I

IDRISI (software). IDRISI, a geographic information and image processing software system, was first released in July 1987. Designed and engineered by J. Ronald Eastman of the Graduate School of Geography at Clark University, Worcester, Massachusetts, IDRISI entered the twenty-first century with continued development, under Eastman's direction, at Clark Labs, a nonprofit research center at Clark University. Over its first twenty years, the system has established a global user base, primarily in the research, government, and educational communities concerned with environment and natural resources.

Initially, the primary goal of the IDRISI system was to provide access to geographic information system (GIS) technology to the broadest community of users, particularly in the educational and international development communities. It was the first GIS specifically designed to be used on microcomputers and has always been designed for the most commonly available hardware and operating system platform. In the late 1980s and early 1990s microcomputers had very limited random-access memory and graphics capabilities. As a consequence, the software was engineered with special algorithms to require a minimum of memory overhead and to maximize the graphical capabilities of dot matrix printers and early graphics cards. Because of this strategy, the United Nations Environment Programme (UNEP), which launched its Global Resource Information Database (GRID) in the late 1980s, selected IDRISI for a global program of GIS training.

A secondary goal of the IDRISI system was to provide a base for the academic and research communities to develop new analytical procedures. To facilitate this work, the system maintains open data formats and a flexible architecture. In the migration to the Windows platform, IDRISI was developed as a COM (component object model) server allowing the development of new analytical components in any COM-compliant computer language. In addition, for nonprogrammers the system provided a graphical modeling environment that supports dynamic modeling and the ability to create submodels.

When GIS software options for microcomputers expanded, the goal of IDRISI refocused on the development of leading analytical tools. In the 1990s IDRISI pioneered the development of GIS-based multicriteria/multiobjective decision support tools. Other notable analytical developments involved change and time series analysis, soft classifiers for the interpretation of remotely sensed images, and machine learning procedures for classification and empirical modeling.

Traditionally, GIS software systems are horizontal applications—that is, collections of tools that can be applied to a wide variety of applications. However, in the early 2000s Clark Labs partnered with Conservation International to develop a vertical application within IDRISI focused on a specific set of tasks for land cover change analysis and modeling, change prediction, and assessment of the impacts of the predicted change on habitat and biodiversity (known as the Land Change Modeler for Ecological Sustainability—LCM). This partnership continued to develop software for biodiversity conservation.

IDRISI is named after al-Sharīf al-Idrīsī, a twelfth-century cartographer and geographer in the court of King Roger II of Sicily. The name was chosen in honor of the collaborative effort that al-Idrīsī headed to describe and map the known world—important resources in the subsequent Age of Discovery.

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SEE ALSO: Software: Geographic Information System (GIS) Software

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IGN (France). See Institut Géographique National (National Geographical Institute)

Illustration Software. See Software: Illustration Software

Imago Mundi. *Imago Mundi: The International Journal for the History of Cartography* was founded in Berlin in 1935 as the *Jahrbuch der alten Kartographie, Yearbook of Old Cartography*. Its coeditors were Leo Bagrow, a Russian emigré, and the bookseller Hans Wertheim. Bagrow ran the journal from the second volume, then known as *Imago Mundi: A Periodical Review of Early Cartography*, until the thirteenth volume, published in 1956. His preferences as a collector molded a tradition that survived his death in 1957. Bagrow's interest was in "early" maps. A glance at his own *History of Cartography*, first published in 1944 (Bagrow 1964), makes clear when he thought "early" ended: no illustration is later than the eighteenth century and the great majority are significantly before that. Bagrow also made plain the principles that were by then already guiding the selection of material for *Imago Mundi*. His concern was explicitly with the "externals of maps: we exclude any examination of their content, of scientific methods of mapmaking, of the way material is collected, or of the compilation of maps" (Bagrow 1964, 22).

The journal Bagrow created in his own image, as a collector, might have sought to become "an international centre of information" but it was the "charm of old maps and charts . . . the beauty of the engraving and decorations of the maps published in the 16th, 17th, and 18th centuries" that provided his inspiration ([Bagrow] 1937). As that made clear, collectors were not interested in recent maps.

J. B. Harley, in his examination of the fifty-year-old journal, suggested that "*Imago Mundi* may perhaps be regarded as a barometer of the development of the history of cartography in general" (Harley 1986, 1). While this judgment is undoubtedly true, it is evident that for much of its life the journal turned its back on the history of recent maps.

Bagrow's successors pointed out that "with only occasional reference to corresponding editors, he made all decisions on acceptance or rejection of contributions" (Anonymous 1962, XI). That perhaps explains why the first article to break the 1800 barrier appeared in 1963, two years after Bagrow's widow transferred rights in the journal to the newly founded Imago Mundi Ltd. But that hardly opened the floodgates. The next five issues added just four more articles on nineteenth-century themes. Interestingly, in the following years some articles took the story up to 1900, as if a new line had been drawn. If so, that limit would not be passed until 1983, twenty-five years after Bagrow's death, during the editorship of Eila M. J. Campbell, by which time the journal was firmly reestablished in London. Even so, several of the first articles to deal with the twentieth century considered it only as the coda to a nineteenth-century subject.

An *Imago Mundi* editor can select articles in terms of quality, regardless of the period covered, but is constrained by current research trends. The delayed acceptance of articles concerning more recent map history might reflect no more than a paucity of submissions. As a check, titles in the journal were compared with those of papers delivered at the International Conferences on the History of Cartography (ICHC). Founded in 1964 by those closely associated with *Imago Mundi*, ICHC would provide *Imago Mundi* with a reservoir of potential articles. Of the fifteen articles in volumes 35–52 (1983–2000) that are focused wholly or partly on the twentieth century, nine had previously been delivered as conference papers.

Table 23 gives the number of twentieth-century topics published or presented in the period 1967–2000. Table 24 summarizes the same data for each of the last two decades, showing the twentieth-century topics as a proportion of all articles and conference papers. The small samples urge caution about generalization; they may just tell us what an individual researcher was engaged in. It is clear, though, that by the mid-1980s articles dealing with the period after 1900 were acceptable, although the subsequent increase was erratic. There is little evidence, however, that the passing of each decade encouraged a systematic advance in the perception of what could be considered "history."

The cataclysmic events of the twentieth century, and the vast amounts of cartography they generated, have been well documented, both at the time and retrospectively. To see what *Imago Mundi* might have included would require an examination of a wide range of journals, as well as conference proceedings devoted primarily to current questions in cartography and geography. Equally, *Imago Mundi* and its associated conference have seen few studies of multisheet map series, the most prevalent cartographic format of the twentieth century.

Superficially, the journal in the early twenty-first century looks similar to that created by Bagrow. The size is the same, and most of the original ingredients remain: illustrated articles (both long and short, and in English since 1937), notices, reviews, obituaries, bibliography, and chronicle. When Harley delivered his postprandial address at the 1985 Ottawa ICHC (the only trenchant analysis to which the journal has so far been subjected), he found other traces of Bagrow's legacy. Although one

TABLE 23. Treatment of twentieth-century cartography in *Imago Mundi* (*IM*) and in the International Conference on the History of Cartography (ICHC), with the subject date ranges of their articles and papers.

	IM	ICHC	Totals		Subject date range					
Year	vol.	no.	*IM*	ICHC	1900–18	1919–38	1939–45	1946–79	1980–	General or unknown
1967		2d		*1*						*1*
1975		6th		*2*	*1*					*(1)*
*****										
1981	33		—							
		9th		*2*				*1*		*1*
1982	34		—							
1983	35		1			1				
		10th		*2*	*(1)*	*1*				
1984	36		1			1+				
1985	37		—							
		11th		*5*	*1, (1)*	*1, (1)*		*(1)*		
1986	38		2			1+			1+	
1987	39		—							
		12th		*3*	*1*	*2*				
1988	40		2			2+				
1989	41		—							
		13th		*1*						*(1)*
1990	42		—							
1991	43		1							1
		14th		*2*		*2*				
1992	44		—							
1993	45		1			1+				
		15th		*6*	*1*		*2*	*1*	*1*	*(1)*
1994	46		—							
1995	47		—							
		16th		*6*	*1, (1)*				*3*	*1*
1996	48		1						1+	
1997	49		4		1+		3			
		17th		*4*	*(1)*		*2*			*(1)*
1998	50		1				1+			
1999	51		1			1				
		18th		*4*	*2*		*1*			*(1)*
2000	52		—							
Totals			15	38	12	14	9	3	6	9

Italic numbers denote ICHC papers.
( ) denotes uncertainty in date range.
+ denotes *Imago Mundi* articles previously delivered as ICHC papers.
Source: Douglas W. Sims, comp., *The International Conferences on the History of Cartography: A Short History and a Bibliography of Papers* (adapted for the World Wide Web by Peter van der Krogt), 1995, 2001 (with updates).

TABLE 24. Treatment of twentieth-century cartography in *Imago Mundi* (*IM*) and in the International Conference on the History of Cartography (ICHC), by number and percentage, 1981–2000.

	IM total	20th-century subjects	%	ICHC total	20th-century subjects	%
1981–1990	69	6	8.7	293	13	4.4
1991–2000	99	9	9.1	247	22	8.9

Source: Douglas W. Sims, comp., *The International Conferences on the History of Cartography: A Short History and a Bibliography of Papers* (adapted for the World Wide Web by Peter van der Krogt), 1995, 2001 (with updates).

of *Imago Mundi*'s original functions, to serve "the interests of map collectors," was catered to elsewhere, he maintained that the journal had failed to respond to criticisms of the history of cartography's "antiquarian and bibliographical bias . . . and its lack of philosophical and methodological direction" (Harley 1986, 2, 6). He continued: "Historians of cartography seldom engaged in the excavation of their own intellectual landscape . . . few articles in *Imago Mundi* have been concerned with explicitly methodological as opposed to substantive subjects . . . too often, perhaps, research in the history of the map has taken the form of a hunt for cartographic truffles" (Harley 1986, 6).

Harley had two other major concerns, first, that the issues up to that date were "largely filled with European authors writing about European subjects" and, second, that too many articles reflected the "national model of development," as contrasted with the "multidisciplinary model" he sought to promote. "The history of cartography," he observed, "lies in a no-man's land" (Harley 1986, 8, 11, 12). His words fell on fertile ground. When Catherine Delano-Smith, who became editor in 1994, wrote to mark the journal's sixtieth year, she stressed its internationality (in terms of contributors and readership) and "its role as a forum for interdisciplinary exchange and debate . . . welcoming empirical, interpretative, and theoretical contributions alike" (Delano-Smith 1995).

Whereas Harley could reasonably deplore "national and linguistic frontiers" (Harley 1986, 9), any editor of *Imago Mundi* has to accept that many historians of cartography prefer to continue within those bounds. A sizeable proportion of *Imago Mundi* articles (and ICHC papers) that dealt, at least partially, with the twentieth century can be called "nationally defined" (whatever thematic approach was taken). It would seem that Harley's utopian dream remained a dream.

Around the millennium several significant developments occurred, including the adoption of the subtitle "The International Journal for the History of Cartography" (the fifth in the journal's history). The introduction of scholarly apparatus, such as article keywords and abstracts (latterly in four languages), combined with a typographical redesign, the addition of color plates, and sharpened professionalism, helped to open the journal to a wider readership and prepare for the commercial partnership with Taylor and Francis beginning in 2003. The new publishers continued the print format (after 2004 as a semiannual publication) but duplicated this with an electronic version. The invitation to join the JSTOR web archive of carefully selected scholarly journals (2003) made the earlier volumes widely accessible as well, through subscribing libraries.

The online availability of the entire journal compensated for the absence of a traditional printed index. All issues in JSTOR are fully searchable, thus giving ready access to the main international bibliography for the subject and the formal news record, both systematically formalized in the late 1970s.

TONY CAMPBELL

SEE ALSO: Bagrow, Leo; Histories of Cartography; Journals, Cartographic

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Imhof, Eduard. Eduard Imhof is one of Switzerland's most important cartographers. He was born on 25 January 1895 in Schiers, in the canton of Graubünden. From 1915 to 1919 he studied at the Eidgenössische Technische Hochschule (ETH) in Zurich, where he received a diploma in surveying in 1919. During this time he fulfilled his military service obligation as a lieutenant in the artillery, guarding the border during World War I. During World War II, when he again served in the military, he held the rank of major. Imhof married Agnes Untersander in 1922 and moved to Erlenbach on Lake Zurich in 1928. This marriage produced four children. Agnes died in 1949, and five years later Imhof married the Berlin geographer Viola May.

In 1925 the Swiss Bundesrat appointed Imhof as "extraordinary professor for plan and map drawing, topog-

FIG. 393. RELIEF DEPICTION OF SÄNTIS MOUNTAIN AND THE APPENZELL REGION, 1:100,000, BY EDUARD IMHOF. Original watercolor designed to be used for maps in the *Schweizerischer Mittelschulatlas* between 1948 and 1976. Size of the original: 30 × 18 cm. Image courtesy of the ETH-Bibliothek, Zurich.

raphy and related subjects" (Hauri et al. 1970, 9). That year he founded the Institut für Kartographie at ETH, which he headed from 1925 to 1965. He was promoted to full professor in 1949.

In 1930 Imhof undertook an expedition to China to determine the height of the recently discovered Gongga Shan (Mount Minya Konka). He was supported by Sun Yat-Sen University (中山大学, Zhongshan daxue), in Guangzhou (Canton), and accompanied by geologists Arnold Heim and Paul Nabholz. Their survey found that the peak elevation was only 7,590 meters above sea level, and Mount Everest continued to hold the title of highest mountain in the world.

Between 1927 and 1934 Imhof lobbied strongly for a new national map of Switzerland with coverage at scales of 1:25,000, 1:50,000, and 1:100,000. His application culminated successfully in a new law, passed on 21 June 1935, calling for a new national map. The new map replaced the previous official map, which included the so-called Siegfriedkarte (1:25,000 or 1:50,000) and the Dufour map (1:100,000). Imhof was responsible not only for the new map's content but also for its representation of rock symbols and hill shading.

Between 1928 and 1974 Imhof edited school wall maps and student outline maps for numerous Swiss cantons (Aargau, Appenzell, Basel-Stadt, Basel-Land, Bern, Glarus, Graubünden, Lucerne, Neuchâtel, Saint Gall, Schaffhausen, Schwyz, Ticino, and Zurich) as well as for the Austrian province of Vorarlberg. Between 1932 and 1976 he served as editor in chief of the *Schweizerischen Mittelschulatlas* for twelve editions, published in 1932 (6th ed.), 1936, 1942, 1948 (jubilee ed.), 1951, 1955, 1958, 1962 (rev. ed.), 1965, 1969, 1972, and 1976 (17th ed.). The Konferenz der kantonalen Erziehungsdirektoren was the client, Orell Füssli AG was responsible for the cartographic production, and a publisher of educational materials handled marketing. Because Switzerland is multilingual, parallel French and Italian versions were published as *Atlas scolaire suisse pour l'enseignement secondaire* (5th–15th eds.) and *Atlante svizzero per le Scuole Medie* (2d–12th eds.). In addition, an offshoot was published as the *Schweizerischer Sekundarschulatlas* (1st–12th eds.). Between 1961 and 1978 Imhof, as editor-in-chief, directed production of the monumental *Atlas der Schweiz = Atlas de la Suisse = Atlante della Svizzera*, commissioned by the Swiss Bundesrat with cartographic editing and publishing by the Bundesamt für Landestopographie (later known as swisstopo).

Imhof is perhaps best known outside Switzerland for his work on relief representation (fig. 393), including three-dimensional scale models. Between 1920 and 1922, he worked on his first relief model, a 1:10,000 representation of Mürtschenstock, in the Glarus Alps. For the Swiss national exhibition in 1939 in Zurich, he crafted 1:2,000-scale relief models for Grosse Windgälle (see fig. 796), also in the Glarus Alps, and for Bietschhorn (170 × 140 × 90 cm), in the Bernese Alps. Relief mapping was the theme of his most important books: *Gelände und Karte* (1950; 2d ed., 1958; 3d ed., 1968); *Kartographische Geländedarstellung* (1965); *Thematische Kartographie* (1972); *Die Grossen Kalten Berge von Szetschuan* (1974); *Bildhauer der Berge* (in both German and French, 1981); and *Cartographic Relief Presentation* (1982), an English translation of *Kartographische Geländedarstellung*.

Imhof published more than 400 atlases, maps, books, and magazine articles, for which he received many awards, including honorary membership in twenty-two societies and clubs. In 1949 he was awarded an honorary doctorate by the University of Zurich. Between 1959 and 1964 he served as the first president of the International Cartographic Association, which in 1980 awarded him its Carl Mannerfelt Gold Medal. Imhof died on 27 April 1986, in Erlenbach, Switzerland.

HANS-ULI FELDMANN

SEE ALSO: Academic Paradigms in Cartography: Europe; Airbrush; Labeling of Maps; Relief Depiction: Relief Shading; Terrain Analysis and Cartography; Topographic Map

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Imperial Cartography. See Colonial and Imperial Cartography

Independence. See Decolonization and Independence

India, Survey of. See Survey of India

Indigenous Peoples and Western Cartography. When volume 2 of *The History of Cartography*, appeared (1992–98), it set forth in rich detail the varied cartographic traditions of indigenous peoples worldwide. This essay looks instead at the interaction of indigenous peoples with Western cartographic practices in the twentieth century. The opening definition of indigenous peoples is followed by discussions of the contentious relationship between indigenous peoples and Western cartographic practices and of the sweeping changes in that relationship after midcentury.

Indigenous peoples claim ancestral occupancy of a place before colonization and state formation. Conservative estimates of total numbers in the year 2000 were approximately 250 million people, with indigenous populations inhabiting approximately one-fifth of the earth's land area, including many of the most difficult, extreme, or remote ecosystems. Many indigenous peoples have remained in small-scale societies, dependent at least partially on subsistence activities. Others have come to live in rural and urban areas of industrialized societies with complete reliance on market economies. In both cases, they have frequently continued to conform to their own social, economic, and political customs rather than totally assimilating to those of another population. For centuries, indigenous peoples experienced land dispossession, racialization, subordination, marginalization, discrimination, assimilation, ethnocide, and genocide.

Although indigenous peoples participated in and experienced the encounter with Western cartography differently around the world, the forces driving change occurred within similar time frames. There were three broad periods: state expansion (1900–1959), indigenous activism (1960–88), and indigenous mapping coincident with the International Labour Organization's (ILO) 1989 Indigenous and Tribal Peoples Convention (1989–2000).

In addition to state expansion and resource exploitation, the period 1900–1959 was characterized by new graphic systems of representation and control. As resource exploitation expanded, indigenous lands increasingly became targets for economic development programs and associated bureaucratic and corporate values. Menial wage labor, evangelism, and transformations of resource bases on which indigenous livelihoods depended were norms. Western cartography's deployment of Newtonian-Cartesian space, including standardized mapmaking conventions such as uniform scales, mathematical projections, and coordinate systems, made indigenous lands more accessible to outsiders. Western societies focused on objective mapping of merchantable resources, paths of access, and the location of permanent indigenous settlements, while moral assertions about who held the right to make maps and for what purpose also remained under state control.

In less-developed countries (LDCs), indigenous peoples experienced that expanding cartography much as they had during the nineteenth century. The principal exception would be Latin America. By the early twentieth century, indigenous peoples there had increasingly gained direct experience with cartographically minded institutions of an expanding state. They routinely interacted with and assisted land surveyors and inventory and census takers interested in ethnic mapping. That was true among peoples as diverse as the Mapuche of Chile and the Nasa of the Colombian Andes, as it was of the many land reform beneficiaries of the Mexican Revolution. By 1940, American governments had signed the Pátzcuaro Convention, creating the Inter-American Indian Institute to advance solutions to the so-called Indian problem. That institutionalized an already active indigenous movement in Latin America by creating national institutes that incubated a new generation of indigenous intellectuals. Although paternalistic, the Washington-based institute and its national affiliates created opportunities to participate in ethnic mapping and cartographic production. One path-breaking example was the Ecuadorian mapping project that produced the *Mapas de grupos indígenas* (Knapp 2011). Such ethnic mapping projects exposed young indigenous leaders to the power and effects of Western cartography, to new accounts of their own history, and to indigenous issues throughout the Americas.

Similar relations pertained to indigenous societies in more-developed countries (MDCs) like Canada, the United States, Australia, New Zealand, Denmark, Norway, and Sweden. There, internal colonialism was standard. Lands once considered uninhabitable in Canada, the United States, and Australia, which had been set aside as indigenous reserves or reservations, slowly began to gain the attention of mineral and timber interests, who received government and private-sector mapping support. State-sponsored spatial cataloging of locations and characteristics of indigenous populations was also a factor in the continuing incursion. Censuses and other inventories supported new large-scale mapping of ethnographic details of indigenous peoples. Contemporaneously funded academic anthropologists provided the necessary field-based data, as in the report of the Danish-led Fifth Thule Expedition to Arctic Canada between 1921 and 1924. There, approximately seventy Inuit-drawn maps were transferred to Western cartographic format for publication (e.g., *Report* 1928, 1930, 1931). Cartographic inventories were also standard in white Australia's mapping of indigenous Australians and their lands. Many Indian claims against the U.S. government were settled with the aid of professionally drawn maps of lands taken illegally during the massive white resettlement of the United States (Sutton 1985). As in Latin America, indigenous leaders living in the MDCs gained greater familiarity with Western mapmaking norms and practices and helped subsequent generations in using Western cartographic traditions to combat government abuses.

Indigenous peoples' increasing interaction with state and religious institutions of education, environmentalists, state- or corporate-sponsored mappers, and revolutionary social movements enabled them to use, adopt, and respond to Western forms of mapmaking. Responding to widespread social unrest in the 1960s, many Latin American states initiated agrarian reforms, distributing land to indigenous and peasant peoples. Actual land demarcation and titling involved interacting with state agencies responsible for land surveying, field mapping, and registering titles in cadastral systems. Those on-the-ground changes coincided with the first pan-American indigenous conferences in the 1970s and the sharing of organizational and cartographic experiences among indigenous peoples.

Some indigenous peoples in Latin America began making their own maps, but with few documented examples. Aymara and Quechua peoples residing around Peru's Lake Titicaca, for example, organized a defense league, the Liga de Defensa de la Totora, to defend longstanding customary rights to community-managed reed beds along the lakeshore. As early as 1976, the league began drawing and using maps to protest state plans to include community beds in a protected area and reserve system (Orlove 1991).

In Asia and Africa, many postcolonial states followed the bureaucratic inertia of colonial predecessors and imposed their authority over common property resources managed by ethnic minorities. Vast tracts of customary-use lands suddenly became nationalized through legal and cartographic collusion. As in Latin America, early local responses often involved the production of maps (Chapin, Lamb, and Threlkeld 2005). Such was the case among the Maasai in Tanzania in the 1980s (Hodgson and Schroeder 2002) and in other parts of Africa, although results were often mixed.

In the MDCs, small mapping projects were conducted sporadically in the Arctic and sub-Arctic regions of Canada and the United States beginning in the 1950s. By the 1970s, land use and occupancy projects (LUOPs) became normalized in Canada, projects involving indigenous peoples and Western cartography to an unprecedented degree. LUOPs employed Western cartographers, academics, and federal employees to document native land uses, travel habits, and pursuit of livelihoods. Those early forerunners of later "participatory mapping" projects (Herlihy and Knapp 2003; Sletto 2009) were conducted with the assistance of indigenous peoples but were by no means under their complete control.

Canada had vast regions of untapped resources. In addition, aboriginal title had not yet been extinguished in British Columbia and in the territories, a colonial requirement of English common law. Indian and Inuit leaders anticipated the coming resource grab for oil, gas, and precious minerals just as they had become concerned about cultural persistence. So the impetus for native peoples to produce hundreds of map-biographies (stories of their lives on the land recorded on maps) came directly from indigenous political organizations. Examples included the 1970s Dene Mapping Project in the Northwest Territories and the LUOP conducted by anthropologist Hugh Brody and bands of Tsattine (Beaver Indians) in northeast British Columbia beginning in 1978 (Brody 1988). The three-volume report of the Inuit Land Use and Occupancy Project was the most comprehensive example (Freeman 1976). Conducted under the auspices of Inuit Tapirisat of Canada in the early 1970s, the project documented Inuit land use ideas and practices across 388 million hectares of land and sea, thus laying the groundwork not only for contesting the state's presumption of unrestricted access but also for the emergence of the Inuit-governed territory now known as Nunavut.

Place-name mapping became important during that period, too. Not only had it become an element of land claims, but also it was crucial for preserving and teaching geographical information to native youth as an antidote to excessive Westernization. Work commencing in the mid-1980s led to two prototype maps of an Inuit place-name map series, a first in North America. Financed by the Makivik Corporation, a private Inuit-owned company with a substantial government subsidy, the Inuit hired Western cartographers to draw Inuit places and names directly on sheets of the government's 1:50,000 topographic map series. The joint copyright is between an Inuit organization and "Her Majesty the Queen in Right of Canada" (Avataq Cultural Institute 1990–).

Some felt such mergings were an important gesture of reconciliation. For example, a Saami activist, Hans Ragnar Mathisenis, sought reconciliation with Norwegians and the Norwegian state when in 1975 he constructed a very popular map of Sápmi, the Saami homeland, from a Saami perspective using Western cartographic techniques.

That period also saw the rise of the cultural atlas. For example, the Zuni in the United States produced an atlas of their historical and contemporary land uses. Leaders viewed and approved its maps before authorizing publication (Ferguson and Hart 1985; Herlihy and Knapp 2003).

A remarkable confluence of events occurred in the early 1990s, heralding a new era in relations between indigenous peoples and Western cartography: the promulgation of the ILO's Convention on Indigenous and Tribal Peoples (ILO 169); the digital technology transformation and concomitant democratization of geographic information systems (GIS), satellite images, global positioning systems, and the Internet; the globalization of neoliberal economic policies; international media attention to problems of environmental sustainability and human rights; the growing prominence of international and national nongovernmental organizations (NGOs) in promoting indigenous rights and environmental conservation on indigenous lands; and the worldwide rise to power of a new generation of media-savvy indigenous leaders steeped in lessons learned earlier in the century (Poole 1995; Herlihy and Knapp 2003; Chapin, Lamb, and Threlkeld 2005). Those developments created opportunities for marginalized peoples to establish a new relationship with Western cartography aimed at gaining greater control over their lands and lives.

Nowhere did that prospect come together more solidly than in Latin America. There, constitutional reforms redefining countries as multiethnic and pluricultural helped indigenous peoples assert rights to traditional lands. Seventeen such reforms swept Latin American countries after 1987. Underscoring the advancement of ethnic rights and the new territoriality in Latin America was the 1989 dissemination of ILO 169, which put pressure on governments to recognize and map indigenous peoples' traditional lands. The specific ways that ILO 169 defined collective cultural rights, in turn, influenced the language of indigenous territorial demands, Latin American constitutional reforms, World Bank operational directives, and other important conventions, such as the 1993 Convention on Biological Diversity (Offen 2003, 44). Once ratified by an individual country, ILO 169 took on the force of domestic law and provided indigenous peoples legal leverage to hold national governments accountable. Since fourteen of the twenty ratifying countries were in Latin America, the impact there was immediate and widespread. Mapping projects emerged rapidly throughout Central and South America in the early 1990s (Poole 1995; Nietschmann 1997; Herlihy and Knapp 2003; Offen 2003; Chapin, Lamb, and Threlkeld 2005). Leading international NGOs, such as the Washington-based Native Lands and the Amazon Conservation Team, institutionalized field and cartographic methods established piecemeal by many indigenous leaders and academics in the late twentieth century. Indigenous and aboriginal mapping forums, online networks and web pages providing working papers, and maps and digitized data sets subsequently proliferated.

Digital technologies and Western cartographic practices were rapidly adopted by many indigenous societies around the globe. Political ecologist Nancy Lee Peluso (1995) coined the term "counter-mapping" to describe that new adoption of Western cartographic practices and conventions by indigenous or other marginalized populations to legitimize and graphically justify customary resource use and occupancy claims against those asserted by the state. Such projects were pursued in every major country with indigenous peoples. China was perhaps the only significant exception.

From indigenous perspectives, adopting Western cartographic conventions and concepts could assist recognition of land use rights, development and preservation of collective knowledge, clarification of the meaning of places, and perhaps protection against government-enforced land clearances. Accordingly, cultural atlases gained favor (e.g., Mathisenis, Aikio, and Henrikson 1996; Herlihy and Knapp 2003), and several how-to manuals appeared (Chapin, Lamb, and Threlkeld 2005; Tobias 2010). For example, the Ford Foundation, World Wildlife Fund (WWF), and several Indonesian NGOs jointly issued a 1996 manual with summaries of several Indonesian projects. The manual promoted Western-style mapping as a means of mediating resource conflict. Subsequently, thousands of Indonesian villages engaged in counter-mapping projects.

Such examples became global, but not without downsides. For example, the WWF and the Indian Law Resource Council (ILRC) were instrumental in using native-drawn and computerized maps to bring illegal logging concessions on Mayangna lands in Nicaragua to the attention of the Inter-American Court of Human Rights (IACHR), a branch of the Organization of American States (OAS). In 2001, the court ruled that Nicaragua had violated its own constitution in granting the concession. It also ruled that land was a fundamental human right for indigenous peoples, a foundational decision that probably would not have been made without cartographic evidence produced by native peoples themselves. The decision, however, also produced the unintended consequence of creating a land conflict with neighboring Miskitu Indian communities (Finley-Brook and Offen 2009).

The growing number of cautionary tales tempered the rush to adopt Western cartography. Skeptics recognized the transformative and reifying power of maps and GIS and questioned whether indigenous ways of knowing and representing space could be digitized or what the impacts might be. For indigenous peoples, rights to what Western cartographers term "resources" were not independent from the social relations that produced them. That is, rights to resources on specific lands were defined by customary and dynamic social practices more than by firm ownership within solid boundary lines marking mutually exclusive territories (Chapin, Lamb, and Threlkeld 2005; Sletto 2009). Kinship networks and obligations, marriage practices, rights to farm and hunt, and other factors imposed a dynamic social atmosphere on land use rights, one frequently at odds with the Western concept of fixed resources on fixed territories. Counter-mapping against the state might require Western cartographic conventions, but indigenous geographies that once justified the mapping project might be altered or replaced, producing more conflict rather than less (Chapin, Lamb, and Threlkeld 2005). Some critics argued that, by operating within a neoliberal economic order, indigenous mapping projects were strengthening the material and conceptual creep of "property" into indigenous land struggles (e.g., Sletto 2009).

There were other concerns, too. How accountable were Western cartographers to nonmapmaking indigenous informants and other members of the community? Who prepared the maps and how was credit assigned? Who were the indigenous representatives who had access to the project and who decided? Were women and youth included? What were the true goals of the large external NGOs and their donors? How would the maps be used after mapping projects were completed? And how clear were the mapping project and its expected effects to the people whose lands were mapped? Such issues led some indigenous peoples to question the legitimacy of adopting Western mapping traditions. Engaging in dialog with a neoliberal state might induce too high a social cost, especially if that dialog had only a slight promise of success.

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SEE ALSO: Community Mapping; Colonial and Imperial Cartography; Counter-Mapping; Geographic Information System (GIS): GIS as an Institutional Revolution; Geographic Names: (1) Social and Political Significance of Toponyms, (2) Applied Toponymy; Histories of Cartography

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Institut Cartogràfic de Catalunya (Cartographic Institute of Catalonia; Spain). The Institut Cartogràfic de Catalunya (ICC), the mapping agency of the Spanish region of Catalonia, was created in 1982, in Barcelona, to develop cartographic information for the Catalan Autonomous Government and provide related technical support. Completely independent of Spain's national mapping agency, the Instituto Geográfico Nacional, the ICC can operate like a private company by providing cartographic services on contract to outside clients.

From its inception the ICC chose to introduce computer systems into the map production process and to become a center of innovation in Spain and Europe. Taking advantage of existing photogrammetric models for aerotriangulation as well as an interactive Gestalt GPM-IV system for the automated correlation and correction of aerial imagery, the ICC initiated a pioneering project to provide orthophotomap coverage of Catalunya at 1:5,000. The series of 6,331 sheets, published between 1986 and 1992, was the first complete regional coverage of its kind in Spain.

To address its specific requirements, the ICC developed in-house software and computer systems for geodesy, photogrammetry, and image processing (Colomer and Colomina 1994). It initiated computer-assisted photogrammetric restitution in 1984, and introduced personal computer workstations in 1989. The ICC made its first photogrammetric flight with an onboard GPS (Global Positioning System) in 1990 and carried out its first aerotriangulation supported by a hybrid kinematic GPS-inertial navigation system in 1994. Recognizing the value of nonphotographic sensors, the ICC acquired a Compact Airborne Spectrographic Imager (CASI) in 1994, and began using radar interferometry that same year to collect data for its first digital elevation model. With the acquisition of two airborne digital cameras in 2004, the entire process of cartographic production was completely digital.

A marked impact on the dissemination of cartographic information became apparent when digital media, most notably the Internet and World Wide Web technology, began to replace the traditional printed map. In 1999 an ICC map server inaugurated online access to a web map of Catalonia. In 2001 more than 10,000 sheets of the cartographic series of Catalonia were available online, and as of 2003 these sheets could be downloaded for free. Distribution of raster data began in 2005, and the ICC assumed management of the Spatial Data Infrastructure of Catalonia as part of the European Union's INSPIRE (Infrastructure for Spatial Information in Europe) Directive (Craglia and Campagna 2009, esp. 35).

Contract work for outside institutions, public and private, has been a significant source of income. The ICC has undertaken its most important projects in Spain, Argentina, and Venezuela. Particularly noteworthy is the 1:50,000-scale radar image map of south Venezuela (250,000 km^2), published between 1998 and 2000 and one of the first map series in the world produced using this technique.

To preserve the Catalan cartographic heritage, the ICC has maintained a map library, which in 2007 contained more than 300,000 sheets of old and modern maps from around the world. To make its collection more accessible, the agency inaugurated an online Digital Map Library in 2007, with initial access to over 7,000 maps (Montaner and Roset 2008).

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SEE ALSO: Instituto Geográfico Nacional (National Geographical Institute; Spain); Topographic Mapping: Western Europe

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Institut Géographique National (National Geographical Institute; France). The Institut géographique national of France (IGN, IGN-France, or IGN-F on military maps) is the French national mapping agency. This agency was created on 1 July 1940, and replaced the Service géographique de l'armée (French military survey, or SGA). The SGA, established in 1887, was created from the three geographic divisions (geodesy, topography, and cartography) of the former Dépôt de la Guerre. Created in 1688, the Dépôt de la Guerre was in charge of the carte d'État-Major, the French base—then military—map series at the scale 1:80,000. These were based on colored survey maps at the scale 1:40,000 and printed from engraved copperplates. The SGA also carried out mapping of foreign territories and topographic surveys in French North Africa. In the late nineteenth century, the SGA launched a new geodetic network of continental France, the Nouvelle triangulation de la France, the undertaking lasting from 1892 to 1980. The SGA also created large-scale mapping at 1:10,000 of border areas. These so-called *plans directeurs* were initially surveyed by topographic teams of military engineers (*brigade topographique du Génie*) and were maps of fortifications. These *plans directeurs* were among the earliest maps to incorporate a grid. Starting in the 1880s, a polychrome series of maps at 1:20,000 with hill shading and contours were issued for the environs of Paris. These large-scale map series gave rise to the idea of a new base map at 1:50,000. Following various experiments, particularly with relief representation (Huguenin 1948), this new map series, La nouvelle carte de France, or Type 1900, was started in 1898. It adopted contour lines for relief representation, a geographic coordinates–based sheet division, centered on the Paris meridian, and relied upon eight (initially) to fourteen colors. Each map sheet covered 0.2 metric grads in latitude (20 km) and 0.4 grads in longitude (ca. 28 km), and used a polyhedric projection (de Margerie 1905, 240).

This new base map series was generally considered aesthetically attractive, but was very expensive and required a long time to produce. By 1914 only nine sheets were available in the area of Paris, and about thirty-six in the north and northeast of France. Early in the century, the only nationwide coverage with contour lines was the 1:200,000 map series, which was initially derived from the 1:80,000 carte d'État-Major when maps were updated. This 1:200,000 map series was used from 1910 by Michelin to derive its famous road map series.

During World War I, the SGA was temporarily boosted by the creation of support teams, *Groupes de canevas de tir*, to help artillery regiments. Another change was the adoption, by the end of 1914, of a conical conformal Lambert projection for all mapping in conflict areas. The topographical squadrons steadily produced maps, partly derived from a range of preexisting cartographic materials, including cadastral maps of conflict areas and drafts of the carte d'État-Major of German-occupied areas. New technical approaches were developed, in particular those based on aerial photographs (Bacchus 2002) that were used intensively to create very large-scale defense maps (*plans directeurs de guerre*) on which trenches were then drawn (see fig. 548).

The production of 1:50,000-scale maps of Alsace-Lorraine in 1919–20 was based on generalized German 1:25,000 maps, and the process helped define the production of the 1:50,000 map series. The Type 1900 process was incredibly slow, so after World War I the new director of SGA, General Léon-Henri-André Bellot (director, 1919–35), proposed changing the specifications in an effort to increase the pace of production and simplify future updating of this map series. He also envisaged the creation of a new map series at 1:20,000 based on the *plans directeurs*. His proposals were accepted in 1922, so the new 1:50,000 and 1:20,000 map series were named Type 1922 maps (France, Service géographique de l'armée 1938, 89). A three-zone Lambert projection was defined (a fourth zone was added later to cover Corsica); five colors were chosen for 1:50,000 (black, blue, brown, green, and gray for hill shading); the maps were drawn on paper glued onto zinc plates (one plate per color) at a scale of 1:33,333; and offset printing was used to produce the map sheets. Scale surveys at 1:10,000 were published as 1:20,000 map sheets, one sheet being one-eighth of a 1:50,000 sheet, in three colors.

Despite intense lobbying and user appreciation of these projects, there was no significant increase of SGA's budget, and production was still slow. While 1,100 map sheets were to be produced, annual production only gradually increased between 1922 and 1937 from two sheets to eight sheets (an average sheet represented 530 km^2). The increase was due to a simplification of cartographic choices, an expansion of the areas covered by 1:20,000 surveys, and more importantly the use of photogrammetry. Terrestrial photogrammetry had been introduced as early as 1907 for topographic surveys in the Alps, which covered 1 percent of continental France, between 1910 and 1939. Based on this experience, the department of optical instrumentation kept working on photogrammetric techniques and developed a process for aerial photogrammetry. Stereoplotters developed by Georges Poivilliers were chosen for this purpose and produced a first sheet in 1930. Progressive improvements of this new production process allowed increased efficiency and faster production than did the traditional approach, despite the greater number of steps involved.

Eventually, the head of the optical instrumentation department, Colonel Louis Hurault, was named head of SGA in 1937. His first concern was the high turnover among the personnel in charge of fieldwork. Many of them were rapidly rotated to join other army units or, more frequently, colonial surveying units. He worked hard to get approval for the creation of new personnel: survey officers (*officiers géographes*) and survey noncommissioned officers (*sous-officiers géographes*). He also received approval for the creation of a squadron dedicated to aerial photography for cartographic purposes. Once World War II was declared, *Canevas de tir* squadrons (*Groupes de canevas de tir aux armées*, or GCTA) and army topographic squadrons (*Sections topographiques de corps d'armée*, or STCA) were redeployed, as in World War I. During the first year of the war, 1939–40, the printing department, together with a few private printing companies, produced stockpiles of maps for military operations. In May 1940 the SGA moved to Bordeaux, in southwest France, to avoid German troops. In addition, Hurault, now a general, successfully lobbied the government to convert the SGA into a civilian department, the Institut géographique national, subordinated to the Ministry of Public Works. At a meeting in August 1940 in Wiesbaden, he received approval from the Franco-German Armistice Commission for a transfer of SGA equipment and archives to the newly created institute.

The surveying department (Nivellement général de la France, created in 1884) was merged with IGN, which was then reorganized, starting with a regrouping of the units and personnel available in Bordeaux and the creation of (civilian) civil service personnel categories: survey engineers (*ingénieurs géographes*), survey adjunct engineers (*ingénieurs des travaux géographiques*), and technicians (*adjoints techniques*, later *techniciens géomètres*), to which IGN personnel were then allocated. In 1941 a training school called the École nationale des sciences géographiques was created, and eventually the IGN started working again on the Carte de France. By the end of the war, the printing department of the IGN, briefly turned back into a military department, produced twenty million maps in less than a year for the Allied forces. It is worth noting that while the printing department had to print maps for the German forces during the occupation (1941–44), it also printed maps of France and French North Africa and sent them to London to replace maps destroyed during German bombing. In addition IGN personnel trained in calligraphy and printing were a resistance hub, expert at providing fake documents and identity cards.

In 1945 the new government confirmed the civilian institute and decided in addition to form a new military survey (the Section géographique de l'Etat-Major de l'armée, later the Section géographique militaire). This new military unit was in charge of producing military geographic documentation and of managing the stockpile of maps produced by the IGN for the armed forces. The IGN itself entered a period of strong growth and steady activity. While the focus for about three decades had been the production of the 1:20,000 topographic map series, with new technical developments introduced shortly before the war, Hurault reorganized the IGN to better accomplish a variety of missions. From 1946 a new aerial department based in Creil, north of Paris, was tasked with imaging the country, and by 1953 the first full coverage of 1:25,000 photographs was completed. A new directorate gathered together all administrative staff, another was tasked with geodetic work and surveying (based on the scientific activities and experts of the former SGA), a third gathered all photogrammetric activities (from stereopreparation to stereoplotting) and topographic works (surveying, field completion, updating), a fourth was dedicated to cartography (drawing department, printing department, and sales—sales at marginal cost), and a fifth was in charge of equipment and logistics, including building maintenance. Logistics was housed in a former World War I U.S. logistic base in Villefranche-sur-Cher. Finally, an auditing department (Inspection générale des services géographiques d'outremer) was in charge of coordinating and monitoring colonial survey activities. These survey departments were now subordinate to the IGN. Mapping colonies was by then a very significant part of IGN activities, leading to the development of new processes to take advantage of aerial coverage of African colonies (Sallat 2003).

An additional change consisted in progressively reorganizing most departments, including the school in the Saint-Mandé facility, where new buildings were erected between 1946 and 1962. The printing department joined in 1988 (by then about half of the staff was located in Saint-Mandé), while the headquarters remained in Paris until 2007.

Another significant change was in staff size. To cope with a more ambitious annual target, it increased from 1,500 people in 1946 to 2,400 in 1986. Staff numbers were later reduced, in part as a consequence of the progressive automation of various tasks, reaching 2,000 at the end of the century. In addition, locally recruited temporary staff were involved in fieldwork.

During the second half of the century about fifty stereoplotters were used in map production. Each plotter had an operator and a technician responsible for cleaning the resulting plot. The cartographic drawing was then subject to field completion by another technician (*géomètre*) who would update and add items such as place-names. Cartographic experts (*artistes cartographes*) were then in charge of creating a map from these cartographic documents, with part of this cartographic activity delegated to draftspersons working at home. Until 1966 maps were first drawn at a scale of 1:20,000, from which the 1:50,000 map was derived.

At the same time, military requirements within the framework of the North Atlantic Treaty Organization (NATO) increased. The IGN-F therefore derived 1:50,000 map sheets with military information overprinted in color from the 1:80,000 map and 1:25,000 maps by photographic reduction from 1:20,000 maps with the addition of a Universal Transverse Mercator (UTM) grid. From 1955 to 1964 this was in part funded by the U.S. Army Map Service. In 1954 a new 1:100,000 map series was started, derived from either 1:50,000 maps or from 1:80,000 maps, followed by a 1:250,000 map series, in line with NATO standards.

In the early sixties the IGN-F moved to scribing on plastic sheets (mylar, Astralon) for map drawing. This helped increase significantly the efficiency of cartographic production, but not enough to cope with further increasing demand, especially in light of defense requirements related to the war in Algeria (1954–62).

In order to reduce the production load, in 1958 the IGN-F stopped its 1:20,000 civilian map series and replaced it with the 1:25,000 series (though without the UTM grid for the civilian version). As this change could not be implemented overnight, in 1964 part of the country (12 percent) was covered by both map series, another 18 percent by the old 1:20,000 series, and 38 percent by the new 1:25,000 series. The new IGN director, Georges Laclavère, who served from 1964 until 1975, decided to speed up the 1:25,000 series and to forget the 1:20,000 series. Many employees objected and claimed that the base map would be of a lesser quality. Former director Hurault added his voice and pointed to other choices that had been implemented too quickly, before a full assessment of the implications for quality, to accelerate production: aerial photographs at a scale of 1:40,000 (instead of 1:25,000), stereoplotting limited to features to be depicted on the 1:50,000 series (hence a simplified 1:25,000), and less time devoted to field completion.

Following these debates, several technical studies took place, as well as a public consultation with map users, leading to the adoption in 1972 of a new specification of the base map series. This new 1972 Type series was based on four colors (black, cyan, orange, green) and showed a quite different aesthetic (Alinhac 1978). A monochrome enlargement at a scale of 1:10,000 was made available for professional users, who typically combined this background map with local area surveys at a scale of 1:5,000. Map series at scales of 1:25,000 and 1:50,000 were then produced in parallel from the same 1:25,000 surveys. These changes help further accelerate production, so that the country was eventually covered at the base scales of 1:25,000 and 1:50,000 by 1980, with a much faster revision cycle.

FIG. 394. DETAIL OF BALARUC-LES-BAINS, HÉRAULT, 1950. Carte de France, 1:20,000, n° 2744, Sète n° 5, 1st ed., type 1922.
Size of the entire original: 68.5 × 45.6 cm; size of detail: 13 × 8.4 cm. Image courtesy of the Cartothèque, Institut géographique national.

FIG. 395. DETAIL OF BALARUC-LES-BAINS, HÉRAULT, 1971. Carte de France, 1:25,000, n° 2744, Sète n° 5–6, 1st ed., type 1922.
Size of the entire original: 53.5 × 65.9 cm; size of detail: 13 × 8.4 cm. Image courtesy of the Cartothèque, Institut géographique national.

Laclavère faced another dramatic change: the ministry turned the IGN into an independent agency in 1967 (an Établissement public à caractère administratif). It was tasked with finding additional funding from sales (Sinoir 1999), such as sales of maps and of on-demand surveys and cartographic production in France (mostly for public authorities, and defense) and abroad (initially mostly as part of the French government's aid to newly independent French-speaking countries). The share of sales in the IGN's annual budget increased progressively to become about half. On the positive side, the IGN could enjoy more flexibility in purchasing goods and services as long as it was backed by sales. Investment in equipment such as airplanes, modern stereoplotters, and large-format printing machines was boosted as a result.

To further develop sales, Laclavère decided to start new map series, road maps, and tourist maps. These large-format maps, folded when sold and named after the color of the map label, included a 1:250,000 road map series (red series with fifteen map sheets), a 1:100,000 topographic map series (green series, with seventy-four map sheets), and a limited mountain map series to cover the most attractive mountain areas (violet series) (Guilhot 2005). In addition, a civilian 1:50,000 map series was also derived and launched in 1974, with hill shading and the UTM grid incorporated in black, to keep within the four colors. Small 1:25,000 map sheets were also assembled, initially two sheets assembled into one, to create a new 1:25,000 map series (blue series), while in the 1980s a larger format (A0+) and six colors

FIG. 396. DETAIL OF BALARUC-LES-BAINS, HÉRAULT, 1986. Série bleue, 1:25,000, n° 2744 ouest, Sète, 2d ed., type 1922–72.
Size of the entire original: 90 × 77 cm; size of detail: 13 × 8.4 cm. Image courtesy of the Cartothèque, Institut géographique national.

FIG. 397. DETAIL OF BALARUC-LES-BAINS, HÉRAULT, 2003. TOP25, 1:25,000, n° 2645 ET, type 1993.
Size of the entire original: 91.6 × 121 cm; size of detail: 13 × 8.4 cm. Image courtesy of the Cartothèque, Institut géographique national.

were chosen (Chappart and Reynard 2007) for tourist areas (the new TOP25 map series).

Beginning in the 1980s, computerized cartography and earth observation activities were also developed. Computerized cartography was first introduced in large-scale mapping of foreign territories and of some French territory. In parallel with the CNES (Centre national d'études spatiales), the IGN took part in the French SPOT (Système Probatoire d'Observation de la Terre) satellite program (the first satellite was launched in 1986), which included technical studies on image geometry and also the production of maps of various areas around the world. The IGN also took part in GDTA (Groupe pour le développement de la télédétection aérospatiale), a joint venture with the CNES and others dedicated to training in earth observation and mapping from satellites. Research in the form of structured department laboratories was developed during the same period of time at the IGN. LOEMI (Laboratory of Optronics, Electronics and Mechanics for Instrument Design) was created in 1984 and developed a first prototype digital camera in 1994. In 2004, based on LOEMI's cameras, France became the first country with full digital photographic coverage. The research department has three other laboratories (focused on geographical information systems [GIS] and cartography, photogrammetry and image processing, and geodesy research) that were progressively created between 1987 and 1991.

A French national policy on geographic information was introduced in 1982 by the Commision nationale de l'information géographique (succeeded, in 1985, by the Conseil national de l'information géographique), headed by the MP Guy Lengagne. The IGN thereafter devoted an increasing share of its workforce to producing digital databases. The first, initially produced between 1979 and 1982, was the elevation database for defense and civilian use partly created by digitizing contour lines. After several studies, a new database called BDCarto started in 1986, with the digitizing of 1:50,000 map sheets. It has been regularly updated over the past twenty years, and this medium-scale reference database (*Référentiel à moyenne échelle*) is the source from which contemporary 1:250,000 (TOP250) and 1:100,000 (TOP100) map series were derived (Lecordix 2007, 111–12) (figs. 394–97). In the early nineties a more ambitious project was launched: the BD TOPO database, a 2.5D database that relies on stereoplotting from 1:25,000 aerial photographs and field completion and aims for one-meter accuracy. The initial plan was to cover the country within thirty years and to derive the base map at a scale of 1:25,000 from this database (Type 93 map series). However, following a report issued by a committee headed again by Lengagne, which advocated that a national geographic information infrastructure be quickly developed and include topographic and cadastral information, changes were introduced in 1999 to accelerate production, based on simplified specifications, to make it the topographic component of a national large-scale reference database. This includes in addition a national orthography, an address database, and a land parcel database. This large-scale reference database (*Référentiel à grande échelle*, RGE) constitutes the core of the IGN's mission. It is kept current by technicians across the country who update a central database (Bacchus 2004, 54–57), but is also helped by data exchanges with other state agencies and local public authorities.

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SEE ALSO: Geodetic Surveying: Europe; Topographic Mapping: Western Europe

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Instituto Geográfico Nacional (National Geographical Institute; Spain). The Instituto Geográfico Nacional (IGN) was the primary Spanish mapping institution throughout the twentieth century. It was established in 1870 with the geodesist and military engineer Carlos Ibáñez e Ibáñez de Ibero as its first director. Throughout its history, the Instituto has had a variety of names, which reflect changes in its mission and responsibilities. The IGN has been, in succession, the Instituto Geográfico (from 1870), the Instituto Geográfico y Estadístico (from 1873), the Instituto Geográfico y Catastral (from 1925, with a few variations in the 1930s), and the Instituto Geográfico Nacional (from 1977).

Since its inception, the IGN has overseen Spain's cartographic foundation and topographic framework, with exclusive responsibility for the geodetic network, the national topographic map at a scale of 1:50,000, and the national topographic map at a scale of 1:25,000. From 1870 to 1971 it was also responsible for cadastral mapping. These responsibilities led to the creation of a series of technically specialized agencies, most notably the Cuerpo de Topógrafos and the Cuerpo de Ingenieros Geógrafos.

The Cuerpo de Topógrafos began in 1870 with 288 employees, most of whom came from the staff hired during the 1860s for the Junta General de Estadística (Muro, Nadal, and Urteaga 1996, 150). The Cuerpo de Topógrafos calculated second- and third-order geodetic triangulation, conducted topographical measurements, drew up maps for the national topographic map, and performed other tasks related to the cadastre and its preservation. With the formation of the Cuerpo de Ingenieros Geógrafos in 1900, the Cuerpo de Topógrafos was refocused to assist geographical engineers with their mapping duties. Throughout the twentieth century, the number of topographers increased dramatically, reaching a total of 673 in 1933, when the Cuerpo de Geómetras, previously assigned to the Ministerio de Hacienda, became part of the Cuerpo de Topógrafos.

The Cuerpo de Ingenieros Geógrafos was created as a result of a surge in jobs related to cadastral mapping. Its initial workforce came from the newly disbanded Cuerpo de Geodestas, as well as from the chiefs and officials of the Cuerpo de Topógrafos. These new employees were hired after a selection from the technical army corps (artillery men, military engineers, General Staff), various corps of civil engineers, and licensed architects. In 1905 the Cuerpo de Ingenieros Geógrafos comprised ninety-five employees, a number that remained around one hundred during the first third of the twentieth century (Urteaga and Nadal 2001, 38–40). The group was assigned all the responsibilities pertaining to the national topographic map, including all orders of the geodetic system, ordinary and precise leveling, and topographical mapping, as well as tasks related to developing and maintaining the cadastre.

The Instituto Geográfico inherited the personnel and the cartographic duties that had been carried out since 1856 by the Junta General de Estadística (Muro, Nadal, and Urteaga 1996). The first of these tasks was to create a preliminary plan and make observations for establishing a geodetic network for the Iberian Peninsula using a baseline measured in Madridejos (Toledo) in 1858 under the direction of geodesist Ibáñez e Ibáñez de Ibero. The primary network consisted of ten chains of large triangles with sides averaging forty kilometers in length. Measurements and precise calculations for this triangulation were not completed until 1915, when effort shifted to increasing the density of the framework with second- and third-order networks. Measurements and calculations for these networks were completed in 1934 (Paladini Cuadrado 1969). The peninsular grid was integrated with two independent triangulation grids, for the Baleares and Canary Islands. The Baleares network was developed by Ibáñez e Ibáñez de Ibero, with observations carried out between 1865 and 1870. The Canary Islands network was completed much later, between 1923 and 1928, under the direction of the geodesist Fernando Gil Montaner.

This geodetic system, consisting of the three networks mentioned above, provided the framework for the first large-scale topographic map of Spain: the *Mapa Topográfico de España a escala 1:50.000*, which was later renamed the *Mapa Topográfico Nacional* and was known as the MTN50. Production of the MTN50's over 1,100 map sheets, each covering ten degrees of latitude by twenty degrees of longitude, was for many years the primary cartographic undertaking of the Instituto Geográfico (Urteaga and Nadal 2001). Sheets were cast on Tissot's polyhedral projection using planes tangent to the Struve ellipsoid. Madrid was used as the reference meridian for longitude, and elevation was based on mean sea level at Alicante. Features were initially plotted at a scale of 1:25,000, and the relief was represented using contour lines with a vertical interval of twenty meters.

Publication of the MTN50 series began in 1875, when sheets 534 (Colmenar Viejo) and 559 (Madrid) were printed. Sheets published between 1875 and 1908 were printed lithographically in five colors from delineations drawn on the stone by hand (fig. 398). The complexity of the fieldwork, the adoption of the lithographic press as a means of reproduction, and organizational and budgetary difficulties all slowed down the execution, but it was understood at the outset that the project would take a long time to complete. In reality, it took much longer than even the most pessimistic observers might have imagined. The last sheets of the first edition were not published until 1968.

After completing the first edition of the MTN50 series, the Instituto Geográfico took up a new cartographic project, in keeping with the needs of an industrial nation: a 1:25,000 map designed by the geographical engineer Rodolfo Núñez de las Cuevas, who served as the IGN's president from 1974 to 1980. The *Mapa Topográfico Nacional a escala 1:25.000* (MTN25) was cast on the conformal projection of the Universal Transverse Mercator (UTM) grid and referenced to the European Datum 1950 (ED50), used for much of Western Europe and based on the International ellipsoid of John Fillmore Hayford, centered at Potsdam, Germany, with longitudes anchored at Greenwich. Sheet boundaries were inherited from the MTN50 series, with each sheet divided into four quarters and identified with Roman numerals. Although the MTN25 series was originally proposed as a companion to the 1:50,000 *Mapa Topográfico Nacional*, with complete nationwide coverage, work was limited to zones of special interest—cities; the Atlantic and Mediterranean coasts; the international borders with Portugal, France, and Andorra—with 1:50,000 as the basic scale for the rest of the country. Not until the 1980s was scope of the MTN25 expanded to cover the entire nation with an edition that eventually consisted of 4,126 sheets.

Production of the MTN25 series had two distinct stages (Cebrián Pascual and García Asensio 1997). The first phase lasted from 1971 through the end of the 1980s. During these two decades, photogrammetric compilation was carried out exclusively using analog

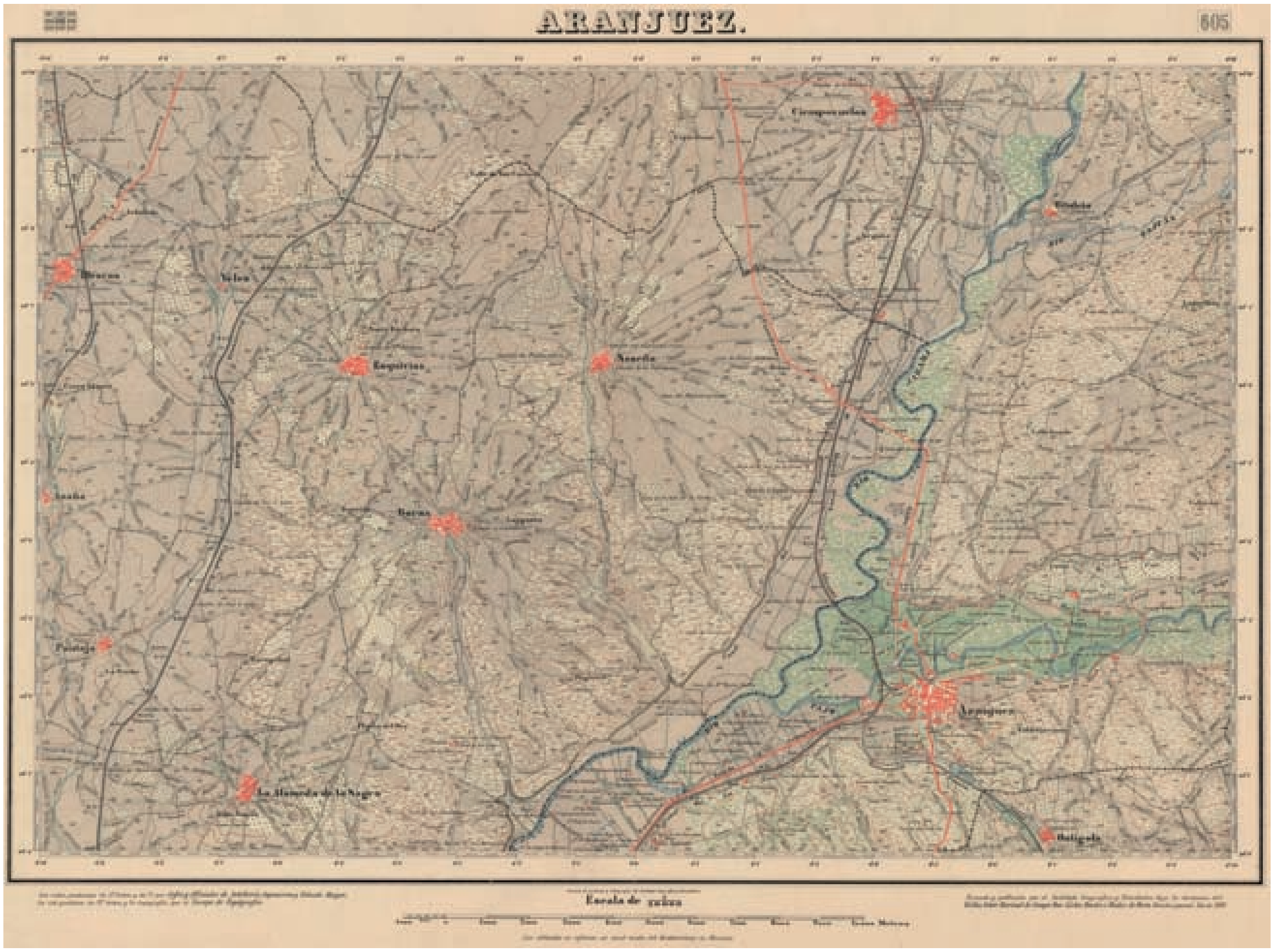

FIG. 398. *ARANJUEZ*, 1880. Sheet 605 of the *Mapa Topográfico de España a escala 1:50.000*. Made and published by the Instituto Geográfico y Estadístico, Madrid, under the direction of Ibáñez e Ibáñez de Ibero. First edition; engraved.
Size of the original: 40 × 60 cm. Image © Instituto Geográfico Nacional de España, Madrid.

rather than digital techniques. Constrained by analog photogrammetry and the slow recording of delineations, production never exceeded eighty sheets a year between 1975 and 1985. The 856 sheets that had been edited by 1986 covered only 20 percent of the nation's territory. That year the IGN sought to expedite production by introducing innovative digital technologies for numerical stereoplotting, electronic editing, and computer-aided drafting (Cebrián Pascual and García Asensio 1997). The result was a vastly improved system for collecting and processing cartographic information. The production of digitally produced maps, using a new editing and computer-aided drafting system acquired in 1989, progressed rapidly after 1991 and soon surpassed the number of sheets produced using analog techniques (figs. 399 and 400). Prepress operations were fully automated when laser imagesetting was introduced in 1992. Technological innovation continued throughout the 1990s until the entire mapmaking process was digital. The last of the 4,126 map sheets comprising the first edition of the MTN25 series was completed in 2003.

From its founding in 1870 through 1971, the Instituto Geográfico also devoted its efforts to cadastral mapping, which required a substantial allocation of personnel and funds. The cadastral work was heavily influenced by significant changes in the agency's mission and by the division of responsibilities between it and the Ministerio de Hacienda. The original charter hampered the ambitious cadastral project designed by geographer Francisco Coello in 1862. The high cost and slow progress of cadastral mapping as well as the competing economic needs of the Finance Ministry diverted attention from cadastral work. After 1870, municipal cadastral maps showing streets and other municipal features were printed, and improved land parcels of more than ten hectares were recorded (Muro, Nadal, and Urteaga 1996, 243).

At the end of the nineteenth century, Spanish agricul-

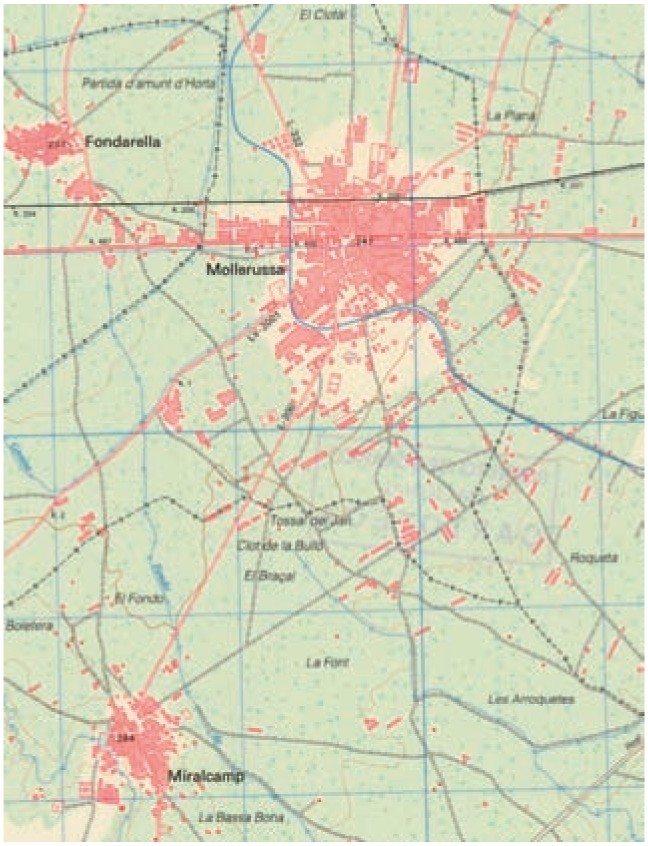

FIG. 399. DETAIL FROM *MOLLERUSSA*, 1983. Sheet 389-I of the *Mapa Topográfico Nacional a escala 1:25.000*, Madrid. Size of the entire original: 52 × 66 cm; size of detail: 18.4 × 14.1 cm. Image © Instituto Geográfico Nacional de España, Madrid.

FIG. 400. DETAIL FROM *MOLLERUSSA*, 2d ED., 2004. Compare figure 399.
Size of the entire original: 52 × 66 cm; size of detail: 18.4 × 14.1 cm. Image © Instituto Geográfico Nacional de España, Madrid.

ture suffered a grave financial crisis, the repercussions of which led to a general cadastral survey of small-holdings (*pequeñas propiedades*). The first step in this direction came in 1895, when legislation called for an official survey for all improved land. The Instituto Geográfico was made responsible for drawing up municipal planimetric maps on which treasury officials were to record the agricultural use and soil quality of each parcel. In 1900 this law led to a series of official definitions of improved or cultivated land as well as an official system of land categories. A few years later, in 1906, a general cadastral survey of small-holdings was officially implemented (Pro Ruiz 1992, 209–44).

Management of the cadastral work underwent an important change in 1925 during the dictatorship of General Miguel Primo de Rivera. The new government halted the work underway and imposed a more legally binding form of parcel mapping and registration. But because insufficient funds were provided for the new project, the number of hectares surveyed increased slowly.

The advent of the Second Republic in 1931 added a new twist to the cadastral work. In August 1932 a new cadastral law partly reestablished the law of 1906. During the years the Republican regime was in power, cadastral work received a major boost because of the large number of personnel committed to the effort as well as the widespread use of aerial photography. In 1935 there were 379 topographers employed in parcel mapping, and cadastral surveying was the primary activity of the Instituto Geográfico (Urteaga and Nadal 2001, 60).

The Spanish Civil War (1936–39) abruptly halted the steady progress of the cadastral survey, which did not resume until 1941 when the government of General Francisco Franco divided cadastral activities into two parts: one dedicated to preserving the parcel mapping and cadastral registration already accomplished and the other focused on creating new cadastral maps by the Instituto Geográfico using aerial photography acquired by the Finance Ministry. A renewed momentum increased coverage from twenty-six million hectares in 1944 to more than forty-five million hectares by 1959. Between the initiation of parcel mapping at the beginning of the twentieth century and 1960, the Instituto Geográfico had surveyed seventeen million hectares in 3,000 municipalities. The cadastre of the rural parcels was completed in 1964, and from that point onward, treasury officials focused on refining the cadastral surveys of urban parcels. The Instituto Geográfico was relieved of cadastral responsibilities in 1971.

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SEE ALSO: Geodetic Surveying: Europe; Topographic Mapping: Western Europe

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Intellectual Property. Intellectual property (IP) is the creation of the mind and includes inventions, designs, literary-artistic works, symbols, names, images, and performances. Intellectual property rights (IPR) may be asserted only for a limited time. Ownership of IPR is the legal recognition and economic reward for creative effort. Rights may be modified by agreement. Copyright, a subset of IP, exists for the public good, namely, to permit and advance the sciences and useful arts. This interpretative essay evaluates the role of IP in its historical, social, economic, and legal-political context vis-à-vis the history of cartography in the twentieth century and assesses future prospects from the perspective of the early twenty-first century (Cho 1998, 2005).

Most IPR establish proprietary rights in creations to control their use and exploitation. Copyright protects creativity of original literary and artistic works from unwanted use and exploitation, a right developed out of a right to copy; hence the term *copyright* (Rose 1993, 9). In addition, copyright creates an incentive for further creativity and encourages public dissemination (Drahos 1999). An exception are works either created originally in the public domain or for which the copyright has expired; works in the public domain are not controlled by anyone and can be copied freely.

Historically, copyright may be traced to the English Statute of Anne of 1709 "for the Encouragement of Learning, by Vesting the Copies of Printed Books in the Authors or Purchasers of such Copies." U.S. copyright law aims "to promote the progress of science and useful arts" and is enshrined in the Constitution (art. I, sec. 8). Other IPR relate to the protection of trademarks, national symbols, and distinctive names associating geographical regions with specific products, such as wine from the French province of Champagne. IPR protection also prevents unfair competition by preserving established reputation, distinctiveness, and goodwill.

Some IPR provide for equitable remuneration and compensatory liability, compulsory licenses, and constraints against unfair competition. There are also sui generis (one of a kind) IPR to cater to particular characteristics such as cultural heritage (von Lewinski 2004; Hoffman 2006).

Maps represent all kinds of inventive, creative, and original endeavors and thus attract IPR. In the United States, however, maps produced by the federal government have historically been in the public domain. But the boundaries separating the public and private domains can be indeterminate and IPR easily transgressed in the digital environment given the ease with which data can be transmitted and replicated and derivative works produced. Here the IPR debate focuses on the issue of maps as *factual* products and their consequent exclusion from protection insofar as most copyright laws do not protect *facts*, only their expression. As components or derivatives of a digital database, electronic maps raise the question of whether these factually accurate compilations are protected under copyright law. Even if the database were protected, it is questionable whether the extraction of some facts and their different expression constitutes an infringement of copyright.

The economic and social rationales for protecting IPR focus on the balance between the rights and interests of owners of IP and the public-at-large. Copyright as a property right prevents others from using the work without authorization. Copyright automatically safeguards original works and is a bundle of economic rights. It subsists in compilations of factual information such as encyclopedias, maps, directories, and map gazetteers because of the way the facts have been presented. But there must be sufficient intellectual effort in the selection, arrangement, and expense in gathering the facts.

By contrast, patents are limited-time monopoly rights given to inventions that are new, useful, and not obvious. However, artistic creations, mathematical models, plans, schemes, or other purely mental processes cannot be patented. Although there is debate about whether maps may be patented, the physical form in which a map is presented, such as the way a map is folded, may be patentable. An example is the tourist map folded in a stellate form that opens out flat. Certain mapping systems have been patented in the United State and Europe. MultiMap, a method for depicting information and maps on a computer monitor linked to the Internet, is an example. Map projections have been patented, but the ready availability of nonpatented alternatives almost always diminishes their value.

Moral rights, which protect a creator's honor and reputation and dictate how, when, and where a creator's property may be used, are European in origin and are a right apart from pure economic rights. In the United States moral rights protection is only for works of fine art, though this has been challenged.

Geographical indications identify a good as originating in a particular place, region, or country where some quality, reputation, or characteristic distinguishes the good. Examples include Champagne, Bordeaux, and Cognac, which identify regions in France and associated drinks. Other things covered by IPR include designs, trade secrets, circuit layouts, plant breeding methods, photographs and other imagery, and fonts. Of cartographic interest here are satellite imagery and fonts, which attract special copyright protection that might call for licenses or agreements.

International IPR protection emanates from international conventions, agreements, and treaties (von Lewinski 2008). The Berne Convention for the Protection of Literary and Artistic Works (1886) and the Universal Copyright Convention (UCC) of 1952, both revised in Paris (1971), are the earliest international agreements relating to copyright. The original provisions and their 1998 revisions cover "every production in the literary, scientific and artistic domain, whatever may be the mode or form of its expression" (Berne Convention, art. 2.1). The Berne Convention sets out the duration of copyright protection—basically the life of an author plus fifty years after death. The principle of national treatment gives the same protection in member states as that provided to the country's own citizens. Copyright protection is automatic without any formal requirements. The copyright symbol © has its origins here. Also, there are exclusive rights including the preservation of moral rights. These principles underpin copyright laws of most signatory countries.

In 1995 the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) strengthened the international IPR environment by setting minimum standards of protection for domestic enforcement. Under TRIPS the main provisions of relevance to the cartographic industry include protection by copyright of computer programs and databases. The main difference between TRIPS and other IP treaties is that failure to comply with TRIPS can lead to normal World Trade Organization (WTO) trade sanctions.

Implemented in 1996, the WIPO Copyright Treaty (WCT) and the WIPO Performances and Phonograms Treaty (WPPT)—the Internet treaties—took account of new technologies. Their centerpiece is a new technology-neutral right of communication to the public. Here copyright owners may authorize the electronic distribution of their creations. In protecting IP both treaties introduce obligations to prohibit circumvention of technological protection measures (TPM) such as encryption and watermarks containing digital rights management (DRM) information. Tampering with TPM is prohibited.

The Digital Agenda describes the implementation of the Internet treaties focusing on the protection of digital copyright content. The United States, the United Kingdom, and Australia have legislation that provides legal protection and remedies for tampering with TPM. An example is the U.S. Digital Millennium Copyright Act of 1998 (DMCA).

Copyright impinges on nearly every aspect of cartographic endeavor. Printed and digital maps are copyrightable because they are interpreted as original literary and artistic works under most copyright laws. Map data stored in an electronic database, even though seemingly factual compilations, are considered literary works. By contrast, a drawing such as a diagram, map, chart, or plan is an artistic work. Originality refers to the notion that the author has expended a minimal degree of skill, judgment, and labor to achieve that result.

Initially, maps, directories, and fact-based works enjoyed judicial beneficence. In *Sayre v. Moore* (1785; 102 Eng. Rep. 139) British Judge Lord Mansfield suggested that prior maps could be used by later cartographers because it was in the public interest to produce more accurate maps. However, by the eighteenth century, the approach had changed toward those adopted in cases involving directories and other types of works. Even so, the obligation remained that the creation be achieved independently rather than by copying, altering, or otherwise using a previous work.

Maps are graphical representations of space. More conventionally, maps depict terrestrial space related to features of the earth. It is possible to divide this space into discrete regions to depict both administrative and social space. Geographic information systems (GIS) superimpose layers of information on a common base map to produce a three-dimensional map. This composition may have multiple IP interests and rights since the data layers may be derived from different sources and at different times (Janssen and Dumortier 2006).

Originality in mapping is often tied to the notion of cartographic generalization, which includes the selection of specific features and a suitable projection. Maps may be scaled to suit the purposes for which they will be used. Some map features are stylized by color, line width, and name placement that involve a high degree of cartographic license and perhaps deliberate "cartographic silences" as well. More generally a cartographer may have to show three-dimensional features in two-dimensions. In so doing some features may be geometrically correct and positioned accurately while the totality of the map content becomes largely representative. These generalized compilations generate IP and IPR.

Data in many electronic geographic databases are digitized versions of maps. As graphical representations, geographic data and software systems not only contain attribute information but integrate data and perform spatial analysis (Longley et al. 2001). Of these functions, graphical representation faces the greatest risk of copyright infringement. For instance, until late 2009, the U.K. Ordnance Survey (OS) licensing agreement (for example, the Ordnance Survey OpenSpace Developer Agreement) prohibited overlaying OS-derived data on Google maps.

The protection of IPR on the Internet for cartographic products hence presents unique problems. A truly powerful medium promoting the wide distribution of content in a timely manner, the Internet is part and parcel of society. In a cartographic context this medium has the same potential to increase the effectiveness and efficiency of GIS by expediting the way we obtain, explore, manipulate, and share all geographic information—graphics, text, and numerical data as well as maps. While it is nearly impossible to prevent illegal copying, attempts need to be made to maintain the paternity of maps and images. Watermarks, sometimes called fingerprinting, have been unobtrusively inserted to discourage unauthorized appropriation (López 2002). Copyright traps (Monmonier 1996, 50–51) such as the insertion or omission of false but insignificant features like cul-de-sacs, deliberately misspelled names, and messages or random colors encoded into the bits comprising a raster image have been used. Vector maps may be drawn with deliberately degraded coordinates that produce distinctively unique but visually reasonable delineations that are not as geometrically correct as the level of detail might suggest. Such strategies have been employed to provide an audit trail potentially useful as evidence in a lawsuit seeking redress for copyright infringement.

DRM requires technology and procedures for identifying, protecting, monitoring, and tracking all forms of IPR. Geospatial DRM, which manages all rights involving digital geographic data, is facilitated by reseller license, by requiring permission to alter or redistribute the data and maps, and by imposing restriction such as mandatory acknowledgments and proper remuneration.

When a map is digitized, IPR ownership can become blurred. Copies can be obtained instantly with a copy or download command, and copyright notices may easily be deleted. Furthermore, when a digital map is enhanced by adding new information, introducing a new perspective, or through some other value-added alteration, there is uncertainty about the point at which a new map (and new IP) is produced. The presence of a metadata (data about data) layer might be helpful in disclosing the alteration or enhancement and in asserting a claim of originality.

Databases derived from remotely sensed data, particularly satellite data, pose the question of whether the raw data can be considered a work and are thus copyrightable. Legal opinion suggests that the answer might depend on the degree of originality, the arrangement of the data, and the skill employed in constructing the database.

Facts per se are not copyrightable. This concept is reflected in various statutes in the United Kingdom and the United States and in the Berne Convention. However, various jurisdictions, including some in the United States, have found ways to protect factual compilations within copyright law. Such protection may serve important social policy objectives such as disseminating public information and promoting open democratic government. This ideal is entrenched in the U.S. Constitution.

Copyright protects a compilation as a whole. No cause of action arises against someone who either took only a small part of the data or arranged the data differently. But for certain types of databases, such as phone books and sports statistics, there is no copyright protection because the effort is in the accumulation of information. As decisions in various "sweat of the brow" and "industrious collection" cases demonstrate, the lack of a minimum degree of creativity and originality precludes copyright protection (Karjala 1995). Most courts in the United States have treated maps as compilations of facts as supported by the 1976 amendments to the U.S. Copyright Act.

Australia, by contrast, has a low threshold of originality and offers copyright protection for merely gathering and listing data, which appears out of step with international approaches. In Canada, for example, copyright could not subsist in a Yellow Pages directory because insufficient skill or judgment is evident in the arrangement of the work. This view is also found in the North American Free Trade Agreement (NAFTA) of 1993, TRIPS, and WCT.

Geospatial databases complicate the distinction between an idea that cannot be copyrighted and its copyrightable expression. What in context of a database constitutes an idea? Is it the configuration of the geospatial database itself as a file of information arranged in a certain way? Or is it the broader idea underlying the purpose of the geospatial database rather than its parameters or structure?

The term "thin copyright" has been coined for maps (Karjala 1995, 408n41). A veneer of copyright protection is afforded to an electronic database made up of various elements including compilations, which normally are not copyrightable, and creative elements, which are. When assembled together, the new work attracts copyright because it is ostensibly an original work. The infringement of copyright is thinly veiled, hence the term thin copyright.

Nordic countries provide special protection to those works that lack the minimum level of originality to safeguard the investment in the database. A 1985 amendment to the Japanese Copyright Act makes specific reference to "data base works." A data base (two words) is defined as "an aggregate of information such as articles, numerals or diagrams, which is systematically constructed so that such information can be searched for with the aid of a computer" (Cho 2005, 158). As intellectual creations they attract copyright protection. In the same vein, the European Union Directive on the Legal Protection of Databases 1996 applies to "a collection of independent works, data or other material arranged in a systematic or methodical way and individually accessible by electronic or other means" (Aplin 2006, 101). Copyright and a right sui generis prevent the unauthorized extraction or reutilization of contents of a database. In the light of the limited protection provided to databases and compilations of fact under copyright law, there have been suggestions that legislation creates a sui generis right in databases independent of copyright law and other common and statutory law (Samuelson 1995).

Droit moral, another set of rights, recognized by Australia, Europe, and the Berne Convention, protects the integrity of a creator's work as well as his or her honor and reputation. This includes the right to claim authorship of the work and protection against false attribution. Moral rights are not transferable and remain with the author and heirs for fifty years from the year of the author's death.

Although the U.S. Copyright Act has not recognized moral rights, U.S. legal practice demonstrated many attributes of moral rights, even though no legislation made such rights explicit. Case law has been claimed to adequately protect such rights under related legal theories such as defamation, privacy, and unfair competition. Thus, while the United States signed the Berne Convention in 1991, moral rights did not exist there for most of the twentieth century (Branscomb 1994, 86).

Patents have traditionally been used for protecting manufactured goods. As of 2005, the U.S. Patent and Trademark Office's online database listed over 100 patents for "geographic information system" and "GIS." The abstracts show patents for image processing, navigation and routing, directory systems, modeling, and general mapping. One noteworthy patent had been awarded for Multimap.com, a "computer system for identifying local resources" (Cho 2005, 173). The patent, which had also been granted throughout the European Union and was pending in various other countries, involved a method for transferring spatial data from a server to a remote computer based on location information requested by the remote device. The cartographic industry was intrigued by this development.

Other forms of copyright protection include portable hardware keys called dongles, passwords, and procedures for matching software registration with computer serial numbers. Embedded digital content was a promising element of the business model for copyright protection and security in the early twenty-first century. The DRM model, while it did not stop all forms of piracy and was ineffective in preventing insider copying of master files, offered a workable approach to preventing the illegal and unauthorized use of digital content (Cahir 2005).

Difficulties of policing and enforcing IPR in information technology (IT) have given rise to free and open-source software (FOSS). Because the source code is available free for public use, FOSS encourages users to debug, change the source code, and redistribute derivative software. The Free Software Foundation (FSF) has developed the GNU General Public License (GPL), a widely adopted standard copyright agreement often called copyleft. The central idea of the GPL is to prevent cooperatively developed FOSS code from being turned into proprietary software. In addition, the Creative Commons (CC) developed a license that offers an enlarged use of copyright material (Lessig 2001).

Provisions of most copyright acts have been difficult to enforce not only because of the way the laws are framed but also because of the nature of the technology, particularly the convergence of IT and the gradual movement away from physical media toward electronic media. For example, in the case of transborder flow of physical as well as electronic data, the enforcement of IP law is problematic. A provision of the Australian Copyright Act of 1968 referred to as a "territorial copyright" entitles owners of copyright to prevent others from importing books, records, and computer software that contain copyright material. In the United Kingdom and Hong Kong copies made by licensees of copyright owners are restricted by the terms of their licenses to particular territories. However, there are no restrictions on parallel importation in either the United States or Japan (Cho 2005, 188–89).

Defenses to copyright infringement include certain kinds allowed in the public interest. These include fair dealing or fair use, whereby scholarly research, study, critique, and news reporting override copyright control. Another defense is independent creation, whereby a work that has not been copied from another will not infringe copyright.

Remedies include restraints by injunction, award of damages, and an account of profits. Criminal offenses attach to illegal importation of copyright works together with seizure and forfeiture. In some countries the infringing copies are deemed to belong to the copyright owner.

Patents on scientific knowledge may not be as useful or valuable as many claim. For example, where map projections have been patented, nonpatented alternatives are almost always readily available. There is a need to reassess the value of patents to protect IP. While it is accepted that science and technology patents are essential for economic growth, the empirical support is scant.

The concept of copyright interests embodied in the 1709 Statute of Anne has become markedly different since the dawn of the microcomputer in 1970. Toward the end of the twentieth century developments in computer-based information systems increasingly suggested that copyright was becoming irrelevant because the medium had not only changed but become far more important than the message it might convey. Indeed, English literature professor Mark Rose (1993, 142) suggested that copyright was "an archaic and cumbersome system of cultural regulation" but notes that we are not ready to give it up.

Arguably, in the electronic age, it appeared that copyright offered the widest and most appropriate means of protecting the expression of ideas in maps, compilations, electronic databases, and GIS in general. Indeed, a lively debate arose in legal and academic circles as to what and how much protection copyright could offer cartography and all its accoutrements in a globalized world in which infringement was difficult to detect.

Moreover, laws governing IPR needed to articulate a generic version of rights, obligations, and prohibitions—a strategy different from resolving problems by passing laws limited to specific situations. This ideal was problematic insofar as cartographic products that were clearly the result of human creativity did not fit neatly into any of the traditional specific categories of literary, dramatic, musical, or artistic works. Unlike other protected works, cartographic creations and the databases accompanying them as well as books and music were open to copying and unauthorized use.

IPR in general, and copyright in particular, provide flimsy protection for GIS and geospatial databases. Practices evolving in the late twentieth century suggested that licenses and agreements, rather than copyright law, might define the boundaries of permitted uses. Indeed, the importance of contract law cannot be underestimated since licensing conditions may benefit both parties. A copyright holder may be able to achieve revenue maximization through a variety of licensing strategies, including licenses that need to be renewed periodically, licenses affording particular groups of users (such as students) a more limited use of the product at a lower price, and licenses allowing unlimited uses for a higher price. Consequently, enforcement has focused on pursuing infringements of the license terms and breach of contract. Users of the technology could benefit because of lower prices, easier access to the data, improved variety of content, and more certainty with the law.

IPR protection for data and information is inherently uncertain, particularly in matters of what is being protected, how it is being protected, and how long protection lasts. Ideally, such protection must exist within an international legal system that is understood by all and mutually enforceable across jurisdictions by way of national treatment (see Ricketson 1992). Such an ideal would mean that all the leakages to IPR can be staunched and civil disobedience by way of pirating, copying, and other infringement can be minimized so that the creators of original products can be justly rewarded for their efforts.

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see also: Marketing Cartographic and Spatial Data; Marketing of Maps, Mass; Public Access to Cartographic Information

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Interactive Map. In the final decade and a half of the twentieth century cartographers embraced interactive mapping as a tool with which users could enhance their understanding of geographic information by manipulating symbols and patterns on the screen. Although conventional electronic maps can portray spatial information effectively, the viewer cannot readily go "beyond the map" to probe additional information about the phenomena displayed. By contrast, interactive maps encourage users to explore related information by clicking elements within the map or elsewhere on the screen.

An interactive or clickable map also serves as an index to other documents in the database (Kraak and Van Driel 1997). By pointing and clicking on map objects, users can supplement the static visual display with complementary media (audio, visual, and animation); request other maps or geographic features, hidden below the surface; and interrogate any part of the map by retrieving metadata describing the acquisition and limitations of information in the database. By adding to or subtracting from the data shown on the map screen, users can construct map displays that suit their particular requirements as well as increase their comprehension of facts by making the map a tool for discovery.

The earliest successful experiments with interactive mapping employed analog videodiscs. In 1976 the Architecture Machine Group at the Massachusetts Institute of Technology, which evolved into the famous MIT Media Lab, devised the notion of a spatial data management system. A "multiple media" system developed with support from the Defense Advanced Research Projects Agency and dubbed Dataland was a seminal step in the development of multimedia (Leutwyler 1995). In 1978 the lab created the Aspen Movie Map, a twin videodisc system that allowed users to "drive" through Aspen, Colorado, by interacting with a touch screen. As the user moved through the virtual city, turning left or right at each intersection, or continuing straight ahead, the system retrieved the appropriate sequence of images, which had been captured with a motion picture camera mounted on a car and stored on videodisc. As shown in figure 401, the interface included clickable symbols that allowed the virtual tourist to turn or pause.

FIG. 401. SCREEN SHOT FROM THE *ASPEN MOVIE MAP* BY REBECCA ALLEN, 1978.
Image courtesy of the Aspen Movie Map Team and the Defense Advanced Research Projects Agency (DARPA).

In 1986 a consortium of the British Broadcasting Corporation (BBC), Royal Philips Electronics, and Acorn Computers developed the Domesday interactive videodisc, a record of life that year in the United Kingdom. Intended as a contemporary version of William the Conqueror's Domesday Book, produced 900 years earlier, this double Laservision videodisc system contained national information on one disc and community information on the other (Rhind, Armstrong, and Openshaw 1988). Information was stored and delivered on six levels. Level 0 provided introductory map coverage of the whole country. Users could zoom into the next level of maps, level 1, by clicking the part of the country on which they wanted to focus. Users were able to zoom in further to levels 2–4. Both level 0 and level 1 maps were specially designed for the project, while the more detailed maps on levels 2, 3, and 4 were scanned from existing Ordnance Survey coverage. Level 5, the most detailed information level, included terrestrial imagery of the areas mapped. Figure 402 illustrates the structure with sample maps from each of the six levels.

The next technology exploited for interactive mapping was Apple Computer's HyperCard application, which linked a graphic user interface to a database organized as a stack of "cards," which could be displayed as screens with clickable symbols. Released in 1987 as a software package for Macintosh computers, HyperCard was a form of hypertext insofar as links embedded in a card's clickable words or symbols cross-referenced other parts of the database. This approach was especially useful for creating electronic atlases, the pages or screens of which could be stored as individual cards (Raveneau et al. 1991). If the information contained within the atlas was organized according to a logical structure, users could navigate easily among the cards. Limitations

included insufficient storage space for digital sound files and imagery and the Macintosh's relatively small black-and-white display, a deficiency removed by later models with color screens and a more powerful software application called SuperCard. Hypertext concepts allowed users to discover spatial information in a manner similar to the human mental process, through nonlinear reading, setting multiple relations between elements of information, and making associations and correlations between data represented in different forms.

The next generation of interactive maps was developed for the compact disc, an optical (rather than magnetic) storage medium commonly known as the CD or CD-ROM (read-only memory). Developed jointly by Sony of Japan and Royal Philips Electronics of the Netherlands in 1982, CDs provided much more storage space than the portable magnetic-storage devices of the day—floppy disks rarely exceeded 2 megabytes (MB), while larger versions called Zip disks typically held only 100 MB. Although the typical CD could hold about 550 MB, these media and their associated drives did not become common accessories to personal computers (PCs) until the mid-1990s, when the large size of some software applications, especially reference works and interactive games, severely taxed the capacity of floppy discs. The CD gained increased acceptance after these media were made to conform to the International Standards Organization's ISO 9660 standard, which assured compatibility with all CD players and computers with CD drives. A wide range of CD products followed—initially databases and photographic collections but later encyclopedias and atlases.

The large storage capacity of CD-ROMs stimulated interest in publishing digital maps. Among the first products to exploit the new storage medium were the Digital Chart of the World (DCW) and the World Vector Shoreline (WVS), both produced by the U.S. Department of Defense, and the *Territorial Evolution of Canada* interactive multimedia map-pack, developed from a prototype atlas as part of the *National Atlas of Canada* by the Geographical Sciences Division, Survey and Mapping Branch, Department of Energy and Resources (Siekierska and Armenakis 1999). The *Territorial Evolution of Canada* provided an innovative overview of Canadian history and exploited the use of interactive multimedia in its truest sense. Figure 403, a typical screen, shows the juxtaposition of a colorful map with various navigation

FIG. 402. LEVELS OF INFORMATION AVAILABLE ON THE BBC DOMESDAY PROJECT COMMUNITY VIDEODISC. From *The Domesday Project* published by Acorn Computers Ltd., 2d ed., July 1987, page 7.
Size of the original: ca. 17.2 × 5.7 cm. Image courtesy of the Centre for Computing History, Haverhill.

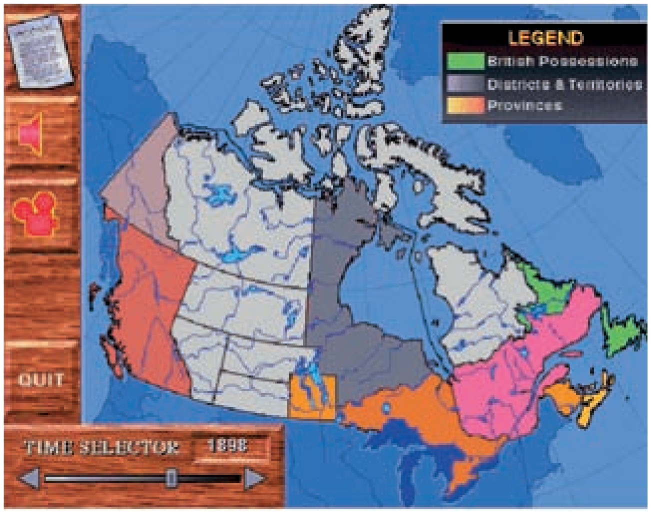

FIG. 403. *TERRITORIAL EVOLUTION OF CANADA*. This CD-ROM-delivered mapping application explored the use of interactive multimedia for the depiction of historical aspects of Canada's geography.
From Siekierska and Armenakis 1999.

tools, including a slider that allowed the viewer to move forward or backward in time.

The Internet emerged as an efficient means of delivering mapping products and large data sets, especially after marked improvements in bandwidth in the late 1990s. The file transfer protocol (FTP) supported the efficient delivery of large files, which were usually compressed to reduce the time required for downloading. File transfers were quick, but the process was burdened with the overhead of file compression and subsequent decompression and the need for appropriate display software on the receiving computer. Collections of scanned paper maps were developed and delivered to consumers, usually as GIF files. While Internet delivery was usually more efficient than its postal counterpart, users typically needed to manipulate the files in some way before they could view the maps.

The World Wide Web, which greatly expedited Internet communications in the mid-1990s, eradicated the need for most postdownload manipulations. Browser-driven information displays first envisioned by Tim Berners-Lee provided a flexible graphic interface that made cartographic information easier to view and manipulate. Even so, early web mapping packages often used text-heavy interfaces to list an inventory typically consisting of scanned images of paper maps. The online *CIA World Factbook*, for example, made available maps of almost any part of the world. Despite the aesthetic shortcomings of scanned paper maps (Peterson 1997), this website made available an abundance of reference maps and general geographical information, as did the Perry-Castañeda Library, University of Texas at Austin, which provided similar products. Many websites were developed to allow access to simple maps and, while powerful media access tools were sometimes provided, the reliance on scanned maps limited their effectiveness. Nonetheless, this type of web resource was helpful in providing access to rare or unique maps that might otherwise be difficult or impossible to view. A prominent example is Oxford University's Bodleian Library, a renowned repository for historical artifacts related to Oxford and Oxfordshire, which made a number of rare maps available via the web. Scholars could consult high-resolution scanned images without having to travel to Oxford (much less disturb the paper original) and could also reproduce the images in scholarly publications without having to obtain permission.

Hybrid products simultaneously published on the web, on CD-ROM, and on paper also emerged. One of the most impressive examples is the *Atlas of Switzerland* (2001), distributed in all three formats. The atlas was developed jointly by the Bundesamt für Landestopographie (later swisstopo), the Bundesamt für Statistik, and the Institut für Kartographie at the Eidgenössische Technische Hochschule (ETH) in Zurich. Founded in 1925 by Eduard Imhof, the Institut produced the maps for the original paper *Atlas der Schweiz = Atlas de la Suisse = Atlante della Svizzera* between 1961 and 1978 on behalf of the Swiss government.

Interactive maps also appeared on mobile devices like cellular telephones and personal digital assistants. Although small in size and limited in functionality, interactive maps displayed on mobile devices met the need for "on-demand" and "at-location" mapping. More sophisticated were the continually updated maps displayed by GPS–based in-vehicle navigation systems, which related the vehicle's current position to nearby streets and highlighted imminent turns along a programmed route between a specified origin and destination. In-vehicle GPS systems began to flourish after May 2000, when U.S. President Bill Clinton deblurred the GPS signal available to civilian users. Enhancements included verbal directions produced with a text-to-speech synthesizer and up-to-the-minute reports on traffic congestion and road closings delivered by wireless telephony. Although similar in operation to interactive maps delivered to stationary computers, these maps required modifications of the interface and functionality to accommodate small screens and slower download speeds.

The mid-2000s witnessed the emergence of another distinct form of interactive map, the web-supported digital globe that could simulate on a flat computer screen a user's interaction with a curved physical globe (Riedl 2007). Zoom in/zoom out commands mimicked the viewer who leaned in close or stepped back, and a pan command replicated the viewer's ability to spin, walk around, or hover over the globe. Commercial software providers like Environmental Systems Research Institute (ESRI) made available products like ArcGlobe, introduced in 2004 as part of ArcGIS 9, and the National Aeronautics and Space Administration (NASA) released World Wind that year as an open-source product. Neither of these products enjoyed the acclaim and usage of Google Earth, a free package from the web search engine company Google, which purchased the technology from Keyhole, a little-known company; expanded the database; and promoted it aggressively online, most notably by allowing users to toggle between a line map, with conventional cartographic symbols and placenames, and a "satellite" map offering an overhead image (often captured from an airplane, rather than from space). For much of the world, Google Earth provided detailed maps and photographs, which could be viewed as both two-dimensional and pseudo-three-dimensional images. Following the commercial success of Google Earth, as much an advertising medium as a geospatial tool, Microsoft Corporation launched a rival product, Virtual Earth.

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SEE ALSO: Atlas: Electronic Atlas; Exploratory Data Analysis; Visualization and Maps; Wayfinding and Travel Maps: Web-Based Wayfinding

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Inter-American Geodetic Survey. In 1944, the Commission on Cartography of the Pan American Institute of Geography and History (PAIGH)/Instituto Panamericano de Geografía e Historia (IPGH), having reviewed the state of cartography in Latin America, requested assistance from the United States for geodetic surveys and the production of topographic maps to internationally accepted standards. In so doing, PAIGH initiated a period of remarkable inter-American cooperation across a range of cartographic activities (Larsgaard 1984, 50–51). The request was timely, as the U.S. government recognized that existing topographic mapping was inadequate in areas that were strategically important to the United States. Indeed, World War II had demonstrated that vital parts of the world lacked maps of sufficient accuracy and precision for fast-moving forces and long-range weapons (Robertson 1955, 449). Rising political instability in Central and South America, brought on by rapid population expansion outstripping socioeconomic development, added to American fears. U.S. President Harry S. Truman responded by instructing the Secretaries of State, War, and the Navy to commence a collaborative mapping program of foreign territories with governments friendly to the United States. Thus began a worldwide mapping program of which the mapping of the Americas was a unique and major part. The Inter-American Geodetic Survey (IAGS) or the Servicio Interamericano de Geodesia was established within the Caribbean Defense Command (CDC) on 15 April 1946. Its task was to coordinate and support a program of geodetic, topographic, and hydrographic surveys with those republics in Central America, South America, and the Caribbean willing to collaborate. This program, known as MAPPLAN, was a part of the worldwide tri-service mapping program established by the Joint Chiefs of Staff. The IAGS, though initially part of CDC (redesignated U.S. Army, Caribbean, 1948–63, and U.S. Southern Command, 1963–72) later became consolidated into the Defense Mapping Agency (DMA) in 1972 before its eventual disbandment in 1991.

MAPPLAN was a collaborative program across all U.S. Armed Forces. The Air Force obtained aerial photography and provided air support, the Army obtained the geodetic and survey data, and the Navy obtained beach and offshore hydrographic data. Completion of the program depended on agreements negotiated through the Department of State with other American governments. Most Latin American governments, with the exception of Argentina and Uruguay, and initially Paraguay, agreed to collaborate. Governments recognized the potential benefits of such a program in supporting the planning of the Western Hemisphere's defenses as well as furnishing republics with the necessary mapping to exploit their rich natural resources and stimulate economic development. Similar agreements were struck with the Netherlands, the United Kingdom, and France to cover their former colonial possessions in Latin America.

The primary objectives of the IAGS were threefold: first, to promote the establishment of standardized national cartographic institutes and render the cartographic agencies of the collaborating countries self-sufficient; second, to standardize equipment and techniques throughout the Americas; and third, to maximize production to meet the hemispheric needs for mapping and charting. The key technical aims of the program were to establish a geodetic framework for the whole of the Americas and establish a mean sea level reference datum for Latin America, thus providing the necessary base upon which all maps could be constructed. Isolated coordinate systems would be transformed to eliminate differences across international boundaries (Anonymous 1951, 53–59).

Considerable financial and human resources had to be committed to the program. By 1955, 650 personnel were directly employed by the IAGS of whom 280 were civilians (Robertson 1955, 450). Though IAGS controlled the operation from its headquarters at Fort Clayton in the Panama Canal Zone, field organizations in each country performed the vital local operations. Field organizations would typically have an officer in charge of a small complement of officers, geodetic engineers, pilots, aircraft and auto mechanics, and supply personnel. Most of the work was completed by the collaborating agencies, and a large part of the equipment was loaned to them. Much of their work was advisory, especially in the use of U.S. supplies and equipment. Some phases of the fieldwork were completed by the IAGS if there was insufficient local staff trained in a particular technique. The program expenditure overall was estimated to be about $12–$14 million annually, employing over 5,000 personnel and using some $50 million worth of equipment (Robertson 1955, 450).

The program was technically very ambitious. Baselines were measured to stations at intervals of roughly 500 kilometers along triangulation arcs. Astronomic determinations provided measurements of latitude, longitude, and azimuth, and gravimetric surveying adjusted the geodetic point of origin for deflection of the vertical due to variations in gravity. Magnetic declinations were measured to allow compass use on the finished maps, and mean sea level for the vertical control reference datum was established using tidal gauging (Anonymous 1951, 54). By 1951, seventy-seven baselines had been measured and a first-order geodetic triangulation arc had been reconnoitered and observed for over 2,700 kilometers from Mexico, through Central America to Colombia, passing through some of the most difficult terrain in the Americas (Anonymous 1951, 57). Accounts testify to the dedication and powers of endurance of the survey parties, sometimes hacking their way through jungle for days only to wait several weeks for weather to clear sufficiently to make their observations (Walker 1953, 76). Robert Leslie Conly (1956) provides a vivid account of the trials and tribulations of the surveying teams enduring the natural hazards of South and Central America.

Though the IAGS supported mapping activities in all countries participating in the project, it concentrated considerable effort in supporting the mapping of Central America, an area of critical strategic importance to the United States and bereft of adequate mapping. IAGS involvement followed a pattern repeated in many Central American countries. After signing an agreement with all interested parties to establish geodetic control, a local office would be established and technicians and equipment brought in. The first operation would establish a geodetic net of horizontal and vertical control throughout the country. Aerial photography taken during the geodetic work would be used to commence map compilation and production following delivery of the field data. This procedure was applied, for example, in Nicaragua, where the Oficina de Geodesia was established to satisfy the conditions of the agreement and became the principal mapping agency responsible for the production of the topographic map series at scales of 1:50,000, 1:100,000, and 1:250,000 (fig. 404). As was typical with most countries, the work shifted from geodesy to cartography, and in recognition of this the Oficina de Geodesia changed its name to the Direccíon General de Cartografía (DGC) (United States, Department of the Army 1963, 249). During the late 1960s the DGC continued to enjoy the cooperation of the IAGS in the form of technical assistance, air support in the field, aerial photography, control adjustments, and map reproducing equipment. By 1967, the DGC had a staff of eighty, most of whom were trained specialists, with an annual budget of $230,000 and cartographic equipment worth $500,000. The IAGS contributed an annual budget of about the same amount (Rugama Núñez 1967, 74–75). The first of the 300 sheets at 1:50,000 were published in 1956 using aerial photography of the Pacific zone flown by the U.S. Air Force in 1954. The maps were produced using the multiplex stereoplotting method with the assistance of the IAGS. However, despite the availability of modern equipment and trained personnel, the series was not completed for another thirty years. Progress with the 1:100,000 series was even slower, with just under one third of the maps completed by 1987 (Parry and Perkins 1987, 214–15). Delay was inevitable, especially in the eastern two-thirds of the country due to the lack of infrastructure, flat terrain, impenetrable jungle, and almost constant cloud cover. These conditions rendered both mapping from aerial photography and plane tabling almost unworkable.

IAGS activities were particularly significant in Cuba, where some of the technical achievements of the program were demonstrated. An IAGS office was established

FIG. 404. DETAIL FROM *MANAGUA*, NICARAGUA, 1956, AT 1:100,000. This monochrome map (2d ed., sheet HOJA 2952) was compiled from aerial photographs taken by Worldwide Surveys in 1954 under contract to the U.S. Army Map Service. Speed of production rather than detail and aesthetics was the priority during the early phase of the MAPPLAN project. The final drawing was completed by the Oficina de Geodesia, Managua, in 1956 using the 1927 North American datum. The use of form lines instead of contours is a consequence of using the slotted template method during production.
Size of the entire original: 41.5 × 56.1 cm; size of detail: 23.3 × 41.5 cm. Image courtesy of the Earth Sciences and Map Library, University of California, Berkeley.

in Cuba in 1947 and collaborated with the Instituto Cartográfico Nacional (ICN) on MAPPLAN. Shoran (short range navigation) surveys conducted between the Florida Keys and Cuba in 1950 allowed the IAGS to extend the North American Datum of 1927 (NAD27) into Cuba (Mugnier 2010, 644). Between 1951 and 1953 aerial-electronic surveying missions were completed using the Hiran (high-precision Shoran) trilateration method. Following final adjustment, all Cuban stations referred to the NAD27, achieving a precision of 1 part in 113,000. Aerial photography was flown in 1956, and full topographic map coverage at 1:50,000 scale was completed in 1960. When Fidel Castro rose to power in 1960, American cartographers and surveyors departed but took with them photo surveys, maps, and ground control used by the Defense Department in 1962 during the Cuban Missile Crisis.

Some work went more quickly with the new electronic distance measuring equipment, and at one point IAGS showed the president of Honduras a display and demonstration of the the new technology and the role it played in mapping his country (Weir 2010, 20) (fig. 405). However, some of the most productive efforts of the IAGS took place during the Kennedy administration's ambitious and coordinated outreach program to Latin America known as the Alliance for Progress, which was initiated in 1961. Air survey missions along the Caribbean coast of Guatemala in the early 1960s contributed to the compilation of maps for the region. In 1962 the geodetic survey opened its first project in Paraguay, while also receiving a citation from the U.S. State Department for its work in the very delicate negotiations that established the proper border between Nicaragua and Honduras. IAGS personnel were also involved in the commencement of a cadastral mapping program in Paraguay with funding provided through the U.S. Agency for International Development (USAID).

The establishment of an IAGS office in each of the collaborating countries combined with the spirit of mutual cooperation generated by the MAPPLAN program gave the United States a channel through which future developments could take place. For example, the IAGS played a significant role in support of Project Vanguard, a program designed to place the first U.S. satellite in space (Naval Research Laboratory 1956). Local IAGS representatives were instrumental in negotiating tracking station sites in Cuba, Peru, Ecuador, Chile, and Panama as part of the Minitrack satellite tracking system, forerunner to the Naval Space Command Surveillance (NAVSPASUR) system.

The impact of the IAGS on the mapping of Central and South America and the Caribbean was profound, not least in the training of personnel. Training in cartography, geodesy, surveying, and hydrography was a key element of the IAGS activities. Initially, much of the training was done on the job, but in 1952 the Cartographic School in Fort Clayton, Panama, was established. Between 1952 and 1974 more than 3,600 personnel were trained. In 1982 it celebrated its thirtieth anniversary and the United Nations (UN) report on the event remarked that the training school "more than any other training institution has left its mark on the development of cartography in Latin America" (Anonymous 1983). In addition to training facilities at Fort Clayton, the Instituto Geográfico Agustín Codazzi in Colombia, together with other specialized training by the Coast and Geodetic Survey and the Army Map Service in the United States, ensured a uniformity of method using standardized and calibrated equipment, tested by the U.S. Bureau of Standards.

During its forty-five year history, the IAGS helped to transform the state of mapping in Latin America. By the end of the century, though large tracts of Latin America remained poorly mapped, the IAGS had introduced modern and rigorous surveying and mapping techniques, which improved the long-term capacity of Latin American mapping agencies to complete the task.

ALASTAIR W. PEARSON

SEE ALSO: Education and Cartography: Educating Mapmakers; Geodetic Surveying: Latin America; Topographic Mapping: Latin America

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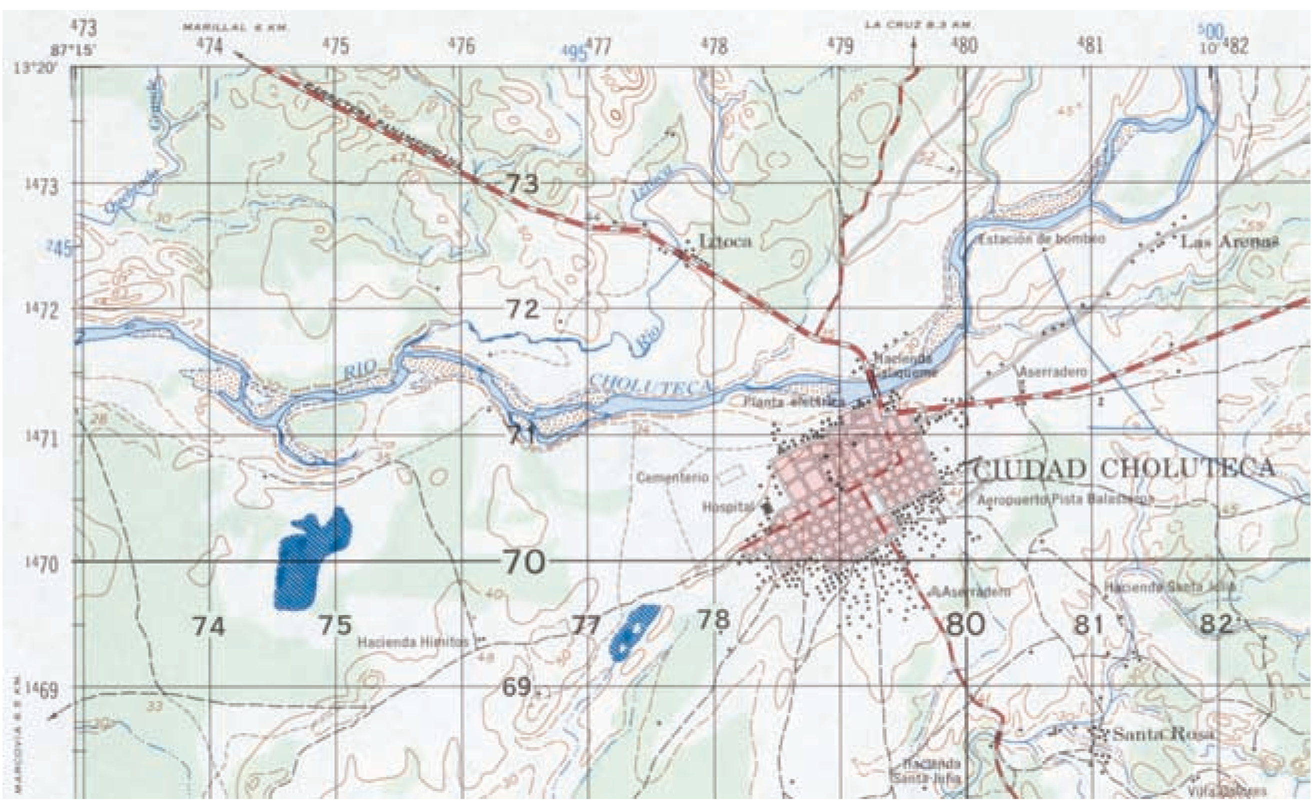

FIG. 405. DETAIL FROM *CIUDAD CHOLUTECA*, HONDURAS, 1959, AT 1:50,000. Published through the combined efforts of the Instituto Geográfico Nacional de Honduras, U.S. Army Map Service, and the IAGS (sheet HOJA 2755 I, serie E752). Vertical and horizontal control was provided by the Comisión Geográfica Especial, Honduras, and the IAGS between 1954 and 1956. The map demonstrates how the cartographic design had been standardized to a familiar U.S. military style.

Size of the entire original: 52.6 × 56.6 cm; size of detail: 12.5 × 20.7 cm. Image courtesy of the Stapleton Library, Indiana University of Pennsylvania.

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Intergraph Corporation (U.S.). In 1969 Jim Meadlock left IBM to cofound M&S Computing. The firm's first contract was to assist the U.S. Army Missile Command in developing systems that would apply digital computing to real-time missile guidance. A National Aeronautics and Space Administration (NASA) contract that followed involved designing printed circuit boards. In 1973 M&S Computing received its first commercial contract, to map the city of Nashville, Tennessee.

With an early emphasis on hardware—terminals, storage tubes, specialized circuit boards, and increased speed—M&S Computing became the world's largest vendor of integrated computer graphics systems by 1980. Its software applications included civil engineering, architecture, plant design, electronics, mechanical design, and a variety of mapping and geographic information system (GIS) applications, notably address-based systems for emergency response.

From initial attempts to automate the production of traditional paper maps, the focus quickly shifted to interactive data manipulation and analysis, including dynamic visualization, three-dimensional modeling, and photorealistic renderings. Complete turnkey systems that included software, host computers, and terminals allowed cartographers to display and interact with drawings and associated alphanumeric information using the language of the specific application rather than programming terminology. This capability resulted in the first interactive computer-aided design (CAD) product, IGDS (Interactive Graphics Design Software), which became an industry benchmark.

In 1980 M&S Computing changed its name to Intergraph. Digital computing was revolutionizing photogrammetric technology, and by the late 1970s mechanical pantographs were being replaced by digital encoders on stereoplotters, followed by the development of servo-driven analytical stereoplotters. In 1980 Intergraph released the first computer graphics terminal to use raster technology. The dual $1{,}280 \times 1{,}024$ pixel displays established an industry standard for high-resolution displays. In 1981 Intergraph introduced a color terminal that featured a 4,096-color palette.

In 1983 Intergraph signed a contract with the Defense Mapping Agency (DMA, predecessor to the National Geospatial-Intelligence Agency) to produce a next-generation analytical stereoplotter for cartographic feature extraction from photogrammetric source imagery. Teaming with Carl Zeiss, Inc., the firm delivered the stereocompilation system to DMA in 1985–86 and shortly thereafter brought out a commercial version called the Intermap Analytic (IMA), which allowed optical superimposition of digital data over the source image. Under subsequent contracts with DMA, Intergraph produced components of an automated cartographic production system and a mapping/charting production system, delivered in 1990, for scanning, automated generalization, symbolization and finishing, and photoplotting color separations for printing. Many of these technologies were embedded in the company's Map Generalizer and Map Finisher software products as well as its MapSetter 6000 large-format scanner/plotter device, which was also offered commercially. By 1990 Intergraph was ranked the number 1 supplier of computer-aided design, manufacturing, and engineering (CAD/CAM/CAE) systems in North America and number 2 in the world, according to industry analysts Daratech and Dataquest (Intergraph Corporation website, History, 1990s).

During the 1990s Intergraph embraced Microsoft's Windows operating system, and between 1994 and 1997 it marketed workstations based on Intel's rapidly evolving microprocessors. In 1996 the firm entered the animation and digital video production market with a digital video-capable workstation that sold well among computer graphics studios in Hollywood.

After 2000 Intergraph largely abandoned its combined emphasis on integrated hardware and software and focused on software applications for creating intelligent maps, managing assets and infrastructure, building and operating plants and ships, and dispatching emergency services. In 2010 the firm was purchased by the Swedish firm Hexagon A.B.

JOEL L. MORRISON

SEE ALSO: Software: Geographic Information System (GIS) Software

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International Cartographic Association. Founded in 1959 to promote the discipline and profession of cartography in an international context, the International Cartographic Association (ICA) grew quickly into the world's leading organization dealing with the conception, production, dissemination, and study of maps. Its members are individual nations, typically represented by the country's national mapping organization or a national committee connected with a society of professional mapmakers and academic cartographers. There were sixty-one national members in 1991 and eighty-three in 2006.

Formation and Growth

In many ways, the ICA was partly an outgrowth of the technological spurts that followed the two world wars, which created a vast market for cartographic products. Most people followed the wars in the news media, and millions actually fought on foreign soil. Millions more were involved, directly or indirectly, in defense-related industries or using maps to track the locations of relatives serving overseas. The economic recovery after World War II, especially in the United States and Europe, fueled an enlarged cartographic industry inspired partly by people's heightened curiosities. Moreover, the rigid state control of cartographic information in Eastern Europe and the Soviet Union during the Cold War stimulated further development in cartographic technology within the Communist Bloc as well as in the West.

The push to recognize cartography within academia was at least as strong as it was in the marketplace. By the middle of the twentieth century, cartography was recognized as a discipline worthy of serious scientific study. Mapping technology had responded to military needs during two world wars, and governments recognized the need for even more well-trained professionals. Scholarly textbooks appeared, most nations now had university curricula and at least one research institute, and the number of cartographers, whether by job title or self-identification, had increased substantially.

Recognizing the wars' impacts on cartography, Carl M:son Mannerfelt of the Esselte Map Service invited leaders of mapping firms and organizations in Europe and North America to the Esselte Conference on Applied Cartography, held in 1956 at Tollare, near Stockholm (Ormeling [1986?], 9). A key outcome was the appointment of the Committee of Six to investigate the formation of an international society for cartography. Chaired by Mannerfelt and including K. W. Bland of Britain, Stéphane de Brommer of France, Daniel Chervet of Switzerland, Erwin Gigas of West Germany, and Duncan M. Fitchet of the United States (Mannerfelt 2009), the committee met twice over the next two years, at Chicago and Mainz. Two important issues evolved: (1) the desirability of creating an international cartographic organization distinct from those serving geodesy, surveying, and photogrammetry—the so-called sister societies, and (2) the exploration of the relationship an organization of cartographers should have with the International Geographical Union (IGU).

In June 1959, at Wabern, Switzerland, an independent International Cartographic Association was formed in response to the first issue (Ormeling [1986?], 13). Thirteen nations were represented, and a provisional executive committee was appointed (table 25) to plan the first General Assembly of Delegates, which met in Paris in 1961. Leaders of the new association pledged the ICA to a free exchange of both theoretical and technical cartographic information, much of which had been kept secret for defense or commercial reasons. With the Cold War starting in earnest, mapping officials in the Soviet Union and Eastern Europe viewed this aim as a threat. Even so, the ICA moved forward with the support of national mapping agencies and major atlas publishers in North America and Europe. During these early years the ICA developed a firm financial base and asserted a strong belief in cartography's role in developing international understanding and cooperation (Ormeling [1986?], 16).

The second issue was addressed in 1960 at the XIXth IGU meeting in Stockholm, where the relationship between the ICA and IGU drew close scrutiny from some geographers, primarily academics, who expressed strong reservations about the ICA's nonacademic origins in private industry and government (Ormeling [1986?], 13). The growing Cold War might explain the skepticism of Soviet geographers, intimidated by a new international organization rooted in Western Europe and North America and advocating the relatively free interchange of cartographic information. Maps, particularly large-scale topographic maps created by governments, were treated as state secrets in the Soviet Union and Eastern

Table 25. Membership of the ICA Executive Committee, 1959–2003

Term	President	Secretary/Treasurer	Vice Presidents
1959–61 Provisional	Eduard Imhof (Switzerland)	Erwin Gigas (Federal Republic of Germany)	Stéphane de Brommer (France) Duncan M. Fitchet (United States) L. J. Harris (Canada) Carl Mannerfelt (Sweden) Carlo Traversi (Italy)
1961–64	Eduard Imhof (Switzerland)	Erwin Gigas (Federal Republic of Germany)	Stéphane de Brommer (France) Granville K. Emminizer (United States) Carl Mannerfelt (Sweden) D. E. O. Thackwell (United Kingdom) Carlo Traversi (Italy)
1964–68	D. E .O. Thackwell (United Kingdom)	Ferdinand J. Ormeling (Netherlands)	Stéphane de Brommer (France) Granville K. Emminizer (United States) Herbert Knorr (Federal Republic of Germany) J. S. Paintal (India) Konstantin Alekseyevich Salishchev (Soviet Union) Carlo Traversi (Italy)
1968–72	Konstantin Alekseyevich Salishchev (Soviet Union)	Ferdinand J. Ormeling (Netherlands)	Abdelatif Belbachir (Morocco) Umberto Bonapace (Italy) F. Bonnet-Dupeyron (France) Brice Burroughs (United States) Janusz J. Klawe (Canada) Herbert Knorr (Federal Republic of Germany) D. E. O. Thackwell (United Kingdom)
1972–76	Arthur H. Robinson (United States)	Ferdinand J. Ormeling (Netherlands)	John Christopher Bartholomew (United Kingdom) F. Bonnet-Dupeyron (France) Olof W. Hedbom (Sweden) Nomura Shōshichi 野村正七著 (Japan) Rodolfo Núñez de las Cuevas (Spain) Lech Ratajski (Poland) Konstantin Alekseyevich Salishchev (Soviet Union)
1976–80	Ferdinand J. Ormeling (Netherlands)	Olof W. Hedbom (Sweden)	John Christopher Bartholomew (United Kingdom) Rolf Böhme (Federal Republic of Germany) K. L. Khosla (India) M. I. Nikishov (Soviet Union) [died 1977, replaced by Anatoliy Komkov] Nomura Shōshichi 野村正七著 (Japan) Lech Ratajski (Poland) [died 1977, replaced by Andrzej Ciołkosz] Arthur H. Robinson (United States)
1980–84	Ferdinand J. Ormeling (Netherlands)	Olof W. Hedbom (Sweden)	Rolf Böhme (Federal Republic of Germany) Andrzej Ciołkosz (Poland) B. E. Goodrick (Australia) K. L. Khosla (India) Anatoliy Komkov (Soviet Union) [replaced by E. P. Arzhanov, 1983] P. Legris (France) Joel L. Morrison (United States)

Table 25. (*continued*)

Term	President	Secretary General (after 1984)	Vice Presidents
1984–87	Joel L. Morrison (United States)	Donald T. Pearce (Australia)	Pankaj K. Agarwal (India) E. P. Arzhanov (Soviet Union) Néstor Duch Gary (Mexico) Hu Yuju 胡毓钜 (China) Ferdinand J. Ormeling (Netherlands) David Rhind (United Kingdom) D. R. F. Taylor (Canada)
1987–91	D. R. F. Taylor (Canada)	Donald T. Pearce (Australia)	E. P. Arzhanov (Soviet Union) Néstor Duch Gary (Mexico) Jean-Philippe Grelot (France) Hu Yuju 胡毓钜 (China) Werner Lichtner (Federal Republic of Germany) [died 1989, replaced by Fred W. Christ] Árpád Papp-Váry (Hungary) David Rhind (United Kingdom)
1991–95	D. R. F. Taylor (Canada)	Jean-Philippe Grelot (France)	E. S. Bos (Netherlands) Toshitomo Kanakubo (Japan) Jaume Miranda i Canals (Spain) Árpád Papp-Váry (Hungary) Donald T. Pearce (Australia) Barbara Bartz Petchenik (United States) [died 1992, replaced by Judy M. Olson] Michael Wood (United Kingdom)
1995–99	Michael Wood (United Kingdom)	Jean-Philippe Grelot (France)	Toshitomo Kanakubo (Japan) Milan Konečný (Czech Republic) Jaume Miranda i Canals (Spain) Judy M. Olson (United States) Bengt Rystedt (Sweden) José Solis (Philippines) Regina Araújo de Almeida (Vasconcellos) (Brazil)
1999–2003	Bengt Rystedt (Sweden)	Ferjan Ormeling (Netherlands)	Milan Konečný (Czech Republic) Li Li 李莉 (China) Elri Liebenberg (South Africa) Robert B. McMaster (United States) Takashi Morita (Japan) Kirsi Virrantaus (Finland) Alberta Auringer Wood (Canada)

Europe, and there was virtually no private, entrepreneurial cartographic industry.

In spite of skepticism among Eastern Bloc geographers, the inaugural meeting of the ICA was convened in May 1961 in Paris (Ormeling [1986?], 13). Eighty-four delegates from twenty-nine nations attended. Statutes to govern the association were adopted, and a president, secretary-treasurer, and five vice-presidents were elected to lead the association (see table 25). Twenty-six nations formed the initial membership.

The first decades of the ICA required a delicate dance between the two Cold War protagonists. Once the Soviet Union and its East European allies determined that the organization was viable, they quickly joined.

Through the sincerity and good will of the many veterans of World War II who had risen to leadership positions in mapping organizations within the ICA's various member nations between 1959 and 1980, conflict was avoided within the ICA, where little time was spent politicizing differences among nations. Instead, ICA officials encouraged each country to display its latest cartographic works and expertise wherever and whenever their governments permitted. Many individuals contributed to the organization's early success, most notably Ferdinand J. Ormeling of the Netherlands, who served as secretary-treasurer from 1964 until 1976 and as president from 1976 to 1984. His outstanding love for the field and his diplomatic skills ensured an initial stability for the young organization.

Tension quickly developed within the ICA on another front—between private map publishers and government mapping agencies. The early organizational meetings had been convened and hosted by private firms. Early attempts to affiliate the ICA with the IGU, primarily an academic scientific organization, created further unease among academics and cartographic practitioners in government and private industry and added to the tension between Cold War adversaries vying for world supremacy and espousing radically different views on access to cartographic information. A common interest in maps has helped hold these diverse communities together.

Another potential source of division was language. At issue was the definition of cartography itself, which had to be rendered in both of the ICA's two official languages, French and English. The initial definitions differed somewhat, which made revision difficult. The initial French definition was "Ensemble des études et des opérations scientifiques, artistiques et techniques, intervenant à partir de résultats d'observations directes ou de l'exploitation d'une documentation en vue de l'élaboration et de l'établissement de cartes, plans et autres modes d'expression, ainsi que dans leur utilisation," while the English definition was "The art, science and technology of making maps, together with their study as scientific documents and works of art. In this context maps may be regarded as including all types of maps, plans, charts and sections, three-dimensional models and globes representing the Earth or any celestial body at any scale" (ICA 1973, 1). It was only in 2001 that the official definition was changed, even though the field of cartography had itself changed drastically between 1959 and 2001. The amended official ICA definition of cartography read "the discipline dealing with the conception, production, dissemination and study of maps."

Governance and Activities

Like many international professional organizations, the ICA is governed by a General Assembly, which meets every four years, and an Executive Committee, elected by the General Assembly to run the organization between meetings (table 26). Each member nation has one vote in the General Assembly, and no nation can hold more than one position in the Executive Committee, which includes the president, the secretary-general (secretary-treasurer before 1984), and several vice presidents. It grew from seven members in 1959, to eight in 1964, nine in 1968 (when the immediate past president was added), and ten in 1987. Although the ICA's steady growth is apparent in the election of vice presidents from outside Europe and North America from 1964 onward, the president was always a European or North American until 2007, when the Australian William Cartwright took office. The scientific and technical work of the association is done by a varying number of commissions approved by the Executive Committee and by vote of the General Assembly.

Sister Organizations and a Broader Scope

The IGU was not the only international organization with a vested interest in the viability of the ICA. The existence of several sister organizations underscored the need for a separate group emphasizing international cooperation in cartography; these related groups include the International Society for Photogrammetry (ISP, founded in 1910, later the International Society for Photogrammetry and Remote Sensing [ISPRS]), the Fédération Internationale des Géomètres (FIG, founded 1878), and the International Association of Geodesy (IAG, founded in 1861). The list of international groups with allied interests also includes the United Nations (UN) Cartographic Section, established in 1951, and the Commission on Cartography of the Pan American Institute of Geography and History/Instituto Panamericano de Geografía e Historia, created in the Western Hemisphere in 1941.

These allied professional organizations carefully scrutinized competition within nations among various groups seeking to represent their country in the ICA. When professional organizations of cartographers were established at the national level at midcentury, their makeup, not surprisingly, varied from country to country. In some nations the professional organization consisted mainly of academic geographer/cartographers while in others governmental control of cartographic information dictated that a government mapping agency lead the professional organization. In still others cartographers in private industry created an organization. With the founding of the ICA each nation had to determine which cartographic body would represent it in the ICA and, of course, pay the requisite membership dues. In trying to recognize these varied national organizations, the founders of the ICA learned to cope with traditional

Table 26. Venues of ICA meetings, 1961–2009

Year	Meeting	Venue
1961	I General Assembly	Paris, France
1962	1st Technical Conference	Frankfurt am Main, Federal Republic of Germany
1964	II General Assembly and 2d Technical Conference	Edinburgh, United Kingdom
1967	3d Technical Conference	Amsterdam, Netherlands
1968	III General Assembly and 4th Technical Conference	New Delhi, India
1970	5th Technical Conference	Stresa, Italy
1972	IV General Assembly and 6th Technical Conference	Ottawa, Canada
1974	7th Technical Conference	Madrid, Spain
1976	V General Assembly and 8th Technical Conference	Moscow, USSR
1978	9th Technical Conference	College Park, Maryland, United States
1980	VI General Assembly and 10th Technical Conference	Tokyo, Japan
1982	11th Technical Conference	Warsaw, Poland
1984	VII General Assembly and 12th Technical Conference	Perth, Australia
1987	VIII General Assembly and 13th Technical Conference	Morelia, Mexico
1989	14th Technical Conference	Budapest, Hungary
1991	IX General Assembly and 15th Technical Conference	Bournemouth, United Kingdom
1993	16th Technical Conference	Cologne, Germany
1995	X General Assembly and 17th Technical Conference	Barcelona, Spain
1997	18th Technical Conference	Stockholm, Sweden
1999	XI General Assembly and 19th Technical Conference	Ottawa, Canada
2001	20th Technical Conference	Beijing, China
2003	XII General Assembly and 21st Technical Conference	Durban, South Africa
2005	22d Technical Conference	A Coruña, Spain
2007	XIII General Assembly and 23d Technical Conference	Moscow, Russia
2009	24th Technical Conference	Santiago, Chile

rivalries among government agencies, academics, private industry, and nongovernmental organizations.

In spite of these problems, the organization flourished. Although the Cold War persistently affected the ICA's early aims and achievements, both scholarly and scientific, the increasing influence of new technology (especially computing and electronic communication) on map production and use posed a formidable but distinctly different challenge, serious enough to turn adversaries into allies. As a result, ICA commission themes and activities expanded to include more technical and management topics.

Although the ICA adopted new, more global aims following the end of the Cold War in 1991, its earlier focus on maps and mapmaking did not diminish. Instead, the scope of interests was broadened to include the use of cartography to analyze and help solve world problems (Rhind 1991). This change led to a more expansive interaction with sister societies as well as with international organizations such as the UN.

By the end of the twentieth century the ICA saw itself as part of a wider international initiative addressing many of the planet's most pressing problems. Sister organizations involved in this common effort included not only the IAG, the ISPRS, and FIG but also the International Hydrographic Organization (IHO), the International Map Trade Association (IMTA), and the International Steering Committee for Global Mapping. As reflected in various commissions and specialist meetings, the ICA itself had increasingly become involved in matters of electronic technology, including the incremental updating of databases, spatial data standards, multiscale issues, Internet and satellite mapping, and the creation and visualization of virtual environments.

The first twenty-five years saw the beginnings of (1) a publication program, (2) scientific work by ICA commissions, and (3) informal collaborations between the ICA and its sister societies. During the 1980s the association began to mature. Representatives to the ICA from its member nations came from the post–World War II generation. Formal liaisons with the UN began in May 1987 when the UN's Economic and Social Council (ECOSOC) granted the ICA "Consultative Status in Category II as a non-Governmental Organization." The same year the ICA applied for and received Scientific Associate Status within the International Council for Science (ICSU). Additionally, the ICA more formally entered into associations with other professional organizations.

The scientific work of the ICA, as carried out by its commissions and working groups, also matured. The number of formal commissions and working groups—the latter could be authorized by the ICA Executive Committee between meetings of the General Assembly—constantly changed and grew in number. The work of ICA commissions was accomplished by individuals appointed by the member nations. Although membership on some of the earlier commissions and working groups had been politically motivated, with the organization's maturation in the century's final decade and the end of the Cold War, the membership of commissions and working groups evolved to include many of the most distinguished scientists in their respective specialties. As a result, the quality of the publications of the commissions and working groups greatly increased.

During the twentieth century the ICA held biennial meetings (table 26). Usually, the General Assembly of national delegates met every four years with a technical conference in the intervening years. Although thirteen of the twenty-one meetings between 1961 and 2001 were convened in Europe, during this interval the ICA met three times each in Anglo America and Asia, and once each in Australia and Latin America. At each of these conferences an international exhibition of the latest maps produced by each member nation was displayed and judged. Also, the host country usually compiled an exhibition of historical maps displaying its territory. In 1993 the ICA established the Barbara Petchenik Children's World Map Competition. Every two years world maps drawn by children under the age of sixteen are submitted by the nations for this prestigious award. The ICA also awarded the Carl Mannerfelt Gold Medal to internationally recognized leaders in the field of cartography and the ICA Honorary Fellowship award to individuals whose work has fostered the aims of the ICA. The award recipients listed in table 27 not only include many of the most noteworthy scholars and practitioners during the last half of the twentieth century but also reflects their country's prominence as a leading center of cartographic activity.

The ICA also generated a wealth of material for future scholars of the history of cartography—at least for those willing to hunt for it. At each meeting of the General Assembly each member organization was required to submit a report epitomizing activities in cartography and geographic information science within its borders during the previous four years. Because these reports followed no standard format and were published within their respective countries, copies are not easily obtained. Within the United States, the Library of Congress collected some of these national reports, and the ICA archives maintained by the Geographic Documentation Service of the Institut géographique national (IGN), in

Table 27. ICA award recipients, 1974–2001

Carl Mannerfelt Gold Medal	
1979–80	Eduard Imhof (Switzerland)
1980	Arthur H. Robinson (United States)
	Konstantin Alekseyevich Salishchev (Soviet Union)
1981	Carl Mannerfelt (Sweden)
1987	Ferdinand J. Ormeling (Netherlands)
1999	Jacques Bertin (France)
2001	Chen Shupeng 陈述彭 (China)
	Joel L. Morrison (United States)
ICA Honorary Fellowship	
1974	Sándor Radó (Hungary)
	Konstantin Alekseyevich Salishchev (Soviet Union)
1980	Akira Watanabe (Japan)
1982	Emil Meynen (Germany)
	Stanisław Pietkiewicz (Poland)
1983	D. E. O. Thackwell (United Kingdom)
1984	Rolf Böhme (Germany)
	Harold Fullard (United Kingdom)
1987	David P. Bickmore (United Kingdom)
	Olof W. Hedbom (Sweden)
1991	Néstor Duch Gary (Mexico)
	Bernard V. Gutsell (Canada)
	Joel L. Morrison (United States)
	Helen Wallis (United Kingdom)
1995	Rodolfo Núñez de las Cuevas (Spain)
	Árpád Papp-Váry (Hungary)
	Donald T. Pearce (Australia)
	Ernst Spiess (Switzerland)
	Joseph W. Wiedel (United States)
1997	Richard E. Dahlberg (United States)
	Miroslav Mikšovský (Czech Republic)
	Christer Palm (Sweden)
1999	R. W. Anson (United Kingdom)
	Christopher Board (United Kingdom)
	Jean-Philippe Grelot (France)
	Toshitomo Kanakubo (Japan)
	Jaume Miranda i Canals (Spain)
	D. R. F. Taylor (Canada)
2001	Bai Bo 白泊 (China)
	Ron Furness (Australia)
	Hu Yuju 胡毓钜 (China)
	Kei Kanazawa (Japan)
	Judy M. Olson (United States)

Marne-la Vallée, France, acquired reports from the last years of the twentieth century. Sometimes the reports appeared as special issues of academic journals published in a respective country or simply in newsletters of the organization representing a nation in the ICA.

Information on the ICA's own activities can also be found in various newsletters and news sections of some cartographic journals. Beginning in 1964, irregular and infrequent notes appeared in the *Bulletin* of the International Geographical Union. In 1983 the University of Toronto Press began publishing the *ICA Newsletter*, and frequent news notes have also appeared in the *Bulletin du Comité français de cartographie*, published by the Comité in Paris.

By the end of the twentieth century, technology made visual displays of spatial information easily and cheaply available. At that time the full implication of these technological advances was unknown but was anticipated to be substantial. The inclusion of spatial information routinely into all societal activities and planning was becoming accepted if not required. The field of cartography was no longer a small group of highly trained knowledgeable individuals. Cartography had become a subject with recognized effects on civilians as well as soldiers, homeowners as well as governments. Against this background it is clear that the ICA was a necessary response to the expanded knowledge in the twentieth century.

JOEL L. MORRISON

SEE ALSO: Journals, Cartographic; Map: Definitions of "Map"; Ormeling, Ferdinand J(an); Robinson, Arthur H(oward); Salishchev, Konstantin Alekseyevich; Societies, Cartographic

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International Civil Aviation Organization. At the end of World War II, the international community recognized that aviation would develop into a mode of worldwide transportation. To lay the infrastructural foundation for international civil aviation, the Convention on International Civil Aviation was signed on 7 December 1944 in Chicago, with fifty-two contracting states participating, and the International Civil Aviation Organization (ICAO) came into being 4 April 1947. The ICAO concerns itself with all aspects of civil aviation. Starting from an initial stipulation of five "Freedoms of the Air," which address international overflight and landing privileges, its scope expanded to cover aircraft design and certification, pilot training and licensing, medical regulations, airport planning and design, airplane operations and maintenance, and air traffic control as well as the standardization and production of continuously updated aeronautical charts. The ICAO established its head office in Montreal, and regional offices are in Paris, Nairobi, Lima, Cairo, Mexico City, Dakar, and Bangkok. By 2009 the number of member states had risen to over 180.

In diverse ways the ICAO has maintained contacts with other important international groups interested at least partly in mapping. These include the Pan American Institute of Geography and History/Instituto Panamericano de Geografía e Historia, the International Cartographic Association (and several of its commissions), the International Hydrographic Organization, the International Society for Photogrammetry and Remote Sensing, and the United Nations (UN). Recognizing the importance of regional cooperation, the ICAO has participated actively in the UN Regional Cartographic Conferences, held every three years.

A key product of the 1944 ICAO conference was the document "Annex J: Aeronautical Maps and Charts," developed by the Map Subcommittee of the organization's then-provisional Air Navigation Committee. Intended to replace a statement on standards adopted in Paris in 1919, "Annex J" was refined several times during the following two decades. In 1948 the ICAO Council adopted a system of Standard and Recommended Practices (SARPS) for aviation maps. The Standard Practices are compulsory for contracting states, whereas the Recommended Practices are strongly advised and intended as future Standard Practices. Initial emphasis was on the World Aeronautical Chart (WAC), produced at a scale of 1:1,000,000 and designed for worldwide visual navigation.

ICAO charts were intended partly to assist air crews who had to cross international borders and thus adhere to a multitude of diverse regulations and procedures laid down by the states traversed. Though originally intended for an office environment rather than for onboard use, the charts were designed to be usable in a cramped cockpit under variable lighting conditions and to allow for the quick comprehension of data by crew members coping simultaneously with the overriding task of flying the airplane. Aeronautical charts must also cater to both visual and instrument flying. Not until 1984 and 1985 did the Council adopt Amendments 46 and 47, which contain specifications emphasizing suitability for in-cockpit use.

After an introductory period, member states were obligated to produce these charts as well as make the underlying topographic and aeronautical data available to the international community. States were also required to publish the information locally in the prescribed Aeronautical Information Publication (AIP) and to provide amendment services. For short-term and temporary changes, timely notification through a NOTAM (notice to airmen) service became compulsory. Though free to combine charting and data-dissemination efforts with the military or through other projects, both nationally and internationally, a member state could delegate production and dissemination but not its responsibility for making accurate charts available in a timely manner. The ICAO also recommended that members distribute information on cartographic techniques and research at no charge.

States have been required to ensure compliance by airlines, which produced their own charts, often taking ergonomic concerns to a more refined level commensurate with their routes and operations. Starting in the early 1970s, airlines slowly began buying off-the-shelf, commercial aeronautical charts, like those produced by Jeppesen. Maintaining readability and avoiding clutter has been a priority for commercial firms as well as for government charting agencies.

Since its inception, the ICAO has had to address a range of technological advances and operational developments such as the shift from visual flying and navigation to flying under instrument conditions; the application of ever lower weather minima; the use of digital autopilots; and the advent of digital technology for acquiring, storing, retrieving, and disseminating data. Increased international cooperation went hand in hand with technical cooperation with international pilots unions and the International Air Traffic Association, an alliance of major airlines, many of which started out as national, state-owned carriers. Chartmaking capability was long considered a strategic necessity. Airlines considered chartmaking an essential activity that they could not leave either to a competing airline or to a state, which for political reasons might decide on short notice to prohibit the export of charts or data. Each airline thus produced its own charts, in a massive duplication of effort that was considered unavoidable until the 1970s, or even later in some cases, when international relations had become more reliable.

Table 28 lists the seventeen types of charts available by the end of the twentieth century and describes their key characteristics. Of these seventeen, six were considered mandatory, six were deemed nonmandatory, and five were judged conditional, that is, strongly recommended for specific situations. The charts listed fall under four categories: planning charts; in-flight charts (used between take-off and landing); ground movement charts; and charts for visual navigation, including plotting and navigation planning. A chart's title may contain "ICAO" only if it is in full compliance with all ICAO specifications.

According to standards established early in the ICAO's history, flight charts have update cycles ranging from twenty-eight days for congested areas to twelve weeks for noncongested areas. By contrast, the more highly generalized WAC, published at scales of 1:1,000,000 and 1:500,000, has update cycles of four years for topographical data and one to two years for its comparatively limited aeronautical data. As late as 1990 ICAO officials were uncertain about how extensively and quickly digital charts could safely replace their on-board paper counterparts. Factors affecting the safe and efficient introduction of electronic aeronautical charts included the availability and dependability of related on-board equipment, uplink/download capabilities, and redundant systems for dealing with technical failures.

Specifications were developed after 1980 for two additional charts: the Electronic Aeronautical Chart display, which involves variable scale, continuous position display, automatic update capability, and a requirement for system back-up; and the ATC (air traffic control) Surveillance Minimum Altitude Chart, which helps a pilot approaching an airport under air traffic control determine a minimum safe altitude below the published minimum. To avoid confusion, the latter chart and the associated area chart must be identical in scale and projection because pilots remain responsible for terrain clearance, even under radar control. Charts must allow pilots to orient themselves spatially and be fully aware of minimum safe altitudes when following a radar vector assigned to maintain proper separation of aircraft.

By necessity, aeronautical charts differ from other maps because the third dimension plays a much larger role than the mere representation of relief. Not only are terrain representation and obstacle clearance basic for flying, but the safe use of airspace depends heavily on an efficient allocation of flight levels and altitudes. Because high-level flying uses barometric altimetry to separate flights, aircraft must follow pressure levels instead of height levels. For low-visibility precision approaches, radar altimetry is used for the final approach to the landing runway to ensure obstacle clearance as well as correct autopilot operation. Because the terrain features near the runway will influence the reading of the radar altimeter, these features—including high-rise buildings—must be known and updated. Instrument approach charts also reflect the fourth dimension (time) insofar as the timing of the final descent (commensurate with the diminishing distance to touch-down) is critically important. Technical development of civil aviation navigation systems has often resulted from prior military concepts.

Since its inception in 1944, the ICAO has had to adapt to significant shifts in aircraft capability. Propeller-driven

Table 28. ICAO charts at the end of the twentieth century

Available charts	Status*	Scale (horizontal)	Scale (vertical)	Projection	Use, comments
Aerodrome Obstacle Chart Type A ICAO	M	1:10,000 to 1:20,000	10 × horizontal scale	none prescribed	for planning maximum aircraft weights for take-off and landing
Precision Approach Terrain Chart ICAO	M	1:2,500	1:500	none prescribed	to determine minimum decision height during approach, accounting for natural and man-made terrain profile features
En-route Chart ICAO	M	no uniform scale		conformal conic; Lambert recommended	for navigation along air routes in compliance with air traffic procedures
Instrument Approach Chart including Category II and III ICAO	M	to scale unless otherwise indicated		conformal conic; Lambert recommended	including vertical profile below the plan view; mention of aerodrome operating weather minima
Aerodrome/Heliport Chart ICAO	M	none prescribed; 1:10,000 considered suitable, linear scale			for ground movement to and from runways
World Aeronautical Chart (WAC) ICAO	M	1:1,000,000		Lambert conic between 0° and 80° N/S lat.; published per 4 degrees of lat. with twin standard parallels; for higher lat. polar stereographic with scales matching Lambert charts at 80°of lat.	basic complete world coverage for visual navigation
Aerodrome Obstacle Chart Type B ICAO	NM	1:10,000 to 1:20,000		as per any suitable topographical map	for obstacle clearance procedures
Aerodrome Ground Movement Chart ICAO	NM	none prescribed, linear scale			expands on Aerodrome/Heliport Chart ICAO
Aircraft Parking and Docking Chart ICAO	NM	none prescribed			expands on Aerodrome Ground Movement Chart ICAO
Aeronautical Chart ICAO	NM	1:500,000		Lambert conformal, published per 2 degrees of lat. with twin standard parallels between 80° N/S lat. only	substituting for or additional to WAC; for navigation over land areas
Aeronautical Navigation Chart Small Scale ICAO	NM	suggested 1:2,000,000 to 1:5,000,000		conformal	for use in long range, high altitude navigation, using visual ground reference

(*continued*)

TABLE 28. (*continued*)

Available charts	Status*	Scale (horizontal)	Scale (vertical)	Projection	Use, comments
Plotting Chart	NM	1:3,000,000 to 1:7,000,000		conformal, where great circle approximates a straight line (earlier, active on-board navigation required a Mercator projection; later on, when passive navigation monitoring, was common, other conformal projections could be used)	for navigation over oceanic or desolated areas; providing a continuous flight record of position in order to maintain the intended track
Aerodrome Obstacle Chart Type C ICAO	C	1:20,000 to 1:100,000 (1:50,000 preferred)		as per any suitable topographic map	for establishing circling and emergency procedures around airports
Area Chart ICAO	C	1:250,000 to 1:2,000,000		conformal conic projection (Lambert)	for transition from en-route to approach phase
Standard Instrument Departure Chart ICAO	C	to scale unless otherwise indicated		conformal projection (Lambert)	for departures into joining the en-route or area chart structure
Standard Arrival Chart ICAO	C	to scale unless otherwise indicated		conformal projection (Lambert)	for transition from area chart or en-route chart structure in order to execute the approach for landing (or go-around) procedure for each runway
Visual Approach Chart ICAO	C	1:250,000 or 1:200,000		conformal, where great circle approximates a straight line	for transition of en-route to approach to runway phase, using visual reference

* Mandatory (M), nonmandatory (NM), or conditional (C).

aircraft operated below 10,000 feet until pressurized cabins allowed altitudes of 25,000 feet. Early civil jets increased speed to 450 knots (over 500 miles per hour), and in the 1960s airplanes could climb to 40,000 feet and reach speeds up to 500 knots (over 575 miles per hour). Wide-body jets appeared in the 1970s, with improved engines, automated navigation, and improved approach and landing capability. Airbus Industrie in Europe designed a family of jet aircraft aimed at reducing the dominance of the United States aircraft industry. Use of aircraft manufactured in the Soviet Union was limited mainly to countries under Communist rule. Following the end of the Cold War in the 1990s, the U.S. military not only offered civil aviation a nondegraded GPS (Global Positioning System) signal but even relinquished on/off authority to a certain extent. Airlines in East Asia developed at a tremendous rate, and in the 1980s ICAO activities started to shift in emphasis away from North America and Europe toward Asia. Aviation mapmaking followed these developments, with market demand driving production. These developments were coordinated through the ICAO at the international level, and the inclusion of the Eastern Bloc countries required the integration of a new set of practices. At times the ICAO, as a political organization, lacked the funding required to quickly and fully meet these fast-paced developments. Even so, the international community became ever more aware of the need to support civil aviation with appropriate infrastructure on a worldwide basis.

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SEE ALSO: Aeronautical Chart; World Aeronautical Chart

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International Geographical Union. As its name implies, the International Geographical Union (IGU) is an organization dedicated to the advancement of geographic knowledge through the systematic study of geography and the coordination of multinational research. IGU members are individual countries, typically represented by national committees affiliated with one or more national societies of academic geographers. Its activities are governed by a General Assembly, which normally convenes every fourth year in conjunction with the IGU's International Geographical Congresses, and an eleven-person Executive Committee (president, secretary-general and treasurer, and nine vice-presidents) with broad authority to manage IGU affairs between meetings of the General Assembly. Principal IGU activities include orchestrating a formal series of international geographic congresses, typically four years apart, and providing institutional oversight and support for commissions appointed to address a specific problem or phenomenon within a specified period of time. Many IGU commissions have focused on mapping or had distinct cartographic overtones.

The IGU emerged as a permanent organization in 1922, following an irregular series of ten international geographical congresses held between 1871 and the outbreak of World War I. All but one of these congresses—1871 (Antwerp), 1875 (Paris), 1881 (Venice), 1889 (Paris), 1891 (Bern), 1895 (London), 1899 (Berlin), 1904 (Washington), 1908 (Geneva), and 1913 (Rome)—were convened in Western Europe. The impetus for a formal, permanent international union came from a 1922 meeting, in Paris, of the International Research Council (IRC). Organized during the war by academies of science in Allied countries, the IRC was committed in the postwar era to expanding formal international scientific cooperation, albeit with prejudice at first against Germany and Austria (Cock 1983). By 1926 geography (along with astronomy, biology, chemistry, geodesy and geophysics, mathematics, physics, and radio science) was one of eight disciplines with an international union. Although the IGU has had two official languages, French and English, the Executive Committee conducted its business largely in French between 1931 and 1949, and mostly in English thereafter, and IGU publications from the second half of the twentieth century were predominantly in English (Harris 2001). By century's end the IGU had convened nineteen more international congresses: 1925 (Cairo), 1928 (Cambridge), 1931 (Paris), 1934 (Warsaw), 1938 (Amsterdam), 1949 (Lisbon), 1952 (Washington), 1956 (Rio de Janeiro), 1960 (Stockholm), 1964 (London), 1968 (New Delhi), 1972 (Montreal), 1976 (Moscow), 1980 (Tokyo), 1984 (Paris), 1988 (Sydney), 1992 (Washington), 1996 (The Hague), and 2000 (Seoul).

Several of the early international geographical congresses focused on questions of considerable interest to cartographers, including agreement on a common prime meridian, and the first twenty-nine congresses typically included extensive exhibits of atlases, globes, maps, and (eventually) national atlases. A persistent topic taken up at the 1891 Bern congress and pursued until 1928 was the preparation of a map of the entire world at a scale of 1:1,000,000 (Martin 1996). Another topic frequently raised and assigned in 1899 to an international commission, retired in 1904, was the formation of an International Cartographic Association (ICA), an objective not achieved until 1959. On several occasions thereafter—London in 1964, Delhi in 1968, Moscow in 1976, and Tokyo in 1980—the IGU and ICA have met concurrently.

As do many similar international organizations, the IGU has assigned its research efforts to commissions and study groups. The proto-IGU had established commissions from the outset, in 1871, and the IGU initiated a series of lesser entities called study groups in 1986. Under this two-tiered system, a study group could be formed relatively easily and advanced to commission status if it proved productive. A commission that completed its mission was typically retired or reconfigured, or if its progress was unimpressive, demoted to a study group. In 2002, when it was apparent that the distinction had become invidious in nature and indefensibly inconsistent in application, the General Assembly voted to recognize commissions only. Prior to this vote, debate over whether a particular research group should be designated a commission or a study group had been an enormous distraction for the Executive Committee. Table 29 lists various IGU commissions focused on topics in cartography, photogrammetry, remote sensing, or geographic information systems and science, and operating through the year 2000, and table 30 lists IGU study groups functioning during the same period.

IGU commissions and study groups have at times pursued research in cartography and related topics in collaboration with other organizations, including, after 1959, the ICA. More often than not, such cooperation has taken the form of cross-membership, with ICA commission members appointed to cognate commission or study groups in the IGU, or vice versa.

Table 29. IGU commissions focused on topics in cartography, photogrammetry, remote sensing, or geographic information systems and science. Compiled from Robic, Briend, and Rössler 1996, 435–40, and *IGU Bulletin*, various dates 1996–2008.

1891–1928, 1949–52	Map of the World at 1:1,000,000
1899–1904	International Cartographic Association
1908	Geographical Orthography
1908–13	Atlas of Relief Forms
1913	Restoration of Ancient Maps
1928–31	Map of the Roman Empire at 1:1,000,000
1928–34	Paleogeographic Map of the Pleistocene Era
1928–49	Publication of Reproductions of Ancient Maps
1931–34	Topographic Aerial Photography
1949–64	Bibliography of Ancient Maps
1949–52, 1964–68	Geographical Utilization of Aerial Photographs
1952–54	Library Classification of Geographical and Cartographic Works
1956–64	World Map of Population
1956–72	National Atlases
1968–80	Geomorphological Cartography
1968–80	International Geographical Terminology
1968–88	Geographical Information and Processing
1988–96	Geographical Information Systems
1988–2008	World Political Map
2000–	Geographic Information Science

Table 30. IGU study groups focused on topics in cartography, photogrammetry, remote sensing, or geographic information systems and science. Compiled from Robic, Briend, and Rössler 1996, 439–40, and *IGU Bulletin*, various dates 1996–2008.

1976–88	Cartography of the Environment and Its Dynamics
1976–88	Atlas of the Environment
1980–84	International Geographical Terminology
1980–88	Geomorphological Cartography
1984–88	Topoclimatological Research and Mapping
1984–88	Political Map of the World
1984–88	Map Use
1992–2000	Environmental Management and Mapping
1996–2000	Geographic Information Science

Interest in cartography among geographers and within the IGU had waned by century's end, and the dates of operation of cartography-related IGU commissions and study groups attest to diminished interest in cartographic research among geographers. This decline seems to have accelerated in the final decade of the twentieth century and the first decade of the twenty-first. By 2010 only one IGU commission—Geographic Information Science—was definitively cartographic, and the annual Environmental Systems Research Institute (ESRI) user conferences were clearly more directly relevant to mapmaking than the IGU's conferences and congresses. Moreover, in most countries of the world, geography and cartography had become institutionally separated, on university campuses and into their own professional societies, and in many countries specialists in cartography, photogrammetry, remote sensing, and geographical information systems were scarce or absent at meetings of geographers. That said, the IGU remained the only avowedly global organization of geographical practitioners, scholars, and teachers.

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SEE ALSO: Antarctica; Geophysics and Cartography; International Geophysical Year

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International Geophysical Year. The International Geophysical Year (IGY) was the brainchild of Lloyd V. Berkner, an American atmospheric physicist who proposed the idea in 1950. The IGY was, in fact, not a year but an eighteen-month period from 1 July 1957 to 31 December 1958 that eventually was extended to thirty months. Initially planned as the third in the series of International Polar Years, the IGY was timed to take advantage of the opportunities for studying the upper atmosphere that would be presented by a maximum in solar activity during 1957 and 1958. With the support of influential figures, including U.S. engineer and science administrator Vannevar Bush and British mathematician Sydney Chapman, Berkner's proposal was rapidly taken up by the International Council of Scientific Unions (ICSU) and its affiliates, and subsequently by the World Meteorological Organization (WMO), gathering both international and interdisciplinary support. Although the principal focus was on polar and upper atmosphere science, the IGY eventually became a platform for a wide range of geophysical survey activities worldwide. In due course, Chapman and Berkner took on the roles of president and vice-president of the IGY organizing committee and were joined in its bureau by geophysicists Jean Coulomb (France), Vladimir V. Beloussov (Soviet Union), and Marcel Nicolet (Belgium).

The United States readily established plans for a massive observation and research program, which were eventually matched by an even more extensive Soviet plan, leading in turn to the further expansion of U.S. efforts. In all, sixty-seven nations participated in IGY themes that included oceanography, meteorology, seismology, glaciology, and even solar physics. The most novel element of the program, however, was the use of rockets, first for suborbital investigation of the earth's atmosphere and then, ambitiously, for making observations from earth-orbiting satellites.

The timing of the IGY proved to be perfectly synchronized with developments in space technology. President Dwight D. Eisenhower announced in 1955 that the United States would launch an artificial satellite as part of its contribution to the IGY. The Soviet Union, however, subsequently stole Eisenhower's thunder by launching Sputnik, the world's first artificial earth satellite, in October 1957 without specific prior announcement, thereby igniting the space race.

As expected, the first important IGY discoveries were largely derived from rocket- and satellite-based missions. For example, the presence of the Van Allen radiation belts—two concentric shells of highly charged particles—was confirmed by early data returned from the U.S. Explorer satellite missions in 1958. Observation of the motions of the orbiting satellites quickly led to confirmation that the figure of the earth is, to first order, an oblate spheroid. More detailed subsequent analysis led to the less anticipated result that variations from that figure take a very slight pear-shaped form (fig. 406). These analyses opened the field of satellite geodesy, which revolutionized the approach to global datums and culminated in global positioning systems and modern surveying methods. Although images of the earth's surface were not retrieved from an orbiting satellite until the Explorer 6 mission (launched 7 August 1959 during the IGY extension period), the satellite-based investigations of the IGY were recognized as the initial steps toward earth observation from space.

Antarctic science developed rapidly through the IGY. A network of stations observing a wide range of

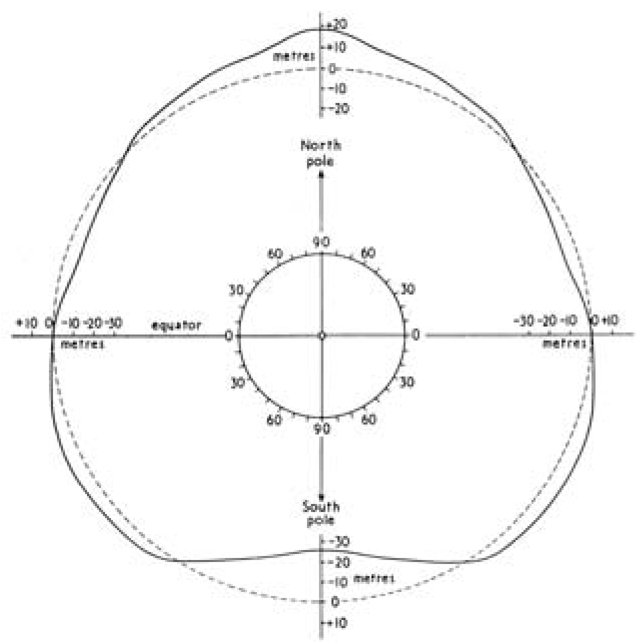

FIG. 406. AVERAGE CROSS-SECTION THROUGH THE EARTH. Calculated in 1974 using data and methods similar to those of the IGY. Relative to the oblate spheroid (dotted line) and greatly exaggerated here, the North Pole and southern subtropical latitudes are seen to be elevated, whereas the South Pole and northern subtropical latitudes depressed, giving rise to a pear-shaped figure of variation.
Size of the original: 8.2 × 8.1 cm. From Desmond King-Hele, *A Tapestry of Orbits* (Cambridge: Cambridge University Press, 1992), 152 (fig. 5.7). Permission courtesy of Cambridge University Press.

atmospheric and terrestrial geophysical parameters was set up and maintained throughout the period. On 1 December 1959, the twelve nations that had been active in that enterprise signed the Antarctic Treaty, which provided the framework for research activities and committed the signatories, eventually numbering forty-six, to the peaceful use of the continent and the freedom to undertake scientific research such as mapping activities and data exchange.

The IGY established the World Data Center (WDC) system in 1957 as a mechanism through which the data acquired could be preserved by a network of national repositories and disseminated to the research community. The WDC system continued to flourish, the range of data available through the centers expanded, and it remained a primary data source for the production of relevant maps throughout the rest of the century.

The IGY captured the attention of the public to an exceptional degree. Not only space technology, but highly publicized events such as the completion of the first overland crossing of Antarctica by a team led by Sir Vivian Fuchs and Sir Edmund Hillary, the issue of special commemorative postage stamps, and Walt Kelly's G. O. Fizzickle in his *Pogo* cartoons combined to fire the imaginations of young people. Over the following decades, this generation established new understanding of geophysical and planetary processes through, for example, the theory of plate tectonics. In this way, the legacy of the IGY permeates modern geoscience.

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SEE ALSO: Geophysics and Cartography; International Geographical Union

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International Hydrographic Chart. As early as 1884, E. R. Knorr, the senior civilian hydrographer at the U.S. Hydrographic Office, espoused the benefits of coordinating the production of charts among the world's numerous national hydrographic offices. In 1918 this concept was further refined by Joseph Renaud, *ingénieur hydrographe*, Directeur du Service hydrographique de la Marine, and one of the founders of the International Hydrographic Bureau (IHB) in 1921 (Renaud 1918). Admiral J. M. Phaff (Netherlands), when addressing the Second International Hydrographic Conference (IHC) in 1926, again raised this initiative (IHB 1926, 9–10).

Over forty years later at the ninth IHC in 1967 a formal motion offered by France and the Netherlands called for a minimum set of charts suitable for international shipping. A resolution adopted by that conference established the Commission on the International Chart, Small Scale. This commission devised the specifications for two series of small-scale charts covering the world: (1) a series of nineteen charts at scale 1:10,000,000 (fig. 407) and (2) a second series of sixty charts at scale 1:3,500,000. Volunteer IHO member states published the individual sheets of these two series during a fifteen-year period starting in 1972. This provided international shipping with uniform modern chart coverage for all ocean passages.

Most hydrographic offices have an obligation to provide nautical chart coverage of their national waters to such an extent, and on such scales, as to permit safe navigation. These charts also constitute an excellent source of information for a variety of national users other than navigators, such as construction engineers concerned with offshore developments, dredging contractors, oceanographers, defense departments, and coastal zone managers. Normally, comparatively large scales are used for port plans, and usually at least two continuous coastal series are available for approach and coastwise navigation, one series on a relatively large scale, the other slightly smaller. International shipping does not need to use every one of these national charts; rather, it needs a set of medium- and large-scale charts covering the main traffic routes and ports.

The success of the small-scale International (INT) Chart Series led to consideration of extending the concept to include charts at larger scales that would satisfy the remaining needs for international shipping. The North Sea International Chart Commission (NSICC) was tasked by the tenth IHC in 1972 to assess the problem by making a pilot study of the North Sea.

Following this study, and to facilitate coordination between hydrographic offices, the IHO agreed on the establishment of INT charting regions (fig. 408). Each region was lead by an INT chart regional coordinator with the responsibility to harmonize the coverage of the INT charts within the region, to develop the limits and the numbering scheme of the charts, and to promote chart production.

To facilitate standardization, draft IHO regulations for international charts were compiled from the reports, agreements, and studies of the NSICC. They were amended and agreed upon by the Chart Specifications Committee and its successor, the Chart Standardization Committee, and were completed in 1984. The standards are compiled in IHO Publication M-4 (IHO 2005). In the early twenty-first century, the IHO Chart Standardization and Paper Chart Working Group (CSPCWG)

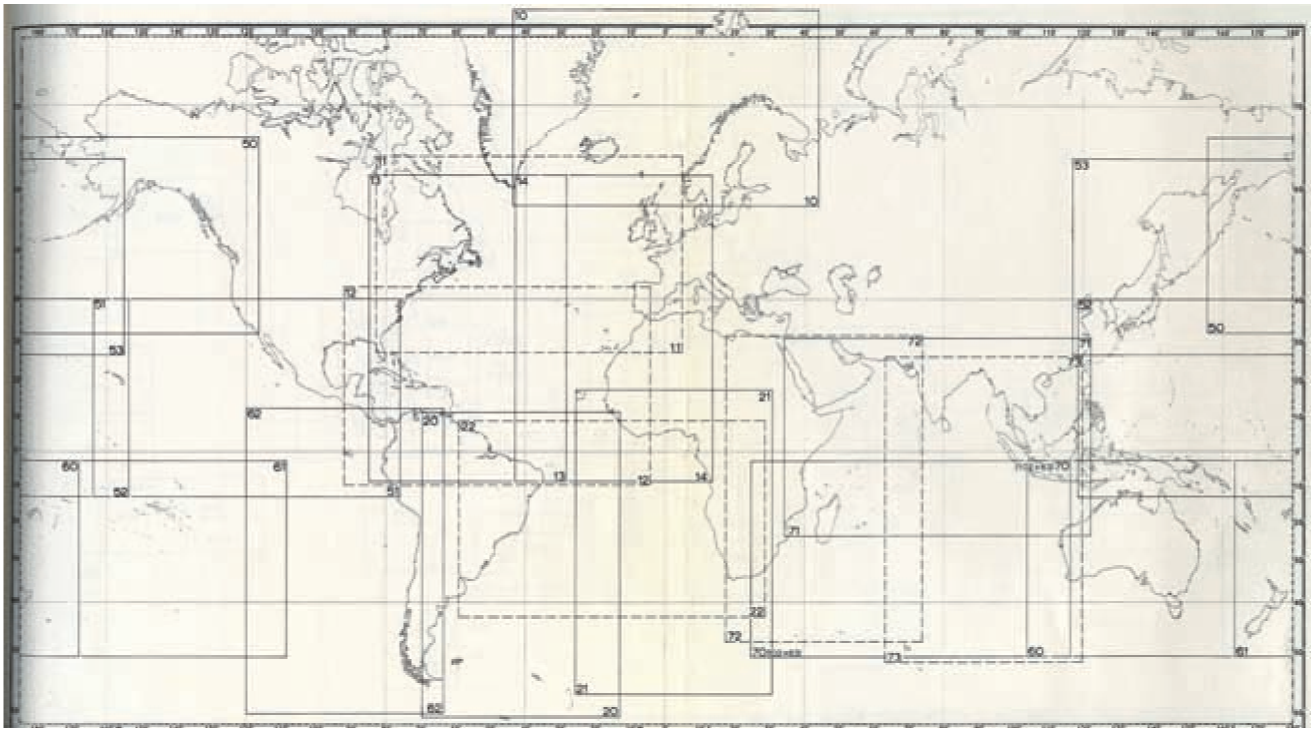

FIG. 407. INTERNATIONAL HYDROGRAPHIC ORGANIZATION (IHO) SMALL-SCALE (1:10,000,000) INTERNATIONAL (INT) CHART SERIES SCHEME PROPOSED BY THE COMMISSION ON INTERNATIONAL CHARTS. It originally had nineteen charts; later, other charts were added. Size of the original: 11 × 16 cm. From IHO, *Circular Letter* 21 (4 July 1970), appendix A. Permission courtesy of the International Hydrographic Bureau, Monaco.

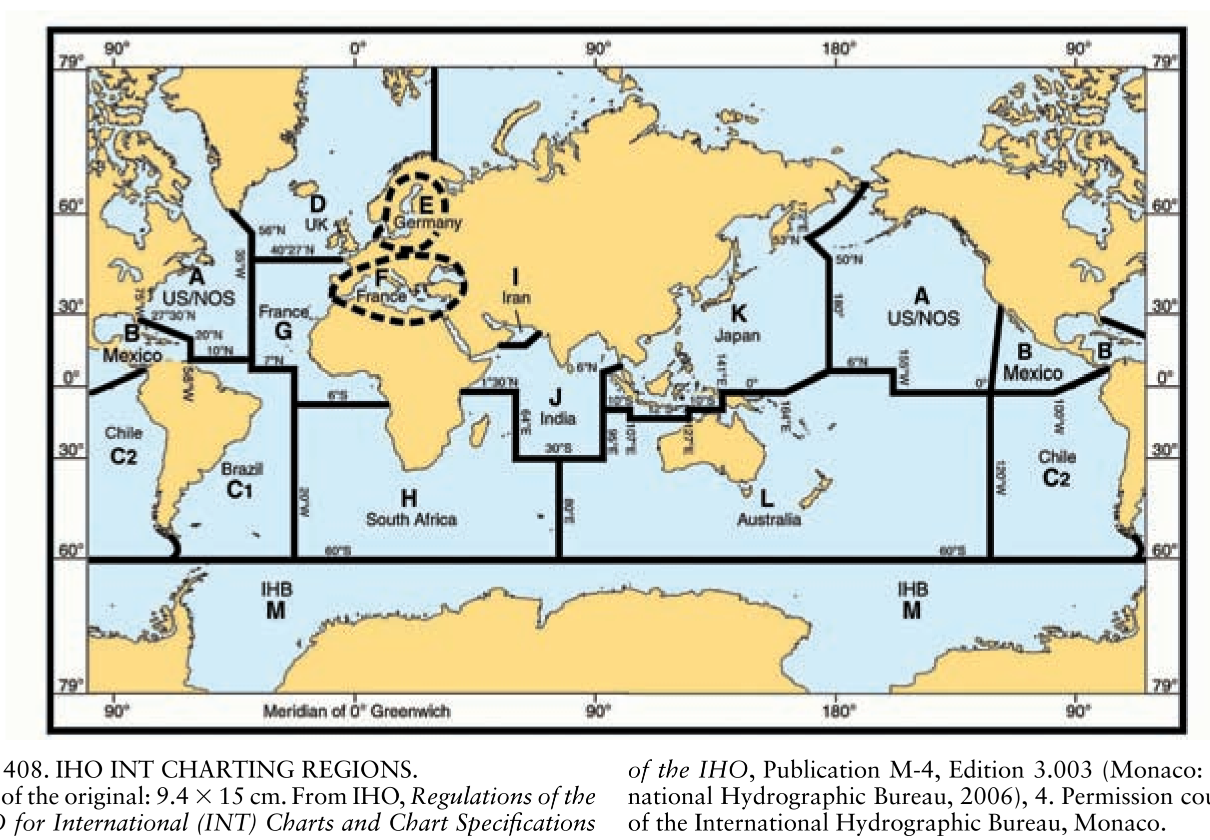

FIG. 408. IHO INT CHARTING REGIONS.
Size of the original: 9.4 × 15 cm. From IHO, *Regulations of the IHO for International (INT) Charts and Chart Specifications of the IHO*, Publication M-4, Edition 3.003 (Monaco: International Hydrographic Bureau, 2006), 4. Permission courtesy of the International Hydrographic Bureau, Monaco.

remained the IHO body responsible for updating the regulations and specifications governing the production of INT charts.

As defined by the IHO, an international chart is a chart that is produced with limits and scale in conformity with an internationally agreed scheme of such charts, carries the INT number of that sheet, conforms to the chart specifications of the IHO, and conforms to the regulations of the IHO for international charts. An IHO member state that undertakes the production of an international chart is known as the producer nation, and a member state that uses reproduction material from a producer nation to print an international chart is known as a printer nation. Bilateral arrangements between IHO member states covering this producer-printer nation arrangement are encouraged.

Each nation, in the role of either producer or printer, accepts responsibility for the operation of a system to ensure adequate maintenance of any international chart included in its national series. The required level of maintenance is determined largely by the rate at which significant new information is received. The IHO INT charts program has played an important role in contributing to safe navigation and establishes the basis on which worldwide electronic navigational chart coverage can be provided.

HUGO M. GORZIGLIA

SEE ALSO: Electronic Cartography; General Bathymetric Chart of the Oceans (GEBCO); Marine Chart; Marine Charting: Overview of Marine Charting

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Renaud, Joseph. 1918. "La carte marine internationale." *Annales Hydrographiques*, 3d ser., 2:29–43.

International Hydrographic Organization (Monaco). The International Hydrographic Organization (IHO) (Organisation hydrographique internationale [OHI] in French, its other official language) is an intergovernmental, consultative, and technical organization that traces its origins to the International Hydrographic Bureau (IHB) formed in 1921 to support navigational safety. The genesis of the IHB began much earlier in response to the continual loss of life and property at sea.

At the turn of the twentieth century, despite the advances of the industrial revolution, going to sea in ships remained a hazardous activity. The sources of these hazards were varied, but major contributors included inadequacies in navigation and in the charts to support it. As early as 1884, E. R. Knorr, the senior civilian hydrographer at the U.S. Hydrographic Office, promoted the benefits of coordinating the production of charts, and again in 1918 *ingénieur hydrographe* Joseph Renaud of France championed Knorr's concept and the goal of attaining uniformity in chart content and appearance (IHB 1926, 9–10). After World War I, the first International Hydrographic Conference (IHC) was convened in London in June 1919. One proposal emerging from this conference was the establishment of an international hydrographic bureau to ensure effective and continuous cooperation between national hydrographic offices. The conference charged a three-member International Hydrographic Conference Committee to formulate the actions necessary to establish such a bureau (International Hydrographic Congress, 1920, 192–225). The committee's work culminated on 21 June 1921 when the eighteen founding member states (Argentina, Belgium, Brazil, British Empire [United Kingdom and Australia], Chile, China, Denmark, France, Greece, Japan, Monaco, Netherlands, Norway, Peru, Portugal, Siam, Spain, and Sweden) approved the statutes and directives that established the International Hydrographic Bureau (IHB). As provided in its original statutes, the IHB had as its objective the establishment of a close and permanent association among hydrographic services of the associated states. Their goals were to coordinate their efforts with a view to rendering navigation easier and safer in all the seas of the world, persuade the national hydrographic offices to adopt the resolutions taken by the various international conferences, try to obtain uniformity as far as possible in hydrographic documents, and advance the theory and practice of the science of hydrography.

In formulating the original statutes of the IHB, the International Hydrographic Conference Committee debated colocating the IHB with a major national hydrographic office. Opting to remove the possible perception that the IHB's policies would be influenced by such a colocation, the Principality of Monaco was selected due to its central and coastal location, its neutrality, its moderate climate, and the gracious invitation of Prince Albert I, a noted oceanographer and navigator (IHB 1926, 8–9). Prince Albert had been a central figure in the formation of the General Bathymetric Chart of the Oceans (GEBCO) project, when, in 1903, he offered to organize and finance this new series of charts under the guidance of his scientific cabinet. In 1929, the responsibility for GEBCO was transferred to the IHB after a brief period under the auspices of the Musée océanographique de Monaco, another farsighted creation of Prince Albert. In 1973, GEBCO was reorganized as a joint project under the management of the IHO and the Intergovernmental

Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO) (Scott 2003).

During the formation of the IHB, discussions with the secretariat of the League of Nations led, on 12 October 1921, to a resolution of the Council of the League of Nations that the IHB become a part of the League. This relationship provided additional international stature to the IHB but was largely limited to the League providing assistance in the yearly audit of IHB finances (Parry 1923, 14). The relationship ended with the dissolution of the League in 1946. Unlike other international organizations associated with the League of Nations, such as the International Labor Organization and the (World) Health Organization, that became specialized agencies of the United Nations (UN) upon its formation in 1945, the IHB remained an independent intergovernmental organization (IHB 1947, 183–84, 228–29).

A Directing Committee of three elected officials with a small support staff administers the IHB. The committee is elected from candidates nominated by the member states and are expected to have significant seagoing and hydrographic experience. The staff consists of professional assistants competent in the various aspects of hydrography and nautical cartography, translators, and administrative staff. At its inception, the support staff of the IHB numbered five but soon grew to thirteen personnel; by the early 2010s, it had a staff of sixteen people.

The principal decision-making mechanism of the IHB is the IHC, which is convened every five years and attended by the heads of the national hydrographic offices of member states. Historically, in most nations hydrography and nautical cartography were the purview of the navy, and naval officers headed all but two of the nineteen delegations to the initial Convention. Although the majority of the delegations continue to be affiliated with their nation's navy, of the seventy-six member states on record in 2006, thirty-five were represented by civilian agencies from the transport, communications, or similar ministries of their government (IHO 2006).

For decisions in the interim periods between IHCs, the Directing Committee polls member states through circular letters, or an Extraordinary IHC could be convened with member states' approval. During the IHCs, various committees are constituted and deliberate over resolutions that include the standardization of content, appearance, and distribution of nautical charts and navigational information and of the methods, accuracy, and units of measurements of the data used to compile these navigational products.

In 1956, the Directing Committee and member states began the groundwork that would more formally constitute the organization as an intergovernmental organization with a juridical personality and entitled to the benefits and immunities normally accorded an international organization. This process spanned several years with three failed attempts to develop and adopt a new Convention. Eventually, at the ninth IHC in 1967, conference delegates approved a new Convention for the IHO that entered into force on 22 September 1970, after ratification by two-thirds of the member states. The new Convention changed the name to the International Hydrographic Organization (IHO) while retaining the name International Hydrographic Bureau (IHB) to denote the secretariat of the organization located in Monaco (Bermejo 2005, 32–35). As required by article 102 of the Charter of the United Nations, the 1967 Convention of the IHO was registered with the United Nations secretariat. The IHO was granted observer status to the UN General Assembly on 12 December 2001 (UN 2003, 1374–75). A UN General Assembly Resolution recognizes 21 June as World Hydrography Day (UN 2008, 1441).

At the sixteenth IHC in 2002, member states agreed to commence a holistic review of the 1967 Convention to ensure the organization's relevance and responsiveness in the new millennium. Proposed amendments that made significant changes in the structure and decision making mechanisms of the organization were approved by member states' delegates in 2005 and sent to member states' governments for ratification. The objectives of the IHO, as stated in the amended Convention, are:

> (a) To promote the use of hydrography for the safety of navigation and all other marine purposes and to raise global awareness of the importance of hydrography;
> (b) To improve global coverage, availability and quality of hydrographic data, information, products and services and to facilitate access to such data, information, products and services . . . ;
> (c) To improve global hydrographic capability, capacity, training, science and techniques;
> (d) To establish and enhance the development of international standards for hydrographic data, information, products, services and techniques and to achieve the greatest possible uniformity in the use of these standards;
> (e) To give authoritative and timely guidance on all hydrographic matters to States and international organizations;
> (f) To facilitate coordination of hydrographic activities among the Member States; and
> (g) To enhance cooperation on hydrographic activities among States on a regional basis. (IHO 2005, 213)

The objectives reflect the original intent to enhance safety of navigation through cooperation, coordination, and uniformity but also acknowledge the importance of hydrography for applications other than safety of navigation and the imperative to foster a worldwide capacity for the collection, production, and dissemination of hydrographic information. These objectives also note the importance of a regional approach to cooperation and capacity building. This regional perspective is acquired through fifteen regional hydrographic commissions, some dating back to 1928, which meet routinely to discuss cooperation, coordination, and capacity building.

Among the important and enduring works initiated upon the formation of the IHB was the publishing of the *International Hydrographic Review* (*IHR*) (titled *Hydrographic Review* until 1947). The early volumes of the *IHR* compiled the information collected by the IHB on the activities of national hydrographic offices; vessels, equipment, and techniques employed in hydrography; and hydrographic training. The *IHR* has evolved into a highly respected publication discussing all aspects of hydrography and related disciplines with most technical articles being peer reviewed. The *IHR* was published semiannually by the IHB from 1923 until 2000 when GITC bv of the Netherlands became the publisher under the sponsorship of the IHO (Kerr 2000). The continual collection of noteworthy events and information included in the early editions of the *IHR* has migrated to the IHO's *International Hydrographic Bulletin = Bulletin Hydrographique Internationale*, its *Yearbook*, and its *Annual Report of the International Hydrographic Organization*. The IHO also produces numerous technical publications relating to bathymetry, hydrography, and cartography—many of them available online at the IHO website. Of particular note in the context of the history of cartography are the *Resolutions of the International Hydrographic Organization* (M-3), which records the resolutions approved by the member states of the IHO. These resolutions include the numerous initiatives that standardized the content, appearance, and format of nautical charts and publications. In particularly complex issues these resolutions have migrated to or been the genesis for publications such as: *Standards for Hydrographic Surveys* (S-44) and *Manual on Hydrography* (C-13), which provide techniques and standards for conducting hydrographic surveys to ensure surveys meet minimum specified accuracies and resolutions; *Status of Hydrographic Surveys and Nautical Cartography, Worldwide* (C-55), which provides a compilation of the adequacy and coverage of surveys and charting to support advocacy for improved hydrographic resources; and *Chart Specifications of the IHO and Regulations for International (INT) Charts* (S-4) and *Catalogue of International Charts* (S-11), which catalog and specify the content, appearance, and organization of an international portfolio of paper charts denoted as INT charts.

Approved by the IHO in 1984, the S-4 represents the fulfillment of Knorr's vision, articulated a century earlier, to increase efficiency and enhance safety of navigation through the sharing of nautical chart information among hydrographic offices. The INT chart regulations authorize a national hydrographic office to undertake the primary production responsibility for charts in a given area. Other hydrographic offices may reproduce these charts, thereby providing their mariners with complete portfolios covering their intended voyages. The IHO INT chart specifications ensure that the mariner will have charts sufficient for his international voyage of uniform content and appearance. Furthermore, hydrographic offices are encouraged to and must comply with the IHO chart specifications in the production of their complete portfolio of national charts. S-11 provides a worldwide scheme for small-, medium-, and large-scale INT charts and the latest production and reproduction information regarding this worldwide portfolio.

Standards of Competence for Hydrographic Surveyors (S-5), *Standards of Competence for Nautical Cartographers* (S-8), *Reference Texts for Training in Hydrography* (C-6), and *Training Courses in Hydrography and Nautical Cartography* (C-47) provide information on training and education in the fields of hydrography and nautical cartography. The compilation of these publications and the certification of curriculum are done in concert with the International Cartographic Association (ICA) and the International Federation of Surveyors (FIG). S-5 and S-8 provide a guide by which curricula can be modeled to receive formal certification as meeting the minimum standards set forth by the IHO, FIG, and ICA. A list of courses that have received this certification as well as other training and education opportunities is in C-47.

IHO Transfer Standard for Digital Hydrographic Data (S-57) and *Specifications for Chart Content and Display Aspects of ECDIS* (S-52) detail, respectively, the data model, data format, and the data schema that describe real world entities for the digital exchange of electronic navigational chart (ENC) data and the content and appearance of an ENC when displayed on an Electronic Chart Display and Information System (ECDIS). These documents, initiated in the 1980s and adopted in the 1990s, represent the official standards for the encoding of navigation features and the subsequent rendering of these features on an electronic display in a manner approved for international navigation. Finally, the *Universal Hydrographic Data Model* (S-100) is a contemporary data model aligned to international standards facilitating integration of hydrographic data into a wide array of geospatial applications.

The IHO maintains close relations with numerous international organizations. In particular, its cooperation with the International Maritime Organization (IMO), a specialized agency of the UN, has strengthened the role of the IHO in establishing standards for the content, format, and appearance of nautical information and advocating for adequately resourced government involvement in hydrography and nautical cartography. The International Convention on Safety of Life at Sea (SOLAS) within a regulatory framework defines a nautical chart as a "special-purpose map or book, or a specially compiled database from which such a map or book is derived, that is issued officially by or on the authority of a Government, authorized Hydrographic Office or other relevant government institution and is designed to meet the requirements of marine navigation" (IMO 2004, 356). SOLAS obligates its signatory governments to "undertake to arrange for the collection and compilation of hydrographic data and the publication, dissemination and keeping up to date of all nautical information necessary for safe navigation" and "to take into account, whenever possible, relevant international resolutions and recommendations" such as those adopted by the IHO to achieve the greatest degree of uniformity and standardization in collection techniques, data management, and product display (IMO 2004, 360–61).

The SOLAS Convention also establishes a requirement for ships to carry a minimum portfolio of nautical charts necessary for safe navigation. An ECDIS may meet that requirement. The characteristics of an ECDIS are addressed in the IMO ECDIS performance standards that stipulate that the database to be accessed is an ENC, which is defined as "the database, standardised as to content, structure and format, issued for use with ECDIS on the authority of government authorised Hydrographic Offices. The ENC contains all the chart information necessary for safe navigation and may contain supplementary information in addition to that contained in the paper chart (e.g. sailing directions) which may be considered necessary for safe navigation" (Hecht et al. 2002, 20). The use of ECDIS, which explicitly implies the use of ENC as the source of the navigation data, can greatly enhance safety of navigation and improve the efficiency of maritime operations.

The IHO has succeeded in addressing its original objectives by fostering communications among the world's hydrographic offices and establishing well-recognized standards for the content, appearance, and format of nautical charts and publications. As the IHO entered the twenty-first century, it faced the challenges of expanding the capacity of coastal states to improve global coverage, availability and quality of hydrographic data, information, products and services and to facilitate access to these products and services by the mariner and other users of geospatial information.

KEN BARBOR

SEE ALSO: General Bathymetric Chart of the Oceans (GEBCO); Geographic Names: (1) Applied Toponymy, (2) Gazetteer; Hydrographic Techniques; Marine Chart; Marine Charting: Overview of Marine Charting; Standards for Cartographic Information

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International Institute for Geo-Information Science and Earth Observation (ITC; Netherlands).

By the time Willem Schermerhorn was appointed professor in surveying and geodesy at the Technische Hogeschool Delft (now the Technische Universiteit) in the Netherlands in 1926 at age thirty-one, he had already led his own geodetic consulting company for five years and had become a pioneer in aerial surveying. In 1928 he started to produce high-precision river maps on the basis of aerial photographs. In 1931 he merged his company with the surveying department of the directorate of water management of the Ministry of Public Works and produced aerial-photograph-based precision maps at the scale 1:1,000 for national road surveys and land reallotment. In 1936 he organized the aerial survey of Dutch New Guinea on behalf of oil exploration for BPM, a Royal Dutch Shell subsidiary, and this survey may be considered pioneer work in geological photo interpretation.

Schermerhorn served as president of the International Society for Photogrammetry (ISP) from 1938 to 1948, and was the first prime minister of the Netherlands after World War II, from 1945 to 1946. It is not strange, therefore, that as a member of a commission of experts he was asked in March 1949 to come to Lake Success, New York (then the headquarters of the United Nations [UN]), to advise on the issue of how cartography, in the broadest sense of the word, could serve UN objectives and how to organize its ensuing activities. The UN Economic Development and Stability Division asked him whether he saw a possibility of starting a training center for aerial survey in the Netherlands. He also visited Jakarta in 1949, where the Dutch staff of the Geografische Instituut van de Topografische Dienst prepared a blueprint for him of a study center for the interpretation of aerial photographs useful in geology, geomorphology, forestry, and soil science. Back home he checked the possibilities for financing such a center as the Dutch contribution of technical support to underdeveloped countries. At the meeting of the UN technical assistance board in June 1950, the Netherlands delegation informed the board of its plans to establish such a center with Dutch financing. The act founding the International Training Centre for Aerial Survey (ITC) was passed on 11 July 1950, and Schermerhorn was nominated dean of the new institute. Scientific staff was hired in 1951, and the first course in photogrammetry was offered. The first student to pass the exam after a one-year course was Frederick J. Doyle from the United States, who came in 1951 to study photogrammetry on a Fulbright fellowship. This started a stream of students from developing countries who were offered fellowships to study at ITC by the Dutch Ministry for Development Aid.

The courses were given in buildings made available by Technische Hogeschool Delft until November 1956, when a customized high-rise building was completed that housed both teaching facilities, staff offices, and student accommodation. The program and policy of the courses gradually changed. The center initially was established for the transfer of technical expertise, but this was extended to full-fledged academic courses, and by 1960 academic degrees were offered in photogrammetry, aerial photography, aerial geology, soil science, and forestry. The number of students slowly increased: courses in 1951 accommodated 6 students, in 1961 there were 138, and in 1971 160, with a very favorable student-to-staff ratio of 1 to 1! By 2001 ITC boasted 15,000 alumni from 163 countries. In 1990 the first ITC PhD (in conjunction with Dutch universities) was awarded, and by 2000, seventy-five ITC students had successfully defended their PhD theses. From the start ITC had state-of-the-art photogrammetric equipment, frequently donated by or leased from the manufacturers, who were keen to have their equipment used by the students.

ITC soon recognized the importance of research, and the first step was the creation of the Organisation européenne d'études photogrammétriques experimentales (OEEPE), an intergovernmental research organization started in 1953 by Belgium, Austria, the Netherlands, West Germany, and Italy. ITC led the Dutch input into OEEPE. It aimed at joint experimental and developmental research in all phases of the mapping process. In 2003 the name was changed to European Spatial Data Research (EuroSDR) and was transferred to the Dublin Institute of Technology. Another important condition for keeping the teaching program abreast of new developments and aware of needs was the consulting program. A formal consulting program was started in 1960. In 1981 this evolved into the Special Projects Bureau.

From the start ITC had very strong links with international organizations in the mapping sciences, and many officers of the ISP and later the International Cartographic Association (ICA) were employed at ITC. ITC started the *International Bibliography of Photogrammetry*, for which correspondents from all over the world made abstracts of publications that were translated, classified, and printed at ITC. This bibliography was accepted in 1960 as an official ISP publication. The institute also started a publication series, the flagship *ITC Journal* (1973–98), and a textbook series.

In 1963 Anton van der Weele was appointed professor of photogrammetry, and in 1965 he took over the position of rector from Schermerhorn. ITC changed in the following years from a training institute into a specialized institute of higher learning. A name change reflected this transformation: it was renamed the International Institute for Aerial Survey and Earth Sciences in 1966. Simultaneously the Institute became more firmly anchored in Dutch academia. The reorganization led to three departments: the Department of Photogrammetry and Aerial Photography (responsible for photogrammetry, aerial photography, survey navigation, mathematics, and physics), the Department of Natural Resources Surveys (geology, geography, geomorphology, soil science, forestry, and cartography), and the Department of Social Sciences (sociology, economics, and urban area studies).

In 1971 ITC moved its premises from Delft to Enschede, with a separate building for student accommodation (Schermerhorn Hall, the present ITC International

Hotel IIH) and a newly equipped state-of-the-art cartography section, led by the then ICA Secretary-General Ferdinand J. Ormeling, who had been appointed at ITC in 1970. Before Ormeling, cartography lectures had been given by Major M. M. H. B. Volkert (1952–55), C. Koeman (1956–64), and A. van der Waag (1964–77). After rector Van der Weele retired in 1979 another reorganization led to the formation of six departments, one of which was cartography, which has been headed initially by Ormeling until 1982 and then successively by Gerald R. McGrath, J. C. Muller, and M. J. Kraak. In 1984 ITC's name changed again, this time to the International Institute for Aerospace Survey and Earth Sciences, to reflect the new developments in scanning and remote sensing and the interpretation of the resulting imagery. Since 1996 ITC has been housed in a new customized building in Enschede. In 2001, the name was changed to the International Institute for Geo-Information Science and Earth Observation; the acronym ITC has always been maintained.

In the mid-1960s a new development aid policy was adopted in the Netherlands, consisting of the transfer of technical knowledge, in situ, to developing countries. Consequently, ITC conducted educational projects in these countries and contributed to the establishment of training centers that have remained linked to ITC as sister-institutes. These include the Indian Photo-Interpretation Institute (IPI), in Dehra Dun, started in 1965 and renamed the Indian Institute of Remote Sensing (IIRS) in 1976, and the Centro Interamericano de Fotointerpretación (CIAF) in Bogotá, founded by the Colombian government in 1967. From the start, ITC was responsible for organizing the building and equipment and for staff training. In 1987 CIAF was incorporated into the national mapping agency, the Instituto Geográfico Agustín Codazzi (IGAC). The Regional Centre for Training in Aerial Surveys (RECTAS) in Ile-Ife, Nigeria, was started by the UN Economic Commission for Africa in 1972 as a regional educational establishment, and ITC organized the teaching programs and provided teaching material. The School for Photogrammetric and Cartographic Operators (PPFK; Pusat Pendidikan Fotogrametri dan Kartografi), in Bandung, Indonesia, began as a bilateral technical cooperation project in 1975 in order to assist and modernize the national Indonesian mapping organizations. This training facility was incorporated into the Institut Teknologi Bandung. The Educational Centre for Urban/Rural Surveying, Planning and Management (ECURSPAM) was established by ITC in 1986 in cooperation with Wuhan cehui keji daxue (Wuhan Technical University of Surveying and Mapping; WTUSM), at its campus in Wuhan. Over the years ITC created a strong global educational network of fifteen institutions that made joint educational programs available.

From 1972 to 1990 cartography was taught at ITC at four levels: technician diploma course, technologist diploma course, postgraduate diploma course, and advanced postgraduate/MSc degree course. It did not cater to courses for cartographic draftsmen, for whom a complete training package (including all equipment) for local use was available. Cartographic education at ITC focused on specialized skills to assist national cartographic agencies in the production of topographic and thematic map products that could be used for economic development. It was aimed at the practice of the profession and set up in such a way that students could immediately and independently apply their knowledge after returning to their home country. Therefore there was a heavy emphasis on practical exercises; students participated in all phases from the design of maps to their color proofing and printing. For technologists and academic cartographers there was also heavy emphasis on management aspects such as flow diagrams and cost estimations. Gradually, the emphasis on map reproduction subsided and that on databases increased, with complete awareness that maps were just one possible form of output from these databases. Part of the practical experience consisted of fieldwork (fig. 409) and visits to mapping establishments all over Europe.

The rapid rise in the 1980s of GIS led to the start of additional applied cartography courses with cadastral, urban, and rural applications. In 1990 a postgraduate diploma course in integrated map and geoinformation production was introduced, and also in the 1990s the technician and technologist courses in cartography were phased out as part of the drive to concentrate on the postgraduate diploma course and the MSc and PhD programs. In 1997 the former four-level cartography

FIG. 409. ITC STUDENTS DOING FIELDWORK IN THE 1970s.
Image courtesy of Faculty ITC @ University Twente.

program was changed to a five-level education program in geoinformatics: a PhD program (in cooperation with universities in the Netherlands), an MSc program, a professional master's degree program, a diploma in geoinformatics, and short courses in various aspects of geoinformatics. Within geoinformatics emphasis shifted between data collection, data analysis, and production- and visualization-oriented specializations.

Courses at ITC were very condensed compared with other universities. As the students were mostly midcareer people already engaged in cartographic or geoinformation professions, they could not be away from home too long, as this would hamper their careers. The lecture, practical exercise, and self-study activities at ITC were supposed to exceed the nine-to-five working day and might also necessitate work in the evenings and weekends. The high staff-to-student ratio meant that there were many possibilities for individual consultation.

FERJAN ORMELING

SEE ALSO: Decolonization and Independence; Education and Cartography: Educating Mapmakers

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International Journal of Geographical Information Systems/Science. The *International Journal of Geographical Information Systems* (*IJGIS*) began publication in 1987, when geographical information systems (GIS) were gaining recognition as an emergent interdisciplinary subject drawing on a range of academic disciplines that included computer science, geography, surveying, soil science, and geology. Because the groundbreaking journal *GeoProcessing* (published by Elsevier and edited by Thomas K. Poiker) had published only four issues over the seven years since its inception in 1978, the subject lacked a recognized journal distinct from less specialized cartographic journals like *Cartographica*. (Before P. A. Burrough published his landmark textbook *Principles of Geographical Information Systems for Land Resources Assessment* in 1986, GIS lacked a general textbook as well.)

IJGIS always tried to publish articles that documented advances in spatial information theory, the human relations involved in using geospatial data and software, and novel uses to which data and software might be put. Peter F. Fisher, who served as editor from 1994 to 2007, identified the representation of spatial information (including spatial information theory, uncertainty, temporal issues, ontology, and geometry) as the foremost set of issues addressed by the journal, followed by modeling (both analytical and process modeling), visualization, cognitive issues and usability, and data policy.

One of hundreds of journals owned by Taylor & Francis, an international scientific publisher headquartered in Britain, *IJGIS* began as a quarterly periodical. Frequency jumped to six issues per year in 1992 and increased to eight issues in 1996, ten issues in 2005, and twelve issues in 2008. In 1997 the journal changed its name to the *International Journal of Geographical Information Science*, to reflect a stronger focus on theoretical issues that underpin the implementation of systems. In the fourteen years between 1994 and 2007 the journal published sixteen special issues, with papers solicited and vetted by guest editors. During this period *IJGIS* filled more than 11,000 journal pages with over 600 papers by authors from around the world, but predominantly from Europe, the Unites States, and Australasia. As with other journals in the cartographic realm, the early twenty-first century witnessed an increase in the number of papers by authors from East Asia in general, and from the People's Republic of China in particular.

The inaugural editors were J. T. Coppock (University of Edinburgh) and K. E. Anderson (U.S. Geological Survey); Stephen C. Guptill (U.S. Geological Survey) took Anderson's place in 1990. Fisher (University of Leicester) became editor in 1994, and Brian Lees (University of New South Wales) in 2008. Fisher collected a number of landmark *IJGIS* articles in an anthology published in 2006. In addition to reprinting articles that helped mold the discipline, the volume contained reflective essays in which the authors commented on why the research was conducted and how it affected subsequent developments, as indicated by later research published on the same topic.

As a peer-reviewed journal, *IJGIS* relied on systematic prepublication scrutiny by scholars and practitioners. Each paper was sent to at least three reviewers, and the acceptance rate was approximately 30 percent. Since the early 1990s citation tabulations by the Institute for Scientific Information (ISI), based on its online bibliographic database ISI Web of Knowledge, yielded an exceptionally high "impact factor" in four subject areas (geography, physical geography, information science, and computer science), which made *IJGIS* the premier journal for the field (Fisher 2007, 1165).

PETER F. FISHER

SEE ALSO: Journals, Cartographic

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International Map of the World. The years prior to World War I were characterized by unprecedented increases in global trade, fueled by developments in communications and long-distance transport. However, this globalization of trade was not matched by any parallel development of standardized topographic maps of the world. Indeed, published maps of different parts of the world were so inconsistent in style that they had become an obstacle to economic development and scientific analysis. In response, a proposal to construct a standard international map was presented at the Fifth International Geographical Congress (IGC) in Bern, Switzerland, in 1891. Albrecht Penck argued that a new 1:1,000,000 map series should be devised through international agreement among the leading national cartographic agencies. The series would create segments of a globe one million times smaller than the earth itself and would allow scientists and students alike to establish meaningful worldwide comparisons for the first time (Penck 1892). (Much of the discussion here is condensed from an earlier article, Pearson et al. 2006.)

Penck's proposal was warmly received, and a special IGC committee was duly established to lay down some provisional guidelines. This committee consisted of twenty members from ten countries, including, in addition to Penck himself, such luminaries as Eduard Brückner, John Scott Keltie, and John Wesley Powell.

Although everyone agreed on the need for a standard specification based on a common projection, there was no consensus as to how this might be achieved. As time passed, the areas of contention and disagreement seemed to increase rather than diminish. Traditional rivalries were never far from the surface. Britain argued for imperial rather than metric units of measurement while France insisted that Paris, rather than Greenwich, should be used as the prime meridian.

Gradually, conventions and guidelines were discussed and agreed upon at the IGC meetings. These were then ratified by the national mapping agencies of the major powers at a full-scale international conference held in London in November 1909. The London conference stipulated that the International Map of the World (IMW) would use a simple polyconic projection at a scale of 1:1,000,000. Greenwich would be the prime meridian, but the meter would be used as the basic unit of measurement. Each sheet would cover six degrees of longitude and four degrees of latitude.

The first sheets made their appearance two years later. These were then reviewed and additional resolutions discussed and agreed on at the Rome IGC in the summer of 1913. A second international conference in Paris was held in December 1913 to confirm final IMW specifications. One of the agreements was a commitment to establish a Central Bureau at the British Ordnance Survey's Southampton headquarters to facilitate the exchange of information between the different national cartographic agencies involved.

It became clear that strict adherence to the specifications would be impossible to enforce as long as national agencies retained control over the production of individual sheets. Indeed, the IMW committee encouraged different mapping agencies to adapt the IGC conventions to suit their individual circumstances in order to maintain the involvement of as many countries as possible.

The difficulty of ensuring consistency and uniformity was not simply the product of a politically weak IMW committee. The huge topographical variation of the world rendered rigid conventions practically unworkable. The depiction of relief illustrates this problem. The logical ideal for the IMW would have been a standard system of contour intervals. However, if this standard was determined by the need to communicate meaningful relief variations in mountainous regions, the equivalent variations in lowland regions would disappear. Conversely, if the standard was determined by the need to show meaningful variations in relief in lowland areas, the sheets depicting mountainous areas would become indecipherably complex. Compromises were inevitable and different national agencies were allowed to use varying contour sequences on IMW sheets depending on the kind of terrain being depicted.

The outbreak of World War I shattered these carefully constructed compromises. However, the IMW did survive in various guises. For example, in Britain around one hundred 1:1,000,000 sheets were prepared at the Royal Geographical Society during the war (Heffernan 1996). This simplified version of the IMW was selected as an

FIG. 410. DETAIL FROM INTERNATIONAL MAP OF THE WORLD 1:1,000,000 *ABERDEEN*, 1924. Compiled from OS 1:253,440 series and British Admiralty Charts in 1922 and published in 1924 (sheet N. O-30).

Size of the entire original: 59 × 41.5 cm; size of detail: 14 × 29 cm. Image courtesy of the National Library of Scotland, Edinburgh.

approved map series for the postwar peace conference, and its usefulness strengthened the case for continuing the IMW after 1918. Several of the newly created countries established at the Paris Peace Conferences signed on to the IMW. Forty-four nations had committed themselves to the conventions, and by 1926 over two hundred sheets had been published (for example, fig. 410; and see also fig. 467), though only half of these sheets were consistent with the 1913 resolutions and only twenty-one conformed exactly (MacLeod 1926).

Between the wars, progress of the IMW was largely dictated by the economic and political interests of the participating nation-states. The mapping of Africa had largely been divided up among the European colonial powers. There were, however, significant gaps. The fact that only four North American sheets had been published by the mid-1920s was a consequence of the virtual withdrawal of the United States from the IMW in 1913. The U.S. Geological Survey concentrated its energies on mapping at scales larger than 1:1,000,000 as more than five-eighths of the country had no topographic mapping (Joerg 1912). Russia was reluctant to contribute to the IMW. Although the first sample sheets were published as early as 1926 and a further eighty completed by 1939, these maps were not made publicly available by the Bolshevik authorities. An absence of accurate compilation material, a lack of technical resources, and (in some cases) political uncertainty meant that no significant progress had yet been made on sheets for northeast Asia, China, Australia, Canada, and Polynesia.

Sheets conforming closely to the Paris conventions were published outside the auspices of the IMW. The Brazilian Clube de Engenharia published a fifty-sheet series titled *Carta do Brasil* based on the 1909 conventions. Perhaps the finest example of non-IMW mapping was the American Geographical Society's (AGS) *Map of Hispanic America*, *Scale 1:1,000,000* initiated by the influential American geographer Isaiah Bowman (Platt 1927; Wright 1952, 300–319). The first sheet was published in 1922 (fig. 411), and all 107 sheets were complete by the end of 1945, under the direction of Raye R. Platt. The series included important innovations, most notably the inclusion of a reliability diagram and the use of pecked line symbols to denote unsurveyed rivers and contours.

Progress of the IMW was once again interrupted by war, this time the outbreak of World War II. However, the military value of the existing sheets was now widely acknowledged, and new military map sheets of many countries at the scale of 1:1,000,000 appeared during the war, substantially expanding global coverage. Between 1941 and 1944 German military cartographers produced a *Sonderausgabe*, later titled *Deutsche Heereskarte 1:1,000,000*, covering Europe, western Asia, and North Africa. Similar series were produced by the other Axis powers and by the Allies.

In 1941 Soviet cartographers began work on a new edition of the 1:1,000,000 Russian state map. By the mid-1950s over 230 sheets had been completed for Europe and large parts of Southeast Asia, though, like its predecessor, this new map was not available for public use. The most extensive new 1:1,000,000 series, however, was produced by the U.S. Army Map Service (AMS) in cooperation with the Geographical Section, General Staff (GSGS) in London. After 1945 the series continued as AMS 1301/GSGS 4646 and finally as a solo American enterprise as AMS 1301. Chinese involvement in the IMW began at the end of the war, culminating with an eighty-three-sheet series of provisional 1:1,000,000 maps of China completed by 1948.

Despite these developments, the future of the IMW remained in serious doubt. The role of the Central Bureau had long been a concern, and a new Commission on the International Map of the World recommended that the bureau should operate from the new United Nations cartographic unit in New York rather than the Ordnance Survey. However, this did little to address the IMW's more fundamental problems. By the early 1950s,

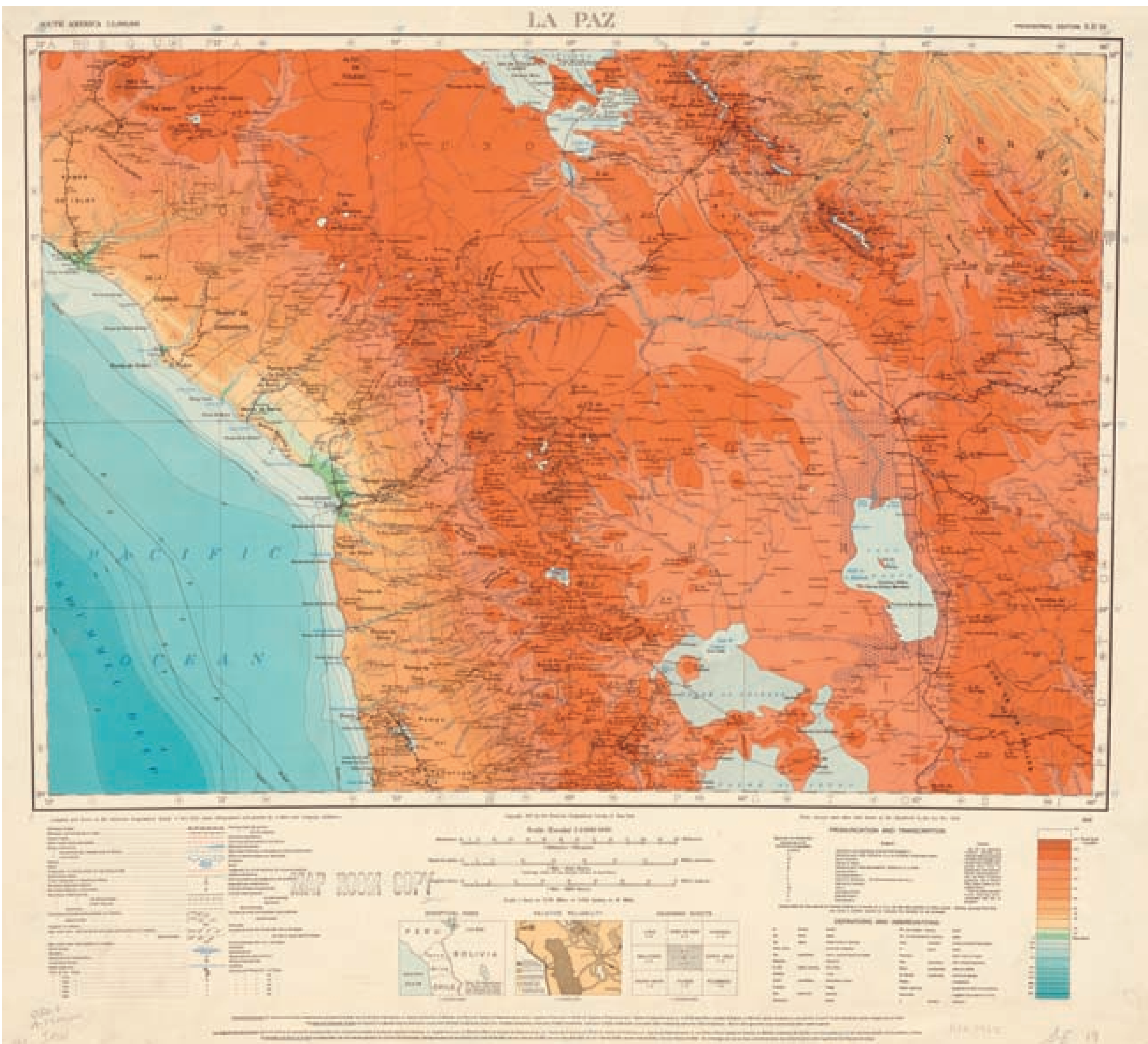

FIG. 411. *LA PAZ*, 1:1,000,000, 1922. This was the first sheet to be published by the American Geographical Society as part of the map of Hispanic America on the millionth scale (Provisional edition, S. E-19). Size of the original: 61.5 × 66.2 cm. Image courtesy of the American Geographical Society Library, University of Wisconsin–Milwaukee Libraries.

less than half of the approximately 1,000 sheets that would have been necessary to cover the entire terrestrial globe had been published, and many required revision. A number of commentators doubted whether a single global map made any sense in a brutally divided world. The quality and quantity of topographical data had improved markedly through the postwar development of photogrammetry so that large areas of the earth's surface were already mapped at much larger scales than 1:1,000,000. The demand for aeronautical charts for military and commercial purposes also posed a direct threat to the IMW. During World War II, the Aeronautical Chart Service of the U.S. Air Force had published a 1:1,000,000 World Aeronautical Chart (WAC) to support long-distance aviation. These sheets were later transferred to the new International Civil Aviation Organization (ICAO). Understandably, most nation-states gave priority to the production and maintenance of the comprehensive ICAO air charts.

Attempts were made to establish a new role for the IMW at a United Nations Technical Conference held in Bonn in 1962 (Meynen 1962). Agreed changes to the specifications recognized recent developments in cartographic design (fig. 412), and greater conformity to the WAC program was achieved through the adoption of the Lambert conformal conic projection. Despite these determined efforts, the IMW's critics were not impressed. The influential American academic cartographer Ar-

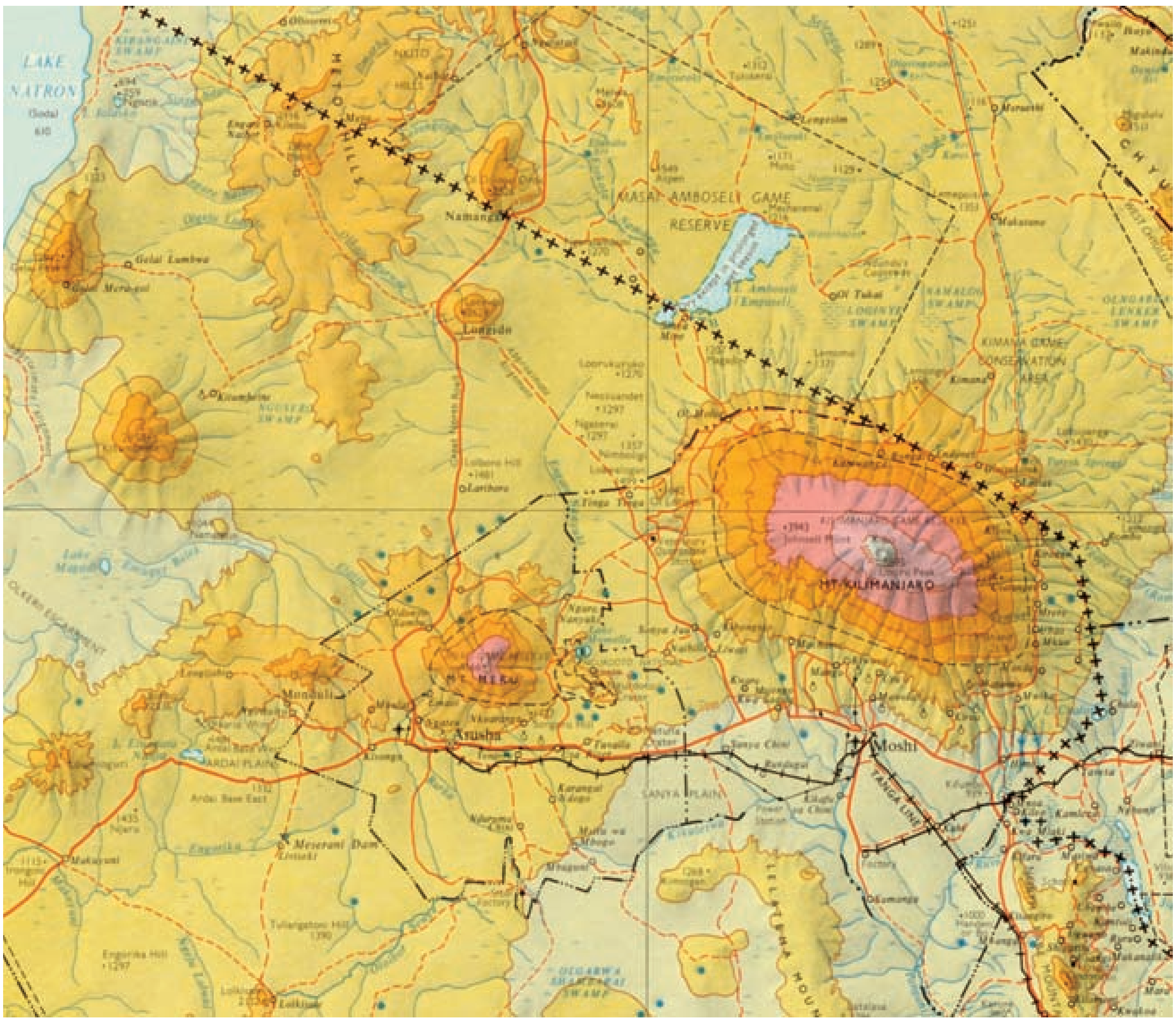

FIG. 412. DETAIL FROM *NAIROBI*, 1:1,000,000, 3d ED., 1969, SHOWING KILIMANJARO. Map prepared using 1962 revised relief depiction (sheet SA-37).

Size of the entire original: 67.1 × 79.7 cm; size of detail: 17.5 × 20.2 cm. Image courtesy of the American Geographical Society Library, University of Wisconsin–Milwaukee Libraries.

thur H. Robinson described the IMW as no more than "cartographic wallpaper" (Robinson 1965, 24).

Only a handful of new editions were released during the 1970s as the series was superseded by the larger-scale digital mapping programs and the many publicly available military products. In 1989 the United Nations ceased monitoring the IMW realizing that the project had simply fizzled out.

The IMW was a valiant attempt to map the world in a standardized and systematic way. However, the project struggled to keep pace with changing technologies and user needs. Clearly ahead of its time at the start, the project was limited by a dearth of adequate data and ended as an outdated product serving little purpose and failing to reflect the technological advances of the latter half of the twentieth century. Despite being compiled from existing maps, the project was also extremely expensive and time-consuming and depended on the goodwill of participating agencies and their respective governments. The Central Bureau, weak and ineffectual, had virtually no authority and served simply to inform participants of progress. The financial resources of the project were negligible. Without adequate resources and clear aims and objectives, the project was doomed to failure.

Despite its many failings, the IMW survived as a serious international scientific project for three quarters of the twentieth century. Perhaps the real impact of the IMW lies in the wider lesson it teaches us about the potential of international cooperation. Its ultimate failure reflected the fragility of international relations during a tumultuous century in which the realities of national self-interest rather than science dominated.

ALASTAIR W. PEARSON

SEE ALSO: American Geographical Society; Digital Worldwide Mapping Projects; International Civil Aviation Organization; League of Nations; Penck, Albrecht; Royal Geographical Society (U.K.); Scale; United Nations; World Aeronautical Chart

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Interpolation. The desire of knowing an unobserved quantity, value, or characteristic of a spatial phenomenon has driven researchers to develop analytical techniques that are broadly referred to as interpolation. Given knowledge of attribute values observed at a limited number of locations (points or areal units), interpolation is a process of estimating attribute values in areas where information could not be directly acquired. Interpolation is an important process when working with spatial information because it can be difficult, impossible, or too costly to obtain attribute values across the entire earth, or even across a town, city, state, or country. The word *interpolate* can be further understood in this context through its Greek origins: *inter* meaning "up, between" and *polare*, the past participle of *polire*, meaning "to smooth, polish."

Interpolation techniques can be classified in a number of ways (Crain and Bhattacharyya 1967; Lam 1983). One classification defines techniques as useful for either point or areal interpolation. Point interpolation methods estimate the attribute value at specific locations (or points) using observed values at other points. Areal interpolation methods are different; they are designed to transform polygon attributes, such as total population, from one set of spatial units (e.g., census tracts) to another (e.g., 30 m raster cells), though the process of smoothing a discrete surface also falls under areal interpolation. A second classification defines the techniques as either an exact or an approximate interpolation method. An exact method always returns observed values at locations where observations are made (for point interpolation) or maintains the total polygon attribute value (for areal interpolation). Approximate interpolation methods, in contrast, may not return or maintain the same observed values. The remainder of this entry discusses the historical evolution of interpolation techniques used in cartography. Details of various types of basic interpolation approaches in this context are also provided.

In cartography, interpolation techniques have been critical for the production of topographic maps. Contour lines have traditionally depicted variation in elevation of the earth's surface; and point interpolation methods have been used since then. Topographic maps generally rely on a set of control points where observed elevation values exist. The elevation values of these control points are consequently used to derive (interpolate) interval elevation values at other points, which are used to draw the contour lines.

It is worth noting that ancient scholars in Greece (e.g., Claudius Ptolemy), China (e.g., Liu Zhuo), and India (e.g., Brahmagupta), as well as more recent Western scientists (notably Isaac Newton and Carl Friedrich Gauss), developed a variety of interpolation methods (Meijering 2002). Though these methods were important in mathematics, physics, and astronomy, their application was limited in cartography, especially in topographic mapping. This is partly because these interpolation approaches generally required intensive computation to fit polynomial functions given observed data. Topographic maps cover large areas represented by very large data sets. Prior to advances in digital computing technology (pre-1950), interpolation in cartography could only be executed manually. The use of computationally intense methods like polynomial function fitting required significant time and effort.

In figure 413, a straightforward manual exact point interpolation method for topographical mapping is used to generate the contour line for the elevation of 20, the points that have an attribute value of 20 are first identified (marked as short, thick bars). The easiest way to make the contour line is to connect the points using straight lines. These straight lines, however, do not realistically represent the earth's surface, and smoothing is needed (as shown by the dashed line). One way of drawing smooth contour lines in the precomputer era was to use splines, locally fit curves manually created using flexible rulers. With the aid of the computational power of computers, the generation of these curves can now be automated using a set of piecewise functions that are continuously differentiable everywhere on the curve.

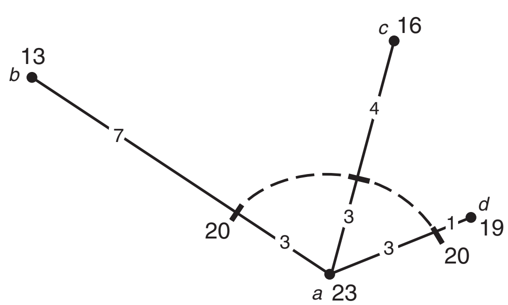

FIG. 413. CONTROL POINTS AND THE INTERPOLATION OF A CONTOUR. Control points *a*, *b*, *c*, and *d* are used to find the contour of value 20.
After Robinson et al. 1995, 511 (fig. 26.26).

Producing topographical maps has historically been a major task in cartography, and enabled by the rapid developments in computing and spatial data acquisition technologies, the second half of the twentieth century saw the introduction of new spatial interpolation methods. In addition to traditional topographic maps, data models such as digital terrain models (DTMs) and digital elevation models (DEMs) became useful and important. Different from making contour lines for topographic maps, creating a DEM requires the derivation of values for a spatial variable at specific locations, normally represented as a regularly spaced grid. Traditional interpolation approaches were insufficient for addressing such a task.

A widely used exact point interpolation approach to generating a DEM, and other similar data models, is inverse distance weighting, which was developed in the 1960s (Crain and Bhattacharyya 1967). This method assumes the attribute value at a point is more related to the observed values of its neighboring points, i.e., the presence of autocorrelation. Formally, the attribute value at an unobserved location can be interpolated as $\sum_{i=1}^{n} z_i d_i^{-p} \Big/ \sum_{i=1}^{n} d_i^{-p}$, where z_i is the value observed at point i in the neighborhood of the current point being interpolated, d_i is the distance between point i and the current point, n is the number of observed points in the neighborhood, and p is an integer constant. Though this method is easy to implement and has been included as a component in a variety of cartographic software packages (e.g., SYMAP, Surfer, and ArcView GIS), selecting different values of p and n will yield different results, making the estimates less reliable.

A more theoretically oriented interpolation approach is called kriging (also an exact point interpolation method), formalized by Georges Matheron (1963) to honor the contribution of D. G. Krige. Originally developed as a method for the mining industry, kriging has been widely used in many fields, including cartography. This method is more theoretically based in the sense that a range of statistical analyses can be conducted to evaluate interpolation results. In kriging, spatial attributes are treated as regionalized variables, which exhibit spatial autocorrelation that can be captured using a statistical model called a semivarigram.

The interpolation approaches discussed so far are point based exact methods. For many applications, exactness may not be required. Instead, trend surfaces may be useful for understanding patterns of spatial variation. A trend surface can be generated using an approximate point interpolation method that searches for a polynomial, determined by the coordinates of observation points: $f(x,y) = \sum_{r+x \le p} (b_{rs} x^r y^s)$, where $f(x,y)$ is the value of the trend surface at a point defined by a pair of coordinates (x,y), b_{rs} is the coefficient, and r, s, and p are integers that determine the order of the trend surface. When $p = 2$, the polynomial has a quadratic form: $f(x, y) = b_0 + b_1x + b_2y + b_3x^2 + b_4xy + b_5y^2$. This type of function can be fitted using multiple regression models. Multiple regression models can also be used to derive the trend surface of spatial variables that are difficult to measure (e.g., zinc concentration), using a set of explanatory variables (e.g., distance to a river and elevation) that are easy to measure or derive for a set of grid cells covering a mapping area (Burrough and McDonnell 1998).

For many social, economic, and ethnic mapping applications, data are often based on population sampling or a regular census and are typically aggregated and released for a set of enumeration units (e.g., census tracts or blocks). A traditional way of displaying such data relies on choropleth maps. However, choropleth maps contain an assumption that is often unrealistic: the attribute exhibits a homogeneous density and is evenly distributed in each enumeration unit. To address this issue, it is necessary to interpolate areal values into different, often smaller, spatial units. Though it is possible to extend point interpolation methods to achieve this goal, they typically do not preserve the data volume for each original unit. In this case, exact areal interpolation methods that preserve volumes can provide more satisfactory results.

John Kirtland Wright (1936) advocated a technique called dasymetric mapping that requires the reallocation of the spatial attribute being mapped within each enumeration unit to smaller spatial units using a set of limiting ancillary variables (see fig. 195). For mapping population density, enumeration units (e.g., townships) can be partitioned into generally inhabited areas and areas totally or largely devoid of inhabitants (e.g., protected wetlands). Let D and D_m be the average population density in a township and the estimated population density in its sparsely populated portion, respectively, and a_m be the fraction of total area in this low-density portion. The population density in the inhabited area can be estimated as $(D - D_m a_m)/(1 - a_m)$. Since the 1990s, due to the development of geographical information systems (GIS), the application of dasymetric mapping has become fairly routine and straightforward.

Waldo R. Tobler (1979) developed the pycnophylactic (or mass-preserving) method that can be used to create a smooth, continuous density surface using aggregated spatial data such as population (fig. 414). A useful way to understand this approach is to imagine the top map in figure 414 as a clay model; the goal is to sculpt the model until it is smooth and the total amount of clay in each enumeration unit remains the same (i.e., clay does not move from one unit to another). To achieve this goal, a set of grid cells is established dividing the entire map; the size of each cell is typically much smaller than the size of original enumeration units. An iterative procedure was devised by Tobler (1979) and later simplified (Lam 1983). This procedure (illustrated in fig. 415) starts by assigning the density value of each original enumeration unit to the value of cells that fall into that unit (fig. 415*a*). The procedure then undergoes two major steps. The first step enforces the smoothness of the surface by assigning each cell the average value of its four neighboring cells (fig. 415*b*). This step, however, may cause the sum of cell values in an enumeration unit to be different from the original unit value. To enforce the pycnophylactic condition, step two is needed to multiply the value of each cell by the ratio between the original value of the enumeration that contains the cell and the sum of the cell values in the unit after the first step (fig. 415*c*). These two steps are repeated until there are no significant changes of cell values between two successive iterations (fig. 415*d*).

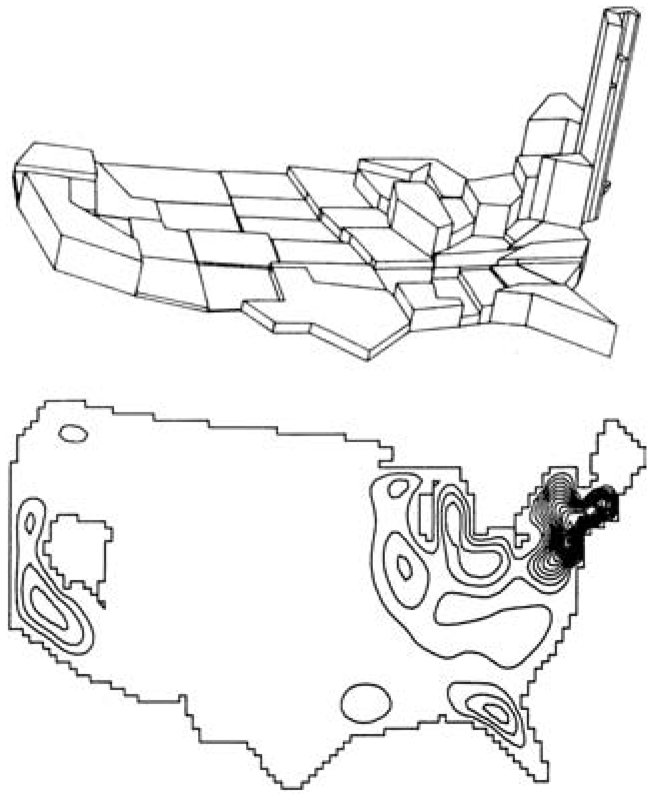

FIG. 414. PYCNOPHYLACTIC INTERPOLATION. Choropleth map of population density of the conterminous United States (top) and the interpolated map showing contours of population density (bottom).
Size of the originals: 6.8 × 9 cm (top); 9.6 × 15.7 cm (bottom). From Tobler 1979, 519 (fig. A) and 527 (fig. H [top]). Reproduced by permission of Taylor & Francis.

1.67	1.67	5.00	5.00
1.67	1.67	5.00	5.00
1.67	1.67	6.67	6.67
6.67	6.67	6.67	6.67

a

1.67	2.78	3.89	5.00
1.67	2.50	4.59	5.56
3.34	4.17	5.00	6.11
4.17	5.00	6.67	6.67

b

1.04	1.72	4.08	5.25
1.04	1.55	4.82	5.84
2.07	2.59	5.95	7.27
4.96	5.95	7.94	7.94

c

1.35	2.19	3.90	4.95
1.51	2.57	4.99	6.04
2.66	3.79	5.84	6.95
3.55	4.88	6.70	7.89

d

FIG. 415. A PYCNOPHYLACTIC INTERPOLATION PROCEDURE. The three original units are delineated using solid lines; original values are interpolated into a grid of 4 × 4 cells.
After Lam 1983, 149 (fig. 6).

The twentieth century witnessed ever-increasing volumes of spatial data. This trend raised some critical questions for cartographers. On the one hand, a great opportunity emerged because scientific research could be conducted at a level that could only be imagined before. On the other hand, the variety of methods developed in the literature made it difficult to select the most appropriate approach to a particular problem. Adding to the complexity of selecting a method were the decisions that had to be made for each method. The inverse distance weighting method, for example, requires the user to specify the order of the model and the neighborhood size. Though the spatial interpolation literature has been cautious about the consequences of using an inappropriate method or a poor set of parameters (see Mulugeta 1996), more rigorous, theoretical examinations are still needed. This is especially critical as the use of automated cartographic systems and GIS has become a mainstream component of spatial analysis. While these systems typically provide a default option, regular users tend to forget about the difference between alternative methods. It is an imperative duty for the research community to provide clear guidance that will help users make these decisions.

NINGCHUAN XIAO AND ALAN MURRAY

SEE ALSO: Analytical Cartography; Kriging; Mathematics and Cartography; SYMAP (software)

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Istituto Geografico De Agostini (Geographical Institute De Agostini; Italy). The Istituto Geografico De Agostini (IGDA) was founded in Rome in 1901 by Giovanni De Agostini, a well-known geographer from a small village in the northwestern Italian province of Novara, with the stated objective of rivaling and surpassing the achievements of French, German, and English commercial cartographic publishers. The IGDA's very first publication was the *Atlante scolastico moderno*, released in 1901. In 1904 De Agostini launched the *Calendario atlante De Agostini*, which by the year 2000 was still published every year. A calendar, atlas, and geographical encyclopedia combined and small in size as well as compact and affordable, the *Calendario atlante* was an original product that proved an instant and long-lasting hit. Other important cartographic works followed. One was the *Atlante geografico metodico*, first published in 1906 and still in production at the beginning of the twenty-first century. In 1906, the firm also initiated work on a new comprehensive cartography of Italy at the scale of 1:250,000 in fifty-eight maps; completed in 1914, this magnificent work almost bankrupted the company.

Deeply in debt to a bank in Novara, where the firm had moved from Rome in 1908, De Agostini was forced in 1914 to relinquish control of the company he had founded only thirteen years earlier. A visionary cartographer prone to taking commercial risks, De Agostini was not a good businessman. Although he stayed on as scientific director for a few years, his role in the IGDA's history was virtually over.

Various changes in management followed, but the company could not recover and was liquidated in 1919. All the existing assets were immediately acquired by Marco Adolfo Boroli—whose descendants still controlled the IGDA at the end of the century—and by Cesare Angelo Rossi. The new owners kept the name, invested heavily in new technologies, and hired a new scientific director, Luigi Visintin, who was to stay in the position for thirty-eight years until his death in 1958. In the 1920s under Visintin's direction, the IGDA published several works, among them the *Grande atlante geografico* in 1922. Reporting on this work, the daily newspaper *Corriere della Sera*, in a rhetorical tone typical of the age, said: "After years of paying homage to the great German, French, and English atlases, we are finally free of this humiliating form of slavery." Two new thematic atlases, *Atlante della produzione e dei commerci* and *Atlante delle colonie italiane*, followed in 1923 and 1928. The company even established its own school, designed to train fourteen- and fifteen-year-old boys (and later also girls) as cartographers in a paid apprenticeship program that lasted three years and led to employment at the firm (fig. 416). The school remained in existence for several decades.

Meanwhile, Benito Mussolini and his Fascist Party had come to power in Italy, seizing control of the government in 1922 and installing a dictatorial regime that lasted until 1943. The 1920s and 1930s saw the IGDA's national and international reputation grow. The company translated and sold several of its publications in foreign markets, took on publishing jobs from foreign clients, and started new product lines, branching out into illustrated books and scholastic publications while also publishing propaganda material for the regime, including new thematic atlases intended to celebrate Fascist Italy's achievements in agriculture, railway construction, and public works. However, the year 1935 saw a new period of financial troubles: because of the war in Ethiopia, the League of Nations imposed economic sanctions on Italy, and the regime officially adopted a policy of autarchy. This severely affected the IGDA, which suddenly

FIG. 416. YOUNG BOYS STUDYING TO BECOME CARTOGRAPHERS AT THE SCHOOL OF THE ISTITUTO GEOGRAFICO DE AGOSTINI IN NOVARA, ITALY. The photograph was taken in the 1950s.

From Davide Colombo, ed., *Meridiani e paralleli: Viaggio nella cartografia De Agostini* (Novara: Istituto Geografico De Agostini, 2006), 25. Permission courtesy of the De Agostini Picture Library, Novara.

lost much of its foreign revenues. Even so, the company was to survive thanks to a strong domestic market; the support of the regime; exports to Spain, Portugal, and South America; and the economic success of several noncartographic publications. During World War II the IGDA continued to produce maps, books, and propaganda material and even printed banknotes and stamps for the government. But the end of the war proved devastating to Rossi, who was accused of collaborating with Nazi Germany's occupation troops in northern Italy and was forced to leave the company. As a result, the Boroli family became sole proprietors of the IGDA.

In the 1950s the company consolidated its role as one of Italy's leading publishers by expanding its product line while continuing to update the *metodico*, *storico*, and *moderno* atlases and the *Calendario atlante*. The year 1959 marked another key moment in the history of the firm, with the introduction of the geographical encyclopedia *Il Milione*, named after the title of Marco Polo's travel accounts, published in fifteen volumes, and sold at newsstands in weekly issues over the course of two years—a marketing strategy new to Italy. Contributing to the success of *Il Milione* was its release at the beginning of the Italian economic boom of the 1960s, which transformed a largely agrarian society into a strong industrial economy. Times were changing at the IGDA as well: in 1961 Marco Adolfo Boroli, who had acquired the company in 1919, died, and Achille Boroli, his son, became company president. The firm expanded its operations in France and Spain, continuing a policy of growth started in the 1930s.

The end of the 1960s saw Marco Drago, grandson of Marco Adolfo Boroli, enter the company. In the 1970s the IGDA continued to publish significant cartographic works. Under the direction of Giuseppe Motta, a new edition of the *Grande atlante geografico* was released in 1982. It was a huge and instant success, with over one million copies sold and several foreign editions, including translations for the American, Japanese, and Chinese markets. In 1986 Achille Boroli left the company, and Adolfo Boroli, Marco Boroli (Achille's son), and Marco Drago took control. Digital cartography made its first appearance in 1987, when the IGDA acquired a Scitex scanner and prepress graphics computer—originally

FIG. 417. DETAIL FROM THE *PIEMONTE VALLE D'AOSTA*, 1998. Map showing the city of Novara where the Istituto Geografico De Agostini is located. The scale of the map is 1:250,000. Size of the entire original: 68.4 × 93.5 cm; size of detail: 11.1 × 18 cm. Permission courtesy of De Agostini Libri.

created for printing on textiles but converted to the cartographic production process—and used it to create the first digital maps in the company's history. By the end of the century cartographic production was almost entirely digital, with a prominent role given to GIS and digital databases like the World Digital DataBase (WDDB).

The late 1980s and early 1990s also saw the publication of two new atlases, the *Grande atlante d'Italia* (1987) and the *Grande atlante d'Europa* (1992), with the latter also sold in France, Germany, and Spain. In the 1990s the company continued its strategy of expansion by acquiring publishers in Italy and consolidating and expanding its product line in Italy and abroad. The IGDA's foreign presence reached a peak in 1993, a record year for the company, with 72 percent of sales originating outside of Italy. With the death of Adolfo Boroli in 1996, Marco Drago became president and CEO. In 2004 the IGDA was active in thirty countries, publishing works in thirteen languages and employing over 1,900 people. One of its six units focused on maps, illustrated books, and travel guides. Total sales reached €1.7 billion in 2004 (over $2 billion U.S.), with €53 million (3%) coming from the Libri and Cartografia unit. While neither geography nor cartography was a core business for the IGDA anymore, the word *geografico* remained in the company's name as testimony to the role of maps in the firm's history and the fact that most Italians still largely associated the name De Agostini with cartography and geography (fig. 417).

ALBERTO GIORDANO

SEE ALSO: Marketing of Maps, Mass; Recreational Map; Travel, Tourism, and Place Marketing

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Italian Touring Club. See Touring Club Italiano

ITC (International Training Center for Aerial Survey; Netherlands). See International Institute for Geo-Information Science and Earth Observation