From Co. for Scientific + Industrial Research.
Melbourne.

E. C. Andrews

State Geologist

# THE GEOPHYSICAL INVESTIGATION OF MINERAL DEPOSITS

# THE DISCOVERY AND INVESTIGATION OF MINERAL DEPOSITS BY GEOPHYSICAL METHODS

EXPLORATION
INVESTIGATION
EXPERT ADVICE

ORE DEPOSITS
PETROLEUM DEPOSITS
ANTICLINES
SALT DOMES
NON-METALLIFE-
ROUS DEPOSITS
COAL
WATER SUPPLY
THERMAL SPRINGS
FOUNDATIONS & DAMS
DEEP BORINGS

„ELBOF" GEOPHYSICAL CO. LTD.
(PIEPMEYER & CO. LTD.)
KASSEL-WILHELMSHOEHE, Rasen-Allee 13
GERMANY

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H. B. BATEMAN
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**BATAVIA**
Geophysikalische Opsporingen
System „ELBOF“
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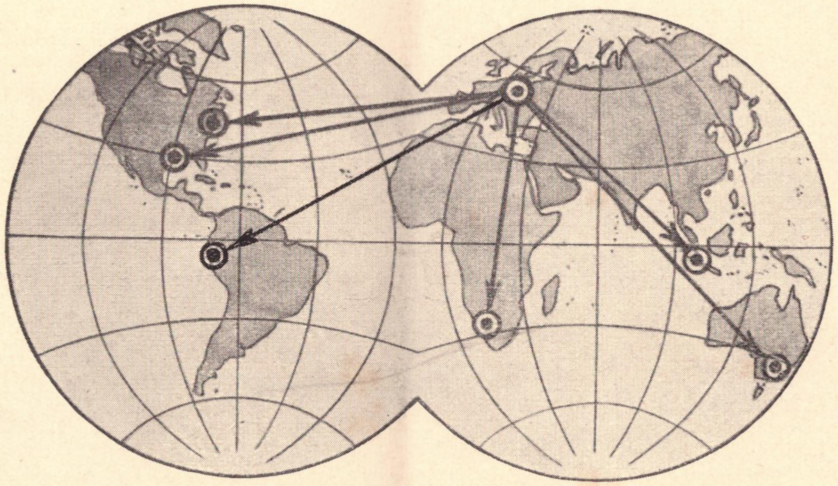

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# I. INTRODUCTION.

The discovery of ore deposits of economic value was solely dependent, until recently, upon the observational methods of the geologist and the prospector with their accompaniment of shaft sinking, trenching & drilling.

During the last decade, further investigational methods have been added; which when suitably applied, save considerable outlay in surface and underground prospecting.

## The application of geophysical methods

consists in examining the different physical properties of the sub-soil with the aid of highly sensitive scientific instruments, giving results which, in the first instance, are of a purely physical nature.

The rocks and minerals of the sub-soil are differentiated, however, by widely different physical properties. A comprehensive study of these properties combined with experimental work on known and developed deposits extending over a number of years have now made it possible to utilise the data obtained to elucidate the tectonic, geological, and mineralogical conditions existing in the area under investigation.

It should be understood that geophysical investigation does not claim to supersede either the pioneer efforts of the Prospector or the mine development work of the Engineer; the methods about to be described cannot take the place of deep boring or sinking for the discovery of mineral or oil deposits, but they can, and they are only intended to, point to the best localities for such operations in order to avoid futile work.

A study of the geological features of the area under investigation is an essential part of the work — the closest cooperation between the geophysicist, the geologist, and the mining engineer is necessary both in the work of locating new deposits and in tracing the continuation or ascertaining the limits of known ore-bodies.

Recent progress has so far improved the sensitivity of the instruments that data can now be obtained at considerable depths in the earth's crust and at great distances in opened-up mines.

Today the following are investigated: -

The differences in Electrical conductivity<br>
Specific gravity<br>
Magnetic properties<br>
Elasticity<br>
Temperature<br>
Radio-activity

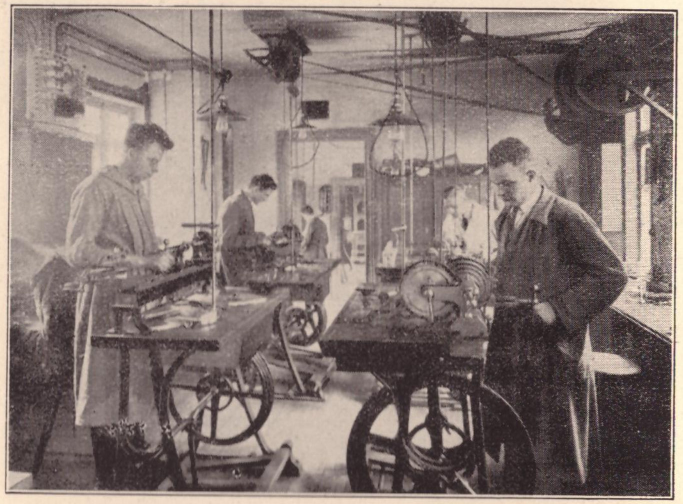


These methods are more fully explained in subsequent pages and a number of practical examples are described.

Owing to the infinite variety in the occurrence of mineral deposits of both ores and non-metallic minerals it is not possible to limit the investigation of any group of minerals to any particular method, usually a combination of methods is employed in any given exploration.

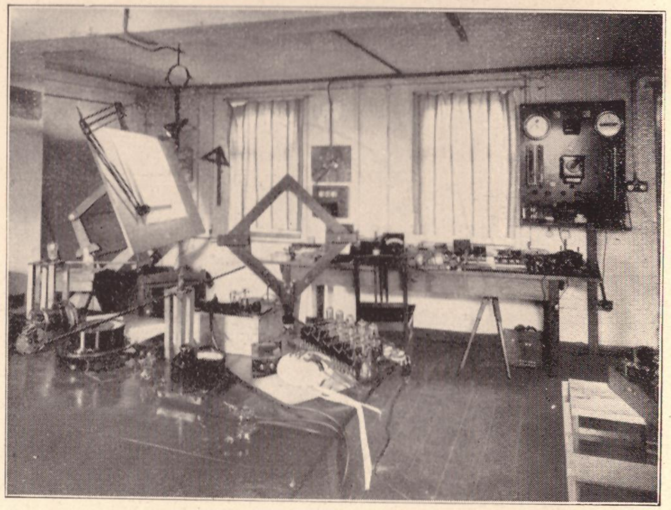
FIELD WORK IN CALIFORNIA.

PART OF WORKSHOPS



also

THE TESTING LABORATORY



# II. GEO-ELECTRICAL EXPLORATION.

When an alternating current field is artificially produced in the sub-soil, differences in electrical conductivity in the rocks cause disturbance in the regularity of this field, the electrical method of investigation is based on a determination of these variations from the normal.

These differences make it possible to locate good conductors such as ore-veins, anthracite, alkaline waters, graphite etc. as well as minerals at the other end of the scale, for example, the bad conductors, petroleum, asphalt, sulphur, salt, mica, asbestos, magnesite, barytes etc. and in addition fault planes, lines of contact, geological boundaries etc. can also be determined.

A table of the electrical conductivity of the more important rocks and minerals is appended.

### ROCKS

| | | | |
|---|---|---|---|
| Porphyry | Badenweiler | $4 \times 10^4$ | ohm/ccm |
| Diabase | Kellog, Idaho | $2 \times 10^4$ | „ „ |
| Mica Schist | Philadelphia | $1.5 \times 10^5$ | „ „ |
| Clay slate | (Carboniferous) Waldenburg | $7.7 \times 10^4$ | „ „ |
| Dolomite | Persburg, Sweden | 3 to $5 \times 10^5$ | ohm/ccm |
| Limestone | (Jura) Gonzen Switzerland | $2 \times 10^5$ | „ „ |

### ORES

(Specific Resistance over 250 K.O./ccm N. Poor conductors)
( „ „ under 250 „ „ C. Good conductors)

**SILVER**

| | | | | |
|---|---|---|---|---|
| C. | Argentite | Freiburg | 4000 | ohms/ccm |
| C. | Pyrargyrite & Proustite | | | |
| N. | Polybasite & Freibergite | | | |

**MERCURY**

| | | | | |
|---|---|---|---|---|
| N. | Cinnabar | | 2000 | K.O./ccm |

**LEAD & ZINC**

| | | | | |
|---|---|---|---|---|
| C. | Galena | U.S.A. | 0.8 | ohm/ccm |
| N. | Zinc blends | Joplin U.S.A. | $5 \times 10^4$ | KO./ccm |
| N. | Cerussite & Pyromorphite | | | |

**COPPER**

| | | | | |
|---|---|---|---|---|
| C. | Copper Pyrytes | Jedo, Japan | 0.2 | ohm/ccm |
| C. | Copper glance | U. S. A. (Jerome) | 3.1 | „ „ |
| C. | Tetrahedrite & Enargite | | | |
| N. | Malachite & Azurite | | | |

**IRON & MANGANESE**

| | | | | |
|---|---|---|---|---|
| C. | Magnetic Iron | Dannemora | 1 | „ „ |
| C. | Hematite | Canada | 5 | K.O./ccm |
| N. | Limonite | | ca. $10^5$ | „ „ |
| C. | Pyrolusite, Psilomelane, Wad | | | |

**NICKEL & COBALT**

| | | | | |
|---|---|---|---|---|
| C. | Kupfernickel (or Niccolite) | | | |
| C. | Cobaltite (or Cobalt glance) | | | |

**TIN & BISMUTH**

| | | | | |
|---|---|---|---|---|
| C. | Cassiterite | | | |
| C. | Bismuthine | | | |
| N. | Stannine | | | |

**ARSENIC & ANTIMONY**

| | | | | |
|---|---|---|---|---|
| C. | Arsenical Pyrites (or Mispickel) | | | |
| N. | Antimonite | Mossiac France | 500 | K.O./ccm |
| N. | Realgar | | | |

**CHROMIUM & WOLFRAM**

| | | | | |
|---|---|---|---|---|
| C. | Chromite | Fatmomahke, Sweden | 120 | K.O./ccm |
| C. | Wolframite | Zinnwald/Erzgebirge | 10 | „ „ |

**MOLYBDENUM & VANADIUM**

| | | | | |
|---|---|---|---|---|
| C. | Molybdenite | Okanogan USA | 5.6 | ohm/ccm |
| N. | Wulfenite | | | |

**URANIUM & ALUMINIUM**

| | | | | |
|---|---|---|---|---|
| N. | Pitchblende | | | |
| N. | Bauxite | | | |

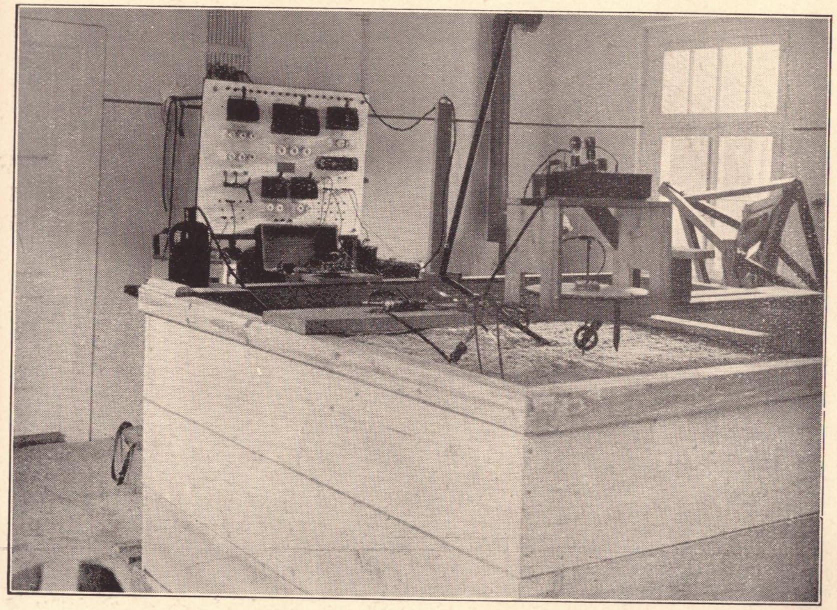
**SULPHUR**

| | | | | |
|---|---|---|---|---|
| N. | Native Sulphur | | $4 \times 10^{12}$ | K.O./ccm |
| C. | Pyrites | Rio, Elba | 0.1 | ohm/ccm |

### NON-METALLIFEROUS MINERALS

| | | | | |
|---|---|---|---|---|
| C. | Anthracite | | | |
| N. | Brown Coal & Lignite | | | |
| N. | Bituminous Coal (20 % gas) | Waldenburg | 1 to $10 \times 10^4$ | ohm/ccm |
| N. | Bituminous Coal (40 % gas) | Waldenburg | $10^7$ to $10^8$ | „ „ |
| N. | Oil-bearing Limestone | Heide-Holstein | $5 \times 10^6$ | ohm/ccm |
| N. | Oil-bearing Sands | Wietze | $3 \times 10^7$ | „ „ |
| N. | Rock Salt | Wesel | $3 \times 10^3$ to $3 \times 10^5$ | „ „ |

Note. Prior to an investigation it is essential to examine and test for their electrical conductivity, samples of the rocks and minerals as found in the area to be surveyed.



IN THE LABORATORY
Experimental Sandbox

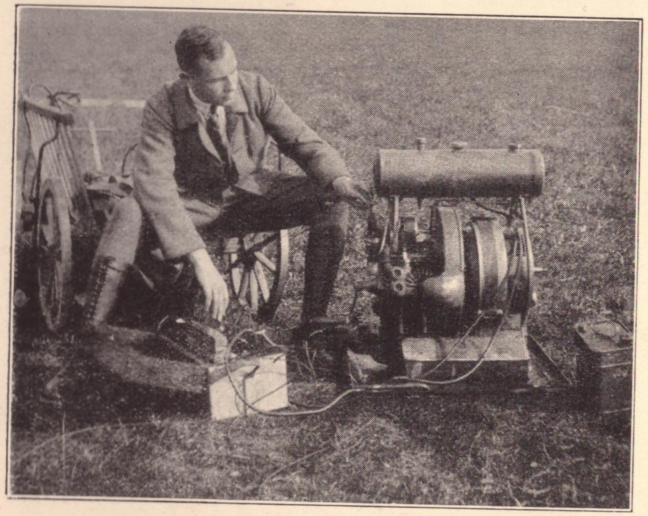
The transmitting gear (see illustration) used for producing the alternating current field is varied according to the nature of the work to be undertaken.

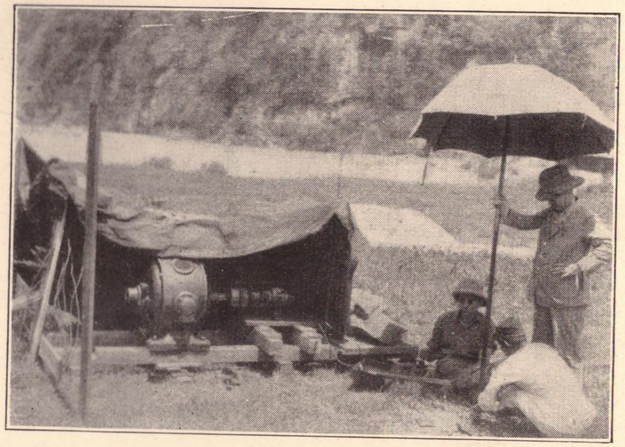
The type of generator selected depends upon the extent of the area to be investigated, the depth to be attained, and other factors.

The current passes to the ground through electrodes, the form and location of which depend upon the existing geological conditions and the objects of the investigation.

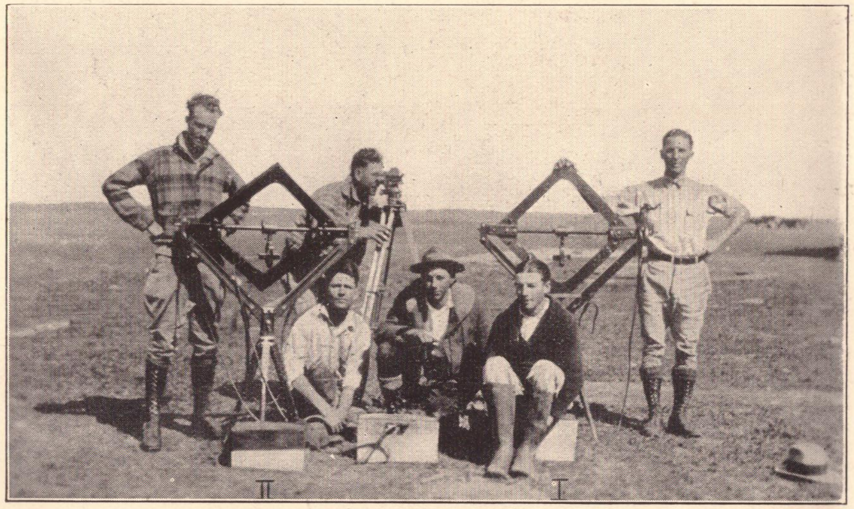








## RECEIVING APPARATUS.




cut

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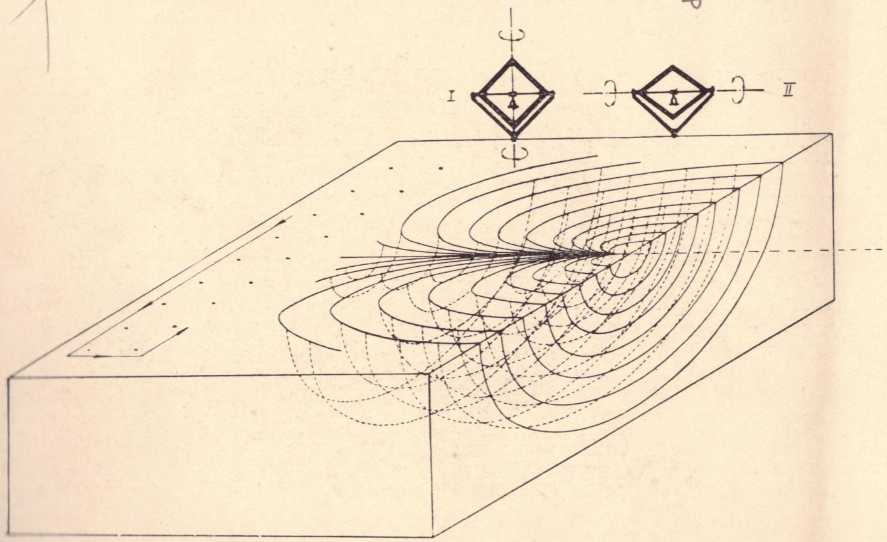


In order to receive the vector directions I in the horizontal plane and II in the vertical plane and also to record the intensity of the alternating—current magnetic field, a frame-aerial is employed.

This frame-aerial is mounted on a tripod (see illustration) and includes a compass and clinometer of suitable design.

Connected with the aerial are an amplifier, telephone, and other instruments.

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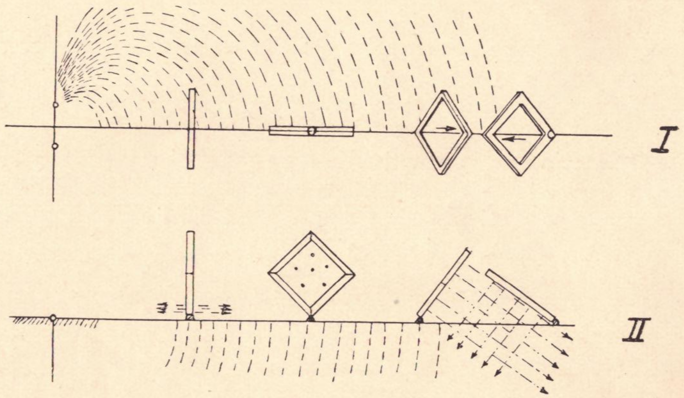
## LINES OF MAGNETIC FORCE SHOWN.




I. in plan
II. in Section



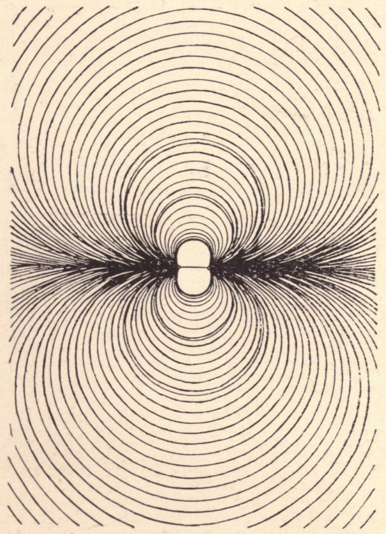
83

In practice, two three or more sets of observations are made (the locality and orientation of the electrodes being varied), the directions of the lines of electro-magnetic force are plotted separately for each group of observations and are compared with the normal diagram for a homogeneous field (see illustration of "normal" field).

From the divergences observed, combined with a geological study of the area, the nature extent and depth of the disturbing elements can be determined.

The location of ore deposits, faults etc. near the surface can also be confirmed by the "sounding method" originated by Schlumberger in which the deviation of the equi-potential lines is studied, this is particularly useful for horizontal or nearly horizontal bedded deposits.

In precipitous country the work is more difficult and consequently may take a little longer to complete, but experience has shown that the accuracy of the results is not impaired.

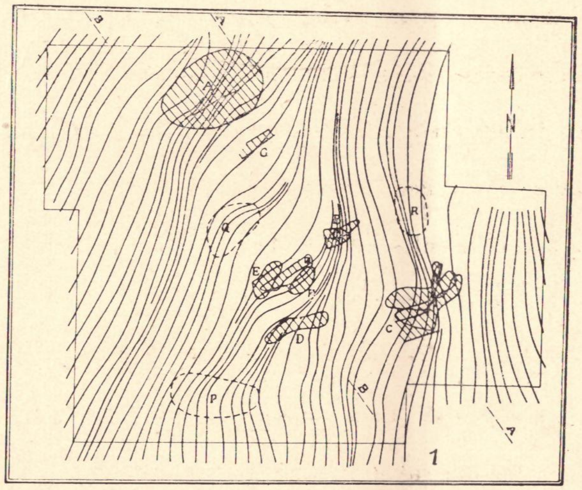


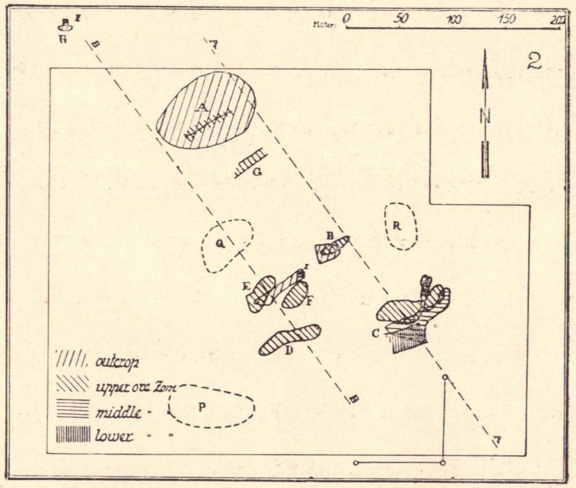
The strike, dip and depth of a deposit are recognised by their characteristic effect on the field measurements obtained by a special variation in the transmitting apparatus designed for this purpose.

Particular apparatus is employed for work underground, the basic principle, however, remaining the same.

A clearer understanding will be gained from a study of the examples now given: —

# COPPER PYRITES DEPOSITS OF THE ROUYN DISTRICT, QUEBEC, CANADA.




In this field it is stated that, as far as geological investigation has as yet been carried, the ore is formed by replacement of basic lavas resulting in the formation of sheet like masses or flat pipes of very low dip.

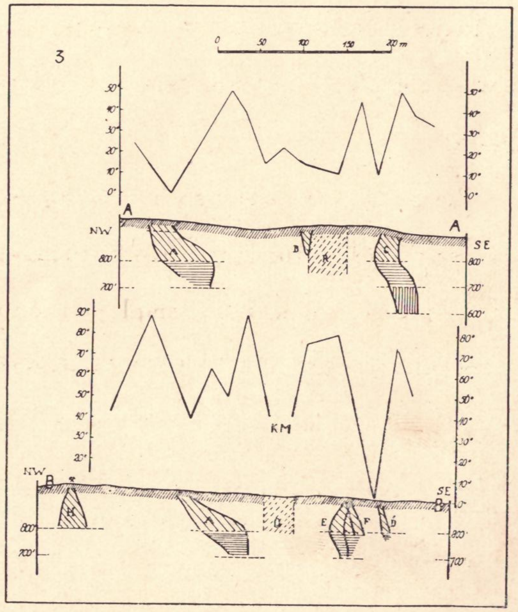
In the area investigated the rocks are covered by a considerable thickness of swamp, soil and decayed vegetable matter some 20—75 ft. in depth, and part of the survey was carried over a lake with 2—10 ft. of water.

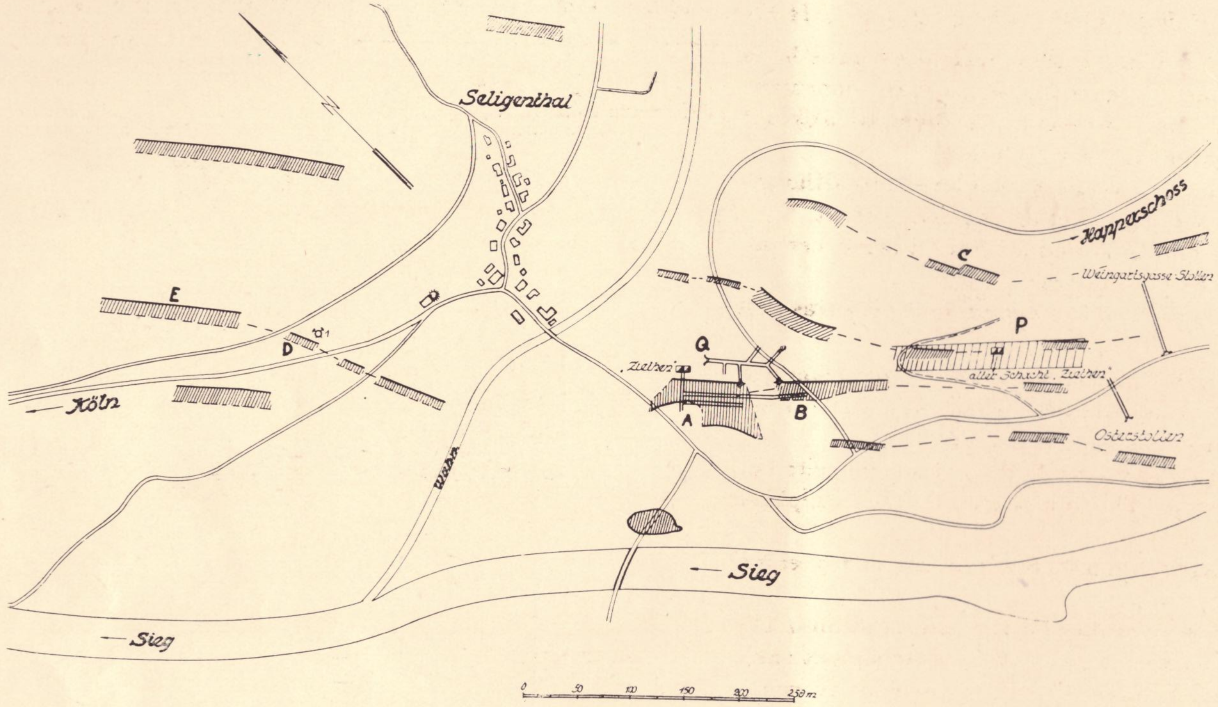
The nearest outcrop of ore is on an adjoining property, distant nearly half a mile.

Reference the attached diagrams: -

In No. 1. The convergence of the lines representing the horizontal direction components indicate the position of the ore bodies.

No. 2. Represents in plan the two lines A—A and B—B along which the vertical direction component has been plotted to give the sections shown in diagram No. 3: the lowest points in the curve show the location of the ore masses. Subsequent development proved the existence of Q and R which were previously unknown. P has not yet been exploited.






ZIETHEN MINING C$^{\underline{o}}$ HENNEF-SIEG

Ore Bodies known before the investigation

Ore Bodies located by the survey

ABCD

Ore Bodies located by the survey and confirmed by subsequent development

Position of outcrop

# LEAD AND ZINC ORES OF THE ZIETHEN MINING CO. HENNEF-SIEG.

In the devonian schists of the Rhine valley, lead ores have been worked for several centuries. Some 40 years ago work was concentrated on the lode near the old shaft. Later, as reserves declined, an attempt was made to trace the western extension of this lode.

The adit (just north of pt A) was at too high a level and although ore was found, it was in the oxidised zone and of no great extent.

The geo-electrical investigation, then undertaken, located certain lodes and numerous ore bodies (see plan p. 12).

It also revealed the fact that part of the known lode (P.) was still undeveloped.

All the other ore bodies marked on the plan were previously unknown.

After the investigation, the "New Ziethen" shaft was sunk (near the adit Q) to 40 metres and continued to 100 metres.

A cross cut at 40 m intersected the lode A, the agreement with the predicted position being within 0,5 m. The lode was of Copper Sulphide ores and Galena.

At 100 m, a cross cut similarly intersected the lode with equal accuracy at its predicted dip.

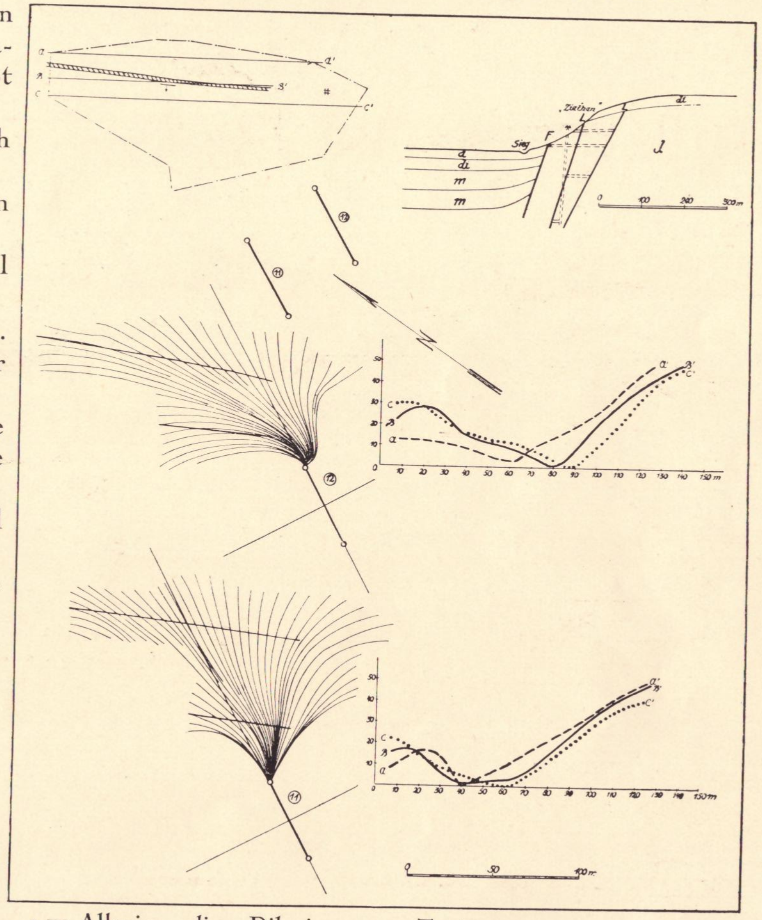
The 40 m and 100 m levels then confirmed the interruption in the ore body which had appeared in the interpretation of the field survey data.

The discoveries at C, D and E have also been verified by minor development work.

Explanatory diagrams are attached.

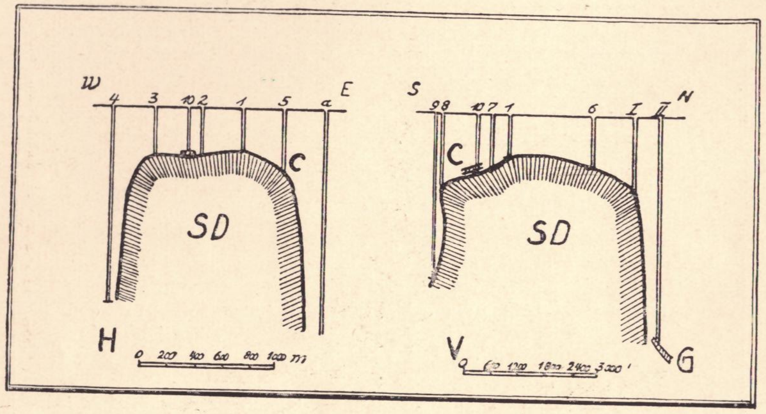
In (1) the lode is shown in plan; though near the surface, it does not outcrop, the dip is steep and to the S. Electrode positions shown at 11 and 12.

Figs: (3) and (5) show the interpretation of the horizontal component current lines for the two positions of the electrodes — they reveal two good conductors in the investigated field, the first near the electrodes, and the second further north (the lode E).



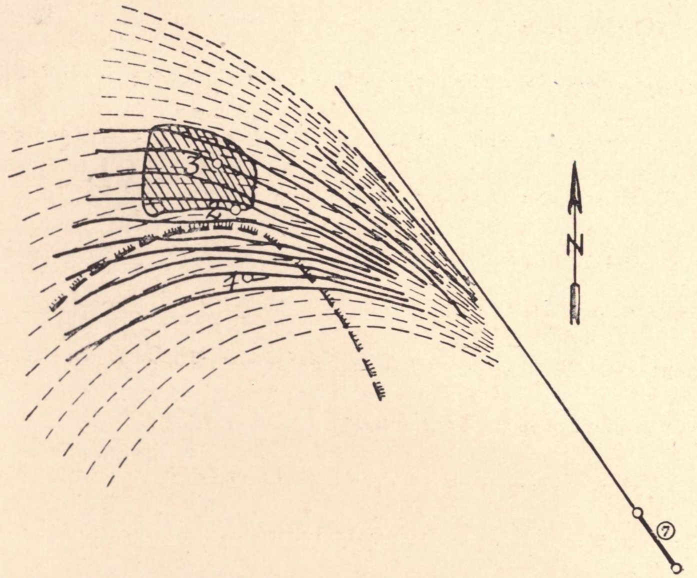
a = Alluvium, di = Diluvium, m = Tertiary,
d = Devonian Schists (folded Rhine schists), F = Fault, L = Lodes

The vertical components are plotted as a curve (fig. 4 for electrode 12, and fig. 6 for electrode 11) each curve a, b and c corresponds to a line of observation, (see a, b, c in Plan Fig. 1), from these curves the position of the lode E at different depths can be determined, and consequently the dip can be ascertained. This information showed that the lode E was an extension of the known lodes A and B, which much facilitated plans for development work. A section showing the relative position of the two lodes, shaft, cross cuts, etc. is given in diagram (2).




C = Cap rock
SD = Salt dome
G = Gas & oil
H = Horizontal scale
V = Vertical scale

## OIL AND SALT DOME (U.S.A.)




DIAGRAM, EARTH No. 7 (Large Scale).

Normal Current Lines
Distorted „ „
Wells (1, 2, 3)
Edge of Salt dome at depth of about, 3000 ft

Position of electrodes (7)

Prior to the electrical survey eleven wells had been put down without obtaining oil, but the boundaries of the salt dome were partly known.

The survey comprised seven double positions, i. e. 14 separate and independent records: for the sake of clearness only Nos. 2, 5, 7, 12 and 13 are shown on the accompanying diagram. (Page 15).

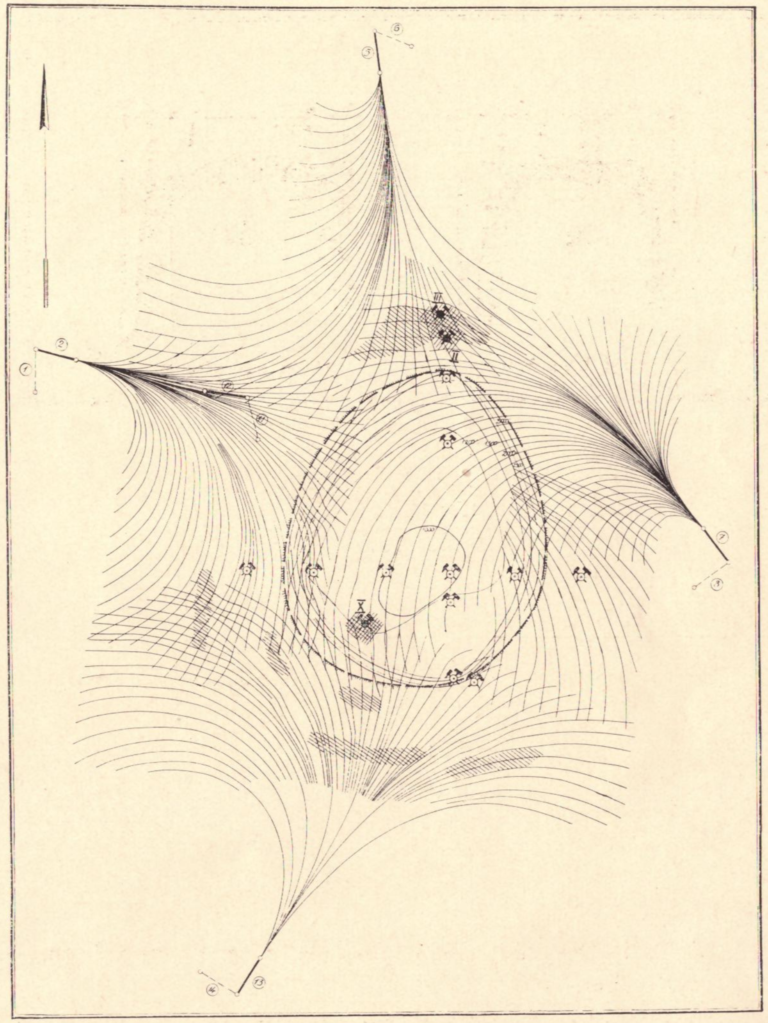
The interpretation of the results showed the most marked divergence from the normal in the west (Earth No. 2), in the north (No. 7) and to the south (No. 13), at depths varying from 3000—5000 ft.

Over the dome itself no deviations occurred except at one point.

After the survey the points for some 10 Wells were marked out in the north, west and south, of these up to date 2 in the northern sector have been drilled, with success, well No. II found a strong occurrence of gas with oil-showing at approximately 5200 ft. and No. III found oil-showing at 5300 ft.

Also the shallow well over the dome was put down at the point indicated (see section) No. 10 and oil sand of 3 ' thicknes located at 850 ft. — several previous drillings over the dome had without exception been futile.

(The larger scale diagram of Earth No. 7 shows more clearly the marked deviations from the normal on the north flank of the dome).



Contour Lines of Salt Dome of different depths

Salt Dome

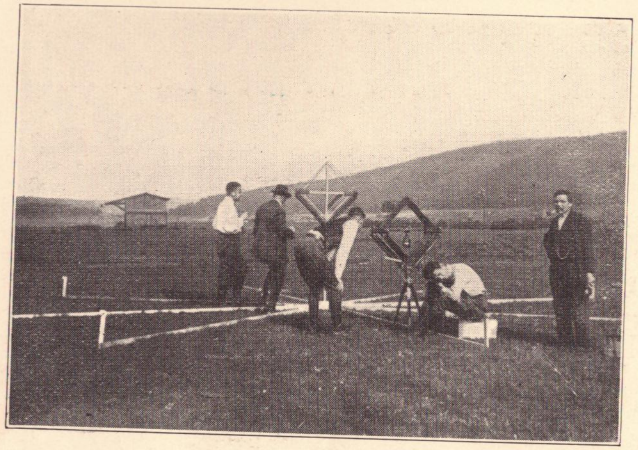
Zones of bad conductivity

Zones of bad conductivity proved to date

Wells previously drilled withoud result

Wells with oil or gas

Position of electrodes



# FIELD WORK WITH ELECTRICAL APPARATUS

## Method of determining the thickness and dip of strata in the vicinity of the observation point.

HUNGARIAN & GENERAL COAL COMPANY, Ltd.

Budapest, May 4. 1926.

H. Peikert, Esq.

Budapest

Dear Sir.

In reply to your letter of the 26th. ult., we are glad to inform you that the data and forecast supplied by you of the locality and extent of the coal seams, after the completion of the „Elbof" Electrical Survey, have been entirely confirmed by the borings which we have subsequently undertaken.

Yours faithfully.

The Director
Prussian Geological Survey
No. 2228

Berlin N. 4, March 18. 1925.
Invalidenstraße 44.

The „Elbof" method of Geophysical Exploration, of the firm of Piepmeyer & Co., Cassel, is founded on a scientific basis. It depends on the deformation from the normal of an artificially produced diagram of electro-magnetic forces.

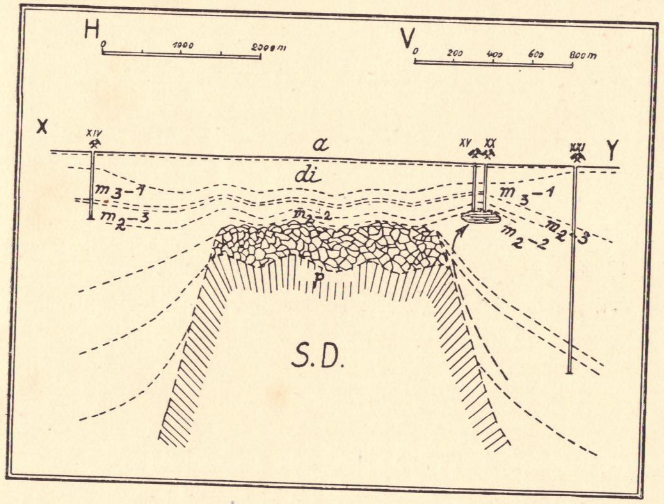
The greater the difference in electrical conductivity between the several strata or rock masses within the area under investigation, the more definite can the interpretation be made.

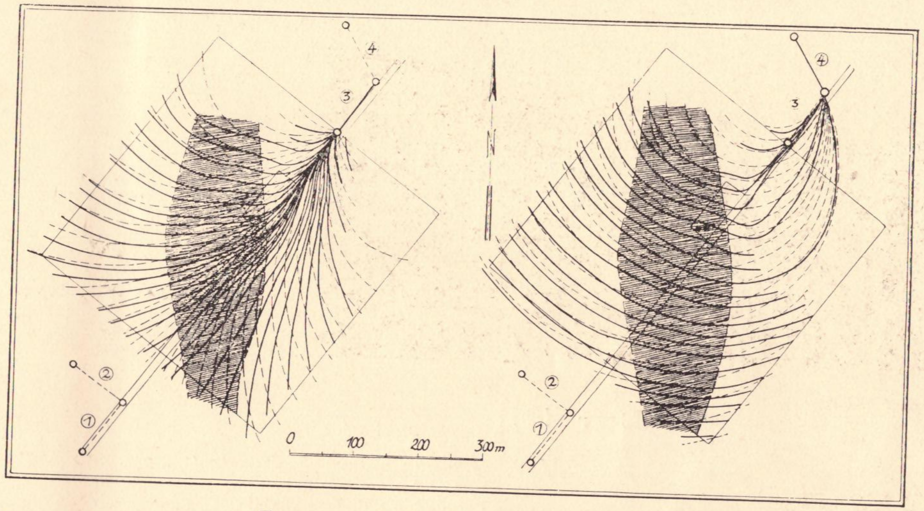
Hitherto the most valuable and important results have been obtained in locating deposits, on the one hand of Sulphide Ores, Magnetic Iron, Graphite, etc. (good conductors); and on the other Bituminous Coal, Petroleum, Talc, etc. (bad conductors).

As a result of numerous field tests, we are in a position to state that, in the hands of engineers trained and experienced in this work, these methods will afford valuable assistance in the discovery and location of mineral deposits of economic importance.

(Sd.) Krusch.

# NATURAL GAS, NEUENGAMME NEAR HAMBURG.




a = Alluvium
di = Diluvium
$m_3-^1$ = Miocene lower

$m_2-^3$ = Oligocene upper
$m_2-^2$ = Oligocene middle
$m_2-^1$ = Oligocene lower

p = Gypsum
S. D. = Salt dome
X = W. N. W.

Y = E. S. E
H = Horizontal-Scale
V = Vertical-Scale

The above section represents the geological conditions as determined by geophysical investigation, and confirms the results obtained by drilling.

The tertiary strata curve up the sides of the salt dome, forming a short anticlinal near the edge of the cap-rock; natural gas rising up along the flanks of the dome collects in the apex of this anticline.

The location of the gaseous zone, which is a bad conductor, is shown by the deviation from the normal — the straightening — of the lines representing the electric direction components.

The location and trend of the gaseous zone agrees with the record of the wells in the area: gas having been found at Nos. 15 and 20, the others outside the defined zone being unproductive.

**The Aflenz Graphite & Steatite Co. Ltd.,**
Sensengasse 10, **Vienna 9/3.**

October 23. 1924.

Messrs. **Piepmeyer & Co.,**

**Kassel-Wilhelmshoehe.**

Dear Sirs.

We are pleased to inform you that we have sent your report to Dr. Alexander Tornquist, the Principal of the Technical University at Graz, for his comments.

He recommended the driving of an Adit level to confirm your results. This has been done.

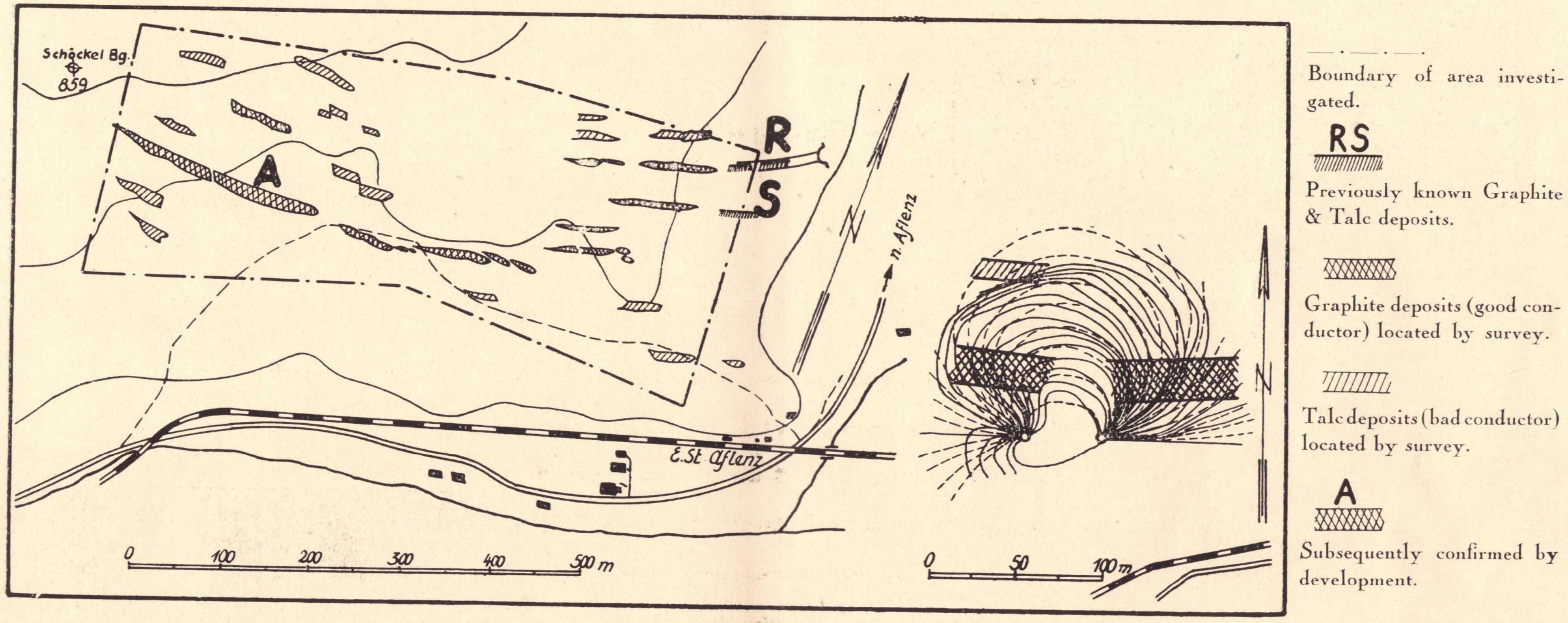
We are extremely pleased to be able to inform you that a graphite deposit was cut at 43 metres; showing a width of 4 metres; and that the graphite is of first-class quality, containing 71% carbon.

Our Manager states that, not only has your prediction as to the position and extent of the deposit proved correct, but the geological data given has also been confirmed — he considers that the results have entirely justified the work.

For the future, we shall always have complete confidence in your work.

Yours faithfully,
**Aflenz Graphite & Steatite Co. Ltd.**
(Sd.) Heinr. Rosenburg.

# INVESTIGATION OF A GRAPHITE AND STEATITE DEPOSIT AT AFLENZ IN (STYRIA) Austria



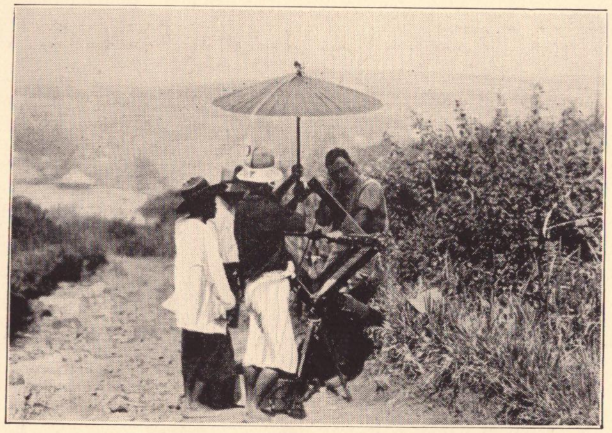

Graphite deposits were being worked at Aflenz on a small scale at the points R and S.

The geo-electrical investigation revealed the fact that there were many graphite lodes and bodies of steatite not visible on the surface.

After the survey, an adit was driven at A which cut the predicted lode at 43 m (see letter on opposite page.)

The Diagram shows the distortion of the current lines caused by the graphite deposit A.

These distortions are typical of a good conductor; conversel the influence of a bad conductor caused by a body of steatite can be seen to the N. W.



FIELD WORK IN JAVA



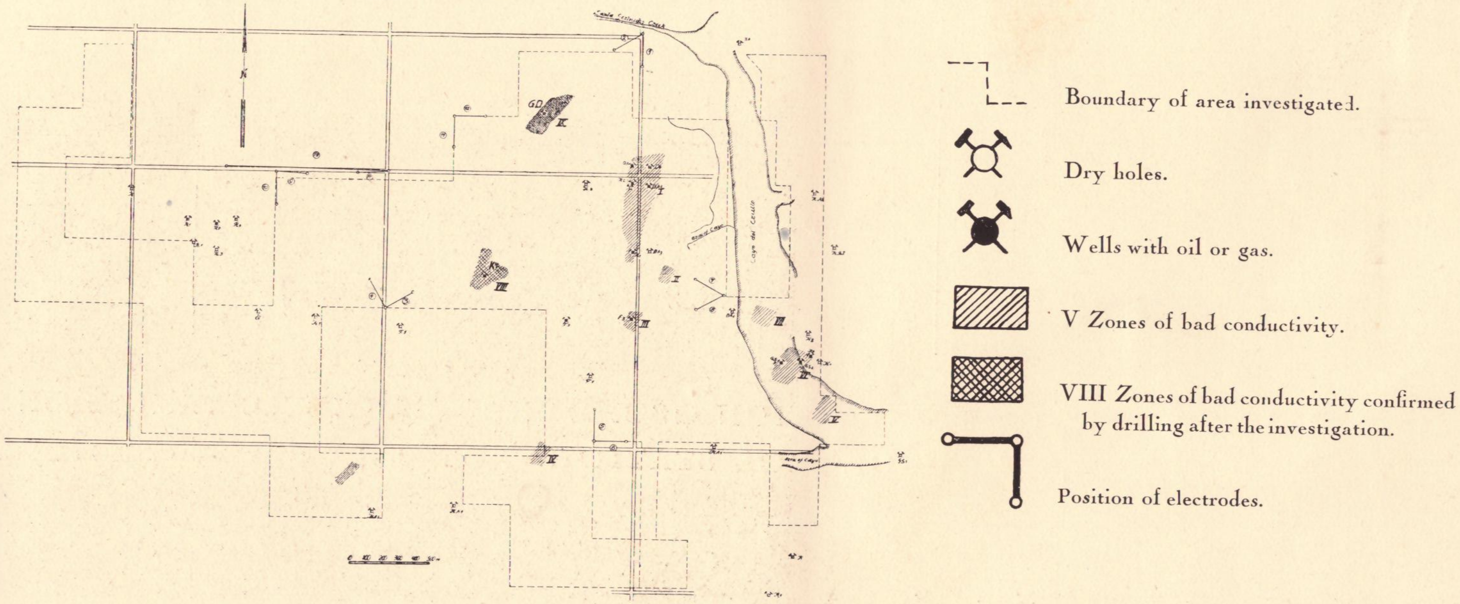
FIELD WORK IN SOUTH AFRICA

# OIL AT KINGSVILLE, TEXAS.

In the absence of salt domes this area is one of the few exceptions to the prevailing conditions in the Gulf Coast Oil Fields. The above plan shows the area, of about 3 square miles, which was investigated.

1. Before the survey, only two wells out of several put down in the Western area, gave a little oil and gas, but were soon abandoned. In the Middle area all holes were dry. On the Eastern side several reached oil but the yield was small. It was supposed that the trend of the oil bearing zones was from E — W.
2. The Geophysical survey revealed areas of bad electrical conductivity only in the E. part — none in the W. The localities I, II, III had in part been tested. The areas VIII and IX were previously unknown.
3. Drilling commenced at once on both these sites.
   (a) At IX GD, 21' of rich oil sands have been reached at a depth of 2200 feet. (And further drilling has been arranged here).
   (b) At VIII (Kleberg No. 4), 16' of oil sand & shale have been found.
   (c) Our conclusion that the trend of the oil is in a N. E. — S. W. direction is confirmed.

Kingsville / Texas.



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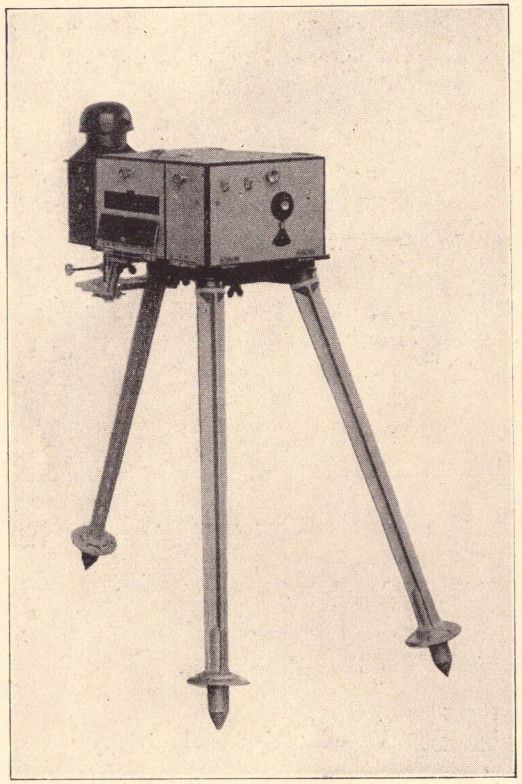
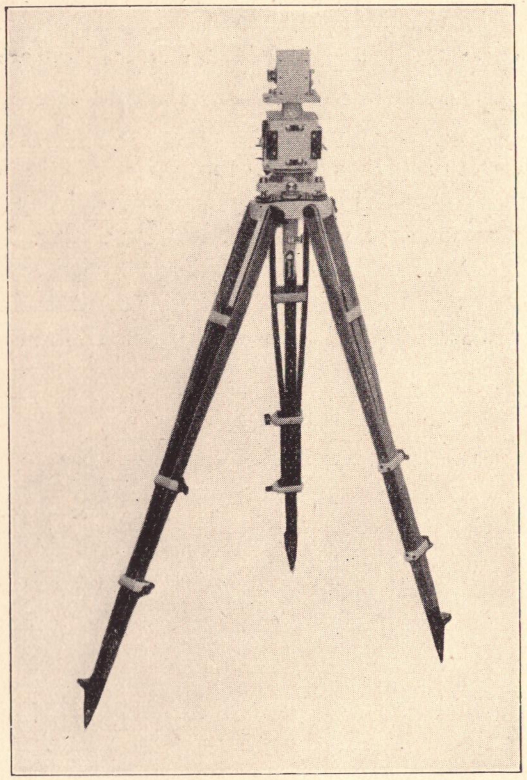




INSTRUMENTS FOR AUTOMATIC REGISTRATION OF DIURNAL MAGNETIC VARIATIONS AT THE CONTROL STATION

# III. MAGNETIC SURVEYS.

This method of investigation is based on the measurement of local variations in the earth's magnetic field due to the differences in the magnetic properties of rocks.

The properties of the magnetic minerals such as magnetite and some eruptive rocks containing magnetite have been studied for a long time.

In the latest methods of investigation it is possible to distinguish between (a) the magnetic minerals such as magnetite and some eruptive rocks containing magnetite, (b) paramagnetic minerals, siderite, menaccanite, etc., and (c) the diamagnetic effects of salt, gypsum, etc.

Magnetic properties of certain minerals and rocks are given in the attached table.

## TABLE OF THE MAGNETIC PROPERTIES OF A FEW MINERALS AND ROCKS

According to Stutzer, Groß and Bornemann, the magnetic susceptibility per unit of volume is, for:

| | | |
|---|---|---|
| Rock-salt | | $-0{,}82 \cdot 10^{-6}$ |
| Quartz | | $-1{,}2 \cdot 10^{-6}$ |
| Calcspar | | $0{,}9 \cdot 10^{-6}$ |
| Fluorspar | | $0{,}9 \cdot 10^{-6}$ |
| Barytes | | $0{,}9 \cdot 10^{-6}$ |
| Sulphur | | $0{,}8 \cdot 10^{-6}$ |
| Dolomite | | 0,91 „ |
| Galena | | 2,63 „ |
| Magnesite | | 3,00 „ |
| Pyrite | | 4,54 „ |
| Marcasite | | 5,43 „ |
| Graphite | | 8,00 „ |
| Ankerite | | 23,55 „ |
| Chalcopyrite | | 32,15 „ |
| Malachite | | 34,41 „ |
| Azurite | | 39,85 „ |
| Hornblende | | 122,66 „ |
| Pyrolusite | | 127,69 „ |
| Augite (pyroxene) | | 133,13 „ |
| Limonite | | 219,61 „ |
| Arsenical pyrites | | 236,82 „ |
| Wolframite | | 240,89 „ |
| Chromite | | 244,51 „ |
| Psilomelane | | 286,06 „ |
| Siderite | | 231,45 „ |
| Red Manganese ore (dialogite) | | 379,90 „ |
| Rhodonite | | 457,48 „ |
| Serpentine | about | 2535,— „ |
| Specularite | „ | 3215,— „ |
| Magnetic pyrites | „ | 7018,— „ |
| Titaniferous iron | „ | 30740,— „ |
| Franklinite | „ | 35640,— „ |
| Magnetite | „ | 97350,— „ |

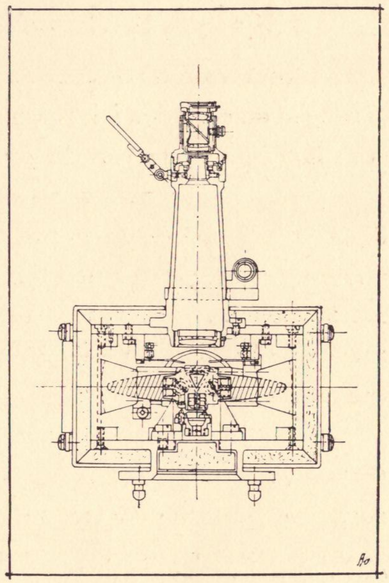
105.

The instruments employed for the determination of the local variations in magnetic intensity are the Local Variometers (see sectional views).

These variometers are designed by Prof. Schmidt of Potsdam and are made in the Askania works in Berlin.

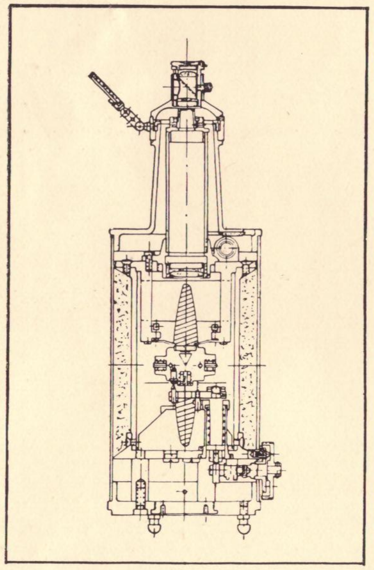
Measurements are made over the area to be investigated either in the form of a net work or in lines; the instruments are highly sensitive and record every minute variation in intensity, the usual daily variations being simultaneously recorded with a „control“ instrument.

The following example further explains the work.



VERTICAL-VARIOMETER

106.



HORIZONTAL-VARIOMETER

# IRON ORE DEPOSIT, SALZGITTER NEAR HANNOVER

Observations were made along two parallel lines arranged at right angles to the strike of the formation, see plan, (upper part of diagram).

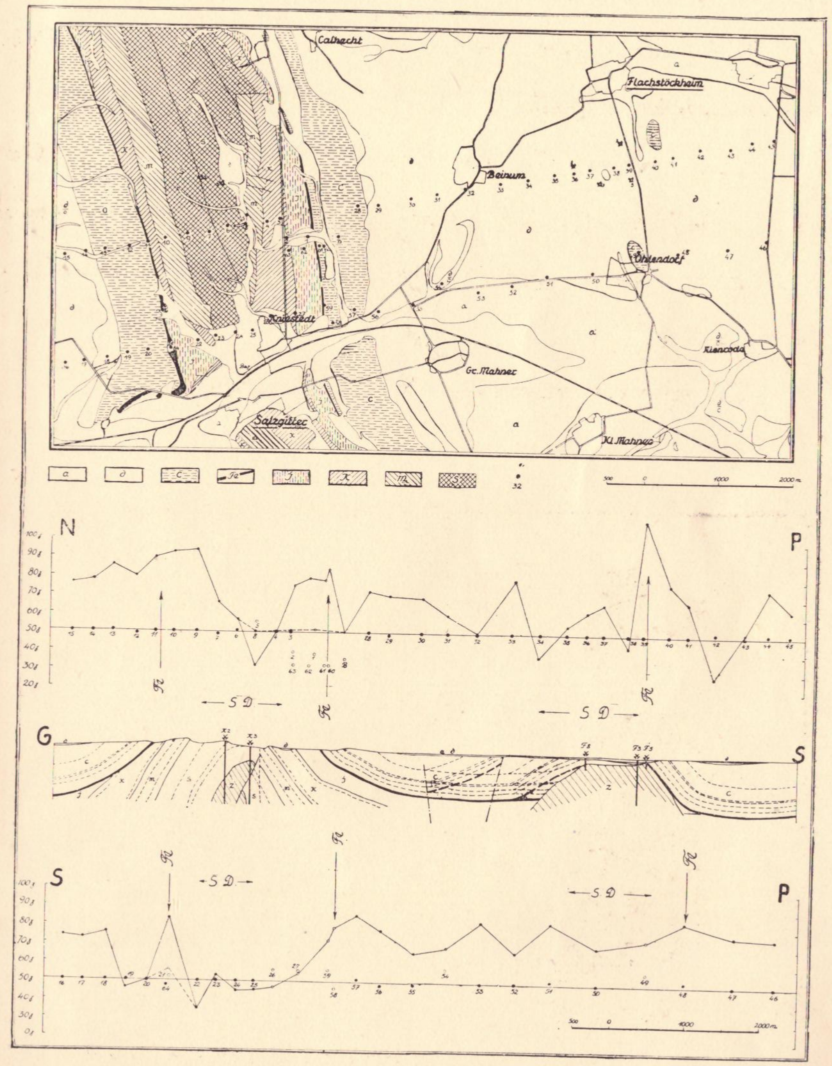
The mean section is shown in the lower half of the diagram and shows the curves of magnetic vertical intensity, the highest values coinciding with the outcrops of the bed, and the lowest values corresponding with the rock salt of the Permian formation at the cores of the anticlines.

It will be observed that between the two ridges there has been considerable tectonic disturbance, not revealed by the geological survey, which is interpreted as a step faulting of the bed, vide dotted line in section.

Owing to the fact that the Iron Ore Bed (Salzgitter Limonite) contains practically no FeO and $Fe_3O_4$ but consists mostly of $Fe_2O_3$, its magnetic effects only differ to a very small extent from the adjoining strata.

N. P. = Northern Magnetic Line, Profile.
G. S. = Geological Section.
S. P. = Southern Magnetic Line, Profile.
Fe. = Ironstone.
S. D. = Salt dome.

a = Alluvium.
di = Diluvium.
c = Chalk.
Fe = Brown Ironstone.
J = Oolite.
K = Marl.
m = Shell Limestone.
s = New red Sandstone.
• = Observation stations.

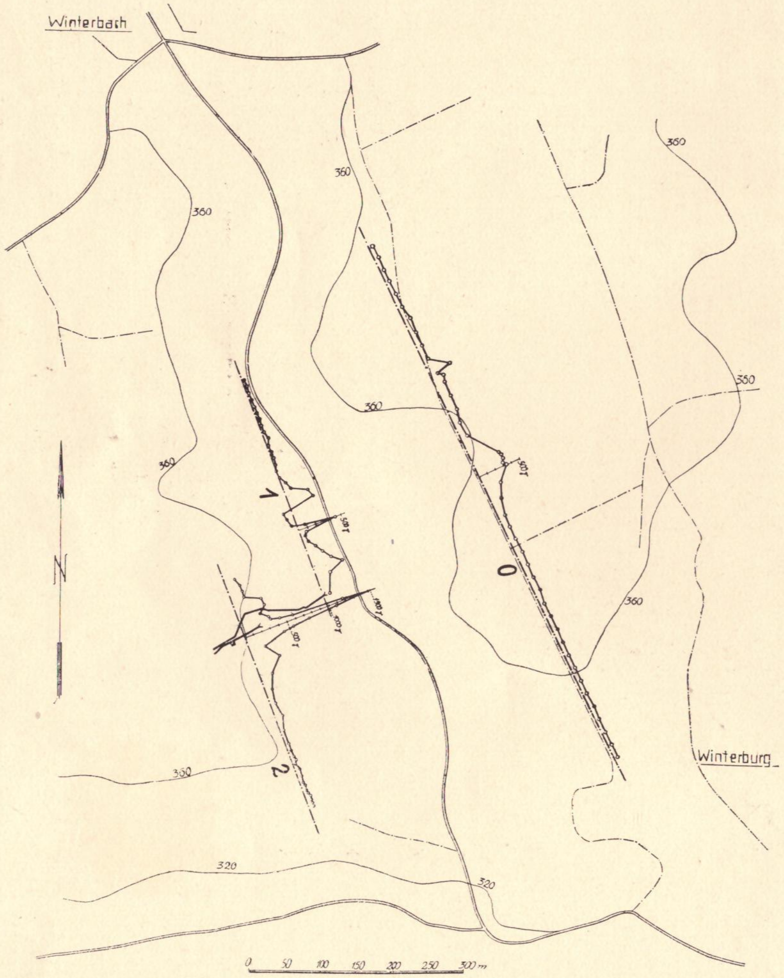


# MAGNETIC IRON ORE DEPOSIT.
## MAGNETIC SURVEY OF THE MARIENHOFFNUNG MINING COMPANY'S AREA.

North West of Bad Kreuznach in the Soonwald, a magnetic iron ore deposit has been opened up by means of two adit levels, an upper and a lower, connected by a shaft, see plan p. 27. The lode was approximately 1 metre in width and the best ore had been found in the neighbourhood of the shaft.

The object of the investigation was to discover whether payable ore existed along the south-western extension of the lode, and also in a parallel lode to the north.

The survey was carried out along 5 parallel lines at right angles to the strike of the lodes; these are shown in the plan on page 26, and survey lines Nos. 2, 3 and 4 are reproduced on a larger scale on page 27.

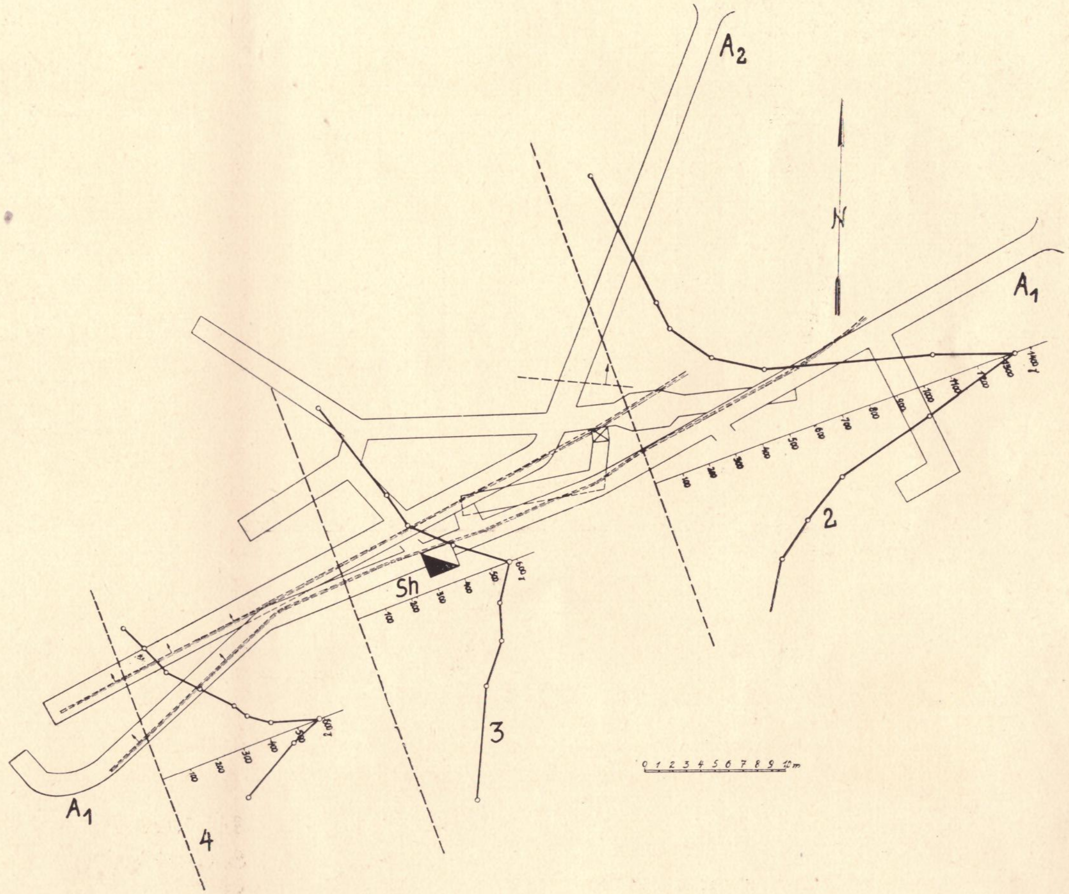



SECTION 0
SECTION 1
SECTION 2

# WINTERBURG NEAR BAD KREUZNACH.

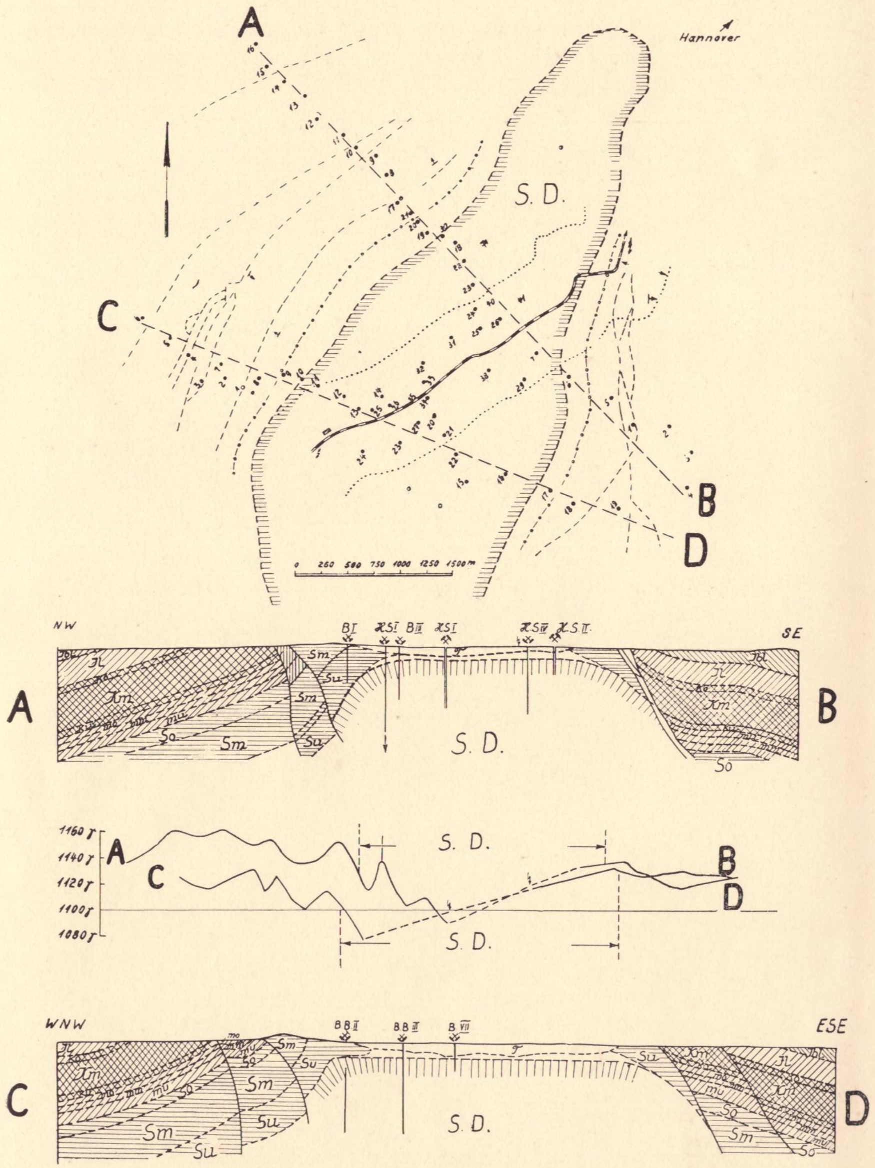
The results of the magnetic survey have defined the course of the lode (to a degree of accuracy of ±0.5 metre), and the diagramatic form of curvature denotes the size and grade of the ore body.

This showed conclusively that the best ore body was known, and that further development work would not be justified.




$A_1$ = Upper Adit.
$A_2$ = Lower Adit.
Sh. = Shaft.
2, 3, 4 = Magnetic Profiles.

MAGNETIC SURVEY – FIELD WORK




# SALT RIDGE AT BENTHE NEAR HANNOVER

## Investigation of the sides of a salt ridge.

The observations were made along two lines set out at approximately right angles to the long axis of the ridge (see plan).

Readings vitiated by proximity to the tram line Hannover-Gehrden, are omitted.

The lower diagram shows the geological sections and the curves of magnetic vertical intensity.

The magnetic effect of the salt ridge being weaker than the surrounding rocks, the location of the former is indicated by the lowest part of the intensity curve.

The steep slope on the west and the flatter slope on the east side of the ridge are shown by the steeper drop from the west and the more gradual rise towards the east of the magnetic curve.

The higher values at the western end of the northern line are due to a general increase of magnetic vertical intensity against the north.

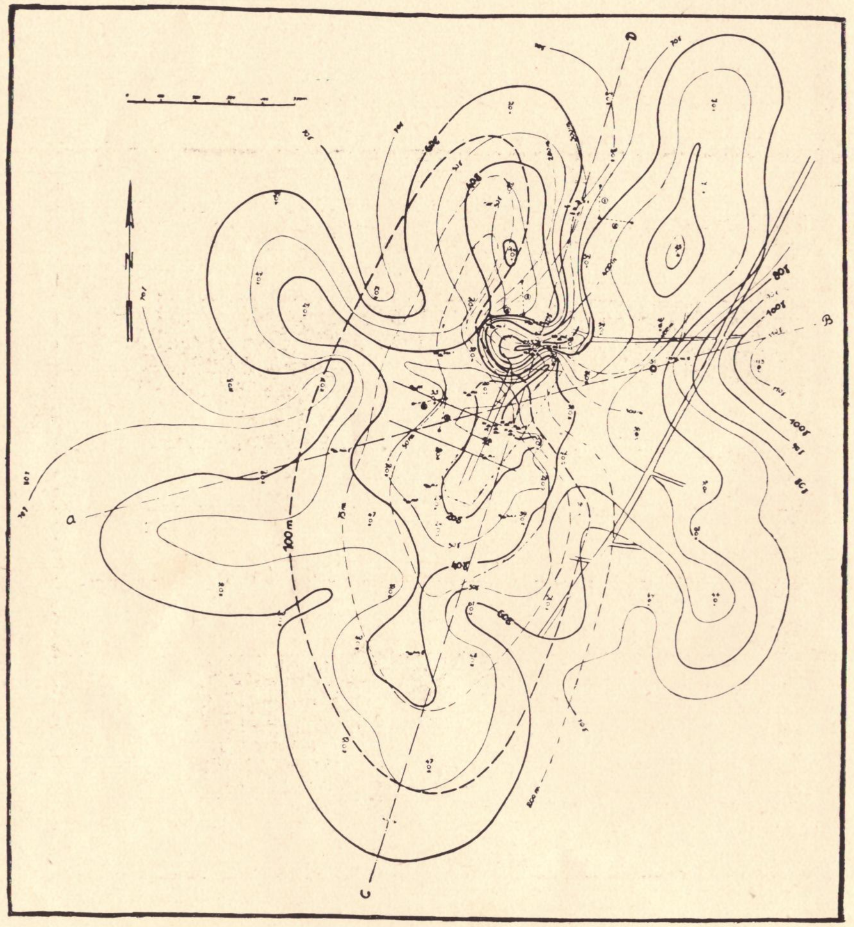
The relative average values for magnetic vertical intensity for the various geological strata, referred to an arbitrary zero, are in $\gamma$

$$(1\gamma = 0.000\,01 \text{ C.G.S.})$$

| | | |
|---|---|---|
| Lias + Oolite . . . . . . . . . . | „Jl + Jbl“ | = 28.4 |
| Marl (Uppĕr Triassic) . . . . . | „k“ | = 50.0 |
| Shell-limestone . . . . . . . . . | „mo + m + mu“ | = 21.8 |
| New red sandstone, upper . . . | „so“ | = 30.0 |
| „ „ „ , middle . . | „sm“ | = 27.2 |
| „ „ „ , lower . . . | „su“ | = 21.3 |
| Salt beds, Permian . . . . . . . | „zo“ | = 3.6 |

A—B = Northern Magnetic Profile.
C—D = Southern „ „
S. D. = Salt-dome.

## OIL BEARING LIMESTONE



As far as the geology of the area is known from borings etc., the lower stratum is cretaceous and several hundred metres in thickness. This is impregnated with oil and rests on Permian-Limestone-formation.

The chalk has a flat dip to the west, but on the east there is a fault in a N — S direction with an easterly downthrow of approximately 300 metres. (see the two sections).

In the left hand diagram the contour lines of the chalk at 100 m, 75 m and 50 m depths, are shown by the dotted lines (isohypses).

At its highest point, the chalk is directly overlain by diluvium. From the west, between the chalk and the diluvium there is tertiary strata, tapering towards the east; the eastern boundary of this formation having a very irregular outline in plan.

East of the fault, the tertiary reaches 300 metres in thickness.

# HEIDE IN HOLSTEIN

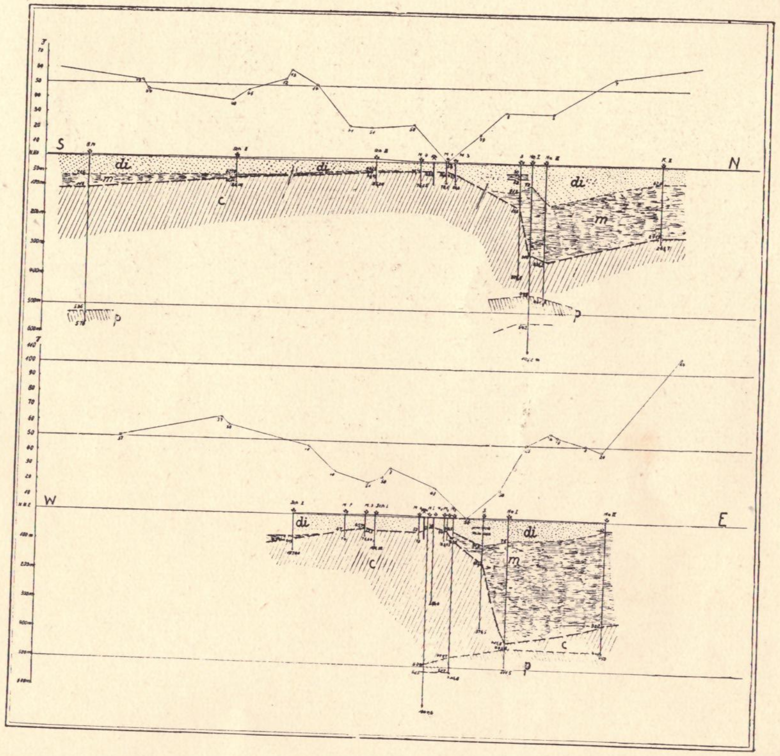
A total of 57 observations was made over the area. In the left hand diagram the isodynamic curves connect points of equal magnetic vertical intensity (the full lines).

The diagram on the right hand (page 31) shows geological sections south to north (C—D) and west to east (A—B) with curves of the corresponding magnetic values.

The agreement between the geological conformation and the results of the magnetic survey are evident, the nearer the chalk approaches to the surface the lower the values for the magnetic vertical intensity; the 75 m isohypse approximately corresponding to the 40 $\gamma$ isodynamic line, and so on.

The highest magnetic values coincide generally with the greatest thickness of the tertiary strata.

Minor fluctuations in the curve are caused by the irregular tapering of the tertiary on the chalk from west to east.




N = North.
E = East.
S = South.
W = West.
di = Diluvium.
m = Tertiary.
c = chalk.
p = Permian Limestone Formation.

TRANSPORT OF TORSION BALANCE & TENT

# IV. GRAVIMETRIC INVESTIGATIONS.

Torsion balance surveys are based on the variations in gravitational effect caused by the differences in density (specific gravity) of the constituents of the earth's crust.

The main field for this type of investigation lies in the location of dykes and large ore masses and particularly in defining anticlinal structure, salt domes etc. associated with oil deposits.

Provided the surface topography is not too precipitous, this method is also applicable to deposits of ore, barytes, lime and coal seams.

A table giving the specific gravity of the more important rocks and minerals is attached.

The Torsion balance used for this work is founded on the original invention of Roland von Eötvös.

We employ the most up to date instrument designed by Professor Schweydar of Potsdam and made by the Askania Works of Berlin.

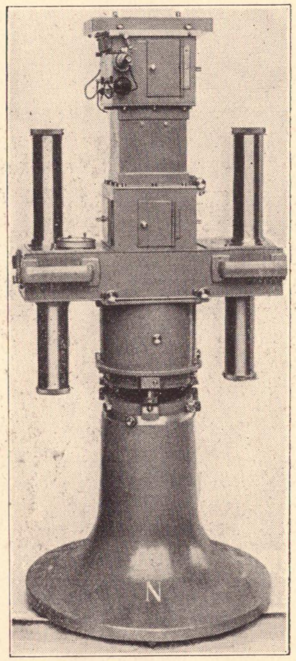
This instrument is very costly, but its operations are entirely automatic- this elimination of the personal factor conduces to much greater accuracy.

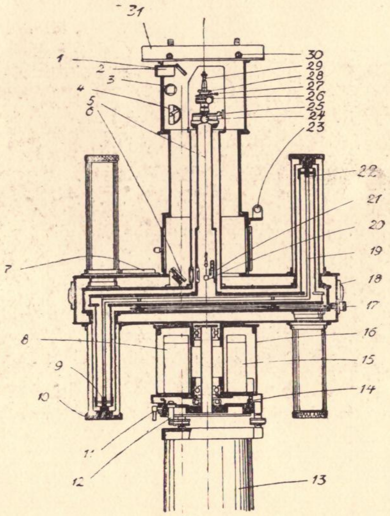
A section and view of the instrument is shown.

The mathematical theory upon which the measurements depend is highly intricate - it is sufficient to state here that four different factors can be evaluated from the set of readings obtained from each observation station.

TABLE OF SPECIFIC-GRAVITIES OF SOME COMMON ROCKS & MINERALS.

| | | |
|---|---|---|
| ROCKS, ERUPTIVE. | Granite | 2,6 |
| | Diorite | 2,8 |
| | Phonolite | 2,5 |
| | Basalt | 3,0 |
| SEDIMENTARY ETC. | Limestone | 2,5 |
| | Dolomite | 2,8 |
| | Sandstone | 2,3 |
| | Schist | 2,5 |
| ORES IRON. | Magnetite | 5,2 |
| | Hematite | 5,1 |
| | Limonite | 3,8 |
| | Pyrites | 5,0 |
| | Arsenopyrite | 6,0 |
| NICKEL & COBALT, | Smaltite | 6,5 |
| | Kupfernickel | 7,4 |
| COPPER. | Chalcopyrite | 4,2 |
| | Erubescite | 5,1 |
| | Tetrahedrite (Fahlerz) | 4,7 |
| | Malachite | 3,9 |
| SILVER. | Horn Silver (Cerargyrite) | 5,5 |
| | Argentite | 7,3 |
| MANGANESE. | Pyrolusite | 4,8 |
| | Psilomelane | 4,2 |
| LEAD. | Galena | 7,5 |
| | Mimetite | 7,1 |
| ZINC. | Franklinite | 5,1 |
| | Blende | 4,0 |
| MERCURY. | Cinnabar | 8,1 |
| TIN. | Cassiterite | 6,8 |
| ANTIMONY. | Stibnite | 5,3 |
| VARIOUS. | Anthracite | 1,5 |
| | Bituminous Coal | 1,3 |
| | Brown Coal | 1,2 |
| | Crude Oil | 0,8 |
| | Gypsum | 2,3 |
| | Rock Salt | 2,1 |
| | Gravel | 1,8 |





1. Direction of gradient.
   The direction of maximum change of gravity from the observation point.
2. Length of gradient.
   Change of gravity for one unit, in the direction of the gradient, measured in Eötvös units.
3. Direction of value of curvature.
   Direction in which the surface of equal gravity shows the least curvature.
4. Length of value of curvature.
   Length of curvature vector, i. e. the difference between the extremes of the reciprocals of the radii of curvature of the surface of equal gravity, measured in Eötvös units.

Taken in conjunction with specific gravity figures for the known strata, the above four factors are sufficient to enable the geological configuration of the strata to be determined.

1. Scale
2. Adjustable Mirror
3. Lamp and holder
4. Resistance
5. Platino-Iridium Torsion Wire
6. Mirror
7. Compass
8. Automatic light control
9. Lower weight
10. Lower weight clamp
11. Orientation clamp
12. Stops for controlling Azimuth intervals
13. Extension Pedestal
14. Gear wheel
15. Driving mechanism
16. Movable covers
17. Beam clamping screw
18. Handles
19. Beam
20. Beam Mirror
21. Fixed Mirror
22. Upper weight
23. Level
24. Torsion head, fixing screw
25. Torsion head — Screws for „centring"
26. Micrometer-Scale
27. Torsion head, clamp
28. Screw for vertical adjustment of wire
29. Torsion head
30. Screws for Camera Cover
31. Camera with clock-control

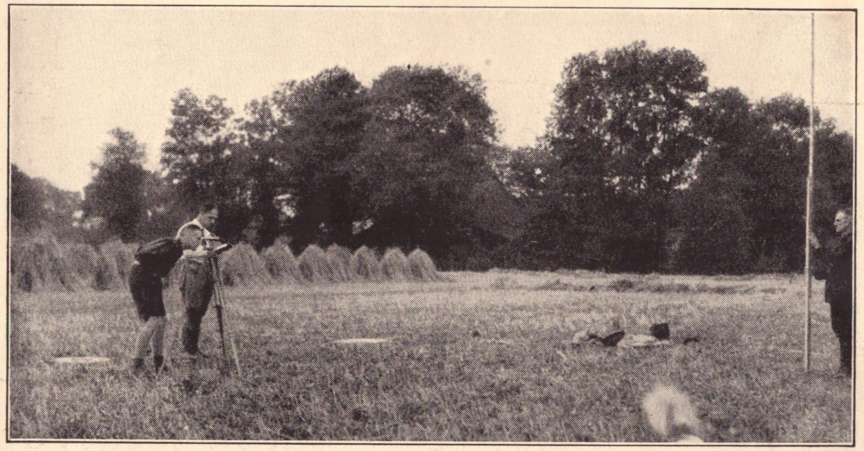
The sensitiveness of the new Torsion balance has been increased to the utmost limit of practical utility, $1.5 \times 10^{-9}$ C. G. S.

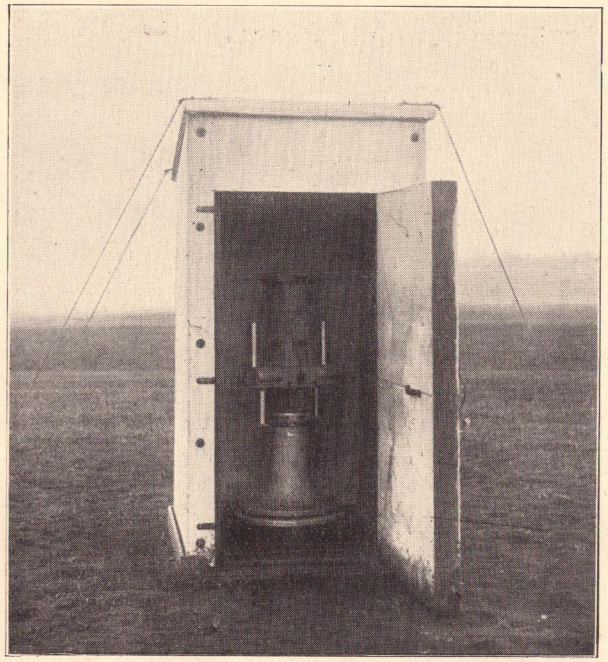
For this reason accurate levelling round the observation station is essential, and is allowed for in the computation.

Further, the instrument must be protected from all atmospheric influences, more particularly from fluctuations in temperature, for this reason a specially constructed housing and tent are provided.

Space only admits of a single example — an investigation of a salt-ridge in N. Germany — this has been selectet as the survey revealed a considerable difference between the supposed configuration, and that shown by the Torsion balance, subsequently comfirmed by drilling.

LEVELLING ROUND A TORSION-BALANCE STATION.





TORSION BALANCE IN TENT OR HOUSING

A TORSION BALANCE STATION
IN THE TROPICS

SALT RIDGE - N. GERMANY. PLAN SHOWING MEASUREMENTS OBTAINED BY TORSION BALANCE.

Explanation of signs:-

Gradients

Curvature values

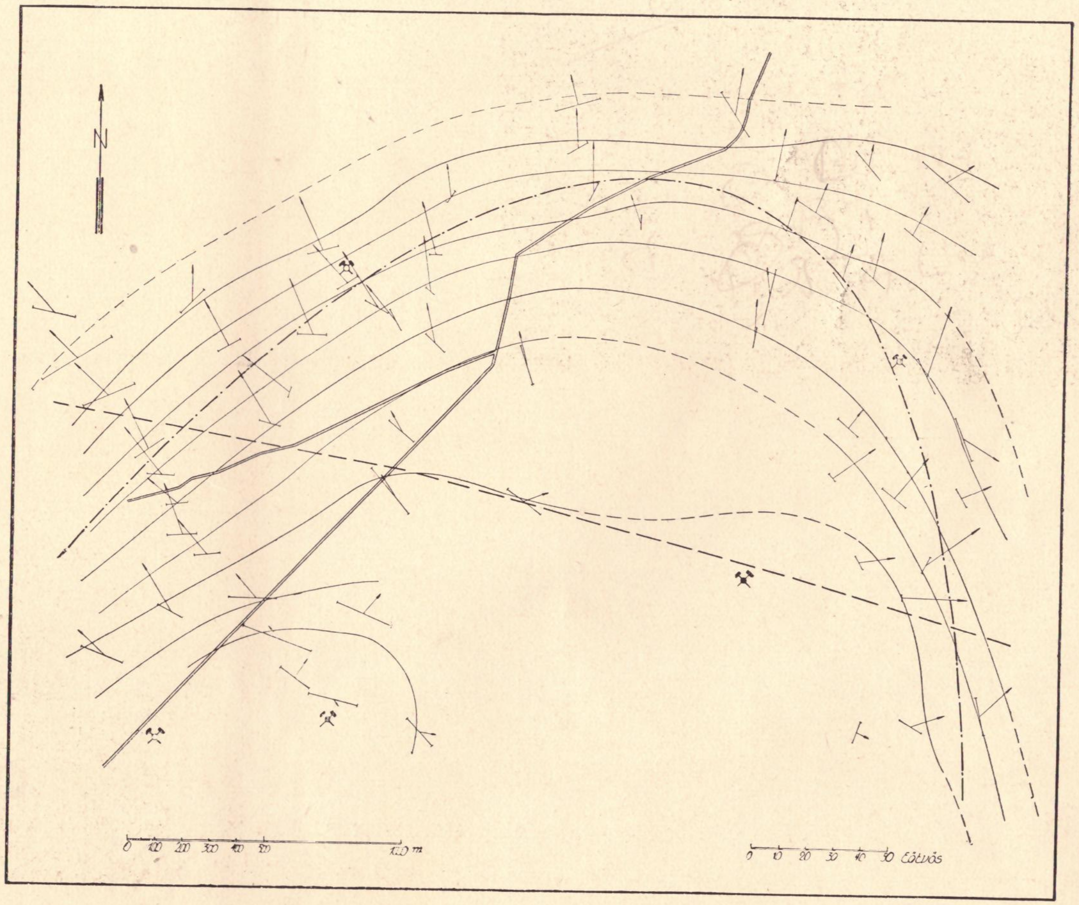
Isogamms; at intervals of $25 \times 10^{-5}$ C. G. S.

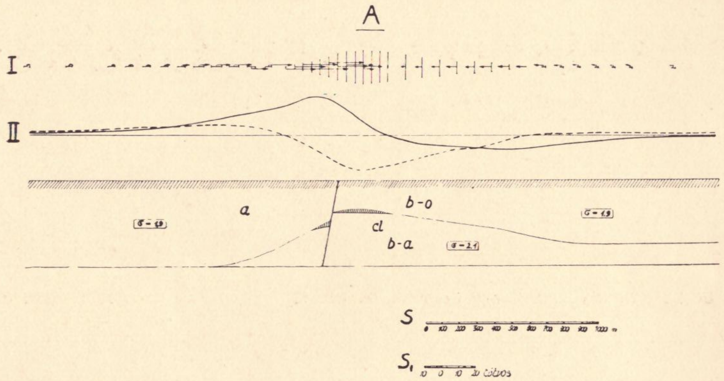
Boundary of Salt Ridge, as determined by survey

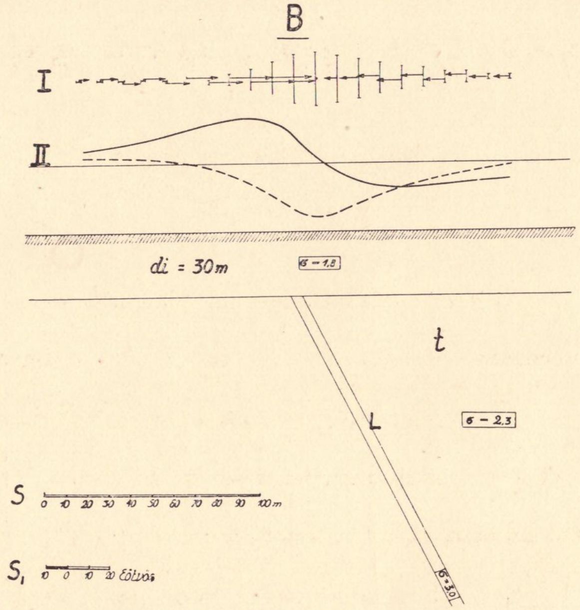
Bore holes, salt found

Bore holes, unproductive

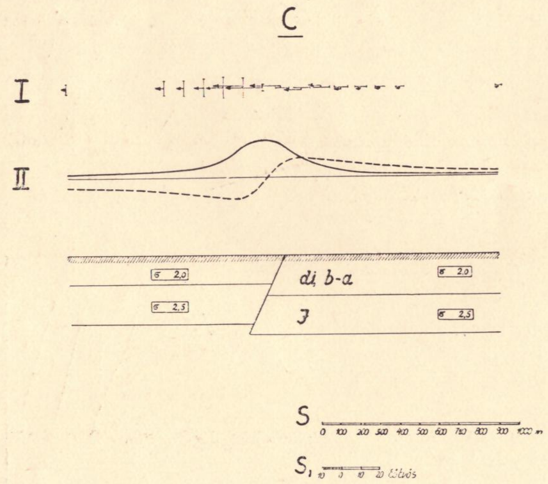
Previously supposed boundary of Salt Ridge






# GRAVIMETRIC SURVEYS OVER (A) OIL ANTICLINE, (B) MINERAL LODE, & (C) FAULT.




Each diagram shows a geological Section, with corresponding Values of gravimetric gradient & curvature.

I = as shown in plan for each observation station.

II = Diagramatically represented in profile.

a = Alluvium.
b-o = upper Tertiary, oil bearing strata.
cl = anticline.
b-a = Lower Tertiary.
$\sigma$ = specific gravity.
gradient line.
curvature line.
di = Diluvium;

t = Tilted Devonian schist.
L = Lode, Spathic Iron & Copper pyrite; 5 m wide
J = Jura Limestone
S = Topographical Scale
S, = Gravimetric Scale

# V. GEO-THERMIC AND RADIO-ACTIVITY INVESTIGATIONS.

Where measurements have been made in Europe, it has been found that on the average, the temperature of the earth's crust increases with depth at the rate of $1^0$ Centigrade for every 33 metres. This is termed the standard geo-thermic gradient.

Variations from this gradient exist, however, and these differences may be due to various causes — the conductivity of the rock itself (in thick beds of schist, heat conductivity is greatest parallel to the planes of schistosity) recent volcanic phenomena, the decomposition of the sulphide ores and other minerals etc.

Such abnormalities are to be found associated with coal beds, petroleum, and ore deposits, where, for example, pyrites and marcasite are in a state of oxidation or a gangue is undergoing kaolinisation.

In the Joachimsthal district, it has been found that the heat liberated from radio-active minerals is insufficient to affect substantially the geo-thermic gradient.

It follows that, in the course of geophysical investigation, a careful record of temperatures in deep borings may supply valuable data, and assist in predicting the course of the observations long before the deposit is actually cut.

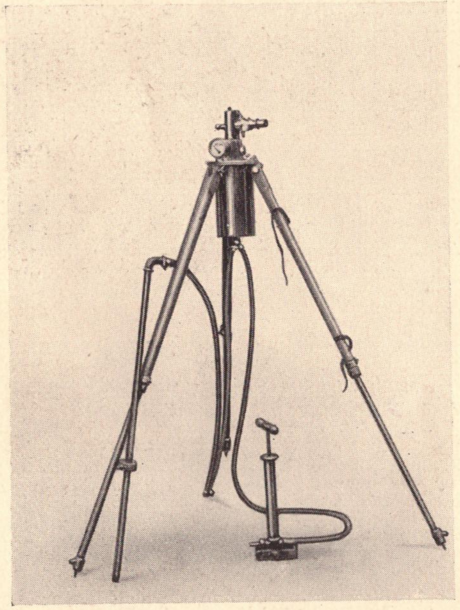
The appliances used in these geo-thermic measurements are simple, and practical examples of their application will be found in the literature dealing with this branch of the subject. (see page 44)

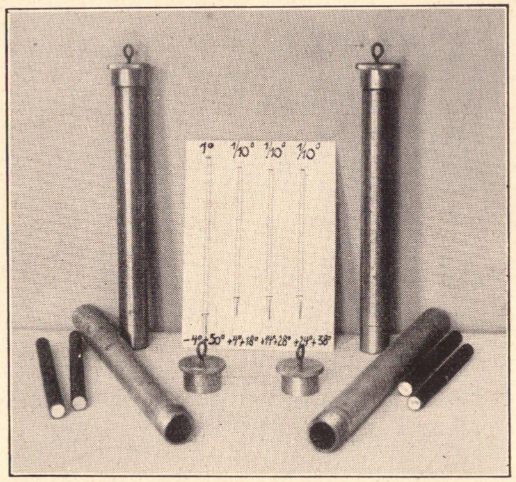
Radio-Activity

This method of investigation also furnishes useful data. The effects are most marked in the vicinity of the rare radium salts and springs possessing medicinally curative properties.

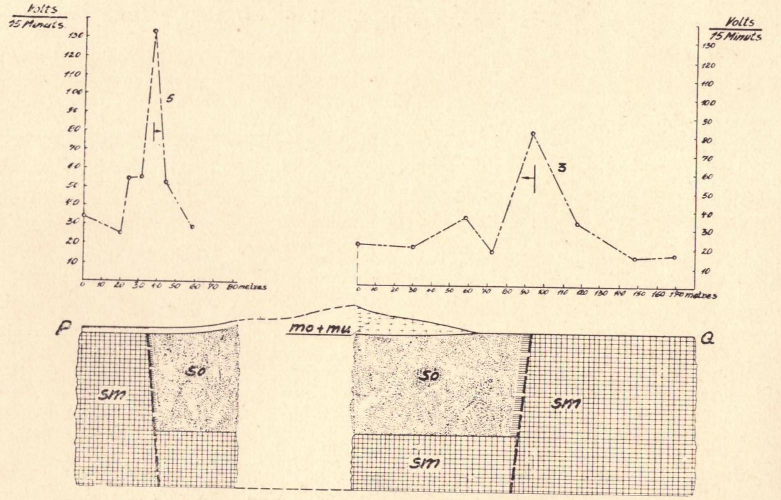
But it has rendered the most important service in connection with the location of faults and fissures, and has proved of great practical value in examining the nature of the foundations intended for large buildings, dams and tunnels etc.

In this work the apparatus used is a Lutz or Wulf Electrometer fitted with an Ionisation chamber; it is simple in construction and operation, and needs no further description here.



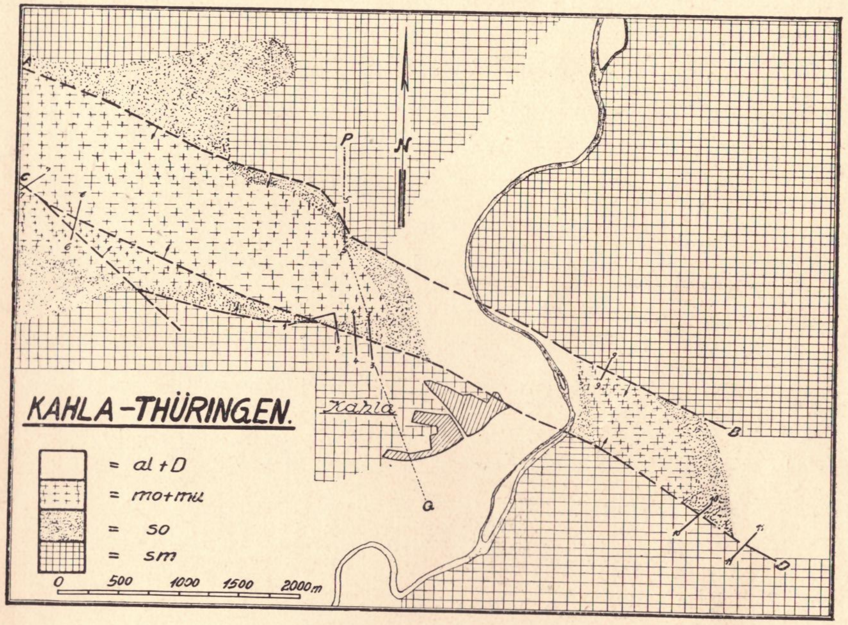


# RADIO-ACTIVITY MEASUREMENTS AT THE LEUCHTENBURG FAULT NEAR KAHLA IN THURINGIA.




al = Alluvium.
D = Diluvium.

so = upper new red sandstone.
mo = upper shell-Limestone.
mu = lower shell-Limestone.
sm = middle new red sandstone.




Measurements were undertaken in this area which is geologically well known.

The main feature is a trough fault, the centre of which has sunk several hundred metres.

The formation is Trias. Shell limestone in the upper layer and new red sandstone in the lower.

The lines of the fault are shown in the plan at A-B, C-D. Under a thin layer of alluvium, limestone is found between the fault planes. Sandstone lying north of A-B and south of C-D.

Observations taken across the fault, along the line P-Q are shown as a curve, with the corresponding geological section below.

It will be observed that a very marked maximum reading is recorded immediately over the fault plane, other observations (not show here) are similar, the average maximum over the fault planes being some 300% greater than the average of the readings obtained either over the trough or outside it

# VI. GENERAL INFORMATION, ESTIMATES, TIME REQUIRED, GROUP ARRANGEMENTS ETC.

Preliminary Diagnosis.

Before an investigation is arranged, it is necessary to know whether the deposit, which it is proposed to examine, is susceptible to exploration by geophysical methods or not.

To reach a decision the following points must receive careful consideration.

1. In what respect do the greatest physical differences exist between the mineral deposit and the enclosing strata.
2. What is the geological character of the deposit, e. g. lode formation, lenticular, anticlinal etc.
3. What data is available regarding the topography and geology of the district.

Enquiry Form.

To enable us to deal fully, with these factors, we have drawn up a number of questions. Two copies of this "Enquiry Form" are supplied, one of which should be returned to us, completed as fully as possible.

Samples.

Wherever possible average samples of the ore and surrounding rocks should be submitted, in order that their physical properties may be examined in our laboratories.

With this information it will be possible to say if, and in what order, the methods of geophysical exploration can be applied and successfully carried out.

Estimates.

Provided adequate information and data of the proposed investigation are available, inclusive estimates can be given for work in any part of the world and of any duration.

Time.

The time occupied in the different methods may be stated approximately as follows:-

Electrical.

The preliminary survey of a large territory would require 12—14 working days to cover an area of 3 to 4 square miles; in this survey which is suitable for the first examination of an unexplored area, the stations are widely placed.

For determining the exact locality where work is to begin, a closer network of stations is necessary, requiring 18 days for one square mile.



The above applies to the survey of oil-structure.

In the case of mineral deposits (lodes, masses etc,) the survey of an area of one square mile, requires for general exploration 20 days; and, as a rule, a further 15 days to determine the sites where exploratory mining work is to begin.

These estimates assume that the work of the geophysical group is preceded by a survey party, who have cut lines and fixed stations in advance.

Gravimetric.

With one torsion balance, 15 to 18 stations can be surveyed per week. The number of stations required for the gravimetric survey of an area depends on the nature of the problem, and varies between wide limits. An area of $^1/_2$ a square mile may need from 5—25 stations according to circumstances.

Magnetic.

With one set of instruments two observers can survey some 15 to 20 stations daily. The number required for an area of $^1/_2$ a square mile may be from 15—150 according to the problem.

Geo-Thermic & Radio-Active.

These problems should not occupy more than 1—3 weeks provided they are not concerned with continuous observations of borings in progress.

The above estimates of the time required for geophysical work can only be considered as very approximate, it will be readily understood that the nature of the problem, of the terrain, and of the climate may considerably modify the time necessary for completion of the work.

Groups.

Each of the groups at home and abroad consists of three or four engineers who are trained physicists, certified mining engineers or practical geologists. The co-operation of geologists acquainted with the particular locality under review will always be very welcome. Every group is equipped with all the instruments necessary for each method of investigation together with spares, repairing outfit, and if necessary motor transport. As a result of long special training, each member of the group is thoroughly versed in all the methods of investigation.

Interpretation.

The detailed analysis of the results of the survey is forwarded by the chief engineer of the group to the headquarters of the Company in Cassel where it is subject to a close scrutiny by geological and technical experts before a final interpretation is arrived at. In all the work undertaken by the Company, the various groups are in close touch with the staff at Cassel, and the closest co-operation is maintained between the field work of the groups, the geological department and laboratories at Marburg and Cassel, and the instrument factory at Marburg.

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