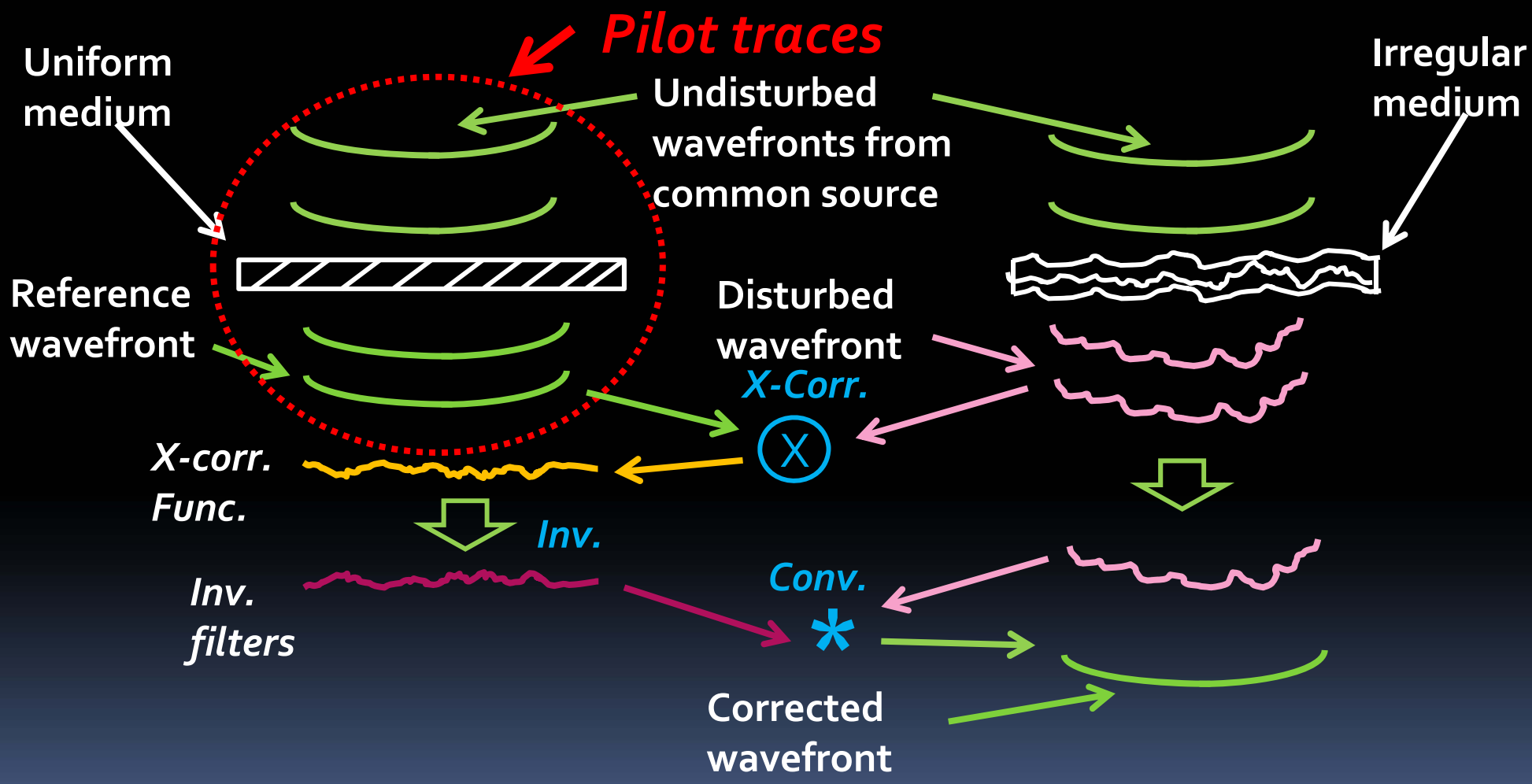
David C. Henley

3D OR NOT 3D: RAYPATH INTERFEROMETRY IN 3D PROCESSING

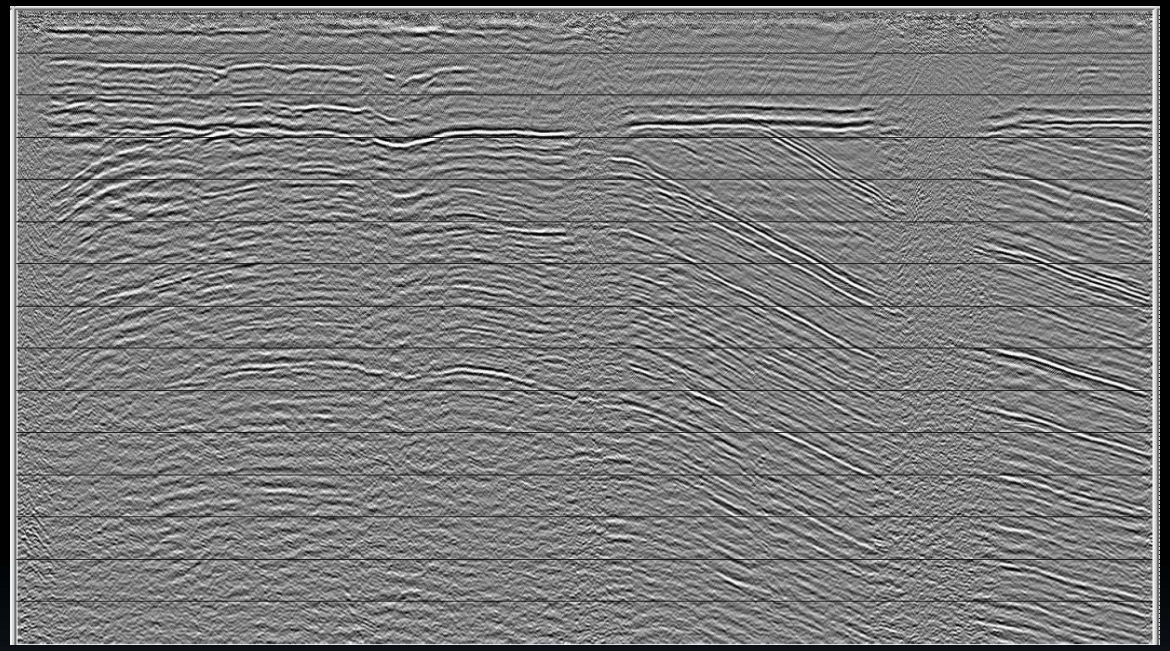
Outline

- Introduction—interferometry in a nutshell
- 2D examples
- The generalized surface function
- 3D acquisition geometry considerations
  - Surface waves
  - Reflections
- The 3D reference wavefield
- 3D raypath interferometry
- Results and discussion

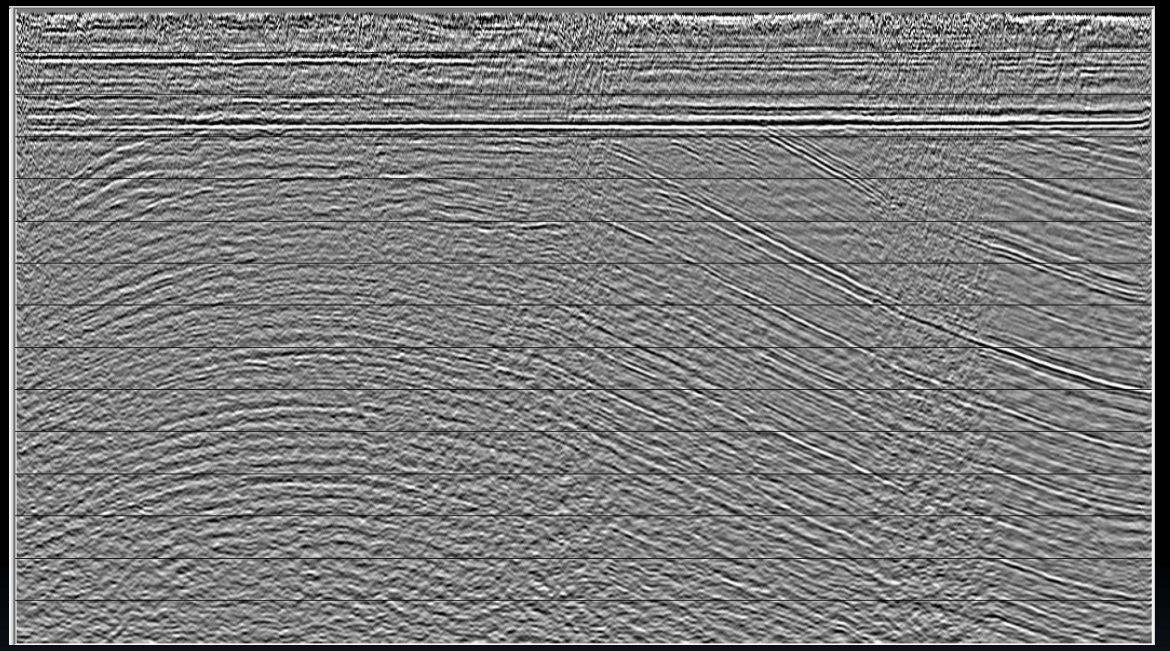
Interferometry concept



MacKenzie Delta PP

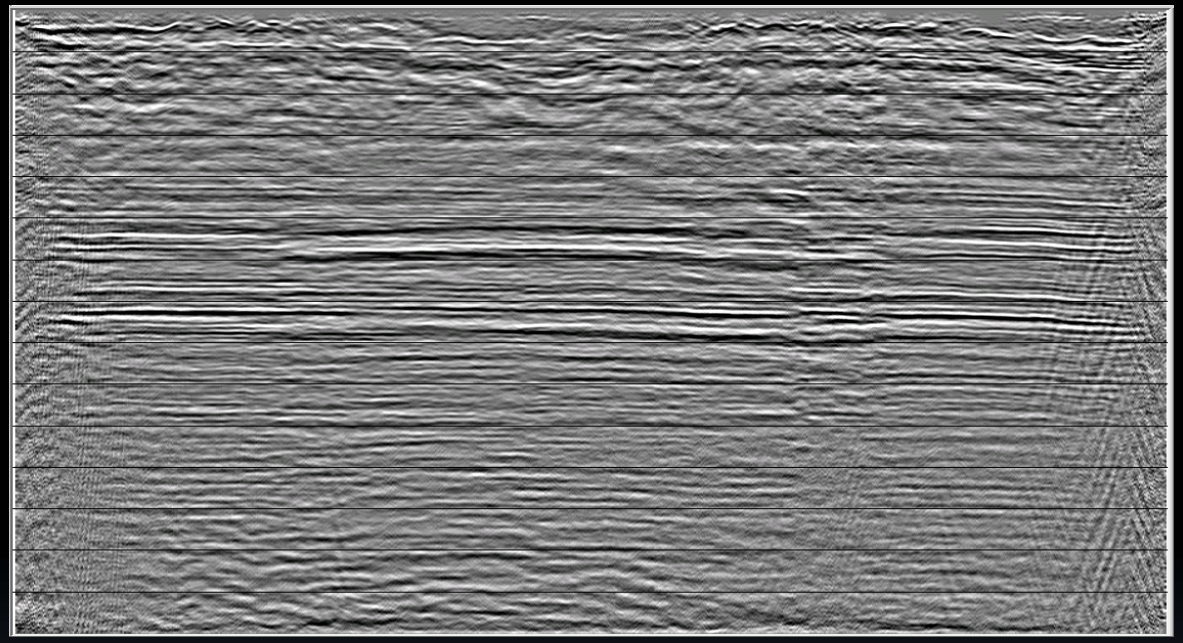


Brute CMP stack—***no statics***

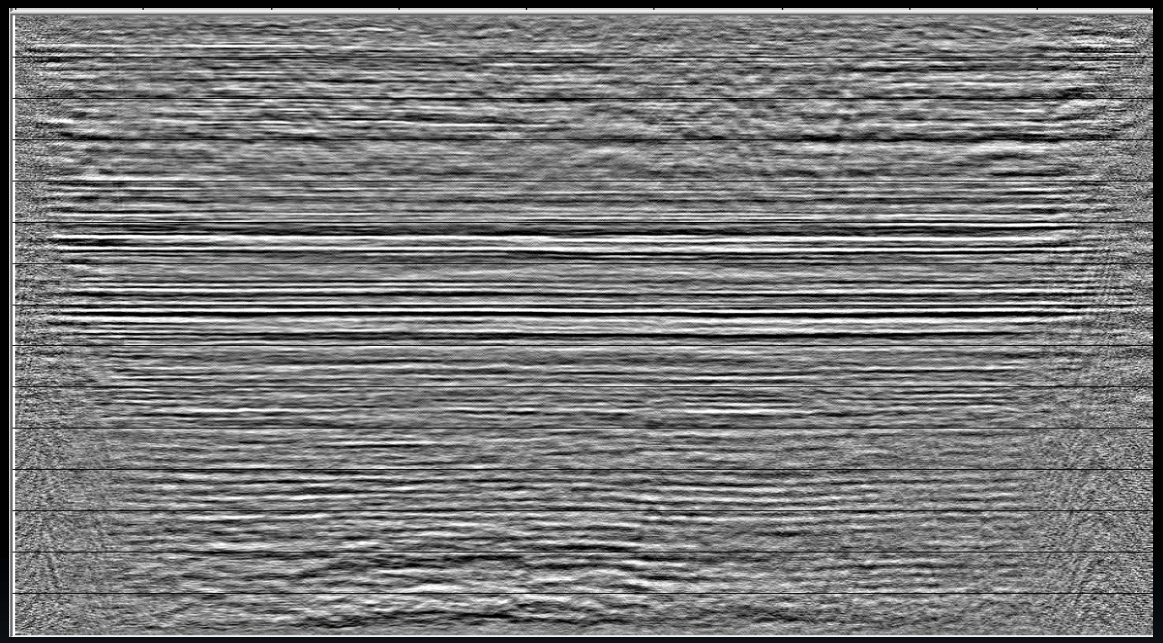


CMP stack—***raypath interferometry***

Hussar PP

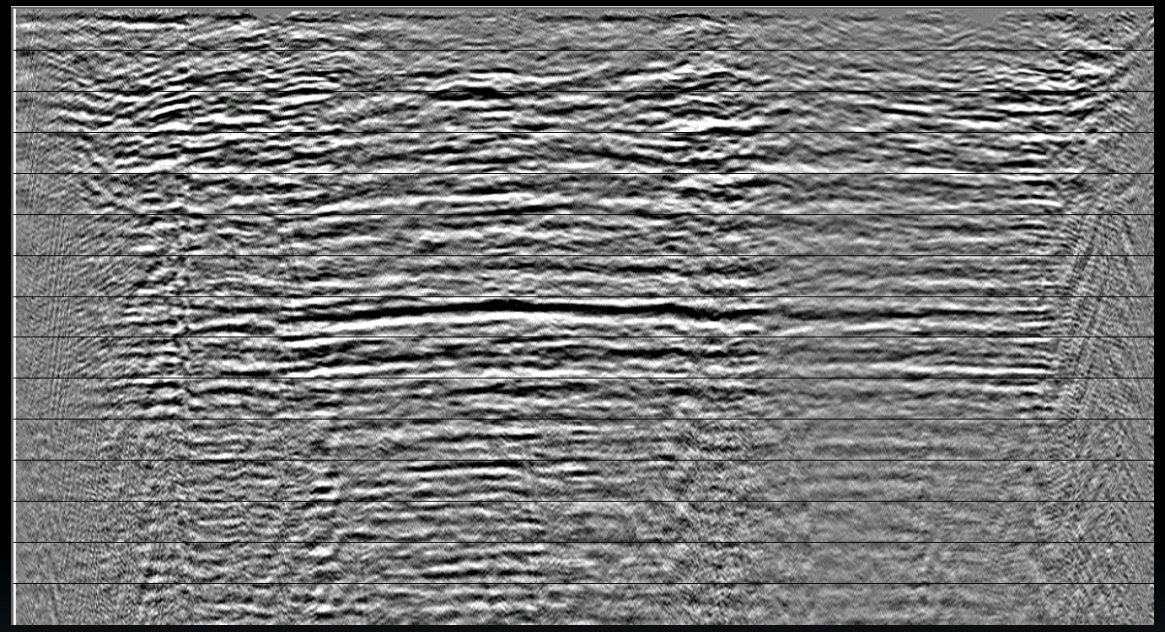


Brute CMP stack—***no statics***

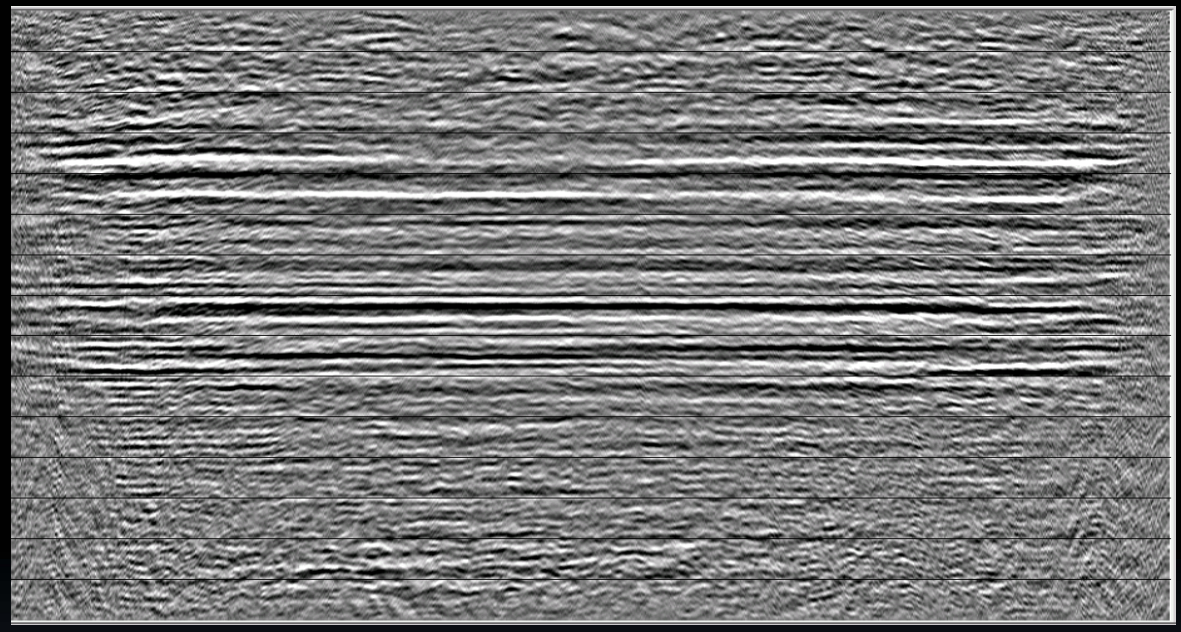


CMP stack—***raypath interferometry***

Hussar PS



Brute CCP stack—***no statics***



CCP stack—***raypath interferometry***

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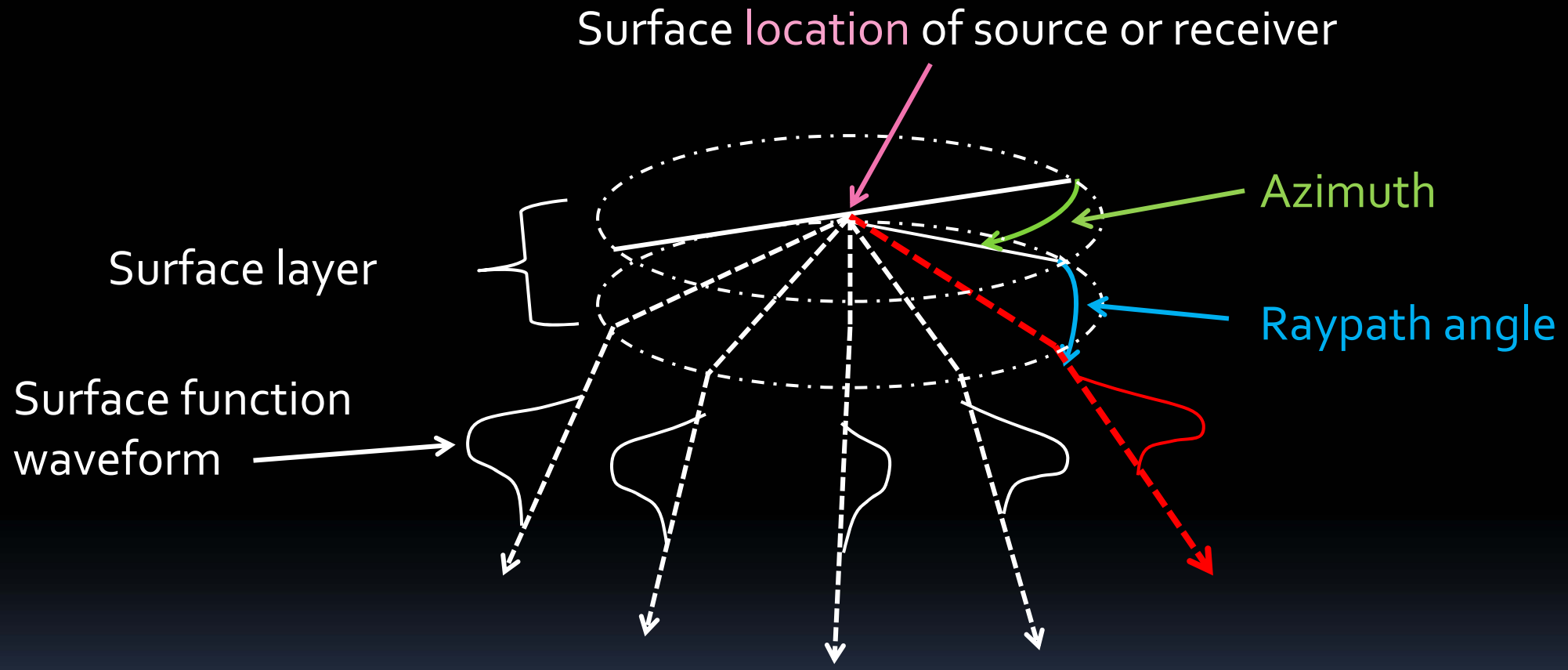
Generalized surface function

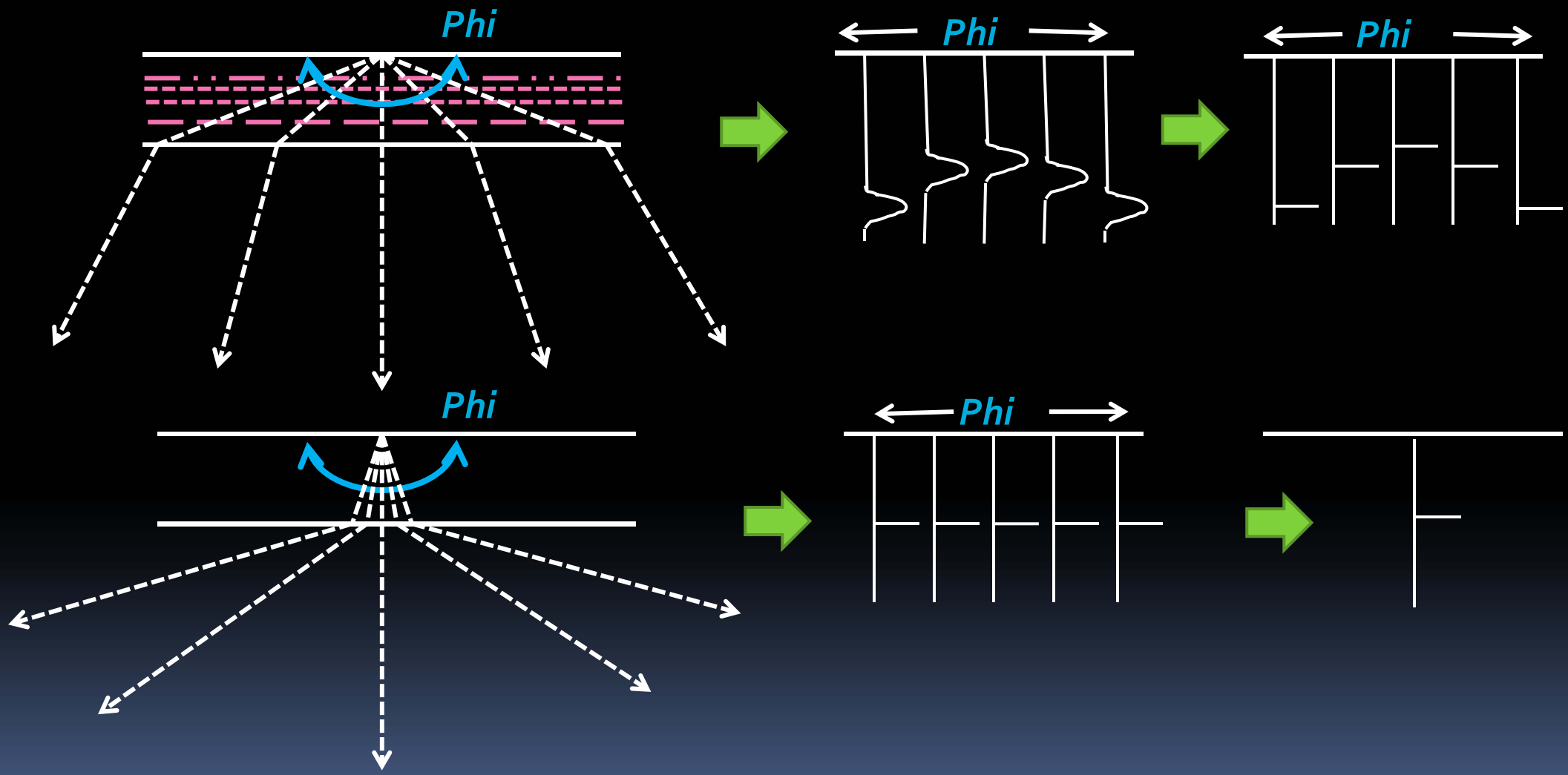


Surface function shape is the travel time ***distribution*** of reflection arrivals and varies with surface ***location***, ***azimuth***, and ***raypath angle***

The *general* surface function

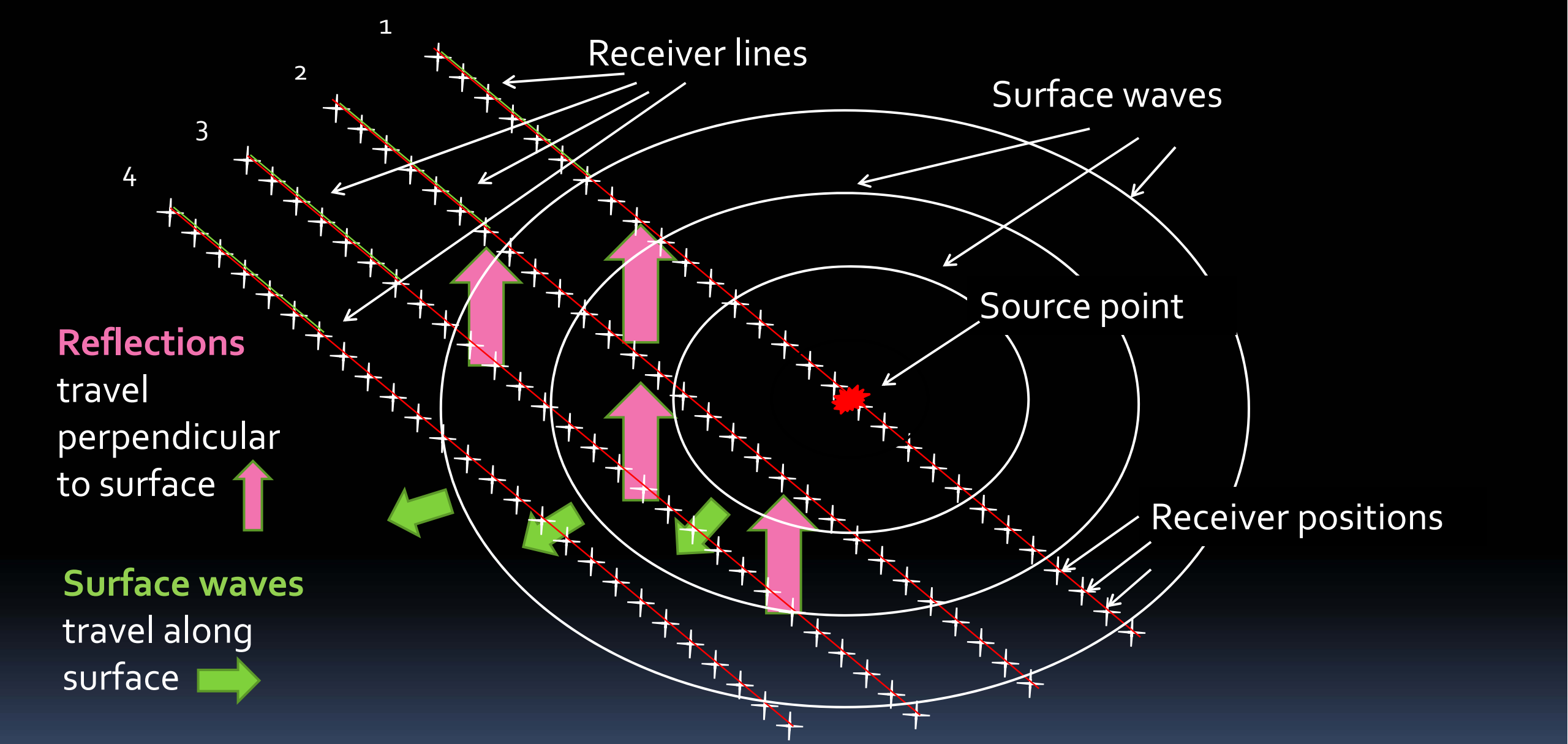
- ***Surface function (waveform) characterizes effects of surface layer on reflection arrivals transiting the layer***
- Varies with ***surface location***, near-surface ***raypath angle***, source-receiver ***azimuth***
- **3D ➡ 2D—*azimuthal*** variation vanishes
- **Surface layer velocity decreases ⬇—*angle*** variation vanishes
- **Surface layer ➡ homogeneous—*waveform*** becomes a spike
- **Hence, in most cases, general surface function ➡ static shift**

Surface function reduces to a static shift as surface layer simplifies

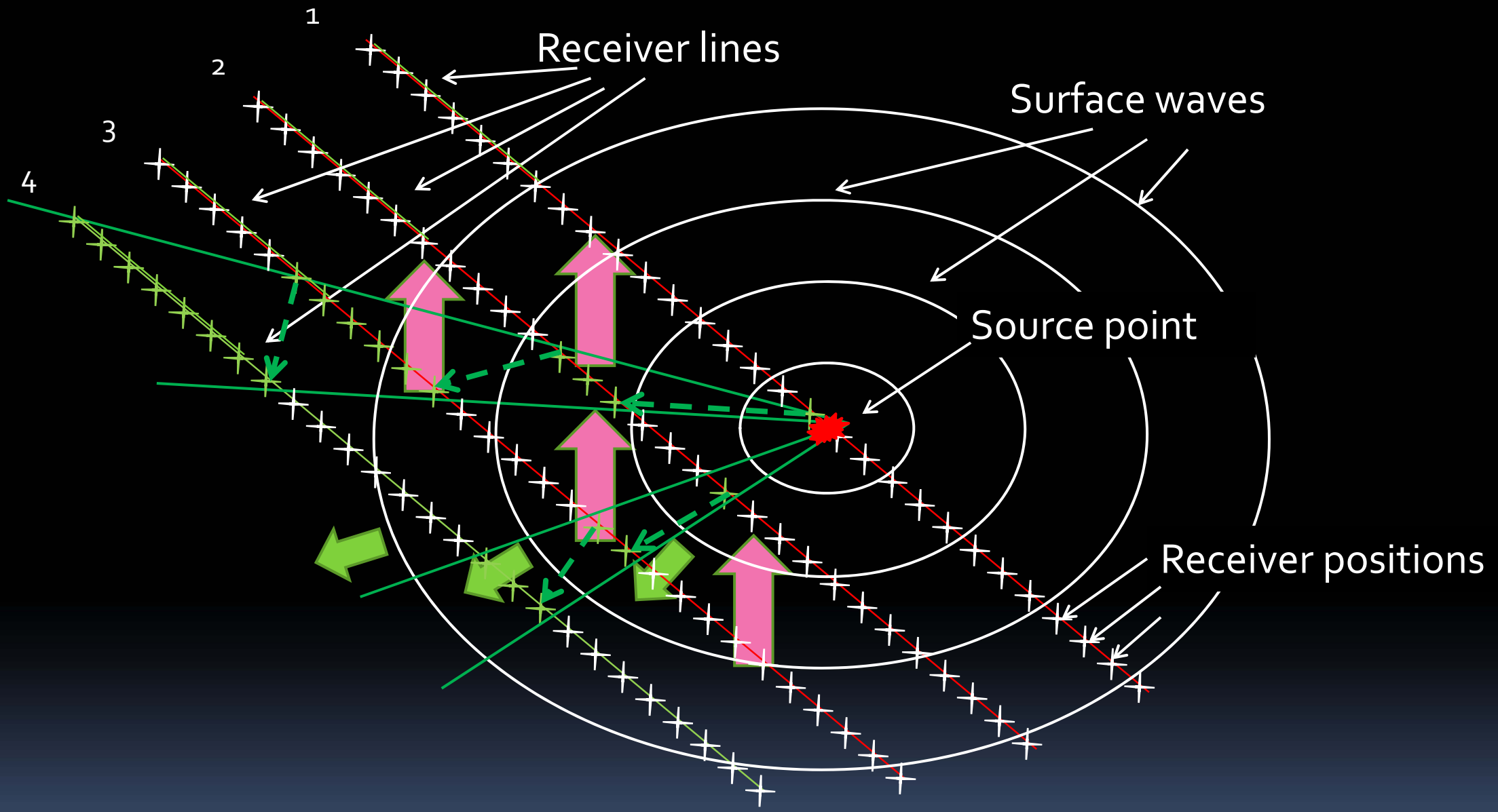


Creating trace gathers compatible with surface functions

- Coordinate choice for 3D ***surface function*** determines coordinates for 3D ***trace gathers: hence surface location, raypath angle, azimuth***
- In ***2D***, a spatial ***transform*** from ***X/T*** to ***'raypath domain'*** introduces ***raypath angle***--same for ***3D***
- 3D acquisition geometry introduces source-receiver ***azimuth***

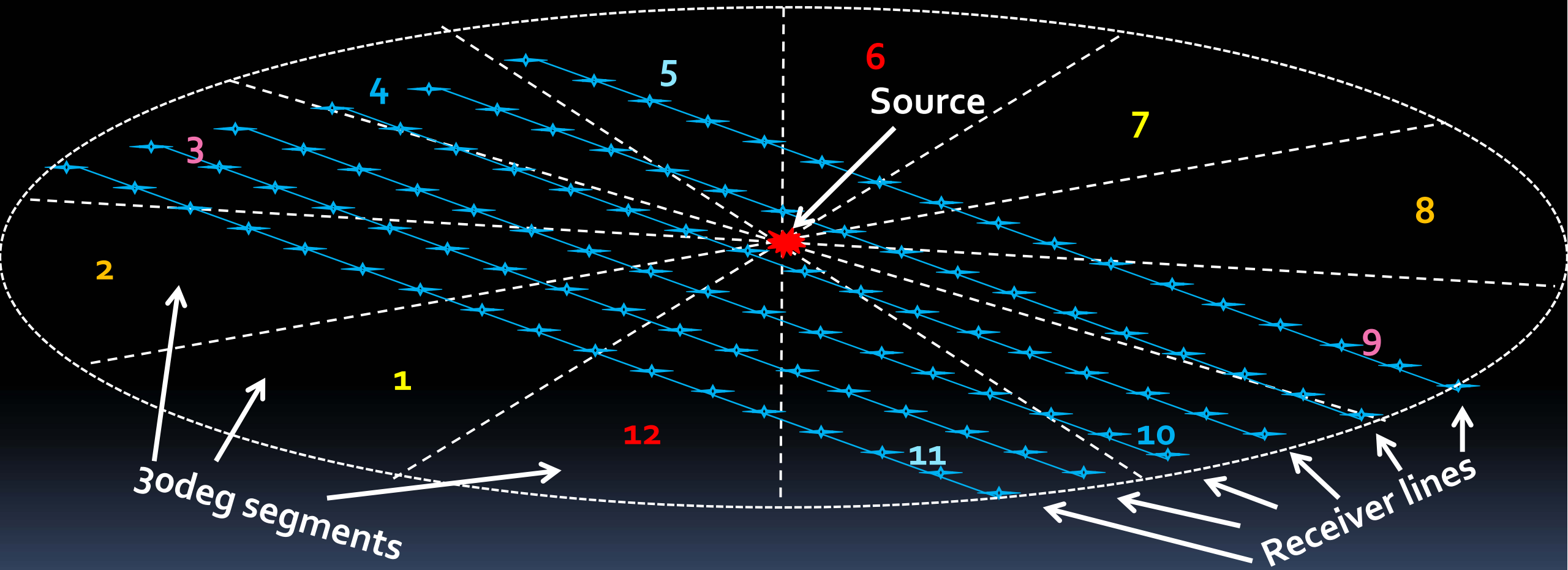


Typical 3D seismic acquisition geometry; reflections strike receiver lines nearly vertically, so spatial aliasing is much less than for surface waves



Gathered by offset within angular segments, trace distribution is often too irregular to properly sample the surface wave but OK for reflections

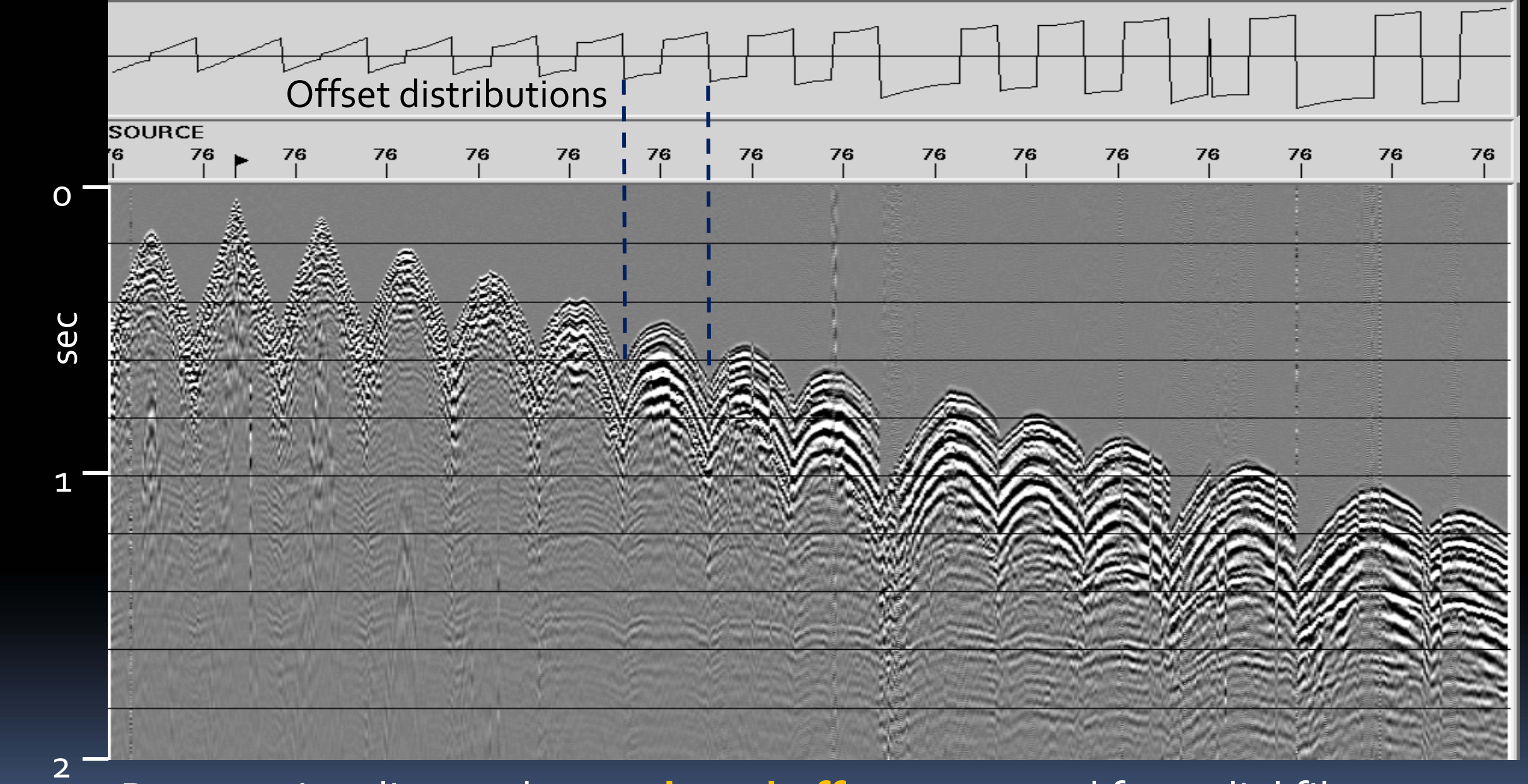
Binning scheme for raypath transform ensembles



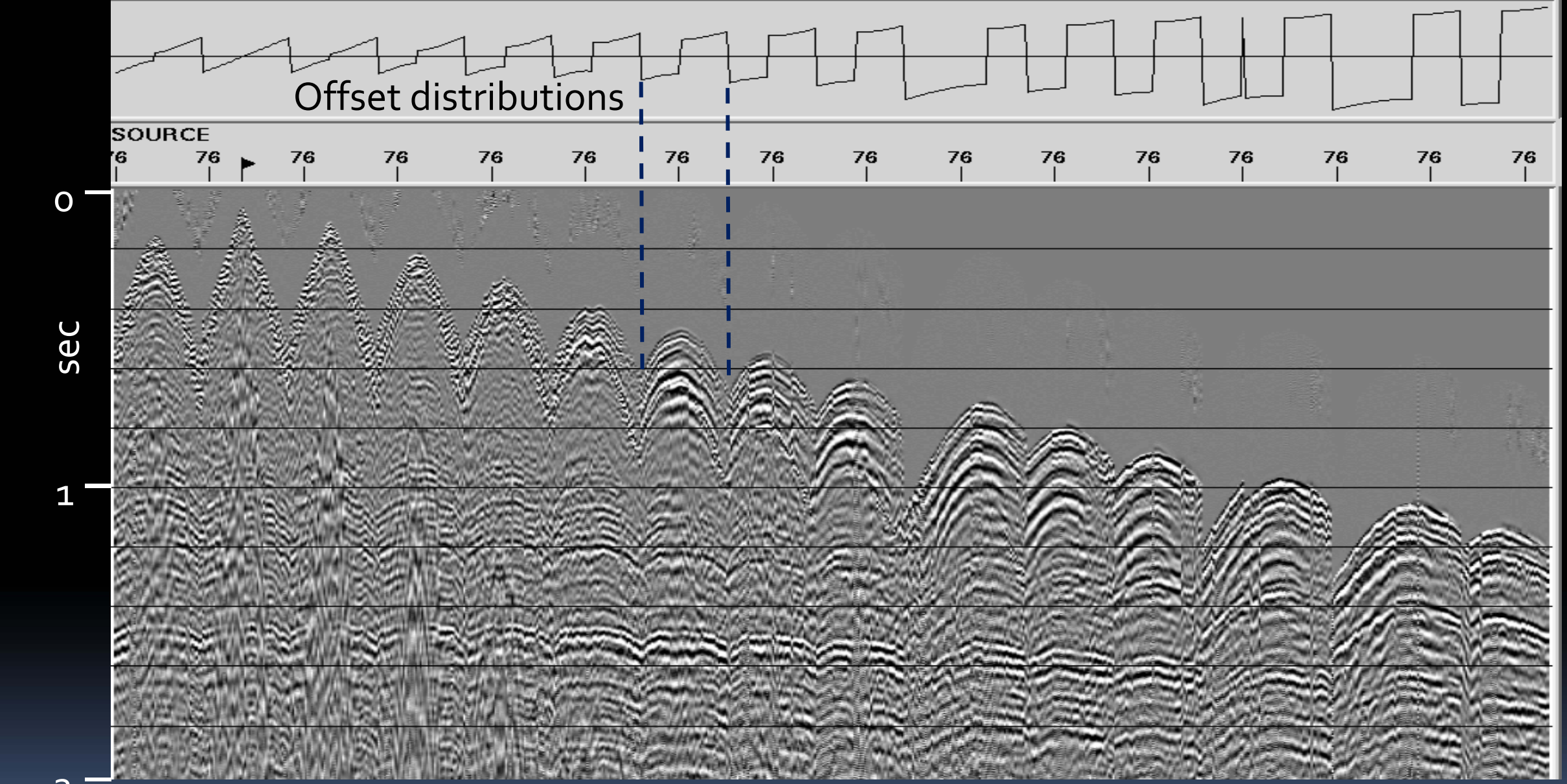
Bins consist of segments 1 + 7, 2 + 8, 3 + 9, 4 + 10, 5 + 11, and 6 + 12

Blackfoot 1995 3D 3C survey attributes

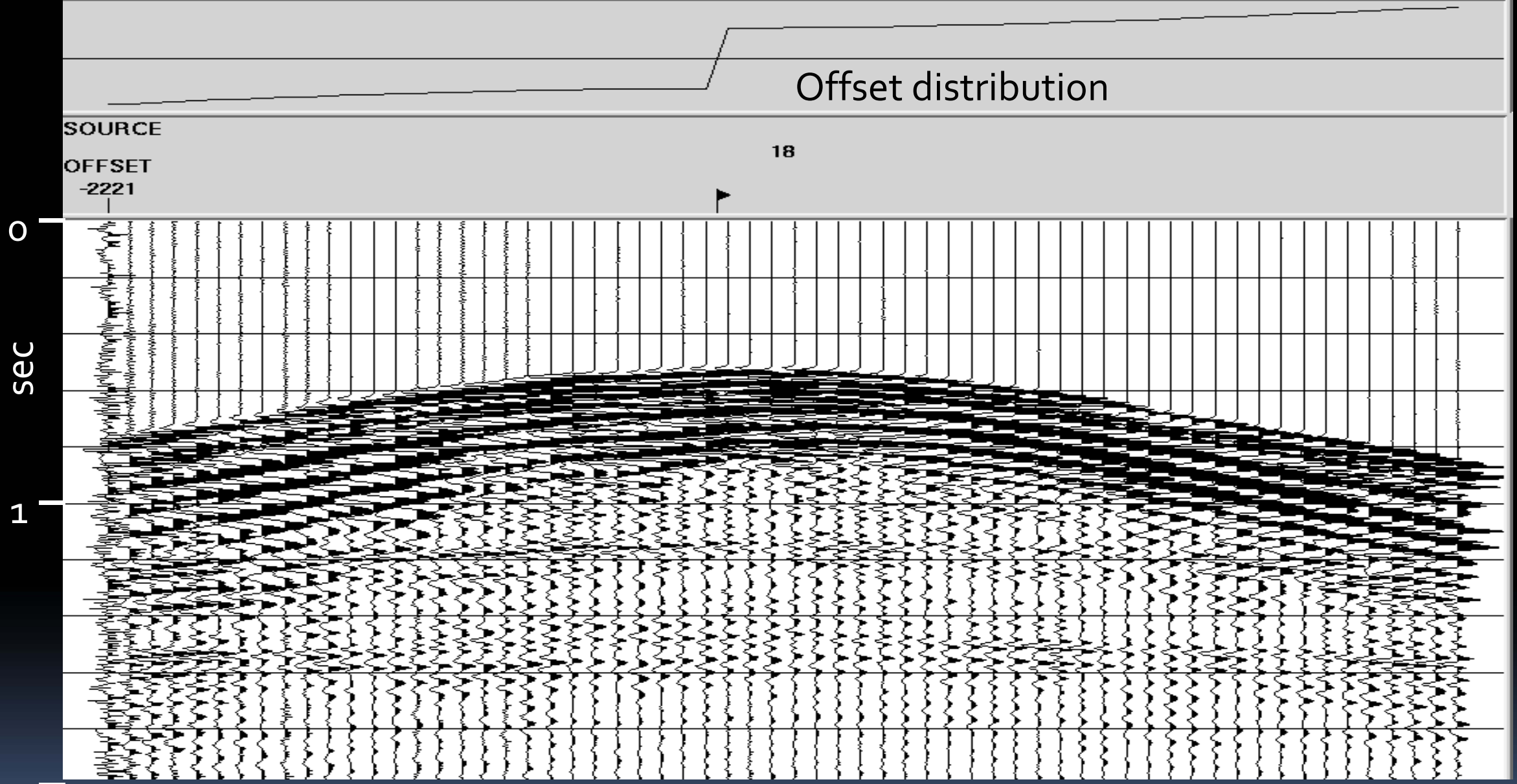
- ***Modest-sized*** survey (~10^6 traces in each component) to keep processing turnaround reasonable
- ***High-quality*** data
- ***Minimal*** geological ***structure***
- ***Visible statics*** throughout survey



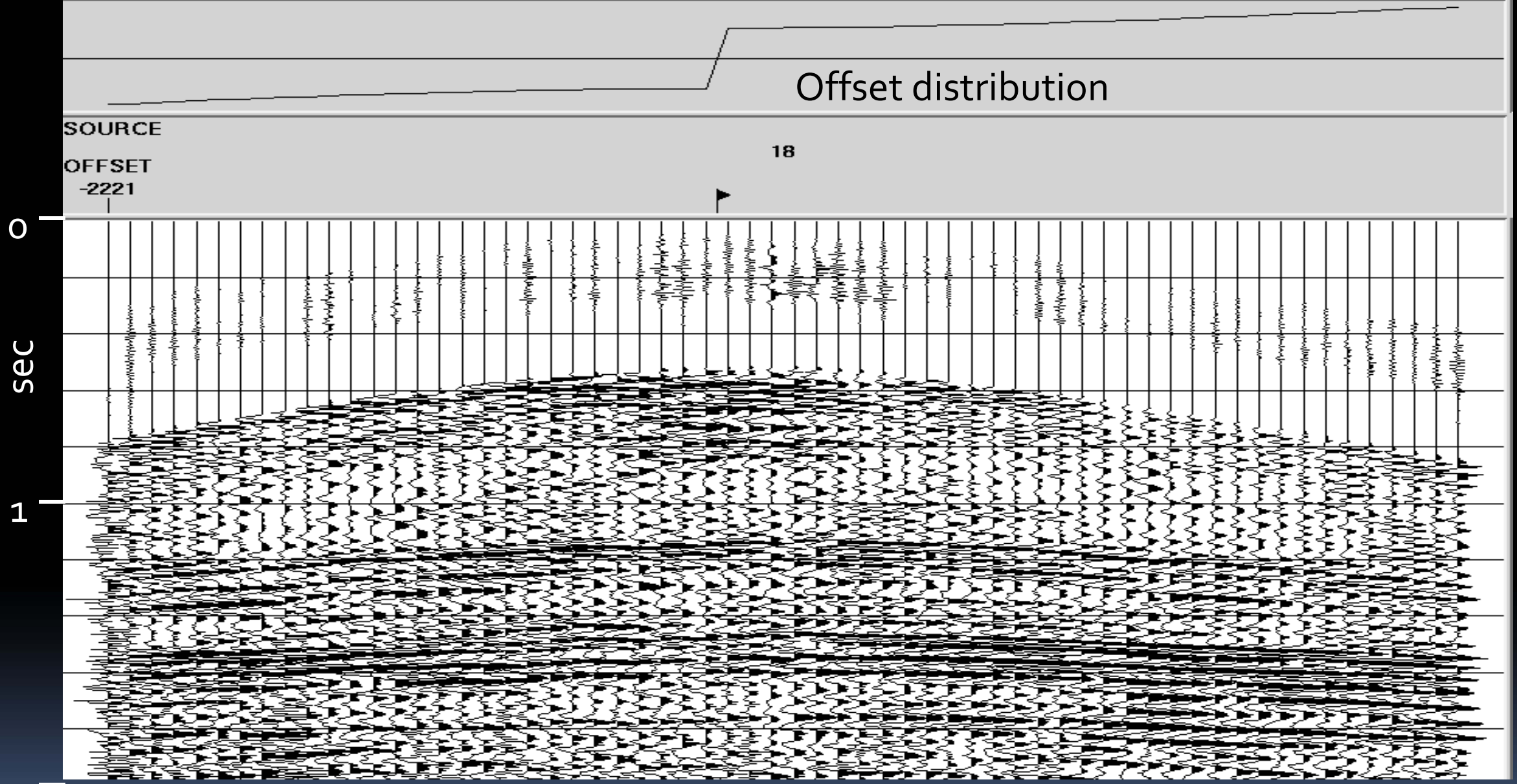
Raw receiver line gathers—**signed offsets** restored for radial filter



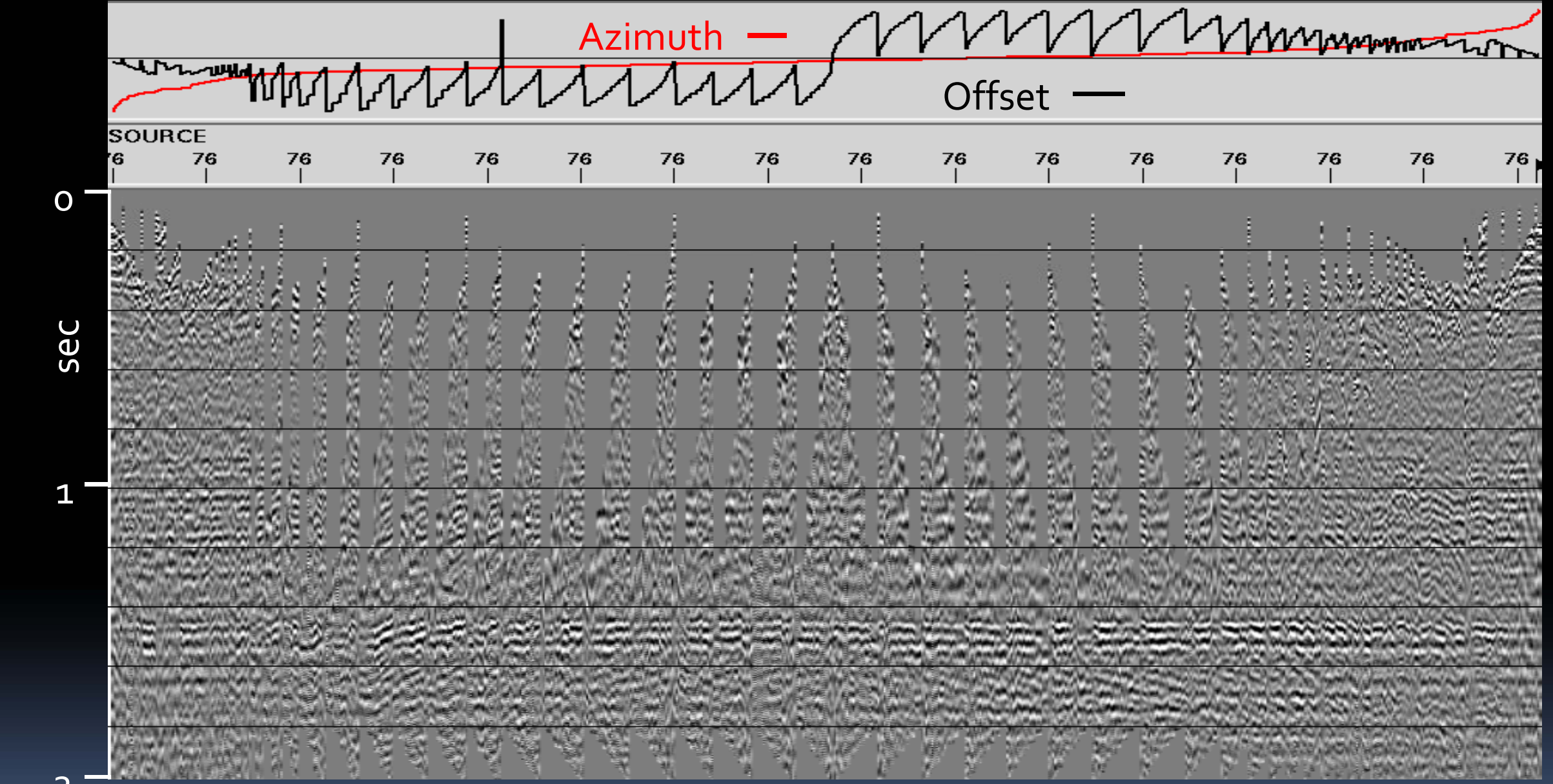
Raw receiver line gathers—one pass radial filter applied to reduce ground roll



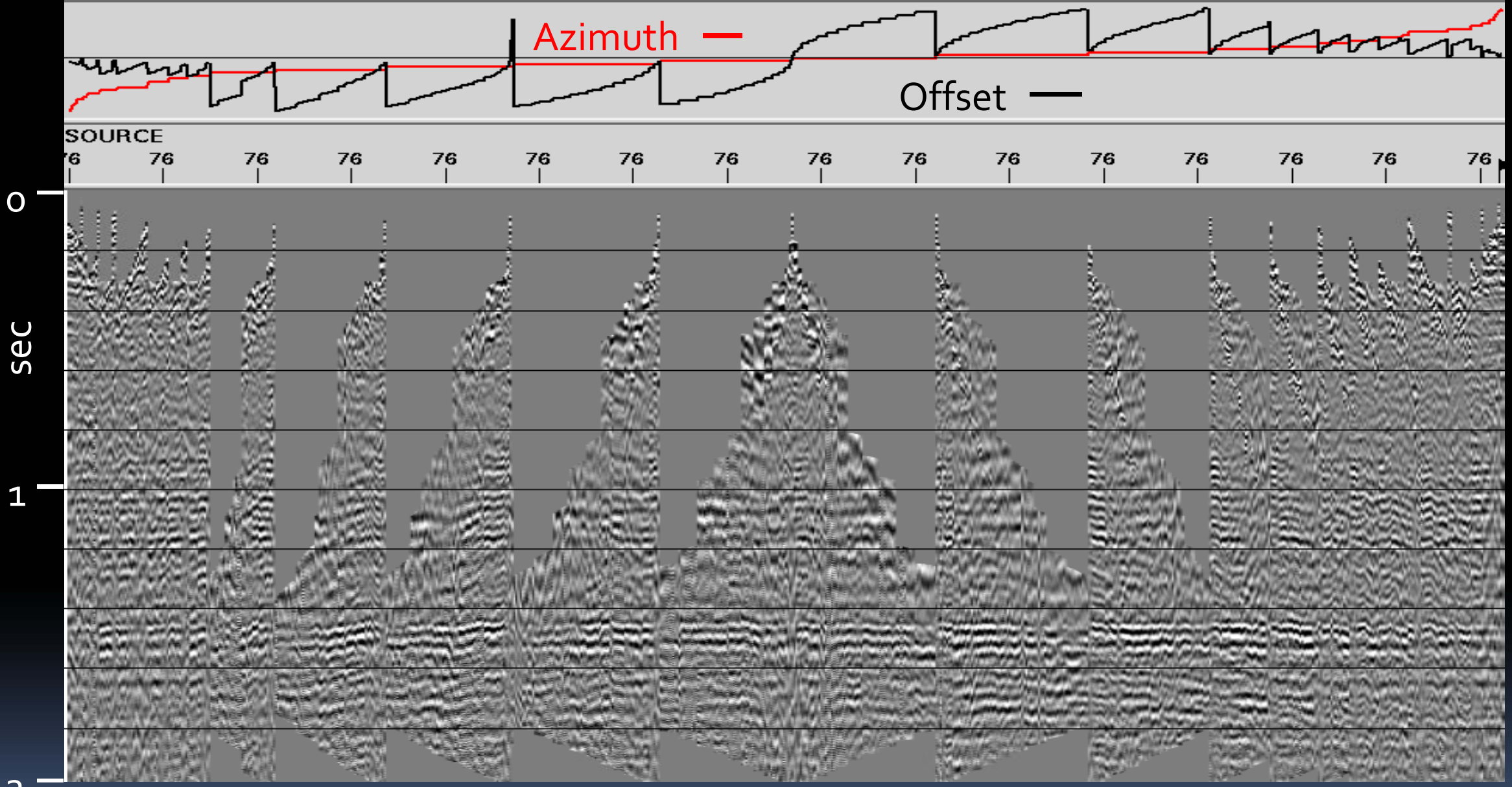
Individual receiver line gather with **signed offsets** restored for radial filter



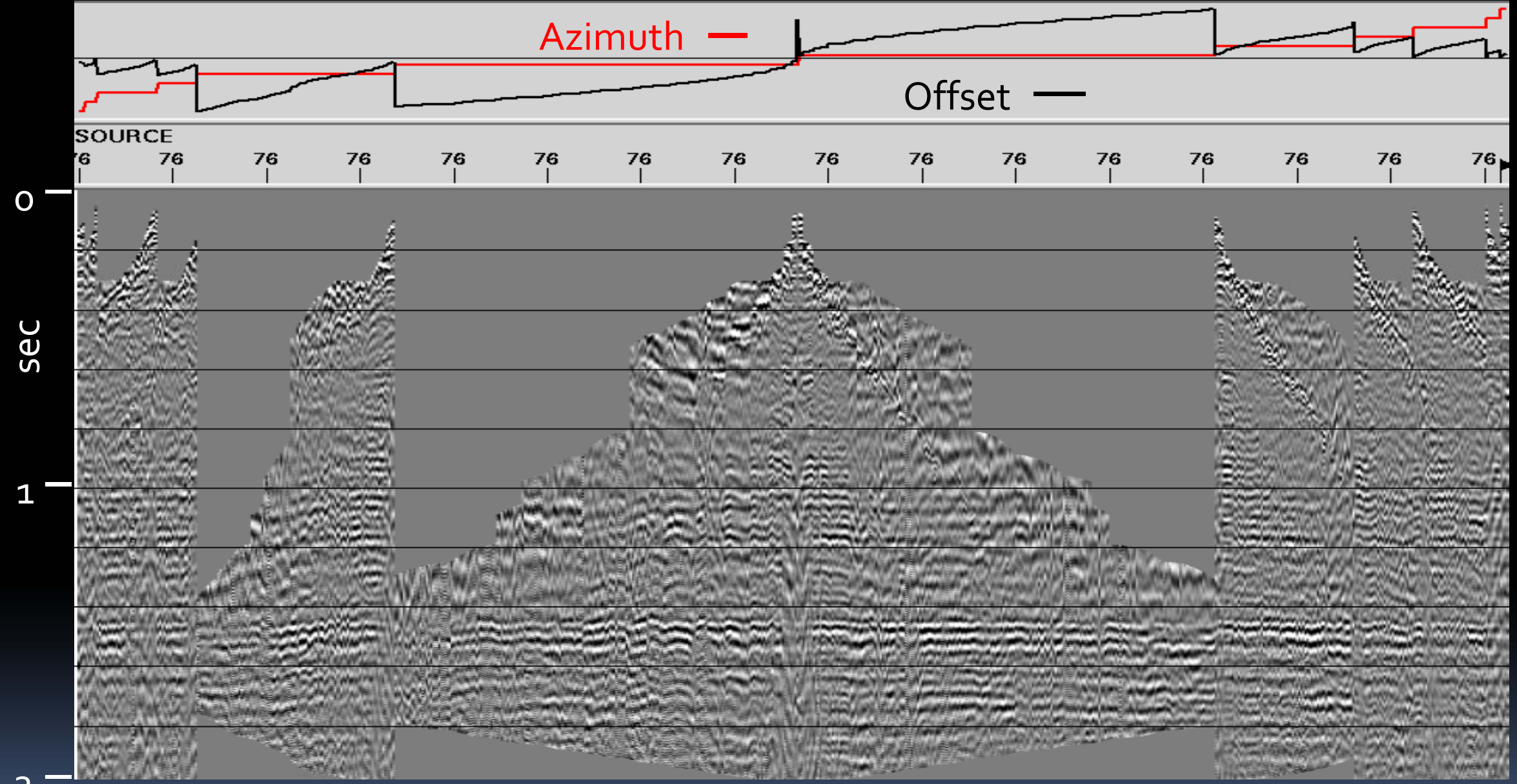
Individual receiver line gather after one pass radial filter



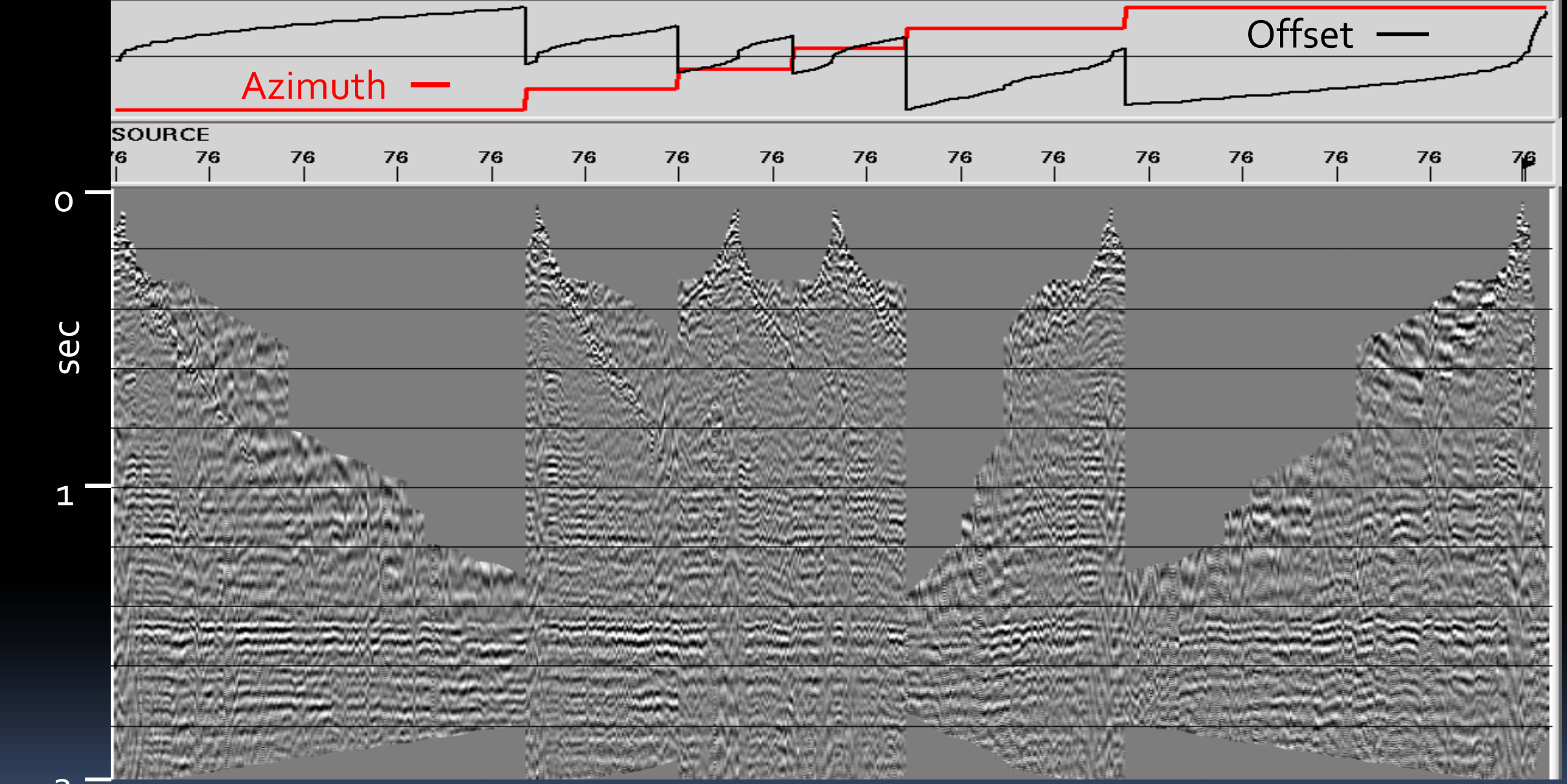
Traces for source 76 binned by azimuth, offset—azimuth bin width = **3deg**



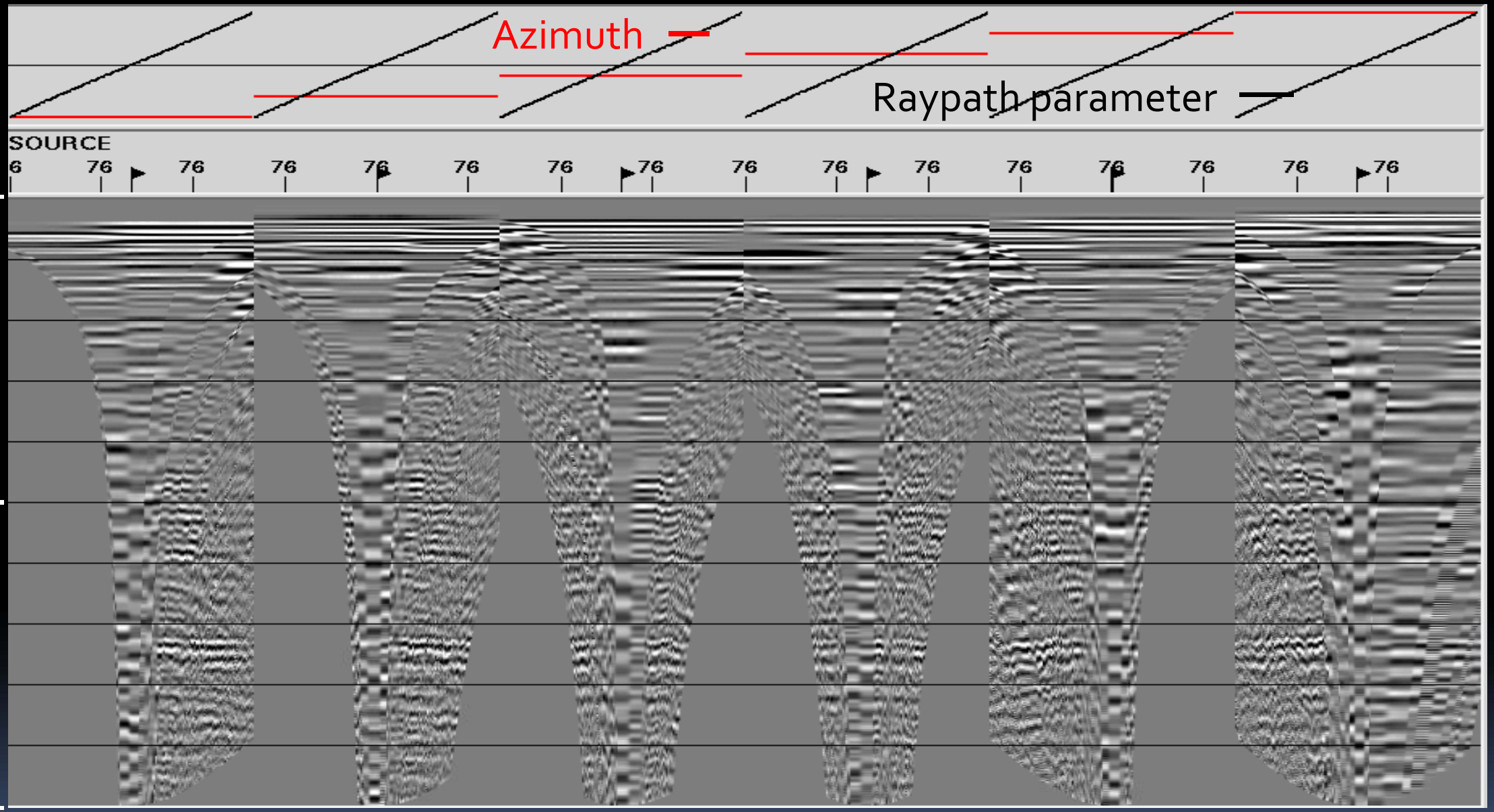
Traces for source 76 binned by azimuth, offset—azimuth bin width = **10deg**



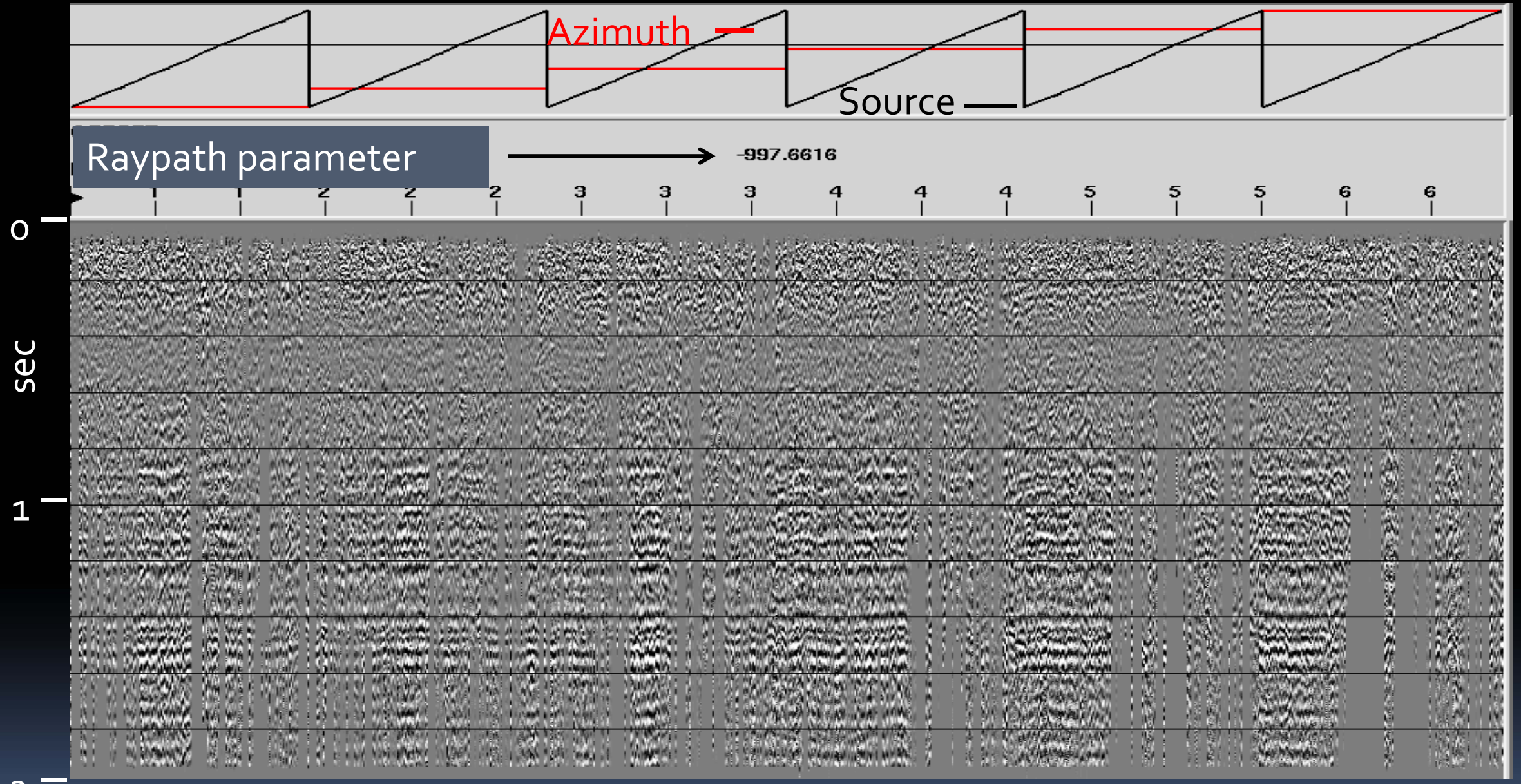
Traces for source 76 binned by azimuth, offset—azimuth bin width = **30deg**



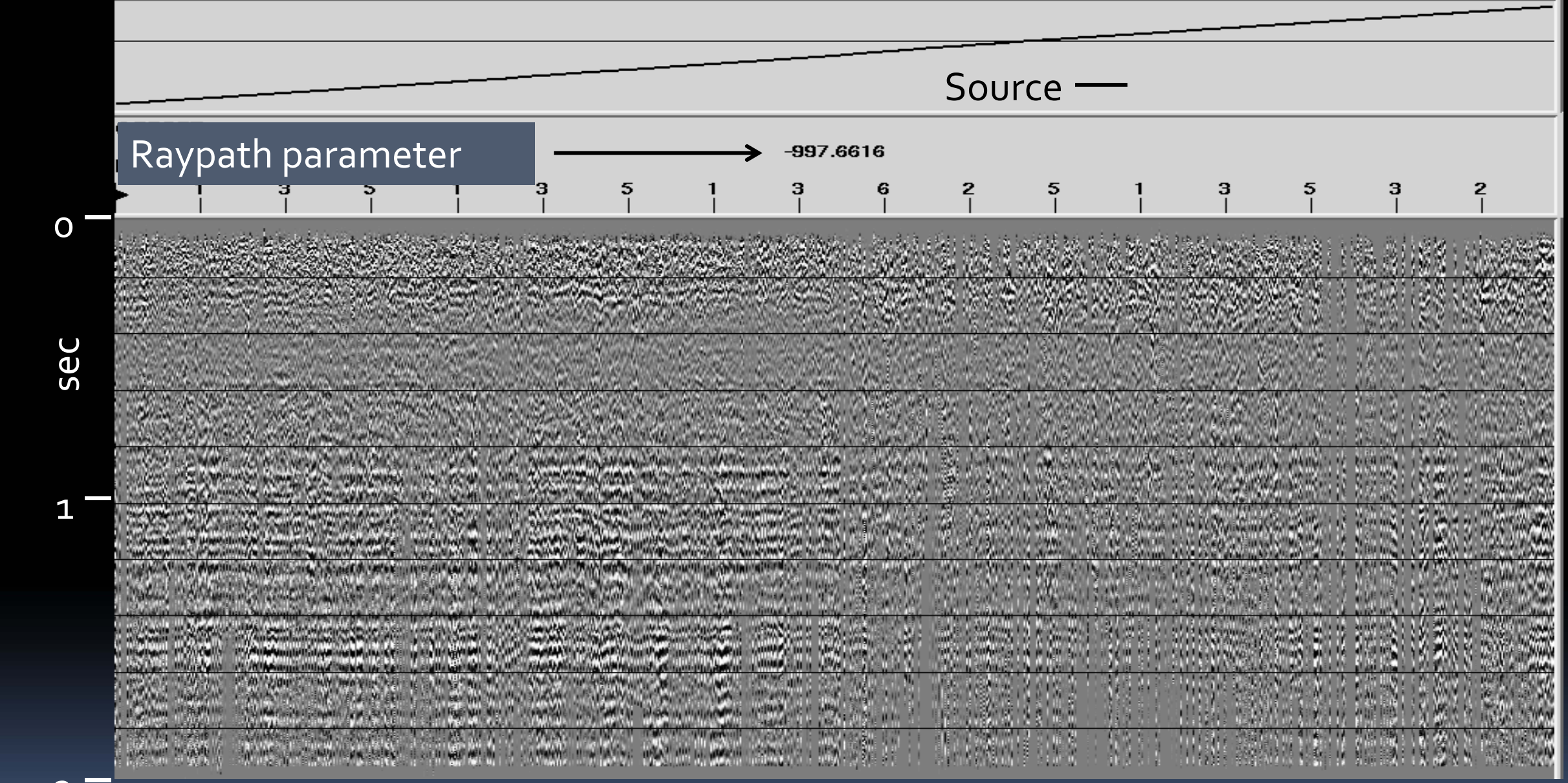
Traces for source 76 binned by azimuth, offset—azimuth bin width = **30deg**, bins aligned at **180deg** combined



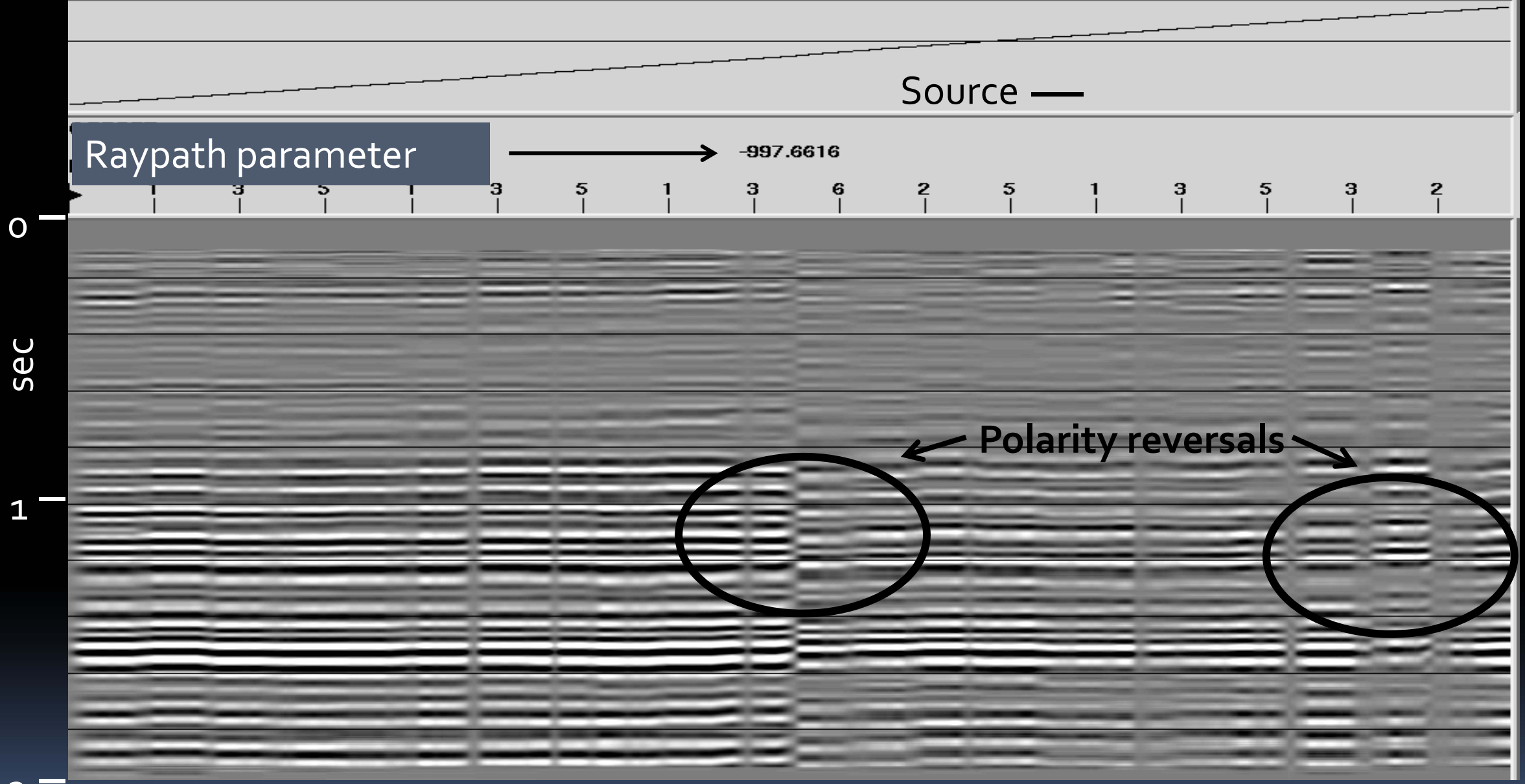
Radial trace transforms of azimuth-offset gathers—**'raypath'** traces



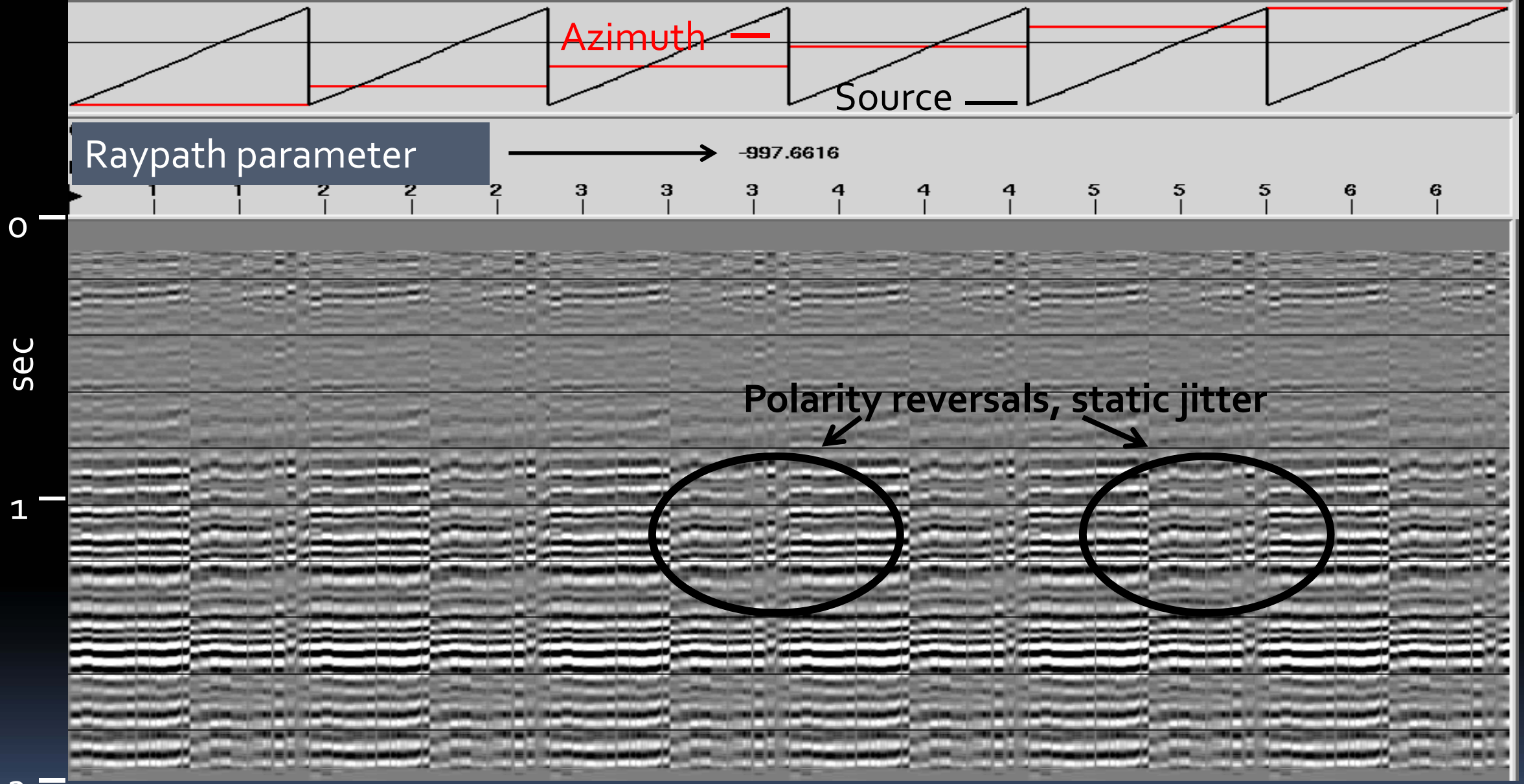
'Raypath' traces sorted by **raypath** parameter, **azimuth**, **source**



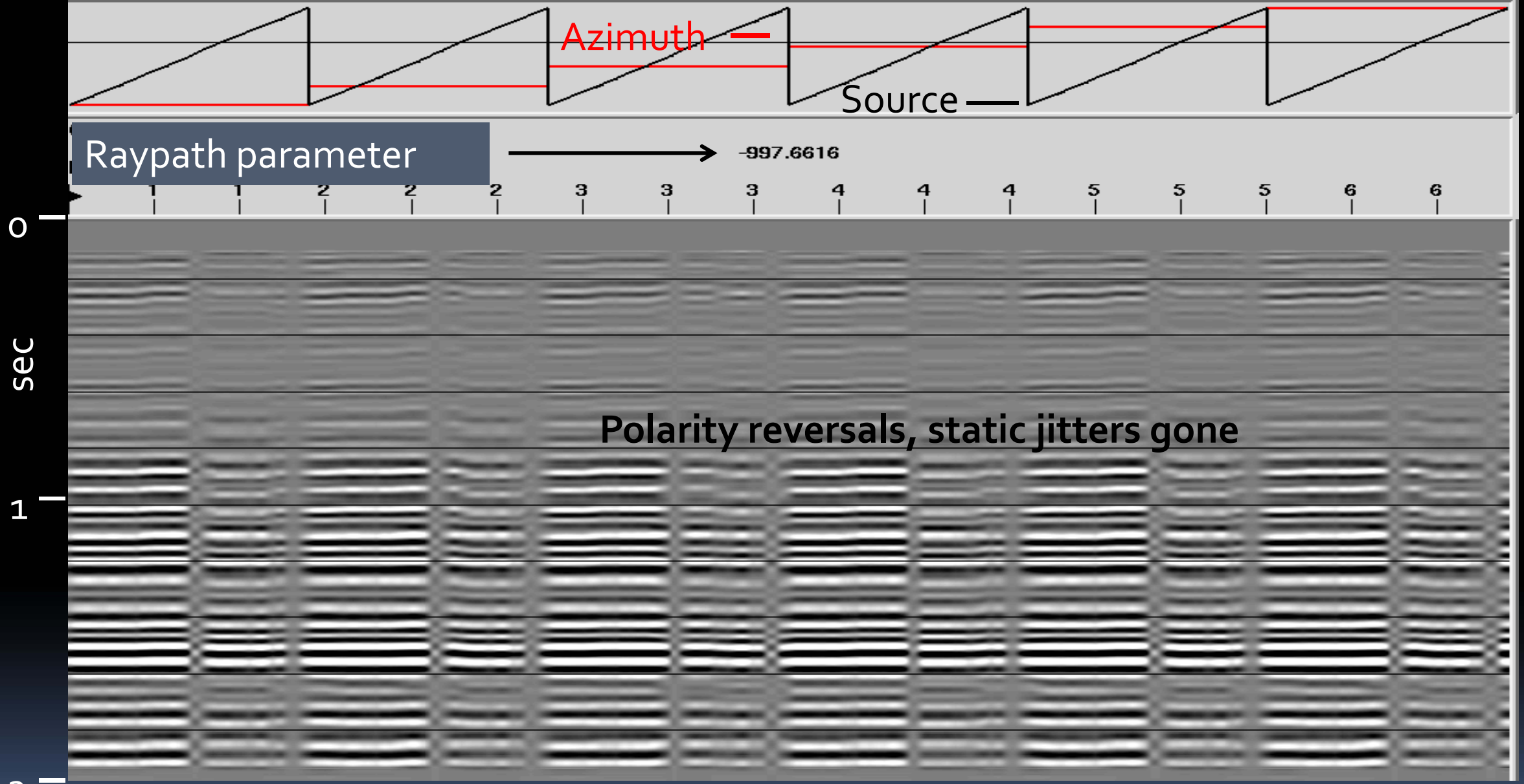
'Raypath' traces sorted by raypath parameter, source, azimuth



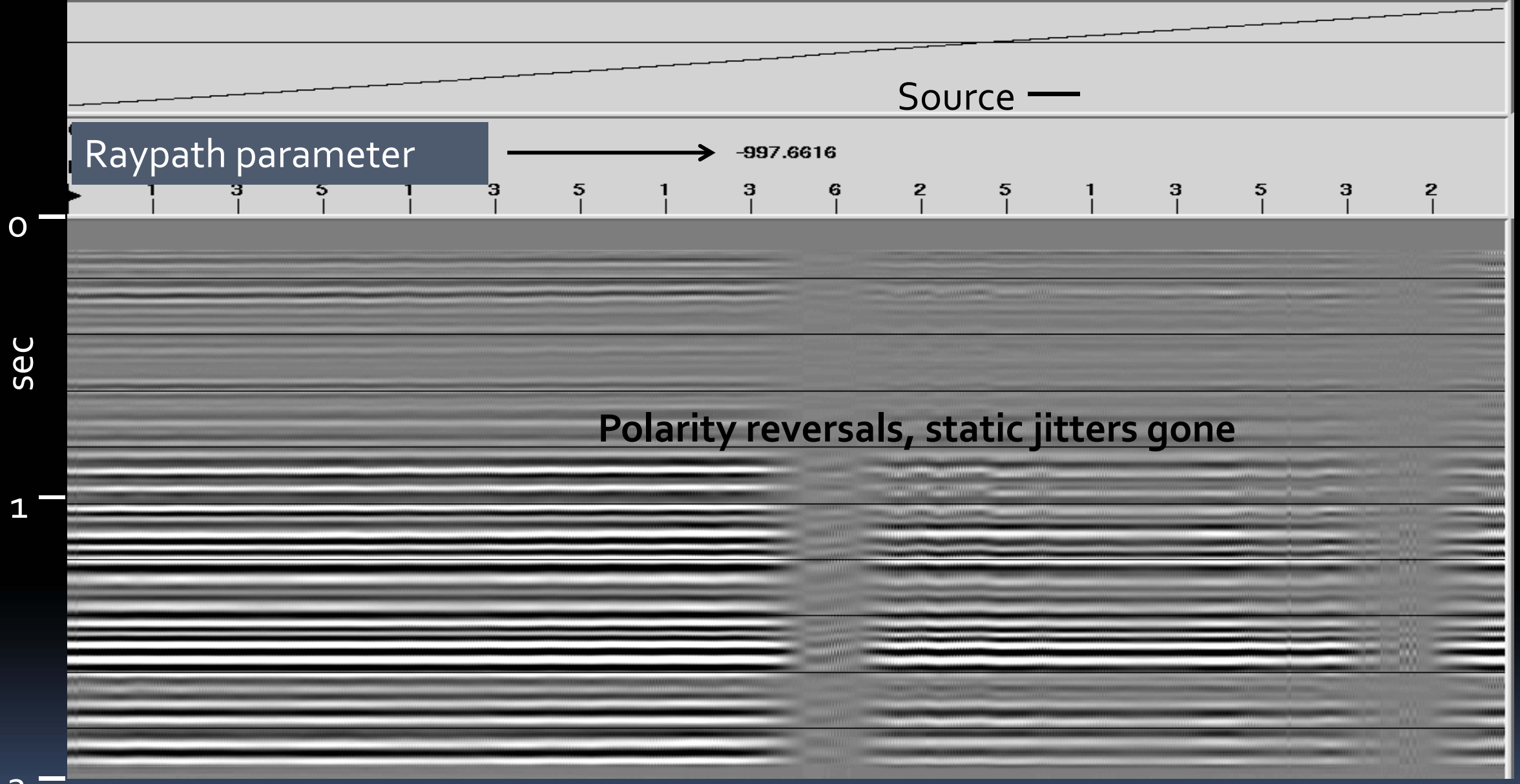
Pilot traces from one pass of smoothing on raypath traces sorted by raypath parameter, source, azimuth



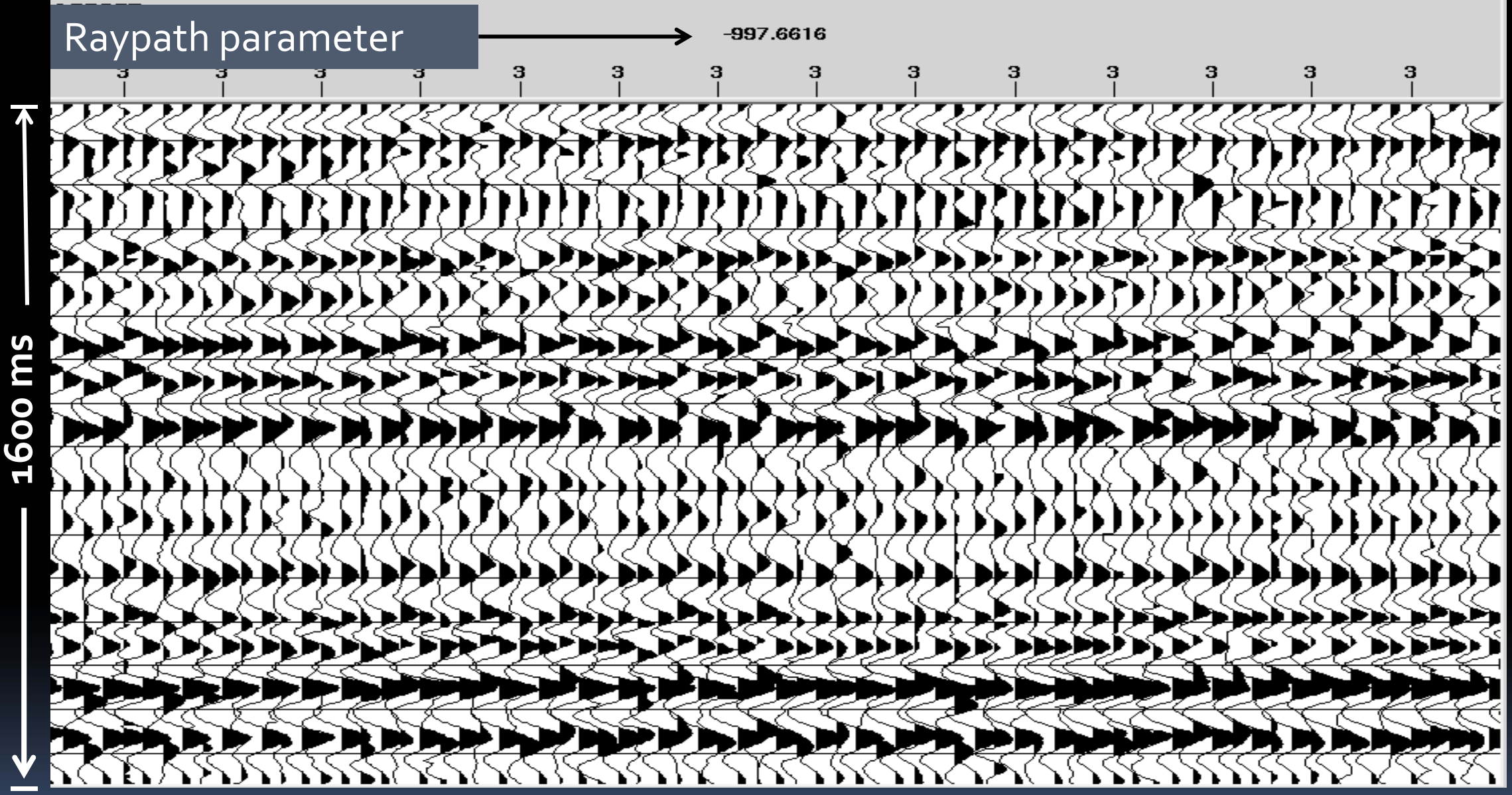
Pilot traces from one pass of smoothing on raypath traces sorted by raypath parameter, azimuth, source



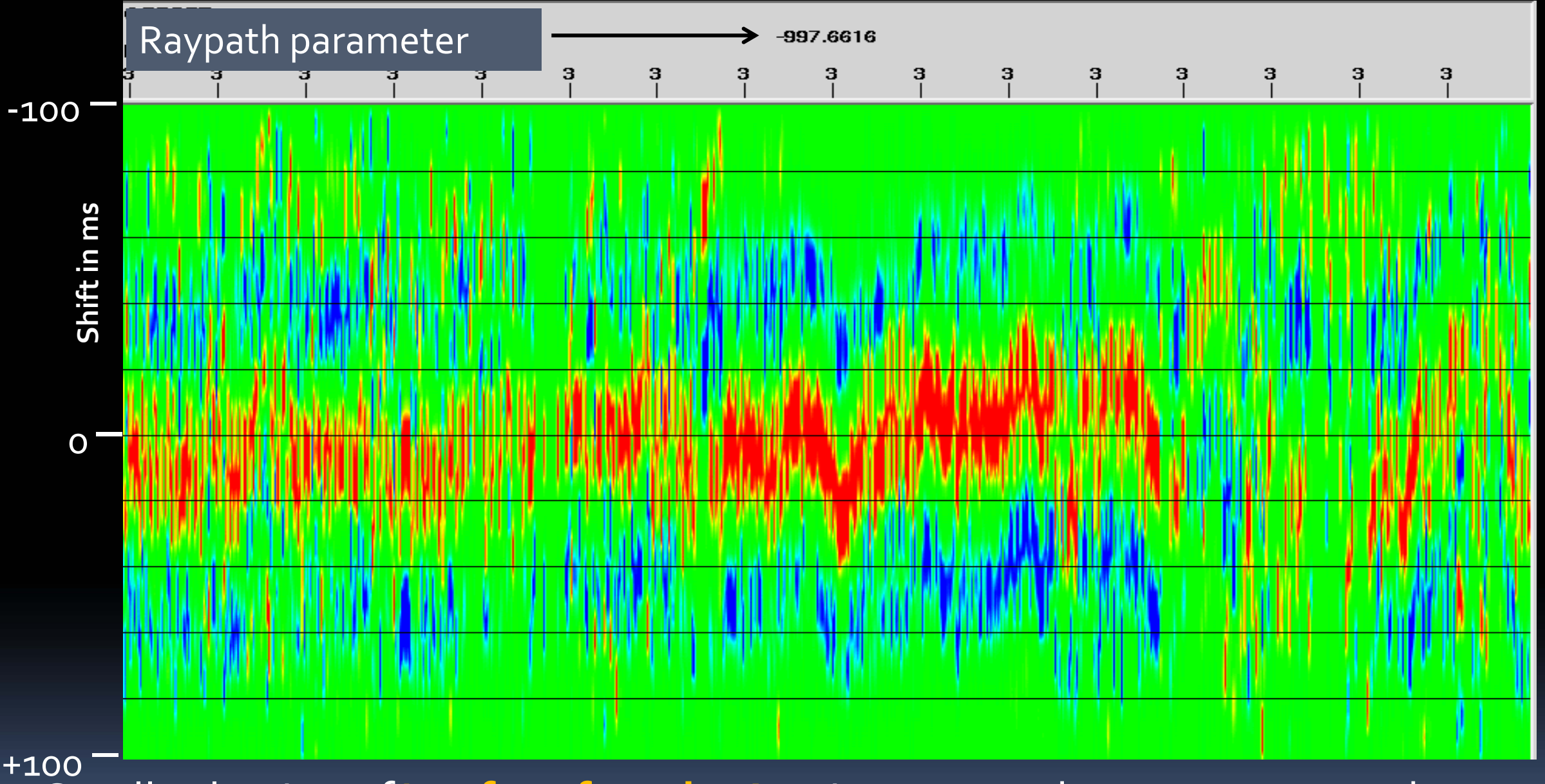
Pilot traces from two smoothing passes on raypath traces, sorted by raypath parameter, azimuth, source



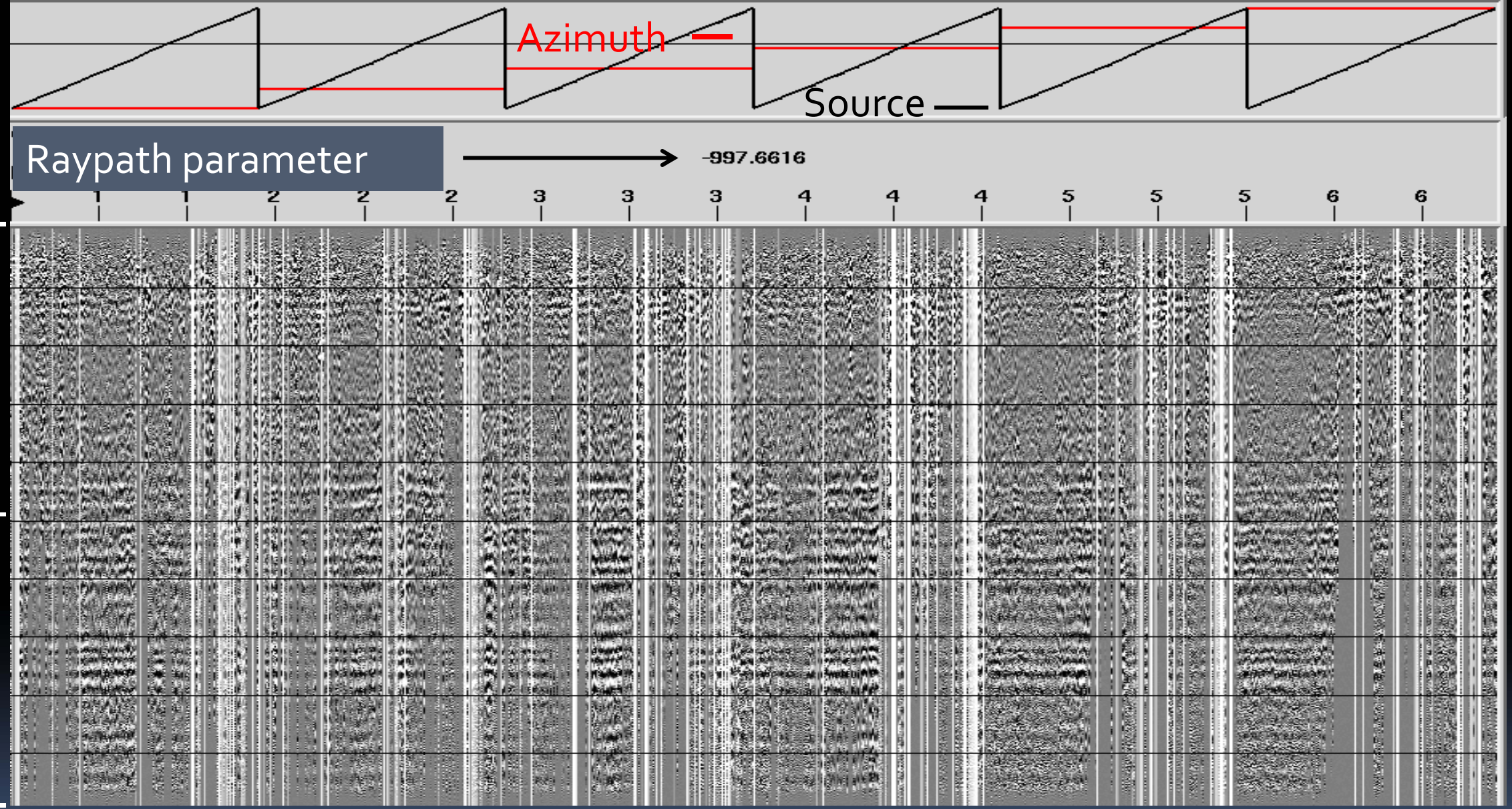
Pilot traces from two passes of smoothing, sorted by **raypath** parameter, **source**, **azimuth**



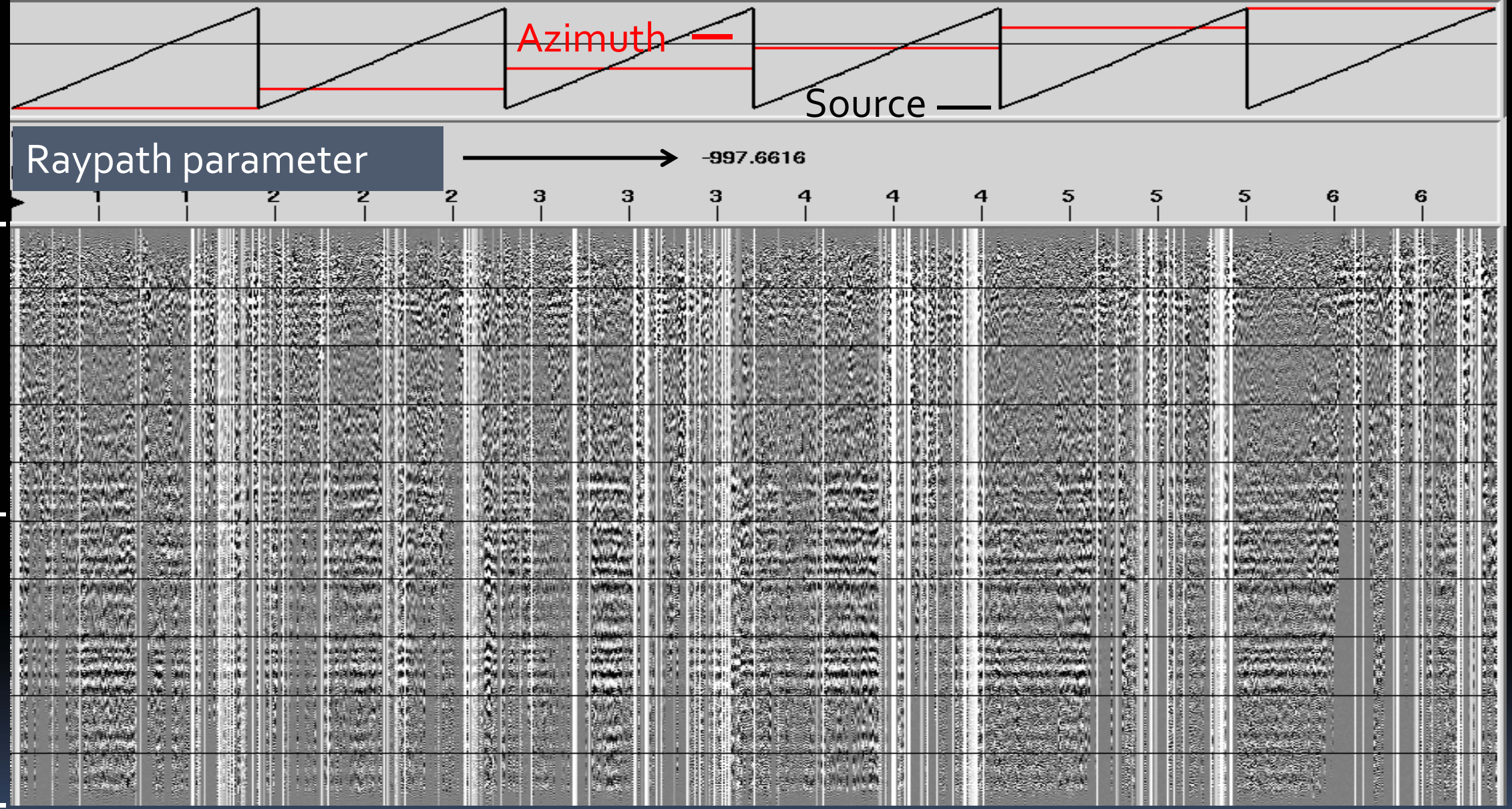
Small sample of raypath trace/pilot trace pairs, showing **differences** to be captured by **cross-correlation** as **surface functions**



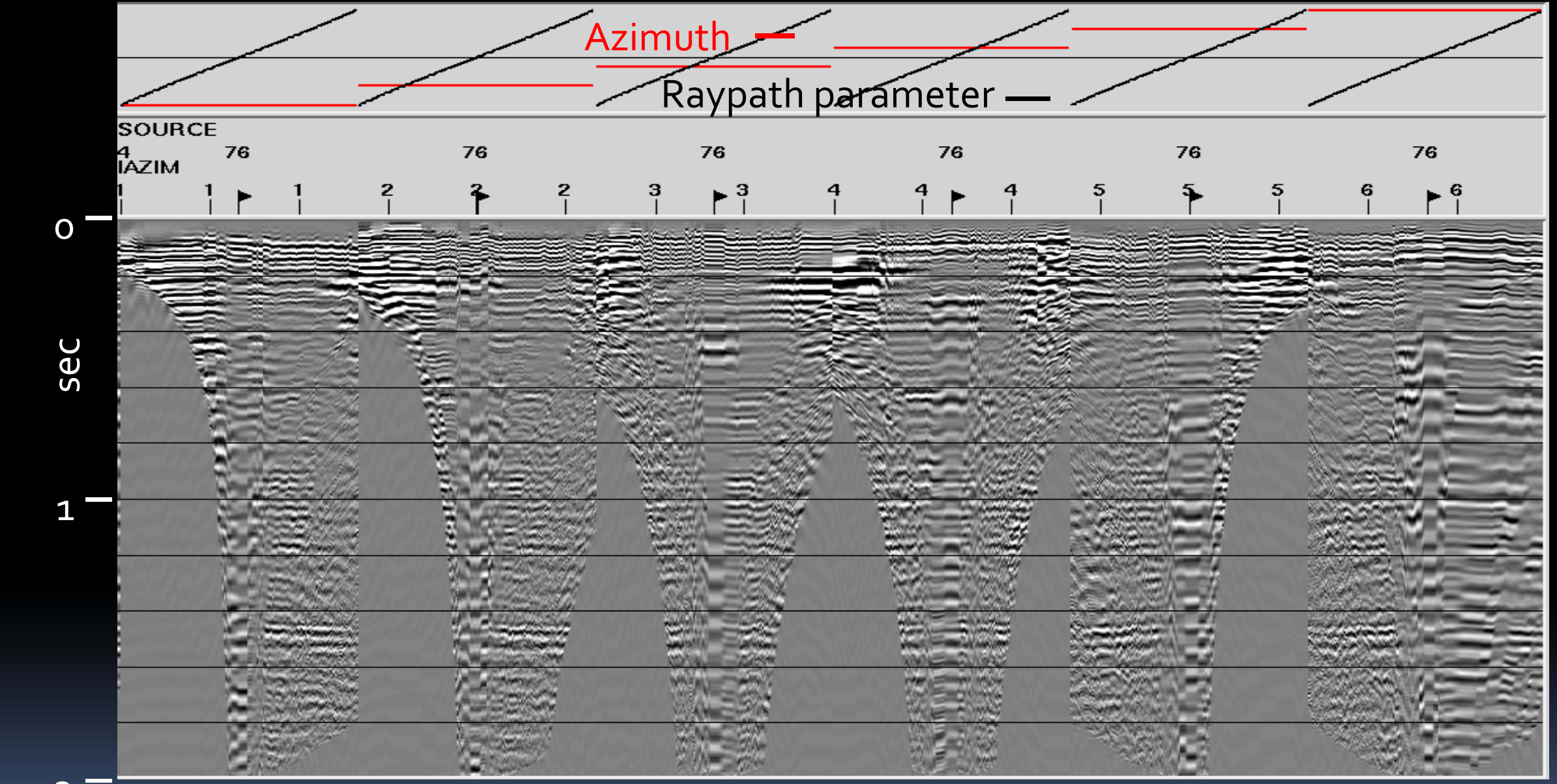
Small selection of **'surface function'** estimates used to correct raypath traces



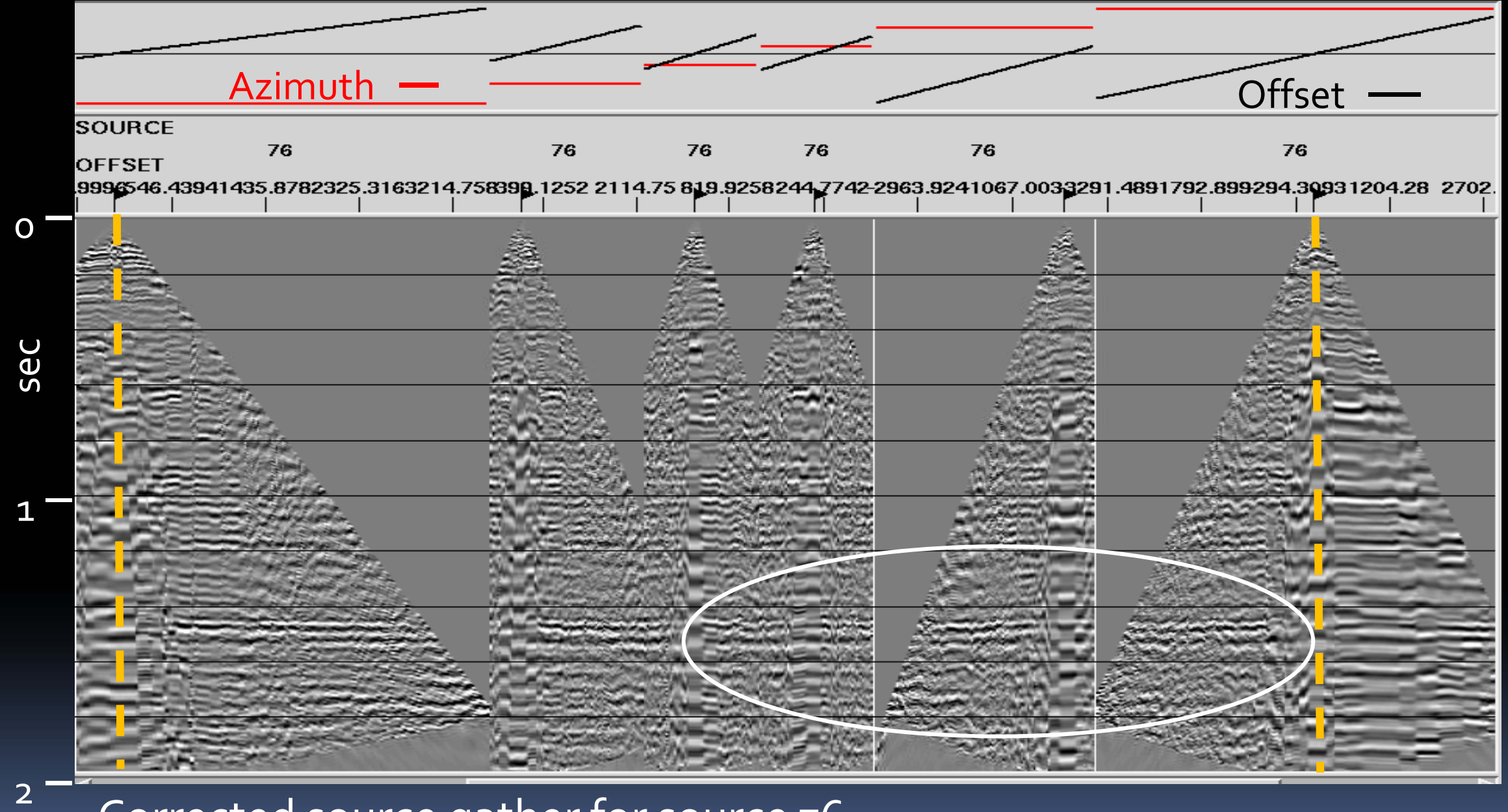
Corrected raypath traces sorted by **raypath** parameter, **azimuth**, **source**—1D smoothed pilots



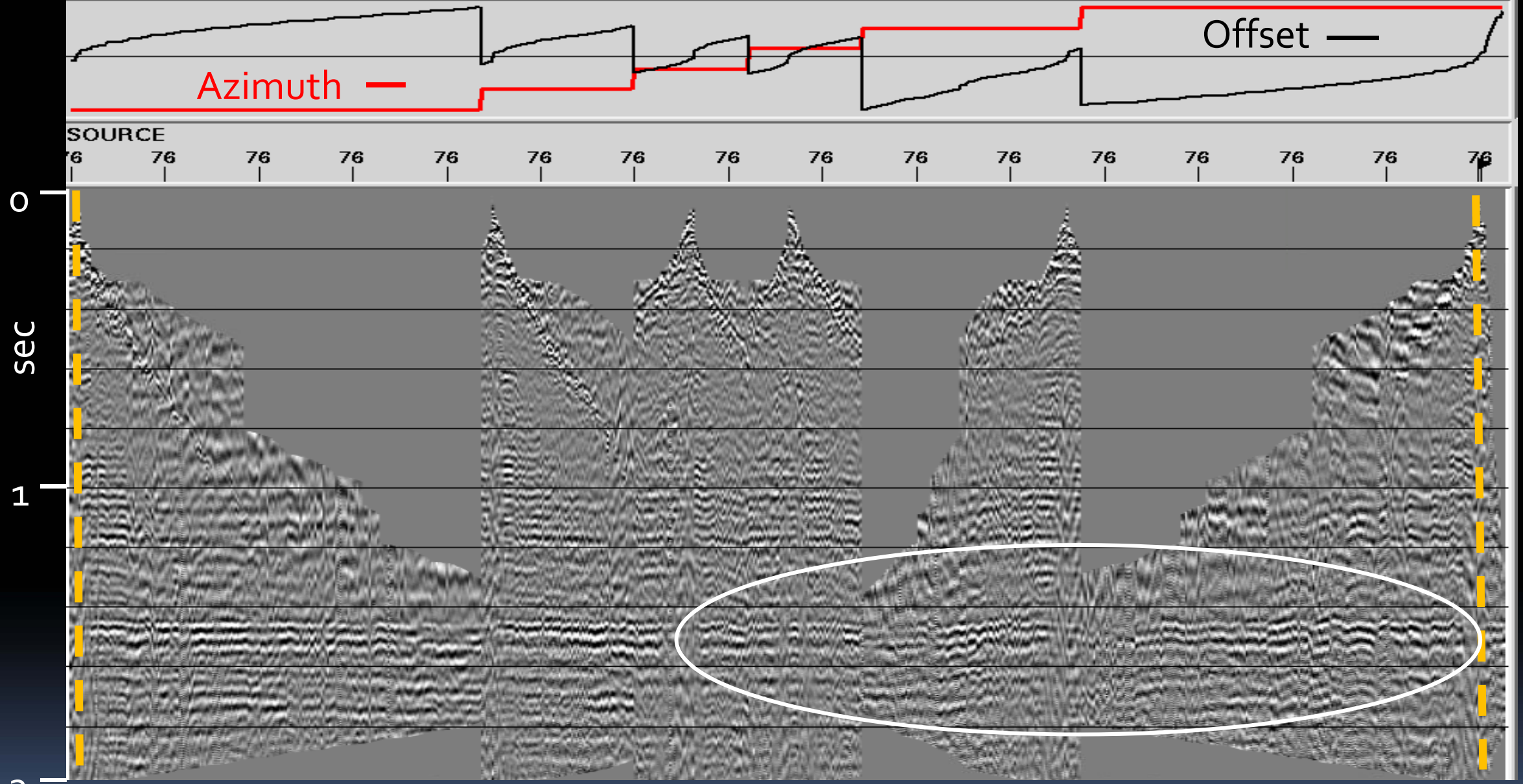
Corrected raypath traces sorted by **raypath** parameter, **azimuth**, **source**—2D smoothed pilots



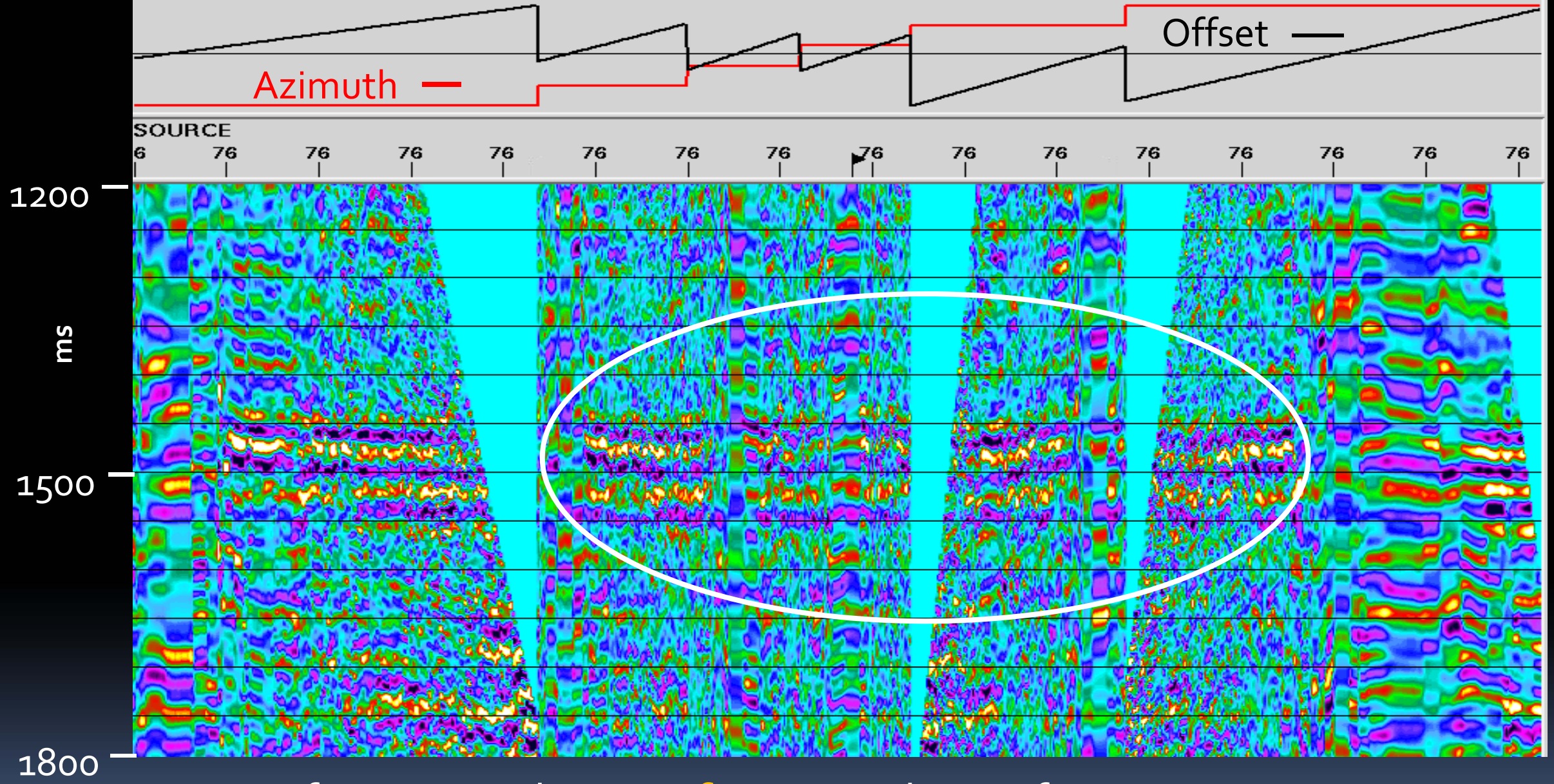
Corrected raypath gathers (RT transforms of azimuth-offset gathers)



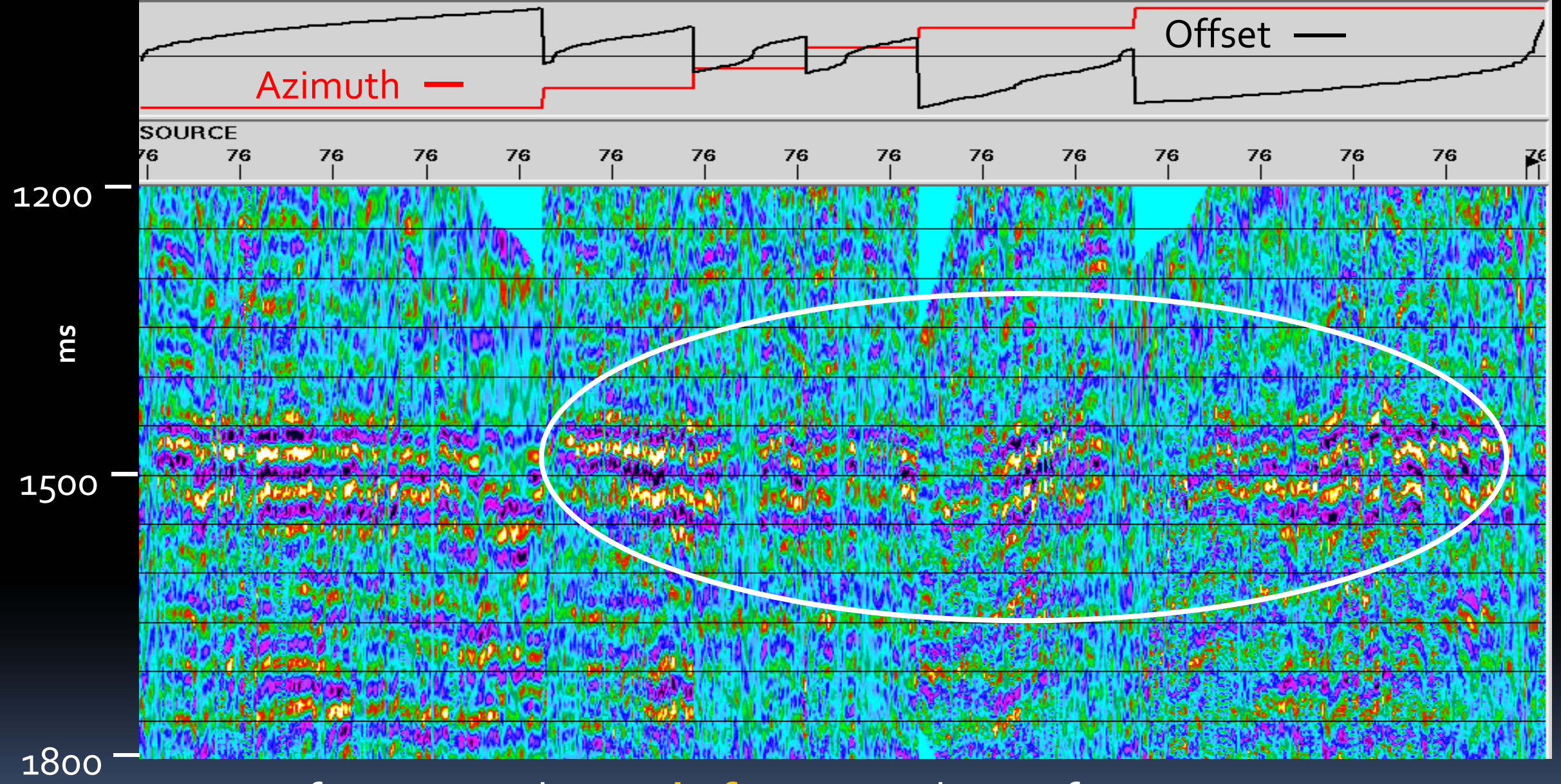
Corrected source gather for source 76



Uncorrected source gather for source 76



Zoom of source gather 76 ***after*** raypath interferometry



Zoom of source gather 76 ***before*** raypath interferometry

Discussion

- ***RT transform*** can be used even in 3D—other transforms should be investigated
- RT transform should be ***rewritten*** to retain all original headers
- Smoothing in ***2 directions*** required for reference wavefront construction—directions need ***not*** be ***orthogonal***
- ***Two passes*** of raypath interferometry likely needed
- Geological ***structure*** will introduce ***difficulties***
- While static jitter obviously reduced on gathers, full **imaging** needed to ***fully verify*** approach

Acknowledgements

- CREWES sponsors and NSERC for funding
- R. Cova for discussions
- K. Hall for SeisSpace support and patience