0.1 (title page)

Imaging the Earth's Interior

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With pistols, and along the Moscow River even!

K. Senin
Literaturnaia Gazeta
28 October 1981
(Translated by Chuck Sword)

How and why one of the most biting and most absurd bestsellers of the current publishing season came to be written

I appeal to all worshippers of the alluring detective genre. To the judges of subjects sharp, puzzling, full of riddles, and hidden. Finally, simply to all readers, writers, and editors, to everyone who is literate and of sound mind. Would you be able, calling upon all the resources of your creativity, to imagine that in 1981 there could come into being in our country a book with this plot:

Chapter 1. New York City, Central Park. All during the winter rock music roared, smog hung over the park, and on dark and not very dark avenues gangsters committed excesses. But one day the music stopped, the smog lifted a bit, and a cop on patrol — a policeman who had drunk a pint of whiskey for courage — risked strolling over to a bush as many as five paces from the nearest streetlamp. And there were revealed three corpses which had been mutilated into unrecognizability — without eyes, without noses, and worst of all, without fingerprints, since the top joints of their fingers had been cut off.

Chapter 2. Sirens, the squeal of brakes. The famous New York detective Christ Halfsmith has arrived in a battered Chevrolet limousine at the scene of the incident. But he is not able to see it with his own eyes, because a luxurious Cadillac limousine has arrived in Central Park carrying the long-time enemy of Halfsmith, Colonel Devil Halfscott of the Special Branch of the FBI. Colonel Devil is rude, disturbs the detectives, tramples the evidence, and in general conducts himself in a poorly-bred fashion. At this point, Halfsmith, in his usual sagacious way, guesses that the matter is suspicious and that it has, apparently, a scandalous international character.

Chapter 3, 5, etc. Detective Halfsmith discovers that involved in the murder in Central Park were: a drug dealer, a beautiful Hollywood extra, a Lieutenant of the Moscow Criminal Police, a highly-placed government official, and a Chairman of the U.S. Supreme Court. On the horizon appears the equally sinister figure of the director of a Moscow soft drink firm. The decisive meeting between Halfsmith and the sinister director takes place in a den of debauchery, which for reasons of secrecy is dug precisely under Macy's. But Halfscott continues his intrigues, the director is able to slip away, that is, to return to Moscow, and Halfsmith is forced to the conclusion that he (the director) has been a long-time agent of the FBI.

Denouement. The murderer, of course, is the director, and the the murder victims are his accomplices. They helped him steal an important government secret — six bottles of Coca-Cola disguised as ancient Greek amphoras -- but he, not wishing to split the profits, cut off his accomplices' ears and noses and flung the pieces into the Hudson. Having discovered this, Halfsmith personally flies to the other side of the Iron Curtain and somewhere in the region of Novie Cheremushki singlehandedly punishes everyone who has not already been killed in the previous chapters. The stolen Coca-Cola is poured into a canal, and America's honor is saved.

Well? A convincing story, is it not? Why, if it even entered the head of some pulp-writer to write some similar idiocy, then I guarantee that the employees at any of our publishers would throw the story-teller out on his ear, even at the risk of having to explain their action to the police.

But don't jump to any conclusions. For this, which is completely unimaginable to us, seems completely possible on the other side of the ocean. Perform this simple operation: substitute half-Russian names in place of half-American, Mosfilm in place of Hollywood, Children's World for Macy's, and Staten Island for Cheremushki, and you get an exact, though abbreviated, account of one of the most popular bestsellers of 1981, Martin Cruz Smith's *Gorky Park*.

The formerly respectable New York publisher Random House, which is now breaking all records for dirty anti-Sovietism, released this masterpiece. *Literaturnaia Gazeta* has already written twice about this publisher and its owner, Mr. Bernstein (See LG, No. 27 and 40 for 1981). And now, it can't be helped, it is necessary to mention them for the third time. [???], but the events which preceded the emergence of this book into the world are very interesting. The book was actually ordered by a completely different publisher, Putnam, but having familiarized themselves with the manuscript, they gave the author the old heave-ho. The same fate befell Martin Cruz Smith at Norton as well. And only at Random House did they exclaim, "Eureka! There has never been such a thing before!" — nor did they scrimp on typographical outlays and advertising.

There has indeed never been such a thing before. The author of these lines, who during the length of his service has written a fair number of books in bright covers, has more than once asked himself: has the artist who paints the book-covers actually read the story that he illustrates? At this point it is necessary to wonder whether even the critics have read the book, the same ones who are flooding the English-language press with enthusiastic reviews. "Martin Cruz Smith is an outstanding writer," *(Saturday Review)*; "You read with growing interest and enthusiasm," *(International Herald Tribune)*; *Gorky Park* is distinguished by a rich social content, and it draws an impressive image of Eastern Europe," *(Time)* Enough, gentlemen, did you really even glance inside the book at all?

Well, if you were in earnest, if you glanced inside and, God forbid, read it, then what forces you to praise to excess a work that is clearly foolish, impoverished even to the most modest taste? What winds carried *Gorky Park* to the very summit of the American literary Olympus? The answer, it seems, is clear, although it is not given by the critics, but by the logic of American political conditions in recent years. John D. Osborn (such is the name the author gave the murderer) is an "old friend of the Soviet Union" and thus its longtime agent and informant, or in other words, its spy. Yes, he is in favor of detente and the development of business relations between the two countries, but he is by no means disinterested, but urged on by Moscow. And this is the point, reader-buyer: is it worth believing only those who call for more attention to the voice of reason, who call for a return, from the hysterical volleys about the "Soviet threat" and billion-dollar military budgets, to negotiations and cooperation? Is it not dangerous to believe them, and might they not also be... what? By presenting Osborn as a complete scoundrel, Martin Cruz Smith discredits all supporters and friends of detente. This sort of thing, apparently, fit the taste of the bosses of the book business — from this source comes the unrestrained publicity boom over a nonentity.

In other respects, in this "original" book there is nothing original. *Gorky Park* is a standard, nearly canonical "Western", only transplanted to Russian soil. "Character is function" — thus one of the fathers of the genre defined the heart of his method. Let the ends not meet, let the plot be sewn with a white thread, only one thing is important: that each chapter stun the reader with unexpected turns of events. And here, *Gorky Park* completely conforms: the heroes chase each other all over Moscow, brandishing pistols, they shoot in flight, in falling, in the forehead, and in the back, and it never even occurs to the reader — to the American reader — that the park is named Gorky, that it is not Central Park at all, and that gangster tactics here are not, to put it mildly, popular...

The biography of Martin Cruz Smith is the typical biography of a hack. In the 38 years of his life he has, under his own name and under pseudonyms, baked about thirty novels and uncountable quantities of stories on all possible subjects — Indians and Gypsies, vampires and sexual perverts. Most often of all he has worked on pornographic publications, and once even edited a journal with the characteristic name *For Men Only*. And, finally, he cooperated with Mr. Bernstein: as the saying goes, they found each other.

However, even before meeting Bernstein he had friends and advisers of a fairly definite persuasion — "Russian emigrants", as they are called in the West, or,more simply put, renegades, who betrayed their native land in the hope of "easy living". Now, from the height of achieved success, Martin Cruz Smith condescendingly bows to them, thanking them for "priceless help". This, however, is not mere bowing: Smith achieved his sole motivating goal; he made a million off of *Gorky Park*. And Random House, one must suppose, made no less. But let us find out: what part of their profits did they give to their "consultants"? One need not guess — a pittance, or else nothing at all: to act otherwise would not be true to the name "Western".

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0.4 Preface ..... ruff draft

Preface for SEP-30

Sometime within the year I am planning to bring my lecture notes to a publisher. As you know, these lectures were mostly prepared on my sabbatical leave in 1979-80. Thus most appeared in SEP-24 and SEP-25. Since then I have cleaned things up quite a bit for my lecturing here at the university and I'd guess that the material included here-in is about 30% revised. A job like this is never really done, but the distance we have covered since FGDP is tremendous, and I sense we may be changing direction, so this may be the time to fill in the 5% gap remaining to produce a landmark texbook.

Intended Preface for "Imaging the Earth's Interior"

Reflection seismologists make images of the earth's interior. Through the 1960's this was done in a rather *ad hoc* fashion. From 1968 to 1972, I conceived and field tested a new method of image making based directly on the wave equation of physics. Previously the wave equation had been used only to predict observations based on simplified, hypothesized models. My implementation, based on finite differences, soon came into widespread use in the petroleum exploration industry. Previously *ad hoc* image making had become systematic. Many other people soon became involved and they made many important improvements. The earlier *ad hoc* methods were reinterpreted and they too improved in the light of wave theory.

An industrial affiliates group, known as the Stanford Exploration Project, (SEP), was founded at Stanford University to pursue the new developments. Of the 35 current sponsoring organizations, many have substantial research departments of their own. Thus began the decade of the 1970's in which much progress was made and continues to be made at a rapid pace.

This textbook was born of the need to teach the best of the many new ideas to the many new people. Because so many people enter this field from outside Geophysics, I have kept specialized geophysical terminology to a minimum and defined everything (hopefully). So this should be a useful book, not only to those interested in petroleum exploration, but also to scholars in all disciplines where waves are analyzed.

My previous book *Fundumentals of Geophysical Data Processing* (FGDP) was published in 1976. It covers more basic aspects of reflection seismic data processing, such as Z-transforms, Fourier Transforms, discrete linear system theory, use of matrices, statistics, and theory of the stratified earth. The previous book introduced wave equation imaging, but extensive supplements became necessary. The supplements eventually evolved into this book.

Style

Because I have lectured to people with such diverse backgrounds, this book is organized somewhat like a newspaper. Most people start at the beginning and read until they get bored, lost, or disagree with the writer. Few actually read until the end, and it is my job to keep readers as long possible. So I begin with the important descriptive matters, pass through analysis and calculation and finish with items which are interesting, but less useful. Both the chapters and the sections (which are lectures) are organized with this philosophy.

As it happens, waves are marvelously geometrical objects, and much can be learned with little analytical effort. This book assumes that the reader has some familiarity with Calculus, complex exponentials and the discrete Fourier transformation. If you know some calculus and something of Fourier transforms then you should be able to read all the way to the end.

Thanks

This book is much less my personal creation than was the previous book. I am indebted to many people. Colleagues who collaborated extensively were Francis Muir and Fabio Rocca. Stanford students who contributed figures were: Junyee Chen, Robert Clayton, Bob Godfrey, Alfonso Gonzales, Dave Hale, Einar Kjartanson, Walter Lynn, Larry Morley, Dave Okaya, Richard Ottolini, Chuck Sword, Jeff Thorson, John Toldi, and Oz Yilmaz. Many useful ideas on presentation came from those who assisted me in industrial teaching, namely Walt Lynn, Rob Clayton, Einar Kjartansson, Rick Ottolini, and Fabio Rocca. Such teaching also helped me clarify the material and thanks is also due those who helped arrange it: Phil Hoyt, Lee Lu, A. Lamer, and Aftab Alam. JoAnn Heydron Pleumer and Pat Bartz helped me struggle through initial manuscript preparation. Towards the end I did much of the typing and revision myself, as computerized typesetting has considerably lightened that load and

contributed to a much more heavily revised and debugged final product.

Major thanks is due to Stanford University and the sponsoring organizations. Without them, much less would have been achieved. A list of sponsor names is found in an appendix.

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59. The first earth colony on Mars has been swept away by an epidemic of Barsoomian flu. The cause: a native Martian virus not yet isolated.

There is no way to identify a newly infected person until the symptoms appear weeks later. The flu is highly contagious, but only by direct contact. The virus transfers readily from flesh to flesh, or from flesh to any object which in turn can contaminate any flesh it touches.

Ms. Hooker, director of the colony, has been seriously injured in a rocket accident. Three immediate operations are required. The first will be per- formed by Dr. Xenophone, the second by Dr. Ypsilanti, the third by Dr. Zeno. Any of the surgeons may be infected with Barsoomian flu. Ms. Hooker, too, may have caught the disease.

Just before the first operation, it is discovered that the colony's hospital has only two pairs of sterile surgeon's gloves. No others are obtainable, and there is no time for resterilizing. Each surgeon must operate with both hands.

"I don't see how we can avoid the risk of one of us becoming infected," said Dr. Xenophon to Dr. Zeno. "When I operate, my hands may contaminate the insides of my gloves. Ms. Hooker's body may contaminate the outsides. The same thing will happen to gloves worn by Dr. Ypsilanti. When it's your turn, you'll have to wear gloves that could be contaminated on both sides."

"Not so," says Dr. Zeno, who had taken a course in topology when he was a young medical student in Paris. "There's a simple procedure that will eliminate all risk of any of us catching the flu from one another or from Ms. Hooker."

What does Dr. Zeno have in mind?

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60. You are walking along the road one day, when you find ten bags which contain 20 gold coins each. At first, you start to celebrate your find. You then find a note in the dirt that warned that all but one of the bags contain fool's gold and are therefore worthless. The only way to tell the coins apart is by weighing them, for a gold coin weighs 3 ounces and the other coins weigh only 2 ounces each. You can not tell which bag contains the true gold just from holding the bags, so you take all of them with you as you continue down the road. You come upon a penny scale, which will allow you to weigh something once for a penny. You dig through your pockets and find that you have only one penny. The question is how can you determine which bag contains the gold from only one weighing?

0.5 Introduction.....ruff draft

Reflection seismic data is voluminous and experimentally repeatable. Much of it is readily comprehensible, but much remains which is not, especially on the first try. From this information, acquired at the earth surface, we construct a picture of what is beneath the surface.

Why is it Fun ?

Many young people have wonderful brains. They enjoy tackling tough theoretical problems. When time comes for application they are often disappointed to find that the theory is in some ways irrelevant or inadequate to deal with the problem at hand. At first this causes a diminished interest in practical problems. But eventually they come to see the real problems as more interesting than the original mathematical model. Why is this?

Maybe life is like a computer game. I have noticed that the games students like the best are not those with a predetermined, intricate logical structure. They like the games where you gradually uncover the rules while you play. It is really fun when a period of frustration is overcome by some application of a personal idea. But to be fun, there must *be* rules, and you must *be able* to uncover them with a reasonable amount of effort. Luckily, reflection seismology, along with modern computers, does provide us with this environment. Sometimes a game can be frustrating and you need some kind of a hint to get you over some obstacle into a new and deeper level. Reading this book is not like playing the game. This book is more like a collection of hints, a bag of tricks, to help you along.

These tricks are rather new, being mostly less than ten years old. They have been selected because they really work, not always, but often enough. I have resisted the urge to include a second bag of tricks which seem promising, but which haven't yet worked out well enough in practice. I'm just beginning work on a third bag of tricks, and I'll give you a peek in a moment.

Practical problems are not only deeper than theoretical problems, but ultimately they yield more interesting theory. For example in Freshman physics laboratory I learned to deduce Newton's laws of motion from experimental work. I should have found experimentally that force equals mass times acceleration. Of course I didn't find exactly that. The experiment didn't work out too well because of friction. *Friction*, now there is a really interesting subject for you. Physicists, chemists,

metallurgists, earth scientists, we all wish we understood friction!

You are holding an interesting theoretical book in your hands. It wouldn't have been written except that two earlier theoretical areas, (1) the theory of mathematical physics in stratified media, and (2) time series analysis, couldn't touch some of the most interesting aspects of our data. Some people thought we just had dirty data! Reflection seismic data is highly repeatable. Many of our problems really arise with the theory. Eventually, of course the theory in this book will be the bottleneck.

I'll make a prediction. In the 1960's we learned how to apply time series optimization theory to seismic data. See *Fundamentals of Geophysical Data Processing* (FGDP) for that. Eventually time series had gone to the point of diminishing returns because it had an oversimplified view of spatial relations. In the 1970's we learned to apply the wave equation. That is what this book is about. One of the big tasks for the 1980's will be to learn to do both at once.

The Next Decade

Let's take a quick peek beyond this book into the future. A seismic image is typically a 1000×1000 plane, derived from a volume of about 1000^3 inter-related data points. There are unknowns everywhere, not only in the earth model, but also in the data as noise and more importantly, as gaps, insufficient spatial density and extent of data recording. To assemble an interpretation we must combine principles of physics along with principles of statistics. Presumably this could be done in some monster optimization formulation. A look at the theory of optimization shows that we can expect solution techniques to converge in a number of iterations proportional to the number of unknowns. Thus the solution to the problem, once we learn how to pose it properly, seems to require about a million times as much computing power as we have available. What a practical problem!

But the more you look at it, the more interesting it becomes. We have first, the optimization problem we want to solve. Then, since we know we will make only a few iterations, say three, we must go as far as we can in those three steps. Not only do we have the original optimization problem but we have the new problem of solving it in an optimum way. Before we started optimizing we saw apparent correlated randomness in the raw data. As we begin optimizing we see the earth model changing in a correlated random way as we move from one iteration to

another. The second optimization problem is not only the practical one, but it is deeper at the theoretical level.

Guide to this Book

Chapters 1 and 3 describe the basic concepts of imaging in reflection seismology. Chapters 2 and 4 describe computer techniques for the analysis of observed wavefields. At Stanford University, chapters 1-3 are taught to Master Degree students in a one quarter course. These students also have an earlier class from FGDP which is helpful but not necessary. You may want to understand concepts, without learning about techniques. This doesn't always work but you could try just chapters 1 and 3. Chapter 4 is used informally by students beginning PhD work. Early versions of lecture notes included a chapter 5 describing wave propagation concepts which have not yet been brought into widespread practical use. This will be omitted, or condensed to a single lecture for this book.

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61. Can you think of a two-digit number, the sum of whose digits is equal to the square of its cube root?

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62. There is one number between 1 and 100, the letters of whose English name are in alphabetical order. What is it?

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63. What is the rule behind this progression, and what is the next number in the series?
5 6 8 9 13 15 16 18 19 25 26 28 29 30

****

64. What is the next letter in the sequence? Z O T T F F S S E ?

****

65. Three pairs of husbands and wives are traveling along when they come upon a river. They find a small rowboat that will be able to carry only two people at a time. The husbands are jealous of their wives, and they do not trust one another. No man is willing to leave his wife alone, in the boat or on the shore, with another man unless that man's wife is also present. How many river crossings are necessary to get all six people to the other side?

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66. You have a quart of orange juice and a quart of tequila. Take one tablespoon of orange juice, transfer it to the tequila, and mix thoroughly. Then take a tablespoon of this mixture and pour back into the orange juice. Is the amount of orange juice in the tequila greater than, less than, or equal to the amount of tequila in the orange juice?