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Third Workshop on 3D Modelling of Seismic Waves Generation Propagation and their Inversion

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Surface Waves in Laterally Inhomogeneous Media: Theory and Observations

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SURFACE WAVES IN LATERALLY INHOMOGENEOUS MEDIA:
THEORY AND OBSERVATIONS

OUTLINE ☛

1. Why I ❤ surface waves ?
2. Conditions for surface waves existence.
3. Surface waves in laterally homogeneous media - asymptotics; factorization; main properties; effects of anisotropy.
4. Surface waves in media with smooth lateral inhomogeneities:
   * focusing/defocusing,
   * energy-depth profile variations,
   * multipathing,
   * coupling,
   * single scattering.

5. Surface waves in media with sharp lateral inhomogeneities:

*** reflection/refraction/conversion,**

*** multiple scattering.**

6. Forward problems:

*** modal approach;**

*** dynamic ray method;**

*** Gaussian beams;**

*** reflection/refraction on vertical boundaries;**

*** finite difference and finite element schemes.**

7. Inverse problems:

***1D inversion of dispersion curves and Q-measurements;**

*** inversion for source moment tensor;**

*** surface wave velocity tomography;**

*** wave-form fitting.**

8. Experimental studies of surface waves:

Existing Data: global and regional broad-band networks and arrays.

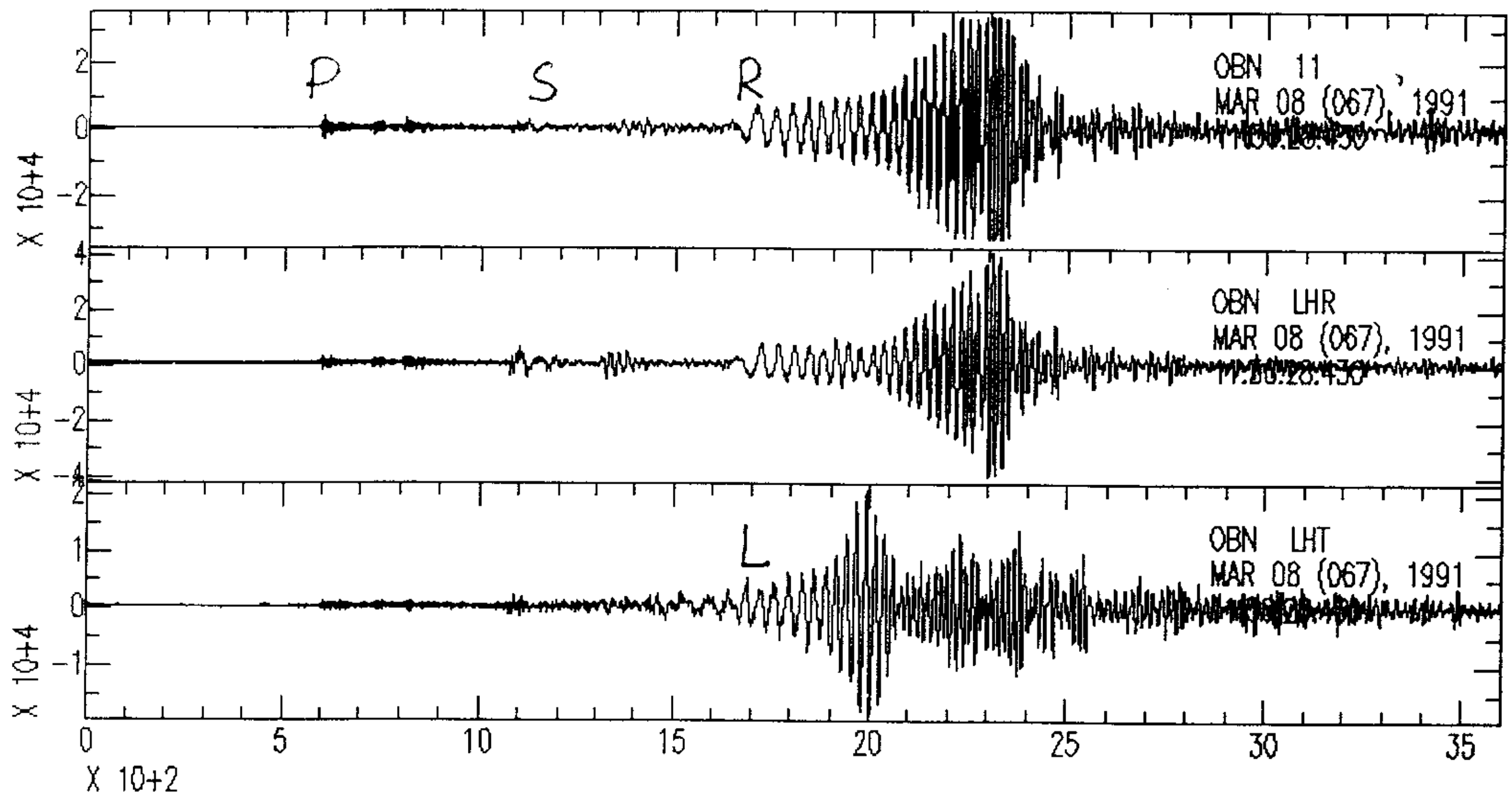
Data processing.

Examples ☞

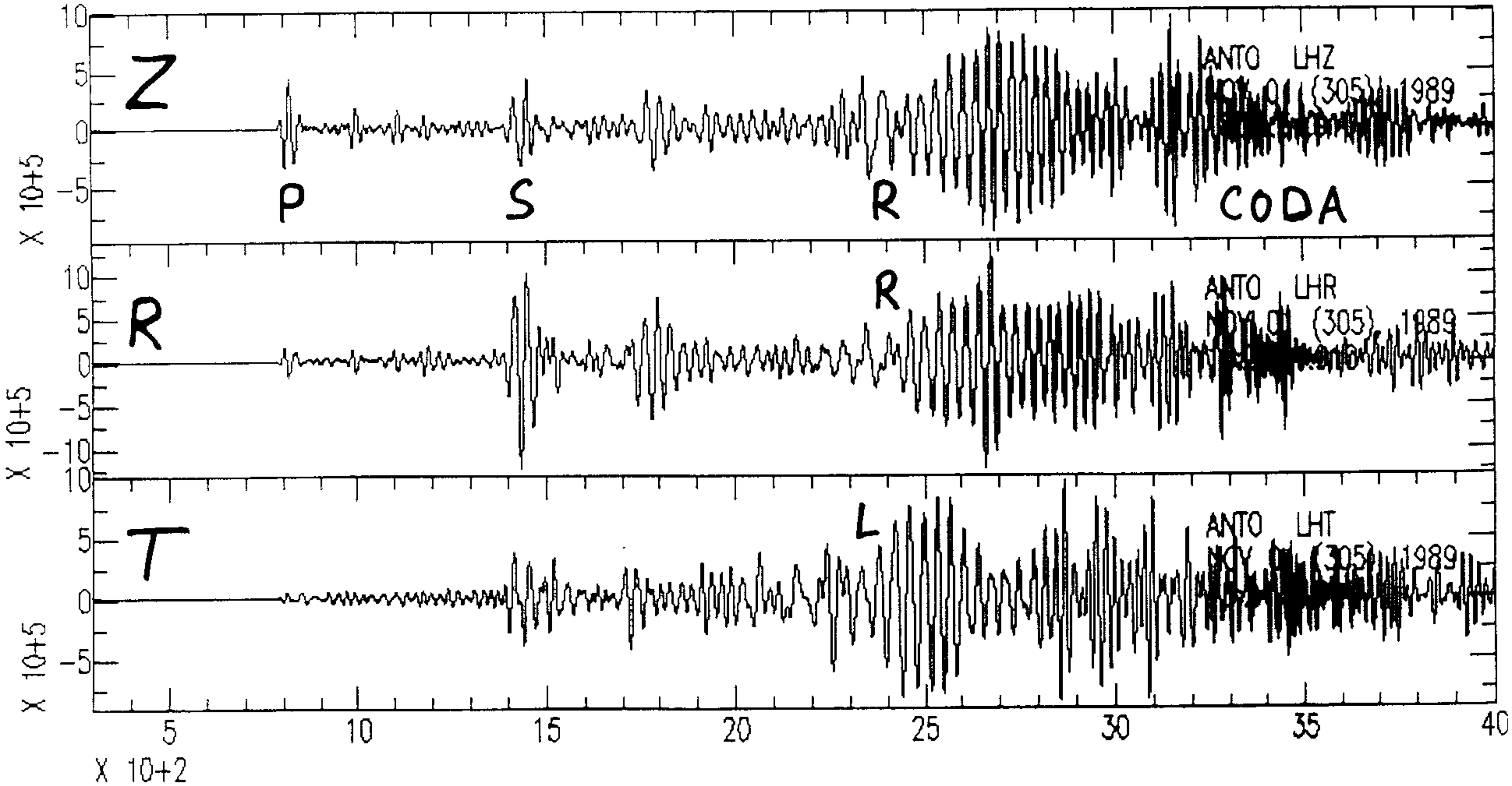
- **✳ group velocity measurements;**
- **✳ tomographic inversion;**
- **✳ multipathing;**
- **✳ polarization anomalies;**
- **✳ discrimination of nuclear tests;**
- **✳ co-seismic tectonic release.**

Event in N.E. Siberia recorded near Moscow

Graphics Window: 1



Event near Japan recorded by ANTO(Turkey)

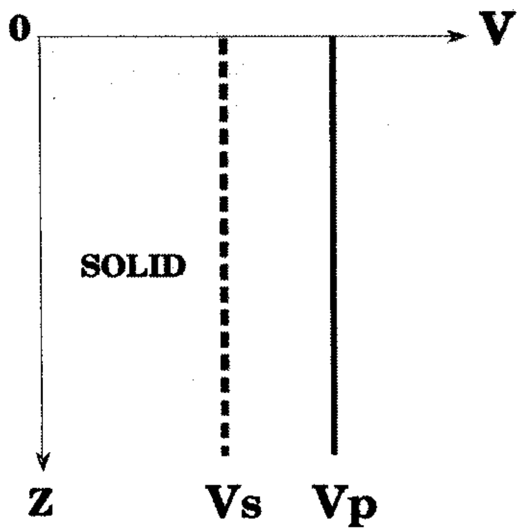


SURFACE WAVE PARAMETERS

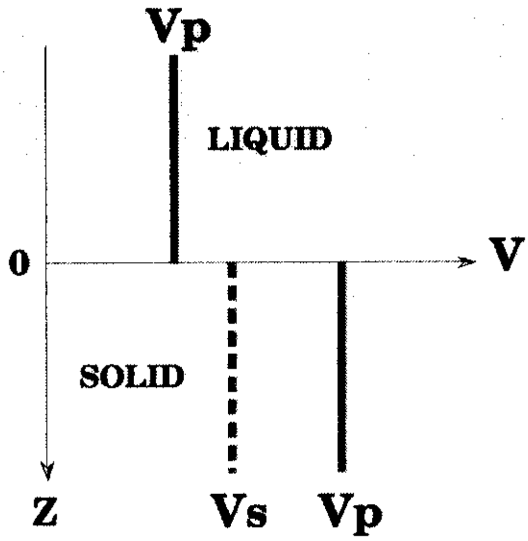
frequency	wavelength	phase velocity	depth of penetration	applications
(Hz)	(KM)	(KM/S)	(KM)	
10-50	0.005-0.05	0.1-0.5	0.020	CIVIL ENGINEERING ARCHEOLOGY L.V.Z. STUDIES
1-2	0.5 - 2.0	0.8 - 1.5	0.5	L.V.Z. AND (Low velocity zone) I.V.Z. STUDIES (intermediate velocity zone)
0.1-0.2	5 - 20	2.0 - 3.0	5	SEDIMENTARY BASINS STUDIES
0.03-0.1	30 - 100	3.0 - 3.5	40	CRUSTAL STUDIES
0.003-0.0	200 - 1000	4.0 - 5.0	300	UPPER MANTLE STUDIES

SURFACE WAVES: CONDITIONS OF EXISTENCE

1. Free or internal boundary

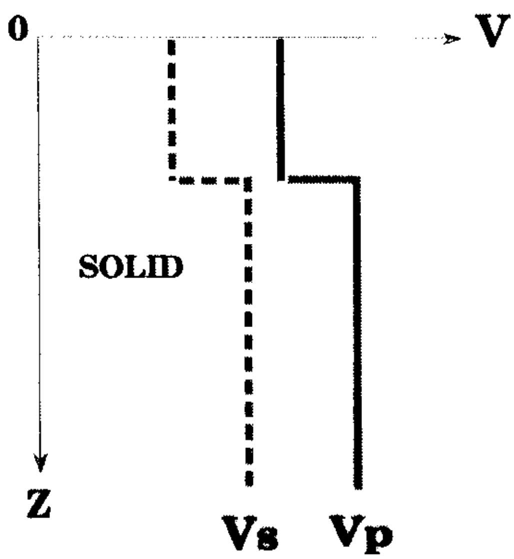


Rayleigh wave

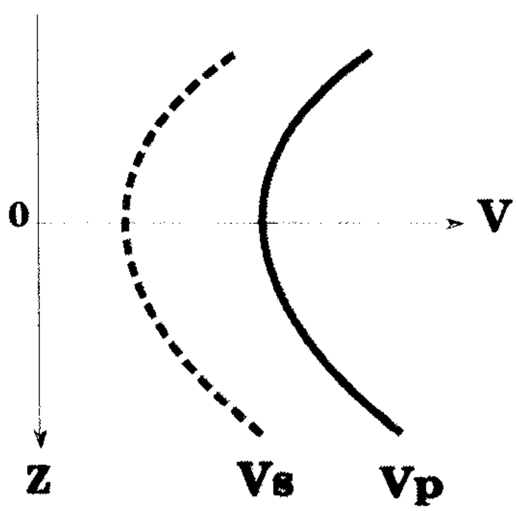


Stoneley wave

2. Waveguide

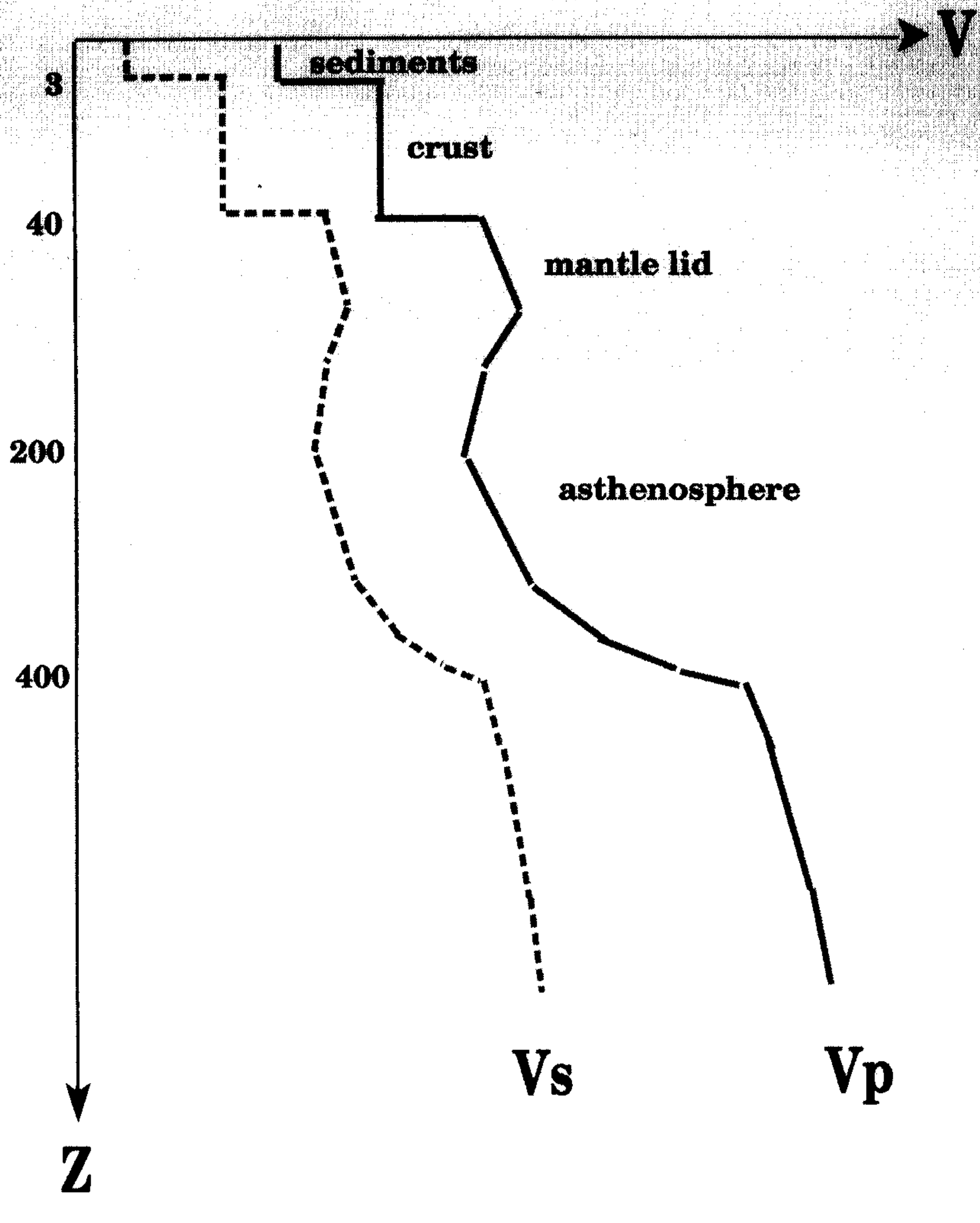


Rayleigh & Love waves



Channel waves

Typical cross-section of the Earth lithosphere



LATERALLY HOMOGENEOUS MEDIUM

$$u^q(\omega, r, \varphi, h) \;=\; \frac{\exp(-i\pi/4)}{\sqrt{8\pi\omega}}\;\frac{\exp[-i\omega\frac{r}{C}]}{\sqrt{r}}\;\frac{\varepsilon^q}{\sqrt{UI}}\;\frac{W}{\sqrt{UIC}}$$

$U(\omega)$ **is a group velocity,** $U(\omega) = \dfrac{C}{1 - \frac{\omega}{C}\frac{dC}{dw}}$;

$I(\omega)$ **is a kinetic energy integral for a given mode;**

$W(\omega)$ **is a source − dependent term;**

for the source described by a moment tensor $m_{qs}(t)$

$$W(\omega) = B_{qs}(\omega, \varphi, h)\,\hat{m}_{qs}(\omega)$$

$$\varepsilon^q = \begin{cases} 1 \\ -i\chi(\omega) \;\; \textit{for Raileigh waves} \\ 0 \end{cases}$$

$$\varepsilon^q = \begin{cases} 1 \\ +i\,[\text{illegible}] \;\; \textit{for Love waves} \\ 0 \end{cases}$$

$$q = z, r, \varphi$$

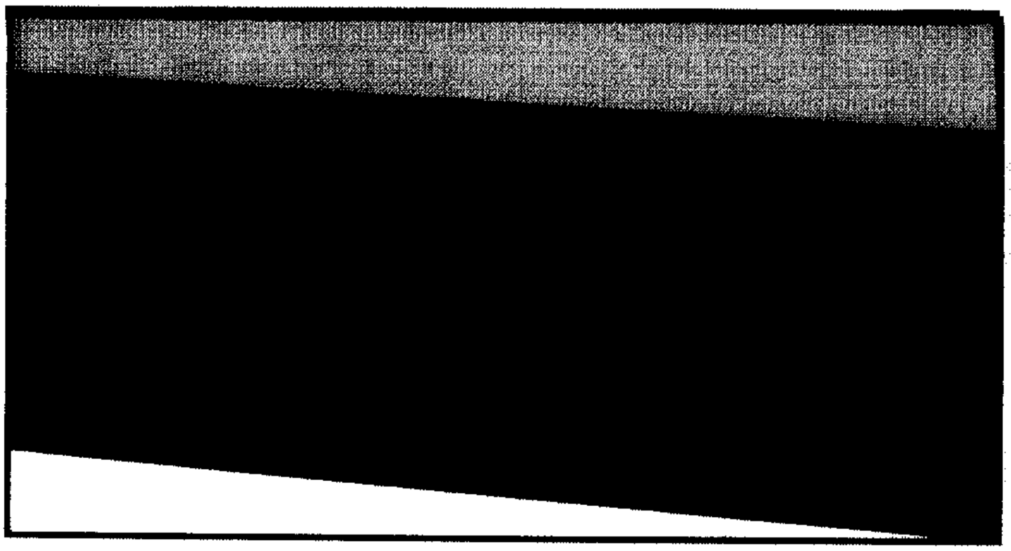
B_{qs} **is a strain tensor**

$\chi(\omega)$ **is ellipticity (aspect ratio)**

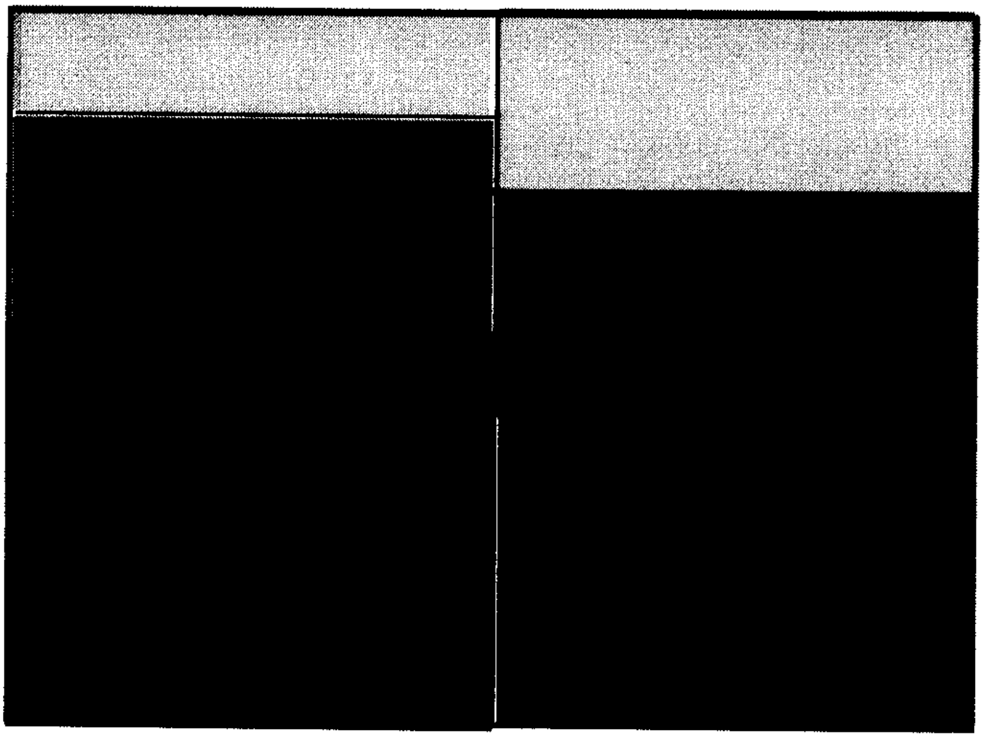
SMOOTHLY LATERALLY INHOMOGENEOUS MEDIUM

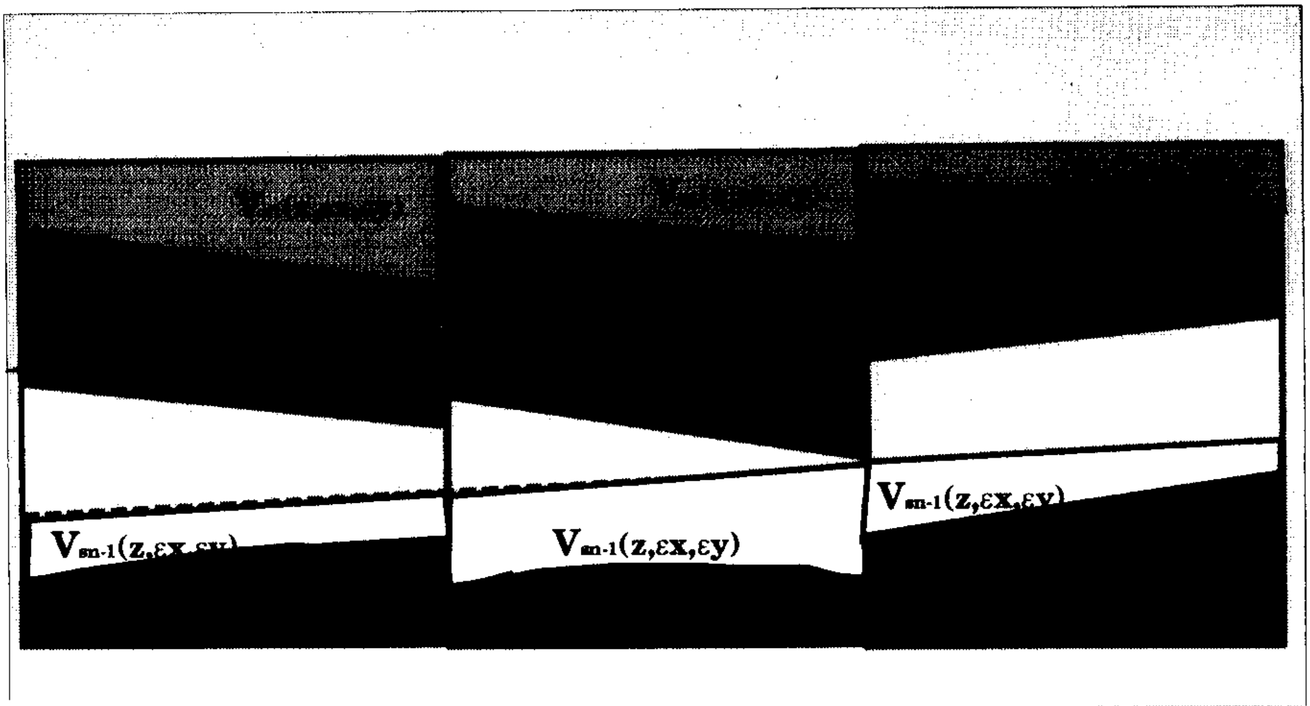
$$[u^q]_M \;=\; \frac{\exp(-i\pi/4)}{\sqrt{8\pi\omega}}\;\frac{\exp[-i\omega\int_l \frac{ds}{C(s)}]}{\sqrt{J}\;|_M}\;[\frac{\varepsilon^q}{\sqrt{UI}}]_M\;[\frac{W}{\sqrt{UIC}}]_{M_O}$$

SMOOTH INHOMOGENEITY



SHARP INHOMOGENEITY





SPECTRAL AMPLITUDE of a SURFACE WAVE MODE

$$[u^q]_M = \frac{\exp(-i\pi/4)}{\sqrt{8\pi\omega}} \exp\left[-i\omega \sum_{j=1}^{N-1} \int_{l_j} \frac{\mathrm{d}s}{C_j}\right] \left[\frac{\varepsilon^q}{\sqrt{UIJ}}\right]_M \times$$

$$\times \prod_{j=1}^{N} \left(\Gamma_{j,j+1} \sqrt{\frac{\cos\Theta'_j\,[UI]'_{Oj}}{\cos\Theta_j\,[UI]_{Oj}}}\right) \left[\frac{W}{\sqrt{UIC}}\right]_{M_O}$$