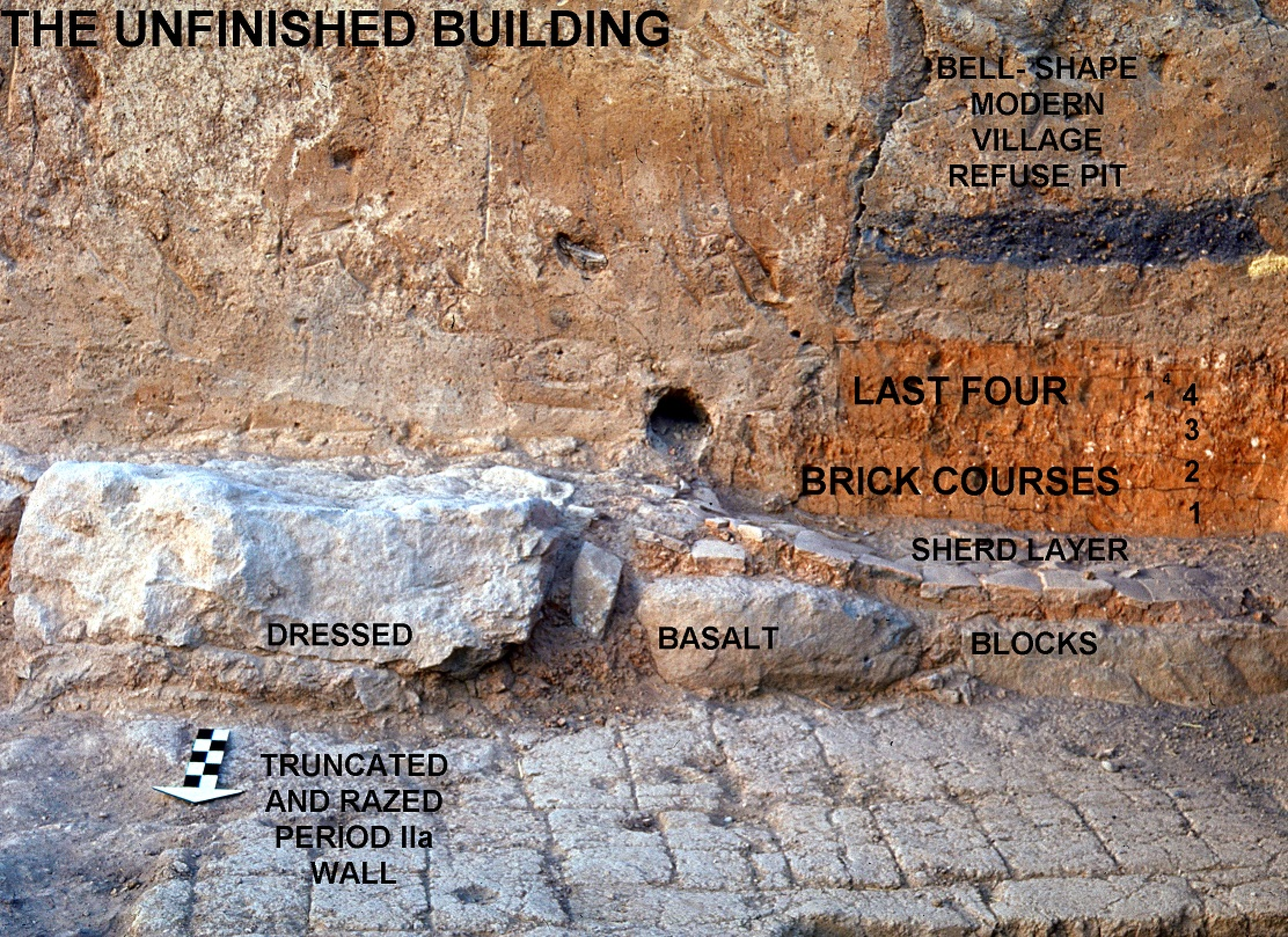
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Megadrought and Collapse

From Early Agriculture to Angkor

Edited by HARVEY WEISS

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CHAPTER 3

4.2 ka BP Megadrought and the Akkadian Collapse

HARVEY WEISS

The Akkadians, of southern Mesopotamia, created the first empire ca. 2300 BC with the conquest and imperialization of southern irrigation agriculture and northern Mesopotamian dry-farming landscapes. The Akkadian Empire conquered and controlled a territory of roughly 30,000 square kilometers and, importantly, its wealth in labor and cereal crop-yields. The Empire maintained a standing army, weaponry, and a hierarchy of administrators, scribes, surveyors, craft specialists, and transport personnel, sustainable and profitable for about one hundred years. Archaeological excavations indicate the empire was still in the process of expansion when the 2200–1900 BC/4.2–3.9 ka BP global abrupt climate change deflected or weakened the Mediterranean westerlies and the Indian Monsoon and generated synchronous megadrought across the Mediterranean, West Asia, the Indus, and northeast Africa. Dry-farming agriculture domains and their productivity across West Asia were reduced severely, forcing adaptive societal collapses, regional abandonments, habitat-tracking, nomadization, and the collapse of the Akkadian Empire. These adaptive processes extended across the hydrographically varied landscapes of west Asia and thereby provided demographic and societal resilience in the face of the megadrought's abruptness, magnitude, and duration.

The Physical Setting

Mesopotamia is the lowland drainage, alluvial plain of the Tigris and Euphrates Rivers and extends from the Anatolian plateau, source of the Tigris and Euphrates Rivers, to the Persian Gulf (fig. 3.1). The Tigris and the Euphrates are fed by the winter precipitation of the cyclonic Mediterranean westerlies, which also provide 200 to 500 millimeters of precipitation along the southern edge of the plateau where the alluvial plain begins, with an interannual variability of about 20 percent. Hence, high-yield cereal dry farming is practiced within the valleys of Anatolia and extensively across the lowland plains that extend from the base of the plateau to the limits of dry-farming precipitation at the 200 to 300 millimeter isohyet. The region extends some 150 to 200 kilometers southward from the base of the plateau and encompasses northern Mesopotamia, including northeastern and northwestern Syria (Wirth 1971).

As the Tigris and Euphrates drop from the Anatolian plateau onto the northern Mesopotamian plains below, they incise their riverbeds to tens of meters and become inaccessible for plain-level irrigation. However, as the rivers course through their near conjunction at ancient Sippar and modern Baghdad, the elevation of the plains gradually drops to just 37 meters above sea level and slows their flow. Still farther south, where precipitation is well below 300 millimeters per annum, the rivers begin to approach plain level and become available for irrigation agriculture (Buringh 1960). Southern irrigation agriculture cereal yields are one-and-a-half to two times greater per unit cultivated than northern dry-farming yields, but they are limited in extent to thin ribbons of canal-watered fields (Weiss 1986). Mesopotamia's agricultural setting, then, encompasses three regions: extensive lowland dry farming to the north, intensive irrigation agriculture to the south, and the semi-arid steppe between that serves the seasonal transhumance of the region's pastoral nomadic populations and their flocks.

Early Irrigation Agriculture

Abrupt century-scale megadroughts occurred across West Asia at nearly millennial intervals of the Holocene and, by their abruptness, magnitude, and duration, severely affected the productivity, socioeconomic sustainability, and social and economic interactions of the three Mesopotamian regions' populations. The earliest abrupt climate change occurred at 8.2 ka BP and was a two-century long global cold and dry period, notable culturally for Anatolian and southeastern European neolithization (Weninger & Clare, ch. 2, this volume). The impact of the 8.2 ka BP event in Mesopotamia, apart from adaptive responses at such sites as Sabi Abyad in the Balikh River drainage (van der Pflicht et al. 2011), can only be suggested at this time, as little fieldwork in Mesopotamia has recently been devoted to this period. Nevertheless, it was during this period that the enigmatic early settlement of southern Mesopotamia occurred, to judge from the radiocarbon dates at Tell Oueilli (Valladas, Evin, & Arnold 1996), suggesting that the two-century megadrought may have pushed central Mesopotamian dry farmers to the refugium of southern irrigation-agriculture domains, the riverine area extending south of Baghdad to the head of the Persian Gulf (Staubwasser & Weiss 2006).

The subsequent Ubaid period (ca. 6500–3800 BC) saw the growth of villages and small towns where the irrigation agriculture was controlled by small, temple-centered, chiefdom-level societies with relatively little centralization of agricultural surplus. Early developments in the Uruk period (ca. 4000–3000 BC) appear to mark the transition from chiefdom to state, with social stratification and an urbanized landscape. By 3500 BC urban Late Uruk society flourished in Sumer, southernmost Mesopotamia, and adjacent irrigation realms

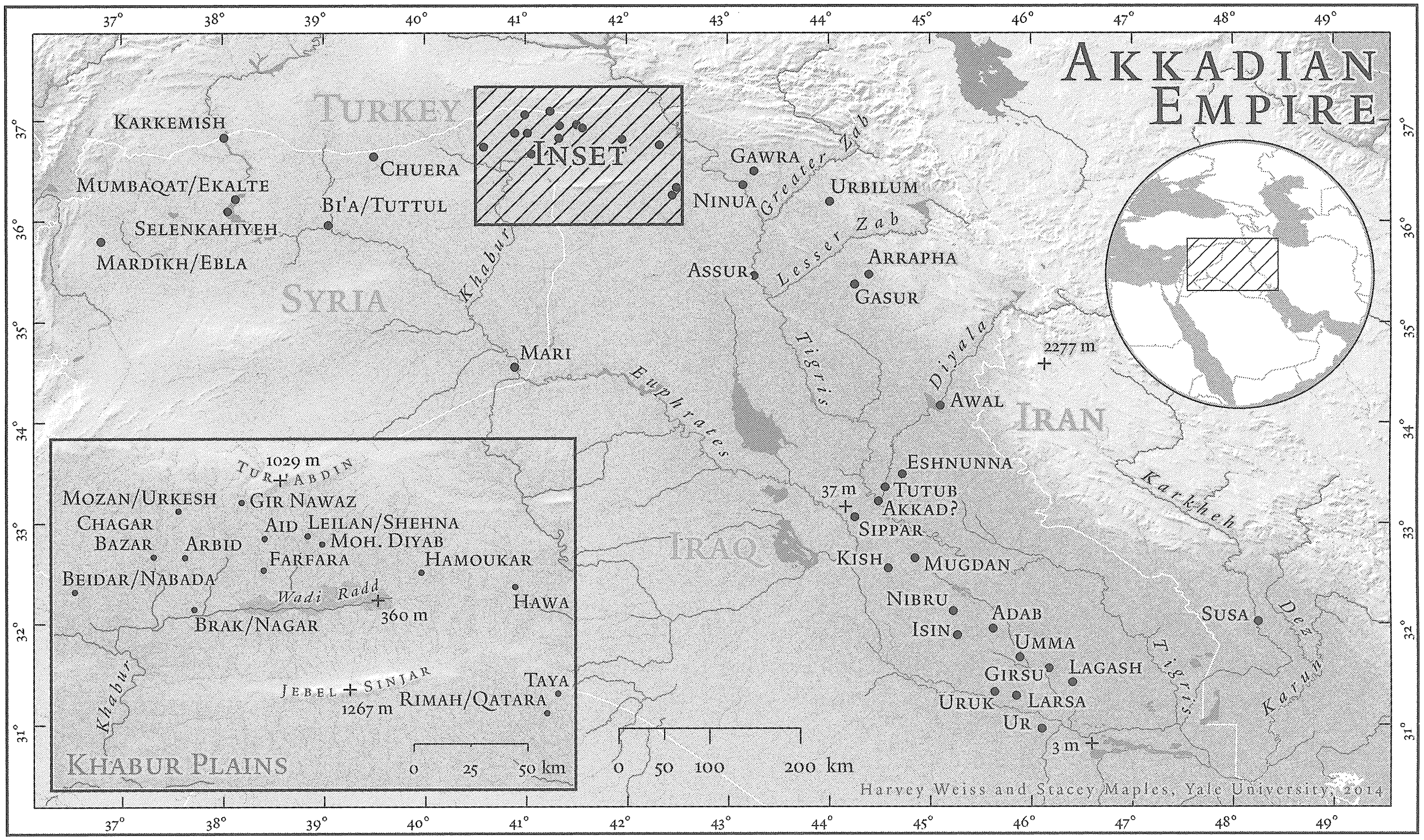

FIGURE 3.1 The Akkadian Empire, ca. 2250 BC, with Khabur Plains settlement and topographic elevations. (H. Weiss and S. Maples)

that extended south from the area of modern Baghdad. This early "urban revolution" comprised Sumerian cities as large as 250 hectares, or approximately 50,000 persons (Finkbeiner 1991), sustained by high-yield cereal irrigation agriculture and low-cost harvest transport via canals (Weiss 1986; Hruška 2007; Algaze 2008).

In the Late Uruk period, increasingly complex exchanges in Sumer between urban institutional managers and their agricultural workers were recorded in accounts rendered with numerical and pictographic notations (Nissen, Damerow, & Englund 1993). At the same time, Late Uruk "colonists" (perhaps long-distance traders pursuing exotic materials) continued a Middle Uruk tradition of settling dispersed communities across the dry-farming plains and plateau valleys of adjacent Iran, Anatolia, and Syria (Petrie 2014; Rothman, ed. 2001). A few northern Mesopotamian towns under dry-farming regimes seem to have grown during this period into ca. 100 hectare, arguably urban, settlements (Brustolon & Rova 2007; Oates et al. 2007), with one even growing to 300 diffuse hectares (al-Quntar et al. 2011).

These Uruk-period colonies and the few large northern settlements, however, were suddenly depopulated or abandoned at ca. 3200–3000 BC. A similar quick retraction or consolidation occurred in southern cities and towns (Postgate 1986). No explanation of this occurrence has been forthcoming but for its coincidence with a severe megadrought at ca. 3200–3000 BC/5.2–5.0 ka BP (Weiss 2003; Charles, Pessin, & Hald 2010). Intriguing as well, but essentially unexplored, is the coincidence of the megadrought and Late Uruk collapse with major social and political innovations in southern Mesopotamia at this time. Reduced Euphrates flow may have generated considerable social and institutional stress and reinforced population agglomeration at some urban sites (Adams 1981; Staubwasser & Weiss 2006). Among the most significant developments was the collapse of the temple authority that regulated Ubaid and Uruk urban society for three thousand years and its innovative replacement by secular, palace-based authorities that now owned and controlled all city-state land and agricultural production (Visicato 2000).

Precipitation rose again by 2800 BC, and in southernmost Sumerian Mesopotamia some cities grew to more than 300 hectares during the Early Dynastic period (ca. 2900–2350 BC). Judging from their temples, palaces, and cemeteries and their highly urbanized riverine landscapes (Adams 1981), these cities reached an apogee of regional extractive wealth accumulation by ca. 2600 BC. For uncertain reasons, Northern Mesopotamian dry-farming landscapes did not undergo this early urban growth and remained small, dispersed villages and towns during the early third millennium—that is, the early Ninevite 5 period, ca. 2900–2600 BC (Weiss 2003).

The Second Urban Revolution

Also yet to be explained is the sudden development of large urban centers at around 2600–2500 BC across the dry-farming landscapes of northern

Mesopotamia and western Syria (Weiss 1990; Akkermans & Schwartz 2008). Emulating the administrative technologies and iconographies of contemporary southern Sumerian cities, many of these northern and western cities grew to the 90 to 120 hectare range, with surrounding towns and villages, and were arrayed evenly across the dry-farming plains. Their pattern of settlement, with dependent village distributions, suggests that the cities were located to maximize the high-yield cereal agriculture potential of the extensive dry-farming plains available to them at such sites as Taya, Nineveh, and Erbil on the Assyrian plains and Leilan, Mozan, Brak, and Hamoukar on the Khabur Plains. To the Sumerians in the south, this region as a whole was likely known as Subir. The region's inhabitants, as we know from the Ebla and Tell Beidar cuneiform archives, spoke Semitic languages and used the southern Mesopotamian cuneiform writing system initially developed to record Sumerian (Sallaberger & Pruss 2015). The agricultural wealth and potential of these dry-farming cities, with populations already highly organized for agricultural production, were soon to be the target of nascent southern Mesopotamian imperialism.

Akkadian Imperialization and Collapse

In the early 24th century BC, a period of warring among southern city-states terminated with the ascent of one "lord of the land." Lugalzaggisi, the king of the city-state of Umma, emerged from decades-long battles to control many, if not all, of Sumer's other city-states, including Nibru, Adab, and Uruk—the first, dozens of kilometers distant from Umma (Almamori 2014). The few known surrounding events include Lugalzaggisi's conquest of Mari on the central Euphrates and royal travel as far as the Mediterranean Sea.

Lugalzaggisi's rule gave way in the immediately succeeding decades to a quantitative and qualitative leap in Sumer's supremacy. The next ruler, according to the Sumerian King List, was Sargon, the founder of a five-generation Akkadian dynasty that created a capital city at Akkad (or Akkade), likely near Sippar (but still unlocated) and spoke and wrote the early Semitic language Akkadian. Within two generations the Akkadians embarked upon an imperial venture that was exponentially more extensive and extractive than envisioned by Lugalzaggisi's "lord of the land." At ca. 2200 BC, only about one hundred years after its launch and full-blown development, this first imperial effort, the Akkadian Empire, was truncated by natural forces at the 4.2 ka BP megadrought. Yet in spite of, or even perhaps because of, this abrupt rupture, Akkadian imperial successes and ideology were emulated and venerated by succeeding empires for the next thousand years. Epigraphic and archaeological data document three stages in the establishment of Akkadian imperial power, marked by the rules of Sargon, his sons Rimush and Manishtushu, and his grandson Naram-Sin, dated in Table 3.1 using the "Middle Chronology," with a range of ca. 60 years (Sallaberger & Schrakamp 2015).

TABLE 3.1 Stages of Akkadian Imperial Power

Stage 1	Sargon (ca. 2324–2285 BC) extended the united realm from Akkad in the north to Ur in the south—ca. 5000 square kilometers—and embarked upon a series of long-distance conquests up the Euphrates, to Mari, Tuttul, and Ebla, respectively ca. 500, 700, and 900 kms distant). This was a departure from regional southern Mesopotamian city conquest, and a qualitative leap from both Mari's and Ebla's more limited efforts towards regional hegemony. Little apparent state building followed Sargon's conquests: with no controlling fortresses left in the conquered cities, they provided only the "primitive", immediate, acquisition of plunder.
Stage 2	Rimush and Manishtushu (ca. 2284–2262 BC), in short order, extended Akkadian imperial power into northern Mesopotamia. This stage marks the beginning of Akkadian designs on the dry-farming cities of the north, at Tell Brak, Nineveh, and Tell Leilan—where the earliest Akkadian texts of the Khabur Plains were retrieved within an enigmatic Akkadian scribal room (deLillis Forrest et al. 2007).
Stage 3	Naram-Sin (ca. 2261–2206 BC), Sargon's grandson, took another qualitative leap, conquering the urbanized landscapes of adjacent dry-farming regions in southwestern Iran, northeastern Iraq, and northeastern Syria. The most detailed examples of this conquest and imperialization process have been retrieved recently on the Khabur Plains, where the Akkadians installed themselves within palace fortresses at Leilan, Mozan, and Brak and ruled the dry-farming lands extending north across Mesopotamia to Taya, Nineveh, Awal, and Gasur/Kirkuk and east to Susa. Henceforth, the Akkadians extracted and deployed revenues from both the rain-fed and the irrigation-agriculture regions of Mesopotamia. This imperialization across Mesopotamia, recorded in Akkadian provincial archives (see, for example, Visicato 1999; Foster 1982; Brumfield 2013), also marked the deployment of a new imperial metrology in the collection of both raw commodities and finished products (Glassner 1986; Powell 1990) as well as land surveying and agrimensorial innovations (Foster 2011; Høyrup 2011).

In southern Mesopotamia the Akkadians created enormous new estates from domains seized or purchased, and then extracted revenues for the empire's administrators and elite officialdom and for imperial projects, such as new temple construction and maintenance of the empire's armies (Westenholz 1987, 1999). The large imperial revenues were dispatched to the capital by water transport: as one record attests, tow barges from southern Adab were loaded with 885,000 liters, or about 539 metric tons, of barley (Maiocchi 2009: 78).

The revenues of the northern dry-farming areas were gathered and retrieved from imperialized regional cities, a deployment made possible in no small part by the state's ability to exploit a large, dependent labor force. At Gasur, near Kirkuk, for instance, agricultural workers were provided with barley rations (*še-ba*) for their agricultural labor, while estate harvests were directed, as in the south, to the local Akkadian administration (Foster 1982), where skilled artisans, as well as dependent and levied labor, were compensated with rations measured to imperial standards (Westenholz 1987). On the Khabur Plains, an Akkadian bulla retrieved from a small, 5-hectare town at Chagar Bazar, alongside the now dry wadi Khanzir, likely records the water-borne transport of as much as 160 gur, or 379 metric tons, of emmer (Chagar Bazar A. 391, Brumfield 2012). One imperial Akkadian account records more than 45,000 liters, or over 30 metric tons, of barley and emmer, probably transported by river from 50-hectare Nagar/Tell Brak, on the Khabur Plains, to Sippar near Baghdad (Sommerfeld, Archi, & Weiss 2004; cf. Englund 2015) In the dry-farming areas, imperial targets were the urban-dominated agricultural landscapes, which comprised a pre-adaptation for Akkadian imperialism. Northern imperialization targets, other than cereal production, are difficult to identify, since the northern plains lack other extractable resources and the Akkadian imperial fortresses did not extend to the adjacent Anatolian and Iranian plateaus' potential precious metal sources—even though silver and cedar were famously retrieved from the Amanus mountains far to the northwest. In fact, the Akkadians ignored the Hakkari sources on the plateau and obtained their copper from Oman and Kerman (Potts 2007).

The 4.2 ka BP Megadrought

In the midst of imperial success and expansionary activity, at ca. 2230 BC in the Leilan radiocarbon chronology, probably in the reign of Shar-kali-sharri, Naram-Sin's son and successor, the abrupt onset of the 4.2 ka BP global megadrought desiccated the dry-farming agricultural landscape of the Mediterranean, West Asia, and northern Mesopotamia with 30–50 percent precipitation reductions and colder temperatures. The chronology and global extent of this abrupt climate change are now well documented and frame the collapse of the Akkadian Empire.

Much has been gleaned about the 4.2 ka BP event from climate science, which traces the direction and intensity of the cyclonic North Atlantic westerlies that are controlled by the North Atlantic Oscillation (Kushnir & Stein 2010; Cullen et al. 2002) and delivered through the Mediterranean trough to West Asia (Lionello, Malanotte-Rizzoli, & Boscolo 2013). The North Atlantic Oscillation's boundaries are reflected in abundant and synchronous Mediterranean westerlies proxy records and the yet inexplicably linked Indian Monsoon paleoclimate proxy records that are plotted in figure 3.2 within the winter season moisture transport. Two high-resolution data sets define the 4.2 ka BP event's chronology and magnitude: (1) Icelandic lake sediment records (Geirsdóttir et al. 2013; Blair, Geirsdóttir, & Miller 2015), and (2) a Greenland lake-sediment record linked to the North Atlantic Oscillation-index and derived from tree-ring and speleothem records (Olsen, Anderson, & Knudsen 2012).

Most of these paleoclimate proxies document the 4.2–3.9 ka BP abrupt climate change, but some anomalous records exist. These anomalies include Jeita Cave, Lebanon (54), surrounded by prominent 4.2 ka BP event proxies, Sofular Cave (110) at the Black Sea, the only Anatolian region that receives precipitation throughout the year, Qunf Cave (77) in the Intertropical Convergence Zone, and Lake Bosumtwi (86), situated between the well-documented 4.2 ka BP event proxies at Lake Yoa (76) and the Gulf of Guinea (96). A few older, low-resolution proxies also do not display the 4.2 ka BP event, among them Bouara, Syria (53), where there may be an analysis error, and the older Greek proxy records surrounded by new high-resolution speleothem and marine core records, such as the Alepotrypa cave speleothem on the Peloponnese (114). A few Anatolian lake proxies, such as Söğütlü Marsh (31) and the poorly dated Eski Açigöl core (33) also miss the event, though they are surrounded by recent high-resolution Anatolian proxies with prominent 4.2 ka BP event proxy excursions, such as Nar Lake (112) and Gulf of Gemlik (113) and the high-resolution speleothem core at Gol-e Zard, Iran (111). The 4.2 ka BP event Mediterranean westerlies proxies, usually ^{14}C and U-Th isotope dated, extend across the seven sub-regions in Table 3.2 and are listed by number in the Appendix.

The 4.2–3.9 ka BP event is now well documented in East African and Indus paleoclimate proxies (fig. 3.2), which detail synchronous abrupt alterations for both Nile flow and Indus precipitation and river flow, functions of the Indian Monsoon as it passes across the Arabian Sea between the sub-continent and the Horn of Africa. Marine, lake, and speleothem cores indicate that the 4.2 ka BP event disruption of the Indian Monsoon (Berkelhammer et al. 2012; Dixit, Hoddell, & Petrie 2014; Prasad et al. 2014) was approximately coincident with disrupted Harappan urbanization along the Indus River, though temporal details await refinement (Ponton et al. 2012), while mitigating cropping strategies may have prevailed in dry-farming regions (Petrie et al. 2016). The weakening of the Indian Monsoon also diminished northeast African precipitation (Marshall et al. 2011; Revel et al. 2014; Davis & Thompson 2006) and consequent Nile flow (Blanchet et al. 2013; Hassan & Tassie 2006; Bernhardt, Horton, & Stanley 2012; Welc & Marks 2014; Revel et al. 2014), coincident with the collapse of the Old Kingdom in Egypt and introduction of the First Intermediate Period (Ramsey et al. 2010).

In Africa, West African and Saharan precipitation were also disrupted (Marchant & Hooghiemstra 2004), as at Lake Yoa (76) and Jikariya Lake (81)—an aridification and dust event that terminated the African Humid Period (Lézine 2009) and likely created the sources of synchronous African dust in Tuscany (17). The same megadrought event is observed in central West African lake cores (90) and Gulf of Guinea marine cores (96). North to south, the event is recorded from coastal Algeria (95) to the 30-degree latitude in southern Africa (Chase et al. 2010; Schefuss et al. 2011).

The abundant West Asian proxy records are also linked to central Asia, the Himalayas (Nakamura et al. 2016), and Mongolia (Yang et al. 2015). In southeastern

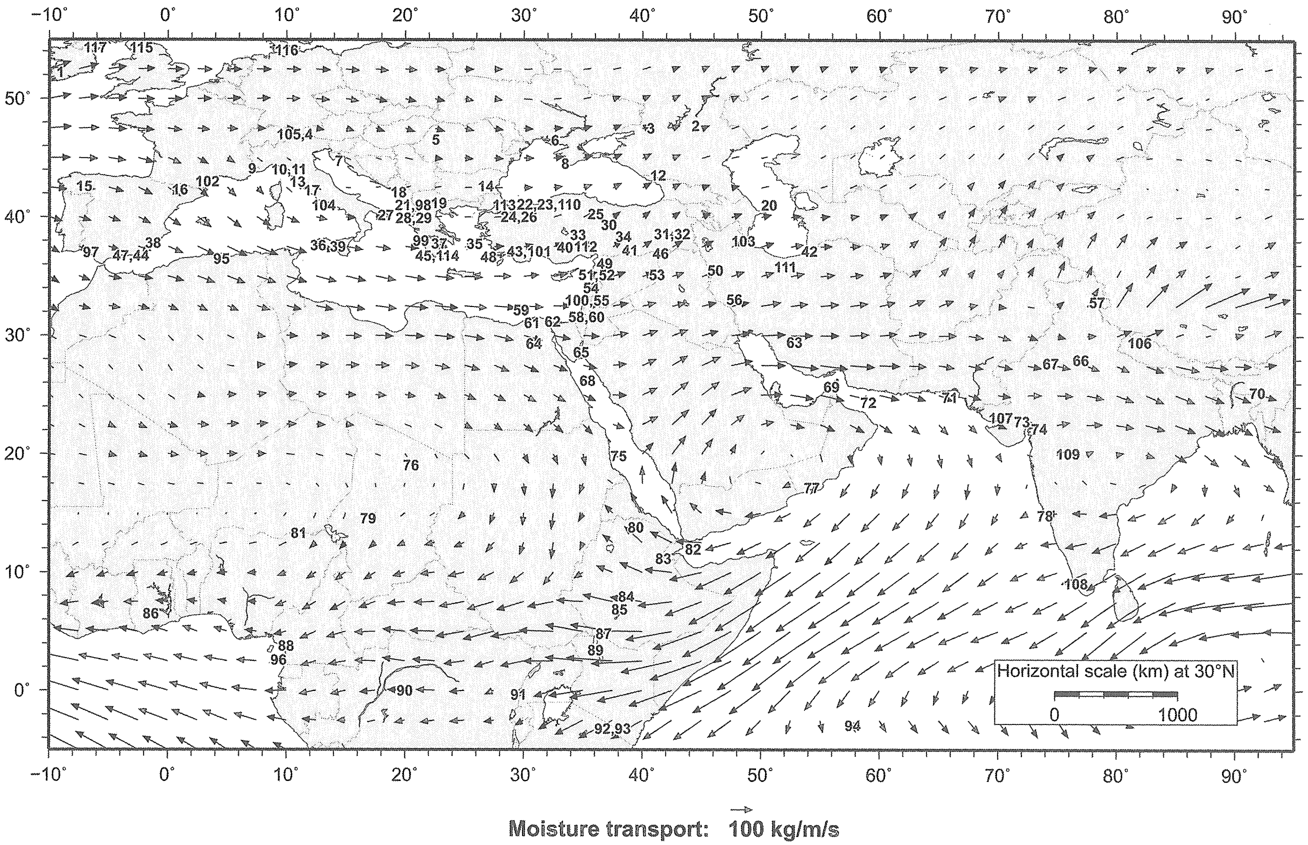

FIGURE 3.2 Paleoclimate proxy sites for 4.2 ka BP event with NOAA Moisture Vectors: Europe, Mediterranean, North Africa, West Asia, and Indus. The vertically integrated moisture transport, as estimated for December 1949 through February 2014, from the National Centers for Environmental Prediction—National Center for Atmospheric Research Reanalysis. The units are in kg/m/s, with the reference vector shown at bottom. (Moisture vectors map by R. Seager)

TABLE 3.2 Mediterranean Westerlies 4.2 ka BP event paleoclimate proxy records. (Numbers refer to figure 3.2 and the Appendix.)

Coastal Spain and France
Doñana National Park (97): Sierra de Gador (47); Cova da Arcoia (15); Borreguiles de la Virgen (44); Lake Montcortès (16); Puerto de Mazzarón (38); Lac Petit (9).

Central Mediterranean Italian lakes
Lago di Pergusa (39); Bucca della Renella (10); Lago Alimini Piccolo (27); Maar lakes (17); Lake Accessa (13); Lago Preolo (36); Corchia Cave (11).

Greece and the Balkans
Lake Lerna (37); Osmananga Lagoon (Pylos) (45); Lake Vrana (7); Lake Prespa (98): Leng et al. 2010; Lake Shkodra (18); Lake Ohrid (21); Lake Dojran (19); Aegean Sea (35); Kos basin, south Aegean Sea (48); Kotychi Lagoon (99): Haenssler et al. 2014; Rezina Marsh (28); Gramousti Lake (29).

Levant and Red Sea
Acre (100): Kaniewski et al. 2014; Tweini (52); Dead Sea (60); Zeelim, Dead Sea; Sedom, Dead Sea; Soreq Cave (58); Shaban Deep (68); northern Red Sea and Gulf of Aqaba (65); central Red Sea (75); Lake Hula (55); Jeita Cava (54); Ghab Valley (51); Tell Mardikh (49).

Anatolian plateau and northern Mesopotamia
Konya lakes (40); Göl Hissar Gölü (43); Eski Açigol (33); Koçain Cave (101): Göktürk 2011; Abant Gölü (23); Yeniçaga Gölü (22); Sogutlu Marsh (31); Nar Lake (112); Lake Iznik (24); Kaz Gölü (25); Gulf of Gemlik (113); Yenişehir (26); Arslantepe (34); Göbekli Tepe (41); Lake Van (32); Lake Tecer (30); Tell Leilan (46).

Persian Gulf
Gulf of Oman (72); Awafi (69); Qunf Cave (77).

Black Sea, Caspian Sea, Iranian Plateau
Lake Zeribar (50); Lake Mirabad (56); Lake Maharlu (63); Black Sea (8); Sofular Cave (110); Caspian Sea (20); southeastern Caspian Sea (42); Gol-e Zard Cave (111).

Tibet, millet crop agriculture persisted to 4.2 ka BP, when drier and colder conditions forced regional settlement abandonment until the adoption of wheat-barley agriculture ca. 3.5 ka BP, while the arrival of wheat and barley ca. 4 ka BP on the northeastern Tibetan plateau allowed for uninterrupted occupation (d'Alpoim Guedes et al. 2016; Wang et al. 2015). In eastern China, numerous 4.2–3.9 ka BP records document East Asian Monsoon instabilities that disturbed late Neolithic settlement systems (Cai et al. 2010; Donges et al. 2015; Dykoski et al. 2005; Liu and Feng 2012; Lu et al 2015) and extended to interruption of the Indonesian-Australian Summer Monsoon (Rosenthal, Linskey & Oppo 2013; Deniston et al. 2013).

In North America, seven glacial, speleothem, and lake-core proxy records of the event cross the continent from New Jersey to the Yukon (Dean 1997; Zhang & Hebda 2005; Booth et al. 2005; Li, Yu, & Kodama 2007; Fisher 2011; Hardt et al. 2010; Menounos et al. 2008). Additionally, now available is the annual-resolution Great Basin tree-ring record (Salzer et al. 2014), which documents the 4.2 ka BP event at the introduction of maize agriculture to the US southwest (Merrill et al. 2009) and the Yucatan (Torrescano-Valle & Islebe 2015). In South America, the well-known glacial record (Davis & Thompson 2006) is now supplemented with other Andean proxy records (Baker et al. 2009; Licciardi et al. 2006, 2009; Schittek et al. 2015) to suggest a causal linkage between 4.2 ka BP and the poorly understood rise and fall of contemporary Peruvian Late Pre-ceramic cities (Sandweiss et al. 2009). 4.2 ka BP proxy records extend southwards to 44° S in Chilean Patagonia (dePorras et al. 2014) and Antarctic glacial cores (Peck et al. 2015).

The Multi-Proxy Stack

The multi-proxy stack (fig. 3.3) portrays several currently available high- to low-chronological resolution paleoclimate proxies at 4.2–3.9 ka BP across the Mediterranean and West Asia (Weiss et al. 2012; Walker et al. 2012). Linear interpolation across uranium-thorium (U/Th) or radiocarbon (^{14}C) dated points is provided for measured quantities of precipitation and temperature proxies, such as stable isotopes, arboreal and other pollen, diatoms, carbonates, lake levels, and magnetic susceptibility. The ranges of chronological resolution in each record are reproduced here within two standard deviations around 4.2–3.9 ka BP. The standard deviation bars illustrate two important qualities of the 4.2 ka BP paleoclimate record. First, the dating is quite variable, extending from very low to very high resolution. Second, chronological resolution is dependent not only upon sampling and dating intervals, but on the standard deviation of the radiometric datings. For comparative purposes, the coincident high-resolution proxies at Mawmluh Cave (Berkelhammer et al. 2012) and Mount Logan (Fisher 2011) represent global records of the 4.2 ka BP event (Walker et al. 2012).

At Lac Petit, France, in the southern Alps, an abrupt detrital pulse triggered by more intense or more frequent rainfall marks a major shift in diatom assemblages at 4300–4100 BC, according to ^{14}C dating (Brisset et al. 2013). The Koçain Cave, Turkey, speleothem (Göktürk 2011) provides high-resolution U/Th dates that constrain abrupt decreases and increases of $\delta^{18}O$ (oxygen isotope ratio). The Eski Açigöl, Turkey, lake core (Roberts et al. 2001) has no radiocarbon dates during a rise in lake-core charcoal misinterpreted as anthropogenic deforestation (Turner, Roberts, & Jones 2008), while the Göl Hissar, Turkey, lake-core carbonate spike and rise in $\delta^{18}O$ are framed by radiocarbon dates 2000 years apart (Eastwood et al. 2007). The Lake Van, Turkey, core (Lemcke & Sturm 1997) displays a quartz spike understood as a dust proxy and is dated by varve counts with slight errors (see Kuzucuoğlu et al. 2011). The dense sampling intervals for the Soreq Cave, Israel, speleothem (Bar-Matthews & Ayalon 2011) $\delta^{18}O$ and $\delta^{13}C$ values are linked to U/Th dates, but with large standard deviations and, therefore, a labile chronology. The Dead Sea lake levels (Kagan et al 2015; Litt et al. 2012; Migowski et al. 2006) are estimated to have dropped abruptly by 45 meters at ca. 4.2 ka BP (see Frumkin 2009). At the Red Sea Shaban Deep core (Arz, Lamy, & Pätzold 2006), 15-year diatom sampling

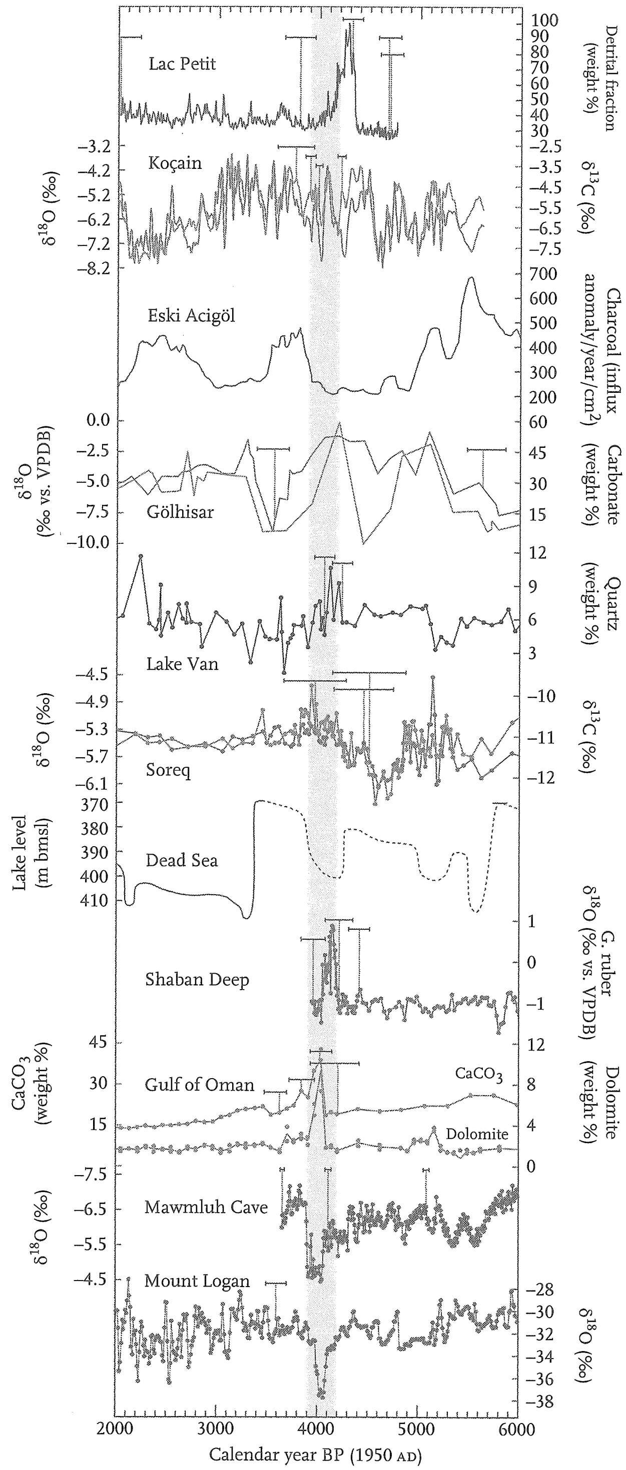

FIGURE 3.3 Multi-proxy stack of Mediterranean westerlies and related paleoclimate proxies displaying the 4.2 ka BP abrupt climate change event within marine, lake, speleothem, and glacial records of varying chronological resolution, with 2-standard deviations dating indicated (Weiss et al. 2012; Walker et al. 2012). (H. Weiss & M. Besonen)

intervals are constrained by high-resolution radiocarbon dates with a marine reservoir correction (see Edelman-Furstenberg, Almogi-Labin, & Hemleben 2009). The Gulf of Oman marine core (Cullen et al. 2000) has dolomite and calcium carbonate (dust) spikes framed by ^{14}C dates and is tephra-linked to Tell Leilan chronostratigraphy (Weiss et al. 1993).

The Mawmluh Cave, India, speleothem (Berkelhammer et al. 2012) provides 6-year $\delta^{18}O$ sampling intervals constrained with U/Th dates and links the Nile flow reductions (see Hassan & Tassie 2006; Bernhardt, Horton, & Stanley 2012), east African lake-level reductions (see Gasse 2000), and the Indian Summer Monsoon deflection (see Dixit, Hodell, & Petrie 2014). The Mount Logan, Yukon, glacial core (Fisher 2011) is cross-dated with the NorthGRIP-core and dated tephra records and exemplifies the 4.2 ka BP event's North American expression, second in magnitude to the 8.2 ka BP event. Illustrative of the abrupt climate-change synchronicity in the Mediterranean are the Lac Petit, France, core (9), and other recent and adjacent cores in Spain, Lake Shkodra, Albania (18), Lake Accessa, Italy (13), and Acre, Israel (100), dated ca. 4.2–3.9 ka BP, or, in some cases, at lower resolution, ca. 4.3–3.8 ka BP (see Figure 3.2, Table 3.2, and Appendix 3.1).

Effects of the 4.2 ka BP Megadrought

The effects of the global 4.2 ka BP abrupt climate change varied regionally and climatically, of course, and the integration of these extensive data comprises a major new research task. In West Asia and northern Mesopotamia, the dry-farming areas contracted when precipitation dropped 30–50 percent at ca. 4.2 ka BP (Bar-Matthews & Ayalon 2011; Frumkin 2009; Staubwasser & Weiss 2006: 380–382, figs. 4–6.) Regional aggregate cereal yields plummeted, and most of the Khabur Plains of northeastern Syria fell below the minimal 200–300 millometer isohyet necessary for dry farming (fig. 3.4). Similar drought conditions prevailed across the Mediterranean, western Syria, and northern Iraq, regions in which precipitation was a function of the same Mediterranean westerlies, and paleoclimate records indicate that the megadrought extended across the Mediterranean to Anatolia, the proximate source of northern Mesopotamian winter precipitation.

The Akkadian Empire's investment in the conquest, control, and manipulation of northern Mesopotamia had included a standing army, weaponry, and a hierarchy of administrators, scribes, surveyors, craft specialists, and transport personnel across a territory of roughly 30,000 square kilometers. This imperial system had proven both sustainable and profitable for about one hundred years (Ristvet 2012). The megadrought, however, eliminated dry-farming cereal cultivation across the Khabur Plains and the north Mesopotamian and Syrian plains to the east as well as the west. The flow of northern imperial agricultural and finished product levies to provincial centers and to the Akkadian capital terminated.

The effects of a 30–50 percent reduction in Tigris-Euphrates flow upon southern Akkadian agriculture can only be estimated. Although the flow always seems to have exceeded the demands of irrigation agriculture, such a reduction would have substantially diminished canal extent and irrigated field areas. At the onset of the megadrought, with reduced Euphrates flow, aggregate Akkadian yields likely fell precipitously. In the course of the megadrought flow reduction, the successor Ur III state redesigned canal systems into linear paths in an attempt to counter channel meandering (Adams 1981: 164). However, in spite of considerable epigraphic documentation for southern Akkadian and Ur III agriculture, it has not yet proven possible to convincingly compare Akkadian and Ur III period agricultural production (van de Mieroop 1999: 125).

Although its economy remains to be quantified, the Empire's collapse was swift. That the capital city, Akkad, has neither been located nor excavated remains a central challenge to our understanding of events in the Akkadian heartland, but the extant cuneiform record is itself graphic in this instance. "Who was king, who was not king?" records the Sumerian King List, perhaps written at the time or shortly thereafter, when "Akkade was defeated and kingship was taken to Uruk" (Black et al. 2004). The "Curse of Akkade" poetically describes the populace's drought-stricken wails when food was scarce and the "canal bank tow-paths' grass grew long," trailed by the invading Gutian mountain neighbors, "with the brains of dogs and the faces of apes," who were brought by divine force to conquer Akkad (Cooper 1983; Black et al. 2004). A series of petty kings followed. Ur III dynasty successors would rule irrigation-agriculture southern Mesopotamia for a hundred years, but they never reclaimed the abandoned, drought-stricken northern realms. Three hundred and fifty years after the collapse, the fall of Akkad was still an exalted event (Grayson 1987: 53). The collapse of the Empire is unquestioned; nevertheless, its demise was ecologically more complicated than "The Fall of Akkad" epigrammatically suggests.

Ecological Variability of Collapse

Adaptive responses to megadrought varied within the ecological zones across West Asia, the dry-farming zone, the riverine irrigation-agriculture zones, and the semi-arid steppe. In the dry-farming zone, the 30–50 percent reduction in precipitation made dry-farming impossible, and region-wide site abandonments quickly followed. These abandonments are most visible now in the excavated sites and regional surveys on the Khabur Plains of northeastern Syria and in the plains of southwestern Turkey, western Syria, and the Levant (fig. 3.4).

Khabur Plains

The collapsed Akkadian Empire's abandonment of the Khabur Plains was swift and sudden, and most of the indigenous regional population departed with the Akkadians. Three major urban settlements—Brak, Leilan, and Hamoukar—and their surrounding towns and villages were abandoned synchronously and completely, while a fourth major settlement at Mozan was 80 percent deserted (Buccellatti & Buccellatti 2000; Pfälzner 2012). These Khabur Plains

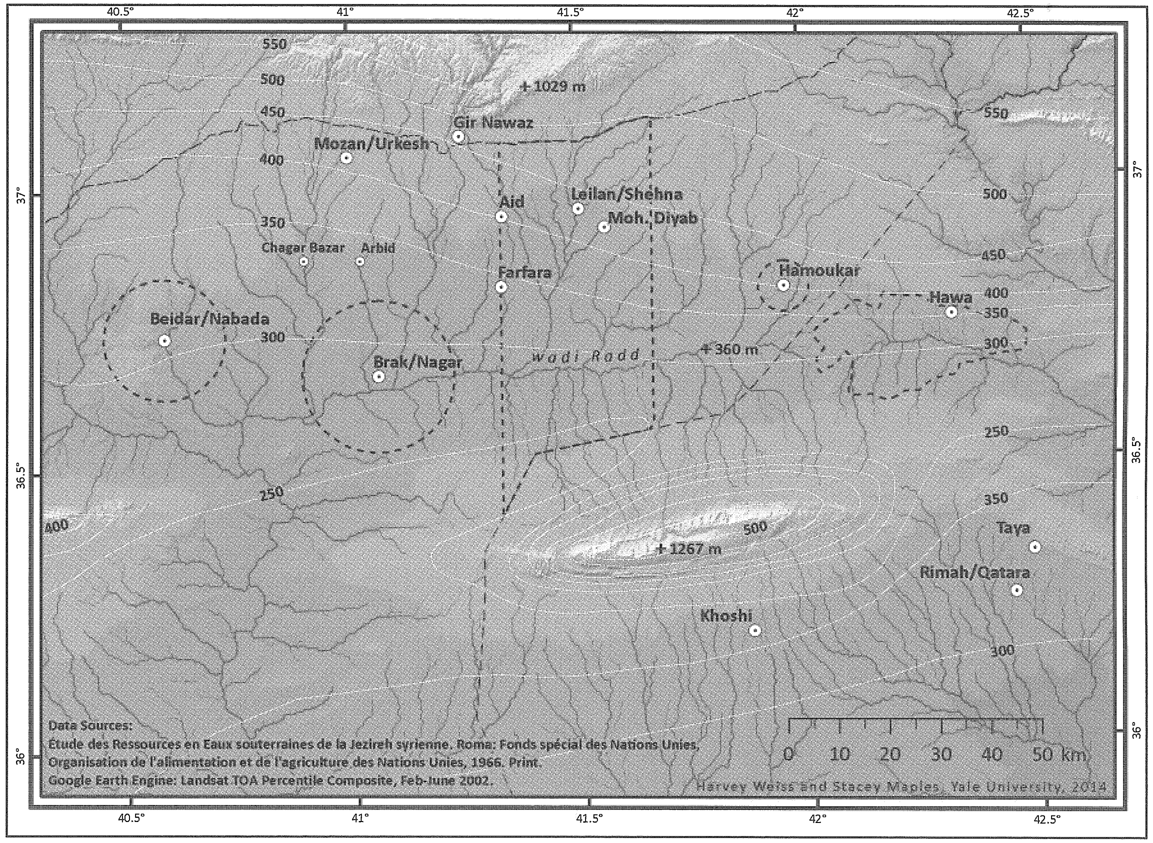

FIGURE 3.4 Khabur Plains, northeast Syria, with modern precipitation isohyets and regional archaeological settlement surveys. (H. Weiss and S. Maples)

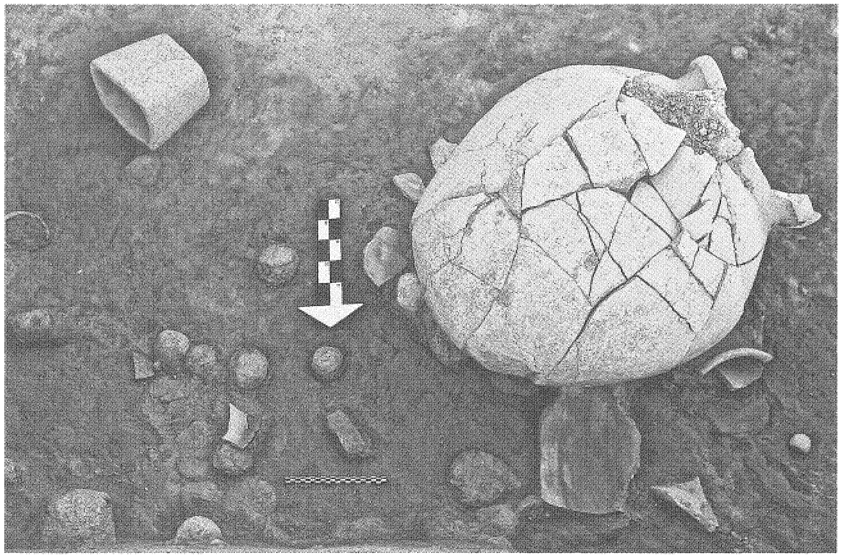

FIGURE 3.5 Clay balls for tablet manufacture; uninscribed clay tablets, cereal storage jar, and basalt 2-liter ration measure, abandoned on Room 12 floor, terminal occupation, Akkadian Administrative Building, Tell Leilan, end period IIb1; AMS radiocarbon dated 2254–2220 BC (68.2 percent) (H. Weiss)

abandonments included the cities' lower town areas, which were each probably populated by upwards of 20,000 indigenous agricultural workers.

The Unfinished Buildings on the Khabur Plains

In three instances, major building projects were abandoned in mid-construction. "The Unfinished Buildings" included the Akkadians' Naram-Sin fortress at Tell Brak, a gateway city at the southern edge of the Khabur Plains. This massive structure was probably intended to serve as a regional grain store, but it was abandoned with unfinished floors and walls, stamped "Naram-Sin" on their lower course bricks (Mallowan 1947).

At Tell Leilan, in the heart of the eastern Khabur Plains, about a hundred years of large-scale grain storage, processing, and redistribution took place in the Akkadian Administrative Building on the Leilan Acropolis. The Akkadians suddenly departed at ca. 2230 BC, however, leaving clay balls for tablet manufacture, uninscribed clay tablets, a large storage vessel, and a 2-liter ground basalt measure on the terminal room 12 floor (fig. 3.5). Across the stone-paved street, The Unfinished Building at Tell Leilan had rough-dressed basalt block walls yet without brick, and some walls still only three or four courses high upon a mud-set sherd layer (fig. 3.6). A semi-circle of partially dressed blocks awaited finishing and wall placement and a line of basalt blocks extended west to the edge of the Leilan Acropolis. At its desertion, the string-impressed clay sealing of the imperial Akkadian minister, "Haya-abum, šabra" (L93–66; fig. 3.7), was left on The Unfinished Building construction surface (Weiss et al. 2012; McCarthy 2012).

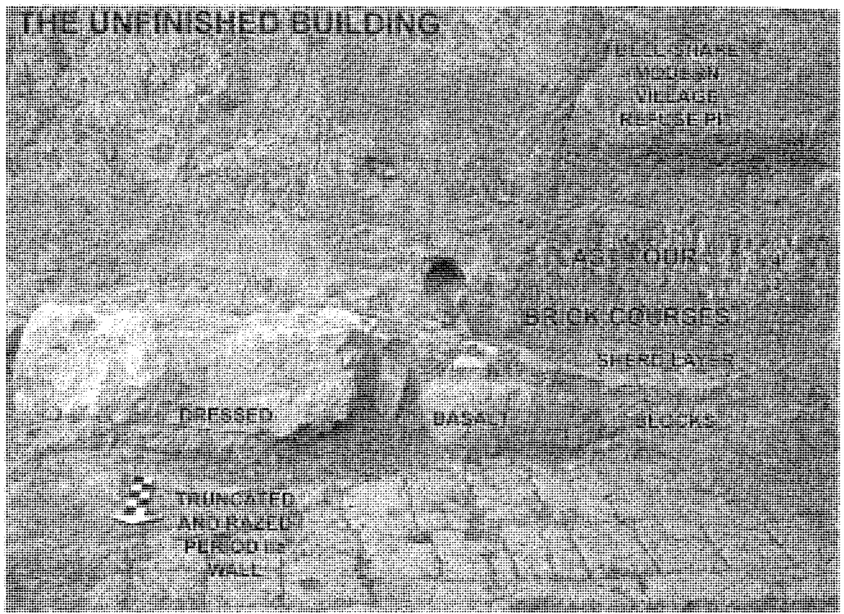

FIGURE 3.6 Tell Leilan 1999, The Unfinished Building, 44W16 south stratigraphic section: Period IIa razed brick wall, Period IIb1 incomplete line of dressed basalt blocks, mud pack, sherd layer, and four courses of calcic horizon mudbrick. Modern village pit halted at calcic horizon mudbrick. (H. Weiss)

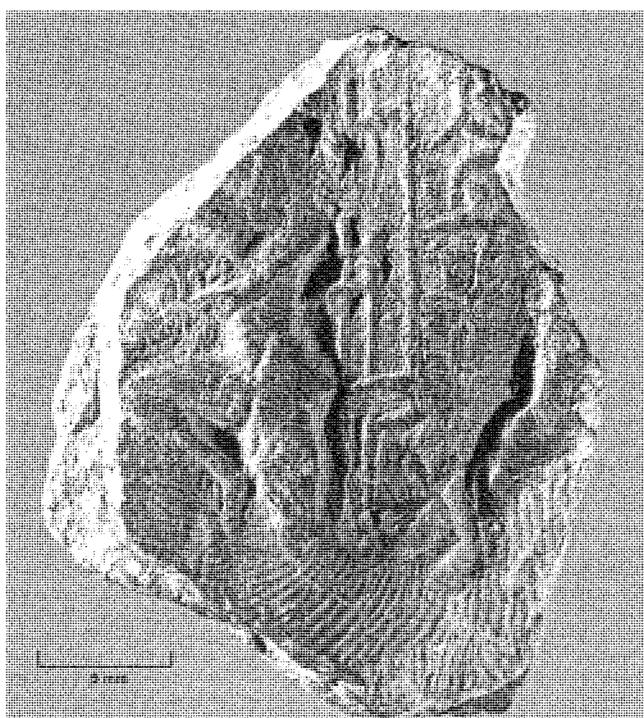

FIGURE 3.7 Tell Leilan 1993, object 66, 44W15, southern Mesopotamian imperial Akkadian seal-impression fragment with inscription "Hayabum, shabra," retrieved from working floor of The Unfinished Building at corner of north and west basalt block walls. Reverse: string impressions. (H. Weiss)

FIGURE 3.8 Post-Akkadian four-room house built around a courtyard, Tell Leilan period IIc, AMS radiocarbon dated 2233–2196 BC (68.2 percent). The house was occupied briefly after the Leilan period IIb Akkadian site abandonment and is the only post-Akkadian occupation located at Tell Leilan to date. (H. Weiss)

Two similar but fragmentary buildings were abandoned mid-construction at Tell Mohammed Diyab, eight kilometers east of Tell Leilan (Nicolle 2006: 64, 133). Taken together, The Unfinished Buildings at Tell Brak, Leilan, and Mohammed Diyab document patterns of both imperial success and expansionary designs up to the very moment of the administrators' decision to abandon the Khabur Plains.

Post-Akkadian Settlement on the Khabur Plains

Following the abandonments, residential and very short-term post-Akkadian occupations are known from excavations at four sites—Brak, Leilan, Arbid, and Chagar Bazar—each of which terminated at ca. 2200 BC, as determined by high-resolution AMS radiocarbon dating (see fig. 3.8; Weiss et al. 2012: 175). Similarly, the Leilan Region Survey, a 1650 square kilometer transect through the center of the eastern Khabur Plains, documents an 87 percent reduction in settled area at the termination of Akkadian imperialization in the post-Akkadian Leilan IIc period (ca. 2230–2200 BC). This brief remnant occupation was followed by an approximately 250-year abandonment of the region, until the return of pre-megadrought precipitation (fig. 3.9; Arrivabeni 2012; Colantoni 2012).

Dry-farming Western Syria, Turkey, the Levant, and the Aegean

Distant from direct Akkadian imperialization, the dry-farming plains of the upper Euphrates drainage near Urfa and Harran in Turkey, including urban sites with cities such as Tilbeşar, Titriş and Kazane, were similarly abandoned

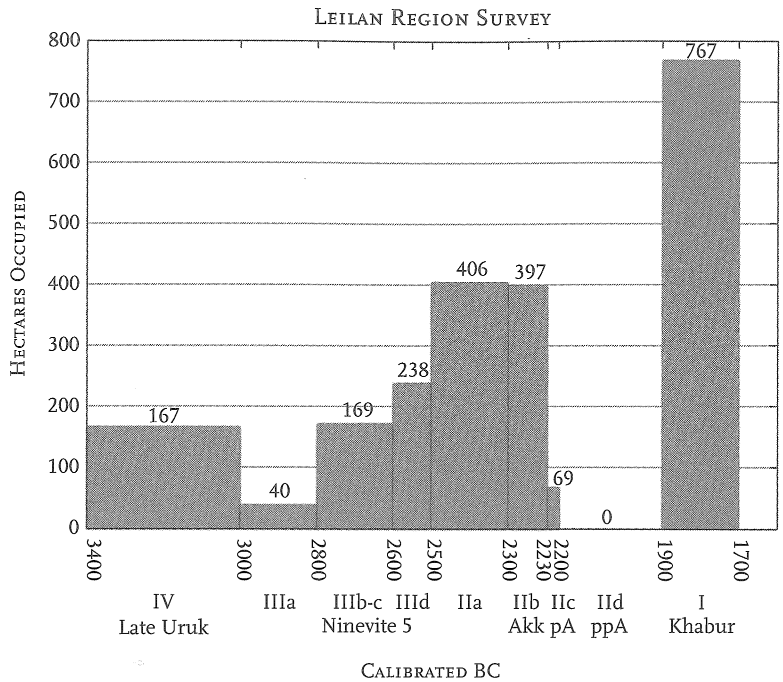

FIGURE 3.9 Leilan Region Survey (1650 sq km) histogram of total settlement hectares/period spans. The end period IIb Akkadian collapse reduced post-Akkadian period IIc settlement by 87 percent at ca. 2230 BC, and by 100 percent at ca. 2200 BC. Major resettlement by formerly pastoralist Amorite populations (Khabur period occupations) is evident by ca. 1950 BC. (M. Arrivabeni, L. Ristvet, E. Rova, & H. Weiss).

at 2200 BC. In western Syria, south of Aleppo, the rebuilt Early Bronze IVB city at Ebla was reduced in size, while its Archaic Palace, singularly fitted with water cisterns, remained unfinished like The Unfinished Buildings at Leilan and Brak and Mohammed Diyab (Matthiae 2013). On the Jabbul Plain, the 20-hectare town at Umm el-Marra was abandoned suddenly (Schwartz et al. 2012), along with Rawda and its environs further south in the semi-arid marginal steppe (Brochier in press; Barge, Castel & Brochier 2014). Synchronous and similar scale abandonments occurred across the dry-farming southern Levant (Haiman 1996; D'Andrea 2012; Harrison 2012; Finkelstein & Langgut 2014), Anatolia (Boyer, Roberts, & Baird 2006), the eastern Mediterranean (Weiberg & Finné 2013; Davis 2013; Weiss 2000: 89–90), and as far east as Turkmenistan (P'yankova 1994). In addition to regional abandonments, Anatolian excavations document conflagration and inter-settlement conflict among the social forces unleashed within the megadrought (Massa 2014; Massa & Şahoğlu 2015).

Riverine Refugia: The Euphrates and Orontes Rivers

In western Syria (fig. 3.10), the karst-fed Orontes River system encompassing the Ghab valley swamp and the Amuq Plain (Voûte 1961) was the habitat-tracking target that attracted and sustained large agricultural populations at such new urban sites as Qatna, Nasriyah, and Acharné (al-Maqdissi 2010; Yener 2005; Morandi Bonacossi 2009). To the west of this karst plateau, along the fertile littoral, springs provided for the town at Tell Arqa and its villages and Tell Sukas. Meanwhile, Ugarit and Byblos, lacking karstic springs, were subject to population reductions and site abandonments (Weiss 2014). In the southern Levant, the period IIId settlement at Tell es-Sultan/Jericho provides an illuminating example of a karstic spring refugium for sedentarizing pastoralists (Nigro 2013), and walled Khirbet Iskander continued to be occupied because of its location along a major perennial wadi (Cordova & Long 2010).

Euphrates River flow during this period, though diminished, still provided for irrigation agriculture in central and southern Mesopotamia. Hence, habitat tracking from desiccated dry-farming areas to irrigation agriculture Euphrates and Orontes River refugia was the adaptive response of dry-farming agriculturalists and Hanaean/Amorite pastoralists (Coope 1979; Eldredge 1985). In southern Mesopotamia, this population movement and its subsequent population doubling within a century generated the hypertrophic Ur III dynasty cities aligned along the Euphrates River (Adams 1981). Urban settlement also flourished and expanded during this post-Akkadian shakkanaku-period at such central Euphrates cities as Mari, Terqa, Tuttul, Emar, Carchemish, and Samsat (Butterlin 2007).

As noted, we lack the data with which to understand the effects of megadrought onset upon the Akkadian imperial agricultural economy in southern Mesopotamia. Euphrates flow alone is estimated to sustain irrigation for an area of 8000 square kilometers (Adams 1981) and a total Tigris-Euphrates flow sufficient to irrigate 30,000 square kilometers (Wilkinson 2003: 76). The extent and size distribution of Akkadian and Ur III period settlement, however, remains uncertain, since diagnostic ceramic indicators have been revised, along with epigraphic reconstructions of settlement areas. Estimates of southern Akkadian harvest are therefore not available. Estimates of aggregate Ur III cultivated area do seem nearly attainable (Nissen, Damerow, & Englund 1994: 142) given the extensive data available for Ur III shipments of, for instance, 30 tons of barley to Nippur (Sharlach 2004: 329). However, we do not know if, or to what extent, these aggregate data resulted from early Ur III attempts to straighten the Euphrates and Tigris meanders, likely generated by 4.2 ka BP/terminal Akkadian reduced river flow (Adams 1981: 164). We may perhaps assume that cereal yield per unit cultivated (Postgate 1984; Maekawa 1984) would not have been affected and that the straightening of Ur III canals could have corrected for potential aggregate yield reductions. Irresolvable, given present data constraints, is the significance of northern dry-farming exports for the wealth and resilience of the southern imperial economy. We cannot quantify the truncation at 2200 BC from either the north or the south from the epigraphic documentation for southern grain imperialization. Its effect was, nevertheless, real, and the constrained successor southern states did not imperialize the desiccated northern domains.

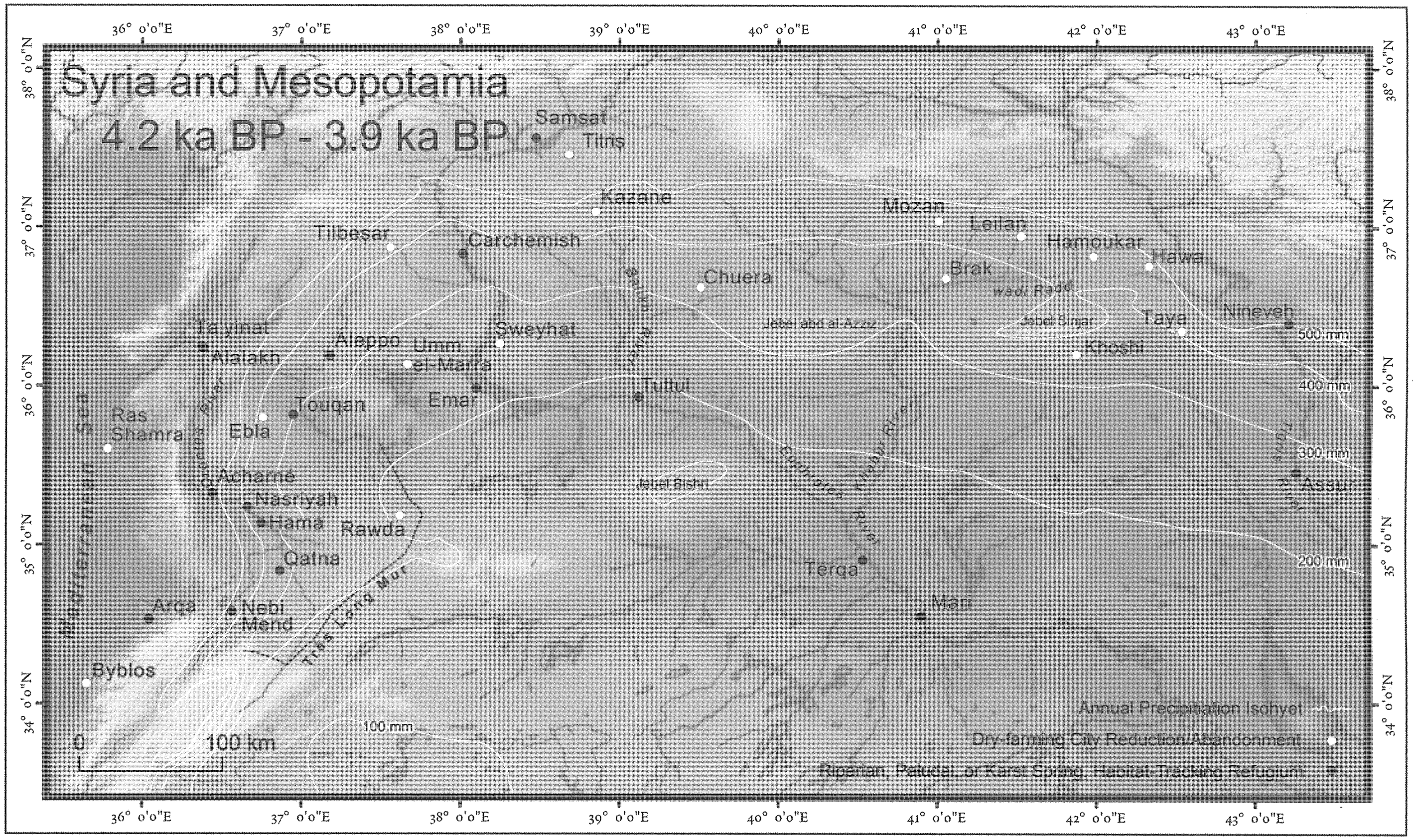

FIGURE 3.10 Map of Syria and Mesopotamia at 4.2–3.9 ka BP, showing West Asian settlement reductions and abandonments in rainfed terrains and riparian, paludal, and karstic-spring refugia. The "Très Long Mur" may have protected the new Orontes River urban refugia from Amorite nomad incursions, much as did its contemporary analog, "The Repeller-of-the-Amorites Wall," in southern Mesopotamia (H. Weiss and S. Maples).

The Steppe and Jebel Bishri

The steppe, with its 100–300 millimeters precipitation per annum, separates the dry-farming northern plains from the irrigation-agriculture south and provided for the base and transit camps of seasonal flock-foraging Hanaean/Amorite sheep-goat pastoralists. In the epigraphic and archaeological records, it is the mountainous Jebel Bishri region, in the steppe south of the Euphrates River, that features as a prominent pastoral nomad landmark, a nexus from which regional nomadization seems to have occurred in three phases.

The first phase of nomadization, at the onset of megadrought, was the interruption of seasonal pastoralist transhumance between the Euphrates River and the Khabur Plains. The drought would have rendered the Khabur Plains inhospitable to seasonal flock forage, forcing pastoralists into the steppe and the adjacent banks of the Euphrates, and then into southern Mesopotamia for Euphrates-fed foraging. Epigraphic documentation for this period of nomadization remains scant, of course, but the impressive tomb cemeteries at the Jebel Bishri point to Amorite pastoral populations (Ohnuma 2010).

The second phase was marked by the construction in southern Mesopotamia of city walls, such as "The Repeller of the Amorites Wall" in the Ur III period, intended to thwart the steppe nomads (Gasche 1990; Sallaberger 2009). The walls proved essentially porous and futile, as the pastoralist presence would only increase.

In the third phase of nomadization, the sedentarized pastoralists emerge as the controlling dynasts of southern Mesopotamian cities (Finkelstein 1966) and, with the opportunistic resettlement ca. 1950 BC that accompanied a return of pre-4.2 ka BP precipitation, undergo sedentarization in the north as well (Heimpel 2003; Ristvet 2008). It was this process that led to the ascent of Shamshi-Adad I and his Amorite kingdom in Upper Mesopotamia, with new capital cities at Ekallatum and Shubat Enlil (Weiss et al. 2012; Ristvet & Weiss 2013; fig. 3.11).

Steppic nomadization remains difficult to quantify, but is nevertheless evident in the Jebel Bishri cemeteries and in the detailed epigraphic record. Significantly, pastoral nomad excursions beyond Jebel Bishri-based camps forced Aramaean-Assyrian conflicts in the twelfth to ninth centuries BC, during the 3.2 ka BP aridification event (Postgate 1992; Kirleis & Herles 2007; Pappi 2006). In the cross-cultural archaeological record, nomadization is evident as a drought response to the conclusion of the African Humid Period in central and southwestern Sahara (Manning & Timpson 2014) and to the Tiwanaku collapse in Bolivia (Dillehay & Kolata 2004).

Conclusions

The causal weight of the global 4.2–3.9 ka BP megadrought in the regional abandonments, collapses, habitat tracking, and nomadization of West Asia

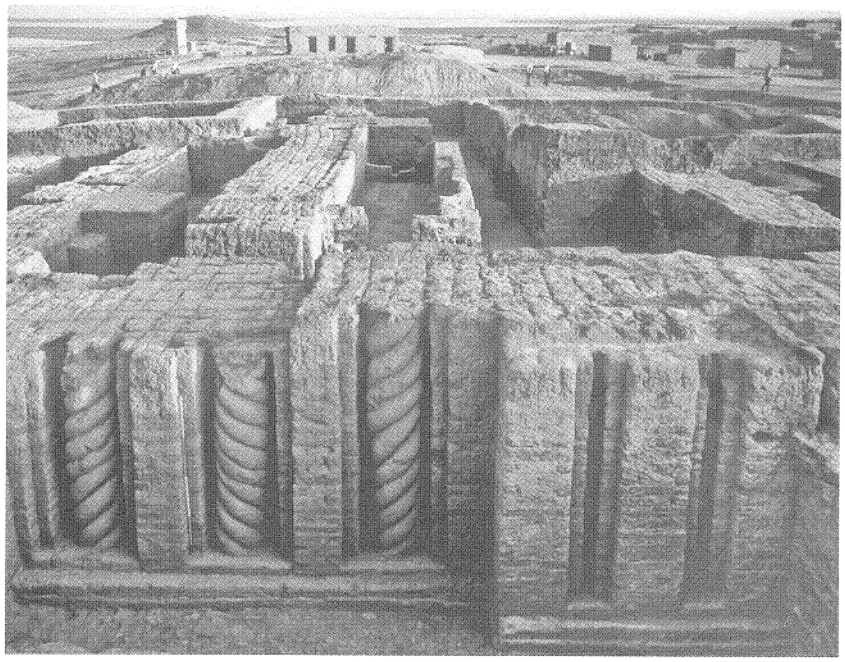

FIGURE 3.11 Tell Leilan, Acropolis Northeast, Period I, Building Level II temple, north façade, erected during the reign of Shamshi-Adad and his successors, ca. 1850–1725 BC. After the pastoralists' resettlement of the Khabur Plains, beginning ca. 1950 BC, the region would be transformed into Shamshi-Adad's north Mesopotamian kingdom, with a capital city, Shubat Enlil, at Tell Leilan (H. Weiss).

is clear, placing the Akkadian imperial collapse within a regional and global frame of abrupt climate change that crossed both ecological zones and continents. Counterfactually, these synchronous West Asian and adjacent collapse and abandonment events and processes would not have occurred without the 4.2 ka BP megadrought.

Five objections to these data and analyses may be noted here. Karl Butzer (2012) dismissed the 4.2–3.9 ka BP event paleoclimate proxies, regional and global, as uncertain and uncertainly dated. In contradiction of the archaeological and epigraphic records, and the high-resolution radiocarbon dating of the Khabur region Akkadian imperialization and abandonments, Butzer believed the apparent widespread decline is rooted in the fact that Akkadian imperialization under Sargon and Naram-Sin destroyed the cities of western Syria and thereby destroyed an interlinked world economy of urban societies and trade networks from the Aegean to the Indus. Unfortunately, Butzer's version of late third millennium history misdates the collapse by about 150 years in southern Mesopotamia, on the Khabur Plains, across western Syria, and across the Mediterranean and ignores the famous Akkadian long-distance trade that even brought boats filled with exotic goods from as far as the Indus Valley to the Akkadian capital.

Neil Roberts et al. (2011) argue that successful urban adaptations during this period disprove the "environmental determinism" of those who quantify the regional abandonments caused by the megadrought's effects upon rainfed and irrigation-agriculture production. Yet the sites purported by Roberts et al. to be successful urban adaptations, such as Brak and Rawda, either famously did collapse or were located in riparian and karstic refugia, such as Mari on the Euphrates River and Qatna along the Orontes River basin. Similarly, Glenn Schwartz (2007) imagines an isotropic, uniform landscape across Syria, thereby missing the region's hydrologic variability, and also mistakes 4.2–3.9 ka BP habitat tracking to riparian Orontes and Euphrates refugia for evidence of stable population centers.

Tony Wilkinson et al. (2007) have hypothesized that the agricultural economies of the Mesopotamian dry-farming zone were "brittle" and susceptible to collapse during brief arid "spells" like those of the instrumental record. The independent urban economies of northern Mesopotamia thrived, however, for almost 300 years without collapse before the Akkadians targeted their success, extracted still greater agricultural surplus for an additional 100 years, and planned further imperial expansion, until the well-documented megadrought made regional dry-farming impossible.

According to another recent disclaimer, the major Khabur Plains cities of Brak, Hamoukar, and Leilan collapsed at different times during the late third millennium BC and for different reasons (Ur 2015). The argument goes that the climate of northern Mesopotamia "[m]ore likely . . . experienced a gradual aridification" (p. 85), and that the farmers of Brak and Hamoukar were able to forestall disaster—unlike their singularly imperialized neighbors in Leilan—by fertilizing their fields with organic domestic refuse that included broken household pottery. Thus, while Leilan was abandoned ca. 2200 BC, Brak and Hamoukar apparently remained occupied. Ur's argument ignores the wealth of global, high-resolution paleoclimate records for the 4.2 ka BP megadrought's abruptness, magnitude, and duration, which distinguish the global event from the modern instrumental drought record for West Asia (Weiss 2012; Weiss et al 2012). Instead, Ur deems relevant an explicitly discounted idea (Weiss et al. 1993) that the megadrought was a product of volcanism and an improbable link between Leilan and Brak pre-Akkadian destruction debris and an extra-terrestrial event (Courty 2001).

The evidence for Ur's hypothesis that Leilan farmers did not fertilize their fields while Brak and Hamoukar farmers did is the relatively limited density of off-site sherd scatters at Leilan (Ristvet 2005) compared to Ur's off-site collections at Brak and Hamoukar. The off-site sherd scatters are hypothesized to be late third millennium BC residues from household manures mixed with potsherds. The sherd-scatter-as-remnant-manure hypothesis has been disconfirmed repeatedly, however (Alcock, Cherry & Davis 1994; Wilkinson 1990: 76–78; Styring et al 2017). Settlement and artifact distributions at Tell Leilan were constrained within its third and second millennium city wall, a feature absent at Brak and at Hamoukar's diffuse settlement, which likely explains the differences in the densities of off-site sherd scatters.

Missing from Ur's discussion is the Akkadian imperialization of northern Mesopotamia. The extensive evidence reviewed above indicates successful agro-production imperialization that was suddenly truncated, not only at Leilan but also across the Khabur and Assyrian Plains, from Brak to Nineveh. That evidence includes The Unfinished Buildings, probably granaries, at Brak, Leilan, and Mohammed Diyab that were suddenly abandoned at ca. 2200 BC along with the already occupied monumental buildings at Brak, Leilan and Mozan (Weiss 2012).

The archaeological record tells us that the abandonment at ca. 2200 BC was region-wide, not limited to Leilan, as Ur posits. The high-resolution radiocarbon dating of terminal occupations at Brak (Emberling 2012), Arbid (Kolinski 2012), and Leilan (Weiss et al. 2012) and the Leilan Region Survey (Ristvet 2012; Arrivabeni 2012) defines the synchronous two-stage abandonments of these cities and other settlement across the Khabur Plains at ca. 2200 BC—that is, at the end of the approximately thirty-year post-Akkadian period—at which time such ceramics also seal the occupation at Hamoukar (Gibson 2012). High-resolution radiocarbon dating places the collapse and abandonments of towns in western Syria, at Umm el-Marra (Schwartz et al. 2012), and Rawda (Brochier, in press) at the same time, coincident with abandonments across the Mediterranean and West Asia, as detailed above.

Finally, Ur's argument that the good citizens of Leilan inexplicably failed to fertilize their fields and thereby suffered collapse disregards the region's millennia-old integrated farming system of cereal cultivation and ruminant stubble grazing, documented as early as the eighteenth century BC (Matthews 1978: 90). Ur discounts sheep manure as oxidizing too rapidly in "semi-arid climates" to be an effective fertilizer, an assumption derived from an informal comment about the "Middle East" (Keen 1946: 48) that was subsequently applied to "arid and hot regions" (Buringh 1960: 253) and then to semi-arid northern Mesopotamia (Wilkinson 1982). However, modern observations of field nitrification of urine and feces by sheep grazing in north Syria, although difficult to quantify, suggest perduring fertilizing effects (Thomas et al. 2006; White et al. 1997), especially as plowing may rapidly follow grazing (Hirata, Fujita, Miyazaki 1998).

The collapse and abandonment of Akkadian imperialized dry-farming settlement and the synchronous collapse of the Akkadian Empire occurred alongside abandonment of adjacent dry-farming domains in West Asia and the Aegean, and the collapse of the Old Kingdom in Egypt due to Nile flow failure. The collapses and abandonments were a direct effect of 4.2 ka–3.9 ka BP megadrought's abruptness (less than 5 years), magnitude (30–50 percent precipitation reduction) and duration (200–300 years), which altogether reduced dry-farming agriculture to unsustainable societal limits and reduced aggregate irrigation-agriculture production. In the absence of technological innovation, or region-wide subsistence relief, the dry-farming region adaptations across West Asia were collapse, abandonment, habitat tracking to agricultural refugia, and nomadization, each a form of demographic and societal resilience. In the steppic zone bordering the Euphrates, the adaptive pastoral response was forage-driven, step-wise movement into southern Mesopotamia, which ultimately generated brief, hypertrophic Ur III-period urbanism. In Euphrates and Orontes riverine environments, both habitat-tracking and urban growth ensued, while imperial reorganization was restricted to the realigned irrigation zone of Ur III dynastic control, where the descendants of Amorite steppe pastoralists eventually achieved state power. The 4.2 ka BP abrupt megadrought provides, therefore, an explanatory causal force behind the dramatic archaeological and epigraphic record of the Akkadian Empire and its collapse.

Acknowledgments

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Appendix 3.1 Proxymap Sites and Sources

SITE #	SITE/RECORD NAME	BIBLIOGRAPHIC REFERENCE
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