CHAPTER 8

On the Ontological Status of Geographical Boundaries

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1 INTRODUCTION

Boundaries occupy a curiously ambivalent position in any geographical ontology. On the one hand, it seems uncontentious that the primary spatial elements of geography are regions of various kinds: regions are where we live and where things are located. From this point of view, boundaries are only of interest because they define the limits of regions. But precisely because of this, boundaries can acquire a life of their own. The existence of a boundary can have a palpable effect on the behaviour of objects and people in its vicinity. Disputes over territory automatically become focussed into disputes over boundaries, and the boundary itself can become a symbol for the territory it delineates: ‘Not only do boundaries give the country a shape, but they suggest a uniformity within that shape which separates it from the outside, from what is alien and foreign’ (Dorling and Fairbairn, 1997). Indeed, in ordinary speech there is a slippage between ‘within this region/area/territory’ and ‘within these boundaries/limits/borders’, pointing to the ease with which we can pass between thinking in terms of regions and thinking in terms of boundaries. The history of language itself can illustrate this. The English word *town,* for example, is derived from an Old English word *tun,* meaning an enclosure. It is related to the Dutch *tuin* which means a garden, an enclosure containing trees, grass and flowers rather than streets and buildings. The original meaning of the word appears to have been not the area enclosed but the fence or hedge which does the enclosing. This meaning persists in the cognate German form *Zaun,* which refers to the fence or hedge itself, not an enclosed area.

Boundaries embody many different functions. A boundary may be erected in order to keep captives in or to keep intruders out, or simply to prevent mixing. But boundaries can be crossed: physical boundaries such as walls usually include gateways or portals by which movement across the boundary is simultaneously facilitated and regulated. Thus there is another slippage in our thinking, between borders and border-crossings: ‘we’ll reach the border soon’ is said in the expectation of crossing it. Consider too how the notion of a *screen* has passed from being a barrier (as in a fire screen) to a bearer of images (painted on the fire-screen, or projected onto canvas) and thence to a kind of window into another world (television and computer screens).

The ambivalence of boundaries extends to their representation, both in maps and in information systems. Boundaries of a sort may be present in a representation even when the representation has no explicit symbols for them. As a child I had a wooden jigsaw puzzle, with pieces shaped like the counties of England and Wales. Each piece represented a county; so one could say that the *edge* of the piece represented the boundary of the county. But boundaries are not just 'boundaries *of*', they can be 'boundaries *between*' as well. When the puzzle was assembled, the boundaries between the counties were represented, implicitly, by the interstices between neighbouring pieces. So the puzzle showed the boundaries even though it contained no explicit boundary symbols. Likewise, in a map, the boundary between neighbouring regions can be shown implicitly as the line of contact between two differently coloured areas, or explicitly as a printed line. In vector-based geographical information systems, it is usual to specify the location of a region by specifying the location of its boundary. Does this mean that such systems necessarily include boundaries as elements within their ontology?

In this chapter I address some of the problems posed by geographical boundaries. I begin with a survey of different kinds of boundaries in an attempt to develop a reasonably comprehensive classification. I then consider relationships between the different kinds of boundary, examining how boundaries of one type can evolve into or otherwise give rise to boundaries of other types. This is followed by a discussion of some of the key properties of boundaries that are of relevance to the problems of how they should be represented. Finally, I examine how boundaries can be represented within the two main paradigms of geographical information science, the field-based and the object-based.

2 CLASSIFICATION OF BOUNDARIES

In this section I shall attempt a broad-brush classification of boundaries. The classification takes the form of a hierarchical tree structure, as shown in Figure 1. The top-level distinction is between *physical* and *institutional* boundaries. This corresponds closely with the distinction between 'bona fide' and 'fiat' boundaries introduced by Smith (1995), although his distinction and mine do not agree in every respect. Physical boundaries are in turn divided into *material* and *epiphenomenal* boundaries. In the case of the former, there is some material substance or phenomenon which constitutes the boundary, and the location of the boundary is the location of its material or phenomenal constituents. An epiphenomenal boundary depends on matter for its existence but has no material or phenomenal substance in itself. Each of these subclasses is itself subdivided; the details are given below. As is usual with the classification of a rich and varied domain, the distinctions here drawn are not in every case entirely clear-cut: some cases can be classified in different ways depending on how they are interpreted, and we may find intermediate cases which seem to occupy a middle ground between two positions in the classification.

2.1 Physical boundaries

All boundaries exist by virtue of the distribution of matter and energy in space and time, but boundaries may differ as to just how their existence depends on such

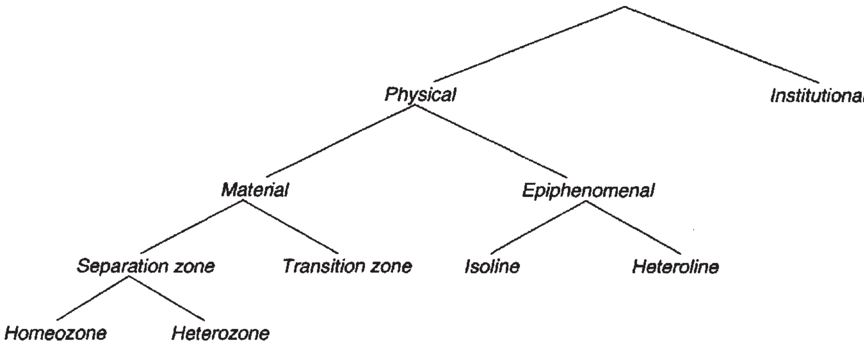

Figure 1: Classification of boundaries

distribution. For some boundaries, for example the International Date Line, the dependence of the boundary on the material facts is mediated by individual or collective human intentionality. These are institutional boundaries; all other boundaries are physical boundaries. Since the latter class is defined by exclusion, i.e., in terms of what they are not, it will turn out to be rather heterogeneous.

Amongst physical boundaries we distinguish *material* boundaries, which are, so to speak, *made of matter,* from *epiphenomenal* boundaries, which exist by virtue of the distribution of matter in space and time but are not themselves made of matter. Consider an area of woodland separated from the adjacent grassland by a wall. The wall is a material boundary between the woodland and the grassland. If it is removed, we may still speak of the boundary between the two regions, but now there is nothing material we can point to and say ‘this is the boundary’. The boundary now exists solely by virtue of the distribution of woodland and grassland in that area: it is epiphenomenal. Similarly, the peel of an orange is a material boundary between the interior of the orange and the outside world; the surface of the orange (which is also the surface of the peel) is an epiphenomenal boundary between the orange and the outside world.

2.1.1 Material boundaries

We may distinguish two kinds of material boundary, which I call *separation zones* and *transition zones.* In both kinds, the boundary occupies a zone—usually a ribbon-like band much longer than wide—whose material or phenomenal contents differ in character from those of the regions on either side. The distinction between the two kinds hinges on the nature of this difference in character. In a transition zone, the character is intermediate between that of one side and that of the other. In many cases there is a smooth gradation in character from one side, across the boundary, to the other. There are many different kinds of transition zone, according to the profile of the gradation; a preliminary classification is given by Plewe (1997). In a separation zone, the character of the zone is distinct from, and not intermediate between, the characters of the regions it separates. The separation zone may often be thought of as a *barrier;* but this is primarily a *functional* notion, characterised in terms of affordances rather than material constitution. If there is gradation between the regions on each side and the separation zone itself, then we have second-order material boundaries, transition zones between a separation zone and the regions it separates. If we regard a mountain range as a separation zone between two low-lying regions, then the foothills can be thought of as second-order transition zones of this kind.

Consider again the edge of a wood where it abuts on the neighbouring grassland. If there is a fence, wall, stream, or other such feature separating the woodland from the grassland, this is a clear case of a separation zone. Particularly in the case of a fence, this feature may be so narrow that the word 'zone' seems inappropriate. There may, of course, be no separator of this kind. One possibility is that the trees abruptly stop and the grassland takes over, in which case the boundary is epiphenomenal, not material; another possibility is that the trees gradually thin out, perhaps over a considerable distance, and here we have a transition zone. The distinction between separation zones and transition zones is not always clear-cut. Suppose there is a scrubby area populated by bushes between the woodland proper and the grassland. Is this scrub zone intermediate in character between the woodland and the grassland or not? No doubt many different aspects could be considered here, some of which would lead one to conclude that the scrub zone is a transition zone, others that it is a separation zone.

We can further subdivide separation zones according to the nature of what is separated. There seems to be a considerable difference between a river meandering through an otherwise uniform plain and a sandy beach separating sea and land. Both can function as boundaries, indeed as barriers, but whereas the river separates regions which are not in themselves distinct in character, the beach separates regions which could hardly be more different. Both are separation zones (though the beach also has a certain transitional character, as discussed more fully below), yet they do not seem to belong together. I therefore classify separation zones into *homeozones,* which separate like from like, and *heterozones,* which separate unlike regions. Since there can be degrees of likeness, there is a gradation between these two types; none the less, there are many clear-cut cases. The protective outer coverings of many everyday objects—the peel of an orange, the walls of a house, the bark of a tree, human skin—are clear cases of heterozones. In many cases features such as roads, railways, rivers, fences, and hedges are homeozones, although of course any of these can also be a heterozone, it being not intrinsic to their nature that they should separate either like from like or unlike from unlike. The walls of a house illustrate this: the exterior walls are heterozones, separating 'indoors' from 'outdoors', but the interior walls are homeozones, separating room from room. But if we were to focus on the different characters of different rooms, then we could come to see these internal walls as heterozones also.

2.1.2 Epiphenomenal boundaries

One kind of epiphenomenal boundary is an *isoline* for a field, defined as 'the locus of all points in the field with the same attribute value' (Worboys, 1995). This need not, of course, be a line, since there could be an area throughout which the field has constant value. Familiar examples of isolines are contours (isolines of elevation), isotherms, and isobars. In themselves they do not partake of the character of boundaries, except insofar as *any* line can be regarded as a boundary; but in particular cases they can give rise to more overtly boundary-like phenomena; some examples will be given below.

Epiphenomenal boundaries can also be defined in terms of what they separate rather than what they join, and in this case they are closer to our normal understanding of a boundary. An example is the 'isogloss' of dialectology, which is a line dividing areas with different speech forms. Despite their name, these are not isolines in the accepted sense, and for this reason some dialectologists use the more satisfactory term 'heterogloss'. In keeping with this, I shall use the term *heteroline* to refer to any line of separation between areas of different attribute values. The attribute takes some constant value *X* on one side of the line and a different constant value *Y* on the other side. All lines of latitude are isolines with respect to the continuous variable 'latitude', but certain geographically salient lines of latitude such as the equator, the tropics of Cancer and Capricorn, and the arctic and antarctic circles may be regarded as heterolines with respect to qualitative features of the annual apparent motion of the sun. Lines of longitude are more artificial, involving as they do an arbitrarily chosen base line, but they too can be regarded as examples of isolines, albeit rather marginal.

In all these cases the boundary is real but lacks physical substance; it is located in space but does not occupy space. It arises as a by-product of particular distributions of matter or energy (including human behaviour) over space and time. It should be emphasised that these are *not* 'fiat' boundaries in the sense of Smith (1995): although the equator is always described as an 'imaginary' line, it has a physical reality (even though no physical substance) that is independent of any human cognitive acts (although in common with many more substantial things it may require specific types of cognitive activity to *discover* it or think it worth considering). Still less are they the product of human intentions.

Epiphenomenal boundaries can exist as a result of human behaviour. Linguistic boundaries are of this kind, both boundaries between sharply distinct languages (e.g., between French and Flemish in Belgium), and dialect boundaries within a single language or closely related group of languages (e.g., between Low German and High German). These boundaries arise as an epiphenomenon of human behaviour patterns, but epiphenomenal boundaries can also *affect* human behaviour. Jones (1945) cites an interesting example given by F.Kingdon Ward, who noted that for the Tibetans, the 'invisible' barriers of the 50-inch rainfall contour and the 75 per cent saturated atmosphere are 'far more formidable…than the Great Himalayan range'.

The 'visibility' or otherwise of a boundary is, of course, relative to a means of 'seeing': implicitly, normal human perception. Imagine a piece of paper, so coloured that, when illuminated in white light, the left half reflects only monochromatic yellow light of wavelength 580nm, and the right half reflects a certain mixture consisting of red and green lights, of wavelengths 670nm and 540nm respectively. The proportion of the mixture can be selected so that the two sides of the paper are indistinguishable to humans with normal colour vision (Hurvich, 1982). Such a person would fail to see the boundary between the two halves of the paper, but that boundary certainly exists in physical reality. It can *become* visible, however: if the paper were viewed through a filter which absorbed light of wavelengths longer than 600nm, then while the left half would still appear yellow, the right half would now appear green, with the boundary between the two clearly visible. Thus the presence or absence of a physical boundary is a separate matter from its visibility or invisibility to a given observer under given conditions.

Often, visible epiphenomenal boundaries are caused by invisible ones. A common case is an isoline (or isoline bundle) giving rise to a heteroline. The area inhabitable by a given plant species will be limited by epiphenomenal temperature boundaries (isotherms), amongst other factors. The tree line encountered as one ascends a mountain, or moves north towards arctic regions, while still epiphenomenal, is the visible expression of a bundle of thermal boundaries pertaining to a variety of tree species. As usual with such boundaries, the details are complex and poorly understood (Tivy, 1971). Tree lines may be more or less sharp: in Europe, the altitudinal tree-line is much more sharply defined in the Alps than in the maritime north-west (Collinson, 1988). Likewise, altitudinal treelines are in general sharper than latitudinal ones. In the northern Alps, 'only a very narrow zone consisting of stunted, low forms provides the transition from forest to treeless alpine belt' (Walter, 1985, p. 209), whereas the transition from boreal forest to treeless tundra 'may extend for hundreds of kilometres' (ibid., p. 283). The existence of such a transition zone suggests the possibility of defining *two* lines, one to mark the boundary between the fully-fledged forest and the transition zone, and one to mark the boundary between the latter and the treeless area. Pears (1977) uses the terms 'timberline' and 'treeline', often treated as synonymous, to distinguish these, modelling his terminology on that used by some European ecologists: *Waldgrenze* ('the upper limit of tall, erect tree growth occurring at forest densities') and *Baumgrenze* ('the line through the last scattered trees on the mountain slopes'). The zone between the two lines is known as the *Kampfzone.*

Something similar occurred with Wallace's line, the boundary originally drawn by Alfred Russel Wallace in Indonesia to separate the area where the fauna is predominantly Asian (Oriental) in character from the area where it is Australian. He found the line to be particularly sharp between the islands of Bali and Lombok, only twenty miles apart but with very distinct faunas. North of there, Wallace drew the dividing line between Borneo and Sulawesi, and between the Philippines and the Moluccas. However, later observations led various researchers to draw the line in different positions; one such line, Weber's line, ran further east than Wallace's line; between them the faunas display intermediate character between the Oriental fauna to the west of Wallace's line and the Australian fauna east of Weber's line. Pielou (1979) declares that 'the whole zone, rather than either of the lines, is the true boundary separating the Oriental and Australasian regions'; the name Wallacea is sometimes given to this zone (Putman, 1984). Since this 'true boundary' is in fact an area, it should, like the *Kampfzone* of the forest margin, be regarded as a material boundary, not an epiphenomenal one. Wallacea is thus a region which can be characterised by the fact that its fauna involves an admixture of Oriental and Australasian elements, just as the *Kampfzone* is characterised by the fact that although it is inhabitated by trees, they do not grow at forest densities, and many of them are 'deformed, twisted, knarled, dwarfed, or prostrate in appearance due to the severe environmental regime at these levels' (Pears, 1977).

A series of epiphenomenal boundaries running roughly parallel to one another gives rise to a zonation. The sea-shore is a good example of this. The epiphenomenal boundaries in question are determined by the variation in tidal levels. Yonge (1949) identifies the shore as the region bounded by the extreme high water level of spring tides (EHWS) and the extreme low water level of spring tides (ELWS), and uses the average high tide level (AHTL) and the average low tide level (ALTL) to divide this into three zones, called the upper shore, middle shore, and lower shore, stating that '[t]his subdivision of the shore does appear best to correspond to our present knowledge of the vertical distribution of the shore population, while it has the merit of much greater simplicity than many previous schemes of subdivision'. Lewis (1964), however, does not find tidal zonation to be an adequate basis for characterising shore ecology, rather taking the view that 'the zones are biological entities which can only be defined by biological means' (Lewis, 1964, p.48). Thus Lewis's key boundaries are the upper limit of the *Littorina/Verrucaria* belt, the upper limit of barnacles, and the upper limit of *Laminaria* (i.e., kelp), these three boundaries defining a 'littoral zone' divided into the 'littoral fringe' and the 'eulittoral zone'. The position of these boundaries in relation to the EHWS and ELWS tidal levels varies greatly from shore to shore, being particularly sensitive to how sheltered or exposed the shore is.

Epiphenomenal boundaries exist in infinite abundance: we have only to define them. This reflects the continuous variation of so many of the measurable values in nature. If it suited us, we could define any number of other tidal levels on the shore, for example the points uncovered by 20 per cent of tides. We can choose any temperature we like and define the isotherm for that temperature; we can pick out the contour for any elevation. The boundaries we choose to define are motivated in some way, for example, because they are easy to define, using simple concepts like mean or extreme values, or 'round' numbers; or because they correlate with some visible features of the environment. Note that the virtue Yonge claims for his chosen subdivision of the shore comprises both these elements: it is simple, and it correlates with ecological zonation. To the extent that motivation by simplicity dominates, the epiphenomenal boundary acquires something of a 'fiat' character; to the extent that motivation by correlation with nature dominates, this fiat character may be negated. Thus epiphenomenal boundaries in general may be thought to occupy an ambiguous intermediate position between the most bona fide physical boundaries, and purely institutional ones.

2.2 Institutional boundaries

Institutional boundaries are those which are stipulated to exist by human fiat, for example in accordance with the terms of a peace treaty. They include all international boundaries and also intranational boundaries such as those between administrative regions, and those defining land ownership. Even where such a boundary is stipulated to follow some pre-existing physical boundary, it must still count as institutional. It is by human fiat, for example, that the boundary between the English counties of Devon and Cornwall is stipulated to follow the river Tamar. The fiat which legitimises the boundary also stipulates the coincidence of the fiat boundary with the pre-existing bona fida boundary. In fact, the strength of the attachment can be quite precisely defined in law: 'natural and gradual shifts of course move the boundary with the stream; changes in a river because of artificial alterations, or owing to sudden floods, do not' (Harley, 1975).

The terms 'accretion' and 'avulsion' have been used to refer respectively to gradual and sudden changes in the course of a river. The latter would include, in addition to artificial alterations and sudden floods, the cutting off of a meander to form an ox-bow lake, a phenomenon that occurred with some regularity in the Rio Grande along the USA-Mexico boundary, leading to the formation of pieces of land ('bancos') which belonged to the state on the other side of the river until the boundary was restored to the actual river course in 1905. Subsequent engineering works simplified the course of the river, leading to further boundary adjustments (Boggs, 1940; Jones, 1945; Prescott, 1965).

Institutional boundaries are generally conceptualised as lines in the Euclidean sense, i.e., as having length but no breadth. If a boundary is truly a line then the precision with which its location can be ascertained is limited only by our measurement capacities. Contrast this with the case of, say, a tree line, which it does not make sense to locate more precisely than the width of a typical tree, i.e., well within our measuring abilities—so that ascertaining the location of a tree line is not a problem of measurement but of definition.

There are some situations in which we seem to need to determine boundaries to arbitrarily fine precision. Ball games such as tennis are a case in point. Whether a ball is 'in' or 'out' depends on which side of a boundary line it first strikes the ground. The difficulty of ascertaining this in critical cases leads to frequent disputes. For the individual players, a good deal can hang on the outcome of such disputes: the loss of a game, a set, a match, a tournament, and all that that entails in terms of financial reward and public prestige. Tennis matches proceed under the implicit assumption that any ball is determinately either in or out, and it is up to us to determine which of these cases holds. When the ball lands close to the boundary, it becomes very unreliable to judge this by eye, and hence it is customary to employ automatic sensors. The reliability of these sensors is often questioned, not least by the players themselves.

The nature of fiat boundaries may be clarified by reference to Searle's theory of *institutional facts* (Searle, 1995). Searle lists six properties which characterise institutional facts, namely:

1. The self-referentiality of many social concepts (part of what makes an institutional fact true is the fact that some social group holds it to be true).
2. The use of performative utterances in the creation of institutional facts (e.g., 'I appoint you chairman', 'War is hereby declared').
3. The logical priority of brute facts over institutional facts.
4. Systematic relationships amongst institutional facts.
5. The primacy of social acts over social objects, of processes over products.
6. The linguistic component of many institutional facts.

With reference to international boundaries, we may note that (1) if *all* social groups cease to believe in the existence of some boundary, then that boundary no longer exists, even if the associated physical paraphernalia (fences, border posts, and the like) persist; (2) many international boundaries are brought into existence by the signing of a bilateral agreement between the parties concerned, and these signings function as performative utterances; (3) underlying their performative character, however, is the brute fact that on one occasion certain humans made particular marks on paper, and later, when the boundary was demarcated on the ground, various erections of stone or barbed wire, etc., were constructed along a linear series of spatial locations; (4) the existence of an international boundary is bound up with an intricate network of trade agreements, immigration procedures, social relations, etc., which together constitute a system; (5) the boundary, as an object, may, to paraphrase Searle, be regarded as in a sense just the 'continuous possibility' of the activities characteristically associated with boundaries, such as the formalised boundary-crossing procedures and the deflection of trajectories that would otherwise cross over the line delineated as the boundary; and finally, (6) the definition of the boundary as expressed in the signed agreement is partly constitutive of the fact of the boundary's existence.

An institutional boundary is distinct from any correlated physical boundaries. Searle imagines a 'primitive tribe' that builds a wall around its territory. This wall functions as a boundary 'in virtue of sheer physics': so far, it is not an institutional boundary. He now supposes that the wall 'gradually evolves from being a physical barrier to being a symbolic barrier', decaying to leave only a line of stones. If the inhabitants and their neighbours continue to *recognize* the line of stones as marking the boundary of the territory, it then functions as a boundary not in virtue of physics but 'in virtue of collective intentionality' (Searle, 1995, p. 39f). Searle contrasts the case in which the members of the tribe 'simply have a disposition to behave in certain ways', so that their behaviour is just like that of animals marking the limits of their territory, with the case in which they 'recognize that the line of stones creates rights and obligations, that they are *forbidden* to cross the line, that they are *not supposed* to cross it', in which case the stones now 'symbolize something beyond themselves; they function like words' (ibid., p. 71). In the former case we have an epiphenomenal rather than an institutional boundary. Searle's remarks indicate that there need be no clear dividing line between epiphenomenal boundaries and institutional ones.

3 DEPENDENCIES AMONGST BOUNDARY TYPES

I have referred several times to cases in which a boundary of one type can evolve into or otherwise give rise to a boundary of another type. Here I survey the range of possibilities a little more systematically. Since my classification recognises six different types of boundary, there are thirty possible types of transition of the form 'boundary of type *X* gives rise to boundary of type *Y*'. I do not discuss all thirty types separately: many of them can be considered together.

3.1 Institutional boundaries arising from physical boundaries

Searle's example of a physical wall decaying to a line of stones which is still respected as a boundary, having deontic rather than physical force, is a clear case of this category of transition. More generally, there are many examples where there appear to be 'natural' lines along which to draw an institutional boundary.

The coastline forms a natural boundary for any nation whose territory abuts the sea. For an island nation, this may form its entire boundary. Even in this case, though, we cannot simply identify the nation's boundary with its sea coast. The boundary of the nation (as opposed to that of the island) is institutional. It may be stipulated to follow the coast, but inevitably there are complications. International law distinguishes inland waters, territorial waters, and the high seas, and disputes often occur as to the exact locations of the boundaries between them. For example, it is usual to draw the boundary between territorial waters and high seas three nautical miles out from the low-water mark of the shore. Inland waters include so-called 'true bays'; but the definition of a true bay is contentious. In 1930, the Hague Conference for the Codification of International Law ruled that an indentation between two headlands less than 10 miles apart was to be classified as a ‘closed bay’ if its area exceeded that of the semicircle with the distance between the headlands as diameter, and an ‘open bay’ otherwise. With closed bays, the seaward boundary of the inland waters is taken to be the straight line joining the headlands, whereas with open bays that boundary is defined as the low-water mark following the sinuosities of the coast (Shalowitz, 1962).

Mountain ranges provide another ‘obvious’ type of physical boundary along which to draw an institutional boundary, but here too there are complications. Should the boundary follow the crest formed by the highest peaks, or the associated water-parting? In general these lines do not coincide; indeed, they may be many miles apart. Choosing one rather than the other can have curious consequences. In the Pyrenees, the boundary between France and Spain was settled by a treaty of 1659 to follow the line of the high peaks. This placed the town of Llívia, in the upper valley of the Spanish Ro Segre, on the French side of the border, even though in its economic and political affiliations it was Spanish rather than French. To rectify this a boundary was drawn round Llívia to form a Spanish enclave entirely surrounded by French territory, a status it has retained to this day—as documented at http://www.llivia.com/ (Peattie, 1944).

River boundaries are equally problematic, as we have already seen in relation to the Rio Grande. Once it has been decided that an institutional boundary is to follow a river, there remains the choice of exactly what line along the river it is to follow. There are three ‘natural’ choices: one of the banks of the river, the ‘median line’ (i.e., the locus of points equidistant from the two banks), and the ‘thalweg’ (i.e., the locus of lowest points of successive cross-sections along the river). The bank, if precisely defined, is a heteroline, otherwise a heterozone or perhaps a transition zone; the median line and thalweg are isolines (although these are not always well-defined). A bank is the most straightforward to identify *in situ,* but it leads to a gross asymmetry: one of the countries effectively owns the river. This is the case with the French-German border where it follows the course of the Rhine: the boundary is stipulated to follow the west bank, so the river itself is German.

Another frequent choice of line for an institutional boundary to follow are the astronomically defined ‘imaginary’ lines on the earth’s surface: lines of latitude and longitude. These are isolines. Boundaries of this kind are frequent amongst the American state boundaries, as well as providing a substantial part of the international boundary between Canada and the USA, which in its western portions follows the 49°N line of latitude—even to the extent of cutting off the tip of a peninsula extending southwards from Canadian territory, giving rise to a small US enclave, Point-Roberts.

In general, institutional boundaries are defined in terms of epiphenomenal rather than material physical boundaries. An institutional boundary should ideally take the form of a line rather than a zone, for a boundary zone must be declared neutral, and as such is susceptible to conflicting territorial claims from either side. It is pertinent here to recall the four main stages of international boundary-making, as expounded by Jones (1945): first, political decisions on the allocation of territory; second, delimitation of the boundary in a treaty; third, demarcation of the boundary on the ground; and finally, administration of the boundary. At the first stage it is not unusual to allocate territory in accordance with some natural barrier such as a river or mountain range, but at the second stage greater precision is required. This is where the decision is made whether to follow the line of high peaks or the waterparting, or with a river boundary the median line, the thalweg, or one of the banks. There is a natural progression from a material boundary to an epiphenomenal one; such progressions form the topic of the next section.

3.2 Physical boundaries arising from other physical boundaries

3.2.1 Epiphenomenal boundaries arising from material boundaries

Epiphenomenal boundaries must arise from material circumstances of some sort, and these 'material circumstances' often amount to the existence of a material boundary. Any reasonably sharply defined separation zone, say between regions A and B, gives rise to two heterolines, representing the boundary between the separation zone and A, and the boundary between the separation zone and B. The banks of a river, where these are sharply defined, are of this kind, likewise the edges of a road and the two sides of a wall. If the edges of the separation zone are graded then they should be classified as secondary transition zones; this would be the case where a river does not have well defined banks but is separated from the dry land by a marshy area of intermediate character.

A transition zone itself gives rise to epiphenomenal boundaries. If the transition is smoothly graded then there are of course innumerable isolines. But the transition zone as a whole may be supposed to have reasonably clear-cut edges, since it represents the transition between two regions each with its own well-defined character. The edges of the transition zone are where this character first begins to change in the direction of the character of the region on the other side of the transition. This may be a purely statistical effect: where the speakers of a language A meet the speakers of language B, there might be a transition zone within which speakers of the two languages intermingle. As we move across the zone from the A side to the B side, the percentage of B-speakers increases (not necessarily smoothly) from 0% to 100%. Thus defined, the edges of the zone are isolines, but they may also be regarded as heterolines.

3.2.2 Heterolines arising from isolines

In fact, any isoline can be regarded as a heteroline. The $x = k$ isoline (where x is a continuous field variable and k is one of its values) is the heteroline separating areas having the character $x < k$ from areas having the character $x > k$. This becomes significant if these two numerically defined characters correspond to or give rise to something more qualitatively salient. In this way, a sharp treeline, where that exists, is a heteroline determined by isotherms.

Even where such qualitative significance is lacking, it is sometimes useful to partition the range of a continuous field variable into a discrete set of qualitative bands, replacing an infinite number of isolines by a finite number of heterolines giving a partial representation of the field. One could regard the elevation contours in a map as being either a selection of isolines (corresponding to, say, 50m, 100m, 150m, etc.), or a set of heterolines (separating 'lower than 50m' from 'higher than 50m', 'lower than 100m' from 'higher than 10m', etc.). In some maps this is made more vivid by assigning different colours to the zones thereby defined. Likewise the Arctic Circle is both an isoline, the locus of points having latitude 66.53°N, and a heteroline, separating those places where the sun is never visible at midnight from those where it sometimes is.

3.3 Physical boundaries arising from institutional boundaries

One way in which an institutional boundary can give rise to a physical boundary is through the demarcation of the former, for example the construction of a fence, wall, or other barrier. As Smith (1995) puts it, 'boundary-markers…tend in cumulation to convert what is initially a fiat boundary into something more real'. More subtle are the long term effects that may arise from the simple existence of the boundary, regardless of how it is physically demarcated. An international boundary drawn across an initially homogeneous region may lead in time to the two subregions thereby separated acquiring marked differences in character. Prescott (1965) cites a detailed study by Daveau of the effects of the Swiss-French boundary in the Jura to the west of Lake Neuchâtel over several centuries, where, for example, the 'small strip fields' of Amont in France are clearly contrasted with the 'summer pastures' of Carroz in Switzerland, 'even though the physical character of the landscape on both sides is the same' (Prescott, 1965, p. 97).

This is a case where the physical effect of a boundary is something directly visible, but in many cases the effect is more subtle, having to do with patterns of movement and interaction. A political boundary introduces discontinuities into such patterns, some of which may be obvious, others only to be uncovered by detailed research. Fielding (1974), for example, notes that '[p]eople in Vancouver…are more likely to marry partners from Toronto or Winnipeg than from Seattle, Tacoma, or Bellingham, despite the proximity of single people in the latter group.' Such differences in patterns of interaction are epiphenomenal. One could, albeit rather artificially, consider a field whose value at a given point is the probability that a randomly-chosen single inhabitant of Vancouver will marry a person living at that point. Then the state of affairs described by Fielding would show up as a heteroline marking a discontinuity in the field values along the border.

4 SOME KEY ATTRIBUTES OF BOUNDARIES

In the light of the foregoing discussion it should be evident that the world of geographical boundaries is highly diverse, encompassing physical, biological, psychological, social, and political phenomena. Yet if we are to represent boundaries in an information system we must extract from this diversity some more general principles that apply across a wide range of cases. The classification introduced earlier is a first step in this direction; I now turn to an examination of some key features of boundaries that a model should take into account.

4.1 Dimension

Modelling geographical entities usually begins with a top-level classification of such entities according to dimension: there are point objects (that is, objects conceptualised as points), line objects such as roads, rivers, railways, coastlines, contours, and boundaries, and areal objects ('regions'). In such a classification, geographical boundaries are naturally assigned to the category of line objects. This category is, however, rather diverse: Mark and Csillag (1989) list five distinct types of 'geographic lines', two of which are further subdivided into two. Boundaries occupy two of these types, which they designate 'legislated line' (including 'some political boundaries') and 'area-class boundary' (e.g., climatic, vegetation, and soil-type boundaries).

Geographic lines represent entities which, at least after idealisation, are intrinsically one-dimensional, that is, positions along the line can be uniquely specified by means of a single numerical variable even though the line itself may weave a complex path in two or three dimensions. The notion of idealisation is important here: many 'lines' are in reality areas or volumes. They can be idealised as lines because all but one of their intrinsic dimensions are of negligible size in comparison with the remaining one: a river, for example, typically has a length of tens, hundreds, or even thousands of kilometres, whereas its width is of the order of one kilometre or less, and its depth of the order of tens of metres at most.

Any geographic line can be *thought of* as a boundary: it is the boundary between the area on one side and the area on the other. Whether or not it *functions* as a boundary depends on a variety of factors. As a first high-level generalisation, a line can be conceived in two ways: from the point of view of possible motion *along* it, and from the point of view of possible motion *across* it. Conceived in the first way, a line is a *way* or *path;* in the second, a *boundary, barrier* or *gateway.* As Couclelis and Gottsegen (1997) put it, 'a freeway is a *way* or a *barrier* depending on which way you look'. Many boundary functions are therefore defined in terms of 'across' rather than 'along'. They have to do with how a boundary regulates movement or communication across it. Examples of such functions are

1. *Inclusion,* which regulates motion and/or communication outwards from the interior of a region to the exterior.
2. *Exclusion,* which regulates motion and/or communication inwards from the exterior to the interior.
3. *Separation,* which combines inclusion with exclusion.
4. *Contact,* the extent to which separation is not complete.

Some other functions such as *protection* are derivative from these. There remain functions such as *differentiation*—by which, for example, the land-use within a conservation area is differentiated from that outside even though there may be no restriction to movement or communication across the border in either direction.

A linear feature may be regarded as a boundary to the extent that it embodies one or more of these functions. As already noted, being a boundary is not incompatible with being a way or path; though students of international boundaries repeatedly assert that rivers do not make good boundaries, in part precisely because they make such good thoroughfares (Boggs, 1940; Peattie, 1944; Jones, 1945; East, 1965; Crone, 1967).

In three-dimensional space, boundaries take the form of *surfaces* or *interfaces.* They are intrinsically two-dimensional, and the regions or objects they bound or separate are three-dimensional. Although geographical space—or at any rate 'naive geographic space' (Egenhofer and Mark, 1995)—is generally thought of as two-dimensional, a three-dimensional view is sometimes essential for a true depiction of some geographical state of affairs. Jones (1945) discusses boundary issues arising in relation to mining rights and underground water resources. He cites (p.31) the case of coal mines on the Germany-Netherlands boundary in 1939. The political boundary at the surface was marked by a meandering river course, but the mines underground were allocated to the state in which the coal was brought to the surface, in accordance with a 'working boundary', ratified by treaty, and in places separated from the political boundary by as much as 1km. Such examples contradict the usual assumption that a boundary on the surface of the earth should be regarded as extending vertically upwards and downwards for the purpose of assigning sovereignty to portions of the atmosphere or the earth's crust.

Likewise, although a geological map can only show the boundaries pertaining to the surface geology, the objects of interest to geologists are three-dimensional chunks of matter. For this reason, geological texts often include, as well as conventional surface maps, vertical transects showing the underground distribution of rock types. Even a map of the surface geology carries information about which strata overlie others, and part of the skill of reading such maps is precisely to draw inferences concerning—indeed to visualise—the sub-surface geology. Boundaries in weather maps can similarly only be read correctly on the understanding that they represent two-dimensional boundaries between three-dimensional air masses.

4.2 Valency

As already noted, we may speak both of the boundary *of* one region or the boundary *between* two regions. This may be described as a difference in 'valency'. The issue sometimes arises as to which of the two concepts—the unary 'boundary of' or the binary 'boundary between'—should have conceptual or logical priority. To some extent they are interdefinable. The boundary of England consists of the boundary between England and Scotland, the boundary between England and Wales, and two stretches of coastline representing the boundary between England and the sea. Conversely, the boundary between England and Wales comprises that part of the boundary of England spatially coincident with part of the boundary of Wales, together with that part of the boundary of Wales spatially coincident with the boundary of England. Kulik (1997) invokes this notion of valency to draw the distinction between the German terms *Rand* ('edge') and *Grenze* ('boundary'), modelling the former by means of a one-place function, the latter by a two-place.

The unary conception of boundary plays a prominent role in recent work by Barry Smith and various co-authors, inspired in part by the work of Brentano on continuity in space and time. For Brentano, the essence of continuity is that a continuous expanse can be divided in thought into two pieces whose boundaries are spatially coincident along their line of contact. According to Smith, this picture applies to geopolitical boundaries: The boundary of France is not also a boundary of Germany: each points inwards towards its respective territory' (Smith, 1995). This contrasts with the discontinuity between an object and the empty space in which it is located: the common boundary here belongs only to the object. Smith and Varzi (1997) advocate two complementary boundary theories: a bivalent theory to handle physically motivated ('bona fide') boundaries, and a univalent theory to handle cognitively motivated ('fiat') ones.

Against this, we may observe that in the geopolitical case, it usually takes two to make a boundary. The boundaries between nations are generally defined by means of a treaty; or if unformalised, by a truce or armistice. The two parties come to an agreement as to how their mutual boundary should be defined. This is primarily a boundary *between* two regions, and only secondarily part of the boundary *of* either region individually. If a nation A has frontiers with nations B, C, D,…, then each boundary segment A-B, A-C, A-D,…, might be defined by a separate treaty. Where three boundaries meet at a triple point, three separate treaties are involved. As Jones says: 'In view of the notorious slowness of boundary negotiations, it is not surprising that overlapping claims in the vicinity of a triple point may exist for many years' (Jones, 1945, pp. 160f).

Sometimes, to be sure, a boundary is acknowledged by only one of the two parties involved: an oft-cited example is the boundary between 'East Germany' and 'West Germany' prior to reunification, a boundary officially held to exist only by the East Germans. Such examples do not weaken the earlier argument: it is not a case of there being a single world view in which there is a one-sided boundary of East Germany that does not coincide along its western parts with any one-sided boundary of West Germany; on the contrary, what we had was *two* conflicting world views, according to one of which there was a two-sided boundary dividing Germany into two parts, while according to the other no such boundary existed.

We may constrast, on the one hand, a situation such as we find almost everywhere in the modern world, in which each piece of land is regarded as the sovereign territory of some nation or other, and, on the other hand, the situation which existed in earlier times in which the notion of territorial sovereignty was not yet fully developed, with human groups pushing their frontiers outwards into unclaimed virgin territory beyond. At this stage, each enclave of humanity has a border (albeit seldom precisely defined) representing the limit of its current expansion: not a boundary between two sovereign territories but a boundary of a single territory. One can, of course, think of this as a binary boundary (the boundary between a piece of claimed territory and the wilderness outside) but it seems more natural to think of it as unary. It is when continued expansion brings the frontiers of two such territories into contact that conflict ensues and the necessity arises for establishing a common boundary by mutual agreement. At that point the two unary boundaries are replaced by a single binary boundary. Historically, this has happened at different times in different parts of the world, the process not becoming completed until the twentieth century. Even now, one might argue that coastal boundaries are of the unary kind, and will remain so until such time as the nations decide to partition between them the entire area of the oceans.

In general, where the function of a boundary is to support an exhaustive and exclusive partitioning of an area of land, it is appropriate to regard it as bivalent. Not all boundaries are of this kind, however; in particular not all institutional boundaries are. The national parks of any country are in general isolated from one another, like islands, and while the boundary of a national park separates it from the land outside, this function is asymmetrical. It is not usual to recognise the totality of land not falling within a national park as a single geographical entity; thus it is not natural to think of the boundary of a national park as also being part of the boundary of anything else. It is unequivocally a unary boundary, more like the surface of an orange than the boundary between two counties.

4.3 Determinacy

Important problems arise from the fact that boundaries are often ill-defined in various ways. Certain types of boundaries are susceptible, in principle, to precise definition. With institutional boundaries, the underlying intention is to define an exact Euclidean line, having length but no breadth. If this intention does not always succeed it may be because of the difficulties in securing an exact delimitation in practice, or because of ambiguities in the wording of document by which the boundary is defined. Again, the isolines of a field whose variation is truly continuous are, in principle, absolutely sharp, any apparent indeterminateness arising from limitations in the accuracy with which we can measure the relevant values. Heterolines, too, will be sharp to the extent that the attributes in terms of which they are defined are precisely determined at each point.

Material boundaries, considered as boundaries, are not sharp in this sense; and since a material boundary is also a region, a further issue arises as to whether its own boundaries are sharp. This leads to higher-order indeterminacy. To revert to an earlier example, the *Kampfzone* is a non-sharp boundary between forested and treeless regions; since it is a transition zone with a distinctive character of its own, its non-sharpness is not due to problems of measurement or definition, rather it is in the nature of things that the regions it separates do not have a sharp boundary. The *Kampfzone* itself has boundaries: the timberline and treeline. These are also not sharp, but this is not because they are themselves transition zones, but because of it is impossible to specify them more narrowly than the size of a typical tree (or the gap between trees).

A major source of indeterminateness arises from attempts to define the boundary of an object which, properly speaking, has no boundary. A well-defined location for a mountain is provided by its summit. But can we encircle the summit with a line enclosing all and only those places that form part of the mountain? One can invent criteria, which may result in quite sharp delineations, but none of them corresponds to our ordinary understanding of what a mountain is—which perhaps includes boundarylessness as a significant attribute. Unfortunately, many representational tools cannot assign a location to anything without assigning a sharply-defined location.

One way to address problems of this kind is by means of inner and outer boundaries, effectively creating a notional transition zone in between. This may or may not be a true transition zone defined in terms of the transition of pre-existing characters. The limits of the transition zone may be more or less arbitrary, the only essential requirement being that everything inside the inner boundary unequivocally belongs to the region whose delineation is in question, and everything outside the outer boundary is unequivocally outside it. Formal developments of this approach are presented by Clementini and Di Felice (1996) and by Cohn and Gotts (1996). More generally, see other chapters in Burrough and Frank (1996) for discussions of indeterminate boundaries in geography.

5 REPRESENTATION OF BOUNDARIES

Suppose we wish to construct a model—mathematical, conceptual, or computational—of part of geographical space. What kinds of boundaries should we represent, and how should we represent them? In the absence of a more specific context, this question has no definite answer. We need to know more about the purpose of the model, and the resources it can draw upon. Here I organise the discussion in terms of two distinct approaches to modelling geographical information. At the conceptual level, appropriate for the initial design of an information system, these are the *field-based* and *object-based* approaches; at the level of implementation, they show up as *raster-based* and *vector-based* GIS.

In the field-based approach, data are presented in the form of *fields,* which are functions assigning values to spatial locations. An example is the elevation field, which assigns to each point on the earth's surface the elevation of the solid surface above or below sea level. When data are presented in this way, there is no natural way of representing boundaries explicitly; but this does not mean that the data cannot be used to derive information about the location of boundaries. The kinds of boundaries we can retrieve depend on the nature of the field data and the underlying spatial framework. This may be continuous or discrete. In the former case it is naturally modelled mathematically by means of tuples of real numbers, in the latter by tuples of integers. Moreover, the field values may also be either continuous or discrete, modelled by reals, integers, or subranges thereof. I shall consider various possible combinations in turn:

Continuous space, continuous field values The *variation* in the field values over space may itself be either continuous or discontinuous. In the former case the natural boundaries are isolines. These are explicitly present in the model in the sense that, for example, the $x = k$ isoline consists of a set of points to which the x-field assigns the value k, and these points, and the assignment of this value to them, are explicitly present; but the model does not in itself draw attention to the points lying along any particular isoline as opposed to the infinitely many alternative possibilities, and in that sense the isolines in such a model are only implicit. This holds even at an idealised conceptual level; any actual implementation must represent the continuous field by means of some finitely-specifiable approximation. Here the isolines may be even less explicit, since interpolation may be required to estimate their courses. It should be stressed that while any isoline *can* be regarded as a boundary, isolines do not in themselves constitute boundaries. A continuous field-based model does not in itself provide a means for us to designate this or that isoline as a boundary.

Similarly, there may also be transition zones present in the field data, but their presence is not explicitly shown by any mechanism within the model itself: the model merely provides the raw data on the basis of which the boundary may be defined. If the variation in the field values is discontinuous, we will find heterolines marking the discontinuities. Separation zones of both kinds may exist with both continuous and discontinuous fields.

Continuous space, discrete field values There is a familiar problem arising in this case. Suppose v and w are two different values of the field, and suppose the area with value v meets the area with value w along a line L. Which value should be assigned to the points along L? This depends on the nature of the discrete field. The easiest case is when the field has arisen by a discretisation of some continuous field f. A typical case is where the values v and w are defined as, say, $f < k$ and $f \geq k$ respectively. In this case, if f is truly continuous, the points along L must take the value w, since f must equal k at those points (see Galton, 1997, for a discussion of the temporal analogue of this case). If the discrete values *v* and *w* are more qualitative in nature, this type of solution is unavailable, and now it seems arbitrary which of the values is taken. An example of this, discussed by Casati and Varzi (1999), is Peirce's puzzle: what colour is the line of demarcation between a black spot and its white background? The puzzle arises as an artefact of the modelling process. In reality the attribute of 'colour' applies to areas, not to individual points. In a continuous field-based model, however, all spatial attributes are ascribed to points; they are ascribed to regions only indirectly via the points which fall within them. In a common-sense view of reality one wants to be able to say that a white area meets a black area without having to ascribe a colour to the points along the boundary; this cannot easily be accommodated in a discrete field defined on a continuous space.

Discrete space, discrete field values In this case the natural boundaries are heterolines. The discrete space consists not of points but of minimal units of area ('cells'), linked by a relation of adjacency. If a block of black cells meets a block of white cells then the heteroline representing the boundary between black and white does not itself consist of cells but rather follows a line of interstices between pairs of adjacent cells. It is an epiphenomenon of the representation, truly reflecting the epiphenomenal character of the boundary in the represented reality. Likewise, a discrete field model may contain separation zones, for example a band of black cells separating areas of blue and green. And as with transition zones in a continuous field, a separation zone in a discrete model is explicit in the sense that it can be identified with an actual collection of cells distinct in value from those on either side, but merely implicit in the sense that the model does not in itself draw attention to this particular heterogeneity by collecting cells together into a unity.

An important characteristic of field-based models to emerge from this discussion is that in such models, boundaries are typically represented *analogically:* that is, a boundary in reality shows up as a boundary in the model—an isoline in reality is represented by an isoline in the model, and likewise with heterolines, transition zones and separation zones. In all these cases, although the brute facts concerning the physical nature of the boundary are explicitly represented, the boundary itself, as a geographical entity with its own particular properties, seems curiously absent. This reflects the fact that field-based models provide rather low-level representations of reality. They are particularly appropriate for handling data collected directly from nature using automatic sensors, for example. But boundaries, as part of our conceptual scheme, seem to belong at a somewhat higher level. This higher-level conceptual character can be more explicitly captured by means of an object-based representation.

In an object-based model, the primary data consist of conceptual elements called *objects,* to which are assigned various *attributes.* Spatial location is just one amongst many possible attributes that can be assigned to objects in such a model. There is no reason why boundaries should not be explicitly represented as objects in their own right. And indeed, it is standard practice, in vector GIS, to specify the location of an area object by specifying the location of its boundary, using the coordinates of a suitably chosen sequence of points located along the boundary.

Any boundary can, in principle, be represented in an object-based model. A boundary is handled like any other linear feature; its location specified as a sequence of points. But being an object, it can have any number of other attributes assigned to it as well: whether it is a physical or institutional boundary, and if physical, whether material or epiphenomenal, and so on. Institutional boundaries can be provided with exact characterisations of their type: whether it is an international boundary, a state boundary, a county boundary, a parish boundary, the boundary of an electoral constituency, and so on. With international boundaries one could distinguish those that are ratified by treaties and those which are merely *de facto;* one could provide information about when the boundary came into being, and so on. None of this is possible in a purely field-based model.

In contrast to field-based models, the representation of boundaries in an object-based model is *symbolic* rather than analogical. That a boundary is an isoline, heteroline, transition zone, etc., is not shown analogically by the fact that the representation shares that character—it does not—but rather by means of particular symbols conventionally understood as representing the various kinds of boundary. On a map, these show up as the many different styles of broken or coloured lines that may be used to represent different forms of boundary—the non-analogical character of such representations is evident in the fact that without consulting the legend it is often not possible to tell which of the many linear features on a map represent boundaries and which represent paths, railways, etc.

Another consequence of the symbolic character of object-based boundary representations is that the issue of indeterminateness becomes highly problematic. In a field-based model, a transition zone can be represented analogically *as* a transition zone, with the intermediate field values directly representing the gradation in the underlying reality. In an object-based model, on the other hand, everything is biased towards a crisp all-or-nothing style of representation, and in order to represent indeterminate boundaries one has to have recourse to artefacts such as the 'egg-yolk' theory of Cohn and Gotts (1996), which models the zone of indeterminacy as a kind of region in its own right, itself with crisp boundaries.

An object-based model is a higher-level representation that is hard to extract mechanically from raw data, involving as it does a conceptualisation imposed on those data by means of human thought processes. Since institutional boundaries essentially involve such higher-level aspects, these boundaries are particularly apt to be represented as objects. While of course it is possible to represent, say, political or administrative regions by means of field values—in which case their boundaries will show up as heterolines in the representation—this does not seem very natural. In Galton (2001) I propose a hybrid model—the 'object-field'—as a way of handling the partition of a land area into institutionally-defined blocks.

In conclusion we may say that the two styles of geographic modelling both provide the ability to represent boundaries, but with very different advantages and disadvantages. To the extent that boundaries are themselves physical features, they can be represented analogically within a field-based representation, which may faithfully reflect various physical characters of different kinds of boundary (material vs epiphenomenal, crisp vs fuzzy, etc.); but these representations do not draw attention to the boundaries themselves. The boundaries do not resolve themselves into discrete objects that we can readily identify and talk about. In object-based models, on the other hand, boundaries can be elevated to the status of objects, to which we can ascribe, by symbolic means, whatever properties we wish; in particular, institutional boundaries, which are not directly grounded in the sorts of properties most readily represented in a field-based model, are much more comfortably accommodated in the object-based framework.

6 CONCLUSIONS

In this chapter I have described a possible classification of boundary types, and in the light of this classification have considered how boundaries of different kinds can be related to one another, what attributes of boundaries are of particular importance in giving a general characterization of them, and how boundaries and their attributes may be represented in an information system. This work may be regarded as a prolegomenon to future studies in which the representation of boundaries in information systems is considered in more detail, with a view to improving the quality of boundary information that can be provided by such systems. It is to be hoped that much of what is said here may also be of interest to wider communities of geographers, philosophers, and others.

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