Analytical Review of the Book “Subsurface Image and Estimation of Medium Parameters in Seismic Exploration”

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A review of the book’s structure, its prefaces, Introduction, key chapters, Conclusion, and appendices leads to a fairly definite conclusion: this is not a conventional textbook on seismic exploration, nor is it simply an expanded second edition of a previously published work. In essence, the book is an authorial scientific monograph in which standard theory serves as the basis for presenting an integrated system of views, methods, and the author’s own results.

The main distinguishing feature of the book

The strongest feature of the book is its single conceptual line:

image → focusing → wavefield kinematics → wavefield dynamics → medium parameters → interpretation → algorithms and software.

It is precisely this sequence that distinguishes the book from many textbooks and monographs in which migration, velocity analysis, tomography, interpretation, attenuation, and other areas are treated primarily as separate technologies.

The fundamental physical concept in the book is the image. The Common Depth Point (CDP) method is interpreted from the standpoint of geometrical imaging theory and by analogy with optics: digital stacking is regarded as an analogue of focusing performed by an optical system. This idea is then developed consistently in the treatment of traveltime-field derivatives, the NIP theorem, multifocusing, migration, and subsequently inverse kinematic and dynamic problems.

Thus, the book develops a genuinely recognizable and internally coherent scientific conception.

The second major distinction — the traveltime field and its derivatives

Chapter 2 occupies a considerably more fundamental place in the overall conception of the book than is usual in educational literature. Through derivatives of the traveltime field, the geometry of the wavefront, image parameters, stacking velocity, the NIP theorem, and the subsequent solution of inverse problems are linked together.

It is important that the significance of this direction is also noted in comments on the book. M. I. Protasov writes in the appendix that very little attention is paid to traveltime-field derivatives in major textbooks and monographs and that this part of the book is especially important. His only substantial suggestion is to provide still more practical material related to the first and second derivatives of the traveltime field.

This part of the book can be regarded as one of its principal competitive advantages when it is presented to a Western publisher.

The third feature — the author's alternatives to established methods

The book does not restrict itself to presenting CRS, MF, migration, and other established approaches. It consistently asks the question: what limits a given method, and can another approach be constructed that is free from those limitations?

- Kinematic Filtering and Spherical Mirror;
- solution of the Lynn equation;
- extraction of diffracted waves;
- seismic-stratigraphic stacking;
- kinematic seismograms;
- demigration;
- the inverse dynamic problem for a viscoelastic medium;
- RGB / "color spot";
- automated delineation of traps.

The SSS method is of particular interest. In MF and CRS, the stacking-time function is locally single-extremum, whereas in SSS local slopes are first determined and then used to construct the complete traveltime function, which may also be multi-extremal. This is no longer merely a new implementation of a familiar method, but a different representation of wavefield kinematics.

The fourth feature — Chapter 11

From the scientific point of view, Chapter 11 is probably the most unusual part of the second edition.

Instead of the traditional FWI scheme — selecting a model, repeatedly solving the forward problem, and then minimizing the misfit — an inverse coefficient problem is posed directly for the wave equation. A local, non-iterative, two-stage recovery of the parameters is proposed: first the elastic parameter is determined, and then the relaxation time.

In addition, a highly unconventional result is considered: in the high-frequency asymptotic approximation, apparent frequency and temporal attenuation cancel from the final formulas, whereas the medium parameters are determined through slowness and the spatial variation of amplitude.

In the model experiments, the stated accuracy is 99.99% for v_p^2 and 99.96% for α_R within the range of parameters considered.

When the book is presented to a publisher, this chapter should be regarded as one of the central scientific innovations of the work as a whole, rather than simply as another chapter in a general course.

The fifth feature — the theory is directly connected with software implementation

This is one of the book's notable strengths. Almost all of the principal ideas are developed to the level of algorithms and implemented in the CubeTechnology system.

Appendix B is not a formal mention of software; it provides a fairly extensive description of an actually implemented research system. It includes the database, visualization, spectral analysis, Prony analysis, multifocusing, SSS, RGB, velocity analysis, migration/demigration, tomography, dynamic analysis, modeling, trap calculation, and a programming manual.

All of the graphics in the book were also created using this system.

The book therefore occupies a rather unusual intermediate position between a scientific monograph, a textbook, and documentation of an actually implemented research system.

Another important distinguishing feature

The book preserves the history of the Soviet and Russian school of seismics not as a formal tribute to the past, but as an organic part of the development of the ideas under consideration.

Puzyrev, Goldin, Alekseev, Klem-Musatov, Chernyak, and other researchers are mentioned specifically in connection with particular scientific directions. In the Preface, the author's scientific biography is directly linked to this school. One of the reviews likewise characterizes the book as a continuation of the traditions of the Novosibirsk school of seismics founded by Puzyrev, Goldin, and Alekseev.

For an English-language edition, this should be regarded not as a weakness but, on the contrary, as an advantage: Western readers are indeed comparatively unfamiliar with this substantial body of scientific literature.

What appears most successful

Chapter 1 is especially successful. One of the reviewers specifically notes the clarity of its presentation. The optical analogy makes it possible to explain CDP not as a sequence of NMO–velocity analysis–stack operations, but as a physical procedure of image formation.

The overall logic of presentation is also successful:

physical meaning → mathematics → algorithm → real or synthetic examples.

This strength was specifically noted by Walt Lynn: textbooks often restrict themselves to theory, whereas in this book theory is directly combined with practical data.

Another strength is that the author does not attempt to create an impression that all the problems considered have been solved definitively. For example, in determining effective thickness it is explicitly stated that the result depends on bandwidth, wavelet stability, processing quality, interference, and well calibration and therefore should be regarded as a statistically calibrated estimate rather than as a direct measurement of thickness.

Such an approach is consistent with a sound scientific style of presentation.

Comments and issues requiring clarification

1. Wording in Chapter 11

On page 155, after Eq. (2.2.11), the text effectively states:

because the equation does not contain α_R, the wavefield $u(x,t)$ satisfying this equation does not depend on α_R.

This is followed by the required conclusion:

$$\frac{\partial M(x,\alpha_R)}{\partial \alpha_R} = 0$$

The first statement appears too strong. The observed viscoelastic wavefield itself can, of course, depend on αR.

A more precise statement follows from Eq. (2.2.11): for a fixed observed wavefield $u(x,t)$, the equation used to recover M contains no α_R; therefore the recovered value of M does not depend on the selected value of α_R.

This is a fundamental distinction.

At the same time, the footnote immediately below already states quite correctly that such an operation "does not change the physical nature of the recorded viscoelastic field".

Thus, the issue concerns not a change in the mathematical conclusion, but a more precise formulation of its physical meaning.

2. The statement concerning frequency, attenuation, and Q should specify its conditions more precisely

In the present text, the wording can at times be perceived almost as a general physical conclusion:

"direct determination of relaxation time from the frequency, attenuation, or quality factor ... is not sufficiently justified."

Within the derivation considered, however, the meaning is more specific: in the present model, under the adopted asymptotic approximation, and within the frequency range considered, the corresponding quantities cancel algebraically.

It is therefore advisable to emphasize throughout the condition:

"within the present inverse formulation and under the adopted seismic-frequency approximation..."

This clarification avoids an unnecessary opposition to the numerous studies in which Q is estimated from attenuation.

The result would then not contradict that literature, but would formulate a more specific statement: Q, Ω, and γ are not independent carriers of information about τ_R specifically in the inverse coefficient solution obtained here.

In this form, the result becomes logically more rigorous and less vulnerable to possible objections.

3. Validation of the results in Chapter 11 is still predominantly model-based

The book itself presents this circumstance quite carefully: synthetic VSP wavefields are used, interfaces are recovered, including a thin 10-m layer, and the accuracy of the solution is investigated.

It is also correctly noted that the physical relationship of τ_R to porosity, permeability, fluid properties, and other petrophysical characteristics requires dedicated studies.

This qualification should be retained and emphasized. For a serious scientific publisher it is more likely to strengthen the work, because it precisely defines the level of the result achieved:

"mathematical and numerical feasibility is established; petrophysical interpretation and field validation remain subjects for further study."

In other words, the mathematical and numerical feasibility of the method has been demonstrated, whereas its petrophysical interpretation and full-scale validation on field data remain subjects for further research.

4. The statement that CDP is a particular case of migration requires precise wording

The book shows that, in the Kirchhoff scheme considered, the CDP image is obtained as the aperture size tends to zero.

This is an interesting unifying idea.

However, the statement

"The CDP method is a particular case of migration"

may be perceived by some Western geophysicists as terminologically controversial.

A more precise formulation is:

“Within the unified focusing formulation used in this book, the CDP imaging operator appears as a limiting case of Kirchhoff migration when the migration aperture tends to zero.”

With this formulation, the statement is no longer a historical or terminological reclassification of the CDP method, but a rigorously formulated mathematical result within the unified focusing framework adopted in the book.

5. The statement concerning a specular boundary and a single source requires a similar clarification

Chapter 1 states that for a perfectly specular surface only one ray emerges from each point of the surface; therefore, with a single source it is impossible to form an image of the surface itself, whereas multifold coverage artificially creates the required family of rays.

This is an interesting and unusual interpretation, but for precisely that reason it requires especially careful explanation.

A migration specialist may object:

“But single-shot migration does produce an image of a reflector.”

The answer to this objection is effectively contained in the definition adopted in the book: a strict concept of an image point formed by a focused bundle of rays is used, rather than the broader conventional use of the term imaging in seismic exploration.

It is advisable to state this distinction explicitly in the text. A potential terminological objection would then become an additional argument in favor of the originality of the proposed conception.

6. The RGB chapter is of interest, but the wording concerning the “physical nature of color” requires caution

The book notes that conventional coloring of a seismic image by amplitude is not related to the wave nature of color, whereas physically color is determined by frequency; the intensities of the RGB components are then specified by the amplitudes of the corresponding frequency bands.

The proposed method itself is clear and of interest.

However, two aspects should be clearly distinguished:

- the physical analogy with optical frequency;
- the RGB-attribute representation of spectral components, in which amplitude determines the intensity of the corresponding color channel.

Without such a distinction, the discussion may shift toward the physiology of color perception, spectral sensitivity functions of the eye, display RGB, and other issues that are not directly related to the proposed seismic method.

The expression direct hydrocarbon detection should also be used with caution. It is preferable to emphasize that the “color spot” is a seismic indicator / attribute associated with probable hydrocarbon accumulations, rather than unique physical proof of the presence of hydrocarbons.

Overall assessment

The distinguishing character of the book can be formulated as follows:

This is not an encyclopedic survey of modern seismic exploration. It is an authorial mathematical and physical conception of seismic imaging and medium-parameter estimation, rooted in the Novosibirsk school of seismics and developed by the author from theoretical formulas to algorithms, software implementation, and processing of real data.

It is in precisely this capacity that the book should be presented to a potential publisher.

There is no need to compete with publications of the “everything about modern seismic processing” type: that is not where its principal strength lies. The strength of the book is elsewhere — in its unusual conceptual unity, the author’s original results, the presentation of a Russian scientific tradition that is comparatively little known to Western readers, and the rare combination of mathematical theory with actually implemented software technology.