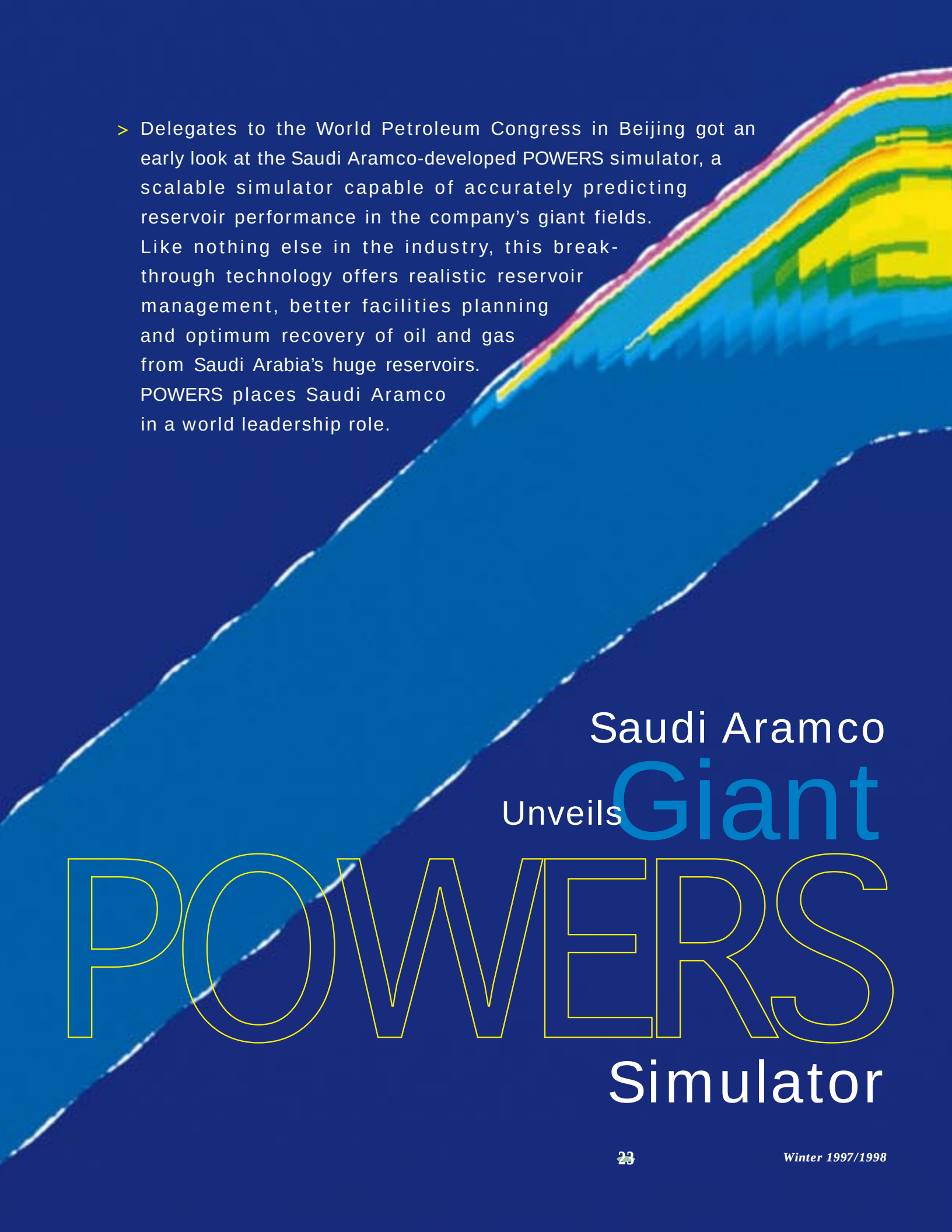
PARALLEL OIL-WATER-GAS-RESERVOIR SIMULATOR

The pioneer POWERS team used the CM5 massively parallel computer to help bring forth the industry's best-yet simulation model for handling Saudi Arabia's hydrocarbon reservoirs.

PHOTO BY HUSSAIN AL-RAMADAN



> Delegates to the World Petroleum Congress in Beijing got an early look at the Saudi Aramco-developed POWERS simulator, a scalable simulator capable of accurately predicting reservoir performance in the company's giant fields. Like nothing else in the industry, this break-through technology offers realistic reservoir management, better facilities planning and optimum recovery of oil and gas from Saudi Arabia's huge reservoirs. POWERS places Saudi Aramco in a world leadership role.

Saudi Aramco Unveils Giant POWERS Simulator

Early development group: (left to right) Gary Li, Nabil Al-Zamel, Husain Al-Sunaidi, Nahil Sobh and Craig Jimenez.

Saudi Aramco chose the 15th World Petroleum Congress in Beijing (see related story, this issue) to announce the development of a Parallel Oil-Water-Gas-Reservoir Simulator (POWERS). Delegates to the influential industry conference were among the first to see how Saudi Aramco, faced with its mandated responsibility to manage the Kingdom's hydrocarbon reservoirs for maximum performance, developed the POWERS simulator.

Computer simulation is a key technology used to predict reservoir performance, and company engineers have used and evaluated the best off-the-shelf simulation technologies available and found them wanting. None proved capable of handling the Kingdom's giant fields with resolution that was high enough. All currently available models oversimplify the detailed geological data to make the processing job easier — or even possible.

The size and complexity of Saudi Arabia's reservoirs is unique, and therein lies the opportunity and the challenge. The lack of accuracy and speed offered by existing technology propelled the company to take an industry leadership role in the research and development of multi-million-cell simulation models.

A multimillion-cell model captures a detailed picture of the reservoir and hence adequately describes the flow of oil, water and gas. Since it is not possible to run such a giant model on conventional computers, a cutting-edge research and development effort was required to select computing platforms and processing languages. This R&D effort at Saudi Aramco gave birth to POWERS.

Incorporating a half-century of production data from hundreds of wells, the POWERS model presents a virtual picture of complex reservoirs.

When researchers put the model to the test recently, the POWERS model successfully simulated three giant oil and gas reservoirs in Saudi Arabia containing more oil than the total of all U.S. and Canadian oil fields. Incorporating a half-century-long production history with hundreds of vertical and horizontal wells, the POWERS model presented a virtual picture of underground conditions in these complex reservoirs.

POWERS simulator is breakthrough technology

Necessity is indeed the mother of invention. Saudi Aramco needs a simulation model that can handle giant-sized reservoirs, taking into account the tremendous advances in reservoir characterization made in recent years.

Envisioning a long-term research project, the company assembled a crack team of petroleum engineers, computer scientists and mathematicians. These technologists are balanced with experienced company geologists.

Saudi Aramco's goal has been to develop its own simulator to duplicate a giant hydrocarbon reservoir by incorporating detailed geological description, linking the surface production network and reducing overall simulation cycle time.

POWERS is a three-dimensional, three-phase simulator which incorporates Saudi Aramco's specific well-management rules and can be linked to the surface production/injection pipe network. Most importantly, POWERS can run multimillion-cell simulation models with great speed and accuracy.

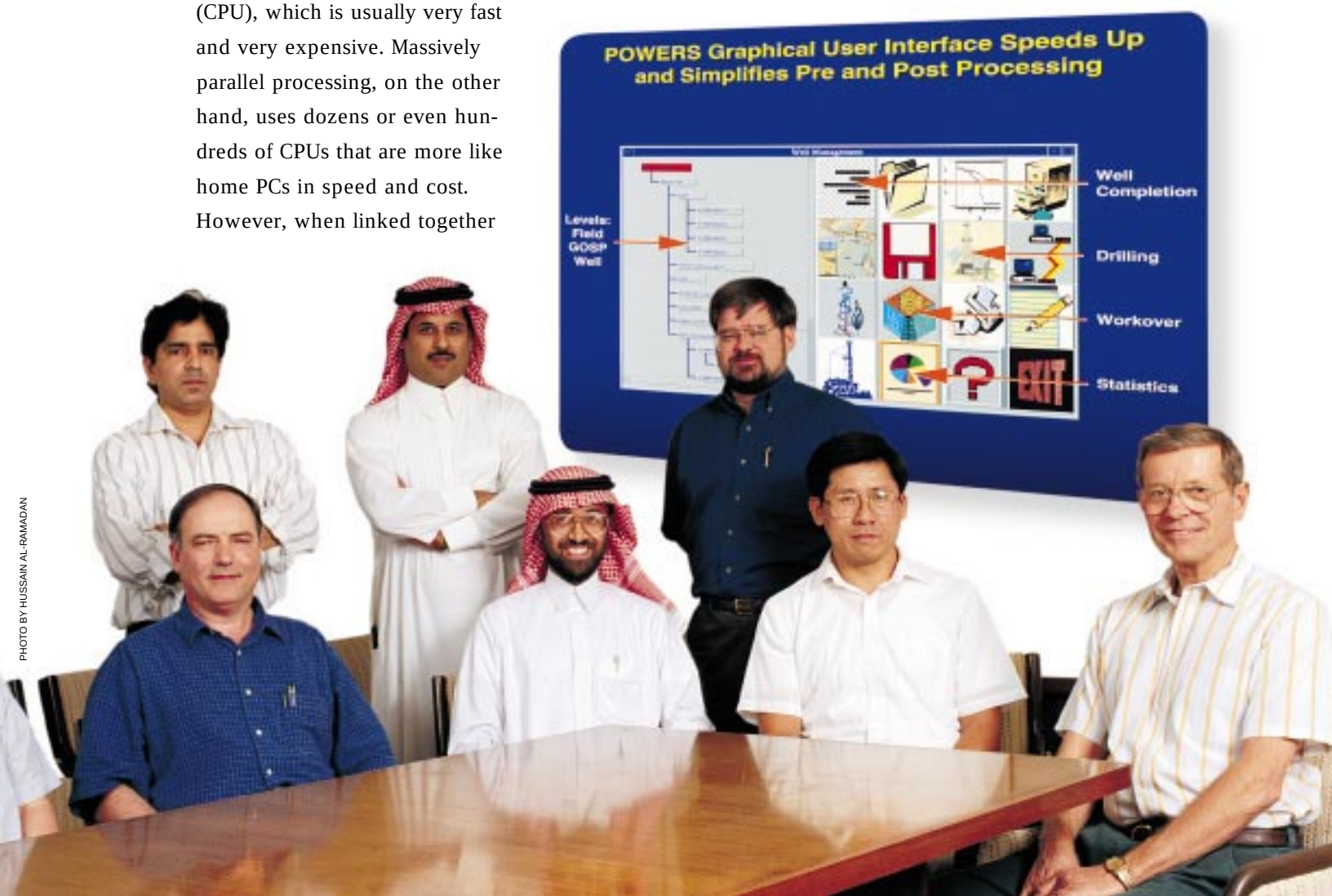
The new simulator makes full use of the latest advances in computations, reservoir description and computer graphics. Essentially, POWERS opens up a whole new horizon in reservoir simulation that will ultimately allow Saudi Aramco to simulate Ghawar, the world's largest oil field, using a single multimillion-cell model.

Top: Sophisticated Graphic User Interface speeds up and simplifies processing.

Bottom: POWERS Team: (seated, left to right) Dalsoo Shin, Ali Dogru, Husain Al-Sunaidi, Gary Li and Alvis McDonald; (standing, left to right) Arvind Sinha, Hussain Al-Mosharef and Tom Dreiman.

Massively Parallel Processing

A conventional supercomputer, or any sequential computer, utilizes a single central processing unit (CPU), which is usually very fast and very expensive. Massively parallel processing, on the other hand, uses dozens or even hundreds of CPUs that are more like home PCs in speed and cost. However, when linked together



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Geophysicists and geologists furnish data which is, in turn, utilized by the POWERS model to simulate the geology of the company's reservoirs.

(scalability), these massively parallel arrangements offer total speeds that far outstrip conventional supercomputers and are much less expensive.

The main challenge in this cutting-edge architecture lies with the algorithms and programming of reservoir simulators in this environment. Others have tried over the last decade, but no simulator before POWERS was successful in meeting the challenge.

Constructed with high-level parallel computer programming languages such as Fortran-90 and High-Performance Fortran, POWERS incorporates newly developed parallel algorithms and runs on scalable parallel computers.

The benefits of scalable parallel processing have been demonstrated by running a million-cell simulation model for an actual Saudi Aramco reservoir which incorporates 50 years of production history data. The model runs in less than four hours on a 32-node, CM5 massively parallel computer. By doubling the number of computer nodes from 32 to 64, the run time can be reduced to two hours. Doubling the nodes again to 128 will reduce the run time to 1.2 hours, thus providing nearly linear scalability.

Using POWERS, the simulation grid and well data of a moderate-sized field usually take about one day to construct. Initialization and verification of the input data typically requires another day. With a 64-node CM5 computer, the user could easily make 13 model runs in the next two and a half days, with a total graphic-processing time of about one hour.

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Graphical User Interface

Anyone who has ever used an ancient word-processing program knows that tiresome commands must be entered before even the simplest document can be generated. More advanced programs now provide for the use of icons and visual push buttons to enter those same commands — with much greater efficiency.

The POWERS model's graphical user interface overcomes the limitations of more conventional approaches, which rely heavily on more primitive text and batch-mode processing. This advanced model provides reservoir engineers with graphics-oriented input technology and direct control of simulation runs.

As an example of this advance, the graphical user interface allows reservoir engineers to build multilevel predictive models using virtual push button and drag-and-drop functions.

Upscaling Eliminated, Providing a Direct One-to-One Handshake

The necessity for upscaling in conventional simulation processes is somewhat similar to making an enlargement of a photo. The smaller the negative, the more detail is lost in the enlargement.

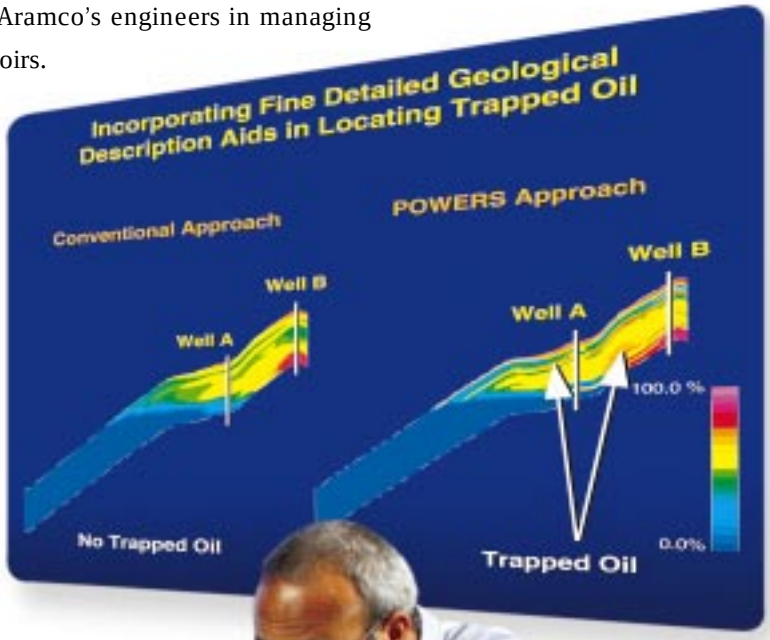
Under conventional simulation processing employing an approximately 100,000-cell model, the fine-grid geological model — which contains a million-plus cells — must be upscaled to run on the coarse-grid simulation model. Much information is lost in the upscaling process, thus sacrificing accurate characterization of the heterogeneity of the reservoir.

POWERS, on the other hand, allows the million cells of geological data to be incorporated directly into a million-cell model, representing a perfect handshake between the geological model and the reservoir model.

The Payoff: Optimum Recovery and Performance

The payoff of using the POWERS model is that it helps improve sweep efficiency, maximizes reserves and assists Saudi Aramco's engineers in managing the country's vast hydrocarbon reservoirs.

By utilizing the latest advances in computer and petroleum industry technologies — plus its own multi-disciplinary research and development team — Saudi Aramco can efficiently simulate its giant reservoirs at fine scale for optimum recovery of precious hydrocarbon resources. ❑



Top: Graphic showing how the POWERS approach aids in locating trapped oil.

Bottom: POWERS Berri Team: (left to right) Ali Dogru, Rick Pavlas, Zaki Al-Shammari, Dick Heil and Abdullah Ahmed.

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