Relocating Odysseus' homeland

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Homer's Ithaca had been viewed as a work of poetic licence and imprecise geography. However, as recent research shows the island's form may have been disguised over the past two millennia by catastrophic rockfalls, co-seismic uplift events and relative sea-level change.

Until the late nineteenth century, it was widely believed that the people and places described in Homer's epic poems the *Iliad* and the *Odyssey* were entirely fictional, with no historical or geographical basis. However, when Heinrich Schliemann rediscovered Mycenae and Troy in the 1870s, and Sir Arthur Evans subsequently unearthed Knossos, opinions had to be revised. It thus became accepted that at least some archaeological reality lay behind the poetry. A wealth of geological, geophysical and geomorphic studies now support the existence of various sites described during the Mycenaean era of Greek mythology (the thirteenth century BC). Furthermore, detailed coring and radiometric dating of sediments have shown that the palaeogeography of the Greek Argolid plain, which Homer describes as the land of Diomedes in the *Iliad*, and the Turkish Troad plain is consistent with Homer's description[1–4].

Yet the homeland of the wandering Odysseus — ancient Ithaca — has never been found. Of course its location has long been sought on the modern Ionian island going by that name, but excavations there have only led to archaeological disappointment while also being plagued with a nagging geographical inconsistency. Homer[5] writes that:

> *Around her a ring of islands circle side-by-side,*
> *Doulichion and Same, and wooded Zacynthos too,*
> *But mine [Ithaca], lies low and away, the furthest out to sea, rearing into the western dusk*
> *While the others face the east and the breaking day*

By contrast, the modern island of Ithaca features a vertiginous coastline, high topographic elevation and an easterly position, leading to a search for alternative sites for ancient Ithaca, mostly centred on neighbouring islands in the Ionian Sea. The westernmost islands of Lefkas and Kefalonia have been at the forefront of the search. Although excavation of Tholos tombs, sarcophagi and walls of Cyclopean construction all lend support to the notion that Kefalonia had a rich and important Mycenaean heritage, there has never previously been any independent geological evidence to direct the search for Odysseus' homeland to that island.

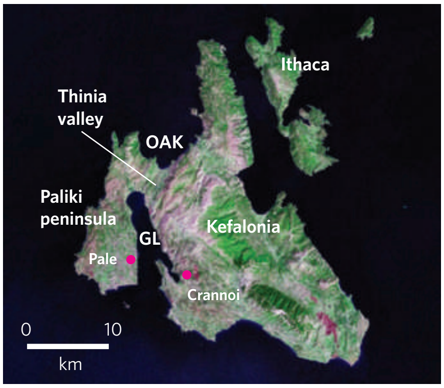

Figure 1 | The modern geography of the Ionian islands. The modern island of Ithaca is mountainous and lies to the east of Kefalonia. Kefalonia consists of the main island and the Paliki peninsula, which is connected by the Thinia valley. The Gulf of Livadi (GL) lies to the south, and the Ormos Agias Kiriakis (OAK) lies to the north. Image courtesy of NASA.

With just a single quote from the *Odyssey*, one might be tempted to think that Homer was simply loose with his language or, if one were harsh, perhaps conclude that he was an incompetent geographer, and abandon the search for Odysseus' Ithaca. However, a detailed geographical description of Kefalonia by an independent observer, Strabo, narrows the search for the location of ancient Ithaca, and hints at an intriguingly neat solution to the conundrum. In his description of the people and places of the Roman Empire in the early years of the first century AD — entitled *Geography* — the Greek geographer describes the island as follows[6]: "Where the island is narrowest it forms an isthmus so low-lying that it is often submerged from sea to sea". Conveniently, Strabo precisely describes the location of the isthmus[6]: "Both Paleis [Pale] and Crannoi are on the gulf near the narrows".

Significantly, the exact position of the ancient towns of Pale and Crannoi are known: Pale is situated on the Paliki peninsula of west Kefalonia, and Crannoi lies to the east (Fig. 1). Their two territories are separated from one another by a shallow 4-km-wide marine embayment, the Gulf of Livadi, at the head of which lies Thinia, a 6-km-long and 2-km-wide steep-sided valley. The valley now forms the only land bridge between Paliki and the rest of Kefalonia (Fig. 1).

Accepting Strabo's observation at face value, it seems that there must have been a low-lying valley that was submerged not always, but sufficiently often to be an effective marine channel. If so, today's Paliki peninsula, periodically separated from Kefalonia by the channel Strabo describes, could have been viewed as a low-lying island in its own right. The westernmost part of Kefalonia is therefore a strong candidate for today's representation of ancient Ithaca as described in the *Odyssey*, explaining Homer's missing island without recourse to fanciful and unsubstantiated, rapid (Atlantis-like) island disappearance.

The geological challenge

This theory is attractively simple, but it poses considerable practical, topographic and geological challenges, as Thinia rises to an elevation of about 180 m in its saddle area. If this valley formed a marine channel two to three millennia ago, its transition to the current landform needs a convincing explanation.

The axis of the valley lies on easily weathered Miocene marl sediments, which in turn lie unconformably on an easterly dipping succession of Cretaceous to Palaeogene limestones (Fig. 2). The marl passes up into younger, more resistant Miocene conglomerates. The conglomerates are separated from steep westerly dipping Cretaceous–Palaeogene limestones on the valley's steep and unstable eastern slopes by a major Hellenide (Alpine) thrust fault — the

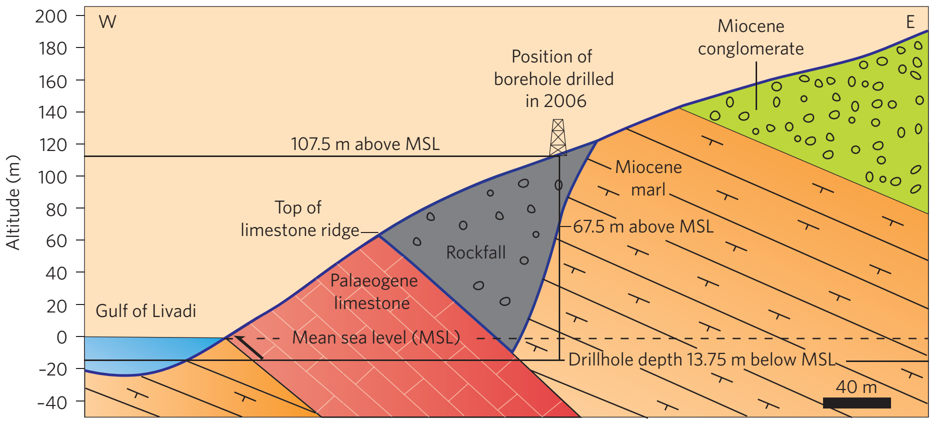

Figure 2 | The geological setting of the Thinia valley. In the Thinia region, Miocene marl lies on top of Cretaceous to Palaeogene limestones. The proposed channel would have cut through the easily weathered marl, to a depth below sea level. Rockfalls and landslides subsequently filled in the channel to its present elevation. The location of the borehole that encountered 40 m of unconsolidated rockfall material is also shown.

Aenos Thrust — where co-seismic movement continues to the present day[7].

The Ionian islands' well-documented history of seismicity and associated damage might provide a solution for rapid landform change. Kefalonia lies at the far northwest region of tectonic collision between Eurasia and Africa in the eastern Mediterranean, and is situated in the outer arc of deformation above the Hellenic subduction system, near the Kefalonia transform fault, where horizontal translation of the Aegean microplate is most pronounced[8–11]. The area is frequently rocked by major earthquakes; the US Geological Survey considers the island to have the highest seismic hazard in Greece. Kefalonia's geographic position is not dissimilar to that of Sumatra in southeast Asia (along the outer arc of plate convergence) and indeed neighbouring areas of the Ionian Sea are thought to have suffered from tsunamis following major seismic events[12–14]. Pronounced wave-cut notches and raised beaches around the island of Kefalonia record uplift from previous seismic events[15]. However, all the field evidence suggests that single seismic events, like the magnitude 7.2 earthquake of August 1953, cause only decimetres to metres of uplift[15], and that only a few metres of uplift can be accounted for during the Holocene. Co-seismic uplift alone would therefore be insufficient to explain the change in topography of the Thinia valley, assuming it lay at or below sea level in Strabo's time.

An alternative explanation may lie in the island's indirect response to the seismic activity. Field mapping and historical records reveal the importance of landslides and rockfalls in and around the valley. Such natural slope failure is caused by the steep dip of the bedrock towards the valley floor[16]. Indeed, large exotic blocks of Cretaceous and Palaeogene limestone derived primarily from eastern slopes are strewn across the valley's sides and floor. Large slope failures have been documented following significant earthquakes like the one in 1953. Furthermore, major non-seismic, weather-induced failures have been reported[17], such as the failure that afflicted the eastern village of Nifi in November 2007. Numerous hourglass-shaped embayments scar the valley sides, and are the source of the rockfall material. The occurrence of freshwater springs along the line of slip has spurred the development of buildings on the talus below, including Petrikata (which translates as 'fallen rocks'). But could the valley have been infilled, and hence elevated to heights of about 180 m, by material carried by rockfalls in just 2,000 years?

The subsurface search

In 2006 we drilled a borehole from an elevation of 107.5 m above sea level in the southeastern part of the Thinia valley to look for bedrock near the south end of the proposed channel (Fig. 2). The results of the borehole show 40 m of unconsolidated material before the drill encountered the Miocene marl bedrock (Fig. 2). Whilst this result lent support to the filled-channel hypothesis, it was clear that a suite of geophysical techniques was needed to map the subterranean geology of the region in more detail.

Over the past three years, ground, airborne and marine geophysical surveys have been deployed in an attempt to survey and hence, understand the subsurface geology of the valley. The ground and airborne techniques allowed us to determine the depth of fill and contours of the buried bedrock surface in the zone of the proposed channel along the length of the present valley. Marine seismic surveys have revealed hitherto undocumented buried ancient drainage patterns beneath the sea floor of neighbouring offshore waters with unparalleled precision. Finally, we used high-resolution airborne laser tele-altimetry mapping to provide detailed information of the topography and ground surface texture, in support of the field geological mapping. All of these data sets have now been integrated to build a comprehensive geological model of the proposed channel area that allow us to test whether the Paliki peninsula could indeed have been a separate island that corresponds to ancient Ithaca.

The principal data helped to characterize the main bedrock units and identify the aerial extent of a young and long-since-drained surficial palaeolake ('Lake Katochori' of Fig. 3) that lies on top of the rockfall debris. Geomorphic reconstructions indicate that the palaeolake was created when drainage pathways were re-routed and focused by rockfall debris, which effectively closed off river outflow in upland areas of the valley following catastrophic slope failure. We are now seeking to drill and core the lake sediments to obtain an upper (radiocarbon) age envelope for the valley rockfall infill, which the sediments onlap and drape. Cosmogenic isotope and thermoluminescence age determinations will provide independent dates for rockfall events.

Strabo's channel

Taken together, the suite of data provides tantalizing evidence for a channel hidden beneath the Thinia valley. Our gravity, seismic refraction and resistivity studies revealed that, down to a depth of at least 90 m, thick layers of unconsolidated material lie above the bedrock. Drill holes are now planned at strategic locations to test whether the sediment consists of Miocene marl *in situ* or slumped and rockfall material. Significantly, volume mass-balance calculations show that there was sufficient material formerly available on the degraded eastern slopes of Thinia to more than fill the valley to its present elevation.

Our new marine seismic data show the presence of a channel outlet carved into the basal sediments of Ormos Agias Kiriakis and the Gulf of Livadi, where the marine channel would have run through to connect the northern and southern parts of the Ionian Sea[17]. Onlap of Late Quaternary and Holocene sediments above the prominent unconformity (Fig. 3b) record the subsequent sea-level rise and drowning of the buried channel. Furthermore, it is now possible to map palaeoshorelines around the island with great accuracy. These results have also revealed the presence of a former estuarine harbour at the northern end of the Gulf of Livadi, which has subsequently been infilled by silt.

The existence of this channel, which remained submerged as late as 2,000 to 3,000 years ago, would have isolated the Paliki peninsula from the rest of Kefalonia. Being flat, low-lying and situated to the west of the three other islands would mean that the resulting island was in accordance with Homer's original description of ancient Ithaca. The channel was subsequently filled by rockfall to a height of over 180 m in the saddle of the present valley, probably during the Dark Ages, after the time of Strabo's writings and before the Venetian occupation, when reliable record keeping was resumed (that is, between the first century and the thirteenth century AD). Significantly, this is a period when the western arc has been shown to have been particularly prone to major earthquake and tsunami events[12–15].

Relative and eustatic sea levels

We suggest that the newly mapped, buried channel formed as a result of sea-level fall from the last (Eemian) interglacial (marine isotope substage 5e, about 126,000 to 115,000 years ago), when sea level is thought to have been a few metres higher than at present[18,19], to the Last Glacial Maximum (about 22,500 years ago), when sea level was 120 m or so lower than it is today[20]. The marine seismic reflection data showed buried sediment sequences that record the history of the subsequent Late Quaternary and Holocene transgression. By recording erosive and transgressive surfaces, our marine seismic data thus could also help quantify the dates and rates of eustatic sea-level change related to the last interglacial–glacial–interglacial cycle. In addition, borehole calibration of the seismic reflection data, including the use of direct radiocarbon dates from sedimentary cores, will hopefully also provide new insights into the rates of relative sea-level change in a tectonically active area.

The seismic reflection data also demonstrate the highly deformed (folded and thrusted) nature of the Cenozoic sediments beneath the glacial erosion surface, something that has been well demonstrated in neighbouring coastal

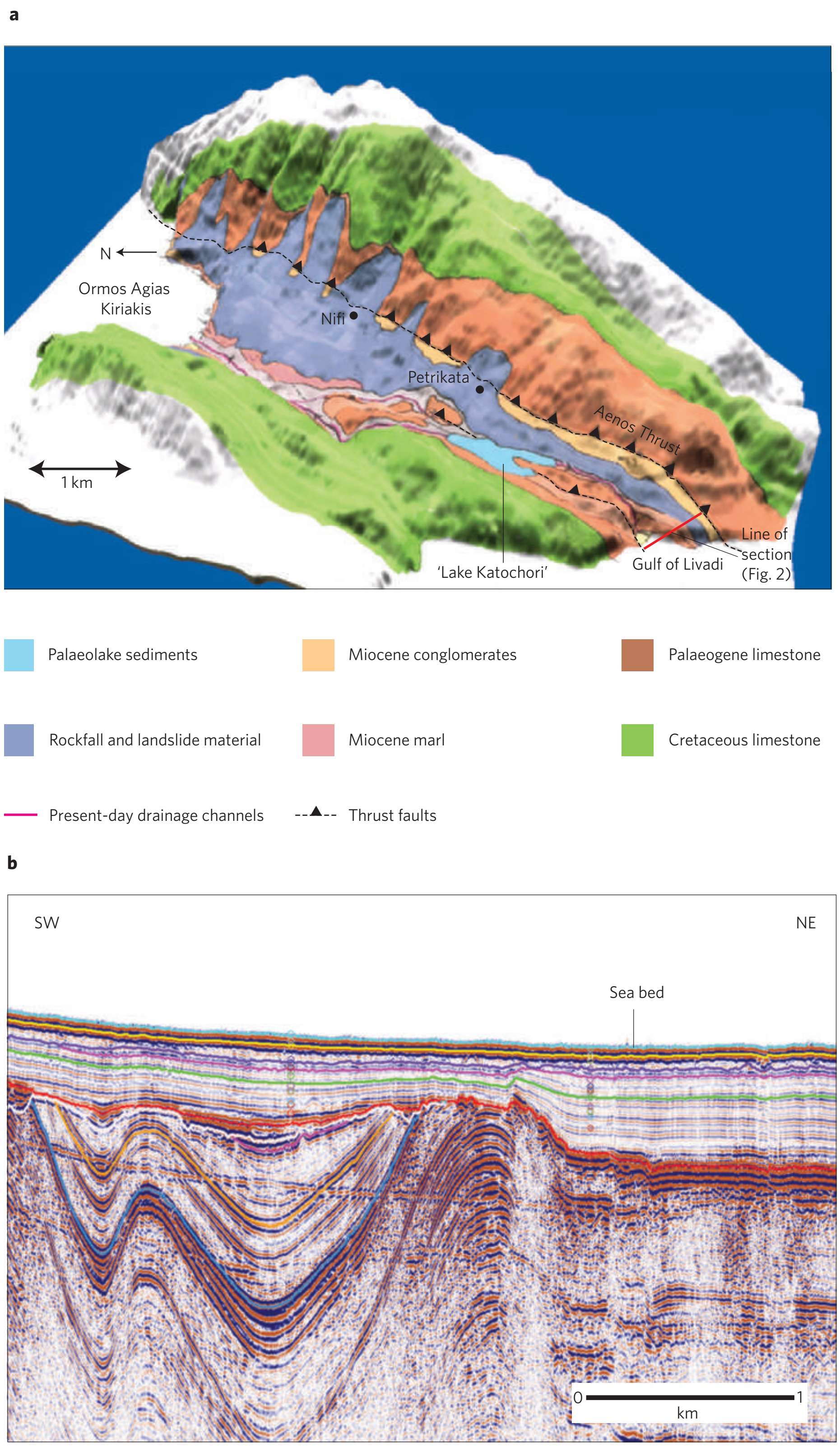

Figure 3 | Geological structures of the Thinia valley and the Gulf of Livadi. **a**, The geological map draped over a digital elevation model of Thinia shows the extent of the surficial rock cover and the extent of the palaeolake Katochori. Triangles mark the direction of the major thrust faults. **b**, The seismic reflection profile from the Gulf of Livadi shows a pronounced buried erosional surface (marked in red) that separates the deformed Cenozoic sediments from the Late Quaternary and Holocene transgression that flooded the channel. Interpretation shown courtesy of Kirsten Hunter, Univ. Edinburgh.

exposures[7,16], but has not been imaged beneath the surface before. Thus, the data permit onshore folds and thrust faults to be traced beneath the bay. Surprisingly, little reactivation of the Late Cenozoic structures is seen beneath the bay, suggesting that during co-seismic events, tectonic strain is highly localized on the Aenos Thrust that runs along the eastern side of the Gulf of Livadi and Thinia valley, thus triggering the largest rockfall events.

Taken as a whole, our data provide compelling evidence that a marine channel could have existed beneath Thinia, in accordance with Strabo's writings. The channel would have defined the ancient island of Ithaca, from where Odysseus reluctantly set out to help conquer Troy. Although his island would still have been recognizable to Odysseus when he returned in disguise 20 years later, topographic change of the narrow channel was probably extremely rapid in geological terms. The integration of geological, geophysical and geomorphic methods demonstrates that it remains feasible that the ancient island of Ithaca was transformed into the Paliki peninsula within only a few thousand years. ❐

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