraformational slip surfaces (ISS) appear together in and above black shale. <u>Common names</u>:
 - 1. Cleavage Duplexes
 - 2. Slickenside Surfaces
- 2. Bedding parallel ISS are preferentially developed on the limbs of folds.
- 3. Maturation-related **pore pressure** appears to play an important role in the development of ISS.

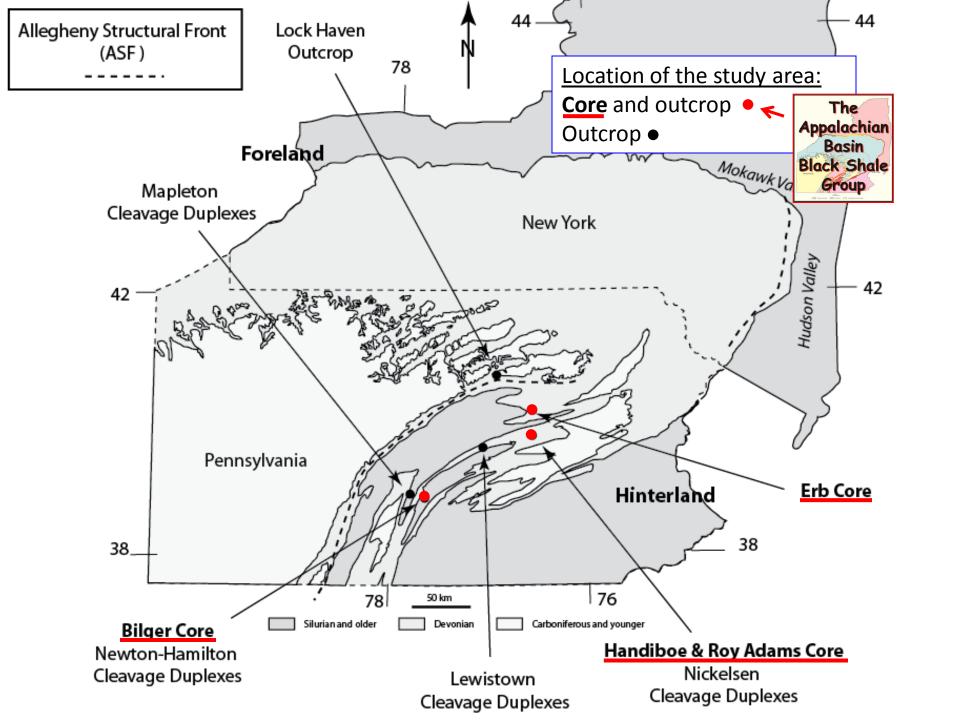
* Background: Eastern Gas Shales Project (EGSP), Cliff Minerals (1982), Evans (1994)

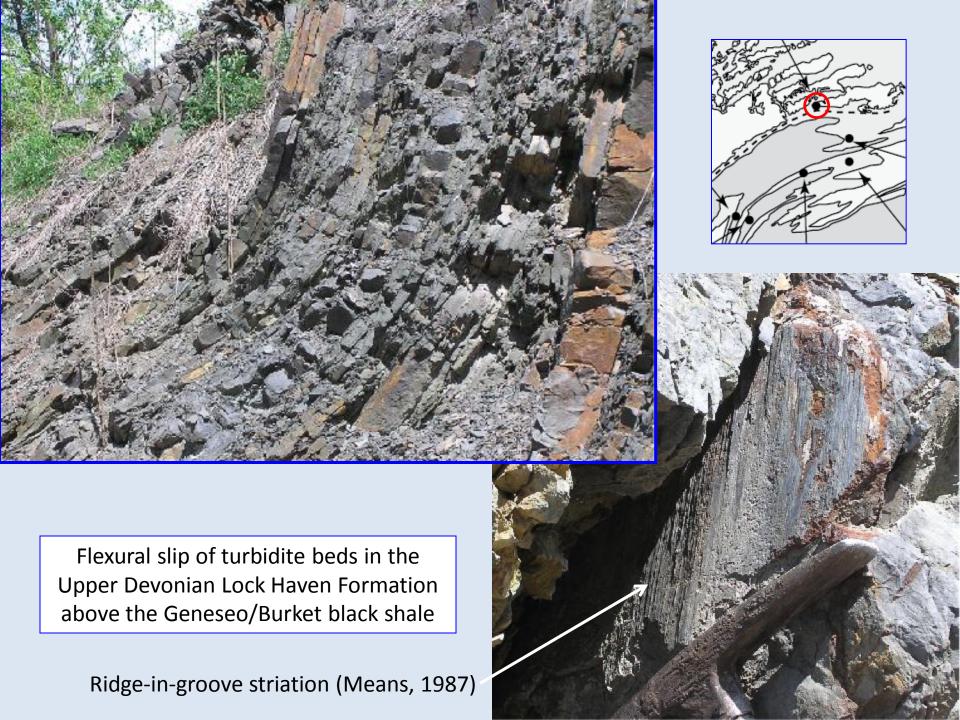
PA2 poles to slickenlines N = 106slickenline trends poles to NHF Cliff Minerals, 1982 Evans, 1994

35th Anniversary of the Eastern Gas Shales Project coring program

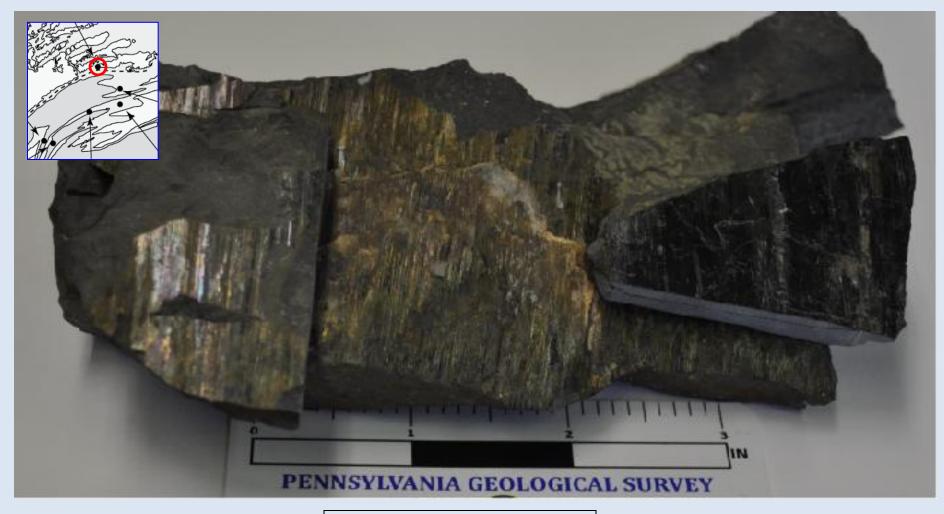


Correlation between slickensides and natural hydraulic fractures





Bedding-parallel slip surfaces in the Lock Haven Formation north of Williamsport, PA.

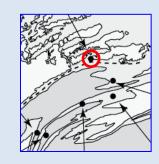


A mirror slip surface.

Green chlorite over white quartz over 'black' graywacke with ridge-ingroove striation.

A mirror slip surface that appears black when green chlorite sits directly on 'black' graywacke.

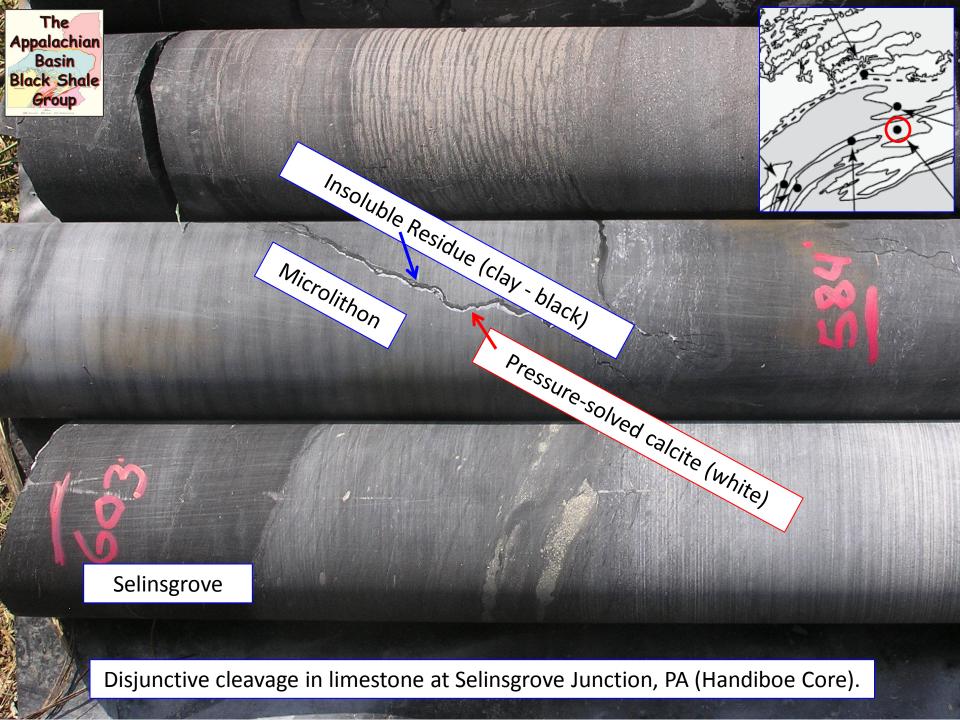


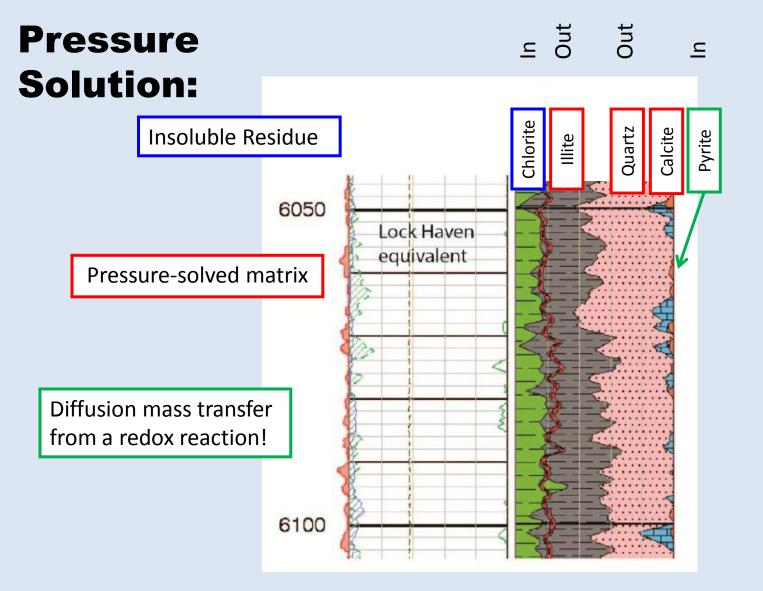


(Left) Mirror slip surface of a chlorite film on a greywacke matrix. Olive green light refracts from the mirror.

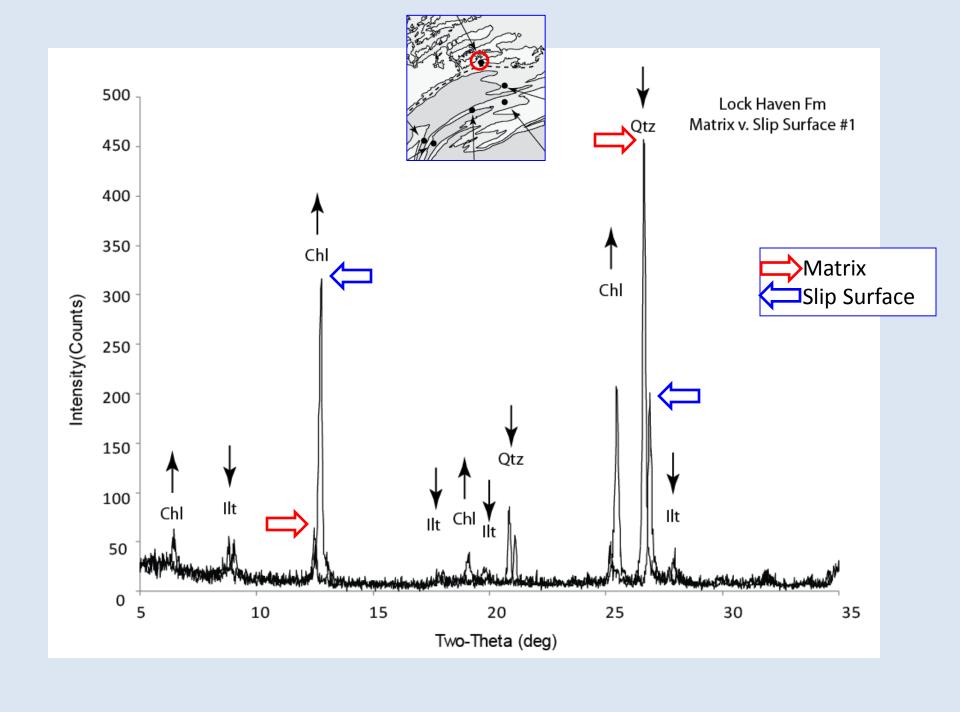
(Right) Ridge-in-groove striation on bedding slip surface in Lock Haven Formation showing the olive green color of a chlorite film on white quartz fibers.

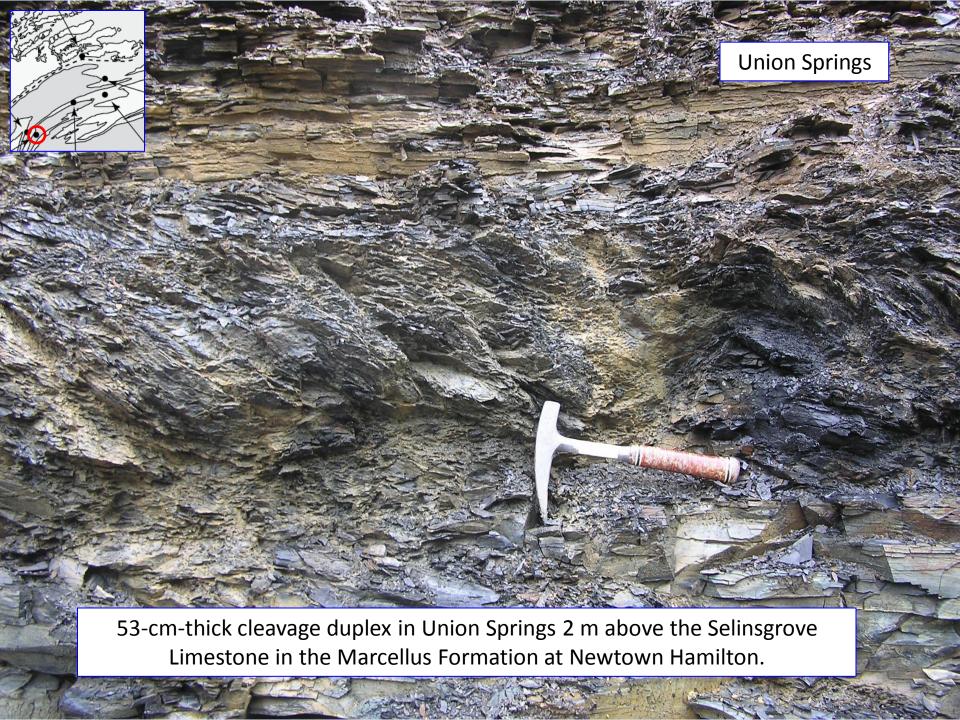




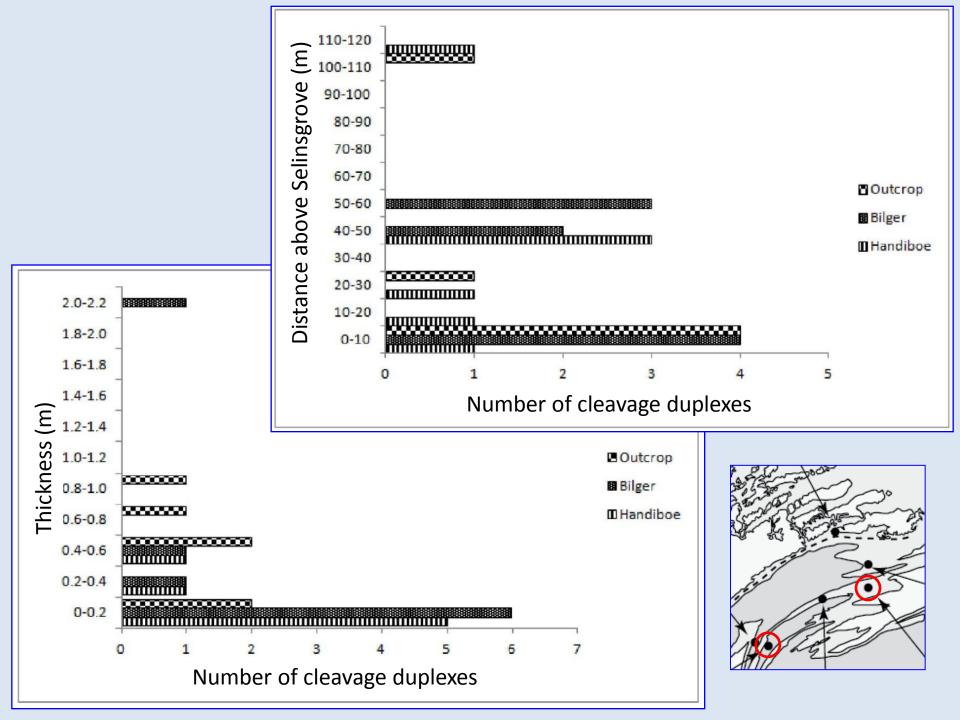


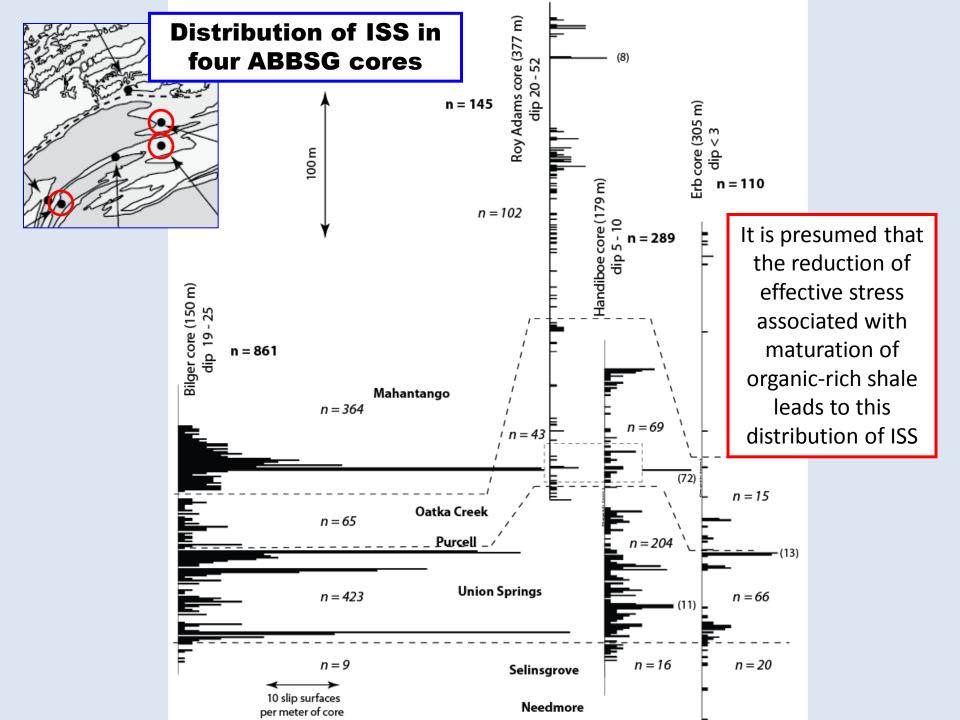
Pressure-solution slip dissolves quartz & illite, leaving a residue of chlorite & pyrite

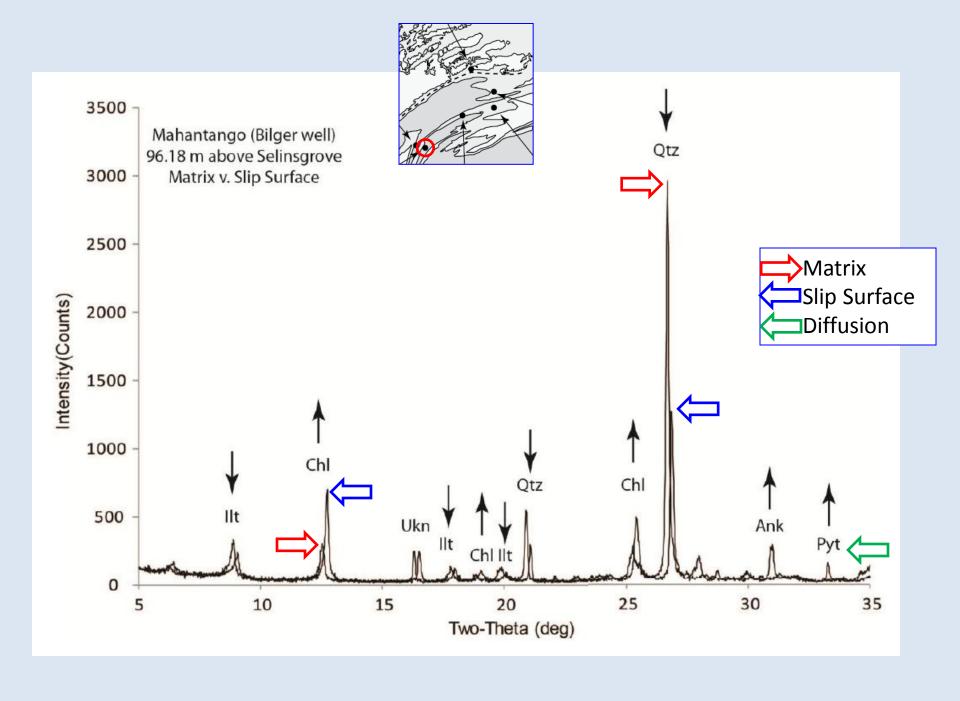


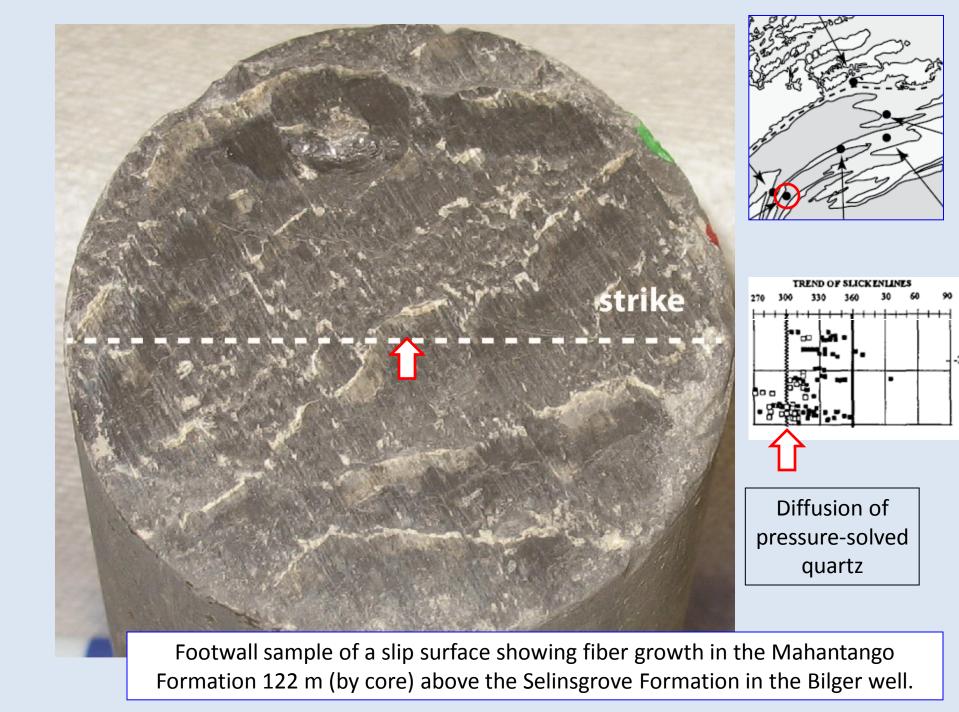












The morphology of intraformational slip surfaces (ISS) in the Mahantango-Marcellus section



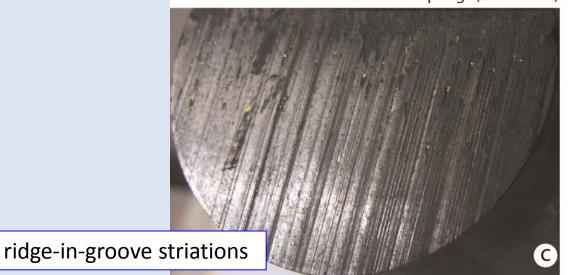


Mahantango (Bilger 117.49 m) Oatka Creek (Handiboe 145.57 m)

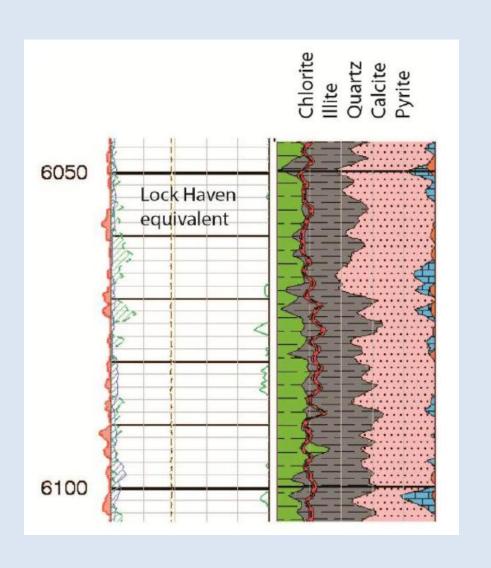
Union Springs (Handiboe 2.36 m)

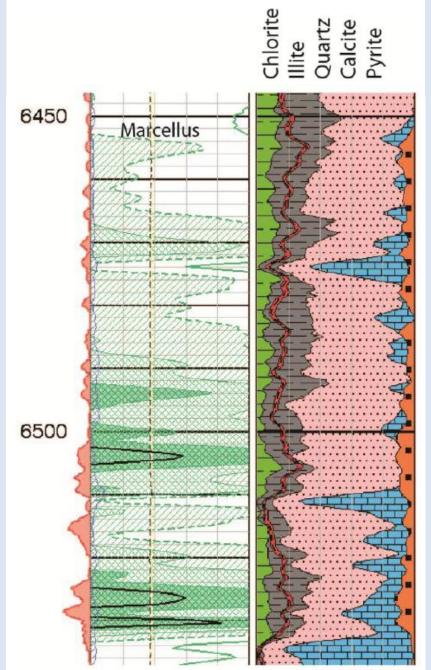
slip fibers

Union Springs (Erb 4.30 m)









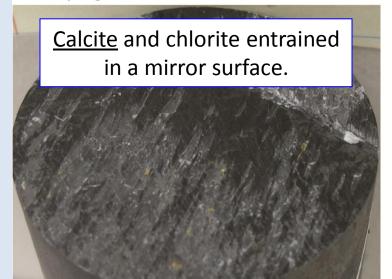
Progressive mineral development on slip surfaces.

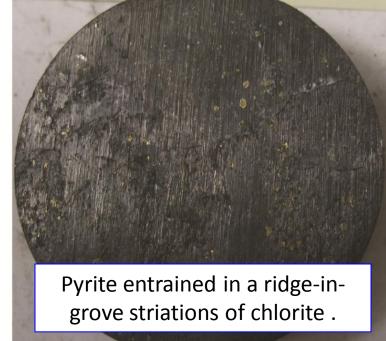


Mahantango (Bilger, 108.81 m)

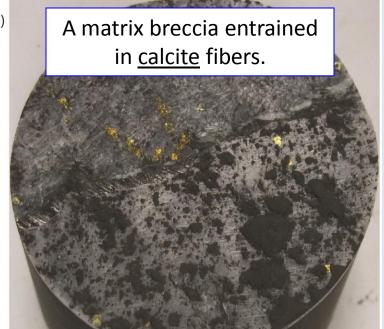
Union Springs (Handiboe, 10.57 m)

Union Springs (Handiboe, 31.84 m)

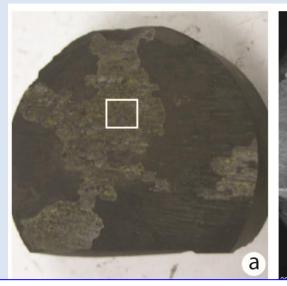


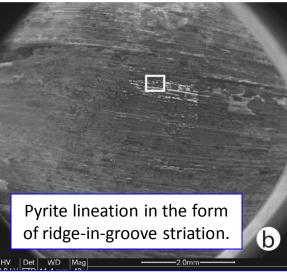


Union Springs (Erb, 4.63 m)

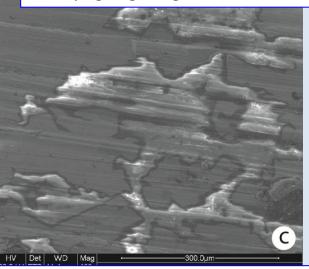


Slip lineations at different scales

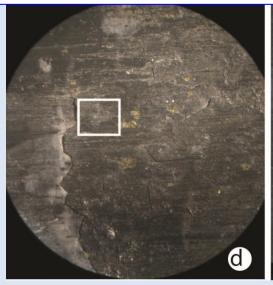


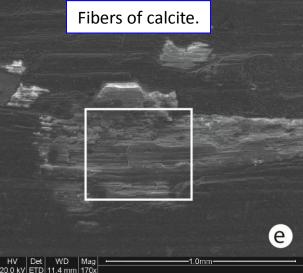


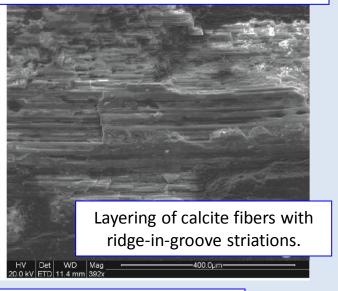
Pyrite with a positive relief while still carrying ridge-in-groove striations.



Ridge-in-groove striation on Marcellus 7 m above the Selinsgrove Limestone in the Erb well.







Fibers of calcite on Marcellus 5 m above the Selinsgrove Limestone in the Erb well.

4391

ISS in

Microscopic Wear Grooves on Slickensides: Indicators of Paleoseismicity

JAMES T. ENGELDER

Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964

ENGELDER: MICROSCOPIC WEAR GROOVES

Tintic quartzite: Mirror-like slip surface with frictional wear grooves!

This surface indicates incremental rapid slip (i.e., paleoseismicity)

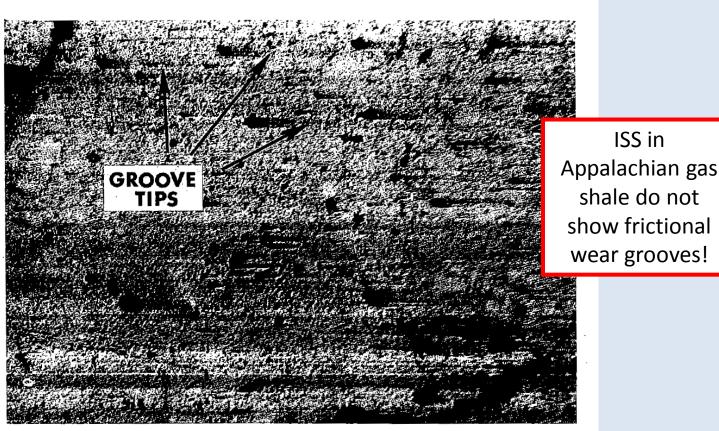
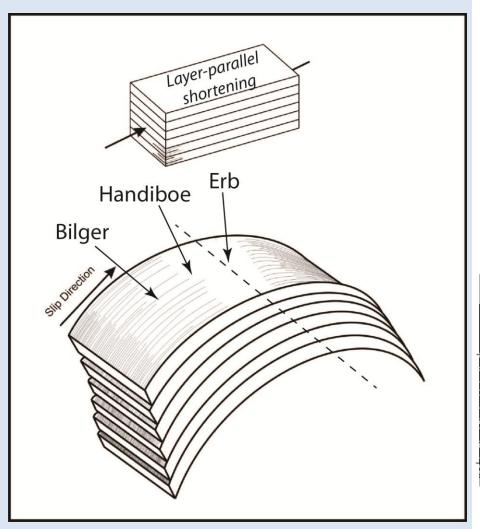
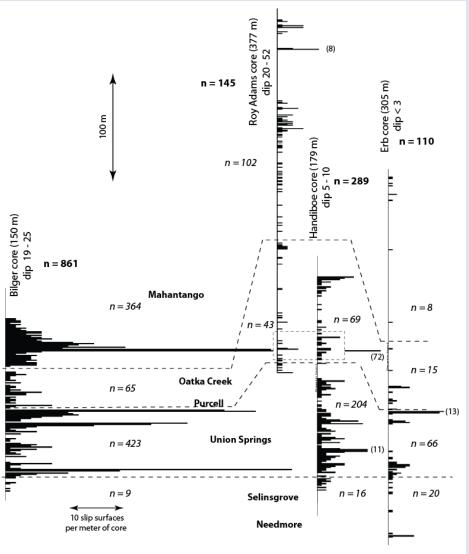
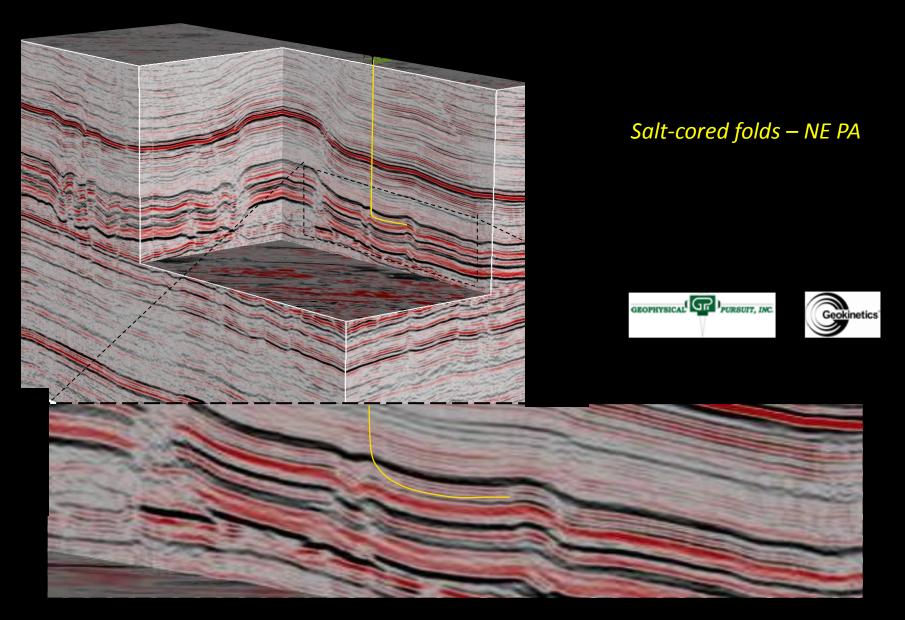


Fig. 5. Micrograph of a natural slickenside surface of Tintic quartitie in reflected light. Grooves are up to 0.4 mm long, and inferred slip direction of surface containing grooves is from left to right. Scale line is 0.5 mm.





Extension over Salt Anticlines



Presenter's Notes:

Why optimize structural resolution?

Beyond a structural interpretation for well placement, hazard avoidance (major fault and lost-circulation zones), and an aid in planning and guiding long laterals - a high-resolution structural image can also be used to derive geometric attributes

- Geometric attributes act as an aid to observing regional and local features within 3D data sets.
- These attributes reveal very subtle local and regional features associated with structural deformation and reflector slope changes.
- Aid in identifying and analyzing the more subtle fault and fracture trends that may not be resolvable on seismic amplitude data alone
 - Energy Ratio is essentially equivalent to coherence, where the energy of the target trace window is compared with the surrounding traces in the local aperture in a 3D sense. It reveals structural- and stratigraphic-type features.
 - Edge is a derivative of Energy Ratio which sharpens the features and provides more fidelity within the textural background.
 - Curvature measures the amount of local curvature within a small spatial aperture on a volume basis. In the simple case the maximum curvature highlights the axial trends of folds, where ridges are positive and valleys are negative.

How – what seismic parameters do we optimize?

Need best possible S/N, Velocity determination and migrations.

What does this mean in the field?

Higher fold and longer offsets – high channel count, regular 3D grid – consistent geometry, and same things as necessary for spatial resolution (broad bandwidth - high fidelity phones and flexible sources, denser arrays)