Archaeology

Propaganda of the pyramids

Jared Diamond

You would have thought that massive monuments would be built by states at the apogee of their pomp and glory. Not so, according to an argument in which it is states on the up that need to impress.

It seems obvious that huge ancient monuments, such as the three Great Pyramids at Giza in Egypt, should be taken as testimony to a powerful ancient state behind them. As Joyce Marcus argues[1] in a contribution to a newly published book, that conclusion is indeed what the builders wanted us to draw — but it's the opposite of the truth. Often, the biggest monuments were built early in a state's history, before it reached its peak power. They were built for propaganda, precisely to conceal the state's lack of real clout.

For example, among those three pyramids at Giza, Khufu's was the largest ever erected in Egypt, with a base area of 5 hectares, a height of 146 metres, and a mass of 6 million tonnes. It may be the bulkiest single building erected in human history, and until recently it was the tallest. That is certainly not because Khufu commanded more resources than did any subsequent leader in history. Many governments today exercise far more power, but none would waste its resources on building a big pyramid just for display and lacking office space, auditoriums and theme restaurants. Khufu's dynasty came early in the Egyptian sequence; it was only the fourth of about 31 dynasties. Even Khufu's two successors didn't try to match him: Khafra's pyramid at Giza is slightly smaller, and Menkaura's is less than half of Khufu's in height. Later Egyptian dynasties drastically reduced the scale of their pyramids.

Yet those later dynasties were much more powerful than Khufu's. They chose to invest their power in other ways: launching long-distance trading expeditions and military campaigns of conquest, maintaining big garrisons, and building big fortresses, irrigation works and ship channels. All of those things were beyond Khufu's capabilities. As head of an early state, he couldn't dominate Egypt's neighbours. The Great Pyramid is a bluff, a proclamation of power as empty as that by Shelley's *Ozymandias*:

'My name is Ozymandias, King of Kings:
Look on my works, ye Mighty and despair!'
Nothing beside remains. Round the decay
Of that colossal wreck, boundless and bare,
The lone and level sands stretch far away.

Investment in architecture followed much the same course in the ancient New World's two main centres of power, Mexico and Peru. Marcus points out that one of the earliest powerful states in the Valley of Mexico arose at Teotihuacan, which built its largest structure, the Pyramid of the Sun, early in its history. Its base area of 5 ha matched that of Khufu's pyramid, although it was 'only' half as high. Teotihuacan continued to grow in population and in geographical extent of power, and the valley's later Aztec Empire was even more powerful, but neither again invested in such a large building. Instead, they poured resources into long-distance trade, outlying colonies, military conquests in the case of the Aztecs, garrisons, intensive agriculture and crafts production — much as had Khufu's successors in Egypt.

The story is similar for Peru's earliest state, that of the Moche, who in the centuries after AD 100 built Peru's largest pyramid, the Huaca del Sol, with a base area of the usual 5 ha but a height only one-fifth that of Khufu's pyramid. (Is there any reason why the largest pyramids of Egypt, Mexico and Peru all arrived at that same magic number for their base areas?) Peru's more powerful successor states of the Chimu and Incas, enjoying unquestioned actual control, evidently saw no need for ostentation. Instead, the Incas constructed a vast road system, storehouses and irrigation canals, sent armies far afield to conquer, and resettled subject peoples. Unable to do such things, the Moche made do with big but useless pyramids.

Tests of a good hypothesis are whether it can interpret cases other than those initially adduced as supporting evidence, and whether it can be broadened to encompass apparent exceptions. Since reading Marcus's article, I've kept asking myself about its relevance to sites that I visit as a tourist during overseas travels. I've come up with one more supportive example, and two cases of understandable exceptions.

When I visited Japan, I read that the emerging Japanese state had built huge keyhole-shaped earthwork mounds called kofun, and I asked my hosts to show me one. They took me to the largest of all kofun, that of the Emperor Nintoku near Osaka. At 32 ha, it covers much more ground than Khufu's pyramid, the Pyramid of the Sun or the Huaca del Sol, but it would have been easier to build because it consists just of earth rather than of stone, brick or adobe. Sure enough, I learned that Nintoku's and the other largest kofun were built early in the kofun era, when Japan's first state (the Yamato state) was just arising. It could only impress rather than conquer its neighbours,

100 YEARS AGO

Perhaps the phenomenon of mirage is not sufficiently rare in England to make its occurrence noteworthy, but I should like to mention a singularly beautiful example that I noticed on Sunday last… I was riding on my bicycle along the Upper Richmond Road towards the west, and against a fairly steady breeze, and had arrived at the part of the road lying between the railway bridge and the Putney High Street—about opposite house No. 110 — when I noticed that the road beyond, some fifty yards in front of me, was apparently flooded ankle deep in water. I was somewhat disconcerted at the prospect of riding through such a quantity of water, but I found to my astonishment that when I arrived at the supposed lake the road was perfectly dry. I thereupon turned and rode back to my previous station, and, dismounting, watched the phenomenon for some while. To assure myself that it was no personal illusion upon my part, I directed the attention of a passing stranger to the scene, and he was as impressed as I had been. I should mention that the road sloped slightly downhill from me, and the sun was high (12.50 p.m.) above on my left.

From *Nature* 20 August 1903.

50 YEARS AGO

It has long been recognized that the forced ascent of air over mountains can produce cloud. Only in the past twenty years has it been realized that thin clouds 10,000 ft. or more above the mountains and with no cloud beneath them may owe their existence to the presence of the mountains. Such clouds are not formed by the direct lifting of the lower air up to cloud-level but in the ascending currents of a system of waves which can be produced by the mountain in somewhat the same way that a rock on a river bed produces waves downstream. The wind and temperature structures of the air have to fulfil certain conditions, as Dr. R. S. Scorer… has shown. The favourable conditions are an increase with height of both wind-speed and of the temperature lapse-rate. An inversion of temperature in the lower layers of the air followed by a rapid fall of temperature higher up is a favourable arrangement; but a steep fall of temperature with height low down, such as occurs on sunny afternoons, is unfavourable.

From *Nature* 22 August 1953.

and hadn't yet succeeded in expanding beyond its homeland in the Kinai region.

I then visited Easter Island, famous for its giant stone statues. There I learned that later statues are bigger than early ones, and that the tallest ever erected (the one named Paro, 9.8 m tall) was the last — in apparent disagreement with Marcus. But Easter Island, unlike Egypt or the Valley of Mexico or Peru, never became tightly unified and remained divided into rival clans that continued to compete visibly with each other. Hence Easter Island might violate the letter but supports the spirit of Marcus's hypothesis.

Finally, the Maya city-states in Central America are famous for their own pyramids and temples. As on Easter Island, later Maya rulers built bigger temples, but again the Maya states were never unified but stayed locked in fierce competition and warfare. In addition, Marcus herself points out that some big late Maya buildings, such as Pacal's tomb at Palenque and Hasaw Chan K'awil's tomb at Tikal, were erected by usurpers or else by kings weaker than their predecessors, and thus with a special need to indulge in flashy displays of power.

Archaeologists studying other ancient monuments will find it challenging to test or expand Marcus's arguments. As she concludes, "We should be as skeptical of ancient propaganda as we are when dealing with modern politicians". ■

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1. Marcus, J. in *Theory and Practice in Mediterranean Archaeology: Old World and New World Perspectives* (eds Papadopoulos, J. K. & Leventhal, R. M.) 115–134 (Cotsen Inst., Los Angeles, 2003).

Earth science

Tiny triggers deep down

Harry W. Green II

The documentation and characterization of remotely triggered earthquakes deep within the Earth is an achievement that provides insight into the mechanisms that initiate such events.

Earthquakes occur widely in the planet's crust and to depths approaching 700 km in subduction zones, where oceanic crust and the associated 50–100 km of mantle dive back into Earth as the return flow of plate tectonics. But we know little about the physics of earthquake initiation (nucleation), especially at great depth, because the mechanisms known to operate close to the surface — brittle failure of virgin rock, or frictional sliding on a pre-existing fault — cannot occur at the high pressures at depth[1].

A new window on the problem may have been opened by Tibi *et al.*[2] (page 921 of this issue). They provide the first analysis of two large (magnitudes 7.6 and 7.7), very deep earthquakes that occurred on 19 August 2002 in the Tonga subduction zone beneath the southwestern Pacific Ocean. Although these earthquakes were separated by about 300 km on the map and by 65 km in depth, they occurred within 7 minutes of each other. Tibi *et al.* argue that the second large earthquake, and a magnitude-5.9 precursor of it, were triggered by passage of the seismic waves generated by the first earthquake.

Although remote triggering is known for earthquakes near Earth's surface[3], Tibi *et al.* provide the first such demonstration for a deep earthquake. Moreover, the authors discuss an earthquake series that occurred beneath Tonga in 1986 (Fig. 1) that now can be seen as probably another remotely triggered sequence. It is clear that regions in which earthquakes are triggered by the small disturbances generated by earthquake waves far from the source must be primed for failure, but for some reason nucleation does not occur readily. It is also clear that the delay between arrival of the triggering seismic waves and the time of the ensuing deep earthquakes varies from minutes to tens of minutes (see Table 1, page 922). Thus, the timescale of this 'incubation' period is likely to be a characteristic of the triggering mechanism.

Three mechanisms have been proposed as potentially responsible for deep earthquakes: (1) dehydration embrittlement[4]; (2) faulting induced by a phase transformation between one mineral form (olivine) and another, denser form (spinel)[5]; and (3) adiabatic shear instability[6]. All three have an experimental basis (although for crystalline materials, the last has been demonstrated only in metals). In each case, shear failure is the end result — rapid slip across a narrow zone such as a fault.

Mechanism 1 basically extends brittle fracture to high pressures by the generation of a pore fluid that assists opening of tensile microcracks, which then self-organize and lead to shear failure. Mechanism 2 is similar in outcome, but the underlying physics is fundamentally different. It involves the generation of another type of defect — microanticracks — which are small, crack-shaped lenses filled with a low-viscosity nanocrystalline aggregate of the stable phase; the microanticracks then self-organize and lead to shear failure[7]. Mechanism 3 involves the localization of deformation into a shear zone as a result of strain-softening: the rock becomes weaker as it flows. Runaway shear heating follows, leading to failure.

All three processes have specific requirements for generating an earthquake. The first requires a hydrous phase at or slightly beyond

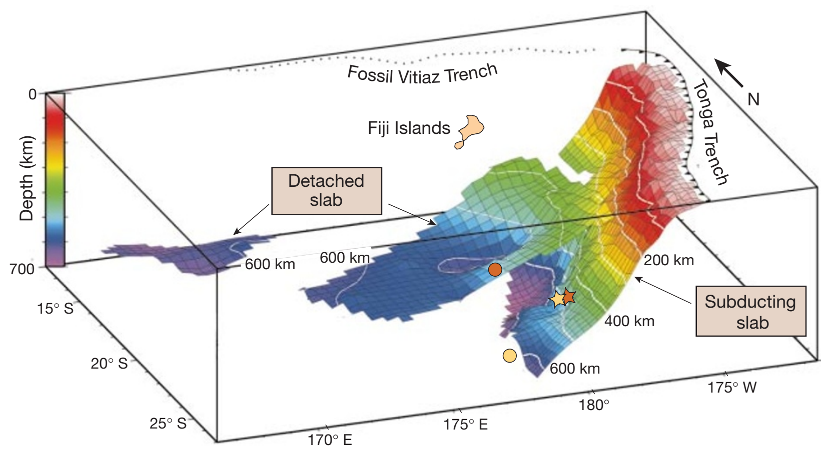

Figure 1 **Earthquakes and subducted slabs beneath the Tonga–Fiji area. The subducting slab and detached slab are defined by the historic earthquakes in this region: the steeply dipping surface descending from the Tonga Trench marks the currently active subduction zone, and the surface lying mostly between 500 and 680 km, but rising to 300 km in the east, is a relict from an old subduction zone that descended from the fossil Vitiaz Trench. The locations of the mainshocks of the two Tongan earthquake sequences discussed by Tibi *et al.*[2] are marked in yellow (2002 sequence) and orange (1986 series). Triggering mainshocks are denoted by stars; triggered mainshocks by circles. The 2002 sequence lies wholly in the currently subducting slab (and slightly extends the earthquake distribution in it), whereas the 1986 mainshock is in that slab but the triggered series is located in the detached slab, which apparently contains significant amounts of metastable olivine[8,9]. (Modified from ref. 13 with permission of the American Geophysical Union.)**