and weakened nucleosome contacts. The chromosomes in TSA-treated cells seemed less compact than in their untreated counterparts, particularly towards the periphery, and microtubules grew extensively through the chromosome surface. This suggests that chromatin compaction, mediated by histone-tail deacetylation, is necessary to prevent microtubules from penetrating chromosomes.

Next, the researchers treated condensin-depleted mitotic cells with TSA. The result was striking. The chromatin in these cells became greatly decondensed and was distributed throughout the cytoplasm. This indicates that histone deacetylation causes complete compaction of mitotic chromosomes in the absence of condensin. Condensin is thus neither necessary nor sufficient for complete chromatin compaction during mitosis.

The team that performed the current study had previously found evidence that short strings of nucleosomes can condense into liquid-like droplets *in vitro*, in a process called liquid–liquid phase separation (LLPS)[8], and that these droplets dissolve after acetylation. In LLPS, a solution of macromolecules separates into two or more liquid phases that have different physico-chemical properties[9]. To investigate whether a similar phenomenon might occur *in vivo*, and have a role in chromosome compaction, Schneider *et al.* injected a restriction enzyme called AluI into living mitotic cells. This treatment fragmented chromatin to relieve the physical constraints imposed by long strings of interacting nucleosomes.

Indeed, AluI-treated chromosomes lost their rod shape, and instead formed round bodies that fused to one another (Fig. 1c). These bodies looked like the liquid droplets formed by LLPS, and the fragmented chromatin within them was highly mobile, supporting the idea that they are liquid droplets. AluI injection alone did not change chromatin density or compaction state, and did not perturb the stiff chromatin surface that prevents microtubules from penetrating. However, treatment of cells with TSA before AluI injection suppressed LLPS and resulted in uniformly dispersed chromatin with almost no local condensation.

The mobility of AluI-fragmented mitotic chromatin might relate to that seen in an earlier phase of the cell cycle, interphase[10,11] (the period between divisions). In interphase, chromatin shows some histone acetylation[7] and has liquid-like motion on a scale of about 200 nanometres, which is mainly driven by thermal fluctuations[10,11], arising from collisions with water and other molecules in the cell. Schneider and colleagues' work therefore implies that a phase transition between interphase and mitosis makes mitotic chromatin more condensed and more constrained than interphase chromatin[12] — these constraints probably suppress its motility. The key to this phase transition seems to be global histone deacetylation. As histones are deacetylated, chromosomes become more solid-like, immiscible in the cell cytoplasm, and so able to resist microtubule perforation. Together, the study offers mechanistic insight into the processes of mitotic chromosome condensation and transmission.

The current study could have implications for our understanding of how condensin is involved in chromosome packaging. Although the team shows that histone deacetylation can induce complete compaction of mitotic chromosomes in the absence of condensin, the shape of the chromosomes is aberrant. To make a proper rod-like chromosome shape, then, loop formation by condensin seems crucial. It is thought that genomic DNA is pushed through the ring-shaped condensin complex to form loops[13] — but one could imagine that the compacted nucleosome clusters that form when histones are deacetylated would get stuck in the ring. We might therefore need to consider alternative possibilities[14,15] that would make sense in the context of mitotic chromatin. Future work combining sophisticated imaging techniques, computational modelling and a technique called Hi-C that captures information about chromosome conformation could shed light on the mechanism of loop formation required to make the rod-like shape of mitotic chromosomes.

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Earth science

Search for eruption signals in volcanic noise

Emily K. Montgomery-Brown

A volcano that erupted with few precursory signals offers a test bed for seeking out ways of forecasting disaster — and a reminder that analysis on a global scale is necessary for a comprehensive understanding of volcanoes. **See p.83**

The beginnings of volcanic eruptions are often heralded by changes in observable features such as seismic activity, gas chemistry and the shape of the volcano. That wasn't the case, however, on 22 May 2021, when Mount Nyiragongo in the Democratic Republic of the Congo erupted. As Smittarello *et al.*[1] report on page 83, the volcano had been undergoing low-intensity eruptive activity since 2002 and had remained mostly unchanged from this condition until its striking and destructive eruption. The authors' analysis provides clues to how such eruptions can be forecast in the absence of the usual precursors.

Nyiragongo is an open-vent volcano, which means that it continually emits products, such as gases and lava, in this case from a lava lake in its summit crater that has existed since at least 1928 (ref. 1) (Fig. 1). Eruptions had previously occurred on the flanks of the volcano in 1977 and 2002, but the 2021 eruption began with fissures opening high on the volcano, with other fissures at progressively lower levels. Over a period of around 6 hours, lava covered an area of about 10 square kilometres. Some 6,000 households were displaced, according to Smittarello and colleagues' analysis, and electrical, telecommunications and water facilities were destroyed, as well as schools, health centres and churches. At least 31 people were killed and more than 750 injured, during the eruption and evacuation.

Before the 2021 eruption, a local seismic network installed in 2015 had detected a persistent, low-level tremor in both seismic and acoustic frequencies, suggesting that

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THIERRY FALISE/LIGHTROCKET/GETTY

Figure 1 | The lava lake in the summit crater of Mount Nyiragongo in the Democratic Republic of the Congo.

the magma was undergoing convection and degassing[2]. The first detectable changes in these seismic and acoustic signals occurred less than 40 minutes before the eruption, providing little time to issue warnings.

Insight into subsurface pressures might have been gleaned from Nyiragongo's lava lake, the level of which can be used as a natural piezometer (a device that measures the pressure in a column of liquid as a function of its height)[3]. This level has risen and fallen intermittently since the 2002 eruption[4], and had regained the pre-2002 level at the time of the 2021 eruption. The level was, however, still around 85 metres lower than that preceding the first documented flank eruption in 1977. As is typical of hazard assessment based on the monitoring of multiple parameters, a single observed anomaly can be concerning, but is not usually sufficient to forecast an eruption.

The 2021 eruption lasted around 6 hours, but seismic activity continued for a further 10 days, culminating in a series of 271 earthquakes on 25 and 26 May. These earthquakes had a magnitude greater than 3, which is around the strength at which people start to feel an earthquake at Earth's surface, and they coincided with deformation of the volcano, which was observed using radar-satellite imaging. Cracks in the surface of the rock were mapped with the help of local people, who reported fractures in the days after the eruption[5]. Such cracks form above and around propagating 'dykes', which are sheet-like bodies filled with magma below the surface.

The local population's effort identified two main north–south networks of fractures through the cities of Goma and Gisenyi. Intriguingly, some fractures were reported to have appeared in the days to weeks before the onset of the eruption, but those observations need to be confirmed before they can be considered a means of forecasting future eruptions, especially because no deformation was visible in radar imaging before the eruption.

Smittarello and colleagues' modelling suggests that a dyke as shallow as 450 metres formed below the surface of Goma, although a previous study of the gases emanating from the cracks had shown no evidence of shallow magma[5]. The formation of such a dyke in the absence of precursory indicators is not consistent with conventional interpretations of volcanic dykes, which are usually associated with the forceful intrusion of pressurized magma from a central reservoir outwards into the flanks. At some other volcanoes, however, dykes can intrude passively through tensile failure of the flank, as the main volume of the volcano (the edifice) spreads owing to its own weight. Such intrusions often lack substantial precursory activity[6].

"Cracks in the surface of the rock were mapped with the help of local people, who reported fractures in the days after the eruption."

The tensile-failure mechanism of passive dykes is similar to events at mid-ocean-ridge systems, in which magma wells up to fill the space created between diverging tectonic plates, as is the case in the East African Rift system in which Nyiragongo is located[7]. In some cases, such as that of the Kīlauea volcano in Hawaii, recognizing regular patterns of recurrence in dyke intrusions has made forecasting possible in cases in which an eruptive vent is open for a long time[6]. But understanding whether this type of forecasting could be useful for other volcanoes will require comprehensive studies of their dyke histories — including dyking events in which magma does not erupt at the surface — as well as an understanding of the interplay of the magmatic and tectonic systems.

Smittarello *et al.* point out that eruptions that have short windows of precursory signals make it difficult to forecast impending hazards in a time frame within which action can be taken. Because precursory signals can be subtle or occur shortly before an eruption, improving ways of interpreting these signals could enable scientists to be better equipped to identify and act on them.

Forecasting is not always possible, however, so building efficient lines of communication, developing public awareness of risks and reducing exposure to unexpected hazards are crucial measures to be undertaken. Although the 2021 eruption at Nyiragongo

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was the result of an edifice rupture, explosions caused by ground or surface water being heated by magma can also occur with little to no warning, as was the case at Mount Ontake in Japan in 2014, and at Whakaari (White Island) in New Zealand in 2019. Such explosions offer further motivation for considering the implications of hazards that give out brief and often subtle precursory signals.

Smittarello and colleagues' study, as well as those examining eruptions at Ambrym in Vanuatu[8], La Palma in Spain[9] and Bárðarbunga in Iceland[10], have provided well-documented analyses of dyke propagation in a number of contexts. In particular, these investigations have examined tectonic regimes that differ from those at well-studied volcanoes such as Kīlauea[11], Mount Etna[12] in Italy or Piton de la Fournaise in Réunion[13]. It is doubtful that these volcanoes exhibit a full range of eruptive behaviours, which makes observations of eruptions across the world all the more valuable.

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Condensed-matter physics

Superlattices taken to another dimension

Berit H. Goodge & D. Kwabena Bediako

A compound comprising both one- and two-dimensional components exhibits an unusual response to a magnetic field, demonstrating the potential for 'heterodimensional' materials that can host intriguing quantum behaviours. **See p.46**

Materials-by-design research aims to create synthetic compounds that have properties with potential either for technological applications or for exploring fundamental physics – ideally, both. One approach is to look for new chemical compositions, but another proven strategy stacks single- or few-atom-thick layers of two or more compounds into close-knit atomic tapestries called heterostructures. Careful engineering of such heterostructures can be used to tailor their properties by manipulating both the short- and long-range interactions between atoms and electrons in the material[1,2]. This idea has now been extended to the synthesis of 'heterodimensional' heterostructures, in which components with different dimensionalities give rise to exotic behaviour, as Zhou *et al.*[3] report on page 46.

The dimensionality of a material usually refers to its atomic connectivity. But the interactions between a material's crystal lattice, and the charge and spin (intrinsic angular momentum) of its electrons, also have a dimensionality. For example, charge-carrying electrons might be allowed to move freely throughout a crystal in all three dimensions, or they could be confined to a flat plane or a single line. Dimensionality can strongly influence a material's behaviour: the properties of pure carbon vary substantially between 3D graphite, 2D graphene and 1D carbon nanotubes. Although each of these compounds comprises carbon atoms arranged in a hexagonal lattice at the atomic scale, the constraints imposed by their dimensionalities modify their nanoscale interactions, giving rise to distinct properties.

Combining more than one dimensionality in a single material could, in principle, give rise to a compound exhibiting a mixture of 1D- and 2D-like material properties. Zhou *et al.* explored this possibility by engineering an ordered arrangement of 1D ribbons of vanadium monosulfide (VS), lined up between sheets of 2D vanadium disulfide (VS_2) (Fig. 1). In doing so, they produced a new kind of compound that shows intriguing behaviour.

The authors' VS_2–VS superlattice displays an unusual response to a magnetic field. In normal conductors, applying a magnetic field in a direction perpendicular to that of an electric current through the material generates a voltage along a direction that is perpendicular to both the field and the current. This is known as the Hall effect, named after US physicist Edwin Hall, who discovered the phenomenon in the late nineteenth century[4]. The effect arises from the force that is exerted on charge carriers, such as electrons, as they move through an electromagnetic field. Surprisingly, Zhou *et al.* found a strong Hall signal in their VS_2–VS superlattice even when the magnetic field was oriented along the same direction as the voltage measurement.

This intriguing response to a magnetic field can be ascribed to the heterodimensionality of the compound: the arrangement of atoms in the superlattice has certain symmetries that give rise to this effect when a magnetic field is introduced. The strong coupling between the electron spins in the material and their orbital motion also has a role – giving rise to an unusual quantum-mechanical property called the Berry curvature. This has a similar effect on electrons to that of a magnetic

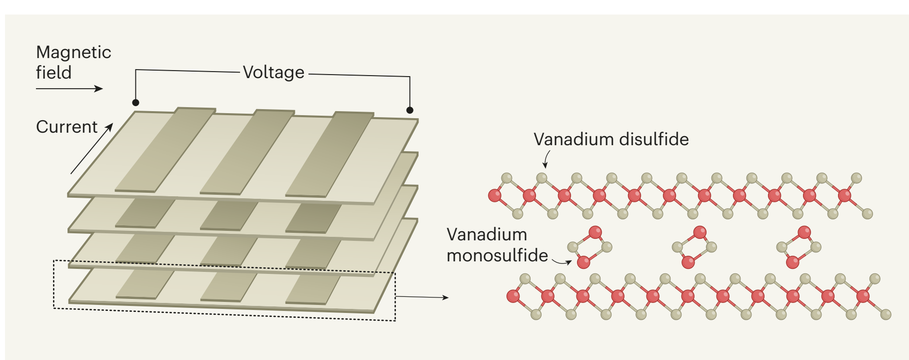

Figure 1 | A 'heterodimensional' superlattice. Zhou *et al.*[3] synthesized a material comprising 2D sheets of vanadium disulfide interspersed with 1D ribbons of vanadium monosulfide. Applying a magnetic field to the material elicited a voltage that was perpendicular to an electric current through the superlattice, but parallel to the field. This voltage, resulting from a phenomenon known as the Hall effect, usually appears in a direction perpendicular to both the field and the current. The authors attributed their unusual observation to the combination of 1D and 2D components, which could give rise to other designer-material properties.

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