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CONTENTS

GEOLOGY AND STRUCTURE OF THE PENDLETON– LA FRANCE AREA, NORTHWESTERN SOUTH CAROLINA

By

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ABSTRACT

Major rock types in the Pendleton – La France area are metasedimentary gneisses and schists and granite gneiss which has injected and partly replaced the country rock. Foliation strike and dip and outcrop pattern of granite and hornblende gneiss indicate a large synclinal structure, termed the Pendleton Syncline, striking and plunging northeast. It appears to exceed 18 miles in length. The structure is complicated by parallel second order anticline-syncline developments and superimposed cross-folds striking northwest.

INTRODUCTION

This report presents the results of a brief geologic investigation in the vicinity of Pendleton and La France, Anderson County, South Carolina. During the course of geologic mapping in the Clemson Quadrangle (Brown and Cazeau, in preparation) an important synclinal structure was partially revealed in the southeast portion of the quadrangle, near the town of Pendleton. This appeared to be the same structure noticeable on a regional geologic map prepared recently by Overstreet and Bell (1961). It supposedly extends to the southwest through the La France Quadrangle. The chief purpose of this study was to delineate more clearly this major structure, which is referred to here as the "Pendleton Syncline" (Henry S. Johnson, Jr., personal communication).

GEOLOGY

Figure 1 shows the generalized lithologic distribution in the area. Two broad categories of rock types are present: (1) gneisses and schists of presumed metasedimentary origin, and (2) younger granitic rocks that have injected and partially replaced the surrounding country rock. These in turn have been metamorphosed to a gneissoid texture in many cases. General descriptions of specific rock types corresponding to those indicated in Figure 1 are given below.

Biotite gneiss: Biotite gneiss is dominant in the immediate vicinity of Pendleton. It is medium to dark gray on fresh surfaces but weathers to a friable, sandy, reddish-brown and/or greenish gray, with foliation

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usually well defined by segregated bands of biotite alternating with quartz and feldspar. In many outcrops the injected nature of the biotite gneiss is apparent, with thin veins and veinlets of quartz and/or granite occurring in the gneiss, both across and with the foliation. The biotite gneiss is typically interlayered with subordinate amounts of muscovite and biotite schist and hornblende gneiss.

Muscovite-sillimanite schist: This lithology is dominant to the southeast of Pendleton. The foliation is produced by aligned crystals of sillimanite and scattered to abundant flakes of muscovite. The foliation is often undulatory. The schist weathers easily and is commonly a light red color in outcrop. Associated with the schist in minor amounts are layers of quartzite up to three feet thick, light to dark gray hornblende gneiss, and hornblende-biotite granite gneiss.

Hornblende gneiss: This zone is most conspicuous northwest of Pendleton and was useful as a key horizon in tracing the general structure of the area. It is dense and medium to dark gray on fresh surfaces, with sharply banded hornblende and quartz-feldspar imparting a distinct layering to the rock. It weathers to a hard, clayey yellow-brown or red-brown residuum, often preserving the original texture. Like other rock bodies in the region, it is not a pure lithology. Intimately associated with it are lesser amounts of mica schist and biotite gneiss. It has been injected and partly replaced by granite in many places.

Granite gneiss: This lithology, although termed "gneiss" in this report, is often non-foliated. It extends in an elongate body to the southwest of Pendleton. It is probably the youngest lithology in the area, having intruded and replaced much of the older country rock. Gradational zones of replacement are observable in all rock types, but particularly so in the hornblende gneiss.

The granite gneiss is white or light gray on freshly broken surfaces and is usually coarse grained. The foliation, when present, is crudely developed. The rock consists of quartz and sodic and potash feldspar which is frequently kaolinized. Mafic minerals are usually biotite or hornblende. The amount present varies considerably. The quantity of granite gneiss occurring at the surface increases to the northeast of Pendleton and occupies extensive areas in southern Pickens County.

STRUCTURE

The structure of the area was determined mainly on the basis of outcrop pattern and strike and dip of foliation. More than 100 measurements were obtained in Anderson, Pickens, and Oconee Counties. The plunge of a few minor flexures was also recorded. These data are shown in Figure 1.

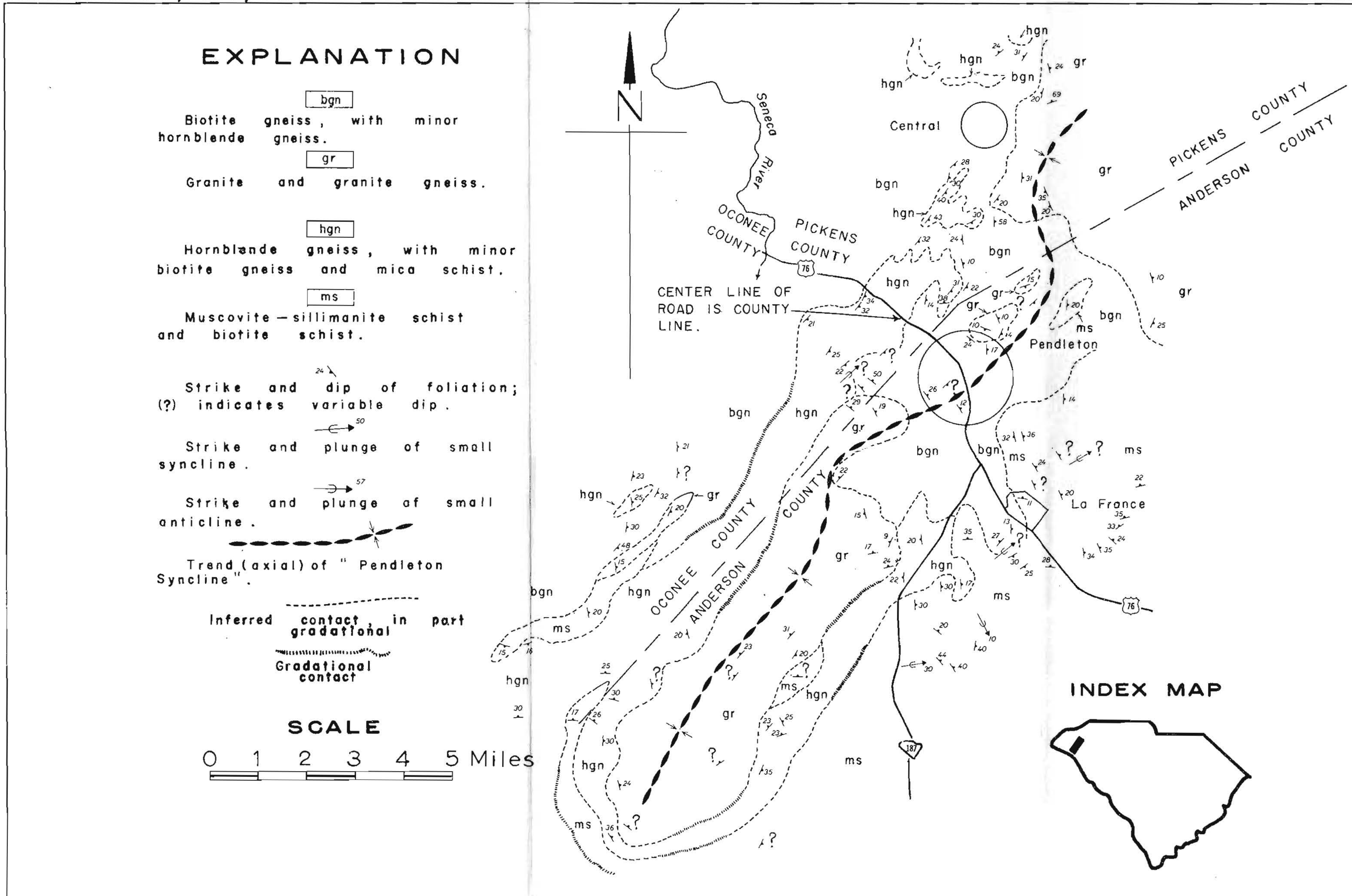

Fig. 1 Areal geology and structure of the Pendleton — La France area, northwestern South Carolina.

The Pendleton Syncline is reasonably well defined, particularly to the southwest of Pendleton. Regional dip is predominantly to the southeast. Numerous reversals to the northwest, particularly within the granite gneiss, permit definition of the major synclinal axis trending northeast and through the town of Pendleton. The amount of dip along the northwest flank of the Pendleton Syncline ranges between 15° and 48°, averaging 25°. On the southeast flank, the range is 15° to 35°, averaging about 23°. From these data the structure appears to be symmetrical. Small scale flexures within the Pendleton Syncline commonly plunge to the northeast. From this, and the position of the nose, it is evident that the structure is plunging northeast with moderate dip.

The outcrop pattern shows granite gneiss centrally located along the inferred axis of the Pendleton Syncline. This is flanked on either side by a belt of hornblende gneiss. On the nose of the syncline the hornblende gneiss wraps around to the south and then northeast. At this point it has been extensively replaced by granite gneiss. Along the southeast flank, the amount of muscovite-sillimanite schist increases both within the hornblende gneiss and as a distinct mappable unit further to the southeast and adjoining the hornblende gneiss. The overall length of the Pendleton Syncline appears to exceed 18 miles.

The Pendleton Syncline is not a simple isolated structure. It is accompanied by subordinate or second order anticline-syncline pairs which are evident in Oconee County northwest of the Pendleton Syncline axis. It is probably that detailed mapping would reveal an S-shaped pattern to tracable rock units such as the mica schist present in Oconee County (Figure 1). Cross-folds striking northwest across the Pendleton Syncline complicate the structural picture. A major cross-fold, as indicated by foliation strike and dip, appears to intersect the axis of the Pendleton Syncline at the town of Pendleton. Similar cross-folds, believed to be superimposed on the major northeast-trending folds, have been previously described in this region (Grant, 1958; Cazeau, 1961).

SUMMARY AND CONCLUSIONS

Foliation measurements and outcrop distribution in metamorphic and granitic rocks show that a major synclinal feature, termed the Pendleton Syncline, is present in northwestern Anderson County, South Carolina. It strikes and plunges to the northeast and appears to exceed 18 miles in length. The structure is complicated by parallel second order anticline-syncline pairs and by superimposed cross-folding striking northwest.

The structure was probably formed as a result of regional metamorphism and folding which caused downwarping and mobilization of the country rock with injection and replacement by granite in the deeper part of the Pendleton Syncline. A later period of deformation produced cross-folds straddling the existent structure.

A relatively conspicuous synclinal cross-fold intersects the axis of the Pendleton Syncline at the town of Pendleton. Other, less obvious, cross-folds appear to crenulate the Pendleton Syncline, as indicated by northwest-striking foliation.

It is suggested that (1) foliation measurement can be a useful tool in determining local and regional structure in the Piedmont, (2) flexures should be suspected in areas of elongate granitic zones, and (3) cross-folds may be present which tend to mask larger structures.

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OCCURRENCE OF BISMUTH AT THE BREWER MINE, CHESTERFIELD COUNTY, SOUTH CAROLINA[1/]

By

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ABSTRACT

The occurrence of bismuth at the Brewer gold mine has been reported in many publications. Michael Tuomey was the only author who actually saw bismuth at the Brewer, although three chemical analyses were made of bismuth samples from this mine confirming identification of the mineral. Documentation of Tuomey's discovery as well as subsequent references to it in the literature are included.

INTRODUCTION

Many publications have reported the occurrence of bismuth at the Brewer gold mine 1 1/2 miles west of the town of Jefferson, Chesterfield County, South Carolina. In a recent study of the literature it was found that only Michael Tuomey, State Geologist from 1843 to 1848, had any firsthand knowledge of the occurrence and that the other references were to material that he collected. There has been some doubt as to the actual presence of bismuth because the earlier references were not readily available; the purpose of this note is to collect the data on the original discovery.

The Brewer lode was discovered in 1843 as a result of placer mining for gold that began as early as 1828. The mine operated fairly steadily until the 1850's but apparently was idle until the 1880's, when a placer operation using hydraulic methods began. The mine closed again in the middle 1890's and has been operated only sporadically since that time. Approximate total production has been $450,000 in gold (Pardee and Park, 1948, p. 106).

BREWER MINE

Pardee and Park (1948, p. 106-111) describe the deposit as being in schistose rocks derived from bedded tuffs of the volcanic series. Foliation of the schists strikes N. 70° E. to N. 80° W. and dips 65° to 70° N.; a mass of granite is exposed 1 to 1 1/2 miles to the northwest.

1/ Publication authorized by the Director, U. S. Geological Survey

The Brewer lode is an indefinitely bounded body 200 to 300 feet wide by 1,000 feet long; it has been worked to a depth of 140 feet. It is chiefly fine-grained brecciated quartz that replaced schistose tuff, in which the ore occurs in closely grouped lenticular shoots. Gold is also disseminated in the surrounding silicified and hydrothermally altered tuff. A large body of massive, very fine-grained topaz is associated with the gold deposit.

OCCURRENCE OF BISMUTH

All references to bismuth at the Brewer mine can be traced back to the original discovery by Michael Tuomey in 1844. Tuomey described his discovery in two separate publications, one in 1844 and one in 1848, which, although differing slightly in wording, seem to relate to a single incident.

In 1844 Tuomey (p. 26) said: "Bismuth --- While examining Brewer's mine, Mr. Craig the superintendent, gave me a piece of white metal, which on examination proved to be bismuth, which was collected in the process of amalgamation; so that it must have existed native at this mine, as the ore is not roasted. I was afterwards presented by one of the men, with some masses of a yellowish mineral, which had excited his attention by its great weight; these masses, which weighed 8 or 10 pounds turned out to be bismuth, ochre or oxide of bismuth, containing from 30 to 65 per ct. of metallic bismuth. The shape of the pieces showed that they did not occur isolated; but unfortunately, I was unable to ascertain the position of the ore in the mine, as the pit from which it was taken was closed, the rest being thrown in to fill it up."

His 1848 description (p. 97) is as follows: "I found here masses of bismuth ochre, of ten or twelve pounds weight, which presented strong indications of the existence of a greater quantity. But gold alone engrosses every one's attention, and I could induce no further search for this valuable ore. Bismuth also occurs native at this mine, and is taken up by the mercury during the process of amalgamation, so that it has sometimes happened that when the miner imagined he had in his amalgam a fine lump of gold, it has turned out to be, on driving off the mercury, nothing more than a piece of bismuth."

In his 1848 description, Tuomey implied that he personally found the masses of bismuth ochre, in contradiction to the statement in his original report of 1844 that the specimens were given to him.

In 1858 O. M. Lieber (p. 88) stated that a specimen of bismuth that he sent to Prof. Rammelsberg in Berlin for analysis came from the Brewer mine; he admitted, however, that he did not actually see any bismuth at the mine. The sample may have come from a mineral collection of the South Carolina Geological Survey, as Lieber held the position of State Geologist after Tuomey.

Lieber states (1858, p. 88), "Professor Rammelsberg, of Berlin, in his dictionary of chemical analyses (4th Supplem. p. 262), gives the results of an analysis of the carbonate of bismuth, which he terms bismuth spar, the specimen being from this mine, presented to him by me. These were:

Oxide of Bismuth	82.63
Perox. of Iron	2.55
Alumina	1.79
Lime	0.28
Magnesia	1.60
Carbonic acid	6.02
Silicic acid	2.97
Water	3.16"

Palache, Berman, and Frondel (1951, p. 260) quote an analysis of bismuth from Chesterfield County, South Carolina, presumably from the Brewer deposit. The analysis is attributed to Rammelsberg (Annals of Physics, 1849, v. 76, p. 564) and differs somewhat from the one quoted by Lieber:

Bi_2O_3	90.00
CO_2	6.56
H_2O	3.44
Rem.	
Total	100.00
G.	7.67

Genth (1857, p. 426) analyzed bismuth from the Brewer mine and obtained results quite similar to those of Rammelsberg. The material for this analysis was given to Genth by Dr. Asbury of Charlotte, North Carolina, Prof. Lewis R. Gibbes of Charleston, South Carolina, and O. M. Lieber of Columbia, South Carolina. All of the specimens were said to have come from the Brewer mine. Genth's specimen descriptions and analyses are included here for comparison with those of Rammelsberg:

"I have analyzed a pale variety (I) and a darker one (II), and made two analyses of each, one by treating the finely powdered mineral with dilute nitric acid (a), the other by digestion with strong chlorhydric acid (b), by which everything, except the silicic acid, is dissolved.

"The quantities of lime and magnesia were found to be very small and have not been determined.

"The following are the results:

	I.		II.	
	a.	b.	a.	b.
Insoluble in dil. NO_5 2/	25.42	———	28.16	———
containing water,	(1.59)	———	(2.62)	———
Teroxyd of bismuth,	64.72	64.24	62.15	61.45
Tellurous acid,	———	0.05	———	0.06
Sesquioxyd of iron,	0.91	6.64	1.30	11.20
Alumina,	0.74	1.18	0.68	2.09
Silicic acid,	0.48	17.78	———	13.99
Carbonic acid,	———	5.08	———	5.12
Water,	———	3.94	———	5.41
	———	———	———	———
		98.91		99.32

"Deducting the amount of water, which the residue insoluble in nitric acid contains, from the whole quantity given in the analyses (b) we obtain pretty correctly (though somewhat too high) the amount of water combined in the pure bismuthite 3/. We would have therefore:

	I. (b)				II. (b)			
Teroxyd of bismuth,	64.24	contains	6.65	oxygen,	61.45	contains	6.36	oxygen.
Carbonic acid,	5.05	"	3.67	"	5.12	"	3.72	"
Water,	2.35	"	2.09	"	2.79	"	2.48	"

The atomic ratio of	BiO_3	:	CO_2	:	HO is therefore:
in analysis I,	2.22	:	1.83	:	2.35
in analysis II,	2.12	:	1.86	:	2.48

The first analysis corresponds nearly with the formula:

$$9(BiO_3, CO_2) + 2(BiO_3, HO) + 10HO,$$

the second with:

$$6(BiO_3, CO_2) + BiO_3, HO + 7HO.$$

"These analyses, like the one made by Prof. Rammelsberg, prove, (and that is all, I think, which can be expected from the examination of so impure a mineral,) that the Bismuthite from Chesterfield District is a basic carbonate of bismuth with water." This analysis was quoted by Lieber (1858a, p. 123).

The following later authors, listed in chronological order, only refer to the earlier accounts: Harry Hammond (1883, p. 137), G. F. Becker

2/ This is probably HNO_3.
3/ Bismuthite is the German spelling of bismutite.

(1895, p. 28); L. C. Graton (1906, p. 91); Earle Sloan (1908, p. 76); and J. R. Cooper (1962).

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THE REFRACTION SEISMOGRAPH AS A GEOLOGIC TOOL IN THE COASTAL PLAIN OF SOUTH CAROLINA

By

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INTRODUCTION

A small portable refraction seismograph manufactured by Geophysical Specialties Company, Minneapolis, Minnesota, has been used successfully by the Division of Geology, S. C. State Development Board, to determine thickness and general lithologic character of surficial deposits in the Coastal Plain of South Carolina. Where the local succession of sediments is known, the instrument provides a quick, reasonably accurate method of determining variations in thickness, and to a certain extent in lithology, to depths of about 50'. The equipment is readily transportable by automobile and can be operated efficiently by a two man crew. Principle use of the seismograph by the Division of Geology to date has been in determining depths to the top of the Cooper Marl (Eocene-Oligocene) in the Ladson and North Charleston Quadrangles, Berkeley, Charleston, and Dorchester Counties, South Carolina. The Cooper is a soft marl which has a load bearing capacity appreciably greater than the unconsolidated sand, clay, and muck overlying it. For this reason it is the unit in which the foundations of most large structures of the Charleston area are footed.

ENGINEERING SEISMOGRAPH MODEL MD-1

Equipment used by the Division of Geology consists of a small refraction seismograph (9 x 16 x 7 inches) weighing 16 pounds, plus an 8 pound sledge hammer, a 25 pound steel plate, 300 feet of connecting wire, and one geophone. All apparatus can be easily placed in the trunk of a car, and so positioned to provide quick emplacement at selected locations. Seismic waves are created by hammer blows against the steel plate at various recorded distances from the geophone. Time, in milliseconds, between the moment the hammer first strikes the plate and the arrival of the first impulse at the geophone is measured by a transistorized binary counter and indicator.

OPERATING PROCEDURE

The operation of this type of seismograph is simple and easily learned.

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The location being selected from topographic sheets, the instrument is transported to the site, usually by car, and turned on. One of the operators, emplaces the geophone in the ground, the geophone cord being usually left permanently attached to the seismograph. The instrument is then grounded to a metal rod driven into the ground, the ground cord being left permanently attached to the instrument. The same operator then measures out 200 feet on the ground surface with a chain and returns to the machine to record readings. The second operator hooks up the instrument to the hammer cord, places the steel plate in a position five feet from the geophone, and commences hammering at selected positions away from the instrument.

In practice in Coastal Plain work, the operators have found that it is best to start with a five foot interval between stations adjacent to the geophone and to keep to this interval until the first marked break in seismic velocity is noted. From this point on out, a ten-foot interval is maintained.

For each location the instrument man must adjust the seismograph for the maximum sensitivity possible without allowing background vibrations to activate the machine at the expense of the hammer impulse. That is, once the counting circuit has commenced counting, background vibrations must not activate the geophone to cause the counting to stop prior to the arrival of the hammer impulse. By starting close to the recording instrument and moving away, eratic readings can be immediately recognized and disgarded and sensitivity adjusted until a correct reading comes through.

In areas covered to date, it is possible to operate the seismograph with an impulse-geophone separation of up to about 200 feet, although on occasion a good signal has been obtained at 300 feet. Once the desired depth or stratum has been investigated, the apparatus is replaced and taken to the next location.

INTERPRETATION

The seismic velocity of a sediment is as much a physical characteristic as any of its other properties. Since each station examined consists of a number of superimposed sediments, it follows that a graph of varying velocity, each influenced by a particular lithic type, should be developed. Table one lists several of the velocities indicated by our experience to date.

Table 1

Sediment type	Velocity in feet per second
Dry sand and soil	1000-1300
Wet sand below water table	3500-4200
Wet sand and clay	3700-4900
Marl	5100-6500

Identification of sediment type may be possible through velocity examination alone. In practice however it has been found advantageous to have a limited number of power auger holes drilled regionally in order to provide a check on seismic data. By this means it is possible to interpret major facies changes in surficial strata.

Interpretation of depths to a given formation can be worked out with facility using graphic aids supplied with the instrument. A velocity computing graph overlay is available that allows the operator to calculate velocity by comparing the inclination of the time vs distance lines recorded at each station with those on the graph. The velocity of the various lines being known, and the distance away from the geophone where the velocities change being observed from the graph made at the station, the depth to this velocity change can easily be calculated using the formula:

$$D_1 = \frac{x_c 1}{2} \cdot \sqrt{\frac{V_2 - V_1}{V_2 + V_1}}$$

where $x_c 1$ is the distance (surface) to the first change of velocities, V_1 is the first velocity, and V_2 the second velocity. If three distinct velocities are apparent (such as dry soil, water table, and marl) the following formula may be used:

$$D_2 = D_1 + \frac{x_c 2}{2} \sqrt{\frac{V_3 - V_2}{V_3 + V_2}} + \frac{D_1}{V_1 \sqrt{V_3^2 - V_2^2}} \cdot \left[V \cdot \sqrt{V_2^2 - V^2} - V_2 \cdot \sqrt{V_3^2 - V_1^2} \right]$$

Or for speed at the expense of minor inaccuracy the latter term may be replaced by $0.8 \times D_1$.

Difficulties in interpretation using the seismograph fall into three categories.

Insufficient penetration of signal is a problem which occasionally arises from several causes. Frequently, background vibrations are the main factor, particularly when working in heavily populated areas or active industrial regions. The gain control may have to be set down so far that response from distances of over 100 feet is impossible to pick up without prior arrival of stray vibrations. Often this can be negated by performing work at times of decreased activity in the region.

High winds have occasionally hindered deeper penetrations, but this problem is easily solved by burying the geophone under several inches of soil. Using this means it has been found possible to have as much as a 300 foot separation between hammer and geophone and still get reliable response.

Inability to supply a strong signal into the ground also has proved a factor, particularly in swampy areas or areas where the water table lies close to the surface. Sometimes this has been surmounted by simple shifting of the striking plate or by using a somewhat larger plate. If neither procedure helps, the location is abandoned.

Similar lithologies possess similar seismic velocities, hence unless power auger holes are drilled occasionally for control the operator's stratigraphic interpretations based on seismograph data may be incorrect. In the southern portion of the North Charleston quadrangle, a marl overlies the Cooper Marl (Oligocene) and is eroded off toward the northwest. Contours drawn on the surface of the Cooper proceeding from the northwest toward the southeast at first showed an anomalous elevation. Only as a result of drilling did the true situation come to light.

Since the instrument is a refraction seismograph, high velocity layers lying at depth will mask lower velocity layers lying below them.

Anomalous depths are frequently found where moderate angle inclinations are indicated on the surface of the formation being investigated. In order more correctly to interpret the depth, it is best to take two sets of readings about the location, one at each end of the chain, and then to average the values. Other interpretive techniques are outlined in a manual supplied with the instrument.

SUMMARY

The advantages of using the small refraction seismograph in conjunction with surficial sediment studies are readily apparent. To date, use has been made in South Carolina in two phases of Coastal Plain investigation.

Contours drawn on the surface of the Cooper Marl in the Ladson and North Charleston Quadrangles, Charleston, Berkeley, and Dorchester Counties, South Carolina, have been greatly facilitated by this technique in conjunction with power auger holes. The information so obtained should prove of assistance to engineers planning surface or underground construction in the area.

Thickness of Pleistocene sand bar deposits in Orangeburg, Dorchester and Berkeley Counties as well has been accurately calculated using the instrument. In addition to these projects, use in any phase of construction where shallow subsurface information is needed should be to advantage, since the obtaining of data is rapid (8-15 stations per day) and relatively easy.