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Preservation of primary magmatic features in subvolcanic pegmatites, aplites, and granite from Rabb Park, New Mexico

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Abstract

An extraordinary example of arrested plutonic development has been preserved in a volcanic and shallow subvolcanic complex in Rabb Park, New Mexico. A hypabyssal rhyolite containing consanguineous fragments of sanidine-rich and groundmass-bearing granite, aplite, and pegmatite is intrusive into the lower half of the 33.4 Ma Kneeling Nun Tuff. This intrusive complex appears to plug the throat of an earlier Kneeling Nun vent and records a gradual change from pyroclastic to intrusive behavior.

Five major rock types, ranging from tuff to pegmatite, are considered consanguineous because of their transitional petrographic character and similar K-Ar ages, mineralogy, composition, and experimental delineation of crystallization fields. They appear to comprise pyroclastic, porphyritic, and phaneritic textural facies of a single magma crystallized at no more than 3-km depth, but arrested at different stages of development. The depth, relative timing, and manner of aqueous-phase separation were key factors in the textural genesis and preservation of these rocks.

Crystallization seems to have chiefly occurred at pressures less than 1 kbar and at temperatures from in excess of 950 to 650°C. Rapid cooling to below 300°C after emplacement has quenched and preserved a unique textural reference state that bridges the usual volcanic-plutonic gap. Comparison of more extensively modified plutonic fabrics with those in this rock suite suggests that information regarding primary magmatic mineralogy and crystal size, form, and intergrowth in developing batholiths may be best preserved in hypabyssal portals such as the Rabb Park Complex.

Introduction

Understanding the evolution of plutonic rocks is hindered by the slow, but generally complete subsolidus recrystallization that affects all but the shallowest and most rapidly quenched intrusions. As Tuttle (1952) emphasized in his classic paper contrasting the mineralogy of extrusive and intrusive salic rocks, such textural modification is most readily observed among the feldspars which exhibit varying amounts of inversion, unmixing, and recrystallization. Plutonic rocks only indirectly preserve primary magmatic features.

Much recent volcanological research has focused on large, vertically zoned magma chambers whose rapid eruption has resulted in major caldera subsidence. These studies have contributed much to our understanding of early-stage crystallization in salic systems but cannot address comparable late-stage phenomena because these systems catastrophically erupt long before approaching 100% crystallization. Hypabyssal intrusions, often emplaced as cone-sheet dikes, shallow sills, or feeders to surface domes, record critical petrologic features from later crystallization stages. If the crystallization of such rocks is arrested at an appropriate stage, their textures can span this volcanic-plutonic gap.

An extraordinary example of such textural preservation with important clues to near-surface plutonic development has been reported from Rabb Park in southwestern New Mexico (Kelley and Branson, 1947; O'Brient, 1980). An intrusive rhyolite porphyry contains a consanguineous suite of high-temperature, groundmass-bearing plutonic rock types including quenched fragments of incompletely crystallized granite, aplite, and pegmatite. Named for the gently contoured topographic bowl in which it is exposed, this intrusion and its phaneritic inclusions are informally called the Rabb Park complex. Located on the Black Range's western slope, it lies at an elevation of 2130 m, approximately 32 km east of Silver City and 12 km west of Emory Pass (Fig. 1).

This paper reviews the geologic, petrologic, and mineralogical features of this occurrence. Evidence for consanguinity of rock types ranging from tuff to pegmatite is discussed and included in a genetic model. Estimates for pressures and temperatures used in this model are derived from analysis of field and laboratory data and from a series of sealed-capsule experiments on natural Rabb Park starting materials. Comparison of this rock suite with typical deeper-seated plutonites suggests that they record a unique stage of arrested plutonic development.

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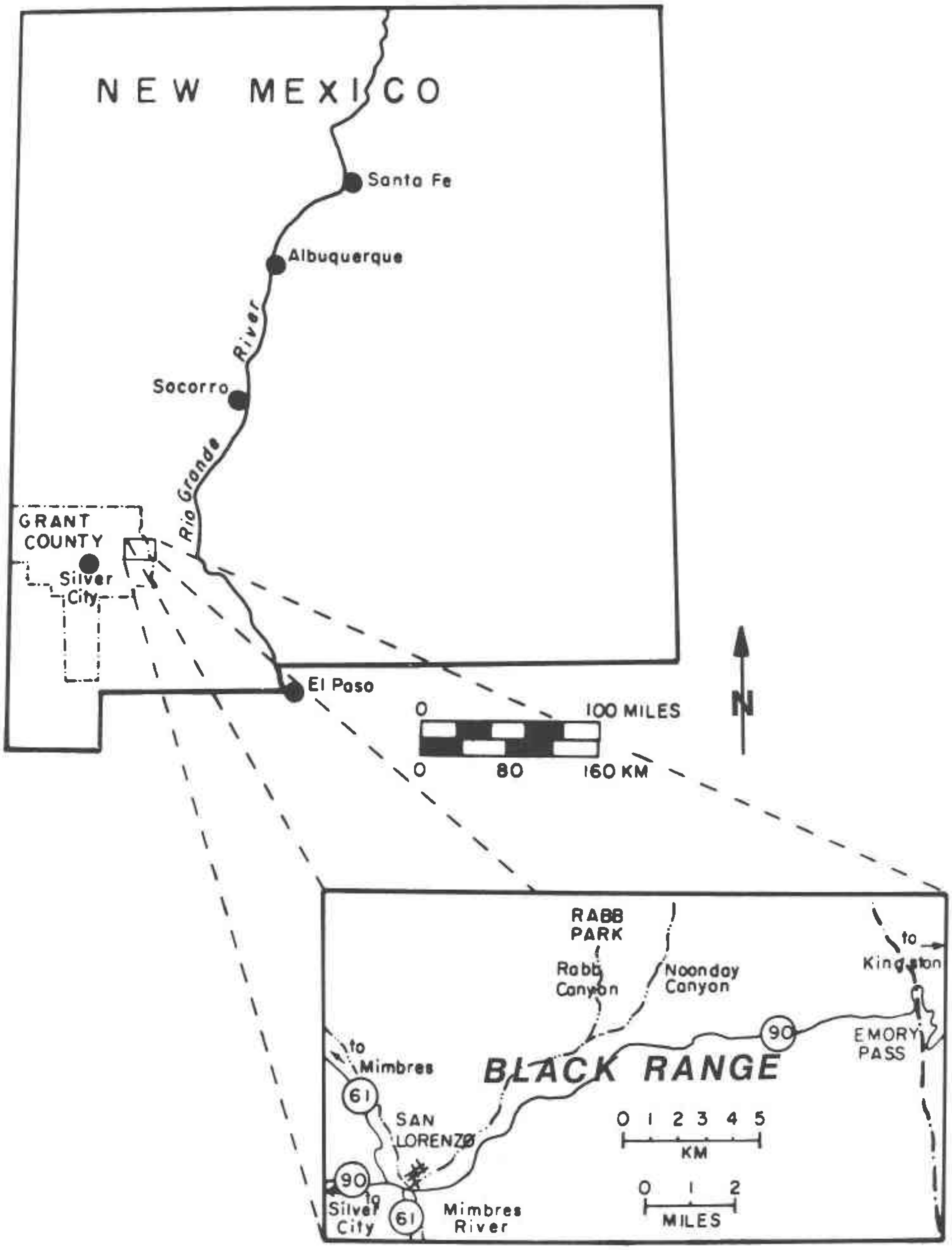

Fig. 1. Rabb Park is located on the western slope of the Black Range in southwestern New Mexico.

Geologic setting

The principal mass in the Rabb Park complex is a flow-layered body of rhyolite porphyry that intrudes the lower half of the Kneeling Nun Tuff (Kuellmer, 1954; Elston, 1957; Giles, 1965, 1967; Hedlund, 1975; Elston et al., 1975; Seager et al., 1978; Elston, 1984). This intrusion lies several miles inside Elston et al.'s inferred Emory Caldera ring fault and has been previously interpreted as a high-level expression of the magma responsible for the caldera's resurgent phase (Elston et al., 1975). An alternative interpretation, presented here, suggests that this intrusive, choked with granitic debris, is a plugged Kneeling Nun vent.

The Rabb Park porphyry is currently exposed at a level only 400–500 m above the floor of the Kneeling Nun caldera which lies exposed about 1 km to the east in a series of propylitically altered Eocene(?) latites and andesites (extreme NE corner of Fig. 2). Six age dates from sanidine separates from the Rabb Park complex (two porphyry, two granite, one aplite, and one pegmatite) yield similar ages that average 33.8 ± 0.7 Ma (O'Brient, 1980). This is statistically identical to the surrounding Kneeling Nun Tuff dated at 33.4 ± 1.0 Ma (McDowell, 1971).

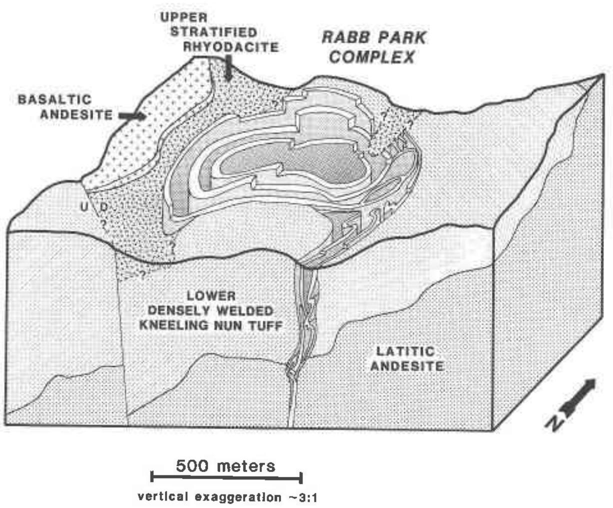

Fig. 2. The Rabb Park complex, illustrated by a few schematic flow structures, intrudes densely welded rhyodacitic Kneeling Nun Tuff (33.4 Ma), but is unconformably overlain along its western and northern edges by younger stratified rhyodacitic tuffs, ash-flow tuffs (29.7 Ma), andesite flows, and epiclastic sediments (Caballo Blanco series equivalent?).

Younger rhyodacitic to andesitic volcanics, including welded tuffs and tuff breccias, unwelded pumice tuffs, epiclastic sediments, and thin flows unconformably blanket the deeply eroded remnants of this complex and the Kneeling Nun Tuff. These younger rocks are 29.7 ± 1.2 Ma old (O'Brient, 1980) and may be correlative with the Caballo Blanco series (Elston et al., 1975). In total, these Oligocene volcanics are more than 600 m thick near Rabb Park. They are uncomformably capped by a younger basaltic andesite (upper Oligocene or Miocene?) to the west.

Postvolcanic faulting along steep WNW-striking normal faults in this area has resulted in a regional 9°SW dip of the block that contains the Rabb Park complex. The exposed northeast margin represents a horizon that was originally 245 m deeper than the corresponding margin to the southwest.

Rabb Park complex and major lithologies

Description of complex

The Rabb Park complex comprises four major rock types that differ from one another mainly in texture. They are rhyolite porphyry, sanidine granite, sanidine aplite, and sanidine pegmatite. Each rock type contains a high-temperature phase assemblage similar to that of the surrounding Kneeling Nun Tuff. All contain cryptoperthitic sanidine, some dipyramidal quartz (originally β-quartz), and vesicular groundmass. The mineral constituents of these four rock types and the enclosing tuff are similar but differ in relative abundance, grain size, and degree of crystalline intergrowth. The groundmass fractions of these five rock types are compositionally similar, but differ in relative abundance, type of devitrification, and percentage and style of vesicular porosity. These rock types are textural facies of a single near-surface granitic magma.

The main mappable unit within the complex is a mass of rhyolite porphyry that is cornucopia-like or "pork-chop" shaped in plan (Fig. 3). Nearly continuous steeply inward-dipping flow structures delineate a main funnel-shaped part of this mass that is elongate in a NE–SW direction. It is nearly 1.5 km in maximum exposed dimension. This funnel cuts a slightly older, arcuate arm of complexly folded rhyolite porphyry that is present along the eastern edge of the complex.

Fragments of the coarser-grained rock types, the sanidine granite, aplite, and pegmatite, are scattered throughout the porphyry, but are most abundant within the funnel-shaped core. These range in size from crystalline clots only a few centimeters across to granite masses that are 100–120 m in maximum exposed dimension. Flow structures wrap around the largest such fragments. Contacts are sharp and generally even. Only rarely are there indications of assimilation such as dispersed wispy streaks of coarser grains within the porphyry near granite masses or irregular and indistinct contacts between porphyry and the enclosed granite.

The aplite and pegmatite occur as interstitial patches, greisenlike streaks, small pods, and discrete cross-cutting dikes within the granite. The largest dikes exceed 10 m in maximum dimension. Several such dikes within the granites are abruptly terminated at a granite/rhyolite porphyry contact indicating that the dikes were emplaced prior to dispersal of the granite within the porphyry.

These coarser-grained rock types are slightly older than the rhyolite porphyry and are interpreted as cognate xenoliths that were mechanically mixed into the rising porphyry mass. Their dispersion, however, appears to have occurred before they were completely crystallized because all contain quenched aphanitic groundmass, thereby preserving a record of hypabyssal crystallization.

Geology and petrography of individual rock types

Welded tuff (Kneeling Nun). The Kneeling Nun Tuff in the vicinity of Rabb Park is part of Elston et al.'s "Cauldron facies" (Elston et al., 1975), and on the basis of stratigraphic height above the underlying andesites, is apparently in the lower half of the Kneeling Nun section. It is densely welded and massive with local discontinuous foliations due to extremely flattened pumice. It is porphyritic, aphanitic, and crystal-rich. Fresh surfaces are pale red to purplish gray to purplish brown and commonly marked by lighter purplish-gray to bluish-gray pumice streaks. Abundant crystals and crystal fragments, typically less than 3 mm in maximum dimension, constitute 30–55% of this rock. In decreasing abundance, these include calcic oligoclase, sanidine, smoky quartz, and Fe-rich phlogopite. Trace magnetite, green hornblende, augite, sphene, apatite, and zircon are present. The groundmass is cryptocrystalline, usually densely welded, and contains at most 1–2% vesicles or amygdules that are nearly always

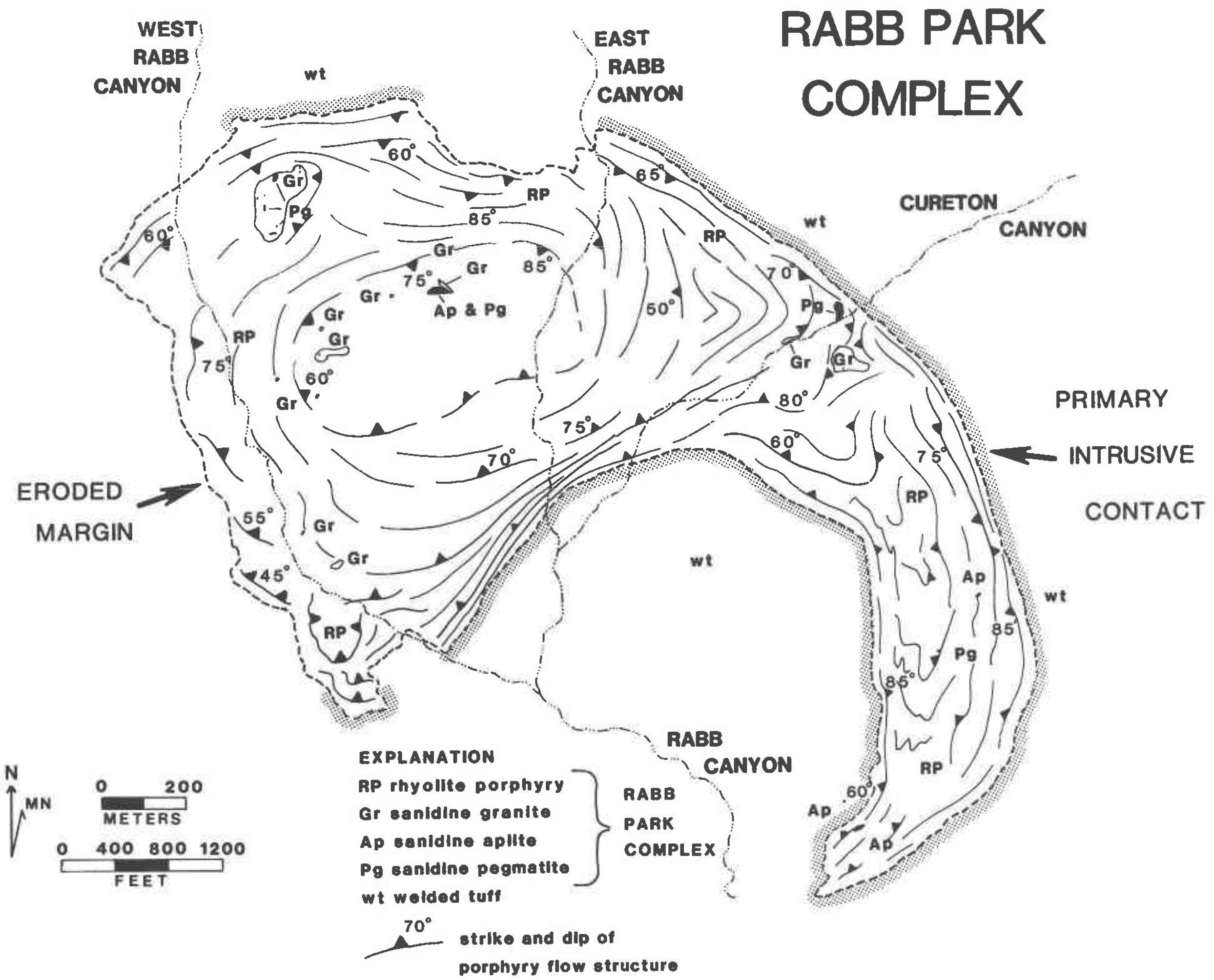

Fig. 3. Flow structures within the main rhyolite porphyry mass wrap around scattered inclusions of granite, aplite, and pegmatite.

flattened. Secondary heulandite, smectite, and calcite locally coat vesicles and fractures.

Rhyolite porphyry. The porphyry is intrusive into the Kneeling Nun Tuff at the present erosional level as indicated by its steep crosscutting contacts and the strong marginal shearing implied by its well-developed flow structures, but probably underlay a dome or domes by no more than a few hundred meters. Flow structures, defined by ribbed weathering surfaces, joints, variegated flow banding, and mineral alignment, are closely spaced (more than 10/m) near the margins but generally grade to less than 5/m (often only 1/m) toward the core. This pattern implies that major flow was pluglike, with most shear concentrated along the margins. However, there were numerous complexities due to local differential movements. Folding, commonly with vertical axes typical of salt-diapir tectonics, is locally present. This implies major lateral movement, perhaps along the roof of a shallow magma chamber, prior to vertical ascent through a narrow conduit analogous to pulling a napkin up through a ring. Younger throughgoing flow structures crosscut and terminate slightly older structures, suggesting that emplacement was episodic and gradually restricted from the margins inward and from SE to NW within the funnel-shaped core. If its emplacement is imagined as a telescoping motion wherever younger and deeper magma aliquots ascended through the core, then the complex preserves in radial section a record of originally vertical variations.

The porphyry comprises two facies, grading abruptly inward from a marginal "pyroclastic facies" to a more massive "core facies" (Fig. 3). The marginal facies is described as pyroclastic because it is generally finer grained and includes flattened pumiceous clasts, broken phenocrysts, and flattened vesicles. In contrast, the coarsely porphyritic core facies lacks pumice clasts, includes more abundant, larger, and unbroken phenocrysts, and is characterized by abundant intergrown crystalline clots and a distinctive vesicular groundmass that is locally "frothlike." These crystalline clots range from intergrowths of a few crystals to centimeter-scale fragments that are unquestionably pieces of the sanidine granite.

Fresh surfaces of the porphyry are pinkish gray to bluish gray and sometimes streaked with white or whitish gray. Generally, this rock is friable and easily weathered. Phenocrysts, generally euhedral, comprise 35–60% of this rock. Many range from 3 to 5 mm across, although coarse satiny white to chatoyant blue sanidine megacrysts in excess of 2 cm are not uncommon. Sanidine, the most abundant phenocryst, is accompanied by pale smoky quartz, white oligoclase, and coppery-black biotite. Accessory crystals include hornblende, augite, magnetite, sphene, apatite, and zircon. The groundmass averages 50% and is typically cryptocrystalline. Vesicular porosity ranges from a few percent to 50% (Fig. 4A). The largest vesicles and most coarsely devitrified groundmass occur as trapped pockets or embayments within phenocrysts such as the quartz crystal illustrated in Fig. 5A. Similar magmatic and fluid inclusions are common in all Rabb Park rock types. Abundant secondary heulandite and minor smectite commonly line these vugs. In its more extreme forms within the vesicular core facies, the porphyry groundmass approaches a pumicelike froth.

This porphyry records a gradual change from pyroclastic materials near the margins of the Rabb Park complex to a crystal-rich and granite-choked rhyolite in the core. It appears to occupy a previously active vent for the Kneeling Nun Tuff and provide a rare record of the progression from pyroclastic to nonfragmental intrusions suggested for some ash-flow vents (Lipman, 1984, p. 8817). At the present erosional level, the partially dismembered remnants of a deeper-crystallizing magma appear to have intruded their own eruptive blanket and plugged a major vent for at least the lower half of the Kneeling Nun Tuff.

Sanidine granite. The granite inclusions within the porphyry appear to be nearly holocrystalline and markedly porphyritic. Fresh surfaces are white to whitish gray, mottled with millimeter- to centimeter-scale patches of pale smoky quartz, and are coarsely granular. Even more friable than the porphyry, this rock literally falls apart, producing low, grus-covered outcrops. A hypidiomorphic-granular fabric of sanidine, quartz, oligoclase, and biotite constitutes 80–90% of the rock. The remaining 10–20% is a partially devitrified, vesicular groundmass (Fig. 4B). Grain size is extremely uneven, ranging from 1 mm to over 2 cm. Rare sanidine megacrysts exceed 4 cm.

Sanidine is the most abundant, coarsest, and most idiomorphic constituent. Its average grain size is 5–10 mm. Quartz is somewhat finer grained, euhedral to subhedral, and varies greatly in modal abundance. Plagioclase is still smaller and less abundant, but typically is very tabular and in part mantled by sanidine. The mafic and accessory minerals, chiefly biotite, hornblende, magnetite, zircon, apatite, and sphene, are typically intergrown in 1–2-mm clots. The average grain size is an order of magnitude coarser than in the porphyry.

The groundmass occurs as thin interstitial septa, polygonal crystal-bounded patches, complex tubular embayments or inclusions within crystals (particularly quartz), or as fracture fillings. Though individual domains appear to be isolated from neighboring patches, most are probably joined in a tortuous three-dimensional web. It is typically devitrified to relatively coarse (100–200 μm) conical spherulites of sanidine and quartz. Vesicles are abundant (locally exceeding 50% of the groundmass), coarser than in the porphyry, and incompletely lined with secondary heulandite (Fig. 5B). Some are true miarolitic cavitites as euhedral quartz and feldspar protrude into large open vugs.

Sanidine pegmatite and aplite. The pegmatites and aplites are typically intimately associated and most abundant within the larger granite masses, but also occur rarely as isolated fragments in the porphyry. The pegmatites are the coarsest, most uneven-grained, and least abundant member of the Rabb Park suite. They also are not entirely holocrystalline, but contain 2–5% devitrified groundmass that occurs as part of associated aplite (Fig. 4C) or as fracture-filling veins, thin septa, and inclusions within the coarser pegmatite (Fig. 4D).

Individual masses of the pegmatite range in maximum exposed dimension from several centimeters to more than 10 m. They record vastly different scales of segregation. The smallest pegmatite and aplite segregations are uneven-grained patches within the granite fabric that are only a few centimeters in size. They are distinct only in that their grain size differs from the surrounding granite and that they comprise only sanidine and quartz. At their smallest, these clots grade into the normal porphyritic fabric; at their coarsest, they grade into the smallest discrete pegmatites, which are spherical to pear-shaped pods that are commonly 5–25 cm across. These pods are consistently zoned with sanidine rims and quartz cores. Aplite is generally absent within the pods, but occurs as thin enveloping margins that in places grade into the enclosing granite. Accessory minerals are commonly lacking in these small pegmatites. Despite their relatively small size, these clotlike aggregates and pods appear to constitute the volumetrically most significant fraction (80–90%) of pegmatite because of their distribution throughout large masses of granite.

Pegmatite also occurs as intermediate-size dikes of uneven thickness or elongate lenses that pinch and swell in thickness from 2 cm to about 1 m and from 30 cm to 3.5 m in length. These pegmatites are sharply bounded by aplitic envelopes and are also zoned with sanidine-rich rims and quartz-rich cores. The largest pegmatite masses, which in places exceed 10 m in size, are the most uneven-grained and texturally complex. Pegmatite is surrounded by and interlayered with abundant aplite that makes up as much as 25% of the rock. In the interior of these dikes or lenses where pegmatite is most abundant, the aplite occurs as interstitial patches and stringers. Toward the edges, it forms coherent enveloping masses or rhythmic

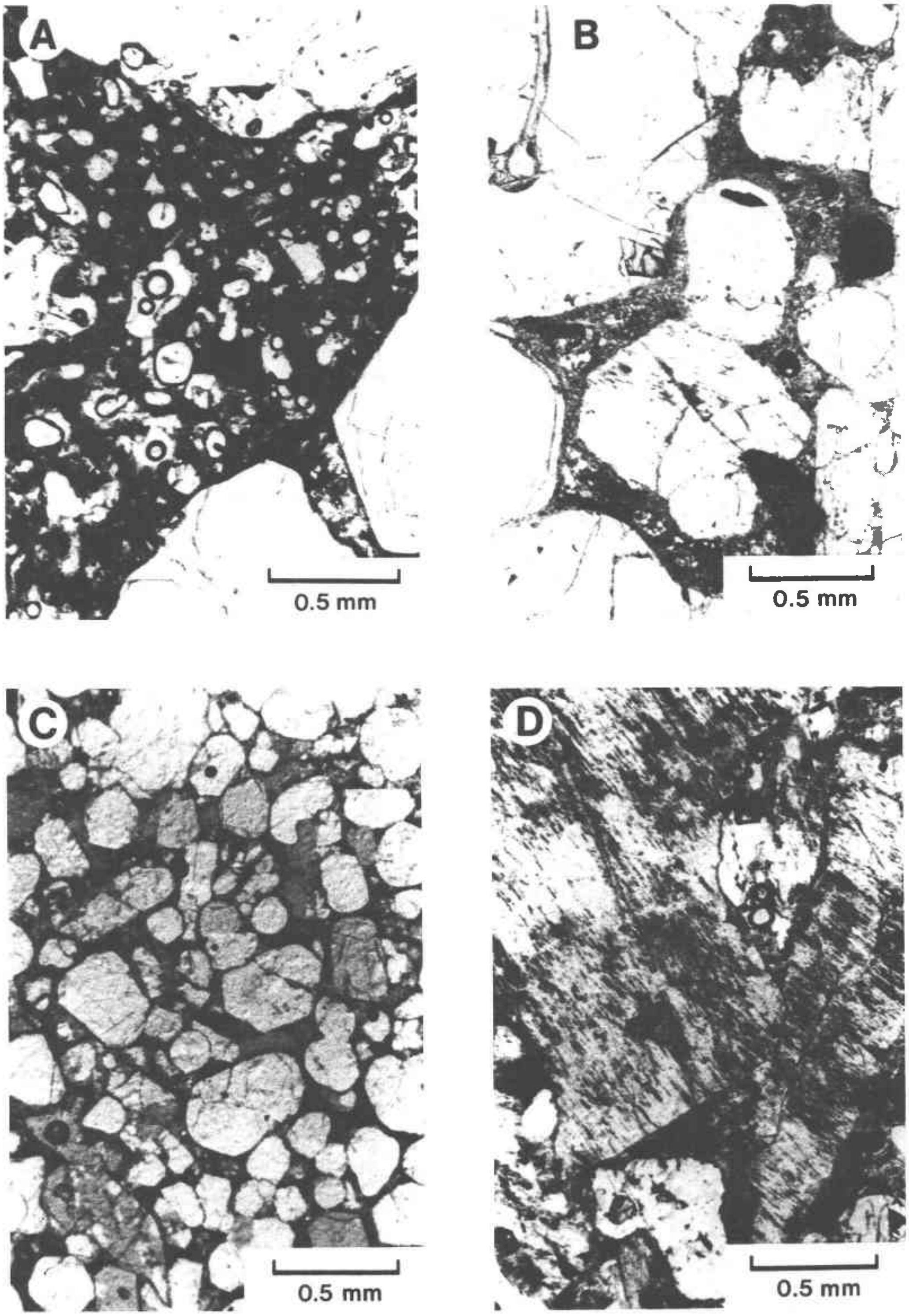

Fig. 4. Plane-light photomicrographs of textural facies in Rabb Park Suite. (A) Vesicle-rich core facies of rhyolite porphyry. (B) Sanidine granite with groundmass containing abundant vesicles, some of which are lined with heulandite. A tubular embayment within a quartz grain (upper left), also encloses vesicular groundmass. (C) Panidiomorphic- to hypidiomorphic-granular aplite with abundant interstitial groundmass. (D) Unevenly grained sanidine pegmatite. The grainy sanidine feldspars average 1 cm or more in diameter. The lighter, less-euhedral quartz crystals are only 1–5 mm across. Polygonal interstices are filled with devitrified groundmass.

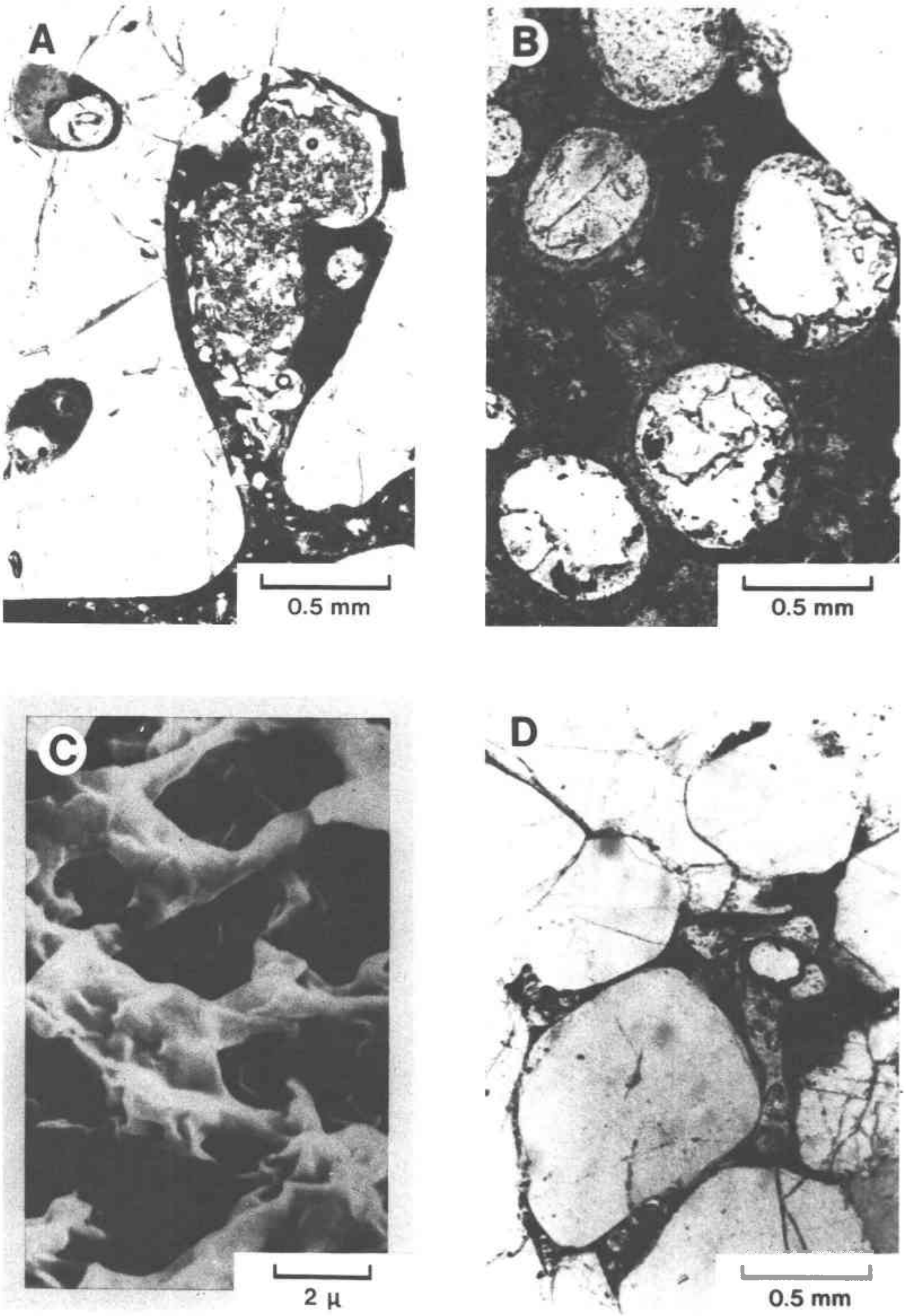

Fig. 5. Plane-light photomicrographs of groundmass and vesicles in different Rabb Park facies. (A) Embayments and pockets within a large quartz phenocryst in the rhyolite porphyry contain large heulandite-lined vesicles. (B) Coarse vesicles within groundmass-rich portions of the sanidine granite locally occupy nearly half the groundmass volume. Incomplete linings of heulandite are common. (C) The aplitic groundmass, magnified in SEM image, is locally so porous that it is frothlike. (D) Interstitial septa of vesicle-rich groundmass even occur in the sanidine pegmatite, the coarsest and most-crystallized member of this suite.

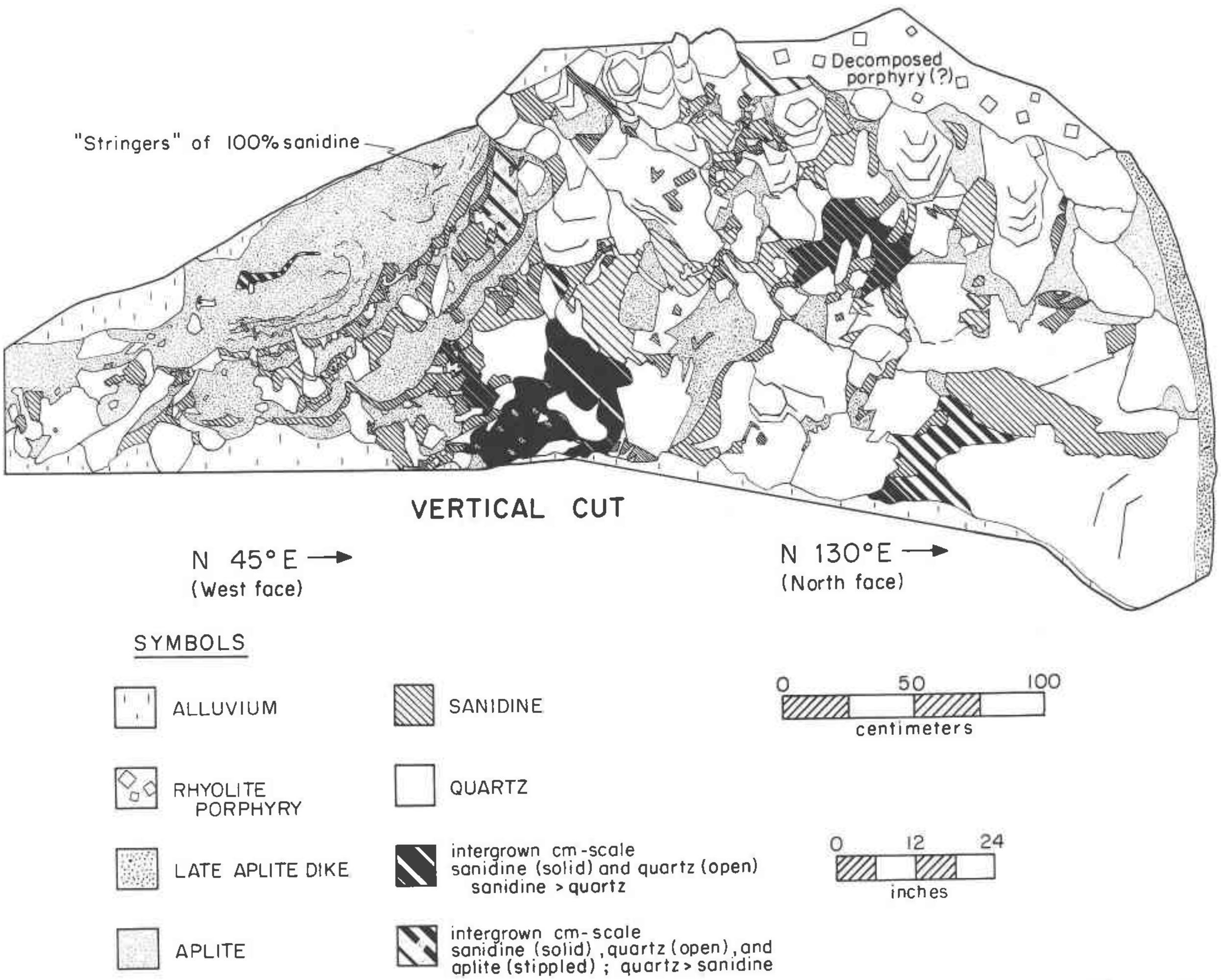

Fig. 6. The lithologic complexity and scale of the coarsest, most completely crystallized rocks are illustrated in this map (1:12 before reduction for printing) of the "North Rattlesnake Pegmatite," Rabb Park, New Mexico.

layers alternating with finer-grained pegmatite. A detailed map of the largest currently exposed pegmatite, included as Figure 6, illustrates these relationships.

The aplite is generally more even-grained and one to two orders of magnitude finer grained then the granite. Fresh surfaces are white, commonly sparkling with silvery highlights, and typically almost devoid of mafic phases. Grain size is generally in the 0.5–3.0-mm range. Rare porphyritic crystals of sanidine or smoky quartz exceed 1 cm. The aplite contains more sanidine and quartz than the granite, and less plagioclase and biotite. Hornblende is absent, but accessory magnetite, zircon, apatite, and sphene are present. The aplite contains between 2 and 30% interstitial groundmass that is slightly less abundant and generally less isolated than in the granite (e.g., cf. Figs. 4B and 4C). It nowhere forms large open patches such as those in the granite (e.g., Fig. 5B). It is spherulitically devitrified, and often notably vesicular, but at a much smaller scale (1–10 μm) than in the granite. In extreme cases, this groundmass is a spongelike, submicroscopic pumice or froth (Fig. 5C) whose porosity exceeds 75%. The average groundmass porosity ranges between 50 and 60%. Unlike most aplites, the texture of this sanidine aplite is hypidiomorphic- to panidiomorphic-granular.

Pegmatite grain sizes range from about 1 mm (transitional with the associated aplites) to about 1 m. Individual crystals measuring 0.95 mm have been mapped. Monomineralic masses, comprising several intergrown individuals, in places measure 1.7 m across. The average grain size is between 1 and 5 cm. Sanidine and quartz are about equally abundant, but proportions range widely in outcrops that cut different parts of zoned pegmatite masses. Together, they comprise more than 95% of most pegmatite masses. Accessory albite, biotite, magnetite, and ilmenite with trace sphene, apatite, and zircon are also present, but generally as finer-grained constituents in the aplitic facies of these masses. The rare patchy groundmass in the pegmatites is identical to that in the aplite. It is often miarolitic (e.g., Fig. 4D), in places frothlike, and sperulitically devitrified. The average porosity commonly

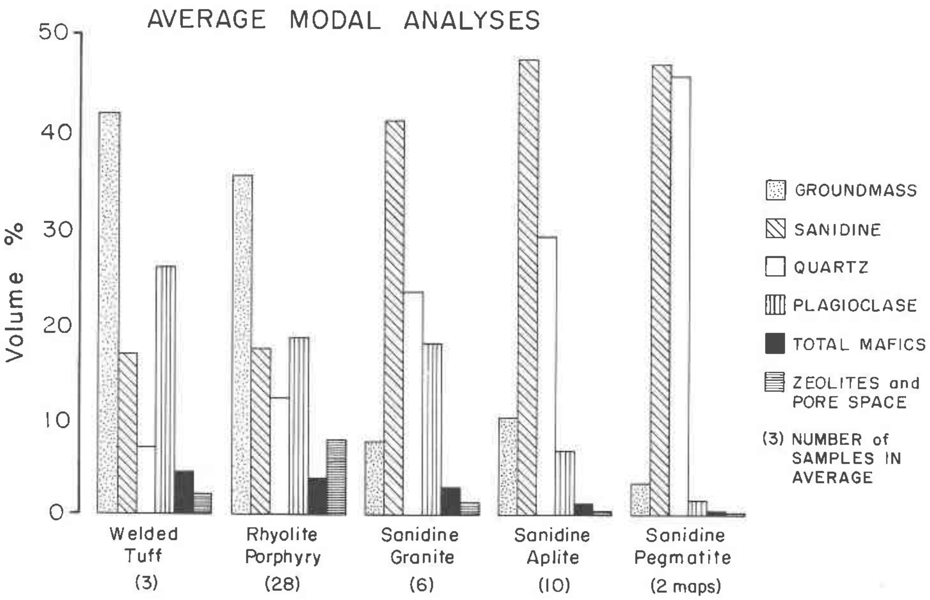

Fig. 7. Differing relative modal abundances define the five major rock types in the Rabb Park suite. Data for the textural series of welded tuff (lower-middle Kneeling Nun Tuff) through sanidine aplite are average point-counting modes (number of samples shown in parentheses). Comparable pegmatite data are drawn from planimetered analysis of 1:12 maps of the two largest pegmatites.

exceeds 60%. Abundant secondary heulandite lines or fills most of these cavities.

Rabb Park moonstone specimens are well known to mineral collectors because of their gem-quality blue schiller, but could never be profitably mined because of widespread fracturing that has broken most of the pegmatite crystals into pieces less than 1 cm in maximum size. These fractures are commonly conchoidal, even in easily cleaved sanidine. They terminate or branch at crystal boundaries. A few are filled with groundmass or heulandite, but most are hairline cracks that lack any visible filling. In places, fracture density within single crystals varies systematically such that regularly spaced zones of intense shattering are separated by concentric domains of less fractured material. These bands define growth zones at a spectacularly coarse scale of several centimeters each in some of the meter-scale quartz euhedra (e.g., Fig. 6). Nested quartz hexagons are separated from one another by 5–10-mm-thick zones of intense shattering and more rarely, thin selvages of pumiceous glass. Subsequent growth bands of less-shattered quartz are individually 8–10 cm thick. Up to six such discrete fracturing episodes are preserved in the largest crystals. They are thought to record episodic thermal shocks to the growing crystals, probably caused by periodic venting, adiabatic decompressions, and rapid temperature changes in the throat of this subvolcanic system.

Petrographic comparison. Over 340 samples were used to characterize the five Rabb Park rock types (porphyry, granite, aplite, pegmatite, and adjacent Kneeling Nun Tuff). About 150 were studied in thin section and 49 were point-counted to provide the modal data plotted in Figure 7. These rocks constitute a continuous series from tuff to pegmatite that is defined by increasing average grain size, decreasing abundance of groundmass, increasing sanidine/plagioclase ratio, and increasing quartz/total feldspar ratio. Additional significant contrasts among these rock types include the relative percentages of crystal fragments (highest in the tuff), the amount of crystalline intergrowth (highest in the pegmatites), and the coarseness and nature of devitrification and vesicular porosity in the groundmasses.

In addition to the gradational petrographic changes that link these texturally heterogeneous rock types, they share a common mineral assemblage including accessory and trace constituents. The compositional similarity among these phases will be explored in the following section and then incorporated into a cogenetic model that emphasizes the essential consanguinity of these rocks, rather than their differences.

Geochemistry

Twenty-six representative samples, spanning the entire textural range within the Rabb Park suite, were analyzed using an ARL-EMX electron microprobe in order to characterize individual mineral chemistry. Data were corrected for matrix effects using MAGIC IV (Colby, 1968). Over 750 analyses of sanidine, plagioclase, biotite, hornblende, clinopyroxene, magnetite, ilmenite, sphene, heulandite, and groundmass were compiled.

The minor phases and groundmasses of the Rabb Park suite are essentially compositionally invariant, as indicated by the small standard deviations in Table 1. Systematic variation occurs only within the feldspar group. Nearly 400 feldspar analyses were used to construct the averages shown in Figure 8. They grade from $Ab_{69}An_{27}Or_{04}$

Table 1. Average chemical compositions of Rabb Park minor phases and groundmasses

	SiO_2	Al_2O_3	MgO	FeO	TiO_2	CaO	Na_2O	K_2O	Anhydrous Total
Biotite (23)*	39.54	12.56	15.12	15.13	3.22	0.28	0.23	8.85	95.47
$Ann_{36}Phl_{64}$	(1.17)	(0.50)	(1.19)	(1.84)	(0.53)	(0.12)	(0.07)	(0.51)	(2.15)
Hornblende (19)	47.62	6.64	14.32	13.41	1.31	11.16	1.60	0.73	96.36
	(0.41)	(0.34)	(0.24)	(0.24)	(0.16)	(0.11)	(0.21)	(0.06)	(0.56)
Clinopyroxene (13)	53.29	0.89	13.93	9.86	0.15	21.10	0.57	0.06	99.84
$Wo_{44}En_{40}Fs_{16}$	(0.09)	(0.06)	(0.12)	(0.07)	(0.03)	(0.14)	(0.02)	(0.00)	(0.25)
				Total Fe as Fe_2O_3					
Magnetite (9)	0.60	0.93	0.68	92.29	5.13	0.09	0.03	0.12	99.87
	(0.64)	(0.05)	(0.10)	(2.91)	(1.31)	(0.03)	(0.03)	(0.05)	(2.03)
Ilmenite (1)	0.16	0.19	1.72	45.33	50.10	0.04	0.00	0.11	97.56
Heulandite (46)	63.62	14.49	1.46	0.05	0.00	4.86	0.06	0.91	85.29
	(1.05)	(0.48)	(0.13)	(0.10)	(0.00)	(0.29)	(0.09)	(0.22)	(1.13)
									D.I.***
Groundmasses									
Welded Tuff** (18)	75.24	13.34	0.27	0.83	0.01	1.41	3.27	5.63	92.67
	(1.91)	(1.16)	(0.16)	(0.30)	(0.01)	(0.54)	(0.37)	(0.72)	
Rhyolite Porphyry (70)	76.19	12.42	0.26	0.80	0.07	0.95	2.58	6.54	94.51
	(2.38)	(1.64)	(0.13)	(0.35)	(0.04)	(0.51)	(0.33)	(0.44)	
Sanidine Granite (40)	73.24	15.78	0.88	0.73	0.02	0.97	2.12	6.58	89.18
	(4.11)	(1.76)	(0.55)	(0.75)	(0.01)	(0.68)	(0.67)	(1.67)	
Sanidine Aplite (33)	73.37	14.57	0.60	0.87	0.02	0.64	2.97	6.95	94.84
	(3.99)	(2.17)	(0.92)	(0.99)	(0.01)	(0.63)	(0.45)	(1.12)	
Sanidine Pegmatite (24)	73.12	13.70	0.48	1.47	0.09	0.63	2.59	7.69	94.11
	(0.74)	(0.66)	(0.30)	(1.27)	(0.05)	(0.23)	(0.09)	(0.78)	

*Number of analyses
**Kneeling Nun Tuff samples from adjacent to Rabb Park Complex.
***Differentiation Index from CIPW norm.

and $Or_{65}Ab_{33}An_{02}$ in the welded tuff to $Ab_{82}An_{12}Or_{06}$ and $Or_{55}Ab_{43}An_{02}$ in the pegmatites. Plagioclase crystals are normally zoned over a range of about 10–15% An. Individual sanidine crystals are unzoned or only slightly zoned, generally becoming a few percent more potassic toward their rims. The alkali feldspars are all cryptoperthitic with a quenched high structural state that is strained according to Stewart and Wright (1974). Thirteen analyses of sanidine cell dimensions are all similar to within ±0.02 Å (O'Brient, 1980). Keefer and Brown (1978) have described an exacting study of the crystal structures and compositions of coexisting, partially coherent phases from one such Rabb Park pegmatite sanidine. They concluded that the coexisting lamallae (Or_{65} and Or_{22}) did not lie on the equilibrium solvus, but best fit a compositionally more restricted chemical spinodal at 465° ± 20°C, indicating that cooling was sufficiently rapid to prohibit further diffusion and recrystallization. This is further evidence for rapid cooling within the otherwise poorly documented interval between magmatic and zeolite-stable temperatures within this shallow intrusive complex.

Whole-rock chemistry is summarized in Table 2. Ranges of individual element analyses are listed for the Kneeling Nun Tuff because of its reported compositional range due to vertical zoning (Giles, 1967). Only samples of known stratigraphic position have been used in this compilation (21 from Giles, 1967, and 11 from Bornhorst, 1980). The other analyses are electron-microprobe analyses of experimental glasses produced from petrographically defined average rhyolite porphyry and sanidine granite samples and from a completely quarried small pegmatite mass, because the composition of this facies cannot be adequately approximated by a single hand sample. These glasses were produced in sealed gold capsules as described in the footnote to Table 2. Microprobe analyses indicated that they were extremely homogeneous even for notably troublesome elements such as sodium. The anhydrous totals are very close to the predicted values of 97.5% (based on a 2.5% H_2O solubility in these melts at these conditions).

The Rabb Park granite, porphyry, and pegmatite are compositionally similar. As might be expected, the pegmatite is markedly poorer than the granite or porphyry in Mg, Fe, Ti, and Ca, resembling instead the groundmass compositions of these facies (cf. with Table 1). The pegmatite appears to be a coarsely crystallized equivalent of the residual liquids derived during crystallization of each of the Rabb Park rock types.

Compositionally, the Rabb Park system appears to correlate best with the transition from the basal to middle part of the zoned Kneeling Nun Tuff. Giles (1967) has demonstrated marked zoning (particularly in the basal 70 m) in the outflow sheet some 20 km southwest of Rabb Park, but the stratigraphic details within the caldera-facies tuffs typical of the wall rocks enclosing the Rabb Park complex are less clear. It is certain that the Rabb Park compositions fall about in the middle of the published compositional range for the Kneeling Nun Tuff and do not correlate with either the high-silica rhyolite at the base or the more mafic latites reported from the upper portions (Giles, 1967; Elston et al., 1975).

Estimated conditions of crystallization

Field relationships, feldspar compositions, and experimental studies of three natural Rabb Park starting materials permit estimation of crystallization conditions. They

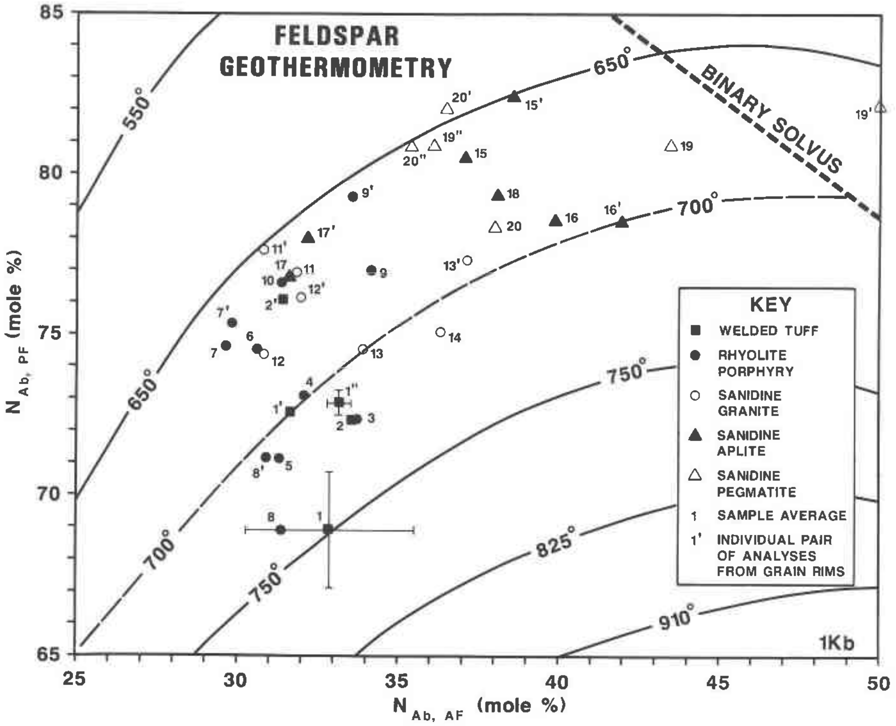

Fig. 8. The five major Rabb Park rock types yield similar temperature estimates of 650–750°C on a feldspar geothermometry plot. Approximate isotherms and location of binary solvus from Brown and Parsons (1981, Fig. 2). Numbered samples are average compositions for single thin section; primed sample numbers are individual pairs of analyses from rims of nearby grains within same sample. A set of representative error bars is shown for each.

indicate that major crystallization and emplacement occurred between 0.5 and 3 km. Pressures are unlikely to have exceeded 1 kbar. Vapor saturation probably occurred at only 2–3 wt% H_2O and well before the conclusion of crystallization. Final temperatures of crystallization before emplacement were likely in the 650–750°C range with rapid cooling (quenching) to below 300°C.

Depth of emplacement and confining pressure

The minimum emplacement depth of the Rabb Park complex is constrained by (1) its position within the lower 500 m of the "Cauldron facies" of the Kneeling Nun Tuff, whose local thickness has been estimated at about 1000 m (Seager et al., 1978); (2) its unconformable capping by 29.7 Ma tuffs some 4 m.y. after emplacement; and (3) the preservation of an open vesicular texture within the porphyry groundmass, which would have collapsed during cooling if covered by more than a few hundred meters of overlying rock. A minimum emplacement depth of 0.5 to 1.0 km and a confining pressure of a few hundred bars are considered reasonable.

An independent estimate of pressure can be generated by plotting the pegmatite whole-rock composition on a normative Ab-Or-Q plot and noting that it falls just on the low-pressure side of the vapor-saturated 1.0 kbar cotectic (Fig. 9). Assuming that this pegmatite liquid was generated by vapor saturation (Jahns and Burnham, 1969) from a granite crystallizing on the cotectic boundary, its composition suggests that this critical stage of crystallization was reached at a pressure of 1 kbar or less. This suggests an upper boundary of 1 kbar or approximately 3 km, establishing a range for major crystallization and emplacement of between 0.5 and 3.0 km. Corresponding pressures would have ranged between 150 and 1000 bars.

Temperature

Feldspar compositions plotted in Figure 8 define a geothermometry plot (Brown and Parsons, 1981; Stormer and Whitney, 1985). The average compositions plot in a band between 750 and 650°C. The welded tuff appears to plot at slightly higher temperature than the other textural facies. Individual analyses from rims of sanidine-plagioclase pairs are consistently 10–50° lower than the average composition for individual samples, suggesting that feldspar cores have not re-equilibrated and preserve an earlier, hotter record of magmatic history.

A second temperature estimate can be calculated from the oxygen isotopes measured by Taylor and Friedrichsen (1983) for coexisting quartz ($\delta^{18}O = +7.1$) and sanidine ($\delta^{18}O = +6.0$) from a Rabb Park pegmatite sample. These are typical values for silicic magmas, but are the lightest such isotopes reported by these authors from a worldwide suite of pegmatites and, unlike most plutonic rocks, are unique in that they have retained their magmatic isotopic signature (Taylor, pers. comm.). Oxygen isotopes fractionate between sanidine and quartz as a function of tem-

Table 2. Whole-rock chemical and normative compositions of Kneeling Nun Tuff, rhyolite porphyry, sanidine granite, and sanidine pegmatite

	Kneeling Nun Tuff*			Sanidine**	Rhyolite**	Sanidine**
	Top	Middle	Bottom	Granite	Porphyry	Pegmatite
CHEMICAL COMPOSITION						
SiO_2	65-78	66-76	71-77	72.92	72.11	75.53
Al_2O_3	13-17	12.5-15.5	12-15.5	13.82	14.13	12.75
MgO	1	1-1.0	1	0.56	0.43	0.20
Fe_2O_3	1.27-2.42	1.72-3.43	0.99-2.29	1.35	1.25	0.36
TiO_2	0.16-0.44	0.26-0.66	0.14-0.42	0.25	0.26	0.10
CaO	0.82-3.33	0.93-2.55	0.37-1.59	1.52	1.07	0.44
Na_2O	2.75-4.51	2.85-4.34	1.62-3.96	2.82	3.44	2.78
K_2O	4.15-4.76	3.60-6.35	4.39-7.63	4.55	4.96	5.66
Total	98.74-100.49	97.13-100.52	96.53-100.37	97.79	97.68	97.82
NORMATIVE COMPOSITION						
Quartz	23.13-39.51	18.73-32.69	29.56-32.91	36.11	30.76	37.37
Corundum	0.61-2.36	N/A	N/A - 9.46	1.63	1.12	1.33
Orthoclase	25.16-26.63	21.95-25.44	27.14-34.68	27.28	30.06	33.96
Albite	24.90-37.69	31.71-40.22	28.57-30.60	24.12	29.89	24.12
Anorthite	4.10-9.84	5.75-12.57	N/A - 3.98	7.79	5.56	2.23
Hypersthene	N/A	N/A	N/A	1.41	1.10	0.50
Hematite	N/A	N/A	N/A	1.38	1.31	0.37
Rutile	N/A	N/A	N/A	0.26	0.27	0.10
Differentiation Index:	73.19-91.04	80.90-89.84	88.62-94.84	87.51	90.71	95.45

(all values expressed in weight %)

*Range of values reported by Giles (1967) and Bornhorst (1980) from samples with reported stratigraphic position.

**Microprobe analyses of experimental glasses prepared in sealed capsules with initial water contents of 4%. At supra-liquidus run conditions of 1050°C and 1 Kb, approximately 2.5% wt % water can be dissolved in these melts, implying that anhydrous totals should be about 97.5%. These run products (after 6 days) were holohyaline, homogeneous, and vapor-saturated.

perature as demonstrated experimentally by several workers with differing curves (e.g., Blattner, 1975, and Friedman and O'Neill, 1977). Using the experimental curves of Friedman and O'Neill (1977, Fig. 24), the Rabb Park quartz-sanidine pair yields an estimated temperature of 670°C, in good agreement with the feldspar temperatures in Figure 8.

Experimental studies

The major stability fields for crystallization from natural porphyry, granite, and pegmatite starting materials were experimentally determined in a series of 1-kbar sealed-capsule experiments at the Tuttle-Jahns Laboratory at Stanford (O'Brient, 1980). The results, summarized in Figure 10, illustrate that these three melts, if subjected to similar conditions, would have produced nearly identical assemblages.

These "pseudo-binary" projections indicate that vapor saturation would have occurred in all three melts with at most 2–3% H_2O. If rapidly cooled or depressurized while still partly liquid, this could have occurred at yet lower values. In all three cases, the vapor-saturated liquidus is bracketed between 900 and 950°C and the solidus between 700 and 725°C, although they are not precisely identical. Slight differences among these diagrams can also be seen in the slope of the vapor-saturation surface above the liquidus. The solidus estimates also provide a third and independent check on the temperature estimates of the preceding section.

Crystallization temperatures in all three melts probably ranged from over 950 to nearly 700°C. Vapor saturation

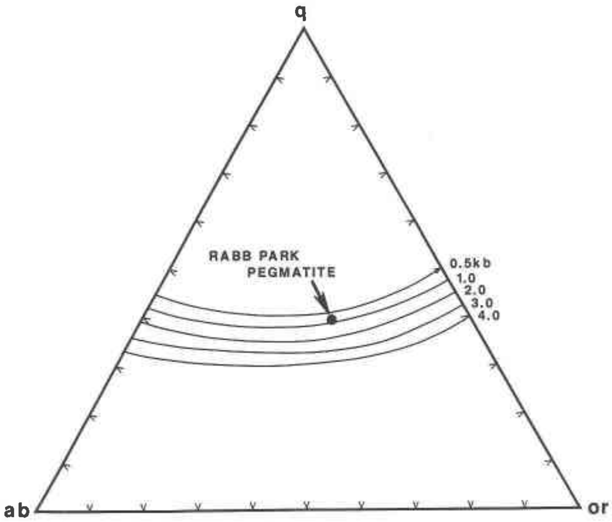

Fig. 9. Normative Ab-Or-Q projection of Rabb Park pegmatite (whole-rock composition) falls below 1.0-kbar curve. Solid curves with designated pressures are cotectic boundaries for vapor-saturated haplogranite system (Tuttle and Bowen, 1958).

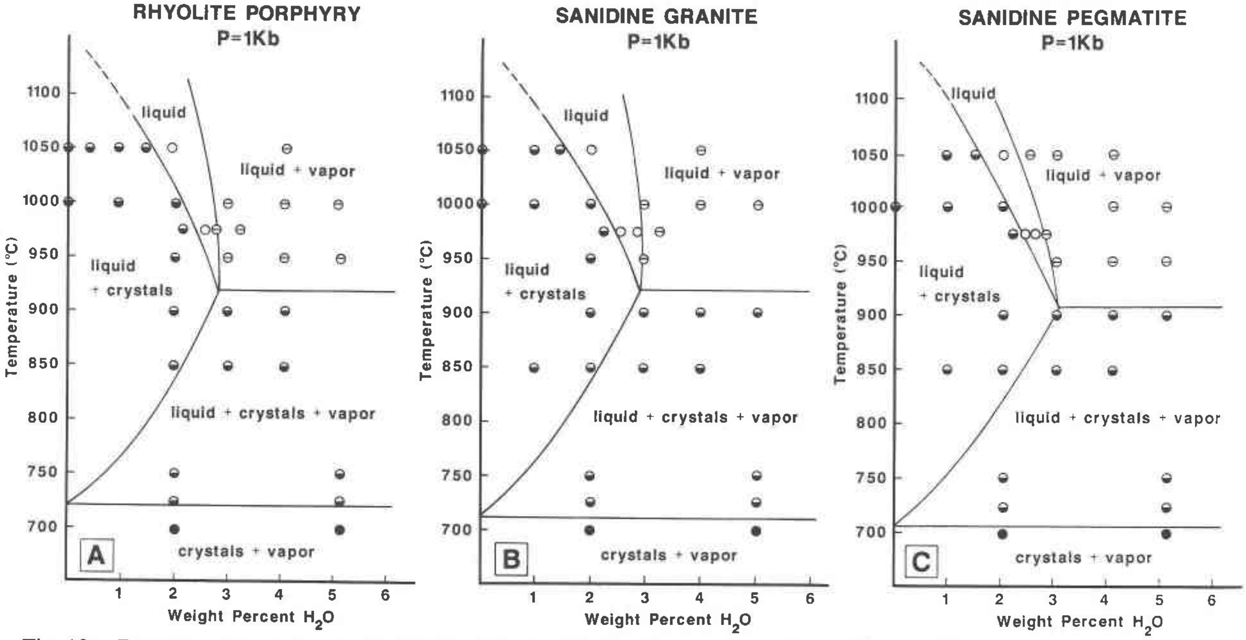

Fig. 10. Experimentally determined stability fields for (A) rhyolite porphyry, (B) sanidine granite, and (C) sanidine pegmatite are very similar at 1-kbar total confining pressure. In these "pseudo-binary" projections of temperature vs. percent H_2O added to the anhydrous natural starting materials, the vapor-saturated liquidus is between 900 and 950° and the solidus between 700 and 725°. Stability fields for phase assemblages are individually labeled.

is likely to have occurred long before 100% crystallization because even if initial water concentration was 1% or less, only 50% crystallization would be required to drive the residual liquid to the vapor-saturation surface. These melts saturated early and at relatively high temperatures. In this regard, it is notable that the initial pegmatite liquid may have separated above 900°C, some 200–300°C higher than

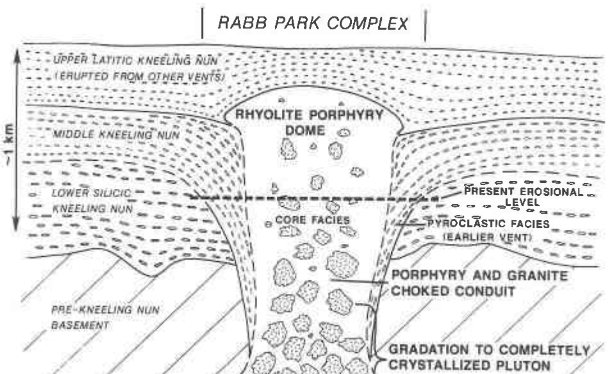

Fig. 11. Schematic model for Rabb Park complex portrays this intrusive as a porphyry lava- and granite-choked feeder to a dome that fills a lower/middle Kneeling Nun vent. Younger, more mafic parts of the Kneeling Nun Tuff erupted from other vents blanket this dome and vent complex. This volcanic throat contains scattered granite clasts in its upper portions, but grades rapidly downward into completely crystalline granite within the top of the underlying batholith.

is typically reported for deeper-seated pegmatites (Jahns, 1955; Jahns and Burnham, 1969).

Discussion

Textural facies

Quenching of the Rabb Park suite appears to have been rapid and everywhere effective. All major rock types, including the pegmatites, contain some groundmass. Sanidines are everywhere cryptoperthitic. The feldspars, even on their outermost rims, record temperatures above 650°C. These rocks record primary magmatic events and can be grouped into three major textural facies that preserve features from three different stages of crystallization within a hypabyssal magma. They are pyroclastic tuff (Kneeling Nun and the petrographically indistinguishable marginal porphyry facies), coarse porphyry (the core facies), and granite-aplite-pegmatite. Each was interrupted and quenched at a different stage in development. The depth, relative timing, and manner of aqueous-phase separation were key factors in determining each facies' textural genesis and preservation.

Evidence for consanguinity

The five major Rabb Park rock types are considered consanguineous for the following reasons:

1. Geologic and textural relations. Field relationships document a transition near the porphyry margin from pyroclastics identical with the surrounding Kneeling Nun Tuff to a nonfragmental coarsely porphyritic core. Included crystalline clots in the porphyry are petrologically indistinguishable from the larger coherent granite inclusions. A complete transition from welded tuff through porphyry to granite (and pegmatite/aplite) can be documented with fewer than ten samples. Such transitions are rarely abrupt in the field, but gradually occur over tens to hundreds of meters.

2. Age. K-Ar dating of sanidine separates from the five rock types yields statistically indistinguishable ages.

3. Mineralogy. A common suite of high-temperature cryptoperthitic sanidine, quartz, oligoclase, and quenched vesicular groundmass occurs in all five units. Moreover, minor phases including biotite, hornblende, clinopyroxene, magnetite, sphene, apatite, and zircon are identical in each unit and nearly compositionally invariant.

4. Composition. The compositional similarity of the major Rabb Park rock types and the enclosing stratigraphically intermediate Kneeling Nun Tuff is striking. This is true of both individual phases (Table 1) and whole-rock compositions (Table 2). These rock types are textural variants (facies) of a common low-silica rhyolite magma.

5. Experimental delineation. Experimental studies of the porphyry, pegmatite, and granite have shown that they have essentially identical liquidus, crystallization, and solidus relationships. The differentiation indices (Table 2), changing feldspar chemistry, and feldspar geothermometry are all consistent with a single suite of near-surface rocks representing different crystallized proportions of a single magma at the time of emplacement.

Evolution of the Rabb Park complex

The Rabb Park complex records a transition from an originally pyroclastic vent-filling phase related to the eruption of the surrounding Kneeling Nun Tuff to a pluglike intrusion of crystal-rich porphyry. This change appears to be gradational over several meters and nowhere are there crosscutting contacts between the marginal and core facies. It appears that a pyroclastic-choked conduit, probably no more than a few tens of meters across, was slowly spread apart and filled by the main pluglike porphyry mass.

The lithologic and compositional equivalence of the marginal porphyry facies and the adjacent lower to middle Kneeling Nun Tuff suggests that this ash-flow vent is related to eruptions of this portion of the tuff rather than to the high-silica rhyolite near the base or the overlying more mafic quartz latites (Giles, 1967; Elston, 1984). In fact, if the magma chamber feeding these eruptions was gravitationally and compositionally stratified, then the porphyry and other Rabb Park rocks must also be derived from this intermediate portion rather than some very late stage mafic fraction. The youngest Kneeling Nun tuffs, which range from latite to high-silica rhyolite, were probably erupted from a series of other vents tapping different portions of the nearly spent magma chamber. They may have blanketed the dome that is inferred to have once overlain the Rabb Park complex, as schematically shown in Figure 11.

The porphyry core facies contains about 45% groundmass, nearly half of which are pores expanded during ascent and emplacement. Prior to this slow vesicular inflation, the porphyry magma must have contained nearly 70% crystals and only 30% groundmass. This would have been a partially interlocking crystalline framework or, stated differently, an immature granitic fabric. Its vapor-saturated residual magma was of sufficient volume to dismember this developing plutonite into a porphyry, albeit one rich in coarse crystals and crystalline clots (the remnants of the developing granite).

The size and abundance of phenocrysts and the percentage of crystalline clots increase toward the center of the porphyry. If the core represents the youngest and deepest arrival in this telescoping intrusive complex, then it also comes closest to sampling the underlying intrusive mass. It is conceivable that a drill hole into the core of the Rabb Park complex would pass downward transitionally into a true granite constituting the roof of the batholith believed to underlie the Emory cauldron.

The fragments of granite scattered throughout the porphyry are probably samples of the upper portions of this batholith torn from the roof or upper walls of the crystallizing magma chamber. They represent a fraction of the magma that was somewhat more fully crystallized than the enclosing porphyry. These sanidine granite clasts, mechanically mixed into the ascending porphyry froth, were able to remain intact during ascent because they had already reached a stage of vapor-saturation and pegmatite formation prior to ascent. They contained only 10–20% groundmass (5–10% after removing vesicular porosity), and much of this was effectively isolated in small patches. Much of the excess water in the granite melt had already bled off in pegmatite residual liquids that were rapidly completing the crystallization of this part of the magma.

Locally within the granite, patches of aplite and pegmatite are typically more abundant than the residual groundmass itself. These, rather than the rarer, more spectacular large pegmatite accumulations, were the final resting place for most of the granite's residual fluids. This resulted in a seriate granite of very uneven grain size that survived essentially intact. If the granite had been rafted upward at a slightly earlier stage it would, like the porphyry, have likely been fragmented. The worldwide abundance of tuffs and porphyries suggest that conditions for their genesis and preservation are common. The lack of coarse-grained granites, aplites, and pegmatites from such hypabyssal terrains, however, suggests that preservation at this stage is far less likely. Fragmented remains of these hypabyssal granites are likely scattered throughout at least some crystal-rich tuffs and porphyries.

After emplacement within the volcanic throat at Rabb Park, cooling must have been rapid, as indicated by the cryptoperthites, cryptocrystalline groundmass, and miarolitic assemblage of abundant heulandite, minor smectite, and traces of calcite. This assemblage formed below 300°C and not during some period of slow cooling from magmatic conditions. The porous nature of the groundmass permitted rapid meteoric circulation in response to steep near-surface temperature gradients. Uniformly rapid cooling and widespread compositional buffering of the secondary mineral assemblage appear to have been the result.

Role of separating aqueous phase

The pyroclastic, porphyritic, and granitic facies record three fundamentally distinct styles of vapor separation, each triggered at a different stage of crystallization. The earliest, represented by the pyroclastic rocks, occurred after approximately 30–50% crystallization. Rapid vesiculation at a micrometer-scale throughout a large magma volume produced discrete pumice clasts, submillimeter shards, and a nearly complete disintegration of the magma resulting in catastrophic ash-flow eruption, tapping deep into the incompletely crystallized magma.

At a somewhat shallower level and at an intermediate stage of crystallization represented by the porphyry, crystallization of about 70% had produced a crystal-rich mush with abundant interstitial vapor-saturated residual melt. Buoyant rise of this mass into the volcanic throat permitted slow vesicular inflation and separation of the crystalline components into isolated clots and phenocrysts. The aqueous phase had sufficient time to collect in millimeter-scale vesicles to produce a frothlike, but generally coherent groundmass.

The granite, aplite, and pegmatite preserve the latest and nearly complete record of crystallization, approaching 90–95%. Initial pegmatite and aplite development, associated with the appearance of a separate aqueous phase, must have occurred substantially earlier as indicated by the experimentally determined low water contents (2–3%) and high temperatures (900°C) of the pegmatite melt. This probably occurred after 65–75% crystallization, not far different from the final record preserved in the porphyry. Unlike the porphyry, the granite managed to achieve substantial vapor saturation with attendant pegmatite development before ascent and quenching. At the estimated pressure of less than 1 kbar, escape of the evolving aqueous phase must have been a significant factor in controlling local temperatures and pressures during crystal growth. Building pressures, characteristic of pegmatite pocket development at depth, could not be long sustained at these shallow levels, and intermittent leaks were undoubtedly common. Episodic and rapid thermal fluctuations due to adiabatic cooling during such pressure drops may have contributed to the periodic fracturing recorded in the nested quartz euhedra within the largest pegmatites (e.g., Fig. 6). Moreover, the rapid and nearly complete separation of crystals and vapor assured the integrity of large granite fragments during subsequent rise within the buoyant porphyry.

Implications for plutonic development

The upward rafting of crystallizing plutonic rocks into the subvolcanic Rabb Park environment has preserved a unique textural reference state to which deeper, more extensively modified, plutonic rocks may be usefully compared. Primary magmatic textures at an advanced stage of hypabyssal crystallization are here preserved. Major subsolidus recrystallization, so common in deeper plutonic rocks, is lacking.

Some features such as preservation of cryptoperthitic alkali feldspars can be directly compared with analogous minerals in more typical plutonic rocks (Tuttle, 1952). Others, such as the quenched vesicular groundmass have no direct analogue in deeper rocks. Moreover, these Rabb Park textures do not precisely model early textural development in deeper rocks because they crystallized under pressures, water saturations, and temperatures more akin to volcanic systems than plutonic ones. Comparison to volcanic suites and experimental studies of textural development (e.g., Fenn and Luth, 1973; Swanson, 1977) clearly shows, however, that these are not volcanic but rather bridge the volcanic-plutonic gap.

The unusually broad seriate distribution of crystal size (0.1 mm to 100 cm) in the sanidine granite–aplite–pegmatite suite is markedly different from most granites, but characteristic of deeper-seated pegmatites (Jahns, 1955). This in part reflects the early vapor saturation of the sanidine granite and in part the probable equalization of grain size during subsolidus recrystallization of most granites. It appears unlikely that most equigranular, interpenetrating granitic fabrics were initially created in that form.

The characteristic idiomorphic or euhedral nature of the Rabb Park crystals, with or without interstitial groundmass, also serves to distinguish these rocks from their deeper analogues. These hypabyssal fabrics are not characterized by interpenetrating crystal growth and thus are notably weak and easily eroded to low, grus-blanketed outcrops. Recrystallization in deeper granites, particularly separation of subsolvus feldspars and continued coarsening of irregular quartz grains, results in a stronger fabric of interlocking subhedral to anhedral grains.

These euhedral crystals are not skeletal as in most experiments and many volcanic rocks, but well faceted. Even the smallest and presumably last-nucleated individuals are well formed. The interpenetrating dendrites and skeletal grains of experiments with artificially high undercoolings model only volcanic phenomena and may provide poor analogues to understanding plutonic textural evolution.

The clustering of minor mafic and accessory phases noted in many granite fabrics is also found in the Rabb Park granite. It appears to be a primary magmatic feature. Moreover, incomplete replacements of earlier stabilized augite and hornblende by biotite and magnetite are common, confirming that these are indeed magmatic reactions (i.e., Bowen's reaction series) and not primarily subsolidus phenomena.

The timing and extent of water saturation within the Rabb Park magma have been noted. Its significance for late-stage crystallization has been discussed by a number of authors (Burnham and Jahns, 1962; Luth and Tuttle, 1969), but most convincingly with regard to pegmatite genesis (Jahns and Burhnam, 1969). In most deeper systems, such saturation occurs after 90–95% crystallization at temperatures less than 700°C and at water concentrations of 5–10%. These residual liquids are generally confined to late dikes or small cupolas. In contrast, the hypabyssal Rabb Park system was probably only 65–75% crystallized, as much as 200°C hotter, and saturated at only 2–3% H_2O. Most significantly, in the hypabyssal environment these residual liquids would still comprise a third of the rock's volume and be evenly distributed. Widespread communication of these simultaneously saturating domains would result in huge available surface areas for scavenging of hyperfusible elements over a relatively brief interval of the total crystallization history. This period of late pluton development is probably not only responsible for the completion of primary crystallization and pegmatite generation, but also for generating certain classes of magmatic ore deposits and hydrothermal fluids (e.g., the Henderson, Colorado, molybdenum deposits as described by Shannon et al., 1982).

Summary and conclusions

Rabb Park represents a unique hypabyssal complex of intrusive rhyolite porphyry and included consanguineous, high-temperature, groundmass-bearing phaneritic rock types. This porphyry passes gradually inward from a marginal pyroclastic facies to a younger vesicular core facies that is choked with entrained granitic debris.

Five compositionally similar, but texturally diverse rock types, the Kneeling Nun Tuff, rhyolite porphyry, sanidine granite, sanidine aplite, and sanidine pemgatite compose the Rabb Park suite. They are considered consanguineous based on transitional petrographic character and similar K-Ar ages, mineralogy, composition, and experimental delineation of crystallization fields. They appear to be textural facies of a single silicic magma crystallized at shallow depth but arrested at different stages in their development.

Crystallization and emplacement appear to have occurred between 3.0 and 0.5 km. Pressures were likely less than 1 kbar. Vapor saturation likely occurred at only 2–3 wt% H_2O and while nearly a third of the magma was still uncrystallized. This resulted in (1) catastrophic eruption of the pyroclastic phases, (2) dismemberment and expansion of a frothlike rhyolite porphyry, and (3) widespread and early development of patchy aplite and pegmatite within the granite. These pegmatites are unusual in that they had low initial water contents (2–3% H_2O) and were initially at relatively high temperatures (900°C). Final crystallization temperatures for all facies were between 750 and 650°C with rapid cooling (quenching) to below 300°C after emplacement.

Primary magmatic textures at an advanced stage of hypabyssal crystallization are preserved in these rocks. Major subsolidus recrystallization, so common in deeper plutonic rocks, is lacking. These define a textural reference state that bridges the usual volcanic-plutonic gap and to which deeper-seated, more extensively modified plutonic rocks can be usefully compared.

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