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SUMMARY OF RESEARCH RESULTS ON THE GEOLOGIC ASPECTS OF RADIO WAVE TRANSMISSION

By

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Introduction

There is presented herein a summary of research results of a geophysical investigation of the transmission of radio waves at the earth's surface and through earth materials. This summary is based on the results of the investigation formally undertaken in 1945 and which is still in progress. Some preliminary studies were made during the two years prior to 1945. At the inception of the project, in the Division of Groundwater Geology and Geophysical Exploration of the Illinois State Geological Survey, it was recognized that in a number of instances there was correlation between the behavior of radio waves and geologic features. Transmission through earth materials, to depths beyond that commonly thought probable, had been established in a few instances. The purpose of the investigation was to determine the relations between geologic conditions and radio wave transmission and to evaluate the variations in radio signal intensity or some other measurable value of radio waves for application to geological and geophysical problems.

Considerable data from this investigation were used as a basis for a thesis which was submitted by the writer in partial fulfillment of the requirements for the degree of doctor of philosophy in geology in the Graduate College of the University of Illinois. Copies of this thesis may be examined in the

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public files of the Illinois State Geological Survey or the Library of the University of Illinois.

The investigation was initiated at the direction of Dr. M. M. Leighton, Chief of the Illinois State Geological Survey. The work was done under the supervision of Dr. Carl A. Bays, at that time Geologist and Engineer and Head of the Division of Groundwater Geology and Geophysical Exploration of the Illinois State Geological Survey. Dr. Harold R. Wanless, Professor of Geology, University of Illinois, was Advisor for the Committee of the Department of Geology and the Graduate College. The provision of the opportunity to undertake this work and the excellent counsel and assistance of these men is gratefully acknowledged. In addition, much cooperation from owners of properties, their engineers, and many others in the mineral industries of Illinois, and the assistance of colleagues in the Survey have materially aided the investigation.

Scope of Investigation

The investigation to date has included several phases of office, laboratory, and field studies. The available literature on the subject and related fields by geologists, geophysicists, electrical engineers, and physicists has been consulted. Laboratory experimental work with rock materials was undertaken. Field measurements and experiments with a variety of types of instruments were made to develop effective and appropriate instrumentation. Many miles of field surveys measuring signal intensities were recorded, and methods to present these data were developed. All phases of the investigation were integrated to interpret the data and establish the findings indicated below. More detailed presentation of the work is being prepared for publication.

Standard broadcast signals (550 to 1600 kc) and signals at lower frequencies (radio range, military, etc.) are everywhere available and had previously been shown to be influenced in some instances by geologic conditions. For this reason studies have been conducted largely at these frequencies. Since the primary objective, relation of radio wave behavior to subsurface geologic conditions, requires as little effect as possible from ionospheric or tropospheric propagated or reflected waves, field work was limited to the ground wave service areas of transmitters, the area where no "sky wave" signals are observed during the daylight hours.

In addition to laboratory studies and field investigations of instrumentation, the studies to date have covered to some extent the relation of radio wave behavior to the following features:

A. Cultural
   1. Wire fences
   2. Electric power, telephone, and other transmission lines
   3. Pipe lines
   4. Bridges
   5. Buildings and towers
   6. Road materials (concrete, black-top, gravel, dirt)
   7. Output variations of radio transmitters

B. Natural
   1. Trees and other vegetation
   2. Bodies of water: streams, lakes, ponds
   3. Topography

C. Meteorological
   1. Barometric pressure
   2. Wind velocity and direction
   3. Sunlight and cloudiness
   4. Temperature
   5. Humidity
   6. Magnetic storms
   7. Precipitation
   8. Natural electromagnetic phenomena

D. Geological
   1. Faulted bedrock
   2. Folded bedrock
   3. Domed structure possibly intruded
   4. Cryptovolcanic structure
   5. Variation in soil types
   6. Buried drift-filled valleys
   7. Variation in bedrock lithology
   8. Variation in depth to uniform bedrock

Field Instrumentation

A variety of field instrumentation has been tested, ranging from metering equipment inserted into conventional automobile radios and portable communications receivers to precise field intensity measuring equipment. Final selection of equipment for wide adaptability to field conditions in Illinois resulted in the combination of a commercial precision field intensity meter, a 10 milliampere movement graphic recorder, and a speedometer drive so arranged that records can be made against either distance or time. These units were mounted in a wooden-bodied station wagon, after careful tests of the effects of the vehicle on signal intensity, to provide highly mobile equipment for field strength measurement, as shown in Figure 1. The records obtained were made using calibrated shielded loop antennae so that precise measurements of signal strength in micro-volts per meter were possible, or so that measurements of relative signal strength could be made, usually using a recorder chart scale of about 10 decibels per scale division, which is approximately the scale of the field chart shown in Figure 3. Some measurements were also made of relative field strength employing non-directional vertical antennae. Studies of comparative parameters of measurement and alternative techniques indicate this combination of instruments to be the best suited thus far for the problems investigated.

Summary of Results

Cultural, natural, meteorological, and geologic features were investigated. With recognition of the effects on signal intensities of wires, bridges, railroad tracks, metal fences, streams, topography, vegetation, etc., the influence of geologic features became recognizable and correlative with intensity anomalies (Figures 2 and 3).

This investigation and previous work indicate that, under proper conditions, radio waves at broadcast frequencies and lower penetrate the earth's crust for considerable distances. The origin of intensity anomalies associated with geologic features, such as the fault in Figures 2 and 3, is interpreted as due to the lithologic and/or chemical discontinuities of the strata which result in electrical or magnetic discontinuities as changes in conductivity and dielectric constant. Theoretical considerations of field intensity behavior in earth materials have been treated only superficially, and primary attention has been given to signal strength behavior as measured in the field and to the factors controlling this behavior.

Under suitable conditions, geologic features such as folding, faulting, and abrupt lithologic changes, whatever their origin, influence the behavior of radio fields measured in air at the surface. Measurement of this signal strength variation provides a means of mapping such commonly concealed features. Concentrations of pyrite, marcasite, and associated zinc and lead ores at shallow depths in the northwest Illinois zinc and lead district are interpreted as causing prominent signal anomalies. Soils developed on glacial drift in Illinois have thus far been found to be a negligible influence on field intensity.

Best reception appears to take place where receiving and transmitting antennae are on or close to the same rock strata. If the physical dimensions of a rock stratum with high electrical resistivity are compatible with those of the wave lengths of the signals used, and if the stratum is bounded above and below by shales or other beds with low electrical resistivity, radio fields appear to be carried by the bedrock stratum, in effect, as a wave guide.

If further geophysical investigation confirms the geologic wave guide concept of radio transmission, a number of very important applications may prove practical. Location of many types of radio transmitters and receivers at the earth's surface could be facilitated by study of the behavior of radio waves above rocks of different types or by use of rocks themselves for electromagnetic transmission.

As a tool for geophysical exploration, direct electromagnetic energization of selected strata (in drill holes if necessary) might permit identification of the areal extent and structure of geologic formations, metallic ore deposits, and lithologic changes, such as reefs in limestone.

Continuing investigations are planned to cover various aspects of these possibilities to geologic problems in Illinois, as well as further development of the concepts herein described.

Note

Due to the fact that the author of this paper is engaged in the continuance of this research, no inquiries can be referred to him. A copy of the thesis on "Geologic Aspects of Radio Wave Transmission" may be consulted either at the State Geological Survey or at the Library of the University of Illinois, Urbana. Inquiries concerning an arrangement to consult the copy at the State Geological Survey should be addressed to the Chief, State Geological Survey, 100 Natural Resources Building, Urbana, Illinois.

A full report is being prepared for publication and distribution approximately one year hence.

February 1, 1950.

M. M. Leighton, Chief
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Fig. 1

Fig. 1 (left): Illinois Geological Survey mobile field intensity equipment used for measuring radio wave signal strength.

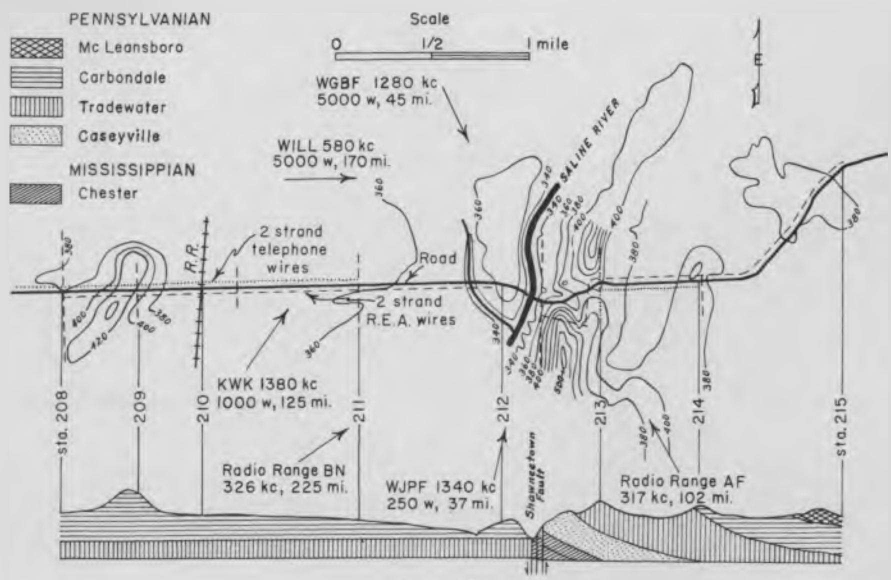

Fig. 2

Fig. 2 (above): Field conditions map and geologic cross-section in area of selected traverse along Illinois Highway No. 1 in Gallatin County. The topography, the recognized possible field hazards such as power and telephone lines, bridges, bodies of water, railroad tracks, and the critical information on radio transmitters used for surveys of the area are shown on the sketch map. The geologic cross-section at the bottom of the figure shows the structure and stratigraphy along the traverse line, crossing the Shawneetown fault. (Surficial materials not shown.) Note: top of map is east.

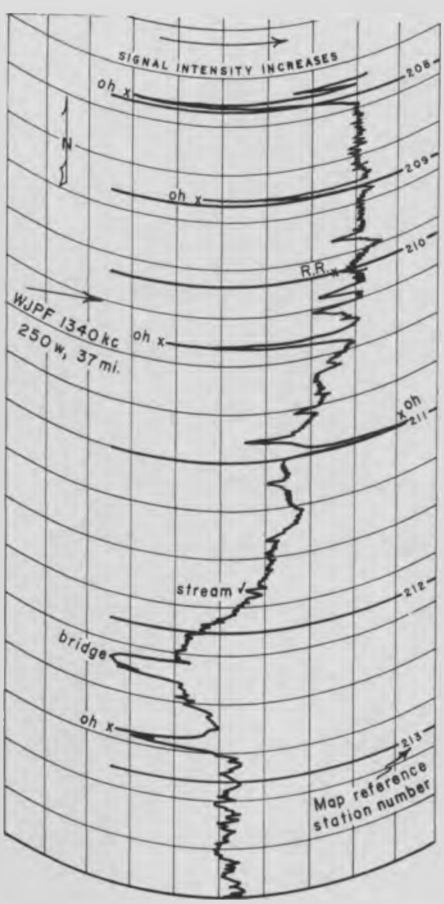

Fig. 3

Fig. 3 (left): One record of signal strength traverse along route shown in Fig. 2. Loss in field intensity in passing from younger Pennsylvanian strata (on which antenna of station WJPF is located at Herrin, Illinois) north of the Shawneetown fault to older strata to the south of the fault is shown between stations 212 and 213 (see text). Effects of the bridge, overhead wires (oh), stream, and railroad tracks are also recorded.