

The John A. Hudson Issue



1940-2019

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ARMA E-NEWSLETTER

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Editor's Note

This issue of ARMA Letters is dedicated to remembering John Hudson, former Ph.D student in Rock Mechanics at the University of Minnesota (1965-70); Professor of Earth Science and Engineering at the Imperial College, London; Editor of the International Journal of Rock Mechanics & Mining Sciences (1983 – 2006); President of ISRM (2007 – 2011); Fellow of the Royal Academy of Engineering (FREng), UK; Fellow of the American Rock Mechanics Association (ARMA); and author of several highly rated books and numerous scientific papers on rock mechanics.

John, one of the most known rock mechanics scientists/engineers of his generation, passed away on February 13, 2019 after suffering a major stroke a few months earlier. His death came to most of us as an unmitigated shock. Even though he had been involved in the field of rock mechanics for the past fifty years, to us and his many friends around the globe, he was still young at heart, and always very productive. Carol, his wife of nearly sixty years, told us that he had just put the finishing touches on a new rock mechanics book he had co-authored when the stroke occurred.

I met John in the mid 1960's, when he enrolled as a Ph.D student at the University of Minnesota, and joined Professor Charles Fairhurst's rock mechanics group. I had been a graduate student there since 1963, and was eager to show John my lab, where for the first time ever we were performing hydraulic fracturing experiments using an MTS-developed servo-control system. John found that system a very interesting concept, one that he later used in initiating the first use of servo-control to conduct uniaxial and triaxial testing of rock samples. Through the exchange of test-related ideas, we became close friends.

After my Ph.D graduation in 1968, I moved to industry, but a couple of years later I joined the University of Wisconsin-Madison as an Assistant Professor in rock mechanics. Soon after that, John received his Ph.D degree. The short distance between Minneapolis and Madison enabled frequent visits and close cooperation on research projects. Several years later, John returned to the UK to take up a post at the Building Research Establishment, but our friendship continued. I visited him several times in Welwyn Garden City, our families toured Scotland together on one occasion, and we spent a relaxing vacation in Cornwall on another. In 1979, at my invitation, John spent a year at the University of Wisconsin-Madison as a visiting professor. There he met my Ph.D student, Paul LaPointe. This led to a remarkable collaboration between them that resulted in several innovations, including a new method of collecting and analyzing fracture data, and the mathematical characterization of natural fractures. These are summarized in two journal articles and a GSA Special Publication (See enclosed tribute by Paul LaPointe).

In the early 1980's John joined the faculty of Imperial College of London. That is where his career really flourished, in teaching, research, and consulting. His international reputation grew immensely through his highly praised

editing of the International Journal of Rock Mechanics and Mining Sciences, and his top positions in ISRM. His many achievements are described in the enclosed tributes by his graduate studies advisor, Charles Fairhurst, and some of his many collaborators.

What was the secret to John's extremely successful career? Without a doubt, his wife Carol (Ph.D in Dentistry), who partnered with John in his diverse research, consulting, and public service activities.

John's many close friends around the world mourn his untimely death. ARMA Letters celebrates his life through the pages of this Special Issue, "The John Hudson Issue".

*Bezalel Haimson Chair,
Publications Committee*

Dr. John A. Hudson – In Memoriam

Submitted by Charles Fairhurst, Emeritus Professor and Chair of the Department of Civil and Environmental Engineering, University of Minnesota.

The rock mechanics and rock engineering community has lost an international leader; many of us have also lost a dear friend.

A brief summary of John's remarkable professional accomplishments is provided on the website of the International Society for Rock Mechanics and Rock Engineering (ISRM) of which he was President from 2007 to 2011. (See <https://www.isrm.net/gca/index.php?id=1022>.)

My first meeting with John Hudson was when he arrived at the University of Minnesota in 1965 to pursue graduate studies in rock mechanics. He has described how he came to choose Minnesota. He was finishing a mining engineering degree at Heriot-Watt University in Edinburgh, Scotland. One of his professors, MacAdam, asked him what he wanted to do next, and he responded that he wanted to study a combination of mathematics and geology, but there was no such subject. As John recalled:

"A few weeks later.....MacAdam came running down the corridor waving a green sheet of paper¹ saying that in fact there was such a subject — it was called rock mechanics. Not only that, but the University of



Carol Hudson stands beside their new Camaro in front of their Minneapolis apartment.

Minnesota was offering financial support leading to a Ph.D. degree. This opportunity solved two of my problems: it provided the circumstances for research into the subject that I wanted and, because I had no money, the opportunity to earn some."²

As an undergraduate in Scotland, John had dreamed of owning a car — but it had remained a dream! In Minneapolis, public transportation was less convenient, and a car became a necessity!

As John noted, he and Carol

'...started off with one Plymouth and then another Plymouth — both ancient and each costing around \$40³. Then came the wonderful day when we bought a

¹ The 'green piece of paper' to which John refers was the announcement that I had prepared describing the rock mechanics program at the University. An earlier announcement sent to U.S. universities only had not attracted much response. Most of the initial group of students in the Minnesota Rock Mechanics program had seen the same 'green piece of paper.'

² Unless attributed otherwise, the quotations in this note are extracts from the book *Charles Fairhurst, The Long Shadow* (2018) Itasca Consulting Group, Minneapolis, MN, USA.

³ \$40 in 1965 is equivalent to about \$300 in 2019.

new 5 litre Camaro in British racing green with a white stripe across the front. This was one of the most wonderful days of my life. We subsequently travelled to many parts of the USA and Canada in this car."

John completed his Ph.D. thesis in 1970,⁴ and remained for a further two years as a Post-Doctoral Fellow. It was during the latter period that another Post-Doctoral Fellow, Dr. E. T. (Ted) Brown, joined the group in Minnesota. Ted and John formed a professional partnership and personal friendship that endured throughout their entire careers. (Ted has prepared a memorial as part of an ISRM tribute to John to take place during the ISRM International Congress, September 23-28, 2019, Foz do Iguaçu, Brazil.) Both Ted (1983-1987) and John (2011-2015) served as ISRM President. Both spent considerable periods associated with the rock mechanics program at Imperial College of Science and Technology, London (Ted, 1975-87; John, 1983 - on)

Bright and keen to learn, John and several of his colleagues enjoyed challenging the 'established wisdom' of visiting lecturers. He was also a leader, introducing rules that he felt should be followed, especially for anyone using potentially dangerous

equipment in the laboratory. For example, when the servo-controlled testing machine for rock was the first such developed by the company, MTS, John became very concerned about the potential for serious accidents, especially if the machine was operated by inexperienced users. He took it upon himself to develop an Operator's License, awarded to anyone proposing to use the machine, but only after the individual had passed a test demonstrating proficiency -- and gaining an awareness of possible dangers.

John recognized that rock mechanics/rock engineering was a truly international discipline. Information on the deformation behavior of a rock mass required observations on large scale projects in rock -- and these projects arise worldwide. The same is true of theoretical and applied contributions; they can be made by scientists and engineers in any part of the world.

Although he worked unceasingly to develop communication and interaction among colleagues internationally, John was considered by many as the 'quint-essential Englishman,'⁵ and was proud of his national heritage. As Chairman of the first ISRM EUROCK Symposium in September, 1992, John was able to showcase the picturesque walled Roman city of Chester,

⁴ Thesis topic: "A Critical Examination of Indirect Tensile Tests for Brittle Rocks."

⁵ John was actually born in Cardiff, Wales.



Dr. Ted Brown and Raquel Derrenberger, Senior Laboratory Technician, Rock Mechanics, with the servo-controlled rock testing machine.

UK, while organizing valuable technical discussion.

Although always a champion of ISRM, and “one of the most active members ever of our Society,”⁶ John’s period as President was perhaps the one that he found most challenging — and satisfying.

John strived constantly to develop international dialog and communication. During his presidency, (2007- 2011) he worked vigorously with his Chinese colleagues, especially Professor Qian Qihu and Professor Xia-Ting Feng, to ensure that the 12th International Congress, to be held in Beijing in 2011, was the success that it proved to be. China is now the center of international activity in rock mechanics and rock engineering. John worked closely with the incoming ISRM President, Professor Xia-Ting Feng of China, to produce the five volume CRC publication *Rock Mechanics and Engineering* in 2017⁷ with Professor Feng as Editor and John as Editorial Advisor. This updates the earlier (1993) five volume Pergamon Press publication, *Comprehensive Rock Engineering - Principles, Practices, & Projects* — for which John was Editor-in-Chief.

John’s influence and participation in rock mechanics was also well known in the USA. He was a frequent visitor. In 2009, he was the first non-US citizen elected a Fellow of ARMA.

⁶ ISRM Secretary General Luis Lamas. See https://www.isrm.net/adm/newsletter/ver_html.php?id_newsletter=166

⁷ See <https://www.crcpress.com/Rock-Mechanics-and-Engineering-5-volume-set/Feng/p/book/9781138027640>

Formation of the ISRM in 1962 by Dr Leopold Müller was a bold step intended to draw international attention to the global importance of rock mechanics and rock engineering, especially on the large-scale of rock engineering projects. Enthusiasm was high initially,⁸ but the launch of Sputnik 1 on October 4, 1957 ushered in the ‘Space Race’ and a global interest in exploration of ‘Outer Space’.⁹ The ongoing and unprecedented world-wide technological revolution in space exploration has brought many benefits — but interest in rock mechanics/rock engineering (i.e. ‘Inner Space’) has waned considerably, certainly in the U.S., Europe and other regions of the world. John Hudson’s productive career was achieved against this ‘backdrop’ of very limited interest globally in the subject of rock mechanics and rock engineering.

Current concern over global issues such as climate change; world population increase; infrastructure decay in developed regions; radioactive waste isolation; carbon sequestration and still others suggests that interest in preserving the quality of life on Earth and the Earth’s sub-surface — may at last start to re-

⁸ The first Rock Mechanics Symposium in the U.S. was held in April 1956 at the Colorado School of Mines. It was the start of the annual U.S. conference series now sponsored by ARMA

⁹ In the U.S., NASA(National Aeronautics and Space Administration) has an annual budget currently around \$18 billion (US). China, Europe and other regions also have vigorous space exploration programs.



Eurock '92 - First ISRM European Symposium: Chester, UK, Sept.1992. John Hudson, Chairman.

Left to Right; Carol and John Hudson; Lord Mayor John Randall of Chester and Lady Mayoress Randall; ISRM President Charles Fairhurst and Margaret Fairhurst.

ceive the attention – especially for associated government financial support, for university graduate programs - that is needed.

The following comments are from key members of the U.S. Apollo Program, when asked recently to reflect on their participation in the Program.¹⁰

We set out to explore the Moon and instead discovered the Earth. The sense of isolation — and closeness — of our humanity. I wish more people would think on it. — Astronaut Frank Borman

We felt we were going there to show you the Moon. No! We went to the Moon; we learned a lot about the Moon; but most of all we learned about a new way to look at the Earth. — John Aaron, Mission Control, Apollo 8

¹⁰ NOVA (2018) Apollo's Daring Mission: Apollo astronauts and engineers tell the inside story of the first manned mission to the moon, aired on PBS December 26, 2018. <https://www.pbs.org/wgbh/nova/video/apollos-daring-mission/> (See video segment from approximately 51 min 30 sec. to 53 min).

Having that unifying experience, I think, is a very profound and moving moment for people on Earth. We are all on the one spaceship together; we'd better start taking care of it. — Frances (Poppy) Northcutt, Mathematician, Apollo 8.

John would have been in the forefront of colleagues applauding — and drawing attention to these comments.

We owe him the obligation to pick up the torch and continue his important and untiring efforts.

Last, but by no means least, thank you Carol for your love and support of John throughout. He recognized this — and so do we. Without you, John would not have made the great contributions that he did. Thank you!



Part of the early UMN Rock Mechanics Student Group ARMA Symposium, University of Minnesota, June 2014

In rows (from left). Front -Bezalel Haimson, Charles Fairhurst, Steve Crouch. Middle -Wolfgang Wawersik, Jaak Daemen, John Hudson, Jean-Claude Roegiers. Top - François Cornet, Emmanuel Detournay, Michael Hardy.

We Will Miss Professor John A. Hudson

Submitted by Xia-Ting Feng, Northeastern University, Shenyang 110819, China.

"I wrote this tribute to express my respect and admiration for John Hudson."

I was extremely sad to hear the news that Professor John Anthony Hudson, a superstar in rock mechanics, passed away on February 13, 2019. His death is a great loss to our community of rock mechanics and rock engineering. Through his career, Professor Hudson made outstanding contributions in rock mechanics education, research and practice.

His accomplishments were many. Professor Hudson supervised 17 Ph.D students and 50 M.Sc. students at Imperial College of London. He was elected as a Fellow of the UK Royal Academy of Engineering (FREng) in 1998 and became a Fellow of the American Rock Mechanics Association (ARMA) in 2009.

Since 1985, Professor Hudson was also an independent consultant on more than 150 projects around the world. He has held Adjunct/Visiting/Honorary professorships at several institutions in different countries, including China. He has also given Short Courses on the principles of rock mechanics in many countries, including Lecture Tours in China, and has written more than 200 papers and several books. Two of these books have been translated into Chinese.

He was the Editor of the International Journal of Rock Mechanics & Mining Sciences for 23 years from 1983 to 2006 during which time he assisted many Chinese authors in successfully publishing their papers in the journal.

Contributions through ISRM

Professor Hudson was President of the ISRM (International Society for Rock Mechanics) from 2007 to 2011. Some of the new initiatives stimulated by his ISRM 'modernization' theme and implemented during the his leadership of ISRM include:

- Erik Eberhardt's lectures on rock mechanics were made available on the ISRM website as a series of downloadable ISRM Lectures.
- Historic videos of Keynote Lectures at ISRM conferences were made accessible from the ISRM website.
- The ISRM Virtual Library, hosted on the OnePetro website, was launched.
- The new ISRM slide collection was made accessible online.



Professor Hudson with Professor Qian Qihu at 2011 ISRM Congress in Beijing

- The ISRM electronic Newsletter (March 2008) with four Newsletters/year was begun.
- Also on the website, a CD containing pdfs of all the ISRM News Journal Issues from 1996 to 2008 was made available.
- The ISRM Lecture Tours in China in May, 2009 and in Colombia and Peru, 2010 were organized.
- The ISRM Fellows and e-Board Member's Forum, convened at ISRM Congresses to provide advice, was created.
- The ISRM Annual Lecture was initiated.
- The Young Members' Slide Show Competition was also begun.
- The Annual ISRM Technical and Cultural Field Trips were started. The first one in 2009 travelled to the Carrara marble quarries and the Florence region, Italy, and was led by Professor Massimo Coli. The second ISRM Technical and Cultural Annual Field Trip in 2010 traveled to the Lausanne region, Switzerland, and was led by Christophe Bonnard.

Other accomplishments during Professor Hudson's time as president of ISRM were:

- Creation of the ITA-ISRM Joint Action Group on "Site Investigation Strategy for Rock Tunnels" with the aim of preparing a Guidance Document.
- Creation of the ISRM Young Members' Presidential Group.
- Creation of an ISRM policy to consider all languages (according to a revision of the Statutes), but to use only English as the official language.
- Creation of a new commission on design meth-

odology.

- Creation of ISRM Specialized Conferences as a new type of ISRM sponsored event.
- Organizing the ISRM 50th year anniversary celebrations, with associated logo and book; these celebrations started at the ISRM Congress in Beijing in October 2011 and continued to the Stockholm EUROCK meeting in 2012.
- Introducing a new ISRM membership management system.

Contributions to Rock Mechanics in China

Professor Hudson worked extensively with Chinese colleagues over many years in promoting and developing rock mechanics and rock engineering in China. Among these activities are the following:

- Supervised five Chinese Ph.D students at Imperial College in the 1980s: Wei Zhang Qing, Wu Bailin, Wei Lingli, Pan Don, and Jiao Yong. The latter is now Deputy Vice-Minister for Water Resources in China.
- Hosted Chinese Academic Visitors at Imperial College in the UK, including Tang Chun'an and me.
- Through re-writing the English in submitted papers, helped many Chinese authors successfully publish their papers in the International Journal of Rock Mechanics, and Mining Sciences in the period 1983–2006.
- Became an Adjunct Professor in the Chinese Academy of Sciences (Institute of Rock and Soil Mechanics, Wuhan) in 2002.
- Co-chaired with me both of the ISRM SINOROCK Symposia, one held in Yichang in 2004, and then in Hong Kong in 2009.
- Became an Honorary Professor in the Department of Civil Engineering at the University of Hong Kong in 2006.
- Assisted Professor Cai Meifeng in organizing the First and Second ISRM International Young Scholars' Symposia on Rock Mechanics held in 2008 and 2011 in Beijing.
- Designated Honorary Editor of the Chinese Journal of Rock Mechanics and Engineering, serving with the Editor-in-Chief, Professor Feng Xia-Ting.
- Served as a Member of the Editorial Board of the Journal of Rock Mechanics and Geotechnical En-



Professor Hudson with Xia-Ting Feng

ineering, working with Editor-in-Chief. Professor Qian Qihu.

- Became a Visiting Professor for Senior International Scientists of the Chinese Academy of Sciences in 2010.
- Named Leader of the Foreign Delegates for the Chinese Society for Rock Mechanics and Engineering Forum on the Key Technology of Safe and Rapid Construction for the Jinping II Hydropower Station High Overburden and Long Tunnels, 2009.
- Co-authored two books with Chinese colleagues which have been published in the international press by the publishers Taylor and Francis: *Rock Failure Mechanisms: Explained and Illustrated* (co-authored with Professor Chun'an Tang of Dalian University and published in 2010), and *Rock Engineering Design* (co-authored with Xia-Ting Feng and published in 2011).
- Supported Xia-Ting Feng during his presidency of the International Society for Rock Mechanics for the period 2011–2015.
- Served as Co-Chairman (with Professor Qian Qihu) of the Chinese Academy of Engineering International Top-Level Forum on Engineering Science and Technology Development Strategy—Safe Construction and Risk Management of Major Underground Engineering Projects, 2012.

Dr. Hudson has been a tutor to many rock mechanics scientists and researchers worldwide, including myself. Unexpectedly, he left us so soon. His work, his contributions and his devotion to work will be always an inspiration to all of us.

John A. Hudson—A Remembrance

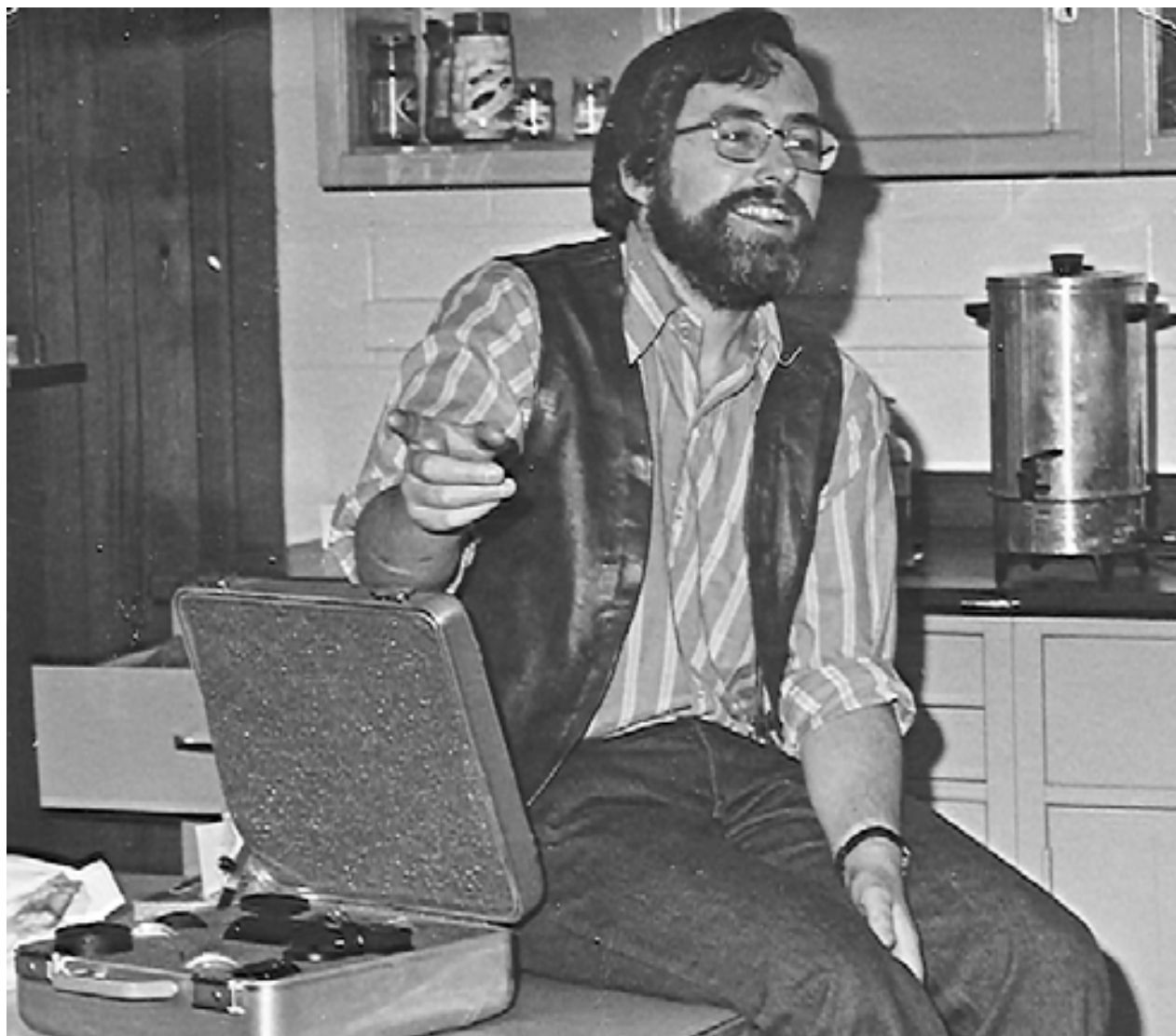
Submitted by Steven L. Crouch, Professor Emeritus, Department of Civil, Environmental, and Geo-Engineering, University of Minnesota.

I join the worldwide community of rock mechanics professionals in mourning the recent passing of our good friend and colleague, John A. Hudson. John was an outstanding leader in the field whose wide-ranging technical contributions will surely stand the test of time. He will also be remembered as an exemplary husband and father and a loyal friend to the many people he worked with during his long, distinguished career.

John and I began our graduate studies together at the University of Minnesota in September 1965. We were part of a group of six or seven new students in a rock mechanics program that had been established in the late 1950s by Charles Fairhurst. I remember those days as a time of hard work but also a time of enlightenment and camaraderie among the students.

We took classes and exams together, we attended seminars together, we sometimes studied together, and we always helped one another when needed. We were fortunate to be part of a program that had a global reach and benefitted greatly from occasional visits and lectures by such rock mechanics luminaries as J. C. Jaeger, N. G. W. Cook, and M. D. G. Salamon. Sometimes those lectures took place on a Saturday morning, but no one ever complained!

I began working more closely with John in 1970 when I returned from South Africa where I had spent two years at the Mining Research Laboratory of the Chamber of Mines of South Africa. I had been hired at the University of Minnesota as an assistant professor and John was a research associate. Over the next two years we were part of a team charged with managing two relatively large research projects, one on the mechanics of coal mine bumps and the other on rock failure and rock mass behavior. John's main role was to expand, equip, and run the rock mechanics laboratory, a task that perfectly suited his organizational





skills and creative leanings and one that he tackled with characteristic zeal. The University had just acquired the first servo-controlled testing machine intended specifically for rock mechanics research, and John designed and built the necessary laboratory infrastructure around this then-novel system. He also took responsibility for training others to use this system and even issued operators' licenses to those who met his stringent safety standards.

It was during this time that John and I collaborated on a review article titled "Soft, Stiff, and Servo-Controlled Testing Machines: A Review with Reference to Rock Failure," (*Engineering Geology*, 1972, Vol. 6, No. 3, pp. 155–189). This article, authored by Hudson, Crouch, and Fairhurst, has had several hundred citations and is still referenced on occasion.

But perhaps the strongest recollection I have of working with John came about because of our (and our project team's) inexperience in running large research projects. We were having such a great time conducting the research that we failed to take notice of the reporting requirements of the sponsoring agencies. Then, one day in the spring of 1971 we became aware that annual reports were soon due on both of the research projects that we were supposed to be managing. At that point we dropped everything else and spent the next week or so writing, editing, and re-writing two annual reports. We started early each morning and worked late into the night. We succeeded in getting the reports issued with no time to spare. Our motto could have been: "Better never



than late." I learned an important lesson about managing projects from that experience. I also learned that John could be counted on as a colleague and friend, something that I can imagine dozens of others learned over the years, too.

In addition to the memories I have of John from those long-ago days I have included a few photographs that show him "at work" in 1971 (or possibly 1972). These photographs were taken by another former student at the University of Minnesota, Michael Voegele, who I thank for preserving them.

The photographs were taken in the rock mechanics laboratory, where John also had his office. The first photograph illustrates my contention that John could light up a room with his presence. He wore that smile as often as he wore that trademark leather vest. The second photograph shows John transacting business of some kind on the telephone. It can be seen from the look on his face as well as the array of books and papers on his desk that the business had to be very serious indeed! Finally, the third photograph shows John, me, and graduate student Krishna Sinha preparing to carry out an experiment. I don't recall what the experiment was about, but I'm sure it was a great success!

I will end this note by saying what a pleasure it was to have known John and to have worked with him, however briefly. When I look at those photographs I can imagine that I'm in the rock mechanics laboratory with John and it's 1971 or 1972 all over again. Sadly, that can't be. Rest in Peace, John.

John Hudson, My Friend and Helpful Colleague

Submitted by Francois Cornet, Ecole et Observatoire des Sciences de la Terre, University of Strasbourg (France)

The very sad news of John's stroke last November, resulting in his death on February 13, has brought back to me some vivid memories of our numerous fruitful interactions.

I first met John in September 1969 at the University of Minnesota, when I joined Charles Fairhurst's Rock Mechanics lab, where John was then a post doc fellow helping freshly arrived graduate students. I had just finished my undergraduate studies in engineering geology in France and had applied as a graduate student to a few American universities. Some of them replied that my mastery of the English language was very poor and prevented me from being admitted; one of them (Berkeley) replied that I would be contacted later when registration for graduate studies would open. Charles Fairhurst answered that I would have to take English lessons in parallel to my rock mechanics education, but that I was welcome to join his group as a graduate student.

This suited me well and I joined the University of Minnesota, where indeed I started my first semester with a lot of English lessons. In December I received a letter from Berkeley telling me that my application was accepted and that I should show up for the first semester of 1970. I was very uncertain about this alternative and discussed the matter extensively with John. He pointed out that the quality of rock mechanics education in Fairhurst's group was top, and that I should think for myself whether I was more interested in the reputation of the university delivering the degree than by the quality of the research program. At that time, I knew nothing about who was doing what in rock mechanics, but I was very impressed by the quality of education I had found in Minneapolis. So, I decided to stay with Charles. It turned out that this would be the first of the many times John would profoundly influence my career.

John Hudson and the development of servo-controlled testing systems

After I passed my preliminary examination allowing me to undertake research toward a Ph.D. degree, Charles assigned me as a research topic the effect of fluids on the compressive strength of rock. Soon after that he departed for an overseas trip. Before leaving, Charles appointed Dr. Chuck Nelson as my temporary advisor, and recommended that I should work

with post doctorate fellows regarding experimental work.

An interesting stiff, thermally controlled, testing system for producing fully controlled stress-strain curves of dry rock samples failing under compression had been developed in the department by a former graduate student, Wolfgang Wawersik. So I started working on this system with the help of Fritz Rummel, a post doctorate fellow in Charles's Rock Mechanics lab. Fritz had adapted the servo-controlled system introduced by Bezalel Haimson for his laboratory experiments on hydraulic fracturing to Wolfgang's press, and was investigating the post failure behavior of rock in compression. In its original version, this testing system was operated in such a way that loading would follow precisely a pattern prescribed by a curve drawn on an electrically conducting support.

Operation of this compression testing system was fairly tedious and not well adapted for conducting tests on saturated rock specimens. During our daily coffee discussions, I talked regularly with John on rock failure, and on the possibility for me to use the system developed by John, together with Ted Brown and Steve Crouch, for investigating rock failure in tension. Their idea was to select a parameter varying monotonically throughout the failure process and impose to it a linear variation through time with time steps of the order of milliseconds.

Based on these ideas, the initial million pound, stiff, servo-controlled, testing system was developed in cooperation with a local company, MTS (Materials Testing Systems), and made available to graduate students in 1972. John helped me design and construct a triaxial cell that allowed continuous monitoring of axial stress and axial strain under constant confining and pore pressure prior to reaching peak strength. Previous work conducted at MIT had shown that crystalline rock samples failing under compression were dilatant, i.e. the rock sample volumetric strain continuously increased after the elastic limit had been reached because of the stable growth of micro-cracks. I decided to use this property for controlling the failure process of saturated porous samples after their peak strength had been reached.

For this purpose, with the help of John, I designed a double loop servo-controlled system to investigate, in a fully controlled, quasi-static manner, the disintegration process of saturated porous rock specimens under compression. The first loop adjusted the axial

load to keep constant the confining pressure. Since rock failure was supposed to be dilatant, as soon as failure would start, confining pressure would increase and the axial load would decrease in order to bring the confining pressure back to the desired value. The second loop imposed a flow of confining fluid out of the pressure cell so that the confining pressure would decrease and the axial load would increase, to compensate for the confining fluid volume loss though the dilatancy of the rock.

On paper this looked perfect and proved very efficient for low confining pressures (500 psi). But when tests were run at a higher confining pressure (2500 psi), the system produced an alarming explosion of the pressure cell that sent pulverized particles and oil throughout the room where the test was conducted — where John was sitting, sipping his coffee. I will never forget John's reaction. He pointed out very casually that, somehow, the system had gone "open loop." In fact these tests showed that the dilatancy of rock was not always a monotonically increasing process during failure. For sufficiently high confining pressures, the development of shear failure implied a drop in shear stress accompanied by an elastic drop in volume for the material surrounding the shearing surface. Failure induced an overall volume decrease of the sample that resulted in a drop in confining pressure, compensated for within milliseconds by a servo-controlled axial load increase, leading to the explosive process. Yes indeed, the system had gone "open loop." This issue was later fixed, and full control of the disintegration process of saturated porous samples was achieved. It produced measurements of the "contractancy" effect caused by shear failure. Interestingly, the technique used for preventing unstable failure is contemplated today as a means for reducing the magnitude of seismic events generated by large scale fluid injections.

After defending my Ph.D thesis, I followed up with a postdoc fellowship financed by the Los Alamos program on Hot Dry Rock geothermal energy development. And again John helped me adapt the servo-controlled system he had developed with Jean Claude Roegiers for monitoring the development of hydraulic fractures in the laboratory. Thanks to John's system, I was able to demonstrate the role of pre-existing fractures on the path of hydraulic fractures and the effect of flow rate. This work has been seminal for me, both for the further development of stress measurements through hydraulic testing, and for the development of efficient hydraulic stimula-

tions techniques for large Enhanced Geothermal Systems (known today as EGS.)

John Hudson and the International Rock Mechanics community

John was a gifted writer and was very helpful in editing articles written in poor English. Upon his return to the United Kingdom, John became the editor-in-chief of the International Journal on Rock Mechanics and Mining Sciences (IJRMMS) and he enrolled me on the editorial board of the journal.

We kept in regular contact over the next twenty five years or so. In particular, he helped me organize special issues of the journal on topics dear to me: forced fluid flow through fractured rock masses, stress measurements and stress field determinations, and fluid induced micro-seismicity.

Together with knowledgeable international colleagues, John took a leading role in the preparation of the gigantic opus on *Comprehensive Rock Engineering* and was more specifically responsible for editing Volume 3 of this five volume treatise. Because of our frequent exchanges on the concept of stress as applied in rock mechanics, we had developed through the years a common view on the topic and he asked me to contribute two articles to his volume -- namely a general text on stress and stress fields and another one more specific on the HTPF technique that I had progressively developed after my experimental work in Minneapolis.

When John became President of the ISRM with its various commissions on specific topics, he asked me in 2003 to participate to the work of the commission on Testing Methods for issues dealing with in situ stress measurements. In this context we published the special issue of IJRMMS titled "ISRM Suggested Methods for Rock Stress Measurements," which has become, over the years, the most cited issue of the journal.

But these are only samples of our common past work. John also contributed to a variety of important rock mechanics topics, one of which I followed more specifically -- the characterization of fracture fields. I have no specific background in statistics and have been very happy to use John's various papers on this topic. I found his seminal paper written together with S.D. Priest very helpful and I refer to it very regularly. In fact, the paper raises important questions on the concept of representative Elementary Volumes, an important issue which I am today exploring further for the definition of large scale stress fields.

And this is certainly a topic for which the distinction between rock mechanics and rock engineering becomes somewhat pointless. The theory helps by introducing rigorous approaches but engineering practice requires that uncertainty be taken into account in no less a rigorous manner. John was excellent at

mastering both, and he was patient enough to transfer his understanding to impatient people like me. I will always keep a keen memory of the time we spent together, our friendship, and the enthusiasm John always exhibited.

John Hudson: A Personal Reflection

Paul LaPointe, Senior Practice Leader and Principal, Golder Associates, Seattle, Washington.

Many key moments in life, for good or ill, are unexpected and are not part of any life's plan. My journey through graduate school resembled one of those twisted and bent trees that you see in the forest. In such forests there are trees with arrow-straight trunks that grew upwards in the same direction from their first sprouting. There are others, however, that have survived and perhaps prospered but have not had such a straightforward growth, twisted and turned as they might be from storms or other events that have blocked their paths. Yet for each bend downward or sideways, there appears to have been something that helped the young tree to grow upward. John Hudson was one of those unexpected, unwarranted and marvelous forces of nature that nurtured the growth of my professional career when it had taken yet another twist, but far more importantly, gave focus and breathed energy into it.

By 1976, I had completed an undergraduate and master's degree in geology, when a series of highly unanticipated events led me to abandon the College of Letters and Sciences after my M.S. and enroll in the College of Engineering to pursue a Ph.D. in Rock Mechanics with Prof. Bezalel Haimson.

My thesis topic was focused on developing methods for improving the mathematical characterization of rock property heterogeneity in large rock engineering sites, incorporating the characterization into finite element-based simulations of stress, strain and displacements, and assessing it against existing approaches. Up to the point of John's arrival at the department in the fall of 1979, I had only been looking at intact rock properties.

John arrived in Madison at the University of Wisconsin for a sabbatical during the academic year 1979-1980. He had been working in the UK with a colleague, Steve Priest, on matters related to the statistical description of natural fractures, especially joints, on which they had published some of the results in a series of articles in the International

Journal of Rock Mechanics. John was evidently keen to continue this work in Madison, because a large, multi-year and multi-disciplinary project to site and construct an underground superconducting energy storage magnet in the Midwest afforded him an opportunity to do so. The funding for my dissertation and for a research assistant came from this project as well.

John presented a series of department seminars on his work with Steve Priest. It immediately caught my attention, because I realized that it was a component of the rock mass that I had largely ignored up to that point in my dissertation work. It simultaneously appealed to both my mathematical/programming bent and to my geological knowledge.

On more than one Saturday morning during that fall, I was one of a number of students that would find ourselves sitting in John's office discussing ways to better collect fracture data and analyze it. One of the ideas John wanted to try out was to collect fracture data along a grid of scanlines, and then to see if we could remove a series of biases that arise from collecting data along linear transects. John enthusiastically organized field trips to a nearby abandoned quarry in Lannon, Wisconsin, where he directed a very diverse group of graduate, undergraduate and work-study students to collect fracture data systematically along scanlines. The photos on page 14 show John explaining some aspects of the fractures at an outcrop in the Lannon quarry, and the students surveying scanlines and collecting fracture data.

Through this effort we were able to obtain a large database of systematically collected fracture data that would serve as a future resource for exploring new ideas for data collection, analysis and application. I became intrigued with the mathematical characterization of natural fractures, because they were very different than intact rock properties that could be treated as a continuum field and demanded new ways of thinking about them, and they were very important for the hydromechanical response of



John Hudson standing next to an outcrop of Niagara Dolomite in the Lannon Quarry, 1979, explaining aspects of the fractures exposed in the outcrop.



Students Karl Buttiens (center) and Esu Esu (right) surveying and collecting fracture data with John in the Lannon Quarry, 1979.

the rock mass. This led to some additional chapters in my thesis, a couple of journal articles with John, and a Special Publication for the Geological Society of America.

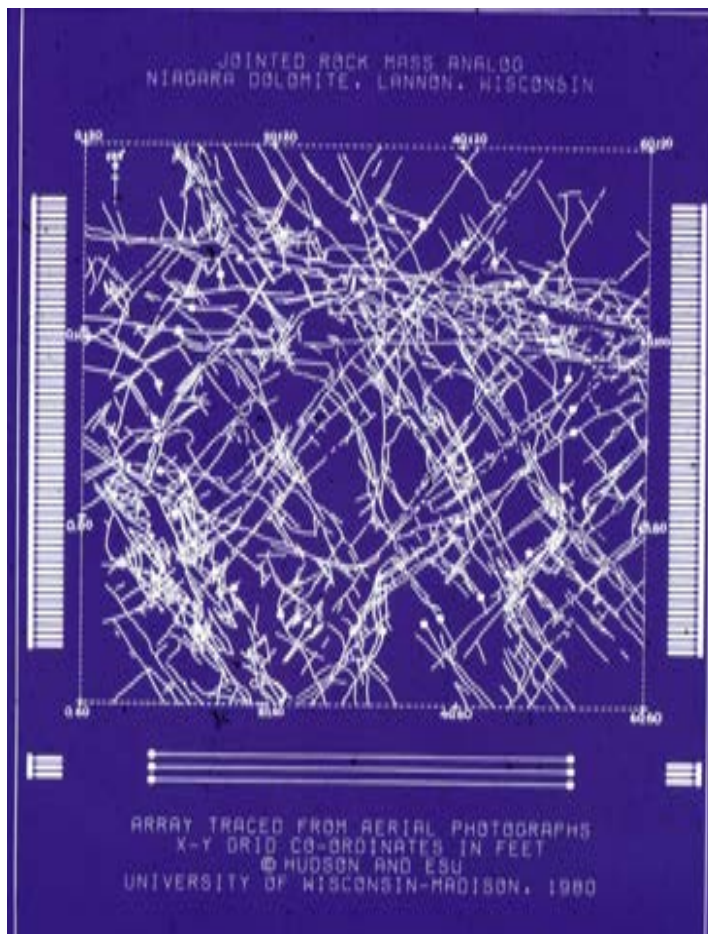
I remember one Saturday morning when we were sitting in John's office after having collected our data from the Lannon quarry, talking about groundwater simulation using networks of resistors and other electrical components — which had been done in the past to solve groundwater problems, prior to the advancement of the computational power of computers in the 1960's. We wondered if you could somehow create a similar pegboard network of electrical components to solve fracture flow problems; somewhere in our discussion, we came up with an idea to make printed circuit boards of fracture networks, but not with circuit board equivalents of resistors and such, but with the actual traces of the fractures. We used the resources within the university to fabricate boards from both actual patterns and those that we generated stochastically using Madison's mainframe computers and line plotters.

We learned a number of interesting new concepts from measuring resistance across the etched fractures in different directions and locations, such as the relation between the principal directions of fracture intensity and the principal directions of flow and flow resistance; the significant impact of fracture termina-

tions; the importance of the chronology of fracture development; and the significant mathematical departure from a tensor representation of permeability even for very simple fracture networks. Although John left Madison at the end of the spring semester in 1980, and I graduated later that summer, we continued to keep in touch and work on some ideas throughout 1980 and 1981.

In September of 1981, I took a job with ARCO to work on a team to commercialize underground coal gasification. I was hired to head up the characterization and modeling of the potential sites, and specifically to incorporate the effects of the natural fractures on cavity growth during gasification and subsequent subsidence above the cavity. In other words, I was hired specifically for the skills and knowledge that I had gained through working with Professor Haimson in Rock Mechanics; the differentiator was that I was seen as being in the forefront of dealing with natural fractures, which were felt to be of significant importance to the process. The influence John had on my professional skills was very important to my first job out of grad school.

By late Spring in 1982, ARCO, other major oil compa-



Examples of printed circuit boards to investigate flow in natural fracture systems.

nies, and national labs had decided that underground coal gasification was unlikely to ever be commercial, and shut down their efforts. I spent about a year working for ARCO's Anaconda subsidiary as a mining engineer doing portal stability and working with field engineers to incorporate natural fracture data into optimizing blasting at ARCO's large open pit Black Thunder coal mine. From there I moved into ARCO Oil & Gas and became part of a structural geology research team located in Texas, where my role was to figure out how to improve recovery from fractured reservoirs. In the fall of 1983, I received a letter from John (There was no internet in those days; unless you had a lot of money to spend on a transatlantic phone call, letters were the common means of communication!) asking if I would be interested in coming to the UK for several weeks to work on some fracture characterization studies in support of nuclear waste repository siting and development research he was undertaking as part of his position with the Building Research Establishment. I knew nothing about the issues related to waste repositories, but it sounded like I might learn some new things that would be of value to the oil and gas work in which I was engaged

— which is how I sold it to my supervisors and managers. The real reason is that I thought it would be great to work with John again, as it had been such a fruitful and fun experience in Madison. So I went to the UK for a number of weeks, spending some of the time living with John and his young family at their house in Welwyn Garden City, and the rest of the time at a nearby boarding house, when we weren't on the road and collecting fracture data underground in the Carnmenellis Granite in Cornwall.

As always, John had a few surprises up his sleeve that had future impacts on my career and personal life. The first was Neville Price. John had also brought in Neville, a Professor of Structural Geology at Imperial College, and author of a significant book on fault and joints that incorporated both geology and mechanics. Neville taught me about mechanical layering and how it affected joint spacing, and gave me a mechanical view of joint formations that I hadn't had before. Mechanical layering has been a significant way in which I have approached 3D joint modeling throughout my career, and I owe John's desire to bring in senior people with great ideas and expose newly-minted professionals to them for giving me tools and concepts that have served me well these many years. As John did in Madison, he never worried about who had what degree or whether they were male, female, young, old, a geologist, an engineer, a student or a senior professor. He cared about ideas, and letting cross-pollination create new concepts and technology. I have always appreciated John's ability to foster enthusiasm which came from his deep desire to learn and explore, and from a non-existent ego. And this experience gave me a new skill and experience for my resume: high level nuclear waste repository fracture work, which has been a significant and rewarding part of my professional career, and I owe it to John.

The next cool thing that John introduced me to was my first experience with a "portable" computer, the InterTec Superbrain, which cost several thousand dollars at the time. Up to that point, all I knew were mainframes, but leave it to John to be in the forefront of something new and promising! He had an early harbinger of all the PCs and related gear that would come into prominence later in the 80's. I got to program it in FORTRAN to analyze joint data and make stereonets using line printer characters so that we could start actually analyzing the joint data *in the field!* That was amazing! It was always like that; if there was something new and on the untested cutting edge of technology, John probably knew about it and was figuring out ways to obtain it and try it out

with his family, friends and professional colleagues.

John was always good for surprises, whether professional or otherwise. On the second day after I had arrived in the UK, John casually mentioned that he had heard that I played chess and had taken the liberty to enter me in the London Open Speed Chess tournament that would be held in a few weeks. I am not sure where John heard that I played chess (I did play chess, fortunately!), but I was not a particularly good player nor had I ever played much speed chess. So rather than cancel the registration, John's solution was the obvious; we would bring a chess board and a clock with us down to Devon and Cornwall where Neville, John and I would play several games against each other every night after dinner.

The tournament was somewhat of a disaster; I won one game in my initial round against an opponent who thought my blunders might be some really clever strategy and he ran out of time before I did. When I got home, I bought an electronic chess board and worked with it a lot, greatly improving my game. When I look back at this chess experience, I think that it showed a lot about John. It was a lot of fun, and it epitomized how John approached life: take on something unknown or that you haven't tried before,

and go for it! Don't worry; the worst you can do is fail, and failure doesn't really matter when trying to do something on the cutting edge, because you learn from it and it can increase your motivation. John was never afraid of pursuing a new idea that might work out, even if the odds were long. Did I mention that he wrote a book-length manuscript while on his sabbatical in Madison involving rock mechanics, a nail gun and a tunnel boring machine? It was quite a thriller!

In the many years after my time in the UK collecting and analyzing fracture data for nuclear waste repository design on an early forerunner of personal computers (in addition to learning to play speed chess), I continued to keep in contact with John. We would meet at various rock mechanics conferences around the world, occasionally cross paths in Sweden having to do with the Swedish repository program, and exchange annual Christmas letters.

Many professors and other people that I've encountered during my life have taught me valuable skills. John gave me a component that allowed me to do something that was immensely personally satisfying in my professional career, and awakened within me my own efforts to dream and pursue dreams.

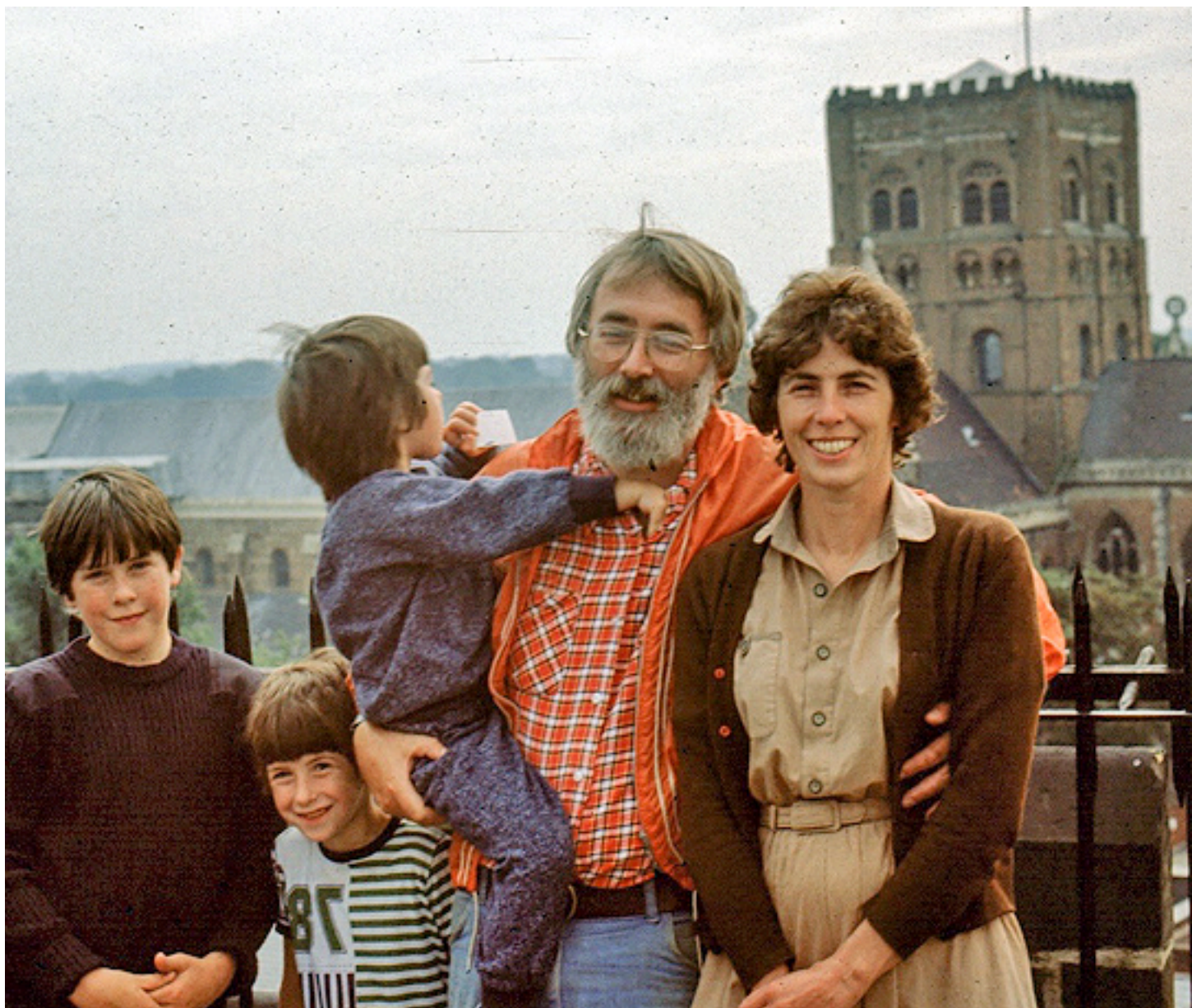
Socrates was alleged to "educate" his students, not to teach them. A classic tale has to do with a slave belonging to a friend named Meno. In this Dialog, Socrates does not tell the slave something that the slave does not already know; rather he "draws out" (the root words from which "educate" is derived) the knowledge that the slave already possessed, but did not know he possessed it.

Working with John was like that in the best sense; he had an ability to draw out knowledge from everyone who worked with him. It wasn't something that he knew necessarily; he showed you how to draw it out of yourself by dreaming, releasing fear of failure, by having a small ego, and constantly bouncing ideas and listening to ideas from as wide a group of people as possible. What little ability I have in this area I owe in large measure to John, and I was fortunate that John provided a fork in life's road for me. As Robert Frost stated in the last line of his poem, *The Road Not Taken*: "...and that has made all the difference".

Godspeed, John. I'll miss our conversations!



John and Neville Price (left) on site at the Rosemanowes Quarry in Cornwall, 1983.



John and his family (from left to right: Miles, Jonathon, Jenny, John and Carol) in 1983.