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Influences of active tectonism on human development: a review and Neolithic example

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Influences of Active Tectonism on Human Development: A Review and Neolithic Example

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Two groups of researchers have independently studied the effects of active tectonism on human development. The first group focuses on tectonically influenced topography in providing varied food sources, security, natural hunting traps, and water resources through Paleolithic times. The second group suggests that active tectonism forced the pace of cultural change in antiquity, accelerating the development of cultural complexity in comparison to neighbors in tectonically quiescent areas. Economic, political, religious, and other modern evidence indicates that this may still be the case. Similarly, the effects of tectonically influenced topography can be traced into ancient agricultural societies and into some segments of the modern world. The effects of topography were particularly important in preurban stages of human development, and effects of the forced pace of cultural change were generally later and centered on towns. Potentially interesting overlaps in the Neolithic are addressed with a look at the Maori of New Zealand, who altered their way of life in response to earthquakes and consequent tsunami in the fifteenth century. The complexity of this example suggests that unidirectional processes should not be expected at the level of individual cultural entities. Many lines of evidence, however, show that tectonic activity should be considered along with other factors such as climate change in evaluating human activity and development.

1. INTRODUCTION

Recent literature presents two hypotheses that both suggest positive reinforcement of the development of our species and its cultures by active tectonism. It might appear that the two hypotheses have no common ground, despite the direction they share. This paper is an attempt to integrate the hypotheses, in order to show the variety of influences that active tectonism can have and the interactions that these influences can show. An example from New Zealand shows how complex and unpredictable a response can be.

In their work over more than a decade, King, Bailey, and their coauthors [e.g., *Bailey et al.*, 1993, 2011; *King et al.*, 1994; *King and Bailey*, 2006, 2010; *Bailey and King*, 2010] have emphasized the influence that active tectonism can have in providing diverse topographic environments and, hence, diverse resources. Humanity, in its various stages of development, has preferentially taken advantage of these resources, in comparison to more quiescent tectonic environments with less diversity. These resources include basins periodically rejuvenated by tectonic activity, with sedimentation and well-watered fertility; barriers created by tectonic activity that

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offer tactical advantage to human predators dependent on mobile and elusive prey; and ongoing creation of a landscape that is not only topographically complex, but often also ecologically complex, offering a variety of resources. The advantages resulting from tectonic activity thus include varied food sources, security, natural hunting traps, and water resources. *King and Bailey* [2006] explored the implications of their hypothesis in delineating probable early human migration routes.

The work of King, Bailey, and colleagues has so far focused on three main areas and times, the late Pleistocene of northern Greece (Paleolithic), and the Pliocene of South Africa and the Afar Triangle. We note that many other areas are pertinent for testing their hypothesis. Since workers elsewhere have suggested similar themes [e.g., *Molnar*, 1990], this seems promising. The argument could be strengthened with description of converse cases. We suggest below that the tectonic landscape approach can be extended in time outside the pre-*Homo sapiens* and Paleolithic interval that the King-Bailey group describes.

Our previous work [*Force*, 2008; *Force and McFadgen*, 2010] addressed the more recent period of classical antiquity, beginning with transitions into the Bronze Age, (i.e., about 3500 B.C. to A.D. 500, or 4000 years), and increasingly, it has focused on the impact of active tectonism on mankind's cultural development. This work began with the counterintuitive observation that "great ancient civilizations" tended to originate along active plate boundaries [*Force*, 2008, Figure 1], and we subsequently developed several other indications that pointed to tectonism forcing the pace of cultural change, eventually resulting in greater cultural complexity along active tectonic boundaries. These indications are (1) continent-scale perspectives showing complexity of ancient cultures decreasing away from these boundaries; (2) a measure of the relative stasis of cultures, which increases away from tectonic boundaries [*Force*, 2008, Figure 2]; (3) the propagation of trade routes, including island hopping, along tectonic boundaries [*Force and McFadgen*, 2010, Figure 2]; (4) the many cultural discontinuities corresponding to ancient tectonic events [*Force and McFadgen*, 2010], especially religious discontinuities [*Soren and James*, 1988; *Rothaus*, 1996; *deBoer and Sanders*, 2005]; and (5) evidence that religious and intellectual traditions molded in part by tectonism in antiquity are still being so influenced in the modern world. Tectonic events still force the pace of cultural change [*Kant*, 1790; *James*, 1906; *Skidmore and Toya*, 2002; *Davis*, 2005; *Vale and Campanella*, 2005a, 2005b; *Rozario*, 2007; *Cuaresma et al.*, 2008], as do other natural disasters (reviews and compilations by *Oliver-Smith and Hoffman* [1999], *Reycraft and Bawden* [2000], and *Hoffman and Oliver-Smith* [2002]); cultural responses to volcanic events are particularly well described [see *Sheets and Grayson*, 1979; *Fisher et al.*, 1997; *Balmuth et al.*, 2005; *Gratton and Torrence*, 2008].

These lines of evidence suggest that our cultural development scenario, although developed for the period of antiquity, is not limited to a particular time period. Remote images of the world at night show that tectonically active plate boundaries are still loci for our own peculiar type of cultural complexity; indeed, they suggest that the main locus has shifted from the Tethyan to the circum-Pacific realm.

2. A SIMPLE INTEGRATION BASED ON TIME PERIODS

A marriage of the two scenarios could have them applicable in different stages of development of our species, and we think that this simple solution is a valid part of a general integration. The topographically based model would be powerfully applicable in the hunter-gatherer stages of development, as it "accentuated and maintained topographic barriers that could be used to tactical advantage in the monitoring, trapping, and control of mobile prey species" [*King and Bailey*, 2010]. We can see that in the transition to agricultural cultures, tectonic topography would still be of great importance, as it forms discrete basins with arable floors and internal reservoirs, margined by highlands with exceptionally productive springs [cf. *Jackson*, 2006], partly due to a set of fractures held open by stress [*Force*, 2008], and with erosion of fresh rocks contributing nutrients.

Our tectonic boundary-culture model is most clearly applied to the period of classical antiquity, when required rebuilding and reordering of urban areas as a result of tectonic activity was first recorded. In some of the late Neolithic cultures that preceded this period, these requisites were already met and show unusually close spatial relations to tectonic boundaries [*Force and McFadgen*, 2010].

3. A SECOND STEP EMPHASIZING DYNAMICS AND TIME OVERLAPS

A more comprehensive synthesis would address different dynamics linking tectonism and human development, and focus on the time overlaps that follow. For example, even at the height of the classical era in Greece when and where tectonically driven cultural acceleration was most apparent (Euripides punctuating his dramas with earthquakes, Herodotus and Thucydides differing on which earthquake more significantly divided history into epochs, temples incorporating increasingly innovative systems to prevent earthquake damage, even as whole cites like Helike are downthrown beneath the waves), aspects of tectonic topography were still of importance. For example, the poet Hesiod (in "Works and

Days" of about 650 B.C.), figuratively manning his plow in Boeotia, noted "in the mountain valleys, fertile lands." This area in its tectonically formed basin provided an agricultural background of subsistence for ancient Attica. Nearby, the tectonic topography of the Gulf of Corinth provided the potential for maritime wealth. In modern cultures based on agriculture in small areas, tectonic topography is still important, as *Jackson* [2006] has shown in southern Persia.

There is no reason to think that tectonism did not promote cultural innovation during the Neolithic and earlier, although tests for this proposition are more difficult to perform. In the early Neolithic, there are already indications that the spread of village-based agricultural systems, complete with ideological trappings, tended to follow tectonic plate boundaries in the Levant and the northern margin of the "Fertile Crescent," quite independently of obsidian sources (e.g., distributions described by *Cauvin* [2000]).

Thus, the Neolithic period, and places and periods where similar lifeways prevailed, appears to be of special interest as stages of probable overlap of the two basic dynamics proposed by the two groups of investigators. Were cultures becoming more innovative at the same time that they were taking advantage of local tectonic topography?

4. A CASE FROM NEW ZEALAND

An opportunity to address this sort of question is provided by cultures that retained Neolithic ways of life into recent historic times. One of us [*McFadgen*, 2007] has studied the response of the Maori to New Zealand's tectonic environment. This example is probably one of the most detailed available responses of a Neolithic culture to tectonic activity. In addition, the unusual isolation of Maori culture allows some focus on the local cultural response to physical change alone without imported response lessons; some results including ethnographic memories were still present and recorded at European contact. This case shows, however, that the long-term results of tectonism can be complex and unpredictable by simple models. Any one example, of course, cannot stand in for the range of responses to tectonism in cultures that show great variety and occupy different environments.

New Zealand straddles the obliquely convergent tectonic boundary in the SW Pacific between the Australian and Pacific plates, some 1500 km east of Australia. It was first settled by Polynesians, the ancestors of the Maori, less than 750 years ago, and rediscovered and settled by Europeans only about 200 years ago. Its prehistory, although short, was nevertheless punctuated by significant cultural change that appears to have been strongly influenced by tectonic events. In economic and social terms, it is suggested here that the late fifteenth century tsunami inundations were a Neolithic equivalent of a "creative destruction" event [*Schumpeter*, 1942; *Rozario*, 2007] that not only destroyed physical elements of Maori culture, but through the deaths of elders, depleted their knowledge base. Maori society nevertheless recovered, but to what extent the creative outcomes of later Maori culture were a carry-on from earlier times, and what were directly stimulated by the events, requires further research to answer. What is clear, however, is that tectonic events can have effects on the landscape that reduce the resources that are available, as well as enhance them, and over a period of time, the one event can have both outcomes.

In the northern part of the North Island (Figure 1), the landscape is dominated by volcanic activity [*Lowe*, 2010], which provided the first settlers with good resources, especially rocks for making tools and soils for growing crops. Volcanic activity during the Maori period was generally minor [*McFadgen*, 2007]; the largest eruption of any real consequence to Maori, the Kaharoa, was close to the time of Maori settlement [*Hogg et al.*, 2003]. The Kaharoa Tephra Formation [*Froggatt and Lowe*, 1990] extends from the Okataina Volcanic Centre well into Northland, but only around the Bay of Plenty was it thick enough to kill vegetation and animals [*Lowe et al.*, 2002]. It would have left the Bay of Plenty landscape desolate, which probably explains why settlement of this part of New Zealand occurred later than in adjacent areas. But the tephra was light and sandy, and it generally fell on a heavier sandy loam soil. When the Maori occupied the Bay of Plenty landscape, they found that the two soils, when mixed together, were most favorable physically for growing kumara (sweet potato, an important food source) [*Gibbs and Pullar*, 1961], and these mixed soils in the Bay of Plenty form one of the largest areas of prehistoric garden soil anywhere in New Zealand.

For the remainder of the North Island and South Island (Figure 1), effects of seismic activity dominate the landscape. Here a long history of active tectonism has resulted in a distinctive landscape of tall, rugged, and steep mountains, hills, and ridges highly susceptible to slope failure, with alluvial plains and fast-flowing rivers, bounded at the coast by sandy beaches and rocky shores. Faults rupture the landscape. The most notable is the Alpine Fault, a strike-slip fault with a displacement and length of more than 400 km, with many major splinter faults to the northeast. The east coast of the North Island and northern South Island is generally being uplifted; to the west, between Taranaki and the northern South Island, the land is generally subsiding (Figure 1).

Major earthquakes drive environmental change [*Goff and McFadgen*, 2002] in this part of New Zealand. Their immediate outcomes are landslips and, in the right circumstances, tsunamis. Steep slopes may be denuded of soil and vegetation

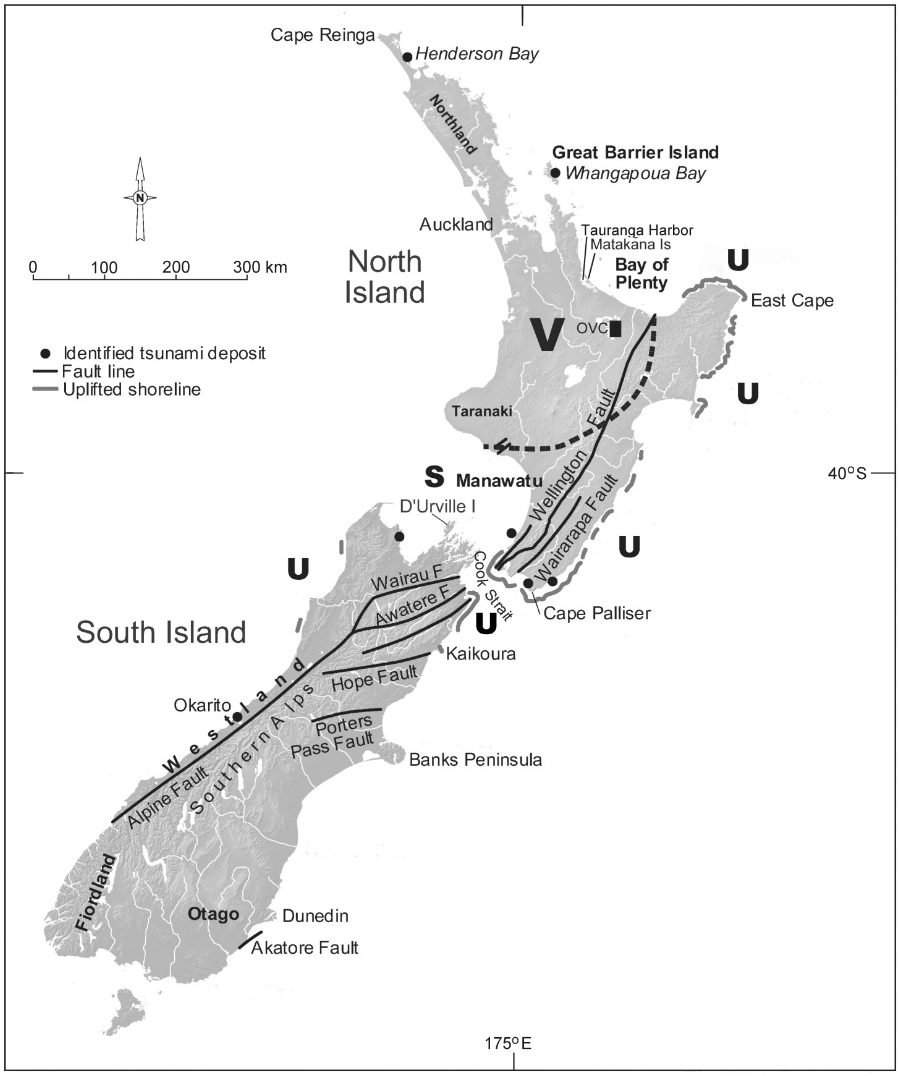

Figure 1. Map of New Zealand showing dominant tectonic influences. Approximate boundary is shown by a dashed line: northwest of the line, the dominant influence is volcanic activity (V); for the rest of the country, the dominant activity is seismic activity: uplifted shorelines (U) and subsided shorelines (S). OVC is Okataina Volcanic Centre.

[e.g., *Grapes and Downes*, 1997], which gets washed into streams and rivers and eventually reaches the sea. Delayed outcomes are the formation of aggradational terraces by rivers and the accumulation of sand dunes in coastal areas. Within 2 years, half the sediment released by landslips can reach the coast; it is mostly sand, the gravel comes later [*Adams*, 1980]. Within a few decades, new coastal dunes become stable and vegetated [*Wells and Goff*, 2006].

Uplift, subsidence, dune building, and river aggradation all had their effect on Maori communities [*McFadgen*, 2007]. Maori occupation was primarily oriented to the coast. Seismic uplift drained lagoons and destroyed habitat, material resources, and food supplies, while subsidence and compaction flooded settlements, enlarged lagoons and estuaries, and caused changes to shellfish habitat. Finally, advancing dunes and accumulating river sediments buried settlements and gardens. Earthquake activity, nevertheless, enabled the formation of friable soils on uplifted shoreline deposits, stream fans, and river terraces and exposed hard, fine-grained metamorphic rocks for tool manufacture. Earthquake shaking, in itself, was not directly destructive for Maori, as they had no masonry buildings. Yet the indirect effects of earthquakes were important.

The fifteenth century was the most seismically active period during Maori occupation [*McFadgen*, 2007]. Sedimentary deposits along the northern South Island and North

Island coasts record one or more large tsunamis that are thought to have struck in the late fifteenth century. The waves were highest in the north, where they washed to more than 30 m above sea level and traveled more than 800 m inland [*Nichol et al.*, 2003a, 2003b, 2004]. In the northern South Island and southern North Island, the waves were somewhat lower, probably around 10 m high. Large waves are mentioned in Maori traditions, but the references are often obscure. The best oral records, however, are reasonably clear and describe waves inundating gardens on cliff tops [*Smith*, 1910] and wiping out entire settlements [*Mitchell and Mitchell*, 2004].

Archaeological evidence consistent with major tsunami inundation is reviewed by *McFadgen* [2007]. Archaeological remains, including pieces of at least one smashed up canoe, along with other wooden objects and broken artifacts, have been found driven inland, along with ripped up peat and plant material. There are pebbles strewn over sand dunes around early settlement sites and shell middens and ovens spread over the landscape, apparently by large waves washing over the sites. Garden soils are buried beneath sand, and there are changes in the shellfish content of middens, consistent with sand deposition, or its removal, affecting shellfish beds. There are indications in areas where food was once plentiful of people scratching for subsistence. On Matakana Island, a sandy island at the entrance to Tauranga Harbor (Figure 1), 4 km of the southeastern end was removed and later grew back.

These seismic events coincide with a significant cultural change recorded by archaeology. Before the fifteenth century, the population appears to have been relatively peaceful: there are no clear signs of warfare, no fortifications. Then, at the end of the fifteenth century, earthwork forts appeared in the North Island and northern South Island [*McFadgen et al.*, 1994; *Schmidt*, 1996], warfare developed, and by the time of European rediscovery by James Cook in 1769, had become endemic [*Davidson*, 1984]. Adze styles changed, from a very sophisticated kit that would have required trained craftsmen to make and use, to a simplified general-purpose tool that potentially anyone could make [*Furey*, 2004]. The rock used for adze manufacture also changed. The D'Urville Island metamorphosed argillite that was widely used and traded during the early period fell out of use in favor of local (inferior) stone, implying that less trade was occurring. Gardening practices changed, and stone row gardens were abandoned. At the same time, people deserted parts of the coast and established their settlements further inland. What appears to have been a more or less uniform East Polynesian culture, shared by people living in much of the North Island and northern South Island, became the regionally distinctive Maori culture encountered by the late eighteenth century European explorers.

The outcome of a major tsunami inundation is necessarily speculative, but based on the effects of recent modern tsunamis such as the 2004 Boxing Day event in Indonesia, a reasonable scenario can be put together that accounts for the changes observed. There would have been extensive loss of resources: food stores, shellfish beds, and gardens (smothered with sand and contaminated with seawater). Coastal settlements would have become uninhabitable and places to avoid because there was no food. Canoes and floatable artifacts would have been washed away. There would be the deaths of young children, the elderly, and women (who tend to stop and help the young and elderly; men appear to have a stronger sense of self-preservation [*Dudley and Lee*, 1998, p. 260]). People whose occupations kept them on the coast would have been vulnerable, especially the craftsmen who made the adzes and canoes, and the sailors and navigators who sailed the canoes.

With the loss of canoes and navigators, long distance trade would have declined. In the absence of traded argillite, local stone was used for adzes, and with the loss of craftsmen, adzes became simpler. With the loss of resources, shortages of food, and a shortage of women, warfare developed, but possibly the most crucial losses were the elders, who were the sources of knowledge; when they died, so would much of the knowledge that kept their culture alive. With the loss of long distance coastal trade, the communication of ideas and new innovations would have been reduced, and the mountainous nature of the hinterland meant that overland communication was more difficult than coastal interchange. It is therefore likely that for a time, parts of the country became isolated from each other, adding to the difficulties of recovery. How long this isolation would have lasted for any region is unknown. Its eventual outcome, however, would be gradual cultural divergence, similar to that proposed for isolated Polynesian islands [*Irwin*, 1992, p. 202]. Long distance communication, however, had certainly been reestablished by the time of European contact in the late eighteenth century [*Firth*, 1929, p. 407; *Beaglehole*, 1968, p. 250], and artifacts from later period archaeological sites indicate its reestablishment sometime earlier.

Unlike modern societies, there was no external support for those afflicted; the scale of the devastation was too large. There is, however, a suggestion of subsequent cultural influence from the southern South Island through the use of nephrite and the adoption of some artifact styles and practices notably related to fishing [*Davidson*, 1984]. Changes to fishing technology would have been appropriate, considering the impact that tsunami inundation would have had on northern coastal areas, but the extent, timing, and exact nature of this influence has still to be documented. At the time of European contact, regional differences in material culture, social organization, and linguistic dialects were apparent [*Skinner*, 1921; *Davidson*, 1984; *Harlow*, 2007], but how much was due to change since the fifteenth century, possibly triggered by reduced trade and communication, and how much predates the events described here is not known.

In summary, New Zealand presented the Polynesian settlers with a resource-rich temperate environment that, climatically, was a significant contrast to the tropical environment from which they had come. Their ability to adapt is well-demonstrated by their innovative approach to cultivation of the subtropical kumara (sweet potato), which led to techniques of soil modification to improve growing conditions and pit storage to overwinter tubers for planting the following season [*Davidson*, 1984]. They retained their innovative skills throughout the pre-European period, well illustrated in the latter part by their sophisticated system of warfare, and later, by readily adapting to European-introduced crops [*Petrie*, 2006]. In addition, after European contact, Maori also demonstrated strong entrepreneurial enterprise [*Petrie*, 2006], which must have had its roots in the pre-European period, although how far back in time requires further research to ascertain. What they were unprepared for, however, were the dangers of living in close proximity to a major tectonic plate boundary: the destruction that could follow major earthquakes and tsunami in a young and fragile landscape. The immediate outcome inferred for Maori culture was breakdown of long distance communication, regional isolation, and warfare. The aggregate culture that subsequently developed was very different from that which had prevailed before.

The path taken by Maori cultural response to tectonic activity is quite distinct from that taken by some other cultures, including Neolithic ones, where increased cultural complexity apparently accompanied active tectonism. Two factors in the difference can be discerned:

1. The tsunamis that Maori endured were more destructive of their coastal habitat than earthquakes per se would have been and, in some instances, led to relocation rather than rebuilding. The Maori were driven away from a rich marine-terrestrial interface, and their impoverished resource base then reduced trade and cultural complexity. Excessive event magnitudes and short recurrence intervals may have discouraged recovery attempts.

2. The cultural and physical isolation of Maori limited their recovery options. This makes their response less like the response in cultures where innovative techniques for rebuilding in situ were available.

The Maori case shows that landscape modification by tectonism can be detrimental and that consequent cultural change can be away from complexity. Maori response was clearly comprehensive, however. Variables that enhance the value of tectonic topography and lead to greater cultural complexity cannot be specified from our example and remain unclear for many Neolithic situations.

5. CONCLUSIONS AND IMPLICATIONS

Tectonic landscapes and acceleration of cultural change, the two hypotheses discussed above, both appear to be consequences of active tectonism that have accelerated the development of our species. The former was, to some extent, more important in earlier stages of our evolution, and the latter is most obvious at the beginnings of history, but both factors probably were operating at any given stage, certainly including the present day.

Our New Zealand example proves to be an odd case of local cultural response to a landscape modified by tectonism, but not in ways predictable in any simple scenario. It shows that such response can go in a variety of directions, especially for individual events. However, tectonism clearly forced the pace of change, and cultural response to tectonism was comprehensive, probably founded on an expectation of further events. Additional studies of historic Neolithic cultures in other physical environments may shed more light on the dynamics of tectonically driven change.

There are many things in the relation between humanity and tectonic activity that we would like to know more about. However, there is more than enough information to conclude that effects of tectonic activity should be considered along with other factors such as climate change in evaluating human activity and development. Tectonic activity has played a central role in the physical and biological evolution of our planet; perhaps, it is not surprising that humankind, in its evolution and development, has both unwittingly taken advantage of Earth's basic machinery and suffered attendant disadvantages.

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