SEAWIFS GLOBAL OCEAN MONITORING

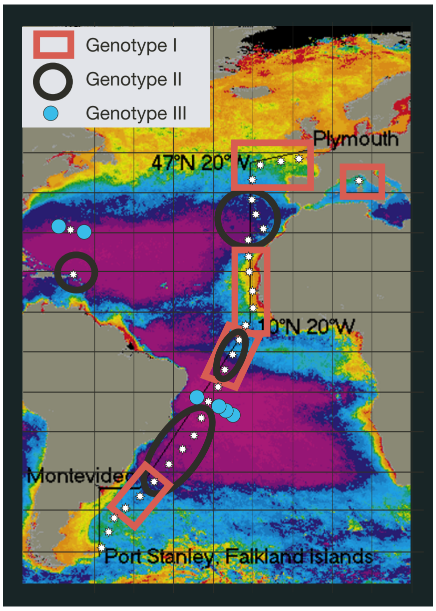

Figure 2 **Ecological differentiation in three distinct genetic groups of the subtropical–tropical planktonic foraminifer *Orbulina universa*[7]. One variant (genotype I) was collected from areas with high chlorophyll concentrations, indicating high biological productivity (red boxes); the second (genotype II) came from waters with lower chlorophyll concentrations (black circles and ovals); and the third (genotype III) was found only in low-productivity waters of the subtropics (blue dots).**

masses[9]. There are hints that the high-latitude species described by Darling *et al.*[1] also have different ecological preferences. Apparently, the various genetic types have become specialized in different surface-water masses from the tropical to the polar oceans.

Clearly, in traditional morphological analyses of planktonic foraminifera, a great deal of diversity has been overlooked or regarded as mere variation. It appears that each of the 50 or so living species[2] is likely to represent clusters of related species. One need will be to find ways of recognizing the various genetic types in the fossil record so that they can be used to reconstruct ancient environments and global climate more accurately. Indeed, the varieties of *Orbulina* appear to be recognizable by their shell porosity, as is the case for other genetically distinctive variants of foraminifera[8]. Limited genetic studies of different groups, such as the phytoplankter *Prochlorococcus*[10] and the fish *Cyclothone*[11], suggest that the underestimation of marine diversity is widespread. Evolutionary models that rely on barriers to dispersal in the oceans may well need a fundamental rethink in light of these new data. ■

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Palaeoanthropology

Coasting out of Africa

Chris Stringer

It is now generally accepted that Africa is the ancestral homeland of modern humans, *Homo sapiens*[1–3]. But the timing of human dispersal from Africa, and the routes taken, remain controversial. Was there only one major dispersal, which took place after 50,000 years ago[1]? Or were there several episodes of migration, starting earlier and covering a longer period of time[2]? Moreover, was the most obvious route taken — through Sinai and the Levant (the eastern Mediterranean coast) — or might there have been other pathways?

On page 65 of this issue, Walter *et al.*[4] present the first well-dated evidence that humans were living along the African coast of the Red Sea during the last interglacial, around 125,000 years ago, and were probably exploiting marine food resources. They argue this finding implies that there was a major change in human adaptive capacities at about that time. It may also indicate that coastal routes were used by early *Homo sapiens* to leave the African homeland. Other shorelines of Late Pleistocene age (oxygen isotope stages 2–5; see Fig. 1 for chronology) might therefore preserve further traces of our exodus from the continent.

At one time it was believed that humans began to exploit marine resources only during the Eurasian Upper Palaeolithic, after 40,000 years ago[5]. But it seems that both early modern humans in southern Africa and Neanderthals in the Mediterranean did this during the Middle Palaeolithic[1,6], at sites such as Klasies and Herold's Bay Caves in South Africa, and Vanguard Cave (Gibraltar) and Moscerini Cave (Italy), respectively (Fig. 2). However, much of the Late Pleistocene evidence of these seaside dwellers must now be submerged beneath the high sea levels that have pertained during the present interglacial, which started some 12,000 years ago. Because of their elevated altitude, due to the higher sea levels of that time, sites of last-interglacial (early oxygen isotope stage 5) age

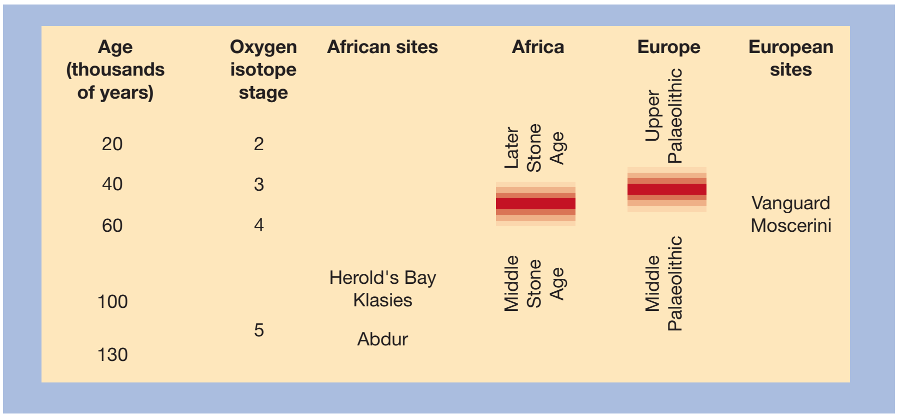

Figure 1 **Chronology for the Late Pleistocene[1]. Oxygen isotope stages reflect climatic changes inferred from isotope ratios in marine microorganisms in deep-sea cores (roughly, odd numbers indicate relatively warm conditions and even numbers relatively cold). The sites mentioned, including Abdur[4] (discussed here), are those with evidence of the early exploitation of marine food resources. The traditional division of the European Old Stone Age is into Lower, Middle and Upper Palaeolithic stages. In Africa, a comparable scheme uses the terms Early Stone Age, Middle Stone Age and Later Stone Age, and there is some evidence that the African transition between the Middle and Later Stone Ages occurred before the European transition from Middle to Upper Palaeolithic. Middle Palaeolithic industries in Europe were produced by Neanderthals, whereas Middle Stone Age industries were probably the product of modern humans.**

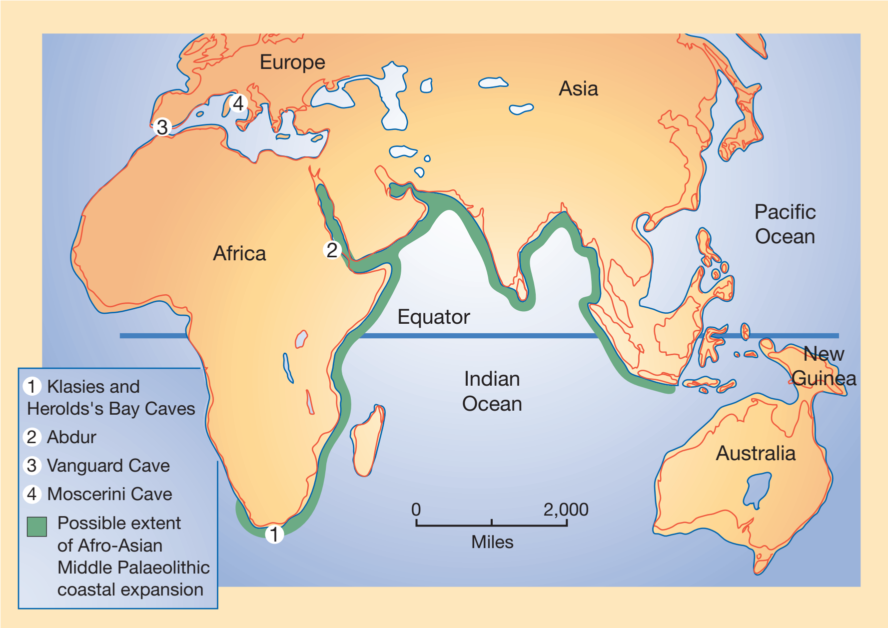

Figure 2 **The Old World as it might have looked during the Late Pleistocene, around 65,000 years ago. At that time, large amounts of sea water were locked up in polar ice sheets, so sea levels were lower and more land was exposed (present-day shorelines are in red). Known coastal sites of human occupation during the Middle Palaeolithic are marked; Abdur is the site investigated by Walter *et al.*[4] and discussed here. A putative route for coastal migration of modern humans from Africa to Asia is shown in green. (Redrawn after ref. 10.)**

are more likely to have remained exposed. This is particularly true where the land has been uplifted by geological processes, as is the case around parts of the Red Sea.

Walter *et al.*[4] recovered Middle Stone Age (African Middle Palaeolithic) artefacts, such as hand axes and obsidian flakes, from strata in a raised fossil reef near Abdur in Eritrea (Fig. 3). Geomorphological considerations and correlation with other Red Sea localities suggest that the site dates to the last interglacial. Walter and colleagues confirmed this age with uranium-series dates that, on average, gave a figure of about 125,000 years. Who made the artefacts is unknown. But there are fossils of near-modern or modern *H. sapiens* from around this time[1,2] in neighbouring regions such as Ethiopia (Omo Kibish), Sudan (Singa), Kenya (Guomde) and Israel (Skhul and Qafzeh). So it is likely that the people concerned were early members of our species.

Klein[1] has argued that the main dispersal of modern humans from Africa probably occurred only after the beginning of the Later Stone Age (equivalent to the Eurasian Upper Palaeolithic). For him, that event heralds the beginning of modern cognitive and adaptive capabilities. According to this view, then, the presence of modern humans in the Levant during the last interglacial, represented by the burials at Skhul and Qafzeh, was only a brief geographical extension of the species from Africa. The real dispersal of *Homo sapiens* was through that region, but did not occur until the Upper Palaeolithic, perhaps 45,000 years ago.

Other workers have favoured an earlier, Middle Palaeolithic, beginning for dispersals. Kingdon[7] proposed that Middle Palaeolithic people left Africa through the Levant and reached southeast Asia by 90,000 years ago. There they adapted to coastal conditions, and developed a boat- or raft-building ability that enabled them both to return to Africa and to move southwards to Australia. By contrast, Lahr and Foley[2] suggest in their 'multiple dispersals model' that a more direct route from Africa to Arabia and further east could have been taken before 50,000 years ago, perhaps using the coast. However, subsequent dispersals to the north, evidence for which comes from early Upper Palaeolithic artefacts found in countries such as Egypt, Israel and Bulgaria, would have followed the Levantine route.

The findings of Walter *et al.*[4], together with new data from Australia, allow further elaboration of these possibilities. There is increasing archaeological evidence[8] that Australia was colonized (by boat, because no landbridges existed during the Pleistocene) before 50,000 years ago — that is, before the proliferation of Later Stone Age and Upper Palaeolithic features such as blade tools and art. Moreover, a modern-human burial site from southeastern Australia, associated with the symbolic use of red ochre, has been re-dated to about 60,000 years ago[9]. This implies that at least one dispersal of modern humans from Africa must have occurred during the Middle Palaeolithic, and that characteristic

100 YEARS AGO

The motion for the second reading of the Sea Fisheries Bill in the House of Commons, on Monday, resulted in a lively discussion. The Bill prohibits the sale of flatfish below a specified size, and its rejection was moved on the grounds that it would not have the effect of preventing the destruction of immature fish, or of increasing the supply of fish. In the course of discussion, an honourable member said that the whole of the trouble arose from the institution of a number of committees composed of farmers, lawyers and captains of the horse, foot, and artillery, who knew little of fishing, and who ventilated strange theories and supported them with portentous and irrelevant statistics. This remark was used as an argument against the Bill, but it may also be taken to mean that if fishery matters were controlled by scientific men familiar with the natural history of the sea, and questions concerning fisheries were referred to marine biologists, recommendations would be made upon which reasonable regulations might be based.
From *Nature* 3 May 1900.

50 YEARS AGO

The possibility of presenting television pictures of an adequate brightness on the large-size screen used in cinemas has been under development in Great Britain for some years. On April 29, the opportunity was taken by Messrs. Cinema–Television, Ltd., to demonstrate the state of this development by showing the B.B.C. Cup Final television programme to a selected audience of about a thousand persons, including television experts from some fifteen countries. The normal programme radiated from the Alexandra Palace transmitter was received in the neighbourhood of the Odeon Theatre, Penge, where the demonstration was given. The received signals were conveyed to special equipment placed in the auditorium of the theatre at a distance of some 12 metres from the screen. A very bright image of the television picture, about 16 cm. × 13 cm. in size, was formed on a special cathode-ray tube operating from a high-tension supply of 50 kilovolts. The optical projection system comprised a spherical mirror and plastic correcting plate by means of which the picture was thrown on to the theatre screen… In spite of the fact that, owing to weather conditions, the daylight at Wembley was on the dull side, the demonstration was very satisfactory.
From *Nature* 6 May 1950.

elements of modern-human behaviour existed by then.

We can now add Walter and colleagues' discoveries[4] to this picture. Middle Palaeolithic people might have spread from Africa along the shorelines of Arabia and into southern Asia during, or soon after, the last interglacial. Continuing along the narrow shorelines, to which they were already adapted, they could have progressed all the way to Indonesia at times of low sea level (Fig. 2). Movement along the coasts meant that they could have been spared the degree of habitat disruption faced by inland populations during the rapid climatic fluctuations of the Late Pleistocene. Coastal migration might also explain why they did not immediately replace archaic peoples living inland, such as those known from Ngandong in Indonesia[1]. At what stage the coastal migrants first ventured out to sea is unknown, but from the Australian evidence it seems that it must have been before 60,000 years ago. Such behaviour may have developed through the need to ford rivers or extend coastal foraging areas.

Archaeologists might now concentrate profitably on exposed fossil beaches in regions such as Arabia and India. Such sites may well contain Middle Palaeolithic artefacts that further document the spread of modern humans and their adaptations to a coastal environment. Southern Asia must have formed an important secondary centre for dispersals of modern humans — there, too, it may have been the coasts that provided the first and fastest routes for migration, before movement inland up river valleys. ■

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Fluid dynamics

Turbulence without inertia

Ronald G. Larson

In the 1880s Osborne Reynolds[1] established that fluid inertia (that is, momentum) drives the irregular patterns observed in water flowing rapidly from a pipe, plumes emerging from a smokestack, eddies in the wake of a bulky object, and many other everyday phenomena. Known as 'turbulence', these patterns occur at high values of the Reynolds number, the dimensionless ratio of inertial to viscous force. Over the years turbulence has become better characterized, and we now know it to be accompanied not only by an increase in drag, but also by certain characteristic spatial or temporal velocity fluctuations.

On page 53 of this issue, Groisman and Steinberg[2] show that both an increased resistance to flow and other features of turbulence can occur in fluids with hardly any inertial forces, if the role of inertia is instead played by elasticity, a force present in solutions of long-chain polymers. The flow studied by Groisman and Steinberg is simple: a polymer fluid confined between two parallel disks is sheared by rotation of one of the disks about their common axis. At increased flow rates (but rates still too low to generate much inertia) the flow acquires turbulent characteristics.

Irregular flow patterns have long been seen in polymeric and other elastic fluids, and have even occasionally been dubbed 'elastic turbulence'[3]. One such flow is that of a polymer melt emerging from the end of a capillary tube. Above a critical flow rate, the polymer jet becomes irregularly distorted (Fig. 1). Distortions in this and other polymer flows can mar products made from polymers, such as films and extruded parts. If the polymer is made more viscous by increasing the length of its polymer molecules, the minimum flow rate producing such irregular flow decreases. This is surprising because an increase in viscocity has the opposite effect on inertially driven turbulence. In fact, for fluids containing long polymer molecules, the Reynolds number at the onset of the instabilities can be minuscule, as low as 10^{-15}. Turbulent flow of water in a pipe, by contrast, has a much higher Reynolds number, around 10^5.

It is clear, then, that inertia has nothing whatsoever to do with this kind of polymeric 'turbulence'. For viscous polymers, instabilities and irregular flows set in at a critical value of the so-called Weissenberg number, the ratio of elastic to viscous forces in the fluid, which for polymeric fluids plays the role of the Reynolds number in creating the nonlinearities that lead to unstable flow. Because elastic forces increase with polymer length more rapidly than do viscous forces, fluids containing long polymers are especially prone to such phenomena, despite having viscosities that can be hundreds to millions of times higher than water. Until the work of Groisman and Steinberg[2], quantitative measurements of the length and time scales of elastic turbulence had been lacking.

Still lacking, even now, is a proper understanding of how the length and time scales of elastic turbulence are produced by the underlying elastic forces. In other words, what is missing is an elastic counterpart of the 'cascade' picture of inertial turbulence. In this, the largest eddies in the flow feed their energy into smaller eddies, which in turn drive even smaller eddies, and so on — until the energy stored in the smallest eddies is finally dissipated as heat. The resulting hierarchy of interacting eddies of various sizes is known as well-developed or hard turbulence. In Kolmogorov's 'bucket brigade' description of hard turbulence, a power-law distribution in length scales is produced by this handing off of energy from larger to smaller eddies[4].

For 'elastic turbulence', the basic mechanisms of instability in the base flow have only recently been discovered. These mechanisms involve 'normal stresses'. Normal stresses are produced by the stretching of polymer molecules in a flow, leading to an elastic force like that in a stretched rubber band. If the streamlines are circular, the polymer 'rubber bands' press inward from all directions, generating a radial pressure gradient. This

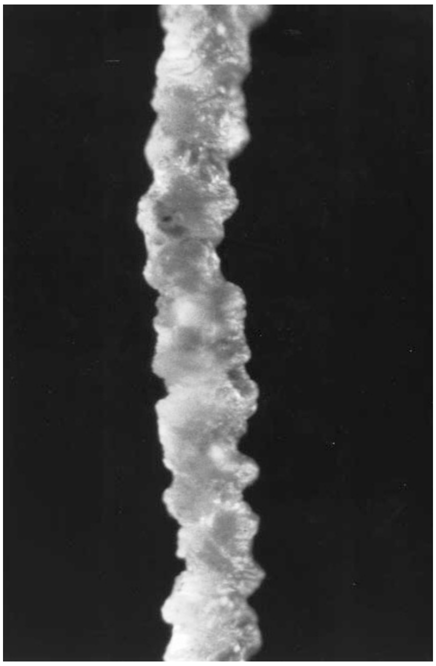

Figure 1 **Is this jet turbulent? Turbulent flow is normally associated with a high Reynolds number. A polymer melt of high viscosity (5,000 pascal seconds) and low Reynolds number is greatly distorted after emerging from a capillary tube[12]. Groisman and Steinberg[2] now confirm that the defining features of turbulence can appear in the flow of a polymer solution with high elasticity but low Reynolds number.**