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Kartographische Nachrichten. *Kartographische Nachrichten* (*KN*), subtitled "Fachzeitschrift für Geoinformation und Visualisierung" since 2003, is a joint publication of the Deutsche Gesellschaft für Kartographie, the Schweizerische Gesellschaft für Kartographie, and the Österreichische Kartographische Kommission, which is part of the Österreichische Geographische Gesellschaft. The journal was founded in 1951 as a newsletter for the Deutsche Gesellschaft für Kartographie, which was established in 1950 at Bielefeld with Fritz Hölzel, Theodor Stocks, and Eberhard Westermann among the founding members (Frenzel 1970; Ermel and Siewke 1970; Ferschke 1984). Controlled by an honorary editorial board appointed by the Deutsche Gesellschaft für Kartographie, it is one of the world's oldest cartographic journals as well as the most prominent outlet for German-speaking cartographic researchers. Chief editors have included Wolfgang Pillewizer (1951–56), Oskar Stollt (1956–68), Hans Ferschke (1968–87), Jürgen Dodt (1988–2000), Uwe Fichtner (2001–2), and Rolf Harbeck (since 2003). Prominent authors who have published in *KN* include Erik Arnberger, Ulrich Freitag, Dietmar Grünreich, Günter Hake, Lorenz Hurni, Eduard Imhof, M. J. Kraak, Werner Lichtner, Liqiu Meng, Ferdinand J. Ormeling, Ferjan Ormeling, Heinz Schmidt-Falkenberg, and Ernst Spiess.

Since its founding *KN* has covered numerous internationally important cartographic developments, and addressed them from the perspective of scientific, public, private, and military cartography. These developments include scribing on glass and film, imagesetting on film, offset printing, cartographic semiotics and symbolization, map projection, the theory of cartographic modeling, techniques of generalization and design, computer-based technologies, multimedia and interactive visualization, the usability of cartographic products and services, and intellectual property rights for both analog and digital cartographic products. Electronic cartography, governmental applications of GIS (geographic information systems), and the commodification and marketing of geographic information were especially prominent after 1990.

Serving as both a specialist journal with scientific and technical articles and a chronicle with practice reports, news items, and reviews covering the activities of three professional societies and their members, *KN* reflects the development of cartography in Germany throughout the second half of the twentieth century (only West Germany until reunification in 1990) (Dodt 2000). Although its articles included abstracts in English from 2005 onward, an increased international focus was especially apparent in 2003, when the journal began to publish contributions in English.

Prior to 1951, Germany cartographic researchers published their work in geographic and surveying journals, such as *Petermanns Geographische Mitteilungen* (founded in 1855) and *Zeitschrift für Vermessungswesen* (1872–2001). German specialist journals that are focused on areas outside cartography also cover cartographic issues. These include *Vermessungstechnik: Geodätisch-kartographische Zeitschrift der Deutschen Demokratischen Republik für Wissenschaft und Praxis* (founded in 1952), *ZfV: Zeitschrift für Geodäsie, Geoinformation und Landmanagement* (from 2002; formerly *Zeitschrift für Vermessungswesen*), and *Photogrammetrie–Fernerkundung–Geoinformation* (founded in 1997).

From 1951 until 1999 *KN* was published in a book format (22 × 16 cm until 1963, 24 × 17 cm thereafter). In 2000 the journal changed to a magazine format (28 × 21 cm). Restricted to one-color printing with occasional multicolored supplements until 2003, the journal has had full four-color printing since 2004. *KN* appears in six issues with about 340 pages yearly.

ROLF HARBECK

SEE ALSO: Journals, Cartographic; Societies, Cartographic: Western Europe

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Keates, J(ohn) S(tanley). John Keates was born on 22 November 1925 and was educated at Wallasay Grammar School and Oxford University. His studies at Oxford started in 1943 but were interrupted from 1944 to 1947 by service in the Royal Navy, in which he saw duty on minesweepers and destroyers and served as an educational instructor. He returned to Oxford in 1947 and graduated with a B.A. in geography in 1949 and an M.A. in 1950.

Keates entered cartographic employment in 1949 at Clarendon Press, Oxford. In 1954 he became cartographic editor at Penguin Books, where he edited the *Penguin Atlas of the World*. He moved to Sweden in 1956 and took the role of cartographer and then chief cartographer with Esselte AB of Stockholm. Here he developed further skill in cartographic design and production, which formed a solid foundation for his future career as an academic cartographer.

In 1960 Keates returned to Britain and took up a post in the Geography Department at the University of Glasgow. Together with Gordon Petrie, he helped to establish the undergraduate degree in topographic science, postgraduate courses in cartography, and later postgraduate courses in digital mapping and automated cartography. He played a fundamental role in developing mapping education and professional cartography in the United Kingdom and, through the graduates of these programs, including many overseas students who came to Glasgow to study with him, influenced cartography globally.

FIG. 438. DETAIL FROM THE *CAIRNGORMS RECREATION MAP*, 1:35,000, DESIGNED BY J. S. KEATES AND PRODUCED WITH M. C. SHAND, 1974.
Size of the entire original: ca. 78.5 × 51.6 cm; size of detail: 11.2 × 17.4 cm. Image courtesy of the Geography and Map Division, Library of Congress, Washington, D.C. Permission courtesy of the School of Geographical & Earth Sciences, University of Glasgow.

His skills in map design and production continued to be well utilized, and many maps produced by the Geography Department at the end of the century had a distinct "Keates" style (fig. 438). His practical experience no doubt influenced many students who appreciated that he could not only talk about the subject in detail but also apply the theory effectively. This experience in teaching led to his writing what for many years was the definitive textbook on the subject, *Cartographic Design and Production*, first published in 1973 with a second, largely rewritten, edition in 1989.

In addition to great skill in map design and production cartography, Keates had a strong interest in many of the discipline's more theoretical aspects, particularly the visual perception of maps. This interest led to *Understanding Maps* (1982), a groundbreaking book with a very different view of cartography than that found in textbooks focused on making maps. A second edition, published in 1996, was a major rewrite that provided a significant critique of recent theories about the nature of cartography.

Keates played a key role in the formation of the British Cartographic Society (BCS) in 1963 and 1964, was the first editor of the *Cartographic Journal* (1963–70), served as BCS president (1974–76), and was awarded the Society's Gold Medal (1988). He was also recognized nationally with the award of an Order of the British Empire (OBE) commendation for Service to Cartography in 1979.

Following retirement in 1991, he remained active in cartography, publishing books and articles. He left Glasgow to live in the Scottish Highlands, where he had had a second home for many years. Always a dignified and modest man, he died at Glen Esk in September 1999.

DAVID FORREST

SEE ALSO: Academic Paradigms in Cartography: Academic Cartography in Europe; Education and Cartography: Cartographic Textbooks

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Wood, Michael. 1999. "John Stanley Keates (1925–1999)." *Cartographic Journal* 36:155–56.

Klett Perthes (Germany). See Justus Perthes

Koeman, Cornelis. Cornelis ("Cor") Koeman was born on 19 August 1918 in Wijdenes, North-Holland, the Netherlands, the third son of a nurseryman. He attended secondary school in nearby Hoorn. After brief training in surveying, Koeman moved to Delft, where he was hired as a mapmaker by the Topografische Dienst. He was allowed to take day courses at the Technische Hogeschool Delft (now the Technische Universiteit), if he made up the "lost time" in the evenings. In 1951 Koeman was among the first group to graduate from the geodetic engineering program established at Delft in 1949. After graduation he worked at the Geodetic Department of the Technische Hogeschool Delft. In 1957 he received an appointment in the Geography Department at Utrecht University, with teaching responsibilities in surveying, cartography, and the history of cartography. In 1968 he was appointed professor of cartography, the first such position in this discipline in the Netherlands. He retired in 1981.

Koeman's reputation is based principally on his efforts to promote scholarly, university-level research on the history of cartography, a discipline formerly in the hands of librarians, dealers, and amateurs. While working in Delft he rediscovered in the collection of the Topografische Dienst the complete map collection of the Cape Colony, taken to Europe by the last Dutch governor in 1795. Undoubtedly, this discovery cultivated Koeman's interest in the history of cartography, and several of his early publications are devoted to this map collection. In 1961 he obtained his doctorate with a historial thesis, "Collections of Maps and Atlases in the Netherlands." He published over 200 books and articles, most of them historical. His *Handleiding voor de studie van de topografische kaarten van Nederland, 1750–1850* (1963) and *Geschiedenis van de kartografie van Nederland* (1983) remain the most important handbooks on the history of the mapping of the Dutch territory.

His thesis was the cornerstone for his most important work, the *Atlantes Neerlandici: Bibliography of Terrestrial, Maritime, and Celestial Atlases and Pilot Books Published in the Netherlands Up to 1880* (6 vols., 1967–85). This pioneering work on the bibliography of atlases is the model for modern atlas description and has led to several other atlas bibliographies.

After his retirement Koeman took the initiative to publish facsimiles of the work of Jacob van Deventer, the sixteenth-century surveyor who mapped the Dutch provinces and over 250 towns in the Netherlands. The town plans were published as *De stadsplattegronden van Jacob van Deventer* (12 portfolios, 1992–2001) and the provincial maps as *Gewestkaarten van de Nederlanden door Jacob van Deventer, 1536–1545* (1994). On his seventieth birthday in 1988, Koeman was presented with *Miscellanea Cartographica*, which contains a biography, a bibliography, and twenty-two of Koeman's most important articles. Koeman died on 1 June 2006 in De Bilt, province of Utrecht.

PETER VAN DER KROGT

SEE ALSO: Histories of Cartography

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Kokudo chiriin* 国土地理院 *(Geographical Survey Institute; Japan). The Geographical Survey Institute (GSI) of Japan (Kokudo chiriin 国土地理院) is the major governmental organization that conducts geological and topographical surveying and mapmaking activities in Japan (Kokudo chiriin 1989). The GSI functions as "the most influential agent for making scientific, systematic and accurate basic maps in cooperation with local governments, other central government agencies, and private companies" (Masai et al. 1989, 56). Among the Institute's other important functions are the development of aerial photographs and the production of both land use and thematic maps. It also engages in disaster prevention programs, does research in earthquake forecasting, and assists developing countries in map preparation. The parent body of the GSI was the Rikugunshō sanbō honbu rikuchi sokuryōbu 陸軍省参謀本部陸地測量部 (Army land survey department), which was established in 1888 in the General Staff office and carried out the surveying and mapping of Japan. Superseding the army land survey department in 1945, the GSI was established in the Naimushō 内務省 (Ministry of home affairs) on 27 December 1945 (Watanabe 1980, 37). At the end of World War II, the Japanese army and navy were abolished and many of their functions were transferred to the newly established GSI. About two years later, in 1947, the Home Ministry was dissolved and replaced by the newly established Ministry of Construction. At that time the GSI began the production of several kinds of thematic maps (e.g., land condition maps, land use maps, lake charts) and large-scale, standard-series maps. In 1977 the GSI compiled *The National Atlas of Japan*, and it too included many thematic maps in categories such as transportation and communication, politics and finance, and social conditions.

Administratively, the GSI consists of nine departments: administration, planning, geodetic, topographic, geographic, map management, crustal dynamics, geodetic observations, and regional survey. As part of Tsukuba kenkyū gakuen toshi 筑波研究学園都市 (Tsukuba Science City), the GSI is located in Tsukuba-shi, Ibaraki prefecture, northeast of Tokyo. Among the facilities at the complex are the main office building, several laboratories, an exhibition hall, and a geodetic observation tower. Kokudo chiriin (1989) provides additional information about the organizational structure and departmental functions of the GSI.

Japan is one of most densely populated countries in the world. However, some 75 percent of the country is mountainous and only about 25 percent is populated. Management of resources was therefore very important with soil maps, population maps, and animal and vegetation distribution maps produced by various governmental agencies such as the ministries of agriculture, forestry and fisheries, the environment agency, and the Japanese coast guard to meet those needs.

During the 1980s Japan embarked on a national large-scale mapping project in which maps at a scale of 1:2,500 and 1:5,000 were produced. The 1:2,500-scale maps were of urban areas and the 1:5,000-scale maps were of mountainous areas and rural areas. Under the guidance of the GSI, local governments produced and printed the urban maps for planning projects and as community maps. These "national large-scale maps are produced for all parts of Japan, but in case demands do not exceed 200, maps are not printed; only blueprints are supplied for minor demands" (Masai et al. 1989, 66). In addition, within the Japanese system 1:10,000-scale maps are classed as large-scale and are also used for urban planning projects. In 1983 the 1:10,000-scale topographic mapping project began. Its purpose was to collect information on urban areas and provide it to administrative planners. This project included the Tokyo, Osaka, and Nagoya metropolitan areas and several other large and overcrowded cities, where 60 percent of the population were living. They featured detailed information on urban facilities and were easy to use because of color coding.

Contents of the large-scale maps vary from scale to scale. For example, over 100 different symbols are included in the 1:2,500 national large-scale maps and the 1:10,000 topographic maps. However, the 1:2,500-scale maps have limited three-dimensional data with only two categories of building height (1–2 stories and 3 or more stories), whereas some privately produced detailed town maps show the actual number of stories for taller buildings. Topographic maps for large urban areas use five colors, while all national large-scale maps are monochrome. There is less generalization of the distribution of buildings on large-scale maps. Road widths of two meters or wider are depicted planimetrically correctly on the 1:5,000-scale maps, and roads of one meter or wider are depicted correctly at 1:2,500.

Widely used smaller-scale maps at scales of 1:25,000 and 1:50,000 were produced for other purposes. The 1:25,000-scale topographic maps are the largest-scale national base maps covering all of Japan. Revisions take place every three, five, or ten years depending on changes in the landscape. The 1:50,000-scale topographic maps were produced from the 1:25,000 scale and some 1,249 sheets cover the entire country. Used for education, recreation, land planning purposes and the like, these maps are categorized as general multipurpose maps (Kokudo chiriin 1989, 13–14).

Land use maps at a scale of 1:25,000 are used for land development planning including industrial, residential, commercial, and recreational use (fig. 439). According to Takekazu Akagiri (1986, 25), "In the country, most of the land is covered by forests and population density is very high. And intensive land use has been concentrated into lowlands and hilly lands. Consequently it is indispensable to develop effective land use based on the future prospects of the Japanese society, and to regulate supply and demand of real estates which can be matched for various purposes." Basic information about the land is essential in order to promote certain kinds of projects based on policies of the government and the private sector.

In addition to publishing the vast majority of its maps as individual sheets, the GSI published an atlas of Japan. The first edition of *Nihon kokusei chizuchō* 日本国勢地図帳 = *The National Atlas of Japan*, was published separately in English and Japanese in 1977 as the country's representative atlas. Consisting of 366 pages and more than 300 maps, this atlas is massive in both content and physical dimensions. In a review, it was pointed out that "the atlas has now developed from a geographical collection into a highly technical work depicting the socio-politico-economic complexities of modern industrial

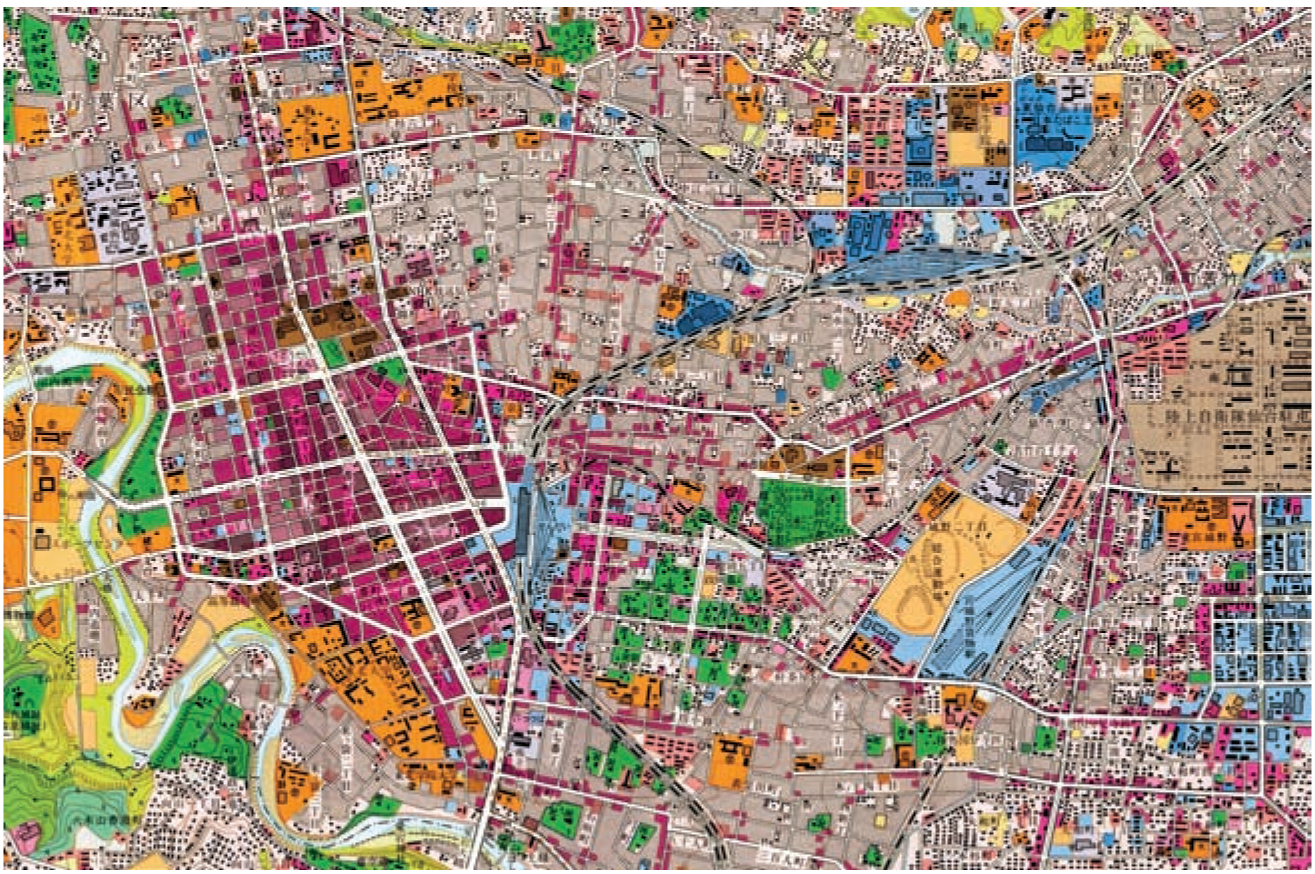

FIG. 439. SENDAI LAND USE MAP, 1:25,000, 1992. The *Niman gosen bun ichi tochi riyōchizu Sendai* 2万5千分1 土地利用地図 仙台 (1:25,000 land use map of Sendai) was made by the Kokudo chiriin. The main categories are: general residency (light pink), mid to high residency (salmon), commercial (bright pink), business (striped pink), industrial (blue), public affairs (brown), education/school (orange), public welfare (silver), parks and green space (green), exercise and athletic facilities (striped orange), transportation and distribution facilities (striped light blue), supply processing facilities (striped darker blue), defense (striped brown), empty land (mottled white), and areas under improvement (mottled pale brown).
Size of the entire original: 60.3 × 90.8 cm; size of detail: 15.8 × 24 cm.

society" (Cooper 1977, 549). The review further noted that perhaps a smaller and less ambitious atlas would have been more useful and easier to update. A revised edition was published in 1990.

The time period 1974 to 1978 was one in which the GSI increased its production of color aerial photography. Urban areas were covered by 1:10,000-scale aerial photographs. All of Japan, except a few small islands, was covered by color aerial photographs with scales between 1:8,000 and 1:15,000 (Kokudo chiriin 1989, 11).

For many years, the GSI and various governmental organizations and universities have examined crustal activities in Japan through surveys of the geodetic networks in order to predict earthquakes. Both geological and geophysical surveys were conducted around the seas of the Kanto district in order to determine active geological structures in earthquake-prone areas. Geological maps are produced by the Chishitsu chōsa sōgō senta 地質調査総合センター (Geological Survey of Japan), and are useful for disaster prevention. Starting in 1979 the Geological Survey and the GSI issued a series of basic maps of volcanoes covering thirty-one active volcanoes at scales of 1:5,000 and 1:10,000. Akira Watanabe (1980) discusses some of the most important cartographic productions from various institutions of the Japanese government during the 1950s–1970s. The GSI's growing interest in computer applications to aid map production led to the digitization of its 1:10,000 and 1:25,000 topographic maps. During the mid-1970s, the digitization project expanded to include land use maps, particularly those related to housing. These maps became much more accessible to would-be users around the world because they were digitized and made available electronically.

In 1992, Japan's Kensetsushō 建設省 (Ministry of Construction) proposed the Global Mapping Project, which develops a geographical data set of the earth's landmass with consistent specifications. It provides geographic data to solve global environmental problems, achieve sustainable development, and mitigate large-scale disasters. Consisting of digital geographic data with one-kilometer resolution, or 1:1,000,000 scale, and updated at five-year intervals, the data set includes four layers in vector format (transportation, boundary, drainage, and population centers) and four layers in raster format (elevation, vegetation, land cover, and land use). In November 2000 at the Global Mapping Forum, Version 1.0 data were released. The GSI contributed to the development of the Global Map by training persons from many countries around the world through a course on global mapping and by assisting developing countries in data development. Easily accessible and downloadable through the Internet, the data were made available universally. Although it continues to use the abbreviation GSI, the institute was renamed the Geospatial Information Authority of Japan in 2010.

JOHN C. PHILLIPS

SEE ALSO: Digital Worldwide Mapping Projects

BIBLIOGRAPHY:

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Watanabe, Akira. 1980. *Cartography in Japan: Past and Present*. Tokyo: International Cartographic Information Center.

Koláčný, Antonín. Antonín Koláčný was a noted Czech cartographer of the twentieth century. He was born on 23 May 1910 in Prague and graduated from high school in Prague-Vyšehrad in 1928. Koláčný studied land surveying at the faculty of special sciences of the České vysoké učení technické, the technical university in Prague, where he received a MSc and a PhD. In 1936 he began working at the inspectorate of cadastral survey, Inspektorát pro katastrální vyměřování, in Martin (Slovakia) and in 1939 joined the Triangulační kancelář Ministerstva financi, the geodetic office of the treasury department, in Prague. In 1947 Koláčný was placed in charge of the cartographic section of the land survey office in Prague, and in 1952 he initiated the world atlas *Malý politický atlas světa*, which was the first self-contained atlas issued in Czechoslovakia after World War II.

After the consolidation in 1954 of the Czechoslovak civil land survey with the central office of geodesy and cartography (Ústřední správa geodésie a kartografie), Koláčný was appointed chief of its cartographic section. In this role he supervised the design and development of a new map series at 1:5,000 and, in 1957, the compilation and production of new topographic maps at 1:10,000, new base maps at 1:50,000, and a map of the entire country at 1:200,000. Koláčný helped establish all state cartographic enterprises in Prague and Bratislava and additional regional cartographic organizations throughout Czechoslovakia.

Koláčný moved to the research institute of geodesy, topography, and cartography (Výzkummý ústav geodetický, topografický a kartografický) in Prague in 1958, where he established the cartographic section. He was active in the work of the Československá akademie věd, first as a member of the geographic commission (1958–61), and later as a member (1962) and vice-chairman (1967) of the scientific board on geology and geography.

Koláčný prepared the mathematical bases and was deputy editor-in-chief, as well as a member of the editorial board, of the *Atlas Československé socialistické republiky* (1966). His scientific research focused on map language and perception, especially for education in geography and history. His pioneering research into the concept that connects mapmaking and map use was adopted at the beginning of the 1970s. This scientific work was presented in 1968 at the International Cartographic Association (ICA) conference in New Delhi using the phrase "communication of cartographic information" (Koláčný 1969, 47; Robinson and Petchenik 1976, 28–30) (see fig. 4). As a result Koláčný was asked to establish and chair the ICA Commission on Cartographic Communication in 1968.

Due to the political situation—essentially a witch hunt—in Czechoslovakia after 1968, Koláčný was forced to resign his ICA position and was not allowed to leave the country during his remaining active career. From within Czechoslovakia, Koláčný continued active participation in ICA projects, such as the *Multilingual Dictionary of Technical Terms in Cartography*, published in 1973. In addition, he published many research works and scientific articles in Czechoslovakia as well as abroad.

Koláčný died in Prague on 17 December 1991. He was posthumously awarded an honorary membership in the newly established cartographic society of the Czech Republic, Kartografická společnost ČR, in 1993.

MIROSLAV MIKŠOVSKÝ

SEE ALSO: Academic Paradigms in Cartography: Academic Cartography in Europe

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Koláčný, Antonín. 1969. "Cartographic Information—A Fundamental Concept and Term in Modern Cartography." *Cartographic Journal* 6:47–49.

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Robinson, Arthur H., and Barbara Bartz Petchenik. 1976. *The Nature of Maps: Essays toward Understanding Maps and Mapping*. Chicago: University of Chicago Press.

Kretschmer, Ingrid. Ingrid Kretschmer was born on 22 February 1939, in Linz, Austria, where she grew up and graduated from high school. From 1959 to 1964 she studied geography and European ethnology at the University of Vienna, where she received a PhD in 1964. She joined the Institut für Geographie und Regionalforschung at the University of Vienna in 1966 as an assistant professor and was promoted to associate professor in 1974 and given the title extraordinary university professor in 1988, converted to university professor in 2002. She taught courses on thematic cartography, map design, cartography in education, and the history of cartography, and continued to lecture after her official retirement in 2004. Fifty-seven students graduated under her supervision.

Kretschmer's oeuvre includes 282 scientific papers, maps, and catalogs. Her career can be divided into three somewhat overlapping phases. During the first period, which extended into the early 1980s, her publications focused on ethnographic cartography and included major contributions to the *Österreichischer Volkskundeatlas*. From 1966 until 1981, Kretschmer was responsible for the atlas's cartographic design and content. Her focus had begun to shift toward theoretical cartography, and she wrote numerous scholarly articles on fundamental aspects of cartography, some jointly with Erik Arnberger. In the final phase, she turned to the history of cartography, which became the core of her scientific career. Her most important publications on map history are an encyclopedia on the history of cartography (Kretschmer, Dörflinger, and Wawrik 1986); a bibliography of Austrian atlases from 1561 to 1994 (Kretschmer and Dörflinger 1995); and a history of Austrian cartography from the fifteenth through the beginning of the twenty-first century (Kretschmer, Dörflinger, and Wawrik 2004). Her other publications on the history of cartography mostly addressed Austrian cartography and the contributions of key individuals to the development of cartography as a science. In addition to orchestrating several map exhibitions and preparing the related catalogs, Kretschmer organized two important conferences on the history of cartography: the Kartographiehistorisches Colloquium, held in Vienna in 1986, and the sixteenth International Conference on the History of Cartography, convened in Vienna in 1995. She was an influential advisor to the editor of volume 6 of *The History of Cartography* since 1999.

Kretschmer was active in numerous national and international scholarly organizations, including the editorial board of *Kartographische Nachrichten*, the International Cartographic Association's Commission on the History of Cartography, the board of the International Coronelli Society for the Study of Globes (since 1980), and the Board of Directors of Imago Mundi (since 1993). She was made an honorary member of the Deutsche Gesellschaft für Kartographie in 1995, chaired the Österreichische Kartographische Kommission from 1995 to 2007, and served the Österreichische Geographische Gesellschaft as its president from 1997 to 2004 and as honorary president since 2006. In 2004 the Deutsche Gesellschaft für Kartographie awarded her its Mercator

Medal in recognition of her outstanding, internationally recognized contributions to cartography.

After her official retirement from the University of Vienna in 2004, she continued to teach, publish, and advise students until around 2009, when amyotrophic lateral sclerosis severely limited the use of her hands. Ingrid Kretschmer died on 22 January 2011 in Linz and was buried on 2 February 2011 in Vienna.

WOLFGANG KAINZ

SEE ALSO: *Imago Mundi*; International Cartographic Association

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Dörflinger, Johannes. 2012. "Ingrid Kretschmer (1939–2011)." *Imago Mundi* 64:108–11.

Kretschmer, Ingrid, and Johannes Dörflinger, eds. 1995. *Atlantes Austriaci*. 2 vols. Vienna: Böhlau Verlag. Vol. 1, *Österreichische Atlanten, 1561–1918*, by Johannes Dörflinger and Helga Hühnel; Vol. 2, *Österreichische Atlanten, 1919–1994*, by Ingrid Kretschmer.

Kretschmer, Ingrid, Johannes Dörflinger, and Franz Wawrik, eds. 1986. *Lexikon zur Geschichte der Kartographie: Von den Anfängen bis zum Ersten Weltkrieg*. 2 vols. Vienna: Franz Deuticke.

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Kriging. Kriging is a method of optimal prediction or estimation in geographical space—a spatial best linear unbiased predictor (BLUP). In the late 1950s Pierre Carlier called this type of prediction "krigeage," in recognition of D. (Danie) G. Krige's contribution to improving the precision of estimating concentrations of gold and other metals in ore bodies and recoverable reserves. Georges Matheron (1963) first used the now-familiar term "kriging" for the method.

In the 1940s the South African gold mines used the sample mean of nearby core sample assays to estimate the average grade of a block of ore to be mined. In the early 1950s Krige observed that variation in the block grade was considerably less than that of the averaged core samples and that the block and core sample grades were correlated. He saw that this relation could improve prediction using regression (Krige 1951). This technique was effectively the first use of kriging, which he later called simple elementary kriging. Matheron (1963) expanded Krige's empirical ideas, in particular the concept that neighboring samples could be used to improve prediction, and put them into the theoretical framework of geostatistics that underpins kriging. Matheron's fundamental contribution was to use locations to define the covariance or variogram of a random process.

Matheron's developments in France did not occur in isolation. At the same time, meteorologist L. S. Gandin (1963) was building similarly on the theoretical work of A. N. Kolmogorov for the optimum interpolation of weather variables. The formulation of optimal prediction by Matheron and Gandin was preceded by those of time series analysts Herman Wold in 1938, Kolmogorov in 1941, and Norbert Wiener in 1949 (Webster and Oliver 2007, 153). Extrapolation in time series to the future is of prime interest, whereas in spatial analysis predictions are usually interpolated within the geographical envelope of known data values.

The fundamental problem mining geologists faced in predicting values from sparse sample data occurs throughout the environmental sciences. Most properties of the environment (soil, vegetation, rocks, water, oceans, atmosphere) can be measured at any of an infinite number of places, but for economic reasons they are measured at few. To know the values elsewhere it is necessary to estimate them from the available data so that they can be mapped. Several mathematical methods of interpolation are available, for example, Thiessen polygons, triangulation, natural-neighbor interpolation, inverse functions of distance, least-squares polynomials (trend surfaces), and splines. These methods take account of systematic or deterministic variation only and disregard errors of prediction. Nearly all methods of prediction, including the simpler forms of kriging, are weighted averages of data. The weights for the mathematical interpolators are based on simple deterministic models, which ignore much of the complexity in the real world, treating it as "noise." By contrast, geostatistics recognizes this complexity by treating what appears to be random as if it were random. This probabilistic, or stochastic, approach provides a statistical model of the variation in the environment to provide the weights for prediction rather than a model of the interpolating function. This underpins the definition of kriging as a method of interpolation for random spatial processes; kriging overcomes the weaknesses of the mathematical interpolators.

The values of environmental variables are usually spatially dependent, so that values at places near one another are generally similar, and on average they become less so as the separating distance increases. Variogram or covariance functions can describe this variation mathematically (fig. 440*a*). Kriging uses the spatial information described by these functions together with the data to predict optimally. Kriging is essentially a local predictor—usually only the nearest sixteen to twenty measurements around the point or block to be predicted carry significant weight. Kriging can be done for point (punctual kriging) or block supports of various size (block kriging), depending upon the aims of the prediction, even though the sample information is for points. Kriging can be linear or nonlinear, although the former methods are more common. The advantage of kriging is that it provides not only predictions but also

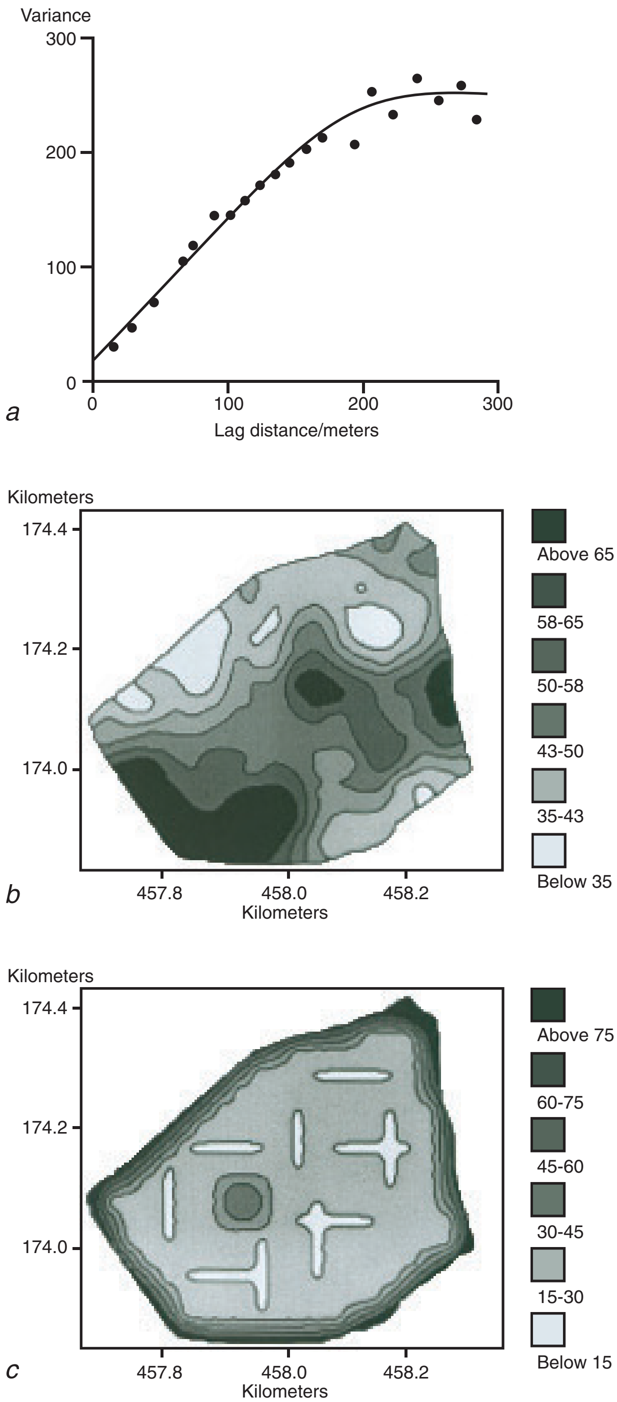

FIG. 440. TOPSOIL SAND FOR A FIELD IN ENGLAND: (a) THE VARIOGRAM, (b) THE BLOCK KRIGED PREDICTIONS, AND (c) THE KRIGING VARIANCES. Sampling was on a thirty-meter grid with additional samples along short transects at fifteen-meter intervals, the effect of which can be seen in the kriging variances.

kriging errors (kriging variances) (figs. 440*b* and 440*c*, respectively).

In linear kriging the estimates are weighted linear combinations of the data. The weights are allocated to the sample data within the neighborhood of the target point or block to be estimated according to their spatial relationship to the target and to one another, as well as to the variogram, which represents the structure of the spatial variation. Weights are chosen to minimize the kriging error. To ensure that the estimates are unbiased, the weights are made to sum to 1 (Webster and Oliver 2007, 155–60). Thus kriging is an optimal predictor. Punctual kriging is an exact interpolator; if the target point coincides with a sample point, the value remains the same and the kriging error is zero. G. M. Laslett and his colleagues (1987) compared kriging with other mathematical spatial prediction methods and found that it performed best.

Kriging has become a generic term for a range of BLUP least-squares methods of spatial prediction in geostatistics. The original formulation of kriging, now known as ordinary kriging (Journel and Huijbregts 1978, 304), is the most robust method and the one most used. Ordinary kriging assumes that the mean is unknown and that the process is locally stationary. Simple kriging, which assumes that the mean is known, is equivalent to the time series methods of optimum interpolation mentioned above. It is little used because the mean is generally unknown. Lognormal kriging is ordinary kriging of strongly positively skewed data transformed by logarithms to approximate a normal distribution. Kriging with trend enables data with a strong deterministic component (nonstationary process) to be analyzed; Matheron originally introduced universal kriging in 1969 for this purpose, but the state of the art is empirical BLUP (Stein 1999), which uses the residual maximum likelihood variogram (Lark, Cullis, and Welham 2006). Matheron introduced factorial kriging (kriging analysis) in 1982 for situations where the variation is nested, that is, has more than one scale of spatial variation. The long- and short-range components of nested variation can then be mapped separately. Ordinary cokriging, formulated by Matheron in 1965, is the extension of ordinary kriging to two or more variables that are spatially correlated. If some property that can be measured cheaply at many sites is spatially correlated with others that are expensive to measure and recorded at many fewer sites, the latter can be estimated more precisely by cokriging with the spatial information from the former. Disjunctive kriging, developed by Matheron in 1973, is a nonlinear parametric method of kriging. It is valuable for decision making because the probabilities of exceeding (or not) a predefined threshold are determined in addition to the kriged estimates. Indicator kriging, described by A. G.

Journel in 1983, is a nonlinear, nonparametric form of kriging in which continuous variables are converted to binary ones (indicators). It can handle distributions of almost any kind and can also accommodate "soft" qualitative information to improve prediction. Probability kriging was proposed by Jeff Sullivan in 1984 because indicator kriging does not take into account the proximity of a value to the threshold but only its geographic position. Bayesian kriging was introduced by Henning Omre in 1987 for situations in which there is some prior knowledge about the drift or trend (Webster and Oliver 2007, 153–266).

Since its original formulation, kriging has been elaborated to tackle increasingly complex problems in disciplines that use spatial prediction and mapping. Kriging is used in mining, petroleum engineering, meteorology, soil science, precision agriculture, pollution control, public health, monitoring fish stocks and other animal densities, remote sensing, ecology, geology, hydrology, and other disciplines. It is also a component in many geographical information systems such as ArcGIS (Esri) and mapping packages such as Surfer (Golden Software) and Gsharp (Advanced Visual Systems).

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SEE ALSO: Analytical Cartography; Geographic Information System (GIS): GIS as a Tool for Map Analysis and Spatial Modeling; Interpolation; Mathematics and Cartography; Statistics and Cartography

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Kümmerly+Frey AG (Switzerland). The commercial map publisher Kümmerly+Frey was the outgrowth of a lithographic printing business founded in Bern in 1852 by Gottfried Kümmerly, who started with a single printing press. One year later, the *Carte des routes et des relais de la post-aux-chevaux de la Confédération Suisse*, a general map of the horse-drawn postal service and its stations, was published as his first cartographic product. In 1869 Kümmerly moved from his original location, in Marktgasse 32 in the old town center, to Hallerstrasse 6, and in 1877 he acquired a second lithographic press. Formany years, Kümmerly printed topographical maps at a 1:50,000 scale for the Eidgenössisches Topographisches Bureau (today the Bundesamt für Landestopografie swisstopo), which did not possess a lithographic press at the time. After Kümmerly's death in 1884, his

FIG. 441. DETAIL OF THE *EVOLENA-ZERMATT-MONTE ROSA*, 1892, 1:50,000. Stone engraving by Rudolf Leuzinger, lithography and print by Gebrüder Kümmerly, Bern, Switzerland.
Size of the entire original: 53.6 × 73.2 cm; size of detail: 14.8 × 8.4 cm.

sons Hermann and Arnold took over the business and renamed it Gebrüder Kümmerly. Hermann Kümmerly worked as the firm's cartographer; his many projects included the *Carte routière/Strassengefällkarte* 1:250,000, the first official road map for the Touring Club Schweiz (TCS), published in 1900.

In 1887 Hermann Kümmerly married Magdalena Frey, and a year later his brother-in-law Julius Frey became a partner in the company, which was renamed Kümmerly & Frey. Hermann Kümmerly died in 1905, and Heinrich Frey joined the firm in 1910 and became its chief executive in 1912. By 1927 Kümmerly & Frey employed seventy-five people. In 1931 the sons of the founders, Walter Kümmerly and Max Frey, joined the management team. In 1944 Kümmerly & Frey became a private limited company, and by 1952 it employed 110 people. Employment peaked at 250 in 1977. During the 1970s the company replaced the ampersand in its name with a plus sign, and became Kümmerly+Frey.

Kümmerly+Frey's rise to prominence as the leading Swiss provider of private cartographic services reflects collaborations with some of the best Swiss cartographers and surveyors of the time, including Xaver Imfeld, Fridolin Becker, Heinrich Keller, and Rudolf Leuzinger, who began working for the company as a freelance cartographer in 1881. The firm produced numerous tourist maps for the Schweizer Alpen-Club (SAC), among them Xaver Imfeld's famous 1:50,000 *Evolena-Zermatt-Monte Rosa* map (1892) (fig. 441), and at the same scale the *La Chaîne du Mont-Blanc* map (1896), a collaboration between Imfeld and Louis Kurz. Imfeld, who trained as an engineer and a topographer, is also well known for his painstakingly exact alpine relief models. In addition, the prominent German cartographer Wilhelm Bonacker worked at Kümmerly & Frey for twenty-one years.

The firm's products addressed a broad range of uses, from travel and tourism to education and reference. In 1895 the firm published *Officielle Eisenbahnkarte der Schweiz 1:500,000*, the official road map of Switzerland; in 1902, its popular 1:200,000 school wall map, which remained in use for more than eighty years (fig. 442). In 1911 Kümmerly & Frey absorbed Heinrich Keller's Zurich-based cartographic firm, Kartographische Anstalt, and established itself as the leading geographical publisher of Switzerland. The company published innumerable cantonal school wall maps and *Schulhandkarten* (maps used at students' desks), as well as a successful series of road maps (the so-called Blues, based on

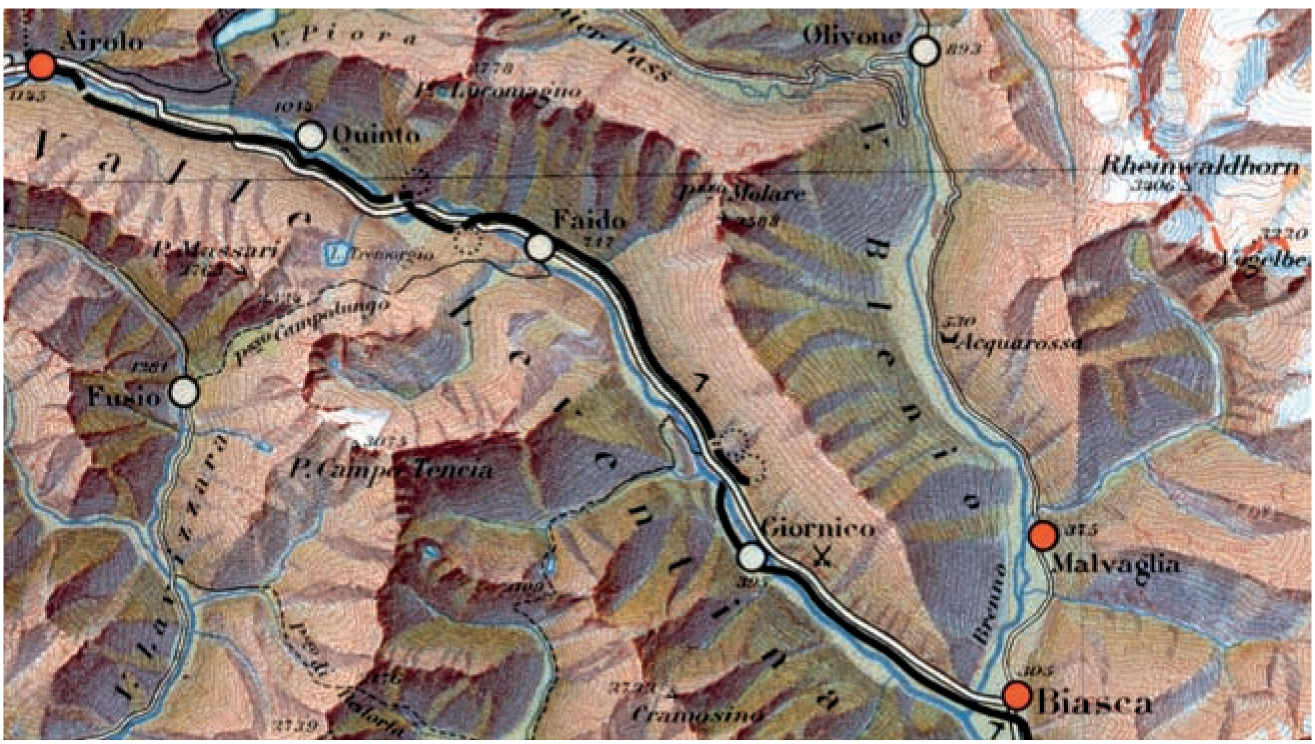

FIG. 442. DETAIL FROM SHEET 4 OF THE SCHULWANDKARTE *SUISSE SCHWEIZ SVIZZERA*, 1902, 1:200,000. Lithography by Hermann Kümmerly, printed at Kümmerly & Frey, Bern, Switzerland.

Size of the entire original: 60 × 93 cm; size of detail: 10.6 × 19 cm. Image courtesy of the Staatsbibliothek zu Berlin–Preußischer Kulturbesitz; Kartenabteilung.

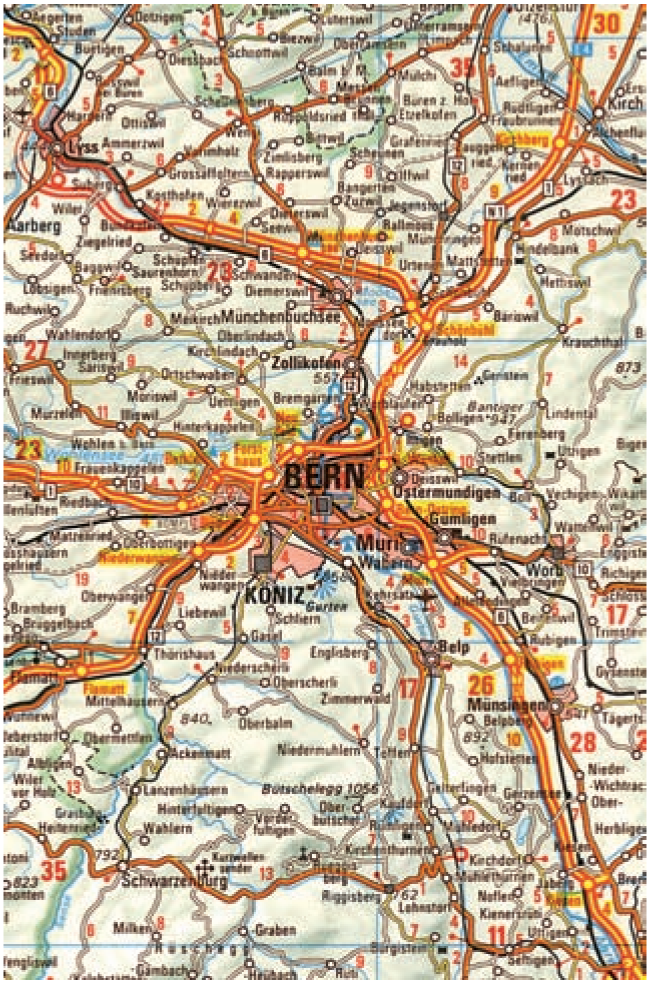

FIG. 443. DETAIL FROM THE *OFFIZIELLE STRASSENKARTE DER SCHWEIZ*, 1984, 1:301,000. Bern and its surroundings—a complicated mix of highways, minor roads, and railways, and the river flowing through the city. Bern: Kümmerly+Frey.
Size of the entire original: 91.6 × 125.4 cm; size of detail: 8.4 × 12.8 cm. Permission courtesy of Hallwag Kümmerly+Frey AG, Schönbühl.

the color of the map cover), hiking maps, bicycle maps, city maps, panoramic maps, general maps, and atlases. The topographic basis for Kümmerly+Frey's maps were the Bundesamt für Landestopographie's maps, which were modified and edited to fit the firm's templates. Because of copyright issues and related reproduction charges, the general map of Switzerland, from 1981 onward, and the hiking maps, from 1989, were published at the unusual scales of 1:301,000 and 1:60,000, respectively (fig. 443).

Management was highly committed to acquiring and adapting new technology. Early innovations included plastic film for color separations and the replacement of traditional lithography with offset printing. After World War II, Kümmerly & Frey adopted photomechanical reproduction based on scribing and peelcoats, and in 1980 it became the first private Swiss cartographic firm to venture into computer-aided map production—a move most likely made too early.

In 1974 Walter Frey and Beat Frey took over the company's management from the old guard. Beat Frey and the Kümmerly family left the firm in 1989, and Walter Frey, who remained as the majority shareholder, restructured the firm into a holding company. An overly ambitious new building in Zollikofen and other poor investment choices led to a substantial downsizing of staff and operations. In 1997 Frey hired a young entrepreneur to run the business, but he was unable to rescue the ailing firm, which declared bankruptcy on 5 December 2001. By the end of that year, the Hallwag firm had absorbed the cartographic division, including its copyrights, name, programs, and stock of maps. The publishing business was relaunched as Hallwag Kümmerly+Frey on 11 March 2002, and continued to make contributions to cartography.

HANS-ULI FELDMANN

SEE ALSO: Marketing of Maps, Mass

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