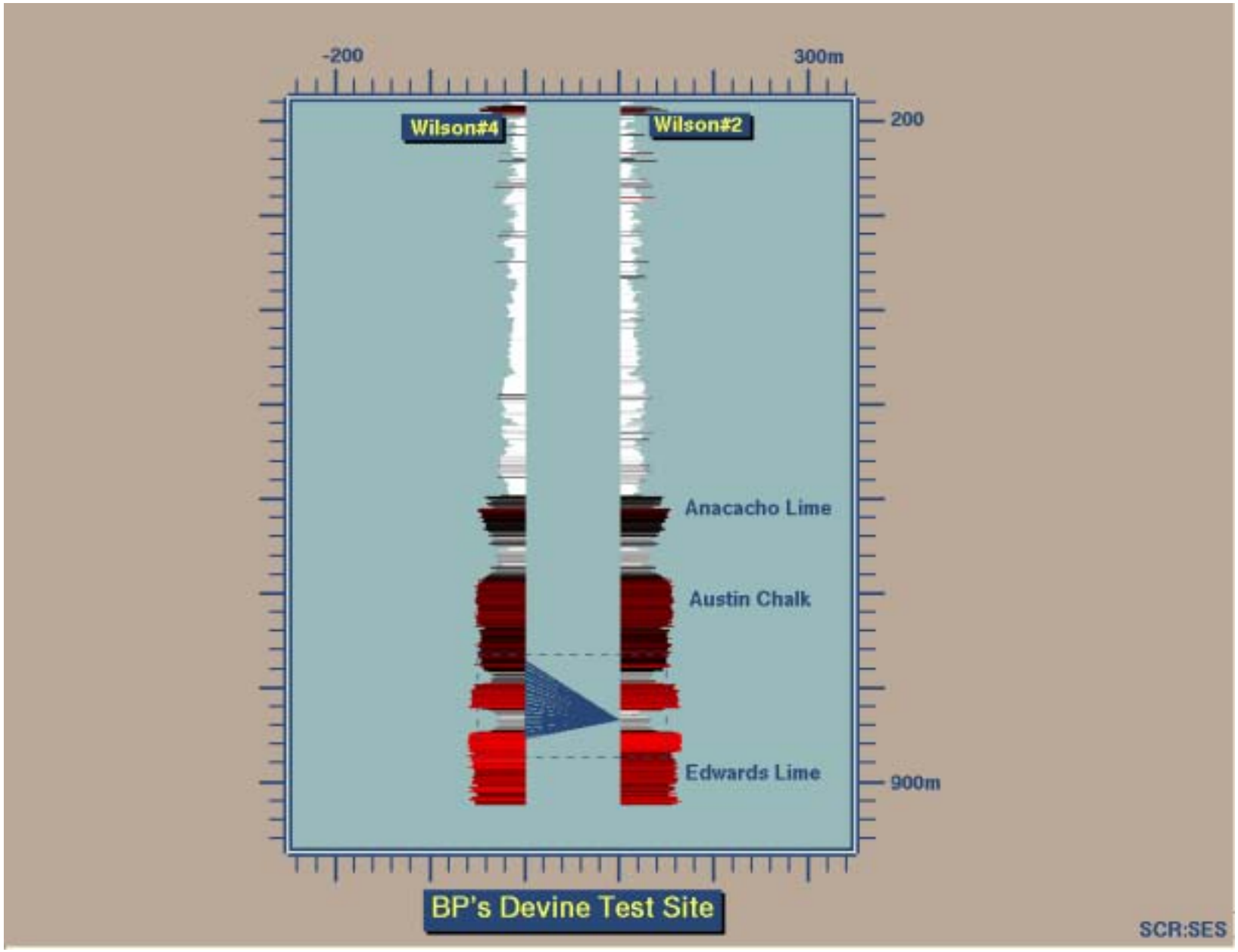
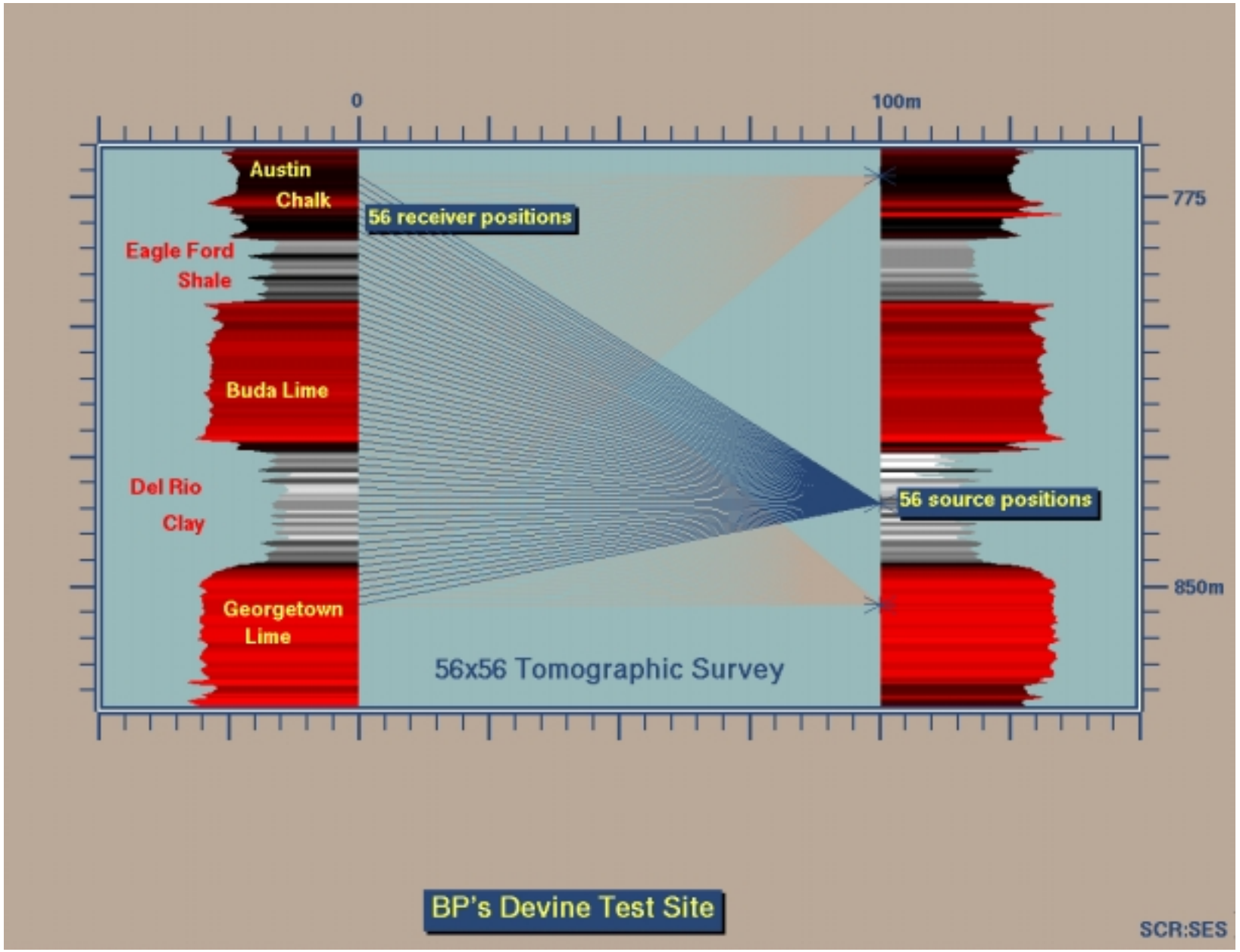
Incontrovertible Evidence of Anisotropy in Crosswell Data

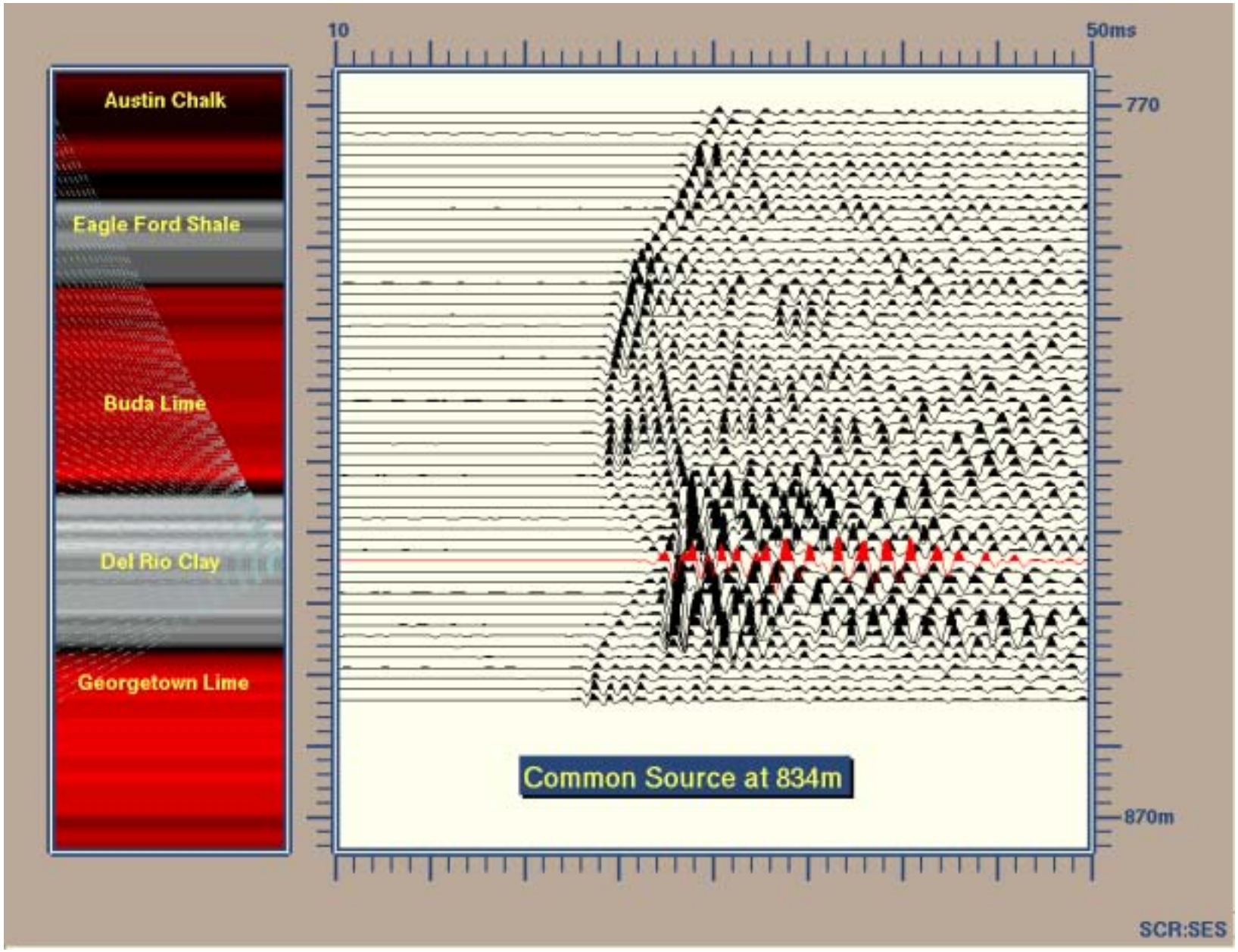
by

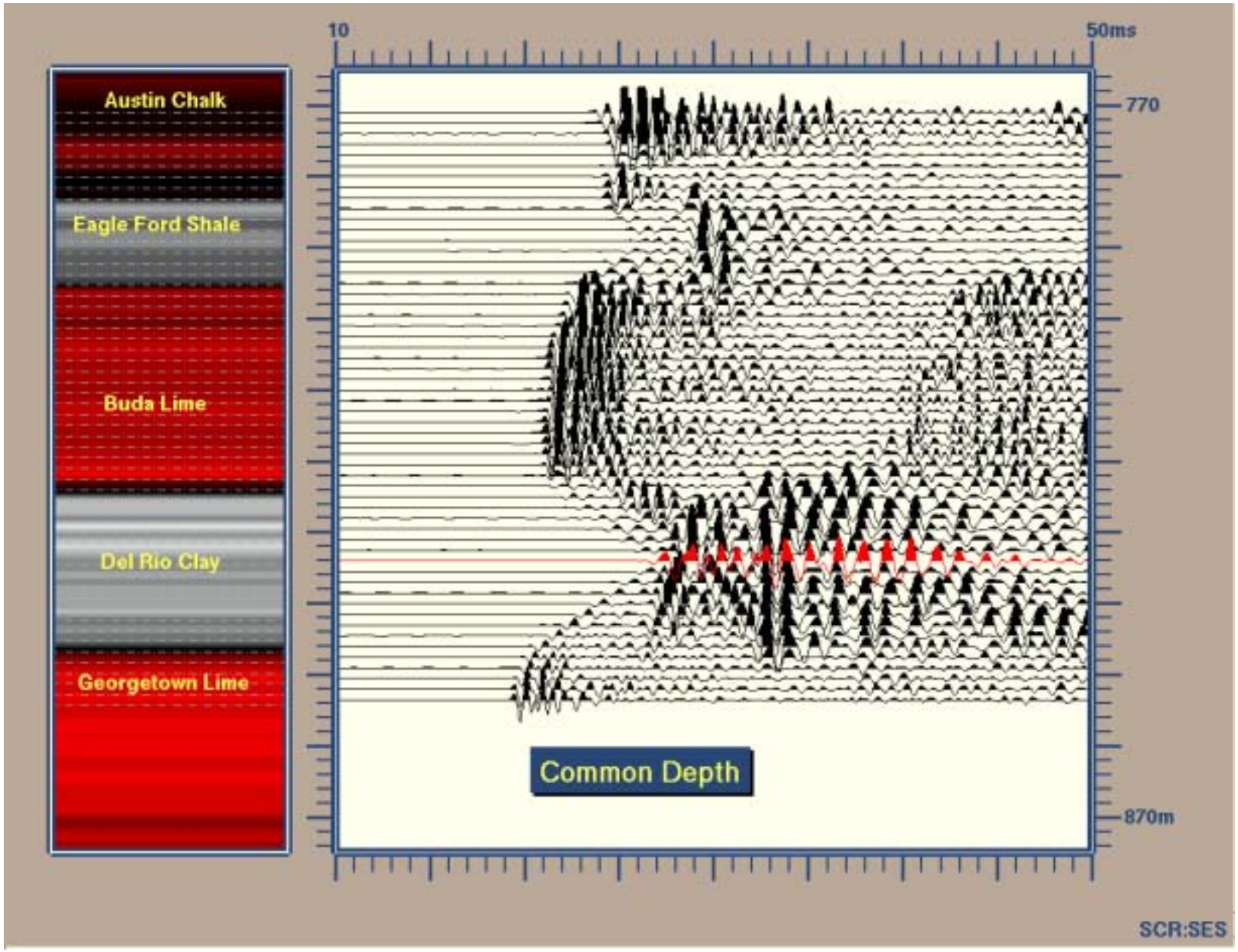
D. E. Miller and C. H. Chapman

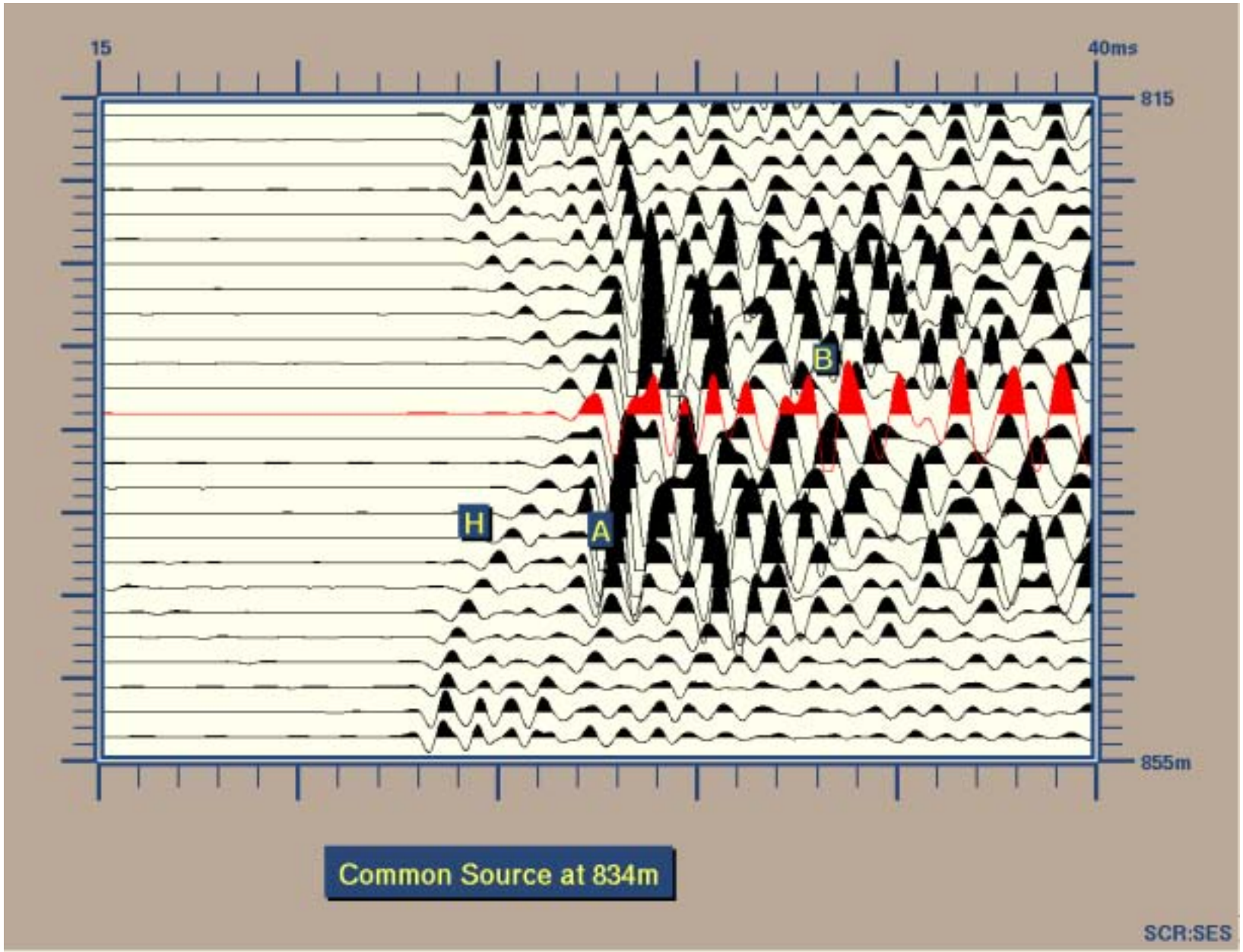
- DESCRIPTION of the Experiment
- ANALYSIS of Raw Data Records
- SYNTHESIS of the Anisotropic Medium
- CONCLUSIONS

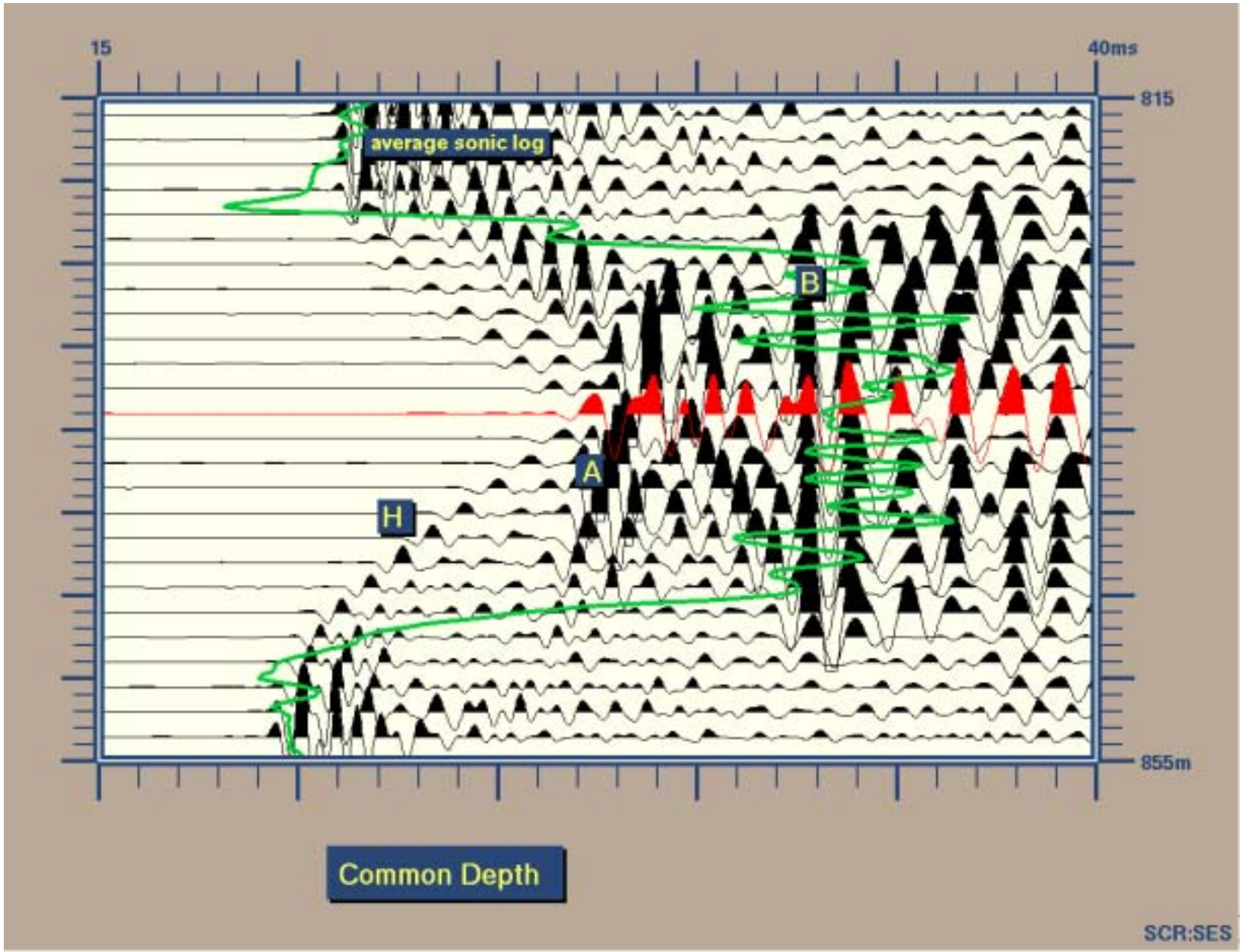

-200
300m
Wilson#4
Wilson#2
200
Anacacho Lime
Austin Chalk
Edwards Lime
900m
BP's Devine Test Site
SCR:SES

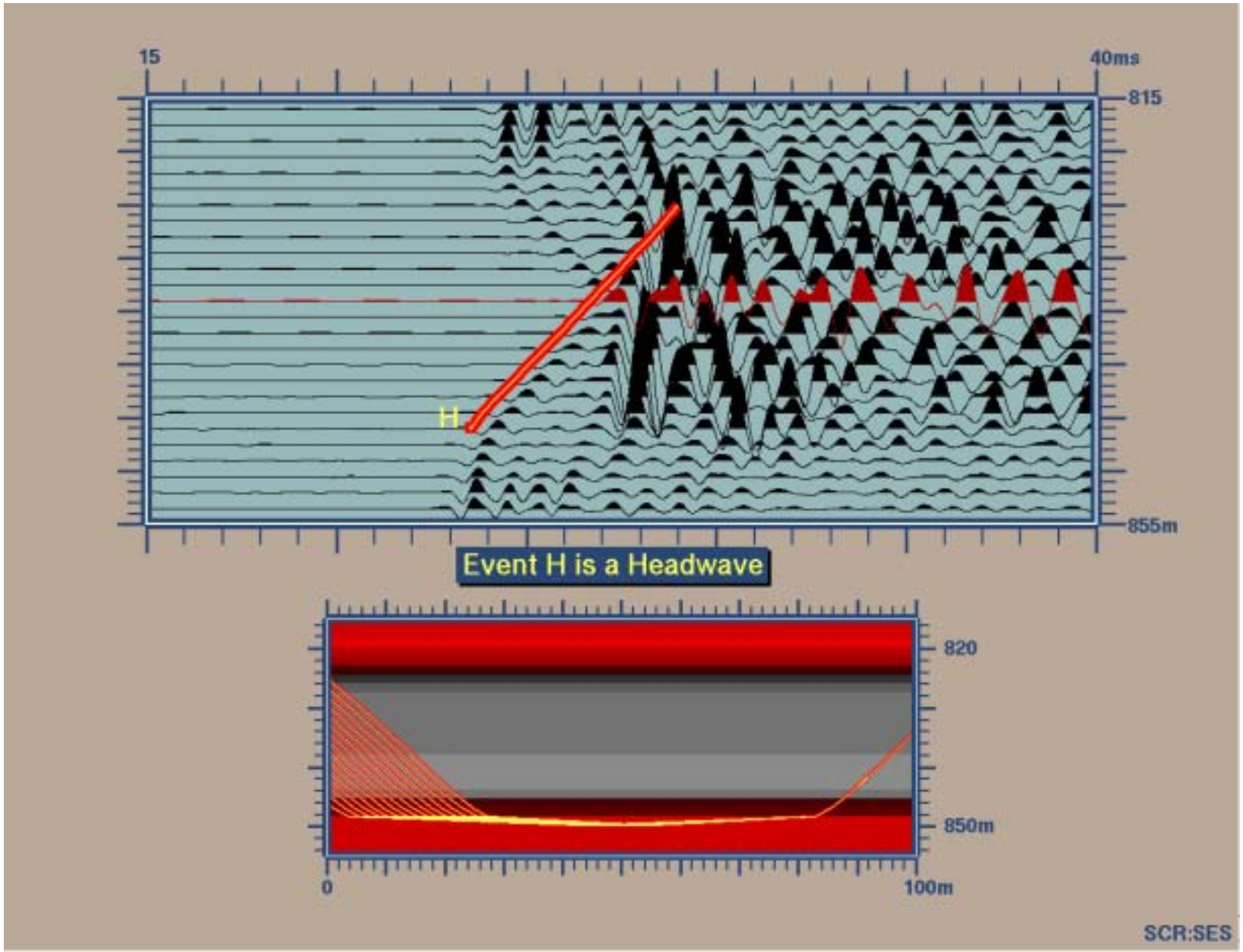

0
100m
Austin
Chalk
56 receiver positions
Eagle Ford
Shale
Buda Lime
Del Rio
Clay
Georgetown
Lime
56 source positions
56x56 Tomographic Survey
775
850m
BP's Devine Test Site
SCR:SES

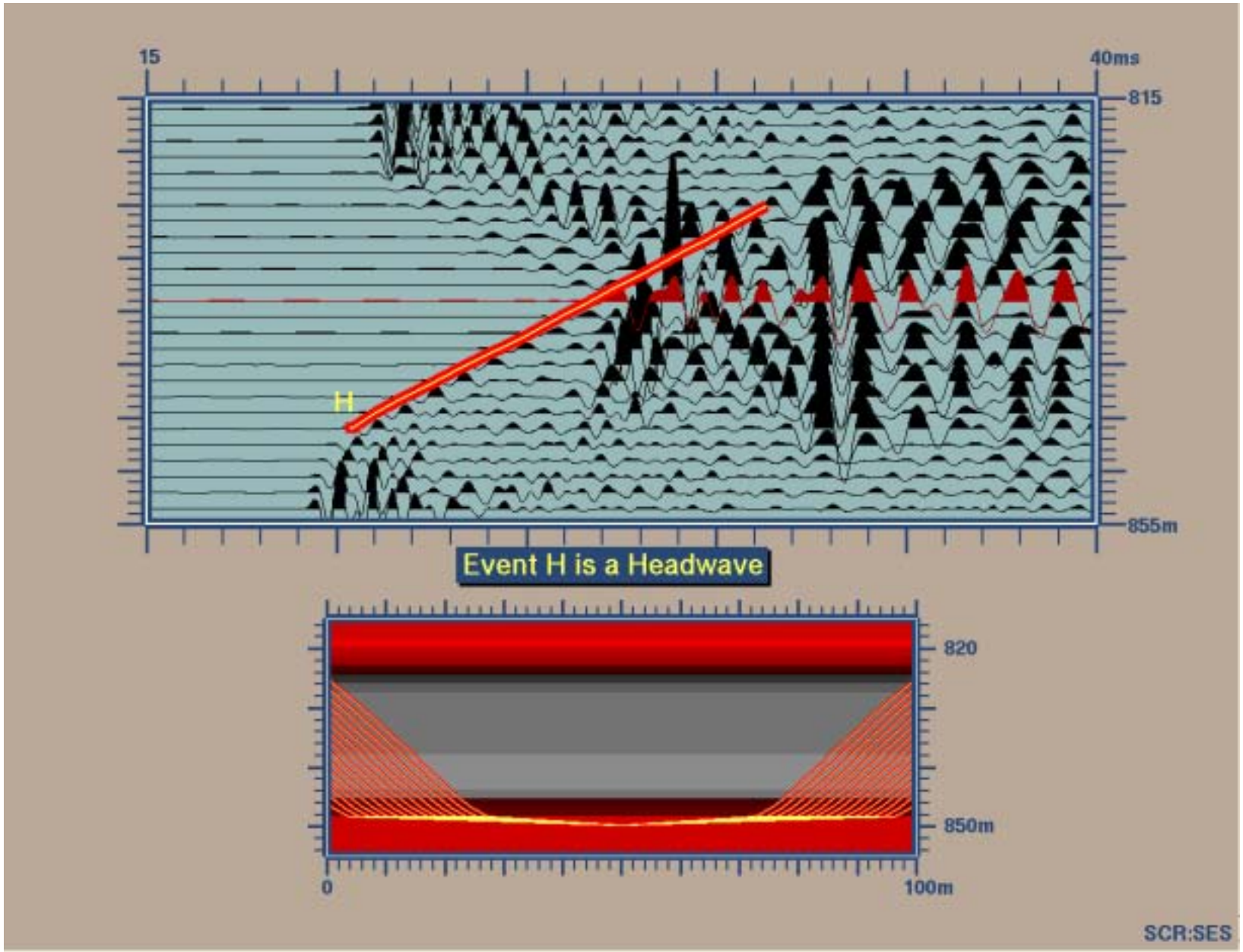

Austin Chalk
Eagle Ford Shale
Buda Lime
Del Rio Clay
Georgetown Lime
10
50ms
770
870m
Common Source at 834m
SCR:SES

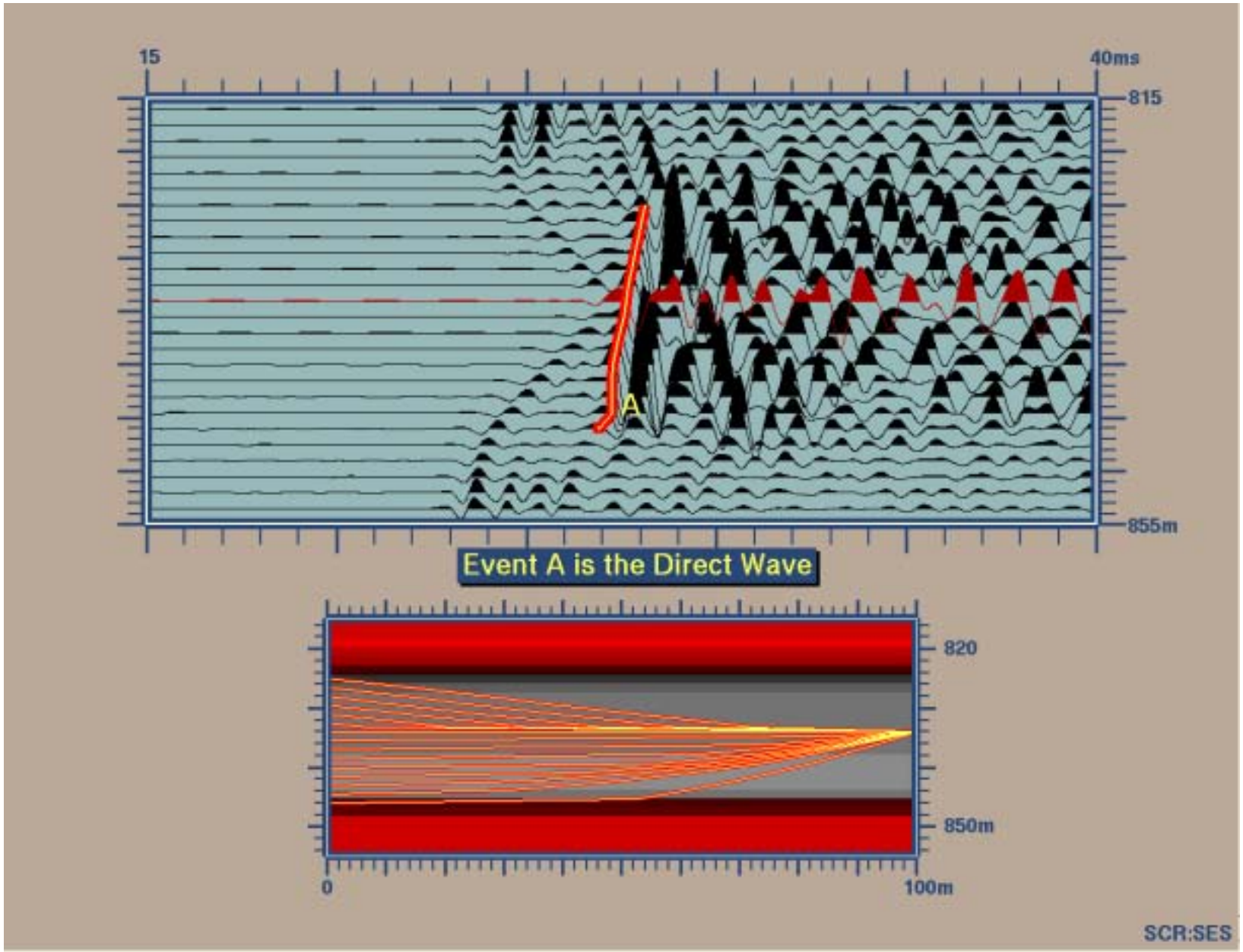

Austin Chalk
Eagle Ford Shale
Buda Lime
Del Rio Clay
Georgetown Lime
10
50ms
770
870m
Common Depth
SCR:SES

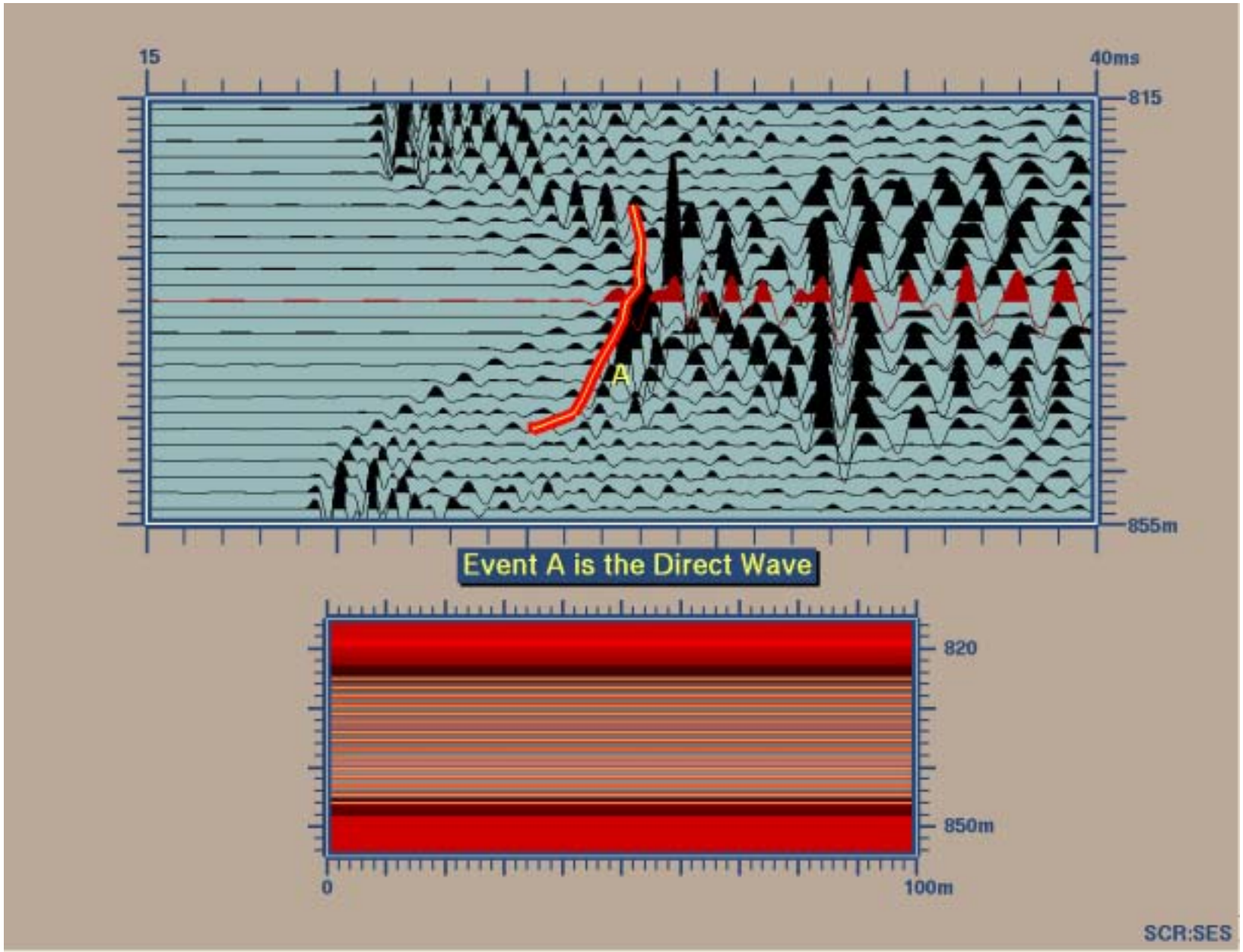

15
40ms
815
855m
B
H
A
Common Source at 834m
SCR:SES

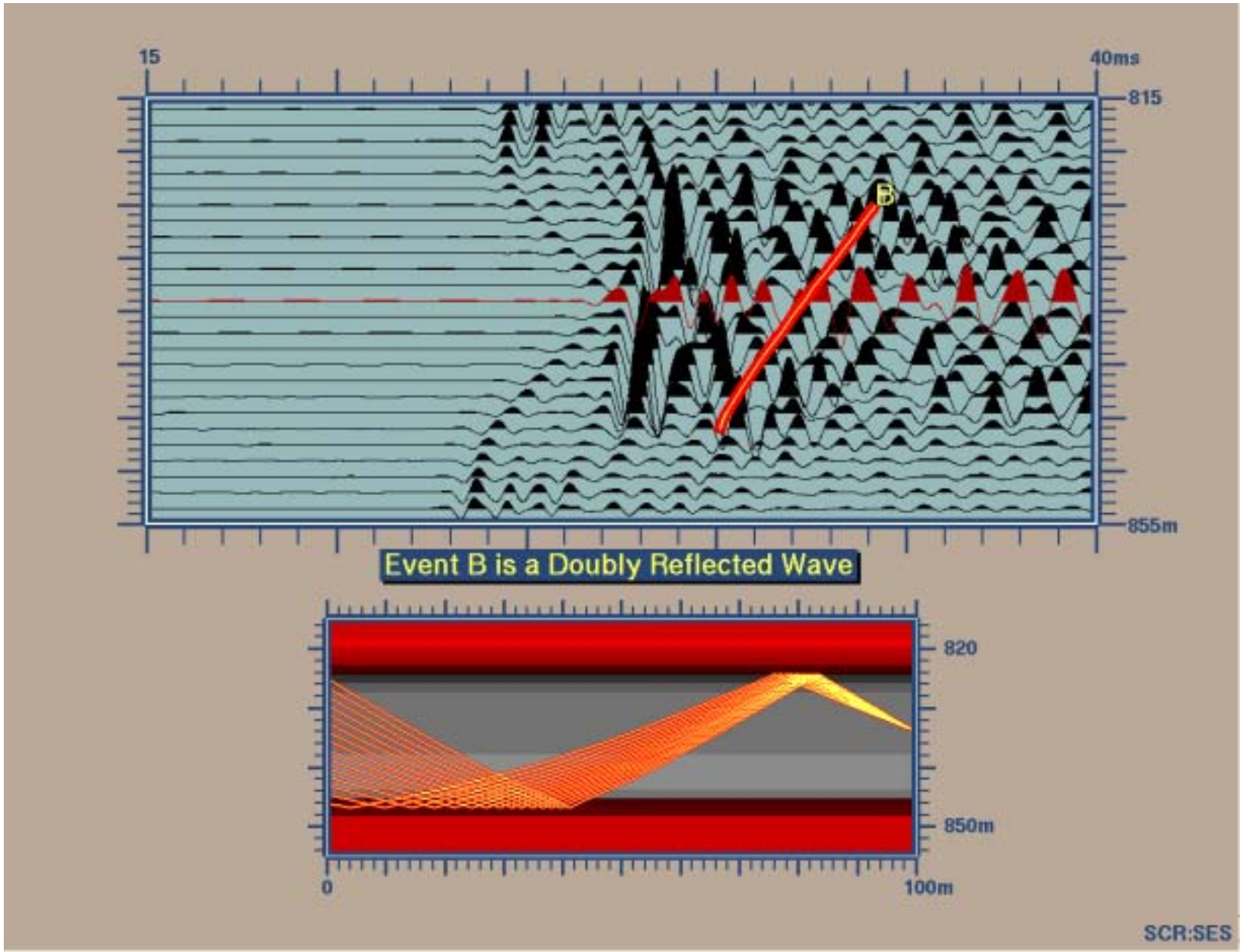

15
40ms
815
855m
average sonic log
B
A
H
Common Depth
SCR:SES

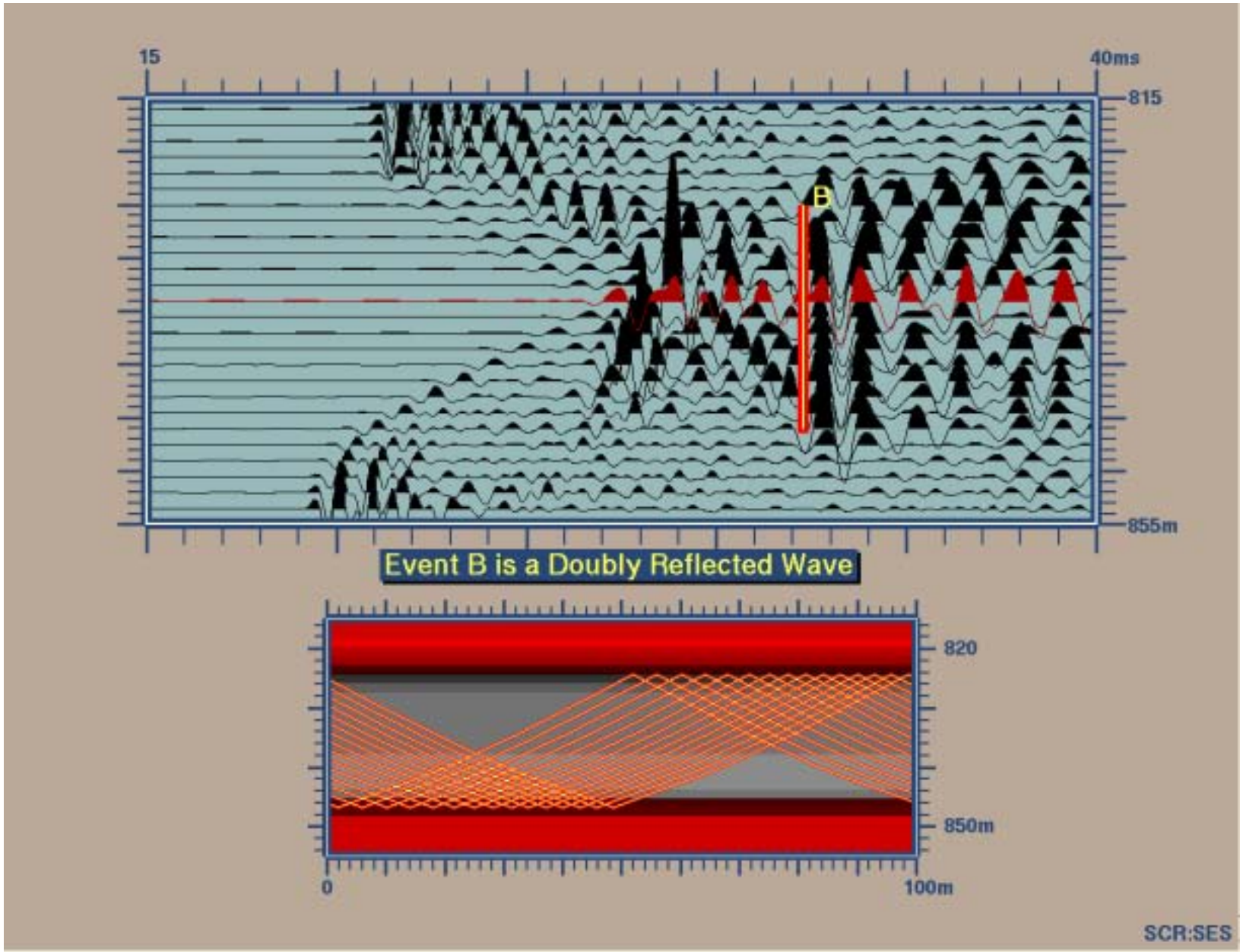

15
40ms
815
855m
H
Event H is a Headwave
820
850m
0
100m
SCR:SES

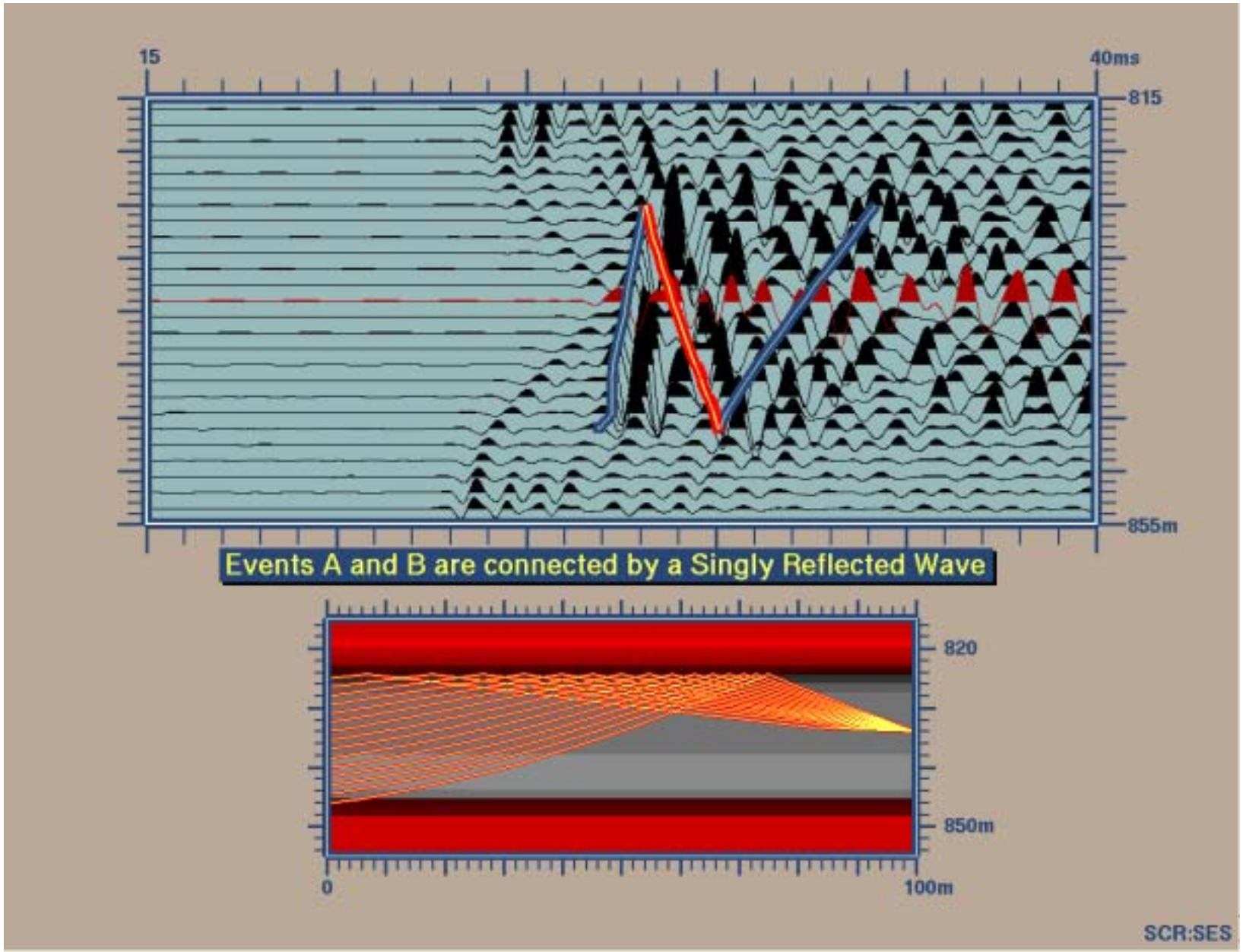

15
40ms
815
855m
H
Event H is a Headwave
820
850m
0
100m
SCR:SES

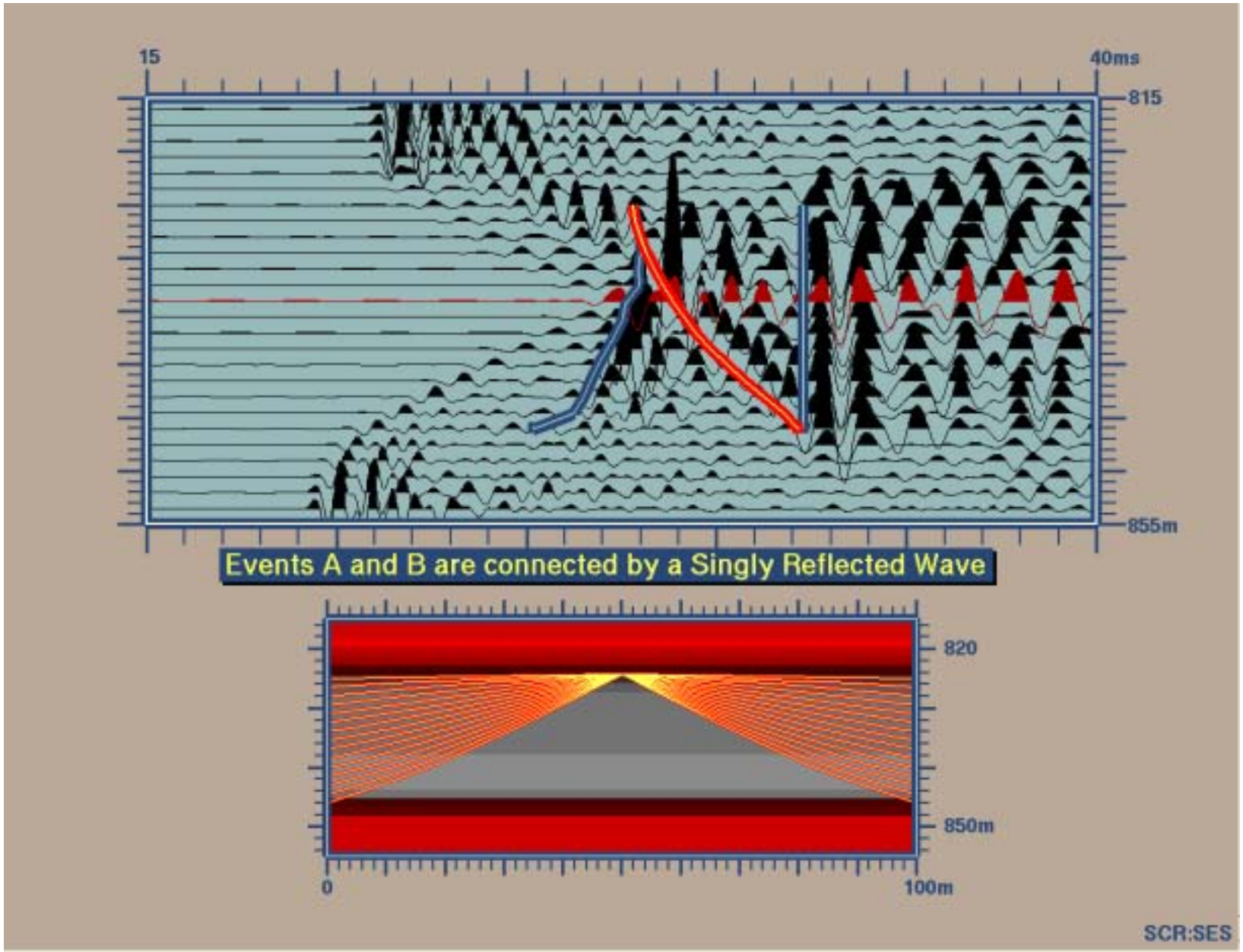

15
40ms
815
855m
A
Event A is the Direct Wave
820
850m
0
100m
SCR:SES

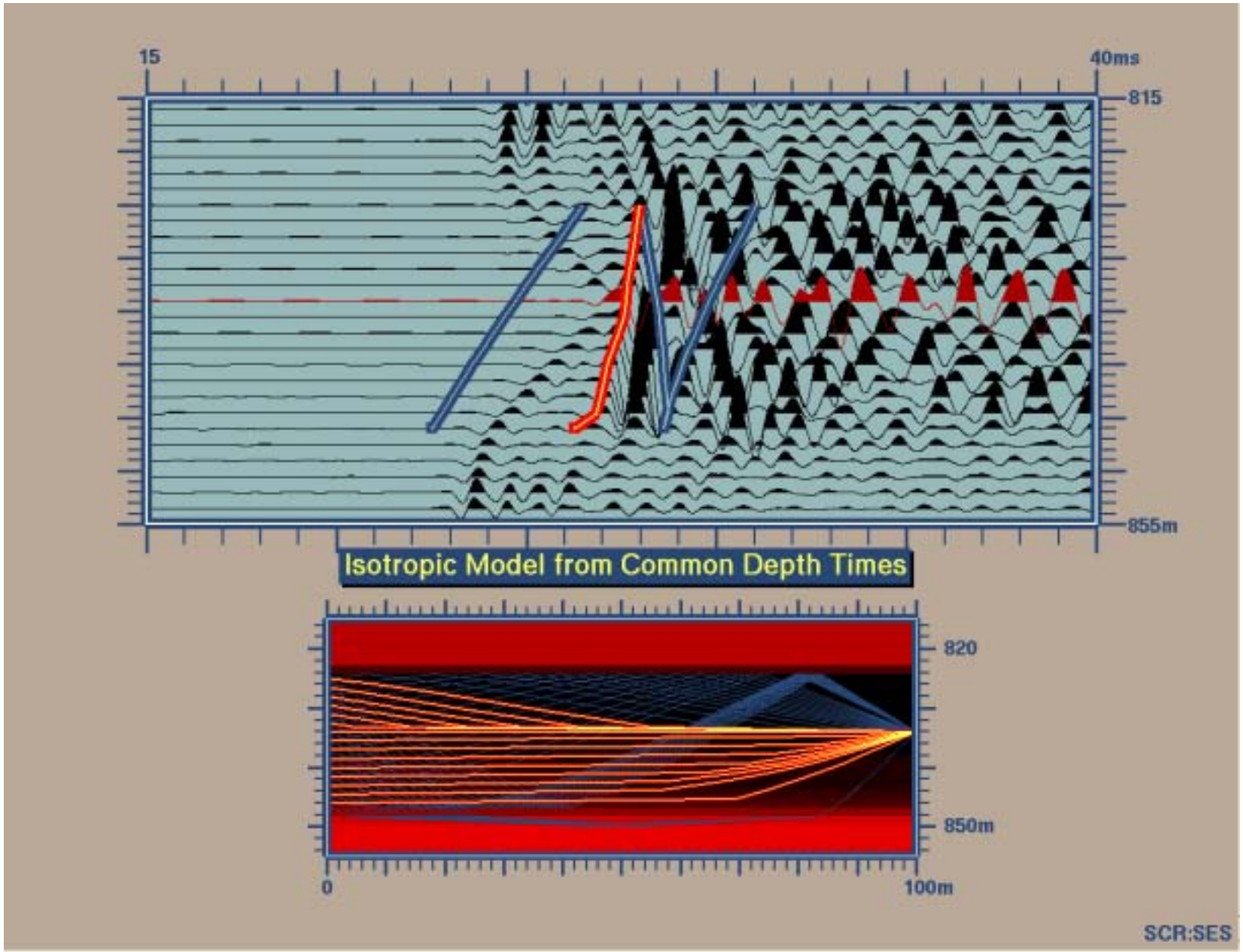

15
40ms
815
855m
A
Event A is the Direct Wave
820
850m
0
100m
SCR:SES

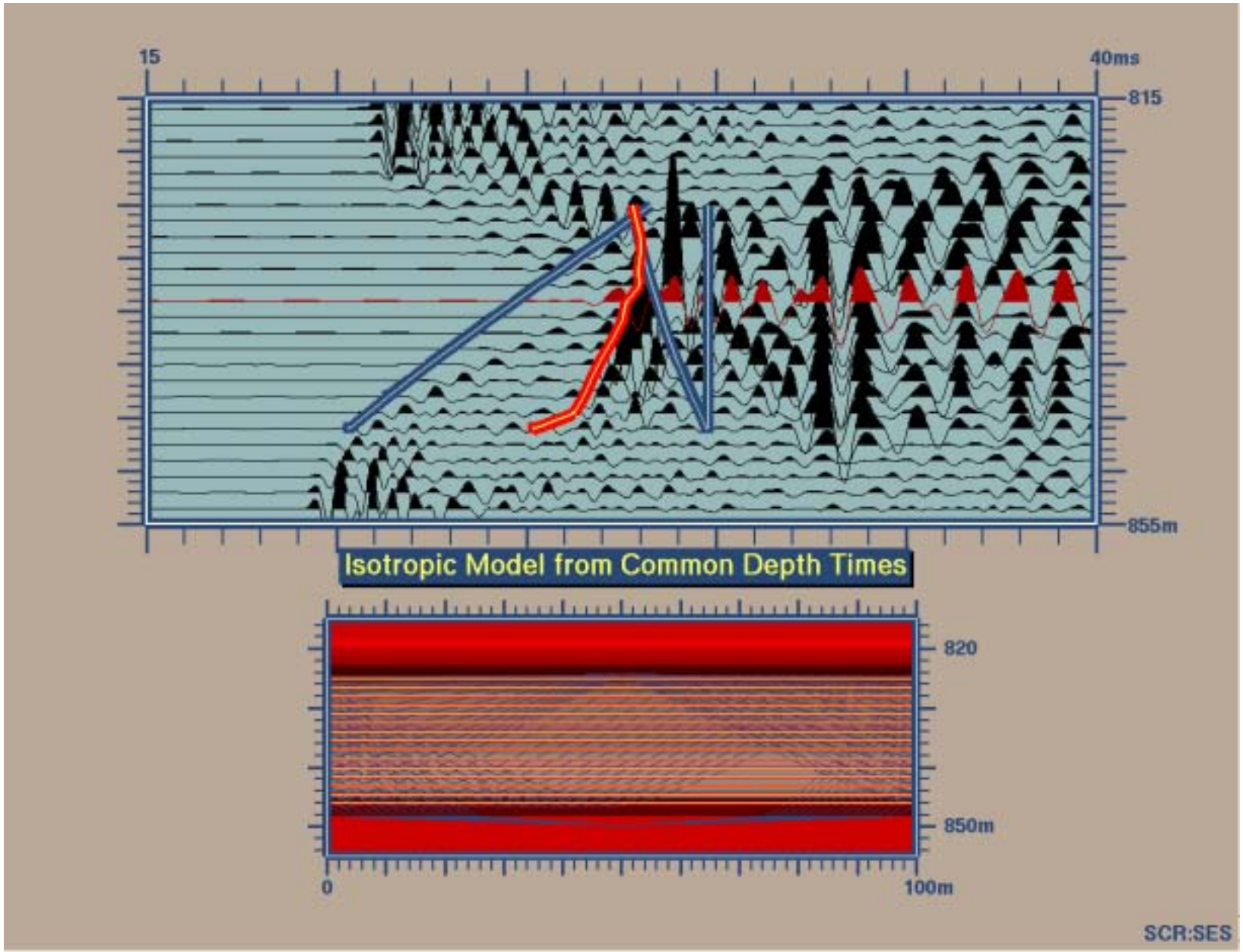

15
40ms
815
B
855m
Event B is a Doubly Reflected Wave
820
850m
0
100m
SCR:SES

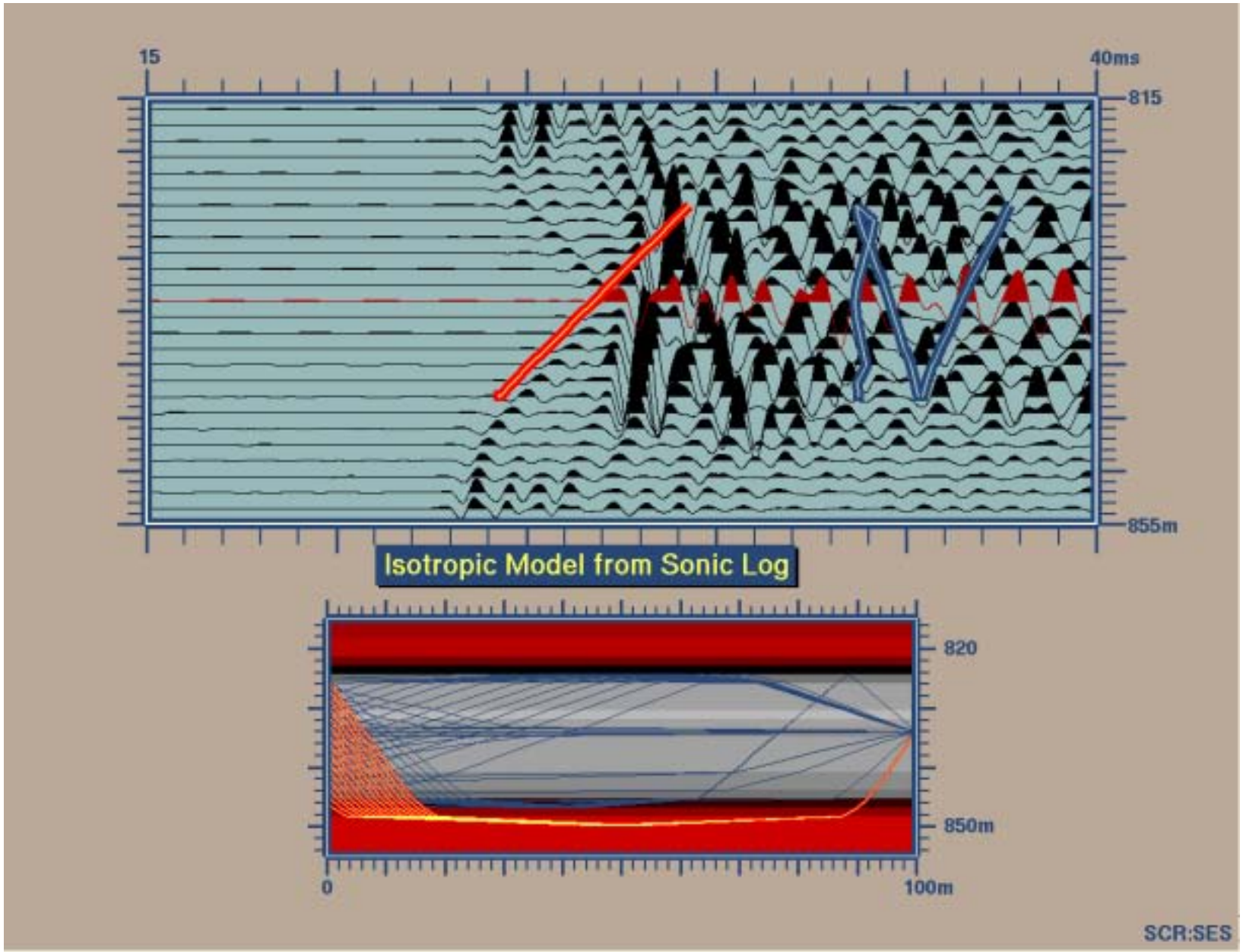

15
40ms
815
B
855m
Event B is a Doubly Reflected Wave
820
850m
0
100m
SCR:SES

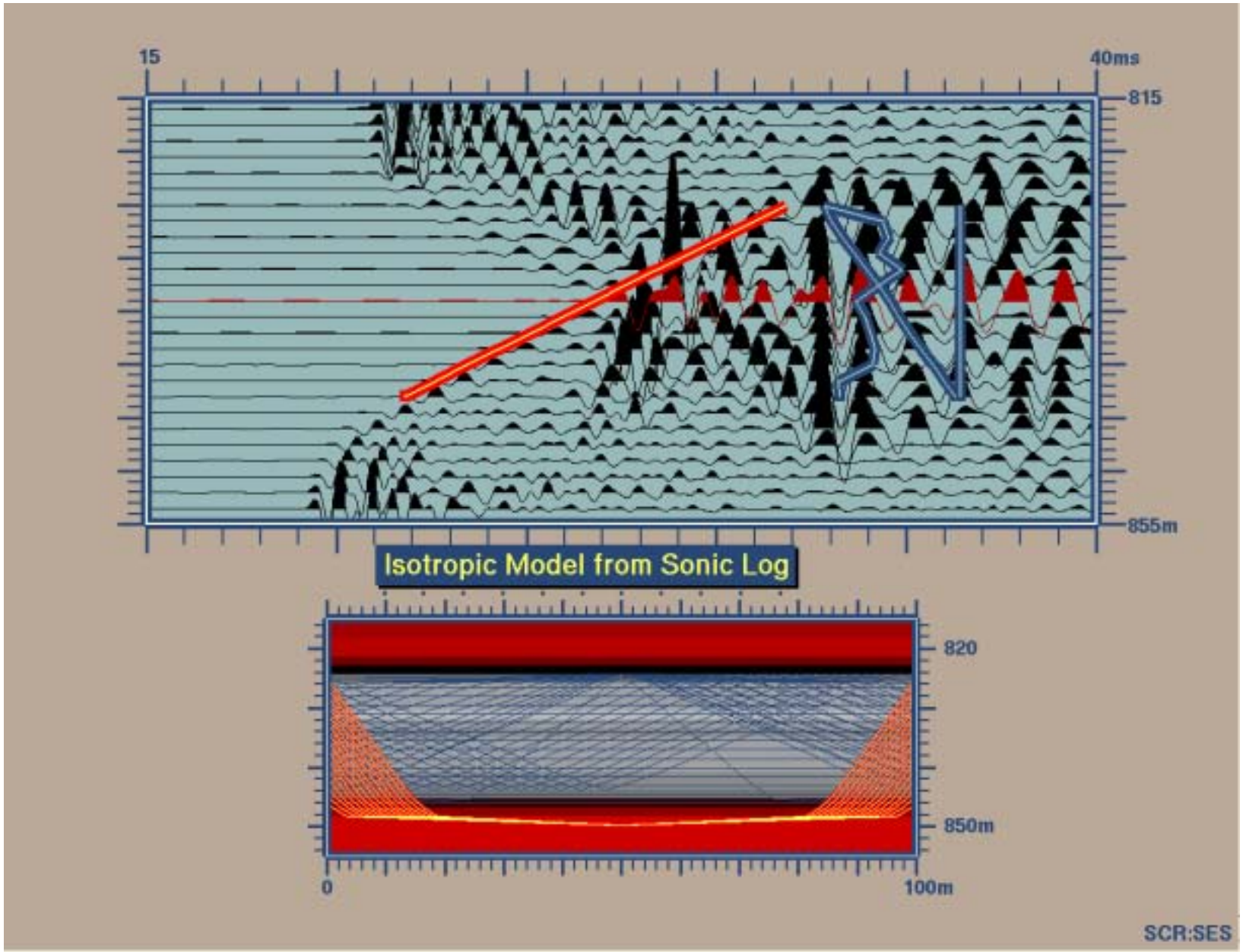

15
40ms
815
855m
Events A and B are connected by a Singly Reflected Wave
820
850m
0
100m
SCR:SES


15
40ms
815
855m
Events A and B are connected by a Singly Reflected Wave
820
850m
0
100m
SCR:SES


15
40ms
815
855m
Isotropic Model from Common Depth Times
820
850m
0
100m
SCR:SES


15
40ms
815
855m
Isotropic Model from Common Depth Times
820
850m
0
100m
SCR:SES


15
40ms
815
855m
Isotropic Model from Sonic Log
820
850m
0
100m
SCR:SES


15
40ms
815
855m
Isotropic Model from Sonic Log
820
850m
0
100m
SCR:SES

- DESCRIPTION of the Experiment
- ANALYSIS of Raw Data Records
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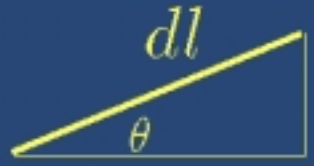
Weak Anisotropy (Chapman & Pratt(1990))

- Rays from a background isotropic medium
- For each ray segment $T = dl\ s_\theta$



$$s_\theta = A\cos^4(\theta) + B\cos^2(\theta)\sin^2(\theta) + C\sin^4(\theta)$$

$$A = s_x, \quad C = s_z, \quad B = 4s_{45} - (s_x + s_z).$$

- 56×56 Equations from raytracing:

$$T_{jk} = \sum_i a_{ijk} s_x(i) + \sum_i b_{ijk} s_z(i) + \sum_i c_{ijk} s_{45}(i)$$

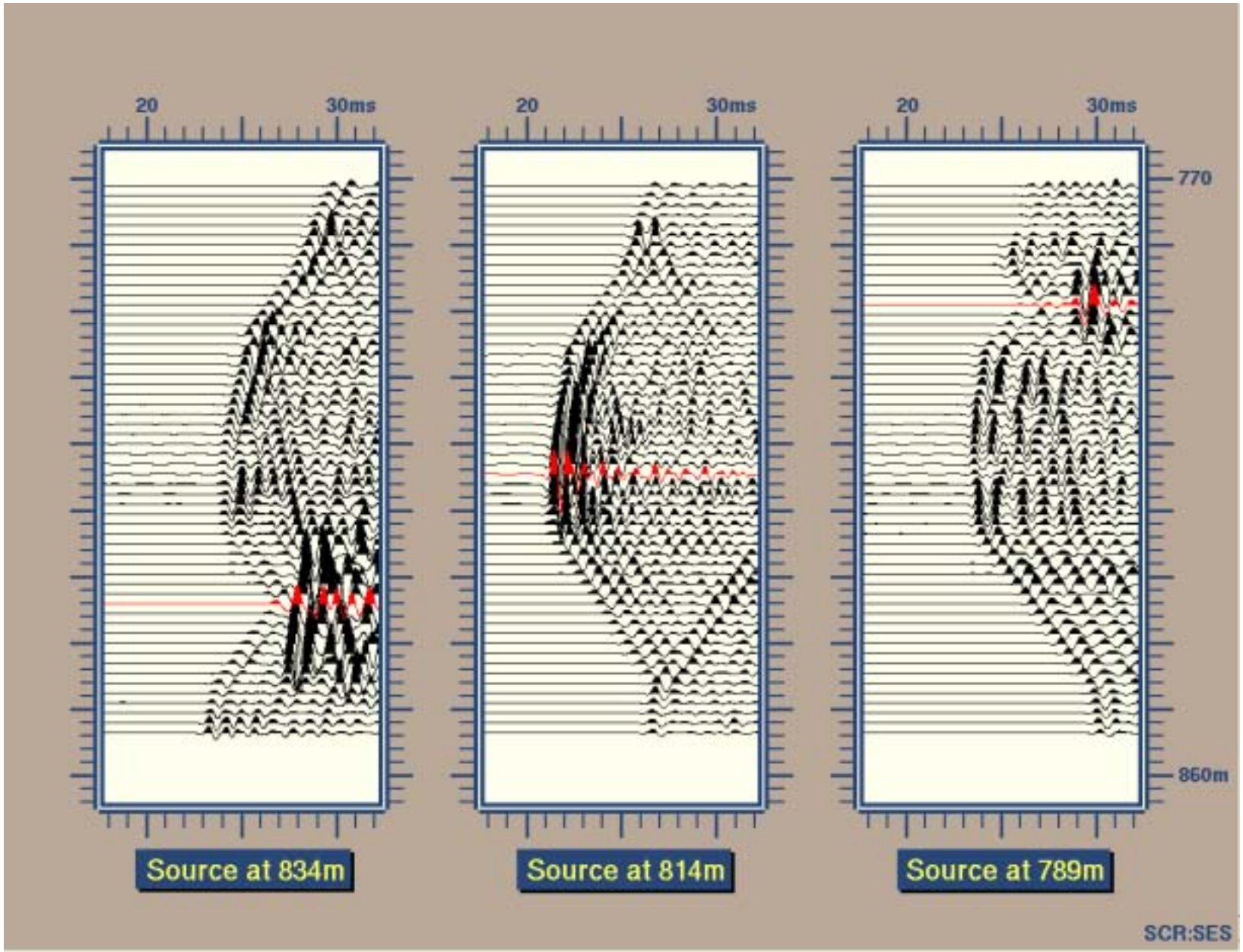
- 56 equations constraining s_z against the log:

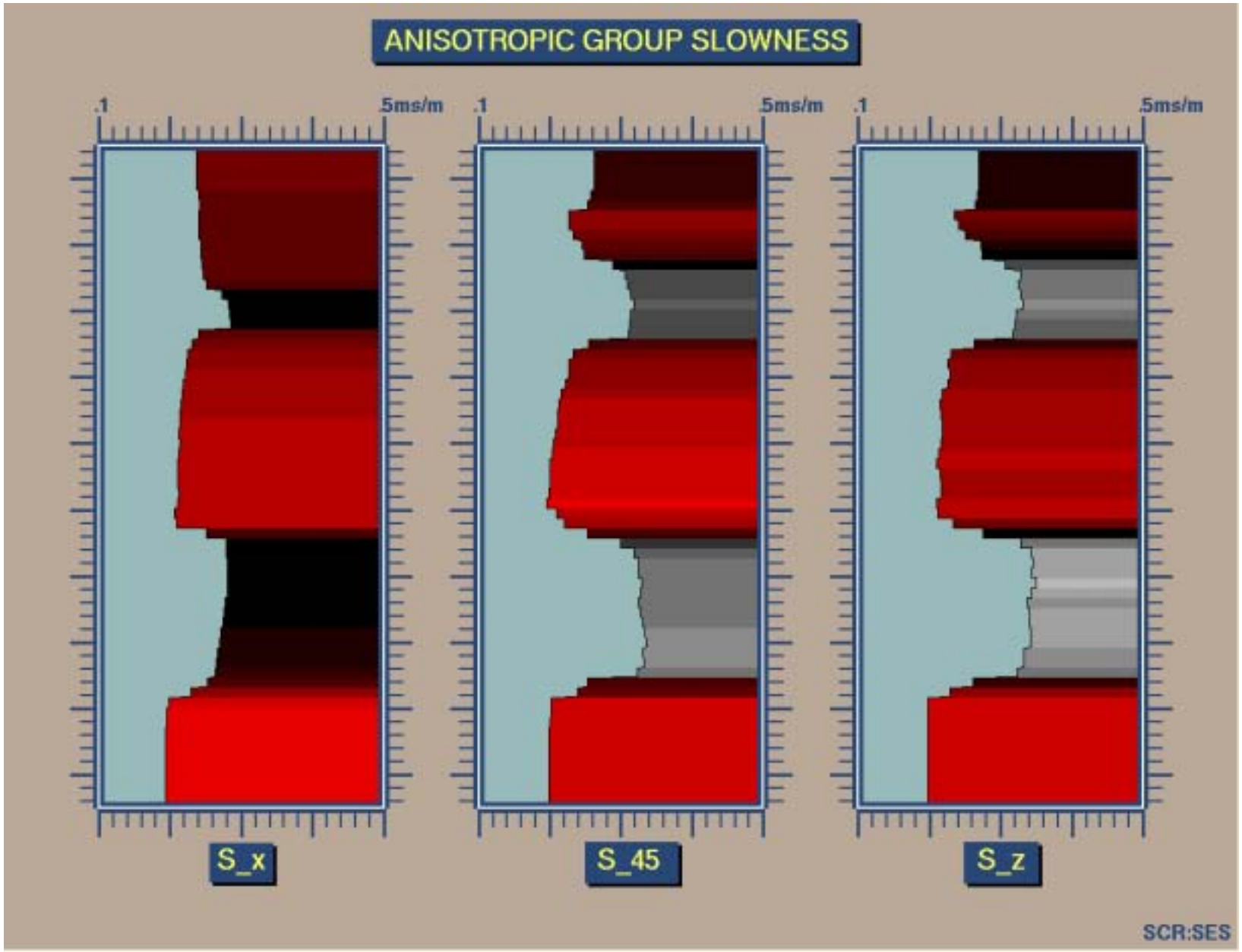
$$\gamma_1(s_z(i) - s_{log}(i)) = 0$$

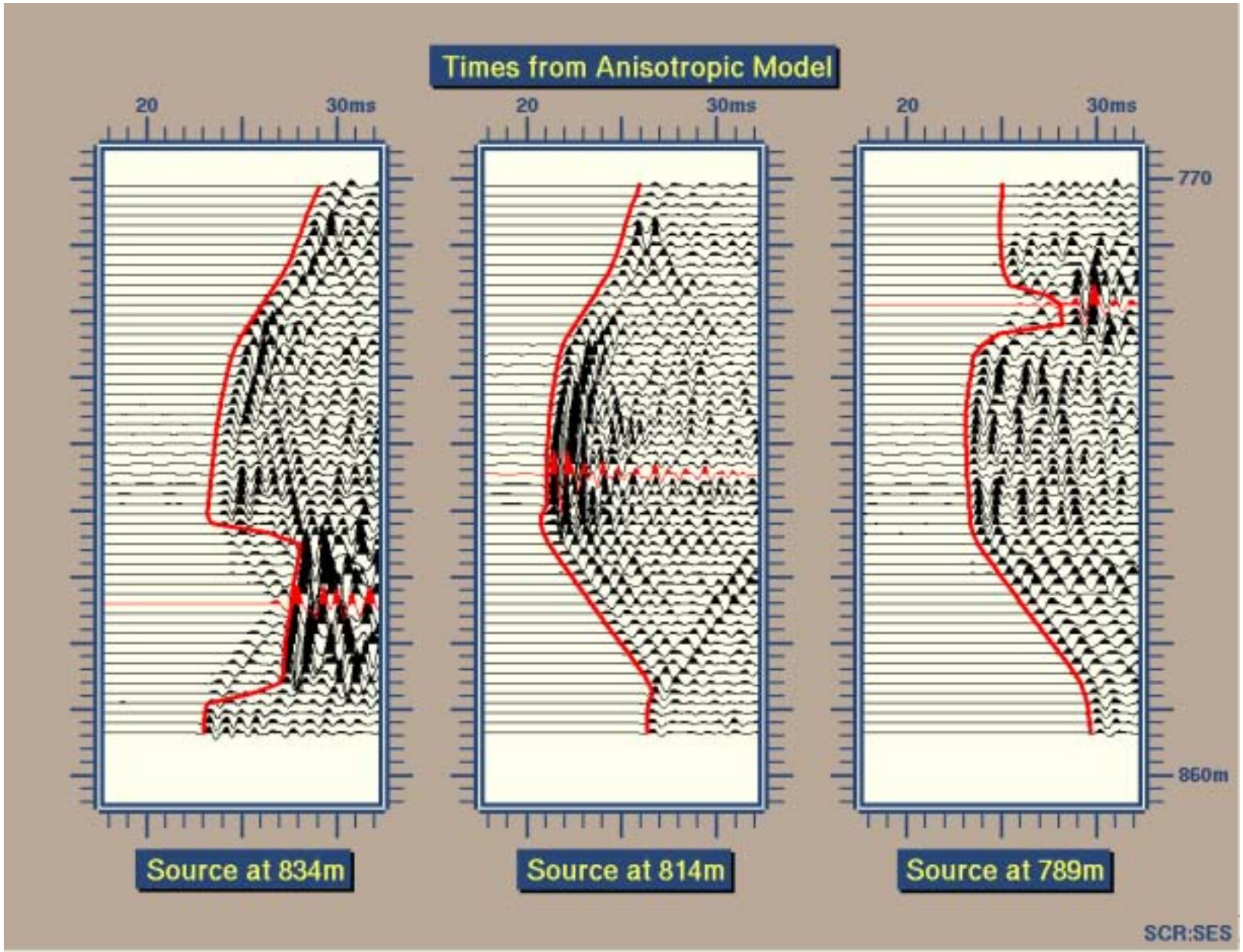
- 49 smoothness equations:

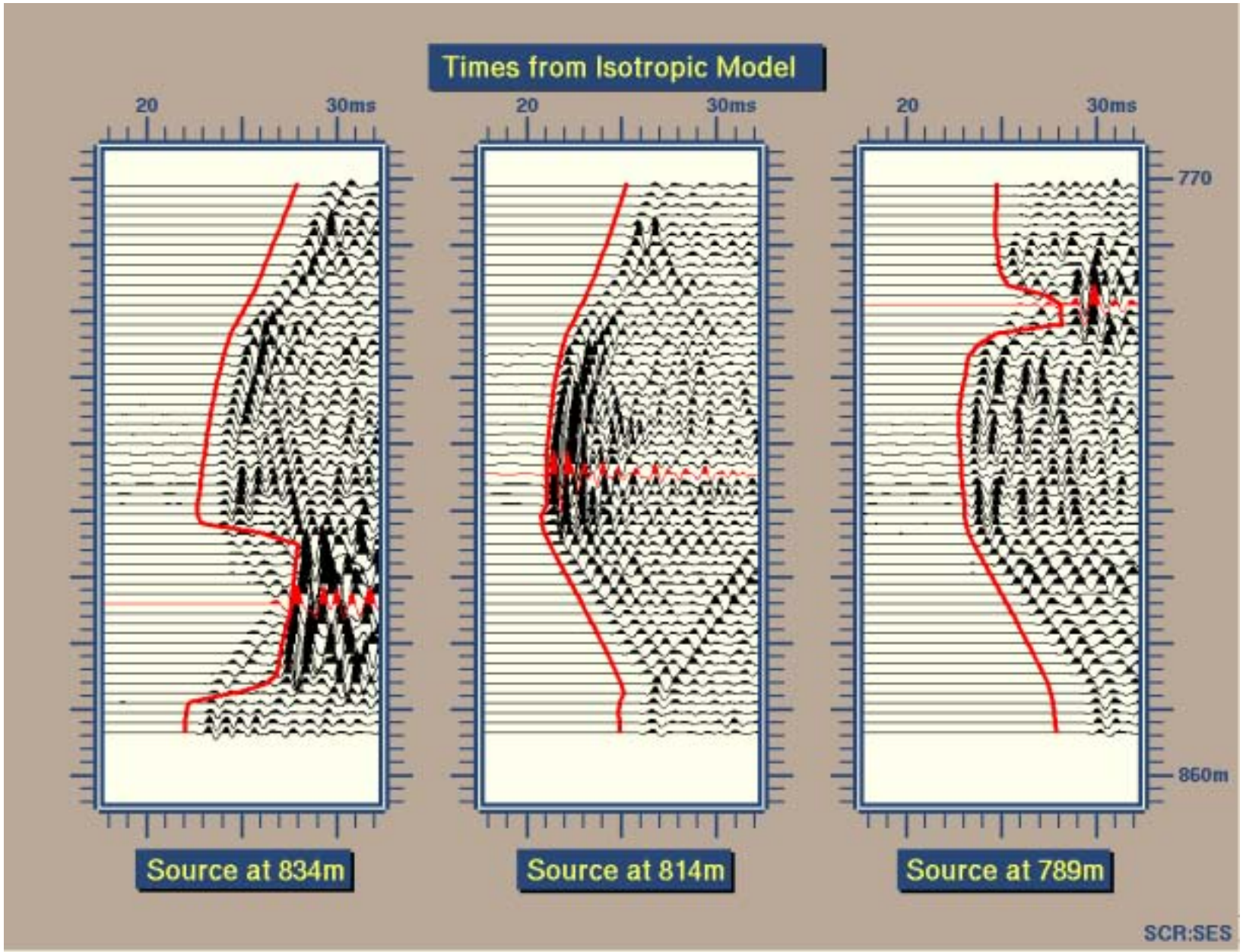
$$\gamma_2(s_\theta(i) - s_\theta(i+1)) = 0$$

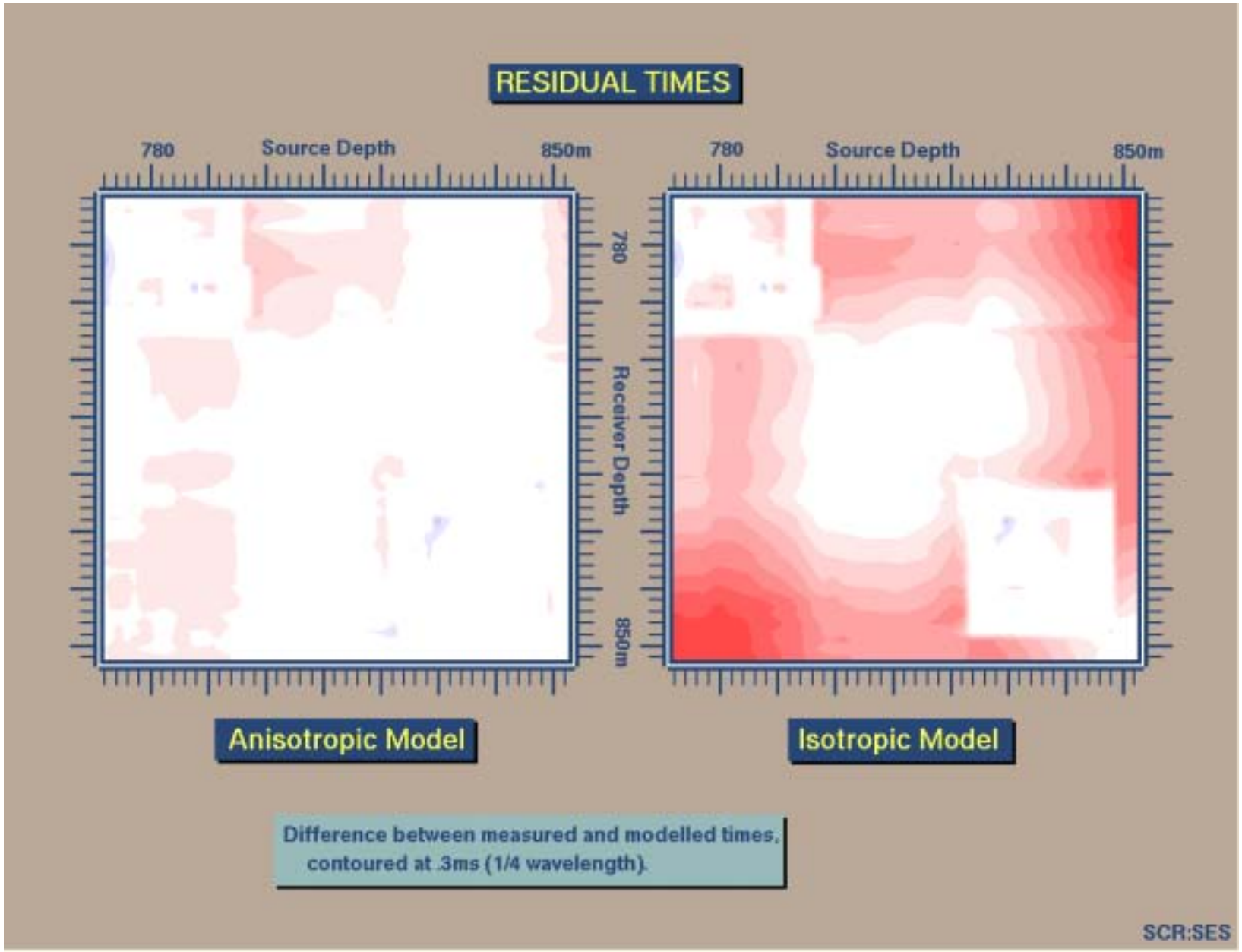
- 56×3 unknowns.

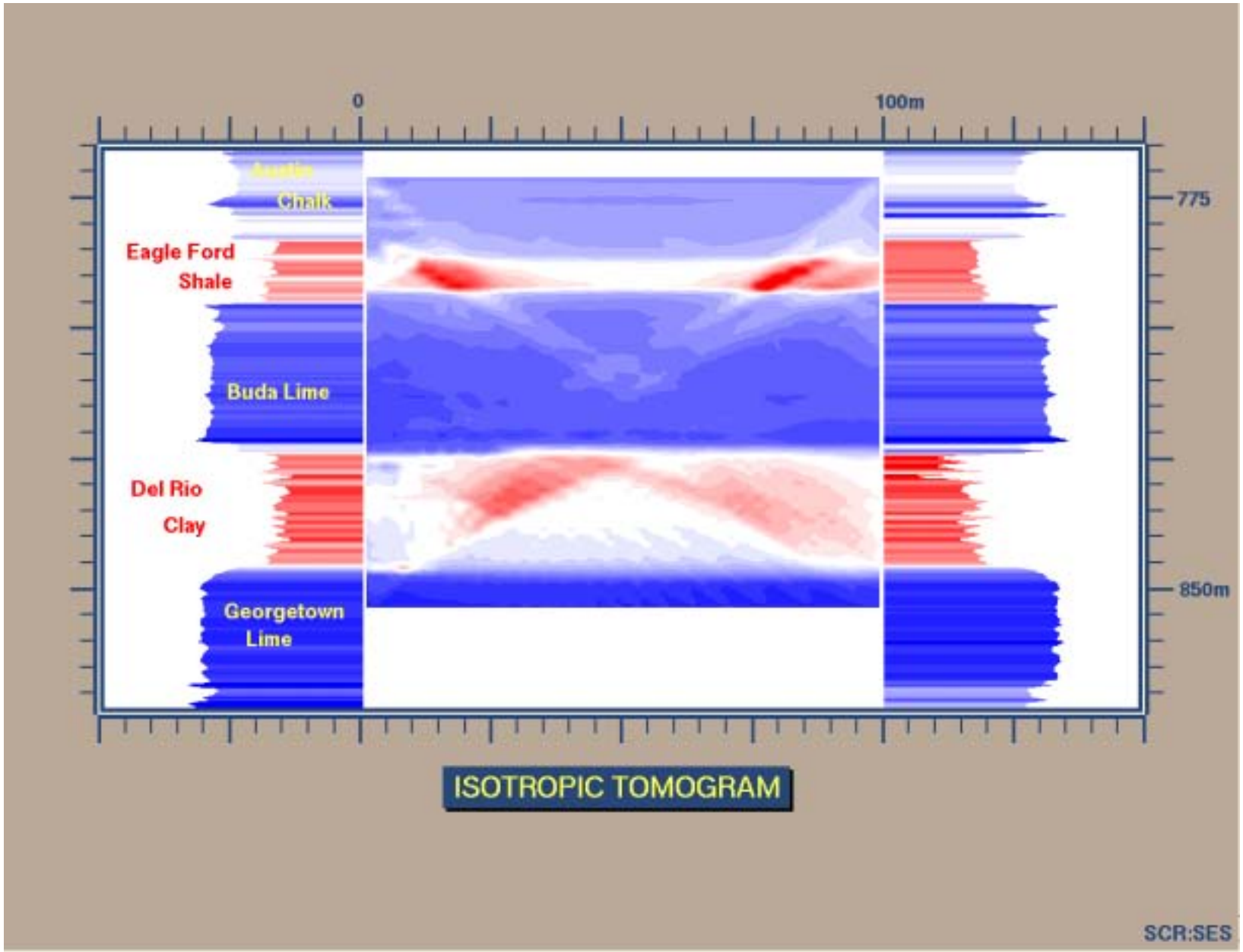

20
30ms
20
30ms
20
30ms
770
860m
Source at 834m
Source at 814m
Source at 789m
SCR:SES

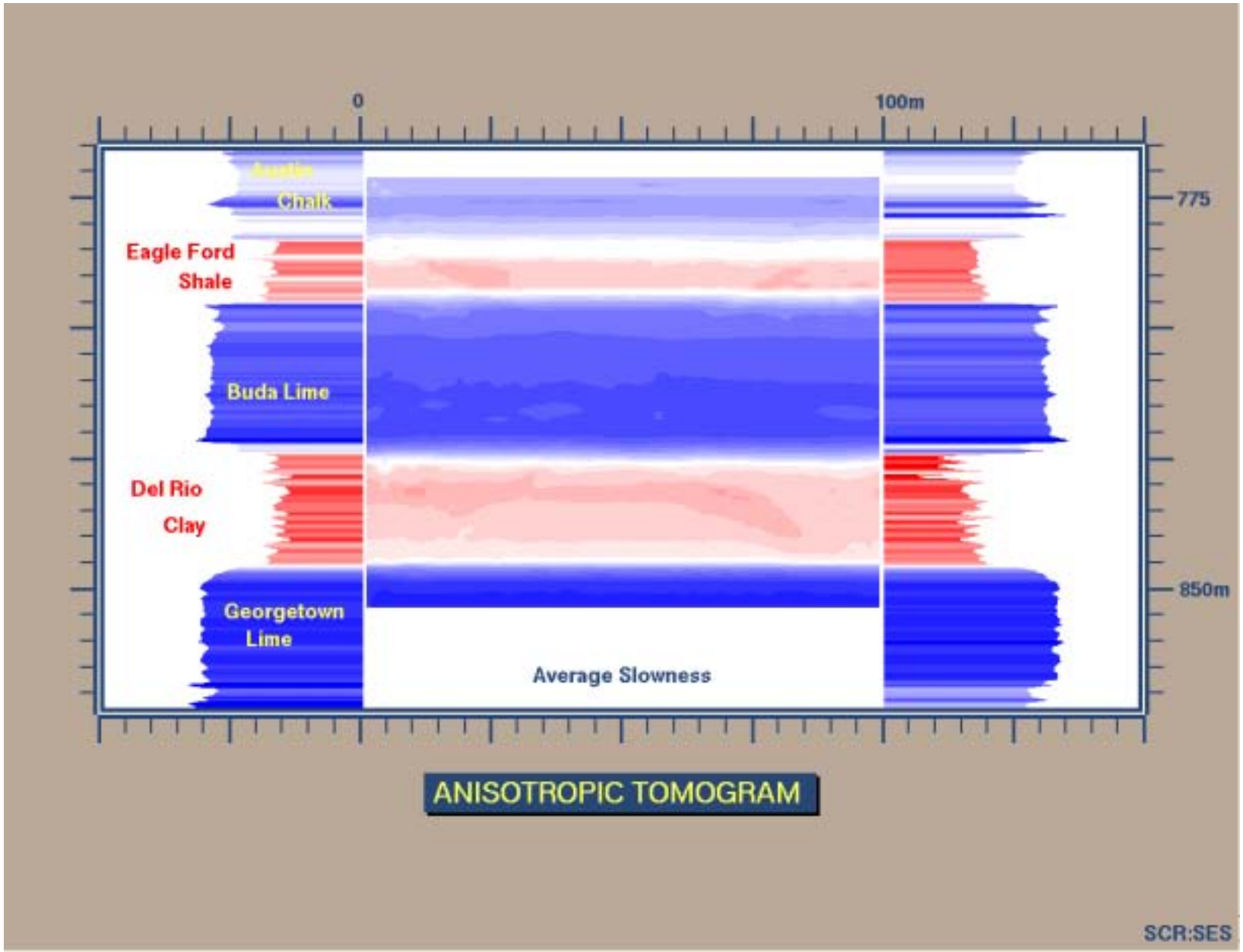

ANISOTROPIC GROUP SLOWNESS
.1
.5ms/m
.1
.5ms/m
.1
.5ms/m
S_x
S_45
S_z
SCR:SES


Times from Anisotropic Model
20
30ms
20
30ms
20
30ms
770
860m
Source at 834m
Source at 814m
Source at 789m
SCR:SES


Times from Isotropic Model
20
30ms
20
30ms
20
30ms
770
860m
Source at 834m
Source at 814m
Source at 789m
SCR:SES


RESIDUAL TIMES
780
Source Depth
850m
780
Receiver Depth
850m
780
Source Depth
850m
Anisotropic Model
Isotropic Model
Difference between measured and modelled times, contoured at .3ms (1/4 wavelength).
SCR:SES


0
100m
Austin
Chalk
Eagle Ford
Shale
Buda Lime
Del Rio
Clay
Georgetown
Lime
775
850m
ISOTROPIC TOMOGRAM
SCR:SES


0
100m
Austin
Chalk
775
Eagle Ford
Shale
Buda Lime
Del Rio
Clay
Georgetown
Lime
850m
Average Slowness
ANISOTROPIC TOMOGRAM
SCR:SES

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- The anisotropy really is incontrovertible.
- s_z/s_x in the Del Rio Clay ranges from 1.15 to 1.30.
- Isotropic tomograms may be dangerously misleading.
- Event identification using only the common-depth gather is perilous.

- THANKS
  - To colleagues at BP
  - To colleagues within Schlumberger