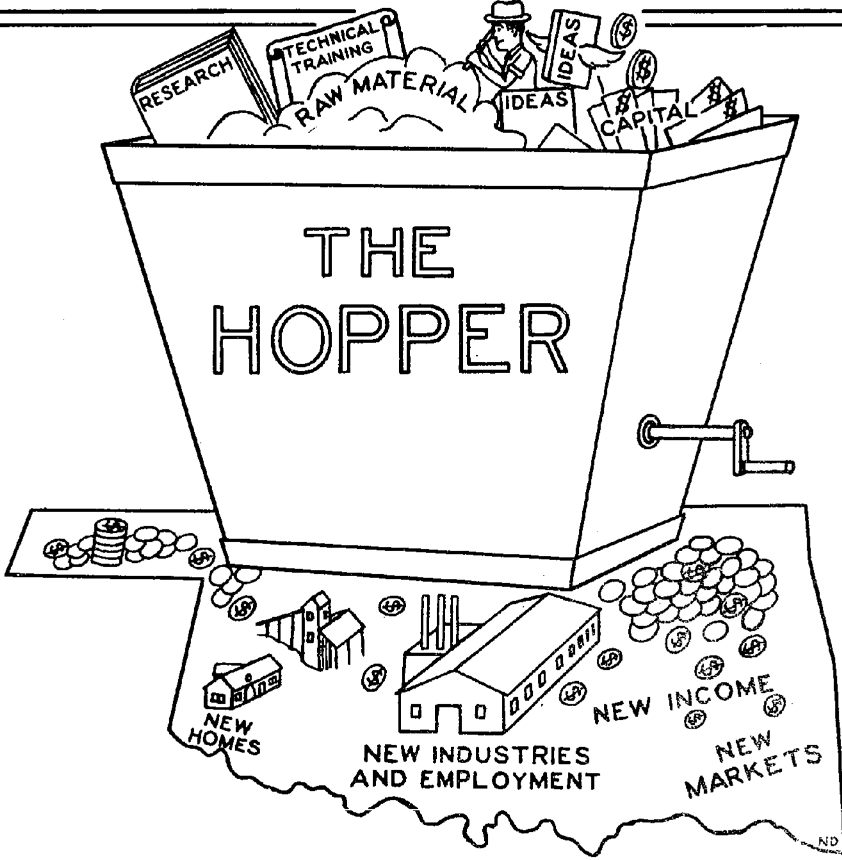
DEDICATED TO OKLAHOMA'S DEVELOPMENT



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THE CENTRAL OKLAHOMA EARTHQUAKE OF APRIL 9, 1952

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The following discussion by Dr. Heinrich is reprinted through the courtesy of the Oklahoma City Geological Society which is excerpted from Vol. 2, No. 9, May 19 issue of Shale Shaker, publication of the Oklahoma City Society. Dr. Heinrich is an authority on earthquakes of the lower Mississippi Valley and surrounding areas.

The seismologist who studies natural earthquakes by recording the vibrations with a seismograph faces a technically different type of problem than the prospecting seismologist in that he has no choice as to where or when his vibrations (natural earthquakes) will be generated. The prospector can set the size, position, and timing of his artificial earthquake. The strong earthquake which was felt over a very wide region of the plains states on the morning of April 9, 1952, is an example of the type of disturbance which supplies basic data for the study of natural activity in an important tectonic province of the United States. Both field and instrumental data concerning this earthquake will be examined for new clues to the evasive solutions of the problems of areal localization, geological relations, and possible causes of midwestern United States earthquakes.

At the present time (April 17) insufficient detailed observations of the distribution of the intensity of the vibrations are available for extended discussion but it is hoped that in time these data will be forthcoming, especially the significant information regarding any effects which were noted in wells in the region. These data can serve a very useful purpose when they are correlated with the instrumental results. In this preliminary note we shall be concerned in the main with the data derived from the first examination of the seismograms at several stations, with some details of the interesting seismograms which were traced at St. Louis, Missouri, and with some possible implications of these and some older related data. While preparing this report the author had available the original records of the two seismograph stations of Saint Louis University at St. Louis and Florissant (a St. Louis suburb), Missouri, and the analysis of nine other seismograph stations reported by wire by the United States Coast and Geodetic Survey.

<u>The Saint Louis Records</u>. Records were written by five different seismographs at St. Louis. Five records were also obtained at Florissant. The different instruments and their orientations allow check and complementary data to be obtained.

If we make some reasonable assumption regarding the depth of focus of the earthquake and the velocities of the longitudinal (P) and shear (S) waves in the upper layers of the earth's crust we can convert the information into distance data which will permit the calculation of an origin time for the earthquake, that is, the time the vibrations began from the focus.

Although other methods of determining the depth of focus of this earthquake will be supplied in the future when the original records of many seismograph stations will be studied, a reasonable assumption for a first approximation is the experience of seismologists with other midwestern earthquakes. Studies of many earthquakes have shown that the Joliat modification of the crustal structure proposed by Jeffrys for Europe will give good results. This structure considers the base of the crust (Mohorovicic discontinuity) at 30 kilometers depth and above this discontinuity places two layers; a surficial layer of 10 kilometers, and an intermediate layer of 20 kilometers. Thus there are three layers (in addition to the overlying sediments) with different velocities for the P and S waves. This allows major waves to arrive at a nearby seismograph station by three different paths.

Joliat's tables for travel times of the various earthquake phases in the Mississippi valley assume that the focus is at the bottom of the first layer. These tables were applied with a fair agreement between the postulated arrivals and the observed arrivals of the major phases for a distance of 473 miles and an origin time of 10h29m25s Central Standard Time.

So the existence of the standard phases can be established on the seismogram but there are other prominent phases which demand explanation. Four of these phases have been designated I_1, I_2, I_3 and I_4, but there are still others on the record. It is the wealth of these "other phases" that makes the records of this earthquake valuable for research. Such research may discover crustal conditions which are peculiar to the epicentral region of this earthquake. In this respect I_1 and I_2 seem significant but their interpretation must await a careful analysis.

Epicentral Region. The epicentral distances for the stations can be computed from the travel times of the P wave obtained by subtracting the estimated origin time of 10h29m25s from the P arrival time. These travel times were converted into distances using the average travel time for the normal P wave which has been compiled from observational data.

These distance arcs suggest an epicenter about 35.5 N., 98 W., near El Reno, Oklahoma. This should not be taken as other than a first graphical approximation and the finally derived epicenter may differ by several tenths of a degree from this point.

Perspective. Have there been prior earthquakes in the vicinity of El Reno, Oklahoma? Yes, but usually not of as great intensity as the earthquake of April 9. On October 22, 1882, an earthquake was felt over much the same area and with about the same intensity as this tremor but that was before the days of seismograph recordings and the epicenter was not located--it could have been near El Reno. The other earthquakes which originated near El Reno on September 10, 1918, December 27, 1929, and August 19, 1933, were slight. A slight aftershock of the April 9 earthquake was recorded at St. Louis on April 15, 1952, at 11h58m08s p.m. CST. The earthquake of April 9 is therefore unique in its intensity and verified location.

The epicentral location and the elliptical shape of the felt area which extended from Texas to beyond Omaha, Nebraska, suggests some relation with the Nemaha granite ridge, either in control of complex casual relations or in control of vibration propagation. The Nemaha uplift has been considered an area of seismic activity for some time particularly in Kansas and Nebraska where slight to moderate earthquakes occur now and then.

If we consider the staple tectonic province of the midwest (and therefore exclude the violent earthquakes of the Mississippi embayment) we find a repetition of this same concept of the association of epicenters with known or inferred structures in the pre-cambrian basement. In eastern Missouri earthquakes have been associated with the Ste. Genevieve fault, the Moselle fault, the Leasburg fault, and the Eureka anticline. In Illinois, earthquakes have been associated with the Waterloo-Dupo anticline, the Duquoin flexure, the Lincoln fold, the LaSalle anticline, and the Rough Creek fault. In Ohio earthquakes have been associated with the Findlay arch.

Both the earthquakes and the structures have a distribution in space and time. The structural elements are the results of forces which have been active in the geologic past, while the earthquakes are generated by currently active forces. The latter forces may represent residual energy of the former; or the earthquakes may be the result of new forces which are guided in their operations by the pattern established by earlier forces; or the earthquakes might be the indication of an entirely new tectonic situation, although geologic experience would suggest that this last possibility is the least likely.

In comparing the earthquake data and the geologic data now available, an observational limitation is imposed. The geologist finds, in attacking spatial distribution, that the structures most fully observed are in the near-surface zone. The seismologist if he is to assist the geologist must accurately determine the focal depth of the earthquake. Here again we see the value of this well-recorded strong earthquake in finding the minimum depth applicable to this earthquake. For if we are to attach interpretive significance to the relations of midwestern earthquakes and structure, it must be through the assumption of relations with depth; that is that the near surface structures are related to deeper structures which are genetically related to the earthquake generating forces. There are strong suggestions that in time earthquake epicenters and depth of foci may furnish valuable data on structural trends in this region.

* * * *

Oklahoma's proved reserves of crude oil, natural gas liquids, and natural gas--all were increased during the year of 1951. For each group, new discoveries during the year were substantially greater than production.

The following information dealing with reserves and production for the year of 1951 is taken from Reports on Proved Reserves of Crude Oil, Natural Gas Liquids, and Natural Gas in the United States, and Proved Reserves of Crude Oil in Western Canada, December 31, 1951, published jointly by American Gas Association and American Petroleum Institute. Each organization has a committee on reserves and each year a report is published giving the results of a study by this committee for the preceding year. The report is for the period ending December 31, 1951.

CRUDE OIL--AMERICAN PETROLEUM INSTITUTE
(Thousands of Barrels of 42 U. S. Gallons)

Total proved reserves of crude oil as of December 31, 1950		25,268,398
Revisions of previous estimates	⁄1,776,110	
Extensions of old pools . . .	2,248,588	
New reserves discovered in 1951 in new fields and in new pools in old fields . .	389,256	
Proved reserves added in 1951		4,413,954
Total proved reserves as of December 31, 1950 plus new proved reserves added in 1951		29,682,352
Less production during 1951		2,214,321
Total proved reserves of crude oil as of December 31, 1951		27,468,031
Increase in crude oil reserves during 1951		2,199,633

NATURAL GAS LIQUIDS--AMERICAN GAS ASSOCIATION AND AMERICAN PETROLEUM INSTITUTE
(Thousands of Barrels of 42 U. S. Gallons)

Total proved reserves of natural gas liquids as of December 31, 1950		4,267,663
Revisions of previous estimates and extensions of old pools .	+648,497	
New reserves discovered in 1951 in new fields and in new pools in old fields . . .	75,494	
Proved reserves added in 1951		723,991
Total proved reserves as of December 31, 1950 plus new proved reserves added in 1951		4,991,654
Less production during 1951		267,052
Total proved reserves of natural gas liquids as of December 31, 1951		4,724,602
Increase in Natural Gas Liquids reserves during 1951		456,939

TOTAL LIQUID HYDROCARBONS--A.P.I. & A.G.A.
(Thousands of Barrels of 42 U. S. Gallons)

Total proved reserves as of December 31, 1950		29,536,061
Revisions of previous estimates and extensions of old pools . .	+4,673,195	
New reserves discovered in 1951 in new fields and in new pools in old fields	464,750	
Proved reserves added in 1951		5,137,945
Total proved reserves as of December 31, 1950 plus new proved reserves added in 1951		34,674,006
Less production during 1951		2,481,373
Total proved reserves of liquid hydrocarbons as of December 31, 1951 . . .		32,192,633
Increase in Total Liquid Hydrocarbon reserves during 1951		2,656,572

NATURAL GAS RESERVES
(Thousands of Cubic Feet)

Total proved reserves as of December 31, 1950		185,592,699,000
Extensions and revisions of previous estimate	13,013,606,000	
New reserves discovered in 1951	3,039,385,000	
Net changes in "stored gas" during 1951 .	132,751,000	
Total proved reserves added and net changes in "stored gas" during 1951		16,185,742,000
Total proved reserves as of December 31, 1950 and additions during 1951		201,778,441,000
Deduct production during 1951 . . .		7,966,941,000
Total proved reserves of natural gas as of December 31, 1951 . . .		193,811,500,000

The following table **dealing** with Oklahoma's reserves for 1951 is assembled from various state tables given by the American Gas Association and the American Petroleum Institute.

OKLAHOMA

(Thousands of Barrels except Natural Gas)

Estimated Proved Reserves of:	Proved Reserves as of Dec. 31, 1950 (1)	Changes in Proved Reserves Due to Extensions (New Crude Oil) and Revisions During 1951 (2)	Proved Reserves Discovered in New Fields & in New Pools in Old Fields in 1951 (3)	Production During 1951 (4)	Proved Reserves as of Dec. 31, 1951 (Columns 1 ≠ 2 ≠ 3 less Col. 4) (5)	Changes in Reserves During 1951 (Column 5 less Column 1) (6)
Crude Oil	1,396,913	234,888	29,781	185,125	1,476,457	79,544
Natural Gas Liquids	279,903	52,715	4,319	25,812	311,125	31,222
Liquid Hydrocarbons	1,676,816	287,603	34,100	210,937	1,787,582	110,766
Natural Gas (Millions of Cubic Feet)	11,634,287	769,182	117,604	727,116	11,804,337*	170,050

*Includes increase of 10,380 million cubic feet in underground storage.

Mineral Production in Oklahoma, 1949-50
(Preliminary Figures prepared by United States Bureau of Mines)

Mineral	1949 Quantity	1949 Value (thousand dollars)	1950 Quantity	1950 Value (thousand dollars)
Clays (except for cement) . thous. tons .	244	222	316	313
Coal . . . . thous. tons .	3,022	15,242	2,679 1/	14,567 1/
Lead (recoverable content of ores, etc.) . . . . short tons .	19,858	6,275	20,724	5,596
Natural gas . . . . million cubic feet .	435,262 2/	20,327 2/	482,360 1/	23,636 1/
Natural-gas liquids:				
Natural gasoline . . . thous. bbls. .	6,855 2/	20,360 2/	7,980 1/	21,579 1/
LP-gases . . . . thous. bbls. .	5,630 2/	8,408 2/	6,753 1/	8,393 1/
Petroleum (crude) . . . . thous. bbls. .	151,660 2/	388,250 2/	164,599 1/	423,020 1/
Sand and gravel . . . . . . thous. tons .	2,921	1,526	3,287	2,357
Stone (except limestone for cement and lime) . . . . thous. tons .	4,342	4,028	5,022	4,848
Zinc (recoverable content of ores, etc.) . . . . short tons .	44,033	10,920	46,739	13,274
Undistributed: Native asphalt, cement, gypsum, lime, pumice and pumicite, salt, and ground sand and sandstone (1949-50).		8,706		9,512
Total Oklahoma		484,264 2/		527,095
Clay sold or used for cement. thous. tons .	236	152	240	180

1/Final figure. Supersedes preliminary figure given in commodity chapter.
2/Revised figure.