CHEMICAL ANALYSIS OF
THE MURRAY GRANITE

CHEMICAL ANALYSIS OF THE MURRAY GRANITE AND ASSOCIATED DIKES, SUDBURY, ONTARIO

By

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ABSTRACT

Samples from two granitic offshoot dikes from the Murray granite, and from the Murray granite itself were analysed for eight major elements using X-Ray Fluorescence, to determine whether or not the dikes represented remobilized parts of the Murray granite and as such could have a different chemical composition from the parent material.

The analyses show that only very minor chemical differences exist between the two granitic dikes and the main Murray granite. However four samples of the dike rocks appear to show element exchange with the Sudbury norite surrounding them, resulting in increased Na_2O and CaO contents and lower K_2O contents, resulting in increased amounts of albitic plagioclase.

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INTRODUCTION

The Murray granite (Fig.1) is approximately 3 miles long and one mile wide and located 2 miles northwest of the city of Sudbury. It intrudes the metavolcanics and metasediments of the lower Huronian, between the southern margin of the nickel irruptive and the Frood-Stobie offset (Gibbins et al. 1971).

The Murray granite has been the subject of several studies (Collins, 1936; Cooke, 1946; Speers, 1956; and Fairbairn et al. 1960,1965); it has also been referred to in other studies of Sudbury geology (Zurbrigg, 1957; Clarke and Potapoff, 1959; Hawley, 1962; and Roscoe, 1969).

Gibbins collected samples for Rb-Sr Isotopic dating, to determine the ages of the granitic dikes intruding the Sudbury Norite, and the age of the main mass of the Murray Granite.

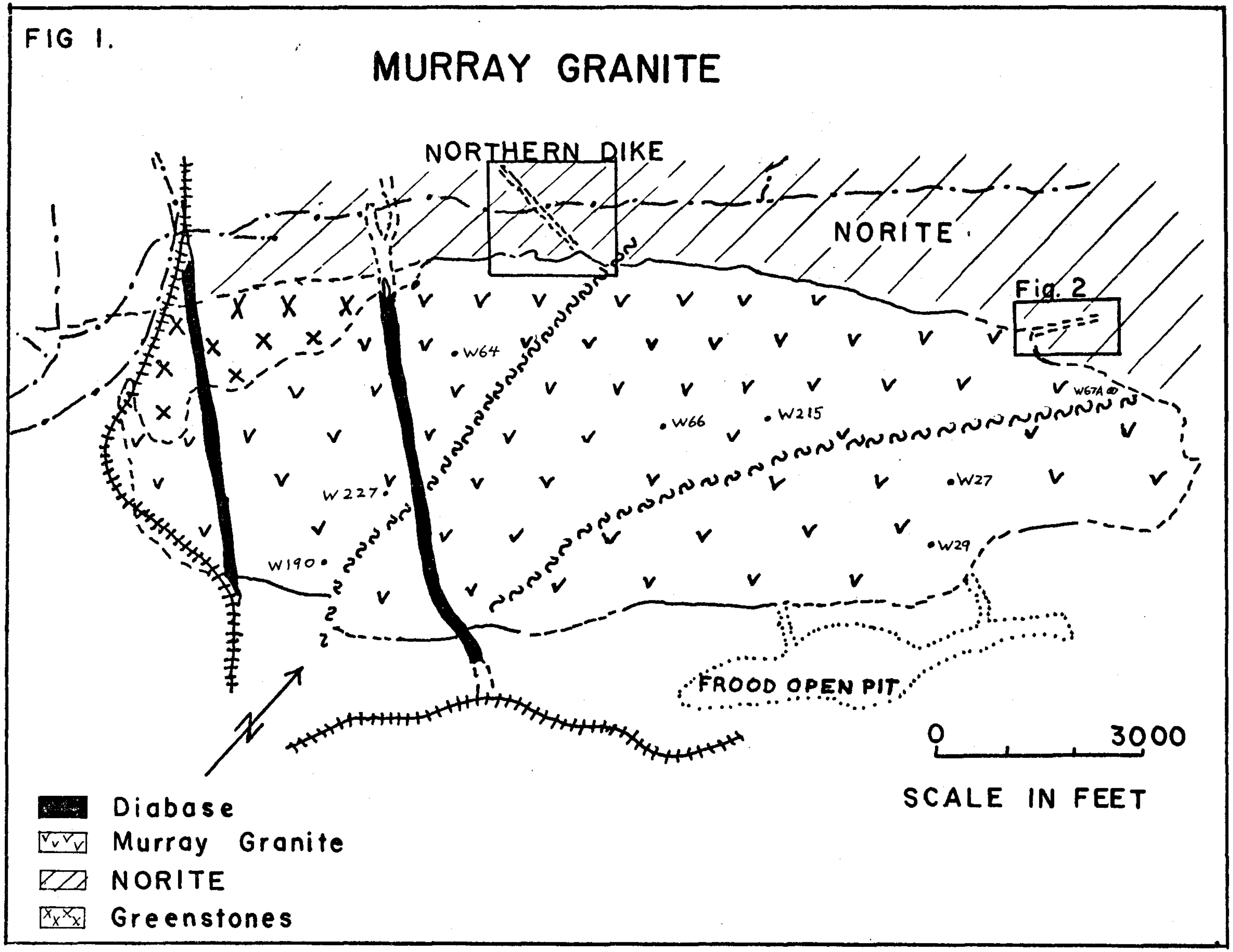
This study was undertaken to see whether any chemical differences exist between two of these granitic dikes and the main body of the Murray Granite. The author chose to analyse five rock samples (W27,W29,W64,W66, and W215) from the main Murray granite; two samples of

Sudbury breccia (W190 and W227), and one sample of a "syenite" (W67A); collected as shown in Fig. 1.

Seven samples (W1, W8, W9, W10, W11, W19 and W20) from the eastern granitic dike, and five samples (W302, W303, W304, W305, and W306) from the northern dike were analysed; having been collected as shown in Fig. 2 and Fig. 3 respectively.

FIG 1.

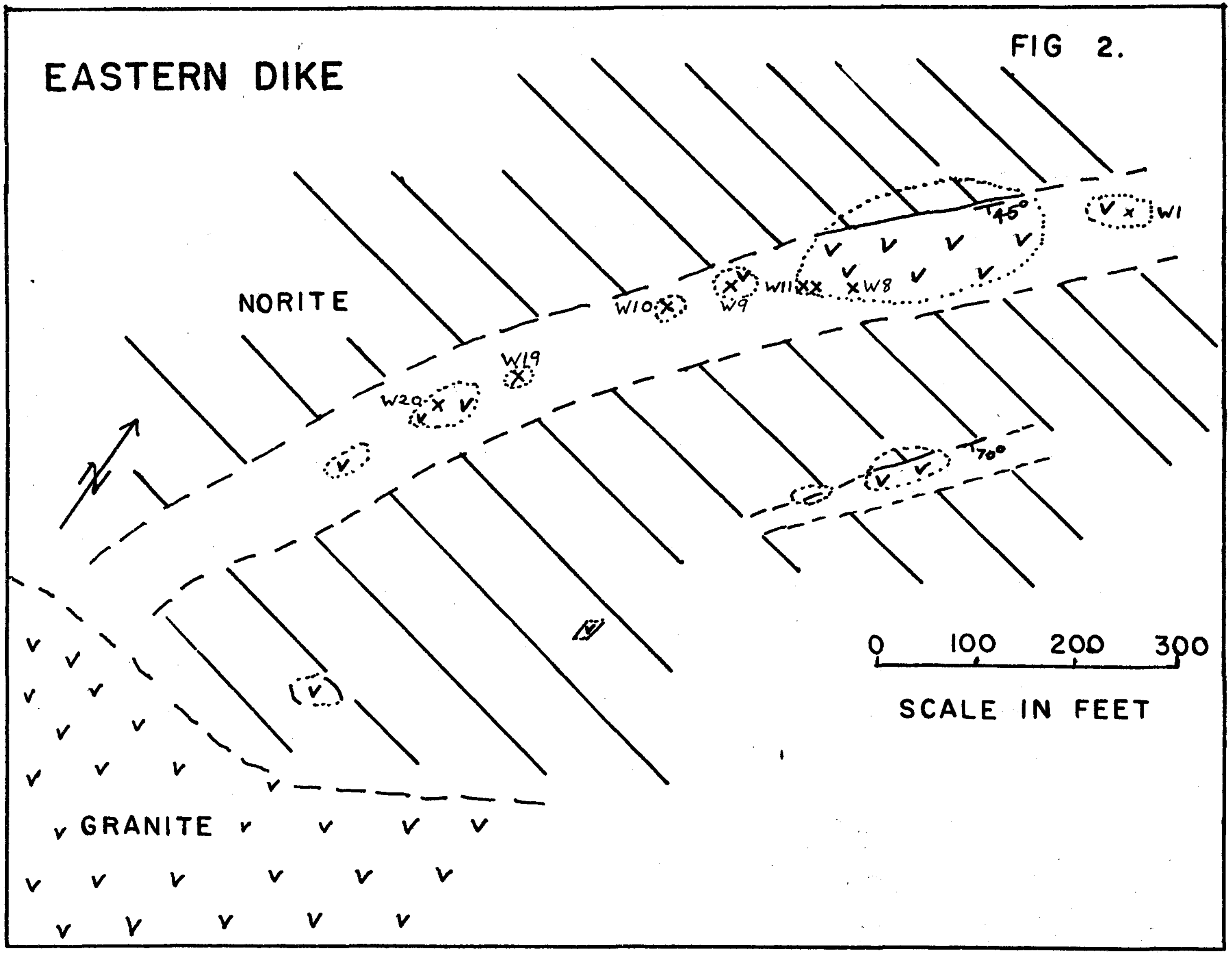
MURRAY GRANITE



Modified from Gibbins et al. (1972)

FIG 2.

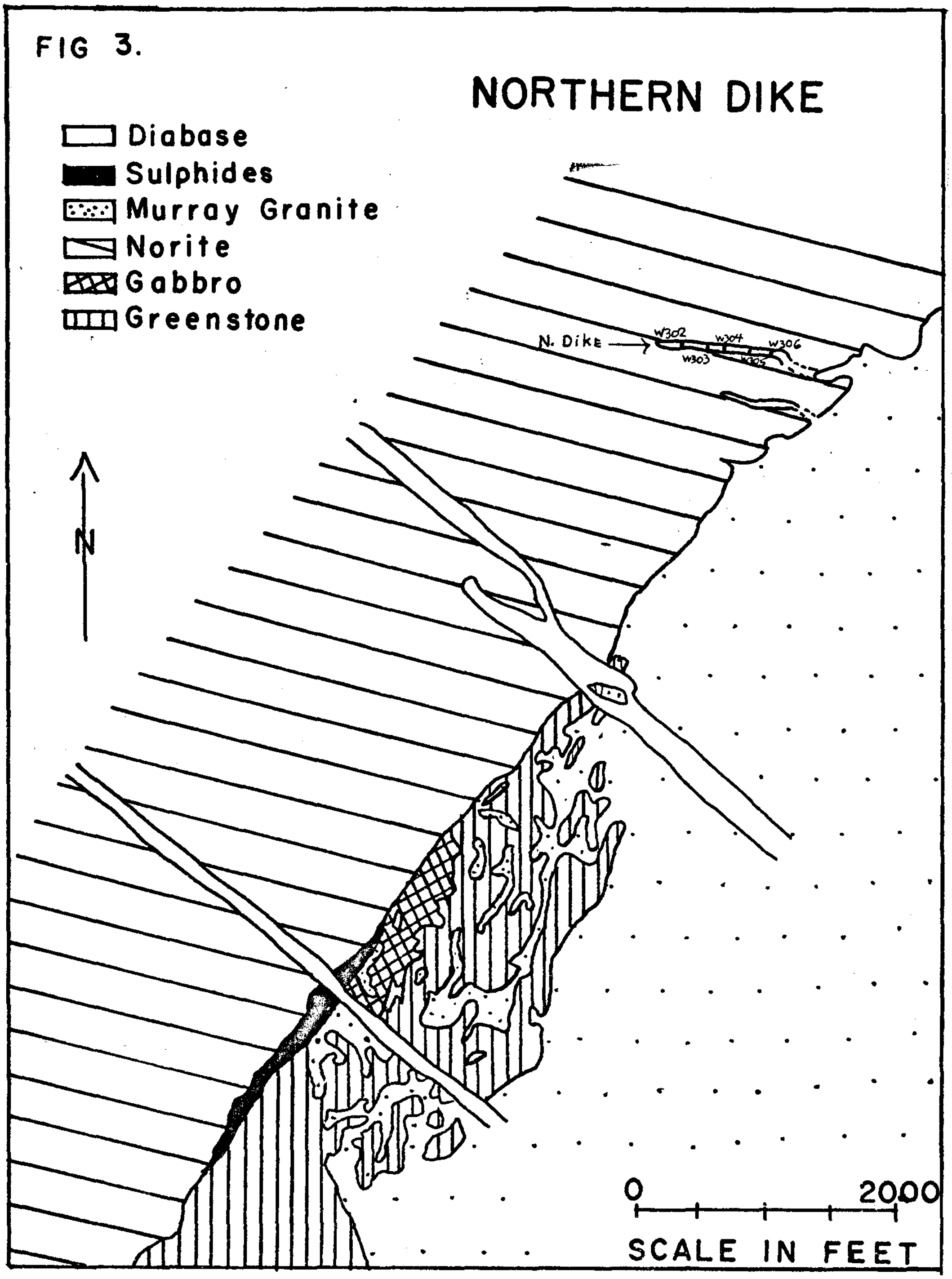
EASTERN DIKE



Modified from Gibbins et al. (1972)

FIG 3.

NORTHERN DIKE



REGIONAL GEOLOGY

General Geology

Hawley, J.E.(1962) states "The history of this region embraces a time interval of well over 1,000 million years, at least 3 major orogenies, and five or six periods of extensive intrusive activity.

The Sudbury basin itself forms an elongated, basin -shaped asymmetrical synclinorium, gently folded on the north, overturned on the south flank, and thrown into a complex system of minor folds in the interior. It is 37 miles long and 17 miles wide.

The Sudbury Irruptive, which consists of a lower norite and an upper micropegmatite or granophyre separated by a relatively narrow transition zone, is overlain inside the Sudbury basin by the Whitewater group: the Onaping "tuffs", Onwatin slate and the Chelmsford "sandstone".

Outside the basin, the oldest Precambrian (Pre-Huronian) Stobie series adjoining the norite consists dominantly of basic volcanics, minor rhyolite, rhyolite breccia and interbedded greywacke. This is followed southward by the Copper Cliff "rhyolite" and the McKim formation, both Huronian in age, and then by the Ramsey Lake Conglomerate and the Wanapitei massive quartzites.

These Huronian rocks are a continuous succession, all facing south and overlain uncomforably, both at the southwest corner and the eastern end of the basin, by infolded and in places faulted uraniferous basal conglomerates and quartzites of the Lower Huronian (Mississagi).

Intrusive into this Huronian system are coarser-grained granite stocks at Creighton, Pump Lake and Murray, as well as the younger prolific post-Cobalt gabbros and diorites (Nipissing diabase); the nickel irruptive and offsets, poast-norite granite and aplite dykes, and still younger trap and olivine diabase dykes of Keweenawan (1020 my.) age.

The Murray granite lies to the south of the Sudbury norite, mostly having sharply defined contacts with it. However, granite or granite-like dykes appear to extend continuously northward into the norite (Figs. 1,2 and 3)".

The granitic dikes investigated in this paper are roughly 100 feet wide and 1,000 feet long.

STRUCTURAL GEOLOGY

Structurally the basin rocks have been intensely folded and faulted in places, probably at different times.

The irruptive itself is metamoprhosed, locally metasomatized, faulted, brecciated, and transected by diabase dykes. The Huronian rocks were deformed by a number of separate tectonic events, with those at Elliot Lake and to the west being in the form of folds gently plunging westward. To the east of Elliot Lake, they plunge eastward. In that part of the Cobalt Group north of Sudbury, the rocks are undeformed or very gently folded about northerly striking axes.

The Murray granite is cut by two north-south trending olivine diabase dykes in its western extremity, and two faults, one trending towards the northeast and the other running ENE.

SAMPLE COLLECTION

The rock samples were collected by W.A. Gibbins from the main Murray granite and two of its offshoot dikes, from the places shown in Figs. 2 and 3.

The samples generally have a light pink matrix of quartz and feldspar grains, with dark biotite and hornblende specks in it; the whole rock having an average grain size of 0.25 to 0.75 mm. The samples were generally all similar in appearance except that the granitic dike rocks contained more biotite and hornblende, and were a lighter pink color than the main Murray granite specimens which were composed of larger but less numerous biotite and hornblende clusters surrounded by a matrix of quartz and feldspar in which the feldspar often showed as distinctly pinkish-red crystals.

ANALYTICAL PROCEDURE

A. SAMPLE PREPARATION

The samples were prepared for analysis by X-Ray Fluorescence Spectrometry as follows:

1. The rocks were broken into pieces less than 2 to 3 inches across with the use of a sledge hammer.
2. These fragments were then placed in a jaw crusher and reduced in size to less than ½ inch across.
3. These small rock chips were then transferred to a Spex Shatter Box Container, ground for 10 minutes to less than 200 mesh size and thoroughly mixed to ensure homogenization.
4. 1.50 grams of rock samples were weighed out into a carbon crucible. 3.00 grams of Lithium Tetraborate Anhydrous (Spex Industries) was added and the mixture fused in a muffle furnace at 1100°C for 30 minutes.
5. Upon cooling, the small, hard, ball-like glass bead was easily removed from the crucible.
6. The glass bead was then cracked in two in a stainless steel mortar and pestle.
7. These fragments,along with one tungsten-carbide ball, were placed in a plastic Spex container which was then shook in a Spex Ball Mill for 20-30 minutes.
8. To prepare the pellets for XRF analysis, about 2.0 to 2.5 grams of the powder from the Ball Mill was mixed

with two drops of Mowiol solution (0.5 grams of Mowiol in 25 ml. of water, and then thoroughly mixed using an agate mortar and pestle. The Mowiol solution acts as a binding agent to hold the sample together.

9. The mixture from 8. was then made into a pellet with a boric acid backing and outer rim using a Spex Ram with an applied pressure of twenty tons for one minute. The pressure was released slowly, taking about thirty seconds to reach zero tons. This produced a pellet which not only had a smooth surface for analysis, but also one which has held together quite well. The boric acid backing also allowed for the labelling of the samples with an appropriate marker.
10. The pellets were then stored for X-Ray Fluorescence analysis.

B. XRF ANALYSIS

The analyses of the pellets were done on a Phillips Model 1540 X-Ray Fluorescence Spectrometer. The experimental conditions can be found in TABLE 1.

Analysis of the samples was done for a total of eight major elements (Si, Al, Fe, Ti, Mg, Ca, K, Na).

GSP-1 (United States Geological Survey) was used as the standard and G-2 (United States Geological Survey), NIM-G (National Institute for Metallurgy, Republic of South Africa), and three samples supplied by J. Dostal

TABLE 1

X-RAY FLUORESCENCE SPECTROGRAPH SETTINGS

Element	Fe	Ti	Ca	K	Si
$K\alpha$ 2θ Position($^\circ 2\theta$)	57.52°	86.18°	113.18°	20.70°	79.14°
Background (2θ)	-	-	-	-	-
Tube	W	Cr	Cr	Cr	Cr
Voltage (Kv)	50	50	40	36	44
Current (mA)	30	32	10	6	22
Collimator	Fine	Fine	Fine	Coarse	Coarse
X-Ray Path	Air	Vacuum	Vacuum	Vacuum	Vacuum
Crystal	LiF[1]	LiF[1]	LiF[1]	PET[2]	PET[2]
Time (secs.)	40	40	40	40	40
Counts	$2x10^6$	10^6	$2x10^6$	10^6	10^6
Attenuation	2^3	2^3	2^3	2^3	2^3
Counter	FPC[3]	FPC[3]	FPC[3]	FPC[3]	FPC[3]
Gas Flow[4] (fph)[5]	0.75	0.75	0.75	0.75	0.75
Counter Voltage(Hv) (Scale Divisions)	4.95	4.95	4.95	4.35	4.65
Threshold (Scale Divisions)	40	40	40	50	50
Window (Scale Divisions)	-	-	-	-	-

[1] LiF(220): Lithium Fluoride

[2] PET: Penta-Erythritol

[3] FPC: Flow Proportional Counter

[4] Gas: P-10: 90% Argon, 10% Methane

[5] fph: Cubic feet per hour

TABLE 1

X-RAY FLUORESCENCE SPECTROGRAPH SETTINGS

Element	Al[6.]	Al[7.]	Mg	Na
$K\alpha$ 2θ Position($^{\circ}2\theta$)	103.24°	103.24°	106.85°	24.04°
Background($^{\circ}2\theta$)	-	-	105.50° 109.00°	22.00°
Tube	Cr	Cr	Cr	Cr
Voltage (Kv)	48	48	50	48
Current (mA)	28	28	30	24
Collimator	Coarse	Coarse	Coarse	Coarse
X-Ray Path	Vacuum	Vacuum	Vacuum	Vacuum
Crystal	ADP[8.]	ADP[8.]	ADP[8.]	ADP[8.]
Time (secs.)	60	60	200	200
Counts	$4x10^5$	$4x10^5$	10^6	10^6
Attenuation	2^3	2^3	2^3	2^3
Counter	FPC	FPC	FPC	FPC
Gas Flow (fph)	0.75	0.75	0.75	0.75
Counter Voltage(Hv) (Scale Divisions)	4.70	4.90	4.90	4.80
Threshold (Scale Divisions)	60	110	160	50
Window (Scale Divisions)	120	110	120	100

6. All samples except W9 and W29

7. Samples W9 and W29

8. ADP: Ammonium-Dihydrogen Phosphate

which had been analysed by atomic absorption in the Rock Analysis Laboratory, McMaster University.

Three unknowns were run in each sequence, GSP-1 being run at the beginning and the end of each sequence as a check for drift in the machine.

Two analyses each, of Na, Al, Si, and Mg were made to increase analytical precision, and duplicate pellets of samples W-9 and W-29 were made to check for Al contamination during crushing in the Spex Ball Mill.

The 2θ peak positions for sodium and magnesium were difficult to locate (due to low total peak to background ratios), so NaCl and MgO respectively, were used to locate these peak positions. The background counts were recorded for these two elements because of total peak to background ratios less than 10.

For each element, count and time maxima were preset so that counting ceased when the count or time maxima was reached, whichever occurred first.

The data from the XRF analysis were fed into X-Ray Preliminary and X-Ray Matrix Correction programs (written by B.M. Gunn), giving the final, corrected values in Table 2. The latter data were also fed into Niggli (after D.M. Shaw) and C.I.P.W. Norm (after I. Mason) programs to give the results shown in Table 3

TABLE 2
CHEMICAL ANALYSES

	W302	W303	W304	W305	W306	W27B	W27C
SiO_2	71.47	73.77	72.62	72.98	72.53	70.39	72.50
TiO_2	.26	.25	.26	.36	.30	.25	.26
Al_2O_3	12.19	12.58	12.76	12.51	12.28	11.81	12.29
FeO	1.66	1.66	1.50	3.01	1.91	2.08	2.04
MgO	.35	.41	.42	.88	.38	.24	.23
CaO	.76	.79	.88	1.64	1.02	1.07	1.10
Na_2O	2.32	2.75	2.95	2.63	2.81	3.05	2.96
K_2O	5.33	5.54	5.49	2.99	5.46	5.11	5.18
TOTAL	94.34	97.75	96.88	97.00	96.69	94.00	96.56

	W29	W64	W66	W215	W1	W8	W9
SiO_2	72.39	72.43	69.09	70.43	72.48	71.40	74.36
TiO_2	.23	.27	.46	.45	.15	.29	.27
Al_2O_3	11.99	12.25	12.43	12.92	12.21	12.33	12.53
FeO	1.92	2.13	3.63	3.41	1.23	1.80	1.88
MgO	.35	.29	.31	.43	.23	.38	.33
CaO	.95	.65	1.48	1.75	.56	.89	.94
Na_2O	2.93	3.06	3.65	4.00	3.10	2.52	2.76
K_2O	5.08	5.42	4.95	4.87	5.56	5.52	5.52
TOTAL	96.84	96.50	96.00	98.26	95.52	95.15	95.76

TABLE 2
CHEMICAL ANALYSES

	W10	W11	W19	W20	W190	W227	W67A
SiO_2	74.36	72.77	72.57	72.63	65.30	63.43	63.13
TiO_2	.26	.30	.23	.24	.70	.80	.32
Al_2O_3	12.47	13.34	12.13	12.35	12.67	12.52	20.82
FeO	1.80	1.51	1.00	1.65	5.75	6.55	.96
MgO	.62	.47	.37	.29	2.34	2.38	.52
CaO	1.03	1.71	1.36	.83	3.25	3.53	1.15
Na_2O	2.81	3.79	5.24	2.93	3.02	3.23	11.24
K_2O	4.35	3.41	1.38	5.57	4.25	2.78	.67
TOTAL	97.70	97.30	94.28	96.49	97.28	95.22	99.01

TABLE 3
NIGGLI CATION NORMS

	W302	W303	W304	W305	W306	W27B	W27C
QZ	34.22	31.79	29.87	38.22	30.35	29.25	30.52
CO	1.44	.71	.42	2.26	0.00	0.00	0.00
OC	33.98	33.97	33.86	18.61	33.84	32.54	32.15
AB	22.48	25.62	27.66	24.87	26.47	29.51	27.92
AN	4.07	4.07	4.56	8.57	5.01	3.72	5.21
NE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DI	0.00	0.00	0.00	0.00	.07	.30	.08
HE	0.00	0.00	0.00	0.00	.17	1.30	.34
EN	1.04	1.18	1.21	2.56	1.07	.56	.63
FS	2.38	2.31	2.05	4.38	2.58	2.45	2.77
FO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IL	.39	.36	.38	.53	.44	.38	.38
AG	0.00	0.00	0.00	0.00	1.24	1.60	.42
HY	3.42	3.49	3.26	6.94	3.65	3.01	3.40
OL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PL	26.55	29.69	32.22	33.44	31.48	33.23	33.13
$\frac{AN}{AN + AB}$	15.33	13.70	14.15	25.63	15.92	11.19	15.72

TABLE 3
NIGGLI CATION NORMS

	W29	W64	W66	W215	W1	W8	W9
QZ	31.99	29.65	22.96	21.71	30.10	31.51	29.89
CO	0.00	.20	0.00	0.00	.09	.69	.36
OC	31.46	33.62	30.78	29.49	34.75	34.82	34.53
AB	27.57	28.85	34.50	36.81	29.44	24.16	26.24
AN	4.79	3.39	3.07	3.00	2.94	4.72	4.94
NE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DI	.03	0.00	.55	.96	0.00	0.00	0.00
HE	.09	0.00	3.18	3.76	0.00	0.00	0.00
EN	1.00	.84	.63	.74	.67	1.12	.97
FS	2.74	3.07	3.66	2.89	1.79	2.55	2.69
FO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IL	.34	.40	.68	.64	.22	.43	.40
AG	.12	0.00	3.72	4.72	0.00	0.00	0.00
HY	3.74	3.91	4.29	3.63	2.46	3.67	3.66
OL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PL	32.36	32.24	37.57	39.81	32.38	28.88	31.18
$\frac{AN}{AN + AB}$	14.80	10.50	8.18	7.53	9.08	16.33	15.84

TABLE 3
NIGGLI CATION NORMS

	W10	W11	W19	W20	W190	W227	W67A
QZ	35.58	30.97	32.37	30.01	17.72	19.06	0.00
CO	1.44	.35	0.00	0.00	0.00	0.00	0.00
OC	26.73	20.87	8.65	34.54	26.11	17.49	3.77
AB	26.25	35.25	49.89	27.61	28.20	30.88	78.91
AN	5.32	8.79	5.84	4.31	8.81	12.20	4.18
NE	0.00	0.00	0.00	0.00	0.00	0.00	10.32
DI	0.00	0.00	.48	0.00	2.86	2.17	.58
HE	0.00	0.00	.57	.01	3.51	2.98	.42
EN	1.78	1.34	.85	.84	5.29	5.91	0.00
FS	2.52	1.99	1.02	2.33	6.49	8.12	0.00
FO	0.00	0.00	0.00	0.00	0.00	0.00	.81
FA	0.00	0.00	0.00	0.00	0.00	0.00	.59
IL	.38	.43	.34	.35	1.01	1.19	.42
AG	0.00	0.00	1.05	.01	6.37	5.15	1.00
HY	4.30	3.33	1.87	3.17	11.78	14.03	0.00
OL	0.00	0.00	0.00	0.00	0.00	0.00	1.40
PL	31.57	44.04	55.73	31.92	37.01	43.08	83.09
$\frac{AN}{AN + AB}$	16.84	19.96	10.48	13.49	23.81	28.33	5.03

TABLE 4

C.I.P.W. MOLECULAR NORM

	W302	W303	W304	W305	W306	W27B	W27C
Q	34.23	33.07	30.88	39.17	31.23	29.29	31.36
OR	31.50	32.74	32.44	17.67	32.27	30.20	30.61
AB	19.63	23.27	24.96	22.25	23.78	25.81	25.05
AN	3.77	3.92	4.37	8.14	4.77	3.44	4.95
NE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DI	0.00	0.00	0.00	0.00	.25	1.62	.44
WO	0.00	0.00	0.00	0.00	.12	.78	.21
EN	0.00	0.00	0.00	0.00	.03	.13	..03
FS	0.00	0.00	0.00	0.00	.10	.72	.20
HY	3.49	3.66	3.37	7.12	3.83	3.16	3.66
EN	.87	1.02	1.05	2.19	.92	..47	.54
FS	2.62	2.64	2.33	4.93	2.91	2.69	3.12
OL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IL	.49	.47	.49	.68	.57	.47	.49
C	1.22	.62	.37	1.97	0.00	0.00	0.00

TABLE 4
C.I.P.W. MOLECULAR NORM

	W29	W64	W66	W215	W1	W8	W9
Q	32.95	30.48	23.55	22.86	30.71	31.85	30.47
OR	30.02	32.03	29.25	28.78	32.86	32.62	25.71
AB	24.79	25.89	30.89	33.85	26.23	21.32	23.35
AN	4.56	3.22	2.91	2.92	2.78	4.42	4.66
NE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DI	.13	0.00	3.88	5.01	0.00	0.00	0.00
WO	.06	0.00	1.85	2.41	0.00	0.00	0.00
EN	.01	0.00	.23	.42	0.00	0.00	0.00
FS	.05	0.00	1.79	2.18	0.00	0.00	0.00
HY	3.95	4.19	4.65	3.99	2.58	3.77	3.83
EN	.86	.72	.54	.65	.57	.95	.82
FS	3.09	3.47	4.11	3.34	2.01	2.83	3.01
OL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IL	.44	.51	.87	.85	.28	.55	.51
C	0.00	.17	0.00	0.00	.07	.59	.31

TABLE 4
C.I.P.W. MOLECULAR NORM

	W10	W11	W19	W20	W190	W227	W67A
Q	36.92	32.27	32.95	30.86	18.39	19.32	0.00
OR	25.71	20.15	8.16	32.92	25.12	16.43	3.96
AB	23.78	32.07	44.34	24.79	25.55	27.33	78.08
AN	5.11	8.48	5.50	4.10	8.46	11.45	4.38
NE	0.00	0.00	0.00	0.00	0.00	0.00	9.23
DI	0.00	0.00	1.05	.02	6.44	5.11	1.09
WO	0.00	0.00	.52	.01	3.20	2.53	.55
EN	0.00	0.00	.20	0.00	1.24	.92	.28
FS	0.00	0.00	.32	.01	2.00	1.66	.26
HY	4.42	3.45	1.85	3.35	11.99	14.05	0.00
EN	1.54	1.17	.72	.72	4.59	5.01	0.00
FS	2.88	2.28	1.13	2.63	7.40	9.04	0.00
OL	0.00	0.00	0.00	0.00	0.00	0.00	1.46
FO	0.00	0.00	0.00	0.00	0.00	0.00	.71
FA	0.00	0.00	0.00	0.00	0.00	0.00	.75
IL	.49	.57	.44	.46	1.33	1.52	.61
C	1.27	.31	0.00	0.00	0.00	0.00	0.00

and Table 4 respectively. The computer programs were run on the CDC 6400 computer at McMaster University.

ANALYTICAL PRECISION

The accuracy of the analyses was checked using the reference chemical analysis of the U.S. Geological Survey's standard granite G-2, and analyses of samples NIM-G, U-68, 125, and U253 done by atomic absorption in the Rock Analysis Laboratory at McMaster University.

A comparison of the analyses listed in Table 5 shows that SiO_2 is up to 3.2% low and Al_2O_3 is up to 0.7% low in the analyses of this study. The Na_2O does not show any systematic deviance from the reference values, and can be up to 0.52% out, or approximately 10% of the total Na_2O .

The other elemental oxide data are felt to be within analytical error limits.

The above-mentioned deviations from the standard analyses are expected to be reflected in all the samples and must be considered in the evaluation of the norms and plots using these analyses. The main difference is that there will be too little quartz in the norm, being up to 5% SiO_2 low; while the low Al_2O_3 values will result in a decrease in the amount of corundum reported in the norms.

TABLE 5
ANALYSES OF STANDARDS, THIS STUDY

	G2	NIMG	U-68	125	U253
SiO_2	68.90	72.89	68.31	63.47	72.30
TiO_2	.48	.11	.50	.56	.15
Al_2O_3	14.79	11.45	15.11	16.86	11.83
FeO	2.39	1.73	2.07	2.40	1.66
MgO	.90	.11	.59	.57	.11
CaO	1.93	.81	.94	1.28	.78
Na_2O	3.89	3.53	4.53	4.44	3.52
K_2O	4.54	4.94	6.32	7.05	4.68
TOTAL	97.82	95.57	98.37	96.63	95.03

ANALYSES OF STANDARDS

	G2	NIMG	U-68	125	U253
SiO_2	69.19	75.83	69.59	65.12	75.53
TiO_2	.53	.09	.51	.57	.13
Al_2O_3	15.34	11.94	15.28	17.25	12.50
FeO	2.41	1.76	2.12	2.52	1.66
MgO	.78	.04	.45	.58	.06
CaO	1.98	.77	.90	1.26	.70
Na_2O	4.15	3.35	4.01	4.57	4.04
K_2O	4.51	5.00	6.24	7.31	4.75
TOTAL	98.89	98.78	99.10	99.18	99.37

ANALYTICAL REPRODUCIBILITY

The duplicate analyses of sample W27 shown in Table 6, show that the greatest variability in the oxides occurs in the SiO_2 and Al_2O_3 contents. The difference in SiO_2 is 2.11% and that of Al_2O_3 is 0.5%.

The differences in the MgO and Na_2O contents is probably due to these elements' low total (peak and background) peak to background ratios of 3:1 and 5:4 respectively.

Since other users of the Phillips Model 1540 X-Ray Fluorescence Spectrometer at McMaster University have reported these low values for SiO_2 and Al_2O_3 for other rock samples (Personal Communication, 1972), these low values must be due to equipment defects.

TABLE 6

DUPLICATE ANALYSIS

	W27B	W27C	Mean
SiO_2	70.39	72.50	71.445
TiO_2	.25	.26	.255
Al_2O_3	11.81	12.29	12.05
FeO	2.08	2.04	2.06
MgO	.24	.23	.235
CaO	1.07	1.10	1.085
Na_2O	3.05	2.96	3.005
K_2O	5.11	5.18	5.145

1. W27B and W27C are duplicate analyses (pellects made from the same crushed powder from the Spex Ball Mill.

PETROGRAPHY

A thin section study of the Murray granite thin sections revealed that it has an average grain size of 1 mm, containing approximately 35% quartz with the rest being feldspar except for a few grains of biotite and magnetite.

The K-feldspar is microcline in the form of anhedral patches that mould around and often enclose round -shaped quartz grains 0.2 to 0.5 mm in size. This microcline consists of microperthite with albite (An5-10) forming exsolutions comprising about 5% of the rock volume.

About 10% of the rock is basic oligioclase (An28), forming irregular anhedral patches which have been replaced along their rims by the microcline which surrounds them; and also altered to epidote in their cores.

The minor brown biotite and black oxides form clusters associated with the microcline, occurring interstitially to the quartz grains. In places small bright olive green hornblende anhedra occur along with this material as an alteration product of biotite.

W215, unlike the above sections W27, W29, W64 and W66, contains approximately 60% plagioclase and 15-20% microcline, plus 25% quartz. The plagioclase (An25-30) is anhedral, forming interstitially to and enclosing in it some of the rounded quartz grains; while the microcline replaces and rims it.

Less than 1% Calcite occurs as minute anhedra, sometimes rimming biotite,that is interstitial to the other minerals.

Northern Dike

Sections W302,W303,W304, and W306 contain about 35% quartz, 35% microcline, 25% plagioclase and 1-2% mafic minerals and opaques.

The subhedral to euhedral oligioclase laths in these samples, are altered to epidote and a little brown biotite, mostly from their cores on outwards, leaving an unaltered outside rim. These irregularly rounded plagioclase grains appear to be partially replaced by microcline as evidenced by the irregular contacts between the two minerals, the irregular veins of microcline in the plagioclase which sometimes results in albite-twinned oligioclase laths being stained yellow,by the sodium cobaltnitrite solution being used to stain K-feldspar, in veins and patches; and the anhedral patches of oligioclase within the microcline which are optically orientated parallel to one another(Speers, 1956).

The microcline is generally in subhedral to anhedral grains less than 1 mm across, showing perthitic texture.

Speers' (1956) observation that albitic plagioclase with microcline can occur in a few places as irregular vein-like forms along grain boundaries and as perthitic intergrowths within the microcline, was also seen.

Section W305 differes from the above, in that the plagioclase is distinctly anhedral and interstitial to anhedral quartz. Furthermore, there is little or no microcline in this section compared to the 35% observed in the other sections of this dike. Biotite is more plentiful,3-4%, and in at least one place, an anhedral crystal of calcite, surrounded by epidote and biotite flakes, occurs interstitially to the quartz and feldspar crystals.

Eastern Dike

Sections W1, W8, W9, and W20 contain approximately 10% oligioclase feldspar and 50% microcline; the former of which is wholly interstitial to the rounded quartz grains, including them to form poikilitic patches of microcline.

The oligioclase forms rounded subhedral to euhedral laths, and anhedral patches interstitial to the quartz grains, the latter feldspar being surrounded and partially replaced by the microcline.

Both forms of oligioclase are only slightly altered to epidote.

As one goes from section W10 to W11 to W19, the proportion of plagioclase relative to the microcline and the quartz, increases to 50% while the microcline decreases from 45% to 30% and the quartz remains relatively constant at about 30%.

Although the plagioclase feldspars are highly altered to epidote in section W10, they are only slightly altered in the other two sections, presenting only a "clouded" appearance in the latter.

Sudbury Breccia

Slides W190 and W227 consist of 1 to 4 mm in size fragments of quartz grains surrounded in places by anhedral plagioclase and minor K-feldspar. These, in turn, are all surrounded by a fine-grained (less than 0.25 mm in size) matrix of green hornblende, anhedral plagioclase and irregular quartz grains. The fragments make up 20% of the rock volume, with the rest of the rock being comprised of the matrix just described.

"Syenite"

Section W67A consists of subhedral laths of oligioclase (An30) to andesine (An35) composition, roughly 0.10 to 0.75 mm long, which are engulfed along with interstitial anhedral quartz grains by large 1.0 to 2.0 mm anhedral poikilitic crystals of antiperthite. About 2% of the rock consists of minor brown biotite and opaques which occur interstitially to the plagioclase and quartz; along with less than 1% anhedral calcite and K-feldspar grains.

An-Ab-Or Plot

The plot of Anorthite-Albite-Orthoclase contents is adopted after the scheme by Tuttle and Bowen (1958) and is fully discussed in that reference, while the An-Ab-Or ratios for each rock come from the C.I.P.W. Norm program.

Tuttle and Bowen state that "Curve B'B represents the composition of two feldspars in equilibrium with a liquid at a lower temperature than that of the dry system represented by the curve LK_sP. The temperature lowering could result from the solution of silica, nepheline, water, or other materials not taken into solid solution in the feldspars. The curve C'C illustrates similar relationships at a still lower temperature, and DE-HG at temperatures where two feldspars can coexist in equilibrium with liquid when no anorthite is present".

Several features of the rocks analysed in this work are to be noted: (1) the Sudbury breccias are more Anorthite rich than either the main Murray granite or the two dikes, (2) there is no major distinction between the main Murray granite and the two dikes, except for a tendency for the Murray granite to be less Or rich than

In Figures 4 to 9, the symbols are as follows:

x - Main body of the Murray Granite

o - Eastern granitic dike

• - Northern granitic dike

* - Sudbury breccia

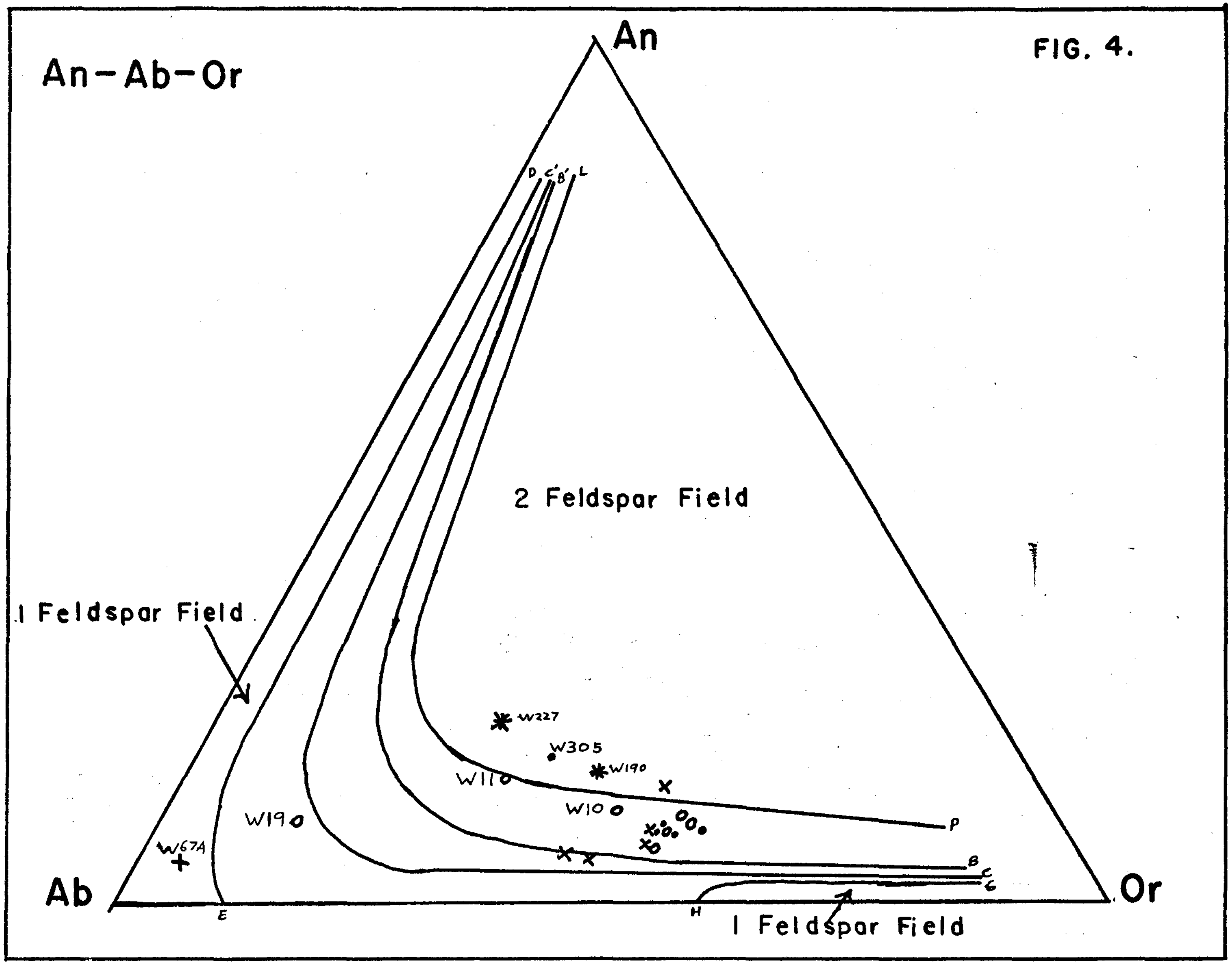

An-Ab-Or
An
Ab
Or
D
C'
B'
L
2 Feldspar Field
1 Feldspar Field
1 Feldspar Field
W227
W305
W190
W110
W100
W190
W67A
E
H
P
B
C
G

FIG. 4.

the two dikes, (3) samples W10, W305, W11 and W19 show progressively higher albite contents than the rest of the samples, and (4) All the samples, with the possible exception of W19, should be two feldspar granites.

The petrography of the various thin sections of these samples supports observations (3) and (4), and shows that sample W19 also contains two feldspars.

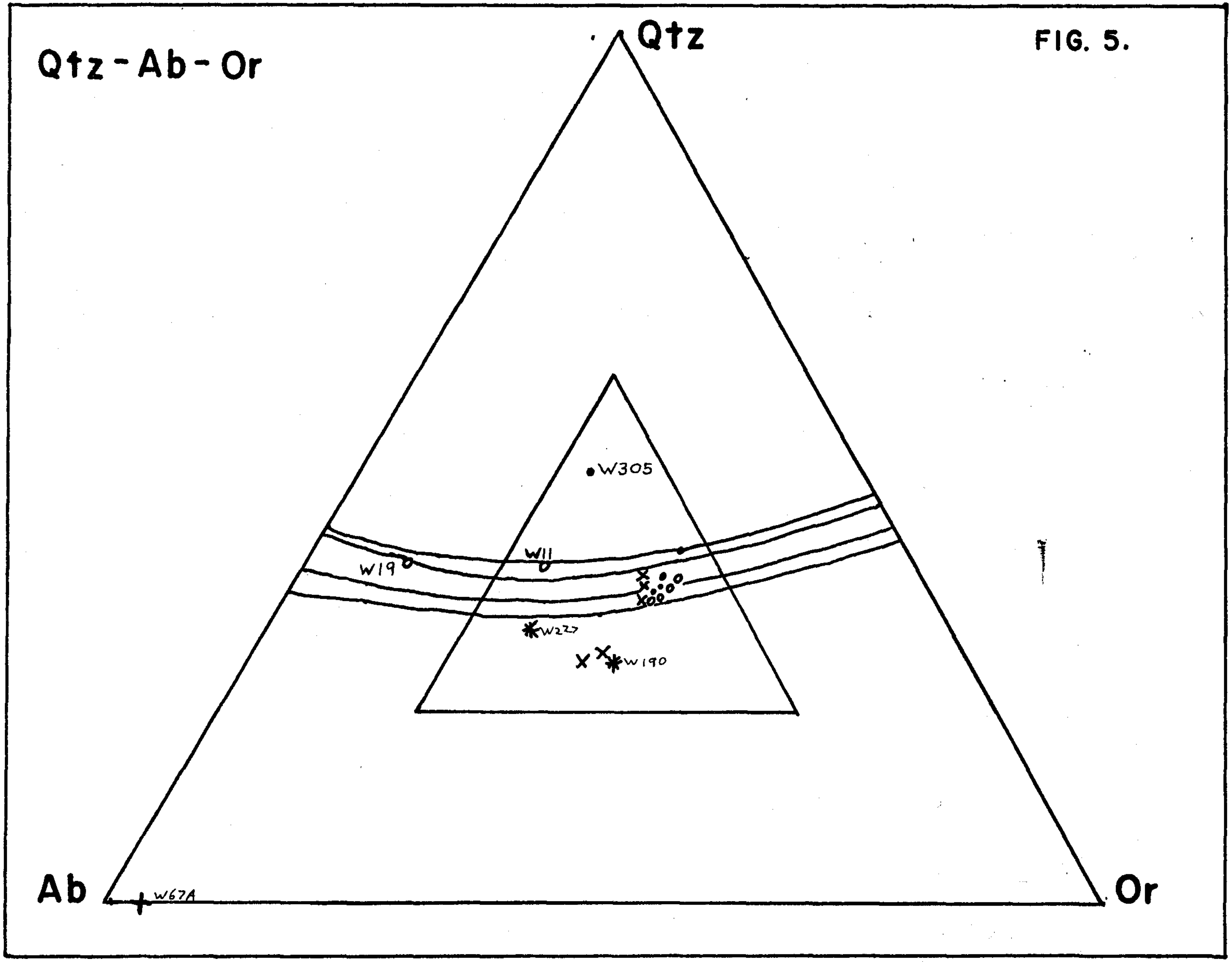
Qtz-Ab-Or Diagram

With the exception of sample W19, all the rocks considered in this work are granites by the classification of Tuttle and Bowen (1958).

Due to the low SiO_2 and high Na_2O values observed for this author's analyses of the standard rocks as compared to their reference values, the points plotted in this diagram should be moved slightly towards higher SiO_2 and lower Na_2O (Ab) values. However this will not affect the general relationships between the samples.

The Sudbury breccias and the two samples, W66 and W215, of the Murray granite, have roughly the same mineral percents of 28% Qtz, 29% Or and 38% Ab. The rest of the samples of the Murray granite,which are closer to the granite's periphery, and the majority of the samples of the two granitic dikes lies in a cluster at approximately 34% Qtz, 36% Or, and 30% Ab.

FIG. 5.



From this composition point, each of the two dikes and also the Murray granite seem to radiate outwards along separate lines towards higher Qtz and lower Ab values. These trends may reflect the relatively few analyses of these rocks, and may or may not be obliterated by increased rock analyses.

Samples W11 and W19 from the eastern dike show a marked increase in the albitic component relative to the other samples of that dike; and sample W305 from the northern dike has a much higher Qtz and a lower Or component than the rest of the samples of that dike.

The linear trends seen for the majority of the samples from the two dikes and the Murray granite may be differentiation trends away from a common point having the composition 34% Qtz, 36% Or and 30% Ab due to remobilization of the main mass of the Murray granite which had a composition similar to the Sudbury breccias and samples W66 and W215.

Alternatively, the Murray granite itself may be chemically differentiated, and these trends may just be due to sampling of different parts of a differentiated, inhomogeneous Murray granite that have been remobilized.

However, it must be states again, that only minor chemical differences exist between these rocks, and that further analyses may obliterate these "trends".

K_2O-Na_2O-CaO Plot

The majority of the samples from the two dikes plot in a cluster centered at 35% Na_2O, 60% K_2O and 10% CaO; along with W64 from the Murray granite.

Descending from this cluster in a roughly linear trace are the rest of the samples from the Murray granite, and samples W10 and W11 from the eastern dike. Sample W19 may or may not be a continuation of this trend,but with a marked increase in Na relative to the other two components.

The majority of the samples from the two dikes are chemically identical, with the Murray granite specimens being only very slightly lower in K_2O and higher in Na_2O. Samples W10, W11, W19 and W305 along with samples W66 and W215 have markedly lower K_2O contents.

K_2O vs. Rb and K_2O vs. Sr Plots

The majority of the samples exhibit a constant K_2O content between 5.0% and 5.5%, while having varying K/Rb and K/Sr ratios, 150 to 500 and 2,000 to 700 respectively.

The same deviant samples, W305, W10, W11 and W19, that were observed in the K_2O-Na_2O-Cao Plot, show a marked decrease in K_2O content with a resultant decrease in

K_2O-Na_2O-CaO

FIG. 6.

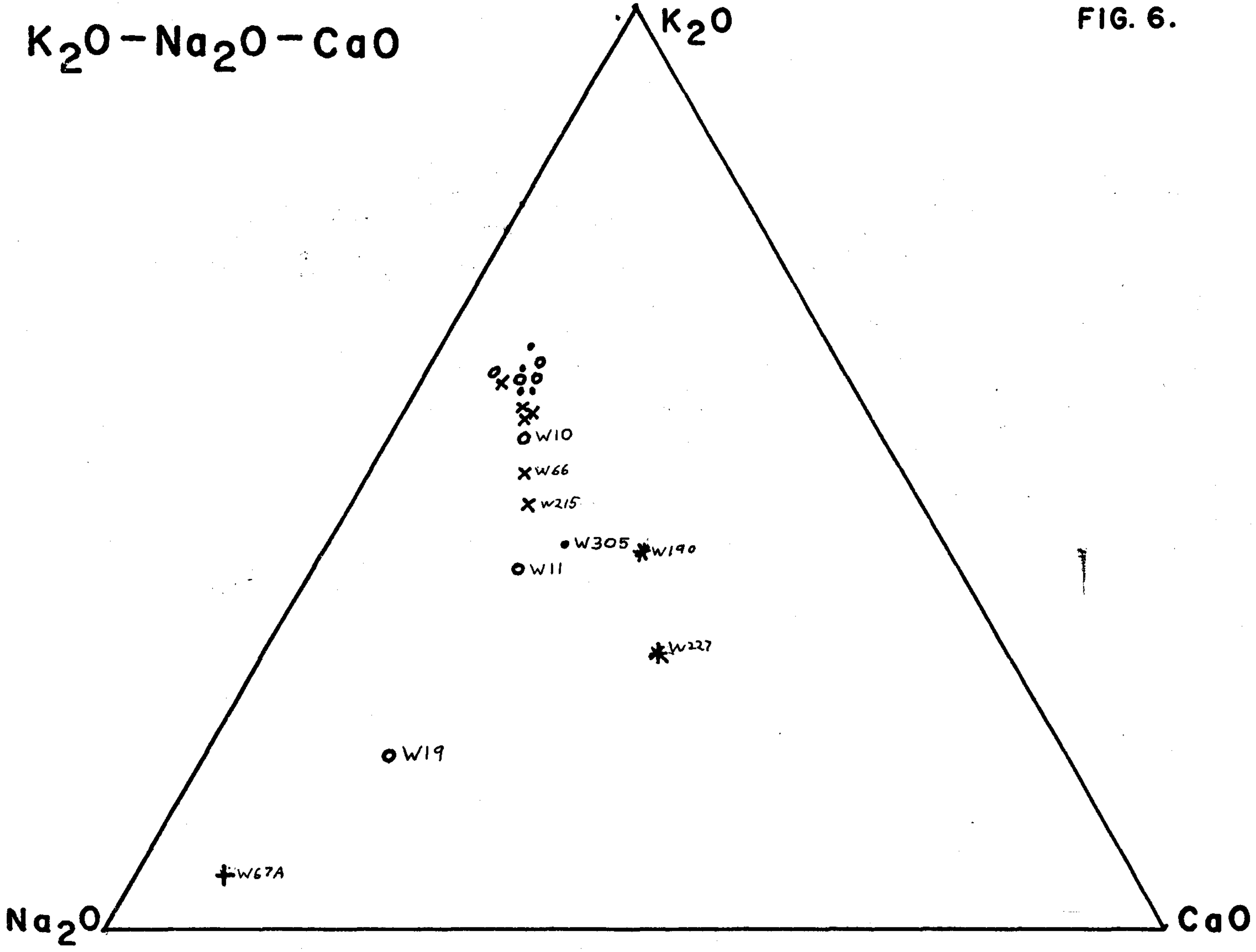
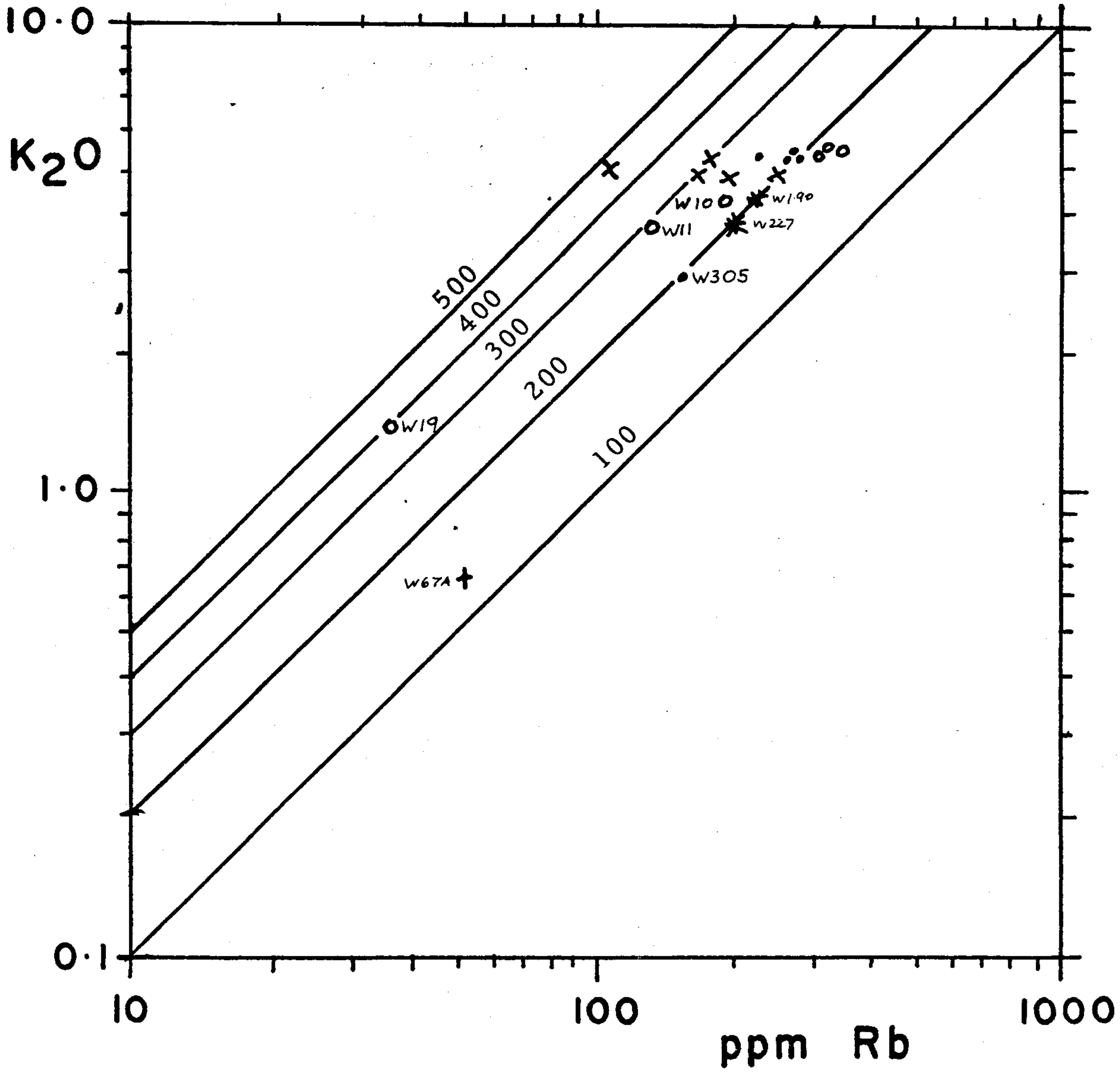
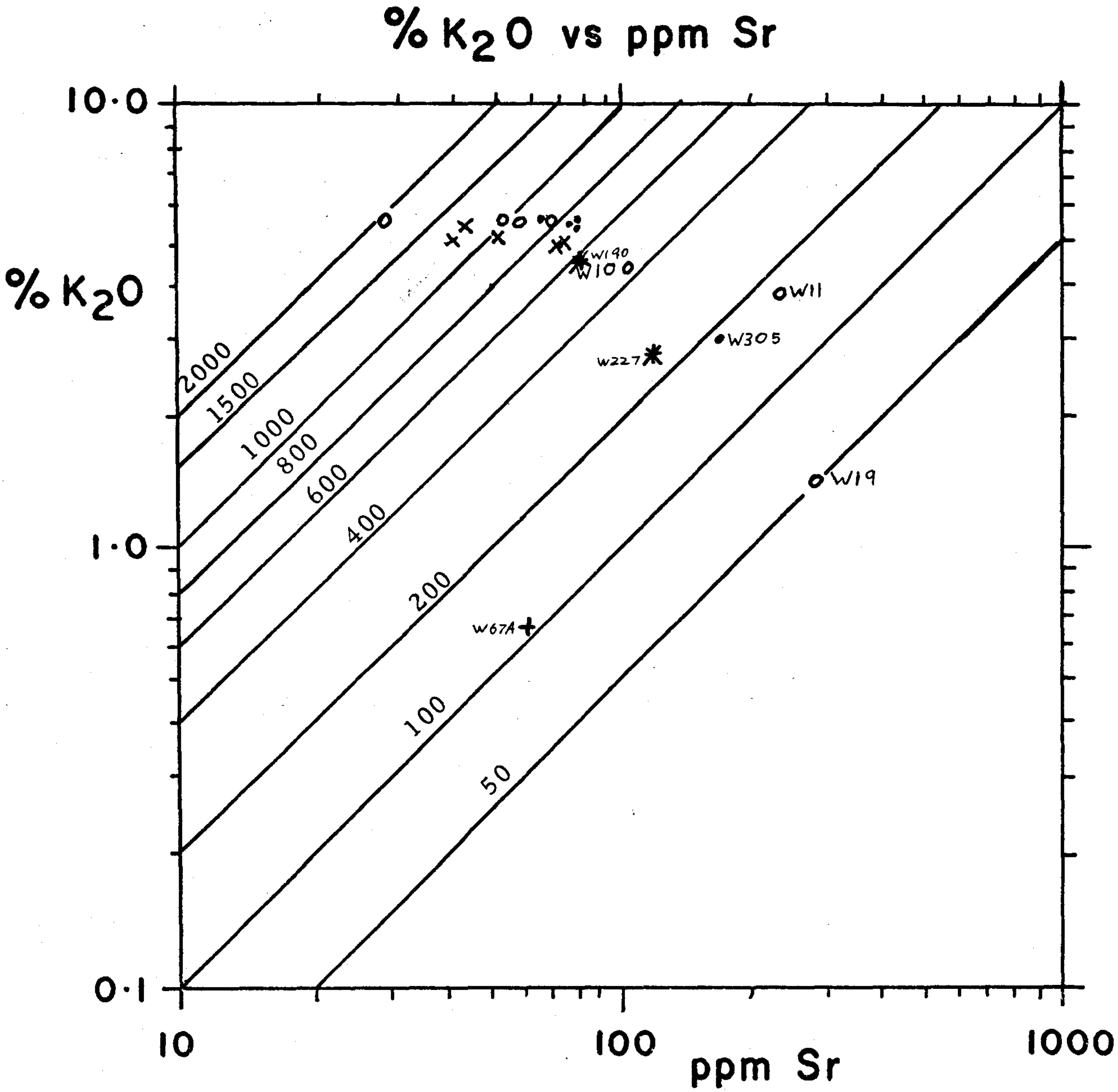


FIG. 7.

$\% K_2O$ vs ppm Rb



FIG, 8.


% K2O vs ppm Sr
10·0
1·0
0·1
% K2O
10
100
1000
ppm Sr
2000
1500
1000
800
600
400
200
100
50
W190
W100
W11
W305
W227
W19
W67A

their K/Sr ratios from 500 to 50 and a increase in their K/Rb ratios from 200 to 400.

Coinciding with this is an increase in the Sr content and a decrease in the Rb content.

This reflects the increase in the plagioclase component of these rocks with respect to the alkali feldspar, and the increase in available sites where Sr can replace Ca while the available sites for Rb to replace K decreases as the amount of microcline declines.

CaO vs. Sr Plot

The Murray granite rocks show a varying Cao and Sr content but with a general CaO/Sr ratio of 200, whereas the samples from tne northern dike show both a constant CaO and Sr content at 0.90% and 80 ppm respectively.

Besides this lower Ca content for the northern dike compared to the Murray granite, there is also a roughly linear trace formed by the rocks of the eastern dike, having a positive correlation between CaO and Sr. This is again due to increasing plagioclase content in these rocks.

FIG. 9.

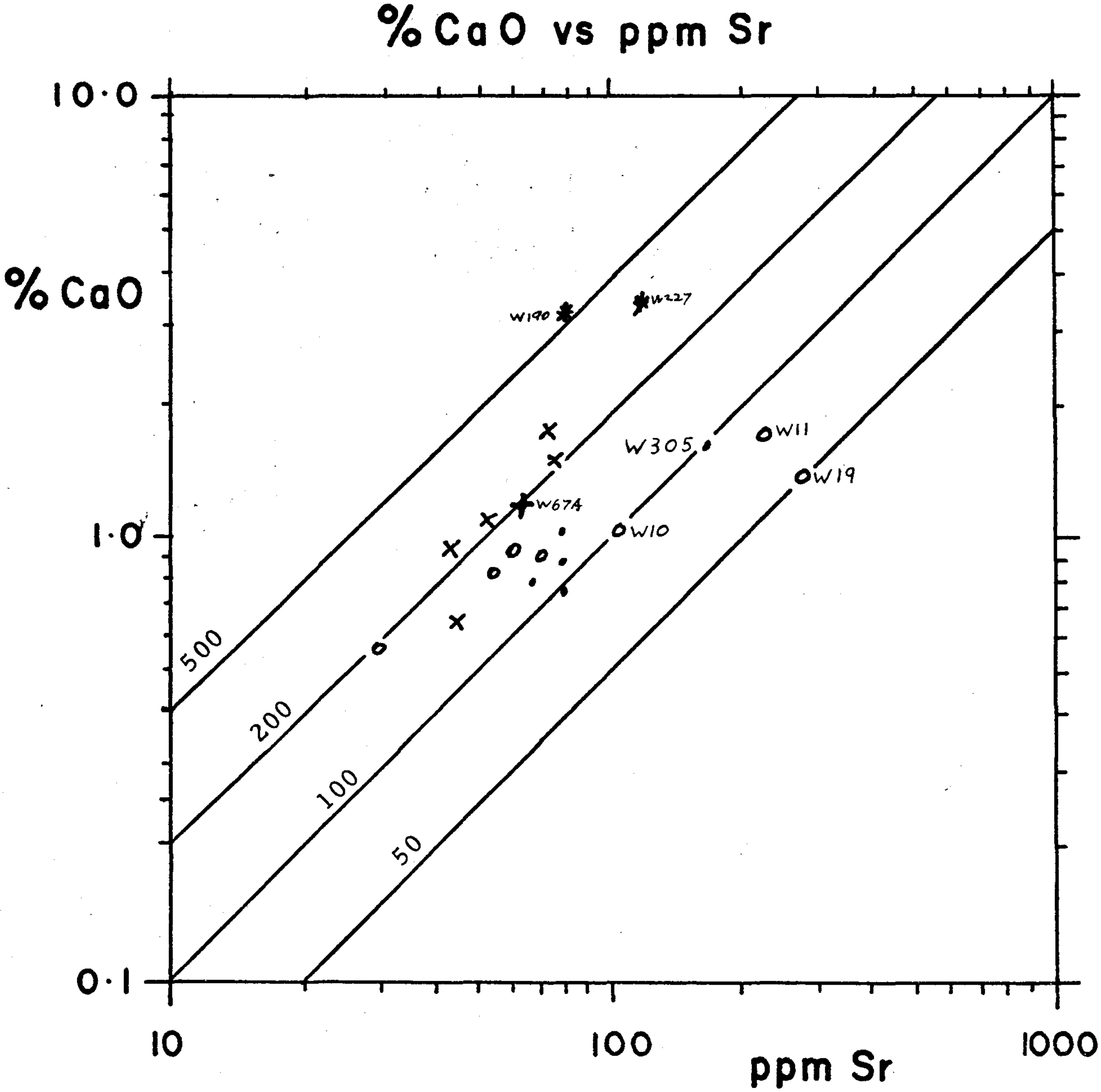

% CaO vs ppm Sr
% CaO
10·0
1·0
0·1
10
100
1000
ppm Sr
500
200
100
50
W190
W227
W305
W11
W19
W674
W10

TABLE 7

Rb and Sr Data[1]

Sample	Sr(ppm)	Rb(ppm)	Rb/Sr
W1	28.9	340.8	11.79
W8	69.7	307.2	4.41
W9	59.6	310.8	5.21
W10	106.7	192.3	1.80
W11	235.4	129.7	.551
W19	282.0	35.3	.348
W20	53.3	305.9	.125
W302	79.5	263.5	3.31
W303	66.9	267.6	4.00
W304	78.7	226.0	2.87
W305	171.7	155.2	.904
W306	78.0	272.3	3.49
W27	52.2	106.1	4.39
W29	41.3	250.7	6.07
W64	44.0	178.2	4.05
W66	74.7	164.7	2.21
W215	73.4	201.7	2.75
W190	79.3	220.6	2.78
W227	133.9	193.9	1.45
W67A	62.6	43.6	0.696

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[1] Personal communication from W. A. Gibbins

General Discussion

The two granitic dikes exhibite minor (less than 0.5%) difference in their weight oxides compared to the Murray Granite. The two dikes are lower in FeO, CaO and Na_2O while higher in K_2O than the Murray granite.

These differences show up in the Niggli and C.I.P.W. Norms in the form of the presence of corundum in both dikes as opposed to its absence in the Murray granite except for a minor amount in sample W64.

The granitic dikes are also higher in the Orthoclase component by 1-2% and lower in the Albitic component, expecially when compared to samples W66 and W215 from the center of the main Murray Granite.

The only other differences are minor variations in the relative amounts of augite and hypersthene.

Generally, then, only very minor differences exist between the main Murray Granite and the two granitic dikes. This is also shown in their close grouping together on the various diagrams and plots, and their thin section petrography.

However sample W305 from the northern dike, and samples W10, W11 and W19 from the eastern dike show pronounced deviations from the above uniformity.

These have higher Na_2O contents on the order of

2 to 3%, lower K_2O contents from 2 to 4% K_2O below the other samples of the dikes and the Murray granite, and higher CaO % by about 0.4%.

This results in a marked increase in normative albite and anorthite with concomitant decrease in the orthoclase component. This is exactly repeated in the thin section petrography of these rocks, with the microcline constituent being subordinated to anhedral plagioclase, along with a minor increase in biotite and the appearance of calcite anhedra.

This relationship cannot be explained by alteration of these samples, as thin section observations indicate that only the plagioclase feldspar is altered, and that only to minor amounts of epidote and sericite. Moreover, the severest alteration of plagioclase occurs in sample W10 which shows the least variation from the other samples of the dikes and Murray granite, while in sample W19, the most deviant one of its group, shows little or no alteration.

Two processes could possibly account for this phenomenon. One is the differentiation of these rocks when they were intruded, and the second is the reaction of these rocks with the surrounding norite and exchange of elements.

The former hypothesis is untenable, due to the increases in CaO% and Na_2O% and decreases in K_2O%

that are not proportional to the samples' distance of intrusion into the surrounding norite. Nor can it account for the similarity between the rest of the granitic dikes rocks intruded further into the norite, and the main mass of the Murray grantie. If these latter samples of the dikes were differentiated from the Murray granite along the same trend as W10, W11, W19 and W305, then their chemical compositions should show an increasing deviation from the chemical composition of the Murray granite along the above-mentioned trend.

The differences in these deviant rock samples can be more readily explained by reaction with the norite, since an increase in the weight percents of Ca and Na to give more plagioclase would be expected, along with a decrease in K and therefore K-feldspar.

Additional evidence for this, is furnished by probable isotopic exchange between the norite and these dikes (Personal Communication, W.A. Gibbins).

Included in this study also were two samples of Sudbury breccia, W190 and W227; and one sample of a "syenitic" rock, W67A, which occurs in the Murray granite near its eastern margin.

The Sudbury breccias are similar in composition to the main Murray granite, especially samples W66 and W215 from the interior of the Murray granite, except that they have higher CaO, FeO and MgO, and lower K_2O.

They are also lower in SiO_2(63.to 65.%), with the total result being that they have lower quartz and orthoclase components and higher albite, anorthite, augite and hypersthene in their norms.

W67A shows extremely high Na_2O and Al_2O_3 values of 11.24 and 20.82%, accompanied by low K_2O, FeO and MgO plus SiO_2 values. The result is a rock containing 78% normative plagioclase and 10% normative nepheline. Petrographically the rock consists of oligioclase and quartz grains engulfed by antiperthite. Therefore the norm and the observed thin section data do not agree, and W67A represents an extremely different mode of origin considerably different from that of the granites in this study.

CONCLUSIONS AND RECOMMENDATIONS

This major element study of two granitic dikes that intrude the Sudbury Norite, and their associated Murray Granite, revealed that only minor differences exist between the dikes and the main Murray Granite.

The two dikes are slightly lower in FeO, CaO and Na_2O generally, while higher in K_2O than the main Murray Granite.

Superimposed upon some of the dike samples is a reaction relationship between them and the norite surrounding them, such that they are enriched in Na_2O and CaO, and depleted in K_2O with respect to the rest of the dike samples.

Also worth noting, is the fact that the samples W66 and W215 and the two Sudbury breccias, are chemically different from the remaining samples of the Murray granite's periphery.

A more detailed analysis should be made to determine whether or not the Murray granite is chemically zoned, and also to correlate element exchange between granitic dikes and the norite where exposures of the two rock types are present.

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