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# GSJ Optical Emission Direct-Reading Spectrograph for the Analysis of Geological Materials

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**Abstract**

An optical emission direct-reading spectrograph, which is specially designed for the analysis of major and minor elements of geological materials, was recently set up at the Geological Survey of Japan. Analytical programs, spectral lines and detailed specifications of the instrument are described. Applications to the analysis of geological materials are also demonstrated.

## 1. Introduction

An optical emission direct-reading spectrograph: a direct-reader was recently set up at the Geological Survey of Japan for the analysis of a wide variety of geological materials. Up to 40 photomultipliers are installed in the GSJ direct-reader for a wide element coverage in the analytical specimens. Analytical programs, spectral lines and detailed specifications of the instrument are described.

The direct-reader was programmed for: silicate major (10 elements), silicate minor (11 elements), iron and manganese oxide (18 elements) and sulfide ore (14 elements) with five different kinds of internal standards and a mercury monitor.

Six basic exitation circuits are available: high voltage AC spark, DC arc, spark ignited uni-arc, spark ignited low voltage AC arc, high voltage AC arc and multisource.

Applications of the direct-reader to the geological materials have been reported by many workers (AHRENS and TAYLAR, 1961; ASTM, 1968; ANDO, 1965; DANIELSSON, LUNDGREN and SUNDKVIST, 1959; DANIELSSON and SUNDKVIST, 1959a, 1959b; GOVINDARAJU, 1960, 1963a, 1963b; HASLER, 1952; HASLER and BARLEY, 1952a, 1952b; MATSUMOTO, 1960; ROUBAULT, ROCHE and GOVINDARAJU, 1962/1963; SCHWANDER and MARLING, 1967; THOMPSON and BANKSTON, 1969; UNITED NATIONS, 1963; VOROB'EV and RUSANOV, 1964).

## 2. Instrumentation

### 2.1 Direct-reader

The direct-reader is a Nippon Jarrel-Ash "Compact Atomcounter" model 66000, a concave grating spectrograph with an electronics system.

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Spectrograph

| | | |
|---|---|---|
| Mounting: | | 1.5 m Paschen-Runge |
| Grating: | concave, | 1200 groove/mm, replica |
| Wavelength range: | | 2000—8000 Å |
| Dispersion: | 5.45 Å/mm | (1st order), 2.7 Å/mm(2nd order) |
| Resolution: | | 0.2 Å |
| Entrance slit: | | 25 $\mu$m (width), vertical |
| Exit slit: | | 75 $\mu$m (width), vertical |

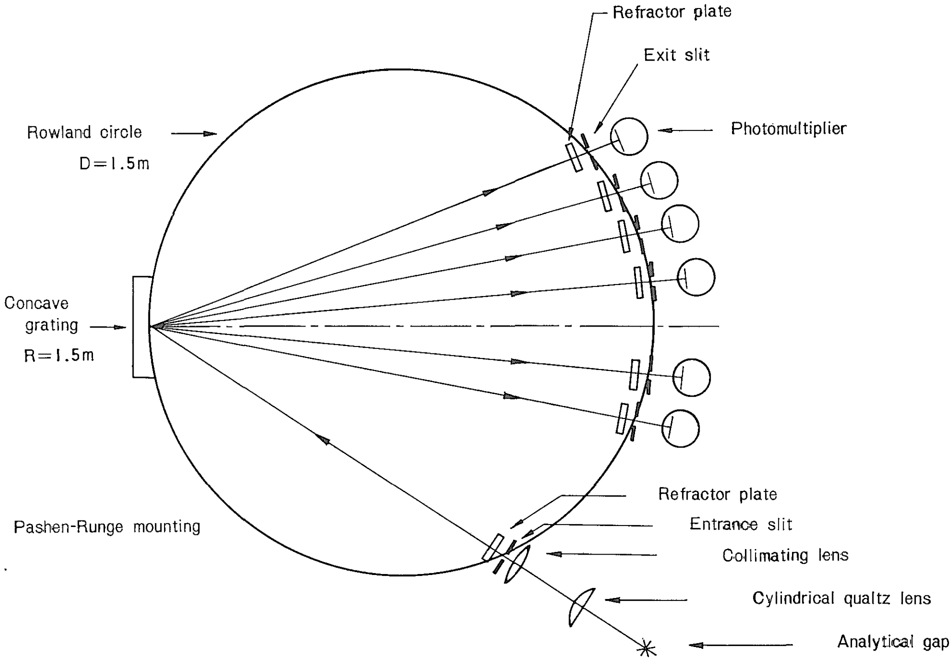


Fig. 1 Optical system, Compact Atomcounter.

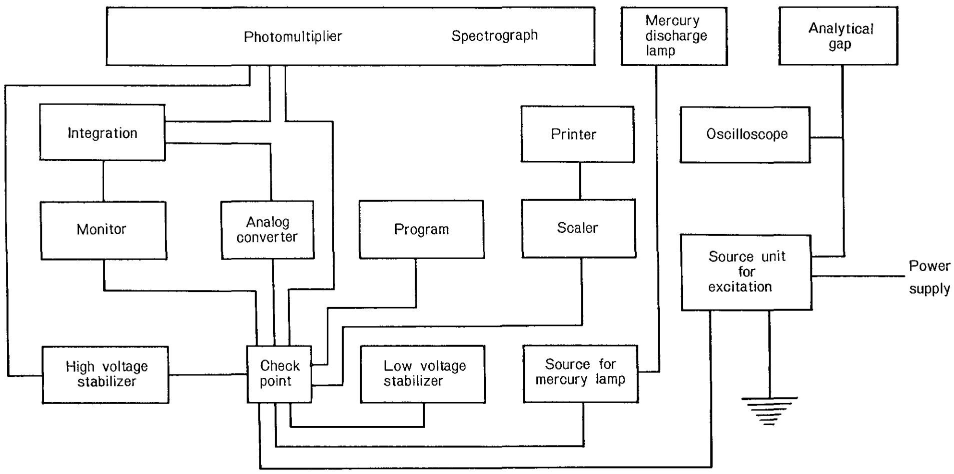


Fig. 2 Constitution of the Compact Atomcounter.

A light beam passes through the vertical entrance slit with refractor plate and to the grating. Exit slits with refractor plates are placed at the chosen wavelength positions on the focal curve of the spectrograph. Spectral energies are received by photomultipliers and integrated for a single explosure. Sequential readout electronics system permits the indication of integrated values both on a disital scaler (5 digits) and also on an automatic typewriter for up to 22 channels. An optical system is shown in Fig. 1 and a construction of the Compact Atomcounter in Fig. 2.

## 2.2 Analytical program

Four analytical programs: silicate major (A), silicate minor (B), iron and manganese oxide (C) and sulfide ore (D) are designed. Programs, wavelengths of both analytical and internal standard lines, and concentration ranges of analytical components are summarized in Table 1.

Table 1 Analytical program—1.

| No. | Component, | Wavelength (Å) | Concentration range (%) | | | |
|---|---|---|---|---|---|---|
| | | | (A) Silicate major | (B) Silicate minor | (C) Iron & manganese oxide | (D) Sulfide ore |
| 1 | $SiO_2$ | 2516 x 2 | 20 -80 | | | |
| 2 | $Al_2O_3$ | 3961 x 2 | 0.5 -20 | | | |
| 3 | $Fe_2O_3$ | 2599 x 2 | 0.5 -30 | | 1 -30 | 0.01-10 |
| 4 | MnO | 2933 x 2 | 0.02- 5 | | | 0.01- 5 |
| 5 | CaO | 3158 x 2 | 0.6 -20 | | | |
| 6 | MgO | 2783 | 0.25-40 | | | |
| 7 | $TiO_2$ | 3685 | 0.1 - 5 | | 0.1- 5 | |
| 8 | $P_2O_5$ | 2149 | 0.1 - 1 | | 0.1- 5 | |
| 9 | $Na_2O$ | 3302 x 2 | 0.1 -10 | | | |
| 10 | $K_2O$ | 4044 | 0.1 -10 | | | |
| 11 | Ni | 3414 x 2 | | 0.0007-0.1 | 0.0007- 5 | 0.0007- 1 |
| 12 | Co | 3453 x 2 | | 0.0007-0.1 | 0.0007- 5 | 0.0007- 1 |
| 13 | Cr | 4254 | | 0.001 -0.1 | 0.001 - 5 | |
| 14 | V | 3202 x 2 | | 0.0025-0.1 | 0.0025- 1 | |
| 15 | Cu | 3247 x 2 | | 0.0003-0.1 | 0.0003- 1 | 0.0003- 1 |
| 16 | Pb | 3683 x 2 | | 0.002 -0.1 | 0.002 - 1 | 0.002 - 1 |
| 17 | Ba | 5535 | | 0.015 -1.0 | | |
| 18 | Rb | 7800 | | 0.001 -0.1 | | |
| 19 | B | 2497 | | 0.0025-0.1 | | |
| 20 | Zr | 3391 | | 0.0015-0.1 | | |
| 21 | As | 2349 | | | 0.05 - 5 | 0.05 - 5 |
| 22 | Zn | 3345 x 2 | | | 0.05 - 5 | 0.05 - 5 |
| 23 | Sn | 2706 | | | 0.002 - 1 | 0.002 - 1 |
| 24 | Si | 2881 | | | 0.01 - 3 | |
| 25 | Al | 3944 | | | 0.01 - 3 | |
| 26 | Mo | 3170 | | | 0.001 - 1 | |
| 27 | Mg | 2798 x 2 | | | 0.0003- 1 | |
| 28 | In | 4511 | | | 0.001 - 1 | 0.001 - 1 |
| 29 | Sb | 2598 | | | | 0.01 - 5 |
| 30 | Bi | 3067 x 2 | | | | 0.001 - 1 |
| 31 | Cd | 3261 | | | | 0.002 - 1 |
| 32 | Ag | 3280 x 2 | | | | 0.0003- 1 |
| 33 | Mn | 2949 | | | 0.1 -25 | |
| 34 | Sr | 4607 | | 0.0015-0.1 | | |
| 35 | Hg | 4358 | Monitor | | | |
| 36 | Li | 4972 I | I.S.#5 | | | |
| 37 | Sr | 3380 II x 2 | I.S.#4 | | | |
| 38 | Co | 4867 I | I.S.#3 | | | |
| 39 | Pd | 3481 I | I.S.#2 | | | |
| 40 | Pd | 2658 II x 2 | I.S.#1 | | | |

Table 2 Analytical program—2.

Program (A) Silicate major

| Element | Wavelength(Å) | Channel No. | Dynode No. |
|---|---|---|---|
| Si | 2516 x 2 | 1 | 1 |
| Al | 3961 x 2 | 2 | 2 |
| Fe | 2599 x 2 | 3 | 3 |
| Mn | 2933 x 2 | 4 | 4 |
| Ca | 3158 x 2 | 5 | 5 |
| Mg | 2783 | 6 | 6 |
| Ti | 3685 | 7 | 7 |
| P | 2149 | 8 | 8 |
| Na | 3302 x 2 | 9 | 9 |
| K | 4044 | 10 | 10 |

Program (B) Silicate minor

| Element | Wavelength(Å) | Channel No. | Dynode No. |
|---|---|---|---|
| Ni | 3414 x 2 | 1 | 11 |
| Co | 3453 x 2 | 2 | 12 |
| Cr | 4254 | 3 | 13 |
| V | 3202 x 2 | 4 | 14 |
| Cu | 3247 x 2 | 5 | 15 |
| Pb | 3683 x 2 | 6 | 16 |
| Ba | 5535 | 7 | 17 |
| Rb | 7800 | 8 | 18 |
| B | 2497 | 9 | 19 |
| Zr | 3391 | 10 | 20 |
| Sr | 4607 | 11 | 34 |

Program (C) Iron and manganese oxide

| Element | Wavelength(Å) | Channel No. | Dynode No. |
|---|---|---|---|
| Ni | 3414 x 2 | 1 | 11 |
| Co | 3453 x 2 | 2 | 12 |
| Fe | 2599 x 2 | 3 | 3 |
| V | 3202 x 2 | 4 | 14 |
| Cu | 3247 x 2 | 5 | 15 |
| Pb | 3683 x 2 | 6 | 16 |
| Ti | 3685 | 7 | 7 |
| P | 2149 | 8 | 8 |
| As | 2349 | 9 | 21 |
| Zn | 3345 x 2 | 10 | 22 |
| In | 4511 | 11 | 28 |
| Mn | 2949 | 12 | 33 |
| Cr | 4254 | 13 | 13 |
| Sn | 2706 | 14 | 23 |
| Si | 2881 | 15 | 24 |
| Al | 3944 | 16 | 25 |
| Mo | 3170 | 17 | 26 |
| Mg | 2798 x 2 | 18 | 27 |

Program (D) Sulfide ore

| Element | Wavelength(Å) | Channel No. | Dynode No. |
|---|---|---|---|
| Ni | 3414 x 2 | 1 | 11 |
| Co | 3453 x 2 | 2 | 12 |
| Fe | 2599 x 2 | 3 | 3 |
| Mn | 2933 x 2 | 4 | 4 |
| Cu | 3247 x 2 | 5 | 15 |
| Pb | 3683 x 2 | 6 | 16 |
| Sb | 2598 | 7 | 29 |
| Bi | 3062 x 2 | 8 | 30 |
| As | 2349 | 9 | 21 |
| Zn | 3345 x 2 | 10 | 22 |
| In | 4511 | 11 | 28 |
| Cd | 3261 | 12 | 31 |
| Ag | 3280 x 2 | 13 | 32 |
| Sn | 2706 | 14 | 23 |

Internal standard and monitor

| Element | Wavelength(Å) | Channel No. | Dynode No. |
|---|---|---|---|
| Pd | 2658 x 2 | I.S.#1 | 40 |
| Pd | 3481 | I.S.#2 | 39 |
| Co | 4867 | I.S.#3 | 38 |
| Sr | 3380 x 2 | I.S.#4 | 37 |
| Li | 4972 | I.S.#5 | 36 |
| Hg | 4358 | Monitor | 35 |

Table 3 Specifications of optical and photoelectric systems.

| Element | Wavelength (Å) | Exit slit width, (μ) | Refractor plate* | Mirror type** | Channel No. A | B | C | D | I.S. | Dynode No. | Photo-multiplier |
|---|---|---|---|---|---|---|---|---|---|---|---|
| P | 2149 | 75 | Q | | 8 | | | | | 8 | HTV R 106 |
| As | 2349 | 75 | Q | | | | 9 | 9 | | 21 | R 106 |
| B | 2497 | 75 | Q | | | 9 | | | | 19 | R 106 |
| Sb | 2598 | 75 | Q | V | | | | 7 | | 29 | R 106 |
| Sn | 2706 | 75 | Q | | | | 14 | 14 | | 23 | R 106 |
| Mg | 2783 | 75 | Q | H | 6 | | | | | 6 | R 106 |
| Si | 2881 | 75 | Q | | | | 15 | | | 24 | R 106 |
| Mn | 2949 | 75 | Q | V | | | 12 | | | 33 | R 106 |
| Mo | 3170 | 75 | Q | | | | 17 | | | 26 | R 106 |
| Cd | 3261 | 75 | Q | | | | | 12 | | 31 | R 106 |
| Zr | 3391 | 75 | Q | | | 10 | | | | 20 | R 106 |
| Pd | 3481 | 75 | Q | | | | | | #2 | 39 | R 106 |
| Ti | 3685 | 75 | Q | | 7 | | 7 | | | 7 | R 106 |
| Al | 3944 | 75 | Q | | | | 16 | | | 25 | R 106 |
| K | 4044 | 75 | G | | 10 | | | | | 10 | R 136 |
| Cr | 4254 | 75 | G | | | 3 | 13 | | | 13 | R 106 |
| Hg | 4358 | 25 | G | V | | | | | #Monitor | 35 | R 106 |
| In | 4511 | 75 | G | H | | | 11 | 11 | | 28 | R 106 |
| Sr | 4607 | 75 | G | | | 11 | | | | 34 | R 106 |
| Co | 4867 | 75 | Q | | | | | | #3 | 38 | R 106 |
| Li | 4972 | 75 | G | V | | | | | #5 | 36 | R 106 |
| Si | 2516 x 2 | 75 | C | | 1 | | | | | 1 | R 106 |
| Fe | 2599 x 2 | 75 | C | | 3 | | 3 | 3 | | 3 | R 106 |
| Pd | 2658 x 2 | 75 | C | | | | | | #1 | 40 | R 106 |
| Ba | 5535 | 75 | G | | | 7 | | | | 17 | 931 A |
| Mg | 2798 x 2 | 75 | C | V | | | 18 | | | 27 | R 106 |
| Mn | 2933 x 2 | 75 | C | | 4 | | | 4 | | 4 | R 106 |
| Bi | 3067 x 2 | 75 | C | | | | | 8 | | 30 | R 106 |
| Ca | 3158 x 2 | 75 | C | | 5 | | | | | 5 | R 106 |
| V | 3202 x 2 | 75 | C | | | 4 | 4 | | | 14 | R 106 |
| Cu | 3247 x 2 | 75 | C | V | | 5 | 5 | 5 | | 15 | R 106 |
| Ag | 3280 x 2 | 75 | C | | | | | 13 | | 32 | R 106 |
| Na | 3302 x 2 | 75 | C | H | 9 | | | | | 9 | R 106 |
| Zn | 3345 x 2 | 75 | C | | | | 10 | 10 | | 22 | R 106 |
| Sr | 3380 x 2 | 75 | C | V | | | | | #4 | 37 | R 106 |
| Ni | 3414 x 2 | 75 | C | | | 1 | 1 | 1 | | 11 | R 106 |
| Co | 3453 x 2 | 75 | C | H | | 2 | 2 | 2 | | 12 | R 106 |
| Pb | 3683 x 2 | 75 | C | | | 6 | 6 | 6 | | 16 | R 106 |
| Rb | 7800 x 2 | 75 | G | | | 8 | | | | 18 | R 136 |
| Al | 3961 x 2 | 75 | C | | 2 | | | | | 2 | R 106 |

*) Q:Quartz G:Glass C:Corax
**) Reflection mirror type, V:vertical H:horizontal

A selector switch permits to select instantly up to five different kinds of internal standard lines for each analytical program. Li I 4972 Å is chosen for the volatile elements, atomic lines (Co I 4867 Å; Pd I 3481 Å) and ionized lines (Sr II 3380 Å; Pd II 2658 Å) are chosen for the arc and spark exitations as internal standard. Choise of spectral lines was made on the basis of reported data (literatures are mentioned in chapter 1).

Specification details with corresponding wavelengths are shown in Tables 2, 3. Arrangement of photomultipliers along the focal curve of the spectrograph is shown in Fig. 3. Four holizontal mirrors are used to deflect the light beam to the photomultipliers. Seven photomultipliers are hunged holizontally and vertical mirrors deflect up the light beam to the photomultipliers (Fig. 4). Other photomultipliers receive spectral energy directly without auxiliary separate mirrors. Number of photomultipliers: 40 is a nearly maximal limit for this spectrograph, hence best lines have not been chosen for some elements by the room limitation around the focal curve.

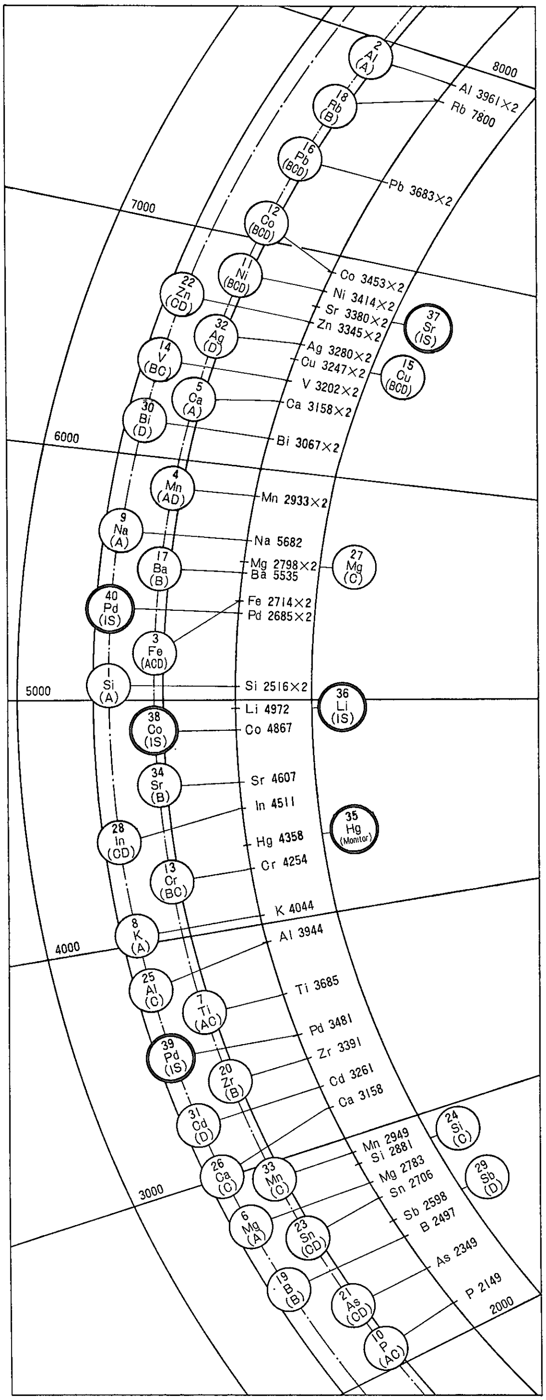


Fig. 3 Arrangement of photomultiplier.

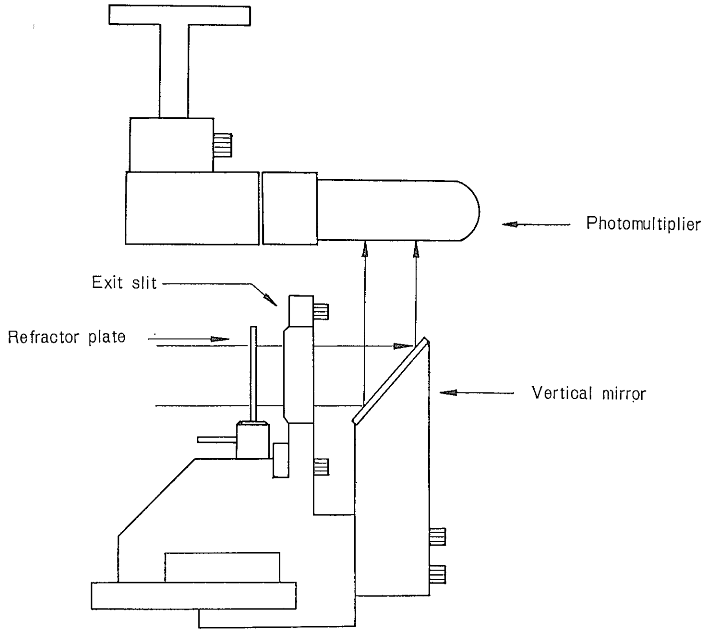


Fig. 4 Some photomultipliers are hunged holizontally and vertical mirrors are used to deflect the light beam to the photomultiplier.

## 2. 3 Exitation source

The Compact Atomcounter is installed combined with Jarrell-Ash Ebert 3.4 m plane grating spectrograph as shown in Fig. 5. Both varisource units in the direct-reader

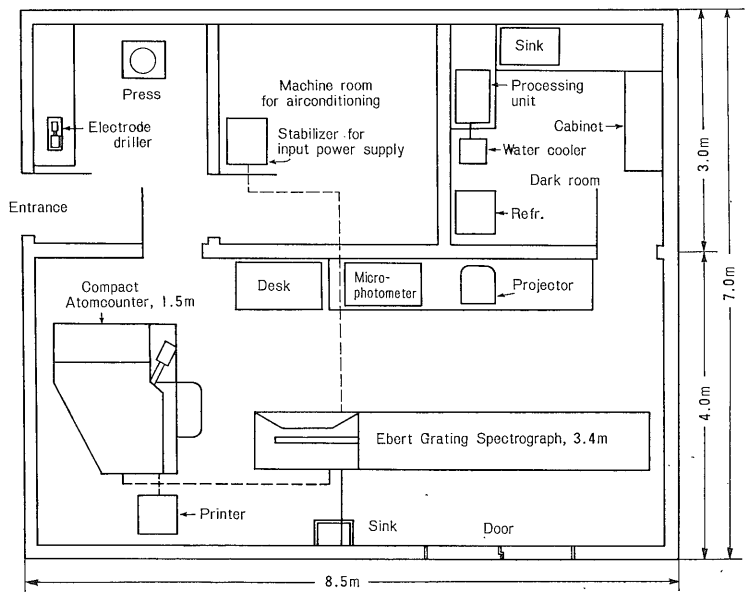


Fig. 5 Floor plan for a spectrochemical laboratory around a Ebert 3.4 m grating spectrograph and a Compact Atomcounter.

Table 4 Parameter specification of varisource units for the GSJ direct reader.

| | |
|---|---|
| Nakanodenshi Multi-source Unit | |
| Multi-source | Input: Single phase, 200V<br>Open circuit voltage: 1KV<br>Inductance, microhenries: 50 and 360<br>Capacitance, microfarad: 2-60, controlled by combination of steps, 2, 5, 5, 10, 20 and 20<br>Resistance, ohms: 0-200, controlled by combination of steps, residual, 2, 3, 10, 10, 25, 50 and 100 |
| JAco Varisource Unit, Custom 4075 | |
| High voltage AC spark | Input: Single phase, 230 V at 20 amps<br>High voltage transforming rating: 7.5 KVA<br>Primary voltage control: Variable auto transformer<br>Open circuit secondary voltage: 31 KV peak<br>Maximum continuous current: 20 RF amps<br>Added primary resistance, ohms: 6 steps, 37-13<br>Secondary inductance, microhenries: 6 steps, residual, 40, 155, 310, 625 and 1250<br>Capacitance, microfarads: 5 steps, .0025, .005, .0075, .010 and .015<br>Secondary resistance, ohms: 4 steps, residual, 1, 2 and 3 |
| DC arc | Input: Single phase, 230 V, 45 amps<br>Open circuit terminal voltage: 280 V DC<br>Output current rating: 2.5-30 amps<br>Current control: Motor driven variable core reactor<br>Ignition: Tesla coil<br>AC ripple component: Average 3% |
| Spark ignited uni-arc | Input: Single pfase, 230 V, 25 amps<br>Open circuit terminal voltage: 280 V DC<br>Output current rating: 1.0-8.0 amps<br>Current control: 24 step resistor<br>Ignitor: AC spark |
| Spark ignited low voltage AC arc | Input: Single phase, 230 V, 25 amps<br>Open circuit voltage: 280 V<br>Output current rating: 2.0-10.0 amps<br>Current Control: 24 step resistor, 1/3 amp steps<br>Ignition: AC spark |
| High voltage AC arc | Input: 230 V, 60 amps<br>Open circuit voltage: 4800 and 2400 V<br>Output current rating: 0.8-2.7 and 1.65-5.5 amps<br>Current control: Motor driven variable core reactor<br>Ignition: Tesla coil |

side (Multisource, Nakanodenshi) and in the Ebert side (Jaco Custom 4075) are available. A selector switch permits to select up to six basic exitation circuits. Parameter specification of varisource units is given in Table 4.

## 3. Application to the analysis of geological materials

### 3.1 Silicate major

Powdered rock sample (0.5 g) is mixed with a flux (2 g, Johnson Matthey spectrographic flux, a fused mixture of lithium tetraborate: 60%, strontium tetraborate: 30% and cobalt oxide: 10%) and funneled into a graphite crusible. A mixture is fused in a electric furnace at 1000°C for 5 minutes. After cooling a glass bead is easely pried from the botton of crusible. The bead is crushed with a tungsten carbide mortors (Elis mortor

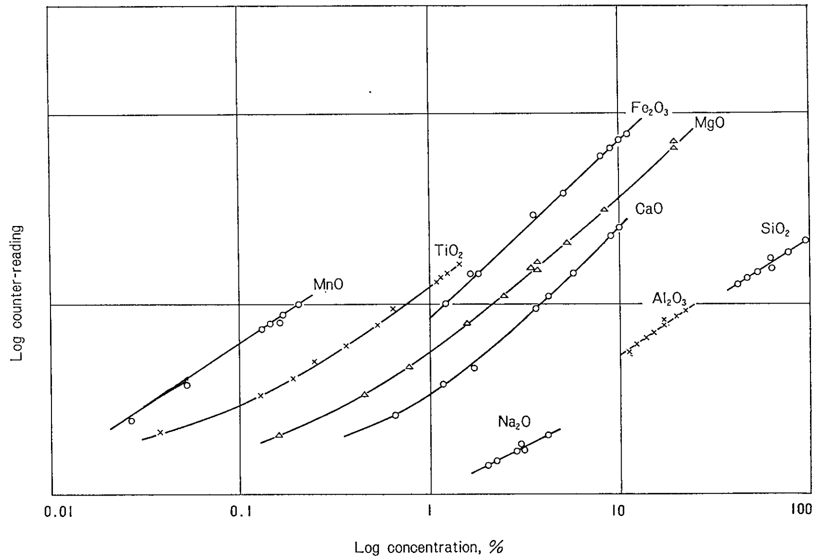


Fig. 6 Working curves for some major elements, by pellet-high voltage spark method. Standard pellets of known concentrations are prepared with geochemical reference samples: W-1, G-1, G-2, GSP-1, AGV-1, BCR-1, DTS-1, PCC-1, SY-1, JG-1, JB-1 (Flanagan, 1973).

and a hand mortor), and is sieved with a 200 mesh screen. An equal amount of (0.5 g) glass powder and a graphite powder for pellet are mixed with a Spex mixer mill using a tungsten carbide capsule for 5 minutes. A mixture is then pressed into a 1/2″ diameter pellet at 80,000 lbs/inch$^2$ for 10 seconds. High voltage spark method is applied for the exitation (30 KV, 0.015 $\mu$F, 0.9 mH, 2 $\Omega$, Ir=4.0 A, 4 Brks/H.C. electrode gap 3 mm, exposure 20 sec. or I.S. counting control, sample pellet: upper electrode, sharpen end graphite rod: lower electrode). Good precisions of about 3% in the coefficient of variation were obtained for the determination of $SiO_2$, $Al_2O_3$, $Fe_2O_3$, MnO, CaO, MgO, $TiO_2$ and $Na_2O$ using Co 4867 Å, Co 3453 Å and Sr 3380 Å as internal standard lines. Working curves for the rock components are shown in Fig. 6.

## 3.2 Minor element

Detection limits for the minor elements in D.C. arc method are presented in Table 1 (lower values in the concentration ranges), and some typical example of working curves in Fig. 7 (D.C. arc: 230 V, 8 A, electrode gap 3 mm, preburn 3 sec., exposure 60 sec.).

One disadvantage inherent in the photoelectric spectrometer is a difficulty in background estimation (Thompson and Bankston, 1969). After a exposure, the total dark current of photomultiplier tube and background signals from the D.C. arc exitation are integrated together with the spectral energy of analytical line. Integrated value of dark current and D.C. radiation signals reaches appreciable amount for prolonged exposure. Photomultiplier responce is linear, however as well known the back ground radiation

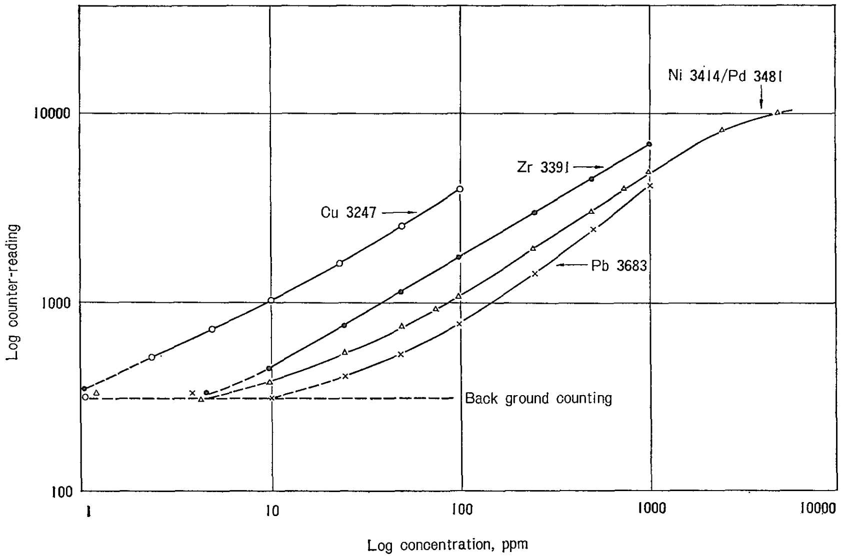


Fig. 7 Working curves for some minor elements, by powder D.C. arc method.
Standard: $SiO_2$+NaCl (1+1) base

of D.C. arc exitation is not stable hence the measurement and correction of background are necessary.

Background correction can made by monitoring on the focal curve one or several positions which are free from the line and band interference. In the analytical programs B, C and D, if a complete lacking of a element is found in the samples, a photoelectric channel which is chosen for the element is usable for the background monotoring. D.C. arc background radiation for each photoelectric channel can measure by arcing of blank samples which has the same major composition and the same buffer material. Two internal standard lines Pd 2658 Å and Pd 3481 Å can serve for the good background monitoring by conversion of an electric connection.

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## References

AHRENS, L. H. and TAYLAR, S. R. (1961) Spectrochemical analysis. 2nd ed., 454 p., Addison-Wesley, London.

American Society for Testing Materials (1968) Methods for emission spectrochemical analysis. 919 p., ASTM, Phyradelphia.

ANDO, A. (1965) The direct-reader for the analysis of nonmetallic materials. *Analysis and instruments* (Bunseki-Kiki), vol. 3, no. 5, p. 12–20 (in Japanese).

DANIELSSON, A., LUNDGREN, F. and SUNDKVIST, G. (1959) The tape machine-I, -A new tool for spectrochemical analysis. *Spectrochim. Acta*, vol. 15, p. 122–125.

——— and SUNDKVIST, G. (1959a) The tape machine-II, -Applications using different kinds of isoformations. *Spectrochim. Acta*, vol. 15, p. 126–133.

——— and ——— (1959b) The tape machine-III, -Notes on useful corrections in spectrochemical analysis with the tape technique. *Spectrochim. Acta*, vol. 15, p. 134–137.

FLANAGAN, F. J. (1973) 1972 values for international geochemical reference samples. *Geochim. Cosmochim. Acta*, vol. 37, p. 1189–1200.

GOVINDARAJU, K. (1960) Contribution a l'analyse spectrochimique des roches silicatées et des silicates naturels, dosage des éléments majeurs. *G.A.M.S.*, p. 221–245.

———(1963a) Nouveaux progrès dans le dosage des éléments majeurs des roches par spectrométrie photo-électrique, avec le quantomètre A.R.L. *G.A.M.S.*, p. 217.

———(1963b) Dosage des éléments de trace dans les roches silicatées par spectrométrie photo-électrique avec le quantomètre A.R.L. *G.A.M.S.*, p. 319–326.

HASLER, M. F. (1952) Quantometry in 1952. *Spectrochim. Acta*, vol. 6, p. 69–79.

——— and BARLEY, F. (1952a) Quantometric analysis of iron slags. *Spectrographer's News Letter* (ARL), vol. V, no. 2, p. 1–2.

——— and ——— (1952b) The direct-reading analysis of steel-making slags. ARL Bibliography, p. 1–7.

MATSUMOTO, C. (1960) Studies on the spectrochemical analysis of silicates (8th report) -Problems on the quantitative analysis of silicates-. *Bunko Kenkyu*, vol. 8, p. 74–82 (in Japanese with English abstract).

ROUBAULT, M., de la ROCHE, H. and GOVINDARAJU, K. (1962/1963) L'analyse des roches silicatées par spectrométrie photoélectrique au Quantométre A.R.L. et son contrôle par des roches étalons. *Science de la Terre*, Tome IX, no. 4, p. 339–371.

SCHWANDER, H. and MARLING, J. B. (1967) Quantitative analysis of the major and minor constituents of silicate rocks and minerals by means of direct reading spectroscopy. Jarrell-Ash reprint no. 67, p. 1–5.

THOMPSON, G. and BANKSTON, D. (1969) Atechnique for trace analysis of powdered materials using the d.c. arc and photoelectric spectrometry. *Spectrochim. Acta*, vol. 24B, p. 335–350.

UNITED NATIONS (1963) Proceedings of the seminor on geochemical prospecting methods and techniques. Mineral resources development series no. 21, p. 52–56, United Nations, New York.

VOROB'EV and RUSANOV, A. K. (1964) Quantometric and spectrographic analysis of silicate rocks. *Zavodsk. Lab.*, vol. 30, p. 945–949 (C. A., vol. 61, 12614, 1964).

## 地質試料分析用の GSJ・直読式発光分光分析装置について

安藤 厚・池田 喜代治

### 要　旨

地質試料を分析する目的でプログラムされた直読式発光分光分析装置（ダイレクトリーダー）が地質調査所（GSJ）に設置された．この装置の分析プログラム，分析線，光学系，光電子増倍管の配置および発光源などの概要と，地質試料分析への適用例をあげた．

分析プログラム

A) 珪酸塩主成分　10元素 (Si, Al, Fe, Mn, Ca, Mg, Ti, P, Na, K)

B) 珪酸塩微量成分　11元素 (Ni, Co, Cr, V, Cu, Pb, Ba, Rb, B, Zr, Sr)

C) 鉄・マンガン酸化物　18元素 (Ni, Co, Fe, V, Cu, Pb, Ti, P, As, Zn, In, Mn, Cr, Sn, Si, Al, Mo, Mg)

D) 硫化鉱　14元素 (Ni, Co, Fe, Mn, Cu, Pb, Sb, Bi, As, Zn, In, Cd, Ag, Sn)

内部標準元素線として，原子線 (Li 4972 Å, Co 4867 Å, Pd 3481 Å) およびイオン線 (Sr 3380 Å, Pd 2658 Å) 計5本を選択した．これらの内標線は上記の各分析プログラムと任意に組み合わせることができる．

装置は，パッシエン-ルンゲ方式，1.5 m 凹面回折格子・直読式分光分析装置（コンパクト・アトムカウンター，日本ジャーレル・アッシュ社製）．波長範囲 2,000–8,000 Å，分散度 5.45 (1次) および 2.7 (2次) Å/mm．分析希望元素の増大に伴い，光電子増倍管の組み込み数は40本に達した．

発光源として，高圧スパーク，マルチソース，直流アークなど6種の励起回路がそなえられ，そのうち任意の回路が選択できる．

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