fluorinated carbon chains should have less interior void space. When these are similarly treated with perfluoro-*n*-octane, fewer molecules are incorporated. For the nonfluorous hexafluorobenzene molecule, no host/guest complex can be detected.

Thus, in contrast to the inaccessible interiors of large fullerenes, the cages reported by *Sato et al.* can readily take up suitable guests. It remains unclear, however, how the guests gain access. Dissociation of linkers from the cages would generate transient channels or pores, but this process is known to be slow. Hence, transport probably occurs through one of the existing large portals.

The same research team has previously reported closely related complexes with other types of interior functionality (*9*). For example, when X is a polyether segment, the core of the cage complex features a dense array of oxygen donor atoms that should be able to bind metal ions. Indeed, when acetonitrile solutions of this complex were treated with sources of La^{3+} ions, about 20 ions were incorporated. When dimethyl sulfoxide (which strongly solvates many metal cations) was added, the La^{3+} ions were extracted, demonstrating that the formation of host/guest complexes is reversible.

How might such assemblies be exploited in future work? One major impetus for the industrial development of fluorous chemistry during the 1990s was the hope that fluorous media might be used in the selective oxidation of methane to methanol (*10*). Small gaseous molecules such as methane and oxygen are usually highly soluble in fluorous phases. Methanol, because of its much greater polarity, might be rapidly scavenged by a nonfluorous phase before further oxidation could occur. Reactions of such guest molecules with the fluorous cages reported by Sato *et al.* are therefore of particular interest. The next logical step would be to immobilize a fluorous oxidation catalyst in the cage interior and treat the system with a mixture of methane and oxygen.

The highly positively charged cages might also be attractive for anionic fluorous guests. Because of toxicity concerns and environmental persistence, several commercial fluorous carboxylates and sulfonates have been removed from the market in recent years (*11*, *12*). It is possible that they could be scavenged by the fluorous cages or by second-generation derivatives.

The results reported by Sato *et al.* are likely to inspire many more ideas for applications. Given that such assemblies can be prepared from a variety of linkers, that guests can easily be incorporated, and that more voluminous analogs are likely to be available soon, this initial study is certain to be followed by many exciting discoveries.

References and Notes

1. I. T. Horváth, D. P. Curran, J. A. Gladysz, in *Handbook of Fluorous Chemistry*, J. A. Gladysz, D. P. Curran, I. T. Horváth, Eds. (Wiley/VCH, Weinheim, Germany, 2004), pp. 1–4.
2. M. P. Krafft, in *Handbook of Fluorous Chemistry*, J. A. Gladysz, D. P. Curran, I. T. Horváth, Eds. (Wiley/VCH, Weinheim, Germany, 2004), pp. 478–490.
3. A. Garcia-Bernabé, M. Krämer, B. Olàh, R. Haag, *Chem. Eur. J.* **10**, 2822 (2004).
4. V. Perec *et al.*, *Angew. Chem. Int. Ed.* **44**, 4739 (2005).
5. M. Moreno-Mañas, R. Pleixats, in *Handbook of Fluorous Chemistry*, J. A. Gladysz, D. P. Curran, I. T. Horváth, Eds. (Wiley/VCH, Weinheim, Germany, 2004), pp. 491–507.
6. D. P. Curran, in *Handbook of Fluorous Chemistry*, J. A. Gladysz, D. P. Curran, I. T. Horváth, Eds. (Wiley/VCH, Weinheim, Germany, 2004), pp. 101–127.
7. L. V. Dinh, J. A. Gladysz, *Angew. Chem., Int. Ed.* **44**, 4095 (2005).
8. S. Sato, J. Iida, K. Suzuki, M. Kawano, T. Ozeki, M. Fujita, *Science* **313**, 1273 (2006).
9. M. Tominaga *et al.*, *J. Am. Chem. Soc.* **127**, 11950 (2005).
10. I. T. Horváth, in *Handbook of Fluorous Chemistry*, J. A. Gladysz, D. P. Curran, I. T. Horváth, Eds. (Wiley/VCH, Weinheim, Germany, 2004), pp. 5–10.
11. C. Hogue, *Chem. Eng. News* **83**, 5 (4 July 2005).
12. S. K. Ritter, *Chem. Eng. News* **84**, 37 (30 January 2006).
13. I thank the Deutsche Forschungsgemeinschaft (grant GL 300/3-3) for support.

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GEOCHEMISTRY

The Hawaiian-Emperor Bend: Older Than Expected

The kink in the Hawaiian-Emperor seamount chain in the Pacific Ocean was initiated ~50 million years ago, at a time when major plate motion changes occurred.

Joann M. Stock

One of the most stunning features of the Pacific Ocean floor is the Emperor-Hawaiian volcanic seamount chain, which stretches for 6000 km from the vicinity of the Kamchatka peninsula to the modern volcanic island of Hawaii, with a 60° kink in the middle (the "Hawaiian-Emperor Bend"). The seamounts and islands get progressively younger from north to south; the oldest mounts in the north were active ~80 million years ago, whereas Hawaii is still an active volcano today.

This age progression has been attributed to the relative motion between the Pacific lithospheric plate and a deeper source of the volcanism (the Hawaiian hot spot source). However, it has been difficult to explain the bend in the chain, because its age of 43 million years (*1*, *2*) did not correspond to any known change in the motion of the Pacific plate with respect to adjacent plates (*3*, *4*). On page 1281 of this issue, Sharp and Clague (*5*) provide new dates for the volcanic rocks that push the age of the bend back to ~50 million years—a time when major plate motion changes occurred. The result has important implications for studies of drift among hot spots, mantle flow fields, and the initiation of subduction.

How could the age of these seamounts have been underestimated by so much? At any volcano, the youngest eruptive products overlie the older ones and are therefore most accessible to seafloor sampling, coring, and dredging. Rocks that erupted during the major shield-building phase—the main phase of eruption of the volcano, during which it is centered over the hot spot source and 90 to 95% of the lavas are erupted—often can only be retrieved by drilling holes in the ocean floor. As more sampling has been done, the multimillion-year life span of the Hawaiian and Emperor volcanoes has become apparent (*6*, *7*). Furthermore, age dating, paleomagnetic studies, and geochemical studies have shown that many previously dated samples postdate the main shield-building events at these volcanoes (*5*) (see the figure). Improvements in isotopic dating techniques have allowed more precise dating of samples, and reevaluation of past results indicates that the ages of some samples reflected not the time of the original eruption but that of a later reheating event (*5*, *8*).

The Hawaiian-Emperor bend is the most widely cited example of a change in the velocity of a tectonic plate relative to an underlying volcanic source. The origin of the volcanism is controversial, but the erup-

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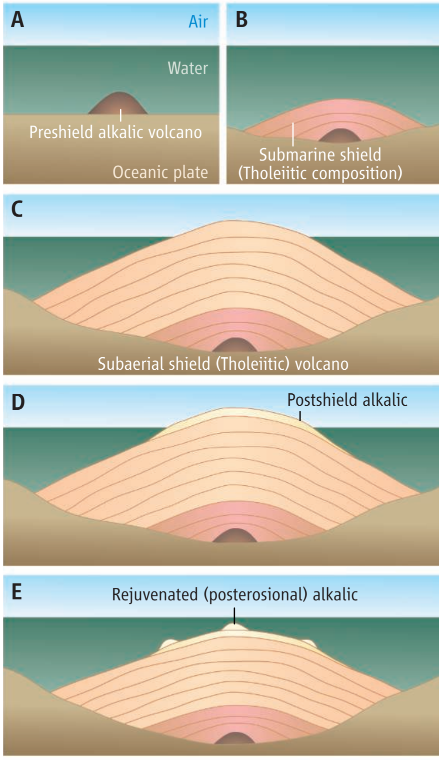

A typical ocean island volcano. These cross sections of an ocean island volcano such as a Hawaiian seamount illustrate the main stages of its evolution: preshield alkalic stage (**A**), main shield-building stage (**B** and **C**), postshield alkalic stage (**D**), and rejuvenated stage (**E**). The rocks most easily sampled or dredged on the volcano's surface can be considerably younger than the major phase of volcanism that built the volcano.

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tion source clearly has not been stationary with respect to Earth's spin axis, because the latitude of the Emperor seamount eruptions decreased with time until roughly the time of the Hawaiian-Emperor bend (*9*). Duncan and Keller (*8*) recently showed that the rate of propagation of volcanism along the Emperor section of the seamount chain varied considerably, first speeding up and then slowing down. Sharp and Clague now show that the change in orientation of the seamount chain was not abrupt: The change started 50 million years ago and took more than 8 million years to complete.

The revision of the age of such a tectonic feature by 7 million years has far-reaching consequences. Studies of plate motions and mantle dynamics that assumed a younger age of the bend will have to be adjusted (*10*, *11*). Plate reconstructions based only on marine magnetic anomalies from seafloor spreading centers are not affected, but the exact rates of relative hot spot drift calculated from these reconstructions (*12*) may have to be adjusted in light of the new ages assigned to the Hawaiian-Emperor volcanism. There will be better agreement between two different methods for determining the northward motion of the Pacific plate—one based on sedimentation patterns that show when locations on the Pacific plate crossed the equator (*13*), the other based on the age progression of the Hawaiian seamounts.

The new ages for the Hawaiian-Emperor bend and seamount chain help to clarify the connections among mantle dynamics, Pacific plate motion, and major reorganizations of plate boundaries in the western Pacific Ocean. The Aleutian, Izu-Bonin-Marianas, and Tonga-Kermadec subduction zones, which all started between 55 and 45 million years ago, involved major changes in the geometry and forces at the boundaries of the Pacific plate (*14*, *15*). None of these geometric changes could have occurred unless there had already been a change in the relative velocity of the Pacific plate with respect to adjacent plates. The time lag between these changes and the occurrence of the Hawaiian-Emperor bend was a major conundrum; the problem has now been removed by Sharp and Clague. Their results will spur new efforts to model mantle dynamics and plate kinematics through times of major changes in plate configuration, as well as additional data collection efforts.

More details of the spatial variation in paleolatitude and in volcanic propagation rates for the Hawaiian-Emperor volcanic seamount chain remain to be identified, and the published age progressions of other volcanic seamount chains will need to be scrutinized. The results of Sharp and Clague highlight the key role played by ocean drilling on this and many other seamount chains.

References

1. D. A. Clague, G. B. Dalrymple, *USGS Prof. Pap. 1350*, 5 (1987).
2. G. B. Dalrymple, D. A. Clague, *Earth Planet. Sci. Lett*. **31**, 313 (1976).
3. T. Atwater, in *The Geology of North America, The Eastern Pacific Ocean and Hawaii*, E. Winterer, D. M. Hussong, R. W. Decker, Eds. (Geological Society of America, Boulder, CO, 1989), vol. N, p. 21–72.
4. I. O. Norton, *Tectonics* **14**, 1080 (1995).
5. W. D. Sharp, D. A. Clague, *Science* **313**, 1281 (2006).
6. B. C. Kerr, D. W. Scholl, S. L. Klemperer, *Geochem. Geophys. Geosyst*. **6**, 10.1029/2004GC000705 (2005).
7. T. A. Bianco, G. Ito, J. M. Becker, M. O. Garcia, *Geochem. Geophys. Geosyst*. **6**, 10.1029/2005GC000945 (2005).
8. R. A. Duncan, R. A. Keller, *Geochem. Geophys. Geosyst*. **5**, 10.1029/2004GC000704 (2004).
9. J. A. Tarduno *et al*., *Science* **301**, 1064 (2003); published online 24 July 2003 (10.1126/science.1086442).
10. M. A. Richards, C. Lithgow-Bertelloni, *Earth Planet. Sci. Lett*. **137**, 19 (1996).
11. B. Steinberger, R. Sutherland, R. J. O'Connell, *Nature* **430**, 167 (2004).
12. C. A. Raymond, J. M. Stock, S. C. Cande, *AGU Geophys. Monogr*. **121**, 359 (2000).
13. J. M. Parés, T. C. Moore, *Earth Planet. Sci. Lett*. **237**, 951 (2005).
14. M. A. Cosca, R. J. Arculus, J. A. Pearce, J. G. Mitchell, E. J. Essene, *Island Arc* **7**, 579 (1998).
15. M. G. Gurnis, C. Hall, L. Lavier, *Geochem. Geophys. Geosyst*. **5**, 10.1029/2003GC000681 (2004).

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BEHAVIOR

The Power of Social Psychological Interventions

Timothy D. Wilson

Brief social psychological interventions that focus on people's perceptions of themselves and their environment have been shown to increase academic performance.

Some readers will undoubtedly be surprised, or even incredulous, that a 15-min intervention can reduce the racial achievement gap by 40%. Yet this is precisely what Cohen *et al.* (*1*) report on page 1307 of this issue. African American seventh graders randomly assigned to write about their most important values achieved significantly better end-of-semester grades than students in a control condition. How can this be?

As the authors note, these results are not unprecedented. Previous studies have found results of similar magnitude in samples of United States college students (see the table) (*2*–*4*). These studies share important features: Each drew on social psychological theories to change people's self- and social perceptions (i.e., people's explanations for their poor performance, their views of the malleability of their own intelligence, or their sense of social connectedness). Each did so with brief, inexpensive interventions. In each study, people in the treatment conditions achieved better grades than people in the control conditions. These increases were

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