THE HOPE LAKE STOCK, LAKE OF THE WOODS REGION, ONTARIO[1]

RICHARD A. HEIMLICH

Department of Geology, Kent State University, Kent, Ohio

ABSTRACT

The Hope Lake stock is a small, concordant, granitic pluton which has intruded a sequence of Precambrian metavolcanic rocks. The metavolcanic rocks, which dip steeply and strike uniformly over broad areas, are greatly distorted in strike near the stock. Their metamorphic grade (almandine amphibolite facies) persists to the boundaries of the stock; evidence of a thermal metamorphic aureole is lacking.

The stock consists of two plugs, subcircular in plan, one of monzonite, the other of granite, both with primary flow structures forming strike patterns integral to each plug. A narrow quartz monzonite border facies rims the southern part of the monzonite plug. Each plug is cut by a small number of felsic dikes.

The available data suggest that the stock was emplaced by multiple forceful intrusion of monzonite and granite magmas. Room was acquired by lateral displacement and by upward wedging of the wallrocks, aided in part by faulting. The physical conditions of emplacement were essentially those of the enclosing regionally-metamorphosed terrain (almandine amphibolite facies), suggesting that the magmas were viscous mixtures of crystalline and liquid material. The plutonic units show little sign of post-emplacement deformation, with the exception of the granite which has been sheared and mineralogically altered at the south end of the stock.

INTRODUCTION

The Hope Lake stock is a small composite pluton of Precambrian granitic rocks located approximately 25 miles northeast of the village of Sioux Narrows, District of Kenora, Ontario (Fig. 1). It is one of three closely associated granitic masses which have intruded a sequence of Keewatin metavolcanic rocks (Heimlich, 1959a, 1963, 1965). The pluton is remarkably similar, in structure and lithology, to the Flora Lake stock which occurs to the northeast along the same structural axis (Fig. 2).

The outer contact of the stock with its wallrocks is largely unavailable for study due to surficial cover, swampy ground, and the waters of Hope Lake and William Bay which collectively obscure over 90 percent of it. However, where observed, the contact is knife-sharp and marked by an abrupt change from fine-grained granite to massive metavolcanic rocks. The dip of the contact surface, inferred from the dip of the adjacent wallrocks and that of foliation within the pluton, ranges from 90° to 80° (outward).

Broadly elliptical in plan, the stock has a relatively smooth and con-

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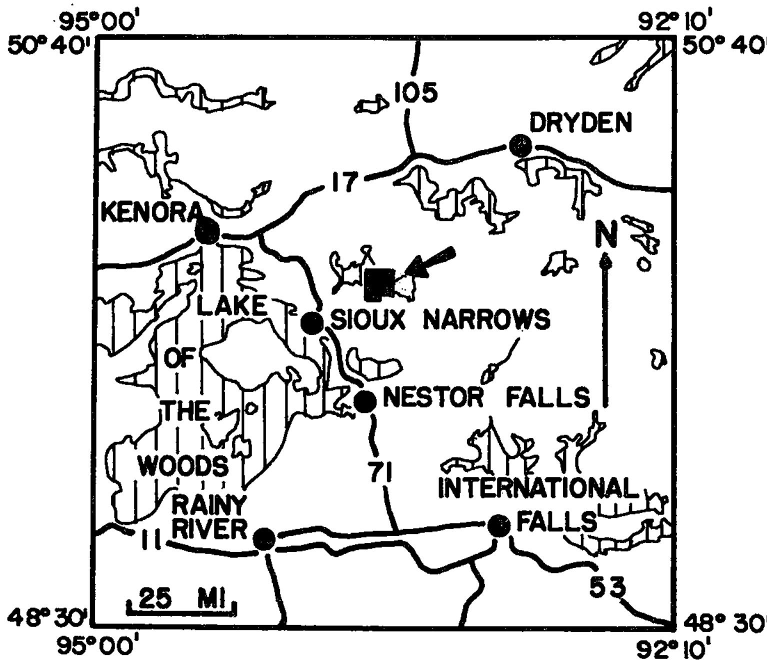

FIG. 1. Location of the Hope Lake stock.

tinuous outline except where faulting has occurred in the southern portion. The long axis of the ellipse strikes north-south, roughly parallel to the regional structural trend which changes strike from northeast-southwest to nearly north-south at the approximate position of the pluton (Fig. 2). It is thus concordant in terms of gross orientation relative to country-rock structure. Local transgressive dikes extending outward from the stock constitute the only evidence of its discordant relations with the country rocks.

Geologic Setting

Regional terrain

The encircling rocks constitute part of a broad regionally-metamorphosed terrain that underlies thousands of square miles in the Lake of the Woods region. In the vicinity of the stock, the rocks are largely metamorphosed volcanics, but include several concordant, lensoid metadiorite bodies which are probably sills. Farther from the stock, layers of metasedimentary rocks are intercalated with the metavolcanics. The entire sequence has been elevated to the almandine amphibolite facies of metamorphism.

Throughout the region the rocks dip steeply and strike generally

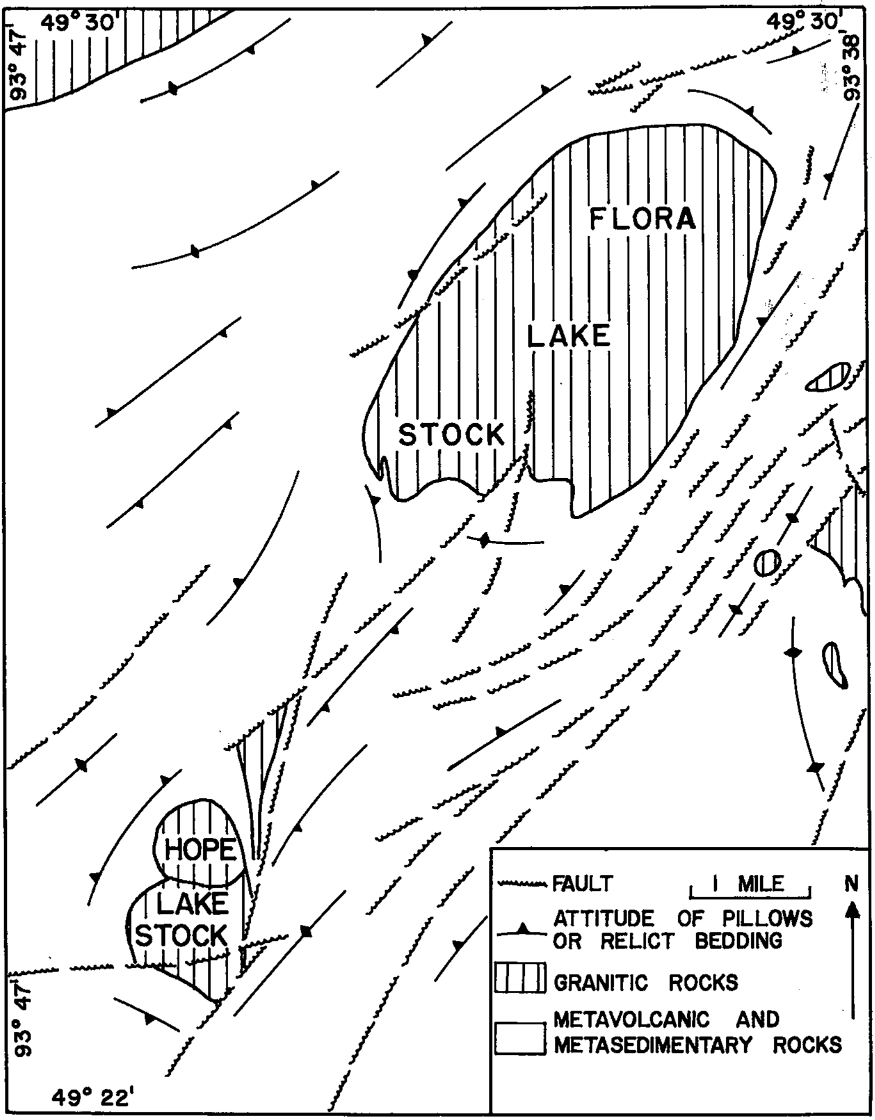

FIG. 2. Geologic setting of the Hope Lake stock.

northeast-southwest. Departures from the general regional strike are notable in the vicinity of the plutons as Figure 2 shows. South of the Hope Lake stock, and south and north of the Flora Lake stock to the north, structural trends swing east-west in part.

All metavolcanic rocks are schistose to variable degrees. Particularly intense zones of shearing associated with topographic lineaments were mapped as faults; these tend to parallel the strike of schistosity between faults. A major northeast-southwest zone of faulting exists roughly one mile east of the stock. Both schistosity and faults are similar in attitude to that of lithologic contacts.

Wallrocks

Information on the wallrocks adjacent to the Hope Lake stock is meagre due to the paucity of outcrops. On the basis of data available, no distinct boundary can be drawn between a contact zone and the regional metamorphic terrain. The mineralogy of the almandine amphibolite facies of regional metamorphism persists up to the border of the pluton. Several contact effects occur in a zone ranging in width from several hundred to 2000 feet from the contact, however, there are no effects of thermal metamorphism present.

Within the contact zone the only dikes are of granite and these are not common. Most are less than one foot wide. Veins of quartz, epidote, and carbonate are more common than are dikes. Most are less than one or two inches wide and rarely over several feet long. Quartz and epidote also occur as crystalline aggregates lining vugs and small breccia zones in the metavolcanic rocks. Garnet is locally associated with these minerals in such occurrences. The linings consist of inter-mixed prismatic epidote crystals, euhedral garnets, and massive quartz. Typically the crystals have average dimensions of 1/4 inch. Determination of the lattice constant (11.92), index (1.790), and specific gravity (3.62) and application of the data to Winchell's charts (1958, p. 597, 598) indicate that the garnet (specimen 7607) is essentially andradite and grossularite in the approximate ratio 65:35.

Structure

The stock consists of four mappable units: granite, altered granite, monzonite, and quartz monzonite. Quartz-feldspar porphyry constitutes a fifth unit, but the porphyry and the lithologic units within the stock may not be consanguineous. As Figure 3 shows, the position of the western boundary of the porphyry body is indeterminate.

Distribution of lithologic units

Granite is clearly the dominant rock unit in the stock. The main granite mass, roughly circular in area, with an average diameter of one mile, is located in the centre. It is in fault-contact with altered granite underlying

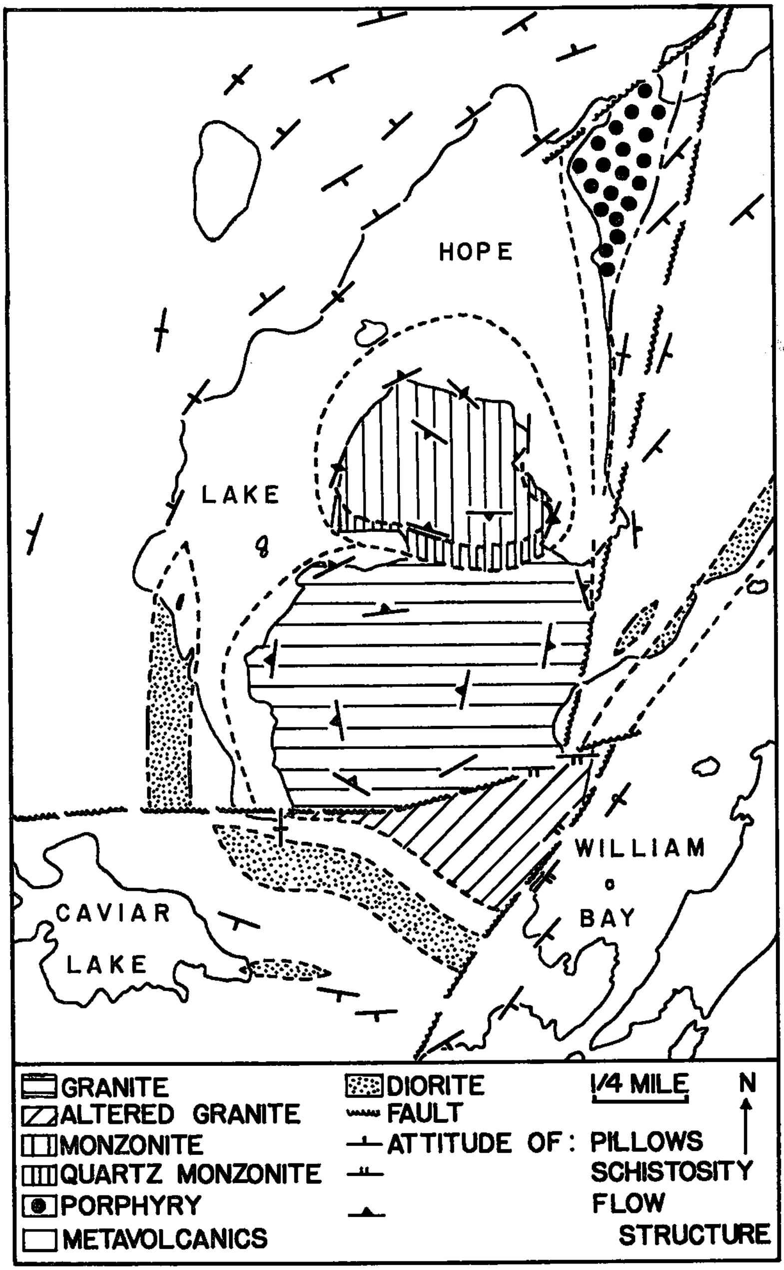

FIG. 3. Geologic map of the Hope Lake stock.

a triangular area to the south. The altered granite is part of the main mass that has been offset slightly to the east. Alteration effects extend about 100 feet north of the fault.

The northern portion of the stock consists of a subcircular plug of monzonite roughly 3/4 of a mile in diameter. The assumed outline of this plug is entirely conjectural but seems reasonable by comparison with the circular strike pattern of its internal structure and by virtue of the crescent shape of Hope Lake which presumably follows the outer contact of the plug with the country rocks. Its contact with the granite mass to the south is not exposed but the relative age of the two units is established on the basis of dikes of granite which transect the monzonite. Porphyry dikes also cut monzonite.

The quartz monzonite occurs as a marginal zone, 300–400 feet wide, along the southern edge of the monzonite plug. The contact between the two units is gradational across a 100-foot interval. The quartz monzonite may represent a border facies that encircles the entire monzonite body.

The relationships cited suggest the following decreasing age sequence: monzonites, granite, porphyry. The porphyry and granite may have been emplaced at the same time; on the other hand, the porphyry may be considerably younger than the stock.

Foliation

Planar structures characterize all rock units except porphyry. In monzonite foliation is expressed by the planar parallelism of tabular feldspar grains. The rock is coarse-grained and the gray feldspar laths stand out clearly on the weathered outcrop surfaces. The structure is imperfectly developed and, commonly, less than 75 per cent of the feldspar grains possess a subparallel orientation. In quartz monzonite and granite, the parallelism of small, tabular clusters of mafic minerals and the alignment of quartz-feldspar contacts impart a very faint foliation to the rock.

The strike of such structures in the two circular plugs (granite and monzonite) boxes the compass, indicating that the foliation is integrally related to the respective plugs. It is not associated with shear zones or faults, nor are cataclastic textures or secondary minerals developed along the foliation planes. These facts suggest that the structure is a primary feature.

In contrast, altered granite (near faults) is characterized by a distinct secondary foliation. The shear planes are steep-dipping, gently curving, slickensided surfaces spaced 1/8 to 1/2 inch apart. They are commonly glossy due to the development of sericite along them. Where the granite has been sheared, its original granitoid fabric has been erased in accord with the intensity of the shearing. All gradations between massive and sheared granite were noted in the field. In the central portion of the altered granite area the rocks are generally devoid of shearing.

Joints

Statistical plots of joints, which are ubiquitous in the stock, show moderate concentrations striking essentially north-south and dipping very steeply east and west. A minor set of subhorizontal joints, absent in the monzonite plug, is present in the granite plug. A comparison of the attitudes of joints in the two felsic plugs with those in the adjacent metavolcanic wallrocks shows that similar sets are not represented in both groups of rocks. The discordance suggests that joints in the plugs are related to their intrusion rather than to a later regional deformation. The presence of dikes and veins with attitudes similar to those of nearby joints further supports the primary relationship of the joints to the stock.

Faults

The presence of two faults associated with the stock is clearly established on the basis of topographic lineaments accompanied by shearing and offsetting of geologic contacts. A major north-south fault runs along the east side of the stock and is responsible for the shearing in the eastern part of the altered granite mass. This fault has been offset by a later east-west fault. Horizontal slickensides on shear planes in both fault zones indicate that the latest movements were essentially strike-slip in nature. Simple strike-slip faulting is adequate to account for the geologic offsets.

Inclusions

Only three metavolcanic inclusions were found within the entire one square mile area of the stock. Two (in monzonite) are less than four inches square and the other (in granite) is less than one foot square. Perhaps if more of the contact areas were exposed, more inclusions would be found. No cognate inclusions were observed.

In the northeastern portion of the monzonite plug, two small areas (less than 50 square feet) are underlain by a variable metagabbro unit which is interpreted as included material. The rock is mottled black and white, medium to coarse-grained, and massive. A local pegmatitic facies is characterized by large, dark green mafic crystals (1 × 0.5 inches) set in a slightly finer-grained matrix of plagioclase and biotite. The boundaries of the metagabbro with enclosing monzonite are not available for study.

Magnetic Data

In Figure 4 magnetic data are superimposed on the geologic map of the stock. The isomagnetic contours are reproduced from the Caviar Lake sheet (Geol. Survey Canada, 1962); the 20 and 10-gamma contours were

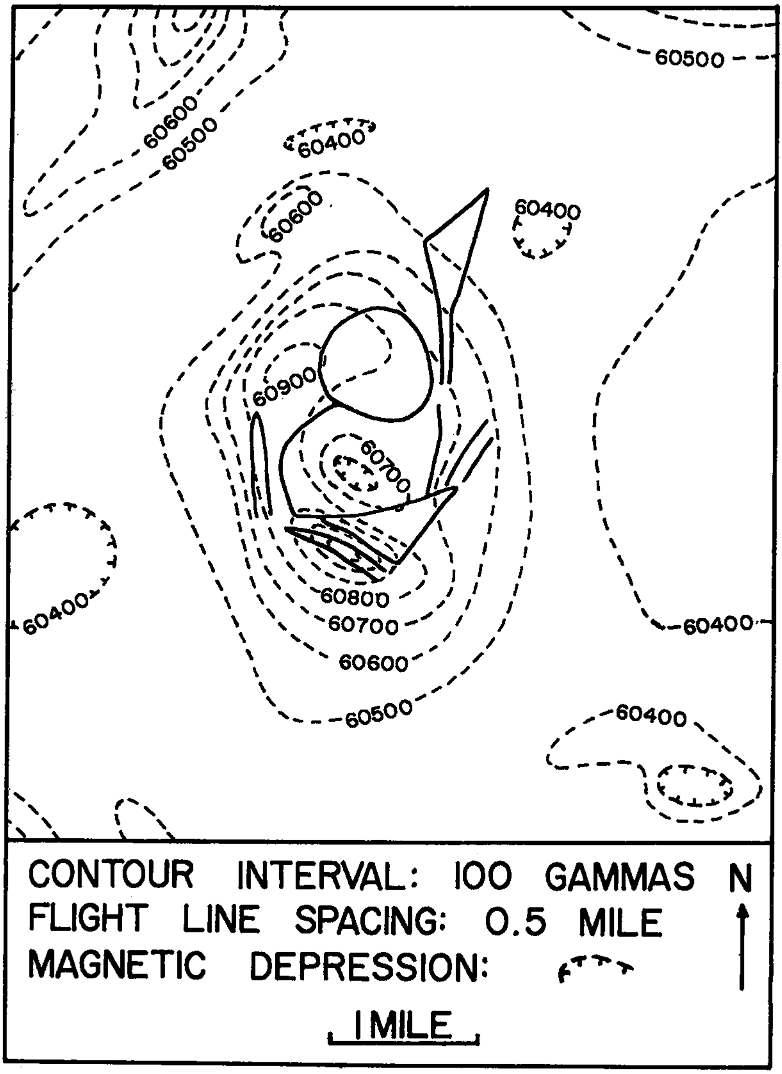

Fig. 4. Magnetic map of the Hope Lake stock.

omitted for the sake of clarity. The contours are based on data obtained from north-south airborne magnetometer traverses run 1000 feet above ground level and spaced at one-half mile intervals.

The main feature of the map is the excellent coincidence with the stock of an elliptical, relatively symmetrical anomaly. The well-defined nature of the anomaly and the fairly uniform spacing of magnetic contours confirm

TABLE 1. MODAL ANALYSES OF THE HOPE LAKE ROCK SUITE

Specimen Number	Plagioclase	Microcline	Quartz	Biotite	Amphibole	Pyroxene	Opaque Accessories	Nonopaque Accessories	Calcite	Sericite
					GRANITE					
7417	48.5	26.2	20.3	4.1			tr	tr		
7419	49.1	22.3	26.9	0.5			tr	tr	0.5	
7423	42.3	36.1	17.8	3.2			tr	tr		
7426	52.4	21.8	23.2	0.7			0.6		1.4	
7447	53.4	27.5	14.6	2.3	1.4		0.5	tr		
7449	47.7	29.0	16.4	4.4	0.9		tr	tr	0.5	
7474	43.0	34.5	19.5	1.6			0.6	tr	tr	
7548	49.2	27.0	16.3	6.5			1.4	0.6	tr	
7550	42.9	31.8	18.9	2.1	3.1		0.5	0.7		
7570	55.1	23.6	18.9	0.5			0.6		1.2	
Mean	48.4	28.0	19.4	2.6	0.5		0.4	0.1	0.4	
					ALTERED GRANITE					
7429	43.2	29.4	10.9				2.1		14.4	tr
7431	24.5	39.3	32.4				tr		3.5	
7470	45.5	14.5	13.5	1.6			1.8		20.4	2.5
7472	49.4	5.8	12.4						2.2	30.1
7572	65.2	3.5	15.1	0.8			tr		2.6	12.3
Mean	45.6	18.5	16.9	0.7			0.8		8.6	9.0
					MONZONITE					
7435	48.7	32.7	2.5		9.5	tr	0.9	2.5	3.0	
7437	55.7	34.2	4.1		2.6		1.9	0.9	0.6	
7440	50.0	42.1	0.6		3.6		tr	2.8	0.6	
7444	48.2	33.0	tr		0.5	14.7	tr	3.2		
7543	48.7	35.0	1.1		1.0	11.9	1.0	1.4		
Mean	50.3	35.4	1.7		3.4	5.1	0.8	2.2	0.8	
					QUARTZ MONZONITE					
7441	52.3	28.3	10.5		7.2		0.6	0.7		
7446	50.3	29.6	4.1		13.5		1.1	0.9		
7532	48.6	35.7	5.5	tr	8.7		tr	0.6		
7547	51.1	25.2	11.4	4.8	6.1		tr	1.1		
Mean	50.6	29.7	7.9	1.2	8.9		0.4	0.8		

the fact that the stock is a relatively homogeneous, steep-walled body. A local magnetic depression is centred directly on the granite plug while the maximum magnetic high (61,100 gammas, not labelled in Fig.4) is situated over the diorite mass just south of the stock. The entire 60,800-gamma contour, which has a closure largely west of the stock, may well be related to more diorite underlying Hope Lake. On the basis of this contour and the presence of the 60,900-gamma closure just west of the monzonite plug, it may be inferred that the diorite body mapped west of the stock extends considerably further north than shown.

Petrography

Thirty specimens were used in quantitative and qualitative petrographic studies of the stock. Their locations are given in Figure 5. On the basis of quartz content and ratio of alkali feldspar to total feldspar (Williams, Turner & Gilbert, 1954), the plutonic units have been classified as quartz monzonite, monzonite, and granite. Table 1 gives the results of modal analyses which were made on stained thin-sections and which are based on counts of 800–1000 points per thin-section. In the Table values for plagioclase include sericite, saussurite, free plagioclase, and plagioclase in microperthite. Microcline values include free microcline and that in microperthite. Most of the monzonite and quartz monzonite microcline is microperthitic.

Plutonic units

Study of thin-sections from all parts of the (unaltered) granite plug indicates that the rock has a typical hypidiomorphic-granular fabric interrupted locally by small, very fine-grained mosaic zones. Subhedral, well-twinned, deeply-sericitized plagioclase (An 7–10), interstitial microcline-microperthite (and microcline), and interstitial quartz make up the bulk of the rock. The plagioclase is clearly replaced by the potassium feldspar (which is commonly poikilitic relative to plagioclase) and is corroded by the quartz. Biotite, pleochroic in shades of chestnut-brown, occurs as intergrown clusters of tiny flakes. Delicate acicular prisms of apatite, anhedral to euhedral ilmeno-magnetite, and ragged masses of leucoxene occur within the biotite. Subhedral pale green amphibole grains (some with epidote interiors) and euhedral, zoned crystals of sphene are present as minor constituents.

Throughout the granite mass, quartz has undulatory extinction, plagioclase twin lamellae are commonly bent, and small recrystallized zones are present. As the east-west fault is approached, the incidence of cataclastic effects increases and the content of calcite and sericite increases. Gradually the rock passes into what has been mapped as altered granite. The

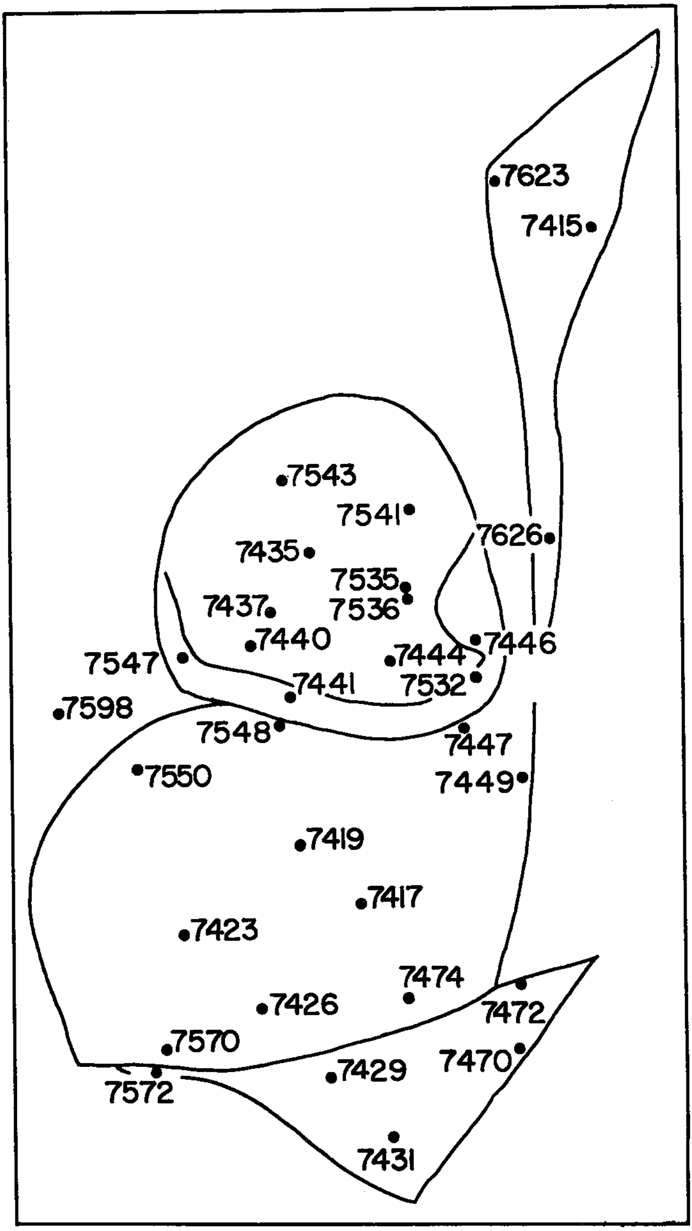

FIG. 5. Specimen location map of the Hope Lake stock.

altered phase is characterized by numerous subparallel sericite veinlets (along shear planes) which truncate mineral grains. Very fine-grained mosaics of quartz, microcline, plagioclase, and calcite are common. Quartz also occurs as late veinlets with or without calcite, and as individual grains (with characteristic trains of inclusions). Most individual quartz grains show comminution at the edges. Twinning is largely obscured in plagioclase (An 7–8), but where present, it is commonly bent or micro-faulted. Microcline-microperthite is commonly crushed at the edges, fractured, and veined by quartz, quartz-calcite, or sericite. Grains of ilmeno-magnetite are invariably altered to leucoxene at the margins and traversed by intricate networks of limonite veinlets.

Hope Lake monzonite consists of microcline-microperthite with minor amounts of amphibole and pyroxene. Only a few grains of plagioclase (An 8) and microcline independent of microperthite were noted. The microperthite commonly encloses subhedral or euhedral, pale blue-green, acicular prisms of amphibole, euhedral sphene granules, and round or diamond-shaped grains of ilmeno-magnetite. Amphibole is characteristically spotted with ilmeno-magnetite and commonly replaced by calcite at the margins or along cleavages. Euhedral pyroxene, moderately pleochroic in pale green shades, is sporadic in occurrence. Deeper-colored green, uralitic amphibole forms rims on many of the crystals. Quartz is present as finely granular patches or as late veinlets. Apatite occurs in most thin-sections and deep brown, irregularly fractured garnet is present in some sections. The garnet is typically anhedral, occurring as irregular masses commonly enclosing small grains of sphene and amphibole. A few grains of biotite are also present.

The quartz monzonite is a hypidiomorphic-granular aggregate of microcline, microcline-microperthite, quartz, and amphibole very similar to the monzonite but finer-grained. The potassium feldspars corrode and enclose deeply sericitized subhedral plagioclase (An 8–10). Interstitial quartz with undulatory extinction and trains of small inclusions also corrodes plagioclase. Amphibole occurs as pale green, moderately pleochroic, acicular grains and broader, locally twinned green to brown prisms. Anhedral and euhedral ilmeno-magnetite, slightly altered to leuocoxene at the edges, is commonly associated with the amphibole or occurs with the felsic minerals. Biotite is typically pale green to brown, and occurs as shreddy grains. Sphene is present as euhedral, wedge-shaped crystals, some of which are exceptionally elongate.

The porphyry consists of roughly 20 percent phenocrysts of quartz and plagioclase in a very fine-grained groundmass of quartz, plagioclase, and biotite (also minor calcite, epidote, and ilmeno-magnetite). The quartz phenocrysts are strictly anhedral and some show lobate outlines relative to the groundmass. Many have undulatory extinction. Plagioclase phenocysts are also largely anhedral; all are deeply sericitized. Quartz and/or calcite veinlets transect some of the phenocrysts.

Metagabbro inclusions

Two modal analyses of the metagabbro masses show that the material consists of roughly 28 percent plagioclase, 30 percent biotite, 24 percent pyroxene, 14 percent amphibole, and the remainder accessory minerals. The pyroxene occurs typically as pale green, non-pleochroic, well-formed, doubly terminated, stubby prisms with strong cross fractures. Some grains show displacement of the 100 parting by slip along the cross fractures. Universal stage studies indicate that the pyroxenes have optic angles of approximately 62°. The index β is 1.675 in one specimen and 1.680 in another. These properties place the pyroxenes in the diopside field (Poldervaart & Hess, 1951). They are optically positive and have extinction angles averaging 45° $Z \wedge c$. The high optic angle and distinct coloring suggest that this pyroxene may have a sodic tendency.

Pale green uralitic amphibole replaces the margins of many pyroxene crystals. The amphibole is strongly pleochroic, green to brown, and characterized by strong amphibole cleavage. A spectrographic analysis of dark-colored amphibole from the metagabbro is presented in Table 2.

Dark green to yellow or brown biotite flakes, many characterized by tri-directional cross-hatching and the presence of euhedral apatite grains, account for a major part of the rock. Cleavage traces are commonly bent and lined with sphene pods. Sphene also forms rims on many biotite

TABLE 2. SPECTROGRAPHIC ANALYSIS OF AMPHIBOLE FROM METAGABBRO. (R. A. HEIMLICH, ANALYST)

Oxide	Specimen 7536
SiO_2	39.3
Al_2O_3	14.5
Fe_2O_3*	20.8
MgO	9.9
CaO	8.0
Na_2O	2.32
K_2O**	0.88
TiO_2	2.63
MnO	0.24
H_2O**	1.40
	99.97

*Total Fe content as Fe_2O_3.

**Values averaged from those in analyses of similar amphiboles from Deer (1938), Rosenzweig & Watson (1954), and Larsen & Schmidt (1958).

flakes. Biotite clearly replaces amphibole and pyroxene (along cleavages and cross-fractures and at the margins); some biotite definitely replaces plagioclase. Plagioclase (An 14–15) is distinctly interstitial and commonly encloses euhedral pyroxene prisms. Most of it is faintly twinned and heavily sericitized, particularly along the twin lamellae. A small amount of ilmeno-magnetite is commonly associated with biotite and amphibole.

Chemical Data

Spectrographic analyses of the Hope Lake rock suite are given in Table 3. With the exception of the metagabbro specimen, all analyzed samples are mechanical averages of three to four hand specimens representing each lithologic unit.

Table 3. Spectrographic analyses of the Hope Lake rock suite. (R. A. Heimlich, Analyst)

Oxide	Altered Granite	Granite	Quartz Monzonite	Monzonite	Porphyry	Metagabbro (7541)
SiO_2	66.3	69.4	65.0	64.1	67.2	45.1
Al_2O_3	15.3	16.8	16.1	17.0	14.9	14.9
Fe_2O_3 (a)	5.4	3.0	3.9	3.5	8.2	11.9
MgO	1.06	0.88	1.60	1.10	1.27	8.10
CaO	2.70	1.80	2.96	4.30	2.95	11.70
Na_2O	3.40	3.10	4.60	3.60	4.67	4.90
K_2O (b)	5.40	4.74	5.16	5.76	0.33	1.85
TiO_2	0.33	0.27	0.43	0.36	0.34	1.46
MnO	0.100	0.061	0.077	0.114	0.101	0.155
	99.93	100.71	99.83	99.83	99.96	100.07
Ga (c)	18	16	21	17	18	18
Cu	31	17	23	24	133	209
Ni (d)		1	12	1	15	53
Cr	49	12	32	20	143	36
V	36	29	48	44	34	202

a. Total Fe content as Fe_2O_3.
b. Values calculated from modal analyses.
c. All trace elements in parts per million (oxides in weight percent).
d. Detection-limit concentration is 3 ppm (Ahrens, 1955, p. 7).

In the progressive sequence from monzonite to quartz monzonite to granite, the content of silica increases systematically whereas the content of lime and potash decrease systematically. The potash decline corresponds roughly with decrease in modal microcline in the rock sequence. The relatively high lime content of the monzonite is undoubtedly related to the substantial amounts of pyroxene and calcite present in some specimens of the unit. The higher percentage of total iron oxide and magnesia in quartz monzonite relative to the other two units, corresponds with the higher mafic mineral content of the quartz monzonite. The substantially high soda content of the quartz monzonite is undoubtedly related to the high modal amphibole in the rock. Of the five trace elements determined, the amounts of nickel, chromium, and vanadium, as expected, are highest in the quartz monzonite, corresponding to the high mafic mineral content of the rock.

Comparison of spectrographic analyses of the fresh and altered granites suggests that the alteration process was not strictly isochemical. The smaller amounts of silica and alumina in the altered granite correspond, respectively, with reduction in modal quartz and modal feldspar. Its increased lime content is related to introduced calcite which appears in all thin-sections of the rock. Several of the other oxide variations appear to be anomalous.

Petrogenesis

Data available on the Hope Lake stock point to a remarkable similarity between it and the Flora Lake stock (Heimlich, 1965) to the northeast (Fig. 2). The close proximity and location of both plutons along the same structural axis and their similarity in mineralogy, lithology, emplacement sequence, internal structure, and effects on wallrocks strongly suggest that both formed by means of the same processes.

The strike of the metavolcanic wallrocks, as depicted in Figures 2 and 3, conforms rather closely with the outline of the stock. Near the pluton, particularly obvious along the eastern and southern flanks, the strike departs from its generally northeast-southwest regional trend implying that major structural dislocations are associated with the stock. Some idea of the magnitude of the dislocations is indicated by the distribution of key diorite bodies which are interlayed with the metavolcanic wallrocks (Fig. 3).

The field relationships indicate that emplacement of the Hope Lake stock began with forceful injection of a plug of monzonite magma. Room for this plug was acquired by lateral east-west displacement and by upward wedging of the wallrocks. The structural bulge indicated by the strike readings in metavolcanic rocks near the stock is sufficient to account for the space occupied by the monzonite body at the present level of erosion.

The emplacement of the monzonite was followed by intrusion of granite magma along the same axis of weakness (presumably a shear zone within the metavolcanics or the interface between flows). Intrusion was accompanied by some amount of lateral bulging and wedging in the same manner as that associated with monzonite intrusion. However, in the case of the granite plug, a major amount of space needed to accommodate the invading magma was acquired by southward displacement of the wallrocks. Movement was predominently southward because the earlieremplaced monzonite plug acted as a relatively resistant buttress to the north. The displacement was aided by the north-south fault along the east flank of the stock. Although the classification of this fault as a strike-slip fault is undoubtedly an oversimplification, lateral movement does explain the offset of the diorite bodies east and south of the stock. These bodies are thought to be segments of a concordant diorite layer which was continuous before and immediately after injection of the monzonite plug. Schistosity and slickensides in altered granite adjacent to this fault indicate that renewed movement occurred subsequent to intrusion of the granite plug. The east-west fault constitutes additional evidence of post-intrusion faulting.

The above evidence of forceful injection, the gross three-dimensional shape (two truncated inverted cones) of the pluton, and the sharp contact with the wallrocks indicate that the stock formed by the upward invasion of discrete quantities of mobile material. This idea is further supported by the presence of internal flow structures which box the compass and dip steeply outward. Monzonite and granite dikes also attest to the former mobility of the major rock units in the pluton.

The absence of a thermal metamorphic aureole encircling the stock indicates that the two plugs were emplaced under conditions of the almandine amphibolite facies of regional metamorphism. Under such conditions the monzonite magma, and perhaps the granite magma, probably had the consistency of a viscous mush. Flow structures within the stock and minor deformational textural features in thin-sections of the plutonic units are compatible with this idea.

The lack of pegmatite bodies associated with the stock suggests that the units may have been emplaced under moderately "dry" conditions, particularly so for the monzonite. This conclusion is supported to some extent by the mineralogy of the granite and monzonite units. Bowen & Tuttle (1958) note that experimental data indicate that some amphiboles are unstable under moderate or high water-vapor pressure whereas the micas are stable under such conditions. Therefore, if amphibole rather than biotite is the principal mafic mineral in a particular granitic unit, it might be concluded that the magma had a low water content. Furthermore, if water content plays a significant role in determining the character and extent of unmixing of alkali feldspar, then the predominance of perthite over two separate alkali feldspars in a granitic unit, should also imply crystallization from relatively dry magma. In Hope Lake granite, biotite is the principal mafic mineral and roughly 60 percent of the alkali feldspar is microcline-microperthite; in monzonite, the only mafic mineral is amphibole and practically all the alkali feldspar is microcline-microperthite. These mineralogic features contrast with those of the Flora Lake granite and monzonite in which biotite is consistently the dominant mafic mineral and microperthite is a relatively minor feature, suggesting that the Hope Lake magmas may have been somewhat lower in water content relative to the Flora Lake magmas.

The chemical composition of Hope Lake metagabbro (Table 3) is almost identical with that of the metavolcanic rocks in the area, and its mineral composition is anomalous compared with that for the average magmatic gabbro. These facts suggest that the two metagabbro masses in the monzonite are reworked metavolcanic inclusions. The presence of sodic plagioclase (An 15), diopsidic pyroxene, and large amounts of amphibole and biotite in the metagabbro reflect the tendency for conversion of the mineral assemblage to one that was in equilibrium with the liquid portion of the intruding monzonite magma (Bowen, 1928) into which the xenoliths were incorporated (presumably at a considerably deeper level).

In conclusion it may be that the Hope Lake stock is another example of the upward advance of lighter-weight, siliceous, infracrustal (deep basement) materials which were partially melted and mobilized, and in response to gravitational inequilibrium, pushed their way through the overlying supracrustal (volcanic-sedimentary) sequence (Kranck, 1959; Walton & deWaard, 1963; Smithson, 1965). The intrusive mechanism may have been essentially that by which salt domes are emplaced (Nettleton, 1934, 1943; Parker & McDowell, 1955; Smithson, 1963, 1965). The intruding magma made room for itself by means of a combination of lateral displacement and upward wedging of the wallrocks, aided in part by faulting.

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