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# STUDIES ON PHYSICAL PROPERTIES OF SOME SULPHIDE MINERALS No. 1.

## Preliminary Report on Their Rectifiability*

by

Yoshiharu UMEGAKI

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Contents

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## 1. Introduction

Notwithstanding various kinds of investigations so far published in connection with the rectifying or detecting power, a sort of the electric characteristics, of certain elements such as selenium, germanium and so forth and of some artificially prepared metal sulphides or sulphide minerals such as argentite, galena, sphalerite, pyrrhotite, pyrite, chalcopyrite and some others, almost all of them have hitherto been dealt with mainly from industrial or technical point of view and accordingly seem to have been nothing but the description or collection of some experimental data as to an average property of each substance but the reality is that even any presumptions at least remain yet to have been obtained. As far as the subject in question is concerned, crystal structures determined ordinarily from analyses of x-ray refraction patterns also are merely useful for inspection of homogeneity of their own and other properties examined commonly by some electrical or magnetic means can not indicate their discontinuity, in the strict sense of the word, which should be regarded as an important clue to solving the question in hand and will be researched in details.

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* Contribution from Geol. Inst., Fac. of Sci., Hiroshima Univ. No. 24.

It is of course that the author is aiming to establish a theory or theorem concerning the rectifying power of some sulphide minerals by means of pursueing the effects of electric current or wave on the very specimens experimentally as well as theoretically and, at the same time, to deduce, if possible, the energy of their formation from the results thus obtained on one hand, while far more desired is that the problems referring either to paragenic relations among certain sulphide minerals, which were partly reported by the author in another paper, or to genesis of some ore deposits concerned can thereby be solved on the other.

Many thanks must here be stated to M. YUKIMORI, Y. NAGAMINE, M. YAMADA and some members in the author's laboratory, by whose assistances the investigation has been continuously advanced and will probably be achieved in the near future.

## 2. Conditions for experiments

First step of the experiments necessary for exploring the rectifying process of the substances is to scrutinize, whether or not, or to what extent, the specimen may play a rôle as a rectifier or a detector, where, however, extraordinarily complicated phenomena originated by certain electric impulse are expected to take place. There is an unavoidable difficulty in such regard that the same sample can hardly be provided for the same kind of experiments in the similar condition though this requirement is far more stronger than others and it also is surely impossible even to sample each specimen of quite same quality at the begining of every experiment. The experiments with cubic crystals of galena, owing to that this mineral is regarded not only as easiest for sampling but also as show the greatest effect among the others, was put into operation. It, however, is remarkable that there appeared somewhat considerable differences in the results obtained from each experiment merely with a slight shock or stress in the case of sampling, and with polishing in order to give better contact for the mineral-holder, As a result that polarizing property of the specimens appearing in the natural state is combined together with that derived through sampling before electrical treatments, potential difference between a pair of parallel cleavage-planes as well as apparent resistivity in ohms are variable in each case, if the holding conditions of the mineral between the electrode-plates were skilfully regulated. Even though the preceding conditions were similarly maintained, the data attained through further procedures or effects of electrical handling are apt to show more or less variation presumably for such reason that the mineral, which is regarded as a sort of semi-conductor carrying vexatious character, is polarizable to certain extent even with the alternating current of lower frequency and, in consequence, is not used to follow the Ohm's rule strictly. It must be mentioned that the electric currents, whatever they may be, are passable densely along the surface, or through the superficial parts, of the specimen and a slight difference of the surface condition, associationg with discontinuity of the very substance in the inner architecture, also gives rise to complication of the problem in question. In a word, difficulties of inspecting the results obtained experimentally seem, for the present, attributable to that examinations with the samples of same quantity can not completely be repeated twice a condition in quite similar manner. It also is probable that the partial difference of current density in a specimen may bring in the question of importance if its anomaly is assumed to play a rôle of a grid, as it were, placed between the plate aad cathode in the vacuum-tube. Inasmuch as it is sure that the conduction of electric current, though neglegible in the case of weak one such as the radio-waves, increases temperature of the sample. resulting in deviation of the natural potential and rectifying power, this factor must necessarily be prevented to intervene. When some kind of transformer controlling the electromotive force of source-current used for experiments happens to cause distortion of the current, which is oscilloscopically examined, true effects of rectifiability of the mineral in question are hardly ascertainable. On condition that alternating current of certain intensity is rectified through the mineral, the possibility of polarization, furthermore, seems to arise because of anomaly of the pulsive current secondarily originated. Polarization of the specimen is considered as an important element in the rectifying proscess but the effects of polarizability depending on rectification, on the contrary, are used to confuse the results. It seems that condition at terninals, that is, the contact resistivity beween electrodes and the mineral, though it may affect on impedance in the circuit concerned to more or less extent, has no relation directly to the rectifying action itself.

Besides the physical conditions mentioned above, it is necessary to scrutinize the chemical constituents connecting closely with the physical properties of the mineral. Generally, each specimen sampled from the same mass occuring in the same locality is to be composed of the similar constituents but it appears difficult to maintain the chemically similar conditions for the specimens obtained from different localities or from different positions of the same locality. Into the bargain, more detailed examination as to the special elements often accompanying with sulphur in sulphides is of great significance since their inclusion may happen to have an intimate relation to certain electric characteristics.

In the light of considerations on various factors, some preliminary tests regarding the main subject have been carried out, as will be shown in the followings.

## 3. Practice of experiments

(a) *Natural potential*

As already presumed, natural potential of the mineral is considered to have been originated owing to complicated combination of primary or self-polarization occuring in the natural conditions, such as horizontal and vertical distribution in the earth's crust, paragenesis with certain kinds of minerals and so on, with secondary or artificial one brought about through sampling and other electrical manipulations.

Potential difference thus appeared in the mineral, which is maintained between two electrodes of copper-plates, is measurable by means of the Leeds-Northrup potentiometer connecting with Weston's cell and mirror-galvanometer in pursuance of compensation-method. It seems of convenience to measure the natural potential as a clue to interpreting the initial state of the specimen concerned but perplexing is that the results obtained are used to show different values not merely for each specimens of similar property but also for the quite same specimen from the same locality in each experiment, even if several conditions such as shape, size or volume of the specimen, temperature variation and so forth are kept as constant as possible. It also is to be noted that potential difference between both ends of the mineral-grain happens to show gradual variation merely in the course of time at the natural state or simply with closing, and opening the circuit. Probable is that cccasional formation of the circuit even results in additional or subtractive effects on the natural potential or, for instance, in giving a sort of inertia to the dipoles, so to speak. It seems more important that potential difference is also closely connected with the proper, and reverse direction of the mineral, which will later be discussed.

Besides certain unavoidable factors, the relation of natural potential to temperature-variation, which is often regarded as a thermal electromotive force but rather belongs to a different category in the true sense, is quantitatively measurable. The apparatus used for the experiments is constructed as follows: The inner glass-tube of ca. 8 mm. in outer diameter is enclosed with the outer cooling tube of 15.9 mm. in outer diameter wound with a coil of 500 $\mu$H in inductance. Passing certain intensity of a direct or an alternating current through the very coil, variation of atmospheric temperature prevailing in the inner tube is measured at the central part of the coil with an alcohol-thermometer in the course of time and thus the relationship between temperature-variation and lapse of time is determined. Potential difference appearing between both ends of the grain placed at the center of the inner tube is ordinarily measured in the cooling condition and then with increasing the temperature. It is clear that temperature-variation of the specimen maintained in the inner tube may be considerably deviated from those of the coil itself and of atmosphere because of differences among their heat-content. When the specimen in question is cooled with running water passing through the the outer tube, its potential difference, though the coil be heated with passing current, remains to hold the definite value not different from that in the beginning. It, however, is generally remarked that variation of natural potential appearing on the mineral is in proportion to atmospheric temperature in such heating manner as is here adopted.

### (b) *Apparent resistivity*

Considering that the mineral in question is essentially a semi-conducter assumed to have special connections with such elements as resistance, inductance and capacitance, and any currents may not be distributed homogeneously throughout the specimen, it seems actually impossible or rather of no significance to know the apparent resistivity which, however, may affect partly or slightly on impedance of the circuit concerned and, at the same time, give convenience for examining the holding conditions of the sample. It is, as a matter of fact, questionable whether or not measurement of the resistance may be serviceable for the present subject since apparent resistivity of the mineral is to include several factors other than contact-resistivity between the sample and its supporter.

However that may be, the resistance has been mrasured many times in each experiment by means of Kohlrausch's bridge using an alternating current of 800 cycles obtained through induction coil.

Each specimen, though it may be sampled from the same locality, shows not always the same resistivity in the respective case where some one increases the values in ohms and the other is nearly invariable in the lapse of time. It is surely impossible macroscopically to determine which direction may be proper or reverse for the given-current but most probable is that the increase of polarization caused through the partly rectified pulsive current, associating with self-polarization of the mineral, affects again on the apparent resistivity of its own, resulting in the increase or decrease of the initial values. As to this regard, further inspection must be necessary.

### (c) *Polarization*

Owing to complication of factors, it is extremely difficult to find the means theoretically to deduce the causes of self-polarizability of the mineral at the natural state. It, however, is already konwn that certain kinds of sulphide minerals are artificially polarizable and several investigations as to the subject in hand have been so far made public. Analogous phenomena, though they may be generically named as a term *polarization*, should be essentially distinguished one from another because of including different kinds of polarization, which are electronic, atomic, dielectric, orientation- and so forth. It seems in general that polarization, to whatever kind it may be pertaining, is ascribable to the reaction, as it were, of the substance for electric impulse or any other external works and consequently the effects suffered remain to more or less extent after the causes were removed.

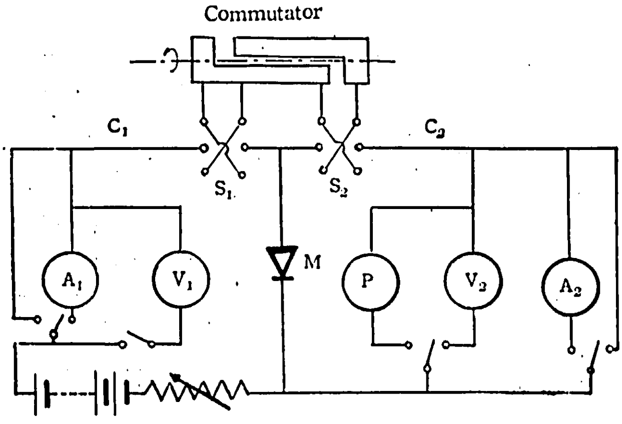

Fig. 1

At any rate, the experiments, which will hereunder be illustrated, are alluded to the polarization of the mineral recognizable in the manner that the secondary current originated with passing the primary one through the specimen is appeared at the moment of opening the circuit of the latter. Quantity of this kind of polarization, though to more or less amount or different in parts, appearing as an inclination to recover the initial state, is measurable as an average effect in the apparatus shown diagrammatically in Fig. 1.

The mineral placed between the holder (M) consisting of two copper-plates is polarizable when the circuit ($C_1$) connected with the source of direct current of certain voltage ($V_1$) and intensity ($A_1$) is closed with the exchanging switch ($S_1$). The current secondarily appeared, as soon as the circuit ($C_1$) is opened, is measured on the circuit ($C_2$) closed with the switch ($S_2$) by means of potentiometer (P), voltmeter ($V_2$) and ammeter ($A_2$). For convenience of continuous meaurements, the circuits ($C_1$) and ($C_2$) are designed to be commutatable about 25 times per second at sixteen terminals of copper-plates alternatively put on a gramophone-record rotating 100 times per minute, a slight difference in duration expected between these two circuits being essentially of no import and accordingly neglected at all.

It must here be repeated that the polarizing effects thus obtained surely depend not merely upon natural potential derived from self-polarizability of the mineral or others but also upon essential characteristics of the specimen in question and thermal effect, though it may be partial or superficial one, originated through electric energy of the source-cutrent.

(d) *Rectification*

(1): Rectified effects appeared with passing alternating current directly through the mineral

On condition that the alternating current dropped from the source of A.C. 100 volts, 60 cycles to certain voltage or intensity through the transformer is inflicted directly on the mineral maintained between the holder, certain pulsive current partly rectified is often appeared in the circuit concerned, and is examinable by means of the apparatus illustrated diagrammatically in Fig. 2.

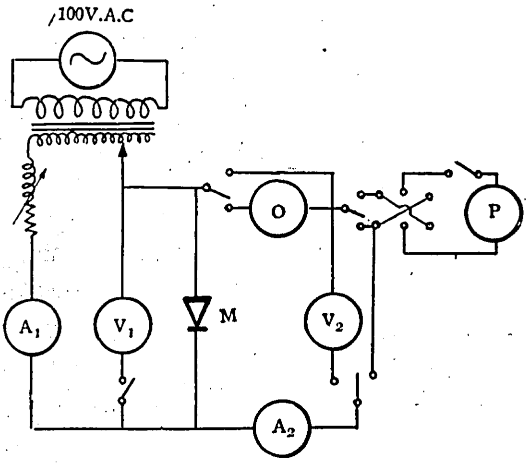

Fig. 2

The primary alternating current can be read on A. C. voltmeter ($V_1$) together with A. C. ammeter ($A_1$) on one hand, while its rectified portion is shown by the reading on the Leeds-Northrup potentiometer as well as D. C. voltmeter ($V_2$) and D. C. ammeter ($A_2$) on the other. Owing to that the mirror-galvanometer attaching to the potentiometer is constructed to require six seconds in a period, direct current only is potentiometrically measurable in this system, no matter how alternating current, if it be weak, may be mingled into the circuit. Cathode-ray oscilloscope (O) provided for inspecting the forms of current-waves is also connected in series with the potential circuit.

Although it is to be noted that the rectified current secondarily appeared may be overlapped or mixed with more or less effects of the alternating current introduced partly from the source and partly from thermal effects, the results attained after 20~30 minutes' duration since closing the circuit concerned are generally used to reach the definite values. More remarkable is that the source current of its own is, on account of construction of the transformer, often distorted when higher voltages than ca. 10 volts is used.

The rectifying effects of the mineral are, of cource, variable with intensity of the primary current but it seems, at the same time. a rule that its efficiency is, beyond certain range, inversely proportional to the voltages and amperes, and the reading on the D. C. meters becomes difficult because of furious adulterating of alternating parts.

It also is noticeable that certain kinds of electric oscillation believed to have been stimulated with passing the alternating current through the mineral may be deducible from the mutual resonance, with the circuit of six-tubes super heterodine connection, peaks of which are recognizable between 700 ~ 1500 kc. within the range of audible frequency.

(2) Rectified effects originated through mutual induction between the mineral and a coil

It is of deep import to have found the resonance, from which, though there is a room for further inspection, the connection including inductance as well as capacitance is presumable in the circuit concerned. In order to find a clue to proving whether or not such a circuit as is expected may be possible, the mineral maintained between the holder (M) is placed in the inner glass-tube enclosed with the outer cooling tube which is wound up with a coil of certain inductance. With passing the alternating current of any given voltage ($V_1$) and ampere ($A_1$) through the coil, the secondary current originated in the circuit including the mineral is measured by means of potentiometer (P), voltmeter ($V_2$) and ammeter ($A_2$), and its form, if need be, is examined with oscilloscope (O), as shown diagrammatically in Fig. 3. It

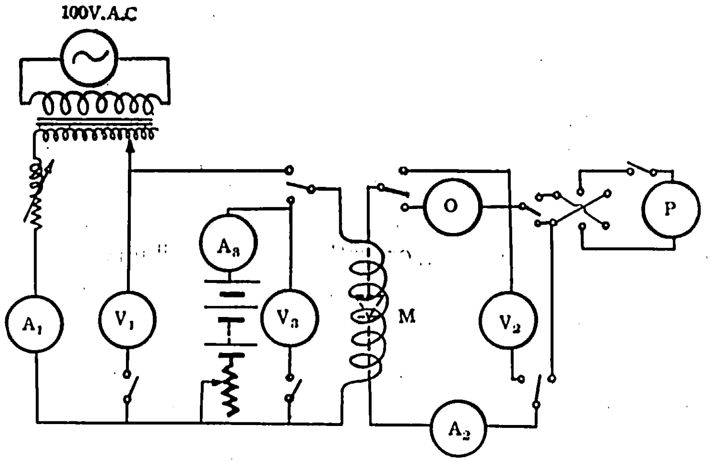

Fig. 3

is to be noted that considerable difference in the secondarily obatined current is clearly recognizable according to whether or not the specimen in the inner tube may be cooled with running water passing through the outer cooling tube. For comparing the relation of temperature-variation to the lapse of time, the circuit of direct current measurable with voltmeter ($V_3$) and ammeter ($A_3$) is connected with the coil.

Atmospheric temperature at the central part of the inner glass-tube without the mineral is gradually increased with heating the coil by direct or alternating current in the course of time and thus the heating velocity of the very coil in the definite condition is preliminarily determinable.

When the sample held between the electrode-plates is inserted into the central part of the inner tube and the coil is heated with direct current of certain intensity, the relation of natural potential of the mineral to temperature-variation is, as already shown, to be clarified.

When the mineral is placed in the same condition as in the former case and the coil is heated with the alternating current of certain intensity, variation of the secondary alternating, and rectified current associating with temperature-inclination is determinable. Although this direct current apparently rectified is simply considered to be composed of the rectified part of the current supposed to appear on account of mutual inductance between the coil and the mineral and to play an important rôle also in polarization, it seems true that the resultant value, because of various factors, should be not simple but rather complicated.

That the mineral is placed in the same condition as before and the alternating current of certain intensity is given on the coil cooled with running water passing through the outer cooling tube similarly results in attaining the secondarily rectified current reaching the constant value somewhat lower than in the former case for about two minutes.

If water vapor is passed through the cooling tube and the similar experiment is again repeated, the results obtained are evidently different form those mentioned in the preceding cases.

Independently of the rectifying action, the fact that an alternating current secondarily induced with the primary solenoid can be originated through the mineral indicates the probability or rather the possibility that the paths of free electrons, whatever their distribution may be, consist of certain circuits similar to the secondary coils.

### (e) *Purity of the mineral*

Purity of the mineral in question was spectroscopically examined. The procedures put into operation are outlined as follows:

The powder of the specimen pulverized as fine as possible is placed in the hole of carbon-electrode which was boiled in aqua regia for about ten days and washed thoroughly. The current-intensity of 5~7 amperes was suitable for emitting sparks between two electrodes separated at the interval of ca. 5 mm. For convenience of comparing each wave-length, arc spectra of iron, carbon and the mineral in question were photographed on the same plate on exporsing for 10~15 minutes.

With all the numerous kinds of elements found in the mineral, it fortunately happens that both selenium and germanium regarded as affect on the rectifying action were hardly recognizable. Details are shown on the Plates 1-7.

## 4. Reference to some experimental data

Some of the representative data, even if those pertaining to exception also are involved, regarding the present subject, are here selected out among collection of the works achieved by the author and his assistants for about two years.

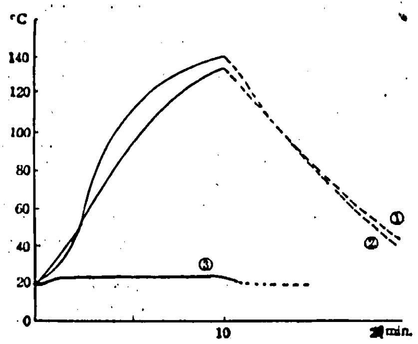

Fig. 4

Fig. 4: Temperature-variation in the inner tube; a) heated for ten minutes with direct or alternating current passing through a coil (1.59mm. in diameter, 550$\mu$H in inductance; similar in each case, if no reference is added to) wound on the outer cooling tube; b) and then allowed to cool; c) or cooled with running water passing through the outer tube at the state same as in the other cases.

①: Heated with 10 V., 680 mA D. C. and allowed to cool.
②: 〃 〃 〃 〃 A. C. 〃 〃 〃 〃
③: Heated with D. C. or A. C. while simultaneously cooled with running water (19.5° C).

These data indicate that thermal effects derived from the heating of coil, even though it may be heated with A. C. or D. C., are almost completely avoidable.

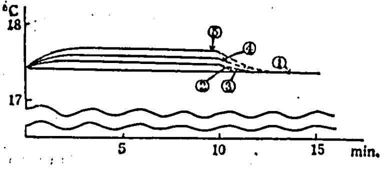

Fig. 5

Fig. 5: Temperature-variation in the inner tube heated with various intensity of D. C., while simultaneously cooled with running water (17.4° C).

①: Heated with 0.6 A. D. C.
②: 〃 〃 0.9 A. 〃
③: 〃 〃 1.2 A. 〃
④: 〃 〃 1.5 A. 〃
⑤: 〃 〃 1.8 A. 〃

The results show that, in spite of heating with D. C., temperature-variation in the inner tube is held within 0.3°C., if the tube is cooled.

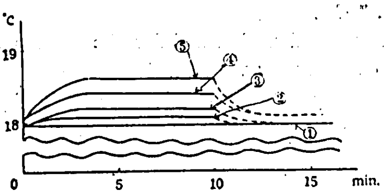

Fig. 6

Fig. 6: Temperature-variation in the inner tube heated with various intensity of A. C., while simultaneously cooled with running water (18.0° C)

①: Heated with 0.6 A.
②: 〃 〃 0.9 A.
③: 〃 〃 1.2 A.
④: 〃 〃 1.5 A.
⑤: 〃 〃 1.8 A.

The results show that, in spite of heating with A. C., temperature-variation in the inner tube is held within 0.6 C., if the tube is cooled.

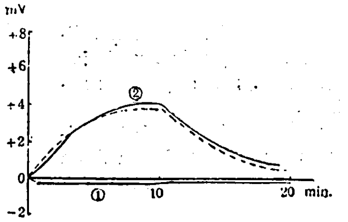

Fig. 7

Fig. 7: Variation of potential difference between a pair of cleavage-planes of the specimen holding 3.36 mm. × 3.09 mm. × 2.96 mm. in volume with increasing temperature when the coil is heated with 12 V., 500 mA. D. C. for ten minutes. Temperature-variation is here represented with time-interval since it is derived from the relation shown in Fig. 4. The edge of 2.96 mm. in length is placed parallel to the axis of the coil.

①: Obtained for one direction (real line) and for the other one (dotted line) opposite to the former, when cooled with running water (18° C).
②: Obtained for one direction and for the other one opposite to the former with heating.

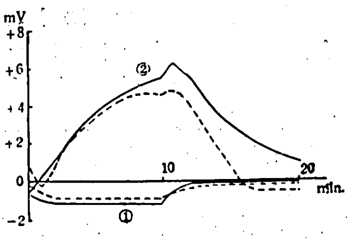

Fig. 8

Fig. 8: Variation of potential difference of the same specimen in the direction parallel to the edge of 3.09 mm. in length in the same condition.

(1): Obtained for one direction and for the other one opposite to the former when cooled with running water (21.0° C.).
(2): Obtained for one direction and for the other one opposite to the former with heating.

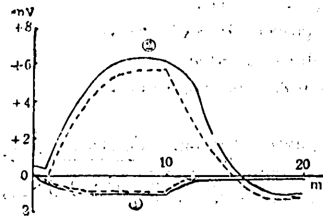

Fig. 9

Fig. 9: Variation of potential difference of the same specimen in the direction parallel to the edge of 3.36 mm. in length in the same condition.

①: Obtaind for one direction and for the other one opposite to the former, when cooled with running water (19.6° C.).

②: Obtained for one direction and for the other one opposite to the former with heating.

Sign for mV. in these cases is defined respectively as positive or negative owing to whether the positive side of potentiometer may coincide with higher potential side of the mineral or not.

The results thus obtained indicate that thermal effects on the mineral seem to be remarkable with heating, but to be neglegible at the cooling state.

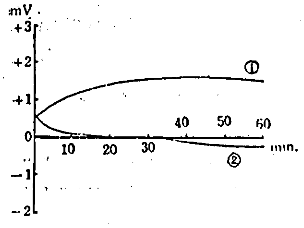

Fig. 10

Fig. 10: Variation of the secondary current polarized with passing the primary direct current through the direction parallel to a four-folded axis of rotation (or normal to cleavage-plane) of the mineral holding 3.17 mm. × 3.29 mm. × 3.77 mm. in volume for an hour.

①: Obtained in the condition that the primary current is passed through the direction parallel to the edge of 3.29 mm. in length and shows gradual variation from 1.95 V., 250 mA. in the beginning to 1.95 V., 125 mA.,; the apparent resistivity of the mineral also varies from 7.5 Ω to 10 Ω.

②: Obtained in the condition that the primary current is passed through the direction opposite to that in the former case and shows gradual variation from 1.94 V., 346 mA. to 1.94 V., 225 mA.; the apparent resistivity of the same mineral varies form 8.5 Ω to 9.0 Ω.

Sign for the polarized current secondarily obtained, in mV., is of course opposite to that for the primary one in each case.

The data indicate that decrease of intensity of the primary current as well as increase of apparent resistivity of the mineral in the course of time are remarkable in each case but the deviation expected from that the experiments were repeated twice with the same specimen assumed to have previously been affected in the preceding treatment is hardly observable in the results attained in the following case. Natural potential measured after the preceding treatment is slightly different from the initial one.

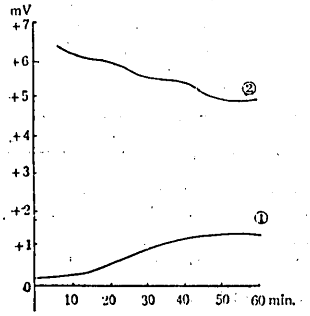

Fig. 11

Fig. 11: Variation of the polarized current through the direction parallel to a four-folded axis of rotation

of the mineral holding 2.72 mm. × 2.80 mm. × 2.90 mm. in volume.

①: Obtained in the condition that the primary current is passed through the direction parallel to the edge of 2.90 mm. in length and shows gradual variation from 1.97 V., 360 mA. in the beginning to 1.96 V., 190 mA ; the apparent resistivity varies from 5.5 Ω to 11.0 Ω.

②: Obtained in the condition that the primary current is passed through the direction opposite to that in the former case and shows gradual variation from 1.96 V., 300 mA. to 1.96 V., 198 mA.; the apparent resistivity varies form 4.0 Ω to 8.0 Ω.

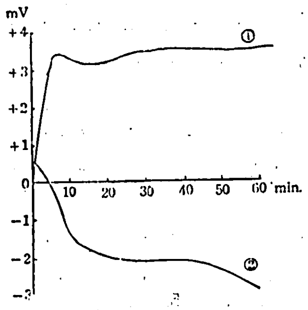

Fig. 12

The data indicate that the after-effect of polarization caused in the former case remains for a while to irregularly higher extent and accordingly the starting voltage in the latter case is exceedingly higher than is expected.

Fig. 12: Variation of the polarized current through the direction parallel to a three-folded axis of rotation of the mineral holding 2.47 mm. × 2.66 mm. × 2.83 mm. in volume.

①: Obtained in the condition that the primary current shows gradual variation from 1.95 V., 250 mA. to 1.95 V., 170 mA.; the apparent resistivity of the mineral varies from 6.5 Ω to 9.5 Ω.

②: Obtained in the condition that the primary current is passed through the direction opposite to that in the former case and shows gradual variation from 1.94 V., 240 mA. to 1.94 V., 100 mA.; the apparent resistivity of the same mineral, from 7.2 Ω to 11.5 Ω.

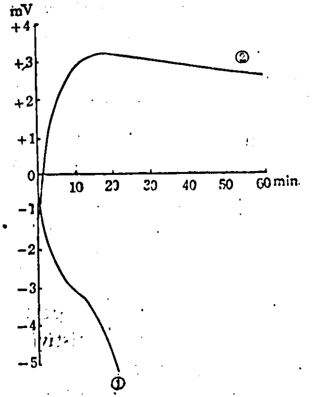

Fig. 13

Fig. 13: Variation of the polarized current through the direction parallel to a three-folded axis of rotation of the mineral holding 1.86 mm. × 1.89 mm. × 2.07 mm. in volume.

①: Obtained in the condition that the primary current shows gradual variation from 1.96 V., 190 mA. to 1.97 V., 149 mA. ; the apparent resistivity varies from 18.0 Ω to 20.0 Ω.

②: Obtained in the condition that the primary current is passed through the direction opposite to that in the former case and shows gradual variationf rom 2.05 V., 520 mA. to 2.00 V., 280 mA.; the apparent resistivity, from 0.1 Ω to 6.5 Ω.

The data indicate that the polarizing effect through certain direction happens to be extremely conspicuous even in the same condition and that occurring in the direction parallel to the three-folded axis of rotation is larger than in the case of the four-folded one.

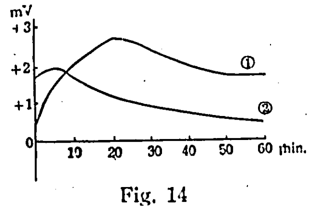

Fig. 14

Fig. 14: Variation of the polarized current through

the direction parallel to a two-folded axis of rotation of the mineral holding 3.17 mm. × 3.27 mm. × 3.77 mm. in volume.

① : Obtained in the condition that the primary current shows gradual varation from 1.94 V., 230 mA. to 1.93 V., 150 mA.; the apparent resistivity varies from 6.5 Ω to 10.0 Ω.

② : Obtained in the condition that the primary current is passed through the direction opposite to that in the former case and varies from 1.94 V., 310 mA. to 1.94 V. 170 mA.; the apparent resistivity, from 4.4 Ω to 10.0 Ω.

This also is the case where the starting voltage at the second step was peculiar because of conspicuous after-effect of polarization at the first step.

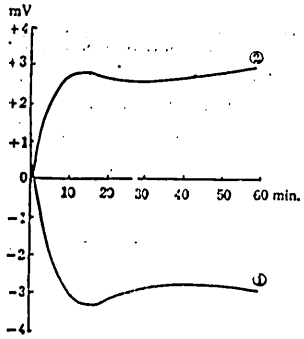

Fig. 15

Fig. 15 : Variation of the polarized current through the direction parallel to a two-folded axis of rotation of the mineral holding 2.72 mm. × 2.80 mm. × 2.90 mm. in volume.

① : Obtained in the condition that the primary current varies from 1.84 V., 750 mA. to 1.84 V., 400 mA.; the appanent resistivity, from 5.0 Ω to 5.8 Ω.

② : Obtained in the condition that the primary current is passed through the direction opposite to that in the former case and varies from 1.81 V., 350 mA. to 1.81 V., 280 mA.; the apparent resistivity, from 4.0 Ω to 6.0 Ω.

Judging from some data mentioned above, there seems no universality predominating in the effects of direct polarization, with which the polarization originated directly by means of direct current is meant, excepting that both smaller grain-size and the direction other than that parallel to the four-folded axis of rotation give comparatively better results.

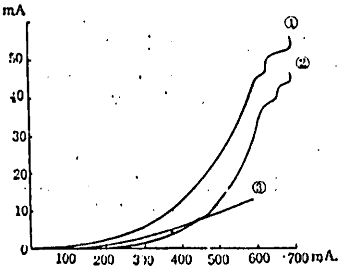

Fig. 16

Fig. 16 : Variation of the directly rectified current appearing through the direction parallel to a four-folded axis of rotation of the mineral holding 3.58 mm. × 3.63 mm. × 3.64 mm. in volume with increasing the intensity of primary alternating current.

① : Obtained in the direction parallel to the edge of 3.63 mm. in length, when the apparent resistivity of the mineral in the begining shows 2.0 Ω.

② : Obtained in the direction parallel to the edge of 3.64 mm. in length, when the apparent resistivity of the mineral in the beginning shows 3.5 Ω.

③ : Obtained in the direction parallel to the edge of 3.58 mm. in length, when the apparent resistivity of the mineral is same as before.

With the current intensity higher than 690 mA, certain amount of alternating portion becomes mingled with rectified current and results in confusing the data expected.

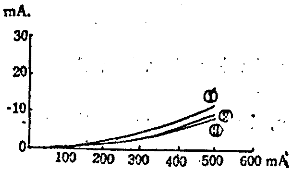

Fig. 17

Fig. 17: Variation of the directly rectified current appearing through the direction parallel to a four-folded axis of rotation of the mineral holding 1.75 mm. × 1.87 mm. × 1.93 mm. × 1.93 mm. in volume with increasing the intensity of primary alternating current.

①: Obtained in the direction parallel to the edge of 1.75 mm. in length, when the apparent resistivity at the initial state shows 10.0 Ω.

②: Obtained in the direction parallel to the edge of 1.93 mm. in length, when the apparent resistivity at the initial state shows 5.5 Ω.

③: Obtained in the direction parallel to the edge of 1.87 mm. in length, when the apparent resistivity at the initial state shows 13.0 Ω.

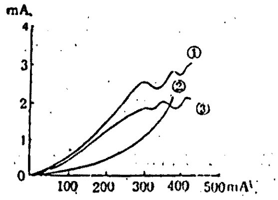

Fig. 18

Fig. 18: Variation of the rectified current appearing through the direction parallel to a four-folded axis of rotation of the mineral holding 1.77 mm. × 1.79 mm. × 1.92 mm. in volume with increasing the intensity of primary alternating current when the voltage is maintained to be 5 V.

①: Obtained in the direction parallel to the edge of 1.92 mm. in length when the apparent resistivity of the mineral is 6.0 Ω.

②: Obtained in the direction parallel to the edge of 1.79 mm. in length when the apparent resistivity of the mineral is 9.0 Ω.

③: Obtained in the direction parallel to the edge of 1.77 mm. in length when the apparent resistivity of the mineral is 10 Ω.

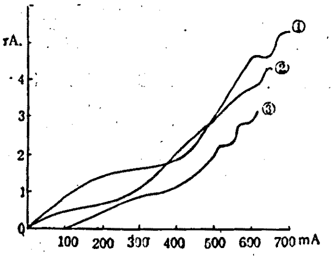

Fig. 19

Fig. 19: Variation of the rectified current appearing through the direction parallel to a four-folded axis of rotation of the same mineral with increasing the intensity of primary alternating current when the voltage is maintained to be 10 V.

①: Obtained in the direction parallel to the edge of 1.92 mm. in length when the resistivity is 12.5 Ω.

②: Obtained in the direction parallel to the edge of 1.79 mm. in length when the resistivity is 5.0 Ω.

③: Obtained in the direction parallel to the edge of 1.77 mm. in length when the resistivity is 3.0 Ω.

The results obtained in two cases can hardly be distinguished one from the other but it seems general that higher voltage of the primary current and longer elongation of the sample are more suitable for attaining higher intensity of the rectified current, and with the definite voltage of primary current, its intensity higher than some hundred mA. results in mixing the alternating part of its own and confusing the rectifying effects.

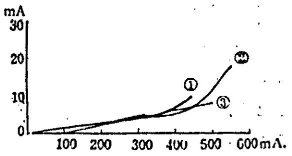

Fig. 20

Fig. 20: Variation of the rectified current appearing through certain directions of the same mineral holding 1.75 mm. × 1.87 mm. × 1.93 mm. in volume

with increasing the intensity of primary current.

①: Obtained in the direction parallel to the edge of 1.75 mm. in length when the resistivity is 10.0 Ω.

②: Obtained in the direction parallel to the edge of 1.93 mm. in length when the resistivity is 5.8 Ω.

③: Obtained in the direction parallel to the edge of 1.87 mm. in length when the resistivity is 13.0 Ω.

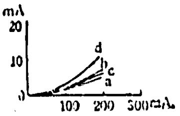

Fig. 21

Fig. 21: Variation of the rectified current in the same condition as in the former case.

a: Obtained in the direction parallel to the first three-folded axis.
b: Obtained in the direction parallel to the second three-folded axis.
c: Obtained in the direction parallel to the third three-folded axis.
d: Obtained in the direction parallel to the fourth three-folded axis.

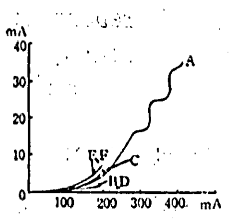

Fig. 22

Fig. 22: Variation of the rectified current in the same condition as in the former case.

A: Obtained in the direction parallel to the first two-folded axis.
B: Obtained in the direction parallel to the second two-folded axis.
C: Obtained in the direction parallel to the third two-folded axis.
D: Obtained in the direction parallel to the fourth two-folded axis.
E: Obtained in the direction parallel to the fifth two-folded axis.
F: Obtained in the direction parallel to the sixth two-folded axis.

With primary current of the intensity higher than 300 mA., it becomes, on account of mingling its alternating portion, difficult to attain the regularly rectified current excepting the mere case regarding the direction parallel to the four-folded axes but the rectified current obtained in other cases is stronger than those in the latter case. These facts seem, at the same time, to suggest that the anomalous distribution of primary current ascribable to the external form or the characteristics of the mineral concerned and any others may be intimately related to the rectifying action.

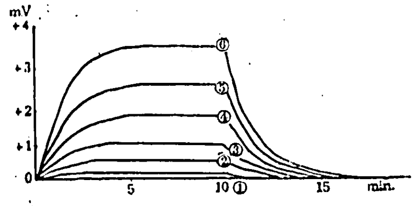

Fig. 23

Fig. 23: Variation of the rectified current originating with mutual induction between the coil used for measuring temperature variation and the mineral holding 3.70 mm. × 3.93 mm. × 4.17 mm. in volume, among which the longest edge is placed parallel to the axis of coil.

①: Obtained when 15.0 V., 0.3 A. A. C. is passed through the coil.
②: Obtained when 26.5 V., 0.6 A. A. C. is passed through the coil.
③: Obtained when 40.0 V., 0.9 A. A. C. is passed through the coil.
④: Obtained when 50.0 V., 1.2 A. A. C. is passed through the coil.
⑤: Obtained when 63.0 V., 1.5 A. A. C. is passed through the coil.
⑥: Obtained when 80.0 V., 1.8 A. A. C. is passed through the coil.

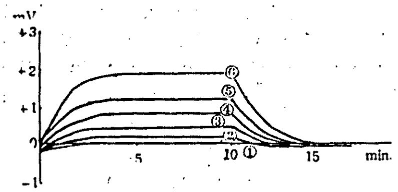

Fig. 24

Fig. 24: Variation of the rectified current obtained quite similarly in the former case excepting that the system is simultaneously cooled with running water (17.5° C.) passing through the outer cooling tube.

①: Corresponding to Fig. 23 ①
②: Corresponding to Fig. 23 ②
③: Corresponding to Fig. 23 ③
④: Corresponding to Fig. 23 ④
⑤: Corresponding to Fig. 23 ⑤
⑥: Corresponding to Fig. 23 ⑥

The data indicate that the secondary current rectified is in proportion to the intensity of primary current passig through the coil and is used to reach the maximal value for about two minutes. As for this regard, its tendency is quite differnt from that of natural potential which is nearly proportional to temperature.

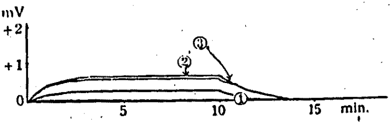

Fig. 25

Fig. 25: Variation of the secondary current rectified similarly to the preceding manners with direction or elongation of the mineral when the primary current is regulated to be 40 V., 0.9 A. A.C.

①: Obtained when the edge of 4.17mm. in length is placed parallel to the axis of coil.
②: Obtained when the edge of 3.93mm. in length is placed parallel to the axis of coil.
③: Obtained when the edge of 3.70mm. in length is placed parallel to the axis of coil.

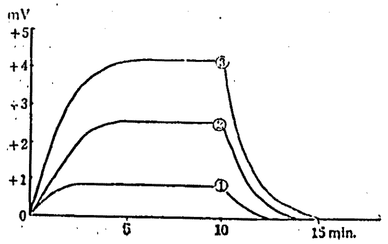

Fig. 26

Fig. 26: Variation of the secondary current rectified simiarly to the preceding manners excepting that the primary current is maintained to be 80 V., 1.8 A. A.C.

①: Corresponding to Fig. 25 ①.
②: Corresponding to Fig. 25 ②.
③: Corresponding to Fig. 25 ③.

The data seem to mean that the rectified current thus obtained is evidently related to direction or elongation of the mineral but it is questionable which factor of the two may be more effective on the rectifying action.

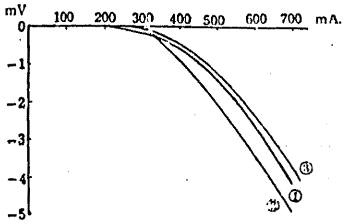

Fig. 27

Fig. 27: Variation of the rectified current with the intensity of primary current passig through a coil of 10mm. in diameter, 168 μH in inductance. when the specimen holds 1.97mm. × 2.08 mm. × 2.34mm. in volume. and the edge of 2.34 mm. in length is placed parallel to the axis of coil.

①, ② and ③: Representing respectively the order of experiments where the rectified current was measured within two minutes, and, in order to regulate the potential difference of the mineral at the starting state, short circuit between both ends of the sample is closed for ten minutes at least between each experiment.

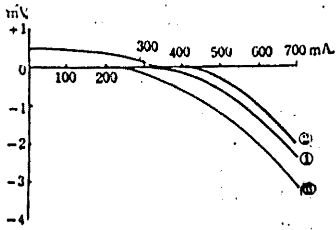

Fig. 28

Fig. 28: Variation of the rectified current with the intensity of primary current passing through a coil of 10mm. in diameter, 30$\mu$H in inductance when the other conditions are quite similar in the former case.

①, ② and ③: Corresponding to those in Fig. 27 respectively.

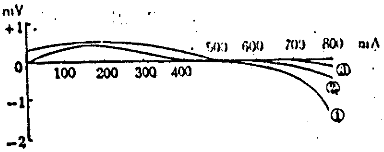

Fig. 29

Fig. 29: Variation of the rectified current with the intensity of primary current passing through a coil of 10 mm. in diameter, 4.8$\mu$H in inductance when the other conditions are quite similar in the former case.

①, ② and ③: Corresponding to those in Fig. 27 respectively.

These results clarify that higher inductance of the coil concerned is more effective on rectification or resonance of the mineral. It is because that these examinations have been practised to inspect the minimal inductance of the primary coil necessary for its mutual induction with the mineral and thus to find, if possible, the inductance of the mineral of its own, assumed to be derived from its inner architecture, as well as the physical meanings of such specific direction, for instance, screw-axis or others, as defined geometrically.

## 5. Summarization of the concept

That the mineral is used to reveal various or undecided quantities of natural potential is considered as is attributable partly to its career spent in Nature and partly to the external works suffered from sampling from its occurring state. Since the apparent histerisis, though be not the case with the mineral in question, may undeniably be derived from electric anomaly such as polarization or rectification, it seems impossible completely either to retain the initial state of the mineral after certain treatment or to repeat the similar experiment in the same condition for each specimen. To measure the potential difference together with apparent resistivity, which may not directly be connected with the rectifying action, seems necessary whereas the rectified current secondarily obtained is believed to have a delicate relation to polarizability and vice versa.

After all, further investigation as to the mutual relation or induction of the mineral with various frequency of electric waves is surely indispensable for solving rectification process and for extending it numerically. It, for the present, seems to have been clarified that the rectifying or detecting circuit is assumed to be formed in such manner as is combined with polarization originated with passing free electrons through complicated paths resembling certain coils, as if the directional difference of resistance, so to speak, between two kinds of metal-plates in the electrolytic rectifier were corresponding to the polarizing action of the minerals, and accompanying with the effects of capacitance, thongh they may be a slight amount, electric oscillation showing the regularly formed sine-curve grows to be asymmetrically distorted until rectified.

It may be problematical why miscelaneous kinds of the impurities included in the specimen were neglected at all but the existence of elements other than selenium and germanium is believed of no significance as to the present subject.

Plate 1

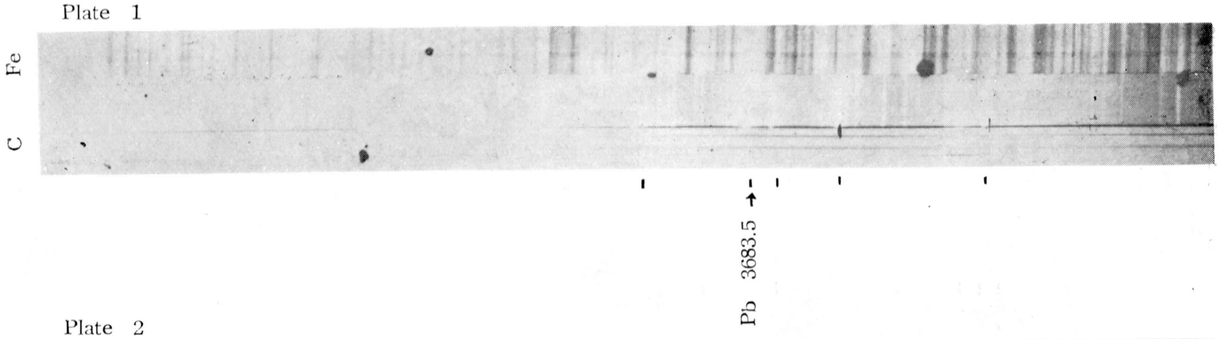

Plate 2

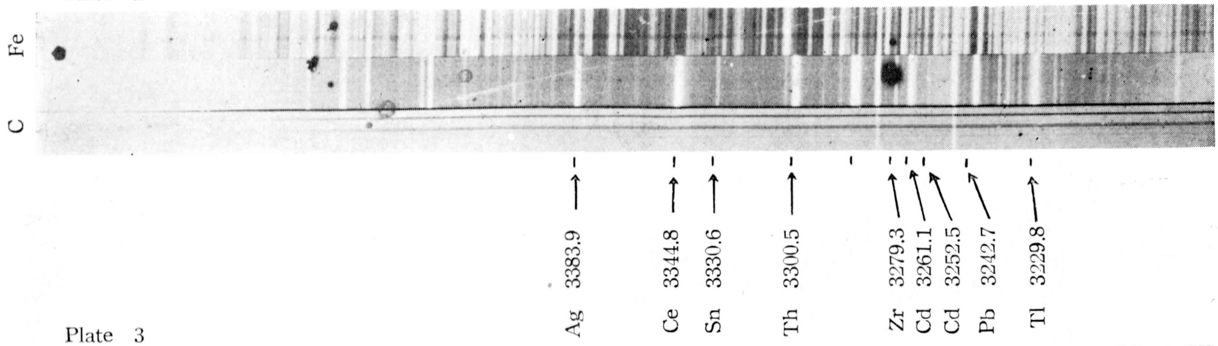

Plate 3

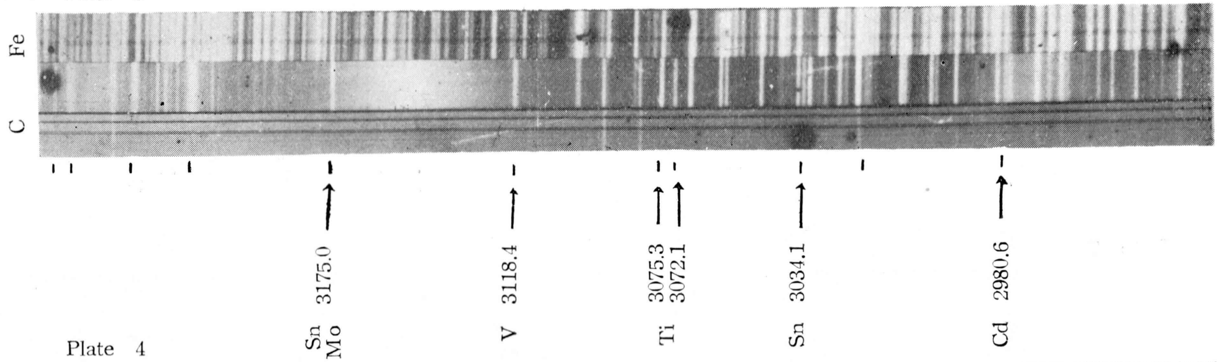

Plate 4

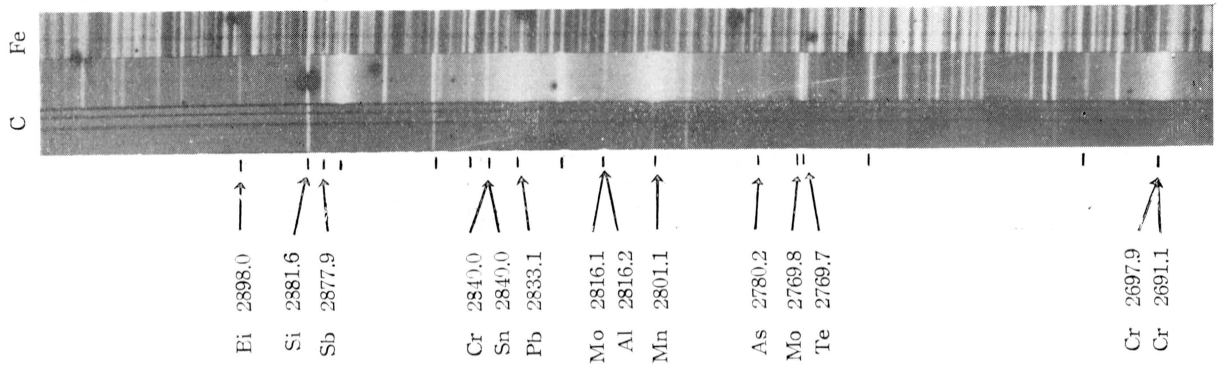

Plate 5

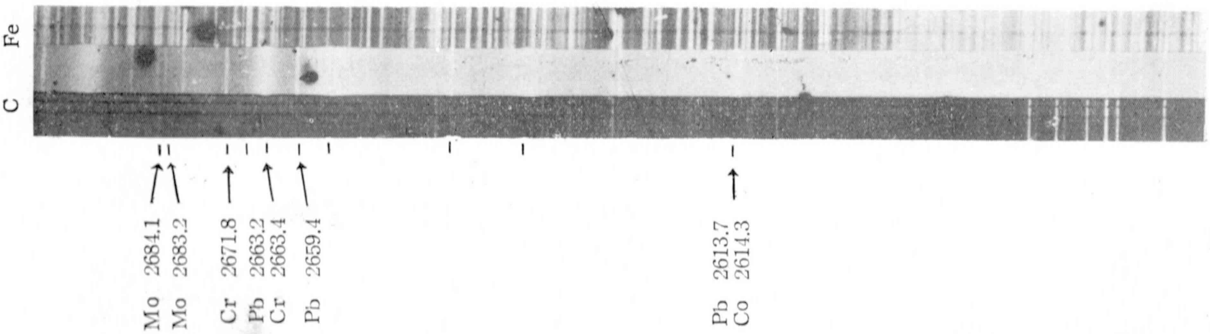

Plate 6

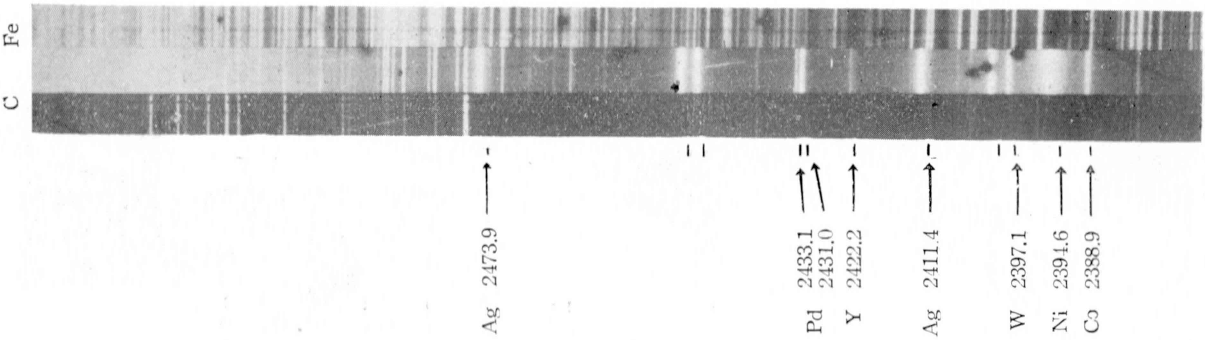

Plate 7