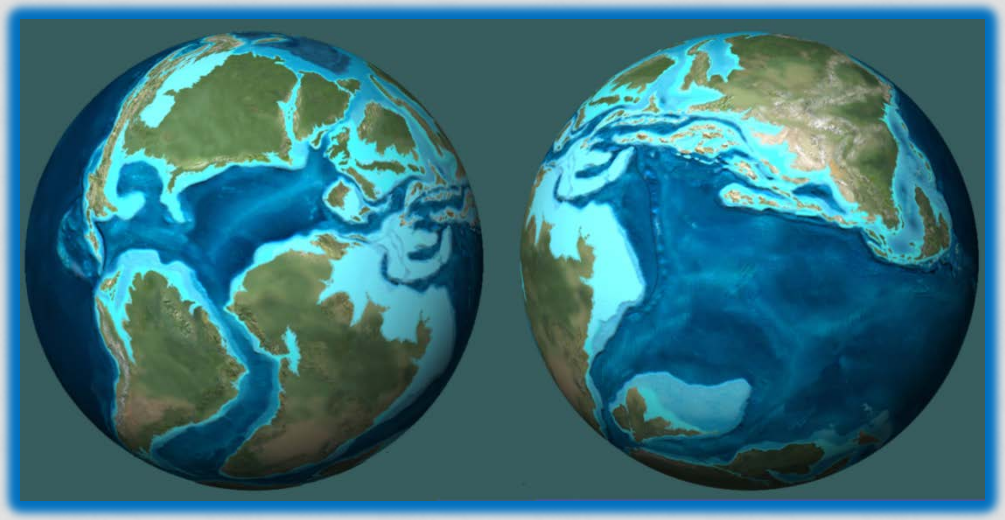
North Dakota Geological Survey
Geologic Investigation No. 192

Edward C. Murphy, State Geologist
Lynn D. Helms, Director Dept. of Mineral Resources



GEOLOGY OF SALTWATER DISPOSAL INTO THE DAKOTA GROUP OF WESTERN NORTH DAKOTA

Jeffrey W. Bader

North Dakota Geological Survey

24th Williston Basin Petroleum Conference

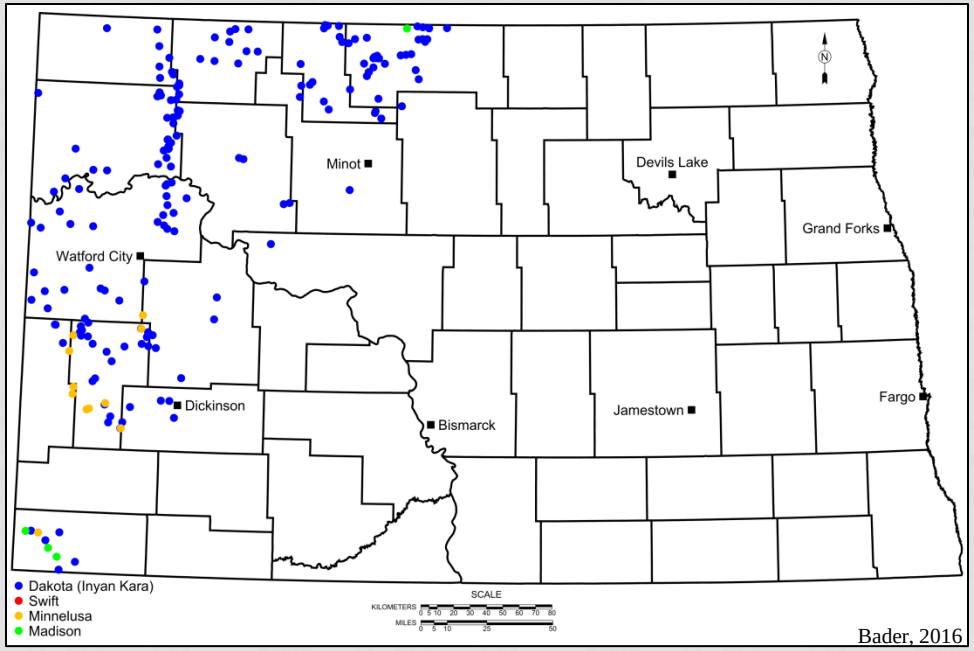
May 25, 2016

ND HISTORIC OIL AND GAS ACTIVITY

- First barrel of oil produced in April 1951
- 1 billion barrels of oil in October 1989
- 2 billion barrels of oil in November 2011
- 3 billion barrels of oil in January 2015
- 4 billion barrels of oil estimated by 2018

= > 4 billion barrels of saltwater = ?

Careful Planning



January 2005

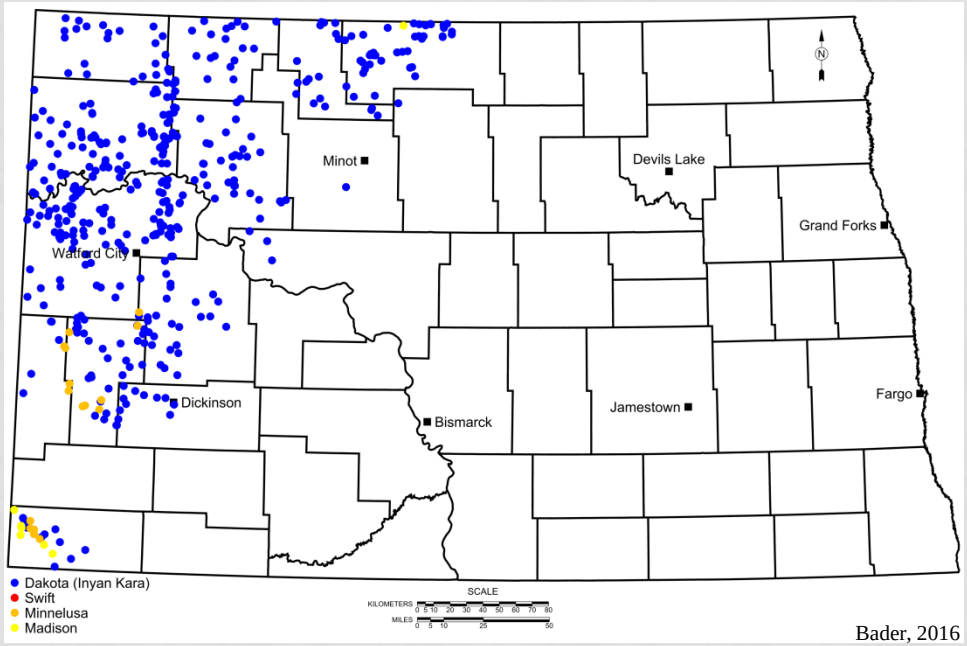
185 Active SWD Wells

143 Dakota

August 2015

435 Active SWD Wells

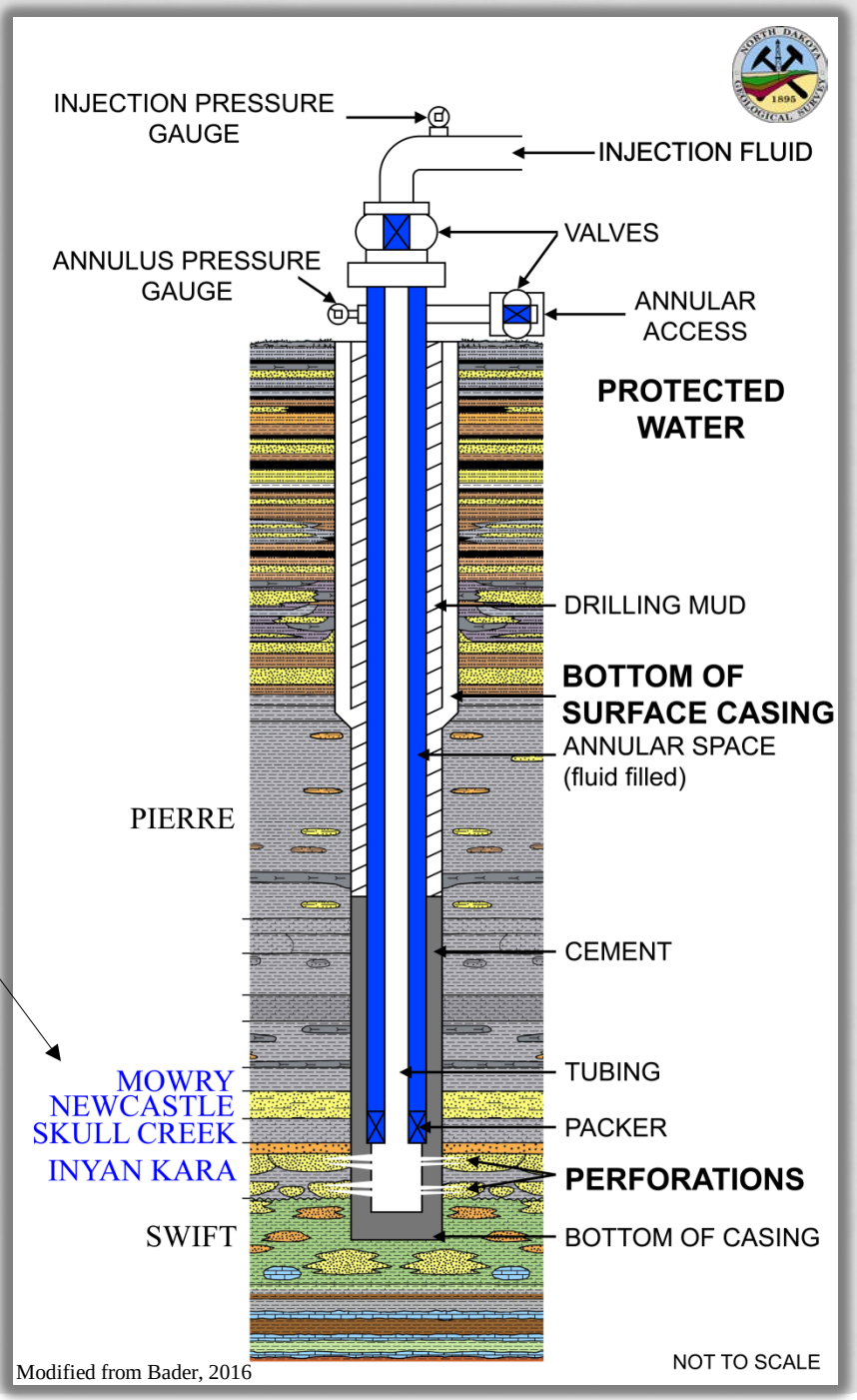
412 Dakota



NORTH DAKOTA CLASS II INJECTION WELL SCHEMATIC

Dakota Group Ideal

- ~ 5,000’ depth
- Thick IK sandstones
  - Continuous
  - Good Phi and K
- Excellent seals

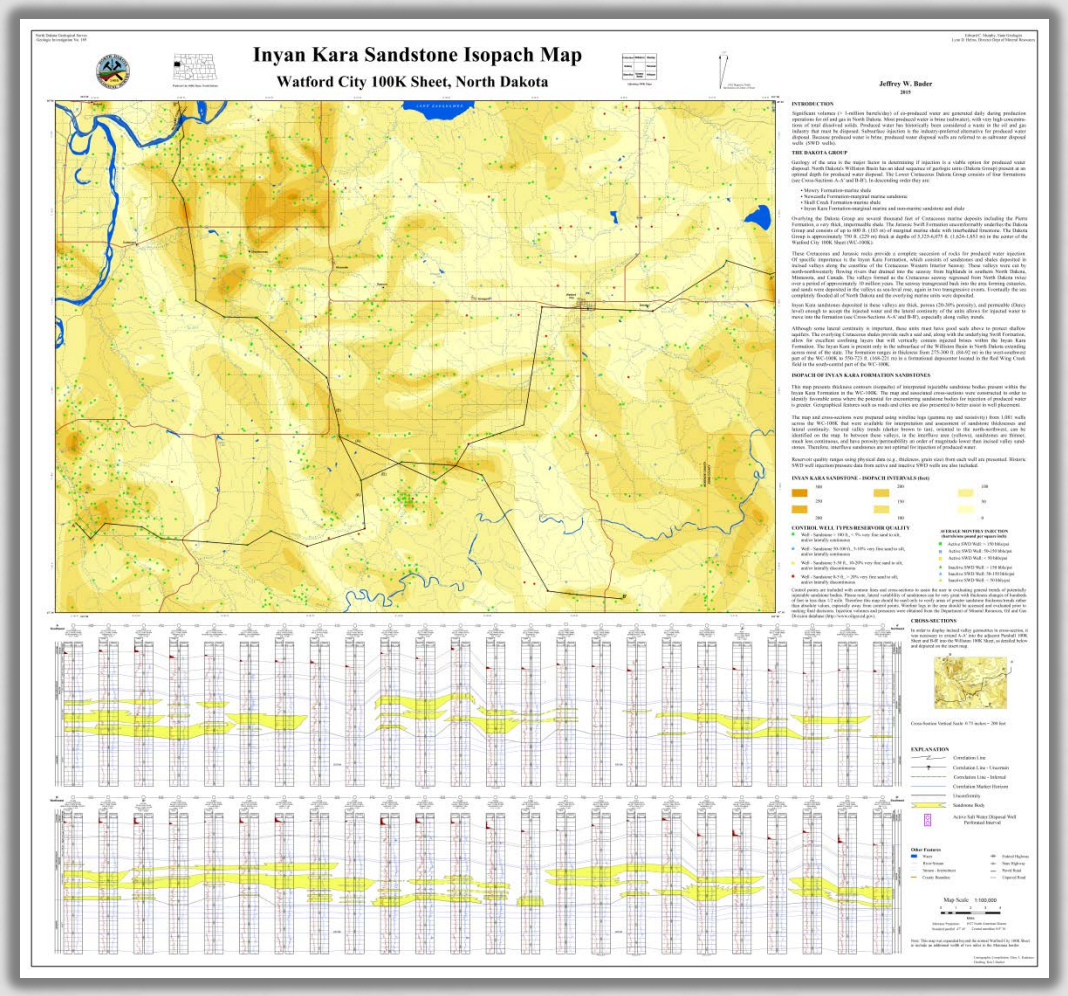


Modified from Bader, 2016

LOCATION, LOCATION, LOCATION

- Locating SWD wells?
  - Access (roads, terrain, etc.)
  - Proximity to nearby drilling/production wells
  - **GEOLOGY**
- Are there ways to make the process better?

THE NDGS DAKOTA STUDY



SPECIFIC METHODS

- Watford City 1:100,000 (GI-189)
  - First of statewide series
- Review published literature, core, logs
  - Understand depositional environment!
- Create isopach map
  - Total thickness of injectable sandstone bodies
- Complete cross-sections
- Add injection data

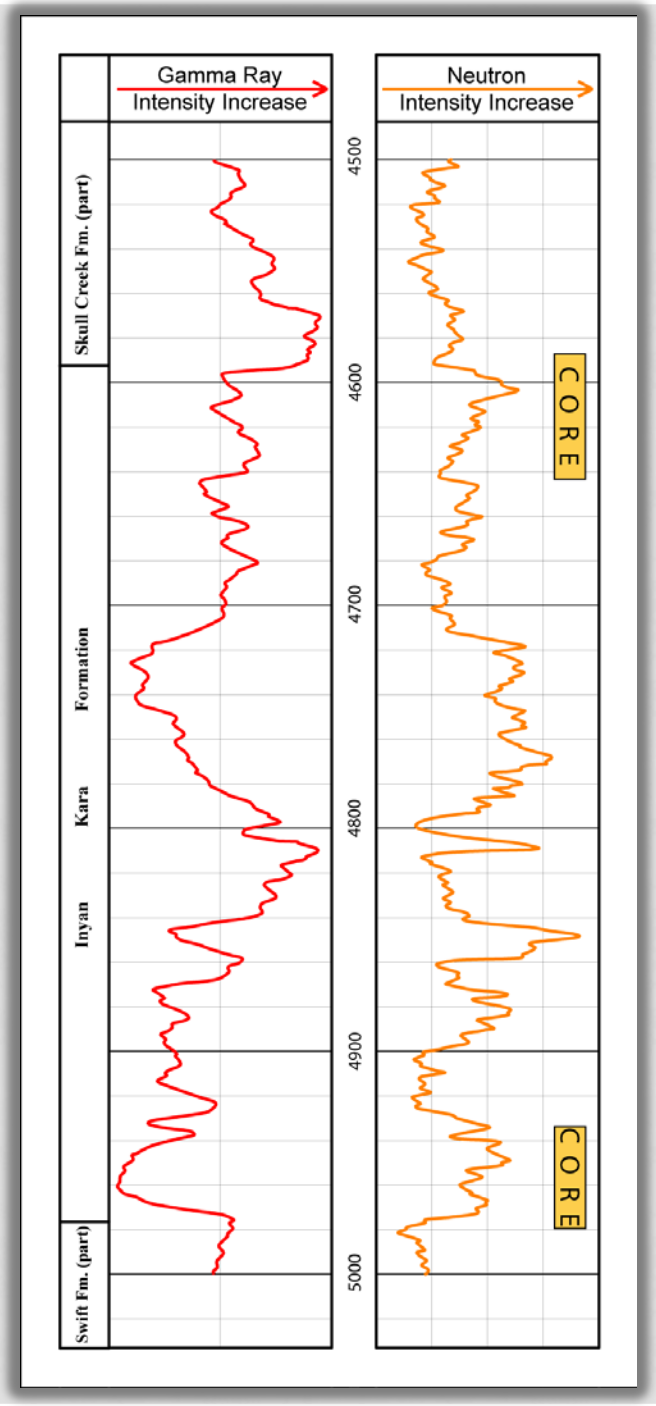
ALBIAN (106 MA)

Modified from Blakey, 2014

MATH IVERSON #1
(WILLIAMS COUNTY)

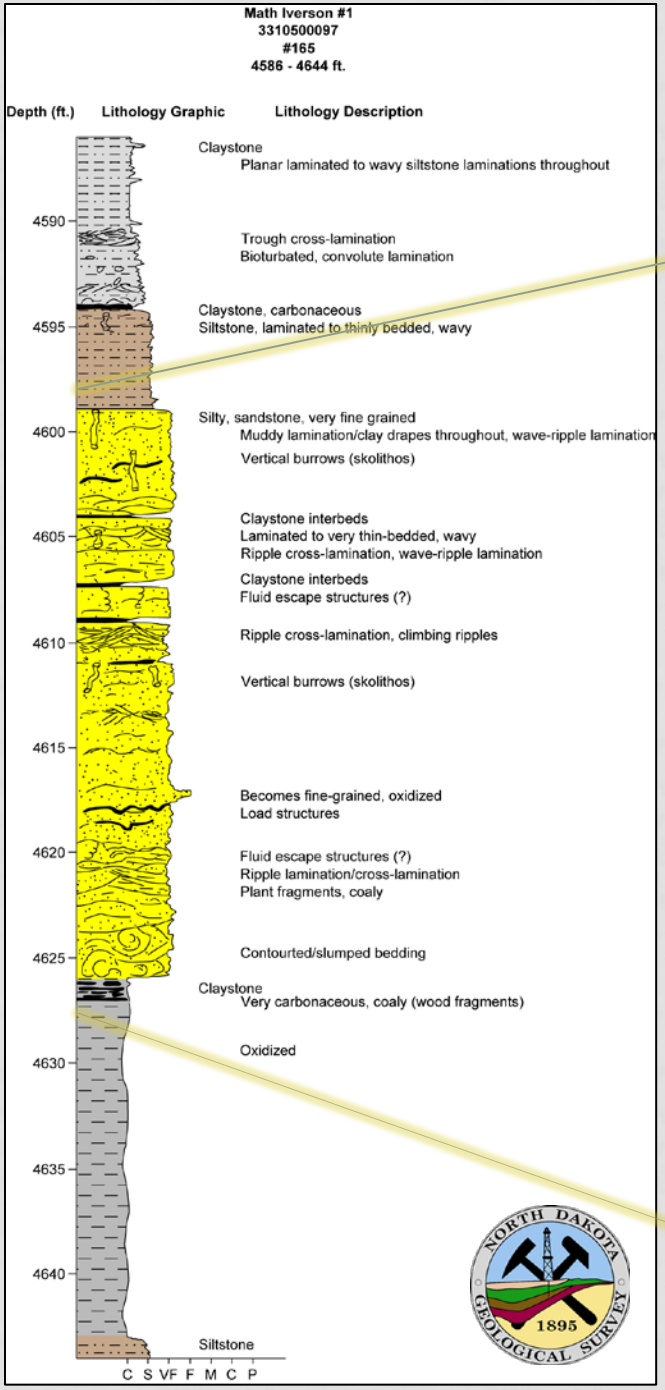
Inyan Kara Fm.

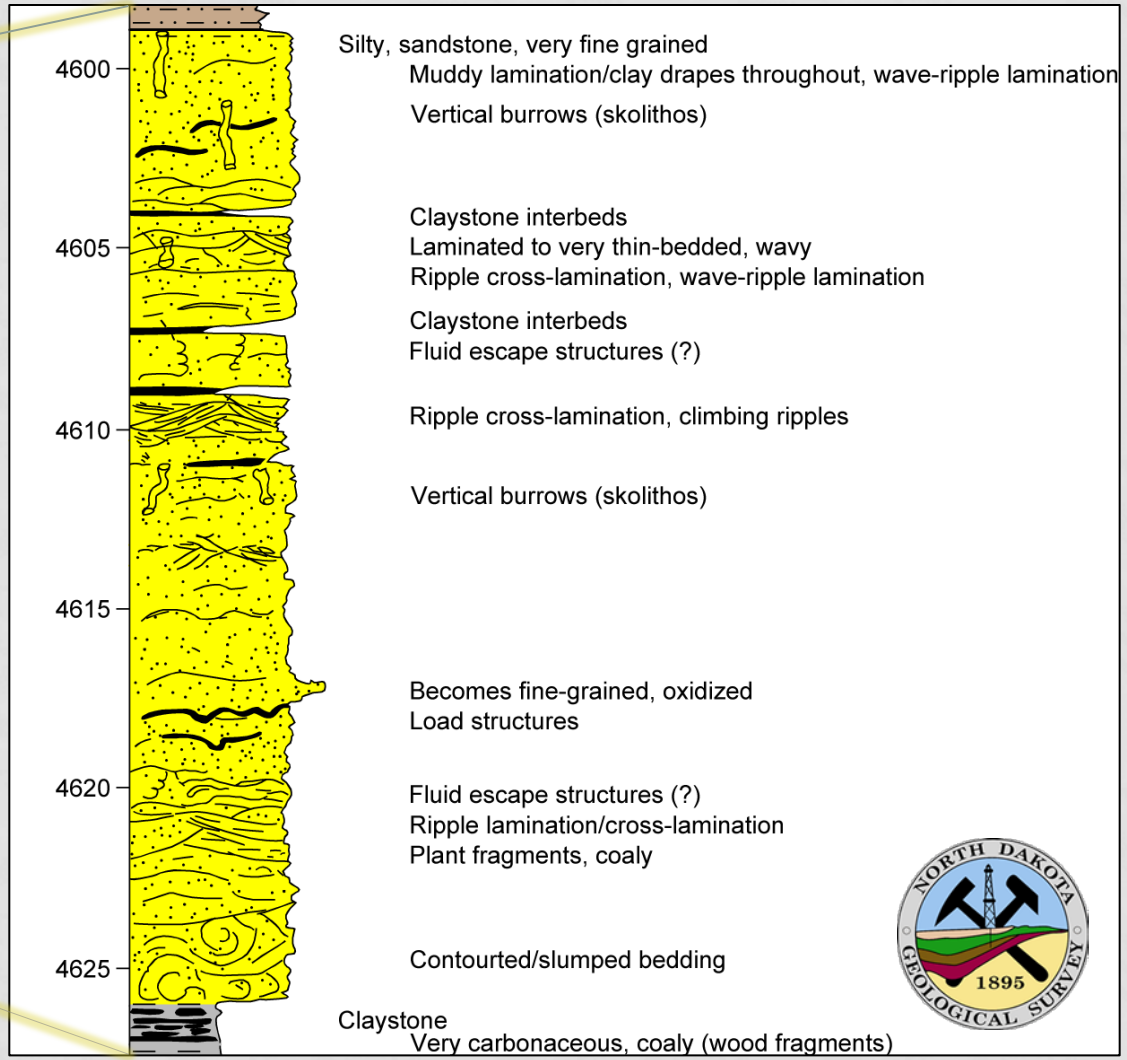
- Kik @ 4,594’-4,970’
- Unconformable above Js
- Conformable below Ksc
- Core
  - 4,586’-4,644’
  - 4,937’-4,980’



MATH IVERSON #1

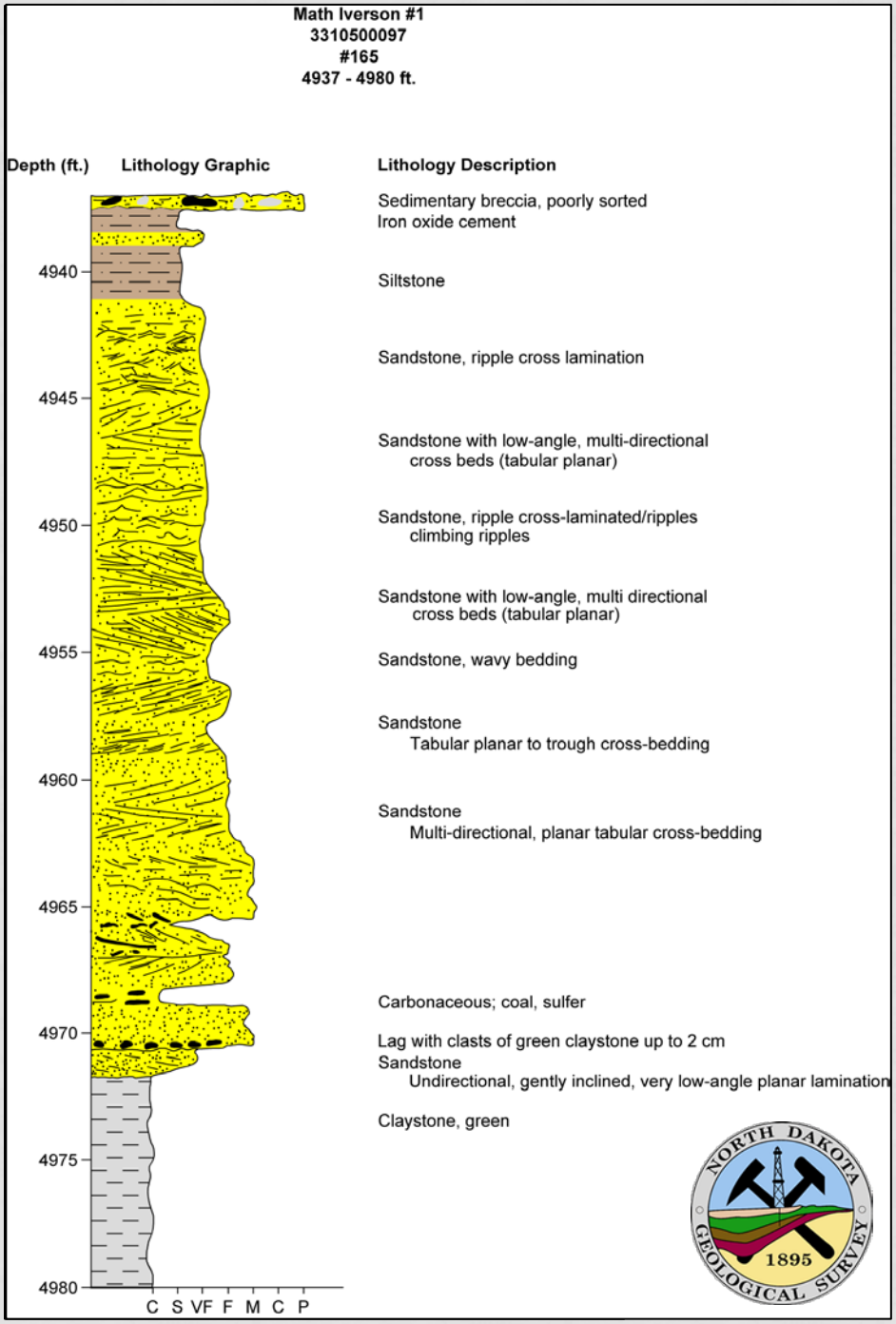
4,586 – 4,644 FEET





MATH IVERSON #1

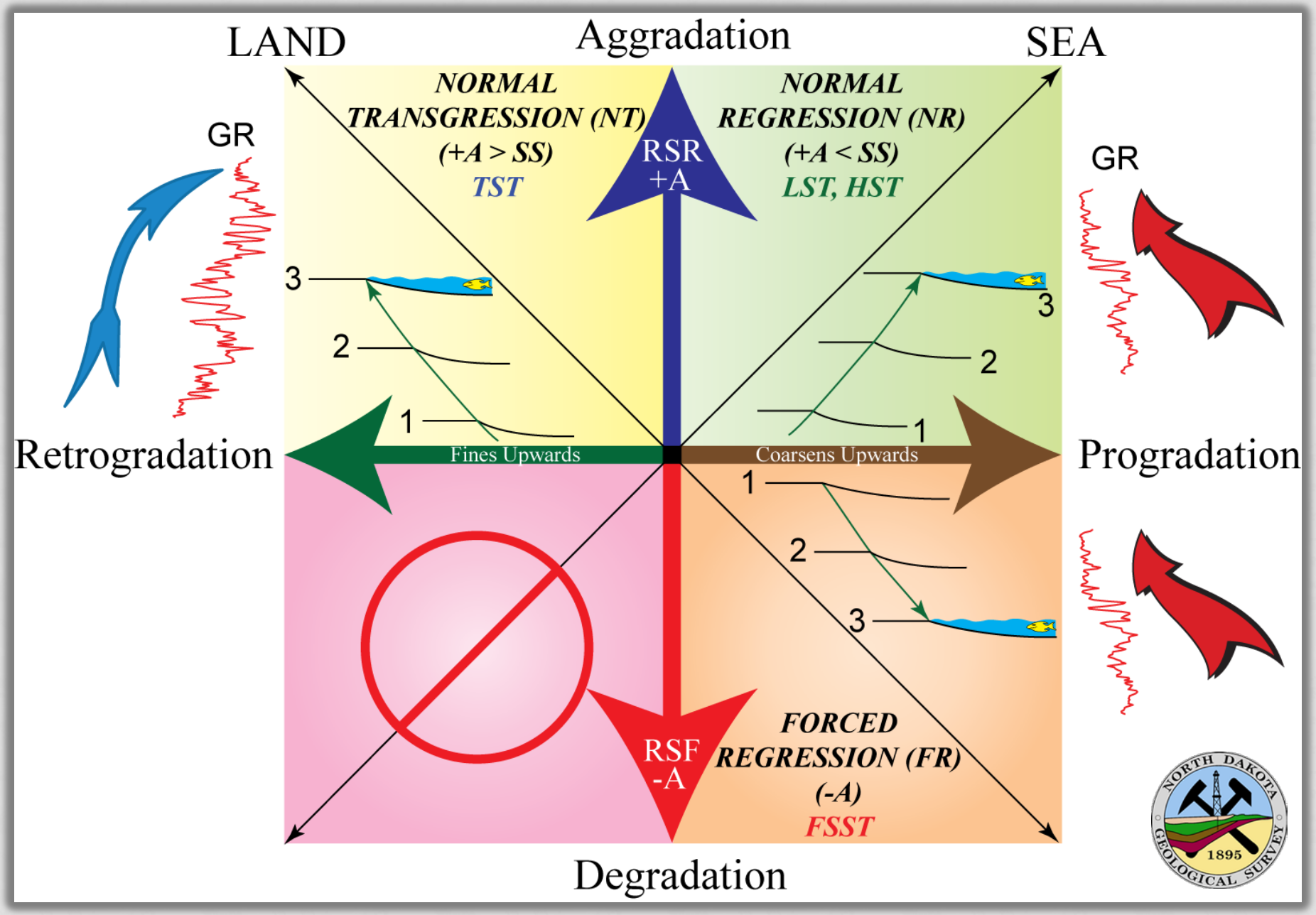
4,937 – 4,980 FEET



KEYS TO THE STUDY

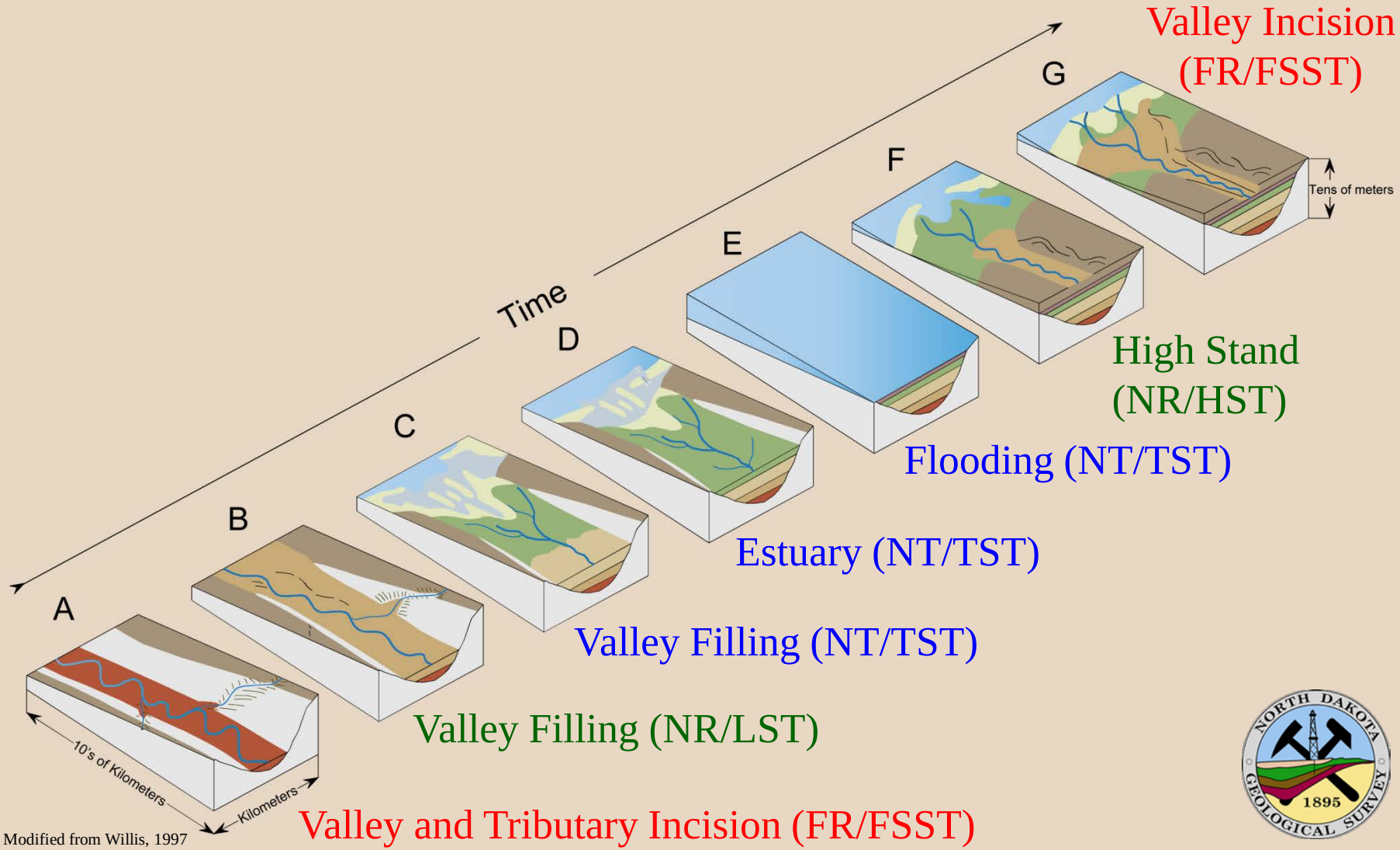
- Core
  - Sedimentary structures
  - Sequence stratigraphic surfaces
- Logs
  - Over 1,000 wells in WC 100K; hundreds across state
  - Stacking patterns
  - Sequence stratigraphic surfaces
- Sea-Level Curve (known model)
  - Sequence stratigraphic surfaces
  - Sequence stratigraphic systems tracts

= Depositional Environment


LAND
Aggradation
SEA
NORMAL TRANSGRESSION (NT)
(+A > SS)
TST
RSR
+A
NORMAL REGRESSION (NR)
(+A < SS)
LST, HST
GR
GR
3
2
1
3
2
1
Retrogradation
Fines Upwards
Coarsens Upwards
Progradation
1
2
3
RSF
-A
FORCED REGRESSION (FR)
(-A)
FSST
Degradation
NORTH DAKOTA GEOLOGICAL SURVEY
1895

EVOLUTION OF AN INCISED VALLEY

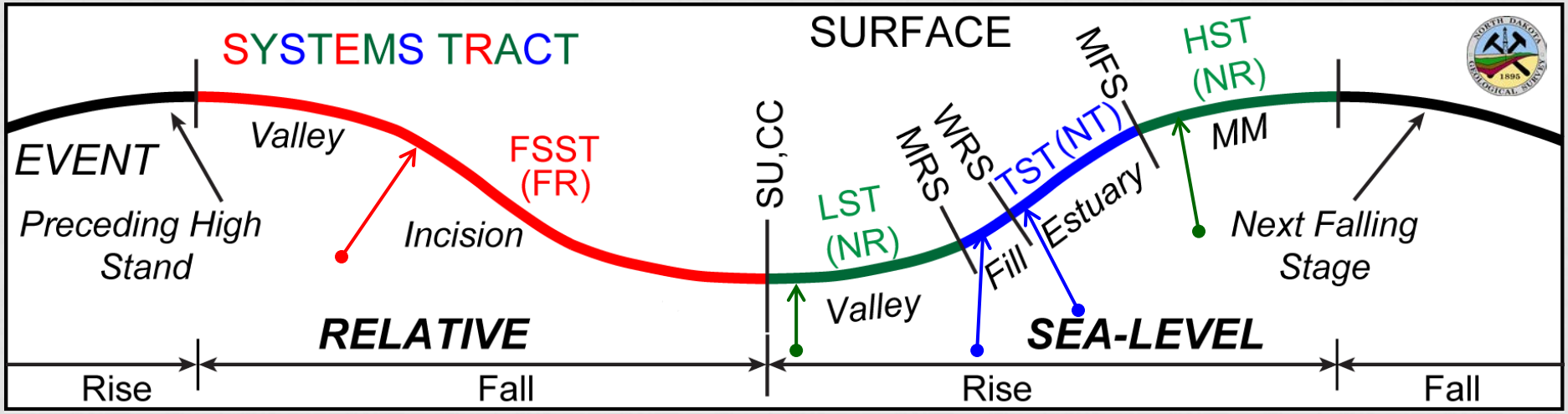
TRANSGRESSIVE RIVER MOUTH



Modified from Willis, 1997

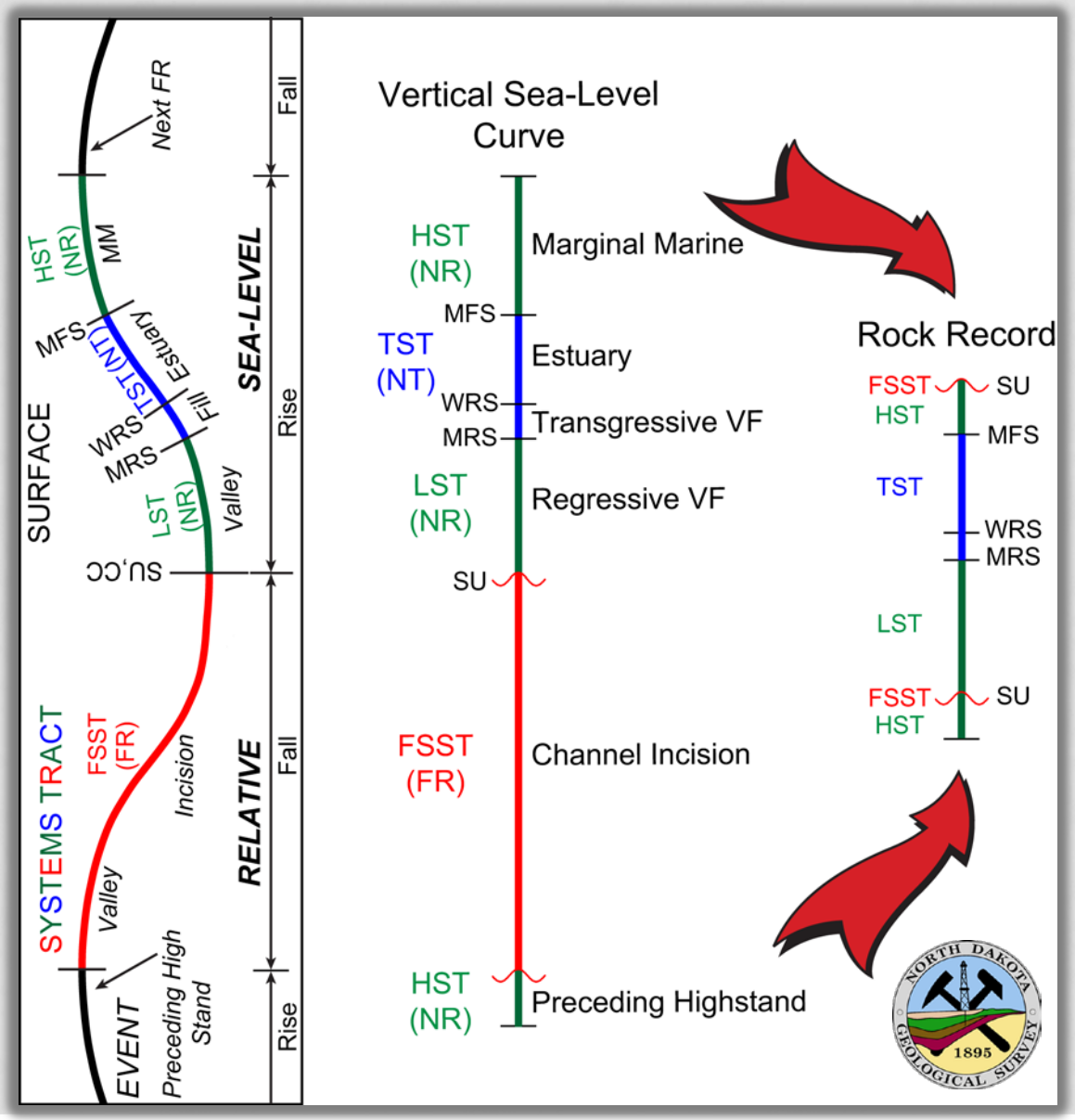
EVOLUTION OF AN INCISED VALLEY

RELATIVE SEA-LEVEL CURVE

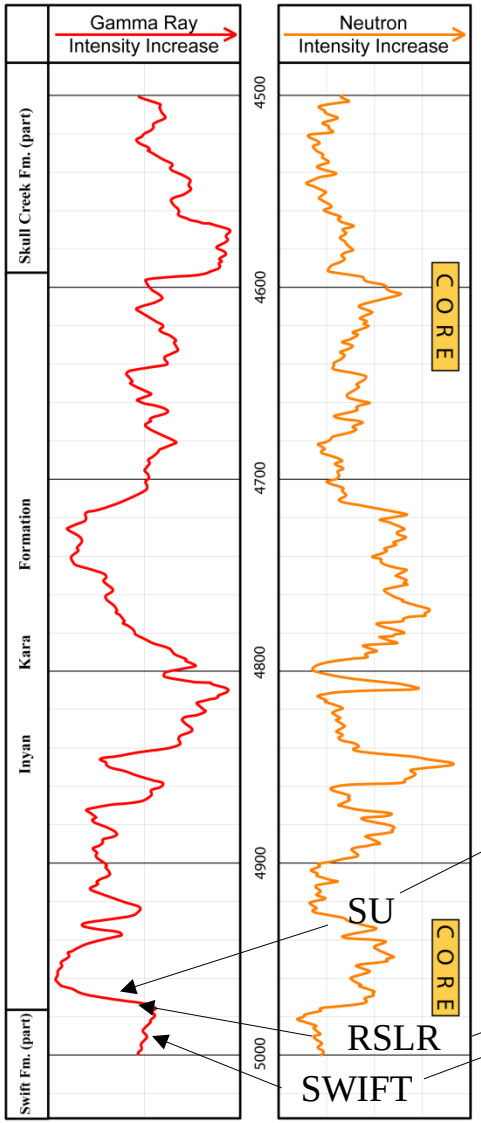


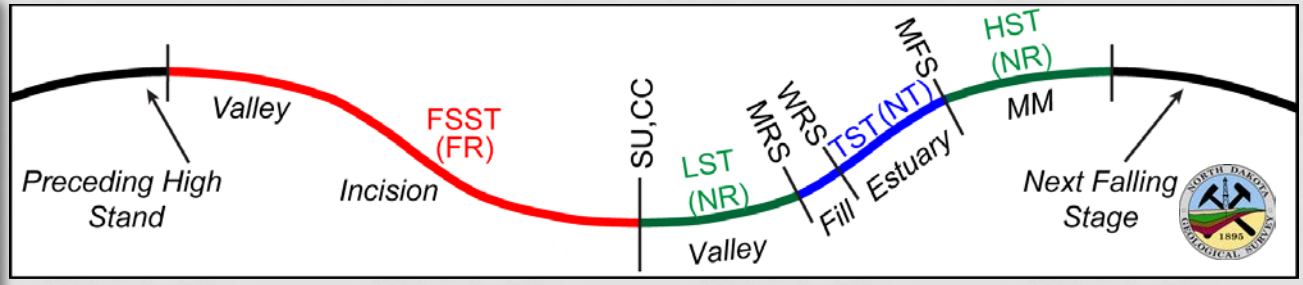
EVOLUTION OF AN INCISED VALLEY

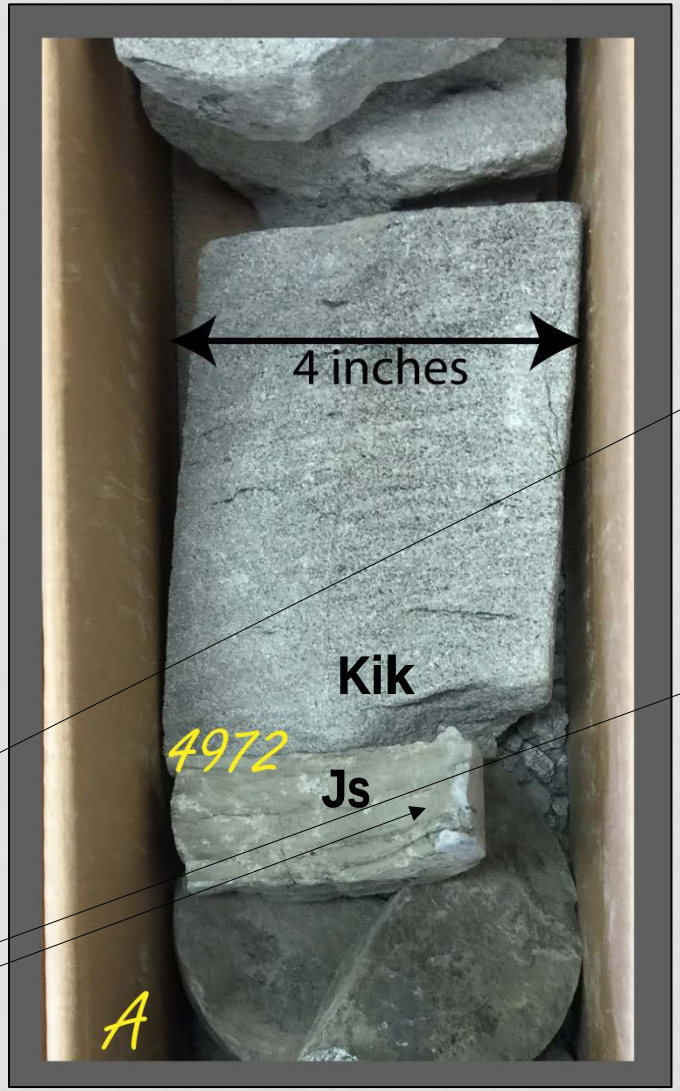
RELATIVE SEA-LEVEL CURVE



#165
33-105-00097-0000
SWNW Sec. 1, T155N R96W
Amerada Hess Corporation
Beaver Lodge-Madison Unit G-11
K.B. = 2,340 ft.







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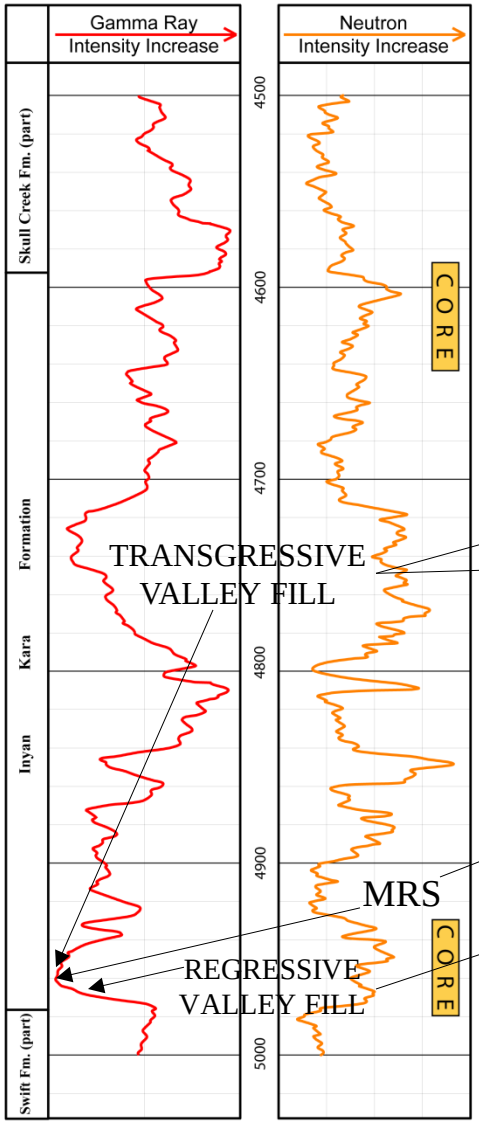

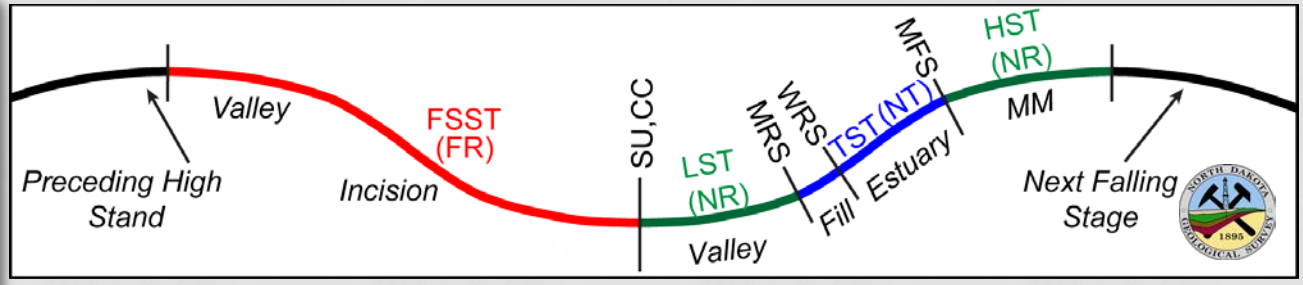

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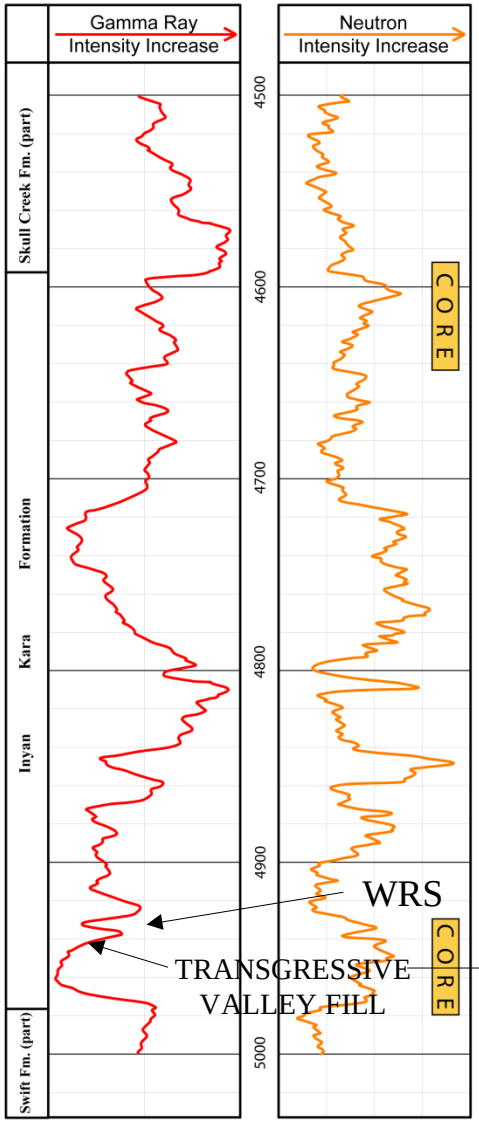
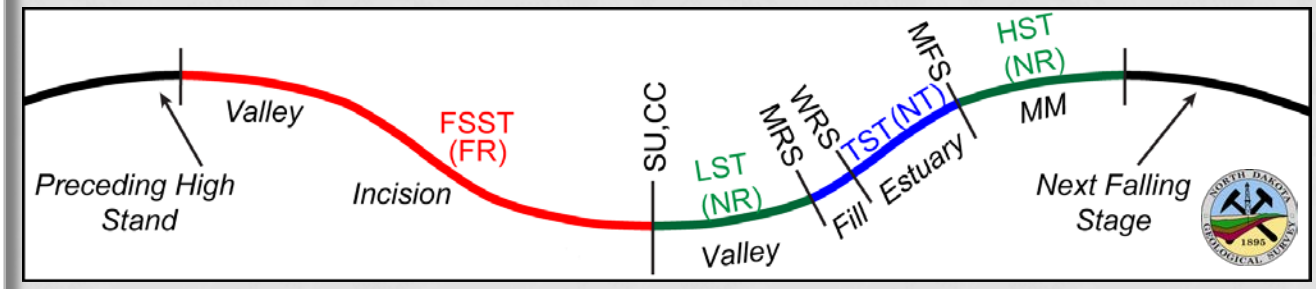
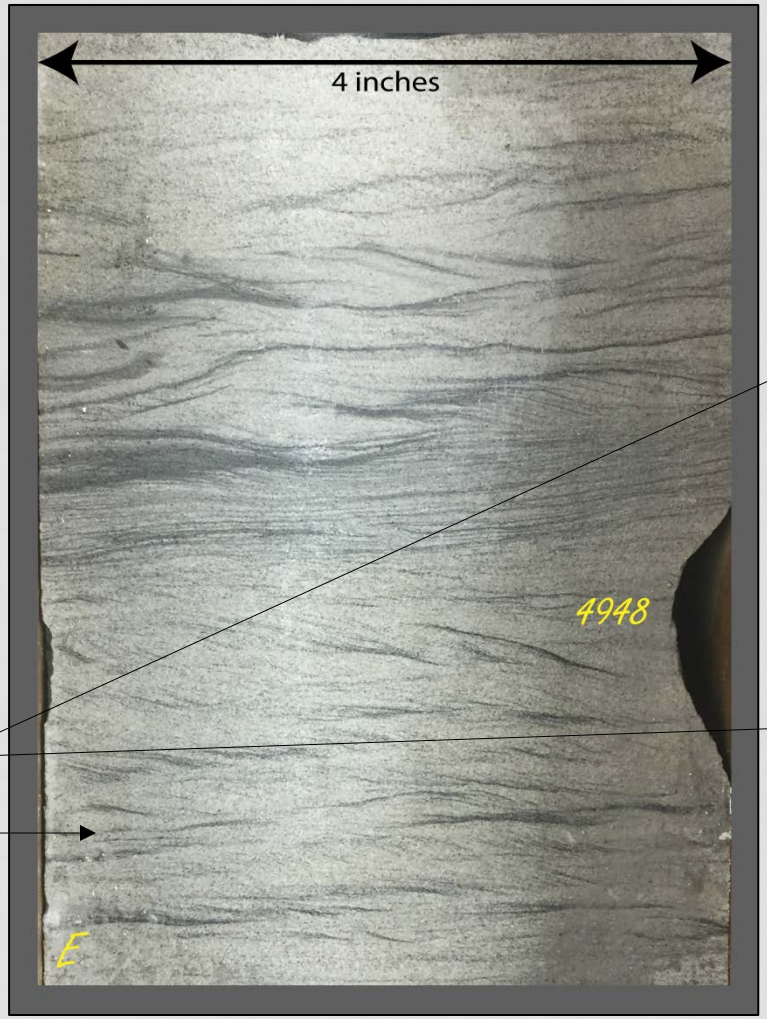
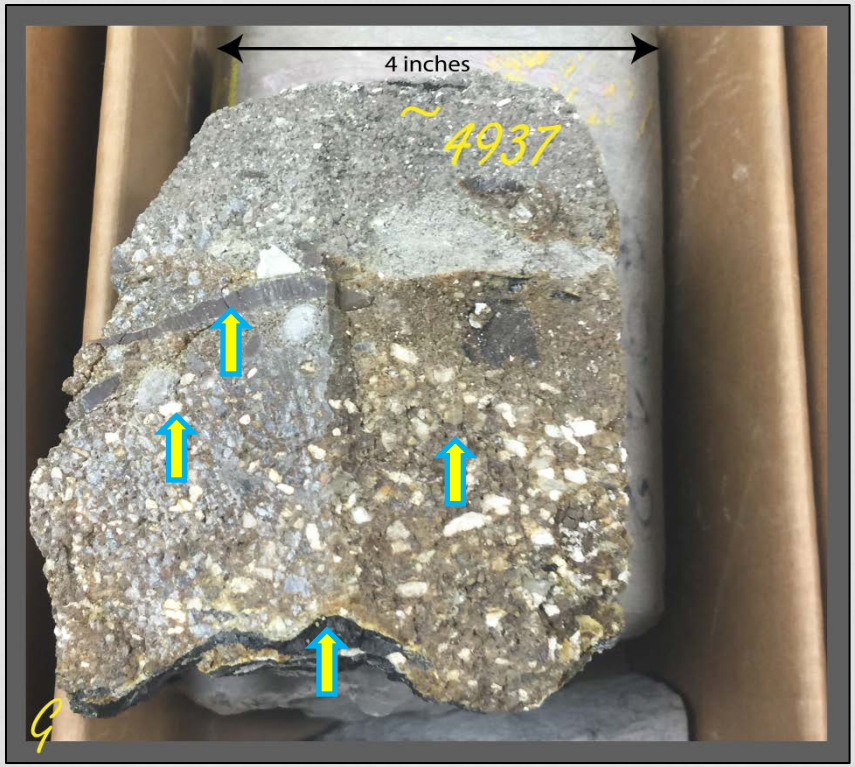


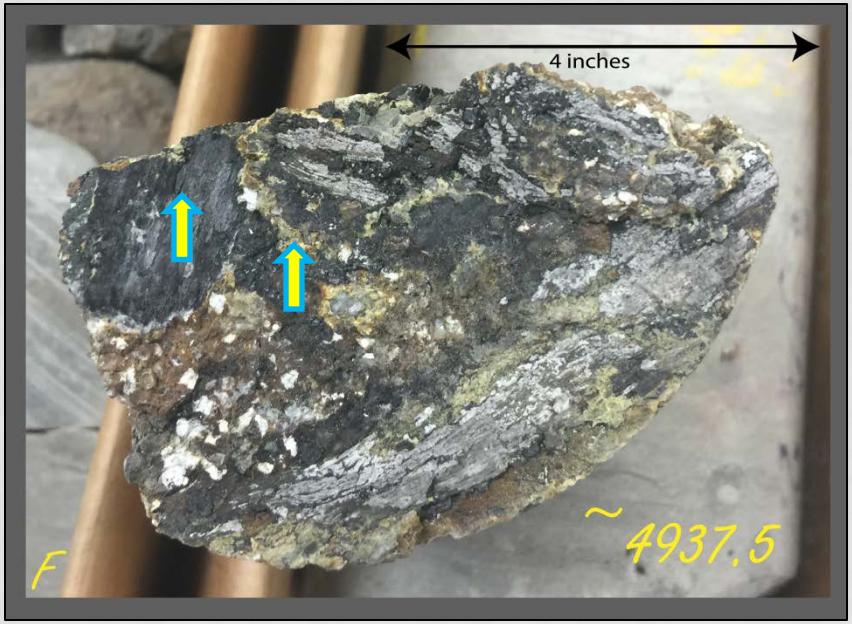






TRANSGRESSIVE LAG

- Shale clasts
- Phosphate nodules
- Coaly/carbonaceous clasts
- Larger clasts in finer-grained matrix



NORTH DAKOTA GEOLOGICAL SURVEY 1895

#165
33-105-00097-0000
SWNW Sec. 1, T155N R96W
Amerada Hess Corporation
Beaver Lodge-Madison Unit G-11
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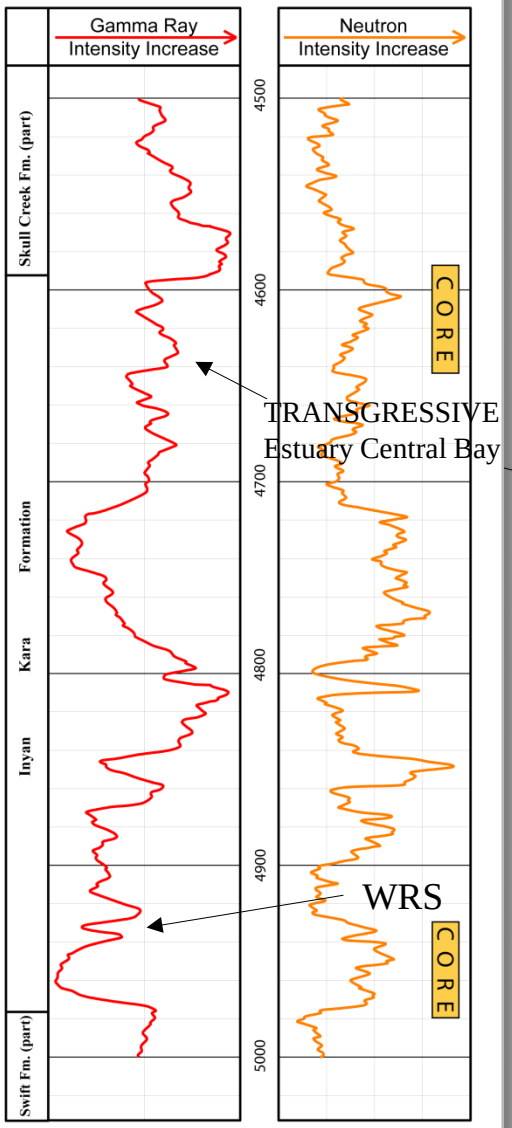
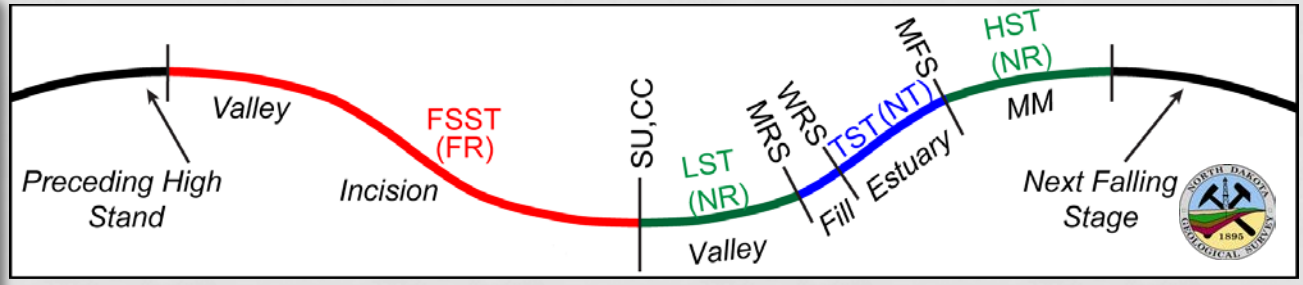


TRANSGRESSIVE
Estuary Central Bay

WRS



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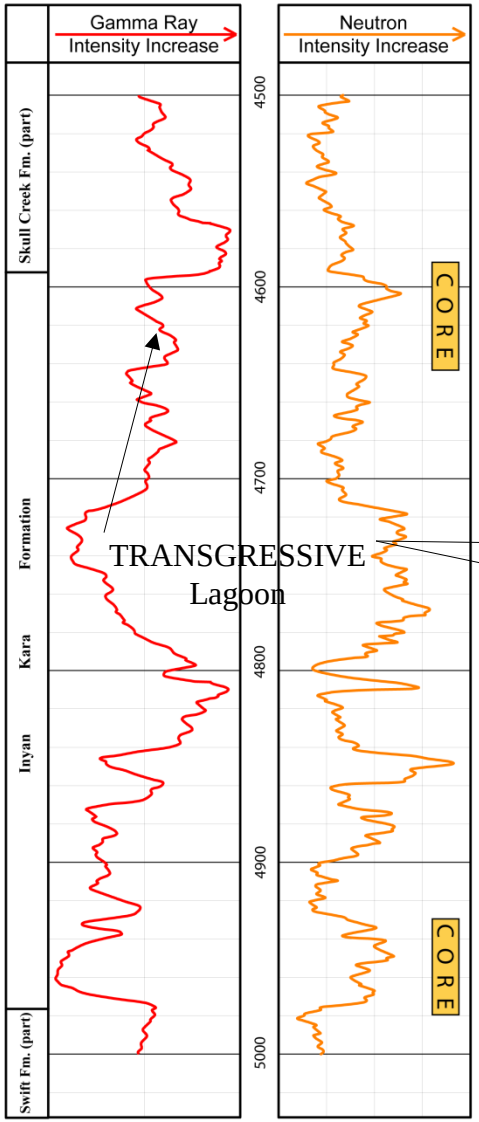

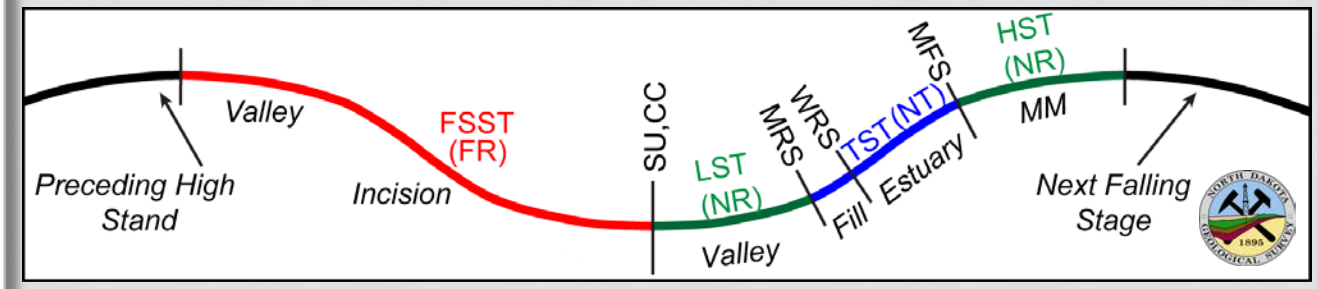

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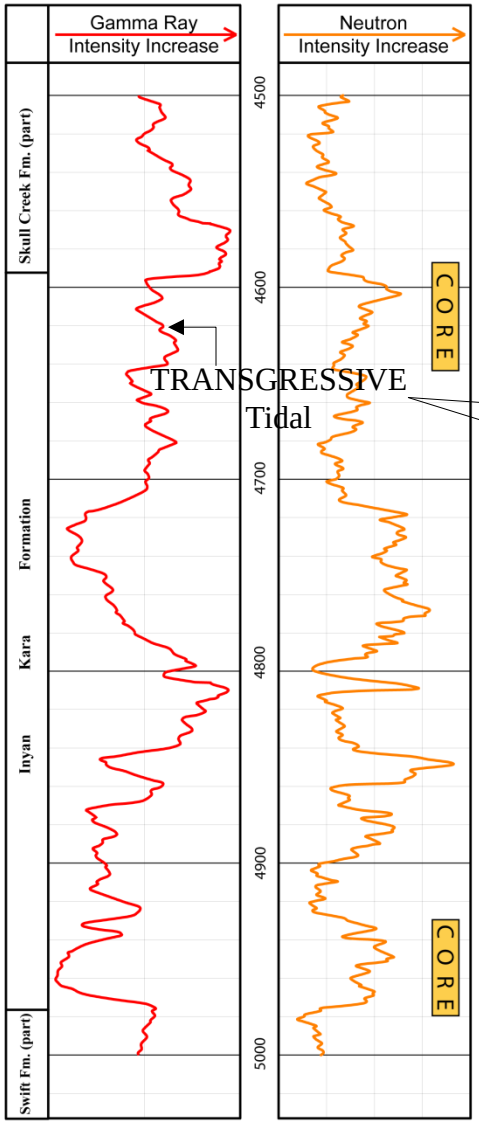

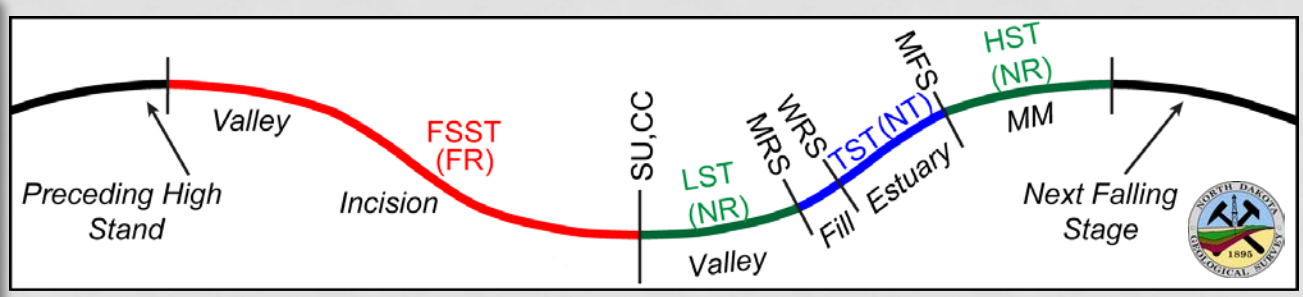

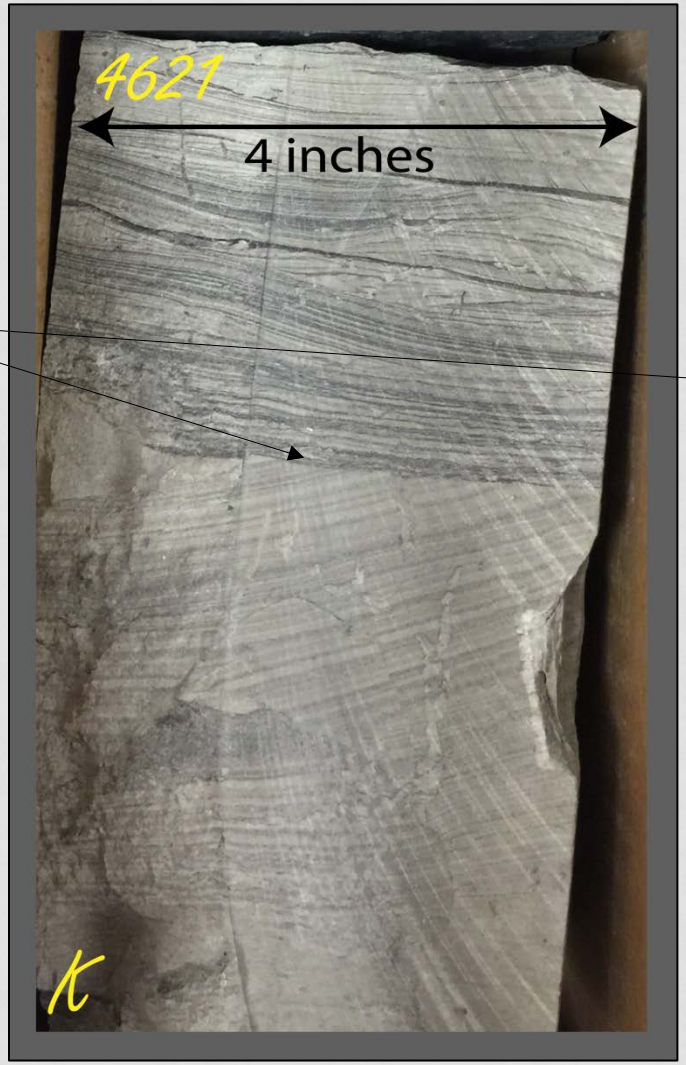

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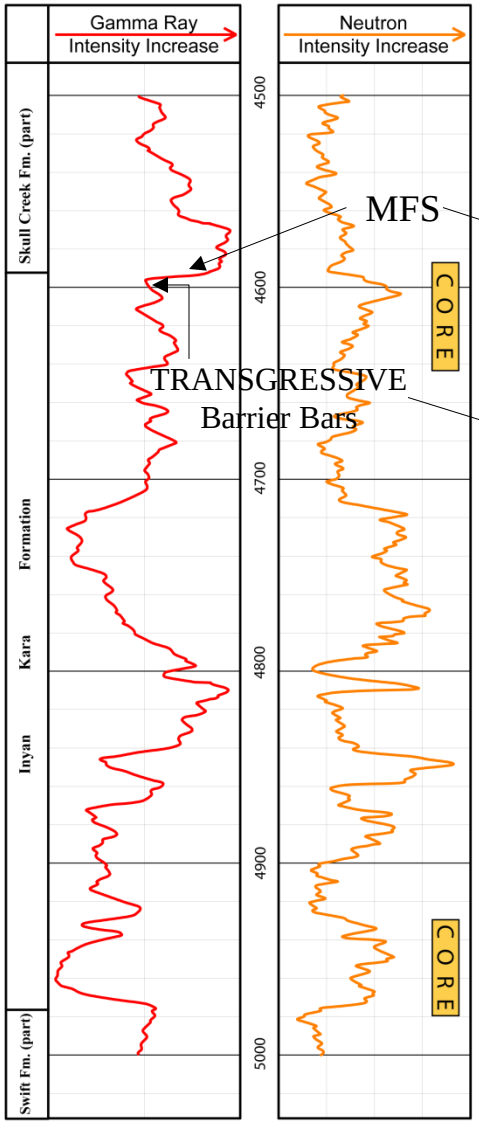
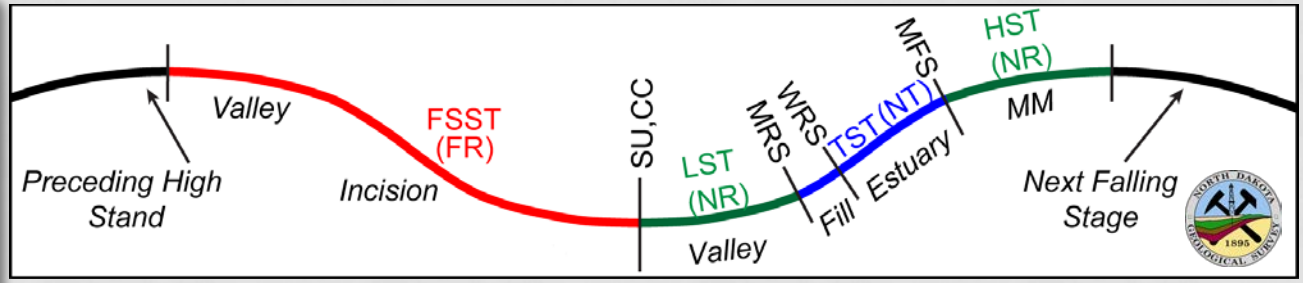
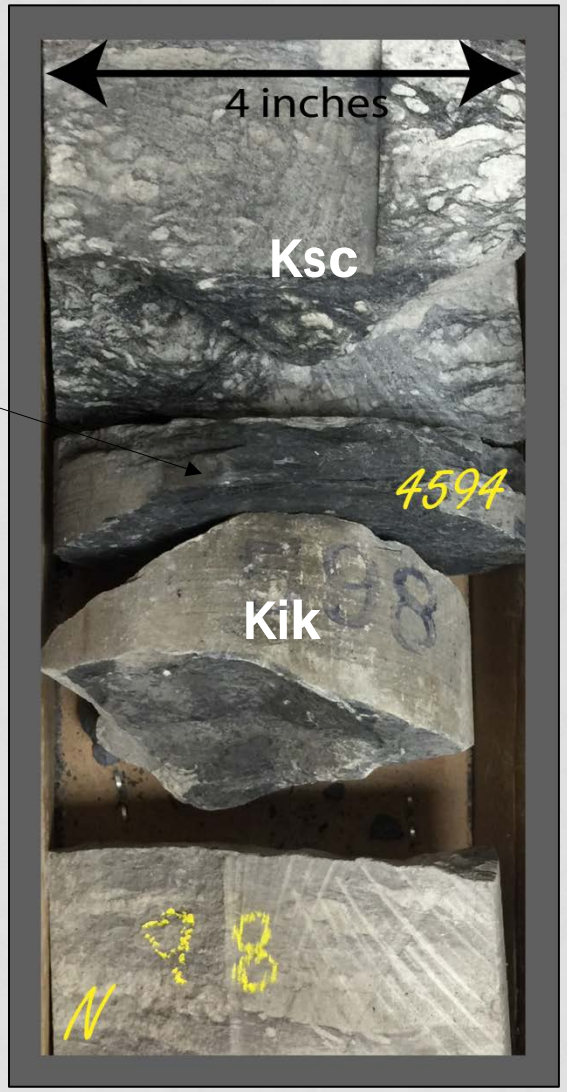
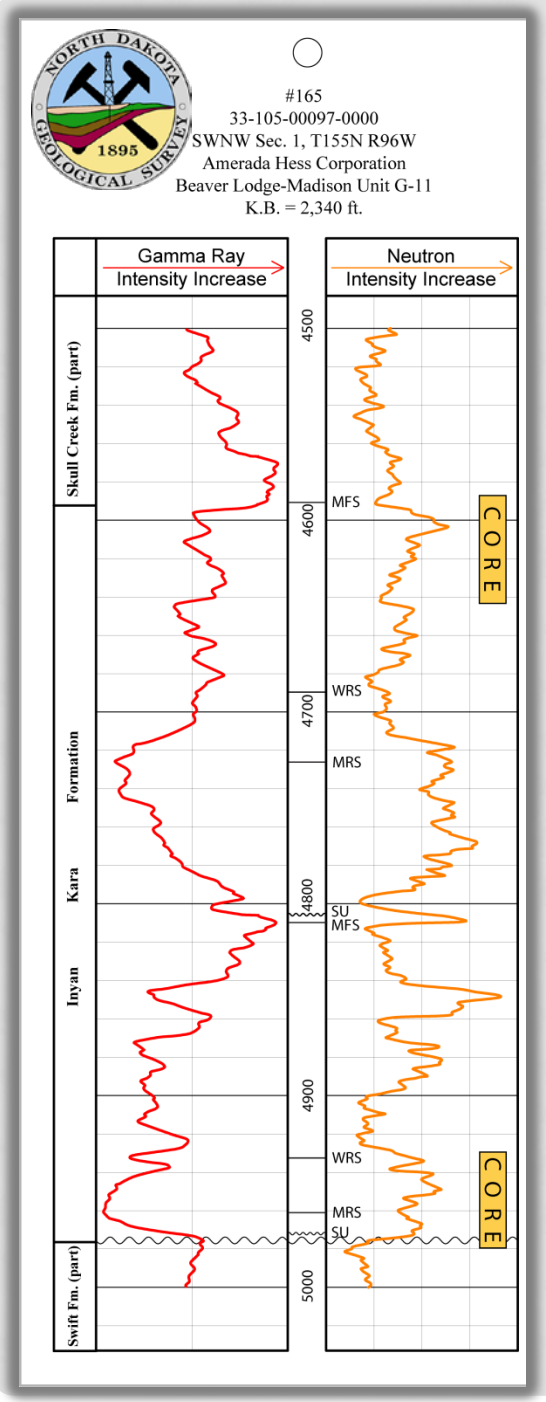








MATH IVERSON #1

SURFACES AND EVENTS

Nearshore Marine Deposits

Maximum Flooding

Shallow Marine Deposits

Estuarine Deposits = Transgression = Flooding

RSLR-Valleys Filled

Maximum Flooding

Shallow Marine Deposits

FR-Valleys Incised = SU

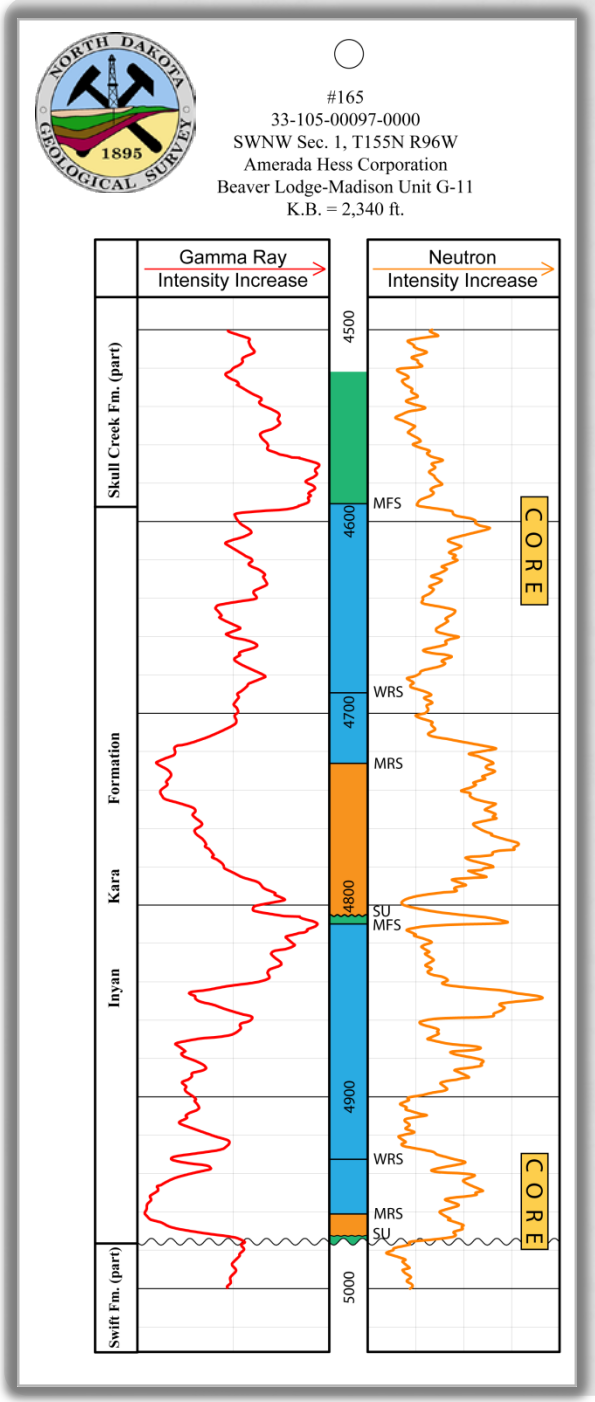
Estuarine Deposits = Transgression = Flooding

Wave Ravinement = Transgression Underway

RSLR-Valleys Filled

RSLR

FR-Valleys Incised = SU



MATH IVERSON #1

SYSTEMS TRACTS

HST

TST

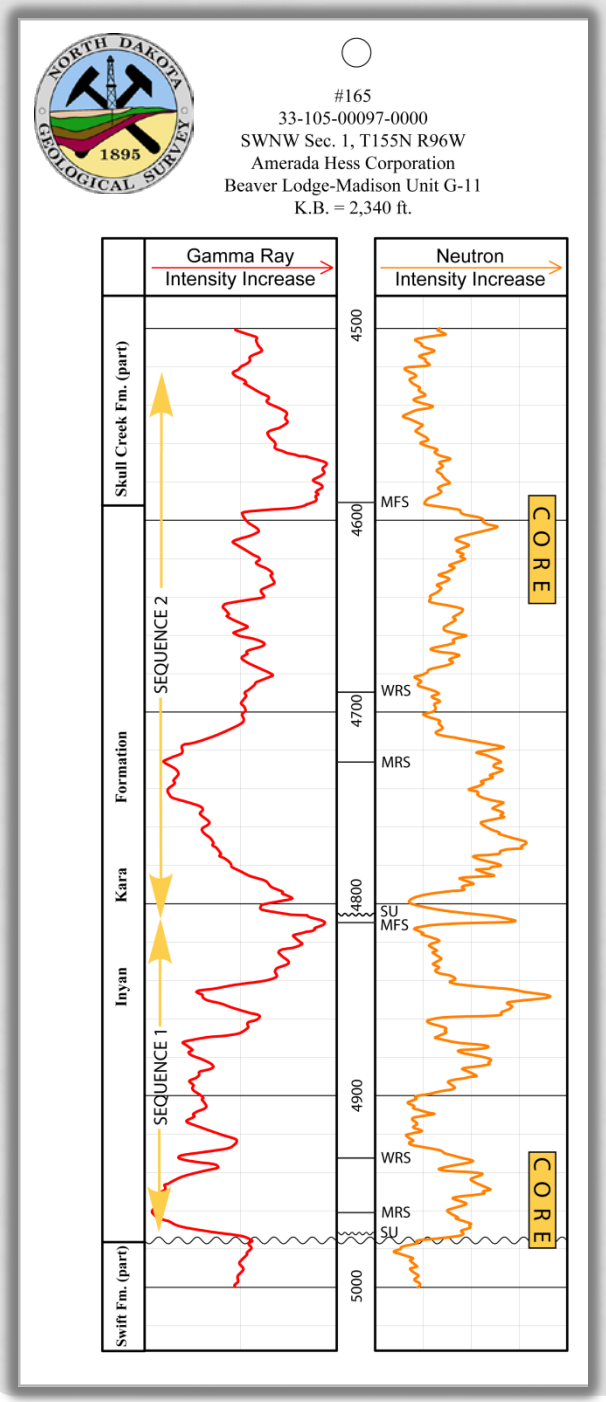
LST

HST FSST

TST

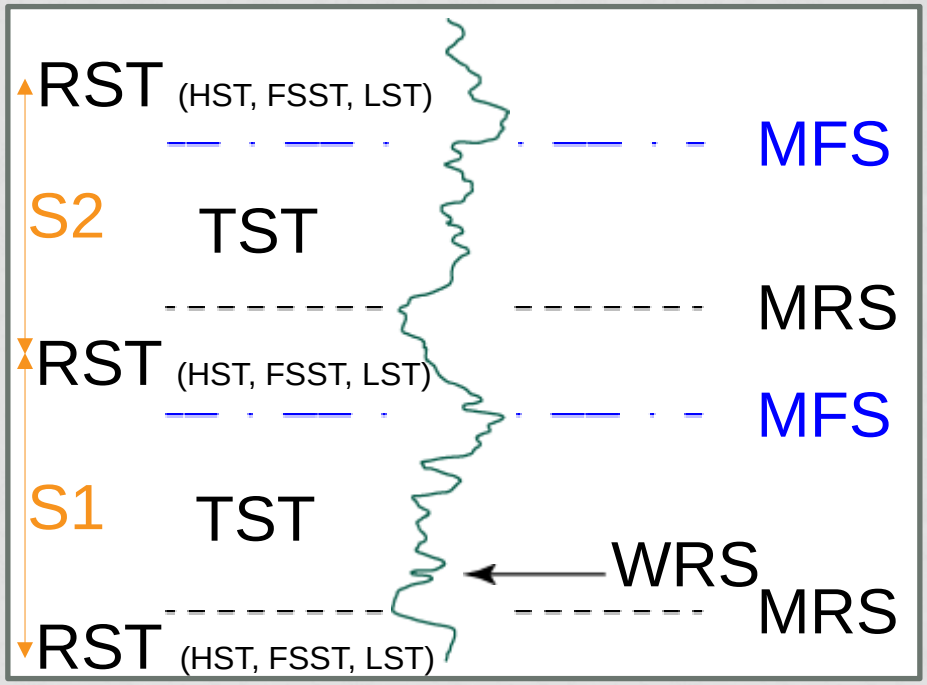
LST FSST

HST



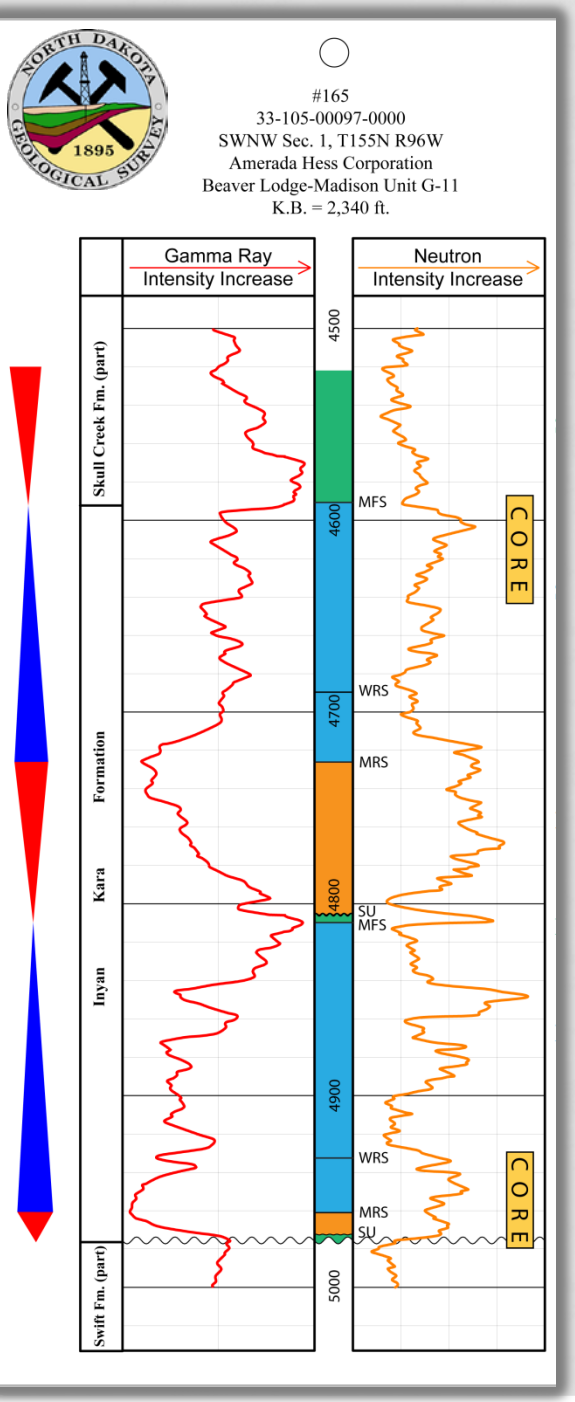
MATH IVERSON #1

SEQUENCES

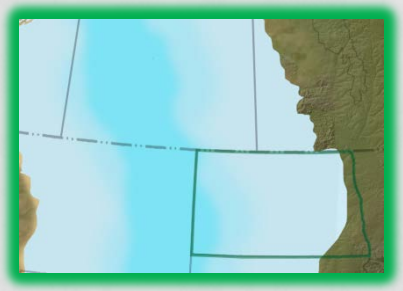


MATH IVERSON #1

REGIONAL T & R EVENTS



Skull Creek High Stand
(105-102 Ma)



Skull Creek
Transgression
(106 Ma)

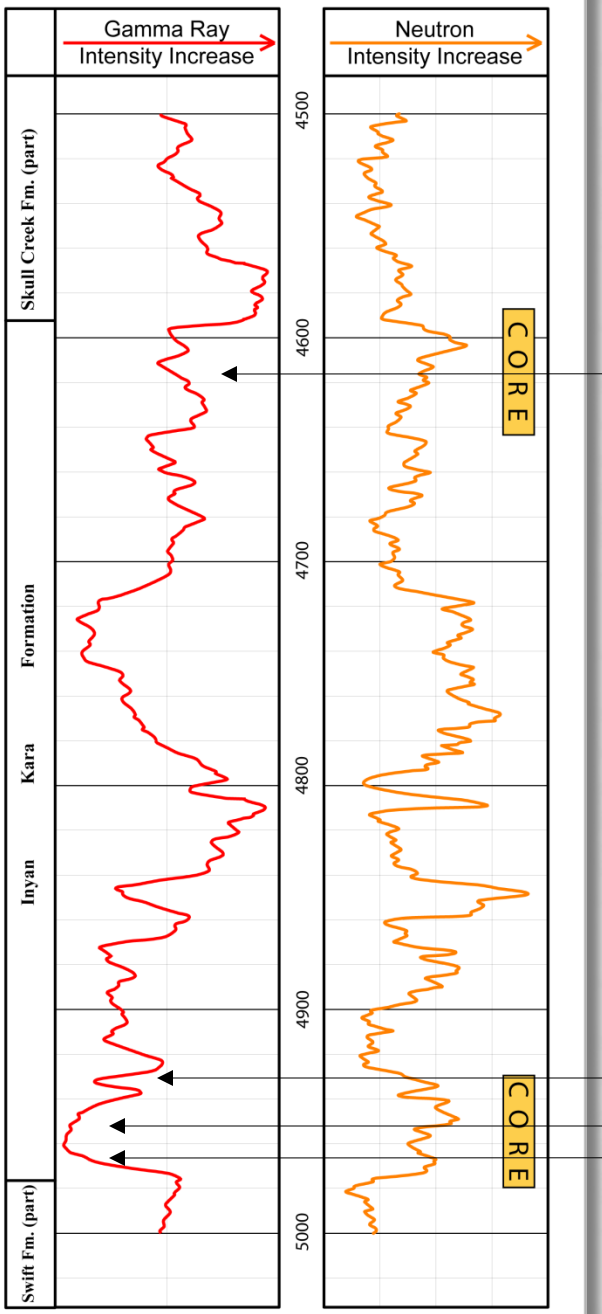
Fall River Low Stand
(107 Ma)

Fall River High Stand
(110-108 Ma)

Fall River
Transgression
(113-111 Ma)

Aptian Low Stand
(120-115 Ma)

Modified from Blakey, 2014

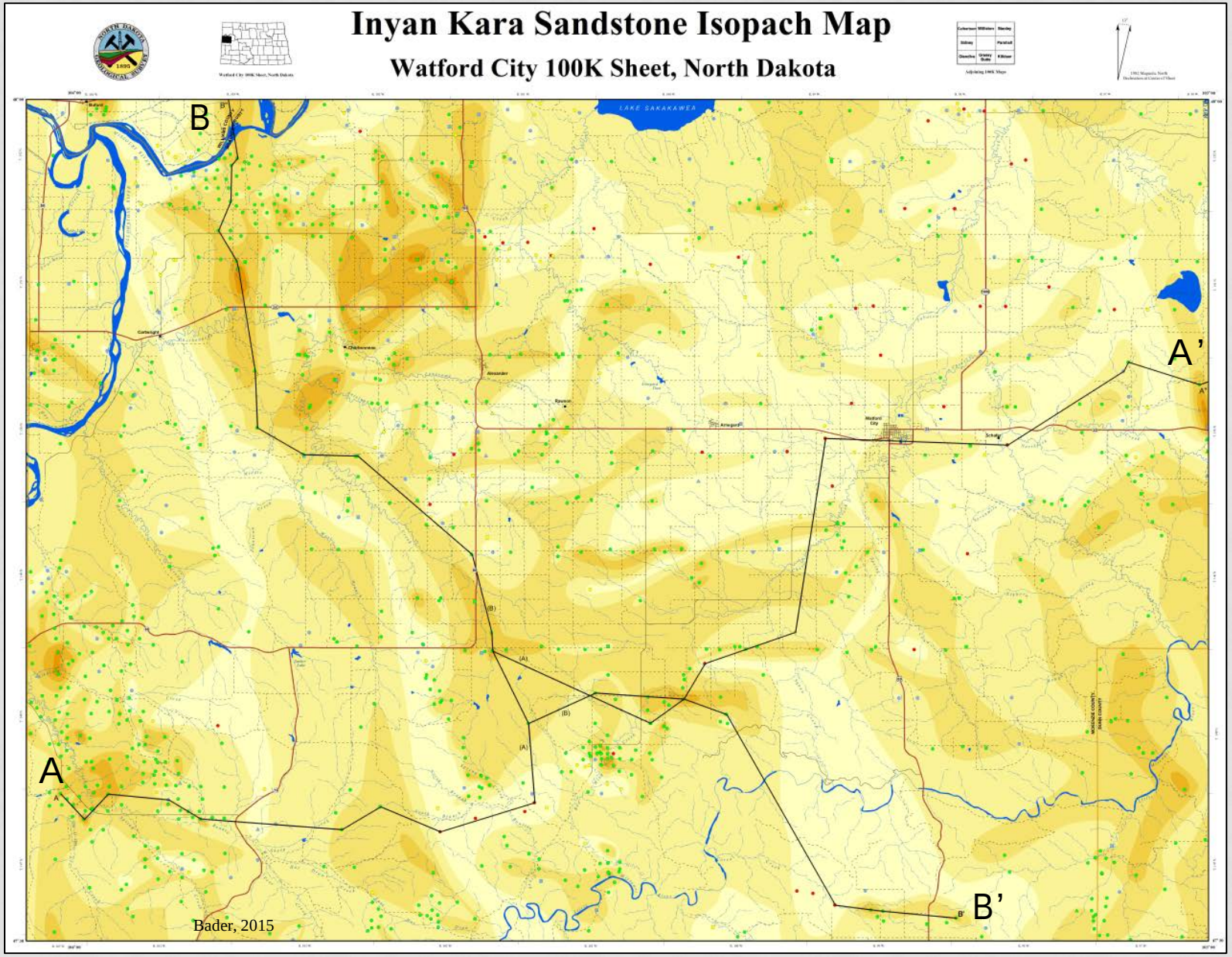


MATH IVERSON #1

PERMEABILITY/POROSITY

Permeability in millidarcies (avg.)	Porosity in % (avg.)	Environment
24	13	Estuary Mouth
1,000	13	WRS
5	24	TVF
350-1,300	23	RVF

INCISED VALLEYS

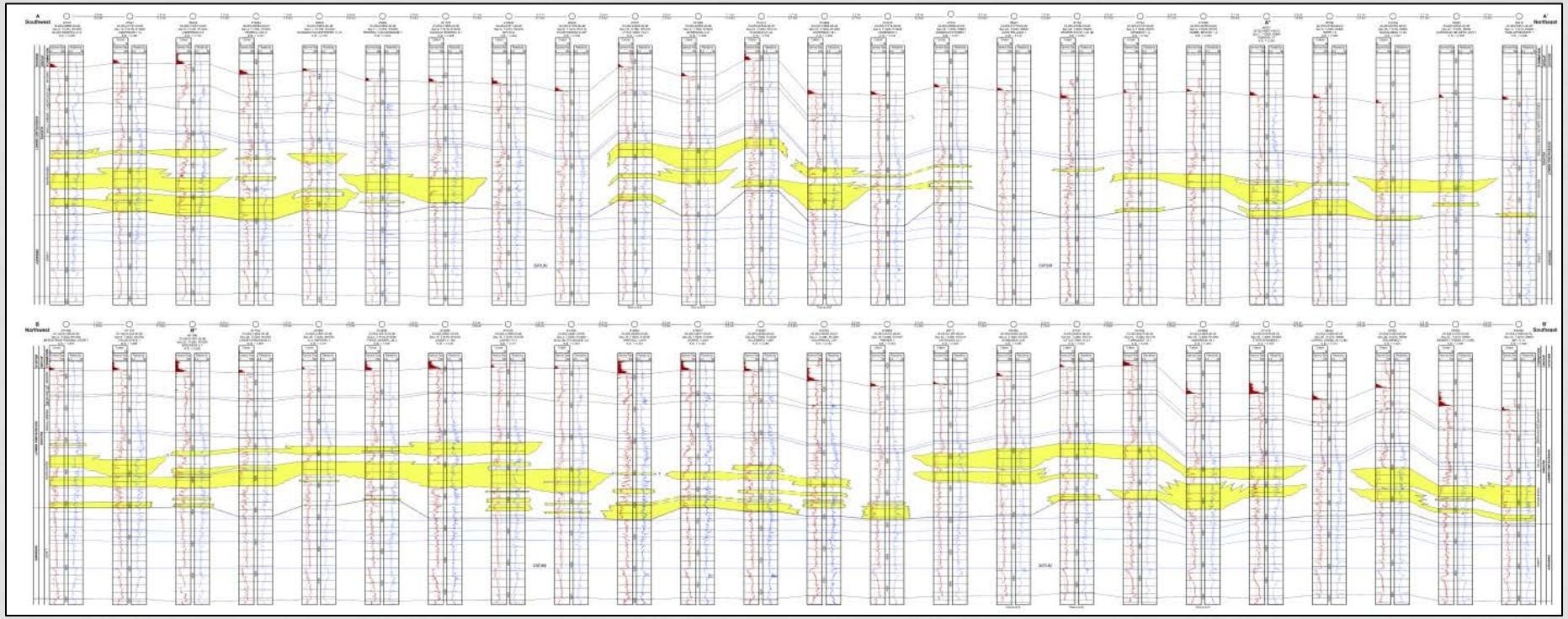


INCISED VALLEYS

- Paleovalleys on A-A’
- Sands more elongate on B-B’
- Depositional environment key!
- Consistent with previous works

A

A’



B

B’

FUTURE WORK

- Parshall 100K
- Other 100Ks adjacent to WC100K
- Publish, publish, publish
- Core Workshops
  - Need more cores ☺