Archaeoseismology and Neocatastrophism

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INTRODUCTION

As we cannot know what will happen in the future, to estimate likely earthquake hazards we have to find out what happened in the past and extrapolate from there. Previous research has uncovered evidence of destructive earthquakes in areas of the eastern Mediterranean where only small events have been experienced recently, with the evidence drawn from realistic physical considerations and input data. For earthquakes before our era, however, historical and archaeological data, which are rarely unambiguous and always of little use to the scientist, have attracted interpretations that are influenced by the dogma of catastrophism, attributing to earthquakes the obliteration of the eastern Mediterranean region in the Bronze Age, large movements of peoples, and the demise of flourishing city-states.

In the early part of the 19th century geology was under the influence of the dogma of catastrophism, the hypothesis that changes in the Earth occurred as a result of isolated major catastrophes of relatively short duration, as opposed to the idea implicit in uniformitarianism, that small changes are taking place continuously. Catastrophism passed off the scene, now more or less completely discarded, and uniformitarianism took over. The last few decades, however, have seen a gradual re-emergence of neocatastrophism, this time in the field of archaeoseismology, particularly for earthquakes before our era in the eastern Mediterranean, bringing back into prominence the ideas of Velikovsky (1950).

To mention a few of the propounders of this dogma, Marinatos in the late 1930's postulated a catastrophic eruption of the volcano of Santorini and a seismic sea wave responsible for the demise of the Minoan civilization (Marinatos, 1939). Then followed Schaeffer (1948), who attempted to account for gaps in the sequence of civilizations in the 3rd or 2nd millennium in the Middle East within a relatively short period by a series of major seismic upheavals. He was followed by, among others, Galanopoulos, who suggested another catastrophe that became quite controversial and still is debated today, that the island of Santorini was the lost continent of Atlantis. Galanopoulos claimed that it was the sinking of Santorini into the Aegean Sea c. 1500 B.C. that wiped out the entire Minoan civilization in a single volcanic eruption that was as "cataclysmic as nuclear war" (Galanopoulos and Bacon, 1969). Then Kilian contributed with another more local catastrophe at the end of the late Bronze Age, one that allegedly caused the collapse of Mycenae and all of Peloponnesus due to a massive earthquake (Kilian, 1983). Others have followed in more recent times, attributing to earthquakes the obliteration of the eastern Mediterranean region in the Bronze Age, large movements of peoples, and the demise of flourishing city-states, including Troy.

The reason for the revival of catastrophe hypotheses is perhaps that they are easy to explain. They are too simple, too obvious, and too coincidental, particularly when they are based on inadequate or biased historical evidence and also because they have become fashionable in recent years. If the solution to a problem is not immediately obvious, a catastrophe theory, which attracts considerable publicity, can account for it (Lewis and Terris, 2002).

This article is written with the archaeoseismologist in mind. Its purpose is not to suggest that destructive earthquakes are unlikely to happen in the eastern Mediterranean region. Instead, the article is written to discuss the reasons for which one should be careful not to accept such theories at face value. The conclusions about the significance of early earthquakes, particularly those that happened before the recent historical era, must be drawn from realistic physical considerations and input data so that theories and uncertainties can actually be verified by testing the data.

PREREQUISITES

Historical information can be used to assess earthquake hazard, *i.e.*, the frequency of occurrence of past earthquakes in terms of their locations, magnitudes, and occasionally associations with surface faulting, three of the most important pieces of information in describing seismicity and tectonics. This information will be of value to the Earth scientist and engineering seismologist only when it is converted into numbers representing the epicentral locations and magnitudes of the events, accompanied by the dates of the earthquakes and an estimate of the reliability of their assessment. The prerequisite for the assessment of earthquake hazard is that these variables are known to within reasonable uncertainty limits.

It is too much to expect that this kind of information can be gleaned from archaeological evidence alone, which is always ambiguous and can seldom be used to provide the more precise answers that are needed by the engineer to assess earthquake hazard. Nevertheless, archaeological evidence can potentially provide confirmation of long-term seismicity rates, and with greater collaboration between disciplines it is likely that many refinements of the existing results will be possible.

This article is meant to be a sequal to Jean Vogt's paper "The Weight of Pseudo-objectivity", published in 1996 in *Annali di Geofisica* **49**, 1,005–1,011, a paper that draws attention to the misuse of historical data by "seismophile" archaeologists/historians, by "philocatastrophist" geophysicists, and by "armchair" geologists. We—P. Albini, N. Ambraseys, and M. Stucchi—his friends and collaborators, dedicate this to his memory.

In its simplest definition the epicentral region of an earthquake is the area over which the most severe damage occurs, and the primary intention of the assessor is to avoid as much as possible the amalgamation of different earthquakes closely spaced in time into one earthquake. Other things being equal, the larger the epicentral region, the larger are the total damage and magnitude of the event.

One must be aware of the possibility that two or more separate earthquakes can be transformed into a large earthquake. This is understandable in view of the tendency of early writers to amalgamate or duplicate seismic events.

To minimize the risk of duplication or amalgamation of historical earthquakes due to dating uncertainties, it is important to establish the simultaneity of the damage observed at different localities. Archaeological sites may have been damaged by separate historical events that occurred in the same week, month, or year but may not be differentiated in the sources or from the excavations. This amalgamation of information leads to an overestimation of the size of the damage area, and hence of the magnitude of the inferred individual earthquake.

Earthquake intensity is a convenient means of conveying in a single rating the effect of an earthquake on man-made structures at a particular place, and it is a useful parameter. Intensity scales have been devised for 20th-century types of construction, however, the vulnerability of which can differ enormously from that of historical dwellings. In the upper range of the scale, maximum intensity in any earthquake affecting vulnerable structures appears to be effectively the same; that is, the scale "saturates" at intensities VII–VIII MSK, at which point all adobe, rubble, stone, and masonry houses are destroyed and timber-framed dwellings are damaged beyond repair, so that any town or village would thus appear equally, but no more, devastated at higher intensities (Tresilian, 2002).

Loss of life is not always a diagnostic criterion of large intensity or magnitude because of the high vulnerability of the building stock and high population density in historical urban areas.

Natural exaggeration in literary sources is not difficult to detect. The authenticity of the sources, the style of narrative, internal evidence in the account, and experience gained from processing this kind of information, all combined, usually allow the estimation of the time, location, and magnitude of an earthquake, parameters which for early events to a certain measure become subjective. If one is in doubt, it is preferable not to report these parameters.

TEST CASES

For most of the earliest historical earthquakes, such as the two events discussed below, the data are insufficient to assess location, magnitude, and date of occurrence. All that we know is that there was an earthquake. Yet, in spite of this and without justification, these events have been associated with the fall of Jericho and with Uzziah's or Zechariah's earthquakes at Jerusalem, the former a Late Bronze and the latter an Early Iron Age earthquake of catastrophic dimensions.

The Jericho Earthquake

It is generally believed that an earthquake occurred during the siege of Jericho (Tell el-Sultan) by the Israelites c. 1400 B.C. This event caused the strong walls of Jericho to collapse, allowing Joshua to take possession of the place and burn it down.

The Bible, the only literary source for this earthquake, does not attribute the collapse of the walls of Jericho to an earthquake but to the besieging Israelites, who "by shouting and blowing their horns caused the walls to come tumbling down" (Joshua 6:20–21).

If we follow the Bible, the invasion of the Israelites into Palestine is usually placed 440 years before the foundation of the Temple in Jerusalem by Solomon in 960 B.C. Therefore, Jericho would have been destroyed about 1400 B.C., but not necessarily by an earthquake. Alternatively, if the views of those scholars who attempt to reconcile the descriptions of events with Egyptian history are accepted, the date of 1260 B.C. is inferred. Another option would be to follow those who reject the historicity of Joshua in favor of belief in peaceful conquest and accept a date far later than 1400 B.C. (Lemonick, 1990).

Turning to the question of what archaeology can contribute to this impasse, the earliest excavation at Jericho, in the beginning of the last century, concluded that the city was already abandoned during the invasion of the Israelites and that it had been destroyed, probably by earthquake, before 1400 B.C. (Sellin and Watzinger, 1913). A second series of excavations in the 1930's supported the biblical account for an earthquake c. 1400 B.C. (Garstang, 1948). But a third series of excavations at Jericho in the 1950's found no archaeological evidence to corroborate the biblical account of the fall of Jericho, dating the event back to a period well before 1400 B.C. (Kenyon, 1957). Jericho's walls were repaired or rebuilt no fewer than 16 times in its known history, and of the layers identified by Kenyon there was none whose destruction could have been singled out as providing special hints for destruction by the hand of Joshua instead of another conqueror, or by earthquake.

In 1997 a limited excavation, which was shrouded in political intrigue, by Nigro and Marchetti on the fringes of Kenyon's trenches found no evidence for destruction from the time of Joshua (Agence France-Presse, 1998). Wood (1999), however, who examined the results of the excavations by Kenyon and by Nigro and Marchetti, claimed that they had found the same evidence uncovered in earlier excavations that fits the biblical story for the destruction of Jericho c. 1400.

The conclusion of all this is that the date or the period of the earthquake—if an earthquake in fact occurred at all—remains highly uncertain, and that archaeology does not help much to establish the invasion period with any degree of certainty, while in Jericho and in other sites in the region the evidence points toward human, deliberate destruction.

From the examination of the available data, taking into consideration the doubts of Kenyon's dating raised by Wood, and those of Garstang's raised by Kenyon, it is prudent to consider that until archaeologists come up with a better unbiased evaluation, that one accept tentatively Kenyon's estimates. Until a better consensus is reached we must be aware that the time of

the siege and destruction of Jericho by Joshua is very uncertain, bracketed within a rather broad chronological range.

It is natural for archaeologists to seek earthquake effects in strata belonging to the conventional period of the fall of Jericho c. 1400 B.C., a period which, as we have seen, is far from being certain. As was to be expected, with Jericho located in the Dead Sea Fault zone, which is capable of producing destructive earthquakes, there is no lack of archaeological evidence to show that during the Bronze Age the site of Jericho was damaged a number of times, probably by more than one earthquake of unknown locations and magnitudes.

The problem here is that archaeological evidence for an earthquake is rarely unambiguous, and its dating is frequently based on, or influenced by, literary sources, and which often, as in our case, provides examples of how their assumed accuracy, coupled with occasional inaccurate commentaries, may influence archaeologists' interpretation and dating. This then develops into a circular process in which the uncertain date of an earthquake is transformed into a fact and used to confirm the dates of the proposed destruction strata.

From Kenyon's estimates three layers in Jericho show some good evidence of earthquake damage, namely during the periods of 8500–7000 B.C. (stratum PPNB), 3400–3100 B.C. (stratum EBA I), and 2300–1950 B.C. (stratum EBA IIIB), none of which, however, can be associated with Joshua and the fall of Jericho.

Nor does archaeological evidence from circa 1400 B.C. support the interpretation of a catastrophic earthquake. If the fall of Jericho had been due to an earthquake that was strong enough to flatten the massive walls of the city, it should have razed to the ground all the rickety dwellings in the city, granaries, and the water supply, with great loss of life, for which there is no evidence. To the contrary, we know that part of the city wall on the north side of the site was left standing (Hebrews 11:30–31). Also, Joshua says that the Israelites entering Jericho "utterly destroyed all that was in the city, men and women alike." But had there been a destructive earthquake that flattened the city walls, the Israelites would have found very few standing houses to destroy or people alive to slaughter. It seems unlikely that such a "newsworthy" event as a catastrophic earthquake would have not been mentioned by the prophets or later chroniclers.

It is natural to attribute the presence of skeletons buried under rubble to a sudden death caused by the collapse of buildings in an earthquake. In the case of Jericho, however, this is not a safe assumption. If we exclude the normal burials around Jericho belonging to the Middle Bronze Age and Garstang's finds which are not dated, the only dated skeleton on the site is not an earthquake victim. It belongs to a woman found in a room by the city wall and provides evidence for violence against the people. The woman was tightly contracted, suggesting that she had been bound in that position before she was decapitated, the vertebrae of the neck having been severed (Kenyon, 1981, p. 217).

Zechariah's Earthquake

The next case is that of the so-called Zechariah's earthquake. Biblical sources and a later historian mention another earthquake, one that affected Jerusalem in the days of Uziah in the middle of the 8th century B.C. (Amos 1:1; Isaiah 2:19, 21; Zecharaiah 14:4–5; Josphus, Ant. 9:10.4). Unfortunately, because of the existing differences between the Egyptian record and the biblical accounts during this period which were mentioned earlier, it is difficult to establish, even grossly, the period in which the earthquake happened (Kitchen, 1986).

Amos mentions the earthquake in passing without an indication of whether it caused any damage in Jerusalem, except for a rent in the Temple. About the effects of the earthquake on the Mount of Olives two other sources provide a little more information.

Zechariah (6th century B.C.) says that at that time the Mount of Olives, to the east of Jerusalem, split apart, making a very wide valley running from east to west, and that half of the mountain moved toward the north and half toward the south. This passage differs slightly from the later Masoritic version.

A later writer, Josephus (1st century A.D.), gives a somewhat different account. He says that "a great earthquake shook the ground and a rent was made in the temple .... And before the city ... half the mountain broke off from the rest on the west, and rolled itself four furlongs and stood still at the east mountain, till the roads, as well as the king's gardens, were spoiled by the obstruction."

Obviously these accounts describe nothing more than a landslide not far from the king's gardens in Jerusalem, which may or may not have been triggered by this or by another earthquake. Landslides in this region are not uncommon. For instance, the relatively large slide on the Mount of Olives, located on the slope that faces west toward the Old City, can be seen halfway up the Mount of Olives. This slide is probably much more ancient than biblical times (Wachs and Lewitte, 1984).

This is all the textual information available about this earthquake, conventionally dated to 759 B.C. and called "Zechariah's earthquake."

DISCUSSION

Regarding the earthquake in Jericho, some Bible readers have supposed that an earthquake toppled the walls of the city. The account of the Israelites conquering the city contains no reference to earthquakes, however. Moreover, we have no conclusive evidence to associate the fall of Jericho with the earthquake damage preserved on the site of the old city, nor with the damming of the River Jordan at Al-Damieh, which may be the result of a series of earthquakes over a long period of time (Kenyon, 1978, p. 36).

Archaeological reports give little or no technical justification to support the conclusion that destruction was due to an earthquake, and if so due to the very same earthquake mentioned by Amos. Available stratigraphic data cannot rule out the possibility that the observed damage was the result of later earthquakes.

In the present case, searching for archaeological evidence for the earthquake destruction of Jericho (which is not men-

tioned in the Bible narrative, our only source), occurring at the time of the Israelite invasion (the date of which is uncertain), reminds one of Kaplan's parable of the drunkard searching under a street lamp for his house key, which he had dropped some distance away, but he searches there because there is more light.

About the effects of Zechariah's earthquake, one is left with even more questions. For instance, on what evidence has the meager historical information in the Bible been translated into a catastrophic earthquake of magnitude $M_{L(sic.)}$ 8.2, which is said to have shaken Jerusalem with intensities between VIII and IX (Ben-Menahem, 1979, p. 262)? Why has this earthquake been associated so precisely with a coseismic left-lateral break of the Jericho Fault, about 25 km east of Jerusalem and from the Mount of Olives (Austin *et al.*, 2000)? Finally, how authoritative is the geological map of The Survey of Israel, which shows the fault break running east-west through the southern part of modern Jerusalem (Karta, 1985)? These are common-sense questions and they should have been answered long ago.

CONCLUSIONS

Biblical history cannot be conveniently synchronized with the stratigraphic sequences of archaeological sites. The want of agreement between biblical chronology and archaeological stratigraphy makes it almost impossible to estimate with confidence seismological parameters for earthquakes before the Archaic Period (5th century B.C.).

It is important not to presume that what we identify as earthquake damage in an excavation is the effect of one of the very few events known from literature, however well attested in the sources, and date the damage to this particular event. It could well have been one of the many missing earthquakes not mentioned in the Bible that caused the damage. Assigning all documented damage to a known earthquake is attractive and economical, but not more than that.

Careful examination of the aftermath of large, well studied earthquakes in the eastern Mediterranean regions over the last 25 centuries—that is, after the Archaic Period—shows that earthquakes seem to have had little, if any, serious long-term influence on historical developments, and no civilization could have ended as a result of earthquake or of a sequence of earthquakes (*viz.* Ambraseys, 1973).

During the last 2,000 years at least 14 earthquakes of magnitude M_s between 7.0 and 7.6 have occurred along the Dead Sea Fault zone, some of which were associated with surface faulting, killing large numbers of people; in the case of the earthquake of A.D. 1202, more than 30,000 people perished in only one district. Yet none of these events caused a serious crisis in human affairs or triggered the demise of a state even in societies of very limited technology. Quite to the contrary; we read about remedial measures taken after destructive earthquakes, of truces between belligerent states, and in a few cases even about the flourishing of the regions after a damaging earthquake.

There are, however, a few cases in which earthquakes have been responsible for the premature decline of a small rural economy, and even for mass exodus, but only when the earthquake caused permanent loss of the water supply. Otherwise there is no evidence that earthquakes seem ever to have been responsible for the ruin of a culturally advanced state, far less the end of a civilization.

In contrast with wars, epidemics, and other long-lasting calamities that have serious and prolonged effects, earthquakes, no matter how large, seem to have had little long-term impact on Man. The Mongol invasion, for instance, caused far greater, lasting damage in the Middle East than all the earthquakes in that region during that period put together. Earthquakes destroy the most vulnerable man-made structures, while warfare and deliberate damage destroy the most important for survival with uncontrollable aftereffects that make all the difference.

It may be that people always react to the inevitable hazard in a special way, distinct from the preventable hazard. Personal, political, and economic interests seem to overshadow, and in some cases suppress, the lessons to be learned from destructive earthquakes. Perhaps it is one of the most interesting findings that the lasting effects of major earthquakes over the last 25 centuries in the eastern Mediterranean region would not seem to have been significant. Soon after a damaging or destructive earthquake, vested interests invariably led people to act once again with disregard for the prospect of further such calamities, and they still do.

The chief problem with neocatastrophe theories is that their propounders do not seem to have read their original sources carefully and perhaps pay little attention to the evidence presented by others or data from outside of their own fields of expertise. They moreover tend to trespass into disciplines in which they seem to have little or no training.

Neocatastrophists must realize that their assessment of locations and sizes of early earthquakes is likely to be used at face value by Earth scientists and engineers in their calculations of long-term slip rates, recurrence rates, and design parameters for small probabilities of exceedance. Their assessments have a direct bearing on the mitigation of earthquake risk, and they must be trustworthy.

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