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Preliminary geologic map of Sequoia and Kings Canyon National Parks, California

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This report and map are preliminary and have not been reviewed for conformity with U. S. Geological Survey editorial standards and stratigraphic nomenclature.

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Introduction

This report describes and provides background for the accompanying preliminary geologic map of Sequoia and Kings Canyon National Parks compiled on the special topographic map of the parks at a scale of 1:125,000. This geologic map of the parks is one-half the scale of the 12 published geological quadrangle maps (scale 1:62,500) that cover more than half of the the parks area. Therefore it was necessary to simplify cartographic detail and to portray a minimum number of lithologic units. All of the various Quaternary deposits have been combined to a single map unit, which includes not only stream and lake deposits, landslides and talus, but also glacial deposits. About a hundred individual granitic masses, many of which represent separate plutonic intrusions emplaced at various times, have been combined into four compositional types belonging to two general age groups. Metamorphosed volcanic rocks are shown as a single unit, and metamorphosed sedimentary rocks are combined into three units according to composition: schist, marble, and quartzite.

This open file map, and the explanatory text, is intended as a general assessment of the regional geology of the parks area, as a resource for planning further geologic research in the parks, and as a guide for the park interpretive staff in the geologic framework and geologic history of the parks. It is also an initial step in the preparation of a final map to accompany a popularized report on the geology of the parks.

Previous Work

The special map of Kings Canyon and Sequoia National Parks covers 12 complete 15-minute quadrangles and parts of 8 adjacent quadrangles (Fig. 1). No geologic work has been done in two of these twenty quadrangles in the southwest (Exeter and Dunlap) as part of this study. Colored geologic maps (scale 1:62,500) on modern topographic bases derived from aerial photographs have been published for 11 of the remaining 18 quadrangles: Huntington Lake (Bateman and Wones, 1972b), Blackcap Mountain (Bateman, 1965), Mount Goddard (Bateman and Moore, 1965), Big Pine (Bateman, 1965), Waucoba Mountain (Nelson, 1966), Marion Peak (Moore, 1978), Mt. Pinchot (Moore, 1963), Independence, (Ross, 1965), Triple Divide Peak (Moore and Sisson, 1987), Mt. Whitney (Moore, 1981), and Kern Peak (Moore and Sisson, 1985). A 12th quadrangle, Olancha, (duBray and Moore, 1985) is available as an uncolored geologic map.

For the 6 remaining quadrangles previous geologic studies have been supplemented by our more recent field investigations. The Patterson Mountain quadrangle includes older geologic mapping by Krauskopf (1953) and Durrell (1940), and recent geologic mapping supporting a mineral resource assessment (Nokleberg and others, 1983). Geology of the Tehipite Dome quadrangle was first outlined by Krauskopf (1953), and more detailed maps were prepared as part of resource studies (Moore and Marks,1972; Nokleberg and others, 1983). Geologic mapping of the quadrangle was recently completed and is currently being compiled (Moore and Nokleberg, 1987, written communication). The geology of the Giant Forest quadrangle was largely mapped on early topographic bases by Durrell (1940) and Ross (1958); this work recently has been expanded and refined utilizing a modern topographic base (Sisson and Moore, 1984; Moore and Sisson, 1987, written communication). The part of the Kaweah quadrangle within Sequoia National Park was partly mapped by Ross (1958), and recently expanded by the authors. The part of the Lone Pine quadrangle that includes the eastern flank of the Sierra Nevada in the parks map area was mapped at the time that the Mount Whitney quadrangle (adjacent on the west) was studied (Moore, 1981). The Mineral King quadrangle has long been a focus of geologic study because of fossil-bearing metamorphic rocks in its north-central part;

the geology of this area is based on the mapping of Christensen (1963) and Busby-Spera (1983). The geology of the southern part of the Mineral King quadrangle south of the Sequoia National Park boundary is based on wilderness study geologic mapping of the Moses and Dennison Peak Roadless areas by M. G. Sawlan (written communication, 1987), and of the Golden Trout Wilderness by duBray and Dellinger (1981). The remainder of the quadrangle was mapped by the authors.

Quaternary volcanic rocks

Quaternary volcanic rocks occur in the map area (Plate 1) primarily along the east flank of the Sierra Nevada and in the Golden Trout Creek area in the central Kern Peak quadrangle. Although they occur slightly outside of the national parks, these young volcanic rocks represent an important phase in the geologic evolution of the area. Sizable alkali basaltic cinder cones and lava flows were produced from volcanic vents associated with some of the normal faults that define the east base of the Sierra Nevada, especially in the Big Pine and Mount Pinchot quadrangles. West of the Poverty Hills in the southern Big Pine quadrangle is a young, only slightly eroded rhyolite plug dome. The basaltic lava flow in Sawmill Canyon appears to overlie one glacial moraine and is overlain by another. This flow has been dated by the K-Ar method as 53,000 $\pm$ 44,000 yrs (Dalrymple and others, 1982), and 119,000 $\pm$ 8,000 yrs (Gillespie and others, 1982). The apparently older Oak Creek basaltic lava flow has yielded a K-Ar age of 150,000 $\pm$ 130,000 yrs by Larsen (1979), and an apparently more reliable ^{40}Ar-^{39}Ar age of 1.2 million years (m. y.) by Gillespie and others (1982)

The volcanic field in Golden Trout Creek contains flows that issued from several cinder cones at different times. The oldest volcanic series has been dated by K-Ar at 743,000 $\pm$ 11,000 yr; the middle one at 176,000 $\pm$ 21,000 yr; and the youngest although undated, has not been glaciated and we estimate its age to be between 5,000 and 10,000 yr (Moore and Sisson, 1985).

Tertiary volcanic rocks

Numerous Tertiary lava-flow remnants, dikes, and volcanic necks, which intrude the dominantly granitic terrane, occur principally in the northern part of the parks area. One dacitic volcanic neck and associated lava flows occurs in the vicinity of the Middle Fork of the Kings River in the northern Marion Peak quadrangle. This volcanic neck is about 2 km in diameter and was emplaced 4.5 million years ago (Moore and Dodge, 1980). It is composed mainly of hornblende, biotite dacite containing about 63 percent SiO_2.

Most of the Tertiary volcanic rocks are alkalic basalt lava-flow remnants of small volume that are scattered throughout the upland areas. The basalt is generally rich in alkalies, particularly potassium, and the mineral leucite is present in the lava at several localities (Moore and Dodge, 1980). A flow remnant in the northwest corner of the Tehipite Dome quadrangle yielded an age of 3.4 $\pm$ 0.1 m. y. and one near Hume Lake, an age of 3.3 $\pm$ 0.1 m. y.(Larsen, 1979). The Tertiary basalt within the parks area is part of the San Joaquin-Kings volcanic field which produced alkalic basaltic intrusions and volcanism during the period 3.2-3.4 million years ago (Moore and Dodge, 1980).

Granitoid rocks

Granitic rock, broadly defined as holocrystalline, quartz-bearing plutonic rock, is by far the most common rock type underlying the parks area. The terms granitoid rock, or granitoids, are used synonymously with granitic rock. The various types of granitic rocks are generally defined by their modal mineral composition, that is the volume percent and proportions of the rock-forming minerals that comprise the specimen. The modal classification scheme utilized herein to subdivide the granitic rocks is that recommended by the International Union of Geological Sciences as shown in figure 3 (Streckeisen, 1973).

In many regions within the mapped area granitic masses have been extensively sampled, and these samples have been analyzed in the laboratory to determine their mineralogical and chemical composition. Reports detailing these analyses are available for 6 quadrangles: Huntington Lake (Bateman and Wones, 1972a), Blackcap Mountain (Bateman, 1965), Mount Goddard (Bateman and Moore, 1965), Big Pine (Bateman, 1965), Mount Pinchot (Moore, 1963), Mount Whitney (Moore, 1987). However, because of the large area underlain by granitic rocks, and the common variation in composition within an individual granitic pluton, intrusion, or mass, it is not practical to analyze either chemically or modally all of the collected samples, or even to collect a large enough sample set to define precisely the average compositions of all the various granitic masses.

However, analyzed samples, both in the parks area and in the partly overlapping Mariposa 1:250,000 map sheet to the north (Bateman and others, 1984), indicate that systematic relationships occur between color index (volume percent of the dark-colored or mafic minerals), specific gravity, and bulk chemical composition of the granitic rocks. The specific gravity and color index of analyzed samples show a systematic relationship with SiO_2 content (Fig. 2). Consequently, the general compositional aspects of a granitoid mass can be estimated from either specific gravity or color index. Specific gravity is routinely measured on all collected samples and color index can be estimated in the field by comparison with a reference collection of modally analyzed standards. Hence, by use not only of chemically analyzed samples, but also by the simple determination of specific gravity and color index, the <u>average</u> composition of individually-mapped granitoid masses can be estimated.

These estimated average compositions permit assignment of the mapped granitoid bodies into 4 general groups based primarily on color index: (1) <u>very dark-colored</u>, more than 25 percent dark minerals, (2) <u>dark-colored</u>, 15-25 percent dark minerals, (3) <u>medium-colored</u>, 6-15 percent dark minerals, and (4) <u>light-colored</u>, less than 6 percent dark minerals. Comparisons with analyzed samples and with the data plotted in figure 2 indicate that group (1) generally contains less than 60 percent SiO_2, group (2) contains 60-66 percent SiO_2, group (3) contains 66-71 percent SiO_2, and group (4) contains more than 71 percent SiO_2.

All of the various mapped intrusive masses (called plutons) have been assigned to one of these four compositional groups based on their estimated average composition. However, the contacts between individual masses are retained on the geologic map, so that they may be distinguished even where plutons of the same average composition are in contact.

Classification, according to the Streckeisen (1973) scheme (fig. 3), of a group of samples that have been both modally and chemically analyzed establishes how the four groups employed in this study compare with the named rock fields. The very dark-colored rocks (group 1) are generally confined to the quartz diorite, diorite and gabbro fields. The dark-colored granitic rocks (group 2) generally fall in the tonalite and granodiorite fields, with some in the quartz monzodiorite field. The medium-colored granitic rocks (group 3) are predominantly in the granodiorite field with a few in the granite field. The light-colored granitic rocks (group 4) are almost entirely restricted to the granite field.

Many of the individual granitoid masses that make up the Sierra Nevada batholith complex have been dated by radiometric methods (Evernden and Kistler, 1970; Stern and others, 1981, Chen and Moore, 1982). The more recent published geologic quadrangle maps, such as Mount Whitney, Kern Peak, and Triple Divide Peak give age data available for these areas. This work shows that the bulk of the batholith in the mapped area was emplaced and cooled during the middle part of the Cretaceous period from about 120-80 million years ago. The older Cretaceous plutons were, in general, intruded in the western region and granitoid emplacement migrated eastward at an average rate of about 2.7 mm/yr to culminate in the intrusion of the youngest and largest masses at the Sierra crest about 80-85 million years ago.

In addition to these voluminous Cretaceous granitic bodies, older granitoids were emplaced during the Triassic and Jurassic periods, chiefly in the eastern part of the mapped area. These plutons generally show more extensive shearing, jointing, and post-magmatic alteration than do the Cretaceous granitoids. In addition to radiometric dating, a hallmark of this older set of granitic plutons is that they are commonly cut by many north-northwest-trending mafic dikes. This regional dike set, called the Independence dike swarm (Moore and Hopson, 1961), has yielded a few late Jurassic radiometric ages of 148 million years (Chen and Moore, 1979).

Many of the granitoid masses within the mapped area have not been dated, but all have been assigned provisionally to one of two broad age catagories: Cretaceous or Jurassic-Triassic. These assignments are based on radiometric dating in the mapped area and adjacent areas, lithologic correlation of units, relative age relations at plutonic contacts, extent of pluton shearing and deformation, and presence or absence of mafic dikes apparently belonging to the Independence dike swarm. Doubtless further work will require some revision of these provisional age assignments.

Origin of the granitic rocks

The granitic rocks of the Sierra Nevada batholith are part of the circum-Pacific belt of Mesozoic igneous rocks formed as a result of movement and interaction of major plates that make up the lithosphere of the Earth. During the Mesozoic era the plate underlying the Pacific and carrying oceanic crust, impinged upon, and rode down beneath the plate to the east carrying continental crust including most of the North American continent (Hamilton, 1969). The actual mechanism by which granitic magmas were produced during this subduction process is a subject of research and debate. A few limits can be placed on the possible means of magma generation.

The granitic rocks cannot have been produced wholly through melting of the sinking slab of oceanic crust. The isotopic makeup of the element neodymium in Sierran intrusive rocks require the involvement of rocks or magmas that have had compositional characteristics unlike oceanic crust or altered oceanic crust for a long period (DePaolo, 1981).

The neodymium isotopic ratios in suites of Sierran intrusive rocks vary in harmony with changes in the isotopic composition of the element strontium (DePaolo, 1981) which itself shows strong regional trends across the Sierra Nevada batholith (Kistler and Peterman, 1973). These sympathetic and regional variations require the involvement of sources for the granitoids that had trace element abundances similar to old continental crust, and indicate a greater involvement of such sources for the eastern part of the batholith as compared to that for the western part.

The Mesozoic continental crust beneath which subduction occurred was on the west edge of the continental mass and thinned and merged westward with oceanic crust. Hence the rising subduction-generated magmas encountered increasingly thicker sections of more silica-rich crust toward the east apparently accounting for lateral changes in bulk composition of the granitic plutons across the Sierra Nevada. From west to east the dominant granitic rock type changes from quartz diorite to granodiorite (Moore, 1959), and K_2O increases systematically (Bateman and Dodge, 1970). The present mapping (Plate 1) shows that the dark-colored granitic rocks predominate in the western part of the map area and the medium-colored granitic rocks predominate in the eastern part of the map area including the crest of the Sierra. This relation is taken as evidence that the SiO_2 content of the granitic rocks systematically increases eastward.

Hot, mantle-derived basaltic magma is erupted at modern volcanic arcs above subduction zones. The darker colored rocks in the map area include gabbros and diorites derived from basaltic magmas and field relations show that basaltic magmas were present throughout the growth of the batholith (Sisson and Moore, 1984; Moore and Sisson, 1985; Moore and Sisson, 1987; Reid and others, 1983). The dark and medium-colored granitic rocks contain abundant dark-colored mafic inclusions, most of which have textures and chemical compositions similar to hydrous evolved basaltic magmas (Pabst, 1928; Reid and others, 1983; Frost and Mahood, 1987). Basaltic magmas were apparently widespread in the source regions for the Sierran granitic rocks and were commonly incorporated as magma blobs, disrupted dikes, or fragments of previously solidified rock before the granitic magmas ascended to high levels in the crust.

The preceding observations suggest that hot, primitive basalts were generated in the mantle by subduction of oceanic crust. These magmas rose, intruded the crust, and produced partial melting of old continental crust. Some of the liquids produced by partial melting rose unadulterated but most mixed and mingled with contaminated basaltic melts. These hybrid magmas ascended through the crust to shallow depths and there crystallized to form the medium- and dark-colored granitic plutons that make up the major part of the batholith.

The lighter-colored granitoids represent the lowest-temperature melting (and solidification) fraction of these magmas. They may in part contain greater amounts of crustally-derived liquids (Kistler and others, 1986) and may also be products of crystallization-differentiation of the more abundant magmas. In general, the light-colored granitoids form intrusive masses that are smaller than the darker-colored rocks, and are more commonly located adjacent to metamorphic masses (and to the older Jurassic-Triassic granitoid masses) than are the medium- and dark-colored granitoids (Plate 1). Being comparitively small, the light-colored bodies would have lost heat rapidly during ascent, and may have been incapable of rising to shallow depths and shouldering aside the country rocks to form large plutons. In addition they may form the silicic tops of plutons that are not eroded as deeply as the neighboring darker-colored, more silica-poor plutons. Therefore, they would more likely occur in places where metamorphic rock and older granitic rock roof materials have not been completely removed by erosion.

Metavolcanic rocks

Metavolcanic rocks that are chiefly Mezozoic in age are scattered widely in the mapped area (Plate 1) and form roof pendants of various sizes sandwiched between the younger granitic plutons. In general, these roof pendants define a north-northwest trending belt through the center of the parks area most of which has been termed the Goddard terrane by Nokleberg (1983). The largest metavolcanic pendant in the parks area is the Goddard pendant extending 100 km southeast through the Blackcap Mountain and Mount Goddard quadrangles into the Marion Peak quadrangle. The rocks in this pendant are primarily silicic volcanic tuffs, breccias, and lava flows, intruded by sills and subvolcanic plutons. Radiometric ages of these metavolcanic rocks range from Late Jurassic to Early Cretaceous (130-160 million years, Tobisch and others, 1986).

The Mineral King pendant, largely in the Mineral King quadrangle, is composed chiefly of silicic volcanic tuffs and volcanogenic marine sediments derived from the volcanic rocks. Fossils found in the pendant indicate a Late Triassic and Early Jurassic age (Saleeby and others, 1978), but radiometric dating indicates the presence of Cretaceous metavolcanic rocks (R. W. Kistler, J. B. Saleeby, written communication, 1987).

The Oak Creek metavolcanic pendant (Mount Pinchot quadrangle) includes dominantly silicic metavolcanic tuffs and breccias yielding Jurassic to middle Cretaceous radiometric dates (R. W. Kistler, J. B. Saleeby, written communication, 1987). The metavolcanic rocks of the Boyden Cave pendent (chiefly in the Tehipite Dome quadrangle) includes dominantly silicic metavolcanic tuffs, but is unique among dated metavolcanic pendants in that only middle Cretaceous radiometric ages have been obtained (R. W. Kistler and J. B. Saleeby, written communication, 1987).

The metavolcanic rocks overlap the plutonic rocks both in age and composition. They were apparently erupted from magma bodies that were rising through the crust. These magmas partly engulfed the overlying volcanic pile that may itself have been descending either by folding and faulting (Tobisch and others, 1986).

Metasedimentary rocks

Metamorphosed sedimentary rocks occur in the parks area as roof pendants surrounded and intruded by the much more abundant granitoid masses of the Sierra Nevada batholith. The metasedimentary roof pendants occur in two generally north-northwest trending belts on each side of the belt of pendants composed chiefly of silicic metavolcanic rocks. The Kings sequence (largely including the Kings terrane of Nokleberg, 1983) includes those metasedimentary masses on the west side of the metavolcanic zone. Included in this zone is the Boyden Cave pendant in the eastern Tehipite Dome quadrangle. Fossils from these rocks include ammonites of Early Jurassic age (Jones and Moore, 1973).

Most of the small metasedimentary masses on the east side of the zone of metavolcanic pendants have yielded no fossils. However, in the northeast part of the parks map (although outside of the national parks) early Paleozoic fossils have been recovered. Metasediments in the Big Pine pendant in the central Big Pine quadrangle are lithologically similar to lower Cambrian rocks in the White Mountains to the east, and also like the White Mountain Cambrian sequence contain trace fossils and archeocyathids (Moore and Foster, 1980). In addition Ordovician graptolites have been found in the eastern part of the Bishop Creek pendant in the northeast corner of the Mt. Goddard quadrangle (Moore and Foster, 1980).

The metasedimentary rocks on both the east and west sides of the central metavolcanic belt are composed chiefly of mica schist but include marble and quartzite. Paleozoic fossils have been found in metasedimentary rocks on the east side of the central metavolcanic belt, to the north of the map area (Rinehart and Ross, 1964; Nokleberg, 1983). Thus, it is likely that the eastern metasedimentary belt is Paleozoic in age, while the western is Mesozoic.

Conditions and timing of metamorphism

Studies of metamorphic minerals and distribution of rock types can provide some constraints on the evolution of the granitic and metamorphic rocks in the Sierra Nevada batholithic complex. The distribution of the three crystal forms of the compound Al_2SiO_5 (andalusite, sillimanite, and kyanite) is instructive. The mineral andalusite is widespread in the mica schists, and gives way to sillimanite near some large granitic masses. Kyanite is never found, indicating that the pressure during metamorphism was less than that of the aluminosilicate triple point (3.8 kilobars, Holdaway, 1971), or less than a depth of about 12 km. Establishment of limiting minimum pressures is based on geologic inference. The areas of individual granitic intrusions are comparable to the areas of volcanic calderas, and it is reasonable to infer that many granitic plutons are solidified magma chambers that fed overlying volcanic calderas systems that have subsequently been removed by erosion. Studies of Tertiary and younger calderas show that they have subsided 1-3 km during their formation (Lipman, 1984). If a caldera floor thickness of 1 km is assumed, then the depth to the top of post-caldera magma chambers is 2-4 km. Within this depth range one would expect to find exposed by erosion caldera floors with associated talus deposits, caldera fill, lake beds, as well as ring dikes, and the tops of cogenetic plutons. However, such features are generally lacking in the area of this study and we assume that erosion must have extended deeper than 4 km, equivalent to pressures exceeding 1 kilobar. Application of a hornblende geobarometer (Hammarstrom and Zen, 1986; Hollister and others, 1987) to rocks from the parks area produces pressures clustering near 2 kilobars, equivalent to about 7 km depth (Sisson, written comm., 1987).

Maximum temperature of metamorphism locally exceeded the solidi of metavolcanic and metasedimentary rocks, leading to the production of small areas of migmatite close to some of the larger granitic intrusions. For migmatitic metadacites this requires temperatures slightly in excess of 700^o C at 2 kilobars (Piwinskii, 1968). The regions of sillimanite-bearing rocks require temperatures slightly in excess of 600^o C at 2 kilobars (Holdaway, 1971), while the widespread andalusite-bearing rocks must have been cooler than this. The close association of migmatitic and sillimanite-bearing rocks with intrusive rocks clearly shows that the highest metamorphic temperatures were produced by intrusion of granitic magmas. Textures in metamorphic rocks show that high temperatures followed folding and cleavage development, or continued after these structures formed. Structures in migmatitic rocks, however, resulted from flattening and folding during partial melting. Regional low-grade metamorphism and folding may have predated introduction of the granitic rocks (Bateman and others, 1963; Nokleberg and Kistler, 1980), but much of the structure and metamorphism was produced by emplacement of the granitic bodies.

Structure

The metamorphic rocks characteristically possess steep relict layering and compositional banding paralleled by cleavage or schistosity. Folds visible on the scale of the map are rare or difficult to establish because of the lack of well-defined through-going stratigraphic sequences. Hand sample- and outcrop-scale folds are common and well-exposed in water-polished river bed outcrops. The small folds are of two types, isoclines and conjugate crenualtions. The isoclines have axes parallelling the local cleavage and compositional banding, whereas the conjugate crenulations deflect cleavage and banding from the local orientation. In a regional sense cleavage, layering, and fold axes trend north-northwest, concordant with the belts of metamorphic rocks described above. In detail, the structure of the metamorphic rocks may deviate strongly from this orientation either because of regional deformation events (Nokleberg and Kistler, 1980) or because of forcible emplacement of irregularly-shaped granitic plutons.

The granitic plutons themselves possess structure shown most clearly by the flattened shape and orientation of the abundant dark-colored mafic inclusions. These dark inclusions are disc-shaped and crudely alligned parallel to the walls of their host granitoid intrusions. The arrangement of the flattened mafic inclusions suggests that many granite intrusions form through inflation with fresh magma feeding into and expanding concurrently crystallizing magma chambers.

The older, sheared granitic masses (generally of Jurassic and Triassic age) are found adjacent to the various metamorphic pendants and possess schistosity oriented similar to that in the metamorphic rocks. Apparently these older intrusive rocks have been subject to many of the same deformation events as the metamorphic rocks. In some places, the older granitoid masses are essentially part of the metamorphic pendants and are closer in age to the metamorphic rocks than to the surrounding Cretaceous granitoid rock.

A major structural feature that post-dates the formation of the batholith is the great north-trending Kern Canyon fault (Moore and duBray, 1978; Moore and Sisson, 1985), which displays right-lateral displacement of about 13 km at the southern margin of the map and decreases to virtually no displacement 20 km north (Plate 1). This fault and its many branches have been inactive for a long period (at least 3.5 m. y) and show extensive erosion since the time of final displacement. In contrast, the complex fault zone on the east flank of the Sierra Nevada has undergone relatively recent vertical offset, and is an important element in the uplift and westward tilting of the range. Strands of this fault system have produced young scarps in alluvium, cut glacial moraines, and, locally have served as vents for lava that has built Quaternary basalt cones at the east base of the range. The base of the older Quaternary Oak Creek basaltic flows have been offset and uplifted several hundred meters on these range front faults.

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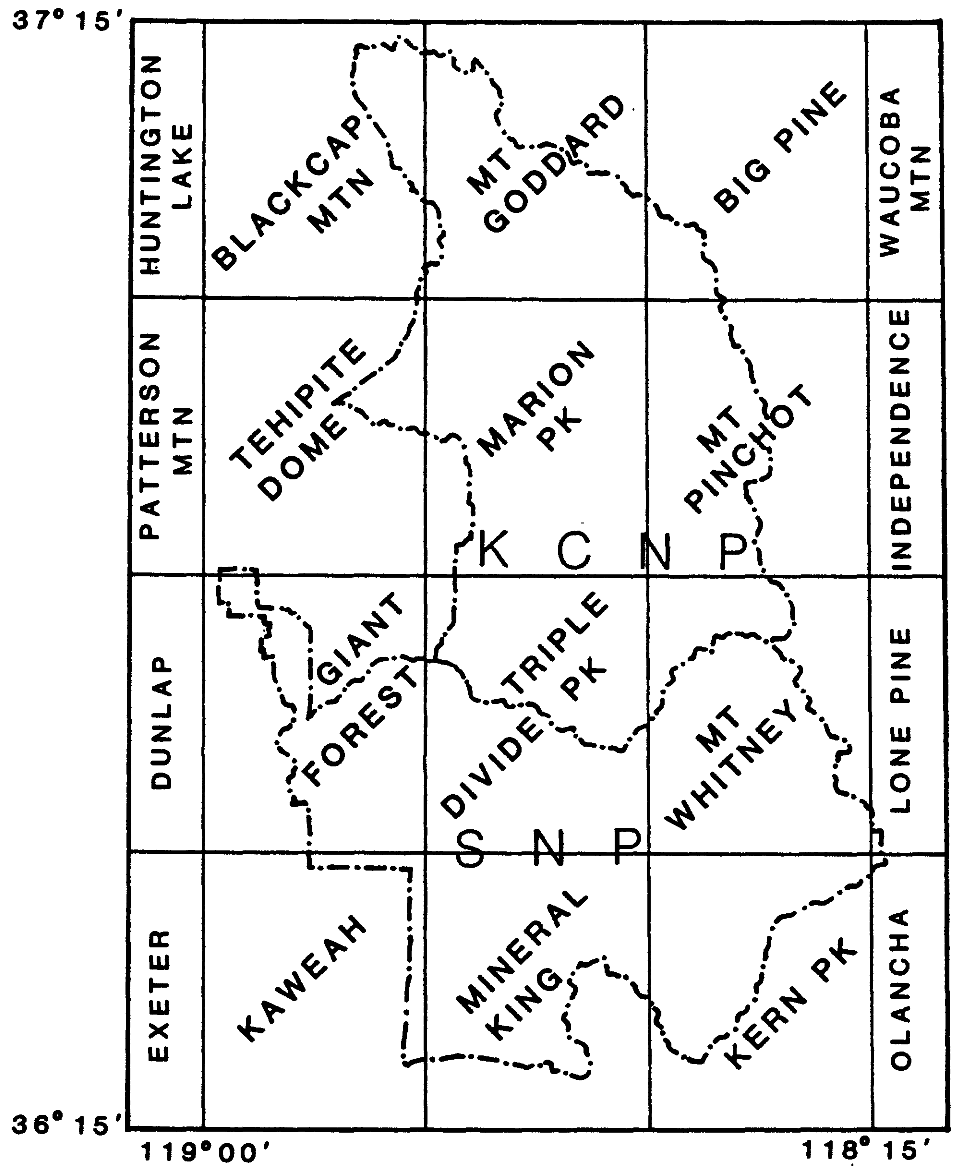
Illustrations

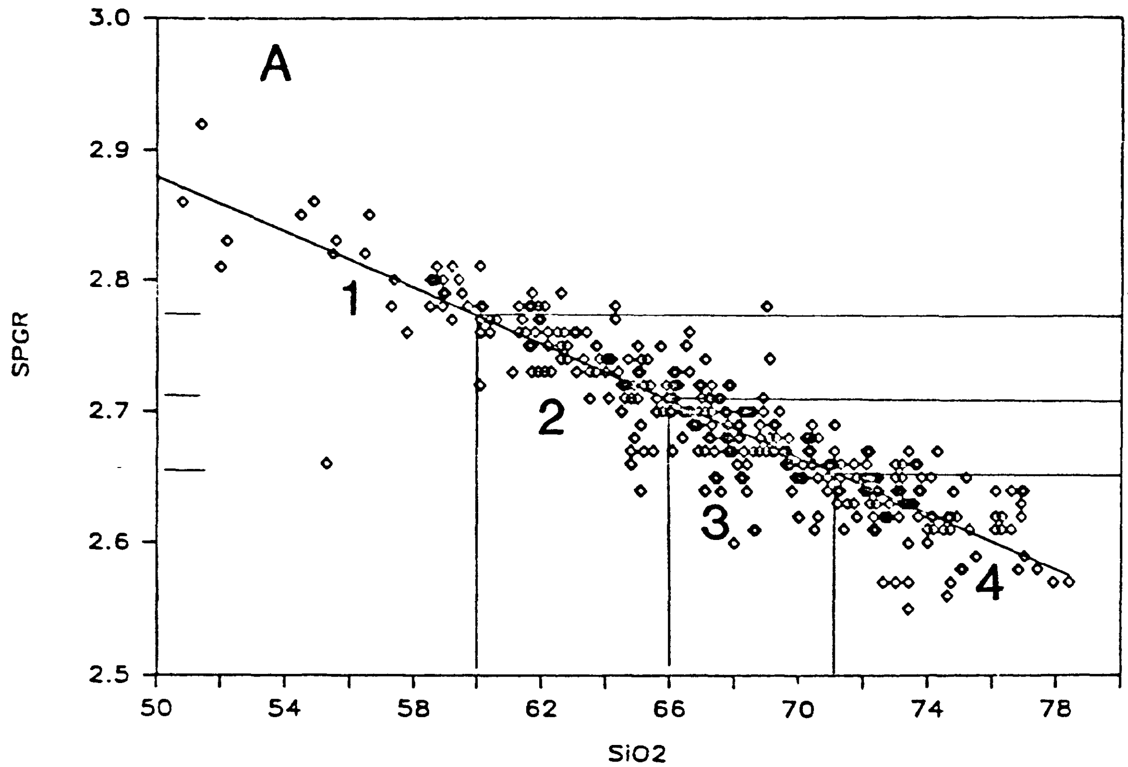
Plate 1. Preliminary geologic map of Sequoia and Kings Canyon National Parks, California

Figure 1. Index map of Sequoia (SNP) and Kings Canyon (KCNP) National Parks' showing the 15-minute topographic maps covering the parks area.

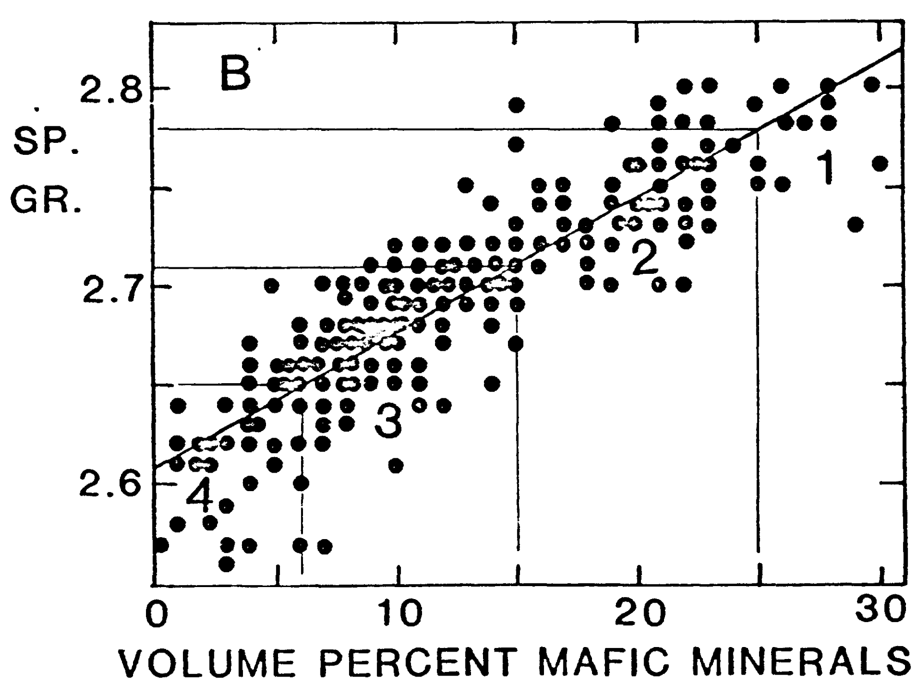
Figure 2. Relation of Specific Gravity to (A) SiO_2 content and (B) to volume percent of mafic (dark) minerals (color index) for granitic rocks from the central Sierra Nevada (after data from Bateman and others, 1984). The specific gravity and color index limits of the four groups of granitoids are indicated.

Figure 3. Relation of volume ratio of major minerals of granitic rocks to the four groups of mapped granitic rocks as defined by their analyzed SiO_2 content. Triangles, less than 66 % SiO_2 (dark-colored rocks); dots, 66-71 % SiO_2 (medium-colored rocks); circles, more than 71 % SiO_2 (light-colored rocks. Classification from Streckeisen, 1973. Data from analyzed rocks from the Mt. Whitney (Moore, 1987), Mt. Pinchot (Moore, 1963), Huntington Lake (Bateman and Wones, 1972a), Shaver Lake (Bateman and Lockwood, 1976), Kaiser Peak, (Bateman and Lockwood, 1970), and Mt. Abbot (Lockwood, 1975) quadrangles.

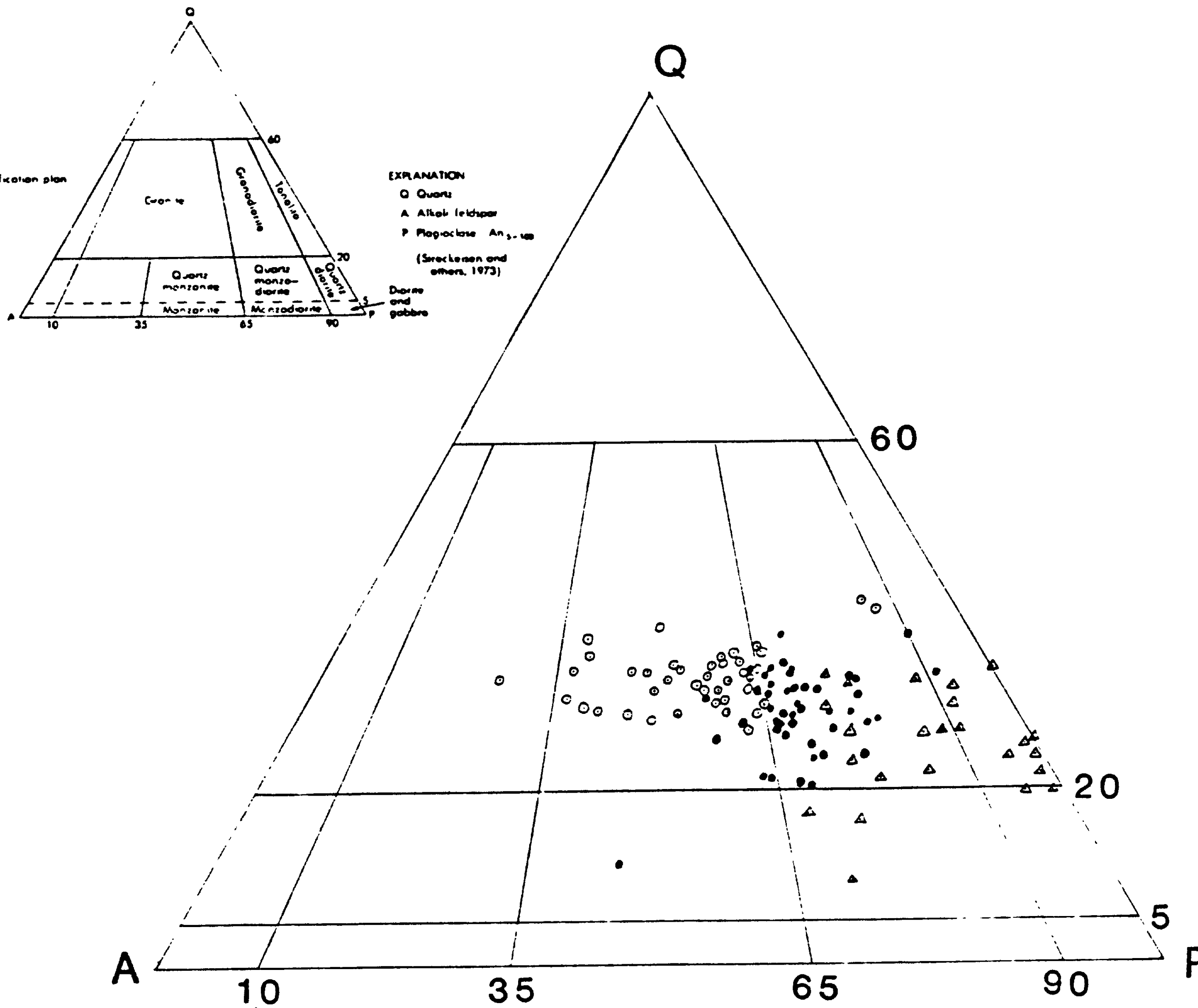

37° 15′
36° 15′
119°00′
118° 15′
HUNTINGTON LAKE
BLACKCAP MTN
MT GODDARD
BIG PINE
WAUCOBA MTN
PATTERSON MTN
TEHIPITE DOME
MARION PK
MT PINCHOT
INDEPENDENCE
K C N P
DUNLAP
GIANT FOREST
TRIPLE DIVIDE PK
MT WHITNEY
LONE PINE
S N P
EXETER
KAWEAH
MINERAL KING
KERN PK
OLANCHA



A
SPGR
SiO2
3.0
2.9
2.8
2.7
2.6
2.5
50
54
58
62
66
70
74
78
1
2
3
4



B
SP.
GR.
2.8
2.7
2.6
0
10
20
30
VOLUME PERCENT MAFIC MINERALS
1
2
3
4


Classification plan
Q
60
Granite
Granodiorite
Tonalite
20
Quartz monzonite
Quartz monzo-diorite
Quartz diorite
5
Monzonite
Monzodiorite
Diorite and gabbro
A
10
35
65
90
P
EXPLANATION
Q Quartz
A Alkali feldspar
P Plagioclase An_{5-100}
(Streckeisen and others, 1973)
Q
60
20
5
A
10
35
65
90
P