'It's not the end (of oil), but it would be the end if we as geophysicists give up...'

– An interview with Enders Robinson

Enders was the invited inaugural speaker for the 2005 CSEG DoodleTrain held in Calgary in the first week of November, and kicked off that educational week with his illuminating talk entitled 'Geophysical Exploration – Past and Future'.

Enders Robinson is a very familiar name in geophysics. All geophysicists have studied digital signal processing of seismic records, which was originally developed by Enders. Amongst the many different firsts that Enders may have to his credit, he is known most of all for his pioneering work on deconvolution. Fondly, he is called 'Father of Deconvolution'.

Enders has received several awards, most notably the SEG's Medal Award and EAGE's Conrad Schlumberger Award in 1969, SEG Honorary membership in 1983, Donald G. Fink Prize Award of IEEE in 1984, was elected to the National Academy of Engineering in 1988 and the SEG's highest honour, the Maurice Ewing Medal in 2001.

Enders holds an endowed Chair at Columbia University. He has written more than 25 books on digital signal analysis, seismic data processing and wavelet estimation, and published over 60 papers.

Larry Lines (University of Calgary) and Satinder Chopra sat down with Enders a day before he delivered his DoodleTrain inaugural talk and asked Enders to go down his memory lane and share some of his experiences and accomplishments. Following are excerpts from the interview.

– (Photos courtesy: Shirley Lines)

S: *I wanted to begin by having you speak a little about your educational background and about your career, which has been long and varied, and tell us what you are doing now.*

E: I was born and raised in Massachusetts and went to MIT in 1946, where I majored in mathematics. Prof. Norbert was the foremost person in the Mathematics Department. With the publication of his books Cybernetics in 1948 and Extrapolation, Interpolation, and Smoothing of Stationary Time Series in 1949, my interest turned to the field of time series analysis. I obtained my bachelor degree in June 1950, and after a short tour in the Army I entered the MIT graduate school as a research assistant in the Mathematics Department under Professors George Wadsworth and Norbert Wiener. My task was to take eight high-interference seismic records provided by the Magnolia Petroleum Company and find a mathematical method to detect any and all reflections that were hidden in the interference. While working on this problem, I completed a Master's Degree in Economics under professors Robert Solow and Paul Samuelson. This success of my seismic work resulted in formation of the MIT Geophysical Analysis Group (GAG) in February 1952. I went into Geology and Geophysics Department as the director of the GAG. I completed a doctorate in Geophysics in September 1954.

S: *Where did you work after that?*

E: Immediately after my doctorate I went to work for Gulf Oil. At first I spent time in Texas on a seismic crew and then went to the Gulf Research Center near Pittsburgh. In July 1955, I returned to MIT as an instructor in mathematics. In July 1956, I went to New York and worked for Standard Oil Company (New Jersey), not in geophysics but in the Coordination and Petroleum Economics Department. It was Prof. Samuelson who made the contact to get me this job. As the parent company, Standard Oil coordinated the activities of its many subsidiary (or daughter) companies, such as Esso (US), Esso (Germany), Esso (France), etc. The daughter companies each made budget requests to the parent company. The job of the Coordination and Petroleum Economics Department was to evaluate all of the requests and advise Standard Oil as to their relative merits. My area was in the storage and transportation of

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petroleum and petroleum products (otherwise known as tankage and tonnage). History changed on October 4, 1957, when the Soviet Union launched Sputnik, the world's first artificial satellite. I made the decision to go back to science. I spent the winter, spring, and summer quarters of 1958 at Michigan State University and then went to the University of Wisconsin in Madison. I was an Assistant Professor in the Mathematics Department, and soon became the Acting Head of Computer Science, which was then called Numerical Analysis. The Numerical Analysis Laboratory had a small IBM computer and a large assortment of IBM tabulating machines. Wisconsin paid a large amount of rental to IBM who owned everything. I recommended that Wisconsin get rid of all that rented equipment in favor of owning a large digital computer. I told the Dean of Engineering, and he replied: "Yes, Wisconsin will get a big computer." The National Science Foundation put up half the money and the Wisconsin Alumni Research Foundation (WARF) put up the other half. Wisconsin got a Control Data Corporation 1604, a powerful computer designed by Seymour Cray. Within a year nearly everyone at Wisconsin was asking – "How did we ever get along without the 1604?" WARF gave me a Fellowship to spend the year 1960-1961 in Sweden to work under Prof. Herman Wold, a pioneer in time series analysis. In Sweden, Wold introduced me to Andre Kolmogorov of Russia, to Kari Karhunen of Finland, and to M. S. Bartlett of England, all great names in time series analysis. As it turned out, I stayed in Sweden for four years and, as a consultant to Pan American Petroleum Company, worked by mail with Sven Treitel. In 1964 I came back and worked in Cambridge, Massachusetts for Geoscience Inc., which was mostly made up of MIT Professors. Then in 1965, as the seventh person, I joined Rudy Prince, David Brown, Pat Poe, David Steetle, George Cloudy, and Bill Shell to found Digicon Incorporated.

S: ***How come you took up mathematics? Were you a whiz in science or mathematics when you were young? Did your teachers inspire you?***

E: My teachers in Grade School and High School had a great influence on me. In Grade School the teachers were more interested in literature and history. In High School I had a geometry teacher who inspired me and stirred up my interest in mathematics.

S: ***Who were some of your mentors?***

E: Three of my mentors at MIT were Professor Norbert Weiner in mathematics, and Professors Paul Samuelson and Robert Solow in economics. My wife Joyce and I were invited to Samuelson's 90th birthday party a few months ago. He looked as good as ever. Prof Solow was also there. Back in 1950, when Samuelson entered the classroom, he carefully pulled down all the blinds to shut out the afternoon sun. Economics is called the dismal science, but not in that classroom where Samuelson's light brightly shined. Also I want to include Professor George Wadsworth in Mathematics, and Professor Patrick Hurley and Dr. Norman Haskell in Geophysics. Haskell, who was a geophysicist at the Air Force Cambridge Research Center (AFCRC) at Hanscom Field, would visit MIT twice a week to teach the graduate geophysics courses. Haskell did early work on seismic waves in layered media.

S: ***Would you tell us about how you got the idea of digital analysis and some of the early developments and how you were able to set up the Geophysical Analysis Group at MIT?***

E: As an MIT undergraduate I was in the Reserve Officers' Training Corps (ROTC) and spent the summer of 1949 at the Aberdeen Proving Ground in Maryland. The ENIAC Computer was there. It was the world's first large electronic digital computer. One Saturday morning the commanding officer said that anyone interested can visit the ENIAC. Only about a dozen ROTC students went out of more than a thousand. That's how I first learned about digital computers. Upon graduation from MIT in 1950, I went into the Army and attended the Ordnance School at Aberdeen Proving Ground in Maryland. Then I got to know more about the ENIAC. Upon graduation from the Ordnance School in September 1950 I was assigned to an early ready reserve unit at the Watertown Arsenal in Massachusetts, which allowed me to enter the Graduate School at MIT. I was accepted into the Mathematics Department as a research assistant. At this point I did an unconventional thing, which most of my friends did not and do not understand. Although in Mathematics, I pursued a Masters' degree in economics, which seemed to be in the opposite direction of what people expected. The reason was Prof. Paul Samuelson of the Economics Department. As an undergraduate I had audited his course on time series. Prof. Robert Solow, also an expert on time series, had just joined the Economics Department. Meanwhile in the Mathematics Department I started doing seismic research. I was working in three departments at once, Mathematics, Economics and Geophysics.

L: ***This leads into the question about your study on deconvolution. Your excellent article "The MIT Geophysical Analysis Group from inception to 1954" appears in the July-August 2005 issue of Geophysics. Your 1954 MIT PhD Thesis "Predictive Decomposition of Time Series with Application to Seismic Exploration" had a huge impact. Did you have any idea at the time that it would influence processing for decades to come?***

E: The GAG showed that deconvolution could be done in seismic exploration on a routine basis. The GAG had involved

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Raytheon in deconvolution, and they offered the service to the oil industry in 1954. However, at that time the scale of today's digital processing could not be foreseen. Nobody envisaged the silicon chip. Its invention made computer power available to everyone. The computer revolution that we are going through is unprecedented. In fact I think I am just starting to appreciate all of the implications. It is changing how people do almost everything. Today people buy a computer for about $500.00 that could not even have been imagined in 1954.

L: 1954 was probably the greatest year in exploration geophysics: Your MIT Thesis on predictive decomposition, Vibroseis at Conoco, and Harry Mayne's CDP. It was a great year. Digital seismic analysis propagated through the oil and gas companies in the late 50s or early 60s. So how did this transition take place and was it automatic?

E: The transition was not automatic; it took time. In the 1950s many, in fact most, sedimentary basins were labeled NR, "No Record." The reason was that few or no reflections could be seen on the seismic records from these regions. Any oil discoveries in such regions were largely dependent upon geologic or other considerations to fill in the missing seismic. Because of reverberations there could be little exploration at sea. The discovery rate was very low in NR regions, and yet they held tremendous potential. When I showed up as a new research assistant in the fall of 1950, Prof. Wadsworth handed me eight NR records that Professor Hurley had obtained from the Magnolia Petroleum Company. They were the old paper records with the traces as wiggly lines. Four of the records had four traces each, two had five traces each, and two had six traces each, making a total of 38 traces in all. Professor Wiener had done mathematical research on autocorrelations and power spectra and he was interested in applications to data. He was used to working with people in the electrical engineering department, and everything they did was analog. Influenced by the ENIAC, I went digital. I took a straight edge and triangle and digitized the traces at a spacing of 2.5 milliseconds. For the fall semester, most of my efforts were spent on spectral analysis. Wadsworth knew Professor John Tukey of Bell Telephone Laboratories, and I was able to correspond with him. I used his spectral methods and computed autocorrelations and spectra, and determined the coherency between traces. This work was the first application of Tukey's methods to multichannel data. However, with the small amount of seismic data we had, the coherency approach could never pinpoint the unseen reflections. In the

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spring of 1951, I took Samuelson's course on economic analysis. Samuelson was probably the best teacher I have ever seen, even though he was primarily a research person. Among other things the course covered Professor Schumpeter's work at Harvard on economic innovations. Schumpeter said that the innovations are unpredictable. Now I turned to Wiener's prediction theory. How would one uncover economic innovations? If you are predicting an economic times series, and if a big unpredictable event comes in, then that event would indicate an innovation. Thus large prediction errors occur at the time instants at which innovations occur; today we know this process as deconvolution. I thought: Let's do the same thing on a seismic trace. We can uncover the unseen reflections by seeking out the instants of time where big prediction errors occur. Virginia Woodward did the computations on a desk calculator for a few weeks during the summer of 1951. The large prediction errors occurred at the times where, according to Magnolia, the reflections should occur. Deconvolution worked. Professor Hurley was overjoyed, but the mathematicians showed little interest. In the fall of 1951, Professor Hurley took the results to Dayton Clewell, who was head of geophysical research at Magnolia in Dallas, Texas. Clewell said, "Well, this is wonderful but it is no good. It can't be implemented on a production basis because it requires too many hand calculations." Yes, it was clear that it would be impractical to do seismic processing by hand. Clewell did not know about digital computers, but I had just learned about the availability of Whirlwind. Whirlwind was a digital computer built at MIT originally for the Navy, but appropriated by the Air Force to serve as the heart of the air defence system for the United States. In 1951 the Air Force allocated some time on Whirlwind for use by the academic people. In the fall of 1951 and the spring of 1952 Howard Briscoe, who was an undergraduate in Geophysics, and I coded the first deconvolution programs. Meanwhile MIT set up the Geophysical Analysis Group (GAG), which got underway in February 1952. The programs were used on additional seismic records and the results were presented to the oil and geophysical companies at a meeting in August 1952. The end result was that fourteen oil and geophysical companies supported the GAG, starting in February 1953.

It was exciting getting the GAG going. The GAG enlisted Raytheon, who coded deconvolution on the Ferranti digital computer in Toronto. That was very exciting, and by 1954 the GAG had established that deconvolution worked on a variety of NR seismic records. In my 1954 thesis I introduced the seismic convolutional model as a justification for deconvolution. The exploration people liked the results of deconvolution, but they didn't like the agony of digital computers. The memories (RAM) of the computers that we used were electrostatic, which was unreliable. The oil companies concluded that they could not depend on such finicky machines for production seismic work. They made the decision to stick with analog methods. However, Jay Forrester at MIT invented magnetic core memory and had just installed it on Whirlwind. This reliable memory was soon installed on every other large digital computer. However, computers still suffered from the failure of vacuum tubes. By the late 1950s and early 1960s, with the replacement of vacuum tubes with transistors, the new computers were considered good enough to do seismic processing. That's when the oil companies decided to get into digital seismic processing full speed ahead.

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L: ***You have talked about a number of landmarks in your career and your scientific interest but have you been able to find spare time for any other interests? I know you have done some research into history, the witchcraft trials.***

E: It is a very appropriate question because tomorrow is Halloween. Many people have an interest in witches and magic. Salem, which used to be a sleepy old town, has now become the witch centre of the world. In the old days, to have convicted witches on your family tree was considered a disgrace. My aunt Nellie, who kept the family history, never mentioned this part. About twenty years ago I was watching Three Sovereigns for Sarah on Public Television. I had tuned in late and saw about eight people in a horse cart going up a hill in Salem to be hanged as witches. One was Samuel Wardwell from Andover and I knew that my grandmother's family were Wardwells of Andover, all descended from Samuel Wardwell. I was upset and wanted to know what happened. I read all the books. In almost any situation there are theoretical people and there are practical people. If you look back to Massachusetts in the witchcraft days, the theoreticians were the ministers and the magistrates. They had book learning. They set forth the theory of witchcraft. The practical people were the farmers and craftsmen. They had little book learning and did not have much influence in the running of things. The witchcraft was presented as a theoretical argument in the churches and the courts. In the Salem incidents a lot of practical people were accused of witchcraft. The theoretical people wrote nearly all of the contemporary accounts. And even today, the academicians who write the books tend to look at the Salem witchcraft trials from a theoretical point of view. On the other hand, I distanced myself from the theoretical arguments and wrote about the practical side. I looked at the relationship between families, and the various alliances that were formed. It was clear that the desire to obtain someone else's land or to gain some other advantage entered significantly into the equation. My book was entirely from the point of view of the people who were accused. There was a tremendous response, not from the academicians who ignored the book, but from the many people who understood the practical side of human events. Although Salem witchcraft was couched in terms of theoretical arguments, it was primarily driven by practical considerations. The nineteenth-century writer Nathaniel Hawthorne had it right. In Hawthorne's book, 'The House of the Seven Gables', the fictional carpenter Mathew Maule is executed for the crime of witchcraft because the fictional Colonel Pyncheon wants Maule's land. Nathaniel had changed his name to Hawthorne from Hathorne. Nathaniel's great great grandfather was John Hathorne, the magistrate most involved in the witchcraft accusations. In the Salem trials, the only carpenter executed for witchcraft was Samuel Wardwell, who was hanged along with seven others on September 22, 1692. Samuel's wife Sarah (now his widow) was the owner of valuable acreage in the town of Lynn, which she had inherited in 1672. In January 1693, Sarah was sentenced to death for witchcraft, but she was reprieved at the last minute by the governor. Yet the loss of all civil rights legally consequent to a death sentence remained in place. Her lands in Lynn were confiscated, falling into the hands of John Hathorne and the other magistrates who divided the plunder of the witch hunt. In Nathaniel Hawthorne's words, they took "possession of the ill-gotten spoil with the black stain of blood sunken deep into it."

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L: ***Yes, you were one of these people that bridged that gap. I found that your books were exceptionally good at explaining things in your teaching. This relates to questions about teaching. What do you enjoy most about teaching? Maybe there's a bit of witchcraft too, to get the message across to students. Do you have to be a bit of an actor as a teacher? You have done an exceptional job in your books of teaching people you maybe never even met. Of course, at the University of Tulsa and at Columbia University, you had classes.***

E: I remember that my French teacher at High School said, "I am really an actor. I get up and act out the French language." He was a good teacher. I don't think it is necessary for a teacher to be an actor but it is important to love the subject matter. The most discouraging thing in geophysics is that it is either feast or famine for the students. Either there are plenty of jobs available or no jobs. My solution is to say, "Learn computing because you can always do that." And that did work out well over the years. Geophysics has a bright future. All of the big problems facing mankind, like global warming, are in essence geophysical problems. Of course, many academics have little interest in exploration, but when it comes down to solving such problems, you need the methods of exploration geophysics.

L: ***You mentioned Samuelson being a great researcher and a teacher. I guess we could put Richard Feynman in that category. There is a question how a Professor should balance research, teaching and administration. Unfortunately administration seems like a huge sponge; it can take all of a professor's time.***

E: I think that computers often make administration much more pervasive. An email usually wants an instant answer and many emails come every day. You become part of a big network and that eats up time.

L: ***As an academic, you also did an exceptional amount of great writing: the perception, sharing, experience, knowledge, insight. You have an incredible output in terms of books and papers. What drew you to writing? My question is: Does inspiration come periodically, constantly or in episodic eruptions like Mt. St. Helens? Do you have dry spells and then times when you find you can really put it all down on paper. How does that come about? Because I think you are probably the leading writer of books of exploration geophysics.***

E: I think Thomas Edison said: It's 95 percent perspiration and 5 percent inspiration. You have to put in that 95 percent. Unfortunately many brilliant people never write down anything. It is a shame.

L: ***Do you re-write a lot of your work, i.e. do you put a draft together and find you rewrite a lot of it? Have you used both word processor and pencil and paper.***

E: In the old days, when you wrote with pencil and paper, it was more efficient in the sense that you were forced to plan the book carefully in advance and then write it down. As a consequence, you had a limited amount of re-writing to do. On a computer you tend to put down a lot of stuff, and then you keep moving it around. With the computer it is easier, but it is still good to have a pencil handy. In mathematics, computers have really been helpful. A computer can not only do the mathematical calculations, but also draw pictures and typeset equations.

L: ***It's so easy now. The papers look beautiful. I guess the incredible disadvantage is that we start to believe what we have typed.***

S: ***Larry, do you work on the computer? Or do you still write it out?***

L: ***Basically I use a word processor most of the time, but I still take the hard copy and mark it up. I find that a bit easier, so I am somewhere in between. Some nights when I am writing, I know I should quit for I am just not ready. In the morning I'll look and ask: "I wrote that?" I was curious because I guess I knew Enders before I even met him at an SEG meeting 30 years ago. I had these books by this guy Enders Robinson. The Robinson-Treitel reader was out there and several books. There was one on multichannel filtering with Fortran codes. I think that saved me at least 6 months in Graduate School, maybe more. It was a great book because the programs were modular, so when I saw Enders at the SEG I just about dropped my tray of slides. This is Enders Robinson. I knew Sven Treitel from before (he was on my committee), but of course Robinson and Treitel, that was essentially the birth of digital time series. I was nervous before my talk, but both you and Sven calmed me down. Then when I went to the Amoco Lab, Sven took care of my air ticket for me. You were really nice guys. That impressed me as much as all of your achievements in research and in writing papers, all these papers you two wrote.***

S: ***We interviewed Sven a couple of years ago when he was here. Are you re-writing or revising your book?***

E: Yes, we are revising it. It's taking time.

L: ***There is concern about R&D in the industry. It seems like it is greatly diminished from what it was. In the heyday of Amoco Research when you were a consultant to the Amoco Research Lab, with the funding of industry and the freedom of the***

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University, that was about the ideal situation. Today I don't think that is the case.

S: Research is funded for the short term. There are no long-term plans for doing some basic research. There is a lot of concern about that, but I don't see anything forthcoming.

E: What's happening today is not just in geophysics, not just in the oil industry, but it is a general trend. Society goes through different acts. Act One has the pioneers. In the oil industry, Colonel Drake was a pioneer; he drilled the first successful oil well in 1859. Other pioneers discovered Spindletop in 1901 and other big oil fields. In the 1920s, Act Two began. Inventors got the seismic method working, perfected the computer, and developed transistors and integrated circuits. Act Three brings managers, and they built the big industries based upon the inventions. The pioneers would be astonished at the large industries so formed. Originally oil was needed for kerosene lamps, not for the automobile, which had yet to be invented. Then all of a sudden you have General Motors and Standard Oil, huge corporations. Act Four, the decline, comes after the peak. Financial people take over the industries. The Wall Street tycoons, the bankers, and the financiers buy and sell, acquire and merge, and downsize and outsource. Research is very predominant in the invention phase. It is also predominant in the management phase, because the manager understands the value of success. But when the financiers take over, executive pay skyrockets and research goes out the window. Unfortunately that is sort of the position we are in today. Any research today is not long-term; it is for some immediate problem that brings in money. You see the demise of all the big industrial research labs, like those of Bell Telephone, General Electric, IBM, and the oil companies. They are all disappearing, and government money as well is going into more immediate things. Universities also are looking for quick money and concentrate on immediate things, and not long-range projects. We feel this effect in geophysics too. It is a general trend, but still I think there is a bright future in geophysics. However, a lot depends upon geophysics being used successfully. Nearly everything affecting the planet must be investigated from the geophysical standpoint. Our natural resources need to be better conserved and better utilized, and that depends upon geophysics. Alternative energy depends on geophysics as to the location of materials, water supplies, and suitable sites and the disposal of wastes. The sequestering of carbon dioxide is a geophysical problem. If we look at geophysics in the broad picture, we have a tremendous future. If geophysics were not used, the world would enter into Act Five, the denouement, and we do not want to go there.

L: Let us return to the question you partly addressed before about students pursuing a career in geophysics. What skills would you advise them to acquire? You mentioned computer science. I would imagine you put physics and math in there as well and geology, certainly geology? I suppose these days with development, a bit of petroleum engineering perhaps would be good. It's a big order. In fact I guess it's going to be more than a four-year program to do all that. We are facing the question of the enrolment of enough students. At our University, the number of students is not declining, especially in Graduate School, but generally speaking they are across the country.

S: In the Western World I think it is so.

L: Yes, I think the University of Calgary is an anomaly in that respect. As to the question of recruiting and getting the word out to High School students and students in early university years to excite them to take geophysics, it doesn't seem like we are doing as good a job as we might.

E: I feel that we are caught up in this trend because there is not the excitement in science that you used to see.

S: That's right. Maybe the money part of it enters in. They find they are not earning that kind of money that other disciplines offer, like business administration.

E: That's it. When the financial people took over, naturally the money gravitated to the financial end, and the science money is no longer there. For example, you see it when geophysicists leave their field and go into law and make much more money.

L: You mentioned John Nash and you probably read the book – A Beautiful Mind—and saw the movie. How authentic is the movie or the book?

E: Sylvia Nassar, the author, dedicated the book to Alicia Larde Nash, who is John's wife. Alicia has devoted her life to John and she well deserves the recognition that both the book and the movie give her. For the academic year 1955-1956, I was an instructor in the MIT mathematics department, and John Nash was an assistant professor. That's when I got to know John well, although I had known him before that. We became good friends for we had a common interest in economic analysis. He would come to my office about 5 or 6 PM and say let's go and eat. Often Alicia would join us. In July 1956 I went to New York and worked for Standard Oil Company (New Jersey). John took a leave from MIT to spend the academic year 1956-1957 at the Institute of Advanced Study in Princeton. He chose to live in Manhattan and commute to Princeton on the train. His first apartment, in a low rent area just outside of Greenwich Village, was what is known as a cold-water flat. A heavy iron bathtub was bolted down in the middle of the kitchen floor. He told me that water heated on the stove could be transferred more easily to a bathtub placed there than somewhere else. Soon Alicia moved to New York, and John and Alicia were married in February 1957. They rented a nice apartment near New York University from a professor on academic leave. The apartment was large and cheerful, and the walls were lined with bookcases filled with the books of the absent professor. I would have dinner there with John and Alicia. Everything was perfect. However John was being recast into the likeness of a "respectable" professor. John did not fit the mould. John and Alicia went back to MIT and I ended up in Mathematics at the University of Wisconsin. I still remember the last postcard that I received from John. It was in 1958. Among other recommendations, he wrote in large letters, "Sell New Jersey Zinc." The

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mines of that ill-fated company were a mile deep and as black as pitch. The postcard seemed like an omen. I went back to Massachusetts for Christmas 1958 to be with family. John telephoned me to go to a Christmas party in Cambridge given by Andrew Gleason, a Harvard mathematics professor who is justly famous for his work on one of Hilbert's unsolved problems. Alicia and John picked me up in their car, and we went to the party and had a good time. To me, John was just the same as always. After the party they drove me back. A few months later, in April 1959, I learned that John had been sent to McLean Hospital, a psychiatric hospital. This was beginning of a downward journey that over the next several years subjected John to hospitalization and to drug and shock treatments. The movie shows one such treatment, grim. The movie is a script written from the book slanted with a Hollywood viewpoint. Entirely fictitious scenes were added to the movie for effect. John was neither as eccentric nor as glamorous as the movie portrays. Along with others, I believe that John's condition was not as bad as imagined. I feel that the treatments were worse than the ailment. Instead, John should have been allowed to revert to his old ways with no set schedule either at work or at home. He was better off in the cold-water flat. The treatments took away his memory and he was finished as a mathematician. A comparable case is that of Ernest Hemmingway, the writer, who was hospitalized and given shock treatments. The result was that Hemmingway lost his memory, and his life as a writer was finished. The pity was that people looked upon John as a distinguished professor who should act as such. They thought that the treatments would render him "normal." They did not truly understand the sensitive and somewhat childlike person underneath and they would not accept John as he was. Today we, as a people, are much more forgiving, and the old destructive types of shock treatments are no longer used.

S: Let me ask you this, during your career you've received many awards and have been recognized by many professional societies. So, out of these, which awards do you value the most?

E: Well, I think, looking back, it is the Maurice Ewing Award. I would like to add that it is time for Larry to be given the Ewing Award. And also it is time for Brian Russell and Tad

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Ulrych. All are deserving. Canadians represent the best in geophysics.

L: ***Canada depends a lot on natural resources, given the immensity of the country and the resources that are there. We need to find ways to develop them in an environmentally responsible way and in an expeditious way. It's an exciting time in geophysics. I personally feel that geophysicists should never be out of work. There is so much to be done. There are so many challenges. It is a pity that the petroleum industry is up and down; it is very cyclical. You can see that with our enrollment at the University of Calgary. It sort of tracks the price of oil.***

E: I do think that now you are going to see it go up.

L: ***I think so. Yes, I think you are going to see continued demand for petroleum.***

E: Yes, oil is far from being finished

S: ***I think we have a bright future. I remember when I first started in the industry, it was "we'll be finished soon," but after 30 years it's still the same picture.***

E: Yes, the same picture. I read a book written about 1923 and it said that oil will last about 15 more years. And that's what everybody is saying now: "it's the end of oil." It's not the end of oil. And that's my talk tomorrow. It's not the end, but it would be the end if we as geophysicists give up. It's up to us. Geophysicists have to make the decision, because if we were to say, "oil is finished," then it would come true.

S: ***It is a little more challenging now and that's fine.***

L: ***Yes, I think we are up to the challenge. It's not just energy. There are chemicals and plastics. Oil is used everywhere, not only for energy.***

S: ***What would you tell a person considering taking up a career in geophysics? What are the most rewarding aspects according to you?***

E: Not only do we as geophysicists have to find all these resources, but also we have to do it in an environmentally conscious way. The safe disposal of waste materials and all the other factors depend upon geophysics. There is a lot of unsolved problems and this makes geophysics a very rewarding field.

S: ***When you look back on your life and career is it a feeling of satisfaction, or happiness, or relief or what?***

E: Well, geophysics provides wonderful opportunities, but most of all it is the people in geophysics. They certainly are a special type of individual that you won't find anywhere else. I would say that geophysics attracts the best people from an overall point of view. They might not be the most people, but they are the best.

S: ***Thank you very much, Enders, it was a pleasure talking to you and knowing more about you.***

E: You are welcome. It is my pleasure. R