A GEOCHEMICAL STUDY OF

THE LOON LAKE

COMPLEX

A GEOCHEMICAL STUDY OF SOME

IGNEOUS ROCKS FROM THE

LOON LAKE COMPLEX

USING SPECTROGRAPHIC

METHODS

By

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SCOPE AND CONTENTS: Spectrographic methods have been used to investigate the distribution of some minor elements in a suite of rocks from the Loon Lake pluton in southeastern Chandos Township, County of Peterborough, Ontario, Canada.   The rocks studied represent a calc-alkalic series. The elements under investigation include Be, Ga, Cr, Ti, Li, Ni, Co, Cu, V, Zr, Mn, Sc, Y, Sr, Ba, Rb, and Fe.   Their abundances are compared with those determined by other analysts, in particular S.R. Nockolds and R. Allen.   The probable host minerals are also considered.   Cr, Ti, Ni, Co, V, Mn, and Fe generally are enriched in the basic rocks whereas Rb is generally enriched in the granitic rocks of the series.   Fairly even distributions are shown by Ga, Cu, and Y, and no clear trends are indicated for Li, Zr, Sr, Ba, Be, and Sc.

ABSTRACT

Fifteen igneous rock samples of the Loon Lake complex have been analyzed spectrographically for minor elements. The samples represent a calc-alkalic series ranging from granitic rocks to gabbroic rocks. The elements investigated were Be, Ga, Cr, Ti, Li, Ni, Co, Cu, V, Zr, Mn, Sc, Y, Sr, Ba, Rb, and Fe.

In this investigation it is shown that Cr, Ti, Ni, Co, V, Mn, and Fe generally are enriched in the basic rocks, and Rb is generally enriched in the granitic rocks of the series. Ga, Cu, and Y abundances show a fairly even distribution while no clear trends are indicated for Li, Zr, Sr, Ba, Be, and Sc.

These results agree reasonably well with previously found trends by other workers, such as Nockolds & Allen (1953) and Turekian & Wedepohl (1961).

ACKNOWLEDGEMENTS

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GENERAL GEOLOGY AND PREVIOUS WORK

The Loon Lake pluton, the subject of this study, is situated adjacent to the Hastings Basin structural subdivision of the Haliburton-Bancroft area, southeastern Ontario, in the Grenville province of the Canadian Pre-cambrian shield. The country rocks include marble, paragneiss, para-amphibolite, schist, arkose and basic volcanics, all of Pre-cambrian age and showing a high degree of metamorphism. These metasediments and metavolcanics have been intruded by gabbro, diorite, syenite and granite. The granites and other intrusives are of two kinds, namely, synorogenic gneisses and migmatites and post-orogenic stocks. The Loon Lake pluton is one of these latter intrusive bodies.

During the Grenville orogeny the area was highly folded producing several sets of folds. The principal one has axes paralleling the regional NE-SW trend and a second strong set has crossfold trends.

Adams and Barlow (1910) produced the first comprehensive report and geological maps of the area. Their work proved to be very thorough and not until over fifty years later was much of their data revised. D.F. Hewitt and J. Satterly of the Ontario Department of Mines made some amendments on their map put out in 1957 (O.D.M. Map No. 1957b). Of more direct interest to this study, is the mapping by A.K. Saha undertaken in his study of the Loon Lake pluton itself for a Ph.D. Thesis (Saha, 1957).

Perhaps another relevant study is that of E. Cloos (1934) principally concerned with the joint patterns in the pluton.

D.M. Shaw mapped Chandos township for the Ontario Department of Mines in the summer of 1958. It is to the resulting report and map (Shaw, 1962) that most reference will be made here.

THE LOON LAKE PLUTON

GEOLOGY

A map of the Loon Lake pluton is given in Figure 1. The principal rock types of this body are gabbro-diorite, monzonite-syenite and granodiorite-granite. In the contact zones, extensive hybrids and hornfelses are observed and within the pluton itself, bodies of aplite and pegmatite are widespread. The contact to the south is quite abrupt and contrasts with the irregular northwest marginal zone of hybrid gneisses. To the east, the pluton passes beneath the Crowe River Swamp which thus conceals the contact. Chandos Lake and the Crowe River Swamp conceal an estimated one third of the outcrop of this intrusive.

PETROGRAPHY

For the present purposes the rocks will be discussed under basic, intermediate and silicic types.

Basic Rocks

The gabbroic or dioritic rocks occur in bodies up to $\frac{1}{2}$ mile long associated with syenites. The basic rocks are dark-coloured, coarse-grained, generally hard and massive, but considerable textural and compositional variations are present. The colour index varies from 30-60

Loon Lake Complex

Southeastern Chandos Twp.
Peterborough County, Ont.

Scale

0 _____ 5000

feet

70-143-6

71-52-1

782

South Bay

71/72-182-1

71/72-181-1

Lasswade Lake

71-53-7

783
71-53-6
71-53-5

Gilmour Bay

71-53-2

71/72-184-4

LEGEND

72-199-4
72-199-5

Granitic Rocks

Older Basic Intrusive
and Meta—intrusive
Rocks

Syenitic Rocks

- - - Geological boundary

⊙ Specimen locality

72-200-3

744
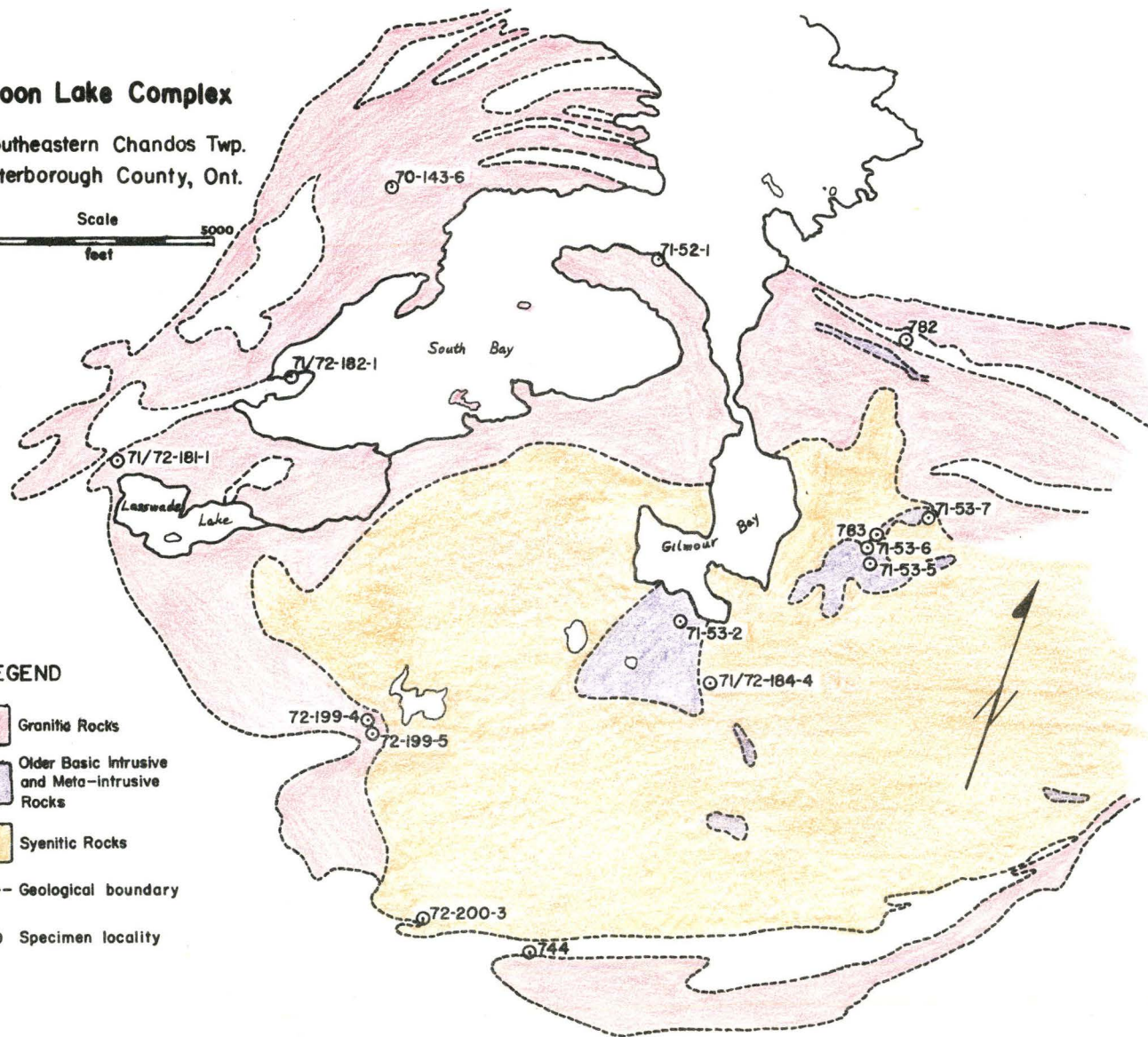
and poikilitic biotite is common. Evidence of shearing is often en-
countered. Diorite containing biotite, hornblende and andesine plagio-
clase is the most basic common rock. More basic facies contain augite
and hypersthene with labradorite and bytownite. Apatite, magnetite,
sphene and quartz generally make up the accessory content. It is im-
portant to note that continuous variation from basic to syenitic rocks
appears to occur although cross-cutting relationships indicate age dif-
ferences.

Intermediate Rocks

In general, these are coarse-grained rocks with a colour index
of 10-30 that are mapped as monzonites or syenites. The monzonitic
members of this group are characterized by grey-green plagioclase
(andesine), biotite and lesser amounts of hornblende, augite, potash
feldspar and quartz. With increasing content of potash feldspar and
resulting decrease in colour index the rock merges into a syenite, just
as these syenites merge with granites as the quartz content increases.
The dark minerals include grains of hornblende, biotite, magnetite,
sphene, and apatite in aggregates. Bent and fractured plagioclase
twins, mortar texture and undulant extinction in quartz are quite
common and indicate shearing.

Silicic Rocks

These rocks are distinguished by quartz visible to the naked eye
or with a lens. They are grey or pink, faintly gneissic, coarse-grained
rocks with a colour index of 0-20. Microcline, quartz, biotite and
plagioclase are always present, the last having a composition ranging

from albite to andesine but which commonly is oligoclase. Muscovite or epidote occur rarely but the former is confined to a zone of hybrids. Accessory minerals such as magnetite, pyrite, sphene, apatite, zircon, allanite, tourmaline and calcite are common.

The majority of rocks of this class are granodiorite or tonalite (quartz diorite), with few examples of a true granite.

In many outcrops, particularly in the northwestern contact zone, the granodiorite is associated with bodies of leucogranite, aplite, and pegmatite. These bodies either cut or grade into the granodiorite. In this region, the pegmatites appear to be definitely part of the pluton.

By way of generalization then, there is continuous variation from basic to syenitic rocks with an increase in microcline and a noticeable decrease in the amount of dark minerals. Saha noted that the pluton becomes more potassic (syenitic) towards the outer edge. He also suggested that a body of granodiorite trending east-west across the pluton could be distinguished between the main syenite body to the south and another granite further north. Shaw did not attempt to draw boundaries between granite and granodiorite in his report.

CONTACT ZONES AND INCLUSIONS

Adjacent country rocks have been affected in a wide variety of ways by this intrusion. Of particular note are the paragneiss and marble inclusions. Some are large enough to suggest that they may be roof pendants or large stoped blocks. The numerous bodies of hornfelses outcropping in the south central area of the pluton have quite widely varying compositions and include such minerals as hypersthene,

cordierite, scapolite and garnet. Paragneiss inclusions are locally rich in red garnet, sillimanite and cordierite, the latter two being pointed to as evidence of contact metamorphism.

A study of element fractionation between coexisting biotite and hornblende in these hornfelses has been made (Chiang, 1965).

FORM AND STRUCTURE

The igneous rocks in the core of the Loon Lake pluton are rather massive indicating that this intrusion is younger than the regional metamorphism of the gneisses surrounding it. Further evidence for this is the presence of hornfelses at the outer contacts. Flow foliation and lineation can be measured, especially near the contacts, thus throwing some light on the mechanics of intrusion, but joint studies reveal no clear pattern in this respect. This latter conclusion was reached by both Cloos (1934) and Shaw (1958). Cataclastic effects in the monzonite and granodiorite have been attributed to later regional faulting.

SAMPLE LOCALITIES AND PREPARATION

The samples analysed were collected by D.M. Shaw and associates in the summer of 1958 and since. Their exact localities are given on the map, Figure 1, and their petrography is given in Appendix 2. Three of the rocks analysed show evidence of being very low grade metamorphic rocks. Both 782 and 744 show a faint foliation and granoblastic texture. 744 contains some epidote, as well. In 783, a definite cataclastic texture is developed.

From each of the collected hand specimens, about 100 grams of chips were obtained. These were broken to about 1/4" diameter fragments and then halved. One half was then completely crushed and ground to pass a 100-mesh stainless steel sieve. All of the 15 samples were first crushed using the Braun Chipmunk crusher, made by Bico, Inc. Eight of the samples were then ground to less than 100-mesh using the Shatterbox (made by Spex Industries Inc.). The remaining seven were reduced to less than 100-mesh in a ceramic disc mill (Pulverizer, made by Bico, Inc.). Mica, as always, slowed the grinding process and several runs were usually required to pass the complete sample. After each powder had been thoroughly mixed, the samples were ready for final preparations in the spectrographic laboratory.

Throughout the preparation procedure care was taken to avoid contamination as much as possible. The most obvious possible contaminants during the above procedure were iron from the hammer and crusher used in breaking down the samples, aluminum from the ceramic discs, and tungsten, cobalt and/or carbon from the Shatterbox.

ANALYSIS PROCEDURE

For spectrographic analysis, each thoroughly homogenised rock powder was mixed in a 1 to 1 ratio with a buffer containing graphite and two internal standard elements, palladium and cesium. Care was taken to exclude moisture by keeping the buffer and the final mixture in a dessicator and by heating each in a sand bath immediately before use.

For the complete outline of the procedures followed, see
Appendix 1.

RESULTS AND DISCUSSION

Results

The analytical results are given in Table 1 in parts per million
of the element (ppm). The result recorded is the average of a tri-
plicate analysis. Two lines were measured for Ba, Ti and Mn, and both
sets of measurements are recorded for each.

Graphs showing the variation in abundance of each element with
respect to rock type are given in Appendix 3. The abscissa in these
plots is a differentiation index taken from Thornton and Tuttle (1960),
and equal to the total weight percentages of normative quartz, ortho-
clase, albite, nepheline, leucite and kalsilite. On this scale,
granite, granodiorite, diorite and gabbro are given values of 80, 67,
48, and 30, respectively. However, some rock types are missing on this
scale. Hence, the syenite quartz monzonite, monzonite and mangerite
are taken as represented by granite, granodiorite, diorite and gabbro,
respectively, for the purpose of plotting the variation diagrams.

Interpretation and Discussion

Comparisons can be made with analyses made by Nockolds and Allen
(1953) of five igneous rock series of calc-alkalic type. One series in
particular, the Southern California batholith, is largely plutonic.
The Scottish Caledonian series has volcanic and hypabyssal members as
well as plutonic.

TABLE 1

ANALYSIS RESULTS FOR THE LOON LAKE PLUTON SUITE (AS PARTS PER MILLION OF THE ELEMENT)

Sample Number	Rock Type	Element Radius(Å)	Be^{+2} 0.33	Ga^{+3} 0.62	Cr^{+3} 0.63	Ti^{+4} 0.68	$T+^{+4}$ 0.68	Li^{+1} 0.68	Ni^{+2} 0.69	Co^{+2} 0.72	Cu^{+2} 0.72	V^{+3} 0.74	Zr^{+4} 0.79	Ma^{+2} 0.80	Mn^{+2} 0.80	Sc^{+3} 0.81	Y^{+3} 0.92	Sr^{+2} 1.16	Bm^{+2} 1.43	Ba^{+2} 1.43	Rb^{+1} 1.57	Fe^{+3} %
71/2-181-1	Granite		tr	16	tr	1690	3250	30	4	9	15	30	650	154	176	tr	55	332	2930	vs	50	2.42
71/2-182-1	Granite		tr	20	tr	2110	2880	8	4	4	10	25	785	476	408	tr	40	487	1950	vs	80	2.58
72-200-3	Syenite		tr	24	tr	vs	3230	15	8	48	21	17	1050	579	512	18	86	60	590	500	67	2.57
71-52-1	Granodiorite		3	24	tr	2440	3680	33	10	6	9	22	1200	853	693	tr	112	210	1707	827	135	3.58
70-143-6	Quartz Monzonite		1	21	tr	vs	5070	45	9	68	16	45	1980	637	634	tr	50	533	3250	vs	110	3.70
71-53-2	Monzonite		tr	15	10	vs	8770	27	1	6	5	65	64	581	493	3	27	553	5600	vs	51	4.30
71-53-6	Monzonite		1	20	tr	vs	8400	15	2	36	15	74	315	1750	1400	4	44	760	5930	vs	38	6.60
71-53-7	Diorite		3	17	tr	vs	9830	31	12	58	9	154	1580	1840	1530	4	77	293	1180	593	24	6.90
71-53-5	Mangerite		1	15	tr	vs	11330	21	2	36	16	102	224	1470	1190	tr	43	807	6030	vs	31	7.60
71/2-184-4	Mangerite		tr	24	30	vs	8100	14	13	12	13	78	262	923	910	tr	39	687	4100	vs	38	5.70
72-199-4	Diorite		4	19	109	vs	10100	18	160	89	69	217	226	1250	1180	16	34	507	1770	950	27	10.2
72-199-5	Gabbro		3	21	93	vs	9830	18	172	64	52	250	257	1190	1140	22	42	563	1820	747	26	9.7
783	Gabbro		2	25	tr	vs	9800	17	2	32	19	148	228	1240	1060	4	47	640	3970	vs	30	8.3
744	Diorite		1	21	46	2490	7300	26	15	68	10	127	293	1300	1060	16	49	333	1050	625	39	6.2
782	Diorite		1	17	42	2170	3700	20	38	91	13	106	119	1480	1320	13	37	227	690	567	38	6.1

Footnotes "tr" – Trace; indicates that the element is present in amounts less than the sensitivity
"vs" – Analysis line too intense for the purpose of measurement
Ionic radii are taken from Green (1959)

The results of the minor element analyses, shown in Table 1, will be discussed, then, in terms of ionic radii similarities, probable host minerals for the elements and agreement of abundances with previous analyses made by Nockolds and Allen (1953) and the compilations of Turekian and Wedepohl (1961), in particular.

Beryllium

The absolute abundances for Be are not very reliable since difficulties were encountered in calibration. The abundances calculated, however, show no trend and the majority of the analyses indicate that extremely minor amounts are present. Previous studies have shown that this element is concentrated in granitic rocks to some extent. The study by Nockolds and Allen revealed no Be.

Gallium

This element has a remarkably constant abundance over the complete series of rocks. This agrees very well with previous studies of its abundance. Because of the similarity of its ionic radius with that of aluminum and ferric iron, one would expect Ga to substitute for them. This has been shown to be especially true for Al. In addition, Nockolds and Allen noted the constancy of the Ga/Al ratio in the calc-alkalic series they studied.

Chromium

Cr was detected only in amounts below the sensitivity limits in many of these samples. It was in the most basic members that the highest concentrations were obtained, however, namely in all 3 diorites, 1 of the mangerites and one of the gabbros.

This enrichment in basic rocks has been noted by previous workers. The similarity in radius to ferric iron and aluminum leads one to expect a concentration in the ferromagnesian and aluminous minerals as well as in opaque oxides. However, Cr does not appear to substitute for Al in feldspar. This could be somewhat complicated, however, by the multiple valency of Cr. Nockolds and Allen state that Cr and Ni both show a trend noticeably linked to Mg content.

Titanium

Two lines were measured for this element and, as the results clearly show, the line T+ gives results which are systematically higher than the other. The calibration curve for the titanium spectral line Ti (wavelength = 3685Å) could not be very accurately determined. In addition, most of the lines of that wavelength were too intense to be measured. Thus the second set of analyses (i.e. T+, 4305Å) appears to be the more reliable of the two.

Regardless of which set of results are more reliable, both sets show that the rocks are enriched in Ti toward the basic end of the series.

Lithium

Li abundances in these rocks show no particular trend. The most highly enriched sample is intermediate in composition.

As Smith (1962) points out, Li is taken up by the ferromagnesian minerals. Nockolds and Allen note a gradual increase in Li abundances as the members of their calc-alkaline series become more acid. In the rocks analysed, there is an obvious decrease in ferromagnesian

content as the rocks become more granitic. In addition, Turekian and Wedepohl's compilation agrees with this trend.

Nickel

This element shows some enrichment in the basic members relative to the most acidic members. Abundances in one diorite and a gabbro are particularly higher than the rest.

This general basic rock concentration is in agreement with Nockolds and Allen who indicate that both Ni and Cr tend to accumulate in the more magnesian (i.e. basic) rocks. This fact can be related, to some degree, to the similarity between the ionic radii of Ni, Cr, and Mg.

The correlation of Cr and Ni trends is quite striking in the abundances here calculated.

Cobalt

In looking at the abundances of Co a weak trend is discernible of its enrichment in the most basic rocks of the series. A strong decreasing trend in the amount of Co is expected towards the granitic rocks according to the averages compiled by Turekian and Wedepohl. But Nockolds and Allen indicate from their studies of calc-alkaline series that this element does not vary much in absolute amount.

Copper

Except for two relatively high values in a gabbro and a diorite, Cu abundances show no marked enrichment. Previous studies all point to enrichment of copper in basic rocks substituting for iron and zinc. Cu is incorporated in the ferromagnesian minerals but there is some disagreement as to its quantitative importance. Of particular note is

the fact that divalent copper's ionic radius is between that of ferrous iron and nickel, so that substitution can be expected.

Vanadium

V shows a pronounced trend toward enrichment in the basic rocks. This is quite in agreement with the two previous studies referred to. Smith (1962) also stresses that this element tends to be incorporated preferentially in minerals that can accept trivalent Al, Fe, and Cr in octahedral coordination, thus being similar to P in this respect. Magnetite, ilmenite, chromite, pyroxene, amphibole and biotite are generally the hosts in more basic rocks. These mineral hosts are listed roughly in order of decreasing content of V. In the more acid and alkalic igneous rocks V follows P in minerals such as apatite. Substitution of V for Si in silicates is not expected to be extensive because the ionic radius of quinquevalent V is significantly larger than that of quadrivalent Si.

Zirconium

Intermediate and acid rocks show enrichment in this element for the samples analysed. The quartz monzonite and diorite analyses are unusually high relative to the others while one of the monzonites shows a marked relative deficiency. In general the absolute values are higher than those analysed previously by Nockolds and Allen, for example. One would expect such high concentrations to be manifested in the development of particular mineral phases, such as zircon. This is not the case in these samples, however. Only relatively small amounts of Zr are incorporated in pyroxene and hornblende.

Manganese

The abundance was measured from two spectral lines, and values agree quite well. A marked trend of increasing Mn toward the basic end is revealed by both of them. This is one of the strongest trends encountered in this study. Nockolds and Allen did not determine Mn in their study of the calc-alkalic series rocks but the data brought together by Turekian and Wedepohl indicates that one should expect concentrations of Mn in the basic rocks. It has been found to be concentrated in ferromagnesian silicate minerals, mostly in the divalent state, much like ferrous iron. In fact, the ratios Mn/Mg and Mn/Fe have been suggested by some authors as indicators of degree of differentiation of igneous rocks.

Scandium

The analysis of this element's abundance was, like Be, hampered by problems in providing a reliable calibration curve. Nevertheless, abundances were measured and except for a relatively high value determined for the syenite and a relatively low value for one of the gabbros, a weak enrichment of Sc in the basic rocks is indicated.

As Smith (1962) states, the size of trivalent Sc permits its capture by divalent magnesium and iron and thus it is found to be concentrated in pyroxene, amphibole and biotite.

Yttrium

This element shows no pronounced trend and may be considered to have a fairly even distribution throughout the series. Somewhat higher values are obtained for the syenite, granodiorite and diorite. However,

previous studies, specifically by Nockolds and Allen, have indicated
that Y is usually fairly evenly distributed with some concentration in
the acidic rocks.

Late stage accessory minerals, such as apatite, zircon and
fluorite are those in which the rare earth elements, and associated Y,
are concentrated. Deuteric minerals such as epidote-allanite may
contain the Y of earlier minerals.

Strontium

No consistent trend appears in Sr abundances. Gabbroic rocks
apparently are more enriched than other members but values have a rela-
tively wide range. The fact that Sr follows Ca in plagioclase to a
considerable extent has been noted by several authors. Other hosts
might be potash feldspar, biotite and alkalic amphiboles and pyroxenes.
However, Nockolds and Allen's calc-alkalic series study indicated that
Sr content does not vary a great deal. Turekian and Wedepohl's compila-
tion, in contrast, shows that Sr is notably more concentrated in the
acid and intermediate rocks.

Barium

This is another element for which two spectral lines were used.
The results obtained from the lower wavelength line (i.e. 4554Å) give
consistently lower values. Because of these differences, the absolute
values cannot be heavily relied upon. Regardless of this, no strongly
developed trend can be seen. It seems that those values measured from
the low wavelength line are in closer agreement with those found by
Nockolds and Allen, however. Even closer agreement is observed for
Turekian and Wedepohl's compilation.

Some relation to the K content of the feldspar has been perceived by several authors.

Rubidium

Rb has significantly higher abundance values in the acidic rocks. There is not a strong trend, but there is a discernible one of concentration in the granitic rocks. This trend is well substantiated by the studies of Nockolds and Allen as well as many others. One feature of particular note is the strong parallelism of this element's concentration with that of K observed for specific rock series but the Rb/K ratio is not the same for all series. This element, along with cesium, is found in potash feldspar, and mica in place of K. The ionic radii of these three elements are quite similar.

Iron

This element is the most abundant of all the elements considered. Abundances are all in excess of 1%. A pronounced trend is shown toward a concentration in basic rocks. Smith (1962) has pointed out that there is a general trend in igneous rocks for trivalent iron to increase in abundance relative to divalent iron with differentiation (i.e. toward granitic rocks). Ferric iron may be tied up in magnetite and ferromagnesian minerals. However, the ferromagnesian minerals remove much more ferrous iron than ferric iron in simple crystal fractionation processes according to Smith.

CONCLUSIONS

This minor element study of a suite of igneous rocks from the Loon Lake pluton indicates some trends. Cr, Ti, Ni, Co, V, Mn, and Fe

generally show enrichment in the more basic rocks while Rb is general-
ly enriched in the granitic rocks of the series.   A fairly even dis-
tribution is shown for Ga, Cu, and Y.   No clear trends are shown for
Li, Zr, Sr, Ba, Be, and Sc.   In the case of the last two elements
problems encountered with the calibration curves prevented derivation
of any reliable absolute abundances from the spectral line readings.

According to Nockolds and Allen's work (1953), the trends ob-
tained in this study agree reasonably well with those of the calc-alkalic
trends.   They found Sc to be concentrated in basic rocks, Y to show a
slight tendency toward concentration in acidic rocks while Ba, Li and
Zr show a stronger tendency toward concentration in acidic rocks,
however.

Interpretations are obviously restricted by the limited number
of samples analysed.   However, chemical analyses for the major elements
would have facilitated more meaningful interpretation.

APPENDIX

1. <u>Silicate Spectrochemical Analysis - Revision of Procedures</u>

Inconsistencies in results obtained on standard rock samples using the established method have led to an examination of the method, covering the following points:

<u>Time Required for Complete Volatilization</u>

A time-study was made to determine the extent to which elements are volatilized. It was found that the arcing process should be continued twenty seconds after the sample has been consumed (approximately 120 seconds) to ensure the complete volatilization of all elements.

<u>Polarity</u>

Polarity effects were absent in the spectrographic lines used.

<u>Suitability of Internal Standard Lines</u>

Other palladium lines were considered, but it was found that those currently in use - 3242.7, 3421.2 and 3609.5 - were most sensitive and least subject to interference.

<div align="center">METHOD</div>

i) <u>Preparation of Buffer</u>

Mixture A contains
$$\begin{cases} 3.0\% \ PdCl_2 \\ 97.0\% \ graphite \end{cases}$$

Mixture A is diluted by a factor of 10: that is, 100 mg. A + 900 mg. graphite will give 1,000 mg. Mixture B.

Mixture B contains   (0.3% $PdCl_2$
(
(99.7% graphite

Mixture B can be prepared in this quantity and stored.

The final mixture is prepared by thoroughly mixing 100 mg. of Mixture B, 500mg. of graphite and 600 mg. Cs_2CO_3. (The Cs_2CO_3 must be weighed rapidly.)

Final mixture contains   (0.025% $PdCl_2$
(
(49.975% graphite
(
(50.000% Cs_2CO_3

NOTE: The buffer mixture must be heated to 200°F in sand bath for one hour immediately before use, cooled in a dessicator and kept stoppered as much as possible during the weighing process.

ii) Sample Preparation

50% sample and 50% buffer are mixed in acetone, dried for one hour in the sand bath, and packed firmly into a #5000 graphite electrode. Best results are obtained if electrodes are filled to the top of the crater. 100 mg of sample - buffer mixture is adequate for the filling of six electrodes.

Immediately before arcing, the electrodes should be heated in a direct bunsen flame for one minute.

iii) Exposure Conditions

a) for area between 2200Å and 4800Å.

- pointed graphite rod 2" x 1/8" used as upper electrode (Fresh rod used
    for each burn)

- 6 mm. arc gap

- tip of anode $2\frac{1}{2}$" mm above Stallwood jet

- mixture of 80% argon/20% oxygen at 18 SCHF used with the Stallwood jet

- cooling water at 15 GPH

- 2 screens

- 30 micron slit width

- 9 mm slit height

- exhaust blower open

- one SA-I plate for <u>lower</u> end of camera*

- one III —F plate for <u>upper</u> end of camera

- power supply on (arc at $9\frac{1}{2}$ amps D.C.)

- spectrograph power on

- sector on

- dark slide down

- arc until 20 seconds after sample is consumed

b) for region between 5700Å and 8300Å, make the following changes:

- no screens used

- yellow filter inserted in sector

- Stallwood jet uses air stream at 18 SCHF

- two I-N plates used

* The <u>lower</u> end of the camera is to the <u>right</u> when standing at the rear
  of the spectrograph facing the camera. This is opposite to the
  wave-length scale on the spectrograph.

iv) <u>Development</u>

- 3 minutes in D-19 developer at 20°C

- rinse in distilled water

- 5 minutes in Amfix solution

- wash in <u>cold</u> running water at least 10 minutes, rinse in distilled water and dry.

<u>Line-Pairs</u>	<u>Symbol</u>	<u>Range</u>			
Ga 2943.6/Pd 3242.7	Ga	20 ppm	to	2000	ppm
Be 3130.4/ "	Be	2 "	to	50	"
V 3183.9/ "	V	20 "	to	2000	"
Cu 3274.0/ "	Cu	10 "	to	100	"
Y 3327.8/ "	Y	40 "	to	2000	"
Zr 3391.9/ "	Zr	20 "	to	1000	"
Ni 3414.7/Pd 3421.2	Ni	10 "	to	1000	"
Co 3453.5/ "	Co	10 "	to	1000	"
Ti 3685.2/Pd 3609.5	Ti	100 "	to	1000	"
Sc 3911.8/ "	Sc	50 "	to	1000	"
Mn 4034.4/ "	Ma	30 "	to	1000	"
Mn 4041.3/ "	Mn	1000 "	to	1.0%	
Cr 4254.3/ "	Cr	30 "	to	1000	ppm
Ti 4305.9/ "	T+	1000 "	to	1.0%	
Ba 4554.0/Cs 4555.4	Ba	30 "	to	1000	ppm
Sr 4607.3/ "	Sr	30 "	to	1000	"
Li 6103.6/Cs 6723.2	Li	100 ppm	to	1000	ppm
Ba 6496.9/Cs 6723.2	Bm	100 "	to	3000	"
Li 6707.8/Cs 6723.2	Lm	2 "	to	100	"
Rb 7800.2/Cs 7609.0	Rb	20 "	to	500	"

2. Petrography of the Samples Analysed

71/72-181-1 - Granite

This is a massive inequigranular rock with a colour index of 25. Feldspar phenocrysts are visible with the naked eye.

An estimated mode from the thin section is K-feldspar-40%, albitic plagioclase-30%, quartz-10%, biotite-10%, muscovite-4%, tourmaline-2%, sphene and opaques in trace amounts.

71/72-182-1 - Granite

This is a massive coarse-grained rock with a colour index of 20.

An estimated mode is K-feldspar-60%, albitic plagioclase 20%, quartz-15%, biotite-5%, opaques-3%, sphene-1% and muscovite and rutile in trace amounts.

72-200-3 - Syenite

This is a coarse-grained rock with a colour index of 20. It displays a faint foliation.

An estimated mode is K-feldspar-55%, albitic plagioclase-25%, quartz-5%, sphene-2%, opaques-2%, and trace amounts of rutile.

71-52-1 - Granodiorite

This is a massive medium-grained rock with a colour index of 25. It has a dull greenish tinge.

An estimate of the mode is K-feldspar-45%, albitic plagioclase-15%, quartz-20%, biotite-10%, opaques-5%, apatite-4%, sphene-2%, and trace amounts of muscovite.

70-143-6 - Quartz Monzonite

This massive medium-grained rock has a colour index of 15.

An estimated mode is K-feldspar-40%, plagioclase-35%, biotite-10%, quartz-10%, sphene-2%, and opaques-2%.

71-53-2 - Monzonite

This is a massive coarse-grained rock with a colour index of 35.

An estimate of the mode is K-feldspar-40%, plagioclase-35%, quartz-3%, biotite-15%, opaques-5%, apatite-2%, and sphene and rutile in trace amounts. This rock shows evidence of cataclastic effects.

71-53-6 - Monzonite

This coarse-grained rock has a colour index of 35 and a faint gneissic texture.

An estimate of the mode is K-feldspar-25%, albitic plagioclase-30%, hornblende-5%, augite-15%, biotite-15%, quartz-2%, opaques-5% and trace amounts of apatite. The mafic constituents occur as chiefly glomeroporphyritic aggregates of sieved hornblende. Again evidence of cataclastic effects are present.

71-53-7 - Diorite

This is a coarse-grained massive rock with a colour index of 30. Besides the light feldspar, black prisms and tiny brown crystals can be seen.

An estimated mode is K-feldspar-20%, albitic plagioclase-30%, pyroxene-45%, sphene-10% and trace amounts of apatite, epidote and opaques. Reaction rims of hornblende surround the augite and of note is the high concentration, relatively speaking, of sphene.

<u>71-53-5 - Mangerite</u>

This is a massive coarse-grained rock with a colour index of 40.

An estimated mode is K-feldspar-20%, plagioclase-40%, hornblende-25%, biotite-8%, opaques-8%, quartz-3%, and traces of apatite and sphene. The hornblende appears to be pseudomorphic after augite, containing apatite, biotite, quartz and opaques (i.e. highly sieved). Again cataclastic features are evident.

<u>71/72-184-4 - Mangerite</u>

This massive coarse-grained rock has a colour index of 40.

An estimated mode is K-feldspar-25%, albitic plagioclase-40%, biotite-10%, hornblende-10%, augite-2%, opaques-8%, and traces of apatite and sphene. Strained and fractured feldspar is again indicative of cataclastic effects.

<u>72-199-4 - Diorite</u>

This is a medium to coarse-grained massive rock with a colour index of 50.

An estimated mode is albitic plagioclase-25%, hornblende-35%, biotite-25%, quartz-3%, opaques-12%, and trace amounts of apatite. The hornblende is sieved and cataclastic activity is in evidence.

<u>72-199-5 - Gabbro</u>

This is a massive, deeply weathered, very coarse-grained rock with a colour index of 60. The weathered surface is rusty-brown.

An estimated mode is plagioclase(An_{50})-55%, biotite-15%, augite-15%, hypersthene-5%, quartz-3%, opaques-7% and trace amounts of apatite and sphene.

783 - Gabbro

This is a medium to coarse-grained massive rock with a colour index of 50.

An estimated mode is K-feldspar-5%, albitic plagioclase-40%, biotite-20%, hornblende-10%, augite-15%, opaques-10% and trace amounts of apatite and sphene. The augite is mantled by the hornblende and a cataclastic texture is developed.

744 - Diorite

This is a medium-grained massive rock with granoblastic texture and a colour index of 50. Local mafic patches can be observed.

An estimated mode is K-feldspar-20%, plagioclase-40%, quartz-10%, biotite-15%, hornblende-10%, epidote-5%, opaques-2% and sphene in trace amounts.

782 - Diorite

This is a medium-grained rock which shows a faint foliation: it has a colour index of 50.

An estimated mode is K-feldspar-5%, plagioclase-25%, quartz-15%, biotite-10%, hornblende-40% and trace amounts of apatite. Some allanite may be present as well. The hornblende is sieved with feldspar and is bright green in colour.
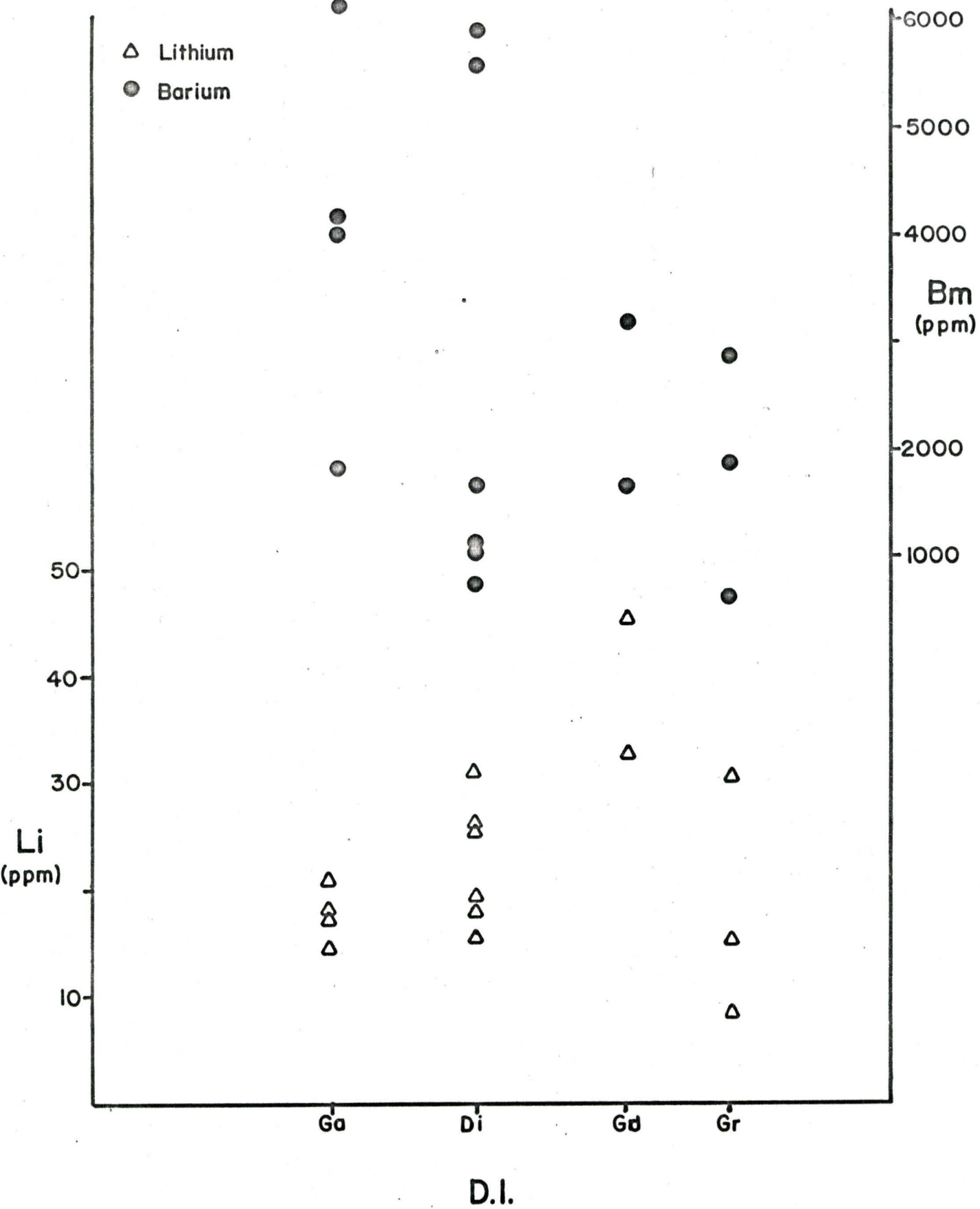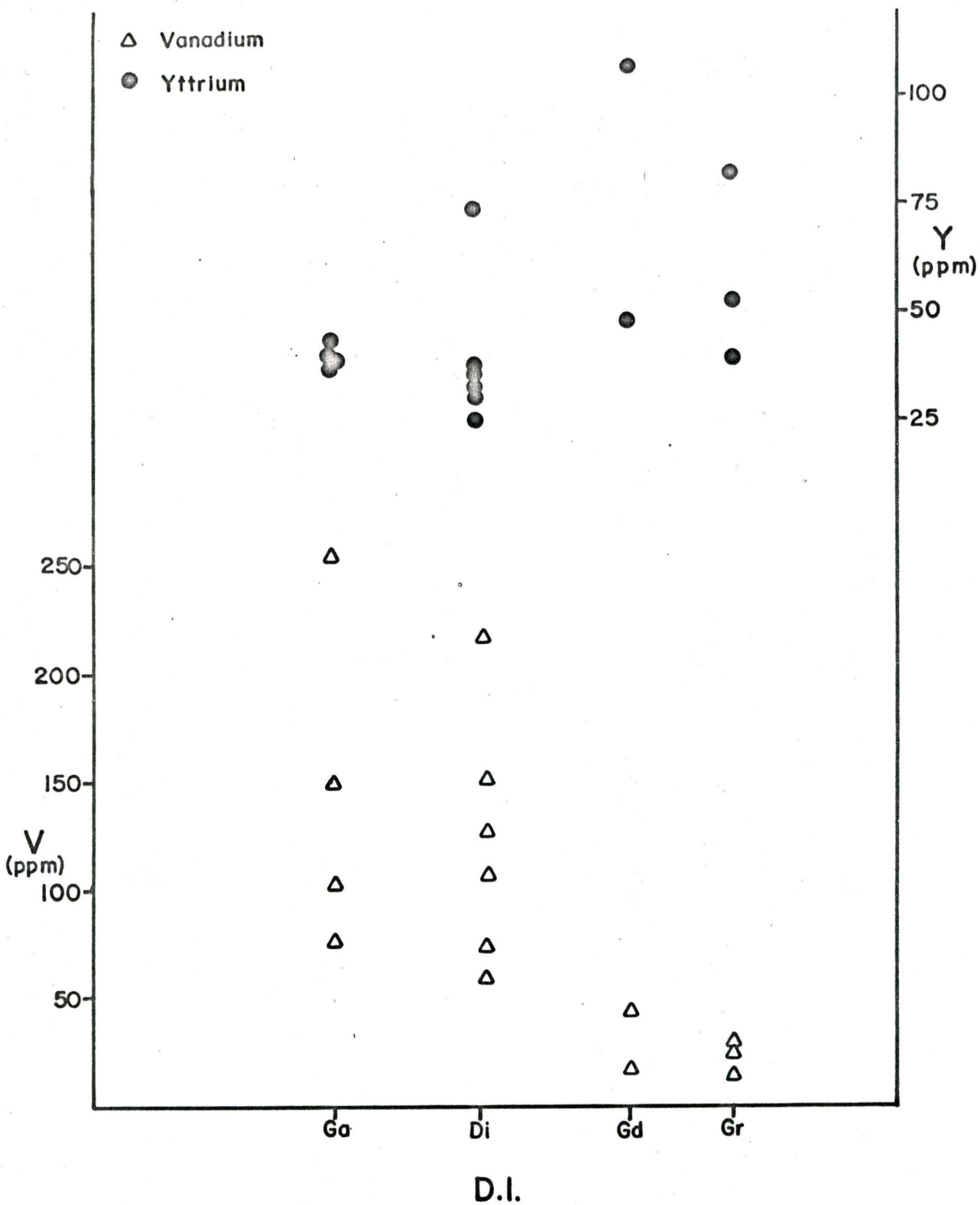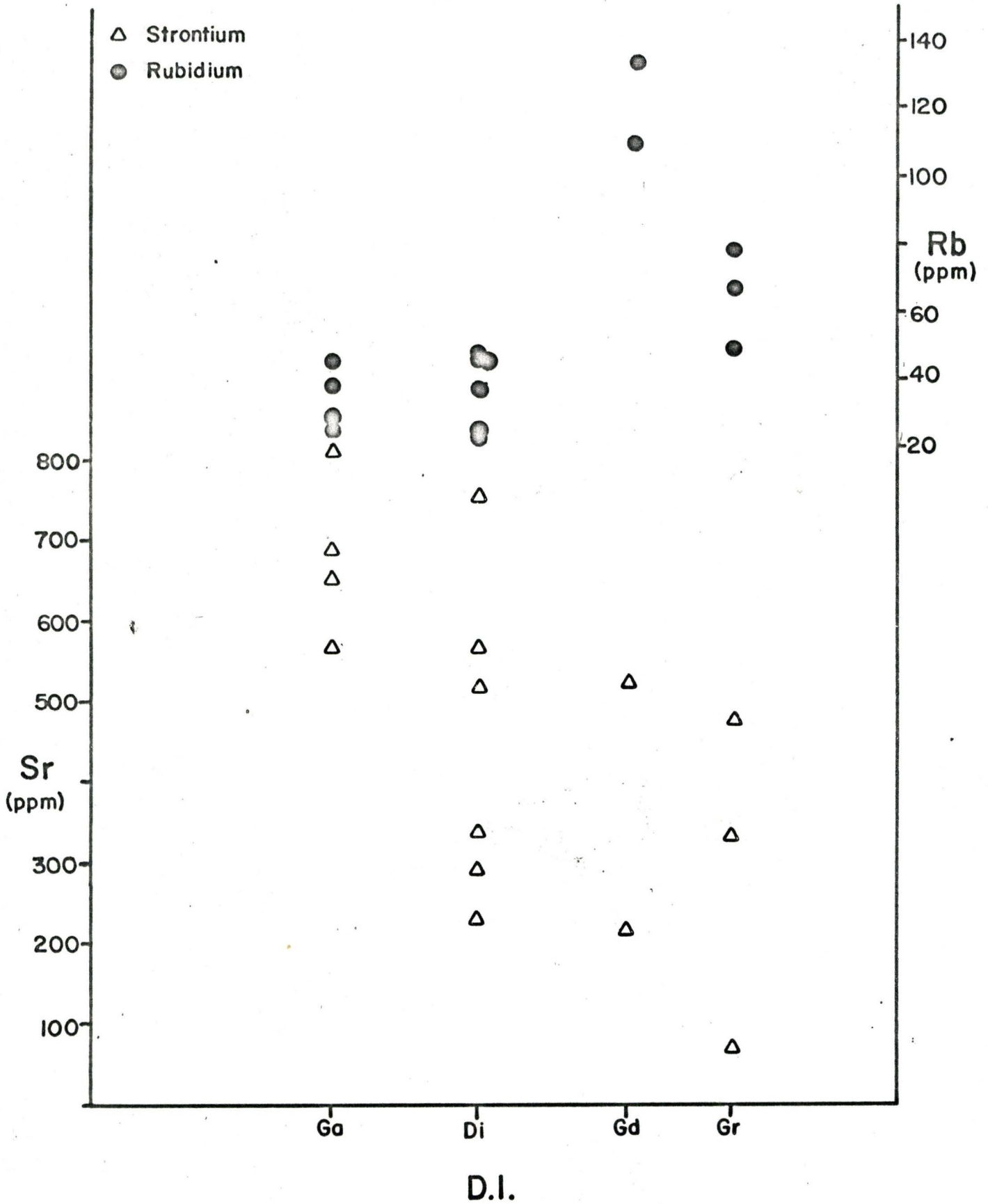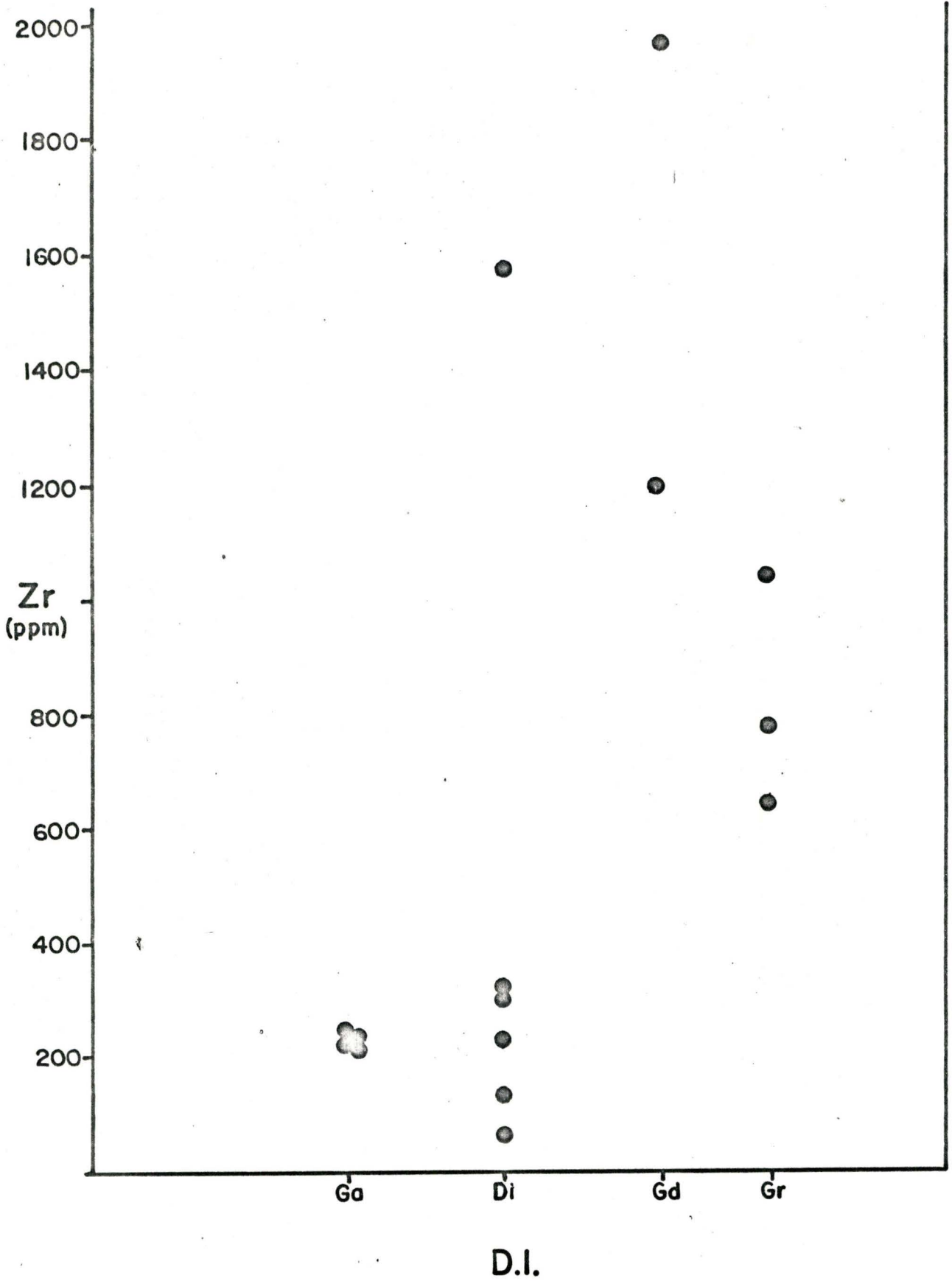
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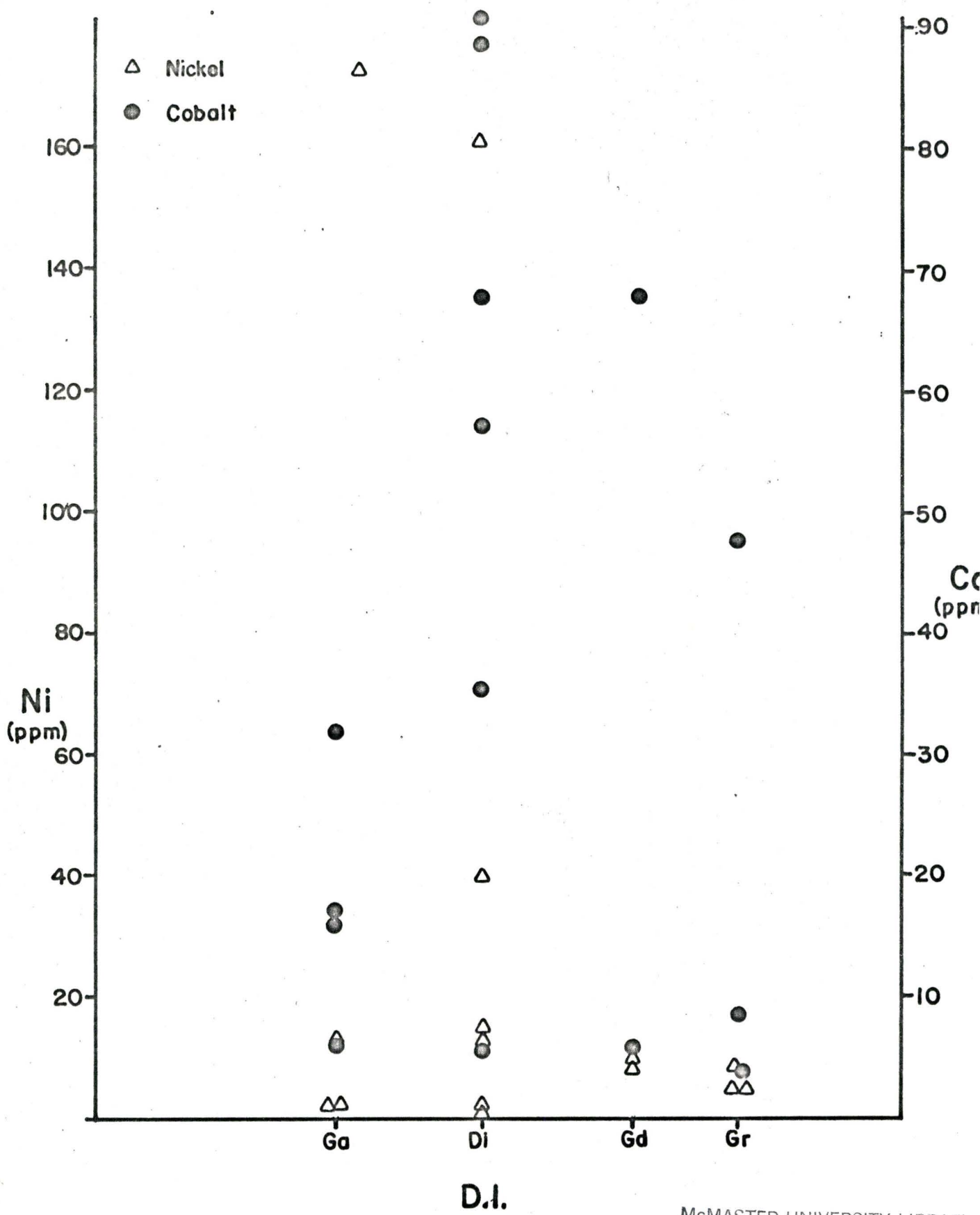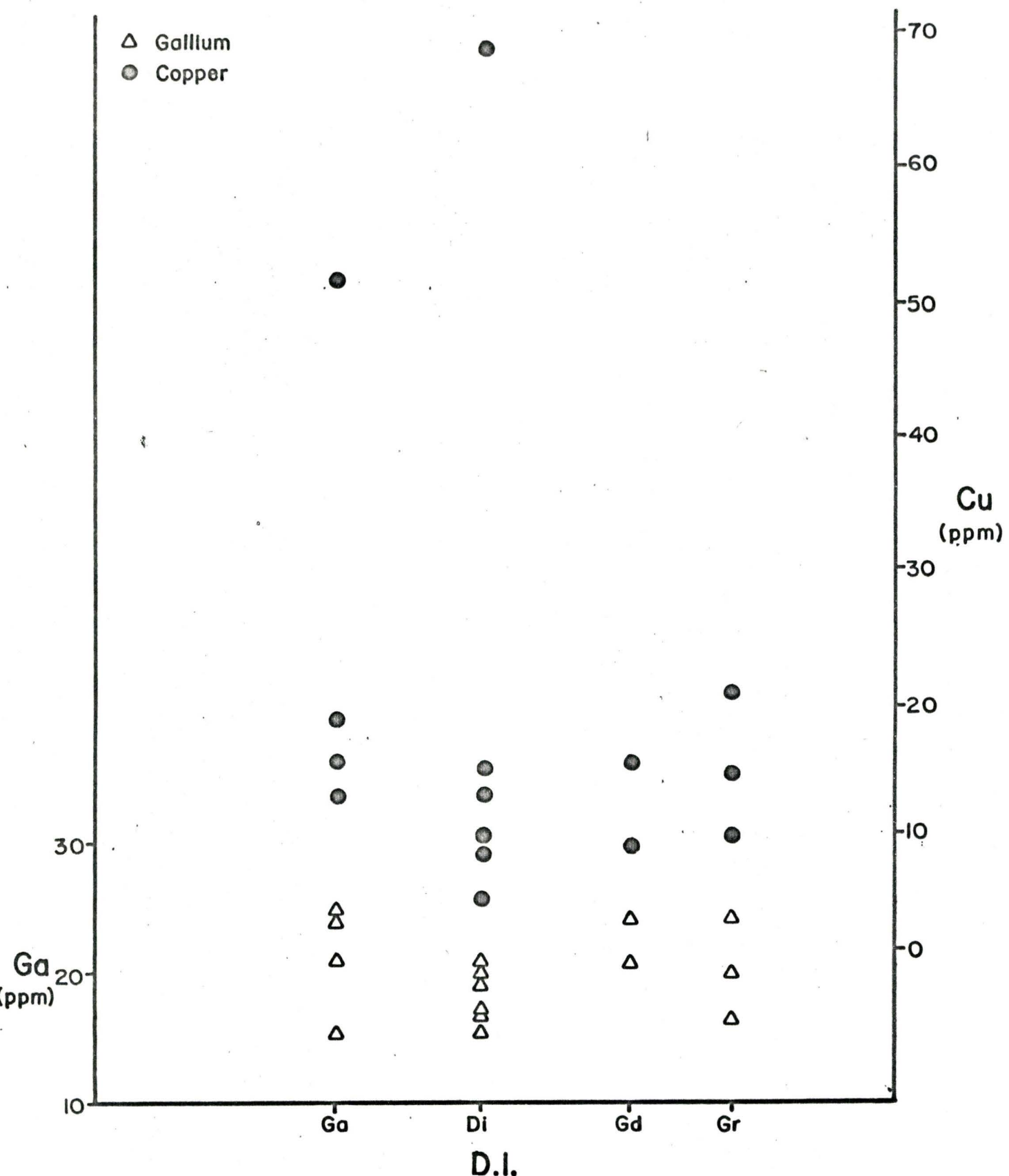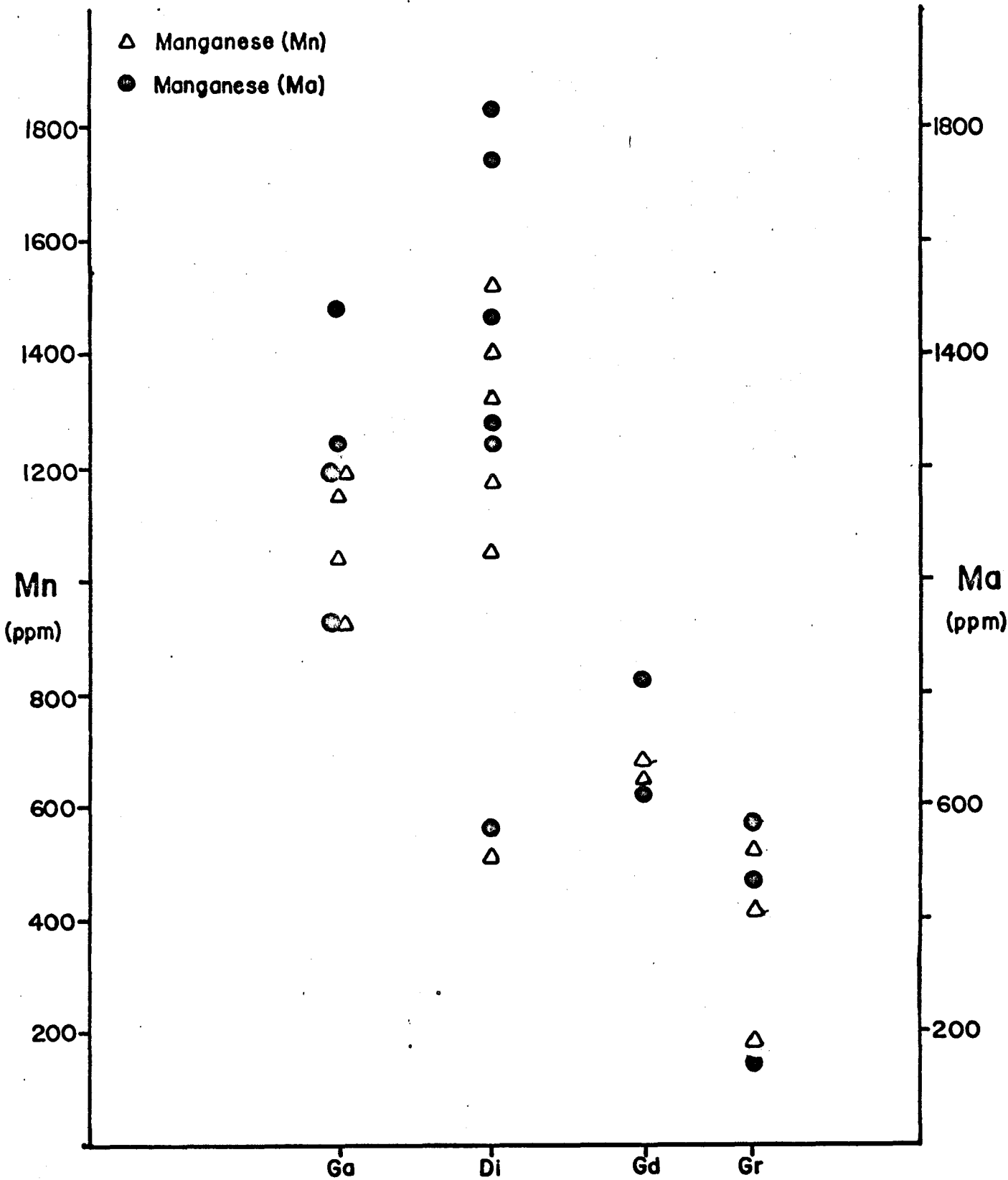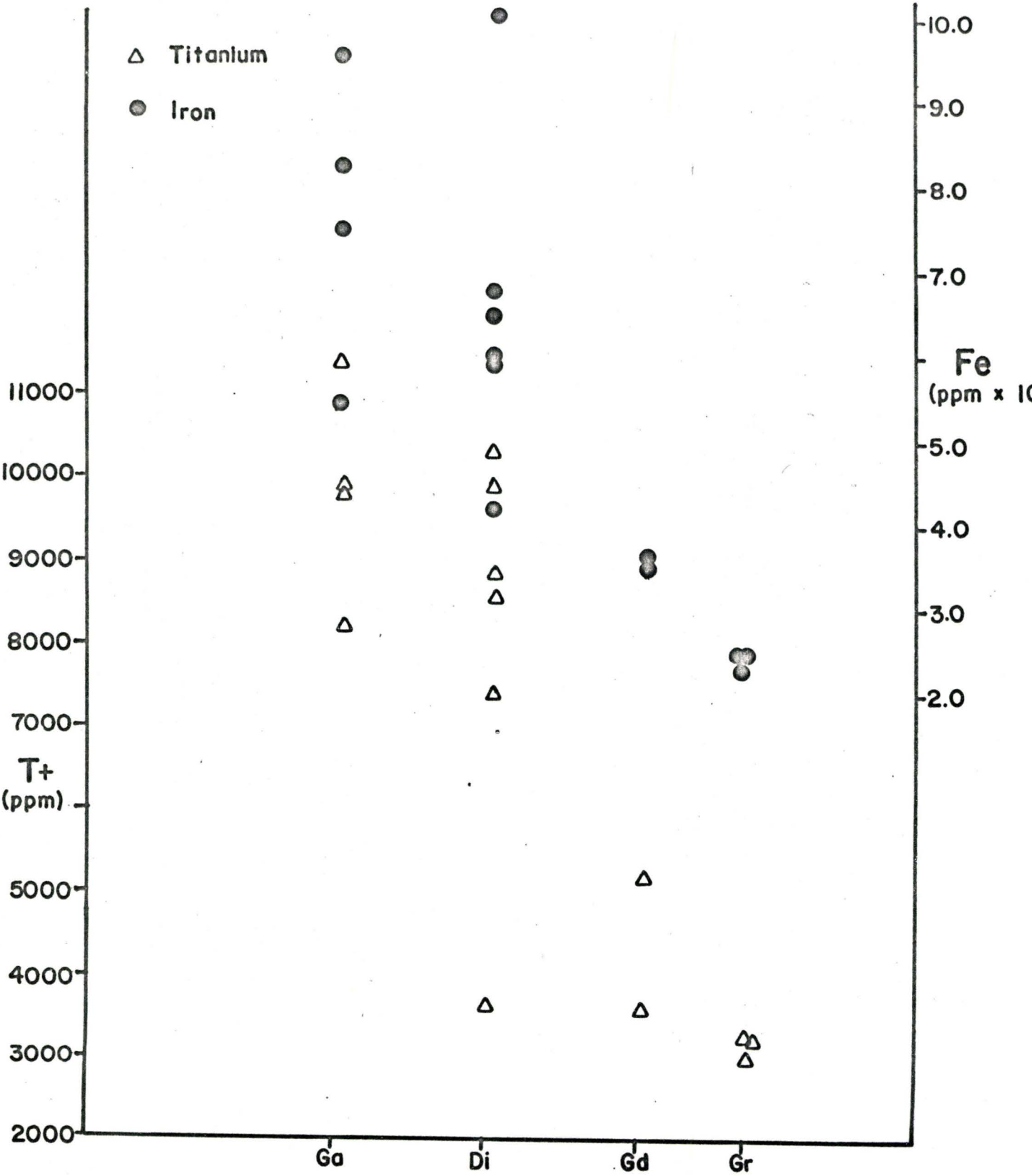
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