amino-acid sequence and the structure in the native state[1], to be reconciled with the evidence that even a protein such as myoglobin can adopt the fundamentally different but highly organized structure present in amyloid fibrils.

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Pattern formation

Spiral cracks without twisting

A fascinating class of patterns, often encountered in nature as meandering cracks on rocks, dried-out fields and tectonic plates, is produced by the fracture of solids[1]. Here we describe the observation and modelling of an unusual type of pattern consisting of spiral cracks in fragments of a thin layer of drying precipitate. We find that this symmetry-breaking cracking mode arises naturally not from twisting forces, but from a propagating stress front induced by the fold-up of the fragments.

Fractured surfaces and lines[2–6] typically show a cellular and hierarchical pattern. Twisting forces produce a spiral fracture, like that often seen in a tibia bone broken in a skiing accident[7]. However, spiral cracks can also be created in other situations, as we show here by drying a fine aqueous suspension of precipitate. During drying, the suspension solidifies and later fragments into isolated parts (Fig. 1a).

Surprisingly, for very fine precipitates in a solidified layer of thickness between 0.2 and 0.5 mm, regular spiral as well as circular cracking pathways show up inside the fragments (Fig. 1b). Depending on the grain size, precipitate type and layer thickness, the size of the spirals varies widely from several hundred micrometres to a few millimetres. To the naked eye, they look like small dots, but their detail is revealed under a microscope (Fig. 1c). These spiral cracks do not occur in one particular material — we were able to generate them in three different precipitates, from nickel phosphate $Ni_3(PO_4)_2$, ferric ferrocyanide $Fe_4[Fe(CN)_6)]_3$ and ferric hydroxide $Fe(OH)_3$.

Careful *in situ* observation suggested a mechanism for the formation of these cracks. The spirals and circle-shaped structures form only after the fragmentation process is over. Owing to the humidity gradient across the thickness, the fragments gradually fold up and detach from the substrate, generating large tensile stresses in the radial direction, at and normal to the front of detachment. The extent of the attached area shrinks as the ring-shaped front advances inwards as a result of ongoing desiccation.

When the stress at the front exceeds the material strength, a crack is nucleated. As the nucleation is seldom symmetrical with respect to the boundaries, the crack tends to propagate along the front in only one direction, where more stresses can be released. By the time the crack growth completes a cycle, the front has already advanced, leading eventually to an inward spiral crack. As the stresses are concentrated at the layer–substrate interface, the spiral is confined there, with a typical penetration of 20–60% of the thickness.

The fact that the patterns are largely spiral suggests that crack propagation is favoured over nucleation, otherwise we would see more cylindrical concentric cracks. Although in a few instances we did observe this type of pattern, the majority are spiral in structure.

To test the proposed mechanism, we implemented it in a mesoscopic computer model[8] that describes fracture on a frictional substrate. In this model, the grains in the layer are represented by blocks on a triangular lattice, interconnected among neighbours by springs. The system is prestrained, and then relieved quasi-statically in a physical way. The relaxation is dictated by the competition between stick-and-slip and bond-breaking.

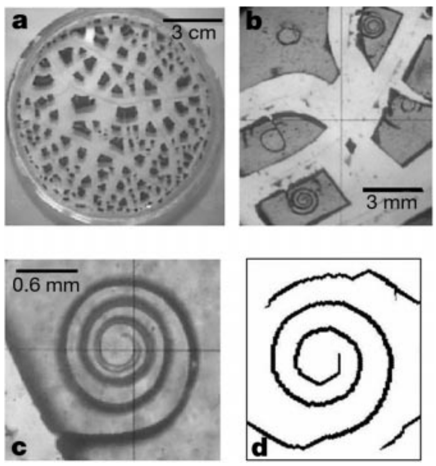

Figure 1 Spiral cracks revealed at small scales. **a,** Typical fragmentation pattern of nickel phosphate precipitate after desiccation in a Petri dish. **b,** Spiral and circular structures obtained inside the fragments. **c,** Close-up of a spiral crack. **d,** Computer-simulated spiral crack obtained using a mesoscopic spring-block model.

Focusing on the post-fragmentation process, we imposed a circular, inwardly propagating stress field to mimic the advancing detachment front. In a rather narrow parameter region, the spiral cracks were successfully reproduced (Fig. 1d). More tightly bound spirals can be obtained for smaller penetration depth, in agreement with experiment and prediction based on screening effects in the stress field. Other evidence has also been reported for the formation of similar spiral crack patterns under specific conditions[9].

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Polynesian origins

Slow boat to Melanesia?

The origin of the Polynesian islanders and of the Austronesian languages that they speak has been debated for more than 200 years. Diamond has presented the predominantly held modern viewpoint, described as the 'express train to Polynesia' model, which proposes that the ancestors of the Polynesians were early farmers who dispersed south from a homeland in South China/Taiwan, through Island Southeast Asia (replacing an indigenous 'Australoid' hunter-gatherer population), and then on east, out into the Pacific — all within the past 6,000 years[1]. However, evidence is accumulating from several genetic markers that Polynesian lineages have a much deeper ancestry within tropical Island Southeast Asia than this hypothesis would suggest. The new evidence implies that the Polynesians originated not in China/Taiwan, but in eastern Indonesia, somewhere between Wallace's line and the island of New Guinea.

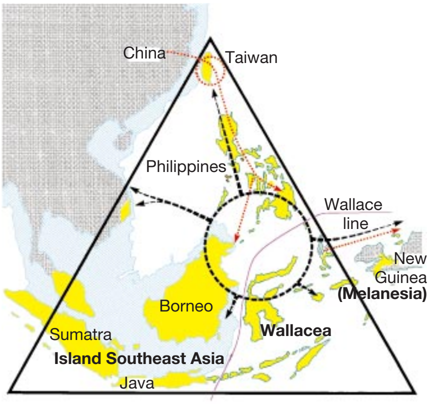

Figure 1 Map showing the two main alternative views of Austronesian origins. The oldest view represented by Meacham[10] (triangle) and Solheim[11] (dashed black lines and circle) argues for an Island Southeast Asian homeland (before 5000 BC). Bellwood's[5] and Diamond's[1] view of a recent rapid migration out of China (3000–4000 BC), spreading to replace all the older populations of Indonesia after 2000 BC is shown as a red dotted line. This is not supported by an ancient mitochondrial sequence haplotype, the 'Polynesian motif', found only to the east of Wallace's line (pink). Blue shading represents the continental shelf; yellow, areas where Austronesian languages are spoken.

Several genetic marker systems point to a primarily insular Southeast Asian ancestry for Polynesians. Much has been made of a hallmark maternal genetic marker known as the 'Polynesian motif'. This unique suite of four single-nucleotide polymorphisms in the control region of mitochondrial DNA identifies a subgroup within a widespread East Asian cluster of mitochondrial DNA lineages, haplogroup B, characterized by an intergenic 9-base-pair deletion[2–4]. The Polynesian motif, so called because it reaches very high frequencies in Polynesian populations, is the main Oceanic variant of haplogroup B.

The Polynesian motif is also distributed throughout the lowland populations of coastal Melanesia and the biogeographic zone of Wallacea (Fig. 1)[2,3]. More important, it is almost absent to the west of Wallace's line. It is not found in the Philippines, Taiwan or China — all key stations along the 'express train' route. Instead, in these regions its immediate ancestor is found with only three of the four polymorphisms, apparently breaking the train ride somewhere around Wallacea, where the final mutation in the motif, at nucleotide position 16,247, evidently occurred. This suggests that Wallacea, long believed to be an admixed buffer zone between Southeast Asia and New Guinea/Melanesia, might have harboured an ancient, indigenous population (of ultimately Asian origin) from which the Polynesian colonists emerged.

We looked into this possibility — that the final mutation did not occur en route in the express train, but earlier — by using the diversity accumulated by the motif to estimate its age using the molecular clock. The motif dates back in Wallacea to roughly 17,000 years before present (95% credible region: 5,500–34,500 years)[4]. But archaeological evidence, mainly from using red-slipped pottery as a marker, argues for a tightly constrained arrival and departure of the express train from Wallacea around 2000 BC (ref. 5), suggesting that the motif originated before an express train carrying Taiwanese farmers could have arrived in Wallacea.

A report describing Y-chromosome variation in the region reaches a similar conclusion[6], and earlier autosomal studies[7,8] and physical anthropology[9] also indicate ancient differentiation between mainland Asia, Taiwan, Island Southeast Asia and Melanesia. It is difficult to reconcile this evidence with the express train view — it seems to be more consistent with Austronesian origins within tropical Island Southeast Asia, as proposed earlier by other archaeologists[10,11]. In particular, it points more to Polynesian origins between insular Southeast Asia and Melanesia, perhaps in the Pleistocene 'voyaging corridor'[12].

Diamond highlights evidence of linguistic diversity to support a Taiwanese origin for Austronesian languages, which identifies ten primary branches in Austronesian, nine of which are spoken only in Taiwan[13]. But the lack of an origin for the tenth branch in Taiwan weakens the case for a Taiwanese origin. The lack of equivalent deep-branch diversity in parts of Southeast Asia such as the Philippines may instead have resulted from the linguistic phenomenon of 'levelling'. If Taiwan had simply been an Austronesian backwater, as argued on the basis of archaeological evidence[10], earlier levels of diversity might well have survived. Maybe the pre-Oceanic distribution of the Austronesian language family — its 'homeland' — was "… the broad triangular area formed by Taiwan, Sumatra, and Timor, where the reputedly oldest Malayo–Polynesian languages are found and where no other languages are spoken today"[10].

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Diamond replies — Until about 4000 BC, there were no domestic animals, farming, Neolithic tools, or pottery anywhere in Island Southeast Asia and the Pacific, except for Neolithic agriculture in the New Guinea highlands. Around 4000 BC, all of these things appeared in Taiwan and then spread eastwards in archaeologically well-dated stages through the rest of Island Southeast Asia out into Polynesia. Apart from some peoples of New Guinea and some adjacent islands, all those in this vast realm now speak Austronesian languages.

Where did this Austronesian expansion ultimately originate? The archaeological, linguistic, zoological and botanical evidence points overwhelmingly to China, where all of the Austronesians' domestic animals, their pottery styles, their Neolithic tools, their irrigation and fishing technology, and many of their crops and artistic motifs originated. The spread south from China into Mainland Southeast Asia of all four of the other major Southeast Asian language families also correlates with archaeologically attested expansions.

Oppenheimer and Richards downplay this body of evidence, favouring instead an Austronesian origin in Island Southeast Asia itself, specifically in the triangle formed by Taiwan, Sumatra and Timor. But they overlook the fact that modern Austronesian peoples predominantly resemble Asian Mainland peoples in their genes, appearance and physical anthropology, whereas the original inhabitants of Island Southeast Asia (still attested by many relict populations today) resembled modern New Guineans and Aboriginal Australians.

Oppenheimer and Richards cite genetic evidence (for example, the Polynesian marker whose age they calculate), but if genetic evidence is to be useful in reconstructing human population movements, it must be based on many loci and integrated with other types of evidence; calculations of marker ages with extremely wide confidence limits must be viewed with caution. Nobody doubts that Melanesians and other original island peoples did make some minor contribution to the gene pool of the Austronesians as they expanded eastwards through the islands into Polynesia. The Polynesian marker, in combination with other genetic markers and other evidence, should eventually prove useful in illuminating where, when and how, among the hundreds of Austronesian peoples, the Polynesians themselves arose and received that minor contribution. But the marker cannot alter the main conclusions about the Austronesian expansion.

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