nized action on the problem. Within 3 weeks, Carsten Lund, Lance Fortnow, and Howard Karloff at the University of Chicago were able to show that multiple proofs were unnecessary—the matchmaker's problem could be verified with a single interactive proof. Their verification protocol works by repeatedly reducing the number of couples in the matchmaker's problem in such a way that the computer is forced to give the wrong answer to the reduced problem if it wants to cover up a wrong answer to the original problem. But this eventually forces it to give the wrong answer for just one couple.

These developments already showed that interactive proofs were more powerful than theorists had anticipated. Then, 2 weeks later, Adi Shamir at the Weizmann Institute in Israel took the final step. Shamir applied the same techniques used by the MIT and Chicago workers to find an interactive proof for a set of PSPACE problems known as Quantified Boolean Formulas.

These problems seek to establish the truth or falsity of complicated logical statements containing multiple users of the quantifiers "for all" and "there exists." Like the interactive proof for the matchmaker's problem, Shamir's approach depends on reducing the number of quantifiers. It was already known that every problem in PSPACE can be translated into a Quantified Boolean Formula problem, so Shamir's result instantly implied that everything in PSPACE has an interactive proof.

While the new results hint at the possibility of computer program answer checkers, don't count on seeing Macintoshes using interactive proofs to check the work of Cray supercomputers anytime soon. The obstacle is that the method assumes that the interrogated computer can instantly solve (or at least claim to solve) the extremely hard matchmaker's problem or the even harder problem of Quantified Boolean Formulas. "In reality we don't have these very powerful [computers] around," Fortnow points out. It would be of interest, he says, to determine exactly how much computing power is required to obtain an interactive proof for a given problem.

There is one other curious caveat on the new excitement. It could conceivably turn out that PSPACE problems aren't inherently unwieldy after all. If an efficient algorithm could be found for Quantified Boolean Formulas, then interactive proofs would be unnecessary. Complexity theorists believe this is an unlikely scenario, but see no way at this point to rule out the possibility. If anything, the unexpected equality of IP with PSPACE indicates that more surprises may yet be in store. ■ BARRY CIPRA

Identifying Fossils by Computer

The paleontologists who classify microfossils for oil drilling companies may soon be able to call upon a new computer program to help with their time-consuming analytical chores. Research presented this month at the conference on Innovative Applications of Artificial Intelligence in Washington, D.C., suggests that computer programs loaded with drawings of fossil parts could help researchers identify the samples taken in exploratory drilling. The program, if it becomes a practical success, may speed up the process by which petroleum companies make multimillion-dollar decisions about drilling at new sites. It promises to expedite a task that Abolfazl Jameossanaie, a fossil expert at Exxon, USA in Houston, now calls "tedious and time-consuming."

BP Research

Clue to oil? *Fossils like these help oil explorers find their targets.*

In choosing drilling targets, oil companies have come to rely on the advice of a variety of specialists, including a limited supply of fossil experts who study the tiny animals and plants that lived in the ocean hundreds of millions of years ago. The skeletons and shells of these sea creatures rained upon the ocean floors over the millennia and, along with organic material, became preserved in undersea rock. The microfossil composition of the rock layers can thus serve as a guide to their age and geological history and help geologists estimate the likelihood that oil deposits are near.

But this research takes a long time. World authorities who have devoted their careers to such work can identify offhand a few hundred or, by consulting catalogues, papers, or notes, can name a few thousand species—only a small portion of the microfossils commonly encountered.

Oil companies may spend a million dollars a day to keep rigs operating while awaiting word from the experts, and so are eager to speed up microfossil identification. This is where an "expert system" designed by Peter Swaby, a computer scientist at British Petroleum's Research International in Middlesex, England, and his colleagues comes in.

The BP researchers have devised a general computer program that incorporates the tricks, shortcuts, and rules of classification experts. When executed and linked with a full library of microfossil data, the program's graphics package kicks in, displaying pictures, textual descriptions, and command menus all on the same screen. A researcher examining fossil samples with a microscope can thus directly compare what he sees with the computer images.

And that makes the expert system much more efficient than traditional methods of identification—using those dusty tomes that, though supplied with illustrations, are organized by Latin name and written description. Swaby capitalizes on the preferred modus operandi of classification experts—to compare visually first. Written descriptions are often vague and sometimes incomprehensible, Swaby says. In contrast, "The human vision system is very powerful and can compare features quite easily."

Swaby's graphical expert system also has another advantage. It allows a paleontologist to begin describing a fossil with any one of a number of features, thereby breaking out of traditional flow chart schemes that are inherently hierarchical. Established schemes can be bothersome if a key feature can't be discerned because a fossil has been damaged. But with the expert system, users can start their descriptions with any of a variety of features. As the description progresses, the number of possible species becomes small enough so that their images may be perused, on screen, until a match is made.

Using BP's program as a guide, two novices, postgraduate students of geology, successfully classified three samples of conodont microfossils in about 2 hours—a job that is usually not approached before a semester of basic training in the use of reference catalogues. Swaby hopes to see his program, which he plans to link with data on the more commonly encountered Foraminifera microfossils, used in the field in a year or two. "Of course, the ultimate would be to scan an image of a microfossil and let a computer identify microfossils for you," Swaby says. But such a capability is far, far down the road.

Meanwhile, says Alan Higgins, a BP conodont expert, computer systems such as Swaby's "are a way of preserving for the next century a lot of experts' knowledge in a usable form that wouldn't otherwise be accessible." ■ SARAH WILLIAMS