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Background Radioactivity in the Decorah Fault Region

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Abstract. A known fault site at Decorah, Iowa, was surveyed for indicative variations in surface radioactivity. A portable ionization chamber revealed significant increases in gamma ray intensity at several locations. At one point the radiation level was 70% greater than the background intensity. Measurements repeated one year later verified this pattern. Radiation contours were plotted over an extensive area in the city of Decorah. This map, with other items of supporting evidence, indicated a possible fault strike of approximately N 55° W.

The association of relatively high levels of surface radioactivity with fractures in sedimentary rock structure was first observed by Ambronn (1921). According to Heiland (1940), this effect has since been detected in widely different localities by other investigators. Nevertheless, radiation surveys have not become a standard technique of geophysical exploration. This may be attributed, in part, to the time limitations imposed by early instrumentation. However, the development of large, high-pressure ionization chambers with suitable amplification permits rapid surveys of extensive areas. To our knowledge, the present investigation was the first attempt in the state of Iowa to detect subsurface faults by radioactive measurements.

According to Fleming (1949), gamma radiation at the earth's surface has three major sources:

- 1) The radioactive substances in the soil.
- 2) The radon gas decay products in the atmosphere which emanate from the earth.
- 3) Cosmic radiation.

Some additional ionization is produced by radioactive impurities embedded in the walls of the ionization chamber. However, the soil radiation is more intense than that from all other sources combined.

Two major hypotheses have been advanced to account for the relatively high radioactivity detected above faults. The first is that an increase in radiation intensity in a fault zone might be expected from the deposition of radioactive minerals by ground water. Support for this concept, specifically in regard to Iowa, may be derived from Brown (1959) who reported ap-

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preciable amounts of radioactive elements in certain Iowa water samples. He found the highest concentrations in the sandstone aquifers: Mt. Simon, Jordan, Root Valley-Oneota, and St. Peter. Water from the St. Peter formation showed a marked increase in radium content toward the east. On the other hand, samples from glacial or alluvial aquifers contained low concentrations.

Another hypothesis, as given by Williams (1957), is that a fault fissure will permit migrating radioactive gases to change direction and thus become concentrated in seeking the line of least resistance to the surface. These gases might otherwise have diffused more or less vertically through porous sedimentary rock strata. The two hypotheses are not mutually exclusive.

THE DECORAH FAULT

In June, 1953, the city of Decorah, Winneshiek County, completed a water well at a depth of 934 feet. The well was such a poor producer that it has since been abandoned. Samples taken from the well gave evidence of faulting.

The well site is located in a small park on the northwest bank of the Upper Iowa River near the bridge on U. S. Highway 52. The old Decorah city well drilled in 1935 to a comparable depth through normal sections is about one-half mile to the south. An even deeper oil prospect well about five miles to the east also showed normal sections. In their surveys of Winneshiek County, neither Calvin (1905) nor Huffman (1941) reported surface features that might have been indicative of a subsurface fault.

The Decorah fault was reported by R. C. Northup in a paper entitled, "A Unique Fault in Northeast Iowa as Shown in Sub-surface Geology of Decorah City Water Well." The paper was given at the geology section of the 1954 meeting of the Iowa Academy of Science but was not published. Northup reported (personal communication from Iowa State Geologist, H. G. Hershey):

"The bedrock at this well was the Platteville limestone of Ordovician age, and the well was completed in the St. Lawrence dolomite of upper Cambrian (St. Croixan) age. Study of the samples from the well revealed an apparent duplication of section from the lower part of the St. Peter sandstone (the basal part of the St. Peter is shale in this well) through the Prairie du Chien group (including in descending order the Willow River dolomite, the Root Valley sandstone, and the Oneota dolomite). This was interpreted to be the result of high angle reverse faulting.

"The well went from basal St. Peter into what was apparently a normal section of Prairie du Chien. The Willow River, the upper member, was drilled from 185 to 414 feet, the Root Valley from 414 to 430 feet, and the lower member, the Oneota, from 430 to 475 feet. Then, at 475 feet, 10 feet of light-green soft clayey shale was found, which was interpreted as a dupli-

cation of the basal St. Peter. This was followed by another section of Willow River dolomite from 485 to 665 feet, Root Valley sandstone from 665 to 680 feet, and Oneota dolomite from 680 to 845, for a total repetition of about 250 feet of section. The typical Jordan sandstone was reached at 845 feet, which was much lower than had been forecast. At 895 feet, the St. Lawrence dolomite was reached, and the well was completed in this formation at 934 feet.

"Further indication of faulting was noted in brecciation in several samples, especially at 330 and 410 feet. Moreover, the disappointing production from the well upon completion may be largely attributed to the fault."

INSTRUMENTATION

A large ionization chamber, especially constructed for field work, was used to measure surface radioactivity in the Decorah area (Figure 1). This type of instrument is mainly a detector of gamma rays. The walls are sufficiently thick so that alpha or beta particles will rarely penetrate into the chamber. However, high energy cosmic ray particles will sometimes produce a burst of ionization.

The ionization chamber proper was constructed from a surplus oxygen cylinder with a volume of 500 cubic inches. It is of conventional design with a positive central wire carefully insulated from the walls. It was operated at "saturation voltage" so that nearly all ions produced by the gamma rays would be collected. The resulting ion currents were directly proportional to the intensity of the ionizing radiation, providing sufficient time for response was permitted. In practice, the operators paused about one minute at each station to assure an equilibrium reading.

The cylinder was filled with argon gas to a pressure of about 35 atmospheres. This assured great sensitivity since under these conditions the ionization produced in the chamber is about 50 times greater than in an equal volume of air at normal pressure. See Rossi (1949) for a thorough discussion of this type of instrument.

The output current of the chamber was applied to a vacuum-tube amplifier and measured with a microammeter. No attempt was made to calibrate the instrument, but the order of magnitude of the radiation being measured was obtained by burying a dosimeter for about five months near the well site. When the dosimeter was recovered, total radiation of 40 milliroentgens had been registered. This amounts to a radiation intensity of about 11 microroentgens per hour.

Numerous readings throughout northeast Iowa indicated that a scale reading of about 15 on the microammeter represented the

average intensity of the background radiation in that region. This value was taken as a reference level for the Decorah survey.

The ionization chamber, including the amplifier circuit, chassis and batteries, weighed about 50 pounds. It proved to be quite stable and easily maintained under field conditions.

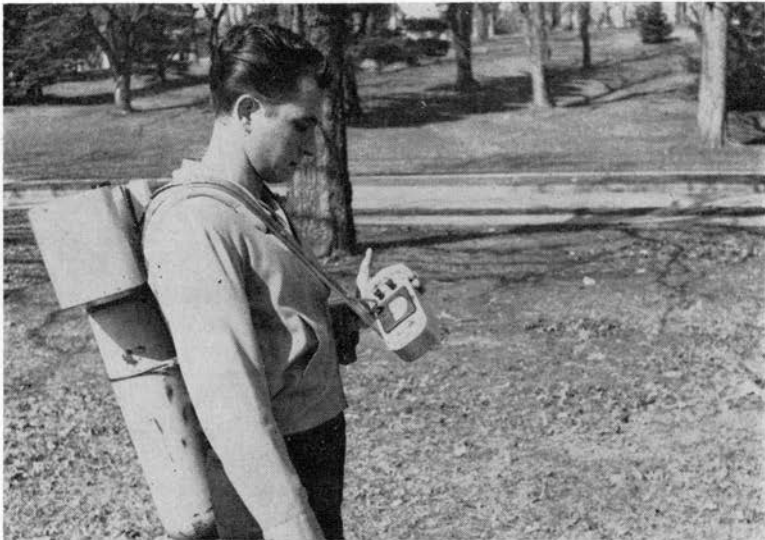


Figure 1. A gamma ray ionization chamber in field use. The large cylinder is the ionization chamber proper. The amplifier system is above the tank. The control panel and microammeter are mounted in front of the operator.

FIELD METHODS

A preliminary survey of the Decorah area was conducted in the fall of 1959. This was a mobile operation with the ionization chamber installed in the back of an automobile. This had the disadvantage of reducing all readings, especially over paved roads, but it permitted a rapid survey of the area. By cruising slowly (at about 15 miles per hour) the response time proved to be sufficiently rapid to indicate the general radiation pattern. The entire Decorah area that could be reached by automobile out to a radius of about four miles from the center of the city was thus explored. The general locations of three regions of significantly high radiation were found in this manner.

Survey work during the winter months proved to be virtually impossible. Frozen subsoil and snow covering reduced the radiation intensity to less than half the previous measurements.

During the fall of 1960, teams on foot explored the area, concentrating on the regions of interest that had been located by mobile survey. An operator carried the instrument and read

the meter. An assistant recorded the data on a map. These duties were frequently exchanged.

Measurements of gamma radiation at more than 500 stations were obtained by this method. Two of the three previously located regions of relatively high radioactivity were confirmed and mapped in finer detail. Several secondary highs were also located. Wherever possible, readings were taken over exposed ground rather than at paved locations.

RESULTS OF THE SURVEY

The three regions of high intensity located by mobile survey seemed to be centered around the Winneshiek County Courthouse, the well site, and a point on county road C about one mile from the northwest city limits of Decorah. A straight line can be drawn approximately through these points with a bearing of about N 55° W. However, no regions of high intensity were located along or near this line to the southeast of Decorah.

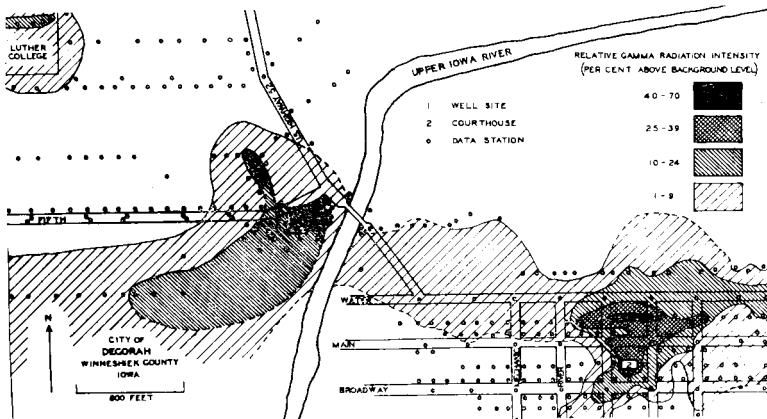


Figure 2. Zones of relatively high gamma radiation intensity in the city of Decorah. The small circles mark points where the field survey team recorded at least one measurement. Zonal boundaries (radiation contours) are not considered to be located with precision.

The 1960 survey revealed an intensity peak about 70% higher than background over a small plot surrounding the pump building at the well site. This was the highest radiation peak observed during the study, but it extended for no more than 20 or 30 feet from the well. It was standard procedure to recheck this measurement, and others in the park, at some time during each operating day. These readings were consistent within a range of about plus or minus one scale unit and were considered to be a good measure of reliability.

The radiation high previously noted near the center of Decorah was found to reach a maximum of about 45% above background level in an alley dividing the block immediately north of the courthouse. No further investigations were conducted on county road C.

The 1960 survey also located a secondary peak of radiation intensity at the northeast section of the block bounded by Iowa Avenue, East Street, Fifth Avenue, and Painter Street. Here the radioactivity was about 30% above background. Another zone of moderately high intensity (about 20% above background) was plotted on the Luther College campus near the statue of Martin Luther. Most of the high radiation intensity zones are shown on the map in Figure 2. No precise location of radiation contours is claimed, but the general pattern of intensity variation seems quite definite.

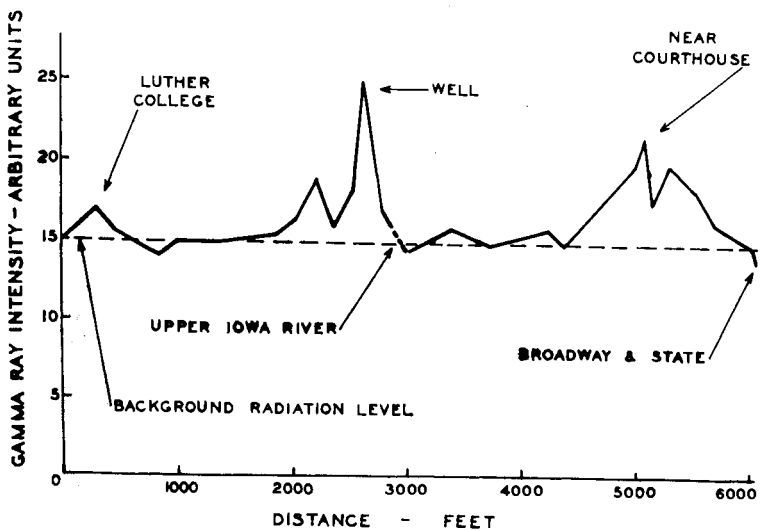


Figure 3. Gamma radiation intensity profile across the northwestern quadrant of the city of Decorah. The bearing of this section is approximately N 55° W.

The Luther College and Painter Street highs are also located near the N 55°W line that was determined by the 1959 mobile survey. An approximate section of the gamma ray intensity profile along this line is shown in Figure 3.

CONCLUSIONS

A relatively high level of surface radioactivity seems definitely to be associated with the one known fault point, i.e., at the well site. However, the restricted area of peak intensity raises doubts as to whether such an unusually high level existed prior

to drilling. In any case, the more extensive region of moderately high radioactivity around this point could probably have been detected.

The near alignment of the five radiation intensity peaks does suggest a possible fault strike of about N 55°W. The locations of the other deep wells, the old city water well to the south and the oil prospect well to the east, give evidence that the faulting does not extend far in those directions. If a single fault structure is the source of the high radiation zones, then differences in surface intensity along the strike might be attributed to variations in fault or overburden porosity, mineralization, or dip angle.

There is no reason to expect that all faults will display a high gamma radiation profile. Also, Heiland (1940) reported that other subsurface structures have been associated with high radioactivity. However, if it could be established that an increase in radiation intensity is generally characteristic of faults in a specific region, a most welcome addition to the methods of geophysical exploration might be developed. A gamma radiation survey of the Fort Dodge fault region is strongly suggested.

ACKNOWLEDGEMENTS

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