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New ideas from ISGS petroleum geologists

May stimulate oil exploration in Illinois, lead to improved oil extraction practices

Don Oltz, head of the Survey's Oil and Gas Section (left), and Dick Howard discuss Pennsylvanian sandstone core samples.

● Coral reefs that developed in shallow seas covering much of Illinois 400 million years ago have yielded nearly 92 million barrels of oil since the 1940s. No one doubts that more reefs are buried in the Illinois Basin—yet no new reefs have been discovered since 1974.

● Sandbars deposited across Illinois in a widespread network of ancient valleys about 300 million years ago have provided porous reservoirs for oil accumulation. One such reservoir in Crawford County was discovered by pure luck in 1955 because it happened to lie on the flank of the much-drilled Hardinville Dome. But its connection to the paleovalley wasn't recognized until more than 20 years later, and only then did substantial production result.

At the ISGS, petroleum geologists are coming up with new ideas about why, how, and where the oil industry might pursue promising targets like these elusive reefs and sandbars. They're also trying to develop ways to improve the recovery rate from existing wells: currently more than 60 percent of the oil in Illinois reservoirs remains in the ground during primary recovery operations.

"Some people believe that these reefs in Illinois have all been played out, or that chasing sandbars down Mississippian-age paleovalleys wouldn't be worth the effort," says Don Oltz, head of the Survey's Oil and Gas Section. "We don't agree. So without being influenced by previous opinions, we're taking a fresh look at data that have been in our files for years, adding data resulting from new techniques we're using, and synthesizing and interpreting all this information. We've come up with a fistful of ideas we think may help stimulate oil exploration in Illinois."

Two new studies resulting from this approach will be issued as ISGS publications early in 1988. In the first, Steve Whitaker challenges the traditional view that Silurian pinnacle reefs are confined to a narrow area stretching northeast from Randolph County to Cumberland County; he provides evidence and interpretations suggesting that the reefs were distributed across a much larger area of Illinois than the current producing area indicates.

In the second publication—a regional study of oil accumulation associated with buried paleovalleys—Dick Howard and Whitaker focus on the long-ignored, now productive, sandstone reservoir at Hardinville. They conclude that oil traps like this one could occur throughout the basin and could prove to be important exploration targets.

In another study of paleovalley reservoirs of a different type, Bev Seyler, Joan Crockett, and Whitaker have analyzed and mapped shallow reservoirs in an area of western Illinois, where an oil boom in the early 1960s was followed by 20 years of dry holes until a new Silurian pool was discovered. They are now developing a set of general strategies that Seyler hopes "will help oil companies make decisions about where they want to drill for oil."

A regional focus

Oltz emphasizes the fact that Survey geologists do not prospect for individual oil wells.

"We're interested in the regional picture," he explains. "We don't say 'drill here'—it's not our job to do the detail work. We work with a 4-inch brush and paint a broad picture of where in the Illinois Basin, given the right economics, most independent drillers could afford to drill because the risk seems less."

The focus of all these studies, Oltz points out, is on reservoirs that people have drilled around and into but never completely understood.

"We want to add to our knowledge of the history of the Illinois Basin," he says. "We want to know why there is oil in this place, how the oil got here, where it came from, why it's trapped in this particular spot, what rocks 'sourced' the oil, and where the 'kitchen' was — the zone in which there was enough heat for oil to be generated."

Illinois' proposed site near Batavia for the Superconducting Super Collider is one of eight (of 43 originally proposed) deemed "best qualified sites" by a special committee of the National Academy of Sciences/National Academy of Engineering.

All divisions of the Illinois Department of Energy and Natural Resources, including the three surveys, are now compiling an environmental impact report to submit to the U.S. DOE in March. In February 1988 the surveys will make presentations at public hearings scheduled by DOE, and in July DOE will announce the single preferred site.

The ISGS has published five major technical reports providing geological data on the site and will complete several additional reports early in 1988.

Computer modeling, seismic studies and other techniques new to the Survey should make it easier to answer such questions. These methods will be used to supplement traditional methods petroleum geologists use for their detective work throughout Illinois: examining logs from wells penetrating the rock strata they're interested in, looking at well cuttings, cores, and outcrops, mapping the subsurface, and working with staff chemists on required types of analyses.

A recently acquired computer software program is being used in a study of the Maquoketa Shale. Chemical and physical analyses of selected well cuttings and core samples of the shale (taken from eight western Illinois counties lying on the edge of the Illinois Basin) indicate that this organic-rich shale has all the qualities a good petroleum source rock should have.

"But in the study area," Crockett explains, "it's too shallow (about 800 ft deep) to have been heated enough for oil generation to occur." She and Oltz plug data from the analyses into the simulated basin model and use it to project the Maquoketa to deeper burial depths further into the basin, to see if at some point the shale falls within the oil window (the "kitchen"). Migration routes from source rock to reservoir are also being studied.

Research to aid recovery

One aspect of the Illinois oil industry of particular concern to the Geological Survey is the rapid production decline in Illinois oil reservoirs. For instance, a well producing 200 to 300 barrels per day may be down to 50 barrels in a few months and then maybe to 10 or 15 a few months later.

Some of these dramatic production declines may be the result of drilling and completion practices. Fluids used during initial drilling, for treatment during well completion, and later for secondary and tertiary recovery can contain acids and other chemicals that may interact chemically with reservoir rock and either plug up or completely break down the pores of the rock near the well bore. Such damage can prevent fluids and oil from flowing into the well.

"If there's no way of getting at oil that's plugged off from the main reservoir, you just have to drill another well," Seyler says. "Independent producers often just can't do that. They don't have the money to do research and find out why they're having problems."

The Oil and Gas Section recently submitted a proposal to the U.S. Department of Energy (DOE) seeking funding for research on recovery problems.

"There used to be a theory that if you drill a well in a reservoir you'd eventually drain the reservoir," Oltz says. "That's not true. The reservoir rock isn't homogeneous; its architecture is different in different areas, and there are different types and combinations of clays and sands and other minerals that are going to react differently to the fluids used in extracting the oil."

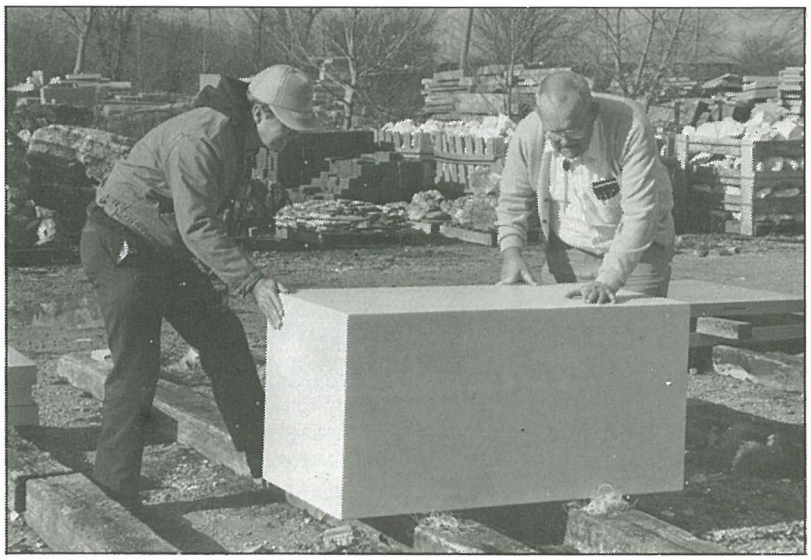
One study proposed for DOE funding would involve characterizing existing Illinois reservoirs geochemically and geologically and then recommending appropriate recovery practices geared to variations in these reservoirs. As part of this project, a classification scheme would be developed to identify oil reservoirs in the Illinois Basin belonging to the same depositional systems and having similar reservoir characteristics.

"Our preliminary studies indicate that it will be possible to increase oil recovery through detailed analysis of the reservoirs." Seyler says.

She has already begun examining reservoir rock with the Survey's new scanning electron microscope (SEM), and is working with ISGS clay mineralogists (now using an upgraded X-ray diffraction unit) to analyze the mineral composition of the reservoirs and determine what kinds of clays are in them. Seyler comments: "We should be able to say to a driller, the Cypress Sandstone in this part of the state

Joan Crockett calls up burial history diagram on computer as Bev Seyler looks on. The program graphically displays the onset of oil generation in a sedimentary basin.

ISGS scientists search for stones to represent Illinois

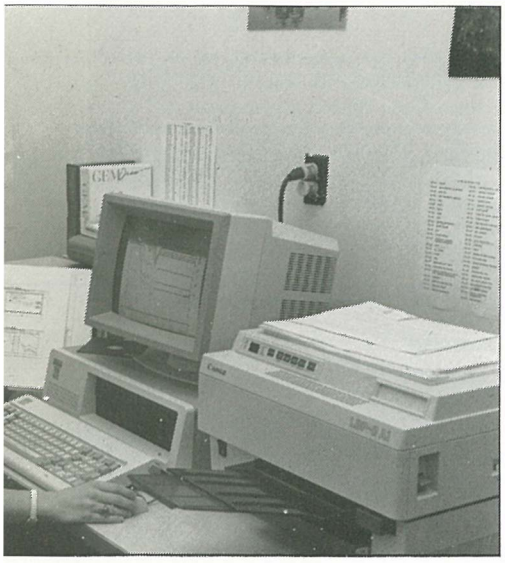


Jack Masters and Dave Reinertsen inspect cut dolomite stone.

Three ISGS geologists ranged across the state during this past year, tracking down stones to represent the State of Illinois in historic monuments to be constructed in the United States and France. For a commemorative wall to be built in Independence National Historic Park in Philadelphia, Jack Masters, Phil Reed, and Dave Reinertsen chose a block of Silurian dolomite, the kind of rock used in the Chicago building stone industry in the 1800s. A 5-ton rock donated by Vulcan Materials Company from its quarry in McCook was finished to specifications by Tri-State Cut Stone Company of Frankfort, Illinois (finished size was 4 ft x 2 ft x 2 ft).

A block of Mississippian limestone from southwestern Illinois was selected as the state's commemorative rock for a garden adjacent to the Battle of Normandy Memorial and Museum, which will be built on the Normandy battleground. The block from which the stone was cut was donated by the Columbia Quarry Company from its plant near Anna; the stone was cut and finished by the Chapman Stone Company in Springfield (finished size: 1 ft x 1 ft x 1 ft). Tri-State and Chapman also donated their services.

ISGS assistance in the projects was requested by Governor James Thompson and the Illinois Department of Veterans Affairs. — *mg*



has this kind of clay problem. Don't use this procedure with your well—try this or that instead."

The Survey's proposal to DOE also seeks funds for upgrading the ISGS Geological Records Unit (GRU) in conjunction with DOE's national assessment of oil and gas data; DOE maintains several databases as part of its program, and the Survey has been cooperating with DOE in updating its information on Illinois oil and gas resources. Computer software and hardware available through the proposed project would not only facilitate national goals but would mean that independent producers in Illinois would have access to ISGS oil data much more quickly than they do at present.

Morris W. Leighton, Chief of the Illinois Geological Survey, is encouraged by indications that the federal government and the State of Illinois are increasing their efforts to combat the complacency about energy issues that has permeated the country for the past several years.

Leighton noted that about 40 percent of the nation's oil is now imported and that according to estimates, 50 percent will be imported by the early 1990s if policies aren't changed. In Illinois, he says, with the price collapse in 1986, there was an 80 percent decrease in the number of drilling rigs, a 60 percent decrease in the monthly average of drilling permits, and a 20 percent reduction in average monthly production.

"Now is the time to generate the ideas and incentives that encourage private industry to explore for oil," Leighton says. "If we wait until the 1990s, how could we respond to any real national emergency if we've continued to lag behind in developing new technology and continuing exploration activities?"

"With the help of DOE and the state, our planned program expansion should not only provide help for the state's depressed oil industry but should also help address the nation's imbalance of payments and ensure greater national security." — *mg*

Survey study may expand search for Silurian reefs in Illinois Basin

"Old ideas restrict where and how to look for coral reefs," Steve Whitaker says. According to Whitaker, the usual method is to look for the characteristic pinnacle structure, with as much as 200 feet of relief from base to peak, and trace developmental trends using locations of known oil-producing reefs ("much like a connect-the-dot puzzle," he explains).

One particular trend has dominated exploration strategy: "We've always assumed that Silurian reefs were confined to a 'hingeline' centered in Clinton County and trending southwest to Randolph County. "Now we have more data, yet nobody's used it to challenge the old view."

According to traditional theory, a "hingeline" formed along a break in slope at the western edge of some localized downwarping (subsidence).

But Whitaker is skeptical: a reconstruction of events that occurred during Silurian time (about 400 million years ago) indicates that there is no isolated case of subsidence recorded in the rocks that lay directly under the Silurian seas and sediments. Data now available show that these layers of rocks — the Maquoketa strata — are uniformly thick across most of Illinois, then grow steadily thicker to the east across Indiana into Ohio.

As Whitaker interprets the evidence, Illinois was actually a broad, gently sloping ramp with no unusual structural features — a broad shelf along the western flank of a large regional basin. The shallow, nutrient-rich seas were ideal for random development of thick carbonate banks and reefs. Later erosion helped create the so-called hingeline trend and planed off the peaks of other reefs, making them difficult to identify and locate.

"If erosion hadn't occurred, we would have no trouble finding reefs scattered widely over the Illinois Basin," Whitaker says. He points out that remnants of reefs have been found north of the "hingeline" (three are producing oil), which finally disproves the old theory.

Pinnacle reefs are small — typically less than one mile in diameter — and they are easy to miss. "So *how* you look for them is just as important as *where* you look," Whitaker says. The traditional method of exploring for oil in the basin is to search for structural high points in layers of bedrock. (Most major oil fields in the basin are located on such structural highs, also known as structural traps.) Although additional coral reefs could be found by mapping structures in beds that drape over these reefs, Whitaker suggests a change in strategy: search for stratigraphic traps, such as remnants of porous reefs with little or no structural expression, because of erosion. For this approach, especially in areas for which well data are scarce, seismic mapping is the best method if it is cost-effective. — *es*

Bev Seyler and Steve Whitaker study seismic lines, which provide valuable information on subsurface structure and stratigraphy.

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Promising exploration targets: sandbars buried in ancient valleys

Almost no fanfare accompanied the accidental discovery in 1955 of a sandstone reservoir on the northeast flank of the Hardinville Dome. At the time nobody realized the significance of finding an oilbearing sand along the floor of a deep paleovalley, because successful wells in higher and lower reservoirs were already being drilled in the area.

When the reservoir was encountered in 1974 (again by chance) on the southwest flank of the dome, well log correlations identified it as a 3-mile-long, 5- to 45-foot-thick sandstone. Twenty wells will recover an estimated 1.5 million barrels of oil from the reservoir.

Dick Howard and Steve Whitaker's study of this reservoir illustrates the difficulties and rewards involved in developing exploration strategies for stratigraphic traps like these. Their study is the first to describe the relationship of a paleovalley to a specific Pennsylvanian hydrocarbon reservoir in Illinois.

"There may be dozens or more oil yielding sandbars buried in these paleovalleys," Whitaker says. "We don't know yet what the potential might be."

In the early 1970s Howard and his colleague, H.M. Bristol, mapped these paleovalleys. Their regional paleogeologic map of the Mississippian surface in the Illinois Basin, published in 1971, clearly showed an intricate, braided pattern of paleovalleys throughout the basin.

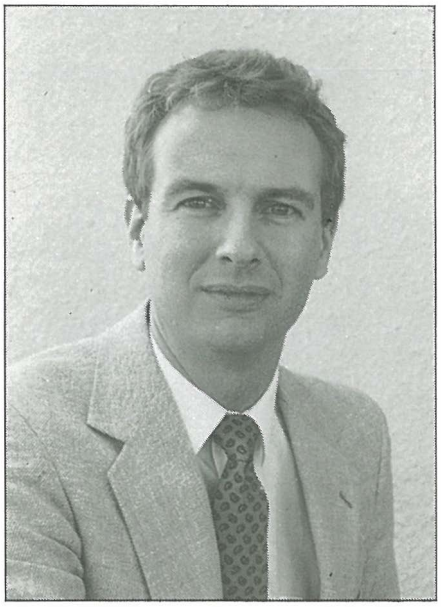
According to Howard, about 300 million years ago the seas that had covered most of Illinois, southwestern Indiana, and western Kentucky began to recede to the south and southwest. Then during subsequent periodic episodes of flooding, the ancient Michigan River System scoured out the paleovalleys. Later during early Pennsylvanian times the seas returned, inundating the valleys.

"As the encroaching seas entered the valley at Hardinville, gravelly sandbars were deposited along the valley floor, Howard explains. "In places where marine mud (shale) was later deposited over the sandbar a potential oil trap was created, and oil migrating into the porous sandstone would have been sealed there. No trap would exist, however, where the shale did not completely seal a sandbar."

Potential petroleum traps within paleovalleys are not restricted to crests of anticlines (folded rock layers) and can be found throughout the basin. Howard admits the search won't be easy.

But he, and Whitaker and geologists from the Indiana and Kentucky Geological Surveys are updating the 1971 paleogeologic map of the Illinois Basin. (The Illinois Basin extends into these states). When the map is completed it can be used to predict areas within the basin that are most likely to contain paleovalleys and associated sandstone reservoirs.

The use of seismic data (from reflections of artifically induced soundwaves) is one exploration method that should be helpful in refining paleovalley maps, Whitaker notes, but he emphasizes that the usefulness of seismic data depends on how much contrast there is between the density of the sandstones in the valley and the rocks surrounding them. — *mg*



Geologist Robert Bauer, supervisor of the Survey's rock mechanics laboratory, recently received the Douglas A. Piteau award from the Association of Engineering Geologists in Atlanta as the Outstanding Young Member of AEG for 1987. The award honors scientists younger than 35 years of age having distinguished records of technical accomplishments and service to the engineering geology profession. Bauer is the second person ever to have won this award.

Since 1984, Bauer has directed the ISGS geotechnical investigation of the Superconducting Super Collider. In addition, he has been the technical manager of the Illinois Mine Subsidence Research Program to develop guidelines for high-extraction coal mining under prime farmland. Bauer has also been involved in evaluating the use of time domain reflectometry to monitor coal mine subsidence movements in bedrock. — js

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