A FAULT OF YOUTH

New scientific ground was broken when geologists finally noticed that the Meers fault is young — much younger than any other surface rupture east of the Rockies

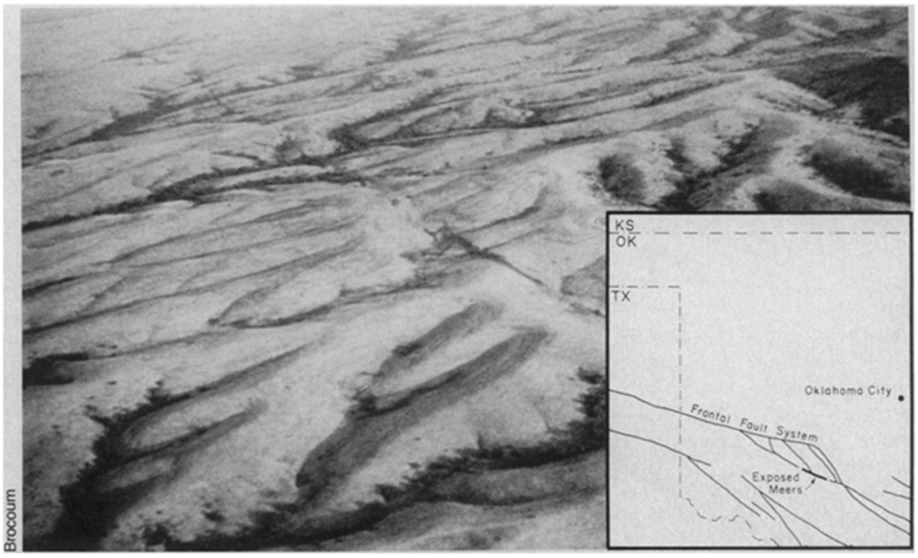
By STEFI WEISBURD

The Meers fault, a 26-kilometer line cutting brazenly through farms and prairie land in southwestern Oklahoma, is spawning something of a legend in geologic circles. For the last 40 years, scores of geologists have trampled all over the fault, thinking it was old and inactive. Even Charles Mankin, Oklahoma's state geologist, recalls spreading out his geologic maps on the fault trace one day 20 years ago without ever noticing just how unusual the Meers fault is. Until recently, no one saw the telltale signs of relatively new movement, perhaps within the last few thousand years, making the Meers fault essentially the only young, surface-breaking rupture east of the Rocky Mountains. Geologists now know that not only is the fault young, but it could produce a magnitude 7 earthquake in the future.

"Sometimes people just don't see what they don't expect to find," said one seismologist on his way to the first symposium on the Meers fault, hosted in April in Austin, Tex., by the Seismological Society of America. And what seismologists and geologists had come to expect, not only in Oklahoma but also over the entire eastern two-thirds of the United States, are old faults, dead and usually buried since they last wrenched the earth hundreds of millions of years ago. In fact, one outstanding problem for seismologists today is to explain where recent earthquakes in the eastern United States have originated. Most eastern young faults are almost impossible to trace because they rarely rupture the surface. "There are just no places where we can find breakage of bedrock at the surface," says petrologist M. Charles Gilbert.

But after repeated visits to the Meers fault a few years ago, Gilbert, of Texas A&M University in College Station, began to see what no one else had noticed. This fault was not just another ancient scar revealed at the surface only because the overlying rocks had eroded away. The Meers fault looked young.

For one thing, land to the north of the fault had been shoved *up* relative to rocks on the southern side, creating a scarp or steep slope of up to 5 meters high. This is just the opposite of what scientists had thought was the last major movement during the Pennsylvanian period some 300 million years ago, in which the Wichita Mountains to the south were uplifted, causing land north of the fault to sink.



Brocoum

From Okla. Geol. Notes, Donovan et al. (1983) V. 43, No. 5

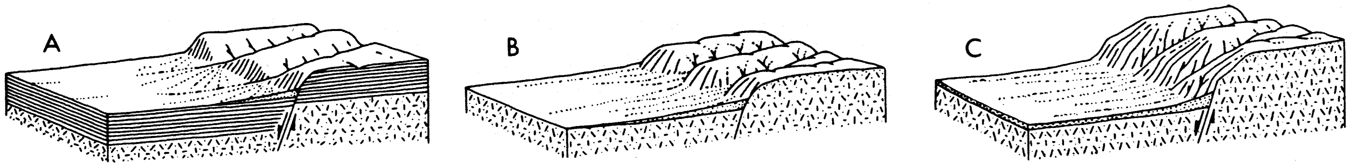
The Meers fault is the only fault in southwestern Oklahoma's Frontal Fault System to have a section exposed at the surface. This northwest-southeast-trending fault lies between the Wichita Mountains to the south and the Anadarko sedimentary basin to the north. Scientists think it may have been originally created in the late Precambrian times, about 600 million years ago, as the earth's crust was stretched apart. In the Pennsylvanian period, 300 million years ago, the underlying fault may have been reactivated as the crust was compressed and the Wichita Mountain block was squeezed up. A smaller movement of the fault is thought to have occurred in Permian times, 200 million years ago. The fault most recently moved, scientists now believe, within the last few thousand years.

Moreover, the fault cut through relatively young landscape, displacing both easily eroded shales and more durable limestone conglomerates. The scarp of a much older fault, such as one from the Pennsylvanian period, would have been considerably more worn and would have been obliterated in the shaley soils.

After Gilbert made his discovery, other researchers scouring the fault found additional signs of the fault's youth practically everywhere. For example, they noted terraces on the northern uplifted block and fans of soils at the base of the scarp, indicating that streams crossing the fault from the north had torn into the uplifted side in order to return to their original flow angles after the fault had moved. With all these signs, says Gilbert, the Meers fault would appear to belong in California, where young faults abound — and certainly not east of the Rocky Mountains.

Among the factors that had prompted scientists to assume the fault was old and inactive were historical records of earthquakes. While a number of earthquakes have been reported in Oklahoma over the last 100 years, seismically the Meers fault has been extremely quiet. Out of all the quakes listed in the seismic catalog, only a small one in 1981 could even remotely be associated with the fault, according to James E. Lawson Jr. at the Oklahoma Geophysical Observatory in Leonard. And since a seismograph station was installed 2 kilometers from the fault last April, only two possible, small events have been recorded, but researchers think even these were due to quarry blasts and not to movement along the fault.

"A lot of other faults that have been active in historic times still have microseismicity associated with them," says Gilbert. "This area is just very quiet and it makes you feel uncomfortable."



Modified by Tilford, after Douglas Johnson (1929)

Tilford/Ebasco Services Inc.

Multiple movements of the fault create beveled scarps. In Figure A, a newly formed scarp is made when one block is pushed up. With time, this scarp is worn down and the erosional debris is deposited on the lower block (B). When the fault moves again, a sharp new scarp is formed next to the older one (C). Photo shows both beveled scarps and eroded sediments deposited at the mouth of the gulley.

While no one understands why the Meers fault is seismically quiet, especially when nearby regions have experienced small earthquakes, it clearly has potential to be active in the future. As such it is of interest to the Nuclear Regulatory Commission and other agencies concerned about the siting of power plants, dams and other critical facilities. But in order to assess the fault's earthquake potential, a number of questions, some of which were discussed at the Austin meeting, have to be resolved. Everyone now agrees, for example, that the Meers fault is young — but exactly how young? When did it last move and what has been the recurrence time between earthquakes? In what directions did the fault move? And what does it look like far below the surface?

The time of the fault's last slippage can be estimated in a number of ways. D. Burton Slemmons and Alan Ramelli at the University of Nevada in Reno have examined the degree to which erosion has worn down scarps along the fault; the more worn the scarp, the older the fault. They report slope angles of up to 25° in soils and sediments above the limestone rocks at the northern end of the fault. By comparing the angles of the Meers fault's slopes with those studied by another researcher in the deserts of Nevada, Slemmons and Ramelli conclude that the Meers fault may have last moved as recently as a few hundred years ago.

Consistent with this timing is the work of Richard Madole of the U.S. Geological Survey in Golden, Colo. From radiocarbon dates of a few alluvial deposits (sediments deposited by streams or rivers) and analyses of soils along the southeastern end of the fault, Madole brackets the time of last movement between 500 and 2,000 years ago. Additional radiocarbon studies of nine soil samples collected last March should help to narrow this range. "My best estimate at this time is that it occurred about 1,300 years ago, give or take a few centuries," he says.

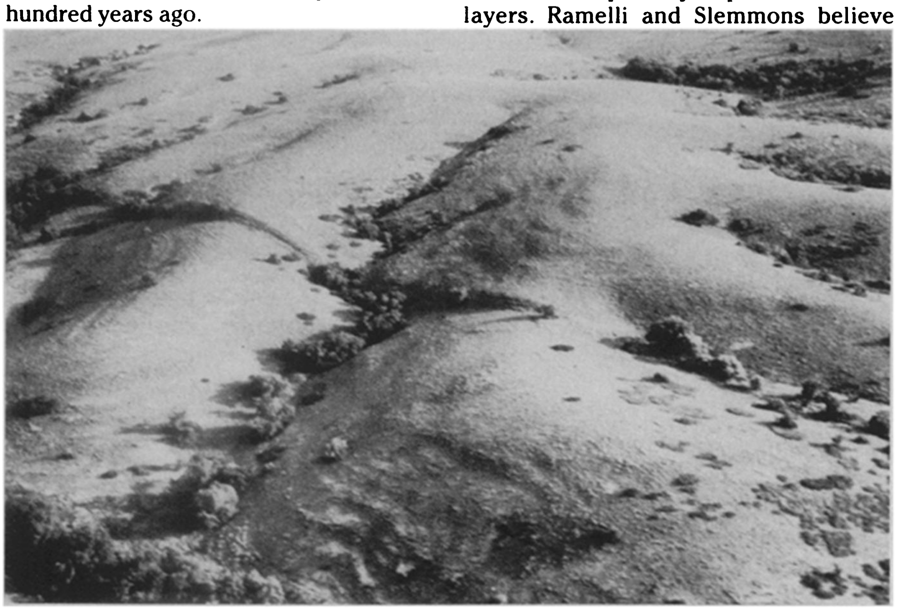
Now that researchers are starting to get an idea of the age of the Meers fault's last movement, they are wondering if there was more than one movement on the fault over the last 1 million or 2 million years, and if so, how often these have occurred. A recurrence time of, say, 1,000 years might mean that the fault is due for another jolt fairly soon, while a recurrence time 10 times longer would probably mean that people living nearby would have little cause for concern.

Slemmons, Ramelli and Diane Westen, a geological engineer at Shell Western E&P, Inc., in New Orleans, all suspect, on the basis of landform studies, that there have been multiple movements of the fault. Westen, for example, found some areas where stream flow had been diverted more than once and others in which two or more slices separately displaced sediment layers. Ramelli and Slemmons believe there is evidence of multiple movements in the verticle scarps on the north side of the fault. If the blocks cut by the fault had moved up only once, there would be one steplike scarp. A series of earthquakes over time, on the other hand, would produce several scarps at the same location, each eroded to a different degree depending on how long ago the movement that produced it had occurred. Indeed, Ramelli and Slemmons found several such beveled tiers of scarps in which the scarps with the gentlest and most worn slopes lie farthest from the fault.

Madole, however, argues that while this evidence is intriguing, it does not necessarily prove that multiple movement occurred. It is conceivable that the stream flow changes and scarps resulted from just one event, he says. Moreover, according to Kenneth Luza of the Oklahoma Geological Survey in Norman, two trenches dug across the fault in March (and since refilled at the landowner's request) revealed stratigraphic evidence of only one movement.

Others point out, however, that those trenches extended to layers dating only about 6,000 years, and that if many movements did occur, the evidence for them might be buried deeper in older rocks. All in all, the researchers say, the issue will be resolved only by detailed stratigraphic studies at several places along the fault trace.

An important ingredient in estimating the magnitude of past and future earthquakes on the Meers fault is knowing how the fault moved in the past — and here, too, there is some disagreement. Slemmons and Ramelli believe it was primarily a left-lateral movement, in

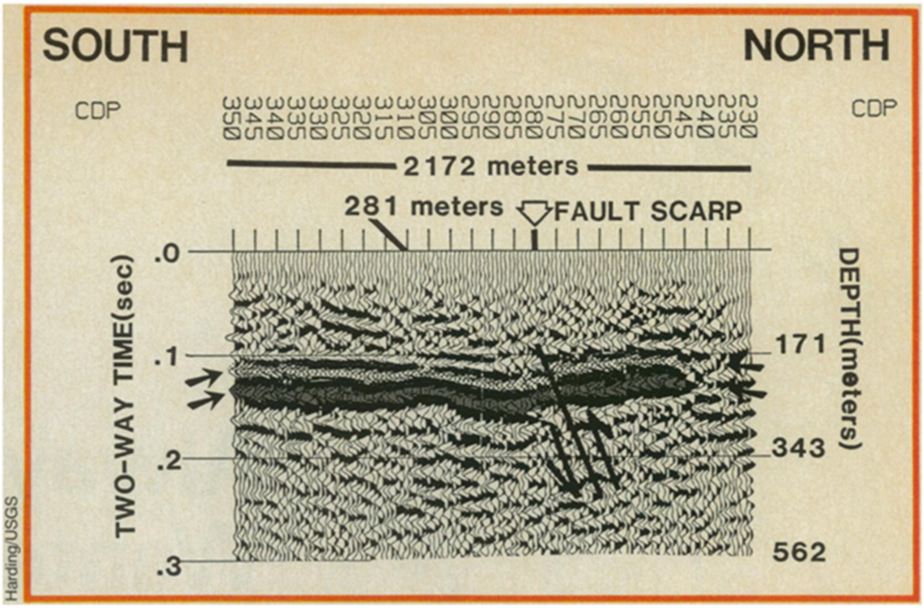


Brocoum

***Left-lateral offset:** A stream once traveled straight across the Meers fault, but its path was altered when fault movement caused the block shown in the upper half of this photograph to move to the left and the block on the lower half of the photo to move to the right. The tree-lined gulley now jogs to the left as it travels across the fault from the lower part of the photo to the top.*

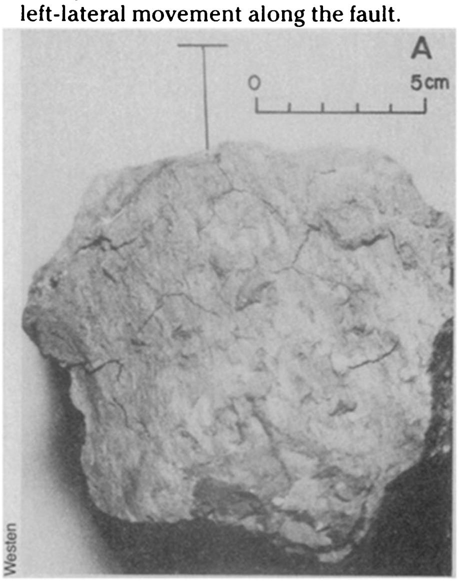
which blocks on either side of the trace slid past one another in a *horizontal* direction, with blocks north of the fault moving to the northwest and those to the south moving to the southeast. By measuring the displacement of ridges and stream channels that once traveled straight across the fault line, they found a horizontal offset of 20 meters, which is three to four times greater than the vertical movement of the fault as marked by scarp heights at those spots. The researchers also believe that left-lateral movement is consistent with what one would expect from the direction of stress measured in the crust in that region (SN: 6/14/80, p. 372).

However, Westen and Norman Tilford, chief geologist at Ebasco Services, Inc., in Greensboro, N.C., think the most recent movement of the fault has had a predominantly vertical component because slickensides (parallel grooves and scratches on the inside face of the fault) at two spots in the shaley soils indicate mostly vertical slippage. Moreover, in their study of stream displacements, they found about the same number of streams diverted to the right as to the left, as well as a number that did not change direction at all, indicating to them that there is no evidence for left-lateral movement along the fault.



Harding/USGS

This high-resolution seismic reflection profile taken across the Meers fault provides a glimpse of what the fault looks like over a certain depth range. At a depth of 171 meters below the surface trace, the profile shows a 30-meter vertical displacement caused by the fault, a much greater offset than the 1- or 2-meter scarp height at the surface. While the profile confirms that the Meers fault slices through deep layers of rocks and shows that it becomes more complicated at depth, says Samuel Harding of the USGS in Denver, Colo., it does not reveal how the fault looks between 171 meters and the surface.



Westen

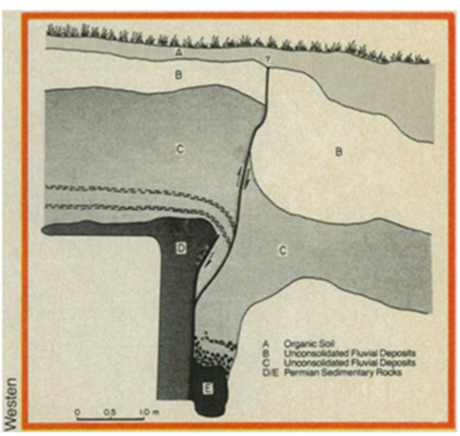
When the fault moved, it left clay "slickensides" on its inner face, with a grain oriented primarily in a near-vertical direction.

When researchers visited the fault together during the recent meeting, there was reportedly little resolution of this debate. An additional problem is that different sections of the fault may have moved in different ways and at different times. Slemmons also points out that the different rock types at the two ends of the fault probably respond differently to fault movement, thereby complicating the interpretation of past movement. In the southern half, for example, where the rocks are less brittle, fault movement deformed and folded rocks rather than breaking them cleanly.

In spite of the uncertainty about the fault's past motion, Slemmons has estimated the magnitude of past, and possibly future, quakes. Assuming that the whole 26- to 30-meter active region of the fault slipped, he concludes that the Meers fault could be capable of a big earthquake in the 6.5 to 7.5 magnitude range. (He obtains the same result if, using another approach, he assumes that there have been three to four movements in the recent geologic past, each creating a vertical offset of 1 to 2 meters and a horizontal displacement of 4 to 5 meters.)

"My personal feeling is that a magnitude 7 would be an ideal representation of the maximum earthquake that could occur in that zone," he adds. However, the seismic risk of the region could be greater, Slemmons says, because the Meers fault is part of a much larger fault zone. That's why he plans to use low sun-angle aerial photography on other scarps in the area to hunt for signs of recent activity along other faults.

The Nuclear Regulatory Commission, which has been funding much of the research on the Meers fault, does not have an official position on the fault with respect to siting of nuclear power plants. But Stephan Brocoum of the commission says he has little doubt that it would be judged a "capable" fault if officially considered. Capability is a legal term used by the commission to denote a fault that has moved once in the last 35,000 years or several times in the last 500,000 years, or one for which seismicity can be directly correlated. Brocoum doesn't think the Meers fault presents any hazard for existing power plants, since the closest one is almost 200 miles away. "We are recommending that more effort be put into studying the Meers fault and that region," he says, "to see if this is a unique feature or if there are other features like it."



Westen

This map of the sediment layers cut by the fault shows two fault slices, indicating to some researchers that the fault moved more than once.

While a lot more work remains to be done, it is clear that the Meers fault has rattled more than just the earth. It has shaken up, to some extent, the way in which seismologists and geologists think about faults in the eastern United States. As Gilbert points out, there may be very interesting faults lurking out there, building up stress in seismically quiet zones that receive less scientific attention than the more earthquake-prone regions. Adds one seismologist: "You start wondering, can this happen anyplace?" □