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Eagle's Habitat

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Locating The

New Madrid Fault Line

by Michael Pallamary

The devastation wrought by the recent San Francisco earthquake shocked the country. Network television replayed the catastrophe for weeks, focusing again and again on collapsed highways, crumbled buildings, fires and human suffering. Will San Francisco be the site of the next big one? Will it be Los Angeles? Or will it be somewhere else in the country?

History shows that the Midwest is as likely a candidate as are these notorious earthquake areas along the Pacific Coastline. The source of concern is the New Madrid Fault line, which runs through a good portion of the Mississippi River Valley. Unlike the San Andreas Fault to the west, the location of the New Madrid Fault has eluded surveyors, geologists and scientists.

While the San Andreas Fault leaves behind obvious evidence or "surface expression," the New Madrid Fault lies beneath a thick layer of alluvial river silt. When it does leave a mark, it does so in a most devastating fashion. Its most visible expression occurred in 1811, when the fault relocated itself; church bells rang in Boston and the Mississippi River ran backwards. An unknown number of settlers and wildlife were killed as a result of the quake.

What would be the effect of such an earthquake on the region today? It is believed by many that the devastation would run from Chicago to New Orleans. Where does the fault lie, and how much is it moving? When will it strike next? Will the Midwest be as prepared as the West Coast?

These and many other questions are being raised by Roy Frank, Jr., a surveyor and assistant professor with the Department of Technology of the Southern Illinois University at Carbondale.

As Frank and his students contemplate the problem, they are currently proposing a program to establish a series of first-order GPS stations along the banks of the Mississippi River. By developing a dense network of permanent control stations, it is hoped that the New Madrid Fault can be precisely located and subsequently monitored. More important, it is hoped that the fault can be defined and studied before it reawakens.

In California, where evidence of the San Andreas and its surrounding faults is everywhere, the monitoring and study is, by necessity, far more refined. It is hoped that the New Madrid Fault can eventually be understood as well as the San Andreas or its neighbor, the Hayward Fault. The immediate history of these two geological features is as fascinating as the history of the state itself.

For San Franciscans, there have been three "Great Earthquakes." The first occurred on October 21, 1868, when the Hayward Fault decided to move around. The fault line, about 18 miles east of the San Andreas, ripped a seam in the earth on that fateful day. At San Leandro, the courthouse and jail collapsed. In Hayward, almost every building was destroyed or damaged.

When the quake struck, a geologist named Davidson wasted no time in beginning to map the fault line in great detail and possibly with high accuracy. His report, however, was subsequently suppressed and then destroyed because of fears that real estate values would suffer.

The U.S. Geological Survey has attempted to reconstruct his work in an effort to pinpoint the fault. In many cases, educated guesses were necessary. The reconstructed report is now available from the agency.

The second great quake struck the region in 1906. By this time the area had been significantly developed and was replete with surface expression. This evidence took the form of altered fence lines, twisted railroad tracks, and radical gouges in the Earth. In some areas the displacement was as much as 20 feet. Not until the Long Beach area was hit with a trembler in 1965, however, was a serious effort made to monitor the San Andreas and Hayward faults.

In February 1970, the East Bay Council on Surveying and Mapping published a technical report titled "Crustal Movement Monitoring." In conjunction with a group of scientists, the local surveying community outlined the methodology to be employed in tracking the fault line. The report noted in part that:

"In the theory and practice of crustal movement investigation, local surveyors can operate more effectively than either

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scientists or engineers in an area between pure science and practical application. The purpose of the report is to ... familiarize participating surveyors with channels for communicating vital information that they are best suited to develop."

Two distinct classes of local surveyors were identified in the study: private practice and government employed. Of the two, the private surveyors were deemed to be in a better position to make initial reports on the types of evidence found. This included:

- Location and description of dikes of gouge material exposed by highway cuts or deep sewer trenching.
- Discrepancies in precisely measured angles between reliable, permanently monumented ground lines and reliable old angles of record between the same lines.
- Identification and rough location of offset fences in rural land.

In addition, private practice surveyors could make significant contributions in the initial report phase of evidence typified by:

- Offset curbs in city streets, connected by "en echelon" pavement cracks.
- Offset rails on railways crossing the roughly located fault lines.
- Offset building foundations.
- Offset retaining walls.

Once the data was collected, the private surveyors would submit brief reports to a local agency designated to receive and file the information. The government surveyors would perform the quantitative monitoring measurements. Other agencies would also be informed, including the National Center for Earthquake Research, a division of the U.S. Department of the Interior; certain offices of the U.S. Geological Survey working in close harmony with the National Center for Earthquake Research, particularly in mapping; the Earthquake Mechanism Laboratory of Environmental Science Services Administration; the United States Coast and Geodetic Survey; and the California Division of Mines and Geology.

This agency maintains a permanent record of the types of information described in this report.

In order to accommodate the local surveyors and standardize their reports, a unique form was generated. Included were evidential findings such as curb offsets, pavement cracks and structural damage. In addition, a substantial portion of the form was devoted to monitoring existing survey records, such as old bearing lines and measurements.

The actual monitoring of crustal movement is divided into 11 distinct but related operations. Since the advent of GPS technology, contemporary methodology is being developed. Following the recent San Francisco quake, NGS and USGS have combined forces to determine the surface deformation associated with the slippage along the Loma Prieta fault. As noted, the New Madrid Fault may also prove to be a testing ground for this new procedure.

Regardless of this aspect of science, historical tracing has proven to be one of the most valuable options available to the surveyor. Documented methods include:

•Repetition of broad, area-wide triangulation, resultant differential measurements being reduced to vector diagrams. Primary purposes are proof of existence of crustal movement, measurement of total area-wide slip, and possible indication of sense and magnitude of any rotation of basins between parallel fault lines. The work is performed by specialists in interested Federal Government agencies.

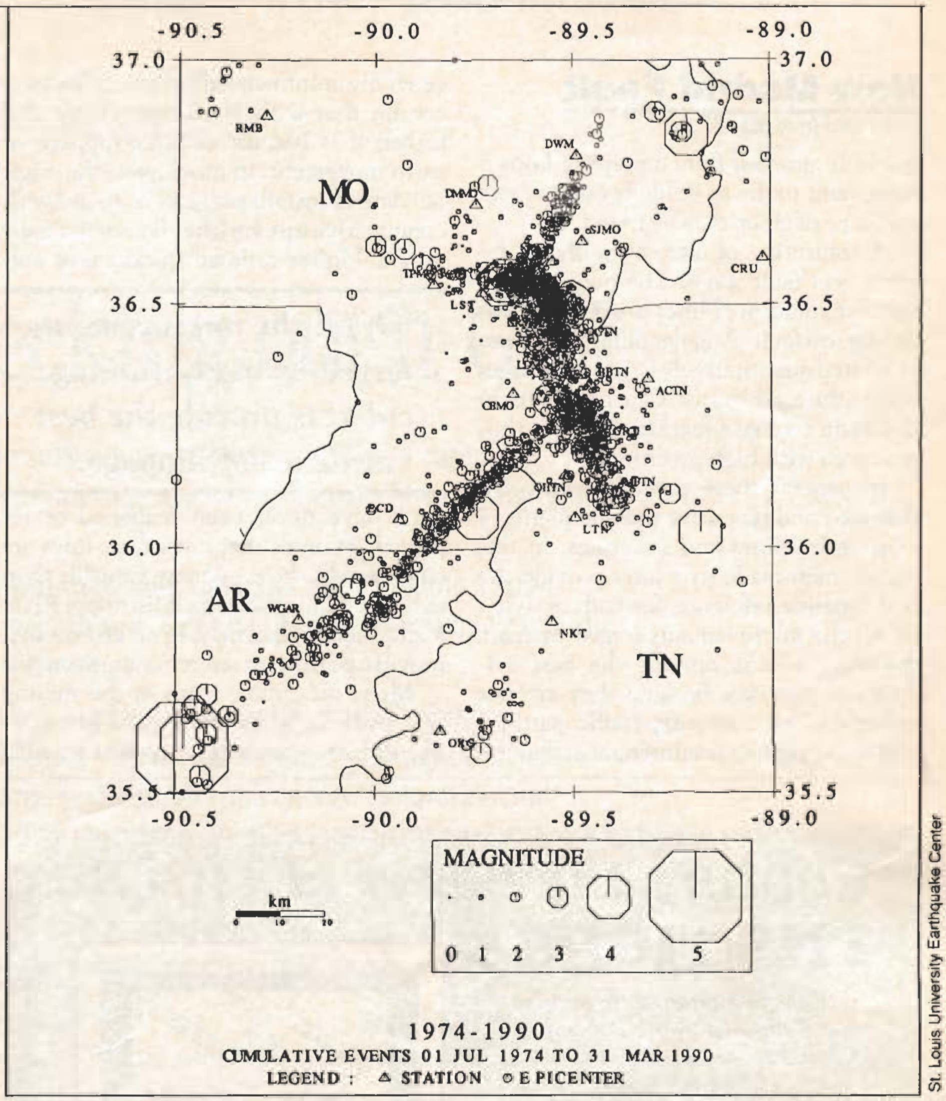
•Original measurement and subsequent monitoring measurement, with modern electronic distance-measuring devices of lengths of lines several miles long across known slippage planes at relatively shallow angles. As far as the local surveyor is concerned, the technique is a means of defining location and magnitude of slippage more precisely than can be done by triangulation. But the method gives promise of more far-reaching consequences.

•Remeasurement of old, reliable record angles in the broad zone identified by triangulation and distance monitoring as being subject to crustal movement. The usual purpose is to confirm the fact of crustal movement and/or to isolate a zone of current slippage within a few hundred feet. But if precision and orientation of original record angles coincidentally approximate those of an ideal monitoring network, comparative measurements can be used for quantitative analysis and more exact location of slippage.

•Measurement of visible offsets in man-made structures such as curbs, building foundations, traffic stripes, railroad tracks, culverts and tunnels. A zone of current slippage is thus located within a few feet, and the magnitude of slippage since date of construction is determined.

•Establishment of permanently marked and closely spaced horizontally controlled survey points in zones of suspected tectonic creep. Purposes are confirmation of creep, precise location, and monitoring of time-space relationships.

•Establishment of vertically controlled points in creep zones. Purposes are similar to purposes of horizontally controlled points, but different from the more orthodox monitoring for subsidence. In crustal



Since 1974, the Department of Earth and Atmospheric Sciences of the University of St. Louis has plotted more than 2,300 earthquakes around Southeastern Missouri, known as the boot heel, using a network of telemetered seismographic stations.

movement studies, scientists are interested in tilt and rate of tilt of a block of the crust, as well as in the traditional differential settlement.

•Specialized instrumentation. The purpose of this task is to monitor tectonic creep at frequent intervals without the expense of survey monitoring. The surveys cover broader areas, where frequency is not as critical.

•Trenching that exposes dikes of fault gouge material. The purpose is to isolate all possible locations of slippage without necessarily finding the particular plane where slippage takes place in the current era. It is thought that fault creep occurs at zones of gouge material which can be identified by its physical characteristics. In many cases, the same ends may be accomplished by inspecting trenches for underground utilities as they are being opened.

•Geophysical methods for precise location of dikes of gouge material. The purpose is the same as for trenching described above, but geophysical methods deliver a lot more valuable information in a shorter period of time. The expense is justified—usually many times over—when private developers need feasible site plans for structures near, but definitely off of, all possible lines of slippage or rupture. The local surveyor is interested in locations of dikes of gouge material because they give him a lead to finding more definitive evidence of actual slippage in that area.

•Field checking for existence of theoretical fault zone characteristics. The purpose is to extend the area of high quality evidence of movement. Various geological and geophysical theories, even though not yet universally accepted, can be used to minimize the amount of exploration re-

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quired to proceed from a point of known movement to the most likely point where evidence of creep may be found.

•Monitoring of astro-azimuths in regions near fault zones. The purpose is to measure rotation of lines roughly perpendicular to a fault. Angular differentials can be related quantitatively to strain changes within the earth's crust. One parameter in the strain change equations theory is thus measured with high precision.

In general these procedures involve densified and repetitive measurements of existing baselines and structures. In this regard, man-made structures provide the best baseline reference for fault activity. Of all the improvements forged by man, drainage culverts provide the best evidence of slippage. Because they are not influenced by confusing traffic patterns and heavy physical maintenance, they are generally uninfluenced by man. In fact it is certain that if their alignments are disturbed it is because of fault slippage or earth movement. In most cases, the original date of installation can be found with comparative ease and the alignment determined. Unlike railroad tracks, most culverts have never been realigned or replaced. Tunnels that cross fault lines are considered to be even more valuable than culverts. Throughout the Mississippi River Valley, old bridges may, in all probability, prove to be the best reference monuments.

"Of all the improvements forged by man, drainage culverts provide the best evidence of slippage."

Many old survey maps of the mining regions of the Midwest may contain valuable clues to recent activity. It is possible that, over the course of time, as section line after section line was measured, a pattern could exist wherein certain regions are experiencing compression or expansion. Until such time as these documents are studied, these questions remain unanswered.

In areas where the fault is clearly defined, intensified networks are laid out. In most cases a "picket fence" line is established. This simple method is extremely efficient and provides invaluable information to the scientific community.

The procedure to establish a picket fence involves laying out a rigidly defined baseline to a millimeter accuracy. Run perpendicular to the fault line, the reference monuments may extend for hundreds of feet beyond the fault. Periodically, or following current seismic activity, the baseline would be remeasured. Fallings to the established markers are noted and precise distances between the points are recorded. The readings are further supplemented by a series of vertical readings. In the case of the Hayward Fault, where the Pacific Plate and the North American Plate meet, one is moving over the other. Again, this rate of deformation is valuable information to the geologist.

Another successful method involves the installation of "Creep Meters," devices utilized to derive instantaneous readings on fault movement or "Tectonic Creep." The meters, laid out and calibrated by precise survey measurements, allow technicians to record slight movements in the Earth's surface without the use of external equipment or manpower constraints.

Given the extensive experience of the California surveyors and the interest of Frank and the students at Southern Illinois University at Carbondale, the mysterious New Madrid Fault may one day be located. Immediate limitations include budgetary constraints and a definition of participating agencies and associations.

Regardless of the methodology, one thing is certain: the outwardly tranquil earth is far from stable. One day it will move again, as it did recently in San Francisco. Ideally, the Midwest will be prepared to respond to one of nature's most violent events—a major earthquake. PS

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