# Earth Resistivity and Geological Structure *

By R. H. CARD

IN connection with inductive coordination problems it is frequently necessary to estimate low-frequency ground-return mutual impedances between power and communication lines. The distribution of currents in the earth is a major factor in the determination of these impedances. This distribution is controlled by the resistivities of the component parts of the earth's crust and the arrangement of these parts. In impedance formulas that are customarily used the effect of the earth is taken care of by the inclusion of a single parameter—the earth resistivity. For a homogeneous earth this would be the actual resistivity of the material composing it. But the crust is nowhere homogeneous; hence, the resistivity used in such formulas is always of the nature of an average of the resistivities of the several parts of the crust—it is termed the effective earth resistivity.

The effective earth resistivities for fundamental power-system frequencies derived from mutual impedance measurements made in many parts of the world range, in general, from 2 to 10,000 meter-ohms. In a few instances values considerably higher than 10,000 meter-ohms have been observed. (The resistivity of a particular material, expressed in terms of the meter-ohm, is equal to the resistance in ohms between opposite faces of a one-meter cube of that material.)

With such a range of earth resistivities to contend with it is to be expected that estimates of ground-return mutual impedances for situations in areas where no earth resistivity data are available may be in error by large factors. In an effort to improve upon the accuracy of such estimates a study was begun several years ago of the relation between effective earth resistivity and geology. Consideration was at that time given only to areal geology, the geology of the strata of the crust lying immediately below the soil and other loose surface materials.

From this preliminary work, it appeared that the resistivities in areas of very old rocks were high and that, in a general way, decreasing resistivity corresponded to decreasing age of the rocks. There were, however, a number of outstanding discrepancies that could not be satisfactorily explained.

* Digest of a paper published in *Electrical Engineering*, November, 1935, and scheduled for presentation at the A. I. E. E. Winter Convention, New York, N. Y., January 28–31, 1936.

It then became apparent that consideration of the areal geology alone was not sufficient; instead, that the earth's structure to depths ranging from several hundred to several thousand feet must be taken into account. Data on this structure and the effective resistivities indicated by mutual impedance measurements at a large number of test sites have now been assembled. Analysis of these data shows a more or less consistent relation between the resistivity at any given point and the age and physical characteristics of the geological formations involved. This relation is such that, in general, decreasing effective resistivity corresponds roughly to decreasing age of the formations, as the earlier study seemed to indicate. However, there are certain exceptions to this rule.

The principal correlation data derived from the tests are summarized in the following tabulation. This is the result of grouping the tests in accordance with the geological periods to which the principal strata comprising the structure in each case belong and noting the ranges within which the resistivities determined by the greater part of the tests of each group lie.

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| Pre-Cambrian and combinations of Pre-Cambrian and Cambrian | 1000–10,000 m.-ohms |
| Cambrian and Ordovician combinations | 100–1000 m.-ohms |
| Ordovician to Devonian, inclusive, and combinations of these periods | 50–600 m.-ohms |
| Carboniferous, Triassic, and combinations of Carboniferous and earlier periods | 10–300 m.-ohms |
| Cretaceous, Tertiary, Quaternary and combinations of these periods | 2–30 m.-ohms |

It would be well to examine briefly the meaning of this summary and to consider its limitations. The geologists tell us that underlying the entire continent are extremely old rocks, extending downward to great depths. Little is known of the relative ages of different parts of this underlying structure. They are here grouped under the general term pre-Cambrian. In some areas pre-Cambrian rocks appear at or near the surface, the only covering being clays, soils, and other loose materials. In other areas they are overlain by rocks and sediments formed during later periods, the total thickness of which ranges up to many thousands of feet. The ages, arrangement, and characteristics of these upper strata are much better known. They are assigned by geologists to various periods in accordance with the ages during which they were formed. These periods appear in the tabulation in order from the oldest to the youngest.

In the case of tests made in areas where the pre-Cambrian rocks are overlain by younger strata it becomes necessary to consider just what portion of the structure probably influenced the test results. For instance, at the test sites included in the second group of the summary the upper part of the structure consists of Ordovician rocks. These are underlain by Cambrian strata which, in turn, lie on the pre-Cambrian base. The question arises whether the results were influenced by the Ordovician strata alone, by both the Ordovician and Cambrian, or by the Ordovician, Cambrian, and pre-Cambrian. Calculations have been made which indicate that probably only the Ordovician and Cambrian strata were involved to any important extent. The tests in the other groups have been treated in a similar manner.

In the cases considered above the measurements were apparently influenced largely by strata of a single period or of two or more periods of about the same age. The problem is not always as simple as this. For instance, in some areas combinations of very old and very young strata occur. Areas in which the oldest rocks, the pre-Cambrian, lie directly under comparatively thin sediments of the latest periods—the Quaternary, Tertiary, and Cretaceous—are not uncommon. The effective resistivities shown by the tests in such areas range between very wide limits and the tabulation should not be taken as indicative of the values which may prevail under such conditions.

The effects of soils, glacial drift, alluvial deposits along the courses of streams, and other surface materials may also in some instances be such as to result in effective resistivities differing widely from those that would be indicated by the tabulation. The effect of local alluvial deposits, where they overlie the older rock strata, is to lower very materially the effective resistivity that would be expected were the deposits not present.

Another limitation which must be considered is concerned with the presence of rocks formed by volcanic action. Apparently such rocks usually have a high resistivity and where they occur in a comparatively young structure, the effective resistivity may be much higher than the tabulation would indicate.

The test results indicate also that the effective resistivities of structures of given periods within certain large geographical regions are markedly different from those of structures of the same periods in other large regions. Within any one of such regions, excluding areas where igneous and highly metamorphosed sedimentary rocks are involved, the effective resistivities of structures of the same period are encompassed within a comparatively narrow band.

To facilitate the use of the correlation data, the different areas within which tests have been made have been divided into groups in accordance with the geological periods of the uppermost strata within these areas and maps have been prepared which show the boundaries of these areas and the results of the tests within them. Two such maps are shown in Figs. 1 and 2. These maps show the geological periods of the upper strata as they would appear were the overlying mantle of soil, glacial drift, local alluvial deposits and such removed. Any one

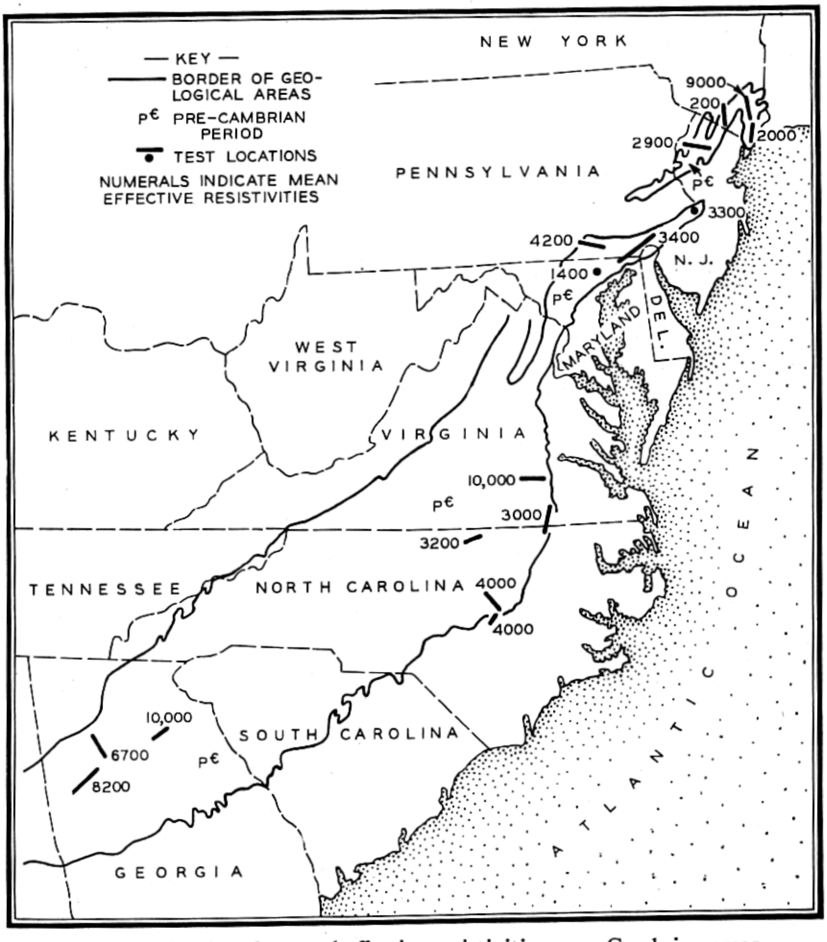


Fig. 1—Areal geology and effective resistivities—pre-Cambrian areas.

"test," as the designation is employed here, may include measurements of ground-return mutual impedances for a number of different conductors or sections of line and the test results for these different conductors or sections may indicate quite a wide range of resistivities—often 2 or 3 to 1 and occasionally 10 or more to 1, depending upon the degree of complexity of the earth's structure at the test site. The maps show, for each test, roughly the average of the resistivities indicated by the different measurements. They also indicate for each test the relative extent of the lines involved in the test.

Within the heavy boundary lines of Fig. 1 the rocks are largely pre-Cambrian. It will be noted that most of the tests in these areas indicated very high earth resistivities—from 1400 to 10,000 meter-

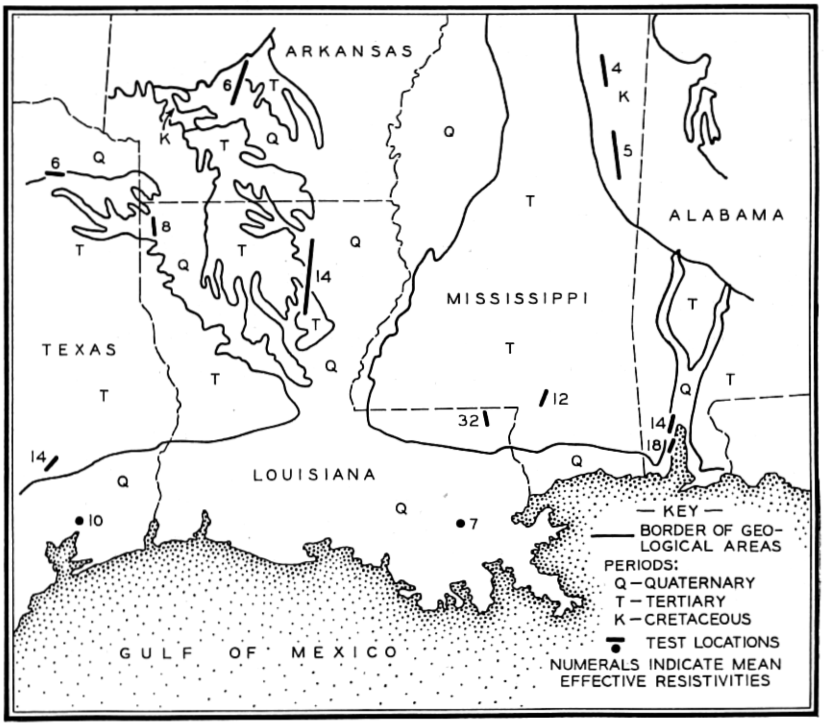


Fig. 2—Areal geology and effective resistivities—Gulf Coastal Plain areas.

ohms. The single exception, one test in New York which showed a value of 200 meter-ohms, is illustrative of the effect of alluvial deposits. The lines involved in this test were located in a narrow valley, the floor of which was partly covered with alluvium. By contrast, the structures of the areas shown in Fig. 2 are of the three latest periods, the Quaternary, Tertiary and Cretaceous, and the effective resistivities are very low—from 4 to 32 meter-ohms.