CHAPTER 3

Do Disasters Always Enhance Inequality?

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Summary for Stakeholders

I believe there are things we have learned in comparing disasters and human responses of ancient societies in Mexico through Central America, as well as some more recent disasters, that could be applied to modern societies. Those societies were successful in adapting to hazardous environments by learning from disasters. Ancient Mesoamericans used performances and reiterations to maintain knowledge of past disasters. By maintaining oral history over centuries or millennia, people remained aware of and could prepare for future disasters. Today we could enhance training beyond first responders, making sure that at least a few people in each neighborhood know how to take rapid action to mitigate the intensity of extreme event impacts and help neighbors cope. A model is the social networks of Hispanic households during the terrible heat wave in Chicago in 1995. They survived much better than white and black households of equivalent resources because they provided mutual assistance. They avoided a passive reliance on federal, state, or city authorities to come to their aid, by taking direct action as the extreme event ensued.

Training individuals in neighborhoods can provide prompt activities and enhance communication with first responders and agencies such as FEMA in the United States and National Recovery Guidance in the United Kingdom, even when landlines and cell phones fail. Localized decision-making can be much more efficient than waiting for a complex bureaucracy to respond.

The example of ancient communities in Costa Rica facing quite different hazards and sharing a cemetery illustrates the advantages of preparing a refuge area when disaster strikes. The village on the eastern side of the continental divide suffered from explosive eruptions of Arenal Vol-

cano, while the western village suffered from occasional droughts. Intermarriage must have occurred, because village populations were so small, cementing relationships for future emergencies. Houston, Texas, was accommodating to refugees from New Orleans after Hurricane Katrina devastated it, but Gulf Coast cities were not as helpful when Hurricane Harvey flooded Houston. If Gulf Coast cities anticipated and organized for future such events, mutual aid could mitigate some suffering and facilitate recovery when the next hurricane strikes. Such agreements among hazard-prone cities could at least slightly decrease the enhanced inequality that so commonly results from disasters in the United States today. Effective programs and legislation to actually mitigate the increased inequality following disasters would require bipartisan efforts by courageous politicians at the national and state levels. Another way in which ancient Costa Ricans mitigated the stresses of explosive volcanic eruptions is in having access to abundant food and water in their refuge areas. We could encourage households or neighborhoods to store food and water to help them get through the initial days of waiting for the bureaucracy to become effective. Tax breaks or direct governmental assistance could provide both support and incentives for storage.

Introduction

This chapter begins with examinations of recent and presently ongoing disasters, involving hurricanes and flooding, as of this writing, December of 2018, to explore how people or institutions with a wide range of resources, from meager to considerable, cope with sudden stress. In such extreme-event situations, the individual agents are discernible in ways that are unavailable in the archaeological record. Lacking in these current disasters are the long-term implications. Archaeology provides that expansive time framework, and ancient cases and interpretations occupy the remainder of this chapter.

In disaster cases where detailed documentation is available, two phases can be identified (Driessen 2018). The first is the emergency, where people and institutions are attempting to save lives and facilities. The second is rehabilitation, which may be differentially successful in more complex societies. Both phases can be examined in recent disasters, but both are more challenging to reconstruct in detail with archaeological cases. Disasters often act as intensifiers of economic, social, and political aspects of societies, particularly in more complex societies where pre-disaster inequalities existed. They also can act as catalysts for innovations in political, economic, or social domains (Gibbs 2003). As will be presented toward the

end of this chapter, smaller societies can rehabilitate without an increase in inequality.

The concepts of resilience and vulnerability are important to apply to the recent and ancient cases. Resilience refers to the abilities of communities to weather the stresses of extreme events, to maintain a high degree of cultural continuity, and in many cases to make creative adjustments with an eye to mitigate future disasters. Vulnerabilities are the socially constructed elements of communities including inequalities, factionalism, bureaucracies, traditions, and other internal factors.

An obvious clear difference in how societies explain why the disaster occurred is between ancient and modern cases. During the past few centuries, more people tend to explain geophysical extreme events in scientific terms. This is not true for many traditional areas today, for instance in Java (Dove 2008). In ancient disasters, people ascribe the forcing mechanism to supernatural beings and often, by extension, to the elites who supposedly had preferential access to those beings.

Ongoing and Recent Disasters

This section examines some recent and ongoing disasters in the United States and other countries where inequality increased. That is followed by ancient cases where inequality similarly increased. The final section presents two cases where extreme events did not increase inequality. The differences are examined to make policy suggestions for stakeholders today.

Recent and presently ongoing disasters often provide opportunities for people of means to take advantage of people adversely affected, resulting in increased economic inequality (Scanlon 1988). Not only is this a recent phenomenon, but analogous cases of increased inequality also occurred in antiquity. As more affluent people use their resources to enhance their wealth, the poor get poorer. Natural disasters almost always result in socioeconomic disasters for those with less resources. Often the poor live in more hazardous areas than the affluent, and in less substantial housing, therefore increasing their risk. Here I explore some ongoing, recent, and ancient natural disasters that did facilitate increased inequality. I also provide cases in which inequality did not result. The reasons inequality was not enhanced by the extreme events are of great importance. Might they provide suggestions for contemporary societies, if decisions or policies prior to the stresses were implemented to decrease the intensity of inequality enhancement?

Hawaii's Kilauea volcano is presently erupting large amounts of lava, destroying hundreds of homes. A total of seven hundred homes have

been destroyed as of July 2018, according to National Public Radio. It previously erupted effusively in 1983, destroying sixteen homes, and then in 1990 another effusive eruption destroyed over one hundred homes. The cost to private insurers was so much that they stopped insuring property in Lava Flow Hazard zones 1 and 2. Why would so many people choose to live on the slopes of an active volcano, with two documented recent records of destruction? The Hawaii State Legislature created a "perverse incentive" for people to live in such a hazardous location (Akina 2018). As Akina states, "Hawaii's lawmakers put citizens in danger by giving them an incentive to live in an area that the market had deemed too risky to insure." People bought homes at unusually low prices for Hawaii, hoping to avoid destruction, but now have lost their homes. This is an obvious case of a legally and socially produced vulnerability, particularly for lower-income households. Developers profited greatly.

Hurricane Harvey devastated Houston in 2017 by dumping almost fifty inches of rain, thus flooding many areas (Romero 2018). That extreme event allowed affluent speculators to buy many of the thousands of flooded houses at low cost and then resell them at higher cost, making considerable profits, sometimes in the same day (Romero 2018). Speculators often paid about half of the pre-flood value of damaged or destroyed homes, leaving former residents so impoverished that they were unable to afford another suitable residence. The history of the Canyon Gate subdivision illustrates how state and private interests combined to create this social catastrophe, this socially produced vulnerability. The Canyon Gate subdivision is in the low-lying reservoir designed to receive floodwaters during extreme weather events so that central Houston is less flood-prone. There is a history to the creation of this reservoir. Downtown Houston flooded badly in 1935, and in response, during the 1940s authorities built flood-control reservoirs to protect the downtown. These reservoirs were not intended to contain housing—they were reservoirs intended to operate in extreme weather events. But in the 1990s massive housing projects were built right in the area that fifty years earlier had been engineered to flood. And flood it did in 2017. In August 2018, exactly one year after Harvey flooded Houston, Mimi Swartz (2018) noted how pitifully little federal or state funding had been offered to assist the most devastated families. She feared the lack of planning was creating great risks for the next hurricane.

A survey of Houstonians a year after Harvey revealed the unsurprising evidence that low-income and minority residents were having more difficulty recovering than more-affluent white residents (Fernandez 2018). The survey by the Kaiser Family Foundation and the Episcopal Health Foundation showed that 27 percent of Hispanic Texans with badly damaged

homes reported that those homes remained unsafe to live in, compared to 20 percent of blacks and only 11 percent of whites. There were similar disparities by income: 50 percent of lower-income respondents said they were not getting the help they needed, compared to 32 percent of those with higher incomes. Clearly a part of the problem is that $5 billion in federal Community Development Block Grant (CDBG) disaster-recovery funds were approved for Texas, but Houston had yet to receive them as of mid-2018. Kurt Pickering, a spokesperson for FEMA in Texas, said the agency had seen no evidence that low-income areas were receiving less support from the agency. He said that federal assistance is not intended to make a family whole after a disaster, but to help start the recovery process. "FEMA does everything possible to assist every family in every way," within the bounds of its regulations, he said.

Insurance companies like to emphasize the great amounts of money they hand out after a disaster, and Harvey is an example. Allstate's catastrophic losses for 2017 totaled $3.23 billion (Sun and Scism 2018), a seemingly overwhelming amount for them to pay out. In spite of that, Allstate posted a profit of $3.07 billion that year. Altogether, the US property-casualty industry had $752.5 billion in surplus in December 2017, an increase of over 7 percent from the previous year, in spite of the increase in disaster damages from the previous year of 2016. Insurance companies can label disaster agents as "acts of God" and thus provide themselves with an easy way out. The households with more resources can afford more insurance and thus can recover more readily than the poor.

Hurricane Florence struck the Carolinas in September 2018, creating record flooding. The conditions shortly after the extreme event seem to be a setup for limited payments on claims filed after the disaster is over. According to the *Wall Street Journal* (14 September 2018), about $14 billion in catastrophe bonds ("cat bonds") could be exposed to the hurricane damage (Friedman 2018). According to Friedman, wealthy families and investors have invested billions in the cat bonds to diversify their investments in order to receive higher returns. The bonds benefit insurance companies by decreasing their exposure to claims. Homeowners' insurance policies usually cover hurricane wind damage but not flooding. If homeowners have sufficient funds and judge the cost worthwhile, they can purchase separate flood insurance from FEMA's National Flood Insurance Program (NFIP). FEMA's cat bond would pay out up to $500 million per disaster, but only if total losses exceed $5 billion. The insurance domain has an "oversupply of capital . . . resulting in minimal risk that insurers will run out of money to pay claims" (Friedman 2018). Flood damages could be well over 95 percent of the total losses from this disaster. The homeowners with the least resources, and without separate flood insurance, will suffer dearly.

Walsh (2018) reported that only 335,000 homes in the Carolinas have flood insurance (2018). The US census lists the Carolinas with 6,967,279 housing units, so one can calculate that only 4 percent have flood insurance. Walsh claims most of those with flood insurance are along the coast, where they expect flooding more than do people living inland, and most of them are relatively affluent homeowners. Most of the flooding from Florence was inland, where few people anticipated it. The system certainly is not weighted in favor of most households, and inequality is exacerbated.

Just a few weeks after Hurricane Harvey in Houston, hurricanes Irma and Maria devastated islands in the Caribbean. Maria completely wiped out the entire electrical system of Puerto Rico, devastated homes and businesses, and set up the opportunities for those with wealth or power to take advantage of the dispossessed. The Puerto Rican economy was in poor condition prior to the hurricane. A federal board established by the US Congress in 2016 oversees the commonwealth's economy. It was created after a recession that pushed the island into a "debt restructuring" akin to bankruptcy (Campo-Flores and Scurria 2018). Goodell (2018) notes the island has $70 billion in debt and 44 percent of people living in poverty, compared to 12 percent in the United States. Puerto Rico had a Gini coefficient—a summary measure economic inequality—that was among the ten worst in the world before the hurricanes (Brown et al. 2018). Many residents had their houses destroyed or damaged, and many lost their jobs. Brown describes drug-manufacturing companies rebuilding their facilities, taking advantage of dispossessed people earning the minimum wage. Had the island not been in such poor financial condition, of course, recovery could have begun from a better base condition.

Robles (2018) reported on FEMA-supported repairs to homes in Puerto Rico, about a year after Hurricane Maria devastated the island. The program is called Tu Hogar Renace (Your Home Reborn). FEMA is spending $1.2 billion to repair up to 120,000 homes, the largest sum that FEMA has ever spent for any disaster. None of the money was for destroyed houses, only for those that needed specific repairs. Unfortunately, over 60 percent of the money is going to multiple layers of middlemen and contractors instead of paying for roofs, windows, and doors. The housing department hired seven contractors to do the repairs. Those companies hired subcontractors, who then hired various companies to actually do the repairs. Contractors charged FEMA $3,700 each for 12,400 generators. The contractors purchased each generator for $800. The markup was 4.6 times the purchase price. The "Renace" certainly applies to the bank accounts of the middlemen and the contractors more than the homeowners (Robles 2018).

Comparing inequality among households, before and after the extreme event, is the focus of much research. In contrast, Durana (2017) considers

intra-household enhanced inequality in her article "Gender Inequality in Puerto Rico Is about to Get Worse." She argues that the gender inequality that was deeply set in the island before the hurricane would intensify because of the stress. The devastation eliminated many jobs held by women, so many had to fall back into worse-paying jobs in the informal economy. Most of the construction jobs in the recovery effort go to men.

Yet another underreported aspect of natural disasters is the aftermath for nature itself. Most of the disaster literature focuses on infrastructure devastation and human impacts, followed by recoveries to varying degrees of success. Hurricane Maria devastated the tropical rainforest on the island, and ecological recovery is in doubt (Amandolare 2018). Because tropical forests contain more than two-thirds of the earth's terrestrial plant biomass, studies of conditions in El Yunque National Forest are of great importance. Global warming may stress many forests prior to hurricanes, generate more intense hurricanes, and inhibit recoveries of the biomass and biodiversity. Prior to the hurricane, multiple ecosystem services were provided by the rainforest, and that certainly happened in ancient times, as detailed below in prehistoric Costa Rica.

Two category 5 hurricanes struck the Cancun area of Mexico, Gilbert in 1988 and Wilma in 2005. Wilma was a category 5, the most powerful hurricane recorded to 2014. Prior to them, tourists went from their scattered hotels into the town to restaurants, markets, and stores, benefiting local Maya/Mexican residents. Both hurricanes created massive devastation, and both received considerable federal assistance to recover and construct new tourist facilities. There was very little assistance to individual families or small businesses in the city, and recoveries were uneven and slow. Following the hurricanes, government officials and developer-investors made radical changes by building all-inclusive destination hotels, thus cutting off local residents from contact with tourists staying there (Cordoba, Baptista, and Dominguez Rubio 2014). Tourists pay in advance, covering room, board, drinks, entertainment, and often other things and thus have little incentive to leave the walled premises of their inclusive venue. Following Hurricane Wilma, large time-share condominiums with gated access and de facto privatization of the beaches were constructed along the waterfront, further isolating tourists from local residents. The authors call this "enclosures within enclosures" to indicate domains and boundaries, supposedly deployed to improve security, economic growth, and the public good. The "enclosure" of the resort is within the "enclosure" of the Hotel Zone, which after the disasters became more isolated from the city. Economic benefits did occur, but far away from Cancun. Most big establishments were owned by large corporations in the United States or Europe, such as the Marriott Vacation Club Timeshare Resort

Cancun. It has three massive towers of thirteen or more stories each and land closures with guards that block beach access to those not staying within. Privatization of formerly public beaches occurred widely, even though it was prohibited by law. Elites with resources benefited by cutting tourists off from locals, to the detriment of the latter. Small local businesses suffered by being cut off from tourists.

Today the poor often live in more hazardous locations than the wealthy, and the latter often take advantage of the poor to enhance their own wealth. Might similar situations have occurred in the ancient past? Or are the recent cases considered above phenomena unique to capitalism? The information for most of the above cases was obtained from newspapers and magazine accounts of these current events, rather than from the academic literature. These recent and ongoing cases can serve as heuristic entryways into the in-depth consideration of archaeological cases. That is followed by a return to present hazard preparedness conditions toward the end of the chapter.

Sixth-Century Archaeological Cases: Effects and Inequality Compared, Pre- and Post-disasters

The examples that follow describe societies stressed to varying degrees by the most severe climatic downturn of the past twenty-five hundred years (Sigl et al. 2015). The cause was two closely spaced immense Plinian explosive volcanic eruptions, in 535 and 539 CE. The first was from at a high latitude in the northern hemisphere, from a yet-unknown source. The second was even greater, slightly north of the equator, evidently from the Ilopango Volcano in El Salvador (Oppenheimer 2011), an eruption I first discovered in 1969 in Chalchupa, El Salvador (Sheets 1976). The two eruptions caused great dislocations in atmospheric circulation, the water cycle (evaporation from water and falling precipitation), and cooling of the earth by fine volcanic ash reflecting sunlight and especially by sulfur aerosols. The strongest effects lasted a decade or two and gradually diminished. Some societies with dense populations living in marginal areas and relying on frost-sensitive crops suffered greatly and collapsed—for example, Teotihuacan, and the Wei dynasty in China (Houston 2000). Others survived but were fundamentally altered, such as Scandinavia (see chapter 4 in this volume, and Graslund and Price 2012). Societies in tropical areas were weakened to different degrees, allowing the slightly stronger to take advantage of the weaker and to prosper (e.g., various Maya city-states). Here, I explore the effects of these extreme environmental downturns on ancient societies in different parts of the world. I show how they

coped with the stresses with quite different degrees of success or failure and emphasize the implications for inequalities in social, economic, and political domains.

The proximal, distal, and worldwide effects of the greatest of explosive eruptions bear consideration here (Oppenheimer 2011). Most explosive eruptions have the most intensive impacts closest to the volcano and diminish with distance, usually within a few kilometers to dozens of kilometers, taking into account wind direction. Their negative impacts are proximal. Near the volcano, lava flows, pyroclastic flows, lahars (debris flows), and deep deposits of airfall volcanic ash can be highly destructive to flora, fauna, people, and their livelihoods. Winds bias the density of volcanic ash, as they push the eruptive column downwind. The ejecta of most explosive eruptions do not push vertically above the tropopause (the boundary between the lower atmosphere and the stratosphere), often at about ten kilometers in height.

In contrast, the colossal explosive eruptions, such as the two under consideration here, blast great amounts of fine volcanic ash and sulfur aerosols above the tropopause and into the stratosphere (Oppenheimer 2011). Once in the stratosphere, the tephra and sulfur circulate around the world. Latitude is a crucial variable. If the volcano is located at high latitude, exemplified here with the 535 CE eruption (Sigl et al. 2015), then the distal distribution stays in that hemisphere. If the eruption is tropical in latitude, the worldwide distribution is in both hemispheres, as happened in the 539 CE eruption. The relative amounts of sulfur in ice cores in Antarctica versus Greenland from a tropical mega-eruption can indicate whether the source is north or south of the equator. The sulfur spike from the 539 CE eruption is slightly stronger in Greenland than in Antarctica, indicating a source somewhat north of the equator (Sigl et al. 2015). What is important here is that proximity to the source is not the relevant factor for how intense the stress was for a society anywhere in the world. Rather, a society thousands of miles away in a semi-arid environment relying on crops that are frost sensitive prior to the eruption would have been highly vulnerable. In contrast, a society in a wet tropical environment only hundreds of miles away can suffer a similar decline in temperature and moisture, but not to the point of devastating food production.

The former, in a climatically vulnerable environment, applies to Teotihuacan's semi-arid environment, above seven thousand feet in elevation, just below the usual frost line. The former also applies to the collapse of the Wei dynasty in northern China in the mid-sixth century (Houston 2000). The Wei dynasty was similar to Teotihuacan in having a dense population in a semi-arid environment vulnerable to cold summers. The latter, the buffered environment, applies to the lowland Maya of the Yucatan

Peninsula. Although the Maya lowlands are much closer to Ilopango Volcano, they did not suffer from the direct proximal effects of deep tephra deposits, and they were only moderately stressed by the climatic downturn. Their lowland tropical moist climate buffered the worldwide stresses of cold and diminished precipitation, while Teotihuacan's precariousness led to its demise. Although the stresses were essentially the same among Maya city-states in the central Maya lowlands, they did not all react in the same way, with markedly different consequences. None of the three Maya cities collapsed like Teotihuacan or the Wei, but they did not handle the stresses equally, for discernible reasons. After dealing with Teotihuacan, I look at three city-states, Tikal, Caracol, and Calakmul. All three were in warm, wet tropical lowland environments, and therefore a lowering of temperature and precipitation would not have been as drastic as the effects that devastated Teotihuacan. However, the differences in adaptations among the three led to very different outcomes, as documented by Dahlin and Chase (2014). After describing these outcomes, I then explore changes in inequalities among the Maya.

Teotihuacan was the biggest and most highly organized ancient city in the early first millennium in Mesoamerica, and even the New World, from about 100 BCE to 550 CE (Cowgill 2015, 1). Its population was somewhere between 100,000 and 200,000, with an additional 300,000 people under its control or influence in the general area. It was organized in a grid system of roads oriented on a major avenue lined with dozens of pyramids with temples on top. The wealthier homes near the major avenue were luxurious and richly frescoed. The residences of the majority of the common people consisted of thousands of substantial, well-built apartment complexes. Insubstantial structures housed less than 15 percent of the people (Cowgill 2015, 246). The nature of rulership in Teotihuacan has been a puzzle for archaeologists for decades, because it apparently was so different from most Mesoamerican civilizations. In contrast to the Maya, there are no sculptures or depictions of individual rulers. Of course, there must have been rulers, but they did not commemorate themselves in any durable medium. The influence of Teotihuacan stretched from western through southern Mexico and Yucatan into Guatemala, Belize, Honduras, and even into El Salvador (Cowgill 2001).

Teotihuacan had strikingly low wealth disparities prior to the sixth-century climatic crisis, but following its collapse, later societies displayed dramatic inequality. Smith (2018) argues that Teotihuacan had no underclass, in his slightly exaggerated article titled "In This Ancient City, Even Commoners Lived in Palaces." The article argues that the inequalities within the city were minimal. The vast majority of people lived in substantially constructed apartments with white lime-plastered floors,

ornamented roofs, and spacious rooms with porches. Smith (2018) convincingly states that the city's residents lived far more economically equal lives than in any other Mesoamerican civilization. A normal Teotihuacan family dwelling was about 200 square meters (2,153 square feet), while during the later Aztec period (1450–1500 CE) a commoner house was only about 25 square meters (215 square feet). To quantify wealth inequality, Smith uses the Gini index, which ranges from 0, meaning complete equality, to 1, indicating all wealth is concentrated in only one household or segment of society. Teotihuacan's Gini index was 0.12, an extraordinarily low level of wealth inequality for any civilization past or present. It compares to the Aztecs at 0.3 to 0.4. Mexico today lies at 0.75 and the United States at 0.8 (see Kohler and Smith [2018] for a detailed explanation of the use of Gini coefficients to describe wealth disparities in the past).

The period following the collapse of Teotihuacan is called the Epiclassic, from about 550 to 850 CE (Cowgill 2015, 239). Although remnant populations still lived in the city, the powerful state had dissolved, and the remaining people created no new civic or ceremonial structures (Cowgill 2015, 240). There are insufficient data to assess the degree of inequality in this small remnant group.

Following the collapse of Teotihuacan, Tula was the next dominant city in the Basin of Mexico area. Tula began during the Epiclassic period, about when Teotihuacan was collapsing, and grew to its apex about four centuries later (Healan 2001, 776). Tula was a sizable city. It reached its peak population from 900 to 1200 CE, with a population perhaps as high as sixty thousand (Healan 2001, 776). Although a Gini index has not been calculated for Tula Grande, wealth disparities are quite evident. Healan (1989) notes the elegance of the central palace Palacio Quemado and the humble architecture of the commoners. The relationship between the demise of Teotihuacan and the rise of Tula is not clear, but the end result is. Following Tula, the wealth disparities of the Aztecs are many times greater than that of Teotihuacan, and they increased even more significantly in the colonial period, after the Spanish conquest. Inequality in Mexico today continues to increase, almost to that of the United States.

Prior to the sixth century Tikal was tremendously successful as the dominant city-state in the central lowlands of Guatemala's Peten (Harrison 2001). It thrived as a trading center and developed monumental architecture, sculpture, an innovative art style, hieroglyphics, and calendric notations. The mid-sixth-century climatic downturn presumably lowered both temperature and precipitation, but not so much that agricultural productivity failed, although it would have declined substantially. There is no evidence that Tikal responded to the stresses in an organized or systematic way (Dahlin and Chase 2014). They did not adjust their adaptation

by terracing hill slopes to increase moisture retention, initiating marketing systems, or increasing alliances. Tikal had large intra-site causeways linking pyramid complexes, but no causeways extending out of the site's center that could have been used for food transport and material exchanges. Tikal lost the nearby city-state of Naranjo as an ally just a few years into the environmental downturn (Dahlin and Chase 2014), a sign of the difficulties to come. A little more than two decades after the downturn began, in 562 CE Tikal was defeated by their rivals Caracol and Calakmul (Dahlin and Chase 2014, 137). Tikal lost political independence, as the conquerors occupied the city and turned it into a vassal state for over a century. When Tikal regained its independence, its royals commissioned great construction of pyramids, temples, causeways, and palaces of unprecedented size. Haviland's (1967) analysis of skeletal material showed that commoners' diets worsened dramatically in the centuries after the environmental downturn, which I interpret as a proxy for increased inequality.

Dahlin and Chase (2014) argue that in contrast to Tikal, Caracol and Calakmul responded in innovative ways to the stress. Caracol improved food production by constructing water storage and distribution facilities, increased terracing, and constructed an elaborate road network to facilitate communication and transport. Terracing hillsides decreases erosion and increases water infiltration. Caracol was a relatively small center until it gained independence from Tikal by the time of the Star War of 562 CE. By the mid-seventh century it had increased in population by some five times (Dahlin and Chase 2014, 140). Both Caracol and Calakmul had centrally directed solar marketing systems that facilitated redistribution of goods (Dahlin and Chase 2014). There is no evidence that Tikal had such a system. In addition to three intra-site causeways, Calakmul had long inter-site causeways reaching dozens of kilometers in various directions. They would have been useful in transporting agricultural production from surrounding areas into the central site and its marketplace. The network of roads would have provided access to perennial wetlands to the northeast and northwest that would have been less affected by drought than upland areas. Calakmul perhaps gained access to or control of the Rio Hondo, an important river and floodplain nearby. If they did, that would have opened rather easy access to the productivity of raised fields near the Caribbean (Dahlin and Chase 2014, 151). Calakmul also became more aggressive in conquering nearby settlements or pressuring them to provide tribute. Calakmul's road system was more regional, while that of Caracol was more internal. The differing responses to the same powerful stresses are revealing lessons of the importance of leadership, and the nature of social and infrastructural networks, when disaster strikes. A simple physical cause and cultural effect model is insufficient and inappropriate. The three cit-

ies shared the same basic culture and cultigens, but significant variations played major roles in their divergent paths under the stress. Tikal had a socially produced vulnerability to the extreme event, while the other two cities had or created buffering mechanisms.

Looking internally at Calakmul and Caracol, the disparities of wealth increased by the mid-sixth century, as populations grew and the royals needed larger elite bureaucracies for administration, construction, and religious purposes. Tikal followed that same increase in inequality, but it was delayed for a century, until it achieved independence.

The impact of the sixth-century climatic crisis on Scandinavia was considerable. Fortunately, much is known about local conditions prior to the mid-sixth century and for centuries afterward. Viewed from the south, the late Roman Empire feared the "barbarians" threatening them from northern Europe (Noble 2006) and sent considerable amounts of gold to placate them. The Scandinavian gold hoards have been explained in two different ways: as caches hidden temporarily and intended for future use, and as supernatural means of connecting with the gods (Hedeager 2008). I suspect some of them were emergency caches when people realized they could not continue in their households under the extreme stress but hoped to return if conditions ameliorated. The fifth and sixth centuries are within the Migration period, when massive ethnolinguistic populations were on the move in Eurasia, and especially Germanic peoples in northern Europe (Noble 2006). Scandinavia prior to the mid-sixth-century stress had only slight disparities in wealth among households, as all engaged in cultivation of seed crops and animal husbandry involving cattle, sheep, and pigs (Graslund and Price 2012). However, the crisis allowed the slightly more wealthy households to take over the poorer ones. Graslund and Price (2012) document the Scandinavian case in detail and in the long time range. The numbers of households increased slowly from 2000 BCE until the first century BCE and then more rapidly until the sixth century CE. Then, about 75 percent of the villages in Sweden were abandoned during the mid-sixth century, constituting "the greatest change in settlement patterns in Sweden for 6000 years" (Graslund and Price 2012, 432). They argue that the "new structures of power" and the great expansion of land owned by elites in the Scandinavian late Iron Age derived from people taking advantage of the sixth-century climatic crisis. The demographic decline was even greater in areas of southern Norway, where the dated burials after the stress ameliorated diminished by 90 to 95 percent. The authors ingeniously relate the devastating stresses to the Norse mythology of the "Fimbulwinter," which describes severe winter with no summer that lasted for years. The Fimbulwinter serves as the warning of the "Ragnarok," which is the destruction of the entire world

and all its inhabitants, even including the gods (Löwenborg 2012; Price and Graslund 2015).

Arenal, Costa Rica, and the Lack of Inequalities

Is there a case where disasters did not enhance socioeconomic inequality? The answer is yes, there is one in western Costa Rica with the multiple eruptions of Arenal Volcano and the residents affected, with their responses (Sheets and McKee 1994). Societies were egalitarian before and after the ten big eruptions that affected our research area, some twenty to thirty kilometers downwind to the east of the volcano. I will explore how and why these early hunter-gatherers and later villagers avoided disparities in wealth, power, and social prestige for sixty-five hundred years. The coping behaviors and long-term results are so dramatically different from the abovementioned ancient and modern cases that the interactions among the natural environment, volcanism, and the ancient cultures warrant detailed consideration here.

Polly Wiessner (2002) provides insights into how cultures can maintain egalitarian structures for hundreds of years. She studied 110 Enga tribes in Papua New Guinea and found that they varied considerably in how the maintained their egalitarian organizations over many generations. Wiessner explains how the sophisticated egalitarian structures benefit small-scale societies politically and economically. She notes the ethos of egalitarian societies rests in redistribution and measured generosity while discouraging differential accumulations of wealth. In addition, she documented the introduction of the sweet potato and how it greatly increased pig production, human demographic growth, overpopulation, and ultimately the institutionalization of inequality.

Wiessner's insights into how small-scale societies can maintain egalitarian organizations over long periods of time may apply well to thousands of years of human occupation of the Arenal area of Costa Rica. In the beginnings of my research to study human-volcanological interactions in the early 1980s, I quickly discovered that archaeology would be inhibited by working too close to Arenal Volcano, because the tephra layers were so thick we would have to excavate many meters down to encounter cultural remains. I also quickly learned that volcanology would be inhibited by working too far away, even though the archaeological discoveries would be abundant. At distances beyond thirty kilometers, the tephra layers are thin, mixed, or nonexistent, thus inadequate to study volcanic-human interactions. The "sweet zone" to integrate volcanology with archaeology turned out to be from fifteen to thirty kilometers west and downwind

from the volcano. Many of the biggest eruptions left identifiable tephra layers intermixed with cultural materials and paleosols in that zone, yet were accessible by excavations in the range of two to four meters deep. Had we decided to focus our research to the northwest or southwest of the volcano, the "sweet zones" would have been much closer to Arenal Volcano, probably less than ten kilometers, due to the consistency of the winds from the east (figure 3.1).

The research area drapes over the continental divide, to include Laguna Arenal and Arenal Volcano on the Caribbean drainage to the east and the Pacific drainage to the west (figure 3.1). Current meteorological conditions seem to be similar to ancient ones (Sheets and McKee 1994). Presently the area around the volcano receives a mean of over 6,000 millimeters of annual precipitation (giving new meaning to the term "mean" precipitation), while at Cañas on the other end of the area, in the Pacific drainage, only 1,300 millimeters of precipitation falls annually on average. At ten degrees north of the equator and with the variable topography, the hot and dry area around Cañas is marginal for agriculture without irrigation. Above that area in elevation, the range of mean precipitation is 1,400 to 2,000

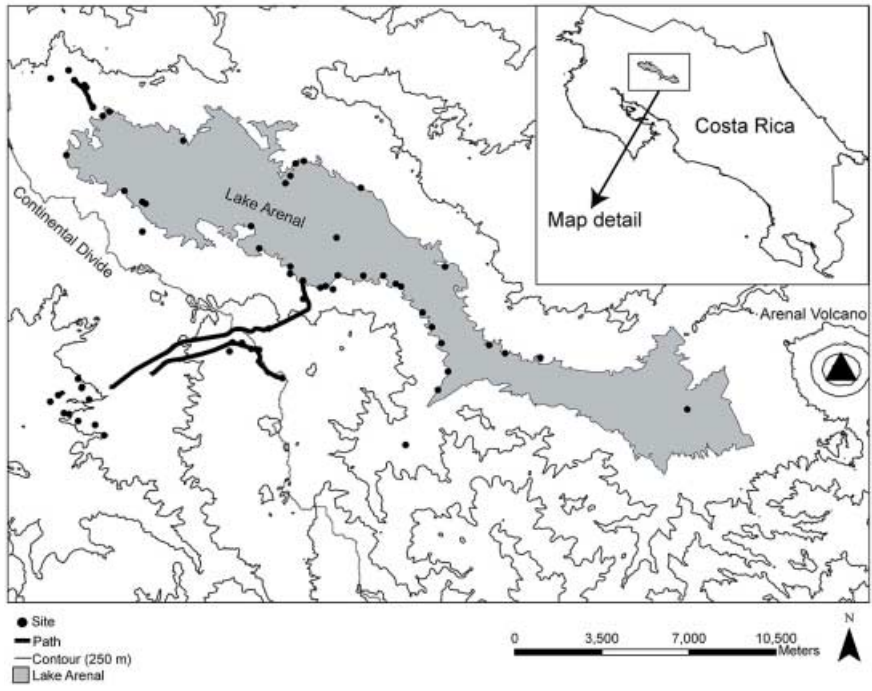

Figure 3.1. Map of the Arenal research area. Each dot is a confirmed and recorded archaeological site. The site in the middle of the lake is an island used for burials. Map by and provided courtesy of Rachel Egan.

millimeters and is suitable for seed crop agriculture without irrigation. However, on the Caribbean side of the divide, in the wetter areas, the precipitation exceeds evapotranspiration for many months. Therefore, the soils are saturated and hence anaerobic and not suited for most cultigens. Malanga (*Xanthosoma*) does grow well in saturated soils, but seed crops do not. An important caveat here is that even during the Silencio phase (see below), when one could expect seed crop agriculture to be at its peak, maize composed less than 12 percent of the diet (Sheets and McKee 1994, 321). This indicates that people in their settled villages continued to exploit the abundant wild foods of their tropical rainforest environment for the bulk of their diets.

Melson (1994) began studying the 1968 explosive eruption of Arenal Volcano shortly after it occurred, and he related it to the major explosive eruptions in the ancient past. The volcanic record of Arenal is summarized on the webpage of the Smithsonian Institution, National Museum of Natural History ("Global Volcanism Program" 2018). A total of twenty-eight explosive eruptions have been documented over a span of 7,000 years, for an average periodicity of 250 years. All have VEIs (volcanic explosivity index) of 4, of considerable magnitude, unless otherwise stated here. Arenal Volcano did not exist prior to 5000 BCE, making it one of the world's younger and more active volcanos. An unknown number of smaller eruptions must have occurred, but no tephra deposits have yet been identified and dated.

Following is an integration of the phases of human occupation in the Arenal-Tilaran research area with the explosive eruptions of Arenal Volcano and the soils that developed between eruptions. The Clovis style projectile point found along the Laguna Arenal shore is evidence of human occupation at about 11,000 BCE (Sheets and McKee 1994), about six millennia before Arenal Volcano erupted for the first time. Apparently, hunter-gatherers continued to occupy the area throughout the Paleo-Indian and Archaic periods. The two earliest Arenal eruptions, about 5060 and 4450 BCE ("Global Volcanism Program" 2018) would have severely impacted flora and fauna and required surviving people to evacuate, at least for a few decades. As the evacuees had been exploiting wild food resources, with few domesticated species, their relocation would not have been onerous. Population densities apparently were very low.

The earliest evidence we have for Archaic occupation is the Fortuna phase, 4000–3000 BCE, for which we found a campsite with two hearths, evidence of stone tool manufacture, volcanic stones used for boiling, and surface finds of lithics (Sheets and McKee 1994). During that millennium, Arenal erupted twice, 3900 and 3350 BCE, and the adjoining Cerro Chato erupted once, at 3190 BCE. Although we do not have direct stratigraphic

associations of tephra with the excavated site, we can be confident that all three eruptions necessitated abandonments because of devastated life support capacity of the environment, even though by this time a slight reliance on a domesticated species or two may have emerged.

Our archaeological record has an unfortunate gap from 3000 to 2000 BCE, during which the transition from the high mobility of the Archaic hunter-gatherers shifted to Formative villages with ceramics. Because ceramics are heavy and fragile, I believe the villages were largely to completely sedentary. Arenal contributed two eruptions, 2800 and 2250 BCE, with predictable consequences, but during this span, we have no detailed cultural data.

The Tronadora phase dates from 2000 to 500 BCE. The Tronadora Vieja site provided numerous circular houses, both prior to and after Arenal's Unit 61 eruption of 1450 BCE (Sheets and McKee 1994, 314). Recovery from the eruption apparently was rapid, perhaps a few decades, and there are no indications of inequality in housing or artifacts, either before or after the eruption. A very black, humic-rich soil developed out of and on top of that eruption in the centuries before the next eruption. Ceramics were sophisticated and decorated by incising and painting, with *tecomate* shapes predominating. No changes in architecture or artifacts were detected, indicating the possibility that the descendants of the pre-eruption villagers were the ones who moved back in. However, there is no definitive evidence for this. Burials were secondary, in small rectangular pits outside the houses.

The Arenal phase began at 500 BCE and ended at 600 CE (Sheets and McKee 1994). It marked the densest populations in the research area, with about ten people per square kilometer. However, compared to populations in chiefdoms in Panama–Costa Rica, and especially with the states in Mesoamerica, this population density is low indeed. Arenal Volcano erupted five times during the phase (380 BCE, 270 BCE, 170 BCE, 400 CE, and 550 CE). The tephra deposits from the earlier four eruptions were not thick enough in our area to be individually discernable. Bioturbation and soil formation were sufficient to mix them. Each of them probably did not necessitate an outmigration of inhabitants seeking refuge from this area, although the ashfalls would have been stressful for flora, fauna, and people. Excavations a few kilometers closer to the volcano would probably reveal the individual tephra layers and would be areas sufficiently devastated to require outmigration until ecological recovery occurred. One of the more prominent paleosols in the sequence (Unit 54) developed at the end of this phase, in the four centuries up to 650 CE, when it was buried by a tephra (see below). Individual villages are about the same size as those in the preceding phase, of about fifty to one hundred people. The number

of sites has doubled, but the sizes of them, and their egalitarian natures, have not changed.

Certainly, the most significant religious culture change in the entire occupation sequence occurred at about 500 BCE. That change does not correlate with any eruption. Instead of burying their dead adjacent to their homes, the villages initiated communal graveyards and situated them at a distance. The distances varied from about one to fourteen kilometers. People traveling to and from cemeteries walked a precise and straight-as-possible procession route, in spite of topography. They walked single file, as the actual path surface was only a half meter wide. On slopes where path erosion occurred, the decades and centuries of use entrenched the paths, often to a few meters deep. If an ethnographic analog might be relevant, the traditional Cuna of Panama bury their dead at a distance from their village and make pilgrimages when they need to get in contact with the spirit of the deceased (Sheets 2009). The Cuna believe the spirits are bothered by barking dogs and crying babies and therefore appreciate the quiet that comes from the distance. The spirits are powerful and therefore are best dealt with when people want or need to take the trip, instead of having them around their home all the time and having to deal with them when they would rather not.

Other culture changes are detectable from the previous phase but are modest, as *tecomate*-shaped vessels declined, while necked jars increased. Styles of decoration changed somewhat, from deeply incised borders of bichrome painting and some shell impressions, to finer incising with black-on-red painting, and some resist decoration. Housing did not change from the Tronadora phase, nor within the Arenal phase. Houses remained circular, and people continued to use boiling stones and some ceramic vessels in cooking. Ground-stone artifacts became more common and include three-legged metates and overhanging bar manos, and celts. What is important here is that no differentiation/inequality has been found in housing, artifacts, or burials within this period.

In the previous Tronadora phase, no clear evidence was discovered to ascertain if the re-settlers after an evacuation were descendants of the original occupants of a village or simply were opportunistic people in search of a suitable village location. Fortunately, excavations at the Arenal phase Cañales site encountered evidence that the re-settlers were descendants of the earlier residents (Sheets 2008). The egalitarian village on the south shore of Laguna Arenal was struck by a particularly deep deposit of volcanic ash during the Arenal phase, which would have necessitated abandonment. The stratigraphy presented in three illustrations (figures 2, 3, and 4 in Sheets 2008) indicate that the processional path to the communal graveyard was used for hundreds of years before and then

after the eruption. The path extends from the village at 540-meter elevation, up over mountainous terrain at 970 meters, and then down through dissected topography to the graveyard at 500 meters, for a distance of 11 kilometers. Reuse of the path also occurred after the smaller eruptions. All eruptions would obscure the path by a new blanket of volcanic ash, and this is especially true of the biggest of eruptions. For someone not already familiar with the path, it would be challenging to locate it. Moreover, and most importantly, if the re-settlers were mere opportunists without relationships to the former villagers, they would not conduct pilgrimages to a cemetery that had nothing to do with their ancestors. The re-settlers must have been kin to the earlier residents. And it is possible that reconnecting with the spirits of their ancestors was a primary motivation to re-occupation of their village (Sheets 2008). Project members examined all architectural and artifactual categories for evidence of inequality and found none, with only one exception. In the Sitio Bolivar cemetery, burial practices were identical throughout, with the exception of complete vessels being sacrificed atop and already broken vessels scattered over the graves slightly downslope (Hoopes and Chenault 1994). At most, this could indicate some intra-community differentiation. Yet, the overall assessment is that the society was fundamentally egalitarian.

The Silencio phase (600–1300 CE) witnessed a decline in population to about half of that of the previous period, that is, back to about the population of the Tronadora phase (Sheets and McKee 1994). The principal change in ceramics is the introduction of polychromes. Chipped and ground stone assemblages showed virtually no change. The tradition of villages establishing communal cemeteries at considerable distances con-

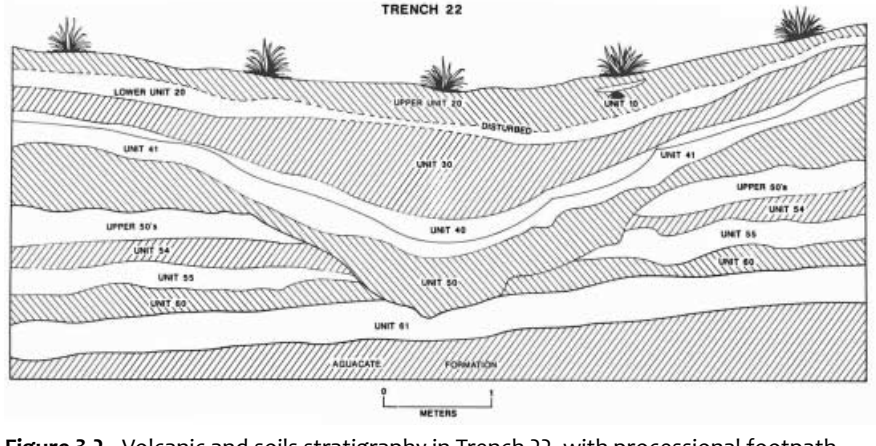

Figure 3.2. Volcanic and soils stratigraphy in Trench 22, with processional footpath eroded into the layers of volcanic ash and soils. Figure created by the author.

tinued. The style of inhumations changed considerably from the primary burial covered with river rocks in the Arenal phase to more deep burials and creating a stone cist or box for the primary burial. The stones used were the flat-fracturing *lajas* that occurred in a few places at significant distances from cemeteries. Those distances were traversed single file along set pathways that stretched many kilometers. The processional pathways from the Silencio cemetery extend to villages well to the west and southwest and well to the east. It is of great significance that villages shared the same cemetery, even though they lived separated by considerable distances. The principal hazard of an eastern village is an eruption from Arenal volcano, as that village would be only about fifteen kilometers away. The principal hazard of a village well down on the Pacific drainage would be drought. The relationships formed from communal use may have assisted people from one end under stress to take refuge in a village at the other end, an example of sophisticated risk perception and management. Cemetery associations provided a form of insurance or assurance in case of disaster. Because villages are so small, they could not be endogamous for many generations, and the extended ceremonies in the shared Silencio cemetery must have provided opportunities for liaisons to form.

Arenal Volcano erupted five times during the Silencio phase (650, 700, 750, and twice in quick succession ca. 1100 and 1250 CE). Three paleosols developed during that sequence, one early (Unit 53), and two prominent

Illustration 3.1. Tom Sever (*left*) and Payson Sheets pointing out two ancient footpaths descending a hill. They date to 600–1300 CE. Photo by the author.

ones later (Units 50 and 30). Cemetery and path use were well established prior to that double eruption, but they must have had sufficient impact that at least villagers living east of the cemetery had to flee and seek refuge to the west, likely in their partner village and perhaps to other areas. Those eruptions were so closely spaced that we do not detect even the beginnings of a soil forming atop the first one. Their combined thicknesses indicate that villages in the "sweet zone" would also have to be abandoned, perhaps for a few decades. Both cemetery use and path use were resumed after the eruption. The re-occupants in the eastern village resumed use of the exact same path to the cemetery, in spite of it having been deeply buried by the tephras and therefore difficult to detect. As with the above example with the Cañales village, I believe this is reliable evidence that the people returning to that eastern village were the same people who abandoned it or perhaps a generation later. If people reestablishing a village had no relation to former residents, but simply decided that would be a nice location in which to settle, they would not find and follow a processional path to a cemetery that did not contain their deceased and the spirits of their deceased. The determination to reoccupy a devastated area is reminiscent of community resilience after the Paricutin eruption in Mexico (Nolan 1979).

The Tilaran phase (1300–1500 CE) marks the final pre-Columbian occupation of the area. It witnessed a considerable decline in population, as the main settlement unit shifted from villages to hamlets widely dispersed across the countryside (Sheets and McKee 1994). The dominant cultural affiliations indicated by ceramics during the earlier phases was to the Pacific side, but those changed in this phase toward the central highlands and Caribbean drainage. The quality of ceramics in techniques and in decoration has deteriorated, and nothing is known from this area in interments. It appears the area was largely depopulated prior to the arrival of the Spanish. Arenal Volcano erupted in a big way about 1500 CE (Unit 20) and then with a relatively small eruption a few decades later. That thick tephra layer is very useful throughout the area, as it stratigraphically isolates pre-Columbian phenomena from colonial and later phenomena.

The multiple eruptions of Arenal over thousands of years brings up the question of oral history. Are the time gaps between eruptions too long for people to have maintained knowledge about the hazards? Russell Blong (1982) documented the oral histories of peoples in Papua New Guinea passing down strikingly detailed accounts of a volcanic eruption three hundred years earlier. That would be over some fifteen generations. The groups called it a "time of darkness," because the tephra blocked sunlight for days. People even remembered the depths of tephra quite accurately. Patrick Nunn's book (2018), *The Edge of Memory*, documents the rise in sea

levels in twenty-one places around Australia some seven thousand years ago. Landmarks and sacred places were inundated, yet the knowledge about them was maintained by song, dance, and public performance for hundreds of generations. Krajick (2005) summarized many cases of societies maintaining knowledge of precursors, extreme events, and suitable anticipatory behavior around the world, for hundreds and thousands of years. Most often, the explanations of the extreme events were supernatural. For example, a battle between the sky deity (thunderbird) and the sea deity (whale) causes a tsunami on the coast near Seattle, and people should avoid shore locations where devastations had occurred in the past. In light of these publications, the abilities of ancient Arenal peoples to maintain accurate geo-ecological knowledge during their occupation of the impacted area should not be in doubt. That presumed sophistication was maintained within an egalitarian social order, with minimal inequality, for thousands of years. That success ended abruptly in the Arenal area, as with so many other areas of the world, when European colonists arrived (Riede 2017).

The native population densities in the Arenal area declined considerably in the centuries prior to the Spanish Conquest, to the point that very few settlements dating to the final Tilaran phase could be found in the area (Sheets and McKee 1994). Not only are the numbers of settlements drastically reduced, they no longer are villages, but just dispersed households. Diseases introduced by the Spanish further reduced native populations to about zero, and the area remained depopulated during the seventeenth to nineteenth centuries. Costa Ricans, of European descent, colonized the area during the late nineteenth and early twentieth centuries, largely for ranching. Geologists in the twentieth century knew that Arenal was a volcano, but the local Costa Ricans did not, and they were greatly surprised by the explosive eruption of 1968 (Melson 1994; "Global Volcanism Program" 2018). Because the precursors were not understood, nearby settlers remained in their homes and were killed by lava bombs and pyroclastic flows. More distant Costa Ricans drove jeeps into the area to try to help people, but they also did not understand the dangers, and many were killed by pyroclastic flows. They were asphyxiated and burned, and their gas tanks exploded. The loss of native traditional environmental knowledge resulted in almost a hundred deaths.

Can a Society Become Less Unequal (More Equal) after an Extreme Event?

I believe the Ancient Puebloans in the US Southwest provide an answer of yes. Ancient Puebloans in the Four Corners area began living sedentary

lives in agriculturally based tiny to large villages in the Basketmaker III period (Lekson 2008, 65). Puebloan settlements evinced no evidence of hierarchical organizations, political or economic, in this period, from about 400 to about 750 CE. They were egalitarian in organization (my interpretations of data in Kantner 2008 and Lekson 2008). The environment then, and now, is semi-arid and relatively high in elevation (4,000–7,000 feet). Droughts are common in the area, and extended droughts have, and had, deleterious effects on rain-fed agriculture.

The subsequent period, Pueblo I, 700–900 CE, was a particularly dynamic one in the Southwest (Kantner 2008). Moderate to quite large villages, with up to 150 structures, formed and were occupied for short periods of one to two generations (Lekson 2008). Some of the larger villages evidently evince nascent hierarchy in the form of a larger residential structure of a leader, the beginnings of ranking in society.

It is during the Pueblo II period (900–1150 CE) that the Puebloan Southwest reached its apex in size of settlements and in political, economic, and social inequality. The massive multistory structures in Chaco Canyon and the dozens of Great House outliers burst upon the scene. Lekson (2008, 205) considers it a city with elites living in palaces. The Great Houses probably were subsidiary elite palaces and were widely scattered across a vast landscape. The prehistoric Southwest had never seen such inequality in Puebloan society—political, economic, or social—and it was never seen to that degree later.

During the Pueblo III period (1150–1300 CE) the largest sites were significantly smaller than the huge ones in the previous period (Lekson 2008), but they were impressive and clearly non-egalitarian. Levels of violence escalated as villages attacked other villages, cannibalism was practiced, and elites lost their power to maintain the social order (Lekson 2008, 160). As Lekson notes, some migrations from the Four Corners region southward to the Rio Grande area of northern New Mexico occurred throughout the period.

The Pueblo IV period that begins in 1300 CE followed four centuries of hierarchical settlements exemplified by Chaco and its regional system and then Aztec in New Mexico. Lekson (2008, 190–200) argues that Pueblo IV peoples deliberately organized against such hierarchy. He states (Lekson 2008, 197), "During Pueblo IV, people made hard decisions to re-form their societies after a history of unhappiness, war, hierarchies, and environmental catastrophes. They created societies that avoided hierarchy." The remaining people living in the Four Corners area abandoned it, as people made a smart move into New Mexico, along the Rio Grande, which provided reliable water. The great drought during the last two decades of the thirteenth century (Kantner 2004, 200) was too much of an additional

stressor, a natural disaster, for the Ancestral Puebloans relying on rainfall. Cordell (1984, 384) notes that the drought from 1276 to 1299 "corresponds strikingly well with the abandonment of the Mesa Verde region." Kantner (2008, 200) describes the drought as "a precipitous drop in rainfall the likes of which had no precedent in the region's human history." Puebloans made deliberate decisions to decrease inequality, to avoid past experience with hierarchical society, and that decision has stuck. Abundant oral history of the terrible times, and the need to avoid hierarchy, still exists among Puebloans today (Kantner 2008; Lekson 2008).

Conclusions

In a discouraging number of examples above, when extreme events cause stresses on societies, those people who survive them with more resources take advantage of those with less. This applies to capitalist and non-capitalist societies, in recent and ancient times. Today, it would take a politician with extraordinary courage to initiate legislation prior to extreme events to ensure that resources would be equitably distributed. For a bill to pass in the US House and the Senate, a majority would be necessary in both chambers, and that is not foreseeable even in the far distant future.

The late eighteenth-century adage that "all men are created equal" is inspirational if it were true. However, considerable disparities in wealth and power existed at that time and have continued to the present day. At that time "men" referred to whites, did not include women, and obviously excluded all men and women brought from Africa as slaves, as well as all native populations already in the New World. Thus, the social inequality that exists prior to disasters is enhanced by the extreme events, in striking contrast to the egalitarian villagers of ancient Costa Rica. Therefore, in our deeply stratified contemporary societies, socially, politically, economically, and in terms of classes, new forms of disaster planning, political organization, and neighborhood functioning could be salutary to the coming disasters. If accompanied by less emphasis on technological fixes and efforts to rebuild in place, then future disasters can be less impactful.

In our decades of research in the Tilaran-Arenal area, we have sought evidence of socioeconomic-political inequalities. We found none in the early phases of occupation by hunter-gatherers in Paleo-Indian and Archaic times. Even when sedentary village life existed, for some four millennia, inequalities were miniscule to undetectable, and the egalitarian structure of society continued.

So what are the factors that contributed to Arenal people's resilience to many volcanic disasters, without enhanced inequality? An obvious one

is the egalitarian organization for more than ten thousand years, from Paleo-Indian times all the way to the Spanish Conquest. Probably inherent in the egalitarian organization were wealth and power leveling mechanisms that were not present in the abovementioned examples. They would have had to be overcome for inequalities to increase following eruptions and their effects and adjustments. The differentials were not inherent in natives prior to any of the disasters, during their need to take refuge, or among the recolonizations. An element of such hunting-and-gathering bands or the later villages that dotted the countryside for some four thousand years is that decision-making was local. The perception of the disaster and the decision to take refuge was at the household level or the band or village, in contrast to complex societies. With the Maya, for instance, major decisions were made by the royals and their elites, and that can take time for the orders to be disseminated and acted upon. Because the royals were the principal liaisons with the deities, a huge natural disaster could be interpreted as a failure of religious belief and the supernatural efficacy of the royals. The loss of the "Mandate of Heaven" by the emperor of the Wei dynasty in mid-sixth-century China is a good example (Houston 2000).

Another key factor in the resilience of Arenal people was their experiencing frequent explosive eruptions. The average periodicity of Arenal's biggest eruptions is 250 years, and that does not include an unknown number of smaller eruptions. The time gaps between eruptions are small enough for oral traditions—that is, traditional ecological knowledge—to be passed on for generations and must have been sufficient to inform people as to coping mechanisms to be put into effect right away. Herein is an element that could be applied to present-day complex societies. Today many people are trained to wait for government-sponsored expert help, which during Hurricane Katrina did not materialize. Fortunately, there are some exceptions, where local agencies encourage people to be their own first responders, and this should be greatly expanded. Local training of people who are potentially in harm's way for hurricanes, floods, heat waves, volcanic eruptions, earthquakes, tornadoes, or other extreme events can go a long way in reducing injuries or deaths. This is training beyond that of first responders. It is training of at least some people on a per-neighborhood basis. This neighborhood training is analogous to oral histories of nonliterate groups, where people familiarize themselves with a hazard, an extreme event, and successful reactions to it.

An example that sticks in my mind, which also includes the topic of communication, occurred during the Katrina hurricane disaster in New Orleans. Hundreds of people took refuge on highway overpasses because all areas around them were flooded. When President Bush and FEMA officials flew over them in helicopters, the refugees looked upward but could

not communicate because cell phones were out of electricity and the network was down. They desperately needed food and water but were unable to send that message. A miniscule of training could have resolved it: one person could organize a few people to spell out the message "DROP WATER" or "DROP FOOD" by means of their bodies lying down. Had TV footage of that been broadcast worldwide, US officials would have had to respond, promptly. Rather, officials did nothing beyond looking out of the window.

The only skeletal material recovered from our work on the Arenal Project was from the Silencio phase, as that was the only time people were buried in protective stone tombs. The mild acidity of the tropical soils removed all human remains from the other phases. Isotopic analyses indicated maize was only 12 percent of the diet at most, which suggests seed crop agriculture played a minor part of the diet. Most root crops would not have produced well because of soil saturation for so many months. It appears that during the millennia of sedentary villages, people relied heavily on the biodiversity of wild food resources of the tropical rainforest. That must have been advantageous when a village took refuge at a distance, as they could rely heavily on wild foods until they could reoccupy their abandoned villages. Here the obvious lesson for the present is for people to stockpile food and water to be self-sufficient for days or weeks.

Another factor is the low population densities during all phases of occupation, so the numbers of refugees would not drastically swamp the life-support capability of areas surrounding the disaster. Yet another aspect assisting in hazard preparedness is having a social network. An example is provided by the evident alliance between at least two Costa Rican villages facing quite different risks and sharing the Silencio cemetery. The alliances presumably functioned to facilitate refuge from extreme events by distant villagers. Might there be a suggestion for hurricane-prone areas of the US Gulf Coast? Cities such as Gulfport, Tallahassee, Houston, New Orleans, and Corpus Christi could enter into cooperative agreements to house refugees and provide quick and organized disaster relief, instead of doing it on an ad hoc basis. Houston was gracious to New Orleans refugees after Katrina, but Houstonians received little support from other cities after Hurricane Harvey.

Social networks have documented success in providing assistance during extreme events. The intense heat wave that lasted for five days in Chicago in July 1995 did not uniformly kill people of different ethnicities. While controlling for wealth, of the approximately eight hundred people who died, Klinenberg (2002) found that the death rate for Hispanics was markedly less than for whites or blacks. His explanation is that Hispanics had more formal and fictive kin relationships that were of assistance than

did whites or blacks. The Hispanics checked on each other to deliver water, food, or fans or provide other assistance.

An important factor in the emergency phase of a disaster is the locus of authority. Centralized authority in complex societies can involve layers of decision makers who often are at significant distances from the actual disaster. The result often is delayed response, inappropriate assistance, or other problems. Small-scale societies such as the Ancient Puebloans and Arenal peoples are decentralized political groups. They can react to the sudden crisis more rapidly because of proximity, political autonomy, and knowledge of local actors and resources (Edwards 2015, 836).

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