selectively remove a substantial fraction of the highest-energy atoms from the magnetic trap. This technique was first used[6] to study the formation dynamics of a BEC.

Weiler and colleagues found a regime in which the gas of rubidium atoms can rethermalize locally on a timescale faster than it would take for atoms on one side of the magnetic trap to let atoms on the other side know what is going on. As a result, a local mini-BEC could form in one place in the trap while another mini-BEC formed elsewhere. Because these mini-BECs (typically referred to as quasi-condensates) do not know about each other, they will each have a quantum-mechanical phase that is independent of one another. When three such mini-BECs with independent phases merge, they can form a vortex, as an earlier experiment[7] showed.

A more formal description of the process of vortex formation would characterize the size of the quasi-condensates by the coherence length, ξ (the spatial extent over which the phase is uniform). If the phase transition is approached while the system is close to thermal equilibrium, ξ diverges at the critical point of the phase transition and there is no length scale for quasi-condensate formation. Thus, no topological defects are expected. But if the critical point is crossed rapidly enough, then the coherence length just before crossing the transition is frozen in, and quasi-condensates of coherence length ξ can form, which, for a big enough system, would lead to the formation of topological defects.

Although the experiments of Weiler *et al.* support the mechanism of Kibble and Zurek, the finite size of the system limits the observation of universal scaling laws, such as the density of defect formation, which should increase as $1/\xi^2$. However, given that non-equilibrium phase transitions have important consequences, as exemplified by the Kibble–Zurek mechanism, these experiments are a welcome addition. Such experiments[1,8] show that trapped atomic gases provide a system in which the microscopic dynamics underlying the important mechanisms in a non-equilibrium phase transition can be probed, understood and controlled. Whether they can be used to model the early evolution of the Universe remains to be seen, but they look promising for providing new insights into these, traditionally difficult to study, phase transitions. ■

Kristian Helmerson is at the National Institute of Standards and Technology, Gaithersburg, Maryland 20899-8424, USA.
e-mail: kristian.helmerson@nist.gov

1. Weiler, C. N. *et al. Nature* **455,** 948–951 (2008).
2. Kibble, T. W. B. *J. Phys. A* **9,** 1387–1398 (1976).
3. Kibble, T. W. B. *Phys. Rep.* **67,** 183–199 (1980).
4. Zurek, W. H. *Nature* **317,** 505–508 (1985).
5. Zurek, W. H. *Phys. Rep.* **267,** 177–221 (1996).
6. Miesner, H.-J. *et al. Science* **279,** 1005–1007 (1998).
7. Scherer, D. R., Weiler, C. N., Neely, T. W. & Anderson, B. P. *Phys. Rev. Lett.* **98,** 110402 (2007).
8. Sadler, L. E., Higbie, J. M., Leslie, S. R., Vengalattore, M. & Stamper-Kurn, D. M. *Nature* **433,** 312–315 (2006).

EARTH SCIENCE

Deducing a reducing mantle

William F. McDonough

Increasingly sophisticated techniques are being used to persuade ancient rocks to yield information about conditions on and in the early Earth — for instance, about the oxidation state of the mantle.

They say that a picture is worth a thousand words. In science, one datum point can be worth a thousand models. On page 960 of this issue, Berry *et al.*[1] report the first results obtained by applying a new approach to estimating the oxidation–reduction (redox) condition of Earth's upper mantle during the Archaean, some 2,700 million years ago. Their study is based on the ratio of different oxidized states of iron (Fe^{3+} to Fe^{2+}) in inclusions of ancient komatiite rock, trapped in crystals preserved in ancient lava flows in Zimbabwe. The crystals should have protected the inclusions from subsequent alteration, which should thus reflect the native lava state.

Berry and colleagues' findings are groundbreaking, both for the experimental method they used (X-ray absorption near-edge structure spectroscopy, which shows that we can interrogate minute and precious fragments of the ancient Earth), and for what the findings reveal about the early Earth. They will embolden others to analyse rare recorders of ancient and remote redox conditions, such as ancient zircons and other minerals, early Solar System condensates in meteorites, and inclusions in diamonds. And they have implications for several aspects of our understanding of Earth's history: the secular evolution of mantle oxidation state; oxidation of the atmosphere; melting conditions for the formation of the ancient lavas; and the nature of the tectonic environment in which these lavas formed.

When, around 2,700 million years ago, the lavas erupted on the Earth's surface, the atmosphere was low in oxygen, and the circumstances that first produced an oxygenated atmosphere (the 'great oxidation event') were still 500 million years off. Ever since the first conjectures about the great oxygenation event[2,3], authors have speculated as to whether the mantle was the source of the oxygen. But the redox conditions of the mantle today do not necessarily reflect those in the early Earth because of the degassing, magmatism, cycling of tectonic plates and mantle convection that have occurred during the past 2,700 million years.

The komatiitic melt inclusions studied by Berry *et al.*[1] have low concentrations of Fe^{3+} (that is, a high degree of reduction and low oxidation), which the authors interpret as reflecting the redox state of the host lavas. That state is comparable to the redox state of the mantle source from which the continents are formed — basalt rocks produced at mid-ocean ridges, where tectonic plates are diverging. These rocks have the most highly reduced condition recorded for major outpourings of basaltic magmas, as compared with other tectonic settings (for example convergent boundaries, where one plate is being thrust beneath another, or where volcanic activity is occurring within a plate).

Today, basalts from convergent, Andean-type margins, which include those from the Pacific's ring of fire, are the most highly oxidized, and this is thought to be due to the addition of water transported along with the down-going, subducted plate to the site of magma generation. Basalts from intraplate settings, such as those beneath Hawaii, have intermediate water content and a transitional oxidation state between those of basalts from Andean margins and from mid-ocean ridges. Berry and colleagues show that their komatiite melt inclusions are not significantly water-bearing. Thus, the low Fe^{3+} and low water content of the inclusions are consistent with komatiite genesis through large-scale melting of the mantle under relatively anhydrous, high-temperature conditions[4,5].

Because these ancient, Archaean melt fragments record such a reduced oxidation state for iron, one comparable to that of the dominant volume of mantle today, the implication is that the mantle is unlikely to have provided the atmosphere's oxygen in the past. It is not impossible that it did; but such an outcome would have required exceptional circumstances.

The early mantle was hotter and more active than it is today, as evidenced by the presence of komatiites (such high-temperature melts are limited to Earth's first 2,500 million years or so); the higher content of heat-producing radioactive elements; and the greater impact flux of asteroids in the first thousand million years of Solar System history. Thus, mantle convection was more vigorous in the early Earth, which probably led to a more homogeneous mantle, one less capable of storing unprocessed, more-oxidized material. Given this hot, active, early Earth, the findings of Berry *et al.* point to a mantle that became more oxidized, not more reduced, with time. This in turn could indicate that the process of recycling oceanic plates back into the mantle perhaps contributed to the progressive oxidation of part of the mantle through time.

The tectonic context for komatiite genesis continues to be a puzzle. Berry and colleagues' results, coupled with an earlier trace-element study on similar melt inclusions from these lavas[6], reveal that these high-temperature melts are more akin to modern lavas from a divergent

margin or from an intraplate setting than they are to lavas from convergent margins. In contrast, komatiitic lavas from the ancient Superior Province of Canada are stratigraphically associated with basalts and other lavas from a convergent margin. Moreover, the discovery of komatiitic deposits of explosively ejected pyroclastic ash, interlayered with lava flows that occurred on land or in shallow water[7], document the eruption of these rock suites in terrestrial and near-terrestrial settings. Thus, it is possible that komatiite genesis occurred at divergent margins, but not at margins associated with deep, mid-ocean-ridge environments.

More work is needed if we are to find and analyse melt inclusions from other komatiites and ancient lavas, with the aim of building a comparative perspective on the secular evolution of the oxidation state of lavas from various tectonic settings. The analytical methodology applied by Berry *et al.*[1] is now available for studying minute geological time-capsules, and so opens the door for many other studies. There are plenty of old hypotheses to be tested with this new tool. ■

William F. McDonough is in the Department of Geology, University of Maryland, College Park, Maryland 20742-4211, USA.
e-mail: mcdonoug@geol.umd.edu

1. Berry, A. J., Danyushevsky, L. V., O'Neill, H. St C., Newville, M. & Sutton, S. R. *Nature* **455,** 960–963 (2008).
2. Holland, H. D. in *Early Life on Earth* (ed. Bengtson, S.) 237–244 (Columbia Univ. Press, 1994).
3. Farquhar, J. *et al. Science* **289,** 756–758 (2000).
4. Arndt, N. *et al. Geology* **26,** 739–742 (1998).
5. Herzberg, C. *J. Geophys. Res.* **97,** 4521–4540 (1992).
6. McDonough, W. F. & Ireland, T. R. *Nature* **365,** 432–434 (1993).
7. Stiegler, M. T., Lowe, D. R. & Byerly, G. R. *Geology* **36,** 779–782 (2008).

CANCER

A ringleader identified

Charis Eng

The childhood cancer neuroblastoma can either run in families or occur sporadically. Several studies find that the gene *ALK* is a chief offender in this disease, because its germline mutations mediate both forms.

Neuroblastoma is the most common childhood cancer diagnosed before the age of one, and accounts for some 15% of all cancer deaths in children. Some patients inherit a genetic predisposition to neuroblastoma due to mutations in the germ line (cells that can give rise to all other cells in an organism); in others, the cancer is sporadic, that is, it may be caused by both germline and somatic (found only in tumour cells) mutations. In this issue, four studies[1–4] implicate various mutations in the gene *ALK* in both familial and apparently sporadic cases of neuroblastoma.

Neuroblastoma tumours are derived from embryonic cells that form the neural crest and that eventually give rise to the peripheral nervous system, among other organ systems. The first gene to be linked to predisposition to neuroblastoma was *PHOX2B* — a master regulator of the normal development of the autonomic nervous system[5,6]. But the *PHOX2B* germline mutations identified occur only in a small subset of familial neuroblastoma cases, and somatic mutations in this gene have not been reported. Furthermore, germline *PHOX2B* mutations result in syndromic neuroblastoma — meaning that the cancer associates with other, very specific clinical features. So it seemed that germline mutations in other, unidentified genes were responsible for most cases of familial neuroblastoma, and the search went on.

After a few red herrings, a clue came from an unexpected quarter: the short arm of chromosome 2 was found to be somatically amplified in a subset of sporadic neuroblastoma cases. This chromosomal region contains both the *MYCN* gene, amplification of which is well established for sporadic cases of neuroblastoma, and *ALK*.

The protein product of *ALK* is a tyrosine kinase, an enzyme that regulates the activity of other proteins through phosphorylation. Abnormal activity of the ALK protein has been implicated in the amplification and translocation of genomic sequences in non-Hodgkin's lymphoma and various solid tumours, including non-small-cell lung cancers. It now emerges that *ALK* is also a major non-syndromic neuroblastoma-predisposition gene.

Mossé and colleagues[1] (page 930), Janoueix-Lerosey *et al.*[2] (page 967) and Chen *et al.*[3] (page 971) together identify four different germline *ALK* mutations in 10 of 16 neuroblastoma pedigrees they studied. Of these, the frequently occurring mutations do not seem to represent founder mutations — which occur in a common ancestor and perpetrate through subsequent generations — but rather mutational 'hotspots'. Hotspots are characteristic of gain-of-function mutations in cancer-predisposing oncogenes[7] that lead to increased activity of the oncoprotein.

Bearing in mind that the number of unrelated families with neuroblastoma studied by these authors[1–3] is relatively small, the weighted mean proportion of individuals carrying the germline mutations who actually develop neuroblastoma (penetrance) seems to be around 57% across all families. One of the germline mutations (substitution of alanine in place of glycine at amino-acid residue 1128) detected in a single large family[1] seemed to have a lower penetrance of about 40% compared with the other three mutations, whose weighted-average penetrance was 61%. These penetrance percentages are relatively low compared with those of other established cancer-predisposition genes such as *RET* and *PTEN* (ref. 7).

Box 1 | Pre-emptive measures to manage neuroblastoma

With the identification of *ALK* as a main neuroblastoma-predisposition gene[1–4], individuals whose families harbour specific *ALK* mutations but who have no clinical features suggestive of neural-crest defects should be offered tests for mutations in this gene as part of genetic counselling. This has certainly proved to be a useful approach in the case of *RET* mutations, because analysis of certain coding sequences within this gene allows sensitive and cost-effective genetic testing for predisposition to a form of cancer called multiple endocrine neoplasia type 2.

Like ALK, RET is a tyrosine kinase expressed in cells derived from the neural crest. Because only a limited number of hotspot gain-of-function *RET* mutations are germane in the pathogenesis of multiple endocrine neoplasia type 2 (ref. 7), by inference it is unlikely that future studies will identify several other mutation hotspots associated with neuroblastoma. So once a family-specific *ALK* mutation is identified, all as-yet-unaffected first-degree relatives of the patient can be offered single-genetic-site testing for that mutation, shortly after birth, to determine their risk of developing neuroblastoma compared with that of the general population.

Those with the mutation, and so at risk, can then be offered organ-specific clinical screening so that tumours can be detected at an earlier, more treatable, stage. **C.E.**