3
Geography and GIS

R J JOHNSTON

Geographers study three major concepts – environment, space, and place – but their approaches to these have varied considerably over recent decades, incorporating three very different conceptions of science and views of the world: all of these can be encapsulated into 'geography as spatial science' and 'geography as social theory'. As reviewed here, most applications of GIS to date have fallen within the first of these categories: their utility in the latter is also discussed.

1 INTRODUCTION

There are very strong links between GIS and the academic discipline of geography, which extend well beyond the commonality of titles. The academic discipline has been the 'home' for much of the research, development, and training for GIS practitioners, and some see GIS as a major element in the discipline's 'survival package' for the foreseeable future, in a period of considerable pressures on public sector funding for academic work (see Gober et al 1995, on employment prospects for geographers in the USA). Nevertheless, the discipline embraces a great deal more than GIS and, as Openshaw (WWW 1996) has argued, much of what is done with GIS has very little to do with that discipline as generally practised: over 90 per cent of all applications, he claims, are 'of no significant consequence to people and society. They ... are concerned with the management of the physical infrastructure ... [and] involve little more than a digital replacement for various large-scale paper map-making, recording and handling industries'. This chapter looks at the context within which much GIS work has been, and continues to be, nurtured, while recognising that the 'child' has grown immensely in stature and influence beyond the 'academic nest' in the last two decades.

Significantly, different views on the practice of geography have been advanced on several occasions over the last half-century, but core beliefs regarding the discipline's *raison d'être* have remained constant. There is little difference, for example, between Hartshorne's (1939) classic definitional statements:

'... geography is a science that interprets the realities of areal differentiation of the world as they are found, not only in terms of the differences in certain things from place to place, but also in terms of the total combination of phenomena in each place, different from those in every other place'

so that '... geography is concerned to provide accurate, orderly and rational description and interpretation of the variable character of the Earth's surface' which

'... seeks to acquire a complete knowledge of the areal differentiation of the world, and therefore discriminates among the phenomena that vary in different parts of the world only in terms of their geographic significance – i.e. their relation to the total differentiation of areas. Phenomena significant to areal differentiation have areal expression – not necessarily in terms of physical extent over the ground, but as a characteristic of an area of more or less definite extent'.

through its updating (Hartshorne 1959):

'... geography is that discipline that seeks to describe and interpret the variable character from place to place of the earth as the world of man' and
'... geography is primarily concerned to describe... the variable character of areas as formed by existing features in interrelationships'.

and McDowell's (1995) modern rendering, that geography is a discipline '... whose *raison d'être* is the explanation of difference and diversity' (1995: 280) with geographers needing '...theoretical perspectives that not only permit the elucidation of the main outlines of difference and diversity, of the contradictory patterns of spatial differentiation in an increasingly complex world, where ever-tighter global interconnections coexist with extreme differences between localities; but perspectives that also allow us to say something about the significance of these differences.' Geography remains the study of differences across the Earth's surface.

Throughout this period, geographical research and writing have focused on three main concepts:

1 *Environment* – or nature
2 *Space*
3 *Place*

although the relative stress placed on each, and on their interactions, has varied somewhat. Geographers are concerned with the where, how, and why of the physical environment on which material life is based, the spatial organisational structures erected and operated by human societies to sustain and promote their material well-being, and the nature of the places which they have created within those structures. In pursuing those interests, they have engaged with a variety of approaches to science, and applied their findings in a number of separate ways.

2 APPROACHES TO SCIENCE

Discussions of the nature of science reflect not only the changing worlds in which scientists live and work but also their own varying conceptions of what comprises knowledge, how it can be obtained, and to what purposes it should be used. This literature is simplified into a typology containing just three categories, each of which has been used and argued about within geography in recent decades.

The first type (that most associated with the term 'science') is the *empirical*, which contains several sub-categories. Knowledge is acquired through direct experience, especially visual: its production involves accurate observation, and its propagation calls for unambiguous reportage. Within empirical science, therefore, facts speak for themselves. The scientist, having decided what to study, is a neutral observer-reporter, presenting material using accepted languages and categories (and, if necessary, proposing extensions to them). The acid test of the validity of a piece of science is that when replicated it produces the same outcome.

Many empirical scientists seek not only to describe accurately but also to explain: geographers aim both to show what is where and to indicate why. Positivist empirical science explains through generalisation: an event is accounted for as an occurrence of the operation of one or more general laws, whose identification is the scientists' goal. (Logical positivist science claims that there is no other route to knowledge.) Scientific laws can be used to predict, and that power is associated with the power to change, applying scientific findings to achieve certain ends.

The empirical sciences are founded on a belief in a separate world outside and independent of any individual observer, and some claim that its methods are equally valid in the social as in the natural sciences – in human as well as physical geography. The *hermeneutic* sciences challenge that: in them, nothing exists outside the observer, because any perception of an empirical event involves interpretation, using human constructs (especially language) to give meaning to what is being recorded. Individuals ascribe meanings to the worlds they live in, and act according to those meanings, so understanding an action involves appreciation of the meanings on which it was based. Natural scientists operate in this way as well as social scientists, but whereas the latter study the creation and transmission of meanings by human actors the natural scientist's subject matter comprises phenomena lacking the distinguishing features of 'humanness' – memory and reason.

The hermeneutic social sciences study people continuously interacting with their natural and human environments – individuals learning and using their powers of reasoning to interpret their observations, in often-changing situations. Explanation through generalisation is not possible,

therefore, since humans cannot be equated with machines which always respond in the same way to given stimuli: they may react differently because of their learning processes (which may involve reinterpretation of the stimulus itself), or because the stimuli and the contexts in which they are encountered are changed. Instead of explanation, therefore, hermeneutic science advances understanding, appreciation of why people acted in particular ways: this promotes awareness of the past and the present, and provides a guide to the future, but no more.

The final type of science – the *critical* – promotes explanation, but not necessarily through generalisation. Underpinning these sciences is a belief that observation is insufficient to appreciate the world, so that theories are needed which can account for the hidden structures involved in creating what is recorded by the senses – the theories must be consistent with the outcomes of those hidden processes. The 'law of gravity' exemplifies this. Gravity cannot be observed: all that can be recorded is behaviour which is consistent with its assumed operation. The law is accepted as valid because of its successful predictive power in repeated experiments under controlled conditions; if it should fail, however, then its validity in similar circumstances must be reconsidered.

Application of the rules of the hidden structures in the subject matter studied by social scientists involves human interpretation and action, as argued in the hermeneutic sciences. Biological drives demand food and liquid sustenance in humans, for example, but what foods and liquids is not determined: people individually and collectively decide how to meet those needs, not by making *ad hoc* decisions every time that they are thirsty and hungry but by developing strategies to meet their requirements on a regular basis. Those strategies vary over time and space, reflecting the conditions within which they are developed (such as the environmental context), the processes of learning, and the lessons which are passed on (as part of a society's cultural inheritance). Their outcomes may be inscribed in the landscape – as with land-use patterns which reflect food-raising strategies. The strategies may occasionally be reconsidered – either as a matter of urgency (because of a crop failure following an environmental disaster, for example) or more slowly (as population pressure on environmental resources builds).

The critical sciences identify three 'domains of interest':

1. The *real*, comprising the underlying, unobservable, mechanisms;
2. The *actual*, involving the operation of those mechanisms;
3. The *empirical*, which is the outcome of those operations.

In the natural sciences, the law of gravity occupies the first level: it is put into operation at the second level when rain falls, for example; and the empirical outcome is the rain's impact on the landscape. In the social sciences, both the biological drives necessary to human survival and the mechanisms put in place to sustain them socially occupy the domain of the *real* – as with the capitalist and socialist modes of production which have evolved to ensure individual and collective well-being, and improving material standards. The domain of the *actual* involves implementing those mechanisms, the myriad decisions made by 'knowing individuals' applying the fruits of their own learning and acquired meanings within the 'rules'; and the domain of the *empirical* contains the outcomes – which become part of the context within which future decisions on operating the mechanisms are made.

In both natural and social science it is possible to observe the outcomes and the procedures by which they are generated, but not the underlying mechanisms – one can no more 'see' capitalism than one can 'see' the law of gravity, so that the nature of each has to be inferred (or theorised) and the validity of that thought process evaluated against reality. Beyond this similarity there is a major difference between the two, however. The law of gravity is assumed to be invariant, and nothing that humans can do will remove it: it is an enduring fact. The mechanisms studied in the social sciences are not invariant: not only are they human creations which can be destroyed by human action but they are also continually being changed, as societies respond to situations in the light of previous decisions and their consequences. Hence, whereas a critical realist approach to the natural sciences underpins the search for explanation via generalisation (since the mechanisms are invariant and all that can alter is how they are put into operation) such a strategy is not viable in the social sciences, since the same conditions may never be repeated: events in the natural sciences may be unique; in the social sciences they may be singular (Johnston 1989).

The three types of science – empirical, hermeneutic, and critical – represent different world-views, different conceptions of how the world can be understood. They are incommensurate and cannot be evaluated for their validity against some external criterion: choosing a world-view involves determining one's conception of what is involved in achieving understanding. Each world-view contains a number of separate approaches (sometimes termed disciplinary matrices), different strategies accepted by scientists for achieving their desired ends. In turn, each of those strategies has its own detailed exemplars, paradigm instances of how the science should be done. When becoming a scientist, therefore, an individual adopts a world-view, a general orientation for her or his work. The next decision is which community to join, whose strategy to adopt. Finally, which detailed exemplar(s) to follow has to be determined. (These three decisions and scales are readily equated with Kuhn's paradigm model of scientific practice: Kuhn 1962 – and for its application to geography: Johnston 1997.) These decisions are not taken in isolation, of course: they are made during the process of becoming a scientist, of being socialised into its culture and accepting its norms, the would-be researcher already having decided his or her scientific subject-matter – what discipline to join. And they can be revisited, with different exemplars being adopted as the models to follow, different strategies being entertained, and even different world-views canvassed.

Those decisions are not irrevocable. Change is most likely at the level of the exemplar, or *modus operandi*: as science progresses so new ways of achieving its goals are identified and adopted by practitioners. It may occasionally occur at the intermediate level, when a scientist decides that one community's strategy is better than another's. Change is rare at the highest level, however, since this involves altering one's world-view which cannot be done 'objectively' against predetermined criteria: it involves deciding that one's approach to science to date has been entirely wrong, and that an alternative offers a 'better' path to understanding – and that decision is at root a subjective one, a 'leap of faith' from one cosmology to another. A number of geographers have made such leaps in recent decades, and many more have switched their preferred disciplinary matrix.

3 GEOGRAPHY AND THE SCIENCES

Over recent decades geographers have encountered, experimented with, and debated the relative merits of a range of approaches to science, at each scale. At the largest, whereas physical geographers have largely remained within the empirical world-view (Gregory 1985; see also Aspinall, Chapter 69), human geographers have embraced all three – with some individuals shifting conceptions (see Sheppard 1995) and many more being socialised into the one proving particularly attractive to their generation. Within each world-view, different strategies have attracted varying support – as exemplified among physical geographers by debates over the relative merits of logical positivism and Popperian critical rationalism (Haines-Young and Petch 1985) and among human geographers by the debates on the relevance of the 'economic man' model (see Barnes 1996; Johnston 1997). Within each strategy, the importance of different exemplars has waxed and waned: technical developments in the analysis of spatial data generated a major shift in methodological orientation between the two editions of Haggett's *Locational analysis in human geography*, for example (Haggett 1965; Haggett et al 1977). A third edition, prepared in the wake of developments in GIS since, would undoubtedly be a very different book yet again.

The history of geography in recent decades has been charted in a number of volumes and will not be repeated here (Gregory 1985; Johnston 1997). Instead, focus is on broad categorisations of how geographers approach their discipline – and why. Some have simply divided geographers into two camps, with separate world-views – the spatial analysts and the social theorists (Sheppard 1995): all physical geographers fall into the former, but human geographers are divided between the two (see Bennett 1989). In slightly more detail, Buttimer (1993) has identified four 'root metaphors' at the heart of different approaches to the discipline and four separate rationales for its study.

3.1 The root metaphors

Metaphor is basic to many approaches to science – it provides a way of moving from the known to the unknown, via analogy (Barnes and Duncan 1992; Barnes 1996). Root metaphors provide analogies for use in a wide range of circumstances.

Buttimer's (1993) first metaphor – *the world as a mosaic of forms* – involves the 'recognition of forms and patterns, similarities and differences, among people, places and events'. These are described – verbally or through other representational forms,

such as maps in geography – using 'language' which stresses their similarity (as with the centre/periphery model applied in a variety of contexts within human geography and the analogies between river systems and settlement patterns identified by Woldenberg and Berry 1967; see also Haggett and Chorley 1969, on networks). The approach provides a way of summarising the vast volumes of geoinformation now available: its main concern is description, saying what is where rather than why it is.

The second metaphor – *the world as a mechanical system* – emphasises the mechanisms that provide an explanatory base for the study of forms, as in developments in physical geography from the late 1960s when a 'systems approach' offered an integration of studies of processes and forms (Chorley and Kennedy 1971; and Bennett and Chorley 1978 promoted its application in human as well as physical geography).

Buttimer's third metaphor – *the world as organic whole* – focuses on the interrelationships among society and nature, using organic analogies to argue that the whole is greater than the sum of its parts. Whereas the mechanistic analogy promotes the study of order, rationality, and certainty, the organic concentrates on human individuality, identity, and ingenuity. The organic metaphor was initially applied to the identification of regions, territorial units in which society and milieu interacted to form identifiable niches in the spatial organisation of urban as well as rural worlds (on which see Gregory 1994; and Livingstone 1992).

Finally, *the world as arena of events* focuses on 'Events, in all their complexity, possible uniqueness, and contingency...; one looks for holistic understanding of particular events rather than ways of fitting them into some *a priori* schema of form, process, or organic whole.' (Buttimer 1993: 187). In its search for explanation this has similarities with the mechanistic vision (rather than the hermeneutic goal of the organic), but it rejects the search for universal truths and order underpinning the Enlightenment project that informs the mechanistic approach (Barnes 1996). It stresses pragmatic decision-making in the critical science mould, drawing conclusions within an embracing context of interpretations, as in the Marxist and realist approaches promoted by Harvey (1982) and Sayer (1992) respectively. This metaphor embraces a wide range of disciplinary matrices, including those such as postmodernism which promotes a relativistic

form of knowledge and denies the existence of universal truths; all accounts are incommensurate (having been produced within different contexts and from different positions) and thus are of equal value.

3.2 The metaphors in use

These four metaphors have varied in their application within the practice of geography. In physical geography, for example, the promotion of studying form rather than process led to its relative demise within the discipline in the United States for several decades (see Marcus 1979) – a situation not repeated in the UK (Johnston and Gregory 1994); the mechanical system metaphor now dominates. Human geography, on the other hand, has experienced considerable, continuing debate over their validity and significant variations in their relative importance (as chronicled in Johnston 1997). These variations have reflected changing emphases on the role of science and social science within society (on which see Taylor 1985). Buttimer (1993) identified four roles, or vocational meanings:

1 *Poesis* encourages curiosity about the relationships among individuals, society and nature by evoking geographical awareness;
2 *Paideia* promotes self-education through reflective practice regarding life and landscape;
3 *Logos* emphasises the search for order and generalisation via analytical rigour;
4 *Ergon* involves a focus on appropriate behaviour (applied geography) in the face of contemporary societal and environmental problems.

As a broad generalisation, the first two are associated with the organic and arena metaphors whereas the others are linked with form and mechanism.

Human geographers have long debated the validity of these metaphors and roles, characterised by Sheppard (1995) as a contest between spatial science and social theory. While that has continued, discussions have taken place within each camp regarding which disciplinary matrix to adopt and which exemplars to follow. Progress within each matrix has led to the replacement of some exemplars by others. With regard to GIS, this has occurred almost entirely within the spatial science world-view, involving the mechanism and form metaphors (and the virtual rejection of organism and arena) and the *logos* and *ergon* roles.

4 GIS AND GEOGRAPHY AS SPATIAL SCIENCE

Progress within geography as spatial science has been substantially linked to technical advances in the collection, collation, display, and analysis of data; computers with greater size, speed, and power have enabled the expansion of existing approaches and the introduction of new.

Several topics illustrate how GIS has enabled analyses which were previously technically extremely time-consuming, if not impossible.

- In the analysis of spatial form, maps of different phenomena are overlaid to identify correlations. This may involve the straightforward linking of point and area patterns, as in Ravenhill's (1955) investigations of the pattern of Celtic settlements in Cornwall. It may, however, involve attempts to link data from incommensurate sources, such as the classic paper by Robinson et al (1961) on areal correlations which related point (rainfall amounts) to area (population density) data through interpolation processes involving manually-created hexagonal tesselations.[1]
- In analyses of spatial diffusion using simulation techniques, time-consuming methods were employed to generate changing patterns over time using mean information fields (as in Hägerstrand's 1968 classic and works by his followers, such as Morrill 1965a, 1965b) – so much so that some simulations were based on a single iteration only (Robinson 1981).
- Although the ultimate focus of much research was on individual decision-making and behaviour, a great deal of the available data related to spatially-defined aggregates. Their analysis involved not only the ecological fallacy of inferring from a population (usually defined as those living in a particular area) to its individual members but also the aggregation and scale problems which exacerbated the difficulties of drawing valid conclusions. The simulation exercises involving what became known as the modifiable areal unit problem (MAUP: Openshaw 1977; Openshaw and Alvanides, Chapter 18) were further examples of time-consuming procedures which significantly constrained evaluation not only of the technical issues but also of the underlying substantive concerns (Wrigley 1995).[2]

In each of these, GIS technology has increased the efficiency of research endeavours many-fold,

illustrated for the first topic by Openshaw's proto-GIS work on the location of nuclear facilities (Openshaw 1986) and his 'geographical analysis machine' for the evaluation of significant clusters of disease outbreaks (Openshaw et al 1987). Their development does not eliminate decision-making regarding technical issues, as illustrated by the concerns of GIS researchers regarding how to integrate datasets compiled on incommensurate spatial frameworks (indeed in some ways they may extend them), but they make experiments much more easy to conduct.

In addition to improving the efficiency and effectiveness of existing research approaches, technological advances open opportunities for work in previously-closed areas. This is exemplified by 3-dimensional modelling of landscapes (Hutchinson and Gallant, Chapter 9) – for which the proto-technology (the Harvard mapping package) was extremely limited and precluded interactive experiments involving, for example, altering perspective and changing various components of a map format.

The introduction of GIS to geographical research thus provided new exemplars for the conduct of original investigations and assisted progress in spatial science approaches to both human and physical geography: use of the form and machine metaphors was significantly enhanced. These changes occurred during a period of very considerable debate over the use to which science should be put and the priorities over investment in its enhancement. In the early–mid 1980s, for example, the funding of new staff positions in British Universities under a competitive 'new blood' scheme focused substantially on investments in 'enabling technologies': of the 11.5 posts allocated to Departments of Geography, five were for work on remote sensing and digital mapping and three for mathematical modelling (see Smith 1985). More recently, investigations of the nature of posts vacated and filled in US university geography departments indicate a net growth in GIS specialists (Gober et al 1995; Miyares and McGlade 1994).

Of the various roles for geography-as-spatial-science, *ergon* has been promoted over *logos*, increasingly so in an economic environment which stresses the material gains to be derived from educational investment (Johnston 1995), on the grounds that successful technical applications are more likely to bring political (and thus financial) recognition for the discipline than are improvements

in explanatory power. Thus established location–allocation models are used in 'spatial decision-making systems' applied to questions regarding the optimal location of service facilities (Birkin et al, Chapter 51; Clarke and Clarke 1995). Some argue that the vast amounts of data available to geographers should be dredged in an empiricist fashion rather than addressed in a theoretically-informed context (Openshaw 1989: 73, refers to 'data-driven computer modelling in an information economy'; and see Openshaw and Alvanides, Chapter 18): their expertise with spatially-referenced data allows them to 'add value' to them, thereby making that expertise more saleable (see also Rhind 1989), as exemplified by the growing field of geodemographics which uses computer-generated classifications of ecological data to identify target markets for 'niche products' (Batey and Brown 1995; Birkin 1995). Openshaw (1994: 202) has argued that a combination of three recent developments – in large-scale parallel computing, the use of artificial intelligence, and what he terms the 'GIS revolution' – is stimulating the emergence of an 'IT State' characterised by:

'large scale, benign, universal data capture covering most aspects of modern life, the computerisation of virtually all of the management and control systems on which societies and economies depend, the linkage of separate computer systems, the dissolution of technical obstacles to systems integration by the emphasis on open systems, and the increased reliance on computers at all levels and all scales for the continuation of life on Earth'.

This offers the potential of a new mode of 'computational geography ... sufficiently broadly defined, generic in its technology, and flexible in philosophical outlook so as to encompass most, if not all, areas of human and physical geography' (208–9; see also the discussions in Openshaw and Alvanides, Chapter 18 and Longley et al, Chapter 72). Despite that claim, however, Openshaw has yet to convince many (mainly human) geographers committed to organism and arena, poesis, and paideia that GIS has much to offer them and their research agenda.

5 GIS AND GEOGRAPHY AS SOCIAL THEORY

The division within geography between spatial scientists and social theorists, the association of GIS with the former, and the intensity of some of the

debate between the two camps (including over GIS: see Johnston 1997) have largely blocked substantial exploration of the potential for GIS (and the 'IT State' more generally) within the latter camp. Gilbert (1995) argued that:

'The use of computers in geography has been stunted by identification with ... GIS, by both its proponents and critics. By and large geographers have come to regard computers as analytical machines, and have ignored their growing potential as a distinctively new mode of expression.'

Computers are much more than ever-faster and more-powerful calculating machines, but within geography the continuity of personnel from spatial science into GIS has created a barrier to this realisation among social theorists, despite the increasingly widespread use of multi- and hyper-media within the humanities.

This has come about despite the early use of a proto-GIS in one of the pioneer hypermedia educational tools – the BBC Domesday project of 1986 (Openshaw et al 1986). This integrated textual and visual material in novel ways, since very significantly enhanced. Spatial scientists increasingly employ hypermedia in decision-support systems, whereby a range of digitally-coded spatial data (remotely-sensed images, maps, other images, video etc.) is combined with textual and other material to aid a range of projects (Shiffer, Chapter 52; Raper and Livingstone 1995). Such usages have been subject to substantial critiques (as in several of the contributions to Pickles 1995) and the role of GIS in creating new images of the world is increasingly appreciated (Roberts and Schein 1995),[3] but the technology's positive potential has been submerged under the weight of this (usually valid) assessment of likely negative impacts.

A central argument of geographers attracted to the postmodernist disciplinary matrix is its emphasis on variety in both space and time that cannot be readily captured by conventional literary forms and styles – contemporaneity is extremely difficult to express (see the attempt by Pile and Rose 1992). Hypermedia make this much more possible, allowing what Gregory (1989) refers to as alternative textual strategies 'which do not attempt to reduce differences and fragmentations to a single overarching account, particularly where there is a concern to convey the spatial simultaneity of different experiences' (Gilbert 1995: 8) which allow 'changes in perspective,

jump-cuts and cross-cuts between scenes, dislocations of chronology and composition, commentaries on the construction of the text by author and reader, and so on'. (See also Crang 1992, on polyphony.) The ability to integrate textual and other materials (including moving images with sound) would enable exploration of many of the issues raised by adherents to the postmodernity approach (as well as, more prosaically, allowing readers to refer to illustrative material alongside the relevant text, and to access cited material without relying on the – potentially biased – selection made by another author; they need not depend on the world as represented to them by someone else, but can access the world directly themselves).

6 CONCLUSION

There have been many changes in the practice of geography over recent decades, but the discipline has sustained its core concern with spatial variations in the nature of and the interactions among environment, space, and place. Four separate world-views, each with a number of associated disciplinary matrices and their paradigm exemplars, have been called on to address these concerns – with four separate 'applied goals'. These have been reduced in this brief discussion to just two major world-views – spatial science and social theory – with their associated applications.

Over the last decade, GIS has been associated with the former world-view – largely because of its perceived strong links with the technical apparatus and empiricist/positivist aims of spatial science. It has both increased the efficiency and efficacy of established research directions therein and opened up other possibilities. By contrast, applications within geography-as-social-theory have been few, and its potential within hypermedia and other applications largely ignored; the challenges thus remain massive and should be extremely fruitful.

Endnotes

1 The hexagons were not regular, because of an error by one of the researchers (personnel information).

2 As in several other areas, Stan Openshaw's creative abilities as computer programmer partially overcame these (Openshaw and Taylor 1979).

3 As exemplified by the NCGIA's Initiative 19 – 'GIS and society: the social implications of how people, space and environment and represented in GIS'. This addressing the

forms of representation adopted and rejected in GIS applications, the level of empowerment which user groups obtain, the ethical and regulatory issues raised by GIS applications, and the potential for using GIS in democratic resolutions of social and environmental conflicts.

References

Barnes T J 1996 *Logics of dislocation: models, metaphors, and meanings of economic space*. New York, Guilford Press

Barnes T J, Duncan J S 1992 Introduction: writing worlds. In Barnes T J, Duncan J S (eds) *Writing worlds: discourse, text & metaphor in the representation of landscape*. London, Routledge: 1–17

Batey P, Brown P 1995. In Longley P A, Clarke G (eds) *GIS for business and service planning*. Cambridge (UK), GeoInformation International

Bennett R J 1989 Whither models and geography in a post-welfarist world. In MacMillan W (ed.) *Remodelling geography*. Oxford, Basil Blackwell: 373–90

Bennett R J, Chorley R J 1978 *Environmental systems: philosophy, analysis and control*. London, Methuen

Birkin M 1995 Customer targeting, geodemographics, and life-style approaches. In Longley P A, Clarke G (eds) *GIS for business and service planning*. Cambridge (UK), GeoInformation International

Buttimer A 1993 *Geography and the human spirit*. Baltimore, Johns Hopkins University Press

Chorley R J, Kennedy B A 1971 *Physical geography: a systems approach*. Englewood Cliffs, Prentice-Hall

Clarke M, Clarke G 1995 The development and benefits of customised spatial decision support systems. In Longley P A, Clarke G (eds) *GIS for business and service planning*. Cambridge (UK), GeoInformation International: 227–46

Crang P 1992 The politics of polyphony: reconfigurations in geographical authority. *Environment and Planning D: Society and Space* 10: 527–49

Gilbert D 1995 Between two cultures: geography, computing, and the humanities. *Ecumene* 2: 1–13

Gober P A, Glasmeier A K, Goodman J M, Plane D A, Stafford H A, Wood J S 1995 Employment trends in geography. *The Professional Geographer* 47: 317–46

Gregory D 1989 Areal differentiation and postmodern human geography. In Gregory D, Walford R (eds) *Horizons in human geography*. London, Macmillan: 67–96

Gregory D 1994 *Geographical imaginations*. Oxford, Blackwell

Gregory K J 1985 *The nature of physical geography*. London, Edward Arnold

Hägerstrand T 1968 *Innovation diffusion as a spatial process*. Chicago, University of Chicago Press

Haggett P, Cliff A D, Frey A E 1977 *Locational analysis in human geography,* 2nd edition. London, Edward Arnold

Haggett P 1965 *Locational analysis in human geography.* London, Edward Arnold

Haggett P, Chorley R J 1969 *Network models in geography.* London, Edward Arnold

Haines-Young R, Petch J R 1985 *Physical geography: its nature and methods.* London, Harper and Row

Hartshorne R 1939 *The nature of geography: a critical survey of current thought in the light of the past.* Association of American Geographers: 21, 462–3

Hartshorne R 1959 *Perspective on the nature of geography.* Chicago, Rand McNally/London, John Murray

Harvey D 1982 *The limits to capital.* Oxford, Basil Blackwell

Johnston R J 1989 Philosophy, ideology, and geography. In Gregory D, Walford R (eds) *Horizons in human geography.* London, Macmillan: 48–66

Johnston R J 1995 The business of British geography. In Cliff A D, Gould P R, Hoare A G, Thrift N J (eds) *Diffusing geography: essays for Peter Haggett.* Oxford, Blackwell: 317–41

Johnston R J 1997 *Geography and geographers: Anglo-American human geography since 1945,* 5th edition. London, Edward Arnold

Johnston R J, Gregory S 1994 The United Kingdom. In Johnston R J, Claval P (eds) *Geography since the Second World War, an international survey.* London, Croom Helm: 107–31

Kuhn T S 1962 *The structure of scientific revolutions.* Chicago, University of Chicago Press.

Livingstone D N 1992 *The geographical tradition: episodes in the history of a contested enterprise.* Oxford, Blackwell

Marcus M G 1979 Coming full circle: physical geography in the twentieth century. *Annals of the Association of American Geographers* 69: 521–32

McDowell L 1995 Understanding diversity: the problem of/for theory. In Johnston R J, Taylor P J, Watts M J (eds) *Geographies of global change: remapping the world in the late twentieth century.* Oxford, Blackwell: 280–94

Miyares I M, McGlade M S 1994 Specialisation in 'Jobs in Geography' 1980–1993. *The Professional Geographer* 46: 170–7

Morrill R L 1965a *Migration and the growth of urban settlement.* Lund, C W K Gleerup

Morrill R L 1965b The negro ghetto. *The Geographical Review* 55: 339–61

Openshaw S 1977 A geographical study of scale and aggregation problems in region-building, partitioning, and spatial modelling. *Transactions of the Institute of British Geographers* NS2: 459–72

Openshaw S 1986 *Nuclear power: siting and safety.* London, Routledge

Openshaw S 1989 Computer modelling in human geography. In MacMillan W (ed.) *Remodelling geography.* Oxford, Blackwell: 70–88

Openshaw S 1994 Computational human geography: exploring the geocyberspace. *The Leeds Review* 37: 201–20

Openshaw S 1996b GIS and society: a lot of fuss about very little that matters and not enough about that which does! In Harris T, Weiner D (eds) *GIS and society*: the social

implications of how people, space and environment are represented in GIS. Scientific report for the Initiative–19 Specialist Meeting, 2–5 March 1996, Koinia Research Center, South Haven, NCGIA Technical Report 96–7: D54–D58. Santa Barbara, NCGIA

Openshaw S, Taylor P J 1979 A million or so correlation coefficients: three experiments on the modifiable areal unit problem. In Bennett R J, Thrift N J, Wrigley N (eds) *Statistical applications in the spatial sciences.* London, Pion

Openshaw S, Wymer C, Charlton M 1986 A geographical information and mapping system for the BBC Domesday optical discs. *Transaction of the Institute of British Geographers* 11: 296–304

Openshaw S, Charlton M, Wymer C, Craft A W 1987 A Mark I geographical analysis machine for the automated analysis of point datasets. *International Journal of Geographical Information Systems* 1: 335–58

Pickles J (ed) 1995 *Ground truth: the social implications of geographic information systems.* New York, Guilford Press

Pile S, Rose G 1992 All or nothing? Politics and critique in the modernism–postmodernism debate. *Environment and Planning D: Society and Space* 10: 123–36

Raper J, Livingstone D 1995 The development of a spatial data explorer for an environmental hyperdocument. *Environment and Planning B: Planning and Design* 22: 679–87

Ravenhill W L D 1955 The settlement of Cornwall during the Celtic period. *Geography* 40: 237–48

Rhind D W 1989 Computing, academic geography, and the world outside. In MacMillan W (ed.) *Remodelling geography.* Oxford, Blackwell: 177–90

Roberts S M, Schein R H 1995 Earth shattering: global imagery and GIS. In Pickles J (ed.) *Ground truth: the social implications of geographic information systems.* New York, Guilford Press: 171–95

Robinson A H, Lindberg J B, Brinkmann L W 1961 A correlation and regression analysis applied to rural farm densities in the Great Plains. *Annals of the Association of American Geographers* 51: 211–21

Robinson V B 1981. In Jackson P, Smith S J (eds) *Social interaction and ethnic segregation.* London, Academic Press

Sayer A 1992 *Method in social science: a realist approach,* 2nd edition. London, Routledge

Sheppard E S 1995 Dissenting from spatial analysis. *Urban Geography* 16: 283–303

Smith D M 1985 The 'new blood' scheme and its application to geography. *Area* 17: 237–43

Taylor P J 1985 The value of a geographical perspective. In Johnston R J (ed.) *The future of geography.* London, Methuen: 92–110

Woldenberg M J, Berry B J L 1967 Rivers and central places: analogous systems? *Journal of Regional Science* 7: 129–40

Wrigley N 1995 Revisiting the modifiable areal unit problem and the ecological fallacy. In Cliff A D, Gould P R, Hoare A G, Thrift N J (eds) *Diffusing geography: essays for Peter Haggett.* Oxford, Blackwell: 49–71