of the earth's at a distance of 100 kilometers.

Vredefort's intense but random magnetism was not apparent from aerial surveys. Those analyses showed anomalously *low* magnetism over the crater, like a hole punched in the prevailing magnetic field. All the magnetic madness on the ground averages out to nothing when seen from too high up.

The results could have implications not only for earth geology but also for studies of Mars. The immense Martian basins Hellas and Argyre displayed virtually no magnetism when measured by the orbiting Mars Global Surveyor. The conventional explanation runs like this: When these craters formed around four billion years ago, the impacts wiped out the preexisting magnetization of the rocks. Therefore, at the time of their creation Mars must not have had a magnetic field, because that field would have been preserved in the magnetization of the basins' rocks when they cooled. Mars does not now have a magnetic field, but long ago it did. Thus, the standard explanation implies that Mars lost its field very early on.

But as Hart points out, if the Hellas and Argyre basins show the same properties as the Vredefort Crater, one cannot conclude anything about Mars's magnetic field when they were formed—it may have still been going strong. Mario Acuña, a principal investigator on the Mars Global Surveyor project, however, points out that data from smaller Martian craters of about Vredefort's size do not agree with Hart's scenario.

Back on earth, Hart has proposed a high-resolution helicopter survey of Vredefort's magnetism, from an altitude low enough to see the magnetic variations. That would produce a complete magnetic map—and make some sense of the crater's weirdness.

INTENSE, RANDOM MAGNETISM in the Vredefort Crater occurs in rocks such as these brown granite boulders. The darker rock is pseudotachylite, which forms from melted granite.

SIMON BARBER *South African IMC*

SHOCKED ROCKS

In the Vredefort Crater, the exceptionally strong and random magnetism exists only in "shocked" rocks—that is, rock that underwent intense pressure but did not melt. Rodger Hart of the iThemba Laboratory for Accelerator Based Science in South Africa, along with colleagues from the Paris Earth Physics Institute, suggests that the shocked rocks, which occur in thin layers, cooled rapidly, locking in a pattern of magnetization caused by the powerful, chaotic field generated at the time of impact. The unshocked rocks, in contrast, melted and formed larger pools that took days to cool down, preserving instead the weaker, more orderly natural magnetism of the earth.

ENERGY

Pumping Coal

COMING SOON TO THE U.S.: CLEANER DIESEL FROM DIRTY COAL **BY GUNJAN SINHA**

The U.S. is plump with coal. The country has one quarter of the world's reserves, and coal accounts for about 50 percent of the nation's electricity. To cut the reliance on oil imports, why not also use it to power cars and trucks or to heat homes, too?

That may happen soon. This year Waste Management and Processors, Inc. (WMPI), will break ground for the first U.S. coal-to-diesel production facility, in Gilberton, Pa. The plant will process 1.4 million tons of waste coal a year to generate approximately 5,000 barrels a day of diesel fuel. Other states, such as Illinois, Virginia, Kentucky, Wyoming and West Virginia, are also considering coal-to-liquid facilities.

Interest in the technology is certainly welcome news to WMPI president John Rich, who has been trying to finance such a facility for more than a decade. "Coal to liquids hadn't taken off, because the price of crude was at $30 to $40 a barrel," Rich says. Oil at about $60 makes coal more attractive.

To create the fuel, coal is first mixed with oxygen and steam at high temperature and pressure to produce carbon monoxide and hydrogen. The second step, referred to as Fischer-Tropsch synthesis, uses a catalyst to transform the gas into a liquid synthetic crude, which is further refined. Along the way, mercury, sulfur, ammonia and other compounds are extracted for sale on the commodities market.

The type of technology required to gasify the coal depends on the starting material. Pennsylvania alone has an estimated 260 million tons of waste coal—coal discarded because of its low energy content. "For every

ISOLATION TO INNOVATION

Coal-to-liquid technology is not new, but it remains confined to the turf of political pariahs. The technology first emerged in Germany in the 1920s, and the Nazis refined the process to power their war machine. After the war, the fuel could not compete with the low cost of crude. During the next few decades, however, South Africa took over the reins. Faced with the constant threat of an oil embargo against its apartheid regime, the country tried to wean itself off oil imports. Today the nation's energy giant Sasol holds key patents on certain parts of the process.

two tons of coal mined, up to half ends up in the reject pile," Rich says. Existing nearby facilities are not equipped to burn it. WMPI will rely on approaches innovated by South African energy giant Sasol; those methods are optimized to work with energy-poor coal, which include lignite and bitumen.

The resultant fuel is cleaner than conventional, sulfur-free diesel. In comparison tests, DaimlerChrysler showed that the coal-derived fuel spews 10 percent of the carbon monoxide and hydrocarbons and 70 percent of the particulates. The firm had plans to unveil a demonstration vehicle with a tweaked V-6 engine in April that cuts nitrogen oxides and other emissions even further, says Stefan Keppeler, senior manager of fuels research at the company.

Though relatively clean at the tailpipe, the fuel is dirty at its source. A similar coal-based power plant discharges about four million tons of carbon dioxide a year. In some facilities, the greenhouse gas can be repurposed—it can be pumped into oil fields or, in the case of WMPI's plant, sold to the beverage industry. Unless scientists develop methods to sequester CO_2 and find other uses for the gas, the technology might languish, warns Rudi Heydenrich, business unit manager at Sasol. The gasification step is also expensive, accounting for two thirds of the cost of a facility. "You need a structure where there is government support to ensure sustainable economics in the long run," Heydenrich remarks.

Under the Bush administration's Clean Coal Power Initiative, a $100-million federal loan guarantee jump-started the new WMPI facility. The state of Pennsylvania also chipped in with tax credits and a plan to buy up to half the plant's output to power its vehicles. Investors may contribute the additional $500 million necessary to build the plant. The initial cost of the fuel is expected to be about $54 a barrel.

Coal is not the only source of synthetic

ROGER RESSMEYER *Corbis*

FILL 'ER UP: Coal can be converted into diesel fuel and compete with crude oil at about $60 a barrel.

diesel; the fuel can be derived from natural gas and more cheaply, too. In fact, Qatar and Nigeria are building gas-to-liquid plants, and Sasol estimates that by 2014, gas-to-liquid fuel may account for at least 5 percent of the global market. But the U.S. does not have nearly as much natural gas as coal. And considering the vast coal reserves in China, which is also considering the technology, coal-derived diesel seems likely to play a bigger role in helping to liberate some countries from dependence on oil imports.

Gunjan Sinha is based in Berlin.

DEFENSE

Enhanced Armor

NEW SHIELDS TO FEND OFF EVOLVING BATTLEFIELD THREATS BY STEVEN ASHLEY

It's an all-too-familiar scene from the war in Iraq: A video shows a convoy of combat vehicles patrolling a dusty causeway. Suddenly, a huge detonation erupts next to one, often followed by a determined ambush. Over time, the guerrillas have steadily upgraded the lethality of their roadside bombs, suicide assaults and surprise attacks. This year, however, the U.S. military plans to field several new armor systems that should better defend its vehicles and personnel.

"The need to stop multiple, ever evolving threats is a tough problem," states Tony Russell, chief technology officer at Armor Holdings, a security products maker based in Jacksonville, Fla. "The systems we develop must defeat repeated armor-piercing bullet hits as well as the fragments and blast overpressures from explosives. And no one material—metal, composite, ceramic—is best at stopping every threat." Moreover, the armor has to be as light as possible. Successful solutions often mix several different substances to achieve the best result, Russell notes.

One of the least apparent recent improvements in armor has been the development of new, ultrahigh-hardness (UHH) steels. Such alloys are as much as 20 percent harder than the hardest off-the-shelf high-carbon steels, but they tend to be brittle and can crack when hit. Russell says that Armor Holdings has introduced an optimized version called UH56 steel, which is "hard enough to fracture armor-piercing ammo but tough enough not to crack with many impacts." UH56 is also easier to shape than many of its UHH cousins. The enhanced steels are being installed on many U.S. light-armored vehicles.

Researchers are also working on better transparent materials for windows, which are typically made from multiple laminations of bonded glass. As new threats loom, "the reaction is to add another layer of glass," explains Ron Hoffman of the University of Dayton Research Institute. But extra glass can make vehicles top-heavy, fuel-thirsty and sluggish.

One promising solution is to replace the glass with significantly cheaper and more effective aluminum oxynitride (ALON), a hard, sapphirelike material developed by industry, the U.S. Army and the U.S. Air Force. ALON offers better protection against armor-piercing projectiles at roughly half the weight and half the thickness of traditional glass-based transparent armor, Hoffman reports.

ALON has been around for years, but it has always been too expensive and too limited in size for vehicle windows. Engineers at Surmet, a ceramics maker in Burlington, Mass., have improved manufacturing processes involving the heating and compressing of ALON powders to make larger pieces of the material and to lower production costs significantly. Still, at around $10 to $15 per square inch, the optical ceramic costs more than military-grade glass ($3 per square inch). Armor Holdings is expected to start installing the lightweight windows this year.

Body armor will soon be in for some significant enhancements as well. Standard-issue ballistic vests, which are reinforced by hard ceramic plate inserts, are massive and bulky but more protective than today's lighter-weight, multilayer fabric alternatives made of woven Kevlar and other high-strength fibers. A new technology called liquid armor may change that, however.

SHEAR-THICKENING FLUID stiffens instantly when an object is dragged through it, enabling a vial of the liquid to be lifted. It can improve Kevlar's bullet-stopping power.

KATHY F. ATKINSON *University of Delaware Photo Services*

NEED TO KNOW: SHIELDS UP!

Electromagnetic armor is perhaps the most futuristic type of protection being explored. Engineers are developing it in response to shaped-charge weapons such as rocket-propelled grenades, in which a specially configured explosive forms a penetrating jet of molten copper that can bore its way through thick metal and ceramic armor. Current reactive armor—externally mounted explosives that break up the jets—is heavy and works only once.

Electromagnetic armor systems, in contrast, detect an oncoming projectile and rapidly generate an intense electric field, creating a powerful magnetic field that diverts charged particles in the hot, high-speed jet, which disrupts the warhead's intended effect. Electromagnetic armor should be ready within a few years, depending on the creation of lightweight power sources.