The global transformation of geomorphology

Andrew S. Goudie[1]*, Tim P. Burt[2] and Heather A. Viles[1]

[1]School of Geography and the Environment, University of Oxford, South Parks Road, Oxford OX1 3QY, UK

[2]Department of Geography, Durham University, Lower Mountjoy, South Road, Durham DH1 3LE, UK

ASG, 0000-0002-5496-8207; TPB, 0000-0001-5908-3718

*Correspondence: andrew.goudie@stx.ox.ac.uk

Abstract: This chapter reviews the various developments in geomorphology in terms of institutions, journals, textbooks, research stations, etc. Among the institutions discussed are the Binghamton Geomorphology Symposium, the Geological Society of America Quaternary Geology and Geomorphology Division, the Association of American Geographers Geomorphology Specialty Group, the British Geomorphological Research Group, the IGU Commission on Measurements, Theory and Application in Geomorphology (COMTAG), the International Association of Geomorphologists, the European Geosciences Union (EGU), the American Geophysical Union (AGU), the International Quaternary Association, and the International Conference on Aeolian Research. Many countries established their own national bodies. A number of new journals appeared, including *Catena*, *Earth Surface Processes and Landforms*, *Géomorphologie*, and *Geomorphology*. In addition, during the closing decades of the twentieth century there was a proliferation of textbooks in geomorphology. One development was that geomorphological research was promoted by the establishment of research stations. These permitted long-term monitoring and provided bases for sustained investigations. The study of fluvial processes was much encouraged in the United States at USDA Forest Service research basins (known as 'watersheds' in the USA) such as the Hubbard Brook Experimental Forest (New Hampshire), Coweeta Hydrologic Laboratory (North Carolina) and the H.J. Andrews Experimental Forest (Oregon). The Royal Geographical Society (with the Institute of British Geographers) organized ambitious research projects in collaboration with host nations. Various US government departments supported much geomorphological research in various parts of the world. Some European countries fostered overseas geomorphological research and created missions. Notable was the work of ORSTOM (Office de la Recherche Scientifique et Technique Outre-mer) in former francophone colonies. In the post-war years, and as independence approached and then occurred, new universities were established in Africa. These employed expatriate geomorphologists and also trained up a new generation of indigenous scholars. The decades since the 1960s have been a period of space exploration and the development of remote sensing. This has had important implications for geomorphology. The period also saw the onset of the digital age and the beginning of the World Wide Web's influence on teaching and research. Applied research became increasingly important. A major cause for international and cross-disciplinary co-operation during the period was the emergence of geoarchaeology. Finally, since the 1950s, an increasing number of women have made important contributions to the discipline.

The last four decades of the twentieth century saw many advances in the theory, techniques, foci and practice of geomorphology (see Wohl *et al.* 2017 for a summary). From a fairly unified position in 1965, where a single textbook could summarize the subject (e.g. see Bruce Sparks' textbook: Sparks 1960), a vast range of quasi-independent themes had emerged by the end of the century. This book is essentially a history of those developments. In addition, however, the period since the 1960s has seen a growth in national and international geomorphological organizations, journals and collaborations, funding sources, and the role of women. Towards the end of the period, the arrival of email and the Internet has enabled even more international collaboration; long gone are the days of having to post draft manuscripts to distant colleagues! The transformation that occurred was remarkable. In this chapter we review some of these developments, starting with the establishment of national and international organizations. Indeed, the latter have had a remarkable influence, greatly extending the experience of academics, practitioners and research students alike, broadening the training opportunities for students (e.g. presenting posters at international conferences), and helping provide a much more diverse and equitable research community across the globe. The American Geophysical Union now has a global influence, with the European Geosciences Union also very important on the international stage; during the study period, these organization started to emerge from the plethora of national societies that were largely founded during the period 1965–2000.

Organizations

Binghamton Geomorphological Symposium

The Binghamton Geomorphology Symposium (BGS) was established in 1970 by Marie Morisawa (1919–94) and Don Coates (1922–2018) at what was then SUNY–Binghamton (now Binghamton University). Although the meeting has subsequently been held in many other locations, the name 'Binghamton' has been maintained. In the first 11 years, all but one meeting was held at Binghamton itself. Thereafter, other scientists located at different universities began to take an active role in the meeting, and the locations reflected that change (Sawyer *et al.* 2014). The BGS has produced a remarkable series of books and special issues of *Geomorphology*, and has proved to be highly durable, holding its 50th anniversary meeting in Denver in 2019. That meeting led to some very useful reviews of progress in the last five decades (e.g. Gardner 2020). The BGS has also been notable for its involvement of overseas scholars in its annual meetings. Janke *et al.* (2020) provide a brief history of the BGS and assess the roles of Morisawa and Coates in its early days, while Baker (2020) gives a penetrating personal analysis of the themes that were explored.

Other US organizations

Butler (2005) discussed the development of other US organizations. One of these, the Geological Society of America, started its Quaternary Geology and Geomorphology Division (QGG: originally the Geomorphology Division until 1970) in 1955. The Association of American Geographers Geomorphology Specialty Group (GSG) was established in 1979. *Geomorphlist* was published by the GSG in the mid-1980s as a means of communication between geomorphologists. It also produced a newsletter, *Geomorphorum*, from 1994 onwards (https://aag-gsg.org/geomorphorum/ accessed 31 March 2020). Geomorphologists also participated in the meetings of the American Geophysical Union (AGU), which was founded in 1919. Since 1983, the Gilbert Club, started by Bill Dietrich, has met on the UC Berkeley campus on the

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Saturday after the AGU's Fall Meeting in San Francisco (https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2011EO240008 accessed 11 April 2020). The purpose of the Gilbert Club, which has no formal affiliation with any organization, is to hear talks and discuss research, especially in theoretical geomorphology. Meeting details since 1985 can be found online (http://eps.berkeley.edu/gilbert/gilbert.htm accessed 31 March 2020).

Costa and Graf (1984) analysed the membership of some of these organizations and where geomorphologists published. They found that GSG had 283 members (1983), while the QGG had 1140 (1981). The chair of the QGG estimated that one-third of the membership were geomorphologists, with the remainder Quaternary geologists. They concluded that in the USA there were approximately 1430 geomorphologists and Quaternary specialists, 22% of who were geographers and the rest geologists. Only 5% of AAG members were geomorphologists. They also noted a decline in geomorphology in US geology departments in the 1980s. This coincided with overall stability of geomorphology courses in geography departments. To outsiders, it was in some ways unfortunate that the USA did not have one single voice for geomorphology. The enormous growth of the AGU Fall Meeting in the past two decades means that it has become an increasingly important forum for geomorphologists, appended as noted above by the Gilbert Club meeting.

British Geomorphological Research Group

The beginnings of the British Geomorphological Research Group (BGRG) lie in a meeting held in Sheffield under the chairmanship of David Linton in 1958 (Goudie and Price 1980; Brunsden 2007). Details of Linton's life are given in Goudie (2004). The purpose of that meeting was to discuss the possibility of initiating a Land Form Survey of Britain and employing working groups to develop mapping techniques. The working groups became the British Universities Geomorphological Research Group in 1960, and in 1961 the BGRG as such was constituted in Birmingham, with Linton as Chairman. There were 39 members. By 1980, the membership was 616. The first Annual General Meeting of what became the BGRG was held on 1 October 1960. Apart from holding meetings and field trips, it encouraged publications, including *Technical Bulletins*, *Earth Surface Processes*, a newsletter (*Geophemera*: from 1973), *Classic Landforms* (from 1981), and many collaborative books including the *Unquiet Landscape* (Brunsden and Doornkamp 1974) and *Geomorphological Techniques* (Goudie 1981). A *Bibliography of British Geomorphology* was one of the first publications of the BGRG (Clayton 1964), and claimed to list all the articles and books by British geomorphologists or concerned with the British Isles up to 1960; there are some 2200 items listed. Another objective source of information for the early part of the period was the *Register of Current Research in Geomorphology*, published by the BGRG in 1963 (Embleton 1983). Since 2006, the BGRG has been renamed as the British Society for Geomorphology (BSG).

Table 1. *National geomorphological organizations founded between 1946 and 1996*

Swiss Geomorphological Society – 1946
German Geomorphologists Group – 1974
Japanese Geomorphological Union – 1979
Australia New Zealand Geomorphological Group – 1982
Spanish Geomorphological Society – 1987
Commission on Geomorphology of the Austrian Geographical Society – 1987
The Czech Association of Geomorphologists – 1988
Association of Polish Geomorphologists – 1991
Canadian Geomorphology Research Group – 1993
Uniao da Geomorfologia Brasileira – 1996
Association of Slovak Geomorphology – 1996

Other national bodies

Many countries have national geomorphological organizations and the establishment of some of these was stimulated by the foundation of the International Association of Geomorphologists (IAG), membership of which is for national bodies rather than for individual scientists (Gregory and Goudie 2011, table 1.3) (Table 1).

IGU Commission on Measurements, Theory and Application in Geomorphology (COMTAG) and its predecessors. Various international bodies appeared in the second half of the twentieth century that led up to COMTAG. The International Geographical Union (IGU) set up commissions (Table 2) (Slaymaker 2019). One of these, on slopes, stimulated the absolutely fundamental studies of Anders Rapp at Karkevagge in Norway (Luckman 2000) (Fig. 1). The Commission on Field Experiments in Geomorphology met in Canada (1972, chaired by Olav Slaymaker), Belgium (1973, Albert Pissart), Israel (1974, Asher Schick), Zaire (1975, Jean Alexandre), the Soviet Union (1976, Gerasimov), France (1978, Jean Dresch), Poland (1979, Alfred Jahn), Japan (1980, Setsuo Okuda), Brazil (1982, Ana Luiza Coelho Netto) and Romania (1983, Dan Balteanu). Many of the results from these meetings are found in supplementary volumes 29, 35 and 46 of the *Zeitschrift für Geomorphologie* and in Slaymaker (1991). The commission also met in the UK in 1981, convened by Des Walling and Tim Burt (Fig. 2). There were conference sessions in Exeter and Huddersfield; in between, there was a tour of field sites near Bristol, on Plynlimon and in the Southern Pennines (Burt and Walling 1984). COMTAG (chaired by Asher Schick from Israel: Fig. 3) itself was one of the commissions and was established in 1984. It ceased to exist in 1992. It held international symposia, had joint meetings with bodies such as the BGRG and produced a number of publications (http://worldcat.org/identities/lccn-nr90022189/ accessed 1 April 2020). The flavour of its meetings and publications is provided in *Geomorphic Processes in Environments with*

Table 2. *IGU Commissions related to geomorphology from 1956 onwards*

Karst Phenomena (1956–68)
Applied Geomorphology (1960–68)
Erosion Surfaces (1960–68)
Periglacial Morphology (1956–76)
Evolution of Slopes (1956–68)
Coastal Sedimentation (1960–68)
Geomorphological Surveying and Mapping (1968–80)
Present Day Geomorphological Processes (1968–76)
Coastal Geomorphology (1968–76)
Field Experiments in Geomorphology (1980–84)
Significance of Periglacial Phenomena (1984–88)
Measurements, Theory and Applications in Geomorphology (1984–92)
Frost Action Environments (1988–96)
Geomorphological Response to Environmental Change (1992–2000)
Environmental Change and Conservation in Karst areas (1992–2000)
Climate Changes and Periglacial Environments (1996–2000)

http://www.homeofgeography.org/fr/archives/tabella5.htm (accessed 3 April 2020)

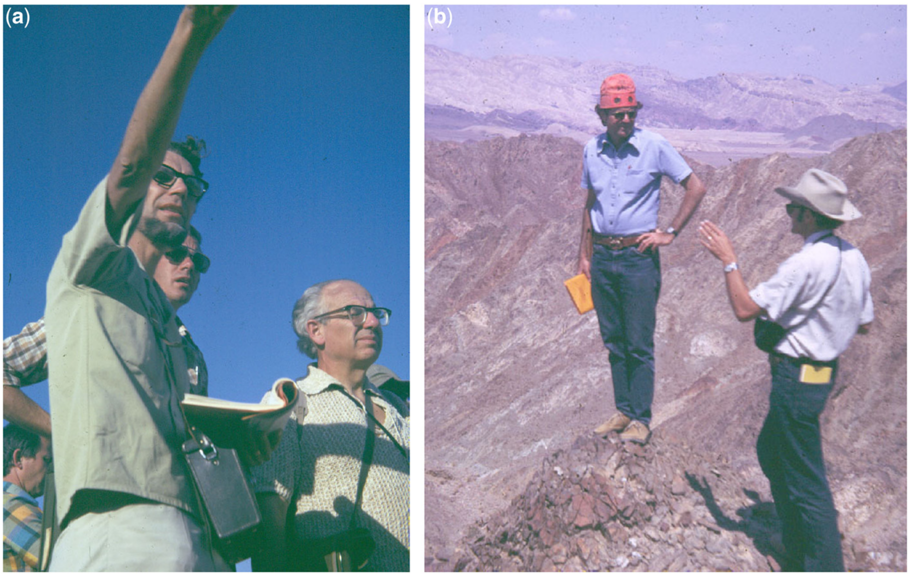

Fig. 1. (**a**) Anders Rapp (1927–98) pointed the way for quantitative studies of processes on slopes (ASG). See Rapp (1960). He also chaired the IGU Commission on Field Experiments in Geomorphology in 1976–80 and was succeeded by Olav Slaymaker (1980–84). (**b**) A new Commission on Measurement, Theory and Application in Geomorphology (COMTAG) was then chaired by Asher Schick (1984–92) (see Fig. 3).

Fig. 2. Tim Burt addresses delegates (IGU Commission on Field Experiments in Geomorphology) at the Slippery Stones gauging station in the Derwent Valley, southern Pennines, England, 22 August 1981. Source: Tim Burt's photograph collection.

Strong Seasonal Contrasts (Imeson and Sala 1987) , in *Recent Developments and Perspectives in Mountain River Research* (Schmidt and Ergenzinger 1994) , and in *Arid and Semi-Arid Environments: Geomorphological and Pedological Aspects* (Yair and Berkowich 1989).

International Association of Geomorphologists. The foundation of the International Association of Geomorphologists (IAG/AIG) (http://www.geomorph.org/; had antecedents in three international meetings organized in the UK by the BGRG. The first of these occurred in London in April 1976 on the theme of 'Geomorphology. Present Problems and Future Prospects' (Embleton *et al.* 1978). The second, also held in London, was on 'Mega Geomorphology' (Gardner and Scoging 1983).

The third conference (organized by Ian Douglas) took place in Manchester in September 1985 and attracted 675 delegates from 51 countries. It became known as the First International Conference on Geomorphology. The proceedings were edited in two enormous volumes by Gardiner (1987), and a note on the background of this conference was provided by Brunsden (1987). Walker (1986, 1987, 1989) gives some of the history of the early days and was a pivotal figure in its development (Mathewson and Brunsden 2015). The IAG itself was formally established in Frankfurt in 1989 (appropriately, given the hugely important role of the German geomorphologists Dietrich Barsch, Hanna Bremer and others in launching the IAG) and the IAG held congresses at four-yearly intervals in Frankfurt (1989), and subsequently in Hamilton, Ontario, Canada (1993), and in Bologna, Italy (1997). The Hamilton meeting attracted 650 delegates from 41 nations, and the Bologna meeting attracted 969 delegates from 67 nations. The IAG also held regional meetings in many parts of the world, of which Ankara, Turkey (1991), and Singapore (1995) were the first and second, with highly successful field trips throughout Turkey and Indonesia associated. Hungary (1996), Portugal (1997), The Netherlands (1998) and Brazil (1999) followed in quick succession.

The IAG was established 'in order to strengthen international geomorphology'. It fulfils its aims through working groups and task forces, and the organization of conferences, publications and information exchange. Membership is normally by countries. It has also provided funding to encourage young geomorphologists, especially from developing countries. It has encouraged publications including a history of geomorphology in different nations (Walker and Grabau 1993). Its first Senior Fellows were Jesse Walker (USA) in

Fig. 3. (**a**) Ian Douglas, organizer of the First International Conference on Geomorphology. (**b**) Denys Brunsden, Founding President of the IAG. (**c**) Dietrich Barsch, second President of the IAG on 3 June 2016, during the colloquium to celebrate his 80th anniversary. (**d**) Olav Slaymaker, third President of the IAG. Source: photographs (a) and (b) are by A.S. Goudie. (c) Photo of D. Barsch is by B. Mächtle (http://www.geomorph.org/2018/10/obituaries-dietrich-barsch/ accessed 31 March 2020). Courtesy of the International Association of Geomorphologists. (d) Photograph courtesy of Olav Slaymaker.

1989, Hanna Bremer (Germany) and Ross Mackay (Canada) in 1993, and Denys Brunsden (UK), Richard Chorley (UK), and Luna Leopold (USA) in 1997. The founding President of the IAG was Denys Brunsden from the UK. He was succeeded in the 1990s by Dietrich Barsch of Germany and Olav Slaymaker of Canada (Fig. 3). Dietrich Barsch suffered a severe stroke on 14 March 1996 and Olav Slaymaker became Acting President.

European Geosciences Union. The European Geosciences Union (EGU) was established by the merger of the European Union of Geosciences (EUG) and the European Geophysical Society (EGS) on 7 September 2002, with the final stages of this transition completed on 31 December 2003 (https://www.egu.eu/about/historical-highlights/ accessed 30 April 2020). The EGS had been founded in 1971 (https://www.egu.eu/about/historical-highlights/egs/), while the EUG was founded in Strasbourg in 1981. The EUG expanded in 20 years from about 300 to more than 3000 members and finally became one of the major scientific unions of Earth Sciences in the world (https://www.egu.eu/about/historical-highlights/eug/). Many geomorphologists have attended the EGU's annual meetings.

International Quaternary Association. The International Quaternary Association (INQUA), which was established in Denmark in 1928, continued to involve geomorphologists through its commissions and congresses. The latter were held in a very diverse range of locations: Boulder (1965), Paris (1969), Christchurch (1973), Birmingham (1977), Moscow (1982) Ottawa (1987), Beijing (1991), Berlin (1995) and Durban (1999). One of the Presidents of INQUA was the great desert geomorphologist Jean Dresch (1905–94). He was also a major figure in the IGU (Goudie and Wise 1994). Details of INQUA's history are given at https://www.inqua.org/about/history (accessed 25 April 2020).

International Conference on Aeolian Research. Among the new international bodies supporting geomorphological research was the International Conference on Aeolian Research (ICAR). The first meeting was held in 1986 and subsequent meetings occurred every 4 years after that. Aeolian geomorphologists from around the world assembled to discuss their research, and to showcase advancements in understanding and modelling of aeolian processes. The locations were Aarhus, Denmark (in 1986) followed by meetings in Sandberg, Denmark (1990), Zzyzx, California, USA (1994) and Oxford, UK (1998) (see Bauer 2009). In common with other branches of the subject, the late twentieth century saw an exponential growth in published papers on aeolian phenomena (Stout *et al.* 2009) (Fig. 4).

Journals, texts and the Internet

Geomorphological journals

Pre-existing journals were the *Zeitschrift für Geomorphologie* (1956 onwards) and the *Revue de Géomorphologie Dynamique* (from 1950 to 1994, the brainchild of Jean Tricart and André Cailleux). The former of these continued to be highly influential and was edited for much of the period by Hanna Bremer (Fig. 5), one of the most noted of tropical geomorphologists (Slaymaker 2012). A number of new journals appeared

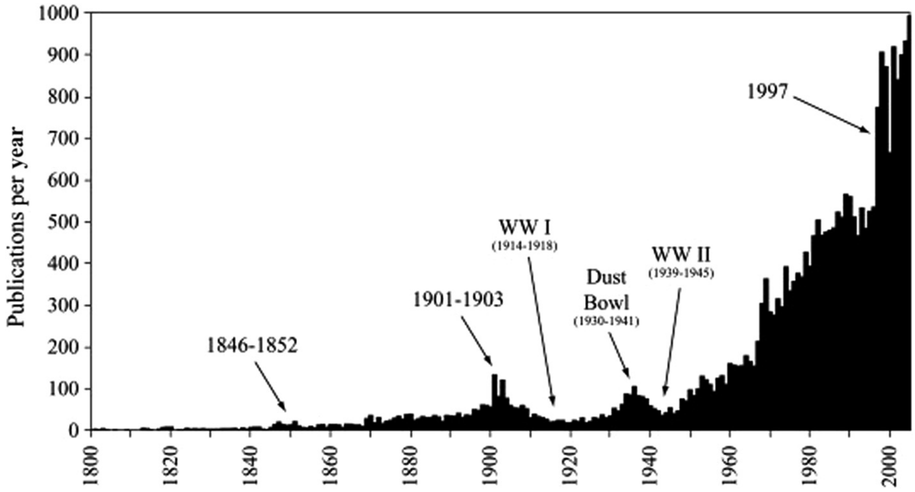

Fig. 4. Trends in publications on aeolian research since 1800. Source: Stout *et al.* (2009, fig. 3). Reproduced by permission of Elsevier.

in the period we are considering. Notable were *Earth Surface Processes,* which started in 1976 and changed its name to *Earth Surface Processes and Landforms* (ESPL) in 1979. Mike Kirkby was Managing Editor from its inception in 1976 to 2007. Another very significant journal was *Geomorphology*, which was established by Marie Morisawa and first appeared in 1989. It was expertly edited by Jack Vitek for many years. The French journal *Géomorphologie* appeared

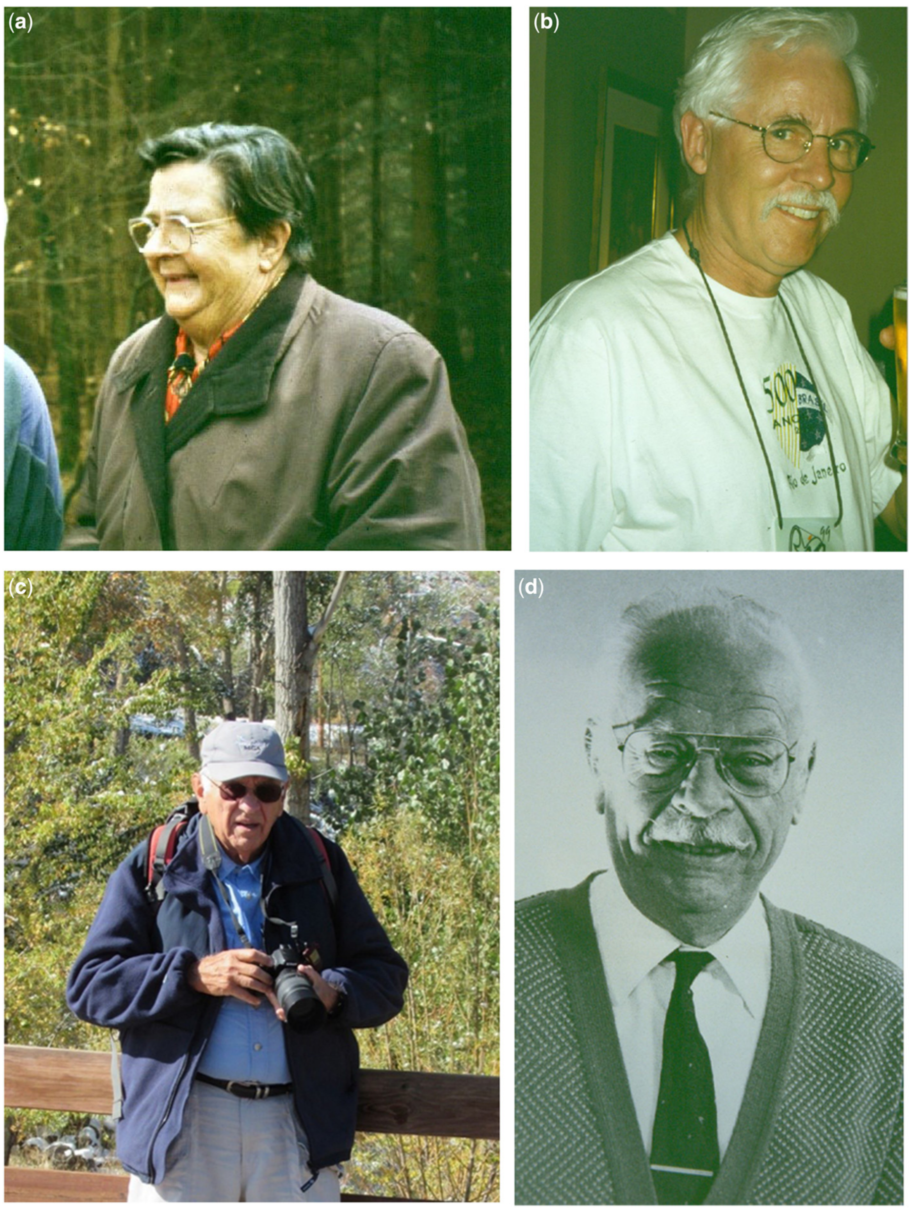

Fig. 5. Four pre-eminent journal editors. (**a**) Hanna Bremer (1928–2012) of the *Zeitschrift für Geomorphologie*; (**b**) Mike Kirkby, founder of *Earth Surface Processes and Landforms*; (**c**) Jack Vitek, Senior Editor of *Geomorphology*; and (**d**) Jean Tricart (1920–2003) of the *Revue de Géomorphologie Dynamique*. Source: photographs by A.S. Goudie.

in 1995, essentially replacing the *Revue de Géomorphologie Dynamique* (RGD). In 1980, the Japanese produced the first volume of the *Transactions of the Japanese Geomorphological Union*, and attracted distinguished foreign authors, while in 1987 Spain produced *Revista Cuaternario y Geomorfología*.

Other more specialized journals that were initiated and which published much geomorphological material included those listed in Table 3 (see also Gregory *et al.* 2014). For those seeking to assess the development of particular types of geomorphology, the regular progress reports in *Progress in Physical Geography* were especially valuable. The content of *Physical Geography*, founded by Tony Orme, a geomorphologist, in 1980, was about 40% geomorphology (Orme 2000).

Vitek (1989) calculated that of 52 journals in which geomorphologists could publish since the appearance of the *American Journal of Science* in 1818, no less than 46% had come into existence since 1960. The increasing output of geomorphologists in general and of fluvial geomorphologists in particular in the major journals since 1986 is reviewed by Piégay *et al.* (2015) and by Wohl (2014). It is clear that fluvial geomorphology has been the dominant component of the discipline, but that the overall output of articles in key journals has shown a general expansion (Fig. 6). Another feature of our period has been the increasing importance of English as a medium of communication (Lewin 2017). In academic journals generally, English use in scientific papers rose from around 55% in the 1970s to over 90% by the end of the century, and even in German- and French-based geomorphological journals English became the *lingua franca*.

Geomorphological texts

During the closing decades of the twentieth century there was a proliferation of textbooks in geomorphology, with skilled editors (such as John Davey at Arnolds and Blackwells, Andrew Schuller and Joyce Berry at Oxford University Press, and Roger Jones at Allen & Unwin and Unwin Hyman) commissioning some valuable and innovative books that synthesized knowledge upon which progress could be built. It would be impossible and, perhaps, invidious to list all of them, but Table 4 lists some successful English language examples.

Table 3. *Some key journals established between 1965 and 1991 that have published geomorphological material*

Annals of Glaciology (1980)
Arctic and Alpine Research (1969)
Boreas (1972)
Catena (1973)
Earth Science Journal (1967)
Geoarchaeology (1986)
Geografisker Annaler A (1965)
Hydrological Processes (1987)
Journal of Arid Environments (1978)
Journal of Coastal Research (1984)
Journal of Hydrology (1983)
Journal of Quaternary Science (1985)
Permafrost and Periglacial Processes (1990)
Physical Geography (1980)
Progress in Physical Geography (1977)
Revista Cuaternario y Geomorfología (1987)
Quaternary Research (1970)
Quaternary Science Review (1982)
The Holocene (1991)

It was perhaps a golden age. More recently, the role of textbooks has probably become less important, not least because of the tendency for students to use electronic resources. In Britain, this apparent decline was partly caused by the UK Government's Research Assessment Exercises since 1986. This led to journal articles being accorded more importance by physical geographers than books.

Not only were large numbers of geomorphology texts produced, but there was also a marked change in the use of the term itself. Through an analysis of books digitized by Google, Woodward (2015) showed that in Britain and the USA its use took off, particularly in the 1960s and largely replaced use of the term 'physiography'. There was, however, a marked decline in the use of the term 'geomorphology' in books published after the early 1990s, with many researchers using alternative terms, such as Earth Surface Processes, Landscape Evolution and Earth System Science.

The digital age and access to the Internet

At a seminar to celebrate the centenary of William Morris Davis' birth in 1950, Arthur Strahler called for the abandonment of qualitative denudation chronology and the adoption of a dynamic, quantitative approach, focusing on process and form (Chorley 2008). There was soon a need to analyse increasing amounts of data from both the field and the laboratory, and to apply statistical tests to the results. All this

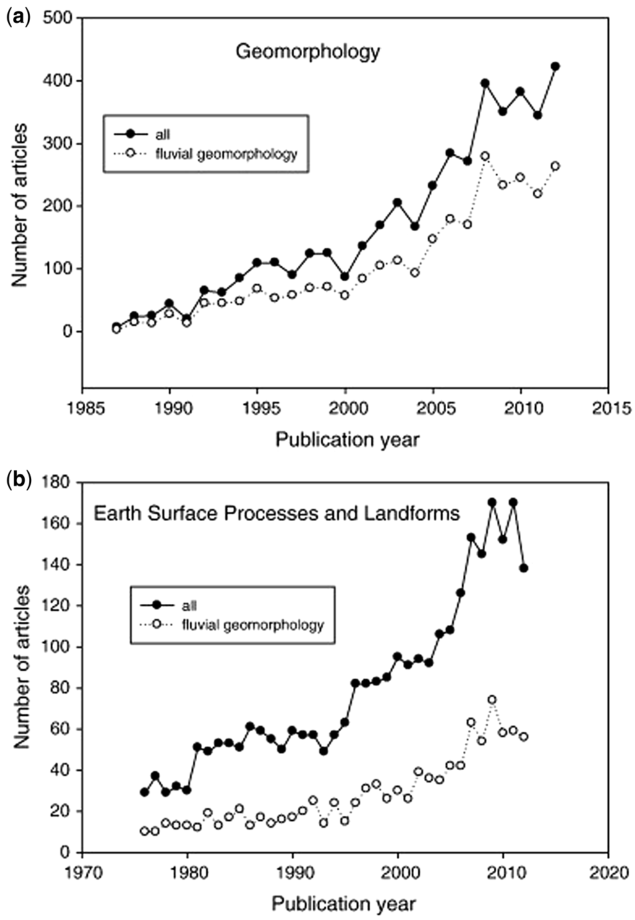

Fig. 6. The growth of the number of articles per year in *Geomorphology* and *Earth Surface Processes and Landforms* showing both the overall upward trend and the proportion of output relating to fluvial geomorphology. Source: Wohl (2014, fig. 8). Reproduced by permission of Elsevier.

Table 4. *Selected examples of student textbooks in Geomorphology between 1960 and 1999*

Subject	*Author*	*Title*	*Publisher*	*Date*
General	Sparks, B.W.	*Geomorphology*	Longman	1960
General	Small, R.J.	*Landforms*	Cambridge University Press	1970
General	Pitty, A.F.	*Introduction to Geomorphology*	Methuen	1971
General	Garner, H.F.	*The Origin of Landscapes*	Oxford University Press	1974
General	Ruhe, R.V.	*Geomorphology, Geomorphic Processes and Surficial Geology*	Houghton Houghton Mifflin	1975
General	Bloom, A.	*Geomorphology*	Prentice-Hall	1978
General	Chorley, R.J., Schumm, S.A. and Sugden, D.E.	*Geomorphology*	Methuen	1985
General	Selby, M.J.	*Earth's Changing Surface*	Oxford University Press	1985
Anthropogenic	Nir, D.	*Man, A Geomorphological Agent*	Keter	1983
Applied	Cooke, R.U. and Doornkamp, J.C.	*Geomorphology in Environmental Management*	Oxford University Press	1974
Applied	Hart, M.G.	*Geomorphology Pure and Applied*	Allen & Unwin	1986
Biogeomorphology	Viles, H.A.	*Biogeomorphology*	Blackwell	1988
Caves	Gillieson, D.	*Caves*	Blackwell	1996
Climatic	Birot, P.	*The Cycle of Erosion in Different Climates*	Batsford	1968
Climatic	Tricart, J. and Cailleux, A.	*Introduction to Climatic Geomorphology*	Longman	1972
Climatic	Budel, J.	*Climatic Geomorphology*	Princeton	1982
Coastal	Guilcher, A.	*Coastal & Submarine Geomorphology*	Methuen	1966
Coastal	Bird, E.C.F.	*Coasts*	MIT Press	1968
Coastal	Davies, J.L.	*Geographical Variation in Coastal Development*	Oliver & Boyd	1972
Coastal	Pethick, J.S.	*An Introduction to Coastal Geomorphology*	Arnold	1984
Deserts	Cooke, R.U. and Warren, A.	*Geomorphology in Deserts*	Batsford	1973
Deserts	Thomas, D.S.G. (ed.)	*Arid Zone Geomorphology*	Belhaven	1989
Deserts	Abrahams, A. and Parsons, A.J.	*Geomorphology of Desert Environments*	Chapman & Hall	1994
Dunes	Pye, K. and Tsoar, H.	*Aeolian Sand and Sand Dunes*	Unwin Hyman	1990
Dunes	Lancaster, N.	*Geomorphology of Desert Dunes*	Routledge	1995
Fluvial	Leopold, L.B., Wolman, M. and Miller, J.	*Fluvial Processes in Geomorphology*	Freeman	1964
Fluvial	Gregory, K.J. and Walling, D.	*Drainage Basin Form and Process: A Geomorphological Approach*	Hodder	1973
Fluvial	Schumm, S.A.	*The Fluvial System*	Wiley	1977
Glacial	Flint, R.F.	*Glacial and Quaternary Geology*	Wiley	1971
Glacial	Price, R.J.	*Glacial and Fluvioglacial Landforms*	Oliver & Boyd	1973
Glacial	Andrews, J.T.	*Glacial Systems*	Duxbury	1975
Glacial	Embleton, C. and King, C.A.M.	*Glacial and Periglacial Geomorphology*	Arnold	1975
Glacial	Sugden, D. and John, B.	*Glaciers and Landscape: A Geomorphological Approach*	Arnold	1976
History	Tinkler, K.J.	*A Short History of Geomorphology*	Croom Helm	1985
Humid	Douglas, I.	*Humid Landforms*	MIT Press	1977
Karst	Sweeting, M.M.	*Karst Landforms*	Columbia University Press	1972
Karst	Trudgill, S.T.	*Limestone Geomorphology*	Longman	1985
Karst	Jennings, J.N.	*Karst Geomorphology*	Blackwell	1985
Karst	Ford, D.C and Williams, P.W	*Karst Geomorphology and Hydrology*	Unwin Hyman	1989
Marine	King, C.A.M.	*Introduction to Marine Geology and Geomorphology*	Arnold	1974
Periglacial	Davies, J.L.	*Landforms of Cold Climates*	MIT Press	1969
Periglacial	French, H.M.	*The Periglacial Environment*	Longman	1976
Phytogeo-Morphology	Howard, J.A. and Mitchell, C.W.	*Phytogeomorphology*	Wiley	1985
Processes	Ritter, D.F.	*Process Geomorphology*	W.C. Brown	1978
Processes	Embleton, C. and Thornes, J.B.	*Process in Geomorphology*	Hodder	1979
Regional	Thornbury, W.B.	*Regional Geomorphology of the United States*	Wiley	1965
Regional	Bird, J.B.	*The Natural Landscapes of Canada*	Wiley	1972
Regional	Soons, J.M. and Selby, M.J.	*Landforms of New Zealand*	Wiley	1982
Regional	Embleton, C.	*Geomorphology of Europe*	Macmillan	1984
Regional	Goudie, A.S.	*Geomorphology of England and Wales*	Blackwell	1990
Rocks	Sparks, B.W.	*Rocks and Relief*	Longman	1971
Rocks	Gerrard, A.J.	*Rocks and Landforms*	Unwin Hyman	1988
Slopes	Brunsden, D.	*Slopes: Form and Process*	Institute of British Geographers	1971
Slopes	Young, A.	*Slopes*	Oliver & Boyd	1972
Slopes	Carson, M.A. and Kirkby, M.J.	*Hillslope Form and Process*	Cambridge	1972
Slopes	Selby, M.J.	*Hillslope Materials and Processes*	Oxford University Press	1982
Slopes	Brunsden, D and Prior, D.	*Slope Instability.*	Wiley	1984
Soil erosion	Morgan, R.P.C.	*Soil Erosion*	Longman	1979

(*Continued*)

Table 4. *Continued*

Subject	*Author*	*Title*	*Publisher*	*Date*
Structural	Twidale, C.R.	*Structural Landforms*	MIT Press	1971
Structural	Tricart, J.	*Structural Geomorphology*	Longman	1974
Techniques	King, C.A.M.	*Techniques in Geomorphology*	Arnold	1966
Techniques	Goudie, A.S.	*Geomorphological Techniques*	Allen & Unwin	1981
Techniques	Gardiner, V. and Dackombe, R.	*Geomorphological Field Manual*	Allen & Unwin	1983
Tectonics	Summerfield, M.	*Global Geomorphology*	Routledge	1991
Tectonics	Ollier, C.D.	*Tectonics and Landforms*	Oliver & Boyd	1981
Theory	Thorn, C.E.	*Theoretical Geomorphology*	Unwin Hyman	1988
Tropics	Faniran, A. and Jeje, L.K.	*Humid Tropical Geomorphology*	Longman	1983
Tropics	Thomas, M.F.	*Tropical Geomorphology*	Macmillan	1974
Volcanoes	Ollier, C.D.	*Volcanoes*	MIT Press	1969
Volcanoes	Francis, P.	*Volcanoes. A Planetary Perspective*	Clarendon	1993
Volcanoes	Chester, D.K.	*Volcanoes and Society*	Arnold	1994
Weathering	Ollier, C.D.	*Weathering*	Oliver & Boyd	1969
Weathering	Birkeland, P.W.	*Pedology, Weathering, and Geomorphological Research*	Oxford University Press	1974
Weathering	Yatsu, E.	*The Nature of Weathering*	Sozosha	1988
Zoogeomorphology	Butler, D.R.	*Zoogeomorphology*	Cambridge University Press	1995

required an ever-increasing ability to make calculations: initially, laboriously, by hand. In the 1970s, the emergence of electronic calculators and mainframe computing helped greatly in this regard. In the 1980s, desktop computers were introduced, independent microcomputers in the first instance, but later linked to mainframe computers (see **Martin 2022**, this volume). Initially, these needed programming skills, but very soon spreadsheets and statistical packages became available to speed up data analysis greatly. Geomorphological studies moved into computer simulation modelling (e.g. Kirkby *et al.* 1987; see also Kirkby 2021), also generating lots of numerical output. The use of large datasets became increasingly common too, often the product of remote sensing, notably Landsat imagery, and digital elevation models (DEMs). Chorley's 'mid-century revolution' quickly became 'normal science' (Kuhn 1962)!

Tim Berners-Lee invented the World Wide Web in 1989, and it was opened to the general public in August 1991. As a result, teaching (Wentz *et al.* 1999) and research in geomorphology were transformed during the last decade covered in this chapter. As Shroder *et al.* (2002) remarked, new electronic media meant that virtual fieldtrips were developed and accessed to reinforce concepts in class. As regards the web's influence on research, this ranged across communication between investigators, data acquisition, scientific visualization and comprehensive searches of refereed sources to interactive analyses of remote datasets (**Eckardt 2021**, this volume). Schimmrich (1996, 1997*a*, *b*) and Schimmrich and Gore (1996) summarized available web resources for use in the study of, *inter alia*, plate tectonics, glaciers, climate change, volcanoes and hydrogeology, while Exton (1999) drew attention to the availability and utility of geomorphological images on the web.

Into the digital age

In the previous volume, Dick Chorley described the mid-century revolution in fluvial geomorphology, 'wherein an essentially geological qualitative-historical discipline was transformed by the application of ideas from engineering and other applied sciences into, what appeared at the time, a new quantitative-dynamic paradigm'(Chorley 2008, p. 925). As demonstrated in this volume, all aspects of geomorphology experienced a quantitative revolution in the second half of the twentieth century, sharing many if not all aspects of this paradigm shift. The collapse of the Davisian cyclic paradigm and its replacement by a dynamical systems approach that focused on contemporary processes has already been emphasized through the appearance of new journals and textbooks (Tables 3 & 4). Process geomorphology can be defined as follows:

> An understanding of the erosional and depositional processes that fashion the landform, their mechanics and their rates of operation must also be obtained in order that the past evolution can be explained and the future evolution predicted. This 'process geomorphology' has a strong utilitarian aspect
>
> (Chorley *et al.* 1984, p. 3).

Whilst geomorphologists continued to debate the precise nature of the new 'functional geomorphology' (e.g. Church 1996), for many geomorphologists the mid-century revolution had to do mainly with technological developments in defining, collecting and analysing data concerning process and form, together with the application of chemical and engineering principles (including hydraulics and hydrology) to the analysis of landforms (Chorley 2008). Changes in approach and method are reviewed in the first two sections of this volume, including spatial and temporal techniques, modelling, field and laboratory experiments, and general systems thinking. A glance at the contents list of Cole and King's (1968) influential textbook *Quantitative Geography* (see next section for a brief review of Cuchlaine King's geomorphological research) summarizes the new approach: Part 1 encompasses mathematics and statistical analysis, both descriptive and inferential; Part 2 covers spatial distributions and relationships; Part 3 explores dimensions of space and time; and Part 4 deals with models, theories and organizational approach. Initially, statistical analysis of field and laboratory data was limited by the available technology, but, as **Martin (2022**, this volume) describes, developments in computing technology soon allowed much more powerful use of inferential statistics and the development of complex mathematical models (e.g. see **Kirkby 2021**, this volume). The radical shift in approach is perhaps most starkly illustrated by comparison of Bruce Sparks' excellent textbook *Geomorphology* published in 1960 and Carson and Kirkby's exceptional *Hillslope Form and Process* published just 12 years later (Table 4).

With the quantitative revolution came much greater emphasis on measurement technique (Goudie 1981). As **Martin (2022**, this volume) explains, the onset of the digital age was founded on the development of electronic technology; this led not only to various types of computer, from mainframe through to personal desktop computers and the emergence of electronic calculators, but also to new laboratory and field equipment. Fieldwork began to make use of data loggers and digital surveying equipment. Remote sensing, both from space (see **Eckardt 2021**, this volume) and airborne, provided large amounts of data for analysis by computer, linking to the development of GIS software for analysis and display, and the development of DEMs. This is all very different to life at the start of our study period when chart recorders depended on clockwork; the clock might stop or the pen run out of ink! Whilst water samples might still be needed for laboratory analysis, by the end of the twentieth century probes connected to data loggers provided continuous monitoring of river-level and water-quality parameters, and automatic weather stations had become commonplace (Fig. 7).

Research stations, overseas research projects and new funding streams

The arrival of cheap air travel by jets enabled geomorphologists to roam the world as never before, and to undertake collaborative research in new environments and locations.

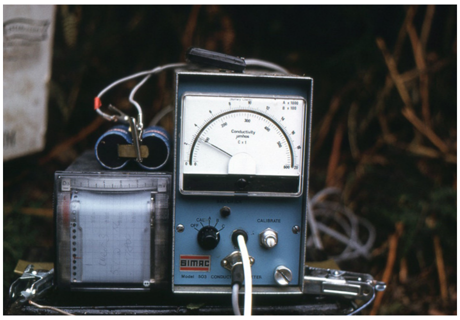

Fig. 7. The start of electronic field data collection in the mid-1970s: a conductivity meter linked to an electric chart recorder powered by a 12 V car battery. Source: photograph by T.P. Burt.

One development was that geomorphological research was promoted by the establishment of research stations. These permitted long-term monitoring and provided bases for sustained investigations. Dryland stations included those at Jodphur in India, Bardai in the central Sahara, Gobabeb in the Namib, Sidi Boqer in the Negev, Fowlers Gap in New South Wales (Australia), the Jornada Experimental Range in New Mexico, the Walnut Gulch Experimental watershed in Arizona, the Desert Institute of Turkmenistan, the Taklamakan Desert Research Station in NW China and the Lanzhou Institute of Desert Research. Of these, Gobabeb (Fig. 8) has probably encouraged the largest corpus of geomorphological work since it was founded in 1962 (Eckardt *et al.* 2013).

A list of Arctic research stations and their dates of establishment is found in https://en.wikipedia.org/wiki/List_of_research_stations_in_the_Arctic (accessed 8 April 2020), and a list of Antarctic stations and their dates of establishment is found in https://en.wikipedia.org/wiki/Research_stations_in_Antarctica (accessed 8 April 2020). There has been a particularly impressive programme of research in Svalbard by Polish geomorphologists (Zwoliński *et al.* 2013), Swedish geomorphologists at Abisko (https://deims.org/64679f32-fb3e-4937-b1f7-dc25e327c7af accessed 8 April 2020), Canadian geomorphologists at the McGill Arctic Research Station (https://www.mcgill.ca/mars/ accessed 8 April 2020) and American geomorphologists at the University of Colorado Mountain Research Station (https://www.colorado.edu/mrs/research-natural-history accessed 8 April 2020). Among rainforest research stations where geomorphological research has been pursued is the Danum Valley Field Centre in Sabah, Malaysia (Douglas *et al.* 1992). Stations were also established on coral reefs, including the Glovers Reef Marine Research Station in Belize and various places on the Great Barrier Reef of Australia, such as Lizard and Heron islands

The study of fluvial processes was much encouraged in the USA at USDA Forest Service research basins (known as ‘watersheds’ in the USA), such as the Hubbard Brook Experimental Forest (New Hampshire), Coweeta Hydrologic Laboratory (North Carolina) and the H.J. Andrews Experimental Forest (Oregon). John Hewlett’s influential work on hillslope hydrology was carried out at Coweeta (Burt 2008) (Fig. 9). Another notable long-term basin study is the Maimai catchment on South Island, New Zealand (McDonnell 2020). In

Fig. 8. The Namib Desert Research Centre at Gobabeb, founded in 1962, has been a major location for desert research by scholars from all over the world. Source: photograph by A.S. Goudie.

Fig. 9. The Coweeta Hydrologic Laboratory was one of several USDA Forest Service watersheds where the study of fluvial processes was much encouraged. This is the place where John Hewlett's influential work on hillslope hydrology was carried out. The photograph shows the main outflow from the Coweeta Basin: an unusual type of sharp-crested weir – a Cipoletti – is used to measure stream discharge. Standing by the weir is Wayne T. Swank, one of Coweeta's most important scientists. Source: T.P. Burt.

the UK, long-term catchment studies have been sustained at Plynlimon in central Wales since the 1970s, operated by the Centre for Ecology and Hydrology. The Field Studies Council, an educational charity, has sustained catchment studies at Slapton, Devon, since 1970 (Burt *et al.* 2019). The UK's Environmental Change Network (ECN) has supported catchment research at a number of sites across the UK (http://www.ecn.ac.uk; since the 1990s; some of the ECN sites have a long history of monitoring, such as Rothamsted and Wytham Woods near Oxford.

The Royal Geographical Society (with the Institute of British Geographers) organized ambitious research projects in collaboration with host nations. Nigel de N. Winser (Expeditions Officer) was involved with the logistics of many of them. Between 1977 and 2001 the RGS ran 11 of these, and those with a major geomorphology component included the International Karakoram Project (run with the Government of Pakistan and Academia Sinica: in 1980), the Jordan Badia Programme (1992–96), the Kimberley Research Project (Australia: 1988), the Kora Research Project (Kenya: 1983), the Maracá Rainforest Project (Brazil: 1987–88), the Mulu Sarawak Expedition (1977–78), the Nepal Middle Hills Projects (1991–98), the Oman Wahiba Sands Project (1985–87) and the Shoals of Capricorn (Indian Ocean: 1998–2001). As examples of the work undertaken, during the International Karakoram Project (Fig. 10) there were studies by British, Chinese and Pakistani geomorphologists of earthquake-resistant structures, the mapping of glacier retreat, the measurement of screes, determination of solute and sediment loads in the Hunza River, mass movements and other hazards along the Karakoram Highway, and the salt weathering of moraines (Miller 1984).

The Kora Project included studies of the petrological controls on inselberg development (Pye *et al.* 1986). The Oman Wahiba Sands Project included studies of dunes, aeolianites and palaeochannels (Dutton 1988). The Kimberley Research Project included the study by Australian and British geomorphologists of Quaternary dune systems, the reconstruction of past flooding in the area's gorges, analysis of karstic phenomena, the classification of tufas, the description of aligned gilgai and the study of cave deposits (Goudie *et al.* 1990). The Jordan Badia Programme included studies of basalt weathering

Fig. 10. Chinese, Pakistani and British geomorphologists contributed to the International Karakoram Project in 1980. Among those shown are Rob Ferguson, Dave Collins, J.J. Li, Alayne Street-Perrot, Brian Whalley, S.Y. Xu, Ron Waters, Andrew Goudie, Ed Derbyshire, Denys Brunsden and David Jones. Source: photograph by A.S. Goudie.

in an arid environment (Allison *et al.* 2000). Full bibliographies of the publications arising from these projects are available (https://www.rgs.org/in-the-field/advice-training/resources-for-expeditions/field-research-programme-publications/ accessed 18 April 2020). In the last two decades, such projects have been suspended.

The period also saw the re-emergence of China on to the international scene, following the end of the Cultural Revolution. In 1975, J.N. Jennings and J.M. Bowler from Australia led the way, and were followed in 1977 by a UK party consisting of M.M. Sweeting, E.H. Brown, K.J. Gregory, E. Derbyshire and D.R. Stoddart (Stoddart 1978; Sweeting *et al.* 1978). Major work followed on such topics as karst and loess. Also in 1977, a US delegation visited China (Ma and Noble 1979), and in the following year Chinese geographers visited the USA. The great development of geomorphological research in China after 1985 is reviewed at length by Leng *et al.* (2017).

Some European countries also fostered overseas geomorphological research and created missions. Notable was the work of ORSTOM (Office de la Recherche Scientifique et Technique Outre-mer) in former francophone colonies (https://en.ird.fr/the-ird/history accessed 15 April 2020) and of Swedish teams in eastern and southern Africa (e.g. see Rapp *et al.* 1972 on Tanzania; Stromquist *et al.* 1985 on Lesotho).

In the post-war years, and as independence approached and then occurred, new universities were established in Africa. Some of them taught geography and related disciplines (e.g. the University of Ghana in 1948, the University of Ibadan in 1948, Makerere College in 1949, the University of Cape Coast in 1961, the University of Lagos in 1962, Ahmadu Bello University in 1962, University College of Nairobi in 1964, the University of Dar es Salaam in 1970, the University of Botswana in 1982 and the University of Swaziland in 1982). This was highly significant on two counts. First, some of the staff of these new universities were expatriate geomorphologists, and they undertook field research in tropical geomorphology. Secondly, these new universities produced a new generation of indigenous geomorphologists who have carried on such research until the present day.

The US Office of Naval Research, established in 1946, supported much research in various parts of the world on coastal environments (Pruitt 1979; Sapolsky 1991). Examples include the work of McMaster *et al.* (1970), Dolan (1973) and Butenko *et al.* (1985). A major figure in its role was Bob Dolan (Fenster 2016). The US Army Corps of Engineers also supported geomorphological research, notably through the encouragement of Hoyte Lemmons and Warren Grabau at the Corps' European Research Office in the 1970s and 1980s. They both contributed to the establishment of the IAG (https://www.geomorphology.org.uk/sites/default/files/Geophemera%20106.pdf accessed 29 April 2020).

The decades since the 1960s have been a period of space exploration. As a consequence (see **Eckardt 2021**, this volume), there was the development of remote sensing of Earth's surface, exploration of extraterrestrial geomorphology (e.g. of Mars) and the search on Earth for planetary analogues, as, for example, in the Libyan Desert, where surveys were carried out by, *inter alia*, Farouk El-Baz and colleagues (El-Baz *et al.* 1979).

Over this period geomorphologists became more professional and research became more applied (see **Griffiths and Lee 2021**, this volume). Engineering geomorphology developed in the early 1970s, with Peter Fookes (1933–2020) (Fig. 11) playing a major role (Lee and Fookes 2015). In The Netherlands, the contribution of Herman Theodoor Verstappen was paramount. The development of the oil-rich states of the Middle East spawned consultancy studies (Cooke *et al.* 1978). Notable was the Bahrain Surface Material Resources Survey (Doornkamp *et al.* 1980). Cooke and Doornkamp (1990, p. 5) noted that in the UK geomorphologists were being employed at the Institute of Hydrology, the Nature Conservancy Council, the Institute of Oceanographic Sciences, the Transport and Road Research Laboratory, the Land Resources Division of the Ministry of Overseas Development, the Soil Survey of England and Wales, and regional water authorities. They also named engineering companies who had used the advice of geomorphologists, and listed foreign agencies and governments for whom geomorphologists had worked, including FAO, UNESCO, World Bank, Bahrain, Egypt, Saudi Arabia, UAE, Oman, Sri Lanka, Hong Kong, Honduras, Bangladesh and Colombia. They discerned that the same developments could be recognized in Europe, India, China and Australia. Particularly in the 1960s and 1970s, geomorphologists were employed to undertake geomorphological mapping (see Smith *et al.* 2011; Griffiths 2019; Hearn 2019) and terrain evaluation for military and development purposes. The role of CSIRO, initiated in the 1940s by C.S. Christian and G.A. Stewart in Australia, is an illustration of the latter type of work, while Mitchell *et al.* (1979) and Kolb and Van-Lopik (1963) indicate the former type of work in the UK and the USA, respectively. With the help of European funding, some major collaborative programmes were instigated, including TESLEC (The temporal stability and activity of landslides in Europe with respect to climatic change) (Dikau and Schrott 1999) and MEDALUS (Mediterranean Desertification and Land Use) (Brandt and Thornes 1996).

A major cause for international and cross-disciplinary co-operation during the period was the emergence of geoarchaeology – a term first used by Karl Butzer in 1973, and which led to the establishment of a new journal – *Geoarchaeology* – in 1986. Butzer's contribution was formative (Cordova *et al.* 2017; Beach *et al.* 2019). From the late 1970s, a number of works defined the field and the position of geomorphology within in it (e.g. Davidson and Shackley 1976; Hassan 1979; Rapp 1987; Waters 1991). Major studies were undertaken in India by Rajaguru and colleagues (Wadia *et al.* 1995).

Working with archaeologists, geomorphologists investigated the effects of climatic, tectonic and sea-level changes on human societies (e.g. Pirazzoli 1976; Flemming 1999; Fouache *et al.* 1999), they assessed the relationship of archaeological sites to geomorphological settings, including dunes (Allchin *et al.* 1978), arroyos (Waters 1991), colluvium (Watson *et al.* 1984) (Fig. 12), tufas (Brookes 1993), caves (Farrand and McMahon 1997), lakes and lunettes (Bowler *et al.* 1970; Holliday 1985), coastal erosion and construction (Goudie *et al.* 2000), deltas (Wells 1992), old river systems (Butzer

Fig. 11. Peter Fookes (left) with Ron Cooke, Bahrain, 1974. Source: photograph by A.S. Goudie.

Fig. 12. An eroded gully system (donga) developed in colluvium in the Middleveld of Eswatini and containing archaeological materials from the Late Pleistocene and the Holocene. Source: photograph by A.S. Goudie.

and Hansen 1968; McHugh *et al.* 1988), badlands (Kuehn 1993), and alluvial deposits (Vita-Finzi 1967; Lewin *et al.* 1995; De Dapper *et al.* 1996; Brown 1997). They also sought to relate site preservation to site erosion (Wainwright 1994) and burial (Blum *et al.* 1992), considered the effects of weathering on the deterioration of sites (Goudie 1977), and related rock varnish formation to rock art development (Cremaschi 1996). Geoarchaeologists were also concerned with the effects of early humans on landforms and rates of erosion (e.g. Bell and Boardman 1992).

The role of women

For much of its history, geomorphology was a man's world. Even by the middle of the twentieth century, women still constituted a small number of the professional population, but they were slowly increasing their participation in more significant occupations, including law, academia, engineering and medicine, but progress was slow in geomorphology. However, since the 1950s, an increasing number of women (Fig. 13) have made contributions to the discipline, including presentation of papers to Binghamton Symposia (Sawyer *et al.* 2014). Sack (2004) drew attention to the role of Cuchlaine King in the UK, Joyce Brown Macpherson in Canada, and Barbara Borowiecki, Marie Morisawa and Jacqueline Mammerickx in the USA. Hart (2007) pointed to the inspirational role of Marjorie Sweeting (the doyenne of karst geomorphologists), Gillian Groom, Jean Grove and Cuchlaine King in the UK, and to that of Margaret Marker in South Africa. In a discussion of women glaciologists, Hulbe *et al.* (2010) drew attention to Jean Grove and Cuchlaine King.

King was a great geomorphologist who undertook field research in some challenging Arctic locations (Whalley 2020), and, as Everett (2020) wrote:

> She never bemoaned the lack of opportunities afforded to women in the 1950s and 1960s, but created her own, breaking down barriers to progress for future generations who, sometimes literally, followed in her footsteps. She was a prolific and influential researcher, writing books and publishing influential articles on her specialist subjects, glaciation and coastal erosion, both of which have such resonance today in relation to climate change.

Fig. 13. Two British female geomorphologists who were very influential in the second half of the twentieth century: (**a**) Cuchlaine King (1922–2019) and (**b**) Marjorie Sweeting (1920–94). Source: photographs by A.S. Goudie.

Her texts on coasts and on oceanography were influential (Dixon *et al.* 2021), as was her book on *Quantitative Geography* (Cole and King 1968). Marjorie Sweeting was the leading karst geomorphologist of the age and worked all over the world, not least with Chinese colleagues in China. She also inspired generations of Oxford women undergraduates (Goudie *et al.* 1987; Goudie 1995; Viles 1997) and supervised more than 30 graduates, many of whom went on to have successful research careers themselves (Baigent *et al.* 2019). The British Society for Geomorphology named its prize for the best undergraduate dissertation in geomorphology the Marjorie Sweeting Award in her honour. Jean Grove played a similar role at Girton College in Cambridge, in addition to her seminal work on glaciers and the Little Ice Age (Goudie 2001; Whalley 2009). She attended Howell's School, Denbigh, Wales, where Marjorie Sweeting was then teaching; and as a result she decided to read geography at Cambridge. She earned her PhD in glaciology from Bedford College, London, in 1956.

Considering some of the above individuals, Margaret Marker (1932–2015), an Oxford graduate and a pupil of Marjorie Sweeting, was a significant presence in South Africa during the apartheid era, and was Professor and Head of the Department of Geography at the University of Fort Hare, where she taught and encouraged black students (Holmes 2016). Marie Morisawa (1919–94) was a fluvial geomorphologist with catholic interests, who spent much of her career at Binghamton, where she co-started the annual symposia (Coates 1995). Barbara Borowiecki (1924–2016) was a glaciologist at the University of Wisconsin-Milwaukee, where she was professor from 1960 to 1992 (https://www.dignitymemorial.com/obituaries/springfield-il/barbara-borowiecki-6851600 accessed 26 April 2020). Jacqueline Mammerickx, a marine geomorphologist, was born in the Belgian Congo in 1935, was educated at the University of Louvain in Belgium, went to the USA in 1961, undertook work on pediments in the SW USA, and then, in 1965, went to the Scripps Institution of Oceanography, from which she retired in 1993 (http://scilib.ucsd.edu/sio/oral/Mammerickx.pdf accessed 26 April 2020). Joyce Brown Macpherson was a glacial geomorphologist who worked in Newfoundland and the Montreal region of Canada, and worked at the Memorial University of Newfoundland from 1966 to 1994 (https://www.mun.ca/geog/people/faculty/jmacpherson.php accessed 27 April 2020).

Jane Soons (Fig. 14), another glacial geomorphologist, played a particularly important role in New Zealand, where she was Canterbury University's first female professor in 1971. Other significant figures who were writing between about 1965 and 1995, included: Barbara Kennedy (Church 2014), Anne Wintle, Rita Gardner, Helen Rendell, Jane Hart, Janet Hooke, Alayne Street-Perrott, Angela Gurnell and Hazel Faulkner in the UK; Nicole Petit-Maire, Monique Fort, Yvonne Battiau-Queney, Yvette Dewolf and Marie Françoise André in France; Hanna Bremer and Helga Besler in Germany; Maria Sala in Spain; Christine Embleton-Hamann in Austria; Karna Lidmar-Bergström and Else Kolstrup in Sweden; Deidre Dragovich and Ann Young in Australia; Denise Reed, Ellen Wohl and Dorothy Sack in the USA; Ana L. Coelho Netto, Maria Regina Mousinho de Meis and Lyliam Coltrinari in Brazil; Suzanne Daveau in Portugal; Cheryl McKenna-Neuman and June Ryder in Canada; Kate Rowntree in South Africa; Paola Fredi in Italy; Rivka Amit in Israel; and Wang Ying in China.

Fig. 14. Jane Soons was a President of INQUA. She was educated at a school in Lincolnshire, where Margaret Thatcher was a contemporary, and at the universities of Sheffield and Glasgow, which awarded her an Honorary DSc in 2009. Source: photograph by A.S. Goudie.

The growing contribution of women to glacial studies is discussed by Hulbe *et al.* (2010). This makes it evident that it was only after about 1980 that their contribution started to grow. Nevertheless, women have still been outnumbered by men. For example, of the 20 editors of the *Proceedings of the First International Conference on Geomorphology* in 1986 (Gardiner 1987), only one (Marjorie Sweeting) was a woman. Not one woman was given the Kirk Bryan Award of the Geological Society of America Quaternary Geology and Geomorphology Division between 1958 and 1999 (https://en.wikipedia.org/wiki/Kirk_Bryan_Award accessed 17 April 2020). Equally, not one woman received the G.K. Gilbert Award of the Geomorphology Speciality Group of the Association of American Geographers between 1983 and 1999 (https://aag-gsg.org/awards/gk_gilbert_award/ accessed 17 April 2020). In 1998, Dumayne-Peaty and Wellens found that in British geography departments only about 20% of geomorphology staff were women, although the figures for postgraduate students and postdoctoral researchers were higher at 35 and 53%, respectively. Even at the present time, a striking gender imbalance is still evident. Of the 48 Fellows of the British Society for Geomorphology only seven are women (https://www.geomorphology.org.uk/list-bsg-fellows accessed 17 April 2020).

Conclusions

Since the mid-1960s there have been numerous developments in geomorphology. One was the establishment of national groups, including the Binghamton Geomorphological Symposium and the BGRG. However, there was also a burgeoning of international organizations and collaborations, including various IGU commissions, the IAG, AGU and the EGU. In addition, new journals were established and textbooks published. The period also saw the beginning of the World Wide Web's influence on teaching and research. Research stations were established, international research projects were organized by bodies such as the RGS, links were established with China, European countries established research programmes overseas and the emergence of geoarchaeology saw an increasing international collaboration with archaeologists. Finally, the role of women in the discipline started to develop, with some pioneers leading the way in both teaching and research. By the end of the twentieth century, geomorphology had become a truly international discipline, ranging from research collaboration around the globe and large international conferences to easily accessed online resources, notably journals. The Internet apart, the study period also saw the advent of the electronic age, influencing all aspects of the subject from field and laboratory measurement to sophisticated computer models, which was barely imagined in 1965. Many of the reviews that follow delve deeply into these technical advances and assess their influence on theory and practice.

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