ground water

Historical Note/ David Deming, History Editor

Gedeon Dagan: A Brief Story of My Life . . .

by Gedeon Dagan

Prologue

I am grateful to *Ground Water* for inviting me to join the distinguished gallery of hydrologists that have filled this rubric in the past. I was particularly motivated by my predecessor and friend Shlomo Neuman, whose moving autobiography (Neuman 2008) was a source of inspiration. Like him, I will not limit myself to presenting my professional career but also personal remembrances and reflections, as they are closely related and intertwined.

Childhood and Adolescence in Romania (1932 to 1950)

My father, David Drimmer, was born in 1898 and grew up in Chernowitz, the capital of the Bucovina region. At the northeast boundary of Romania, it was part of the Austro-Hungarian Empire for more than 150 years. Chernowitz was a flourishing and culturally effervescent town of around 150,000 inhabitants of different ethnic affinities, a third being Jewish. The prevailing language was German, and the town was dubbed as ''the little Vienna.'' In variance with his brothers and the general trend, my father studied at the Technical University of Vienna toward a degree in civil engineering. By the time of his return to Chernowitz, at the end of the First World War, Bucovina was annexed by Romania. My father then started to work as a young engineer at the National Railway Company, his employer until retirement.

After marrying my mother, he moved to Galatz, the town of her family, where I was born on December 24, 1932. Galatz and the neighboring town of Braila were harbors on the Danube, which served as a waterway for active trade with Europe. Both flourished at the beginning of the 20th century and hosted foreign communities, which gave them a somewhat cosmopolitan flavor. I had a happy childhood there, grew up in a well-to-do family, and was surrounded by the extended one of grandparents, uncles, aunts, and cousins. I was a precocious child whose everlasting passion was reading books.

The general scene changed, however, toward the end of the 1930s, as the political situation became tense, the fascist and fiercely anti-Semitic ''Iron Guard'' movement gaining ground. They succeeded in committing a few pogroms before being forcefully suppressed by the right-wing military dictator Antonescu. Romania, under his regime, joined the Axis powers and entered the Second World War, the Romanian army following the German one in the invasion of the Soviet Union.

Harsh anti-Semitic laws were promulgated, and Jews were subjected to persecution and restrictions. Due to his technical competence, my father kept his job, though under limiting conditions, and we moved to the nearby town of Braila. In spite of the hardship, our fate was infinitely better than that of Jews in countries occupied by Germany, who were sent to death in extermination camps (see the vivid description of Shlomo's childhood [Neuman 2008]). The reason for our survival was that in spite of the pressure exercised by Germany, the Romanian regime decided not to surrender the Jewish community, the atrocities committed by the Romanian Army in the conquered Russian territories notwithstanding. Our luck endured again when, in 1944, at the time of the advance of the Red Army, a coup took place, and Romania joined the Allied Powers and started to fight the retreating German Army. This occurred in a short period, and we were saved the fatal fate of the Hungarian Jews (Neuman 2008).

In the following period of 3 years (1944 to 1947) of general postwar hardship, Romania enjoyed a somewhat democratic regime. Although Jews regained their rights, the majority decided to leave grim Europe and emigrate to what was to become Israel. I became an active member of a Zionist Youth Movement, regarding Israel as my genuine country and making preparations to emigrate. However, the communist party established a new dictatorship in 1947 and Zionism became unlawful, while emigration was tightly controlled.

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Bucharest and Undergraduate Studies (1950 to 1962)

In view of the rejection of my family's repeated applications to emigrate, I decided to follow university studies. One of the merits of the regime was the granting of free education, and despite political limitations, a good record facilitated entering the university.

This was the first station that shaped my professional life. Due to my attraction to mathematics in high school, it became clear to me that I was going to embark on science or engineering studies. In choosing a particular field, I was guided by the desire to follow a subject of importance to the newly founded State of Israel, and I heard that development of water resources was high on the national agenda. I therefore enrolled in 1951 in the Department of Hydraulic Engineering of Bucharest Civil Engineering Institute.

The basic science courses were of high level, and the engineering ones were focused on hydraulic structures, mainly hydroelectrical plants. By the end of the first year, it became clear to me that I was attracted by mathematical and related theoretical subjects. I took advantage of a unique opportunity offered to engineering students, to follow in parallel studies toward a degree in applied mathematics at Bucharest University. This way I expanded my mathematical knowledge, and I was exposed to advanced courses in fluid and solid mechanics.

By 1956, with a degree in engineering and a B.Sc. in applied mathematics, and with a clear interest in research, I started to work at the Institute of Hydraulic Research in Bucharest, which investigated mainly models of hydraulic structures. In the following 3 years, I succeeded in publishing a few papers in the local technical journals.

This period ended abruptly in 1959 when I was arrested by the (in)famous Securitate, under accusation of subversive political activity, because of my Zionist background. The 8 months spent in the communist prison were the most difficult period of my life due to the harsh conditions in spite of the false nature of the accusations. In the 2 years following my release, I could not get a research position due to the double stigma of a formed detainee and a candidate for emigration to Israel. These 2 years of menial jobs ended at the beginning of 1962 when I received the permit to leave Romania.

Israel: The Technion Period (1962 to 1976)

The day I landed in Israel was one of the happiest days of my life as it marked the fulfillment of two dreams: living in what I regarded as my country and the escape from the oppressive communist regime. As it was the custom at the time, I changed my name to the present Israeli one, as a sign of the beginning of a new life and of integration into society.

Very soon, I started to look for a job, and I contacted the Hydraulic Laboratory of the Technion, Israel Institute of Technology, in Haifa. There I was told that a young senior lecturer, returned from Ph.D. studies in United States, was seeking to hire an engineer for a research project. His name, to become well known, was Jacob Bear (Bear 2003). The project topic was the development of a fresh water collector above the sea water interface of the Israel Coastal Aquifer. The field studies were carried out by Tahal (Water Planning for Israel), under the sponsorship of the UN Food and Agricultural Organization (FAO), the Technion serving as a subcontractor. Jacob hired me after an interview, being impressed by my background and my knowledge of Hebrew. As it happens so often in life, I entered by chance the new field of flow through porous media, in which I kept working until these very days.

While I started to work on the project, I decided to publish the outcome of research carried out in Romania in the journal *La Houille Blanche* (quite reputable at the time; see Dagan [1963]). This was the first and last time that I published in French, in which my name was spelled Gedeon. Subsequently, I published exclusively in English, but I maintained the spelling after discovering that the Columbia Dictionary gives it as an alternative to the common one of Gideon.

The year 1962 started therefore as a memorable one, the most important subsequent event being my marriage to my wife Ora, who has accompanied and supported me in my life and career since then. At the same time, I was offered the possibility to turn my research into work for a doctoral degree, and I became Jacob's first graduate student. Jacob gave me considerable freedom and helped me to become acquainted with ground water hydrology and the Western literature on the subject. This was a productive period in which I published a few papers on sea water intrusion and free surface flows in porous media. I was pleased to see that there was renewed interest in these works (for instance, the publication [Dagan and Bear 1968] based on my thesis was cited four times in 2006 and similarly for Dagan 1967a). By 1964, I finished writing my thesis, and the graduation ceremony in 1965 marked an even more important event, namely the imminent birth of my elder daughters Cigal and Noga (to be followed in 1971 by Adi).

Subsequently, I was offered a tenure track position with the Faculty of Civil Engineering at the Technion, and I embarked on a research and teaching career, culminating with my promotion to full professor in 1974. Until 1967, the focus of my research was modeling free surface flows in porous media by analytical methods, and one of the papers of the period, on pumping tests (Dagan 1967b), is still used and cited.

The next turning point in my professional life took place in 1965, when the Technion was visited by Marshall Tulin, a young American scientist who was the cofounder and technical director of the research company Hydronautics, which conducted research for the U.S. Navy. Marshall gave a seminar on one of his major contributions to fluid mechanics, namely mathematical modeling of supercavitating flows past bodies. I was deeply impressed by the talk, and I realized that there is common ground with my interests, and I passed him with timidity the draft of my paper (Dagan 1967a). To my surprise, he

not only read it but also showed understanding and interest. At his invitation, I gave a seminar at Hydronautics the next year, when I visited United States for the first time at the invitation of Don Kirkham, for summer work on a research project. At Marshall's invitation, I spent my first sabbatical, in 1967 to 1968, at Hydronautics, and that year had a tremendous impact on my further development. The mode of operation of a company was different from that of a university, for example, with respect to flexibility in research. Thus, I became involved in different subjects and primarily in naval hydrodynamics and water waves. However, the most lasting impact stemmed from my interaction with Marshall. One of the most important lessons I learned from him, which I have tried to follow since, was to strive to understand the physical essence of problems and to reduce them to simple terms before embarking on their solution by detailed computations. This sounds like an elementary and obvious step, but is not necessarily recognized, as witnessed by the many publications of a formal nature that deal with mathematical manipulations per se.

After my return to the Technion, I followed in the coming decade two lines of research in parallel: primarily flow through porous media, but also naval hydrodynamics and water waves. In the first one, my research diversified, covering topics such as modeling of unsaturated flow, solute transport, and convective currents (Figure 1). I was also blessed with a few talented doctoral students, like Y. Mualem and M. Stiassnie, who have subsequently made outstanding academic careers.

Moving to Stochastic Modeling and to Tel Aviv University (1976)

Two major events took place in 1976. The first one was my move to Tel Aviv University, where I was offered a position in the newly created Faculty of Engineering.

This appointment, initiated by my colleague and friend Touvia Miloh, a leader of his field by now, created an opportunity to join a young and energetic department. The collaboration with Touvia on water waves culminated in my last paper in this area (Miloh and Dagan 1985),

The second one was the pursuit of a new area of research, namely stochastic modeling of flow and transport in porous formations, which has since remained my major field. First, I must confess that I do not remember how I became attracted by this new topic nor the precise point in time (around 1973) marking its beginning.

I am taking here the liberty to sidestep and to share with the readers a few reflections on a more general subject, namely, how do scientists plan and start to work on new topics. I personally do not have an organized and planned strategy, and I do not know in advance what I am going to investigate beyond a horizon of, say, 1 year. I believed at the beginning of my career that scientists operate in a more organized and rational fashion, and I was embarrassed when I was not able to answer questions about my long-range projects. I got solace and a new perspective, however, after reading in 1988 the book by Natalie Angier (Angier 1988), a journalist who followed closely for 2 years the work and life of scientists at one of the most advanced research institutions in molecular biology (the Whitehead Institute). I found the preface written by a renowned science essayist and biologist of the time, Lewis Thomas, particularly illuminating. Herein, is an excerpt: "*There is, I suppose, a way of going about work of this kind that can be called the scientific method, but I have never been quite clear in my mind about what this means. Method has the sound of an orderly, preordained, step-by-step process; one maneuver leading sensibly and logically to the next; a beginning, a middle, and then an ending. I do not believe it really works that way most of the time. . .Surprise is what scientists live for, and the ability to capitalize on moments of surprise, plus the gift,*

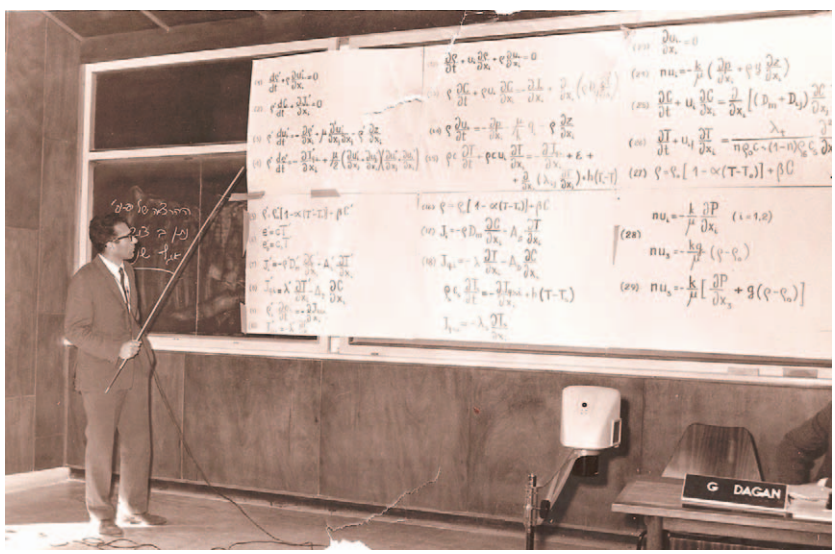

Figure 1. Lecturing at the IAHR Symposium on Transport in Porous Media in Haifa (1969).

amounting to something rather like good taste, of distinguishing an important surprise from a trivial one, are the marks of good investigators".

At any rate, my first stochastic hydrology publication (Dagan 1976) had only one reference, the pioneering article of Allan Freeze (Freeze 1975). In the next article (Dagan 1979), I could cite already two other pioneers of the field, L. Gelhar and the late A. Gutjahr. By that time, the community started to expand tremendously and to attract many more leading, as well as young, scientists. Thus, together with a few other colleagues, I had the privilege of being one of the initiators of a field that acquired growing popularity in the scientific community.

What were the prime movers for this development? Of course, everything started from the realization that natural formations are of spatially variable properties, at a scale much larger than the pore scale, on one hand, and that their variation is seemingly erratic and subject to uncertainty because of scarcity of data, on the other hand. Without trying to summarize here the various factors that caused the surge in research on the impact of heterogeneity, I would rather mention two of the most significant ones.

First, this was a new and open field to which a few branches of advanced science contributed, for example, statistical physics, theory of composite materials, and geostatistics. This convergence elevated the field to one of modern science. This may explain the enthusiasm and enrollment of many young researchers of diverse backgrounds.

Second, the central subject of stochastic modeling is transport of contaminants in the subsurface, a topic of interest to the environmental community and to the general public as well (as illustrated by the cases of ground water pollution that have motivated the successful Hollywood movies *A Civil Action* and *Erin Brockovich*). This may also explain the readiness to invest in a few large and costly field tests that serve to today as an experimental basis for modeling.

While devoting my research to various topics of stochastic hydrology, at a certain point, I felt the need to present the approach in a comprehensive and systematic manner, resulting in a monograph (Dagan 1989), and since then, a few other books have enriched the literature, particularly (Rubin 2003) by my former Ph.D. student Yoram Rubin, an established scientist by now.

One of the rewards of this intensive research activity was the realization that stochastic hydrology not only takes advantage of modern developments in various fields but also contributes to other disciplines. This manifested in my case, as well as in that of others, in publications in journals of general interest like the *Journal of Fluid Mechanics*, *Multiscale Modeling and Simulation*, and *Physical Review Letters*.

Forging Collaborations and Friendships

One of the most rewarding and unexpected benefits of my research career was the emergence of collaboration with other scientists, beyond the one with graduate students. I was fortunate to enjoy many such partnerships, which were intellectually stimulating and led to fruitful exchanges. To use an analogy close to my heart, I would describe such joint ventures as playing chamber music. This is an ensemble in which the performers are soloists and who are able, nevertheless, to succeed only by playing together in harmony. Beyond this joy of sharing, the turning of a few collaborations into deep and lasting friendships was an even less expected reward. I would like to mention here a few of them, the ones who had a great impact on my research and my personal life, and I will start with the two who unfortunately are not among us anymore.

In 1976, when I moved to Tel Aviv, I started to collaborate with Eshel Bresler, the Head of the Soil and Water Department of the Volcani Institute for Agricultural Research. For a few years, I spent a day a week there, and our collaboration led to 16 joint publications over the following 10 years. Eshel had a very good grasp of the physics of flow and transport in the unsaturated zone and its relevance to applications. Our joint work introduced stochastic concepts and models in this important field, and a few of our papers are still cited frequently (e.g., Dagan and Bresler 1979). I was also fortunate to know and to help one of his bright Ph.D. students, David Russo, who has since become a leader of the field. Eshel personified the "sabra" (Israeli born) qualities: directness, honesty, and openness on one hand and modesty and shyness on the other. We became close friends, and his death in 1991 was a sad event.

A completely different type of scientist, with whom I developed a fruitful collaboration and a close friendship, was Peter Indelman. He emigrated to Israel from Russia in 1989, after starting a promising research career at the Moscow Institute for Petroleum and Gas, in the group led by his Ph.D. advisor, Mark Shvidler. He was involved in the developments of stochastic modeling, which were not well known in the West. Peter had qualities of a true scholar: a superb mathematical background, a determination to provide elegant solutions to complex problems,

Figure 2. At the IAHR Symposium on Transport in Aquifers in Switzerland, with the stochastic "dream team." From right to left: first row (Y. Rubin, G. Dagan, and A. Bellin) and second row (A. Rinaldo, V. Cvetkovic, G. Destouni, J.O. Selroos, and A. Fiori) (1994).

Figure 3. With HM King Carl XVI Gustaf at Stockholm Water Prize Ceremony (1998).

and a total commitment to science. Our collaboration lasted for 15 years and resulted in 14 significant joint papers on upscaling (e.g., Indelman and Dagan 1993) and flow and transport toward wells in heterogeneous aquifers. His premature death at the age of 55 in 2005 left me with a feeling of sorrow and dear memories.

I would like to mention next a few younger scientists living abroad, with whom I started to collaborate at the beginning of their careers and who have become leaders in the field (Figure 2). This was facilitated by the advent of the email, which in my view constitutes the most important advance in scientific communication of modern times. The first is Vladimir Cvetkovic, from the Royal Institute of Technology (KTH) in Stockholm, with whom I had and still have a wonderful collaboration in the field of reactive transport in heterogeneous media (see, e.g., Cvetkovic and Dagan 1994). The other one, belonging to the young generation, is Aldo Fiori from Rome University, who spent a prolonged period in Israel during Ph.D. studies under the guidance of another close friend, Andrea Rinaldo. Among other subjects, we explored over the years the topic of concentration fluctuations in aquifer solute transport, altogether having published 21 joint papers (e.g., Fiori and Dagan 1999). In the last few years, we were joined by Igor Jankovic from the University at Buffalo, an accomplished numerical hydrologist. We have become a trio steadily publishing papers on flow and transport in highly heterogeneous formations (e.g., Jankovic et al. 2003). They have become personal friends, and I apologize to several others whose names I had to skip because of space limitation.

Honors and Awards

Besides the rewards of intellectual challenges and personal friendships, I was lucky to have my work recognized by the professional community. This manifested in honors and awards that I received over the years. Most of them came unexpectedly and left me with the feelings of a child marveling at the gifts bestowed upon him. The list includes the Award of the Hydrology Section of American Geophysical Union (AGU) (1984), a Fellowship in AGU (1989), an Honorary Doctoral Degree from Pierre and Marie Curie University in Paris initiated by my friend Ghislain de Marsily (with a ceremony of French elegance and tradition in the Sorbonne festive hall in 1997), the Horton Medal of AGU (2005), an Honorary Degree from my Alma Mater in Bucharest (2006), and later, the Rothschild Prize and the election to the Israel Academy (2006).

However, the pinnacle in terms of public awareness and extent of festivities was the Stockholm Water Prize, received from the hands of the King of Sweden in 1998 (Figure 3). I then became aware of the existence of the annual Stockholm Junior Water Prize Competition, and I initiated its inception in Israel as a community service, serving since as its director.

Concluding, I consider myself fortunate for experiencing an exciting research career, for the friendships acquired through science, and for the recognition of my work by the professional community.

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