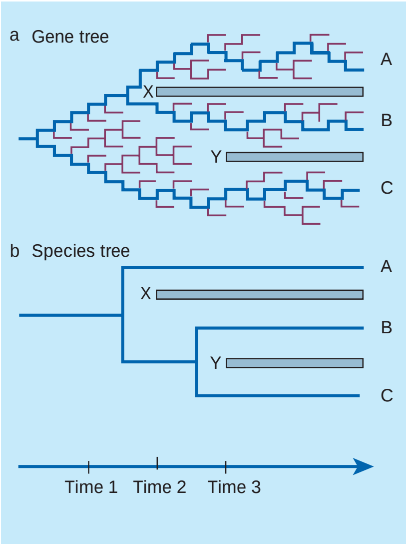

Figure 1 **The difference between gene trees and species trees.** a, **An ancestral species contains many mitochondrial DNA variants (time 1). The evolution of a species barrier (X) separates the ancestral population into two gene pools (time 2). A second species barrier (Y) arises later, producing the full set of species (A, B, C). Phylogenetic reconstruction from the mitochondrial gene sequences suggests that species A and B are most closely related. But as shown in** b, **B and C are the most recent and closely related species, having shared a common gene pool until time 3.**

the confines of Lake Victoria. These cichlids still represent the fastest known rate of vertebrate speciation, whether they shared an ancestor 10,000 or 100,000 years ago. So, what can these phylogenetic studies tell us about the characteristics that predisposed the ancestor of the Lake Victoria flock to undergo such rapid radiation? Verheyen *et al.* suggest that the immediate ancestors were already well adapted to the lake environment because *H. gracilior* shares the key ancestral haplotype with six other, ecologically diverse species from Lake Kivu. Likewise, Seehausen *et al.* point out that the genus *Thoracochromis* is already diverse in colour pattern and feeding habits, presaging the variation among species that occupy different ecological niches in Lake Victoria. But in fact the capacity for rapid and extensive radiation lay already in a *Haplochromis* species that lived at least a million years ago, because that species was the common ancestor of both the Lake Victoria flock and the spectacular parallel radiation of Lake Malawi cichlids in the southern Rift Valley[8].

The challenge is to extend these phylogenies down to the level of incipient species. Only at this level can we study the selective forces acting on particular morphological and behavioural characteristics. Genomic techniques now enable us to identify the genes underlying key adaptive differences. It is the evolutionary history of these genomic regions in particular that should illuminate the selective mechanisms responsible for the fantastic diversity of East African cichlids. ■

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1. Johnson, T. C. *et al. Science* **273,** 1091–1093 (1996).
2. Verheyen, E., Salzburger, W., Snoeks, J. & Meyer, A. *Science* **300,** 325–329 (2003).
3. Nagl, S., Tichy, H., Mayer, W. E., Takahata, N. & Klein, J. *Proc. Natl Acad. Sci. USA* **95,** 14238–14243 (1998).
4. Nagl, S. *et al. Proc. R. Soc. Lond. B* **267,** 1049–1061 (2003).
5. Albertson, R. C., Markert, J. A., Danley, P. D. & Kocher, T. D. *Proc. Natl Acad. Sci. USA* **96,** 5107–5110 (1999).
6. Seehausen, O. *et al. Proc. R. Soc. Lond. B* **270,** 129–137 (2003).
7. Suzuki, Y., Glazko, G. V. & Nei, M. *Proc. Natl Acad. Sci. USA* **99,** 16138–16143 (2002).
8. Meyer, A., Kocher, T. D., Basasibwaki, P. & Wilson, A. C. *Nature* **347,** 550–553 (1990).

Earth science

A slice of history

Paul D. Asimow

Investigations of an exposed slice of oceanic crust and mantle have provided a dramatic picture of temporal variation in the activity of the Mid-Atlantic Ridge — including its pulse rate of 3–4 million years.

In textbooks, mid-ocean ridges are often described as 'tape recorders': new crust is continuously being created by the partial melting of upwelling mantle and its eruption onto the ocean floor, where it solidifies and is 'rafted' away to either side of the ridge by seafloor spreading. The result — at least in textbooks — is an easily accessible map-view record of the formation of tectonic plates on the sea floor. The reality is much more messy. Not least, the tape is quickly obscured by sediments. In the central Atlantic, however, at about 11° N, a quirk of movement has elevated a slice of sea floor and exposed a section through the crust and upper mantle at the Mid-Atlantic Ridge. This slice, known as the Vema transverse ridge, provides a view of 310 km, or 20 million years of Earth history. On page 499 of this issue[1], Bonatti *et al.* describe the insights into mid-ocean-ridge activity that may be gained from the Vema exposure.

To geophysicists using 'remote' techniques, the tape-recorder history remains

100 YEARS AGO

The extraction of the perfume from flowers such as jasmine, tuberose, violet and cassia has long been carried out by the process of enfleurage, the blossoms being left in contact with purified lard for a few days, and then replaced by fresh blossoms. The lard is either sold as such, or the essential oil may be extracted from it by melting it under strong alcohol. As the process of enfleurage is somewhat tedious, attempts have frequently been made to extract the oil directly from the flowers by means of light petroleum, but these processes have not as a rule proved successful, and it has recently been found that a very large proportion of the perfume is actually produced for the first time in the blossoms during the time occupied by the enfleurage. An interesting illustration of this is given by Dr. Albert Hesse in a recent number of the *Berichte*, in which he states that a ton (1000 kilos.) of tuberose blossoms only yielded 66 grams of oil when extracted with light petroleum, but during enfleurage yielded 801 grams of oil to the fat in which they were embedded, whilst a further 78 grams remained in the faded blossoms and could be separated by extraction or distillation.
From *Nature* 28 May 1903.

50 YEARS AGO

Although many papers have been written, there is still much that is not understood concerning the external and internal factors responsible for the cyclic nature of reproduction in reptiles. Investigations of the seasonal fluctuations in various parts of the reproductive system of several species of lizards, snakes and turtles have revealed interesting species differences. For a more complete understanding of reptilian reproduction it would appear that detailed descriptions of the seasonal changes of many species are desirable… Such a study was carried out by Wade Fox on the common garter snake (*Thamnophis*), several species and subspecies of which could easily be obtained throughout the year in the vicinity of San Francisco Bay. These investigations showed that the gonads of the male garter snake, *Thamnophis elegans terrestris*, exhibit marked seasonal variation. The testes begin to increase in size in the early spring, reach their maximum size and weight in late July, decline in the autumn, and are of minimum size during the winter months.
From *Nature* 30 May 1953.

readable for more than 100 million years in the magnetic, gravitational and topographical characteristics of ridges and their offspring plates. But for those who depend on direct collection of rock samples for chemical analyses to determine the composition and origins of the rocks, the tape is ruined within tens of kilometres — equivalent to a few hundred thousand years — by sediment cover. A full picture of the processes occurring at mid-ocean ridges requires a '4-D' view of the architecture of the oceanic lithosphere, the cold and hence relatively rigid crust and upper mantle that constitute the tectonic plate. Yet from a chemical perspective, in most circumstances we can only work systematically in one dimension (along the ridge axis at zero age and at the seafloor depth at which the rocks are exposed).

The sequence of rock types to be found on the ocean floor is quite systematic, and each rock carries evidence of its origin in the crust-forming process. The upper mantle is dominated by rocks called peridotites. When plate spreading draws peridotite upwards beneath the ridge, the rock undergoes partial melting. The liquid fraction separates and rises to form the intrusive 'gabbroic' rocks of the lower oceanic crust and the erupted basalts that constitute the upper oceanic crust. The remaining solid material — the residual peridotite — is chemically modified by the loss of the more fusible elements (becoming richer, for example, in chromium relative to aluminium, in titanium relative to zirconium, and in magnesium relative to iron). Some of these residues of melting eventually end up near the base of the crust and, as they cool, become incorporated into the lithosphere.

Rocks that have undergone melting, together with their residues, are evident elsewhere on Earth, of course — for instance in volcanoes on land. But attempts to use them to investigate Earth's interior are often confounded by the difficulty in distinguishing the source (the composition of the rock that entered the melting region) from the process that modified it (the extent of melting, the temperatures and pressures involved, and the subsequent segregation, migration, differentiation, and so on). Yet at mid-ocean ridges, the entire crust is constructed in one episode of melting, and so the thickness of the crust provides a key overall constraint on the extent of melting. Given that there is a positive correlation

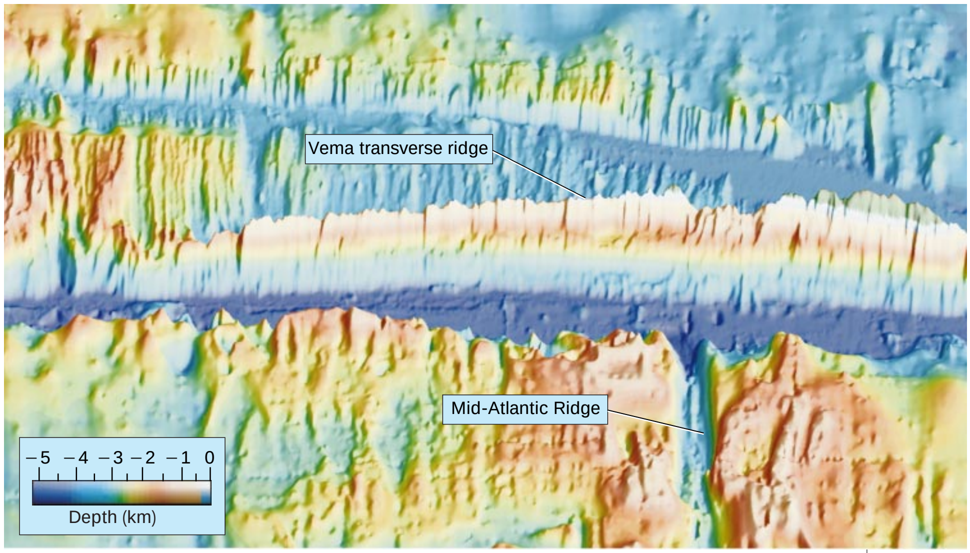


Figure 1 **Ocean deep, mountain high. Under the waters of the central Atlantic, straddling the axis of the Mid-Atlantic Ridge, is a remarkable geological feature. The Vema transverse ridge is an exposed section of crust and mantle rocks, rising from a depth of more than 5,000 m at its valley floor to only 450 m below the sea surface at its highest point. Mapped by Bonatti *et al.*[1], and viewed here from the north, the ridge is a 20-million-year chronicle of tectonic activity.**

Astronomy

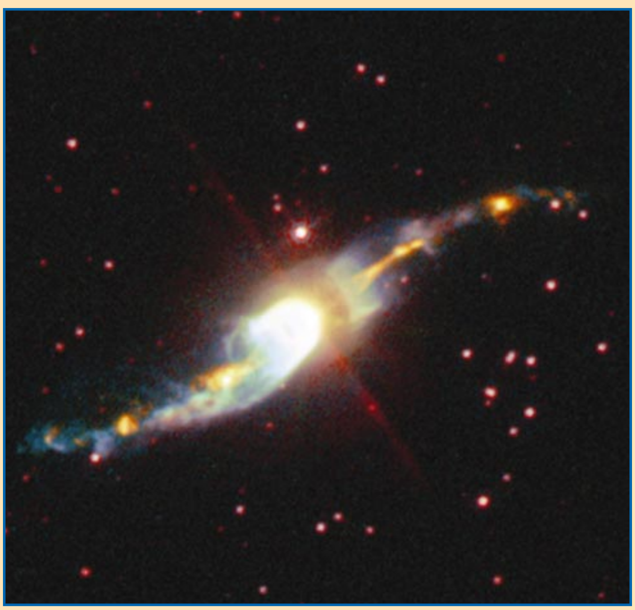
Sprinkler system

Henize 3-1475 is a planetary nebula — an expanding shell of gas surrounding a star that is entering the last stages of its life (and, in fact, nothing to do with planets at all). The gas shell of such an object may be spherical, dumb-bell-shaped or even completely irregular, but in the case of Henize 3-1475 it is concentrated into two fast-moving jets that emerge with velocities of up to 4 million kilometres per hour. As the system is also rotating, astronomers have nicknamed it the 'garden-sprinkler' nebula.

Angels Riera and colleagues have produced this composite image of Henize 3-1475 using different filters on a wide-field camera that is part of the Hubble Space Telescope. Coupled with observations from ground-based telescopes, their data reveal that the fast outflow of gas from the central star is not regular. Instead, the gas is ejected in clumps, roughly once every hundred years. How the jets are created is still a mystery, but this clumping effect could be caused by interactions with a nearby companion star, or by magnetic processes in the central star (similar to the 22-year cycle of magnetic activity that creates sunspots on our own star).

The misnomer 'planetary nebula' was coined by William Herschel in 1784: cataloguing these objects, he was struck by how closely they resembled (viewed through a telescope considerably less powerful than Hubble) the planet he had recently discovered, Uranus.

Alison Wright



A. RIERA, TECH. UNIV. CATALONIA/P. GARCIA-LARIO, ISO/ESA between crustal thickness and the mean extent of melting inferred from the chemistry of erupted basalts[2] and residual peridotites[3], only the remaining, uncorrelated chemical variability can be attributed to the source.

This has led to the idea that variability along the mid-ocean-ridge system is mainly caused by temperature changes in the underlying mantle, which would affect the extent of melting of a reasonably homogeneous source. Such an idea is consistent with most (but not all) of the isotope data on the long-term history of the mantle sources of mid-ocean-ridge basalts. The zero-age view, however, gives little useful information about the geometry and dynamics of the flow of rock through the region of the mantle where melting occurs, or how this flow may vary with time.

This is where Bonatti and co-workers come in[1]. The exposure of the Vema transverse ridge (Fig. 1) has allowed them to dredge up and analyse rock that would normally be deeply buried. They have therefore been able to measure an apparent time-delay between changes in crustal thickness, as estimated from gravity data, and in residual peridotite chemistry over the 20-million-year timescale. Their chain of logic derives from the following observations. The signals indicating crustal thickness and the extent of peridotite depletion show oscillations that have a wavelength of about 60 km (corresponding to a 3–4-million-year frequency), superposed on an overall 20-million-year trend of increasing peridotite depletion and crustal thickness. The variations seen in the two signals are correlated, but there is a phase lag of 22 km (or some 1.3 million years of spreading time) between the signals.

Bonatti *et al.* attribute the overall 20-million-year thickening trend to long-term warming of the mantle beneath the equatorial Atlantic, caused by southwards flow of mantle from 'hotspots' in the North Atlantic (although they acknowledge that it could also be due to along-axis growth of this particular ridge segment with time). The most exciting aspect of this study, though, is the interpretation of the 3–4-million-year signal. Experts might ask for a tighter correlation between the time series of crustal thickness and extent of melting derived from peridotites, but this correlation seems to dispense with the need to invoke explanations for the observed variation in crustal thickness that depend entirely on melt migration or variation in the composition of the source rock.

That leaves variations in mantle temperature and flow geometry. There is no obvious reason why mantle temperature should oscillate at this 3–4-million-year frequency, but dynamical calculations, making certain assumptions about viscosity changes and the internal buoyancy of basalts and residual peridotites, predict that there would be bursts of increased flow through the melting region[4]. These episodes of rapid flow can explain times of high crustal thickness. But the mechanism by which they generate more depleted residual peridotites is unclear, as is the basis of the sawtoothed form of the crustal-thickness signal (as strikingly depicted in Fig. 3d on page 501). Bonatti *et al.* propose that the flow variation is restricted to the deeper, water-bearing, and hence low-viscosity, part of the melting regime[5] and that the intervals of active flow somehow deliver hotter material to the shallower, high-viscosity part of the melting regime. An alternative explanation is that the episodes of active flow change the balance between advection and conduction in the shallowest part of the melting region, as hinted at by equilibration temperatures that record different cooling rates in the same peridotites.

What of the 22-km offset between the signals denoting residual peridotite and crustal thickness? Melt migration is much more rapid than solid flow through the melting region, so there would be a time delay between melt extraction from a given parcel of peridotite to create basalts, and the eventual emplacement of that same peridotite as a residue at the base of the lithosphere. In other words, the oscillation signals carried by the melt volume and by peridotite chemistry propagate upwards at different speeds and are recorded at different times, being spatially offset by the plate spreading rate. Bonatti *et al*. use the phase lag between their extent-of-melting signals from peridotite and from crustal thickness (assuming that the bulk of the melt separates at a depth of 35 km and that melt velocity can be taken as infinite) to calculate the solid upwelling rate, and they arrive at an estimate of 25 mm per year. This is faster than the rate at which the plate is moving away from the ridge (14–17 mm per year) and hence is consistent with a component of buoyant flow.

Mid-ocean ridges have different characteristics according to their speed of spreading. At the Vema anomaly, the Mid-Atlantic Ridge is slow spreading, and Bonatti and colleagues' study adds to our understanding of how the oceanic crust grows in these circumstances. Similar understanding of fast-spreading sections, which do not tend to create such spectacular tectonic exposures, seems further away, but there is plenty more to learn from the Vema feature. For instance, it will be interesting to see whether informative chemical variations have been preserved in the basaltic rocks at the top of the section, and whether they correlate with the picture that Bonatti *et al.* have compiled from the data on crustal thickness and exposed mantle rocks. ■

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1. Bonatti, E. *et al. Nature* **423,** 499–505 (2003).
2. Klein, E. M. & Langmuir, C. H. *J. Geophys. Res.* **92,** 8089–8115 (1987).
3. Dick, H. J. B., Fisher, R. L. & Bryan, W. B. *Earth Planet. Sci. Lett.* **69,** 88–106 (1984).
4. Scott, D. R. & Stevenson, D. J. *J. Geophys. Res.* **94,** 2973–2988 (1989).
5. Braun, M. G., Hirth, G. & Parmentier, E. M. *Earth Planet. Sci. Lett.* **176,** 339–356 (2000).

Cell division

Genome maintenance

Jordan W. Raff

Early fruitfly embryos have an unusual means of halting the division of any nuclei containing damaged DNA. A key component of this mechanism has now been identified, and might have implications for cancer.

Maintaining the integrity of the genome is a crucial task for any cell. Two proteins, called checkpoint kinases 1 (Chk1) and 2 (Chk2), help to achieve this in many species, and mutations in the genes encoding these proteins have been linked to the generation of cancer in humans. The proteins are activated by DNA damage, and help to initiate cellular defence responses that include the stimulation of DNA-repair pathways and the slowing down of the cell-division cycle to allow time for repair[1,2]. In multicellular organisms, if the DNA is not successfully mended, the damaged cells usually kill themselves — thereby eliminating the defective genome. As they describe in *Cell*, Theurkauf and colleagues[3] have discovered that Chk2 is also involved in a rather different defence mechanism that is triggered by DNA damage in early fruitfly embryos.

This particular defence response is especially well suited to the early fruitfly (*Drosophila*) embryo, in which the cell nuclei undergo a series of 13 rapid divisions within a common cytoplasm[4]. These swift nuclear divisions occur synchronously, and consist entirely of alternating phases of DNA synthesis (S phase) and DNA segregation (mitosis or M phase), with none of the intervening gap phases that separate S and M in more typical cell cycles. Because there is no gap