long-term changes in species composition and forest structure (*27*). Ecological studies of tropical forest responses to logging and other forms of forest degradation should be incorporated into regional, national, and international land-use policies.

Studies such as that of Cannon *et al.* reinforce a new paradigm in management of tropical biodiversity that embodies a regional approach and extends conservation to human-impacted lands. Just as natural forest management focuses on mimicking natural disturbances within a heterogeneous stand of forest, such regional management would maintain a diverse landscape with managed areas embedded in a matrix of intact forest. A tropical landscape containing a matrix of old-growth forest fragments, second-growth forest, logged forest, and agricultural fields could conceivably protect most of the species present in the regional biota. Regional, multi-taxa inventories of species and monitoring are needed to address this critical biodiversity issue. Examples of this kind of conservation are the UNESCO Biosphere Reserves and social forestry initiatives in India, which strive to balance biological and cultural diversity with economic development.

The regenerative capacities of degraded, fragmented, or cleared tropical forests carry a hopeful message, with clear implication about how to prevent further species loss. Although nature's cornucopia might appear to be half empty, it could just as well be half full. Today, we have a fleeting opportunity to build on these remnants, to refill the cornucopia, at least in part. If we fail to recognize the inherent worth of human-impacted areas, we will not only lose more species, but we may forfeit our last opportunity for a positive human impact on tropical forests.

References

1. A. Gomez-Pompa, C. Vázquez-Yanes, S. Guevara, *Science* **177**, 762 (1972).
2. G. S. Hartshorn, *Ecology* **70**, 567 (1989).
3. C. Uhl *et al.*, *Ecologist* **19**, 235 (1989).
4. R. J. Buschbaker, *Ambio* **19**, 253 (1990).
5. B. Finegan, *For. Ecol. Manage.* **47**, 295 (1992).
6. A. E. Lugo, *Ecol. Appl.* **5**, 956 (1995).
7. I. M. Turner and R. T. Corlett, *Trends Ecol. Evol.* **11**, 330 (1996).
8. T. C. Whitmore, *An Introduction to Tropical Rain Forests* (Oxford Univ. Press, Oxford, ed. 2, 1998).
9. R. E. Rice, R. E. Gullison J. W. Reid, *Sci. Am.* **276**, 44 (April 1997); I. A. Bowles, R. E. Rice, R. A. Mitermeier, G. A. B. da Fonseca, *Science* **280**, 1899 (1998).
10. C. H. Cannon, D. R. Peart, M. Leighton, *Science* **281**, 1366 (1998).
11. K. S. Bawa and R. Seidler, *Conserv. Biol.* **12**, 46 (1998).
12. S. P. Horn and R. L. Sanford, *Biotropica* **24**, 354 (1992).
13. M. B. Bush and P. A. Colinvaux, *Ecology* **75**, 1761 (1994).
14. J. G. Saldarriaga and D. C. West, *Quat. Res.* **26**, 358 (1986).
15. M. C. Godt and M. Hadley in *Restoration of Tropical Forest Ecosystems*, H. Lieth and M. Lohmann, Eds. (Kluwer, the Netherlands, 1993), pp. 25–36.
16. T. C. Whitmore and D. F. R. P. Burslem, in *Dynamics of Tropical Communities*, D. M. Newberry, N. Brown, H. H. T. Prins, Eds. (Blackwell, Cambridge, UK, 1998), pp. 549–565.
17. M. Guariguata, R. L. Chazdon, J. S. Denslow, J. M. Dupuy, L. Anderson, *Plant Ecol.* **132**, 107 (1997).
18. P. Mausel, Y. Wu, Y. Li, E. F. Moran, E. S. Brondizio, *Geocarto Int.* **4**, 61 (1993).
19. A. D. Johns, in *Tropical Deforestation and Species Extinction*, T. C. Whitmore and J. A. Sayer, Eds. (Chapman & Hall, London, 1992), pp. 15–53.
20. M. Pinard, B. Howlett, D. Davidson, *Biotropica* **28**, 2 (1996).
21. N. Shelton, *Ambio* **14**, 39 (1985).
22. J. Terborgh, in *Tropical Forests: Management and Ecology*, A. E. Lugo and C. Lowe, Eds. (Springer-Verlag, NY, 1995), pp. 331–342.
23. A. R. Holdsworth and C. Uhl, *Ecol. Appl.* **7**, 713 (1997).
24. J. G. Goldammer and B. Seibert, in *Fire in the Tropical Biota*, J. G. Goldammer, Ed. (Springer-Verlag, NY, 1990), pp. 11–31.
25. A. Gomez-Pompa, J. S. Flores, V. Sosa, *Interciencia* **12**, 10 (1987).
26. D. H. Janzen, *Vida Silvestre Neotropical* **2**, 64 (1990).
27. M. R. Guariguata and J. M. Dupuy, *Biotropica* **29**, 15 (1997).

PERSPECTIVES: HIGH-PRESSURE PHYSICS

Superconductivity in a Grain of Salt

Russell J. Hemley

Seventy years ago, Bernal proposed that all materials would become metals if compressed under sufficiently high pressure (*1*). Taking this idea one step further, Abrikosov predicted that electron pairing, the mechanism that creates superconductivity, would be enhanced in metals at high density (*2*). For years, these tenets remained untested and generated controversy (*3*) owing to a lack of adequate experimental techniques. A series of breakthroughs in the past year have not only placed this field on a sound experimental footing but are revealing new and surprising phenomena. The most recent example, reported on page 1333 of this issue by Eremets *et al.*, is a study of the rather ordinary ionic solid CsI (*4*). When compressed to more than 200 GPa (2 megabars), CsI is not only a metal but also a superconductor in its very high density state (*4*).

Every field has its benchmark organism; in the field of high-pressure research, CsI is the equivalent of the molecular geneticist's *Drosophila* or *Escherichia coli*. Study of its transformations and transmutations under pressure—phase transitions, equations of state, optical spectra, soft modes, disproportionation, and metallization—by static compression, shock waves, and theory has served as a testing ground both for new ideas about compressed matter and for new techniques to study it. The new report is another chapter in the not-so-simple story of this simple salt. Eremets and colleagues from Osaka University (*4*) pressed CsI into the metallic state (*5*, *6*) and directly measured the temperature and pressure dependence of the electrical resistance of the sample. They first provide direct evidence for metallization, at 115 GPa. Upon further increase in pressure a characteristic drop in resistance was found at 2 K near 180 GPa. Moreover, application of a magnetic field caused the resistance to reappear, a convincing sign of superconductivity.

Many advances in high-pressure techniques have been made in recent years, but probing the electronic transport properties of materials at megabar pressures has been a major challenge: It is difficult to run current through microscopic samples as small as 1/10th the diameter of a human hair inside the pressure cell and to accurately measure it. Moreover, the necessary complementary magnetic measurements were equally difficult because of the small sample size. These obstacles were overcome during the past year with the development of ultrasensitive techniques in diamond anvil cells. Amaya's group from Osaka University has pioneered the development of electrical techniques and tested them on a growing number of materials under pressure. The latest milestone is the first report of the application of the technique to above 200 GPa—nearly doubling their previous record pressure.

Experiments on CsI inevitably seem to generate new questions, and with this new report some earlier issues return. Disproportionation of the material to form elemental Cs and I was proposed to explain an apparent difference in the static and shock-wave equations of state (*7*). This discrepancy was finally resolved with the identification (*8*) of the high-pressure crystal structure (see figure). But the volumes of the elements are in fact lower as phase-separated components than in the compound, thereby

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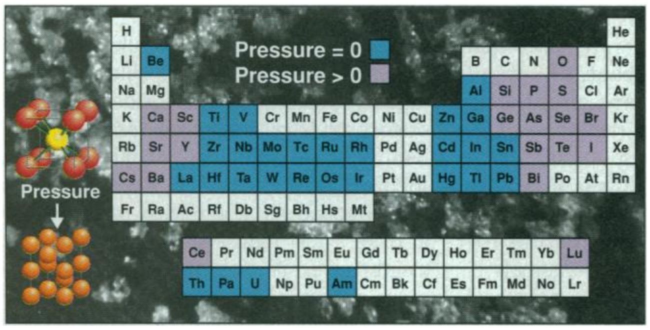

Super under pressure. Cesium iodide, a white crystalline salt (left) with a cubic structure in its low-pressure "normal" state (yellow, cesium; dark red, iodine), transforms to a "hexagonal close-packed" metal on compression (atoms have similar electronic cores, orange) and is a superconductor (*4*). At right are the superconducting elements found by pressure application.

imparting a driving force for dissociation, and this could be promoted by shear stresses. So is CsI the superconductor, or is one of the possible breakdown products responsible? Pure iodine has a transition temperature (T_c) of ~1 K measured at 28 to 74 GPa; the differences could be due to different states of crystallization or a pressure effect on T_c (*9*). Notably, SnI_4 is also a superconductor with a maximum T_c of 2 K in a crystalline state formed from its amorphous form (*10*), suggesting that a related transformation might also be considered for this material.

But the alternative interpretation of elemental superconductivity is in itself significant. Already 20 new elemental superconductors have been found at high pressure, increasing the number of known superconducting elements to at least 49 (see figure). The Osaka group has also made the extraordinary finding of superconductivity in oxygen at 100 GPa with a T_c of 0.6 K (*11*). This followed observations of superconductivity in sulfur at a similar pressure (*12*, *13*); higher pressure studies of sulfur by magnetic susceptibility showed that T_c reaches 17 K at 160 GPa, the record T_c for an element (*13*). The chalcogenide family of elements is in fact a family of superconductors with a wide range of T_c values. Notably, some of the results confirm reports of metallization and T_c from the early, crude diamond-indentor studies, which were discredited because of the lack of sample control and measurement of pressure (*3*).

With these recent experiments, more and more substances are giving up their "normal" state status as gases and liquids, and as insulators and semiconductors, to join the growing list of superconducting materials under pressure. Moreover, these "new" high-pressure superconductors may embody new mechanisms (*14*). Thus, understanding the origin of T_c in these materials, together with other new, but more well-known, ambient pressure superconductors—high T_c cuprates, fullerites, and borocarbides—represents a serious challenge to theory.

References

1. See footnote in E. Wigner and H. B. Huntington, *J. Chem. Phys.* **3**, 764 (1935).
2. A. A. Abrikosov, *Sov. Phys. JETP* **18**, 1399 (1963).
3. See news article by A. L. Robinson, *Science* **236**, 671 (1987).
4. M. Eremets *et al.*, *ibid.* **281**, 1333 (1998).
5. R. Reichlin *et al.*, *Phys. Rev. Lett.* **56**, 2858 (1986).
6. Q. Williams and R. Jeanloz, *ibid.*, p. 163.
7. ______, *ibid.* **59**, 1132 (1987).
8. H. K. Mao *et al.*, *Science* **246**, 649 (1989); H. K. Mao *et al.*, *Phys. Rev. Lett.* **64**, 1747 (1990).
9. K. Shimizu *et al.*, *J. Supercond.* **7**, 921 (1994).
10. N. Takeshita *et al.*, *Rev. High Pressure Sci. Technol.* **7**, 595 (1998).
11. K. Shimizu *et al.*, *Nature* **393**, 767 (1998).
12. S. Kometani *et al.*, *J. Phys. Soc. Jpn.* **66**, 2564 (1997).
13. V. V. Struzhkin *et al.*, *Nature* **390**, 382 (1997).
14. C. F. Richardson and N. W. Ashcroft, *Phys. Rev. Lett.* **78**, 118 (1997).

PERSPECTIVES: PALEOMAGNETISM

Faster Is Better

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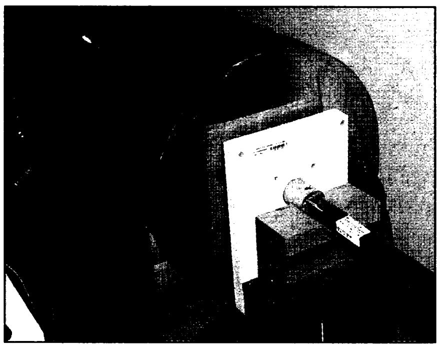
Think of a laboratory procedure that requires 1 hour of intensive labor to measure each sample. Now imagine the impact on any field of a new instrument that can measure 150 samples in 2 hours, without the presence of an operator. Such is the case with the automated, long-core cryogenic magnetometer, which has started to revolutionize the way that paleomagnetists study the magnetic properties of rocks, sediments, and soils. The data obtained by this new instrument are having a profound effect on studies of the behavior of Earth's magnetic field and on our understanding of climatic and other environmental processes.



New tool. With improved instruments such as this automated long-core magnetometer, samples can be processed much faster.

Traditionally, paleomagnetic samples have been collected as discrete, oriented cores or cubes of material with dimensions on the order of a few centimeters. Each sample is subjected to a magnetic cleaning procedure, known as demagnetization, which systematically removes secondary magnetizations that might be masking the primary signal. A typical 10-level demagnetization takes 1 hour and involves repeated manual transfer between the demagnetizer and the magnetometer, the instrument that actually measures the magnetization. With the new long-core cryogenic magnetometers (see figure), all of the processes are automated and incorporated into a single instrument. Samples are loaded onto a track that moves them between a set of demagnetization coils and a measurement region. Seven discrete samples can be measured at once, and a 10-level demagnetization of seven samples can be done in 20 minutes, which represents a 20-fold increase in throughput and productivity.

But that is not the end of the story. In recent years, scientists have been turning to sediment cores from the marine and continental realms to obtain information about paleoclimatic and other environmental processes. These cores can be sampled for paleomagnetic study with plastic u-channels, which, despite their name, have a square cross section, 2 cm across, and a length of up to 1.5 m. The u-channel is pushed upside-down into the flat face of a sediment core that has been split lengthwise. Monofilament fishing line is then used to free the u-channel and its sediment sample from the core. Once free, the u-channel is covered with a tight-fitting cap, and the ends are sealed to prevent desiccation of the sample. The entire procedure can take as little as 5 minutes.

The entire u-channel can be placed on the track of a long-core cryogenic magnetometer. At the usual sampling interval of 1 cm, the magnetometer can do a 10-level demagnetization of a u-channel in about 2 hours. This is equivalent to 150 individual paleomagnetic samples and represents the equivalent of a 75-fold increase in through-

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