Triple Divide Peak Quadrangle, Fresno and Tulare Counties, California—Analytic Data

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Triple Divide Peak Quadrangle, Fresno and Tulare Counties, California—Analytic Data

By THOMAS W. SISSON

Modal and chemical analyses of granitic rocks of the Triple Divide Peak quadrangle, California

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Triple Divide Peak Quadrangle, Fresno and Tulare Counties, California—Analytic Data

By THOMAS W. SISSON

ABSTRACT

The Triple Divide Peak quadrangle encompasses 620 km^2 of the central Sierra Nevada, including the headwaters of the Kings, Kern, and Kaweah Rivers. Cretaceous granitic rocks make up most of the bedrock of the quadrangle. A total of 11 percent of the quadrangle is composed of rocks belonging to the Sequoia Intrusive Suite, 40 percent by rocks of the Mitchell Intrusive Suite, and 27 percent by rocks of the Mount Whitney Intrusive Suite.

The 80 modal and 42 chemical analyses in this report are of typical granitic rocks and indicate that the average plutonic rock in the quadrangle contains 66.5 wt. percent SiO_2 and 3.4 wt. percent K_2O, estimates similar to those for the Earth's upper continental crust. Fractionation modeling indicates that derivation of the average composition from the average mafic rock requires separation of 45-48 percent (by mass) of early-forming crystals. If accumulated together, these minerals would produce a cumulate body recognizable by geophysical methods. The evidence for such a body is lacking, and it is concluded that significant crustal fusion has accompanied crystal fractionation to produce the granitic rocks of the quadrangle. This report supplements the geologic quadrangle map by documenting analyses and sample locations.

INTRODUCTION

The Triple Divide Peak quadrangle encompasses about 620 km^2 of mountainous terrain of the central Sierra Nevada in Fresno and Tulare Counties, California. Elevations range from 975 m at the southwest corner of the quadrangle up to 4,196 m at the summit of Black Kaweah in the southeast corner. The quadrangle is named for Triple Divide Peak, which lies in the eastern part, and separates the headwaters of the Kern, Kaweah, and southern Kings Rivers (fig. 1). The quadrangle also contains the Great Western Divide, a chain of high peaks lying well to the west of the Sierran crest, separating the south-flowing Kern from the west-flowing Kaweah River. The quadrangle lies within Kings Canyon and Sequoia National Parks, except for a small area in the northwestern corner within Sequoia National Forest.

Granitic rocks of the Sierra Nevada batholith comprise more than 98 percent of the quadrangle. This report supplements the geologic map of the Triple Divide Peak quadrangle (Moore and Sisson, 1987a), by providing modal and chemical analyses of granitic rock samples.

GENERAL GEOLOGY

The oldest rocks of the quadrangle (fig. 2) are metamorphosed sedimentary and volcanic rocks. Both are

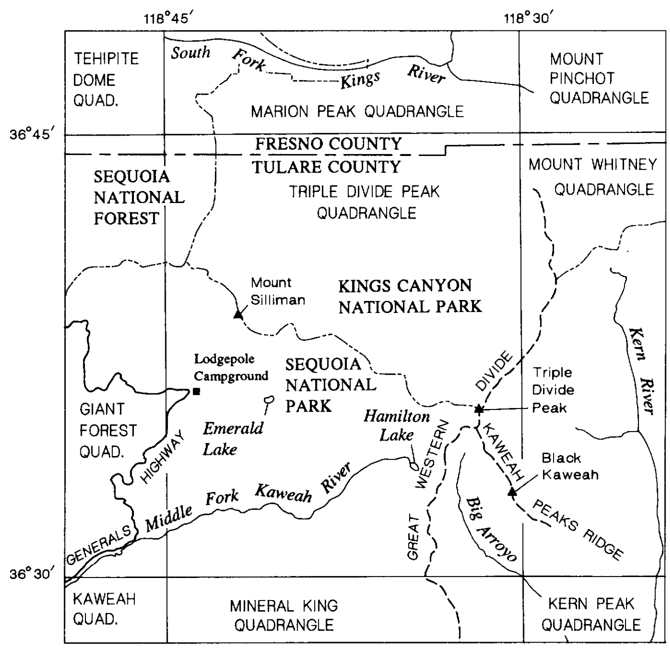

Figure 1. Index map showing location of Triple Divide Peak and other quadrangles cited in report.

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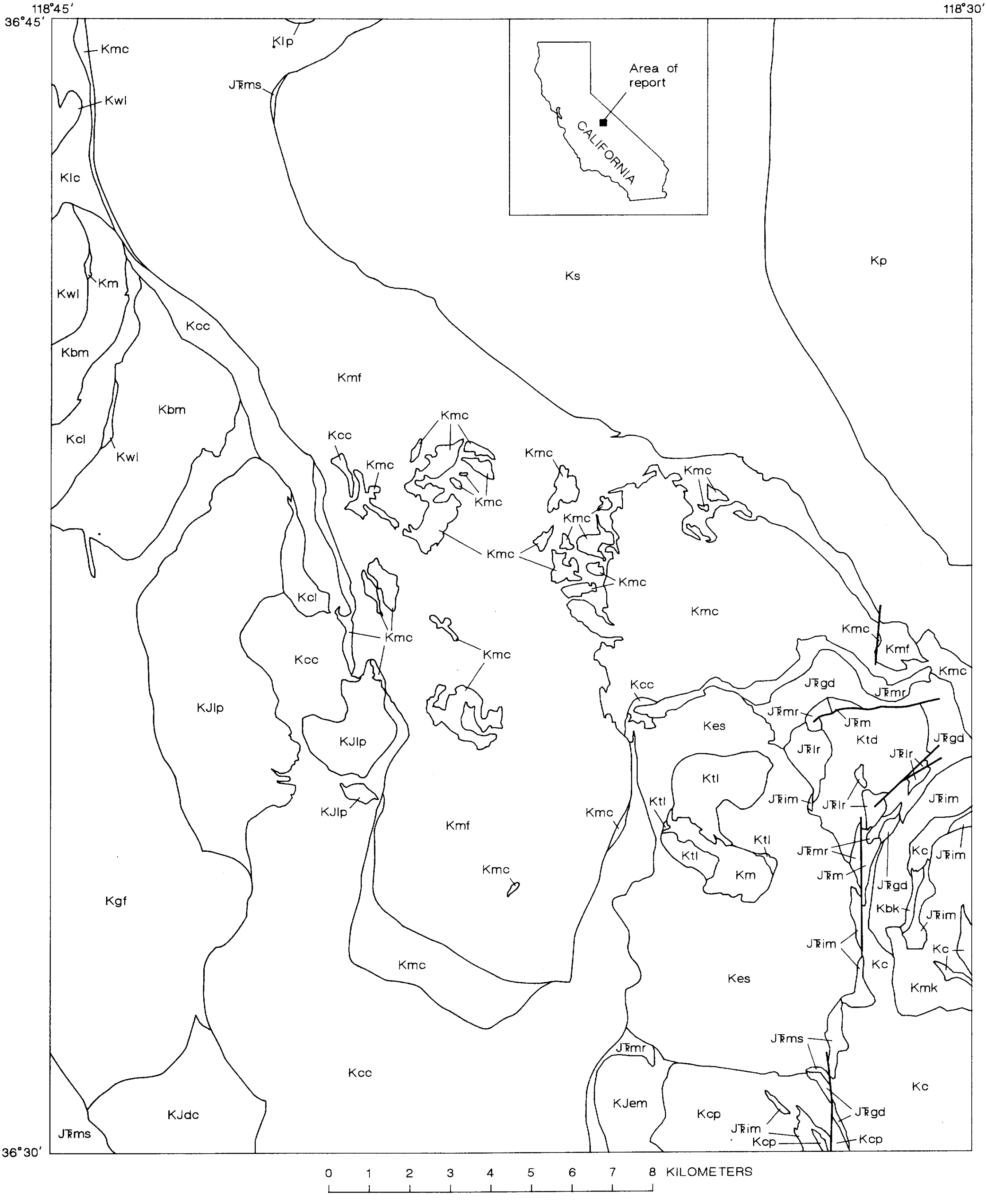

Figure 2. Generalized geologic map of the Triple Divide Peak quadrangle (modified from Moore and Sisson, 1987a).

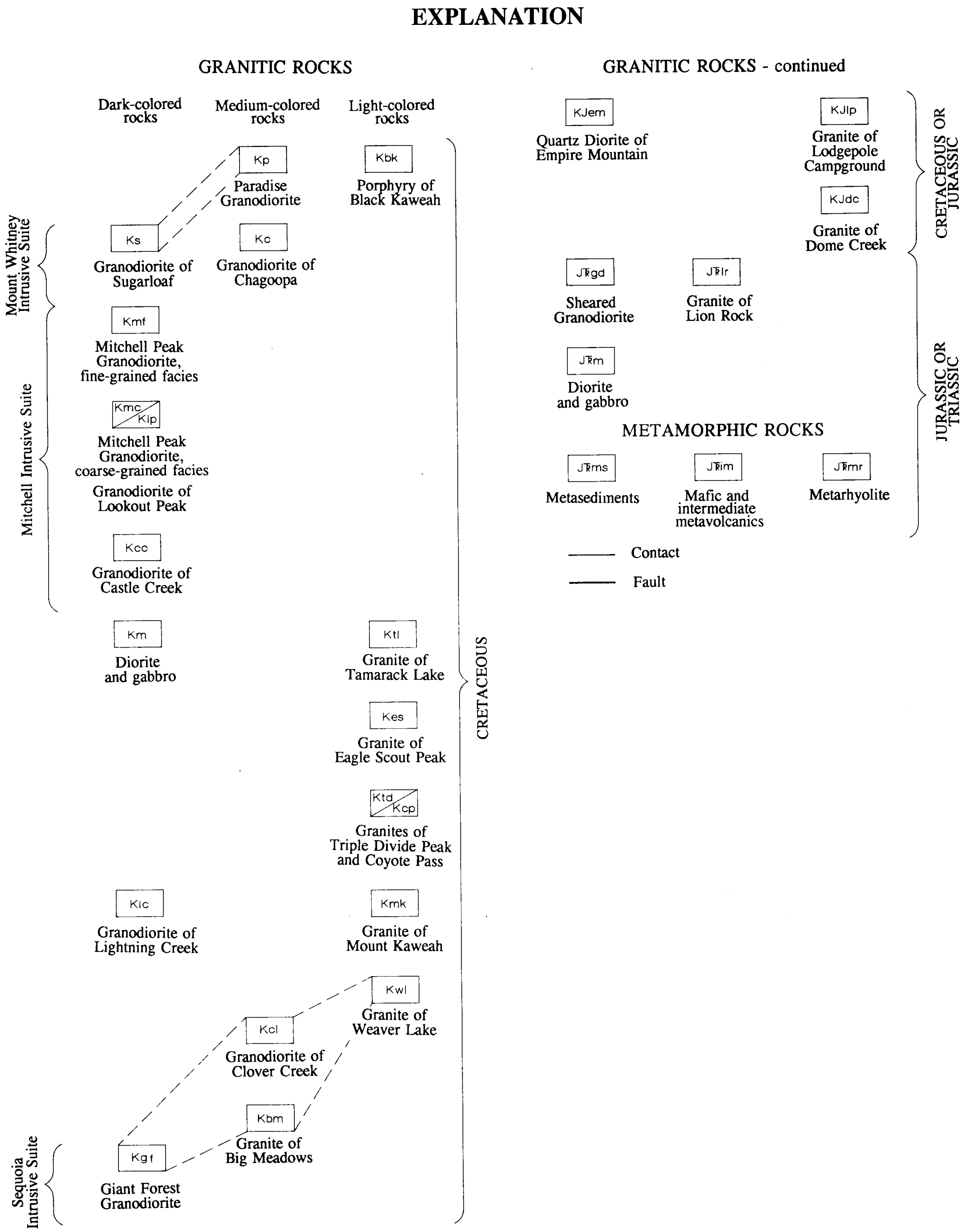

Figure 2.—Continued

associated with small bodies of sheared, schistose intrusive rocks. The metamorphic rocks and schistose granites are cut by fine-grained dikes of hornblende gabbro and diorite that may be members of the Late Jurassic Independence dike swarm.

Large masses of granodioritic and granitic magma intruded the region during the Cretaceous. These intrusive masses are present as discrete bodies (plutons) with sharp boundaries and are internally almost uniform in texture, mineralogy, and chemistry. Individual plutons form the principal map units of the quadrangle (fig. 2). Some plutons are nested one within another, with the inner plutons generally being younger and lighter colored than the outer plutons. Such an arrangement suggests a related, cogenetic origin for these plutons. Parts of three such intrusive suites are exposed in the Triple Divide Peak quadrangle (Moore and Sisson, 1987a). Eleven percent of the quadrangle is made up of rocks belonging to the Sequoia Intrusive Suite, 40 percent by rocks of the Mitchell Intrusive Suite, and 27 percent by rocks of the Mount Whitney Intrusive Suite.

SAMPLING AND ANALYTIC METHODS

Eighty samples of plutonic rocks were analyzed for their modal mineralogy and specific gravity (table 6). Forty-two samples were analyzed for their major-element chemistry (tables 1-4). Locations of chemically or modally analyzed samples are shown in figure 3. Modal analyses were performed by counting over 1,000 points on stained rock slabs (Norman, 1974). Data are reported in terms of volume percent quartz, plagioclase, K-feldspar, and mafic minerals (chiefly biotite, hornblende, and magnetite) and are presented graphically in figure 4. The rocks are classified using the modal limits of Streckeisen and others (1973) and average or estimated modal abundances (fig. 5). Older chemical analyses (with field numbers prefixed 6-) were determined by the rapid method of Shapiro and Brannock (1962). All other analyses were made by standard X-ray fluorescence techniques, with Na_2O and in some cases K_2O determined by flame photometry. Ferrous iron, CO_2, H_2O+, and H_2O- were determined by standard wet chemical methods. Specific gravity was determined by beam balance weighing of hand samples in air and water.

Representative samples were collected of most map units, but no rigorous attempt was made to establish a uniform sampling distribution (fig. 3). Instead, sampling was concentrated on plutons with distinctive and informative field relations and in areas with particularly unweathered rocks.

SEQUOIA INTRUSIVE SUITE

Ross (1958) recognized a sequence of intrusions starting with the Giant Forest Granodiorite, followed by the granite of Big Meadows and the granodiorite of Clover Creek, and ending with the granite of Weaver Lake. The inward-younging, grossly concentric arrangement of these plutons led him to propose that they were genetically related. Uranium-lead ages from zircon and sphene for samples from these plutons (Chen and Moore, 1982) fall in a narrow range from 97 to 102 Ma and support this interpretation. Modal mineral abundances were not measured on samples of the granite of Big Meadows and granodiorite of Clover Creek or the granite of Weaver Lake from within the Triple Divide Peak quadrangle. These plutons have been classified on the basis of measurements of samples from the adjacent Giant Forest quadrangle, as well as on modes reported in Ross (1958).

The Giant Forest Granodiorite is dark, equigranular, and medium grained. It contains prominent, subhedral crystals of hornblende and biotite. A few hornblende grains contain resorbed cores of augite, commonly altered to actinolitic amphibole. Honey-brown sphene is an accessory in all samples. Dark mafic inclusions, generally 5-10 cm in size, are particularly abundant in the granodiorite and range from three to seven in a square meter. A zone up to 1 km thick along the outer border of the Giant Forest Granodiorite contains phenocrysts of K-feldspar.

The granite of Big Meadows is lighter colored than the Giant Forest Granodiorite and, except locally, contains far fewer mafic inclusions. Biotite makes up a larger proportion of the mafic minerals, and allanite is present in some very light colored samples. The granite of Big Meadows contains phenocrysts of K-feldspar chiefly along its northeastern margin. A sharp contact has not been found separating the porphyritic and nonporphyritic facies. Samples of the granite of Big Meadows include both granite and light colored granodiorite in nearly equal proportions.

The granodiorite of Clover Creek cuts the granite of Big Meadows. The granodiorite of Clover Creek is darker than the granite of Big Meadows and locally contains variably disaggregated blocks of the granite of Big Meadows. Chemical analyses of samples of the granodiorite of Clover Creek show straight-line trends on silica variation diagrams, with end-member compositions corresponding to the granite of Big Meadows and an unexposed tonalite. Diorite dikes also cut the granite of Big Meadows, but do not have compositions appropriate to have produced the granodiorite of Clover Creek by assimilation of granite of Big Meadows.

The granite of Weaver Lake is the youngest member of the Sequoia Intrusive Suite. It forms a swarm of light-colored, fine-grained sills that intrude both the granite of Big Meadows and of Clover Creek. These sills commonly contain small (1 cm) phenocrysts of K-feldspar. The latest crystallizing areas of the granite of Weaver Lake are stocks or plugs of medium-grained, alaskitic granite containing vuggy pegmatitic pods and veins.

MITCHELL INTRUSIVE SUITE

The rocks of the Mitchell Intrusive Suite dominate the geology of the Triple Divide Peak quadrangle. The suite lies centered in the middle of the quadrangle (fig. 2), covering 40 percent of the total area (250 km^2, table 5). The suite stretches 60 km by 16 km in maximum length and breadth from the southern Marion Peak quadrangle (Moore, 1978) to the southern Mineral King quadrangle (Moore and Sisson, unpub. mapping).

The oldest member of the suite is the granodiorite of Castle Creek. This intrusion is formed of dark rocks similar to those of the Giant Forest Granodiorite. Two facies have been mapped in the Triple Divide Peak quadrangle. The westernmost is poor in mafic inclusions and possesses a faint layering of the dark minerals. This facies is intruded by dark granodiorite containing abundant mafic inclusions and generally lacking modal layering. A sample of the inclusion-bearing facies from the Mineral King quadrangle was dated at 98±2 Ma by the uranium-lead zircon method (Busby-Spera, 1983).

The next younger members of the suite are the coarse-grained facies of the Mitchell Peak Granodiorite and the correlative granodiorite of Lookout Peak. These rocks contain phenocrysts of K-feldspar as large as 4 cm in size. The coarse-grained facies can be subdivided into lighter and darker colored members, the darker being similar to the granodiorite of Castle Creek but with K-feldspar phenocrysts. The lighter colored member is more voluminous and consists of coarse-grained, porphyritic biotite granite, with few mafic inclusions. A sample of the granodiorite of Lookout Peak from the Marion Peak quadrangle was dated at 97 Ma by the uranium-lead zircon technique (Chen and Moore, 1982).

Following intrusion of the coarse-grained facies, the plutons of the Mitchell Intrusive Suite were arranged in a form typical of zoned intrusions and intrusive suites in the Sierra Nevada batholith: an outer equigranular dark granodiorite with abundant mafic inclusions intruded core-ward by progressively lighter colored porphyritic granodiorites and granites with few mafic inclusions. The later intrusion of the voluminous fine-grained facies of the Mitchell Peak Granodiorite disrupted this general form.

The fine-grained facies of the Mitchell Peak Granodiorite consists of dark granodiorite with abundant large (10-50 cm) mafic inclusions (6-18/m^2). Plagioclase forms the most prominent phenocrysts, reaching 4 cm in length. Most of the hornblende and biotite are groundmass minerals, but some are scattered subhedral phenocrysts. The scattered dark phenocrysts in a fine-grained matrix give the rock a salt-and-pepper appearance. Augite forms ragged cores in some hornblende phenocrysts; most augite grains are variably altered to actinolite. Plagioclase phenocrysts with a distinctive boxwork or cellular microtexture are present in both the host granodiorite and in some mafic inclusions. This suggests that these inclusions were sufficiently fluid to mix with some of their host magma. Quartz and K-feldspar are found only as groundmass minerals.

The fine-grained facies magma intruded into the center of the coarse-grained facies, following intrusion of a few small stocks of diorite and dikes of fine-grained granodiorite. Many areas of the fine-grained facies are crowded with blocks of the earlier coarse-grained facies. The blocks range from meters to hundreds of meters across. Many of the smaller blocks now have smooth fluidal outlines, elongate concordant with the foliation of the host fine-grained facies and suggesting that the blocks were incompletely solidified when they were engulfed. Ascent of the magma parental to the fine-grained facies was probably accompanied by venting of overlying silicic magma from the center of the intrusive suite in major volcanic eruptions. These could have been triggered by intrusion of fresh, primitive magma related to the growth of the adjacent Mount Whitney Intrusive Suite. The fine-grained facies of the Mitchell Peak Granodiorite was dated at 91 Ma by the uranium-lead zircon technique (Chen and Moore, 1982).

MOUNT WHITNEY INTRUSIVE SUITE

Parts of two plutons of the giant Mount Whitney Intrusive Suite (Moore, 1987) make up the northeast corner of the Triple Divide Peak quadrangle (fig. 2). The older of these, the granodiorite of Sugarloaf, is a dark equigranular granodiorite with subhedral crystals of hornblende and biotite and abundant mafic inclusions (6/m^2). Hirt (1989) reports augite cores in some hornblende crystals in samples of the granodiorite of Sugarloaf and provides several whole-rock chemical and modal analyses. Two uranium-lead zircon analyses of a sample of the granodiorite of Sugarloaf from the Marion Peak quadrangle indicate inherited old zircon, but nevertheless constrain the pluton to be younger than 88 Ma (Chen and Moore, 1982). The granodiorite of Sugarloaf was followed by the Paradise Granodiorite, a medium-colored granodiorite with K-feldspar phenocrysts masked by abundant inclusions of hornblende and biotite. Mafic inclusions are rare ($<2/m^2$). Uranium-lead zircon ages for samples of the Paradise Granodiorite from the Marion Peak quadrangle range from 83 to 88 Ma (Chen and Moore, 1982).

OTHER GRANITIC ROCKS

Numerous intrusive masses are present that cannot be assigned to larger intrusive suites. These generally form small to medium-sized plutons either much poorer or moderately richer in silica than the large granodiorite plutons.

The granite of Lodgepole Campground is sandwiched between the Sequoia and Mitchell Intrusive Suites and locally forms a roof over the top of the granodiorite of Castle Creek. Pyrite is present on the surfaces of many joints in the granite and has weathered to produce iron oxides and, apparently, sulfuric acid. The iron oxides have stained the jointed areas red, whereas the sulfuric acid has etched minerals in the rock. In extreme cases, the resulting rock is cavernously weathered, red, and soft. An analysis of such rock (table 3) from the Emerald Lake area shows enrichment in total iron oxide and K_2O and strong depletion in silica compared to nearby unaltered granite.

The granite of Lodgepole Campground contains late-crystallizing pegmatitic areas with open cavities. Pegmatitic areas contain the minerals quartz, albitic plagioclase, and K-feldspar. Some contain massive magnetite and iron-rich biotite, others contain magnetite without biotite. If a total pressure of 2 kbar is assumed, conditions near or more oxidizing than the nickle-nickle oxide buffer were reached at the final stages of consolidation (following calculations in Czamanske and Wones, 1973). Chen and Moore (1982) report a discordant U-Pb zircon analysis that constrains the granite of Lodgepole Campground as older than 115 Ma.

The granites of Triple Divide Peak and Tamarack Lake consist of light-colored granite generally with no mafic inclusions. Both of these plutons are only shallowly unroofed, with either gently dipping upper contacts or isolated remnants of their former roofs. Both granites are poor to very poor in MgO and rich in silica (table 3).

The granites of Coyote Pass and Eagle Scout Peak are darker colored than either the granite of Triple Divide Peak or Tamarack Lake. Mafic inclusions are present and occur in swarms in some areas, but their abundance usually does not exceed $2/m^2$. The granite of Eagle Scout Peak contains areas with small (1-2 cm) K-feldspar phenocrysts.

Dark-colored rocks form the slopes rising from Hamilton Lakes up to Kaweah Gap, and dark dikes lace the granite cliffs both north and south of the lakes (figs. 1, 2). The dark rocks are rich in hornblende, and the presence of hornblende-plagioclase pegmatites and tiny open cavities indicate crystallization with abundant water. The fine-grained dikes, sills, and medium-grained stocks have the composition of silica-poor andesites, some containing olivine in their norms (table 4). Rocks that formed from accumulated early crystals are also present.

The granodiorite of Chagoopa extends into the quadrangle from the southeast (fig. 2) and is the source of thick dikes and sills that intrude the granite of Mount Kaweah and the metamorphic rocks of the Kaweah Peaks Ridge. A few mafic inclusions from this intrusive mass have a distinct and unusual habit. They are very fine grained and have bulbous shapes similar to magmatic inclusions in volcanic rocks (Bacon, 1986). Altered ferromagnesian phenocrysts (augite?) have skeletal forms, suggestive of quenching. An analysis of such an inclusion is presented in table 3. Most of the mafic inclusions in the granodiorite of Chagoopa resemble common Sierran mafic inclusions, such as those described by Pabst (1928).

AVERAGE PLUTONIC ROCK COMPOSITION

An attempt is here made to estimate the average chemical composition of the intrusive rocks in the Triple Divide Peak quadrangle. This is done by assigning compositions to the various plutons and then weighting the compositions by the areas of their plutons (table 5). A similarly calculated average chemical composition is presented by Moore (1987) for the adjacent Mount Whitney quadrangle.

The assignment of compositions was performed as follows: the fine-grained facies of the Mitchell Peak Granodiorite is the average of seven analyses (table 1), the coarse-grained facies and the granodiorite of Lookout Point are the average of three analyses (table 1), the granodiorite of Castle Creek is the average of two analyses (table 1), the Giant Forest Granodiorite and the similar granodiorite of Lightning Creek and the Jurassic or Triassic granodiorite are given the average of four Giant Forest Granodiorite analyses (table 2), the granodiorite of Clover Creek is the average of two analyses (table 2), the granite of Big Meadows is given a single analysis (table 2), the granite of Weaver Lake is given the average of two unpublished analyses of samples from the Giant Forest quadrangle, the granite of Tamarack Lake is the average of three analyses (table 3), the granites of Eagle Scout Peak and Triple Divide Peak and the granodiorite of Chagoopa are their single analyses (table 3), the granite of Lodgepole Campground is given by the average of three analyses of unaltered granite, the mafic plutonic rocks and the Jurassic or Triassic diorites and the quartz diorite of Empire Mountain are given the average of six analyses (table 4), the granodiorite of Sugarloaf is given by the average of three analyses presented by Hirt (1989) and sample 7-27 of Moore (1987) with $FeO/FeO+Fe_2O_3$ in Hirt's samples set to the value in sample 7-27, the Paradise Granodiorite is given by the average of nine samples from the west side of the pluton presented by Hirt (1989) with $FeO/FeO+Fe_2O_3$ in Hirt's samples set to the mean of three Paradise Granodiorite analyses given by Moore (1987), the granites of Lion Rock and Dome Creek are given the analysis of the granite of Eagle Scout Peak (table 3), the granite of Mount Kaweah is given the analysis presented by Moore (1987) for a sample from the Mount Whitney quadrangle, and the granite of Coyote Pass is given the average of three unpublished analyses from the adjacent Mineral King quadrangle.

The average granitoid rock for the Triple Divide Peak quadrangle is given in table 7. The quadrangle average of

66.5 wt. percent SiO_2 is markedly lower than that for the adjacent Mount Whitney quadrangle on the east (70.6 wt. pct. SiO_2, Moore, 1987) and illustrates the general increase in SiO_2 content from west to east across the Sierra Nevada batholith. The average Triple Divide Peak composition is that of a typical granodiorite. For comparison, an estimate of the composition of the bulk upper continental crust (Taylor and McLennan, 1985) and the average of two estimates of the bulk composition of the Precambrian Canadian Shield (in Taylor and McLennan, 1985) are also presented. The average Triple Divide Peak granitoid and these estimates are similar, indicating that the average upper continental crust is and has been a product of igneous processes similar to those that have produced the Sierra Nevada batholith.

FRACTIONATION MODELING

The rocks of the Triple Divide Peak quadrangle vary in chemical composition in a fashion typical of granitoid batholiths formed along the margins of continents. As noted above, the average composition is also close to estimates of the bulk composition of the upper continental crust. The origin of granitoid batholiths and the upper continental crust are questions of profound importance in geochemistry and igneous petrology. Although addressing these questions is well beyond the scope of this report, the simple model of fractional crystallization can be examined and the implications tested against independent observations.

Modeling has been performed through the use of a computer program developed by T. Juster (1988, written commun.) for general crystal-fractionation calculations. The procedure began by plotting the average pluton compositions, used above, as oxide variation diagrams against MgO. The trends on the variation diagrams were then fit by multiple regression of MgO polynomials until equations were obtained that closely matched the oxide-MgO trends. In this way, weight percents of all oxides could be calculated for any specified MgO content. The calculated oxide concentrations are defined by the trends regressed through the natural data. For the purposes of fractionation modeling, it was assumed that the observed trends represent a spectrum of (now crystallized) liquid compositions. The range of observed MgO contents was divided into 10 or more equally sized intervals, and bulk compositions were calculated for the end points of each interval. Synthetic mineral compositions were calculated for each synthetic liquid composition using known or estimated mineral-liquid exchange distribution coefficients (table 8). Each liquid composition interval was then regressed using a variety of petrologically reasonable mineral assemblages plus the low-MgO liquid for that interval until an acceptable combination was obtained that matched the high-MgO liquid for that interval. The following restrictions were applied: (1) the modes of liquid plus crystals must sum to 1.000, (2) no assimilation of minerals was allowed, (3) no more than two ferro-magnesian silicate minerals were allowed in modeling each interval, (4) in keeping with petrographic evidence, K-feldspar, quartz, and biotite were not allowed in any interval in which clinopyroxene was employed, and (5) solutions are acceptable if their Q statistic equals or exceeds 0.01 and their Chi-squared statistic equals or lies below 11.000. The coarse-grained cumulate rock sample 85S69 (table 4) was excluded from the average mafic rock starting composition because it clearly does not represent a crystallized liquid.

Acceptable solutions were obtained for compositions ranging from 55 to 66.5 wt. percent SiO_2 using the assemblage plagioclase+hornblende+apatite+titanomagnetite. Modeling was continued from 66.5 wt. percent SiO_2 to 70.5 wt. percent SiO_2, after adding biotite and sphene. Sixty-six percent SiO_2 is close to the calculated average composition for the quadrangle, and modeling results are not reported for more silicic compositions.

Derivation of the most common plutonic rock composition from the mean mafic rock (~55 wt. pct. SiO_2 andesite) by fractional crystallization requires separation of 45-48 percent of the original mass of liquid as cumulate minerals. If these cumulate minerals were entirely separated from liquid, the cumulate material would have an aggregate density of ~3.09 g/cm^3. The approximate density of a 66 wt. percent SiO_2 plutonic rock can be estimated as 2.72 g/cm^3 (Moore and Sisson, 1987b), and from this it is seen that the volume of cumulate minerals is approximately 0.7 of the volume of (now crystallized) derivative 66 wt. percent SiO_2 liquid.

A regional gravity and density study by Oliver and others (1986) concludes that the exposed plutons of the Sierra Nevada maintain their individual density contrasts to depths between 8 and 12 km depending on location. If the average pluton from the Triple Divide Peak quadrangle is uniform in density to a depth of approximately 10 km, the fractionation model presented above would require an additional 7 km of cumulate material. Bateman and Eaton (1967) present a model cross section for the Sierra Nevada in which the crust in the central region is 40 to 55 km thick and in which the lower 30 km consists of material with compression wave velocity of 6.9 km/s and a bulk density of 3.03. The fractionation model would require that approximately one-quarter of the crust below the batholith consists of cumulates. If the modeling was continued to more silicic compositions, as would be appropriate in the adjacent Mount Whitney quadrangle (Moore, 1987), the volume of cumulates would be even greater. Using a volume fraction of cumulate rocks of 0.25, a cumulate density of 3.09, and a bulk density of 3.03, the calculated country rock density of the sub-batholithic crust is 3.01 g/cm^3.

Chen and Moore (1982) calculate that Cretaceous plutonism migrated at a rate of 2.7 mm/yr eastward across the batholith. For the combined volumes of cumulate and fractionated liquid calculated above, this leads to a magma production rate of 4.6×10^{-5} km^3/yr/km (neglecting the density difference between granodiorite liquid and crystalline granodiorite). Integration over the length of the entire batholith (~800 km) would imply a production rate of 3.7×10^{-2} km^3/yr. These numbers only apply to the model outlined above.

Peterson and others (1974) present compression wave velocity measurements of unweathered cumulate gabbros with densities from 2.9 to 3.2 g/cm^3. They find that most of their measurements lie above 6.9 km/s, in the range 7.4 to 7.5 km/s. The gabbros that they measured have density similar to the model cumulates, so it is likely that any pure, sub-batholithic cumulates would have compression wave velocities in excess of 7.0 km/s and perhaps as high as 7.5 km/s. Bateman and Eaton (1967) found no evidence to suggest the presence of a layer with this high seismic velocity flooring the batholith. If the fractionation model outlined above is correct, then the cumulate rocks must occur as small masses heterogeneously dispersed within less dense, seismically lower velocity country rocks.

The absence of large volumes of suitable unfractionated parents and the apparent lack of (geophysically recognized) cumulates are evidence against interpretations favoring the production of the common plutonic rocks through simple crystal fractionation from the average mafic rocks (=andesite). Considerable crustal fusion must have accompanied fractionation of mafic magmas. Major element models involving combined crystal fractionation, assimilation, and crustal fusion have proven notoriously non-unique, and they are not reported here.

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FIGURES 3–5; TABLES 1–8

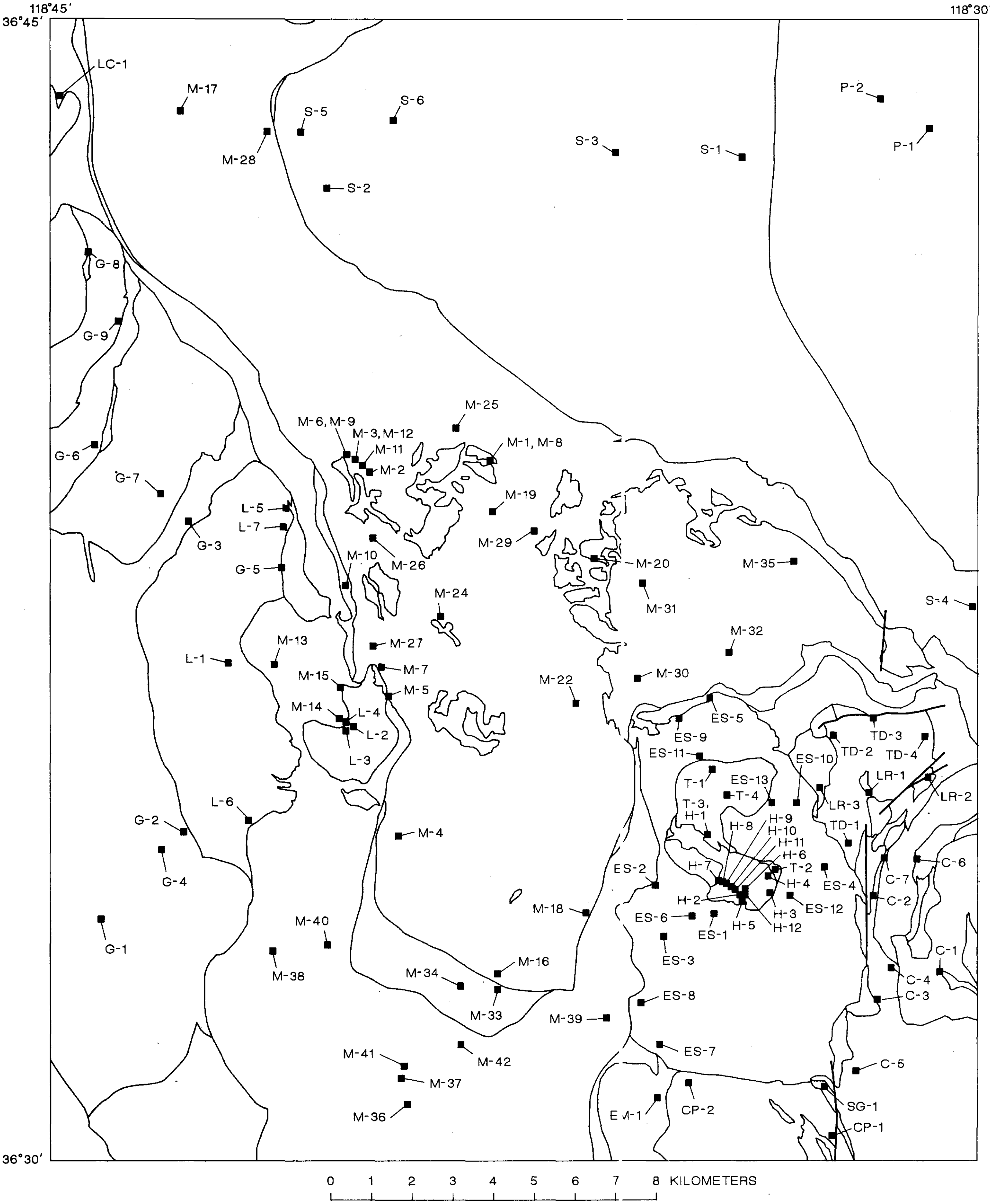
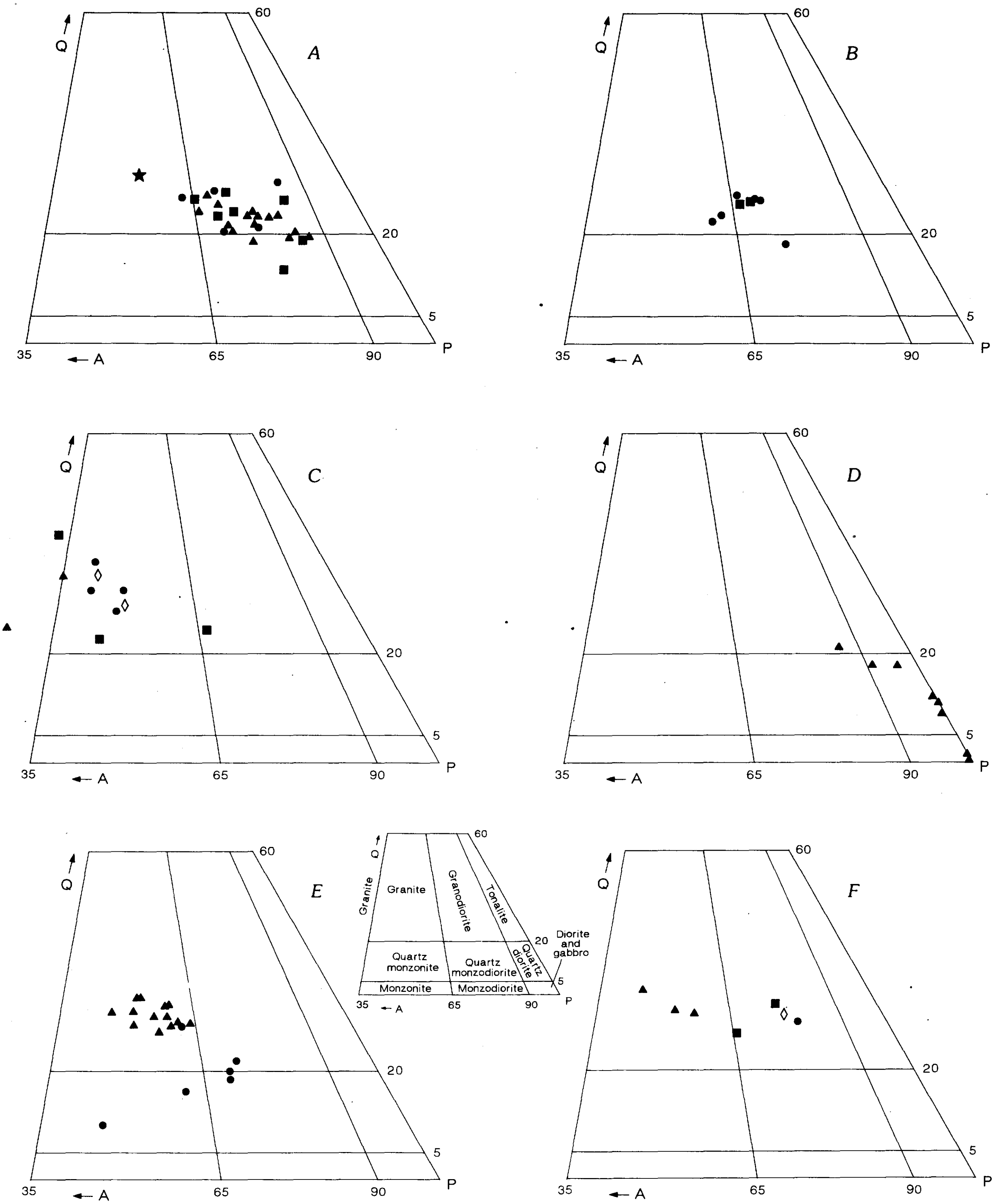


Figure 3. Map showing location of modally and (or) chemically analyzed granitic rock samples. Location numbers correspond to those in tables 1 to 4 and 6. See figure 2 for geologic units and explanation.


A
B
C
D
E
F
Q
A
P
60
20
5
35
65
90
Granite
Granodiorite
Tonalite
Quartz monzonite
Quartz monzodiorite
Quartz diorite
Diorite and gabbro
Monzonite
Monzodiorite

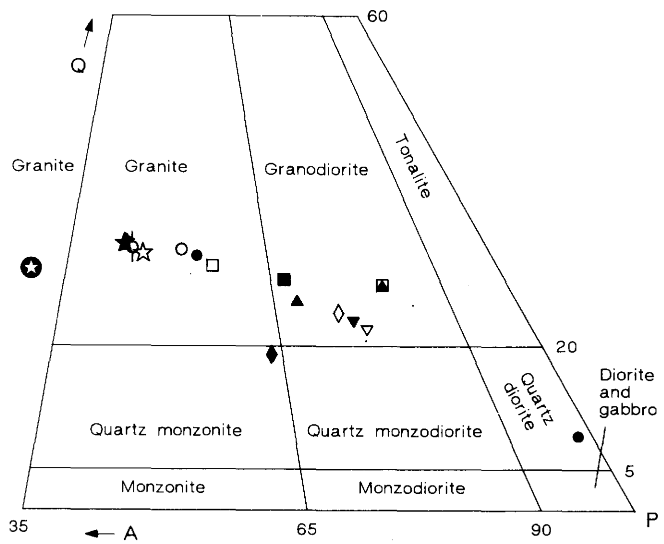


Figure 5. Plot of average modal compositions for analyzed plutons of the Triple Divide Peak quadrangle. Q, quartz, P, plagioclase, A, alkali feldspar. Filled star, granite of Triple Divide Peak; open star, granite of Lodgepole Campground; star in circle, granite of Coyote Pass; circle and vertical bar, granite of Tamarack Lake; open circle, granite of Lion Rock; open square, granite of Eagle Scout Peak; filled inverted triangle, granodiorite of Castle Creek; small dot, Mitchell Peak Granodiorite, light-colored facies; open diamond, Mitchell Peak Granodiorite, coarse-grained dark-colored facies; inverted open triangle, Mitchell Peak Granodiorite, fine-grained facies; filled diamond, granodiorite of Chagoopa; filled square, granodiorite of Sugarloaf; filled triangle, Paradise Granodiorite; triangle in square, Giant Forest Granodiorite; large dot, mafic intrusives. Classification from Streckeisen and others (1973).

◀ **Figure 4.** Plots of modes of granitic rocks from the Triple Divide Peak quadrangle. Classification scheme for granitic rocks from Streckeisen and others (1973). Q, quartz, P, plagioclase, A, alkali feldspar. *A,* Mitchell Intrusive Suite: squares, granodiorite of Castle Creek; dots, Mitchell Peak Granodiorite, coarse-grained, dark-colored facies; star, Mitchell Peak Granodiorite, coarse-grained, light-colored facies; triangles, Mitchell Peak Granodiorite, fine-grained facies. *B,* Mount Whitney Intrusive Suite: dots, granodiorite of Sugarloaf; squares, Paradise Granodiorite. *C,* Very light colored granitic rocks: diamonds, Granite of Tamarack Lake; squares, granite of Lodgepole Campground; dots, granite of Triple Divide Peak; triangles, granite of Coyote Pass. *D,* Mafic intrusive rocks, undifferentiated. *E,* Dots, granodiorite of Chagoopa; triangles, granite of Eagle Scout Peak. *F,* Miscellaneous granitic rocks: diamond, granodiorite of Lightning Creek; squares, sheared granodiorites; triangles, granite of Lion Rock; dot, Giant Forest Granodiorite.

Table 1. Chemical analyses and CIPW norms of rocks from Mitchell Intrusive Suite

[Analyses performed by staff of the U.S. Geological Survey, L. Shapiro, J. Taggart, P. Lamothe, supervisors]

	Mitchell Peak Granodiorite, fine-grained facies					Mitchell Peak Granodiorite, fine-grained facies (cont.)		Mitchell Peak Granodiorite coarse-grained facies			Mitchell Peak Granodiorite, miscellaneous rocks		Granodiorite of Castle Creek		
Map No. (fig. 3)	M-1	M-2	M-3	M-4	M-5	M-6	M-7	M-8	M-9	M-10	M-11	M-12	M-13	M-14	M-15
Field No.-------	84M1	84S1	84S3	6-340	83S296b	83S293a	83S298	84M2	83s293b	83s236	84S2 (gabbro plug)	84S4a (dike)	83S201	83S243	83S244a
Chemical analyses															
SiO_2------------	60.2	63.8	57.3	63.1	61.1	62.3	63.8	70.0	71.6	63.4	50.4	62.0	67.5	67.1	73.3
Al_2O_3-----------	17.0	16.1	17.6	16.2	16.4	16.8	16.4	14.6	14.1	16.2	18.8	17.3	15.8	15.3	12.4
Fe_2O_3-----------	2.54	2.10	2.85	1.9	2.31	2.21	1.94	1.34	1.15	2.11	3.34	2.26	0.04	1.52	2.12
FeO-------------	3.27	2.63	4.14	2.9	3.05	2.82	2.44	1.30	1.20	2.46	5.69	3.00	2.78	2.00	1.32
MgO-------------	2.84	2.16	3.39	2.3	2.55	2.29	1.98	1.04	0.87	2.04	4.75	2.01	1.36	1.51	0.53
CaO-------------	5.75	5.11	6.63	4.5	4.82	5.38	4.41	2.92	2.63	4.43	8.95	4.76	4.09	3.37	1.47
Na_2O------------	3.97	3.59	3.76	3.6	3.48	3.80	3.73	3.42	3.18	3.77	3.36	4.49	3.27	3.56	2.45
K_2O-------------	2.20	2.95	2.31	2.8	3.34	2.73	3.52	4.02	4.36	2.97	1.57	1.67	3.43	3.59	5.30
H_2O+------------	0.77	0.48	0.76	0.66	0.69	0.62	0.58	0.33	0.34	0.63	1.10	0.68	0.45	0.67	0.29
H_2O- -----------	0.06	0.07	0.05	0.15	0.15	0.02	0.03	0.09	<0.01	0.06	0.05	0.02	0.03	<0.01	0.01
TiO_2------------	0.76	0.59	0.90	0.71	0.76	0.65	0.59	0.37	0.32	0.63	1.38	0.98	0.43	0.52	0.34
P_2O_5------------	0.24	0.20	0.29	0.19	0.25	0.22	0.19	0.12	0.10	0.20	0.44	0.34	0.12	0.16	0.12
MnO-------------	0.12	0.08	0.11	0.09	0.10	0.09	0.09	0.04	0.03	0.07	0.11	0.08	0.04	0.06	0.03
CO_2-------------	0.07	0.02	0.04	0.01	0.05	0.04	0.07	0.03	0.03	0.06	0.06	0.08	0.07	0.05	0.02
Total-----	99.8	99.9	100.1	99.1	99.1	100.0	99.8	99.6	99.9	99.0	100.0	99.7	99.4	99.4	99.7
CIPW norms															
Q-------------	12.7	18.1	7.84	18.0	14.2	15.4	16.6	27.2	29.7	17.8	--	16.5	23.2	23.1	35.2
C-------------	--	--	--	--	--	--	--	--	--	--	--	0.45	--	--	0.29
or-------------	13.0	17.4	13.7	16.6	19.7	16.1	20.8	23.8	25.8	17.6	9.28	9.87	20.3	21.2	31.3
ab-------------	33.6	30.4	31.8	30.5	29.5	32.2	31.6	28.9	26.9	31.9	28.4	38.0	27.7	30.1	20.7
an-------------	22.1	19.1	24.3	19.8	19.3	20.7	17.6	12.6	11.3	18.5	31.6	21.0	18.3	15.1	6.38
di-------------	2.64	2.84	3.68	0.71	1.60	2.51	1.52	0.57	0.54	1.08	5.47	--	0.30	0.11	--
he-------------	0.94	1.04	1.51	0.30	0.58	0.94	0.56	0.14	0.17	0.35	2.26	--	0.34	0.04	--
en-------------	5.85	4.07	6.74	5.40	5.61	4.54	4.23	2.32	1.92	4.58	8.09	5.01	3.25	3.71	1.32
fs-------------	2.38	1.71	3.16	2.59	2.32	1.95	1.77	0.67	0.69	1.68	3.84	2.17	4.26	1.65	0.17
mt-------------	3.68	3.04	4.13	2.75	3.35	3.20	2.81	1.94	1.67	3.06	4.84	3.28	0.06	2.20	3.07
il-------------	1.44	1.12	1.71	1.35	1.44	1.23	1.12	0.70	0.61	1.20	2.62	1.86	0.82	0.99	0.65
ap-------------	0.56	0.46	0.67	0.44	0.58	0.51	0.44	0.28	0.23	0.46	1.02	0.79	0.28	0.37	0.28
fo-------------	--	--	--	--	--	--	--	--	--	--	0.85	--	--	--	--
fa-------------	--	--	--	--	--	--	--	--	--	--	0.44	--	--	--	--
cc-------------	0.16	0.05	0.09	0.02	0.11	0.09	0.16	0.07	0.07	0.14	0.14	0.18	0.16	0.11	0.05
H_2O------------	0.83	0.55	0.81	0.81	0.84	0.64	0.61	0.42	0.34	0.69	1.15	0.70	0.48	0.67	0.30
Total----	99.9	99.9	100.1	99.3	99.1	100.0	99.8	99.6	99.9	99.0	100.0	99.8	99.5	99.4	99.7

Table 2. Chemical analyses and CIPW norms of rocks from Sequoia Intrusive Suite

[Analyses performed by staff of the U.S. Geological Survey, L. Shapiro, J. Taggart, P. Lamothe, supervisors]

	Giant Forest Granodiorite				Granodiorite of Clover Creek		Granite of Big Meadows	Diorite dikes	
Map No. (fig. 3)	G-1	G-2	G-3	G-4	G-5	G-6	G-7	G-8	G-9
Field No.-------	83S210	83S213	83S245	6-325	83S225	83S288	83S246	83S299b	83S300a
					Chemical analyses				
SiO_2------------	65.6	66.7	67.1	64.8	67.4	65.8	69.2	58.1	56.0
Al_2O_3-----------	15.4	15.5	15.3	15.9	14.9	15.5	14.7	16.5	18.4
Fe_2O_3-----------	1.26	1.37	1.82	1.4	0.92	1.81	1.24	2.16	2.65
FeO-------------	3.06	2.58	2.23	3.1	2.93	2.49	1.66	4.81	5.05
MgO-------------	1.73	1.31	1.26	1.6	1.07	1.50	0.90	3.90	2.49
CaO-------------	4.02	3.58	3.36	4.0	3.01	3.95	2.28	7.09	6.65
Na_2O------------	3.53	3.72	3.77	3.5	3.46	3.71	3.66	2.66	3.61
K_2O-------------	3.11	2.88	2.96	2.9	3.94	3.07	4.30	1.83	1.79
H_2O+------------	0.76	0.46	0.54	1.0	0.38	0.73	0.34	1.16	0.99
H_2O- -----------	0.17	0.08	0.04	0.04	0.05	0.06	0.09	0.05	0.11
TiO_2------------	0.56	0.48	0.49	0.61	0.55	0.70	0.43	1.19	1.12
P_2O_5------------	0.12	0.17	0.13	0.13	0.16	0.21	0.13	0.18	0.40
MnO-------------	0.08	0.07	0.08	0.07	0.07	0.09	0.07	0.12	0.14
CO_2-------------	0.10	0.06	0.10	0.01	0.07	0.09	0.06	0.04	0.03
Total-----	99.5	99.0	99.2	99.1	98.9	99.7	99.1	99.8	99.4
					CIPW norms				
Q--------------	21.2	23.7	24.5	21.1	23.1	21.9	25.1	14.1	9.22
C--------------	--	0.30	0.33	0.07	0.02	--	0.33	--	--
or-------------	18.4	17.0	17.5	17.1	23.3	18.1	25.4	10.8	10.6
ab-------------	29.9	31.5	31.9	29.6	29.3	31.4	31.0	22.5	30.6
an-------------	17.0	16.3	15.2	18.9	13.4	16.6	10.1	27.7	28.7
di-------------	0.72	--	--	--	--	0.59	--	3.34	0.68
he-------------	0.55	--	--	--	--	0.29	--	1.59	0.53
en-------------	3.98	3.26	3.14	3.99	2.67	3.46	2.24	8.17	5.89
fs-------------	3.51	2.94	1.93	3.66	3.84	1.94	1.44	4.46	5.21
mt-------------	1.83	1.99	2.64	2.03	1.33	2.62	1.80	3.13	3.84
il-------------	1.06	0.93	0.93	1.16	1.04	1.33	0.82	2.26	2.13
ap-------------	0.28	0.40	0.30	0.30	0.37	0.49	0.30	0.42	0.93
fo-------------	--	--	--	--	--	--	--	--	--
fa-------------	--	--	--	--	--	--	--	--	--
cc-------------	0.23	0.14	0.23	0.02	0.16	0.20	0.14	0.09	0.07
H_2O------------	0.93	0.54	0.58	1.04	0.43	0.79	0.43	1.21	1.10
Total----	99.6	99.0	99.2	99.0	99.0	99.7	99.1	99.8	99.5

Table 3. Chemical analyses and CIPW norms of rocks from miscellaneous plutons

[Analyses performed by staff of the U.S. Geological Survey, L. Shapiro, J. Taggart, P. Lamothe, supervisors]

	Granite of Lodgepole Campground				Granite of Tamarack Lake			Granite of Triple Divide Peak	Granite of Eagle Scout Peak	Granodiorite of Chagoopa	
Map No. (fig. 3)	L-1	L-2	L-3	L-4	T-1	T-2	T-3	TD-1	ES-1	C-1	C-2
Field No.-------	83s200	87TD6	87TD7	87TD2 (altered)	6-130	85S74	85S76b	6-109	6-332	6-138	85s13d (mafic inclusion)
					Chemical analyses						
SiO_2------------	68.2	75.4	71.2	57.0	75.6	74.3	75.3	77.1	71.4	66.0	57.4
Al_2O_3-----------	15.3	13.0	15.5	15.4	13.0	13.5	13.0	12.3	14.4	15.9	16.8
Fe_2O_3-----------	1.04	0.71	0.45	9.9	0.42	0.88	0.79	0.66	1.1	1.4	1.56
FeO-------------	2.04	0.54	0.86	1.80	0.76	0.64	0.53	0.40	1.0	2.4	5.18
MgO-------------	0.82	0.20	0.29	0.13	0.16	0.35	0.24	0.12	0.57	0.93	3.25
CaO-------------	2.63	1.13	1.58	1.45	0.84	1.23	1.15	0.76	1.80	2.3	5.62
Na_2O------------	3.91	3.12	4.16	3.23	3.4	3.30	3.11	3.8	3.8	4.7	5.00
K_2O-------------	3.95	5.13	5.21	7.09	4.4	4.97	5.28	4.4	4.2	3.4	2.19
H_2O+------------	0.31	0.15	0.13	1.62	0.42	0.43	0.22	0.20	0.44	0.86	0.91
H_2O- -----------	0.05	0.07	0.06	0.30	0.02	0.02	0.04	0.02	0.11	0.15	0.15
TiO_2------------	0.45	0.11	0.14	0.39	0.13	0.19	0.21	0.08	0.32	0.66	0.95
P_2O_5------------	0.16	0.05	0.06	0.08	0.05	0.05	<0.05	0.02	0.08	0.17	0.24
MnO-------------	0.05	0.03	0.04	0.05	0.04	0.04	0.03	0.05	0.06	0.11	0.17
CO_2-------------	0.08	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.02	0.01	0.01	0.08
Total-----	99.0	99.6	99.7	98.4	99.3	99.9	99.9	99.9	99.3	99.0	99.5
					CIPW norms						
Q--------------	23.1	34.9	22.9	8.03	36.7	33.0	34.2	36.4	28.5	18.8	2.69
C--------------	0.38	0.38	0.29	--	1.26	0.58	0.08	--	0.55	0.74	--
or-------------	23.3	30.3	30.8	41.9	26.0	29.4	31.2	26.0	24.8	20.1	12.9
ab-------------	33.1	26.4	35.2	27.3	28.8	27.9	26.3	32.2	32.2	39.8	42.3
an-------------	11.5	5.28	7.45	6.58	3.78	5.78	5.70	3.51	8.34	10.2	16.9
di-------------	--	--	--	0.07	--	--	--	0.0	--	--	4.17
he-------------	--	--	--	--	--	--	--	0.0	--	--	3.13
en-------------	2.04	0.50	0.72	0.29	0.40	0.87	0.60	0.30	1.42	2.32	6.16
fs-------------	2.24	0.28	1.05	--	0.91	0.21	0.03	0.15	0.51	2.37	5.30
mt-------------	1.51	1.03	0.65	4.83	0.61	1.28	1.15	0.96	1.59	2.03	2.26
il-------------	0.85	0.21	0.27	0.74	0.25	0.36	0.40	0.15	0.61	1.25	1.80
ap-------------	0.37	0.12	0.14	0.19	0.12	0.12	<0.1	0.05	0.19	0.40	0.56
fo-------------	--	--	--	--	--	--	--	--	--	--	--
fa-------------	--	--	--	--	--	--	--	--	--	--	--
cc-------------	0.18	--	--	--	0.02	--	--	0.05	0.02	0.02	0.18
H_2O------------	0.36	0.22	0.19	1.92	0.44	0.45	0.26	0.22	0.55	1.01	1.06
hm-------------	--	--	--	6.57	--	--	--	--	--	--	--
Total----	98.9	99.6	99.7	98.4	99.3	100.0	99.9	100.0	99.3	99.0	99.4

Table 4. Chemical analyses and CIPW norms of rocks from mafic intrusions near Hamilton Lake

[Analyses performed by staff of the U.S. Geological Survey, L. Shapiro, J. Taggart, P. Lamothe, supervisors]

	Dike cutting granite	Sills and stocks				Coarse cumulate
Map No. (fig. 3)	H-1	H-2	H-3	H-4	H-5	H-6
Field No.	85S76a	6-117	85S72a	85S73c	85S70a	85S69
Chemical analyses						
SiO_2	57.6	58.0	55.6	52.8	53.3	48.2
Al_2O_3	17.4	17.0	18.1	18.8	17.1	13.8
Fe_2O_3	3.14	3.0	3.84	4.28	3.65	3.41
FeO	3.80	4.2	4.16	4.53	4.56	7.82
MgO	2.83	3.0	3.18	3.77	4.48	12.1
CaO	6.50	6.2	7.22	8.73	9.04	6.55
Na_2O	3.93	3.6	3.73	3.45	3.39	2.18
K_2O	2.22	2.3	1.39	1.38	1.35	2.99
H_2O^+	0.80	0.74	1.25	1.01	1.03	2.08
H_2O^-	0.08	0.11	0.12	0.10	0.25	0.12
TiO_2	1.16	1.1	1.05	1.29	1.26	0.95
P_2O_5	0.38	0.31	0.37	0.40	0.30	0.20
MnO	0.12	0.11	0.20	0.19	0.10	0.36
CO_2	<0.01	0.02	<0.01	<0.01	0.05	<0.01
Total	100.0	99.7	100.2	100.7	99.9	100.8
CIPW norms						
Q	9.35	10.9	9.06	4.82	5.04	--
C	--	--	--	--	--	--
or	13.1	13.6	8.21	8.16	7.98	17.7
ab	33.3	30.5	31.6	29.2	28.7	18.5
an	23.3	23.4	28.5	31.7	27.5	19.0
di	3.91	2.94	2.91	5.61	9.52	7.45
he	1.30	1.24	1.00	1.56	2.58	2.29
en	5.24	6.11	6.57	6.79	6.75	1.27
fs	2.00	2.96	2.57	2.17	2.09	0.45
mt	4.55	4.35	5.57	6.21	5.29	4.94
il	2.20	2.09	1.99	2.45	2.39	1.80
ap	0.88	0.72	0.86	0.93	0.70	0.46
fo	--	--	--	--	--	17.8
fa	--	--	--	--	--	6.93
cc	--	0.05	--	--	0.11	--
H_2O	0.88	0.85	1.37	1.11	1.28	2.20
Total	100.0	99.7	100.2	100.7	99.9	100.8

Table 5. Areal size of geologic map units

Unit (fig. 2)	Area (km^2)	Percentage of total area
Giant Forest Granodiorite	42.9	6.9
Granite of Big Meadows	19.0	3.1
Granodiorite of Clover Creek	5.1	0.8
Granite of Weaver Lake	3.1	0.5
Granite of Lodgepole Campground	28.8	4.6
Granite of Dome Creek	8.4	1.4
Granodiorite of Castle Creek	68.5	11.1
Mitchell Peak Granodiorite, coarse facies	50.9	8.2
Mitchell Peak Granodiorite, fine facies	125.8	20.3
Granodiorite of Lightning Creek	3.1	0.5
Granodiorite of Lookout Peak	<0.1	<0.1
Granodiorite of Sugarloaf	117.5	19.0
Paradise Granodiorite	51.8	8.4
Granite of Tamarack Lake	4.6	0.7
Granite of Eagle Scout Peak	34.9	5.6
Granite of Coyote Pass	7.4	1.2
Granodiorite of Chagoopa	13.5	2.2
Granite of Mount Kaweah	5.5	0.9
Granite of Lion Rock	1.8	0.3
Granite of Triple Divide Peak	6.2	1.0
Porphyry of Black Kaweah	0.2	<0.1
Mafic plutonic rocks	6.5	1.0
Sheared granodiorite	6.3	1.0
Metamorphic rocks	8.3	1.3
Total	620.1	100.0

Table 6. Modes of plutonic rocks

[O. Polovtzoff and T. Sisson, analysts]

Map No. (fig. 3)	Field No.	Quartz	K-feldspar	Plagioclase	Mafic minerals	Specific gravity
Dioritic rocks near Hamilton Lake						
H-2	6-117	14.7	6.3	63.3	15.7	2.770
H-7	6-112	6.4	0.0	56.8	36.7	2.945
H-8	6-113	0.8	0.0	65.3	33.9	2.938
H-9	6-114	7.9	0.1	63.8	28.2	2.849
H-10	6-115	0.0	0.0	64.6	35.4	2.930
H-11	6-116	13.8	1.8	61.6	22.8	2.766
H-12	6-118	3.8	0.0	39.6	56.6	2.950
Average		6.8	1.2	59.3	32.8	2.878
Standard deviation		5.8	2.4	9.1	12.9	0.083
Granodiorite of Sugarloaf						
S-1	68m18	20.4	25.1	41.0	13.4	2.698
S-2	68m23	20.0	27.3	41.8	10.9	2.643
S-3	68m17	22.8	18.7	45.8	12.7	2.702
S-4	8-17	24.5	21.7	43.0	10.8	2.675
S-5	68m27	14.8	16.4	48.0	20.8	2.736
S-6	68m13	23.2	19.7	45.4	11.7	2.660
Average		21.0	21.5	44.2	13.4	2.686
Standard deviation		3.5	4.1	2.7	3.8	0.033
Granite of Eagle Scout Peak						
ES-1	6-332	26.8	30.0	38.2	5.0	2.630
ES-2	6-329	29.4	28.6	37.5	4.5	2.625
ES-3	6-111	25.6	29.9	39.6	4.9	2.636
ES-4	6-110	27.6	24.5	43.4	4.5	2.650
ES-5	3-19	32.1	31.7	34.3	1.9	2.635
ES-6	6-331	26.7	26.0	41.1	6.2	2.635
ES-7	8-52	31.0	30.2	32.8	6.0	2.650
ES-8	8-51	30.1	26.0	38.7	5.2	2.640
ES-9	75m27	30.0	35.0	31.0	4.0	2.630
ES-10	6-338	27.7	27.1	39.0	6.2	2.615
ES-11	6-129	28.7	31.8	33.0	6.5	2.634
ES-12	6-328	27.1	32.9	34.9	5.1	2.613
ES-13	6-339	26.4	25.5	39.0	9.2	2.637
Average		28.4	29.2	37.1	5.3	2.633
Standard deviation		2.0	3.2	3.6	1.7	0.011
Granodiorite of Chagoopa						
C-1	6-138	17.6	22.4	53.5	6.5	2.667
C-3	6-135	17.9	21.2	50.4	10.5	2.665
C-4	6-136	25.2	24.0	40.0	10.8	2.665
C-5	6-345	20.2	18.6	49.7	11.5	2.690
C-6	6-145	9.4	45.3	38.4	6.9	2.650
C-7	6-143	13.0	25.3	40.0	21.7	2.675
Average		17.2	26.1	45.3	11.3	2.669
Standard deviation		5.5	9.7	6.6	5.5	0.013

Table 6. Modes of plutonic rocks—Continued

Map No. (fig. 3)	Field No.	Quartz	K-feldspar	Plagioclase	Mafic minerals	Specific gravity
Granite of Triple Divide Peak						
TD-1	6-109	31.0	34.7	33.0	1.3	2.610
TD-2	6-128	27.6	37.5	33.5	1.4	2.600
TD-3	9-13	31.2	40.5	27.6	<0.1	2.610
TD-4	8-18	35.4	35.3	24.4	4.9	2.625
Average		31.3	37.0	29.6	1.9	2.611
Standard deviation		3.2	2.6	4.4	2.1	0.010
Granite of Tamarack Lake						
T-1	6-130	27.4	35.5	33.1	4.0	2.595
T-4	6-337	33.1	36.9	26.3	3.7	2.615
Average		30.3	36.2	29.7	3.9	2.605
Standard deviation		4.0	1.0	4.8	0.2	0.014
Granite of Coyote Pass						
CP-1	6-131	23.8	56.3	17.6	2.3	2.622
CP-2	8-43	32.9	42.0	22.1	3.0	2.620
Average		28.4	49.2	19.9	2.7	2.621
Standard deviation		6.4	10.1	3.2	0.5	0.001
Mitchell Peak Granodiorite, fine-grained facies						
M-4	6-340	21.6	18.4	45.4	14.6	2.715
M-16	8-45	18.2	15.1	51.9	14.9	--
M-17	9-14	22.2	18.5	41.6	17.7	2.760
M-18	6-330	17.7	19.2	49.1	14.0	2.692
M-19	3-16	19.7	14.1	48.8	17.4	2.735
M-20	75m23	15.3	15.9	51.0	17.8	2.740
M-21	75m24	15.6	10.2	53.8	20.4	2.765
M-22	75m25	18.8	19.6	49.7	11.9	2.715
M-23	75m29	19.4	15.1	49.5	16.0	2.740
M-24	75m30	18.1	11.8	50.1	20.0	2.760
M-25	75m32	15.1	9.2	56.6	19.1	2.725
M-26	75m33	19.5	10.6	52.5	17.4	2.738
M-27	75m35	20.8	21.8	43.9	13.5	2.700
M-28	68m24	16.5	12.1	43.2	28.2	2.735
M-29	3-17	16.4	9.6	55.1	18.9	2.765
Average		18.3	14.7	49.5	17.5	2.735
Standard deviation		2.3	4.1	4.4	3.9	0.023
Mitchell Peak Granodiorite, coarse-grained facies						
M-30	75m28	24.9	8.6	51.3	15.2	2.730
M-31	3-18	28.6	29.6	34.5	7.3	2.660
M-32	3-20	24.7	19.0	46.2	10.1	2.675
M-33	8-38	17.9	14.6	52.2	15.3	2.695
M-34	8-46	21.3	23.0	38.6	17.1	2.700
M-35	9-10	18.2	20.7	51.1	10.0	2.730
Average		22.6	19.3	45.7	12.5	2.698
Standard deviation		4.2	7.2	7.5	3.9	0.028

Table 6. Modes of plutonic rocks—Continued

Map No. (fig. 3)	Field No.	Quartz	K-feldspar	Plagioclase	Mafic minerals	Specific gravity
Granodiorite of Castle Creek						
M-36	8-47	20.3	16.8	48.0	14.9	2.695
M-37	8-48	19.8	7.9	46.7	25.6	2.760
M-38	8-39	23.0	16.3	44.3	16.4	2.705
M-39	8-42	13.6	8.7	50.7	27.0	2.745
M-40	8-41	23.4	22.7	42.7	11.2	--
M-41	8-49	10.5	13.2	52.9	23.6	--
M-42	8-50	20.0	20.0	47.4	12.8	--
Average		18.7	15.1	47.5	18.8	2.726
Standard deviation		4.8	5.5	3.5	6.5	0.031
Paradise Granodiorite						
P-1	75m15	23.3	22.6	45.5	8.6	2.685
P-2	75m17	24.0	21.1	46.9	8.0	2.690
Average		23.7	21.9	46.2	8.3	2.688
Standard deviation		0.5	1.1	1.0	0.4	0.004
Giant Forest Granodiorite						
G-4	6-324	23.3	10.8	46.9	19.0	2.708
Granite of Lodgepole Campground						
L-5	3-15	41.2	41.2	17.0	0.6	2.610
L-6	6-326	22.5	23.9	44.8	8.8	2.645
L-7	75m34	27.2	43.1	28.1	1.6	2.605
Average		30.3	36.1	30.0	3.7	2.620
Standard deviation		9.7	10.6	14.0	4.5	0.022
Granite of Lion Rock						
LR-1	6-139	28.9	28.6	38.5	4.0	2.633
LR-2	6-341	28.7	30.8	35.3	5.2	2.650
LR-3	9-12	31.8	33.9	28.2	6.1	2.650
Average		29.8	31.1	34.0	5.1	2.644
Standard deviation		1.7	2.7	5.3	1.1	0.010
Granodiorite of Lightning Creek						
LC-1	2-59	24.8	13.4	46.3	15.5	2.690

Map No. (fig. 3)	Field No.	Quartz	K-feldspar	Plagioclase	Mafic minerals	Specific gravity
Quartz Diorite of Empire Mountain						
EM-1	8-44	12.9	12.6	55.1	19.4	2.730
Sheared Granodiorite						
SG-1	6-133	24.2	12.3	40.9	22.6	2.700
SG-2	9-11	21.9	21.6	41.4	15.1	2.735
Average		23.1	17.0	41.2	18.9	2.718
Standard deviation		1.6	6.6	0.4	5.3	0.025

Table 7. Average chemical composition, in weight percent, of plutonic rocks, with estimates of the average upper continental crust and Precambrian Candian Shield (Taylor and McLennan, 1985)

[*, indicates all iron expressed as FeO]

	Triple Divide Peak quadrangle	Upper continental crust	Canadian Shield
SiO_2	66.5	66.0	65.1
Al_2O_3	15.5	15.2	15.5
Fe_2O_3	1.70	--	--
FeO	2.21	4.5*	4.21*
MgO	1.60	2.2	2.22
CaO	3.75	4.2	3.76
Na_2O	3.64	3.9	3.68
K_2O	3.41	3.4	2.99
TiO_2	0.54	0.5	0.53
P_2O_5	0.17	--	0.16
MnO	0.07	0.08	0.07

Table 8. Mineral-liquid modeling parameters

[K_D, mineral-liquid exchange distribution coefficients; calculated as the ratio of a pair of cations in a mineral divided by the corresponding ratio in the coexisting liquid. For example, for equilibrium between hornblende and liquid the Fe-Mg K_D is $((Fe/Mg)_{hbl.}/(Fe/Mg)_{liq.})$. Thus, equilibrium mineral compositions can be calculated from liquid composition, exchange K_D, and mineral stoichiometry]

Mineral compositions calculated as follows:

Plagioclase:	Ca-Na K_D (min./liq.) 1.800		cations Fe 0.030	cations Mg 0.030
Hornblende:	Fe-Mg K_D 0.250	Al-Si K_D 1.000	cations Ti: function of Al/Si	cations Na: function of Al/Si

Apatite (wt. percent):

SiO_2	TiO_2	Al_2O_3	FeO	MgO	MnO	CaO	Fe_2O_3	P_2O_5
0.00	0.00	0.00	0.00	0.00	0.00	55.82	0.00	42.39

Magnetite (wt. percent)

SiO_2	TiO_2	Al_2O_3	FeO	MgO	MnO	CaO	Fe_2O_3	P_2O_5
0.40	8.10	2.40	49.87	1.20	1.00	0.10	36.37	0.00

Mineral densities:

Plagioclase:	linear function of An content (An percent: 68.5-52.6; sp. gr.: 2.72-2.69)
Hornblende:	linear function of Mg/Mg+Fe (sp. gr.: 3.24-3.08).
Apatite:	fixed = 3.17
Magnetite:	fixed = 5.16

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