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52 THINGS
YOU SHOULD
KNOW ABOUT
GEOPHYSICS

EDITED BY MATT HALL & EVAN BIANCO

"A marvellous little book, full of nuggets of wisdom from the 'who's who?' of our industry. I highly recommend this book to all young and aspiring geoscientists."

Dan Hampson

co-founder of Hampson–Russell

"This is a great book... The contributing authors are among the best known names in our profession. The subject each author selects is an essential 'thing' that we all need to know about geophysics. I predict that when you get a copy of this book in your hand, you will look at every page."

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President of SEG

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Henry Posamentier

Seismic geomorphologist

"Fascinating. In the current world of instant gratification this provides rapid 'bites' of insight into many aspects of geophysics, seen through the eyes of some of the science's best practitioners."

David Monk

President-Elect of SEG

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Introduction



This book is an experiment. From the minute we first talked about the idea in May 2011, we have only been sure about one thing: we aren't sure about anything. Well, okay, maybe a few things... We knew we wanted to bring together a group of personal heroes, mentors, friends, colleagues, and well-known interpretation visionaries. We knew we wanted short, highly relevant, fun-to-read, easy-to-share, and above all useful, essays. We knew we wanted to make a book that cost under \$20, with an ebook version. We knew we wanted to make it easy to share. And we knew we wanted to do it ourselves.

Lots of people asked us, 'Why not ask the SEG to publish it?' A fair question, since they obviously know what they're doing and we, well, don't. But we're curious people, and maybe we have grand ideas about doing a series, and straying away from geophysics, and doing who-knows-what. We knew enough to know that we didn't know enough to give the project away. We wanted to own it, experiment with it, and see where it ended up.

It has not ended up anywhere yet, far from it, but this book is the end of the beginning. Now we know how to invite people, how to collate, read, edit, re-read, re-edit, and proof 52 pieces of writing by 39 authors. We know how to design cover art, build page layouts, and typeset equations. And we know how to make a manuscript into an actual book that you can sell to actual people. We are not astute businessmen — we have no idea how many we will sell (100? 1000? 10 000?), or if the project will come close to breaking even. We hope it does, not because we want to make lots of money, but because we want to do it again.

It all started at the annual convention of the Canadian Society of Exploration Geophysicists in May 2011. We'd already decided that for the book to be remarkable, we'd need to somehow convince one or two of a handful of highly accomplished people to contribute something. We weren't at all sure how this bit would work, if anyone would even listen. Evan mentioned the project to Brian Russell at the convention, and he seemed genuinely interested, enthused even. Encouraged enough to put some invites out, we emailed a few potential authors a couple of weeks later.

Brian — Brian Russell, über-geophysicist, ex-president of SEG and CSEG, award-winning entrepreneur — emailed his first contribution, *Don't neglect your math*, 23 hours later. It was perfect, exactly the sort of thing we wanted. We

were ecstatic. And we knew the book was going to work. When Matt expressed his surprise at getting such a fast response from such an awesome geoscientist, his wife Kara (and the book's managing editor) was incredulous: 'It's not surprising at all: that's precisely why he's awesome,' she said.

Well, we had many more moments like this as contributions came in from the amazing, and incredibly busy, geoscientists we'd written to. We don't want to make it sound like this project is all about celebrities, far from it. Admittedly, getting chapters early on from well-known veterans was highly motivating, but ultimately no more so than the insightful chapters from the many energetic young professionals who also contributed.

One of our core principles at Agile is that expertise is distributed — we all have specializations and experience that others can enjoy hearing about and learning from. We are committed to this idea. Insight and creativity come from everyone in this industry, not just from veterans, chiefs, and superstars. If we can cultivate a culture of more open and accessible writing and knowledge, we believe we can spark more ideas, connect more people, and have more fun than ever.

Welcome to the first of these short collections of *Things You Should Know*. If you like it, please share it — give this book to someone you respect.

Matt Hall & Evan Bianco
Nova Scotia, May 2012

Geophysics is all around

José M Carcione



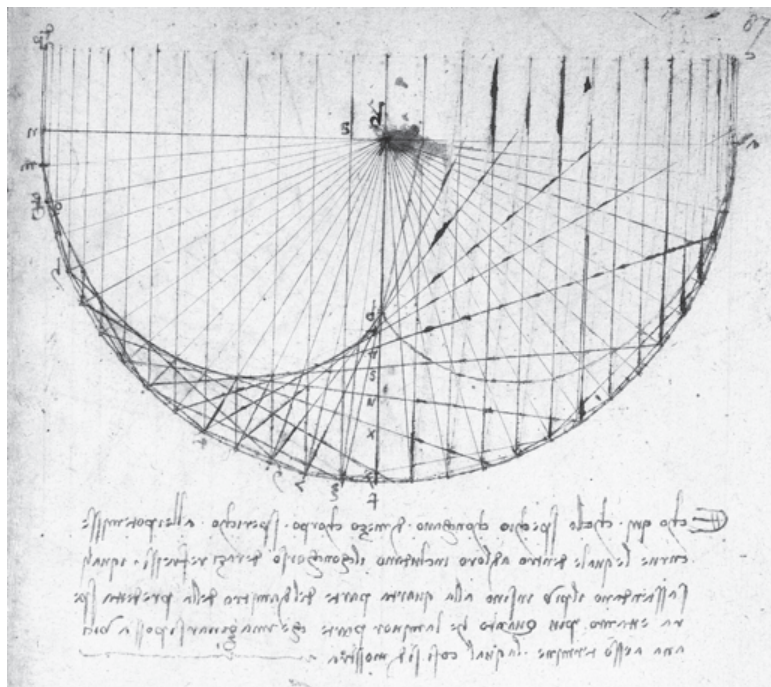
Hold a well-filled cup of milky coffee on a sunny day and on the liquid's surface you will see a *catacaustic*. This word has a Greek root and means 'burning curve'. The sun is a point source at infinity whose parallel rays hit the cup according to the laws of geometrical optics. The rays are reflected from the reflective inner wall of the cup generating the bright curve, the caustic, formed by the envelope of the rays. The cusp at the centre of the caustic is called the *paraxial focus* and the liquid surface is brighter below the caustic curve. This particular shape of caustic is called *nephroid*, meaning kidney-shaped.



The phenomenon was known to Huygens in about 1679, and Bernoulli described it mathematically as an *epicycloid*. But almost two centuries earlier, Leonardo da Vinci observed the caustic when he was experimenting with using concave mirrors to generate heat — he called them fire mirrors. He argued that given equal diameters, the one with a shallower curve concentrates the most reflected rays, and 'as a consequence, it will kindle a fire with greater rapidity and force'.

Syncline-shaped reflectors generate seismic reflections resembling these types of caustics.

*The shallower curve...
will kindle a fire with greater
rapidity and force.*



Leonardo da Vinci's early 16th-century sketch of a caustic, including his famous mirror writing.

Acknowledgments

This chapter is adapted from Carcione, J M (2007). *Wave fields in Real Media*, Elsevier. The cup image is original. The drawing is © The British Library Board, from *Codex Arundel*, MS 263, ff. 86v–87, ca. 1503–05, and used here with permission.

Leonardo was a geophysicist

José M Carcione



The science of geophysics studies the physics of our planet, considering the atmosphere, the hydrosphere, and the core, mantle, and crust of the earth. It is highly interdisciplinary since it involves geology, astronomy, meteorology, physics, engineering, and scientific computing. Today, it is impossible for a single researcher to deal with all these fields.

Before the scientific method was introduced, Leonardo da Vinci (1452–1519), one of the brightest minds of all time, excelled in every aspect of art, humanity, and science. Leonardo foresaw a number of geophysical phenomena. The list below is incomplete but illustrative of his discoveries.

Wave propagation, interference, and Huygens' principle (1678):

Everything in the cosmos is propagated by means of waves...

Manuscript H, 67r, Institut de France, Paris.

I say: if you throw two small stones at the same time on a sheet of motionless water at some distance from each other, you will observe that around the two percussions numerous separate circles are formed; these will meet as they increase in size and then penetrate and intersect one another, all the while maintaining as their respective centres the spots struck by the stones.

Manuscript A, 61r, Institut de France, Paris.

The Doppler effect (1842):

If a stone is flung into motionless water, its circles will be equidistant from their centre. But if the stream is moving, these circles will be elongated, egg-shaped, and will travel with their centre away from the spot where they were created.

Manuscript I, 87, Institut de France, Paris.

Newton's prism experiment (1666):

If you place a glass full of water on the windowsill so that the sun's rays will strike it from the other side, you will see the aforesaid colours formed in the impression made by the sun's rays...

Codex Leicester, 19149r, Royal Library, Windsor.

Explanation of the blue sky, before Tyndall's 1869 experiments and Rayleigh's theory of 1871:

I say that the blue which is seen in the atmosphere is not given its own colour, but is caused by the heated moisture having evaporated into the most minute and imperceptible particles

Codex Leicester, 4r Royal Library, Windsor.

The principle of the telescope, first constructed in the Netherlands in the early 17th century:

It is possible to find means by which the eye shall not see remote objects as much diminished as in natural perspective...

Manuscript E, 15v, Institut de France, Paris.

The further you place the eyeglass from the eye, the larger the objects appear in them

Manuscript A, 12v, Institut de France, Paris.

Construct glasses to see the Moon magnified.

Codex Atlanticus, 190r, a, Ambrosiana Library, Milan.

A statement anticipating Newton's third law of motion (1666):

As much pressure is exerted by the object against the air as by the air against the body.

Codex Atlanticus, 381, Ambrosiana Library, Milan.

The principle of least action, before Fermat in 1657 and Hamilton in 1834:

Every action in nature takes place in the shortest possible way.

Quaderni, IV, 16r.

The evolution of the earth and living creatures, preceding George Cuvier (1804) and Charles Lyell (1863), and plate tectonics, anticipating Wegener (1915):

That in the drifts, among one and another, there are still to be found the traces of the worms which crawled upon them when they were not yet dry. And all marine clays still contain shells, and the shells are petrified together with the clay.

...Strata were covered over again from time to time, with mud of various thickness, or carried down to the sea by the rivers and floods of more or less extent; and thus these layers of mud became raised to such a height, that they came up from the bottom to the air. At the present time these bottoms are so high that they form hills or high mountains, and the rivers, which wear away the sides of these mountains, uncover the strata of these shells,...

Codex Leicester, Royal Library, Windsor.

List of contributors



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Don't rely on preconceived notions

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Use the rock physics bridge

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Art Barnes received a BS (1974) in physics from Denison University, an MS (1980) in geophysics from the University of Arizona, and a PhD (1990) in geophysics from Cornell University. His work experience includes seismic data acquisition, data processing, software development, and research. He is currently a geophysical researcher with Petronas in Malaysia. His research interests include seismic attributes, seismic processing, and pattern recognition applied to problems of seismic interpretation. He is a member of SEG, EAGE, and AAPG.

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Evan Bianco is the Chief Scientific Officer at Agile Geoscience. He is a blogger, freelance geophysicist, entrepreneur, and knowledge-sharing aficionado. He has an MSc in geophysics from the University of Alberta and four years' experience as an industry consultant in Halifax, Nova Scotia. Evan's interests span a range of disciplines from time-lapse seismic in oil sands to geomodelling, seismic rock physics, and geothermal reservoir characterization. Evan tries to teach himself something new every day, and every so often, it proves useful. He can be reached at evan@agilegeoscience.com, or you can follow him on Twitter @EvanBianco.

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Recognize conceptual uncertainty and bias 66



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Wrong is good for you 114



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Geophysics is all around 34

Leonardo was a geophysicist 42



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Mind the quality gap 44



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Why you care about Hashin–Shtrikman bounds

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Seek out the biostrat

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Paul de Groot is president of dGB Earth Sciences, dgbes.com. He worked 10 years for Shell where he served in various technical and management positions. Paul subsequently worked four years as a research geophysicist for TNO Institute of Applied Geosciences before co-founding dGB in 1995. He has authored many papers covering a wide range of geophysical topics and co-authored a patent on seismic object detection. Together with Fred Aminzadeh, Paul wrote a book on soft computing techniques in the oil industry. He holds MSc and PhD degrees in geophysics from Delft University of Technology in the Netherlands. Find him on LinkedIn at [ageo.co/1hwEUg](https://www.linkedin.com/company/ageo-co/).

No more innovation at a snail's pace

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Duncan Emsley graduated with a BSc from the University of Durham in 1984. He worked for processing contractors for several years before joining Phillips Petroleum in 1992. Continuing in the seismic processing vein, he worked with data from all sectors of the North Sea and northeast Atlantic. The merger of ConocoPhillips brought about moves to Scotland, Alaska, and Calgary, Canada, and a progression into rock physics and seismic attributes and their uses in the interpretation process.

Know your processing flow

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Maitri Erwin is a geophysicist at an independent oil and gas company, where she currently specializes in the inversion and interpretation of deepwater data. She has previously worked as a 3D geospatial technology executive as well as a geoscientist and subsurface information technologist at an oil major. Maitri is an advisor to Project Gutenberg, the oldest producer of free electronic books. She is [@Maitri](https://twitter.com/Maitri) on Twitter.

We need integrative innovation

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Tooney Fink has been involved in the Canadian energy industry as a geophysicist for over 37 years, working for Gulf Canada Resources and successive companies which have since joined together to become ConocoPhillips Canada where he is now Supervisor of Geophysical Services. After graduating from the University of British Columbia in 1974, Tooney's career in the Canadian energy industry involved seismic field acquisition in the Mackenzie Delta and Parsons Lake, seismic processing, exploration in many of Canada's frontier basins, several international projects, and an endless number of projects in the Western Canada Sedimentary Basin. Tooney has been an active member of the CSEG Chief Geophysicists Forum since 2001, and helped compile *Practice Standard For Use Of Geophysical Data*. In 2008, Tooney was the CSEG General Chairman at the CSEG/CSPG/CWLS joint convention. Tooney also holds membership in AAPG, APEGA, NAPEGG, and SEG.

Remember the bootstrap

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What I learned as a geophysicist wannabe

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Taras Gerya is a professor at the Swiss Federal Institute of Technology (ETH-Zurich) working in the field of numerical modelling of geodynamic and planetary processes. He earned a PhD in petrology from Moscow State University in 1990 and a habilitation in geodynamics from ETH-Zurich in 2008. His recent research interests include modelling of subduction and collision processes, ridge-transform oceanic spreading patterns, intrusion emplacement into the crust, and core formation of terrestrial planets. He is the author of *Introduction to Numerical Geodynamic Modelling* (Cambridge University Press, 2009).

Calibrate your intuition

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Bill Goodway obtained a BSc in geology from the University of London and an MSc in geophysics from the University of Calgary. Prior to 1985 Bill worked for various seismic contractors in the UK and Canada. Since 1985 Bill has been employed at PanCanadian and then EnCana in various capacities from geophysicist to Team Lead of the Seismic Analysis Group, to Advisor for Seismic Analysis within the Frontier and New Ventures Group, and subsequently in the Canadian Ventures and Gas Shales business unit. In 2010 he ended his career with EnCana to join Apache as Manager of Geophysics and Advisor Senior Staff in the Exploration and Production Technology group. Bill has received numerous CSEG Best Paper awards as well as the CSEG

Medal in 2008. He is a member of the CSEG, SEG, EAGE, and APEGA as well as the SEG Research Committee. In addition, Bill was elected Vice President and President of the CSEG for the 2002–04 term and in 2009 he was selected as the SEG’s Honorary Lecturer for North America.

The magic of Lamé

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David Gray received a BSc in geophysics from the University of Western Ontario (1984) and a MMath in statistics from the University of Waterloo (1989). He worked in processing for Gulf, Seismic Data Processors, and Geo-X Systems and in reservoir and research for Veritas and CCGVeritas. He now works for Nexen, where he is a Senior Technical Advisor responsible for geophysical reservoir characterization in the Oil Sands group. David is a member of SEG, CSEG, EAGE, SPE, and APEGA. He has published and presented more than 100 papers, holds two patents, and is a registered Professional Geophysicist in Alberta.

Explore the azimuths

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Vladimir Grechka received his MSc degree (1984) in geophysical exploration from Novosibirsk State University, Russia and a PhD (1990) in geophysics from the Institute of Geophysics, Novosibirsk where he worked from 1984 to 1994 as a research scientist. He was a graduate student at the University of Texas at Dallas from 1994 to 1995, then joined the Colorado School of Mines where he was Associate Research Professor and co-leader of the Center for Wave Phenomena. From 2001 to 2012, Vladimir worked at Shell as a Senior Staff Geophysicist. Currently he is a Geoscience Consultant with Marathon Oil. Vladimir is the author of three books and more than 300 research papers devoted to various aspects of elastic wave propagation and seismic exploration. He is a member of SEG and EAGE. In 2009–2011, he served as the Editor-in-Chief of *Geophysics*. He received the East European Award from the European Geophysical Society in 1992 and the J Clarence Karcher Award from the SEG in 1997.

Anisotropy is not going away

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Five things I wish I'd known

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Marian Hanna is President and Director of ION/GX Technology Canada. She has 23 years of diverse experience in the oil and gas industry. Marian started out as a seismic processing geophysicist with Amoco, moving into interpretation with an emphasis on reservoir characterization. Marian's experience includes many collaborative technical and business contributions to discoveries in international and domestic North American basins from onshore to deep water settings in all aspects of exploration, development and production, including business development/new ventures. Marian is a native of New Orleans, Louisiana.

One cannot live on geophysics alone 52



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Practise smart autotracking 58

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Geology comes first 32



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Seek out the biostrat 74



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The fine art of Mother Nature 82



Derik Kleibacker is currently the Chief Geologist for ConocoPhillips Indonesia. He graduated with an MSc degree in geology from Oregon State University and has worked for ConocoPhillips in various exploration and development roles since 2002. Derik hates to admit it, but he loves geophysical interpretation as much as geological field mapping.

You are a geologist

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John Logel is lead geophysicist for Talisman Energy in Stavanger, Norway, leading them in the application of value-adding geoscience technology to improve prospect quality and reduce risk. Prior to Talisman, John held several technical management and advisory positions with Anadarko Canada and Petro-Canada in Calgary, Alberta, and before that worked 19 years for Mobil on numerous assignments in Europe and North America. John teaches professional development courses for PetroSkills in basic geophysics, AVO, inversion, and attributes. John is a professional geophysicist and holds a BS and MS from the University of Iowa. He is a member of SEG, CSEG, APEGA, and AAPG.

Simplify everything

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Dave Mackidd started his career at Esso in Calgary, Alberta, and enjoyed exploring the Canadian Arctic before moving to Canadian Hunter and, later, PanCanadian and EnCana. Throughout his career, he has been a prolific creator of geophysical tools and workflows, devising such marvels as the grid balance algorithm for 2D seismic lines. He is now a Geophysical Advisor at EnCana, pushing the boundaries of geophysics every day.

My geophysical toolbox, circa 1973

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Mostafa Naghizadeh received a BSc in mining engineering from the University of Kerman, Iran, and an MSc in geophysics from the University of Tehran in 2003. He received his PhD in geophysics from the University of Alberta in 2009. He worked as a postdoctoral researcher with CREWES at the University of Calgary from 2010–11. His interests are in seismic data reconstruction methods, sampling theory, and seismic imaging. He currently holds a postdoctoral fellow position with Signal Analysis and Imaging Group (SAIG) at the University of Alberta. In 2011, Mostafa received the J Clarence Karcher Award from SEG.

The magic of Fourier

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Rachel Newrick obtained her BSc (geology; 1992) and BSc Honours (applied geophysics; 1993) at Victoria University of Wellington, New Zealand and her PhD (exploration seismology; 2004) at the University of Calgary. Since 1992 she has worked for BHP Petroleum in Melbourne, Warburg Dillon Read in London, Telecom NZ and Bank of NZ in Wellington, Occidental Petroleum in Houston, Exxon Mobil in Houston, Veritas DGC in Calgary, Nexen Inc in Calgary, and Nexen Petroleum UK in London. She is currently a senior geophysicist for Cairn Energy in Edinburgh

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Carl Reine graduated from the University of Alberta in 2000 with a BSc in geophysics. He worked a variety of conventional and heavy oil fields with Nexen Inc until 2006, when he attended the University of Leeds to complete a PhD. His research involved developing an algorithm for robustly measuring seismic attenuation from surface seismic data. Since 2010, Carl has worked for Nexen in the shale gas group, where he works on projects defining fracture/fault behaviour and reservoir characterization. He is an active member of CSEG, SEG, and EAGE, and is a professional member of APEGA.

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Brian Romans is a sedimentary geologist and assistant professor in the Department of Geosciences at Virginia Tech. He graduated from SUNY Buffalo with a geology degree in 1997 and then worked as a geotech for small oil and gas companies in Buffalo, New York and Denver, Colorado for a few years. Brian received an MS in geology from Colorado School of Mines in 2003 and then headed to California where he earned a PhD in geological and environmental sciences from Stanford University in 2008. He worked as a research geologist for Chevron Energy Technology from 2008 to 2011 before joining the faculty at Virginia Tech. Brian's research on the patterns and controls of clastic sedimentation during and since graduate school have resulted in numerous papers, which you can access at www.geos.vt.edu/people/romans. Brian is [@clasticdetritus](https://twitter.com/clasticdetritus) on Twitter and writes the blog *Clastic Detritus* where he shares thoughts and photos about earth science.

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Brian Russell started his career as an exploration geophysicist with Chevron in 1976, and worked for Chevron affiliates in both Calgary and Houston. He then worked for Teknica and Veritas in Calgary before co-founding Hampson-Russell in 1987 with Dan Hampson. Hampson-Russell develops and markets seismic inversion software which is used by oil and gas companies throughout the world. Since 2002, Hampson-Russell has been a fully owned subsidiary of Veritas and Brian is currently Vice President of Veritas Hampson-Russell. He is also an Adjunct Professor in the Department of Geology and Geophysics at the University of Calgary. Brian was President of the CSEG in 1991, received the CSEG Meritorious Service Award in 1995, the CSEG medal in 1999, and CSEG Honorary Membership in 2001. He served as chair of *The Leading Edge* editorial board in 1995, technical co-chair of the 1996 SEG annual meeting in Denver, and as President of SEG in 1998. In 1996, Brian and Dan Hampson were jointly awarded the SEG Enterprise Award, and in 2005 Brian received Life Membership from SEG. Brian holds a BSc in geophysics from the University of Saskatchewan, an MSc in geophysics from Durham University, UK, and a PhD in geophysics from the University of Calgary. He is a registered Professional Geophysicist in Alberta.

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Pick the right key surfaces 54



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Pre-stack is the way to go 60



Rob Simm is a seismic interpreter with a special interest in rock physics, AVO, and seismic inversion technologies. Rob's early career (1985–1999) was spent with British independent oil and gas exploration companies Britoil, Tricentrol, and Enterprise Oil, working in both exploration and production. An interest in applying rock physics in prospect generation and field development led him to set up his own consultancy, Rock Physics Associates. His training course *The Essentials of Rock Physics for Seismic*

Amplitude Interpretation is recognized worldwide. Rob is the author of numerous papers as well as co-author of *3-D Seismic Interpretation* (Cambridge University Press, 2007). Since May 2010, Rob has had a staff position as Senior Geophysical Advisor at Agora Oil and Gas, a North Sea exploration company.

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Publish or perish, industrial style 64



Fereidoon Vasheghani received his PhD in geophysics in 2011, and MEng in petroleum engineering in 2006, both from the University of Calgary, Alberta. He is currently working as a geophysicist at ConocoPhillips. He is a member of SEG and SPE.

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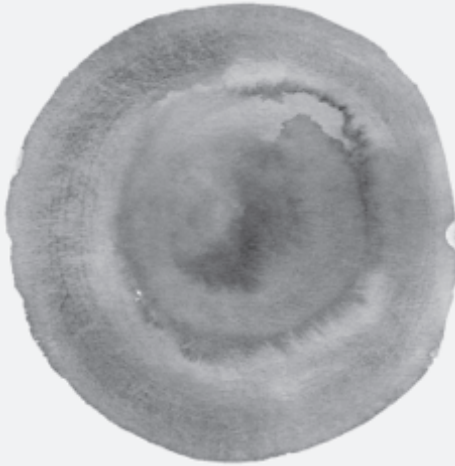
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