# Tectonic Archaeology

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Tectonic Archaeology is conceived as an umbrella term for efforts to deal with evidence of volcanic eruptions, earthquakes, and tsunami in the archaeological record and the consequences for society. It also can serve as a foundation for Geoarchaeology in general.

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## 1. A New Discipline of Applied Plate Tectonics?

Plate Tectonics and Geoarchaeology both emerged as new fields of study in the early 1970s after many decades of incubation. By the mid-1980s, references were often made to tectonics in geoarchaeological works, particularly in the assessment of coastal and shoreline change as affecting human habitation. However, the focus of Geoarchaeology developed to deal explicitly with the Earth's *surface*, entailing areal geomorphology, local sediments, site formation processes, the living environment, and accessible raw materials. In contrast, Tectonic Archaeology deals first with *deep* Earth processes—starting with mantle convection in creating tectonic plates and governing their movements, and in generating land parcels—and surface manifestation of those processes as they affect archaeological sites. The creation of this term was stimulated by the development in Japan of three subdisciplines that deal with the effects of Plate Tectonics on archaeology: Earthquake Archaeology, TephroArchaeology, and Tsunami Archaeology.

How different are Geoarchaeology and Tectonic Archaeology? The fields of Geoarchaeology and its mirror discipline Archaeological Geology are *centripetal*: they begin with the archaeology and bring only disciplines and techniques into it that are helpful for analysing the anthropogenic record; we might also call it *inductive* for this reason because it begins with the archaeology, specifically the archaeological sediments and works outwards. Tectonic Archaeology, on the other hand, is *centrifugal*: it begins with the geology and sets up expectations for what we might encounter in the material record emanating from it according to the location of the archaeological remains; in this sense it is *deductive*. Tourloukis [1], for example, offers a model based in tectonically active regimes to predict the locations of Palaeolithic sites. King and Bailey rightly note that tectonic phenomena characteristically operate over broad areas that reach far beyond an archaeological site *and* its catchment [2] in what is called 'dynamic topography' [3] or 'dynamic landscapes' [2][4][5].

The naming of a field is always difficult, as it ostensibly defines the boundaries as well as the contents of work done under its name. Regarding the two subdisciplines based on the interface between geology and archaeology, Karl Butzer [6] described Geoarchaeolgy as "archaeology pursued with the help of geological methodology" versus Archaeological Geology as "geology pursued with an archaeological bias or application", as reported in [7]. It is often difficult to distinguish between these, but Rapp and Gifford [8] proposed that they "do not characterize two ends of a spectrum of techniques but rather two contrasting and equally legitimate research goals"—while assignment to one or the other subdiscipline often depends "on the investigator and the project", not the content! Goldberg and Macphail go even further and dismiss this debate on definitions as entirely "irrelevant", proposing that "any issue or subject that straddles the interface between archaeology and the earth sciences" falls under the remit of Geoarchaeology [9]. In a sense, the conflation of Geoarchaeology and Archaeological Geology is reasonable, and below, the term Geoarchaeology is employed to include both Archaeological Geology *and* Landscape Archaeology to act as the main discipline dealing with the Earth's surface.

Meanwhile, Tectonic Archaeology has a broader remit to include the Earth Sciences. It is a term designed to begin archaeological analysis from the deep end in order to describe and explain the resources, forms, and compositions that landmasses acquire and the geological processes they are subject to over time. Depending on where archaeological investigation is conducted, Plate Tectonics may be more or less relevant but *never irrelevant*, because all continental and insular landmasses ride on tectonic plates. McKenzie now distinguishes between oceanic tectonics and continental tectonics; he states that "The important difference between oceanic and continental tectonics is that deformation of continental lithosphere is distributed, rather than occurring on narrow plate boundaries" [10]. Nevertheless, tectonic activity operates on both types of plates, whether along the margins or in the interior (intraplate). As examples of continental tectonics, even perceived 'stable' continental areas such as the Renish Shield in Germany can be subject to incipient rifting, generating much volcanic activity (e.g., [11][12]). In North America, there are other tectonic zones that have generated seismic and volcanic activity: the Midcontinent Rift, a horseshoe-shaped failed rift that runs from Oklahoma up around Lake Superior down to Alabama [13], accounting for volcanic rocks around Lake Superior; the currently active Rio Grande rift running from Leadville, Colorado to El Paso, Texas [14]; and the New Madrid Seismic Zone, affecting seven states in the central south [15]. Thus, continents, just because they are large, are not necessarily stable or uniform; both North America and China, for example, are composite blocks of many ancient cratons (the first of the Earth's crust to have formed) as shown in the United States Geological Survey-based map [16]. Knowing the rocks of an area (volcanic, metamorphic, or sedimentary) will provide clues to what kind of processes have acted on that area but *not* the extent of the structures they belong to: that is tectonics.

The most active tectonic regions of the world are modern subduction zones. These usually consist of oceanic plates being drawn under continental plates, setting off a series of associated seismic and volcanic processes. Present-day subduction zones occur primarily around the Pacific Ring of Fire (an out-moded term but still popularly used) and in the Mediterranean. But fossil subduction zones are inherent in collision zones, such as that causing the Himalayas, where the oceanic plate of the Tethys Ocean was subducted under Eurasia until the Indian continent collided with it. Such collision zones, also referred to as suture zones or mobile belts when completed, thus represent former active margins, i.e., fossil subduction zones. Such belts or zones may be sandwiched within present-day continental regimes, such as the Qinling Orogenic Belt in China or the Central Asian Orogenic Belt (CAOB). These zones/belts are often loaded with ores and other raw materials that have been important to previous inhabitants and often form important economic zones today. Pinpointing where both past and present subduction zones occur on the map, and understanding what they consist of, will assist the geoarchaeologist in assessing the potential resources and expected landform activity within their area of investigation—or nearby, whence materials could be mined or traded, or where natural hazards from subduction processes affected human occupation.

Perhaps the most outstanding work in Tectonic Archaeology, without being named as such, is research by Bailey, King, and Force [2][5][17][18]. Working in the former Tethys subduction zone of the Mediterranean, these researchers begin their presentations with an ode to Plate Tectonics and continue to evaluate how tectonic activity has affected the landscape and, by extension, human habitation in their regions of interest. As King and Bailey have stated [2]:

> Few attempts have been made to incorporate tectonics into palaeogeographical reconstructions of early hominin sites and their associated landscapes. Tectonic processes, if they are not ignored completely at this local scale, are usually treated as background events, as occasional disruption of sedimentary processes, or as sources of volcanic raw material for stone tools.

If this has been the case for studies in hominin evolution, how much truer has it been for general Quaternary archaeology? A 'background mention' only works if the reader fully understands that background, and few archaeology courses include holistic introductions to the disciplines of the Earth Sciences to allow geoarchaeologists to do so.

## 2. Tectonic Archaeology Deriving from Japan

It is not surprising that the idea for Tectonic Archaeology, as an umbrella subdiscipline to incorporate archaeological phenomena affected by Plate Tectonics, came from a Japanese context. The Japanese Islands occupy a modern subduction zone and its accompanying supra-subduction zone (the rifted Japan Sea back-arc basin). The archipelago is far less complicated geographically than the Mediterranean subduction zone, but its internal geology is quite complex. Japan is generally known as a volcanic island arc, but this obscures more than 500 million years of its formation which contribute to the Japanese landmass being 80% sedimentary in origin [19][20]. These sedimentary accumulations include Accretionary Complexes (AC) that date to when the Japanese landmass was part of the continental edge prior to 16 million years ago. AC form primarily from sedimentary trench fill that is 'bulldozed' into the continental shelf during subduction of an oceanic plate. AC also incorporate sporadic slices of oceanic floor (ophiolites), seamounts, and limestone reef fragments which were not subducted but obducted into the AC, and metamorphosed mantle rocks known as serpentinite melangés. Several AC have also been metamorphosed at deep levels then exhumed to the surface, adding to the complicated structure. Few AC are forming in the world today because subduction generally causes tectonic erosion of the continental edge instead of accretion. This is why the southwestern Japanese coast is of great scientific interest because accretion is still ongoing, forming the offshore Nankai prism.

Japan has inherited granite basements (batholiths) that formed on the continental edge before the rifting of the archipelago. These are the magma chambers of very ancient volcanic eruptions whose surface manifestations have all eroded away. The unroofed batholiths now form the granite backbone mountain ranges of southwestern Inner Zone Japan. Present-day volcanic landforms date from several eruption phases beginning ca. 20 million years ago at the start of rifting. The footprint of Active Volcanoes is relatively small among Japan's mountainous character, which is primarily due to compression folding. Nevertheless, every square inch of Japan's surface has been subjected to tephra fallout at one time or another, or indeed multiple times. Tephra, however, is not the only volcanic product that might affect inhabitants: lava and gas emissions are also of concern. These have prompted researchers to propose a Volcanic Archaeology [21] instead of TephroArchaeology as constituted by Japanese researchers [22][23], and the name Archaeological Volcanology is also under consideration.

Together with volcanoes, earthquakes and tsunami are also subduction-zone hazards that must be endured. Landslides are also important consequences of earthquakes, but like tsunami, not all landslides can be assigned to earthquake activity, and no specific archaeological approach to landslides has yet been developed. Thus, the three subdisciplines of archaeology that have developed indigenously in Japan to monitor tectonic hazards in the archaeological record are *jishin kōkogaku* ('Earthquake Archaeology') [24], *tsunami kōkogaku* ('Tsunami Archaeology') [25], and *kazanbai kōkogaku* ('Volcanic Ash Archaeology') [23]. These can be bundled into a higher-order perspective that can be called Tectonic Archaeology.

## 3. The 'Geo' in Geoarchaeology

In distinguishing Geoarchaeology from Tectonic Archaeology, it is good to review how the Earth is treated in Geoarchaeology. 'Geo' has several meanings as a short form of 'geology' which itself is derived from Greek: the gê (in Doric, gâ) meaning 'earth, land, country', with the connecting vowel -o- and -logia meaning the 'study of' [26][27]. All the translations of gê given above are appropriate to our discussion here, but let us select 'earth' as the most inclusive as it entails an increasingly large scope of research. The use of 'earth' in geoarchaeological writing can be considered on a scale of five levels from the particular to the general:

- Level 1 is 'earth' as dirt [28]—the sediments of sites and their stratigraphic layering as recovered in archaeological excavation; this formed the topic of the first conference in Geoarchaeology in 1973 [29]. The focus on sediments by Schiffer [30] aimed at understanding site formation as a product of human behaviour; investigating stratigraphy was thus a tool for an 'anthropological archaeology' approach, aiming to reconstruct people's place in their environment (Level 4, see below). The attention given to anthropogenic layers—to the exclusion of the natural stratigraphy of archaeological sites—stimulated Karkanas and Goldberg [31] to propose a reorientation to the 'sedimentary matrix': treating artefacts, features, and anthropogenic sediments not as the primary focus but as components equal to natural sediments in an archaeological deposit.

- Level 2 is 'earth' as landforms—this is a geomorphological approach which outlines the nature and form of rocks and sediments as they occur in different environments: wet, dry, glacial, desert, fluvial, colluvial, etc. The volumes by Stein and Farrand [32][33] address these different forms of sedimentary sources and processes but mention tephra and tephrochronology only in passing.

- Level 3 is 'earth' as resources—raw materials that can be turned into artefacts. Identifying sources of raw materials is a geological exercise, while matching artefacts to their sources is generally the province of archaeometry involving geochemistry and mineralogy. A good example of this focus is the session on Geoarchaeology at the Geosciences '98 Conference at Keele University; the contents of the conference were determined by the volume's editor, Mark Pollard, who was then affiliated with the Department of Archaeological Science at the University of Bradford [34][35].

- Level 4 is 'earth' as terrane—the geology of a region which produces materials as both sediments and raw materials. Terrane is different from 'terrain', the latter essentially topographic. The geological meaning of terrane is, according to ITA [36]:

  > A rock formation or assemblage of rock formations that share a common geologic history. A geologic terrane is distinguished from neighboring terranes by its different history, either in its formation or in its subsequent deformation and/or metamorphism … An exotic terrane is one that has been transported into its present setting from some distance.

Although Japanese geologists consider the geotectonic belts making up Japanese landmass as terranes bounded by faults, recent research elsewhere suggests that terranes need not be fault bounded and that the boundary between terranes evolves over time [37]. The origin and formation of terranes, both autochthonous (including cratons) and allochthonous, are one aspect of what Tectonic Archaeology seeks to provide for understanding the locale of archaeological research.

- Level 5 is ‘Earth’ as a sphere covered by mutually moving and self-reorganising tectonic plates which entail billions of years of Earth’s history. The changing tectonic context of any particular plate or fragment thereof is what provides the geological variety created over time. That variety is the product of specific geological processes, particularly at the edges of the plates and their fragments in active subduction zones, as plates subduct one under the other, collide to form mountain ranges, or accrete intra-oceanic terranes. The various processes that occur within subduction zones include some of the natural hazards that affect society as mentioned above: volcanic eruptions, earthquakes, and tsunami—obvious targets of a Tectonic Archaeology. Once activity ceases in a former subduction zone, the geological products of those processes are frozen into the body of the Earth’s crust in mobile belts, suture zones, and fossil subduction zones—or eroded to provide trench fill for future AC or metamorphic belts. These zones may currently occupy inland positions, so that Tectonic Archaeology is not limited to currently active subduction zones.

- Level 6 is ‘earth’ as environment: the living and non-living stage for habitation on the continents and oceans carried by tectonic plates. This is the realm both of Environmental Archaeology (à la (Butzer [6]) and the Earth Sciences themselves, as the oceans, atmosphere, even other heavenly bodies are taken into account. Geologists no longer find themselves between a rock and a hard place but in the company of vapours, liquids, thunder and lightning, and a lot of biomatter.

The above scalar effects within the concept of ‘earth’ are seldom addressed in Geoarchaeology (but see Stein [38]); discussions of methods and techniques are typically applied within one of the above levels. Moreover, Geoarchaeology did not evolve in this ordering of the levels. Environmental Archaeology (Level 6) was an early concern as proposed by Butzer [6], preceding Waters’ emphasis on Level 1 stating that the job of the geoarchaeologist is to reconstruct “the geological factors of the human ecosystem from the sediments and soils” [39]. Level 2 was the focus of Stein and Farrand [32][33] in their categorising landscapes and sediments according to their geomorphological formation, in order to assess the cultural geography in different time periods. Level 3 forms the arena of Archaeological Science, particularly in identifying the raw materials and their sources as made into artefacts. Levels 4 and 5 are the domain of Tectonic Archaeology, which has heretofore been excluded from holistic characterisation for archaeology and which is our current concern.

## 4. Tectonics in Geoarchaeology

The history, development, and definition of the field of Geoarchaeology have been extensively covered by many authors (e.g., [7][8][35][38][40][41][42][43][44][45][46]). Barnes [47] takes a different tack and examines an arbitrary selection of the major geoarchaeological books and the main scientific archaeology journals to assess 1) whether and how 'tectonics' are dealt with in these publications, as well as 2) the frequencies of discussions on the specific subduction-zone processes of volcanic activity, earthquakes, and tsunami.

A definition of tectonics from Keller and Pinter is helpful,  referring to “the processes, structures, and land-forms associated with deformation of the Earth’s crust” [48]. The authors calculate that subduction zones account for 15% of the Earth’s surface, but they point out first, that deformation is distributed over a much broader zone up to several hundred kilometres wide (as in the Andes), and second, that unstable areas can occur within continents, as noted above. Intraplate tectonic activity is often due to the incipient development of oceans: rifting, as in the Red Sea or the Great Rift Valley in East Africa; or the North Sea rift isolating the British Isles from mainland Europe. Another intraplate volcanic activity is hot spot magma eruption, producing the Columbia River Basalt Province and Yellowstone, and the Siberian and Deccan Traps; or new activity in former subduction zones around ancient cratons such as the distributed volcanic fields along the southern edge of the Colorado Plateau; or the complicated geological subsurface fault system of the New Madrid seismic zone affecting seven states in the south-central United States. These examples counter the ‘faulty’ idea that large continental interiors have nothing to do with Plate Tectonics. Additionally, of course, most places that have mountains are orogenic (Greek òros mountains + gèneis) zones related to an ancient or operating subduction zone.

The term ‘tectonics’ is used here as a cover term for Plate Tectonics and all its associated processes. Geologists may object to the application of the adjective ‘tectonic’ to archaeology. However, this word simply refers to ‘building’ or ‘construction’, deriving from Greek (tektōn ‘carpenter, builder’). In the archaeological context, it can be taken to indicate that societies are often structured or constrained by tectonic processes, and archaeological sites will contain structural evidence of tectonic activities—often to the detriment of their contemporaneous occupants. Tectonic Archaeology is thus surely a more relevant term than, for example, the ‘tectonics of transcultural transactions’ [49]. Even the use of ‘tectonic plates’ has moved beyond its original context when historians and journalists speak of shifts in the tectonic plates of political relations and state systems, etc. Back when the term was first being developed [50][51]), geologists objected to the use of the term ‘Plate Tectonics’ outside of the strict meaning of the kinetics of moving plates on a sphere. An archaeological application, therefore, seems acceptable sensu lato. As mentioned above, the value of an overall Plate Tectonics approach to assessing archaeological sites and remnant human behaviour can be seen in earlier work of researchers (e.g., [17][18][52]), who nevertheless did not use the term ‘Tectonic Archaeology’ themselves.

In their textbook, Geoarchaeology, Rapp and Hill state that: “One of the major integrating concepts in the earth sciences is that of tectonics. Many of the geologic and biologic features associated with the archaeological record can be more fully understood within the context of plate-tectonic theory” [45]. Despite this, their textbook had very little explanation of Plate Tectonics itself. In promoting the study of Plate Tectonics for archaeologists, we should heed the instructive comments by George ‘Rip’ Rapp on how difficult it is to grasp another field; as a prominent Archaeological Geologist; he stated, “I was fairly narrowly trained in mineralogy and geochemistry. It has been an uphill struggle for me to learn the necessary other earth sciences and the relevant archaeology” [53]. Archaeologists need to do the opposite: needing a grounding in Plate Tectonics, it is impossible to avoid having to “master the geoscientific jargon and literature” [33]. Understanding sister disciplines is hard work, but the effort is well worth it. In that vein, geological ‘jargon’ should not be avoided, for this is the language of the field that is needed for understanding.

Geology and archaeology are sometimes each treated as holistic entities; this is far from reality in that both disciplines have developed many subdisciplines and specialisms over the decades, with much specialist jargon. Moreover, the field of geology itself has been encompassed within ‘Earth Sciences’ or ‘Geosciences’ (see an interesting distinction in [54]). Earth Sciences include geophysics, geochemistry, oceanography, seismology, petrology, sedimentology, marine geology, paleontology, and many more. Dan McKenzie, author of plate kinetics, laments that though he studied geology (stratigraphy, sedimentology, and paleontology) what he really needed was “fluid dynamics, earthquake seismology, petrology and geochemistry”; and more than just self-study from textbooks, he says he needed to learn to think like a scientist in those fields [10]. If it was difficult for geologists and physicists, like Rip Rapp and Dan McKenzie, to come to grips with all of Earth Sciences, then how easy is it for archaeologists to gain a foothold knowledge? Kearey et al. [55] show us that we are not alone in grappling with this problem of coming to terms with Earth Sciences, for they are all-encompassing:

> The initial impact of the plate tectonic concept, in the fields of marine geology and geophysics and seismology, was quickly followed by the realization of its relevance to igneous and metamorphic petrology, paleontology, sedimentary and economic geology, and all branches of geoscience. More recently its potential relevance to the Earth system as a whole has been recognized. In the past, processes associated with plate tectonics may have produced changes in seawater and atmospheric chemistry, in sea level and ocean currents, and in the Earth’s climate… This extension of the relevance of plate tectonics to the atmosphere and oceans, to the evolution of life, and possibly even the origin of life on Earth is particularly gratifying in that it emphasizes the way in which the biosphere, atmosphere, hydrosphere, and solid Earth are interrelated in a single, dynamic Earth system.

Geoarchaeology has heretofore grown out of archaeological investigation where problems are addressed or solved by techniques from Earth Science disciplines, ad hoc as needed. Although seldom addressed directly, several aspects of Plate Tectonics play a role in geoarchaeological assessments, and following McKenzie’s advice, geoarchaeologists need to learn to think more like Earth Scientists in taking tectonic processes into account in research planning.

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