PS Meandering Channel Facies Architecture Using Ground Penetrating Radar, Ferron Sandstone (Upper Cretaceous) Emery Co., Utah *

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Abstract

Detailed investigations of meandering channel belts in the Ferron Sandstone was made using ground penetrating radar (GPR) with the aim of characterizing riffle facies elements. Riffles facies architecture elements are developed along channel thalweg reaches between two successive pools and flanked by lateral accretion bar facies architecture elements. Riffle elements have received little attention, despite their potential importance to pore-fluid flow within meandering channel reservoirs. This study describes the geometry and facies architecture of meandering channel fill using 2-D GPR imaging data. GPR data acquisition was guided by outcrop exposures of a meandering channel belt segment, indicating the presence of a channel thalweg between successive pools. 2-D GPR data were acquired in three 100m X 100m grids and five smaller dimension grids for a total area of 44,300 sq. meters. GPR data were processed and corrected for direct wave influences, topography and background noise. Using an average velocity of 0.15m/ns, estimated depth to the base of the channel-fill deposit is a maximum of 4m below the surface which corresponds to a basal, laterally continuous strong reflector.

Ground penetrating radar reflector geometries (inclination, continuity and termination configurations) and amplitude characteristics are used to define five GPR facies. In addition, reflectors are compared to facies architecture boundary surface hierarchy established from outcrop studies. Geometry of outcrop exposures of lateral accretion bars projected into the subsurface can be observed in the GPR data as less continuous reflectors down-lapping against the basal reflector. A pseudo 3-D GPR data volume constructed from 2-D GPR data is used to identify a riffle element as having continuous horizontal reflectors with relatively low variable density (VD) contrast amplitude values when compared to other meandering channel GPR facies, which might be due to a high level of textural sorting in riffle sandstones. Other GPR facies include the channel floodplain, characterized by chaotic reflectors; the levee deposits characterized by gently dipping oblique reflectors divergent from an up-dip termination; and the abandonment-fill characterized by a structureless, reflection free zone in radar data. Channel evolution was determined using strike and dip information from the internal reflector of lateral accretion deposits.

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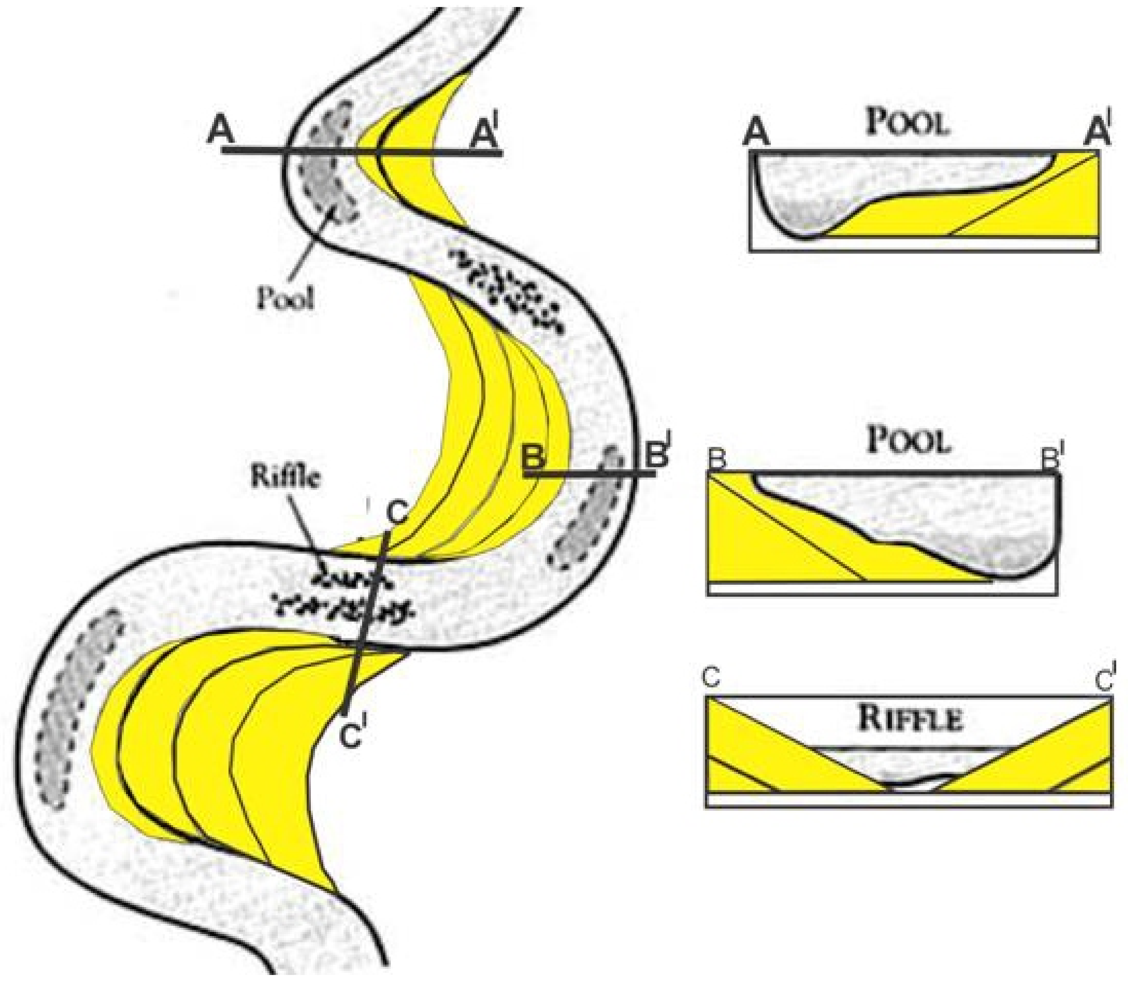
1. Introduction

Research Goals

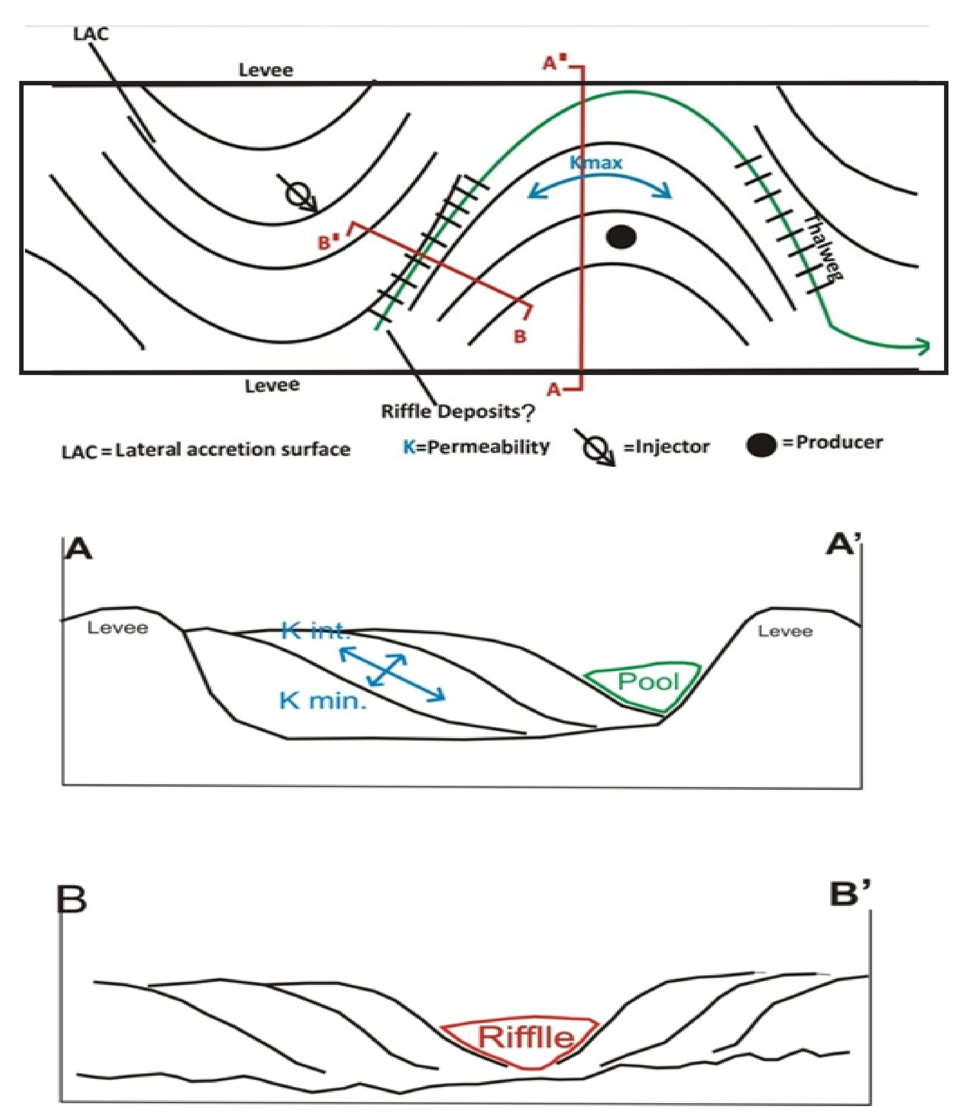
- Acquire Ground Penetrating Radar (GPR) data along a mapped out meandering channel where the riffle elements and adjacent channel fill elements can be imaged.
- Identify radar facies representative of meandering fluvial architectural elements as observed in the Ferron Snadstone outcrop.
- Describe geometry and distribution of riffle element facies architecture as observed in radar data.



• Meandering channel with riffle elements illustration. Riffles are the deposits of channel thalweg reaches between two successive pools and flanked by adjacent lateral accretion bars of a meandering fluvial channel (Compare A-A' to C-C').

Motivation

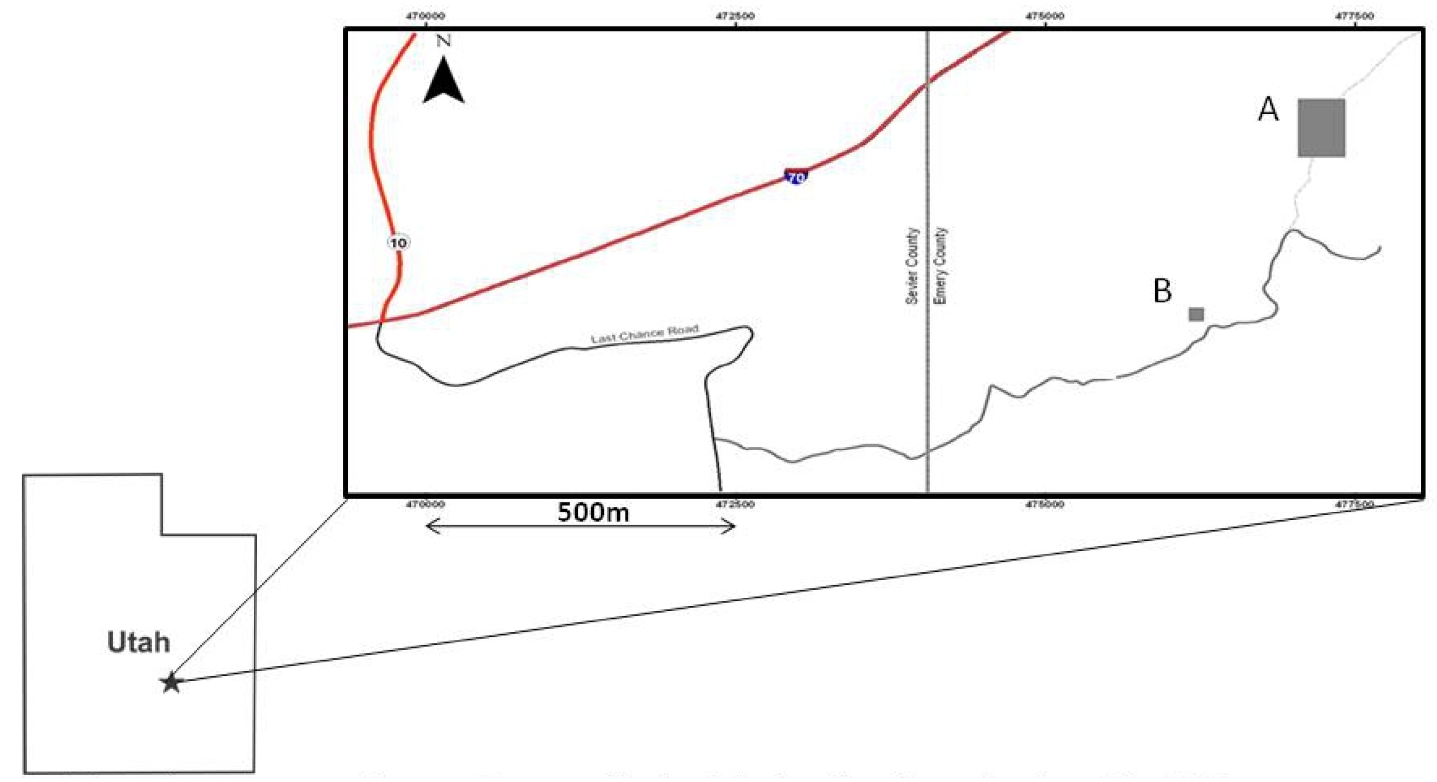
- Knowledge of riffle elements as it relates with adjacent meandering channel fill elements will help understand connectivity of meandering channel reservoir elements (which can be important when locating wells for effective hydrocarbon exploitation).



• illustration of the importance of riffle elements in fluid transmissivity in petroleum exploitation.

- Most studies on meandering fluvial deposits fail to describe in detail the nature of riffle elements.

Study Area

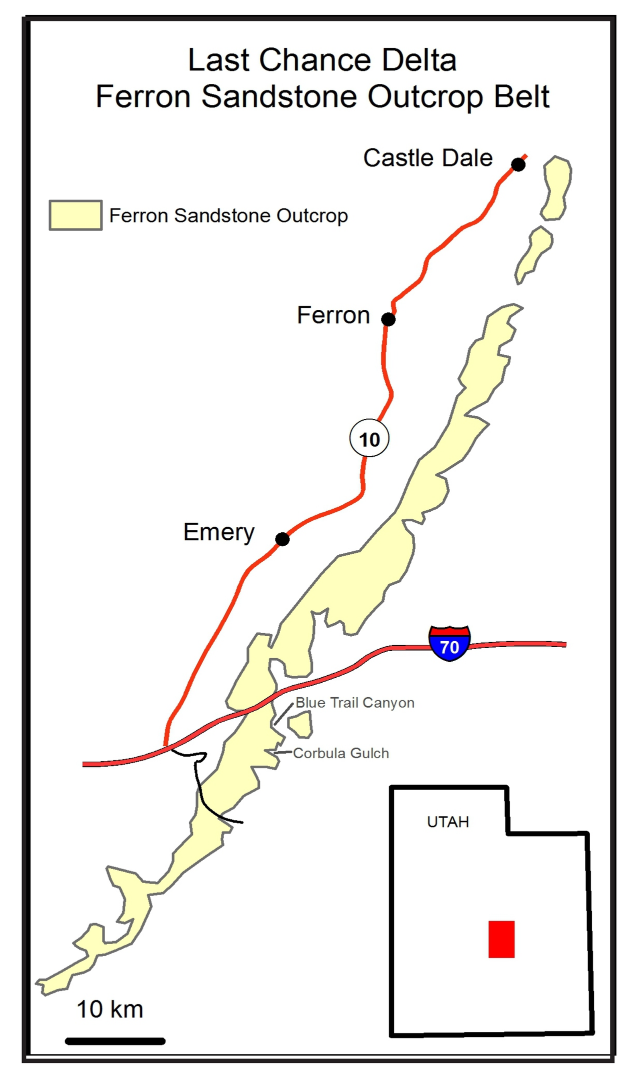


• Map of study area, Emery County, Utah.

- The study site the is the Ferron Sandstone outcrop located south of I-70, Emory County, Utah, USA.
- Study site A is the main study site termed north study area. Study site A has lateral accretion bar elements dipping northeast and southwest towards single thalweg.
- Study site B termed GPR type section site is where GPR sedimentary signature was acquired.

Geologic Setting

- The Ferron Sandstone Member of the Mancos Shale is part of the Cretaceous (Turonian) outcrop in Emery County, Utah.



• Ferron Sandstone outcrop belt.

Meandering Fluvial Facies Architecture Using Ground Penetrating Radar, Ferron Sandstone (Upper Cretaceous) Emery County, Utah

The University of Tulsa

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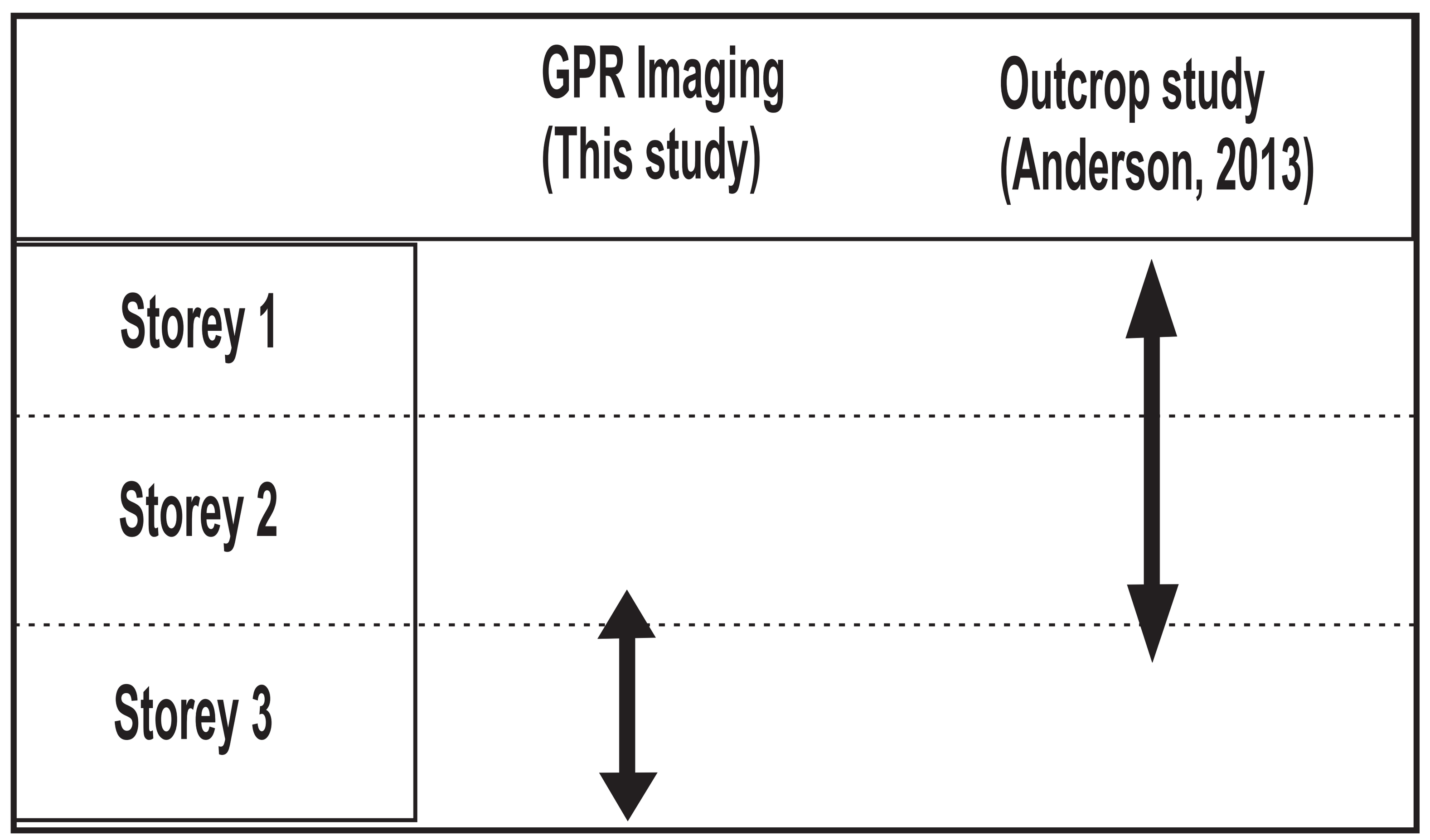
- The Ferron Sandstone was subdivided into seven major stratigraphic cycles (SC) made up of stratigraphic sequences. SC4-SC7 are aggradational and retrogradational deposits; and stratigraphic sequence SC1-SC3 are progradational (Garrison, 1997). The sequences are capped by coal zones.

- The north study area is part of the SC4 – SC7 which forms the river dominated area of Last Chance Delta.

- Outcrop study of north study site revealed three storeys of meandering channel elements. A channel storey consists of all cahnnel-belts occuring at a single stratigraphic height (Anderson, 2013).

- Most of the area imaged with the GPR is channel-belt of storey one, the stratigraphically lowest of the three storeys encountered in the north study site. Storey two and three was imaged by Anderson (2013).



- *Chart showing the method of study of the meandering fluvial channel storeys at the north study site (study site B).*

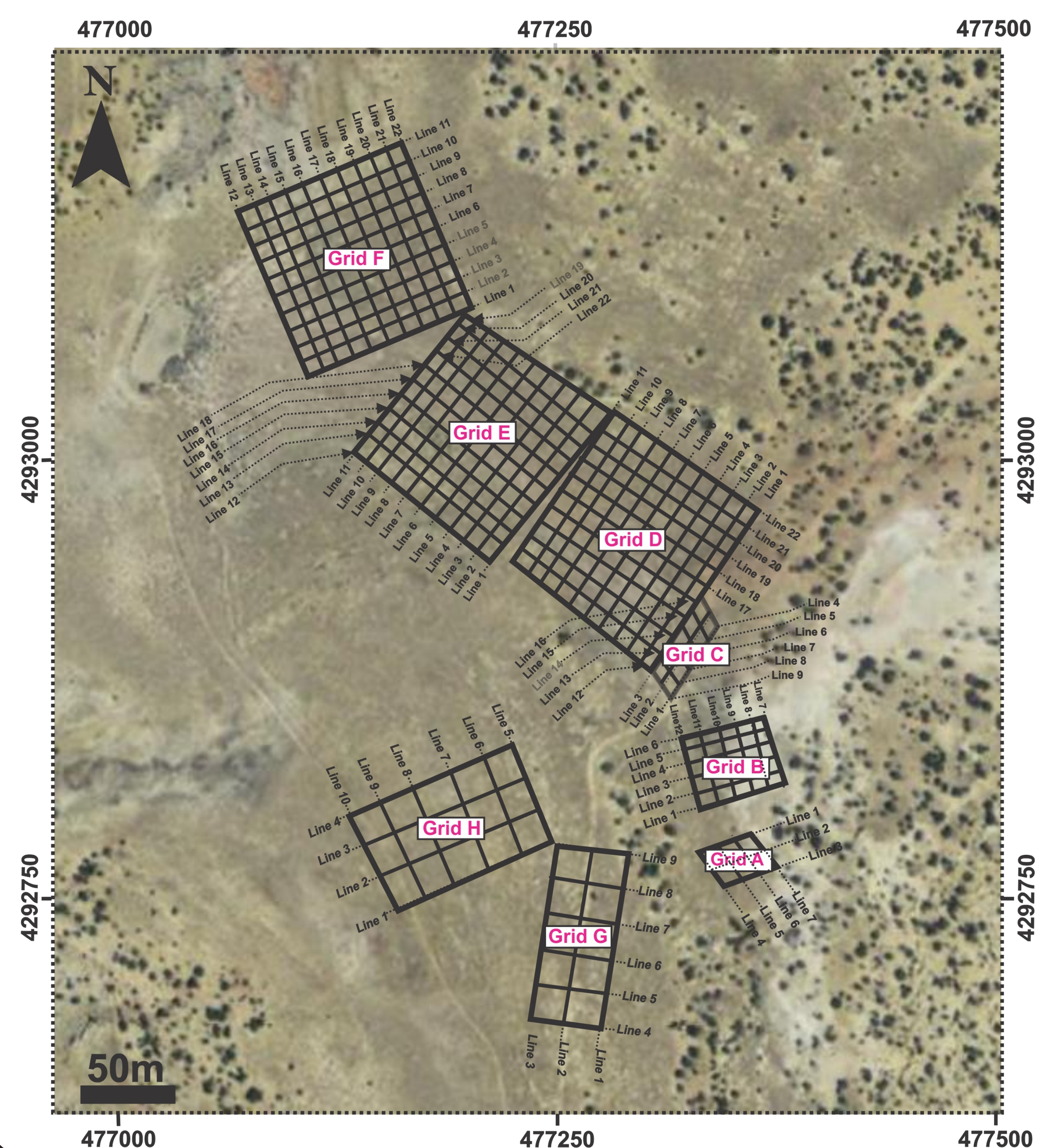
2. Data Acquisition and Analysis

Data Acquisition

- GPR was used in acquisition of data for sub-surface study of meandering channel elements. GPR is a geophysical method that uses electromagnetic radiation in the microwave band of the radio spectrum, and detects the reflected signals from surfaces of materials with contrasting dielectric properties.

- GPR data was acquired along 110 profile lines that make up the grids in the map of north study site. Area covered is 44,000 m^2 .

- GPR grids A to F are along a channel thalweg of a channel belt. Grids G and H are on the edge of the channel-belt.



- *Study site A (North study site) with GPR profiles overlay.*
- *Grid A is 30x20m*
- *Grid B is 50X50m*
- *Grid C is 50X20m*
- *Grid D is 100X100m*
- *Grid E is 100X100m*
- *Grid F is 100X100m*
- *Grid G is 100X40m*
- *Grid H is 100X60m*

Map coordinates are UTM grid NAD83 datum

GPR Type Section

- GPR response to meandering channel fill elements of the Ferron Sandstone were analyzed by comparing outcrop features with GPR data acquired over the outcrop. This study was at study site B.

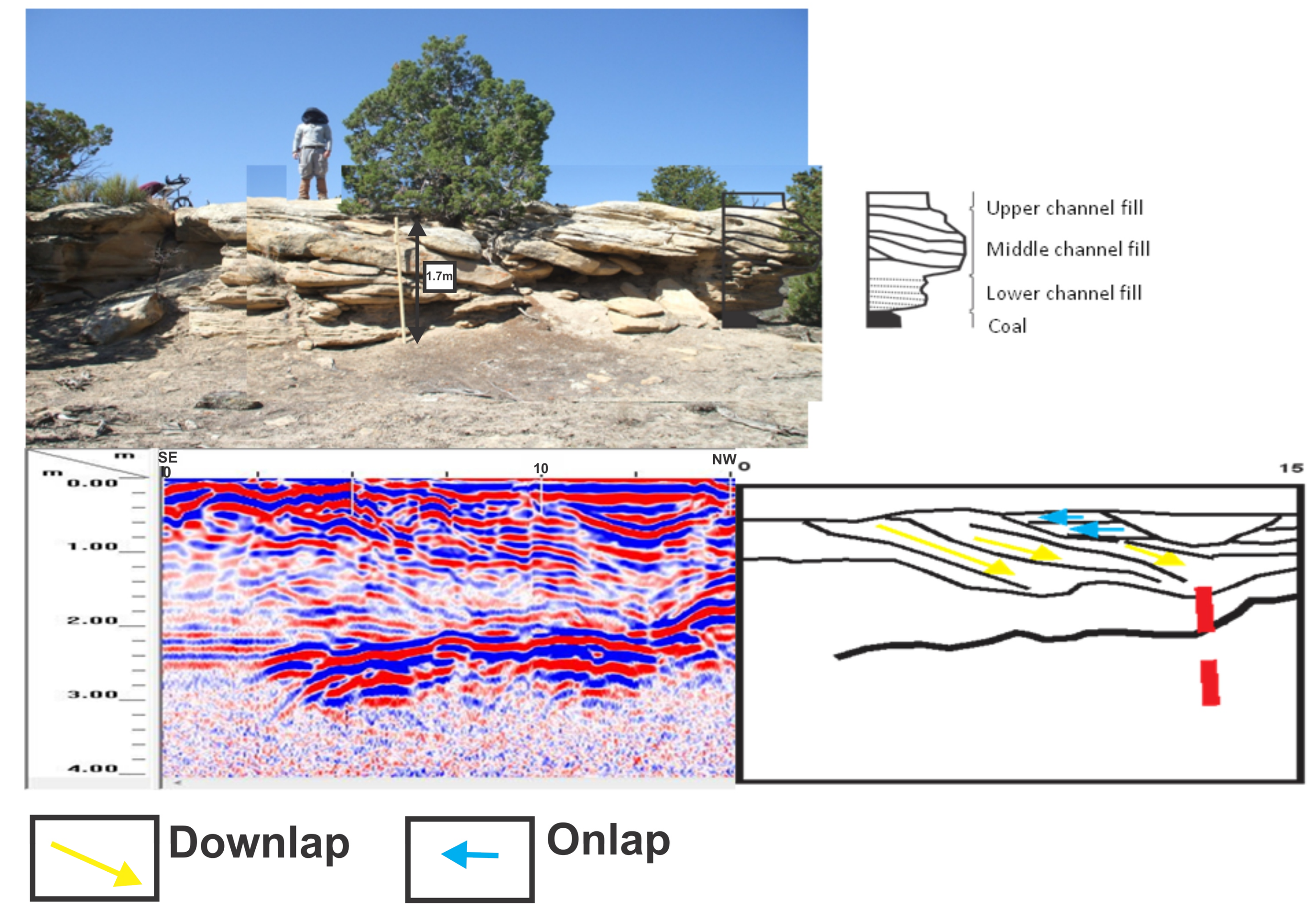
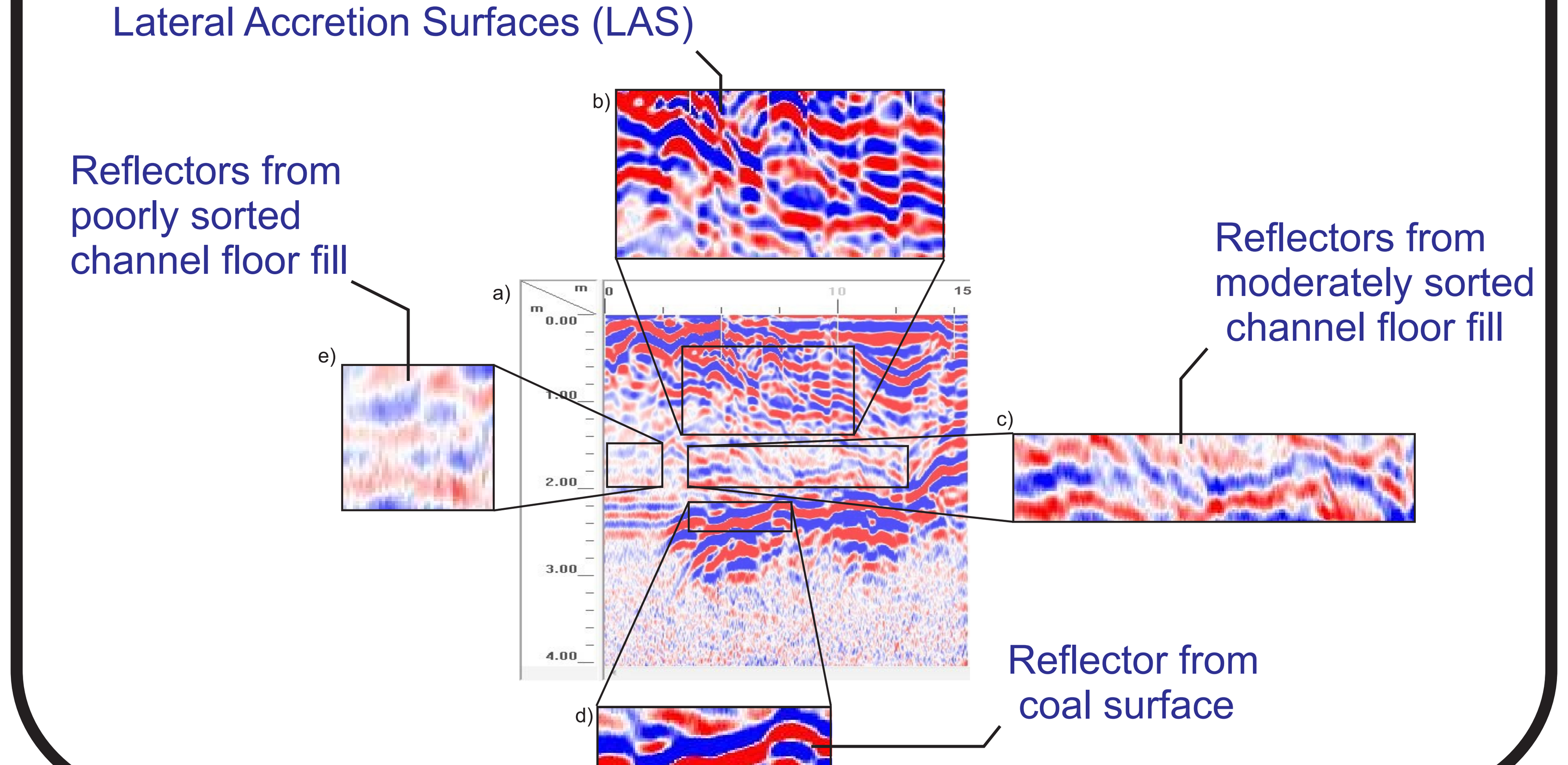
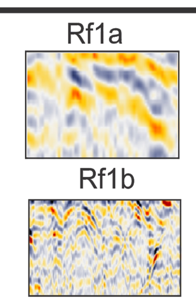
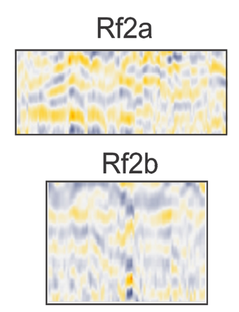
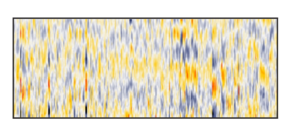
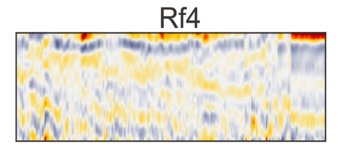
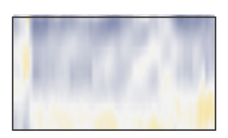


Image of GPR type section outcrop and radar data

- Comparism of GPR reflection with outcrop geometry revealed similar geometry and characteristic GPR response to sedimentary texture (Anderson 2013).

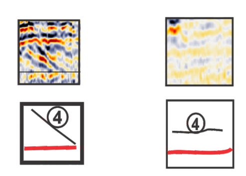
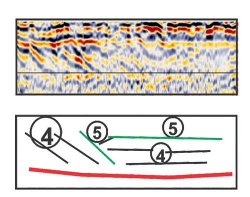
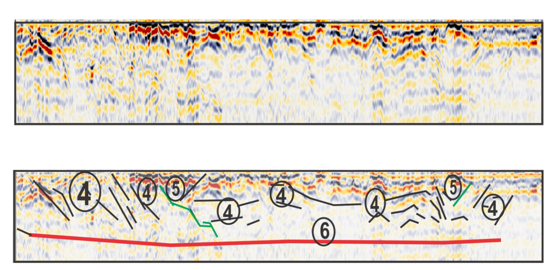
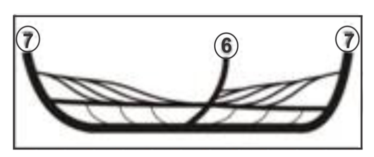
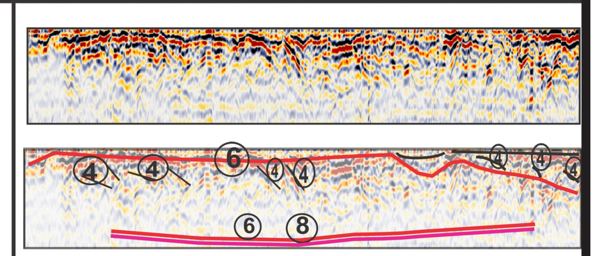


North Study Site

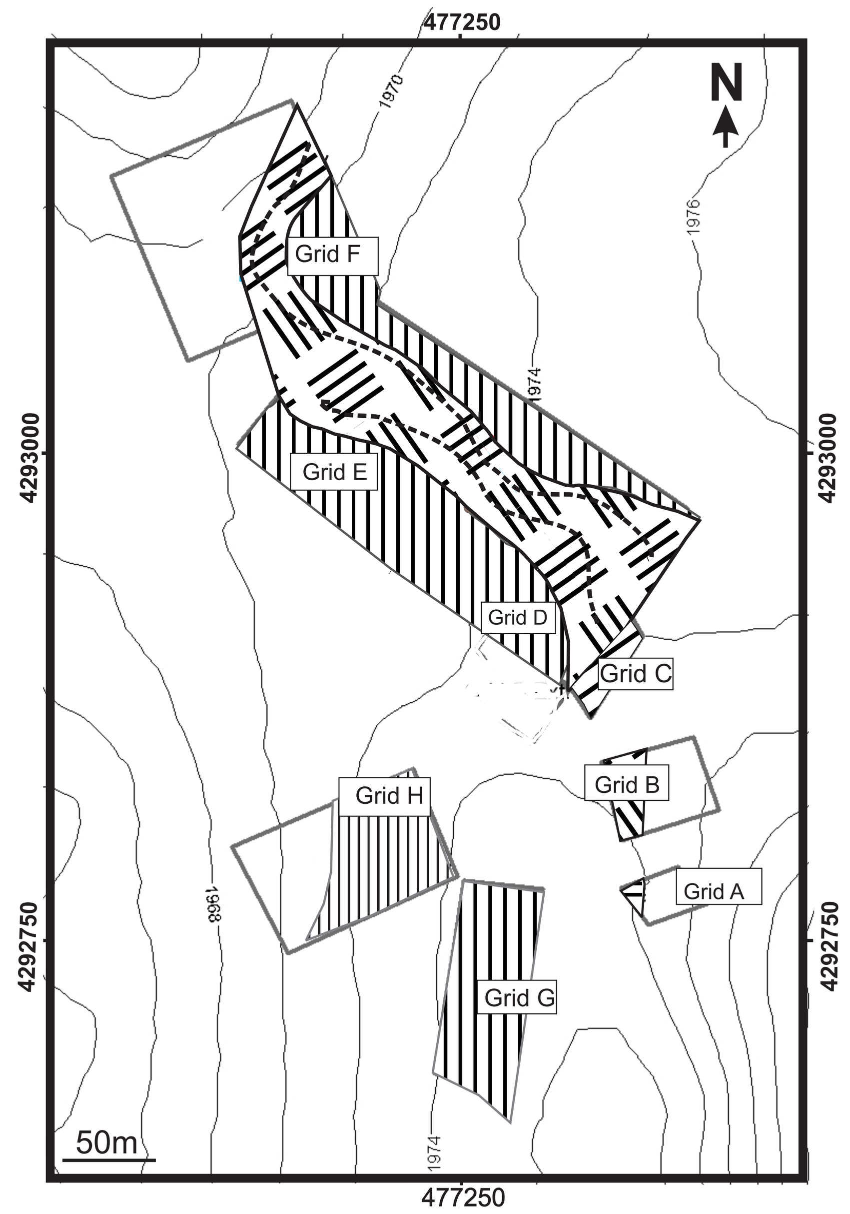
Radar Facies	Description	Image
Radar facies 1 (Rf1)	• Inclined Reflectors. • Rf1a are inclined reflectors from a lateral accretion surfaces. • Rf1b are contorted inclined reflectors.	
Radar facies 2 (Rf2)	• Near horizontal, moderately continuous, sub-parallel (Rf2a) and Sometimes chaotic reflectors (Rf2b). • Rf2a are reflectors from surfaces of moderately sorted channel floor fill. • Rf2b are reflectors from surfaces of poorly sorted channel floor fill.	
Radar facies 3 (Rf3)	• Chaotic reflectors. • Rf3 are reflectors from surfaces of mud rock and iron cemented sediments.	
Radar facies 4 (Rf4)	• Gently dipping oblique reflectors divergent from up-dip termination. • Rf4 are reflectors from surfaces of levee deposits.	
Radar facies 5 (Rf5)	• Structureless, reflection free zone. • Rf5 are reflectors from surfaces of homogenous lithology or clay component lithology.	

- *Radar facies of meandering channel elements of the Ferron Sandstone.*
- *Five radar facies were identified based on reflector geometry, continuity and amplitude.*

- *Bounding surface facies architectural hierarchy of meandering fluvial channel storey one of study site A modified from Miall 1985 and Anderson 2013.*
- *Each reflector is interpreted as a bounding surface of a rock volume that is characteristic of a unic environment in the meandering fluvial channel.*

Order	Description	Radar Facies	Radar Image and Illustration
4	Single reflector from Individual stratum. (Could be single inclined reflector or single horizontal reflector)	Rf1 or Rf2	
5	Set of reflectors (Several inclined reflector with similar inclination geometry forming a sigmoidal set of inclined reflectors or several horizontal reflector that form set of sub-parallel reflectors)	Rf1 or Rf2	
6	Basal reflector which underlay Rf1 and Rf2 and encompasses Rf1, Rf2 and Rf5 of a single interpreted channel-fill (Acts as base over which Rf2 terminates or overlays)	Rf1, Rf2 and Rf5	
7	Single basal reflector that encompasses two Sixth order surface that are at the same startigraphical level	Rf1, Rf2, Rf3, Rf4 and Rf5	
8	Single basal reflector for sixth order and seventh order surface representative of multiple channel belt at different stratigraphic height	Rf1, Rf2, Rf3, Rf4 and Rf5	

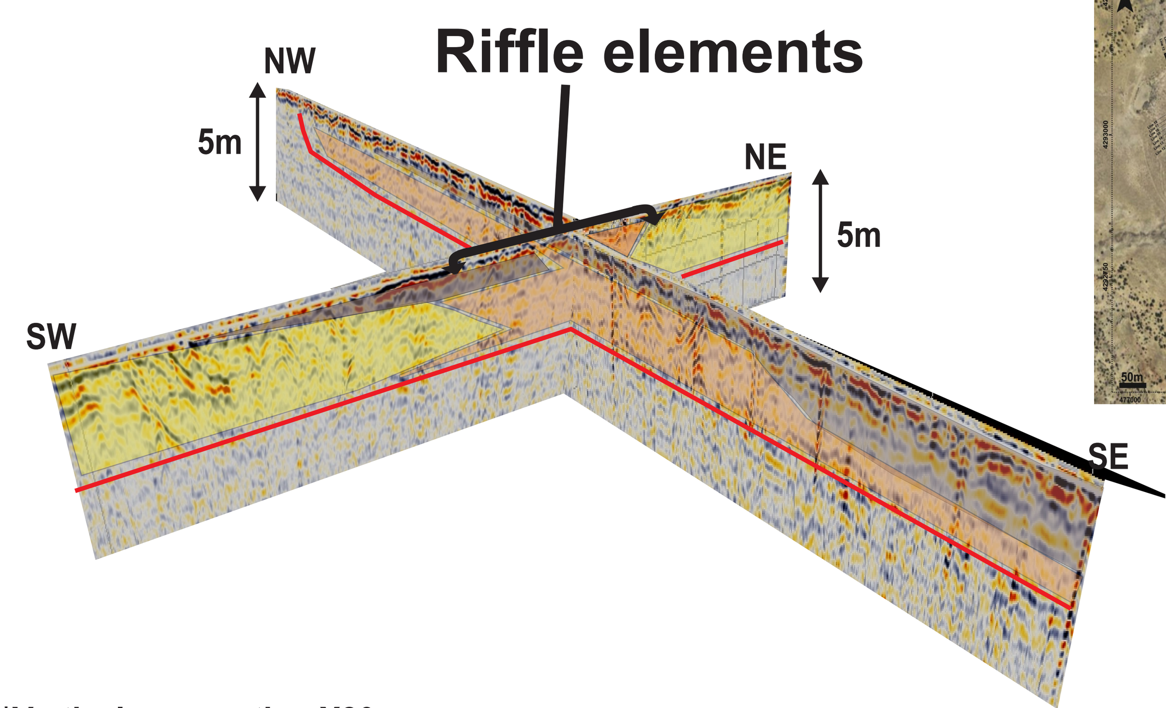
4th order bounding surface
5th order bounding surface
6th order bounding surface
8th order bounding surface

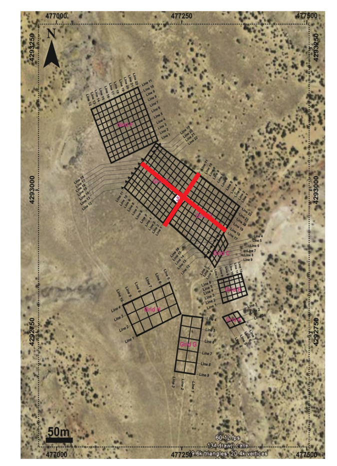


LAS = LATERAL ACCRETION SURFACE
CH.F = CHANNEL FILL

ELEVATION CONTOUR LINE
UPPER CONTACT OF LAS WITH UPPER CH.F
LOWER CONTACT OF LAS WITH LOWER BASAL CH.F
CHANNEL FLOOR FILL (Rf 2)
LATERAL ACCRETION ELEMENTS (Rf1)

- *Meandering channel of storey one facies elements distribution at time of abandonment based on interpreted radar data.*
- *Distribution of lateral accretion elements is determined using radar facies one (Rf1)*
- *Distribution of channel floor fill elements is determined using radar facies two (Rf2)*



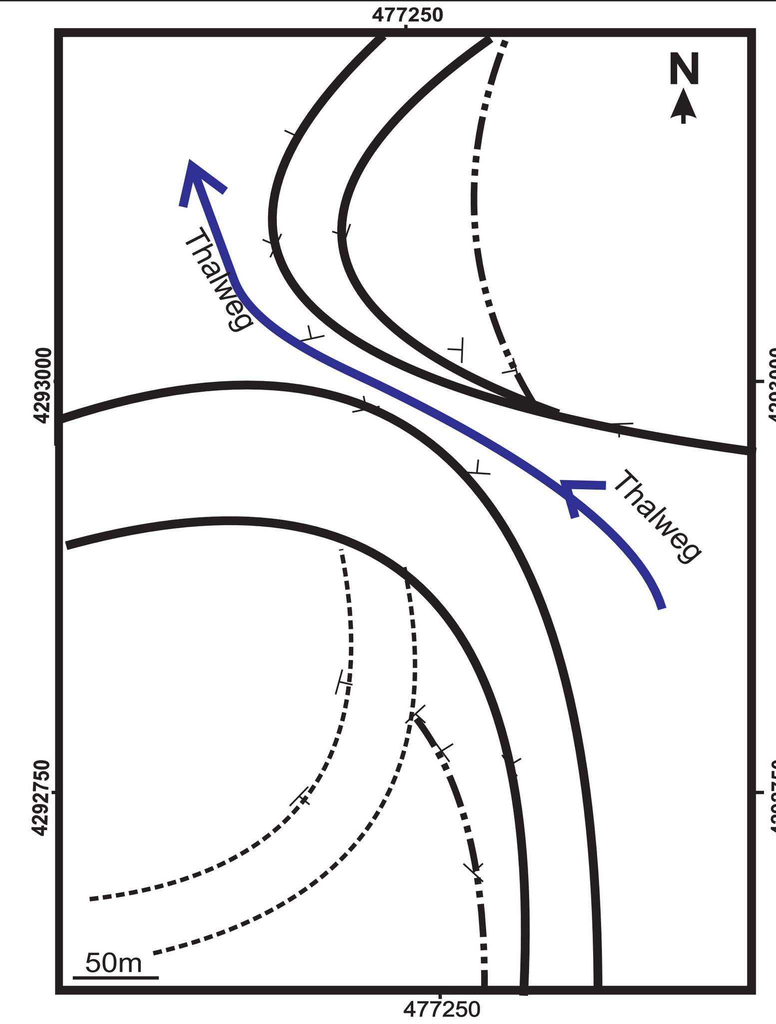


*Vertical exageration X20

Radar facies 1. Inclined reflectors from surfaces of lateral accretion elements
Radar facies 2. Horizontal reflectors from surfaces of channel floor fill
Radar facies 5. Large interval of reflector free structureless zone

- *Fence diagram of radar facies distribution in storey one at study site A. Insert is the location of radar profiles in map of study site A. (Fence diagram developed from 3D interpolation of radar profiles)*

- *Reconstruction of meandering channel belt storey one using lateral accretion surface (LAS) history.*
- *Radar data from LAS showed discordance of LAS within lateral accretion bar indicating lateral accretion bar migration and adjustment of channel thalweg.*



STRIKE AND DIP OF LATERAL ACCRETION SURFACES
LATERAL ACCRETION DEPOSITS - EARLY HISTORY
LATERAL ACCRETION DEPOSITS - INTERMEDIATE HISTORY
LATERAL ACCRETION DEPOSITS - RECENT HISTORY BEFORE ABANDONMENT

3. Conclusion

- Ground penetrating radar imaging was used to identify five radar facies of a meandering fluvial channel.
- Radar data shows riffle elements as near horizontal continuous to discontinuous reflectors that onlap or downlap adjacent lateral accretion surfaces.
- Radar facies (Rf2) of riffle elements deposits have relatively lower amplitude than lateral accretion surface reflectors indicating more homogeneity in riffle deposits.
- Cases where lateral accretion reflector amplitude strength is similar to the amplitude strength of adjacent riffle elements indicate homogeneity in lithologic properties of both deposits and might encourage fluid transmissivity between the two bodies.

4. References

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