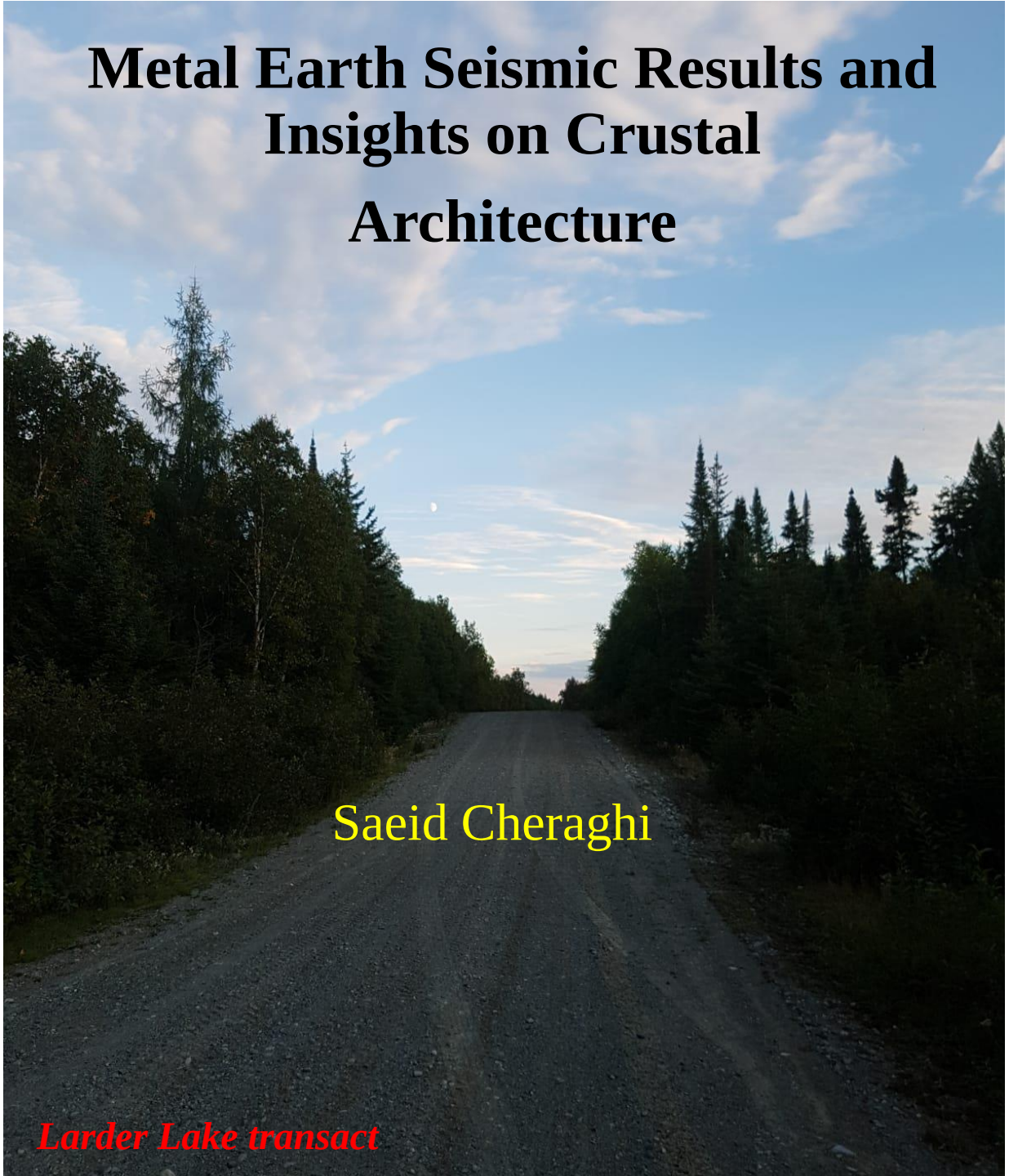
Metal Earth Seismic Results and Insights on Crustal Architecture



Saeid Cheraghi

Larder Lake transact

METAL EARTH

A new Canadian research initiative funded by Canada First Research Excellence Fund.

CANADA FIRST RESEARCH EXCELLENCE FUND

Canada

Laurentian University
Université Laurentienne
HARQUAIL SCHOOL OF EARTH SCIENCES
ÉCOLE DES SCIENCES DE LA TERRE

MERC
Mineral Exploration Research Centre

Outline

- Seismic surveys in the Swayze, Larder Lake, Matheson
- Evaluating the survey geometry
- Industry scale processing flow applied to crooked surveys
- 3D swath processing
- Future work

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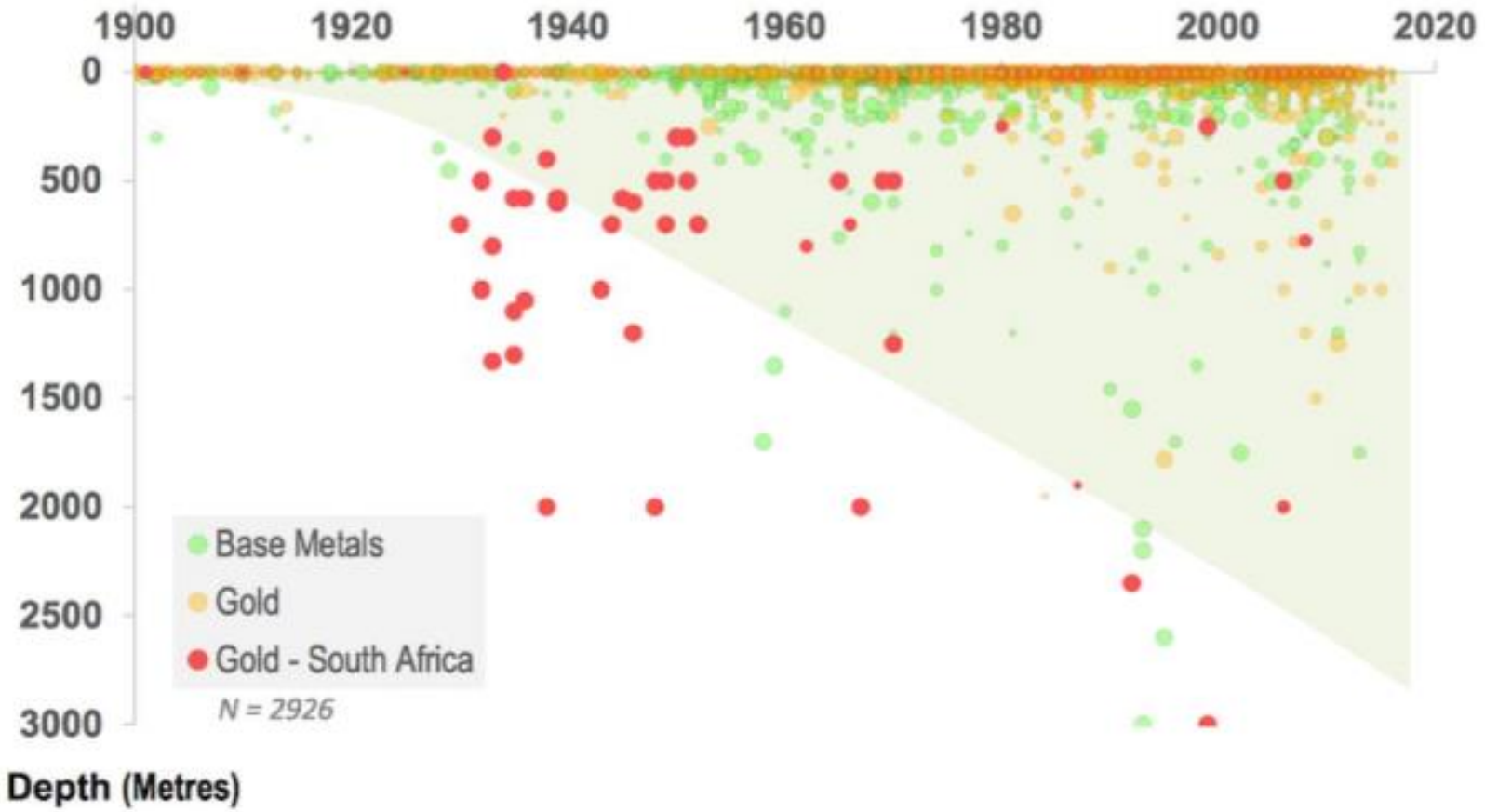
Exploration Depth



Modified from Schodde, 2017

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Introduction

- **After more than 30 years experience of acquiring seismic surveys in hard rock environment, greenstone belts (e.g., Lithoprobe, Discover Abitibi, TGIs program)**

  - New regional and high-resolution seismic surveys were acquired in northern Ontario/Quebec for Metal Earth project

  - The focus of study is Precambrian and younger terrains

  - Metal Earth will transform our understanding of the genesis of base and precious metal deposits during Earth's evolution.

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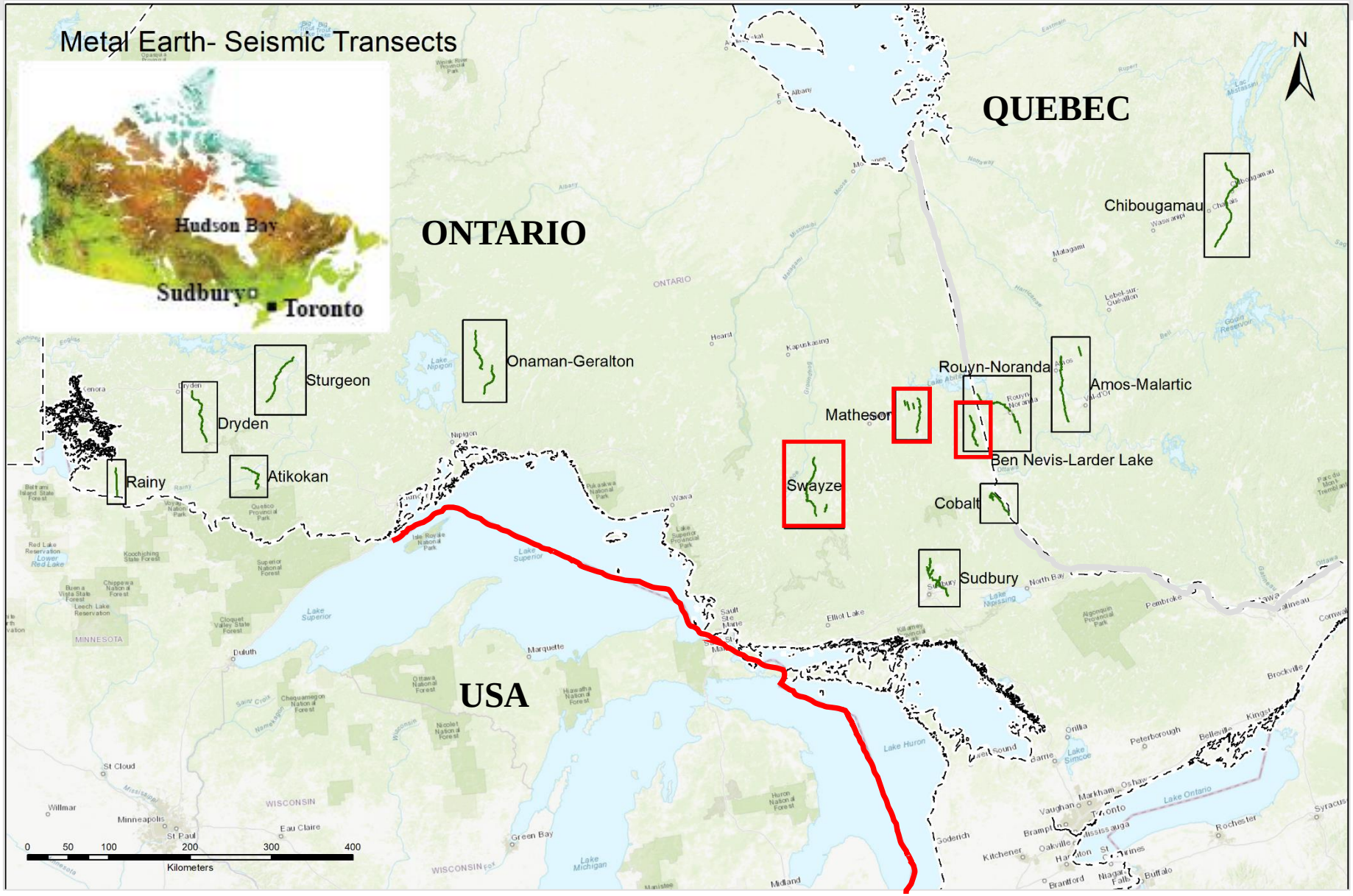
Metal Earth exploration transacts



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- **Regional surveys (R1):**

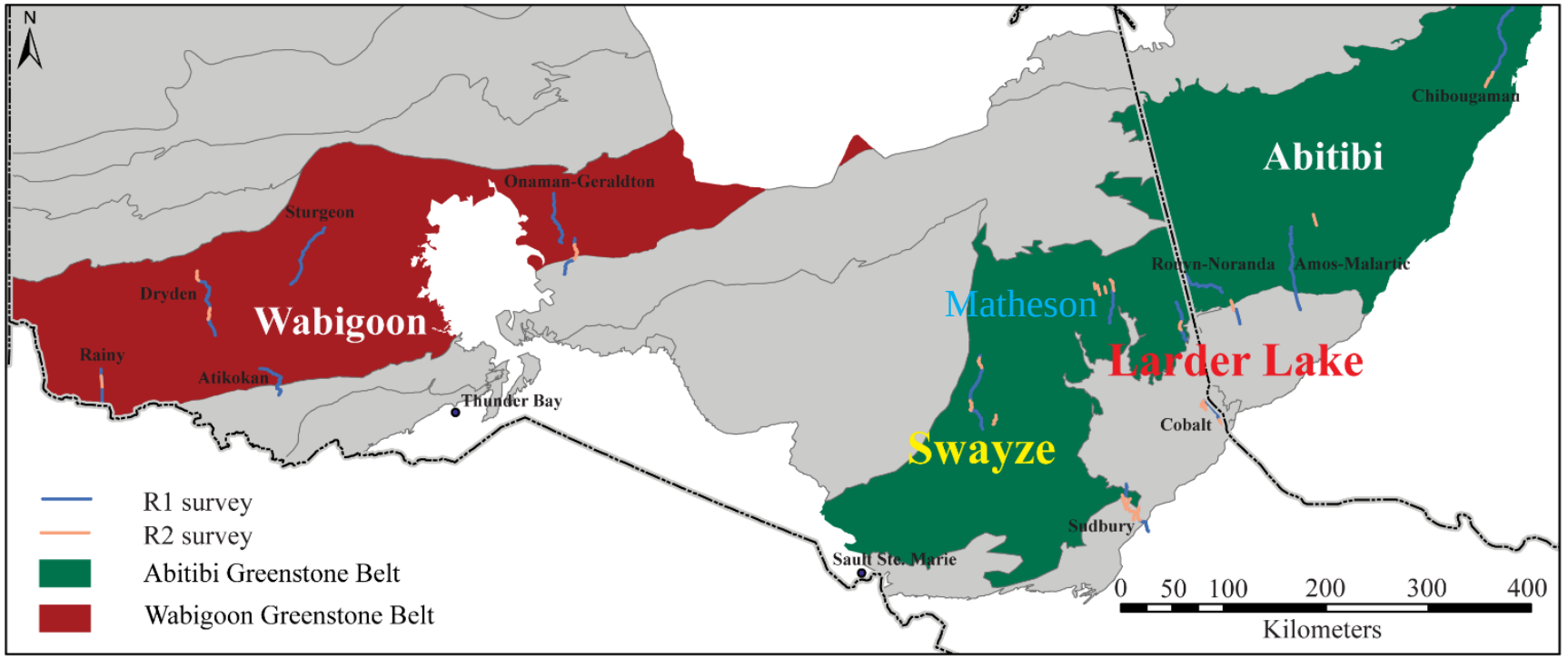
Shot-spacing: 50 m

Receiver-spacing: 25 m

- **High-resolution surveys (R2):**

Shot-spacing: 6.25 m

Receiver-spacing: 12.5 m



- Acquired regional and high-resolution surveys for Metal Earth (13 transacts, ~ 1000 km R1 and ~ 200 km R2)

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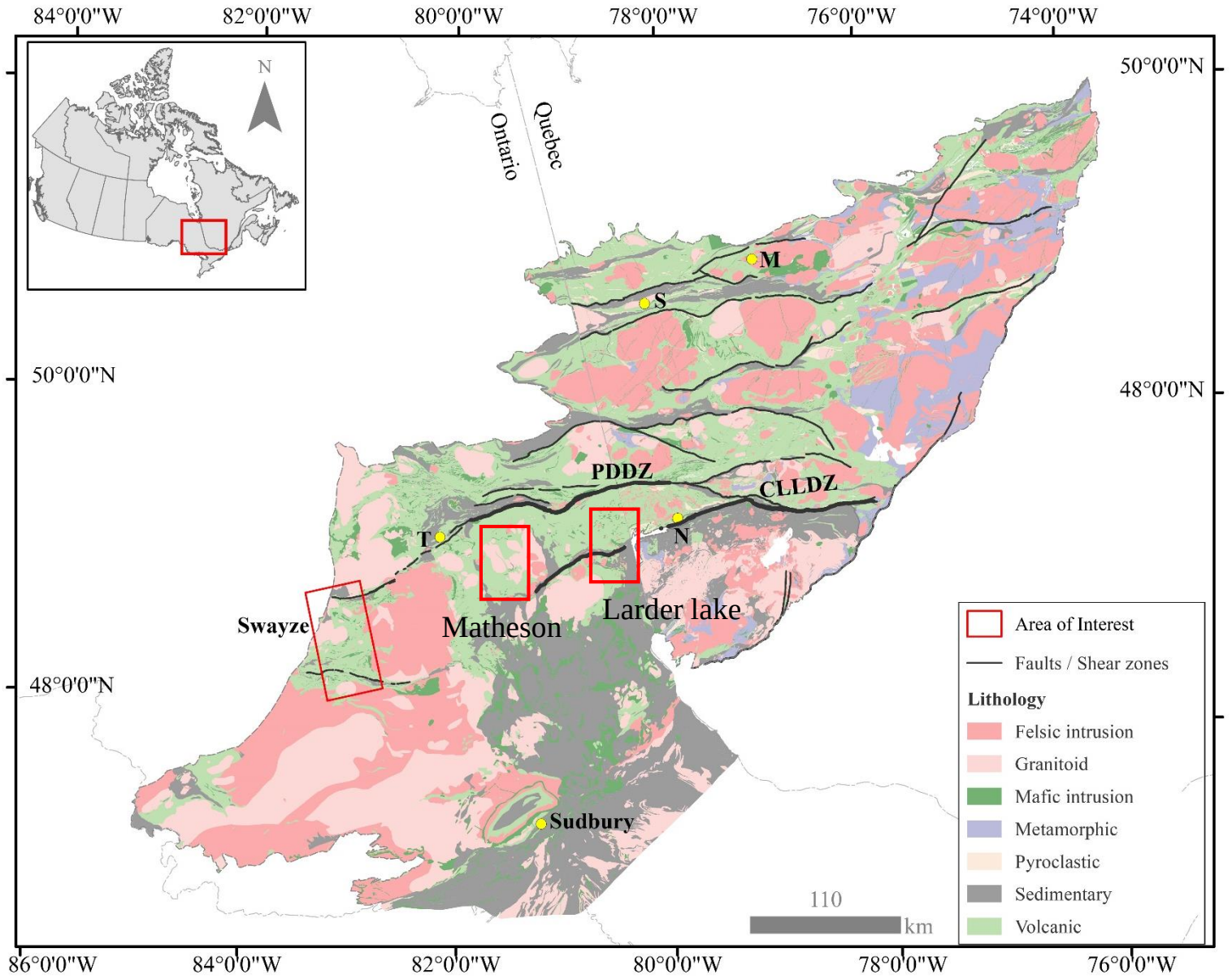
Abitibi geological map

PDDZ:
Porcupine–Destor deformation zone

CLLDZ:
Cadillac–Larder Lake deformation zone

Mining camps:
M:Matagami
N:Noranda
S:Selbaie
T:Timmins



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Survey attributes

	Regional survey (R1)	High-resolution survey (R2)
Spread type	Split spread	Split spread
Recording instrument	Geospace GSX Node	Geospace GSX Node
Field data format	SEGD	SEGD
Geophone type	5Hz, single component	5Hz, single component
Source type	VIBROSEIS	VIBROSEIS
No. of source	4	3
Sweep length (s)	28	28
No. of Sweeps	4	1
Source starting frequency (Hz)	2	2
Source ending frequency (Hz)	96	120
Field low cut (Hz)	1	207
Field high cut (Hz)	1	207
Recording length (s)	12	12
Sampling rate (ms)	2	2
Shot spacing (m)	50	6.25
Receiver spacing (m)	25	12.5
Nominal maximum offset for processing (km)	15 km	10 km

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Metal Earth Vibroseis 2D Seismic Acquisition

Youtube Video: “Metal Earth Seismic Survey 2017”
https://www.youtube.com/watch?v=G_-nkMJxI-g&t=14s

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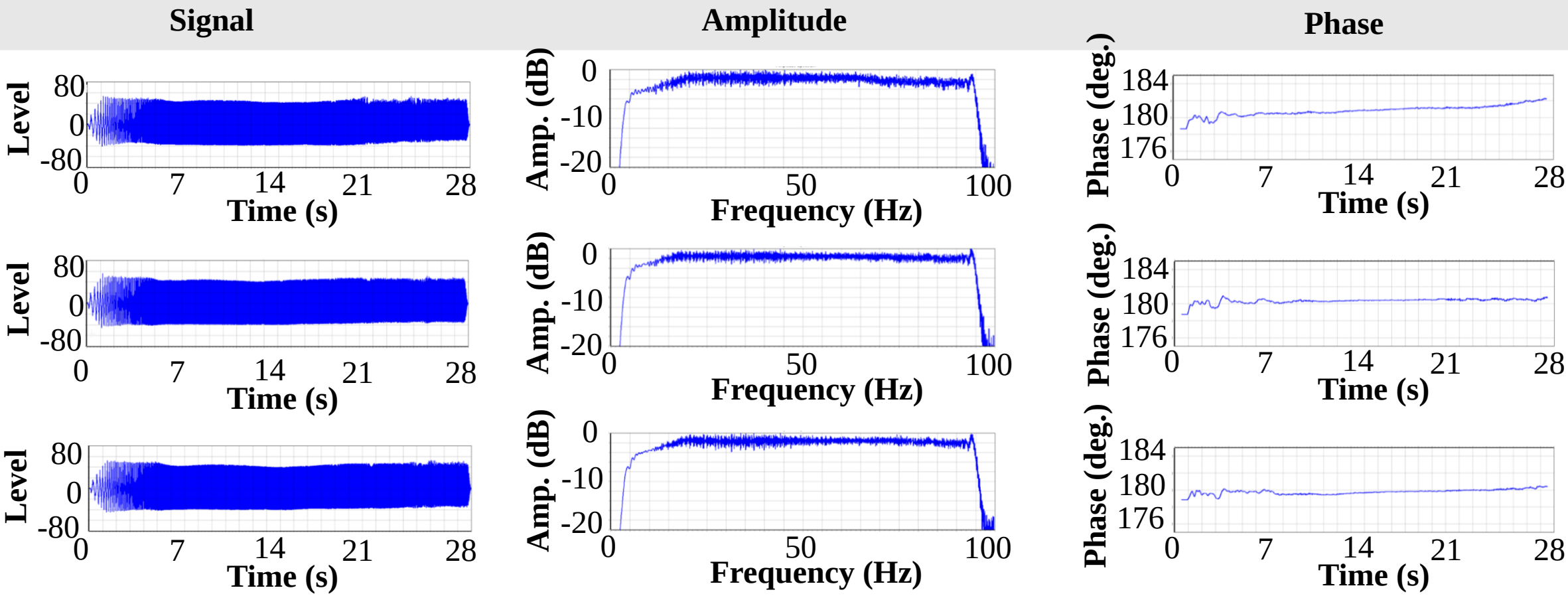

Seismic source attributes

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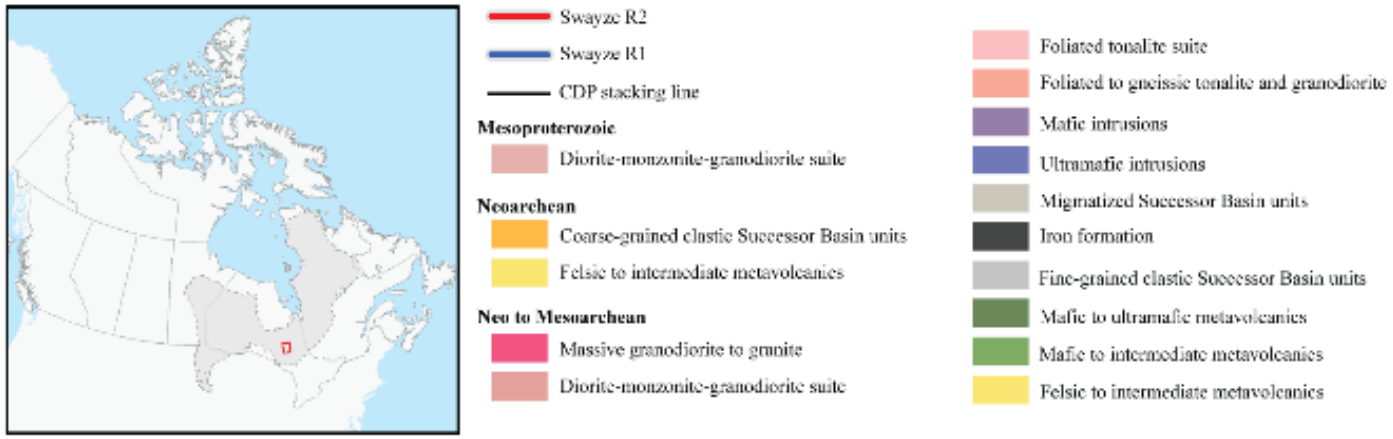
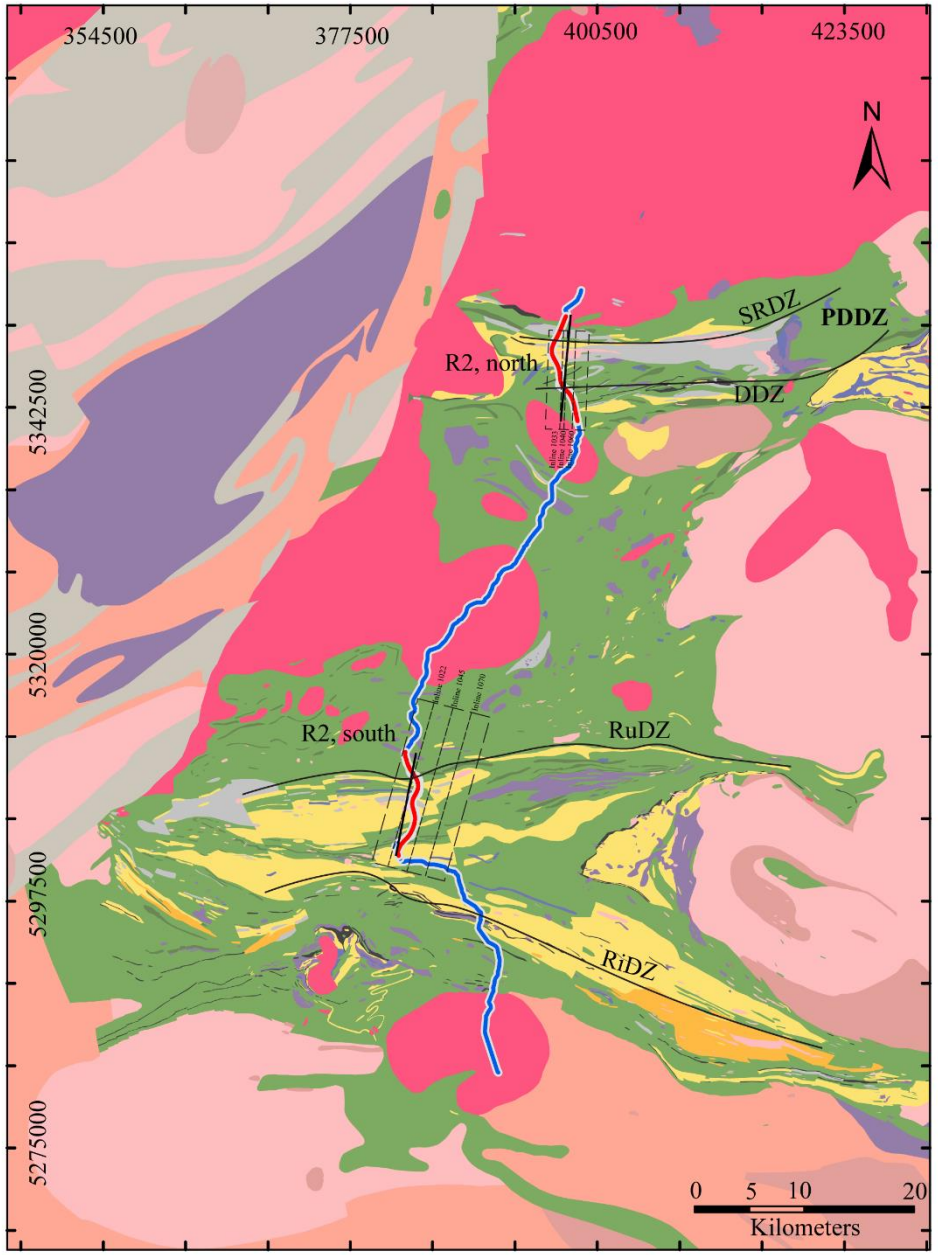
R2 surveys in Swayze area

Swayze north

Swayze south

- Each survey is about 10 km
- The survey is acquired on the complex geology
- The survey follows local roads /forest trail





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Geophysical Prospecting

EAGE EUROPEAN ASSOCIATION OF GEOSCIENTISTS & ENGINEERS

Geophysical Prospecting, 2019 doi: 10.1111/1365-2478.12854

High-resolution seismic imaging of crooked two-dimensional profiles in greenstone belts of the Canadian shield: results from the Swayze area, Ontario, Canada

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ABSTRACT

In 2017, the Metal Earth multi-disciplinary exploration project acquired a total of 921 km of regional deep seismic reflection profiles and 184 km of high-resolution seismic reflection profiles in the Abitibi and Wabigoon greenstone belts of the Superior province of Canada. The Abitibi belt hosts several world-class mineral deposits, whereas the Wabigoon has sparse economic mineral deposits. Two high-resolution surveys in the Swayze area, a poorly endowed part of the western Abitibi greenstone belt, served as pioneer surveys with which to better understand subsurface geology and design a strategy to process other surveys in the near future. Swayze seismic data were acquired with crooked survey geometries along roads. Designing an effective seismic processing flow to address these geometries and complex geology required straight common midpoint lines along which both two-dimensional prestack dip-moveout correction and poststack migration processing were applied. The resulting seismic sections revealed steeply dipping and subhorizontal reflections; some correlate with folded surface rocks. An interpreted fault/deformation zone imaged in Swayze north would be a target for metal endowment if it extends the Porcupine–Destor structure. Because of the crooked line geometry of the surveys, two-dimensional /three-dimensional prestack time migration and swath three-dimensional processing were tested. The prestack time migration algorithm confirmed reflections at the interpreted base of the Abitibi greenstone belt. The swath three-dimensional images provided additional spatial details about the geometries of some reflections, but also had less resolution and did not detect many reflectors observed in two dimensions. Geological contacts between felsic, mafic and ultramafic greenstone rock layers are thought the main cause of reflectivity in the Swayze area.

Key words: Data processing, Seismic, Imaging, Interpretation, Swayze greenstone belt.

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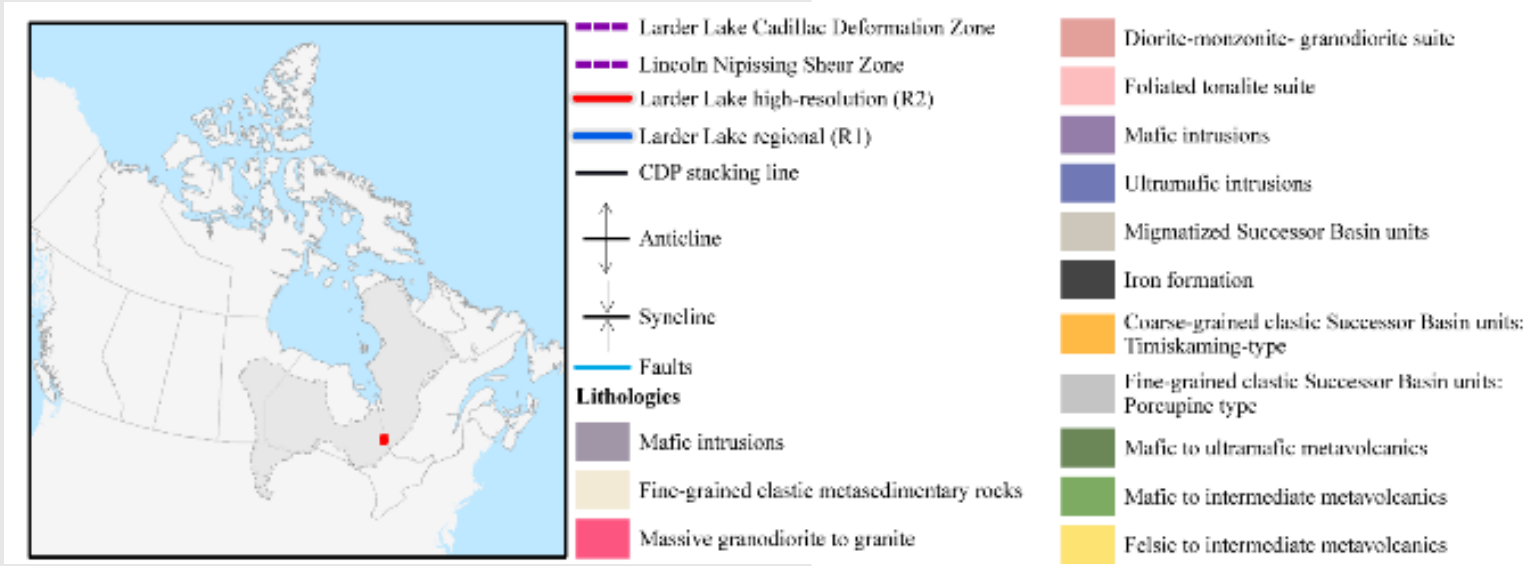
R2 survey in Larder Lake area

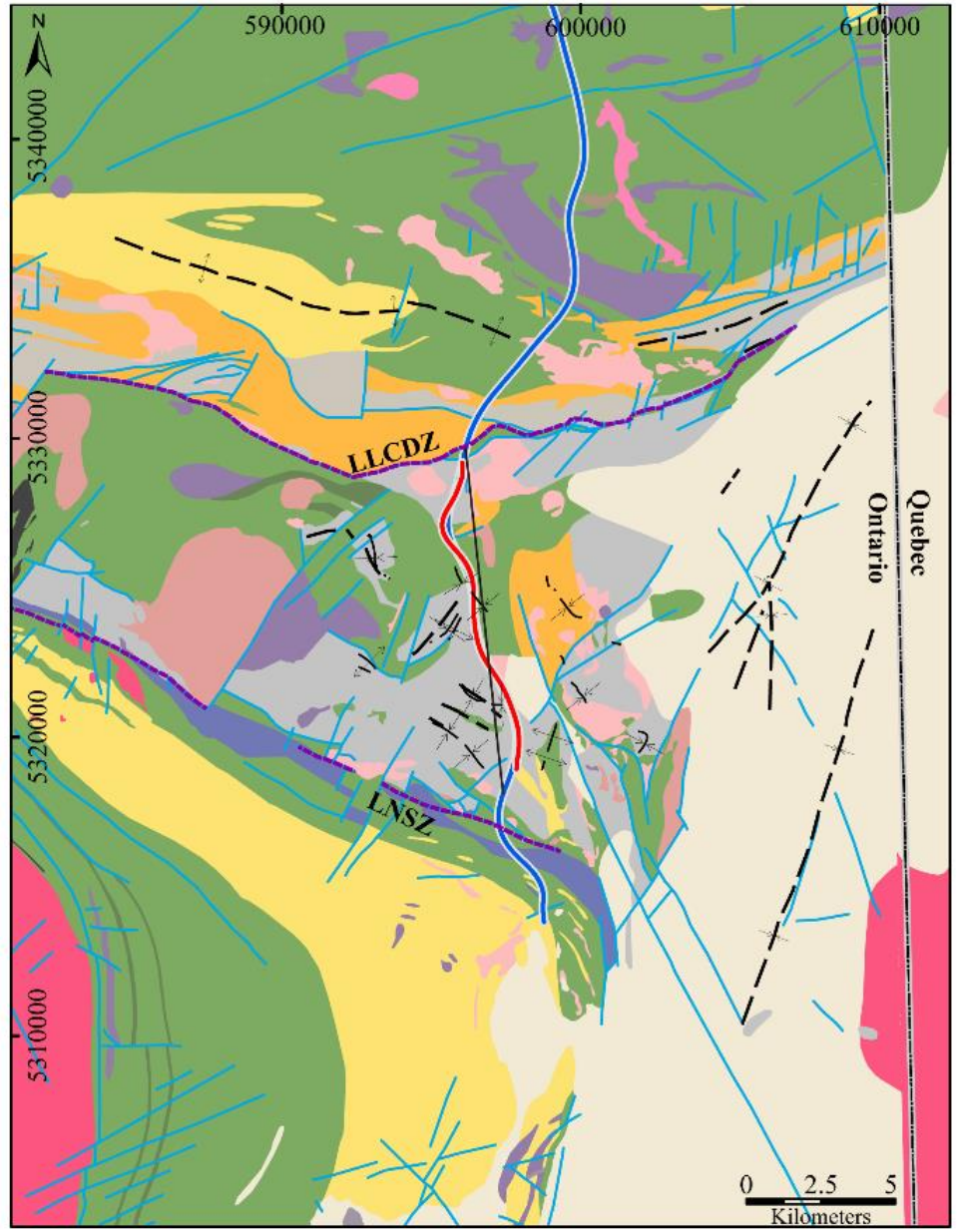
10 km high resolution survey is acquired between:

Larder-Cadillac deformation zone (LLCDZ) and

Lincoln Nipissing shear zone (LNSZ)

- Complex geology
- Crooked survey





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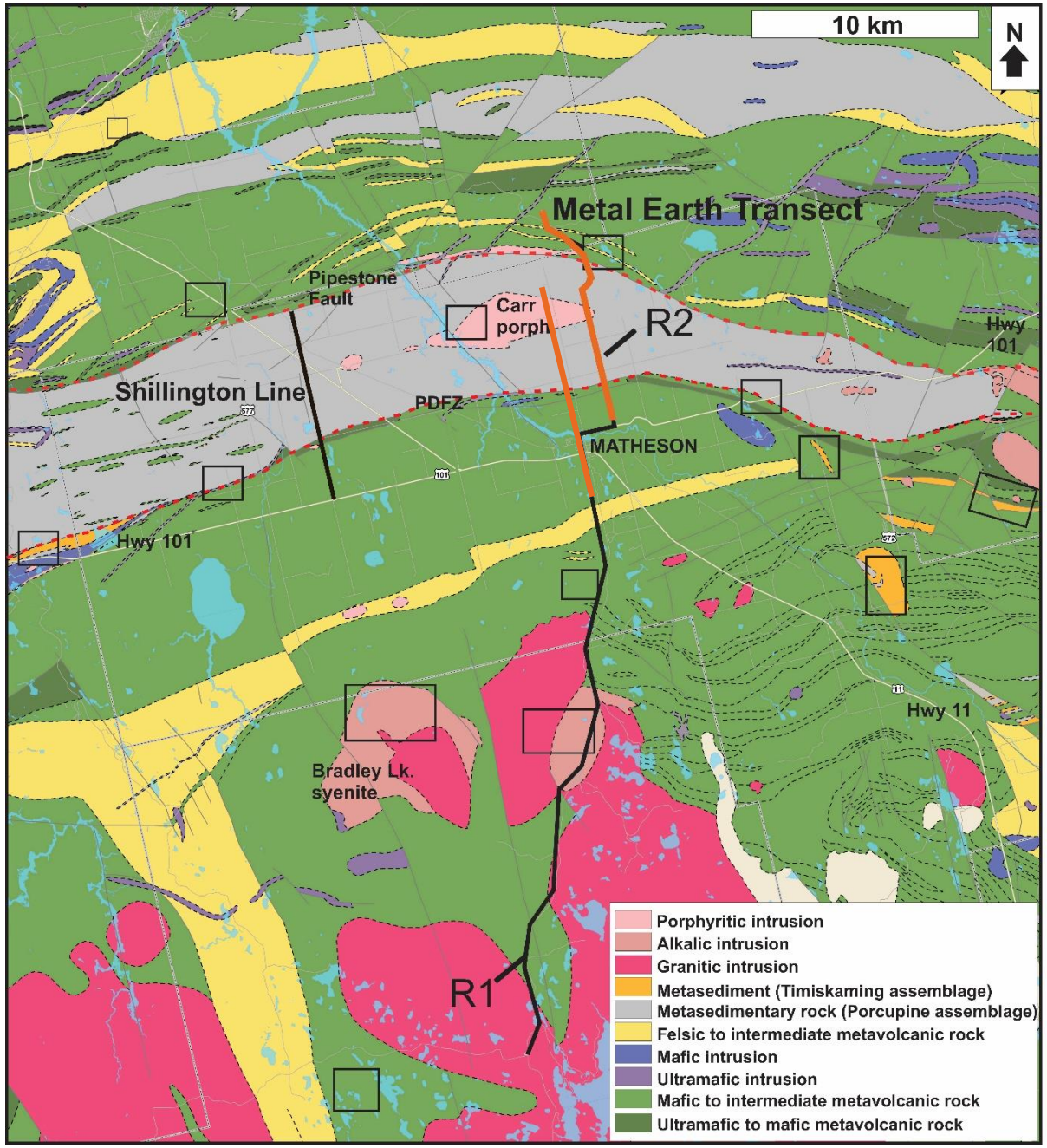
R2 survey in Matheson area

~ 20 km high resolution survey is acquired.

- Two parallel receiver lines
- Shots are acquired only on eastern line



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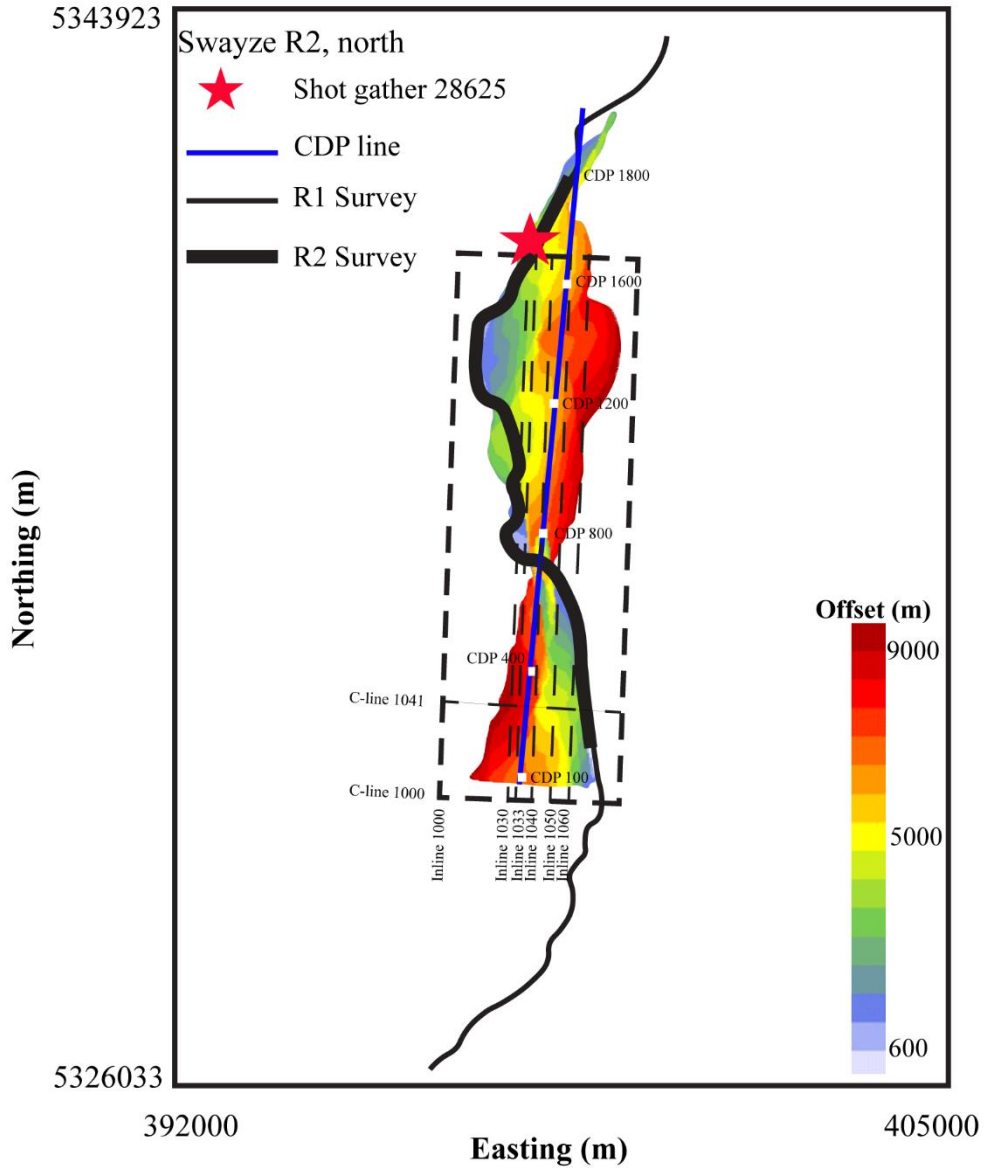
2D and 3D processing

- CDP spacing: 6.5 m (2D)
- CDP bins: 50 m by 50 m (3D)



METAL EARTH

2D and 3D processing

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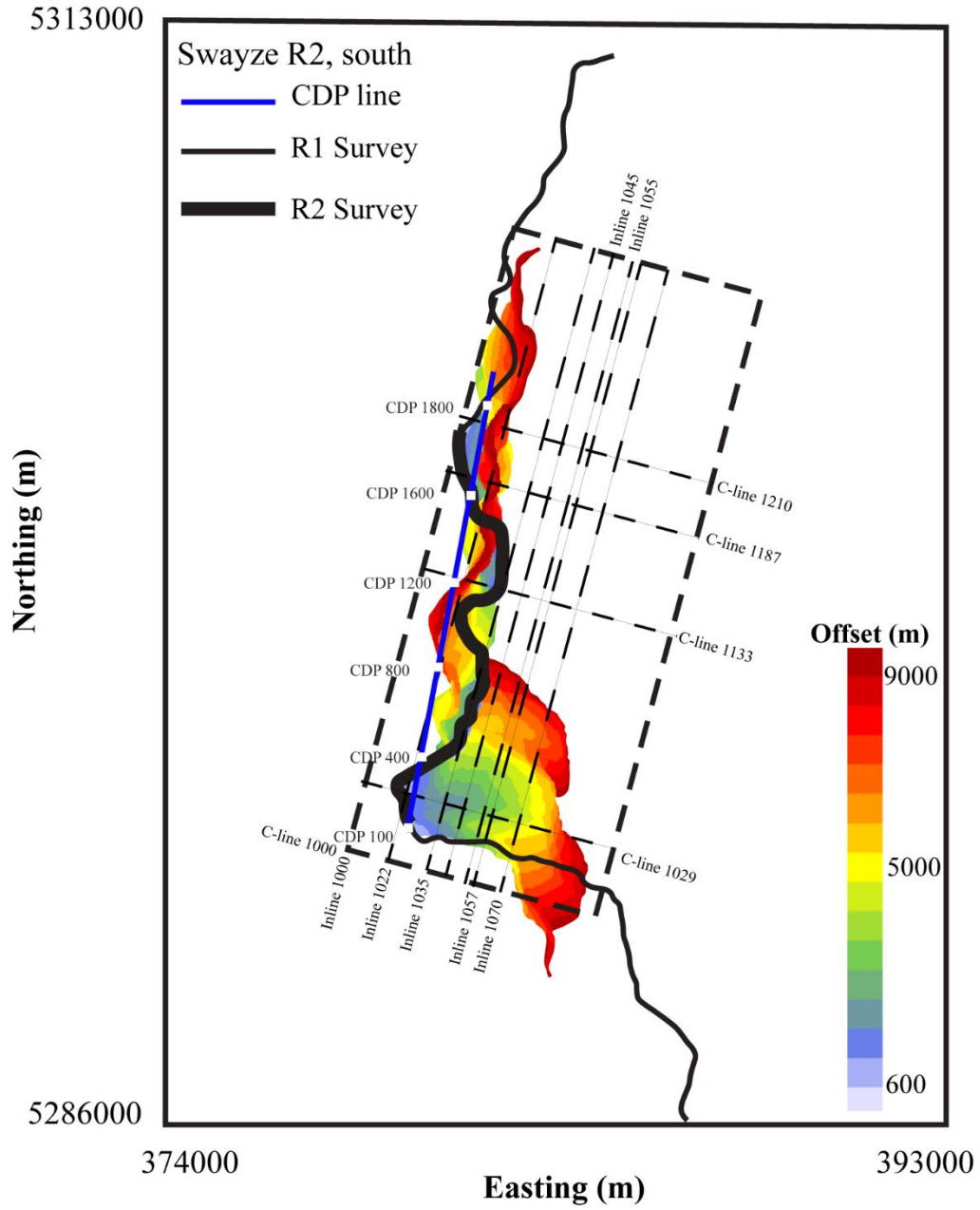
- CDP bins: 50 m by 50 m (3D)



METAL EARTH

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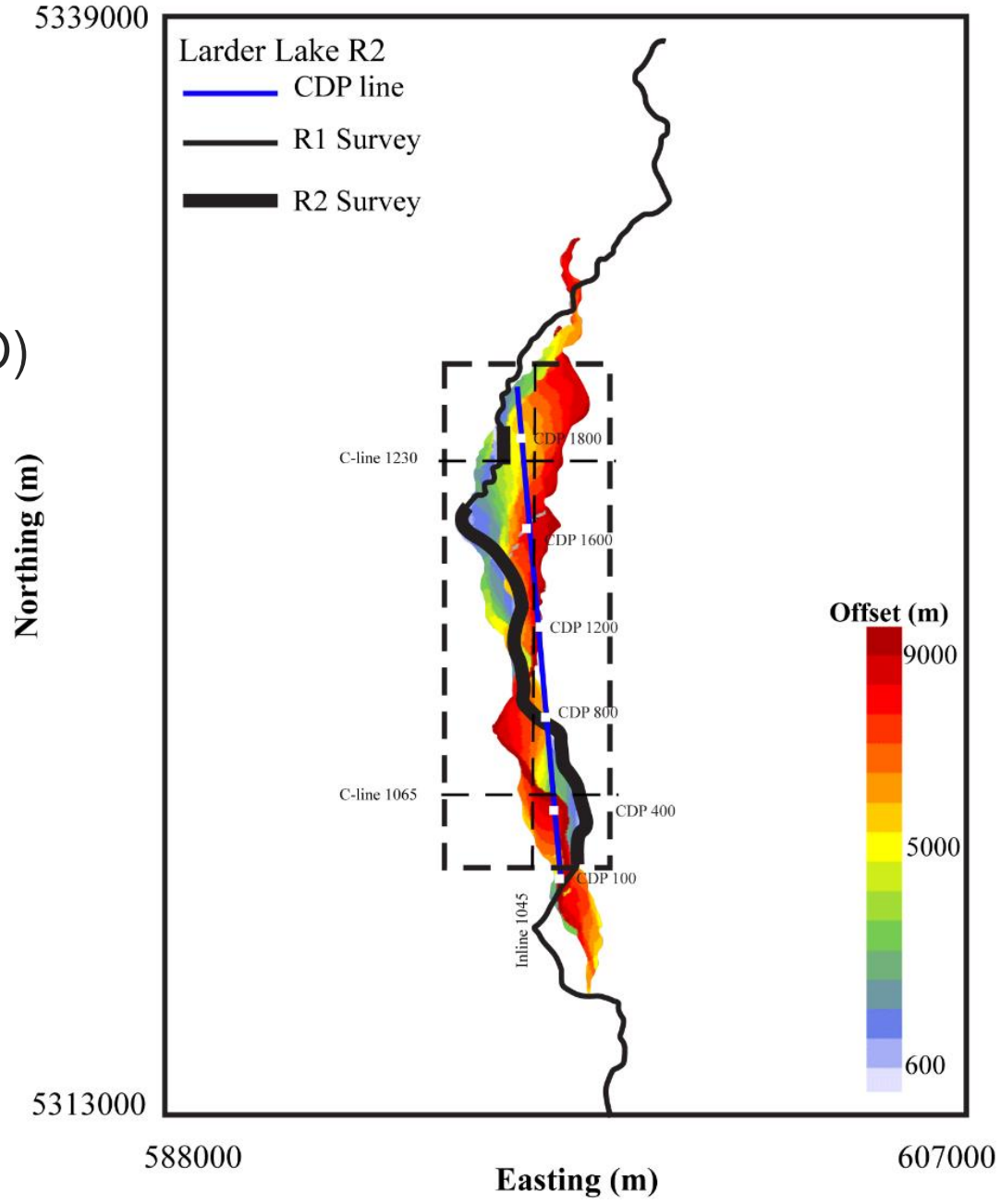


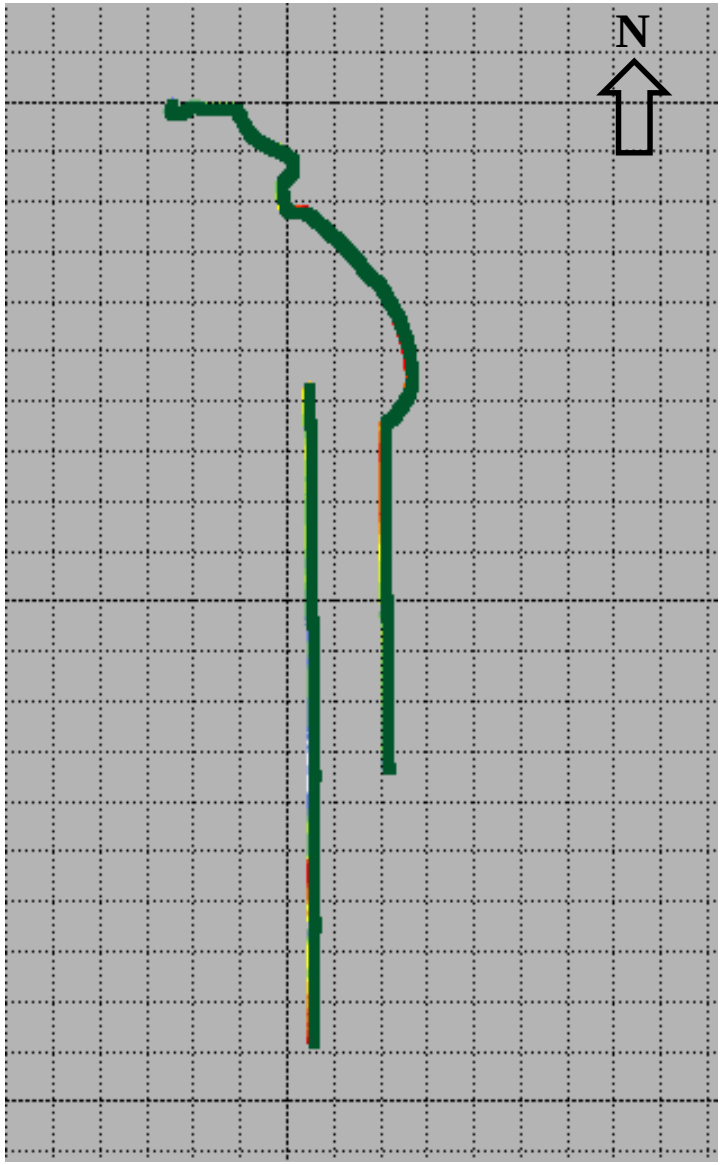
2D and 3D processing

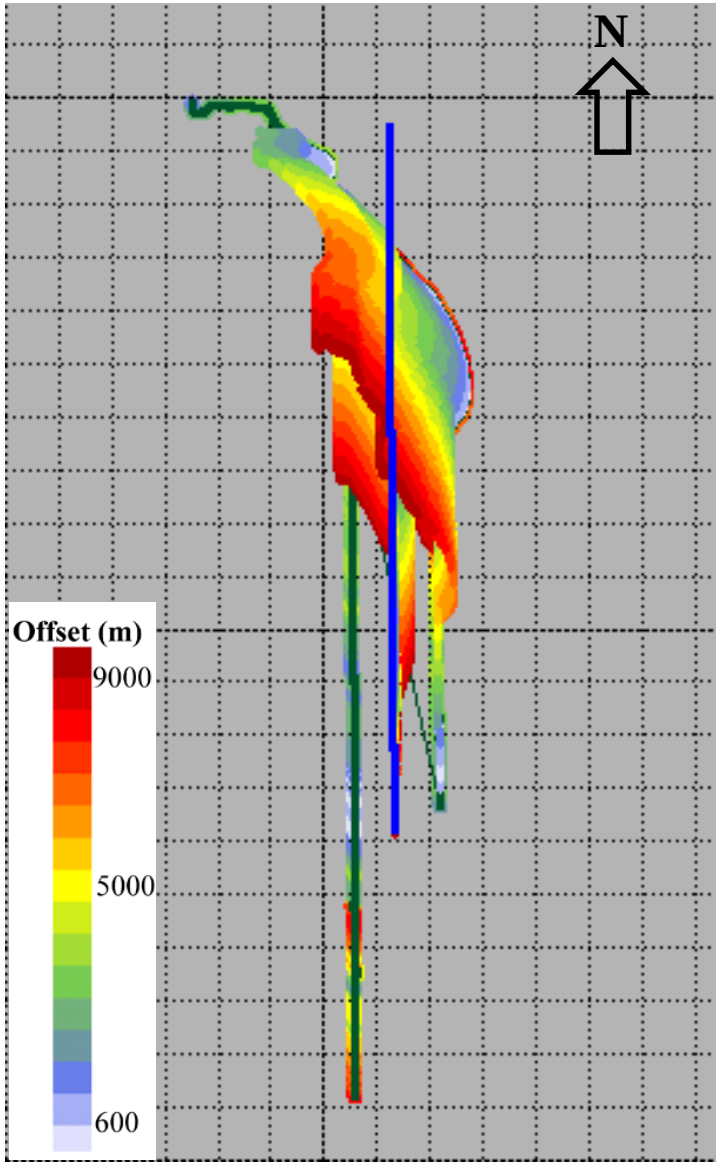
Matheson survey

Is it a spoon-straw survey?

- CDP spacing: 6.5 m (2D)
- CDP bins: 50 m by 50 m (3D)

CDP line





Seismic shots only on the east line
Receivers on east and west line

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Swayze north and south surveys
Reading data in SEGD format and converting them to SEGY format
Setup geometry
Trace editing (manual)
First arrival picking (0-10000 m)
Elevation and refraction static corrections (replacement velocity 5200 m/s, V0 1000 m/s)
Spherical divergence compensation (velocity power of 2 and travel time power of 1, V^2t)
Median velocity filter (1400, 2500, 3000 m/s)
Band pass filter (20-35-100-120 Hz)[a]
Airwave filter
Surface-consistent deconvolution (filter length of 100 ms and gap of 25 ms)
Trace balancing
AGC (window of 150 ms)
Velocity analysis
Surface consistent residual static corrections
DMO corrections
Top-muting
Stacking
Coherency filter (F-X deconvolution, filter length of 19 traces)
Trace balancing
Phase shift time migration (5000 m/s)

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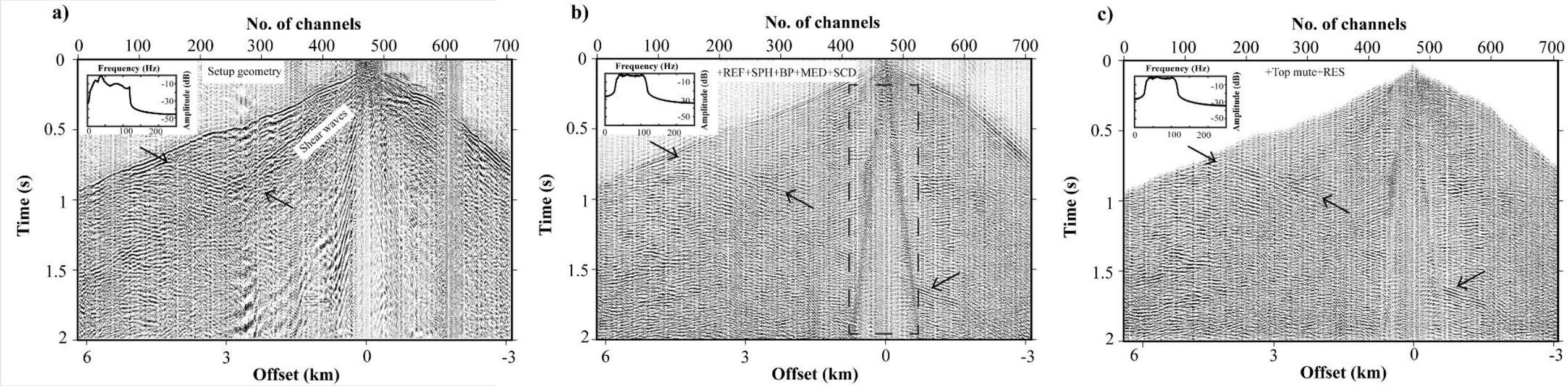
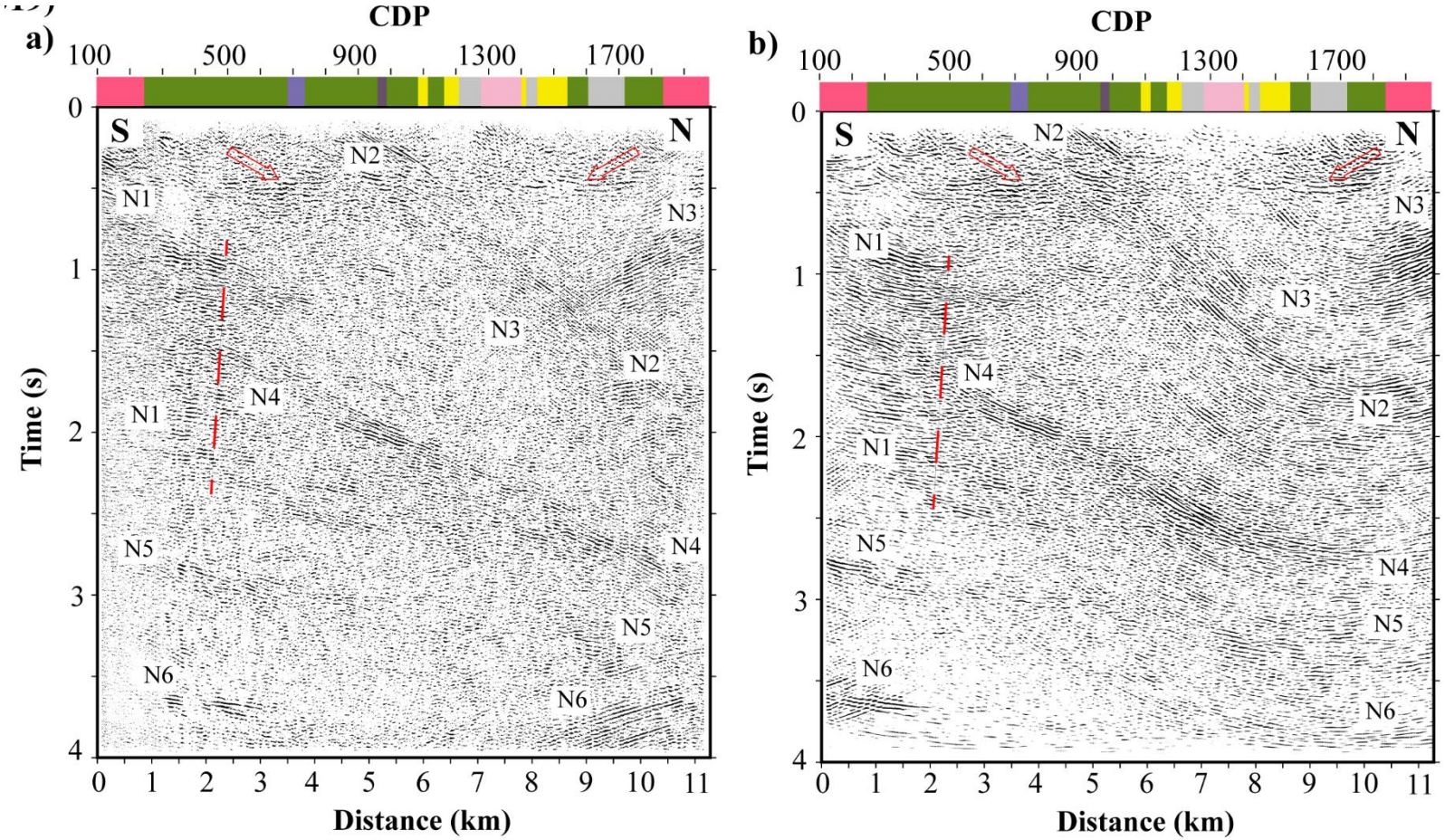
Example shot from Swayze north survey



Swayze north:

a) DMO-stacked

b) Migrated-stacked



Felsic metavolcanic rocks

Intermediate metavolcanic rocks

Massive granodiorite to granite

Mafic metavolcanic rocks

Mafic intrusions

Fine-grained clastic Successor Basin units

Ultramafic intrusions

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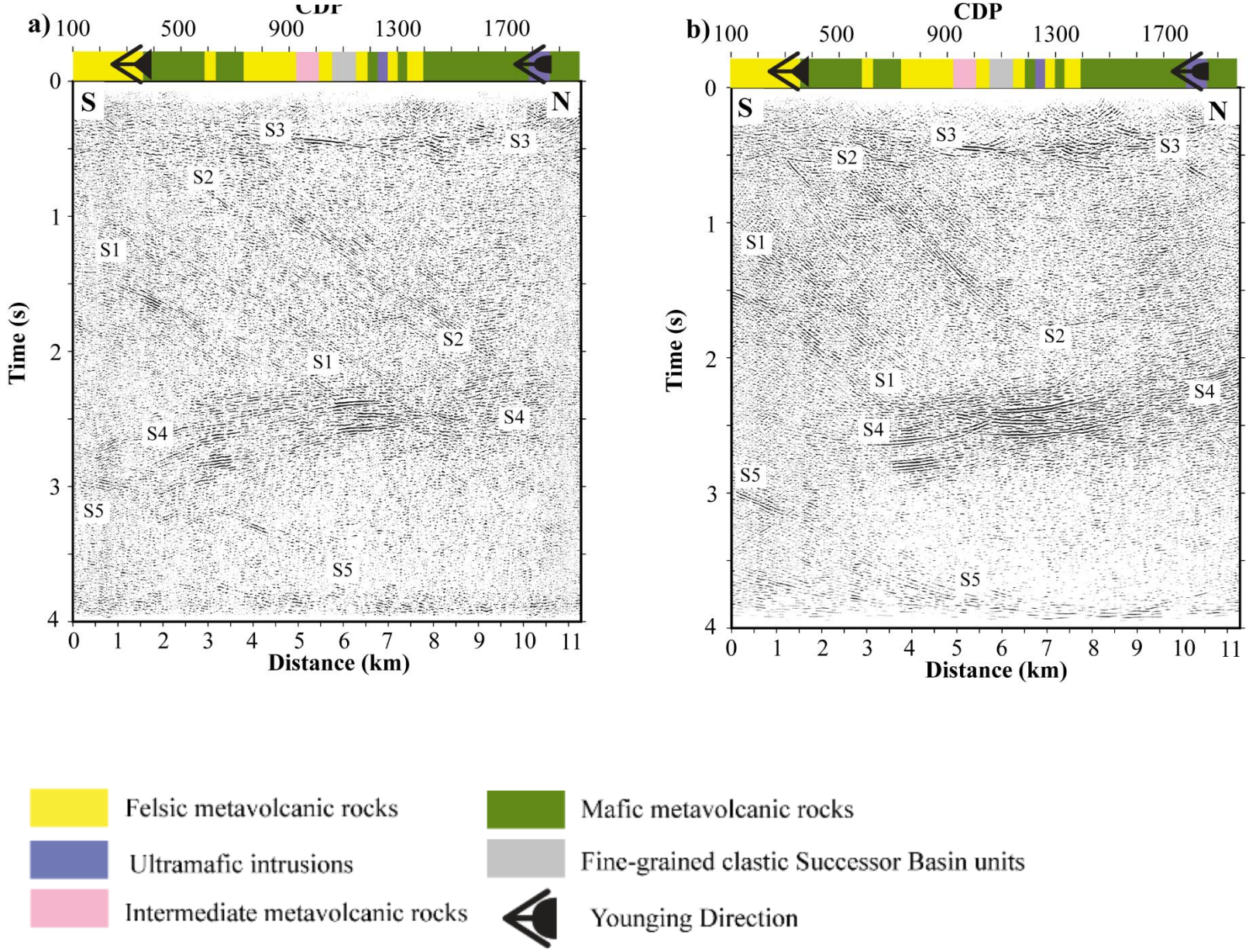
Swayze south:

a) DMO-stacked

b) Migrated-stacked



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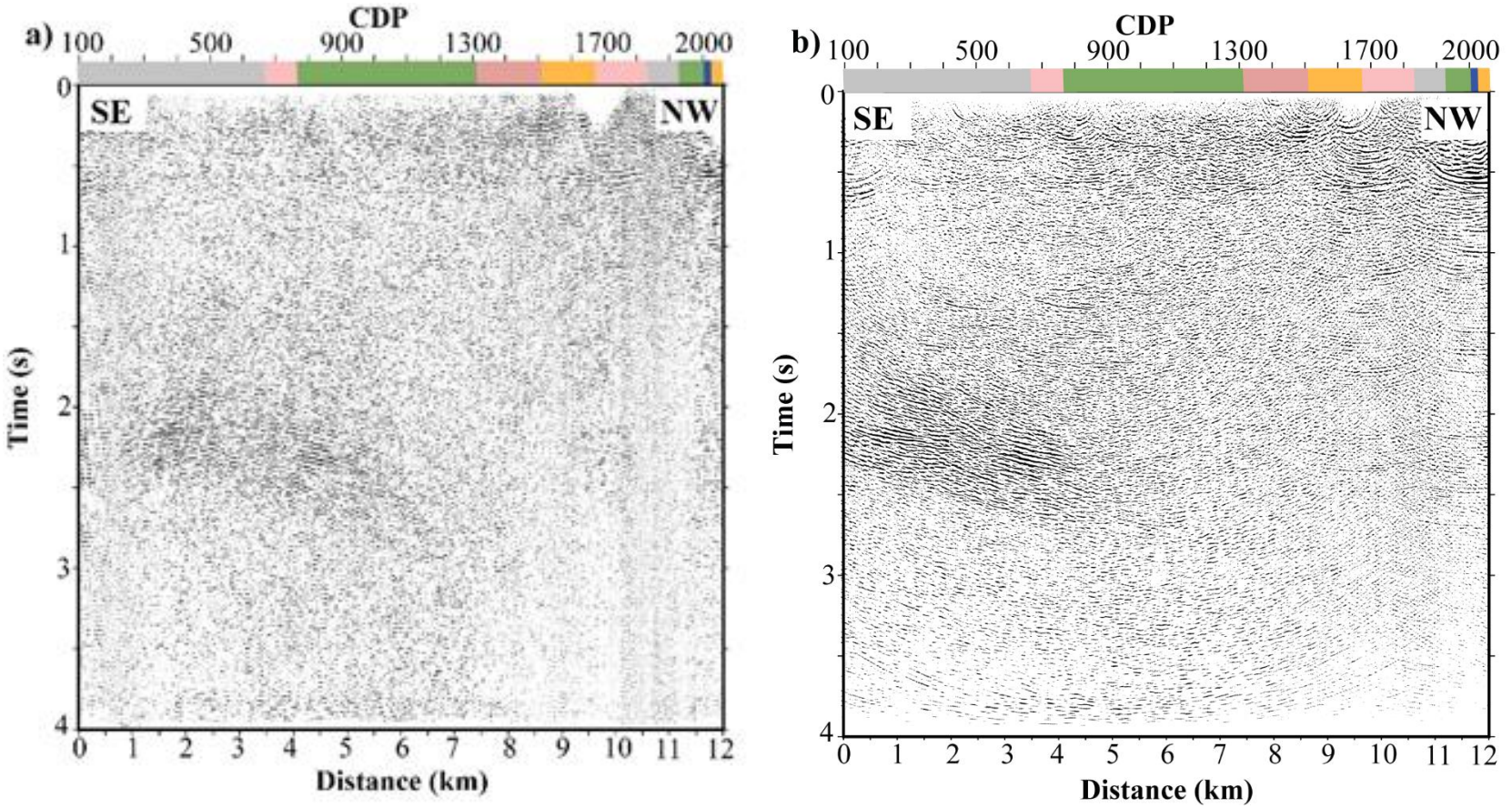
Larder Lake:

a) DMO-stacked

b) Migrated-stacked



Granitoid Rocks

Diorite - monzonite - granodiorite

Foliated tonalite suite

Metasedimentary units

Coarse clastic successor basin units: Timiskaming-type

Fine clastic successor basin units: Porcupine-type

Mafic to intermediate metavolcanic rocks

Larder-Cadillac Deformation Zone

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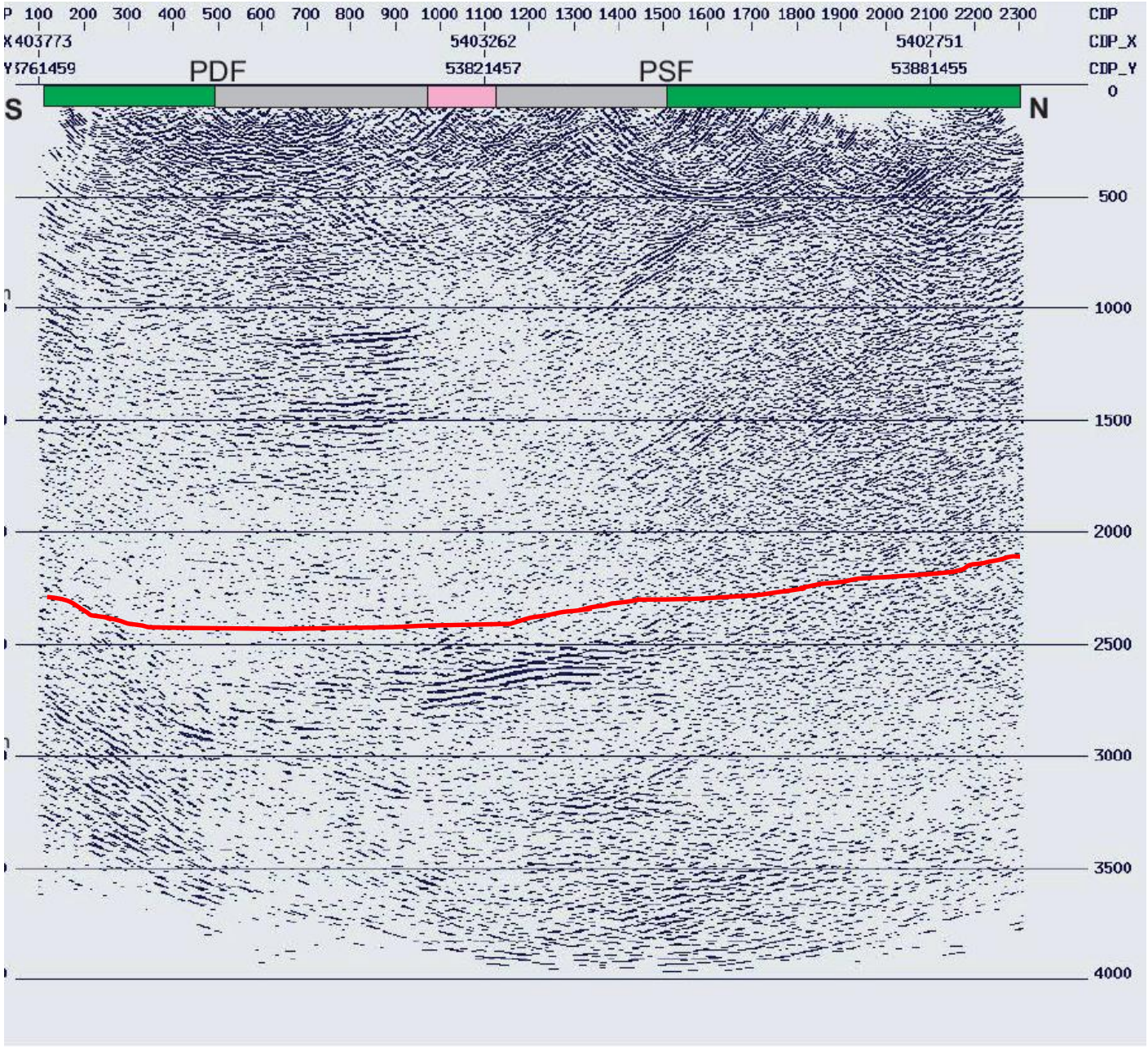
Matheson:

Migrated-stacked

Shallower deflections



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3D swath processing

- Crooked nature of the acquired surveys causes the distribution of midpoints in both inline and crossline of the survey.
- CDP binning of 50 m by 50 m was considered.
- Processed 2D shots + 3D geometry
- Velocity analysis to find the best velocity model
- Stacking
- Migration

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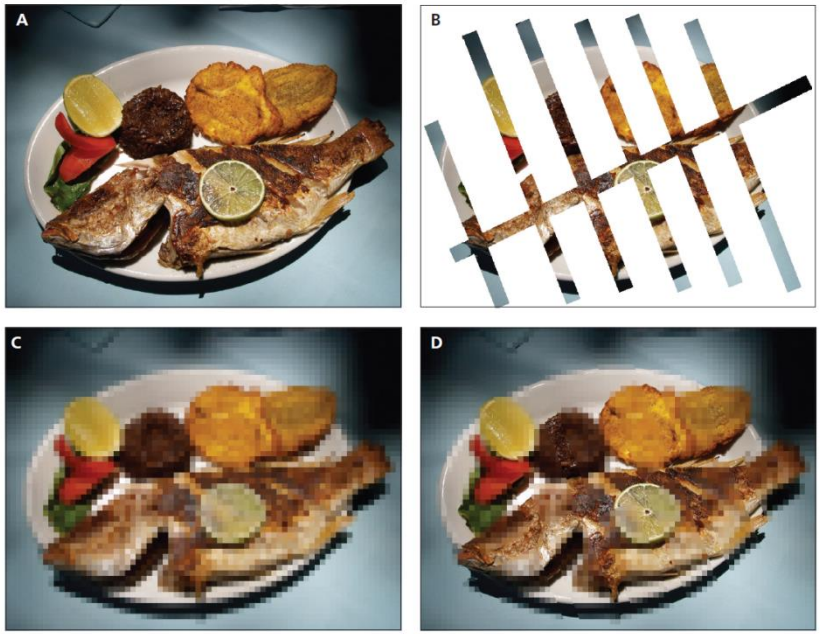
2D versus 3D

2D Survey	3D survey
For a specific CMP fold, 2D survey has better resolution in shallower part	Cost issues
First arrivals have better statistical distribution (better refraction statics)	Sparse 3D survey results in weaker subsurface illumination
Lower size of 2D survey allows for faster testing of velocity models	Better migration results Extra information about subsurface geology



Vestrum and Gittins, first break 2009

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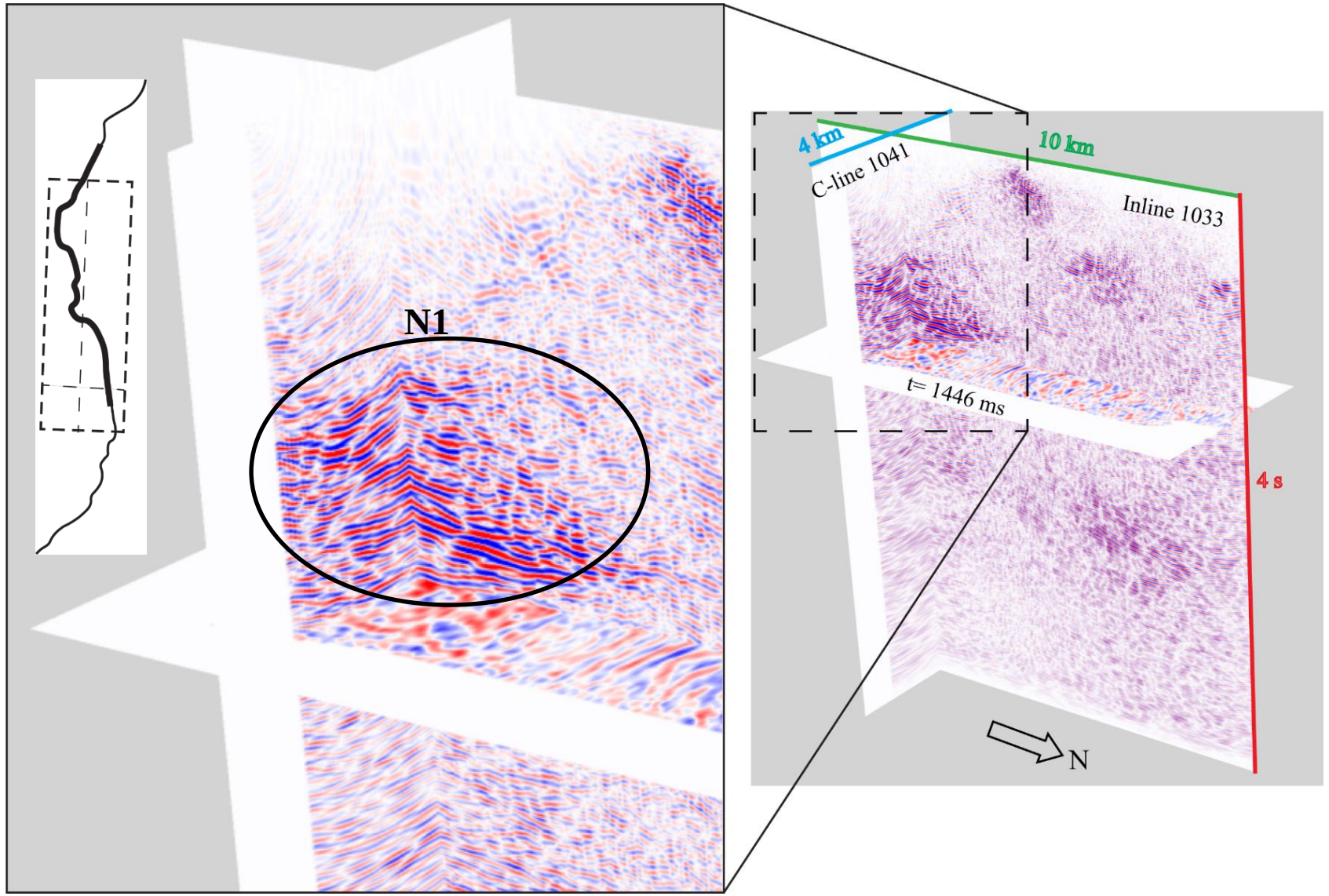
3D swath processing

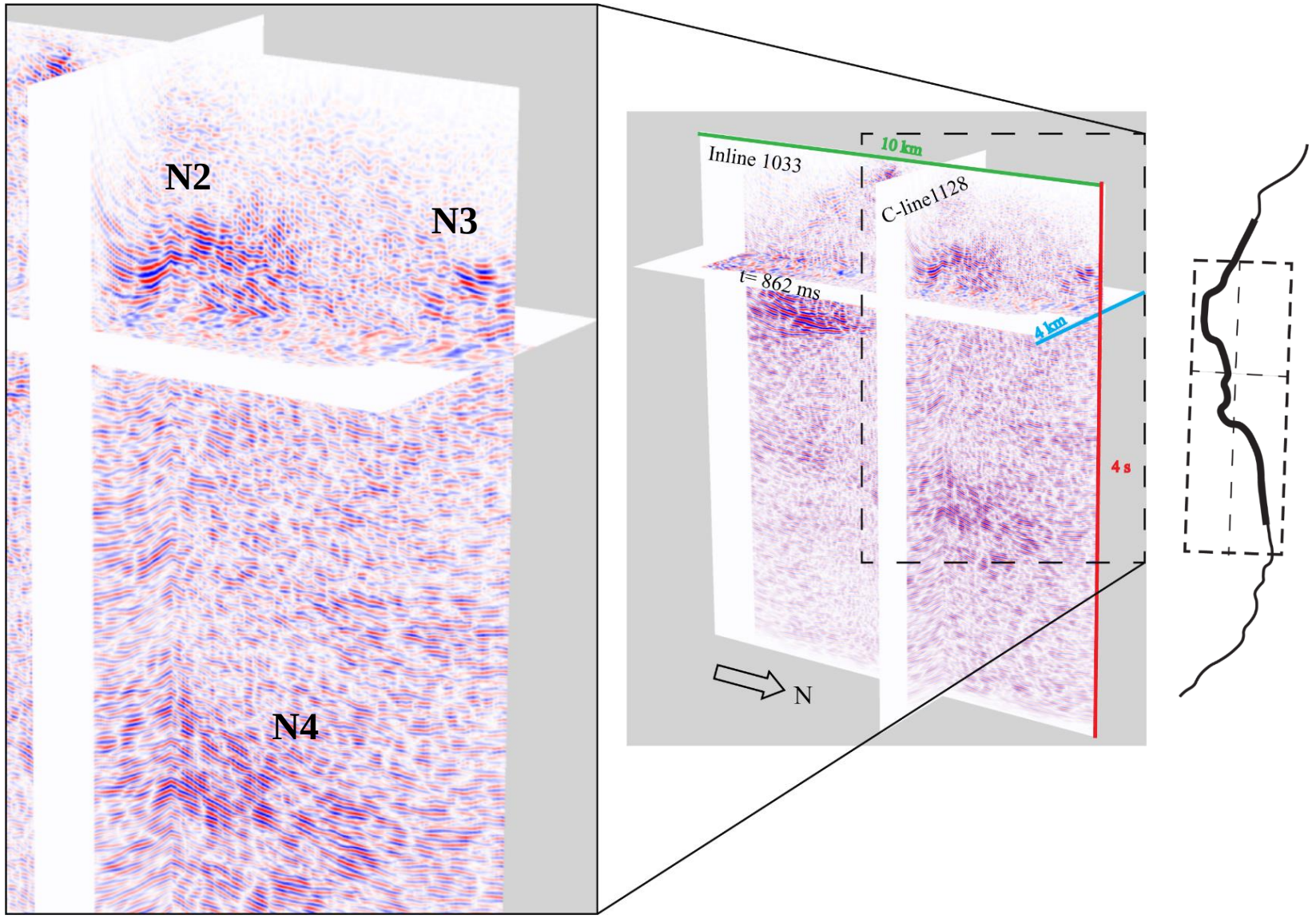
Swayze north



METAL EARTH

3D swath processing

Swayze north



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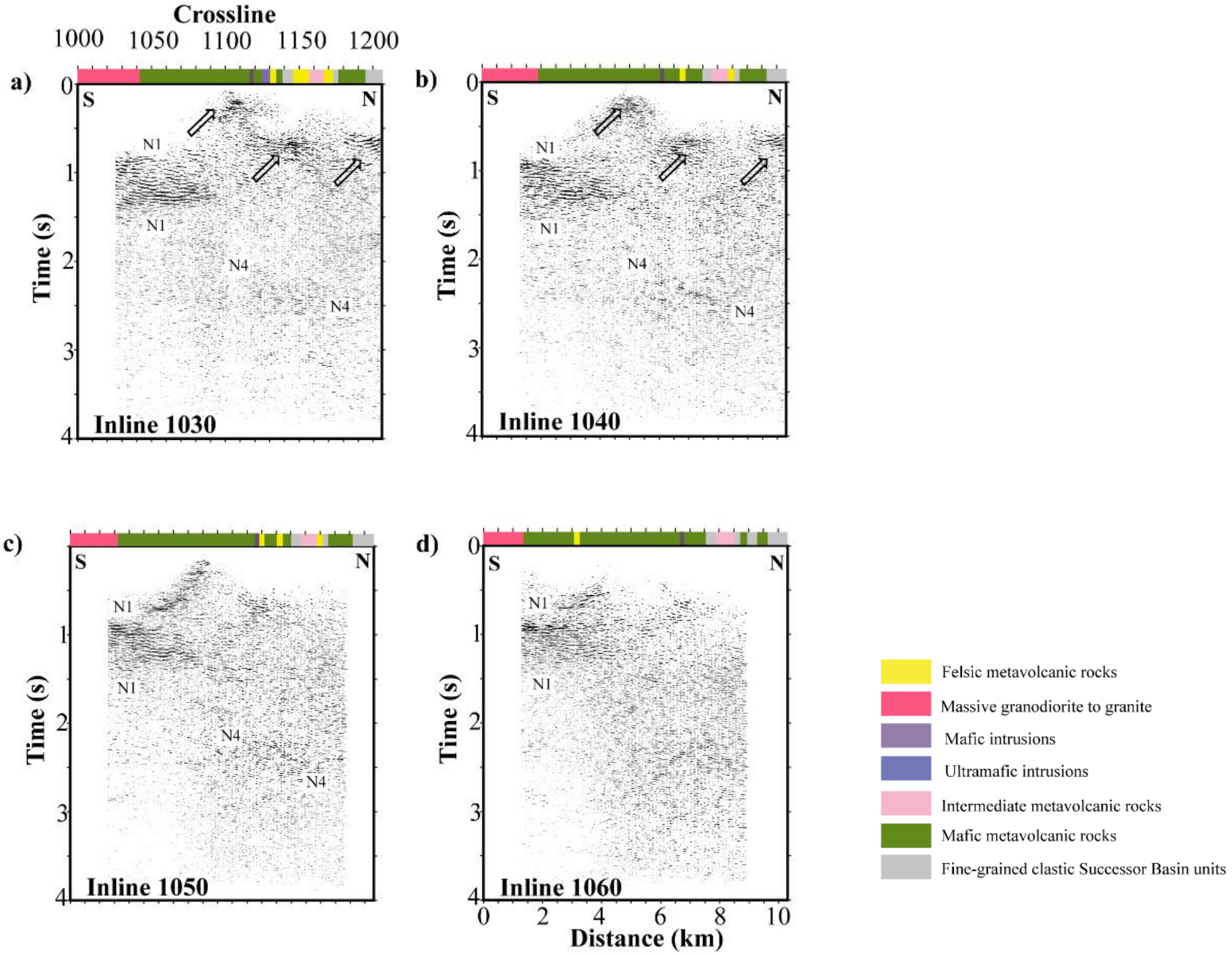
Inline sections from Swayze north



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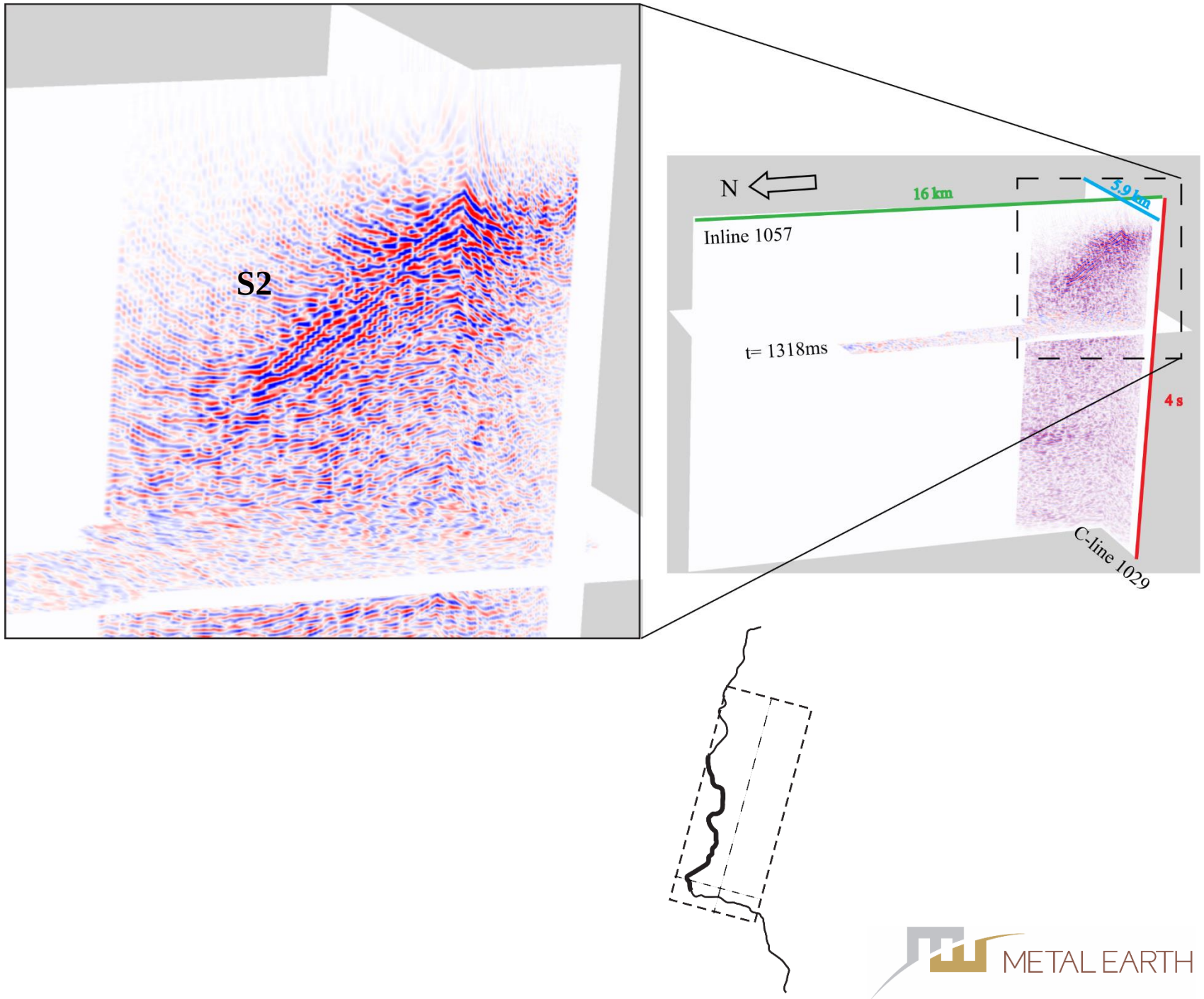
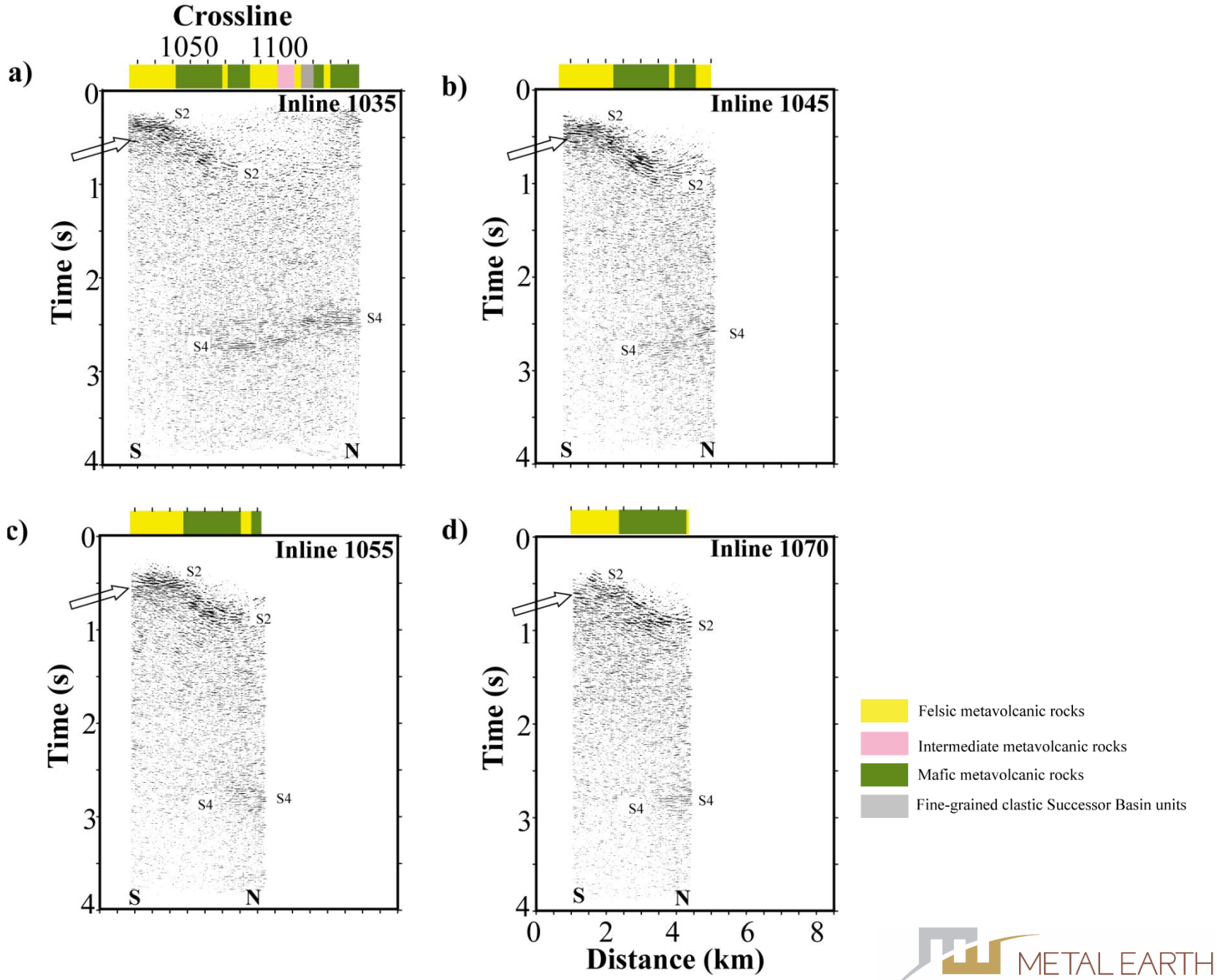
3D swath processing

Swayze south



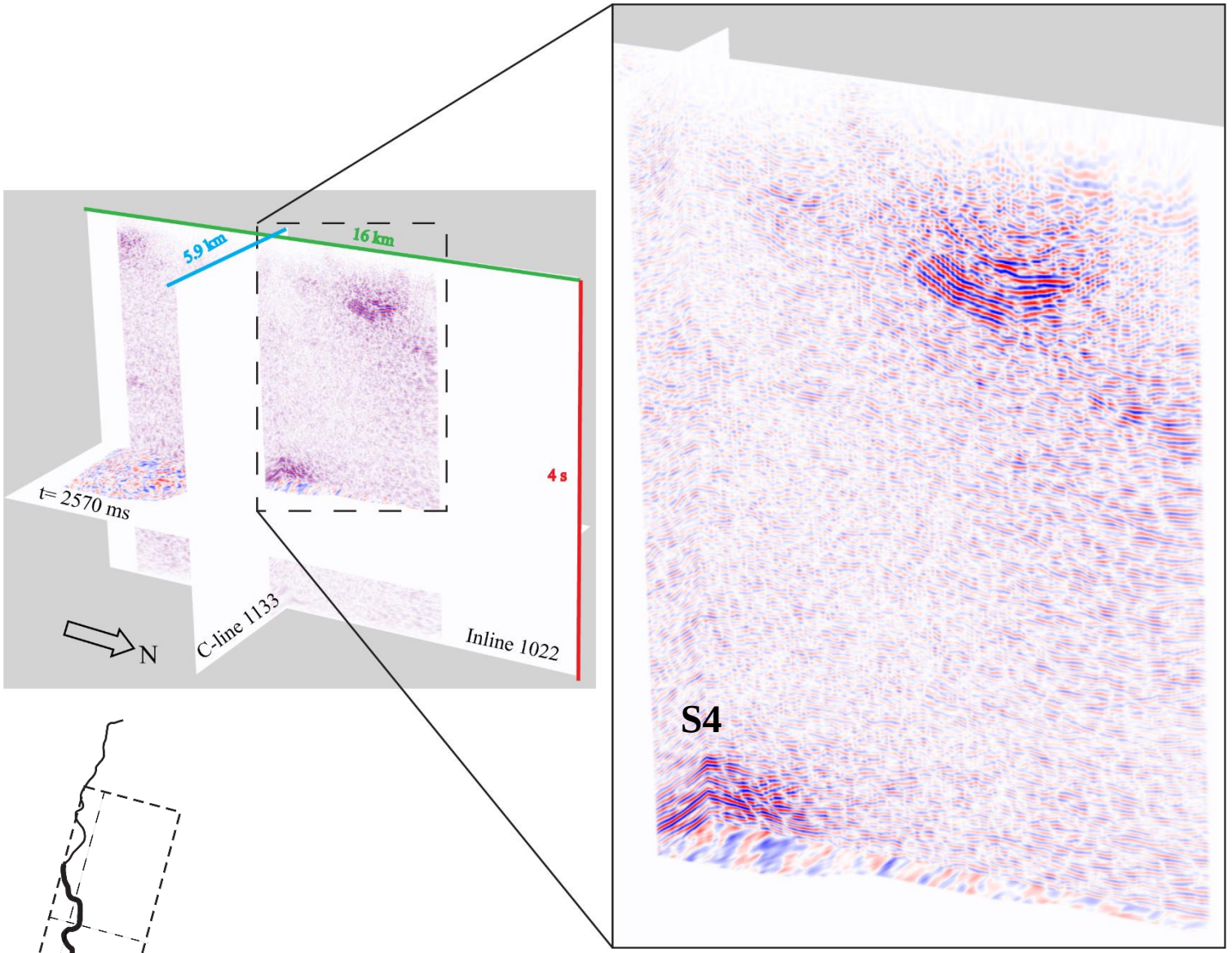
METAL EARTH

Inline sections from Swayze south



3D swath processing

Swayze south



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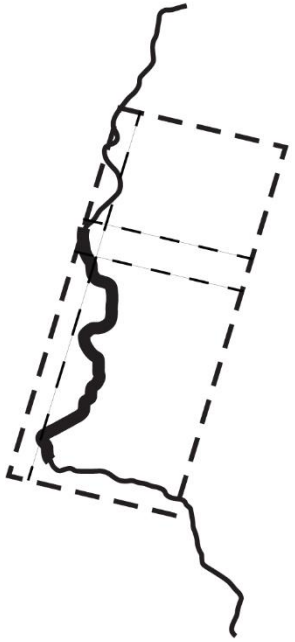
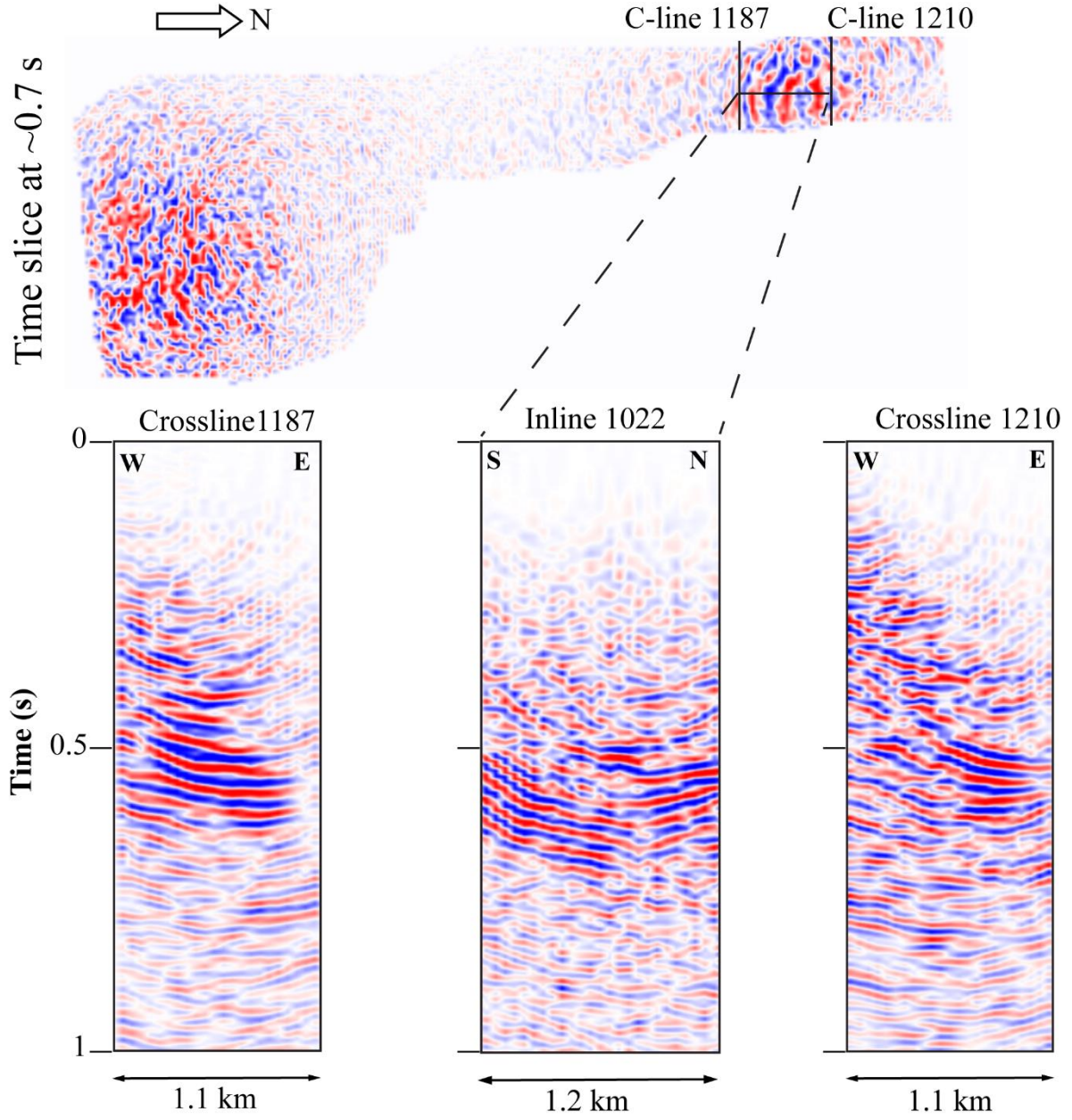
3D swath processing

Swayze south





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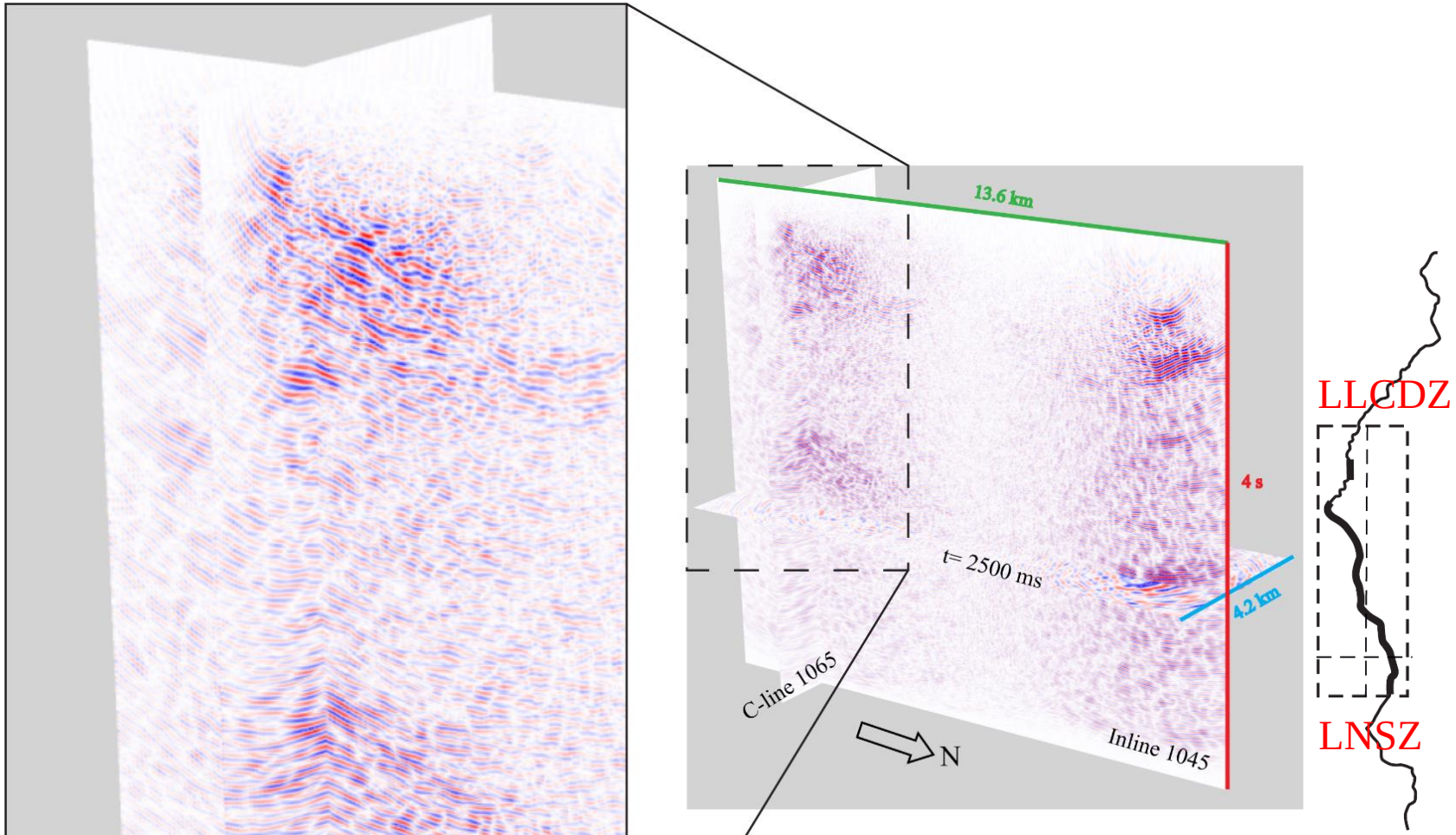
3D swath processing

Larder Lake



Larder-Cadillac deformation zone (LLCDZ) and Lincoln Nipissing shear zone (LNSZ)

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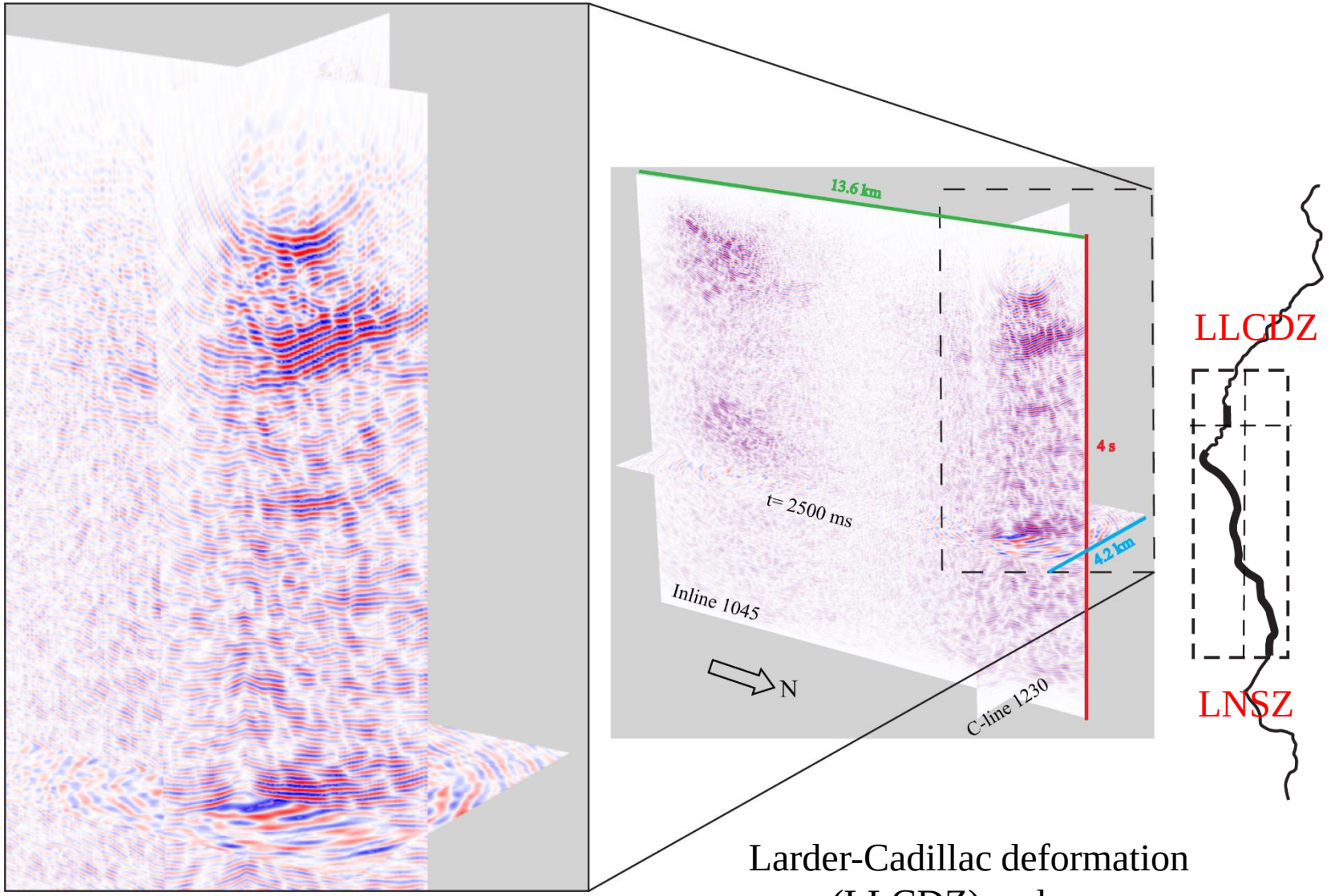
3D swath processing

Larder Lake



Larder-Cadillac deformation zone (LLCDZ) and Lincoln Nipissing shear zone (LNSZ)

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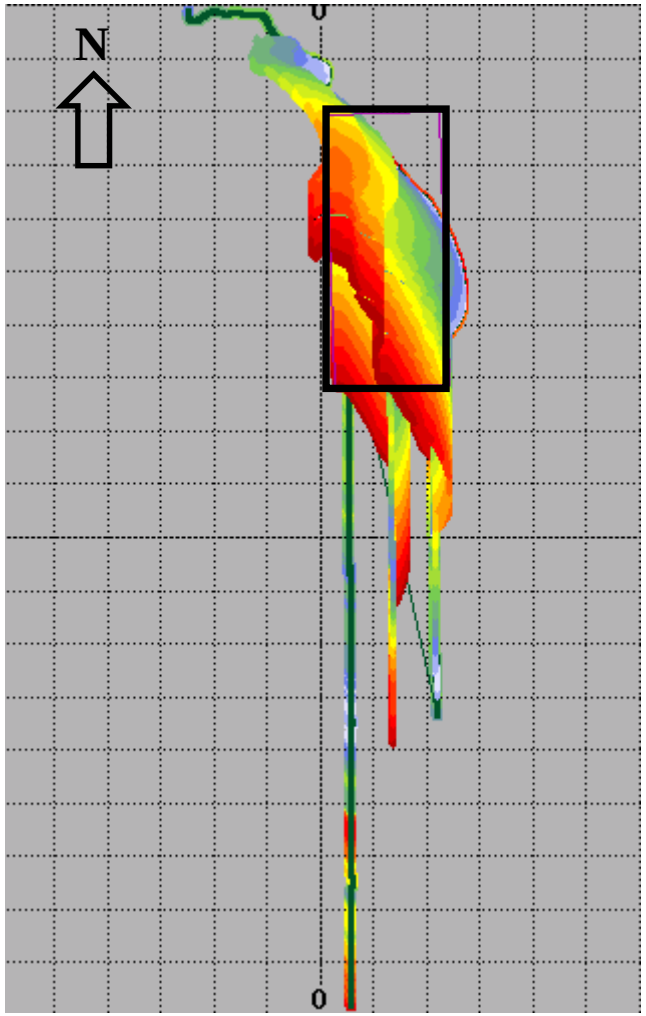
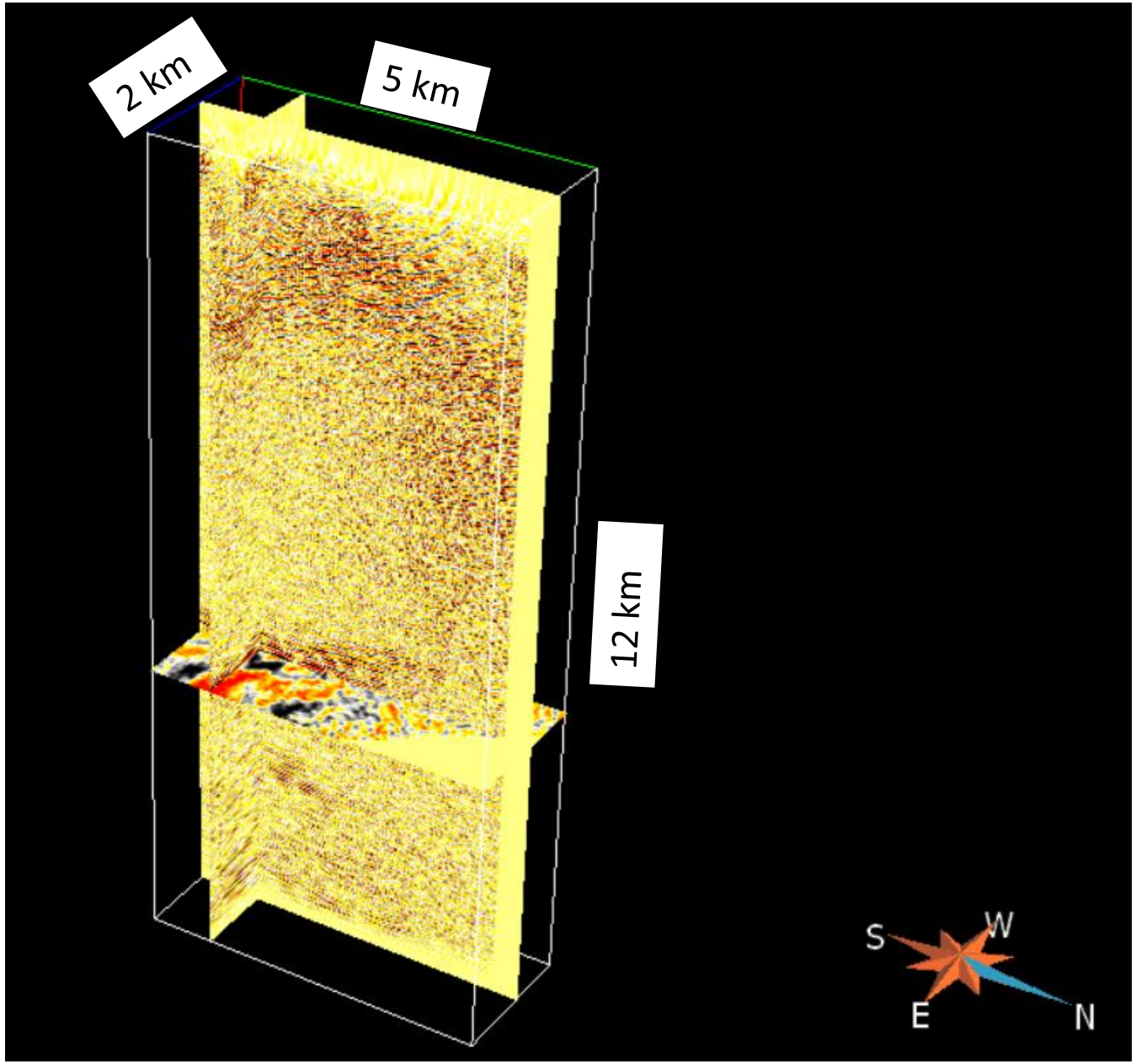
Geometry of 3D Swath, Matheson

Bin size: 50 m by 50 m





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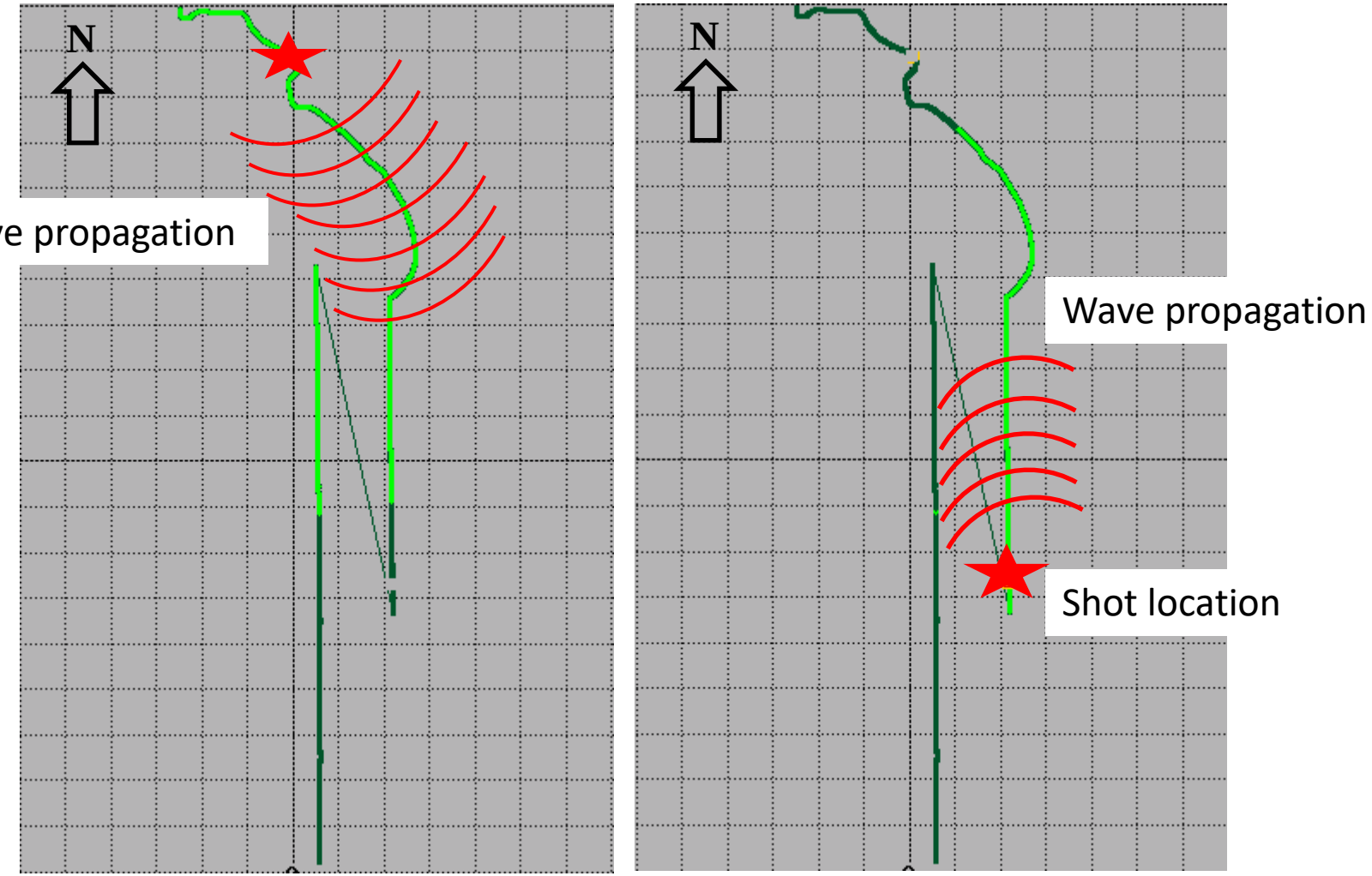
Acquired shots in Matheson survey

a) First shot of the survey

b) Last shot of the survey



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new ways to explore the subsurface

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Effects of static corrections

- **Elevation in each receiver location is different:**

1. **Higher elevation (reflections delay)**
2. **Lower elevation (reflections are too early)**

- **The effect of weathering:**

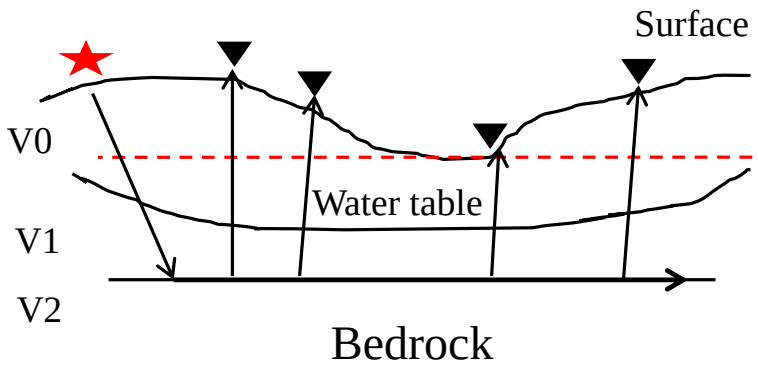
1. **Joints and features in the upper few meters (up to 10's of meters)**
2. **Very low velocity near the surface**

Reflections will be delayed

Static corrections

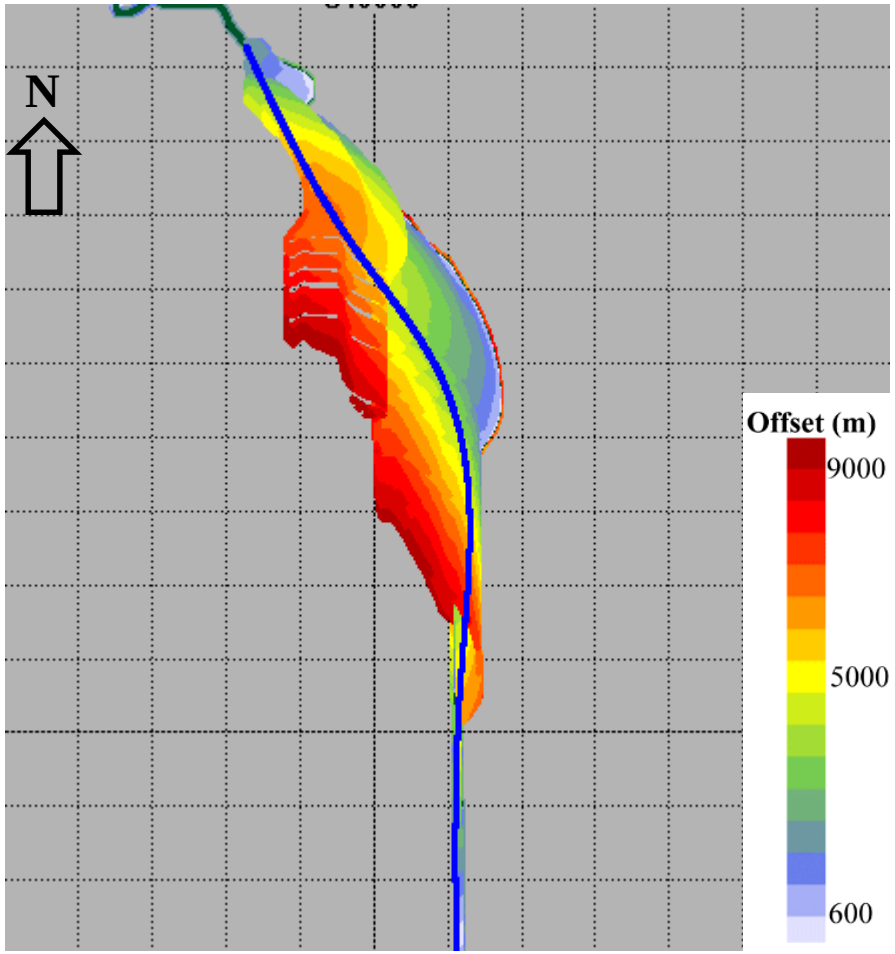
A fixed datum is considered

The velocity effect of first layer is removed



Eastern survey:

- Shots and receivers on the eastern profile are only considered.
- Curvy CDP line is considered



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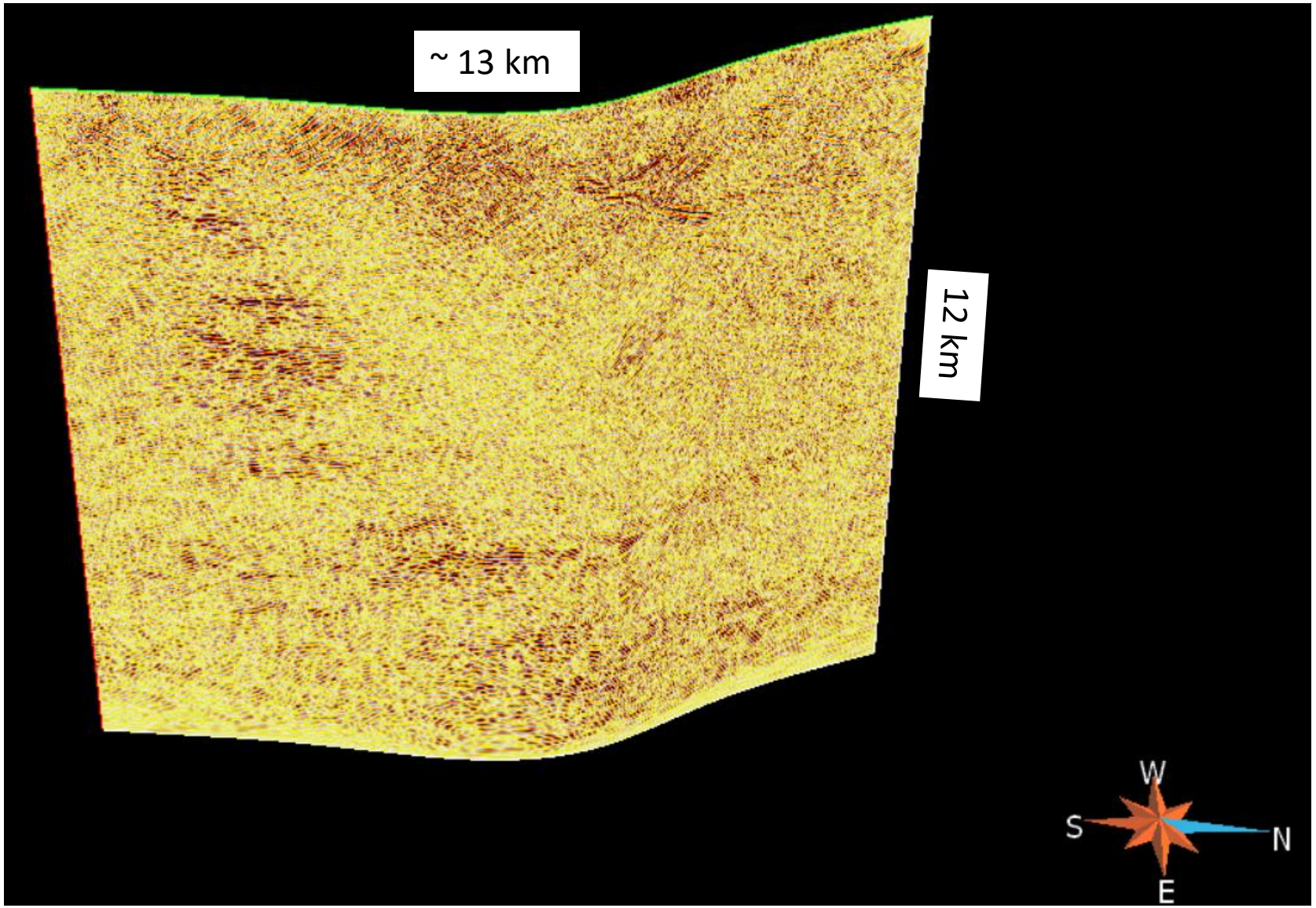
NMO-stacked migrated section of eastern curvy profile



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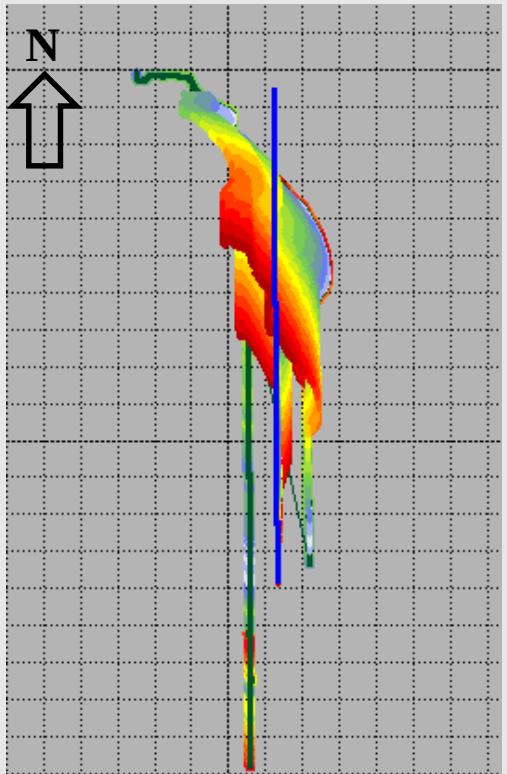
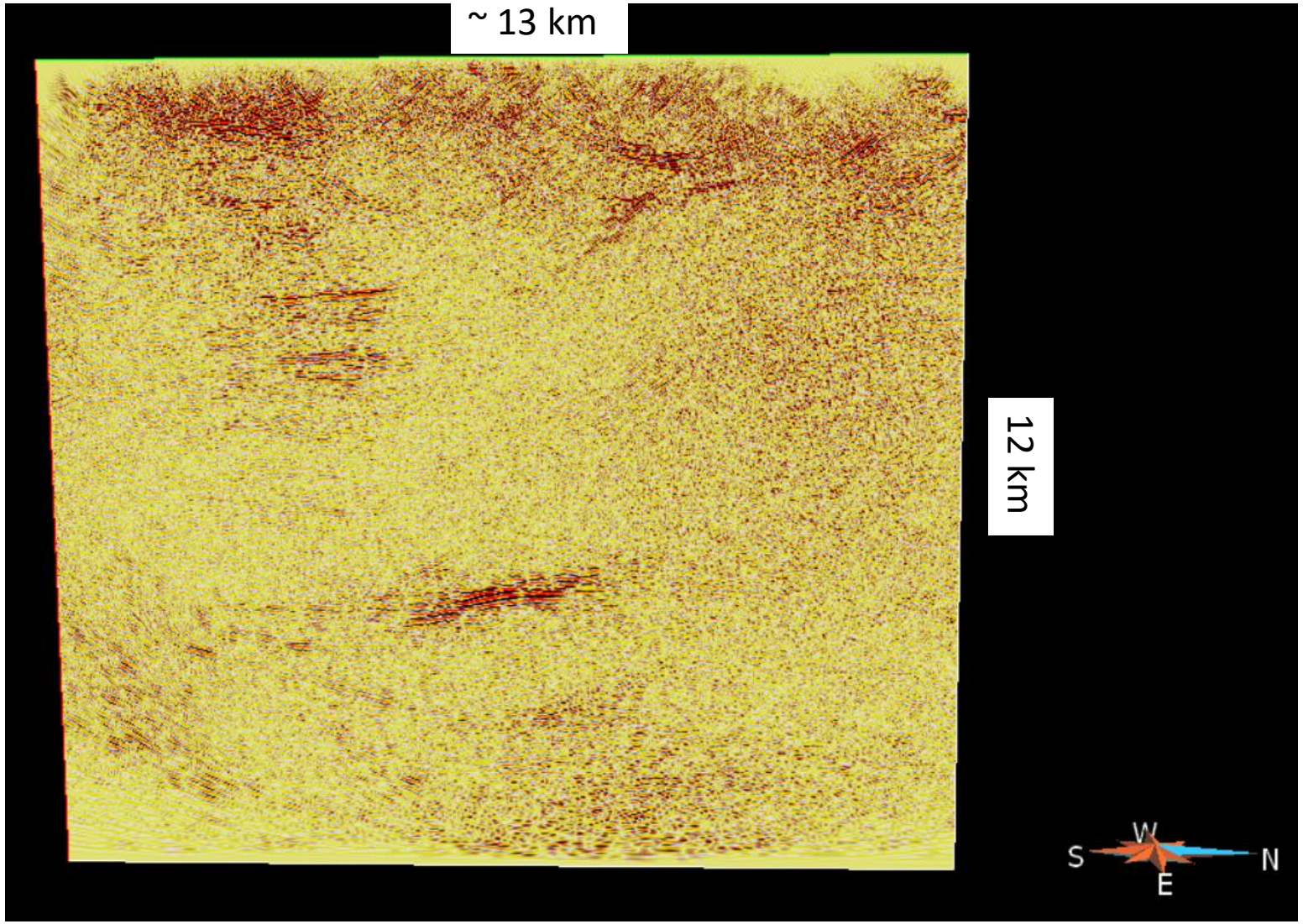
NMO-stacked migrated section of entire survey





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SMARTEXPLORATION
new ways to explore the subsurface

METAL EARTH

Future work

Crooked surveys demand to test several imaging methods:

- Conventional processing (DMO corrections and migrations)
- Application of Pre-stack time migration
- Amplitude-versus-offset (AVO)
- Cross-dip analysis

Acquiring new surveys

- Vertical seismic profiling and petrophysical measurements (Laval University, Quebec, Canada)
- Passive seismic

METAL EARTH

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A new Canadian research initiative funded by Canada First Research Excellence Fund.

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