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A FEW UNSOLVED PROBLEMS OF APPLIED GEOPHYSICS

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The paper describes eight unsolved problems, stemming from statistical geophysics or rock physics: computation of effective physical properties in fluid-filled sedimentary rock *(Problems 1, 2)*; dependence of the absorption coefficient of sound waves in heterogeneous rocks on the randomness of the rock *(Problems 3, 4)*; fluctuation of the signal characteristics propagating through random media *(Problem 5)*; computation of the reflected energy from an infinite, randomly dissipative half-space *(Problem 6)*; and the statistical properties of the seismic signals, backscattered from randomly uneven boundaries *(Problems 7, 8)*. In all cases basic references are provided and applications pointed out.

Keywords: rock physics, sedimentary rocks, wave propagation, seismic data processing

Introduction

I shall briefly describe – somewhat in the vein of RUELLE's "Five Turbulent Problems" [1983] – eight loosely connected puzzles, all stemming from statistical geophysics or rock physics. In all cases I provide the basic references for further work, including the history, motivation and possible applications of the problem. This paper is an outgrowth of a lecture held in 1982 at the Geology Department of the University of Houston; I dedicate it to the memory of Milton B. Dobrin, (1915–1980), late Professor of that Department, Man, Teacher, Geophysicist.

1. Hierarchy of velocity equations: generalized mixture rules

The first problem is frequently encountered in geophysics, rock physics and solid state physics.

Suppose we are given a composite material of volume V consisting of two phases of the respective volume fractions P, Q; $P+Q = V$, and suppose these constituents are uniformly distributed within the total volume. Suppose g is some physically measurable property that assumes the values g_1 and g_2, respectively, for the two constituents, and a value $\bar{g}$ for the composite. Suppose, further, that the value of $\bar{g}$ is unambiguously determined by the volume fractions P, Q and the specific properties g_1, g_2:

$$\bar{g} = M(g_1, g_2, P, Q) \tag{1}$$

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In KORVIN [1982a] it is shown that, if a set of physically plausible conditions is met, the only possible functional form of $M(g_1, g_2, P, Q)$ is the "general mixture rule"

$$M(g_1, g_2, P, Q) = \{\Phi g_1^t + (1-\Phi)g_2^t\}^{1/t} \tag{2}$$

for some real t, $t \neq 0$, or

$$M(g_1, g_2, P, Q) = g_1^{\Phi} g_2^{1-\Phi} \tag{3}$$

which follows from Eq. (2) by l'Hôspital's rule for $t=0$. In Eqs. (2), (3), Φ is porosity, defined as $\Phi = P/(P+Q)$. The general mean values have the very important property [cf. BECKENBACH and BELLMAN 1961 § I.16] that for $g_1, g_2 > 0$, $\Phi \neq 0$, $\Phi \neq 1$ and $g_1 \neq g_2$ the expression $\{\Phi g_1^t + (1-\Phi)g_2^t\}^{1/t}$ is a strictly monotonously increasing function of t in $(-\infty, \infty)$.

In case of sound speeds, e.g., in fluid-filled sedimentary rocks the general rules (2), (3), contain, in particular, the following widely used "velocity formulae":

- for $t=-2$ the "approximate Wood equation" [WATERMAN and TRUELL 1961, KORVIN 1977a, 1978 b];
- for $t=-1$ the "time-average" equation [WYLLIE et al. 1956];
- for $t=0$ the "vugular carbonate" formula [of MEESE and WALTHER 1967];
- for $t=1$ the average velocity formula [BERRY 1959].

TEGLAND's [1970] method of sand–shale ratio determination also assumes a $t=-1$ time average equation; MATEKER's [1971] effective attenuation factor in an alternating sequence of thick sand–shale layers is a linear weighted (i.e. $t=1$) combination of the specific attenuations, further examples from different fields of geophysics are to be found in KORVIN [1978b, 1982 a].

The functional forms (2), (3) are derived in KORVIN [1982a] from the following set of physically plausible conditions. (The derivation is based on the theory of functional equations, particularly on the results of ACZÉL [1961].)

Condition 1. reflexivity

$$M(g_1, g_1, P, Q) = g_1 \quad \text{for all } P, Q \ (P+Q > 0) \tag{4}$$

Condition 2. idempotency

$$M(g_1, g_2, P, 0) = g_1 \quad \text{for all} \quad P > 0 \tag{5}$$

$$M(g_1, g_2, 0, Q) = g_2 \quad \text{for all} \quad Q > 0 \tag{6}$$

Condition 3. homogeneity (of 0-th order) with respect to the volume fractions

$$M(g_1, g_2, P, Q) = M(g_1, g_2, \lambda P, \lambda Q) \tag{7}$$

for all P, Q, λ such that $P+Q > 0$, $\lambda > 0$

Condition 4. internity. The property $\bar{g}$ measured on the composite lies between the specific values g_1, g_2 of the constituents; if $g_1 < g_2$, say, then for $P+Q > 0$:

$$M(g_1, g_2, 1{,}0) \leq (g_1, g_2, P, Q) \leq M(g_1, g_2, 0{,}1) \tag{8}$$

Condition 5. bi-symmetry (this concept is due to Aczél [1946]). Given two composites, the first consisting of P_1 and Q_1 parts of materials of g_1 and g_2 properties; the second of P_2 and Q_2 parts of materials of G_1 and G_2 properties, the following two expressions for the measured property $\bar{g}$ of the four-component aggregate must be equal:

$$\begin{aligned} &M[M(g_1, g_2, P_1, Q_1); M(G_1, G_2, P_2, Q_2); P_1+Q_1; P_2+Q_2] = \\ &= M[M(g_1, G_1, P_1, P_2); M(g_2, G_2, Q_1, Q_2); P_1+P_2; Q_1+Q_2) \end{aligned} \tag{9}$$

Condition 6. monotonicity with respect to the volume fractions.

$$\text{If } g_1 < g_2, \quad \text{say,} \quad P+Q_1 > 0, \quad Q_2 > Q_1$$

$$\text{then} \quad M(g_1, g_2, P, Q_1) < M(g_1, g_2, P, Q_2) \tag{10}$$

Condition 7. monotonicity with respect to the physical properties.

$$\text{If } P+Q > 0, \quad g_2 < g_3 \quad \text{then} \quad M(g_1, g_2, P, Q) < M(g_1, g_3, P, Q) \tag{11}$$

Condition 8. homogeneity (of first order) with respect to the physical properties

$$M(\lambda g_1, \lambda g_2, P, Q) = \lambda M(g_1, g_2, P, Q)$$
$$\text{for all} \quad P, Q, \lambda \quad \text{such that} \quad P+Q > 0, \quad \lambda > 0 \tag{12}$$

In Korvin [1982a] it is proved that if the function $M(g_1, g_2, P, Q)$ defining the effective physical property $\bar{g}$ of a two-component material satisfies Conditions 1–8 (Eqs. 4–12) then

$$\bar{g} = M(g_1, g_2, P, Q) = \{\Phi g_1^t + (1-\Phi) g_2^t\}^{1/t}$$

$$\text{for some real} \quad t, t \neq 0, \quad \Phi = \frac{P}{P+Q} \quad \text{or} \quad g = g_1^{\Phi} g_2^{1-\Phi}.$$

In case of sound speeds, e.g. in sandstone, *Fig. 1* shows porosity–velocity curves for different values of the parameter t ($g_1 = v_{fluid} = 1545$ m/s; $g_2 = v_{matrix} = 5542$ m/s, after Meese and Walther 1967; the Berea, Boise, Miocene, Page sandstone data are taken from Meese and Walther [1967], the Texas data from Hicks and Berry [1956]). It is seen from Fig. 1 that the sandstone data are best fitted by a $t = -0.6$ curve, i.e. by the formula

$$\bar{v} = \{\Phi \cdot v_{fluid}^{-06} + (1-\Phi) v_{matrix}^{-06}\}^{-1/0.6}$$

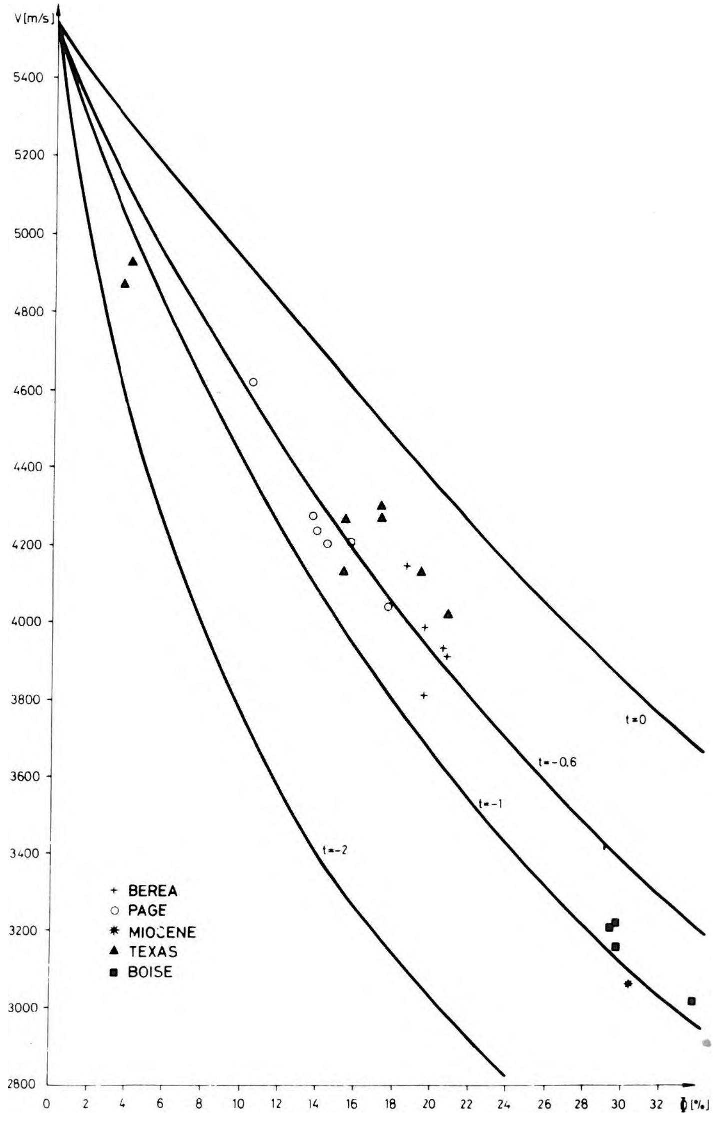

Fig. 1. Porosity–velocity master curves for sandstone [From KORVIN 1978b]

1. ábra. Porozitás–sebesség görbesereg homokkövekre [KORVIN 1978b-ből]

Рис. 1. Кривые зависимости скорости от пористости для песчаниках [По KORVIN 1978b]

Thus, we are led to *Problem 1*: What is the physical meaning (if any) of the parameter t in Eq. 2? Does $t = -0.6$ have any particular meaning for sandstone?

There is also another, variational approach, for the determination of the effective properties of composite materials, culminating in the celebrated HS [HASHIN-SHTRIKMAN, 1963] bounds on the effective properties in terms of the specific ones. A very recent summary of the topic, with many references, is HUGHES and PRAGER [1983], see also STELL [1983]; the standard reference for earlier work is HASHIN [1964].

It would be nice to see somebody solve *Problem 2*, that is, to reconcile the functional equation approach [of KORVIN 1978b, 1982a] with the HS variational approach, or at least to use HS bounds to derive non-trivial bounds for t.

2. Sound absorption and rock entropy

In 1978 BELTZER studied elastic wave propagation in randomly porous materials. He concluded that "for low frequency regimes the randomness of porosity leads to an increase in the attenuation and dispersion of the elastic wave".

BELTZER's result is highly plausible and in agreement with the general understanding that the heterogeneity of a medium causes additional dissipation of the propagating elastic wave. (It is well known, for example, that the sound attenuation in crystalline materials is less for a single crystal than for an aggregate; [BRADLEY and FORT 1966].) Prior to BELTZER's work similar conclusions had already been reported by the present author, in connection with elastic waves propagating in a random stack of layers (the hypothesis was published in 1976, its heuristic proof in 1978c). KORVIN [1980] applies stochastic perturbation methods of random wave propagation theory [KELLER 1964, KARAL and KELLER 1964] in order to generalize BELTZER's results for rocks of random structure. In KORVIN [1980] it is shown that in multicomponent rocks the low-frequency attenuation coefficient is proportional to (more exactly, positively correlated with) the quantity

$$E = -\sum_{i=1}^{n} p_i \log p_i \qquad (13)$$

where p_i ($i = 1, \ldots, n$) is the relative volume ratio of the i-th phase, $\Sigma p_i = 1$. The quantity E, however, measures the randomness of the constitution of the rock and, in Russian literature, is termed "rock entropy" [cf. BYRYAKOVSKIY 1968]. Recalling that in the statistical theory of phase transitions of disordered systems the entropy of a random aggregate of several components always consists of two parts

$$S = S_{configurational} + S_{mixture} \qquad (14)$$

where $S_{mixture}$ has the same form as the entropy E in Eq. (13). Eq. 14 is the so-called Flory–Huggins formula, [see ZIMAN 1979, §. 7.2.], we immediately see (*Problem 3*) that either the concept of rock entropy should carefully be redefined, or the random wave equation solved more precisely in order to decide whether or not the attenuation depends on the configurational part of rock entropy.

The hypothetical connection between attenuation and randomness (entropy) of the rock presents us with a further, much more delicate problem.

It is well known that frequency-dependent attenuation and velocity dispersion lead to a distortion of propagating acoustic pulses; BARKHATOV [1982, §. 3.6.4.] and BARKHATOV and SHMELEV [1969] even speak about the changes of signal entropy during hydroacoustic propagation. KUZNETSOV et al. [1973] and HOLLIN and JONES [1977] propose that the correlation between the propagating pulses for the determination of the attenuation characteristics be measured. Theoretically, the propagation of the two-point correlation function (as of any other quadratic quantities) can be described by the Bethe–Salpeter equation [BOURRET 1962] or by appropriate transport equations [see e.g. BUGNOLO 1960]. In connection with the latter approach FRISCH [1968 p. 145] comments: "...there are some physical difficulties in the interpretation of the solution, which have not been settled yet. It appears, for example, that in contradistinction to the homogeneous nonrandom case, there is an energy loss, even when the medium is not dissipative."

It seems to us that this problem, together with that concerning the interconnection of attenuation and randomness, can be solved by following up the pioneering ideas of CASTI and TSE; these authors showed in 1972 that the Kalman–Bucy optimal filtering theory and radiative transfer theory "which from a physical point of view seem to have very little in common, may be brought together by careful examination of their respective initial value formulations" [*op. cit.* p. 42].

In their concluding remarks CASTI and TSE [1972 p. 53] state: "In conjunction with the active filtering problem, let us mention a radiative transfer function ...this is the absorption function which is defined by means of conservation law, i.e. it corresponds to the radiative energy which is input to the atmosphere, but which is neither transmitted through nor reflected back out... In the active filtering case there is reason to suspect that this function may correspond to a loss of inherent information in the known control input due to interaction with the noisy system. If this correspondence can be made precise, it would seem to be possible to establish a conservation of information law for stochastic systems".

That is, we can state our *Problem 4* as: Derive attenuation in random media from "conservation of information" principles!

3. Ignorance versus depth: the turbidity factor paradox

One of the basic results of seismic wave propagation in randomly inhomogeneous media is that velocity- and density inhomogeneities cause scattering of waves, the scattered waves are superimposed on the primaries and lead to amplitude and phase fluctuations in the observed wave pattern. We shall neglect density fluctuations and assume that an acoustic wave of frequency f propagates along a distance $AB = L$ in a random medium where sound-speed randomly fluctuates around some constant C_0 as

$$C = \frac{C_0}{1+\varepsilon} \tag{14}$$

where

$$\langle\varepsilon\rangle = 0, \langle\varepsilon^2\rangle \ll 1, R_{\varepsilon\varepsilon}(r) = \langle\varepsilon(\mathbf{x})\varepsilon(\mathbf{x}+\mathbf{r})\rangle =$$
$$= \langle\varepsilon^2\rangle \exp[-|r/r_0|] \quad (r = |\mathbf{r}|),$$

r_0 is the correlation distance of the inhomogeneities. Denoting mean transit time L/C_0 by T, its fluctuation by ΔT and mean wavelength by λ, it can be shown that, if $r_0 \gg \lambda$:

$$\langle(\Delta T)^2\rangle = \frac{L}{C_0^2}\langle\varepsilon^2\rangle r_0\sqrt{\pi} \tag{15}$$

(see CHERNOV [1960], or KORVIN [1973] for a more general case). The gist of Eq. (15) is that the square of the fluctuation of transit times linearly increases with the distance travelled. To show a practical example of Eq. (15), let us recall the classical paper of GRETENER [1961] who analysed the deviations between the integrated travel times computed from conventional and continuous velocity loggings in wells. The deviations found by him consisted of a systematic and a random part. The systematic deviations were ascribed, in a much-discussed paper of STRICK 1971, to velocity dispersion while the random scattering was found to increase with the square root of the distance travelled by the seismic wave (in accordance with Eq. (15), see *Fig. 2*).

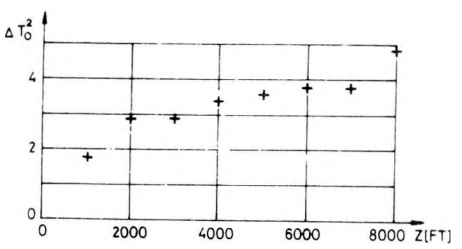

Fig. 2. Scattering of arrival times. [After GRETENER 1961]

2. ábra. A beérkezési idők szórása [GRETENER 1961 után]

Рис. 2. Отклонения времен вступления [По GRETENER 1961]

The companion formula to Eq. (15) refers to the logarithmic amplitude fluctuation of the propagating waves and states that

$$\left\langle \left(\Delta \log \frac{A}{A_0} \right)^2 \right\rangle = g \cdot L \tag{16}$$

where A_0 is wave-amplitude in the homogeneous medium and g is a function, which possibly also depends on frequency, correlation distance, etc.

The factor g is termed "inhomogeneity factor", or "turbidity factor" ([GALKIN and NIKOLAEV 1968, NIKOLAEV and TREGUB 1970]; the definitive monograph on the subject is [NIKOLAEV 1973]).

A great number of studies have been carried out in seismology to determine the inhomogeneity of the crust and upper mantle using time- or logarithmic amplitude fluctuation, or both [AKI 1973, CAPON 1974, BERTEUSSEN et al. 1975, etc]; most recently by POWELL and MELTZER [1984]; a similar study in reflection seismics was carried out by KORVIN [1977b]. For exploration geophysicists, the message of Eqs. (15), (16) is that the error of the seismic measurements linearly increases with the depth studied (as was observed by POSGAY as early as 1954) i.e. our ignorance about the Earth linearly increases with depth! This triumphant feeling of ignorabimus has recently been shattered by the fascinating model experiments reported by Gertrude NEUMANN and K. SCHIEL in 1977. NEUMANN and SCHIEL prepared more than 20 two-dimensional models (somewhat in the vein of LEVIN and ROBINSON [1969]) consisting of 2000 × 800 mm macrolon and 2000 × 1200 mm perspex plates with inhomogeneities quasi-randomly arranged in rows *(Fig. 3)*. They estimated the logarithmic amplitude fluctuation and computed the turbidity factor assuming the validity of Eq. (16) (where L should be substituted by the number of "rows" of inhomogeneities in the model). Their results are reproduced in *Fig. 4*, for one family of the macrolon models. The estimated g factor first increases with the number of rows N, then begins to decrease, i.e. instead of (16), they found a

$$\left\langle \left(\Delta \log \frac{A}{A_0} \right)^2 \right\rangle = g \cdot L^{\alpha} \tag{17}$$

law, for greater distances with an exponent α less than 1. This, of course, reminded NEUMANN and SCHIEL of Brownian motion or diffuse multiscattering (*op. cit.* p. 225).

Since these model experiments are extremely well-documented, it is worth while to call the reader's attention to this paper and to pose *Problem 5* as: Explain quantitatively the findings of NEUMANN and SCHIEL [1977] in terms of diffuse multiscattering! The problem becomes even more important since a very recent paper of POWELL and MELTZER [1984] has cast renewed doubts on the overall applicability of the CHERNOV- (i.e. NIKOLAEV-, i.e. RYTOV-) method.

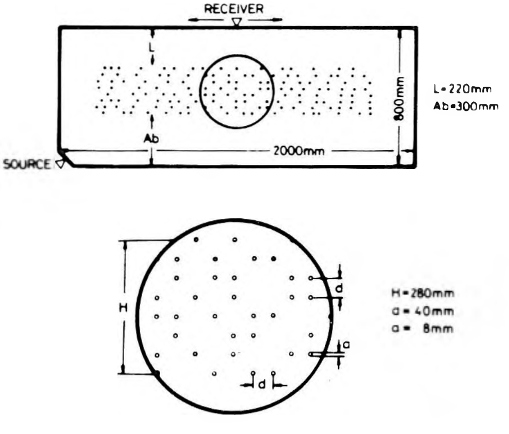

Fig. 3. Structure and model parameters used in the experiments of NEUMANN and SCHIEL [1977]

3. ábra. Felépítési- és modell-paraméterek NEUMANN és SCHIEL [1977] kísérleteiben

Рис. 3. Параметры строения и модели в экспериментах NEUMANN-а и SCHIEL-а [1977]

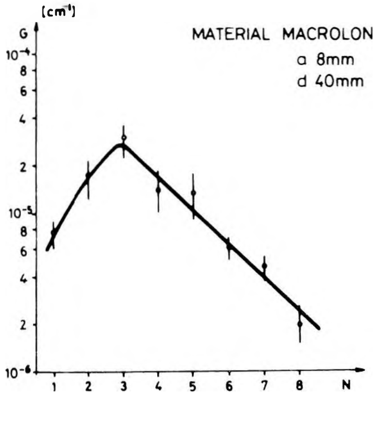

Fig. 4. Dependence of the turbidity factor *G* on the number of rows *N* in one of the NEUMANN–SCHIEL macrolon models. [After NEUMANN and SCHIEL 1977]

4. ábra. *G* turbiditás-faktor függése *N* sorszámtól, NEUMANN és SCHIEL egyik makrolon modelljében. [NEUMANN és SCHIEL 1977 után]

Рис. 4. Зависимость фактора мутности *G* от номера *N*, на макролонной модели NEUMANN-а и SCHIEL-а. (По NEUMANN и SCHIEL 1977)

4. Energy return from a dissipative half-space

There is an interesting theorem of ROBINSON and TREITEL [1965, 1966] which states that any series of parallel layers, characterized by an arbitrary sequence of reflection coefficients, which is bounded by a totally reflecting "wall" ($r = \pm 1$), completely reflects the incident energy in an infinite observation time. In [1977 a] KORVIN, in an attempt to generalize the Robinson–Treitel theorem, restated the problem in terms of a one-dimensional random walk of acoustic energy quanta, applied the invariant embedding technique of BELLMAN et al. [1958], and derived a partial integro-differential equation for the description of the total energy $U(t)$ reflected from a random infinite half-space in the time interval $(0, t)$. It was proved that for one-dimensional inhomogeneities, assuming a stationary sequence of random reflection coefficients and that the reflecting interfaces obey a Poisson distribution, the total incident energy is reflected from the inhomogeneous half-space during an infinitely long observation time. The asymptotic form of $U(t)$ is also given, in Eq. (79) of KORVIN [1977 a].

It turned out later that various formulations of this problem can be encountered in the most different branches of physics (in solid state physics, for example, the phenomenon is closely connected to the "localization theorems", see ZIMAN [1979, Chapter 8], or the recent summary of STEPHEN [1983].

The most ingenious proof of the total reflection by a semi-infinite random medium was given by SULEM and FRISCH [1972] [see also SULEM 1973] who used the Ricatti transformation to reduce the Helmholtz equation to a single-point boundary problem, observed that the complex impedance Z_N of a random stack of N layers constitutes a kind of "random walk" on the half-plane C^+ ($Im\, z > 0$) as the number N of layers is gradually increased, and used the ergodic theory of dynamic systems [ARNOLD and AVEZ 1967, HALMOS 1956] to prove total reflection.

Of course, ergodic theory gives no indication as to the rate of development of a system towards its equilibrium. The Monte Carlo computer simulations in SULEM and FRISCH [1972], however, suggest that the mean reflection coefficient exponentially converges to one, rather similarly to the asymptotic Eq. (79) in KORVIN 1977a.

In SULEM and FRISCH [*op. cit.*, p. 225] there is posed the important problem connected with the more realistic case of a slightly dissipative medium which, obviously, cannot be totally reflecting. Computer simulations (*Fig. 5*) indicate that the Césaro means of the reflection coefficients

$$\frac{1}{N} \sum_{n=0}^{N-1} |r_N|$$

still converge, but more slowly than for a non-dissipative half-space, and to a finite limit less than one. Unfortunately, the ergodic theory, used by SULEM and FRISCH for the nondissipative case, does not apply if we assign complex values to the refractive index since the measure corresponding to the random walk of the complex impedance Z_N will not be invariant any more.

At the same time, in the dissipative case, the integro-differential equation in KORVIN [1977] will also yield divergent solutions. Thus, it seems justifiable to invite the reader to solve *Problem 6*, i.e. to generalize the theorem of ROBINSON and TREITEL and compute the energy returned from a, finite or infinite, stack of random dissipative layers!

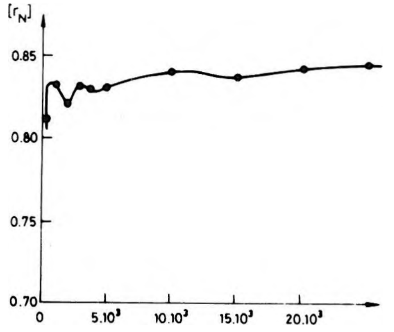

Fig. 5. Césaro mean of the reflection coefficient in a randomly alternating stack of two slightly dissipative layers with the refractive indices $n_1 = 2 + 5i \cdot 10^{-3}$ and $n_2 = 5 + 5i \cdot 10^{-3}$, respectively, and with a mean layer thickness of unity. [After SULEM and FRISCH 1972]

5. ábra. Két, enyhén disszipatív réteg véletlenszerűen váltakozó sorának reflexiós koefficienseiből képezett Césaro átlag. A törésmutatók: $n_1 = 2 + 5i \cdot 10^{-3}$, ill. $n_2 = 5 + 5i \cdot 10^{-3}$, az átlagos rétegvastagságok egységnyiek. [SULEM és FRISCH 1972 után]

Рис. 5. Среднее Césaro полученное из коэффициентов отражений случайно изменяющегося множества двух слабодиссипативных слоев. Коэффициенты преломления: $n_1 = 2 + 5i \cdot 10^{-3}$; $n_2 = 5 + 5i \cdot 10^{-3}$, средняя мощность слоев составляет единицу. [По SULEM и FRISCH 1972]

5. Langleben's phenomenon and the diffuse reflection shadow

It has long been a basic problem of Hungarian reflection seismics that in many cases we can get only intricate diffuse reflections from the uneven surface of the basement [SZÉNÁS and ÁDÁM 1953]. Due to these diffuse reflections it is rather difficult at some places to map the basin floor accurately: diffraction arrivals coming from the surface unevennesses follow the basement reflection as a "diffuse shadow" of a few hundred ms length so that it tends to be very difficult to detect eventual deeper reflections. In marine seismic profiling, similar difficulties were reported by CLAY and RONA [1964]. The existence of the diffuse reflection shadow following rough boundaries has also been demonstrated by model experiments [VOSKRESENSKY 1962, LEONG et al. 1971]. For a special non-differentiable random surface model the time-behaviour of the diffuse reflection shadow was theoretically investigated in the low-frequency limit by Biot [1957]; for Gaussian differentiable random surfaces, and in the high-frequency limit, by Korvin [1982b]. Recent interest in the topic is indicated by Tsai [1984] who proposes special CDP stack and velocity filtering techniques to reduce coherent scattered noise.

In 1970 Langleben reported a very strange series of experiments, carried out under the ice cover in Tanquary Fiord, Ellesmere Island, NW Territories, Canada. He measured the specular reflection of water-borne sound at the water–sea-ice interface as a function of the angle of incidence and of frequency. The geometrical configuration of his measurement is reproduced in *Fig. 6* (the frequency varied from 20 kHz to 450 kHz). His results *(Table I)* do not show any systematic change of the specular reflection coefficient with frequency. The "striking insensitivity of back-scattering to frequency", in cases when the scales of irregularities range from many times smaller to many times greater than the radiation wavelength, had also been observed by Marsh [1961, p. 332]. Note that the dendritic growth of ice very likely also results in such an ill-defined phase-boundary of fractal geometry [cf. Brady and Ball 1984], containing irregularities at all scales. (The possible fractal nature of the underside of sea ice was first observed by Rothrock and Thorndike [1980]; see also their more recent paper [1984].)

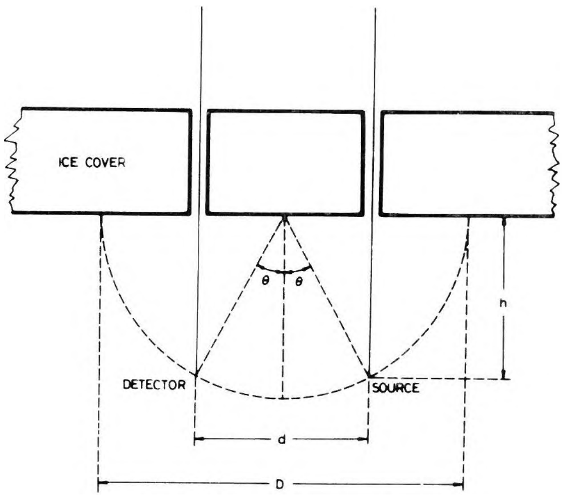

Fig. 6. Geometrical configuration of Langleben's experiment. Source and detector move along the semicircle indicated. [After Langleben 1970].

6. ábra. Langleben kísérletének geometriai elrendezése. Adó és vevő egy félkörön mozog. [Langleben 1970 után]

Рис. 6. Геометрия эксперимента Langleben-а. Датчик и приемник движутся на одном полукруге. [По Langleben 1970]

Table I. Amplitude of reflection coefficients at the water–sea-ice interface [after LANGLEBEN 1970]

Frequency	Angle of incidence [degree]				
kHz	15	30	45	60	75
17.9	0.24	0.20	0.48	0.36	0.88
23.1	0.091	0.034	0.18	0.41	0.51
24.8	0.13	0.070	0.29	0.63	0.38
47.0	0.056	0.17	0.89	0.89	1.22
56.5	0.083	0.25	0.42	0.75	0.75
89.9	0.039	0.053	0.41	0.63	0.96
118	0.13	0.16	0.72	0.88	1.06
126	0.055	0.036	0.32	0.69	0.81
184	0.056	0.11	0.56	0.75	0.97
227	0.021	0.005	0.43	0.44	0.91
332	0.17	0.22	0.019	0.50	0.45
387	0.083	0.091	0.36	0.16	1.00
435	0.066	0.088	0.016	0.11	0.94

The surprising feature of LANGLEBEN's data is that, when averaged over frequency, the mean reflection coefficients become a reasonably smooth function of the angle of incidence *(Fig. 7)*. Since, using the jargon of data processing, averaging over frequencies is equivalent to a deconvolution operation in the time domain, LANGLEBEN's results suggest the hypothesis *(Problem 7)*, that a suitable generalization of the single- or multichannel deconvolution procedure could be profitable in the elimination of the diffuse reflection shadow.

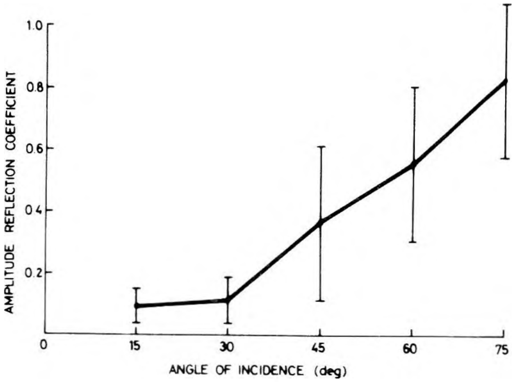

Fig. 7. Amplitude reflection coefficient of water-borne sound waves reflected at the underside of the sea ice cover, as a function of angle of incidence. [After LANGLEBEN 1970]

7. ábra. A tengert boritó jég alsó határfelületéről visszavert hanghullámok reflexiós koefficiense a beesési szög függvényében. [LANGLEBEN 1970 után]

Рис. 7. Коэффициент отражения звуковых волн, отражающихся от нижней поверхности границы льда, покрывающего море, в зависимости от угла падения. [По LANGLEBEN 1970]

In the single-channel solution it should be recalled that the diffuse "reverberated" signal is very likely not minimum-phase [see KORVIN 1982b], i.e. the deconvolution filter must be specially designed (as, for example, in RISTOW and JURCZYK [1975]). The design of the multi-channel filter for the removal of the diffuse reflection shadow could very likely be made along the general lines described in BACKUS et al. [1964]. For the estimation of the horizontal and temporal correlations of the diffuse noise, that is necessary for the design of the optimum multichannel filter, use should be made of the results in LEVIN and ROBINSON [1969], DUNKIN [1969], KORVIN [1978a]. It goes without saying that a physical explanation of LANGLEBEN's phenomenon (i.e. why is the frequency-averaged backscattering coefficient equal to the backscattering coefficient of an effective smooth surface, at least for a certain kind of random surfaces?) is still badly needed and it is posed here as *Problem 8*.

* * *

The main ordering principle behind this set of problems has been my continuous interest in the last 15 years in applying random wave propagation concepts and statistical ideas to the physics of sedimentary rocks. I do hope my readers will find some of these problems sufficiently interesting so as to solve them – as I called for in the original title of this lecture: *"A few problems I'd like to see solved"*.

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AZ ALKALMAZOTT GEOFIZIKA NÉHÁNY MEGOLDATLAN PROBLÉMÁJA

KORVIN Gábor

A cikkben nyolc megoldatlan problémát tárgyal a szerző, amelyek a statisztikus geofizikából, vagy a kőzetfizikából származnak. A problémák a következők: folyadékkal telített üledékes kőzetek effektív fizikai paramétereinek számítása *(1. és 2. probléma)*; hanghullámok abszorpciós koefficiensének függősége a heterogén kőzetek véletlenszerűségétől *(3. és 4. probléma)*; véletlenszerű közegen áthaladó jel jellemzőinek ingadozása *(5. probléma)*; véletlenszerűen disszipatív féltérről visszaverődő energia számítása *(6. probléma)*; és a véletlenszerűen egyenetlen határfelületekről visszaszórt szeizmikus jelek statisztikai tulajdonságai *(7. és 8. probléma)*. Minden esetben közli a leglényegesebb irodalmi hivatkozásokat és rámutat az alkalmazási területre.

НЕКОТОРЫЕ НЕРЕШЕННЫЕ ПРОБЛЕМЫ ПРИКЛАДНОЙ ГЕОФИЗИКИ

Габор КОРВИН

В статье автор обсуждает восемь нерешенных проблем, которые вытекают из статистической геофизики или из физики пород. Это следующие проблемы: вычисление эффективных физических параметров осадочных пород насыщенных жидкостью *(проблемы 1 и 2)*; зависимость коэффициента абсорбции звуковых волн от случайности гетерогенных пород *(проблемы 3 и 4)*; изменение параметров сигнала, проходящего через случайную среду *(проблема 5)*; вычисление отраженной энергии от случайно диссипативного полупространства *(проблема 6)*; статистические свойства отраженных сейсмических сигналов от случайно негладких поверхностей раздела *(проблемы 7 и 8)*. Автор в всех случаях дает самые важные ссылки на литературу и указывает области применения.