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Autor: Gassmann, Fritz

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Recent Geophysical Research-Work

By FRITZ GASSMANN,

Swiss Federal Institute of Technology,
Head of the Department of Geophysics.

Abstract

The present paper is a short report on the recent geophysical research work carried out by the Department of Geophysics (Swiss Federal Institute of Techno logy).

Chapter A gives the aims of the research work of the department.

Chapter B deals with the magnetic anomalies in Switzerland and with problems connected with them, i. e. the mapping of strong anomalies and the magnetic properties of rocks.

Chapter C treats the use of modern gravity-meters in mountainous regions and the graphical methods of interpretation of gravity anomalies.

Chapter D deals with seismic apparatusses constructed and tested at the Department of Geophysics, and with theoretical and experimental investigations concerning the elastic properties of soil material and rocks.

A. Introduction

The Department of Geophysics of the Swiss Federal Institute of Technology first of all serves to instruct the future geologists (Lit. 8, 9). Therefore, supplementary to the lectures in geophysics, practical exercises have to be carried out in order to make the students familiar with the different methods of applied geophysics. Generally, the scientific activity of the Department has to be directed in such a way that the students can treat geophysical problems more or less independently, e. g. as is the case with the thesis for the doctorate. Especially for the students who intend to apply for a job in the field of oil exploration a sound knowledge of the possibilities and limits of geophysical methods of exploration will prove very useful, as is well known.

An important part of the activity of our department is the constructing and improving of geophysical apparatusses, in order to adapt them to the requirements of geophysical work in our country, especially in the Alps. In our workshop the apparatusses are made ready for use in the laboratory as well as in the field.

B. Terrestrial Magnetism

The main features of the geomagnetic field of our country have been measured and mapped by Brückmann (Lit. 1). The maps show two regional anomalies, one of them lies in the neighbourhood of Lausanne and has been measured in detail by

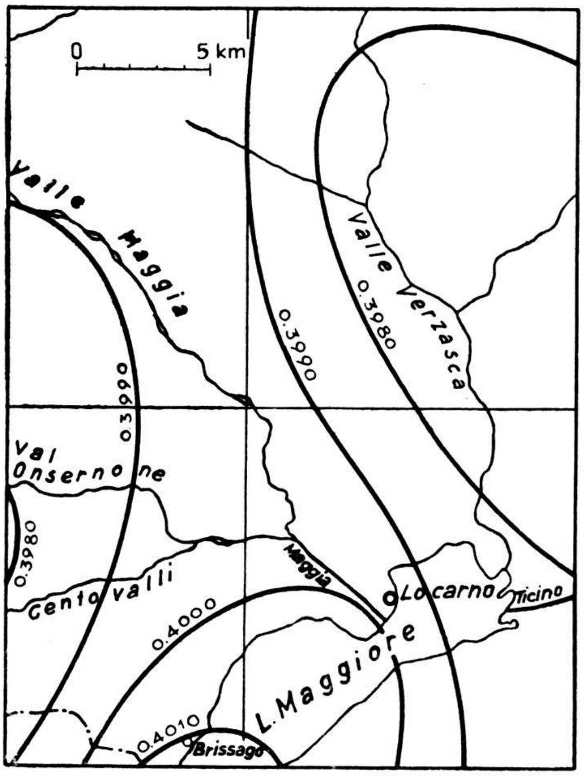

Fig. 1a. Map of the surroundings of Locarno, Switzerland, vertical component of the geomagnetic field, map 1931, based on few stations (Lit. 1).

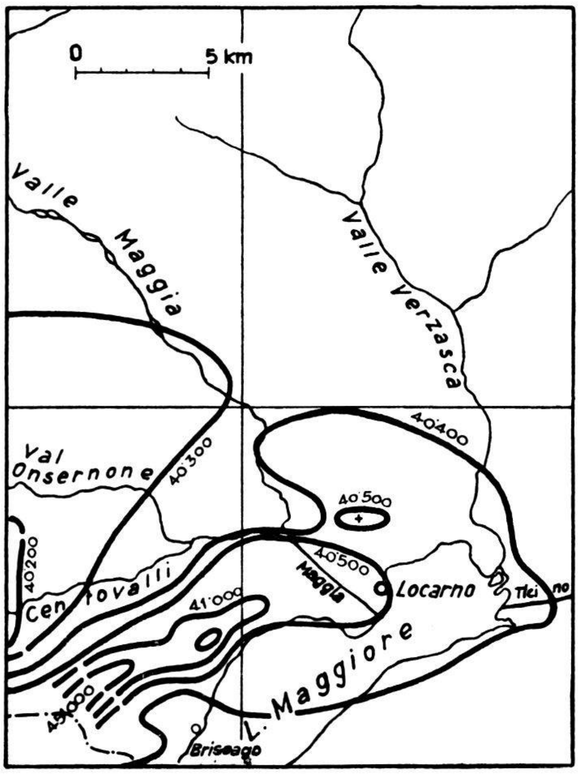

Fig. 1b. Map of the surroundings of Locarno, Switzerland, vertical component of the geomagnetic field, map 1944, based on more stations (Lit. 32).

Mercanton and Wanner (Lit. 27); the other one, to the west of Locarno, has been charted by our Institute (Lit. 12, 32). The anomaly of the vertical intensity of the latter is shown in figs. 1 a and b. Apart from the two regional anomalies just mentioned, there are, especially in the Alps, a number of strong local anomalies due to orebodies or strongly magnetized rocks. Some of these have been mapped by our Institute, i. e. Mont Chemin near Martigny (Lit. 7, 26), Chamoson (Ct. Valais), Erzegg (Ct. Unterwalden), Fianell (Ct. Graubünden), (Lit. 29). By doing these investigations we want to develop our knowledge of the connections between the magnetic and the petrographic properties of rocks (Lit. 10). An example is shown in figs. 2 a, b and c. The different amounts of magnetite contained in the three samples is in close connection with the intensity of magnetization.

At Fianell a small alpine manganese-iron deposit has been investigated. It is of particulary interest that there was found a very small magnetization of the iron ores (mostly hematite), but typically ferromagnetic properties of the manganese ores were discovered which were caused by jacobsite, $(Mn, Fe)_3O_4$, a mineral which, up to the investigations at Fianell, had never been found in Switzerland before.

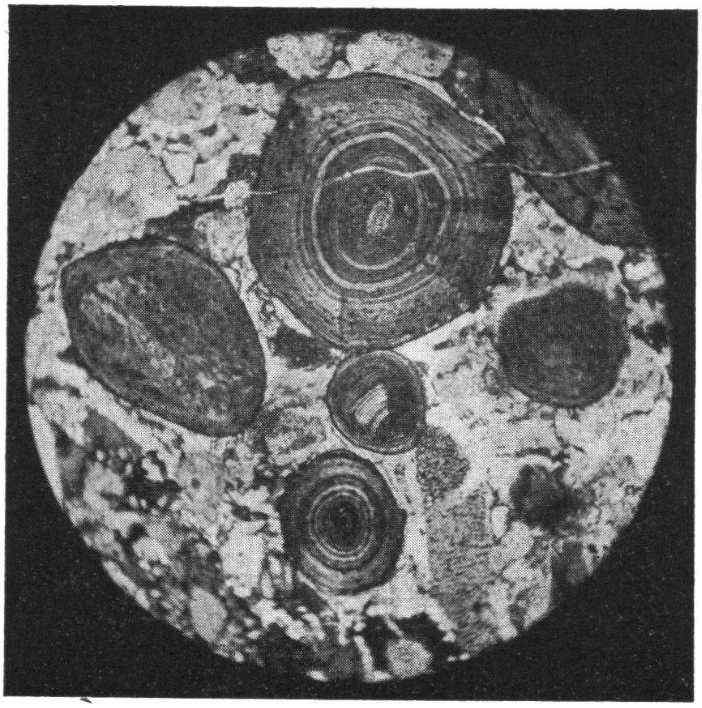

Fig. 2a. Thin section of oolitic chamosite without magnetite × 33.

In many countries we have to map smaller magnetic anomalies together with bigger ones. In such cases, it is impossible to draw the curves for equidistant values systematically. For practical use we work with values of a geometric progression. There are places, though, where ferromagnetic rocks are exposed and therefore magnetic mapping is impossible. At such places a magnetic compass cannot be used for topographic work. It is an important task for our Institute to record all these «prohibited» areas of our country, a task which requires a well founded knowledge of the magnetic properties of rocks.

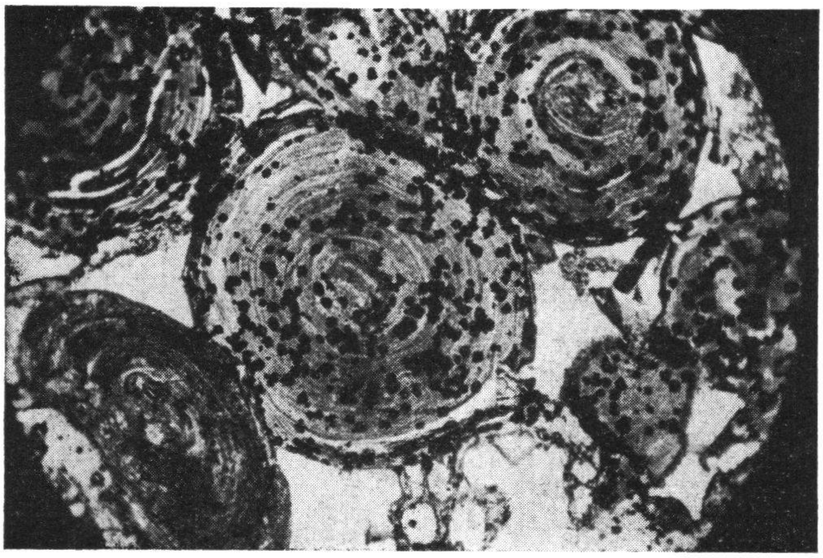

Fig. 2b. Thin section of oolitic chamosite with inclusions of magnetite × 40.

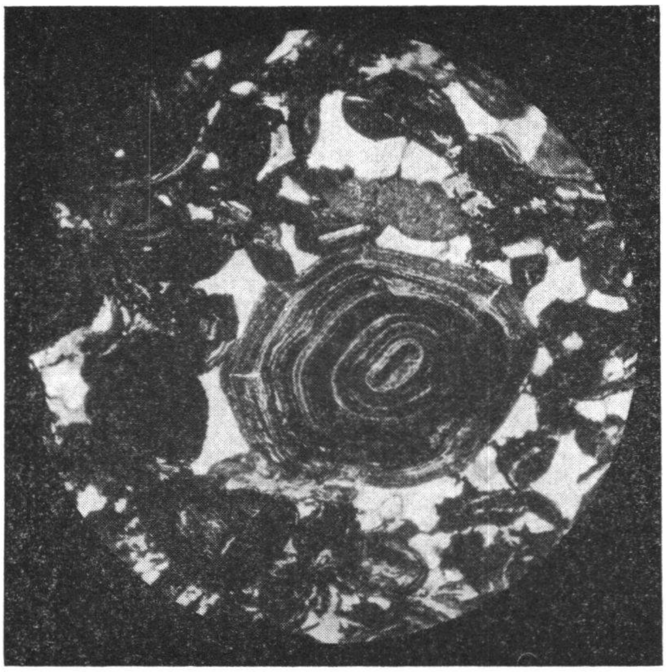

Fig. 2c. Thin section of oolitic chamosite with a great quantity of magnetite × 33.

C. Gravity

Generally, geophysical methods are indispensable in matters of oil exploration. The geophysical work usually begins with a regional gravity-investigation. The results of gravity measurements have to be reduced to a definite level (Bouguer's reduction). For such a reduction the density of the bedrock must be determined first. Instead of measuring the density of rock samples in the laboratory we prefer to-day the well known measuring in the field by using suitable gravity profiles. In mountainous countries, like Switzerland, additional to Bouguer's reduction, topographic corrections have to be considered. However, in a region where the topographic effects are too strong, a determination of gravity anomalies is difficult or impossible, the topographic corrections not being exact enough. At our Institute we have been carrying out investigations on the possibilities of gravity measurements in mountainous regions, and it seems that good results in direct gravimetric density measurements can be achieved too, if good topographic maps are available.

In oil prospecting gravity anomalies have to be interpreted and quickness of the methods of interpretation is more important than highest accuracy. Therefore we have improved a graphical method for two-dimensional gravitational or magnetic fields (table 1 shows part of the gravity reticule) and we extended the method in order to get it applicable for the gravitational or magnetic fields of three-dimensional bodies of any shape (Lit. 11, 13, 14, 17, 18). Interesting examples of application of our methods have been taken (Lit. 30, 19) from the map of Switzerland containing the Bouguer anomalies (Lit. 28).

D. Seismic methods

Amongst the geophysical methods of oil exploration, the seismic methods are of predominant importance. Therefore these methods have been developed above all in countries with big oil deposits, like the U. S. A. On account of the impressive standard of electronics it is possible to-day to build up seismic field

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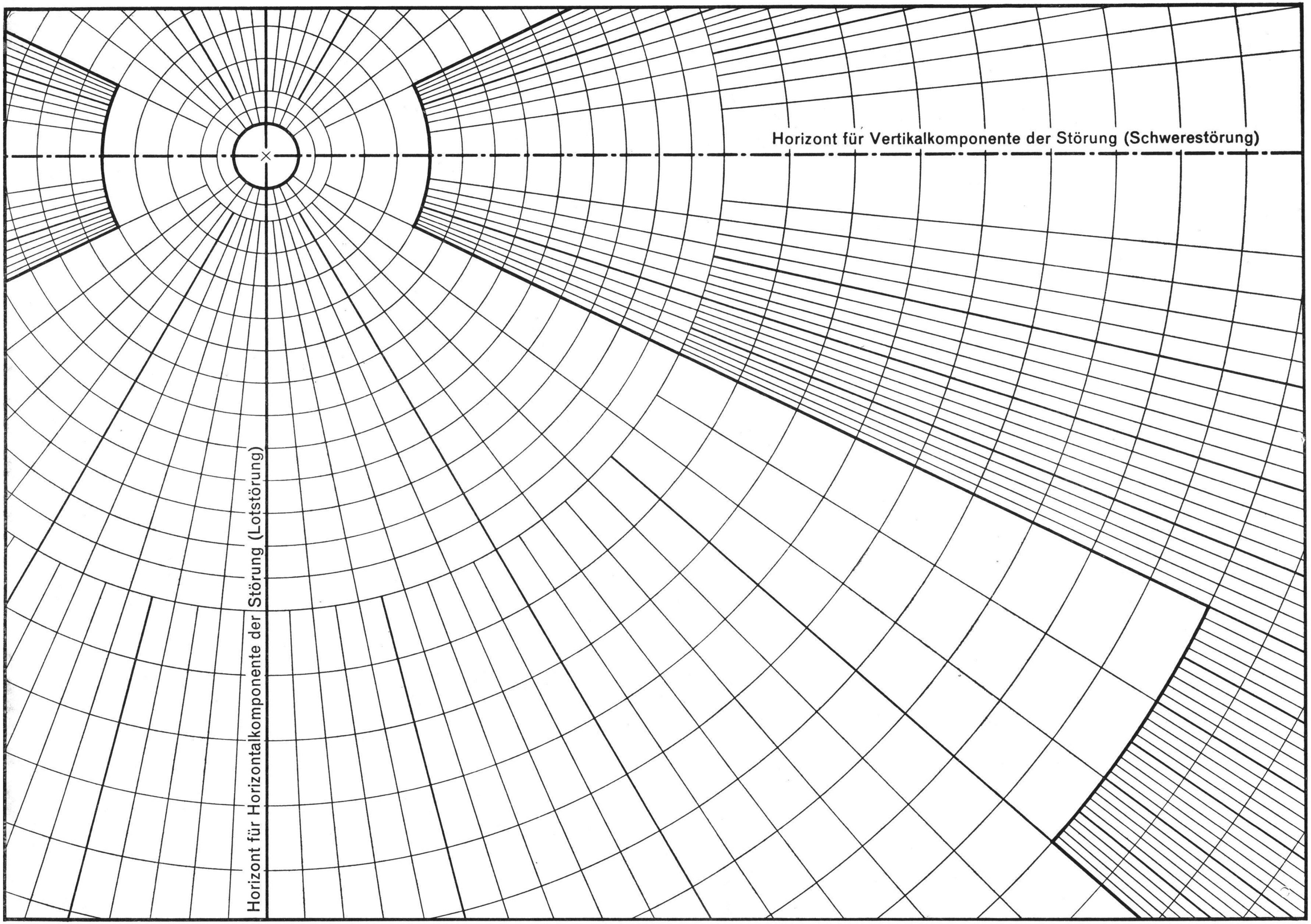

late 1 Part of a diagram for the graphical computation of attraction due to «two-dimensional» masses (from. K. Jung, modified). $w = \varrho \frac{L}{10^5}$ milligals = value of attraction for a «normal» section
ɔw = value of attraction for each of the four sections at the centre. 0,1 w = value of attraction for the sections belonging to the parts of finer subdivision. ϱ = density. 1:L = scale of the drawing used for computation.

instruments of high sensitivity giving results of an accuracy never to be attained by any other geophysical method in the exploration of oil or other deposits. As no oil deposits have been discovered in Switzerland, the construction of electronic seismometers was not started in our country until some years ago, although the standard of our electric and precision-tool industry would certainly have helped us to do it. In order to obtain a basis for instruction and scientific research as well in the field of applied seismic and vibration measurements, we decided, some years ago, to start constructing electronic seismometers in our own workshop, and we were given special financial help for that purpose.[2])

To-day the construction of our electronic seismometers is not yet finished, because we have to make up for the loss of a quarter of a century during which other countries had gained the advantage on us. But the results attained so far enable us to carry out seismic prospections and vibration measurements of high precision. We spent a long time on theoretical investigations before we tackled the actual constructions (Lit. 3, 4, 5, 6, 16, 15, 25).

The seismometers have been designed by M. Weber (Lit. 33, 21, 34) and were built in our workshop with the aid of our experts R. Berger and M. Dietiker. The seismometers will be manufactured for sale by the firm: Physikalische Instrumente Huggenberger, Zürich.

An electronic seismic apparatus consists of one or several «canals» and of different accessories, e. g.: registering instrument, time marker, generator, cable controller, blasting devices etc. The chief parts of a canal are: the mechanical receiver, an amplifier and an oscillographic element. Fig. 3 shows different parts of a four-canal electronic accelerometer built at our Institute.

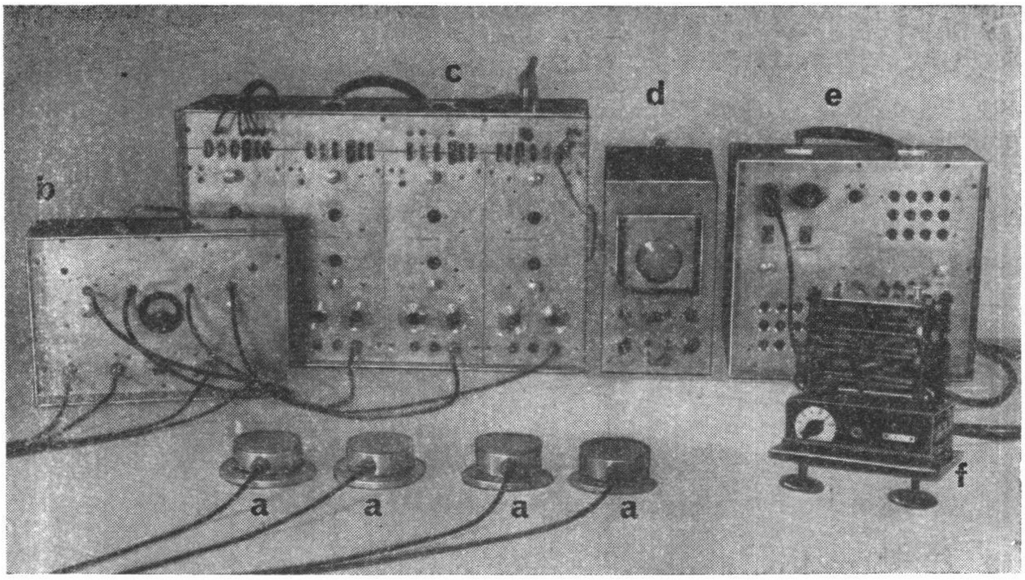

Fig. 3 Four-canal accelerometer

a) Piezo-electric seismometers. b) Control-device. c) Four-canal amplifier. d) Cathode-ray oscillograph. e) Power supply. f) Piezo-electric galvanometers.

As to the aims of our seismic research programme, we have not confined ourselves to attain the standard of the commonly available instruments. We have worked

2) We should like to express our warmest thanks to the executive committees of the following organisations for granting us these credits: Bundesamt für Industrie, Gewerbe und Arbeit (Arbeitsbeschaffungskredit), Eidg. Volkswirtschaftsstiftung, Verband Schweiz. Elektrizitätswerke.

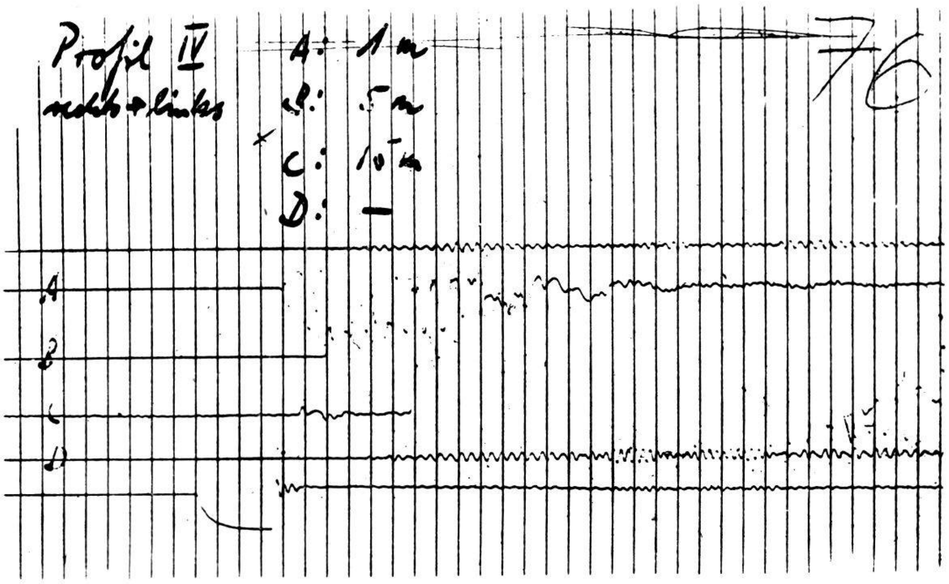

Fig. 4 Seismogram with time-marks $^1/_{800}$ sec.

with an accuracy of travel-time measurement of $^1/_{10\,000}$ sec (figs. 4 and 5). Particular care has been taken to test the different elements of the seismometric canals. Special shaking devices were built in order to test the mechanical receivers. The amplifiers have been stabilized. Therefore the canals are adapted to quantitative vibration measurements with known amplification and accuracy (for an exemple of application see Lit. 2).

Improvements in seismic oil prospecting and of seismic methods in general are based on our progress concerning the knowledge of the elastic properties of soil material and rocks. Therefore the chief object of our seismic research work is the theoretical investigation on elasticity of rocks and soil material combined with experimental researches at our laboratories and in the field.

The following problems have so far been treated theoretically: Lit. 20 deals with the absorption of elastic waves running through matter of non-ideal elasticity. Lit. 22 and 23, deal with the elasticity of porous media and its dependence on the compressibility of the filling of the pores (e. g. sandstone, dry and wet).

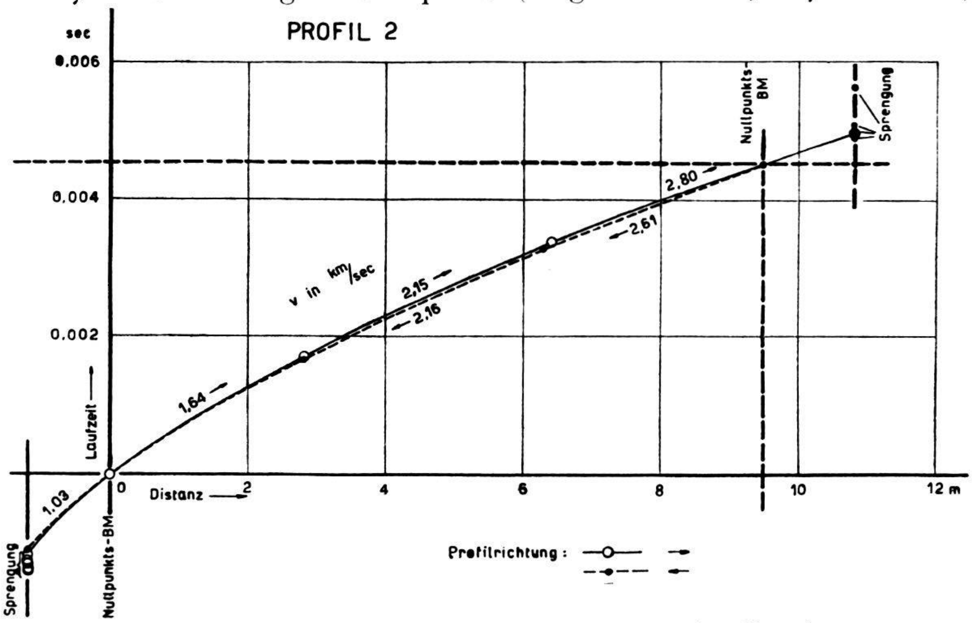

Fig. 5 Travel time curves, taken in two opposite directions

Lit. 24 is a summary of a paper dealing with the elasticity of a hexagonal packing of equal elastic spheres. The packing may be considered as a simple model of sand or gravel, dry or wet. Investigations prove that the packing has the properties of porous material, elastically inhomogeneous and anisotropic. This fact is one of the reasons for the difficulties which, in seismic prospecting, arise in connection with the highest layer of the subground, called the weathering zone.

We have begun to use our seismic instruments for experimental investigations on the elasticity of sandstones and other rocks (figs. 6 and 7). (Lit. 31 and figs. 4, 5, 6 and 7).

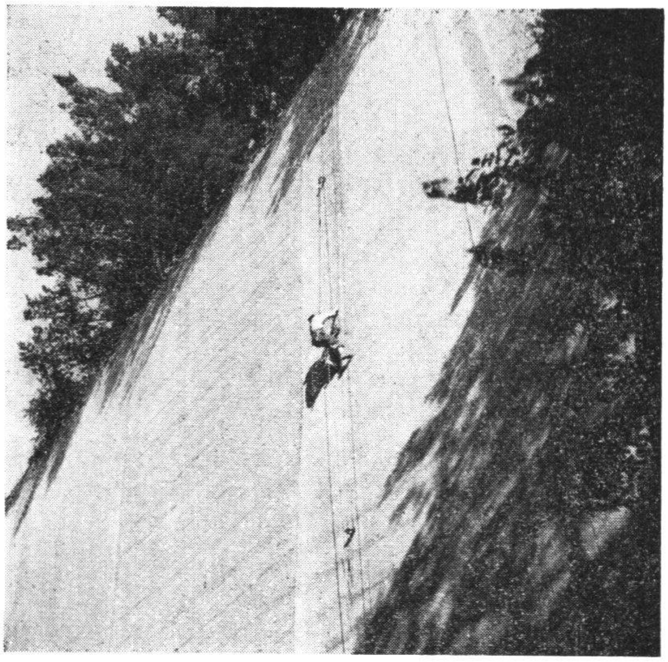

Fig. 6 Fastening of accelerometers at a sandstone-quarry

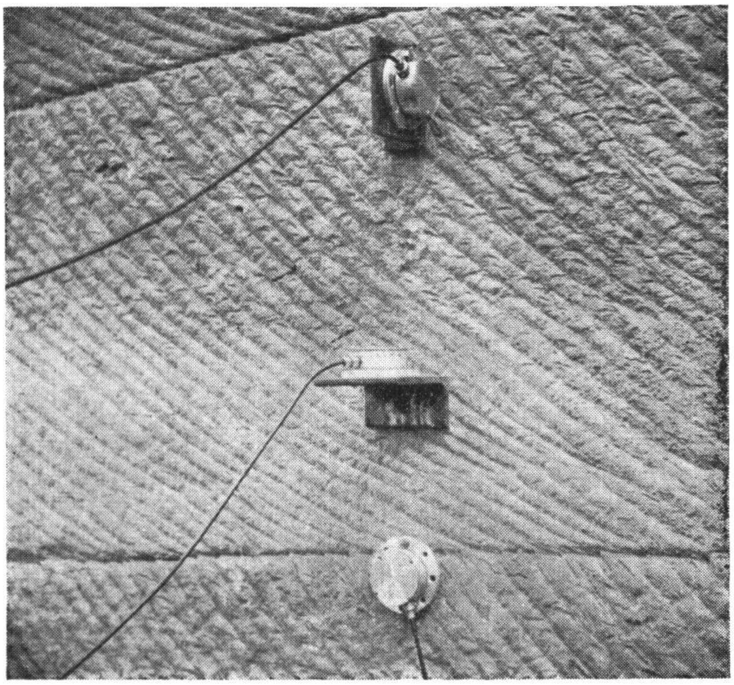

Fig. 7 Three accelerometers tacked on a sandstone-wall

E. Epilogue

We have the intention to carry out further theoretical and experimental investigations and we hope that the results will be a useful contribution towards the improvement of the methods of geophysical prospecting.

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