Estimating seismic attenuation (Q) from VSP data at a heavy-oil field: Ross Lake, Saskatchewan

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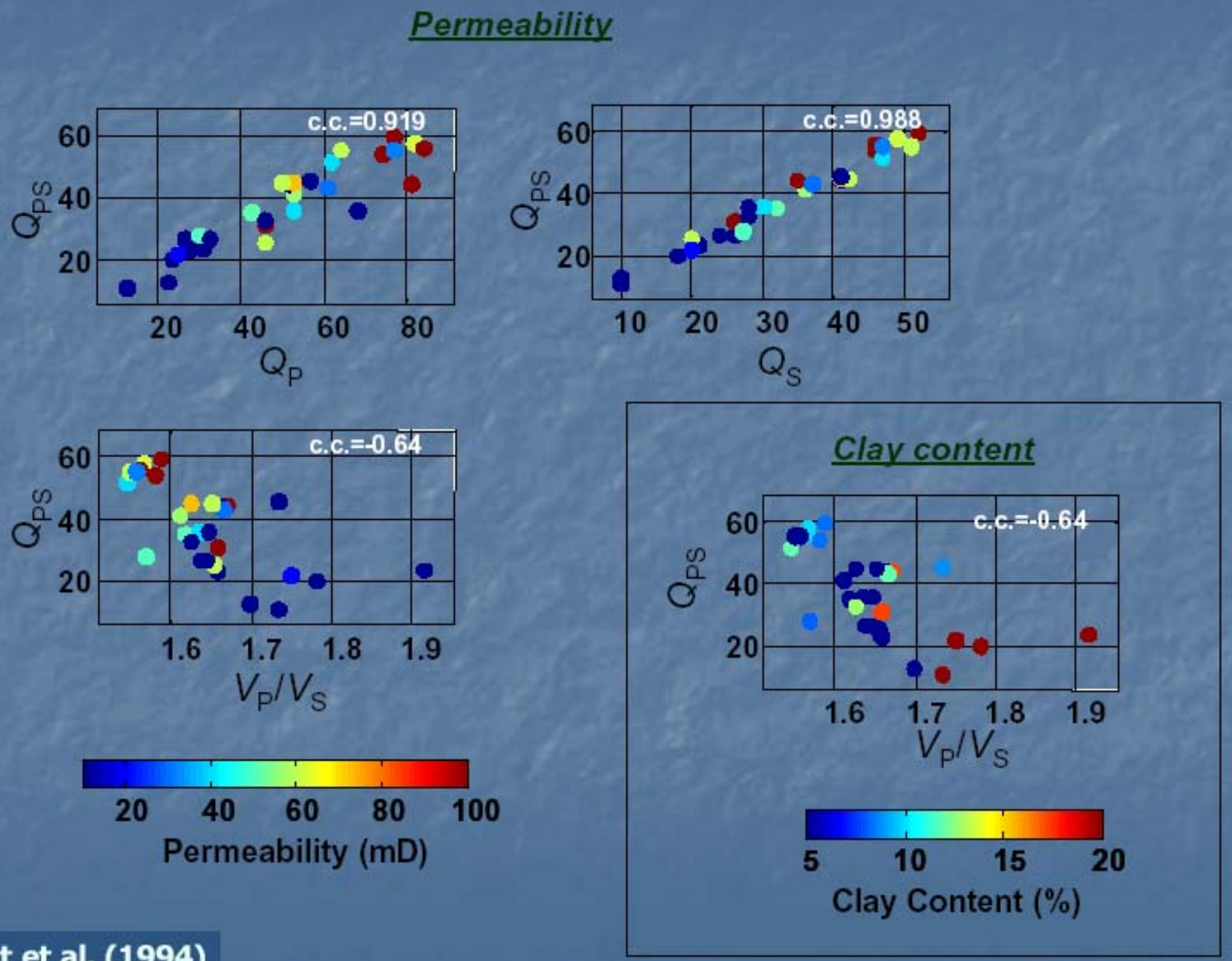
CREWES

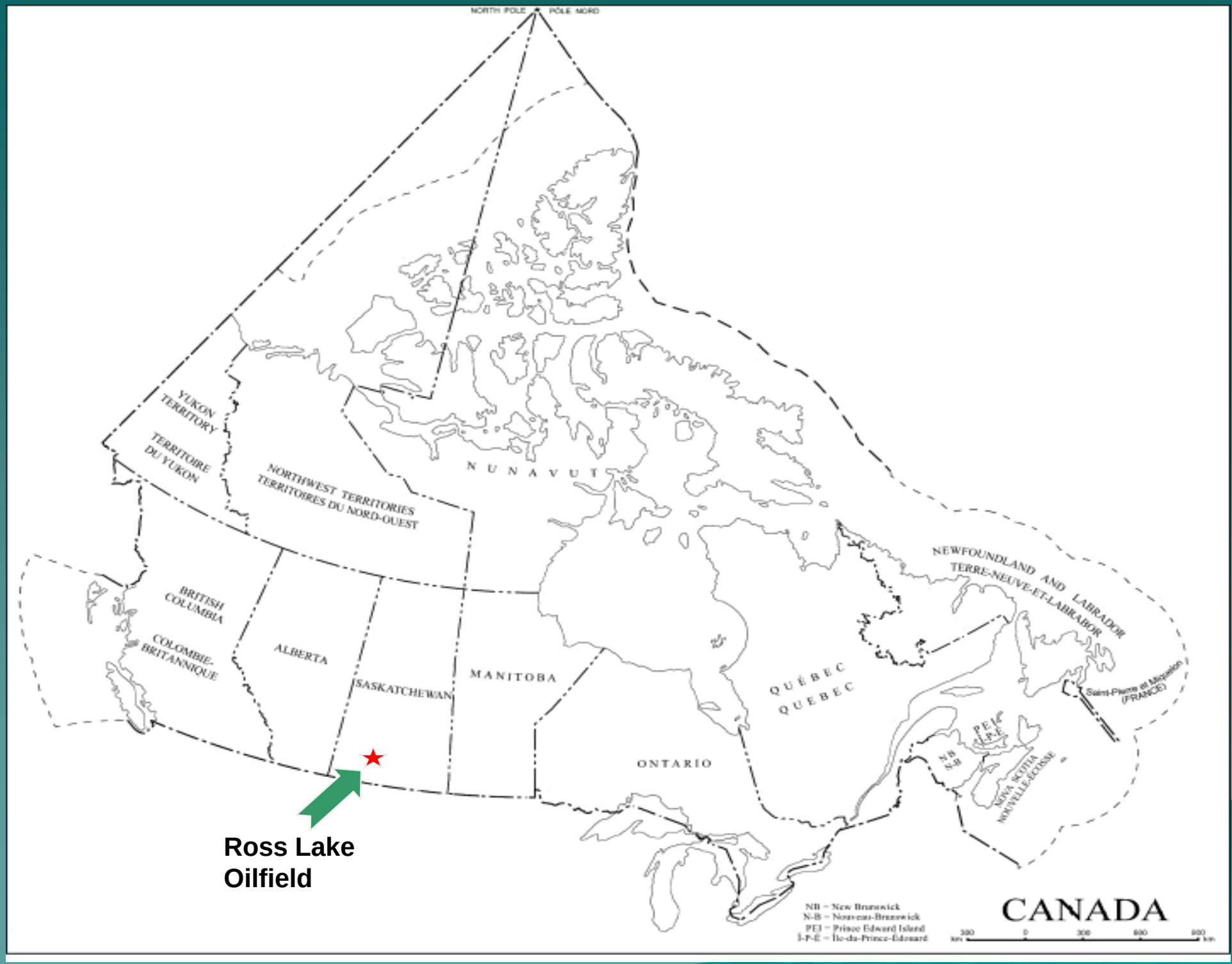
Outline

- Introduction
- Motivation, location
- New Q-applications
- Review of analytical signal method for Q-estimation
- Q_p estimation from downgoing P-wave isolated from offset VSP
- Q_s estimation from upgoing C-wave isolated from offset VSP
- Conclusions

Q_{PS} and petrophysical properties

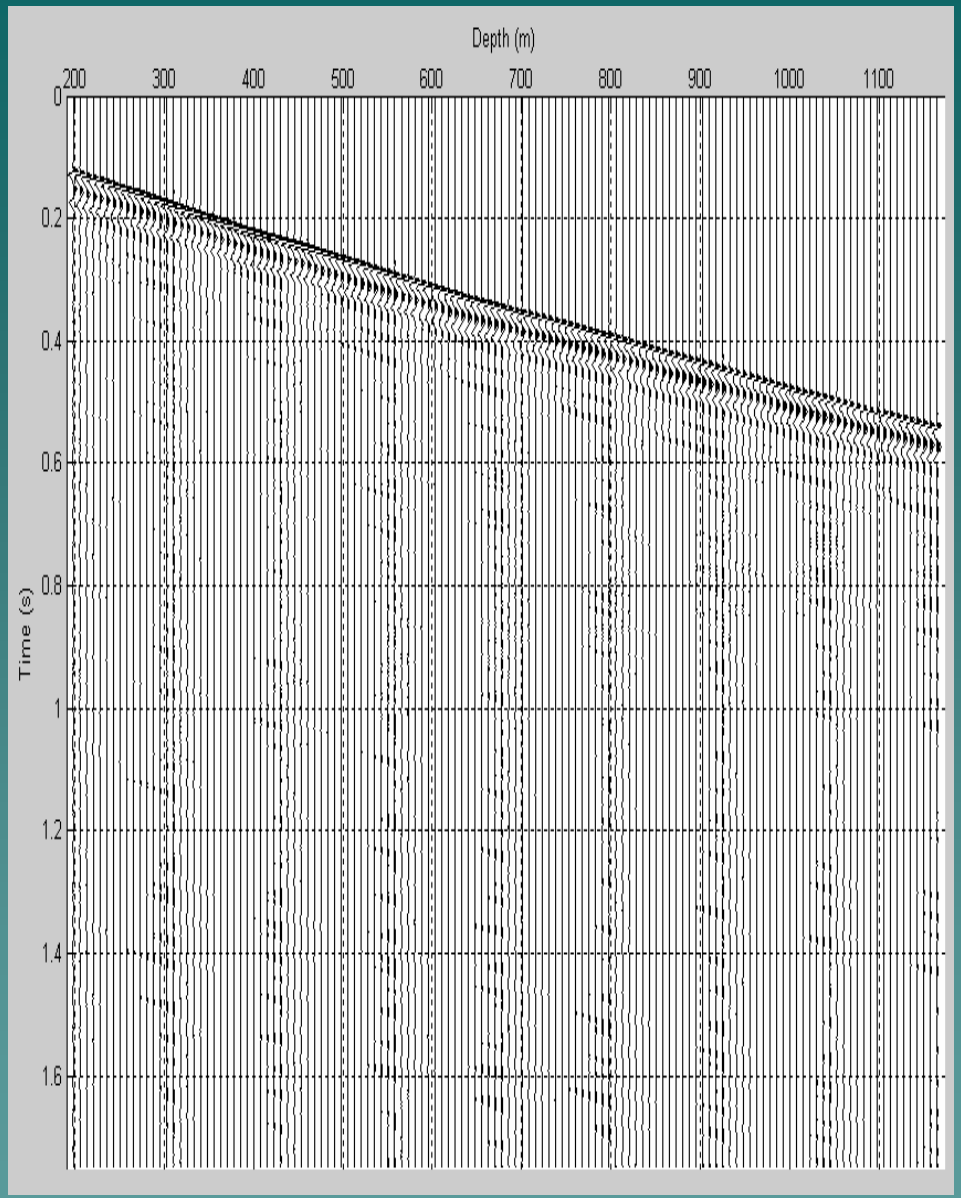


(Calderón-Macías et al., 2004)

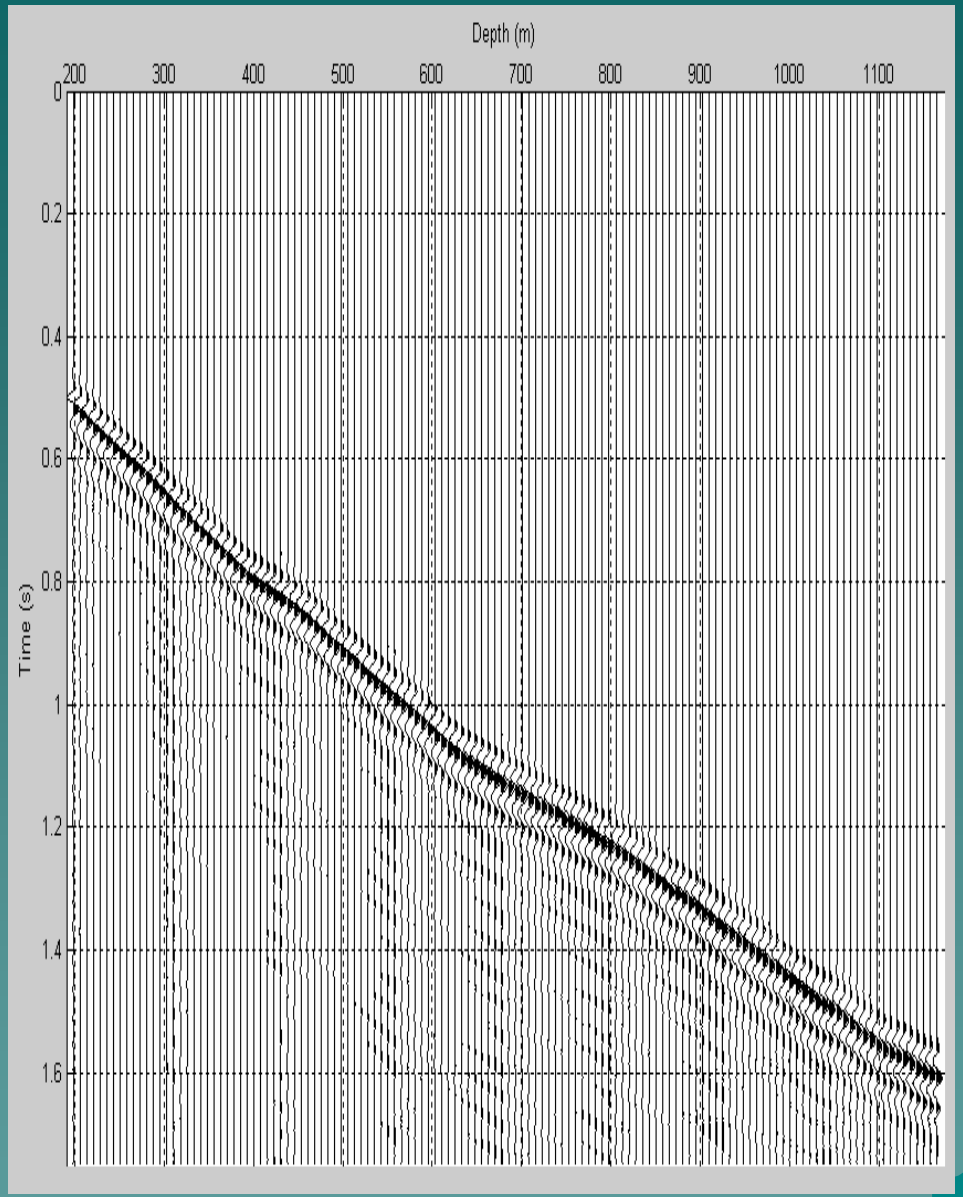

NORTH POLE
PÔLE NORD
YUKON TERRITORY
TERRITOIRE DU YUKON
NORTHWEST TERRITORIES
TERRITOIRES DU NORD-OUEST
NUNAVUT
BRITISH COLUMBIA
COLOMBIE-BRITANNIQUE
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUÉBEC
QUEBEC
NEWFOUNDLAND AND LABRADOR
TERRE-NEUVE-ET-LABRADOR
Saint-Pierre et Miquelon (FRANCE)
PEI
I-P-É
NB
N-B
NOVA SCOTIA
NOUVELLE-ÉCOSSE
Ross Lake Oilfield
NB = New Brunswick
N-B = Nouveau-Brunswick
PEI = Prince Edward Island
I-P-É = Île-du-Prince-Édouard
CANADA

Ross Lake, Saskatchewan – View of field and well 11-25

11-25 well site
with VSP survey
underway



Separated Downgoing P-Wave Field
(54m offset source – vertical vibrator)



Separated Downgoing S-WaveField
(54m offset src. – horizontal vibrator)

Previous Results

Method	Spectral Ratio	Drift Correction	Empirical Equation	Convolutional/ WE Modeling	Average
Q_P	67	37 to 41	57	80/84	61
Q_S	23	37	11		24

$$u(t) = a(t)\cos\varphi(t)$$

$$z(t) = u(t) + iv(t) = 2\int_0^{\infty} U(\omega)e^{i\omega t}\,d\omega$$

$$a(t) = \sqrt{\left(u^2(t) + v^2(t)\right)}$$

Complex trace analysis (Engelhard et al., 1986; Tonn, 1991)

$$z'(t) = 2i \int_0^\infty \omega U(\omega) e^{i\omega t} d\omega$$

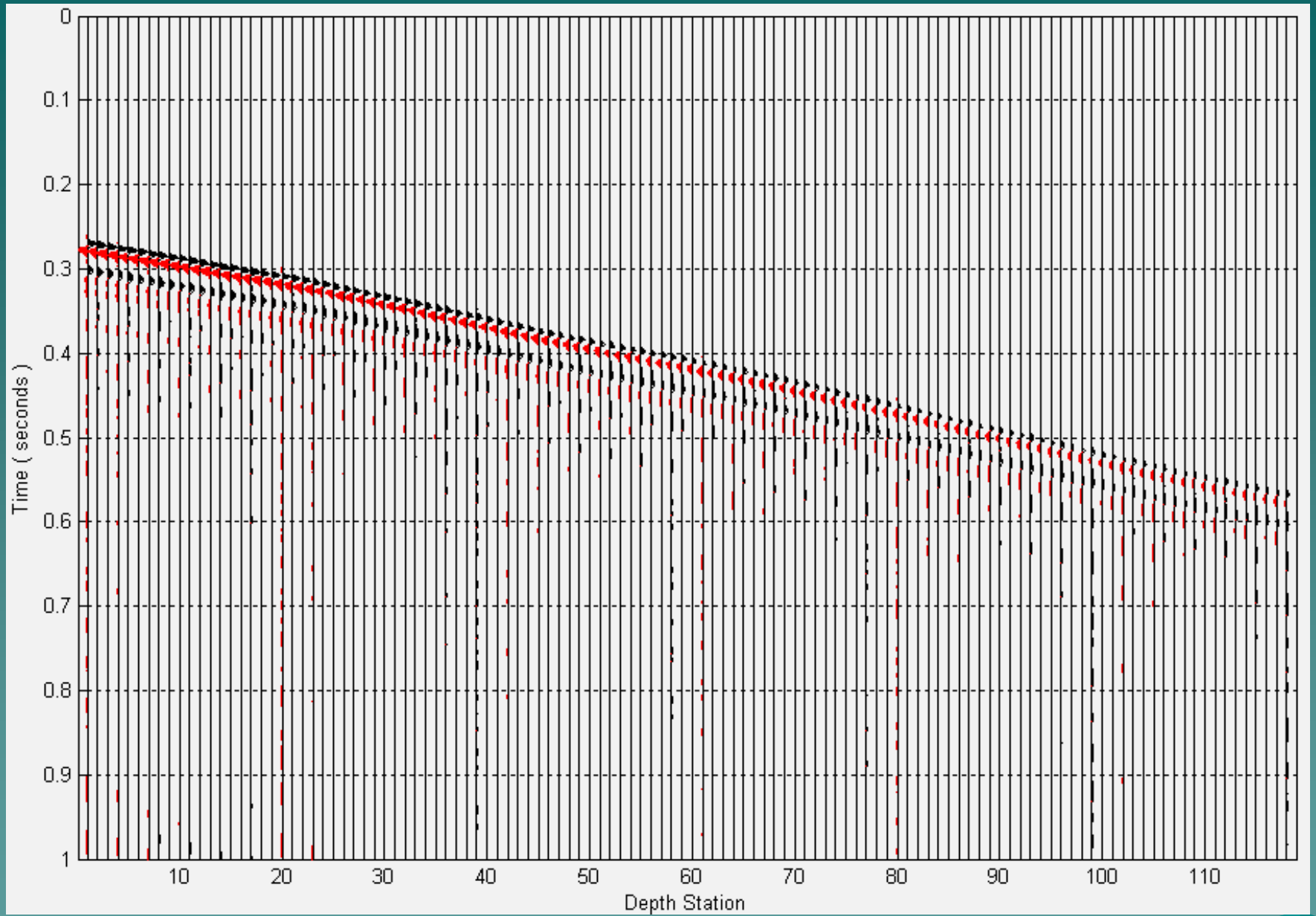
Time derivative of complex trace (Engelhard et al., 1986)

$$\omega(t) = \frac{d\varphi(t)}{dt} = \frac{z^{*}z^{'} - zz^{'*}}{2izz^{*}}$$

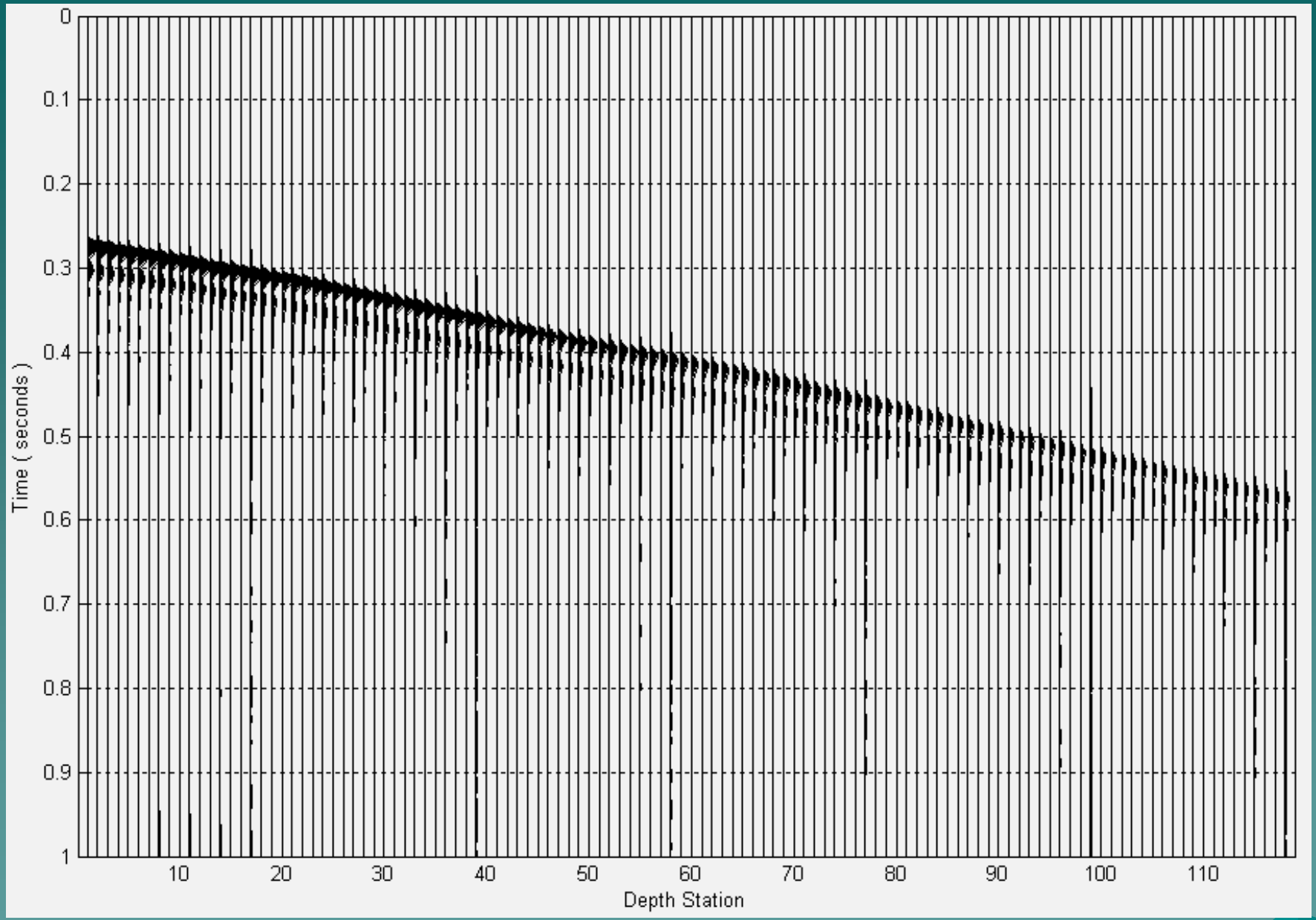
Instantaneous frequency (Engelhard et al., 1986)

$$\ln\left[\frac{a(t_2)}{a(t_1)}\right] = \ln\left[\frac{G_2}{G_1}\right] - \frac{\Delta t}{4Q}\left(\omega(t_1) + \omega(t_2)\right)$$

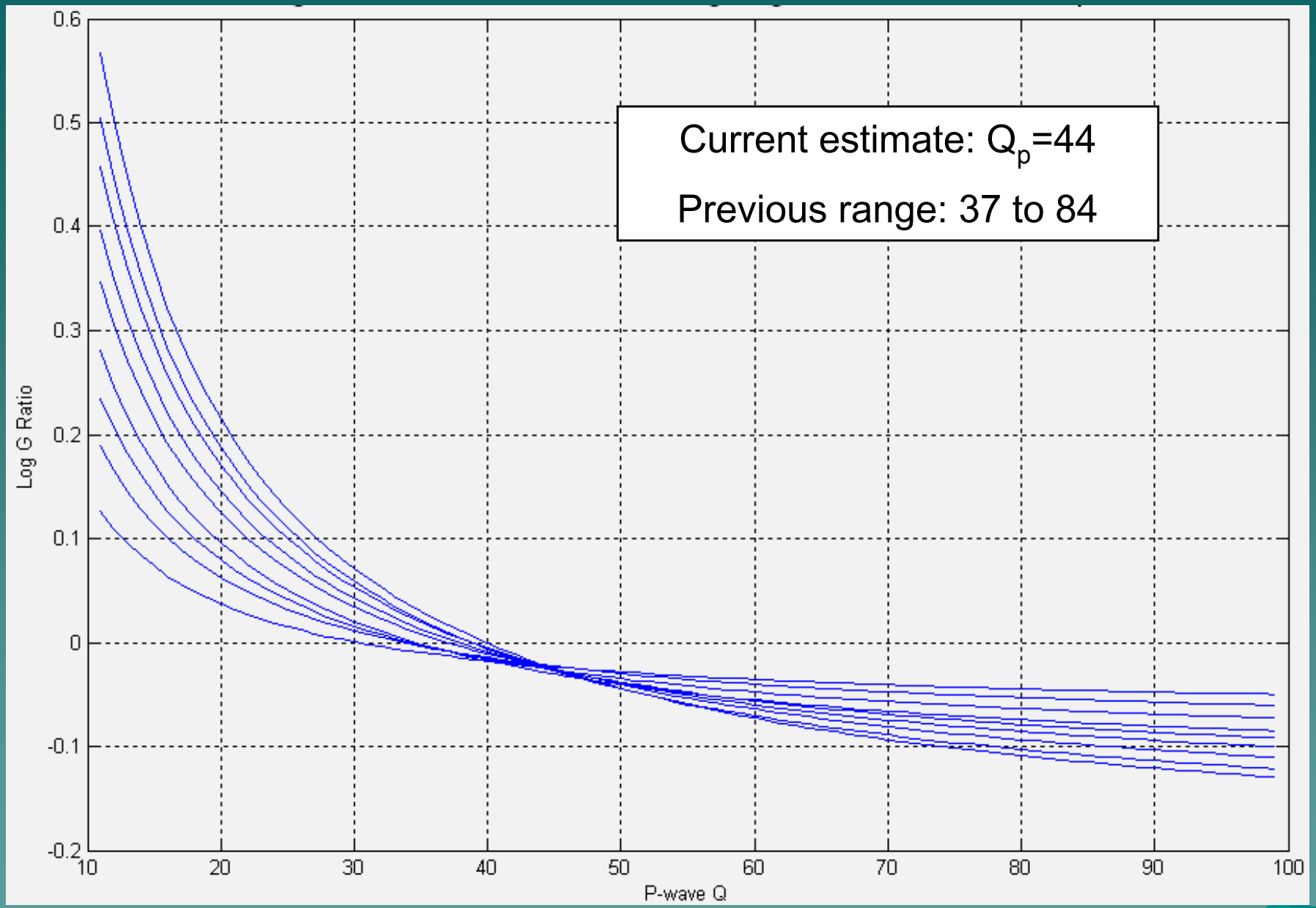
Log instantaneous amplitude ratio
(Engelhard et al., 1986; Tonn, 1991)



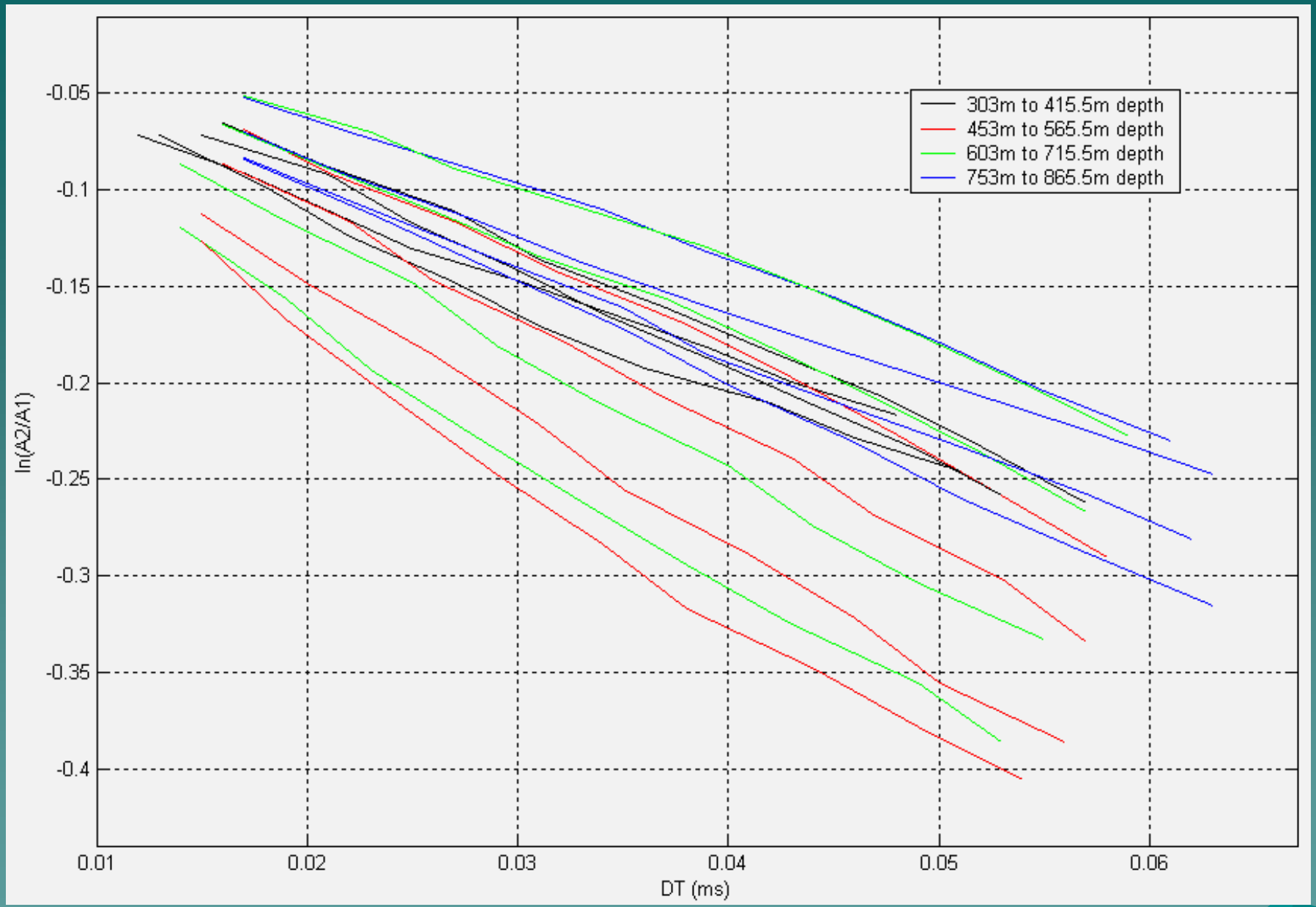
Separated Downgoing P-Wave Field (400m offset source – vertical vibrator)



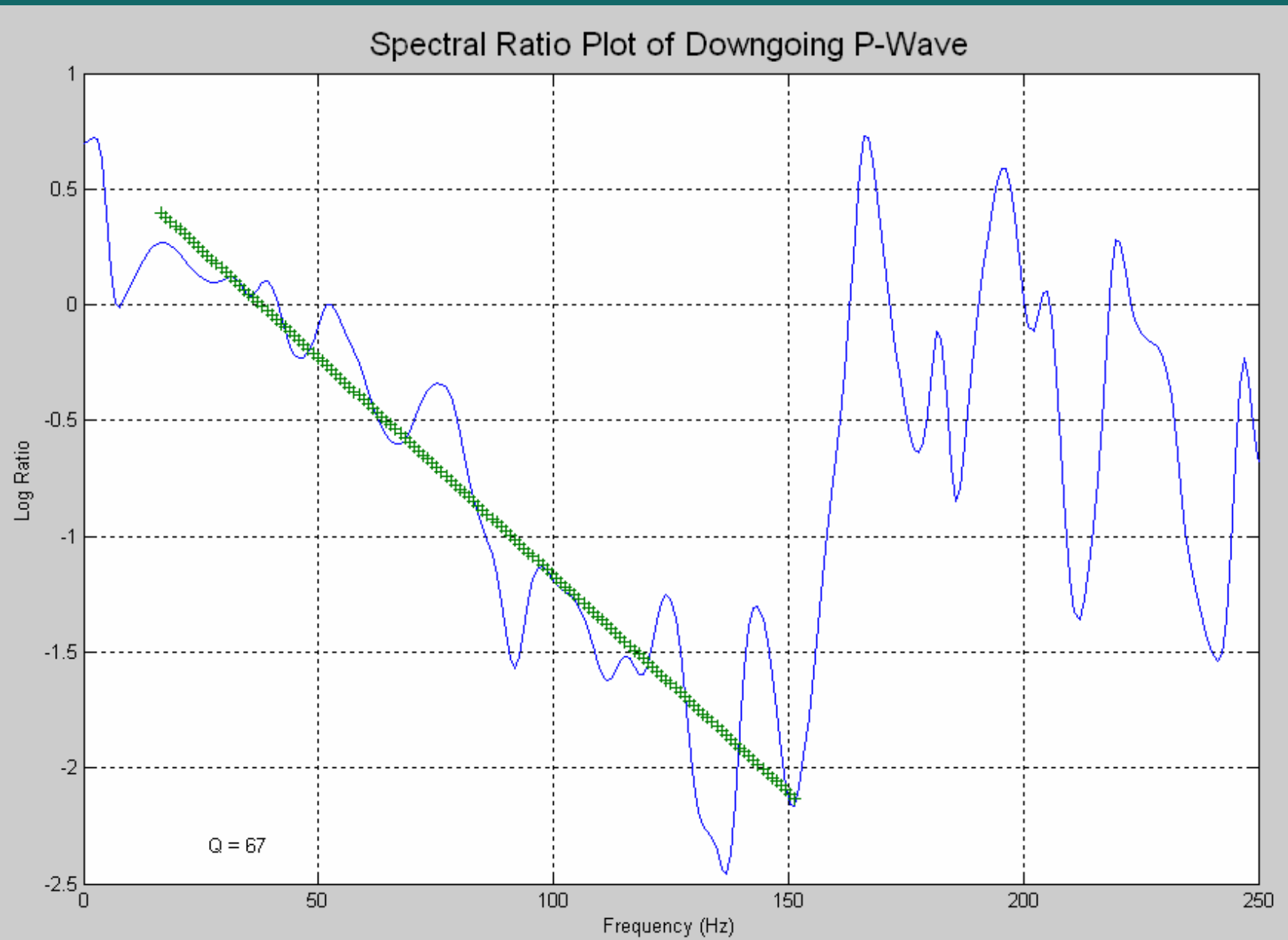
Instantaneous Amplitude of Separated Downgoing P-Wave Field

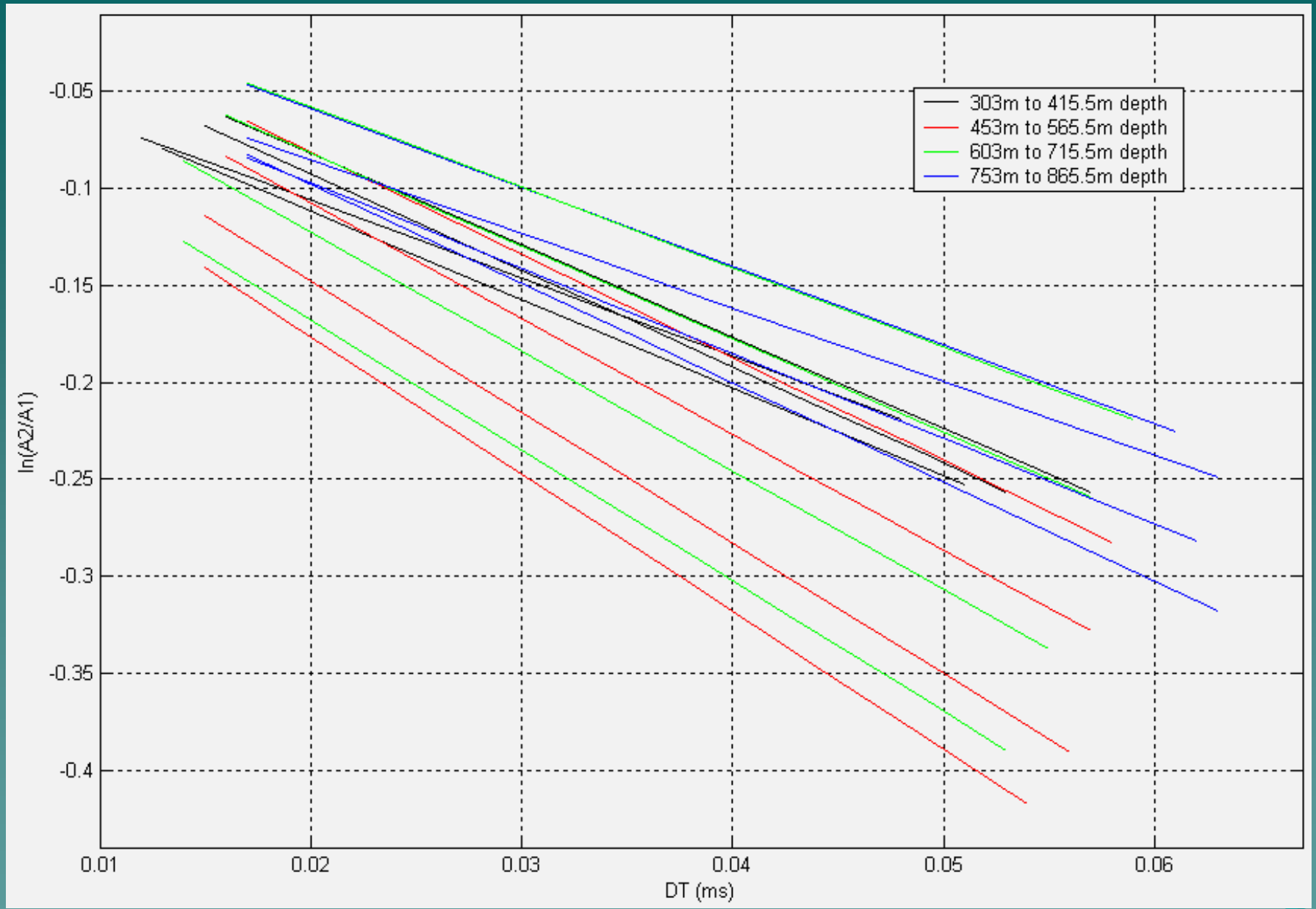


Log Spreading Ratio versus Q for Downgoing P-Wave Field at 303m Depth

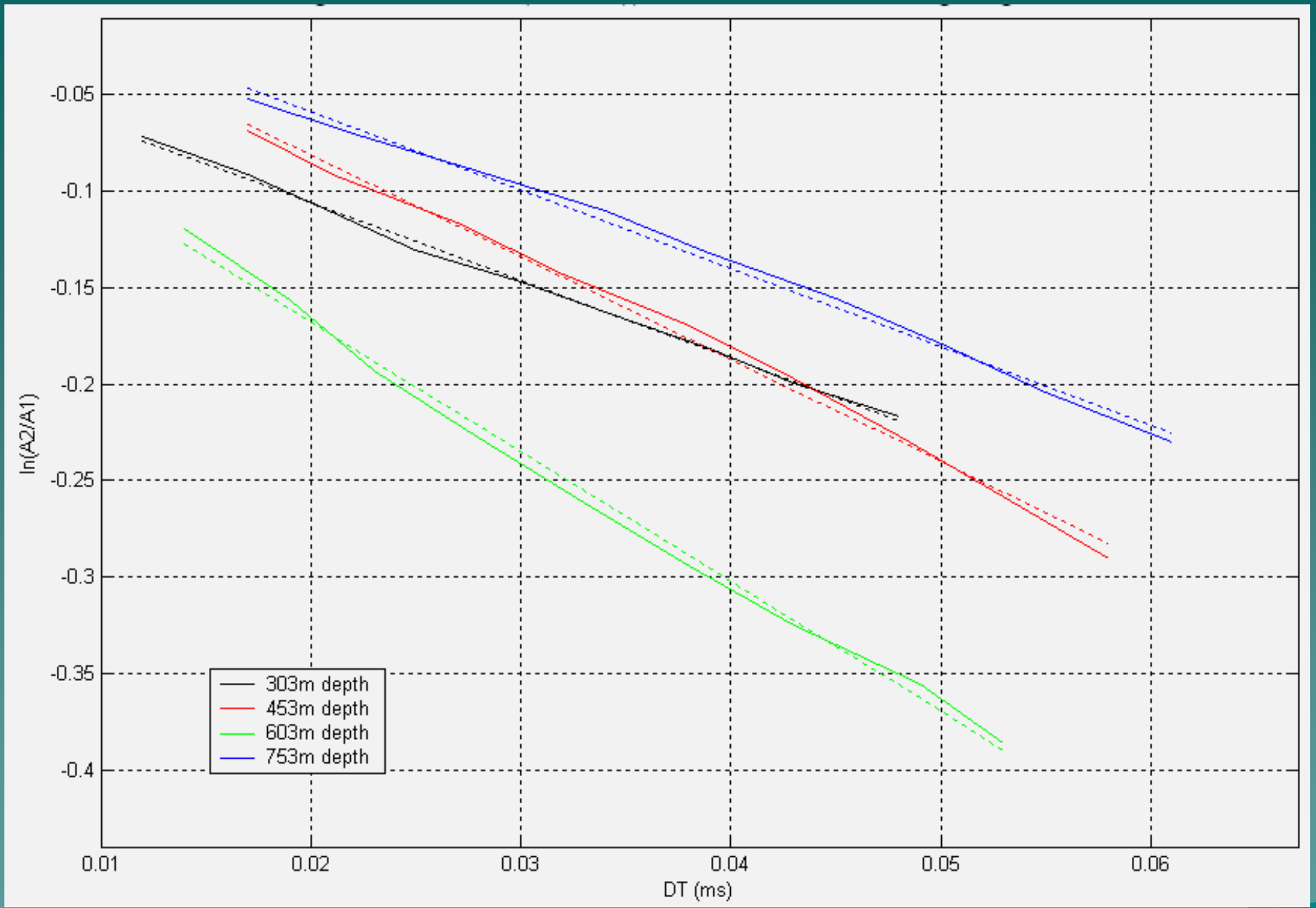


Log Amplitude Ratio versus Δt for Downgoing P-Wave Field

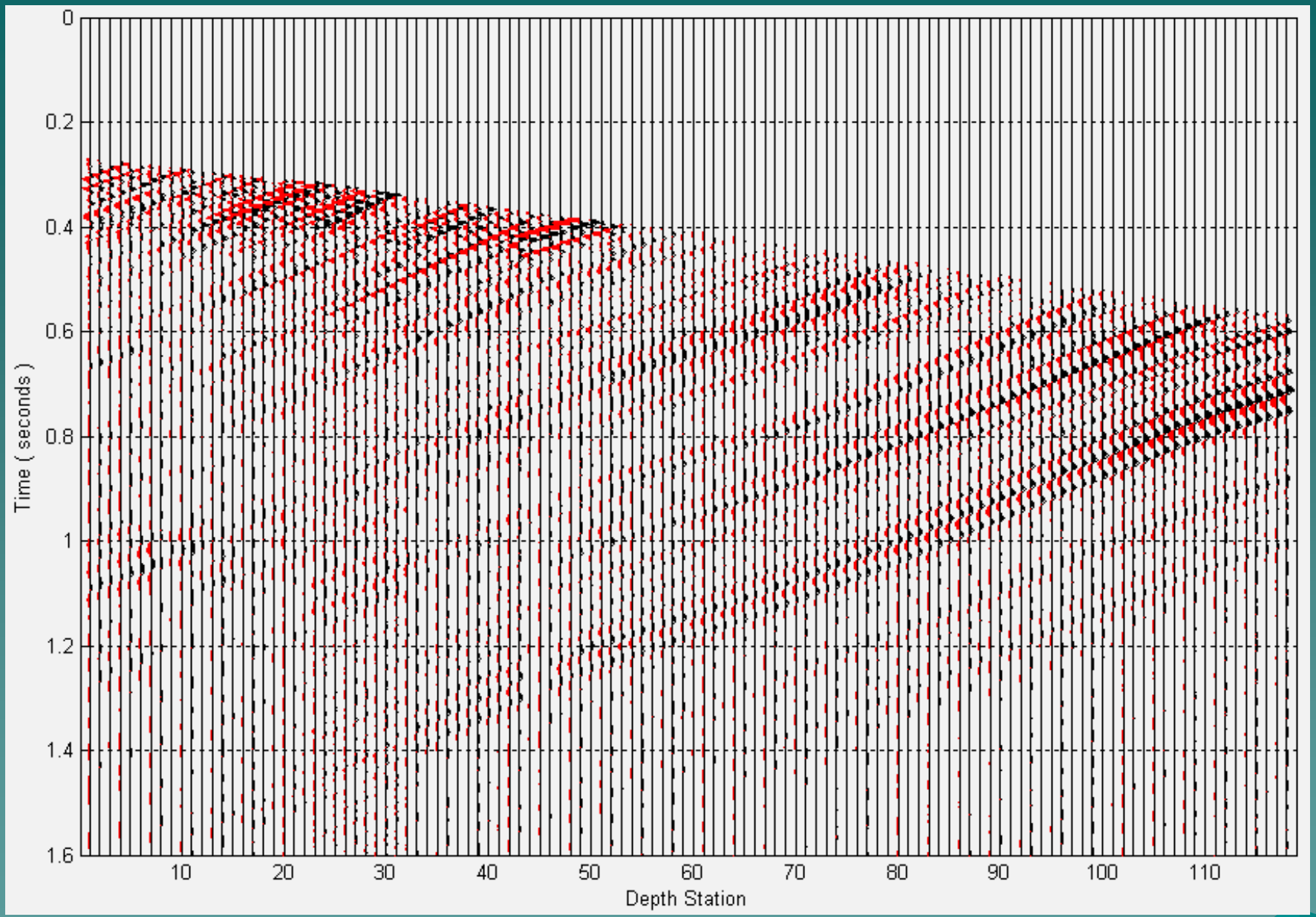

Spectral Ratio Plot of Downgoing P-Wave
Log Ratio
Frequency (Hz)
Q = 67
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
0
50
100
150
200
250



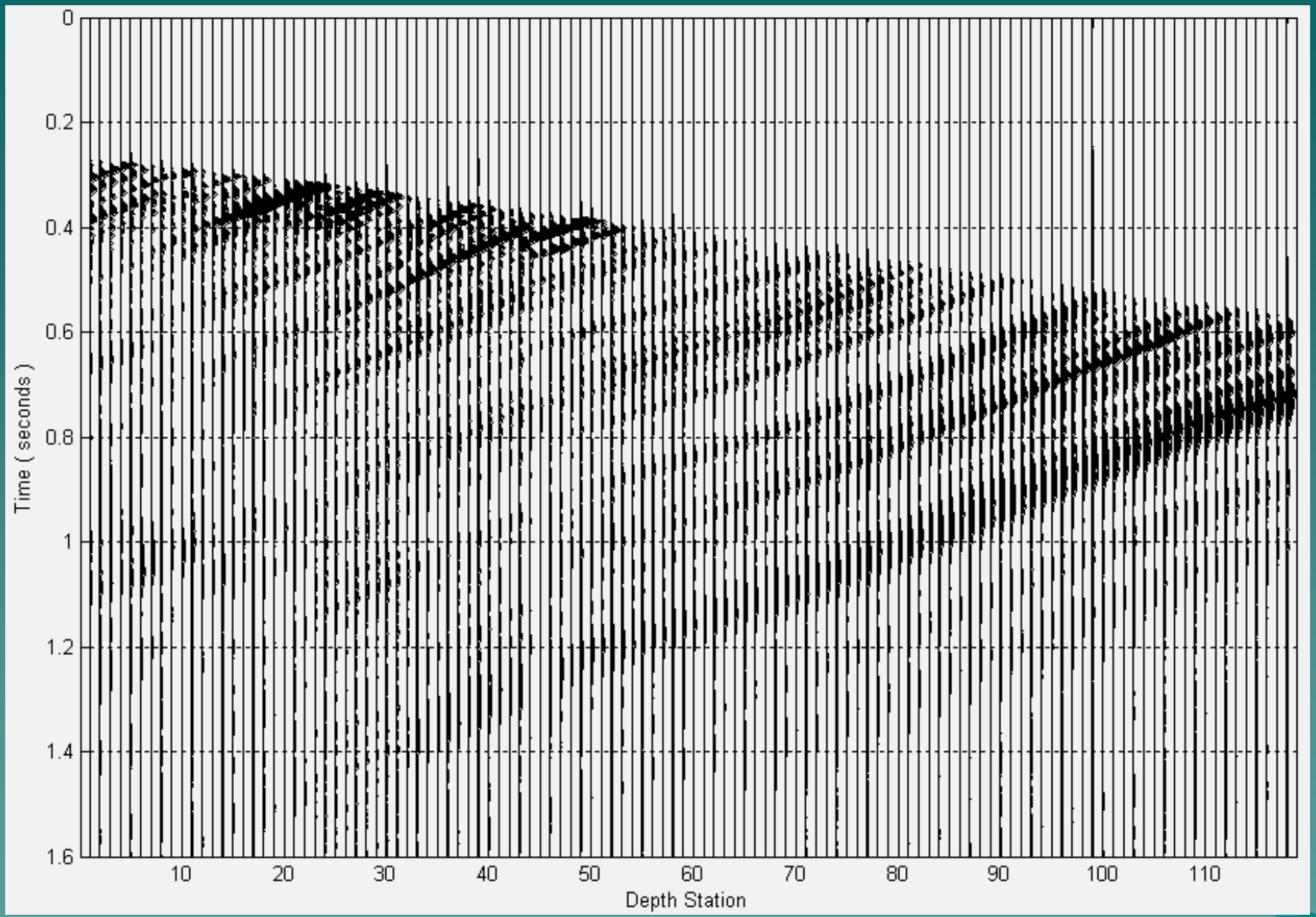
Linear Fit of Log Amplitude Ratio versus Δt for Downgoing P-Wave Field



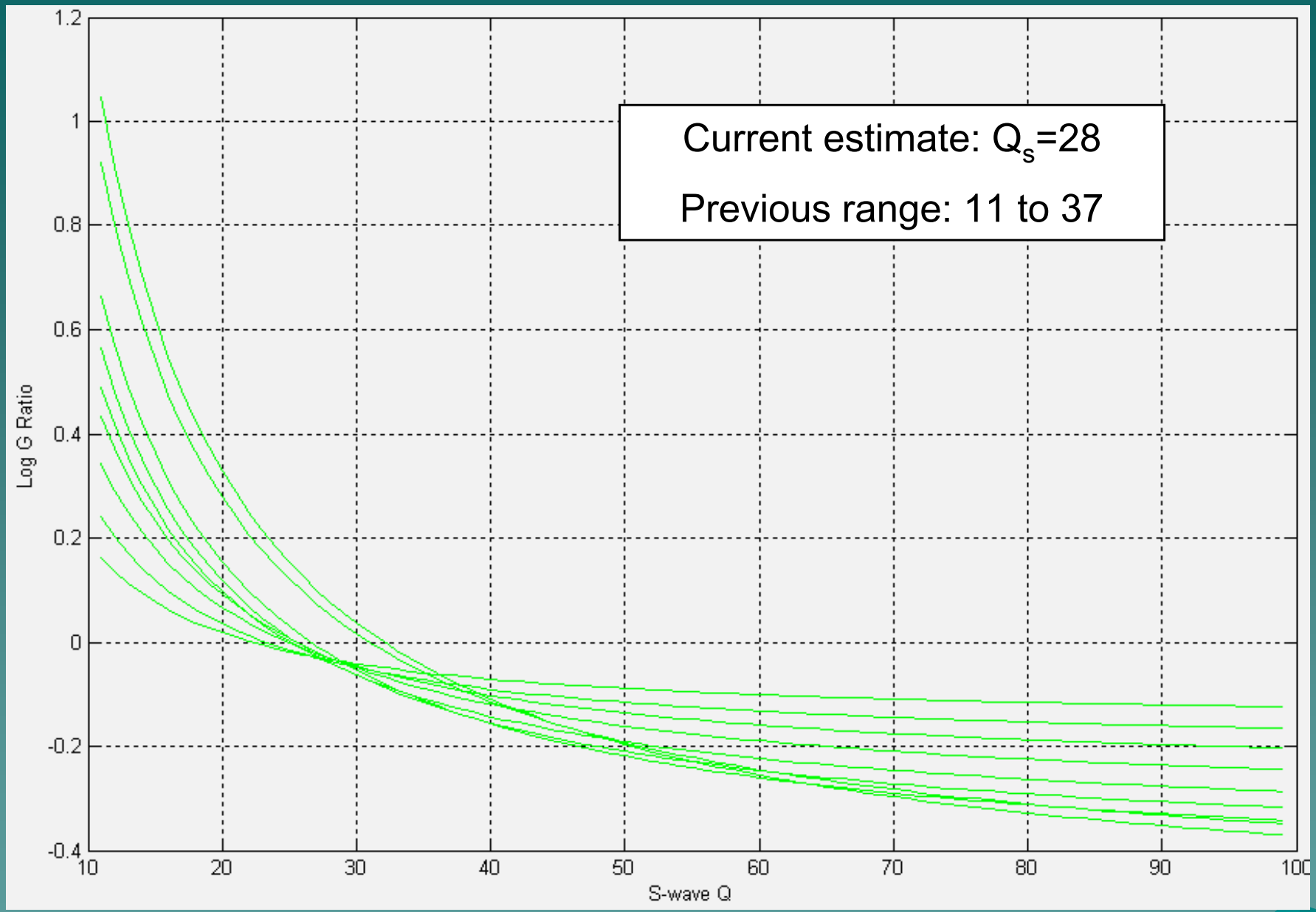
Linear Fit of Log Amplitude Ratio versus Δt for Downgoing P-Wave Field



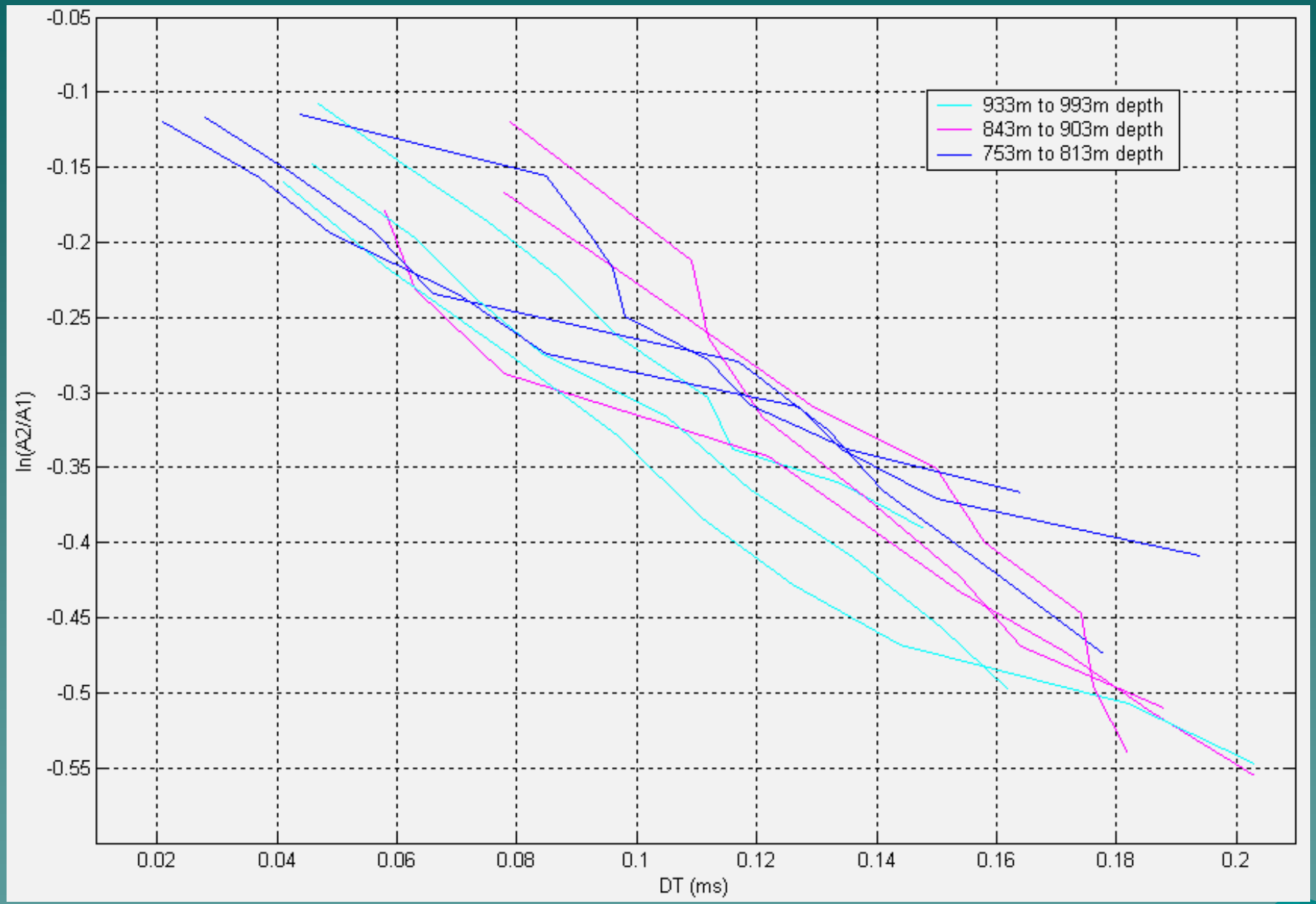
Separated Upgoing C-Wave Field (400m offset source – vertical vibrator)



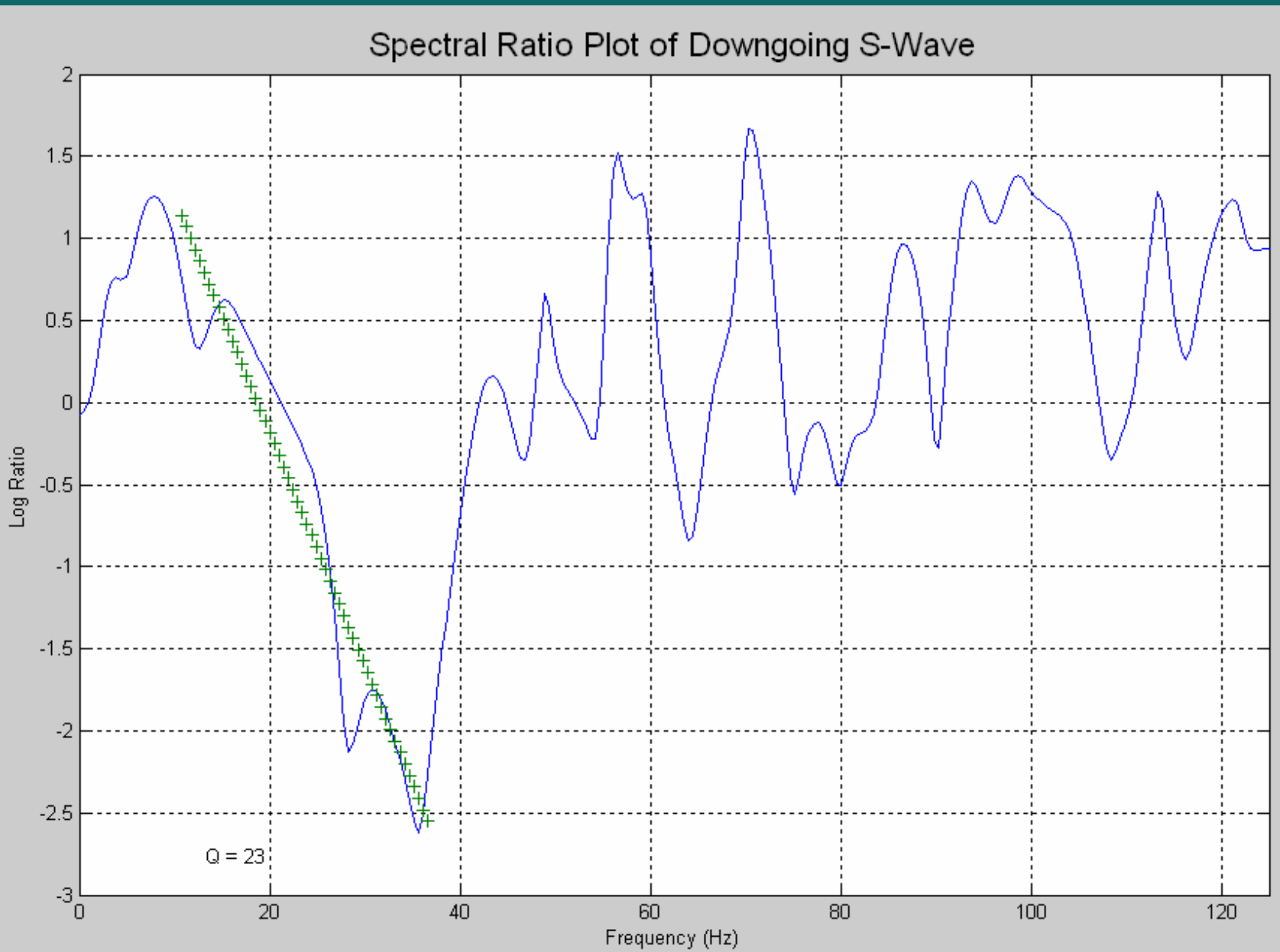
Instantaneous Amplitude of Separated Upgoing C-Wave Field

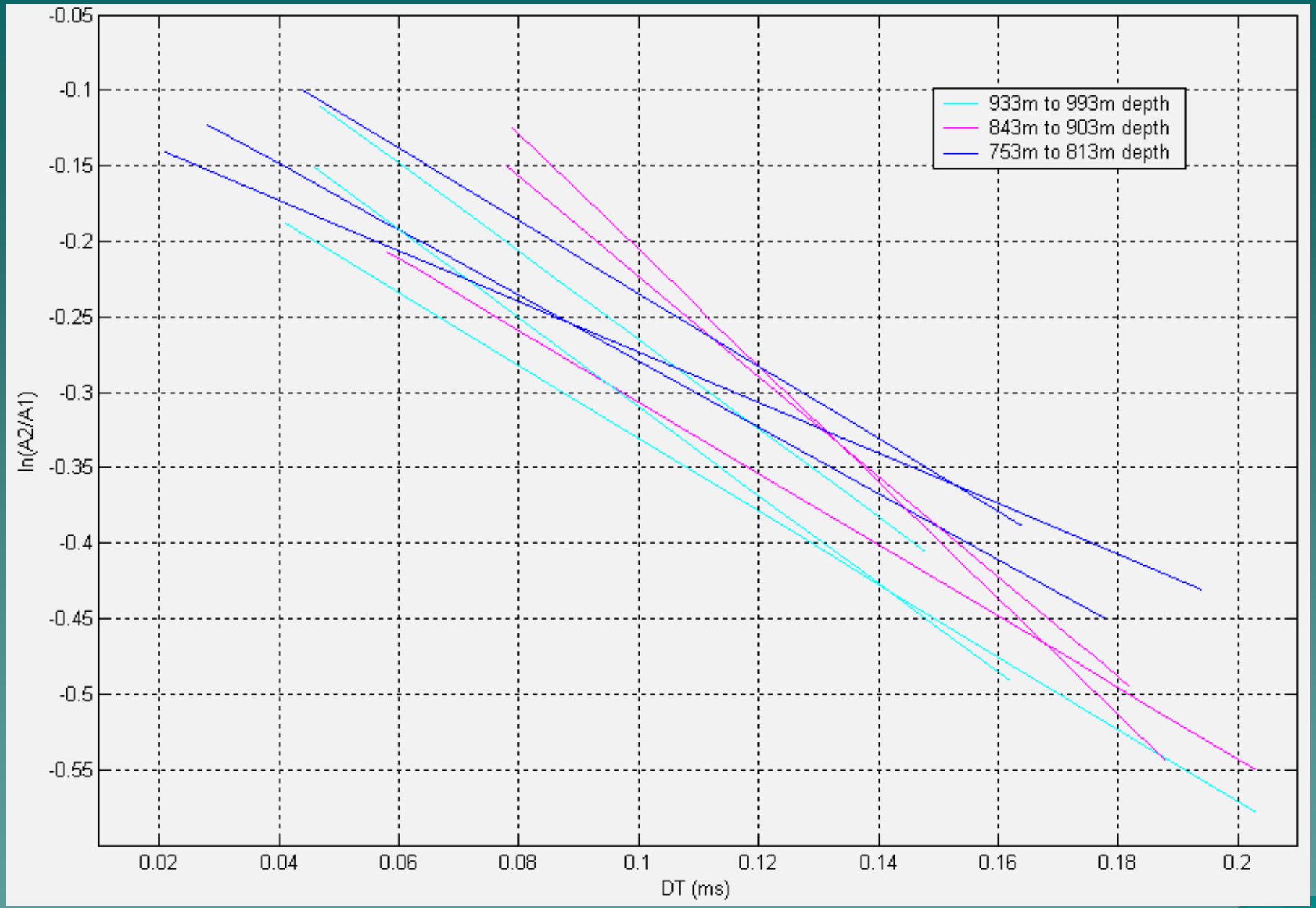


Log Spreading Ratio versus Q for Upgoing C-Wave Field at 933m Depth

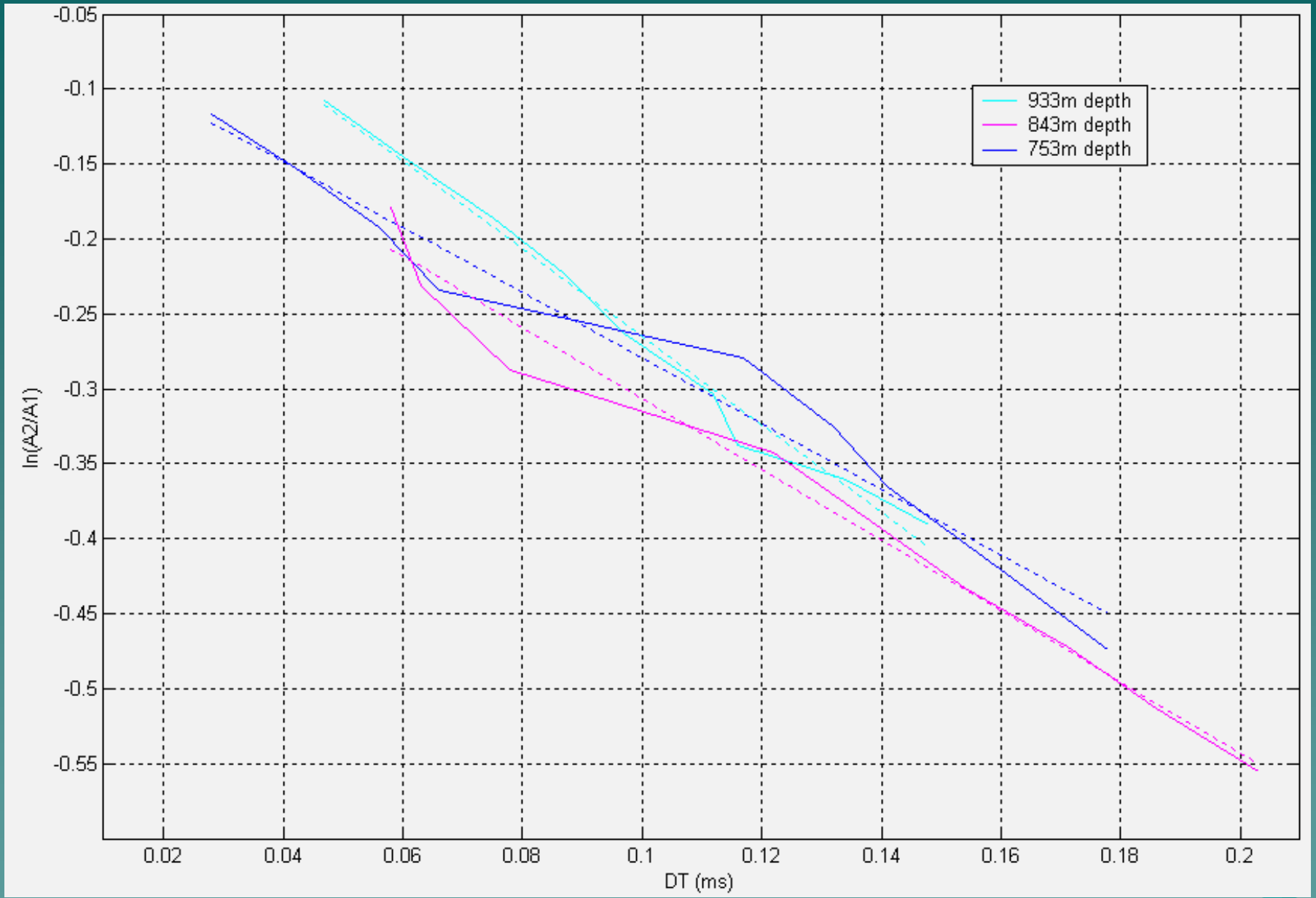


Log Amplitude Ratio versus Δt for Upgoing C-Wave Field

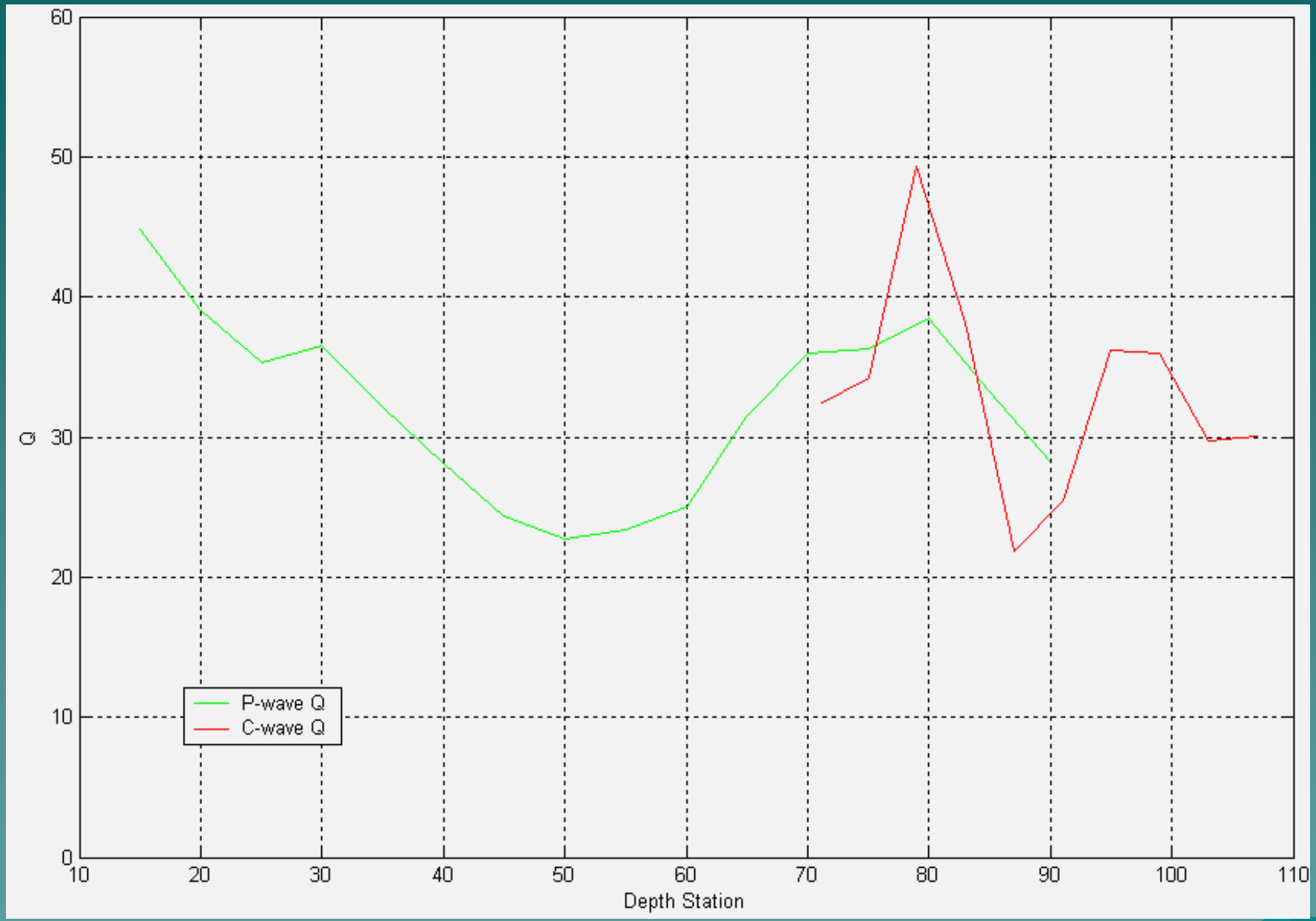

Spectral Ratio Plot of Downgoing S-Wave
Log Ratio
Frequency (Hz)
Q = 23
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
0
20
40
60
80
100
120



Linear Fit of Log Amplitude Ratio versus Δt for Upgoing C-Wave Field

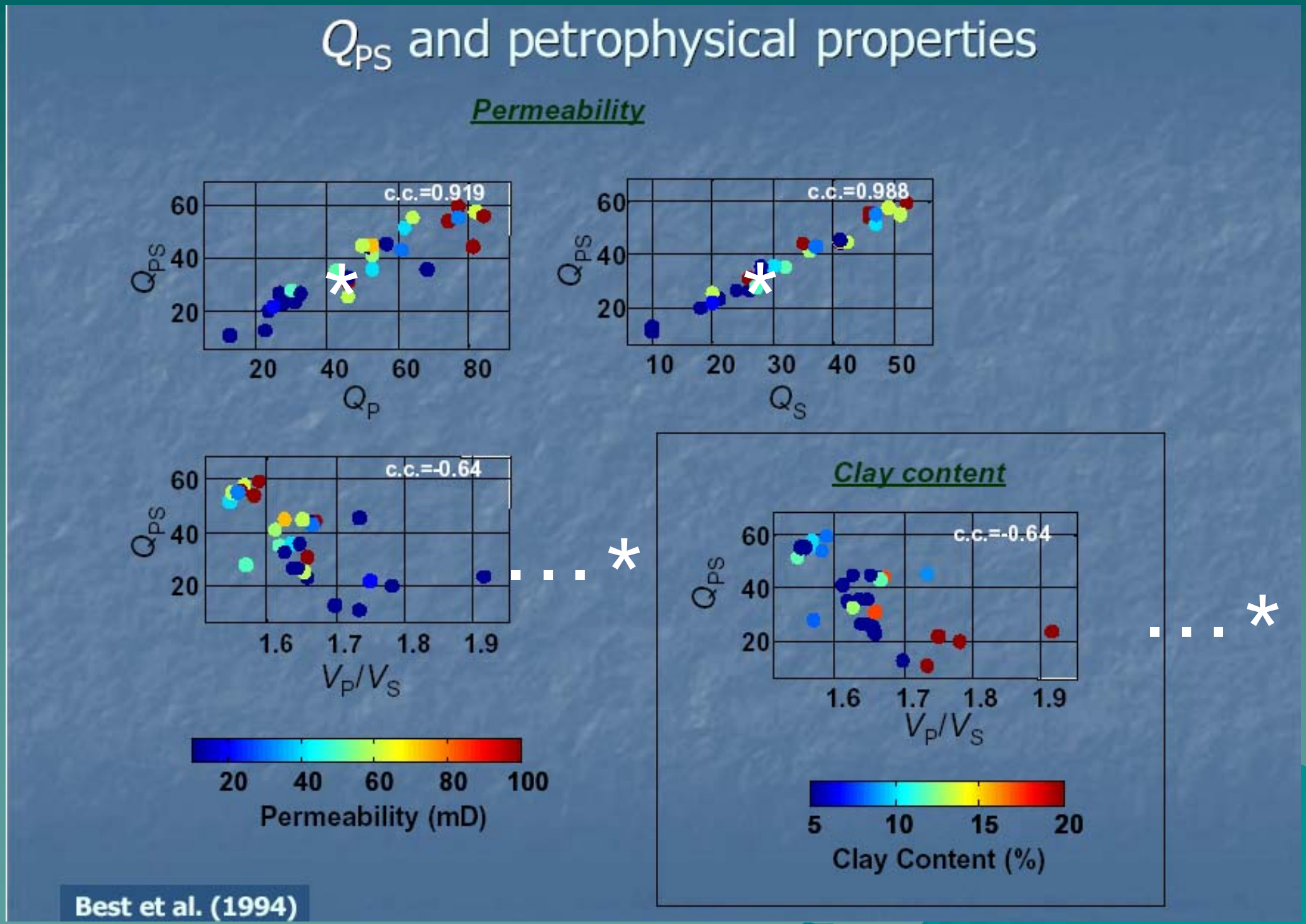


Linear Fit of Log Amplitude Ratio versus Δt for Upgoing C-Wave Field



Q versus Depth Station

Q_{PS} and petrophysical properties



(Calderón-Macías et al., 2004)

Conclusions

- New Q estimates within range of previous results
- Log amplitude ratio versus Δt curves are almost straight for P-waves
- Log amplitude ratio versus Δt curves not as smooth for C-waves but still useful for Q_s
- Results need to be verified by synthetic examples
- Transmission effects should be investigated

Acknowledgements

Thank you to Husky Energy Inc., in particular Mr. Larry Mewhort, for release of the VSP-data.

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