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SURVEY PAPER



Cartographic Design as Visual Storytelling: Synthesis and Review of Map-Based Narratives, Genres, and Tropes

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ABSTRACT

In this article, I review considerations and techniques for approaching cartographic design as visual storytelling. Stories, like maps, are a method for documenting and explaining, for meaningfully abstracting our experiences, for communicating and sharing, and for asserting a particular worldview. I argue that visual storytelling offers an entry point for *hybridization* in cartography, uniting technology with praxis, product with process, and design with critique while opening rich new avenues for transdisciplinary research and design. I begin by introducing influences on map-based visual storytelling and review ten recurring themes that make visual storytelling different from traditional perspectives on cartographic design. I then offer three of potentially many ways to articulate and organize the design space for map-based visual storytelling: foundational *narrative* elements and their adaptation to geographic phenomena and processes, visual storytelling *genres* delineating different story experiences, and visual storytelling *tropes* used to advance narratives across text, maps, images, and other multimedia. I conclude with a call for future research on visual storytelling in cartography, including visual design, visual ethics, and visual literacy.

KEYWORDS

Cartographic design; visual storytelling; data journalism; spatial narratives; story map; geohumanities

Introduction: cartographic design as visual storytelling?

Stories, like maps, are a method for documenting and explaining, for meaningfully abstracting our experiences, for communicating and sharing, and for asserting a particular worldview. Energy is surging around ‘spatial narratives’, ‘story maps’, and ‘visual storytelling’ in cartography and related fields, due in part to geoweb technologies that make maps responsive across display devices, personalized to the viewer’s content and context, and viral across social media (Haklay *et al.*, 2008; Sui and Goodchild, 2011; Sieber *et al.*, 2016). Spatial narratives are an emerging research thrust in geography and cartography alike, with scholarship drawing from an eclectic set of disciplines and methods (Elwood, 2006; Caquard and Cartwright, 2014). Story maps are now a commercial platform, inviting a diverse and non-expert user group to participate in the mapmaking process, to tell their own place-based stories (Kerski, 2015; Buckley and Butler, 2018). Visual storytelling has transformed the cartographer into a ‘data journalist’ at major news companies, with professional practice outpacing research and education as a generation of cartographer/journalist experiments with new combinations of technology and multimedia, new forms of presentation and rhetoric, and new dimensions of the user experience (Wallace, 2016; Cairo, 2017). But, are ‘spatial narratives’, ‘story maps’, and ‘visual storytelling’ merely academic buzzwords or company slogans? What can storytelling actually tell us about cartography and design?

Following Caquard (2013), I argue that visual storytelling offers an entry point for *hybridization* in cartography, illuminating conceptual and epistemological tensions and offering rich new avenues for transdisciplinary research and design. While we often claim cartography as both art and science, data-driven and map-based storytelling truly realizes this autobiography, generating new hypotheses for scientific inquiry (e.g., Ma *et al.*, 2012; Boy *et al.*, 2015) while also making space for a ‘digital’, ‘spatial’, and ‘geo’ humanities (e.g., Knowles *et al.*, 2015; Dodge, 2017; Kallagher and Gamble, 2017). Visual storytelling combines the primarily quantitative and analytical approaches developed from journalism, information visualization, and visual analytics with the primarily qualitative and reflexive approaches developed from critical cartography, Indigenous mapping, and participatory GIS. Visual storytelling gives cartography multiple ways to unite technology with praxis, product with process, and design with critique. In these ways, my experience researching and teaching visual storytelling has revealed new cartographies to me and reshaped my understanding of maps.

In this article, I review considerations and techniques for approaching cartography as visual storytelling. While there is an important and growing corpus of work on the history, application, and critique of narrative and story in

cartography and related fields, my contribution here is to *design*: How can a hybrid approach drawing on storytelling influence a cartographer's design decisions and push cartographic conventions in new ways? I begin by synthesizing the broad, transdisciplinary influences on visual storytelling generally and story maps specifically. Rather than reviewing all aspects of storytelling potentially relevant to maps and graphics, I focus on ten themes recurring across disciplines that often separate spatial narratives, story maps, and visual storytelling from traditional perspectives on cartographic design. Drawing on literature in cartography and adjacent disciplines, I then offer three of potentially many ways to articulate and organize the design space for map-based visual storytelling: foundational *narrative* elements and their adaptation to geographic phenomena and processes, visual storytelling *genres* delineating different audience experiences, and visual storytelling *tropes* used to advance narratives across text, maps, images, and other multimedia. With a few exceptions, I focus my literature review onto storytelling that is explicitly visual, cartographic, and geographic. I conclude with a call for future research on visual storytelling in cartography, including visual design, visual ethics, and visual literacy.

Influences and definitions: what is visual storytelling?

Interest in narrative and storytelling is not new to cartography, as many of the most celebrated maps from antiquity worked not because they were accurate or complete, but because they aligned with a dominant oral tradition or cultural narrative (Woodward and Harley, 1987; Crampton, 2011). Storytelling was used as an organizing metaphor in formative texts establishing cartography as an academic discipline, such as Brown's (1949) *Story of Maps* presenting cartography in a historical 'chronicle' and Robinson's (1952) foreword to *The Look of Maps* presenting cartography as a story still 'unravelling'. Storytelling also was used as a primary critique of these early works, contesting a cartography presented as singular and neutral while calling for a narrative approach that reveals the intentions of the map/story and mapmaker/storyteller (e.g., Wood, 1987; Harley, 1989). Arguably, Western cartography's twentieth-century search for objectivity was an effort to hide the storyteller during map design.

Today, cartographic research on narrative and storytelling draws from an eclectic set of disciplines and methods. Caquard and Cartwright (2014) outline three storytelling forms – oral, written, and audio-visual – for which maps provide spatial structure to enhance the storytelling experience. Each exchange between maps and an alternative story form has disciplinary influences and emerging spaces of hybridization: oral storytelling drawing from anthropology, folklore, and history and taking shape in Indigenous (e.g., Chapin *et al.*, 2005; Pearce and Louis, 2008) and participatory (e.g., Elwood, 2006; Miller, 2006) cartographies, written storytelling building upon linguistics, literature, and cartooning and forming in literary (e.g., Moretti, 2005; Bushell, 2012) and imaginative (e.g., Joliveau, 2009; Caquard, 2011) cartographies, and audio-visual storytelling integrating art, music, and film for cinematic (e.g., Caquard and Taylor, 2009; Muehlenhaus, 2014) and multimedia (e.g., Monmonier, 1992; Cartwright, 1999) cartographies. Taken together, these roots ground *narrative cartography*, and the intersections of maps with oral, written, and audio-visual storytelling frame a cartographic research agenda for the digital, spatial, and geo humanities.

In addition to the humanities, visual stories and story maps increasingly are created through code by technical professionals working in computer science, user experience (UX) design, and web development (Roth, 2015). Visual storytelling is now a cardinal research topic in cartography's sibling discipline of information visualization (Kosara and Mackinlay, 2013), with much of this work calibrated to support the growing profession of *data journalism*, or news reporting with a blending of text, images, and data-driven graphics (Gray *et al.*, 2012). Storytelling also is a theme in geovisual analytics (Robinson *et al.*, 2017), where visual and computational methods are used to glean patterns and trends from non-visual stories (e.g., Correll *et al.*, 2011; Reuschel and Hurni, 2011), extract story elements from unstructured records (e.g., MacEachren *et al.*, 2011; Straumann *et al.*, 2014; Tateosian *et al.*, 2019), and summarize insights from analytical reasoning into a coherent story for presentation (e.g., Pirolli and Card, 2005; Eccles *et al.*, 2008). Designers from information visualization, data journalism, and visual analytics often develop on and contribute to geoweb technologies (e.g., Haklay and Weber, 2008; Bostock *et al.*, 2011), enabling broad distribution of interactive maps and inviting the public to participate in the storytelling process.

But, what is visual storytelling? The concepts of 'narrative' and 'story' are so fundamental to the human experience that the terms often are not explicitly defined in the literature, and when they are, their definitions vary widely given their truly transdisciplinary treatment described above. Narrative is the combination of story with discourse, with narrative being 'the presentation of [a] story in a particular way[...]shaped by temporality and [having] a beginning, middle, and an end, although not necessarily presented in that order' (Pearce, 2008: 20–21). In the following, I use *story* to describe an account of specific events, places, and people, and I use *narrative* to describe the structure and presentation of this content that shapes the meaning of the story. A

data-driven story then draws – at least in part – on quantitative and/or qualitative information to find the narrative structure and develop the story content. While the term ‘story map’ was first used to juxtapose authoritative, planimetric, and sterile ‘grid maps’ with deep, imaginative, and personal alternative representations (Macfarlane, 2007), I adopt a more inclusive definition of *story map* to consider any cartographic representation that exhibits narrative elements. Finally, I use *visual story* to describe stories communicated through illustrations, graphics, imagery, and video instead of or in addition to oral, written, and audio formats (Segel and Heer, 2010), with a map potentially just one scene in the overall story.

Some common visual storytelling themes

While offering definitions is useful for clarity in the remaining discussion, delineating the exact bounds of a visual story or story map is not productive given their broad disciplinary influences and diverse treatment. However, amid this variability, I noticed some repeating (though at times contested) ways these concepts are evoked and discussed in the literature, offering opportunities for hybridity. In the following, I present ten common themes in visual storytelling with maps. No single characteristic separates a ‘visual story’ from a ‘visualization’ or a ‘story map’ from a ‘map’, and arguably the following characteristics apply to any map or visualization to a degree. But taken together, these visual storytelling themes serve as both background review on narrative cartography and creative inspiration for designers. To this end, visual stories commonly are described as:

1. **Designed:** Making a visual story, much like making a map, is a deliberate process that draws on the designer’s understanding of and interests in the represented phenomena and target audience (Pearce, 2008). Again like a map, a visual story has an intended purpose, with the designer making intentional decisions about composition to develop the broader lesson or moral. In this way, the goal of visual storytelling is not just to ‘show’ but also to ‘explain’ (Tufte, 1997). In addition to the wide range of cartographic design decisions for traditional maps, visual stories also typically enforce an order and pacing to the reading of visual elements, with the designer creatively choosing this sequence to advance the narrative (Ormeling, 1995).
2. **Partial:** Visual stories prioritize essential information needed to follow the narrative, often emphasizing a small set of key characters, places, and events while ignoring others. Visual stories privilege brevity over completeness, with story maps often containing cropped geographic extents, interior holes or occluded features, and inconsistent cartographic scales and levels of detail (Pearce, 2009, 2014). A small assemblage of actors can be selected to exemplify broader patterns and trends, serving as an anecdotal lead that helps to make sense of complex, big data through a tidy, small story (Moore *et al.*, 2019). However, Cronon (1992: 1349) warns that ‘in the act of separating story from non-story, we wield the most powerful yet dangerous tool of the narrative form,’ calling into question whose voices are heard in the story and whose are not.
3. **Intuitive:** For many, visual stories are more grokable than other modes of communication, offering a more approachable way to mix hard numbers with anecdotal descriptions (Gershon and Page, 2001). That visual stories are partial abstractions generally makes them easier to understand due to reduced information complexity. However, visual storytelling also closely reflects the human experience of place-based events, serving as a congruent metaphor to improve communication (Cartwright, 1999). Our abilities to follow narratives and glean meaning from stories have been explained from both social-cultural (e.g., Mink, 1978; White, 1984) and biological-cognitive perspectives (e.g., Schank and Abelson, 1977; Carr, 1986). Regardless of aetiology, visual storytelling operationalizes these abilities, establishing a clear entry point to start the story and clean transitions between scenes to mark unambiguous story progression (Segel and Heer, 2010).
4. **Compelling:** Not just intuitive, visual stories also are considered a more meaningful way to communicate a message, offering a deep, contextualized account versus a superficial, sanitized overview (Macfarlane, 2007). Visual stories often capture our attention through a vivid array of graphics, images, and other multimedia, that, when combined with maps, develop a richer sense of place than vector linework alone (Cartwright, 1999). Creating a visual story that is both intuitive and compelling requires a keen design sense, and designs that slip to one extreme risk becoming either understated or sensationalized (Muehlenhaus, 2012), obfuscating the narrative and masking the designer’s intentions.
5. **Relatable:** Visual stories promote empathy; the audience puts themselves into the story setting, assumes the roles of the characters, and draws from personal experience to add context (Gershon and Page, 2001). In this way, visual storytelling humanizes maps, ‘bringing to life’ the real people imperfectly captured by the data (Caquard *et al.*, 2009: 90). Visual storytelling often is described as more appealing approach to cartography and visualization, but these feelings need not be pleasant if the story deserves a somber, irritated, or even enraged mood. Story and narrative are central to cartographic research on affect and emotion (e.g., Kwan, 2007; Kwan and Ding, 2008; Nold, 2009; Roberts, 2014), with visual stories designed both to represent the

emotions of people in the story and evoke emotions from the audience (Griffin and McQuoid, 2012). Accordingly, visual stories perhaps should be judged less on how efficiently or effectively they are read or understood, but instead how they make the audience feel about and connect to other people and places.

6. **Memorable:** Visual stories – through their intuitive, compelling, and relatable designs – tie seemingly unrelated information together in a memorable way through logical continuity (van Elzakker, 1993; Kosara and Mackinlay, 2013). Oral, written, and, more recently, audio-visual storytelling forms have served as much to document and explain as remember and share across generations (Caquard *et al.*, 2009). Story maps and geoweb technologies capture memories as traces through the landscape, providing a record of where we have been and thus who we are becoming (Tasker, 1999 in Caquard and Cartwright, 2014). But visual stories do not just capture memories, they also shape them. Embellishments once considered superfluous ‘chart junk’ may help to remember the contents of a map or visualization (Borkin *et al.*, 2013), particularly if they support a narrative (Bateman *et al.*, 2010). However, there also is preliminary evidence that not all storytelling elements may be remembered equally, with detailed information about specific events, places, and people sacrificed for the story broader problem and resolution (Song 2017).
7. **Situated:** Visual stories present meaning from a grounded perspective (Pearce, 2014), from ‘somewhere’ and ‘someone’ in contrast to the objective view from ‘nowhere’ and ‘no one’ often assumed in cartography and related design fields (Haraway, 1991; Rose, 1997; Elwood and Leszczynski, 2018). Visual storytelling offers opportunities to fold feminist interventions into cartographic design practice. First, visual storytelling invites designers to be reflexive about their positionality and subjectivity (Ricker, 2017; Kelly, 2019). Just as data cannot speak for themselves (Gould, 1981), stories cannot tell themselves, and stories that include the designer’s voice in the telling can be more compelling and relatable (e.g., Hermann and Pearce, 2010; Pearce and Hermann, 2010). Second, visual storytelling embraces pluralism and varying perspectives (D’Ignazio and Klein, 2016; D’Ignazio and Klein, 2020). Arguably, visual stories welcome multiple interpretations more than other authoritative forms of documentation, allowing individuals to draw from their personal backgrounds when developing multiple, equally valid story meanings. Finally, the cardinal promise of geoweb storytelling tools is empowerment of the public to share their own stories (Warf and Sui, 2010), promoting multiplicity of both designer and audience while embracing our different lived experiences.
8. **Persuasive:** Visual stories do not only ‘explain’, they also ‘argue’ from their situated positions (Harley, 1989). As Cronon (1992: 1374) writes, ‘We tell stories *with* each other and *against* each other in order to speak *to* each other’ (original emphasis). Persuasive maps and graphics employ rhetorical techniques to advance the narrative and suggest a specific interpretation (Tyner, 1982). Visual methods of persuasion tie directly to emerging practices in data journalism, with research on rhetoric in cartography and visualization commonly drawing examples from online news media (e.g., Segel and Heer, 2010; Hullman and Diakopoulos, 2011; Muehlenhaus, 2011; Vujaković, 2014; Knight, 2015); it is no wonder that the design of maps for news reporting is sometimes described as ‘editorial’ cartography (Monmonier, 1989). But this persuasion goes beyond just the framing of meaning, as persuasive visual stories also mobilize the audience to act in a specific way (Caquard, 2013). Accordingly, it is necessary to question if such persuasive visual storytelling without an accompanying visual ethics is doing more harm than good to our collective geographic understanding and global citizenship (Kent, 2017).
9. **Political:** That visual stories are partial, situated, and persuasive also means they are inherently political, exercising power by promoting particular voices and interpretations while obscuring others (Cronon, 1992). While all mapping is political, visual storytelling and spatial narratives often are employed to confront rather than edify inequities and marginalization (e.g., Peluso, 1995; Elwood, 2006; Counter Cartographies Collective *et al.*, 2012). Story maps stake new claims, empowering people and communities to reassert control over their surroundings (Nold, 2009; Caquard, 2013). In addition to their political objectives, visual stories often foreground the politics of their creation through transparency in the design process (Cattoor and Perkins, 2014). Perhaps the first tenet of ethical visual storytelling is to ‘show your work’ by documenting the design process and releasing all datasets (Cairo, 2017; Rooney *et al.*, 2017) while also recognizing the labour involved in completing the design (D’Ignazio and Klein, 2020).
10. **Fluid:** Finally, the meanings of visual stories – both those intended by the designer and interpreted by the audience – are not static, and change across cultures and through time (Pearce, 2014). Maps do not tell stories in themselves, but instead ‘stories are thrust upon the map’ (Denil, 2017: 19), shaped by context and experience. In this way, visual stories are ‘living’, with interactive geoweb technologies enabling continuous curation of visual stories and story maps as they evolve (Caquard *et al.*, 2009). Such an emphasis on process over product in visual storytelling aligns with calls for ontogenetic (Kitchin and Dodge, 2007) and post-representational (Caquard, 2015) cartographies, presenting additional outlets for hybridity between design and critique.

Elements of a linear three-act spatial narrative

A first way to describe the design space for visual storytelling is by the narrative sequence used in the story. Narrative often is described as an ordering of basic elements common to most stories (Cohn, 2013). In film, journalism, and literature alike, the narrative sequence typically is defined by the *temporal* order of events, which together form the *plotline* (Phillips, 2012). A narrative that hangs upon a temporal plot explicitly evokes one-dimensional linearity in its organization, although storytellers can break dramatically from the temporal order of events to foreshadow or surprise (Muehlenhaus, 2014). However, maps and other visualizations using a spatial metaphor are inherently two-dimensional and thus often lack a temporal sequence or relevant linear axis to inform a plotline (Mocnik and Fairbairn, 2018). Therefore, the designer must select narrative elements and enforce linearity in the reading of the visual story (Gershon and Page, 2001; Hullman *et al.*, 2013).

What, then, should the designer seek when ‘finding the narrative’? Narrative elements and sequences often are discussed in relation to a linear, three-act narrative (Figure 1a). Dating to Aristotle’s *Poetics* (335 BCE), a *three-act narrative* has distinct plot sections (i.e., *acts*) forming the beginning, middle, and end. Each act contains *narrative elements* recurring across stories that can be visualized as unique symbols within a single graphic or separate frames within a larger, multi-scene story (Thöny *et al.*, 2018).

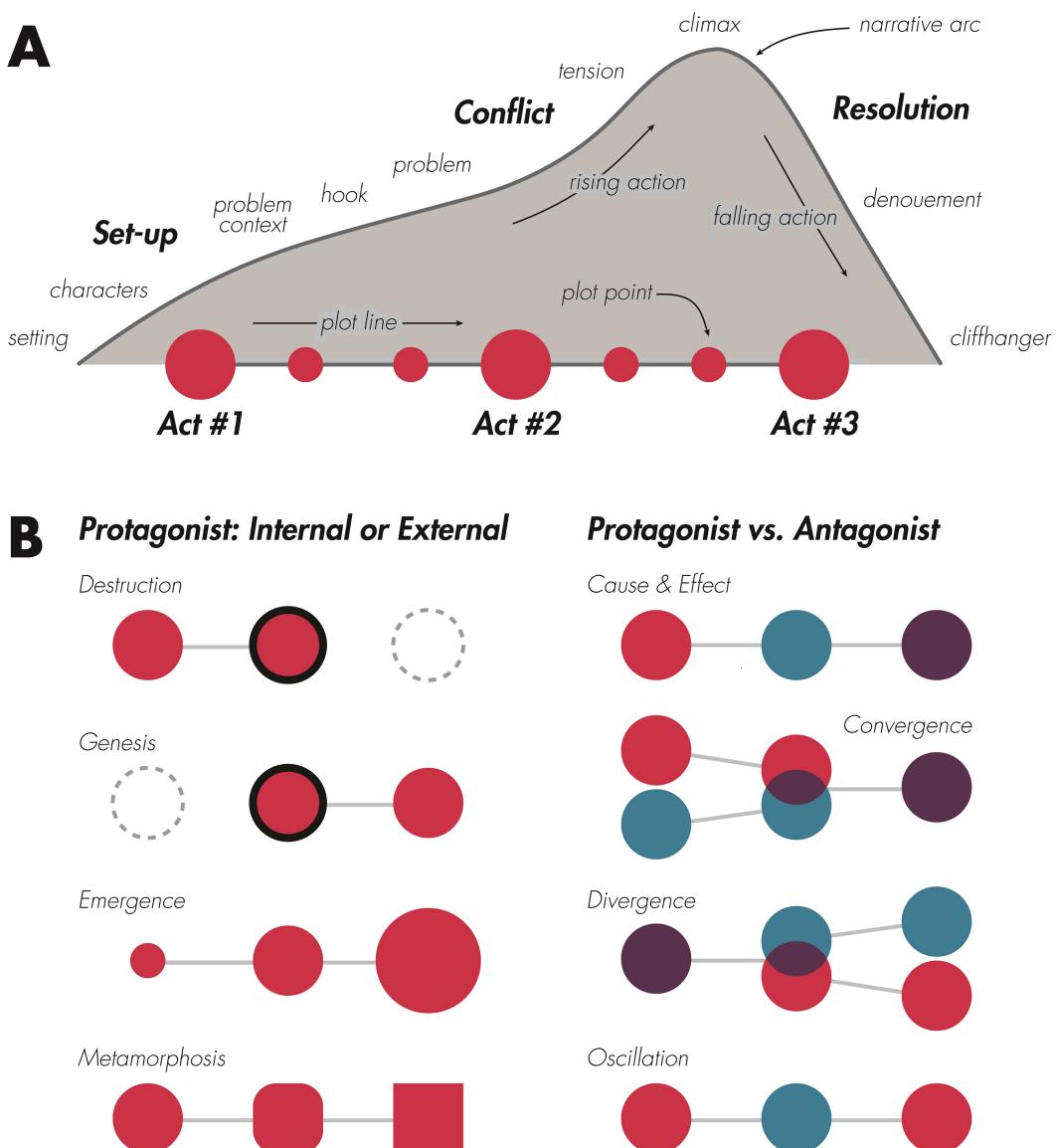


Figure 1. Linear three-act spatial narratives. (A) Classic elements of a three-act narrative. While visual storytelling often departs from a linear narrative, it is helpful during design to consider the classic three-act narrative comprising the set-up, conflict, and resolution. Individual narrative elements (the setting, characters, problem context, etc.) can be visualized as unique symbols within a single graphic or separate frames within a larger, multi-scene story. The figure presents a mixture of narrative elements drawn from literary and film studies, which are presented in a typical rather than fixed order and relative rather than absolute location within the narrative arc. (B) Spatial narrative arcs. Phillips (2012) identified eight narrative arcs commonly used in geography and the geosciences, with the narrative arcs differing in how conflict is resolved. Four narrative arcs focus on a single protagonist – commonly a place or region – with conflict arising from either internal or external forces: destruction, genesis, emergence, and metamorphosis. Four narrative arcs emphasize the conflict between two or more characters, sometimes evolving from or resulting in a third state: cause-effect, convergence, divergence, and oscillation.

Act 1: set-up

A three-act narrative begins with the *set-up*, introducing the setting, characters, and the problem context. The set-up opens by describing the *setting*, putting the audience into a specific place, time, and social context and giving the story a geography that constrains the plotline (Burke, 1969). The setting makes a narrative explicitly spatial, with a story map serving as a spatial reference for the setting and the actions of characters within it (Caquard and Cartwright, 2014). The setting defines not just the story location, but also the geographic scale of the spatial narrative, with story maps often needing to be multi-scalar to properly frame the narrative across space and through time (Weber Reuschel *et al.*, 2014).

The set-up then inserts *characters* into the setting who embody the narrative and act-out the plot (Ryan, 2003). Characters can include *protagonists*, the leading or hero roles featured by the narrative, *antagonists*, the oppositional or foil roles who contend with the protagonists, and other supporting roles that provide context and advance the narrative (Fontaine, 2015). Character-driven storytelling presents alternative, situated motivations and perspectives, helping the audience assume multiple perspectives (Pearce, 2014). For spatial narratives, places as well as people can be treated as characters, enabling critical juxtaposition of different places who serve as exemplars for broader geographic patterns.

The set-up also provides *problem context*, or additional – often qualitative – background information needed to interpret the story later in the narrative sequence (Fontaine, 2015). Problem context draws from ancillary or supplemental geospatial datasets to describe contingent information about the characters, setting, and their activities, as well as the broader story purpose and theme. Accordingly, problem context is a primary way that the designer shapes the meaning of the story through selective inclusion and omission, with the problem context often fully erased from authoritative maps and visualizations (Muehlenhaus, 2012). Vujaković (2014: 15) provides a useful taxonomy of geographic problem contexts, described as ‘news map themes’, within and against which the majority of story maps are framed (Table 1).

Finally, the set-up often includes a *hook*, or an early scene (i.e., the ‘teaser’ or ‘click-bait’) that captures attention and builds buy-in from the audience (Kosara and Mackinlay, 2013; Roth, 2015). In data journalism, the hook is the lede to an ‘inverted pyramid’ or ‘inverted triangle’ model of storytelling, presenting the most compelling piece of information first using persuasive rhetoric and moving from critical to mundane information as the narrative progresses (Kosara, 2017). The hook can be interactive for visual storytelling, drawing on geoweb technologies to support non-linear, user-driven story map exploration before entering the linear narrative; such a design strategy is consistent with Segel and Heer’s (2010) ‘drill-down’ narrative structure.

Act 2: conflict

A three-act narrative then progresses into the *conflict*, introducing the problem, building tension, and incrementally advancing the plot (Fontaine, 2015). The conflict begins with the *problem*, or central confrontation, obstacle, or setback driving the story, which produces a *tension* in character-driven storytelling either between characters (typically the selected protagonist and antagonist), internally within a single character, or externally between a

Table 1. Geographic problem contexts.

Geographic problem context	Description
Politics, Domestic, Non-violent	Government, legislation, electoral, parties, non-violent protests, non-violent strikes
Politics, Domestic, Violent	Riots, terrorism, civil conflict, civil war, coups
Politics, International, Non-violent	International relations, negotiations, agreements (non-trade)
Politics, International, Violent	Military conflict, war, defense issues, territorial disputes, forced relocation
Disaster Events, ‘Natural’	Earthquakes, weather-related events (floods, hurricanes, avalanches, tornados), epidemics, etc.
Disaster Events, Human	Accidents, explosions, fires, industrial disasters, etc.
Science, Medical	Biomedical research, disease prevention and intervention, public health
Science, Natural Environment	Environmental problems, environmental impacts, climate change science, pollution, conservation and preservation
Science, Urban Built Environment	Transportation, development and planning, civil engineering
Science, Non-urban Built Environment	Agriculture, fisheries, logging, land use, resource management
Society, Demography	Demographics, social trends, housing, employment, education
Society, Public Safety	Crime, courts, judicial activity, policing, missing persons
Society, Human Rights	Famine, representation, equality
Cultural, Heritage	History, geography, archaeology, the arts and humanities
Cultural, Entertainment	Travel, tourism, recreation, sport
Cultural, Human Interest	Human interest, celebrity, scandals (non-political), VIPs, gossip
Economics, Local	Microeconomics, business, finance, industry, commerce
Economics, Global	Macroeconomics, trade agreements, international monetary issues, foreign aid, economic development, NGOs

Notes: Vujaković (2014: 15) identified 18 ‘news maps themes’ organized into seven higher levels: politics, disasters, environment and science, society, cultural affairs, and economics. The themes serve as a useful organization for common geographic problem contexts in visual stories and story maps. A single visual story may relate elements across multiple problem contexts, such as the relationship to climate change science and ‘natural’ disaster. Problem contexts are expanded and modified from Vujaković (2014).

single character and a larger force. Such character development humanizes the story for the audience, with personifications differing in their appeals to emotion (pathos), ethics (ethos), and reason (logos) to sharpen the narrative continuity and persuade the audience.

Characters are developed following the problem through *plot points*, or pauses along the linear narrative that incrementally introduce new or complicate prior information about the evolving setting, characters, and problem context. Plot points are anchored and grounded in place (Roberts, 2014). For story maps, a plot point can be a single ‘point’ on the map, symbolized and annotated to fit within the linear narrative, or a stand-alone map ‘plot’, sequenced within a series of maps and graphic panels. Plot points are paced for rising action in a narrative arc (Pearce, 2008), intensifying the tension and galvanizing the characters (and perhaps the audience as well) to build interest and suspense.

Literary scholars recognize a number of traditional plotlines or narrative arcs based on recurring strategies for imposing conflict (see Booker, 2004 for an overview). Importantly, Phillips (2012: 156) describes ‘eight basic plots’ specific to geography and geosciences – thus defining *spatial narrative arcs* available for visual storytelling – that differ by the way characters develop in response to the conflict (Figure 1b). Articulating different spatial narrative arcs provides designers with story templates for assembling narrative elements into visual sequences; however, there are two important caveats to the practical use of these templates. First, the same geographic problem context could be described using all eight spatial narrative arcs, resulting in markedly different rhetoric and conclusions (Table 2). While this flexibility is useful and demonstrates the potential of visual storytelling, designers may abuse control over the narrative by selecting an arc not fully evinced by the available information or by suppressing alternative arcs also supported by information. Second, the spatial narrative arcs assume some form of character evolution beginning in the second act, making a visual storytelling approach best suited for explaining change rather than stability in geographic phenomena and processes (Cronon, 1992; Ma *et al.*, 2012).

Act 3: resolution

A three-act narrative ends with the *resolution*, bringing the narrative arc to its culminating moment and presenting concluding (re)solutions to the problem. The resolution opens with the *climax*, a final plot point bringing characters together to face their tension and consider competing solutions to the problem (Fontaine, 2015). Through this final character development, the climax again helps the audience assume multiple perspectives, enriching their understanding of how solutions to the problem will have a differential impact on people and places. Like the hook, visuals also can be interactive for the climax, with the maps and visualizations not provided to gain an initial overview through exploration (as in the hook), but instead to directly interrogate competing scenarios and outcomes at the most critical point in the narrative arc (Proulx *et al.*, 2006).

Following the climax, the designer may choose to impose a single solution, arguing for one interpretation of the story – and thus of the mapped information – over others. This rhetorical structure connecting evidence to a central claim is common in data journalism, where the closing resolution ‘ties together the events of the story and provides a form of closure’ (Kosara, 2017: 1). Such resolution is a final way in which the designer shapes the meaning of the visual story through persuasive rhetoric. Arguably, most maps and visualizations created outside of a storytelling framework present only the resolution, obscuring the full story and how the designer came to such a conclusion.

The narrative arc then concludes with falling action in the *denouement*, in which all remaining matters with the setting, characters, and problem context are explained or resolved. One common form of denouement in visual storytelling is a credits section, in which all sources are listed and data provenance provided. The denouement also is a third narrative element that lends itself well to interactivity, with the audience invited to explore the data most relevant to their context after experiencing the linear narrative (Kosara and Mackinlay, 2013); such a design strategy is consistent with Segel and Heer’s (2010) ‘martini glass’ narrative structure.

In contrast, the designer may choose not to side with any solution, instead leaving the narrative arc unresolved as a *cliffhanger*, encouraging the audience to ‘fill the gaps’ using their own experiences (Gershon and Page, 2001). Cliffhangers make the visual story compelling and memorable as well as situated and fluid. As Pearce (2008: 29) writes, ‘Without closure, the reader or viewer must become personally involved in the narrative in order to close the gap, in turn energizing the narrative’.

Should all visual stories follow a three-act narrative and are all narrative elements needed for effective visual storytelling? Absolutely not. For many visual storytelling contexts, the three-act narrative is either an idealized or overly-formulaic structure, and there are many other narrative sequences and elements not reviewed here. Hullman *et al.* (2013) and Thöny *et al.* (2018) provide an additional discussion on alternative linear, parallel, and non-linear narrative structures. However, the basic narrative elements and possible structures for combining them gives cartographers new ways to think about data and design for visual storytelling, ultimately

Table 2. Eight visual stories about climate change.

Narrative Arc	Description (Phillips 2012)	Act 1: Set-up	Act 2: Conflict	Act 3: Resolution
Destruction	Describes loss, disappearance, or degradation	The Florida Everglades are an expansive wetlands area supporting biodiversity and providing storm surge protection to adjacent urban areas.	Climate change results in substantial increase in global sea levels, threatening large portions of the Everglades.	The Everglades collapse, displacing wildlife and putting Florida urban areas at greater risk of flooding.
Genesis	Describes addition, creation, or establishment	Despite its geographic location between Europe and Asia, Canada has a relatively small shipping industry due to the lack of a navigable shipping route through the Arctic.	Climate change results in loss of sea ice in the Arctic, opening a year round Northern passage for shipping.	The Northern passage becomes one of the most heavily travelled shipping routes worldwide and Canada becomes a global shipping power.
Emergence	Describes expansion, maturation, or development through realization of explanatory processes	The American Southwest is a large arid region spanning multiple desert environments, with water security an important issue for its urban areas such as Las Vegas, Los Angeles, and Phoenix.	Climate change results in decreased precipitation and increased evaporation in the American Southwest, deteriorating already stressed water reserves.	Water security becomes the central governance issue in the American Southwest, jeopardizing the sustainability of urban areas in the region.
Metamorphosis	Describes rearrangement, reorganization, or modification	American cities prioritize individualized transportation on multilane highway infrastructure as part of its legacy leading the automotive industry.	Climate change results in policy to decrease reliance on individualized travel as a means of reducing fossil fuel emissions, rendering highway infrastructure suboptimal.	American cities reinvent transportation infrastructure to support mass transportation through rail, electric buses, and autonomous ridesharing.
Cause and Effect	Describes relationships between actions, conditions, processes, etc., and outcomes, forms, responses, etc.	The burning of fossil fuels results in an increased release of carbon dioxide (CO ₂) into the Earth's atmosphere.	The increased CO ₂ acts like a greenhouse, preventing the energy reaching Earth from the Sun from escaping the Earth's atmosphere.	The Earth overall warms on average, with climate regimes changing across the globe and many places experiencing greater temperature volatility, including prolonged warm and cold snaps.
Convergence	Describes arrival at similar paths, solutions, or outcomes	Arizona, a traditionally conservative US state, and California, a traditionally progressive US state, vote differently on climate action policy.	Climate change stress on constituent populations results in expanded support for solar energy in Arizona and wind energy in California.	Both Arizona and California allay reliance on fossil fuels, reducing their carbon footprint.
Divergence	Describes deviation to different paths, solutions, or outcomes	Researchers in the European Union and the United States share a common scientific objective of better understanding our changing planet in order to predict and prevent deleterious impacts.	Climate change denial results in regressive national policy in the United States, whereas embracing climate science leads to actionable policy within the European Union.	The United States becomes more vulnerable to environmental disasters, including drought, severe storms, and coastal flooding, whereas members of the European Union become more resilient.
Oscillation	Describes a cyclical or recurring transition	Panda bears, among the most charismatic megafauna, have a diet exclusively comprising bamboo.	Climate change results in a shift of viable habitat for bamboo, and thus pandas, combining with poaching and deforestation to jeopardize panda populations.	New protected areas are established to accommodate the shifting range of pandas, resulting in a rebound of their population.

Notes: Depending on the available information, the same geographic problem context can be expressed through each of Phillip's (2012) eight spatial narrative arcs. The table defines each narrative arc and provides abridged three-act scripts for a hypothetical visual story about climate change.

presenting new opportunities for cartographic research and practice (e.g., Table 3; Song 2017). Additionally, drawing on familiar narrative sequences and elements, such as the linear, three-act narrative, further reinforces the intuitive, relatable characteristics of visual stories described above.

Visual storytelling genres

A second way to describe the design space for visual storytelling is by the composition technique used to construct the narrative for the story, described by Segel and Heer (2010: 1139) as different 'genres of narrative visualization'. First used to refer to storytelling in cartography by Cartwright (1999), a *genre* is a category of literature, music, or other kind of art exhibiting similarities in form and style. For instance, Esri Story Maps supply a growing array of templates that offer different default layouts and user interactions for organizing narrative elements and story content (Austin, 2018). Segel and Heer delineate visual storytelling genres by the number and order of unique *frames*, or individual sections, panels, slides, etc., that comprise narrative elements and plot points. Segel and Heer then employ seven genres in their analysis of visual storytelling, each of which can be made interactive: magazine style, annotated chart, partitioned poster, flow chart, comic strip, slide show, and film/video/animation.

Table 3. Comparison of narrative elements in two scripts.

Narrative Element	Description	Example #1: Presidential Campaign Donations	Example #2: Sea-level Rise Vulnerability
Title Summary	The Presidency's Price Tag: Campaign Donations and the 2012 Presidential Election	This story follows two swing states – Colorado and Ohio – to explain the impact of campaign donations on the US presidential election results. Differences in party campaign donations influenced voting results in many swing states during the 2012 Presidential Election. Colorado and Ohio represent different alternatives for addressing campaign donations.	Soaking in Water: Sea-Level Rise and Vulnerable Coastal Properties Since 2012 This story follows two coastal states – New York and North Carolina – to explain the impact of sea-level rise on the vulnerability of coastal properties in US Rising sea-levels have increased the vulnerability of properties on the East Coast of US since 2012. New York and North Carolina represent different alternatives for addressing sea-level rise
Act #1: Set-up	The specific place, time, and social context giving the story a geography People or places who embody the narrative and act-out the plot	Space: US swing states. Time: The 2012 Presidential Election. Protagonist: Colorado, a swing state whose voting support increased for the Democratic candidate as Democrats gained an advantage in campaign donations. Antagonist: Ohio, a swing state whose voting support was not largely influenced by an advantage in campaign donations by either party.	Space: US states on the east coast. Time: The 2012 hurricane season. Protagonist: New York, a coastal state whose vulnerability increased as sea-level rose. Antagonist: North Carolina, a coastal state whose vulnerability was not largely influenced by rising sea-levels.
Problem Context	Additional background information needed to interpret the story later in the narrative sequence	Why do costs matter? More than 50% of campaign funds were from donations in 2012. Colorado: The average person in Colorado donated \$3.3 during the 2012 presidential election. Ohio: The average person in Ohio donated only \$1.5 during the 2012 presidential election.	Why do coasts matter? More than 50% of US citizens live in coastal areas by 2012. New York: 3,081 people live in an average square mile of New York coasts. North Carolina: Only 73 people live in an average square mile of North Carolina coasts.
Hook	An early scene that captures the audience's interest and encourages them to continue reading	Private donations, not public discourse, shape the outcome of the presidential election.	Even small rises in sea-level dramatically increase coastal vulnerability to storms.
Act #2: Conflict Problem	Central confrontation, obstacle, or setback driving the story	So what? Increasing donations pose a problem. The Democrat advantage in campaign donations reached \$253 million for the 2012 presidential election. Democrats received \$51 million more donations than Republicans in September, the largest donations advantage during the 2012 president election.	So what? Rising sea levels pose a problem. The US average sea levels in 2012 reached 47.8 mm above the 2002 average. Global sea levels rose 8.4 mm in 2012, the largest sea-level rise from 2002 to 2012.
Tension	The impact of the problem on key characters in character-driven storytelling	Particularly for States on the East Coast. New York: The average value of vulnerable properties in coastal areas is \$24,800 in New York. North Carolina: The average value of vulnerable properties in coastal areas is only \$7,730 in North Carolina.	Particularly for States on the East Coast. New York: The average value of vulnerable properties in coastal areas is \$24,800 in New York. North Carolina: The average value of vulnerable properties in coastal areas is only \$7,730 in North Carolina.
Example Plot Point (Rising Action)	One in a sequence of events motivated by the problem that impacts the characters	A deeper look: Democrats gained their largest donation advantage in major cities. Democrats drew 140% more urban-based donations per person in Colorado than Ohio, largely attributed to the progressive Denver metro area. The Democrats gained an advantage of \$4,400,000 in Denver, the highest urban lead in swing states.	A deeper look: Sea-levels rose the most in major stations. Sea-level rose 50% more in urban-centers in New York compared to North Carolina, particularly due to the dense infrastructure in New York City and Long Island. Sea-level annual rate in Bergen Point is 4.4 mm, the highest rate among stations in coastal states.
Act 3: Resolution	The final plot point bringing characters together to face their tension and consider competing solutions	As a result, campaign donations have a different influence on election results in swing states like Colorado versus Ohio. Colorado: Every \$100 advantage for the Democrats bought 7.5 votes in Colorado. Ohio: Every \$100 advantage for the Democrats bought only 2.8 votes in Ohio.	As a result, sea-level rise has a different impact on vulnerability in coastal states like New York versus North Carolina. New York: Every inch in sea-level rise exposes \$3,900 of property in New York. North Carolina: Every inch in sea-level rise only exposes \$1,400 of property in North Carolina.
Dénouement	Falling action in which all remaining matters with the setting, characters, and problem context are explained or resolved	What's next? Colorado and Ohio represent different alternatives for addressing campaign donations. Colorado: Colorado has imposed new regulations to limit campaign funding since the 2012 presidential election. Ohio: At the same time, Ohio has failed to act on campaign funding.	What's next? New York and North Carolina represent different alternatives for addressing sea-level rise. New York: New York has invested considerable public funds to prevent sea-level rise related crises. North Carolina: At the same time, North Carolina has failed to act on sea-level rise.
Cliffhanger	The dramatic ending, leaving open strands for audience to ponder	What do you think we should do as a nation? Colorado: The Democrats are predicted to make only a 2.3% gain in Colorado in the 2020 presidential election if campaign funding remains consistent from 2016. Ohio: The Republicans are predicted to make a whopping 12.5% gain in Ohio in the 2020 presidential election if campaign funding remains consistent from the 2016.	What do you think we should do as a nation? New York: The value of vulnerable properties per person in North Carolina is predicted to increase a surprising \$325 by 2020 if sea-level continue to increase at a consistent rate.

Notes: Considering a linear three-act narrative and constituent narrative elements opens opportunities for the design of visual stories and stories maps. The table defines common elements of a linear three-act narrative and provides abridged scripts from the pair of visual stories described in Song (2017).

While foundational, the genres proposed by Segel and Heer (2010) have several limitations restricting practical use for design. First, the number of frames does not cleanly define the genres, with all proposed genres potentially supporting a similar number of frames and thus the same visual story. Arguably, the only important distinction in the number of frames for visual storytelling is between one and many, resulting in a fluid versus fragmented layout (see Dondis, 1973; Muehlenhaus, 2011). Further, the important distinction for spatial narratives and story maps is not how many frames, but if the map frame plays a *central* or *supporting* role in the narrative compared to other text, images, and graphics (McCloud, 1993).

Second, the Segel and Heer (2010) taxonomy does not capture visual storytelling genres now possible with new media and geoweb technologies. While the majority of proposed genres are based on the print design (Kosara and Mackinlay, 2013), it is evident now that designers are not simply porting existing techniques to a web environment, but rather rethinking composition entirely to leverage the interactive and mobile possibilities of the web (Muehlenhaus, 2013). Building on Segel and Heer, I propose a revised taxonomy of visual storytelling genres, with the genres defined *only* by the visual or interactive technique used to enforcing linearity in the narrative sequence (Figure 2). Figure 2 discusses a visual example of each genre while Table 4 summarizes their relative advantages and limitations.

Static visual stories

Static visual stories enforce linearity through partitioning of the layout into frames (through neatlines, deadspace, etc.) and use of annotation to clarify reading (e.g., arrows, numbering, and other visual accenting techniques) (Figure 2a).

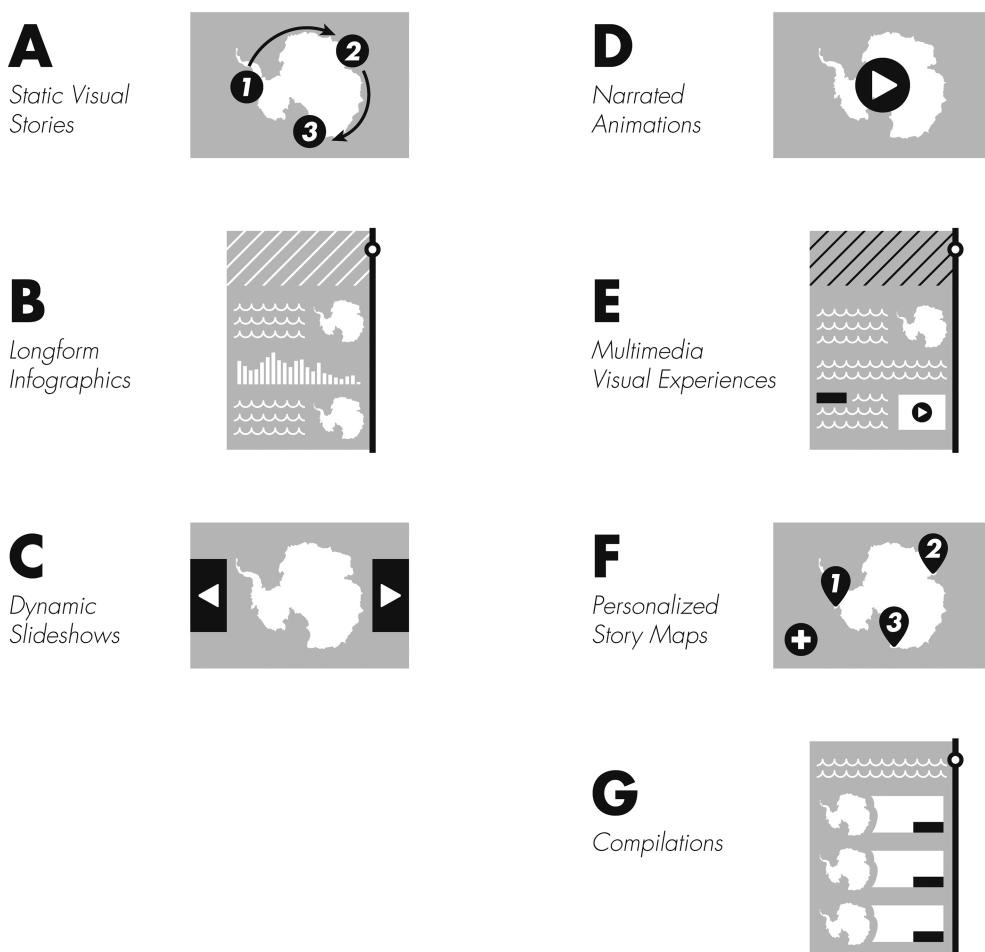


Figure 2. Visual storytelling genres. Visual storytelling genres differ by the visual or interactive technique used to enforce linearity in the narrative sequence. The black components of each genre diagram represent prototypical visual or interactive elements used by the genre to enforce linearity. (A) Static visual stories. Linearity is enforced through partitioning of the layout into frames and clarifying reading with annotation, the latter of which may include any of the visual accenting techniques illustrated in Figure 6. (B) Longform Infographics. Linearity is enforced through vertical reading and browser scrolling. (C) Dynamic Slideshows. Linearity is enforced by advancement through a series of slides, which may include horizontal swiping or 'next' and 'back' buttons. (D) Narrated Animations. Linearity is enforced by the progression of digital display time, with the animation starting either on page load or through a play control. (E) Multimedia Visual Experiences. Linearity is enforced by anchor tags and hyperlinking, with content often activated dynamically while scrolling. (F) Personalized Story Maps. Linearity is enforced by the order that an individual contributes content to the map, with the story often presented from older to newer updates. (G) Compilations. Linearity is enforced unfolding events in near real-time or major updates to the design, with maps often organized in a stack from newer to older with links to the full story.

**Table 4.** Comparison of visual storytelling genres.

Genre	Linearity Definition	Fragment/Fluid	Pros	Cons	Example
Static Visual Story	Enforce linearity through partitioning of the layout into frames and clarifying reading with annotation	(1) Small multiple maps (fragmented), (2) central map with annotation (fluid), (3) inset map used in a supporting role among other frames (fragmented)	<ul style="list-style-type: none"> Displays all content for visual comparison Familiar to audience Does not require web development skills Draws from existing cartographic design conventions, particularly flow mapping Good for introducing the setting and providing spatial reference for plot points Can be interactive through dashboard tools Easiest to respond between print and digital media 	<ul style="list-style-type: none"> Poor for showing movement and trends (small multiples) Emphasizes stability over change (small multiples) Often devoid of embellishments (small multiples) Most susceptible to breakdown in linearity Relies on focusing attention techniques that may impede or be missed by the audience Does not respond well for small screen and mobile viewing 	'The Melting of America' published in <i>National Geographic</i> (Tierney & Treat, 2017) explains the increased susceptibility of Antarctic ice to climate change. The static visual story uses layout, negative space, and annotation to enforce linearity. A comparison of the original static magazine version to a narrated animation of the same content is described in Tierney (2018; see Figure 3). Source: https://doi.org/10.14714/cp89.1469
Longform Infographic	Enforce linearity through vertical reading and browser scrolling	Fluid or fragmented	<ul style="list-style-type: none"> Digitally native and mobile-first Optimized for small screen and mobile viewing Intuitively support 'quest' plotlines (strip maps) Continuous interactive pacing by audience Grab-and-drag scrolling intuitive on mobile devices Inclusion of slippy web map supports drilling-in and martini glass storytelling 	<ul style="list-style-type: none"> Majority of content is offscreen at any time Increased skimming, leading to missed plot points Exhibits 'quicksand' issue for embedded slippy web maps, leading to shift of scrolling focus 	'How Trump Redrew the Electoral Map, from Sea to Shining Sea' published online by <i>The Washington Post</i> (Gammie & Keating, 2016) uses two maps with novel symbolization to illustrate the shift in party voting in the US Presidential Election from 2012 to 2016. The maps are oriented east-up and read like strip maps, with linearity enforced through browser scrolling. Notably, the scrolling mimics the closing of polls from Eastern to Pacific time zones, adding a temporal dimension to the linear storytelling. Source: https://www.washingtonpost.com/graphics/politics/2016-election/election-results-from-coast-to-coast/
Dynamic Slideshow	Enforce linearity by advancement through a series of slides	Fragmented	<ul style="list-style-type: none"> Controlled dosing by designer Reduced skimming, leading to regularized delivery of plot points Saves mobile data plans when audience does not want to review entire story A portion of the layout or interface can remain persistent for context and nonlinear breaks from the narrative (e.g., Esri StoryMaps) 	<ul style="list-style-type: none"> Majority of content is offscreen at any time Uses discrete (clicking, tapping, keying, swiping) rather than continuous interaction, increasing workload Difficult to advance or backtrack multiple frames Loading lags, breaking audience attention Reduced retention and preference (compared to longform infographic) 	'Amazonia Under Threat' published online by <i>National Geographic</i> (Baptista et al., 2015) describes risks to biodiversity and the environment from human activities in the Amazon basin. The dynamic slideshow uses a persistent interface docked on the right to enforce linearity. The slide content is dynamic, enabling a break from linear storytelling through vertical scrolling, map panning and zooming, and animations. Source: https://www.nationalgeographic.com/climate-change/explore-amazonia/#/
Narrated Animation	Enforce linearity by the progression of digital display time	Fluid; breaks between scenes	<ul style="list-style-type: none"> Display time can congruently represent real-world time in the story Intuitive, enjoyable, and compelling Display time can explain process, fly-through a landscape, or fluid transition between frames Draws on film techniques and integrates audio-visual content for a compelling story Embeds designer's voice into the visual story Good for showing movement and trends 	<ul style="list-style-type: none"> Difficult to compare any two frames Passive pacing controlled by the designer Majority of content is offscreen at any time Biased by first and last frame when interpreting and recalling the visual story Interactivity interferes with narration Difficult to create, requiring special software and technical skills 	Videos from 'The Joy of Stats' videos published on GapMinder.org (videos collected 2010–2018; accessed July 1, 2018), which use statistics and visualization to describe worldwide sociodemographic changes over the past two centuries. Linearity is enforced through display time in the narrated animation. Beyond just voice narration, Hans Rosling inserts himself into the animated graphics, further humanizing the visual story. Source: https://www.gapminder.org/videos/the-joy-of-stats/

(Continued)

Table 4. Continued.

Genre	Linearity Definition	Fragment/Fluid	Pros	Cons	Example
Multimedia Visual Experience	Enforce linearity by anchor tags and hyperlinking	Fragmented across webpages; fluid within page	<ul style="list-style-type: none"> Web-enabled and multimedia Uses an immersive array of images, graphics, audio, and video that accompany and amplify a central textual narrative Mashes up easily with other genres Supports both martini glass and drill-drown storytelling structures Continuous interactive pacing by audience Embeds designer's voice, as well as the voices of people described in the story Develops a deep sense of place 	<ul style="list-style-type: none"> Includes more text than other genres, with most content offscreen and on different webpages Exhibits 'quicksand' issue for embedded slippery web maps Higher attrition or bounce rate than other genres Map is usually supporting rather than central to the narrative Requires rich set of quantitative and qualitative primary information that the designers need to collect 	'Snowfall: The Avalanche at Tunnel Creek published online by <i>The New York Times</i> (Branch, 2012) details the experiences of skiers and snowboarders trapped in an avalanche in Washington State (US). The multimedia visual experience uses a compelling array of text, images, maps, and videos, activating dynamic content through anchor tags and hyperlinks while scrolling. Source: http://www.nytimes.com/projects/2012/snow-fall/
Personalized Story Map	Enforce linearity by the order that an individual contributes content to the map	Fluid	<ul style="list-style-type: none"> Can be made by non-experts untrained in design Embraces pluralism and promotes multiplicity Makes use of a central map to activate all content Interactive pacing by audience Georeferencing facilitated by mobile-first story mapping services Exhibits elements of gamification and playful maps Popular for education and research outreach 	<ul style="list-style-type: none"> Limited design flexibility Regularized pacing by the point-based story map platform May have poorer quality, misleading symbolization, and inherent narratives potentially erodes privacy and enables surveillance 	'Snap Map' maintained by SnapChat (accessed July 1, 2018) is a platform for sharing photos and videos as georeferenced visual stories that last for 24 hours. The service aggregates clusters of stories to represent current events for viewing online, with the linearity of these events enforced by the order of user contributions. In the mobile application, users can embed themselves into the map using an avatar, sharing their location with friends at a high spatial precision as they contribute visual media. Source: https://map.snapchat.com/
Visual Story Compilation	Enforce linearity by unfolding events in near real-time or major updates to the design	Fragmented	<ul style="list-style-type: none"> Best for extreme events or recurrent themes Organizes disparate visual stories around common activities, themes, or places Provides a visual summary of changing conditions, "putting the audience" into the narrative as it unfolds and inviting them to return for updates Utilizes and organizes existing content while allowing easy integration of new content 	<ul style="list-style-type: none"> Narrative and pacing emerges from the events, rather than from designer Fragmented layout dividing content across multiple webpages 	'Maps: Tracking Harvey's Destructive Path Through Texas and Louisiana' maintained by <i>The New York Times</i> (Aisch et al., updated August 25-31, 2017) tracks the development and impact of Hurricane Harvey in the Gulf region of the US. As the event unfolds, map updates are placed at the top of the compilation, enforcing linearity from newest to oldest updates. Many of the maps in the compilation link to other content from <i>The New York Times</i> , enabling non-linear storytelling. Source: https://www.nytimes.com/interactive/2017/08/24/us/hurricane-harvey-texas.html

Notes: Different visual storytelling genres offer different opportunities and constraints for design based on the way they enforce linearity and other practical aspects of composition. Thus, the designer makes a purposeful decision when selecting a particular genre or mixing elements from multiple genres.

Static visual stories encapsulate many of Segel and Heer's (2010) genres based on print design, including magazine style, annotated chart, partitioned poster, flow chart, and comic strip. These sub-genres differ primarily by their mixture of partitioning and annotation. Annotated charts have fluid layouts, with call-out annotation positioned around a central graphic to enforce linearity. The magazine style and flow charts are more fragmented, using whitespace to segment content. Magazine or newspaper layouts enforce linearity through cultural reading convention (e.g., left-to-right, top-to-bottom in Western cultures) while flow charts add arrow annotation to enforce linearity. Finally, partitioned posters and comic strips are heavily fragmented, so much so that techniques exist to 'break the frame' to enforce linearity and relate plot points (McCloud, 2011).

For spatial narratives, static visual stories typically employ maps using one of three strategies: small multiple maps, a central map with internal annotation, or a supporting map in a multi-frame visual story. Small multiples work best for visual storytelling with spatiotemporal data, fitting the narrative to the temporal dimension. Small multiples support nonlinear comparison of any pair of individual frames, but are relatively less effective than animations for identifying movement and trends from start to finish across frames (Griffin *et al.*, 2006), often the purpose in visual storytelling. Therefore, small multiples may be most effective when only including a few frames, such as before-and-after maps and imagery providing visual comparison around the conflict (Ormelinc, 1995). Further, small multiples include a large amount of redundant information (Fish, 2018), producing a small, highly generalized sequence of graphics that emphasizes stability rather than change and eliminates the embellishments that make visual stories compelling, relatable, and memorable.

Static visual stories anchored upon a central map mostly follow existing cartographic design principles, particularly flow mapping (see Kraak, 2014 for discussion). Supporting maps in static visual stories closely resemble locator or inset maps and are particularly useful for introducing the setting and providing spatial structure for plot points (Caquard and Cartwright, 2014). Static visual stories have the advantage of being familiar to the audience given their traditional use in print. These also do not require web development skills to customize. Static visual stories can have interactive elements, with data-driven geoweb dashboard tools (e.g., Carto, Esri, and Tableau) supporting interactive versions of Segel and Heer's (2010) partitioned poster. However, static visual stories are the most susceptible genre to a breakdown in linearity and rely on visual accenting techniques (see below) that may impede map reading or be missed by the audience. Static visual stories also do not respond well for small screen and mobile viewing (Ricker and Roth, 2018), resulting in decreasing use in web-based data journalism.

Longform infographic

Longform infographics – not to be confused with longform journalism – enforce linearity through vertical reading and browser scrolling (Figure 2b). Although many longform infographics are simply large image files, they draw on convention in modern web design by stacking text, graphics, and multimedia with a constrained width for a single scrolling direction. Longform infographic designs are digitally native and mobile-first, with the genre often described as 'scrollytelling' by data journalists (Stolper *et al.*, 2016). Longform infographics can be fluid, with the map, timeline, or other graphic extending throughout the visual story, or fragmented to delineate transitions in the narrative.

For spatial narratives, longform infographics can resemble *strip maps*, a cartographic technique that follows a single linear corridor and omits detail away from the corridor (MacEachren, 1986; MacEachren and Johnson, 1987). Strip maps commonly distort the orientation of geographic features similarly to a linear cartogram (Kraak, 2014), converting configural knowledge about absolute spatial relationships into procedural knowledge of the sequence of places encountered along a route (MacEachren, 1995), with the sequential order of places then intuitively defining the narrative arc. Thus, longform infographics using a central strip map are particularly well purposed for 'quest' plotlines in which characters move through the landscape from an origin to a destination (Booker, 2004).

Compared to other genres, the dimensions of longform infographics are optimized for small screen and mobile viewing, with grab-and-drag scrolling particularly intuitive on post-WIMP (windows, icons, menus, pointers) mobile devices (Ricker and Roth, 2018). The exaggerated dimensions keep the majority of content offscreen at any time, a constraint that can be used dramatically for visual storytelling. The audience also interactively controls the narrative pacing through continuous scrolling, drawing them into the story. However, eyetracking studies on webpage design suggest that the continuous scrolling may result in skimming, producing an F-pattern for textual stories (Nielsen, 2006) and potentially leading the audience to miss important plot points in longform information graphics. Finally, the inclusion of a 'slippy' multiscale web map providing panning, zooming, and detail retrieval (Sample and Ioup, 2010) at the start or end of the longform infographic supports Segel & Heer's (2010) drill-in and martini glass narrative structures, respectively. However, embedding a slippy web map as a single frame in a longform infographic causes the 'quicksand' issue when scrolling with a mousewheel, shifting input focus from the webpage to the map and initiating unwanted zooming of the map (Tolochko, 2016).

Dynamic slideshow

Dynamic slideshows, a genre from the Segel and Heer (2010) taxonomy, enforce linearity by advancement through a series of slides, or discrete visual panels of consistent size and format (Figure 2c). Drawing on the metaphor of a physical slide deck, passive slideshows are common for scholarly presentation, industry pitches and project updates, and higher education (Kosara and Mackinlay, 2013), despite their known problems (Tufte, 2003). User-driven interactive slideshows are increasingly popular for web ‘listicles’ as well as image carousels and other aggregated collections on social media (Lieb, 2015). Compared with the vertical scrolling of longform infographics, dynamic slideshows have a conceptual horizontal scrolling, but with extreme fragmentation due to the lack of conventional side-to-side scrolling in modern web design. For spatial narratives, dynamic slideshows share similarities with bounded atlases, progressing page-by-page through a series of maps intentionally ordered to introduce and describe with increasing depth a fixed range of places and people (van Elzakker, 1993; Ormeling, 1995), albeit often without many standard elements of a three-act narrative (e.g., a single problem and resolution).

Like longform infographics, the majority of story content is offscreen in dynamic slideshows. However, the interface for accessing offscreen content is different between the genres: the narrative advances using discrete clicking, tapping, keying, or swiping for dynamic slideshows, rather than continuous scrolling or dragging in longform infographics (Ricker and Roth, 2018). Such interaction gives the designer more control over pacing, limiting skimming by regularizing delivery of plot points. However, such discrete interaction can be frustrating for long slide decks due to the increased pointing workload and difficulty in advancing or backtracking multiple frames at once (Harrower and Sheesley, 2005). Further, dynamic slideshows often load frames individually upon user request, saving mobile data plans when the audience does not want to review the entire story, but also causing loading lags, breaking audience attention, and ultimately leading in reduced retention and preference for slideshows (Song 2017). Importantly, a portion of the slideshow layout or interface can remain persistent across slides to indicate progress or support non-linear breaks from the narrative.

Narrated animations

Narrated animations, the final genre treated by Segel and Heer (2010), enforce linearity by the progression of digital display time (Figure 2d). Animation is a longstanding research topic in cartography (see Campbell and Egbert, 1990; Harrower, 2004 for reviews), with data-driven animated maps having a temporal scale in addition to a spatial scale that relates real-world time to display time (e.g., 1 second = 1 year) (Harrower and Fabrikant, 2008). Such animated maps congruently represent dynamic phenomena using dynamic visuals (Tversky *et al.*, 2002), and are generally considered more intuitive and enjoyable than static spatiotemporal representations (Olson, 1997). However, animated maps need not represent real-world time, with display time instead used to explain a geographic process or fly-through a landscape (Lobben, 2003), or fluidly transition between frames in a linear narrative (Heer and Robertson, 2007). Animation is fundamental to emerging cinematic cartography, combining film techniques with audiovisual content to make the story more compelling (Caquard, 2009; Muehlenhaus, 2014). Narrating over data-driven animations also is a powerful way to embed the designer’s voice and situated perspectives into a visual story, a technique introduced to cartography by Monmonier (1992) as ‘graphic scripts’ and made popular in visualization by the Rosling *et al.* (2005) commentaries on GapMinder.

However, evidence exists that data-driven animated maps often exceed our cognitive limits (Harrower, 2007). While animations are more effective for following movement and trends across frames compared to small multiples (Griffin *et al.*, 2006), the ability to compare any two frames in the animation is severely inhibited due to the complexity and speed of the animation (Fish *et al.*, 2011). Further, animations passively enforce the linear narrative, with the pacing of offscreen content controlled by the designer rather than the audience. As a result, the audience might miss key narrative elements, becoming biased by the first and last frame when interpreting and recalling the visual story. Both narration and interaction are recommended strategies to reduce cognitive load and focus attention in animations (Slocum *et al.*, 2009), and overall increased familiarity with new media may offset some cognitive load issues with cartographic animations. Finally, narrated animations remain difficult to create, requiring special software and technical skills, although this barrier continues to decrease in new media and geoweb technologies.

Multimedia visual experiences

Multimedia visual experiences are a relatively new, web-enabled visual storytelling genre that enforce linearity by anchor tags and hyperlinking (Figure 2e). Hyperlinked text and multimedia make the internet a ‘web’ (Kraak and van Driel, 1997), and, in the simplest form, dynamic hyperlinking divides the visual story into chapters on multiple webpages. However, multimedia visual experiences also use hyperlinking to activate an immersive array of images, graphics, audio, and video that accompany a central textual narrative, a strategy first employed in the map-heavy visual story ‘Snow Fall: The Avalanche at Tunnel Creek’ (Branch, 2012). Accordingly, the genre sometimes is described as ‘snowfalling’ by data journalists (Usher, 2016; Cairo, 2017).

Multimedia visual experiences mashup well with other genres and can include slippy web maps at the start or end to support drill-down or martini glass narrative structures (Segel and Heer, 2010). Like longform infographics, the audience interactively controls the pacing through continuous scrolling, although resulting in the same quicksand issue for embedded slippy maps (Tolochko, 2016). As with narrated animations, the multimedia content can include the designer's voice, as well as embody the situated perspectives of the people in the visual story. They also develop a deep sense of place through rich integration of images, maps, videos, and sounds. However, multimedia visual experiences typically support longform journalism and include more text than other genres, with most content offscreen and fragmented across multiple webpages. Accordingly, multimedia visual experiences can lose the succinct, partial quality that makes them relatable and memorable, potentially leading to a higher attrition or 'bounce' rate before completing the narrative than other genres. For spatial narratives, the maps are included only to support the narrative rather than as a centrepiece for the narrative. Finally, multimedia visual experiences draw from a rich set of quantitative and qualitative primary information that the designers need to collect and thus may not be available for all visual stories.

Personalized story maps

Personalized story maps enforce linearity by the order that an individual contributes content to the story. Personalized story maps collapse the distinction between designer and user – storyteller and audience – inviting non-designers to create visual accounts of their lived experiences and to share these stories collectively through easy-to-use geoweb technologies (Caquard, 2014). In doing so, they embrace pluralism, empowering individuals to voice their situated perspectives (Pearce and Hermann, 2010; Warf and Sui, 2010; D'Ignazio and Klein, 2016). Personalized story maps can depict individual accounts or aggregated experiences, the latter serving as a collaborative and place-based storytelling alternative to traditional media (Kelly, 2016). Personalized story maps align with calls for 'amateur cartography' (McConchie, 2015), 'citizen science' (Haklay, 2013), 'crowdsourced cartography' (Dodge and Kitchin, 2013), 'democratized cartography' (Rød *et al.*, 2001), 'neogeography' (Turner, 2006), and 'volunteered' (Goodchild, 2007) or 'contributed' (Harvey, 2013) geographic information, and personalized story maps carry with them the same opportunities and challenges discussed in these arenas (see Crampton, 2009; Elwood and Leszczynski, 2013; for reviews).

Non-experts can create visual stories in any genre, and, as stated above, barriers to using new media and geoweb technology are continuing to decrease. However, the personalized story maps genre tends to be defined by a simplified, fluid layout with a central slippy map displaying georeferenced point symbols for interactive access to all content. While the basic design invites participation from a wide audience, it also limits creative flexibility compared to other genres. Personalized story maps often (although not always) are facilitated by web-enabled, mobile-first story mapping services that use smartphone GPS receivers to automate the georeferencing of contributed content. The audience interactively controls the linear narrative, although the pacing typically is regularized by a point-based story mapping service. Further, personalized story maps often exhibit elements of gamification and play – such as level- or point-based reward systems, augmented and immersive displays, collaborative mapping and peer-rating, and unlockable features or locations – and maps supporting first-person narrative and roleplaying is one of many research opportunities for integrating narrative cartography and video game design (Ahlqvist, 2011; Thorn, 2018).

Personalized story maps are growing in popularity for use cases in k-12 and higher education (e.g., Battersby and Remington, 2013; Strachan and Mitchell, 2014; Marta and Osso, 2015) as well as scientific outreach (e.g., Silbernagel *et al.*, 2015; Eanes *et al.*, 2018), but are not without concerns. Designers warn that non-expert design can lead to visual stories with poor data quality, misleading symbolization, and ultimately incoherent narratives, although many initial fears have been allayed with smart default choices and design support 'help' resources (Mead, 2014; Austin, 2018). However, the intimate, multisensory, and spatialized content that make visual stories compelling, relatable, and situated also impose new concerns around power, privacy, and surveillance (Elwood and Leszczynski, 2011; Wilson, 2012).

Compilations

Finally, *compilations* enforce linearity through unfolding events in near real-time or major updates to the design. Pioneered by The New York Times as 'map stacks' (Wallace, 2018), compilations provide a 'visual abstract' often with a link to other story content (visual or non-visual) and stack the visual abstracts vertically or in a grid for rapid browsing. In data journalism, compilations primarily are created for extreme events requiring critical attention or recurrent themes spanning numerous news cycles, with each new entry representing a new plot point. Outside of data journalism, compilations make sense for organizing otherwise disparate visual stories around common activities, themes, or places.

Compilations provide a visual index of changing conditions, putting the audience into the narrative as it takes place and inviting them to return to the compilation for updates. Compilations are explicitly temporal in their linearity, with the narrative and pacing emerging only from the events rather than the designer or audience. For spatial narratives, the visual abstracts usually are maps with a similar spatial extent and cartographic design, but with updated information, mimicking small multiples as introduced above. The layout is heavily fragmented, dividing content across a number of pages. However, this strategy does utilize and organize existing content presented in other genres, allowing for easy integration of new content as it becomes available.

Visual storytelling tropes

The final way to describe the design space for visual storytelling presented in this article is by the emerging suite of visual design techniques applied not to represent data, but to enhance narrative and its elements (Gershon and Page, 2001; Pearce, 2009). In the following, I suggest the term ‘tropes’ to capture this range of storytelling techniques. Derived from the Greek ‘*tropos*’ meaning to turn in direction, a *trope* is a rhetorical device used to advance a plotline. Smith (1996) established the relationship between literary tropes and spatial narratives, interpreting each of Burke’s (1969) master tropes for geographic phenomena. Smith’s (1996) treatment of tropes for spatial narratives is non-visual, and my use of ‘tropes’ is an imperfect translation of the concept to visual design. However, I think the concept best evokes the purpose of these visual design techniques without confusing established design terminology (e.g., figure/figure-ground, symbolism/symbolization). In the following, I propose seven visual storytelling tropes and paired design techniques, with each trope delineated by the work they do to advance the narrative and develop narrative elements.

Continuity

Continuity unifies otherwise disparate visual elements into a logical structure (Gershon & Page 2001). As discussed above, continuity makes visual stories more memorable than other kinds of maps and visualizations. Continuity can be promoted through a linear three-act narrative and enforced using one of the pacing solutions from different visual storytelling genres (e.g., by visual layout, browser scrolling, slide advancement, display time progression, hyperlinking, user contributions, near real-time updates). However, continuity does not simply mean linearity, with non-linear continuity between narrative elements also promoted through annotation (see discussion of visual accenting techniques below) or interaction, particularly sequencing, panning, zooming, and detail retrieval (see Roth, 2013). Continuity as a trope also glues or even blends frames in the sequence together (Ormelinc, 1995). Such *visual transition* techniques include static and dynamic strategies (see the McCloud, 1993 taxonomy of transition types in cartooning). Dynamic transitions such as fading, panning, swiping, and tweening (see Gersmehl, 1990; Battersby and Goldsberry, 2010) are potentially applicable to genres beyond narrated animations to promote continuity between narrative elements.

Mood

Mood sets a visual tone congruent with the narrative and its elements (Gershon and Page, 2001). Mood influences the audience’s immediate, visceral reaction to the visual story (Norman, 2004), and therefore should be established at the start of the narrative when introducing the setting, characters, and problem context. The visual mood also suggests how the audience should cognitively and emotionally react to a particular plot points, and thus the mood can change with each act, foreshadowing upcoming frames (Pearce, 2008). For spatial narratives, the mood often is set through design of map elements (e.g., legend, north arrow, title) and inclusion of other map adornments described as *marginalia* (Caquard and Cartwright, 2014). Such embellishments not only set a visual mood, but also make the map more memorable (Bateman *et al.*, 2010; Borkin *et al.*, 2013).

Beyond specific map elements and marginalia, mood broadly refers to the story’s *visual style*, or aesthetically cohesive and distinct set of visual design characteristics (Kent and Vujaković, 2009). Each style evokes a different set of emotions, draws on different design influences, and suggests different story interpretations – all of which contribute to mood – although lived experience and personal taste still result in different reactions across the audience. Aesthetics, style, and taste are topics of increased interest in cartography (e.g., Kent, 2005; Buckley and Jenny, 2012; Denil, 2012) and recent cartographic work has identified common persuasive (Muehlenhaus, 2011, 2012) and pastiche (Christophe and Hoarau, 2012; Knoppke-Wetzel, 2014) visual styles potentially useful in specific storytelling contexts. While visual style has potentially infinite facets, I find it helpful to organize the planning and design a visual style by:

- *form*: variation in the linework generalization and symbolization (e.g., line weights, cap and join styles, tapering);
- *colour*: the overall palette of primary and accent colours (see McCandless, 2014 for a cross-cultural guide to the social connotation of colours);
- *type*: the selected typefaces, their placement (e.g., compression, leading, tracking), and their internal microaesthetics (e.g., case, posture, serifs, strokes, weight; Guidero, 2017); and
- *texture*: additional embellishments that give features a flat, raised, tactile, shiny, etc., look and feel (e.g., pattern fills, gradients, overlays, dashing).

Geoweb technologies have made it possible to develop unique visual styles for digital maps and graphics. Figure 3 deconstructs four basemaps by their stylistic dimensions of form, colour, type, and texture and the associated mood they might evoke when used for a visual story.



Figure 3. Mood as a visual storytelling trope. The visual style of maps and graphics set the mood for a story, influencing the audience's affective and emotional reaction. The following deconstructs four basemap designs by the stylistic elements of form, colour, type, and texture. (A) OpenStreetMap. The default OpenStreetMap design is similar to a reference road map. The linework form is complex, using precise, thin strokes to outline roads, buildings, and other built infrastructure. The colour palette is similarly complex to symbolize the numerous layers, producing a visual hierarchy that emphasizes major roads over other features. The type is dense, using a simple sans serif font to communicate a sense that there are many features in the landscape. There are few textures, particularly for natural features. Overall, the visual style likely activates the audience affectively, giving an authoritative sense (perhaps too much so) of the accuracy and trustworthiness of the basemap. (B) Esri World Gray Canvas. Esri's various grey styles are designed specifically to layer thematic information on top. The linework form is simpler, with most features removed and roads given subtle outlines; as a result, the water features and other aspects of the natural environment are more visible. Per the name, a greyscale colour palette is used, with most colours on the lower half of the value range. The type is sparse, using a thin sans serif in uppercase for major throughways. There are few textures (e.g., the railroad), further subduing the palette. Overall, the visual style likely deactivates the audience affectively, leading them to ignore the basemap. (C) CARTO Dark Matter. There are many similarities of CARTO's Dark Matter to the Esri World Gray Canvas. The linework form is simple, the palette is in greyscale, the type is sparse (although using a thicker sans serif in lowercase), and there are few textures. However, the colours are dark, almost ominous, allowing for any added bright, saturated thematic layers to contrast markedly against the basemap. Because of the dark palette and high contrast, the visual style likely activates rather than deactivates the audience, and, depending on other aspects of design, could evoke an angry, anxious, or otherwise unpleasant reaction, a response that can be used purposefully to build suspense in the visual story. D: Stamen Watercolor. Stamen's Watercolor is a creative departure from most slippy basemaps. The linework form again is simple, with many features outlined in a white stroke for contrast and their lines whimsically varying as if brushed by hand. The colour palette is bright, using many primary colours while balancing lights and darks. The textures mimic the movement of watercolour on the canvas – pooling at edges and spreading in a gradient over large expanses – and thus give the audience the impression of a physical material rather than a digital map. There is no type, allowing the symbols to take lead. Overall, the visual style likely activates the audience, creating a pleasant experience that invites the audience to get lost in the map and its many arrangements of form, colour, and texture.

Dosing

Dosing reduces the overall complexity of story content into incremental chunks of information. Thus, dosing as a design trope makes the visual story partial and intuitive (Gershon and Page, 2001), emphasizing specific characters or places rather than overall patterns and layering related visuals to build interest and understanding with the rising narrative arc (Ma *et al.*, 2012). At a broad scale, information dosing includes dividing the story into sequential frames for a linear narrative. Dosing also refers to organizing unique narratives into individual modules (e.g., Caquard *et al.*, 2009), as with the personalized story maps or compilation genres. Dosing is facilitated by the process of *storyboarding*, or the organization and sketching of narrative elements and story content into a sequence of visual panels (Thöny *et al.*, 2018). While storyboards may lead directly to unique sections in longform infographics or slides in dynamic slideshows, they can be used to model and plan the audience experience for any visual storytelling genre. Tierney (2018) provides a useful discussion of converting content static visual story into a narrated animation using storyboarding as a dosing technique (Figure 4).

At a finer scale, dosing controls the pacing of each individual piece of information, visual or non-visual, within the frame (Pearce, 2008). Static dosing includes clarifying the entry point to the story through layout and visual hierarchy (Roth, 2015) and subsequent *visual partitioning* techniques using neatlines, negative space, and other annotations that segment and organize the layout content (Segel and Heer, 2010). Dynamic dosing techniques include selective pausing or slow motion in the narrative animation genre to emphasize content visually or expand time for voice over (Monmonier, 1992; Harrower, 2007) as well as the interactive pacing solutions specific to other genres (e.g., browser scrolling, slide advancement, hyperlinked text). Information pop-ups in slippy maps are a common interactive dosing solution for the drill-down and martini glass narratives structures, allowing the audience to self-dose by retrieving details on demand.

Attention

Attention emphasizes important or unusual information that cannot be missed in the story (Gershon and Page, 2001). In psychology, ‘visual attention’ describes the portion of the visual field on which the eye-brain system is focused (Ware, 2004). Our visual attention is controlled by both bottom-up (e.g., relative contrast, emergent gestalt features) and top-down (e.g., cognitive tasks, cultural reading conventions) processes (MacEachren, 1995). Designers focus attention through the visual hierarchy such that certain features rise to figure and others recede to ground (Tait, 2018). Attention as a visual storytelling trope is related to *focalization* in cinema, a visual complement to audible voice (see below) that together develop a subjective point of view (Pearce, 2008). Thus, focusing attention shapes the visual hierarchy around a particular perspective – or reshapes the hierarchy around multiple perspectives – rather than or in addition to the visualized information itself (Cattoor and Perkins, 2014).

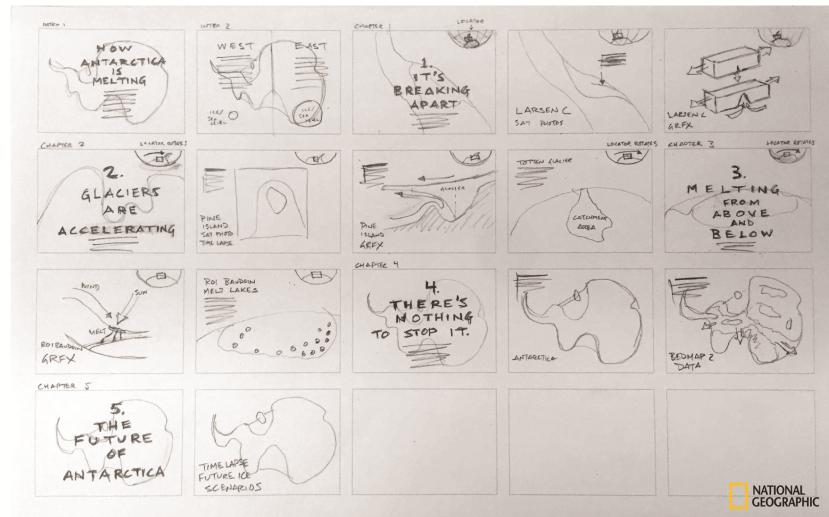
Perhaps the most common technique for focusing attention is *framing* the map extent, narrowing the view to a localized setting and eliminating surrounding context (Pearce, 2008). Attention also can be focused through *visual accenting*, or design techniques used to direct the eye to particular features in the display while preserving surrounding context (Figure 5). For instance, *highlighting* manipulates one or several ‘visual variables’ – or the perceptible dimensions of a visual scene and thus the basic building blocks of any graphic representation (Bertin, 1967/1983) – non-uniformly across visualized features to draw attention. Robinson (2011) provides a useful discussion in the context of coordinated, multiview visualization of the relative strengths and limitations of each visual variable as a solution for interactively highlighting a subset of features rather than encoding information about the features. Interestingly, while interactive highlighting is no longer common in mobile-first design using post-WIMP interfaces and touchscreen devices (where probing or ‘mouse over’ are not intuitive; Ricker and Roth, 2018), insight from interactive highlighting remains relevant in visual storytelling for focusing attention on important narrative elements.

Rather than manipulating the visual variables within maps and graphics, a second visual accenting technique focuses attention by adding an *annotation* layer conceptually atop all other visual content (Pearce, 2008). Essential for enforcing continuity in static visual stories, annotation techniques include leader lines and flow arrows indicating relationships, appended geometric frames or opacity masks enclosing features and delineating regions, numbering or enumerated bullets suggesting linear sequence, changes in map scale or variable levels of detail, and call-outs and other labelling clarifications. Finally, many dynamic techniques exist for focusing attention, such as blinking or flickering (Evans, 1997), dynamic panning and zooming (Gershon and Page, 2001), and focus + context visualization (Weber Reuschel *et al.*, 2014).

A



B



C

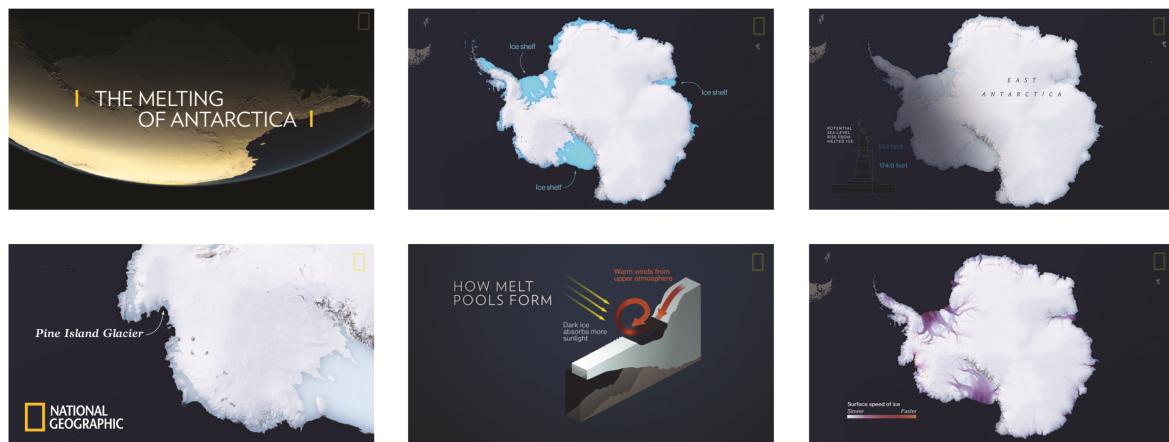


Figure 4. Storyboarding to plan information dosing. 'The Melting of America' published by *National Geographic* (Tierney & Treat, 2017) explains the increased susceptibility of Antarctic ice to climate change. Tierney (2018) describes the process the *National Geographic* team completed to design the original static visual story for the printed magazine and then convert the visual story into a narrated animation for digital consumption. (A) Static Visual Story. The original static visual story was designed to fill a double-gatefold spread within the magazine. The print design effectively enforces linearity using a 12-column layout, balanced arrangement of negative space to separate major visual elements, and text annotation to clarify reading. (B) Storyboarding. The *National Geographic* team used storyboarding as a technique to dose the original static visual story into a series of five chapters for inclusion in the narrated animation. The storyboard roughly follows the sequence of narrative elements illustrated in Figure 1. The storyboard first sets-up the visual story through an initial hook (the title sequence) and introduces problem context about the geophysical processes underpinning glacial melt, stressing the key problem that glaciers are breaking apart (Chapter 1). The storyboard then paces plot points about the conflict using rising dramatic action, building concern about glacial acceleration (Chapter 2) and glacial melting from above and below (Chapter 3). The storyboard reaches its climax – that there is no way to stop the melting (Chapter 4) – concluding with a cliffhanger about the future of Antarctica (Chapter 5). (C) Narrated Animation. The resulting 3:40 minute narrated animation uses display time to enforce linearity across the five chapters. The maps and graphics are individually less complex than the original static visual story to optimize viewing on smaller screen mobile devices. However, the maps and graphics are animated to aid interpretation of the dynamic geophysical processes. The text annotation largely is replaced by the audio narration, embedding the voice of expert scientists into the visual story.

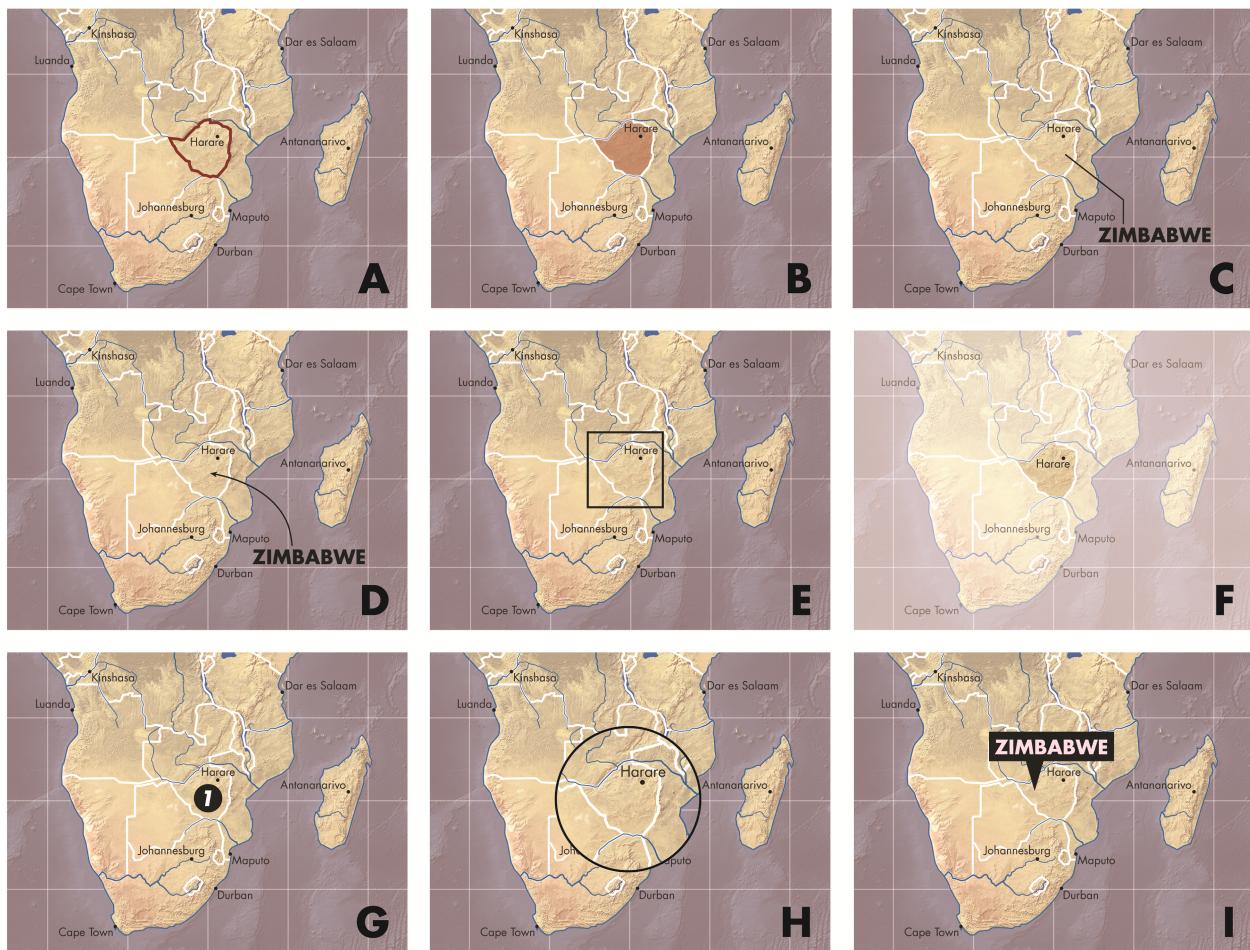


Figure 5. Visual accenting techniques for focusing attention. I use the term ‘visual accenting’ to describe a range of design techniques used to focus visual attention on specific features in the display. The figure provides nine visual accenting solutions for focusing attention on Zimbabwe in Southern Africa. (A) Highlighting on polygon stroke (colour hue). (B) Highlighting on polygon fill (colour hue). (C) Leader lines with label. (D) Flow arrow with label. (E) Geometric frame. (F) Opacity mask. (G) Numbering. (H) Scale change. (I) Call-out with label. Many dynamic techniques also exist for focus attention (not illustrated), such as blinking or flickering, dynamic panning and zooming, and focus + context visualization.

Redundancy

Once attention is focused, *redundancy* then repeats important or unusual information to develop story themes (Gershon and Page, 2001). Effective redundancy makes visual stories more memorable compared to traditional maps and visualizations. As Pearce (2014: 117) writes, ‘repetition is a form of mental economy; it condenses the amount of information that the listener must remember’. Effective redundancy also makes visual stories more intuitive, signalling transitions between plot points and reinforcing the linear narrative. In this way, redundancy teaches the audience a single visual syntax for acquiring critical information in the opening scene and then consistently applies this syntax throughout the story (Segel and Heer, 2010). Finally, effective redundancy makes visual stories more compelling, combining the visual style with the story content into *visual motifs* that are repeated throughout the visual story and can hold symbolic meaning (Figure 6). Such visual motifs can be clever and playful, explicitly reinforcing the theme through figural depictions, as well as political and persuasive, connoting the designer’s subjective position towards the story and potentially subverting the story altogether.

Because redundancy is the repetition of attention on narrative elements, the visual hierarchy and accenting techniques described above largely apply. Accordingly, designers need to consider three ways for using the visual variables for map-based storytelling that work in harmony: representing information in the maps and graphics (Bertin, 1967|1983 only considered use of the visual ‘variables’ for encoding information and not as visual dimensions for design embellishments), highlighting narrative elements within the maps and graphics, and establishing a coherent style and recurring visual motifs across the maps and graphics.

Metaphor

Metaphor brings together seemingly unrelated concepts in a single frame to facilitate understanding of complex narrative elements (Fontaine, 2015). Metaphor is common in cartography, particularly in the design of

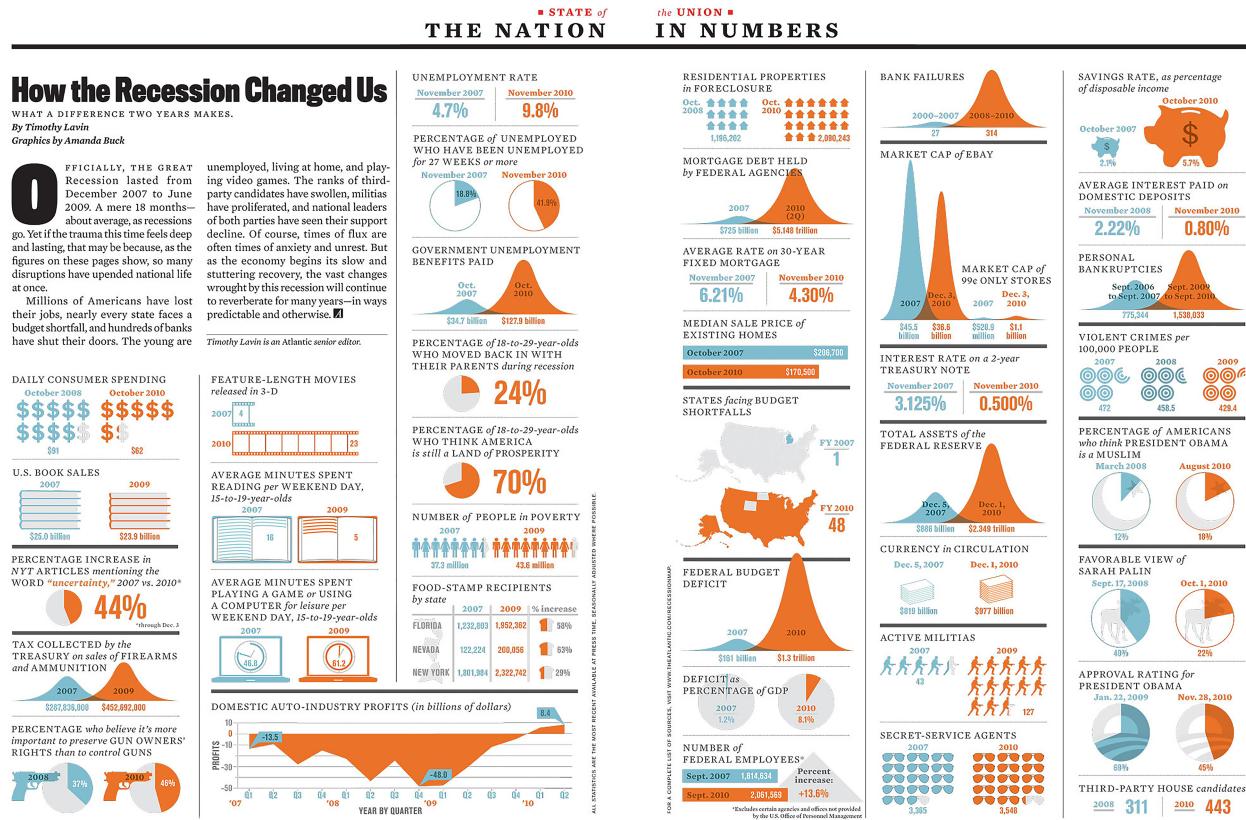


Figure 6. Redundancy and continuity as visual storytelling tropes. ‘How the Recession Changed Us’ published in *The Atlantic* (Lavin & Buck, 2011) uses a series of frames to compare the US before and after the ‘Great Recession’, which lasted December 2007 to June 2009. The designers establish a recurring motif across all panels, redundantly encoding pre-recession in light blue and post-recession in dark orange. In this way, the visual grammar of the story is learned once by the audience, with this redundancy contributing to the rising action as the panels move from livelihoods to (sometimes nefarious) activities to political viewpoints. Note also how the ‘Federal Budget Deficit’ graphic breaks the frame, with the bell curve extending into the maps above. This visual transition technique promotes continuity, suggesting a top-down rather than left-right reading of the visual story.

associative point symbols that resemble a concept related to the symbolized feature (e.g., a balloon to represent the location of a party) rather than directly mimic the feature in a literal way (MacEachren, 1995). Such use of metaphor is essential when the represented feature itself is an abstract concept lacking a material or embodied form (e.g., a clenched fist to represent solidarity). In visual storytelling, metaphors often draw from ancillary or supporting materials for problem context, calculate or derive original information, generate non-traditional visual representations, or leverage natural interfaces to add something new and creative into the story. As with redundancy, metaphors when repeated create motifs and embed symbolic connotations into the visual story (Vujaković, 2014).

Visual storytelling often emphasizes *visual juxtaposition* techniques for the purpose of metaphor. The simplest juxtaposition is an overlay of two or more layers of information. Such overlays include visual benchmarks showing the minimum, maximum, average, etc., values for context (Harrower, 2003) or alternative scenarios enabling critical consideration of multiple propositions, or for visual storytelling, multiple voices (Ormeling, 1995). More compelling juxtapositions use cartooning and illustration to set embodied figures, impossible objects, and apparent motion against the data-driven components of the visual story (Caquard and Dormann, 2008). In contrast, equally compelling juxtapositions make use of realism and hyperrealism, shocking and even fooling the audience by viewing abstract statistical information in a metaphorical landscape (Figure 7). Complex juxtapositions of caricature and hyperrealism develop into collages (within one frame) and montages (across frames) (Salimian *et al.*, 2013; Cattoor and Perkins, 2014), techniques used in cinema to introduce a large amount of information quickly, speeding some plot points in order to slow the pacing for others.

Notably, metaphor as a visual storytelling trope often includes hints of humour, irony, and satire (see Caquard and Dormann, 2008), providing comedic relief within the narrative arc. I am clearly biased, but I often say that cartographers are the funniest, most engaging people I know, and think that many of the ways that we present ourselves in everyday life through anecdotes and yarns can translate into intuitive and relatable visual metaphors in our designs.



Figure 7. Metaphor as a visual storytelling trope. ‘Earth at Night, Mountains of Light’ published by Petrichor Geovis Studio (Wasilkowski, 2019) visualizes nighttime light emissions as a hyperrealistic, psuedo-3D surface, with brighter locations represented as taller mountain peaks in a metaphorical terrain. Such use of a metaphorical landscape is one way to make any visual story explicitly spatial, and arguably all thematic maps of abstract statistical information employ such a landscape metaphor to some degree. Other examples of a landscape metaphor include ‘The Two Americas of 2016’ published in *The New York Times* (Wallace, 2016) and ‘Human Terrain’ published by *The Pudding* (Daniels, 2018).

Voice

Finally, *voice* embeds situated experiences, opinions, and values into the visual story to clarify meaning (Pearce, 2009). Prior to the twentieth-century Western push for objectivity, cartographers used stories from the field to ‘fill in the blanks on their maps’ (Caquard, 2013: 136). Accordingly, voice is a primary way in which storytelling can be reintegrated into cartographic design.

There are at least three kinds of voices that can be present in a visual story: designer, character, and audience. First, the designer can serve as the narrator in visual storytelling, helping to enforce continuity and focus attention, while also establishing their politics and revealing their judgments (Cronon, 1992). Following feminist perspectives in mapping, embedding the designer’s voice also can serve as a *reflexivity statement*, making space in the visual story to critically acknowledge their own situated relationship to the mapped people and places and thus the information about these people and places (Ricker, 2017; Kelly, 2019).

Giving voice to key characters in the visual story builds tension while also makes the story more human and relatable, creating intimacy with and encouraging empathy from the audience. Giving voice to characters also can confront inequities and marginalization. The challenge is allowing marginalized voices to speak without appropriating or misrepresenting these voices to fit the designer’s intentions (England, 1994). To this end, D’Ignazio and Klein (2016) forward principles of feminist visualization that inform the design process and work towards more equitable design products, including rethink the binaries in data, embrace pluralism, examine power and aspire to empower, consider context, legitimize embodiment and affect, represent uncertainties, and make labour visible. Voice as a trope is one approach for making each of these principles explicit in a visual story, to speak truth to power.

Geoweb technologies now make it possible for the audience to insert their own voices into the visual story through commenting and social media, enabling collective and collaborative storytelling (Caquard, 2013). In this way, the audience now can ‘fill in the blanks on their maps’ themselves, resolving ambiguity and arriving at closure on their own terms, even publishing new takes on the narrative using personalized story maps. This expression of audience voice makes visual stories fluid over time and space. As Pearce (2014: 119) writes, ‘The last piece of the map, of course, is you’.

Typography is the primary static technique used for embedding voice (Hermann and Pearce, 2010; Pearce and Hermann, 2010). Replacing abstract symbols with textual commentary and quotations shifts control of the narrative from the designer to specific people and places referenced in the story as well as slows the pace of the

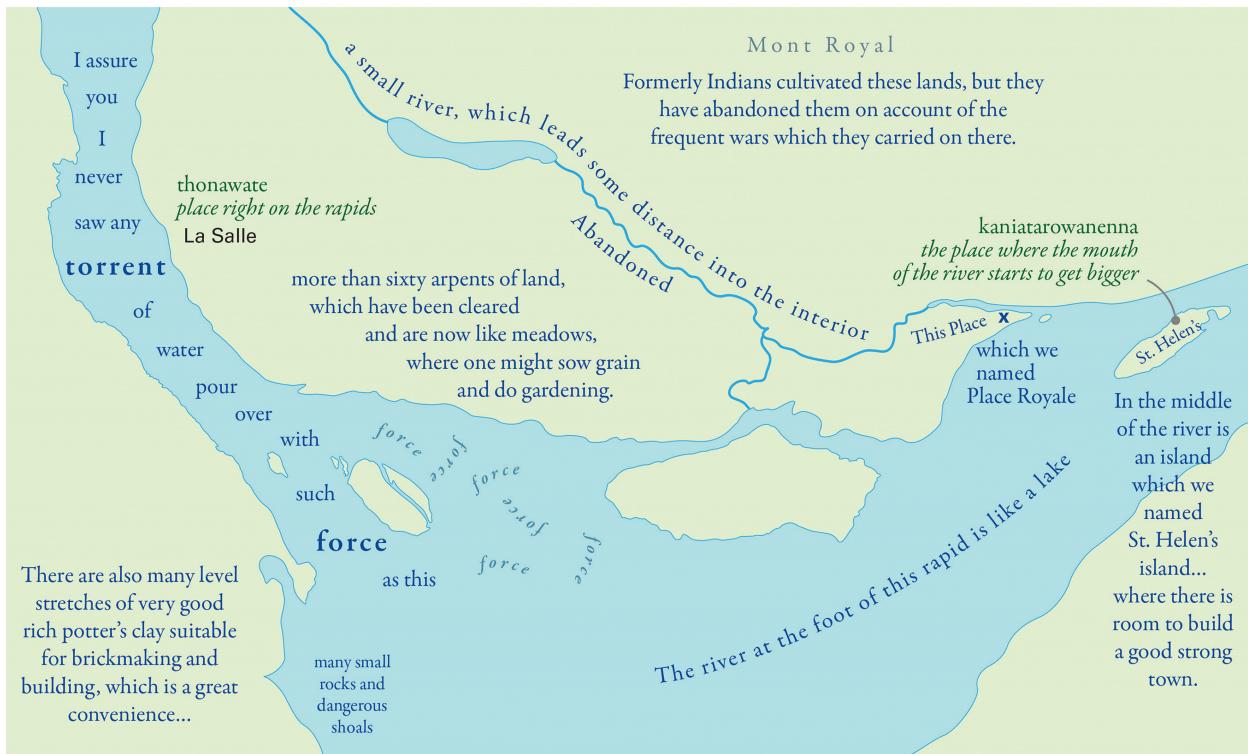


Figure 8. Voice as a visual storytelling trope. 'They Would Not Take Me There; People, Places, and Stories from Champlain's Travels in Canada, 1603–1016' published by the University of Maine Canadian-American Center (Pearce & Hermann, 2010) follows the explorations of Samuel de Champlain through what would become New France. Drawing from his journals, the designers insert Champlain's voice into the map using typography (blue Garamond). Alongside Champlain's voice is an imagined Indigenous voice (green Garamond), 'add[ing] context to a landscape that Champlain often refers to as empty or barren' (2010: 46). The designers' voice also is inserted into the map for narration and context (black Univers Light), resulting in a juxtaposition of different perspectives, time periods, and power structures.

visual story for greater engagement. The text also can vary in colour, size, style, etc., to represent different voices, distinguishing among designers, characters, and the audience (Figure 8). As described above, voice combined with focalization produces a unique *vantage point*, which, for spatial narratives, shifts the map scale and projection from a planimetric, north-up view to be grounded from 'somewhere' and 'someone' (Pearce, 2008). Dynamic techniques for voice draw from cinematic cartographies and include audio or audiovisual solutions common to the narrated animation and multimedia visual experience genres, respectively.

Outlook: cartographic design as visual storytelling

So, what can storytelling actually tell us about cartography and design? In this article, I adopt visual storytelling as an entry point for *hybridization* in cartography, opening new avenues for transdisciplinarity. My focus is on *design*, teasing out new considerations and techniques when approaching cartography as visual storytelling. To this end, I identify three of potentially many ways to articulate and organize the design space for visual storytelling – narrative elements, genres, and tropes – synthesizing related transdisciplinary work and linking storytelling concepts to potential design techniques. Highlights from the survey include:

- Cartographic research on narrative and storytelling draws from an eclectic set of disciplines, ranging from primarily quantitative and analytical approaches to primarily qualitative and reflexive approaches. Because 'narrative' and 'story' are so fundamental to the human experience, they offer important sites for hybridization in cartography, and related fields: they allow us to speak to each other, despite our theoretical, methodological, and artistic differences.
- While definitions for 'narrative' and 'story' vary widely across disciplines, there are some repeating themes in how these concepts are evoked and discussed in the literature. Visual stories commonly are described as: designed, partial, intuitive, compelling, relatable, memorable, situated, persuasive, political, and fluid. While no single characteristic separates a 'visual story' from a 'visualization' or a 'story map' from a 'map', these visual storytelling themes serve as both background review on narrative cartography and creative inspiration for designers.
- Oral, written, and audio-visual narratives often evoke one-dimensional, temporal linearity in their organization, but maps and other visualizations using a spatial metaphor are inherently two-dimensional, complicating linear

Table 5. Visual storytelling tropes.

Trope	Definition	Related terminology	Visual design techniques
Continuity	Unify otherwise disparate visual elements into a logical structure	Linearity, Conflict and Ambiguity Resolution, Sequencing	<ul style="list-style-type: none"> • Linear three-act narrative • Genre pacing: visual layout, browser scrolling, slide advancement, display time progression, hyperlinking, user contributions, real-time updates • Annotation • Interaction: sequencing, panning, zooming, & detail retrieval • Transitions; fading, panning, swiping, tweening
Mood	Set a visual tone congruent with the narrative and its elements	Style	<ul style="list-style-type: none"> • Map element design • Marginalia and other adornments • Visual style <ul style="list-style-type: none"> ◦ Form: line weights, cap/join styles, tapering ◦ Colour: palette, primary/accent ◦ Type: typefaces, placement, microaesthetics ◦ Texture: pattern fills, gradients, overlays, dashing • Persuasive styles: authoritative, understated, propagandist, sensationalist • Pastiche styles: antique, surrealist/realist/hyperrealism, modernism, pop/optical art, minimalist
Dosing	Reduce overall complexity of story content into incremental chunks of information	Modularity	<ul style="list-style-type: none"> • Linear sequencing • Modularized design • Storyboarding • Clear entry point: layout and visual hierarchy • Partitioning: neatlines, negative space, segment annotations • Selective pausing or slow motion in an animation • Genre-specific interactive pacing: browser scrolling, slide advancement, hyperlinked text • Slippy map information pop-ups/detail retrieval
Attention	Emphasize important or unusual information that cannot be missed in the story	Focalization	<ul style="list-style-type: none"> • Visual hierarchy / figure-ground • Visual accenting: <ul style="list-style-type: none"> ◦ Highlighting & visual variables ◦ Annotation: leader lines, flow arrows, appended geometric frames, opacity masks, numbering, changes in map scale, variable levels of detail, call-outs, labelling clarifications ◦ Dynamic: blinking/flickering, dynamic panning/zooming, focus + context visualization
Redundancy	Repeats important or unusual information to develop story themes	Repetition	<ul style="list-style-type: none"> • Visual motifs & symbolism • Figures and Easter eggs • Visual hierarchy & accenting (see Attention)
Metaphor	Brings together seemingly unrelated concepts in a single frame to facilitate understanding of complex narrative elements	Simile, Symbolism	<ul style="list-style-type: none"> • Associative point symbols • Visual motifs & symbolism • Visual juxtaposition: <ul style="list-style-type: none"> ◦ Overlay ◦ Visual benchmarks ◦ Scenarios ◦ Cartooning & illustration ◦ Hyperrealism ◦ Collage & montage • Humour, irony, & satire
Voice	Embeds situated experiences, opinions, and values into the visual story to clarify meaning	Pluralism	<ul style="list-style-type: none"> • Designer voice: reflexivity statement • Character voice: feminist visualization ◦ Rethink binaries ◦ Embrace pluralism ◦ Example power/aspire to empower ◦ Consider context ◦ Legitimize embodiment a& affect ◦ Represent uncertainties ◦ Make labour visible • Audience voice: commenting, social media, personalized story maps • Typography • Vantage point & projection • Narration: audio (narrated animations) & audiovisual (multimedia visual experiences)

Notes: Visual storytelling tropes offer new ways to conceptualize and execute visual design, map-based or otherwise. The table summarizes a list of visual design techniques potentially useful for employing each trope in a visual story.

storytelling. To this end, elements of a linear three-act narrative give cartographers new ways to think about data and design for visual storytelling (Tables 1–3). Some useful narrative elements include (setup) the setting, key characters, problem context, and the hook; (conflict) the problem, tension between characters, and plot points; and (resolution) the climax, denouement, and cliffhanger (Figure 1).

- Visual storytelling genres are defined by the visual or interactive technique used to enforce linearity in the narrative sequence. I identify seven genres that make use of maps, and more will become possible as new media and geoweb technologies evolve: static visual stories, longform infographics, dynamic slideshows, narrated animations, multimedia visual experiences, personalized story maps, and compilations (Figure 2). Delineating visual storytelling genres helps designers weigh the pros and cons of different solutions for enforcing linearity (Table 4), as well as explore innovative genre mashups to push cartographic design and visual storytelling in new directions.
- Visual storytelling tropes describe an emerging suite of visual design techniques applied not to represent data, but to enhance narrative and its elements. I propose seven tropes applicable to map-based visual storytelling: continuity (Figure 2), mood (Figure 3), dosing (Figure 4), attention (Figure 5), redundancy (Figure 6), metaphor (Figure 7), and voice (Figure 8). Tropes elucidate a new suite of cartographic design techniques for visual storytelling, such as visual transitions (continuity), visual style (mood), visual partitioning (dosing), visual accenting (attention), visual motifs (redundancy), visual juxtaposition (metaphor), and vantage point (voice), among many others (Table 5).

Where do we go from here? In the following, I outline three avenues for research on visual storytelling derived from the above survey that I find to be particularly pressing for cartography and related fields moving forward:

Visual Design: Above, I reviewed a range of prospective visual storytelling techniques that seem reasonably well-suited for cartography. Where possible, I draw from the literature to assemble some preliminary considerations and guidelines for employing these techniques in story maps and spatial narratives, for treating cartographic design as visual storytelling. This review is an opening act, not the denouement, and future research and design are needed to substantiate and advance these claims. A starting point could be an assessment of different narrative arcs, different genres, and different tropes to understand the relative utility and limitations of these techniques for map-based visual storytelling. Additional opportunities regarding visual design include content analyses of existing visual storytelling design practices in different media and for different audiences, as well as capture of expert experience and opinion from cartographers working in data journalism, information visualization, and visual analytics, among others.

Building upon a ‘digital’, ‘spatial’, and ‘geo’ humanities, research also is needed from artistic, literary, and critical perspectives to inform visual design. This includes new design techniques that augment or replace traditional mapping with oral, written, and audio-visual forms established in critical cartography, Indigenous mapping, participatory GIS, and other influential domains on narrative cartography. Further, new measures of success are needed, with the ten visual storytelling themes reviewed above providing a potential blueprint for future design evaluation. New outcomes also are needed, shifting ‘what counts’ as research and design on map-based visual storytelling, and may include live performances, video documentaries, zines, and physical installations as well as engagement with immersive technology such as video games and other virtual environments. Finally, new collaborations are needed to get designers, thinkers, and storytellers with different backgrounds and skillsets together on cross-cutting projects centered upon pressing and important geographic problems, truly hybridizing cartography through collective visual storytelling.

Visual Ethics: I continually asked myself while completing this survey if visual storytelling is something we should pursue at all. From my review, I am convinced that visual storytelling, spatial narratives, and story maps can do a great amount of good, but without a visual ethics, can and likely will do more harm than good. Of course, cartography, data journalism, and visual storytelling will continue with or without any singular voice of reason, adding to the urgency in this moment to hybridize theory and practice, forge partnerships across sectors, and together move towards a more equitable future. Cartographers must search outwardly for insight into these guidelines, drawing from critical theory as well as professional standards to establish tent poles of ethical visual design.

The survey identified several principles that may seed an ethics for visual storytelling, map-based or otherwise. As discussed above, ‘show your work’ may be a first tenet of ethical visual storytelling. Following feminist critiques, ‘show yourself’ may be another ethical obligation, encouraging designers to

be reflexive about their situated positionality and subjectivity to the story and its mapped people and places. ‘Speak to power’ is an ethical responsibility in all cartographic design and visual storytelling, and we must constantly confront rather than edify inequities and marginalization when using data to find narrative structure and develop story content. ‘Speak to each other’ may be a final ethical tenet derived from the survey, and visual stories perhaps should be judged less on how efficiently or effectively they are read or understood, but instead how they make the audience feel about and connect to other people and places.

Visual Literacy: The processes of visual storytelling already are at work in our maps and graphics, even if we lack a uniform lexicon to discuss these processes during design. One of the great personal revelations of this survey was how little I noticed map-based narrative elements, genres, and tropes until I really started looking for them in popular examples. In an era of fake news and post-truth, we need to leverage insight from design and ethics to promote visual literacy among our audiences. In other words, we need an audience capable of identifying inaccuracies and bias in what they see while also fully aware of the potential to tell their own story in a way that is deep and meaningful.

Promoting visual literacy starts with curriculum and pedagogy. Specifically, we need a reimagined ‘map use’ curriculum that approaches visual stories, spatial narratives, and story maps as visual culture that unevenly confines and expands our individual lived experiences and collectively shapes our geographic understandings. This map use curriculum must itself be hybridized, uniting technology with praxis, product with process, and design with critique through experimental mapping and storytelling assignments. The curriculum also should adapt pedagogical strategies from additional fields that influence data journalism, such as creative writing, film studies, and photography. However, promoting visual literacy is not limited to educators, as all storytelling is an exercise in teaching. As designers, it is not enough just to ‘show’, as we must also ‘explain’. Additional narrative components of the visual story can be used in part to evoke the designer’s voice and educate the audience about how to use the included maps and visualizations. As Cronon (1992: 1375) writes, we need to tell ‘stories about stories’ to the end of promoting literacy and enhancing understanding.

For my own reflexivity statement – my own story about the story presented in this article – I had attempted to write this survey article three times before actual submission: once in 2011 as a newly minted professor at UW-Madison trained in social science methods but redesigning an advanced cartographic design class to recruit journalism students and support a startup visual cultures certificate, again in 2013 to integrate exciting new developments on visual storytelling into my research on user experience design, and once more in 2016 after advising a dozen outstanding graduate students whose diverse interests across cartography were unbounded by any prior assumptions, definitions, or traditions, especially my own. In many ways, this article was the most difficult I have written to-date as, in my experience, embracing hybridity means to be constantly at the edges of your comfort zone, to slow down the pace of scholarship, and to fold-in rather than cut-out. It was only after my 2017–2018 sabbatical in Europe – utterly defeated upon departure by the US political context and fully rejuvenated upon return from the bright conversations with many new colleagues and friends – that I finally was ready to challenge myself to finish this article (or at least, to find some closure). My story of this survey anecdotally illustrates the power and potential of this line of thinking: there are innumerable ways to approach cartographic design as visual storytelling, any of which reflect the situated perspectives derived from our ever-accumulating lived experiences and the shifting, hybridizing, and unravelling possibilities of cartography and design.

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