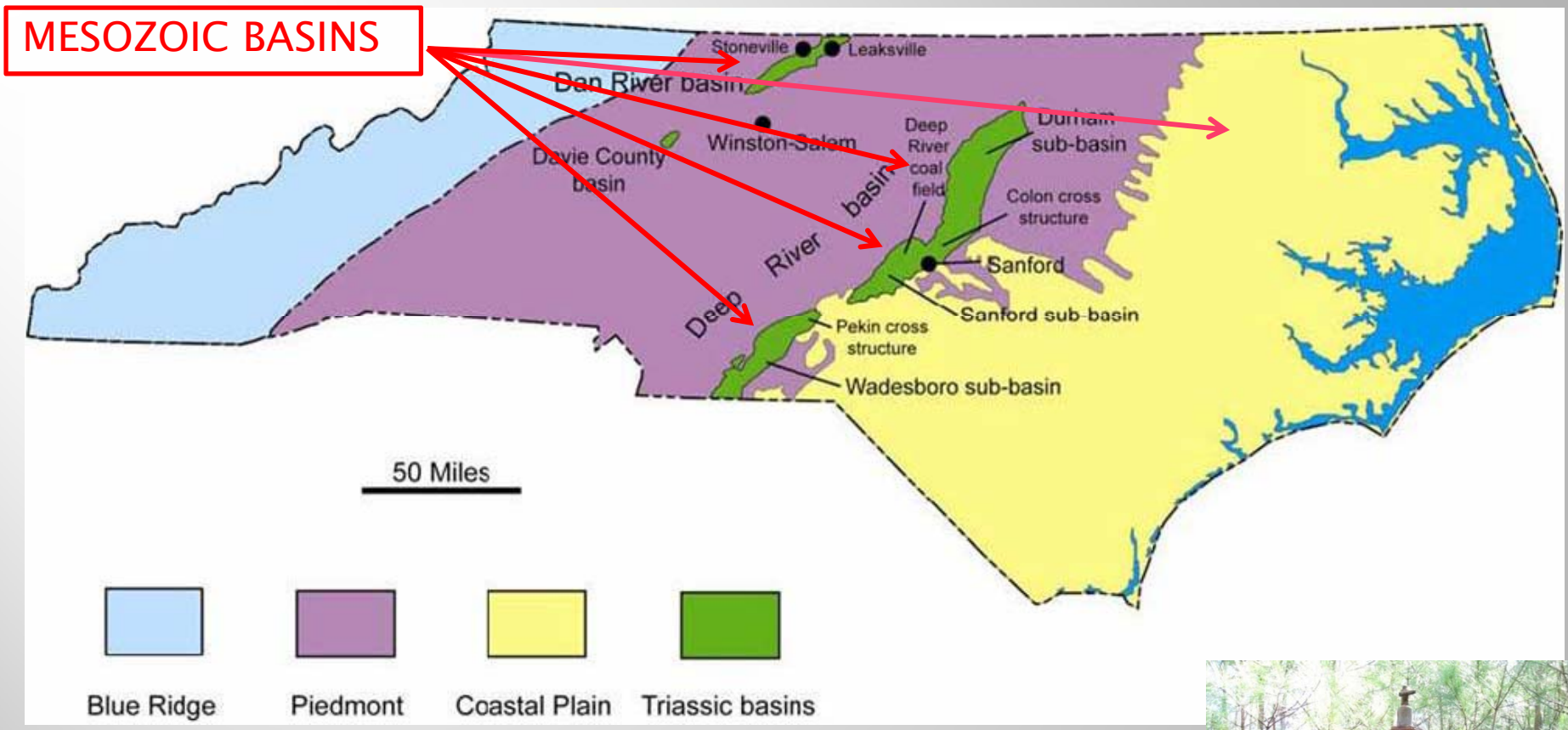

SHALE GAS POTENTIAL IN THE TRIASSIC STRATA OF THE DEEP RIVER BASIN, LEE AND CHATHAM COUNTIES, NC, USA: MULTIDISCIPLINARY METHODS FOR SCIENCE DATA ACQUISITION

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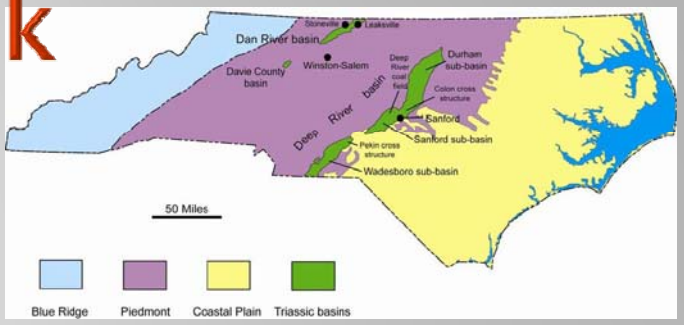
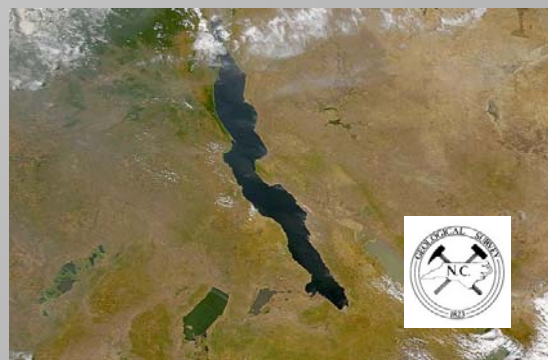
Basin and Source Rock Overview



Map showing the distribution of Mesozoic basins in North Carolina (from Reid and Milici, 2008).

- Eastern North American Triassic rift lacustrine basins related to the opening of the Atlantic (similar to eastern offshore Newfoundland); contrasted with western Newfoundland lacustrine rift basins related to the closing of the Iapetus Ocean.
- Deep River Basin – 150-mile-long northeast trending half-graben (rift basin) with a steeply dipping eastern border fault.
- ~7,000+ feet of Triassic strata; paleo-equatorial location.
- Fresh water, shallow lake deposits similar to African rift valley lakes – aerated; current action, no deep water shales; cyclic sedimentation with wet- and dry cycles.
- ~135,000-acres with inferred %Ro≥0.8.
- Total petroleum system containing:
  - Source rock,
  - Seal, and
  - Traps / reservoir.
- Relatively untested exploration area; leasing underway (6,000 acres since January 2010).



Rift / Lacustrine Petroleum Systems

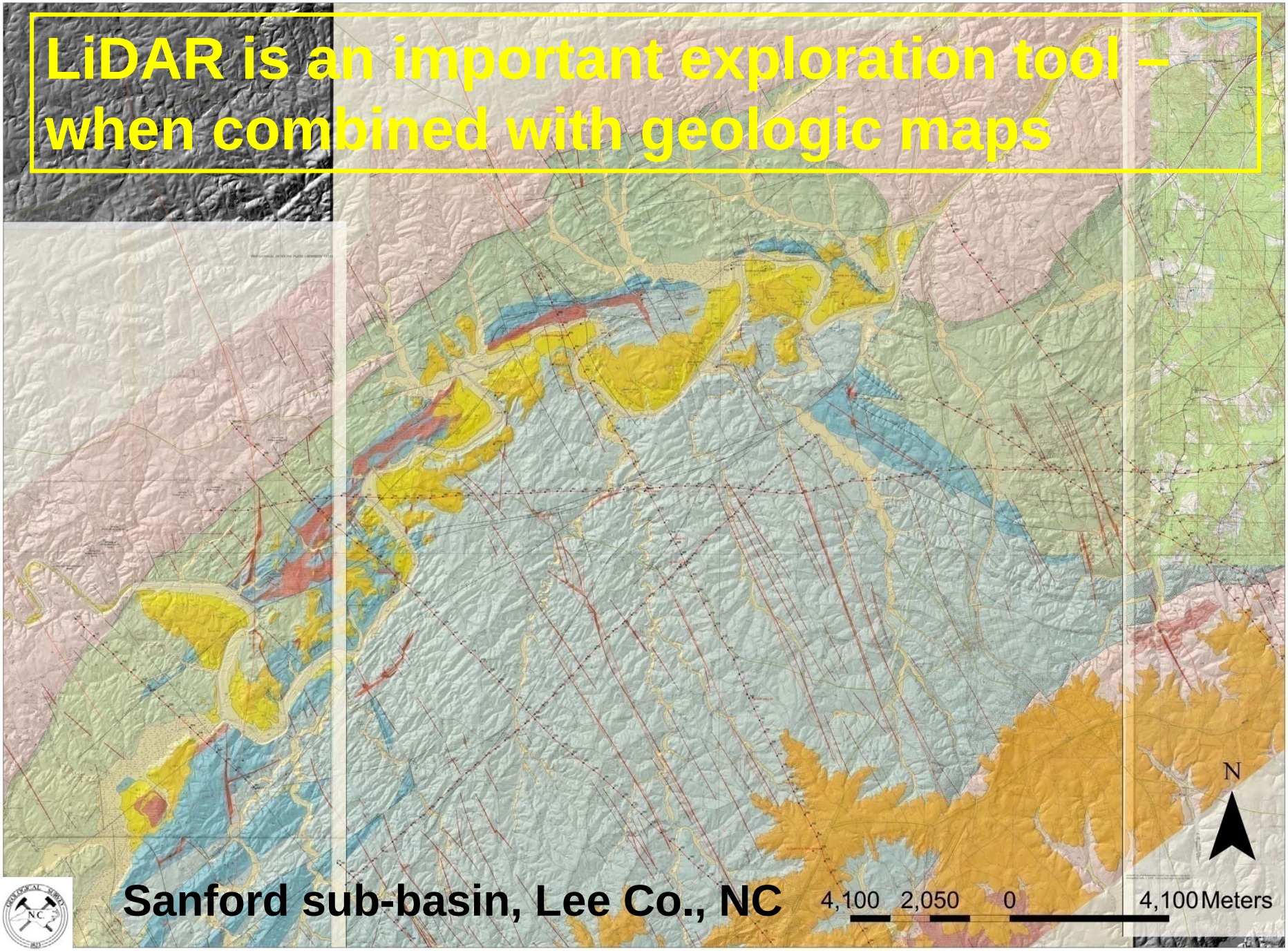
- Producing examples: Offshore Brazil and Angola:
  - Moncton sub-basin (McCully, NB); Albertine Basin (Uganda).
- Small in area but can be highly productive as sediment packages often very thick with rich organics
- Complex depositional history.
- Paleo-water input/ climate studies critical
- Heat flow may be elevated.

Multidisciplinary techniques

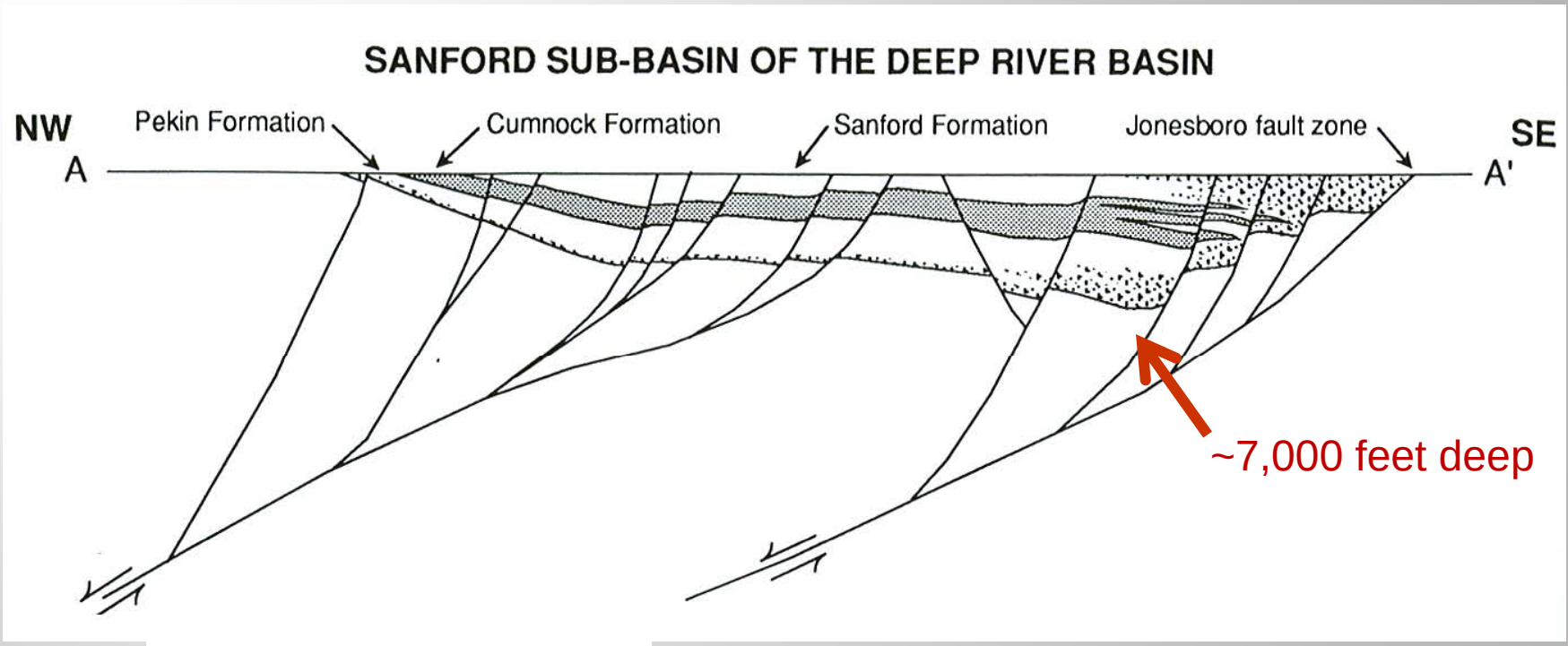
- LiDAR (fractures and structure),
- Seismic interpretation (depth to basement and isopach of source rock thickness),
- GIS (digital platform for data integration, display and analysis),
- Organic geochemistry (TOC, maturation),
- XRD (clays and rock brittleness for fracing), some SEM (porosity); limited petrophysics,
- Molecular gas analysis (BTU, composition, stable isotopes for nitrogen, carbon and deuterium),
- Core logging and interpretation, data mining to recover historic technical data,
- Geologic mapping to outcrop scale, petrography, and
- Conversion of paper logs and seismic sections to digital products for use with digital seismic software.

USGS/NCGS Resource Assessment

- *Current focus:* Rigorous, science-based assessment of technically recoverable natural gas.
- *Assessments units (AU's):* Developed for:
  - Coal bed methane (CBM),
  - Shale gas, and
  - Tight gas.
- *Methodology*: Numeric, conservative approach to be computed by the U.S. Geological Survey (FORSPAN Model – USGS OFR-03-384) [used for continuous accumulations of petroleum].
- *Completion target date*: Fall, 2010.
- *Publication date*: Sometime in 2011.


LiDAR is an important exploration tool – when combined with geologic maps
Sanford sub-basin, Lee Co., NC
4,100 2,050 0
4,100 Meters
N

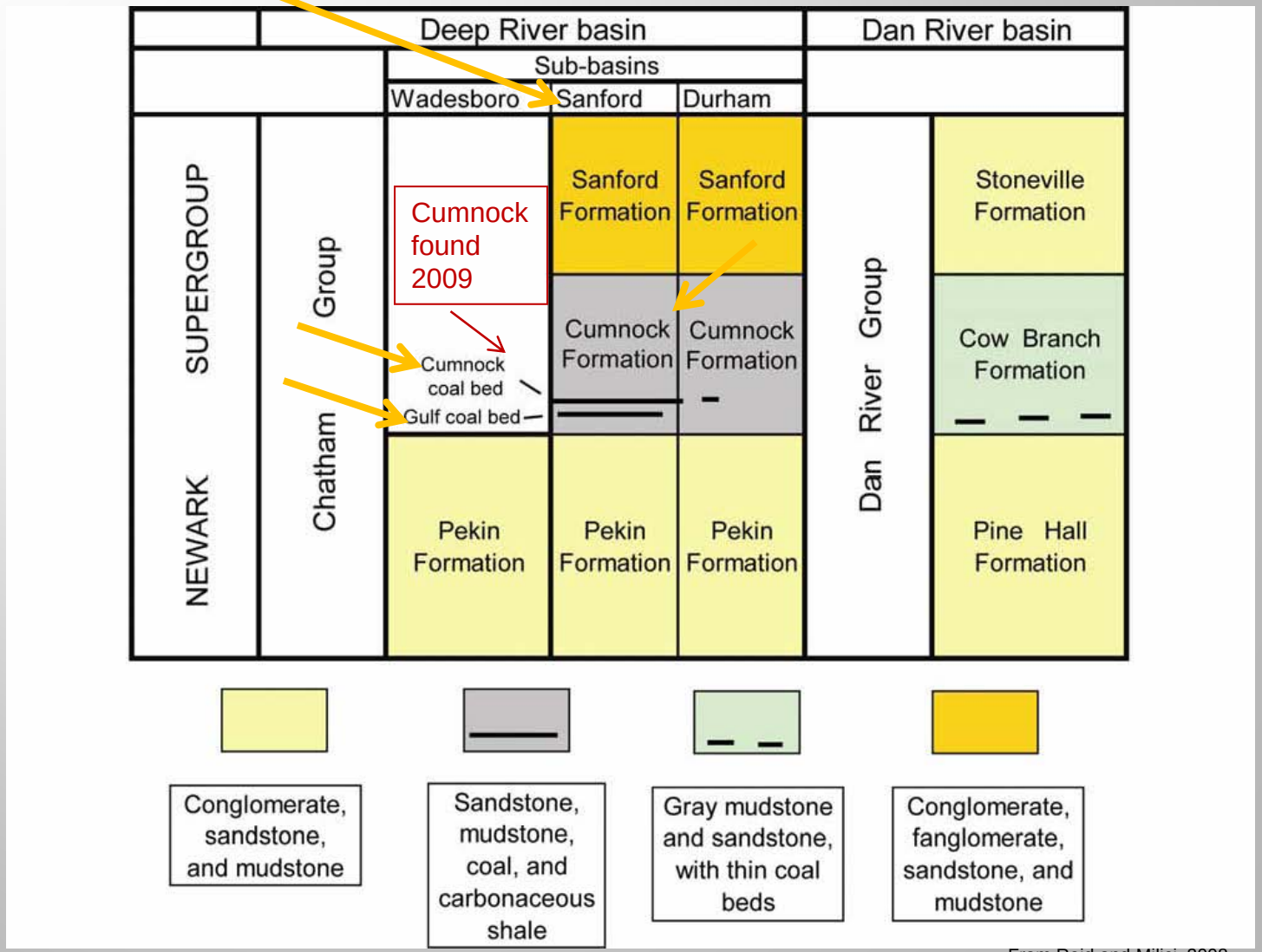
Generalized cross section



Generalized lithologies and stratigraphy.

From Olsen and others, 1991

Stratigraphy



From Reid and Milici, 2008

Drill Hole : USBM DH-2

NCGS No.: CH-C-1-45

Box No. : 118

From : 1423 feet
to 1440 feet

Drill Hole :USBM DH-2

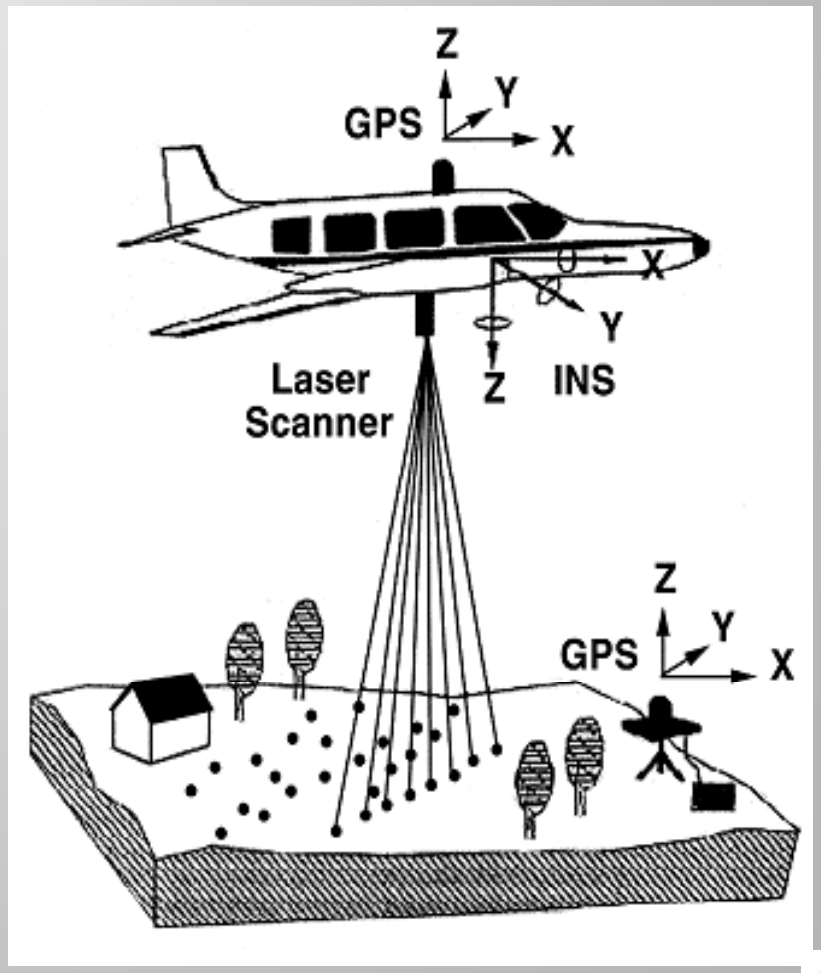
NCGS No.: CH-C-1-45

Box No. : 119

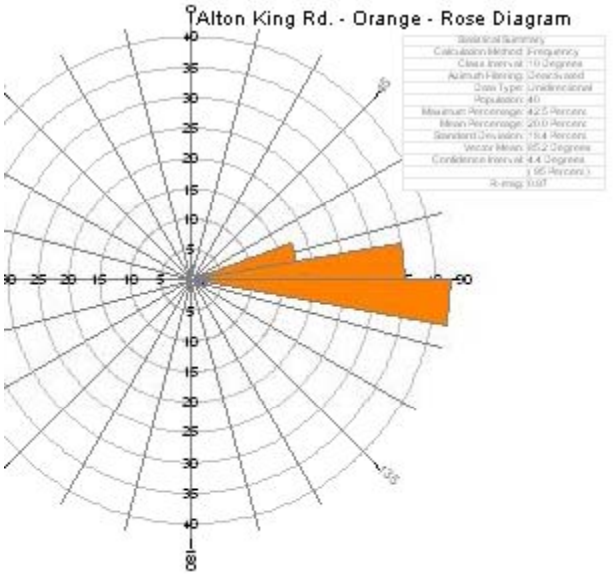
From : 1440 feet
to 1449 feet

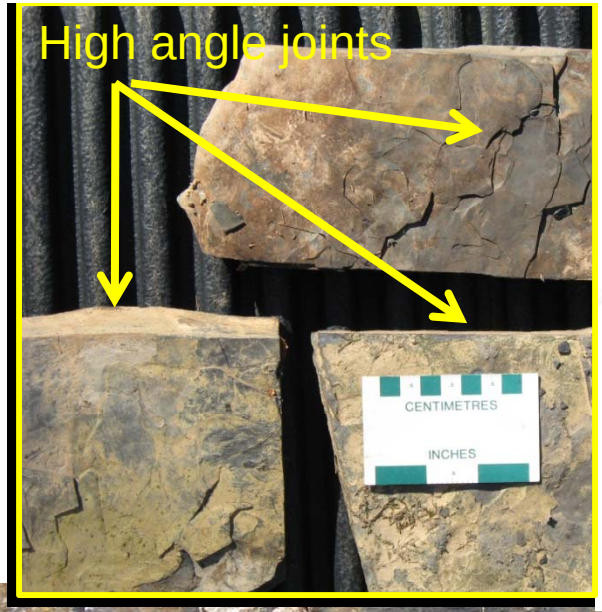
Light Detection and Ranging (LiDAR) – Operational Theory

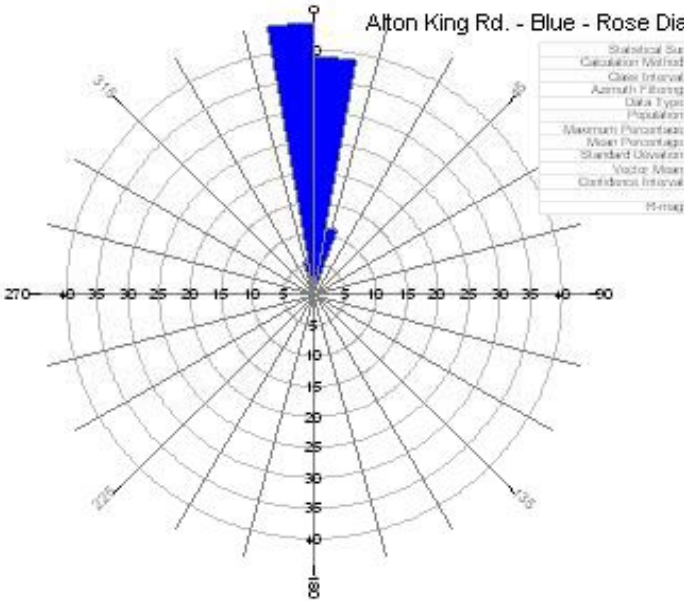
- NC has complete LiDAR coverage (~49,000 sq. miles)
- Remote Sensing Technology similar using laser light pulses instead of sound waves or radio waves.
- Always combined with IMU (Inertial Measurement Unit) & Airborne GPS.
- Produces a data point cloud.
- Can also provide data based on the nature of the reflected light pulses (Intensity)
- Can fly day or night (but not in rain or through cloud cover)
- Large land areas can be covered relatively quickly
- Useful for areas where ground access is limited, prohibited or too risky for field crews.




Hillshade LiDAR – shows trends of dikes, fractures and beds
N
4,100 2,050 0 4,100 Meters


Alton King Rd. - Orange - Rose Diagram


High angle joints
CENTIMETRES
INCHES


Alton King Rd. - Blue - Rose Dia


LiDAR fracture patterns can be traced to outcrops, and possibly to drill core
North

Seismic Line 113

NW

SE