

# **Circular 75**

## **Reconnaissance Geology of the Little Black Peak Quadrangle, Lincoln and Socorro Counties, New Mexico**

**by Clay T. Smith**

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NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

E. J. Workman, President

STATE BUREAU OF MINES AND MINERAL RESOURCES

A. J. Thompson, Director

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# GEOLOGY OF THE LITTLE BLACK PEAK QUADRANGLE SOCORRO AND LINCOLN, COUNTIES, NEW MEXICO

Clay T. Smith

New Mexico Institute of Mining and Technology  
Socorro, New Mexico

## INTRODUCTION

The Little Black Peak quadrangle lies 8 miles north of Carrizozo, New Mexico between parallels of long  $105^{\circ}45'$  and  $106^{\circ}$  W., and between lat  $33^{\circ}45'$  and  $34^{\circ}$  N. (See plate 1). A network of ranch and mining roads branching from U.S. Highway 54, which passes north-south through the eastern quarter of the quadrangle, brings any point to within  $2\frac{1}{2}$ -3 miles of motor transport. However, except for State Road 10, which traverses the northwest quarter of the quadrangle, and U.S. 54 the roads are unimproved and often impassable after rains or snow.

Scattered mesas and broad alluviated valleys averaging 6,000 feet above sea level dominate most of the area. The rugged topography of Lone Mountain and its surrounding peaks attains elevations of over 8,000 feet along the extreme eastern and southeastern edge of the quadrangle. In the southwest corner of the quadrangle a Recent lava flow, apparently derived from a small cinder cone called Little Black Peak, occupies more than 17 square miles and extends many miles to the south. Older flows from craters farther west locally modify the topography along the western margin of the quadrangle.

The geology of the eastern half of the quadrangle was published by Smith and Budding (1959) and most of the quadrangle is included in Griswold's (1959) bulletin on the Mineral Deposits of Lincoln County. Kelley (1949) describes a few of the iron deposits on the flanks of Lone Mountain, and Allen (1951) published a brief note on the Little Black Peak lava flow.

The major part of the quadrangle is typical of the semi-arid southwest; it receives less than 14 inches of precipitation annually and the vegetation is dominated by cactii, chamisa, rabbit brush, and subordinate grasses. On the higher elevations of Lone Mountain ponderosa pine, juniper, and pinon are common. Water is extremely scarce and where wells have developed meager ground-water supplies, the quality is very poor. The average mean temperature is between  $55^{\circ}\text{F}$  and  $60^{\circ}\text{F}$ , but the extremes may range from a few degrees below  $0^{\circ}\text{F}$  to  $110^{\circ}\text{F}$ .

## GEOLOGY

The Little Black Peak quadrangle lies in a broad gentle trough between the Carrizozo anticline to the west and the complexly folded and intruded beds of the Jicarilla Mountains to the east. The structure is synclinal plunging gently to the south and southwest where it merges with the larger and more complex Tularosa Basin. The San Andres Limestone of Permian age is the oldest formation exposed with rocks of Triassic, Cretaceous, and Tertiary-Quaternary age overlying it. Small

intrusive masses and numerous dikes of variable compositions are closely associated with the tightly folded beds of the Jicarilla Mountains on the eastern margin of the quadrangle. These are presumed to be Tertiary in age although some of the basaltic dikes may be younger and related to the recent lava flows (See pl. 1 in pocket).

## Sedimentary Rocks

### San Andres Formation

The San Andres Formation was first described by W. T. Lee (1909) for exposures in the San Andres Mountains of southern New Mexico. Needham and Bates (1943) remeasured the old type section giving more detail regarding the units. Kottowski and others (1956) re-examined all the units in the San Andres Mountains and measured a slightly better exposed section of the San Andres Formation west of the original type locality. North and west of the Little Black Peak quadrangle a prominent mappable unit, the Glorieta Sandstone, occurs at the base of the San Andres Formation. The U.S. Geological Survey considers the Glorieta Sandstone a member of the San Andres whereas others (Keyes, 1915; Hager and Robitaille, 1919) describe it as a separate formation. In the Little Black Peak quadrangle a sandy facies at the base of the San Andres which may be equivalent to the Glorieta Sandstone is not a mappable unit.

The San Andres Formation is over 700 feet thick, although complete sections are not exposed within the quadrangle. A thickness of 765 feet was measured on the west slope of Lone Mountain, but folding near the contact makes this section somewhat incomplete. Another incomplete section measured in secs. 15 and 22, T. 5 S., R. 11 E., gave 595 feet of beds, a calculated thickness of 660 feet was determined on the south slope of Lone Mountain, but this too is an incomplete section. However, the formation appears to be thicker in this quadrangle than at the type locality to the southwest.

The San Andres Formation in the Little Black Peak quadrangle is divisible into three units — a lower sandy facies, a middle limestone facies, and an upper gypsum facies — although these are not readily mappable. Near the base soft buff-yellow friable quartz sandstone beds weathering reddish brown are interbedded with gray fine-grained massive limestone beds. In areas to the east the sandstone also intertongues with the underlying Yeso Formation. This sandy facies is the Glorieta Sandstone of the Chupadera Mesa region to the northwest. However, in the Little Black Peak area the sandstone beds are lenticular and discontinuous and grade upward into more massive limestone beds; no sharp boundary can be demarcated.

The middle limestone facies is composed of massive limestone beds ranging from blue to gray to dark gray in color interbedded in the lower part of the unit with medium-grained, well-sorted quartz sandstone beds and in the upper part with narrow gypsum stringers. Solution cavities are common throughout, and locally the beds are fossiliferous. Several genera of gastropoda, fragments of crinoid stems, *Dictyoclostus* sp. ?, and possibly some coiled nautiloids are represented. Much of the limestone is fetid and occasionally contains sparse hydrocarbons.

The upper gypsum facies of the San Andres Formation is well-developed in the area and locally may comprise nearly 400 feet of the formation. Gypsum and light-gray limestone alternate in layers from 20 to 30 feet thick. The gypsum beds are massive, white and contain few impurities. The limestone beds have thin shaly partings and an occasional thin sandstone layer. Solution fretwork is common on exposed limestone surfaces and collapse structures resulting from removal of gypsum in solution are common. Most of the surface exposures of the upper part of the San Andres Formation are mantled with a soft, fine, silty gypsiferous layer, the residue from solution of both limestone and gypsum beds.

Fossils are lacking in the upper part of the San Andres Formation in the major part of the formational exposures and no diagnostic forms were identified in the Little Black Peak quadrangle, but the lithologic relationships and the stratigraphic position left no doubt regarding the age nor identity of the formation. Kottowski and others (1956) report diagnostic ammonoids from the upper part of the formation in the San Andres Mountains which indicate a Leonardian age.

The contact between the San Andres Formation and the overlying Bernal Formation is a disconformity on which a karst topography developed. Large sink holes filled with layers of the overlying material as well as breccia of the upper gypsum facies of the San Andres Formation suggest that the development of some of the karst topography antedated the deposition of the Bernal Formation. Largo Canyon, the principal drainage channel in the western and northern part of the quadrangle, has been controlled by the coalescence of several large filled sink holes in the underlying San Andres limestone and gypsum. Resistant knobs of limestone are often surrounded by the Bernal beds representing the old highs from the Permian karst which have been exhumed by recent erosion. Relief on the surface ranged from a few tens of feet to perhaps a few hundred feet during deposition of the overlying Bernal Formation. Karst action, however, is not confined to late or immediate post-Permian time, but appears to have been almost continuously operative, since a few sink holes contain collapsed remnants of late Tertiary gravels.

### Bernal Formation

The Bernal Formation was defined by Bachman (1953) from exposures near Bernal, Mora County, New Mexico. Originally the Bernal was considered to be an upper member of the San Andres Formation, but the marked disconformity at its base suggested formational status. Other writers (Allen and Kottowski, 1958; Bates,

1942; Wilpolt and Wanek, 1951; and Griswold, 1959) have variously interpreted these beds as Chalk Bluff, Whitehorse Group, or upper San Andres Formation depending upon locality, thickness, and exposures. Outcrops are very limited in the quadrangle and contact relations are vague; field evidence would ally the Bernal more closely with the overlying Triassic beds than with the underlying Permian rocks. In the Little Black Peak quadrangle the formation is considered Permian and Triassic and transitional because of a lack of definitive evidence in either direction.

The Bernal Formation is predominately clastic and fine-grained; silt sizes predominate and claystone stringers can be found interbedded with the fine sandstones and siltstones. Because of the relief on the basal contact and apparent gradation into the overlying Santa Rosa Formation, the thickness varies from nearly 300 feet in the east-central portion of the quadrangle, to less than 200 feet on the south flank of Lone Mountain, and to only a few tens of feet in the southwest corner of the quadrangle.

The basal part of the Bernal is buff-colored, poorly-sorted, medium-grained sandstone which grades upward into siltstone. The main bulk of the formation is reddish-brown to yellowish-brown fine-grained sandstone and siltstone with interbedded claystone layers weathering to a bright orange-red soil. Most of the formation is very friable and weathers easily so that outcrops are rare. Locally, cross-bedding, and some channeling and scour-and-fill structures may be seen in the coarser sandstone layers. The upper part of the formation is siltstone and claystone and the contact is generally chosen on the basis of a soil color change, and the appearance of small chert pebbles and rounded grit in the soil indicating the presence of the overlying Santa Rosa conglomerates.

No fossils were found in the Bernal beds and precise determinations of the age are not possible. For reasons already cited the unit is considered as Permian and Triassic and transitional between the marine environment of the underlying San Andres limestone and the fluvial non-marine deposits of the overlying Santa Rosa Sandstone.

### Santa Rosa Sandstone

The Santa Rosa Sandstone was named by Darton in 1919 but publication was delayed (Darton, 1922). No type locality other than the "... prominent in mesas of Guadalupe Co. and along Pecos River at Santa Rosa" (Wilmarth, 1938) has ever been designated and the thickness is variously reported as 500 to 600 feet and 50 to 100 feet. Darton himself (1922) does not give a thickness for the unit. Affinities to the Shinarump Conglomerate of Arizona have been suggested for the Santa Rosa Sandstone and the stratigraphic positions are similar; however, direct equivalence cannot be proven and the vertebrate faunas are too sparse to allow detailed correlation. There is considerable question regarding its formational status because of the gradational nature of the upper contact with the overlying Triassic mudstones and siltstones of the Chinle Formation. However, in the Little Black Peak quadrangle it is a mappable unit.

The Santa Rosa Sandstone is principally a coarse- to medium-grained, cross-bedded, sandstone and pebble conglomerate. Thin-bedded claystone and siltstone partings less than 2 feet in thickness are interbedded with the sandstone layers. The beds are predominantly red to reddish brown on fresh surface and weather to dark reddish brown or buff. Locally near the top of the formation buff to white, coarse-grained, cross-bedded sandstone beds are prominent. Exposures in the lower part of the unit are fair because the pebble conglomerate often forms resistant cappings on cuestas and mesas. The upper part of the formation grades upward into the overlying Chinle siltstones and mudstones and the contact is rarely exposed. The variation of the upper contact, because of such gradation, results in considerable differences in measured thickness in the Santa Rosa Sandstone. Around Lone Mountain less than 150 feet has been measured, although 6 miles to the north in sec. 16, T. 5 S., R. 11 E., nearly 250 feet are assigned to the formation. There is no break in sedimentation between the underlying Santa Rosa Sandstone and the overlying Chinle Formation and the Santa Rosa is here considered a basal sandy phase of the Late Triassic sedimentation.

#### Chinle Formation

The Chinle Formation was first described by Gregory (1916) from exposures in the Chinle valley of northeastern Arizona. The name has since been extended over much of the Colorado Plateau region, westward into southern Nevada, and eastward into northern and central New Mexico. Similar Triassic red beds were described by Cummins (1890) as the Dockum Group in northwestern Texas, and these have since been extended northward into Kansas and Colorado and westward into New Mexico. Because of lithologic similarity, a lack of diagnostic fossils, and the writer's personal familiarity with the Arizona nomenclature, the term Chinle is preferred for the Little Black Peak quadrangle.

The Chinle Formation in the quadrangle is thin-bedded siltstone, mudstone, and claystone with thin sandstone and limestone-pebble conglomerate lenses. The rocks are purplish red to chocolate brown, weathering to reddish brown. The layers are soft and friable and outcrops are rare. The formation is characterized by reddish sandy soil alternating with darker reddish-purple clayey soil. It forms covered slopes beneath the mesa cappings of the overlying harder beds, and broad valleys with very little relief throughout the central part of the quadrangle. A few fragments of fossil wood have been found, but no other fossils have been reported. The Late Triassic age and assignment of these beds to the Chinle Formation in the Little Black Peak quadrangle is based upon lithologic similarity and stratigraphic position.

There is a marked disconformity at the top of the Chinle Formation, although the relief on this contact is only a few feet at the most. From 200 to over 400 feet of Chinle Formation is present in the Little Black Peak quadrangle, the variability probably being due in part to differences in selection of the lower contact with the Santa Rosa Sandstone. Triassic beds extend only a few tens of miles south of the latitude of the mapped area in this part of New Mexico so that some depositional

variation near the edge of the basin might also be expected.

#### Dakota Formation

The Dakota Sandstone was first described by Meek and Hayden (1862) from exposures in Dakota County, Nebraska. Subsequent workers have extended the name to encompass almost all of the basal sandstones of the Upper Cretaceous rocks in the Rocky Mountains. The fluctuations in strand lines and marine environments which characterize the Upper Cretaceous rocks in New Mexico suggest that many of the basal sandstone units are not time-equivalent. In the Little Black Peak quadrangle the basal sandstone of the upper Cretaceous sequence is referred to as Dakota Formation with no implication regarding its specific age or relationship to the other Dakota units which have been described to the north, west, and south.

The Dakota Formation is confined to the southern and eastern parts of the quadrangle forming prominent cuestas and mesa cappings. The best exposed section is in a railroad cut about half a mile north of Coyote siding, where the upper contact is marked chiefly by the disappearance of the exposures to the south, and the lower contact is clearly defined at the north end of the cut.

The basal part of the formation is thick-bedded (2-4 feet) to massive, white quartz sandstone, medium-grained, and weathering buff to brown. Thin shaly partings and thin, even-bedded siltstone and sandstone comprise the central part of the formation. Interbedded sandstone and shale forms the upper part of the formation which grades upward into the overlying Mancos Shale. Some of the sandstone beds are coarse-grained and conglomeratic and many exhibit varying degrees of cross-bedding. Locally, thin coal seams are found in the shaly central portion of the formation. Complete sections of the Dakota Formation could be measured only in the southeast corner of the quadrangle. Here the thickness ranged from 144 feet south of Lone Mountain to 182 feet in the railroad cut north of Coyote siding. At least part of the variation probably is due to the placing of the upper contact which is conformable with the overlying Mancos Shale. The contact is arbitrarily selected at that point where shale predominates over sandstone; such a point is a function of exposures as well as lithology.

#### Mancos Shale

The Mancos Shale was named by Cross (1899) from exposures in Mancos valley in and around the town of Mancos, Colorado. Reeside (1924) pointed out that faunas of Greenhorn, Carlile, Niobrara, and Pierre age had been reported from the Mancos Shale. Obviously parts of the shale from some areas are not the same age as shale having similar lithologies in other regions. However, despite the variation in age, the drab, lead-gray shale containing sparse thin-bedded limestone and sandstone layers has the same uniform, monotonous lithology throughout most of New Mexico, Colorado, Arizona, Utah, and Wyoming.

A complete section of Mancos Shale is not exposed

in the Little Black Peak quadrangle, although 600 to 700 feet of beds are indicated. Exposures are poor; the shale weathers into a brownish-gray soil and is too soft to resist erosion. Some of the deeper recent arroyo banks and deep road cuts are the only places where the beds can be observed in reasonably fresh condition. The shale is sandy near the base and grades upward into dull-gray to black calcareous fissile layers less than a few inches thick. About 100 feet above the base fossils are abundant and *Ostrea lugubris*, *Camptonectes platessa*, *Inoceramus labiatus*, *Cardium pauperculum*, and *Helio-ceras pariense* have been identified. The Late Cretaceous age is clearly determined from the above forms.

### Tertiary Volcanic Breccia

In the extreme southeast corner of the quadrangle the upper part of the ridge trending northward from Baxter Mountain is capped with volcanic sediments, agglomerate, tuff, and breccia, interbedded with mudstone, sandstone, and shale. These beds resemble in some ways the Cub Mountain Formation of Bodine, 1956, (Weber, personal communication, 1964) but the isolated nature of the outcrop and the abundance of volcanic debris makes correlation doubtful. There is no question but that the unit is some part of the Sierra Blanca volcanic pile, but no indication is available as to whether it is early or late in the sequence. The beds contain fragments of the Lone Mountain intrusive mass and lap onto the outcrop surface, so they are post-Lone Mountain; however, they are cut by monzonitic, latitic, and lamprophyric dikes and thus are earlier than the latest phases of the intrusive activity. A tentative late Tertiary age is herein assigned although this may represent anything from late Miocene to early Pleistocene.

The volcanic debris is irregular and lenticular and individual beds are difficult to trace. The basal unit in one area is flow breccia containing large inclusions (boulder size) of Mancos Shale in a fine-grained groundmass which is light gray on fresh surface and weathers to mottled red, green, or yellow; irregular and contorted flow structure is common. In other areas the basal unit is well-cemented quartz sandstone, so thoroughly lithified that it resembles quartzite on broken surface. The sandstone is fine- to medium-grained, gray to white on fresh surface, weathering to buff to brown. In places it is conglomeratic with fragments similar to those in the flow breccia. These basal units seldom exceed 30 feet in thickness, although where both are present the sandstone overlies the flow breccia and the two units combined may be as much as 50 feet thick.

The principal mass of the volcanic debris is agglomerate with thin mudstone and sandstone interbeds in the lower third of the layers. The lower 100 feet is a greenish-gray fine-grained matrix in which abundant inclusions of shale, limestone, sandstone, monzonite, and latite occur in a wide variety of shapes and sizes. Feldspar fragments and phenocrysts are abundant. The middle 150 feet is finer-grained agglomerate, light gray on fresh surface but weathering reddish brown. The groundmass is felsitic and the inclusions are usually less than 3 inches in diameter; most are angular to subrounded. Where rounding is pronounced the beds appear conglomeratic. The upper 100 or more feet is very coarse

agglomerate with inclusions up to 2 feet in diameter. It is light gray on fresh surface weathering pale red, reddish orange, and grayish orange to brown. It is well-indurated forming conspicuous knobs and resistant cliffs near the top of the unit. The three agglomerate layers with the interbedded mudstone and sandstone exceed 375 feet in thickness and the entire Tertiary unit is estimated to be a minimum of 400 feet thick.

The Tertiary material rests upon Mancos Shale and the older beds with angular unconformity. The surface of deposition was very irregular (relief of more than 100 feet is common). Bedding within the unit is vague or contorted, but generally strikes north-south and dips westerly at 10 to 15°.

### Quaternary Deposits

Deposits of gravels and alluvium containing fragments of most of the earlier rocks cover considerable areas in the western part of the Little Black Peak quadrangle. At least two stages of deposition of this type can be recognized and farther east a still earlier and more lithified deposit has been correlated with the Ogallala Formation (Budding, 1964).

Older gravels cap small mesas and form high level terraces along some of the larger stream valleys. There is some reason to believe that some of these gravels may be lag or deflation deposits from a former much more extensive gravel sheet correlative with the Ogallala Formation farther east. These beds contain cobbles and pebbles of quartzite, monzonite, sandstone, and limestone. The quartzite indicates sources far beyond the limits of the quadrangle.

More recent alluvium fills the valley floors and some of the sink holes. It commonly reflects the nearby rock outcrops since most of the material is locally derived. Drainages have very low gradients and most of the alluvium is thus very fine-grained; the arid climate also results in considerable amounts of wind-blown sand and silt accumulating as alluvium.

### Igneous Rocks

Tertiary and Quaternary intrusive and extrusive rocks are abundant in the southern and eastern portions of the Little Black Peak quadrangle. Sills, dikes, small stocks, and flows are represented in a wide variety of compositions and textures. The lack of exposures and the paucity of contemporaneous sediments and cross-cutting relationships makes dating the different compositional types difficult. At least three and possibly four periods of igneous activity are delimited by the rocks exposed.

### Intrusive Rocks

The intrusive rocks can be grouped into two major types, those with abundant megascopic quartz, and those with little or no visible quartz. The Lone Mountain stock is typical of those with little or no visible quartz although more basic types are known, and a sill in the Mancos Shale in secs. 23, 24, and 26, T. 6 S., R. 10 E., is characteristic of those with abundant megascopic quartz. Intrusive rock exposures are limited to the ex-

tre eastern and southern parts of the quadrangle with the largest outcrop that of the Lone Mountain stock; a similar but smaller exposure occurs in secs. 2 and 11, T. 5 S., R. 11 E., east of Largo. Numerous dikes and sills are associated with the larger intrusive masses, but no direct connections can be demonstrated.

The great bulk of the intrusive rocks are of the Lone Mountain type and contain little or no visible quartz. The Lone Mountain stock has been described in some detail by Butler (1964) and compared to similar intrusives farther east.

"Lone Mountain is formed of Kaliaaskite porphyry . . . From one side of Lone Mountain to the other, the intrusive rock is remarkably uniform in appearance. The color of a fresh rock surface is a distinctive brownish gray. Feldspar phenocrysts compose about one-third of the rock and reach 5 mm in size. Little quartz is visible in the rock.

"The dark mineral content of most Lone Mountain specimens is about 5 percent, but the mineralogy of these dark minerals varies. In specimens obtained near the Ferro mine and in specimen A47, the dark minerals are hornblende, biotite, and magnetite. In the northeast half of the mountain, however, bright-green pyroxene (aegerine-augite) is the dominant dark mineral, and it is accompanied by some hornblende. No magnetite or biotite is visible in specimens from this side of the mountain.

"Lone Mountain intrusive rocks weather to a dull reddish brown. Because hornblende decomposes readily, some hornblende grains are partially altered to limonite. This alteration can even be observed on otherwise fresh rock surfaces." In thin section Butler (1964) observed that a few of the plagioclase phenocrysts have been broken and the pieces slightly rotated with respect to one another. He interprets this as evidence that the plagioclase crystallized early, before the magma was completely emplaced.

A second type of quartz-free intrusive occurs in the White Oaks mining district in the southeast corner of the quadrangle. Dark colored dike rocks of varying compositions cut the lighter colored dikes associated with the Lone Mountain stock. The dark dikes are composed of feldspar and a dark mineral, sometimes hornblende, sometimes biotite, and more commonly pyroxene. Gratton (Lindgren and others, 1910) described these as lamprophyres principally kersantite or minette; Griswold (1959) in his detailed mapping in the White Oaks district used the term "mica trap." One late dike associated with mineralization in the western part of the White Oaks district would be a vogesite from megascopic examination. Budding (1964) reports compositions which would include all the typical lamprophyres, kersantite, minette, vogesite, spessartite, or possibly even camptonite, depending upon slight variations in mineral content.

Two small dikes of basaltic composition crop out south and west of Coyote siding. They are dense, greenish-black, olivine basalt, weathering dark yellowish brown. Megascopically, they are identical with the extrusive Little Black Peak basalt flow, although lacking the vesicular and scoriaceous surface. No evidence as to their age other than post-Cretaceous and post-rhyolite

was obtained, and since earlier basalt flows than the Little Black Peak flow occur to the west, no direct correlation is possible.

The rocks containing visible quartz are granitic in composition, usually containing abundant hornblende or biotite. They are fine-grained, often aphanitic, gray to white on fresh surface and weathering to dark gray or brown. They are found mostly north and west of Lone Mountain cutting the sediments that enclose the main intrusive mass. They generally contain less than 25 percent quartz and may represent slightly more silicic differentiates of the same parent magma. Compositional and textural terms such as microgranite, rhyolite, and granodiorite have been used to describe different dikes or sills of this group which indicates the variations which have been observed. Within the mass of the Lone Mountain intrusive local areas containing visible quartz are recognized and one large enough to map is shown near the northeastern boundary.

The intrusive rocks of the Little Black Peak quadrangle are obviously closely related to one another and to similar intrusive masses farther east (Budding, 1964). Compositionally they fall near petrographic classification boundaries and thus the nomenclature is confused. Butler (1964) has followed Johannsen's classification (1939), although the rock names are somewhat misleading. The almost complete lack of plagioclase coupled with an average of less than 10 percent quartz in most samples allies the Lone Mountain rocks with the alkali-syenites. An applicable name to this type of material would be nordmarkite (Brogger, 1890). The paucity of dark minerals and a similar lack of plagioclase in those rocks containing from 25-30 percent visible quartz would place such rocks in the kaliaaskite category of Johannsen (1939). Some definitions of granophyre would also describe these rocks, as could the term granite-porphyry. The abundance of alkalis and the deficiency of silica make this general province petrographically interesting.

### Extrusive Rocks

The extrusive rocks of the Little Black Peak quadrangle are confined to the southwestern corner of the quadrangle and are exclusively basaltic. Two flow episodes apparently distinctly separated in time, but relatively recent, are recognized. An earlier series of basaltic flows emanate from Broken Back crater about four miles west of the quadrangle and crop out over portions of secs. 2, 3, and 10, T. 6 S., R. 9 E., and parts of secs. 27, 28, 33, 34, and 35, T. 5 S., R. 9 E. The Little Black Peak flow is younger, nearly overlapping some of the Broken Back flows in the SE $\frac{1}{4}$  sec. 2, T. 6 S., R. 9 E., and extending some 44 miles southward into the Tularosa Basin. The difference in age is determined by the thin soil cover and weathered surface found on the Broken Back flows as compared to the lack of weathering and soil on the Little Black Peak flow.

The Little Black Peak flow is greenish-gray to black on fresh surface and weathers reddish brown to grayish black. The rock is extremely vesicular, particularly in the upper 2 feet. It is dense, fine grained to aphanitic, with lath-like phenocrysts of plagioclase and small

green phenocrysts of olivine. In thin section a very crude trachytic texture is discernible particularly around the olivine phenocrysts. The principal minerals are calcic labradorite ( $An_{66}-An_{70}$ ), titaniferous diopside augite, olivine ( $Fa_{20}-Fa_{23}$ ), and magnetite. Alteration is very slight, hematite being the only identifiable secondary product. Reddish-brown rims on a few of the olivine crystals may be iddingsite, but the development is too fine grained for certainty in the determination.

A complete chemical analysis of a sample of the Little Black Peak flow was published by Allen (1951) and showed:

SiO <sub>2</sub>	50.77%	Na <sub>2</sub> O	3.50%
Al <sub>2</sub> O <sub>3</sub>	14.00	K <sub>2</sub> O	1.51
Fe <sub>2</sub> O <sub>3</sub>	2.34	TiO <sub>2</sub>	1.71
FeO	7.48	P <sub>2</sub> O <sub>5</sub>	0.34
MnO	0.16	H <sub>2</sub> O - 110° +	1.72
MgO	6.96	H <sub>2</sub> O - 110° -	0.07
CaO	9.08	CO <sub>2</sub>	0.00

This is a typical alkali olivine basalt and as such the relatively low silica content coupled with the relatively high alkali suggests close affinities with monzonite in the White Oaks mining district in the southeast corner of the quadrangle, a partial analysis of which was reported by Lindgren and others (1910).

These flow rocks are very young, and the Little Black Peak flow may have been extruded within historic time (Allen, 1951). The Broken Back flows have been modified sufficiently by erosion and weathering so that although a post-Pleistocene age is suggested, they could be older.

### Structure

The Little Black Peak quadrangle lies at the extreme northeastern end of the Tularosa Basin where a synclinal structure is more pronounced than the fault trough pattern characteristic of the Tularosa structure farther south. Most of the northern part of the quadrangle is a broad plain with a gentle homoclinal dip to the southeast. Along the eastern and southern margins of the quadrangle numerous folds are exposed. The folds are closely related to the Tertiary intrusive activity; in most cases they are domed structures apparently resulting from the intrusion of rounded plug-like bodies. A small syenitic mass is exposed in the northernmost dome in sec. 35, T. 4 S., R. 11 E., and in sec. 11, T. 5 S., R. 11 E., and the nordmarkite plug of Lone Mountain occupies several square miles in the southeast corner of the quadrangle. The domes are generally circular or elliptical in outline with the surrounding beds upturned sharply around the margins of the structure and nearly flat over the tops. The vertical nature of the deforming forces is best illustrated in secs. 16 and 28, T. 5 S., R. 11 E., where beds dipping from 30-40° change strike through more than 90° in distances of less than 1,000 feet; the result is a remarkable dome with square corners.

Tightly compressed synclines are found between the domes where the thin sedimentary cover has not been pushed upward by the doming action. The synclines plunge steeply in a westerly direction but their axes are determined by the intrusive centers which they

border and thus have random directions. A larger syncline plunging to the southwest crops out west of Lone Mountain; the structure is outlined by the Dakota Formation and may represent broader and more open folding not associated with the Tertiary intrusives. The western limb of this syncline is concealed beneath the Little Black Peak basalt flow along the southern margin of the quadrangle, but kipukas of Dakota Formation farther south attest to the southwesterly continuation of the structure. In the extreme southwest corner of the quadrangle the northeasterly-plunging nose of the Carrizozo anticline is outlined by the San Andres-Bernal contact. Apparently the easterly limb of the anticline and the westerly limb of the aforementioned syncline coincide. The dips of the beds on the limbs of these folds seldom exceed 20°, and the broad open folding is in sharp contrast to the abrupt bending associated with the domes to the east.

Faulting is practically non-existent in the Little Black Peak quadrangle. Two types of faults are recognized: fractures of minor displacement (less than 50 feet) associated with the intrusive activity and commonly filled with later dikes or veins, and fractures associated with landslide or slump blocks practically confined to the Dakota Formation.

Faults of the first type are most prominent in the extreme southeast corner of the quadrangle in the White Oaks mining district. The area of the mines is extensively fractured but displacements are practically nil, and the introduction of the several dikes and sills seems to have simply resulted in a dilation of the country rocks without much relative shifting of adjacent blocks.

The landslide blocks are torveva type and the individual blocks have rotated downward and outward with respect to the original mesa position. Total displacements are difficult to assess because erosion has removed some of the intervening material. However, in secs. 25 and 26, T. 5 S., R. 10 E., a single block of Dakota lies 300 feet below and nearly one-half mile north of the present undisturbed mesa position. This particular mesa is surrounded by such blocks at various levels with a much smaller and slightly lower mesa half a mile to the southeast, also surrounded by similar torveva blocks. The terrain surrounding these mesas is not particularly steep and such extensive landsliding is puzzling. It is suggested that the mesas may be associated with a large sink hole in the underlying San Andres Formation which is concealed by the Chinle Formation and which provides the local steep slopes necessary for the development of the torveva blocks. Similar sliding may have affected the strip of Dakota Formation just east of the railroad in secs. 18, 19, and 20, T. 5 S., R. 11 E., but exposures are too poor to identify the fault planes.

## ECONOMIC GEOLOGY

### Ground Water

Ranching and mining have contributed to the economy of the Little Black Peak quadrangle, but the lack of adequate water both in quantity and quality, has severely handicapped development. Abandoned ranch houses abound, particularly in the northern and western

parts of the quadrangle. Dry farming on a small scale has been unsuccessful and forage for cattle requires extremely large holdings to support a herd of economic size. Many wells have been drilled and abandoned because the underlying San Andres and Glorieta formations, which serve as aquifers, contain ground water so high in carbonate and sulfate that the water is unfit even for cattle or irrigation. Precipitation is insufficient for the average size tank and the amount of gypsum at the surface, particularly in the northern part of the quadrangle, increases the dissolved solids in the surface water nearly to tolerable limits. Locally, wells in the alluvium may often produce good water under favorable circumstances, but these are sporadic producers. To the east and south where the Santa Rosa Sandstone or the Dakota Formation may be tapped for ground-water supplies the quality is better, but recharge areas for these units are limited and supplies may be rapidly exhausted. In some areas of the arid southwest recent lava flows such as the Little Black Peak flow have proved to be excellent aquifers. However, the Broken Back and Little Black Peak flows do not seem to be sufficiently confined to provide such storage.

### Mining

Mining in the Little Black Peak quadrangle is confined to the southeast part and is concentrated around the Lone Mountain nordmarkite stock. Gold, tungsten, and iron ores have been produced from this area which is included in the White Oaks mining district. Production has been sporadic and the records are poor (Griswold, 1959). Gold mining has yielded the bulk of the total value, although the iron ores have the greatest reserve.

The gold veins are discussed by Griswold (1959), although detailed information is lacking. Limited examination and exploration was done shortly after World War II, but the district has been abandoned for at least ten years. The veins are narrow and pockety and the grade averaged less than \$12 per ton during the years of best production. The veins occur along the margins of monzonitic and syenitic dikes or in small fractures cutting the dikes. The intrusive masses cut the Mancos Shale and parts of the Tertiary sediments on the eastern slope of the ridge between Baxter and Lone Mountains. No pattern of intrusion or vein structure has been established because of the lack of outcrops, but, where measured or exposed in old mine workings, the veins generally strike north-south and are almost vertical. Several mines were productive and the reader is referred to Griswold (1959) for the most recent information.

Tungsten is present in the White Oaks district as huebnerite ( $MnWO_4$ ) associated with the gold veins. During World War I over 100,000 pounds of concentrates were produced and a few thousand pounds have been produced intermittently since then. The most recent recorded production was 20 pounds in 1952 (Griswold, 1959). The old dumps probably contain some tungsten values since it was not considered an ore during the principal gold mining period.

Iron ore in the form of magnetite and hematite has been mined from several localities in and around the Lone Mountain stock. Kelley (1949) has described the

major deposits and published detailed maps of some. Official records of production exist for only the Yellow Jacket and Ferro mines, although prospects and pits from which a few tons of ore have been extracted are found around the periphery of the stock.

Magnetite and hematite occur as pyrometamorphic and replacement deposits in the lower members of the San Andres Limestone. Some calcisilicate minerals have been developed but skarn zones so characteristic of typical pyrometamorphic deposits are lacking. The magnetite and hematite occur disseminated throughout the limestone and as layers and veins of completely replaced limestone. In the Ferro mine the ore was localized along the contact between the intrusive and the limestone. West of the Little Black Peak quadrangle similar magnetite and hematite deposits are being worked as replacements of limestone and sandstone beds as well as replacing some of the massive gypsum beds in the Yeso Formation. Such occurrences offer intriguing possibilities regarding the occurrence of additional ore in depth around the Lone Mountain stock. The stock has been intruded near the base of the San Andres Formation and drilling depths of less than 1,000 feet should prospect the contact zone with most of the upper part of the Yeso Formation, the zone that is particularly favorable in the deposits to the west.

A little gypsum from the upper part of the San Andres Formation has been burned locally for plaster and some of the gravels have been utilized for road metal. Parts of the Little Black Peak flow have been quarried for road metal and large parts of the cinder cones west of the quadrangle which mark the source for the Broken Back flows have been used for the same purpose.

### GEOLOGIC HISTORY

Mapping to the south of the Little Black Peak quadrangle suggests that during the early part of the Paleozoic the quadrangle was part of the Pedernal positive area and was reduced to an area of low relief. Pennsylvanian seas inundated the area and about 1,750 feet of limestone, sandstone, and shale was deposited. Following the retreat of the Pennsylvanian seas the sandstone and siltstone of the terrestrial Abo formation was spread over the flood plain. Permian seas returned to the area, alternately advancing and dessicating, and sandstone, siltstone, limestone, and gypsum of the Yeso Formation was deposited. The Glorieta Sandstone and San Andres Limestone are repetitions of the alternate advance and dessication of the Permian marine invasions. After the final gypsum deposits of the upper San Andres beds were laid down the area remained above sea level for a considerable period of time. Fluvial and lacustrine conditions are reflected by the Bernal Formation, and the Santa Rosa Sandstone is a broad sheet of river gravels and sands. The finer muds and silts of the Chinle Formation represent a continuation of such savannah-like conditions with considerably reduced elevations in the sedimentary provenance. From the end of Triassic time until Upper Cretaceous time the area was undergoing erosion although any crustal movements were epeirogenic as they had been throughout the Paleozoic. The Upper Cretaceous marks the last



marine invasion of the area and the Dakota Formation and the Mancos Shale represent the beach and off-shore deposits of the Upper Cretaceous seas. Uplift at the end of the Cretaceous resulted in withdrawal of the sea but no orogeny assignable to the Laramide is recognizable.

The Tertiary marks the advent of igneous activity and the first events were the intrusions of the Lone Mountain and associated stocks. Their forcible introduction into the upper crust domed and warped the thin overlying sedimentary cover perhaps creating the fractures which were later filled with dikes and sills of similar material. However, following the intrusion of the stocks, certainly not later than Miocene and perhaps earlier, volcanic activity on a broad scale began south of the quadrangle. Debris was spread over a wide area and this cover was also intruded by the later dikes and sills. During the last stages of igneous activity, or perhaps earlier in the case of the magnetite and hematite deposits, mineralization occurred around the Lone Mountain stock. Associated with the mineralization were lamprophyric dikes. During or after these last stages of intrusive activity basaltic dikes were intruded which may have been the feeders or precursors of the later basaltic flows of Broken Back crater, and Little Black Peak. Spreading westward and southward from sources to the east and north a broad sheet of gravels was deposited over the eroded surface of the domed and warped beds. These gravels, correlated with the Ogallala Formation of the High Plains to the east, contain fragments of all the rock units except the Broken Back and Little Black Peak flows. This gravel sheet is presumably Pliocene in age and places an upper limit on the duration of the intrusive and mineralizing activity of the Lone Mountain area. Quiescent eruptions extruded the Broken Back and Little Black Peak flows, the latter so recently that it fills present-day topographic features. Erosion is continuing to sculpture the present surface.

Soon after the retreat of the Permian seas solution of gypsum and limestone in the San Andres Formation created a karst topography upon which the Bernal Formation was deposited. Such solution has continued to the present time and recent sink holes have developed in the San Andres Formation in the northern part of the quadrangle. The age of any particular depression is not readily determined, although the recent ones can be recognized by their topographic expression. The present course of Largo canyon, the principal drainage for the northern and western parts of the quadrangle is apparently controlled by the coalescence of a series of large sinks or depressions. This is also the course which the Little Black Peak flow followed through the quadrangle.

The entire area is characterized by a lack of orogenic movement and remarkable stability throughout a long period of geologic time. The folding present is due principally to vertical forces accompanying the intrusion of the stocks and the emplacement of the numerous dikes and sills has resulted only in dilation of the crust rather than crumpling or shortening. The prevalence of alkaline igneous rocks also points to a stable block as opposed to organic belts.

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