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Tectonic environments of ancient civilizations: Opportunities for archaeoseismological and anthropological studies

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ABSTRACT

The close spatial relation between ancient civilizations and active tectonic boundaries is robust in the Eastern Hemisphere but counterintuitive given the seismic disadvantages it implies. Explanations for the observation remain debatable, and no single explanation seems sufficient. Some possibly important factors are unrelated to seismicity, e.g., the influence of tectonism on local water resources and on resource diversity. When examined on finer spatial scales, the relation is still robust. A quantifiable influence of tectonism on civilization locations even along Mediterranean shores is suggested by their distribution. The stronger links of tectonism with derivative civilizations suggest a role of ancient trade connections. Several clues point to cultural response as an important ingredient in the dynamics resulting in the spatial relation. These are: correlation between static character and location of civilizations relative to tectonic locus; archaeologic and historic records of accelerated cultural (especially religious) change following tectonic events; and evidence that the spatial relation evolves through time via trade goods and routes. Archaeoseismology is in a key position to provide additional clues to this paradoxical relation in at least three ways: (1) providing detail on evolving societal response; (2) determining the most pertinent tectonic styles; and (3) determining the role of seismicity in Neolithic cultures that eventually became civilizations.

INTRODUCTION

The papers in this volume offer abundant evidence of the destructive seismic environment of many ancient sites. Yet, the highest civilizations to which these sites belong are clustered along the very seismogenic tectonic boundaries that give rise to the documented destruction (Fig. 1). This counterintuitive pattern requires further attention, much more than a slender literature in this direction presently supports (Bailey et al., 1993; King et al., 1994; Trifonov and Karakhanian, 2004; Force, 2008).

The tectonic boundaries that belong in this pattern are mostly convergent to transcurrent ones, associated with the southern margin of the Eurasian plate. The civilizations are those conventionally regarded as the greatest of antiquity (they could be defined as those that score eight or higher in the ten original criteria of Childe, 1950). It is worth recalling that conventional criteria for greatness in a civilization have valued cities, monumental (preservable) architecture, and (preserved and deciphered)

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writing—and anthropologists these days are equally interested in other aspects of cultural complexity. However, it is this particular assemblage of traits that corresponds so closely with tectonic boundaries, regardless of the semantic label that is attached.

Quantification of the relation was attempted for the Eastern Hemisphere by Force (2008) based on probabilistic comparison to random distribution. Measurements were taken from originating sites (to avoid the problem of imperial sprawl) of 13 civilizations to the nearest tectonic plate boundary as conventionally mapped, and these resulted in an average distance of 75 km, with two prominent exceptions (Egypt and China; the influence of tectonism on development of the latter is appreciable but not treated here). This distance can be converted to a polygon averaging 150 km wide (civilizations could be on either side of a tectonic boundary) along the total on-land length of the boundaries, and the probability was calculated for 11 of 13 civilizations finding themselves in this tectonically defined polygon, assuming random distribution. These probabilities were calculated for two different assumptions of available land areas, and both the included civilizations and tectonic boundary locations (especially where plate boundaries are partitioned) were varied to provide a sensitivity analysis. The calculations were necessarily approximate, but the calculated probabilities are so miniscule that random distribution can be rejected. The conclusion that ancient civilizations seem to be preferentially located near active tectonic boundaries seems robust.

The observed pattern is a simple one, but many mechanisms and dynamics seem possible. All of them are inherently untestable in real time, and this limits the rigor with which linkages can be proven. However, we can constrain the factors that are most consistent with our information. It is possible that the importance of tectonism acts via some other variable that is more obviously required for civilization to become established and thrive, such as climate, soils, water, and transport potential. Volcanism appears not to be of systematic importance, since few of the ancient civilizations are near Holocene volcanic centers (except in the Western Hemisphere, an intriguing relation outside the purview of this volume). Quaternary volcanism, however, did provide important soil and building material assets in Italy.

The civilizations differ so much from each other in their apparent environmental characters that it is difficult to say which of them might be related to tectonism (Table 1). Climate-controlled vegetation varies greatly and may have changed since antiquity, but latitudes ranging from ~27° to 42° have not (the difference between Tampa and Boston). Relation to type of water resource varies similarly. The relation to slightly varying styles of active tectonism is more commonly shared.

So far, it is not possible to say for certain whether seismic activity per se is important in the relation, or whether some other aspect of position near an active tectonic boundary is involved. For example, the relation shown in Figure 1 is clearly more closely related to plate boundaries than to seismic risk, especially in Iran, Tibet, western China, etc. One positive effect that is independent of seismicity is local water resources, which can be enhanced by active tectonism. If fractures in fault gouge are abundant and randomly oriented, one set will be held open by active stress, permitting greater permeability of active faults than old inactive ones (Hickman et al., *in* Force, 2008). Along tectonic boundaries, the prevalence of malarial paleopathology in those Neolithic villages that were involved in transitions to civilization (locations from Maisels, 1999) is consistent with this being an important factor.

TABLE 1. VARIATIONS AMONG RIVERBORNE WATER SUPPLY, CLIMATIC VARIABLES, AND TECTONIC MICRO-ENVIRONMENT OF ORIGINAL SITES OF SOME ANCIENT CIVILIZATIONS

Civilization	Rivers	Climate		Tectonic micro-environment
		Latitude	Vegetation	
Roman	M	41°50′N	1	E + S
Etruscan	S	42°10′N	1	E + S
Greek	S	38°N	1	E > S + Tr
Mycenaean	S	37°50′N	1	E > S + Tr
Minoan	S	34°40′N	1	E + S
SW Asian	S & M	31°50′–33°20′N	1, 2	Tr > E
Assyrian	L	36°30′N	2	Th + Tr
Mesopotamian	L	31°N	2	Th + Tr
Persian	S	30°–32°20′N	2, 3, 4	Th + Tr
Indus	L	27°20′N	5, 7	Th + Tr
Aryan India	L	29°30′N	5, 6	Th
Egyptian	L	29°50′N	7, 8	N.A.
Chinese	L	34°40′N	9	N.A.

Notes: Rivers: S—small, M—mid-size, and L—large. Vegetation: 1—Mediterranean scrub; 2—short-grass steppe; 3—conifer forest; 4—mountain vegetation; 5—dry tropical forest; 6—dry tropical scrub; 7—desert; 8—floodplain; 9—mixed and broadleaf forest. Tectonic environment: E—extensional; S—subduction-related; Tr—transcurrent; Th—thrust. N.A.—not applicable.

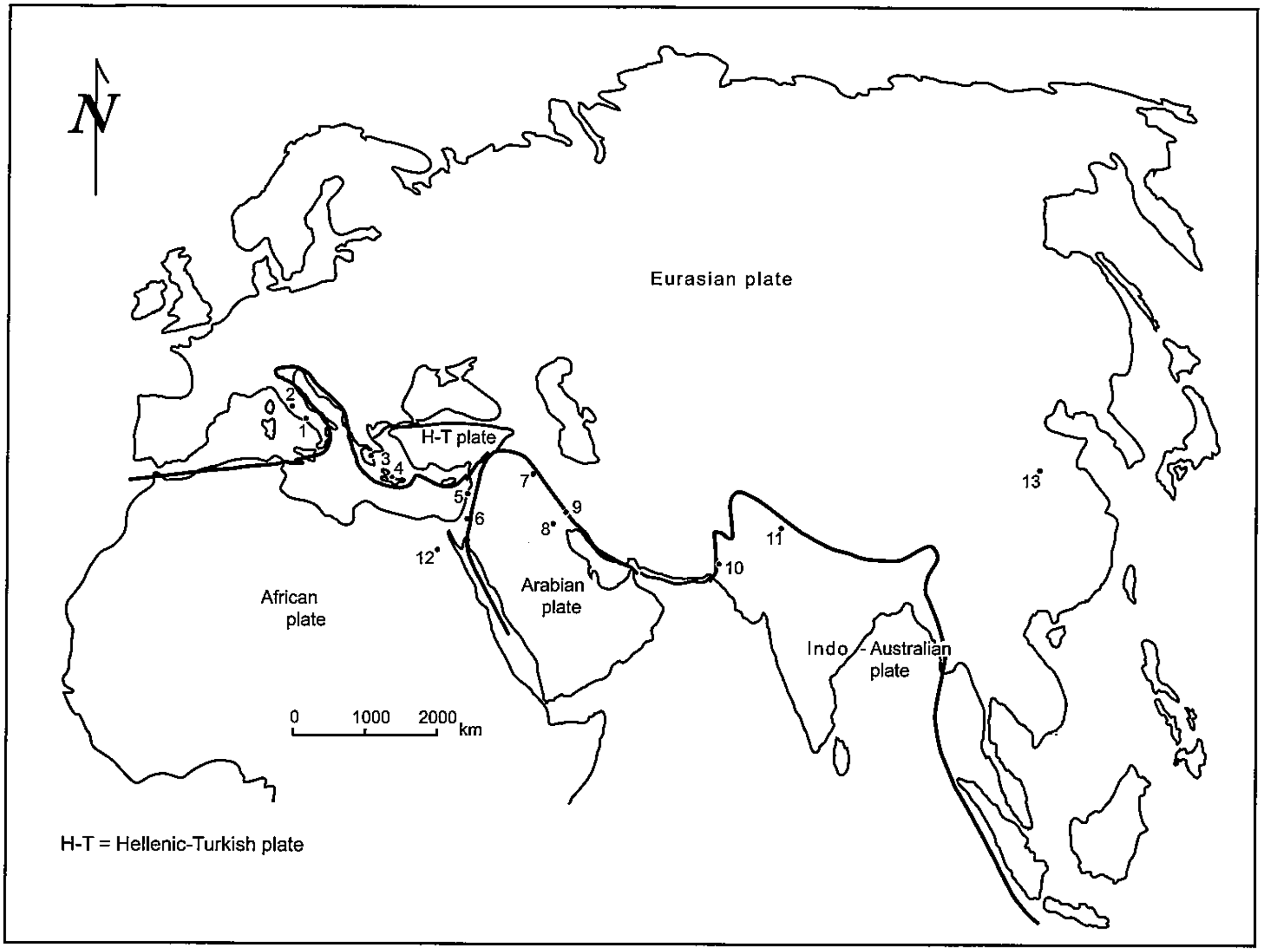

Figure 1. Locations of originating sites of 13 prominent ancient civilizations relative to various aspects of the southern boundary of the Eurasian plate (after Force, 2008). Civilizations (and sites) shown are 1—Roman (Rome), 2—Etruscan (Tarquinii-Veii), 3—Greek (Corinth) and Mycenaean (Mycenae), 4—Minoan (Knossos-Phaestos), 5 and 6—West Asian (Tyre and Jerusalem), 7—Assyrian (Ninevah), 8—Mesopotamian (Ur-Uruk), 9—Persian (Susa-Pasargadae), 10—Indus (Mohenjodaro), 11—Aryan India (Hastinapura), 12—Egyptian (Memphis), and 13—Chinese (Zhengzhou).

Another proposed factor independent of seismicity is the juxtaposition of different soils and topographies along active faults, especially transcurrent faults (cf. Bailey et al., 1993), providing a greater diversity of resources in the cultural equivalent of a biological edge effect. Trifonov and Karakhanian (2004) suggested the presence of anomalous geochemical fields along active faults, a possibility that seemed remote until de Boer et al. (2001) documented an example at Delphi.

ADDITIONAL QUANTIFIABLE LINKS

The relation between ancient civilizations and tectonic boundaries seems apparent not only at hemispherical scale but also at finer scales, for example, along the shores of the Mediterranean. These shores were certainly important to emerging civilizations there, and some would say this factor predominates. However, if the distribution of the African-Eurasian plate boundary is compared to ancient sites of civilization along opposing shores, a probable influence of tectonism shows through. The tectonic boundary broadly follows the south shore in the western Mediterranean but the northern and north-insular shores in the eastern part (Fig. 1). Ancient sites of civilizations (using a looser definition to allow more cases) follow the same path (Carthage, Syracuse, Rome, Tarquinii-Veii, Corinth, Mycenae, and Knossos-Phaistos). This relation itself looks persuasive, but an additional quantitative test would complement it. We can compare distances of tectonic boundaries versus seashores (of the time, where this is known) for the 11 originating sites of Figure 1.

The average seashore distance is ~1.48 times greater than the tectonic-boundary distance, implying a probability of random distribution that is very small but ~75 times greater than that for tectonic boundaries. Even along Mediterranean and Near Eastern shores, civilizations apparently located their originating sites near active tectonic boundaries.

Does the relation result in finer-scale vignettes? Perhaps a tectonic influence suggests itself in the Hellenic realm (Fig. 2). Mycenaean and later Greek civilization nucleated in a zone of distributed deformation along the on-land prolongation of the North Anatolian fault and its offsets along the Gulf of Corinth and other extensional structures. Where the tectonic zone passes northward into the Aegean, the spread of each civilization stalled, at Iolkos for the Mycenaeans and on Euboea (Evia) for the Greeks, though earlier, simpler Neolithic villages continued across this boundary into more quiescent parts of Thessaly.

Force (2008) attempted to constrain the number and structure of possible solutions by comparing subsets of both the civilizations and their pertinent geologic environments. He showed that the closest relation is between tectonic boundaries and those ancient civilizations generally called derivative, i.e., those that evolved under some influence from more senior civilizations. This relation of civilization subsets suggests an influence of trade (however accomplished).

The propagation of trade routes, from more advanced settlements in the Near East to sites that eventually became great ancient civilizations, mimics tectonic boundaries more closely than one would expect given the availability of other routes. Figure 3 shows such propagation from Bronze Age through early Iron Age times in the Eastern Mediterranean area. Perhaps most impressive is the replication of the "draped" shape of the plate boundary between Cyprus and Crete by trade routes, based on the distribution of Bronze age stone anchors. Other trade routes existed also, of course, extending, for example, to Maikop, Danubian, Hallstatt, Scythian, etc. (cultures in seismically more quiescent north-central Eurasia), but these routes did not produce civilizations (as defined here) until long after the period of antiquity, if ever.

If one measures the length of trade routes propagating toward eventual ancient civilizations as shown in Figure 3, ~79% of this length is within 100 km of an active plate boundary. (Routes destined for other sites of production or resource exploitation such as Kanesh do not count in this calculation.) A probability analysis was not attempted, because the appropriate structure for it is unclear, but perhaps it is unnecessary because its conclusion is intuitively obvious. Trade routes to eventual civilizations tended for some reason to follow tectonic boundaries, perhaps because each incremental stage in trade-route propagation was to

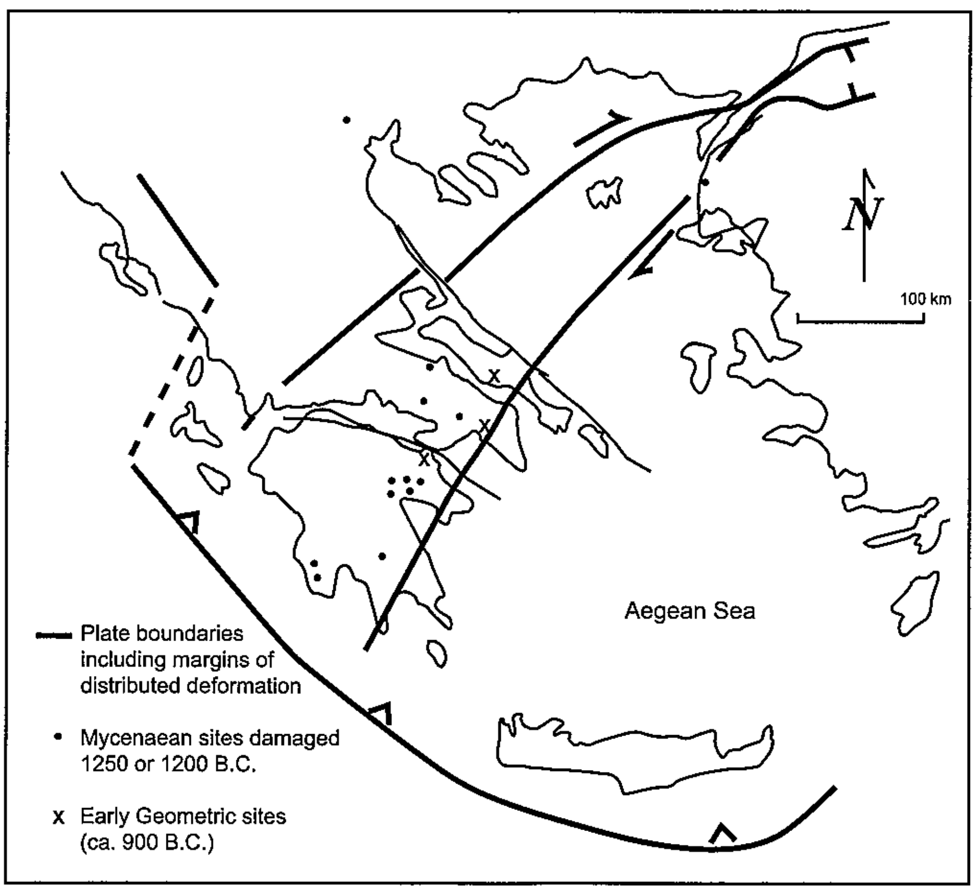

Figure 2. Sites of Mycenaean palaces destroyed by earthquakes in 1200 and 1250 B.C. (from Kilian [1996] and other sources) relative to approximate boundaries of distributed deformation along the projection of the North Anatolian fault in the Hellenic realm (from McClusky et al., 2000). The distribution of destroyed Mycenaean palaces, with only a few exceptions, includes all the palaces of that civilization, suggesting not only ancient tectonic activity along this structural trend, but also the localization of palaces along it. The major early Geometric Age sites shown (from Coldstream, 2003) follow the same trend ~300 yr later.

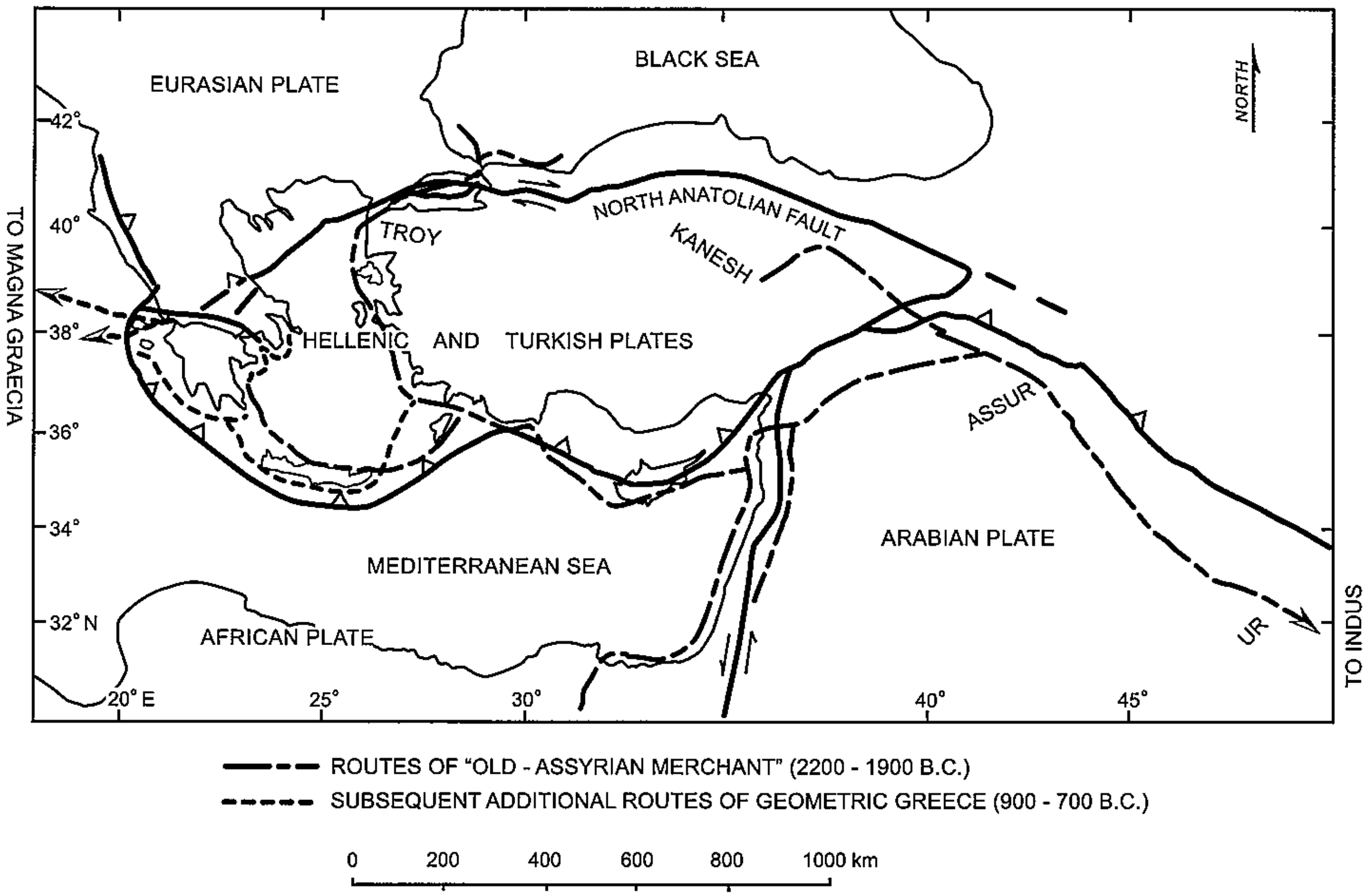

Figure 3. Evolution of trade routes in the Near East and Eastern Mediterranean from Bronze Age through early Iron Age times, superposed on plate boundaries. Trade in tin and copper from 2200 to 1900 B.C. is from Kuhrt (1998) and that for Geometric Greece (900–700 B.C.) is from Coldstream (2003), using distribution of late Bronze Age stone anchors in the marine realm from McCaslin (1980, route 2).

a settlement where an expectation of change produced more receptivity to "civilized" goods.

This trade-route clue and two others suggest the importance of long-term cultural response in the observed spatial relation. One of these is a relation between cultural character of civilizations and their distance to active tectonic boundaries. Those farthest from these boundaries tended to endure longer times with essentially the same character (Force, 2008, Fig. 2 therein), i.e., they were more static (and perhaps used their building material resources more slowly). A third clue suggesting the part played by cultural response is the link with cultural change, especially religious change, corresponding to tectonic events. Earthquakes in Greece and Cyprus in the fourth century A.D. correspond to changes in predominant religion in Corinth and in Kourion, respectively (Rothaus, 1996; Soren and James, 1988). An earthquake in Sparta ca. 464 B.C. provided the opportunity for a revolution (noted by Thucydides; see de Boer and Sanders, 2005). Earthquakes in Gortyn on Crete separate its Roman-era history into phases (DiVita, 1996). An earlier earthquake in southern Crete separates the Bronze Age archaeology of Kommos into different modes pre– and post–1700 B.C. (Shaw, 2006). Many other examples (reviewed by de Boer and Sanders, 2005; Nur, 2008) provide abundant evidence of societal change catalyzed by earthquakes.

Thus, we have some clues about the structure of a relation between ancient civilizations and active tectonism, but many questions remain, and explanations remain unclear. It therefore seems appropriate to turn to the potential contribution that archaeoseismology can make in explicating the true nature of the relation. This discipline (in cooperation with other archaeologists) is in a key position to provide clues that can be supplied no other way. There are at least three possible avenues of investigation that seem promising; they will now be discussed.

ARCHAEOSEISMOLOGY IN DELINEATING AN EVOLUTION OF SOCIETAL RESPONSES

Archaeoseismologists have concentrated until now on providing evidence of seismic destruction at ancient sites, and have been very successful at many of them despite many doubts among earlier archaeologists (reviewed by Nur, 2008). Progress in this direction will undoubtedly continue, and it could be harnessed in new ways. First of these is to determine the progression of societal response following destructive events.

The work of many archaeologists has shown that habitation layers below and above seismic destruction horizons are different. A variety of causes have been attributed. An especially intriguing example to archaeoseismologists is the increasing sophistication of antiseismic devices through antiquity (cf. Stiros, 1996).

We have seen examples of cultural discontinuities that apparently correspond with horizons giving evidence of tectonic activity. Perhaps most remarkable in this regard is the work of the late Klaus Kilian at Mycenaean Tiryns; he showed that archaeologic evidence of earthquakes corresponds temporally in at least three horizons with the emergence of newly dominant pottery styles. He concluded "earthquakes marked the beginning of a new phase and were related to, or even responsible for, changes in the organization and planning of the site" (Kilian, 1996, p. 67).

Discontinuities of this sort can be modeled in a number of ways. One end member is represented by a combination of archaeologic and historic evidence about the 1855 earthquake of magnitude 8.2 in the Wellington area of New Zealand, which emptied nearly all kitchen cupboards and smashed the ceramics they contained (Grapes, 2000). The destroyed ceramic population was a mixture of modes that went back several decades, whereas their replacements would have been chosen from what was in vogue at that time (McFadgen and Clough, 2009). The same principle could apply to the architecture of the containing structures and even town layout, as was better demonstrated by the 1848 Marlborough earthquake (Grapes, 2000) and 1931 Napier earthquake of New Zealand. This type of case amplifies change that has already taken place, but in itself would generally not stimulate evolutionary change. To some extent, change is only stylistic.

At another extreme, there is cultural change that involves innovation, values, and/or cultural evolution. For example, the 1755 "Lisbon" earthquake set in motion important philosophical changes throughout the Age of Enlightenment world (de Boer and Sanders, 2005). We have seen examples that involve religious change. This cultural-discontinuity model too has historical support. Rozario (2007) reviews evidence of accelerated cultural change initiated by disasters, including its treatment in the economic and psychological literatures. A third end member can be change in habitation patterns as a result of changes in the physical environment of the site, from sea level to landslides, that result from earthquakes (cf. McFadgen, 2007).

For all three models, tectonism disrupts societal inertia and thus forces the pace of change. These three end-member models apply in some respects to cultures independent of their complexity. Indeed, it might be useful to better understand the cultural response to tectonism of many different types of cultures, not just the very complex ancient ones addressed here. There is some interest in the anthropological community for this question (Eiselt, 2009).

If a net long-term effect of tectonic activity in antiquity was an evolution toward civilization, we would like to know how the observed shorter-term changes might link up to contribute to this evolution. This will require the attention of archaeoseismologists in conjunction with archaeologist colleagues to determine the responses that are immediate, in closest association with earthquake damage, and those evolutionary changes that occur in response. It would be quite instructive to know at Tiryns, for example, whether characteristic types of pottery or any other cultural material closely followed seismic events but preceded the establishment of longer-lived styles. It would also be interesting to know whether any of these changes themselves form a pattern across a succession of seismic events.

ARCHAEOSEISMOLOGY IN ESTABLISHING TYPICAL SEISMIC STYLES OF ANCIENT CIVILIZATIONS

A tendency of ancient civilizations of the old world to be located along plate boundaries of transcurrent to convergent type seems clear (Fig. 1). For a number of these civilizations, however, the most pertinent tectonic micro-environment involves extensional faulting in association with such boundaries, as, for example, extension above subduction zones (Table 1). This implies that particular tectonic styles, including seismic styles, are associated with ancient civilizations, and because societal response of some sort must be involved, one would suspect that the styles in question must have characteristic recurrence intervals and/or intensities of events. Recurrence intervals less than human lifetimes (even those of antiquity) seem typical of the pertinent tectonic structures, and the close proximity of originating sites to those structures (Force, 2008) shows that these recurrence intervals did indeed affect civilizing societies. In Assyrian Nineveh, for example, typical recurrence intervals were of sufficient importance and regularity that scribes recorded them as being 21 yr, a figure similar to that derived by Kilian (1996) for Tiryns.

Much more could be known about the relations among recurrence, intensity, and the development of civilized society. For example, are there optima in recurrence or intensity that accelerate this development relative to locales with too much activity (leading in extreme cases to abandonment) or too little? Archaeoseismology can potentially establish the chronologies and intensity records upon which the answers must be based.

ARCHAEOSEISMOLOGY OF NEOLITHIC SITES

In the area of this study, almost all the great ancient civilizations grew from indigenous roots (Aryan India being the one exception), though all those called derivative did so with inputs from adjacent established civilizations. These inputs could have spread to indigenous societies in many directions, but they seem to have preferentially spread instead along tectonic boundaries. It is therefore the influence of tectonism on indigenous prehistoric societies that needs attention, and the links that lead to civilization must be sought among them. In the region of this volume, this means Neolithic cultures, and some later cultures that retained Neolithic lifestyles as metal trade goods began to arrive (reviewed by Renfrew, 1972; Redford, 1992; Whittle, 1996, for different regions).

The case for tectonic influence for some Neolithic (and "Chalcolithic") societies is stronger than that for the civilizations that evolved from them because those precursors were closer to the tectonic boundaries. This is especially the case for the complex pre–Bronze Age cultures of Mesopotamia and the Indus-Saraswati area, as located by Maisels (1999). The first indications of advanced culture arose in the foothills east of the Tigris (at sites like Choga Mami; Oates and Oates, 1976) and west of the Indus (Mehrgarh and Nausharo; Kenoyer, 2000) near the thrust components of partitioned plate boundaries. Some of these in Mesopotamia and the Indus are the Neolithic sites, from which come the previously mentioned evidence of abundantly productive springs associated with active faults. Only when the need for increased irrigation scale arose did the nascent civilizations move away from those boundaries.

For the formative stages of these cultures, we of course have no written records; archaeology alone can supply reliable information, and archaeoseismology alone can supply information on the influence of tectonism on these societies. This can then be contrasted with the development of coeval societies in quiescent settings.

Since nominally Neolithic societies have survived into historic times in many parts of the world, a complementary approach would be to study effects of tectonism on their lifestyles and history. The processes that influenced cultural change in these societies might contribute to understanding the processes of cultural change that led to civilization elsewhere. McFadgen (2007), for example, showed ties between tectonism and cultural change based on precontact archaeology for the New Zealand Maori.

CONCLUSIONS

The dynamics of long-term change in cultures subject to active tectonism are ambiguous, but, in contrast, the eventual result seems fairly clear in the area treated in this volume—those cultures that, in addition to having a range of environmental advantages, were subjected to particular varieties of tectonic activity tended to become exceedingly complex ("great ancient civilizations" and some particularly precocious Neolithic precursors).

Though the observed spatial relation of ancient civilizations with active tectonism associated with the southern boundary of the Eurasian plate is most apparent at hemispheric scale, it seems valid in some areas at finer scales also. A previously documented closer relation to tectonic boundaries of derivative compared to primary civilizations suggests a relation to trade, and comparison of tectonic boundaries with trade-route propagation toward emerging sites of civilization shows some startling resemblances. Two other lines of evidence also suggest that long-term cultural evolution may be directly related to tectonic activity—correlation between static character and location of civilizations relative to tectonic locus, and archaeologic and historic records of accelerated cultural (especially religious) change following tectonic events. If this is the case, anthropological comparisons of "tectonic" and "nontectonic" societies of different sorts seem promising.

The existence of any spatial relation between ancient civilizations and active tectonism raises many questions, and most of them remain unresolved. Archaeoseismology is in a unique position to provide important clues in at least three areas:

1. Previous work with seismic destruction horizons has shown corresponding discontinuities in ceramic and/or architectural remains; these tectonic events have forced the pace of change but may or may not reflect cultural discontinuities. Input from the archaeoseismologist is required to differentiate first responses from subsequent ones in order to establish an evolution of changes, and to see if these link up from one event to the next to delineate any kind of long-term influence.

2. The style of societal response may vary with the typical recurrence interval between destructive events and with their intensities. Such variations are implicit in the relation of ancient civilizations to specific tectonic environments—especially extensional faulting within convergent to transcurrent boundaries—and in the typical distances of originating sites to seismogenic structures. The archaeoseismologist is indispensible in compiling the chronologic and intensity records required to establish such links.

3. The region treated in this volume is blessed with ancient historical records in addition to archaeoseismologic evidence. However, the relation probably precedes the historic period; the relation behaves as if certain Neolithic cultures were somehow favored by tectonic factors to become civilizations with histories. The archaeoseismologist is a necessary source of relevant information on the ways in which tectonism influenced Neolithic cultures.

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