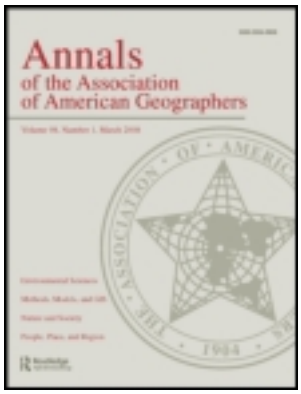

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Researching Volunteered Geographic Information: Spatial Data, Geographic Research, and New Social Practice

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Researching Volunteered Geographic Information: Spatial Data, Geographic Research, and New Social Practice

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The convergence of newly interactive Web-based technologies with growing practices of user-generated content disseminated on the Internet is generating a remarkable new form of geographic information. Citizens are using handheld devices to collect geographic information and contribute it to crowd-sourced data sets, using Web-based mapping interfaces to mark and annotate geographic features, or adding geographic location to photographs, text, and other media shared online. These phenomena, which generate what we refer to collectively as *volunteered geographic information* (VGI), represent a paradigmatic shift in how geographic information is created and shared and by whom, as well as its content and characteristics. This article, which draws on our recently completed inventory of VGI initiatives, is intended to frame the crucial dimensions of VGI for geography and geographers, with an eye toward identifying its potential in our field, as well as the most pressing research needed to realize this potential. Drawing on our ongoing research, we examine the content and characteristics of VGI, the technical and social processes through which it is produced, appropriate methods for synthesizing and using these data in research, and emerging social and political concerns related to this new form of information. *Key Words: Geospatial Web, neogeography, spatial data infrastructure, volunteered geographic information, Web 2.0.*

新的基于网络的交互式技术与互联网上传播的，越来越多的，用户生成的内容实践相衔接，正产生地理信息的一种显著的新形式。公众使用手持设备收集地理信息，并把它贡献给基于人群来源的数据集，并使用网站的映射接口来标记和批注地理特征，或把地理位置添加到照片，文字和其他网上共享的媒体。这些现象，产生我们统称的自愿地理信息（VGI），代表了地理信息在如何被创建和共享，及其内容和特点方面的一个范式转变。这篇文章，借鉴我们最近完成的对 VGI 举措的清点，目的是给地理学和地理学家们建筑 VGI 的关键维度，并确定自愿地理信息在我们领域的潜力，以及实现这一潜力最紧迫的研究。借鉴于我们正在进行的研究，我们探索 VGI 的内容和特点，通过它产生的技术和社会进程，并探索在研究中合成和使用这些数据的适当的方法，以及与这种新的信息形式有关的，新出现的社会和政治关注。*关键词：地理空间网络，新地理，空间数据基础设施，自愿地理信息，网络 2.0。*

La convergencia de nuevas tecnologías interactivas de la Web con creciente uso de contenidos generados por usuarios y difundidas en Internet, están generando una notable nueva forma de información geográfica. Los ciudadanos están usando dispositivos de mano para recopilar información geográfica y aportarla a conjuntos de datas de fuentes agrupadas usando interfaces de mapeo basadas en la web para marcar y anotar sus características geográficas, o añadir ubicaciones geográficas a fotografías, textos y otros medios compartidos en la red. Estos fenómenos que generan lo que nos referimos colectivamente como *voluntariado de información geográfica* (VGI), representan un cambio paradigmático en cómo la información geográfica es creada y compartida y por quienes, así como su contenido y características. Este artículo que se basa en nuestro inventario recientemente terminado de iniciativas del VGI, se pretende enmarcar las dimensiones fundamentales de este para la geografía y los geógrafos con miras a identificar su potencial en nuestro campo, así como el más apremiante estudio necesario para hacer realidad esta posibilidad. Basándonos en nuestra investigación en curso, se analiza el contenido y las características del VGI, los procesos técnicos y sociales mediante los cuales se produce, los métodos apropiados para la síntesis y uso de estos datos en la investigación, y las emergentes inquietudes sociales y políticas relacionadas a esta nueva modalidad de información. *Palabras claves: Web, neogeografía, infraestructura de data espacial, voluntariado de información geográfica, Web 2.0.*

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In recent years a remarkable new source of geographic information has become available in the form of user-generated Web content, supported by technologies loosely known as Web 2.0 (O'Reilly 2005; Vossen and Hagemann 2007). Examples of such efforts include Wikimapia, which is attempting to build a world feature directory under the mantra "Let's describe the whole world"; Flickr, which now contains several hundred million georeferenced photographs; Geonames, which provides geographic access to Wikipedia entries; and OpenStreetMap, one of several efforts to build global maps as patchworks of voluntary contributions. Numerous citizen science efforts (e.g., the Cornell Lab of Ornithology, http://www.birds.cornell.edu/LabPrograms/CitSci) also contain explicit geographic information. With geotags (hidden codes that link content to geographic locations; Ransom 2006; Shankland 2007) increasingly attached to online information, the entire Web is fast becoming a potential source of geographic data, information, and perhaps even knowledge.

Goodchild (2007) refers to these phenomena as *volunteered geographic information* (VGI), to contrast them with more conventionally produced and mediated forms of geographic information and to emphasize their role in augmenting our knowledge of the geographic world through the efforts of volunteers. Here we define geographic information as information that links names and descriptive information to particular places, features, or locations on the Earth's surface. Compared to conventionally produced forms of geographic information, VGI is different along several axes: the content of the information, the technologies for acquiring it, issues surrounding its quality, the methods and techniques for working with it, and the social processes that mediate its creation and impacts.

Citizen-driven data collection efforts are not new. A host of related movements have helped enable VGI as a phenomenon. Stamp's 1930s and 1940s land use surveys of Britain were primarily carried out by teachers and school children (Stamp 1931), and in the 1980s, the BBC's Domesday Project assembled a massive digital spatial data archive for the country, much of it compiled from contributions of volunteers and community groups (Openshaw, Rhind, and Goddard 1986). In the United States, Bunge's (1971) "Geographical Expeditions" involved urban residents in local countermapping efforts. Sunshine laws and other freedom-of-information protections, the open-source movement (Haklay, Singleton, and Parker 2008), activists' use of the Internet to disseminate "secret" information (Perkins and Dodge 2009; O'Loughlin et al. 2010), and different versions of the People's Geography Projects (http://peoplesgeography.com and http://www.peoplesgeographyproject.org) are all part of the broader context that gives rise to VGI. Yet throughout this article, we hold that the case of collectively generated geographic information mediated through Web 2.0 presents new challenges and necessitates further research.

There is some existing research on the volunteering of data and programming code for software and the attendant surrendering of ownership, right to compensation, and even the personal identity of the creator (Hars and Ou 2002; Anthony, Smith, and Williamson 2005; Lakhani and Wolf 2005; Borland 2007; Cook 2008; Coleman, Georgiadou, and Labonte 2009). Yet, as some scholars have argued within the nascent literature on VGI, the case of geographic information presents unique issues. Elaborate arrangements have emerged over the past few centuries for the production of geographic information, dominated by the national mapping agencies and mapping companies.[1] Certain types of information have been privileged and other types ignored or marginalized (Harley 2001; Wood and Fels 1992), and production has been dominated by experts, leaving no explicitly defined role for the citizen amateur in the mapping process. We show here that VGI represents a dramatic shift in the content, characteristics, and modes of geographic information creation, sharing, dissemination, and use.

Yet little is known about why people contribute geographic information in this context, the accuracy or quality of what they produce, appropriate methods for synthesizing or analyzing these data, how the digital divide might operate to inhibit some people from contributing VGI, or how this phenomenon might impact privacy and confidentiality. Nevertheless, it is clear that a vast amount of data is becoming available through this mechanism and that these data are a rich and immediate source of information for a variety of purposes. VGI is not only of interest to GIScientists but also potentially can make significant contributions to various branches of physical geography (Lawrence 2006), human geography (Zook and Graham 2009), and geographic education (Jahnke and Koch 2009; Moulder 2009). The successful integration of these multiple sources of geographic information could offer geographers an unprecedented opportunity to conduct research on a variety of topics at multiple scales. Further, this bottom-up process of creating geographic information through the contributions of citizens has great potential

to be integrated with top-down processes. Before any of these integrations are possible, however, there are some crucial questions regarding VGI that must be addressed.

As geographers it is incumbent on us to observe, research, and reflect on what might be one of the most important phenomena to impact our discipline in recent years and one that could dramatically alter the landscape of geographic information production. Drawing from ongoing VGI research by the authors and a recently completed inventory of VGI sites and activities, our primary goal is to report our early findings and catalyze further research. We offer a framing of key issues confronting the emergent VGI research community and discussion of the diverse forms of geographic scholarship that might be brought to bear on them.

Our discussion of VGI is necessarily multifaceted, intentionally informed by several possible ontological and epistemological positionings of this phenomenon. Geographers' engagements with VGI encompass a diverse range of assumptions about what VGI is, and in the following section we show how these foundations point to different research priorities, lend themselves to different epistemologies and theoretical frameworks, and suggest different societal considerations. After that, we examine VGI as a form of spatial data, as information produced through particular institutional and political economic histories and relationships. From these perspectives, it is important to account for the emergence of VGI (and its modes of production) and to characterize its content, applications, and potential role vis-à-vis more conventionally mediated forms of spatial data. We then examine VGI as a form of evidence, as a way of knowing the world for research purposes, or of making (scientific) knowledge. From these foundations, VGI constitutes a profound transformation in how we know the world, make and validate knowledge, and, in so doing, reproduce and challenge constructs such as accuracy or reliability that guide knowledge production in research. In the final section, we examine VGI as social practice, a framing that is attentive to the particular ways in which VGI structures and represents knowledge, as well as its role in reproducing and transforming institutions, material conditions, and power relations of many kinds. The article includes discussion on research about VGI, in the second and fourth sections, and on research with VGI in the third section.

Our framing of these three facets of what VGI is and might be offers a more comprehensive account of the variety of ways in which geographers engage this phenomenon, with explicit attention both to the breadth of research priorities and approaches that will emerge from various starting points and to important areas of intersection across these approaches. In doing so, we draw on and contribute to a diversity of studies around spatial technologies in the past two decades. Geographic information systems (GIS) are now engaged as a collection of tools for spatial analysis and representation in digital environments, as a negotiated set of methodological practices, and as an assemblage of practices embedded in historically situated relationships around science, knowledge, and power. Similarly, geography and geographers must engage VGI on multiple registers, and this article is meant to provide a more comprehensive framework for doing so, to situate and complement the plethora of emerging research studies that examine VGI through a more particular lens. We offer here the basis of a "small s" science of VGI, one that involves negotiation and integration across multiple approaches.

VGI production has sometimes been identified as a form of *neogeography* (Turner 2006; Graham 2009; Rana and Joliveau 2009), in which the traditional distinctions between professional geographers and others have largely disappeared. Neogeographers (Goodchild 2009a; Hudson-Smith et al. 2009) have been empowered by the widespread availability of cheap positioning devices, fine-resolution imagery, and mapping software and are able to make maps that reflect personal and often transitory needs, in contrast to the general-purpose maps of traditional cartography. Some scholars argue that this framing implies that the expertise possessed by professional geographers and cartographers is no longer needed or that the only role of geographers is to produce geographic information (Goodchild 2009a). Our discussion of the preceding questions illustrates that VGI has important roles to play in geographers' research and underscores the importance of a diverse range of geographic scholarship in realizing the potential benefits of this phenomenon and understanding its societal impacts.

The Domains of VGI

Rapid advances in technology, along with changing demands for geographic information, have dramatically altered the environment within which this information is produced and accessed, effectively removing the economies of scale and assured patterns of use that allowed national mapping agencies such as the U.S. Geological Survey (USGS) to evolve and flourish (Goodchild, Fu, and Rich 2007). Perhaps the most important is the growth of the Web, particularly the increasing

participation of its users in generating its content. An early but prescient study conducted by the National Research Council's Mapping Science Committee (NRC 1993) predicted that the traditional system of central production and radial dissemination of geographic information would be replaced by a complex patchwork, a radically restructured National Spatial Data Infrastructure, and that the distinction between producers and users would become increasingly blurred.[2] The term *Geospatial Web* (Scharl and Tochtermann 2007) or *geoweb* has been widely adopted to describe this evolving set of Internet-based arrangements.

Several other terms are used in describing this new context of geographic information production, each linked to a distinct concept. Early visions of the Web emphasized a radial flow of information from servers to users, echoing the traditional arrangements of centralized production of geographic information. More recently, Web 2.0 suggests a new, reconceptualized World Wide Web (O'Reilly 2005; Vossen and Hagemann 2007), characterized by a more decentralized mode of production, the role of servers as accumulators of content from distributed sources, and the exchange of content among users (Surowiecki 2004). So-called user-generated content (UGC) first began to appear in large quantity through sites such as eBay and is exemplified today by such social media sites as Wikipedia and Facebook. VGI in this context is simply that subset of UGC that concerns the explicit characterization of the geographic domain; in other words, the Earth's surface and near-surface, or any other information that has been associated with a specific geographic location.

Archives of UGC (such as Wikipedia) do not rely on traditionally authoritative sources of information but are based on an assumption that content contributed or edited by many individuals, even if they do not have specialized expertise, will converge on a consensus and, in appropriate cases, on the truth. This approach is termed *crowdsourcing* (Howe 2008), *collective authorship* (Hardy 2008; Rimmer 2009), *collective intelligence* (Lévy 1997), or *co-creative labor* (Banks and Deuze 2009). In this vein, VGI carries none of the guarantees of data quality associated with conventional geographic information produced by mapping agencies. Instead, it can be said to be *asserted*, in contrast to the *authoritative* products of traditional sources that derive their authority from their creation by highly trained experts.

There are many reasons for the rise of VGI. Historically, one of the strongest motivations for centralization of the mapping enterprise was its high fixed costs, such as expensive equipment and the specialized skills needed by cartographers. Today ready access to Global Positioning System (GPS) for geopositioning, mapping software for data integration and compilation, broadband connections to the Internet, and open programming interfaces to services such as Google Earth or Microsoft's Virtual Earth (Bing) have largely removed these motivations (Haklay, Singleton, and Parker 2008; Goodchild 2009c). Another contributing factor is the rising demand for geographic information for in-vehicle navigation systems, Web sites dealing with travel, real estate sites, virtual globes, mainstream news media, and others. Indeed, digital geographic information, and the tools and services that rely on it, have now penetrated virtually all aspects of human activity for many individuals and institutions (Longley et al. 2011).

Moreover, although in principle a vast number of distinct attributes can be recorded about locations, only a very small subset of these have been compiled by mapping agencies and only at comparatively coarse scales. Only the most widely used and persistent facts, such as ground elevation, soil characteristics, or the locations of streets or coastlines, attract sufficient numbers of users to justify the high cost of map production. Other important information, such as transient and fast-changing phenomena, or phenomena that are difficult or impossible to quantify, have never been mapped to any large extent. Thus, in considering the nature and significance of VGI, we cannot limit our discussion to the types of primary geographic information that have been produced in the past. Some forms of VGI mirror familiar types of information used by geographers in general and GIScientists in particular, but other forms are entirely new, and there exists no body of knowledge in geography about how best to analyze, handle, and make use of them.

The diverse information that is being generated as VGI presents a number of challenges for developing methodologies to make use of it and for understanding the societal implications of this phenomenon. A crucial first step in geographers' emerging work on VGI involves coming to grips with its content and characteristics, as we begin to do here. Our discussion of the content and characteristics of VGI emerges from our recent inventory and analysis of current VGI initiatives. In early 2009, we conducted a keyword search of the Web to identify a sample of Web sites gathering and sharing user-generated geographic content or geotagged multimedia, as well as those offering mapping interfaces set up to allow user contributions of map objects or annotations. Our search generated a collection of ninety-nine VGI initiatives, which we assessed for

their intended geographic extent of the information collection effort, date the initiative was begun, type of organization or group initiating the project, and primary purpose of the initiative. Drawing on techniques from qualitative methods, we examined online materials for each of these VGI initiatives, inductively developing from these data a typology for characterizing the inventory results along the dimensions described previously (where, when, who, why). Countless VGI projects have been undertaken or abandoned since our early 2009 inventory, and our collection of ninety-nine English-language initiatives is but a small fraction of the total in existence. The intent of this inventory and the resulting typology, however, is not to provide an up-to-the-minute characterization or comprehensive summary of VGI initiatives. Rather, we begin to offer a systematic overview of this new phenomenon and develop a framework for characterizing VGI activities. The inventory and the characterizing typologies we have generated from it complement the bulk of existing scholarship on VGI activities, much of which has conducted in-depth study of a single initiative.

In conducting the inventory it quickly became obvious to us that a clearer definition of VGI was needed. Earlier in this article we defined VGI as "that subset of UGC that concerns the characterization of the geographic domain." We found many instances, however, where the contribution of geographic content by users was involuntary or where the geographic content was inferred or added later by others. An individual whose use of a toll road is recorded automatically is not volunteering geographic information in a conscious fashion, even though the information created is geographic by our definition, and does not intend to contribute to society's knowledge of the planet. Similarly, if Google assembles data on the number and type of searches conducted by people in a geographic region, the result is geographic information but it does not meet our definition of VGI because no conscious volunteering by individuals or groups occurred. Thus, we define VGI as geographic information acquired and made available to others through the voluntary activity of individuals or groups, with the intent of providing information about the geographic world. The volunteering aspect thus places VGI in sharp contrast to the traditional practices of map-making by authorities.

Table 1 shows the elements of this descriptive typology, as well as the distribution of the inventory results within it, and the remainder of this section discusses the inventory results in more detail. Our results reinforce some prior claims about VGI activities and suggest the need to rethink others. With respect to the geographic extent, the bulk of the sites we reviewed are local in extent (76 percent), in keeping with prior suggestions that VGI is a highly localized phenomenon (Goodchild 2007). These discussions largely cite 2005, when Google's application programming interfaces (APIs) to its mapping services were released, as a watershed moment when collaborative online mapping and geoinformation initiatives began to grow exponentially, and our inventory mirrors this claim, with 73 percent of the sites initiated in 2005 or later. Our inventory nuances characterizations of such activities as unprecedented or brand new, however: 20 percent were initiated prior to 2005. With respect to sponsoring entities, some commentators suggest that we are in a new age of citizen-initiated efforts to collectively gather and share geographic information (Turner 2006). Indeed, 18 percent of the projects were initiated by individuals or groups of citizens not operating within a formally structured organization. Yet with 63 percent of VGI projects in the inventory initiated by private companies and other for-profit entities, the role of the private sector in the geoweb clearly extends well beyond the provision of APIs and online geoservices. Among the wide range of self-stated purposes for the initiatives we examined, we discern three primary groupings: initiatives primarily oriented toward mapping user-contributed information (geovisualization,

Table 1. Findings of 2009 inventory and analysis of volunteered geographic information initiatives

Geographic extent of initiative	Percentage
Local	76
Regional	11
Global	13
Date initiated	**Percentage**
Pre-2000	6
2000–2004	14
2005–2009	73
Unable to identify	7
Sponsoring entity	**Percentage**
For-profit institution	63
Individual/collective	18
Nongovernmental organization	7
Government	7
Academia	3
Multiple sponsoring entities	2
Primary purpose of initiative	**Percentage**
Geoinformation	51
Geosocial	35
Geovisualization	14

Note: $n = 99$.

14 percent)[3]; initiatives oriented toward capturing, compiling, and integrating geotagged content, data generated through location-based services, and geolocational information for place names (geoinformation, 51 percent); and initiatives that allow users to share geolocated media with others in their professional or social networks (geosocial, 35 percent). With a small number of geosocial applications such as FourSquare or Facebook Places receiving a great deal of attention, it is notable that fully half of the initiatives in the inventory focus instead on collecting and compiling thematic data based on geographic location or associating geographic coordinates with other thematic information.

VGI and the Geographic Information Framework

A growing number of VGI initiatives are developing *framework* data through various crowdsourcing approaches. Framework data are "the most common data themes geographic data users need" (Federal Geographic Data Committee [FGDC] 1997). An earlier study used the term *foundation* and defined this as "the minimal directly observable or recordable data from which other spatial data are referenced and compiled" (NRC 1994, 1). Framework data typically include seven themes: geodetic control, orthoimagery, elevation, transportation, hydrography, governmental units, and the cadaster. The data represent relatively static phenomena and are commonly used for administrative programs, wayfinding, geopositioning, geotagging, and other widely used services, so they have been a traditional focus of government data production. Together they constitute the core of a spatial data infrastructure (SDI), a term coined in the 1993 NRC study cited earlier and subsequently operationalized in the U.S. National Spatial Data Infrastructure.

Not all seven types of framework data are or could be acquired from citizens or through collaborations between citizens and authorities. Maintenance of the primary geodetic control system, acquisition of orthoimagery, and the compilation of accurate data on elevation all require a high level of expertise and major investment in equipment even today, leaving little room for the activities of citizen volunteers. Delineations of land tenure and ownership or of governmental units such as voting districts, for instance, are structured by laws and government policies, so primary responsibility for data compilation will likely remain with professionals such as licensed surveyors.[4]

In contrast, examples have already been cited of VGI activities generating information on transportation and hydrography. The best known and most studied example is Open Street Map (OSM), which intends to create an open, free, digital map of the world through volunteer efforts. Volunteers capture the locations and geometries of road, rail, river, and other prominent topographic features using GPS. They identify feature names and other attributes and merge the results into a collective database via the OSM Web site. Once compiled, these data are freely available as rendered online maps, along with a variety of services. Users are free to develop their own applications as long as they acknowledge their use of OSM data. This open access is in stark contrast to the limited accessibility and high costs of conventionally curated framework data from many national mapping agencies and corporations.

To date, the project has acquired strikingly comprehensive data on large parts of the developed world, although other parts of the world are underrepresented. In early 2010 the Haiti earthquake created an immediate demand for accurate framework data and led to an intensive effort on the part of volunteers in many countries to augment the existing rudimentary OSM coverage. Informal gatherings of neogeographers, or *crisis camps*, were held in many places, at which digital geographic information was compiled from available online sources. Within days, a detailed, open, free digital map was available and was quickly adopted by relief agencies (Hesse 2010).

Several VGI initiatives are gathering the names of places, features, and points of interest. The traditional resource used to associate place names with particular locations (typically through latitude and longitude) is the *gazetteer* (Hill 2006). It is surprising, given the importance of such information, that a *names layer* is not part of the FGDC's seven framework data sets, although a gazetteer has long been a popular product of the U.S. Board on Geographic Names.[5] Whereas traditional gazetteers are limited in content to places with officially recognized names, extensive Web services have been developed, by both the public and private sectors, to provide points of interest, street addresses, business names, and many other easily recognized features that are likely to appear in driving directions. These services essentially convert informal references to formal ones (latitude and longitude or other coordinate systems), permitting a degree of interoperability between the informal world of everyday human discourse and the formal world of GIS (Goodchild and Hill 2008). These services enable simple interoperation among street address, latitude and longitude, place name, and many

other forms of formal and informal georeferencing, and their availability undoubtedly contributed to the rapid growth of the VGI phenomenon.

The general public is familiar with many geographic features and their names, so it is perhaps not surprising that gazetteer-like data are now a prominent form of VGI. Wikimapia's effort to describe the whole world allows users to identify and provide detailed descriptions of Earth-surface features, along with links to related online information. To date, over 14 million features have been described through the contributions of thousands of individuals (the exact number of contributors is not tracked), creating what amounts to an asserted version of a traditionally authoritative gazetteer. Further, whereas most gazetteers include feature name, feature type, and location (usually given as a single coordinate pair), the Wikimapia information is significantly richer. Contributors can delimit features with rectangles or irregular polygons, provide unlimited textual description, and link to other Web-based sources of information through hyperlinks. The number of entries is already substantially greater than the size of the largest published gazetteer. Moreover, the information is arguably more current, given that augmentation and updating of gazetteers has virtually ceased in recent decades because of the high costs of traditional mechanisms for gazetteer data acquisition (Estes and Mooneyhan 1994).

Another important potential role for VGI, because of its currency and timeliness, is that of maintaining framework data. Framework data have traditionally been produced by mapping agencies or companies, with specially trained staff gathering and compiling necessary information for a defined map area during a fixed period of time. The team then moved on to a new map area, achieving complete coverage over time. By then, however, changes in the map areas covered first would necessitate remapping. The average *age* of a map, defined as the difference between the current date and the date of validity of the map's data, was thus half the average period between visits to a map area, plus whatever delays existed between a visit and the publication of the final map.

The impact of VGI on this process could be profound. Instead of intermittent coverage by professionals when time and funds allow, VGI could offer more timely observations by densely distributed amateurs acting as an early warning system for local changes. This approach is already widely used by both corporations and mapping agencies (e.g., the USGS's National Map Corps, http://nationalmap.gov/TheNationalMapCorps/) to dramatically reduce the average age of their geographic information. An interesting hybrid approach has emerged in the case of OSM, in which teams of volunteers travel[6] to an unmapped target area for a *mapping camp*, perhaps over a weekend (Helft 2009).

VGI Beyond the Framework

Other VGI initiatives are producing crowd-sourced data sets that are not framework data but, rather, document the location and characteristics of other phenomena with locations that have been determined through use of the framework. These nonframework VGI intiatives assemble data about some phenomenon for which the spatial distribution or patterns are significant and compile the observations of many contributors. For example, Tulloch (2008) has documented the State of New Jersey's effort to gather information about the presence and location of vernal pools (seasonally present wetlands) from field surveys completed by citizen volunteers. Such VGI efforts extend longer standing citizen-science efforts such as the Audubon Society's Christmas Bird Count, in which volunteers spend a portion of the Christmas period counting the number and species of birds in selected locations. A growing number of VGI efforts to develop nonframework data use interactive mapping interfaces on the Web, such that users of the site can contribute information to the map and data set or gather information from it. Platforms such as GoogleMaps and the Google API make it possible for anyone with a Web connection to create and disseminate their own maps, often in collaboration with many other people.

Four recent wildfires in the Santa Barbara, California, area provide an interesting example of this type of activity and serve to emphasize the value of VGI as a mechanism for creating and sharing geographic information in time-critical situations, a point made earlier in the context of framework data (Goodchild and Glennon 2010). The Tea Fire (November 2008) and the Jesusita Fire (May 2009) generated large amounts of Internet traffic, as citizens posted text descriptions, photographs, and other kinds of information within minutes of the fire's outbreak. Individuals and groups of citizens used the framework to compile this information on a minute-by-minute basis into situation maps, showing the location of the fire front, areas under evacuation orders, and other relevant information. By the end of the Jesusita fire, some twenty-seven maps had been posted and maintained by volunteer effort, one of which received more than 600,000 hits during the two days of the fire crisis. These maps served for many citizens as

the timeliest source of information, supplanting official sources that could not keep up as well with the rapidly evolving situation. We return to this example later in the discussion of VGI quality.

Our initial investigation suggests that there are differences worldwide in the mechanisms through which information can be contributed to these collectively produced information resources. Whereas Internet and smartphone systems are predominant in the global North (i.e., the industrialized world), a growing number of initiatives in the global South rely on text messaging from cell phones. A nonprofit group called Ushahidi has developed Short Message Service (SMS) tools that activists, nongovernmental organizations, and humanitarian groups are using to enable contributors to submit information about local events and conditions. The information is compiled and disseminated via an online map interface. Initially launched in 2008 to gather, aggregate, and disseminate information about ethnic violence following a national election in Kenya, the use of Ushahidi's tools has expanded to include election monitoring, "stock out" monitoring of essential pharmaceuticals shortages, and a host of other citizen oversight activities. It also played a significant role in the Haiti earthquake response.

Much VGI is constituted by georeferencing UGC online, typically through the practice of geotagging photographs, text, or other online media using the framework and its associated services. Geotagging provides locational information for some digital artifacts through the use of a convenient framework data set and associated service: by searching for the location in the imagery of a service such as Google Maps or by providing a street address or looking up a place name or point of interest in a digital gazetteer. The photo-sharing service Flickr, for example, encourages users to contribute geotagged photographs that can then be retrieved through a map interface, along with text descriptions and links to other sources. To date the collection includes several hundred million photographs, and automated procedures have been developed for integrating them into mosaics (e.g., Microsoft's Photosynth) and for extracting models of buildings and other features (Hays and Efros 2008). Google's Goggles is an interesting effort to automate the georeferencing of photographs by comparing them to an extensive library.

Geotagged UGC is being put to use in a wide range of contexts. For example, VoicesOfSanDiego, an independent nonprofit newspaper, uses these tools to enable people to submit geotagged photographs of water being wasted. The microblog service Twitter enables users to tag their small postings (or *tweets*) with locational information, a function that has already fostered interesting new possibilities for understanding the spatial patterns of very immediate or quickly changing situations, such as threat from wildfires or postelection protests in Iran in 2009 (Sui 2009b). Other organizations are compiling and geovisualizing tweets to provide online maps for their users, as in the case of the Muslim Network for Baha'i Rights, which provides a map of tweets about human rights violations against Baha'is around the world.

Finally, although geotagging typically occurs through users applying tags to their own content, a growing number of *geosocial networking* applications are closely related. Applications such as FourSquare and Loopt rely on GPS-enabled mobile devices, typically smartphones, and users opt in to share their activities and interests with others, with geographic information attached. These location-based services compile and rank information gathered from their users and then provide them with information about locations popular in their social group or new locations that might be of interest, often through a map interface. These geosocial applications are VGI in the sense that users must opt in to share information on their activities, but they differ somewhat from other georeferenced multimedia in that the assigning of locational information is automated, performed by the user's digital device and defined by the device's actual geographic location. We distinguish in this regard between *egocentric* services that volunteer the user's actual location and *allocentric* services such as Wikimapia that allow users to volunteer information about any location. Additionally, although compiled VGI is often available to anyone without charge, various forms of licensing and terms of use might restrict the ways such information can be used, as demonstrated in the recent Haiti earthquake relief effort (Heinzelman and Waters 2010).

VGI and Spatial Data Infrastructure

These examples illustrate the range of geographic information that constitutes VGI: framework data describing the location of features on the surface of the Earth, traditionally produced by government agencies and corporations and now complemented, augmented, or even replaced by VGI; and nonframework data such as citizens' observations of conditions, events, or activities and their locations, often by georeferencing multimedia online content that is noncartographic in nature. These two types of VGI constitute a potentially

productive complement or alternative to traditionally authoritative forms of geographic information and extend earlier modes of information production in novel ways.

VGI has the potential to address several constraints and omissions that plague SDIs. Conventional framework data are now largely created and updated through remote sensing, but remotely sensed data are often constrained by the orbits of satellite platforms or the presence of clouds or smoke that obscure features and cannot provide an adequate source for administrative boundaries or for the addresses, place names, and points of interest that are so important to many services. Framework data created and maintained by mapping agencies or corporations might not be made available to the public, could be prohibitively costly, or might carry use restrictions. Conventional nonframework data are often developed through direct observation (such as the *windshield surveys* that local government staff might make to determine land use or property conditions), but temporal and budgetary constraints often render these data sets incomplete or inaccurate, especially in situations of rapid change.

With respect to realizing these and other possibilities, VGI presents significant new challenges for GIScience research, where existing theory and practice are geared almost exclusively toward conventionally authoritative forms of spatial data. VGI represents a *wikification* of GIS (Sui 2008) and a broader societal transformation in how geographic information is created and used. Compared to other disciplines that have begun to study key scientific and societal questions raised by the profound transitions associated with Web 2.0 and social media in general, geographers have remained relatively silent until very recently. Yet as we argue in the following section, there is much about this phenomenon that necessitates research by geographers, and there is a pressing need to revisit a number of core concepts and methodologies on which geographers, especially scholars in GIScience, have relied.

VGI and Geographic Research

Geographic information (as we have defined it here) is a substantial part of the infrastructure of sciences ranging from geophysics to anthropology and is also essential in public administration and the everyday lives of citizens. Thus, these new ways of creating, compiling, and sharing massive amounts of descriptive information have the potential to impact science and society in novel and important ways. If this potential is to be realized, however, a great deal more must be learned about the characteristics of these data and appropriate methodologies for working with them. VGI requires rethinking many of the important concepts that geographers have previously used to understand geographic information, its uses, and its impacts. As well, given the extent to which VGI constitutes a unique case in the context of Web 2.0, UGC, and social computing, the work of geographers on VGI has much to offer related research agendas within information science, computer science, and social studies of science and technology. The neogeography argument framed at the outset of this article has legitimacy in pointing to new developments in the acquisition of geographic information, but in this section we argue that the expertise, tools, and theoretical frameworks of professional geographers are essential to addressing many of the more profound questions associated with VGI, including its potential as a data source for research, issues of data quality, and VGI's role in research methodologies.

VGI as Input to Research

Citizen science (Irwin 1995) has a long-standing and honorable tradition in several disciplines. Meteorological observations, for example, have in the past been organized hierarchically, with a sparse network of expertly staffed observation stations augmented by a much denser network of lower grade stations maintained by amateurs. The Christmas Bird Count mobilizes a dense network of amateur observers who work within protocols established by the Audubon Society and its academic advisors. Project Globe (http://www.globe.gov) is a worldwide network of schools through which students learn to make observations of their environment that are then uploaded, synthesized, and redistributed. Given sufficient attention to the selection and training of participants, volunteers can make useful contributions to the acquisition of raw scientific data. On the other hand, many VGI projects operate without these kinds of controls, and the information produced lacks the rigorous sampling design and assurances of quality that the scientific community demands.

Consider, for example, the case of Pop vs. Soda (http://www.popvssoda.com), a site created by Alan McConchie, at the time of this writing a graduate student in geography at the University of British Columbia. An exercise in the geography of language, it aims "to plot the regional variations in the use of the terms Pop and Soda to describe carbonated soft

drinks." Respondents are asked to select the term they commonly use and also to provide their ZIP code, and results are displayed in map form. Some striking patterns emerge, but the data in no way satisfy the normal requirements of random sampling, virtually nothing is known about the demographic characteristics of respondents, and there is no basis for arguing that the results represent the U.S. population as a whole or any of its well-defined subsets. This approach is rewarding in many ways yet does not satisfy conventional expectations about data collection for research.

Large-scale survey instruments or highly structured sampling and observation protocols are not always needed, however. Various stages in the research process require different forms of information, as do different modes of enquiry. Preliminary observations are often used to formulate hypotheses and conceptual frameworks, select suitable study sites, and stratify populations, and VGI could be appropriate for all of these purposes. Sites such as Flickr, with their massive collections of georeferenced photographs, provide a powerful basis for reviewing potential study sites in these early stages. Inductive ethnographic approaches favor intensive conversations with a few subjects, in the interests of exposing concepts that might otherwise be hidden. For some such projects, VGI could constitute an appropriate source of evidence. Toronto's [murmur] (murmurtoronto.ca), for example, is one of many oral history projects that invite volunteers to record unstructured accounts about points in the city, which can then be replayed by residents and visitors through cell phones.

VGI is also proving valuable in addressing research questions that involve human perception, concepts of place, and other constructs traditionally difficult to address through other techniques and sources of evidence. For example, geotagged photos posted on Flickr have been used as the primary data source to reconstruct tourists' movements at various sites (Girardin et al. 2008; Girardin et al. 2009). Crandall et al. (2009) have analyzed the Flickr database in an effort to discover and rank the importance of places, Zook and Graham (2007) have analyzed VGI to locate communities through shared use of key words, and Jones et al. (2008) have shown how Web content can be used to provide operational definitions of poorly defined geographic places such as "the Cotswolds" that are absent from traditional gazetteers. Cultural and historical geographers used information posted on eBay to fill in the gap left by conventional sources in historical geography research (DeLyser, Curtis, and Sheehan 2004). Political geographers have relied on VGI to map out local and national election patterns (Shin 2009). Medical and health researchers have also used VGI to address many challenging issues in disease surveillance as well as health care accessibility (Boulos et al. 2008; Cheung et al. 2008; Brownstein, Freifeld, and Madoff 2009).

The Quality of VGI

Geographic information is subject to measurement error, loss of detail, vagueness of definitions, and many other sources of uncertainty and inaccuracy (Zhang and Goodchild 2002). It is impossible to create a perfect representation of any aspect of the geographic world—all geospatial data are of limited quality. Users must always conduct a systematic investigation of whether a given data set is sufficiently accurate for a given use. Traditional authoritative sources address these issues by following rigorously defined procedures, providing precise specifications of the content of geographic databases, conducting periodic assessments of quality, and publishing data quality standards. VGI initiatives typically use none of these practices, and data quality is perhaps the primary issue that occurs to geographers on first encountering VGI. Our work on this topic to date has yielded several initial insights.

First, the geographic aspects of VGI give it properties with respect to data quality that are not often encountered in other types of UGC, the most prominent of these being context (Goodchild 2009c). With today's abundance of digital geographic information, it is easy to place a volunteered fact about some location into the context of existing information about that (*thematic* or *vertical* context) and nearby (*spatial* or *horizontal* context) locations. For example, when a photograph is volunteered to Flickr, both its content and its descriptive text could be checked for feasibility and reasonableness against other information. This practice is already common in those programs that engage volunteers in correcting and updating the geographic databases of agencies and corporations. In short, the richness of geographic context (and basic principles of the construction of the geographic landscape) makes it comparatively difficult to falsify VGI, either accidentally or deliberately.

Second, modes of quality control in VGI are entirely different from those used in the traditional production of geographic information, in large part because these data are produced through crowdsourcing. Instead of review by experts against established standards, crowdsourcing substitutes review by varying numbers of peers. Indeed, Grira, Bedard, and Roche (2010) and

DeLongueville et al. (2010) proposed models for involving VGI producers in the spatial data quality management process. Thus, whereas one might define the authority of an agency by the qualifications of its experts, the quality of VGI is more appropriately measured by the number of peers who have reviewed or edited its content, a principle sometimes known as *Linus's law*.[7] Facts about well-populated places and readily observed phenomena are likely, therefore, to be more accurate than facts about remote places and obscure phenomena, a pattern that is already evident in research on the accuracy of Wikipedia (Giles 2005).

Third, VGI does not typically include traditional measures of accuracy or inaccuracy. The data quality standards of agencies and corporations merely establish upper bounds on the inevitable inaccuracies of all geographic information, documenting them in metadata. With VGI there are no such thresholds and generally no metadata. In spite of the absence of such practices, some forms of VGI have proved to be comparable. Research on OSM's street network in the United Kingdom has shown that its accuracies are comparable to those of authoritative sources (Haklay 2010). Other findings are more mixed, as in the Antoniou, Morley, and Haklay (2010) study of the reliability of spatial content associated with user-contributed photographs on Flickr. Further, authoritative data include the legacy of decades of data production, and older data are generally less accurate because technology was not as advanced and applications were not as exacting. Thus, because of possible improvements in spatial accuracy, and its greater temporal currency, VGI might be in many cases more accurate than comparable data produced through traditional processes.

Although VGI typically lacks metadata, the notion of UGC central to Web 2.0 suggests a different approach to describing and documenting the characteristics of geographic information. In the early 1990s the FGDC defined and promulgated the first significant effort at standardizing geospatial metadata in the Content Standard for Digital Geospatial Metadata (http://www.fgdc.gov/metadata), an important part of the U.S. National Spatial Data Infrastructure. This subsequently became the basis for international standards, and has been widely adopted. It remains, however, a producer-centered approach in which the agencies responsible for traditional geographic information production take on the responsibility to document the important properties of each product. Missing from this approach is the user perspective, based on the experience of users in attempting to make use of each data set in specific applications. Goodchild (2009b) has developed this argument at length and has described an alternative approach in which metadata would be assembled from commentaries supplied by users. Such practices are now common in other domains, including tourism, and many sites now routinely gather and publish online commentaries provided by customers of hotels or restaurants. Moreover, although it has proven notoriously difficult to motivate the producers and custodians of geospatial data sets to provide metadata, we suspect that many users would be willing to assist future users by describing their experiences, just as restaurant customers are evidently willing to provide online reviews.

Finally, there are a host of situations in which VGI is important and beneficial, even if information quality is difficult to assess. In the Santa Barbara fires discussed earlier, there were no guarantees that information provided by volunteers about the status of the fires was accurate or that quality did not degenerate when volunteers compiled that information into maps. But in an emergency, decision makers must make choices between acting immediately with questionable data and waiting for better data to arrive. Information from official sources was inevitably delayed by the need for verification and lagged minutes and sometimes hours behind the volunteered information. Many actions were taken, including evacuation, despite the risk of false positives in the VGI. Delays in official information in effect constituted temporary false negatives and carried much greater risks from failing to act.

The previous discussion suggests that there might be potential issues of legal liability associated with VGI. Onsrud (1999) and others have discussed the legal liabilities associated with traditional authoritative geographic information, and we see a clear need to extend such analyses to VGI. Ethical issues abound both in the collection and publication of VGI and in the use of VGI in research. The recent controversy over the Bowman Expedition (Herlihy et al. 2008) concerned the ethics of community mapping among indigenous peoples (Wainwright and Bryan 2009). There is also a clear need to define the limits to what geographic information an individual or group can volunteer about others.

Methodologies for Using VGI: Mashup for a New Synthesis?

The explosive growth of VGI via its bottom-up creation, coupled with the traditional top-down approach

for geographic data collection, has created what Miller (2010) has called a *massive data avalanche*, and others have called the *exaflood* (Swanson 2007). We concur that the productive use of these massive georeferenced spatial and temporal databases will rely on developing new analytical techniques in the context of spatial data mining and geographic knowledge discovery (Alvarez et al. 2008). Many exciting developments in data mining and knowledge discovery have been reported elsewhere (e.g., Miller and Han 2009), but robust methodologies for productive VGI applications should not be confined to analysis alone. Instead, the current tide seems to place new emphasis on synthesis. Services such as Microsoft's Photosynth, IBM's ManyEyes, HistoryFlow, and TouchGraph provide examples of services for synthesizing data in diverse media.

The science of complex systems has advanced dramatically in recent years, as research has shifted from an older model of the single investigator to today's multidisciplinary collaborations. Future scientific advances are likely to involve mining of multidimensional data sets and to require the kinds of data synthesis that can only be achieved if systems are to a large degree interoperable. Gober (2000) called for a new emphasis on synthesis in geography in her Presidential Address, and a recent paper in *Bioscience* called for a new effort to accelerate synthesis in and between ecology and the environmental sciences (Carpenter et al. 2009).

Many forms of synthesis in the context of VGI applications can be described as *mashups* (e.g., Yee 2008). Borrowed from the music industry, the term originally refers to a song or composition created by blending two or more songs. Yet in the context of Web-based applications, a mashup might have multiple meanings (Sui 2009a). At the functional or service level, a mashup might be a Web page or application that combines data or functionality from two or more external sources to create a new service. In terms of actual content, a mashup can be a digital media file containing a combination of text, maps, audio, video, and animation, which recombines and modifies existing digital works to create a derivative work. The term implies easy, fast integration, frequently using open APIs and data sources to produce something new. A growing number of industry leaders such as Google, Microsoft, Yahoo!, and MapQuest have developed APIs that users are adapting to develop their own creative applications. But mashup is much more than a technical advance (Batty et al. 2010), and we believe that the true significance of mashup lies in its potential promotion of a new habit of mind toward synthesis. Many cognitive psychologists suggest that synthesis, rather than analysis, is the defining characteristic of human creativity (Wallace and Gruber 1989; Gardner 2009), and geography is uniquely positioned to lead this new wave of synthesis with respect to geographic information.

When mashup is used to integrate multiple sources of data based on shared references to the same geographic locations, the operation is conceptually related to the traditional GIS function of *overlay*, a type of *spatial join* (see, e.g., Longley et al. 2011), although the technical processes are quite different. Pioneers such as Manning, Dusseldorf, Lewis, and McHarg used manual overlay methods to integrate multiple layers of information to develop a comprehensive understanding of spatial patterns and relationships (Parker, Jordan, and Steinitz 1976). Better integration and synthesis of diverse sources of georeferenced information was a top priority during the early days of GIS development in the 1960s and 1970s, but spatial analysis has been at the forefront in GIS during the past twenty years, with a primary focus on improving spatial analytic functions (see, e.g., de Smith, Goodchild, and Longley 2007). The spatial analysis tradition often took a reductionist approach, focusing on individual layers to identify spatial patterns, rather than on the synthesis of multiple layers. We contend that the growth of mashup practices in the age of Web 2.0 is revitalizing an interest in synthesis in GIS. Mashup, as both a concept and a practice, resonates well with the traditional spirit of geography in its quest to understand the multidimensional nature of the Earth's surface. Although mashup is often couched in different terms (e.g., data conflation, data fusion, or data integration), geographers in general, and GIScientists in particular, have developed a considerable number of useful techniques for synthesizing data from multiple sources (Hall and McMullen 2004; Mitchell 2007; Liggins, Hall, and Llinas 2009; L. Li 2010).

Admittedly, synthesis is much more challenging than analysis from a methodological perspective, due to its involvement with data in multiple formats and media (number, text, oral story, photo, video, simulation, etc.). Geographers' current efforts to develop a more eclectic approach by linking diverse quantitative and qualitative methods can be tapped for VGI applications. Unlike the spatial analysis of a previous era that was often conducted by a lone analyst, synthesis of VGI tends to be much more participatory, through a mixing and remixing of multiple data and methods, as demonstrated in VGI applications in several recent disaster-relief efforts (Liu and Palen 2010; Zook et al. 2010). Instead

of seeking truth, the new mashup efforts focus more on developing narratives about various locales. At an even deeper level, the synthesis tide prompted by VGI mashup efforts also resonates well with geographers' call for a more hybrid geography (Whatmore 2002; Kwan 2004) to bridge divides between the physical and human, spatial-analytical and social-critical traditions.[8]

Although reductionism has dominated scientific practice since the scientific revolution in the sixteenth century, scientists in various fields have never abandoned their search for a more holistic understanding of how the universe works. From the unified theory of fields in physics to the Gaia hypothesis in ecology, from evolutionary economics to Gestalt psychology and holistic health in medicine, humanity has never ceased its quest for a more comprehensive understanding of the world and ourselves. Although much of the success of our scientific enterprises to date has come from a reductionist analysis of a system's parts, understanding and seeing the whole can be fundamentally more gratifying.

Perhaps there are no better words to capture the spirit of mashup and its significance for applications of VGI than *consilience*, a term originally coined by British philosopher William Whewell in the mid-nineteenth century but popularized by E. O. Wilson (1998) in his best-seller *Consilience: The Unity of Human Knowledge*. Consilience literally means "jumping together of human knowledge" and is used widely to refer to the unity of human knowledge in the conceptual realm. Today, however, the ever-expanding numbers of people creating VGI are in some ways putting the abstract concept of consilience into meaningful practice, potentially creating an information resource that is much more than the sum of its parts.[9]

VGI as Social Practice

Strongly informed by concepts from critical GIS (Schuurman 2000; Sheppard 2006) and critical cartography (Crampton and Krygier 2005; Harris and Harrower 2006), geographers and others are also conceiving of VGI as social practice, with attention to ways in which the processes, relationships, and products of VGI initiatives structure and represent knowledge and shape social and political relations. Earlier, we examined a range of issues associated with conceiving of VGI as a type of *information*—a kind of spatial data or as a form of evidence. Here we consider questions associated with VGI conceived as a social practice—as a particular bounded expression of a much broader realm of geographic knowledge. This conceptualization foregrounds several important issues for scholars, including who is included or excluded from the practices of making or using VGI and why, the extent to which VGI can fully represent their knowledge, the social and political significance of knowledge expressed as VGI, and even the limits of what it is possible to know through VGI.

Engaging VGI as a social practice, some early research has centered on the digital divide, examining disparities in the people and places that VGI represents or from which it originates and the mechanisms that foster these inequalities. Crutcher and Zook's (2009) study of user-generated information in Google Maps illustrates patterns of inclusion and exclusion in VGI that mirror prior manifestations of the digital divide: an overrepresentation of advantaged people from advantaged places, and a persistent underrepresentation of information from and about disadvantaged people and places. Yet another study of Google placemarks found that locations attracting international tourists are well represented, even when they are located in extremely underresourced places for which few other data are available (Zook and Graham 2009). These findings suggest the need to reconceptualize the mechanisms and impacts of the digital divide in the context of VGI. In the preceding examples, we see the emergence of new ways for privileged individuals to contribute information, alongside evidence suggesting that underlying structural inequalities remain unaltered and reinscribe some aspects of the digital divide. Although some early discussions emphasize VGI as an expression of richly experiential local knowledge, these examples suggest that the digital divide might mean that VGI for some places will be predominantly based on more fleeting observations or experiences. Any rethinking of the digital divide must also encompass disparities in the modes of representation available to different social groups and in different places. The phenomenon of VGI encompasses a vast realm of georeferenced artifacts: numerical codes or data schemes, sentences or phrases, digital images, digital animation or videos, and more.[10] Yet these representational forms are differently available around the world, and to different social groups. In the global South the most commonly used mobile devices are SMS-based cell phones, whereas in the global North, multimedia smartphones are also in use (Mobile Marvels 2009), introducing clear differences in the forms of VGI that can be created.[11]

Another key dimension of VGI as a socially embedded form of knowledge is the role this knowledge is understood to play in social and political life. As discussed

earlier, VGI is part of a transformation in the roles associated with creating digital spatial data. Legitimate information producers might be novices, laypersons, or volunteers, not only experts (Goodchild 2007; Budhathoki, Nedovic-Budic, and Bruce 2010; Coleman, Sabone, and Nkhwanana 2010). Such roles associated with knowledge making structure who can contribute information, as well as the motivations or conditions of information production. Recognizing novices or laypersons as legitimate sources of information opens the door to a greater diversity of contributors and ways of asserting the authority of information (Elwood 2009). The role of a volunteer hints at altruistic motivations and deliberate choice to contribute, although there are many examples where geographic information is harvested from contributors without their knowledge or where individuals are compelled to disclose information if they wish to obtain services (Obermeyer 2007; Sieber 2007; these are not VGI according to our earlier definition). We also note the importance of avoiding assumptions that a large VGI data set is necessarily broadly inclusive of many contributors or was created by a large number of individuals. The bottom-up potential of VGI projects is not necessarily always matched by reality, reflecting prior work on the long-tail phenomenon in economics (Brynjolfsson, Hu, and Smith 2010).

Closely related to these shifts in the subjectivities associated with creating spatial data are the primary purposes of spatial data creation and use. Here, too, VGI is introducing some new dimensions. Many VGI initiatives emphasize fun and recreation or capturing free labor and unused time. Kingsbury and Jones (2009) and Dodge and Kitchin (2007) provided several examples of large groups of people marking and sharing information gathered from virtual globe imagery that identifies or documents a host of funny, obscene, and frightening activities or sites, as a form of entertainment. A 2008 online service called The Extraordinaries recruits individuals to perform *microvolunteering* for nonprofit organizations, often by collecting geotagged photographs or other observations during otherwise wasted moments of everyday life, such as riding the bus. Motivational texts emphasize that this labor will be fun and not demanding of their time. These examples do not illustrate all activities in which VGI is embedded, but they show some of the new social roles and practices that are emerging. These practices diverge not just from conventional state-based data creation efforts but also from many community-based mapping and participatory GIS initiatives that have tended to emphasize self-representation, empowerment, and collective action (Sieber 2006; Dunn 2007).

Another key aspect of theorizing VGI as social practice entails accounting for its impacts on practices related to sharing or concealing information, such as privacy, surveillance, or identification. Recent research on the Geospatial Web is informative for efforts to theorize how VGI might transform privacy or surveillance. Recent work on virtual globes has argued that the Internet-mediated circulation of georeferenced imagery, together with large-scale collective recreational and activist efforts to monitor this imagery, transforms the nature of secrecy and surveillance (Perkins and Dodge 2009). Elwood and Leszczynski (2011) focused on the nature of representation, arguing that geotagged photographs and pseudo-realistic panoramas of public spaces introduce much more immediate, embodied, less abstract modes of identification than in prior digital representations of spatial information, with implications for social contracts around privacy. Indirectly, this work on the Geospatial Web forwards two propositions as to the mechanisms through which VGI alters privacy, surveillance, and other practices of revealing and identifying: the ways in which people, places, and their characteristics are represented and the social relations through which information is compiled and examined (with crowdsourcing suggesting a shift from a panoptic one-watching-all relation toward a many-watching-many relation).

Finally, accounting for VGI as a socially embedded knowledge project also requires examining the structures and discourses used to position VGI as authoritative. GIS-based information has long been positioned as authoritative on the basis of already-validated structures or practices associated with science, such as quantification, objectivity, abstraction, generalization, cartographic representation, and the use of digital technologies and other specialized instruments (Elwood 2006; Crampton 2011). VGI is being positioned as authoritative not on the basis of its objectivity but on the basis of its situated locality, positioning UGC as authoritative on the basis that it originates from direct local knowledge and observations (Iskold 2007). As we noted earlier, the reliability of VGI is also sometimes assumed to stem from its magnitude, assuming that more contributions will generate convergence on reliable information or consensus as to the most authoritative account (Flanagin and Metzger 2008).[12]

The structures used to position VGI as authoritative or reliable validate particular ways of knowing, with implications for what we can know and whose knowledge

is recognized. For example, legitimizing VGI based on its locality or the nearness of observer to observed (Bishr and Mantelas 2008) further elevates already-powerful cultural conventions that position the acts of looking and seeing as valid ways to perceive what is true about the world. Recognizing information as legitimate based on the magnitude of similar submissions or the size of a data set might ignore the sometimes equally reliable information of the minority. An emphasis on consensus as a way of validating contributed information conceives of difference or heterogeneity in information primarily as a kind of error or inaccuracy, eliding rich insights that might be gleaned from a more purposeful engagement with difference and its social production. These examples suggest some ways that epistemologies foregrounded and validated around VGI serve to create and silence in particular ways.

Conceptualizing VGI as social practice calls our attention to its role in reconfiguring the digital divide, the cultural and political projects carried out through this form of knowledge, and fundamental transformations in the representational practices and epistemological politics that have been associated with geographic information and representation to date. Studying VGI as social practice around these issues suggests several trajectories of work. We clearly need critical historical ontologies (Hacking 2004) or spatial histories (Elden 2002) examining how VGI might rewrite what it means to make a valid knowledge claim in a variety of social contexts. Of equal importance would be a project of critique examining the assumptions that underlie VGI as system of knowledge and their implications for identities, subjectivities, and power relations or critical geographies attentive to the political economic relationships in which VGI is situated and to its possibilities and limits in emancipatory projects (Crampton and Krygier 2005; Sheppard 2006). Although very different from efforts to engage VGI as a data type or form of evidence for research, such efforts are a crucial element in going full circle in our disciplinary engagement with this new phenomenon.

Summary and Concluding Remarks

Gould (1999) anticipated the arrival of a spatial century and further argued that "there is a geographer in most people" (314). The phenomenon of VGI that emerged during the first decade of the twenty-first century is one of the many manifestations of a spatial century. VGI represents an unprecedented shift in the content, characteristics, and modes of geographic information creation, sharing, dissemination, and use. Our goal in this article has been to provide a framing of this phenomenon, with attention to the ways in which geographers are engaging, and might continue to engage with VGI, as well as some of its broader implications. Despite concerns over the quality and trustworthiness of VGI, preliminary assessment seems to indicate that VGI could serve as a potential data source to address research questions across geography. Diverse VGI contributed by citizens via a bottom-up process complements, and in some cases integrates well with, the spatial data infrastructure constructed by authoritative sources via a top-down process. Scrutinizing the social and political dimension of VGI could further advance our understanding of the political economy of the Web. 2.0 era.

If we consider the VGI phenomenon in conjunction with the spatial turn across the sciences, social sciences, and humanities, it seems to us that in the beginning decade of the spatial century, geographers no longer have exclusive claims on the production of either geographic information or geographic knowledge. This is both exciting and worrisome for geography as a discipline. It is exciting because unlike many other disciplines, we have a much broader base of interest and awareness among the general public as well as within the academy, and VGI opens the possibilities of a dense network of individual, intelligent observers. The current trend is also worrisome, however, because our disciplinary identity is becoming increasingly blurred and because of the implied assumption that geography is about describing the world rather than understanding and explaining it. It is easy to find examples of the problems that result from an inadequate popular understanding of geography and its principles, from the international incidents caused by a naive assumption that the world's boundaries are neutral and universal (see, for example, the recent controversy over boundary claims in the Himalayas by India and China, and the problems these cause for Google Maps) to the conceptual difficulties caused by flattening the Earth (NRC 2006).

We have drawn attention at many points in this article to the need for research on VGI and for action by the community of academic geographers. Topics as diverse as data quality, the legal and ethical issues of VGI, and the technical demands of bridging the digital divide cry out for the kinds of research that only academic geographers can undertake. The research methods needed to address them span many paradigms, from the technical dimensions of GIScience to the critical dimensions of contemporary human geography, and thus have the power to engage a broad cross-section of the discipline.

We hope this article serves as a call for action, both to take advantage of this exciting opportunity and to develop a new disciplinary identity that places geography in the forefront of this spatial turn across the disciplines.

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Notes

1. In recent years, the private sector has also helped to upset the traditional apple cart by taking an increasingly significant role in the production, use, and archiving of geographic information, exemplified by the commercial production of road-network data by TeleAtlas and Navteq, of the locations of businesses by Dun and Bradstreet, and by the online services of Google, Microsoft, MapQuest, and Yahoo!
2. Indeed, early work on VGI supports this claim, positing a blurring of the boundaries between user and producer, the emergence of a hybrid "produser" or "prosumer" (Budhathoki, Bruce, and Nedovic-Budic 2008).
3. This is not to say that the remaining sites do not offer mapping interfaces—many do. This category represents sites such as Google Earth that primarily facilitate geovisualization of UGC.
4. This is not to suggest that the process of redistricting cannot be done by citizens but rather that responsibility for spatial data files representing such units is likely to remain with government entities.
5. The U.S. Board on Geographic Names was established in 1890 for the express purpose of standardizing the use of place names.
6. In the mapping effort following the Haiti earthquake, much of the OSM coverage was generated remotely from fine-resolution imagery. Feature names cannot normally be obtained from imagery, so mappers relied on the memories of expatriate Haitians, among other sources.
7. Linus Torvald, a software engineer and leader of the Linux kernel project, propounded the principle as a basis for assuring the quality of software.
8. It is also clear that mashups present multiple challenges to existing legal and policy structures related to spatial data and maps, as examined by S. Li and Yan (2010).
9. We are using the word consilience in its original sense, which is conceptually consistent with the practice of Web 2.0; we are not necessarily endorsing Wilson's biological reductionism.
10. As has been debated extensively around GIS (Crampton 2009; Leszczynski 2009), as a digital form of representation, VGI is, of course, always a limited expression of human knowledge and experience.
11. Different forms of VGI raise very different issues with respect to using these data. The use of VGI to assist in rescue and relief efforts following Haiti's 2010 earthquake hints at some of the pragmatic issues that might arise around VGI in different representational forms. The primary form of VGI emerging from within Haiti via Ushahidi's crisis mapping platform (http://haiti.ushahidi.com/) was text messages. These messages were in three different languages and tended to use linguistic descriptors of location, requiring significant additional processing before they could be integrated with other data. On another level, disparities in access to different modes of representation matter because they carry differing social and political meaning and forms of authority. We return to these questions later in this section.
12. Ushahidi's SwiftRiver system, for example, validates VGI through a crowd-sourced filtering process that combines automated techniques and review of the data by any user who wishes to participate (Fildes 2010).

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