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2 Drought, epidemic disease, and the fall of 3 classic period cultures in Mesoamerica 4 (AD 750–950). Hemorrhagic fevers as a cause 5 of massive population loss

6 Rodolfo Acuna-Soto ^{a,*}, David W. Stahle ^b, Matthew D. Therrell ^b,
7 Sergio Gomez Chavez ^c, Malcolm K. Cleaveland ^b

8 ^a *Departamento de Microbiología y Parasitología, Facultad de Medicina, Universidad Nacional Autónoma*
9 *de México, Ciudad Universitaria, México City, D.F. C.P. 04510, Mexico*

10 ^b *Tree-Ring Laboratory, Department of Geosciences, Ozark Hall 113, University of Arkansas,*
11 *Fayetteville, AR 72701, USA*

12 ^c *Zona Arqueológica de Teotihuacán, Instituto Nacional de Antropología e Historia, Teotihuacán,*
13 *Estado de México, Mexico*

Received 1 November 2004; accepted 1 February 2005

Summary The classical period in Mexico (AD 250–750) was an era of splendor. The city of Teotihuacan was one of the largest and most sophisticated human conglomerates of the pre-industrial world. The Mayan civilization in southeastern Mexico and the Yucatan peninsula reached an impressive degree of development at the same time. This time of prosperity came to an end during the Terminal Classic Period (AD 750–950) a time of massive population loss throughout Mesoamerica. A second episode of massive depopulation in the same area was experienced during the sixteenth century when, in less than one century, between 80% and 90% of the entire indigenous population was lost. The 16th century depopulation of Mexico constitutes one of the worst demographic catastrophes in human history. Although newly imported European and African diseases caused high mortality among the native population, the major 16th century population losses were caused by a series of epidemics of a hemorrhagic fever called Cocoliztli, a highly lethal disease unknown to both Aztec and European physicians during the colonial era. The cocoliztli epidemics occurred during the 16th century megadrought, when severe drought extended at times from central Mexico to the boreal forest of Canada, and from the Pacific to the Atlantic coast. The collapse of the cultures of the Classic Period seems also to have occurred during a time of severe drought. Tree ring and lake sediment records indicate that some of the most severe and prolonged droughts to impact North America–Mesoamerica in the past 1000–4000 years occurred between AD 650 and 1000, particularly during the 8th and 9th centuries, a period of time that coincides with the Terminal Classic Period. Based on the similarities of the climatic (severe drought) and demographic (massive

* Corresponding author. Tel.: +52 7773131519; fax: +52 5556232382.

E-mail address: yvonne@ibt.unam.mx (R. Acuna-Soto).

population loss) events in Mesoamerica during the sixteenth century, we propose that drought-associated epidemics of hemorrhagic fever may have contributed to the massive population loss during the Terminal Classic Period.

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36 Introduction

37 Mesoamerica, the region extending from central
38 Mexico to Central America, is considered one of
39 the cradles of human civilization. Beginning
40 approximately five thousand years ago, cultural
41 evolution led to an era of splendor known as the
42 Classic Period (AD 250–750). During this time Mes-
43 oamerica was home to some of the most advanced
44 civilizations of the pre-industrial world, among
45 them the Teotihuacan, Maya, Zapotec, Mixtec,
46 and other cultures [1,2]. This prosperity came to
47 a sudden end during the Terminal Classic Period
48 (AD 750–950), with massive population loss
49 throughout Mesoamerica. This is indicated by the
50 permanent abandonment of large urban centers
51 and villages, the end of commercial exchange,
52 the cessation of large construction projects, and
53 a marked decline in the manufacture of luxury
54 items such as fine pottery. The end of the Classic
55 Period was heralded by the fall of the city of Teo-
56 tihuacan around AD 650–750. In the Mayan area,
57 the first signs of disintegration began about AD
58 770. Between AD 770 and 890 the cities of
59 Bonampak, Palenque, Uxmal, Yaxchilan, Copan,
60 Caracol, Tikal and many others were deserted. By
61 AD 950 the entire Mayan region was uninhabited
62 [3–5]. During the same period, the Zapotec, Mixtec
63 and Cholula cultures also collapsed [6]. Current
64 explanations for Classic Period decline include lim-
65 ited agricultural potential of the region, soil ero-
66 sion, drought, famine, hurricanes, earthquakes,
67 social upheaval, warfare, and political failure to
68 sustain the complex urban infrastructure and far-
69 flung trade networks,. However, none of these
70 arguments are supported by unequivocal evidence
71 and the precise cause of the collapse remains
72 unknown [3–5].

73 Sixteenth century population collapse in 74 Mexico

75 Mesoamerica experienced another episode of mas-
76 sive depopulation in the sixteenth century. Esti-
77 mates of the number of inhabitants in 1519, the
78 year of the arrival of the Spaniards, vary from 10
79 million up to 30 million. Without entering the de-
80 bate about the size of the Mesoamerican popula-

tion of 1519, what is indisputable is that by 1600
only two million individuals remained in the area.
Thus, based on the high estimate of 30 million
the total mortality was 93%, while for the low esti-
mate of 10 million total mortality amounted to
80%. In any case, the decimation of the native pop-
ulation in Mexico between 1519 and 1600 consti-
tutes one of the worst demographic catastrophes
in human history [7]. It is true, of course that newly
imported diseases such as smallpox, measles and
mumps caused high mortality among the immuno-
logically unprotected native population, leading
to approximately seven million deaths [7]. The ma-
jor population losses, however, were caused by a
series of epidemics of a hemorrhagic fever called
Cocoliztli, a disease unknown to both Aztec and
European physicians. The first cocoliztli epidemic
started in 1545, and caused eleven million deaths,
or 84.6% of the pre-epidemic population, leaving a
population of only four million inhabitants [8,9]. A
second epidemic of cocoliztli began in 1576, result-
ing in the death of another two million people [10].

Although the etiological agent of cocoliztli
remains unidentified, we know that the disease
was swift and deadly. It started with high fever,
severe headache, insatiable thirst, weak pulse,
and jaundice. Next, patients became demented
and restless. Hard painful nodules appeared
behind one or both ears, sometimes so large that
they occupied the entire neck and half of the
face. This was accompanied by intense chest and
abdominal pain and dysentery. Blood flowed from
the ears, anus, vagina, mouth and nose. Relapses
were common and the few survivors were left
emaciated and extremely weak. Autopsies of
those who succumbed to the disease showed the
liver to be enlarged and hard. Splenomegaly and
lung hemorrhage were also found. Hemorrhagic
fevers reappeared briefly during the 17th, 18th
and 19th centuries, although by this time the dis-
ease was called Matlazahuatl. Those epidemics
also caused high mortality [9].

Did eight century drought contribute to classic decline?

The 16th century cocoliztli epidemics occurred
during a severe and sustained megadrought, when

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127 drought extended at times from central Mexico to
128 the boreal forest of Canada, and from the Pacific
129 to the Atlantic coast [11]. Subsequent outbreaks
130 of hemorrhagic fevers in the 17th, 18th and 19th
131 centuries were also associated with drought [11].
132 Here, we propose the hypothesis that the massive
133 population loss of the Terminal Classic Period in

Mesoamerica (AD 750–950) may have been due in
part to epidemics of hemorrhagic fevers during
the megadroughts of the eighth, ninth and tenth
centuries. Our hypothesis is based on the similar-
ities of the climatological (drought) and demo-
graphic (large population loss) events of the
sixteenth century in the same area.

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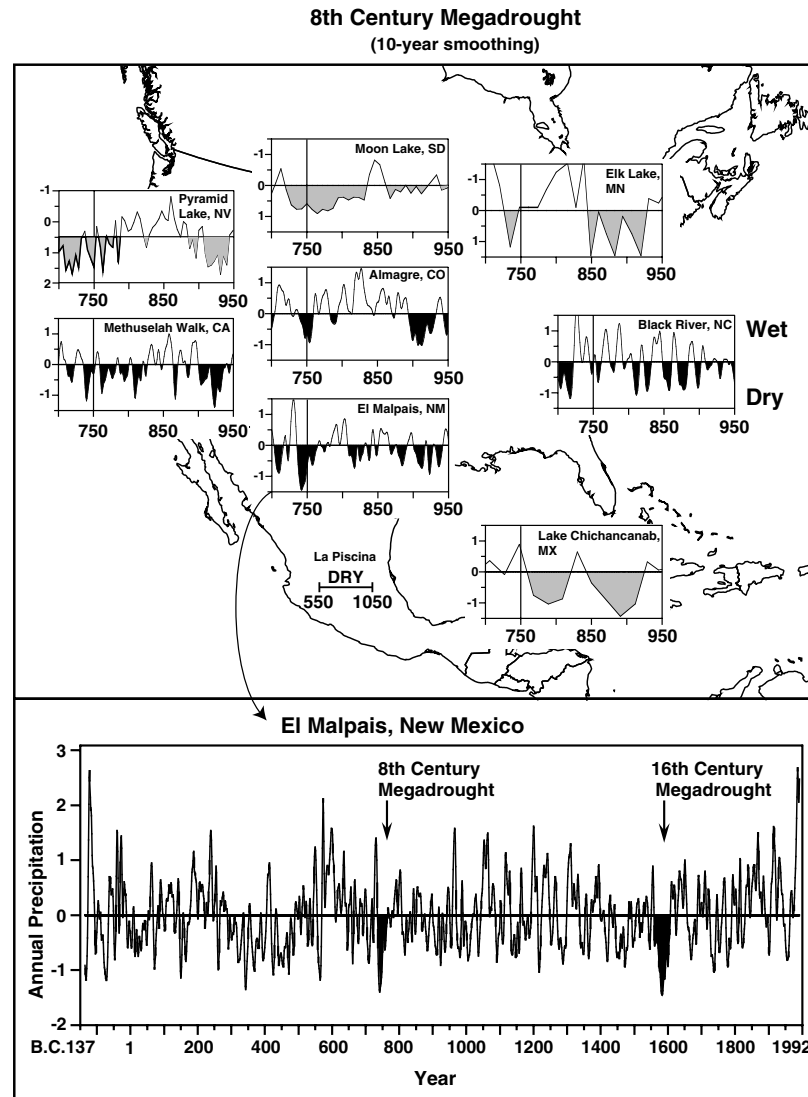


Figure 1 Selected climate proxies from North America provide preliminary documentation of widespread and prolonged drought during the Terminal Classic Period (10 year smoothing has been applied to all normalized proxy time series). Tree ring and lake sediment data indicate that the 8th and 9th century megadrought extended from the northern Great Plains, across the southwestern United States, and into central Mexico and the Yucatan peninsula (top). The annual precipitation reconstruction for El Malpais, New Mexico (bottom), based on tree rings indicates that the 8th century megadrought was one of the worst multi-decadal droughts in the past 2000 years. Tree-ring data from Colorado and New Mexico document severe drought from AD 735 to 765, and may provide accurate and precise dating for the onset of the epic droughts of the late first millennium AD. Sedimentary records from Elk Lake, Minnesota; Moon Lake, South Dakota; Pyramid Lake, Nevada; La Piscina de Yuriria, Guanajuato; and Lake Chichancanab, Yucatan, suggest much greater persistence to the 8th century megadrought than indicated by the tree-ring data, and show a strong second pulse of prolonged drought late in the first millennium (ca. 900). Recent analyses of sediments from the Cariaco Basin in the southern Caribbean Sea indicate that severe decadal drought during the 8th and 9th centuries extended to the coast of Venezuela [17].

141 Precipitation reconstructions from El Malpais,
142 New Mexico and Durango, Mexico, together with a
143 recently developed tree-ring chronology from Pue-
144 bla in central Mexico, indicate that the drought
145 from 1540 to 1625 was the worst event to impact
146 North America and Mesoamerica in the past 1000
147 years [12]. In fact, the 16th century megadrought
148 appears to have begun in central Mexico and spread
149 north and eastward into the United States and
150 southern Canada. A closer analysis reveals that
151 both the 1545 and 1576 cocoliztli epidemics oc-
152 curred during brief wet episodes within the era of
153 prolonged drought. This pattern resembles the se-
154 quence of dry-then-wet extremes that prevailed
155 during the initial outbreak of Hantavirus pulmonary
156 syndrome in 1993 and 1994 in the Four Corners Area
157 [13]. The Hantavirus reservoir *Peromyscus manicul-*
158 *atus* proliferates in response to rain after a pro-
159 longed drought. This experience provides a model
160 for cocoliztli, in which an animal reservoir may am-
161 plify the etiological agent of cocoliztli in response
162 to rain after being subject to the constraints of a
163 long drought.

164 **Proxy evidence for terminal classic**
165 **drought**

166 The collapse of Mesoamerican cultures appears to
167 have occurred during a period of severe drought
168 [14–18]. Between the 8th and 10th centuries a
169 severe and prolonged drought impacted a huge
170 region over North America and Mesoamerica
171 extending from the Mayan area, across Mexico to
172 the southwestern United States and into the
173 northern Great Plains (Fig. 1). This is indicated
174 by long tree ring and sediment records extending
175 across much of western North America, Mexico,
176 and the Caribbean Sea. Together, these data indi-
177 cate generally dry conditions between AD 650 and
178 1000, particularly during the 8th and 9th centu-
179 raries, which coincides with the Terminal Classic
180 Period (AD 750–950). These appear to have been
181 some of the most severe and prolonged droughts
182 to impact North America–Mesoamerica in the past
183 1000–4000 years.

184 The best documentation of severe sustained
185 drought during the mid-8th century may be seen
186 in the El Malpais tree-ring record from New Mexico
187 (Fig. 1). Analyses of instrumental precipitation and
188 drought indices during the 20th century, along with
189 tree-ring reconstructions of climate in Mexico and
190 the Southwestern United States, indicate that an-
191 nual and decadal droughts can both simultaneously
192 impact the entire region from New Mexico and

Texas down into central Mexico. The 1950s
drought, for example, persisted for a decade and
extended from the Colorado Plateau in the south-
western USA southward into the Mesa Central of
Mexico.

The tree-ring data from New Mexico also indi-
cate several short periods of abundant rain within
the 8th century megadrought (not shown). As in
the 16th century, these short wet periods within
the megadrought may have created the favorable
conditions for the outbreaks of hemorrhagic fevers.
This could be explained by the existence of a
drought-rain sensitive reservoir that multiplies
the etiological agent.

Severe multi-decadal drought is indicated for
the Terminal Classic Period by most of the proxies
presented in Fig. 1 (excluding North Carolina), but
the only high resolution record available for this
time period in Mesoamerica was recovered from
Lake Chichancanab in the Yucatan [14,15]. Exactly
dated, climate sensitive tree-ring chronologies
and other high resolution paleoclimatic proxies
will have to be developed in Mexico for this time
period before the magnitude and spatial scale of
Terminal Classic drought can be determined for
Mesoamerica. Nonetheless, the available data
from the Yucatan and southwestern USA imply
widespread drought over Mexico in the 8th and
9th centuries.

Conclusions

The events during the Terminal Classic Period were
very likely complex, dynamic, and distributed over
a long time. The effects of hemorrhagic fevers do
not exclude other concurrent disasters promoted
by drought such as famine or war. A definitive test
of the drought and disease hypothesis would be the
identification of the same etiological agent in hu-
man remains from Terminal Classic Period and
the sixteenth century. Perhaps in the future, and
with the help of new molecular technologies this
may be achieved [19].

The massive population losses of the Terminal
Classic Period and 16th century caused cata-
strophic and irreversible damage to Mesoamerican
society. At the end of the Classic Period, entire civ-
ilizations headed by large urban conglomerates dis-
appeared. In the case of the epidemics of cocoliztli
of the 16th century, Mesoamerica went from being
an overwhelmingly Indian population before the
epidemics, to a predominantly mestizo society,
creating the culture and demographics of modern
Mexico. Four hundred years passed before the

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245 country recovered the population level of 1544.
246 Indeed, many questions remain to be answered
247 about the role of epidemic disease in Mexican his-
248 tory and prehistory. But perhaps the most impor-
249 tant for the present is if whether there may be a
250 highly lethal microorganism still present in a cli-
251 mate-sensitive animal reservoir in Mesoamerica.

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