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# Book review

**Seismic Reflection Processing**
**With Special Reference to Anisotropy**
Upadhyay S.K., *Springer,* 2004, ISBN 3-540-40875-4, Hardcover, 636 pp, £69.


## SUMMARY

This book may be useful to late stage geophysics undergraduates or graduate students, or to seismic processors who would like to understand theory behind isotropic or anisotropic processing. It is a book published in 2004 that is full of the pleasant air, turn-of-phrase and conceptual images of a text written in by-gone times. It covers topics at a manageable pace, is easy to read while traversing fairly advanced processing concepts, and the final 200 pages convey information almost flawlessly. Yet, in the first 200 pages the reader constantly stumbles across editorial over-sights concerning language, formatting and consistency of notation. The author introduces most of the classic papers in each area of seismic processing in their proper historical context, but does little to consolidate the different proposed forms of anisotropic theory into a single theoretical framework. Consequently, this review is mixed, conveying many positive aspects but also a few that are particularly detrimental. The latter render the book difficult to recommend in its current form. My conclusion is that while it fills a useful niche, it badly requires a second edition in which the many errors have been corrected.


## INTRODUCTION

I decided very early in my reading that a review of this volume should attempt to separate the editorial and technical contributions. In what follows I begin with two sections describing these editorial aspects that include both some of the advantages and key failings of this edition. In a third section I review the technical content of the book before concluding.

## SCOPE AND STYLE

### Scope

The author has chosen to follow neither of two obvious and more specialist philosophies followed by other, previous books: this is not an 'isotropic' text that makes reference to the hidden, mainly unaddressed complexities to be considered in anisotropic media. It is also not a book that plunges headlong into the complex mathematics that wave propagation in anisotropic media can involve.

Instead, the author devotes the first 150 pages to the introduction of general processing techniques and justification of the need for anisotropic processing. Thereafter he follows the tenet that the Earth can affect seismic waves in either an isotropic or anisotropic manner so each processing step is developed for both types of media in equal measure. The book thus has the potential to fill a useful niche that is otherwise unaddressed. It might appeal to any late stage undergraduate or postgraduate geophysics students, or to data processors, apart from the best informed in anisotropy for whom there will be little new in this text. However, the book contains few set problems or worked examples, and hence is probably best used as a reference text rather than as a principal student course text.

The array of subjects spanned is broad. The book covers isotropic, horizontally and vertically transversely isotropic (TI), and more generally anisotropic media in most chapters. The chapters themselves cover the following areas: data acquisition; seismogram modelling; routine processing; anisotropic models of sedimentary sections; ray theory, wavefront curvature and normal move-out (NMO) velocity; arrival time analysis and velocity for anisotropic media (with a chapter devoted to TI media); estimation of anisotropic layer parameters; dip move-out (DMO) processing and true amplitude imaging; anisotropic reflection theory; amplitude versus offset (AVO) interpretation; migration; wave-equation based imaging; the value of fracture-induced anisotropy to exploration objectives; future vision. Each chapter progresses from fairly simple concepts to the more complex at a manageable pace and so, the scope of each chapter is generally also appropriate.

My only caveat is that this is not a book that demonstrates how to process seismic data, but one that presents the theory behind seismic processing. There are, in fact, relatively few examples that illustrate typical data sets being processed according to the theory developed in the text. Consequently I suspect that some processors will feel there is too little attention devoted to subsidiary yet important issues that arise during real seismic data analysis and which require corrections, filtering, or at least understanding. Nevertheless, this book is supposed to provide a theoretical foundation to the more advanced processing methods in use today and with respect to that goal the scope is appropriate. If you need a manual to help you to process data, buy a different book.

### General presentation

The style of the cover matter is very appealing in a now common format employed by many publishing houses for technical books: simple design for the front cover and a back cover presenting concise information about the author and the contents. A hint of the traditional red and blue stripes of a seismic section pervades the background, bringing cohesion to the small, front image of a seismic section delineating a 'perfect' salt intrusion.

Inside, this book has the look and feel of an older text, not a book published in 2005. I am undecided as to whether this is positive as it probably depends on the penchant of individual readers. The majority of diagrams are conceptual in that they are not generated based on quantitative synthetic or real data, and many are hand-drawn (including the annotations). To me this appeals as the author has a clear focus on presenting isolated, fundamental concepts. This style is reminiscent of texts written before computing power was sufficiently widespread for authors to generate their own examples. However, it may raise the ire of more applied readers who will yearn for real data by the end of the first few chapters.

The only unambiguous criticisms that I have of the general presentational style are first, that in the font chosen for the equations in the main text '$\alpha$' looks almost identical to the round form of 'a' used in the diagram annotations. The difference between the two requires a magnifying glass to discern, and this causes confusion in several equations until the reader becomes accustomed to detecting such instances. Secondly, the production of some diagrams is poor, particularly in reproduced figures from published papers. Consequently, portions of a number of figures are either difficult or impossible to read or interpret.

### Writing style and language

The author has achieved a remarkable, easy-reading style of writing which holds the reader where they would normally tire, drawing them in like a novel. This is rare in a book on this topic! In part this is achieved by the use of well-judged simplicity and eloquence of language which, although old-fashioned in places, develops modern theory as a story, and with a lilt that periodically reminds the reader of older, classic texts.

There is one issue of style that is problematic and which pervades almost every chapter of the book. The author tends to use terms or concepts before they have been properly defined, and states results of classic research papers before they have been proven. This would be acceptable if it was stated that the definition or exposition would follow, but in most instances this is not done. Consequently readers are left to wonder whether they will be further enlightened, and I found myself flicking backwards and forwards to verify whether current text had elucidated the meaning of preceding ideas.

The final issue of note in terms of style is that in my opinion there are too few worked examples, and only a handful of set problems posed throughout the book. As a result it will be difficult for a novice in the field to test their knowledge, and I suspect this aspect may decrease the attractiveness of the book to late-stage undergraduates or Masters-level students.

## EDITORIAL REVIEW

This deserves special focus as its failing is the principle reason that I cannot recommend this book to potential readers. By 'Editorial Review' I mean the two review processes for which all editors are ultimately responsible: ensuring the book is thoroughly reviewed by competent scientists, and ensuring that it has been properly copy-edited.

My first feelings of foreboding developed on reading the back cover. This includes two paragraphs, the first about the author, the second concerning content. The first reads well: a succinct summary of the professional life of an eminent academic. The second consists of 15 short lines, and contains four English-language mistakes. Opening the book at the Preface, one discovers similarly poor editing: the English vocabulary is in places contorted, and the formatting has a glaring error in the middle of the first page (a new paragraph is not indented and is followed by a blank line).

I do understand how such instances of cover- and front-matter can slip through the system un-detected, but in this case there are three aspects of note. First, the editorial errors persist throughout the first third of the volume, decreasing in frequency as one proceeds beyond about chapter 5 (page 207). Typical examples are formatting errors, language errors (usually grammatical), other unambiguous errors in the text (including use of jargon well before it has been defined), and inconsistencies or errors in mathematical notation. I counted 300 such errors in chapters 1 to 5 alone.

Secondly, the errors often occur in dense 'patches' with up to 10 mistakes on a single page. I wonder whether different editors reviewed different parts of the book, or whether the final draft of some parts passed an editor or reviewer at all.

Thirdly, this introductory reading (a fairly normal progression through front cover, rear cover then Preface) heightens the readers awareness of such errors throughout the book, making it difficult to 'read through' them undistracted.

The only other issue of note in this section is that the back index also needs a thorough revision. The first uses of a least half of the terms or concepts that I checked occurred well before the first indexed page number, and the principal definition of some terms was on occasion not highlighted in the Index.

## TECHNICAL CONTENT

The content of this book naturally divides into two distinct parts, but this 'natural' organization differs from that proposed by the author in chapter 1. According to the author, chapter 1 is a general motivation for processing seismic reflections (really a few examples of how seismics can be useful), while chapters 2 through 6 are an overview of the entire data acquisition, processing and interpretation process, including an introduction to the physical link between recorded wavefront characteristics and subsurface properties.

However, as a reader I find an abrupt and complete distinction between chapters 1–4 and chapters 5 onwards. Chapters 1 to 3 provide both motivation and overview of seismic acquisition and processing with simple examples and a light writing style. These chapters include a liberal scattering of concise, interesting, conceptual examples illustrating apparent oddities of wave phenomena when comparing propagation through isotropic and anisotropic media. Unfortunately these chapters also have a few sections that are poorly explained. I felt that this occurred mainly because some concepts which could have been defined precisely mathematically were described with careful avoidance of equations. While great care has been taken in this regard, there is still ambiguity in the text, and I wonder whether a little more carefully introduced mathematics might not be acceptable, and more illuminating. Nevertheless, for someone inexperienced in seismic processing I suspect that these first few chapters will provide a welcome overview of the field.

Chapter 4 summarizes various 'attributes' of seismic data. These are features, interpreted from the arriving waves, which are thought to be indicators of specific subsurface characteristics. Examples include travel time, amplitude, inferred reflectivity, etc. Chapter 4 also presents some examples of pitfalls that can occur in the use of such attributes, mainly problems caused by anisotropy of typical layered, Earth-like media.

This chapter first highlighted one problem that pervades the book: references to other books or papers are made for most equations, and the text seldom explains whether we should be able to deduce an equation from previous results in this book or whether we are required to read the referenced texts to understand its derivation. In many of these cases, results were left unproven even though the text read as though they were logical deductions. This caused considerable frustration.

However, ignoring the typographical errors and deficiencies in some of the descriptions, I found these first four chapters to provide excellent motivation for including anisotropy as a staple component of the rest of the book, in preparation for the change in style that occurs at the beginning of the next chapter.

Chapter 5 onwards seems like a different book. It is both readable and far more theoretically rigorous than previous chapters, and from chapter 6 the copy-editing errors begin to reduce to levels at which they do not distract from the content. In chapter 5 the author returns to fundamentals with a proper description of elastic behaviour in a generally anisotropic medium, working upwards in scale from crystal lattices, through the representation of a solid medium, to a (Backus) averaged layered medium. Simplifications that occur mathematically when describing less general (isotropic, TI, orthorhombic) media are illustrated, including Thomsen parameters for HTI, VTI and Orthohombic media, and weak anisotropy approximations. The elastic wave (Christoffel) equation is defined in isotropic and anisotropic solids, dispersion relations are deduced providing an introduction to group and phase velocity relationships with frequency. The chapter ends with a short section on polarization and the use of propagator matrices.

Consequently, by page 200 one is rewarded with a foundation in basic wave theory. This would have been worthwhile if I had started reading at the beginning of chapter 5 (page 144), but I was left feeling somewhat frustrated that it had taken so long to get to this point in the book. Consequently, this tremendous distinction prior to and post page 144 should be made far more clear in the Introduction and Contents list. While many students may benefit from (a revised version of) Chapters 1 to 4, someone who already knows that they want to learn rigorous theory underlying seismic processing in more than isotropic media should be forwarded directly to page 144.

Thereafter the book progresses at a well-judged pace, presents roughly the same degree of rigour as in chapter 5, and progressively introduces more detail to the general framework outlined in chapters 1–4. Chapter 6 begins with descriptions of rays, the various forms of Snell's law in anisotropic media, and includes a concise algorithm for ray tracing in elliptically anisotropic, layered media. A description of normal move-out (NMO) follows, and from this point onwards almost all processing steps are described for both isotropic and anisotropic media. In this instance there is a nice progression from NMO in an isotropic medium, through a single transversely isotropic (TI) layer over a half-space, to a recursive formula for NMO in multiple TI layers. In other instances the progression extends to azimuthally anisotropic and orthorhombic media.

Chapter 7 covers reflection time and velocity analysis, beginning from Fermat's principle of least time, and progressing through Dix equations for interval velocity, stacking velocity and semblance measures in isotropic media, while chapter 8 extends this to TI media. It is in chapter 8 that it becomes clear that this book is a nice compilation of fundamental results of past anisotropic literature, but does little to integrate these into a common framework. Equations that appear are often presented as derived in the cited papers, even though they are similar to those in previous chapters. This is a shame as there are several instances where a little extra input would allow a more continuous progression creating a more unified (and simplified) theory. Instead, I have the uneasy feeling that I can only understand the results presented if I also read the cited papers. If true, what is the point of the book?

Chapter 9 analyses the interpretation of $t^2$–$x^2$ plots were $t$ is arrival time and $x$ is offset. This is simply a different domain to study move-out relationships, but is probably justified as being separate from chapters 7 and 8 since it focuses on interpretation methods. Chapter 10 introduces more sophisticated methods for interpretation: semblance analysis, layer-stripping, simple inversion methods and interval velocity analysis for azimuthally anisotropic layers. A nice finale to this chapter illustrates the magnitude of errors committed when isotropic interpretation methods are applied to data from anisotropic media – a well-placed reminder that efforts to understand anisotropic theory are worthwhile.

Chapter 11 begins with an introduction to dip move-out (DMO) theory (i.e., NMO corrections for dipping layers) with extensive coverage of the DMO impulse response in various types of media. This is used to explain so-called 'true-amplitude' migration (i.e., that preserves a proportionality between the migrated image peak amplitudes and corresponding reflection coefficients). This excellent chapter both weaves key historical references into their proper context and provides a clear introduction to a potentially difficult area.

Chapter 12 introduces basic reflection theory in anisotropic media, including non-linear and linearized theory, while Chapter 13 examines reflection amplitudes in more detail, and their interpretation using amplitude-versus-offset (AVO) techniques. Neither chapter 12 nor the first half of chapter 13 was enlightening in themselves – they are really guides to key literature, and should really be consolidated into a self-contained text. A good example of this is that within three pages results of Wright (1986) appear to contradict those from Shuey (1985), but no reference to this contradiction is made, and no explanation given – they are simply reported individually. Another issue that arises in this regard is that results (including figures) from various cited papers are presented directly. Thus, results from consecutive theoretical developments are presented using different models (media with different elastic parameters), rendering the reader unable to compare results directly. Again, more consolidation and demonstration of the results on a single model (or a limited set of standard models) would help the reader greatly.

The second half of chapter 13 does, however, present a very nice progression through Zoeppritz equations, simplifications for reflection amplitudes in various media, and the inclusion of factors like geometrical spreading, source radiation, vector attenuation, dispersive anelasticity, all in isotropic and anisotropic media. The chapter then ends with an oddity: an appendix that includes a computer code for numerical solutions of $P$–$P$ reflection coefficients at interfaces between HTI media. While this may be useful to some readers, it seems bizarre to include a code for this specific purpose but not for any other algorithm presented in the book!

Chapter 14 covers seismic migration. For some reason, for the first few sections of this chapter the author reverts to geometrical description with as little mathematics as possible, similar in style to Chapters 1 to 3. This is useful in order to present the concepts, but my impression is that the mathematics would have made this chapter easier to follow. In fact, the mathematics is left to one of the few exercises (14.1) in the book, but no hint of this is given in the main text. Again, this chapter offers a nice progression through point diffractors, geometrical migration techniques in different domains, finite-difference migration, the use of one-way wave equations for exploding reflector models and wavefield continuation, and finally slant stack migration. These are nice sections with concepts clearly explained, but again the detail is left to other cited papers so the reader can only easily understand the concepts, not the detail.

Chapter 15 covers imaging using integral solutions to the wave equation, working from Green's theorem and Kirchoff's integral to provide solutions to the wave equation. This is an excellent chapter that describes imaging in stacked and unstacked domains, converted and unconverted waves, and derives solutions to the wave equation and reflection/conversion coefficients for full elastic tensors. The derivations contain satisfying detail, the text is concise and clear, and I would thoroughly recommend this to students as an introductory chapter on the subject.

Chapter 16, is potentially an excellent chapter, but is another bizarre surprise. The title is, 'Miscellaneous Interpretation Tools', providing no clue as to its contents. On reading it turns out to be one of the most useful chapters of all for inexperienced readers, and should certainly have been cited frequently throughout the rest of the book. It contains all of the details of basic methods that have been mentioned or used to derive results throughout previous chapters: convolution and deconvolution, correlation, digital filtering, Z-transforms, Fourier analysis, and wavelet phase. It then describes more sophisticated methods and results: tomography, petrophysical 'laws' and empirical relationships between elastic and petrophysical parameters, and lithology predictors. A final section describes methods tailored to particular objectives: detecting coal-seams, over-pressured zones, and anisotropic shales. Buried within this final section is even an algorithm for the reflectivity method of generating synthetic seismograms.

This chapter is a mish-mash of techniques and results that need to be organized more logically (part of this chapter is really reference material on techniques used in previous chapters, part is an extension to methods not covered in the rest of the book). Nevertheless, the descriptions are clear and if only readers would know about this chapter's existence from chapter 1 onwards, they would be able to understand far better the contents of the book.

The final technical chapter of the book, chapter 17, is on fracture-induced anisotropy and is also very good. It presents anisotropy due to stress and resulting fracturing in a variety of different geometries, Schoenberg & Muir (1989) theory for the calculation of fracture compliance, and a method to separate fracture-induced anisotropy from background formation anisotropy. The latter half of the chapter presents several case study-type examples including the estimation of fracture orientation from shear wave splitting, the use of borehole-to-surface seismic measurements to detect fractures close to a well, and estimation of fracture orientation using only *P*-wave AVO. These examples are welcome as they demonstrate the practical use of theory developed earlier in the book.

The book ends with chapter 18 entitled 'Future Vision'. I found this to be rather limited, as its main emphasis is on converting the methods developed for deep exploration to be more suitable for shallow investigation. While this is without doubt a worthy endeavour, it is by no means the only possible extension of these techniques, and is probably far from the most innovative.

## CONCLUSIONS

In conclusion, this is a book filling a useful technical niche, and into which huge effort has clearly been poured by the author. It is a book in two parts, the first four chapters providing a general overview of seismic processing, chapters 5 to 17 presenting detailed theory in isotropic and anisotropic media alike. It describes the main results from most classic papers in the field, and gives many useful references. However, it is littered with editorial mistakes and in my view the book needs a thorough revision and a second edition before it becomes an attractive purchase.

## REFERENCES

Schoenberg, M. & Muir, F., 1989. A calculus for finely layered anisotropic media, *Geophysics,* **54,** 581–589.

Shuey, R.T., 1985. A simplification of the Zoeppritz equations, *Geophysics,* **50,** 609–614.

Wright, J., 1986. Reflection coefficients at pore-fluid contacts as a function of offset, *Geophysics,* **51,** 1858–1860.

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