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COSMIC IMPACT, THE YOUNGER DRYAS, ABU HUREYRA, AND THE INCEPTION OF AGRICULTURE IN WESTERN ASIA

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Abstract

The Younger Dryas was a major environmental event in the transition from Pleistocene to Holocene. The onset of this 1,200 year episode of cold, dry climate ca. 12,900 cal BP was sudden and swift. Recent evidence suggests that it was triggered by the impact of a comet or asteroid that fragmented in the Earth's atmosphere. The effects of this impact were felt over a wide area of the northern hemisphere. It appears to have destabilized the Laurentide ice sheet, causing a pulse of meltwater to flow into the North Atlantic, which precipitated the Younger Dryas.

The onset of the Younger Dryas was the catalyst for the transition from foraging to farming at Abu Hureyra, an early village in Syria. New evidence from the site suggests that the same cosmic event caused an airburst near Abu Hureyra. The evidence comes from soil samples dated to ca. 12,900 cal. BP, which contain glass impact spherules and scoria-like objects that formed at temperatures above 2,200°C. These are comparable to melt products from cosmic impacts elsewhere on Earth. The airburst would have destroyed the settlement and many of its inhabitants. Yet occupation resumed there, apparently immediately afterwards. Following the airburst and associated inception of the Younger Dryas, the environment around the site changed to an arid open steppe. This obliged the inhabitants of Abu Hureyra to alter their economy. Accordingly, they adopted farming and also modified their foraging practices to suit the new ecological circumstances.

Key words: Younger Dryas, cosmic impact event, airburst, Abu Hureyra

THE YOUNGER DRYAS AND THE BEGINNING OF FARMING

The inception of agriculture in Western Asia was a seminal event. It marked the transition from a way of life based on gathering and hunting to a farming economy in which the role of foraging steadily diminished. Sedentary life began shortly before this transition and became the normal mode of existence thereafter. These farmers and their descendants lived in villages, some of which became very large indeed, one of several indications of a significant increase in population following the development of farming. The agricultural economy became the basis for all later cultural and social developments across Western Asia. All of this was new and, while somewhat similar changes took place in other centers of agricultural development across the world, this transformation began earlier in Western Asia than elsewhere. From there, in time, farming and settled life spread into Central Asia, North Africa and Europe. Thus, these innovations had a profound impact well beyond their region of initial development.

Archaeologists have long considered that the alterations in climate that took place towards the end of the Pleistocene contributed to the switch from foraging to farming (Bellwood, 2005:25; Childe, 1928:42; Richerson *et al*., 2001). In the last two decades it has become clear that the onset of the Younger Dryas was a crucial catalyst

(Moore and Hillman, 1992; Smith, 1995:79; Bar-Yosef, 1998). Evidence from Abu Hureyra on the Euphrates River in North Syria indicates that it was directly responsible for the decision by the hunter-gatherer inhabitants of that village to begin farming (Moore *et al*., 2000:479).

Late in the last glaciation the climate began to ameliorate. Temperatures rose and, in many parts of the world, rainfall also increased. This process was anything but regular, however. There were several episodes of climatic warming followed by significant reversals. Of these, the Younger Dryas was the sharpest and most prolonged, an unusually long period of cold, dry climate whose effects had a major impact across almost the entire globe. Data from the Greenland ice cores demonstrate that the Younger Dryas began at 12,900/12,850 cal. BP and ended around 11,650/11,500 cal. BP (Alley, 2000; Rasmussen *et al*., 2006; Steffensen *et al.,* 2008) when warmer and more stable climatic conditions set in at the beginning of the Holocene. We have known for some time that a meltwater pulse into the North Atlantic probably triggered the onset of the Younger Dryas (Broecker, 2006). This disrupted the circulation of seawater in the North Atlantic with a consequent immediate impact on the climate in the northern hemisphere and, ultimately, worldwide. There followed hemisphere-wide cooling that caused the temperature to drop as much as 15° C (Severinghaus *et al*., 1998:145); this cool episode persisted for about 1,200 years. The question that scientists had not been able to resolve was what caused the meltwater pulse into the North Atlantic and the lengthy cold episode of the Younger Dryas.

An increasing body of evidence suggests that a major cosmic impact coincided with the onset of the Younger Dryas (YD). This hypothesis was first formulated based on observations of microspherules, nanodiamonds and iridium in late Pleistocene age deposits across North America (Firestone *et al*., 2007; Kennett *et al*., 2009a, b). These materials are rare in the geological record and only associated with other known cosmic impacts (e.g., KPg boundary, Alvarez *et al*., 1980; Gilmour *et al*., 1992). In North America this layer of exotic material occurs directly above Clovis age deposits dating between 13,100 and 12,800 cal. BP (Waters and Stafford, 2007). The layer also serves as a boundary (YD Boundary [YDB]) marking the extinction of multiple Pleistocene animal genera (mammoths, horses and others; Haynes, 2008), and possibly human population declines in some areas (Kennett *et al*., 2008; Anderson *et al*., 2011). The hypothesis remains controversial (see Holliday and Meltzer, 2010; Boslough *et al.,* 2013; van Hoesel *et al*., 2014), but multiple independent studies now confirm that these cosmic impact proxies are concentrated in the YDB, and rarely above or below in well stratified deposits and in the absence of bioturbation (Bement *et al.* 2014; Israde *et al.* 2012; LeCompte *et al.* 2012; van Hoesel *et al.,* 2012; Tian *et al*., 2011). Other studies expand the geographic range of these proxies to South America, Europe and the Middle East (Mahaney *et al*., 2010; Wittke *et al*., 2013) and the variety of other more definitive impact proxies (e.g., very high temperature melt products [Bunch *et al*., 2012; Fayek *et al*., 2012], impact spherules formed at temperature >2,200°C [Wittke *et al*., 2013], melt products with terrestrial osmium isotope ratios in YDB sediments [Wu *et al*., 2013]). Multiple measures of atmospheric chemistry are also consistent with a cosmic impact (Melott *et al*., 2010; Overholt and Merlott, 2013), and a major platinum peak found precisely at the beginning of the YD in the Greenland ice sheet is strongly supportive of a cataclysmic event (Petaev *et al*., 2013a).

The type, size and geographic extent of this cosmic impact is less certain and so are the knock-on biotic effects. More research is required to determine the type and size of the impactor (Wittke *et al*., 2013, Petaev *et al*., 2013a), but the geographic extent and quantity of impact materials (e.g., an estimated 10 million tonnes of spherules over ~50 million square kilometers; Wittke *et al*., 2013) is suggestive of a large comet or asteroid up to several kilometers in size fragmenting in the Earth's atmosphere (Israde *et al*., 2012). This resulted in multiple airbursts and small direct impacts with the Earth's surface. The geographic extent of the ejecta is comparable in size to the Australasian field that is accepted as resulting from a large fragmented comet. This scenario is consistent with the absence of a large impact crater; however, at least one sizable submerged candidate crater has been identified in the Gulf of St. Lawrence (Higgins *et al*., 2011).

If the source of Pt in the Greenland ice sheet is from the impactor itself, then this would be more consistent with an Ir-poor iron meteorite and not a comet (Petaev *et al.*, 2013a). However, the osmium isotopic composition of spherules and magnetic grains from YDB deposits is inconsistent with this hypothesis and suggests that the Os, and possibly Pt, anomalies result from melted surficial sediments in northern portions of eastern North America (Wu *et al.*, 2013). More work is needed (e.g., Petaev *et al*., 2013b) because the airbursts and fireballs associated with a swarm of fragmented comets would have been far more lethal and had greater biotic effects than an Iridium-poor iron meteorite. Regardless, this event could have destabilized the Laurentide icesheet and been partly responsible for the flux of freshwater into the North Atlantic that shutdown the ocean conveyor and precipitated the onset of the Younger Dryas and the cascading changes in global temperature and hydrology evident in the record (Rach *et al*., 2014). There is increasing evidence that the atmospheric changes at the beginning of the Younger Dryas occurred suddenly, that is in less than a decade and likely in a single year (Rasmussen *et al*., 2006:13; Steffenson *et al.*, 2008; Brauer *et al.*, 2008).

AN IMPACT OR AIRBURST NEAR ABU HUREYRA

The village of Abu Hureyra was founded by hunter-gatherers around 13,500 cal. BP. They began to farm c. 12,900 cal BP, starting with a few domestic cereals and legumes that later developed into a mature farming system (Moore *et al*., 2000:507-508). Thus, Abu Hureyra is one of the very few sites anywhere in the world where we can examine the transition from hunting and gathering to farming in a single community. The chronology for Abu Hureyra that we have derived from radiocarbon dates, most of them obtained using AMS ^{14}C, indicates that occupation was continuous throughout this process, and for several millennia thereafter through the end of the Neolithic period and beyond.

The connection between the onset of the Younger Dryas and the beginning of farming at Abu Hureyra has been clear for over a decade (Hillman *et al*. 2001; Moore *et al*., 2000: 491). The site was founded towards the end of the Allerød warm climatic interval. During this period the temperature rose and rainfall increased across Western Asia; in consequence, the forest and open woodland expanded from their Last Glacial Maximum refuges (Moore *et al*., 2000:77). This provided an unusually favorable environmental setting for the hunter-gatherer founders of the village, as can clearly be seen in the record of plant remains from the site. After several centuries of continued year-round settlement by this founding group, there was an abrupt change in environment. Again, it is the plant remains from the site that tell the story. The open woodland to the south of the site was replaced by an arid steppe. We estimate that this change took place ca. 12,900 cal. BP and that it occurred rapidly.

It was clear to us that the changes we detected in the environment were the direct consequence of the onset of the Younger Dryas. The inhabitants adopted farming immediately after (Moore *et al*., 2000:376). Although they continued to gather wild plants and to hunt animals, this represented a fundamental change in their way of life. It seems that in order to continue to live at the site under very different environmental conditions, they needed to modify their economy and so decided to take up farming. This enabled them to preserve their sedentary life but it led, in time, to major changes in settlement and society.

There were other changes, too, in the configuration of the settlement. The original hunter-gatherer settlement was composed of multi-roomed pit dwellings (Phase 1/Period 1A). Coincident with the adoption of farming, the inhabitants began to live in huts built on the surface of the ground (Phase 2/Period 1B). Adjustments in the proportions of ground stone tools could be linked to the shift to farming but, otherwise, there were no major changes in the other artifacts. It should always be remembered, however, that most of the equipment used by the inhabitants would have been made of wood, reeds, and other perishable materials that did not survive.

When we published our major study of the site (Moore *et al*., 2000) the link between the Younger Dryas and the development of farming at Abu Hureyra was strong. It appeared that the one was the catalyst for the other. That observation still stands. Evidence connected with the passage of a comet or asteroid across the northern hemisphere ca. 12,900 cal. BP presents a startling scenario for what actually took place at Abu Hureyra, however. The data come from several soil samples dated previously to the beginning of the Younger Dryas and recovered in the original excavations of the site 40 years ago. Work is ongoing, but so far these sediments contain high concentrations of glass impact spherules (20-50 μm) and unusual vesicular, scoria-like objects (SLOs >5.5 mm in size) that are comparable in character to melt products from known cosmic impacts (e.g., Meteor Crater, Arizona) and nuclear airbursts (Trinity, 1945; summarized in Bunch *et al.*, 2012). The SLOs are composed of lechatelierite intermixed with CaO-rich glasses that both form from melted calcium-rich target rock at temperatures >2,200°C (boiling point of quartz). It is highly porous and bubbles/tubes suggest vapor outgassing in semi-molten post-shock conditions. The glassy magnetic spherules are composed of the same material, and compositional characterization has ruled out formation by volcanism, anthropogenesis, authigenesis, lightning, and meteoritic ablation (Wittke *et al.*, 2013). Geochemical analysis and microstructural characterization of these spherules are most consistent with the melting of sediments in the vicinity of Abu Hureyra at >2,200°C. Sediment samples above and below the YDB at Abu Hureyra contained only trace amounts of SLOs or spherules, suggesting some mixing or none at all. These data are consistent with the hypothesis that a high-energy airburst/impact occurred close to Abu Hureyra at ca. 12,900 years ago.

The impact/airburst event and the onset of the Younger Dryas occurred in the transition from Phase 1/Period 1A to Phase 2/Period 1B at Abu Hureyra, dated to 12,900 cal BP. In the excavations we had observed a thick level of burned material covering one of the pit dwellings (Fig. 1). Part of this area of burned material lay beside the entrance to the dwelling so we had interpreted it as the remains of cooking fires (Fig. 2; Moore *et al*., 2000:113). It now appears that this burned level actually represents the combustion of the settlement during the airburst/impact that generated enormous heat on its way.

Evidently, the airburst/impact occurred within one or two kilometers of Abu Hureyra, close enough to incinerate the village and all other combustible materials nearby. Any humans present would similarly have been instantly burned to death or, if at a little distance, severely injured. This would have interrupted human life and activities at Abu Hureyra. Given this scenario, one might assume that humans would have abandoned the location altogether. This is not what happened. Instead, the settlement was rebuilt, and occupation resumed, but now with the addition of farming to the previous foraging economy.

What is our evidence for this remarkable sequence of events? The stratification indicates clearly that the village was reoccupied and new huts were built there, albeit now above ground with clay floors (Moore *et al*., 2000:122). Flint and bone tools continued to be made in much the same ways as before, indicating significant cultural continuity. Only the amounts of ground stone tools diminished over time, a trend that we have associated with the adoption of farming (Moore *et al*., 2000:180). It would be reasonable to suppose, therefore, that it was members of the same community who continued to live there. These were presumably people who escaped the inferno caused by the airburst because they were at some distance from the site when it occurred. All this is confirmed by the AMS ^{14}C dates we have obtained for Abu Hureyra 1, which strongly indicate that occupation at the site was apparently continuous, within the errors of AMS ^{14}C dating (Moore *et al*., 2000:fig. 5.27, Appendix 1; additional unpublished dates obtained recently strengthen the case for continuity).

POSSIBLE CONSEQUENCES OF AN IMPACT/AIRBURST EVENT AT ABU HUREYRA AND ELSEWHERE IN WESTERN ASIA

The evidence suggests that the asteroid or comet passed through the northern hemisphere c. 12,900 cal. BP, breaking up and causing a series of airbursts and impacts on the way. It is hypothesized that explosions destabilized and melted portions of the Laurentide ice sheet and

Fig. 1. The burned area at the time of excavation. It covers nearly all the unexcavated portion of the trench (scale 1 m)

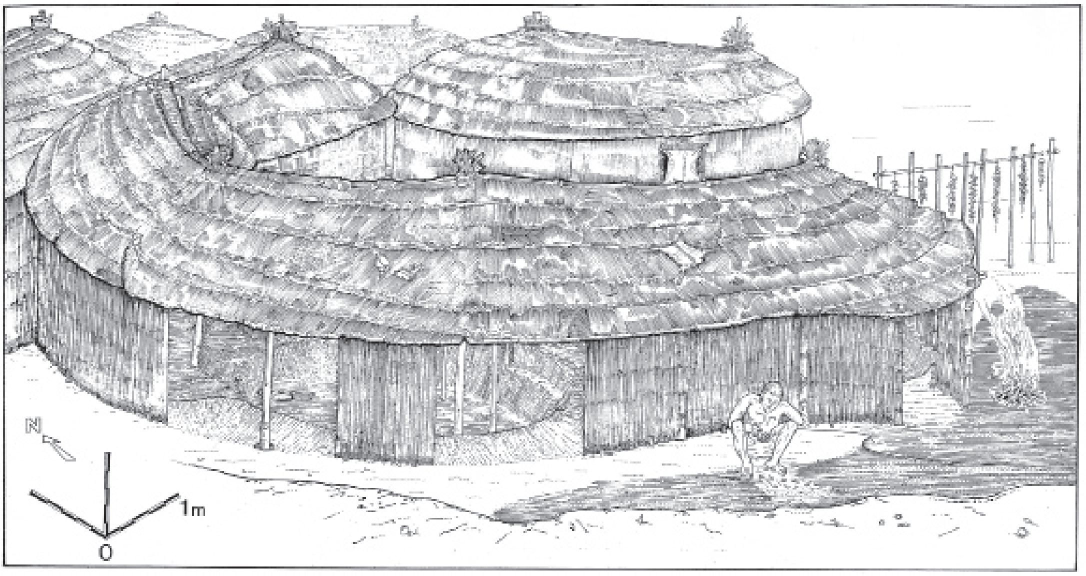

Fig. 2. The burned area beside a pit dwelling in a reconstruction drawing (Figure 5.20 in Moore *et al*., 2000)

that this drained into the North Atlantic and disrupted climate worldwide. The onset of the subsequent cold period, the Younger Dryas, precipitated disruptions in human activity in several areas of the world. At Abu Hureyra it triggered the adoption of farming.

In an extraordinary coincidence, one of the impacts/airbursts occurred in the vicinity of Abu Hureyra, destroying the site and many of its inhabitants. As the survivors rebuilt their village they found the landscape around them had irrevocably changed. The open woodland had gone, to be replaced by arid steppe brought on by the cold, dry climate of the Younger Dryas. Although the location of Abu Hureyra remained a favorable one in which to live, lying as it did on the edge of the Euphrates floodplain, the old hunting and gathering economy could no longer be continued in these changed environmental circumstances. The inhabitants decided to take up farming, cultivating a variety of domestic crops on the moister bottom-lands nearby. They did not abandon foraging, choosing to modify this element of the economy and to exploit the edible plants characteristic of the new environment. They continued to hunt gazelle which had always been a staple source of meat and which still migrated past the site each spring.

The response of the inhabitants of Abu Hureyra to this drastic event and its consequences was unusual. Elsewhere, settlement was disrupted and the hunter-gatherer communities of the late Allerød scattered across the landscape (Moore *et al*., 2000:516; Bar-Yosef, 2011). Only later did farming become the basis of existence in settlements across Western Asia.

One issue arising from this new information is the extent of the impacts/airbursts across Western Asia. We know that they occurred widely in North, Central and South America, and also in Northern Europe (Wittke *et al*., 2013). It is likely that the impact/airburst that destroyed Abu Hureyra had broader effects also. The trajectory of the fragments that caused such destruction would have been narrow, probably just a few kilometers in width, but they should still have had devastating consequences for the landscape and settlements along their path. Tracing these effects, however, is a challenge. Very few sites anywhere in Western Asia were inhabited across the Younger Dryas boundary. Of these, only open air settlements are likely to have experienced the full effects of an impact/airburst; the interiors of caves and many rockshelters would have been shielded from incineration. The necessary soil samples have rarely been collected from such open sites. And several that might be candidates for further investigation are located in regions not currently accessible to archaeologists. It will be some time, therefore, before we can trace the wider impacts of this extraordinary event across Western Asia.

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