

Patagonian toothfish found off Greenland

This catch is evidence of transequatorial migration by a cold-water Antarctic fish.

A large (1.80 metres in length and weighing 70 kg) Patagonian toothfish (*Dissostichus eleginoides* Smitt, 1898) has been caught in the northwest Atlantic, representing the first Northern Hemisphere record of the diverse, abundant and mainly Antarctic suborder Notothenioidei. This extraordinary catch indicates that large, cold-temperate fishes may occasionally migrate from sub-Antarctic to sub-Arctic waters by using deep, cold water, supporting a widely accepted but unproven proposal that the anti-tropical distribution patterns of many marine biota could be explained by transequatorial migration^{1–3}.

During commercial gill-net fishing for Greenland halibut in the Davis Strait (63° 02' N, 53° 32' W, at a depth of 1,331 m), a large, unknown fish was caught on 23 November 2000. Olaf Sólsker, the captain of the vessel *Isak L*, decided to freeze this strange specimen. We examined the fish and identified it as a male Patagonian toothfish, which is well known for being controversially caught by trawl and long-line fisheries in sub-Antarctic waters⁴.

None of the 139 notothenioid species has previously been recorded in the Northern Hemisphere⁵, but morphological analysis of the specimen (for example, IX and 28 rays in the dorsal fins, 28 in the anal fin and 26 in the pectoral fins) is consistent with data⁶ for *D. eleginoides*, except in a few details: the mid-lateral line does not extend forwards to the tip of the pectoral fin (Fig. 1), although the number of middle lateral-line scales (74) is within the range for *D. eleginoides* (64–77) and outside the range (35–48) for its sister species *D. mawsoni* Norman, 1937; there are two scaleless areas on the head as opposed to 12; the lower jaw has a short inner row of small teeth and a long outer row of large teeth, rather than a single row; in the upper jaw there are four rows and not two; the pectoral fin is shorter (12% of standard length, rather than 17–26%); and the body is deeper (23% of standard length, rather than 16–21%). These minor differences can be explained by allometric growth and are not indicative of a separate population or species. The only stomach content was an unidentifiable cephalopod upper beak.

It is unlikely that an unknown population of toothfish exists off Greenland, as none has been recorded during intensive fishing and surveying activity over the past 15–20 years. The species is already known to migrate over long distances (up to 1,800 km has been recorded by tracking⁷), and we consider it more likely that this was a stray specimen from a south Atlantic population.

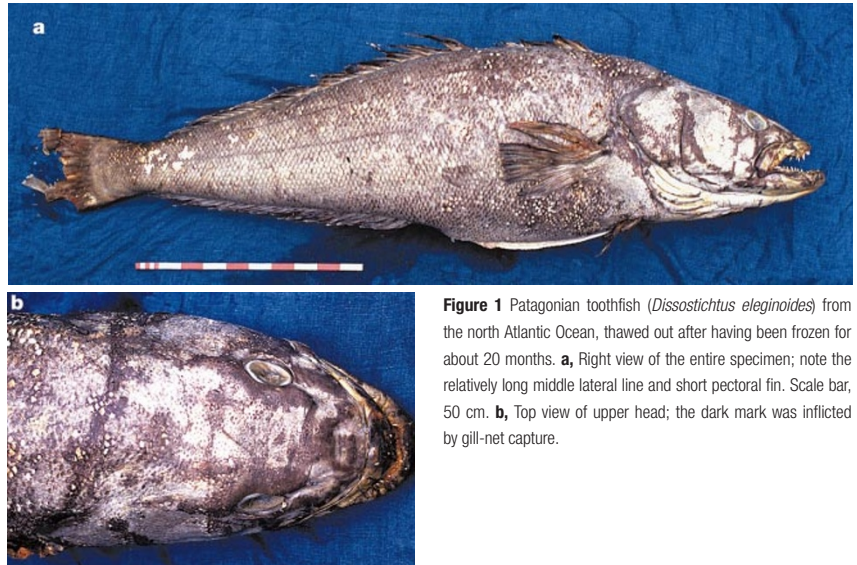


Figure 1 Patagonian toothfish (*Dissostichus eleginoides*) from the north Atlantic Ocean, thawed out after having been frozen for about 20 months. **a**, Right view of the entire specimen; note the relatively long middle lateral line and short pectoral fin. Scale bar, 50 cm. **b**, Top view of upper head; the dark mark was inflicted by gill-net capture.

The furthest north that a Patagonian toothfish has been recovered before⁸ is in the Atlantic Ocean off Uruguay at about 32° S, indicating that that specimen must have migrated at least 10,000 km.

The temperature range of *D. eleginoides* is 2–11 °C (ref. 9), so the transequatorial migration of the Greenland specimen must have included submergence beneath the intervening warm tropical waters, where temperatures are less than 10 °C at depths of 500–1,500 m (ref. 6); this strategy would enable the fish to travel all the way from Patagonia to west Greenland¹⁰.

Identified species of Greenland fish fauna have increased from 116 to more than 250 in 20 years, mainly as a result of increased fishing in deep waters. However, the discovery there of a Patagonian toothfish is so far unique. This finding supports the theory that transequatorial migration can occur by isothermal submergence^{1–3}, which has been proposed to explain the origin of marine anti-tropical distribution patterns.

Materials

Ultrahard polycrystalline diamond from graphite

Polycrystalline diamonds are harder and tougher than single-crystal diamonds and are therefore valuable for cutting and polishing other hard materials, but naturally occurring polycrystalline diamond is unusual and its production is slow. Here we describe the rapid synthesis of pure sintered

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polycrystalline diamond by direct conversion of graphite under static high pressure and temperature. Surprisingly, this synthesized diamond is ultrahard and so could be useful in the manufacture of scientific and industrial tools.

We used a multi-anvil apparatus for high-pressure synthesis¹. A pure polycrystalline graphite (99.9995%) rod was found to transform into a transparent, colourless phase in only a few minutes at temperatures of 2,300–2,500 °C and at pressures of

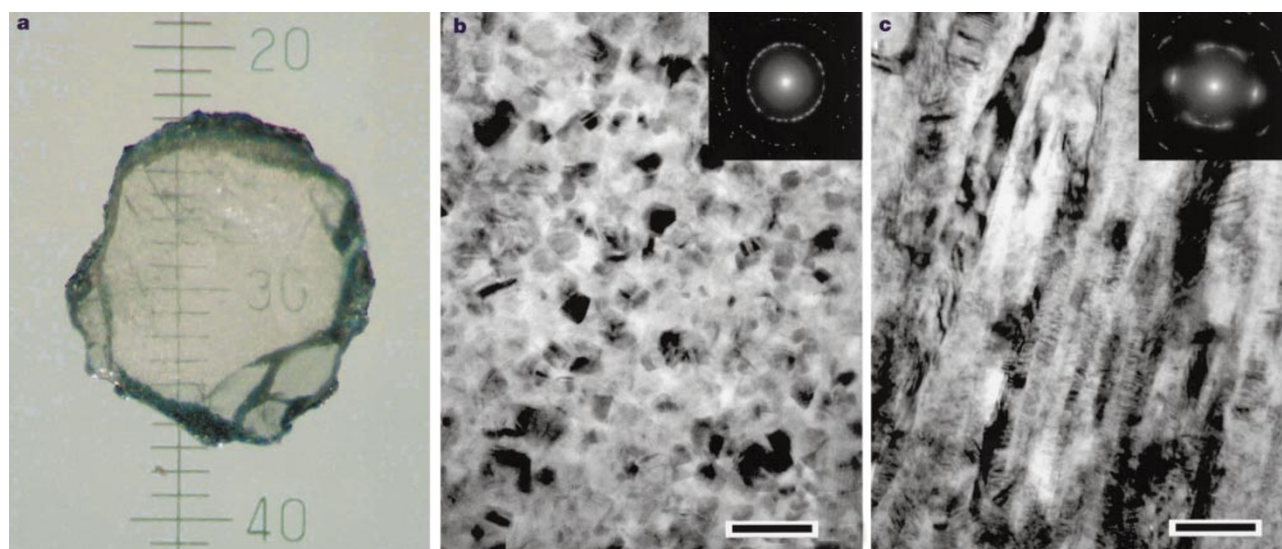


Figure 1 Sintered polycrystalline diamond synthesized by direct conversion of graphite. **a**, Optical microscopic image of a sample of the synthesized diamond (about 0.1 mm in diameter and 0.3 mm thick). **b, c**, Transmission electron microscopy reveals that this diamond material consists of minute crystals that are 10–20 nm across (**b**) and of larger, elongated (100–200 nm) crystals, which are evident in another region of the same sample (**c**). Scale bars, 50 nm. Insets, electron-diffraction patterns of each crystal type, obtained using a beam size of 400 nm.

12–25 gigapascals (GPa). X-ray diffraction and Raman spectroscopic measurements showed that this phase was pure cubic diamond. At lower temperatures (1,600–2,200 °C), a mixture of cubic and hexagonal diamonds, with a small amount of compressed graphite², was formed, which was opaque and dark grey in colour.

We studied a thin section taken from a transparent diamond sample (Fig. 1a) using a transmission electron microscope. The sample was seen to consist of very fine granular crystals, which were typically 10–20 nm across; electron diffraction indicated that these were randomly orientated (Fig. 1b). In other parts of the same sample, we observed elongated crystals of up to 100–200 nm in length that had a lamellar texture (Fig. 1c).

We measured the hardness of one opaque and two transparent samples, using a pure synthetic single-crystal diamond as a reference³. The transparent samples were found to have Knoop hardnesses of 110–130 GPa and 120–140 GPa, respectively, at several arbitrarily selected points, whereas the opaque sample was less hard (70–95 GPa).

Although diamond is the hardest known material, the Knoop hardness of single-crystal diamond varies from about 60–120 GPa, depending on the crystallographic plane and direction of measurement⁴. Our polycrystalline diamond is therefore as hard as (or even harder than) single-crystal diamond; moreover, this hardness is constant throughout the sample, unlike single-crystal diamond.

Previous attempts have been made to synthesize sintered polycrystalline diamond from graphite either by shock compression or by using static high pressure, but these were unsuccessful, mainly because the reaction time was too short and/or sample

heating was not homogeneous^{5–8}. Sintering diamond powders to produce a single large diamond also failed, because of heterogeneous stress distribution within the sample as a result of the extreme hardness of the raw diamond⁹.

Pure polycrystalline diamond has been produced previously by chemical-vapour deposition, but in a thin film and over several months to obtain millimetre-sized samples (see, for example, ref. 10). These diamonds were not sintered and had poor intergrain adhesion; the crystals were much larger than ours and their orientation was higher. They were accordingly less tough, with a hardness of 80–100 GPa (ref. 10).

Hard, sintered polycrystalline diamond is produced commercially by using a binder of metal or inorganic material^{11,12}, but this method reduces the hardness of the product to about 50–70 GPa. These sintered diamonds can be used only at temperatures of up to 600–700 °C — particularly in the presence of metal binders, which help diamond to transform back to graphite at ambient pressure. As our polycrystalline diamond is stable up to about 1,200 °C in an inert atmosphere, its hardness should exceed that of binder-containing polycrystalline diamond at high temperatures.

Improving the synthesis of the ultrahard polycrystalline diamond described here could give rise to better-quality products and to new industrial applications, for example in scientific instruments that operate at high pressure. A better understanding of the process by which our diamond is formed should also provide insight into the enigmatic origin of natural polycrystalline diamonds¹³.

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correction

Memory enhancement in early childhood

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In emphasizing references pertaining to brain maturation rather than to behavioural development, our brief list implied that this study was the first to demonstrate the emergence of long-term memory for events in infants. On the contrary, a large body of work published by P. Bauer, among many others, addresses this issue exactly and also forms the basis of the methodology developed for our study. Our contribution was to assess retention in children at three different ages after a four-month delay in order to test the *a priori* prediction, based on earlier studies of brain maturation, that nine-month-olds would be compromised relative to children in their second year. More extensive citation of work in this area was not possible because of the limited number of references permitted.

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Ecology

Parthenogenesis in an outsider crayfish

It has been rumoured¹ that an unidentified decapod crustacean, a crayfish of marbled appearance and of uncertain geographical origin that was introduced into the German aquarium trade in the mid-1990s, is capable of unisexual reproduction (parthenogenesis). Here we confirm that this marbled crayfish (*Marmorkrebs*) is parthenogenetic under laboratory conditions and use morphological and molecular analysis to show that it belongs to the American Cambaridae family. Although parthenogenesis is widespread among the Crustacea², and shrimp, lobsters, crayfish and crabs are otherwise versatile in their modes of reproduction^{3–5}, it has not been reported before in decapods, the largest and economically most important

crustacean group. By virtue of its parthenogenetic reproduction, the marbled crayfish emerges not only as an interesting laboratory model but also as a potential ecological threat in that it could outcompete native forms should even a single specimen be released into European lakes and rivers.

To determine the origin and phylogenetic position of the marbled crayfish (Fig. 1a), we compared the sequences of sections of two mitochondrial genes with those of other related species, with particular reference to a similar-looking cambarid species, *Procambarus fallax*, from Florida. The sequences in both genes of the marbled crayfish differ at only a few positions from those of other cambarids, which supports their morphological similarity (the presence of a spermatheca)⁶. Our phylogenetic analysis indicates a particularly close affinity with *P. fallax*, although the marbled crayfish's species identity remains to be verified (Fig. 1b).

We tested whether *Marmorkrebs* could be parthenogenetic by studying a mature female from a laboratory population in Berlin whose spermatheca contained no evidence of spermatophores from copulation, but which repeatedly laid eggs. Between two broods, this crayfish moulted, a procedure that clears any remnants of sperm from the spermatheca. We also sexed laboratory populations in Berlin (93 specimens from 7 mothers of two generations) and Heidelberg (39 specimens), beginning at the earliest stage at which sex can be determined. We found that all specimens (body length, 0.8–8.0 cm) showed female morphology, which excludes protandric hermaphroditism as the mode of reproduction. No spermatophore was detected in our study.

To rule out internal autogamy, we studied the histology and ultrastructure of the reproductive system of all 39 specimens of the Heidelberg population from juvenile (1.9 cm) to post-brooding (6.8 cm) stages. All gonads were normal ovaries with oviducts, and there was no evidence of ovotestes or male gonoducts (results not shown), which are usually present in hermaphroditic crayfish⁷. Azan staining of some adult gonad sections revealed an abundance of large, primary vitellogenic oocytes, and proliferating clusters of small pre-vitellogenic oocytes in the presence of hatchlings, indicating that a new reproductive cycle was already under way (Fig. 1c). These results provide convincing evidence for parthenogenesis in the marbled crayfish.

Our findings have several practical implications. This marbled crayfish will be

useful in the laboratory for physiological, ecological, evolutionary, developmental and genetic studies, having the advantages of fitness, high fertility, fast growth, unisexuality and isogenic progeny⁸. The large oocytes are easily accessible for genetic manipulation, making this species a candidate model for transgenesis⁹ in decapod crustaceans. The rapid reproduction of this crayfish might also be of interest for commercial farming purposes.

Last but not least, this crayfish, which is now widespread in Europe's aquaria, could become a menace to European freshwater ecosystems, as the release of even one specimen into the wild would be enough to found a population that might outcompete native crayfish. As an American species, it is a potential transmitter of the infectious crayfish plague that almost caused the extinction of the native European crayfish and which still threatens wild and farmed populations¹⁰.

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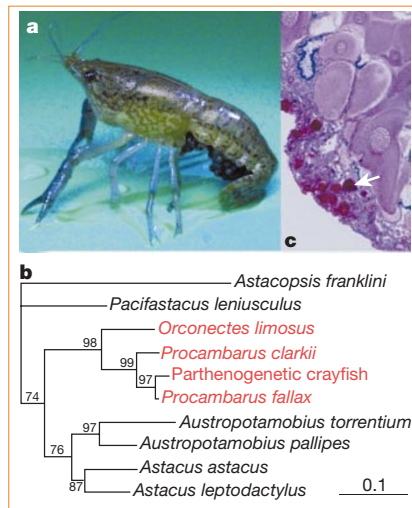


Figure 1 Characteristics of the marbled crayfish. **a**, Lateral view of the crayfish, showing the eggs attached to its pleopods. Adult specimens are 3–10 cm in length (rostrum to telson). The basic colour is brown–green, with light and dark spots. **b**, Phylogenetic relationships of the marbled crayfish based on a comparison of the partial sequences of two mitochondrial genes, *Cox1* and the gene encoding 12S ribosomal RNA; GenBank accession numbers, AY151515–AY151524, AY151525–AY151534. Maximum-likelihood analysis used the Hasegawa–Kishino–Yano model, assuming rate heterogeneity with a log likelihood of –3075.69; the reliability of branches is given as a percentage of puzzling steps where the appropriate node arises. Parsimony analysis produced similar results. The marbled crayfish belongs to the American Cambaridae (red) and is closely related to *Procambarus fallax* (only 2.2% of base positions different). Scale bar, 0.1 nucleotide substitutions. **c**, Azan-stained histological section of a gonad of a female with hatchlings exclusively composed of ovarian tissue. Arrow, pre-vitellogenic oocyte; arrowhead, primary vitellogenic oocyte.

correction

Ultrahard polycrystalline diamond from graphite

T. Irifune, A. Kurio, S. Sakamoto, T. Inoue, H. Sumiya *Nature* 421, 599–600 (2003)

In the legend to Fig. 1a of this communication, the diameter of the transparent polycrystalline diamond shown is 1 mm, and not 0.1 mm as published; the scale divisions represent 0.1 mm. Also, the first full paragraph in the second column on page 600 should read: "Recent chemical-vapour deposition techniques provided pure polycrystalline diamonds, but these diamonds are not sintered and have poor intergrain adhesion. Accordingly, they have been reported to have a hardness of ~80–100 GPa (ref. 10), which is significantly lower than the highest value (~120 GPa; ref. 4) for single-crystal diamonds."