TRIPS A-2 and B-1

GEOLOGY AND PETROLOGY OF IGNEOUS BODIES WITHIN THE KATAHDIN PLUTON

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Introduction

The Katahdin Pluton is a prominently placed plutonic body within a discontinuous bimodal belt of plutonic rocks extending northeastward from Rangeley, NW Maine, toward south of Presque Isle, NE Maine (Fig.1, Fig.2, see also Fig.1 of Ayuso, Wones -this guidebook). This belt, named here as the Greenville Plutonic Belt (after the town of Greenville approximately in the middle of the belt), consists of a series of NE-SW elongated plutons ranging in size from a few km to 70 km and ranging in composition from ultramafics (dunites of Moxie Pluton: Visher, 1960) to granites (IUGS classification) with under-representation of intermediate compositions.

The Greenville Plutonic Belt is defined here as a separate geological entity principally due to its unique tectono-petrogenetic characteristics. First, the belt marks an abrupt NW termination of large-scale Acadian plutonism within the Appalachian Orogen. Second, it parallels a belt of penecontemporaneous acidic volcanic rocks preserved in several synclinorial structures immediately to the northwest (Piscataquis Volcanic Belt, Rankin, 1968 -Fig.2). Third, within the belt there are several large gabbroic bodies (Fig.2) which point to a mantle-crust coupling of igneous activity during the Acadian orogenic event. Finally, the belt cuts across several metamorphic isograds, from a subchlorite zone in the NE of Maine to the sillimanite zone in the SW (Fig.3). Since the exposures of sillimanite grade are a reflection of later, postorogenic isostatic rebound due to continuing erosion, it is possible, by assigning reasonable lithostatic pressures to each of the isograds to make an estimate of the magnitude of the rebound. These calculations indicate that the present surface of the Greenville Plutonic Belt resulted by a differential regional "uplift" (tilt) of 5% grading linearly upward from NE to SW. Alternatively, the surface exposures in the Rangeley region represent conditions and environments which, immediately following the Acadian orogenesis, existed at a depth 8 km greater than the conditions of similar exposures at the Katahdin Pluton. This difference gradually diminishes to zero toward the Katahdin Pluton. The Katahdin Pluton is located further to the NE where it is situated between the shallower quartz diorite of the Moxie Pluton and the volcanics of the Traveler Rhyolite. The volcanics of Traveler Rhyolite are included in the upcoming general discussion of the Katahdin Pluton. This is for reason that the Traveler Rhyolite, as it will be shown later, is comagmatic with the Katahdin Granite.

The area of interest to this report was mapped in the early 60's by D. Rankin and A. Griscom (Ph.D. theses - Harvard University) and in the early 70's by the author (Ph.D. thesis - M.I.T.). D. Rankin mapped the area of Traveler Rhyolite; A Griscom the area of Katahdin Pluton; and R. Hon studied both units petrologically, mineralogically, and geochemically.

Figure 1. Index Map

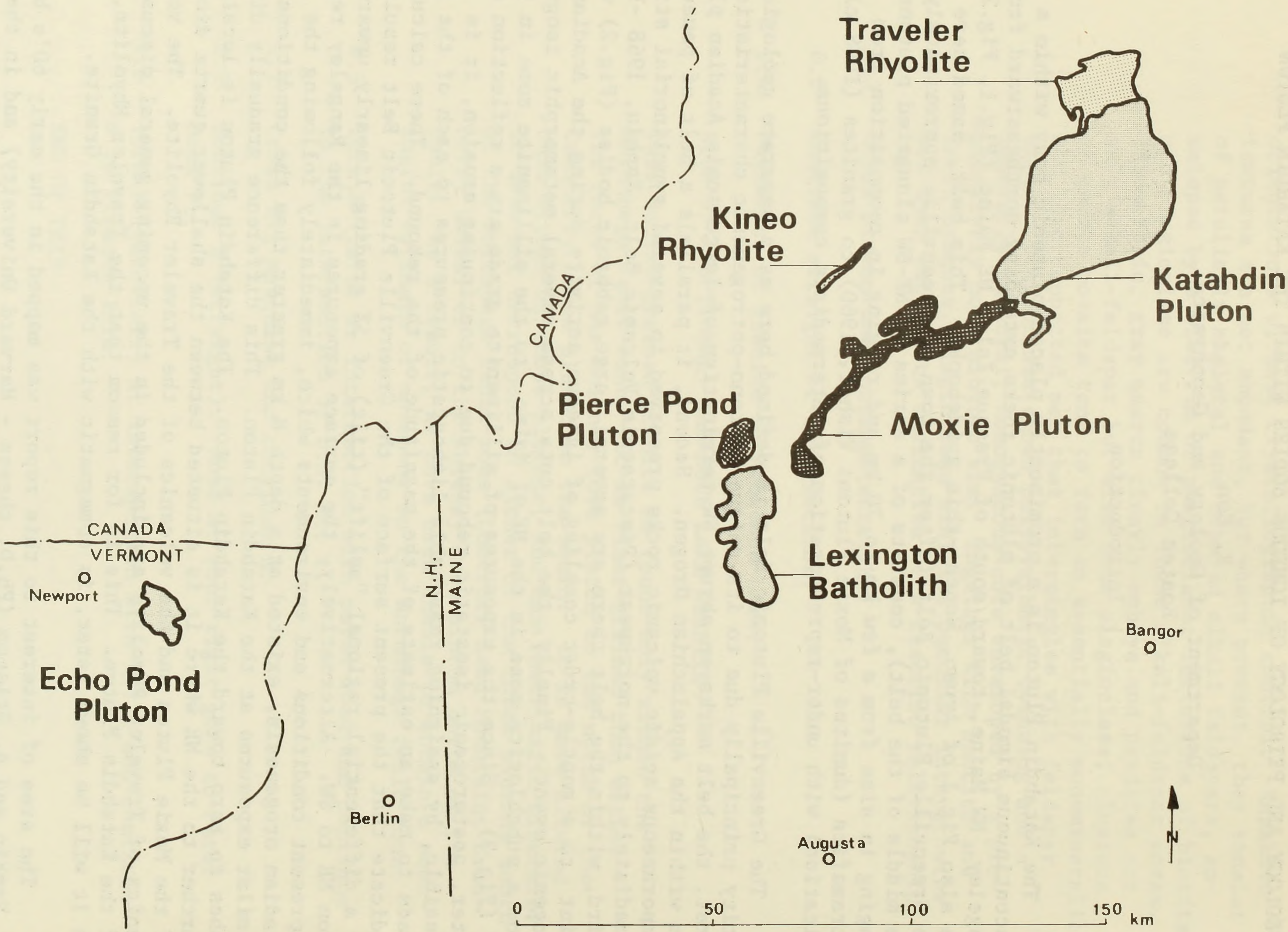
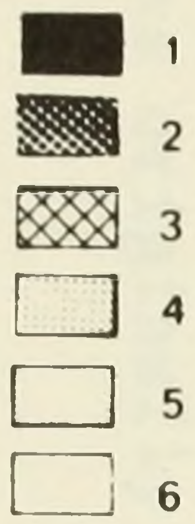
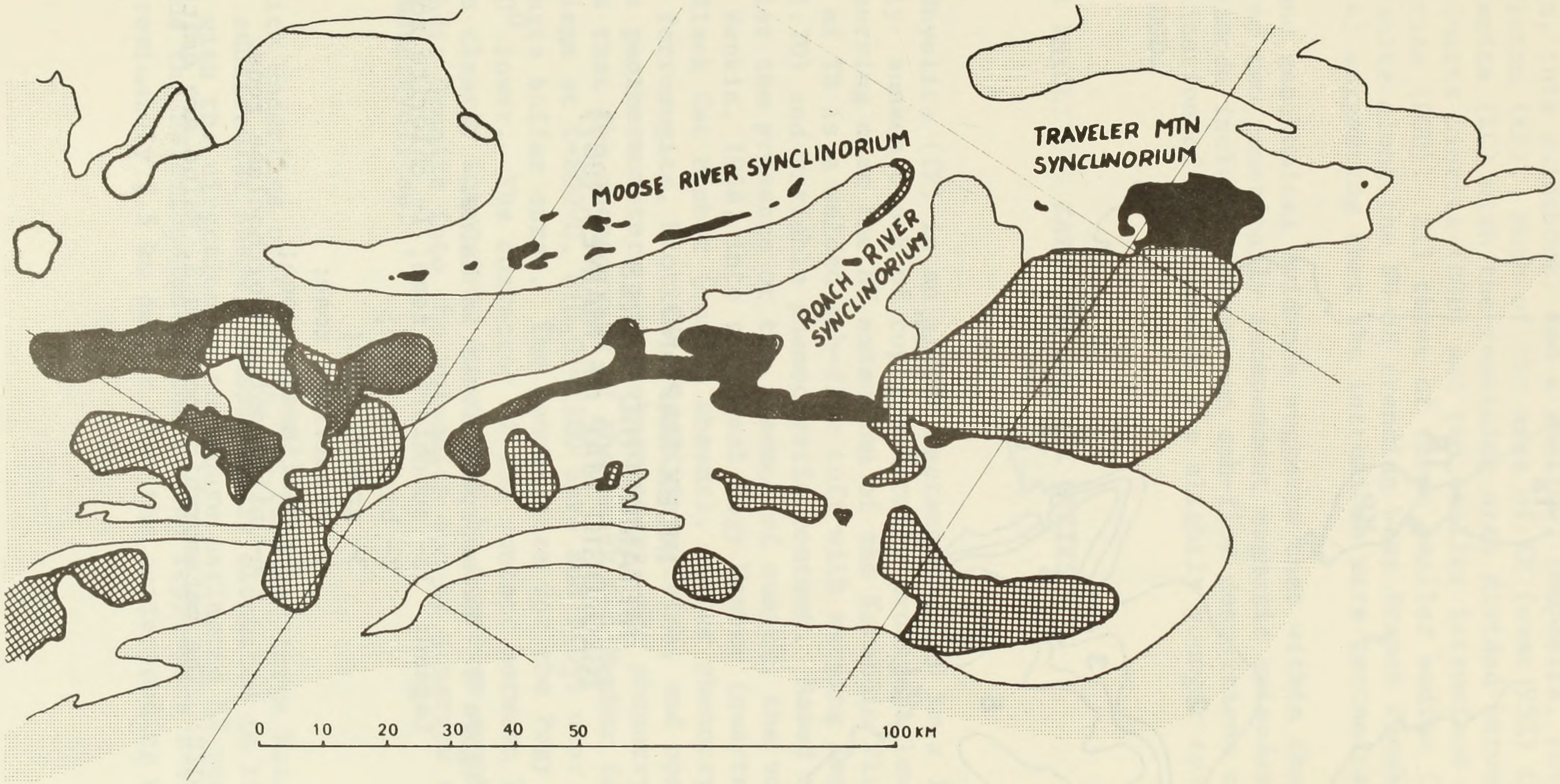


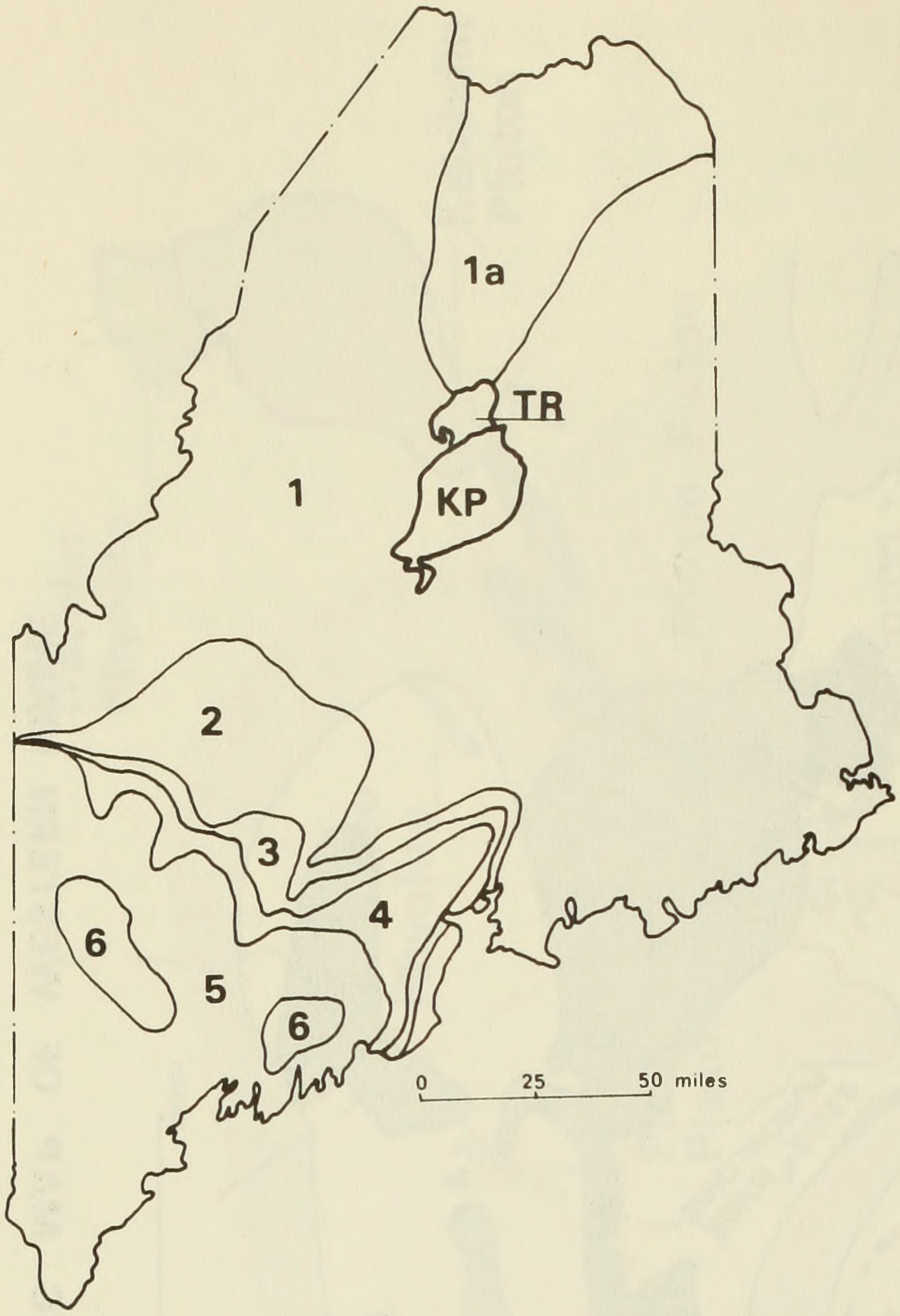
Figure 2. Greenville Plutonic Belt in western Maine.



Legend: 1- Piscataquis Volcanic Belt;
2- Mafic plutons of Greenville Plutonic Belt;
3- Granites of Greenville Plutonic Belt;
4- Other L. Devonian granites;
5- Pre-Devonian sediments;
6- Devonian sediments.



GENERALIZED GEOLOGIC MAP OF WESTERN MAINE



INDEX MAP AND
METAMORPHIC ZONES
(GEOLOGIC MAP OF MAINE, 1967)

Figure 3. Metamorphic zones in Maine.

Legend: 1a- subchlorite zone; 1- chlorite zone;
2- biotite zone;
3- garnet zone;
4- staurolite zone;
5- sillimanite zone;
6- sillimanite & orthoclase zone.

NOTE: The metamorphic zones in S. Maine are omitted for clarity.

TRAVELER RHYOLITE - KATAHDIN PLUTON IGNEOUS COMPLEX

The Traveler Rhyolite - Katahdin Pluton igneous complex consists of a 3.2 km thick sequence of rhyolitic volcanics of the Traveler Rhyolite (TR) Rankin, 1968;(Rankin, this guidebook) and a shallow, composite, predominantly granitic Katahdin Pluton (KP). Much of the area of KP (over 95%) is underlain by Katahdin Granite (KG) with the remaining area divided between a stock of Horserace Quartz Diorite (HQD) and two smaller intrusions of Debsconeag Granodiorite (DGD). All three of these smaller bodies (HQD, DGD) intrude Katahdin Granite along the NW-SE trending West Branch Penobscot River fault system (Fig. 4) suggesting that the intrusions were tectonically controlled.

Petrological and geochemical evidence suggests that within the TR-KP complex there existed two genetically independent magmatic episodes. The slightly younger episode includes voluminous ash-flow depositions of TR and subsequent crystallization of KG, where-as the slightly younger episode includes the HQD and DGD.

TRAVELER RHYOLITE - KATAHDIN GRANITE SERIES

Traveler Rhyolite

The Traveler Rhyolite (TR) is an almost rectangular (20 km x 12 km), largely tectonically sunken block of topographically prominent Lower Devonian volcanic rocks, occurring near the NE extension of the Katahdin Pluton. The dominant rock type of TR is a welded ash-flow tuff with varying degrees of compaction (up to 1:20) and variable phenocrystic content. Based on the latter, in particular the presence or the absence of quartz, the volcanic pile is divided by Rankin, 1968, into the basal Pogy Member (quartz present) and the overlying Black Cat Member (quartz absent). Other phenocrysts include plagioclase, ferroaugite, biotite, fayalitic olivine, and opaques. By applying various geothermometers and geobarometers, the phenocrystic assemblage indicate that the phenocrysts of the Black Cat Member form an equilibrium assemblage at $T=800^0C$, $P(H_2O)=1100$ bars and $f(O_2)$ near the fayalite-magnetite-quartz buffer curve. The temperature for the Pogy Member is approximately 40^0 lower. The character of the contact between TR and Katahdin Granite is clearly intrusive, documented by numerous apophysical injections of Katahdin Granite into the volcanics and by a narrow zone (100 m) of recrystallized metarhyolites.

Katahdin Granite

Katahdin Granite underlies over 95% of the 1350 km^2 large Katahdin Pluton. The pluton is of a subcircular shape, conspicuously elongated in the NE-SW direction parallel with the direction of the above estimated 5% postintrusive regional tilt. Thus the SW extension of the pluton represents a section which was originally approximately 3.5 km deeper than the corresponding section at

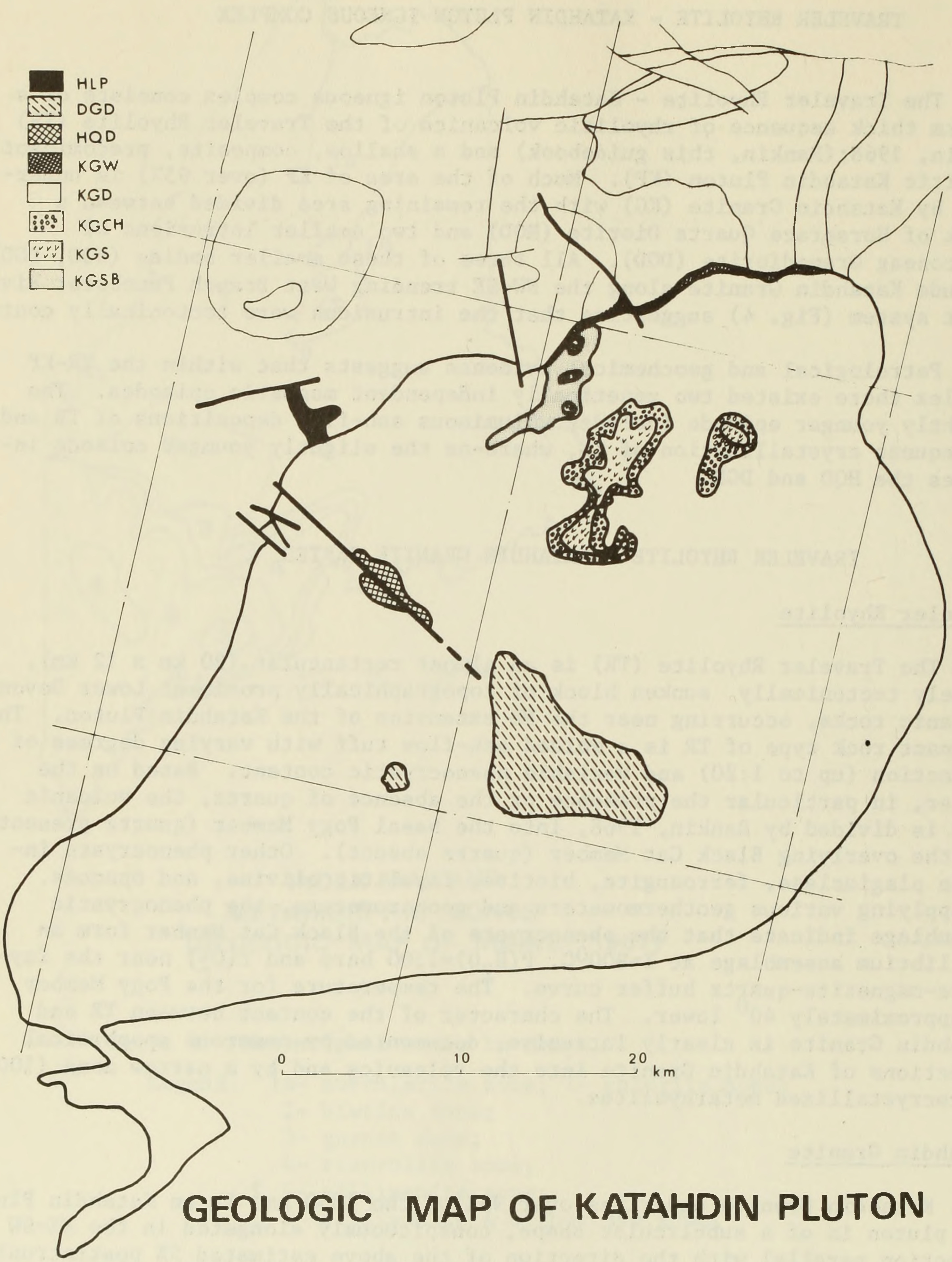


Figure 4. Geologic Map of Katahdin Pluton.

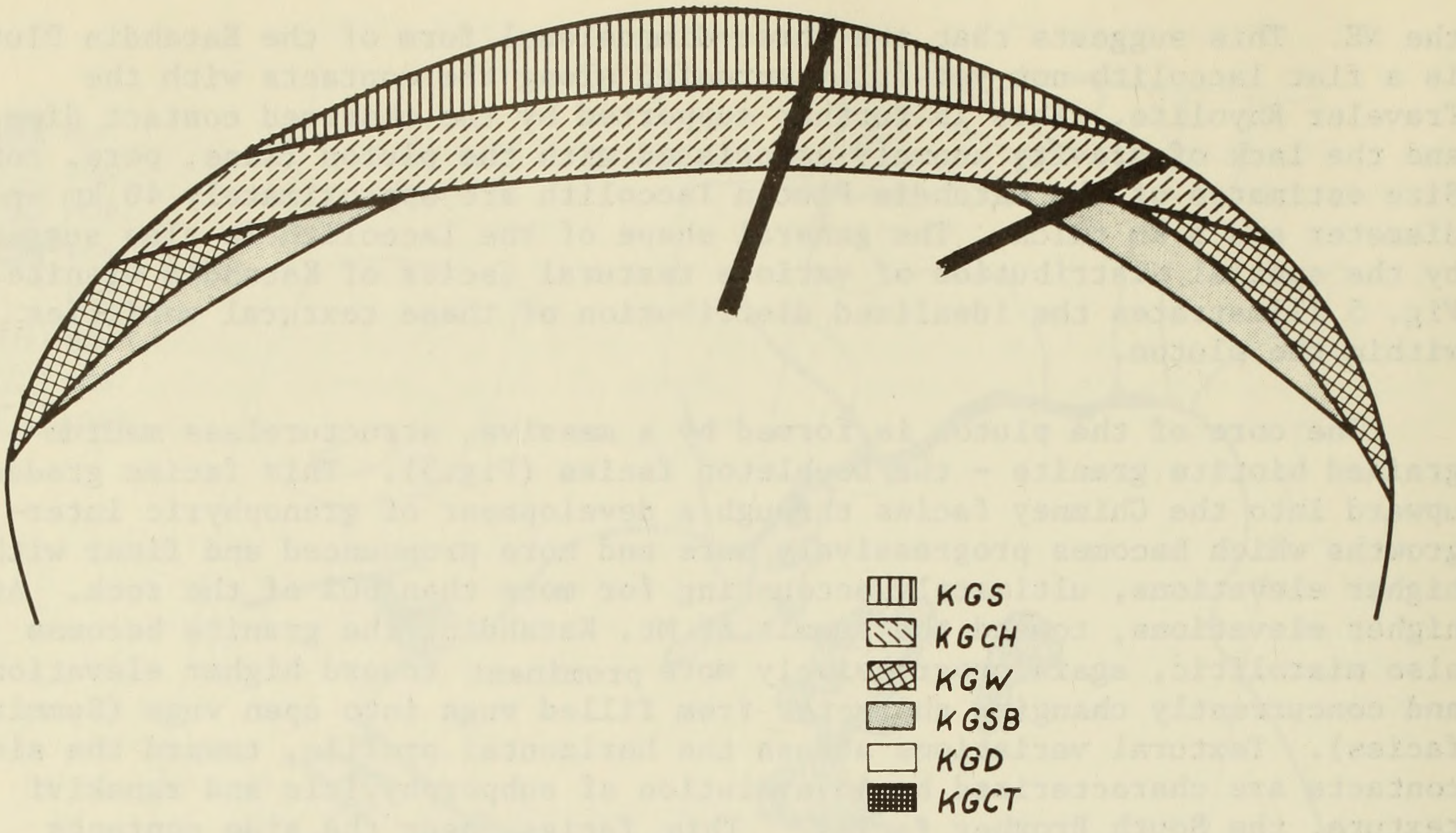
HLP - Harrington Lake Porphyrg
DGD - Debsconeag Granodiorite
HQD - Horserace Quartz Diorite
KG - Katahdin Granite

the NE. This suggests that the three-dimensional form of the Katahdin Pluton is a flat laccolith not yet fully unroofed along the contacts with the Traveler Rhyolite. This is further supported by the observed contact dips and the lack of gravity anomaly associated with the pluton (Kane, pers. comm.). Size estimates of the Katahdin Pluton laccolith are approximately 40 km in diameter and 5 km thick. The general shape of the laccolith is also suggested by the spatial distribution of various textural facies of Katahdin Granite. Fig. 5 illustrates the idealized distribution of these textural varieties within the pluton.

The core of the pluton is formed by a massive, structureless medium-grained biotite granite - the Doubletop facies (Fig.5). This facies grades upward into the Chimney facies through a development of granophyric intergrowths which becomes progressively more and more pronounced and finer with higher elevations, ultimately accounting for more than 60% of the rock. At higher elevations, toward the summit of Mt. Katahdin, the granite becomes also miarolitic, again progressively more prominent toward higher elevations and concurrently changing character from filled vugs into open vugs (Summit facies). Textural variations across the horizontal profile, toward the side contacts are characterized by an evolution of subporphyritic and rapakivi texture, the South Brother facies. This facies, near the side contacts becomes aplogranitic with occasional "nests" containing abundant linings of black to dark blue tourmaline (Wassataquoik facies). The observed thickness of the "outer zone" facies varies from zero to a minimum of 450 m, which is best explained by local differences in the cooling rates.

Aplitic dikes occur throughout the pluton and their frequency seems to be independent of elevation. The frequency of pegmatitic dikes is however inversely proportional to the frequency of miarolitic cavities. The pegmatites are absent at higher elevations but become more frequent toward the core of the pluton.

Also of interest is the relative erosional resistance of the "outer zone" granites. The Summit facies, by its extreme resistance against weathering provides an effective anti-erosional capping at higher elevations, topographically identified in the northern part of the pluton as an elevated plateau contoured by sharp edges, deep valleys and glacial cirques. The plateau, surrounding near its southern edge the highest point in Maine (Mt. Katahdin: Baxter Peak - 5267 ft.), dips gently toward the NNE from 4600 ft. to 2800 ft. over a distance of 8.8 km. The calculated mean slope of the plateau (6%) correlates closely with the estimated postorogenic tilt in this region (5% - see Introduction). It is believed that the inclination of the plateau is not intrinsic to the pluton but rather a result of later isostatic crustal re-equilibration. Wherever the anti-erosional "shield" of the outer zone granites erodes away, the granites of the Doubletop facies are subject to a relatively quick erosion due to their poorer resistance. This explains the existence of steep hillsides around the exposures of the Summit facies and the topographic lows in the remaining part of the pluton.



DISTRIBUTION	FACIES OF KAT. GRANITE		TEXTURE
Core	Doubletop	KGD	Granitic
	Chimney	KGC	Granophyric
Outer zone	Summit	KGS	Granophyric and Miarolitic
	South Brother	KGSB	Subporphyritic with Rapakivi Overgrowth
	Wassataquoik	KGW	Aplogranitic
Porphyritic dikes	Cathedral	KGCT	Porphyritic with Aplitic Groundmass

Figure 5. Schematic distribution of textural facies of Katahdin granite within the Katahdin Pluton Laccolith.

Irrespective of its textural variations, the Katahdin granite is a homogeneous, massive, medium to fine-grained biotite granite of constant chemistry and mineralogy (Fig.6): alkali feldspar OR70:AB28.5: ANI.5 (34%), zoned plagioclase AN34 to AN25 (26%), quartz (34%), biotite (6%), and accessory apatite, allanite, zircon, tourmaline, opaques. There is no known occurrence of muscovite, garnet, or sphene. Various geothermometers and geobarometers indicate temperature of crystallization at $T=710^{o}C$, $P(T)=P(H_2O)=1200$ bars, and $f(O_2)$ near the fayalite-magnetite-quartz buffer curve. The pressure estimate compares well with the estimated 1100 bars for the phenocrystic assemblage of the Traveler Rhyolite, suggesting that the KG represents a solidified magma chamber underneath the Traveler volcano.

HORSERACE QUARTZ DIORITE - DEBSCONEAG GRANODIORITE SERIES

Horserace Quartz Diorite

The Horserace Quartz Diorite (HQD) forms a small elongated stock intruding the Doubletop facies of Katahdin granite in the western part of the pluton (Fig.4). The stock is about 5.5 km long, and at its maximum 2.0 km wide with outcrops on both sides of the West Branch Penobscot River. The HQD intrusion parallels a prominent fault system extending NW-SE for a minimum of 30 km from Chesuncook Lake to the center of the KP. On both sides of the HQD stock, also parallel with the fault system, are numerous lamprophyre-like dikes which are mineralogically and chemically identical with the HQD. The ascent of the quartz dioritic magma was therefore tectonically controlled and the fault remained active even after the intrusion solidified.

From aeromagnetic data, Allingham, 1960, deduced that the intrusion is symmetrical with contacts dipping outward at about 55^{o} to a depth of at least 3 km. Projecting the contacts upward, the upper contact can be estimated to have been about 1.5 km above the present exposures. The contacts with the surrounding KG are consistent with the model of a forceful tectonically controlled intrusion. Brecciation of the granite and granitic inclusions within the HQD are commonly observed near the contacts.

The HQD intrusion is concentrically zoned with a composition of biotite-amphibole quartz diorite at the margins grading inward into amphibole-bearing biotite granodiorite. Color index varies accordingly from about 25 to about 7 in the center. The principal mineral components (Fig.6) are plagioclase (andesine to oligoclase), quartz, alkali feldspar, hornblende, biotite, and accessoric apatite, sphene, opaques and fine primary "droplets" of sulphides (probably pyrrhotite and chalcopyrite almost exclusively in the cores of amphiboles). Fig.6 shows compositional variations plotted on the IUGS classification triangle as well as variation diagrams suggesting that the principal cause of differentiation involves simultaneous removal of plagioclase and amphibole. Estimates of $f(O_2)$ yield values above or near the Ni-NiO buffer curve.

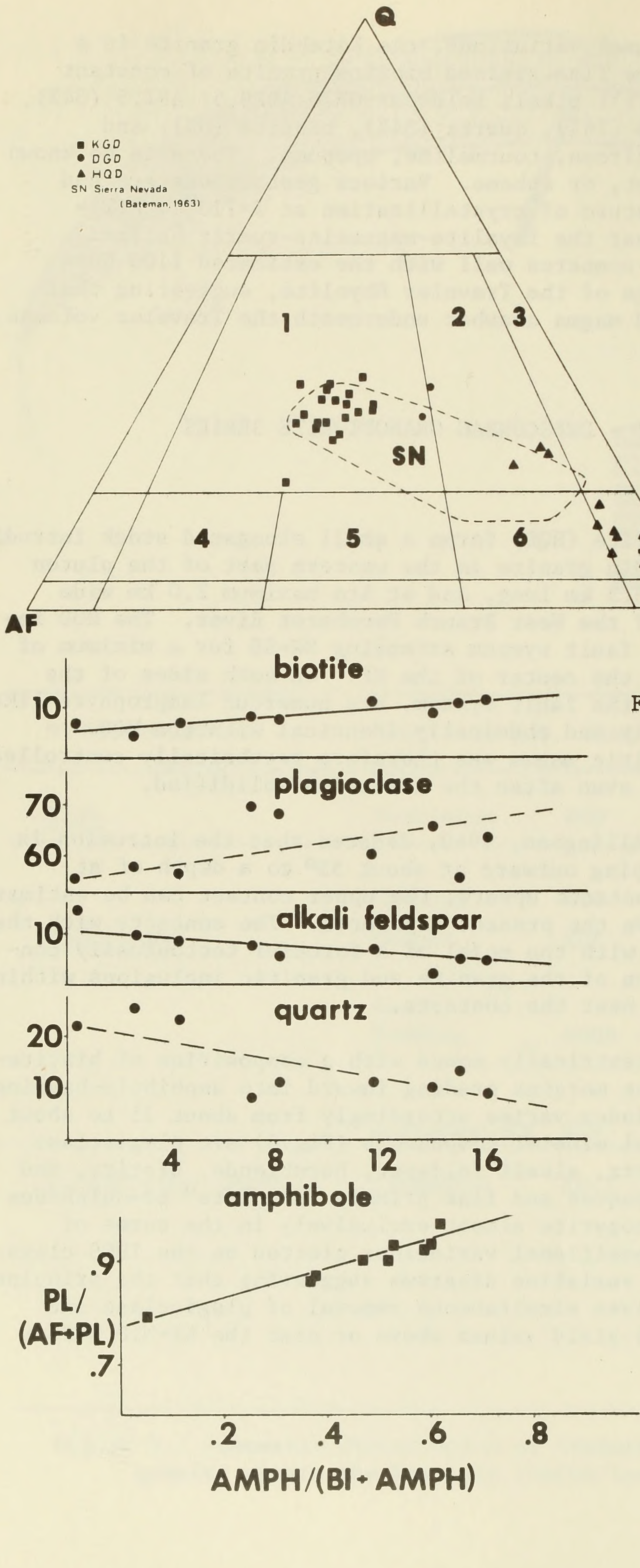


Figure 6. TOP: At top IUGS classification triangle for acidic plutonic rocks with plotted model analysis of rocks from the Katahdin Pluton.

BOTTOM: Mineral variation diagrams in Horserace Quartz Diorite.

Debsconeag Granodiorite

Debsconeag Granodiorite (DGD) is a medium grained amphibole-bearing biotite granodiorite found principally in a 80 km^2 large body in the central part of the Katahdin Pluton (Fig.4). Another occurrence of DGD is a small stock (1.5 km^2) located in the southern part of the KP. The larger of the 2 stocks is intruded by dikes associated with the HQD.

DGD in hand specimen is similar to the Doubletop facies of the Katahdin granite but with a noticeably higher content of biotite and ever present traces of amphibole. Modal analyses are plotted in Fig.6. Typically, DGD contains alkali feldspar (21%), cyclically zoned plagioclases: AN35 to AN18 (37%), quartz (31%), biotite (9%), hornblende (1%), and accessory apatite, zircon, allanite and opaques.

Major Element Geochemistry

Major element analyses of representative samples of each of the rock types are plotted on an AFM (wt%) diagram and their normative compositions are plotted on an AB-Q-OR diagram (Fig.7). From these diagrams a clear distinction exists between the more reducing TR-KG sequence and the more oxidizing HQD-DGD series. AFM plots are compared to the Skaergaard trend (reducing trend) and to the Lower California Batholith trend (oxidizing trend). The trend shown for Lower California Batholith is also typical of calc-alkaline magmatism associated with destructive plate margins (high alumina basalt-andesite-dacite association). From major element geochemistry, it is also deduced that the Traveler Rhyolite at its origin was at 8 kb total pressure, 4 kb water pressure and in equilibrium with two feldspars and quartz. The low oxygen fugacity of the TR magma was presumably maintained through equilibrium with graphite, which is a common component of Appalachian eugeosynclinal sediments.

Trace Element Geochemistry

Fig.8 shows chondrite normalized REE abundances of all the rock types within the Katahdin Pluton. The REE, as well as other trace elements, clearly indicate that the two magmatic sequences are of different origin. Modeling of trace element abundances show that the Katahdin Granite can be derived from the Traveler Rhyolite magma if 15-25% phenocrysts are removed from the TR magma by fractionation. Debsconeag Granodiorite is best explained by mixing of approximately 40% Traveler magma and 60% Horserace magma. Trace elements also suggest that the TR magma could have been produced by 20% partial melting of eugeosynclinal sediments. Trace element and major element abundances of the Horserace Quartz Diorite are consistent with abundances of calc-alkaline associations of continental margins. If this inference is correct then the HQD magma may represent magma derived along a subducting oceanic crust.

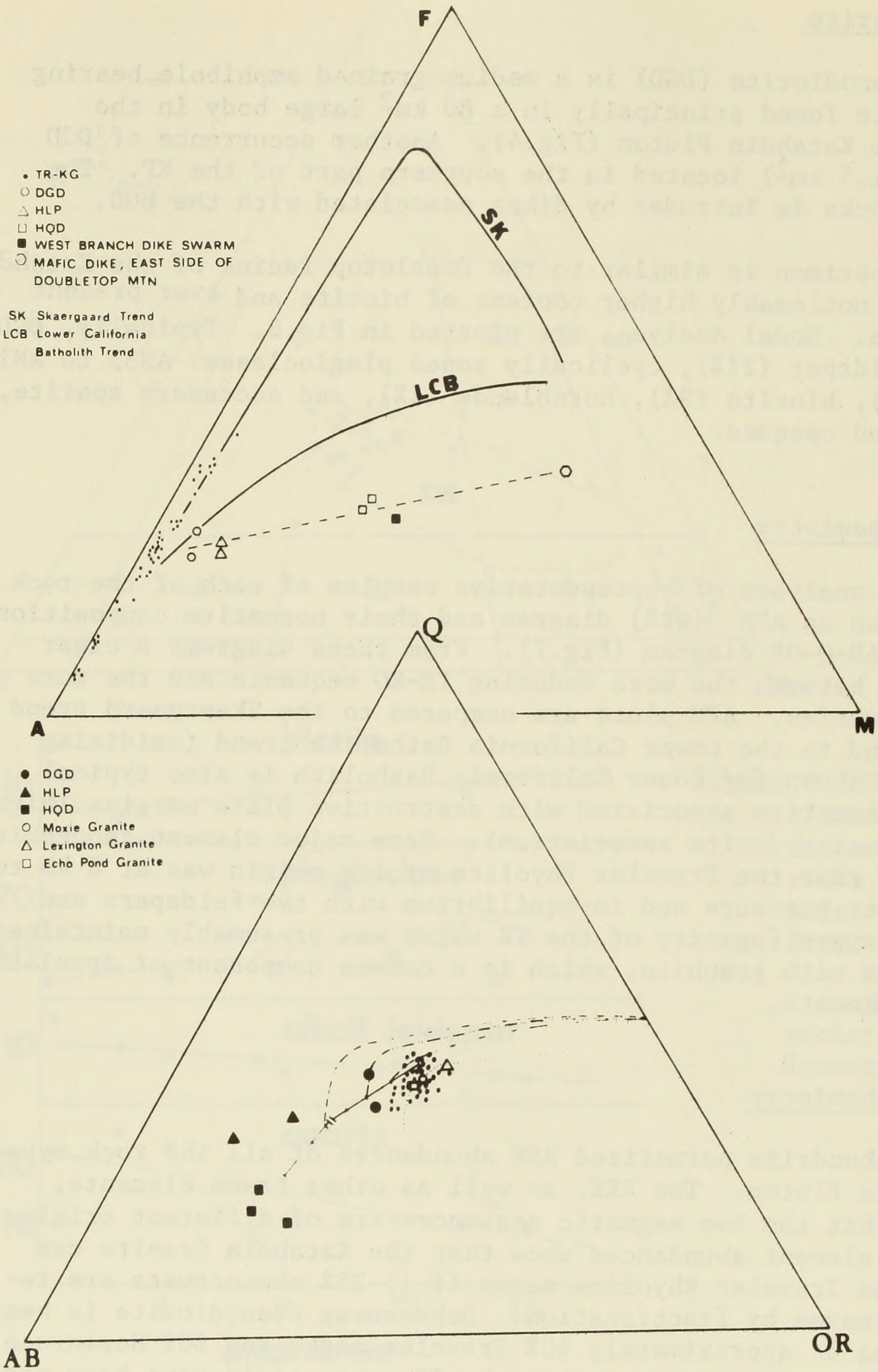


Figure 7. TOP: AFM (wt %) plot of chemical analysis for rocks within the Katahdin Pluton.
BOTTOM: AB-Q-OR plot of normative compositions of Katahdin Pluton.

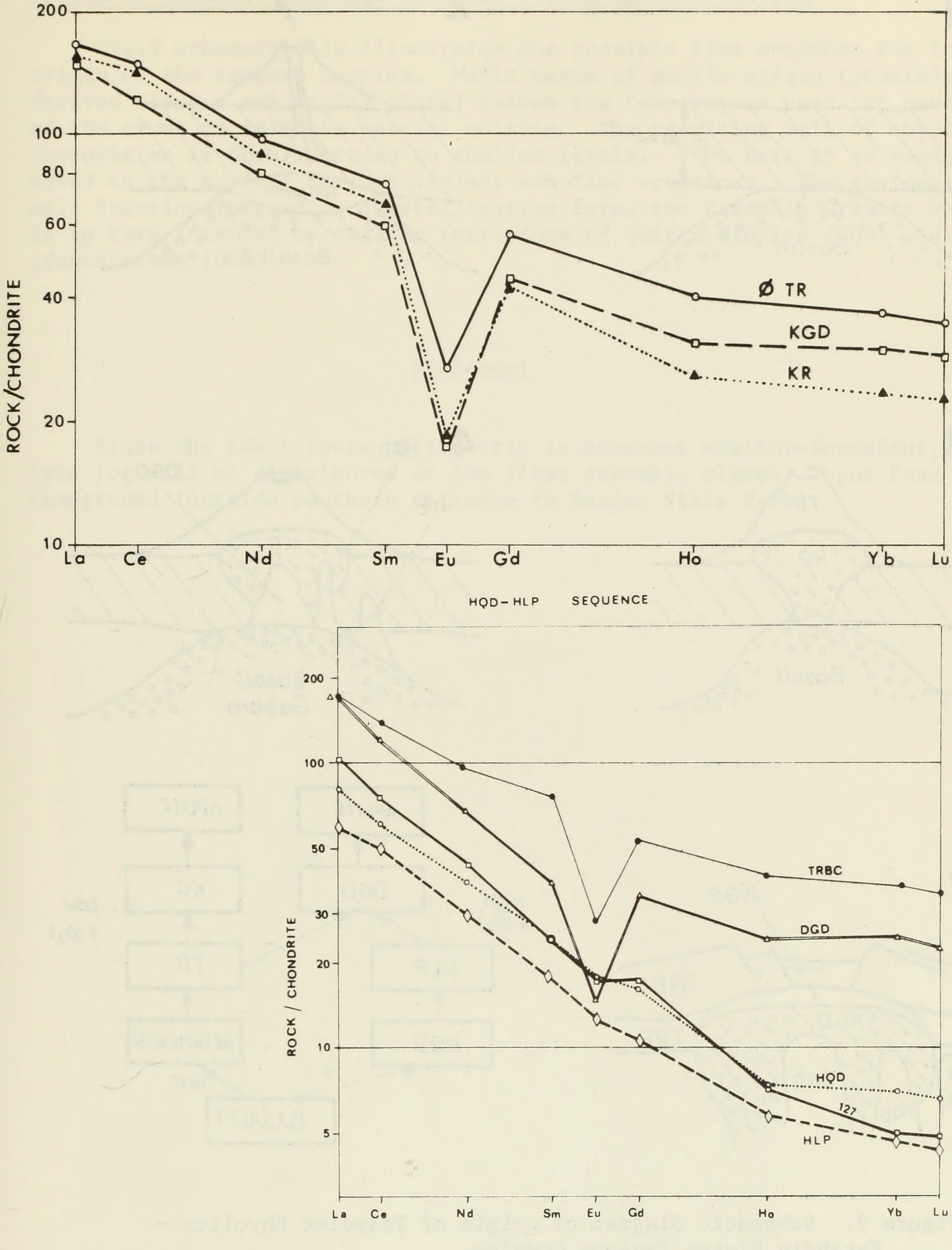


Figure 8. Chondrite normalized REE abundances for rocks of Katahdin Pluton. Sample 127 is from the dike associated with the HQD intrusion. KR-Kineo Rhyolite.

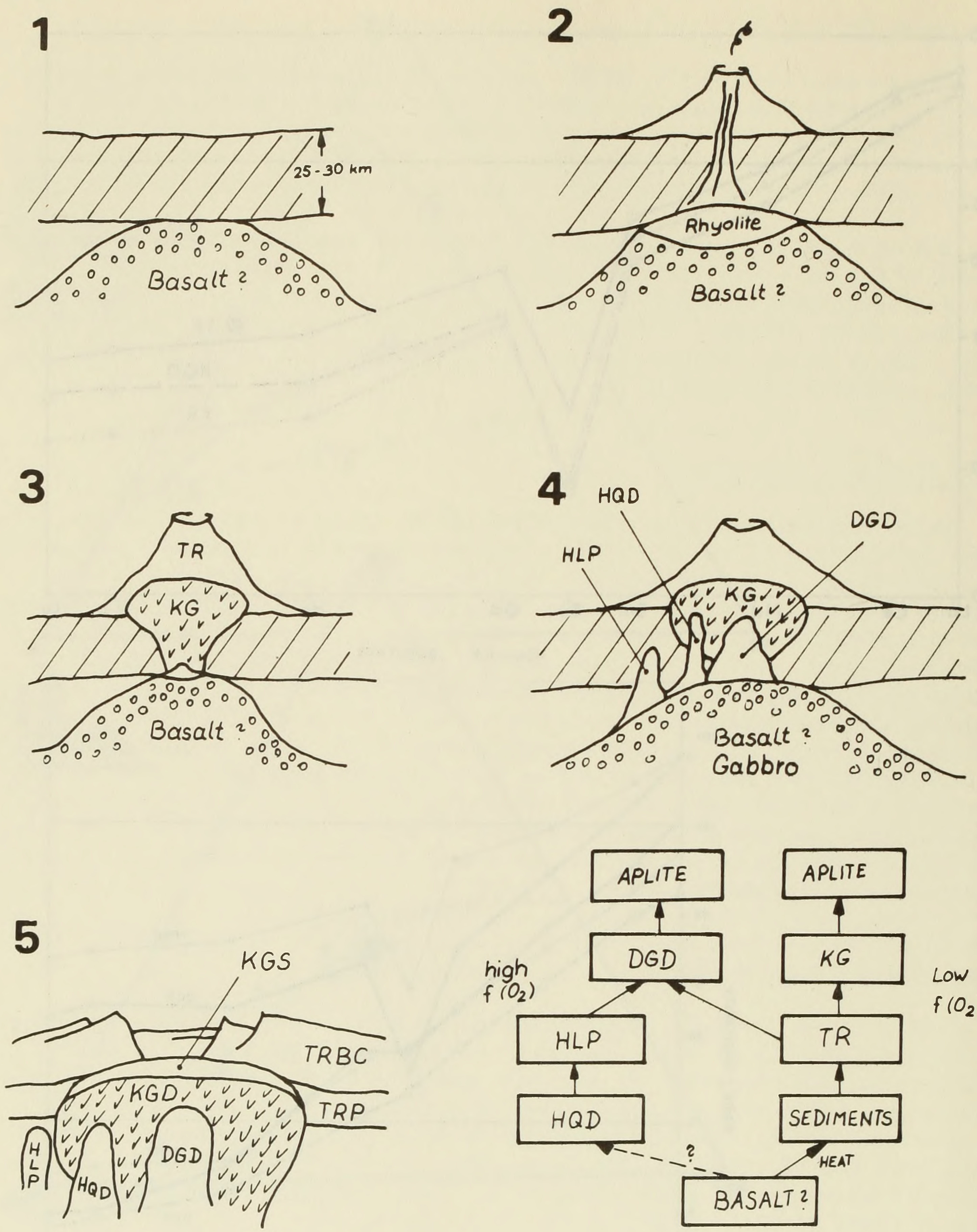


Figure 9. Schematic diagram of origin of Traveler Rhyolite - Katahdin Pluton Igneous Complex.

Origin of Traveler Rhyolite-Katahdin Pluton Igneous Complex

Fig.9 schematically illustrates the possible time sequence for the origin of the igneous complex. Mafic magma of mantle origin (possibly derived along a subducting plate) raises the temperature near the base of the crust to initiate partial melting. The resulting melt of rhyolitic composition is then intruded to shallow levels. From here it is rapidly moved to the surface through violent ash-flow eruptions. The residual melt fractionates and on crystallization forms the Katahdin Granite which is in turn intruded by smaller intrusions of quartz diorite (HQD) and granodiorite (DGD).

Statement

Since the exact route of the trip is somewhat weather-dependent, the trip log will be distributed at the first assembly place: Togue Pond Campground (outside southern entrance to Baxter State Park).