Geology of the Igneous Rocks of the Spanish Peaks Region Colorado

GEOLOGICAL SURVEY PROFESSIONAL PAPER 594-G

GEOLOGY OF THE IGNEOUS ROCKS OF THE SPANISH PEAKS REGION, COLORADO

The Spanish Peaks (Las Cumbres Espanolas).

Geology of the Igneous Rocks of the Spanish Peaks Region Colorado

By ROSS B. JOHNSON

SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY

GEOLOGICAL SURVEY PROFESSIONAL PAPER 594-G

A study of the highly diverse igneous rocks and structures of a classic geologic area, with a discussion on the emplacement of these features

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GEOLOGY OF THE IGNEOUS ROCKS OF THE SPANISH PEAKS REGION, COLORADO

By Ross B. Johnson

ABSTRACT

The Spanish Peaks region includes nearly 2,000 square miles in Las Animas and Huerfano as well as small parts of Costilla and Custer Counties in south-central Colorado. The region is mainly an upland area in the westernmost part of the Great Plains, and it borders the eastern foothills of the Sangre de Cristo Mountains. Maximum altitudes are 13,623 feet on West Spanish Peak and 12,708 feet on East Spanish Peak. Regionally, the land slopes in all directions from the Spanish Peaks, but the major streams drain northeastward to the Arkansas River.

The Spanish Peaks region and adjoining areas in Colorado and New Mexico are well known to geologists for highly diverse igneous rocks and structures. The topography is dominated mainly by intrusive and extrusive igneous rocks; stocks, laccoliths, sole injections, plugs, dikes, and sills have invaded the sedimentary rocks over the entire region, and many of these intrusives form mountains, hills, or buttes that dominate the landscape. Basaltic lava sheets cap high mesas east of Trinidad, Colo., and Raton, N. Mex. Lava sheets also cap sedimentary rocks north of Huerfano Park and in the San Luis Valley as well as sedimentary rocks and Precambrian igneous and metamorphic rocks in the Sangre de Cristo and Wet Mountains. Volcanic cones are scattered throughout the plains east of Raton and occur locally in the Wet Mountains, in the San Luis Valley, and on the Raton mesas.

Although the larger igneous masses dominate the topography of the Spanish Peaks region, dikes are characteristic. Most dikes are members of a large radial dike system associated with the Spanish Peaks, a smaller radial dike system associated with Dike Mountain, or a large subparallel system that strikes generally east-west throughout the region normal to the strike of the folded sedimentary rocks. Many dikes, however, belong to small sets or occur singly.

The dikes range in width from 1 foot to more than 100 feet and extend for a maximum distance of almost 14 miles. They are generally more resistant to erosion than are the intruded sedimentary rocks and consequently, stand as nearly vertical walls as much as 100 feet high. Some of the more mafic dikes when weathered erode more rapidly than the adjacent rocks, however, and form trenches.

Petrographically, the igneous rocks make up a continuous serial gradation from granite to gabbro. These rocks include phaneritic, aphanitic, porphyritic, and lamprophyric varieties of granite, granodiorite, syenite, syenodiorite, diorite, syenogabbro, and gabbro; syenodiorite is the most common rock type in the region. Almost all the rocks are holocrystalline, although locally a few of the lamprophyre dikes have ground masses of slightly to highly devitrified glass.

Chemically, the rocks range from felsic to ultramafic and from oversaturated to undersaturated types. They are also peraluminous to subaluminous and calcic to alkalic.

INTRODUCTION

September 10.—We soon came in sight of "Las Cumbres Espanolas" or the Spanish Peaks, their twinned summits towering above the clouds that drifted midway up their sides. Our route bore direct for the peaks.

September 14.—I made a sketch of the Spanish Peaks; there were light clouds hanging around them, but although they lent great beauty to the mountains by ever varying contour of their shadows, that curved about in "mazes intricate, eccentric, intervolved, yet regular, when most irregular they seem," and the rays of light that pierced these clouds were ever changing; thus, the same scene presented endless variety.

Lt. J. W. Abert . . . 1846 (1848)

The beauty of the Spanish Peaks of southern Colorado has inspired men for untold centuries. With the majestic Sangre de Cristo Mountains as their backdrop the summits of these twin peaks tower more than 6,500 feet (East Spanish Peak) and more than 7,500 feet (West Spanish Peak) above the 6,000-foot level of the flat High Plains. The Spanish Peaks can be seen for many miles from the north and east in Colorado and for as much as 100 miles from the south in northeastern New Mexico.

The Spanish Peaks have served as the home of Apache, Comanche, and Ute gods, the legendary sites of lost treasures, and as landmarks for traveling bands of Indians, Spanish explorers from Santa Fe, French voyageurs from the "Illinois country," and Americans from the young nation to the east. The Americans came last and in waves: Army explorers, mountain men and trappers, buffalo hunters, traders from Independence to Santa Fe along the Santa Fe Trail, the U.S. Army under General Kearney on its way to Chihuahua and southern California, miners on their way to the gold fields of California, cattlemen, farmers, geologists and topographers of the Hayden and Wheeler Surveys, miners coming to the coal field beneath the Spanish Peaks, lumbermen, health seekers, and modern tourists.

Among the men who have traveled to and from the Southwest with the Spanish Peaks to guide them are: Juan de Ulibarri in 1706, Antonio de Valverde in 1719, Pedro de Villasúr in 1720, Pierre and Paul Mallet in 1739, Juan Bautista de Anza in 1779, Zebulon M. Pike in 1806–07, Stephen H. Long in 1820, William Becknell in 1821, Jacob Fowler in 1821–22, Josiah Gregg, the Bent brothers, Kit Carson, Ceran St. Vrain, Julian B. Maxwell, Dick Wooten, John C. Frémont, and John W. Gunnison.

Although scientists with some of the Army exploration parties made geological observations in the vicinity of the Spanish Peaks and collected samples of coal, rocks, minerals, and fossils, the peaks themselves were not closely observed until 1869 when F. V. Hayden made a geological expedition from Cheyenne to Santa Fe by way of the Spanish Peaks and returned to Denver by way of the Rio Grande and South Park. Hayden (1873, p. 153) regarded the Spanish Peaks "as a gigantic dike, with the strike about northeast and southwest." He also stated, "The entire surface of the country, from the Spanish Peaks to the Raton Mountains, is penetrated with dikes, which often reach far across the country with a trend about northeast and southwest."

The first geological report of the Spanish Peaks region was by Endlich (1877), who mapped the peaks in 1875 (pl. 16). He noted (1877, p. 131, 133) the radial nature of the dikes (las vetas) near Muralla Peak (Dike Mountain) and the Spanish Peaks. The rocks of the central intrusives and the associated dikes were classed by him as "porphyritic trachyte" (1877, p. 127–136). Endlich was thrilled by the beauty and intrigued by the geologic character of the Spanish Peaks, for he wrote (1877, p. 128–129):

> A most interesting group is that of the Spanish Peaks. Approaching them from the north, the two mountains are seen to rise far above the level of the surrounding country, and, standing isolated as they do, the effect of their height is still increased. The fertile valley of the Arapahoe (Bear Creek) is in the foreground, and from it rise abruptly the forms of these two giants. Innumerable walls, high and of great length, stretch from the valley up toward the summit of the peaks, while solitary volcanic buttes give evidence of others that have crumbled away. On the west side of the mountain narrow, sharp ridges, surmounted by the same walls that caused their present existence, lead up to the sharp summit of the higher peak.

In his later report on the erupted rocks of Colorado, Endlich (1878, p. 234–235) stated enthusiastically: "Among all the mountains that have come under my observation, none has been fraught with the absorbing interest presented by the Spanish Peaks."

In 1894–95, Hills (1899, 1900, 1901) examined the Spanish Peaks region and reported the remarkable diversity of igneous rock types, the great variety of types of igneous features, the sequence of magmatic invasion, and the amazing patterns of the numerous dikes associated with Silver (Dike) Mountain and the Spanish Peaks.

Cross (1914), although he had never been in the area, discussed the dike rocks of the Apishapa quadrangle which were collected by G. K. Gilbert in 1894. Cross (1914, p. 29) wrote that, "the dikes in the Apishapa quadrangle belong to a great system of radial dikes, with associated sills, which surround the Spanish Peaks, an eruptive center situated 25 miles southwest of the border of the quadrangle."

Knopf (1936) gave a detailed petrographic description of some of the rock types in the Spanish Peaks region and presented (p. 1745–1749) his famous discussion on "the lamprophyre concept."

In 1951 the first of a series of maps of the Spanish Peaks region (Wood and others, 1951) by the Geological Survey was published. These maps show the size, shape, and location of most of the igneous features in the Spanish Peaks region. Other maps in this series include those by Johnson and Stephens (1954a, b; 1955), Wood, Johnson, and Dixon (1956), Harbour and Dixon (1956), and Johnson, Wood, and Harbour (1958). Associated with these maps are reports on the geology of the Starkville-Weston area (Wood and others, 1957); the Walsenburg area (Johnson, 1958); the Trinidad-Aguilar area (Harbour and Dixon, 1959); Huerfano Park (Johnson, 1959); and the Trinidad coal field (Johnson, 1961a), in which a generalized description of the igneous rocks is given.

Much new information on the igneous geology of the Spanish Peaks region was derived from the Survey's recent studies there. Modern mapping techniques and petrographic examination of numerous thin sections supplemented by abundant chemical and spectrographic analyses of the igneous rocks have contributed to this new store of knowledge.

Odé (1957) presented a mechanical analysis of the dike patterns near the Spanish Peaks. Various aspects of the igneous geology of the Spanish Peaks region have been discussed briefly by the author (Johnson, 1960; 1961b, c; 1964).

Regionally, the land rises gently westward, but the large igneous masses that form the Spanish Peaks, Mount Mestas, Rough Mountain, Dike Mountain, Sheep Mountain, Little Sheep Mountain, Black Hills, and Little Black Hills stand above the surrounding country and are prominent features of the Spanish Peaks region. These masses are stocks, laccoliths(?), and sole injections, but plugs, dikes, sills, and lava flows form mesas, buttes, ridges, and walls that add character to the landscape. Lava sheets that cap the high Raton mesas southeast of the Spanish Peaks rise abruptly above the plains to a maximum height of 9,627 feet on

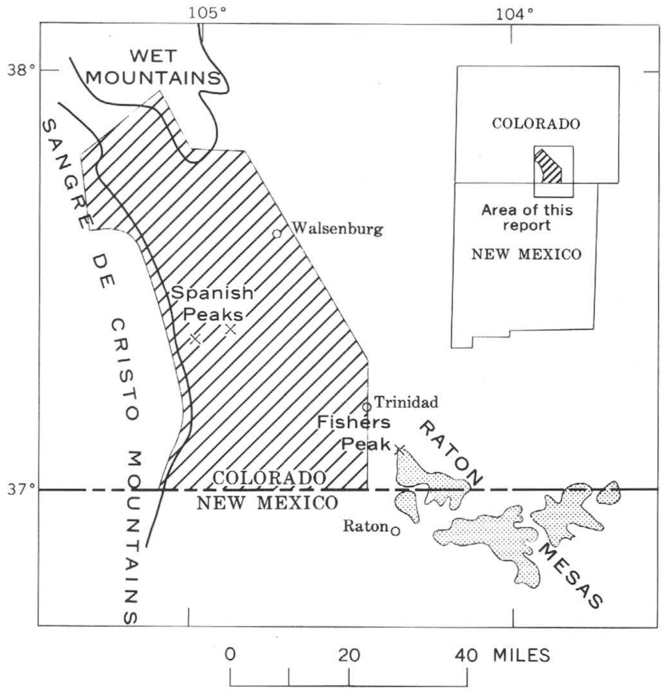

FIGURE 1.—Index map of Spanish Peaks region.

Fishers Peak. Volcanic cones are scattered throughout the plains southeast of the Spanish Peaks and occur locally on the Raton mesas. The entire region, of course, is dominated by the Spanish Peaks, which rise sharply above the surrounding country to culminate at 13,623 feet on West Spanish Peak. Among the most unusual geologic features are the numerous relatively straight vertical-walled dikes as much as 100 feet high that crisscross the region.

The Spanish Peaks region of south-central Colorado includes parts of the Sangre de Cristo and Wet Mountains, some of the High Plains, Huerfano Park, and a large part of the Raton Mesa region as well as the Spanish Peaks. The area includes nearly 2,000 square miles, mostly in Las Animas and Huerfano Counties and small parts in Costilla and Custer Counties (fig. 1).

Fieldwork was done during the summer and early fall in 1948–53 and 1956. Several weeks were spent in the field during 1954, 1957, 1958, 1960, and 1962. I express my appreciation to my associates for the use of their maps, field notes, and drawings. Proctor Hayes and Julian Tracy of La Veta, Colo., because of their knowledge of the country and interest in prospecting, acted as willing guides to the more remote parts of the region.

GEOLOGIC SETTING

GENERAL FEATURES

Many igneous rock types have intruded the sedimentary rocks of the Spanish Peaks region as stocks, laccoliths, sole injections, plugs, sills, and dikes. West Spanish Peak, East Spanish Peak, the White Peaks, Rough Montain, Dike Mountain, the Little Black Hills, and several smaller bodies (pl. 1) are classed as stocks. The intrusives that make up the Black Hills and Sheep Mountain–Little Sheep Mountain are classed as laccoliths. The igneous mass at Mount Mestas is a sole injection. Ten to 15 plugs occur in and adjacent to the mapped area, but only Goemmer Butte, Gardner Butte, and Santana Butte are sufficiently large to have been formally named. Although the larger igneous masses dominate the topography and sills are very numerous, dikes are the characteristic igneous features of the Spanish Peaks region.

Most dikes are members of the large radial dike system associated with the Spanish Peaks, a smaller radial dike system associated with Dike Mountain, or a large subparallel system that strikes generally east-west throughout the region normal to the strike of the folded sedimentary rocks (Johnson, 1964, p. B69). Many dikes, however, belong to small sets or occur singly.

The dikes range in width from 1 foot to nearly 100 feet and extend for a maximum length of almost 14 miles. Most of the dikes vary in thickness, but abrupt thinning and thickening are not common. Locally, several dikes apparently fill a single joint; at other places a single dike fills a single joint and is discontinuously exposed along the entire length of the joint. The dikes are generally more resistant to erosion than are the intruded sedimentary formations, and consequently they stand as relatively straight walls (fig. 2) that rise as much as 100 feet above the surrounding country. Almost all dikes are vertical or nearly so. Polygonal joints normal to the sides of the dike walls are common, and at some places country rock bleached by contact metamorphism adheres to the dikes (fig. 3).

Petrographically, the igneous rocks make up a continuous serial gradation from granite to gabbro. These

FIGURE 2.—Profile Rock, granodiorite porphyry dike. One of several silicic dikes that stand more than 100 feet above the surrounding country. View is eastward.

include phaneritic, aphanitic, porphyritic, and lamprophyric varieties of granite, granodiorite, syenite, syenodiorite, diorite, syenogabbro, and gabbro. Chemically, these rocks range from acidic to ultrabasic and from oversaturated to undersaturated types. They also are peraluminous to subaluminous and calcic to alkalic.

The various igneous rock types appear to represent separate magmatic phases, and the general sequence of invasion of the several phases was determined in the field by studying the structural relationships of the various types of igneous rocks and features. Intersections of dikes were particularly useful. Generally, the sequence of intrusion does not seem to have been from mafic to silicic; instead, it seems to have been almost the reverse—the oldest intrusive is probably the granite porphyry of the East Spanish Peak stock, and mafic dikes and sills of the parallel dike system are among the youngest (Johnson, 1961b, p. 585).

Metamorphic rocks include gneiss and schist of Precambrian age in the Sangre de Cristo and Wet Mountains and contact metamorphic rocks associated with intrusives of Tertiary age throughout the Spanish Peaks region. The effect of contact metamorphism on the sedimentary rocks generally was not great. Locally, bleached sandstone and baked shale adhere to the walls of some of the smaller intrusive bodies. Shale has been altered to slate and phyllite near the White Peaks, Mount Mestas, Rough Mountain, Black Hills, and other intermediate-size intrusive bodies. Contact metamorphism is very prominent next to the intrusive mass of West Spanish Peak, where conglomerate, sandstone, and shale beds have been altered to conglomeratic quartzite, hornfels, and slate.

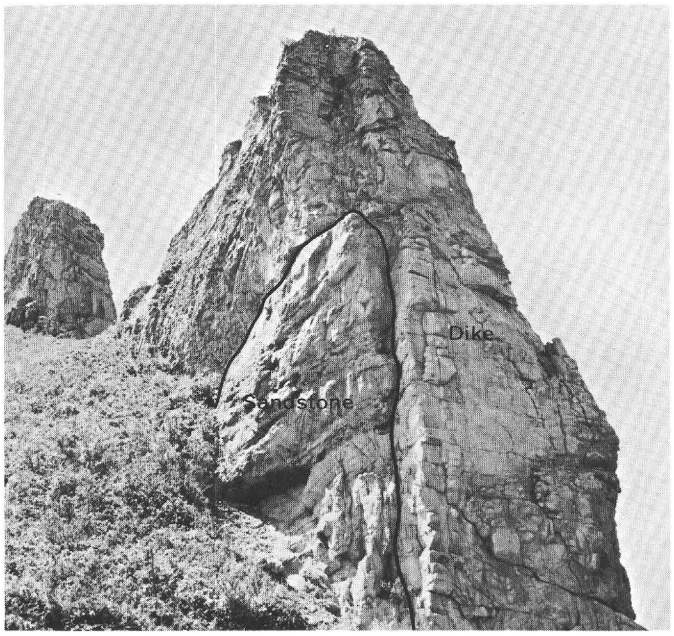

FIGURE 3.—Bleached sandstone adhering to east wall of Devils Stairway granite porphyry dike (pl. 1, loc. 78). View is southwestward.

SEDIMENTARY ROCKS

Sedimentary rocks of Paleozoic, Mesozoic, and Cenozoic ages crop out in the Spanish Peaks region and have been discussed in several reports (Johnson and Wood, 1956; Johnson and Baltz, 1960; Johnson, 1961a, 1962). The sedimentary formations are an unnamed unit of Pennsylvanian age; the Sangre de Cristo Formation of Pennsylvanian and Permian ages; the Lykins(?) Formation of Permian(?) and Triassic(?) ages; the Johnson Gap Formation of Triassic(?) age; the Entrada Sandstone, the Ralston Creek(?) Formation, and the Morrison Formation of Jurassic age; the Purgatoire Formation, the Dakota Sandstone, the Graneros Shale, the Greenhorn Limestone, the Carlile Shale, the Niobrara Formation, the Pierre Shale, the Trinidad Sandstone, and the Vermejo Formation of Cretaceous age; the Raton Formation of Cretaceous and Paleocene ages; the Poison Canyon Formation of Paleocene age; the Cuchara Formation and the Huerfano Formation of Eocene age; the Farisita Conglomerate of Oligocene(?) age; and the Devils Hole Formation of Miocene(?) age.

Quaternary alluvium occurs in most of the stream bottoms and on adjacent flood plains. Soil and pediment deposits cover large parts of the region. Landslide debris surrounds many of the mountains.

Rocks of pre-Cretaceous age are exposed in the Sangre de Cristo Mountains, Huerfano Park, the Wet Mountains, and the canyons of the Purgatoire, Apishapa, Cuchara, and Huerfano Rivers east of the Spanish Peaks. Cretaceous and younger rocks crop out over most of the region.

STRUCTURE

The principal structural feature of the Spanish Peaks region is the Raton basin, which is a broad asymmetric trough whose axis trends generally northward from near Ute Park, N. Mex., into Huerfano Park, Colo. The trough of the basin in Colorado has been named the La Veta syncline (Johnson and Stephens, 1954a). At the north extremity of the syncline, near Black Mountain (pl. 1) in Huerfano Park, the fold is masked by the relatively flat lying beds of the unconformably overlying Farisita Conglomerate. The east limb of the syncline has a gentle dip, but the west limb dips steeply and is vertical to overturned in places. The Sangre de Cristo Mountains border the syncline on the west, and eastward thrusting in the mountains has deepened the syncline and greatly modified its west limb in Huerfano Park. The trough of the La Veta syncline, except where it has been warped locally by thrusting from the west, parallels the frontal thrust fault of the Sangre de Cristo Mountains. The Greenhorn anticline plunges southward from the Wet Mountains and splits the La Veta syncline into a major syncline to the west and a minor one, the Delcarbon (Johnson and Stephens, 1954a), to the east. In cross section the Delcarbon syncline is shallower and more symmetrical than the La Veta syncline.

THRUST AND REVERSE FAULTS

Southward from Middle Creek, west of La Veta, one to three thrust faults parallel the east front of the Sangre de Cristo Mountains along the steep west limb of the La Veta syncline (pl. 1). Northward from Middle Creek and into Huerfano Park large imbricate thrust sheets that lie in advance of the frontal thrust fault of the Sangre de Cristo Mountains have piled up to cause intense faulting and folding of the sedimentary rocks in the west limb of the syncline (Johnson, 1959, p. 107–111). The imbricate thrust sheets are salients of the main thrust sheet that has overriden the west limb of the syncline at most places in Huerfano Park.

West of Huerfano Park the Sangre de Cristo thrust complex is a hinterland mass from which several imbricate overthrust salients project eastward. The hinterland is made up of beds of unnamed rocks of Pennsylvanian age and the Sangre de Cristo Formation and it is bordered on the east by a high-angle thrust fault. The Paleozoic beds within the hinterland mass dip steeply west but have not been complexly folded and so are in their normal stratigraphic position.

East of the Sangre de Cristo thrust fault lie thrust salients consisting of imbricate and locally folded plates that have been overthrust to the northeast. These thrust plates consist of sedimentary rocks of Pennsylvania, Permian, Jurassic, Cretaceous and early Tertiary ages. Each thrust plate is bordered on the east by a secondary thrust fault, which usually has been moved along bedding planes. The salients are thrust over highly contorted beds of sedimentary rocks of Permian, Jurassic, Cretaceous, and Tertiary ages. The margins of the individual overthrust salients generally are clearly marked by the traces of the bordering thrusts. The bordering thrusts originally may have extended beyond the present margins of the overthrust salients. In Huerfano Park, where they are well developed, the salients have been named (Johnson, 1959, p. 108) the Paludura Creek overthrust salient, the Greaser Creek overthrust salient, and the J. M. overthrust salient. East of these overthrust salients are areas consisting largely of highly folded sedimentary rocks of Cretaceous and Tertiary ages.

Along the southwest flank of the Wet Mountains, an early longitudinal high-angle reverse fault, the Reveille Canyon fault (Johnson, 1959, p. 111), has been broken and offset by later transverse faults. The broken remnants of the block uplifted by the Reveille Canyon reverse fault are preserved in a series of small tilted blocks along the southwest flank of the mountains. The sedimentary rocks in the fault blocks are Jurassic and Cretaceous in age. Precambrian gneiss and schist rest at a high angle upon westward-dipping beds of Dakota and Entrada Sandstones.

NORMAL FAULTS

Normal faults are not characteristic of the Spanish Peaks region, but isolated groups of normal faults occur throughout the region. Two normal faults near the northeast margin of the region cut the two flanks of the Delcarbon syncline and trend generally parallel to the axis of the syncline, with their upthrown sides toward the axis. The throw of each fault is less than 50 feet.

The highly fractured and altered block of sedimentary rocks that lie between the Spanish Peaks seems to have been brought from depth by the intrusion of the East Spanish Peak magma. The relations of the faulting are obscured by cover, but the faults seem to be normal. The rocks are highly fractured and faulted, and only the major faults were mapped. The vertical displacement along these major faults may be as much as 6,000 feet.

Several small normal faults occur northeast of Weston. These faults trend north, east, northeast, and northwest and seem to be related to a small anticline or dome. Faults north of the dome have been downthrown on the south, southeast, and southwest sides, whereas faults south of the dome have been downthrown on the west, northwest, and northeast sides. Most of these faults are nearly vertical and have displacements of less than 50 feet.

The large longitudinal normal fault along the southwest flank of the Wet Mountains (pl. 1) is called the Wet Mountains fault (Johnson, 1959, p. 111). This fault has a sinuous trace that is convex to the northeast, and its scarp is a prominent feature of the present topography of Huerfano Park. The fault generally parallels the margin of the southern Wet Mountains. East of Huerfano Park it continues eastward for several miles and then again turns northward along the east flank of the Wet Mountains. Many transverse normal faults have resulted from the movement along the Wet Mountains fault. A fault that generally parallels Maes Creek is the only transverse fault believed to cut and offset the Wet Mountains fault in Huerfano Park. Another transverse fault extends southward from Maes Creek and splits near Gomez Canyon to form two faults; near Farisita the two faults converge to form a single fault that continues southward until its trace is lost in the Pierre Shale.

Solitary vertical or nearly vertical normal faults occur locally but have such small displacement and extent that they are not shown on the geologic map (pl. 1).

FOLDS

The Greenhorn anticline south of the Wet Mountains fault plunges southward and splits the La Veta syncline. It is a single anticline where it is breached by the Huerfano River near Badito, but northward it splits to form a double anticline and an intervening syncline whose trough forms the crest of the present topographic hill that is the southernmost extention of the Wet Mountains. The intrusion of the Black Hills magma in the nose of the anticline south of Badito further domed the sedimentary rocks, and beds of the Poison Canyon Formation arch over the southern part of the intrusive mass.

At two other places in the region, folds in the sedimentary rocks have been caused by intrusion of igneous rocks. The intrusion of the East Spanish Peak magmas to form the stock domed beds of the Cuchara Formation directly west and south of the stock but did not fold beds north and east of it. At Morley a large sill, which does not crop out in the mapped area, has been intruded between the Purgatoire Formation and the Dakota Sandstone and arched the beds above it in an irregular dome called the Morley dome.

A narrow, slightly sinuous monoclinal flexure occurs 3 miles northwest of Aguilar. The monocline trends northeastward through beds of the Trinidad Sandstone and the Vermejo, Raton, and Poison Canyon Formations. The rocks on the northeast side of the monocline are downfolded through a zone less than a quarter of a mile wide. Dips are as steep as 50° in places. The vertical displacement is about 50 feet at the northeast, and it increases southwestward to a maximum of nearly 200 feet. The fold is sharp, and at places along the edges of the flexure the dip increases from less than 2° to more than 40° within horizontal distances of less than 400 feet (Harbour and Dixon, 1959, p. 464).

In the southwestern part of the region are the Tercio anticline and the Cuatro syncline. The anticline may have a closure of almost 1,000 feet. Several long narrow irregular folds of low structural relief occur south of the Spanish Peaks. The axes of these folds have no preferred orientation (Wood and others, 1957, pl. 2). Southwest of the Spanish Peaks, the Whiskey Creek anticline extends for approximately 9 miles north-south in the Sangre de Cristo Mountains. The east limb has been broken and thrust eastward at a high angle over other beds east of the fault. Here the fault generally parallels bedding planes in the Sangre de Cristo Formation and has caused many transverse faults along the southeast nose of the faulted anticline. The west limb has been overridden by a low-angle thrust fault to displace the axis of the anticline at the south. To the east the beds in both limbs are steeply dipping to nearly vertical, but none, including those overridden by the subsequent thrust fault, are overturned.

South of Mount Mestas an overturned and compressed anticline and syncline occur on an imbricate thrust plate. The axial planes of these folds parallel the trace of the major thrust faults and are inclined to the west. The anticline has been strongly sheared by a thrust fault.

A small syncline whose east limb is cut by a thrust fault lies in the eastern part of an overthrust salient east of Paludura Creek and south of the Huerfano River. The sedimentary rocks beneath and east of the salient have been folded and locally overturned by the eastward movement of the salient to form the Malachite syncline and the Little Sheep Mountain anticline. A series of small steeply plunging tight folds north of Redwing probably was formed by the eastward movement of an overriding thrust salient. Southwest of Redwing along Huerfano River the sedimentary rocks are highly folded into an overturned recumbent anticline whose axis probably does not intersect the surface in the mapped area. An anticline and a syncline on the upper limb of the recumbent anticline are exposed on the surface and appear to be completely overturned. A nonimbricate thrust salient occurs in the northwestern part of Huerfano Park along Muddy and Bruff Creeks; it is composed of the tightly folded rocks of two sharply folded synclines and two sharply folded anticlines that become more tightly folded toward the bordering thrust fault. The most easterly anticline is slightly torn by a small fault, and the beds of the east limb north of the tear fault are overturned for a short distance. South of this thrust salient the Malachite syncline and the Little Sheep Mountain anticline have been torn, and the axes of these folds have been dragged eastward.

JOINTS

Throughout the Spanish Peaks region the competent sedimentary rocks, such as conglomerate, sandstone, and limestone, are highly jointed (Johnson, 1961b, p. 581). The dominant joint system strikes generally east normal to the strike of the folded sedimentary rocks, and it apparently formed as a result of tension during the folding of the La Veta syncline. All major joints in this system extend for many miles. Other less well developed joint systems occur in the region and may have been formed by intermittent orogenic stresses of varying direction during folding of the syncline. The joints have not been mapped owing to poor exposures over large areas. Numerous joints of all systems have been filled with igneous magma to form the characteristic dikes for which the Spanish Peaks region is so well known.

GENERAL FEATURES OF IGNEOUS ROCKS

The highly diverse igneous rocks and structures of the Spanish Peaks region are well known to geologists. Intrusive igneous masses—stocks, laccoliths, sole injections, plugs, dikes, and sills—have invaded the sedimentary rocks, and many of these intrusives form the mountains, hills, and buttes that dominate the landscape. Basaltic lava sheets cap the high Raton mesas southeast of Trinidad, Colo., and east of Raton, N. Mex. Volcanic cones are scattered throughout the plains southeast of the Spanish Peaks and occur locally on the Raton mesas. The stocks that make up the Spanish Peaks rise sharply above the surrounding country to culminate at 13,623 feet on West Spanish Peak. Southeast of the Spanish Peaks the Raton mesas rise abruptly above the plains to a maximum height of 9,627 feet at Fishers Peak.

In the Spanish Peaks region most intrusive igenous rocks probably were emplaced at various intervals during late Eocene or early Oligocene time, as they cut sedimentary rocks as young as the Huerfano Formation of early and middle Eocene age but do not cut the Farisita Conglomerate of probable Oligocene age or the Devils Hole Formation of probable Miocene age. Possibly, however, some of the dikes and sills in the southeastern part of the region (pl. 1) and some of the plugs are contemporaneous with the upper Tertiary(?) and Quaternary lava sheets of the Raton mesas (Hills, 1899, p. 2; Griggs, 1948, p. 39).

Most of the intrusive igneous rocks were probably emplaced soon after the structural Raton basin had been fully developed and after the eastward thrusting of the Sangre de Cristo Mountains had subsided. By and large, the intrusive bodies show no structural deformation that occurred after consolidation of the magma. Exceptions are the igneous mass a short distance north of Stonewall (pl. 1, loc. 2) and two sills southwest of Sheep Mountain, which have been cut by tear faults.

Petrographically, the igneous rocks have great diversity and make up a continuous gradation in rock types from granite to gabbro. These include phaneritic, aphanitic, and porphyritic varieties of granite, granodiorite, syenite, syenodiorite, diorite, syenogabbro, and gabbro as well as lamprophyric varieties of syenite, syenodiorite, diorite, syenogabbro, and gabbro. These rock types also include leucocratic, mesocratic, or melanocratic varieties, of which many contain large amounts of olivine and analcime. The extrusive rocks are made up of basalt. In this report, the igneous rocks are classified petrographically according to the quantitative mineralogic system of Johannsen (1939, p. 141–161).

Chemically, the igenous rocks analyzed show a wide variance in composition. On the basis of silica content these rocks range from acidic to ultrabasic types and from oversaturated to undersaturated types. They are classified as peraluminous to subaluminous on the basis of the amount of alumina present and as calcic to alkalic on the basis of the ratio of lime to alkalies.

The igneous rocks have been studied microscopically, chemically, and spectrographically. Many of the igneous bodies were examined microscopically by means of 278 thin sections; 87 chemical and spectrographic analyses were made. All the bodies were not sampled; instead typical rocks were identified, and the rock types of the remainder determined megascopically in the field. Generally only one sample was collected from what appeared to be the dominant rock type of a particular igneous body, and thus vertical and horizonal changes in texture, mineralogy, and chemistry are unknown. Some igneous bodies were sampled to study these changes, but only one, Walsen dike (pl. 1, locs. 28 and 38), was studied in detail (Johnson, 1964). Here, to study not only the three separate intrusives that make up the dike but also the associated chill borders, xenoliths, facies changes, structural features, and the effects of alteration and weathering, samples were collected for the preparation of 17 thin sections and for 15 chemical and spectrographic analyses. The specimens studied are therefore, only a small sample of the entire petrologic suite of the region, but these specimens probably are representative of this diverse group of igneous rocks.

Almost all the specimens examined display decomposition and disintegration of certain minerals due to weathering, and most specimens show the effects of deuteric, intratelluric, or hydrothermal alteration. The introduction of minerals from ground-water solutions seems to have been less widespread. The mafic rocks are generally much more altered than the silicic rocks. In the intermediate and mafic rocks the ratio between the various feldspars is often difficult to determine because of decomposition and alteration.

INTRUSIVE BODIES

STOCKS

Stocks make up East Spanish Peak, West Spanish Peak, Rough Mountain, the White Peaks, and the Little Black Hills. Smaller stocks make up Dike Mountain and several unnamed mountains along the eastern front of the Sangre de Cristo Mountains from near the State line to Huerfano Park. The four small igneous masses that intrude sedimentary rocks southwest of Tercio and the group of igneous bodies near Stonewall may be offshoots of concealed stocks. Two small narrow stocks are southwest of La Veta, and small stocks are adjacent to Mount Mestas and west of Sheep Mountain.

East Spanish Peak

East Spanish Peak is made up of two separate intrusions of granite porphyry and granodiorite porphyry that intrude the Cuchara Formation a short distance east of the axis of the La Veta syncline. The stock is roughly circular in plan (pl. 1) and has a large northwest-trending extension that terminates in two sills (fig. 4). In outcrop the mass is about 5½ miles long and 3 miles wide. The enclosing sedimentary rocks have been domed along the western and southern flanks of the peak without apparent metamorphism; however, on the southwest margin of the stock a faulted block of metamorphosed sedimentary rocks of Paleocene and Cretaceous age was carried up by the granite magma.

Hills (1901, p. 4) stated that an augite granite porphyry occupies the summit and the western face of the East Peak, and that a granite porphyry forms the main mass of the East Peak and the ridge extending northwestward from it. He believed that the granite porphyry grades upward into the augite granite porphyry and that the change from one to the other takes place through a very narrow zone. Knopf (1936, p. 1735, 1736) classified Hills' augite granite porphyry as granodiorite porphyry and considered it intrusive into the granite porphyry. Knopf's observation is confirmed by the presence of a black fine-grained border facies where the granodiorite porphyry has been chilled against the granite porphyry. This border facies can be traced throughout the southeast quadrant of the peak.

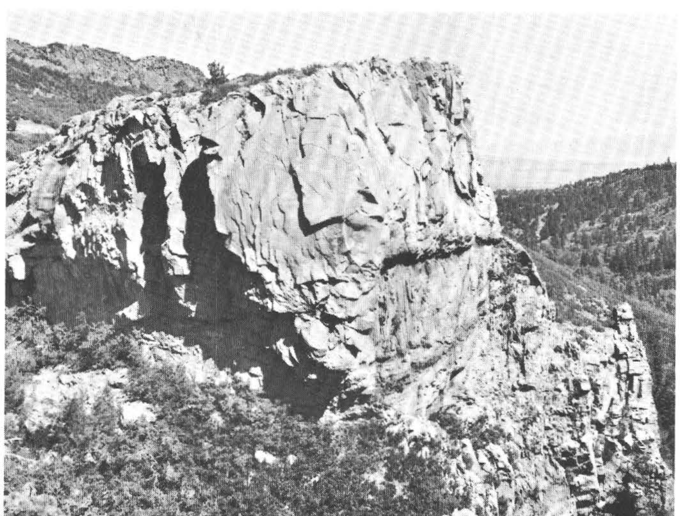

FIGURE 4.—Two granite sills at northwest termination of East Spanish Peak intrusive. Lovers Leap in Wahatoya Canyon. View is northward.

West Spanish Peak

The West Spanish Peak stock is made up mainly of syenodriorite porphyry, and it intrudes the Huerfano and Cuchara Formations near the axis of the La Veta syncline (pl. 1). In outcrop the stock is about 2¾ miles long and 1¾ miles wide. The western part of the mass is laccolithic(?) and caps metamorphosed sedimentary rocks and basaltic sills near the top of the peak. The base of the intrusive cuts across these older rocks at a very low angle (Johnson, 1961b, pl. 1). Near the center of the intrusive, however, the base cuts sharply downward so that the contact between the igneous mass and the sedimentary rocks is several thousand feet lower in altitude than at the west end of the stock. The sedimentary rocks are altered to at least 900 feet from the border of the stock, but there is no apparent doming or faulting of the enclosing rocks as a result of the invasion of the West Spanish Peak magma. Rocks domed by the earlier invasion of the East Spanish Peak magma were intruded by the West Spanish Peak magma without further structural deformation. Locally, many quartz veins cut the laccolithic part of the stock and the adjoining metamorphic rocks.

Hills (1901, p. 4) termed the rocks of the West Spanish Peak stock "augite-diorite," and Knopf (1936, p. 1735) stated that the West Spanish Peak stock consists of several facies of syenodiorite. West Spanish Peak is surrounded by an impressive system of nearly radial dikes, most of which seem to have their foci in the area occupied by the stock (Johnson, 1961b, p. 583).

North, Middle, and South White Peaks

A short distance west of West Spanish Peak, a smaller elongate stock of granite porphyry forms the three hills known as North, Middle, and South White Peaks (pl. 1). The mass is intruded into steeply eastward dipping beds of the Pierre Shale, the Trinidad Sandstone, the Vermejo Formation, the Raton Formation, and the lower part of the Poison Canyon Formation. The stock is elongate north and south and terminates in sills to the north. The mass is 3 miles long and is ⅓ to more than ½ mile wide in outcrop. The boundary of the stock is largely covered, and no apparent deformation of the enclosing sedimentary rocks has resulted from the intrusion. Exposures are fair along the west margin of the stock, and here the contact with the altered Pierre Shale underlying the stock appears to be nearly planar and horizontal.

The relations of the White Peaks stock to structural features and other types of igneous features are obscure. The stock is intruded into an area along the western limb of the La Veta syncline where the dip of the sedimentary beds is less steep than north and south of the intrusive, and the beds form an arcuate flexure toward the west. The thrust fault that is evident elsewhere along the eastern front of the Sangre de Cristo Mountains is not evident here.

The granite porphyry of the White Peaks stock is petrographically similar to the granite porphyry of the East Spanish Peak stock, and the two stocks may have been derived from the same magma almost contemporaneously. The White Peaks stock is apparently older than the radiating dikes associated with West Spanish Peak, but the stock is not cut by them. Instead, it seems to have been a partial barrier to the invasion of the dike magma into the sedimentary rocks west of the stock.

Rough Mountain

An elongate stock at Rough Mountain is mainly syenite porphyry but is locally syenodiorite porphyry. It intrudes steeply dipping overturned and thrust-faulted beds of the Pierre Shale near the west margin of the Raton Mesa region (pl. 1) and at its northern extremity appears to have been intruded along the plane of the Sangre de Cristo thrust fault in much the same manner as the mass of Mount Mestas (p. G11). Several smaller bodies of syenite porphyry near Rough Mountain may be apophyses of the larger mass. The Rough Mountain stock is irregular in plan and is about 2½ miles long and ¼–½ mile wide in outcrop. Talus and landslide debris cover the boundary of the stock except at its northernmost exposures, where the contact with the underlying Pierre Shale appears to be nearly flat. Here the adjacent shale is metamorphosed for almost 750 feet from the contact; this metamorphism, however, appears to be due in large part to the injected microsyenite that makes up nearby Mount Mestas.

Dike Mountain

The Dike Mountain stock of syenodiorite porphyry intrudes the Cuchara Formation near the axis of the La Veta syncline (pl. 1). The stock is very irregular in outcrop, about 1¼ miles long in a southwest-northeast direction and only about 450 feet wide at its narrowest part. The contact of the intrusive with the surrounding sedimentary rocks is covered, and no metamorphism or doming and faulting of the enclosing rocks is apparent. A very striking and conspicuous system of dikes radiate in all directions from Dike Mountain (Johnson, 1961b, p. 586).

Little Black Hills

The Little Black Hills are made up of an irregular crescent-shaped stock of syenodiorite porphyry that intrudes the Pierre Shale along the axis of the Greenhorn anticline (pl. 1). In outcrop the stock measures about 1½ miles across, east-west and northwest-southeast, but the width near the apex of the crescent is one-half mile. The contact between the igneous and the surrounding sedimentary rocks is not well exposed, but metamorphism extends into the sedimentary rocks. The magma invaded the Pierre Shale on the crest of the Greenhorn anticline apparently without deforming the sedimentary rocks. Several small circular bodies of syenodiorite porphyry intrude the Pierre Shale near the south margin of the stock and are probably offshoots from the main mass.

Other stocks

Four small bodies that may be apophyses of a concealed stock of syenite porphyry (pl. 1, loc. 1) appear to intrude the Poison Canyon Formation along the axis of the Cuatro syncline about 4 miles southwest of Tercio, in the extreme southwestern part of the mapped area. The exposures extend along the axis of the syncline for about 1½ miles. They are variously shaped, and in outcrop they range in width from 400 to 2,400 feet. These igneous masses form small rounded hills in a heavily wooded area, and consequently the rocks are very poorly exposed. From what can be observed, the invasion of the magma did not warp or metamorphose the surrounding sedimentary rocks.

Farther north near Stonewall (pl. 1, loc. 2), seven igneous bodies of various sizes and shapes have intruded nearly vertical shale beds of Late Cretaceous age. The intrusives may be offshoots of a buried elongate stock of granodiorite. The magma seems to have invaded the shale along several zones of weakness, because the group extends for nearly 4 miles north and south and generally parallels the strike of the sedimentary rocks. The smallest offshoot, northeast of Russell Lake, is almost 350 feet across in greatest dimension. The northernmost, and largest, offshoot is 1½ miles long north-south, and its greatest width east-west is almost 200 feet. This offshoot is cut by two tear faults related to the frontal thrust fault of the Sangre de Cristo Mountains to the west and is the only stock that is known to have been faulted. Another tear fault may separate this mass from the body to the south (Wood and others, 1956). These igneous bodies form steep rugged hills that stand high above the flat valley formed on the easily eroded shale beds of Late Cretaceous age, but talus at the base of the hills and soil mantling the shale obscure the contact relations. The enclosing shale has been metamorphosed for various distances from the igneous contacts, but there is no evidence of deformation due to the invasion of the magma.

A small sill-like stock of granite porphyry (pl. 1, loc. 3) intrudes nearly vertical shale beds of Late Cretaceous age east of Monument Lake, about 2 miles north of locality 2. The structural relations at this locality are similar to those at locality 2, and the igneous bodies are on the same trend. The intrusive is slightly more than 1 mile long north-south and averages 250 feet wide. The contact with the enclosing rocks is mostly covered by pediment gravel and alluvium, but the mass appears to be generally concordant. Although the shale is highly baked near the stock, metamorphism does not appear to be areally extensive.

Two small narrow stocks of microgranite (pl. 1, locs. 4 and 5) intrude steeply dipping and overturned shale beds of Late Cretaceous age near the frontal thrust fault of the Sangre de Cristo Mountains about 5 miles west of La Veta. The masses are elongate north-south, and crop out as high rugged hills above the intruded beds of shale. The smaller mass is one-half mile long and about 250 feet wide. The larger mass is more than 1½ miles long and is 400–1,600 feet wide. Although the large stock intruded generally parallel to the strike of the sedimentary rocks, it bulges locally and is discordant at all places observed. At isolated exposures nearly 20 feet from the stock, baked shale is conspicuous. Many basaltic sills terminate against the larger stock, but the age relations could not be determined.

The two stocks may be offshoots of a larger buried mass that might have been injected along the sole of the Sangre de Cristo thrust fault. The smaller mass is less than 500 feet east of the trace of the thrust and may have been injected along the sole of the thrust, but talus on the west side of the mass obscures the structural relations.

West of Rough Mountain a small stock of syenite porphyry (pl. 1, loc. 6) intrudes overturned sedimentary rocks and cuts across the Sangre de Cristo thrust fault. The mass is subparallel to the strike of the beds of the Sangre de Cristo Formation in the upper thrust plate but cuts across the bedding of rocks of Cretaceous age below the sole. The mass is three-fourths of a mile long and about 500 feet wide. Where exposed the country rock appears to have been metamorphosed very little.

West of Sheep Mountain a short distance east of the Sangre de Cristo fault, three small stocks (pl. 1, loc. 7) of syenite porphyry intrude overturned sedimentary rocks. Two of the stocks cut the Entrada Sandstone, the Ralston Creek (?) Formation, and the Morrison Formation subparallel to the strike of the bedding, and the westernmost of the three intrusives cuts across beds of the Sangre de Cristo Formation at most places. These stocks are associated with several short dikes and thick sills of syenite porphyry in the immediate vicinity. No metamorphism of the enclosing rocks was noted.

Between Sheep Mountain and Rough Mountain are two small masses of igneous rock surrounded by landslide debris and talus derived from the larger igneous bodies. The shape of these small masses is unknown, but they may be small stocks that have been partly buried by the landslide debris and talus. The northern body (pl. 1, loc. 8) is composed of microsyenite similar to that of the Sheep Mountain–Little Sheep Mountain intrusive and may be related to that body. The southernmost body (pl. 1, loc. 9) is a syenite porphyry similar to that of Rough Mountain and may be an offshoot of that stock.

LACCOLITHS

Two plutonic bodies at the Black Hills and at Little Sheep Mountain and Sheep Mountain have some of the structural characteristics of laccoliths. Critical information concerning certain structural aspects is missing, however, so these intrusives cannot be definitely classified as laccoliths.

Black Hills

At the Black Hills a large intrusive body of syenodiorite porphyry, measuring approximately 2 miles by 1½ miles, has been intruded along an unconformity between the Pierre Shale and the Poison Canyon Formation on the axis of the Greenhorn anticline (pl. 1). The laccolith(?), which appears to be a series of thick sills, seems to have been intruded from the south and attained its greatest thickness at the Black Hills. Beds of the Poison Canyon Formation arch over the southern part of the intrusive, but they have been eroded from the mass elsewhere. A block of highly fractured limestone on the northwest margin of the laccolith(?) probably was torn from the Fort Hays Limestone Member of the Niobrara Formation at depth and moved by the magma to its present position. The outcrop of the laccolith(?) is irregularly crescent shaped in map view. The base is relatively flat and generally well exposed. The underlying Pierre Shale has been extensively altered to slate, and the overlying conglomeratic sandstone beds of the Poison Canyon Formation have been bleached for a short distance from the margin of the intrusive. Several small circular isolated outcrops of syenodiorite porphyry bordering the Black Hills may be offshoots or erosional outliers. No feeder for the laccoliths(?) was observed, although one or more of the large dikes of syenodiorite porphyry radiating from Dike Mountain may have been conduits. One of these dikes is within several hundred feet of the Black Hills laccolith(?) at the surface and may be connected with it at depth. Hills (1900, p. 3) thought that the intrusives of the Dike Mountain and Black Hills were genetically related.

Sheep Mountain–Little Sheep Mountain

An elongate pluton of microsyenite and syenite porphyry comprises the Sheep Mountain–Little Sheep Mountain laccolith(?) (pl. 1). The laccolith(?) is very irregularly shaped in map view; two constrictions that separate Little Sheep Mountain to the north from Sheep Mountain were caused by erosion. A small outlying mass at the south end has been separated from the main body by erosion. The intrusive is over 6 miles long north-south and averages about 1 mile wide, but it narrows to 700 and 1,250 feet at the central constrictions. The base of the laccolith(?) is a nearly plane surface inclined a few degrees to the northwest (fig. 5) and overlies sedimentary rocks of Late Cretaceous and Paleocene age along the axis of the Little Sheep Mountain anticline. No sedimentary rocks arch onto the intrusive. The sedimentary rocks underlying the laccolith(?) are largely covered by talus and landslide material, and the amount of metamorphism and deformation could not be ascertained. The source of the magma is not known. At one time the laccolith(?) was thought possibly to have been fed by an injection along the sole of the Paludura Creek thrust fault south of Huerfano Park (Johnson, 1959, p. 106), but further study in that area did not prove this conjecture (pl. 1).

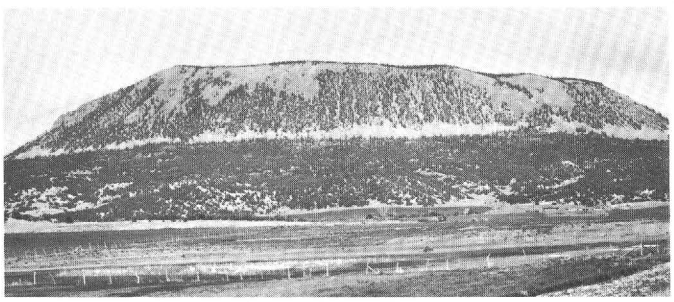

FIGURE 5.—Little Sheep Mountain, showing base of laccolith(?). View is southeastward.

SOLE INJECTIONS

The igneous body at Mount Mestas (pl. 1) is an elliptical mass of microsyenite and microgranite that has been injected along the plane of the Sangre de Cristo thrust fault. Beds of the Sangre de Cristo Formation arch up onto the southwest flank of the intrusive for a short distance but have been eroded from the mass elsewhere. The exposed intrusive is over 2½ miles long northwest to southeast and averages about 1 mile wide; the feeder extends southward along the trace of the thrust for more than 1½ miles from the main mass. An erosional remnant lies a short distance northeast of the main mass. At its thickest part the intrusive probably exceeds 1,200 feet in thickness. The base becomes nearly horizontal a short distance east of the thrust. The sedimentary beds below are part of an imbricate lobate salient in advance of the Sangre de Cristo thrust fault and are made up of steeply dipping and overturned rocks of Cretaceous and Tertiary age. The rocks are metamorphosed for at least 500 feet below the base of the intrusive, where shale has been altered to phyllite and some slate.

A narrow linear body of syenogabbro extends for nearly 1½ miles along the trace of a low-angle imbricate thrust fault east of Mount Mestas (pl. 1, loc. 10); it does not seem to be related to the intrusive of Mount Mestas. The northern part of the syenogabbro body is covered by landslide debris and talus from Mount Mestas. A small sill-like body of gabbro has been injected along a high-angle thrust fault a short distance south of Mount Mestas (pl. 1, loc. 11), several hundred feet east of the Sangre de Cristo thrust fault. It is about ¾ mile long and is terminated at the south by a tear fault. No metamorphism attended the injection of these magmas except for baking of the enclosing rocks within a few inches from the contact.

At the south end of Huerfano Park (pl. 1, loc. 12), two linear bodies of syenite porphyry are inferred to have been injected along one of the low-angle imbricate bedding-plane thrust faults of the Paludura Creek overthrust salient. The northern mass bulges to 250 feet in width at its south end, and the southern mass bulges to 500 feet at its north extremity. Both bodies are on the same alinement, and they crop out for more than 2 miles; they may be joined a short distance below the surface. Three miles west (pl. 1, loc. 13) a short linear sill-like body of microsyenite porphyry is also inferred to have been injected along the trace of a low-angle imbricate bedding-plane thrust fault of the Paludura Creek overthrust salient. Metamorphism has been slight at these localities, and the enclosing rocks were bleached only for several inches to 1 foot from the contact.

PLUGS

Seven small isolated igneous bodies that are scattered throughout the report area north of the Spanish Peaks may be classed as plugs because of their size, shape, and contact relations and the composition and texture of the rock. No plugs are in the report area south of the Spanish Peaks, but a short distance east of Morley a large plug cuts the Raton Formation on the western slope of Raton Mesa (Hills, 1899, p. 3; Johnson, 1960, p. 118). East of the Spanish Peaks region, plugs form many conspicuous buttes on the plains. Four plugs cut the Pierre Shale and the Smoky Hill Marl Member of the Niobrara Formation 2–9 miles northeast of Walsenburg, and two small plugs cut the Smoky Hill Marl Member 5 miles east-southeast of Walsenburg (Johnson, 1958, pl. 47). A cluster of basaltic plugs occurs 11–14 miles northeast of Barilla Mesa (Johnson, 1960, p. 118), southeast of Trinidad.

Goemmer Butte

Goemmer Butte is a latite plug that intrudes the Cuchara Formation 2½ miles southwest of La Veta (pl. 1). It forms a conspicuous and picturesque butte that stands nearly 500 feet above the surrounding country (fig. 6). The plug is irregularly circular and is about 900 feet across in greatest dimension. The contact is vertical, and no doming of the surrounding sedimentary rocks is apparent. Alteration of the enclosing rocks is slight, but bleached sandstone adheres to the walls of the plug. The plug contains several blocks of sandstone that seem to have been stoped. Knopf (1936, p. 1778–1779), who identified the rock as latite and Goemmer Butte as a volcanic neck, wrote: "Coarse breccia of sandstone and latite fragments, in irregular association with massive latite, makes up the plug, which is, therefore, interpreted as a volcanic neck."

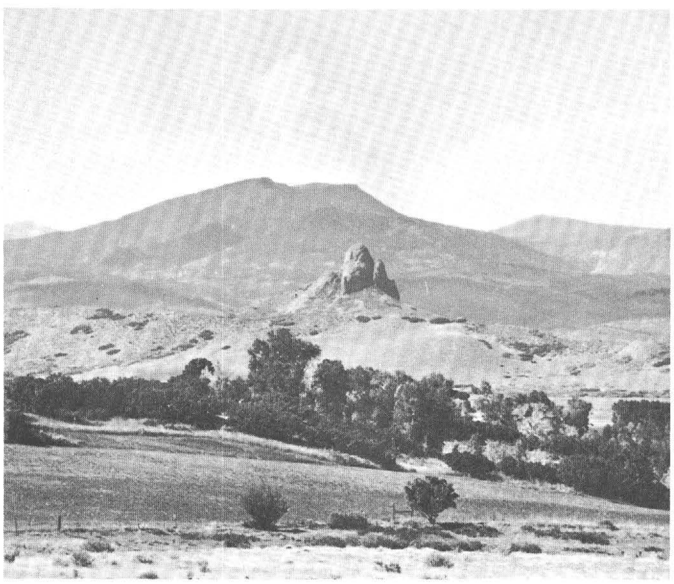

FIGURE 6.—Goemmer Butte, a latite plug. View is southwestward.

Gardner Butte

The igneous plug of microsyenodiorite that makes up Gardner Butte intrudes the Huerfano Formation about 1 mile east of Gardner, in Huerfano Park. It forms a conspicuous landmark that projects about 100 feet above the lowlands along Huerfano River (Johnson, 1959, p. 106). The mass is very irregular in map view and is nearly 1,200 feet across in greatest dimension; an apophysis extends several hundred feet to the east. The contact is vertical, and there is little doming and metamorphism of the enclosing rocks. A crudely defined ring dike curves around the southwestern margin of the plug. The outer wall of this dike is vertical and arcuate. Between the inner margin of this ring dike and the main mass of the plug are large blocks of country rock irregularly associated with syenodiorite. The exact relations could not be determined because the rocks are much weathered and covered with talus. The plug contains blocks of altered shale, siltstone, and sandstone that have stoped. The plug has been highly fragmented in its northeast quadrant, possibly by explosion of gases in the magma.

Santana Butte

Santana Butte is a plug that has been injected along a transverse normal fault on the western flank of the Wet Mountains about 6½ miles northeast of Gardner. The mass is generally circular in map view and is about 750 feet in diameter. The contact is mostly covered by talus from the plug, but apparently the country rock was not deformed by the invasion of the magma, inasmuch as it is only slightly metamorphosed. The rock has been megascopically identified as syenodiorite porphyry.

Other plugs

A small plug megascopically classed as syenodiorite intrudes the Smoky Hill Marl Member of the Niobrara Formation south of Gomez Canyon in the eastern part of Huerfano Park (pl. 1, loc. 14). The mass is generally circular, and its greatest dimension is about 600 feet. A very small plug intrudes the Huerfano Formation near the confluence of Reed Sand Arroyo Creek and Williams Creek about 3½ miles north of Gardner (pl. 1, loc. 15). This plug is circular in map view and is less than 100 feet across in greatest dimension. It also is classified megascopically as syenodiorite. The contacts are nearly vertical, and the country rock about the plugs is only very slightly metamorphosed.

A plug of microgranite 4 miles south of the Black Hills (pl. 1, loc. 16) is intruded into flat-lying beds of the Cuchara Formation. The outcrop is elliptical and is less than 100 feet across in greatest dimension. The mass which is truncated at the top by a pediment, is not well exposed, and it has no topographic expression. The contact is vertical, and there is no doming or metamorphism of the enclosing rocks.

About 7½ miles northwest of Walsenburg (pl. 1, loc. 17) a small circular plug of scoriaceous basalt cuts the Pierre Shale. The perimeter of the plug is pumiceous, and the interior contains many unoriented and rounded gneissic cobbles as much as 6 inches in diameter (fig. 7). The large size of the cobbles indicates that they were derived directly from Precambrian rocks and not from younger sedimentary formations. The plug is less than 25 feet across and stands as a low mound above the sur-

FIGURE 7.—Gneissic cobble-sized xenoliths in scoriaceous basalt plug (pl. 1, loc. 17).

rounding shale. The contact is vertical, and the shale has been baked for several feet from the contact.

DIKES

Numerous dikes crop out in the vicinity of the Spanish Peaks, and they are prevalent everywhere except in Huerfano Park and south of the Purgatoire River. Several dikes west and southwest of the Spanish Peaks in the Sangre de Cristo Mountains cut rocks older than Cretaceous; elsewhere they intrude surface rocks of Late Cretaceous and Tertiary age.

The dikes in the region make up at least three well-defined swarms and several poorly defined groups, and many occur as isolated single dikes or in small sets of dikes that have no apparent relation to the large dike swarms or other large intrusive bodies. The most conspicuous group is the radiating dike swarm associated with the Spanish Peaks (Johnson, 1961b, p. 583–584). A second large and well-defined group is made up of subparallel dikes that strike N. 60° E. in the northeastern part of the region to N. 86° E. in the southern part (Johnson, 1961b, p. 584). Dikes radial to Dike Mountain compose the third conspicuous group (Johnson, 1961b, p. 586–588).

The dikes range from one to more than 100 feet in width, extend for a maximum distance of almost 14 miles, and have a vertical exposure of at least 4,200 feet. Abrupt thinning and bulging, although present locally, is uncommon. Several dikes that apparently filled single joints occur discontinuously along the length of these joints at the surface. Most dikes follow single joints, but a few bifurcate along a transverse joint or cross to an adjacent parallel joint along a transverse joint. A few dikes are composite or multiple in that two or more magmas were injected along the same joint at different times.

Generally the dikes are more resistant to erosion than the intruded formations, and consequently they stand as impressive relatively straight vertical walls (fig. 8) as much as 100 feet above the surrounding country. Some of the more mafic dikes, however, weather more rapidly than the intruded formations and form trenches, and, locally, indurated sandstones along the margins of the dikes stand as low parallel walls above the more easily eroded igneous and unindurated sedimentary rocks (fig. 9). Polygonal joints normal to the dike walls are common. At some places country rock bleached by contact metamorphism adheres to the sides of the dikes (fig. 3).

The rocks of the dikes have a wide chemical mineralogical and textural variance and range from microgranite and granite porphyry to olivine gabbro. The most abundant dike rock is syenodiorite porphyry. Lamprophyres are numerous throughout the Raton Mesa region, and many contain olivine and analcime.

Radial dike swarm of the Spanish Peaks

The Spanish Peaks are surrounded by a very impressive system of nearly radial dikes (pl. 1). The projected intersections of these dikes are mainly within the West Spanish Peak stock, but several dikes converge toward the East Spanish Peak stock, and the foci of some dike trends are outside both stocks. The outer margin of the dike swarm forms an ellipse whose long axis trends N. 80° E., normal to the axis of the La Veta syncline and the eastern front of the Sangre de Cristo Mountains. The stocks of East Spanish Peak, West Spanish Peak, and the White Peaks, as well as an arcuate flexure along

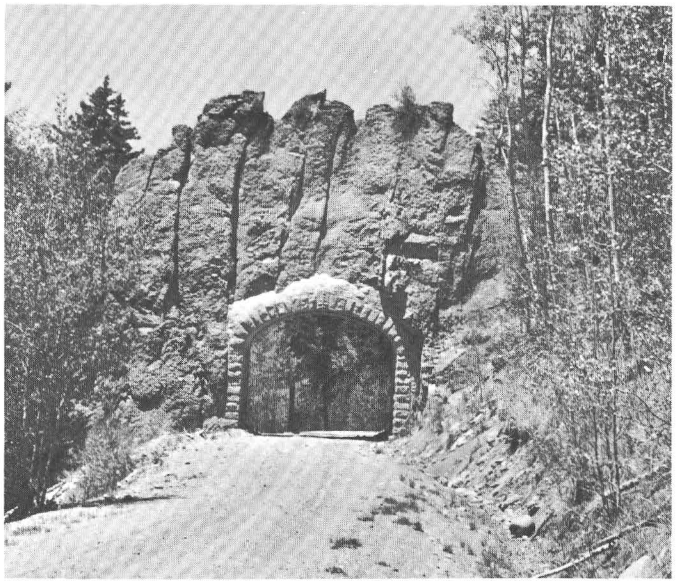

FIGURE 8.—Dike with archway cut through it for road along Apishapa River southeast of West Spanish Peak. View is westward.

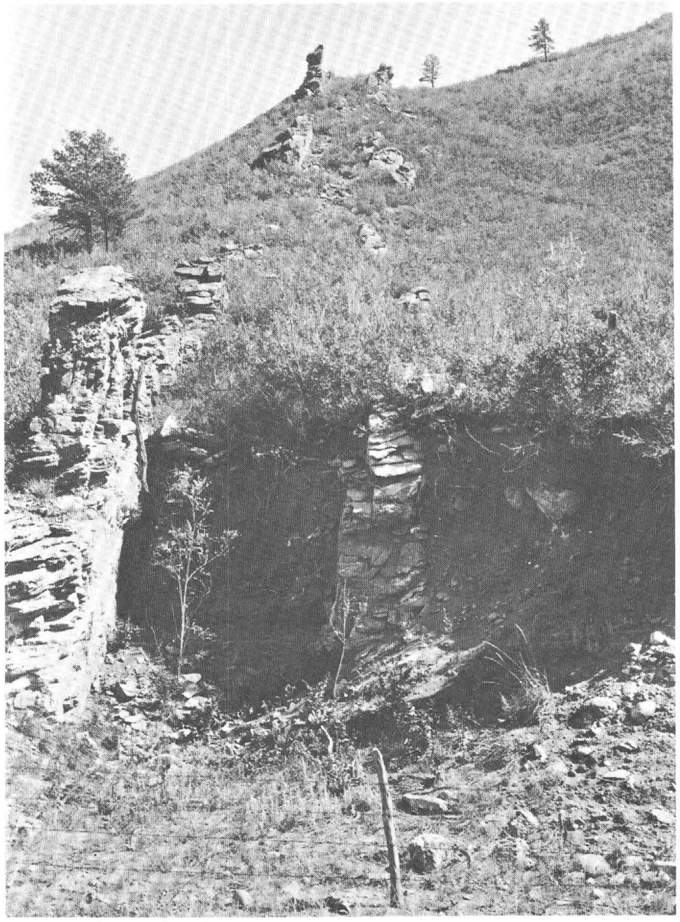

FIGURE 9.—Parallel walls formed by indurated sandstone on margins of a lamprophyre dike that forms trough. View is southward (pl. 1 near loc. 78).

the eastern front of the Sangre de Cristo Mountains, are bisected by the long axis of this ellipse. Dikes west of West Spanish Peak are much shorter than those to the east so that the focal area of the dikes appears to coincide generally with the western focus of the ellipse. Certain areas within the ellipse apparently lack dikes, but except in the area southwest of West Spanish Peak (pl. 1) dikes may be present beneath extensive sheets of pediment gravel.

Many of the dikes, especially in the northeast and southeast quadrants, curve eastward; though most of the dikes in the region are straight, some are sinuous and a few curve westward. One of the long curvilinear dikes (pl. 1 loc. 18) southeast of West Spanish Peak is exposed from an altitude of 7,000 feet to more than 11,200 feet on the southeast flank of West Spanish Peak—a vertical distance of at least 4,200 feet. The dikes range from several hundred feet to more than 10 miles in length, and they extend 13 miles from the West Spanish Peak stock. Dikes are sparse among the sills and metamorphosed sedimentary rocks surrounding the stock of West Spanish Peak, and none of them contact the stock at the surface; some dikes originate as much as 5 miles from the margin of the stock.

Intersections of the radial dikes are fairly common (pl. 1, locs. 19 and 20), and they are the most useful characteristics for determining the sequence of intrusion of the different magmatic phases of the various types of dikes (Johnson, 1961b, p. 585). Locally, the dikes are forked (pl. 1, locs. 21 and 22). Also locally, two parallel dikes of similar composition are connected by a short dike of the same type intruded along a transverse joint (pl. 1, loc. 23). Some dikes are discontinuously exposed along their lengths (pl. 1, locs. 24 and 25). None of the radial dikes are known to be composite, but one is multiple (pl. 1, loc. 82).

Subparallel dike swarm

A second system of dikes transects the radial dike swarm of the Spanish Peaks and crops out from about lat. 37°10′ N. to 37°40′ N. (pl. 1). This system is made up of subparallel dikes that strike N. 86° E. in the southern part of the region and N. 60° E. in the northern part; this trend is normal to the general strike of the folded sedimentary rocks. Some dikes of this system are almost 14 miles long, including the longest in the region. Many of the dikes are remarkably straight for long distances, although some display local curvature (pl. 1, locs. 26 and 27), and some are arcuate (pl. 1, locs. 28 and 29). Locally some are forked (pl. 1, locs. 30 and 31) and others are connected by short transverse dikes of the same composition (pl. 1, loc. 32). At two places (pl. 1, locs. 33 and 44) a dike splits to form two dikes but converges again in a short distance. Many dikes are discontinuously exposed along their lengths (pl. 1, locs. 35–37). Some are composite or multiple (pl. 1, locs. 38 and 39) in that two or more dikes of different or similar minerological and chemical compositions intrude the same joint; Walsen dike (pl. 1, loc. 38) is composite (Johnson, 1964, p. B69). Several dikes terminate in sills to the east (pl. 1, locs. 40–42). Dikes of the parallel system cut dikes of the Spanish Peaks radial system and are transected by several isolated dikes and small sets of dikes, but dikes of the parallel system do not intersect each other.

Many of the parallel dikes change texturally, mineralogically, and chemically throughout their length and breadth; most are finer grained near their margins. A large dike (pl. 1, loc. 43) south of the Spanish Peaks is a glassy andesite lamprophyre along most of its length but locally changes to a quartz aplite near its east extremity (pl. 1, loc. 81).

Radial dike swarm of Dike Mountain

Dikes radial to the Dike Mountain stock compose a third conspicuous system. This system is more perfectly radial than that of the Spanish Peaks, and the dikes have their focus within the small area occupied by the stock. Unlike the radial dikes from the West Spanish Peak stock, several of the Dike Mountain dikes apparently join but do not cut the stock.

The outer margin of this radial swarm is oval in outline, and the longer axis trends N. 65° E., normal to the axis of the La Veta syncline. As in the Spanish Peaks swarm, the dikes radiating westward are much shorter than those radiating eastward. In contrast to the Spanish Peaks swarm, however, there is no great concentration of dikes west of the Dike Mountain stock. The dikes on the west are extremely short and cross two thrust faults; the longest dike west of the stock extends a short distance into the nearly vertical beds of the Pierre Shale. The longest dikes of the swarm extend east-northeastward along the axis of the oval to within a few hundred feet of the Black Hills laccolith. They do not cut the Pierre Shale in this locality.

Most of the dikes are straight, although some curve slightly. They generally range from 100 feet to 2½ miles in length and extend for a distance of 5 miles from the stock. Some dikes originate as much as 3 miles from the margin of the central intrusive.

No areas within the oval are strikingly deficient in dikes, and at only one place (pl. 1, loc. 44) does one dike intersect another of the system. One radial dike is cut by a lamprophyre dike of the subparallel dike swarm (pl. 1, loc. 45) southeast of the Dike Mountain stock. Locally, some of the dikes are forked (pl. 1, locs. 46 and 47), and many of them are discontinuously exposed along their lengths (pl. 1, locs. 48–50). None of these dikes are known to be multiple, nor do they appear to vary much texturally, mineralogically, or chemically.

Several dikes southwest of the stock terminate in sills. One of these dikes is nearly horizontal (pl. 1, loc. 51) and may be the result of invasion of magma into a nearly horizontal feather joint associated with nearby thrust faults.

Smaller dike sets and isolated dikes

Eight miles northeast of the East Spanish Peak stock, a large dike (pl. 1, loc. 52) of microsyenodiorite (Knopf, 1936, p. 1743) cuts across older dikes in an east-west direction. It is arcuate, and the concave face is toward the south. The strike varies as much as 12° from one end to the other. The dike is discontinuously exposed along its extent and terminates in a sill to the east. At Ideal Canyon (pl. 1) it is offset laterally for nearly 1,000 feet. The structural relations are obscured by alluvium along the stream, but Hills (1900, "Igneous Geology" sheet) explained this lateral displacement as a result of a fault.

North of the arcuate dike and a few miles southwest of Walsenburg a small group of syenogabbro dikes (pl. 1, loc. 53) were intruded into joints that are at angles both to the strike of the folded sedimentary rocks and to the trend of nearby dikes of the subparallel dike system. These dikes are locally discontinuous and one is forked.

Two small dike sets are present in the extreme northern part of the Raton Mesa region, about 7 miles northwest of Walsenburg; one is comprised of gabbro lamprophyre dikes (pl. 1, locs. 54 and 55), and the other of syenogabbro and gabbro porphyry dikes (pl. 1, loc. 56). Two lamprophyre dikes strike almost due east, at angles to the strike of the folded sedimentary rocks on the western flank of the Delcarbon syncline. These dikes dip 75°–85° N. The westernmost dike (pl. 1, loc. 54) is displaced short distances at two places by small normal faults. The set of porphyry dikes has invaded the sedimentary rocks near the axis of the Delcarbon syncline between two short normal faults of small displacement. The two larger dikes intersect at an angle of nearly 90° and cut the sedimentary rocks at an angle of about 45° to the strike. The east-trending dike appears to cut the north-trending dike, but the contact relations are obscure because of vegetation and soil cover. Two smaller north-trending dikes abut, but do not cut, the large east-trending dike.

Scattered short and narrow dikes of microsyenite (pl. 1, locs. 57–59) crop out between Sheep Mountain and Little Sheep Mountain on the west, between the Black Hills and the Little Black Hills on the east, and north of the Dike Mountain radial dikes. Although the dikes seem to be randomly oriented, many have intruded joints that strike approximately 30° north or south of a line drawn normal to the strike of the folded sedimentary rocks. Several of these dikes intersect; at all intersections those that trend more eastward seem to cut those that trend more northward.

Along Pass Creek west of Sheep Mountain are several narrow dikes of syenite porphyry (pl. 1, locs. 60–62) that are associated with thick sills (pl. 1, loc. 76) and small stocks (pl. 1, loc. 7) of syenite porphyry. These dikes cut overturned beds of the Sangre de Cristo and Lykins(?) Formations, the Entrada Sandstone, and the Ralston Creek(?), Morrison, and Purgatoire Formations on the east margin of the Sangre de Cristo Mountains.

Many isolated dikes and small dike sets are scattered throughout the region and seem to have no common orientation or patten and no general association with the other types of intrusives. These dikes are mainly thin and short and include diverse rock types.

SILLS

Numerous sills, which are generally dark gray to black and fine grained, have invaded shaly and coaly units of the Upper Cretaceous and Tertiary formations throughout the Spanish Peaks region (Johnson, 1961a, p. 147). A few sills have invaded the more competent rocks of the older formations west of Rough, Sheep, and Little Sheep Mountains. The highest beds intruded by most of the sills are the lowermost beds of the Poison Canyon Formation (pl. 1, locs. 63 and 64). Knopf (1936, p. 1774) reported a sill of microgranite 20 feet thick intruding the metamorphosed beds of the Huerfano Formation near the Spanish Peaks.

Most of the sills occur along the east and west margins of the region from the latitude of Walsenburg south to the latitude of Trinidad (pl. 1), and along the drainage of the Purgatoire River (pl. 1, loc. 65). Several dikes radiating northwestward from West Spanish Peak are apparently parallel to the strike of strata of the Poison Canyon and Cuchara Formations west of the Cuchara River (pl. 1, loc. 66). They are sill-like in plan view but are actually dikes. Although the sedimentary rocks are steeply dipping at 25°–51°, the dikes are nearly vertical and probably cut across the beds below the surface.

The sills in the Spanish Peaks region are commonly multiple intrusions that range in thickness from a few inches to nearly 40 feet and may extend over several square miles. They are generally not thick individual sheets but are made up of anastomosing stringers that appear to concentrate in narrow zones. Some of the sills cut across bedding, but poor exposures make determination of the exact relations difficult. The sills are usually more resistant than the intruded formations and commonly form strike ridges and ledges. North of Cuchara Pass (pl. 1, loc. 67) and near Santa Clara Creek and south to Trinidad (pl. 1, locs. 68–73), sills are connected with dikes of the subparallel dike system and are lithologically similar to the dikes.

South and west of Sheep Mountain and Little Sheep Mountain a thick body of syenite porphyry (pl. 1, locs. 74–76) intrudes steeply dipping overturned sedimentary rocks that range in age from Pennsylvanian to Late Cretaceous. The syenite porphyry intrusive is actually two sills joined near the middle of their outcrops. It is associated with small stocks (pl. 1, loc. 7) and several short dikes (pl. 1, locs. 60–62) of syenite porphyry that crop out a short distance to the west.

EXTRUSIVE BODIES

A small spatter cone of scoriaceous basalt has been erupted onto the Pierre Shale a short distance west of Rough Mountain (pl. 1, loc. 77). It is less than 50 feet across and less than 10 feet high. The base is parallel to the slope of the topography and dips about 10° W. The general form of the mass is roseate.

Extrusive igneous rocks are common in areas surrounding the Spanish Peaks region. The Raton Mesa region southeast of the Spanish Peaks is characterized by the high mesas capped by thick basaltic lava sheets southeast of Trinidad, Colo., and east and northeast of Raton, N. Mex. (Johnson, 1960, p. 120). North of Huerfano Park along Promontory Divide, a brecciated andesite flow rests on an undulating surface cut upon the uppermost beds of the Devils Hole Formation (Johnson, 1959, p. 106). Rocks of volcanic origin form the crest of the Wet Mountains (Hills, 1900, p. 4) and crop out in large patches in the Sangre de Cristo Mountains west of Huerfano Park (Burbank and Goddard, 1937, pls. 4 and 7; Briggs and Goddard, 1956, pl. 1) and near the State line. Large volcanic terranes occur in the Rio Grande Valley of southern Colorado and northern New Mexico and on the Great Plains of northeastern New Mexico (Stobbe, 1949). Two small volcanic cones stand above the lava sheets on Bartlett and Barilla Mesas near the Colorado–New Mexico boundary east of Morley, Colo.

PETROGRAPHY

TERMINOLOGY

The igneous rocks of the Spanish Peaks region are grouped into the following types, on the basis of amounts and kinds of minerals in the rocks as determined by thin-section inspection: Granite, granodiorite, syenite, syenodiorite, diorite, syenogabbro, and gabbro. Syenodiorite is the most common rock type in the region. Granite occurs in dikes, a plug, stocks, and a sole injection; granodiorite, in a sill, dikes, and stocks; syenite, as sills, dikes, stocks, and a probable laccolith; syenodiorite, in stocks, a laccolith, plugs, sills, and dikes; diorite, in dikes and sills; syenogabbro, in sills and dikes; and gabbro, in sills, dikes, plugs, and as lava flows.

All the rock types have porphyritic and aphanitic representatives. Lamprophyres are found among rocks classed as syenite, syenodiorite, diorite, syenogabbro, and gabbro. Phaneritic rocks occur only among the rocks classed as syenodiorite. Aphanitic and porphyritic textures are present in all habitats for igneous rocks in the Spanish Peaks region. Lamprophyric texture is found only in dikes and sills, and phaneritic texture occurs only in a few plugs, dikes, and sills.

Almost all the rocks are holocrystalline, although locally a few syenodiorite and diorite lamprophyre dikes have groundmasses of slightly to highly devitrified glass. Many syenite, syenodiorite, diorite, syenogabbro, and gabbro lamprophyres and aphanites have groundmasses of analcime or zeolitized sanidine. Unusual mineral associations are common in many of the lamprophyres; for example, large phenocrysts of olivine occur in rocks classified petrographically with syenites, syenodiorites, diorites, syenogabbros, and gabbros.

GRANITE

PORPHYRY

Granite porphyry makes up the outer stock of East Spanish Peak; the bulk of the stock that constitutes North, Middle, and White Peaks; a small stock on the west margin of the region (pl. 1, loc. 3); the Devils Stairway dike (pl. 1, loc. 78; fig. 9); and two radial dikes south of West Spanish Peak (pl. 1, locs. 79 and 80).

The granite porphyry stock of East Spanish Peak (Knopf, 1936, p. 1734–1736) is very light gray and consists of phenocrysts of anorthoclase, oligoclase (An_{25}), quartz, biotite, and hornblende set in a fine holocrystalline groundmass of anorthoclase, plagioclase, microperthite, quartz, sphene, magnetite, and apatite. The anorthoclase makes up 40 percent of the volume of the rock, and phenocrysts are as much as 10 mm across. Plagioclase makes up 31 percent of the rock, and phenocrysts of oligoclase may be as much as 3.5 mm across. Quartz makes up 17 percent of the rock and occurs as anhedral to subhedral crystals as much as 3 mm across. Biotite, hornblende, and the accessory minerals constitute 2–5 percent of the rock. The groundmass makes up 19–31 percent of the rock, and microperthite approximately 9 percent.

The granite porphyry stock of North, Middle, and South White Peaks is mineralogically similar to the granite porphyry of East Spanish Peak. The porphyry of the White Peaks is very light gray and locally is microcrystalline in the upper part of the intrusive (Knopf, 1936, p. 1738). Small phenocrysts (less than 2 mm) of quartz, oligoclase (An_{30}), hornblende, and biotite are set in a groundmass of orthoclase, quartz, biotite, and magnetite. Locally, some of the biotite has been altered to a chloritelike mineral. The average mode of the rock, in percent, is: quartz, 17; orthoclase, 37; oligoclase, 30; biotite, 8; hornblende, 3; and accessory and secondary minerals, 4.

The granite porphyry dikes are slightly less silicic and somewhat darker—light to medium gray—than the granite porphyry stocks. Phenocrysts are as much as 4 mm across, and most of them are oligoclase (An_{20}), but locally a few phenocrysts are orthoclase, quartz, and biotite. The mineralogic composition of the dikes, in percent, is: quartz, 5–15; orthoclase, 30–50; oligoclase, 30–38; biotite, 2–6; hornblende, 0–3; magnetite, 1–5; and corundum, trace. Although quartz is usually crystalline in these rocks, it is mainly cryptocrystalline and interstitial in the Devils Stairway dike (Knopf, 1936, p. 1742–1743). Chlorite, epidote, clay, calcite, and an unidentified zeolite are the secondary constituents and although generally sparse, may locally make up as much as 9 percent of the rock. In one dike (pl. 1, loc. 80) a trace of emerald-colored penninite was found in the chlorite.

APHANITE

Microcrystalline varieties of granite are commonly highly silicic. They occur as a large laccolithlike sole injection at Mount Mestas, a plug (pl. 1, loc. 16), and an aplitic residuum (pl. 1, loc. 81) near the upper levels of a glassy andesite lamprophyre dike of the subparallel system.

The intrusive that forms Mount Mestas is a very light gray holocrystalline rock that is so fine grained that its texture appears to be porcelaneous. It is composed of 20 percent quartz, 60 percent anorthoclase, 17 percent oligoclase (An_{15}), a trace of biotite, and 2 percent magnetite. Traces of limonite, chlorite, and clay are the secondary constituents.

The microgranite plug (pl. 1, loc. 16) northeast of La Veta is a very fine grained very light brown leucocratic holocrystalline rock that has a porcelaneous texture. The mineral composition, in percent is: quartz, 6; orthoclase, 60; antiperthite, 20; albite, 10; biotite, trace; corundum, 1; and rutile, 1. Secondary minerals, limonite and calcite, make up 2 percent of the rock.

The aplite residuum (pl. 1, loc. 81) of the andesite lamprophyre dike (pl. 1, loc. 43) is actually a medium-light-gray quartz aplite in that it contains 33 percent quartz that occurs as microphenocrysts. Although the rock appears to have a sugary texture, it is seen under the microscope to be porphyritic. The phenocrysts are embedded in a groundmass that is largely microperthite and contains some limonite and calcite. The total groundmass makes up 23 percent of the volume of the rock, and 17 percent of the rock is microperthite. Orthoclase phenocrysts make up 21 percent; oligoclase (An_{20}), 9 percent; brown biotite, 7 percent; green biotite, a trace; hornblende, 3 percent; corundum, 1 percent; sphene, a trace, and red monazite, a trace.

GRANODIORITE

PORPHYRY

Granodiorite porphyry makes up the inner stock of East Spanish Peak, a sill-like stock near Stonewall (pl.

1, loc. 2), several radial dikes north of the Spanish Peaks (pl. 1, locs. 82, 83, and 87), and a sill near Aguilar (pl. 1, loc. 86).

The granodiorite porphyry stock of East Spanish Peak (Knopf, 1936, p. 1736–1737) is light gray and contains phenocrysts of anorthoclase, 30 percent; oligoclase (An_{25}), 50 percent; augite, 4 percent; and biotite, trace. The phenocrysts are in a fine holocrystalline groundmass that makes up 16 percent of the rock and consists mainly of quartz and plagioclase and small amounts of magnetite and apatite. A black microcrystalline chill border is in contact with the outer stock of granite porphyry; it is made up of, in percent: quartz, 17; orthoclase, 31; oligoclase, 47; augite, 4; and magnetite, 1.

The intrusive of granodiorite porphyry near Stonewall is a light-gray holocrystalline microporphyritic to porphyritic rock. Phenocrysts, as much as 5 mm across are made up of oligoclase (An_{20}) set in a very fine to fine-grained groundmass of quartz, orthoclase, oligoclase, biotite, hypersthene, corundum, magnetite, ilmenite, and chlorite. The rock is composed of, in percent: quartz, 10; orthoclase, 31; oligoclase, 42; biotite, 6; hypersthene, 2; corundum, 1; magnetite and ilmenite, traces; and chlorite, 8. The chlorite appears to be derived mainly from the hypersthene.

The granodiorite porphyry dikes are less silicic and somewhat darker—light medium gray—than the granodiorite porphyry stocks. The dike rocks differ considerably from each other mineralogically and texturally. The rocks of the dike at Profile Rock (pl. 1, loc. 82) and Wahatoya dike (pl. 1, loc. 87) contain very large phenocrysts of oligoclase (An_{20}), as much as 11 mm across, and small to large phenocrysts of microcline, biotite, and hornblende set in a finely crystalline groundmass of quartz, orthoclase, oligoclase, biotite, corundum, apatite, magnetite, ilmenite, chlorite, clay, and an unidentified zeolite. The modal composition, in percent, is: quartz, 8; orthoclase, 28; microcline, 1; oligoclase, 45; biotite, 4; hornblende, 1; magnetite and ilmenite, 3; corundum and apatite, less than 1; and secondary minerals, 10. The chlorite seems to have been derived mainly from the alteration of biotite, but large relict crystals of hornblende are filled by chlorite as well as by zeolite and magnetite. The zeolite occurs largely as fillings in vesicles.

At one exposure on the Cuchara River, the dike of Profile Rock is made up of many very thin vertical and parallel layers of textural varieties of granodiorite. The margins of every layer are parallel to the walls of the dike.

The dike of granodiorite porphyry (pl. 1, loc. 83) high on the north slope of West Spanish Peak is a medium-light-gray holocrystalline rock containing phenocrysts of andesine (An_{35}) less than 3 mm across in a groundmass of microcrystalline quartz, orthoclase, andesine, magnetite, ilmenite, clay, calcite, and chlorite. There are also scattered large (4–5 mm) phenocrysts of hornblende. Mineral constituents, in percent, are: quartz, 6; orthoclase, 29; andesine, 36; augite, 1; magnetite and ilmenite, 4; clay, 14; chlorite, 7; and calcite, 3. The clay and calcite appear to be alteration products of the feldspars, and the chlorite seems to be derived in part from the small amount of hornblende in the rock. However, because of the generally fresh appearance of the hornblende, it is uncertain how such a large amount of chlorite can be present in the rock.

The sill of granodiorite prophyry south of Aguilar is a medium-gray holocrystalline rock containing small phenocrysts (2 mm) of orthoclase set in a microcrystalline groundmass of quartz, oligoclase (An_{30}), biotite, magnetite, ilmenite, pyrite, zircon, limonite, clay, and chlorite. The modal composition, in percent, is: quartz, 5; orthoclase, 25; oligoclase, 48; biotite, 12; magnetite, ilmenite, and pyrite, 4; limonite, 1; clay, less than 1; and chlorite, 4.

APHANITE

Microgranodiorites occur as radial dikes north (pl. 1, loc. 84) and south (pl. 1, loc. 85) of the Spanish Peaks. The aphanitic varieties of granodiorite are less silicic and slightly darker—medium gray—than the prophyritic varieties.

The microgranodiorite in upper Wahatoya Canyon (pl. 1, loc. 84) is a marginal facies of a syenodiorite lamprophyre dike and is an equigranular holocrystalline rock. The modal composition, in percent, is: quartz, 13; orthoclase, 23; andesine ($An_{40?}$), 32; magnetite and ilmenite, 20; corundum, 3; dolomite, 7; and an unidentified zeolite, 2.

The microgranodiorite dike south of the Spanish Peaks (pl. 1, loc. 85) is a holocrystalline microporphyry. Several small phenocrysts of oligoclase (An_{30}) and hornblende occur in an altered groundmass whose composition, in percent, is: quartz, 8; orthoclase, 17; oligoclase (An_{30}), 32; hornblende, 2; biotite, corundum, apatite, and sphene, traces; magnetite and ilmenite, 8; epidote and chlorite, 19; limonite, 5; and trace of zeolite. Seven percent of the rock is made up of vesicles that may have contained hornblende phenocrysts in that small fragments of weathered amphibole adhere locally to the cavity walls.

SYENITE

PORPHYRY

Syenite porphyries occur as stocks, dikes, and sills. Rough Mountain is a stock comprised largely of syenite porphyry but locally including facies of syenodiorite porphyry. The rock is light gray and consists of phenocrysts of oligoclase (An_{25}) and biotite in a finely crystalline groundmass of quartz, orthoclase, hornblende, magnetite, and clay. Quartz usually makes up 1–2 percent of the rock; orthoclase, 45–57 percent; oligoclase, 37–49 percent; hornblende, 5 percent; and magnetite and clay, traces. South of Stonewall (pl. 1, loc. 1) is a very light gray highly weathered syenite porphyry consisting of phenocrysts of oligoclase ($An_{25?}$), 46 percent, and biotite, 4 percent, in a very finely crystalline orthoclase groundmass containing traces of hornblende and magnetite.

Three small stocklike bodies of syenite are clustered in a small area crossed by Pass Creek (pl. 1, loc. 7). The rocks of these intrusives are nearly identical, light-gray holocrystalline porphyries containing coarse phenocrysts in fine- to medium-grained groundmasses. The modal composition, in percent, is: orthoclase, 39–54; sanidine, 19–24; antiperthitic oligoclase (An_{20}), 20–28; light-brown biotite, 1–2; magnetite, 1–2; and traces of apatite, corundum, chlorite, and limonite, and relict hornblende. Locally, a zeolite that may be analcime fills round cavities as large as 3 mm across. Very large sanidine phenocrysts are as much as 15 mm across and at many places have been rounded by resorption. Laths of antiperthitic oligoclase are as much as 6 mm long, and biotite crystals are as large as 1 mm.

Syenite porphyry dikes of the radial dike system occur in the vicinity of Apishapa Pass and in the area between West Spanish Peak and the White Peaks. Near the top of Apishapa Pass (pl. 1, loc. 86) a light-gray syenite porphyry crops out along the highway. The phenocrysts in the rock consists of large crystals of oligoclase (An_{30}), as much as 9 mm across, and green augite, as much as 5 mm across, as well as smaller crystals (less than 3 mm) of red biotite and a highly weathered red amphibole. The phenocrysts are in a crystalline groundmass that consists of all the minerals of the rock except the ferromagnesian minerals. The modal composition, in percent, is: quartz, 1; orthoclase, 45; oligoclase, 36; biotite, trace; augite, 4; amphibole, 3; corundum and apatite, traces; magnetite, 3; limonite, trace; calcite, 3; clay, 3; and zeolite, trace.

Two small dikes of syenite (pl. 1, locs. 61 and 62) occur a short distance south of the small stocks on Pass Creek. They are medium-light-gray holocrystalline porphyries, and although a little darker than the rocks of the stocks, they are similar in aspect. The modal composition of the dikes, in percent, is: orthoclase, 48–59; sanidine, 16–20; antiperthitic oligoclase (An_{20}), 13–19; lightbrown biotite, 2–4; hornblende, 2–6; magnetite, 2–3; and traces of apatite, corundum, limonite, and calcite. Locally, analcime fills spherical cavities and fractures and may make up as much as 5 percent of the rock. The groundmass is very fine to fine-grained and contains very large (15 mm) phenocrysts of sanidine, large (6 mm) phenocrysts of oligoclase, and small (1 mm) phenocrysts of biotite and hornblende.

On the west side of Apishapa Pass the highway cuts the same syenite porphyry dike at two places (pl. 1, loc. 88) about 1 mile apart. There is very little lateral variation in the mineralogy of the dike. The rock at the western exposure, however, is considerably more porphyritic than the rock at the eastern exposure. The dike consists of phenocrysts of oligoclase (An_{20}) up to 9 mm across; biotite, up to 2 mm across; and hornblende, up to 6 mm across. The phenocrysts are set in a microcrystalline groundmass of quartz, orthoclase, oligoclase, biotite, hornblende, corundum, apatite, magnetite, limonite, clay, and an unidentified zeolite. The modal composition, in percent, is: quartz, 1; orthoclase, 43–47; oligoclase, 37 (phenocrysts, 16–32); biotite, 4–5 (phenocrysts, 3); hornblende, 5–8 (phenocrysts, 1); magnetite, 2–4; zeolite, 1–2; and apatite, corundum, limonite, and clay, traces.

A very similar rock (pl. 1, loc. 89) makes up a radial dike striking between West Spanish Peak and the White Peaks. In it phenocrysts of oligoclase (An_{20}), 36 percent, biotite, 4 percent, and hornblende, 8 percent, occur in a microcrystalline groundmass of orthoclase, 38 percent; magnetite, 12 percent; and limonite, chlorite, clay, apatite, and corundum, traces.

A finely porphyritic syenite of the subparallel dike system is exposed in an old roadcut north of Santa Clara Creek near U.S. Highway 85 (pl. 1, loc. 90). The rock contains small phenocrysts of oligoclase (An_{25}) less than 2 mm across in a microcrystalline groundmass of quartz, anorthoclase, biotite, magnetite, and chlorite; no plagioclase was found in the groundmass. The mineralogic composition of the rock, in percent, is: anorthoclase, 51; oligoclase, 36; biotite, 2; magnetite, 10; and chlorite and quartz, traces.

An independent set of dikes and sills occurs along Pass Creek north from the divide that is the Costilla-Huerfano County line, and it may be related to the larger syenite intrusives of Rough Mountain and Sheep–Little Sheep Mountain and other smaller syenitic intrusives in the vicinity. A common and somewhat distinctive constituent in these rocks is antiperthite. At the county-line divide (pl. 1, loc. 91) and north on Pass Creek (pl. 1, loc. 60) are two short dikes of light-medium-gray syenite porphyry. Along Pass Creek are two long thick stocklike sills (pl. 1, locs. 12 and 74) emplaced in steeply dipping to overturned beds of the Sangre de Cristo Formation. The dikes and sills are nearly identical mineralogically and texturally. Phenocrysts of antiperthitic oligoclase (An_{15}), biotite, and hornblende are embedded in a fine holocrystalline groundmass made up mostly of orthoclase. Antiperthitic oligoclase phenocrysts as large as 7 mm across make up 15–25 percent of the rock. Smaller phenocrysts (less than 2 mm across) of red and green biotite and brown and green hornblende make up 4 and 11 percent of the rock, respectively. The groundmass is composed of orthoclase, 46–67 percent; magnetite, 2 percent; and local traces of interstitial quartz, limonite, calcite, zeolite, and clay. The zeolite fills small cavities and appears to be heulandite.

The large sills (pl. 1, loc. 76) just east of Pass Creek and generally paralleling it are medium-gray holocrystalline porphyries that are slightly different texturally and mineralogically from the previously described syenites. Phenocrysts of sanidine (5 mm), antiperthitic oligoclase (An_{20}; 8 mm), and biotite (4 mm) are imbedded in a very fine to fine-grained groundmass consisting of orthoclase, hornblende, magnetite, apatite, and limonite. The modal composition, in percent, is: sanidine, 3; orthoclase, 53; antiperthitic oligoclase, 24; biotite, 6; hornblende, 13; magnetite, 11; limonite, 3; and apatite, trace.

APHANITE

Microsyenite is the dominant rock type of a probable laccolith at Sheep and Little Sheep Mountains (fig. 5), the margin of a radial dike, a subparallel dike, two independent dikes, and a sill.

The large intrusive body that forms Sheep and Little Sheep Mountains is comprised of light-gray microsyenite and local facies of syenite porphyry. The texture of the microsyenite is microporphyritic; microphenocrysts of oligoclase (An_{15}), 22 percent, are set in a microcrystalline groundmass composed largely of orthoclase, 73 percent, and some interstitial quartz, 2 percent. Chloritized augite crystals that have a remnant hourglass structure make up about 2 percent of the rock, and there are minute traces of magnetite or ilmenite. Locally, where the rock is porphyritic, phenocrysts of oligoclase as much as 7 mm across are set in a finely crystalline groundmass. At these places, about half of the oligoclase in the rock is in the groundmass.

East of Sheep Mountain are several short dikes (pl. 1, loc. 59) of a small independent dike system. These dikes are medium-dark-gray aphanitic rocks, which under the microscope are found to be holocrystalline equigranular microsyenites whose texture is slightly trachytic. The average modal composition of these dikes, in percent, is: quartz, 2; orthoclase, 30; oligoclase (An_{25}), 23; hornblende, 5; augite, 13; hypersthene, 9; magnetite and ilmenite, 9; calcite, 4; and open vesicles, 5.

Southeast of Mount Mestas a cluster of short dark-gray aphanitic dikes (pl. 1, loc. 92) intrude the Pierre Shale. They are microlamprophyric in that scattered small phenocrysts of augite make up about 1 percent of the rock. Although highly altered, the rock appears to be a microsyenite because it contains 36 percent orthoclase and 20 percent oligoclase (An_{30}?). Other minerals, in percent, are: biotite, 7; augite, 4; magnetite and ilmenite, 7; chlorite, 20; calcite, 5; and clay and limonite, traces.

The altered aphanitic border facies of an augite syenite lamprophyre, or vogesite, dike (pl. 1, loc. 93) of the radial dike system, which generally parallels Bear Creek southwest of Walsenburg, is actually a syenite microlamprophyre. Serial sizes of biotite, 6 percent, and augite, 8 percent, as much as 1 mm across occur in a microcrystalline groundmass of sanidine and plagioclase, 50 percent; ilmenite and magnetite, 13 percent; and clay and limonite, traces.

South of Mauricio Canyon (pl. 1, loc. 94), between East Spanish Peak and Aguilar, a dike that may be classed as a microsyenite is part of the subparallel dike system. It is a greenish-gray holocrystalline nearly equigranular rock composed in large part of secondary minerals. The modal composition, in percent, is: quartz, trace; orthoclase, 20; andesine (An_{35}), 16; biotite, 21; augite, 6; apatite, 1; sphene, 1; magnetite and ilmenite, 5; calcite, 16; clay, 11; limonite, 2; and chlorite, 1.

Near Redwing in Huerfano Park a large aphanitic sill (pl. 1, loc. 95) intrudes steeply dipping beds of the Sangre de Cristo Formation. The rock is a medium-gray holocrystalline microsyenite, which may be related to the syenitic intrusives to the south along Pass Creek in that it contains antiperthitic oligoclase (An_{15}). The modal composition, in percent, is: orthoclase, 66; antiperthitic oligoclase, 13; biotite, 4; hornblende, 8; magnetite and ilmenite, 2; and clay, 7.

LAMPROPHYRE

Syenite lamprophyres are classified in this report as minettes or vogesites depending on whether biotite, hornblende, or augite forms the dominant phenocrysts. In minettes the dominant phenocrysts are biotite, whereas in vogesites the dominant phenocrysts are augite or, rarely, hornblende. Olivine forms large conspicuous phenocrysts in most of the minettes and vogesites, and either analcime or analcitized sanidine generally makes up most of the groundmass. Syenite lamprophyres are localized and sparse; the similar syenodiorite lamprophyres (soda-minettes and soda-vogesites) are more numerous and widespread.

Minettes

Minettes occur mainly in the subparallel dike system, but two occur as apparent independent dikes. They are found largely in the northeastern part of the Spanish Peaks region near Walsenburg.

At Walsenburg (pl. 1, locs. 28, 38, and 96–98) the Walsen dike (Knopf, 1936, p. 1764–1766) is comprised of three separate intrusives (Johnson, 1964)—a minette that intrudes previously formed shrinkage cracks in a double dike made up of a minette and a soda-minette. The soda-minette was the earliest dike to intrude the joint. A mixed zone between the early minette and the soda-minette is an aphanitic equivalent of the early minette and may be classed as a microminette.

The later minette intrusive that occurs as fracture filling in the two previously intruded dikes was sampled at three places (pl. 1, locs. 28, 97, and 98). It is a friable easily weathered rock that displays flow banding on fresh exposures. The color ranges from light medium gray in fresh rocks to medium reddish brown at highly weathered exposures. The fresh rock consists in part of analcitized sanidine, 24 percent, and oligoclase (An_{25}), 18 percent. In the weathered rock, both the sanidine and oligoclase are highly analcitized, and together they make up 42–43 percent of the rock. Red biotite, in serial sizes up to phenocrysts as large as 3 mm across, makes up 22–31 percent of the rock volume. Gray-green augite occurs as clustered small crystals in the groundmass and makes up 1–8 percent of the rock. Apatite is abundant as small groundmass crystals, which may make up as much as 6 percent of the rock. Iron-oxide minerals are common; ilmenite and magnetite compose 5–17 percent of the rock, and hematite and limonite, 0–14 percent. In one sample, serpentine makes up as much as 3 percent of the rock, but its origin could not be determined. In all samples, small vesicles are filled with calcite and an unidentified zeolite. The vesicles make up 1–6 percent of the volume of the rock.

The earlier minette is the northernmost dike of the double dike and was sampled at three places (pl. 1, locs. 28, 96, and 98). It is a hard, durable medium-light-gray holocrystalline rock. The groundmass is microcrystalline and consists of analcitized sanidine, andesine (An_{35}), red biotite, gray-green augite, apatite, ilmenite and magnetite, hematite, and locally serpentine, clay, and an unidentified zeolite. Phenocrysts are mainly red biotite as much as 2 mm across but include some olivine crystals as much as 4 mm across, a few augite crystals as large as 1 mm, and some crystals of sanidine as much as 3 mm across. The modal composition, in percent, is: analcitized sanidine, 20–28; andesine, 15–23; biotite, 12–30; augite, 2–17; olivine, 4–5; apatite, 3–5; ilmenite and magnetite, 11–16; hematite, 1–2; and serpentine, clay, and zeolite, local traces.

The mixed zone was also sampled at three places (pl. 1, locs. 28, 96, and 98). It is a very hard and durable medium-dark-gray microcrystalline rock which under the microscope proved to be microlamprophyric. The small phenocrysts are mainly biotite, augite, and olivine. The modal composition, which is similar to that of the central part of the early minette, is, in percent: analcitized sanidine, 19–33; andesine (An_{35}), 19–25; red biotite, 9–16; gray-green augite, 10–25; olivine, 1–10; ilmenite and magnetite, 4–10; and apatite, 3. Locally there are minor amounts of zeolite, serpentine, calcite, and hematite. The serpentine and zeolite fill relict crystals of olivine, and in one sample a few large relict crystals of olivine are rimmed by small augite crystals and filled with zeolite.

Unfug dike (Knopf, 1936, p. 1751) south of Walsenburg (pl. 1, loc. 99) is a medium-olive-brown minette belonging to the subparallel dike system. The rock is a highly altered holocrystalline aphanite that contains microphenocrysts of red biotite, 16 percent, and olivine, 4 percent. The groundmass is composed of, in percent: analcitized anorthoclase, 34; oligoclase (An_{15}), 8; augite, 8; apatite, 1; corundum, trace; ilmenite and magnetite, 5; interstitial analcite, 7; calcite, 10; and limonite, 7. Most of the calcite is masked by limonite and, thus, is not readily apparent.

A dike of similar appearance, although less altered, crosses Trujillo Creek (pl. 1, loc. 100) and appears to be structurally independent of the major dike systems. This dike is a medium-olive minette consisting of phenocrysts of biotite and augite in a microscopic crystalline groundmass. The modal composition, in percent, is: orthoclase, 36; andesine (An_{40}), 11; biotite, 24; augite, 8; hornblende, 6; ilmenite and magnetite, 6; chlorophaeite, 5; and calcite, 4.

Another minette, east of Wahatoya Creek (pl. 1, loc. 101), also appears to be independent of the radial and subparallel dike systems. It is a light-olive-gray holocrystalline rock containing biotite phenocrysts, 10 percent, in a microcrystalline groundmass of orthoclase, 23 percent; plagioclase ($An_?$), 5 percent; biotite, 2 percent; augite, 13 percent; apatite, 7 percent; magnetite and ilmenite, 13 percent; limonite, 2 percent; chlorite, 12 percent; calcite, 3 percent; clay, 1 percent; and traces of sphene and an unidentified zeolite.

Vogesite

Only three vogesite dikes have been found in the Spanish Peaks region; two (pl. 1, locs. 93 and 102) occur a short distance south of Walsenburg, and the other (pl. 1, loc. 103) is an isolated independent dike north of Little Sheep Mountain in Huerfano Park. The two vogesite dikes south of Walsenburg are similar mineralogically but are not related structurally in that one is a radial dike and the other is of the subparallel dike system.

Along Bear Creek (pl. 1, loc. 93) the dike of the radial system is made up mainly of vogesite and has a thin aphanitic border facies of similar mineralogic composition. The vogesite is a dark-greenish-gray altered rock that has an aphanitic groundmass and phenocrysts of augite, 5 percent, and red biotite, 1 percent. The groundmass composition, in percent, is; analcitized sanidine and plagioclase, 34; augite, 15; red biotite, 10; magnetite and ilmenite, 6; long needles of sphene, 2; apatite, trace; clay, 4; calcite, 6; limonite, 3; and an unidentified zeolite, 2. Relict crystals of olivine as large as 3 mm across are filled with chlorite and make up 12 percent of the rock.

Crossing Ideal Canyon (pl. 1, loc. 102) is a vogesite dike belonging to the subparallel dike system. The rock is a greenish-gray slightly altered lamprophyre containing phenocrysts of augite that make up 25 percent of the rock. The groundmass is very fine grained; its composition, in percent, is: highly analcitized orthoclase and plagioclase, 39; biotite, 9; magnetite and ilmenite, 7; calcite, 11; and chlorite, 1. Large crystals of olivine have been altered to antigorite, 7 percent, and iddingsite, 1 percent.

A short isolated dike north of Little Sheep Mountain (pl. 1, loc. 103) is very different mineralogically from the vogesite dikes south of Walsenburg. Phenocrysts of diopsidic augite, 10 percent; hypersthene, 2 percent; unaltered olivine, 5 percent; and iddingsite pseudomorphous after olivine, 21 percent, are in a very fine grained groundmass of quartz, 1 percent; orthoclase, 45 percent; oligoclase(?), 5 percent; biotite, 1 percent; and clay, 2 percent. Clusters of needle-shaped crystals of a zeolite that may be thomsonite fill cavities in unaltered olivine and make up 2 percent of the rock.

SYENODIORITE

Syenodiorite occurs as stocks, a probable laccolith, plugs, dikes, and sills, and it is the most common rock type in the Spanish Peaks region. Syenodiorite makes up the large intrusive masses that constitute West Spanish Peak, Dike Mountain, Black Hills, and Little Black Hills.

PHANERITE

Four plugs of phaneritic syenodiorite intrude the Pierre Shale and Niobrara Formation a short distance east of the mapped area (Johnson, 1958, p. 566, pl. 47); two plugs are 2 miles northeast of Walsenburg, and the other two are 5½ miles east-southeast of Walsenburg. Although the rocks of both sets are classed as syenodiorites, they are very different mineralogically. The plugs northeast of Walsenburg are light gray, holocrystalline, equigranular, and coarse grained. The modal composition, in percent, is: quartz, 1; anorthoclase, 27; oligoclase (An_{25}), 50; red biotite, 6; hornblende, 7; magnetite and ilmenite, 4; apatite, 2; sphene, trace; and chlorite, 3. Near the contacts with the enclosing Pierre Shale, the syenodiorite is locally porphyritic and has a glassy groundmass.

The other two plugs, east-southeast of Walsenburg, are greenish gray, holocrystalline, equigranular, and medium grained. Their composition, in percent, is: orthoclase, 14; andesine (An_{35}), 46; hornblende, 11; a highly chloritized orthopyroxene that may be hypersthene, 4; magnetite and ilmenite, 3; chlorite, 9; calcite, 8; and an unidentified zeolite, 5.

PORPHYRY

The largest intrusive body of syenodiorite is the porphyry of West Spanish Peak. The main stocklike part of the intrusive is coarsely porphyritic and contains phenocrysts of oligoclase as large as 15 mm across; the western laccolithic part is nearly equigranular and contains crystals 5–10 mm across. The rock varies greatly in mineral content and locally can be classed as granodiorite; but, in general, the mass consists of several facies of syenodiorite (Knopf, 1936, p. 1735, 1737–1738).

The main rock type is a light-medium-gray holocrystalline porphyry whose crystals range from very fine to very coarse. Phenocrysts of anorthoclase, 14 percent; oligoclase (An_{30}), 28 percent; biotite, 2 percent; and augite, 3 percent, are embedded in a groundmass of interstitial quartz, 3 percent; anorthoclase, 3 percent; oligoclase, 30 percent; hypersthene, 2 percent; augite, 4 percent; magnetite and ilmenite, 3 percent; zircon and apatite, traces; and chlorite, 8 percent. Locally, the potassium feldspar is orthoclase rather than anorthoclase, the plagioclase is zoned (An_{45-25}), and the augite may be uralitized. The composition, which ranges locally, is (in percent): quartz, trace to as much as 6; orthoclase-anorthoclase, 14–27; oligoclase, 54–62; biotite, 1–7; augite (including uralite), 2–10; and hypersthene, trace to 4.

The rock that makes up the stock of Dike Mountain is a medium-gray holocrystalline syenodiorite porphyry containing phenocrysts as much as 5 mm long. These are composed of hornblende, 15 percent; hypersthene, 6 percent; and andesine (An_{35}), 28 percent. The composition, in percent, of the fine- to medium-grained groundmass is: interstitial quartz, 3; orthoclase, 25; andesine, 5; biotite, 1; augite, 7; magnetite and ilmenite, 6; apatite, trace; and chlorite, 4. Locally, dark-green hornblende phenocrysts are as much as 3 inches long, and clusters of hornblende crystals occur in isolated masses as much as 4–5 inches across.

The syenodiorite porphyry that makes up the probable laccolith at the Black Hills is nearly identical with the rock of the Dike Mountain stock, including the large crystals and masses of hornblende. The two rocks are dissimilar only in that the intrusive of the Black Hills contains no hypersthene where examined. The modal composition, in percent, is: interstitial quartz, 3; orthoclase, 22; andesine (An_{35}), 50; hornblende, 7; biotite, 1; augite, 8; magnetite and ilmenite, 6; and chlorite, 3. All the hornblende and most of the andesine occur as phenocrysts.

At the Little Black Hills the stock consists of medium-pinkish-tan holocrystalline to partly glassy syenodiorite porphyry with locally pronounced flow structures. Locally, near the periphery of the stock, the groundmass is partly glassy and vesicular. The phenocrysts are as much as 3 mm across and give a modal composition, in percent, of: quartz, 2; andesine (An_{35}), 20; hornblende, 1; augite, 4; and hypersthene, 1. The groundmass is microcrystalline and is composed, in percent, of orthoclase, 10; andesine, 40; biotite, 1; magnetite and ilmenite, 5; apatite, trace; chlorite, 6; limonite and hematite, 6; and an unidentified zeolite filling the vesicles, 4. Where the groundmass is glassy, the glass may make up as much as 60 percent of the groundmass.

The short radial dike paralleling the north fork of Trujillo Creek (pl. 1, loc. 104) is composed of syenodiorite porphyry. It is an altered greenish-gray holocrystalline rock containing phenocrysts less than 2 mm across of andesine (An_{35}), hornblende, and biotite embedded in a very finely crystalline groundmass. The modal composition, in percent, is: orthoclase, 15; andesine, 39; hornblende, 10; biotite, 9; magnetite, 4; chlorite, 21; and clay, 2.

Cutting across the south fork of Trujillo Creek (pl. 1, loc. 105) is a long curvilinear dike of the radial system made up of syenodiorite porphyry. It is a medium-gray holocrystalline rock containing phenocrysts as much as 4 mm long of andesine (An_{35}), biotite, and hornblende in a finely crystalline groundmass. The modal composition, in percent, is: quartz, trace; orthoclase, 33; andesine, 37; biotite, 14; hornblende, 4; magnetite and ilmenite, 2; chlorite, 10; and clay, trace.

A long curvilinear syenodiorite porphyry dike of the radial system extends southeastward from West Spanish Peak to cross the Apishapa River (pl. 1, loc. 106) and Jarosa Canyon (pl. 1, loc. 107). At both localities it is a medium-gray holocrystalline rock containing phenocrysts as much as 3 mm long of quartz, andesine (An_{35}), hornblende, and augite in a microcrystalline to finely crystalline groundmass. The modal composition, in percent, is: quartz, trace; orthoclase, 15; andesine, 66; biotite, 5; hornblende, 3; augite, trace; magnetite, 2; chlorite, 17; clay, 2; and an unidentified zeolite, trace.

Closely paralleling the last described dike for many miles is another syenodiorite porphyry dike, but of different aspect (pl. 1, loc. 108). The rock is a light-gray holocrystalline porphyry containing phenocrysts as much as 4 mm across of oligoclase (An_{25}), hornblende, and augite in a microcrystalline to finely crystalline groundmass. Large spheroidal cavities as much as 15 mm across are filled with a zeolite that appears to be analcime. The modal composition, in percent, is: orthoclase, 15; oligoclase, 45; red biotite, 3; green hornblende, 2; green augite, 4; apatite, 1; magnetite and ilmenite, 5; limonite, 3; chlorite, 4; and zeolite, 17.

Nearby (pl. 1, locs. 109 and 110) are two quartz-bearing curvilinear syenodiorite porphyry dikes of the radial system. They appear to be closely related structurally and are of similar appearance, although they differ somewhat mineralogically and texturally. The rock of the dike at locality 109 is a medium-gray holocrystalline porphyry containing small (less than 2 mm) phenocrysts of quartz, orthoclase, and oligoclase (An_{25}) set in a microcrystalline groundmass. The modal composition, in percent, is: quartz, 3; orthoclase, 17; oligoclase, 54; augite, 7; magnetite, 6; chlorite, 13; and clay, trace. The dike at locality 110 is a light-medium-gray holocrystalline porphyry containing phenocrysts of oligoclase (An_{25}) in a finely crystalline groundmass. The modal composition, in percent, is quartz, 2; orthoclase, 18; oligoclase, 37; biotite, 10; augite, 8; hornblende(?), trace; sphene, trace; magnetite and ilmenite, 7; chlorite, 18; and clay, trace.

A cluster of dikes (pl. 1, loc. 111) of the radial system south of West Spanish Peak is made up of identical syenodiorite porphyry. The dikes are composed of light-gray holocrystalline rocks containing phenocrysts of oligoclase (An_{20}) as much as 12 mm across and hornblende crystals as much as 2 mm across in a very fine to medium-grained groundmass. Oligoclase phenocrysts make up 28 percent of the volume of the rock; the edges of these large phenocrysts are slightly resorbed. The modal composition, in percent, is: quartz, 1; orthoclase, 20; oligoclase, 51; biotite, 1; hornblende, 7; corundum, 1; apatite and sphene, traces; magnetite and ilmenite, 7; limonite, 3; clay, 6; and calcite, trace.

Nearby (pl. 1, loc. 112) is a long dike of the radial system that is mineralogically similar to, but texturally different from, the preceding dikes. The rock is a medium-light-gray holocrystalline syenodiorite prophyry containing phenocrysts of lath-shaped oligoclase (An_{25}) as much as 5 mm across, biotite as much as 2 mm across, and hornblende as much as 3 mm across embedded in a microcrystalline groundmass. Oligoclase phenocrysts make up 32 percent of the volume of the rock. Fine-grained aggregates of oligoclase as much as 15 mm across are scattered throughout the rock. In these aggregates small crystals less than 1 mm across of oligoclase, biotite, and hornblende are embedded in a microcrystalline groundmass; these crystals make up more than 60 percent of the volume of the aggregates. The modal composition of the syenodiorite porphyry, in percent, is: quartz, 2; orthoclase, 33; oligoclase, 49; green biotite, 8; olive-green hornblende, 5; corundum, apatite, and sphene, traces; magnetite and ilmenite, 4; chlorite, 3; calcite, 1; and limonite and clay, traces.

In the same area is another syenodiorite porphyry (pl. 1, loc. 113) of the radial dike system, but it has a different aspect. This rock is a light-medium-gray holocrystalline porphyry containing crystals ranging serially from microcrystalline to large phenocrysts 10 mm across. Crystals of hornblende as much as 10 mm across and oligoclase (An_{25}) as much as 3 mm across are the prominent phenocrysts. The modal composition of this rock, in percent, is: quartz, 2; orthoclase, 12; oligoclase, 41; hornblende, 9; light-green augite, 6; red biotite, 1; apatite and sphene, traces; magnetite, 11; chlorite, 6; epidote, trace; unidentified zeolite, 5; and clay, 4.

Near Cuchara Pass is a short dike of medium-dark-gray syenodiorite porphyry (pl. 1, loc. 114) made up of phenocrysts of andesine (An_{40}) and hornblende in a microcrystalline groundmass. The andesine phenocrysts are as large as 5 mm across and make up 35 percent of the volume of the rock; hornblende phenocrysts, locally clustered and aggregated, may be as much as 4 mm long and make up 11 percent of the rock. The modal composition, in percent, is: orthoclase, 7; andesine, 63; hornblende, 16; magnetite, 4; and chlorite, 10.

Several dikes along the Cuchara River southwest of La Veta that are classed as syenodiorite porphyries appear to be less porphyritic than those previously described because the phenocrysts are rarely as large as 3 mm across. The rock of the dike at locality 115 is a medium-light-gray holocrystalline rock containing small phenocrysts of andesine (An_{40}) and augite in a microcrystalline groundmass. Andesine phenocrysts make up 30 percent of the rock and may be as large as 2 mm; augite phenocrysts make up 10 percent of the rock and are as large as 1 mm. The modal composition, in percent, is: quartz, 2; othoclase, 10; andesine, 40; green augite, 11; brown biotite, 2; apatite, sphene, and corundum, traces; magnetite, 11; chlorite, 13; epidote, 2; zeolite, 1; calcite, 1; and clay, 6.

Nearby (pl. 1, loc. 116) is a similar syenodiorite porphyry dike. Here, however, the phenocrysts, which are in a very finely crystalline groundmass, are orthoclase, 14; andesine (An_{35}), 30 percent; and hornblende, 15 percent. The modal composition, in percent, is: quartz, 3; orthoclase, 24; andesine, 38; hornblende, 17; brown biotite, 2; apatite, 2; magnetite, 5; and chlorite, 5.

Intruded into the Cuchara Formation along Wahatoya Creek between East and West Spanish Peaks (pl. 1, loc. 117) is a medium-light-gray syenodiorite porphyry dike containing phenocrysts of oligoclase (An_{25}) and biotite in a microcrystalline to fine-grained groundmass. The oligoclase phenocrysts are as much as 4 mm across, and the biotite phenocrysts are as much as 3 mm across. The modal composition, in percent, is: quartz, 2; orthoclase, 24; oligoclase, 50; biotite, 12; magnetite, 2; chlorite, 10; and clay, trace.

Two dikes of the radial system that occur between Bear Creek and Ideal Canyon south of Walsenburg (pl. 1, locs. 118 and 119) have an unusual texture. They are medium-gray syenodiorite porphyries containing a few phenocrysts in a fine- to medium-grained groundmass. The phenocrysts are orthoclase, 6 percent; andesine (An_{25})., 2 percent; and hornblende, 3 percent. Orthoclase crystals are as much as 2 mm across and are highly resorbed; andesine crystals are up to 5 mm across; and hornblende crystals are as long as 4 mm. The modal composition of the dike at locality 118, in percent, is: orthoclase, 28; andesine, 43; biotite, 6; hornblende, 11; magnetite, 6; and chlorite, 4. The modal composition of the dike at locality 119, in percent, is: orthoclase, 13; andesine (An_{45}), 26; biotite, 3; hornblende, 3; augite, 4; apatite, 1; magnetite and ilmenite, 16; limonite, 13; chlorite, 7; calcite, 13; and an unidentified zeolite, 1.

A long dike of the radial system extends along Santa Clara Creek (pl. 1, loc. 120). It is an olive-gray syenodiorite porphyry containing phenocrysts of andesine (An_{35}), diopside(?), and hornblende. The andesine phenocrysts are as much as 4 mm long and make up 42 percent of the rock volume. Diopside(?) phenocrysts make up 5 percent of the rock, and hornblende phenocrysts 2 percent; both minerals have crystals as large as 2 mm. The groundmass is microcrystalline. The modal composition, in percent, is: interstitial quartz, 1; orthoclase, 19; andesine, 52; a clinopyroxene that appears to be diopside, 7; colorless hornblende, 2; tan biotite, 2; apatite, 2; corundum and sphene, traces; magnetite and ilmenite, 5; chlorite, 5; limonite, 3; and calcite, 2.

The dikes of the Dike Mountain radial system are made up mainly of syenodiorite porphyry. Some of the dike rocks are similar to the syenodiorite porphyry of the stock, but many are facies of syenodiorite and approach the mineralogical composition of granodiorite, syenite, and diorite. Four porphyry dikes were sampled, and they show considerable variation in texture and mineral composition.

A large dike northeast of Dike Mountain (pl. 1, loc. 121) is made up of medium-gray holocrystalline syenodiorite porphyry containing prominent phenocrysts of biotite as large as 7 mm across. Other phenocrysts are of sanidine, as much as 1 mm across, orthoclase, as much as 3 mm across, and hornblende, as much as 3 mm across. The groundmass is microcrystalline and is made up mainly of oligoclase (An_{15}) microlites. The modal composition, in percent, is: quartz, 4; sanidine, 18; orthoclase, 4; oligoclase, 60; biotite, 8; hornblende, 2; magnetite, 2; and chlorite, 2.

Another dike (pl. 1, loc. 122) is also a medium-gray holocrystalline syenodiorite porphyry but contains prominent phenocrysts of hornblende as long as 5 mm and of hypersthene as much as 3 mm across. Small phenocrysts of oligoclase (An_{20}) as much as 2 mm across also occur. The groundmass is microcrystalline to finely crystalline. The modal composition, in percent, is: orthoclase, 27; oligoclase, 33; biotite, 4; hornblende, 20; hypersthene, 4; apatite, trace; magnetite, 4; and chlorite, 8.

The rock at locality 123 is similar in appearance to that at the previous locality, but it is very different mineralogically. The phenocrysts are andesine, hornblende, hypersthene, and augite. The modal composition, in percent, is: quartz, 3; orthoclase, 26; andesine (An_{40}), 31; biotite, 1; hornblende, 11; hypersthene, 8; augite, 5; apatite, trace; magnetite, 13; and chlorite, 2.

A dike of the Dike Mountain radial system (pl. 1, loc. 124) a short distance southwest of the intrusive of the Black Hills is made up a medium-light-gray holocrystalline syenodiorite porphyry. Narrow prisms of hornblende as much as 4 mm long are the prominent phenocrysts. Also present are many small phenocrysts less than 2 mm across of andesine (An_{35}), hypersthene, augite, and biotite. The groundmass is microcrystalline and makes up only 42 percent of the rock volume. The modal composition, in percent, is: orthoclase, 17; andesine, 35; hornblende, 12; hypersthene, 6; augite, 10; biotite, 8; apatite and sphene, traces; chlorite, 4; and calcite, trace.

A few dikes of the subparallel dike system are classed as syenodiorite porphyries. One of the dikes between Bear Creek and Ideal Canyon (pl. 1, loc. 125) is a medium-gray holocrystalline syenodiorite porphyry containing prominent phenocrysts as much as 3 mm across of augite and hornblende. Smaller phenocrysts of andesine (An_{35}), less than 2 mm across, are less conspicuous but make up a larger part of the rock than the augite and hornblende. Large relict olivine crystals have been replaced by chlorite and an unidentified zeolite. The modal composition, in percent, is: orthoclase, 15; andesine, 44; biotite, 2; hornblende, 8; augite, 9; magnetite, 4; chlorite, 17; and zeolite, 4.

A medium-dark-gray syenodiorite porphyry crosses the north fork of Trujillo Canyon (pl. 1, loc. 126). Prominent phenocrysts of augite as much as 4 mm across and smaller phenocrysts of andesine (An_{45}) less than 2 mm across are in a fine- to medium-grained groundmass. The modal composition, in percent, is: orthoclase, 25; andesine, 27; hornblende, 15; augite, 11; biotite, 4; magnetite, 3; chlorite, 14; and clay, 1.

A faintly porphyritic highly altered dike classed as syenodiorite porphyry crosses the Apishapa River south of West Spanish Peak (pl. 1, loc. 127). Small phenocrysts of andesine (An_{45}) less than 1 mm across are in a microcrystalline groundmass. Scattered masses of chlorite as much as 2 mm across may be altered biotite or augite crystals. Only about 14 percent of the volume of the rock is made up of megascopic crystals. The modal composition, in percent, is: orthoclase, 20; andesine, 34; biotite, 1; hornblende, 3; magnetite, 3; chlorite, 17; calcite, 13; and clay, 9.

A syenodiorite porphyry dike of the subparallel dike system occurs in Zarcillo Canyon about 6 miles north of Weston (loc. 128). The rock is dark gray and mainly aphanitic and is the only intermediate, nonmafic rock in the vicinity. A few small crystals of orthoclase and oligoclase (An_{25}) are scattered in a microcrystalline groundmass. Calcite and an unidentified zeolite fill cavities 1 mm in diameter left after the weathering out of biotite or augite crystals. The modal composition, in percent, is: quartz, 3; orthoclase, 8; andesine microlites (An_{35}), 37; oligoclase, 14; corundum, 3; apatite, 1; chlorite, 14; calcite, 5; clay, 3; and zeolite, 3.

Only one sill has been classified as a syenodiorite porphyry. It intrudes the Vermejo Formation on Middle Creek northwest of La Veta (pl. 1, loc. 129). It is a medium-greenish-gray holocrystalline microporphyry containing a few visible crystals of andesine (An_{35}). Calcite and an unidentified zeolite are conspicuous as cavity-filling material. The modal composition, in percent, is: orthoclase, 16; andesine, 46; biotite, 2; magnetite, 5; chlorite, 18; zeolite, 7; and calcite, 6.

APHANITE

Rocks classed as microsyenodiorites occur in plugs, in radial, subparallel, and independent dikes, and in sills. Gardner Butte near Gardner in Huerfano Park is a structurally complex plug largely made up of microsyenodiorite, although locally the rock is porphyritic. The rock is a light-gray holocrystalline aphanite containing a visible zeolite filling small cavities. The modal composition, in percent, is: orthoclase, 20; oligoclase (An_{25}), 40; a colorless clinopyroxene that appears to be pigeonite, 5; augite, 1; apatite, trace; magnetite, 3; clay, 20; and an unidentified zeolite, 11.

Goemmer Butte, which Knopf (1936, p. 1778–1779) interpreted as a latite volcanic neck, is here classed as a microsyenodiorite. The rock is a medium-gray holocrystalline aphanite containing scattered small xenoliths of quartz and microcline. Much of the rock is so finely crystalline that it is classified on the basis of the microphenocrysts. The mode of the visible crystals, in percent, is: quartz, 2; microcline, 17; oligoclase microlites (An_{25}), 70; augite, 4; and magnetite, 7.

A microsyenodiorite dike of the Spanish Peaks radial system crops out as a low linear mound on a predimented surface between North Santa Clara Creek and South Santa Clara Creek (pl. 1, loc. 130). The rock is an altered medium-light-gray holocrystalline aphanite containing sparse weathered relict phenocrysts of olivine filled with antigorite, calcite, and an unidentified zeolite. The modal composition, in percent, is: orthoclase, 5; andesine (An_{35}), 30; red biotite, 3; augite, 3; apatite and corundum, traces; magnetite and ilmenite, 17; limonite, 19; calcite, 2; zeolite, 6; antigorite, 3; and clay, 11.

Between the Apishapa River and Trujillo Canyon (pl. 1, loc. 131) is a light-greenish-gray microsyenodiorite dike of the radial system. The rock is a holocrystalline microporphyry containing relict crystals of olivine replaced by chlorite, calcite, and zeolite. The modal composition, in percent, is: quartz, 2; orthoclase, 13; andesine (An_{35}), 43; biotite, 2; green hornblende, 4; red amphibole, 2; apatite and sphene, traces; magnetite and ilmenite, 8; chlorite, 13; calcite, 2; clay, 5; and an unidentified zeolite, 2.

A radial dike of microsyenodiorite was sampled at the divide between Seco Creek and the Apishapa River (pl. 1, loc. 132). The dike is made up of a light-gray holocrystalline, microequigranular rock. The modal composition, in percent, is: quartz, 2; orthoclase, 17; oligoclase (An_{20}), 48; biotite, 12; hornblende, 7; apatite, 1; magnetite and ilmenite, 7; chlorite, 5; clay, 1; and calcite, trace.

Crossing the Apishapa River east of Apishapa Pass (pl. 1, loc. 80) is a granite porphyry dike of the radial system whose aphanitic chill margins are made up of a medium-light-gray holocrystalline rock with a felty texture. This marginal rock is classed as microsyenodiorite, and its modal composition, in percent, is: quartz, trace; orthoclase, 17; oligoclase (An_{20}), 41; biotite, 2; magnetite, 8; calcite, 11; clay, 1; an unidentified zeolite, 1; and chlorite, 20.

Microsyenodiorite dikes of the subparallel system occur north and south of the Spanish Peaks. In the northeastern part of the region (pl. 1, loc. 133) is a highly altered medium-greenish-gray holocrystalline microsyenodiorite dike. Its modal composition, in percent, is: orthoclase, 5; oligoclase (An_{20}), 41; corundum, trace; magnetite and ilmenite, 9; chlorite (clinochlore), 25; calcite, 18; and an unidentified zeolite, 2.

A short extremely altered dike that is probably best classed as a microsyenodiorite occurs east of Walsenburg (pl. 1, loc. 134). It is a grayish-brown aphanitic rock made up mainly of analcitized plagioclase largely altered to calcite and clay. The dark minerals are altered completely to chlorite, and relict crystals of olivine are filled with analcime, calcite, and magnetite.

Two long dikes made up of microsyenodiorite, closely parallel the drainage of Jarosa Canyon and the Apishapa River. The northernmost of the two dikes was sampled at three places (pl. 1, locs. 135–137), and it is remarkably constant in lithology except where affected by alteration and weathering. The least altered rock is medium dark gray, and the weathered rock is medium olive brown. The average modal composition, in percent, is: orthoclase, 6; andesine (An_{40}), 31; biotite, 2; augite, 8; acmite(?), 6; magnetite and ilmenite, 3; apatite, 3; calcite, 5; clay, 4; chlorite, 25; and limonite, 7.

The southernmost of the microsyenodiorite dikes (pl. 1, loc. 138) is dark gray and holocrystalline. The modal composition, in percent, is: quartz, 3; orthoclase, 11; andesine (An_{40}), 37; biotite, 8; augite, 13; apatite, 1; magnetite and ilmenite, 14; chlorite, 10; clay, 3; and calcite, trace.

Several independent dikes are made of microsyenodiorite. The long curvilinear dike northeast of East Spanish Peak (pl. 1, loc. 52) is one (Knopf, 1936, p. 1743) of the most conspicuous dikes in the region. It is a medium-light-gray holocrystalline aphanite composed, in percent, of quartz, 1; orthoclase, 15; oligoclase (An_{25}), 50; biotite, 1; hornblende, 1; reddish augite, 5; apatite, 2; magnetite, 5; limonite, 2; calcite, 1; clay, 2; and chlorite derived mainly from biotite, 10. Phenocrysts of augite as large as 15 mm across are spaced 1–4 feet apart in the aphanitic mass of the dike rock.

A short independent dike just north of Gardner Butte (pl. 1, loc. 139) may be best classed as a microsyenodiorite from the few diagnostic minerals present. It is a light-gray aphanitic rock consisting mainly of analcime. The modal composition, in percent, is: analcitized orthoclase, 6; analcitized plagioclase, 7; biotite, 1; hornblende, 7; calcite, 2; chlorite, trace; and analcime, 75.

Another highly altered independent dike of microsyenodiorite intrudes the Pierre Shale north of Middle Creek northwest of La Veta (pl. 1, loc. 140). It is a greenish-gray aphanite composed, in percent, of orthoclase, 17; andesine (An_{35}), 28; magnetite, 8; limonite, 2; chlorite, 23; calcite, 15; and an unidentified zeolite, 7.

Several sills are made up of microsyenodiorite. The sill at the east terminus (pl. 1, loc. 72) of the large curvilinear dike of microsyenodiorite (pl. 1, loc. 52) is a medium-light-gray microporphyritic syenodiorite and is similar in composition to the dike. Microphenocrysts of augite, 15 percent, and hornblende, 4 percent, are in an extremely fine-grained holocrystalline groundmass. The modal composition, in percent, is: orthoclase, 14; oligoclase (An_{25}), 42; reddish augite, 19; hornblende, 5; biotite, 2; apatite, 1; magnetite and ilmenite, 3; limonite, 7; calcite, 2; chlorite, 4; and clay, 1.

A large sill at the east terminus of a subparallel dike near the mouth of Road Canyon south of Aguilar (pl. 1, loc. 141) is made up of altered dark-greenish-gray microsyenodiorite. The modal composition, in percent, is: orthoclase, 5; andesine (An_{40}), 40; biotite, 8; hornblende, 5; augite, 1; magnetite and ilmenite, 6; chlorite, 20; calcite, 6; hematite, 5; zeolite, 3; and clay, 1.

A highly altered dike north of Middle Creek northwest of La Veta (pl. 1, loc. 142) is classed as microsyenodiorite. It is a greenish-gray holocrystalline aphanite composed, in percent, of quartz, trace; orthoclase, 12; andesine (An_{40}), 40; biotite, 2; magnetite and ilmenite, 12; chlorite, 16; and calcite, 18.

LAMPROPHYRE

Syenodiorite lamprophyres are classified in this report as soda-minettes or soda-vogesites, depending on whether biotite, hornblende, or augite forms the dominant phenocrysts. Large phenocrysts of olivine are found in many of the soda-vogesites and in some of the soda-minettes. Locally, the groundmass of one of the soda-minettes contains analcitized sanidine.

Soda-minette

Only three dikes are classed as soda-minettes, and these are of the subparallel dike system. At Walsenburg the Walsen dike is comprised of three intrusives; here a double dike comprised of a soda-minette and a minette has been invaded along shrinkage cracks by a later minette (Johnson, 1964). The soda-minette is the earliest dike to intrude the joint and is the southernmost dike of the double dike. It was sampled at three places (pl. 1, locs. 28, 96, and 97). The groundmass is microcrystalline and consists of analcitized sanidine, andesine (An_{35}), red and brown biotite, gray diopsidic augite, apatite, ilmenite, and magnetite, and locally hematite, chlorite, bowlingite, iddingsite, and an unidentified zeolite. Phenocrysts are mainly biotite as much as 3 mm across, making up 20–23 percent of the rock; augite as much as 2 mm across, 0–13 percent; and some olivine as much as 4 mm across, 0–3 percent. The average modal composition, in percent, is: analcitized sanidine, 17; andesine, 24, biotite, 24; augite, 8; olivine, 2; ilmenite and magnetite, 17; apatite, 4; hematite, 3; and zeolite, chlorite, bowlingite, iddingsite, and clay traces.

A short distance north of, and parallel to, Mauricio Canyon is a soda-minette apparently of the subparallel dike system (pl. 1, loc. 143). It is a dark-greenish-gray lamphophyre containing phenocrysts of hornblende and augite up to 2 mm across and biotite phenocrysts up to 1 mm across in a microcrystalline groundmass. The modal composition, in percent, is: orthoclase, 10; andesine (An_{35}), 24; biotite, 18; hornblende, 10; augite, 6; ilmenite and magnetite, 6; chlorite, 21; and clay, 5.

A highly altered soda-minette north of Trujillo Canyon (pl. 1, loc. 144) is apparently a subparallel dike. It is a dark-greenish-gray lamphrophyre containing scattered phenocrysts of biotite and augite in a microcrystalline groundmass. Biotite phenocrysts are as much as 1 mm across, and augite phenocrysts are as much as 2 mm across. The modal composition in percent, is: orthoclase, 10; andesine (An_{35}), 29; biotite, 5; augite, 3; ilmenite and magnetite, 8; chlorite, 36; calcite, 7; and clay, 2.

Soda-vogesite

Most of the soda-vogesite dikes are units of the subparallel dike system, but two are apparently part of the radial system. A radial dike between West Spanish Peak and East Spanish Peak (pl. 1, loc. 84), is a soda-vogesite with a marginal facies of microgranodiorite (p. G18). The lamprophyre is medium gray and contains abundant augite phenocrysts as much as 2 mm across in a microcrystalline groundmass. Chlorite and an unidentified zeolite are also visible to the eye as fillings of cavities left after the weathering out of augite phenocrysts. The modal composition, in percent, is: orthoclase, 26; andesine (An_{40}), 29; augite, 13; biotite, 2; corundum, trace; magnetite and ilmenite, 8; chlorite, 14; limonite, 4; calcite, 2; and zeolite, 2.

Between Mauricio and Trujillo Canyons (pl. 1, loc. 145) is a soda-vogesite multiple dike apparently of the radial system. It is a medium-gray lamprophyre containing phenocrysts of augite as much as 2 mm across and olivine as much as 4 mm across. Olivine phenocrysts make up 9 percent of the rock volume, and augite phenocrysts make up 5 percent. The modal composition, in percent, is: orthoclase, 7; andesine (An_{35}), 37; biotite, 6; hornblende, 2; augite, 15; olivine, 9; magnetite and ilmenite, 8; iddingsite along cracks in olivine, 1; chlorite, 11; clay, 2; calcite, 1; and zeolite, 1. This dike displays the most extreme thinning of any in the region. Over most of its extent the dike ranges from 4 to 6 feet in width. At this sample locality, however, it thins to a few inches in a vertical distance of 3 feet.

South of Walsenburg (pl. 1, loc. 146) is a short friable dike of soda-vogesite that weathers to pea-sized spheroids. It is a dark-olive-gray highly altered punky rock where least weathered. Small phenocrysts of reddish-brown augite, making up 4 percent of the rock, and olivine, making up 10 percent of the rock, are in an aphanitic groundmass. The modal composition, in percent, is: glass, 28; analcime, 12; red biotite, 7; augite, 18; olivine, 10; apatite, 1; picotite (?), trace; ilmenite and magnetite, 8; limonite, 4; iddingsite, 5; chlorite, 4; and calcite, 3.

North of Mauricio Canyon (pl. 1, loc. 147) is a dark-olive-gray soda-vogesite of the subparallel dike system. Phenocrysts of augite as much as 2 mm across, making up 6 percent of the rock, and olivine as much as 4 mm across, making up 10 percent of the rock, are in an aphnitic groundmass. The modal composition, in percent, is: orthoclase, 6; andesine (An_{35}), 19; pale-green augite, 10; reddish-brown arfvedsonite (?), 27; olivine, 4; magnetite and ilmenite, 15; apatite, 1; sphene, trace; limonite, 2; chlorite, 5; clay, 3; and calcite, 2.

A medium-light-gray soda-vogesite of the subparallel dike system occurs south of Mauricio Canyon (pl. 1, loc. 148). Scattered (3 percent) phenocrysts of colorless augite as much as 3 mm across are in a microcrystalline groundmass. The modal composition, in percent, of the rock, is: orthoclase, 10; andesine (An_{35}), 51; augite, 7; biotite, 7; sphene, 1; apatite, 1; corundum, trace; magnetite and ilmenite, 7; chlorite, 8; clay, 5; limonite, 1; calcite, 1 and a brown zeolite, 1.

South of Gulnare (pl. 1, loc. 31) is a long subparallel dike made of light-brown highly altered soda-vogesite. Very small phenocrysts of augite, making up 7 percent of the rock, are in a microcrystalline groundmass composed, in percent, of orthoclase, 13; andesine (An_{35}), 41; magnetite and ilmenite, 10; chlorite, 17; clay, 10; sericite, trace; and zeolite, 2. The zeolite fills cavities in chlorite.

A dark-greenish-gray glassy soda-vogesite dike of the subparallel system is near the head of Canyon del Agua (pl. 1, loc. 149). Small phenocrysts of augite and large phenocrysts of relict olivine filled with chlorite are in an unaltered microcrystalline and glassy groundmass. The modal composisition, in percent, is: glass, 15; orthoclase, 6; andesine (An_{30}), 27; brown biotite, 9; brown hornblende, 7; light-green augite, 16; olivine, 1; apatite, 1; magnetite and ilmenite, 9; chlorite, 5; limonite, 3; and zeolite and clay, traces. The augite crystals are in clusters.

The double Jarosa dike (pl. 1, loc. 43) is on the divide between Jarosa and Wet Canyons. The northern dike consists of andesite, and the southern dike is a dark-greenish-gray soda-vogesite containing small phenocrysts of augite in a microcrystalline groundmass. The modal composition, in percent, is: orthoclase, 11; andesine (An_{35}), 39; red biotite, 9; light-green augite, 16; apatite, 2; magnetite and ilmenite, 10; chlorite, 12; limonite, 1; and zeolite and clay, traces.

A coarse olive-gray granular rock on the west side of Apishapa Pass (pl. 1, loc. 150) make up an unusual dike apparently of the subparallel system. The rock might normally be called a prophyry, but it contains scattered huge phenocrysts of hornblende as much as 2½ inches long. The phenocrysts are in a fine- to coarse-grained groundmass. The modal composition, in percent, is: orthoclase, 15; andesine (An_{35}), 37; biotite, 3; hornblende, 7; sphene, 1; apatite, trace; magnetite and ilmenite, 14; limonite, 14; and chlorite, 1.

DIORITE

PORPHYRY

Diorite porphyry occurs only as dikes of the Spanish Peaks radial system and as a single independent dike. The independent dike is north of Cuchara Pass (pl. 1, loc. 151), and its exposed length is very short—mainly in a roadcut. The dike is a deeply weathered diorite porphyry containing large phenocrysts of anorthoclase, as much as 4 mm across, and small phenocrysts of augite, as much as 1½ mm across. The modal composition, in percent, is: anorthoclase, 3; andesine (An_{40}), 52; biotite, 4; augite, 4; magnetite and ilmenite, 10; chlorite, 16; serpentine, 2; calcite, 6; and clay, 3.

A very short dike east of Apishapa Pass (pl. 1, loc. 152) is made up of medium-dark-gray altered and weathered diorite porphyry. Phenocrysts of andesine (20 percent) as much as 5 mm across and hornblende (7 percent) as much as 3½ mm long are in a microcrystalline groundmass. The modal composition, in percent, is: quartz, 2; orthoclase, 3; andesine (An_{45}), 55; green biotite, 2; hornblende, 7; sphene, 1; apatite, trace; magnetite and ilmenite, 13; limonite, 2; hematite, trace; epidote, trace; chlorite, 9; clay, 5; and calcite, 1. Locally, fairly large quantities of penninite and an unidentified zeolite are present.

A long diorite porphyry dike extends from near the West Spanish Peak stock almost to Jarosa Canyon. The dike was sampled along Seco Creek (pl. 1, loc. 153), where the rock is a dark-greenish-gray diorite porphyry containing phenocrysts of andesine (An_{45}) and biotite in a microcrystalline to finely crystalline groundmass. Andesine phenocrysts make up 20 percent of the rock. The modal composition, in percent, is: quartz, 3; orthoclase, 5; andesine, 64; biotite, 1; augite, 6; magnetite and ilmenite, 3; chlorite, 15; sericite, 3; and clay, trace.

APHANITE

Microdiorites and andesites occur as subparallel and independent dikes and as sills. A subparallel dike in the northeastern corner of the region near Delcarbon (pl. 1, loc. 154) is made up of medium-gray holocrystalline microdiorite. It is composed, in percent, of orthoclase, 2; andesine (An_{40}), 43; biotite, trace; magnetite and ilmenite, 10; chlorite (clinochlore?), 25; and calcite, 20.

The northern dike of the double dike at the Jarosa–Wet Canyon divide (pl. 1, loc. 43) is a medium-dark-gray microcrystalline and glassy andesite. The modal composition, in percent is: glass, 11; andesine (An_{35}), 56; reddish-brown biotite, 4; reddish-brown augite, 10; apatite, 2; ilmenite and magnetite, 3; zeolite, 3; chlorite, 2; and clay, trace.

Another andesite dike is south of the Jarosa dike and crosses Wet Canyon (pl. 1, loc. 155). It is a light-olive-gray microcrystalline and glassy aphanite containing large local aggregates of small augite crystals. Its modal composition, in percent, is: glass, 22; orthoclase, 3; andesine (An_{35}), 33; reddish-brown biotite, 3; red hornblende, 5; light-green augite, 10; apatite, 1; ilmenite and magnetite, 9; epidote, trace; chlorite, 6; limonite, 2; zeolite, 3; and clay, 1.

A medium-dark-gray holocrystalline microdiorite near the head of Reilly Canyon (pl. 1, loc. 156) has a modal composition, in percent, of andesine (An_{45}), 44; chloritized augite, 15; ilmenite and magnetite, 17; apatite, 1; chlorite, 13; clay, 6; and calcite, 4.

A similar dike of microdiorite is nearby (pl. 1, loc. 157.) Its modal composition, in percent, is: andesine (An_{45}), 31; augite, 9; olivine, trace; apatite, 2; ilmenite and magnetite, 12; chlorite, 31; clay, 8; calcite, 5; and zeolite, trace. A third of the chlorite fills large relict crystals of olivine.

Two short independent dikes of microdiorite near Cuchara Pass intrude beds of the Sangre de Cristo Formation. These dikes are altered and highly weathered; both are light olive brown. The modal composition of the dike at locality 158, in percent, is: orthoclase, 3; andesine (An_{45}), 59; hornblende, 6; biotite, 1; chlorite, 23; ilmenite and magnetite, 11; and clay, 1. The modal composition of the dike at locality 159, in percent, is: quartz, 1; orthoclase, 3; andesine (An_{45}), 40; biotite, 5; augite, 4; sphene, 1; apatite, trace; ilmenite and magnetite, 21; limonite, 19; chlorite, 6; and zeolite and clay, traces.

A sill of microdiorite south of Cuchara Pass at Wildcat Creek (pl. 1, loc. 160) intrudes the Pierre Shale in a complex of many sills of similar appearance. The sill weathers to light olive gray, and its composition, in percent, is: andesine (An_{40}), 32; biotite, 3; ilmenite and magnetite, 8; calcite, 46; chlorite, 8; clay, 2; and zeolite, 1.

LAMPROPHYRE

Diorite lamprophyre or spessartite is sparse in the Spanish Peaks subparallel and independent dike systems. Two spessartite dikes of an independent dike system occur short distances northeast and southeast of La Veta (pl. 1, locs. 161 and 162). The northern dike is cut by another spessartite dike, apparently of the same system. The dike at locality 161 is dark olive gray and contains phenocrysts of augite and olivine as much as 3 mm across in a microcrystalline groundmass. The modal composition, in percent, is: orthoclase, 3; andesine (An_{40}), 31; biotite, 9; hornblende, 1; augite, 18; olivine, 3; apatite, trace; magnetite and ilmenite, 13; bowlingite, 9; iddingsite, 1; calcite, 6; and zeolite, 6. The dike rock at locality 162 is black and contains smaller and fewer phenocrysts of augite and olivine, generally less than 1 mm across, than the dike at locality 161. The modal composition, in percent, is: orthoclase, 4; andesine (An_{40}), 39; biotite, 11; hornblende, 2; augite, 14; olivine, 4; apatite, 1; magnetite and ilmenite, 16; and bowlingite, 9.

A light-greenish-gray lamprophyric dike of the subparallel system south of West Spanish Peak between Seco Creek and Jarosa Canyon (pl. 1, loc. 163) is classed as a spessartite. The modal composition, in percent, is: orthoclase, 3; andesine (An_{35}), 62; red biotite, 4; reddish-brown augite, 10 (half as phenocrysts); apatite, 1; magnetite and ilmenite, 8; chlorite, 18; and clay, 2.

The long lamprophyre dike of the subparallel system crossing Wet Canyon north of Weston (pl. 1, loc. 164) shows flow banding. It is a medium-dark-gray partly glassy spessartite containing phenocrysts of augite and hornblende less than 1½ mm across and isolated olivine crystals as much as 10 mm across. Hornblende and augite occur in serial sizes, and most of them are included in the microcrystalline groundmass. Analcime fills vesicles as large as 3 mm across. The modal composition, in percent, is: glass, 10; analcime, 11; andesine (An_{45}) microlites, 35; hornblende, 3; augite, 21; olivine, 2; ilmenite and magnetite, 13; chlorite, 3; and calcite, 1.

An altered greenish-brown independent lamprophyric dike near Monument Lake (pl. 1, loc. 165) is classed as a spessartite, owing to the absence of potassic feldspar. Small phenocrysts less than 2 mm across of biotite and hornblende are in a very fine grained groundmass. The modal composition, in percent, is: analcime, 23; andesine (An_{40}), 28; biotite, 12; hornblende, 13; magnetite, 1; limonite, trace; chlorite, 22; and clay, 1.

SYENOGABBRO

PORPHYRY

A syenogabbro porphyry and a gabbro porphyry have intruded a joint near Delcarbon (pl. 1, loc. 56). These dikes are part of a small independent dike system in the northeastern part of the region. The syenogabbro porphyry is a dark-gray altered rock containing phenocrysts of biotite and hornblende as much as 7 mm across and orthoclase and labradorite (An_{60}) as much as 3 mm across. All the orthoclase, labradorite, and hornblende occur as phenocrysts visible to the eye. The biotite occurs in serial sizes; about one-third of the crystals are of microscopic size. The modal composition, in percent, is: analcime, 5; orthoclase, 5; labradorite, 35; biotite, 14; hornblende, 15; augite, 7; apatite, 1; sphene, trace; magnetite and ilmenite, 10; chlorite, 4; thompsonite, 4; and prehnite, trace.

A short radial dike in Trujillo Canyon (pl. 1, loc. 166) is classed as a syenogabbro porphyry. It is a medium-gray porphyry containing a few phenocrysts of labradorite (An_{60}) as much as 3 mm long in a microcrystalline groundmass. Large aggregates (as much as 9 mm across) of chlorite, calcite, magnetite, and ilmenite have replaced large pyroxene or amphibole crystals. No hornblende was seen in the thin sections, but large unweathered hornblende crystals as much as 2½ inches long are exposed 3–5 feet apart in the dike. The modal composition, in percent, is: interstitial quartz, 1; interstitial orthoclase, 13; labradorite phenocrysts, 4; labradorite microlites, 27; biotite, trace; apatite, 2; sphene, trace; corundum, trace; ilmenite and magnetite, 15; chlorite, 21; calcite, 16; and limonite, trace.

APHANITE

The margin of the previously described dike (pl. 1, loc. 166) is a microsyenogabbro. It is a medium-gray aphanitic rock containing scattered 2½-inch long crystals of hornblende. This rock, like the rock previously described, contains no hornblende. The modal composition, in percent, is: orthoclase, 15; labradorite (An_{60}), 40; biotite, trace; augite, 2; corundum, trace; ilmenite and magnetite, 17; chlorite, 17; limonite, 5; and calcite, 4.

Several of the sills on Cuchara Pass (pl. 1, loc. 167) are microsyenogabbro, and probably all the sills in that area are of the same mineralogical composition. The sills are made up of a medium-gray microlamprophyric rock containing scattered relict phenocrysts of olivine 1–3 mm across filled with chlorophaeite. Smaller relict crystals of biotite are replaced by chlorite, calcite, magnetite, and an unknown pyrobole. The modal composition of the rock, in percent, is: quartz, 3; orthoclase, 8; labradorite (An_{60}), 29; red biotite, 3; sphene, 2; apatite and corundum, traces; magnetite, 13; chlorite, 26; calcite, 12; and limonite, 4.

LAMPROPHYRE

Syenogabbro lamprophyres are classed here as odinites and monchiquites. Odinites of syenogabbroic composition in the Spanish Peaks region contain phenocrysts of hornblende and labradorite in a microcrystalline groundmass consisting mainly of orthoclase, labradorite, biotite, and hornblende or augite. Locally, phenocrysts of augite and olivine are present. Monchiquites of syenogabbroic composition in the Spanish Peaks region are composed of phenocrysts of olivine, augite, hornblende, or biotite. The groundmass consists of glass or analcime and small crystals and microlites of orthoclase, labradorite, augite, hornblende, biotite, magnetite, ilmenite, and apatite.

Odinite

The only radial dike classed as a microsyenogabbro lamprophyre is an odinite cut by the Apishapa River west of Gulnare (pl. 1, loc. 168). It is a medium-dark-gray rock containing scattered phenocrysts of labradorite (An_{55}) as much as 8 mm across and green hornblende and green biotite as much as 4 mm across. Labradorite phenocrysts make up 6 percent of the rock volume, and the green hornblende and green biotite crystals make up 4 percent. The modal composition, in percent, is: orthoclase, 8; labradorite, 17; red biotite, 3; green biotite, 2; red hornblende, 1; green hornblende, 11; apatite, 2; magnetite and ilmenite, 6; chlorite, 8; calcite, 6; clay, 11; and an unidentified zeolite largely filling voids left by olivine phenocrysts, 25.

A medium-dark-gray lamprophyric dike of the subparallel system cut by Ideal Canyon south of Walsenburg (pl. 1, loc. 169) is perhaps best classed as an odinite. This classification is based on the high ratio of orthoclase to labradorite (An_{55}) rather than on the minerals constituting the phenocrysts. The composition of the phenocrysts, in percent, is: labradorite, 6; augite, 20; and olivine, 14. All the phenocrysts are less than 2 mm across. The modal composition, in percent, is: orthoclase, 4; labradorite, 24; biotite, 10; hornblende, 4; augite, 36; olivine, 14; apatite, trace; magnetite and ilmenite, 6; antigorite, 2; and iddingsite, trace.

Another dike of the subparallel system near Bear Creek to the southwest (pl. 1, loc. 170) is classed as an odinite. The rock is aphanitic except for scattered (7 percent) relict phenocrysts of olivine, which was replaced by antigorite and labradorite (4 percent); none of the phenocrysts are larger than 2 mm. The modal composition, in percent, is: orthoclase, 8; labradorite (An_{55}), 28; colorless diopside, 30; yellow and brown biotite, 8; olivine, trace; pyroxene reaction rim around relict olivine phenocrysts, 1; antigorite, 7; iddingsite, 1; apatite, 2; magnetite and ilmenite, 9; sphene, trace; clay, 3; and zeolite, trace.

Monchiquite

Monchiquite of syenogabbroic composition is more abundant in the region than odinite of similar composition, and it occurs in the subparallel and independent dike systems. The Maitland dike north of Walsenburg (pl. 1, loc. 171) is made up of three separate intrusives of monchiquite. At this locality, the dike cuts the Trinidad Sandstone and consists of three megascopically similar intrusives with intervening chill borders. The dike was sampled from the central intrusive, which is a dark-greenish-gray foliated lamprophyre containing macrophenocrysts of olivine (9 percent) as much as 4 mm across. Microphenocrysts are composed, in percent, of orthoclase, 3; green augite, 8; brown hornblende, trace; red biotite, 7; and antigorite, 3. The exceedingly fine groundmass is composed, in percent, of analcime, 5; orthoclase, 6; labradorite (An_{55}), 25; augite, 14; brown hornblende, 1; red biotite, 2; apatite, 2; magnetite and ilmenite, 8; hematite and limonite, 6; and calcite, trace.

A small independent dike system west of Walsenburg (pl. 1, loc. 172) is comprised of monchiquite dikes. The rock is a dark-greenish-gray lamprophyre containing phenocrysts of olivine (13 percent) as much as 4 mm across, augite (8 percent) as much as 1 mm across, and biotite (3 percent) as much as 2 mm across. These phenocrysts are set in a groundmass composed, in percent, of analcime, 30; analcitized sanidine, 6; analcitized labradorite ($An_{60?}$), 7; augite, 3; biotite, 4; apatite, 2; magnetite and ilmenite, 13; chlorite, 3; antigorite, 6; and calcite, 1.

A large prominent dike of monchiquite is cut by Ideal Canyon south of Walsenburg (pl. 1, loc. 173). The dike is made up of a medium-dark-gray lamprophyre containing phenocrysts of olivine (4 percent) as much as 2 mm across and yellow-green titanaugite (8 percent) as much as 4 mm across. Some of the augite phenocrysts are zoned. The groundmass consists, in percent, of analcime, 3; analcitized orthoclase, 8; labradorite (An_{55}), 24; titanaugite, 29; red hornblende, 4; brown biotite, 4; apatite, 1; ilmenite and magnetite, 7; chlorite, 3; iddingsite, 3; and bowlingite, 2.

A multiple dike of medium-dark-gray monchiquite cut by Mauricio Canyon (pl. 1, loc. 174) contains phenocrysts of olivine (3 percent) as much as 3 mm across and hornblende (7 percent) as much as 1 mm across. The scattered phenocrysts are in a groundmass composed, in percent, of analcime, 4; orthoclase, 8; labradorite (An_{56}), 32; augite, 2; biotite, 3; magnetite and ilmenite, 5; calcite, 15; chlorite, 14; and clay, 7.

A dark-greenish-gray altered monchiquite just south of Mauricio Canyon (pl. 1, loc. 175) includes phenocrysts of olivine (1 percent) as much as 4 mm across and augite (21 percent) as much as 2 mm long. The groundmass consists, in percent, of analcite, 2; analcitized orthoclase, 10; labradorite, 25; biotite, 8; magnetite and ilmenite, 5; chlorite, 20; calcite, 5; and clay, 3.

A light-olive-gray independent dike north of Cuchara Pass (pl. 1, loc. 176) is a syenogabbro classed as a monchiquite. It is part of a double dike and is the northernmost of the pair; the southern dike is a lamprophyre of gabbroic composition. This monchiquite is considerably different in aspect and mineralogy from the other monchiquites and might well be classed as a fourchite because it lacks olivine. Scattered phenocrysts as much as 3 mm long of grayish-green augite, making up 6 percent of the rock, are in an aphanitic groundmass. The modal composition, in percent, is: glass, 9; orthoclase, 6; labradorite (An_{65}), 35; red and green biotite, 6; red hornblende, 2; grayish-green augite, 8; apatite, 1; sphene, a trace; ilmenite and magnetite, 14; epidote, 3; chlorite, 7; limonite, 3; and clay, 3. Calcite, making up 3 percent of the rock, fills some vugs.

GABBRO

PORPHYRY

Gabbro porphyry occurs mainly in the interior of thick sills, but it forms a single dike in both the radial and subparallel systems.

A short dike south of Santa Clara Creek (pl. 1, loc. 177) and probably of the radial system consists of dense medium-dark-gray porphyry. Conspicuous phenocrysts, as much as 4 mm across, of andesine (An_{45}) compose 5 percent of the volume of the rock. A highly altered pyroxene occurs as phenocrysts 1-mm across that make up 2 percent of the rock. The groundmass is microporphyritic and contains microphenocrysts of andesine, which make up 4 percent of the rock, and a trace of corundum. The mode of the remainder of the groundmass, in percent, is: intergranular orthoclase, 2; microlites of labradorite (An_{55}), 31; magnetite and ilmenite, 12; chlorite, 16; calcite, 13; limonite, 11; and clay, 3.

The long dike cut by Wet Canyon north of Weston (pl. 1, loc. 178) is the southernmost subparallel dike. It is a medium-olive-brown porphyry containing phenocrysts composed in percent, of labradorite (An_{60}), 9; red biotite, 2; red hornblende, 3; and green augite, 11. The phenocrysts range from microscopic to 2 mm across, and all occur in serial sizes. Large relict phenocrysts of olivine as much as 4 mm across are filled with chlorite and make up 14 percent of the rock. The groundmass is composed in percent, of labradorite (An_{60}) microlites, 15; red biotite, 2; red hornblende, 2; green augite, 9; apatite, 1; magnetite and ilmenite, 12; chlorite, 12; calcite, 2; limonite, 2; and zeolite, 4.

A medium-dark-gray porphyritic sill south of Aguilar was sampled at two places (pl. 1, locs. 179 and 180). At both localities phenocrysts of labradorite (An_{55}), as large as 3 mm across and making up 37 percent of the rock, are in an aphanitic groundmass. The groundmass composition, in percent, is: interstitial quartz, trace; labradorite (An_{55}), 19; biotite, 10; magnetite and ilmenite, 9; zircon trace; calcite and dolomite, 14; limonite, 4; and chlorite and clay, traces. At locality 179 the gabbro porphyry contains scattered large relict hexagonal crystals filled with calcite.

A dark-gray porphyritic sill along the Cuchara River southwest of La Veta (pl. 1, loc. 181) is classed as a gabbro porphyry. Phenocrysts include orthoclase (1 percent) and labradorite (An_{55}, 26 percent) crystals as much as 3 mm across and sparse augite crystals as much as 2 mm across. Scattered vesicles as much as 4 mm across are filled with zeolite and clay. The composition of the groundmass, in percent, is: labradorite microlites (An_{60}), 31; biotite, 2; magnetite and ilmenite, 9; and chlorite, 16. In the vesicles, clay makes up 9 percent of the filling material and zeolite 2 percent.

A similar gabbro porphyry sill cut by Indian Creek southwest of La Veta (pl. 1, loc. 182) contains 4-mm-long phenocrysts of labradorite (An_{60}) and 2-mm-long phenocrysts of augite. Labradorite phenocrysts make up 35 percent of the rock, and augite phenocrysts 17 percent. The modal composition in percent, of the groundmass, is: labradorite (An_{60}), 9; biotite, 11; hornblende, 2; magnetite and ilmenite, 13; chlorite, 9; bowlingite, 2; calcite, 2; and iddingsite, trace.

APHANITE

Aphanitic rocks of gabbroic composition are classed as microgabbros and basalts; the distinction between the two rocks, as used in this report, is that basalts contain glass. Glass is also found locally in the gabbroic lamprophyres, monchiquites and fourchites.

Basalt

A scoriaceous basalt plug east of Delcarbon (pl. 1, loc. 17) has a pumiceous perimeter, and its interior contains many xenoliths of gneiss as large as 6 inches across (fig. 7). The modal composition, exclusive of the gneissic xenoliths, in percent, is: rounded microscopic xenoliths of quartz, 12; glass, 5; labradorite (An_{60}), 50; biotite, 18; augite, 1; apatite, trace; chlorite, 9; and magnetite and ilmenite, 5. Scattered hexagonal clouds of iron-ore dust surround labradorite, biotite, and chlorite.

A very dark gray aphanitic dike of the subparallel system that occurs in Wet Canyon (pl. 1, loc. 183) is classed as a basalt. Its modal composition, in percent, is: chloritic glass, 11; labradorite (An_{55}), 47; biotite, 1; augite, 16; apatite, 2; magnetite and ilmenite, 8; and calcite, 3.

Microgabbro

Most of the microgabbros occur as thin sills or as the margins of thick sills with porphyritic interiors. However, a deeply weathered and altered medium-dark-gray aphanitic dike of the radial system near Trujillo Canyon (pl. 1, loc. 184) may be classed as a microgabbro. The modal composition, in percent, is: orthoclase, 3; labradorite (An_{55}), 48; an unidentifiable amphibole, 7; biotite, 2; magnetite and ilmenite, 12; chlorite, 18; clay, 8; and calcite, 2. Relict phenocrysts of what appears to have been a pyroxene are filled with chlorite.

Two sills cut by the Apishapa River southeast of Aguilar (pl. 1, loc. 185) are made up of medium-olive-gray microgabbro containing small phenocrysts (less than 1 mm across) of olivine. The modal composition, in percent, is: orthoclase, 2; labradorite (An_{60}), 45; biotite, 1; olivine, 17; magnetite and ilmenite, 11; chlorite, 18; iddingsite, 2; calcite, 2; and clay, 2.

Many microgabbro sills occur south of Aguilar. One (pl. 1, loc. 186) is a highly weathered light-olive-gray microgabbro. The modal composition, in percent, is: labradorite (An_{55}), 42; biotite, 3; magnetite, 5; calcite, 31; chlorite, 3; clay, 3; and zeolite, trace.

A short sill at locality 187 is classed as a microgabbro. It is a light-brown highly weathered aphanite containing scattered small phenocrysts of olivine. The modal composition, in percent, is: labradorite (An_{60}), 51; biotite, 13; olivine, 2; augite, trace; magnetite and ilmenite, 7; limonite, 11; calcite, 13; chlorite, 3; clay and zeolite, traces. The augite occurs as very fine crystals in reaction rims around the olivine phenocrysts.

Another sill nearby (pl. 1, loc. 188) is an altered dark-greenish-gray microgabbro composed, in percent, of analcime, 13; labradorite (An_{60}), 44; biotite, 1; magnetite, 5; chlorite, 30; and clay, 7.

The sill complex in the western part of the region south of Cuchara Pass is comprised mainly of microgabbroic rocks. Differences in the composition of the separate sills are due largely to alteration and weathering.

The sill at locality 189 (pl. 1) is a medium-gray highly weathered microgabbro composed, in percent, of microlites of labradorite (An_{55}), 52; magnetite, 3; limonite, 21; chlorite, 7; calcite, 12; and zeolite, 5. Much of the calcite and zeolite fill 1–2 mm vesicles.

Another nearby sill (pl. 1, loc. 190) is made up of medium-gray slightly weathered migrogabbro. Its modal composition, in percent, is: labradorite (An_{55}), 50; biotite, 1; magnetite, 2; limonite, 2; chlorite, 11; calcite, 10; zeolite, 11; and clay, 8. Most of the calcite and zeolite fill 2–4 mm vesicles.

Another of these microgabbro sills (pl. 1, loc. 191) is less weathered. It is a dark-gray aphanite containing sparse (2 percent) 1-mm long phenocrysts of augite. Its modal composition, in percent, is: labradorite (An_{55}), 37; biotite, 12; augite, 11; corundum, 3; magnetite, 5; limonite, 2; chlorite, 12; calcite, 11; zeolite, 5; and clay, 2.

The sill complex in the central part of the region along the Purgatoire River (pl. 1, locs. 65 and 192) is made up mainly of dark-gray microgabbro. The modal composition of these rocks does not vary much, and the average modal composition, in percent, of the rocks sampled is: labradorite (An_{60}), 52; augite, 3; magnetite, 5; chlorite, 23; calcite, 13; zeolite, 3; and clay, 1.

The sills in the western part of the region west and northwest of La Veta are also largely of microgabbro. A dark-greenish-gray microgabbro along U.S. Highway 160 (pl. 1, loc. 193) is composed, in percent, of orthoclase, trace; labradorite (An_{55}), 36; augite, 2; olivine, 3; magnetite and ilmenite, 8; chlorite, 38; calcite, 12; and iddingsite, 1. The olivine occurs as 2–3 mm phenocrysts.

Crossing Middle Creek (pl. 1, loc. 194) is a medium-dark-greenish-gray highly altered sill of microgabbro containing microphenocrysts of augite, which make up 8 percent of the rock. The extremely fine groundmass is composed, in percent, of labradorite (An_{55}), 37; magnetite and ilmenite, 13; chlorite, 40; and calcite, 2.

LAMPROPHYRE

Gabbro lamprophyres are classed as odinites, monchiquites, and fourchites and are fairly common members of the radial, subparallel, and independent dike systems in the Spanish Peaks region. Gabbroic odinites in the region contain phenocrysts of labradorite, olivine, or augite in a crystalline groundmass composed largely of labradorite, biotite, augite, or hornblende. Monchiquites contain phenocrysts of olivine, augite, or hornblende in a groundmass consisting of analcime or glass. Local fourchites contain phenocrysts of biotite or augite in a groundmass of analcime or glass.

Odinite

A short radial dike south of the South Fork of Trujillo Canyon (pl. 1, loc. 195) is classed as odinite. It is a medium-dark-olive-gray lamprophyre containing phenocrysts of labradorite (An_{55}), 2 percent; augite, 3 percent; and olivine, 1 percent. The groundmass is composed, in percent, of groundmass orthoclase, 1; labradorite (An_{60}), 35; biotite, 2; magnetite and ilmenite, 8; chlorite, 32; clay, 9; and calcite, 7.

Another radial dike west of Aguilar in the Apishapa valley (pl. 1, loc. 196) is a dark-gray odinite containing small phenocrysts of labradorite (An_{55}, 4 percent), augite (13 percent) as much as 5 mm across, and olivine (13 percent) as much as 6 mm across. The modal composition of the groundmass, in percent, is: labradorite (An_{55}), 20; biotite, 2; augite, 4; apatite, 1; magnetite, 14; calcite, 11, of which about a third fills voids in olivine phenocrysts; chlorite, 5; limonite, 6; iddingsite, 2; and zeolite, 4.

A short radial dike east of Apishapa Pass (pl. 1, loc. 197) is a medium-olive-brown odinite containing prominent 3-mm long phenocrysts of augite, 8 percent, and scattered 1.5-mm long phenocrysts of labradorite, 2 percent. The modal composition of the groundmass, in percent, is: labradorite (An_{60}), 48; augite, 6; biotite, 2; apatite, trace; ilmenite and magnetite, 21; chlorite, 17; limonite, 16; clay, 3; and calcite, trace.

An odinite dike of the subparallel system west of Ideal Canyon (pl. 1, loc. 198) cuts an independent curvilinear dike of microsyenodiorite (pl. 1, loc. 52). This odinite is a very dark gray unweathered rock containing inconspicuous phenocrysts of labradorite, 6 percent; augite, 7 percent; and olivine, 6 percent. All phenocrysts range in size from 1 to 3 mm. The modal composition of the groundmass, in percent, is: slightly analcitized labradorite (An_{60}), 42; biotite, 7; augite, 25; apatite, trace; magnetite and ilmenite, 6; and chlorite, 1.

A short odinite dike of the subparallel system occurs a few miles northwest of Aguilar (pl. 1, loc. 199). The dike is a weathered medium-olive-gray rock containing small phenocrysts composed of labradorite, 2 percent; augite, 10 percent; and olivine. The olivine crystals are the largest phenocrysts but do not exceed 3 mm across. The modal composition of the groundmass, in percent, is: labradorite (An_{55}), 32; biotite, 8; hornblende, 6; magnetite and ilmenite, 9; limonite, 1; chlorite, 20; calcite, 4; antigorite, 2; and zeolite, 1.

An odinite dike crosses the highway from La Veta to Badito north of La Veta (pl. 1, loc. 200). Structurally, the dike appears to be a part of the subparallel dike system, but, as it is isolated from most of the dikes of this system, it may be part of a small independent set. The rock of the dike is a slightly altered medium-olive-gray lamprophyre containing phenocrysts composed, in percent, of labradorite, 3; hypersthene, 10; augite, 8; and olivine, 15. Most of the labradorite, hypersthene, and augite phenocrysts are less than 1 mm across, but locally olivine crystals are as large as 4 mm across. The modal composition of the groundmass, in percent, is: orthoclase, trace; labradorite (An_{55}), 36; hypersthene, 5; augite, 6; magnetite and ilmenite, 8; bowlingite, 11; limonite, 1; chlorite, 2; and calcite, 1.

Monchiquite

A short dike of the radial system crops out along the road along Wahatoya Creek (pl. 1, loc. 201). It is a medium-dark-gray monchiquite containing phenocrysts of olivine (19 percent) as much as 4 mm across and augite (6 percent) as much as 2 mm across. The modal composition, in percent, is: analcime, 4; labradorite (An_{60}), 46; biotite, 21; augite, 1; magnetite, 4; and clay. Reaction rings of small crystals of augite surround many of the large olivine phenocrysts.

The long dike of the subparallel system cut by Wet Canyon (pl. 1, loc. 202) is a double dike of medium-gray monchiquite. Both dikes are nearly identical mineralogically and contain 1-mm-long phenocrysts of augite, 8 percent, and biotite, 3 percent, and 2- to 5-mm phenocrysts of olivine, 8 percent, in an aphanitic groundmass. The groundmass composition, in percent, is: partly devitrified glass, 37; analcime, 7; reddish-brown biotite, 3; green augite, 18; magnetite, 9; clay, 3; iddingsite, 1; and calcite, 1. The glass has been partly devitrified to microlites of bytownite (An_{75}).

An independent monchiquite dike near Monument Lake (pl. 1, loc. 203) is exposed in a roadcut. It is a lightly-gray rock containing scattered phenocrysts of hornblende (3 percent) as much as 6 mm long and olivine (3 percent) as large as 4 mm across in an aphanitic groundmass. The groundmass composition, in percent, is: analcime, 44; analcitized labradorite (An_{60}), 33; biotite, 6; magnetite, 1; chlorite, 5; and clay, 5.

A small independent dike system in the northeastern part of the region (pl. 1, locs. 56 and 204) is made up largely of monchiquite. The dikes at the two localities vary somewhat mineralogically. At locality 56, the dike rock is a dark-olive-gray lamprophyre containing 3-mm-long and smaller phenocrysts composed, in percent, of green augite, 22; green arfvedsonite(?), 5; red biotite, 5; and olivine, 16. These phenocrysts are in an aphanitic groundmass composed, in percent, of analcime, 21; analcitized labradorite (An_{55}), 17; apatite, 1; magnetite and ilmenite, 7; thompsonite, 3; chlorite, trace; and calcite, trace. At locality 204 the monchiquite is similar to that at locality 56. The phenocrysts, however, are less than 2 mm across and are composed, in percent, of red biotite, 11; green augite, 24; and olivine, 12. The mode of the groundmass, in percent, is: analcime, 8; analcitized labradorite (An_{55}), 34; apatite, 1; magnetite and ilmenite, 8; and iddingsite, 2.

Fourchite

A short fourchite dike along Wahatoya Creek (pl. 1, loc. 205) may be an isolated unit of the subparallel system or may be an independent dike. It is a medium-olive-green lamprophyre containing phenocrysts of brown biotite as much as 4 mm across. The biotite phenocrysts make up 20 percent of the rock volume, and biotite is not found in microscopic sizes. The groundmass composition, in percent is: analcime, 20; labradorite (An_{55}), 26; hornblende, 18; magnetite, 7; chlorite, 3; calcite, 5; and clay, 1.

A medium-gray independent dike north of Cuchara Pass (pl. 1, loc. 176) is classed as a fourchite. It is the southernmost of a pair of dikes; the northern dike is a monchiquite. The fourchite contains phenocrysts of light-green augite (2 percent) in an aphanitic groundmass. Calcite, making up 5 percent of the rock, and limonite, making up 2 percent of the rock, fill vugs that are visible to the eye. The modal composition of the groundmass, in percent, is: glass, 5; orthoclase, 3; labradorite (An_{70}), 35; light-green augite, 9; red biotite, 11; green hornblende, 10; sphene, 3; magnetite and ilmenite, 6; epidote, 2; and chlorite, 8.

A short fourchite dike of the subparallel dike system is exposed in a roadcut a short distance south of Walsenburg (pl. 1, loc. 206). It is a brownish-gray microlamprophyre containing phenocrysts of red biotite (10 percent) less than 1 mm across. The groundmass composition, in percent, is: analcime, 14; analcitized labradorite (An_{65}), 64; augite, 4; apatite, 2; magnetite, trace; and calcite filling vesicles, 6.

The short independent dike east of the Black Hills (pl. 1, loc. 54) is a fourchite. A few scattered phenocrysts composed of green augite, 3 percent, are scattered throughout an aphanitic groundmass, and few are as much as 2 mm across. The groundmass composition, in percent, is: analcime, 4; analcitized labradorite (An_{65}), 50; red biotite, 5; green augite, 20; apatite, 2; magnetite and ilmenite, 7; chlorite, 7; and calcite, 2. Large relict crystals of biotite are almost completely replaced by calcite and minute grains of magnetite. Some of the material described as chlorite may be chloritic glass.

CHEMICAL COMPOSITION OF THE VARIOUS ROCK TYPES

The igneous rocks of the Spanish Peaks region are as varied chemically (tables 1–21) as they are petrographically. The SiO_2 content ranges from 41.1 to 73.6 percent and more than half of the rocks contain less than 50 percent. The percentage of Al_2O_3 ranges from 10.8 to 17.9, but in most of the rocks studied it is near 11.5 or 15.5 percent. Many of these rocks are rich in some of the rarer elements, such as titanium, phosphorus, barium, chromium, copper, nickel, strontium, and vanadium. These elements are especially abundant in the lamprophyres and in many dikes of the subparallel dike swarm.

Normative compositions calculated from the chemical analyses of the various rocks are considerably different from the modal compositions. Normative quartz is more abundant than modal quartz, normative olivine is generally more abundant than modal olivine, and modal nepheline is never present as indicated by the normative composition of some of the rocks. In tables 1–21 the rock types are grouped according to their actual mineral composition.

Granite.—Chemical analyses (table 1) and spectrographic analyses (table 2) were made of seven rocks classed petrographically as granite. The SiO_2 content ranges from 58.3 to 73.6 percent and falls within the percentage range of SiO_2 in granites. However, the normative compositions of these rocks (table 3) indicate that they would be classed chemically as granodiorite, according to the ratio of plagioclase feldspars to orthoclase.

Granodiorite.—Chemical analyses (table 4) and spectrographic analyses (table 5) were made of three rocks classed petrographically as granodiorite. The normative compositions (table 6) also indicate that these rocks may be classified chemically as granodiorite.

Syenite.—Chemical analyses (table 7) and spectrographic analyses (table 8) were made of 11 rocks classed petrographically as syenite. The SiO_2 content ranges from 45.1 to 47.9 percent and from 60.3 to 69.2 percent. The rocks in the lower SiO_2 range are lamprophyres, and those in the upper range are syenite prophyries. The percentage of Al_2O_3 is also in two distinct ranges—lamprophyres, 10.1–11.6 percent, and porphyries, 15.4–17.0 percent. There is also a marked distinction between the lamprophyres and porphyries in the amounts and kinds of the rarer elements (table 8).

The normative composition of the syenite porphyries (table 9) is more silicic than the modal composition, and these porphyries may be classed chemically as granodiorite. The lamprophyres, although some contain normative nepheline and olivine, are classed chemically as syenites.

Syenodiorite.—Chemical analyses (table 10) and spectrographic analyses (table 11) were made of 30 rocks that had been classed petrographically as syenodiorite. The SiO_2 content ranges from 41.1 to 63.7 percent, and the Al_2O_3 content ranges from 11.2 to 17.9 percent. There is no clear-cut separation here, as in the syenites, between the lamprophyres and the other syenodioritic rocks. The range in the content of SiO_2 in the lamprophyres is 41.1–51.6 percent, and for the syenodiorite porphyries and aphanites it is 42.0–63.7 percent. Although the SiO_2 content of the lamprophyres is generally lower than in the other rocks, there is almost a complete overlap in the ranges of SiO_2 percentage of the two groups. The syenodiorite lamprophyres are distinct from the other varieties of syenodiorite. The element cerium, if present, occurs almost always in the lamprophyres. Barium, strontium, and chromium are typically very abundant in the lamprophyres.

The syenodiorite lamprophyres and many of the porphyries and aphanites are chemically classified as syenodiorites from their normative compositions (table 12); however, some of the syenodiorite porphyries contain enough normative quartz to be classed chemically as granodiorite.

Diorite.—Chemical analyses (table 13) and spectrographic analyses (table 14) were made of eight dike rocks classed petrographically as diorite. The SiO_2 content is 44.5–54.4 percent, and the Al_2O_3 content is 14.1-16.8 percent. There seems to be no chemical distinction between the dioritic lamprophyres and the other dioritic rocks; both the SiO_2 and Al_2O_3 contents of the lamprophyres are intermediate in the range of these oxides for all the diorites analyzed. Also, no distinction is apparent between the lamprophyres and the other dioritic rocks in the types and amounts of the rarer elements. The normative composition (table 15) of the lamprophyres indicates large amounts of olivine. Although analcime occurs naturally in some of the diorites, normative nepheline is absent in these rocks.

Syenogabbro.—Chemical analyses (table 16) and spectrographic analyses (table 17) were made of eight rocks classed petrographically as syenogabbro. The SiO_2 content is 43.5–49.2 percent, and the Al_2O_3 content is 11.7–15.9 percent. Most of the syenogabbros analyzed are lamprophyres with chemical compositions similar to an aphanitic sill and porphyritic dike (table 16) of syenogabbro. However, the lamprophyres are rich in phosphorus, cobalt, chromium, lead, and strontium (table 17). The normative compositions (table 18) may indicate an unusually high percentage of quartz in several of these rocks. Nepheline is found normatively in some of the lamprophyres, and normative olivine occurs in most of them.

Gabbro.—Chemical analyses (table 19) and spectrographic analyses (table 20) were made of nine rocks that had been classed petrographically as gabbro. The SiO_2 content is 41.3–46.0 percent, and the Al_2O_3 content is 11.8–16.6 percent. Normative compositions (table 21) show several of the rocks to be high in quartz, which does not occur as a modal mineral. Some of these rocks contain olivine, which is not always demonstrated by the norms. Modal analcime is indicated by lesser amounts of normative nepheline.

DISCUSSION

AGE AND ORDER OF MAGMATIC INTRUSION

The general sequence of the invasion of the magmas that produced the various types of intrusive igneous features in the Spanish Peaks region was determined in the field by study of the relations of the gross igneous structures to adjacent igneous features, igneous rock types, and metamorphic and structural alteration of the country rock. Intersections of the dikes are common, and they were the most useful feature in determining the relative age of the individual dikes as well as the larger dike swarms. However, the plugs and many of the isolated dikes and sills have no surface relationship to the other igneous features, and their relative ages in the sequence of magmatic invasion cannot be determined.

Generally, the compositional order of intrusion does not seem to have been from mafic to silicic but almost the reverse. The oldest intrusion is probably the granite porphyry stock of East Spanish Peak, and among the youngest are the mafic dikes and sills of the parallel dike system. The order of intrusion of the radial dikes of the Spanish Peaks swarm, however, if considered as a single group, seems to have been from mafic to silicic.

The interpreted sequence of magmatic invasion for the types of igneous rocks and features is summarized as follows:

1. Granite porphyry of the East Spanish Peak stock.
2. Granite porphyries of the White Peaks and several unnamed stocks.
3. Microgranite of the Mount Mestas sole injection and several unnamed stocks.
4. Granodiorite porphyries of the East Spanish Peak and the Stonewall stocks.
5. Syenite porphyry of the Rough Mountain and several small unnamed stocks and microsyenite of the Sheep Mountain–Little Sheep Mountain laccolith (?).
6. Syenodiorite porphyries of the West Spanish Peak, Dike Mountain, and Little Black Hills stocks and the Black Hills laccolith (?).
7. Microgabbro sills associated with the West Spanish Peaks stock.
8. Radial dike swarm of Dike Mountain (sequence indeterminate).
   (a) Syenodiorite porphyry dikes and related sills.
9. Radial dike swarm of West Spanish Peak.
   (a) Gabbro porphyry, microgabbro, and gabbroic odinite and monchiquite dikes.
   (b) Syenogabbro porphyry and syenogabbroic odinite dikes.
   (c) Diorite porphyry dikes.
   (d) Syenodiorite porphyry, microsyenodiorite, and soda-vogesite dikes (two or three separate phases).
   (e) Syenite porphyry, microsyenite, and vogesite dikes.
   (f) Granodiorite porphyry and microgranodiorite dikes.
   (g) Granite porphyry dikes.
10. Subparallel dike swarm and related sills (sequence indeterminate).
   (a) Gabbro porphyry, microgabbro, basalt, and gabbroic odinite, monchiquite, and fourchite dikes and sills.
   (b) Microsyenogabbro, and syenogabbroic odinite and monchiquite dikes and sills.
   (c) Microdiorite, andesite, and spessartite dikes and sills.
   (d) Syenodiorite porphyry, microsyenodiorite, soda-minette, and soda-vogesite dikes and sills.
   (e) Syenite porphyry, microsyenite, minette and vogesite dikes.
11. Independent dikes and sills (sequence indeterminate).
   (a) Gabbro porphyry sills and gabbroic odinite, monchiquite, and fourchite dikes.
   (b) Syenogabbro porphyry and syenogabbroic monchiquite dikes.
   (c) Diorite porphyry, microdiorite and spessartite dikes and sills.
   (d) Syenodiorite porphyry and microsyenodiorite dikes and sills.
   (e) Syenite porphyry, microsyenite, minette, and vogesite dikes.
12. Plugs.
   (a) Latite of Goemmer Butte, microsyenodiorite and syenodiorite porphyries in Huerfano Park, and microgranite northeast of La Veta.
   (b) Scoriaceous basalt near Delcarbon.

This sequence of magmatic invasion for the intrusive rocks of the Spanish Peaks region as summarized above differs slightly from a previously proposed sequence (Johnson, 1961b, p. 585) for those intrusive rocks in a smaller area adjacent to and including the Spanish Peaks.

ORIGIN OF THE RADIAL DIKE PATTERNS

Hills (1901, p. 3) apparently believed that the dikes adjacent to West Spanish Peak occupy radial fissures formed during doming of the sedimentary rocks by the emplacement of magma. Doming of sedimentary rocks by a rising magma theoretically should result in vertical tension joints, faults, and perhaps inward-dipping shear joints (Parker and McDowell, 1951). Subsidence of the domed rocks following withdrawal or escape of the magma should generally result in ring-dike fractures in the rocks (Modell, 1936, p. 1925–1931; Richey, 1948, p. 49–53). However, aside from the presence of dikes intruded into what might be vertical radiating joints, there is no evidence in the sedimentary rocks adjacent to the West Spanish Peak or Dike Mountain stocks to support the idea of doming by these magmas, and there is no evidence of ring-dike fractures resulting from collapse of domes.

Recent structural studies in the Spanish Peaks region indicate that several systems of joints were formed throughout the region by intermittent orogenic stresses of varying direction during the folding of the La Veta syncline. The writer believes that selective intrusion into this older joint complex at West Spanish Peak and Dike Mountain accounts for the radial patterns.

At least five times during latest Cretaceous, Paleocene, and Eocene time (Johnson and Wood, 1956, p. 707–720), the rocks of the Spanish Peaks region were subjected to stresses of varying magnitude and direction. The La Veta syncline was formed early in Tertiary time, and it deepened as compressive forces were exerted in an east-west direction. Near the end of Eocene time major thrusting from the west overturned the western limb of the La Veta syncline, and thrust plates overrode the western part of the region.

The folding of the La Veta syncline resulted in the formation of shear and tension joints, especially in the competent sedimentary rocks of the basin (Johnson, 1961b, fig. 4, p. 588). Tension joints form parallel to the principal stress direction, and shear joints theoretically form at acute angles bisected by the principal stress direction (Anderson, 1951, p. 3–4; Sitter, 1956, p. 123–125). Later change in the direction of stress would create new tension and shear joints, would create tension along previously formed shear joints, or would extend existing joints along curved or straight lines. The initial joint system would thus be modified into a more complex and random pattern.

Several types of igneous bodies intruded the jointed sedimentary rocks of the Spanish Peaks region at the close of Eocene time, during and after the final pulsations of the last major orogenic episode in the region. The igneous masses that constitute the West Spanish Peak and Dike Mountain stocks were emplaced during this period. These masses apparently did not fold the intruded sedimentary rocks. The writer believes that the radial dike swarms are fortuitously associated with these two stocks because low-viscosity magmas were available for the dike injection subsequent to the intrusion of the stocks. Theoretically, the magmas would be intruded selectively into those preexisting joints, which are normal to domical or nearly domical equipotential pressure surfaces, and thus would produce radiating dike systems. Most dikes apparently were intruded into only those joints normal to these equipotential pressure surfaces.

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TABLES 1–21

TABLE 1.—*Chemical analyses, in percent, of granites in the Spanish Peaks region*

[P. L. D. Elmore, S. D. Botts, G. W. Chloe, Lowell Artis, and H. Smith, analysts. Rock type: SI, sole injection; RD, radial dike; SD, subparallel dike]

Locality (pl. 1) / Rock type	Mount Mestas SI	16 Plug	East Spanish Peak Stock	80 RD	78 RD	81 SD	79 RD
SiO_2	73.6	72.5	71.2	69.1	67.9	67.2	58.3
Al_2O_3	15.2	14.6	14.6	15.1	15.4	14.9	16.6
Fe_2O_3	.60	.35	1.1	1.3	1.7	2.6	2.5
FeO	.20	.16	.98	1.4	1.4	3.3	2.3
MgO	.20	.26	.71	.80	1.2	1.7	2.1
CaO	.83	1.3	1.1	1.9	2.1	.86	3.7
Na_2O	4.3	4.7	3.6	4.7	4.3	1.9	4.7
K_2O	4.4	4.2	4.6	3.4	3.5	2.6	3.3
H_2O-	.23	.16	.28	.18	.39	1.2	.35
H_2O+	.74	.64	.98	1.1	1.1	2.7	2.2
TiO_2	.06	1.2	.33	.44	.49	.66	1
P_2O_5	.02	.02	.12	.21	.21	.24	.45
MnO	.01	.02	.10	.08	.01	.10	.10
CO_2	<.05	.29	.22	.75	<.05	<.05	2.3
Total	100	100	100	100	100	100	100

TABLE 2.—*Semiquantitative spectrographic analyses of granites in the Spanish Peaks region*

[J. C. Hamilton, analyst. Results are reported in percent to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc., which represents approximate midpoints of group data on a geometric scale. The assigned group for semiquantitative results will include the quantitative value about 30 percent of the time, Symbols: M, major constituent—greater than 10 percent; 0, looked for but not detected; ---, not looked for. Rock type: SI, sole injection; RD, radial dike; SD, subparallel dike]

Locality (pl. 1) / Rock type	Mount Mestas SI	16 Plug	East Spanish Peak Stock	80 RD	78 RD	81 SD	79 RD
Si	M	M	M	M	M	M	M
Al	7	7	7	7	7	7	M
Fe	.5	.5	.7	1.5	2	3	5
Mg	.03	.15	.15	.7	.5	1.5	1.5
Ca	.7	1	.5	1	1.5	.7	2
Na	3	3	3	2	3	1	3
K	3	5	3	2	3	2	2
Ti	.03	.03	.1	.2	.2	.3	.5
P	0	0	0	0	0	0	0
Mn	.01	.01	.05	.02	.03	.05	.07
Ba	.15	.1	.07	.2	.15	.15	.2
Be	.0003	.0003	.0005	.0002	.0002	0	.0002
Ce	0	0	0	0	0	0	0
Co	0	0	0	.0007	.0007	.001	.001
Cr	0	.0015	.00015	.0007	.001	.005	.005
Cu	.0007	.0005	.001	.0005	.005	.003	.005
Ga	.002	.005	.003	.002	.002	.002	.002
La	0	0	0	0	0	0	.007
Nb	.002	.005	.005	.002	.002	0	.003
Ni	0	.0005	0	.001	.0007	.002	.002
Pb	.002	.002	.003	.003	.005	.002	.002
Sc	0	0	0	0	0	.001	.0007
Sr	.05	.07	.1	.1	.1	.05	.15
V	.003	.001	.001	.002	.015	.007	.01
Y	.001	.001	.002	.0015	.0015	.003	.002
Yb	0	---	.0002	.0001	.00015	.0005	.0002
Zr	.005	.005	.0003	.005	.02	.01	.01
Nd	---	---	---	0	---	---	0

TABLE 3.—*Normative composition, in percent, of granites in the Spanish Peaks region*

[Rock type: SI, sole injection; RD, radial dike; SD, subparallel dike]

Locality (pl. 1) / Rock type	Mount Mestas SI	16 Plug	East Spanish Peak Stock	80 RD	78 RD	81 SD	79 RD
Q	30.16	26.79	31.16	29.83	24.68	41.55	27.09
C	2.02	.68	2.50	2.48	1.53	8.09	4.98
or	26	24.81	27.18	20.09	20.68	15.36	19.50
ab	35.77	39.75	27.82	30.81	34.82	15.47	12.35
an	3.99	4.48	4.67	8.05	9.04	2.70	15.41
ne	0	0	0	0	0	0	0
nc	.12	0	.53	1.81	.31	.12	5.54
mt	.50	0	1.59	1.88	2.46	3.77	3.62
hm	.25	.35	0	0	0	0	0
il	.11	.38	.63	.84	.93	1.25	1.90
ru	0	1	0	0	0	0	0
ap	.05	.05	.28	.50	.50	.57	1.07
cc	0	.66	0	0	0	0	0
di	0	0	0	0	0	0	0
hy	.50	.65	2.30	2.91	3.44	7.24	5.92
ol	0	0	0	0	0	0	0
Total	99.47	99.60	98.67	99.19	98.39	96.12	97.37

TABLE 4.—*Chemical analyses, in percent, of radial dikes of granodiorites in the Spanish Peaks region*

[P. L. D. Elmore, S. D. Botts, G. W. Chloe, Lowell Artis, and H. Smith, analysts]

Locality (pl. 1)	82	84	85
SiO_2	67.7	63.1	61.3
Al_2O_3	15.4	15	16
Fe_2O_3	1.4	3.6	2.9
FeO	.80	1.6	2.6
MgO	.69	2	2.9
CaO	1.3	2.9	2.6
Na_2O	5	3.7	3.6
K_2O	3.1	4.4	2.6
H_2O-	.47	.41	.80
H_2O+	1.8	1.5	2.9
TiO_2	.32	.67	.98
P_2O_5	.14	.26	.35
MnO	.03	.09	.11
CO_2	<.05	1.2	<.05
Total	100	100	100

TABLE 5.—*Semiquantitative spectographic analyses of radial dikes of granodiorites in the Spanish Peaks region*

[J. C. Hamilton, analyst. Results are reported in percent to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc., which represent approximate midpoints of group data on a geometric scale. The assigned group for semiquantitative results wil include the quantitative value about 30 percent of the time. Symbols: M, major constituent—greater than 10 percent; 0, looked for but not detected; --, not looked for]

Locality (pl. 1)	82	84	85
Si	M	M	M
Al	7	7	7
Fe	1.5	3	3
Mg	.5	1.5	1.5
Ca	.7	2	1.5
Na	3	3	2
K	2	5	2
Ti	1.5	.3	.7
P	0	0	0
Mn	.02	.05	.05
Ba	.1	.3	.2
Be	.0002	.00015	.0002
Ce	0	0	0
Co	.0007	.001	.0015
Cr	.001	.005	.007
Cu	.0007	.005	.003
Ga	.002	.002	.002
La	0	.005	.005
Nb	.0015	.0015	.002
Ni	.0007	.002	.007
Pb	.0015	.002	.002
Sc	0	.0015	.001
Sr	.07	.15	.15
V	.005	.015	.015
Y	.001	.003	.002
Yb	.00015	.0005	.003
Zr	.007	.01	.01
Nd	--------	0	0

TABLE 6.—*Normative composition, in percent, of radial dikes of granodiorites in the Spanish Peaks region*

Locality (pl. 1)	82	84	85
Q	22.77	26.13	21.50
C	1.91	2.28	3.49
or	18.31	26	15.36
ab	41.69	17	29.85
an	5.53	12.69	10.61
ne	0	0	0
nc	.12	2.89	.12
mt	1.75	3.51	4.20
hm	.19	1.18	0
il	.61	1.27	1.86
ru	0	0	0
ap	.33	.62	.83
cc	0	0	0
di	0	0	0
hy	1.72	4.98	8.18
ol	0	0	0
Total	97.94	98.53	96.01

TABLE 7.—*Chemical analyses, in percent, of syenites in the Spanish Peaks region*

[P. L. D. Elmore, S. D. Botts, G. W. Chloe, Lowell Artis, and H. Smith, analysts. Rock type: RD, radial dike; SD, subparallel dike; ID, independent dike]

Locality (pl. 1) / Rock type	7 Small stock	87 RD	88 RD	86 RD	[1] 28 SD	[1] 28 SD	[1] 96 SD	[1] 97 SD	[1,2] 99 SD	[1] 98 SD	[1] 101 ID
SiO_2	69.2	65.2	65.1	60.3	47.9	47.1	46.9	46.7	46	45.6	45.1
Al_2O_3	15.4	16.1	16	17	11.4	11.6	11.1	10.9	11.1	10.8	11.4
Fe_2O_3	1.4	2.2	2.5	3.3	7.7	6.4	7.9	9.5	4.5	7.1	7.5
FeO	.46	1.8	1.7	1.8	2.6	3.4	3.1	1.8	1.3	4	2.4
MgO	.42	1.7	1.9	2	6.9	8.3	6.3	6.8	4.1	8.9	8
CaO	2.9	2.8	2.4	3.3	9	9.4	10.6	8.6	10.8	9.8	9.3
Na_2O	4.2	5.1	5.1	4.7	2.2	2.3	2.1	2.1	1.1	2.3	1.2
K_2O	3.3	3.4	3.4	3.8	4.8	4.5	4.5	4.6	6.6	4.1	4.7
H_2O-	.80	.21	.28	.51	1.4	1.3	.37	2	2.9	.90	1.4
H_2O+	.95	.79	.84	1.5	2	2.2	2	2.8	1.8	2.4	2.7
TiO_2	.15	.61	.65	.86	2	2.1	2.5	2	1.1	2	1.8
P_2O_5	.10	.33	.36	.41	1.8	1.4	2.1	1.8	.44	1.7	1.6
MnO	.07	.08	.10	.12	.13	.16	.09	.16	.28	.19	.19
CO_2	1.1	<.05	<.05	.56	<.05	<.05	<.05	<.05	7.8	<.05	2
Total	100	100	100	100	100	100	100	100	100	100	99

[1] Lamprophyre.
[2] SO_3 = 0.18.

TABLE 8.—*Semiquantitative spectrographic analyses of syenites in the Spanish Peaks region*

[J. C. Hamilton, analyst. Results are reported in percent to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, and 0.1, etc., which represent approximate midpoints of group data on a geometric scale. The assigned group for semiquantitative results will include the quantitative value about 30 percent of the time. Symbols: M, major constituent—greater than 10 percent; 0, looked for but not detected; ----, not looked for. Rock type: RD, radial dike; SD, subparallel dike; ID, independent dike]

Locality (pl. 1)	7	87	88	86	[1] 28	[1] 28	[1] 96	[1] 97	[1] 99	[1] 98	[1] 101
Rock type	Small stock	RD	RD	RD	SD	SD	SD	SD	SD	SD	ID
Si	M	M	M	M	M	M	M	M	M	M	M
Al	M	7	7	7	7	7	M	7	7	7	7
Fe	2	3	3	3	5	7	7	7	5	7	7
Mg	.5	1.5	1.5	2	3	5	5	5	3	7	7
Ca	3	2	1.5	3	5	M	7	5	M	7	7
Na	3	3	3	3	2	3	3	3	2	3	1
K	3	3	3	3	5	5	5	7	7	5	5
Ti	.1	.5	.5	.7	1.5	1.5	2	1.5	.5	1.5	1.5
P	0	0	0	0	.3	.5	.7	.5	0	.5	0
Mn	.05	.07	.07	.1	.07	.07	.07	.05	.15	.1	.15
Ba	.2	.15	.2	.2	.3	.7	.5	.5	.07	.5	.5
Be	.0002	.00015	0	.00015	0	0	.0002	.00015	.0002	.00015	.00015
Ce	0	0	0	0	<.05	<.05	<.05	0	0	<.05	.02
Co	0	.001	.001	.001	.003	.005	.005	.003	.003	.007	.003
Cr	.0015	.003	.003	.002	.03	.05	.03	.03	.1	.03	.03
Cu	.0007	.002	.002	.002	.01	.01	.01	.015	.01	.015	.01
Ga	.003	.002	.002	.002	.003	.003	.003	.007	.003	.005	.003
La	0	0	.005	.005	.01	.015	.015	.007	0	.01	.01
Nb	.003	.002	.002	.003	.005	.005	.007	.007	.002	.005	.003
Ni	.001	.0015	.002	.0015	.02	.02	.02	.03	.02	.03	.015
Pb	.002	.002	.003	.002	.001	.0015	.0015	.0015	0	.001	.0015
Sc	.0007	.0005	.0005	.0007	.002	.003	.003	.003	.003	.003	.002
Sr	.1	.15	.15	.2	.3	.7	.7	.3	.1	.5	.2
V	.005	.007	.007	.015	.05	.05	.07	.03	.02	.05	.03
Y	.002	.0015	.0015	.002	.003	.003	.003	.003	.003	.003	.003
Yb	.0002	.0002	.0002	.0003	----	----	----	----	----	----	.0003
Zr	.01	.01	.01	.02	.02	.03	.03	.02	.03	.03	.02
Nd	----	----	0	0	.015	.03	.03	.015	----	.015	.015

[1] Lamprophyre.

TABLE 9.—*Normative composition, in percent, of syenites in the Spanish Peaks region*

[Rock type: RD, radial dike; SD, subparallel dike; ID, independent dike]

Locality (pl. 1)	7	87	88	86	[1] 28	[1] 28	[1] 96	[1] 97	[1] 99	[1] 98	[1] 101
Rock type	Small stock	RD	RD	RD	SD	SD	SD	SD	SD	SD	ID
Q	28.61	15.16	15.82	14.14	0	0	0	0	7.65	0	5.35
C	2.44	0	.55	1.44	0	0	0	0	1.64	0	0
or	19.50	20.09	20.09	22.45	28.36	26.59	26.59	27.18	38.99	24.22	27.77
ab	35.52	42.54	42.54	33.08	18.61	13.61	16.41	17.76	9.30	12.92	0
an	6.78	11.32	9.55	13.69	7.06	8.04	7.58	6.73	1.40	7.04	17.23
ne	0	0	0	0	0	3.16	.73	0	0	3.54	0
nc	0	.12	.12	1.35	0	0	0	0	0	0	2.05
mt	1.28	3.19	3.62	3.70	3.01	5.39	3.04	.53	1.92	7.71	3.14
hm	.52	0	0	.75	5.63	2.68	5.80	9.14	3.18	1.78	5.34
il	.28	1.16	0	1.63	3.80	3.99	4.75	3.80	2.09	3.80	3.42
ru	0	0	0	0	0	0	0	0	0	0	0
ap	.24	.78	.85	.97	4.26	3.32	4.97	4.26	1.04	4.03	3.79
cc	2.50	0	0	0	0	0	0	0	17.74	0	2.61
di	0	.31	0	0	20.10	22.91	24.35	18.81	0	23.71	8.71
hy	1.05	4.71	4.90	4.98	.66	0	0	3.66	10.21	0	15.88
ol	0	0	0	0	5.05	7.04	3.08	3.19	0	7.83	0
Total	98.71	99.39	99.28	98.17	96.53	96.73	97.30	95.05	95.15	96.58	95.28

[1] Lamprophyre.

TABLE 10.—*Chemical analyses, in percent, of syenodiorites in the Spanish Peaks region*

[P. L. D. Elmore, S. D. Botts, G. W. Chloe, Lowell Artis, and H. Smith, analysts. Rock type: RD, radial dike; SD, subparallel dike; ID, independent dike]

Locality (pl. 1)	112	111	113	207	111	132	115	131	108	106	150	138	120	138	52
Rock type	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD	SD	SD	RD	SD	ID
SiO_2	63.7	59.5	59.4	59.3	59.2	57.5	57	57	56	54.3	54.2	53.6	53.5	53.2	52.4
Al_2O_3	16.3	17.9	16.9	17.8	17.9	15.6	15.6	14.8	17.5	15.5	16.4	15.3	15.8	15.3	16.7
Fe_2O_3	2.7	3.1	3	3.5	3.2	3.7	3.4	4.4	3.8	3	5.1	3.8	5.3	3.3	6.7
FeO	1.8	2	2.8	1.9	2.2	2.9	3.3	2.8	2.7	4.6	2.3	4.3	2.9	4.9	3
MgO	1.7	1.7	2.4	1.8	1.8	4.3	4.2	5.2	2.3	5.1	3.9	5	4.4	6.3	3
CaO	3.5	3.2	4.2	2.9	3.2	3.9	4.8	3.8	4.3	5	6.2	6.5	5.6	5.1	4.9
Na_2O	4.6	5.2	4.5	4.8	5.1	4.6	4	3.6	5.2	4.1	4.1	3.5	4	3.5	4.8
K_2O	3.9	3.9	3.3	4.1	3.9	3.1	2.7	2.8	3.2	2.6	2.6	2.4	2.9	2.1	2.8
H_2O-	.16	.42	.22	.35	.35	.59	.50	.94	.69	.60	1.9	2.1	1.4	2	.95
H_2O+	.97	1.5	1.6	1.9	1.4	2.1	2.2	2.3	2.5	2.7	1.3	1.5	1.3	2.4	2.2
TiO_2	.73	1.1	1	1.1	1.2	1.3	1.2	1.2	1.3	1.4	1.2	1.3	1.8	1.4	1.2
P_2O_5	.41	.55	.55	.56	.49	.45	.48	.45	.67	.56	.64	.51	.78	.51	.73
MnO	.09	.08	.11	.09	.09	.12	.11	.10	.12	.18	.11	.12	.10	.15	.18
CO_2	<.05	.56	<.05	<.05	<.05	.20	.28	.16	.08	.55	.28	<.05	<.05	.11	.27
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Locality (pl. 1)	[1] 148	128	Gardner Butte Plug	[1] 149	130	[1] 43	137	[1] 96	[1] 147	124	136	[1] 28	[1,2] 97	133	[1] 146
Rock type	SD	SD		SD	RD	SD	SD	SD	SD	RD	SD	SD	SD	SD	SD
SiO_2	51.6	51.5	51.4	50	48.5	48	47.4	47.1	46.8	46.7	46.2	45.3	45.2	42	41.1
Al_2O_3	16.6	17.7	17.4	14	17.2	16.1	16.3	11.5	12.6	13.8	16.9	11.2	13	16.8	11.9
Fe_2O_3	5.2	2.4	7.1	6.4	6.8	4.6	8.3	6.5	5.4	9.3	6.6	8.6	5.7	2	7.2
FeO	3.3	4.7	2.7	3.2	3.7	6.7	2	3.4	3.8	3.8	4.8	3.6	2.5	7.5	2.9
MgO	4.2	3.4	3.8	7.2	5	5.4	4.3	7.8	9.4	6.3	4.4	7	6.1	3.4	10.6
CaO	5.4	6.6	5.2	7.4	5	7.5	7.8	10.9	7.8	9.8	7.9	9.6	6.9	10.2	9.7
Na_2O	4.7	3.8	3.8	3.8	4.1	3.9	3.7	2.5	2.9	3.4	3.5	2.6	3.2	3.3	2.3
K_2O	2.8	2.3	2.6	1.9	1.5	2	1.5	3.8	2.3	2.1	1.3	4	3.8	1.4	1.8
H_2O-	.65	.97	3.8	2.1	1.8	.93	3.1	.54	2.6	.38	1.3	.90	2.5	1.2	3.4
H_2O+	1.9	2.7		1.3	3	1.6	1.8	2.3	2	2.3	3	2.5	4.2	3.9	3.4
TiO_2	1.6	1.2	1.2	1.8	2.2	2.2	2.1	1.8	1.7	1.4	1.2	2.3	2.7	1.9	1.6
P_2O_5	.83	.65	.70	.58	.66	1.2	1.5	1.9	1.1	.87	1.2	2.3	2	.79	1.69
MnO	.16	.22	.20	.14	.19	.18	.19	.15	.14	.20	.22	.15	.05	.20	.1
CO_2	.46	2.2	.24	<.05	.24	<.05	<.05	<.05	<.05	<.05	1.8	<.05	<.05	5.8	1.3
Total	99	100	100	100	100	100	100	100	99	100	100	100	99	100	99

[1] Lamprophyre.
[2] SO_3=1.2.

TABLE 11.—*Semiquantitative spectrographic analyses of syenodiorites in the Spanish Peaks region*

[J. C. Hamilton, analyst. Results are reported in percent to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, and 0.1, etc., which represent approximate midpoints of group data on a geometric scale. The assigned group for semiquantitative results will include the quantitative value about 30 percent of the time. Symbols: M, major constituent—greater than 10 percent; 0, looked for but not detected; ----, not looked for. Rock type: RD, radial dike; SD, subparallel dike; ID, independent dike]

Locality (pl. 1)	112	111	113	207	111	132	115	131	108	106	150	138	120	138	52
Rock type	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD	SD	SD	RD	SD	ID
Si	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Al	7	M	7	M	7	M	7	7	M	7	M	M	7	M	M
Fe	3	5	5	5	5	5	5	5	5	7	7	7	7	7	7
Mg	1.5	1.5	2	1.5	1.5	3	3	5	1.5	3	5	3	5	3	1.5
Ca	3	2	3	2	2	5	3	2	5	5	5	7	5	7	3
Na	3	5	2	5	3	3	2	2	5	3	2	3	2	3	3
K	2	3	2	5	3	3	2	3	3	3	2	3	2	3	3
Ti	.3	.7	.5	.7	.7	.7	.7	.5	.7	1	1	1	1.5	1	.7
P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mn	.07	.07	.07	.07	.07	.03	.1	.05	.03	.07	.1	.07	.07	.07	.07
Ba	.2	.15	.15	.2	.15	.3	.5	.3	.2	.5	.2	.2	.15	.2	.3
Be	.0002	.0003	.00015	.0003	.0003	.00015	0	0	.0002	.0002	.0002	.00015	.0003	.00015	0
Ce	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Co	.001	.001	.0015	.0015	.001	.003	.002	.002	.0015	.003	.002	.003	.003	.005	.003
Cr	.002	.0015	.002	.0015	.001	.02	.01	.02	.003	.02	.015	.03	.02	.02	.002
Cu	.003	.002	.005	.003	.003	.007	.007	.005	.005	.007	.005	.005	.007	.007	.003
Ga	.003	.005	.002	.005	.003	.005	.007	.002	.005	.003	.003	.003	.003	.005	.005
La	.007	.005	.007	.007	.005	.007	0	.003	.007	.007	.005	.007	.005	.007	.005
Nb	.003	.003	.003	.003	.003	.003	.002	0	.005	.005	.003	.005	.003	.003	.0015
Ni	.002	.0015	.002	.0015	.0015	.015	.007	.01	.002	.02	.007	.02	.01	.015	.001
Pb	.002	.001	.0015	.0015	.003	.002	.001	.002	.002	.0015	.0015	0	0	.001	.001
Sc	.0007	.0007	.001	.0007	.0007	.0015	.001	.001	.001	.0015	.0015	.002	.0015	.002	.0015
Sr	.15	.2	.15	.2	.15	.2	.15	.15	.2	.15	.15	.1	.2	.1	.3
V	.01	.01	.015	.015	.015	.02	.05	.015	.015	.03	.03	.05	.02	.05	.02
Y	.002	.002	.002	.003	.002	.003	.002	.002	.003	.005	.003	.005	.002	.005	.003
Yb	.0002	.0003	.0002	.0005	.0003	--------	.0002	.0003	--------	--------	.0003	--------	.0003	--------	--------
Zr	.007	.015	.01	.015	.015	.03	.01	.01	.03	.03	.02	.03	.02	.03	.015
Nd	0	0	0	.01	0	0	--------	0	0	0	0	0	0	0	0

Table 11 continued on p. G44.

TABLE 11.—*Semiquantitative spectographic analyses of syenodiorites in the Spanish Peaks region*—Continued

Locality (pl. 1)	[1]148	128	Gardner Butte Plug	[1]149	130	[1]43	137	[1]96	[1]147	124	136	[1]28	[1]97	133	[1]146
Rock type	SD	SD		SD	RD	SD	SD	SD	SD	RD	SD	SD	SD	SD	SD
Si	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Al	7	M	M	7	7	M	M	7	7	7	7	7	7	M	7
Fe	7	5	7	7	M	M	M	7	7	M	7	7	5	7	7
Mg	3	2	2	5	5	3	3	5	7	5	2	3	3	2	7
Ca	3	5	3	7	5	5	7	M	7	7	5	7	5	M	M
Na	3	3	3	3	2	3	2	3	1.5	3	2	3	3	5	2
K	3	3	3	3	2	2	2	5	2	3	2	5	5	3	2
Ti	.7	.7	.5	1	1.5	1.5	1.5	1.5	.7	1	1.5	1.5	1.5	1	1
P	0	0	0	0	0	.5	.5	.7	0	.3	.5	.7	.5	0	.5
Mn	.1	.15	.1	.07	.1	.07	.1	.1	.1	.1	.1	.07	.05	0	.1
Ba	.7	.3	.15	.15	.3	.2	.2	.5	.5	.15	.15	.5	.7	.1	.7
Be	.00015	0	0	0	0	.00015	0	.0002	.00015	0	0	.0002	0	0	0
Ce	<.02	0	<.02	0	0	0	0	<.05	0	0	0	<.05	<.05	0	<.05
Co	.002	.002	.0015	.003	.003	.005	.005	.005	.005	.005	.005	.005	.003	.005	.005
Cr	.002	.015	.0007	.03	.003	.015	.01	.03	.07	.007	.01	.03	.03	.02	.05
Cu	.007	.005	.003	.005	.007	.01	.005	.01	.01	.02	.005	.01	.015	.005	.015
Ga	.003	.005	.002	.005	.003	.003	.003	.003	.002	.005	.003	.003	.003	.005	.003
La	.007	.007	.003	.005	.005	.007	.007	.015	.007	.005	.007	.015	.01	.007	.015
Nb	.003	.0015	.0015	.003	.002	.002	.002	.005	.005	.002	.002	.005	.005	.003	.005
Ni	.002	.007	0	.015	.005	.015	.007	.03	.02	.002	.007	.02	.015	.005	.05
Pb	0	.0015	.001	0	0	.001	.0015	.0015	0	.001	0	.0015	.001	.001	.002
Sc	.0015	.0015	.002	.0015	.0015	.0015	.0015	.003	.002	.005	.0015	.002	.002	.002	.005
Sr	.3	.1	.1	.15	.15	.3	.2	.7	.5	.3	.2	.5	.5	.2	.5
V	.02	.02	.015	.05	.03	.03	.03	.05	.02	.07	.03	.05	.05	.03	.03
Y	.003	.005	.003	.003	.002	.005	.005	.003	.002	.003	.005	.003	.003	.005	.005
Yb	.0003	--------	.0005	--------	.0003	--------	--------	--------	.0003	--------	--------	--------	--------	--------	--------
Zr	.015	.02	.007	.015	.02	.015	.015	.02	.02	.015	.015	.03	.05	.02	.02
Nd	.015	0	0	0	0	.015	.015	.03	.015	0	.015	.03	.015	0	.015

[1]Lamprophyre

TABLE 12.—*Normative composition, in percent, of syenodiorites in the Spanish Peaks region*

[Rock type: RD, radial dike; SD, subparallel dike; ID; independent dike]

Locality (pl. 1)	112	111	113	207	111	132	115	131	108	106	150	138	120	138	52
Rock type	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD	SD	SD	RD	SD	ID
Q	14	6.93	9.61	8.81	6.89	6.31	10.34	12.06	3.32	3.79	6.48	5	4.46	4.63	2.06
C	0	.74	0	1.65	.76	0	0	.39	0	0	0	0	0	0	0
or	23.04	23.04	19.50	24.22	23.04	18.31	15.95	16.54	18.91	15.36	15.36	14.18	17.13	12.41	16.54
ab	38.31	43.38	37.46	40	42.54	38.91	30.49	28.54	43.98	34.67	31.82	29.60	33.23	29.60	40.59
an	12.64	12.28	16.49	10.73	12.67	12.77	18.41	15.91	14.97	16.22	20.19	18.96	16.92	19.84	15.76
ne	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
nc	.12	.12	.12	.12	.12	0	.67	.39	0	0	.58	0	.12	0	0
mt	3.91	3.52	4.35	3.23	3.91	5.36	4.93	5.87	5.33	4.35	4.29	5.51	4.46	4.78	6.78
hm	0	.67	0	1.27	.51	0	0	.35	.13	0	2.14	0	2.23	0	2.02
il	1.39	2.09	1.90	2.09	2.28	2.47	2.28	2.28	2.47	2.66	2.28	2.47	3.42	2.66	2.28
ru	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ap	.97	1.30	1.30	1.33	1.16	1.07	1.14	1.07	1.59	1.53	1.52	1.21	1.85	1.21	1.73
cc	0	0	0	0	0	.45	0	0	.18	1.25	0	0	0	.25	.61
di	1.58	0	.59	0	0	1.85	1.78	0	1.15	1.16	4.97	7.91	4.49	1.14	1.61
hy	3.53	4.23	6.91	4.48	4.48	10.19	11.09	12.95	5.19	16.13	7.41	11.52	8.87	19.38	6.72
ol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	99.50	98.31	99.24	97.93	98.36	97.70	97.10	96.33	97.21	96.92	97.02	96.36	97.12	95.90	96.72

Locality (pl. 1)	[1]148	128	[1]149	130	[1]43	137	[1]96	[1]147	124	136	[1]28	[1]97	133	[1]146
Rock type	SD	SD	SD	RD	SD	SD	SD	SD	RD	SD	SD	SD	SD	SD
Q	2.40	6.94	0	4.60	0	2.45	0	0	0	4.89	0	0	4.35	0
C	0	3.62	0	1.88	0	0	0	0	0	2.42	0	0	6.64	0
or	16.54	13.59	11.22	8.86	11.82	8.86	22.45	13.59	12.41	7.68	23.63	22.45	8.27	10.63
ab	34.27	32.14	32.14	31.82	32.98	31.29	16.26	23.93	25.61	29.60	18.38	26.18	27.91	19.45
an	18.84	14.59	15.54	20.49	20.52	23.44	8.94	14.89	16.20	19.97	7.08	9.89	8.77	16.83
ne	0	0	0	0	0	0	2.64	0	1.70	0	1.95	.48	0	0
nc	1.11	0	0	.58	0	0	0	.12	0	0	0	0	0	0
mt	6.52	3.48	5.55	6.17	6.67	.98	6.23	7.78	8.84	9.57	5.43	.39	2.90	5.33
hm	.70	0	2.57	2.55	0	7.62	2.20	.04	3.20	0	4.46	5.43	0	3.52
il	3.04	2.28	3.42	4.18	4.18	3.99	3.42	3.23	2.66	2.28	4.37	5.13	3.61	3.04
ru	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ap	1.97	1.54	1.37	1.56	2.84	3.55	4.50	2.61	2.06	2.84	5.45	4.74	1.87	3.79
cc	0	5	0	0	0	0	0	0	0	4.09	0	0	13.19	2.96
di	1.96	0	13.52	0	7.11	4.24	25.47	12.93	20.80	0	19.86	8.77	0	9.82
hy	9.55	13.54	9.83	12.45	2.67	8.74	0	9.16	0	12.74	0	0	17.82	5.33
ol	0	0	1.28	0	9.05	0	5.34	5.78	4.23	0	5.76	7.79	0	11.57
Total	96.89	96.71	96.45	95.13	97.84	95.17	97.45	94.05	97.72	96.08	96.37	91.25	95.33	92.28

[1] Lamprophyre.

Table 13.—*Chemical analyses, in percent, of diorites in the Spanish Peaks region*

[P. L. D. Elmore, S. D. Botts, G. W. Chloe, Lowell Artis, and H. Smith, analysts. Rock type: RD, radial dike; SD, subparallel dike; ID, independent dike]

Locality (pl. 1)	152	155	[1] 163	[1] 164	43	159	157	156
Rock type	RD	SD	SD	SD	SD	ID	SD	SD
SiO_2	54.4	50.2	49.2	47.3	47.3	46.6	45.7	44.5
Al_2O_3	15.8	14.1	15.4	15	16.3	16.7	16	16.8
Fe_2O_3	3.6	6.1	5.3	3.5	5.3	10.4	5.4	7.4
FeO	3.7	3.2	4.6	7.9	5.6	2.5	5.5	5.6
MgO	4.6	7.1	6.4	7.9	5.1	5	6.3	4.1
CaO	6.8	6.9	6.4	8.9	7.4	5.7	9	8
Na_2O	2.9	3.8	4.3	2.9	4	3.3	3.4	3
K_2O	.80	2.2	1.5	1.5	1.6	1.1	.67	1.4
H_2O-	.99	2.5	1.2	.91	2.1	3.7	1.7	1.6
H_2O+	3.9	1.7	3.2	1.7	1.9	1.8	1.6	2.5
TiO_2	1.4	1.7	1.8	1.8	2.1	2.6	2.3	2.5
P_2O_5	.56	.72	.79	.70	1.5	.59	.83	.71
MnO	.18	.18	.16	.17	.13	.16	.29	.46
CO_2	<.05	<.05	<.05	.24	<.05	<.05	.38	1.8
Total	100	100	100	100	100	100	100	100

[1] Lamprophyre.

Table 14.—*Semiquantitative spectrographic analyses of diorites in the Spanish Peaks region*

[J. C. Hamilton, analyst. Results are reported in percent to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, and 0.1, etc., which represent approximate midpoints of group data on a geometric scale. The assigned group for semiquantitative results will include the quantitative value about 30 percent of the time. Symbols: M, major constituent—greater than 10 percent; 0, looked for but not detected; --, not looked for. Rock type: RD, radial dike; SD, subparallel dike; ID, independent dike]

Locality (pl. 1)	152	155	[1] 163	[1] 164	43	159	157	156
Rock type	RD	SD	SD	SD	SD	ID	SD	SD
Si	M	M	M	M	M	M	M	M
Al	7	7	M	7	M	7	M	7
Fe	5	7	M	7	M	7	M	M
Mg	2	7	5	5	3	5	5	2
Ca	3	7	5	7	5	3	7	5
Na	2	1	3	2	3	2	2	3
K	1	5	2	2	2	1	0	2
Ti	.7	1	1	1.5	1.5	1.5	2	1.5
P	0	.3	.3	0	.7	0	0	0
Mn	.1	.1	.1	.07	.07	.1	.2	.3
Ba	.1	.5	.5	.2	.2	.07	.3	.3
Be	0	.00015	.00015	0	.00015	0	0	0
Ce	0	<.05	0	0	0	0	0	0
Co	.002	.005	.005	.005	.005	.003	.005	.005
Cr	.01	.05	.03	.03	.015	.01	.007	.005
Cu	.007	.015	.01	.01	.007	.007	.007	.007
Ga	.002	.005	.005	.003	.003	.002	.003	.005
La	.005	.01	.007	.005	.007	0	.007	.007
Nb	.002	.007	.005	.003	.003	.0015	.003	.003
Ni	.01	.03	.02	.02	.01	.01	.007	.007
Pb	.0015	.0015	.0015	0	.001	0	.001	0
Sc	.001	.0015	.002	.0015	.0015	.002	.003	.0015
Sr	.15	.5	.2	.15	.3	.15	.2	.15
V	.02	.05	.03	.03	.03	.03	.07	.05
Y	.0015	.005	.005	.003	.005	.003	.005	.005
Yb	.0002	--------	--------	-------	--------	.0003	------	-------
Zr	.01	.03	.02	.02	.015	.01	.015	.02
Nd	0	.015	0	0	.015	-------	0	0

[1] Lamprophyre.

Table 15.—*Normative composition, in percent, of diorites in the Spanish Peaks region*

[Rock type: RD, radial dike; SD, subparallel dike; ID, independent dike]

Locality (pl. 1)	152	155	[1] 163	[1] 164	43	159	157	156
Rock type	RD	SD	SD	SD	SD	ID	SD	SD
Q	14.65	0	0	0	0	5.63	0	4.97
C	0	0	0	0	0	1.25	0	1.68
or	4.73	13	8.86	8.86	9.45	6.50	3.96	8.27
ab	23.93	32.14	36.37	24.53	33.83	27.31	28.75	25.37
an	28.05	14.93	18.30	23.49	21.80	24.42	26.42	23.66
ne	0	0	0	0	0	0	0	0
nc	.12	0	0	0	0	.12	0	0
mt	5.27	5.97	7.68	5.07	7.68	1.04	7.83	10.73
hm	0	3.23	0	0	0	9.68	0	0
il	2.66	1.98	3.42	3.42	3.99	4.94	4.37	4.75
ru	0	0	0	0	0	0	0	0
ap	1.33	1.70	1.87	1.66	3.55	1.40	1.97	1.68
cc	0	0	0	.55	0	0	.86	4.09
di	1.59	11.36	6.51	11.76	4.05	0	8.21	0
hy	12.54	10.81	9.53	6.94	8.55	12.45	11.60	11.10
ol	0	1.12	3.35	11.58	3.50	0	1.84	0
Total	94.82	96.24	95.89	97.85	96.41	94.73	95.82	96.31

[1] Lamprophyre.

Table 16.—*Chemical analyses, in percent, of syenogabbros in the Spanish Peaks region*

[P. L. D. Elmore, S. D. Botts, G. W. Chloe, Lowell Artis, and H. Smith, analysts. Rock type: ID, independent dike; RD, radial dike; SD, subparallel dike]

Locality (pl. 1)	167	[1] 172	[1] 176	166	[1] 168	[1] 173	[1] 171	[1] 170
Rock type	Sill	ID	ID	RD	RD	SD	SD	SD
SiO_2	49.2	46	45.7	45.6	45.5	43.8	43.7	43.5
Al_2O_3	13.5	11.9	15.9	15.6	11.7	12.2	12.5	12.3
Fe_2O_3	5.4	6	7.9	3.4	4.5	5	6.8	5.6
FeO	4	4.4	2.5	5.7	5.3	6	3.7	5.8
MgO	5.6	9.2	6.4	4.3	9.1	10.3	10.2	12.1
CaO	5.8	8.7	8.6	10.4	8.9	9.7	10.2	8.7
Na_2O	2.4	1.6	3.1	2.9	1.3	2.3	2.2	2.1
K_2O	2.3	3.7	1	1.3	4	2.2	2.2	2.4
H_2O-	1.8	2.5	3.4	.68	1.1	.94	2.4	.57
H_2O+	3.2	2.3	2	2.5	2.8	3.1	3.5	2.8
TiO_2	1.7	2.1	1.9	1.6	2.6	2	1.4	2.2
P_2O_5	.98	.88	.68	.49	1.2	1.1	.95	1.1
MnO	.14	.18	.17	.14	.22	1	.16	.18
CO_2	2.7	.11	.89	5.2	1.6	<.05	.13	<.05
Total	99	100	100	100	100	100	100	99

[1] Lamprophyre.

TABLE 17.—*Semiquantitative spectrographic analyses of syenogabbros in the Spanish Peaks region*

[J. C. Hamilton, analyst. Results are reported in percent to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, and 0.1, etc., which represent approximate midpoints of group data on a geometric scale. The assigned group for semiquantitative results will include the quantitative value about 30 percent of the time. Symbols: M, major constituent—greater than 10 percent; 0, looked for but not detected; ---, not looked for. Rock type: ID, independent dike; RD, radial dike; SD, subparallel dike]

Locality (pl. 1)	167	[1] 172	[1] 176	166	[1] 168	[1] 173	[1] 171	[1] 170
Rock type	Sill	ID	ID	RD	RD	SD	SD	SD
Si	M	M	M	M	M	M	M	M
Al	7	7	7	3	7	7	7	7
Fe	5	7	7	5	M	M	7	M
Mg	5	3	7	3	7	7	5	7
Ca	5	7	7	5	7	7	M	7
Na	2	1.5	2	1.5	2	2	3	1
K	3	5	1	1.5	5	2	3	3
Ti	1	1.5	1	.7	1.5	1.5	.7	.7
P	0	.3	0	0	.5	.5	.5	0
Mn	.1	.1	.15	.1	.15	.1	.1	.07
Ba	.5	.3	.07	.07	.5	.3	.2	.2
Be	0	0	0	0	.00015	0	0	0
Ce	0	0	0	0	<.05	<.05	0	0
Co	.002	.007	.005	.002	.005	.01	.005	.005
Cr	.02	.07	.03	.015	.05	.05	.05	.05
Cu	.01	.015	.01	.007	.015	.015	.01	.01
Ga	.003	.003	.002	.002	.003	.003	.003	.003
La	.005	.007	0	0	.01	.01	.007	.007
Nb	.002	.005	.002	0	.005	.005	.003	.003
Ni	.015	.03	.02	.007	.02	.05	.03	.02
Pb	0	.001	0	0	.0015	.001	.01	.0015
Sc	.0015	.003	.002	.002	.003	.003	.003	.002
Sr	.15	.2	.15	.15	.3	.5	.5	.3
V	.02	.03	.05	.02	.03	.05	.03	.03
Y	.002	.005	.003	.002	.003	.003	.003	.002
Yb	.0003	---	.0003	.00003	---	---	---	.0003
Zr	.015	.03	.007	.01	.05	.02	.015	.02
Nd	0	0	---	---	.015	.015	.015	.015

[1] Lamprophyre.

TABLE 18.—*Normative composition, in percent, of syenogabbros in the Spanish Peaks region*

[Rock type: ID, independent dike; RD, radial dike; SD, subparallel dike]

Locality (pl. 1)	167	[1] 172	[1] 176	166	[1] 168	[1] 173	[1] 171	[1] 170
Rock type	Sill	ID	ID	RD	RD	SD	SD	SD
Q	24.97	0	6.42	19.50	0	0	0	0
C	5.12	0	0	3.74	0	0	0	0
or	13.59	21.86	5.91	7.68	23.63	13	13	14.18
ab	0	13.53	15.61	0	10.99	15.25	16.15	15.78
an	16.07	14.36	32.15	28.56	14.28	16.47	17.74	17.37
ne	0	0	0	0	0	2.28	1.33	.75
nc	4.10	0	2.14	4.96	0	0	0	.12
mt	7.83	8.68	3.11	4.93	6.52	7.25	8.39	8.12
hm	0	.01	5.76	1.16	0	0	1.01	0
il	3.23	3.99	3.61	3.04	4.94	7.80	2.66	4.18
ru	0	0	0	0	0	0	0	0
ap	2.32	2.08	1.61	7.14	2.84	2.60	2.25	2.61
cc	2.27	.25	0	0	3.64	0	.30	0
di	0	17.39	4.72	0	9.36	19.42	20.10	14.61
hy	14.28	7.53	13.74	15.98	18.27	0	0	0
ol	0	5.13	0	0	1.51	15.59	11.26	18.38
Total	93.77	94.82	94.78	96.66	95.98	95.66	94.19	96.09

[1] Lamprophyre.

TABLE 19.—*Chemical analyses, in percent, of gabbros in the Spanish Peaks region*

[P. L. D. Elmore, S. D. Botts, G. W. Chloe, Lowell Artis, and H. Smith, analysts. Rock type: ID, independent dike; RD, radial dike; SD, subparallel dike]

Locality (pl. 1)	176	[1] 197	[1] 200	183	178	177	[1] 202	56	[1] 196
Rock type	ID	RD	SD	SD	SD	RD	SD	ID	RD
SiO_2	46	45.2	44.9	44.8	44	43.6	43.4	42.2	41.3
Al_2O_3	15.7	13.3	11.8	15.1	13.7	16.6	12.9	12.1	12.2
Fe_2O_3	7.5	9.7	4.5	5.5	8	4.5	5.7	6.9	6.2
FeO	2.8	2.1	5.1	5.8	4	6.6	4	4.5	4.9
MgO	6.3	8.7	12.5	6.4	8.8	4.7	9.9	10.6	7.5
CaO	8.8	7.4	9.8	10.8	9.5	8.7	11.9	10.2	12.5
Na_2O	3.1	2.1	2.1	2.7	2.2	3.6	1.2	2.3	2
K_2O	1	.61	1.5	1	1.2	.56	2.8	2.1	1.1
H_2O-	3	5.4	2	1.3	3	1.4	1.8	2.1	2.4
H_2O+	1.8	2.8	3.3	1.9	2.4	3.2	3.9	3.3	2.8
TiO_2	1.9	1.8	.06	2.2	1.7	2	1.5	2.1	1.2
P_2O_5	.72	.44	.75	.74	.52	.57	.91	1.1	.59
MnO	.19	.13	.24	.28	.18	.22	.21	.14	.28
CO_2	1.4	<.05	.86	1.8	.86	3.8	<.05	.15	5
Total	100	100	99	100	100	100	100	100	100

[1] Lamprophyre.

TABLE 20.—*Semiquantitative spectrographic analyses of gabbros in the Spanish Peaks region*

[J. C. Hamilton, analyst. Results are reported in percent to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, and 0.1, etc., which represent approximate midpoints of group data on a geometric scale. The assigned group for semiquantitative results will include the quantitative value about 30 percent of the time. Symbols: M, major constituent—greater than 10 percent; 0, looked for but not detected; --, not looked for. Rock type: ID, independent dike; RD, radial dike; SD, subparallel dike]

Locality (pl. 1)	176	[1] 197	[1] 200	183	178	177	[1] 202	56	[1] 196
Rock type	ID	RD	SD	SD	SD	RD	SD	ID	RD
Si	M	M	M	M	M	M	M	M	M
Al	7	7	7	7	7	7	7	7	7
Fe	7	M	M	7	7	M	7	7	7
Mg	5	7	7	3	5	5	5	5	7
Ca	7	7	7	7	7	7	5	7	7
Na	1.5	1	2	2	1.5	3	3	2	1.5
K	1	0	2	1.5	1.5	1	3	3	2
Ti	1.5	1.5	.7	.7	.5	1.5	1.5	.7	.7
P	0	0	.3	0	0	0	0	.5	0
Mn	.15	.1	.15	.15	.07	.15	.1	.05	.15
Ba	.07	.07	.15	.07	.1	.1	.15	.3	.15
Be	0	0	0	0	0	0	0	0	0
Ce	0	0	0	0	0	0	0	0	<.05
Co	.005	.005	.007	.005	.005	.003	.005	.003	.005
Cr	.02	.05	.1	.03	.05	.01	.03	.05	.05
Cu	.01	.015	.015	.01	.01	.01	.01	.01	.01
Ga	.002	.002	.003	.003	.002	.003	.005	.005	.003
La	0	0	.007	0	0	0	.007	.007	.005
Nb	.002	.0015	.005	.002	.002	.002	.003	.005	.002
Ni	.005	.03	.05	.01	.03	.005	.02	.03	.03
Pb	0	0	.0015	0	0	0	.0015	.0015	.001
Sc	.002	.002	.005	.002	.003	.002	.002	.003	.003
Sc	.002	.002	.005	.002	.003	.002	.002	.003	.003
Sr	.15	.07	.2	.15	.1	.1	.3	.3	.15
V	.05	.05	.03	.03	.03	.02	.03	.03	.02
Y	.003	.002	.003	.003	.003	.002	.003	.003	.003
Yb	.0003	.0003	--	--	--	.0003	0	--	--
Zr	.01	.007	.015	.015	.015	.02	.015	.015	.01
Nd	--	--	0	0	0	0	.015	.015	0

[1] Lamprophyre.

TABLE 21.—*Normative composition, in percent, of gabbros in the Spanish Peaks region*

[Rock type: ID, independent dike; RD, radial dike; SD, subparallel dike]

Locality (pl. 1)	176	[1] 197	[1] 200	183	178	177	[1] 202	[1] 56	[1] 196
Rock type	ID	RD	SD	SD	SD	RD	SD	ID	RD
Q	10.30	5.32	0	0.67	0	18.32	0	0	2.91
C	0	0	0	0	0	4.43	0	0	0
or	5.91	3.60	8.86	5.91	7.09	3.31	16.54	12.41	6.50
ab	9.54	17.16	17.76	22.83	18.61	0	7.30	13.71	16.91
an	34.82	25.38	18.34	26.13	23.97	31.56	21.54	16.49	21.07
ne	0	0	0	0	0	0	1.54	3.11	0
nc	3.37	.12	0	0	0	6.16	0	0	0
mt	4.14	1.98	6.52	7.97	8.55	6.52	8.26	8.87	8.99
hm	4.65	8.34	0	0	2.10	0	0	.78	0
il	3.61	3.42	.11	4.18	3.23	3.80	2.85	3.99	2.28
ru	0	0	0	0	0	0	0	0	0
ap	1.71	1.04	1.78	1.75	1.23	1.35	2.15	2.60	1.40
cc	0	0	1.96	4.09	1.96	2.83	0	.34	11.37
di	3.21	6.58	15.80	8.90	11.15	0	24.61	20.21	4.32
hy	14.20	18.61	6.62	14.72	16.74	17.21	0	0	19.05
ol	0	0	16.40	0	0	0	9.66	11.93	0
Total	95.45	91.55	94.12	97.16	94.69	95.48	94.47	94.45	94.8

[1] Lamprophyre.