ne Late Bronze Age Crisis

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editerranean, a rich linkage of Aegean, Egyptian, Syro-Palestinian, and Hittite
go and has remained one of the mysteries of the ancient world since the event's
. Iconic Egyptian bas-reliefs and graphic hieroglyphic and cuneiform texts portray the
ons of the "Peoples-of-the-Sea" at the Nile Delta, the Turkish coast, and down into the
es clashed, famine-ravaged cities abandoned, and countrysides depopulated. Here
the Late Bronze Age crisis, alongside a radiocarbon-based chronology integrating
s, which reveal the effects of abrupt climate change-driven famine and causal linkage
Syria. The statistical analysis of proximate and ultimate features of the sequential
lriven famine, sea-borne-invasion, region-wide warfare, and politico-economic
ew ideologies were created.

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litude of Holocene climate fluctuations is less pronounced. Nevertheless, climate
me-scales and rapid shifts occurred during the Holocene [1]–[4], and significantly
has recently been shed by both paleoclimate [11]–[16] and archaeological
vent, also termed Late Bronze Age (LBA) collapse or crisis [20]–[21] This event was
ca. 1200 BC, with population migrations and wars. From this crisis arose new

ern Mediterranean hosted some of the world's most advanced civilizations. In the
ng with powerful urban centres such as Mycenae and Tiryns in Argolis, Pylos in
omenus in Boeotia, Iolkos in Thessaly, and Knossos in Crete [23]. The Hittites had
ge part of Anatolia, the north-western region of Syria, and extending eastward into
Canaanite coastal cities were prospering through trade from Egypt to Mesopotamia,
Egyptian and Hittite empires [25]. In Egypt, the New Kingdom was at its height during
r: 1307–1296 cal yr BC; historical date 1295–1279 BC) and Ramses II (first regnal
79–1213 BC) [26]–[27]. However, around 1200 BC, at the end of the LBA, the Eastern
ed 20,28–33. Several not mutually exclusive causes were put forward to explain the
s (tsunami, earthquake), technological innovations, internal collapses, and
g with states of inequality and the resulting political struggle between urban centre
Written sources from Ugarit (Syria) and Medinet Habou (Egypt) [32], [34], [40]–[42]
of cities and states in motion was due to vast movements of seafaring and inland
itten correspondences between Levantine, Hittite, and Egyptian kings indicate that
for the coastal towns as well as great empires and vassal kingdoms [34].

e Sea peoples, we still do not know exactly who they were, where they came from,
sappeared to after their raids. Some scholars are even uncertain whether the Sea
of the decline of the LBA. Recent studies [12], [22] have suggested that the Sea

complex spiral of decline in the Eastern Mediterranean world, and that this unstable
ıental causes operating over sizable areas. A climate shift, centred on the 13th–9th
ıces on Eastern Mediterranean and West Asian environments where dry farming agro-
ere the primary or secondary subsistence systems. Reduced precipitation probably
rain-fed cereal agriculturalists to habitat-tracking when agro-innovations are not
ry, the enigmatic Sea Peoples were not a bunch of pirates merely in pursuit of the
ıstituted a set of ethnic entities fleeing inhospitable regions to conquer new lands,
ht [22].

in shaping ancient societies has emerged because a direct causation fails to be
linkages are proposed at a wide regional scale. An unequivocal spatial and temporal
vidences, may offer a valuable case for emphasizing an ecological-climate influence

at the heart of the ancient civilizations and trade routes of the Eastern Mediterranean
atic proxy based on a pollen record from Hala Sultan Tekke, Larnaca Salt Lake, details
ıtern Cypriot coast during the LBA crisis (Fig. 1). Data from Hala Sultan Tekke were
ı Gibala-Tell Tweini, a thriving trade center located on the coast of the Ugarit kingdom
carbon (^{14}C) date for the LBA crisis and the Sea People raid. Cyprus and Syria had a
s before the Sea People event. They now meet through a common climate story to
crisis.

Larnaca Salt Lake (Hala Sultan Tekke) in the Larnaca Bay.
ıodern salty area. High concentrations of *Posidonia oceanica* fibers are highlighted

04.g001

36′43.68″E) was sampled in the Larnaca Salt Lake, near Hala Sultan Tekke, in
s were required for this location and this type of activity because the lake belongs to
European citizens. The field studies did not involve endangered or protected species.
arbon dated by accelerator mass spectrometry (AMS) ^{14}C on short-lived samples
ated using the program Calib Rev 6.0.1 with IntCal09 [49]. The base of the core B_{22} is
) cm depth, intercept: 3540 cal yr BP; 2 sigma (σ) calibration: 3580–3450 cal yr BP);
ı depth, intercept: 3370 cal yr BP; 2σ calibration: 3400–3340 cal yr BP). The top at
'30 cal yr BP; 2σ calibration: 790–680 cal yr BP). Terrestrial plant remains are scarce

the core B_{22}.
04.t001

ı analysis using the standard palynological procedure for clay samples. Pollen grains
cation using an Olympus microscope. Pollen frequencies (%) are based on the
ytes and spores of non-vascular cryptogams. Aquatic taxa frequencies are calculated

to the terrestrial pollen sum. Dinoflagellate cysts were counted on pollen-slides, and n^{-3}). The fire history was retrieved by counting the pollen-slide charcoal particles (50–agments per cm^{-3}). Concentrations have been plotted on a linear depth-scale. The erile in bioindicators (salty deposits) [50]–[51].

ining (NJ) analysis, principal components analysis (PCA), cluster analysis, and linear method is an alternative process for hierarchical cluster analysis, finding hierarchical based on pollen-type time-series (presence/absence and abundance). NJ analysis of a tree, using branches as ecological distances between groups of taxa g. 2) using *correlation* as similarity measure and *final branch* as root. The pollen-types len-derived vegetation patterns (PdVs). A PCA was then performed to test the anges in PdV-frequencies. The main variance is loaded by the PCA-Axis1. PCA-Axis1 cale (Fig. 3). A biplot PCA was finally performed to test the distribution of samples al factors (Fig. 4). The ordination of the PdVs was further tested using basic cluster

taxa from the core B_{22} computed with *correlation* as similarity measure and *final branch* as

ummed to create pollen-derived vegetation patterns.
04.g002

d 3500 years BP to present.

ability is drawn as PCA-Axis 1 scores (PdVs). The cultivated species, charcoal wn on a linear age-scale. The main climatic event, and the historical-cultural ram.

04.g003

samples according to the two main PdVs and environmental factors.
e cumulative variance. The cluster analysis of the two main PdVs and
as computed with paired group as algorithm, and correlation as similarity measure.
04.g004

and Syria are chronologically linked, $_{LD}$CC (*P=0.05*) were computed (Fig. 3). The
e series by means of the correlation coefficient (CC). The PCA-Axes1 time-series have
al match in time and the potential delay between the two time-series. The CC is then
is numerical approach is well-adapted to detect and quantify potential links between
icients are considered, focusing on the Lag_0 value (with +.50 as significant threshold).
st the inverse- or non-correlation between the two time-series (with −.50 as a
ndicate a complete lack of correlation.

nost important natural standing water bodies in Cyprus, consists of four main lakes
agoon system that has many characteristics of semi-arid temporary salt lakes, is one
351.5 mm per year, mean annual temperatures: 19.6°C), which has been shaped
erature, net evaporation and precipitation [54]. A palynological study of modern
ninsula, Cyprus, provides a framework to understand pollen-based reconstructions of

mboula harbour, the sheltered marine environment turned to a leaky lagoon at ca. 150
AD. At Hala Sultan Tekke, the presence of *Posidonia oceanica* fibers and rhizomes
. 3) in the lower strata indicates a direct marine influence on the deposits [57], and a
lex remained constantly connected to the sea throughout the period ca. 1600–1350
e Hala Sultan Tekke, Enkomi, and Toumba tou Skourou ensured the availability of
copper ingots, and of imported goods such as ivory, tin ingots, Aegean and Levantine
as also exported to the Levant [59]. Similar material culture between the urban
ow close cultural contacts and similar economic functions within the Eastern
ysts and *Posidonia* fibers in the sedimentary sequence indicate a shift from sheltered
. 1450 and 1350 cal yr BC. This first environmental shift is concomitant with the
e harbour. Iacovou [60] mentioned that the settlement of Kition-Bamboula was not
13th century BC. Kition acquired importance as a port of export for the southern coast
ad begun to malfunction. The Hala Sultan Tekke harbour, which had served as the port
he Late Cypriot period (ca. 1600 BC) [61]–[62], started to become the Larnaca Salt
lagoon, coastal marsh and finally into an enclosed salt lake), while Kition maintained a
[61].

ll-reflected in the core B_{22} pollen record. The two main PdVs (Fig. 2) isolated for the
ranean woodland (MW), correspond to two contrasted environments (Fig. 3). The
3C may be primarily due to ecological imbalances following the closure of the
led to the decline of the florishing harbour economy as suggested by Iacovou [60].
d to the important fire activity in the area, probably for agricultural purposes (Fig. 3).
ion from a MW-dominated to a DS-dominated environment is gradual. The first step
second step was reached at ca. 1200 cal yr BC. The drivers of environmental
nt as no fire activity or changes in the lagoon are attested. The agricultural activity, rich
.200 cal yr BC. The PCA-biplot (Fig. 4) indicates that agriculture only became one of
nics since ca. 850–750 cal yr BC.

sis had affected most of the Eastern Mediterranean and adjacent regions [58], [63]–
l political organization that typified the LBA had come to an end. This major
urst of renewed activity [66]–[67] that had repercussions far beyond the original
w social and economic structures dictated the establishment of new population and

curred at Hala Sultan Tekke during the period encompassing the LBA crisis and the
lVs correspond to the main loadings in the PCA, explaining most of the variance for
ccounts for +0.746 of total inertia (Fig. 3). DS (+0.82) is loaded in positive scores,
+0.56) and wet forbs (+0.11). The other clusters show no significant scores (lower
distant branches in the NJ (Fig. 2), and samples during the LBA period are clearly split
axis shows a dry *versus* wet time series, variations in PCA-Axis 1 scores may only
ıe LBA and IA periods.

e recorded between ca. 1200 and 850 cal yr BC (Fig. 3). The area surrounding Hala
e precipitation and groundwater probably became insufficient to maintain sustainable
ıounts of precipitation at Hala Sultan Tekke, leading to a dry LBA-IA boundary (Fig. 5),
an by marked increases in $\delta^{18}O$ values on Ashdod Coast [68]–[69] and Soreq Cave
d Ras El-Ain [71], in the Dead Sea [15], as well as reduced Nile floods [14], [72]–[73],
ıarges [30]–[31], [74], and a dry event in coastal Syria [11] corroborate the hydrologic
in Cyprus during the Late Bronze Age crisis. A vegetation model-based climate
reconstructed from pollen data extracted from the European Pollen Database, also
s period (Fig. 5).

e last 5000 years.

the 3200 cal yr BP drought event. (**a**) Pollen-derived climatic proxy from Hala
Axis1. Negative scores correspond to higher humidity whereas positive scores
natic proxy from Tell Tweini, Syria, expressed as PCA-Axis1. Positive scores
gative scores indicate dry periods [11]; (**c**) Time-series (5000 BP to present by step
ıalies from the present in mm/yr) averaged on Southeastern Mediterranean region
; the data are reconstructed from pollen data extracted from the European Pollen
dicated by lake level variations of Lake Qarun (Fayum depression, Egypt) inferred
73]; (**e**) reconstruction of annual precipitation based on botanical-climatological
ım Ain Gedi sediments (Dead Sea shore) [15]; (**f**) Abundance of Cyperaceae pollen,
ıt core from Burullus Lagoon in the north-central Nile Delta [14]. Interval of high
nterpreted in terms of increased (decreased) Nile flow; (**g**) fluctuations of the $\delta^{18}O$
el, for the last 3600 years [70]. A lower ratio indicates an increase in humidity; (**h**)
ım the core GA-112, Ashdod Coast, Israel [68]–[69]. A lower ratio indicates an
egimes at Tell Breda, Syria, obtained by correcting mean annual precipitation at
es at Ras El-Ain, Syria, obtained by correcting mean annual precipitation at

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of the drought event during the 9th century BC. In Cyprus, the belated reappearance
8th century BC seems incontestable on archaeological grounds [58]. Archaeological
ıpation reappears at the end of the 9th or the 8th century BC [75]. Egyptian, Aegean,

ersified agro-production, pastoral activities, and sustained a cultural revival during this

t an ecological-climate influence on past societal shifts. The climate proxies from Hala
[11]–[12] firmly link the island and the mainland through their comparable climatic
L), tested by $_{LD}$CC, are significantly correlated with the highest correlation coefficient
oth proxies reveal a hydrological anomaly for the 1200–850 cal yr BC period,
ught event, recorded both on the island and on the continent. The onset of the drought
e LBA crisis and the Sea People event.

te and agricultural productivity from Gibala-Tell Tweini, Northwest Syria.
l proxies are plotted against time (1500–500 cal. BC). Radiocarbon dates for the
ed stars. The time-window of the invasions at the Bronze-Iron Age boundary is
ruction layer (blue). At the top, the cross-correlogram shows the correlation
ure availability from Hala Sultan Tekke and that from Gibala-Tell Tweini. Vertical
rizontal axes show the lag (1 unit=1 sample). Significance level *P=0.05*.
04.g006

structions led by a flow of migrants, the Sea Peoples, is clearly attested in Cyprus with
e Late Cypriot IIC-IIIA transition dated to 1220–1190 cal yr BC [76]–[77]. Late Cypriot
o found at Gibala-Tell Tweini (Fig. 6), in the destruction layer dated from the end of the
enter located on the coast of the ancient Ugarit kingdom, where large-scale
arthed a well-preserved destruction layer coeval with the end of the Bronze Age world.
2] has given the first chronology for the Sea People raids with a pooled mean
ated to 1 σ at 1215–1190 cal yr BC. This ^{14}C calibration range is identical to the Late
a firm chronological link between these events. At the same time, evidence of a long-
sequent food shortages after 2970±40 ^{14}C yr BP [11]–[12] derive from a pollen record
Tell Tweini (Fig. 6). The $_{LD}$CC has revealed that this long-term dry period marked by
ne identified in Cyprus, at Hala Sultan Tekke (Fig. 3). The congruence of drought-
Mediterranean is confirmed by textual evidence [12], but the human-environmental

n Cyprus and Syria) were dated by radiocarbon chronology, we choose an objective
vocal fit. The first date for the climate event and the fall of crop yields in Syria (core
d in a matrix of radiocarbon data obtained from the destruction debris (Fig. 6). The
pooled in the matrix are statistically the same at the 95% confidence level using a
6.125<15.5). The weighted average date (2963±13 ^{14}C yr BP) gives a 1 σ calibrated
% relative probability and another age range of 1180–1160 cal yr BC with 24.3%
] and Oxcal 4.1 [78] with IntCal09. The weighted average date previously obtained for
s a pooled mean age of 2962±14 ^{14}C yr BP, with a 1 σ calibrated age range of 1215–
and another age range of 1180–1160 cal yr BC with 26% relative probability. The
and 2962±14 ^{14}C yr BP indicates that the two pooled mean ages are statistically the
key 1, where T=0.002<3.84). The weighted average date obtained by combining
r BP with no changes in the calibrations. This indicates that the LBA crisis, the Sea
riod are the same event.

astal Syria are numerically correlated, as the LBA crisis shows an identical calibration
:ause this narrative was confirmed by written evidence (correspondences, cuneiform
complex but single event where political struggle, socioeconomic decline, climatically-
migrants definitely intermingled.

:oastal Syria, this study shows that the LBA crisis coincided with the onset of a ca.
climate shift caused crop failures, dearth and famine, which precipitated or hastened
man migrations at the end of the LBA in the Eastern Mediterranean and southwest
chaeological data along the Cypriot and Syrian coasts offers a first comprehensive
opened during this chaotic period. The 3.2 ka BP event underlines the agro-productive
to climate and demystifies the crisis at the Late Bronze Age-Iron Age transition.

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