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Figure 1 | Element panning, old-school style.

But this situation has been changing. The synthesis of several superheavy nuclei in fusion reactions involving heavy ions has been reported recently[5]. These spectacular results had, however, been questioned because other groups had failed to reproduce them. Eichler *et al.*[1] have just succeeded — at least in one case.

In an experiment lasting several weeks, the authors, working at the Flerov Laboratory of the Joint Institute for Nuclear Research in Dubna, Russia, bombarded a target of the plutonium isotope ^{242}Pu with an intense beam of calcium (^{48}Ca) ions. Their hope was that two nuclei would occasionally fuse to form the superheavy isotope ^{287}114, after the emission of three neutrons. From previous experiments at the same laboratory, ^{287}114 was known to decay within about half a second by the emission of an α-particle (a helium nucleus, ^{4}He, of two protons and two neutrons) to ^{283}112.

Owing to the relatively long half-life (several seconds) of ^{283}112, this nucleus can be trapped in helium gas and thus swept to a detector consisting of a narrow channel formed of gold-covered silicon detectors. To cover for the eventuality that element 112 is highly volatile (as, for example, the heavy noble gas radon is), the authors cooled the far end of this channel to −180 °C. Under these same conditions, a diffusion-led process would deposit radioactive mercury isotopes on to the gold surface near the warm entrance of the detector; the still-more-volatile radon isotopes, by contrast, would be collected near the cold end.

So, would single atoms of element 112 behave in a manner becoming of their class — in other words, similarly to mercury, as predicted by new, very elaborate theoretical predictions[6]? Or would they act more exotically — that is, like radon, as speculated by Pitzer[4]? The former, say Eichler and colleagues, who observed two unique mercury-like signals near the warm end of their detector. First, they saw an α-particle with an energy of 9.5 megaelectronvolts, characteristic of the decay of ^{283}112 to the darmstadtium isotope ^{279}Ds; the signal was followed shortly after by the signal of this isotope's spontaneous fission.

The observations of long-lived α-decay of ^{283}112 confirm that the island of stability is not just a mirage. Indeed, the ground on its neutron-poor shores is seeming ever more solid. As the synthesis of relatively long-lived isotopes of element 114 in reactions of ^{244}Pu and ^{48}Ca has been reported, the next step should be to perform first experiments with this element. After all, element 112 seems to behave chemically quite 'normally'; that is, similarly to its lighter group partner mercury — although it could be that 112 is considerably more inert and volatile. The current experiment was not designed to investigate that, and further observations are needed.

So should we resume searching for superheavy elements in nature? Perhaps: armed with experiments such as those of Eichler and colleagues[1], we at least have a much better idea what to look for. Like the authors, we might, against all odds, strike it rich. ■

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EARTHQUAKES

Relationships in a slow slip

Heidi Houston and John E. Vidale

The size and duration of disparate, slow, low-amplitude earthquake processes seem to obey a single scaling law. The relationship is very different from that which governs their more violent and impulsive cousins.

Subduction zones — those regions of Earth's crust where one tectonic plate dives beneath another — are usually associated with frequent and violent earthquake activity. But not always. Occasionally, the downgoing tectonic plate lurches slowly, smoothly and almost silently under the overriding plate, accompanied by weak bursts of tremors[1,2]. These subtle episodes of tremors and slow slip, low in amplitude (and therefore only recently discovered), but lasting up to months, are sometimes associated with as much deformation as a magnitude-7 regular earthquake.

In this issue, Ide *et al.* (page 76)[3] present the first compilation of these slow processes' fundamental seismic parameters, and obtain relationships between them that are very different from those of regular earthquakes. These investigations are of more than academic interest: the slow-slip processes might signal times of enhanced probability for potentially hazardous regular earthquakes[4], and the zone where they are active might delineate the lower boundary of the locked zone storing stress for the next megathrust earthquake[5].

The fundamental descriptive parameters of regular earthquakes, such as size and duration, follow relationships over many orders of magnitude called scaling laws[6]. The primary measure of earthquake size, its seismic moment, is calculated by multiplying the rock rigidity, the slipping area and the amount of lateral slip, known as the fault offset. Slipping area and fault offset vary greatly, so the seismic moment itself varies over more than ten orders of magnitude. Another crucial parameter, the velocity of a rupture's propagation, is quasi-constant: it is controlled dynamically by the seismic waves generated by the already broken and slipping portion of the fault, which travel at a constant velocity set by the rock's material properties. Over a wide range of sizes, therefore, the fault length involved in an earthquake is proportional to the earthquake's duration. Furthermore, a rough proportionality between fault offset and fault length leads to a well-known scaling law: earthquake duration is proportional to the cube-root of seismic moment[6,7].

For slow-slip events, on the other hand, the control by dynamic waves is absent. The relations between seismic moment, length, rupture velocity, duration and offset are probably therefore also different. The subdued signals, and the events' gradual beginnings and endings, make determining these quantities a tricky undertaking.

Ide and colleagues' insight[3] was to recognize that many different slow-slip phenomena might be aspects of the same process, and so follow a single scaling law. This was not immediately obvious, because these processes occur on such highly varying scales of space and time, and so had been detected and analysed with different instrumentation and techniques. Most slow-slip events occur in subduction zones, but some instances have been reported[8] on the San Andreas Fault, a very different strike–slip fault where two plates slide past each other laterally. Improved geodetic and strain monitoring since the 1990s have detected single silent earthquakes with magnitude up to 7.5, slow aseismic afterslip following large earthquakes, and episodic slow-slip events. Improved analysis applied to more-complete archives of seismic data has also revealed long-duration, low-amplitude tremor similar to that seen below active volcanoes, and many earthquakes of anomalously low frequency.

All these slow events are distinguished from regular earthquakes of the same size, by definition, by their longer durations. But strikingly, Ide *et al.* show that, for the whole menagerie, duration is roughly proportional to seismic moment — rather than to its cube-root, as for regular earthquakes. The implication, that tremor amplitude does not grow much with increasing seismic moment or event duration, is consistent with the amplitude-limited appearance of some tremor episodes.

The authors explore the implications of their new scaling law, assuming two possible relations for how fault offset grows with fault length, L. First, they assume that the two are proportional, as for regular earthquakes. In this case, duration is proportional to L^3, the drop in stress during an event is constant and about 100 times lower than for regular earthquakes, and rupture velocity must change as L^{-2}. The authors' alternative assumption is that fault offset is quasi-constant, limited by the accumulated strain due to plate motion since the previous major slow-slip event. This leads to a duration proportional to L^2, a larger drop in stress for smaller events, and a rupture velocity that changes as just L^{-1}.

The data collected so far are insufficient to distinguish between the two models. The authors favour the second, pointing out that duration proportional to L^2 has the form of a diffusive process, and that fluids have been detected in the Nankai subduction zone in Japan. The fluid diffusivity that would be inferred from some of their results, however, is more than 1,000 times larger than known values in shallow tectonic crust.

A key to further progress will be more accurate location of slow events. Recent results in Japan by some members of the same research team show that the low-frequency earthquakes lie on a dipping plane at, or very near, the subduction interface[9]. But non-volcanic tremor has also been observed to the west, far above the subducting slab[10], and tremor episodes in the Cascadia subduction zone off the US Pacific coast, although more difficult to locate accurately, seem to span a large range of depths[11]. The debate on the nature of the tremor process is currently tipping towards a shear–slip origin, rather than fluid movement[12]. A better idea of the space-time development of the slow phenomena would also help to adjudicate.

The approach taken by Ide *et al.*[3] is a natural first step, but subject to possible pitfalls. Their lumping together of seemingly disparate events might conflate a single event with a series of events. Comparing small to large slow-slip phenomena involves comparing individual migrating low-frequency events to parameters derived from their overall migration pattern[13], somewhat analogous to comparing a mainshock to subevents within the mainshock. It's not entirely clear that a valid scaling law can be gleaned from comparing apples and oranges — or rather, papayas and papaya seeds. Also questionable is the authors' assumption in their analysis that slow events have a circular geometry. Considering the tectonic setting of slow slip along the lower edge of the locked portion between the overriding and downgoing plates in a subduction zone, an assumption of constant or limited width, at least for the larger events, might be more appropriate.

As a provocative first synthesis, the results of Ide *et al.* raise further questions. How long is a particular location in a large slow-slip episode active? Do events repeat in detail? Are there events intermediate between slow and regular earthquakes? That so many questions naturally arise and are already being attacked with such alacrity is a sign of the intense interest in the nature of such phenomena in the geophysical and wider community. ■

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MATERIALS SCIENCE

Nanotubes see the light

Dirk M. Guldi

When it comes to having their conduction properties tweaked, carbon nanotubes are bothersome customers. One way to do it is to incorporate a photosensitive dye into the nanotubes' walls.

One of the great challenges of nanotechnology today is scaling electronic and mechanical devices down to atomic dimensions. A notably successful example has been the field-effect transistor (FET), in which a weak electric field is used to switch on and off a flow of electricity in a nearby semiconductor material. FETs are now used in their millions to, for example, amplify wireless signals. Writing in *Physical Review Letters*, Simmons *et al.*[1] report a further refinement of such nanoscale devices: the incorporation of a photosensitive dye into a single-walled carbon nanotube, so that its electrical conductivity can be controlled by light.

Single-walled carbon nanotubes — long, thin carbon 'wires' just a nanometre or so across, but up to many thousands of times longer — have exciting mechanical, optical and electrical properties that would seem to make them ideal nanoscale materials[2]. But despite this great promise, materials scientists have encountered huge problems in actually working with nanotubes. This is partly because all methods used to synthesize them in reasonable quantities produce mixtures of metallic and semiconducting species. In addition, very strong attractive potentials build up between individual nanotubes, leading them to stick together in ropes or bundles.

But transistor applications, for instance, require semiconducting nanotubes, and these will be overpowered by their metallic counterparts when stuck together. So far, there is no practical way, beyond individual manipulation of the nanotubes, to separate the two species, or to arrange them into molecular transistor circuits.

Some of these limitations can be overcome through the controlled covalent functionalization of the nanotubes' side walls[3,4]: in other words, tweaking their properties by attaching covalently linked molecular 'handles'. The formation of the covalent linkages guarantees the structural integrity of the nanotube skeleton, but it also fundamentally changes the electronic structure of the individual carbon atoms. The most notable effect is that the inherent conductivity of the nanotubes is destroyed altogether.

Simmons and colleagues[1] demonstrate an alternative strategy that bypasses this problem by facilitating the integration of a molecular handle — a photosensitive dye — while on the other hand preserving the carbon atoms' original electron-orbital structure. They achieve this through a strategy of non-covalent, 'supramolecular' functionalization. Supramolecular