Fifty Years of Gas Chromatography — The Pioneers I Knew, Part II

This month's "Milestones in Chromatography" column is the second of a two-part series dealing with the lives and activities of important chromatographers who were active during the early unparalleled growth and expansion of gas chromatography.

In the February 2002 installment of "Milestones in Chromatography," I reminisced about some of the pioneers of gas chromatography (GC) whom I knew well (1). I mentioned Archer Martin, the inventor of partition chromatography, and seven former colleagues and friends who, unfortunately, are no longer among us. In this column, I continue this discussion and remember eight additional important chromatographers. As in the first part, the information presented in this column relies upon various editorials and obituaries dealing with the activities of the pioneers; foremost, however, it is based on my personal recollections and memories of the many years I had the honor to collaborate with these true pioneers of chromatography.

Clark Hamilton (1912–1987)

One of the practical problems encountered by scientists who started in GC in the 1950s was introducing reproducible, small liquid volumes into the instruments. The only syringes available at that time were those used in medicine, the smallest of which had 0.5–1 mL volumes, which obviously were too large for GC. Other devices also were introduced in that period, but none of them worked properly. Within two years, the situation changed with the availability of the Hamilton microsyringes. In an editorial, Georges Guiochon made the statement that "without the Hamilton syringes, gas chromatography could not have become everybody's technique" (2). I don't believe that this statement was an exaggeration.

The Hamilton microsyringes were developed by Clark Hamilton, one of the forgotten pioneers of GC. He studied chemical engineering at the University of Nebraska and graduated in 1935. After holding a number of positions, including one in a gold mine, he enrolled at the Massachusetts Institute of Technology (Cambridge), but he joined the Army when World War II broke out and advanced in rank from enlisted man to captain. In 1947, he went to work at the Radiation Laboratory (Livermore, California) of the University of California at Berkeley. There, he developed various devices, including glove box syringes for handling radioactive materials. In the early 1950s, he moved to North American Aviation; at that time, he also started what became the Hamilton Co., making a limited number of lead-shielded syringes. In 1953, he made an important decision: he and his wife Trudy started their own business for the development, manufacture, and marketing of precision microsyringes.

*If I have seen further it is by **standing upon the shoulders of giants.***

— Sir Isaac Newton, 5 February 1675

The first Hamilton microsyringes were fairly clumsy devices. Clark also developed a syringe with a replaceable needle that he hoped to market to the medical field. Meanwhile, however, disposable medical syringes were introduced, so there was little interest in his more-sophisticated device. At that time, he heard about early gas chromatographers' sampling problem; as a solution, he developed two precision microsyringes that had needles cemented in place and liquid sample volumes of 50 and 10 μL. The 10-μL syringe became an instant success: in a short time, it was accepted as the standard device for sample introduction into a gas chromatograph (3). It is interesting to note the price of this

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syringe is roughly the same 40 years later as it was at the time of its introduction (4).

After the introduction and success of these syringes, Clark wanted to learn about additional needs in the field, and he consulted a number of companies involved in GC. When he visited Perkin-Elmer (Norwalk, Connecticut) in early 1959 I met him for the first time. I still remember our meeting very well. My friend and colleague Dick Condon explained very eloquently the sampling problems we faced with the introduction of the flame ionization detector and capillary columns. After Dick finished, Clark turned to me and asked my opinion. At that time my English was very limited, and I could not compose an elaborate statement such as Dick's. My answer, therefore, was a single sentence: "We want to inject zero volume in zero time." Apparently, Clark took this seriously and soon developed new microsyringes with 1- and 5-μL capacities. The 1-μL syringe in particular was an engineering marvel because it contained a syringe within a needle.

Originally located in Whittier, California, Hamilton Co. moved in 1970 to Reno, Nevada, its present headquarters. Clark also established a plant in Bonaduz, Switzerland, in 1968. In its first two decades, the company's annual sales grew steadily but relatively slowly, and by the mid-1970s they reached approximately $4 million. Since then, the company has widened its product line and expanded into other fields in addition to microsyringes, resulting in an exponential rise in sales to more than $100 million today.

In addition to his syringes, Clark made another significant contribution to the evolution of chromatography. These activities are not well known in the United States; however, they were very important in Europe, particularly during the last two decades of the Cold War. He was instrumental in setting up the Scientific Exchange Agreement (SEA), a foundation that distributed grants to postdoctoral fellows from Eastern European countries that allowed them to work for as long as one year in a Western European scientific establishment and learn the latest advances in chromatography. In addition, the SEA provided grants for participation in meetings, symposia, or lecture tours. All these grants were supported generously by the Hamiltons. By permitting exposure to modern instrumental research, this exchange program had a significant effect on the evolution of chromatography in Eastern Europe.

Clark was a decent man with strong ideas about honesty and ethics. He loved challenges and enjoyed doing the impossible. When he started his business, he specially designed all the production machinery and taught his employees how to use the equipment. I heard stories about the startup of his Swiss plant, when the newly hired workers were astonished to see the big boss from America personally and very patiently teaching them how to use the very complicated, high-precision machines.

Clark officially retired in 1975, giving the company's helm to his son. However, he remained active in various projects, and the company was in his spirit until his death. I last met him in September 1987 in Lausanne, Switzerland, where we had a very pleasant dinner. Soon after returning home, Clark contracted meningitis, and he died on 31 October 1987. With his passing, chromatography lost a true pioneer and a great benefactor.

Clark Hamilton and Trudy Hamilton (right) with Clark's mother (middle) circa 1960.

Hiroyuki Hatano (1924–1998)

Scientific discourse between Japan and the United States started to develop during the middle of the 1960s and grew rapidly in the 1970s. At that time, we learned about the high quality of the scientific instruments produced by Japanese companies and became acquainted with our Japanese colleagues. Probably the most important representative of our field was Hiroyuki Hatano, a professor at the University of Kyoto and director of the Instrumental Analysis Research Institute at the university. He had very wide international experience; he had been a visiting professor at universities in the United States, England, Switzerland, France, and Canada and had built important connections with scientists in many countries.

Prof. Hatano had several important achievements in GC, particularly in the investigation of flying ash from urban incinerators for the presence of dioxins. He was the organizer of the first international meeting on the dioxin question, which was held in 1994. However, his real love was liquid chromatography (LC). In 1959 and 1960, he developed the first automated liquid chromatograph with a UV–vis detector, which became the basis of a series of amino acid analyzers manufactured in Japan. He also was involved in interfacing a liquid chromatograph with electron spin resonance and mass spectrometers, and he

Hiroyuki Hatano in 1982.

made significant contributions to the development of ion chromatography, particularly in the use of small-bore, fused-silica capillaries as the separation column (5).

Prof. Hatano's most long-lasting contribution has been the organization of the Japanese Research Group on Liquid Chromatography, from which the Japanese Society for Chromatographic Sciences ultimately evolved. These associations were instrumental in hastening the advancement of chromatography in industry and research.

According to Japanese customs, Prof. Hatano had to retire in 1988. He then organized the International Institute of Technological Analysis, a major Japanese research organization in Kyoto, and served as its director. In January 1998, he entered a hospital for a minor problem and caught pneumonia while in the hospital. They could not save him, and he died on 25 January 1998 (6).

I personally knew Hatano-san since the beginning of the 1970s, and I began visiting him regularly in Kyoto beginning in 1980. It always was a great pleasure to be with him; he always had something interesting to show and discuss. He also was an excellent host: to go with him to his favorite sushi bar, a formal Japanese dinner, or after-dinner entertainment were the highlights of my trips. He not only was an excellent scientist but a man of command, highly respected and followed by his Japanese colleagues as a *primus inter pares.* His sudden death left a void that will be difficult to fill.

Evan C. Horning (1916–1993)

In GC's first decade, its main field of application was the analysis of hydrocarbons and other volatile organic compounds. Biochemists rarely used the technique, mainly because of their fear about the possible decomposition of the compounds. This fear was real for two reasons: First, the biologically important compounds had very little, if any, vapor pressure and would have to be analyzed at high temperatures at which decomposition was very likely. Second, the columns, particularly the support material, used at that time were not completely inert, thus catalyzing sample decomposition. Analysts began to use derivatization to make compounds that were more stable thermally and more volatile, but this fear still seriously restricted the use of GC in the biochemical field. The breakthrough occurred toward the end of the 1950s, and it was due mainly to the pioneering work of Evan Horning.

For a decade beginning in 1950, Evan C. Horning served as the chief of the Chemistry of Natural Products Laboratory at the National Heart Institute of the National Institutes of Health (NIH, Bethesda, Maryland). During this period, the connection between arteriosclerosis and fat intake from food and the effect of cholesterol and fatty acids on the development of cardiovascular disorders were recognized. It also became clear that the existing methods for the analysis of complex samples of biological origin were highly inadequate. GC had great promise; however, the instruments and columns used at that time were inadequate for these investigations, and no satisfactory methodology was available for handling the samples.

Starting in the late 1950s and within a few years, Evan and his associates developed methods to prepare inert support materials, columns containing low stationary phase loadings, and methods for the derivatization of complex polyfunctional compounds that enhanced their stability and increased their volatility. These techniques revolutionized biochemical analysis. Also, he showed the way to build gas chromatographs that were fully adequate for these applications.

In 1961, Evan was appointed a professor of chemistry at Baylor College of Medicine (Houston, Texas) and the head of the newly organized Institute for Lipid Research. During the next 25 years, he built this institute to be one of the most important centers for the development of modern analytical methods in biochemistry. He was one of the first people to combine GC and high performance liquid chromatography (HPLC) with mass spectrometry (MS) for the analysis of biochemically important substances. Equally important, he took the function of a university professor as a teacher seriously: he invited associates from the United States, Europe, and Japan to learn the new methodologies. After returning to their homes, they became leaders in biochemical analysis in their countries. Evan maintained close personal contact with his former associates and informed them about new developments that occurred since their departure. He retired in 1986.

I knew Evan for more than 30 years. We met at various meetings, and I visited him many times in Houston, not only professionally but also personally. I esteemed his friendship and that of his wife Marjorie, who had her own career and also served as a professor at Baylor, very much.

Today, some of the analyses developed by Evan, such as the GC analysis of steroids, have been replaced by newer methods. However, bioanalytical methodology still is based largely on his achievements, and the schools he initiated continue to flourish in a number of countries.

Evan Horning (left), K.I. Sakodynskii (middle), and A. Zlatkis at the 1973 International Symposium on Advances in Chromatography in Toronto, Ontario, Canada.

A.I.M. Keulemans (1908–1977)

Those of us who started in GC in the latter part of the 1950s learned most of the technique's fundamentals from the book about GC written by A.I.M. Keulemans of the Koninklijke/Shell Research Laboratories (Amsterdam, The Netherlands), which was first published in 1957 and translated into six languages (7,8).

Aloysius I.M. Keulemans originally studied to be a mathematician and started to work for a life insurance company after graduation. However, he became unemployed unexpectedly after three years due to a company merger and decided to change professions. He studied chemical engineering at the University of Delft (The Netherlands) and graduated in 1938. After graduation, he joined Koninklijke/Shell Laboratories and worked on industrial problems while preparing his Ph.D. thesis. Lou finished his thesis in 1942, but the university was closed due to the German occupation, so he didn't receive his degree until 1945.

Lou heard about GC as early as 1952, and he was one of the Dutch Shell scientists who immediately recognized its importance. From then on, his main activities were in this field. In 1958, he was appointed a professor and head of a chair on instrumental analysis at the new University of Technology (Eindhoven, The Netherlands), the first such laboratory in Europe. He built his laboratory to worldwide fame: 150 students obtained their masters' degrees and 20 earned their doctorate degrees under his guidance.

In addition to organizing this laboratory at Eindhoven, Lou's principal achievement was the dissemination of information and the exchange of ideas. He traveled frequently and tirelessly to discuss the newest achievements with scientists at various places and advise about how others solved a particular problem. For 15 years, he served as a kind of roving ambassador of GC and participated at many symposia in Europe and the United States. Lou strongly believed that the world should not be divided by national and political boundaries. In 1969, he helped Clark Hamilton form the SEA, the foundation helping the exchange of scientists between East and West, and he personally managed it until 1976.

I first met Lou in 1959, and from then on we were in frequent contact. In addition to meeting at the numerous symposia, I also visited him a number of times in Eindhoven, both officially and socially, playing bridge in his home.

In the mid-1970s, his health started to deteriorate, and he was forced to retire from the university and stop traveling. Lou settled in Prague and died there in February 1977. He was one of the great representatives of the founding generation.

Andrei V. Kiselev (1908–1984)

In the novels of the great Russian writers of the nineteenth century, one reads about a special group of people living in Moscow and other major cities. These people were not hereditary landowners but professionals — physicians, lawyers, teachers, merchants, and businessmen — and were characterized by having very broad knowledge. They were multilingual and progressive in their thinking. For me, Prof. Kiselev was a typical representative of this group of people. He also was an outstanding scientist, recognized not only in his own country but also abroad. He was one of the few Russians to be elected a member of the British Faraday Society and to be awarded the medal of the Societé Chimique de France.

Andrei Vladimirovich Kiselev started his scientific career in 1931, first at the Textile Institute in Moscow and then at Lomonosov State University of Moscow, where he organized the Laboratory of Adsorption, which expanded into the Laboratory of Adsorption and Chromatography in 1960. As was customary in the scientific system of the Soviet Union, he also was associated with the Institute of Physical Chemistry of the Academy of Sciences as the head of the Chemistry of Surfaces Laboratory. He remained active until his death; in fact, he was the oldest active professor at the university. He was very popular with his students. Many junior scientists came to him and his laboratory for training, not only from the different republics of the Soviet Union but also from many foreign countries, even as far away as Argentina, Mexico, and Australia.

Andrei Vladimirovich spent more than 50 years studying solid surfaces and adsorption. His first paper in 1936 correctly interpreted the phenomenon of bound water on silica-gel surfaces as surface silanol groups. In subsequent decades, he carried out fundamental research in three fields: the theory of surfaces and

A.I.M. Keulemans (left) and L.S. Ettre in the spring of 1963.

A.V. Kiselev (left), J.F.K. Huber (middle), and J. Janák at the 1962 International Chromatography Symposium in Hamburg, Germany.

adsorption, the investigation of adsorbents and the development of new adsorbents, and the use of combined chromatographic and spectroscopic methods for their study (9). His book on gas adsorption chromatography, co-authored with his former student, Ya.I. Yashin, was published first in 1967 (10) and then expanded in 1979 to include liquid adsorption chromatography (11). These books also were translated into English, French, German, Czech, and Polish, and they still represent the basis of adsorption science.

Andrei Vladimirovich published more than 800 scientific papers and received many honors. One, however, eluded him: he was not elected a member of the Academy of Sciences of the USSR, a rank that would have been expected for a person of his stature. He had engaged in a scientific dispute with one of his peers during the early part of his career. He made two major mistakes: his opponent already was high in the political hierarchy of the Soviet Union and later became one of the secretaries of the academy, and, even worse, Andrei Vladimirovich was right. His opponent never forgot it.

In 1964, Andrei Vladimirovich visited the United States to participate in the Second International Symposium on Advances in Chromatography in Houston, Texas. He presented an excellent lecture on graphitized carbon black. I had the good fortune to serve as his host. I remember his major concern: when flying home, he wanted to stop for a day in Amsterdam to see the Rembrandt paintings in the Rijksmuseum. This request presented some complications, and my fellow organizers and I had to help him obtain the necessary Dutch visa. There also was some excitement during his stay because we heard the news about Khrushchev's fall from leadership during the meeting. He was invited 10 years later to Houston to the same symposium, at which he was awarded the Tswett Chromatography Medal, but Soviet authorities did not give him permission to travel. I had the opportunity to visit him in Moscow every year from 1976 on. I enjoyed his hospitality both at his home and when he showed me around Moscow to visit the Kremlin and the Tretyakov Gallery. His knowledge was encyclopedic, and he could place any event, building, or painting in its proper historical and international context.

In the summer of 1984, Andrei Vladimirovich entered a hospital in Moscow for a minor operation. He expected to be back in his laboratory within a couple of weeks. Before going to the hospital, he almost finished the preparation of four manuscripts that he planned to submit to the journal *Chromatographia* after his return. The operation was successful; however, he died a few days later, and the manuscripts were submitted posthumously by his associates. They were published in the September 1985 issue of the journal. With his sudden and unexpected death, adsorption science lost one of its greatest representatives.

Seymour R. Lipsky (1924–1986)

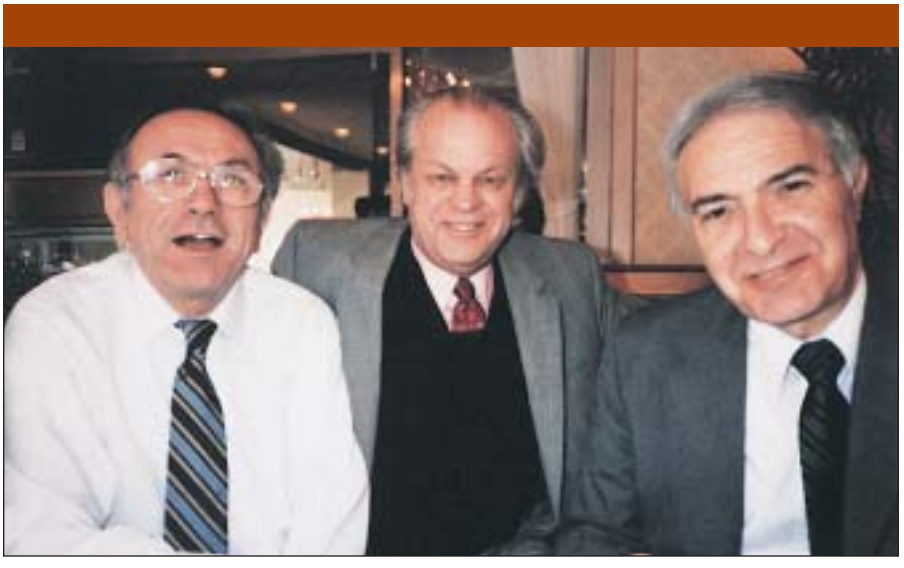
The pioneers of chromatography were representatives from many disciplines: chemistry, biochemistry, physics, engineering, and even medicine. One of the most prominent physicians involved in the early development of GC and, later, LC was Seymour "Sandy" Lipsky.

In 1952, just after finishing his residency training, Sandy was offered a research fellowship at Yale University's School of Medicine (New Haven, Connecticut). This offer changed his original plans; instead of becoming a practicing physician, he started a career in biochemical research. He moved through the ranks of the medical school and was appointed a professor of physical sciences and director of the section of physical sciences in 1966. Sandy retired from his university position in 1983.

Sandy's original research project dealt with plasma lipids and studying the rates of synthesis and transport of certain fatty acids present in blood plasma. A key problem he faced, along with others working in the same field, was the lack of suitable analytical methods that permitted the accurate determination of the individual fatty acids. After trying a number of unsatisfactory methods, he read two papers by A.J.P. Martin and A.T. James, published in the same 1956 issue of *Biochemical Journal*, which dealt with the separation of C_1–C_{18} saturated and unsaturated fatty acid methyl esters and a GC system using the newly developed gas-density balance as its detector (12,13). These papers were just what the doctor ordered as the solution to his problem. His adaptation of the method represented the start of Sandy's lifelong commitment to GC. He had to overcome many obstacles, including the resistance of his peers who claimed that the long-chain fatty acids would decompose at the temperatures used for GC analysis. Immediately after Golay's description of capillary columns in 1958, Sandy was the first to explore the possibility of their use for fatty acid analysis, and he published one of the earliest benchmark papers on this subject. His fruitful collaboration with Jim Lovelock led to the electron-capture detector, without which environmental analysis would not be where it is today. He also collaborated in establishing the criteria for suitable GC instrumentation in the biochemical field.

Circa 1964, Sandy realized the potentials of extending the accumulated knowledge in GC to the field of LC. With his new associate, Csaba Horváth, he embarked upon a project that led eventually to the development of HPLC.

In the 1970s, Sandy returned to his love, capillary GC, and became the foremost authority in glass and, later, fused-silica



A. Zlatkis (left), L.S. Ettre (middle), and S.R. Lipsky at the 1979 International Symposium on Advances in Chromatography in Lausanne, Switzerland.

columns. Based on the ideas of his good friend Denis Desty (whose proposals were first mentioned in a lecture at the 1975 Hindelang Symposium [14]), Sandy experimented with the possibility of preparing columns from fused silica — well before the disclosure of Ray Dandeneau's results in the spring of 1979. Thus, he immediately switched to the technology of making flexible, thin-walled tubes. Through his newly formed company, Quadrex (Woodbridge, Connecticut), he was able to introduce these columns practically simultaneously with Hewlett-Packard Co. (now Agilent Technologies, Wilmington, Delaware). From then on, he devoted his time to perfecting high-resolution GC and developing capillary columns for applications at or above 400 °C.

In addition to biochemical analysis and the development of capillary columns, Sandy also was involved in a special research field; namely, detecting the possible presence of organic compounds on other planets in the solar system and on the moon. He served as a principal investigator of the National Aeronautics and Space Administration's (NASA's) project to investigate lunar rock samples and of the Mariner Mars exploration program. He was the first to use GC–MS for this purpose.

Sandy had other interests in addition to science. Few realize that he was one of the foremost experts on rhododendrons. His home in Woodbridge was surrounded by scores of them. Each spring, the sight of hundreds or thousands of beautiful blossoms in a great variety of colors was simply breathtaking.

I knew Sandy for more than 25 years, and we became close friends over the years. He always was available for advice and help, not only in the field of science, but also in personal matters and as a trusted physician, if needed. He also was an excellent companion; I will always remember the capillary GC symposia in Hindelang, Germany, in the Bavarian mountains, where we shared an apartment in the hotel.

By the beginning of the 1980s, Sandy's health started to deteriorate. As a good physician, he was well aware that he had an incurable disease, but he did not slow down. A few days before his death, we had a long discussion about some problems. With his sudden death, chromatography lost one of its true pioneers.

Karl I. Sakodynskii (1930–1996)

Until the 1970s, scientists from the Soviet Union rarely participated at chromatography meetings in Western Europe or the United States. Typically, if an invitation was extended to somebody, even one offering to cover all the expenses, the organizers of the meeting didn't know until practically the last hour and learned only at the airport whether the expected guest was permitted to travel. I was told many times that our invited guests didn't know whether they could travel and that they were sitting on their suitcases at Moscow's airport, waiting for permission to board the plane. Karl Ivanovich Sakodynskii largely was responsible for the change in this situation — in opening a door between the Western world and the USSR. Without question, he was instrumental in promoting and facilitating the cooperation of scientists; he used his official function at the All-Union Scientific Council in Chromatography of the USSR Academy of Sciences to make it possible. In addition, he carried out unique investigations on

preparative chromatography that were little known outside the former Soviet Union. Thus, he deserves to be included among the pioneers of chromatography.

Karl Ivanovich joined the Karpov Institute of Physical Chemistry in Moscow (the Soviet Union's foremost industrial research establishment in chemistry) in 1957 and spent almost 30 years there, advancing from a junior scientist to the deputy director of the institute. In 1983, he left Karpov and moved his whole group to the Institute of Reagents, where he established a chromatography department. At approximately the same time, he organized the Russian M.S. Tswett Association of Chromatographers and served as its first president. In the spring of 1996, he planned to participate at the forthcoming Capillary Chromatography Symposium in Riva del Garda, Italy, and he compiled a small, lovely book, titled *About Chromatography Seriously and With a Smile* (15), which he planned to distribute to the participants of the meeting. One week before his planned departure, he fell ill and was rushed to the hospital, where doctors operated but could not save his life.

As mentioned above, Karl's main activities were related to industrial preparative chromatography. Apart from some early investigations, this possibility never was seriously pursued in the Western world, mainly because the energy costs would have been too high. However, in the Soviet Union these considerations were practically unknown, so scientists and engineers had the freedom to indulge in the construction of large-scale GC units. These units were practically unknown outside the former Soviet Union; some information was published only recently (16), so it is worthwhile to briefly mention the technology here. Karl was involved in the construction of GC-based production plants at three locations, all in present-day Ukraine. The first, installed in 1971 at Donetsk, used 50-cm diameter columns to isolate thiophene from benzene. In the other two plants, column diameters were enlarged to 120 cm. The plant at Makeevka was established to isolate indole and had a capacity of 200 tons per year; starting with raw material that contained only 3.5–4.5% indole, the operators succeeded in concentrating it to 96%. The plant at Shostka produced toluene with a purity of 99.9% and had a capacity of 1200 metric tons per year. I have no information about these plants after the dissolution of the Soviet Union.

One of Karl's achievements for which the chromatographic community always will be grateful is the detailed study of the life and activities of M.S. Tswett, the inventor of chromatography. He unearthed a large amount of previously unknown information and presented it in several publications (17–21).

Karl was an excellent organizer, and it was amazing how he could overcome the formidable obstacles presented by the Soviet system, which was suspicious of any foreign visitor. He organized two major symposia with international participation: one in 1972 in present-day St. Petersburg that celebrated the centennial of Tswett's birth and a second in 1976 that was a general chromatography symposium in the faraway place of Samarkand, in present-day Uzbekistan.

I first met Karl in 1972 at the Montreux Symposium; soon we became good friends and spent many pleasant occasions together, both in his native country and in various parts of the world. I enjoyed his hospitality, and I'm sure he enjoyed his visits here, learning the rules of a Texas-style barbecue and the intricacies of eating a Maine lobster. He was a very open person whom everybody could befriend at the first moment. He had a soft humor and a deep knowledge of the physicochemical foundation of chromatography. He was a real Russian in his soul but at the same time was a man of the world who understood people of different origins and philosophies.

Albert Zlatkis (1924–1998)

For roughly 25 years between 1963 and 1988, the field of chromatography was dominated by the International Symposia on Advances in Chromatography. These meetings attracted the top researchers in the world and were the place to be for young chromatographers. Although other symposia were the work of societies and committees, the International Symposia on Advances in Chromatography were organized almost entirely by a single person — Albert Zlatkis of the University of Houston (Texas).

Al Zlatkis grew up in Canada and studied chemical engineering at the University of Toronto (Ontario, Canada). After graduation, he continued his studies in the United States at Wayne State University (Detroit, Michigan) and received his Ph.D. in 1952. His doctoral research dealt with analytical methodology to determine serum cholesterol levels; according to the *Science Citation Index*, this paper was one of the most widely cited publications in chemistry.

After two years at Shell research laboratory (Houston, Texas), he joined the faculty of the University of Houston. At that time, this university was a small, fairly unimportant school, but in the next decade it went through unparalleled growth and became one of the major universities of the American South. He remained at this school practically for the rest of his life and retired officially in the spring of 1997. By then he had already experienced a five-year struggle with serious heart problems that temporary slowed him down; however, he bounced back and reassumed most of his activities. A new illness came suddenly in the fall of 1997, and it destroyed his activity and took his life within a few months. He died in the first weeks of 1998.

Al was one of the real pioneers of GC. He started to work in this field in 1954 and was active in almost every aspect of the technique. His research interests included capillary GC, ionization detectors, and concentration techniques and their application in clinical chemistry and environmental analysis. He was one of the few who immediately followed Golay's first reports and, simultaneously with Sandy Lipsky at Yale, published the first papers on the use of capillary columns. He had been involved with Jim Lovelock in the development of the electron-capture detector and took it from being a research tool to a universally used detector. He was the first to use Tenax and to demonstrate its usefulness in concentration techniques, in which it permitted ultratrace analysis. In these and many other fields, Al made significant contributions and helped translate the new innovations into everybody's tools.

Al's most important characteristics were an openness and friendliness toward everybody, regardless of origin, social level, or knowledge; a faith in the goodwill of mankind; a sixth sense in realizing what is or will be important; and an immense energy to carry out what he considered to be worthwhile. He honestly believed that everybody is entitled to have an opportunity to succeed and that it is the duty of those who have established themselves to help the beginners or less privileged. He personally helped many young, promising scientists in their starts and was proud when he could see that they were worth his trust.