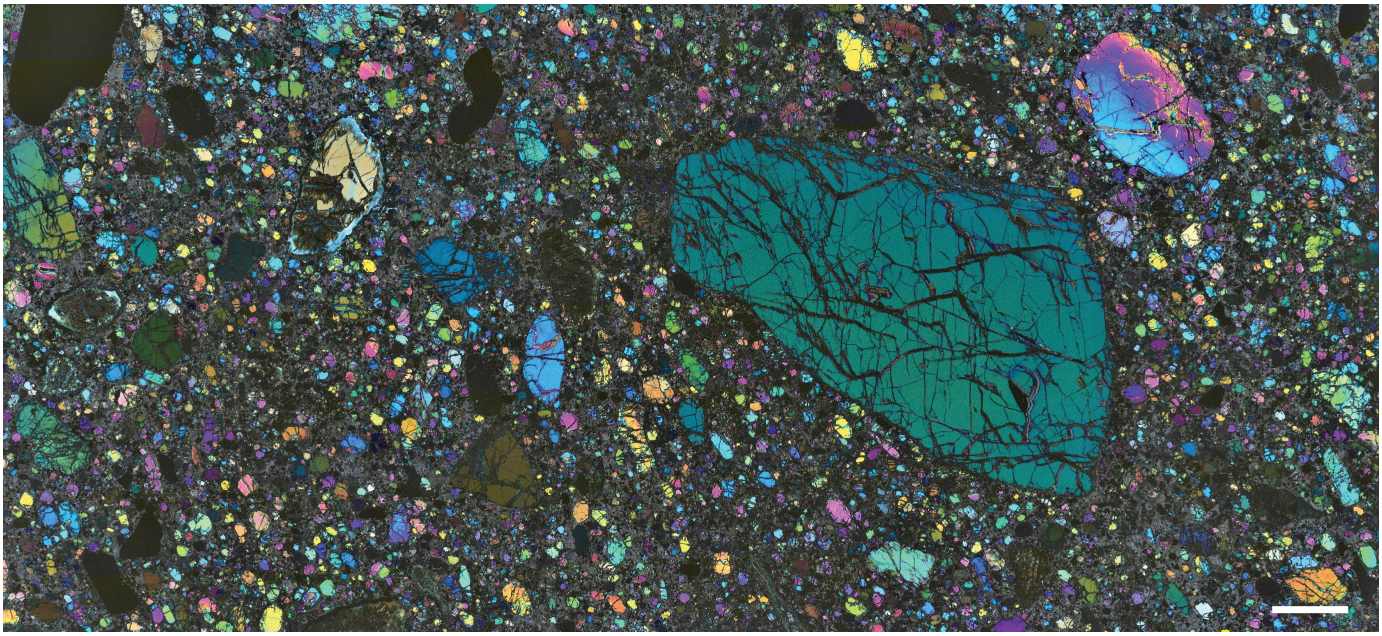

Figure 1 | Cross-section of kimberlite from West Greenland. Woodhead *et al.*[1] suggest that volcanic rocks called kimberlites originate from a reservoir that has survived deep in Earth's mantle for most of the planet's history. This image, which was made using polarized light, shows the wide range and complex structure of minerals (such as diamonds, garnets and zircons) in these rocks. Scale bar, 2 millimetres.

GEOCHEMISTRY

Origin of diamond-bearing rocks

Kimberlites are volcanic rocks that derive from deep in Earth's mantle, but the nature of their source is uncertain. A study of this source's evolution over two billion years provides valuable information about its properties. SEE LETTER P.578

CATHERINE CHAUVEL

Rare volcanic rocks known as kimberlites are produced from magmas that originate in Earth's mantle and then erupt onto the planet's surface. These rocks have a violent eruption style, and a chemical and mineralogical composition that is unlike any other magmatic rock on Earth. In particular, kimberlites can contain centimetre-sized crystals of rare minerals such as garnets, zircons and, most notably, diamonds. Moreover, they have exceptionally high amounts of incompatible trace elements — those that preferentially enter a magma formed by melting of the mantle. These peculiar characteristics raise questions about the nature of the kimberlite source and its location in the mantle. On page 578, Woodhead *et al.*[1] suggest that all kimberlites originate from a single deep reservoir that has survived for most of Earth's history.

There is a general consensus on several aspects of kimberlite formation. First, kimberlites must be extremely enriched in water and carbon dioxide to explain their violent eruption style and the presence of associated diatremes — conical or pipe-like structures that extend from Earth's surface to depths of more than one kilometre. Second, some kimberlites must form exceptionally deep in the mantle, as evidenced by inclusions in kimberlitic diamonds of minerals that are unstable at the planet's surface. These minerals include ringwoodite[2], which is stable only in the transition zone between the upper and lower mantle (at depths of 410–660 km), and bridgmanite[3], which is the dominant mineral in the lower mantle.

Third, in addition to containing minerals that crystallized from the ascending magmas, kimberlites contain a large assemblage of minerals and xenoliths (rock fragments) that were collected from surrounding material during the rapid ascent from the kimberlite source (Fig. 1). Some minerals, such as the diamonds that have ringwoodite inclusions, come from the deep mantle, some derive from shallower mantle and some originate from the planet's crust.

By contrast, there is little consensus on the exact location of the kimberlite source in the mantle and, even more crucially, on the nature of this source. It could be a rather primitive material — one that has survived deep in the mantle from soon after Earth's formation. Alternatively, it might be a material that was at some stage present at or near the planet's surface and has since been recycled into the deep mantle. Both interpretations exist in the literature[4] and a clear argument for the existence of the two types of source is the presence of two groups of kimberlites that have contrasting mineralogy and geochemistry.

Minerals in the first group, often referred to as archetypal kimberlites, have compositions of strontium and neodymium isotopes that resemble those of the primitive mantle. Those in the second group, commonly called orangeites, have much more enriched strontium and neodymium isotopic compositions that resemble those of continental materials[4]. The enriched nature of orangeites is usually attributed to interaction of the magmas with continental crust or the uppermost solid part of the mantle during ascent and probably does not represent the composition of the kimberlite source.

Woodhead and colleagues present a compilation of newly acquired and previously published neodymium and hafnium isotopic data, measured on archetypal kimberlites. These kimberlites cover a large age range, from less than 200 million years old up to 2 billion years old. The authors demonstrate that, over this long time period, kimberlites seem to always tap a source whose isotopic composition resembles that of the primitive mantle. This observation puts constraints on the nature of the kimberlite source, and favours a pristine reservoir — one that has survived untouched deep in the mantle for most of Earth's history.

The idea that part of the deep mantle has remained isolated from its surroundings is supported by the discovery of traces of primitive material in volcanic rocks called ocean island basalts, which might originate from regions known as seismically anomalous zones that are found at the core–mantle boundary[5,6]. A primitive source has also been attributed to many other types of rock, such as granitoids[7]. The case for a primitive kimberlite source is bolstered by the evidence that this source is deep.

For the other rock types, a near-primitive isotopic composition might be explained by the presence of recycled crust in the rock source. Woodhead *et al.* dismiss this interpretation for kimberlites by arguing that the contribution of recycled oceanic crust would have had to have been constant over the two billion years of recorded history. Moreover, they suggest that the presence of high helium ratios (ratios of helium-3 to helium-4) in diamonds of some kimberlites indicates a deep source, close to the core–mantle boundary.

The authors' interpretation might be correct, but a few independent observations need to be reconciled before the model can be applied to all kimberlites. For example, the presence of anomalous amounts of sulfur-33 in kimberlitic diamonds suggests that the source contains material that was present at Earth's surface more than 2.5 billion years ago, when the planet's atmosphere was not yet oxidized[8]. How this recycled material can coexist with the rest of the source is unclear.

Another potential concern is the unknown relationship between high helium ratios and isotopes produced by radioactive decay that are measured in diamonds. Some diamonds have low helium ratios, and strontium and lead isotopic compositions that are similar to those of Earth's crust. But no strontium and lead isotopic data are available for previously analysed diamonds that have high helium ratios[9]. As a result, such high ratios might or might not trace a pristine deep source.

Finally, kimberlitic diamonds are plucked from the mantle during ascent, and the information that they provide might be irrelevant in terms of the kimberlite source. To confirm a pristine and deep origin of kimberlites, we need to demonstrate that the kimberlite magmas themselves have pristine characteristics, such as high helium ratios, tungsten isotopic anomalies that could trace interaction of the magmas with the planet's core, and so on. A lot of work is still ahead of us. ■

Catherine Chauvel *is at the Institut de Physique du Globe de Paris, University of Paris, CNRS, F-75005 Paris, France.*
e-mail: chauvel@ipgp.fr

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CANCER

Dangerous liaisons as tumours form synapses

Why brain tumours progress rapidly is unclear. The finding that such cancer cells form synaptic connections with neurons uncovers an interaction that accelerates tumour growth rate and lethality. **See Articles p.526, p.532 & p.539**

ANDRES BARRIA

People with brain tumours have a range of symptoms that can vary in severity, from headaches to a decline in cognitive function. The symptoms depend on the tumour type and its size, location and growth rate. Understanding what controls the growth rate of brain tumours might therefore lead to the development of therapies that slow cancer progression and improve the quality of life of people who have this type of cancer. In this issue, Venkataramani *et al.*[1] (page 532), Venkatesh *et al.*[2] (page 539) and Zeng *et al.*[3] (page 526) report that, in the brain, neurons and cancer cells form a type of connection between cells called an excitatory synapse, and the formation of this connection boosts tumour growth.

An excitatory synapse is a structure in which two adjacent neurons — termed the presynaptic and postsynaptic neurons — communicate using a neurotransmitter molecule, usually glutamate (Fig. 1). Glutamate release by the presynaptic neuron activates glutamate receptors, known as AMPA receptors and NMDA receptors, on the postsynaptic neuron. Receptor activation causes ion movement across the cell membrane, which produces depolarization — an increase in positive charge inside the postsynaptic neuron that leads to excitation. Certain non-neuronal brain cells called glia surround a synapse and regulate signal transmission across it by removing released neurotransmitter[4]. Other types of glial cell affect neuronal excitability (the ease with which neurons are depolarized) by regulating extracellular potassium ions[5].

Glial cells can give rise to a type of brain tumour called a glioma, which is the leading cause of death from brain cancer in the United States[6]. One common characteristic among many different types of glioma is that their growth requires the activity of their neighbouring neuronal cells[7], but the reason has not been fully understood until now.

Healthy glial cells form interconnected cellular networks. This is because structures on the glial-cell membrane, called gap junctions, enable signalling molecules, such as calcium ions, to move into neighbouring glial cells[5]. Glioma cells also create interconnected cellular networks by forming gap junctions in what are called tumoural microtubes — long, thin, cell-membrane protrusions that extend from these cells into the surrounding tissue, and which contribute to tumour infiltration and proliferation[8].

Using an imaging method called electron microscopy, Venkataramani and colleagues examined tumoural microtubes formed by human gliomas that had been transplanted into mouse brains. They observed that the microtubes had structures characteristic of excitatory synapses, called postsynaptic densities, where glutamate receptors are normally present. Adjacent to these postsynaptic densities, in a nearby neuron, the authors noted clusters of vesicles that store neurotransmitter molecules, which are a feature of a neuronal presynaptic zone. Venkatesh and colleagues made similar observations of synaptic structures arising between glioma cells and neurons.

Venkatesh *et al.* and Venkataramani *et al.* provide evidence that genes encoding glutamate receptors and structural components of the postsynaptic region are expressed in a subset of cells in human gliomas, suggesting that glioma cells exploit the same molecular mechanisms used by neurons to establish synapses.