

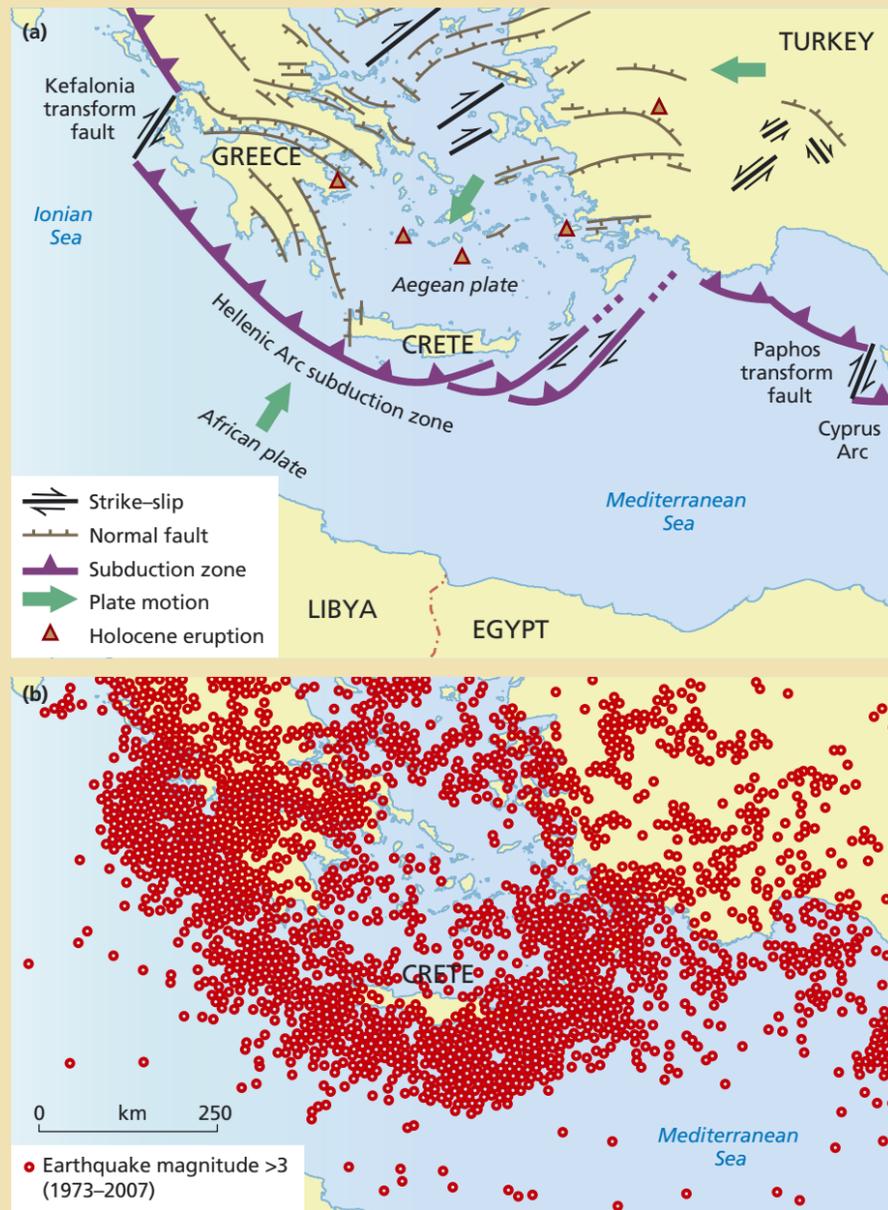
Ancient Crete

A catastrophic earthquake

In AD 365 Crete was hit by an extraordinarily powerful earthquake. This Centrepiece looks at the tectonic setting of this event and how some of its impacts — such as uplifted shorelines — can be used to estimate earthquake and tsunami hazard risk today

The Hellenic Arc

Crete lies in a subduction zone — the Hellenic Arc — where the African plate sinks below the Aegean microplate and the larger Eurasian plate behind it (Figure 1a). Plate motions create enormous stresses, so the crust in this area is riddled with active faults. Earthquakes, volcanic eruptions and tsunamis are part of the deep history of this region. Figure 1b shows the observed pattern of earthquakes (magnitude >3) between 1973 and 2007. Note the dense belt of seismic activity along the subduction zone close to the island of Crete.



Source: Taymaz, T. et al. (2007) *The Geodynamics of the Aegean and Anatolia*, Geological Society.
Figure 1 The tectonic setting of the Aegean region (a) and the distribution of recent earthquakes (b)

The earthquake of AD 365

In AD 365 Crete was hit by a devastating earthquake (magnitude >8.5) that caused widespread destruction. It was probably triggered by the rupture of a major thrust fault to the southwest of the island. The earthquake was so powerful that the southwestern corner of the island was uplifted more than 9 m, and >100 km of the coastline was raised between 4 and 8 m. Figure 2 shows the uplift contours at 1 m intervals.

This remarkable landscape change left the Roman harbour of Phalasarna on the northwest coast — quite literally — high and dry. The earthquake generated widespread mass movements in deep marine sediments and a tsunami that caused havoc across the eastern Mediterranean, from the Nile delta to Dubrovnik.

The palaeoshoreline

The photograph shows the distinctive shoreline scar on the limestone coastal cliff at the small village of Sougia in southwest Crete, where the uplift was about 6 m. This is a clear marker of the sea level before the uplift event. Radiocarbon dating of coral and shell samples from this palaeoshoreline show that the uplift is associated with the AD 365 earthquake. By dating such features we can use them to estimate long-term earthquake risk.



Risk assessment

Plate movements can be measured directly using GPS. By combining these data with our knowledge from radiocarbon dating, we can estimate the frequency of major earthquakes. Recent measurements of crustal motions near Crete suggest a 5,000-year return period for the massive earthquake and tsunami of AD 365. However, it has been suggested that if the tectonic process that caused that event takes place along the entire Hellenic Arc, such events could occur in this region every 800 years. A repeat of such an earthquake and tsunami would have dire consequences for today's densely populated Mediterranean coasts.

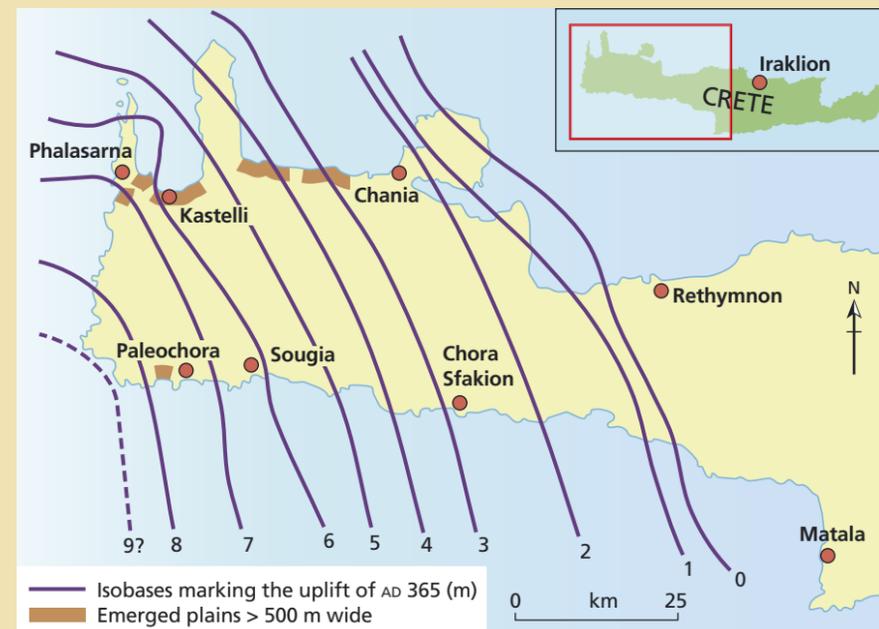
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Uplift and gorge formation

High-magnitude earthquakes can have long-lasting impacts that influence landscape processes for many centuries. They can trigger thousands of rockslides and landslips that force adjustments in river-basin processes by increasing the volume of sediment in valley bottoms available for transport during floods. All the rivers draining to the coast of western Crete were forced to adjust to a new long profile after the rapid vertical displacement of AD 365. Some channels have cut down through the bedrock.

Crete has experienced about 1,000 m of net uplift over the last 5 million years or so. Over these time scales, interactions between uplift and river erosion have created the spectacular limestone gorges of southern Crete.



Source: Kelletat, D. (1991) *Zeitschrift für Geomorphologie*, suppl. 81.
Figure 2 Uplift in western Crete associated with the AD 365 earthquake based on palaeoshorelines, raised beaches, and archaeological data

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