CHAPTER 5

Lines and Areas

Putting lines on a map is an exercise of power with consequences for the areas they delineate. We have already seen the complicated relationship between the delineation of areas on a map and concepts of where different places are (see Chapter 4). Conceptually places do not depend for their existence on being well-defined: It is not a problem if they are ambiguous. By contrast, the intention behind drawing lines on maps is to claim that some spatial entity—whether a country, administrative subdivision, parcel of land, or whatever—is unambiguously defined as existing within the bounds marked. Often such claims are contested and problematic. This is obviously so in the political realm, but may also be true when lines are drawn that supposedly indicate changes in land cover, vegetation, geology, or habitat, and so on. In these cases the contestation may be over knowledge claims rather than political per se. Either way, drawing lines on maps, delineating areas, is inherently an exercise of authority, political, scientific or of some other kind. The line is a claim about the world, resting on the authority of whoever drew it, and that authority is then passed on through maps or in data.

In this chapter we examine some implications of taking seriously this perspective on lines on maps and in data. As elsewhere, we consider relevant debates in geographical theory and also aspects of work in giscience where lines—more precisely, the polygons they delineate—are more complicated than they appear. While the patently fictional abstraction of the infinitesimal, simple point location passes almost without comment in giscience, problems with polygons are more widely appreciated, even if the implications of the difference between *bona fide* and *fiat* boundaries are rarely followed through. Many of these problems are understood to be merely technical in nature, as in the case of the *modifiable areal unit problem*, and *regionalization*, both of which we consider. As we shall see, all these giscience concepts relate directly to the deeper philosophical and political questions raised by critical cartography and political geography.

DRAWING LINES: THE ORIGINARY POWER OF MAPS

The Map and the State

Denis Wood argues in *Rethinking the Power of Maps*[1] that maps did not exist in their recognizable modern form until the advent of the modern state: "People create maps only when their social relations call for them, and the social relations that most insistently call for maps are those of the modern state" (2010b, p. 19). He firmly rejects the idea that maps are representations of the world, because of how this naturalizes map making and map use. Maps in the modern sense have *always* been about power and the exercise of authority. They set out who has authority over what, and in which places that authority attains. At the same time, they call some places into existence, by naming them and locating them, and also erase other places and their names by omitting them completely. Maps are thus quintessentially platial, both insofar as they define places out of thin air, and also designate what is permitted or not in the places so created (see Chapter 4).

[1] *Rethinking the Power of Maps* is a substantially rewritten edition of *The Power of Maps* (Wood, 1992), "as in hindsight I would wish to have written it" (Wood, 2010b, p. 10).

In place of the idea of maps as representations, Wood offers this definition:

> maps are more or less permanent, more or less graphic artifacts that support the descriptive function in human discourse that links territory to other things, advancing in this way the interests of those making (or controlling the making) of the maps (2010b, p. 20).

While this avoids using "representation," the term "descriptive function in human discourse" enters in its place and does much of the same work.[2] The suggestion is that maps are graphical tabulations of those other things that pertain to particular pieces of territory. There is a foreshadowing here of the geoatom, or at any rate of the geometric entity in a geospatial data table, although this is hardly surprising given the close ties of GIS to cartography. I am comfortable with the idea that representation (for some actors in some contexts) remains a function of maps and I don't think there is an urgent need to make the argument against the idea that maps are representations so absolute. Wood's vehemence is because *maps become powerful when we unquestioningly accept that they simply represent reality*. Power relations like land ownership—which often did not exist before they were mapped—are legitimized by the authority of maps, making them even harder to challenge. The conclusion surely is that maps are not simple or natural representations of an uncomplicated, unmediated real world out there, so much as they are representations of power relations. They are representations all the same, even if what they represent is not what we might naïvely assume.

Wood's definition does use the word *territory*, a far from simple concept, which we look at more closely below. For now, following Delaney, it is enough to recognize that "[t]erritorial configurations are not simply cultural artifacts. They are political achievements" (2005, p. 12), and that maps are crucial to their achievement. Indeed, a claim that maps are central in regulating power relations is unremarkable if we are concerned with the boundaries of national or subnational territories, or with

[2] Andrews (1996) finds in an analysis of over 300 definitions of the word map that representation looms large, so successfully avoiding using it in a definition is no mean feat!

cadastral maps showing land parcels and their ownership. But even maps that are not *explicitly* about power, suggests Wood (2010b), project power in a variety of ways. Along with many others, he argues that the map is not only an instrument for the operation of state control, it was essential to the construction of the modern state as we understand it in the first place (Buisseret, 1992; Edney, 1997; Pickles, 2004; Carroll, 2006; Branch, 2014). States are abstract things compared to the everyday places in which people go about their everyday lives. Maps and map making have made and continue to make the abstract notion of a nation-state real. They assert the existence of a thing that is otherwise hard to grasp still less submit to or feel allegiance to. "It's almost as though it were the map that in a graphic performance of statehood conjured the state *as such* into existence" (Wood, 2010b, p. 32), or, as Branch puts it, "forms of authority not depicted in maps were undermined and eventually eliminated, while map-based authority claims became hegemonic" (2014, p. 6) in the process of modern state formation.

In fulfilling this function, the most important feature of the map is how the territory of a state is defined by boundaries. This is why drawing lines on maps is so central to the idea of the state and of cartography. Drawing on Winichakul (1994), Wood suggests that "[s]tate borders are brought into being through mapping, both by the imperative *to be mapped* and *through* the medium of mapping" (2010b, p. 32). Maps were and are active agents in processes of state formation. In the present, maps—and by extension GIS—remain central to the maintenance of state power and property rights, while also having a more mundane part to play in the management of state and corporate functions from rubbish collection to the delivery of healthcare and education.

New Lines and Countermapping

Maps and GIS are definitively instruments of the state and other powerful interests, but they can potentially also advance opposing interests, albeit often at the cost of accepting underlying assumptions about land, ownership, and power embodied by maps. In a groundbreaking paper, Nancy Peluso suggests that "maps can be used to pose alternatives to the languages and images of power and become a medium of empowerment or protest" (1995, p. 387), labeling such efforts *countermapping*. However, she also argues that

> [t]he practical effect is far-reaching: the use of maps and a highly 'territorialized' strategy redefines and reinvents customary claims to standing forest resources and harvestable products as claims to the land itself (1995, p. 384).

and that

> mapping almost forces the reinterpretation of customary rights to resources *territorially*, thereby changing both the claim and the representation of it from rights in trees, wildlife, or forest products to rights in land (1995, p. 388).

When state or corporate usurpation of customary rights is countered through mapping, it is difficult for those making countermaps not to assert similar rights to those claimed by the usurpers, even when the previous relation to land was not one of ownership, but one of stewardship or a pattern of recurrent use over time. Crucially, a cartographic language for depicting such contingent relations between people, land, and places remains elusive. More nuanced depictions of the complexity of customary rights might also struggle in any case for political or legal recognition in a world of maps depicting crisp lines and the polygons they enclose. Branch's (2014) argument about the hegemony of map-based claims applies with equal force to counterclaims, so that the path of least resistance is often to accept the terms on which maps operate, and enter into the territorial relation to the world depicted in maps.

Although Peluso's reservations are rarely far from view (see, e.g., Hodgson & Schroeder, 2002), countermapping and its cousins *participatory GIS* and *community mapping* are vibrant fields (Mukherjee, 2015). In many cases, Peluso's concerns have been well-founded. Referring to several countermapping projects in the Americas, Bryan and Wood claim that

> [i]n every case, [counter]mapping provided a means of nominally recognizing indigenous peoples' rights, while at the same time

> assimilating them into a territorial order whose lines were codified by the law (2015, p. 97).

That the projects they are considering were funded through the U.S. Agency for International Development (USAID) and related organizations helps to account for such depressing outcomes. Not everyone is so pessimistic about the possibilities, and more genuinely bottom-up community-led projects are less likely to be co-opted by state and corporate interests. Reflecting on lessons from countermapping, Dalton and Stallmann point to "the importance of a critical approach [and] the conceptual and practical importance of participation not only in data collection, but also in analysis" (2018, p. 100). Similar conclusions have been drawn in more community engagement-oriented contexts, where capitalist property rights are already fully embedded, a description that often characterizes projects under the participatory GIS umbrella (Elwood, 2006). The important lesson from all these domains is the emphasis placed on the importance not of maps as end-products (although these clearly do also matter), but on the *processes* of community involvement (who maps), data collection (what is mapped), and analysis (what kinds of maps are made). From the perspective of this book's overarching argument that giscience should engage geographical thought, the latter of these challenges, what is mapped and how, pushes us to think more deeply about the different kinds of representations we could make by moving beyond standard geospatial architectures.

TERRITORY AND TERRITORIALITY

The notion of territory embedded in the previous discussion is so bound up with the emergence of the modern state that it is difficult to think of a state separate from some defined area of Earth's surface over which it has exclusive sovereignty. Stuart Elden suggests that territory has been paid insufficient attention in political geography because

> territory is often assumed to be self-evident in meaning,[3] allowing the study of its particular manifestations—territorial disputes, the territory of specific countries, etc.—without theoretical reflection on 'territory' itself. Where it is defined, territory is either assumed to be a relation that can be understood as an outcome of territoriality, or simply as a bounded space (Elden, 2010, p. 800).

Territoriality, in turn, is a concept that demands careful thought. One approach understands it as almost biological in character, an extension into the human sphere of animal territoriality (see Storey, 2012, 14–18, for a useful review). A second approach is more nuanced, recognizing that human territoriality is social, but tends to treat it as ahistoric (Sack, 1986). But in both cases, Elden argues, territory remains underexplored and assumed to be self-evident. He goes on to sketch, drawing on ideas in a short book by Soja (1971), what a more complete understanding of territory would look like, suggesting that it demands consideration of land, terrain, and territory. These, respectively, revolve around questions of resources and property relations; power, competition and (military) control; and cooperation and social organization. An understanding of territory therefore requires an understanding of land and terrain, and also that territory "is both of these, and more than these" (Elden, 2010, p. 804).

Building on these foundations, in *The Birth of Territory*, Elden (2013) develops a history of the emergence of territory as a concept in Western political thought. This requires tracing developments in philosophy, law, and politics, but also, significantly, scientific thinking about space, including debates around the absolute or relative nature of space (see "The Geometry of the Political" in Elden, 2013, pp. 290–98). Absolute space triumphed over relative space in the scientific and political realms, even if in the latter context this manifests relationally:

> Sovereignty, then, is exercised over territory: territory is that over which sovereignty is exercised (2013, p. 329).

[3] Wood's (2010b) definition of maps, quoted previously, is guilty in this regard.

Elden concludes that "[t]he idea of a territory as a bounded space under the control of a group of people, usually a state, is therefore historically produced" (2013, p. 322). Territory is a "bundle of political technologies" that "comprises techniques for measuring land and controlling terrain" (2013, pp. 322–23). Those techniques are not restricted to maps and mapping, but clearly include them.[4]

A number of historical geographical accounts show how the concept of territory was rolled out in different settings, and confirm the significant role of mapping and surveying in each case (see, e.g., Edney, 1997; Hannah, 2000; Carroll, 2006). A key reference point for many such accounts is James Scott's *Seeing Like a State*, which posits "legibility as a central problem in statecraft" (1998, p. 2). The state is centrally concerned with ordering and recording all that it governs—people, land, resources, and so on—a process that demands the kinds of simplification exemplified by a cadastral map, which "does not merely describe a system of land tenure; it creates such a system through its ability to give its categories the force of law" (1998, p. 3). The organization of land surveys was of central importance to the development of the Irish colonial state (Carroll, 2006), and of the United States (Hannah, 2000). Edney's more explicitly cartographic history of the construction of British India (1997) also highlights the importance of mapping.

These are colonial settings, but, Scott also contends,

> modern statecraft is largely a project of internal colonization [. . .] [t]he builders of the modern nation-state do not merely describe, observe, and map; they strive to shape a people and landscape that will fit their techniques of observation (1998, p. 82).

We considered aspects of these processes of making the governed (land and people) legible in relation to how address systems and toponyms make ambiguous places legible for various purposes (see §Making Space

[4] It is interesting that while territory is bounded *land*, the world-ocean is sometimes thought to be ungovernable, beyond territorial control (Steinberg, 2009), in part because the ocean can't be marked out in the same way, and is so obviously in constant flux (but see Havice, 2018).

Legible: Addressing the World, Chapter 4). In delineating areas, mapping goes beyond merely labeling ambiguous places to defining the places themselves, as specific bounded territories subject to various legal, political, and social arrangements. If space becomes place through experience, then places become territory through mapping.

Escaping the Territorial Trap

These historical accounts of territory open up ways to escape from what John Agnew (1994) called "the territorial trap." The trap he has in mind is the overly simplistic mode of thinking where states are understood as exercising sovereignty over an unambiguously delineated region of space. Furthermore, the boundary of the state's territory neatly distinguishes its domestic and foreign affairs. Finally, this model posits territories as discrete containers for their societies.

Agnew's critique is aimed principally at international relations rather than at geography, although Alison Mountz (2013) suggests that he was writing at a time when political geography was in abeyance, in part because of these moribund spatial concepts. Mountz's survey suggests that the simplifications of the territorial trap have been superseded by more recent work in political geography. She argues that such innovation is no accident but "reflects recent geographical shifts in the operation of sovereign power" (2013, p. 830), particularly with respect to "spaces of war and terror associated with the United States and its allies' 'war on terror' " (2013, p. 830). In this context, the complex sovereign status of sites like Guantánamo Bay highlights just how distant from geopolitical reality is the territorial trap. She claims that geographical thinking on scale (see Chapter 3) has been an important corrective to focusing on the nation-state, and that "most political geographers do not examine the nation state directly, but the spatial dimensions (such as locational intensity, transnational reach, and territorial limits) of sovereignty" (2013, p. 831).

Mountz goes on to discuss "prison, island, sea, body, and border" (2013, p. 830) as examples of sites where sovereignty is much more complicated than can be represented by lines on maps. For example, prisons are spaces where citizenship rights of the territory are suspended. Prisons are usually hidden away from population centers (Simes, 2021), even as their impacts are most often sharply felt in urban communities (Gilmore, 2007). Their usual invisibility renders prisons disturbing when they are not hidden (see Davis, 1990, particularly chapter 4). The incongruity arises because prisons confront us directly as places where the usual rules are suspended.[5] The rights of prisoners are curtailed, so that prisons are inherently gray areas in the territory of the state.

Islands sometimes serve as prisons (Mountz, 2015),[6] but more generally are also places where states experiment with different regulatory regimes, such as the tax havens of Britain's Channel Islands, or its various Overseas Territories (most notably the Cayman Islands). Some islands, both independent states and not—for example, Singapore, Hong Kong, Malta, Cyprus, and Ireland—deploy their offshore status to apply different, often more business-friendly commercial regimes than those in force in neighboring mainland markets. The offshore model has often moved onshore in the shape of enterprise zones, themselves a kind of island within the territory of the state, where the standard commercial and employment regimes of the host state do not apply.

Borders are the most obvious sites where sovereignty gets "weird" and territory becomes fuzzy. Real borders are far from simple lines crossed in a single step, even if the floor markings in airport immigration halls suggest otherwise. Airport duty-free shopping rests on legal fictions about the relationship between the space where the shops are located and the national territory.[7] In many Canadian airports (also in Dublin, Ireland), it is possible to clear United States immigration and customs before boarding, meaning that travelers are already "in the United States" while still in Canada. Similarly, on disembarking in another country, you are not *really* in that country until after clearing immigration. Many countries require airlines to check travelers' documentation before allowing them to board flights, and travelers whose documentation is deemed insufficient for

[5] Aotearoa New Zealand's quarantine hotels, in operation from 2020 to 2022 during the COVID pandemic, engendered similar feelings.

[6] The title of Solzhenitsyn's *The Gulag Archipelago* is no accident.

[7] Duty-free retail and free trade and special economic zones are related experiments in territory; see Neveling (2020).

entry may be deported and returned to the port of departure at the airline's expense. Airline check-in is then the de facto first (extraterritorial) stage of the destination country's border. Since refugees can only seek asylum in the country at the border, this extension of national boundaries offshore has serious implications. Clearly, the question of where is the border of a state's territory is not a simple one, when immigration enforcement can potentially happen *anywhere* within the territory (see Stuesse & Coleman, 2014), or even beyond it.

These examples highlight "the power of states to alter the relationship between geography and the law" (Mountz, 2010, p. xv), and to manipulate that relationship to the detriment of marginalized people. Border "fast lanes," facilitated by extensive pre-screening of qualified individuals highlight how the border can even become the body (Coutin, 2010; Mountz, 2018), and provide another example of how scale is socially constructed and politically effective (Varsanyi, 2008, see also Chapter 3). They also dramatically illustrate how inadequately conventional maps embody "the descriptive function in human discourse that links territory to other things" (2010b, p. 20) in Wood's representation-free definition.

Fiat and Bona Fide Boundaries and Objects

Turning to the giscience literature, in a series of papers[8] Barry Smith (1994, 1995, 2001; see also Smith & Varzi, 1997, 2000) directly addresses a question raised by the foregoing discussion, "[w]hat sorts of entities are these, which can be brought into being simply by drawing lines on a map?" (2001, p. 131) Consideration of this question yields a conceptually useful distinction between fiat and bona fide objects.[9] *Bona fide objects* are those whose boundaries exist at some physical discontinuity or where some qualitative heterogeneity occurs, and which therefore are usually directly perceivable as things in the world. *Fiat objects*, on the other hand, depend for their existence on the definition of boundaries that

[8] One of them is even called "On drawing lines on a map" (Smith, 1995).
[9] These Latin terms, respectively, mean "let it be done" and "in good faith."

result from "acts of human decision or fiat, to laws or political decrees, or to related human cognitive phenomena" (2001, p. 133).

Administrative boundaries, national boundaries, and so on are clear examples of fiat boundaries defining fiat objects. In fact, it is unclear if *any* examples of genuine bona fide[10] objects exist at geographical scales. Many examples that come to mind such as shorelines, forest edges, and so on, on closer consideration, are not at all clear-cut, their precise definition dependent on scientific definitions and agreement about more or less arbitrary datums. We know when we are definitely on the land, and when we are definitely at sea, but the shoreline is a zone of transition whose precise location is not obvious. It nevertheless is likely to appear as a crisp line in many geographical datasets (see, among many others, Smith & Mark, 2003; Bittner, 2011; Feng & Bittner, 2010; Bennett, 2001).

Smith's interest is primarily ontological in a metaphysical vein, and only secondarily computational, and so he is more concerned with the limits that geometry and logic place on fiat objects and their boundaries, than with the social and cultural processes that underpin the power of drawing lines on maps. Even so, some interesting points emerge from his philosophico-mathematical considerations. The boundary of a fiat object, as a Jordan curve, "must be free of gaps and must nowhere intersect itself" (Smith, 2001, p. 142). Following from this, the boundaries between fiat objects are shared, with no intervening gaps and no overlaps. In the next section we consider a few of the situations where the world fails to match this mathematical idealization, and the incongruities that can arise as a result. Also arising out of the discussion is an argument that

> [t]here are no (or no obvious) candidate 'atoms' or 'elements' in the geographical world from out of which geospatial fiat objects could be seen as being constructed in analogy with the way in which sets are constructed out of their members (Smith, 2001, p. 142).[11]

[10] "Genuine bona fide" is almost (but not quite) a tautology.

[11] Smith made the same point in an earlier formulation (1995, p. 476). Again, the geoatom-as-point-location (Goodchild et al., 2007) is called into question. Arguably the concept survives this critique, albeit reformulated, such that the most granular elements in a fiat subdivision of the landscape are (arbitrarily small) geoatomic areas.

This is a deep, if subtle, critique of the dominant approach in giscience, where a polygon is a topological *point set* (Egenhofer & Franzosa, 1991). The possible relationships between two polygons understood as point sets can be enumerated in terms of the possible relations between their interiors and boundaries (see Figure 5.1). The interior and boundary require careful set-theoretic definition that need not concern us here (Egenhofer & Franzosa, 1991, pp. 164–65). The fiat/bona fide boundary distinction potentially simplifies this framework in the case of fiat objects, because a collection of fiat objects have boundaries that, by definition, *cannot* intersect, meaning that many of the relationships shown in Figure 5.1 cannot occur. This does not have any practical implications

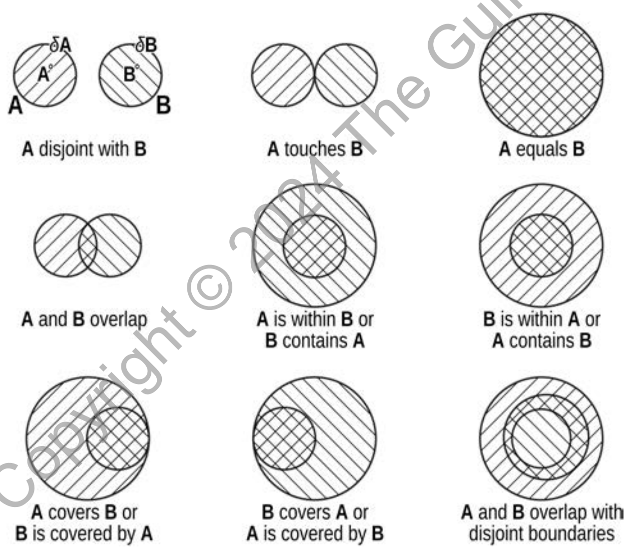

Figure 5.1. The 9-intersection model of topological relations between two polygons (Egenhofer & Franzosa, 1991). The different possible relations depend on the relations of both the interior A° and boundary δA of the polygons. Smith (2001) argues that possible relations among fiat objects are limited to being disjoint or touching.

for GIS implementation unless applications are restricted to nonoverlapping collections of polygon layers (which might be the case for a dedicated cadastral system, for example). It points again to the importance of thinking carefully about data structures for collections of spatial objects and whether they explicitly encode spatial relationships or not (see §Prospects for Relative/Relational Giscience, Chapter 2). However, even in settings where only fiat objects exist, it is commonplace to assemble polygons in nested hierarchies (e.g., census blocks, block groups, tracts, and so on), so that at least a few more of the spatial relations between boundaries shown in Figure 5.1 might be encountered, even if it is unnecessary to test for them geometrically, given that the hierarchical nesting relations are known in advance and can be encoded in polygon IDs or lookup tables.[12]

These technical arguments miss larger points about the process by which boundaries and the resulting polygons were defined historically. The deeper truth which Smith is pointing to, and which fully coheres with thinking about the power of maps, is that the elements are essentially arbitrarily defined by fiat—not arbitrarily in a historical sense, but in relation to physical phenomena on the ground. Fiat objects are those whose existence is an outcome of human cognition and action, and recognition of the concept in giscience aligns well with insights from critical cartography, countermapping, and theoretical geography. State boundaries, electoral districts, school zones, ownership and other rights in land, along with other less impactful things besides (like mail delivery routes) do not exist on Earth's surface. Where they do exist is on maps and in geospatial databases maintained and operated by corporations and government agencies. While these insights have been prominently discussed, their overall impact on implemented geographical computing platforms has been limited. GIS remains an instrument of states and corporations deploying abstractions in the form of unambiguously defined polygons and polygon coverages, which produce a "map as territory" mindset. This

[12]The computational efficiencies of this idea are an important driver of recent interest in hierarchically nested spatial indexing schemes such as Google's S2 and Uber's H3; see Figure 4.1.

connection is so powerful that many countermapping efforts seem gravitationally drawn into the same modes of thought (see §New Lines and Countermapping, this chapter).

WHEN THE MAP IS AND IS NOT THE TERRITORY

The ontological commitments of surveyors, cartographers, giscientists, and others notwithstanding, territory has a habit of resisting being easily mapped. The world itself—even the social and legal world—defies the simplifications of fiat boundaries. We examine some of the frictions that arise in this section. In this context the term territory stands in for all the areally extended fiat objects that giscience calls into existence when they are represented in geospatial data and manipulated computationally.

Exclaves: Territory Interruptus

There are many examples of how international boundaries defy expectations that they should define national territories that are whole and undivided. One class of examples is that of enclaves and exclaves. Without getting into the details of the nomenclature, in this context, an *enclave* is a state entirely surrounded by the territory of one other state, while an *exclave* is an area of a state that constitutes an enclave inside another state, such that it is disconnected (disjoint) from its parent state. The term exclave is inherently ambiguous, since a Belgian exclave might be a part of Belgium that is an enclave in some other state, or it might be an exclave of some other state enclosed within Belgium. For now, I will use the terms enclave and exclave loosely and assume that the sense is clear from the context.

Robinson defined a number of subcategories of exclave, but suggested that "[e]xclaves are not important phenomena in political geography. They are rare and mostly small" (1959, p. 283). Both Robinson and Catudal (1974) provided surveys of then extant exclaves, although more recent work suggests these were far from comprehensive (Whyte, 2002). Catudal (1974) concluded that exclaves are temporary phenomena and indeed, since the time of writing many exclaves in his account have been rationalized out of existence by international treaties swapping the territory in question.

Undeterred, Vinokurov (2007) sets out a theory of enclaves, in part prompted by the appearance, after the dissolution of the Soviet Union, of many new enclaves (see also Berger, 2010, and the accompanying special issue articles). Vinokurov argues that life in enclaves is difficult if the states involved do not have good relations, so that political geographers ought to take these issues seriously, and not treat enclaves as mere curiosities. Life can be more than merely difficult in enclaves: According to Vinokurov (2007), numerous deaths resulted from the lawlessness and ambiguities associated with the Cooch Behar enclave complex that persisted on the India–Bangladesh border from 1947 until agreed territorial exchanges in 2015 simplified the border, leaving only one large exclave of Bangladesh connected to its mainland by the 78 m wide Tin Bigha corridor. The complexity of the geography of that area is apparent in the map in Figure 5.2, and also when we consider that before the 2015 settlement, there was one counter-counter-enclave, that is, a part of India, within Bangladesh, within India, within Bangladesh(!), along with many other doubly nested enclaves.

For present purposes, what is interesting about enclaves is that while mapping them poses no particular challenges—given sufficient attention to detail—this is a case where the map both is and is not the territory. The map defines the territory in some legal sense. But experiences of such territories may be profoundly affected by how the state is maintained or (very often) not maintained in everyday practice (Shewly, 2013). The map is only the territory to the extent that it represents an ongoing process of state action, and in these liminal spaces, many functions of the state do not operate.

It is worth noting also that the literature above focuses on more or less unusual enclaves, while ignoring more mundane examples like embassies and other diplomatic missions (Mamadouh et al., 2015), military bases (Davis, 2011), or the spaces in ports and airports, where which state's territory is operative can be ambiguous to the nonexpert (Mountz, 2013).

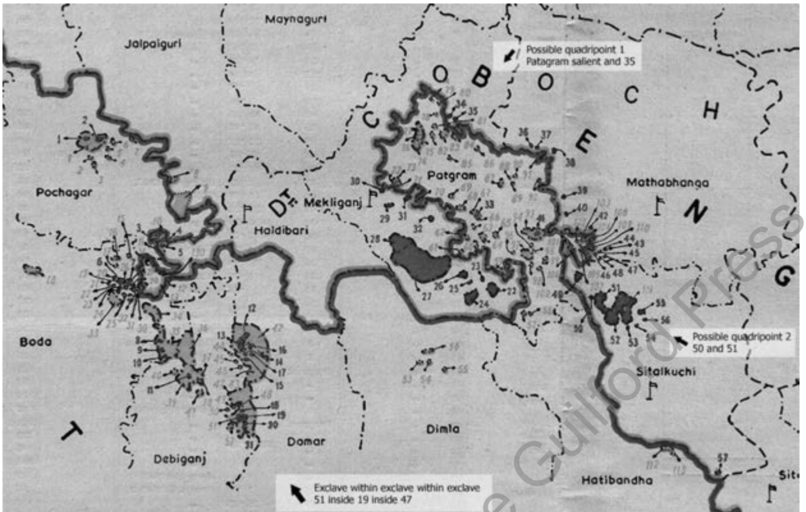

Figure 5.2. The enclave complex of the Cooch Behar region on the India–Bangladesh border. This sketch map is part of a map by Cyberpunk7282 CC BY-SA 3.0 available at https://commons.wikimedia.org/w/index.php?curid=15903195. A detailed large-scale map is available in Whyte (2002).

Territory, Borders, and Movement

Borders, however messy they might be, are made both to contain *and* to be crossed. States use borders to regulate movement of people and material (Cresswell, 2006; Mountz, 2010). As Ruth Wilson Gilmore succinctly puts it, "edges are also interfaces" (2007, p. 11). This idea finds direct expression in the geometric notion of *duality* where any configuration of relations can be transformed into its *dual* configuration. In this case the transformation is that every edge shared by two areas becomes a link connecting them (see Figure 5.3). Gilmore continues, "even while borders highlight the distinction between places, they also connect places into relationships with each other and with noncontiguous places" (2007, p. 11), but this is where the geometric duality

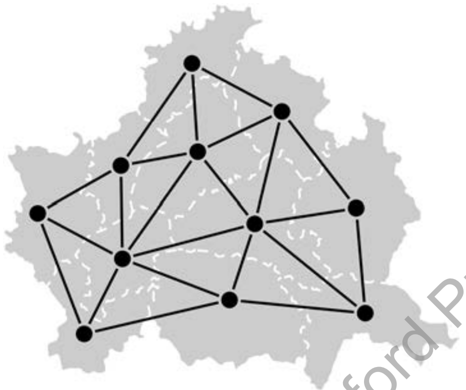

Figure 5.3. The geometric dual relation between borders and crossings. Dashed white lines are borders and solid black lines are the links between neighboring areas.

analogy falls down. Areas that don't share a boundary are not connected in planar geometry, but the same is not true of national boundaries, where it is possible to move between noncontiguous states, again calling attention to the complexity of borders and the imperfection of lines on maps as a representation of territory. Reflecting on a potentially nonobvious evolution from writing about place (Cresswell, 1996) to writing about mobility, Cresswell notes that "transgression involves displacement, the moving between in place and out of place" (2006, p. ix), again referencing this dualism. We examine movement/mobility more closely in Chapter 7.

Territory and Property: Cadastral Data

Often, enclaves are a result of property rights that pre-existed the delineation of national boundaries. Cadastral maps and databases concerning land ownership have been a significant driver of GIS development (Moudon & Hubner, 2000), particularly in relation to tracking changes in ownership and the amalgamation or subdivision of land parcels over time (see §Cartography and Giscience's Problem With Time, Chapter 7). The creation of cadastral maps and databases is closely bound up with processes of state formation, particularly in settler colonial contexts where appropriation and alienation of land from Indigenous peoples is central.

The legacy of such mapping is particularly clear when any attempt is made to determine the present-day land entitlements of descendants of the originally dispossessed, who were often subject to arbitrary judicial determinations, documented in distant courts, based on incommensurable notions about the relation between people and land (see §New Lines and Countermapping, this chapter). Specific examples in Aotearoa New Zealand are provided by recent work unpicking such a mess (Kukutai et al., 2022). The work of Shep et al. (2021) shows how methods similar to some of those used in grappling with ambiguities of place (see §Place as Vague Location: Gazetteers, Chapter 4) can potentially be used to assist in tracing land rights granted and promised many years ago, but never fulfilled. Prominent in this work is the importance of understanding land as a complicated set of relations between parcels of land that change through time, on the one hand, and people, kinship groups, and other collectives, also changing through time, on the other.

Territory and Governance: Statistical Aggregations

If maps "blossom," as Wood (2010b, p. 15) puts it, as a consequence of the rise of the modern state, then it is also to the emergence of the state that we owe the existence of censuses and other statistical[13] instruments describing populations. In much the same way that maps can be thought of as making the state, censuses make populations. Census outcomes are used as a basis for the redrawing of other maps, such as electoral maps, and for the allocation of state resources for all kinds of purposes, and as an imposition of the state, they have sometimes been opposed (Anderson & Shuttleworth, 1994; Hannah, 2009). National censuses are also frequently used as a kind of base layer for all kinds of social geographic

[13] The word statistics derives from the word state.

research. To take just one example, studies of spatial segregation of populations by race or ethnicity typically rely on census data, both for the spatial frame that is used and for the definitions of ethnicity deployed (see, e.g., Lloyd et al., 2015). The arbitrary nature of census geographies with respect to the social and demographic characteristics they record is an important technical concern much discussed in giscience, as we explore more fully in the next section.

In closing this section on how the map is (or is not) the territory, census boundaries or other administrative or statistical geographies might be the geoatoms that make up the territory from the perspective of the state (or for that matter social scientists), but they are almost invisible in everyday life. They are a kind of infrastructure of governance, largely unnoticed, unless something goes wrong. As an example, in the aftermath of the Flint water crisis of 2014 to 2017, the misalignment of ZIP codes with the municipal boundaries was identified as a major reason why the emerging crisis was not identified earlier (Sadler, 2019; see also Figure 5.4). Health data were compiled in relation to ZIP code boundaries and aggregation of health statistics to these areas masked serious problems with water quality, since many of the ZIP code areas included large populations outside the municipal boundary relevant to the water infrastructure. ZIP code boundaries are designed for mail sorting and delivery with those logistical needs in mind, and are affected by things like the presence of large office buildings, or other centers of employment, and also the infrastructure of the postal system (where it has large sorting facilities and so on). They are not designed other than coincidentally, in relation to population characteristics, or in relation to any other infrastructure. Municipal boundaries, on the other hand, result from complex local, regional, and national histories of urban and industrial development, and state formation, and often embed much earlier configurations of population and land use. There is no particular reason other than convenience to collate health data using ZIP code tabulation areas.[14] Even when convenience is an important consideration, and it is

[14]Strictly speaking, ZIP codes are not associated with areas at all, but with address points and mail delivery routes; but area representations are widely used to make it easier to

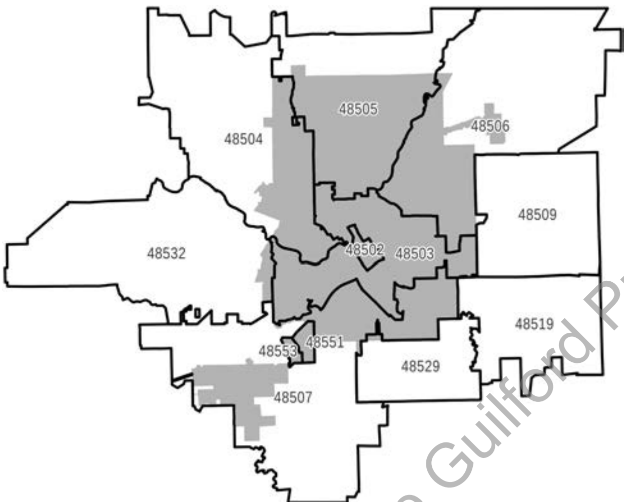

Figure 5.4. The misalignment of the municipal boundary of the city of Flint, Michigan (grey polygon), with the ZIP code boundaries used for collation of health data (black boundaries and numeric labels).

difficult to obtain or use more precise geospatial information, it seems that information as badly flawed as it was in this case (see also Grubesic & Matisziw, 2006) was no better than no information at all might have been.

THE ARBITRARINESS OF BOUNDARIES

As with scale (see Chapter 3), the social contestation and production of boundaries and territories is not explicitly represented in any concrete way in geographical computation, but defined boundaries and the resulting spatial units can have profound effects on analytical outcomes.

visualize data and perform spatial data analysis on data with associated ZIP codes (see Krieger et al., 2002).

Choosing which areas to use in a particular context, or even designing boundaries appropriate to a particular project, is a frequently encountered challenge in giscience. Ideally, the bounded areas used in any analysis would be real—bona fide boundaries to use Smith's term—but as we have seen, there are often really no such boundaries available, unless we are exploring specific technical questions about particular bureaucracies. So, it might make sense to work with ZIP codes if the questions at hand are about the speed of mail delivery, or with school enrollment zones if the questions are about outcomes in schools. More general questions about social, political, economic, and cultural geographies may not have any associated geographies that are fit for analytical purpose.

Furthermore, there is no single list of desirable characteristics of a set of geographies that can guarantee their usefulness for a wide range of uses, although we *can* identify characteristics that are generally *not* desirable! All else equal, it is better if areas have roughly similar populations, or more generally, populations that are broadly comparable to one another. In this context, the widespread use of counties and states for mapping geographical patterns in the United States provides a good example of *very bad* spatial units—at least from a technical perspective. The maps in Figure 5.5, based on counties in California, give some sense of the extent of the problem. Counties are just not a comparable set of things—their wildly divergent populations are almost their defining feature.

An associated problem this causes is that counties with smaller populations tend to dominate the extreme positions when we measure the rate of occurrence of anything—such as disease incidence, voter turnout, unemployment, and so on. This is because large populations will tend toward the mean rate of occurrence. These problems are particularly marked in dealing with rare events in spatial epidemiology (see chapter 5 in Cromley & McLafferty, 2012). Disentangling such artifacts of the spatial units from real effects associated with differences between rural and urban places can be challenging. Another difficulty with highly variable spatial units is that large-area, sparsely populated polygons dominate conventional maps, while densely populated areas disappear from view (see the middle panel of Figure 5.5). Cartograms offer one possible way to

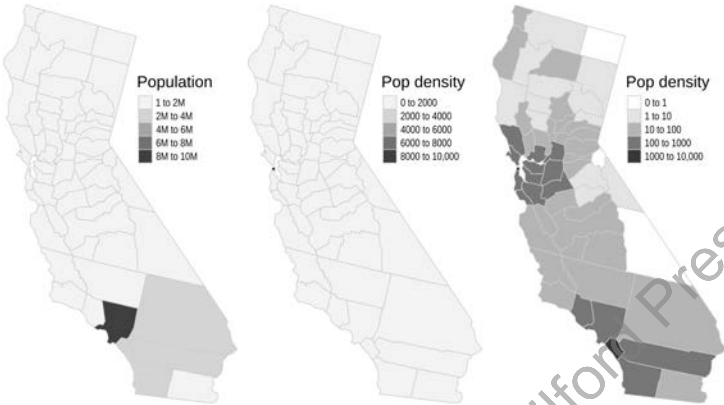

Figure 5.5. The challenge of maps when areas have very different base populations. The left-hand map shows the problem: Populations of the counties of California range from around 8,000 to almost 10,000,000. Mapping population density does not help much (middle map). Changing to a logarithmic scale (right-hand map) yields a more useful map, but also emphasizes just how different the counties are from one another.

mitigate this problem (see Figure 2.2) at the expense of less immediately accessible maps and visualizations.

The Modifiable Areal Unit Problem

These challenges point to the need for careful consideration of the system of geographies to be used in particular studies, which leads directly to consideration of the *modifiable areal unit problem* (MAUP). It is obvious that any system of geographies (usually polygons) applied to a region and used to aggregate statistical or count data translates a set of underlying observations into a table of numbers.[15] Less obvious (perhaps) is that the particular set of polygons used can alter the resulting distributions and patterns. A simple example (see Figure 5.6) suffices to demonstrate

[15]Another instance of the linking of "territory to other things" of Wood (2010b) in practice.

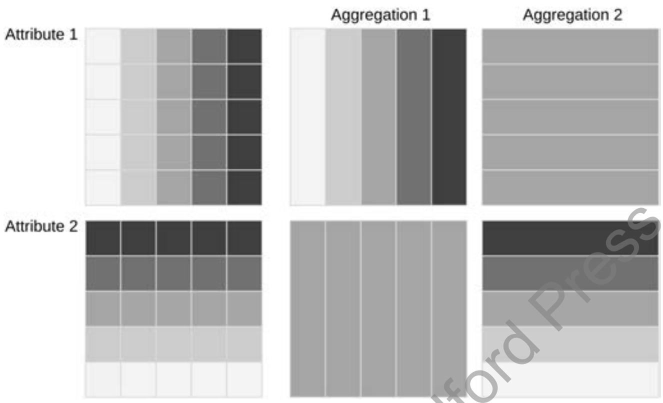

Figure 5.6. Simple illustration of the modifiable areal unit problem. Two attributes (the column and row numbers of the squares) are averaged across columns and rows respectively. In each aggregation the pattern of only one of the two attributes is preserved.

the effect. This is an extreme case to demonstrate the problem, but the effect is real, and in practice much more subtle than this. Perhaps surprisingly, the effect impacts not only simple summary values of attributes, but also secondary measures like the correlations between variables. This was dramatically illustrated by Openshaw and Taylor (1979) who showed how different aggregations of smaller polygons into larger ones could lead to the apparent correlation between two variables ranging anywhere between -1 and +1.

How this can happen is illustrated in Figure 5.7. Depending on whether observations that are similar or dissimilar are combined, an initial correlation can be strengthened or even changed in direction, and it is also possible for data that are not correlated at all to appear correlated after aggregation. The example in the figure is for non-spatial data. In a geographical setting, the impact of aggregating data from neighboring zones into larger agglomerations depends on the scales at which similarities and differences manifest in the data, that is on the

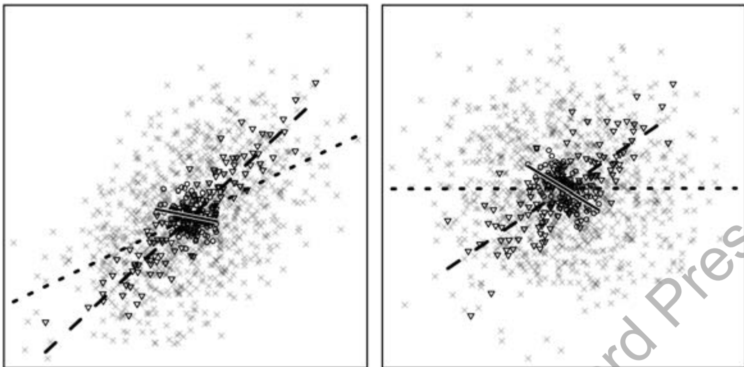

Figure 5.7. How aggregating data can increase or decrease correlation. Original data are shown in the background as crosses with the associated best-fit line dotted. In the left-hand panel the original correlation for these data is 0.47. Aggregating groups of eight similar observations yields the data shown as triangles, which have a correlation of 0.92 (the dashed line), while aggregating sets of eight dissimilar observations gives the data shown as circles with a *negative* correlation -0.21 (the solid line). In the right-hand panel initially uncorrelated data aggregate to correlations of 0.77 and -0.55, respectively!

scale, extent, and sign of any spatial autocorrelation. This aggregation behavior in data is an instance of an ecological correlation (Robinson, 1950) and the effect was familiar long before Openshaw and Taylor's experiments (Gehlke & Biehl, 1934). However, often finer-grained data are unavailable, and it may thus be impossible to know the degree to which observed correlations relate to effects the correlation statistics are intended to estimate.

The MAUP is driven by two different effects. First is an aggregation effect, which is the ecological correlation already considered, and a clear example of a scale effect (see §Scale-dependencies, Chapter 3). Second is a zoning effect, which reflects differences that can arise aggregating data at a single level, but in different ways, by drawing different lines to delineate different sets of polygons. It is the zoning effect that was explored by Openshaw and Taylor (1979) and that is illustrated in Figure 5.6. The

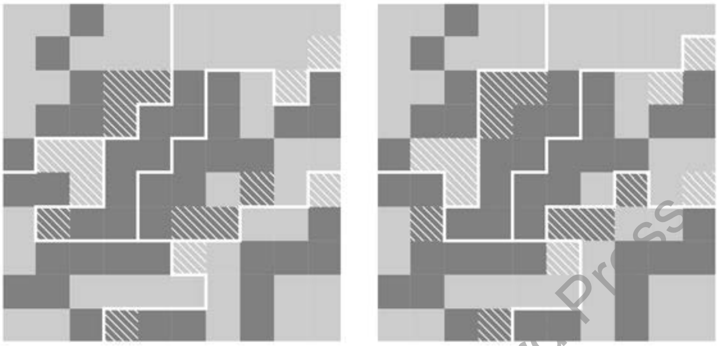

Figure 5.8. The zoning effect as a gerrymandering effect. In the left-hand panel the light gray group is in a narrow majority in four of five districts, while in the right-hand panel the result is reversed, after only a few sub-areas (hatched white) are swapped between districts.

zoning effect could equally be called the "gerrymandering effect" as it centers on how aggregate outcomes change as boundaries between zones shift (see Figure 5.8).

Gerrymandering is the political process by which electoral district boundaries are manipulated to make election outcomes less uncertain for the parties involved in the design of the districts. Given accurate information about the voting preferences of populations, an effectively gerrymandered map of electoral districts is one that makes the most efficient use of the votes available to the party designing the map. This involves some combination of "packing" an opponent's votes into large safe majorities where many of their votes are wasted, because they are not required to guarantee a win, or by "cracking" concentrations of the opponent's voter base by splitting them across several electoral districts (see Monmonier, 2001, especially pp. 8–12). Gerrymandering can be significantly refined using GIS software.

Concerns about gerrymandering, especially in the United States, have led to numerous ideas for assessing how fair a given map is. Some approaches center on assessing the efficiency of votes for different parties, that is, how many votes each party had to accrue per elected representative. If one party has to stack up more votes than the other to win seats, then perhaps it points to deliberately biased design of districts. Other approaches focus on the *shape* of districts, suggesting that extremely convoluted district boundaries are an indicator of deliberate, and by implication, bad intention in the design of districts, and that fair districts would have less convoluted, substantially convex shapes. Many of these approaches seem naïve at best. If the desired outcome is that the numbers of elected representatives be proportional to the votes cast for each party, then proportional voting systems are guaranteed to achieve that outcome. What the MAUP tells us is that outcomes in first-past-the-post representative systems inevitably depend on where, by whom, and how the electoral lines are drawn. Meanwhile, it is unclear what would constitute fair design of electoral districts, a question unavoidably entangled with the question of what constitutes a community of interest, which is the legal notion (in the United States) that has become relevant to these questions (Morrill, 1987; Forest, 2004).

Given the strong negative connotations of the term gerrymander, it is worth noting that the design of zoning systems can also aim to achieve equitable outcomes. An example, current in the 2010s, is the middle school zones of Berkeley, California, shown in Figure 5.9. This is related to a suggestion made by Openshaw

> that the MAUP is not so much an insoluble problem but rather a powerful analytical tool ideally suited for probing the structure of areal data sets. The growing speed of computers opens up the tremendous potential offered by heuristic solution procedures, such as the AZP [automating zoning procedure], to identify the most appropriate zoning systems for any particular purpose (1983, p. 38).

In other words, instead of treating the MAUP as an inconvenience, consider it an opportunity to get a better understanding of the geography of a study area by partitioning it in ways appropriate to the topic at hand. Openshaw (1983) also described an outline AZP drawing on earlier work (Openshaw, 1977), and some of these ideas were taken up in designing flexible output geographies for census data (Openshaw & Rao, 1995;

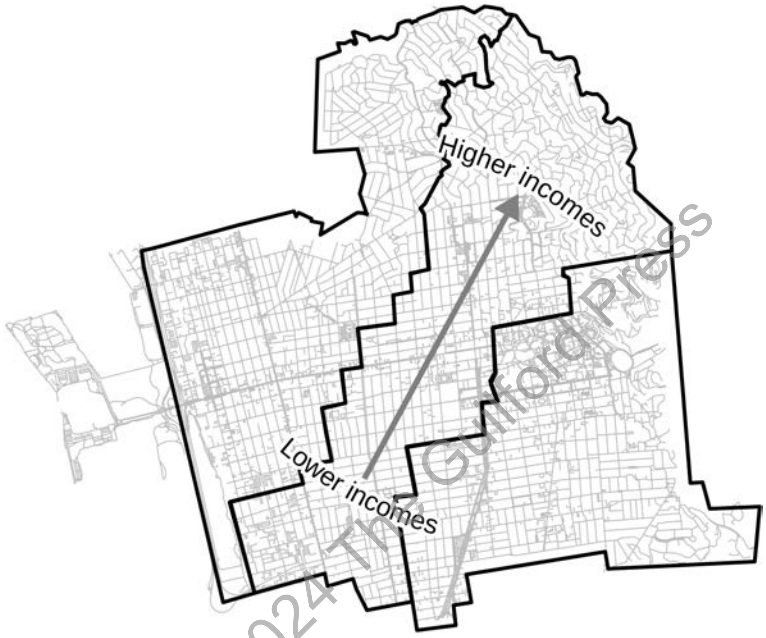

Figure 5.9. The (approximate) middle school enrollment zones in Berkeley, California, c. 2015. Each zone spans neighborhoods across levels of the socio-economic hierarchy in the city. They are an attempt to mix school populations on that basis.

Martin, 1998). More recently, perhaps following the development of efficient algorithms for partitioning networks (see §Connection, Disconnection, and Communities, Chapter 6), these ideas have resurfaced (see, e.g., Poorthuis, 2018).

Regionalizing Space

The inversion of the MAUP into a problem of zone design leads directly to the question of how we can partition a region into meaningful subregions for some purpose. Given the primacy of the region as a central concept in geography at various times (see Chapter 7), how to regionalize space has been a consistently prominent question. In this context, regions have generally been considered to be areas with shared characteristics across a range of aspects—economic, cultural, biophysical, ecological, and so on—with the emphasis on different aspects varying depending on the interests and inclinations of particular researchers. For example, Zelinsky (1980) presents vernacular regions of the United States based on the appearance of various toponyms in the names of enterprises (for profit and nonprofit)—work that has much in common with recent efforts at mapping vernacular or otherwise ill-defined places. In addition to the density mapping discussed in relation to that work (see §Place and Meaning, Chapter 4), statistical clustering (or classification) methods are a possible approach to regionalization.

These methods partition a set of observations into groups called *clusters*. A cluster is a set whose members are similar to one another and different from observations in other clusters. The difference between two observations is measured by combining the differences between the values of each attribute for the two observations. For example, if observation $\mathbf{x}$ has attribute values $x_1, x_2, \ldots x_n$ and observation $\mathbf{y}$ has attribute values $y_1, y_2, \ldots y_n$, then a Euclidean difference measure would be

$$d(\mathbf{x}, \mathbf{y}) = \sqrt{\sum_{i=1}^{n} |x_i - y_i|^2}$$

Alternatively, the difference could be based on the sum of the absolute differences between attributes (the Manhattan distance)

$$d(\mathbf{x}, \mathbf{y}) = \sum_{i=1}^{n} |x_i - y_i|$$

These two options are both Minkowski distance metrics

$$d(\mathbf{x}, \mathbf{y}) = \left(\sum_{i=1}^{n} |x_i - y_i|^m \right)^{1/m}$$

with m set to 2 and 1, respectively. Any of a wide range of alternative distance metrics can also be used (Deza & Deza, 2016).

Differences between every pair of observations are somehow determined, and then observations can be combined into clusters by a variety of procedures. The simplest approach, k-means, selects k initial seeds as cluster centers, and assigns observations to the cluster whose center is closest (i.e., most similar), then recalculates the cluster center, and iterates until cluster assignments stop changing. Agglomerative methods start by pairing the nearest pair of observations, then recalculating the difference between the newly formed cluster of two members and all other observations. Clusters continue to agglomerate in this way until all observations are in single cluster with hierarchical structure, based on the order in which observations were merged. Many other algorithms for clustering data are available (see Hennig et al., 2016).

Applied to spatial data, clustering analysis can produce candidate regionalizations, which will vary depending on stochasticity and parameter choices in the algorithm used, and—hopefully, more importantly—on the choice of attributes included in the process. A simple demographic example is shown in Figure 5.10. The important point here is the subjective nature of any regionalization arrived at by such methods. The definition of a cluster ends up being a set of observations identified as a cluster by a clustering technique in a particular context (Hennig, 2015)! Similarly, there is no generally applicable definition of similarity and difference. Instead, what is meant by similar and different is determined in the context of particular data and a particular clustering method. These circular definitions are fine given the exploratory nature of clustering as a method, but are worth keeping in mind before taking the results of a particular analysis too seriously as truth. A less often noted weakness is that these approaches treat the spatial units in the analysis as independent of one another, which is open to question given relational understandings of space and place (see Chapter 2). Closely related community detection methods from network science may partially address this concern (see §Connection, Disconnection, and Communities, Chapter 6). Regardless of these criticisms, the continued influence of Chicago School urban analysis is testament

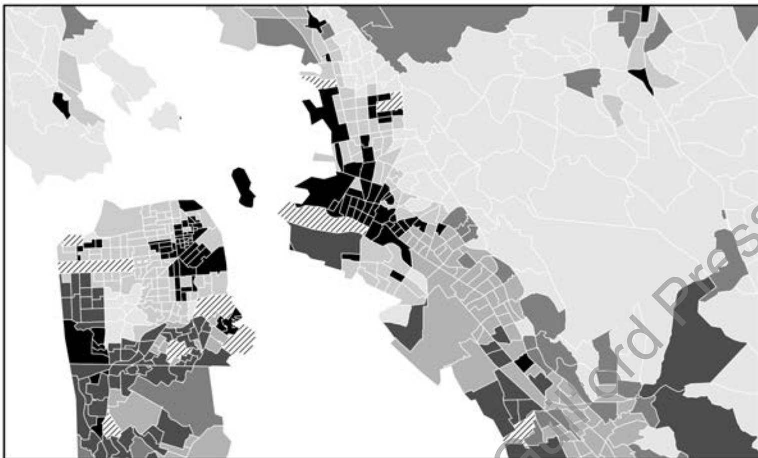

Figure 5.10. A possible regionalization of the San Francisco Bay Area based on demographic variables, such as age, household size, ethnic composition, income, education, and so on. Data available at https://github.com/lucguillemot/bayareageodemo although this clustering is a simple *k*-means result with *k* set to 5, rather than the more complex hierarchical approach presented in that work. Areas with no data are hatched.

to the usefulness of these approaches (Sampson, 2012), when applied with care.

An area where these cautions could be taken more seriously is geodemographic analysis (Singleton & Spielman, 2013). Geodemographic analysis is nothing more than the clustering approaches described above, albeit at much larger scale, and using more extensive datasets than those employed to make the example in Figure 5.10. Commercial products in this area often emphasize the large number of attributes used in the analysis, although beyond (say) a couple of dozen variables, it is questionable how much discriminatory value extra variables add. They also develop fine-grained classifications of dozens, even hundreds, of market segments.[16] Beyond such technical concerns, and reflecting on the discussion of drawing lines on maps earlier in this chapter, the question arises of the extent to which the use of such classification schemes produce and reproduce the different kinds of neighborhood they purport to represent. If commercial, political, and increasingly state action (Longley, 2005) are influenced by such classifications, then to what extent do the resulting actions produce or reinforce the classifications over time?

Such concerns are not only relevant to commercial, closed implementations, but also to ostensibly preferable open versions (Vickers & Rees, 2007; Singleton & Longley, 2009). It is also important to recognize that such questions can equally be asked of classifications of biophysical landscapes. The Land Environments of New Zealand (LENZ) classification (Leathwick et al., 2002) was originally developed to support biodiversity conservation by means of a detailed classification of all land in Aotearoa New Zealand based on 15 biophysical variables, pertaining to climate, landform, soil, and so on. A questionable aspect of LENZ, or any classification like it, is that as already noted it treats each location (in this case each 25 m pixel) as independent of every other, with no concept of their relational structure. Given the importance of flows of energy, water, nutrients, and so on through landscape, this limitation should be kept in mind. Returning to the issue central to this chapter, it is notable that among the potential applications of LENZ listed on its website[17] is "optimising the management of productive land uses, including locating optimal sites for particular crops or cultivars," which could easily run counter to LENZ's original purpose, and is certainly likely to reshape land over time, in another instance of the map potentially making the territory (see, for example Watt et al., 2010).

---

[16]These are often amusingly—or disturbingly—given catchy names like "American Royalty," "Birkenstocks and Beemers," or "Urban Survivors." These labels are from Experian's Mosaic USA classification (Experian, 2015).

[17]See https://www.landcareresearch.co.nz/tools-and-resources/mapping/lenz/.

MOVING ON FROM GEOMETRY

Lines and the polygons that they delineate are a much less convenient giscience abstraction than simple point locations. However, unlike point locations, polygons in a GIS or on a map directly represent things in the world. In fact, they often do much more than represent a thing in the world, they actually *are* that thing, legally and politically. A line in a geospatial database often has precedence over any physical manifestation of the corresponding boundary on the ground. If a property owner builds a fence that lays claim to more land than is associated with that parcel in a cadastral database, the line on the map is likely to take precedence over the fence in any legal dispute.

This inversion of the map-territory relationship—the map *is* the territory, it *makes* the territory—is to a large extent accepted in both geographical theory and in giscience. Geographers recognize that maps make places, and it is recognized in giscience that many (if not all) lines on maps are fiat objects, that is, "acts of human decision" (Smith, 2001, p. 133). An alternative approach to the fundamentals of geospatial computing follows from the view that fiat objects are the proper geoatoms on which geospatial data structures should be built. This approach is grounded in *mereology*, the philosophical study of part-whole relations, the topology of part-whole relations *mereotopology*, and mathematical treatments of these (Simons, 1987). In giscience discussion of how naïve geography concepts (Egenhofer & Mark, 1995), such as near, far, in front of, around, and so on, might be represented and reasoned with computationally is where these ideas have seen most uptake and interest. An alternative to standard GIS's foundational 9-intersection model for spatial relations between topological point sets (see Figure 5.1) is provided by *qualitative spatial reasoning* (Cohn & Renz, 2008).

For example, Worboys and Duckham (2021) show how qualitative reasoning about the relations among the Voronoi regions associated with spatial entities (see §The Voronoi Model of Space, Chapter 2) might enable automated descriptions of complex spatial arrangements more meaningful than those offered by the 9-intersection model. Stell discusses these ideas in relation to how space as it is experienced might be represented computationally, arguing that "qualitative relations can be used computationally as abstractions from quantitative data instead of being seen as an alternative and separate representation" (2017, para. 7). We touch on these ideas again in discussing time and process (see Chapters 7 and 8). Stell (2017) sets out the relevance of these discussions to the present context in discussing how boundaries cannot be coherently handled by point set topologies. Where two spatial entities touch, if our geoatom is an infinitesimal point, then it is impossible to say to which of the two entities a point arbitrarily close to the boundary belongs. This might sound like (literal) philosophical hairsplitting, but it also arises in practical geospatial work in dealing with spatial relations between geometries (very) near one another as a result of imprecision in floating point calculations. Often, the only workaround is to enforce arbitrary precision on calculations, which in effect makes the geoatom not a point, but a tiny pixel and introduces myriad other inconsistencies.

In the present context of dealing with lines, boundaries, polygons, and their relations, such problems reflect the dual nature of boundaries, which contain *and* connect areas (see Figure 5.3). This highlights (again) the importance to any coherent understanding of geographical space of relations, which are the focus of the next chapter.