# Use a toad to catch a quake

The world's first seismoscope was created in AD 132 by polymath Zhang Heng, but did his legendary device really work? The evidence is shaky, finds **Andrew Robinson**

CLANG! An ornate dragon's head suddenly spat a metal ball into the mouth of a bronze toad crouching patiently beneath it, and officials at the court of the Han emperor were astonished. And sceptical too: this supposedly revealed that an earthquake was happening elsewhere in China, yet they felt no tremors in the capital Luoyang. Sure enough, just a few days later, galloping horsemen brought news of a destructive earthquake in Longxi, 700 kilometres away. "Upon this everyone admitted the mysterious power of the instrument," or so the story goes. From then on, officials in the Bureau of Astronomy and Calendar were required to note the occurrence and direction of earthquakes in the imperial realm indicated by this, the world's first seismoscope.

China has kept records of earthquakes since at least 780 BC – longer than any other country – and has suffered the two deadliest quakes in history. So perhaps it's unsurprising that a Chinese official, Zhang Heng, should have been the first to create a seismoscope, around AD 132. His striking story is told in the chronicles of the *Hou Han Shu* (the history of the Later Han dynasty).

And what a device it was. Shaped like an urn some 2 metres across, its curved bronze case was adorned with eight dragons' heads and toads oriented in the directions of the compass. The position of the dragon that released its ball indicated the direction of an earthquake's epicentre. Zhang called it *houfeng didongyi*: literally, a "wind-observing earth-movement instrument"; less literally, an "earthquake weathercock". He believed earthquakes were linked to air movement, especially storm winds encountering obstacles, such as mountains. The chief reason for detecting earthquakes, thought Zhang, was because they were heavenly omens indicating misconduct of government officials. "The heavens crack, and the earth shakes," is one of many Chinese sayings about high politics and everyday life.

After a particular earthquake shook the capital, Zhang submitted a statement to Emperor Shun describing the disaster as a divine comment on the failure of a new policy for recruiting the talented and virtuous for office. If movements within the earth were portents of corruption within the court, an instrument to detect earthquakes might greatly assist the emperor. The imperial eunuchs – advisers with the ear of the emperor – probably felt differently. On one occasion, the young emperor was said to have summoned Zhang to his chambers and asked him to name the most despised men in the kingdom. The eunuchs present during the audience were prime candidates, but glared at Zhang so menacingly that he thought better of nominating them. Nevertheless, they later slandered him to the emperor, so it was not surprising that his career encountered periodic setbacks. He reflected upon his travails in some of his many poems, which won him literary fame, such as these closing lines from his final composition, written during his retirement: "If I set my mind free beyond the common world / Why care for worldly glory or disgrace?"

One of many variations on the seismoscope, in London's Natural History Museum collection

## Heavenly inspiration

Zhang spent the first few decades of his life far from the centre of imperial power. He was born in AD 78 to a distinguished but not wealthy family and it wasn't until 112 that he was summoned to the capital by Emperor An to become a junior official, as a result of his broad learning. Zhang then worked his way up the ranks, including taking a stint as imperial astronomer/astrologer. Inspired by the heavens, he wrote the first clear Chinese description of the celestial sphere including the equator and sun's apparent path during the year. He is also said to have designed the world's first water-powered armillary sphere – the earliest in a long line of water-driven astronomical clocks in China. Zhang finally became a palace attendant in 134, allowing him to offer personal advice to the emperor.

Despite his many talents, Zhang's attitude to authority prevented his becoming the official court historian. He opposed the idea – favoured by the emperor and certain officials – of revising the Chinese calendar and compiling the history of the Han dynasty according to some apocryphal teachings akin to the prophecies of Nostradamus. In 136, perhaps as a result of increasing political pressure, Zhang left the capital and became the chief administrator of a princely kingdom, and in 138 retired to a peaceful life of scholarship in his home town. But not for long. He was recalled to the capital, now with the rank of imperial secretary, but died shortly thereafter, in 139. Whether the dramatic success of his *houfeng didongyi* was a factor in his recall is, alas, unrecorded.

Whatever the truth, the enigmatic seismoscope is his enduring legacy. It remains a mystery partly because it vanished without trace and partly because seismologists still cannot agree on its inner mechanism. While the *Hou Han Shu* speaks volumes on the device's outer appearance, it contains only a minimal description of the innards: "A central column capable of lateral displacement along tracks in the eight directions [so arranged as to operate] a closing and opening mechanism" in the dragons' mouths. According to historian Christopher Cullen, an authority on ancient Chinese science, "The description of the device that has come down to us is sufficiently detailed to have led to numerous attempts at reconstruction, but not clear enough to enable any of the attempts to be taken as definitive." Surely, the central column was a sensitive pendulum. Yet, seismologists have no clue how the complete mechanism could have kept mechanical friction low enough to detect tiny movements of the ground more sensitively than a human could.

ROGER-VIOLLET/REX/SHUTTERSTOCK

Zhang Heng pictured with a scale model of his "earthquake weathercock"

To add to the uncertainty, we can never know if the seismoscope's famous quake detection happened as chronicled in the *Hou Han Shu*, which was completed around 440, centuries after Zhang's death. Suspiciously, the detection goes unmentioned in an earlier history, the *Hou Han Ji*, source of the *Hou Han Shu*'s description of the device. Moreover, the later document lists seven earthquakes between 132, when the seismoscope was made, and 139. And although one of these quakes, in 138, caused destruction in Longxi, the record clearly states that the tremors were also felt in the capital. Cullen suspects the detection story is "fan fiction", inspired by admiration for Zhang's undoubted mechanical creativity.

**"Was the quake-detection story 'fan fiction' inspired by his mechanical creativity?"**

These doubts haven't stopped many experts in China, Japan and elsewhere attempting to reconstruct the seismoscope. In China, museum curator Wang Zhenduo modelled it twice: in 1936 with a conventional pendulum and in the 1950s with an inverted pendulum. Neither responded to real earthquakes, including the devastating Tangshan quake of 1976, which killed hundreds of thousands of people. This quake caused tremors in Beijing, where the second of Wang's models was kept.

During the past decade or so, a Chinese Academy of Sciences team led by retired geophysicist Feng Rui has built and tested a handsome new model with a conventional pendulum that is now prominently displayed in Beijing's Science and Technology Museum. But it has yet to detect an earthquake, including the great Sichuan quake of 2008.

Another model, in London's Natural History Museum collection (pictured, left), made for a BBC TV programme in the 1970s from Wang's 1936 design, has failed to detect an earthquake, too – less surprisingly, given the UK's seismic stability. Nevertheless, the model's popularity suggests that the puzzle of Zhang's unique invention continues to fascinate not only China, but also the rest of the world.

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